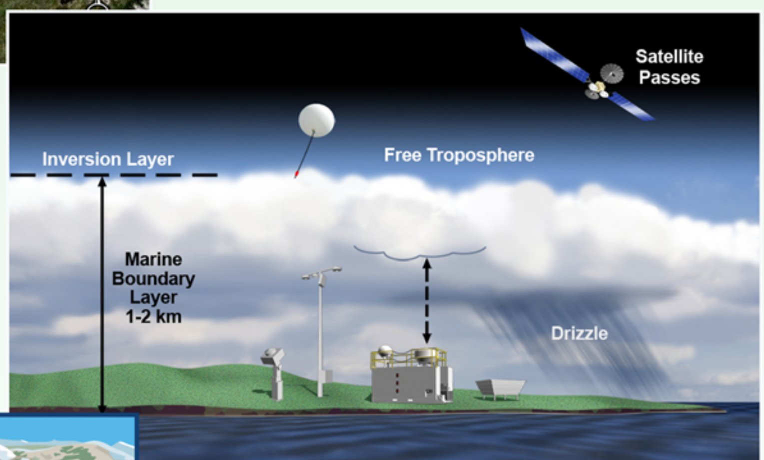
ASR Atmospheric System Research
Science Team Meeting

San Antonio, Texas • March 28 – April 1, 2011

Carbonaceous Aerosols and Radiative Effects Study (CARES)



Clouds, Aerosol, and Precipitation in the Marine Boundary Layer (CAP-MBL)

Storm Peak Lab Cloud Property Evaluation Experiment (STORMVEX)

U.S. DEPARTMENT OF ENERGY

Office of Science

ABOUT THE FRONT COVER

Images on the program cover highlight three recent field campaigns that address ASR scientific objectives. Please refer to the agenda for related topical sessions.

CARES: Led by principal investigators Rahul Zaveri and Will Shaw from Pacific Northwest National Laboratory, CARES used two ground sites and two aircraft to obtain aerosol and trace gas measurements in the Sacramento Valley region throughout the month of June 2010. Along with radiative and meteorological measurements from the ground sites, these data will be used to study the evolution of climate-affecting aerosol properties moving from an urban to a rural environment.

CAP-MBL: Led by principal investigator Robert Wood from the University of Washington, CAP-MBL used ARM Mobile Facility instruments to obtain data on Graciosa Island in the Azores from May 2009 through December 2010. This prolonged deployment provides researchers with the first climatology for studying the detailed vertical structure of cloud and precipitation properties of low clouds at a remote subtropical marine site.

STORMVEX: Led by principal investigator Gerald Mace from the University of Utah, STORMVEX began in November 2010 in Steamboat Springs, Colorado, using remote sensing instruments at Storm Peak Lab and at three lower elevations using the ARM Mobile Facility. The combined in situ and remote sensing data will be used for measurement validation and studies of cloud, aerosol, and precipitation properties and processes.

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March 28–April 1, 2011

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Contents

1.0 Executive Summary

Introduction

This document contains the summaries of papers presented in poster format at the 2011 Atmospheric System Research (ASR) Science Team Meeting held in San Antonio, Texas. More than 240 posters were presented during the Science Team Meeting. Posters were sorted into the following subject areas: aerosol-cloud-radiation interactions, aerosol properties, atmospheric state and surface, cloud properties, dynamics/vertical motion, field campaigns, infrastructure and outreach, instruments, modeling, precipitation, and radiation. To put these posters in context, the status of ASR at the time of the meeting is provided here.

Background

The U.S. Department of Energy's (DOE) Atmospheric System Research (ASR) is an observation-based research program created in October 2009 to advance process-level understanding of the key interactions among aerosols, clouds, precipitation, radiation, dynamics, and thermodynamics using data from the Atmospheric Radiation Measurement (ARM) Climate Research Facility. The ARM Facility is a DOE scientific user facility for the study of global climate change by the national and international research community. Planned enhancements to the ARM Facility, funded through the American Recovery and Reinvestment Act of 2009, were implemented in 2010 and 2011 and resulted in 143 new instruments and increased research capabilities for the ARM user community, including ASR scientists.

A tight coupling of the ARM Climate Research Facility and ASR will allow the atmospheric system to be better observed and understood in a comprehensive, end-to-end fashion. ASR is designed to recognize the atmospheric system as an aerosol-cloud-precipitation continuum operating within a microphysical and macrophysical environment characterized by radiation, dynamics (including meteorology), and thermodynamics. That continuum stretches seamlessly across scales from gases and primary particles emitted to the atmosphere, through evolving aerosol populations, to the clouds that form on aerosol particles, and the cloud systems that produce precipitation to complete the hydrologic cycle. ASR's defining objective is a detailed, process-level understanding of this system that leads to improved simulations by climate models.

References

Atmospheric System Research (ASR) Science and Program Plan. 2010. U.S. Department of Energy. http://science.energy.gov/~/media/ber/pdf/Atmospheric_system_research_science_plan.pdf.

2.0 Aerosol-Cloud-Radiation Interactions

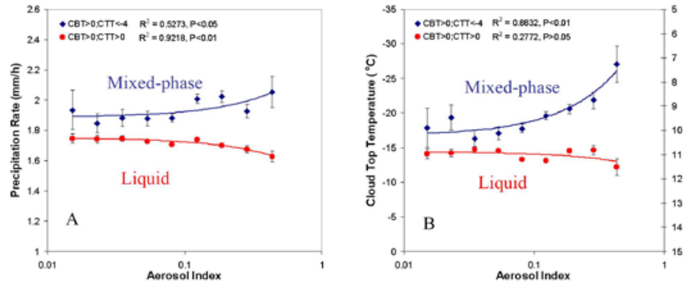
3D effects on spectrally invariant behavior near cloud edges: implications for retrieving aerosol and cloud properties in these challenging regions

J.-Y. Christine Chiu, University of Reading
Alexander Marshak, NASA Goddard Space Flight Center
Yuri Knyazikhin, Boston University
Warren Wiscombe, Brookhaven National Laboratory
Tamas Varnai, UMBC/JCET
Hailong Wang, Pacific Northwest National Laboratory

Fuzzy cloud edges, with the transition from cloudy to clear air spanning as little as 50 m to as much as several hundred meters, are the battleground where the fate of aerosol indirect forcing is decided. However, measuring aerosol and cloud properties near and within cloud edges from remotely sensed data remains problematic because the separation between cloudy and clear air is always ambiguous, and because effects of the 3D nature of clouds on measurements need to be considered. Recently, we discovered a surprising spectrally invariant behavior in zenith radiance spectra measured by the shortwave spectrometer of the Atmospheric Radiation Measurement (ARM) Climate Research Facility. The relationship suggests that the shortwave spectrum near cloud edges can be determined by a linear combination of zenith radiance spectra of the cloudy and clear regions. More importantly, 1D radiative transfer calculations show that the relationship is mainly determined by cloud properties and is insensitive to aerosol properties and the underlying surface type. Here, we will demonstrate how 3D effects may modulate the spectrally invariant relationships. We will also show the extent to which the general conclusions drawn from 1D calculations hold in 3D calculations, which will shed light on development of a new retrieval method that works for cloud edges.

Aerosol-induced changes of convective clouds observed from ground-based observations and CloudSat/CALIPSO

Feng Niu, University of Maryland - College Park
Zhanqing Li, University of Maryland



Precipitation rate (A) and corresponding cloud-top temperature (B) from CloudSat as functions of AI for mixed-phase (blue dots) and liquid clouds (red dots) over the tropical ocean. Note that only clouds with precipitation rates greater than 1 mm/h are included here. The right-hand y-axis of (B) represents the cloud-top temperatures of liquid clouds. CBT and CTT stand for cloud base and cloud top temperature, respectively.

Aerosols have strong impacts on deep convective clouds and associated precipitation through complex microphysical or thermodynamic effects. Using 10-year ground-based observations, we show that warm base mixed-phase clouds in summer are strongly invigorated by aerosols, while this effect does not exist for shallow warm clouds. This finding is further confirmed by using a large ensemble of satellite data acquired by the Moderate Resolution Imaging Spectroradiometer onboard the Earth Observing System's Aqua platform, the CloudSat cloud profiling radar, and the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) satellite over the tropical regions. We identified two distinct responses of clouds and precipitation to increases in aerosol loading. Cloud-top temperatures decrease significantly with increasing aerosol index (AI) over oceans and aerosol optical depth (AOT) over land for mixed-phase clouds with warm cloud bases; no significant changes were found for liquid clouds. The distinct responses are explained by two mechanisms, namely, the aerosol invigoration effect and the microphysical effect. Aerosols can significantly invigorate convection mainly through ice processes, while precipitation from liquid clouds is suppressed through aerosol microphysical processes. Precipitation rates are found to increase with AI for mixed-phase clouds, but decrease for liquid clouds, suggesting that the dominant effect differs for the two types of clouds. These effects change the overall distribution of precipitation rates, leading to more or heavier rains in dirty environments than in cleaner ones.

Aerosol effects on shallow cumulus clouds in a global model

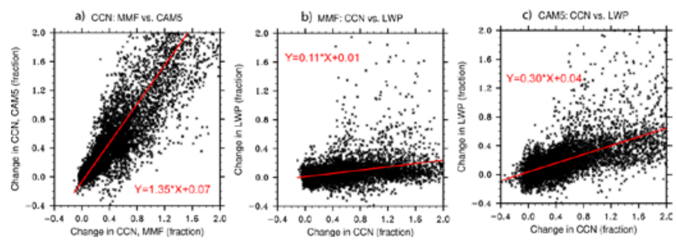
Steven Ghan, Pacific Northwest National Laboratory
Sungsu Park, National Center for Atmospheric Research

Almost all previous efforts to represent aerosol effects on clouds in global models have been limited to effects on stratiform clouds. We have applied a parameterization of droplet nucleation to shallow cumulus clouds represented in the Community Atmosphere Model (CAM5), including the effects of entrainment, and have expressed the cloud optical properties in terms of the diagnosed droplet number. We will compare estimates of aerosol indirect effects by CAM5 with and without this treatment.

Aerosol indirect effects in the PNNL-MMF multi-scale aerosol-climate model

Minghuai Wang, Pacific Northwest National Laboratory
Steven Ghan, Pacific Northwest National Laboratory
Mikhail Ovchinnikov, Pacific Northwest National Laboratory
Xiaohong Liu, Pacific Northwest National Laboratory
Dick Easter, Pacific Northwest National Laboratory
Evgueni Kassianov, Pacific Northwest National Laboratory
Yun Qian, Pacific Northwest National Laboratory
Hugh Morrison, National Center for Atmospheric Research

Much of the large uncertainty in estimates of anthropogenic aerosol effects on climate arises from the multi-scale nature of the interactions between aerosols, clouds, and large-scale dynamics, which are difficult to represent in conventional global climate models (GCMs). In this study, we use a multi-scale aerosol-climate model that treats aerosols and clouds across multiple scales to study aerosol indirect effects. This multi-scale aerosol-climate model is an extension of a multi-scale modeling framework (MMF) model that embeds a cloud-resolving model (CRM) within each grid cell of a GCM. The extension allows the explicit simulation of aerosol/cloud interactions in both stratiform and convective clouds on the global scale in a computationally feasible way. The simulated change in shortwave cloud forcing from anthropogenic aerosols is -0.77 W m-2, which is less than half of that in the host GCM (NCAR CAM5) (-1.79 W m-2) and is also at the low end of the estimates of most other conventional global aerosol-climate models. The smaller forcing in the MMF model is attributed to its smaller increase in LWP from preindustrial conditions (PI) to present day (PD): 3.9% in the MMF, compared with 15.6% increase in LWP in large-scale clouds in CAM5. The much smaller increase in LWP in the MMF is caused by a much smaller response in LWP to a given perturbation in cloud condensation nuclei (CCN) concentrations from PI to PD in the MMF (about one-third of that in CAM5), and, to a lesser extent, by a smaller relative increase in CCN concentrations from PI to PD in the MMF (about 26% smaller than that in CAM5). The smaller relative increase in CCN concentrations in the MMF is caused in part by a smaller increase in aerosol lifetime from PI to PD in the MMF, a positive feedback in aerosol indirect effects induced by cloud lifetime effects. The smaller response in LWP to anthropogenic aerosols in the MMF model is consistent with observations and with high-resolution model studies, which may indicate that aerosol indirect effects simulated in conventional global climate models are overestimated and point to the need to use global high-resolution models, such as MMF models or global CRMs, to study aerosol indirect effects. The



Scatter plots and regressions of (a) the relative changes [(PD-PI)/PI] in annual-mean CCN concentrations (at 0.1% supersaturation) in CAM5 versus the MMF , (b) the relative changes in annual-mean liquid water path (LWP) versus the relative changes in annual-mean CCN concentrations in the MMF model, and (c) like (b) but in the CAM5 model. LWP in CAM5 only includes the contribution from large-scale clouds. Annual mean data are sampled on each GCM grid column from 60°S to 60°N. CCN concentrations are averaged over the lowest eight model levels (surface to about 800 hPa). Red lines and equations are from the linear regression. (a) shows that the relative increase in CCN concentrations from PI to PD in the MMF is about 26% smaller than that in CAM5, while (b) and (c) show that the response in LWP to a given perturbation in cloud condensation nuclei (CCN) concentrations from PI to PD in the MMF is about one-third of that in CAM5.

simulated total anthropogenic aerosol effect in the MMF is -1.05 W m-2, which is close to the Murphy et al. (2009) inverse estimate of -1.1±0.4 W m-2 (1 σ) based on the examination of the Earth's energy balance.

Aerosols, clouds, and precipitation in the marine boundary layer at the Azores AMF

Matthew Wyant, University of Washington
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Robert Wood, University of Washington
Christopher Bretherton, University of Washington

The Clouds, Aerosols, and Precipitation in the Marine Boundary Layer Project (CAP-MBL) aims to better understand cloud-aerosol-precipitation interactions. This project utilizes continuous measurements from the ARM Mobile Facility (AMF) deployment at Graciosa Island in the Azores during May 2009–December 2010. Here we present a few preliminary results from CAP-MBL. The Azores region of the North Atlantic hosts a variety of cloud types in the MBL including stratocumulus, trade cumulus, and transitional clouds. Back trajectories from the MBL at Graciosa imply diverse geographic sources of aerosol, including anthropogenically modified air from Europe and northern North America and relatively pristine air from the Arctic. We find that ground-based sunphotometer measurements of AOD at Graciosa agree reasonably well with daily MODIS AOD measurements over a four-month period starting in July 2009. Measured surface CCN concentrations correlate only weakly with the AOD. We compare output near Graciosa of a collection of NCAR CAM 5.0 and GFDL AM3p9 global forecast-mode simulations for the same period. These new GCM versions include aerosols interactive with cloud microphysics. The models produce reasonable simulations of daily variations of cloud and boundary layer depth, but have difficulty reproducing variations of AOD at Graciosa.

Assessment of the CALIPSO-CloudSat-CERES-MODIS (CCCM) data product at TOA and surface

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The Clouds and the Earth's Radiant Energy System (CERES) project calculates irradiance profiles beneath CERES observations in the Clouds & Radiation Swath (CRS) data product. Cloud properties and profiles required to execute the radiation transfer code depend upon a cloud retrieval algorithm that utilizes MODIS pixels collocated within CERES fields of view (FOV). A new product, the CALIPSO-CloudSat-CERES-MODIS (CCCM) product, merges cloud vertical profiles retrieved from these "active" sensors, providing additional information that improves estimates of atmospheric radiative heating rates and potentially the estimate of the global surface radiation budget. These CALIPSO and CloudSat cloud vertical profiles are combined as well, with aerosol properties derived from CALIPSO in addition to those derived from directly from MODIS. Regarding assessment of the irradiance calculations, two problems present themselves. The first regards comparisons at the top of the atmosphere (TOA). The clouds analyzed by the merged product represent a "slice" through the CERES FOV, not covering its entire extent. Over time, assuming cloud fields are uniform across the FOV, this would increase the RMS of the calculations compared with CERES observations but should not introduce a bias. At the surface, another sampling problem arises. The merged data is available only along the Nadir path of the CERES FOV; sampling around the globe is significantly smaller than for the full-swath CRS product. Thus matching FOV to surface observations, given the orbit track of Aqua, is quite problematic as FOVs may never directly view surface locations where irradiance observed at the surface is available. We analyze a subset of CCCM irradiance calculations based on the surface location of CERES footprints located to within 150 km of 25 surface locations that have long-term records of observed surface irradiance. Surface sites are grouped to increase sample size, and statistics are presented at both TOA (compared to CERES observations) and at the surface (compared to surface radiometry). We find the primary improvement over nighttime skies is because the active sensor's ability to retrieve low clouds trumps the passive methodology. This is best seen at polar surface locations where the longwave, surface-down irradiance bias (model-observation) drops from -12Wm-2 down to +1Wm-2 and RMS is reduced by approximately 5Wm-2 at the four polar site surface locations.

Effect of aerosols on shallow cumuli sampled during RACORO

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The classical second aerosol indirect effect occurs when increases in aerosol concentration lead to reductions in cloud droplet sizes, affecting the precipitation efficiency, and consequently leading to increases in liquid water content (LWC) and cloud lifetime. Even though numerous studies have provided evidence of this effect in stratus and stratocumulus, an opposite effect may occur in shallow cumulus where decreases in LWC have been observed with increases in aerosol. In this study, data collected in warm shallow continental cumuli during the 2009 Routine AAF Clouds with Low Optical Water Depths (CLOWD) Optical Radiative Observations (RACORO) field project are used to investigate the second aerosol indirect effect. RACORO was held in the vicinity of the ARM Southern Great Plains site at Lamont, Oklahoma from January to June 2009. The CIRPAS Twin Otter aircraft measured aerosol, cloud microphysical, and radiative properties in both clear and cloudy conditions for 260 hours, 85 of which were classified as shallow cumuli conditions. Daily averaged sub-cloud aerosol concentrations in the accumulation mode (0.1 µm < D < 2.2 µm) measured by Passive Cavity Aerosol Spectrometer Probe (PCASP), NPCASP, varied from 70 to 1300 cm-3 for the 19 shallow cumuli flights, with a median value of 740 cm-3. Sub-cloud aerosol concentrations in the Aitken mode (D > 10 nm) measured by a Condensation Particle Counter varied from 800 to 9500 cm-3 with a median value of 2030 cm-3. For cloud measurements, a number of cloud probes, including the Forward-Scattering Spectrometer Probe (FSSP) and the Cloud Aerosol Spectrometer for D < 50 µm, the 2D-Stereo probe for 50 µm < D < 100 µm, and the 1d-Cloud Imaging Probe (CIP) and 2d-CIP for D > 100 um, were used to generate an integrated cloud product of the size distributions and bulk microphysical properties. Using 1-second averaged cloud data from the FSSP, 2337 penetrations into cumuli were identified. Most of the cumuli occurred at heights below 2500 m, and their median width was on the order of 200 m. The maximum vertical velocity in cloud reached 15 ms-1, whereas the maximum cloud-mean-vertical velocity was 5.5 ms-1. The average and maximum LWC decreased as the PCASP concentration increased, with a median value of 0.078 g m-3 for NPCASP < 740 cm-3, and 0.056 g m-3 for NPCASP > 740 cm-3. Statistical tests describing the complete dependence of the cloud and velocity field on aerosol concentration and implications will be presented at the ASR meeting.

Effect of ice on mixed-phase cloud dynamics

Mikhail Ovchinnikov, Pacific Northwest National Laboratory

High sensitivity of mixed-phase cloud properties to ice number concentration, Ni, found in previous modeling studies is investigated here using simulations of a stratiform Arctic cloud observed on 26 April 2008 during flight 31 of the Indirect and Semi-Direct Aerosol Campaign (ISDAC). A 3D large-eddy simulation model with a spectral bin microphysics treatment is shown to lose its ability to maintain the liquid phase in the mixed layer when Ni increases from the observed value of 0.5 1/L to 2 1/L. In order to better understand this highly non-linear model response to changes in Ni, the simulations are compared to a model run with liquid phase only, which produces a cloud with the largest and growing liquid water path (LWP) because the depth of a mixed layer is increasing and more moisture is kept in that layer due to lack of precipitation. The simulations with smaller ice concentration stabilize the LWP near the initial value, while in the higher Ni simulation, the cloud starts losing liquid water almost immediately and the LWP is reduced by half in less than two hours. The changes in liquid water are accompanied by corresponding reduction in the radiative cooling of the layer and a slowdown in the vertical mixing, confirming the important role of interactions among microphysics, radiation, and dynamics in this type of clouds. It is shown that at early stages, changes in liquid and ice water as well as in radiative cooling/heating rates are proportional to the Ni change, while changes in the vertical buoyancy flux are highly nonlinear, and, at some levels, differ even in sign between lower and higher Ni simulations. At higher Ni, the degree of reduction in positive buoyancy flux within and below the liquid cloud layer is large enough to slow down the circulation, making vertical motions too weak to sustain continuous formation of liquid water in the considered case.

Indirect effects in Arctic liquid-phase clouds during ISDAC

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Aircraft measurements during the Indirect and Semi-Direct Aerosol Campaign (ISDAC) in April 2008 are used to investigate aerosol indirect effects in Arctic clouds. Two aerosol-cloud regimes are considered in this analysis: single-layer stratocumulus cloud with below-cloud aerosol concentrations (Na) below 300 cm-3 on April 8 and April 26–27 (clean cases); and inhomogeneous layered cloud with Na > 500 cm-3 below cloud base on April 19–20, concurrent with a biomass burning episode (polluted cases). Vertical profiles through cloud in each regime are used to determine cloud microphysical and optical properties, while horizontal flight legs below cloud are used to characterize the physicochemical properties of precursor aerosol. The former are used to assess relationships between droplet effective radius (Re) and the cloud optical depth (τ) or albedo (A), which have been applied previously to investigations of indirect effects based on aircraft and satellite observations (vertical profile component); the latter are used in an aerosol-cloud droplet closure study, which examines the roles of aerosol number concentration, physicochemical properties, and vertical (updraft) velocity in droplet activation (droplet closure component). The analysis in the vertical profile component showed positive correlations between Re and

τ for both clean and polluted cases, which are characteristic of optically thin clouds such as those in the present analysis. The average Re for polluted cases was slightly larger than that for clean cases, despite significantly higher Nd, contrary to the typical trend for indirect effects, in which droplet size decreases with the number of droplets formed. This discrepancy was attributed to the higher liquid water path (LWP) for polluted cases relative to clean cases. In the droplet closure component, analysis using an adiabatic cloud parcel model indicated that most of the below-cloud aerosol in clean cases was activated to form droplets, and that activation was relatively insensitive to the updraft velocity. For the polluted case, a smaller number fraction of the below-cloud aerosol was activated, owing to the competition for vapour amongst the more numerous particles, which limited activation to larger and/or more hygroscopic particles; this case was therefore more sensitive to the updraft velocity. The results also indicated that for these cases, particle size was more important for activation than chemical composition and mixing state.

The influence of mixed-phase clouds on surface shortwave irradiance during the Arctic spring

Dan Lubin, Scripps Institution of Oceanography
Andrew Vogelmann, Brookhaven National Laboratory

The influence of mixed-phase stratiform clouds on the surface shortwave irradiance is examined using spectral irradiance measurements from the Indirect and Semi-Direct Aerosol Campaign (ISDAC). An Analytical Spectral Devices (ASD, Inc.) spectroradiometer measured downwelling spectral irradiance in the interval 350–2200 nm, in one-minute averages, throughout April–May 2008, from the ARM North Slope of Alaska (NSA) site at Barrow. The contrasting influences of mixed-phase clouds and liquid water clouds are discerned using irradiances in the 1.6 μm and 2.2 μm windows. Compared with liquid water clouds, mixed-phase clouds during the Arctic spring cause stronger attenuation of shortwave irradiance at the surface. At fixed conservative-scattering optical depth, the presence of ice water in cloud reduces the near-IR surface irradiance by an additional several watts per square meter. Typically, this additional forcing is ~3 watts per square meter near solar noon over Barrow, decreasing with increasing solar zenith angle. However, for some cloud decks this additional forcing can be as large as 5–6 watts per square meter. Mixed-phase clouds generally show larger conservative scattering optical depth than liquid-water clouds, implying that less shortwave irradiance tends to reach the surface at all wavelengths under mixed-phase clouds as compared with liquid-water clouds. Approximately 26% of the measurements were consistent with clouds having their optical properties dominated by liquid water; most of the rest were more consistent with a noticeable influence of ice particles.

Infrared remote sensing of ambient small particles observed during ARM SPARTICUS

Steven Cooper, University of Utah
Tim Garrett, University of Utah
Gerald Mace, University of Utah

There is currently significant uncertainty about the extent to which cirrus clouds are composed of ”small” ice crystals smaller than about 20 μm effective radius. This is due in part to concerns that in situ measurements from aircraft are plagued by ice-particle shattering on instrument inlets, artificially biasing effective radii low. Here, we apply space-based measurements as a constraint on these in situ estimates. Based upon signal-to-noise considerations, a retrieval scheme based upon the infrared split-window technique was designed to confidently identify the presence of small ice particles, regardless of potential inversion assumptions. The more commonly used operational retrieval approach using visible and near-infrared measurements was shown to suffer from potential uncertainties in inversion assumptions such as surface albedo and crystal habit that may make retrieved effective radii highly dubious. Airborne probe estimates of particle size from the ARM SPARTICUS field campaign were compared to infrared observations from Aqua MODIS instrument for co-incident A-Train overpasses. For these cases, agreement between retrieval results and in situ estimates were good in general, implying that the impact of inlet shattering on measurements must have been limited.

The linkages of aerosol and ice initiation in Arctic mixed-phase clouds as observed by long-term ARM ground-based and A-train satellite observations

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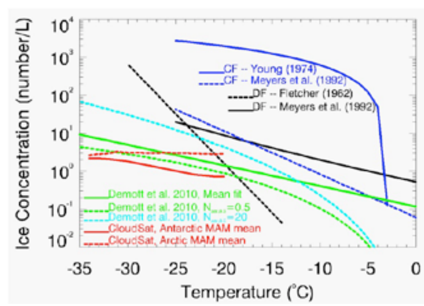
Damao Zhang, University of Wyoming
Min Deng, University of Wyoming
Tao Luo, University of Wyoming

A recent model intercomparison study highlighted the challenge of simulating arctic mixed-phase clouds in a variety of state-of-the-art numerical models. An advanced understanding and representation of them in climate models is critical to reduce the uncertainties of arctic climate predication due to the high occurrence of mixed-phase clouds over the Arctic. Understanding the linkages of aerosol and ice initiation in mixed-phase clouds is a critical step to develop a physically sounded mixed-phase representation in numerical models. This poster will present the new potentials of combining long-term ARM measurements at the Barrow site and the NASA A-train satellite measurements to study the problem. With ARM data, we found that the long-range transport dust aerosols have a significant impact on mixed-phase clouds properties in the spring season compared with the other seasons. The satellite measurements clearly indicate that this aerosol impact on mixed-phase clouds through ice production is evident Arctic-wide. By combining these two data sets, we show how aerosol seasonal variations over the region affect the liquid water path, ice-liquid mass partition, and their radiative forcing of arctic mixed-phase clouds. Furthermore, the potential to develop new heterogeneous ice nucleation parameterizations with these remote measurements will be also discussed. ARM measurements provide richer information for cloud microphysical processes studies than A-train satellite measurements. On the other hand, A-train satellite measurements provide much-needed spatial coverage. The complementary aspects of these two measurements will be highlighted.



Very large differences exist among different parameterizations of ice number concentration through heterogeneous ice nucleation. DF stands for deposition-condensation freezing nucleation, and CF stands for contact freezing nucleation. CloudSat and ARM remote sensing results (red) show a potential to provide new constraints on atmospheric heterogeneous ice nucleation.

Marine primary and secondary organic aerosols and their effect on indirect radiative forcing

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Brett Gantt, North Carolina State University

The effects of marine biogenic volatile organic compounds (BVOCs) and primary organic carbon aerosol emissions on microphysical properties of clouds were explored by conducting 10-year CAM5.0 model simulations at a grid resolution of 1.9°×2.5° with 30 vertical layers. The model-predicted relationship between ocean physical and biological systems and the abundance of cloud condensation nuclei (CCN) in remote marine atmosphere was compared to in situ measurements and data from the A-Train satellites. Model simulations show that on average, primary and secondary organic aerosol emissions from the ocean can yield up to a 5% increase in droplet number concentration of maritime shallow clouds and up to a 4% increase in liquid water path. Changes associated with cloud properties increase shortwave forcing over the oceans by -0.2 W/m2 and by -0.8 W/m2 over the Southern Ocean. By using different emission scenarios and droplet activation parameterizations, this study suggests that the addition of marine primary aerosols and biologically generated reactive gases makes an important difference in radiative forcing assessments.

Microphysical and optical properties of shallow convective clouds in large-eddy simulation with a double-moment warm-rain microphysics

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Wojciech Grabowski, National Center for Atmospheric Research
Hanna Pawlowska, Institute of Geophysics, University of Warsaw, Poland
Hugh Morrison, National Center for Atmospheric Research

This paper will present application of the double-moment bulk warm-rain microphysics scheme of Morrison and Grabowski to the simulation of a field of shallow convective clouds. The key components of the scheme are: (1) prediction of the cloud and raindrop concentrations in addition to the prediction of the mixing ratios; (2) prediction of the in-cloud supersaturation field; and (3) representation of various subgrid-scale mixing scenarios associated with the evaporation of cloud water due to entrainment. Prediction of the supersaturation field allows secondary in-cloud activation of cloud droplets above the cloud base. Pristine and polluted aerosol environments conditions are contrasted. Numerical simulations show that about 40% of cloud droplets originate from CCN activated above the cloud base. As a result, the mean cloud droplet concentration is approximately constant with height in agreement with aircraft observations and in contrast to simulations where the activation above the cloud base is disabled. The in-cloud activation significantly affects the vertical distribution of the effective radius and thus the mean albedo of the cloud field. The difference between pristine and polluted conditions is consistent with the previous modeling studies, but the impact of the subgrid-scale mixing scenario is significantly reduced. Possible explanations of the latter involve a combination of numerical and physical aspects that will be discussed at the meeting. These results will be presented in the context of recent observational and modeling studies concerning indirect aerosol effects in shallow convective clouds.

New particle formation observed in-cloud during STORMVEX

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Galina Chirokova, Desert Research Institute
Douglas Lowenthal, Desert Research Institute
Ian McCubbin, Desert Research Institute

Atmospheric aerosols can impact climate through direct and indirect radiative forcing, degrade air quality and visibility, and have detrimental effects on human health (e.g. Charlson et al. 1992, Akimoto 2003). Recent evidence suggests that newly formed particles exhibit enhanced hydroscopicity, may be more effective as cloud condensation nuclei (CCN), and may increase the indirect radiative effect beyond our current estimates (O'Halloran et al. 2009). Thus, understanding aerosol nucleation and growth is critical for assessing their role in climate change and atmospheric chemistry. Aerosol nucleation is defined as a rapid growth or "burst" of nanometer-sized particles. Nucleation mechanisms describe the initial formation of new atmospheric particles with diameters smaller than 3 nm. This is followed by rapid particle growth into the accumulation size mode (Kulmala et al. 2004a). During the Storm Peak Lab Cloud Property Validation Experiment (STORMVEX), winter 2010–2011, the second ARM Mobile Facility (AMF2) was deployed to Steamboat Springs, Colorado. The overall goal of this campaign was to measure cloud properties with remote sensing instruments such as cloud radars while aerosol and cloud microphysical measurements are made on the mountain crest at the Storm Peak Laboratory (SPL) and aloft from the University of Wyoming King Air research aircraft. An extensive suite of instruments was deployed for measurement of aerosol and cloud properties across the Steamboat Springs Ski Resort. At SPL, a TSI Nano-Scanning Mobility Particle Sizer (SMPS), a standard SMPS, and three Droplet Measurement Technology Cloud Probes (FSSP, CIP, and PIP) measured aerosol and cloud particle size distributions from 3 nm to 6.2 mm. An SMPS was also deployed at the AMF2 Aerosol Observing System (AOS) below SPL. Additionally, measurements of the cloud droplet size distribution were made from the King Air above SPL during the NSF-funded Colorado Airborne Multi-Phase Cloud Study (CAMPS) study. This presentation describes several case studies demonstrating new particle formation within clouds at SPL during STORMVEX, often with the King Air aircraft overhead. The growth evolution of newly formed 3 nm particles was observed at SPL. Concurrent cloud microphysical data collected at SPL and aboard the King Air will be presented. Aerosol growth episodes observed below cloud base at the AOS site will be discussed.

Optically thin ice clouds in Arctic: formation processes

Caroline Jouan, UQAM Laboratoire Atmosphères, Milieux, Observations Spatiales

Arctic ice cloud formation during winter is poorly understood mainly due to the lack of observations and the remoteness of this region. Their influence on climate is of paramount importance, and the modification of their properties, linked to aerosol-cloud interaction processes, needs to be better understood. High concentration of aerosols (Na) in Arctic during winter is associated with long-range transport of anthropogenic aerosols from the midlatitudes. Observations and models show that this may lead to a significant transport of acidified aerosols. Laboratory and in situ measurements show that at cold temperature (<-30 °C), acidic coating lowers the freezing point and deactivates ice nuclei. The IN concentration is reduced in these regions, and there is less competition for the same available moisture. Large ice crystals form in relatively small concentrations. It is hypothesized that the observed low concentration of large ice crystals (NIce) in thin ice clouds (TICs) is linked to the acidification of aerosols. To check this, we are combining case studies and statistical approaches to analyze aerosol transport and cloud properties in Arctic. Extensive measurements from ground-based sites and satellite remote sensing reveal the existence of two types of extended TICs in Arctic during the polar night and early spring. The first type (TIC1) is seen only by the lidar but not the radar and is found in pristine environments, whereas the second type (TIC2) is detected by both sensors, associated with high Na, possibly anthropogenic, and characterized by low NIce that are large enough to precipitate. To investigate the interactions between TICs and aerosols, airborne and satellite measurements of specific cases observed during the ISDAC field experiments have been first analyzed. This field campaign took place in Alaska in April 2008. The airborne instruments include a complete set of dynamic, thermodynamic, radiation, aerosol, and microphysical sensors. From these observations, a first classification has been performed, and significant differences have been identified between flights. A comparison of microphysical properties of different TICs will be presented. The Lagrangian Particle Dispersion Model FLEXPART is used to study the origin of observed air masses, to be linked with pollution sources. First results from the statistical analyses of cloud properties over the ISDAC area using the database created from CloudSat and CALIPSO observations will be discussed.

An overview of the 2012 Two-Column Aerosol Project (TCAP)

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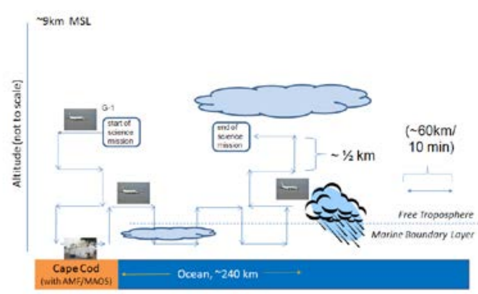
The 2012 Two-Column Aerosol Project (TCAP) will deploy the ARM Mobile Facility (AMF) and the Mobile Aerosol Observing System (MAOS) on Cape Cod (Massachusetts) for a 12-month period starting in the summer of 2012 in order to quantify aerosol properties, radiation, and cloud characteristics at a location subject to both clear and cloudy conditions and clean and polluted conditions. These observations would be supplemented by two aircraft intensive observation periods (IOPS), one in the summer and a second in the winter. The aircraft will be equipped with a suite of in situ instrumentation to provide measurements of aerosol optical properties, particle composition (sampled through both an isokinetic and counterflow virtual impactor inlets), and direct-beam irradiance. Each mission will consist of making measurements within two columns of air. One column will be located over the AMF/MAOS Cape Cod site, while a second column would be located a few hundred kilometers east of Cape Cod. The aircraft will make a series of stair-step



Schematic of proposed flight plan showing stair-step profiles over the two columns of air and sampling strategy during transit between the columns. Each horizontal arrow represents 10 minutes of flight time.

profiles within the first column followed by sampling within and above the marine boundary layer as it transits to the second, more remote column for a second set of stair-step profiles. Measurements will be used to address four broad scientific objectives:

- Perform a local radiation closure study and a chemical closure study of cloud condensation nuclei, both of which make use of collocated airborne and surface measurements (three projects).
- Evaluate a new retrieval algorithm to evaluate aerosol optical depth (AOD) in the presence of clouds using passive remote sensing.
- Document cloud microphysical properties in terms of aerosol loading, chemistry, and cloud dynamics related to aerosol indirect effects.
- Use the observations and the results of the analyses from the above to evaluate the performance of both a regional-scale model and a global circulation model (two projects).

It is our strong desire that these measurements also serve the interests of the Aerosol Life Cycle, Cloud Life Cycle, and Cloud-Aerosol-Precipitation Interactions working groups of the DOE's Atmospheric System Research (ASR) program and the broader climate research community.

http://www.arm.gov/news/features/post/10708

The Pico and Graciosa cloud optical thickness experiment

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Deployment of the first ARM Mobile Facility 1 (AMF1) at Graciosa, Azores, Portugal, and a portable radiation package near the summit of the nearby Pico Island volcano afforded a rare opportunity to directly measure radiation transmission in a variety of boundary-layer cloud configurations. Pico's summit, which extends above the marine boundary layer, was instrumented with a multifilter shadowband radiometer (MFRSR), pyrgeometer, and pyranometer. Beneath the clouds near the ocean surface at nearby Graciosa Island was an identical set of radiometers deployed as part of AMF1 operating alongside the full complement of AMF1 active remote sensors. This geographic region often lacks the aerosol loads associated with continental locations whereupon aerosol radiative influences are minimized, enabling the radiative impacts of the clouds to be isolated. Relatively unambiguous direct and continuous measurements of radiation transmission were possible in broken clouds and in overcast conditions. These transmission measurements are classified according to cloud and boundary-layer structure using the AMF1 active remote sensors, and important benchmarks such as the obscuration of the sun's disk at optical thickness eight are directly observed, lending credibility to the accuracy of this measurement approach. Basic cloud and boundary-layer morphology are related to transmission, revealing interesting aspects of the radiation field.

The role of small aerosols in the microphysics and precipitation of deep maritime cumulus clouds

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Some observational evidence such as bi-modal size distributions, comparatively high concentrations of supercooled drops at upper levels, high concentrations of small ice crystals in cloud anvils leading to high optical depth, as well as lightning that can take place in the eye walls of hurricanes, indicate that the traditional view of microphysics of deep maritime clouds requires, possibly, some revisions. Numerical simulations using the spectral microphysics Hebrew University cloud model show that these observed features can be attributed to existence in the atmosphere of small aerosols with diameters less than about 0.05 microns in the cloud condensational nuclei (CCN) size spectra. Intense drop collisions below and around the freezing level lead to a dramatic decrease in droplet concentration during ascent in convective updrafts. Being accompanied by intense vertical velocity, this decrease in the drop concentration leads to a dramatic increase in supersaturation, activation of the smallest CCN aerosols, and production of new droplets several kilometers above cloud base. The increase in supersaturation and in-cloud nucleation during ascent can also be partly related to a decrease in droplet concentration by riming at cold temperatures. Successive growth of these droplets leads to formation of supercooled water and significant ice crystal concentrations aloft. The role of giant CCN is reconsidered. The synergetic effect of the smallest CCN and giant CCN in production of small supercooled water and ice crystals in cloud anvils is analyzed. Significant effects from small aerosols on various microphysical parameters of clouds such as precipitation, cloud updrafts, and radar reflectivity were found. The possible role of these small aerosols in formation of conditions favorable for lightning in deep maritime clouds is discussed. As far as we are aware, this is the first study in the literature to chart the diverse impacts on the physics and dynamics of maritime deep convection from such soluble aerosols smaller than 0.05 microns.

The roles of aerosols in the climate and its changes: what have we learned from the AMF-China campaign and future challenges?

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Heavy and widespread presence of aerosols in China could impinge significantly on regional and global climate depending on aerosol distribution, transport, and evolution of optical, physical, and chemical properties. To unravel the impact and interactions between aerosols and regional climate, several field experiments have been conducted in the region, most notably the Atmospheric Radiation Measurement (ARM) Climate Research Facility's Mobile Facility deployment in 2008 (AMF-China). Thanks to the field experiments, rich data have been acquired pertaining to aerosol properties, meteorological regimes, cloud, radiation, and precipitation, which allow us to gain insights into the potential mechanism by which aerosols affect and interact with the monsoon regime. By taking advantage of the field observation data, many investigations have been carried out with major findings published in a special issue of the Journal

of Geophysical Research. A subset of the studies by means of data analysis and modeling (GCM and CRM) will be reviewed that is concerned with aerosol direct and indirect effects on the climate via altering radiation budget (from top to the bottom), atmospheric thermodynamics (adiabatic heating), cloud microphysical processes, and atmospheric circulation. Remaining challenges and proposed solutions for future studies will be discussed as well.

http://www.agu.org/journals/jd/special_sections.shtml?collectionCode=EASTAIRC1

Size-resolved CCN composition in cumulus humilis

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The Cumulus Humilis Aerosol Processing Study (CHAPS) provided a unique opportunity to study cloud processing of aerosols. Clouds play an active role in the processing and cycling of atmospheric constituents. Within in a cloud, gases and particles can partition to cloud droplets by absorption and condensation as well as activation and impact scavenging. The Department of Energy (DOE) G-1 aircraft was used as one of the main platforms in CHAPS. G-1 flight tracks were designed to characterize aerosols at cloud top and cloud base as well as within individual cumulus humilis (or fair-weather cumulus) in the vicinity of Oklahoma City. Measurements of interstitial aerosols and residuals of activated condensation cloud nuclei were conducted simultaneously. The interstitial aerosols were measured downstream of an isokinetic inlet and the activated particles downstream of a counter-flow virtual impactor (CVI). The sampling line to the Aerodyne Aerosol Mass Spectrometer (AMS) was switched between the isokinetic inlet and the CVI to allow characterization of non-activated particles outside of clouds in contrast to particles activated in clouds. Trace gases including ozone, carbon monoxide, sulfur dioxide, and a series of volatile organic compounds (VOCs) were measured. Key meteorological state parameters included liquid water content, cloud drop size, and dew point. In this presentation, we will focus on case studies of CCN properties in cumulus humilis. The first analysis summarizes three case studies of measurements made at cloud bottom and in-cloud by the AMS. The size-resolved composition is different between background and activated particles. The second analysis links in situ measurements of aerosol, trace gas, and VOCs to look into the sources of CCN. For instance, by comparing the characteristic m/z ratios by AMS and tracers like CO or isoprene, one can gain more insight into the role of primary and secondary organic aerosols in CCN and background aerosols. The third analysis will use a recently developed method to bin data collected within the cumulus humilis to study the correlation between CCN composition and cloud properties. The presentation will provide an improved picture of CCN in cumulus humilis.

Stratus fog formation and dissipation: a six-day case study

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A suite of active and passive remote sensing instruments and in situ sensors deployed at the SIRTA Observatory (Instrumented Site for Atmospheric Remote Sensing Research) near Paris, France, for six months (October 2006 to March 2007) document simultaneously radiative, microphysical, and dynamic processes driving the continental fog life cycle. The study focuses on a six-day period between December 23–29, 2006, characterized by several stratus cloud lowering and lifting events and almost 18 hours of visibility lower than 1 km. The formation, the development, and the dissipation phases of four major stratus fogs are here analyzed to quantify the impact of each physical process. The coupling between the surface and the stratus cloud altitude shows a very good agreement for the six-day period except for some specific periods studied here. A first dense but short in duration fog event is driven by the in-cloud dynamics. The turbulent mixing rate and the sedimentation process (vertical velocity near -1 ms^{-1}) are the dominant processes involved in the dissipation of the fog. In two other cases, the significant near-surface turbulence with a turbulent kinetic energy in excess of 1 $m^{-2}s^{-2}$ induced by wind shear modulates the intensity of the stratus cloud lowering periods. The study also shows the impact of a high-altitude cloud on the infrared radiative cooling at the stratus cloud top. The cloud-top infrared flux budget ranges from -160 to -130 Wm^{-2}, and it corresponds to strong changes in radar reflectivity (-10 to -22 dBZ) and in-cloud velocity (-0.3 to 0 ms^{-1}), producing a strong variability in visibility.

Surface dimming and cloud response due to black carbon and absorbing organic carbon aerosols

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Surface measurements have shown significant decreases in solar radiation (dimming) in many regions since the 1960s. At least half of the observed dimming could be linked to the direct radiative effect of anthropogenic aerosols, especially absorbing aerosols like black carbon (BC) due to their strong atmospheric absorption. However, model-data comparisons indicate that absorption by aerosols is largely underestimated in current GCM simulations by several factors over some regions. Using a global chemical transport model coupled with a radiative transfer model, we include a treatment for absorbing organic carbons (OC) from bio-fuel and open biomass burnings in optical calculations and estimate aerosol radiative forcings for two anthropogenic aerosol emission scenarios representative of the 1970s and circa 2000. Assumptions about aerosol mixing and the OC absorption spectrum are examined by comparing simulated aerosol absorption and atmospheric heating against surface and aircraft measurements. We will also examine regional variations in cloud liquid content and thickness in the presence of absorbing aerosols (BC, OC, and dust), with a focus on the ARM fixed sites and AMF deployments. The calculated aerosol single-scattering albedo (0.93+/-0.044) is generally consistent with the AERONET data (0.93+/-0.030) for the year 2001. On a global scale, inclusion of absorbing OC enhances the absorption in the atmosphere by 11% for July, globally. The estimated present-day direct

radiative forcing by anthropogenic aerosols (-0.24 W/m2) is similar to the TOA average value by the AeroCom models based on the same 2000 emissions, but significantly enhanced negatively at surface by about 53% (-1.56 W/m2) and increased in the atmosphere by +61% (+1.32 W/m2). About 87% of the atmosphere absorption and 42% of the surface dimming is contributed by BC. Between 1975 and 2000, the calculated all-sky flux at surface has decreased about 6 W/m2 over east China (equivalent to about 5 W/m2 per decade in clear sky), but increased about 1 W/m2 in Europe. The non-uniformly regional trends in surface solar radiation correspond to changes in BC and sulfur emissions from fossil fuel and bio-fuel combustion sources. By considering OC absorption and internal mixing of aerosols, we improved the simulated dimming trend in regions like Asia where the observed clear-sky reduction is as much as 9 W/m2 per decade due to rapidly increasing anthropogenic emissions, which have been linked to the recent regional climate anomalies.

Surface summertime radiative forcing by shallow cumuli at the ARM SGP

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Shallow cumuli are common over large areas of the globe, especially over the oceans. Their impact on the surface cloud radiative forcing (CRF), however, has not been carefully evaluated in the past. This study addresses this shortcoming by analyzing data collected during selected periods with single-layer shallow cumuli over eight summers (2000 through 2007) at the U.S. Department of Energy Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) site. During periods with shallow cumuli, the average shortwave and longwave CRF at the surface are 45.5 W m-2 (out of 612 W m-2 estimated for clear sky conditions) and +15.9 W m-2 (out of -105.2 W m-2 estimated for clear sky conditions), respectively. Instances of cloud-induced enhancement of the shortwave irradiance over that estimated for clear skies are observed to occur nearly 20% of the time and are caused by the spatial and temporal inhomogeneity of fields of cumuli. Such enhancement is responsible for occurrences of positive shortwave CRF with instantaneous values as large as +75 W m-2. The total amount of shortwave and longwave energy deposited at the surface is found to depend non-linearly on the fractional sky cover, and the largest values of the deposited energy occur for intermediate cloud amounts between 0.4 and 0.6.

Testing a new aerosol-dependent ice nucleation parameterization for predicting ice nuclei and simulating mixed-phase clouds during ISDAC

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A new aerosol- and temperature-dependent ice nucleation parameterization valid for mixed-phase cloud activation conditions is reviewed and then compared to independent ice nuclei and aerosol measurements made during the Indirect and Semi-Direct Aerosol Campaign (ISDAC). We show good correspondence in many cases, within a factor of two on average, for situations where ice nuclei processing conditions matched those for which the parameterization is considered valid. We then performed cloud-resolving model (System for Atmospheric Modeling–SAM) simulations of a single-layer Arctic stratus case from ISDAC on April 26, 2008. Using prescribed aerosols based on actual measurements on this day, cloud microphysical properties were well reproduced. Sensitivity studies through increasing or decreasing ice nuclei by a factor of 10 did not successfully reproduce cloud properties. The implications that ice nuclei exert a strong controlling factor on proper simulation of these clouds must be further examined in future simulations using fully prognostic ice nuclei.

Toward ice formation closure in Arctic mixed-phase boundary-layer clouds

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Mixed-phase stratus clouds are common during winter and transition seasons in the Arctic and through various feedback mechanisms are expected to exert a strong influence on Arctic climate. Despite their important role, their representation in cloud models remains problematic. In particular, models of all types experience difficulties reproducing observed ice crystal number concentrations and liquid-ice phase partitioning in these clouds. The supply rate of heterogeneous ice nuclei (IN) to the boundary layer from air aloft is typically too slow—relative to the sedimentation sink at the surface—to explain observed number concentrations of ice crystals (only counting sizes that are expected to minimize shattering artifacts), as has been found by a number of studies. This longstanding discrepancy has driven consideration of alternative ice nucleation mechanisms or IN sources that may elude detection by the standard portable IN measurement method (the Continuous Flow Diffusion Chamber). Recent advances in the design of probe tips for instruments measuring ice-crystal size distributions reduce shattering artifacts and provide greater confidence in measured ice concentrations. These improved tips were deployed during the Indirect and Semi-Direct Aerosol Campaign (ISDAC) in April 2008. A well-studied case study from another field project (M-PACE) was complicated by the presence of a variety of ice crystal habits with different mass growth rates and fall-speed relationships or complicated shapes for which the fall-speeds are not well constrained. The April 8 case study from ISDAC presents a contrasting case. The in situ observations indicate predominance of pristine dendritic ice crystals and their aggregates with no riming, which have slow fall speeds and thus provide a slow removal rate of ice concentration by number, which favors the possibility that IN entrained into the boundary layer from aloft—at concentrations far greater than found in the M-PACE case—can maintain sufficient ice concentrations. Also, much of the instrumentation on the Convair-580 was operational for this case, and the aircraft overflew the Barrow ground site, allowing intercomparison of measurements and greater constraints on model simulations. We note that Mie calculations for soft spheres are inadequate for computing Ka-band backscatter coefficients for mm-size dendrites and aggregates, so we use more complex treatments (finite-difference time-domain and generalized multi-particle Mie methods) to compute radar reflectivities from particle size distributions (from simulations and in situ measurements). Using large-eddy simulations with size-resolved microphysics, we find that if there is a reservoir of IN below the cloud base in this decoupled boundary layer, or if there are four times the IN above the boundary layer as observed, we can generally match the observed particle size distributions and probability distributions of radar reflectivity by treating the ice as stellar dendrites and including their aggregation. However, the measured mass concentration of ice remains an outstanding issue in this study. In addition, results are sensitive to a number of factors, including assumed upwind fetch, details of aggregation, and size-segregated ice crystal properties (and their distribution) that are not directly constrained by measurements.

Toward improving ice nucleation parameterization and aerosol effects on mixed-phase and ice clouds

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Ice nucleation is an important microphysical process in mixed-phase and ice clouds. However, our current understanding of nucleation mechanisms is still very poor. In order to include aerosol effects on ice-containing clouds, ice nucleation processes must be described in terms of aerosol properties. Classical Nucleation Theory (CNT) can be used to do that if its key parameters are properly constrained. In this study, the new laboratory data for deposition nucleation on mineral dust collected at the Pacific Northwest National Laboratory Atmospheric Measurements Laboratory (AML) together with published data from other laboratories are used to constrain the parameters in CNT, such as contact angle (a parameter in CNT to represent the ice-nucleating ability of aerosols). Lognormal probability distribution functions (PDF) of contact angle are derived for different dust types, temperatures, and dust particle sizes. Using cloud-resolving model simulations, we evaluate the sensitivity of cloud properties to changes in the PDF parameters (mean and standard deviation) for contact angle distribution. We find that with the derived lognormal distribution of contact angle, the observed freezing probability can be reasonably reproduced. Simulated cloud microphysical properties, cloud onset time, thickness, and lifetime are very sensitive to changes in contact angle distribution, which suggests the importance of improving the ice nucleation parameterizations.

The variation of the microphysical properties of arctic stratus clouds as a function of aerosol concentration: results from ISDAC

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During the Indirect and Semi-Direct Aerosol Campaign (ISDAC), a comprehensive data set on the microphysical and radiative properties of boundary layer clouds and aerosols was collected using an unprecedented 41 state-of-the-art cloud and aerosol instruments installed on the National Research Council of Canada Convair-580, which flew 27 sorties for more than 100 hours on 12 different days in the vicinity of Barrow, Alaska, in April 2008. Data from a cloud droplet probe, a two-dimensional stereo probe, and cloud and precipitation imaging probes are used to determine best estimates of cloud drop concentrations, ice crystal concentrations, liquid and ice crystal effective radii, and maximum crystal sizes as a function of aerosol concentrations measured using a Passive Cavity Aerosol Spectrometer Probe (PCASP) and ice nuclei concentrations measured by a Continuous Flow Diffusion Chamber (CFDC). In this presentation, the relationship between the aerosol and cloud microphysical quantities is examined in the context of varying meteorological and surface conditions in an effort to assess the impact of the glaciation, riming, and second indirect effects in arctic boundary layer clouds.

