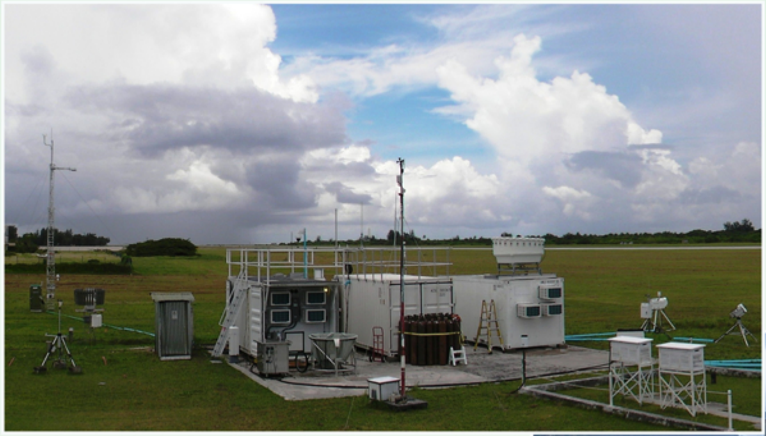
ASR Atmospheric System Research
Science Team Meeting

Arlington, Virginia • March 12 – March 16, 2012



ARM Madden-Julian Oscillation Investigation Experiment (AMIE)

Ganges Valley Aerosol Experiment (GVAX)

Midlatitude Continental Convective Clouds Experiment (MC3E)

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.

AMIE: Led by principal investigator Charles Long from Pacific Northwest National Laboratory, AMIE is obtaining data from an ARM Mobile Facility deployment on Gan Island in the Maldives and from ARM's fixed site on Manus Island, Papua New Guinea, from October 2011 through March 2012. Data gathered at these two sites will allow studies of the initiation, propagation, and evolution of convective clouds within the framework of the Madden-Julian Oscillation.

GVAX: Led by principal investigator V. Rao Kotamarthi from Argonne National Laboratory, GVAX is using ARM Mobile Facility instruments to gather data in Nainital, located in northern India, from June 2011 through March 2012. The objective of this field campaign is to obtain measurements of cloud, precipitation, and complex aerosols to study their impact on cloud formation and monsoon activity in the region.

MC3E: Led by principal investigator Michael Jensen from Brookhaven National Laboratory, MC3E took place at ARM's Southern Great Plains site from April to May 2011. This highly complex campaign took advantage of new instrumentation at SGP, as well as supplemental instrumentation and coordinated aircraft. The resulting characterization of convective cloud systems, precipitation, and their environment will provide details for the representation of cumulus clouds in computer models that have never before been available.

http://asr.science.energy.gov

CONTENTS

INTRODUCTION

Welcome to the third annual Atmospheric System Research (ASR) Science Team Meeting. Much of the meeting will be devoted to examining ASR's core scientific themes, which are organized within ASR through three science working groups: Aerosol Life Cycle; Cloud Life Cycle; and Cloud-Aerosol-Precipitation Interactions. Scientific findings are shared through poster and breakout sessions and a series of invited talks. The meeting also provides the opportunity to collectively examine the implementation and operation of the Atmospheric Radiation Measurement (ARM) Climate Research Facility (e.g., sites and instruments); to identify and discuss areas of concern and potential improvements; and to examine proposed special measurement objectives and plans to meet those objectives. In addition, the meeting provides a forum for other agency programs to gain a familiarity with ASR and ARM, to share goals and objectives, and to suggest collaborations of mutual interest. Each of these activities is crucial to the success of the program and is pursued in a variety of forms.

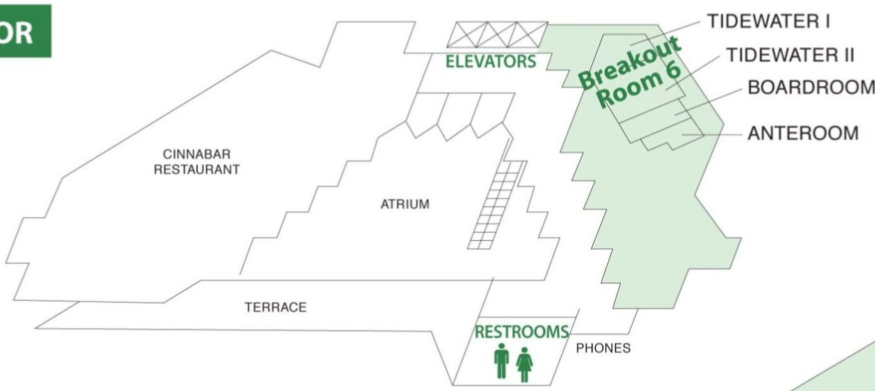
In this Program, you will find detailed information on the 2012 ASR Science Team Meeting activities. The first section of the Program contains a floor plan showing the locations of the ASR meeting areas, a map of the poster session floor layout, and a list of meeting administrative staff and points of contact. The second session of the Program includes biographies for the three invited speakers, who will speak at the plenary session on Tuesday morning. The full meeting agenda is included as an insert to the program; the agenda is also available on signs throughout the meeting area and online at http://asr.science.energy.gov/meetings/stm/2012/agenda.

The Program contains title and author information for poster abstracts, sorted by 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. A full version of the program, containing the text of poster abstracts, can be viewed in PDF format at http://asr.science.energy.gov/meetings/stm/2012/program.pdf. To view abstracts sorted by title, category, or author, visit http://asr.science.energy.gov/meetings/stm/posters/2012.

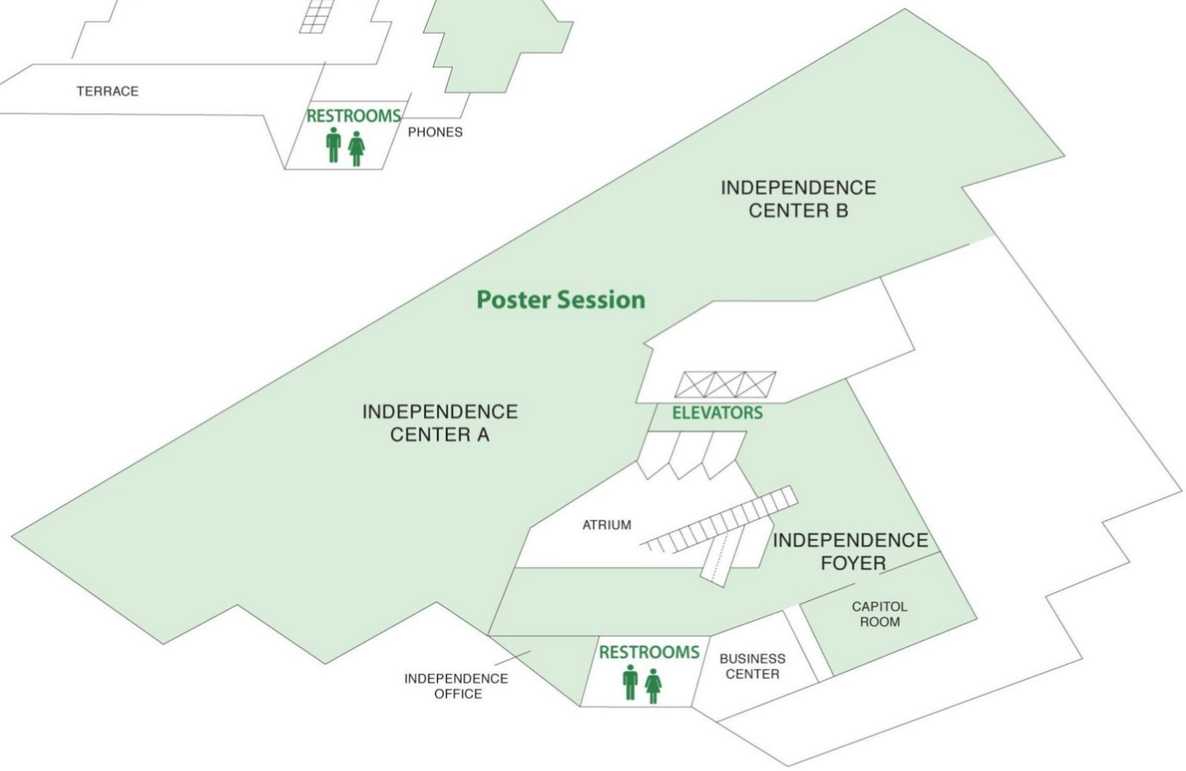
2012 ASR Science Team Meeting Floor Plan