3.0 Aerosol Properties

Aerosol optical and microphysical properties from passive remote sensing during CARES: temporal and spatial changes

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One of the main purposes of the recently conducted Carbonaceous Aerosol and Radiative Effects Study (CARES) is to investigate the spatio-temporal changes of aerosol optical properties in the central part of California during late May and June. In this presentation we focus on column-integrated aerosol optical properties, such as aerosol optical depth (AOD), single-scattering albedo (SSA), and asymmetry parameter (AP). These column properties are retrieved from data obtained with ground-based instruments, namely the multifilter rotating shadowband radiometer (MFRSR) and the Cimel sunphotometer. To explore the spatial distribution of aerosol properties, two MFRSRs are deployed at two sites with a mean distance between them of about 30 km. Both the MFRSR- and Cimel-based data capture large diurnal and day-to-day variations of aerosol properties. For example, wide ranges of daily averaged AOD (0.05–0.15) and SSA (0.80–0.98) values at 500 nm are observed. Also, the analysis of the MFRSR and Cimel data suggests that the retrieved aerosol size distribution (SD), and particularly its coarse mode, is characterized by substantial diurnal and day-to-day changes. The coarse mode is sometimes so large that it may exert a powerful influence on the aerosol optical properties. To examine the robustness of the retrieved aerosol properties (SSA, AP, and SD), we compare them with measurements provided by the corresponding in situ ground-based instruments. The results of such comparison will be presented as well.

Aerosol optical depth climatology observed by micropulse lidar at ARM Southern Great Plains site in northern Oklahoma

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A polarized micropulse lidar (MPL) at the U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) site in Northern Oklahoma (36.606 N, 97.50 W, 320 m asl) has been in operation since late 2006. The MPL database now contains over four years of atmospheric backscattered signals from this system. We have used these data to calculate aerosol optical depths. Of the approximately 1500 days observed, 250 were found as clear days; the data on those days were used in this aerosol optical depth (AOD) climatology. AOD is a measure of the extinction of the sun's beam due to aerosols. Based on the method of Fernald (1984), using the derived AOD from the nearly collocated multifilter rotating shadowband radiometer (MFRSR) measurement and a modeled molecular scattering profile, the vertical distribution of aerosol extinction coefficients and AODs were retrieved and analyzed. The results were also compared with collocated Raman lidar and are in good agreement. A multiyear AOD climatology, including diurnal and seasonal variability, will be presented.

Aerosol sources and processing at the Ganges Valley Aerosol Experiment (GVAX) Pantnagar supersite

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The Ganges Valley (GV) region has some of the highest observed aerosol optical depths in the world. The aerosol layer extends over a vast area, and increasing aerosol loading may have significant impacts on regional and global climate. Evaluating the role of aerosols in climate change requires understanding the sources, sinks, and atmospheric processing of aerosol particles. These are not well-characterized in the GV, one of the least-sampled areas of the world. The DOE Ganges Valley Aerosol Experiment (GVAX) campaign will address aerosol-climate connections through a year-long campaign of radiative measurements at the Nainatal Observatory (at 2000 m) in the foothills of the Himalayas. A two-month intensive, planned for early 2012, will focus on aerosol chemical composition and aging as particulate matter is transported across the Ganges Valley plain and into the foothills. Intensive measurement sites include Pantnagar (25 km south of Nainatal) and Lucknow (360 km south of Pantnagar), as well as flights of the DOE G-1 instrumented aircraft from Lucknow. In addition, an instrumented van operated and funded by the Indian Institute of Science/Indian Space Research Organization (IISc/ISRO) and supported by DOE will operate between these measurement sites. At the Pantnagar supersite, we will deploy instruments to make critical measurements for understanding aerosol life cycle processes and the fundamental microphysics of aerosol-cloud interaction, including continuous, high-time-resolution measurements of aerosol chemistry and microphysics, gas-phase tracers and secondary organic aerosol (SOA) precursors, hygroscopic properties of the aerosol particles, and in situ and column aerosol optical properties. Specific goals include optical and CCN closure studies, particulate emissions source characterization, and understanding the atmospheric processing of aerosol particles in the GV. We will combine in situ, remote sensing column, and vertical profile observations of SOA precursor trace gases and aerosol optical properties to link the ground-based data set with that from DOE's G-1 aircraft, assess boundary layer dynamics, and bridge to the spatial scales predicted by atmospheric models. The Pantnagar supersite and instrumented van are critical for coupling surface observations to the remote sensing and radiation measurements at Nainital site for a regional overview of aerosol chemical and physical properties.

Cloud activation properties of organic aerosols observed at urban sites during CALNEX-LA and CARES

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Atmospheric aerosols strongly influence the global energy budget. Currently, the indirect effects of aerosols remain the most uncertain components in forcing of climate change over the industrial period. This large uncertainty is in part due to our incomplete understanding of the ability of aerosol particles to form cloud droplets under climatically relevant supersaturations. During two recent field campaigns, size-resolved cloud condensation nuclei (CCN) spectrum and aerosol chemical composition were characterized at urban supersites in Pasadena, California (CALNEX-LA) and Cool, California (CARES) in summer 2010. At both sites, monodispersed aerosol particles were first classified using a differential mobility analyzer at sizes ranging from 25 to 320 nm. The activation efficiency of the classified aerosol, defined as the ratio of its CCN concentration (characterized by a DMT CCN counter) to total CN concentration (measured by a condensation particle counter, TSI 3771), is derived as a function of both particle size and supersaturation, which ranges from 0.08% to 0.39% during CAlNEX-LA and 0.15% to 0.45% during CARES. Aerosol chemical composition was characterized using a high-resolution time-of-flight aerosol mass spectrometer (HR-ToF-AMS). At both sites, increases in aerosol mode diameter, organics mass loading, and aerosol organics volume fraction were often observed from ~10:00 AM to 16:00 PM during weekdays. Some of these increases are attributed to the morning traffic pollution from downtown Los Angeles and downtown Sacramento, respectively. Positive matrix factorization (PMF) analyses of AMS measurements at both sites were carried out, and the organics O:C ratios were examined. Particle overall hygroscopicity (κ, Petters and Kreidenweis, 2007, ACP) was derived from the size-resolved CCN measurements ranging from 0.2 to 0.3 under the range of measured supersaturations. The derived particle κ increases with increasing particle diameter, which is consistent with observed decrease in organics volume fraction as particle size increases from 100 nm to 300 nm. Based on the particle hygroscopicity and aerosol chemical composition, the organics hygroscopicity (κOrg) was derived and correlated with the O:C ratio. The comparison of aerosol source, aerosol chemical composition, and organics hygroscopicity between the two sites will be discussed. Besides particle critical supersaturation, the influence of organics species on droplet growth is also examined.

Cloud condensation nuclei (CCN) activity and composition of secondary organic material

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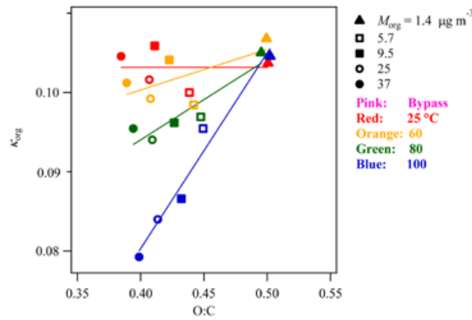
Mikinori Kuwata, Harvard University
Qi Chen, Harvard University



Dependence of Korg on O:C ratio. Lines are drawn through the data at each thermodenuder temperature to guide the eye. Marker shape represents M prior to heat treatment. Marker color represents thermodenuder temperature.

The effects of thermodenuder treatment on CCN activity and composition of organic particles grown by α-pinene ozonolysis were investigated. The secondary organic material (SOM) was produced in a continuous-flow chamber, with steady-state organic particle mass concentrations M ranging from 1.4 to 37 μg m-3. Particles exiting in the outflow were heated to temperatures T of up to 100 °C in a thermodenuder. The oxygen-to-carbon (O:C) and hydrogen-to-carbon (H:C) ratios were measured on-line. The observed elemental ratios were fit by a linear function, given by (H:C) = -0.8 (O:C) +1.8 for 0.38 < O:C < 0.50. This fit included the dependence on both M and T. The implication is that a single variable, specifically M following thermodenuder treatment, served as an accurate predictor for O:C(M(T)) and H:C(M(T)). This result suggests that equilibrium partitioning largely governed the initial volatilization in the thermodenuder. By comparison, the CCN activity had a different dependence on thermodenuder treatment. At 25 °C, the CCN activity was independent of M, having an effective hygroscopicity parameter Korg of 0.103 ± 0.002. At 100 °C, however, Korg varied from 0.105 for 1.4 μg m-3 to 0.079 for 37 μg m-3, indicating that for high mass concentration, the CCN activity decreased with heat treatment. The interpretation is that the oligomer fraction of the SOM increased at elevated T, both because of particle-phase reactions that produced oligomers under those conditions and because of the relative enrichment of lower-volatility oligomers accompanying the evaporation of higher-volatility monomers. Oligomerization reactions increase the effective molecular weight, thereby significantly influencing CCN activity. The types and rates of oligomerization reactions that occur depend strongly on the types and concentrations of functional groups present, which in turn are strongly influenced by M. We conclude with a hypothesis, which is supported by a detailed molecular kinetic model, that the changes in Korg at high T were more significant at high M compared to low M, because particle-phase SOM at high M contained a mix of functional groups favorable to oligomerization, such as carbonyl groups. The oligomerization reactions at elevated T might serve as a laboratory-accelerated model system for similar reactions that occur in the atmosphere at longer timescales, such as timescales of days to weeks not easily accommodated directly in laboratory studies.

The diurnal cycle of particle, size, composition, and density in Sacramento, California, during CARES

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A central objective of the Carbonaceous Aerosol and Radiative Effects Study (CARES) was to characterize all aspects related to organics in aerosols. To this end, a range of instruments measured loadings, size distributions, compositions, densities, CCN activities, and optical properties of particles in Sacramento, CA during June 2010. We present the results of measurements conducted by our single particle mass spectrometer, SPLAT. SPLAT measured the size, composition, and density of individual particles with diameters between 50 to 2000 nm. Each day, SPLAT measured the size of ~2 million particles and the compositions of ~350,000 particles. In addition, SPLAT, combined with a DMA, measured the density of individual particles twice per day: in the morning and mid-afternoon. Preliminary analysis of the data shows that under most conditions, the particles were relatively small (below 200 nm), and the vast majority were composed of oxygenated organics mixed with various amounts of sulfates. Analysis of the mass spectra shows that the oxygenated organics in these particles are the oxidized products of biogenic volatile organic precursors. In addition, we detected and characterized fresh and processed soot particles, biomass burning aerosol, organic amines, sea salt—fresh and processed—and a small number of dust and other inorganic particles commonly found in the urban environment. SOA mixed with sulfates were the vast majority of particles at all times, while the other particle types exhibited episodic behavior. The data show a reproducible diurnal pattern in SOA size distributions, number concentrations, and compositions. Early in the morning the particle number concentrations are relatively low, and the particle size distributions peak at ~70 nm. 80 nm particles have a density of 1.3 g cm-3, and the density of larger particles (200 nm) is 1.6 g cm-3. The mass spectra show that the smaller particles are composed of organics mixed with ~10% sulfates, and larger ones contain mostly sulfate with a small amount of organics. As biogenic emissions are processed, nucleation events lead to a large increase in the concentrations of very small particles. As the day progresses, particle number concentrations increase and particles grow. By mid-afternoon, the density of 80 to 200 nm particles is ~1.3 g cm-3, and particles are composed of oxygenated organics mixed with a ~10% sulfate. A detailed analysis of the mass spectra shows that there are two types of SOA particles. Interestingly, we find evidence to suggest that in both particle types, a large fraction of the intensity in peaks at m/z 44 and 73 is related to surface compounds.

Elemental analysis and oxidation of chamber organic aerosol

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The principal means of assessing the rates of formation and composition of organic aerosol is laboratory chamber studies. Aerosol composition measurements with the Aerodyne Aerosol Mass Spectrometer (AMS) have demonstrated the wide range in the degree of oxygenation of ambient and chamber secondary organic aerosol (SOA). In this work, we investigate the elemental composition (C, H, O) and oxidation of chamber organic aerosol from a wide assortment of anthropogenic and biogenic precursors, including glyoxal, alpha-pinene, isoprene, aromatics, naphthalene, methoxyphenols, and unsaturated aldehydes. Using the "triangle plot" (Ng et al. 2010) and the Van Krevelen diagram (Heald et al. 2010), we compare SOA spectra from different precursors and discuss the similarities of elemental ratios derived from HR AMS spectra and offline speciation techniques. We find that elemental composition estimates from the AMS agree well with molecular speciation studies that have a substantial percentage of mass closure. We also find that LV-OOA O:C ratios can be achieved with oxygenated precursors in chamber experiments, and the "triangle region" can be outlined by chamber SOA spectra.

Evaporation kinetics and phase of laboratory and ambient secondary organic aerosol and the effect of adsorbed spectator gases

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Field measurements of secondary organic aerosol (SOA) find significantly higher mass loads than predicted by models, sparking intense effort focused on finding additional SOA sources but leaving the fundamental assumptions used by models unchallenged. Current air-quality models use absorptive partitioning theory assuming SOA particles are liquid droplets, forming instantaneous reversible equilibrium with gas phase. Further, they ignore the effects of adsorption of spectator organic species during SOA formation on SOA properties and fate. Using an accurate and highly sensitive experimental approach for studying evaporation kinetics of size-selected single SOA particles, we characterized room-temperature evaporation kinetics of laboratory-generated α-pinene SOA and ambient atmospheric SOA. We found that even when gas phase organics are removed, it takes ~24 hours for pure α-pinene SOA particles to evaporate 75% of their mass, which is in sharp contrast to the ~10-minute timescale predicted by current kinetic models. SOA formed in the presence of "spectator" hydrophobic organic vapors like dioctyl phthalate, dioctyl sebacate, pyrene, or their mixture, were shown to adsorb noticeable amounts of these organics, forming what we term here "coated" SOA particles. We find that these adsorbed coatings further reduce evaporation rates of SOA particles. Moreover, aging of coated SOA particles dramatically reduces evaporation rates, and in some cases nearly stops it. To address the question of how closely the laboratory observations described above reflect reality in the atmosphere, we characterized the evaporation kinetics of size-selected atmospheric SOA particles sampled in situ during the recent Carbonaceous Aerosols and Radiative Effects Study (CARES) field campaign. Ambient SOA was found to exhibit evaporation behavior very similar to that of laboratory-generated coated and aged SOA. Like laboratory SOA, their evaporation is size-independent and does not follow the kinetics of liquid droplets, in sharp contrast with model assumptions. The findings about SOA phase, evaporation rates, and the importance of spectator gases and aging all indicate that there is a need to reformulate the way SOA formation and evaporation are treated by models. Presently we are developing a new modeling approach that takes into account these new findings. Some preliminary modeling results will be presented.

A general framework for predicting CCN activity of organic molecules from functional group data

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Sonia Kreidenweis, Colorado State University
Christian Carrico, Colorado State University
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Anthony Prenni, Colorado State University
Sarah Suda, North Carolina State University
Christopher Sullivan, Colorado State University

Secondary organic aerosols (SOA) formed from anthropogenic and biogenic precursors comprise a significant fraction of the atmospheric aerosol burden and play an important role in direct and indirect aerosol effects on climate. To model SOA-cloud interactions, we ultimately seek relationships that can predict a compound's contribution to a particle's ability to serve as a cloud condensation nucleus (CCN) based on its chemical composition. Towards this end, we designed experiments with pure organic compounds and model SOA systems to investigate the role of molecular size and the abundance of specific functional groups on promoting CCN activity. The relative CCN efficiency of a compound is described by the hygroscopicity parameter kappa. We find that for sufficiently functionalized molecules, kappa is well-modeled using predictions based on molar volume as described by the Flory-Huggins combinatorial. Compounds with fewer functional groups strongly deviate from this model, resulting in a continuum of reduced kappa values between the molar volume model and zero. We use experimentally determined derivatives of d(kappa)/d(number of functional groups of type i) to quantify this effect and to develop a framework that can be used to compute kappa based on the molar volume, number of carbon atoms, and the number and type of functional groups present in the molecule. To validate the approach, the framework is applied to compute kappa data for pure organic compounds and functional group data for complex mixtures; results from the parameterization are compared to the directly observed kappa values.

Growth rates of freshly nucleated particles

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Chongai Kuang, Brookhaven National Laboratory
Kelley Barsanti, University Corporation for Atmospheric Research
Jim Smith, National Center for Atmospheric Research

The birth of new particles in the atmosphere is a significant process because both nucleation and growth rates are much higher than expected based on early naïve models. Our research aims to elucidate the mechanisms responsible for these high rates. This poster focuses on work we've done over the past year that will contribute to our understanding of fast growth rates of freshly nucleated particles. This work includes the development of improved methods to measure size distributions of particles down to 1 nm and methods to use these data to quantify size-dependent growth rates down to 1 nm. In late 2010 and early 2011, McMurry's group hosted a workshop on nanoparticle detection (with new condensation particle counters [CPCs]) that can detect particles as small as 1 nm. Instruments from the University of Minnesota, Brookhaven National Laboratory, TSI Inc., and the University of Helsinki were evaluated in this study. The responses of instruments to monomobile particles consisting of sodium chloride, sucrose, silver, tungsten, polyethylene glycol, proteins, and molecular ions were evaluated. Some results from these measurements will be presented. Particles as small as 1.1 nm in mobility diameter (0.8 nm in geometric size) can now be detected with CPCs, but detection efficiencies are sensitive to the chemical composition of both the particles and the condensing vapor. The use of size distributions to infer growth rates of freshly nucleated atmospheric particles as small as 1 nm will also be illustrated. We find that at 1 nm, most growth is due to the condensation of sulfuric acid vapor. However, growth rates increase linearly with diameter above 1 nm, and this increase is due to the uptake of vapors other than sulfuric acid. We have not yet identified those vapors with certainty. TDCIMS measurements by Dr. James Smith have shown that organic salts account for 20%–50% of the particle mass for 10-nm particles, and we hypothesize that those compounds may also contribute to growth of smaller particles as well. Furthermore, efforts are ongoing to identify other constituents that contribute to growth and to explain the size-dependent growth mechanisms.

Hygroscopicity frequency distributions of secondary organic aerosols

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Secondary organic compounds contribute to ambient aerosol and lower the supersaturation that is required for individual particles to serve as cloud condensation nuclei (CCN). Secondary organic aerosol (SOA) formed from a single reaction can be composed of hundreds of different compounds, and their overall CCN efficiency has been reported for many different SOA systems. The relative contribution of different compounds to the overall CCN efficiency can be described by a single hygroscopicity parameter, kappa. However, this kappa comprises an unknown distribution of underlying kappas. Here we report on a new technique characterizing this distribution. Precursor compounds were oxidized in an environmental chamber to form SOA, collected on filters, extracted using a mixture of acetonitrile and water, passed through a high-pressure liquid chromatography column, and measured as a function of retention time using scanning flow CCN analysis. Kappa generally decreased with retention time, reflecting in part the sorting of the products by polarity. Overall kappa values reconstructed by integrating over the chromatogram agreed well with online measurements from the environmental chamber, suggesting that kappa for SOA represents the volume-weighted average of the constituent compounds' kappa values. These distributions show that many SOAs consist of a continuum of products with $0 < \text{kappa} < 0.3$, rather than a pseudo-binary mixture of water-soluble and water-insoluble compounds. We anticipate that our measured hygroscopicity distributions will serve as validation points for mechanistic models that treat the generation and evolution of organic aerosols in the atmosphere.

Laboratory studies of black carbon particles: characterization and atmospheric processing

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Justin Wright, Boston College
David Croasdale, Boston College
Paul Davidovits, Boston College
Timothy Onasch, Aerodyne Research, Inc.
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Black-carbon-containing soot particles generated by incomplete combustion processes have a significant, though highly uncertain, effect on the direct (and indirect) radiative forcing of the global climate. The uncertainty in the climatic effects of soot particles is due to several important factors: (1) poorly understood rates of emission from various combustion sources (i.e., biomass burning, diesel engines, etc.), (2) highly irregular shapes of emitted soot particles (i.e., fractal-like) that can affect their atmospheric lifetimes, surface areas, and optical properties, (3) poorly quantified rates of atmospheric processing (e.g., hydrophobic into hydrophilic), and (4) rates of deposition. All these uncertainties are complicated by the lack of measurement techniques that can unambiguously measure soot particle chemical, physical, and optical properties. We are currently approaching this problem by developing new instrumentation for characterizing ambient soot particles and by studying soot particle properties in the laboratory. We have recently developed the Soot Particle–Aerosol Mass Spectrometer (SP-AMS). The SP-AMS utilizes an intracavity laser to selectively vaporize black carbon- and metal-containing particles, allowing the measurement of black carbon mass loading and size distributions, as well as measurement of the mass and chemical composition of any coating material (e.g., primary organic compounds and secondary organic and inorganic aerosol condensate). The measurement capabilities of the SP-AMS are currently being characterized in the laboratory and field. Results of these studies will be presented. We are also conducting laboratory studies of the physical, chemical, and optical properties of black carbon particles as a function of oxidation and condensational processes. Results from the Mexico City MILAGRO 2006 study indicate that soot particles can be rapidly processed in urban environments via secondary aerosol coatings, though it is unclear how these processes differ for primary soot particle sources located in urban and rural environments. Our current studies focus on the heterogeneous oxidation of “fresh” soot particle surfaces and the effects on particle chemical, physical, and hygroscopic properties. These studies set the baseline for atmospherically relevant studies on the effects of soot particle processing using well-characterized, laboratory-generated secondary organic and inorganic aerosol coatings.

Laboratory studies of SOA CCN activity as a function of oxygen-to-carbon ratio for a range of organic precursors

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Douglas Worsnop, Aerodyne Research, Inc.
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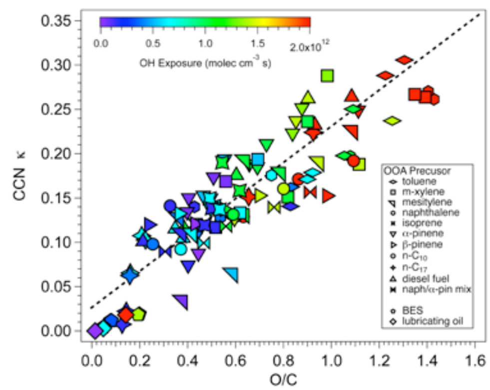

CCN activity (κ) of oxygenated organic aerosol (OOA) plotted as a function of O/C ratio. Markers are colored by OH exposure.

Currently the greatest challenge for climate-predictive models is the reliable characterization of climate forcing effects of organic aerosols that constitute 20% to 90% of the ambient particle mass. The difficulty of characterizing such aerosols is due to their chemical and physical complexity and to the incomplete understanding of multi-step processes such as oxidative aging. Specifically, oxidative aging affects the cloud-forming potential (CCN activity) of the aerosol. Inadequate representation of CCN activity and resulting effects on cloud albedo and cloud lifetime are a particularly large source of uncertainty in climate models. We present results of laboratory experiments with secondary organic aerosol (SOA) produced by oxidation of both gas-phase and particle-phase precursors. Ten gas-phase and two particle-phase precursors representing atmospherically relevant biogenic and anthropogenic sources were studied. SOA particles were generated via controlled exposure of precursors to the radicals OH and/or O3 in a flow reactor. The precursors were exposed to oxidants equivalent to 0.3–15 days of atmospheric aging. The goal was to generate SOA with similar chemical characteristics to those measured in the field. Chemical composition and CCN activity of the SOA particles were measured as a function of oxidant exposure. The oxygen-to-carbon (O/C) ratio as measured by an aerosol mass spectrometer (AMS) ranged from 0.01–1.4, which encompasses the O/C ratio measured in the field. The CCN activity of the SOA was characterized in the form of the hygroscopicity parameter, κ. In the figure, κ is plotted as a function of O/C ratio. As is evident, the CCN activity is positively correlated with SOA chemical composition (i.e. O/C). A best-fit straight line is shown in the figure. This result suggests that given a measured O/C ratio, CCN activity (κ) may be predicted to within ±20% for organic aerosol with O/C = 0.4–1.4. Measurements relating SOA hydrogen-to-carbon (H/C) to the O/C ratio as a function of OH exposure will also be presented.

Laboratory studies of the optical properties of warming aerosols with the SP2 and photoacoustic spectrometer: soot and hematite

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Most aerosols cool the atmosphere by scattering radiation. Absorbing aerosols, such as black carbon (BC) from combustion and hematite in dust, absorb radiation, resulting in a warming of the atmosphere. It is currently thought that BC is the second most important factor in global warming behind carbon dioxide, while dust is one of the major components of ambient aerosols globally. Direct online measurements of BC and hematite, an absorbing dust aerosol, can be made with the single-particle soot photometer (SP2), which measures the size and mass of the particles by incandescence and scattering on an individual particle basis. Measurements from the SP2 are combined with absorption measurements from the three-wavelength photoacoustic soot spectrometer (PASS-3) at 405, 532, and 781 nm and the ultraviolet photoacoustic soot spectrometer (PASS-UV) at 375 nm in order to determine wavelength-dependent mass absorption cross sections (MACs). Aerosols are generated by atomizing particles from aqueous solution, dried with a diffusion drier, and can be size-selected with a diffusion mobility analyzer (DMA) before being sent simultaneously to the SP2, PASS-3, PASS-UV, and a laser aerosol spectrometer (LAS) for measuring size distributions. Aerosol samples include flame-generated soot, fullerene soot, Aquadag, glassy carbon, and hematite. MACs from the absorbing aerosols measured in the laboratory are compared with those from ambient aerosols. Size-resolved information with bulk spectroscopic data is used to predict optical properties and is compared with our ambient observations for closure.

Measurements of urban and regional particulate using CAPS PMex-based aerosol light extinction measurements

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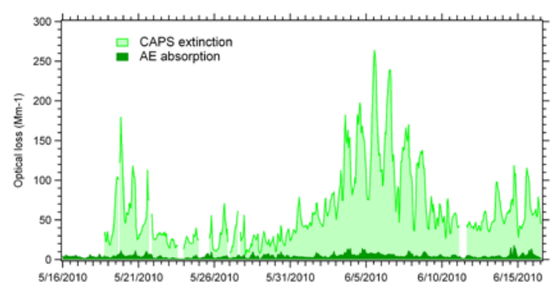
We present results of optical property characterization of ambient particulate during two field deployments where measurements of aerosol light extinction were obtained by using an Aerodyne Cavity Attenuated Phase Shift Particle Extinction Monitor (CAPS PMex). The CAPS PMex is a lightweight, compact instrument able to perform precise and accurate measurements (3-sigma detection limit of 3 Mm-1 for 1s integration time) of atmospheric aerosol particles in field conditions. Two CAPS PMex instruments (measuring extinction at 630 and 532 nm) were also deployed during the CalNex 2010 study (May 14–June 16) at the CalTech ground site in Pasadena, California. During the same time, a photoacoustic spectrometer (PAS, DMT) and an aethalometer instrument (Magee Sci.) measured particle light absorption of submicron aerosol particles from the same sample line as the CAPS PMex monitors (see figure for time series of extinction and absorption at 532 nm during CalNex



Time series of aerosol extinction and absorption at 532 nm during CalNex 2010.

2010). We combine the CAPS PMex and the aethalometer data to provide multi-wavelength particle single-scattering albedo trends for the one-month campaign. Two CAPS PMex measuring extinction at 630 are also currently deployed in Steamboat Springs, Colorado, as part of the STORMVEX campaign (November 2010–April 2011), for which a primary goal is to characterize the role of aerosols, both natural and anthropogenic, in cloud and precipitation processes. A first CAPS PMex instrument is located at the mountaintop site (Storm Peak Laboratory, SPL, elevation 3200 m), whereas a second CAPS is located at the nearby Christie Peak site (elevation 2400 m) as part the ARM Mobile Facility (AMF2) payload. At both sites, complementary optical measurements of aerosol absorption and scattering are also performed, along with ancillary measurements of aerosol size distribution and cloud condensation nuclei. This optimal setup allows comparing trends of the aerosol single-scattering albedo between the two locations. The influence of local meteorology (e.g. thermal inversion) on optical properties of the aerosols throughout the vertical profile will be also discussed.

Microscopic analysis of aerosols collected during the CARES campaign

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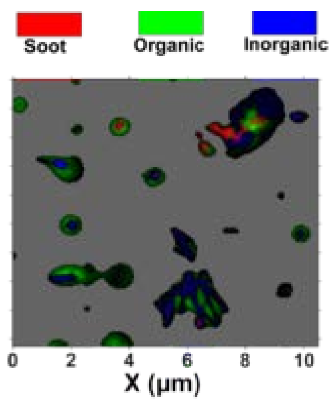
Alexander Laskin, Pacific Northwest National Laboratory
Mary Gilles, Lawrence Berkeley National Laboratory

As part of the Carbonaceous Aerosols and Radiative Effects Study (CARES), continuous sampling was performed to determine the potential effects of aerosol mixing state on optical properties. In central California, samples were collected with 20-minute resolution at fixed sites located in the urban Sacramento area (T0) and at a rural site located in the foothills of the Sierra Nevada Mountains (T1). Additional samples were collected onboard the G-1 aircraft with 3-minute time resolution. Preliminary results from scanning electron microscopy/energy-dispersive X-ray spectroscopy (SEM/EDX) and scanning X-ray microscopy/near-edge X-ray absorption fine-structure spectroscopy (STXM/NEXAFS) will be presented. The SEM/EDX measurements provide insight into the elemental composition and nanostructure of thousands of individual particles. STXM/NEXAFS provides complementary information on the molecular characteristics of carbon with 35-nanometer resolution.



STXM/NEXAFS composition map of particles collected during CARES. Of particular interest here is the mixing of soot (red) with organic (green) and inorganic material (blue).

Modeling water content and solute activities of atmospheric aerosols at extremely low relative humidities: extension of the Brunauer-Emmett-Teller (BET) adsorption isotherm equations

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Xinlei Ge, University of California
Simon Clegg, University of California
Anthony Wexler, University of California

Multilayer adsorption isotherm models describe a lattice adsorption of a solvent (e.g., water) molecule onto sites on a substrate (e.g., an electrolyte). The seminal adsorption model, Brunauer-Emmett-Teller

(BET), successfully reproduces solute concentrations of solutions at water activities (aw, equivalent to the equilibrium relative humidity) of <0.4 to 0.5 using only two parameters: (1) the number of adsorption sites and (2) the energy of adsorption of the solvent directly on to the solute. The Guggenhein-Anderson-deBoer (GAB) model applies to solutions of aw <0.7 to 0.8 by adding a single additional energy of adsorption to approximately account for the extended hydration shell surrounding the solute molecule. In this work, statistical mechanics is used to modify the BET and GAB model to include distinct energies of adsorption of the solvent on to n layers in the hydration shell. Equations for the excess Gibbs energy, solute activity, and solute concentration are derived. The inclusion of additional hydration layers of distinct energy results in remarkable agreement of the solute concentration and osmotic coefficients for solutions of aw as high as 0.9 to 0.95. New insights into solute and water activity for single- and multi-component systems are presented. In particular, the model can be shown to be consistent with models commonly used in atmospheric science for estimating water contents of aerosols containing more than one solute. The model will be incorporated into the Extended Aerosol Inorganics Model (E-AIM) and made available on the web.

Clegg, SL, AS Wexler, and P Brimblecombe. Extended Aerosol Inorganics Model (E-AIM). http://www.aim.env.uea.ac.uk/aim/aim.php.

Molecular characterization of organic compounds in atmospheric aerosols

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Julia Laskin, Pacific Northwest National Laboratory
Sergey Nizkorodov, University of California

Understanding the molecular composition and fundamental chemical transformations of organic matter dissolved in atmospheric aerosols during their formation and aging is both a major challenge and the area of great uncertainty in atmospheric environmental research. Particularly, little is known about the fundamental relationship between the chemical composition and physicochemical properties of organic aerosol (OA), their atmospheric history, evolution, and the impact on the environment. Ambient soft-ionization methods combined with high-resolution mass spectrometry (HR-MS) analysis provide detailed information on the molecular content of OA that is pivotal for improving the understanding of their complex composition, multi-phase aging chemistry, direct (light absorption and scattering) and indirect (aerosol-cloud interactions) effects on atmospheric radiation, climate, and health effects. The HR-MS methods can detect thousands of individual OA constituents at once and provide their elemental formulae from accurate mass measurements and structural information based on tandem mass spectrometry. Integration with additional analytical tools, such as chromatography and UV/Vis absorption spectroscopy, makes it possible to further separate OA compounds by their polarity and ability to absorb solar radiation. This poster will present contemporary HR-MS methods along with recent applications in field and laboratory studies of OA and explain how the information obtained from HR-MS methods can be translated into an improved understanding of OA chemistry.

New CALIPSO level-3 aerosol and cloud products for quantifying aerosol and cloud spatial distribution and optical properties

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Charles (Chip) Trepte, NASA
David Winker, NASA Langley Research Center
Brian Getzewich, Science Systems and Applications, Inc.

Characterizing the global spatial distribution of aerosols and clouds in both the horizontal and vertical dimension is crucial for evaluating outputs of climate models that provide estimates of radiative forcing. However, obtaining a large number of observations on a global scale is difficult, particularly with aerosols in the vertical dimension, since few instruments resolve vertical information. Furthermore, measurements over long time periods are required to generate meaningful statistics and to capture seasonal variability. After five years in orbit, CALIPSO presents the capability to observe seasonal variability of aerosol and cloud spatial distributions, discriminate aerosol type and cloud ice-water phase, and to examine vertical profiles of aerosol extinction on a global scale. The next step to make this information useful for quantifying the role of aerosols and clouds in the climate system is to aggregate CALIPSO observations into level-3 products, which is the topic of this presentation. In 2011, the CALIPSO Lidar Science Working Group will release level-3 aerosol cloud and data products. The aerosol products will provide quality-screened aerosol extinction coefficients, aggregated monthly onto a latitude, longitude, and altitude grid. This presentation highlights the upcoming CALIPSO level-3 aerosol product, focusing on the rationale for the statistics included and the methods used for quality screening. Examples are given to show how the product can be used to understand global spatial variability of aerosol properties and how this data product lends itself to MODIS aerosol optical depth versus CALIPSO aerosol optical depth comparisons. Additionally, information describing the proposed content of the forthcoming CALIPSO level-3 cloud product is provided to encourage feedback from the scientific community and ensure that useful, high-quality information is included.

Non-sea-salt chloride in submicron particles at multiple locations in the Northern hemisphere

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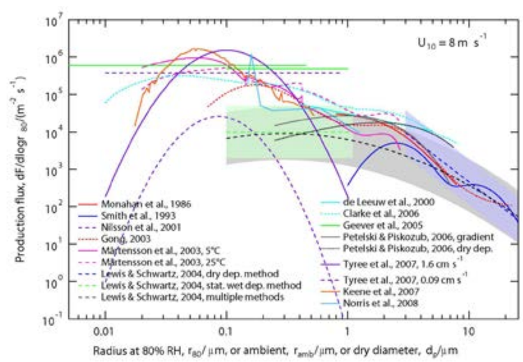
Yele Sun, University of California, Davis
Ari Setyan, University of California, Davis
Douglas Day, University of Colorado at Boulder
Allison Aiken, Los Alamos National Laboratory
Kenneth Docherty

Non-sea-salt chloride is often observed as a minor component of submicron particles, accounting for 1–2% of the mass worldwide (Zhang et al. 2007 GRL). Recent studies indicate that despite its low concentration, it may play disproportionally important roles affecting the atmospheric composition and the climate (Thornton et al. 2010 Nature). This is because chloride-containing particles react with gas phase N2O5 heterogeneously, forming nitryl chloride (ClNO2) with greater than 50% yield (Thornton et al. 2005 JGR). ClNO2 accumulates during the night but quickly photolyzes into chlorine radical (·Cl) and NO2 after sunrise. Since both ·Cl and NO2 are important precursors of major oxidants (e.g., ·OH and O3) that regulate the concentrations and life cycles of a wide spectrum of atmospheric species including secondary aerosols, this chloride activation mechanism may have important implications for climate. The significance of this mechanism in the atmosphere relies on the availability of aerosol chloride and NOx—precursors of N2O5. Even in continental air masses, in which sea-salt aerosol loadings are expected to be low, significant concentrations of ClNO2 (>0.1 ppb) are frequently observed (Thornton et al. 2010 Nature). This is an indication that non-refractory chloride in the form of ammonium chloride may have played an important role and that more information is needed to understand the chemistry of this species in airborne particles. Here we report the results of a survey using the global Aerosol Mass Spectrometer (AMS) field measurement database and present an overview of the concentrations and temporal variation of non-refractory chloride in submicrometer aerosols. We will also present the correlations of chloride with other non-refractory species including nitrate, sulfate, ammonium, and organic components. Implications for atmospheric chemistry and formation and aging will be discussed.

Observational constraints on concentration and production of sea-spray aerosol

Ernie Lewis, Brookhaven National Laboratory
Stephen Schwartz, Brookhaven National Laboratory



Estimates of the size-dependent SSA production flux as a function of radius at 80% RH, r80, at wind speed at 10 m above the sea surface U10=8 m/s, from de Leeuw et al., "Production flux of sea-spray aerosol," Reviews of Geophysics, accepted, 2010.

Quantification of the production flux of sea-spray aerosol (SSA) is essential to understanding aerosol, cloud, and radiation processes in the marine atmosphere. SSA is a major and often dominant component of marine aerosol mass; the relative contribution of SSA to aerosol number is much more variable, and present estimates of production flux vary by more than two orders of magnitude. SSA number, area, and mass concentration can be constrained by measurements; together with estimates of removal rates, such measurements may also provide constraints on production fluxes. For instance, filter measurements of total sodium concentration (a conservative proxy for SSA) typically yield SSA mass concentrations of 10 to 50 µg/m^3; such mass concentrations in turn provide an upper bound on the number concentrations of SSA particles with *r*80 (radius at 80% relative humidity RH, a commonly used measure of SSA particle size) greater than 1 µm of 10 to 50/cm^3, respectively, and of particles with *r*80>3 µm, 0.3 to 1.5/cm^3. Similarly, as particles that provide the dominant contribution to extinction of visible radiation are sufficiently large that their extinction efficiency is near 2, measurements of aerosol optical thickness (AOT) provide a constraint on the column burden of the concentration of aerosol surface area. Measured AOT in the marine atmosphere relatively free of anthropogenic influences, which includes contributions from stratospheric aerosols and tropospheric aerosols other than SSA, is typically 0.05 to 0.1. For typical marine boundary-layer height of 0.5 km with uniform RH 80%, the upper bound on the column-average number concentration of SSA particles with *r*80>1 µm would thus be 15 to 30/cm^3, and for particles with *r*80>3 µm, 2 to 3/cm^3, the expected increase in RH with increasing height would decrease these upper bounds, as would a greater MBL height. Measurements of total aerosol number concentration, which is dominated by smaller particles which similarly include particles other than SSA, provide an upper bound on the number concentration of SSA particles. Total aerosol number concentrations reported under conditions of minimal continental and anthropogenic perturbation range from 200 to 500/cm^3. Such measurements, together with estimated removal rates, also bound SSA particle production flux. The dominant factor in determining the lifetimes of particles in the size range 0.01 µm< *r*80<3 µm, removal by precipitation,, results in particle lifetime given by the time between precipitation events, typically ~3 days, nearly independent of size for particles in this size range. Such a lifetime yields an upper bound estimate on the SSA number production flux. For marine boundary-layer height 0.5 km, this upper bound would be 4 to 10 x 10^5/m^2/s, near the low end of current estimates of SSA production flux but two orders of magnitude less than other current estimates.

Optical properties and chemical composition of stratified aerosol layers and aerosol spatial/temporal variability in springtime Arctic

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The objective of this work is to investigate the variability in the particle number concentration (Na) as well as to study the optical and physicochemical properties of stratified aerosol layers that may affect climate change assessment for Arctic regions. The Indirect and Semi-Direct Aerosol Campaign (ISDAC) was conducted in April 2008, in the vicinities of Fairbanks and Barrow, Alaska. Variability in Na for cloud-free conditions was observed for both vertical profiles and constant altitude flight legs. Observations from four flights during ISDAC were used to examine properties of aerosol particles in stratified Arctic layers. Flight 31 on April 26, with the lowest overall number concentrations (compared to the cases studied here, with Na<250 cm-3), had particle size distribution mode diameters of 0.15–0.2 µm, and the chemical compositions were varied mixes of organics and sulfates with some indications of biomass burning (BB) influence. On April 8 (Flight 15), the aerosol properties resembled more typical Arctic Haze conditions with relatively high levels of soot and sulfate and lower levels of organics. On April 19–20, two flights (Flight 25 and 26) demonstrated strong BB influences, with Na exceeding 2000 cm-3, and larger modal diameters within the BB plumes were observed, reaching 0.3 µm. It is possible that the larger BB plumes were influenced by significant contributions from secondary organic aerosol production during transport from the source region leading to larger particle sizes within the BB plume. During the BB plumes, the absorption had increased significantly, but the single-scattering albedo was 0.94–0.95, indicating that despite the higher absorption, these plumes still contained significant amounts of materials that scatter efficiently. In the lower Na cases, such as Flight 31, the single-scattering albedo was 0.88–0.91, suggesting overall more absorption than the polluted cases. This may be explained by deposition of the higher scattering material (which may have been more soluble), and thus the higher absorption material may have remained. It is concluded that the variation in the particle light-scattering coefficient among these transported aerosol layers indicates the importance of accurately representing the evolution of the particle-size distributions for cloud-climate studies.

Optical properties of moderately absorbing organic and mixed organic/inorganic particles at very high humidities

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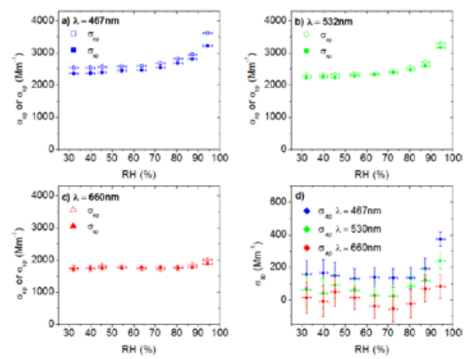
Mark Rood, University of Illinois
Tami Bond, University of Illinois



Optical properties at varying RH conditions for primary OC aerosols generated by pyrolysis of biomass. Extinction σep and scattering σsp for three wavelengths are shown in the top two (a), (b), and lower left graph (c); absorption σap by difference is shown in the bottom graph (d).

This project involves in situ closure studies between predictions and measurements of aerosol optical properties including absorption, scattering, and extinction at three visible wavelengths, for organic carbon (OC) biomass combustion aerosols, inorganic aerosols, and their mixtures at controlled relative humidity (RH) conditions. Novel components of this project include investigation of: (1) changes in all three of these optical properties at continuously scanned RH conditions; (2) optical properties at RH values up to 95%, which are usually extrapolated instead of confirmed; and (3) examination of aerosols generated by the pyrolysis of wood, which is representative of primary atmospheric organic carbon and its mixture with inorganic aerosols. This year's activities focused on the measurement of wood pyrolysis generated OC aerosols. Light absorbing benchmarks (polystyrene microspheres (PSMs) and nigrosin) were additionally evaluated to verify the operation of the instrumentation. The newly developed equipment measures scattering and extinction to infer light absorption and single-scattering albedo values. The measured single-scattering albedo for PSMs agreed within 0.02 with previously reported results at 530 nm wavelength. Increasing RH values from 39% to 95% enhanced the light absorption of the nigrosin benchmark by a factor of 1.25. Such an enhancement is higher than expected, but modeling results suggest that it could be caused by incomplete dissolution of nigrosin in the aqueous droplets. Results for the biomass OC aerosols indicate an increase in light absorption by a factor of two between 32% and 95% RH. Additionally, the spectral dependence of absorption by OC that was observed previously with filter measurements was confirmed in situ. Work in the immediate future will study the effect of mixing the pyrolysis-generated OC aerosols with inorganic compounds on the optical properties of the resulting aerosols at controlled RH conditions.

Raman lidar and HSRL measurements of aerosol and water vapor variability

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Observations by surface, airborne, and satellite sensors have noted significant changes in aerosol properties in proximity to clouds. Some of these changes are due to hygroscopic growth of the aerosols. We use Southern Great Plains (SGP) Raman lidar aerosol and water vapor measurements and NASA Langley Research Center airborne High Spectral Resolution Lidar (HSRL) measurements acquired during the Cumulus Humilis Aerosol Processing Study (CHAPS-June 2007) and Routine ARM Aerial Facility (AAF) Clouds with Low Liquid Water Depths (CLOWD) Optical Radiative Observations (RACORO-June 2009) campaigns to investigate aerosol hygroscopicity and variations in aerosol properties in the daytime boundary layer. The Raman lidar measurements of relative humidity are compared with coincident measurements from the Center for Interdisciplinary Remotely-Piloted Aircraft Studies (CIRPAS) Twin Otter and SGP radiosondes. Aerosol humidification factors are derived using the high (10-sec) temporal resolution Raman lidar profile measurements of aerosol backscatter and relative humidity at or near the top of the daytime boundary layer. These humidification factors are compared with similar factors measured by the surface Aerosol Observing System (AOS) at SGP. Preliminary results from the CHAPS campaign show that the humidification factor f(RH=85%/60%) derived from the Raman lidar measurements can vary widely but is on average consistent with AOS values. Coincident airborne HSRL measurements of aerosol backscatter, depolarization, and extinction are used along with the Raman lidar profile measurements of relative humidity to investigate how both aerosol extensive and intensive optical properties vary with relative humidity and distance from clouds. Raman lidar measurements and airborne CIRPAS Twin Otter aircraft in situ measurements from June 2007 show relative humidity was about 5–10% higher in proximity to clouds. Preliminary results using the Raman lidar and HSRL data from CHAPS show that aerosol backscatter and extinction decreased by approximately 25–40% moving 1–2 km away from clouds. The variations in aerosol optical thickness are smaller, typically around 10–15%, since the changes in aerosol backscatter and extinction were generally confined to the top of the boundary layer. Variations in the coincident HSRL aerosol depolarization and backscatter wavelength dependence measurements also suggest that aerosol nonsphericity and size changed in response to variations in relative humidity. These changes are due in part to hygroscopic aerosol growth. This presentation will discuss these preliminary results as well as ongoing investigations using data acquired during the RACORO campaign.

Representation of arctic mixed-phase clouds and the Wegener-Bergeron-Findeisen process in climate models: perspectives from a cloud-resolving study

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Philip Rasch, Pacific Northwest National Laboratory
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Two types of Arctic mixed-phase clouds observed during the ISDAC and M-PACE field campaigns are simulated using a 3-dimensional cloud-resolving model (CRM) with size-resolved cloud microphysics. The modeled cloud properties agree reasonably well with aircraft measurements and surface-based retrievals. Cloud properties such as the probability density function (PDF) of vertical velocity (w), cloud liquid and ice, the regime of ice growth at the expense of liquid water (i.e., Wegener-Bergeron-Findeisen (WBF) process), and the inherent relationships among cloud properties/processes in the mixed-phase layers are examined to gain insights for improving the representation of the mixed-phase processes in general circulation models (GCMs). We find that the WBF process only occurs in about 50% of the mixed-phase regime with the vast majority occurring in the downdrafts. In updrafts both liquid and ice grow simultaneously. But in GCMs, it is not necessary to treat the WBF process at the subgrid scale. Our CRM results produce a w distribution well represented by a Gaussian normal function, validating, at least for arctic clouds, the subgrid treatment used in GCMs. Our CRM results also support the assumption frequently used in GCMs that mixed-phase clouds maintain water vapor very near liquid saturation. A Gamma function with a fixed variance does not accurately represent the subgrid variability of cloud liquid. The PDFs of cloud liquid and cloud ice can be fitted with Gamma functions, and a normal function can be used for total water, but the variance should not be fixed. The relationship between the ice depositional growth rate and cloud ice strongly depends on the capacitance of ice particles. At large scales, the maximum overlap assumption looks appropriate.

A review of chemistry-aerosol treatments in CAM5 and implementation of a sectional aerosol package with comprehensive SOA formation

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Arthur Mirin, Lawrence Livermore National Laboratory
Dan Bergmann, Lawrence Livermore National Laboratory
Philip Cameron-Smith, Lawrence Livermore National Laboratory

Virtually all properties of atmospheric aerosols and clouds depend strongly on aerosol size distribution, composition, and mixing state. These microphysical characteristics underlie the major role of aerosols in radiative forcing of climate. Current interactive chemistry-aerosol modules in CAM5 include a “bulk” approach based on the Model of Ozone and Related Tracers (MOZART) that simulates mass concentrations of externally mixed aerosols as well as a “modal” treatment (MAM) that predicts mass/number concentrations and mode radii of externally and internally mixed aerosols. Both existing treatments do not resolve the detailed aerosol size distributions, and they oversimplify the formation of secondary organic aerosols (SOAs) that make up a significant portion of the global aerosol burden. A wide range for the estimates of global SOA formation (12–70 Tg/year) leads to a significant uncertainty

in the spatial and temporal distributions of atmospheric aerosols. In this study, we examine the simulated regional ozone levels with resolutions from CAM5/MOZART, compare aerosol concentrations and optical depth from MOZART and MAM, and reveal cloud properties associated with different aerosol modules. We also introduce our ongoing effort to implement a sectional aerosol package into CAM5 that integrates MOZART gas chemistry with MADRID aerosol microphysics (Model of Aerosol Dynamics, Reaction, Ionization, and Dissolution). This new chemistry-aerosol package includes SOA formation from two anthropogenic and six biogenic organic precursors. Preliminary results from CAM5/SECT will be presented.

Sea-salt aerosol particles during 2008 VOCALS: production, distribution, and modification by gas, aerosol, and in-cloud processes

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Peter Daum, Brookhaven National Laboratory
Larry Kleinman, Brookhaven National Laboratory
Gunnar Senum, Brookhaven National Laboratory
Stephen Springston, Brookhaven National Laboratory
Jian Wang, Brookhaven National Laboratory

Bulk sea-salt aerosol (SSA) mass concentration in the marine boundary layer (MBL) was determined as Na+ and Cl- using the PILS-IC technique deployed on the DOE G-1 aircraft during the 2008 VOCALS field campaign. Although the SSA concentrations were in rough agreement with the predicted values that are typically uncertain to a factor of 3, they were rather insensitive to wind speed. This suggests that the MBL steady-state SSA concentration (observed over a wind speed range of 2 to 10 m/s) was governed by the residence time of an air parcel entraining the SSA particles as well as the SSA production rate, the two processes having the opposite wind speed dependencies. Regarding SSA chemistry, a lowered Cl- to Na+ ratio in SSA particles compared to that of sea water was observed. This SSA modification, referred to as Cl- deficit, results from acidification of SSA by strong acids, primarily HNO3 and H2SO4, followed by desorption of HCl. Because the uptake of gaseous HNO3 by SSA accounted for only a portion of the Cl- deficit, H2SO4 was also implicated. While in-cloud H2SO4 production from oxidation of SO2 by H2O2 and O3 is potentially important, coagulation (in clear air and in cloud) of SSA particles with strongly acidic H2SO4 aerosols advected into the MBL from coastal sulfur emission sources characteristic of the VOCALS study region also needs to be investigated. The relative importance of acidification of SSA by H2SO4 through gas-phase, aqueous-phase, and coalescence processes are compared using time constants evaluated for a range of concentrations of O3, H2O2 (not measured), and SO2 (< 0.2 ppb) and coagulation coefficients appropriate for aerosol particles and cloud droplets.

Submicron aerosol characterization during CARES 2010 field campaign using high-resolution aerosol mass spectrometry at the suburban site

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John Shilling, Pacific Northwest National Laboratory
Rahul Zaveri, Pacific Northwest National Laboratory
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Qi Zhang, University of California, Davis

An Aerodyne High-Resolution Time-of-Flight Aerosol Mass Spectrometer (HR-ToF-AMS) was deployed downstream to a thermodenuder at the campus of American River College, Sacramento, California (the T0 site, a suburban area, ~ 15 km to the northeast of the Sacramento downtown area) during the DOE Carbonaceous Aerosol and Radiative Effects Study (CARES) in June 2010 to investigate the aerosol chemical composition and volatility. Preliminary data analysis from the HR-ToF-AMS shows that the dominant component in the particle phase is organics (62.5%), accompanied by a significant fraction of sulfate (22.0%) and small amounts of nitrate (6.1%) and ammonium (8.6%), while the particle phase chloride is almost negligible (< 1%). The total particle concentration ranged from 0.1 to 11.0 ug/m3 with an average of 2.4 ug/m3 during the whole campaign. A diurnal pattern, with particle mass concentration peaked in the early afternoon, was observed throughout most of the campaign with a few exceptions. In addition, the particle number concentration measured by a TSI Scanning Mobility Particle Sizer (SMPS) shows a similar diurnal pattern to that of particle mass. Fast growth of particles with small sizes was often observed starting in the early or mid-morning, indicating new particle formation that is dominated by both organics and sulfate. Further data analysis including positive matrix factorization (PMF) and chemical speciation based on size distribution and volatility will also be discussed.