Hyatt Regency Crystal City

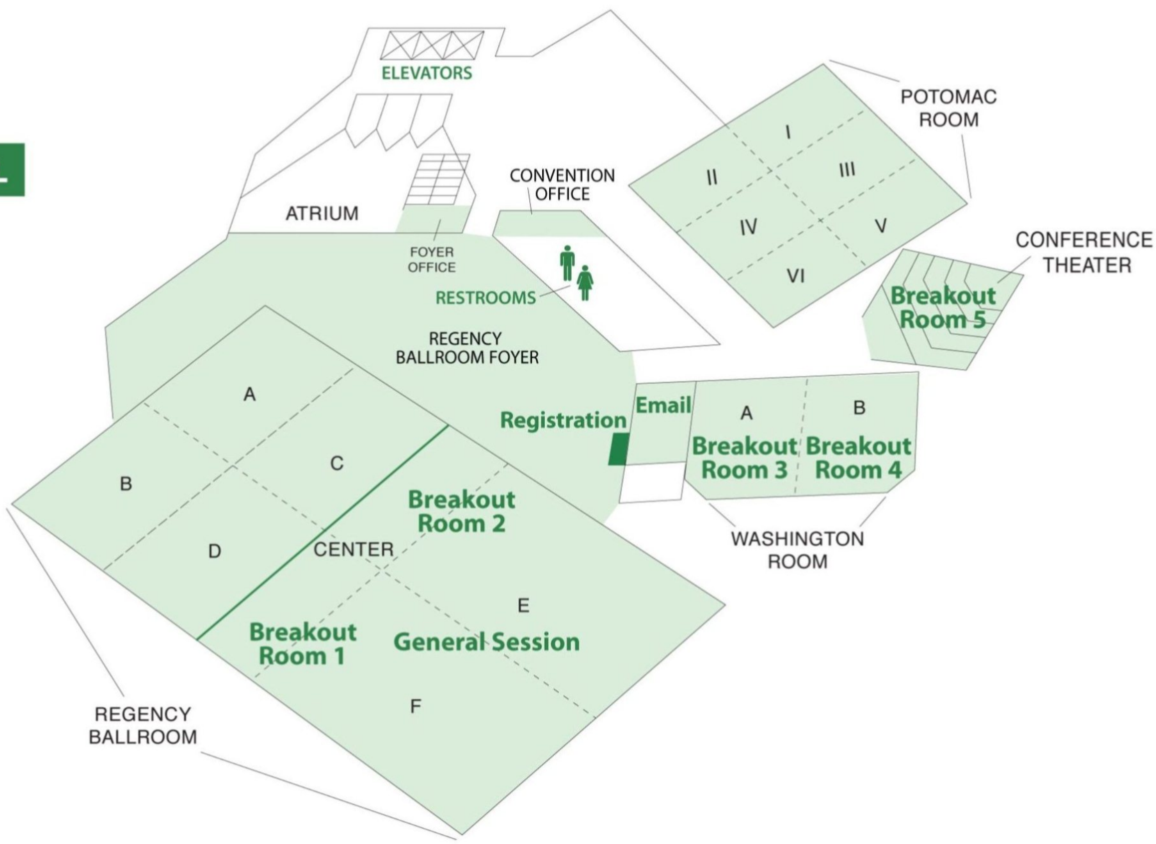
SECOND FLOOR



INDEPENDENCE LEVEL



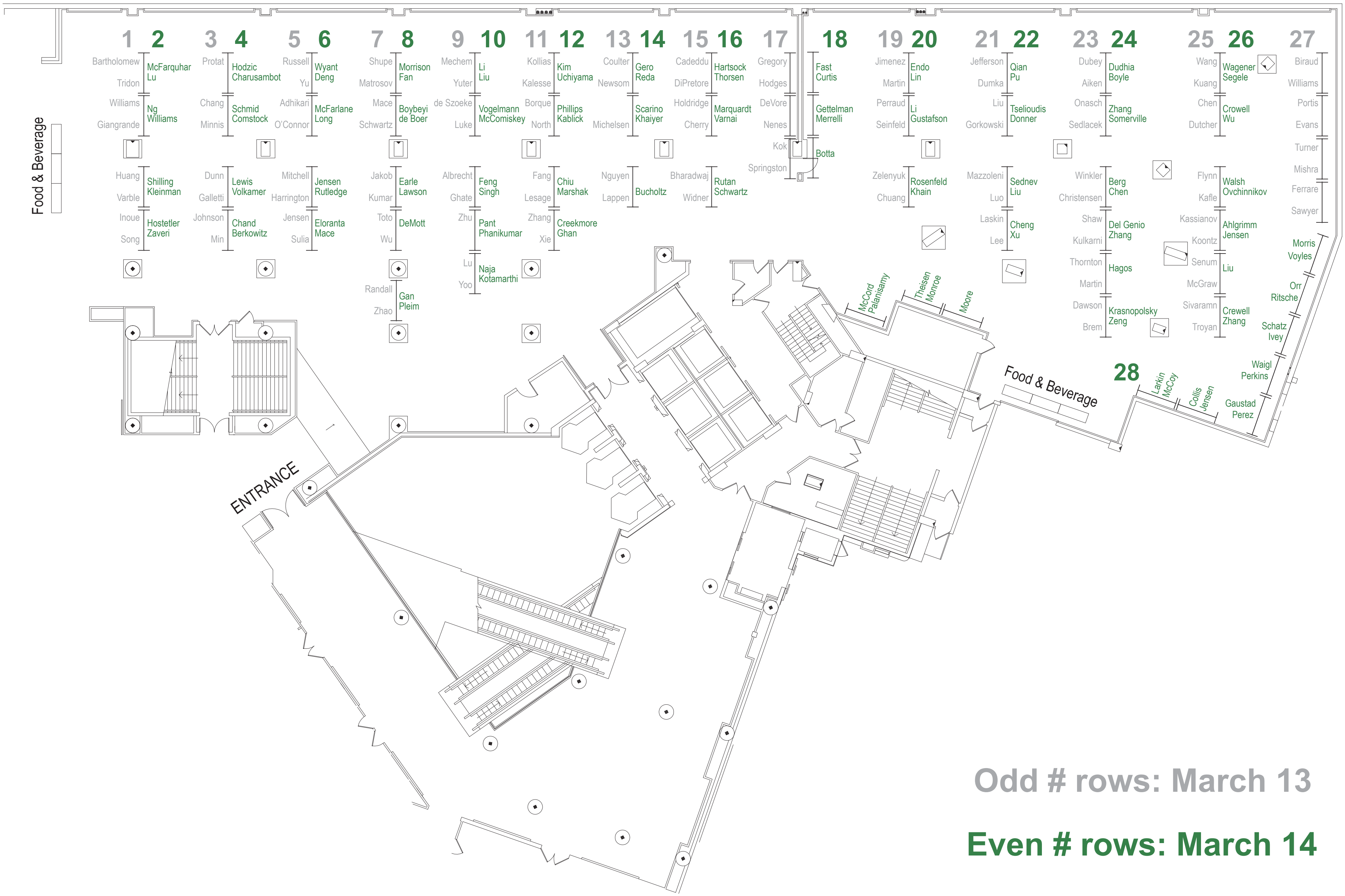
BALLROOM LEVEL



ASR Atmospheric System Research

2012 ASR Science Team Meeting

Hyatt Regency Crystal City • Independance Hall A



Odd # rows: March 13

Even # rows: March 14

POINTS OF CONTACT

ASR Science Team Meeting Administrative Staff
Jane McKinney, Kelle Smith, Dana Dupont, Jackie Marshall, Valerie Sparks, Sharon Zuhoski, and Todd Hull. Specific points of contact are listed below.

Agenda
Dana Dupont and Valerie Sparks

Badges
Kelle Smith

Breakout Room Schedule
Sharon Zuhoski and Valerie Sparks

Email Station/Internet
Todd Hull

Equipment Requests
Todd Hull

Meeting Logistics
Jane McKinney

Presentation Technical Support
Todd Hull and Matt Macduff

Presentation Collection
Jackie Marshall

Poster Board Assignments
Valerie Sparks

Poster PDF Submissions
Dana Dupont

Registration/Help Desk
Kelle Smith

Workshop Agreements
Kelle Smith

NOTE: If you are unable to locate a specific contact, please check with any of the administrative staff listed above for assistance.

Invited Speakers

INVITED SPEAKERS

Steven Klein, Lawrence Livermore National Laboratory

Dr. Stephen Klein is a research scientist in the Program for Climate Model Diagnosis and Inter comparison at LLNL. His research interests include clouds, their role in climate change, and the fidelity with which climate models simulate clouds. Major achievements of his career include observational analyses that demonstrate how marine boundary-layer clouds are related to environmental conditions; the development of the International Satellite Cloud Climatology Project "simulator," which has been incorporated into most global climate models; leadership of the team that developed the atmosphere portion of the NOAA Geophysical Fluid Dynamics Laboratory's climate model CM2; and the widespread utilization of weather-forecast techniques for the evaluation of cloud-related processes in climate models.

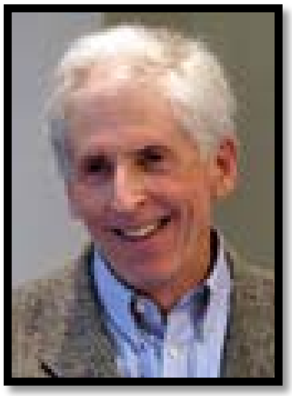
Dr. Klein received his PhD in atmospheric sciences from the University of Washington in 1994 and he has been a lead author or co-author on more than 70 peer-reviewed publications. His professional career began as a visiting scientist at Princeton University and consultant for the European Center for Medium Range Weather Forecasting. He then worked at the GFDL, co-chairing the Global Atmospheric Model Development Team, before joining LLNL where he leads efforts to integrate observational data with numerical models. From 2005 to 2008, he was the science leader for ARM's Cloud Modeling Working Group. Since 2008, he has been a member of the international Cloud Feedback Model Intercomparison Project Steering Committee and in 2011 began his role as co-chair of the Global Atmospheric System Studies, the successor to the Global Energy and Water Cycle Experiment Cloud Systems Studies.

Graham Feingold, NOAA Earth System Research Laboratory

Dr. Graham Feingold is a research scientist at NOAA's Earth System Research Laboratory in Boulder, Colorado. His research interests include modeling and measurement of aerosol-cloud-precipitation interactions, and more recently, exploration of emergence and self-organization in these systems. His focus is on process-level studies using high-resolution models and observations (aircraft and surface remote sensing) at the cloud scale (tens of meters to tens of kilometers). He has given dozens of invited talks and authored or co-authored more than 115 peer-reviewed articles on these subjects.

Dr. Feingold received his PhD in geophysics from Tel Aviv University in 1989, returning as a guest lecturer there in 2006 and at other institutions over the years. He is a lead author on the Intergovernmental Panel on Climate Change Fifth Assessment Report, Chapter 7 (Clouds and Aerosol); a contributor to the Climate Change Science Program; an associate editor of the online journal Atmospheric Chemistry and Physics; and a member of the International Commission on Clouds and Precipitation. Throughout his career, he has received numerous fellowships and awards, and currently serves on steering committees for the International Global Atmospheric Chemistry Project, the Aerosol-Cloud-Precipitation-Climate research program, and the ASR Cloud, Aerosol, and Precipitation Interactions Working Group. He has been on science teams for numerous field studies and is currently engaged in planning for the DOE's Green Ocean Amazon 2014 campaign.

John Seinfeld, California Institute of Technology



Dr. John Seinfeld is the Louis E. Nohl Professor in the Divisions of Chemistry and Chemical Engineering and Engineering and Applied Science at the California Institute of Technology. His research interests lie in the formation and evolution of atmospheric aerosols and the role of aerosols in climate. He was among the earliest to establish the laboratory chamber as a means to study atmospheric aerosol formation, and data from the Caltech chamber on the formation of secondary organic aerosols have been used worldwide. He also established thermodynamic models of both inorganic and organic atmospheric aerosols, and his group has been involved in global modeling of aerosols. He has also served as the principal investigator for the Navy's CIRPAS Twin Otter aircraft, which has participated in numerous field studies worldwide, especially devoted to aerosol-cloud relationships.

Dr. Seinfeld received his PhD from Princeton University in 1967 and is a member of the National Academy of Engineering and a fellow of the American Academy of Arts and Sciences. He received the ACS Award for Creative Advances in Environmental Science and Technology and a Special Creativity Award from the National Science Foundation. He served as chair of the National Research Council (NRC) Committee on Rethinking the Ozone Problem in Urban and Regional Air Pollution and is chair of the National Research Council Panel on Aerosol Radiative Forcing and Climate Change. He has served as advisor to 78 PhDs and 39 postdoctoral fellows, 52 of whom occupy positions as faculty members in universities around the world. He has published more than 650 papers and four books.

Agenda

3rd Annual ASR Science Team Meeting
AGENDA

Hyatt Regency Crystal City
Arlington, VA
March 12–16, 2012

Sunday, March 11

4:30 p.m. – 6:00 p.m.	ARM Communications Meeting – *Invitation only*	Breakout Room 6 – Tidewater 2

Monday, March 12

Starting at 7:00 a.m.	Registration	Regency Ballroom Foyer
9:00 a.m. – 11:30 a.m.	**Morning Session** ARM Orientation for New and Current PIs	General Session Room – Regency Ballroom
11:30 a.m. – 1:00 p.m.	Lunch Break	
1:00 p.m. – 9:00 p.m.	**Breakout Sessions**	
1:00 p.m. – 3:00 p.m.	Aerosol Life Cycle IOP at BNL Arthur Sedlacek	Breakout Room 3 – Washington A
1:00 p.m. – 3:00 p.m.	Quantification of Uncertainty in Cloud Retrievals (QUICR) Shaocheng Xie	Breakout Room 4 – Washington B
1:00 p.m. – 6:00 p.m.	FAst-physics System TEstbed and Research (FASTER) Yangang Liu	Breakout Room 2 – Regency F
3:00 p.m. – 3:15 p.m.	Break	
3:15 p.m. – 5:15 p.m.	Aerosol Deep Cloud Interaction Interest Group Meeting Zhanqing Li	Breakout Room 1 – Regency E
3:15 p.m. – 5:15 p.m.	Broadband Radiometry Instrument and Measurement Interest Group – *Invitation only* Chuck Long	Breakout Room 3 – Washington A
3:15 p.m. – 5:15 p.m.	Marine ARM GCPI Investigations of Clouds (MAGIC) Ernie Lewis	Breakout Room 5 – Conference Theater
3:15 p.m. – 5:15 p.m.	Lidar Group Meeting Rob Newsom	Breakout Room 4 – Washington B
7:30 p.m. – 9:00 p.m.	Entrainment Michael Jensen	Breakout Room 2 – Regency F
7:30 p.m. – 9:00 p.m.	Instrument Team Meeting Doug Sisterson	Breakout Room 1 – Regency E

Tuesday, March 13

7:15 a.m. – 8:30 a.m.	Registration	Regency Ballroom Foyer
8:00 a.m. – 11:30 a.m.	**Morning Plenary** Opening	General Session Room – Regency Ballroom
8:00 a.m. – 9:00 a.m.	**Welcome and Introduction to Meeting**	General Session Room – Regency Ballroom
8:00 a.m. – 8:20 a.m.	Sharlene Weatherwax, Associate Director of Science for Biological and Environmental Research	General Session Room – Regency Ballroom
8:20 a.m. – 8:35 a.m.	Gerald Geernaert, Director, Climate & Environmental Science Division	General Session Room – Regency Ballroom
8:35 a.m. – 9:00 a.m.	Ashley Williamson, ASR Program Manager	General Session Room – Regency Ballroom
9:00 a.m. – 9:45 a.m.	**Invited Speakers**	General Session Room – Regency Ballroom
9:00 a.m. – 9:45 a.m.	Cloud Life Cycle Plenary Talk Clouds in CMIP5: How Can ASR/ARM Influence IPCC-Class Climate Models? Steven Klein	General Session Room – Regency Ballroom
9:45 a.m. – 10:00 a.m.	Break	
10:00 a.m. – 11:30 a.m.	**Invited Speakers (continued)**	General Session Room – Regency Ballroom
10:00 a.m. – 10:45 a.m.	Aerosol Life Cycle Plenary Talk Atmospheric Organic Aerosols John Seinfeld	General Session Room – Regency Ballroom
10:45 a.m. – 11:30 a.m.	Cloud-Aerosol-Precipitation Interactions (CAPI) Plenary Talk New Conceptual Ways of Addressing Aerosol-Cloud Interaction Graham Feingold	General Session Room – Regency Ballroom
11:30 a.m. – 1:00 p.m.	Lunch Break	
1:00 p.m. – 2:30 p.m.	**Breakout Sessions**	
1:00 p.m. – 2:30 p.m.	Midlatitude Continental Convective Clouds Experiment Michael Jensen	Breakout Room 5 – Conference Theater
1:00 p.m. – 2:30 p.m.	Azores: Results from the CAP-MBL AMF Deployment and Plans for a New Fixed Site Robert Wood	Breakout Room 4 – Washington B
1:00 p.m. – 2:30 p.m.	Ice Nucleation Xiaohong Liu	Breakout Room 2 – Regency F
1:00 p.m. – 2:30 p.m.	New Particle Formation and Evolution Peter McMurry	Breakout Room 1 – Regency E
2:30 p.m. – 2:45 p.m.	Break	

2:45 p.m. – 4:15 p.m.	**Breakout Sessions**	
2:45 p.m. – 4:15 p.m.	Convective-Stratiform-Anvil Transition (CSTAT) Ann Fridlind	Breakout Room 3 – Washington A
2:45 p.m. – 4:15 p.m.	Cloud Effects on Aerosols Robert Wood	Breakout Room 4 – Washington B
2:45 p.m. – 4:15 p.m.	Ganges Valley Aerosol Experiment (GVAX) Rao Kotamarthi	Breakout Room 1 – Regency E
4:15 p.m. – 6:30 p.m.	**Poster Session A**	Poster Session Room – Independence Center
7:30 p.m. – 9:00 p.m.	**Breakout Sessions**	
7:30 p.m. – 9:00 p.m.	Arctic Clouds/Indirect and Semi-Direct Aerosol Campaign (ISDAC) Intercomparison Mikhail Ovchinnikov	Breakout Room 3 – Washington A
7:30 p.m. – 9:00 p.m.	Radar Group Meeting Kevin Widener	Breakout Room 1 – Regency E
7:30 p.m. – 9:00 p.m.	Two-Column Aerosol Project (TCAP) Larry Berg	Breakout Room 4 – Washington B

Wednesday, March 14

7:15 a.m. – 8:30 a.m.	Registration	Regency Ballroom Foyer
8:00 a.m. – 2:30 p.m.	**Plenary** Principal Investigator Talks	General Session Room – Regency Ballroom
8:00 a.m. – 9:30 a.m.	**Principal Investigator Talks—Cloud Life Cycle**	General Session Room – Regency Ballroom
8:00 a.m. – 8:15 a.m.	Raman Lidar Retrievals of Mixed-Layer Heights Rich Ferrare	General Session Room – Regency Ballroom
8:15 a.m. – 8:30 a.m.	Precipitation Estimation from the ARM Distributed Radar Network during the MC3E Campaign Scott Giangrande	General Session Room – Regency Ballroom
8:30 a.m. – 8:45 a.m.	On the Influence of Ice Habit on the Lifetime of Arctic Mixed-Phase Clouds Kara Sulia	General Session Room – Regency Ballroom
8:45 a.m. – 9:00 a.m.	Determining Conditions for Stratocumulus Clouds at the Azores Simon de Szoeke	General Session Room – Regency Ballroom
9:00 a.m. – 9:15 a.m.	Comparison of Water Budget between AMMA and TWP-ICE Clouds Xiping Zeng	General Session Room – Regency Ballroom
9:15 a.m. – 9:30 a.m.	Improving the ECMWF's Model Representation of Supercooled Layers in Arctic Mixed-Phase Clouds Maike Ahlgrimm	General Session Room – Regency Ballroom
9:30 a.m. – 9:45 a.m.	Break	

9:45 a.m. – 11:15 a.m.	**Principal Investigator Talks—Aerosol Life Cycle**	General Session Room – Regency Ballroom
9:45 a.m. – 10:00 a.m.	Optical Properties of Moderately Absorbing Organic and Mixed Organic/Inorganic Particles at High Humidities Benjamin Brem	General Session Room – Regency Ballroom
10:00 a.m. – 10:15 a.m.	Determination of and Evidence for Non-Core-Shell Structure of Particles Containing Black Carbon Using the Single Particle Soot Photometer (SP2) Arthur Sedlacek	General Session Room – Regency Ballroom
10:15 a.m. – 10:30 a.m.	Understanding the Biogenic Species Responsible for Atmospheric New Particle Growth Paul Winkler	General Session Room – Regency Ballroom
10:30 a.m. – 10:45 a.m.	Enhanced SOA Formation from Mixtures of Biogenic and Anthropogenic Emissions during the CARES Campaign John Schilling	General Session Room – Regency Ballroom
10:45 a.m. – 11:00 a.m.	Coupling the Stochastic Particle-Resolved Aerosol Model PartMC-MOSAIC with WRF Jeffrey Curtis	General Session Room – Regency Ballroom
11:00 a.m. – 11:15 a.m.	Variability of Aerosol Properties and Mixing-Layer Heights from Airborne High Spectral Resolution Lidar, Ground-Based Measurements, and the WRF-Chem Model during CARES and CalNex Chris Hostetler	General Session Room – Regency Ballroom
11:15 a.m. – 11:30 a.m.	Discussion Period	General Session Room – Regency Ballroom
11:30 a.m. – 1:00 p.m.	Lunch Break	
1:00 p.m. – 2:30 p.m.	**Principal Investigator Talks—CAPI**	General Session Room – Regency Ballroom
1:00 p.m. – 1:15 p.m.	Comparison of Vertical Velocity Observations between the ARM Doppler Lidar and the 915-MHz Radar during MC3E Rob Newsom	General Session Room – Regency Ballroom
1:15 p.m. – 1:30 p.m.	Do Polluted Clouds Have Sharper Cloud Edges? J.-Y. Christine Chiu	General Session Room – Regency Ballroom
1:30 p.m. – 1:45 p.m.	Impact of Aerosols on Cloud and Precipitation: A Critical Review of Observational Evidence Zhanqing Li	General Session Room – Regency Ballroom
1:45 p.m. – 2:00 p.m.	Evaluation of Aerosol-Cloud Interactions in GISS ModelE Using ARM Observations Gijs de Boer	General Session Room – Regency Ballroom
2:00 p.m. – 2:15 p.m.	The Dependence of Arctic Mixed-Phase Stratus Ice Cloud Microphysics on Aerosol Concentration Using Observations Acquired during ISDAC Greg McFarquhar	General Session Room – Regency Ballroom

2:15 p.m. – 2:30 p.m.	Constraining Ice Cloud Microphysics Parameterizations in Community Atmospheric Model Version 5 Using SPARTICUS Measurements Xiaohong Liu	General Session Room – Regency Ballroom
2:30 p.m. – 2:45 p.m.	Break	
2:45 p.m. – 4:15 p.m.	**Breakout Sessions**	
2:45 p.m. – 4:15 p.m.	ARM MJO Investigation Experiment (AMIE)/Madden-Julian Oscillation (MJO) Discussions Chuck Long	Breakout Room 2 – Regency F
2:45 p.m. – 4:15 p.m.	Precipitation Susceptibility Graham Feingold	Breakout Room 4 – Washington B
2:45 p.m. – 4:15 p.m.	Ice Physical and Radiative Processes Interest Group Greg McFarquhar	Breakout Room 5 – Conference Theater
2:45 p.m. – 4:15 p.m.	Vertical Velocity Focus Group Pavlos Kollias	Breakout Room 1 – Regency E
2:45 p.m. – 4:15 p.m.	ClearFlo-Detling IOP Overview Andrew Freedman	Breakout Room 3 – Washington A
4:15 p.m. – 6:30 p.m.	**Poster Session B**	Poster Session Room – Independence Center
6:30 p.m. – 9:00 p.m.	**Evening Breakout Sessions**	
6:30 p.m. – 7:30 p.m.	AMIE/DYNAMO Observation-Modeling Integration Chidong Zhang	Breakout Room 3 – Washington A
7:30 p.m. – 9:00 p.m.	Measurements of PBL Properties Using Doppler Lidars and Wind Profilers Pavlos Kollias	Breakout Room 1 – Regency E
7:30 p.m. – 9:00 p.m.	New ARM Sites – Oliktok and Azores Mark Ivey	Breakout Room 2 – Regency F