Wavelength-dependent optical properties, mass absorption coefficients, and closure studies for carbonaceous aerosols at the 2010 CARES campaign, Sacramento, California

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Allison Aiken, Los Alamos National Laboratory
Manvendra Dubey, Los Alamos National Laboratory
Madhu Gyawali, University of Nevada, Reno
Pat Arnott, University of Nevada
Kyle Gorkowski, Michigan Technological University
Claudio Mazzoleni, Michigan Technological University
R. Subramanian, Droplet Measurement Technologies
Arthur Sedlacek, Brookhaven National Laboratory
Gunnar Senum, Brookhaven National Laboratory
Stephen Springston, Brookhaven National Laboratory
Ari Setyan, University of California, Davis
Qi Zhang, University of California, Davis
Chen Song, Pacific Northwest National Laboratory
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Josef Beranek, Pacific Northwest National Laboratory
Alla Zelenyuk, Pacific Northwest National Laboratory
Rahul Zaveri, Pacific Northwest National Laboratory

Aerosol absorption and scattering coefficients measured at ground sites and by the DOE G-1 aircraft during the Carbonaceous Aerosols and Radiative Effects Campaign (CARES) of summer 2010 are analyzed. We report wavelength-dependent single-scatter albedo (σsca/σext) from simultaneous measurements of aerosol absorption and scattering at nine wavelengths between 1047–355 nm by eight separate integrated photoacoustic/nephelometer (IPN) instruments. The 9-λ absorption coefficients are combined with black carbon mass measurements from single-particle soot photometers (SP2) to derive wavelength-dependent mass absorption coefficients, including new results at UV wavelengths. The absorption and scattering data are combined with concurrent particle size distributions to estimate complex refractive indices (n-ik). The imaginary part of the complex refractive index (ik) is sensitive to enhanced absorption by organic coatings on soot cores and/or directly emitted primary and secondary organic particles. Closure studies will compare the estimated top-down refractive indices with bottom-up calculations using the observed chemical composition from aerosol mass spectrometers (e.g. Flowers, et al. ACP 2010). The wavelength dependence of optical properties and MACs for fresh and aged urban and rural emissions, including biomass burning, will be presented to help models accurately estimate net radiative effects for carbonaceous aerosol.

4.0 Atmospheric State & Surface

Cold pool properties from Oklahoma Mesonet data

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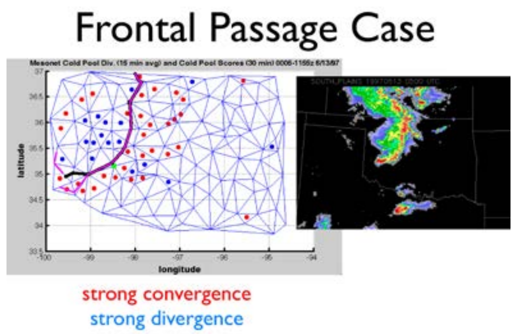
We have implemented an objective method to locate cold pool boundaries (fronts) using mesonet station time series and have applied the method to four summer months of 5-minute data from the Oklahoma Mesonet. Our method is similar to that used by Engerer, Stensrud, and Coniglio (2008). To locate a front, we first calculate a cold pool "score", which (currently) combines three indicators of frontal passages: surface pressure rise, surface temperature drop, and surface wind vector change, over 30-minute time intervals. A frontal passage occurs at a station if (1) the cold pool score exceeds a threshold and (2) the cold pool score has reached its largest value during the 40-minute interval centered on this time. If a front eventually reaches all three stations that define a mesonet triangle, the front can be tracked as it traverses the triangle. As expected, frontal passages are characterized by strong surface convergence ahead of the front and strong surface divergence behind the front. The number of frontal passages during June–August 1997 varied substantially across the mesonet. The number generally decreased from northwest to southeast by a factor of 1/2 to 1/4. The median surface temperature drop associated with frontal passages was 7 K. The largest drops were 13 K. The median surface pressure rise associated with frontal passages was 1.5 mb. The largest rises were 7 mb. There was only a weak correlation between temperature drop and pressure rise. This indicates that the vertical structure of the temperature perturbation in the cold pools varies from case to case. Future work will include further refining the cold pool score formula, attempting to define cold pool area, and compiling a cold pool properties data set for a multi-year time period. Such a data set could be used to evaluate parameterizations, such as for cold pools in a cumulus parameterization, or for microphysics in cloud-resolving models.



Example of front location determined from mesonet data (left) and radar image at the same time (right). Red and blue dots indicate mesonet triangles with strong surface convergence (red) or surface divergence (blue).

Exploring the use of ensemble Kalman filtering for the assimilation of local observations in a continuous single-column model evaluation at the ARM sites

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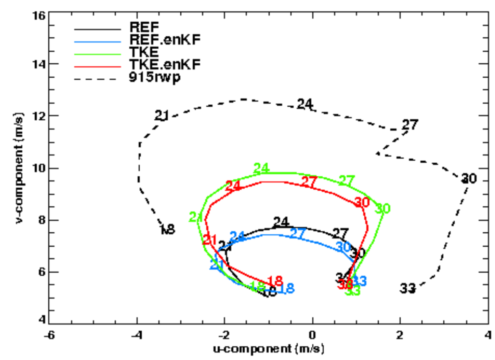
Roel Neggers, Royal Netherlands Meteorological Institute

Single-column models (SCMs) have become a widespread and successful tool to evaluate model parameterizations. An SCM simulation consists of the offline integration of all sub-grid physical processes from a general circulation model, using prescribed forcings and boundary conditions. Generally, the purpose is to gain insight in the behavior of the physics and to highlight deficiencies of the parameterizations. However, the prescribed large-scale forcings always carry uncertainties. This potentially hampers an evaluation of SCM results against observations. Therefore, in SCM modeling, relaxation is often applied towards a “true” state that can be either observations or model products. Relaxation prevents excessive model drift, while still allowing the physics to develop its own unique state. In this way, a valid comparison of SCM results with observations remains possible. A possible alternative to relaxation is the assimilation of local measurements. As such, in the present study we explore the use of an ensemble Kalman filter (enKF). Here, we study the impact of assimilating 10-m observations of temperature, specific humidity, and both components of the horizontal wind obtained from the ARM archive of SGP measurements. Additionally, we assimilate soil temperature and soil moisture as provided by ERA-interim. We utilized the SCM version of the Integrated Forecasting System (IFS) of the European Centre for Medium-Range Weather Forecasts (ECMWF). In this study we compare two model versions. One applies a first-order closure formulation of turbulent diffusion (IFS CY31r1, REF); the other employs a TKE-closure (TKE) formulation. As large-scale forcings, we use data from the ARM SGP variational analysis and ERA-interim. The purpose of our study is twofold. Firstly, we investigate which of the two model versions gives a better representation of momentum mixing. A comparison of one year of SCM simulations with observations from a 915-MHz wind profiler shows that TKE gives a much better representation of the wind, in particular for the nighttime hours. Among others, this is reflected in a better representation of the nocturnal low-level jet. Secondly, we study the impact of the enKF. During daytime the influence is much stronger than during nighttime. Compared to independent atmospheric sounding data, the assimilation of near-surface observations gives a considerable reduction of the rms errors of temperature and relative humidity.



Composite hodograph of the nocturnal 200-m wind for one month of SCM simulations (July 1999) for the SGP Central Facility site. The full lines indicate various SCM versions; the dashed line indicates averaged observations of the 915-MHz wind profiler. Numbers indicate local time. While still underestimating the amplitude of the LLJ, the TKE scheme clearly performs better than the REF version. In this case, the assimilation of near-surface data does not lead to improved simulations. However, since both model versions still develop their own unique state, this result suggests that the enKF method can be used as an alternative to commonly applied relaxation techniques.

Impact of ARM radiosonde humidity correction on calculation of convective indices

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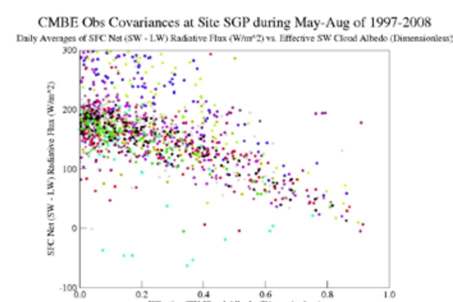
Michael Jensen, Brookhaven National Laboratory
Tami Toto, Brookhaven National Laboratory

Over the course of the history of the ARM and ASR programs, there have been efforts to improve the humidity profiles that are produced from radiosonde launches. Work began in the late 1990s with research by Clough et al. (1996), Miller et al. (1999), and Lesht (1999). These studies detected a dry bias and a loss of humidity calibration in ARM-used Vaisala soundings. Determining additional problems, devising and implementing numerical solutions to the known problems, and correcting the humidity readings from all types of Vaisala (RS-80, RS-90, and RS-92) radiosondes resulted in at least eight papers in the 2000s. Miloshevich et al. (2009, 2006, 2004, 2001), Hume (2008), Wang et al. (2002), Turner et al. (2003), and Vomel et al. (2007) present research that serves to enhance the community's knowledge of the radiosonde problems and to propose appropriate algorithmic solutions. These solutions to the humidity problems are incorporated in the Sondeadjust evaluation product. In addition to including the original sounding output, derived fields contained in the output include (1) rh_smooth (relative humidity smoothed from the coarse resolution of the original sounding in order to better capture the physical surroundings), (2) rh_biased (relative humidity that is adjusted to eliminate the dry bias as reported in the literature), (3) rh_adjust (relative humidity that has been corrected for the sensor time lag and for solar warming), and (4) scaled relative humidity field (rh_adjust scaled by the integrated precipitable water vapor from the microwave radiometer). Using the original RH profile, the scaled RH profile, and the three intermediate RH profiles to calculate various convective indices (e.g. CAPE, CIN), this study's goal is to demonstrate the sensitivity of each RH correction on these thermodynamic variables.

Land-atmosphere coupling manifested in warm-season observations at the SGP site

Thomas Phillips, Lawrence Livermore National Laboratory Program for Climate Model Diagnosis and Intercomparison

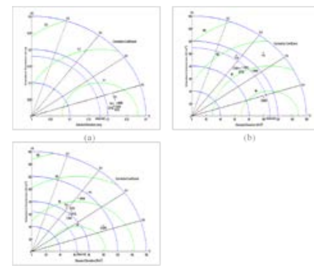
This study investigates the features of land-atmosphere coupling during the May to August period, when it displays its greatest strength at the ARM Southern Great Plains (SGP) site. Following the perspective of boundary-layer meteorologist Alan Betts, the land-atmosphere coupling is manifested by covariances of surface moisture/energy fluxes and related variables, e.g., as illustrated by scatter plots (see figure). The ARM Climate Modeling Best Estimate (CMBE) data sets provide the required surface observations at hourly sampling intervals for the years 1997–2008, thus allowing the characteristics of the SGP land-atmosphere coupling to be analyzed in considerable detail. Initial results suggest that covariances among the surface radiative fluxes and atmospheric variables are more robust than those involving the turbulent fluxes or precipitation.



The scatter plot illustrates the covariation of daily averages of Climate Modeling Best Estimate observations of surface net total radiation and effective shortwave cloud albedo in May–August of 1997 to 2008 (color-coded by year) at the U.S. Southern Great Plains site.

Offline evaluation of six surface-layer parameterization schemes against observations at the ARM SGP site

Gang Liu, Brookhaven National Laboratory
Yangang Liu, Brookhaven National Laboratory
Tami Toto, Brookhaven National Laboratory
Michael Jensen, Brookhaven National Laboratory
Satoshi Endo, Brookhaven National Laboratory



Taylor diagrams of (a) the momentum flux, (b) the sensible heat flux, and (c) the latent heat flux for comparisons to the EC observations.

Surface momentum, sensible heat, and latent heat fluxes are critical for atmospheric processes such as clouds and precipitation formation, and are parameterized in models of various scales. However, direct evaluation of the parameterization schemes for these surface fluxes using observations is limited. This study takes advantage of the long-term observations of surface fluxes collected by the DOE (Department of Energy) ARM (Atmospheric Radiation Measurement) Climate Research Facility at the Southern Great Plains (SGP) site to evaluate the surface layer parameterization schemes commonly used in the Weather Research and Forecasting (WRF) model and global climate models (GCMs). Effort has also been made to quantify the uncertainty/discrepancy between the ARM measurements based on the EC (Eddy Correlation) and EBBR (Energy Balance Bowen Ratio) methods. To minimize potential feedback influences resulting from online evaluation, the "offline" mode is used to evaluate the surface layer parameterization schemes. The turbulent fluxes are calculated by the schemes using the corresponding measurements of mean meteorological quantities as inputs, and the parameterized turbulent fluxes are evaluated against the concurrent measurements of surface turbulent fluxes. The results show that the momentum flux is parameterized best, and all the schemes parameterize the friction velocity very well compared to the EC observations. The MM5 scheme is the best at parameterizing the sensible heat flux compared to the EC observations, while the Eta scheme is the worst. The three schemes used in the GCMs are relatively better at parameterizing the latent heat flux, while the three schemes used in the WRF model are worse. The results are valuable for understanding and improving parameterization of turbulent fluxes in particular, and atmospheric boundary-layer processes in general.

Regimes of boundary-layer structure in the Azores using data from the ARM Mobile Facility

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Mark Miller, Rutgers University

Boundary-layer cumulus and stratocumulus clouds cool the ocean or land surface by reflecting a significant fraction of incoming solar radiation back to space while simultaneously emitting longwave radiation comparable in magnitude to that which would have been emitted by the surface if no cloud cover was present. Cloud coverage and cloud vertical structure are intimately connected to the thermodynamic and the dynamical structure of the boundary layer, but there are relatively few observations of these connections. A unique opportunity to study these connections was presented by the deployment of the ARM Mobile Facility (AMF1) on the island of Graciosa in the Azores. The present study utilizes data from the soundings launched from June 2009 until December 2010 to characterize the boundary-layer thermodynamic structure in the region, and coincident data from cloud sensing instruments including the W-band ARM cloud radar (WACR), microwave radiometer, and ceilometer are used to describe the accompanying cloud structure. Low level clouds are identified by AMF1 cloud sensors, which are also used to exclude deep convective clouds observed during the frontal passages. Diurnal variations of the BL structure are investigated along with the relationships that exist between the observed cloud structure and the Convective Available Potential Energy (CAPE), BL inversion, liquid water path, and large-scale subsidence.

Retrieving latent heat vertical structure using precipitation and cloud profiles

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Qilong Min, State University of New York at Albany
Xiaoqing Wu, Iowa State University

The latent heating is a major contributor to the convective heating (Q1). There is no observation of heating profiles available for evaluating GCM parameterized convective and stratiform heating rates and understanding impacts of the vertical and horizontal structure on climate mean state and variability. Many studies instead use the heating profiles estimated from the temperature and moisture budgets of NCEP and ECMWF reanalysis. Our novel approach, distinguished from existing schemes, is directly using observable precipitation and cloud profiles in combination with phase change partition parameterization of various kinds from the CRM simulations to produce the latent heating profiles. This hybrid latent heat algorithm separately deals with the condensation-evaporation heating (LHc_e), the deposition-sublimation heating (LHd_s), and the freezing-melting heating (LHf_m) for convective rain, stratiform rain, and shallow warm rain. Each component is based on physical processes, such as nucleation and autoconversion, by combining observable precipitation and cloud profiles. The partition of various components is derived from the CRM simulations. Although the proposed algorithm utilizes microphysical parameterizations from a specific CRM, the general LH vertical structure is primarily determined by the precipitation and cloud profiles observable from cloud and precipitation radars available at the ARM SGP site or from satellite platforms, and less sensitive to the specific CRM. The self-consistency tests of this algorithm show good agreements with the CRM-simulated LH at different spatial and temporal scales, even at simultaneous and pixel level. The applications of this algorithm are expected to provide new information for understanding the heating budget in the atmosphere and its impacts on the atmosphere circulations at various spatial and temporal scales.

Seasonal and interannual variability in 13C composition of ecosystem carbon fluxes in the U.S. Southern Great Plains

Margaret Torn, Lawrence Berkeley National Laboratory
Sebastien Biraud, Lawrence Berkeley National Laboratory
Christopher Still, University of California
William Riley, Lawrence Berkeley National Laboratory
Joseph Berry, Carnegie Institution of Washington

The δ13C signature of terrestrial carbon fluxes (δbio) provides an important constraint for inverse models of CO2 sources and sinks, insight into vegetation physiology, C3 and C4 vegetation productivity, and ecosystem carbon residence times. From 2002–2009, we measured atmospheric CO2 concentration and δ13C–CO2 at four heights (2 to 60 m) in the U.S. Southern Great Plains (SGP) and computed δbio weekly. This region has a fine-scale mix of crops (primarily C3 winter wheat) and C4 pasture grasses. δbio had a large and consistent seasonal cycle of 6–8 permil. Ensemble monthly mean δbio ranged from

−25.8 ± 0.4 permil (±SE) in March to −20.1 ± 0.4 permil in July. Thus, C3 vegetation contributed about 80% of ecosystem fluxes in winter-spring and 50% in summer-fall. In contrast, prairie-soil δ13C values were about –15 permil, indicating that historically the region was dominated by C4 vegetation and had more positive δbio values. Based on a land-surface model, isofluxes (δbio × NEE) in this region have large seasonal amplitude because δbio and net ecosystem exchange (NEE) co-vary. Interannual variability in isoflux was driven by variability in NEE. The large seasonal amplitude in δbio and isoflux implies that carbon inverse analyses require accurate estimates of land cover and temporally resolved 13CO2 and CO2 fluxes.

The SIRTA climate testbed data set (SCTD)

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Jean-Charles Dupont, Laboratoire de Météorologie Dynamique/Institut Pierre Simon Laplace
Martial Haeffelin, Institut Pierre Simon Laplace
Ludmilla Klenov, Laboratoire de Météorologie Dynamique/Institut Pierre Simon Laplace/Ecole Polytechnique

Observation of the decadal variability of atmospheric properties is a challenge to improve the understanding of atmospheric processes and climate feedback. Since 2002, the SIRTA atmospheric observatory has been collecting many co-localized observations from meteorological instruments and passive and active remote sensing. From this large quantity of observations, it is now possible to build a decadal database (2002–2011) that describes the 3D atmospheric column in the Paris area. This database construction is based on the same approach as the "ARM Climate Modeling Best Estimate Data": one entire netCDF file containing homogeneous data every hour, with particular attention to quality control, that could be used by scientists that are not specialists in measurement techniques. Documentation of the quality of the data is central to the SCTD. We classify the data into three classes: (1) quality check okay, (2) exceeding extreme limit test, and (3) exceeding physical limit test. Quality controls are processed at the highest resolution source file (1 to 5 min) to quantify error bars for each variable. When multiple remote sensing instruments are combined to derive a high-level quality product (e.g., vertical distribution of cloud fraction–low, middle, and high), a more complex flag is given to document the availability and the quality of each variable. Some additional surface meteorological stations around the SIRTA site (narrower 50 km) are used to quantify the representativeness of the SIRTA measurement concerning standard surface data, so a complete spatial, temporal, and instrument measurement uncertainty is processed.

Validation of the ACOS/GOSAT column CO2 data product using ground-based TCCON measurements

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Paul Wennberg, California Institute of Technology
Charles Miller, California Institute of Technology
Brian Connor, National Institute of Water & Atmospheric Research

The Total Carbon Column Observing Network (TCCON) is a ground-based network of Fourier Transform Spectrometers that make measurements of important atmospheric gases around the world. TCCON instruments measure the column average dry-air mole fractions of CO2, CO, CH4, N2O, and H2O TCCON by observing the absorption of direct sunlight by atmospheric gases in the near-infrared (NIR) spectral region. The TCCON includes ARM-sponsored instruments at the Southern Great Plains site in Lamont, Oklahoma, and at Darwin, Australia. Measurements from the TCCON network are a critical component of validating satellite measurements of carbon dioxide. A specific example is the planned use of TCCON data for validating measurements from the Orbiting Carbon Observatory-2 (OCO-2) satellite, which is scheduled to launch in 2013. The validation plan for OCO-2 is based on the one developed for the original OCO instrument that launched in 2009 but failed to achieve orbit due to a launch vehicle malfunction. The validation strategy involves using data from TCCON sites, including the one at the SGP site, to connect the space-based data to the World Meteorological Organization (WMO) CO2 standard used with ground-based measurements. This connection is made by validating the satellite data against the TCCON measurements, which are calibrated against aircraft observations (which use the WMO standard). The OCO-2 and TCCON teams are testing their validation plan using data from the TANSO-FTS instrument that was launched aboard the Greenhouse Gases Observing Satellite (GOSAT) in 2009 to measure total columns of CO2 (XCO2) and methane (XCH4). The OCO-2 algorithm team is working on retrieving XCO2 from the GOSAT data in an effort called the Atmospheric CO2 Observations from Space (ACOS) using the OCO-2 retrieval algorithm. The ACOS/OCO-2 validation team is using the TCCON data to validate the ACOS retrievals. Some preliminary validation results will be presented in this poster. The full validation strategy for ACOS and OCO-2 and how it uses TCCON data taken at the SGP site and other locations will be described.

5.0 Cloud Properties

Aircraft icing potential and ice- and mixed-phase cloud particle size distributions

Dorothea Ivanova, Embry-Riddle Aeronautical University

Ice clouds play an important role in Earth's climate by influencing the radiation balance and hydrological cycle. Improved parameterizations of cold clouds in the climate models require good understanding of the cloud properties, and especially of the role of the ice particles' size distribution (PSD). Ice and mixed-phase clouds have an important impact on aviation. In-flight icing is a significant threat to aircraft, resulting in loss of lift, reduced airspeed, and, in some cases, loss of control (Bernstein et al. 2005). Based on recent data, freezing precipitation often forms through nonclassical formation mechanisms, without requiring the formation of a melting layer. However, these relationships are still not thoroughly studied. The focus of this research is to help improve our understanding of winter aircraft icing occurrence through better parameterizations of the ice microphysical cloud properties. The study explores possible relationships between different ice crystals' size distributions and airplane icing. The study utilizes data for different ice crystal size spectra in winter cold clouds and data for the corresponding airplane icing occurrences. The microphysical cloud properties are primarily a function of the ice water content (IWC) and the size distributions (SDs), while the radiative properties also depend on temperature (T) and the size distributions (Mitchell 2001). Hence, it is important to know not only the IWC, but how the ice particle size distribution itself is likely to vary as a function of environmental parameters, because they are the main input for the ice cloud parameterizations and may relate to the possible aircraft icing. Cold-cloud interactions with aircrafts that fly through them require knowledge of cloud microphysics. Aircrafts must be designed to fly into supercooled clouds, or they must avoid those clouds in order to prevent problems associated with airframe and engine icing. De-icing or anti-icing systems must be engineered to withstand reasonable extremes in terms of ice water content (IWC), supercooled liquid water content (LWC), ice particle size distributions (SDs), and temperature. The aircraft design or certification envelopes (FAR 25, Appendix C; Federal Aviation Administration 1999) were developed before the advent of modern cloud physics instrumentation. In the case of ice and mixed-phase clouds, data from the aircraft measurements during recent field campaign suggest that cloud temperature is one of the main parameters governing cloud microstructure, the size distributions, and the current icing potential (CIP). This study may help improve airplane icing prediction through better understanding of the ice microphysical properties.

Analysis of cirrus cloud particle size distributions from SPARTICUS

Michael Schwartz, University of Utah
Gerald Mace, University of Utah

The ARM Small Particles in Cirrus (SPARTICUS) campaign collected 150 hours of midlatitude cirrus cloud in situ measurements during the period January to June 2010. Cirrus particle size distributions (PSDs) are constructed with measurements made via the 2D Stereo Probe (2D-S). The PSDs are fit using modified gamma distributions, according to two methods. First, bimodal fits are made using a mixture of two modified gamma distributions; and second, unimodal fits are made using a single modified gamma distribution that contains an added location parameter. A covariance analysis of the fit parameters is demonstrated, and efficacies of the two fitting methods are compared. A covariance analysis of several microphysical parameters, i.e., ice water content, extinction coefficient, and total number concentration, is also demonstrated.

ARSCL post-ARRA: upcoming cloud radar value-added products

Karen Johnson, Brookhaven National Laboratory
Pavlos Kollias, McGill University
Scott Giangrande, Brookhaven National Laboratory
David Troyan, Brookhaven National Laboratory
Michael Jensen, Brookhaven National Laboratory
Eugene Clothiaux, The Pennsylvania State University

The widely used ARSCL (Active Remotely Sensed Cloud Locations) value-added product (VAP) will be completely revamped this year to accommodate and leverage the new capabilities of ARM's suite of ARRA-funded cloud radars and to address known limitations of the current VAP. Two separate products will be developed: an improved two-dimensional time-height ARSCL product and an initial version of a three-dimensional product based on ARM's new scanning cloud radars. The post-ARRA time-height ARSCL product will merge observations from ARM's new zenith-pointing 35-GHz cloud radars with those from the micropulse lidar, ceilometer, and disdrometer. The new product will have increased temporal and height resolution. Radar reflectivities will be adjusted for water vapor attenuation. Automatic clutter removal will be improved by taking advantage of the radars' enhanced polarimetric capabilities. The newly improved VAP is expected to run in a fully autonomous manner, facilitating timely data processing. The ARSCL product family will also be extended into three dimensions using observations from the new scanning ARM cloud radars (SACRs). The initial version of the VAP will provide a hydrometeor mask for radar moments on a three-dimensional grid. Prior to gridding, moments will be corrected for water vapor attenuation, velocity folding, and non-hydrometeor clutter.

ASR activities in the Centre for Australian Weather and Climate Research

Peter May, Bureau of Meteorology
Melita Keywood, Centre for Australian Weather and Climate Research
Alain Protat, Laboratoire Atmosphères, Milieux, Observations Spatiales
Vickal Kumar, Bureau of Meteorology
Guillaume Penide, Bureau of Meteorology

The Centre for Australian Weather and Climate Research is a partnership between the Bureau of Meteorology and CSIRO. This poster will highlight current activities related to and supported by ASR. These include:

- An analysis of cloud properties as a function of large-scale regime
- The observed impact of aerosol variations on rain DSD's
- Cloud property retrieval improvements
- Validation of global and regional NWP models using ARM and A-Train data
- Upgrades of Darwin observing capability including radar upgrades and deployment of aerosol and greenhouse gas measurements at Gunn Point in addition to ARCS upgrades.

Future activities will expand on these areas. This includes planned intensive observing campaigns.

Broadening of drop-size spectra by ice crystal vapor growth

Jerry Harrington, The Pennsylvania State University
Kara Sulia, The Pennsylvania State University
Zachary Lebo, California Institute of Technology

Observations of ice and liquid within mixed-phase clouds sometimes show correlations between the existence of ice and larger drops. This observation has led to the speculation that ice crystal production may be explained by the existence of the larger drops. How nucleation occurs in mixed-phase clouds is a critical problem in understanding mixed-phase cloud evolution; observed clouds appear to be able to maintain larger ice precipitation rates and concentrations along with supercooled liquid water than models can predict. Nevertheless, we present theoretical and model simulations that suggest ice crystals can produce preferential regions of larger drops through the process of diffusional growth alone. This mechanism produces natural broadening of the drop-size spectrum as the smaller drops evaporate and the larger drops grow. We present cases that show that this effect is most strongly evident at lower ice concentrations and at particular temperatures.

Cloud, drizzle, and turbulence observations in marine stratocumulus clouds in the Azores

Jasmine Rémillard, McGill University
Pavlos Kollias, McGill University
Edward Luke, Brookhaven National Laboratory

The recent deployment of the AMF at the Azores provided a unique, long-term record (May 2009 to December 2010) of cloud observations in a regime dominated by low-level stratiform clouds. First, a comprehensive cloud classification scheme that utilizes the radar, lidar, and thermodynamic observations is applied to determine the occurrence of different cloud types (e.g., stratus, cumulus, cirrus) and precipitation (e.g., shallow and deep) over the 20-month long data set to identify stratocumulus periods. Around 30 days dominated by stratocumulus clouds were selected for the analysis. A diurnal cycle was obtained for the cloud and drizzle occurrences, as well as their depth. The strength of the drizzle is further studied in conjunction with various other parameters. For instance, the LWP correlates well with the occurrence of drizzle, with the highest values of LWP found in heavier drizzle events. Also, the effects of the stability and adiabaticity of the cloud layer, as well as the presence of decoupling in the sub-cloud layer on the drizzle production and strength are studied. The mass flux from up and downdrafts are assessed from the cloud radar velocity measurements.

Comparative study of different cloud fraction estimates over the Southern Great Plains

Wei Wu, Brookhaven National Laboratory

A variety of observations and retrieval methods have been used to estimate cloud fraction, creating an increasing need to quantify the range of uncertainty in these estimates to facilitate evaluation of model results against observations. Here we use the most recent decade-long surface- and satellite-based cloud fraction estimates over the Southern Great Plains (SGP) region of the United States to investigate the uncertainty in estimation of cloud fraction. Results show significant discrepancy in SGP cloud fraction estimates. Major sources of the discrepancy are examined, including variations in the measurement methods and/or retrieval algorithms. In this study, we examine the three cloud fraction estimates from the

Atmospheric Radiation Measurement (ARM) Climate Research Facility's Climate Modeling Best Estimate (CMBE) value-added products: (1) from surface-based, vertically pointing remote sensing observations (ARSCL: Active Remotely-Sensed Cloud Locations), (2) from a surface-based hemispheric imager (TSI: Total Sky Imager), and (3) from geostationary satellite observations (GOES: Geostationary Operational Environmental Satellite). We also employ cloud fraction estimates from hemispheric radiometer observations: the Solar Infrared Radiation Station (SIRS) and three different satellite-based cloud fraction estimates—the International Satellite Cloud Climatology Project (ISCCP), Pathfinder Atmospheres Extended (PATMOS-x), and the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO). These results will be useful for evaluating and improving cloud parameterizations in climate models.

Comparison of cloud vertical structure from passive satellite measurements and ARM radar-lidar measurements

Patrick Minnis, NASA Langley Research Center
William Smith, NASA Langley Research Center
Robyn Boeke, Science Systems and Applications, Inc.
Helen Yi, Science Systems and Applications, Inc./NASA Langley Research Center
Fu-Lung Chang, Science Systems and Applications, Inc.
Kris Bedka, NASA
Xiquan Dong, University of North Dakota
Baike Xi, University of North Dakota

The vertical and horizontal structure of cloud fields is critical for characterizing the radiative and moisture budgets of the atmosphere. Measurements taken by active sensors at the surface provide a relatively detailed depiction of cloud depth, layering, and moisture content over the location where the measurements are taken. Typically, data from passive satellites have been used to monitor the horizontal distribution of cloud cover and cloud-top heights. Neither type of measurement has been able to adequately provide large-scale characterizations of 3D cloud fields. Recently, data from CloudSat and CALISPO have been used to develop global empirical methods to generate cloud thickness and water content profile information from passive satellite cloud retrieval products. Additionally, multilayer cloud retrieval methods have been developed, providing a means for adding more information about cloud vertical structure to the passive measurements. Thus, the potential to characterize cloud fields over large areas accurately has been increased. Determining how advanced such retrievals are requires independent validation, because the empirical techniques were developed for only one time of day and from somewhat limited data. The information about water content profiles and cloud base from CloudSat is reliable only above 1 km or higher. Furthermore, attenuation by upper-layer clouds sometimes affects the CloudSat retrievals of water content in the lower layers. The ARM lidars and radars provide an independent characterization of the cloud vertical structure and can be used to assess the passive retrievals. This paper presents comparisons of cloud thickness and water content profiles determined from GOES and MODIS data with similar data retrieved from active and passive sensors at one or more ARM sites. The results will be used to evaluate the empirical methods and perhaps refine them.

The difference between thin and thick fair-weather shallow cumulus inferred from ARM observations over the Southern Great Plains

Yunyan Zhang, Lawrence Livermore National Laboratory
Stephen Klein, Lawrence Livermore National Laboratory

During summertime over large areas at the U.S. Southern Great Plains (SGP), fair-weather shallow cumulus clouds tend to occur frequently. The diurnal evolution of these clouds is closely related to surface fluxes and atmospheric boundary layer development. Based on 13 years of observations by millimeter-wavelength cloud radar at the ARM Central Facility and GOES satellite images, we carefully select and categorize days with "thin" and "thick" shallow cumulus clouds to study forced and active fair-weather shallow cumulus. Composite forcings are also constructed to drive the large-eddy simulation and single-column model cases to test models with observations. By so doing, we address (1) the differences in cloud properties and their radiative impacts between days with “thin” versus “thick” clouds and (2) the differences in environmental conditions between these days and what controls the vertical extent of shallow cumuli.

Drizzle variability in marine stratocumulus in the Azores

Edward Luke, Brookhaven National Laboratory
Pavlos Kollias, McGill University

The ARM Mobile Facility (AMF) has recently completed its operation at Graciosa Island in the Azores as part of a 21-month field campaign to study marine stratus clouds. The AMF instrumentation suite and location provide a unique opportunity to observe the properties of marine stratocumulus clouds, utilizing a variety of active and passive remote sensors, including a 95-GHz cloud radar, ceilometer, and microwave radiometer. Drawing from over 20 different case days from four seasons, we apply a novel technique that decomposes cloud radar Doppler spectra into separate cloud and drizzle constituents. Using the decomposed radar observations, the temporal and spatial variability, both horizontal and vertical, of intra-cloud drizzle particle size distributions (PSD—total number concentration, characteristic size and spread) are described. The variability of the drizzle PSD parameters is classified according to a number of controlling factors including cloud thickness, liquid water content, and turbulence. Evidence suggests that drizzle is omnipresent in marine stratocumulus clouds. Furthermore, our observations demonstrate that conventional radar-based approaches to detecting and characterizing drizzle are challenged.

Dynamical and microphysical characteristics and interactions in Arctic mixed-phase clouds

Matthew Shupe, University of Colorado
Ola Persson, CIRES/NOAA Earth System Research Laboratory
David Turner, NOAA

Arctic mixed-phase clouds play a key role in Arctic climate through their persistent nature, variability of phase composition, and frequent precipitation. Many of the key mechanisms that characterize these clouds are poorly understood due to the complexities associated with a three-phase water system, the complex interactions with aerosols, and a general dearth of observational history. A number of past and ongoing experiments have provided insights into these clouds in many different conditions, including coastal fall observations during the Mixed-Phase Arctic Clouds Experiment (M-PACE) in 2004, coastal spring observations during the Indirect and Semi-Direct Aerosol Campaign (ISDAC) in 2008, summer observations over the sea ice during the Arctic Summer Cloud Ocean Study (ASCOS) in 2008, and fall observations over the central Greenland Ice Sheet in 2010. In spite of the unique environments encountered in each of these locations, the mixed-phase stratocumulus clouds maintain a qualitatively similar structure of supercooled liquid water, formed via cloud-scale circulations, from which ice crystals form and fall. Thus, these different observational perspectives provide important insight into why Arctic mixed-phase stratocumulus are so persistent in spite of differing forcing mechanisms and frequent mass loss through precipitation. Many aspects of Arctic mixed-phase stratocumulus are explored in this presentation in order to build a better understanding of their remarkable persistence. In particular, measurements from active and passive ground-based remote sensors are combined to characterize these clouds in terms of their phase partitioning, microphysical, macrophysical, and dynamical properties. In some cases this information will be considered within the context of measurements of atmospheric thermodynamic stability to further characterize the interactions between the cloud and surface. Lastly, seasonal impacts on the cloud layers and their interaction with the surface and free troposphere will be discussed.

Evaluating the role of mid-level clouds in WRF simulations of the Madden-Julian Oscillation

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Sally McFarlane, Pacific Northwest National Laboratory
Samson Hagos, Pacific Northwest National Laboratory
L. Ruby Leung, Pacific Northwest National Laboratory

Many previous studies have examined the possible role of mid-level clouds in the modulation of the Madden-Julian Oscillation (MJO) and have suggested that the mid-level congestus clouds play an important role in the moisture preconditioning ahead the MJO deep convection. Our recent studies, using the observational data sets from the Atmospheric Radiation Measurement (ARM) Tropical Western Pacific (TWP) site at Manus Island, depict a clear role for congestus clouds during the preconditioning of mid-troposphere moisture; they transfer moisture upward to the mid-troposphere as detrained altocumulus and altostratus, which moistens the environment and favors the transition of MJO deep convection. To further explore this process, a high-resolution (grid spacing 4 km) Weather Research and Forecasting (WRF) simulation without a cumulus parameterization is conducted to simulate two MJO events observed during October 1, 2007, and January 31, 2008, over the Indian Ocean, maritime continent, and western Pacific. We will present an analysis of these simulations with an emphasis on the cloud evolution associated with the moisture processes during the MJO life cycle to explore the role of congestus in the mid-troposphere moisture preconditioning and contribute to the conceptual and theoretical understanding of MJO. Our preliminary analysis will start by checking the general MJO signal through the precipitation rate, outgoing longwave radiation (OLR), temperature, and zonal wind. The cloud processes associated with the vertical moisture profile during the two MJO events will then be examined to illustrate the role of the mid-level congestus clouds over different locations (the Indian Ocean, maritime continent, and western Pacific). Additionally, the simulated congestus and mid-level cloud near the Manus Island will be compared with the observations from the ARM TWP Manus Island data sets to evaluate the model simulations of congestus during the MJO life cycle.

Evaluation of in situ and satellite-derived cirrus microphysical properties during SPARTICUS

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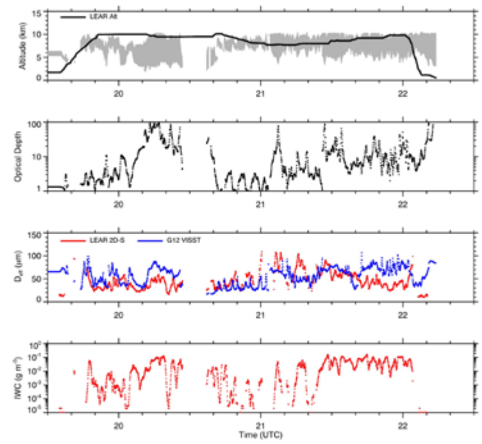
Patrick Minnis, NASA Langley Research Center
J Ayers, NASA Langley Research Center/Science Systems and Applications, Inc.
Rabindra Palikonda, Science Systems and Applications, Inc./NASA Langley Research Center
Douglas Spangenberg, Science Systems and Applications, Inc.
Fu-Lung Chang, Science Systems and Applications, Inc.
Szedung Sun-Mack, Science Applications International Corporation
Patrick Heck, University of Wisconsin
Paul Lawson, SPEC Inc.



Time series of (a) cloud boundaries and Learjet altitude, (b) cloud optical depth, (c) effective particle size, and (d) ice water content on 19 January 2010.

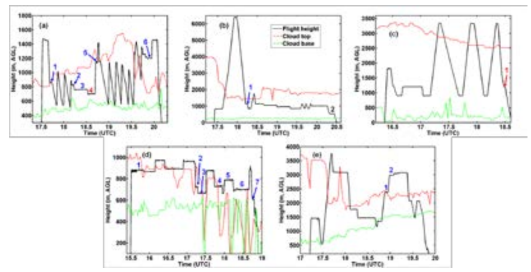
Quantifying the microphysical properties of cirrus clouds in global climate models is a difficult but necessary task in order to determine whether they have a net warming or cooling effect on the present and future climate. The amount of shortwave radiation reflected back to space and the longwave radiation emitted back to Earth by cirrus is determined by the size, shape, and concentration of the ice particles composing the cloud. During the Small Particles in Cirrus (SPARTICUS) field campaign, which took place between January and June 2010, the SPEC Learjet 25 was outfitted with several instruments designed to measure such cloud properties. The Geostationary Operational Environmental Satellites (GOES) provided a broad and concurrent view of the large-scale cloud conditions throughout the field experiment, and cloud properties such as cloud-top altitude, optical depth, and effective particle size were routinely derived from these measurements. Similar retrievals were performed using Moderate Resolution Imaging Spectroradiometer (MODIS) data on Terra and Aqua, except that effective particle size is derived from four different wavelengths corresponding to different depths in the cloud. In situ measurements of the cloud particle number concentration are integrated over the size distribution to obtain an effective particle size, a quantity that can also be retrieved from satellite observations. Estimates of ice water content (IWC), which were measured in situ by the 2D-Stereo Probe, are also obtained remotely by simultaneous GOES and some MODIS measurements. Mean profiles of particle size and ice water content are obtained by taking advantage of the Learjet's ability to take measurements at different altitudes within the cirrus. This study evaluates the small-scale in situ cloud properties and the large-scale satellite-derived properties and documents to what extent the two data sets can be compared.

http://www-pm.larc.nasa.gov/

Examination of entrainment-mixing mechanisms using a combined approach

Chunsong Lu, Brookhaven National Laboratory
Yangang Liu, Brookhaven National Laboratory
Shengjie Niu, Nanjing University of Information Science and Technology

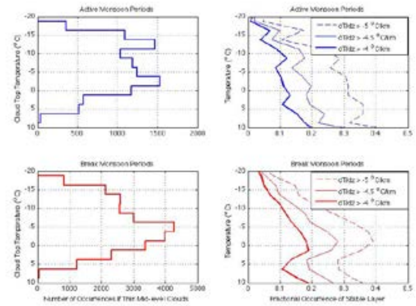
Turbulent entrainment-mixing mechanisms are studied with the aircraft measurements of three drizzling and two non-drizzling stratiform clouds collected over the U. S. Department of Energy's Atmospheric Radiation Measurement Southern Great Plains site during the March 2000 Cloud Intensive Observation Period. The inhomogeneous entrainment-mixing process occurs both near cloud top and in the middle level of a cloud, and both in the non-drizzling clouds and non-drizzling legs in the drizzling clouds. The inhomogeneous entrainment-mixing process occurs much more frequently than the homogeneous entrainment-mixing process, and most cases of the inhomogeneous entrainment-mixing process are close to the extreme scenario whereby the cloud droplet number concentration varies substantially, but the volume-mean radius remains roughly constant. We argue that the dominance of inhomogeneous entrainment-mixing mechanism is related to the difference between the transition length and Kolmogorov microscale; the scale differences are smaller for the legs affected by the inhomogeneous entrainment-mixing process compared with the leg affected by the homogeneous process. Filaments smaller than the spatial resolution of the instrument are indirectly confirmed, which also partially contributes to the dominance of inhomogeneous entrainment-mixing mechanism. Further analysis indicates that the processes of homogeneous and inhomogeneous entrainment-mixing likely conspire to affect ambient clouds; the difference lies in the different degrees of their domination. A combined study of microphysical relationships, dynamic, and thermodynamic structures is recommended for thorough analysis of entrainment-mixing processes.



Temporal evolutions of the aircraft height, cloud top, and base in the five cases at the Southern Great Plains (SGP) site on (a) 3 March 2000, (b) 17 March 2000, (c) 18 March 2000, (d) 19 March 2000, and (e) 21 March 2000. The numbers in the figure are horizontal leg numbers, and their different colors represent different mechanisms. Blue: extreme inhomogeneous entrainment-mixing mechanism, red: inhomogeneous entrainment-mixing with subsequent ascent, and black: homogeneous entrainment-mixing mechanism.

Formation and climatology of mid-level clouds at Darwin, Australia

Laura Riihimaki, Pacific Northwest National Laboratory
Sally McFarlane, Pacific Northwest National Laboratory
Jennifer Comstock, Pacific Northwest National Laboratory



Comparison of thin mid-level cloud top temperature frequency distributions (left) and frequency of stable layers (right) for active and break monsoon periods at Darwin, Australia. During the active monsoon periods (top), a double peak in cloud-top temperature does not directly correspond to occurrence of stable layers. During the break period (bottom), however, there is a maximum in cloud tops that occur at the temperatures of a peak in stability.

Thin tropical mid-level layer clouds may be formed by different mechanisms, including detrainment from convective clouds at stable layers, or by the cooling caused by melting of ice and snow from precipitating stratiform clouds. The preconditioning of the atmosphere by mid-level clouds is thought to be necessary for organized convection like the Madden-Julian Oscillation to occur, yet we underestimate the frequency of occurrence of mid-level clouds in GCM simulations. We find that mid-level cloud climatologies determined from combined radar and lidar observations differ during the active and break monsoon periods at Darwin, Australia. During the break monsoon period, a single wide peak is seen in cloud-top temperature distributions slightly above the melting layer, at approximately -5 degrees C. This cloud-top temperature peak corresponds to a peak in the frequency of stability as measured by radiosondes. In the active monsoon period, however, cloud-top temperature distributions of mid-level clouds have two distinct peaks at -2 and -12 degrees C that do not directly correspond to stability peaks. We discuss the possibility that different formation mechanisms cause the differences seen during the active and break monsoon periods. To contribute to the discussion, we use cloud-phase determinations from lidar and cloud radar and comparisons to convective and stratiform precipitation from the scanning precipitation radar.

High-resolution simulations of mesoscale convective systems during AMMA

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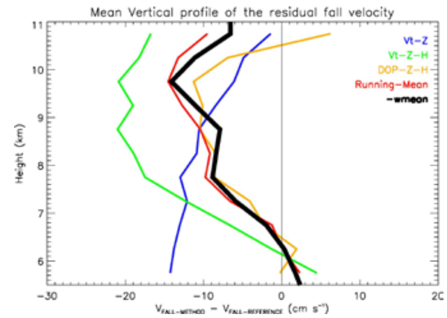
Robert Houze, University of Washington
Xiping Zeng, NASA Goddard Space Flight Center
Wei-Kuo Tao, NASA Goddard Space Flight Center
Sally McFarlane, Pacific Northwest National Laboratory
Paul Ciesielski, Colorado State University

Mesoscale convective systems (MCSs) that developed during the AMMA (African Monsoon Multidisciplinary Analysis) campaign are simulated using a high-resolution cloud-resolving model (CRM). We verify the structures of anvil clouds extending laterally in the upper troposphere from the simulated MCSs by comparing simulated radar reflectivities from modeled anvil cloud to W-band radar and lidar returns from the ARM Mobile Facility in Niamey, Niger. Simulated longwave and shortwave radiative fluxes in the anvil are also compared to those calculated from ARM observations using a radiative transfer model. A water budget illustrates the transport of water from precipitating regions into the anvil.

Ice terminal fall speed and in-cloud vertical air velocity from vertically pointing doppler radar measurements

Alain Protat, Laboratoire Atmosphères, Milieux, Observations Spatiales
Christopher Williams, University of Colorado at Boulder/NOAA Earth System Research Laboratory



Mean vertical profile of the terminal fall speed residual (technique-reference) for the Vt-Z technique (blue), the running-mean technique (red), the Vt -Z-H technique (green), and the DOP-Z-H technique (orange).

Doppler radar measurements at different frequencies (50 MHz and 2835 MHz) are used to characterize the terminal fall speed of hydrometeors and the vertical air motion in tropical ice clouds and evaluate statistical methods for retrieving these two parameters using a single vertically pointing cloud radar. In this work it is found that the natural variability of terminal fall speeds within narrow reflectivity ranges is typically within the acceptable uncertainties for using terminal fall speeds in ice cloud microphysical retrievals. This study also evaluates the performance of previously published statistical methods of separating terminal fall speed and vertical air velocity from vertically pointing Doppler radar measurements using the 50/2835 MHz radar retrievals as a reference. It is found that the variability of the terminal fall speed-radar reflectivity relationship (Vt-Z) is large in ice clouds and cannot be parameterized accurately with a single relationship. While a well-defined linear relationship is found between the two coefficients of a power-law Vt-Z relationship, a more accurate microphysical retrieval is obtained using Doppler velocity measurements to better constrain the Vt-Z relationship for each cloud. A new technique is proposed that incorporates simple averages of Doppler velocity for each (Z, height H) couple in a given cloud. This technique, referred to as DOP-Z-H, was found to outperform the three other methods at most heights, with a mean terminal fall residual less than 10 cm s-1 at all heights. This error magnitude is compatible with the use of such retrieved terminal fall speeds for the retrieval of microphysical properties.

The influence of large-scale dynamical forcing and meteorological regime on Arctic cloud microphysical properties

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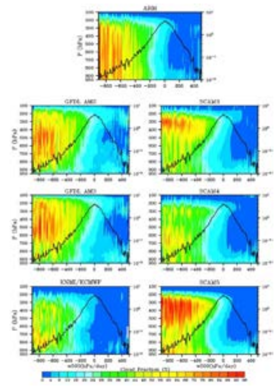
Lynn Russell, Scripps Institution of Oceanography
Dan Lubin, Scripps Institution of Oceanography

The objective of this work is to determine how the entire time series of cloud property and radiation measurement data from the NSA site (now well into its second decade) can be used to test and refine climate model parameterizations. This is particularly germane given recent attention to improving mixed-phase cloud representation in climate models. We determine the time periods in which the NSA site is under the influence of major meteorological regimes (e.g., Aleutian Low, Siberian High, Central Arctic/Beaufort Sea High) in two ways: (1) inspection of daily mean NCEP reanalysis data, and (2) k-means clustering on surface meteorological data from NSA itself. We then describe the cloud properties and their ranges for each of these significant regimes and for each season, as derived from ARSCL, MWR, SKYRAD, and other sensors. In this way, we create "ensembles" of test cases for cloud properties, physically relevant to actual meteorological states, that can be used to robustly test climate model parameterizations. This enables testing of the climate model parameterizations over the full range of meteorological variability found in nature and explained by large-scale dynamical forcing. We present this technique as a potentially valuable supplement to the more common method of testing climate model parameterizations against individual "case studies" from intensive aircraft field campaigns such as ISDAC and M-PACE.

Intercomparison of long-term single-column model simulations of clouds at the ARM SGP Site

Hua Song, Brookhaven National Laboratory
Wuyin Lin, Brookhaven National Laboratory
Yanluan Lin, Geophysical Fluid Dynamics Laboratory
Leo Donner, Geophysical Fluid Dynamics Laboratory
Roel Neggers, Royal Netherlands Meteorological Institute
Yangang Liu, Brookhaven National Laboratory

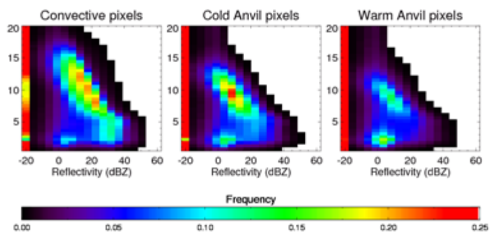


PDF of 500hPa vertical pressure velocity (black line, right Y-axis). The average cloud fraction (shaded, left Y-axis) is binned by 500hPa omega (10hPa/day bins) in ARM observations and SCMs. Units of omega, PDF of omega, and cloud fraction are hPa/day, % and % respectively.

This study quantitatively evaluates the overall performances of six SCMs by comparing simulated clouds with observations at the ARM SGP site. The six SCMs from GFDL AM2 and AM3; KNMI/ECMWF; and NCAR CAM3, CAM4, and CAM5 are forced with the three-year (January 1999–Decmber 2001) continuous large-scale forcing data. The observed and simulated clouds are sorted by 500hPa vertical pressure velocity and precipitation to assess the model skills in distinct dynamical regimes and to partition the influences of convective and stratiform parameterization schemes on model clouds. Results show that precipitations in models are largely constrained by the large-scale forcings, with slight underestimation of the observed precipitation under the strongly forced ascending regime. However, there are large differences in cloud fraction distributions between SCMs and ARM observation under both ascending and descending regimes. The cloud distributions binned by convective precipitation are significantly different from those binned by stratiform precipitation in that the cloud amount associated with convective precipitation is much smaller and vertically has a higher degree of inhomogeneity. Qualitatively, this is consistent with the fundamental assumptions in cloud parameterizations. However, the results also show that different models attribute the precipitation to convective and stratiform processes very differently, suggesting there is still a long way to go for reasonable partitioning of convective and stratiform precipitation.

Life cycle of tropical convection and anvil from satellite and radar data

Sally McFarlane, Pacific Northwest National Laboratory
Jennifer Comstock, Pacific Northwest National Laboratory
Samson Hagos, Pacific Northwest National Laboratory



Frequency distributions of radar reflectivity from the C-POL precipitation radar for convective systems that pass over Darwin. Distributions are calculated separately for pixels identified as convective (left), cold anvil (center), and warm anvil (right) based on satellite brightness temperatures.

Tropical convective clouds are important elements of the hydrological cycle and produce extensive cirrus anvils that strongly affect the tropical radiative energy balance. To improve simulations of the global water and energy cycles and accurately predict both precipitation and cloud radiative feedbacks, models need to realistically simulate the life cycle of tropical convection, including the formation and radiative properties of cirrus anvils. By combining remote sensing data sets from precipitation and cloud radars at the ARM Darwin site with geostationary satellite data, we can develop observational understanding of the lifetime of convective systems and the links between the properties of convective systems and their associated anvil clouds. The relationships between convection and anvil in model simulations can then be compared to those seen in the observations to identify areas for improvement in the model simulations. We identify and track tropical convective systems in the Tropical Western Pacific using geostationary satellite observations. We present statistics of the tropical convective systems including size, age, and intensity and classify the life cycle stage of each system as developing, mature, or dissipating. For systems that cross over the ARM Darwin site, information on convective intensity and anvil properties are obtained from the C-POL precipitation radar and MMCR cloud radar, respectively, and are examined as a function of the system life cycle. We also present initial results from applying the convective identification and tracking algorithm to a tropical simulation from the Weather Research and Forecasting (WRF) model run to evaluate the convective life cycle in the model.