Thursday, March 15

7:15 a.m. – 8:30 a.m.	Registration	Regency Ballroom Foyer
8:00 a.m. – 9:45 a.m.	**Morning Plenary** Research Results from Recent Campaigns	General Session Room – Regency Ballroom
8:00 a.m. – 8:15 a.m.	Awards and Meeting Comments	General Session Room – Regency Ballroom
8:15 a.m. – 8:45 a.m.	Field Campaign Talk: CARES Rahul Zaveri	General Session Room – Regency Ballroom
8:45 a.m. – 9:15 a.m.	Field Campaign Talk: RHUBC-I/II David Turner	General Session Room – Regency Ballroom
9:15 a.m. – 9:45 a.m.	Field Campaign Talk: TWP-ICE Ann Fridlind	General Session Room – Regency Ballroom
9:45 a.m. – 10:00 a.m.	Break	

10:00 a.m. – Noon	CAPI Working Group	General Session Room – Regency Ballroom
Noon – 1:30 p.m.	Lunch Break	
1:30 p.m. – 3:30 p.m.	Aerosol Life Cycle Working Group (parallel session)	Breakout Room 1 – Regency E
1:30 p.m. – 3:30 p.m.	Cloud Life Cycle Working Group (parallel session)	Breakout Room 2 – Regency F
3:30 p.m. – 3:45 p.m.	Break	
3:45 p.m.	Meeting Adjourned	
3:45 p.m. – 7:00 p.m.	Science and Infrastructure Steering Committee Meeting – *Invitation Only*	Breakout Room 6 – Tidewater 2

Friday, March 16

8:00 a.m. – Noon	Science and Infrastructure Steering Committee Meeting – *Invitation Only*	Breakout Room 6 – Tidewater 2

Abstracts

Poster Abstract Introduction

More than 240 posters will be presented during the Science Team Meeting. Author, title, and category information for each poster is included here, sorted by 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. Abstracts, as well as full-size versions of images, are available at http://asr.science.energy.gov/meetings/stm/posters/2012.

To recognize the important contributions of students to ASR research, awards will be presented for student-led posters. The student poster competition will be judged by the chairs of the three working groups. Awards will be based on content (scientific merit), clarity, and originality and will be presented during the Thursday morning plenary session.

Abstracts

Aerosol-Cloud-Radiation-Interactions

Absorption of sunlight by cloud-borne black carbon aerosol

Steven Ghan, Pacific Northwest National Laboratory
Xiaohong Liu, Pacific Northwest National Laboratory

Absorption of sunlight by black carbon (BC) aerosol can be enhanced several-fold when the particles are embedded within a larger scattering medium such as water. This enhancement is thought to contribute to the large estimates of radiative warming by anthropogenic BC. However, cloud-borne BC constitutes only a small fraction of the total atmospheric burden of BC, so solar absorption by cloud-borne BC is unlikely to contribute a large fraction to the total atmospheric absorption. Yet the collocation of cloud-borne BC with clouds suggests a potentially important role through the so-called semi-direct mechanism in which warming due to solar absorption in clouds reduces the cloud liquid water content. We have implemented solar absorption by cloud-borne BC in the Community Atmosphere Model (CAM5) and have estimated the impact of anthropogenic aerosol on the planetary energy balance with and without that absorption. We find that the direct effect of the cloud-borne BC is smaller than 0.01 W/m2, and the semi-direct effect is a cooling of less than 0.1 W/m2, with contributions from cloud changes on longwave radiation larger than shortwave radiation. This suggests that absorption of solar radiation by cloud-borne BC can be neglected in climate change simulations.

Analysis of trends in observations of aerosol concentration and radiation, also development of 20-year emission inventories and trend analysis of emissions

Chuen Gan, National Exposure Research Laboratory
Jia Xing, U.S. Environmental Protection Agency
Jonathan Pleim, U.S. Environmental Protection Agency
Rohit Mathur, U.S. Environmental Protection Agency

Anthropogenic aerosols play a key role in dictating global and regional trends in “dimming and brightening.” However, the decadal variation in the distribution of atmospheric aerosols and clouds and their effect on the radiation budget are not well understood. In order to better evaluate and characterize the behavior of aerosol and clouds in atmosphere, a long-term study of their optical properties (e.g., optical thickness, single-scattering albedo, and extinction coefficient) and physical properties (e.g., size distribution and spectral refractive index) as well as their effects on surface radiation is critical. Simulation of these trends requires an accurate description of emissions of aerosol precursors. Title IV of the U.S. Clean Air Act Amendments required annual emissions of SO2 and NOx to be reduced by ten and two million tons, respectively, from their 1980 levels. It is believed that these reductions of SO2 and NOx emissions have caused considerable effects on anthropogenic aerosol loading and regional radiation budgets over the past two decades, which is a good reference period to be researched. The main task of this study is to understand the multi-decadal changes in surface solar radiation and its relationship with the historic emission trends and associated aerosol burdens during 1990–2010. By utilizing surface measurements (e.g., ARM sites, AERONET, and CASTNET) with satellite measurements such as MODIS, CERES and CALIPSO, we obtain a better picture of the aerosol effects and radiation trend. Approximately 20 years of measurements from several sources (e.g., CASTNET, SURFRAD, and AERONET) are presented. The 20-year emission inventories over North America are developed correspondingly. National emissions inventory (NEI) air pollutant emissions trends data as well as selected years of NEI data sets and detailed hourly continuous emissions monitoring (CEM) data were used to best-estimate the emissions in both total amounts and spatial/temporal variations. This newly developed 20-year emission inventory is now being used for 3D CTM simulations of this period. From our results, the anthropogenic emissions of SO2 and NOx were significantly decreased by 66% and 49%, respectively, over the past two decades in the United States. Trends in aerosol loading and radiation inferred from surface and remotely sensed platforms will be analyzed in conjunction with estimated trends in SO2 and NOx emissions.

Ceilometer observation of clouds during Indian summer monsoon: Relation with boundary layer and surface meteorology

Narendra Singh, Aryabhatta Research Institute of Observational Sciences
Manish Naja, ARIES
D Phanikumar, ARIES
V Pant, ARIES
Umesh Dumka, ARIES
S Sahai, ARIES
P Pant, ARIES
Ram Sagar, ARIES
S. Satheesh, Indian Institute of Science
K Krishna Moorthy, Space Physics Laboratory
V. Rao Kotamarthi, Argonne National Laboratory

Monsoon is an economically important weather pattern in the Indian subcontinent and the most anticipated weather event. Yet it is only partially understood and notoriously difficult to predict. In order to understand this phenomenon at synoptic scale, it is essential to disseminate the cloud type and patterns at local scales during the season. Nainital is a high-altitude station (nearly 2 km above MSL), which often witnesses the pre-monsoon thunderstorms and rains basically driven by localized convective clouds. However, the contribution to the rains from monsoon clouds is more significant and can be better utilized to understand cloud microphysics. To study the cloud-base height and hence indicating the cloud type (basically stratiform or boundary-layer clouds) a Vaisala ceilometer (VCEIL) installed at the ARM Mobile Facility (AMF1) site (ARIES), in Nainital as part of the GVAX field campaign has been operational since June 2011. VCEIL is a self-contained, ground-based, active remote sensing device designed to measure cloud-base height to a maximum of 7.6 km and potential backscatter signals by aerosols. It transmits near-infrared pulses of light (905 nm), and the receiver telescope detects the light scattered back by clouds and precipitation at every 15 m in the vertical. These measurements are used to produce derived products that are recorded, and the data archived during monsoon are analysed. The day-to-day first cloud base observed during the month of June 2011 ranges between 400 m to 3000 m, above ground level. In addition, the data obtained from the radar wind profiler and the collocated facilities for meteorological parameters are utilized to understand the lower atmospheric dynamics over the site of study. Details will be discussed during the poster presentation.

Cirrus cloud observations over different meteorological and aerosol conditions

George Kablick III, University of Maryland
Zhanqing Li, University of Maryland

This poster presents a global analysis of cirrus clouds with A-Train observations for different meteorological regimes and background aerosol conditions. Baseline properties are established for cirrus in the tropics and midlatitudes, focusing on active convection and convective detrainment in both regions, and large-scale frontal cyclones in the mid-latitudes. Comparisons are made with cases that have increased aerosol loading from either dust or smoke entrainment. For cirrus with increased aerosol loading, CALIPSO total attenuated backscatter and MODIS radiances are consistent with dense, optically thick clouds, but CloudSat equivalent reflectivities become negligible for cases with the most extreme aerosol amounts. This may indicate that aerosols are affecting the ice particle size distribution by increasing the number concentration and decreasing the effective radius.

Combined effect of urbanization and aerosol on the light precipitation in the mid-Korean peninsula

Byung-Gon Kim, Gangneung-Wonju National University
Seung-Hee Eun, Gangneung-Wonju National University
Kyo-Sun Lim, Yonsei University
Song-You Hong, Yonsei University

Many observational and numerical studies have indicated that urbanization and aerosols can change or modify local and nearby meteorological phenomenon. Our previous study presented the analysis of long-term (1972~2007) precipitation trends in the mid-Korean peninsula around Seoul for the westerly condition, along with the WRF model simulations with the change of anthropogenic heat and surface roughness length. From 1972 to 2007, the precipitation amount (PA) and frequency (PF) together in the downwind region of Seoul significantly increased for the westerly and light precipitation (PA≤1 mm d-1) cases, while PA and PF in the mountainous area decreased. Especially the enhancement ratio of PA and PF for the downwind area versus urban area remarkably increased, implying the possible urbanization effect on the downwind precipitation. The WRF simulation applied for a golden case (2009/2/11) also demonstrated enhanced updraft and its associated convergence in the downwind area, leading to an increase in the cloud mixing ratio. Sensitivity simulation with an increase in anthropogenic heat shows that updraft is enhanced in the near-downstream region together with the low-level convergence, but creates an insignificant change in cloud water mixing ratio. On the other hand, additional simulations with the WDM6 (WRF Double-moment Six class) microphysics scheme varying CCN concentrations demonstrate a decrease in cloud water mixing ratio in the near-downstream region (up to 60 kilometers from the urban region) and an increase in far-downstream region. In spite of limitations in the observation-based analysis and simulation, the preliminary result could represent combined response such as cancellation and enhancement of urbanization and aerosol effects, especially on the light precipitation in the mid-Korean peninsula.

Comparison of boundary-layer detection between instruments at the Southern Great Plains site

Virginia Sawyer, University of Maryland
Zhanqing Li, University of Maryland

The planetary boundary layer (PBL) and its associated entrainment zone govern the mixing of pollutants into the upper troposphere, with consequences for air quality and climate simulation. The difficulty in directly observing the thermodynamic vertical structure of the atmosphere makes ground-based remote sensing particularly important. Because of the effect the PBL has on aerosol distribution, it is possible to use aerosol lidar backscatter as a proxy for the PBL. This PBL detection algorithm combines the wavelet covariance transform approach developed in Davis et al. (2000) and Brooks (2003) with an iterative curve-fitting process from Steyn et al. (1999). The former method provides a reasonable first guess for the latter, making the curve-fitting algorithm less dependent on prior knowledge while retaining its greater robustness against extraneous backscatter peaks. The lidar-derived PBL heights from multi-year retrievals at the SGP site are compared to PBLs derived from radiosonde and the atmospheric emitted radiance interferometer (AERI), both of which measure thermodynamic properties rather than aerosol.

Dependence of aerosol effect on meteorological variables

Yanni Ding, University of Maryland
Jiwen Fan, Pacific Northwest National Laboratory

Generally, aerosols influence cloud development and precipitation processes through suppression effect on shallow clouds and invigoration effects on deep convective clouds. However, it is not always the case if the meteorological variables change. Previous studies have shown the possibility of the anti-Twomey effect, and some model simulations have shown that wind shear and relative humidity (RH) can regulate aerosol's invigoration effects. This study attempts to identify and evaluate the dependence of aerosol effects on meteorological variables using long-term observational data from the ARM Southern Great Plains site. Various factors such as RH, wind shear, cloud water mixing ratio, and surface fluxes are investigated.

Do polluted clouds have sharper cloud edges?

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Julian Mann, University of Reading
Robin Hogan, University of Reading
Alexander Marshak, NASA Goddard Space Flight Center
Graham Feingold, NOAA Earth System Research Laboratory
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The transition zone between cloudy and clear air is a region of strong aerosol-cloud interactions. A number of large eddy simulations have found that clouds in more polluted air have sharper edges than those in cleaner air, due to faster evaporation of the smaller cloud droplets produced by pollution near cloud edges. If this finding is valid, cloud edge sharpness, to the extent it can be quantified from observations, can be a valuable parameter to evaluate the fidelity of aerosol-cloud microphysical parameterizations used in models. However, cloud edges are difficult to measure in reality, especially because of their tortured, fractal character, and thus this model finding has not been extensively tested from observations. In this paper, we will use high-temporal resolution zenith radiance measurements to test this model finding and to test whether aerosols modulate cloud edge sharpness in a similar degree between models and observations. We will also show how this aerosol effect varies with cloud type in environments with radically different degrees of pollution, using data collected from the ARM Mobile Facility field campaigns in China, the Azores, and Black Forest, Germany.

Doppler lidar observations over the Central Himalayan region: preliminary results

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A Doppler lidar is installed at the Aryabhatta Research Institute of Observational-Sciences (ARIES), in Nainital, India, in the Central Himalayan region as a part of the Ganges Valley Aerosol Experiment (GVAX). Doppler lidars have an eye-safe, near-infrared laser source of wavelength 1.5 µm and have a high-speed scanner to achieve 30-m, 1.2 sec, and 3.8 cm/sec vertical, temporal, and Doppler velocity resolutions respectively. Doppler lidar is mainly used to study the boundary-layer dynamics and cloud microphysics over the Central Himalayan region and has been operational since June 2011. In this context, preliminary analysis is focused on studies related to clouds and boundary-layer evolution from June 2011 to October 2011. Some clear signatures of clouds are observed in most of the cases at different height regions, which was also evident from the ceilometer. The present study also reports diurnal variations in the boundary-layer evolution over this region for the first time. Some cases of extended structures above the boundary layer have been observed; those can be attributed to elevated aerosol layers during nighttime. These observations are also related to the presence of cloud presence at an altitude region of 4.5–7km. Short period modulations in the cloud layer are also observed with a periodicity of ~ 1 hour, which can either be attributed to short-period gravity waves or mountain waves generated due to the orography of the site. Our preliminary observations will be discussed in the light of current understanding of the boundary-layer dynamics.

Droplet closure analysis of Arctic stratocumulus clouds during ISDAC

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Motivated by the climate implications of aerosol-cloud relationships in the Arctic, the Indirect and Semi-Direct Aerosol Campaign (ISDAC) was conducted in Alaska in April 2008. An instrumented research aircraft provided the platform for process-based analysis of these relationships through an aerosol-cloud droplet closure study. Measurements of aerosol particles below the base of stratocumulus clouds, representing potential cloud condensation nuclei, were obtained using an optical probe (PCASP-100X) for number concentration and size information and a single particle mass spectrometer (SPLAT II) for composition information. Measurements of droplet properties within cloud were obtained using two optical probes (CDP and FSSP-100). The updraft velocity (w) was measured in-cloud using a gust probe and also simulated in a large-eddy simulation cloud model (LES). Using a separate adiabatic parcel model, representations of w based on both the measurements and LES output were used to simulate cloud droplet number concentrations (CDNC), with the objective of increasing knowledge of how updrafts influence CDNC. Cases considered in the analysis were separated into two regimes with respect to aerosol particle number concentration (Na): three clean cases (Na < 250/cc), characteristic of background and boundary-layer concentrations in Arctic spring; and three polluted cases (Na > 250/cc) influenced by biomass burning plumes. The updraft velocity for each case was considered in terms of the normally distributed probability distribution function (PDF). Separate sets of parcel model simulations, in which CDNC was computed by integrating over the in-cloud PDF or by using a single, characteristic updraft velocity w*, gave modelled CDNC values within the estimated measurement uncertainty (Figure 1). However, the specific values of w* that produced the best agreement between measured and modelled CDNC differed for clean and polluted cases, owing to differences in activation between the regimes. Updraft velocity PDFs from the LES compared favourably with observations, pointing to their potential use in model parameterizations when measurements are not available. The results from this analysis improve our understanding of updraft-CDNC relationships in Arctic clouds, helping us move toward a better representation of aerosol activation processes in global models.

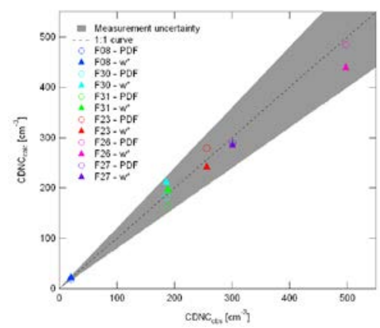

Figure 1: Comparison of cloud droplet number concentrations (CDNC), calculated using an adiabatic parcel model with two different representations of the updraft velocity, with CDNC values observed in-cloud. Six cases during ISDAC are considered: three from flights in clean aerosol conditions (F08, F30, F31) and three from flights in polluted aerosol conditions associated with biomass burning plumes (F23, F26, F27).

Episodes of enhanced condensation nuclei concentrations during the GVAX campaign at ARIES, Nainital

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K Krishna Moorthy, Space Physics Laboratory
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Simultaneous measurements of condensation particles (NCN) and cloud condensation nuclei (NCCN) concentrations were made along with the measurements of solar radiation and meteorological parameters during the Atmospheric Radiation Measurement Mobile Facility (AMF1) deployment at a high-altitude site—ARIES, Nainital (29.4°N, 79.5°E; 1950 m amsl)—in central Himalaya as part of the Ganges Valley Aerosol Experiment (GVAX). The preliminary analysis of the data obtained during June 15–September 30, 2011, shows significant signatures of transport of atmospheric particles to the observation site with prevailing and episodic winds over the region. While the nominal concentrations of NCN, with some occasional spikes, were in the range of 500–2000 cm-3, their concentration increased to about four times with a change in surface wind direction. A similar trend in concentrations of NCCN with respect to the change in wind direction was also observed at all seven air supersaturations between -0.01 to + 0.75%. The absolute increase in NCCN during the episodes of reversal of surface winds was more in higher supersaturations (> 0.31 %). The wind-rose diagram clearly shows two prominent wind direction sections, i.e., easterly/southeasterly sector and westerly/northwesterly sector with frequency of occurrence ~30% and ~4 % of total winds, respectively. The wind speed versus wind direction scatter diagram suggests stronger winds of the order of 6–12 ms-1 associated with the westerly sector. The pronounced signatures of transport of aerosol particles with prevailing winds are clear from these observations and suggest different origins for the air masses arriving at observation site. The 5-day backward trajectories derived from the HYSPLIT trajectory model also indicate different pathways of transport of air parcels with changes in wind directions during the southwest monsoon period. In addition to scavenging of aerosols due to precipitation, the events of new particle formation and role of aerosols in modifying cloud properties will be studied from the GVAX data. Detail analysis of data from additional instruments operated in GVAX is planned to understand the physical properties of aerosols in the Ganges valley and their effect on monsoons and climate of the region.

Evaluation of aerosol-cloud interactions in GISS ModelE using ARM observations

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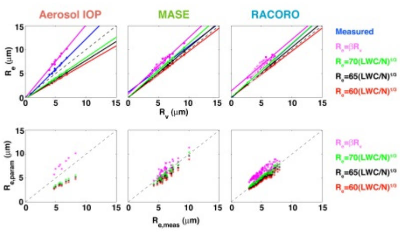
Andrew Vogelmann, Brookhaven National Laboratory
Maureen Cribb, University of Maryland

The impacts of aerosol particles on clouds continue to rank among the largest uncertainties in global climate simulation. In this work we assess the capability of the NASA GISS ModelE, coupled to MATRIX aerosol microphysics, in correctly representing warm-phase aerosol-cloud interactions. This evaluation is completed through the analysis of a nudged, multi-year global simulation using measurements from various U.S. Department of Energy-sponsored measurement campaigns and satellite-based observations. Campaign observations include the Aerosol Intensive Operations Period (Aerosol IOP) and Routine ARM Aerial Facility Clouds with Low Optical Water Depths (CLOWD) Optical Radiative Observations (RACORO) at the Southern Great Plains site in Oklahoma, the Marine Stratus Radiation, Aerosol, and Drizzle (MASRAD) campaign at Pt. Reyes, California, and the ARM Mobile Facility's 2008 deployment to China. This combination of data sets provides a variety of aerosol and atmospheric conditions under which to test ModelE parameterizations. In addition to these localized comparisons, we evaluate the global impact of changes in parameterizations studied. We will provide a basic overview of simulation performance, as well as a detailed analysis of parameterizations relevant to aerosol indirect effects.



Evaluation of effective radius parameterizations using measurements from three ARM campaigns. The top row compares volumetric radius against parameterized and measured droplet effective radius, while the bottom row compares measured and parameterized values for effective radius.

How do aerosols impact atmospheric circulation and radiative forcing through deep convection?

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L. Ruby Leung, Pacific Northwest National Laboratory
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Yanni Ding, University of Maryland

Aerosol-cloud interaction is recognized as one of the key factors influencing cloud properties and precipitation regimes. For deep convection clouds (DCCs), latent heat could be significantly changed through aerosol microphysical effects, which could impact large-scale circulation. The study explores the possibilities of changes on large-scale circulation through aerosol microphysical effect by examining how aerosols change horizontal and vertical mass fluxes, latent heat, and radiation fluxes under different wind shear conditions for typical convective clouds (i.e., warm- and cold-based) from the ARM Mobile Facility (AMF) China field campaign and the Southern Great Plains (SGP) intensive operational period (IOP) 2006. Using model simulations from the Weather Research and Forecasting (WRF) model coupled with a spectral-bin microphysics (SBM) and the observational analysis from the long-term data at the SGP site, we demonstrate that large-scale circulation can be dramatically changed by aerosols through modifying latent heat and updraft and downdraft mass fluxes. Under weak wind shear conditions, aerosol microphysical effects invigorate DCC, enhance latent heat release, and increase vertical velocity and subsidence. The effect is particularly significant for warm-based DCC. However, it does not hold anymore when wind shear becomes stronger. For both warm- and cold-based DCC, the changes on latent heat, vertical velocity, and vertical mass fluxes are becoming much smaller. We note that increasing wind shears could change the sign of aerosol impact on convective strength: from the invigorating effect under the weak wind shear to the suppressing effect when wind shear gets stronger, consistent with our previous finding for an isolated DCC case. This finding may significantly enhance our understanding in aerosol-deep convection interactions and provide a scientific basis to better parameterize aerosol effects on convection and large-scale circulation. Therefore, it will have important implications for reducing uncertainties in climate simulations and projection.