Maintenance of springtime Arctic mixed-phase stratocumulus in nested LES simulations

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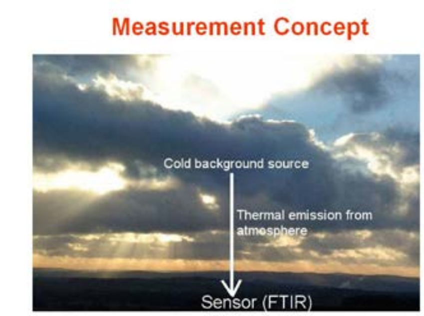
Matthew Shupe, University of Colorado
Ola Persson, CIRES/NOAA Earth System Research Laboratory
Hugh Morrison, National Center for Atmospheric Research

Arctic mixed-phase stratocumulus (AMPS) are observed to occur approximately 45% of the time per year on the North Slope of Alaska, with a significant increase in occurrence during the spring and fall transition seasons. Due to the presence of liquid water in these clouds, they play an important role in the structure of the Arctic atmospheric boundary layer and surface energy budget. AMPS are typically observed to persist for days in both the spring, when the Arctic Ocean is essentially ice-covered, and fall, when the open ocean produces large fluxes of heat and moisture into the atmospheric boundary layer. The persistence of AMPS under both strong and weak surface conditions may be an indication that the mechanisms that maintain these clouds differ during spring and fall. However, there are also studies that indicate that a similar mechanism may be operating in spring and fall to maintain AMPS, since in cases with and without open water, for example, Pinto (1998) observed entrainment of warm air by turbulent mixing that was forced by cloud-top radiative cooling. AMPS have not been studied as extensively as stratocumulus that occur in regions of the descending branch of the Hadley circulation over relatively cool subtropical oceans. Observations indicate that the processes that maintain subtropical and Arctic stratocumulus differ, due to the different environments in which they occur. For example, in the Arctic, humidity inversions are frequently observed to occur at cloud top, causing turbulence to entrain moist air into the cloud layer, while in the subtropics subsidence at cloud top mixes dry air into the cloud layer, capping the cloud layer and limiting entrainment. In this presentation we present results from nested LES simulations of AMPS during the DOE ARM Indirect and Semi-Direct Aerosol Campaign (ISDAC). Budgets of cloud water, cloud ice, vapor, and equivalent potential temperature are used to quantify the processes that maintain the AMPS. A conceptual mixed-layer model of AMPS is proposed and contrasted with mixed-layer model studies of subtropical stratocumulus.

Measurement of air pollution gases under cloud with AERI

Wayne Evans, NWRA
Henry Buijs, ABB Bomem
Claude Roy, ABB Bomem

The remote measurement of tropospheric gas concentrations can be achieved by utilizing the technique of thermal emission under cloud. The cloud deck acts as a cold optically thick blackbody at the cloud base temperature. The emission features from bands of the atmospheric gases below the cloud are superimposed on the cloud blackbody emission. In the thermal spectral region, there are bands and lines from ozone, carbon dioxide, water vapor, methane, nitrous oxide, CFCs, nitric acid, and other air pollution gases. Ozone is used as an example gas since it is both a major air pollutant and a strong greenhouse gas. Zenith spectral measurements made under cloudy conditions enable the radiative flux from O_3 in the lower troposphere to be determined, since the downward emission from the stratospheric ozone is blocked by the cloud layer. The measurement of the surface forcing irradiance flux from gases requires a well-calibrated high-resolution measurement of spectral radiance in the thermal infrared region from 700 to 2500 wave numbers. Such measurements are made routinely with the AERI instruments at the DOE ARM sites.



The technique of the measurement of gases in the troposphere using AERI spectra beneath clouds is demonstrated in the image.

Well-calibrated infrared spectral measurements of the downward infrared thermal radiation have been routinely made by the robotic AERI instruments at the three main ARM sites for over 11 years with a 15-year record at the ARM Southern Great Plains site. The AERI instrument is a Fourier Transform Spectrometer that has internal blackbody calibration sources. It is fully automated for operation over the long term. Zenith spectra of the radiance from clouds above the sites will be shown. The features from carbon dioxide, water vapor, ozone, and several greenhouse gases are evident. Although the technique was designed for radiative forcing measurements of greenhouse gases, the conversion to mixing ratios is simple for air quality applications. Of particular interest is the measurement of ozone below cloud since the combination of the total column and the cloud base height yields a mean mixing ratio below the cloud base. Examples of measurements of the ozone mixing ratio in the lower troposphere will be shown. A time series of the tropospheric ozone mixing ratio measurements will be shown in comparison to ground level measurements with a TECO ozone analyzer. Sample measurements of NO, CO, CH4, HNO3, CFC11, CFC12, and N_2O mixing ratios will be shown. Potential applications to air quality field projects such as Pacific 2001 will be demonstrated.

Millimeter wave scattering from ice crystal aggregates: comparisons with radar measurements at X- and Ka-Band using cloud model simulations

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Kultegin Aydin, The Pennsylvania State University
Johannes Verlinde, The Pennsylvania State University
Alexander Avramov, Columbia University
Andrew Ackerman, NASA Goddard Institute for Space Studies
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Mengistu Wolde, National Research Council

Arctic clouds are often mixed-phase, such that the radiative properties of the clouds are a strong function of the relative amounts of cloud liquid and ice. The poorly understood ice phase processes are the regulators of the liquid water fraction; in particular, ice precipitation, which in the Arctic is dominated by pristine ice and aggregates. This study evaluates results of different ice microphysics representations in a cloud-resolving model (CRM) using cloud radar measurements. An algorithm is presented to generate realistic aggregates of ice crystals from which radar backscatter cross-sections may be calculated using a generalized solution for a cluster of spheres. The aggregate is composed of a collection of pristine ice crystals, each of which is constructed from a cluster of tiny ice spheres. Each aggregate satisfies the constraints set by the component crystal type and the mass-dimensional relationship used in the cloud-resolving model, but is free to adjust its aspect ratio. This model for calculating radar backscatters is compared to two spherical and one spheroidal (bulk model) representation for ice hydrometeors. It was found that the refined model for representing the ice hydrometeors, both pristine crystals and their aggregates, is required in order to obtain good comparisons between the CRM calculations and the radar measurements. The addition of the radar-CRM comparisons to CRM-in situ measurements comparisons allowed conclusions about the appropriateness of different CRM ice microphysics representations.

A multi-scale model evaluation data set of small cumulus

Allison McComiskey, NOAA
Graham Feingold, NOAA Earth System Research Laboratory

Shallow cumulus convection has been increasingly recognized as important to radiative forcing and climate sensitivity. Clouds of small size present a challenge for representation in global-scale models, and process-level models have shown sensitivity in simulating these clouds to model resolution and domain size. Additionally, little is known about aerosol effects on this cloud type due to difficulties in sampling aerosol collocated with cloud and cloud 3D radiative effects. Comprehensive evaluation data sets for small cumulus are needed but lacking. Observations also present a challenge as cloud sizes are typically much smaller than the pixel size of commonly used satellite remote sensors and ground-based and in situ observations can be biased due to directional sampling issues. The scale of observation may bias results

substantially. We present an approach for a model evaluation data set of shallow cumulus clouds using available observational platforms from SGP, including ground-based observations, in situ airborne observations, and satellite-based remote sensing at a wide range of scales. We will examine this wide range of measurement scales and approaches in the context of model evaluation with the intent to provide information needed for improving simulations of this important cloud type.

Objective determination of 3D cloud locations using scanning millimeter-wavelength radars

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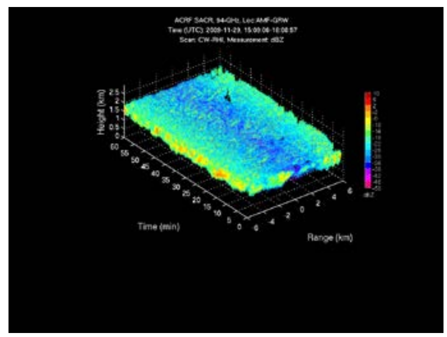
Ieng Jo, McGill University
Aleksandra Tatarevic, McGill University
Kevin Bowley, McGill University
Karen Johnson, Brookhaven National Laboratory
Scott Giangrande, Brookhaven National Laboratory
Eugene Clothiaux, The Pennsylvania State University

The scanning ARM cloud radars (SACRs) are the primary instruments for the detection of cloud properties (boundaries, water content, particle size and habit, dynamics, etc.) beyond the soda-straw view. The first step before high-value-added products (VAPs) can be developed using the multi-parametric radar measurements is the objective determination of 3D cloud locations (3D-ARSCL: Active Remote Sensing of 3D Clouds). The importance to the ARM data user community of determining cloud locations at the ARM sites is evident by the success of the 2D ARSCL VAP pioneered by Clothiaux et al. The development of the 2D ARSCL VAP required substantial resources and introduced the use of combined radar-lidar observations for the determination of the hydrometeor layer boundaries. Furthermore, the profiling ARM radars addressed the reduction of radar sensitivity with the square of the distance from the radar through the implementation of multiple operating modes that offer superior sensitivity at different parts of the atmospheric column. Thus, in the current ARSCL VAP, the height of the clouds above the ground is not a factor of concern. The transition from the profiling view to 3D contains several challenges that will be analyzed here. First, in 3D, the radar-lidar instrument synergy is not available and the determination of the cloud locations will be based on radar only. Second, due to fast scanning, the ability to operate modes with different sensitivity is limited, and we will have to address the reduction in sensitivity with range. Third, gridding of the quality-controlled radar data from spherical coordinates to a Cartesian grid is required. The coordinate system transformation is expected to ease the use of the scanning millimeter-wavelength radar data by the ARM user community. However, gridding cloud radar data is challenging especially if we consider the sparseness of radar observations with distance from the radar and the scales of clouds relevant to ASR scientific objectives. The aforementioned issues are discussed and potential solutions are presented in order to develop an objective methodology for the determination of 3D cloud locations.



Example of gridded 3D cloud locations from the SWACR deployment at the Azores.

http://www.clouds.mcgill.ca/research/sacr_data.html

On the influence of ice habit on the lifetime of Arctic mixed-phase clouds

Kara Sulia, The Pennsylvania State University
Jerry Harrington, The Pennsylvania State University

Mixed-phase clouds are common over the Arctic sea ice for much of the year. The persistence of supercooled liquid in these clouds is not well understood, but it is climatologically important because of the strong impact it has on the surface radiative budget. Most prior studies of mixed-phase cloud lifetime have assumed spherical particles or, at times, simple shapes. We show that these simplified methods lead to an over-estimate of mixed-phase cloud lifetime. Predicting ice habits have the strongest effects on cloud lifetime at -6C and -15C, where needle and dendritic crystals grow. Furthermore, we show that predicting ice habits is most critical at low ice concentrations (less than about 100 L-1), whereas at high ice concentrations, simple models of ice growth are sufficient. Cloud dynamics modify these results, since vertical motions can support the simultaneous growth of both liquid and ice. We show that dynamics can extend cloud lifetime when ice concentrations are low, and ice crystals grow in at temperatures that promote isometric growth (around -10C). Growth at habit-prone temperatures such as -15C and -6C requires higher vertical motions and lower ice concentrations to maintain the liquid. Our results suggest a strong temperature-dependence to supercooled liquid maintenance in Arctic clouds.

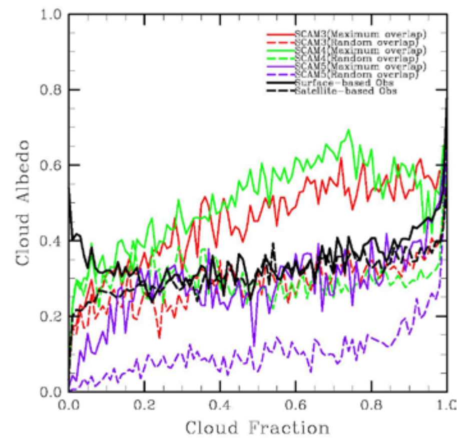
A preliminary analysis of STORMVEX cloud reflectivity spatial characteristics

Roger Marchand, University of Washington

The ongoing Storm Peak Laboratory Cloud Property Validation Experiment (STORMVEX) is creating a large correlative data set of remote sensing observations and direct in situ measurements by combining mountain-top observations at Storm Peak Laboratory with nearby/collocated measurements from the second ARM Mobile Facility. A prerequisite to using these data sets in cloud microphysical retrieval development is to understand when clouds and precipitation directly above the ARM scanning radar (where the observed Doppler spectra provide information on particle fall velocities) have the same distribution of microphysical properties as that measured at Storm Peak Lab. In this poster, we present results of a preliminary analysis of the scanning W-band cloud radar observations gathered during the experiment. We examine the spatial heterogeneity of cloud occurrence and radar reflectivity distributions from the radar range-height-indicator scans at several fixed azimuths, as well as the consistency of reflectivity observations directly above the radar and mountain-top sites with in situ microphysical data sets.

Relationship between cloud fraction and cloud albedo: a combined observational-modeling-theoretical investigation

Yangang Liu, Brookhaven National Laboratory
Hua Song, Brookhaven National Laboratory
Wei Wu, Brookhaven National Laboratory
Wuyin Lin, Brookhaven National Laboratory
Michael Jensen, Brookhaven National Laboratory
Tami Toto, Brookhaven National Laboratory

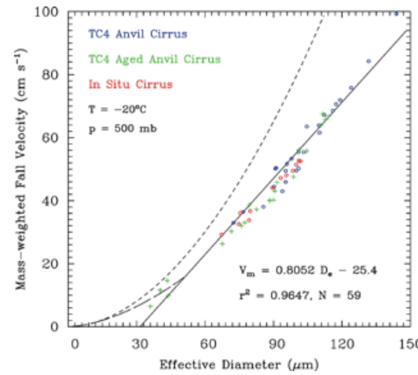


Relationship between cloud albedo and cloud fraction based on three-year (1999–2001) hourly data. The surface-based and satellite observations are derived from ARM-ground-based and GOES radiation measurements, respectively. SCAM3, 4, 5 correspond to the three versions of the NCAR CAM.

Cloud fraction and cloud albedo have long occupied the central stage as key cloud quantities in studying cloud-climate interaction; however, their quantitative relationship has been much less studied and understood, in both observations and climate models. This work explores this crucial relationship using a combined approach of empirical analysis of observational data, comparative examination of climate model results, and theoretical development of parameterizations. Three years (1999–2001) of hourly averaged ARM surface-based observations and GOES satellite retrievals at the SGP site are analyzed and compared with the corresponding three years of SCM simulations driven by the continuous ARM large-scale forcing. The preliminary results show that (1) cloud albedo is positively related to cloud fraction, and (2) although all the models catch the general feature of positive correlation, they differ significantly in details, with inter-model difference markedly larger than that between the two measurements. This finding poses a new challenge to parameterization development—self-consistency of parameterizations for cloud fraction and cloud albedo and the role of cloud-overlap assumptions. Further theoretical effort will seek to understand the physics underlying the albedo-fraction relationship and take up this challenge.

Representing the ice fall speed in climate models: results from TC4 and ISDAC

Subhashree Mishra, Desert Research Institute
Paul Lawson, SPEC Inc.
David Mitchell, Desert Research Institute



Relationship between De and Vm for all TC4 cirrus cloud types and some NAMMA in situ cirrus (solid line). The dashed curve is the best fit curve obtained by Heymsfield et al. (2003) for anvil cirrus sampled during the TRMM project. The long-dashed curve estimates Vm in the Stokes flow regime.

Ice fall-velocity is a critical climate feedback parameter influencing cirrus cloud coverage and radiative forcing as well as upper troposphere relative humidity. This study aims to provide the atmospheric modeling community with better parameterizations of the ice fall-speed in cirrus clouds based on aircraft measurements from recent field campaigns, especially the Tropical Composition, Cloud and Climate Coupling (TC4) campaign in 2007 and the Indirect and Semi-Direct Aerosol Campaign (ISDAC) in 2008. Historical measurements of the ice particle size distribution (PSD) have been flawed by ice artifacts produced by natural ice particles colliding with the inlet tube of various measurement probes. Data processing techniques used in conjunction with new probes used in recent field campaigns appear to have significantly reduced the artifact concentration of small ice particles. The mass-weighted fall velocity (Vm) depends on the PSD and ice particle shapes. The characterization of ice particle projected area and mass (i.e. a representation of ice particle shape) was also improved based on data collected during at least one of the field campaigns, allowing realistic estimates of Vm to be obtained. The calculation of Vm was based on improved direct measurements of the PSD, ice particle area, and estimated mass. The effective diameter (De) was calculated in a similar way. The TC4 analysis has provided diagnostic relationships that relate Vm to (1) both cloud temperature and ice water content (IWC) with an r2 of 0.75 and (2) to temperature alone with r2 = 0.72. Similar relationships for De were also obtained. However, a critical climate feedback parameter like the ice fall-speed needs to be coupled with the cloud microphysics and radiation in climate models. This is made possible through strong correlations between De and Vm regarding TC4 and ISDAC cirrus, and it ensures that Vm is consistent with the cloud microphysical and optical properties. Finally, TC4 satellite retrievals of De and Vm are found to be consistent with corresponding observations.

Retrievals of cloud optical depth and effective radius from a thin-cloud rotating shadowband radiometer (TC-RSR)

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Qilong Min, State University of New York at Albany
Minzheng Duan, Institute of Atmospheric Physics, Chinese Academy of Sciences
Andrew Vogelmann, Brookhaven National Laboratory
Mary Jane Bartholomew, Brookhaven National Laboratory
David Turner, NOAA

A thin-cloud rotating shadowband radiometer (TC-RSR) was developed and deployed in a field campaign at the ARM SGP site. The TC-RSR measures the forward scattering lobe of the direct solar beam (i.e., the solar aureole) through a thin cloud. We applied Min and Duan's retrieval algorithm to the field measurements of TC-RSR to derive cloud optical depth, effective radius, and LWP from the measured forward scattering lobe of the direct solar beam. After carefully calibrating and pre-processing, the retrieved cloud optical depth, effective radius, and LWP from TC-RSR showed reasonable agreement with other retrievals of MFRSR, MWR, and AERI. Our results indicate that the TC-RSR is able to simultaneously retrieve cloud optical depth, effective radius, and LWP for optically thin water clouds.

Routine cloud-boundary algorithm development for ARM micropulse lidar

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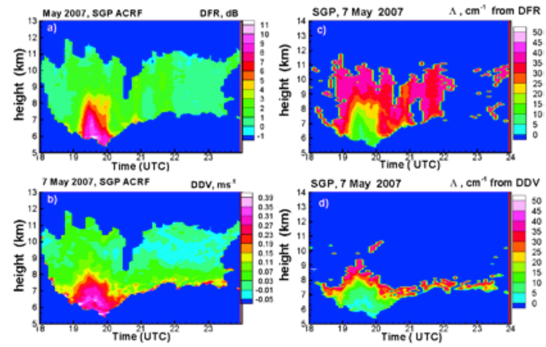
Jennifer Comstock, Pacific Northwest National Laboratory
Karen Johnson, Brookhaven National Laboratory
Connor Flynn, Pacific Northwest National Laboratory
Zhien Wang, University of Wyoming
Sally McFarlane, Pacific Northwest National Laboratory

An operational cloud boundary algorithm (Wang and Sassen 2001) has been implemented for use with the ARM micropulse lidar (MPL) systems. As part of this value-added product (VAP) named MPLCMASK, we have applied range, background, deadtime, and overlap corrections to the measured backscatter lidar signal to provide a corrected attenuated backscatter profile. This VAP will be the primary lidar cloud mask for input to the Active Remotely Sensed Cloud Locations (ARSCL) product and will be applied to all MPL systems, including historical data sets. We will present examples of the available data products.

Sizing particles in thick ice clouds using different dual-frequency radar approaches

Sergey Matrosov, CIRES, University of Colorado/NOAA Earth System Research Laboratory



Constrained DFR (a) and DDV (b) measurements in an ice cloud observed on 7 May 2007 at the ARM SGP site and the corresponding DFR-based (c) and DDV-based (d) retrievals of the size distribution slope lambda.

Measurements from the collocated Ka- and W-band vertically pointing cloud Doppler radars were used to evaluate dual-frequency approaches to retrieve a size parameter of the aggregate particle distributions in thick ice clouds. These approaches are based on non-Rayleigh scattering effects that exist when larger particles are present. The dual-frequency ratio (DFR) and the differential Doppler velocity (DDV) methods were tested using case study observations from the Atmospheric Radiation Measurement (ARM) Southern Great Plains site. Both methods were tuned for retrievals of the exponential distribution slope Λ, which is directly related to the median volume particle size, using appropriate assumptions about ice particle shapes, densities, and fall velocities. Due to measurement errors and uncertainties, meaningful retrievals were generally available for the interval 8 cm-1< Λ < 35 cm-1, although, using the DFR method, slightly larger values of Λ could also be estimated. The expected retrieval errors in the interval between 10 cm-1 and 25 cm-1 were about 30–40% for the DFR-based estimates and about a factor of two larger for the DDV-based estimates. Larger errors for retrievals with the Doppler approach can be explained by higher measurement noise and additional assumptions which are required for this approach. Comparisons of the DDV- and DFR-inferred values of Λ revealed their general consistency with a relative standard deviation between results of both methods being around ~40%, which is within expected retrieval uncertainties. While the DFR approach appears to be more accurate, it requires a 0 dB constraint near cloud tops, which mitigates uncertainties in absolute radar calibrations and differing attenuation paths. The DDV approach generally does not require such a constraint if radar beams are perfectly aligned in vertical (which might not be exactly the case during the SGP observations). Given this, DDV measurements may potentially allow ice particle sizing in situations when DFR constraining is not effective (e.g., in precipitating clouds and in clouds with substantial amounts of supercooled water).

The Storm Peak Lab Cloud Property Validation Experiment: description and early results

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Linnea Avallone, University of Colorado
Matthew Shupe, University of Colorado
Roger Marchand, University of Washington
Sergey Matrosov, CIRES, University of Colorado/NOAA Earth System Research Laboratory
Gannet Hallar, Storm Peak Laboratory Desert Research Institute
Ian McCubbin, Desert Research Institute
Chuck Long, Pacific Northwest National Laboratory
Paul Lawson, SPEC Inc.

Location of the AMF2 Thunderhead site during STORMVEX. The AMF2 van is located to the right and slightly below the Lodge. Picture taken from the face of Storm Peak just below the Storm Peak Lab.

From November 2010 through April 2011, the second ARM Mobile Facility (AMF2) was deployed to Steamboat Springs, Colorado, USA, to collect routine remote sensing data while aerosol and cloud property data were collected by mountain-top probes operated by the Storm Peak Laboratory (SPL) and by the University of Wyoming King Air research aircraft. The ground-based instruments included a scanning W-band radar (SWACR) and the new high spectral resolution lidar. The AMF2 instruments were deployed at various locations on the mountain ranging from the valley floor to just 400 m below the SPL laboratory elevation. The late autumn and early winter of 2010/2011 (December–January as of this writing) provided nearly continuous cloud cover and frequent, almost daily, precipitation events that ranged from blizzards with intense upslope wind to light snow and even liquid-phase drizzle in light wind. Conditions at SPL ranged from thick liquid cloud with heavy snowfall to liquid clouds with no measureable precipitation to light snowfall with no measureable liquid cloud. In short, both remote and in situ sensors measured an extremely wide range of conditions over a period of time spanning many months. Early science is focusing on the degree to which cloud and precipitation signals can be extracted from the vertically pointing W-band radar spectra and the extent to which cloud and precipitation retrievals derived from vertically pointing data can be applied to off-zenith volume scans. Scanning polarization sensitive W-band radar is revealing the degree to which orientation and riming of snow influence the measurement of radar reflectivity at vertical incidence. This has significant implications for the retrieval of snowfall by cloud radars. These issues will be explored more fully in this presentation.

http://meteo04.chpc.utah.edu:8080/stormvex

Studying mixed-phase cloud microphysical processes using cloud radar Doppler spectral moments

Guo Yu, The Pennsylvania State University

Previous observations demonstrate that a considerable fraction of low-level Arctic stratus clouds contain volumes composed of both water and ice (i.e., mixed phase). Although mixed-phase clouds are prevalent in the Arctic, quantifying the liquid phase within these clouds using remote sensors is a challenge. As a result, a complete understanding of the microphysical and dynamical processes that shape the formation and evolution of mixed-phase clouds is lacking. Ground-based remote sensors are important for monitoring and studying clouds and their microphysical, macrophysical, and dynamical processes. The complexities of clouds demand multiple remote sensor measurements in their study. Data from a millimeter-wavelength cloud radar (MMCR) and a high spectral resolution lidar (HSRL) collected during the Mixed-Phase Arctic Cloud Experiment (M-PACE) on the 6th and 12th of October 2004 are used to characterize Arctic stratus clouds, including their liquid component. The HSRL is employed to distinguish cloud-hydrometeor phases and determine cloud bases because of its excellent sensitivity to cloud droplets and its ability to detect changes in polarization. Because HSRL signals can be completely attenuated by cloud droplets short distances above cloud base, the possibility of using moments of MMCR Doppler spectra to identify, separate, and quantify the liquid contribution to the total reflectivity is investigated. We use theoretical (i.e., Gaussian-shaped) and measured multimodal Doppler spectra to retrieve liquid and ice phases and their evolution as a function of height. These results are used to identify and interpret different microphysical processes operating within Arctic mixed-phase clouds.

Study of cloud lifetime effects using the SGP heterogeneous distributed radar network: preliminary considerations

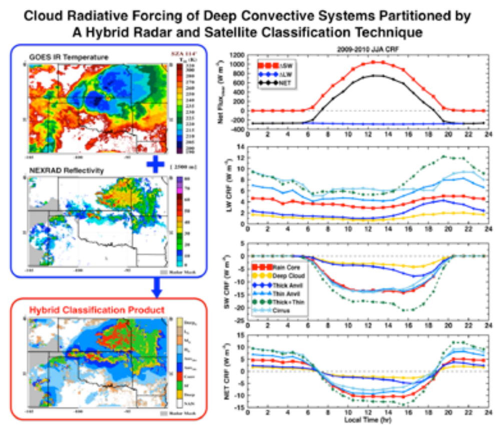
Paloma Borque, McGill University
Pavlos Kollias, McGill University
Scott Giangrande, Brookhaven National Laboratory

Despite decades of active research, there exist limited observational resources for the multi-dimensional morphology and life cycle of clouds. Detailing key cloud processes as they transit from the formation stage to precipitation onset and cloud dissipation is critical towards establishing uncertainties in climate models linked to cloud-climate radiative feedbacks. This challenge is exacerbated by the need for detailed measurements at scales often not suitable for single platform. One path forward is to capitalize on ARM's multi-frequency, multi-radar scanning radar facility to document temporal and spatial cloud evolution. In this work, we examine the potential of the SGP heterogeneous distributed radar network to detect and monitor different stages of cloud development. Here, we express cloud life cycle in terms of the temporal evolution of maximum cloud radar reflectivity (Zmax(t)). Using the locations and expected performance of the weather and cloud radars deployed for the Midlatitude Continental Convective Clouds Experiment (MC3E) in central Oklahoma, maps of minimum detectable reflectivity have been developed. Also, different hypothetical scenarios of cloud lifetime, in terms of the temporal evolution of maximum cloud radar reflectivity, are tested to evaluate the spatial and temporal capabilities of the radar facility to provide qualitative measurements of the different stages of the cloud lifetime.

A study of deep convective systems and their associated anvil cloud properties over the SGP through an integrated analysis of NEXRAD, GOES, and ARM MMCR data

Zhe Feng, University of North Dakota
Xiquan Dong, University of North Dakota
Baike Xi, University of North Dakota
Patrick Minnis, NASA Langley Research Center
Min Deng, University of Wyoming

Cirrus anvil clouds associated with deep convective systems (DCS) are strongly connected to the water budgets of the upper troposphere and have strong influence on climate processes through modulating the atmospheric radiation budget. Feng et al. (2011) have developed an objective classification technique to identify DCS and accurately partition anvil cirrus clouds with parent convective rain cores using a combination of NEXRAD radars and GOES satellite data from two summers (JJA 2009–2010) over the SGP region (8×15° centered at the ARM SCF). There are three steps in this study. First, we have developed an objective classification technique to identify Deep Convective Systems (DCS) and separate their rain core and associated anvil clouds using merged NEXRAD and GOES observations. Second, we have calculated the SW, LW, and NET Cloud Radiative Forcing (CRFs) of different cloud types within DCS (core, anvil) and quantitatively estimated their impact to the TOA radiation budget. The preliminary results have revealed that the averaged total SW CRF is -34 Wm-2 and LW CRF is 22.5 Wm-2, resulting in a net cooling of -11.5 W m-2 during summer months over the SGP region. Of all clouds, DCS clouds contribute 48% in SW CRF, 59% in LW CRF, and 52% in NET CRF. Within DCS, the SW, LW, and NET CRFs contributed from anvil clouds are 26%, 35%, and 30%, respectively. These values are slightly higher than those contributed from DCS core regions (22%, 24%, and 22%). Finally, we will compare the vertical profiles of cloud microphysical properties between DCS anvils and cirrus clouds, such as ice water content and effective diameter, retrieved from ARM SGP radar observations over the ARM SCF. It is our goal that these results can be used to evaluate the climate-model-simulated DCSs, their associated anvil cloud properties, and radiative impact over the midlatitudes.



Cloud radiative forcing of deep convective systems partitioned by a hybrid radar and satellite classification technique.

Understanding uncertainties in current cloud retrievals from ARM ground-based measurements

Chuanfeng Zhao, Lawrence Livermore National Laboratory
Shaocheng Xie, Lawrence Livermore National Laboratory
Stephen Klein, Lawrence Livermore National Laboratory
Renata McCoy, Lawrence Livermore National Laboratory
Jennifer Comstock, Pacific Northwest National Laboratory
Min Deng, University of Wyoming
Maureen Dunn, Brookhaven National Laboratory
Dong Huang, Brookhaven National Laboratory
Robin Hogan, University of Reading
Michael Jensen, Brookhaven National Laboratory
Gerald Mace, University of Utah
Sally McFarlane, Pacific Northwest National Laboratory
Matthew Shupe, University of Colorado
David Turner, NOAA
Zhien Wang, University of Wyoming

Accurate observations of cloud microphysics are critical to improve the representation of clouds in current climate models. However, large discrepancies are found in current cloud retrieval products. This poses a severe restriction in cloud modeling studies. Understanding the discrepancies is an important step to address the uncertainties in cloud retrievals. In this study, an in-depth analysis of seven existing ARM ground-based cloud retrievals is carried out. High-level ice clouds and boundary layer stratus clouds, which are the focus of most current retrievals, are specifically studied. Differences in the algorithm complexity and assumptions of cloud retrievals, the data used, and the cloud retrieval constraints are analyzed to understand their potential impacts on the retrieved products. It shows that the large discrepancies between different cloud retrievals, both in the retrieved cloud properties and the relationships between different cloud properties, can be partly expected from the differences in the retrieval techniques, like the algorithm parameters and the assumptions of particle-size distributions and ice crystal habits. The impact of input data used in the retrievals, such as cloud boundaries, cloud phase, and hydrometer classifications, is also an important contributor to the large discrepancies of cloud properties between different retrieval products. It indicates the need of improving accuracy and consistency in the input measurements for current retrievals. The impact of cloud retrieval constraints, such as MWR liquid water path, is also briefly described. A statistical cluster analysis technique is used to further demonstrate the systematic discrepancies between different retrievals.

Use of a cluster analysis to investigate the relationship between large-scale dynamics and clouds

Stuart Evans, University of Washington
Roger Marchand, University of Washington
Thomas Ackerman, University of Washington

Cloud parameterizations are an attempt at statistically connecting large-scale dynamics to local cloud and precipitation properties. We investigate those relationships through the use of a clustering technique developed by Marchand and co-authors (2009, Journal of Climate) to classify regional atmospheric states. These atmospheric states are created by a neural network classifier acting on reanalysis data and are refined and shown to be statistically significant through the use of independent cloud radar data. Here we

present results from the application of this method to regions surrounding the ARM sites at both Southern Great Plains and Darwin, Australia. In both cases we use ERA-Interim data and observations from the vertically pointed millimeter-wavelength cloud radars at the ARM sites. Having contemporaneous observations of atmospheric state and other atmospheric observables allows us to create distributions of observables associated with each state. Examples of observables include ground-based observations such as cloud occurrence, precipitation, and liquid-water path along with satellite retrievals of the same properties. The multi-year record allows us to investigate the seasonal and interannual variability of the dynamic states and the relationship between these states and larger-scale phenomena such as the Madden-Julian Oscillation (MJO). In addition, we can examine the diurnal cycle of the states, the duration of particular patterns (since we classify the atmospheric state several times a day), and the transition probability from any state to any other state. Our near-term goal is to apply this technique to climate model output to determine to what extent climate models can duplicate both the occurrence of the atmospheric states and the observed linkage between the dynamical states and associated hydrological properties.

Using ARM data to evaluate and improve multilayer cloud properties retrieved from the GOES-East data

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Patrick Minnis, NASA Langley Research Center
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Current satellite cloud retrieval methods applied to the Geostationary Operational Environmental Satellite (GOES) imager data often adopt single-layered cloud assumptions, while day-to-day observations of cloud vertical profiles like those from the Atmospheric Radiation Measurement (ARM) Climate Research Facility exhibit frequent occurrence of multilayer clouds. It has been a challenge using traditional GOES imagery data to retrieve multilayered cloud properties. Here we present a feasible method for the retrieval of multilayered cloud properties using a new suite of multispectral observations onboard the designated GOES-East imager located at 75°W, which provides a basic element of continued cloud observations over the United States. The designated GOES-East imager, started with GOES-12 and replaced by GOES-13 on April 14, 2010, carries five spectral channels at nominally 0.6, 3.9, 6.5, 10.7, and 13.3 μm. The new added 13.3-μm CO2 absorption channel, mainly different from the 12-μm channel of the current GOES-West imager, allows for an improved retrieval of upper-troposphere cloud-top height using a modified CO2-absorption technique developed by Chang et al. (2010). Accurate retrieval of the uppermost cloud top height is fundamental and critical in the feasible method for retrieving multilayer cloud properties. An iterative retrieval procedure invoked ice-overlap-water, two-cloud-layered radiative transfer modeling, similar to the scheme of Chang and Li (2005), which is then used to determine a multilayered cloud mask from the GOES data. The method retrieves separately upper- and lower-layer cloud properties when a multilayered cloud pixel is determined. In this study, the ARM Active Remotely Sensed Cloud Locations (ARSCL) data taken at the Southern Great Plains (SGP) site are used to evaluate the multilayered clouds retrieved from the GOES-East data. Comparisons with the ARSCL data show that the GOES-retrieved upper-layer cloud top heights are generally lower, whereas lower-layer cloud top heights generally higher. The biases and improvements in the GOES-retrieved multilayered cloud properties are presented and discussed.

Using Self-Organizing Maps to evaluate the NASA GISS AR5 SCM at the ARM SGP site

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Xiquan Dong, University of North Dakota
Baike Xi, University of North Dakota
Anthony Del Genio, NASA Goddard Institute for Space Studies
Audrey Wolf, NASA Goddard Institute for Space Studies

Cluster analyses have gained popularity in recent years to establish cloud regimes using satellite and radar cloud data. These regimes can then be used to evaluate climate models or to determine what large-scale or subgrid processes are responsible for cloud formation. An alternative approach is to first classify the meteorological regimes (i.e., synoptic pattern and forcing) and then determine what cloud scenes occur. In this study, a competitive neural network known as the Self-Organizing Map (SOM) is used to classify synoptic patterns over the Southern Great Plains (SGP) region to evaluate simulated clouds from the AR5 version of the NASA GISS ModelE single-column model (SCM). In detail, 54-class SOMs have been developed using North American Regional Reanalysis (NARR) variables averaged to 2 x 2.5 degree latitude-longitude grid boxes for a region of 7 x 7 grid boxes centered on the ARM SGP site. Variables input into the SOM include mean sea-level pressure and the horizontal wind components, relative humidity, and geopotential height at the several standard pressure levels. These SOMs are produced for the winter (DJF), spring (MAM), summer (JJA), and fall (SON) seasons during the period 1999–2009. This synoptic typing will be associated with observed cloud fractions and forcing properties from the ARM SGP site and then used to evaluate simulated clouds from the SCM. SOMs provide a visually intuitive way to understand their classifications because classes are related to each other in a two-dimensional space. An example of a feature map for meteorological features at 925 hPa is provided in Figure 1. ARM ARSCL and GISS SCM mid-level (2–6 km) cloud fractions are given in Figure 2. It is clearly seen that the majority of the mid-level clouds occur in association with low-pressure systems. Despite producing clouds during the right conditions, the SCM produces too few mid-level clouds during cyclonic activity.

Using Self Organizing Maps to Evaluate the NASA GISS AR5 SCM at the ARM SGP Site

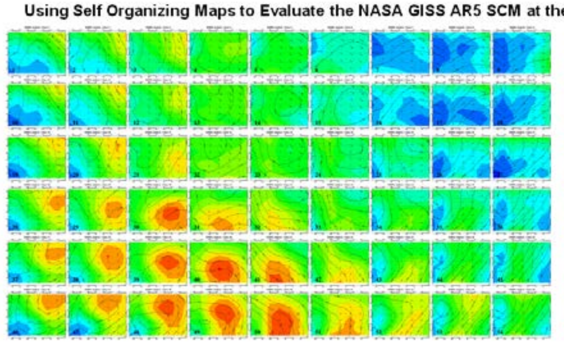

Figure 1. Feature map for a 54 class SOM during DJF of 1999-2001. Displayed are 925 hPa winds, MSLP (contoured), and relative humidity (filled contours).

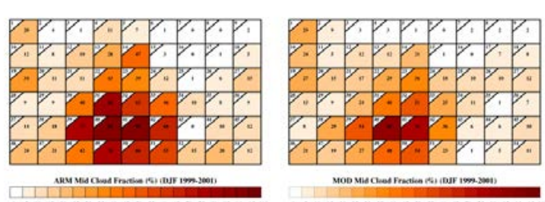

Figure 2. Mid-level (2-6 km) cloud fractions for ARM (left) and the SCM (right) for the SOM provided in Fig. 1.

Validation and comparison of cloud layers from radiosonde and WACR-ARSCL VAP data in China

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Zhanqing Li, University of Maryland
Hongbin Chen, Institute of Atmospheric Physics, Chinese Academy of Sciences

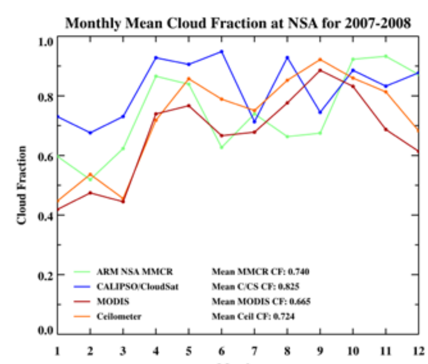
The Atmospheric Radiation Measurement (ARM) Mobile Facility (AMF) was deployed in Shouxian, Anhui Province, China, from May 14 to December 28, 2008, but the 95-GHz W-band ARM cloud radar (WACR) was operated only from October to December. By virtue of the radar imagery data and coincident radiosonde launches, cloud vertical distribution was obtained for the longer period of the AMF campaign. If the approach is sound, the method could be applied to generate a cloud climatology over a much longer period and larger spatial domain, pending on the availability of radiosonde data. The recent release of the WACR Active Remote Sensing of Clouds (WACR-ARSCL) value-added product (VAP) allows us to evaluate the radiosonde-based detection of cloud layers by comparing the cloud layers obtained from the radiosonde and WACR-ARSCL VAP (WVAP). Overall, the two products agree reasonably well, and each method has its limitations. While the frequency of the radiosonde launches is much less than the frequency of WVAP, cloud layers derived from the radiosonde are similar to the WACR. Many near-surface moist layers are classified as cloud layers by the WVAP but are deemed to be clear by the radiosonde. The former is suspicious because of the low relative humidity (RH). A few cloud layers at high altitudes are detected by the radiosonde but missed by WVAP. Cloud layers that are detected by the radiosonde but missed by WVAP are generally thin and located at high altitudes.

http://www.agu.org/journals/jd/jd1023/2010JD014030/

Validation of CERES-MODIS and CALIPSO/CloudSat Arctic cloud properties using ARM NSA observations

Kathryn Giannecchini, University of North Dakota
Xiquan Dong, University of North Dakota
Baike Xi, University of North Dakota
Patrick Minnis, NASA Langley Research Center

Studies of cloud properties in the Arctic are often affected by complex snow and ice cover that make it difficult to differentiate between clouds and ground cover using satellite remote sensing techniques. In this study, the Arctic cloud fraction and microphysical properties derived from NASA CERES team (CERES-MODIS) and CloudSat/CALIPSO have been compared with the DOE ARM NSA observations from January 2007 through December 2008. The ARM cloud properties used in this study include monthly means of cloud fraction, cloud base and top heights, and cloud liquid water path derived from the ARM ceilometers, millimeter-wavelength cloud radar (MMCR), and microwave radiometer (MWR) measurements at the ARM NSA site. The NASA CERES-MODIS cloud properties are retrieved by the 4-channel VISST (Visible Infrared Solar-Infrared Split-window Technique), an updated version of the 3-channel visible



Cloud fraction derived from CALIPSO/CloudSat, MODIS, and MMCR at the ARM NSA site at Barrow, Alaska, for January 2007–December 2008.

infrared solar-infrared method described by Minnis et al. (1995). The cloud properties from CloudSat/CALIPSO are Level 2B data products, including cloud base and top heights determined by both 94-GHz radar and lidar with a vertical resolution of 240 m, with LWP retrieved from the 94-GHz radar. To match the surface and satellite observations/retrievals, the ARM surface observations have been averaged into 1 hour centered at the satellite overpass, and the satellite observations have been averaged within a 1°x1° grid box around the Barrow site. Preliminary results have revealed that the CERES-MODIS derived effective cloud height (2.349 km) and CloudSat/CALIPSO derived cloud base (2.77 km) and top (4.471 km) heights are within the ARM ceilometer- and MMCR-derived cloud base (0.929 km) and top (5.388 km) heights. The ARM ceilometer- and MMCR-derived CFs have an excellent agreement (0.724 vs. 0.74), whereas the CERES-MODIS- and CloudSat/CALIPSO-derived CFs are slightly lower (0.665) and higher (0.825), respectively. The LWP values derived from ARM, CERES-MODIS, and CloudSat/CALIPSO are close to each other (76, 66, 57 gm-2) with a general trend of increasing from winter to late summer/early fall.

A warm cloud microphysical data set based on ARM Ka- and W-band cloud radars

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Maureen Dunn, Brookhaven National Laboratory
Yangang Liu, Brookhaven National Laboratory
Michael Jensen, Brookhaven National Laboratory
Warren Wiscombe, Brookhaven National Laboratory

Microwave attenuation is directly proportional to cloud liquid water content (LWC) and can be calculated accurately from dual-frequency radar measurements. The dual-frequency radar attenuation approach, unlike Z-LWC approaches, makes no assumptions about the cloud drop size distribution. This poster shows that, by combining these simple physics and advanced mathematical inversion techniques, accurate retrieval of vertically resolved cloud LWC can be obtained using operational ARM Ka- and W-band cloud radars. We have applied the dual-frequency approach to retrieve microphysical properties of warm clouds using the ARM radar observations from 2006 to 2008. This poster will present the comparisons between the dual-frequency and the MICROBASE cloud retrievals.

6.0 Dynamics/Vertical Motion

Characterization of the mass-flux in fair-weather cumuli using long-term cloud radar measurements at the SGP site

Arunchandra Chandra, McGill University
Pavlos Kollias, McGill University
Bruce Albrecht, University of Miami
Stephen Klein, Lawrence Livermore National Laboratory
Yunyan Zhang, Lawrence Livermore National Laboratory

The diurnal cycle of fair-weather cumuli over land is strongly coupled to the surface forcing. Fair-weather cumuli are one of the main mechanisms for moistening the lower troposphere and preconditioning the deep convection. Despite their importance and relevance to both weather and climate, fair-weather cumuli are sparsely observed and hence poorly understood. The first step towards understanding fair-weather cumuli is to document their properties using a statistically large sample. The diurnal cycle and the mass-flux profile associated with these clouds are the two most important areas that can lead to increasing our understanding of the coupling of these clouds to the surface and the role of their life cycles in regulating cloudiness and mass-fluxes. Using the entire cloud radar data set from SGP, statistics parameters of the fair-weather cumuli fields have been derived—in particular, the cloud fraction, the cloud aspect ratio, cloud spacing, and the profile of the in-cloud mass flux. The derived cloud base mass flux is used to evaluate aspects of proposed mass flux parameterizations (e.g., mass flux, critical velocity, updraft/downdraft fraction, vertical velocity distributions at the cloud base, etc). In addition, the in-cloud mass flux profiles of individual clouds are used to classify the clouds into active and passive and study the diurnal variation of these cloud categories. The goal is to identify the active cloud fraction and investigate its relationship to surface and subcloud conditions.

A comparison of vertical velocity PDFs in the cloudy and cloud-free atmosphere

Julia Flaherty, Pacific Northwest National Laboratory
Larry Berg, Pacific Northwest National Laboratory
Jennifer Comstock, Pacific Northwest National Laboratory

The Routine Atmospheric Radiation Measurement (ARM) Aerial Facility (AAF) Clouds with Low Optical Water Depths (CLOWD) Optical Radiative Observations (collectively, RACORO) study was conducted from January through June of 2009. During RACORO, 59 flights were conducted in the vicinity of the ARM Southern Great Plains (SGP) site, including flights in clear and cloud-topped boundary layers. Vertical velocity measurements made at 10Hz temporal resolution have been analyzed using wavelet analysis to determine the distribution of vertical velocity perturbations at time scales of 1–10 sec and 10–50 sec. Flights were conducted at a number of altitudes, including flights through shallow cumuli. Vertical velocity perturbation probability density functions are presented for the cloudy and cloud-free atmosphere. These in situ measurements of vertical velocity can be used to verify velocity statistics from a range of remote sensing instruments, as well as assumptions that are commonly applied in global and regional scale models of the atmosphere.

Controls on cloud base mass flux and cloudiness of fair-weather cumuli in a marine environment

Bruce Albrecht, University of Miami
Pavlos Kollias, McGill University
Virendra Ghate, Rutgers University

The parameterization of fair-weather cumuli in numerical models is frequently based on cumulus mass flux approaches. Two critical components of these fluxes are the cloud base mass flux and the vertical distribution of the cumulus mass flux. Direct evaluation of existing mass flux parameterizations has been limited primarily to the use of Large-Eddy Simulations (LES). In this study we apply the evaluation approach used with LES to clouds characterized by a profiling Doppler cloud radar operating as part of the Atmospheric Radiation Program (ARM) Climate Research Facility at Nauru Island (0.5°S, 167°E). The radar measurements provide statistics on the in-cloud vertical air motions in non-precipitating fair-weather cumuli observed from 1999–2000 during a prolonged period of suppressed conditions at the island. These (nighttime only) observations are used to estimate cumulus mass fluxes extending from cloud base to cloud top for 24 consecutive months. Application of a mixed-layer model to the subcloud layer using monthly averaged near surface temperature and moisture measurements and cloud base height estimates from a ceilometer indicates that the subcloud layer is in radiative-convective equilibrium. The associated surface virtual temperature fluxes from these steady conditions provide monthly estimates of the convective velocity scale w*. This velocity scale is used with the boundary layer thermodynamics and static stability at the top of the sub-cloud layer for evaluating different cloud base mass flux parameterizations. The vertical profiles of the observed mass flux are compared with those from LES. The monthly averaged fractional cloudiness used in this study varies from about 10–20% on a seasonal time scale. The factors affecting this observed variability in the cloudiness are examined in light of the Nauru observations.

Convectively generated gravity waves during TWP-ICE

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Mai Nguyen, Monash University
Todd Lane, University of Melbourne
Christian Jakob, Monash University
Andrew Heymsfield, National Center for Atmospheric Research

All convective clouds emit gravity waves. As they propagate, the gravity waves emitted by clouds displace air parcels vertically, possibly producing further clouds. These waves also transport momentum and energy large distances from the site of their generation, exerting a stress on the atmosphere wherever they dissipate. The larger project examines the part played by convectively generated gravity waves in the formation of cirrus and in the subgrid-scale momentum transport and associated large-scale stresses imposed on the troposphere and stratosphere. The work reported here focuses specifically on the characteristics of the convectively generated gravity waves analysed from the radiosonde soundings taken during the Tropical Warm Pool-International Cloud Experiment (TWP-ICE). Fluctuations in the ascent rate of the radiosonde are used to characterize the high-frequency waves, whereas the fluctuations in the horizontal winds are used to determine the properties of the inertia-gravity waves. A basic assumption underpinning both approaches is that the perturbations in the radiosonde sounding represent gravity waves. Following May et al. (2008), TWP-ICE is divided into three periods. As the character of the convection changes during the experiment, so does the character of the gravity wave spectrum. Regime 1 is characterized by active monsoon convection. In this regime, the wave field, like the convection, shows little diurnal variation. Regime 3 is characterized by diurnally forced break convection embedded in deep

easterlies. Accordingly, the gravity wave field is of higher frequency and exhibits a strong diurnal variation. Regime 2 is characterized by suppressed convection with strong westerlies associated with deep tropical lows to the south of Darwin. In this regime, the high frequency wave activity is modulated on a time scale of 3–4 days. Interestingly, the meridional wind just above the top of the tropopause fluctuates with a similar period. It appears that the convectively generated high-frequency gravity wave activity is modulated by the large amplitude low-frequency inertia-gravity wave.

The Midlatitude Continental Convective Clouds Experiment (MC3E)

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Walter Petersen, NASA Marshall Space Flight Center
Nitin Bharadwaj, Pacific Northwest National Laboratory
Anthony Del Genio, NASA Goddard Institute for Space Studies
Scott Giangrande, Brookhaven National Laboratory
Daniel Hartsock, University of Oklahoma
Andrew Heymsfield, National Center for Atmospheric Research
Gerald Heymsfield, NASA Goddard Space Flight Center
Arthur Hou, NASA Goddard Space Flight Center
Pavlos Kollias, McGill University
Peter Lamb, University of Oklahoma
Brad Orr, Argonne National Laboratory
Steven Rutledge, Colorado State University
Mathew Schwaller, NASA Goddard Space Flight Center
Edward Zipser, University of Utah

The Midlatitude Continental Convective Clouds Experiment (MC3E) is a joint field campaign by the DOE ARM Climate Research Facility and NASA's Global Precipitation Measurement Mission set to take place April 22–June 6, 2011, at the Southern Great Plains Research Facility in Oklahoma. MC3E will use a multiscale, multiplatform measurement strategy of surface-based remote sensing, aircraft in situ, and satellite observations to provide the most complete characterization of convective cloud systems, precipitation, and the environment that has ever been obtained, providing constraints for model cumulus parameterizations and space-based rainfall retrieval algorithms over land. This campaign will highly leverage the assets available at the ARM Southern Great Plains facility, especially the new scanning radar systems purchased as part of the American Recovery and Reinvestment Act. In addition to these new and existing ARM permanent instruments, two scanning radar systems (Ka/Ku and S-band), vertically pointing profiler systems (S-band, UHF), an array of disdrometer systems, and a five-station radiosonde array will be deployed. This poster will present a scientific overview, the expected instrumentation, and an overview of final preparations for this field campaign.

http://www.arm.gov/campaigns/sgp2011midlatcloud

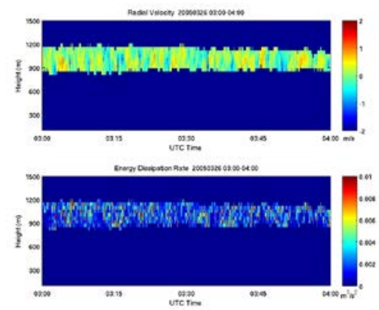
Studies of organized convection

Siwon Song, University of Miami
Brian Mapes, University of Miami

In support of a project aimed at parameterizing convective organization for CAM5, we describe observational studies of organized convection fields in observations and cloud-resolving simulations.

Turbulence estimates in continental stratocumulus using ARM cloud radar data

Ming Fang, University of Miami
Bruce Albrecht, University of Miami
Virendra Ghate, Rutgers University



Time-height display. The upper panel is vertical velocity and the lower panel is the EDR calculated from spectrum width. The data were recorded by the SGP MMCR during 03:00 to 04:00 UTC on 26 March 2005.

Observations from the Atmospheric Radiation Measurement (ARM) millimeter wavelength cloud radar (MMCR) are used to examine the turbulence structure associated with 18 hours of stratocumulus observations over the Southern Great Plains site. The MMCR has a 0.2° angular resolution that limits the influence of shear and the coupled term on the spectrum width measurements and makes this radar particularly suitable for estimating turbulence in clouds. The magnitude of the energy dissipation rate (EDR) calculated from spectrum width agrees with that calculated from turbulent velocity power spectra. The EDR calculated from the spectrum width is more self-consistent, robust, and reliable than that from the resolvable velocity power spectra. Because moments are generated from an averaged Doppler spectrum, the single MMCR-measured spectrum width, as well as its spatial or temporal average, can be used to compute EDR. In the time-height display for the case investigated, updraft cores correspond to low EDR areas. Larger EDR values surround the updraft core and appear on the top and edges of the updraft core. In contrast to the updraft, the downdraft often corresponds to a large EDR area. These large and low EDR value areas constitute a wave train that is not easy to recognize in the velocity and reflectivity fields.

Uncertainties of radar-derived vertical velocities in deep convective clouds using ARM precipitation radars

Kirk North, McGill University
Scott Collis, Argonne National Laboratory
Scott Giangrande, Brookhaven National Laboratory
Pavlos Kollias, McGill University

Vertical air motions have a direct effect on convective cloud life cycles and microphysical processes. Measurements of updrafts and downdrafts on scales comparable to cloud-resolving models are required to evaluate and improve convective parameterization. Despite their importance, the availability of these measurements in deep convective clouds is still rather sparse. One of the primary goals of the new ARRA enhanced radar networks is to provide such measurements routinely. The retrieval approach utilizes multi-Doppler analysis techniques. However, the accuracy of these retrievals is not well characterized, particularly the sensitivities associated with radar configuration. In order to address this issue we have developed a forward model radar simulator, known as the McGill Multi-parameter Radar Simulator (MMRS). Coupling MMRS with WRF model output, synthetic radar volumes associated with a particular scanning strategy are generated. Vertical air motions are then extracted from these synthetic volumes using the retrieval algorithms to be tested: for example, an OTS Cartesian mapping system combined with a three-dimensional variational wind retrieval scheme. A comparison between the model field and the retrieved field can be performed allowing for a study on the impact undersampling storm features has on vertical velocity retrievals.

Vertical air motion uncertainties in profiling radar observations

Christopher Williams, University of Colorado at Boulder/NOAA Earth System Research Laboratory

Vertically pointing profiling radars operating at 50 MHz (VHF) are able to directly measure the vertical air motion even when precipitating cloud systems pass overhead. During deep convective rain, updrafts exceeding 10 m/s are commonly seen in the Darwin, Australia, VHF profiler data set. During stratiform rain, updrafts and downdrafts are on the order of +/- 20 cm/s. This study developed a Monte Carlo simulation to estimate the vertical air motion measurement uncertainty that complements the vertical air motions estimated for the Tropical Western Pacific-International Cloud Experiment (TWP-ICE). The Monte Carlo simulation was constructed by adding realistic noise to idealized Doppler velocity power spectra. For each idealized spectrum, the spectrum moments (signal-to-noise ratio (SNR), mean radial velocity, and spectrum width) were estimated for 1000 noisy spectra. The mean deviation from the expected value and the spread of the 1000 moments provides estimates of the measurement bias and uncertainty. The simulations confirmed previous work that measurement uncertainties increase with decreasing SNR. But interestingly, the simulations showed that measurement uncertainties increased with increasing spectrum width. The Monte Carlo simulation also showed that the uncertainties are dependent on the radar operating parameters. Using the VHF profiler operating parameters, it was found that for convective rain events with mean updrafts exceeding 5 m/s, the velocity uncertainty ranged from 0.1 to 0.6 m/s. For stratiform rain, the velocity uncertainty was less than 2 cm/s. In the future, the Monte Carlo simulations developed in this study can be used to estimate measurement uncertainties for other radars, including the MMCR.

7.0 Field Campaigns

Airborne high spectral resolution lidar aerosol measurements during CalNex and CARES

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Sharon Burton, NASA Langley Research Center
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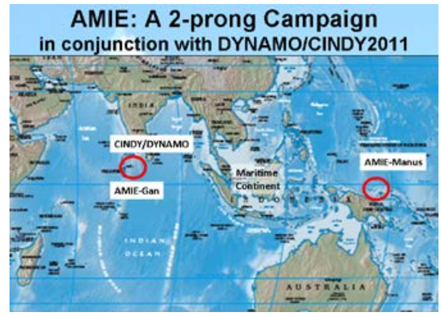
Evgueni Kassianov, Pacific Northwest National Laboratory
Brent Holben, NASA Goddard Space Flight Center
Stephen Springston, Brookhaven National Laboratory
Charles Brock, NOAA Aeronomy Laboratory

The NASA Langley Research Center (LaRC) airborne high spectral resolution lidar (HSRL) on the NASA B-200 aircraft measured aerosol extinction (532 nm), backscatter (532 and 1064 nm), and depolarization (532 and 1064 nm) profiles during the 2010 CalNex and CARES field missions. During the CalNex deployment in May 2010, HSRL data were acquired during eight science flights that were located mainly over Los Angeles. During the CARES deployment in June 2010, HSRL data were acquired during 23 science flights that were located mainly over Sacramento. The B-200 flights were conducted so that the NOAA WP-3, NOAA Twin Otter, CIRPAS Twin Otter, and DOE G-1 aircraft often collected coincident data within the HSRL "curtains," thereby facilitating extensive intercomparisons and combined analyses. The HSRL data are used to characterize the vertical and horizontal distribution of aerosols and to provide the vertical context for the airborne in situ measurements acquired from these other aircraft. Aerosol intensive parameters derived from HSRL data are used to infer aerosol types and determine the fraction of aerosol optical thickness (AOT) contributed by these types. Preliminary analyses of data acquired over the Los Angeles region during CalNex show cases where elevated layers of dust, likely transported from Asia, were located above urban aerosols. HSRL and ground-based Cimel sunphotometer and multifilter rotating shadowband radiometer (MFRSR) measurements show low (<0.1 at 532 nm) AOT values were generally found over the Sacramento region during CARES; a larger and wider range of AOT values was found over Los Angeles during the CalNex flights. HSRL measurements are also used to determine planetary boundary layer (PBL) height and investigate the spatial and temporal variability of PBL height in these regions, as well as to evaluate PBL heights derived from the WRF-Chem model. Preliminary comparisons of aerosol extinction derived from the HSRL measurements and in situ measurements of aerosol scattering and absorption on the DOE G-1 aircraft during the CARES "golden day" on June 28 show good agreement; additional analyses combining the HSRL data with airborne in situ measurements are underway.

AMIE: A two-pronged campaign to study the MJO

Chuck Long, Pacific Northwest National Laboratory
Sally McFarlane, Pacific Northwest National Laboratory

The Madden-Julian Oscillation remains a significantly elusive target for both physical understanding of its causes and accurate modeling. Several hypotheses have been put forth as to the mechanisms that cause the MJO to initiate in the equatorial Indian Ocean, propagate westward through the Maritime Continent, and persist into the Pacific. Yet further progress in understanding has been hindered due to a lack of adequate field measurements for study of the mechanisms and hypotheses suspected of being related to the MJO. The ARM MJO Investigation Experiment (AMIE) includes two field campaign sites. AMIE-Manus will be held in conjunction with the ARM TWP Manus facility in Papua New Guinea, especially taking advantage of the new scanning radars recently deployed. AMIE-Gan will be a deployment of the second ARM Mobile Facility on Gan Island, Addu Atoll, Maldives. Both campaigns will run from October 1, 2011 through end of March 2012 in conjunction with the larger international CINDY2011*, and the U.S. contribution to CINDY2011 called DYNAMO (Dynamics of the MJO). The synergy of the AMIE/DYNAMO/CINDY2011 campaigns will allow study of MJO initiation, plus aspects of its propagation and evolution. We will describe various aspects of the AMIE campaign, including scientific aspects, siting, collaborations, and synergies. *Cooperative Indian Ocean experiment on intraseasonal variability in the Year 2011

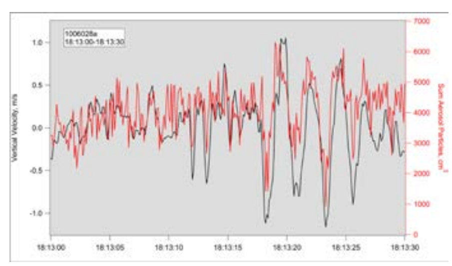


Schematic map of AMIE-Gan/DYNAMO/CINDY2011 study area in the Indian Ocean (left red circle), and AMIE-Manus site in the tropical western Pacific (right red circle), with the Maritime Continent area in between.

Boundary layer (BL) thermal eddies over a pine forest from CARES 2010

Gunnar Senum, Brookhaven National Laboratory
Stephen Springston, Brookhaven National Laboratory

The Gulfstream G-1 research aircraft (AAF) participated in the CARES 2010 field campaign in June 2010. Included in the onboard research equipment was the BNL accelerometer and the BNL high-sensitivity gustprobe. These two instruments provide two independents means of measuring the vertical velocity of the boundary layer sampled by the G-1 along its flight path. The sampling rate of both of these instruments was 200 Hz, which with G-1 aircraft speed of 100 m/s, provided a spatial resolution of 0.5 meters. After signal processing to remove the motion of the G-1, the vertical velocity data was averaged to 10 Hz, which corresponds to a spatial resolution of 10 meters. The resolution of the vertical velocity as measured by the gustprobe was about 0.1 cm/sec; the accelerometer resolution was about 0.25 cm/sec, slightly noisier. The agreement between the vertical velocities as measured by these two techniques (accelerometer and gustprobe)



Boundary-layer thermal eddies over a pine forest, CARES 2010. The vertical velocities, in red, define the thermal eddies as measured by the gustprobe. The black trace is the sum of all aerosol particle per cc from 55 to 1000 nm as measured by the UHSAS.

was excellent. An aerial UHSAS (Ultra High Sensitivity Aerosol Spectrometer) was also included in the G-1 research package, which was a ARRA purchase. The UHSAS measured the boundary-layer aerosol particle concentration from 55 to 1000 nm diameter, sized into 100 bins. The attached figure, a plot of the vertical velocity, is in m/s on the left axis, and shows the sum of all aerosol particles per cc, as measured by the UHSAS versus time. This is a 30-second segment of the June 28, 2010 morning flight, from 18:13 to 18:13:30 UTC. This corresponds to a 3-km segment flown in the boundary layer over a pine forest east of Sacramento, California, the most easterly leg of the sampling flight plan. Note the high degree of correlation between the vertical velocity and the total number of aerosol particles. The three sets of downdraft/updrafts beginning at about 18:13:18 UTC are three thermal eddies, about 250 meters wide, in the boundary layer. These thermal eddies are formed from the solar heating of the surface and help to form the boundary layer. The eddy updrafts are transporting aerosols from the pine forest below, and the eddy downdrafts are transporting air from above the boundary layer, diluting the aerosol particle concentration. These measurements will be used to calculate the aerosol particle fluxes from the pine forest into the boundary layer.

Considerations for a marine deployment of AMF2

R. Reynolds, Remote Measurements & Research Company
Ernie Lewis, Brookhaven National Laboratory
Warren Wiscombe, Brookhaven National Laboratory

The ARM Mobile Facilities (AMFs) have been deployed at numerous locations around the world and have contributed many valuable long-term data sets advancing knowledge of clouds, aerosols, and radiation. However, all deployments thus far have been from continental or island sites. As oceans cover roughly 70% of the Earth, it is vital that future AMF deployments include marine-based platforms. Such deployments could provide information along transects, and repeated transits could provide climatologies of cloud, aerosol, and radiation properties along these transects. There are a number of issues that must be considered for a successful marine deployment. A major issue is finding a platform for the AMF2 on a ship that traverses the region of scientific interest. It would be advantageous if the ship was a U. S- flagged ship, although there are still many issues that must be dealt with, including location of the AMF2 and associated instrumentation aboard that ship that does not interfere with (or is not interfered with by) other activities of the ship (including loading and unloading cargo, radar interference, etc.); but yet provides access to the containers and instruments, a clear view of the sky and sea and access to clean marine air, balloon launches, ship motion, the corrosive nature of the marine environment, power issues, and so forth. A plan for deployment of AMF2 and associated instruments aboard a cargo ship is presented, and concerns with this plan, and with marine deployment of AMF2 in general, are discussed.

Possible deployment scenario for AMF2 aboard a container ship.

Entrainment and mixing and their effects on cloud droplet size distributions of the stratocumulus clouds observed during VOCALS

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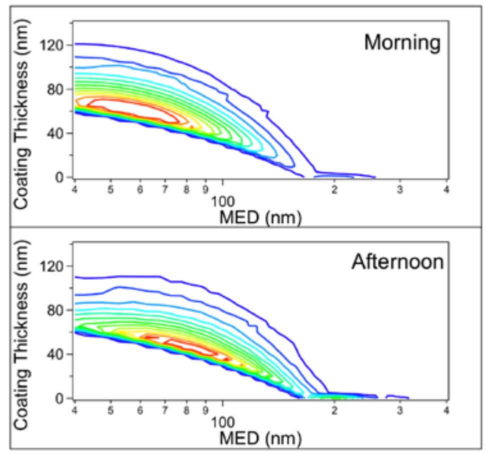
Jian Wang, Brookhaven National Laboratory
Peter Daum, Brookhaven National Laboratory
Gunnar Senum, Brookhaven National Laboratory
Stephen Springston, Brookhaven National Laboratory

Cloud droplet size distribution is determined by several factors. Cloud condensation nuclei distribution and updraft velocity may determine the droplet size distribution of an adiabatic cloud parcel. However, adiabaticity cannot be maintained in most clouds due to entrainment and mixing of the clear air, which then affect the cloud droplet size distribution. How the entrained clear air mixes with cloudy air has been of great interest for the last several decades due to its crucial implication on the warm rain initiation problem. Basically, two mixing mechanisms have been proposed. Homogeneous mixing postulates that turbulent mixing of the clear and cloudy air is so fast that all droplets in the mixed parcel experience the same degree of evaporation. The opposite is the case when mixing is inhomogeneous, where droplets in some portion of the cloudy air completely evaporate while the droplets in the remaining portion experience no evaporation. As such, cloud droplet size distribution can differ depending on how mixing proceeds, and therefore the evolution of cloud droplet size distribution after mixing will also differ. In this study we analyze the cloud microphysics data obtained from the G-1 aircraft during the VOCALS field experiment conducted in October–November, 2008, off the coast of Chile over the southeastern Pacific. Three different mixing diagrams are used as a tool to examine the mixing mechanism. In most cases, comparison of the estimated time scales of turbulent mixing and evaporation suggests that inhomogeneous mixing is dominantly favored. However, what is shown in the mixing diagrams often deviates from what is expected from inhomogeneous mixing. Non-uniform updraft velocities and further evolution of droplet size distribution after mixing can be suggested as a possible reason for such deviation. Furthermore, examination of high-resolution data often suggests that mixing proceeds homogeneously in the parcels where severe entrainment occurs. Detailed analysis will be shown at the meeting.

Evolution of black barbon mixing-state in the Sacramento urban-biogenic admixed environment

Arthur Sedlacek, Brookhaven National Laboratory
Larry Kleinman, Brookhaven National Laboratory
John Shilling, Pacific Northwest National Laboratory
R. Subramanian, Droplet Measurement Technologies
Stephen Springston, Brookhaven National Laboratory
Rahul Zaveri, Pacific Northwest National Laboratory

As part of the CARES campaign, the G-1 was deployed to investigate the temporal evolution of aerosols in a mixed urban-biogenic environment through morning and afternoon flights. Of specific interest to the present poster is the evolution of the black carbon (BC) mixing state. As will be discussed, the incandescence and scattering channels available on the SP2 can be combined to allow details of the BC mixing state to be studied. SP2 analysis of data collected on June 28 reveals that significant evolution in the BC mixing state took place, as evidenced by the growth of coated accumulation mode BC particles. In addition, probing the BC mixing state, it is also shown that the coated soot distribution for the afternoon flight can be reconstructed via an estimate of the coating thickness for a given soot core diameter along with a simplified condensation model. Using the G-1 AMS observation that nominally 90% of the non-refractory material was organic and the reconstructed coated core distribution, the expected light absorption enhancement can be calculated and compared to that measured in the field. Comparison of this model with that tabulated using the PSAP (Mm-1) and SP2 (ng/m3) reveals that the field measurement is nominally 2x larger. It is suggested that this difference is attributed to an organic aerosol bias in the PSAP measurement (Lack et al. 2008). In addition to the strictly airborne comparisons, comparisons were also carried out between the G-1 and ground sites. On June 15, SP2 calculated mass mean diameters (MMD) for the T0 (Sacramento) and T1 (Cool) ground sites were found to be 143 nm and 175 nm respectively. It is also reported that mixing-state analysis suggests that while both sites were dominated by thinly coated BC, there are likely more thickly coated, sub-100 nm MED BC cores at T1. (ASR poster: Subramanian et al. 2011) This mixing-state observation is consistent with that observed aboard the G-1 where analysis of the mixing layer suggests that BC is dominated by fresh emissions while the residual layer is comprised of an admixture of nascent and thickly coated soot aggregates, similar to that observed over the foothills (T1 site location). However, comparison of the
G-1/ground MMDs is mixed. Whereas the G-1 mixing layer MMD of 147 nm is in excellent agreement with that reported for the T0 site (143 nm), the T1 MMD (175 nm) is nominally 15% higher than the measured 150 nm aboard G-1 while over the foothills area.



Comparison of the incandescence-based mass equivalent diameter for BC particles to the light scattering-based estimates optical diameter enables the SP2 to probe the mixing state of BC. In the plot above, it can be seen that while coated 115 nm BC particles were negligible in the a.m., by the afternoon flight these particles gained a coating to yield optical diameter Dp ~ 225 nm. Put another way, between the morning and afternoon flights conducted on June 28, 115 nm diameter BC particles become encapsulated within a shell that is nominally 55 nm thick.

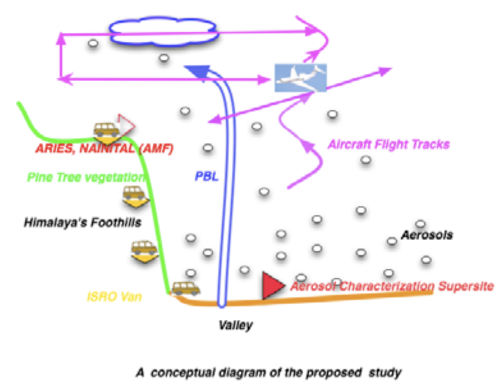
Field experiment for cloud-aerosol interaction study in the arctic Svalbard

Masataka Shiobara, National Institute of Polar Research

Clouds and aerosols are key elements having the potential to change climate by their radiative effects on the energy balance in the global climate system. In the Arctic, we have been continuing ground-based remote-sensing measurements for clouds and aerosols using a sky radiometer, a micropulse lidar, and an all-sky camera in Ny-Alesund, Svalbard. In addition to the regular operations, we are planning an intensive observation campaign for clouds in May 2011. This campaign aims at low-level clouds to investigate cloud optical and microphysical properties and cloud-aerosol interaction processes in the Arctic, mainly from cloud radiation measurements and active remote-sensing at the surface, and in situ microphysics measurements at a mountain-side facility located 470 meters high. The instrumentation for in situ measurements includes conventional cloud microphysics probes and a newly developed cloud particle microscopic imager. An aerosol particle counter to be placed in the ropeway cabin is used for measuring particle size distribution to see the difference between in-cloud and out-of-cloud conditions. In this poster, the experimental design will be introduced and discussed for further experimental studies of cloud-aerosol interaction.

Ganges Valley Aerosol Experiment: proposed experiment details, expected data, and forecast modeling products

V. Rao Kotamarthi, Argonne National Laboratory
Yan Feng, Argonne National Laboratory
S. Satheesh, Indian Institute of Science
S. Suresh Babu, Space Physics Laboratory



A conceptual diagram for the proposed GVAX study.

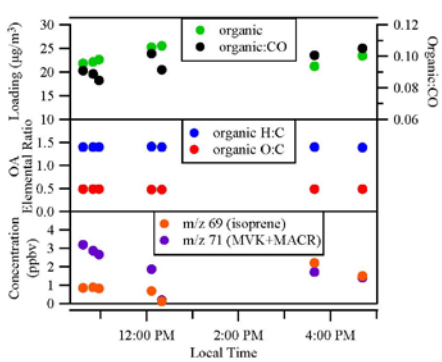
The Ganges Valley region is one of the largest and most rapidly developing sections of the Indian subcontinent. Recent satellite-based measurements have indicated that the upper Ganges Valley has some of the highest persistently observed aerosol optical depth values. The aerosol layer covers a vast region, extending across the Indo-Gangetic Plain to the Bay of Bengal during the winter and early spring of each year. Our proposed field study will provide critical data to address these hypotheses and will contribute to developing better parameterizations for tropical clouds, convection, and aerosol-cloud interactions. The primary science questions for the mission are as follows: (1) What are the sources and sinks of the aerosols comprising the aerosol cloud over this region and what effects does it have on clear-sky radiation fields, as well as on cloud microphysical and macrophysical properties? What effect does the diurnal PBL cycle in the Ganges Valley have on the atmospheric distribution of aerosols? (2) What effect do increasing aerosols in the Ganges Valley have on the ISM? What effect do aerosols have on shortwave radiative forcing, mid-tropospheric heating, and convective activity over continental India? To achieve these science objectives, an implementation has been devised in collaboration with scientists in India. The primary anchor facility for the project is the ARM Mobile Facility. A deployment starting in approximately April 2011 and lasting to April 2012 at the ARIES observatory located in Nainital is anticipated for AMF ground operations. During this one-year deployment of the AMF there will be two intensive periods, one during the pre-monsoon and the second during the winter-early spring of 2012. These measurements and the subsequent data sets must be placed in a larger regional context in order to relate the data to a particular dynamic state of the atmosphere and begin developing hypotheses that explain observed phenomena. The regional context will be developed within the conditions generated by a 3D regional scale model. Baseline simulations of the 3D regional scale model will provide the necessary analytical support for the scientific studies done under GVAX. In support of the one-year deployment, we plan to produce daily model forecasts for the Nainital site and the two intensive periods. Expected model products, models used for the forecasts, and plans for making them available to interested users and project participants will be presented.

http://www.arm.gov/sites/amf/pgh/

Gas- and particle-phase chemical composition measurements onboard the G-1 research aircraft during the CARES campaign

John Shilling, Pacific Northwest National Laboratory
Lizabeth Alexander, Pacific Northwest National Laboratory
John Jayne, Aerodyne Research, Inc.
Ed Fortner, Aerodyne Research, Inc.

An Aerodyne High Resolution Aerosol Mass Spectrometer (AMS) and an Ionicon Proton Transfer Reaction Mass Spectrometer (PTRMS) were deployed on the G-1 research aircraft during the CARES campaign in Sacramento, California, to investigate aerosol gas- and particle-phase chemical composition. Preliminary analysis of PTRMS data suggests that biogenic volatile organic compounds (VOCs), particularly isoprene, dominate the region with anthropogenic VOCs, such as benzene and toluene, providing much smaller contributions to the VOC pool. Data from the AMS shows that the particle phase is dominated by organic material (81% on average) with smaller concentrations of sulfate (10%), nitrate (6%) and ammonium (4%) observed. Organic particle mass concentrations are strongly influenced by SOA generated when isoprene-rich air from the foothills mixed with the Sacramento urban plume. A case study examining the formation and chemical evolution of the organic aerosol on June 28 will also be presented.



Chemical evolution of the aerosol plume observed from the G-1 research aircraft on June 28 during the CARES campaign in Sacramento, California. The loss of the gas-phase biogenic precursors isoprene, MVK, and MACR correlates with morning production of particle-phase organic material (OM). The elemental O:C and H:C ratios of the OM are constant through the day, consistent with laboratory observations of SOA formation from isoprene. However, mass of OM that was observed to form from the measured precursors is higher than expected.

A multi-year record of airborne continuous CO2 in the U.S. Southern Great Plains

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William Riley, Lawrence Berkeley National Laboratory
Margaret Torn, Lawrence Berkeley National Laboratory

We report on three years of airborne measurements of continuous atmospheric CO2 concentrations over the Atmospheric Radiation Measurement (ARM) Climate Research Facility in the U.S. Southern Great Plains. These continuous measurements are collected weekly from a small aircraft (Cessna 206) on a series of horizontal legs ranging from 17,500 feet down to 1500 feet above sea level. The continuous CO2 observations are measured using a CO2 analyzer built by Atmospheric Observing System Inc., based in Boulder, Colorado. The analyzer has non-imaging optics and negligible sensitivity to motion of platform. The NDIR Analyzer is the core element of the system. Accuracy, including bias, is approximately 0.1 ppm of CO2 DMF at 1 Hz. Each flight lasts between 2.5 and 3 hours, yielding about 10,000 CO2 measurements per flight. Since November 2007, more than 150 continuous CO2 vertical profiles have been collected, along with NOAA/ESRL 12-flask (carbon cycle gases and isotopes) packages for validation. Comparison between the continuous and flask CO2 measurements indicates a difference of no larger than 0.2 ppm.

Northern Oklahoma CO2 Attribution with Tracers Study (NOCATS) 2010: first deployment of a new mobile laboratory for atmospheric carbon-cycle science

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Ray Bambha, Sandia National Laboratories
Paul Schrader, Sandia National Laboratories
Fred Helsel, Sandia National Laboratories
Brian LaFranchi, Lawrence Livermore National Laboratory
Bradley Flowers, Los Alamos National Laboratory
Thom Rahn, Los Alamos National Laboratory
Manvendra Dubey, Los Alamos National Laboratory
Thomas Guilderson, Lawrence Livermore National Laboratory
Mark Ivey, Sandia National Laboratories
Bernard Zak, Multiple Academic Affiliations

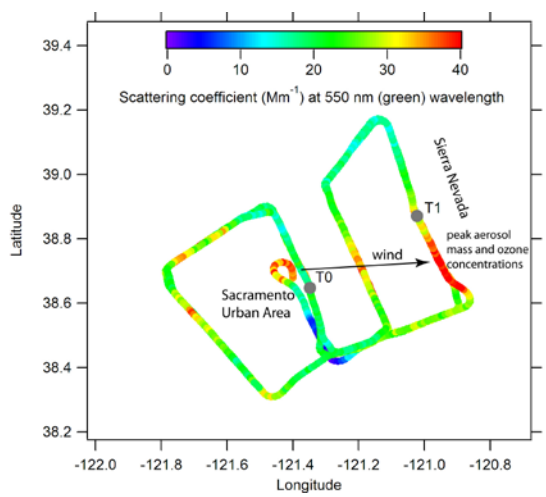
The Atmospheric and Terrestrial Mobile Laboratory was deployed for the first time at the ARM SGP Central Facility to study biogenic and anthropogenic CO2 source attribution.

Anthropogenic sources of carbon dioxide represent a significant portion of the global carbon budget, but partitioning CO2 measurements into their biogenic and anthropogenic sources has been difficult using only measurements of CO2 abundances and those of a small number of additional tracers. An intensive field campaign was conducted in fall 2010 at the ARM SGP Central Facility (IDP1) to measure CO2 and tracers for its sources using a new mobile laboratory. Two trucks carrying over 15 instruments for gases and particles were deployed along with a gas-calibration system. Air was drawn into both trucks from a 10-meter tall mast. All measurements were made either from a common inlet or closely located inlets. Instruments were selected to provide measurements of tracers of both biogenic and anthropogenic sources. High-frequency measurements of abundances of CO2 and its stable isotopologues (13CO2 and C18OO) were made simultaneously with measurements of CO, SO2, NOx, O3, CH4, water vapor isotopologues (H2O, HDO, and H218O), volatile organic compounds, black and organic carbon aerosol, and particle count. Automated flask samplers collected whole-air samples for offline 14C analysis using accelerator mass spectrometry. Redundancy between CO2, CH4, and H2O measurements provided a valuable crosscheck for the calibrations and the measurements. Good agreement between CO2 measurements from four different instruments was attained following careful post-processing and calibrations. Similarly good agreement was demonstrated between four instruments that measured water vapor and two instruments that measured CH4. The agricultural region that surrounds the ARM SGP site had experienced little rainfall prior to the campaign, and land cover and crop growth were minimal during the period in which measurements were made (3 October–9 November 2010). Correlations between various tracers and CO2 provide insight into the different sources, including the anthropogenic component, which includes biomass and fossil fuel combustion.

Overview of preliminary results from the 2010 CARES field campaign

Rahul Zaveri, Pacific Northwest National Laboratory

The primary objective of the DOE Carbonaceous Aerosol and Radiative Effects Study (CARES) in June 2010 was to investigate the evolution of carbonaceous aerosols of different types and their optical and hygroscopic properties in central California, with a focus on the Sacramento urban plume. Carbonaceous aerosol components, which include black carbon (BC), urban primary organic aerosols (POA), biomass burning aerosols, and secondary organic aerosols (SOA) from both urban and biogenic precursors, have been shown to play a major role in the direct and indirect radiative forcing of climate. However, significant knowledge gaps and uncertainties still exist in the process-level understanding of: (1) SOA formation, (2) BC mixing state evolution, and (3) the optical and hygroscopic properties of fresh and aged carbonaceous aerosols. The CARES 2010 field study was designed to address several specific science questions under these three topics. During summer, the Sacramento-Blodgett Forest corridor effectively serves as a mesoscale daytime flow reactor in which the urban aerosols undergo significant aging as they are transported to the northeast by upslope flow. The CARES campaign observation strategy consisted of the DOE G-1 aircraft sampling upwind, within, and outside of the evolving Sacramento urban plume in the morning and again in the afternoon. The G-1 payload consisted of a suite of instruments to measure trace gases, aerosol size distribution, composition, and optical properties. The NASA B-200 aircraft, carrying a High Spectral Resolution Lidar (HSRL) and a Research Scanning Polarimeter (RSP), was also deployed to characterize the vertical and horizontal distribution of aerosols and aerosol optical properties. The aircraft measurements were complemented by heavily instrumented ground sites within the Sacramento urban area and at a downwind site in Cool,



Scattering coefficient at 550 nm in the Sacramento plume and surrounding areas during the afternoon of June 28 as the plume was photochemically aged and transported to the east into the foothills of the Sierra Nevada Mountains.

California, to characterize the diurnal evolution of meteorological variables, trace gases, aerosol precursors, aerosol size, composition, and optical and cloud activation properties in freshly polluted and aged urban air. The CARES campaign overlapped with the CalNex 2010 field campaign led by NOAA and CARB. This poster will present an overview of the campaign, preliminary results, and a list of various planned model evaluation exercises, which will facilitate the integration of new knowledge and data from the field campaign into regional and global climate-chemistry models.

http://campaign.arm.gov/cares/

Parameterization of ice fall speeds for reducing cloud uncertainties in climate models

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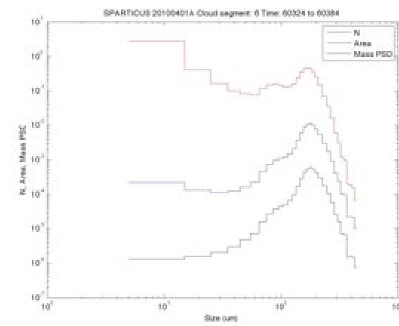
David Mitchell, Desert Research Institute
Brad Baker, SPEC Inc.
Paul Lawson, SPEC Inc.

According to a study by Sanderson et al. (2008), the ice fall velocity is the second most important factor affecting the global feedback parameter in climate models. The focus of this research is to improve the parameterization of ice mass sedimentation rates in GCMs, which is the product of the ice water content (IWC) and the mass weighted fall-speed (Vm). To accurately estimate ice mass sedimentation rates, accurate measurements of the PSD regarding ice particle number, projected area and mass are needed. A relatively new probe called the 2D-Stereo (or 2D-S) probe measures these three quantities from 10 to 1280 μm, using an ice particle projected area-mass relationship to estimate the size-resolved mass concentrations. The 2D-S estimates of ice water content (IWC), based on PSD integrations using the area-mass relationship, generally agree well (within ~ 20%) with CVI measurements of IWC during the TC4 campaign. This study uses 2D-S data along with data from other probes flown on the Learjet during SPARTICUS, a recent field campaign sampling midlatitude cirrus. These data are used to identify optimal cloud segments as per the guidelines given by SPEC Inc., Colorado. A segment begins when the extinction exceeds 0.1 Km-1. As each second of data is added to the segment, the maximum, mean, and minimum of the 1 Hz extinction and 1 Hz mean volume diameter (MVD) are found and compared. If both maximums do not exceed twice the mean and the minimums are not less than 0.4 times the mean, the segment passes and another second is added. A segment must reach 60 seconds in length to be kept, and when an acceptable segment reaches 120 seconds, the first half is cut off and kept as a segment and the second half continues adding seconds and comparing. 2D-S measurements of ice particle size, area and mass are used to calculate v(D) for each 2D-S size-bin using the methodology of Heymsfield and Westbrook (2010), which differs from the approach of Mitchell and Heymsfield (2005) by ~ 6% on average. Using this equation, the measured PSD of size-resolved number, area, and mass concentration can be used to solve for Vm. Standard temperature and pressure are assumed when calculating v(D) and Vm, and a prefactor is applied to Vm to adjust it to the desired temperature and pressure. The Vm-temperature and Vm-effective diameter relationships obtained from SPARTICUS will be compared with corresponding relationships obtained from a Tropical campaign (TC4) and an Arctic campaign (ISDAC).



A sample size distribution plot from a SPARTICUS cloud segment on April 1 (flight A) showing N (l-1µm-1), A (mm2l-1µm-1), and Mass PSD (gm-3µm).

The PARISFOG field campaign at SIRTA site

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Y. Morille, Institut Pierre Simon Laplace
Christophe Pietras, Laboratoire de Météorologie Dynamique/Institut Pierre Simon Laplace/Ecole Polytechnique
Bernard Romand, Laboratoire de Météorologie Dynamique/Institut Pierre Simon Laplace/Ecole Polytechnique
Thierry Elias, HYGEOS
Laurent Gomes, Centre National de Recherches Météorologiques, Meteo-France
Frédéric Burnet, Centre National de Recherches Météorologiques, Meteo-France
Thierry Bourrianne, Centre National de Recherches Météorologiques, Meteo-France
Alain Protat, Laboratoire Atmosphères, Milieux, Observations Spatiales
Julien Delanoë, University of Reading
Daniel Richard, nstitut de Physique du Globe de Paris
Luc Musson-Genon, Centre d'Enseignement et de Recherche en Environnement Atmosphérique
Eric Dupont, Centre d'Enseignement et de Recherche en Environnement Atmosphérique
Yannick Lefranc, Centre d'Enseignement et de Recherche en Environnement Atmosphérique
Thomas Lhoir, Centre d'Enseignement et de Recherche en Environnement Atmosphérique
Jean Sciare, Laboratoire des Sciences du Climat et l'Environnement
Jose Nicolas, Laboratoire des Sciences du Climat et l'Environnement

Fogs are weather conditions with significant socio-economic impacts, associated with increased hazards and constraints in road, maritime, and air traffic. While current numerical weather prediction models are able to forecast situations that are favorable to fog events, these forecasts are usually unable to determine the exact location and time of formation or dissipation. One-dimensional assimilation-forecast models have been implemented at a few airports and provide improved local predictions of fog events, but this approach is limited to locations. The occurrence, development, and dissipation of fog result from multiple processes (thermodynamical, radiative, dynamical, and microphysical) that occur simultaneously through a wide range of conditions and that feed back on each other, inducing non-linear behaviors. Hence, to advance our ability to forecast fog processes, we must gain better understanding on how critical physical processes interact with each other, to improve their parametric representations in models. To provide a data set suitable to study these processes simultaneously in continental fog, a suite of active and passive remote sensing instruments and in situ sensors are currently deployed at the SIRTA observatory (http://sirta.ipsl.polytechnique.fr/) near Paris, France, for six months (October 2010–March 2011) to monitor profiles of wind, turbulence, and microphysical and radiative properties, as well as temperature, humidity, aerosol, and fog microphysics and chemistry in the surface layer. This field experiment, called ParisFog (http://sirta.ipsl.polytechnique.fr/parisfog/), is focused on droplet and aerosol microphysics (size distribution between 4 nm and 50µm, liquid water content, black carbon, PM2.5) and on near-surface dynamics (vertical profile between surface and the top of boundary layer height). During this period almost 170 hours of fog, 180 hours of quasi-fog, and 800 hours of near-fog have been documented. Multiple radiative and stratus-lowering fogs occurred, conducting to dense and shallow events of low visibility. The ParisFog field campaign is described and several fog events are analyzed in order to better understand the different processes driving the fog life cycle, especially for the formation and the dissipation period.

Pole-to-pole observations of black carbon aerosol in the remote Pacific and Arctic

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Anne Perring, NOAA Earth System Research Laboratory/CIRES
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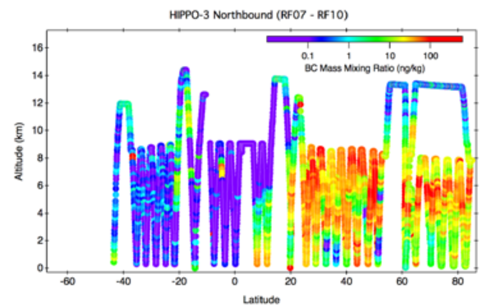
Steven Wofsy, Harvard University

Efforts are now underway to expand global measurements of black carbon (BC) aerosol from aircraft to better assess the impact of fossil fuel combustion and biomass-burning sources of BC on global air quality and climate. Understanding the processes controlling BC aerosol abundance in the atmosphere is necessary to constrain transport and microphysics in global aerosol models, evaluate climate impacts, and develop mitigation strategies. Yet measurements of BC above the surface have been very limited until recently, and measurement-model comparisons of BC often show large discrepancies. Recent measurements from the HIAPER Pole-to-Pole Observations (HIPPO) study add new insight into the global distribution of BC and greenhouse gas species at finer spatial resolution than obtainable from satellite measurements with the goal of assessing emissions, transport timescales, and removal processes. Three HIPPO campaigns have been completed over three seasons and include over 400 vertical profiles from 0.3 to 14 km altitude between 85°N and 67°S latitude in the remote Pacific and Arctic regions. Two additional HIPPO missions will occur in summer 2011. In the Arctic, highlights include observations of persistent stratified pollution from boreal autumn through spring. In the northern Pacific midlatitudes and subtropics, very polluted conditions were encountered over a deep portion of the troposphere, with BC mass loadings varying between 100 and 1000 ng/kg in large-scale plumes from anthropogenic and biomass burning sources in Asia in boreal spring. Some of the first airborne observations of BC mass loadings in the southern hemisphere show large interhemispheric gradients in boreal spring. The northern hemisphere BC mass loadings account for over 90% of the pole-to-pole burden in the remote Pacific in boreal spring.



Black carbon mass mixing ratio along the flight track of the NCAR/NSF G-V aircraft in early April 2010 in the central Pacific and Arctic regions. This is the time of year when transport from Asia advects large amounts of pollution to North America.

Properties of Arctic aerosol particles and residuals of warm and ice clouds: cloud activation efficiency and the aerosol indirect effect

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Dan Imre, Imre Consulting
Richard Leaitch, Environment Canada
Mikhail Ovchinnikov, Pacific Northwest National Laboratory
Peter Liu, Environment Canada
Ann Marie Macdonald, Environment Canada
J. Walter Strapp, Environment Canada
Alexei Korolev, Environment Canada
Steven Ghan, Pacific Northwest National Laboratory

The single-particle mass spectrometer, SPLAT II, was deployed onboard research aircraft to characterize the properties of Arctic aerosol particles, including those that serve as cloud condensation nuclei and ice nuclei. Here we present a detailed comparison between properties of aerosols characterized during clean and highly polluted days. We used the data to: (1) develop a clear picture of what the properties of atmospheric aerosol particles in the Arctic spring are, which includes particle number concentrations, size distributions, and compositions; (2) establish the relationship between particle properties and CCN activity; and (3) establish the relationships between particle properties and IN activity to provide information about the mechanisms responsible for the ice formation. On clean and polluted days we find the Arctic spring atmosphere to be highly stratified, with particle number concentrations exhibiting high variability. On clean days, particle number concentrations were below 250 cm^3, and they were composed of organics and organics mixed with sulfates, biomass-burning (BB) particles, fresh and processed sea salt, and a small number of soot and mineral dust particles. On polluted days, aerosol plumes with number concentrations as high as 2500 cm-^{3} were dominated by BB particles, organics associated with BB, and their internal mixtures with sulfate. Under clean conditions more than 90% of particles activated to form cloud droplets, while during polluted days fewer than 50% of particles were activated. In both cases, the compositions of cloud-activated particles were virtually the same as those of interstitial particles, but the activated particles were somewhat larger. Data analysis for all ISDAC flights points to a simple relationship between particle number concentrations and activation fraction, indicating a kinetically controlled process. Characterization of ice crystal residuals presents at concentrations that are 3–4 orders of magnitude lower than background aerosol, represent a significant challenge. Nevertheless, using data collected on five flights, we established that these ice clouds were formed by heterogeneous nucleation on mineral dust particles.

Regional Aerosol Warming Experiment (RAWEX): A new experiment of ISRO over the Indian region

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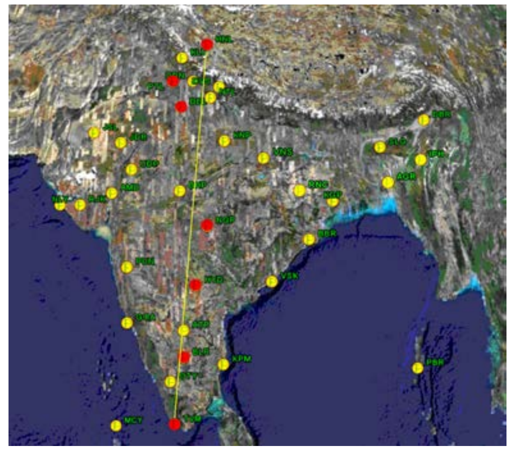
S K Satheesh, Indian Institute of Science
K Krishna Moorthy, Space Physics Laboratory

The recent multi-platform field experiment, Integrated Campaign on Aerosol gases and Radiation Budget (ICARB), over the Indian region has provided unequivocal evidence for the persistence of elevated layers of enhanced aerosol extinction over the Indian region with a northward gradient in the layer height and warming amplitude (Satheesh et al., 2008, GRL). With synthesis of ground-based ARFINET (Aerosol Radiative Forcing over India Network) data with the thermal IR data from METEOSAT, Moorthy et al. (2007, JGR) have demonstrated that the absorption efficiency of dust over the Indian region is substantially higher than that over Saharan regions. Aircraft measurements during ICARB have shown enhanced BC concentration above the boundary layer in the region of 2 to 4 km (Babu et al., 2008, JESS). Examining these exciting discoveries against the backdrop of the climate simulations of the possible impacts of the elevated warming on monsoon circulation and rainfall distributions over Asia, a new multi-year, multi-disciplinary, field campaign called RAWEX (Regional Aerosol Warming Experiment), which involves aircraft and high-altitude balloon-borne measurements of aerosols and meteorological parameters, has been taken up under ISRO-GBP. Under this experiment, a chain of super-sites is being set up along the meridional line, having intense observations; all other ARFINET observatories will provide the necessary supporting data. The details of the experiment will be presented.

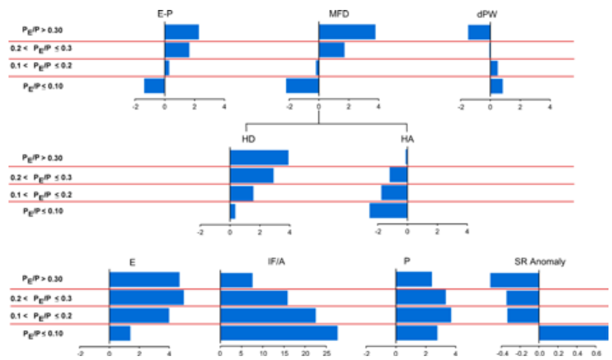


ARFINET stations involved in the RAWEX; stations marked red forming the meridional chain will be making intense observations of possible warming signatures.

Relative importance of local recycling versus external advection for CLASIC rainfall and clouds

Peter Lamb, University of Oklahoma
Diane Portis, University of Oklahoma/CIMMS
Abraham Zangvil, Ben Gurion University

The ARM Cloud and Land Surface Interaction Campaign (CLASIC) was conducted over the ARM SGP site during June 2007. A primary goal of CLASIC is to understand the interactive roles of horizontal moisture advection and land surface processes in the evolution of cumulus convection. Our study is providing the larger-scale (Oklahoma-Texas) atmospheric moisture budget background for the interpretation of results derived from CLASIC observational platforms. Extremely wet conditions prevailed during CLASIC, when Oklahoma experienced its wettest June since records began in 1895. Three other contrasting May–June periods were chosen for analysis: 2006 (very dry), 2002 (intermediate wetness), and 1998 (very dry, especially upstream in Texas). Using a recycling methodology that was developed during an earlier investigation of the atmospheric moisture budget for the Corn Belt in the upper Midwest (Zangvil et al. 2004), estimates were made of the contributions of locally evaporated moisture (i.e., recycled from within the region) versus externally advected water vapor for the precipitation (and cloud development) on a range of timescales (daily, monthly, bimonthly). The figure (top two rows) depicts the mean values of the daily atmospheric moisture budget when the recycling ratio (P_E/P) was in one of four categories shown. Within the moisture budget, the surplus/deficit of evaporation (E) over precipitation (P) is balanced by the moisture flux divergence (MFD) and atmospheric storage change (dPW). The two MFD components are horizontal water vapor advection (HA) and horizontal velocity divergence in the presence of water vapor (HD). The last row includes the stratifications by recycling ratio for its two components (E and the inflow of water vapor into the region [IF/A]), precipitation (P), and a solar radiation (SR) anomaly that is based on the mean daily SR value over the eight study months. The largest recycling ratios occur with large E-P surpluses and large MFD, and not when E-P ~ 0, which is a condition that some have interpreted as all P has its origins in E (recycled moisture). Variations in the recycling ratio above 0.20 are reflected more in the externally advected water vapor (IF/A) than locally evaporated moisture (E). There is a striking correlation that is also supported by linear correlations between the externally advected water vapor with MFD and its components HD and HA. The largest negative SR anomaly (most clouds) occurs in the largest recycling category.



Mean values of the daily atmospheric moisture budget (top two rows) when the recycling ratio (PE/P) was in one of four categories shown. The abbreviations for these budget terms are defined in the text. The daily values from all eight study months are considered. The last row includes the stratifications by recycling ratio for its two components (E and IF/A), precipitation (P), and a solar radiation (SR) anomaly that is based on the mean daily SR value over the eight study months. The number of cases in each category from lowest to highest recycling ratio is 81, 87, 45, and 27. Except for dimensionless PE/P and SR anomaly in MJ m-2 day-1, all of the variables have units of mm day-1.

Solar Fourier Transform Spectrometry for high spectral resolution monitoring of radiation, aerosol, climate and, carbon: early results and future campaigns for ARM

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Keeley Costigan, Los Alamos National Laboratory
Jon Reisner, Los Alamos National Laboratory
Petr Chylek, Los Alamos National Laboratory
Hope Michelsen, Sandia National Laboratories
Ray Bambha, Sandia National Laboratories
Bernard Zak, Multiple Academic Affiliations
Paul Schrader, Sandia National Laboratories
William Cotton, Colorado State University
Rainer Volkamer, University of Colorado at Boulder

We have developed and installed a solar-tracking Fourier Transform Spectrometer (FTS) in San Juan County, New Mexico, to monitor regional-scale greenhouse gas, pollution, and aerosols from two power plants. Our system, deployed December 2010, is part of the Total Column Carbon Observing Network to validate satellites measuring CO2 from space. Our system has aluminum optics; InSb, InGaAs, and Si detectors; and CaF2 and quartz beam splitters, allowing it to cover the mid-near IR and UV-VIS regions, which allows us to monitor other trace gases and aerosol optical properties. We also have in situ instruments measuring CO2 and CH4 (Picarro Cavity Ringdown), CO, NOx, SO2, O3, and aerosols at our trailer. There will be an Aeronet station monitoring aerosols in the column and ARM micropulse lidars to measure boundary-layer heights. We are using these comprehensive multi-scale measurements to execute a systematic and coordinated observational, modeling, and satellite validation program. We will show early results on retrievals that allow us to evaluate signature relations between air pollutants and CO2 for attributions. We will show the utility of FTS spectra in evaluating radiation modules in climate models and deriving aerosol optical models at 10–100km scales relevant to models. We will report on our 2014 ARM field deployment in Manus, Brazil. We will also discuss the proposed 2013 Four Corners Aerosol Cloud Climate Experiment and Testbed for Scaling (FACETS) campaign that leverages our FTS, the new Atmospheric Terrestrial Mobile Laboratory, and the upgraded ARM facilities to improve model parameterizations precipitation processes in the southwest United States.

The FTS deployed at the San Juan substation with infrastructure that can be leveraged for the FACETS campaign proposed to ARM in 2013.

https://tccon-wiki.caltech.edu/Sites/Four_Corners

Source characteristics and mixing state of black carbon during CARES 2010

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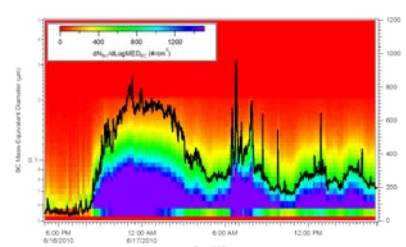
Greg Kok, Droplet Measurement Technologies
Arthur Sedlacek, Brookhaven National Laboratory
Darrel Baumgardner, Droplet Measurement Technologies
Rahul Zaveri, Pacific Northwest National Laboratory

During the recent Carbonaceous Aerosols and Radiative Effects Study (2010) in California, two single- particle soot photometers (SP2s) were run in parallel at the T0 and T1 sites in Sacramento and Cool, respectively. The SP2 uses laser-induced incandescence (LII) to detect black carbon mass, while scattering is used to determine the mixing state of individual BC-containing particles. At the T0 site near downtown Sacramento, BC concentrations higher than 1 µg/m3 were measured at times, and BC particles tended to be thinly coated. This suggests that the T0 site was impacted by fresh emissions, as expected for an urban area. Two high-BC-mass events were recorded in the early morning hours of



BC mass concentration and BC mass-equivalent diameter distributions recorded at T0 during a high-BC event. at the U.S. Southern Great Plains site.

June 13 and June 17, but the BC mass-size distributions were different for these two events. The first appears to be biomass smoke, while the second is more indicative of fresh vehicular exhaust. On June 15, the urban plume was forecast to be transported to T1. A closer look at the SP2 results show that though both sites were dominated by thinly coated BC cores, T1 appears to show more thickly coated, sub-100 nm MED BC cores. The mass-mean BC MED at was 143 nm at T0, and 175 nm at T1.

Vertical profiles of NO2, SOA precursor gases, and aerosol extinction measured from ground: the Ganges Valley Aerosol Experiment (GVAX) and first data from CARES

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Sunil Baidar, University of Colorado at Boulder
Hilke Oetjen, University of Colorado at Boulder
Roman Sinreich, University of Colorado at Boulder
Rainer Volkamer, University of Colorado at Boulder

The Ganges Valley Aerosol Experiment (GVAX) presents a unique opportunity to study aerosol sources and distributions in a region that stands out on global scales in terms of high aerosol optical depth and trace gas vertical columns. The GV is also one of the least-sampled areas of the world. The University of Colorado will combine in situ and innovative remote sensing instruments based on Multi-Axis DOAS (MAX-DOAS) and Light-Emitting Diode Cavity Enhanced DOAS (LED-CE-DOAS) to measure near-surface and vertical profile observations of SOA precursor trace gases and aerosol optical properties. This presentation will give an overview about the instruments that have been developed in the Atmospheric Trace Molecule Spectroscopy Laboratory (ATMOSpeclab) recently, and how this novel information facilitates to link the ground-based data set with that from DOE’s G-1 aircraft, assess boundary layer dynamics, and bridge to the spatial scales predicted by atmospheric models. MAX-DOAS has the unique capability to measure multispectral aerosol extinction vertical profiles, aerosol, and ozone precursor gases with a single instrument, simultaneously, and over the same extended spatial scale, thus averaging over local concentration gradients and measuring directly regionally aggregated distributions. LED-CE-DOAS measures most of these parameters in situ. The GVAX measurement strategy will be discussed. Further, from 11 to 29 June 2010, a CU ground MAX-DOAS instrument was installed at the T1 site, also known as the Cool site, during the CARES (Carbonaceous Aerosols and Radiative Effects Study) campaign in California. Results will be presented for NO2, CHOCHO, and aerosol extinction. These data are especially useful for validation purposes since the spatial scales are similar to the footprint of satellite pixels and model grid boxes. Our initial plan is to deploy an updated version of the MAX-DOAS instrument in the Ganges Valley, India, during GVAX. Details of the mission, with emphasis on the information content towards aerosol properties achievable with the extended observation geometry, will be discussed using radiative transfer simulations.

Why is ARM Climate Research Facility needed on the west coast of Korea?

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Seong Soo Yum, Yonsei University
Lim-Seok Chang, Global Environmental Research Center
Young-Sung Ghim, Hankook University of Foreign Studies
Song-You Hong, Yonsei University
Jhoon Kim, Yonsei University
Maeng-Ki Kim, Kongju National University
Sang-Woo Kim, Seoul National University, School of Earth and Environmental
Young-Joon Kim, Gwangju Institute of Science and Technology
Gyuwon Lee, Kyungpook National University
Kwon-Ho Lee, ESSIC, University of Maryland
Meehye Lee, Korea University
Seoung-Soo Lee, University of Michigan at Ann Arbor

Study domain with measurement locations (red diamond) proposed in the text. Blue diamond denotes stations used in the previous AMF-China. Gosan on the west coast of Jeju Island or Anmyeon on the west coast of the Korean Peninsula will be the major site for the AMF deployment. Both are about 500 km to the east of the Chinese continental coastline. The final decision will be made after consultation of the AMF2 site experts. If one is selected as the major site, the other and the Baengnyeong site will be used as complementary sites. All three sites are equipped with aerosol observing systems (AOS) largely equivalent to AMF AOS. Because of the dominant westerly winds in this midlatitude region, all three sites are strategically located for monitoring continental outflow. Uniquely to these sites, evolution of aerosol properties during the transport over the Yellow Sea can also be monitored.