Impact of aerosols on cloud and precipitation: a critical review of observational evidence

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As a major agent for clouds to form and a significant attenuator of solar radiation, aerosols can significantly alter cloud properties and precipitation. Identification of such effects has been a major challenge, for the latter two variables are dictated primarily by meteorological conditions. The availability of extensive coherent measurements of aerosol and meteorological variables from ground-based, space-borne, and airborne sensors have accumulated such ample data from which it is possible to detect the impact of aerosol on cloud and precipitation from the influences of meteorological variables, although attribution and quantification are always fraught with uncertainties and difficulties. Well-designed field campaigns and careful analysis of multiple data sets are required to address this issue from an observational viewpoint. In this review, I will present some sound observational evidence obtained from a variety of platforms including satellite sensors (e.g., A-train), conventional meteorological stations, and extensive and high-quality ground-based observations such as the U.S. Department of Energy's Atmospheric Radiation Measurement (ARM) Climate Research Facility. ARM has provided such rich information, it is possible to investigate the climatological effects of aerosol-cloud-precipitation interactions beyond case-by-case studies. Despite ever-escalating efforts and the virtually exponential increase in published studies concerning aerosol-cloud-precipitation interactions, we are still puzzled by many seemingly contradictory findings, attesting to the complexity of the problem. Many findings reported are critically reviewed, especially those concerning aerosol and convective cloud and precipitation, based on a recent review study by Tao et al. (2012, Reviews of Geophysics).

Investigation of aerosol optical properties and their sources using GVAX surface data, satellite observations, and WRF-Chem model

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The Indo-Ganges Valley is a regional hotspot polluted with high aerosol concentrations. During the monsoon season, aerosols can be elevated by strong convection to high altitudes in the mid- and upper troposphere and thus have a significant impact on clouds and precipitation. It has also been hypothesized that the build-up of aerosols in the dry winter may affect the onset and intensity of the summer monsoon. The focus of the present study is to examine aerosol optical properties and vertical distribution over the Indian subcontinent during the 2011 monsoon to post-monsoon months (July to October) using surface data, satellite observations, and regional WRF-Chem model simulations. We will present preliminary evaluation of aerosol vertical transport using the ground-based profiling of aerosol extinction, cloud liquid water, water vapor, and temperature at Nainital from the ongoing Ganges Valley Experiment. Spectral measurements of aerosol absorption will be used to investigate aerosol sources and mixing state. We will also present the WRF-Chem simulations of aerosol distributions, vertical profiles, and optical properties over south Asia, constrained with the GVAX surface data and the CALIPSO satellite observations. Aerosol heating effect and radiative impact on clouds will be discussed. These observation and model studies will provide insights on the aerosol composition, transport, and climate effects over this region.

Investigation of multi-decadal trends in aerosol direct radiative effect using a continental-scale coupled meteorology-chemistry model

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Rohit Mathur, U.S. Environmental Protection Agency
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While aerosol radiative effects have been recognized as some of the largest sources of uncertainty among the forcers of climate change, there has been little effort devoted to verification of the spatial and temporal variability of the magnitude and directionality of aerosol radiative forcing. A comprehensive investigation of the processes regulating aerosol distributions, their optical properties, and their radiative effects is needed in order to build confidence in the projected impacts from changes in anthropogenic forcing and climate change. This study addresses this issue through a systematic investigation of changes in anthropogenic emissions of SO2 and NOx over the past two decades in the United States, their impacts on aerosol loading in North America, and subsequent impacts on regional radiation budgets. A newly developed two-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 run for 20 years (1990–2010) on a 12-km resolution grid that covers most of North America. During this period, U.S. emissions of SO2 and NOx have been reduced by about 66% and 50%, respectively, mainly due to Title IV of the U.S. Clean Air Act Amendments that aimed to reduce emissions that contribute to acid deposition. Thus, by simulating this period we can assess model performance for reproducing observed trends in air pollutants, such as sulfate and nitrate aerosols, and their consequences on trends in surface radiation. The WRF/CMAQ model includes direct effects of aerosols on SW radiation and the direct effects of tropospheric ozone on LW. A new Mie scattering algorithm has been developed for a wider range of wavelengths, which will enable consideration of aerosol direct effects on LW radiation. The two-way WRF-CMAQ also includes an experimental implementation of indirect effects where aerosols from CMAQ are activated as CCN 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. Indirect effects are being tested by comparing cloud radiative forcing to satellite and aircraft measurements. Preliminary model simulations for the summer seasons of 1990 and 2006 are being evaluated both for their performance in comparison to observed concentrations and simulation of observed trends in concentrations and surface radiation.

Large-scale thermodynamic and dynamic controls on aerosol-induced invigoration of tropical deep convection

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Wojciech Grabowski, National Center for Atmospheric Research

Several modeling studies have supported the idea of convective invigoration in polluted conditions resulting from a delay in warm rain formation and release of additional latent heat through enhancement of freezing. However, this process-level viewpoint neglects feedbacks between convection and its environment, which may obscure the effects of cloud microphysics. To investigate such interactions, we performed multi-day large-member ensemble cloud-resolving simulations with increased latent heating in updrafts above the freezing level, mimicking the effect of enhanced ice processes in polluted conditions. Increased latent heating produces an initial invigoration, but convection returns to its unperturbed characteristics over a timescale of several hours because of accompanying changes in mean stability. Factors controlling the adjustment timescale will be discussed. The significant difference in temperature profiles in simulations with and without latent heating perturbations (of order 1 K) suggests that strong mesoscale circulations may develop between perturbed and unperturbed regions. To investigate this aspect, simulations were performed with heating perturbations applied in updrafts, but only to a portion of the domain. In these simulations, larger-scale circulations driven by differences in mean radiative and latent heating between the perturbed and unperturbed regions help to sustain weak convective invigoration in the perturbed region. Overall, these results suggest that convective invigoration from aerosol-induced enhancement of freezing and latent heating may occur but is limited primarily to the impacts on larger-scale heating gradients and circulations. This presents a much different picture compared to previous studies in which only convective-scale buoyancy effects were considered.

Microphysical and radiative properties of the ISDAC 26 April mixed-phase case

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David Mitchell, Desert Research Institute
Eric Jensen, NASA Ames Research Center

In situ microphysical data collected by the Canadian Convair 580 are analyzed in detail. The Convair executed a sawtooth pattern through a shallow (300-meter thick) single-layer mixed-phase cloud, climbing and descending five times from below cloud base to above cloud top. Measurements from a Fast FSSP, 2D-S, HVPS, and CPI are used to separate particles into water drop and ice particle size distributions. CPI images are analyzed to size-sort water drops from ice particles. CPI image sorting is combined with fast FSSP, 2D-S, and HVPS measurements to produce quantitative ice and water drop size distributions. CPI and 2D-S images are used to determine ice particle habit. Optical properties of water drop and ice size distributions are computed and fed into a radiative transfer model to determine cloud heating rates. The cloud heating rates using actual measurements are compared with results from a numerical model using typical parameterizations.

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

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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.

Microphysical properties of boundary-layer mixed-phase clouds observed in Ny-Alesund, Svalbard: observed cloud microphysics and calculated optical properties

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Akihiro Yamazaki, Meteorological Research Institute
Masataka Shiobara, National Institute of Polar Research
Hiroshi Kobayashi, University of Yamanashi

The cloud-radiation interaction plays an important role in the global climate system and has been investigated by many researchers. However, the understanding of mixed-phase boundary-layer clouds in the Arctic has remained one of the unknown factors. During the period of May to June, 2011, in situ measurement of mixed-phase boundary-layer clouds were carried out at Zeppelin Station of Norwegian Polar Institute (NPI) in Ny-Alesund (78.9N, 11.9E), Svalbard. The instruments consist of Cloud, Aerosol and Precipitation Spectrometer (CAPS), PVM-100 (Gerber Particulate Volume Monitor), and Cloud Particle Microscope imager (CPM). CAPS is composed of Cloud and Aerosol Spectrometer (CAS) and Cloud Imaging Probe (CIP). CAPS-CAS and CAPS-CIP have the same measurement capabilities of the Forward Scattering Spectrometer Probe (FSSP) models 100 and 300 and two-dimensional optical imaging probe (2D-OAP), respectively. PVM-100 measures liquid water content and effective radius of water droplet clouds. CPM, which was newly developed by one of the authors, consists of a CCD camera and microscope and takes an image of cloud particles. These instruments were installed on the roof of Zeppelin Station of NPI, which is near the top of Mt. Zeppelin and is at an altitude of 474 m. During the observation period, the clouds associated with cyclonic disturbance and the clouds associated with outbreak of westerly cold air mass from the sea were observed. The atmospheric temperature during all the measurements is from 0° to -5°C. In every case, the large part of cloud particles that were measured by CAPS-CIP consisted of column type. We show the cloud microphysical properties on June 9, 2011: cloud particle size spectrum, liquid water content, ice water content, and so on. We also show the optical properties calculated based on the observed cloud microphysical properties.

Multi-scale observations of small cloud systems

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Graham Feingold, NOAA Earth System Research Laboratory
Andrew Vogelmann, Brookhaven National Laboratory

Shallow cumulus dominates cloud feedbacks in general circulation models (GCMs) and also exhibits the greatest amount of inter-model spread. A major challenge for this cloud regime is that the horizontal dimension of a GCM grid cell is large relative to the high frequency variability that governs radiative forcing. Evaluation of these models is often based on means, or sometimes simple distributions of properties retrieved from space; however, simple averaging of sub-grid scale variability may create biases in the representation of individual properties or parameterizations that are not based in physics. Sub-grid distributions of cloud liquid water, cloud fraction, and microphysical properties are essential for representing accurate grid-scale radiative fluxes but raise some questions: To what extent do distributions of cloud characteristics vary under different conditions of aerosol concentrations or environmental variables? What are the factors controlling the various distributions? Do distributions vary as a function of observational approach or scale? To answer these questions, we combine surface, in situ (RACORO), and satellite observations at ARM’s Southern Great Plains site. We analyze radiatively pertinent characteristics of small clouds and their determining factors, including the larger-scale environmental state, cloud-scale dynamics, and aerosol. The internal consistency of these systems is examined using multivariate distributions of many of these properties.

A new three-moment-based framework for parameterizing CCN and droplet activation

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Peter Daum, Brookhaven National Laboratory
Robert McGraw, Brookhaven National Laboratory
Mark Miller, Rutgers University

Aerosol effects on clouds and precipitation in large-scale models and the subsequent effects on radiative properties and climate remain one of the most uncertain climate forcings. Much of the uncertainty arises from poor understanding and quantification of the relationship of aerosol properties to cloud condensation nuclei (CCN) and further to cloud properties. Most existing parameterizations are based on either one moment (aerosol mass or number concentration) or two moments (aerosol number and mass concentration), and further, on the assumption of known mathematical forms of aerosol size distributions such as the power-law, lognormal, Gamma, and Weibull distributions. To evaluate parameterization of aerosol-cloud interactions in climate models against long-term ARM measurements poses a further challenge. To address these challenges as part of the FASTER project, this study extends previous works by establishing a new theoretical framework based on three aerosol moments that accounts for not only aerosol number concentration and mass concentration, but also the relative dispersion of aerosol size distribution. The new three-moment framework permits quantification of the differences in CCN spectra and cloud properties resulting from using those commonly assumed forms of aerosol size distributions. Measurements collected at the ARM SGP site will be examined in the context of evaluating the new formulation. The results will shed light on how to best use ARM aerosol-related measurements to evaluate model performance.