Fast economic growth and increases of industrial activities in East Asia are equally matched with the fast increase of anthropogenic aerosols in this region. The Yellow Sea between the Chinese continent and the Korean Peninsula provides a long enough time and space for the aerosols emitted from the source region in China to be processed during the transport. Furthermore, the weather and precipitation patterns in East Asia are dominantly affected by seasonal monsoon, adding complexity to ever-changing aerosol conditions in this region. Thus, East Asia is a strategically important region for studying the effects of aerosols on climate change. The first international aerosol measurement campaign in the East Asian region, Aerosol Characterization Experiment-Asia (ACE-Asia), took place during the spring of 2001 off the coast of China, Japan, and Korea (Huebert et al. 2003). However, the intensive measurement period was limited only to the spring season, and the main focus was on dust particles. The Atmospheric Brown Clouds (ABC) East Asian Experiment (ABC-EAREX) in 2005 and continued effort afterwards put more emphasis on the characterization of black carbon (BC) and its radiative forcing in East Asia (Nakajima et al. 2007, Ramana et al. 2010). Despite these efforts, East Asia remains one of the least-observed regions in the world especially in terms of aerosol and cloud properties. For these reasons, the ARM Mobile Facility-China (AMF-China) experiment was carried out in China in 2008–2009, but detailed aerosol-cloud interaction mechanisms in East Asia are still poorly understood due to few synchronized aerosol and cloud samplings undertaken. Further, the recent studies (Kim et al. 2007, Lee and Kim 2010) suggested that spring precipitation in East Asia may be shifted northward and reduced as a result of the modulation of the jet stream and associated secondary circulation at the entrance of the jet stream induced by the aerosol forcing. The broad spectrum of aerosol properties and meteorological environments in East Asia with distinct seasonal characteristics could provide us with a better opportunity to solve the conundrum of the intertwined cloud-aerosol-precipitation interaction (CAPI) mechanisms.

8.0 Infrastructure & Outreach

AMF2 STORMVEX deployment at Steamboat Springs, Colorado

Karen Sonntag, Atmospheric Technology Services Company
Michael Ritsche, Argonne National Laboratory
Brad Orr, Argonne National Laboratory
Richard Coulter, Argonne National Laboratory
Timothy Martin, Argonne National Laboratory
Cory Stuart, Argonne National Laboratory

The AMF2 deployed to Steamboat Springs, Colorado, in support of the STORMVEX campaign beginning on September 15, 2010. The modular design of the AMF2 and its component parts were paramount to supporting the STORMVEX science goals that required making simultaneous and coordinated measurements at four different geographic locations, three of which were AMF2-instrumented sites. One site was located in the valley near the base of the Steamboat Springs Ski Resort. The other two AMF2-instrumented sites are located on the mountain. The three sites are separated by up to 700 meters in the vertical and nearly 4 kilometers in the horizontal. Data transfer between the three locations and to instruments in the field is done wirelessly, including the final data transfer out of the site, which goes up to Storm Peak Laboratory. The requirements of multiple geographic locations and six-days-a-week attention to the sensors required that two staff members, at minimum, be deployed at all times. Local volunteers interested in seeing meteorology research first-hand covered routine balloon launches, while IOP balloon launches were covered by ATSC staff or on-site scientists and graduate students. An overview of the STORMVEX deployment and associated challenges of supporting a complex terrain deployment will be presented.

AMF2: design and concept

Michael Ritsche, Argonne National Laboratory
Brad Orr, Argonne National Laboratory
Richard Coulter, Argonne National Laboratory
Timothy Martin, Argonne National Laboratory
David Cook, Argonne National Laboratory

Instrumentation for AMF2 is, with a few notable exceptions, the same as that used by AMF1 or the other fixed sites when used for land-based deployments. However, differences exist in the base configuration in that measurement systems are based out of modules that are stand-alone packages, allowing them to be deployed by themselves without significant infrastructure support. Because shipboard deployments were a primary design criterion for AMF2, the baseline suite of instruments is marine-focused and has been designed to withstand deployments in salt-rich environments. Several of the instrument systems are different or have been modified for shipboard deployments, mostly to counteract leveling and directional concerns as well as accommodating the space restrictions typically encountered on ships. Additional instruments have been added to the baseline instrument suite that are less susceptible to the motions of a moving platform. These additional instruments are intended to enhance and in some cases replace baseline AMF2 instrumentation. New instruments were added to AMF2 through the American Recovery and Reinvestment Act (ARRA) that significantly enhanced the AMF2 measurement capabilities over those proposed in the original design. The High Spectral Resolution Lidar, the KAZR (upgraded MMCR), the SACR radar, and the AMF2 Aerosol Observing System, in addition to numerous other enhancements, were all accomplished through ARRA funding for AMF2. An overview of AMF2 and its capabilities for both land- and ship-based deployments will be presented.

ARM Archive data extraction capabilities and plans

Sean Moore, Mission Research
Raymond McCord, Oak Ridge National Laboratory
Giri Palanisamy, Oak Ridge National Laboratory

The ARM Climate Research Facility Data Archive has built into their ordering and delivery process a data extraction sub-system that allows users to request and receive custom data sets, without requiring them to download an entire datastream. This system will extract, rename, and reorder measurements to the user's liking. It will deinterleave specific radar modes from MMCR datastreams. It can deliver output in ASCII or NetCDF format and optionally merge many days' worth of values into single files. Changes in metadata over time will be detected and reported. Plans for system enhancements include the ability to filter output based on the existence of data quality reports or filter on the existence of specific data quality flags. Filtering based on more general user preference, such as the existence of clouds or precipitation is also being considered. Enhanced slicing by time or other data dimensions is in the works. We encourage feedback from the user community regarding additional requirements for data extraction capabilities that will further improve the effectiveness of the Archive.

http://www.archive.arm.gov/

ARM Climate Research Facility: outreach through collaborative blogging

Rolanda Jundt, Pacific Northwest National Laboratory
Lynne Roeder, Pacific Northwest National Laboratory
Dana Dupont, Pacific Northwest National Laboratory

The ARM Climate Research Facility is a global scientific user facility for the study of climate change. As part of ongoing outreach efforts, the ARM Facility website launched a blog in 2010. Personnel from across the ARM and ASR organizations contribute posts about field campaigns, operations, conferences, education, and many other topics. Blog entries are created using WordPress software, a simple interface that allows contributors to easily post text, images, and captions. The "comment" feature lets visitors comment on blog entries and create a dialogue with the post's author and other readers. WordPress also provides RSS feed capability so that users can subscribe directly to blog posts. The blog is integrated with the ARM News Center and other social media tools, such as Twitter and Facebook.

ARM Data Quality Office inspection tools and techniques

Adam Theisen, CIMMS/ARM Data Quality Office
Kenneth Kehoe, University of Oklahoma
Justin Monroe, University of Oklahoma
Sean Moore, Mission Research
Trisatria Noensie, University of Oklahoma
Randy Peppler, University of Oklahoma

The ARM Climate Research Facility Data Quality (DQ) Office develops and utilizes a wide range of tools and analysis methods to support the needs of the Atmospheric System Research program. Now in our eleventh year of operation, the DQ Office is expanding the inspection tools and techniques used to ensure users receive the highest possible level of research-quality data. We continuously produce plots for the majority of ARM instruments and use web-based browsers for individually tailored displays of these plots. In addition to these static plots, we use interactive tools to directly inspect ARM NetCDF data files and other techniques to view and interpret long-term trends in the data. This year, we have begun developing a new system that will allow an individually tailored view of quality control information to meet a particular user's needs. This new system will allow the DQ Office to: display quality control information stored in varying formats; flag data beyond what is currently provided in NetCDF files processed at the ARM Data Management Facility; process and display data collected by the new instruments funded by the American Recovery and Reinvestment Act, including cloud and precipitation radars; display one- or two-dimensional quality control information graphically for the user; and greatly expand our ability to evaluate ARM value-added products.

http://dq.arm.gov/

ARM Recovery Act instruments

Jimmy Voyles, Pacific Northwest National Laboratory

Through the American Recovery and Reinvestment Act of 2009, the U.S. Department of Energy's Office of Science allocated $60 million to the ARM Climate Research Facility for the purchase of instruments and improvement of research sites. With these funds, ARM is in the process of deploying a broad variety of new instruments that will greatly enhance the measurement capabilities of the facility. New instruments being purchased include dual-frequency scanning cloud radars, scanning precipitation radars, Doppler lidars, a mobile Aerosol Observing System and many others. A list of instruments being purchased is available at http://www.arm.gov/about/recovery-act. The deployment status of all Recovery Act instrument systems will be presented.

Big Data Systems at the ARM Archive I: interactive visualization opportunities

Giri Palanisamy, Oak Ridge National Laboratory
Raymond McCord, Oak Ridge National Laboratory
James Mather, Pacific Northwest National Laboratory
Pavlos Kollias, McGill University
Ieng Jo, McGill University
Pete Eby, Oak Ridge National Laboratory
Karen Gibson, Oak Ridge National Laboratory
Eric Stephan, Pacific Northwest National Laboratory
Michael Jensen, Brookhaven National Laboratory

A new ARM infrastructure resource provided by the ARM Archive includes a new system that will be dedicated to visualization and software development based on the very large data volumes from new ARM instrumentation (e.g., scanning radars and lidars). As part of the "Big Data System" (BDS) design, the ARM Archive is currently setting up a system with various interactive visualization tools. The registered archive users will be able to request access to this system and perform various visualization and small-scale data extraction tasks. This system will have radar software such as TITAN, IRIS, and IDV, and data processing and visualization tools such as IDL, MATLAB, and NetCDF libraries. In addition to the interactive visualization capabilities, this system will also be used to produce a very large number of pre-computed plots for large volumes of radar data. These plots will be used in various ARM web pages and Archive user interfaces as part of the data discovery and data ordering processes. This system will also have programming languages and their libraries such as C, C++, Perl, Java, Python, and ScientificPython libraries. The ARM Integrated Software Development Environment (ISDE) will be installed as part of the script development feature. The users will be able to use a large collection (10s of TB) of locally stored data or request data through Archive user interfaces for transfer to this system for further processing. This poster will also explain hardware and use policies and operational scheme for this system.

http://www.archive.arm.gov

Big Data Systems at the ARM Archive II: data processing opportunities

Raymond McCord, Oak Ridge National Laboratory
Giri Palanisamy, Oak Ridge National Laboratory
Jay Manneschmidt, Oak Ridge National Laboratory
Pete Eby, Oak Ridge National Laboratory
Matt Macduff, Pacific Northwest National Laboratory
James Mather, Pacific Northwest National Laboratory

A new ARM infrastructure resource provided by the ARM Archive includes a new system that will be dedicated to data processing tasks based on the very large data volumes from new ARM instrumentation (e.g., scanning radars and lidars). The "Big Data System" (BDS) data processing tasks will focus on generating secondary data products to be archived and accessible to the ARM user community. These tasks will be proposed to ARM as a "virtual field campaign" preproposal that identifies the user's resource requirements and objectives for each task. BDS users may include members of the ARM infrastructure and the ASR research community. Roles for the users include specifying the required input data, describing the expected output data, providing the data processing software, monitoring processing progress, and reviewing the results. Data processing software can be developed using the ARM Integrated Software Development Environment (ISDE) tools on a development system at the Archive or other user-obtainable computing resources. Roles for the Archive staff include supervising the data flow with the Mass Storage System (MSS), acquiring approval for user access to the system, and assisting with installation of data processing software. This system is designed to support user-provided software and processing tasks requiring ~10–30 TB of input and output data. Adjacent installation of this system with the Archive MSS will optimize data transfers for these tasks. The *poster* will provide more details about the hardware and software configurations, example processing tasks, operational procedures, and requests for additional user input about the requirements for this system.

Does anyone really know what time it is? Does anyone really care?

Nicole Keck, Pacific Northwest National Laboratory
Robin Perez, Pacific Northwest National Laboratory

The Atmospheric Radiation Measurement Climate Research Facility collects thousands of time-stamped records each hour from instruments located around the world with temporal resolutions ranging from 200 milliseconds to 60 minutes. In theory, all ARM instruments and data systems are time-synchronized with GPS or dedicated NTP time servers to Greenwich Mean Time. In practice, this is not always the case. We will identify eight distinct configuration methods used to attempt to maintain time synchronization and demonstrate the shortcomings of those methods. We will present time synchronization reset frequency statistics and discuss a notable clock failure at the SGP E21 facility in summer 2010. We will discuss the downstream implications of time clock synchronization failures and the costs associated with correction of time errors when it is possible and feasible to do so.

Improved search, discovery, and accessibility of field campaign data

Alice Cialella, Brookhaven National Laboratory
Kathy Lazar, Brookhaven National Laboratory
Anne Glanville, University of Kansas
Richard Wagener, Brookhaven National Laboratory
Richard Cederwall, Oak Ridge National Laboratory
John Bell, Oak Ridge National Laboratory

The Atmospheric Radiation Measurement (ARM) Climate Research Facility receives a wide variety of data from different atmospheric instruments regularly deployed during field campaigns. In order to make the data publicly known and accessible to the world's research community, a description of the data (the metadata) must be entered by knowledgeable ARM personnel into the ARM Field Campaign (FC) Database. ARM metadata includes instrument classes and categories as well as primary measurement types (PMTs) and measurement categories. The ARM website accesses the FC database to populate web pages with information from the campaigns. The Campaigns, Instruments, and Measurements tabs can then be used to identify data of interest via the website. As of June 2010, a significant portion of the field campaign data did not have metadata assignments. The current project addressed this problem by redoubling efforts to assign metadata to past field campaigns, in preparation for the influx of former ASP field campaign data. In the process, a more efficient way of syncing databases was developed. This tool will also lend itself to routine ARM datastream metadata assignments.

http://www.arm.gov/campaigns

Infrastructure and instrumentation enhancements at the SGP

Brad Orr, Argonne National Laboratory
Dan Rusk, Native Energy and Technology, Inc.
John Schatz, ARM Climate Research Facility
Steve Hercyk, ARM Climate Research Facility

Significant changes have occurred at the SGP over the last year. The influx of funding from the American Recovery and Reinvestment Act (ARRA) has led to significant enhancements at the SGP. ARRA money provided much-needed infrastructure and capital improvements to the SGP. Five new radar systems have been installed, including a dual-frequency scanning cloud radar, three X-band radars, and a C-band radar. Additionally the installation of a scanning Doppler lidar and numerous other instruments and instrument upgrades have occurred over the last year. These new instrument systems will provide unique 3- and 4-dimensional data sets for cloud and atmospheric process studies that will lead to improved climate model physics and parameterizations. Other improvements to the SGP include a more dense surface flux network, new office buildings, an expanded electronics repair lab, and increased shipping and receiving storage for all the ARM facilities. An overview of these SGP improvements will be presented.

Integrated Software Development Environment: enabling scientific research through advanced tools

Eric Stephan, Pacific Northwest National Laboratory

High-quality and well-characterized observational data sets form the foundation for assessing the current state of the climate and enable climate predictions. To consistently deliver observational data products, standardized approaches must be applied when developing data processing software. The Integrated Software Development Environment (ISDE) developed by Pacific Northwest National Laboratory ensures a standardized approach for value-added product (VAP) software developers. ISDE provides: tools capable of specifying datastreams as input and configuring the resulting NetCDF file, a project wizard that automatically constructs a customized VAP C source project, and an extensive library, providing developers a standardized approach for retrieving, manipulating, and saving datastreams. Using these approaches, developers can rely on ISDE for handling the mundane and repetitive tasks, leaving more time to concentrate on developing and enhancing science algorithms.

Overview of the ARM Aerial Facility

Jason Tomlinson, Pacific Northwest National Laboratory
Celine Kluzek, Pacific Northwest National Laboratory
Jennifer Comstock, Pacific Northwest National Laboratory
John Hubbe, Pacific Northwest National Laboratory
Beat Schmid, Pacific Northwest National Laboratory

The ARM Aerial Facility (AAF) provides airborne measurements to answer science questions proposed by the ASR Science Team and the external research community. The AAF has access to a multitude of research aircraft operated by other agencies; operates a Gulfstream-1 (G-1) turboprop aircraft; and maintains a comprehensive suite of in situ probes and remote sensing instruments to measure the thermodynamic, radiative, gas phase, aerosol, and cloud properties of the atmosphere. The development of some of the instrumentation was done in collaboration with other Department of Energy national laboratories, United States government agencies, universities, and private industry. The G-1 has undergone a number of improvements in recent years: new engines have increased the flight duration, new generators and invertors have increased the available research power, wing pylons enable the aircraft to carry eight external probes, and the onboard data system has been modernized. The AAF now provides real-time mission monitoring (RTMM) during field campaigns, which enables researchers on the ground to view data in Google Earth as they are collected. The AAF is also providing merged data sets for each field campaign following the submission of the final data to the archive. An overview of these capabilities, improvements, and collaborations will be presented.

Recommended data sources for core geophysical parameters

Sherman Beus, Pacific Northwest National Laboratory
James Mather, Pacific Northwest National Laboratory
Giri Palanisamy, Oak Ridge National Laboratory

For years the ARM website has displayed a rather lengthy list of measurement types for which ARM data sets are available. For many of these measurements, the corresponding list of data sources is very long, which can be confusing for ARM data users as to which sources are preferred or recommended over the others. In response to this shortcoming, a list of ARM "core" geophysical parameters has been developed, including a prioritized list of ARM data sources for each. This information will be integrated into the ARM website to make finding the right data set simpler for users. In addition, a prototype web tool has been developed that displays timelines of data availability for routine ARM datastreams designated as recommended for a given parameter.

https://engineering.arm.gov/~sbeus/rdatagrid

Update on Recovery Act-funded additions to the U.S. DOE Atmospheric Radiation Measurement Climate Research Facilities on the North Slope

Mark Ivey, Sandia National Laboratories
Jeffrey Zirzow, Sandia National Laboratories
Fred Helsel, Sandia National Laboratories
Valerie Sparks, Sandia National Laboratories
Johannes Verlinde, The Pennsylvania State University
Scott Richardson, The Pennsylvania State University
Jessica Cherry, International Arctic Research Center, University of Alaska Fairbanks
Martin Stuefer, Geophysical Institute, University of Alaska Fairbanks

The U.S. Department of Energy (DOE) provides scientific infrastructure and data archives to the international Arctic research community through a national user facility, the ARM Climate Research Facility, located on the North Slope of Alaska. Funding from the Recovery Act (American Recovery and Reinvestment Act of 2009) will be used to install new instruments and upgrade existing instruments in Barrow. These instruments include:

- scanning precipitation radar
- scanning cloud radar
- automatic balloon launcher
- high spectral resolution lidar
- eddy correlation flux systems
- upgraded ceilometer, AERI, micropulse lidar, and millimeter-wavelength cloud radar.

Information on these planned additions and upgrades will be provided in our poster. An update on activities planned at Oliktok Point will also be provided.

Value-added products (VAPs) associated with the Cloud-Aerosol-Precipitation Interactions (CAPI) working group

Sally McFarlane, Pacific Northwest National Laboratory
Krista Gaustad, Pacific Northwest National Laboratory
Steven Ghan, Pacific Northwest National Laboratory
James Mather, Pacific Northwest National Laboratory
Yan Shi, Pacific Northwest National Laboratory
Timothy Shippert, Pacific Northwest National Laboratory
Chitra Sivaraman, Pacific Northwest National Laboratory
David Turner, NOAA

In this poster we will present an update on current value-added products (VAPs) and plans for future products associated with the Cloud-Aerosol-Precipitation Interactions (CAPI) working group. With regards to current VAPs, we will present: (1) the status of the microwave radiometer retrieval of column water vapor and liquid water path (MWRRET); (2) recent updates and status of the retrieval of cloud optical depth for overcast clouds from the MFRSR; (3) plans and initial results for the development of a VAP to retrieve cloud condensation nuclei at cloud base using lidar data (CCNProf) and (4) results from the Radiatively Important Parameters Best Estimate (RIPBE) and initial runs of the broadband heating rate profile (BBHRP) using the RIPBE inputs. We will also discuss plans for future VAPs including updates to MWRRET for the new 3-channel microwave radiometers and proposed VAPs for planetary boundary-layer height, droplet number, and drizzle parameters.

Value-added products: from evaluation to production, here's a status

Chitra Sivaraman, Pacific Northwest National Laboratory
Rolanda Jundt, Pacific Northwest National Laboratory
Dana Dupont, Pacific Northwest National Laboratory

There are currently about 38 distinct ARM value-added products (VAP) and evaluation products. Some of the VAPs are site- and date-specific and are dependent on the availability of other data products. Every production-ready VAP is required to meet certain standards. An example of how a VAP has been developed and the complexities involved in producing an autonomous product will be presented. This poster will also provide an update on the status of the VAPs that are run autonomously at the DMF and outline the development activities for the VAPs under development.

http://www.arm.gov/data/vaps

VAP development: initiation, development, evaluation, and release

Michael Jensen, Brookhaven National Laboratory
Scott Collis, Argonne National Laboratory
Jerome Fast, Pacific Northwest National Laboratory
Connor Flynn, Pacific Northwest National Laboratory
James Mather, Pacific Northwest National Laboratory
Sally McFarlane, Pacific Northwest National Laboratory
Justin Monroe, University of Oklahoma
Chitra Sivaraman, Pacific Northwest National Laboratory
Shaocheng Xie, Lawrence Livermore National Laboratory

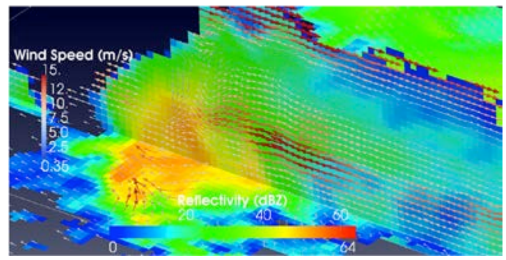
ARM value-added products (VAPs) provide an important translation between the instrumental measurements and the geophysical quantities needed for scientific analysis, particularly model parameterization and development. The production of VAPs is the responsibility of the ARM infrastructure (translators and developers) with guidance from the ASR science working groups. In recent years, a review of the VAP development process has helped to identify improved pathways for the timely delivery of quality-controlled data products important for scientific inquiry and advancement. This poster outlines the pathway from a geophysical quantity produced from an individual scientist's retrieval algorithm to a production-level product provided by the ARM infrastructure.

9.0 Instruments

Adding value to ARM precipitation radar measurements

Scott Collis, Argonne National Laboratory
Nitin Bharadwaj, Pacific Northwest National Laboratory
Kevin Widener, Pacific Northwest National Laboratory
Scott Giangrande, Brookhaven National Laboratory

The procurement of a network of C- and X-band scanning radars has lead to a flow of specialized measurements, which need value-adding to be of use to a wider cross-section of the ASR and broader modeling community. This presentation will outline the plans and systems being implemented in order to retrieve geophysical parameters from multiple sensors in a three-dimensional domain over the ARM sites. A particular focus will be on parameters highlighted in recent white papers by the Science and Infrastructure Steering Committee, specifically vertical velocity and quantitative precipitation estimates. Example algorithms will be highlighted and first results presented.



Slices through three-dimensional grids of reflectivity and retrieved wind vectors from the C-POL radar in Darwin.

Aerosol chemical speciation monitor

John Jayne, Aerodyne Research, Inc.

Ambient particles are known to play a significant role in altering the chemistry and the radiative balance of the Earth's atmosphere, reducing visibility, and adversely affecting human health. The chemistry of atmospheric aerosol has been the subject of much research. In order to address aerosol effects on health and the environment, instrumentation is needed that is capable of reporting the chemical and microphysical properties of atmospheric particles. We present results on the development and demonstration of a compact aerosol mass spectrometer system, the Aerosol Chemical Speciation Monitor (ACSM), which measures aerosol mass and chemical composition of non-refractory submicron aerosol particles in real time. The ACSM provides composition information for particulate ammonium, nitrate, sulfate, chloride, and organics. It is designed and built on the same technology as our larger research-grade Aerosol Mass Spectrometer (AMS), combining an aerodynamic particle-focusing lens with high vacuum thermal particle vaporization and mass spectrometric analysis. The system is smaller, uses lower-cost components, and thus operates with lower performance than the research-grade AMS. The ACSM is designed for longer-term routine monitoring of PM with sufficient sensitivity to provide chemically speciated mass loadings and aerosol mass spectra at data rates up to 15 minutes for typical urban aerosol loadings. Results are presented from recent field trials that compare the ACSM performance with collocated aerosol chemical instruments. Data quality and data analysis methods will be presented, and updates on the deployment of the DOE ARM ACSM systems will also be presented.

Aerosol Observing Systems (AOS): new capabilities for ASR researchers

Stephen Springston, Brookhaven National Laboratory

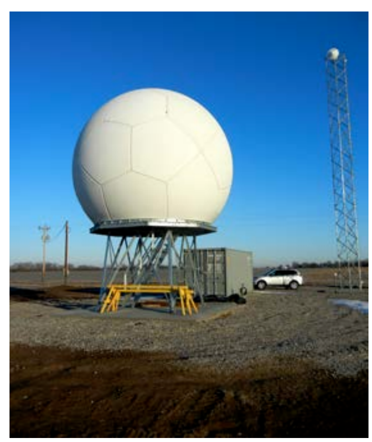
ARM Mobile Facility 2 Aerosol Observing System (AMF2-AOS) at Christie Peak as part of the 2010-2011 STORMVEX field campaign.

Three new AOS units, including the Mobile Aerosol Observing System (MAOS) with an extended instrument suite, are coming online as part of the ARM Climate Research Facility. These units represent a new generation of instrumental capabilities for aerosols and trace gases. The labs are independent and designed for rapid deployment, harsh environments, more autonomous operation, and uniform data output across diverse instruments. An updated list of instruments and their status will be presented. Data are redundantly stored within each AOS, again at the Site Collector Computer, and at the ARM Data Management Facility. A system of remote access over the Internet allows mentors complete control over AOS infrastructure and instrument computers and direct control of most instruments. Mentors can view outputs in real time and communicate with on-site technicians. The units are also designed to accommodate guest instruments in addition to the standard suite. The first AOS unit, ARM Mobile Facility 2 (AMF2), is now operating as a stand-alone unit at STORMVEX, and data are flowing into the ARM system. The second unit will be deployed to the Tropical Western Pacific in early spring. MAOS A and C (for Aerosol and Chemistry) will be deployed during the 2011 Aerosol Life Cycle IOP followed by overseas operation during GVAX. Development of the data flow stream for all AOS units and the extended components of MAOS is ongoing.

ARM cloud/precipitation radars: status and plans for 2011

Kevin Widener, Pacific Northwest National Laboratory
Nitin Bharadwaj, Pacific Northwest National Laboratory
Karen Johnson, Brookhaven National Laboratory
Scott Collis, Argonne National Laboratory
Annette Koontz, Pacific Northwest National Laboratory

The Recovery Act has brought ARM four X-band scanning ARM precipitation radars (X-SAPRs), two C-band scanning ARM precipitation radars (C-SAPR), three X/Ka-band scanning ARM cloud radars (X/Ka-SACRs) , three Ka/W-band scanning ARM cloud radars (Ka/W-SACRs), and the replacement of the venerable MMCRs with the new Ka-band ARM zenith radars (KAZRs). In addition to these, we still field a zenith-pointing W-band ARM cloud radar (WACR) and scanning W-band cloud radar (SWACR) with the two ARM Mobile Facilities. We present the current status of the deployment of all of these radars.



Southern Great Plains C-SAPR.

A balloon-sonde gas sampling system for full-column trace gas profiling

Marc Fischer, Lawrence Berkeley National Laboratory

In situ measurements of the vertical structure of CO2 and other greenhouse gases (GHG) are essential for evaluation of GHG remote sensing, errors in inverse model GHG emission studies, and GCM representation of GHG radiative forcing. Current in situ measurements at the ARM Facility include airborne measurements of CO2 and flask sampling for other species (e.g., CH4, N2O, SF6, and halo carbons). However, this work is currently limited to altitudes up to 5 km (50% of the column), and occasional flights of opportunity have only reached ~ 12 km (90% of the column). Here, we describe a balloon-sonde sampling system, termed an AirCore, that collects atmospheric samples from the stratosphere (> 20 km) to the Earth's surface, and describe preliminary planning for balloon-sonde flights at the Southern Great Plains Atmospheric Science Research Facility. The AirCore described here is a 150-m-long stainless steel tube, open at one end and closed at the other, that relies on positive changes in ambient pressure for passive sampling of the atmosphere. The AirCore evacuates while ascending to a high altitude and collects a sample of the ambient air as it descends. It is sealed upon recovery and measured with a continuous analyzer for trace gas mole fraction. Measurements of CO2 and CH4 mole fractions in laboratory tests indicate a repeatability and accuracy of better than 0.05 ppm for CO2 and 0.4 ppb for CH4 under a variety of conditions. Comparisons of AirCore data with continuous in situ and flask data in aircraft field tests indicate average absolute differences of 0.3 ppm and 5 ppb for CO2 and CH4, respectively, with no apparent bias. Accounting for molecular diffusion and flow-induced mixing, the expected measurement resolution for CO2 and CH4 is 110 m at sea level and 260 m at 8000 m above sea level after three hours of storage. As part of planning for flights in the ARM SGP area, we analyze balloon-sonde trajectories and identify prospective launch locations that facilitate recovery of the Aircore package.

Calibration of the Cloud Extinction Probe and some results of measurements

Alexei Korolev, Environment Canada
Alexander Shashkov, Environment Canada
Howard Barker, Environment Canada

Theoretical and laboratory study of the accuracy of the extinction coefficient measured by the newly developed Cloud Extinction Probe (CEP) are discussed. The Cloud Extinction probe utilizes the transmissiometric method. This method enables the calculation of the extinction coefficient from first principles based on the Beer-Bouguer law. In spite of the high sensitivity (~0.2km-1), the question about the effect of the size of cloud particles on the measured extinction coefficient remains open. In the case of large cloud particles, the CEP may underestimate the extinction coefficient due to receiving extra light caused by the narrow forward-scattering lobes and limited receiving aperture of the Extinction probe. A laboratory installation was developed for calibration of the extinction probe in the frame of the ARM Aerial Instrument proposals #09-5755 and used for the study of the effect of forward-scattering on the CEP measurements. The extinction probe has been installed on the NRC Convair 580 and participated in 26 flights during the DOE ARM ISDAC project in Alaska during April 2008. The results of this work will be used for the parameterization of the extinction coefficient in Arctic ice and mixed-phase clouds.

Cimel sun photometers: updates on new deployments and cloud-mode zenith radiance data

Richard Wagener, Brookhaven National Laboratory
Laurie Gregory, Brookhaven National Laboratory
Lynn Ma, Brookhaven National Laboratory

Since March 1998, ARM has deployed Cimel sun photometers (CSPHOT) at several, but not all, ARM sites. This past year, as part of the deployment of the Boundary Layer Cloud System, six new units were acquired. The ARM CSPHOT deployments were expanded to include the second ARM Mobile Facility (AMF2), Manus, and Darwin. The older units at the Southern Great Plains (SGP) and first ARM Mobile Facility (AMF1) were replaced. An additional spare was added to the rotation to ensure units get calibrated at NASA's Aerosol Robotic Network (AERONET) between deployments with a minimum of interruption to the observations. This last unit will be part of the Aerosol Life Cycle campaign at Brookhaven National Laboratory in the summer of 2011 to make a connection to column aerosol properties for the very detailed in situ aerosol observations of the Mobile Aerosol Observing System (MAOS). In the past, the CSPHOTs were only used under predominantly clear-sky conditions to derive aerosol properties, and the instrument remained in sleep mode during cloudy periods. Marshak et al. (2004) suggested that over vegetated surfaces, cloud optical depth could be derived from ground-based zenith radiance measurements. Christine Chiu worked with AERONET using the CSPHOT at SGP to alter the observing strategy to include a number of zenith radiance observations during previously idle periods (Chiu et al., 2010). This "Cloud Mode" has now been enabled operationally on all ARM CSPHOTs. However, since the wet sensor does not always detect snow, and since the cloud optical depth retrieval algorithm requires vegetated surfaces, the cloud mode is turned off during snow seasons. The provisional cloud mode data are now available in the AERONET archive (http://aeronet.gsfc.nasa.gov/new_web/cloud_mode.html) and will soon be available through the ARM archive.

References:

Chiu, JC, C-H Huang, A Marshak, I Slutsker, DM Giles, BN Holben, Y Knyazikhin, and WJ Wiscombe. 2010. "Cloud optical depth retrievals from the Aerosol Robotic Network (AERONET)." *Journal of Geophysical Research* 115, D14202, doi:10.1029/2009JD013121.

Marshak, A, Y Knyazikhin, K Evans, and W Wiscombe. 2004. "The 'RED versus NIR' plane to retrieve broken-cloud optical depth from ground-based measurements." *Journal of the Atmospheric Sciences* 61, 1911–1925.

Combining new and legacy instruments yields routine measurements of absolute spectral radiation spanning the thermal IR, near-IR, visible, and UV

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James Barnard, Pacific Northwest National Laboratory
Derek Hopkins, Pacific Northwest National Laboratory
Albert Mendoza, Pacific Northwest National Laboratory
Dan Nelson, Pacific Northwest National Laboratory
Randy Norheim, Pacific Northwest National Laboratory
Luc Rochette, LR Technologies, Inc.
André Lanouette, LR Technologies, Inc.
Michel Gaudreau, LR Technologies, Inc.

New spectral radiometers deployed at the ARM Climate Research Facility this year represent a major expansion in terms of the breadth of continuous spectral radiation measurements. The Shortwave Array Spectrometer measuring zenith spectral radiance from 350 nm to 2.1 microns has been repaired, recalibrated, and redeployed to SGP. Two new Shortwave Array Spectrometer – Zenith (SAS-Ze) instruments have been received measuring zenith spectral radiance over a slightly reduced spectral range of 350 nm to 1.7 microns but with improved resolution and sensitivity. One of the SAS-Ze is deployed at SGP, while the second is awaiting deployment with AMF1 in Nainital, India in support of GVAX. Two new Shortwave Array Spectrometer – Hemispheric (SAS-He) instruments measuring the direct solar and diffuse hemispheric spectral irradiance over the sample spectral range have also been received and will be collocated with the SAS-Ze systems. The SAS-He instrument at SGP complements the existing rotating shadowband spectrometer (RSS), overlapping the wavelength range in the UV and visible and extending it to the near-IR. Rapid-sampling FTS providing measurements of absolutely calibrated zenith radiance over the thermal IR spectral range from 3–19 microns have also been received, including the ASSIST II instrument installed with the AMF2 and operating at the Thunderhead site in support of the STORMVEX field campaign. Preliminary data sets from each of these new instruments are reported.

E-AERI calibration performance certification

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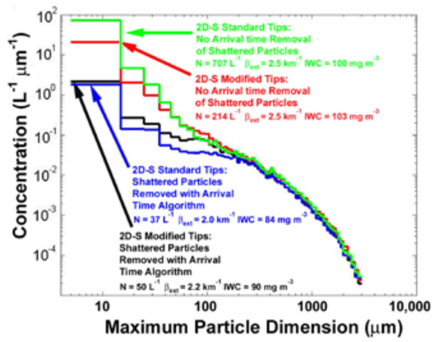
Joe Taylor, University of Wisconsin-Madison
Fred Best, Space Science and Engineering Center, University of Wisconsin
Nick Ciganovich, Space Science and Engineering Center, University of Wisconsin
Ray Garcia, Space Science and Engineering Center University of Wisconsin
Denny Hackel, University of Wisconsin
Henry Revercomb, University of Wisconsin-Madison
David Turner, NOAA

The University of Wisconsin-Madison Space Science and Engineering Center (UW-SSEC) is certifying the calibration performance of a new generation of instruments for the measurement of the downwelling atmospheric infrared spectrum at the surface. The E-AERI instrument series is the commercial follow-on to the successful Atmospheric Emitted Radiance Interferometer (AERI), which was developed at UW-SSEC in the early 1990s with support from the U.S. Department of Energy Atmospheric Radiation Measurement (ARM) Program. This paper describes the E-AERI instrument specification, the UW-SSEC certification methodology, and examples of preliminary of results obtained to date. The E-AERI instrument is a commercially available product of ABB/Bomem of Quebec, Canada, using technology licensed by the UW-SSEC. The E-AERI meets the same specification as the original AERI instrument in a fully automated system for use in both research and operational profiling networks.

Effects of ice crystals shattering on probe tips

Paul Lawson, SPEC Inc.
Brad Baker, SPEC Inc.



Ice particles shattering on the inlets and tips of cloud particle probes produce small ice artifacts that can be erroneously included in measurements of ice particle size distributions. While the issue surrounding ice particles shattering on the inlets and tips of optical particle probes (hereafter referred to simply as "shattering") has been known since the 1970s, it has only been recently that the magnitude of the effect has been brought to the attention of the cloud physics community. Advances in high-speed digital videography and cloud particle probes have provided new insights into the shattering process. High-speed videography of ice particles shattering on probe tips in the icing research tunnel (IRT) at the National Aeronautics and Space Administration (NASA) Glenn Research Center (GRC) showed some remarkable results. Dr. Alexei Korolev of Environment Canada (EC) has shown digital videography of millimeter-size ice particles shattering on probe tips, with small ice particles bouncing several mm upstream into the 100 m s^{-1} airflow, and then traversing up to 3 cm across the airflow into the probe sample volume. Advances in the electro-optics of linear-array cloud particle probes have provided new insights into measurements of cloud particle size distributions. In particular, the 2D-S probe has been demonstrated to have 10-µm pixel resolution at airspeeds exceeding 200 m s^{-1}. This presentation is focused on exposing suspected errors in measurements of ice particle size distributions due to shattering and evaluation of techniques used to reduce the errors. Korolev recently evaluated shattering effects on 2D-C and CIP probes and suggested that that specially modified tips were more effective than an arrival time algorithm in reducing the effects of shattering. In our work it is seen that when considering the newer technology 2D-S probe, we find the opposite; i.e., an arrival time algorithm is more effective in reducing the apparent effects of shattering than modified tips. Measurements are compared from two 2D-S probes, one with standard tips and one with modified tips. The two probes were installed side-by-side on the SPEC Learjet for the recent DOE ARM SPARTICUS field project. While modified tips did reduce the number of shattered particles, the arrival time algorithm was more effective in removing effects of shattering, regardless of whether the tips were modified or not. 2D-C, CIP, and 2D-S data from the recent Airborne Icing Instrumentation Evaluation (AIIE) field experiment are presented and discussed. Finally, an improved algorithm for removing shattered particles from Fast FSSP and Fast CDP instruments is discussed.

Enhanced detection of 1-nm condensation nuclei using diethylene glycol and butanol condensation particle counters

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Modi Chen, University of Minnesota
Peter McMurry, University of Minnesota
Jian Wang, Brookhaven National Laboratory

Atmospheric aerosols influence climate and climate change on local to global scales by affecting the atmospheric radiation balance directly through scattering and absorbing incoming solar radiation and indirectly as cloud condensation nuclei. New particle formation (NPF) by photochemical reactions of gas-phase precursors greatly increases the number concentrations of atmospheric aerosols, and therefore their impact on climate. Although methods for measuring sizes and concentrations of newly formed particles of diameter greater than 3 nm are well established (Stolzenburg and McMurry 1991), measurements of nanoparticles and neutral molecular clusters smaller than this are needed to constrain nucleation rates and to better understand nucleation mechanisms. A diethylene glycol-based ultrafine condensation particle counter (DEG-UCPC) has recently been developed for sub-2 nm detection, enabling the measurement of laboratory-generated aerosol standards with a detection efficiency of 2% at 1.19 nm (Iida et al. 2008, Jiang et al. 2010). By increasing the flow rate and operating temperature difference in the DEG-UCPC, this detection efficiency has been increased to over 20% at the same particle size. Similar operating modifications to a commercial butanol-based CPC (TSI 3025A) have increased the detection efficiency of 1.68 nm particles from less than 1% to over 35%. Laboratory characterization of CPC detection efficiency as a function of particle size, charge, and composition will be presented for both instruments. Based on these results, a viable solution for long-term sub-2 nm aerosol measurement through modification of existing instrumentation will also be presented.

Iida, K, et al. 2008. "Effect of working fluid on sub-2 nm particle detection with a laminar flow ultrafine condensation particle counter." *Aerosol Science and Technology* 43(1): 81–96.

Jiang, J, et al. 2010. "Electrical mobility spectrometer using a diethylene glycol condensation particle counter for measurement of aerosol size distributions down to 1 nm." *Aerosol Science and Technology* 45(4): 510–521.

Stolzenburg, MR, and PH McMurry. 1991. "An ultrafine aerosol condensation nucleus counter." *Aerosol Science and Technology* 14(1): 48–65.

Evaluation of Infrared Sky Imagers at the ARM Southern Great Plains site

Victor Morris, Pacific Northwest National Laboratory
Dimitri Klebe, Solmirus Corporation

Uncertainty in the characterization of clouds in general circulation models (GCMs) is one of the major causes of the broad spread of future climate change predictions (ASR Science and Program Plan, January 2010). Cloud fraction, which is closely related to cloud coverage, has been an integral part of the observational data set that feeds these GCMs. Cloud fraction, however, has only been reliably determined at the ARM sites during daytime hours utilizing the Total Sky Imager (TSI). Nighttime cloud fraction has been and remains a critical programmatic gap in ARM's observational data set. It has long been recognized that infrared sky imaging technology has held great promise in closing this gap. In addition, this technology has the distinct advantage that its ability to characterize clouds is identical for day or night conditions. Therefore, instrument demonstrations were conducted at the ARM Climate Research Facility Southern Great Plains site in 2005, 2007, 2009, and 2010 to evaluate measurements of cloud fraction from different types of infrared sky imagers and to compare the daytime values with an operational TSI. The most promising of the instruments

Three of the four instruments deployed in the Infrared Sky Imager Intercomparison Study conducted in 2007 are visible in this photo taken on the Guest Instrument Facility platform at the SGP site. They are the Solmirus All Sky Infrared Visible Analyzer (foreground), Heitronics Nubiscope (top right), and Atmos Cloud Infrared Radiometer-4 (far left).

tested is Solmirus Corporation's All Sky Infrared Visible Analyzer (ASIVA). Preliminary analysis of the hemispheric infrared sky images captured by the ASIVA, using simple techniques to provide cloud fraction, shows very good agreement with the TSI results during daylight hours. A comprehensive data analysis of observations made during the 2009 campaign has been performed using more sophisticated algorithms to attain an even better correlation with the TSI instrument. Also in development is a robust nighttime cloud fraction data product utilizing the radiometrically calibrated data from ASIVA's two infrared channels.

http://www.arm.gov/campaigns/sgp2007irsiintercompar

A high-resolution oxygen A-band spectrometer (HABS)

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Bangsheng Yin, Atmospheric Sciences Research Center, State University of New York
Jerry Berndt, Atmospheric Sciences Research Center, State University of New York
Lee Harrison, State University of New York
Piotr Kiedron, NOAA

An important challenge is to detect three-dimensional (3D) structures of clouds and aerosols and their effects on radiative transfer. Current ability to resolve 3D cloud structure is limited to scanning pulsed active sensors and imaging instruments, not at the scale of radiative transfer of horizontal and vertical inhomogeneity. An oxygen
A-band spectrometer provides a basis for applications of path length distribution in development and validation of remote sensing and radiative transfer parameterizations that account for 3D effects. To face the challenge, a high-resolution oxygen A-band spectrometer (HABS) has been developed and well tested at State University of New York. The HABS has the capability to measure both zenith and direct-beam radiances with a field of view of 2.7 degrees. The direct-beam measurements can be used to calibrate the spectrometer and construct retrieval kernels for zenith measurements. HABS also measures polarizations of A-band spectra with four polarizers, which substantially enhances the retrieval ability for aerosols and ice clouds. Our tests indicate that HABS achieves an out-of-band rejection of 10-5, a resolution of better than 0.3 cm-1, and a high signal-to-noise ratio. It is ready for a field campaign at the ARM SGP site to demonstrate its capability in radiative transfer and remote sensing applications.

High spectral resolution lidars for AMF2 and the North Slope

Edwin Eloranta, University of Wisconsin

The University of Wisconsin has constructed a pair of new High Spectral Resolution Lidars: one for the second ARM Mobile Facility (AMF2) and the other for the North Slope site at Barrow, Alaska. The first of these was installed on January 21, 2011, in AMF2 during the STORMVEX deployment at Steamboat Springs, Colorado. This poster will describe the new instruments and their performance. The basic design follows that of the system we have operated at Eureka, Nunavut, for the past five years. The optical design is nearly identical to the airborne system we designed for use on the National Center for Atmospheric Gulfstream V aircraft, except that they have been repackaged for ground-based deployment. The mechanical structure has been redesigned to minimize thermally induced shifts in optical alignment, and the telescope has been packaged inside the instrument to protect the optics from contamination.

htttp://lidar.ssec.wisc.edu

In situ checks of sonic anemometer temperature calibration

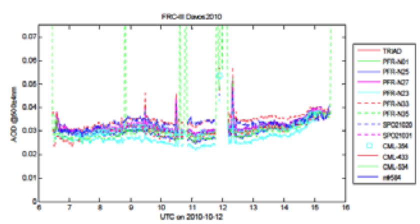
David Cook, Argonne National Laboratory
Michael Negale, Argonne National Laboratory

The temperature calibration of the Gill Instruments WindMaster Pro sonic anemometer used in the ARM SGP ECOR systems is actually a curve, but is approximated with a linear fit for field use. The original calibrations were performed in a temperature-controlled chamber. The linear fit slope is only applied to the calculation of sensible heat flux and not to the reported temperature. The linear fit results in an underestimate of sensible heat flux during cold ambient temperatures and an overestimate during hot ambient temperatures. In situ calibrations performed using five years of ARM SGP data reveal how poorly the temperature is measured by the ECOR using the linear fit approximation during cold and hot temperatures. Linear and non-linear in situ calibrations were determined for each sonic anemometer at each extended facility. In several cases, the linear calibration slopes presently being used in the ECOR configuration files need to be changed. The non-linear slopes will be used in the ECOR VAP to convert the measured temperature to ambient temperature.

International Filter Radiometer Comparison results

Gary Hodges, NOAA ESRL Global Monitoring Division/CIRES
Joseph Michalsky, DOC/NOAA Earth System Research Laboratory

In conjunction with the eleventh International Pyrheliometer Comparison (IPC XI) held in Davos, Switzerland, from September 27 to October 15, 2010, the Physikalisch-Meteorologisches Observatorium Davos/World Radiation Center (PMOD/WRC) also conducted the 3rd Filter Radiometer Comparison (FRC III). Two refurbished ARM multifilter rotating shadowband radiometers (MFRSRs) were included in the comparison, along with a new version of the MFRSR that uses a thermopile sensor for broadband solar measurements replacing the silicon photodiode that is used in the earlier (and all of ARM's) MFRSRs. The unprecedented temperature stability, required to successfully operate the thermopile, also improves the narrowband filter measurements significantly. At the conclusion of the measurement period, a nagging heater problem was discovered with one of the ARM MFRSRs, although it was functioning when shipped to Davos, rendering its data suspect and untrustworthy. All the participating instruments were compared to a group of precision filter radiometers (PFRs) that are owned and operated by the World Radiation Center. Initial results show that the MFRSRs compare favorably to the reference group, and are, in fact, within the limits set by the FRC II working group in the previous comparison, i.e., ±0.005 + 0.01/air mass.



The scatter plot illustrates the covariation of daily averages of Climate Modeling Best Estimate observations of surface net total radiation and effective shortwave cloud albedo in May–August of 1997 to 2008 (color-coded by year) at the U.S. Southern Great Plains site.

Other participating instrument makes and models were:

- Middleton SP02
- CIMEL CE318
- PMOD/WRC PFR

Molecular-level organic aerosol composition and volatility using chemical ionization high resolution time-of-flight mass spectrometry

Joel Thornton, University of Washington
Reddy Yatavelli, University of Washington
Julia Wargo, University of Washington
Joel Kimmel, Aerodyne Research, Inc./Tofwerk
Jose-Luis Jimenez, University of Colorado
Amber Ortega, University of Colorado at Boulder
Douglas Worsnop, Aerodyne Research, Inc.

The sources and transformations of aerosol organic matter remain uncertain. Mapping the evolution of organic aerosol composition on a molecular level remains crucial to developing accurate source attribution and mechanisms of chemical processing required for constraining coupled chemistry-climate models. Towards this end, we have developed an instrument coupling soft chemical ionization with a high-resolution time-of-flight (TOF) mass spectrometer for molecular-level analysis of organic matter in both the gas and particle phases without a chromatographic separation. Laboratory studies indicate the prototype has a high sensitivity to carboxylic acids
(~ picogram detection limits) with a mass resolution of >4000 and mass accuracy of ~ 20 ppm. Together with the fast spectrum acquisition rate provided by TOFMS (0–500 amu at >10 Hz), these characteristics provide the potential to constrain aerosol component vapor pressures as a function of elemental composition and molecular mass. We demonstrate instrument performance using select standards, output from a Potential Aerosol Mass chamber, and preliminary field measurements. Finally, we discuss the planned application of this instrument to chamber studies of the aerosol life cycle and field measurements as part of the DOE GVAX campaign.

The new Atmospheric Radiation Measurement (ARM) 3-channel microwave radiometers: initial data and retrievals

Maria Cadeddu, Argonne National Laboratory

In January 2011 two new 3-channel microwave radiometers (MWR3C) began operations. The new MWR3Cs have been acquired partially with funding provided by the American Recovery and Reinvestment Act (ARRA), and their initial operational deployment marks the completion of a year-long series of acceptance tests conducted at the SGP. The tests led to a substantial redesign of the instrument's hardware and software to meet the high quality standards required by the ARM instrumentation. One unit was installed on January 11 at the ARM Mobile Facility (AMF2) site in Steamboat Springs, Colorado, and one unit was installed on January 26 at the Southern Great Plains (SGP) Central Facility site. The new radiometers measure sky brightness temperatures at 23.8, 30, and 89 GHz, providing improved sensitivity to small amounts of cloud liquid water. The new 3-channel radiometers will gradually be deployed at all ARM sites where they will operate next to the MWRs before replacing them. We present the instrument design and capabilities and give an overview of the instrument's standard mode of operation. Data from the two deployments are presented. Initial retrievals of precipitable water vapor and liquid water path are examined and compared with those obtained from the 2-channel MWR at the SGP site. Future plans for the development of new retrievals are discussed.

A new mobile laboratory for greenhouse gas source and sink attribution and carbon cycle science

Ray Bambha, Sandia National Laboratories
Manvendra Dubey, Los Alamos National Laboratory
Thomas Guilderson, Lawrence Livermore National Laboratory
Fred Helsel, Sandia National Laboratories
Ryan Herrmann, Sandia National Laboratories
Mark Ivey, Sandia National Laboratories
Hope Michelsen, Sandia National Laboratories
Claudia Mora, Los Alamos National Laboratory
Thom Rahn, Los Alamos National Laboratory
John Roskovensky, Sandia National Laboratories
Paul Schrader, Sandia National Laboratories
Larry Yellowhorse, Sandia National Laboratories
Bernard Zak, Multiple Academic Afflilations
Jeffrey Zirzow, Sandia National Laboratories

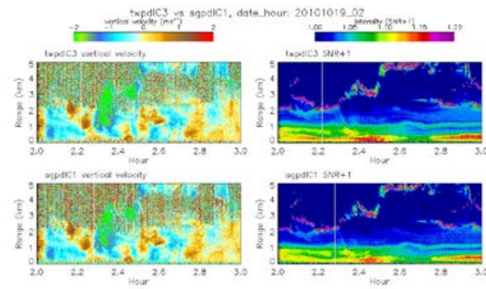
ATML1 and ATML2 deployed at the ARM Southern Great Plains site during the Northern Oklahoma CO2 Attribution with Tracers Study (NOCATS), fall 2010.

We have developed a mobile laboratory to quantify fluxes of CO2 within the terrestrial biosphere and quantitatively attribute greenhouse gas (GHG) emissions to diverse biogenic and anthropogenic sources. Our new mobile lab facilities include (1) two climate-controlled 30-foot trucks, referred to as the Atmospheric and Terrestrial Mobile Laboratories (ATML1 and ATML2), which house instruments for in situ measurements of GHGs and tracers of GHG sources and sinks, and (2) an insulated trailer, which houses upward-viewing remote sensing instruments. The trucks were recently deployed at the ARM SGP facility for six weeks to demonstrate the utility of this suite of instruments for carbon-cycle science and GHG attribution. The trailer was deployed downwind of the Four Corners Power Plant in Farmington, New Mexico, to measure the evolution of the coal-fired power-plant plume. We have also developed capabilities to analyze trace-gas data using the Weather Research and Forecasting (WRF) model. The trucks are equipped with gas-bottle racks, instruments racks, and inlet systems for air sampling. ATML1 has a pneumatic mast to collect air at a height of 10 meters. The inlet for ATML2 extends to allow sampling on an eddy-covariance tower separate from the truck or from the top of the ATML1 mast. Both trucks are line-powered, but ATML1 can be powered by built-in generators if needed. Having two trucks with some redundant instrumentation allows for more flexibility during deployments and the ability to make measurements upwind and downwind of GHG sources. ATML1 currently carries instrumentation for CO, SO2, NOx, and O3 abundances; four Picarro spectrometers for 12CO2, 13CO2, CH4, H216O, H218O, and HD16O abundances; a flask sampling system for 14CO2; a drum sampler for elemental particle composition; a PASS-3 photoacoustic particle sensor; and an AirCore sampler for sampling aloft. ATML2 houses an Aerodyne laser absorption spectrometer for 12CO2, 13CO2, C16O18O, C16O2, and H2O abundances and fluxes; a proton-transfer reaction mass spectrometer for VOC abundances and fluxes; a sonic anemometer; and soil and air temperature and humidity sensors for validating flux measurements. The trailer includes a sun-tracking photometer for aerosols, a ceilometer for boundary layer height, a total sky imager for clouds, a radiosonde system, and a solar-viewing FTIR spectrometer, which enables smokestack-plume or atmospheric-column measurements in the near-infrared and thermal infrared spectral region.