A numerical investigation of the aerosol effects on a mesoscale convective system

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Priyanka Roy, George Mason University

Mesoscale convective systems (MCS) are frequent occurrences during summer months in the midwest of the United States and bring almost 30% of the rainfall to the region. This work investigates the effects of anthropogenic aerosols, like sulfate and black carbon, and natural aerosols like dust on an MCS. The coupled meteorology and chemistry Weather Research and Forecasting– Chemistry (WRF–Chem) model was employed for the numerical study of the MCS. The selected MCS case occurred on June 20, 2007, covering large parts of Kansas, Oklahoma, and northern Texas. The aerosol effects are analyzed by inputting the aerosol optical properties into the shortwave scheme and the physical properties into the microphysics scheme. The interaction of aerosols with the incoming shortwave radiation is higher due to the wavelength being similar to particulate sizes found in the atmosphere. The nested domain simulations have higher inner domain resolutions (6 and 1.5 km) and as a result resolved the MCS reasonably well. The combined aerosol effects are investigated by increasing the amount of the sulfate, black carbon, and dust aerosols and considering their dominant characteristics. Sulfates are the major constituents of the anthropogenic emissions, and they are scattering and reflecting in nature. On the other hand, black carbon and dust absorb radiation, evaporating clouds and also warming the atmosphere. The dust particulates form giant cloud condensation nuclei (CCN), which can enhance precipitation in the presence of moisture in the atmosphere. The combination of the radiative effects due to each of these aerosols has shown that scattering due to aerosols is a dominant factor for all the types of aerosols. The presence of aerosols interacting with the microphysics and radiation schemes produces a more organized MCS structure, as well as more liquid and ice clouds. The black carbon particulates do not solely warm the atmosphere, but also prevent a large amount of the solar radiation from reaching the surface. The giant CCN due to dust particles enhances the precipitation instead of suppressing it. Thus two absorbing aerosols when increased in amounts show very different effects on cloud cover and precipitation.

Obtaining number of activated CCN from satellite-retrieved vertical profiles of cloud drop size in convective clouds

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Here we present our first preliminary results from the first year of the funded proposal titled "Vertical microphysical profiles of convective clouds as a tool for obtaining aerosol cloud-mediated climate forcing." A major challenge towards this goal is retrieving CCN from space in the cloudy boundary layer. CCN can be obtained if we can retrieve the number of activated CCN, Na, and the maximum super saturation near cloud base, S. We have already shown that vertical profiles of aircraft-measured cloud drop effective radius, Re, in convective clouds can be used for calculating Na (Freud et al., 2011). In principle, the same can be achieved with satellite-retrieved vertical profiles of Re in convective clouds. When combining Na with estimated cloud base updrafts, S can be calculated and respectively the CCN concentration at that S can be obtained. We used such satellite retrievals for calculating Na in convective clouds over the SGP site and compared Na to the CCN measured at the ground. Lidar measurements are used for validating that the cases are in well mixed boundary layer, so that the surface-measured CCN are applicable to the cloud base. The S for which CCN and Na are the same is found, and the required updraft for sustaining this S is calculated using the model developed in the companion research of Dr. Khain. The validation of this method will pave the way for retrieving Na in convective clouds from MODIS and AVHRR, as a major milestone towards quantifying the climate impacts of cloud-aerosol interactions. Reference: Freud E, D Rosenfeld, and JR Kulkarni. 2011. “Resolving both entrainment-mixing and number of activated CCN in deep convective clouds.” Atmospheric Chemistry and Physics 11: 12887–12900, doi:10.5194/acp-11-12887-2011.

Parameterizing ice nuclei concentration dependence on aerosol concentration, temperature, and composition

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It has been suggested that ice nuclei concentrations active in mixed-phase cloud conditions can be parameterized in an average sense for global models as a function of aerosol concentrations > 0.5 micron and temperature alone (DeMott et al. 2010). Comparison of this parameterization with independent ice nuclei and aerosol data collected in the Indirect and Semi-Direct Aerosol Campaign (ISDAC) suggests that such a representation may be quite suitable for use in modeling ice nuclei influences on Arctic mixed-phase clouds. Nevertheless, additional dependencies on aerosol composition can be expected at different times and places: for example, where stronger local and regional sources exist. In any case, quantifying compositional dependencies would be expected to provide more robust prediction of ice nuclei concentrations for use in modeling studies. Here we report on measurements of ice nuclei specific to strong potential sources such as desert dust plumes, smoke plumes, ocean wave spray, and terrestrial biological particles. We utilize data from both laboratory and field studies to show that consideration of ice nuclei sources can potentially provide more robust parameterizations for models that are capable of specifying different compositional categories for ice nuclei. Reference: DeMott, PJ, AJ Prenni, X Liu, MD Petters, CH Twohy, MS Richardson, T Eidhammer, SM Kreidenweis, and DC Rogers. 2010. "Predicting global atmospheric ice nuclei distributions and their impacts on climate." Proceedings of the National Academy of Sciences 107 (25): 11217–11222.

Preliminary results from the Nainital AMF study

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The first ARM Mobile Facility (AMF1) has been operating at Nainital, India, since June 2011. Several months of data from the aerosol observing system, meteorology, radiative transfer, and cloud properties are now available. Here we present some preliminary analysis of the observations of aerosol physical and optical characterization and radiation measurements. The analysis will focus on the observations before monsoon, during the monsoon, and post-monsoon at the site. The various options of using the aerosol measurements to determine the brown carbon fraction from the available total absorption measurements at this site, the episodes of high absorption at this site and then prevailing meteorological conditions during these periods and the diurnal patterns will be presented. We will try to answer the question about the aerosol optical depth measured at this site and the contribution of black carbon, brown Carbon and dust. Measurements of radiation will be used to constrain the estimates in addition to the aerosol measurements.

Quantifying aerosol direct effects from broadband and spectral irradiance observations

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Chuck Long, Pacific Northwest National Laboratory

We outline a methodology using broadband and spectral irradiance observations to quantify aerosol direct effects on the diffuse shortwave (SW) surface irradiance. The data span an 11-year (January 1998–May 2010) timeframe at the Department of Energy Atmospheric Radiation Measurement (ARM) Climate Research Facility Southern Great Plains (SGP) site. Identified irradiances (Long and Ackerman 2000) and aerosol optical depth (τa), for solar zenith angles ≤ 65° are used to derive an empirical formulation to estimate clear-sky diffuse irradiance. Our approach estimates aerosol effects using ancillary input regarding changes in τa; Long and Ackerman (2000) excludes such input. The method is verified using irradiance observations from SGP's Basic Radiation System (BRS). We evaluated the degree of accuracy of the considered correlation to fit the BRS observed data using the root mean square error (RMSE; non-systematic error) and mean bias error (MBE; systematic error). Resulting BRS diffuse irradiances were in accordance with estimates, producing a RMSE and MBE of 4 W/m2 and 1.4 W/m2, respectively. Frequency histograms of the absolute difference between the BRS and estimated diffuse show 99% of estimates are within ±10 W/m2 of BRS observations. The clear-sky diffuse estimates are used to derive quantitative estimates of aerosol radiative effects as a difference between measured and clear-sky (i.e., background aerosol conditions; τa = 0.008) amounts, represented as aerosol diffuse irradiance (ADI). The diurnal mean ADI ranges from about -50 W/m2 to 120 W/m2, implying notable altering in the relative proportion of the diffuse fraction due to scattering processes from changes in τa. Negative estimates are due to possible misidentification of clear skies, measurement errors, vagaries in fitting, and errors in τa retrieval. The estimated slope for the ADI as a function of τa was 229.59 W/m2 per unit τa, indicating an increase of ~23 W/m2 in diffuse SW per unit τa. This positive relationship suggests significant increases in the diffuse fraction in the presence of aerosols could possibly increase photosynthesis at SGP (Xia et al. 2007). Estimates of aerosol effects on the diffuse fraction are required to understand how much direct forcing is canceled out, how increased scattering at the surface leads to more efficient use of sunlight by plant canopies, and how much of the diffuse fraction increases under varying aerosol conditions (e.g., urban, rural, and oceanic).

RACORO aircraft data case study development for FASTER

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As part of the FAst-physics System TEstbed and Research (FASTER) project, RACORO aircraft data are being used to construct case studies to assess and improve models of continental boundary-layer clouds (stratus, stratocumulus, and cumulus). RACORO was a first-of-a-kind, extended-term cloud aircraft campaign that was conducted by the Atmospheric Radiation Measurement (ARM) Aerial Facility (AAF) to obtain an in situ statistical characterization of boundary-layer clouds. The field campaign operated for five months over the ARM Southern Great Plains (SGP) site, from 22 January to 30 June 2009, collecting 260 hours of data during 59 research flights over a range of conditions associated with the winter-to-summer seasonal transition. A comprehensive payload aboard the Center for Interdisciplinary Remotely Piloted Aircraft Studies (CIRPAS) Twin Otter aircraft measured cloud microphysics, solar and thermal radiation, aerosol properties, and atmospheric state parameters. Proximity to the SGP's extensive complement of surface measurements provides additional data that support development of these case studies for use by FASTER and the Atmospheric System Research community.

Study of mechanisms of aerosol indirect effects on glaciated clouds

Vaughan Phillips, University of Leeds

The Tropical Warm Pool-International Cloud Experiment (TWP-ICE) campaign, partly funded by the U.S. Department of Energy, involved observations of aerosol size distributions and aerosol composition with probes flown on aircraft near Darwin in Australia, as well as microphysical properties of glaciated clouds. In this presentation, microphysical improvements to an aerosol-cloud model using our newly developed scheme of 2-moment bulk microphysics, including an empirical scheme to treat heterogeneous ice nucleation, and prognostic treatment of six aerosol species are described. These improvements include treatment of size-dependent morphology (bulk density, shape) of ice particles and use of emulated spectral (bin) microphysics to treat collision and sticking efficiencies of coagulation. A month-long simulation of the TWP-ICE case by the aerosol-cloud model is compared against observations of ice and droplet concentrations for cases with coincident observations of aerosol and thermodynamic conditions as its input. Detailed treatments of droplet evaporation near -36°C during homogeneous droplet freezing and of the evolving mean size of sulphate aerosol are shown to enable correct prediction of ice concentrations by the aerosol-cloud model. For cold clouds generally, the problem of whether it is possible to predict correctly the observed ice concentration using as input the observed aerosol conditions is discussed.