Performance evaluation of the new ARM Doppler lidars

Rob Newsom, Pacific Northwest National Laboratory

In 2010 the U.S. Department of Energy's Atmospheric Radiation Measurement Climate Research Facility acquired three new coherent Doppler lidars. These instruments are now being used to fill a long-standing measurement gap within the ARM Facility by providing long-term measurements of clear-air vertical velocities in the lower troposphere. Prior to operational deployment, all three Doppler lidars underwent acceptance testing at ARM's Southern Great Plains (SGP) site in October 2010. During the tests, the systems were run in side-by-side comparisons over a period of several days, and the data were analyzed to evaluate radial velocity differences, as well as measurement precision and bias. The results showed that the lidars produced consistent measurements. Correlation coefficients between radial velocity time series at fixed heights exceeded 0.9 within the atmospheric boundary layer under convective conditions. The measurement precision, which was estimated using two different techniques, was found to be less than 10 cm/s at high signal-to-noise-ratio (SNR) and consistently less than 20 cm/s within the atmospheric boundary layer (below ~2km). At high SNR, the mean velocity differences were quite small (<10 mm/sec), but all three systems showed a tendency for positive bias at low SNR. This poster summarizes the results of the side-by-side intercomparison study.

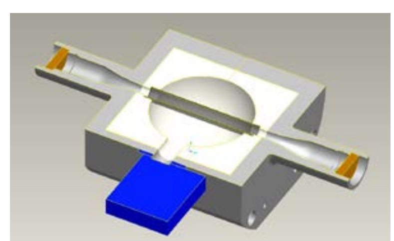


Comparisons between vertical velocity and signal intensity from the TWP DL (top) and the SGP DL (bottom) during a period of thunderstorm activity on 19 October 2010. These data were acquired while the systems were operated side-by-side as part of acceptance testing at the SGP site.

Simultaneous measurement of particle optical extinction and scattering (single scattering albedo) using the CAPS PM-SSA monitor

Paola Massoli, Aerodyne Research, Inc.
Timothy Onasch, Aerodyne Research, Inc.
Paul Kebabian, Aerodyne Research, Inc.
Andrew Freedman, Aerodyne Research, Inc.

We present results of studies detailing the efficacy of a compact, robust instrument that determines the single-scattering albedo of ambient particles by simultaneously measuring both total extinction and scattering of a common ambient air parcel; measurement wavelengths of 450, 530, and 630 nm are available. Particle extinction is measured using the cavity attenuated phase shift approach as it is in the CAPS PMex monitor. Particle scattering is determined using an inverse nephelometer facilitated by the incorporation of an integrating sphere within measurement volume. This approach, as compared to using a cosine-corrected detector, results in minimal truncation errors— <10% for particles of diameter 1



Schematic of CAPS PM-SSA monitor.

micron or less and ≤20% for particle diameter of 2.5 microns. Both extinction and scattering can be measured with a time response (10–90%) of ~ 1 second. The short-term noise in both extinction and scattering channels is less than 0.5 Mm-1 with 1-second sampling time. The CAPS PMSSA is designed to operate autonomously, without the need for user intervention or expendables except for occasional calibration of the scattering channel. The scattering channel can be readily calibrated with any available gas that has a larger Rayleigh scattering coefficient than that of air without knowing the actual value.

http://www.aerodyne.com

Update on the performance and evaluation of the Total Precipitation Sensors on the North Slope of Alaska

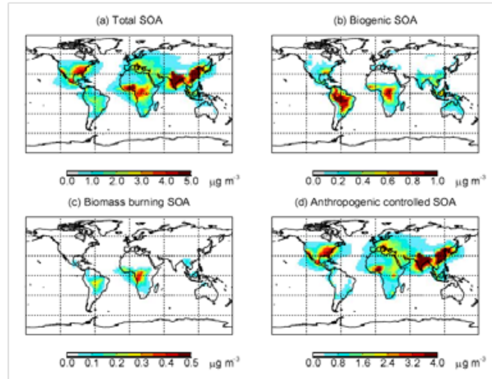
Jessica Cherry, International Arctic Research Center, University of Alaska Fairbanks
Mark Ivey, Sandia National Laboratories

The authors provide an update on the performance of the Total Precipitation Sensor (TPS) installed at the Atmospheric Radiation Measurement (ARM) Climate Research Facility North Slope of Alaska (NSA) sites in Barrow and Atqasuk, as well as University of Alaska-managed sites. The TPS design is intended to avoid the undercatch biases of traditional gauges, but may not detect smaller-sized snow particles. Output from the TPS is compared to that from the collocated NOAA's Climate Reference Network (CRN) sites, snow particle counters, and changes from snow depth sensors. The CRN site has a Geonor gauge with a modified double fence, as per the national network standard. Output from the Vaisala FD12P present weather sensor (PWS) at the ARM NSA site is also considered. Recent results from wind tunnel testing with the manufacturer, Yankee Environmental Systems, have led to changes to the sensor algorithm as described here. Precipitation measurements in Barrow will be important for scanning radar data analyses and calibrations.

10.0 Modeling

Aerosol mass spectrometer constraint on the global secondary organic aerosol budget

Jose-Luis Jimenez, University of Colorado



Surface annual mean concentrations of SOA simulated using the optimised SOA sources: (a) Biogenic, Biomass burning and anthropogenic pollution controlled SOA, (b) biogenic SOA only, (c) biomass SOA only, and (d) anthropogenic pollution controlled SOA only. Colour scale saturates.

The budget of atmospheric secondary organic aerosol (SOA) is very uncertain, with recent estimates suggesting a global source of between 12 and 1820 Tg (SOA) a-1. We used a data set of aerosol mass spectrometer (AMS) observations and a global chemical transport model including aerosol microphysics to produce top-down constraints on the SOA budget. We treated SOA formation from biogenic (monoterpenes and isoprene), lumped anthropogenic, and lumped biomass burning volatile organic compounds (VOCs) and varied the SOA yield from each precursor source to produce the best overall match between model and observations. Organic aerosol observations from the IMPROVE network were used as an independent check of our optimised sources. The optimised model has a global SOA source of 140±90 Tg (SOA) a-1 comprised of 13±8 Tg (SOA) a-1 from biogenic, 100±60 Tg (SOA) a-1 from anthropogenically controlled SOA, 23±15 Tg (SOA) a-1 from conversion of primary organic aerosol (mostly from biomass burning) to SOA, and an additional 3±3 Tg (SOA) a-1 from biomass burning VOCs. Compared with previous estimates, our optimized model has a substantially larger SOA source in the Northern Hemisphere midlatitudes. We used a data set of 14C observations from rural locations to estimate that 10 Tg (SOA) a-1 (10%) of our anthropogenically controlled SOA is of urban/industrial origin, with 90 Tg (SOA) a-1 (90%) most likely due to an anthropogenic pollution enhancement of SOA from biogenic VOCs, almost an order of magnitude beyond what can be explained by current understanding. The urban/industrial SOA source is consistent with the 13 Tg a-1 estimated by de Gouw and Jimenez (2009), which was much larger than estimates from previous studies. The anthropogenically controlled SOA source results in a global mean aerosol direct effect of -0.26±0.15 W m-2 and global mean indirect (cloud albedo) effect of −0.6(−0.14 +0.24) W m-2. The biogenic and biomass SOA sources are not well constrained due to the limited number of OA observations in regions and periods strongly impacted by these sources. To further improve the constraints by this method, additional observations are needed in the tropics and the Southern Hemisphere.

Additional authors: DV Spracklen, KS Carslaw, D Worsnop, MJ Evans, Q Zhang, M Canagaratna, GW Mann, J Allan, H Coe, G McFiggans, A Rap, and P Forster.

University of Leeds, University of Colorado-Boulder, Aerodyne Research, University of California-Davis, and University of Manchester.

Are cloud forecasts improving?

Ewan O'Connor, University of Reading
Robin Hogan, University of Reading

The ARM Climate Research Facility now has nearly a decade of weather forecasts from NCEP, ECMWF, and the UK Met Office archived over its observational sites, a period over which we might expect to see some improvement in the forecasts with respect to the observations. In this poster we analyze the performance of these models over SGP and Darwin in a number of different ways, looking at skill and bias versus height, time of day, season, forecast lead time, and mid-troposphere vertical wind. We also investigate whether there has been a detectable improvement in cloud forecasts over the decade in terms of reduced bias, increased skill, or increased forecast half-life (the lead-time into a forecast it takes until some measure of skill falls to half its initial value). This work is part of the FASTER project.

Climate Modeling Best Estimate data set (CMBE): update and future plans

Renata McCoy, Lawrence Livermore National Laboratory
Shaocheng Xie, Lawrence Livermore National Laboratory
Stephen Klein, Lawrence Livermore National Laboratory
Baike Xi, University of North Dakota
Xiquan Dong, University of North Dakota
Mandana Khaiyer, Science Systems and Applications, Inc.
Patrick Minnis, NASA Langley Research Center
Giri Palanisamy, Oak Ridge National Laboratory
Raymond McCord, Oak Ridge National Laboratory

The Climate Modeling Best Estimate (CMBE) data set was created to serve the needs of climate model developers. The data set is assembled from the highest quality ARM observational and value-added product (VAP) data relevant to climate model evaluation and diagnostics. The temporal resolution is chosen to be comparable with the climate model resolution of one hour. It is a multi-year data set, currently available over the five primary ARM Climate Research Facility sites at the Southern Great Plains (SGP), North Slope of Alaska (NSA), and Tropical Western Pacific (TWP). The CMBE data set consists of hourly averaged cloud fraction (narrow field-of-view and total sky), liquid water path, precipitable water, surface radiation fluxes (cmbe-cldrad) and soundings, surface precipitation, surface turbulent fluxes, surface meteorology fields, top-of-the-atmosphere radiative fluxes, and Numerical Weather Prediction (NWP) model analysis data (cmbe-atm). The recent additions include updating the data sets with the most recent available data, adding satellite data from VISST and CERES data sets for the NSA and all three TWP sites. As a new initiative the CMBE will be also published in the Earth System Grid and used for the evaluation of model runs for the CMIP5 intercomparison and the AR5 report. The future plans include developing the CMBE for the ARM Mobile Facilities (AMF). The data availability, product highlights, and future CMBE product plans are presented.

http://www.arm.gov/data/pi/36

Cloud-land surface interactions and water recycling in the Southern Great Plains: observations and regional simulations

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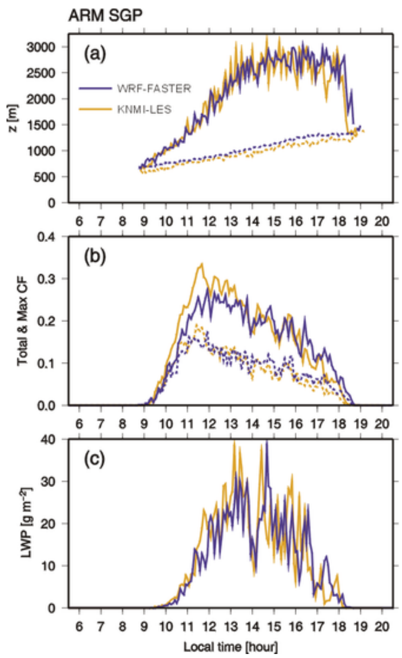
Maoyi Huang, Pacific Northwest National Laboratory
Larry Berg, Pacific Northwest National Laboratory
Peter Lamb, University of Oklahoma
Diane Portis, CIMMS/University of Oklahoma

Locally generated continental cumulus convection, a cloud type showing particular sensitivity to the underlying land surface, is an important component of the atmospheric radiation budget and hydrologic cycle in the Southern Great Plains (SGP), particularly during the summertime growing season. Modeling and observational studies have shown that the configuration of the land surface can significantly impact the formation and structure of the cumulus cloud by determining the partitioning of surface sensible heat (SH) and latent heat (LH) fluxes, which affects the evolution of the convective boundary layer. Clouds, in turn, impact the responses of the land surface by altering the incident radiative fluxes and precipitation. In this study, we conduct two regional simulations over SGP from May to September of 2006 and 2007, a typical dry and a wet summer respectively, based on the WRF regional model coupled with the NOAH land surface model. We first evaluate various components of the modeled water cycle and energy budgets against observations, including SH, LH, shortwave and longwave radiative fluxes, precipitation, evapotranspiration, soil moisture, and atmospheric moisture flux divergences, and calculate the bulk moisture budget and water recycling ratio over SGP for 2006 and 2007. We also examine the relationships between soil moisture, SH/LH partitioning, cloud base height, cloud depth, cloud cover fraction, convective available potential energy (CAPE), based on observations and model results, and discuss how land surface properties affect the formation and structure of cumulus cloud under a typical dry or wet condition. The results could potentially advance our understanding of the physics of cumulus cloud convection and its interaction with land surface over the study region.

Cloud-resolving simulations using the WRF model driven by large-scale forcings

Satoshi Endo, Brookhaven National Laboratory
Yangang Liu, Brookhaven National Laboratory
Wuyin Lin, Brookhaven National Laboratory
Gang Liu, Brookhaven National Laboratory

Cloud-resolving model (CRM) and large-eddy simulation (LES) have been demonstrated to be effective tools in the evaluation and development of parameterizations of various fast processes in climate models. The Weather Research and Forecasting (WRF) model can be used as a LES model. However, the default WRF-LES is not suited for the cloud-resolving simulation with large-scale forcings. Under the Fast-Physics System Testbed and Research (FASTER) project, we extend the capability of WRF-LES to simulate clouds with time-varying large-scale and surface forcings and evaluate simulations by the modified WRF (WRF-FASTER) against observations and other models' results. First, the WRF-FASTER is evaluated by a well-tested continental cumulus case at ARM's Southern Great Plains (SGP) site in GCSS model intercomparison studies. The shallow cumulus clouds produced by WRF-FASTER have very similar properties to another LES model in terms of the diurnal variation (see figure) and vertical profiles of mean state and turbulent moments. Second, the simulations with continuous forcings are tested using the data in the Cloud IOP in March 2000 at ARM SGP. WRF-FASTER roughly follows the time variation of observed cloud pattern but also shows mis- and over-predictions of cloud fraction, which also have been seen in the previous simulations of other CRMs. Further evaluation will be performed using a nocturnal drizzling stratocumulus case based on the second research flight of the DYCOMS-II project.



Time series of cloud properties in the ARM SGP case. (a) Maximum height of cloud top (solid line) and minimum height of cloud base (dash line). (b) Total (solid line) and maximum (dash line) cloud fractions. (c) Liquid water path. Blue and orange lines indicate WRF-FASTER and KNMI-LES, respectively.

Comparison of CFMIP GCM cloud statistics to long-term ARM data

Benjamin Foreback, University of Utah
Gerald Mace, University of Utah
Stephanie Houser, University of Utah

Cloud occurrence and radiative forcing statistics derived from long-term, continuous ground observations from the ARM SGP and TWP Darwin sites are compared to similar statistics derived from general circulation models submitted to CFMIP2 in order to show accuracies and inaccuracies in the representation of clouds. Quantities considered include the annual cycles of cloud cover, volumetric cloud fractional occurrence, solar and IR cloud forcing at the surface and TOA, and solar and IR atmospheric cloud forcing. During a period of twelve years of monthly averages, the models rarely produced accurate descriptions of cloud cover and volumetric cloud fraction. The models often underestimated cloud cover, especially for low- and mid-level clouds, sometimes only producing less than 40% of the cloud cover that is observed at these levels. High clouds were somewhat more accurately modeled, and in some cases, the models produced too much cirrus. However, despite the fact that cloudiness was not well-modeled, the models produced cloud forcing values throughout the year that compared very well to the column calculations and observations. Therefore, it is concluded that the models inaccurately represent the cloud processes and physics in their cloud parameterizations.

Constraining model uncertainties in nested simulations of winter storms in the Southern Great Plains

Esther White, CIMMS/University of Oklahoma
Lance Leslie, Ohio University
Peter Lamb, University of Oklahoma

We have shown that the WRF-ARW model is able to reliably simulate the observed evolution of a number of thermodynamic and physical parameters within Southern Great Plains winter storms. However, our recent analysis of a number of cases has revealed uncertainties in the simulation of cloud and precipitation evolution. This makes evaluation of cloud properties difficult due to large displacement errors, both spatially and temporally. We will examine the role of input and boundary conditions in the evolution of the simulation of three winter storms. Three input and boundary data options are being considered: the NAM-AWIPs, NCEP-FNL, and NARR. We will then examine the effectiveness of WRF four-dimensional data assimilation (FDDA) options, including both grid (analysis) and observational nudging of the upper-level wind fields in constraining simulation error. Model output will be compared to ARM SGP data, along with NCEP Stage IV radar-derived precipitation and satellite observations. The role of input and boundary conditions on the evolution of cloud systems and structure also will be evaluated and compared to recent microphysics sensitivity studies.

Continuous single-column model evaluation at permanent meteorological supersites

Roel Neggers, Royal Netherlands Meteorological Institute
A. Siebesma, Royal Netherlands Delft University of Technology

Uncertainties in numerical predictions of weather and climate are often linked to the representation of unresolved processes that act relatively fast compared to the resolved general circulation. These processes include turbulence, convection, clouds, and radiation. Single-column model (SCM) simulation of idealized cases has become an often-used and relied-upon method to obtain insight at process-level into the behavior of such parameterization schemes; benefits are the enhanced model transparency and computational efficiency. Although having achieved demonstrable success, some shortcomings of this approach have been identified; (1) the statistical significance and relevance of single idealized case studies might be questioned, and (2) the use of observational data sets has typically been relatively limited. The recently initiated project described in this presentation, named the KNMI Parameterization Testbed (KPT), is part of a general move towards more statistically significant process-level evaluation. With the emphasis on the representation of atmospheric boundary-layer processes, KPT has two main goals that are designed to address the shortcomings of single idealized case-studies as mentioned above:

1. To reproduce with the SCM the same statistical level at which a GCM climate is typically evaluated, by means of generating continuous series of SCM simulations that cover long (i.e. multiyear) periods of time

2. To evaluate the complete parameterized system at multiple time-scales against as many independent observational data sets as possible: for example, as available at permanent meteorological sites.

This presentation is dedicated to motivating this strategy and illustrating its potential. Example model evaluation studies are discussed that make use of observational data products from, among others, the ARM SGP site and the Cabauw Meteorological site in the Netherlands. The KPT project takes part in the ongoing European Union Cloud Intercomparison, Process Study and Evaluation (EUCLIPSE) project, as well as the Fast-physics System Testbed and Research (FASTER) project funded by the Department of Energy's Earth System Modeling (ESM) program.

The 213m tower at the Cabauw meteorological site in The Netherlands. More information can be found online at http://www.cesar-observatory.nl.

http://www.knmi.nl/~neggers/KPT

CRM intercomparison based on the TWP-ICE field campaign: part I (simulations versus observations) and part II (vertical transport)

Ann Fridlind, NASA Goddard Institute for Space Studies
Andrew Ackerman, NASA Goddard Institute for Space Studies
Jean-Pierre Chaboureau, University of Toulouse/Centre National de la Recherche Scientifique
Jiwen Fan, Pacific Northwest National Laboratory
Wojciech Grabowski, National Center for Atmospheric Research
Adrian Hill, UK Met Office
Guosheng Liu, Florida State University
Hugh Morrison, National Center for Atmospheric Research
Sunwook Park, Iowa State University
Jon Petch, UK Met Office
Jean-Pierre Pinty, University of Toulouse/Centre National de la Recherche Scientifique
Courtney Schumacher, Texas A&M University
Adam Varble, University of Utah
Xiaoqing Wu, Iowa State University
Shaocheng Xie, Lawrence Livermore National Laboratory
Minghua Zhang, State University of New York at Stony Brook

Results of an intercomparison study for cloud-resolving models (CRMs) based on the TWP-ICE field campaign are summarized in two parts. Six modeling groups submitted simulations with up to three microphysics schemes, based on either 2D or 3D dynamics, and with an optional sensitivity test to investigate the impact of error accumulation over the 16-day simulation duration. In Part I, simulations are compared with domain-wide observations to establish the degree to which diagnostics agree with measurements within experimental uncertainty. In Part II, simulated vertical mass transport and anvil evolution is investigated, including comparison with more limited point and profile measurements. Results indicate that although all models reproduce observed total surface precipitation rate and timing quite accurately, the cloud structures that deliver precipitation differ systematically from observed structures in a manner that can be traced back in part to the treatment of boundary conditions and large-scale forcing. Results also differ across models in a manner that can be traced to treatments of both microphysics and dynamics, as well as radiation. Differences in predicted cloud properties lead to significant spread in predicted radiative fluxes and vertical transport of mass and moisture to the upper troposphere.

CRM simulations of organized convection during TWP-ICE and their implications for cumulus parameterization

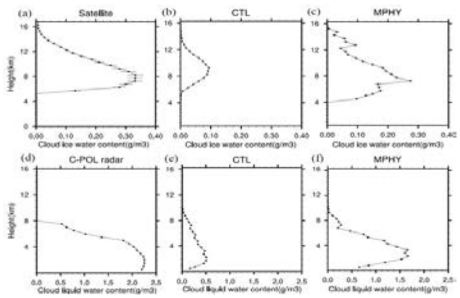
Anthony Del Genio, NASA Goddard Institute for Space Studies
Jingbo Wu, Columbia University
Yonghua Chen, Columbia University

Most GCMs neglect the mesoscale organization of moist convection, which affects the diabatic heating profile, precipitation, the radiation budget, and the tropical general circulation. Cloud-resolving models (CRMs) can potentially provide insights into relationships between convection, stratiform rain and anvil regions, and the environment to guide parameterization development. CRMs are an imperfect standard, however, in part because of inadequacies in ice-phase microphysics. This is important because the primary physics distinction between the convective and stratiform regions is whether the updraft speed generally exceeds the ice crystal fall speed or vice versa. We have conducted simulations of the TWP-ICE active and break monsoon periods with WRF version 3.2 at 600 m horizontal resolution. We use updraft speed, cloud vertical extent, and surface rain rate criteria to partition the cloudy part of the WRF domain into convective, transition rain, stratiform rain, and anvil regions. The transition region adjacent to the convective region includes the air directly detrained from the parent convection, the air that is entrained into convective updrafts, and convective downdrafts and resulting boundary layer cold pools, all relevant to parameterization assumptions about how convection interacts with the "environment." We note the following relevant features of the simulations for parameterization: (1) the strongest updrafts in the transition region are 1 m/s or greater, versus tens of cm/s in the stratiform region, suggesting that a mesoscale updraft parameterization should be initiated with detrainment of cumulus kinetic energy; (2) the relative humidity of lower troposphere transition region air is 10–20% higher than the domain mean when the domain is substantially sub-saturated, thus reducing the efficacy of entrainment; (3) convective area is a good predictor of stratiform rain area several hours later, but the lag is sensitive to the microphysics scheme used; (4) cumulus mass flux is an excellent predictor of stratiform region hydrometeor content 1–2 hours later, the lag also depending on the microphysics; (5) C-POL radar inferences of cluster component areas and hydrometeor type occurrence reveal inadequacies of different microphysics schemes; (6) temperature anomalies in the stratiform region are less than 0.5 K, implying that mesoscale updraft speed might be diagnosed in a GCM from the balance between diabatic heating and adiabatic cooling.

Development and evaluation of convective cloud microphysics parameterization in the NCAR CAM5

Guang Zhang, University of California, San Diego
Xiaoliang Song, Scripps Institution of Oceanography

A two-moment microphysics parameterization scheme for convective clouds is developed to improve the representation of convective clouds and their interactions with stratiform clouds and aerosol in GCMs. The scheme explicitly treats mass mixing ratio and number concentration of four hydrometeor species (cloud water, cloud ice, rain, and snow) and describes several microphysical processes, including autoconversion, self-collection, collection between hydrometeor species, freezing, cloud ice nucleation, droplet activation, and sedimentation. This physically based scheme is suitable for investigating the interaction between convection and aerosol and the indirect aerosol effect on climate. An evaluation of the scheme in the single-column version of NCAR Community Atmospheric Model version 3.5 (CAM3.5) with the Tropical Warm Pool-International Cloud Experiment (TWP-ICE) data shows that the simulation of cloud microphysical properties in convective core is significantly improved, indicating that the new parameterization describes the microphysical processes in convection reasonably well. The contribution from convective detrainment to large-scale cloud ice and liquid water budgets is enhanced greatly. With more realistic convective cloud microphysical properties and their detrainment, the surface stratiform precipitation is increased. The scheme is implemented into CAM5 for further tests. Comparison with CloudSat observations of convective cloud ice water content draws similar conclusions on a global scale to those from single-column model simulation. The global simulation of clouds and hydrological cycle in CAM5 shows increased low- and middle-level cloud fraction and large-scale precipitation in the tropics.



Vertical profiles of cloud IWC (g m-3) in convection core during active monsoon period (19¬–25 January, 2006) of ARM TWP-ICE from (a) satellite, (b) SCM control run (CTL), and (c) SCM experiment including convective microphysics (MPHY), and vertical profiles of cloud LWC (g m-3) from (d) C-POL radar, (e) CTL, and (f) MPHY.

Development and evaluation of the 2-way coupled WRF-CMAQ model

Jonathan Pleim, U.S. Environmental Protection Agency
Rohit Mathur, U.S. Environmental Protection Agency

A new 2-way coupled meteorology and air quality model composed of the Weather Research and Forecasting (WRF) model and the Community Multiscale Air Quality (CMAQ) model is being developed and tested at the U.S. EPA. The new model system runs as a single executable with 2-way data communication between the WRF and CMAQ components via buffer files. This design requires minimal changes to either model, which allows for easy updating and maintenance of compatibility with the "offline" system. The main purposes of the coupled model are: (1) to allow efficient frequent data exchange for high-resolution (down to 1-km grid cell size) simulations, (2) to allow feedback of gases and aerosols from CMAQ to WRF where they can affect radiation and microphysics processes, and (3) to allow for more integrated treatment of chemical and physical processes. The direct effects of aerosols on shortwave radiation and the direct effects of tropospheric ozone on longwave (LW) radiation have been implemented in the CAM and RRTMG radiation schemes. Model simulations of the 2-way WRF-CMAQ have been evaluated for a summer month in the eastern U.S. and an outbreak of wildfires in California in 2008. Comparisons between runs with and without direct feedbacks show significant impacts on solar radiation, 2-m temperature, PBL height, and ozone and PM2.5 concentrations, especially in areas affected by smoke plumes. The WRF-CMAQ also includes an experimental implementation of indirect effects where aerosols from CMAQ are activated as cloud condensation nuclei that determine the droplet number concentration for the cloud microphysics model. The resulting effective droplet radius is used in the radiation model to compute cloud optical properties. We are just starting a DOE-funded project to evaluate the capability of the 2-way WRF-CMAQ model to accurately represent the effects of aerosol loading on radiative forcing over the past 25 years during which there were substantial reductions in aerosol precursor emissions (e.g. SO2, NOx) in North America and Europe. Model evaluation will utilize long-term aerosol, cloud, and radiation measurements collected at the SGP site to evaluate high-resolution model simulations for North America and measurements from the NSA site to evaluate coarser resolution Northern Hemisphere model simulations. In addition, we will use field campaign data from VOCALS and CARES to investigate modeled interactions of aerosols, clouds, and radiation on an event basis.

Development of ensemble neural network convection parameterizations for climate models using ARM data

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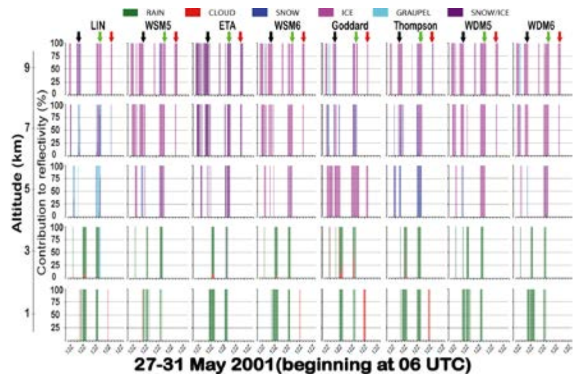
Vladimir Krasnopolsky, NOAA
Philip Rasch, Pacific Northwest National Laboratory
Yefim Kogan, University of Oklahoma/CIMMS
Alexei Belochitski, University of Maryland

The neural network (NN) approach is formulated and used for development of a NN ensemble stochastic convection parameterization for climate models. This fast parameterization is built based on data from Cloud Resolving Model (CRM) simulations initialized with and forced by TOGA-COARE data. The SAM (System for Atmospheric Modeling), developed by D. Randall, M. Khairoutdinov, and their collaborators, has been used for CRM simulations. The observational data are also used for validation of model simulations. CRM-simulated data have been averaged and projected onto the GCM space of atmospheric states to implicitly define a stochastic convection parameterization. This parameterization is emulated using an ensemble of NNs. An ensemble of NNs with different NN parameters has been trained and tested. The inherent uncertainty of the stochastic convection parameterization derived in such a way is estimated. Due to these inherent uncertainties, the NN ensemble is used to constitute a stochastic NN convection parameterization. The major results and challenges of development of the stochastic NN convection parameterizations are discussed. The developed NN convection parameterization has been tested in a diagnostic CAM (CAM-NN) run versus the control CAM run. The obtained results are encouraging: total precipitation (P) and cloudiness (CLD) time series, diurnal cycles, and distributions for the tropical Pacific Ocean for the parallel CAM-NN and CAM runs show similarity and consistency. The P and CLD distributions for the tropical area for the parallel runs have been analyzed first for the TOGA-COARE boreal winter season (November 1992–February 1993) and then for the winter seasons of the follow-up parallel decadal simulations. A NN bias correction procedure was introduced and resulted in a measurable improvement of the CAM-NN simulation. The next steps of the project will include development of the stochastic NN convection parameterizations using SAM-simulated data forced by: (a) the long-term ARM SGP (Southern Great Planes) data set for testing NN convection over land, and (b) CAM-simulated data for testing NN convection over the entire globe. These NN convection stochastic parameterizations will be then validated and analyzed using the parallel CAM-NN and the control CAM simulations. Acknowledgments: The investigators would like to thank Prof. Marat Khairoutdinov (SUNY) for providing SAM and consultations and Dr. Peter Blossey (UWA) for consultations on SAM.

Do we need cloud microphysics parameterization to simulate convection?

Zewdu Segele, CIMMS/University of Oklahoma
Lance Leslie, Ohio University
Peter Lamb, University of Oklahoma

This study evaluates the ability of the Weather Research and Forecasting model to reproduce the observed cloud and convection characteristics in the vicinity of the Southern Great Plains Central Facility (SGP CF). Eight microphysics simulations were conducted for the warm season heavy precipitation case of May 27–31, 2001. For validation, we used cloud observations at the ARM Facility and the National Weather Service's Weather Surveillance Radar-1988 Doppler (WSR-88D) reflectivity data over the SGP. The timing of convection and vertical structure of the microphysical properties of simulated storms were assessed by analyzing the contributions of individual water species to total simulated cloud radar (Ka-band) reflectivity. All microphysics schemes produced ice that accounted for much of the simulated cloud radar reflectivity, but simulated cloud water and rain are much less frequent and less abundant. Importantly, there is a vertical misalignment in the production of frozen water in the upper troposphere and liquid water in the lower troposphere at the time of observed deep convection. This misalignment is the main reason for the inability of the model to reproduce the observed large precipitation rate at the SGP CF. To correct this model deficiency, a simulation was performed without activating any microphysics scheme. From this no-microphysics simulation, the large-scale convection was estimated from the 900–400 hPa layer average of the product of grid-scale ascending velocity and grid-scale water vapor mass deficit. The maximum radar reflectivity (mm6 m-3) was estimated using the WSR-88D radar-precipitation rate empirical formula. An EOF analysis was then performed on the resulting reflectivity field for the entire innermost simulation domain. Inspection of the simulated (no microphysics) and observed (WSR-88D) EOF1 modes shows improvements in the simulation of large-scale convection compared to the results of microphysics-enabled simulations. In particular, the dynamically estimated reflectivity for the no-microphysics simulation reproduced reasonably well the observed large-scale convection in the innermost domain, especially the most dominant first and third convection events that all microphysics-enabled experiments failed to simulate. The correlation between the EOF1 score time series of simulated and WSR-88D composite reflectivity is +0.54, which is a significant improvement compared to the near-zero correlations for the eight microphysics CNTRL simulations.



Contributions (%) of individual hydrometeor species to total simulated cloud radar (Ka-band) reflectivity for eight WRF microphysics CNTRL simulations at five representative altitudes (1, 3, 5, 7, and 9 km) for May 27–31, 2001. For Eta microphysics, snow and ice are not differentiated. WRF single/double-moment five-category scheme (WSM5/WDM5) provides explicit treatment of cloud water, rain water, snow, and ice species. Lin, WSM6, WDM6, Goddard, and Thompson microphysics schemes predict the additional graupel species. Black, green, and red arrows at top indicate the timing of three organized convective storms that passed over the SGP CF.

Establishment of cloud regimes for systematic evaluation of cloud modeling

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Andrew Vogelmann, Brookhaven National Laboratory
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Dan Lubin, Scripps Institution of Oceanography

Distinct cloud regimes can exist locally and globally. Such cloud regimes usually have a close association with meteorological conditions, but not necessarily a one-to-one correspondence. For this reason, the classification of cloud regimes may be based on cloud properties and/or meteorological conditions. This study aims to establish a cloud regime database with robust physical and dynamical consistency for systematic cloud modeling evaluation. A multi-step classification approach has been employed that begins with a top-down approach by classifying cloud measurements at the DOE Atmospheric Radiation Measurement (ARM) Climate Research Facility's Southern Great Plain (SGP) site, using the K-means clustering method and both satellite and ground-based cloud measurements. Three sets of cloud parameters derived from the International Satellite Cloud Climatology Project (ISCCP) D1 product are evaluated for the classification; the set based on equivalent classical cloud morphology is adopted, which gives the best physical and dynamical consistency. The classification is then extended into nighttime, using the matching ARSCL profiles to provide a continuous classification, which enables the derivation of additional cloud regime properties to depict the cloud life cycle and the transition between cloud regimes. It is also found that cloud regimes under stormy environments may have drastically different dynamical conditions. This poses another challenge for cloud modeling, and the multi-step classification approach is particularly helpful in isolating such distinct regimes based on their dynamical properties. A suite of single-column model simulations of the cloud regimes is further analyzed to systematically quantify the models' skills in representing different cloud regimes.

Evaluating ECMWF global model cloud and precipitation fields with observed radar reflectivity: How do we ensure a fair comparison?

Richard Forbes, European Centre for Medium-Range Weather Forecasts
Maike Ahlgrimm, European Centre for Medium-Range Weather Forecasts

Remote sensing data from ground-based and space-borne radar and lidar provide a wealth of information on cloud and precipitation that can be used to evaluate atmospheric models. One common approach to take account of the different quantities and spatial and temporal scales between model and observations is to use a forward operator to derive the observed quantity using information from the model. However, it is vital to understand the limitations and uncertainties of the comparison in order to separate real deficiencies in the model from artefacts of the forward model. Here we use the ECMWF global Numerical Weather Prediction model and radar reflectivity data from the CloudSat and ARM radars to assess the sensitivity of uncertainties in the radar reflectivity forward model. We highlight issues relating to microphysical assumptions, representation of hydrometeors in discrete categories, and sub-grid scale heterogeneity that need to be taken into account when evaluating model cloud and precipitation fields with radar reflectivity observations.

Evaluation of CAM4 in weather-forecast mode with ARM site data

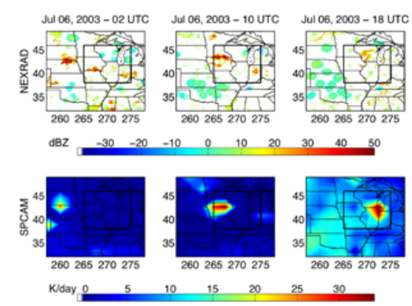
Jim Boyle, Lawrence Livermore National Laboratory
Stephen Klein, Lawrence Livermore National Laboratory

As part of the Cloud-Associated Parameterizations Testbed, weather hindcasts with the new Community Atmosphere Model Version 4 are performed for every day in the period between May 2008 and April 2010. Analysis will focus on comparison of model simulations to ARM observations of radiation, clouds, rainfall, and precipitable water and satellite observations of the International Satellite Cloud Climatology Project. The drift of the model from the initial to climate states will be investigated as well as the ability of the hindcasts to reveal information relevant to understanding the model's biases in simulating the climate at the locations of the ARM sites. To the extent possible, attention will focus on all seasons and all sites to provide a broad view of the strengths and limitations of the model in simulating moist processes.

Forecast simulations in a multi-scale modeling framework: maximizing the use of high-value observations

Gabe Kooperman, Scripps Institution of Oceanography
Michael Pritchard, Scripps Institution of Oceanography
Richard Somerville, Scripps Institution of Oceanography

The conventional approaches to evaluating global climate models (GCMs) against heavily averaged and sub-sampled observations cannot fully take advantage of high-value intermittent measurements taken during well-instrumented field campaigns or at fixed sites, such as the ARM SGP site. Such composite analysis makes untangling the causes of model deficiencies and assessing simulated variability, timing, and intensity of individual processes very difficult. An alternative approach, following the Cloud-Associated Parameterizations Testbed (CAPT) methodology, offers an improved perspective. The approach applies evaluation techniques previously limited to weather prediction models by using GCMs to simulate short weather periods initialized with observed atmospheric states—forecasts simulations. The CAPT approach is applied here to a super-parameterized GCM, also known as a multi-scale modeling framework (MMF), in which two-dimensional cloud-resolving models (CRMs) are embedded in each grid cell of a GCM to explicitly represent sub-grid convection and replace conventional cloud and boundary layer parameterizations. Over the Central U.S., the MMF in free-running mode yields an improved representation of nocturnal summer organized convection, but the mechanisms that allow this are poorly understood. CAPT forecasts offer a better vantage point to understand advantages of the multi-scale modeling approach at the process level, at the ARM SGP site, to inform future conventional parameterization development. However, running an MMF in forecast mode introduces a new challenge not previously faced by the CAPT community—initializing a high-resolution internal CRM. This poster presents a method to overcome this challenge by spinning the model up in an observationally constrained mode through nudging to generate forecasts' initial conditions at both the GCM and CRM scales.



NEXRAD radar reflectivity on July 6, 2003, for UTC times 2, 10, and 18 are shown in the top three panels. A model storm proxy for SPCAM, the vertical standard deviation of atmospheric heating tendency in the lower troposphere, is shown in the bottom three panels for forecast day 1.

How much does the shallow cumulus regime contribute to the ECMWF model's shortwave radiation bias at ARM SGP?

Maike Ahlgrimm, European Centre for Medium-Range Weather Forecasts
Richard Forbes, European Centre for Medium-Range Weather Forecasts

Routine global evaluation using CERES observations suggests that the ECMWF model lacks shortwave cloud forcing over land. This appears to be consistent with an annual mean surface shortwave bias at the ARM SGP site over the period spanned by the CMBE record. Previous studies have suggested that lack of shallow cumulus cloud cover might contribute significantly to this bias, but results were based on relatively short time periods in the face of highly variable shallow cumulus cover from year to year. Also, the ECMWF data available from the ARM Archive is from the model cycle operational at the time of forecast, such that model cycles over a decade old are compared with more recent versions over the long record of observations at SGP. This study aims to systematically assess the impact of days dominated by shallow cumulus clouds on the surface shortwave radiation from the full available CMBE record. We use 146 days with non-precipitating shallow cumulus clouds between 1997 and 2009 to compare modeled and observed cloud amount and radiative impact. The current operational forecast model (CY36R4) is re-run for these days to ensure that the results apply to the model's latest cloud and radiation schemes. The diurnal composite shortwave cloud forcing is reproduced quite well by the model. A small bias remains, but its contribution to the annual mean bias is small. A closer look at individual days of the time series reveals that the model fails to produce shallow clouds in about 13% of cases, but compensates for this deficiency by a stronger reduction of downwelling shortwave radiation on cloudy days.

Impact of mesoscale organizations and precipitation on boundary-layer clouds

Ping Zhu, Florida International University
Bruce Albrecht, University of Miami
Zhenduo Zhu, Florida International University

ARM observations and the observations collected from other field campaigns often show that the evolution of boundary-layer clouds is not only controlled by the boundary layer-processes but also strongly affected by cloud mesoscale organizations and precipitation processes. Although cloud mesoscale organizations and rainfall can be readily detected by the advanced remote sensing instruments, the impact of mesoscale organizations and precipitation on cloud fields and the vertical transport induced by the boundary-layer clouds cannot be quantified solely from observations since some of the variables needed for such quantifications cannot be measured directly by the existing instrumentation. In this study, we reproduced cloud mesoscale organizations and simulated precipitation using multiple-scale WRF simulations. To quantify (or separate) the effects of mesoscale organizations from a rich range of scales involved with boundary-layer clouds, a novel approach, 2D wavelet transform (WT), was used to decompose the simulated cumulus fields and determine the individual effects from the processes with different scales. The analyses show that the cloud mesoscale organizations can substantially affect the vertical fluxes and energy associated with boundary-layer clouds. The significant impact of cloud mesoscale organizations suggests that the effects of mesoscale organizations need to be considered in boundary-layer cloud parameterizations. Our sensitivity tests on precipitation also show that precipitation can modulate cloud vertical turbulent structure and cloud mesoscale organizations.

Impacts of aerosols on cloud system-resolving model simulations of tropical deep convection during TWP-ICE

Hugh Morrison, National Center for Atmospheric Research
Wojciech Grabowski, National Center for Atmospheric Research
Steven Massie, National Center for Atmospheric Research

This presentation will summarize results from several-hundred-member ensemble simulations of aerosol indirect effects on tropical deep convection and associated outflow cirrus clouds. A two-dimensional cloud system-resolving model with a sophisticated two-moment liquid and ice microphysics scheme is used. Simulations are performed with aerosol loadings representing either pristine or polluted conditions and applying forcing data from a 16-day period of monsoon conditions during the 2006 Tropical Warm Pool-International Cloud Experiment (TWP-ICE). Aerosols are shown to have little impact on the atmospheric storage of water and static energy tropospheric as well as tropospheric destabilization, and therefore, surface precipitation is practically insensitive to aerosols given the prescribed large-scale forcing and SST. The spread of the TOA radiative fluxes among different ensemble members for the same aerosol loading is surprisingly large, exceeding 30 W/m2 even when averaged over the entire 16-day period. The ensemble approach demonstrates that there is a statistically significant small weakening of convection in the polluted simulations compared to pristine, in contrast to the hypothesis of convective invigoration as a result of aerosol loading. Despite this weakening, the cloud-top heights and ice water paths are higher in polluted conditions because of smaller ice particle sizes and thus smaller fall velocities. Such a conclusion offers a different interpretation of recent satellite observations of tropical deep convection in pristine and polluted environments. A more extensive analysis of satellite data (CALIPSO, CLOUDSAT, and MODIS) shows that aerosol impacts are significantly smaller than suggested by previous studies.

Improving boundary-layer turbulence and cloud processes in CAM with a higher-order turbulence closure scheme and ARM measurements

Kuan-Man Xu, NASA Langley Research Center
Anning Cheng, NASA Langley Research Center

A major difficulty in addressing cloud feedback and climate sensitivity stems from the inadequate representation of cloud physical processes in general circulation models (GCMs) with traditional cloud parameterizations. An alternative approach is to use a cloud-resolving model (CRM) to replace cloud parameterizations in every GCM grid box, i.e., the multiscale modeling framework (MMF), and implement a sophisticated higher-order turbulence closure (HOC) scheme in its CRM component to better represent turbulence and low clouds. This approach is shown to produce realistic global distribution of low clouds, but the computational cost increases by nearly a factor of two compared to that of the original MMF (with a first-order turbulence closure in its CRM component) and a factor of 400 compared to that of the CAM at T42 resolution. The improved low-cloud simulation motivates us to directly implement the HOC scheme in a GCM. The goal of this investigation is to deliver a physically based HOC parameterization package for the global modeling community through its implementation in CAM and other models, which requires simplifications and development of an optical approach from the HOC used in CRM that likely take years to complete. In this investigation, we propose to undertake three tasks that enable improvement of CAM5 and make it useful for the global modeling community for further refining other parts of model parameterizations such as a tight coupling between subgrid cloud distributions and radiative transfer. These tasks are

- simplifying the HOC turbulence/low-cloud parameterization to a diagnostic package as one of the options and developing an optimal approach, which will combine the implicit time differencing for the equations with time derivative terms with the diagnostic approach in the remaining equations. This will be done in a step-by-step fashion through extensive testing
- testing the simplified scheme(s) in a single-column model, a 2D CRM using the prototype boundary-layer cloud cases and ARM intensive operational period data, and in an MMF and CAPT for global simulations
- performing long-term climate simulations with the modified CAM and CAM5, comparing with the available global data sets and the Climate Modeling Best Estimate data at selected ARM sites, and evaluating the low-cloud feedback.

In this poster, some preliminary results to illustrate the approach adopted in the first two steps will be given, and future research will be discussed.

Improving numerics of bulk microphysics schemes in WRF model: time integration scheme impact on warm rain processes and precipitation

Igor Sednev, Lawrence Berkeley National Laboratory
Surabi Menon, Lawrence Berkeley National Laboratory

Bulk microphysics (BLK) schemes that use Eulerian forward-in-time integration are conditionally stable and not positively definite. Implemented in the Weather Research and Forecasting (WRF) model, these schemes might show better performance for finer spatial resolutions when time steps that are used to advance microphysical prognostic equations have an order of magnitude from seconds to tenths of seconds. For coarser spatial resolutions, time steps are usually increased from hundredths up to thousands of seconds, but it might lead to the degradation of WRF BLK schemes' performance because of corrections such as "mass adjustment" (for single-moment schemes) and additional "concentration adjustment" (for double-moment schemes). Based on analytic stability and positive definiteness criteria, we analyze the impact of Eulerian forward-in-time (EFTI), adaptive substepping (ADSS), semi-implicit (SITI), and fully implicit (FITI) time integration techniques on warm rain processes in different BLK schemes implemented in the WRF model. We also analyze spatial and temporal distribution of accumulated precipitation and time series of maximal surface precipitation rates obtained in idealized large-scale WRF simulations. Differences between the control run (Morrison-Curry-Khvorostyanov BLK scheme with EFTI) and runs with ADSS, SITI, and FITI will be presented and discussed.

Intercomparison of cloud model simulations of Arctic mixed-phase boundary layer clouds observed during SHEBA

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Paquita Zuidema, Rosenstiel School of Marine and Atmospheric Science, University of Miami
Andrew Ackerman, NASA Goddard Institute for Space Studies
Alexander Avramov, Columbia University
Gijs de Boer, Lawrence Berkeley National Laboratory
Jiwen Fan, Pacific Northwest National Laboratory
Ann Fridlind, NASA Goddard Institute for Space Studies
Tempei Hashino, University of Tokyo
Jerry Harrington, The Pennsylvania State University
Yali Luo, Chinese Academy of Meteorological Sciences
Mikhail Ovchinnikov, Pacific Northwest National Laboratory
Ben Shipway, UK Met Office

A long-lived precipitating mixed-phase boundary layer cloud observed during the Surface Heat Budget of the Arctic Ocean (SHEBA) experiment is used as a case study for intercomparison of six cloud and large-eddy simulation models. In general, there are large differences among the models in terms of cloud phase, condensed water path, surface radiative fluxes, and other quantities. Overall, the simulations tend to group into two quasi-steady states within the first few hours of integration: (1) long-lived mixed-phase cloud, or (2) all-ice cloud after rapid glaciation of the mixed-phase cloud. Due to close coupling between the microphysics, radiation, and cloud dynamics, these two states have distinctly different characteristics. In particular, simulations with mixed-phase clouds tend to have greater rates of cloud-top radiative cooling, a more well-mixed boundary layer, greater kinetic energy, and larger water vapor flux convergence in the cloud layer, relative to the simulations with all-ice clouds. These results suggest that the simulated mixed-phase clouds are in part self-maintaining. All models exhibit significant sensitivity to the specified ice crystal concentration. In most models, an increase in crystal concentration results in rapid glaciation and transition from the mixed-phase to all-ice state. Various processes are analyzed and compared among the simulations to elucidate specific causes of the differences.

An inventory of gaseous and primary carbonaceous aerosol emissions from India for the Ganges Valley Aerosol Experiment (GVAX)

Zifeng Lu, Argonne National Laboratory
David Streets, Argonne National Laboratory
V. Rao Kotamarthi, Argonne National Laboratory

India is one of the most rapidly developing countries in the world. In the past decade, high aerosol concentrations and aerosol optical depth (AOD) values have been observed by both ground- and satellite-based measurements over this region, and increasing emissions in India have been reported to modify the regional climate through the direct and indirect radiative effects of aerosols. In this study, a new inventory of gaseous (SO2, NOx, and NMVOC) and primary carbonaceous aerosol (black and organic carbon, BC, and OC) emissions from India in 2010 is developed to support the Ganges Valley Aerosol Experiment (GVAX). A reliable emission inventory for the region is necessary to support atmospheric chemistry modeling, data analysis, and flight planning. In this inventory, the emission sources are categorized into five major sectors: power generation, industry, residential, transport, and open biomass burning. For SO2, BC, and OC, a detailed technology-based methodology is used to estimate emissions. Activity data are

from the International Energy Agency (IEA) and various Indian national statistics. Emissions are first estimated for 2008 (the latest year for which actual activity data are available) and extrapolated to 2010 based on fast-track statistics. Emissions are then gridded at a resolution of 0.5° × 0.5° using up-to-date surrogate distributions, including the exact locations of all power generation units with capacity larger than 20 MW, urban and rural population, industrial GDP, road networks, crop land cover, etc. For NOx and NMVOC, sectoral gridded emissions from EDGAR4.1 in 2005 are used as a baseline and then extrapolated to 2010 according to appropriate scale factors such as the growth rates of energy consumption and GDP. EDGAR emissions will also be used for surrounding parts of the South Asian region. Our preliminary estimates of SO2, BC, and OC emissions for India are 8.83 Tg, 1.05 Tg, and 2.88 Tg, respectively, in 2010. Coal-fired power plants and traditional cookstoves are the main sources of SO2 and carbonaceous aerosols, respectively. Monte Carlo simulations are used to quantify the emission uncertainties, and the 95% confidence intervals are -16% to 18%, -40% to 77%, and -41% to 82% for SO2, BC, and OC, respectively. The major contributors to emissions uncertainty in India are coal sulfur content for SO2 (60%) and fuelwood emission factors of traditional cookstoves for BC (55%) and OC (61%).

Investigation of diurnal cycle simulation at SGP in the GFDL single-column model and AM3

Patrick Taylor, NASA Langley Research Center
Yanluan Lin, Geophysical Fluid Dynamics Laboratory

The diurnal cycle is a principal mode of climate system variability spanning processes important for the determination of climate state, including convective and radiative processes. Representation of the diurnal cycle time scale in climate models is a long-standing weakness of climate simulation, especially over land. The cause for poor diurnal cycle representation is uncertain but is likely related to convective, surface turbulent flux, and boundary-layer parameterizations and possible biased correlations between these parameterizations and large-scale meteorology. The inclusion of a more inhibitive convective trigger is a popular speculated solution. This work investigates the GFDL Single-Column Model (SCM) diurnal cycle simulation fidelity using cloud, precipitation, thermodynamic profile, and surface radiative flux observations at the ARM SGP site in combination with NASA CERES Terra top-of-atmosphere (TOA) flux observations. ARM SGP 4D variational analysis was used to force three years of GFDL SCM simulation, corresponding to 1999 through 2001. In this work, mean diurnal cycle biases exhibited by the model are investigated in all seasons and grouped by large-scale forcing. Particular attention is paid to the SGP summer season where convection is most common and the diurnal cycle is most prominent. At SGP, summer season convection generally takes two forms that exhibit different diurnal cycles: (1) locally triggered convection and (2) convective systems propagating from the Rocky Mountains. The second convective regime will not be present in the SCM simulations. To investigate the second regime statistically, a full 20-year GFDL AM3 simulation is used.

MJO prediction in GCMs: Is an accurate heating distribution critical?

Cara-Lyn Lappen, Texas A&M University
Courtney Schumacher, Texas A&M University

What if an accurate distribution of heating in the tropics was all that was needed in order to simulate a realistic Madden-Julian Oscillation (MJO) in large-scale models? If we could simplify the problem to this extreme, we could focus our efforts on improving the simulation of diabatic heating in large-scale models.

This study assesses whether or not taking an approach like this is a viable way to proceed. In this study, heating distributions are added to the atmospheric component of CCSM4.0 (CAM4) using a newly developed technique. The heating distributions added range from idealized blobs representing top-heavy, bottom-heavy, and middle-heavy heating to realistic distributions of heating derived from observations. All vertical heating profiles input to CCSM4 are Gaussian in the horizontal. The heating input is shifted among latitude and longitude points in a manner that is consistent with the eight phases of the MJO. The CCSM4 is then run for 15 years, and the resulting MJO that is produced by all distributions is compared to that of a control run done with no additional heating. While the runs done with an idealized heating distribution simulate a more realistic MJO than that of the control run, these runs are missing some key features of the MJO. Many of these missing features are captured by the run done with observed heating, suggesting that realistic variations in the height of maximum heating are necessary to simulate the MJO.

New data support activities for the FAst-physics System TEstbed and Research (FASTER) Project

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Michael Jensen, Brookhaven National Laboratory
Andrew Vogelmann, Brookhaven National Laboratory
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Yangang Liu, Brookhaven National Laboratory
Wuyin Lin, Brookhaven National Laboratory

The multi-institution FAst-physics System TEstbed and Research (FASTER) project, funded by the U.S. DOE Earth System Modeling program, aims to evaluate and improve the parameterizations of fast processes (those involving clouds, precipitation, and aerosols) in global climate models, using a combination of numerical weather prediction models, single-column models, cloud-resolving models, large-eddy simulations, full global climate model output and ARM active and passive remote sensing, and in situ data. The FASTER data integration team provides tailored data sets, statistics, best estimates, and quality control data, as needed and defined by FASTER participants. This poster highlights the latest activities by the data integration team including cloud, atmospheric state, and aerosol properties for customized grids and averaging intervals; extended time series of integrated thermodynamic quantities (CAPE, CIN, mixing layer height, etc.); and partitioning of stratiform and convective precipitation using high-time-resolution and pixel-level data from continuous ARM observations and complementary data sets. A particular emphasis has been placed on IOPs at the ARM SGP site including the Spring 2000 Cloud IOP, the Spring 2003 Aerosol IOP, and RACORO (2009). In addition to the FASTER team, these data sets will be made available to the ASR Science Team.

Numerical model simulations of the AMMA and TWP-ICE mesoscale convective systems

Wei-Kuo Tao, NASA Goddard Space Flight Center
Scott Powell, University of Washington
Paul Ciesielski, Colorado State University
Xiping Zeng, NASA Goddard Space Flight Center
Robert Houze, University of Washington
Jian Yuan, University of Washington
Richard Johnson, Colorado State University

Field observations and high-resolution cloud-resolving model (CRM) simulations are used to simulate the mesoscale convective systems (MCSs) that developed in AMMA (African Monsoon Multidisciplinary Analysis) and TWP-ICE (the Tropical Warm Pool-International Cloud Experiment). The model results in terms of rainfall, cloud properties, radiation, and water budget will be compared to observations and to each other. In addition, the MCSs are classified into convective, stratiform, and anvil regions, with each region further divided into three vertical layers: from the surface to the freezing layer, from the freezing layer to -35 C, and from -35 C layer to the top of the cloud. These model budget calculations can provide a better understanding of the formation/evolution of stratiform and anvil clouds and the role of convective transport processes on anvil development in two different environments (i.e., continental and monsoon).

Orogenic propagating precipitation systems over the central U.S. in a global climate model with embedded explicit convection

Michael Pritchard, Scripps Institution of Oceanography
Richard Somerville, Scripps Institution of Oceanography
Mitchell Moncrieff, National Center for Atmospheric Research

In the lee of major mountain chains worldwide, diurnal physics of organized propagating convection project onto seasonal and climate time scales of the hydrologic cycle; but this phenomenon is not represented in conventional global climate models (GCMs). Analysis of an experimental version of the Super-Parameterized- (SP-) Community Atmosphere Model (CAM) demonstrates that propagating orogenic nocturnal convection in the central U.S. warm season is however representable in GCMs that use the embedded cloud-resolving model (CRM) approach (Multiscale Modeling Frameworks [MMFs]). SP-CAM admits propagating organized convective systems in the lee of the Rockies during synoptic conditions similar to those that generate Mesoscale Convective Systems (MCSs) in nature. The simulated MCSs exhibit spatial scales, phase speeds, and propagation speeds comparable to observations, and the genesis mechanism in the model agrees qualitatively with established conceptual models. Convective heating and condensate structures are examined on both resolved scales in SP-CAM, and coherently propagating cloud “meta-structures” are shown to transcend individual CRM arrays. In reconciling how this new mode of diurnal convective variability is admitted in SP-CAM despite the severe idealizations in the CRM configuration, an updated discussion is presented of what physics may transcend the re-engineered scale interface in MMFs. We suggest that the improved diurnal propagation physics in SP-CAM are mediated by large-scale first-baroclinic gravity wave interactions with a prognostic organization life cycle, emphasizing the physical importance of preserving “memory” at the inner resolved scale.

The performance of CAM5 physics modules at high spatial resolution

Philip Rasch, Pacific Northwest National Laboratory
Jerome Fast, Pacific Northwest National Laboratory
William Gustafson, Pacific Northwest National Laboratory
Balwinder Singh, Pacific Northwest National Laboratory
Dick Easter, Pacific Northwest National Laboratory
Gabi Pfister, National Center for Atmospheric Research
Stacy Walters, National Center for Atmospheric Research
Jean-Francois Lamarque, National Center for Atmospheric Research

Rapid development and evaluation of the next generation physics suite for global climate models requires the ability to easily isolate processes and test parameterizations across a range of scales. Current computing capabilities do not allow one to run a global model at resolutions anticipated in ten years. In addition, the performance of the current physics suite when simulating regional-scale atmospheric variability has not been characterized. In parallel with the development of the new computational architectures for climate models, we have adopted a methodology of running and evaluating the performance of global climate model physics parameterizations at a range of spatial scales. As part of a Laboratory Directed Research and Development (LDRD) project under PNNL's Aerosol Climate Initiative, the physics suite from the Advanced Physics Community Atmosphere Model v.5 (CAM5) is currently being ported to the regional Weather Research and Forecasting (WRF) model. This includes the Zhang and McFarlane scheme for deep convection, the Park and Bretherton scheme for shallow convection, the Morrison and Gettleman scheme for microphysics, the Bretherton and Park scheme for the planetary boundary layer, the Modal Aerosol Model (MAM) representation of aerosols, and a reduced MOZART gas-phase chemistry mechanism. The RRTMG radiation scheme employed by CAM5 is already available in WRF version 3.2, and other groups have coupled the CLM land-use scheme to WRF. While the full MOZART mechanism is available in WRF version 3.2, we are porting a reduced version that is typically employed by CAM5. By porting the CAM5 physics suite to WRF, we will be able to evaluate those parameterizations at multiple spatial scales. The modular nature of WRF will also enable individual CAM5 physics parameterizations to be directly compared to other parameterizations used for research applications in regional models. In this study, we will show the performance and behavior of some of the CAM5 physics parameterizations compared to field campaign data as well as with other parameterizations. When evaluating simulated aerosols, we have employed the strategy of the Aerosol Modeling Testbed, in which the initial and boundary conditions, emissions, meteorology, trace gas chemistry, and emissions for the MAM aerosol module are the same for other aerosol models. In this way, an objective and systematic assessment of the performance of simulating aerosol properties in relation to computational expense can be obtained. A similar approach is also used when evaluating clouds and other meteorological processes.

Quantification of parameterization behavior across scales

William Gustafson, Pacific Northwest National Laboratory

The current methodology used to downscale climate simulations is to nest a high-resolution regional model into a coarse global climate model domain. This nesting approach works because parameterizations can be chosen and configured independently for each grid such that the setup is appropriate for the grid spacing used at each scale. This mixed physics-parameterization choice leads to the application of differing assumptions at different scales, which prevents the use of the same parameterization suite for both grids. Complicating matters, many next-generation climate models currently being developed will most likely not use this nesting approach. Instead, they will use a single global domain that has variable resolution. Higher resolution will be used where needed, either for improving model accuracy or where regional details are deemed more valuable, and lower resolution will be used elsewhere. This multi-resolution grid methodology imposes new requirements on model physics parameterizations. The parameterizations will need to be scale-aware and able to adapt to the range of grid spacing used throughout the domain. To prepare for these next-generation models, a methodology is proposed to test the scale adaptability of physics parameterizations. A testbed is being developed that uses separate grids within an atmospheric model for dynamical processes (e.g., transport) versus physics processes (e.g., clouds and radiation). The methodology for this approach will be described, showing its benefits for designing an appropriate parameterization suite for the next-generation multi-resolution climate models.

The relationship of large and small scales in a convecting atmosphere

Christian Jakob, Monash University
Laura Davies, Monash University
Peter May, Bureau of Meteorology

The core task of convection parametrizations in climate and weather prediction models is to faithfully describe the behaviour of the unresolved convective scales and their effects as a function of a “known” large-scale state. In models, this large-scale state is represented by the grid-average variables that are resolved in the model equations, and typical small-scale variables produced are the diabatic heating and moistening terms as well as associated rainfall fields. All parametrizations hinge on the assumption that there exist discernible relationships between small and large scales to begin with. Furthermore, current parametrizations assume that the signal in the relationship is much stronger than the noise, and that therefore parametrizations can be designed in a deterministic fashion, i.e., one large-scale state corresponds to exactly one small-scale state. The purpose of this study to use ARM data sets to explore the large-scale small-scale relationships from observations and to determine whether key assumptions in current parametrization schemes actually hold. A long-term large-scale data set is constructed for the Darwin region by applying the continuous variational analysis approach previously used for the SGP site to Darwin. Small-scale variables are derived using data from a scanning polarimetric research weather radar (C-POL) at Darwin. The two data sets are related to each other using basic statistical tools. It is shown that there is a strong relationship between area-averaged rainfall and measures of moisture convergence. It is further shown that this relationship is largely one between rain area and convergence. Relationships with stability measures, such as CAPE, are shown to be significantly weaker. All relationships identified exhibit significant noise around their signal, questioning the current deterministic approach to convection parametrization. However, they also show that the signal-to-noise ratio is not constant and is a function of the large-scale state itself, with stronger forcing implying larger signal-to-noise ratios. This indicates that current stochastic approaches to convection parametrization might also require adjustment to take the variation in signal-to-noise into account.

Sensitivity of idealized squall line simulations to the level of complexity used in two two-moment bulk microphysics schemes

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Andrew Vogelmann, Brookhaven National Laboratory
Hugh Morrison, National Center for Atmospheric Research
Jason Milbrandt, Meteorological Research Division, Environment Canada

Regional-scale weather forecasting models now operate using multi-moment bulk microphysics, predicting two or three moments of various liquid and ice hydrometeor distributions. Such complexity is difficult to duplicate in global climate models, mainly due to the large computational burden. Hence, an important question to address is: what level of complexity is required to simulate the essential processes relevant to climate studies, given their increasing interest in convective scales? To tackle this question, we investigate the sensitivity of idealized squall line simulations to the level of complexity used in the microphysics schemes. Factors examined include the number of predicted moments, the number and nature of predicted ice categories, and the formulations of the conversion processes. These investigations are conducted within the framework of two commonly used two-moment microphysics schemes (Morrison et al. 2005; Milbrandt and Yau 2006) and serve to also help understand which aspects are most responsible for variability between both schemes. Cold-pool development was mainly influenced by the number of predicted moments of the graupel category in both schemes; subsequent to its melting, it dramatically changed the rain size distribution and hence evaporation characteristics. Surface precipitation seemed to be controlled to a large extent by how much water entered the snow (and to a lesser extend the graupel) category. The more water stored in these slowly sedimenting categories, the more delayed the precipitation fallout and the smaller the peak precipitation. This aspect was mainly controlled by the formulation of the snow-growth terms and also explained most of the variability between both microphysics schemes (given an identical setup in terms of size distribution assumptions). However, total precipitation accumulations after four hours of simulation seemed to be rather unaffected by any of the experiments. The distribution of water among the ice categories tends to be very sensitive to the precise conversion or size distribution formulations. This research in general advocates the use of newer approaches of representing microphysics that predict the rimed fraction of a single precipitating ice category (e.g., Morrison et al. 2008, Colle et al. 2010), which avoids the artificially abrupt separation between either totally rimed (quickly sedimenting) or unrimed (gently sedimenting) categories.

Simulating aerosols entrained into fair weather cumulus during CHAPS

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Manishkumar Shrivastava, Pacific Northwest National Laboratory
Elaine Chapman, Pacific Northwest National Laboratory
Richard Ferrare, NASA Langley Research Center
Chris Hostetler, NASA Langley Research Center
Larry Berg, Pacific Northwest National Laboratory

The Cumulus Humilis Aerosol Processing Study (CHAPS) was conducted during June 2007 and was designed to investigate cloud-aerosol interactions in the vicinity of Oklahoma City, Oklahoma. The primary instrument platform was the U.S. Department of Energy's Gulfstream-1 (G-1) aircraft, which was configured to make in situ measurements of the chemical and optical properties of aerosols, cloud microphysics, trace gas concentrations, and meteorological variables. The High-Spectral Resolution Lidar

(HSRL) was deployed on the NASA King Air B-200 to obtain coincident profiles of aerosol optical properties along the G-1 flight paths. Previous analyses of CHAPS data have indicated that optical and CCN properties associated with anthropogenic emissions entrained into shallow cumulus were different than those sampled outside of the Oklahoma City plume. In this study, we investigate whether simulated cloud-aerosol interactions associated with emissions from a mid-sized city can be adequately represented by state-of-the-science treatments of aerosol processes in the WRF-Chem model. An outer domain that encompasses most of the central United States with a grid spacing of 10 km and an inner domain that encompasses the G-1 flights in the vicinity of Oklahoma City with a grid spacing of 2 km are employed. Simulated aerosol mass, composition, and size are compared with G-1 aircraft data. The volatility basis set approach of representing secondary organic aerosols has been incorporated into WRF-Chem and will be evaluated using the Aerosol Mass Spectrometer measurements on the G-1 aircraft. Simulated vertical profiles of extinction that are affected by uptake of water on aerosols in the vicinity of clouds will be compared with observed profiles obtained from the HSRL. Similar to the previous studies on the CHAPS measurements, analyses of the simulated quantities are conducted for aerosols below cloud, within cloud, and above clouds. Sensitivity simulations are performed with and without cloud-aerosol interactions to determine the impact of simulated aerosols on clouds, cloud-processing on aerosols, and radiative effects over the entire region, and whether those changes are consistent with the aircraft measurements.

Towards a particle-resolved aerosol representation for the simulation of the aerosol impact on regional scales

Matthew West, University of Illinois
Nicole Riemer, University of Illinois at Urbana-Champaign

Individual aerosol particles are a complex mixture of a wide variety of species, such as soluble inorganic salts and acids, insoluble crustal materials, trace metals, and carbonaceous materials, so modeling them accurately requires a high-dimensional representation. The capabilities of traditional models to treat this high dimensionality are currently very limited, and this introduces serious shortcomings in our understanding of the impact of aerosol particles on climate. To improve this, we have recently introduced the particle-resolved model PartMC-MOSAIC (Riemer et al. 2009), a new approach to examining the evolution of aerosol properties without making a priori assumptions about the evolution of particle composition. While particle-resolved aerosol simulations offer unprecedented resolution of the aerosol mixing state, they are significantly more expensive than conventional models. In this project we explore a number of strategies to improve the efficiency of PartMC-MOSAIC to enable its extension from a Lagrangian box model to a model that is coupled to a 1D and eventually 3D transport code. Here we will present advances regarding two specific aspects: (1) the development of new algorithms for parallel particle simulation, and (2) the introduction of “superparticles” as a coarse-graining method, each superparticle representing a distribution of particles. We found such a modified PartMC-MOSAIC scheme to be more accurate and efficient than the original method by several orders of magnitude when applied to an urban plume scenario where we simulated the evolution of the mixing state of an aerosol population in a polluted environment.

Transferring the knowledge from ARM observations and CRM to improving GCM simulations of precipitation characteristics

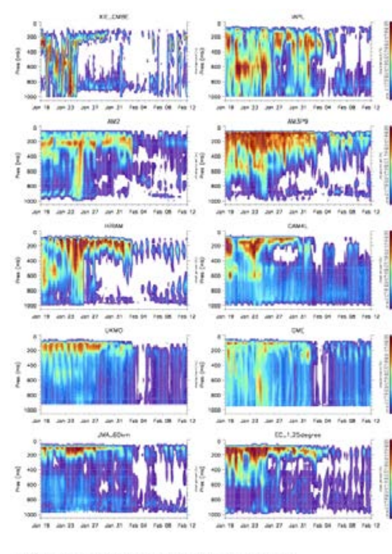
Xiaoqing Wu, Iowa State University
Zachary Mangin, Iowa State University

The transfer of understanding of convection, cloud, and precipitation processes from ARM observations and CRM simulations to GCM is a challenging but important task. The combination of a CRM approach with ARM observations has gained knowledge in physical processes associated with convection, cloud, and radiation. Recently, we incorporated five modifications, including the improved convection scheme (closure, trigger, and convective momentum transport), the mosaic treatment of subgrid cloud variability, and the cloud scheme, into ISUGCM, which is based on a version of NCAR GCM. The ten-year simulation shows great impacts of modified schemes on the diurnal cycle and frequency of precipitation, seasonal migration of ITCZ, and MJO, which are closer to available observations. The observed diurnal cycles of precipitation over the central U.S. and the southeast U.S. are nicely reproduced by the ten-year GCM simulations for the first time. The inclusion of subgrid cloud variability in the radiation calculation allows the simulated cloud (liquid and ice) water paths and the TOA radiative fluxes to agree with the observations simultaneously. The comparison between ISUGCM and NCAR CAM4 will be presented to illustrate the importance of consistent treatment of convection, cloud, and radiation processes in the climate simulations.

TWP-ICE global model intercomparison: resolution impact and diurnal cycle

Yanluan Lin, Geophysical Fluid Dynamics Laboratory
Leo Donner, Geophysical Fluid Dynamics Laboratory
Jon Petch, UK Met Office

Global models, including global forecast and climate models, from seven modeling centers were used to compare tropical cloud and precipitation simulations during the Tropical Warm Pool-International Cloud Experiment (TWP-ICE) period. As part of the ARM GCSS TWP-ICE intercomparison, this intercomparison aims to assess current global model performance of tropical cloud and convection and the resolution impact. Models were initialized from ERA-40 each day with day 2 forecasts compared with available observations. All models capture the transition of three distinct regimes (wet, break, and dry monsoon period) and their associated cloud, radiation, and precipitation variation during the TWP-ICE. However, large discrepancies are found in cloud, radiation, and precipitation among models. Stratiform precipitation fraction is sensitive to cumulus parameterizations used and generally increases with resolution. But cumulus parameterization impact on model cloud fraction and microphysics (LWC and IWC) is not straightforward. Model cloud fraction and hydrometeor fields differ significantly (up to one order of magnitude) among models and are greatly modulated by cloud schemes used. Though most models are able to produce the realistic Q1 and Q2 profiles during different regimes, their components, such as



Time-height plot of cloud fraction from observation and models.

convective and stratiform heating, differ significantly, even in sign, among models. This reflects the model's ability to achieve realistic temperature profile via compensation among various parameterized physical processes. Most models are unable to capture the cloud and precipitation diurnal cycle triggered by localized forcing during the dry period, though resolution indicates slight improvements in this regard. The study illustrates the complexity involved in tropical convection and suggests the importance of using ARM observations to better constrain model physical parameterizations and their interactions.

Understanding the linear response functions of shallow convection using a stochastic parcel model

Ji Nie, Harvard University
Zhiming Kuang, Harvard University

A better understanding of the linear response functions of a shallow cumulus ensemble to large-scale temperature and moisture perturbations could be used to evaluate and to improve cloud parameterizations. A stochastic parcel model is used to investigate the physical processes behind such linear response functions. The undisturbed BOMEX case is used in the present study. The responses of the parcel model to temperature and moisture perturbations are able to match the results from the simulations of a cloud-resolving model. Analysis of the history of convecting parcels in the parcel model shows that the temperature perturbation can form a buoyancy barrier, inhibits convection, and changes the properties of convecting parcels. The response to moisture perturbation is much smaller, and the physical interpretation for that is still being investigated.

Using boundary-layer equilibrium to reduce uncertainties in CO2 flux inversions

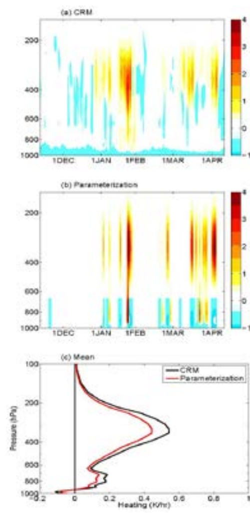
Ian Williams, University of Chicago
William Riley, Lawrence Berkeley National Laboratory
Margaret Torn, Lawrence Berkeley National Laboratory
Joseph Berry, Carnegie Institution of Washington
Sebastien Biraud, Lawrence Berkeley National Laboratory

The relationship between CO2 concentration gradients and time scales of transport and mixing is explored and used to test the feasibility of previously proposed hypotheses for errors in CO2 flux inversions and atmospheric transport models. A diagnostic of vertical CO2 gradients is developed based on equilibrium boundary-layer concepts and applied to observations from the U.S. Southern Great Plains Atmospheric Radiation Measurement Climate Research Facility and to a global data assimilation system based on Transport Model version 5 (TM5). The finite time scale over which vertical concentration gradients relax toward equilibrium is diagnostic of mixing rates between the boundary layer and free-troposphere and can be applied to observations and model simulations of conserved boundary-layer tracers with surface sources and sinks. This diagnostic does not require dynamical variables from the transport models and is independent of the prior- and post-inversion seasonal surface fluxes that may have complicated previous interpretations of CO2 vertical gradients in terms of modeled mixing rates. Boundary-layer depth is found to be an unreliable indicator of mixing rates, which depend on but are not necessarily proportional to boundary-layer depth. Seasonality in transport and mixing can be reversed at some sites, diminishing in summer when the boundary layer is deepest. Results indicate that observations frequently cited as evidence for systematic biases in atmospheric transport models are insufficient to prove that such biases exist, and in some cases the proposed errors would only further confound inverse estimates.

Vector formulation of the convection-environment interaction problem in the tropics

Samson Hagos, Pacific Northwest National Laboratory
L. Ruby Leung, Pacific Northwest National Laboratory

Cloud-resolving model simulations are performed over TWP Darwin and Manus sites to identify the unique moist-thermodynamic environmental conditions favorable for shallow and deep convection. Deep convection is associated with moist mid-troposphere, while shallow convection is associated with warm and moist lower troposphere. On average, deep and shallow convection environments have minimum equivalent potential temperature higher than those of clear sky environments by about 100K. The results of the cloud-resolving simulations and vector analysis are used to derive a relationship between large-scale convection and large-scale environment. The results are evaluated using radar observations of latent heating. The potential application of the new technique to parameterization of convection in global models is discussed.



Comparison of heating over TWP Darwin during the winter of 2005–2006 from a cloud-resolving model (K/day) with that derived from the large-scale moisture and potential temperature profiles, using the vector formulation discussed in the poster.

WRF/Chem modeling of atmospheric effects of aerosols from wildfires and volcanic eruptions

Martin Stuefer, Geophysical Institute, University of Alaska Fairbanks
Georg Grell, NOAA
Saulo Freitas, Center for Weather Forecast and Climate Studies

We have developed tools to use WRF/Chem for modeling wildfire smoke and volcanic ash. Wildfire smoke: Models for biomass burning emission and wildfire plume rise implemented online in WRF/Chem have been used to study the impact of smoke aerosols on weather. Using test cases from the extreme Alaska wildfire year of 2004 with 6.6 millions of burned acres of mostly boreal forest, it was possible to show increased large numbers of cloud condensation nuclei (CCN) in areas with high concentration of fine particulate (PM2.5). WRF/Chem runs with wildfire smoke were compared to “clean air” reference runs and showed significant differences in temperature and humidity profiles as well as in precipitation amounts. Volcanic ash: A volcanic ash plume model has been included in the source generation package for WRF/Chem. The model includes eruption source parameters for 1535 volcanoes globally. Ash particles are organized in the model in 10 bins according to their size from small particles (< 3.9 μm) to large-sized particles up to 2 mm; an umbrella-shaped vertical ash distribution is assumed to initialize WRF/Chem. The model was used to successfully predict the dispersion of volcanic ash from the recent eruptions of Eyjafjallajökull in Iceland and Mount Redoubt in Alaska. Validated atmospheric dispersion models for aerosols resulting from volcanic eruptions as well as from large wildfires are key for improving climate models. We are in the process of validating our WRF/Chem applications using remote sensing satellite data, airborne data, and data from ground-based stations. Aerosol and radiation measurements from permanent, mobile, and aerial ARM Climate Research Facilities will be a main reference for future efforts determining the characteristics and properties of volcanic and smoke aerosols.

11.0 Precipitation

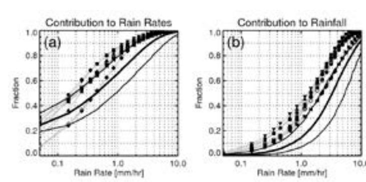
Doppler radar measurements and implications for the microphysical study of drizzle formation

Robert McGraw, Brookhaven National Laboratory
Edward Luke, Brookhaven National Laboratory
Pavlos Kollias, McGill University

This poster presents a statistical examination of in-cloud updraft and downdraft velocities using new ARM scanning Doppler radar and radiosonde measurements. The measurements, together with moments and other statistical properties derived from them, are used in conjunction with adiabatic parcel and entrainment models to derive the properties of turbulence-induced fluctuations in saturation ratio and cloud droplet size. An especially important parameter for models of cloud droplet evolution and dispersion and also for predicting conditions at the drizzle threshold is the ratio of saturation ratio fluctuation variance to correlation time (McGraw and Liu, GRL, 33, L03802 [2006]). The goal of the present analysis is to develop methods to estimate this key turbulence parameter needed in the kinetic potential theory of drizzle formation from remote sensing methods and in particular from the Doppler radar measurements.

Investigating simulated convective and stratiform structures of monsoonal convection using TWP-ICE observations

Adam Varble, University of Utah
Edward Zipser, University of Utah
Ann Fridlind, NASA Goddard Institute for Space Studies
Andrew Ackerman, NASA Goddard Institute for Space Studies
Jean-Pierre Chaboureau, University of Toulouse/Centre National de la Recherche Scientifique
Scott Collis, Argonne National Laboratory
Jiwen Fan, Pacific Northwest National Laboratory
Adrian Hill, UK Met Office
Sally McFarlane, Pacific Northwest National Laboratory
Jean-Pierre Pinty, University of Toulouse/Centre National de la Recherche Scientifique
Ben Shipway, UK Met Office



The 2.5-km stratiform rain rate normalized cumulative distribution is shown in (a) with models represented by symbols and observations by the thick black line. Thin black lines show the observational error bounds. The cumulative contribution of stratiform rain rates to total stratiform rainfall is shown in (b). Observations are derived from the C-POL radar.

Essential to improving general circulation models is improving cloud-resolving models that guide single-column models. From previous work, we have found that nine separate TWP-ICE simulations of monsoonal convective systems did not reproduce the observed distribution of radar reflectivity above the melting level. Differences across models were found to be strongly dependent on assumed graupel and snow hydrometeor properties and less dependent on ice water content. Furthermore, all simulations vastly underestimate stratiform rain rate regardless of dynamical framework or bulk microphysics scheme. To further investigate these findings, several important properties relevant to the distribution and evolution of radar reflectivity and rain rates are compared to observations. Updraft vertical velocity is compared with dual Doppler analyses, hydrometeor fall speeds with S-band profiler Doppler velocity, and rain median volume diameters with radar-based observational retrievals. These comparisons give insight into the model processes that are leading to incorrect three-dimensional radar reflectivity structure and lower-than-observed stratiform rain rates.

Life cycle of deep convection and rainfall simulated in cloud-resolving model

Toshiro Inoue, University of Tokyo

Cloud-system-resolving model (Nonhydrostatic Icosahedral Atmospheric Model; NICAM) represented semi-diurnal peaks of surface rainfall at afternoon and early morning over southern Africa of 15E–35E and Eq-25S. We constructed mean daily variation of near-surface rain using TRMM/PR and TMI from 3G68 data and found the same afternoon peak and early morning peak, although the TMI afternoon peak was slightly behind the PR. Temporal variation of areal coverage of deep convection (DC) defined by the infrared data showed significant diurnal variation instead of semi-diurnal variation. However, we found clear semi-diurnal variation in the mean size of DC at afternoon and early morning, when we studied the temporal variation of number and mean size of DC within the area of 15E–35E and Eq-25S. Although the afternoon peak of mean size is slightly behind the peak time of near-surface rainfall by TRMM/PR, the peak time of number of DC is close to the TRMM/PR peak time. The rainfall peak over the study area corresponds to the time when the number of DC is large, with an increase in the mean size of DC. Thus the afternoon peak of rainfall can be understood as the time when a large number of DC of developing stage occurred simultaneously. This temporal variation of number and mean size of DC can be seen in DC defined by OLR simulated by NICAM. The NICAM afternoon peak in surface rainfall also corresponds to the time when a larger number of the developing stage of DC occurred.

Precipitating cloud-system response to aerosol perturbations

Seoung-Soo Lee, NOAA Earth System Research Laboratory
Graham Feingold, NOAA Earth System Research Laboratory

We simulate aerosol effects on a tropical western Pacific mixed-phase convective cloud system of two-day duration that is well constrained by observations. This facilitates exploration of aerosol-induced changes in precipitation pathways. A tenfold increase in aerosol produces a small (9 %) increase in the simulated precipitation due to an enhancement in convective rain countering a reduction in stratiform rain. A more distinct feature is that in stratiform clouds, precipitation efficiency (PE) and scavenging efficiency (SE) decrease significantly with increasing aerosol. There is very close agreement between PE and SE both temporally and for stratiform versus convective rain. The time required for a perturbed system to relax back to the unperturbed aerosol state is ~10 days, with only weak sensitivity to the magnitude of the aerosol perturbation and the modeled increase (or decrease) in precipitation. The upper tropospheric relaxation time is substantially longer, with implications for direct forcing and heterogeneous chemistry.

http://www.agu.org/pubs/crossref/2010/2010GL045596.shtml

Randomization method for comparing station and satellite observations of cloud and precipitation

Samuel Shen, San Diego State University
Max Velado, San Diego State University

According to the derivation of the partial differential equations (PDE), a physical quantity in a climate model is defined in a grid box based on the continuum mechanics principles. However, a PDE solution is a function with values on points. The values at points and on grid boxes are linked by continuity properties of the PDE solution. However, when validating the climate models by using gauge and satellite observations, one needs to unify the two data sets. This presentation will describe a randomization method to bridge the two data sets. The method will randomize the gauge location and estimate the expected values of the gauge observation's sampling error. Application examples for precipitation using TRMM (Tropical Rainfall Measuring Mission) satellite precipitation data, SGP (Southern Great Plains) cloud data, and CAM5 (Community Atmospheric Model) output will be presented.

Towards vertical velocity and hydrometeor classification from ARM wind profilers

Scott Giangrande, Brookhaven National Laboratory
Edwin Campos, Argonne National Laboratory
Christopher Williams, University of Colorado at Boulder/NOAA Earth System Research Laboratory
Michael Jensen, Brookhaven National Laboratory
Pavlos Kollias, McGill University
Richard Coulter, Argonne National Laboratory

With support from the ARM Climate Research Facility infrastructure, two radar wind profilers (915-MHz) were operated for a year-long campaign (2009) in the southwest part of the Southern Great Plains site. The goal of this field campaign was to re-evaluate wind profiler opportunities for studying deep convective clouds as part of larger ARM efforts towards the estimation of vertical velocity and precipitation microphysics. During this period, ARM wind profilers operated under a new sampling strategy designed to better capture deep convective cores (to 15 km) at high temporal resolution (five-second profiles). Algorithms to estimate the vertical air velocity and precipitation type are offered and capitalize on a diverse collection of over 25 events observed for the deployment.

Variability in rainfall drop-size distributions observed at the ARM Darwin site

Mary Jane Bartholomew, Brookhaven National Laboratory
Scott Giangrande, Brookhaven National Laboratory
Mick Pope, Bureau of Meteorology
Michael Jensen, Brookhaven National Laboratory

The variability of rainfall drop-size distributions as a function of large-scale atmospheric conditions and cloud/storm characteristics is investigated using observations from the Atmospheric Radiation Measurement (ARM) Climate Research Facility's site at Darwin, Australia. Drop-size distribution observations are obtained from an impact disdrometer over a four-year period (2006–2010). The suite of complementary long-term observations from the ARM collocated surface instruments, including a millimeter cloud radar and nearby radiosondes, etc., provides a means to describe the cloud and storm characteristics as well as local and regional atmospheric state accompanying these statistics of the drop-size distributions.

12.0 Radiation

Best-guess water vapor profiles for the RHUBC-II campaign

Eli Mlawer, Atmospheric and Environmental Research, Inc.
Jennifer Delamere, Atmospheric and Environmental Research, Inc.
Vivienne Payne, Atmospheric and Environmental Research, Inc.
David Turner, NOAA
Maria Cadeddu, Argonne National Laboratory
Scott Paine, Smithsonian Astrophysical Observatory

Emission and absorption of far-infrared radiation by water vapor in the mid-to-upper troposphere are important drivers of that region's dynamics. Surface radiation measurements in typical conditions contain no pertinent information about these radiative processes due to absorption by water vapor in the intervening lower atmosphere. The resulting relatively high uncertainty in our knowledge of these processes is reflected in a corresponding uncertainty in climate models' predictions for the mid-to-upper troposphere. The ARM Climate Research Facility recently conducted a set of field experiments, the Radiative Heating in Underexplored Bands Campaigns (RHUBC), targeted at lowering these uncertainties. RHUBC-II was held from August–October 2009 at a site at 5400 m in the Atacama Desert of Chile, during which the precipitable water vapor during clear periods was as low as 0.2 mm. Under these conditions, the increased transparency allows ground-based far-IR measurements to contain useful information about these radiative processes. The RHUBC-II campaign included a number of instruments that provided spectrally resolved measurements in strong H2O absorption bands, including two instruments that measure throughout the far-IR. Improving far-IR spectroscopic parameters using RHUBC-II measurements requires accurate specification of the water vapor profiles in the radiating column above the site. Vaisala RS-92 radiosondes were regularly launched during operational periods of RHUBC-II, but these sondes have well-known accuracy issues in conditions of low humidity and during daytime. Previous ARM radiative closure studies have demonstrated that measurements associated with well-characterized H2O absorption lines in the microwave can provide information that improves the accuracy of water vapor profiles measured by sondes. This study will utilize an optimal estimation approach to refine the sonde profiles using observations from the RHUBC-II GVRP instrument, which has 14 channels on the 183.3 GHz H2O line. Different retrieval approaches will be evaluated, as will the accuracy of the methodology specified by Miloshevich et al. (2009) for removing biases in sonde H2O profiles. These methods for obtaining RHUBC-II H2O profiles will be evaluated via comparisons to measurements in the sub-mm region by the collocated Smithsonian FTS. This study will result in a best-guess water vapor profile for each RHUBC-II clear-sky case; the complete set will be placed in the campaign archive.

Evaluating the accuracy of the far-infrared spectral observations, water vapor measurements, and the radiative transfer model in extremely dry, clear-sky periods during RHUBC-II

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Aronne Merrelli, University of Wisconsin
Maria Cadeddu, Argonne National Laboratory
Eli Mlawer, Atmospheric & Environmental Research, Inc.
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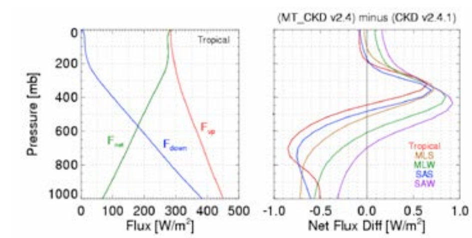
Luca Palchetti, Istituto di Fisica Applicata "Nello Carrara"
Giovanni Bianchini, Istituto di Fisica Applicata "Nello Carrara"
Martin Mlynczak, NASA Langley Research Center
Richard Cageao, NASA Langley Research Center
Dave Johnson, NASA Langley Research Center

The far-infrared (wavelengths between 15 and 100 µm) is an extremely important spectral region, as nearly 40% of the outgoing longwave radiation and a significant portion of the infrared radiative cooling in the middle-to-upper troposphere are directly attributable to radiative processing in this spectral band. Radiative transfer models in this spectral region have significant uncertainties due to the relative lack of data to use in developing and validating models. ARM/ASR, in collaboration with other national and international agencies, recently conducted two field experiments called the Radiative Heating in Underexplored Bands Campaign (RHUBC), with RHUBC-I held at the ARM site in Barrow, Alaska, in February–March 2007 and RHUBC-II held in the Atacama desert in Chile at over 5000 m MSL in August–October 2009. Analysis of data from RHUBC-I suggested that the water vapor continuum absorption model used in infrared radiative transfer calculations needed adjustment in the far-infrared. The changes made to the continuum model have a significant impact in the atmospheric cooling in clear skies, resulting in negative net flux differences approaching -0.8 W/m2 for atmospheres below approximately 500 mb and net flux increases approaching 0.9 W/m2 above 500 mb. We are evaluating the impact of these differences in the net longwave radiative flux profile on the global circulation using the NCAR Community Earth System Model (CESM). Initial results will be shown from decadal simulations with and without this modification to the water vapor continuum absorption model at the meeting. The minimum amount of precipitable water vapor (PWV) observed during RHUBC-I was 0.95 mm, resulting in the atmosphere being semitransparent in the 17 to 26 µm region; thus, the radiative transfer model could only be evaluated in this spectral interval. The minimum amount of PWV observed during RHUBC-II was nearly five times drier (0.2 mm), allowing the spectral region from 17 to 45 µm to be evaluated. The RHUBC-II data set provides a more complete test of the accuracy of the adjustment made to the continuum model; however, the analysis must also investigate the accuracy of the PWV retrievals and water vapor profiles as well as the radiometric accuracy of the spectrally resolved radiance observations. Initial results from this analysis will also be shown.



The longwave net flux profile, in a wide variety of atmospheric conditions, shows a marked difference when computed with the pre-RHUBC-I water vapor continuum model (CKD v2.4.1) versus the post-RHUBC-I model (MT_CKD v2.4). The accuracy of the two continuum models is being evaluated with RHUBC-II data, and GCM simulations are being used to gauge the impact of the difference in the LW flux.

The full-spectrum correlated k method for longwave atmospheric radiative transfer: treatment of gaseous overlap

Robin Hogan, University of Reading

The correlated k-distribution (CKD) method is widely used in the radiative transfer schemes of atmospheric models and involves dividing the spectrum into a number of bands and then reordering the gaseous absorption coefficients within each one. The fluxes and heating rates for each band may then be computed by discretizing the reordered spectrum into of order 10 quadrature points per major gas and performing a monochromatic radiation calculation for each point. In this poster it is shown that for clear-sky longwave calculations, sufficient accuracy for most applications can be achieved without the need for bands; reordering may be performed on the entire longwave spectrum. The resulting full-spectrum correlated k (FSCK) method requires significantly fewer monochromatic calculations than standard CKD to achieve a given accuracy. The concept is first demonstrated by comparing with line-by-line calculations for an atmosphere containing only water vapor, in which it is shown that the accuracy of heating-rate calculations improves approximately in proportion to the square of the number of quadrature points. For more than around 20 points, the root-mean-squared error flattens out at around 0.015 K/day due to the imperfect rank correlation of absorption spectra at different pressures in the profile. The spectral overlap of m different gases is treated by considering an m-dimensional hypercube where each axis corresponds to the reordered spectrum of one of the gases. This hypercube is then divided up into a number of volumes, each approximated by a single quadrature point, such that the total number of quadrature points is slightly fewer than the sum of the number that would be required to treat each of the gases separately. The gaseous absorptions for each quadrature point are optimized such that they minimize a cost function expressing the deviation of the heating rates and fluxes calculated by the FSCK method from line-by-line calculations for a number of training profiles. This approach is validated for atmospheres containing water vapor, carbon dioxide, and ozone, in which it is found that in the troposphere and most of the stratosphere, heating-rate errors of less than 0.2 K/day can be achieved using a total of 23 quadrature points, decreasing to less than 0.1 K/day for 32 quadrature points. It would be relatively straightforward to extend the method to include other gases.

http://www.met.reading.ac.uk/clouds/publications/fsck.pdf

Hyperspectral radiometer measurements during RACORO

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Anthony Bucholtz, Naval Research Laboratory
Chuck Long, Pacific Northwest National Laboratory
J.-Y. Christine Chiu, University of Reading
Haflidi Jonsson, Naval Postgraduate School CIRPAS
Dan Lubin, National Science Foundation
Qilong Min, State University of New York at Albany
Alexander Marshak, NASA Goddard Space Flight Center

During the RACORO field program, the multi-disciplinary instrumentation flown onboard the Center for Interdisciplinary Remotely Piloted Aircraft Studies (CIRPAS) Twin Otter included a Hydrorad-3 Hyperspectral Radiometer. It simultaneously measured upward and downward spectral irradiances, as well as the radiance for a three-degree field of view that could be either upward- or downward-looking. Measurements covered the visible range from 350 to 850 nm at down to 0.3-nm resolution with a fast response time. The poster will examine the performance of this new instrument and explore its potential use for scientific applications such as cloud property retrievals.

http://acrf-campaign.arm.gov/racoro/

Improved TOA shortwave and longwave broadband fluxes derived for the Southern Great Plains

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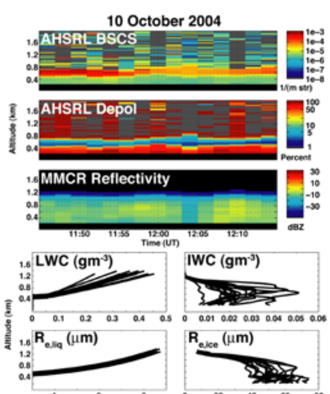
Patrick Minnis, NASA Langley Research Center
David Doelling, Science Systems and Applications, Inc.
Rabindra Palikonda, Science Systems and Applications, Inc./NASA Langley Research Center
Michele Nordeen, Science Systems and Applications, Inc./NASA Langley Research Center
Helen Yi, Science Systems and Applications, Inc./NASA Langley Research Center
David Rutan, Science Systems and Applications, Inc./NASA Langley Research Center

The Geostationary Operational Environmental Satellite (GOES-11) provides half-hourly coverage of the western United States, including the Southern Great Plains (SGP) region. By using narrowband-to-broadband (NB-BB) conversion coefficients, useful climate information can be derived from GOES-11 narrowband sensors. Past studies have employed NB-BB coefficients, derived using GOES data matched with broadband longwave (LW) and shortwave (SW) fluxes from the Clouds and the Earth's Radiant Energy Budget (CERES) instrument aboard Terra. However, Terra is limited to twice daily overpasses, with a 10:30 local crossing time. To improve the availability of broadband data for the NB-BB fit, Aqua CERES fluxes (1:30 local crossing time) will be included in the CERES BB data. NB-BB coefficients are derived seasonally from coincident 1 degree-averaged 2007 GOES-11/CERES LW and SW fluxes; LW fits are derived separately for day and night. Validation of these fits is made using 2008–2010 CERES Terra and Aqua data. Comparison of the newly derived fluxes is made to those derived from the Terra-only NB-BB fit, as well as results derived using the Fu-Liou radiative transfer model.

Mixed-phase cloud radiative forcing during M-PACE: estimates from surface-based remote sensors

Gijs de Boer, Lawrence Berkeley National Laboratory
William Collins, Lawrence Berkeley National Laboratory
Surabi Menon, Lawrence Berkeley National Laboratory
Chuck Long, Pacific Northwest National Laboratory

The influence of clouds on the surface radiative budget is an important component in understanding how changes in cloud cover may influence future climate states. In the Arctic, mixed-phase stratiform clouds are commonly observed and have been shown to be among the most radiatively influential structures. Previous efforts detailing the radiative forcing of mixed-phase clouds have demonstrated importance of the liquid water component in governing both long and shortwave radiation. Radiative forcing from these cloud structures is positive (net increase in energy into the surface) for much of the year, due to low sun angles and a dominance of longwave effects. During Arctic summer, these clouds impart negative cloud forcing due to their high shortwave albedo. Estimates of cloud radiative forcing are obtainable from surface radiometric measurements, when available. At sites that do not offer such measurements, estimates of cloud radiative forcing can be obtained using a radiative transfer model initiated with conditions measured by remote sensors. In this study, we utilize a suite of ground-based remote sensors, including radar, lidar, and microwave



An example of measured and retrieved mixed-phase cloud properties from M-PACE. Included (from top to bottom) are lidar aerosol backscatter cross-section, lidar depolarization ratio, millimeter cloud radar reflectivity, retrieved liquid (left) and ice (right) water content profiles, and retrieved liquid (left) and ice (right) effective particle sizes.

radiometers, along with a state-of-the-art set of retrieval algorithms and radiative transfer models. These tools are used to estimate surface radiative forcing from mixed-phase clouds observed over Barrow, Alaska, during the 2004 Mixed-Phase Arctic Clouds Experiment (M-PACE). An overview of retrievals will be provided along with an analysis of model-calculated and measured surface radiative fluxes. Finally, an overview of cloud radiative forcing will be provided, along with a sensitivity analysis covering the most uncertain aspects of the retrievals.

Parameterization of shortwave horizontal photon transport effects

Tamas Varnai, University of Maryland, Baltimore County Joint Center for Earth Systems Technology
Jerry Harrington, The Pennsylvania State University

In order to keep the computational demands of radiative calculations manageable, most dynamical atmospheric simulations use one-dimensional (1D) radiation models. These 1D models calculate radiative processes separately for each atmospheric column, without considering horizontal interactions between neighboring columns. As several studies and our earlier results have indicated, these horizontal interactions can lead to significant inaccuracies in 1D estimates of radiative heating. To help improve the accuracy of radiation calculations in regional and global cloud-resolving simulations, we are developing a fast parameterization that can adjust 1D radiation model outputs by considering horizontal radiative interactions. This parameterization provides corrections to 1D radiation model outputs by using a neural net, which estimates the needed corrections based on horizontal gradients in the dynamical simulation's cloud field. The poster will discuss this neural net approach and will show results about the corrections improving the accuracy of 1D radiation calculations.

Radiative heating rate profiles at the ARM TWP Manus site using cloud properties from a combined remote sensor retrieval

Tyler Thorsen, University of Washington
Qiang Fu, University of Washington
Jennifer Comstock, Pacific Northwest National Laboratory

The vertical distribution of radiative heating plays an important role in determining dynamic atmospheric processes. In the tropics, the radiative energy budget in the tropical tropopause layer (TTL) places constraints on the vertical transport of air from the troposphere to the stratosphere. In this study we quantify radiative heating rate profiles over the ARM TWP Manus site. The PNNL combined remote sensor retrieval is used for cloud inputs; it uses the MMCR, MPL, and MWR to obtain cloud and precipitation properties for all sky conditions. Radiative heating profiles are compared to several previous studies which used radar-only cloud retrievals. We explore several causes of discrepancies in heating rate profiles among previous studies and the current study. Also explored is the impact of lidar observations on radiative heating rate profiles, particularly for the TTL.

The radiative impacts of implementing RRTMG on NASA's GEOS-5 Atmospheric GCM

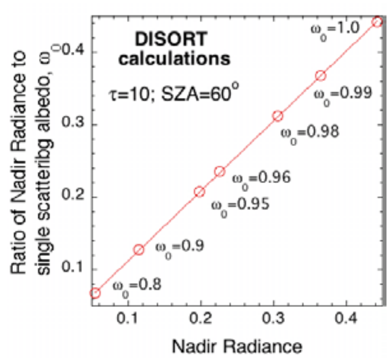
Lazaros Oreopoulos, NASA
Dongmin Lee, University of Maryland, Baltimore County Goddard Earth Sciences & Technology Center/Seoul National University
Eli Mlawer, Atmospheric and Environmental Research, Inc.
Michael Iacono, Atmospheric and Environmental Research, Inc.

It has been demonstrated that Monte Carlo spectral integration can be combined with Independent Column Approximation (ICA) calculations to replace CPU-intensive explicit spectral integration with negligible influences on GCM simulations. Such a "McICA" approach has been implemented in Goddard's GEOS-5 GCM in conjunction with the ARM-supported RRTMG radiation package. GEOS-5 with McICA can adopt horizontally variable clouds that are allowed to overlap arbitrarily both in terms of cloud fraction and layer condensate distributions. In our presentation we will show radiative and other impacts of the combined horizontal and vertical cloud variability on multi-year simulations of an otherwise untuned GEOS-5 with fixed SSTs. Introducing cloud horizontal heterogeneity without changing the mean amounts of condensate reduces the reflected solar and increases the emitted thermal radiation to space, but disproportionate changes may yield increased radiative imbalance at TOA. The net radiation at TOA can be modulated by allowing the parameters of the generalized overlap and heterogeneity scheme to vary, a sensitivity whose limitations we will discuss. Results from our investigation on the extent to which other mean cloud properties need to be retuned in order to get closer to net radiation flux balance at TOA will also be presented.

Spectrally invariant approximations within atmospheric radiative transfer

Alexander Marshak, NASA Goddard Space Flight Center
Yuri Knyazikhin, Boston University
J.-Y. Christine Chiu, University of Reading
Warren Wiscombe, Brookhaven National Laboratory

Certain algebraic combinations of single-scattering albedo and solar radiation reflected from, or transmitted through, vegetation canopies do not vary with wavelength. These are called "spectrally invariant relationships" and are the consequence of wavelength independence of the extinction coefficient and scattering phase function in vegetation. This wavelength independence does not in general hold in the atmosphere, but in cloud-dominated atmospheres, the total extinction and total scattering phase function are only weakly sensitive to wavelength. We identify the atmospheric conditions under which the spectrally invariant approximation can accurately describe the extinction and scattering properties of cloudy atmospheres. Validity of the assumptions and accuracy of the approximation are tested with 1D radiative transfer calculations using publicly available radiative transfer models: DISORT and SBDART. We show that, for cloudy atmospheres with cloud optical depth above 3, and for spectral intervals that exclude strong water vapor absorption, the



Linear relationship between the ratio (Nadir Radiance)/(single scattering albedo w0) and (Nadir Radiance) for cloud optical depth=10, solar zenith angle=60 deg, a Henyey-Greenstein scattering phase function with asymmetry factor g=0.85, and 7 values of w0 from 0.8 to 1.0. Surface is black. Nadir Radiance is calculated with the 1D radiative transfer code DISORT.

spectrally invariant relationships found in vegetation-canopy radiative transfer are valid to better than 5%. We discuss the physics behind this phenomenon, its mathematical basis, and possible applications to remote sensing and climate. This is the first step towards theoretical justification of a spectrally invariant relationship recently found in ARM shortwave spectrometer observations and confirmed by SBDART simulations.

Surface radiation budget of the SGP ARM Climate Research Facility

Daniel Hartsock, University of Oklahoma
Claude Duchon, University Of Oklahoma

Our goal is to develop a climatology of the monthly surface radiation budget at the SGP extended facilities of at least 10 years. A few of the sites we begin with (Pawhuska, El Reno, Plevna, etc.) were selected because of their comparatively homogeneous surface properties based on a 1998 field study (Duchon and Hamm 2006). The surface radiation budget is the sum of a shortwave budget and longwave budget. All upward and downward components of radiation are measured with the SIRS instrument. Surface albedo is computed from the shortwave components. The procedure for obtaining a monthly budget is as follows. A day for accumulating shortwave radiation begins with the first minute an upward or downward component of radiation is greater than zero and ends when the component again becomes negative. There are three components of downward shortwave radiation: global sky, direct solar, and diffuse sky. A second estimate of global sky radiation can be computed from direct solar and diffuse sky. There is one upward component. Each component is summed minute-by-minute throughout the course of a day, yielding a daily sum in units of MJ/m2. Each daily sum is added to produce two monthly sums of global sky radiation. The procedure for obtaining daily and monthly sums of upward and downward longwave radiations parallels that for shortwave, except that each daily sum is derived from 1440 minutes. This investigation should provide insight into regional climate change in terms of the radiation budget on the time scale of a decade. We envision producing for each month at each site a figure of monthly summaries providing the data for climatological analyses. A potential problem in developing a high-quality climatological surface radiation data set is the occurrence of bad or missing data. In either case, a replacement value has to be estimated for each bad or missing datum. We will be using Pawhuska as a testbed and example for this poster.

13.0 Conclusion

More than 240 posters were presented during the Science Team Meeting. Abstracts for each poster are included here, sorted into the following subject areas: aerosol-cloud-radiation interactions, aerosol properties, atmospheric state and surface, cloud properties, dynamics/vertical motion, field campaigns, infrastructure and outreach, instruments, modeling, precipitation, and radiation.

Full-size and color versions of images are available at http://asr.science.energy.gov/meetings/stm/posters/2011.

People's Choice Poster Awards, voted on by meeting attendees, were presented to Mark Ivey (Sandia National Laboratories), Giri Palanisamy (Oak Ridge National Laboratory), and Mike Ritche (Argonne National Laboratory).

To recognize the important contributions of students to ASR research, awards were presented for student-led posters. The student poster competition was judged by the chairs of the three working groups. Awards were based on content (scientific merit), clarity, and originality and were presented during Thursday morning's plenary sessions. Student Poster Awards were given to Puneet Chhabra, Stuart Evans, Chunsong Lu, Joanna Slawinska, Sarah Suda, and Kara Sulia.

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