Value-added Product Highlights from the Cloud-Aerosol-Precipitation Interactions Working Group

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We will present an update on the development of value-added products (VAPs) associated with the Cloud-Aerosol-Precipitation Interactions (CAPI) working group. VAP highlights for this year include the following efforts: (1) Initial development of a planetary boundary-layer height (PBL Height) product. (2) Re-processing of all historical QCRAD data to correct algorithm errors, make quality control flags consistent, add instrument-specific corrections for infrared loss, and submit data quality reports (DQRs) on the input and output data. (3) Submission of data from the Cloud Condensation Nuclei Profile (CCNPROF) data to the ARM Evaluation Area and initial comparison to aircraft data. (4) Release of the Radiatively Important Parameters Best Estimate (RIPBE) code and submission of five years of data to the ARM Data Archive. (5) Processing of five years of instantaneous broadband heating rate profiles using RIPBE data (BBHRP-RIPBE) and submission of the data to the ARM Evaluation Area. (6) Prototype of RIPBE and BBHRP averaged products for flux closure evaluation. (7) Processing of all historical micropulse lidar (MPL) data through the MPL cloud mask (MPLCMASK) algorithm. (8) Processing of microwave radiometer retrieval (MWRRET), MPLCMASK, and QCRAD for AMF deployments. We will also discuss plans for future CAPI VAP efforts including continued work on the PBL Height product, addressing user comments and updating CCNPROF, development of a BBHRP testbed, and implementation of a new retrieval for the 3-channel microwave radiometers.

Vertical profiling of meteorological parameters using AMF1 in the central Himalayan region during GVAX: implications on aerosols and trace gases variations

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The Indo-Gangetic Plain (IGP) region in northern India is one of the most populated regions of the world and encompasses a variety of anthropogenic and biogenic emission sources. This region is considered to be the most polluted region in India. However, ground-based observations are very limited to verify the same. Model simulations show vertical lifting of pollutants from this region and the widespread transport during prevailing higher wind speed, hence influencing the radiation budget, chemical composition, and air quality over a wide region. Further, the chemical characteristics of the South Asian emissions are different from those in other parts of the world because of their disproportionately large contribution from bio-fuel and biomass burning, making this region a unique place for tropospheric studies. In view of this, the first ARM Mobile Facility (AMF1) has been set-up at ARIES, Nainital (29.37°N, 79.45°E; 1958 m amsl), under the GVAX field campaign. Observations of physical-optical properties of aerosols, radiation, and meteorological parameters are being made since June 2011. Vertical profiling of meteorological parameters are also being made using radiosonde launches at 00, 06, 12, and 18 GMT on a regular basis. Vertical winds are being measured using a wind profiler. A Doppler lidar, microwave radiometer profiler, and ceilometer are also operational. Seasonal variation in the tropopause height is estimated, and its dynamical nature is analyzed. Diurnal and seasonal variation in the boundary-layer mixing height is derived, and its implication on trace gases and aerosols are studied. Apart from regional emissions and biomass burning, impacts of long-range transport are studied. Setup of a WRF-Chem is also in progress for GVAX-related studies. Details will be discussed during the poster presentation.

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Abstracts

Aerosol Properties

Aerosol measurements in the free troposphere at the North Atlantic Pico Mountain Observatory in the Azores

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Sumit Kumar, Indian Institute of Tropical Meteorology
Seth Olsen, University of Illinois
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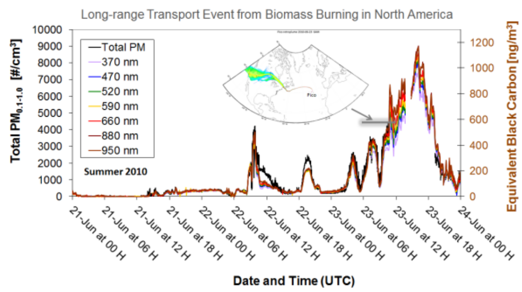
Pico is a small island (447 km2) in the archipelago of the Azores, Portugal, in the North Atlantic Ocean. The island has a very steep inactive volcano. An atmospheric monitoring station (Pico Mountain Observatory) was established close to the summit of the volcano by the late Dr. Richard Honrath and colleagues in 2001. The station, far from persistent local sources, is located near the northern cliff of the summit caldera at an altitude of 2225 meters. The station altitude is typically well above the boundary layer during summertime, when average marine boundary-layer heights are below 1200 meters and rarely exceed 1300 meters. Air masses reaching the station are often transported from North America and seldom from Europe or North Africa. The station's uniqueness and significance lie in its location that allows study of the transport and evolution of gases and aerosols from North America in the free troposphere. Until recently, the focus was on the measurement and analysis of trace gases (ozone, carbon monoxide, non-methane hydrocarbons, nitrogen oxides) and light-absorbing aerosol (black carbon and iron oxide). Aerosol light attenuation has been measured at the site since 2001 using a seven-wavelengths aethalometer. An optical particle sizer was installed at the site in 2010 and has been running in parallel to the aethalometer for two seasons. A three-wavelength nephelometer, to measure the aerosol total- and back-scattering, and aerosol samplers for morphological and chemical analysis will be installed at the site in 2012. Our goal is to enhance the observatory monitoring capabilities for aerosol research. The objectives of this new research program are to: (a) assess background as well as specific event tropospheric aerosol properties, (b) compare aerosol and gases measurements with model outputs, and (c) use the data collected to provide satellite validation. This research is anticipated to enhance our understanding of the interactions between tropospheric aerosols, clouds, and climate by allowing, for example, the analysis of North American outflows and seasonal changes, the assessment of different source regions, the estimation of aerosol radiative forcing above marine clouds and in clear sky, and the study of the relative contribution of anthropogenic versus biomass burning emissions. In this poster we present a preliminary analysis of the black carbon and aerosol size data in conjunction with retroplume model analysis.



Long-range transport event from biomass burning in North America to the Pico Mountain Observatory in the Azores, Portugal.

Aerosol optical depth at the ARM Mobile Facility deployments

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Connor Flynn, Pacific Northwest National Laboratory

The aerosol optical depth (AOD) is the most fundamental property related to the abundance of aerosol in the atmospheric column and its direct radiative effect. This property is of critical importance in describing the significance of aerosols present at a given location. One of the key instruments within ARM capable of retrieving this core parameter is the multifilter rotating shadowband radiometer (MFRSR). The MFRSR-AOD value-added product has been operating routinely for ARM fixed-sites for several years; however, the automated routines developed for these locations were repeatedly challenged by the unique conditions presented by AMF locations. We describe adaptations of the automated routines that were implemented to retrieve AOD from the MFRSR instruments at the AMF deployments. Time series of successful AOD retrievals spanning the duration of each AMF deployment are presented.

Aerosol optical depth climatology derived from micropulse lidar data at various ARM sites worldwide

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Micropulse lidar (MPL) systems have been running at all U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Climate Research Facility sites, including five permanent and two mobile facilities. The locations of the sites represent a broad range of climate conditions around the world (http://www.arm.gov/sites). Aerosol optical depth (AOD) is a measure of the extinction of solar radiation due to aerosols: liquid and solid particles suspended in the air from natural or man-made sources. In the absence of clouds, the MPL, operating at 532 nm, produces profiles of atmospheric scattering that result from aerosols (Mie-scattering) and molecules (Rayleigh-scattering). In combination with AOD data from the nearly collocated multifilter rotating shadowband radiometer (MFRSR), these data can be used to calculate profiles of AOD. The raw data used in this study are averaged in time for 30 seconds and 30 meters in altitude. MPL backscatter observations at the DOE ARM sites from 2007 through 2010 have been examined and used in this AOD climatology. The AOD values at the Southern Great Plains (SGP) site are also compared with the corresponding values obtained from a nearly collocated Raman Lidar (RL) operating at 355 nm. The comparison shows good agreement. A multi-year vertical profile of AOD climatology at different ARM sites, including diurnal and seasonal variability, will be presented. These results are expected to be of significant importance to the scientific community to understand the aerosol properties and the boundary-layer dynamics better, as well as to improve global climate models by better incorporating the aerosol radiative effects.

Aerosol optical properties from the Himalayan foothills site during GVAX

Anne Jefferson, CIRES, University of Colorado

Aerosol at the GVAX Manora Peak site emanates from local vegetation, biofuel burning, and pollution from the Ganges River Valley as well as long-range transport, especially during downslope periods. Source and seasonal variability of the aerosol optical and cloud-forming properties are presented for the summer monsoon season and fall transition to the dry season. Aerosol loading has a seasonal low during the summer with an average June–August aerosol scattering coefficient at 550 nm of 74 Mm-1 and a mid-September–mid-November average value of 205 Mm-1. As evidenced by changes in the aerosol single-scatter albedo and Ångstrom exponent, the aerosol is slightly smaller and darker during the summer and may reflect wet scavenging of larger, more hygroscopic aerosol. A strong diurnal trend is apparent with higher loading around solar noon. The most remarkable feature of the GVAX aerosol during both seasons is its relatively large size. The average Ångstrom exponent for the 450/700 nm wavelengths is ~ 1.0. The large size persists through both seasons and during upslope and downslope conditions.

Aerosol optical properties of smoke from the Las Conchas wildfire, Los Alamos, New Mexico

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Manvendra Dubey, Los Alamos National Laboratory
Allison Aiken, Los Alamos National Laboratory
Bradley Flowers, Los Alamos National Laboratory
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China Swarup, Michigan Technological University

The Las Conchas wildfire in northern New Mexico started on June 26, 2011 and spread rapidly, eventually burning an area of 634 square kilometers (245 square miles). Due to the close proximity to the fire, the Los Alamos National Laboratory (LANL) was shut down and the town evacuated for several days. Immediately after LANL reopened (July 7, 2011) the Earth and Environmental Sciences Division (EES-14) attained unique measurements of the smoke by sampling the ambient air. Three Integrated Photoacoustic/Nephelometer Spectrometers (DMT Inc.) were set up to measure aerosol light absorption and scattering coefficients. A University of Northwest Switzerland thermodenuder was used to remove compounds that are volatile at temperatures up to 200C. The aerosol's optical properties were measured before and after denuding the sample at 405nm (blue), 532nm (green), 781nm (red), and for non-denuded particles also at 375nm (ultraviolet). The aerosol size distributions were measured after the denuder with a Laser Aerosol Spectrometer (LAS, TSI Inc.) and black carbon was measured with a Single Particle Soot Photometer (SP2, DMT Inc.). These measurements are used in conjunction with numerical simulations to determine the bulk optical properties of the aerosol. Aerosols in wildfire smoke are composed of organic and black carbon (soot) particles that are formed during wood combustion and pyrolysis. The optical properties of the smoke particles are complex and lead to large uncertainties in assessing the global climate. During the measurement period, the Las Conchas fire provided very high particle concentrations (up to 200 μg/m3) that were exploited to investigate their optical properties. By heating the particles to temperatures ranging from 75 to 200C in the denuder, volatile organics were removed and the optical properties of the remaining particles were measured. Denuding of the aerosols removed the outer organic coatings, leaving behind the inner core of black carbon (soot) and any compounds that did not volatize completely. By simultaneously measuring the optical properties of the non-denuded as well as the denuded aerosol, we can study how the coatings affect the optical properties. The absorption coefficient measurements showed that coatings can cause an increase or decrease in absorption.

Aerosol retrievals from 4STAR observations in support of TCAP: sensitivity tests

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The Two-Column Aerosol Project (TCAP) field campaign will start in the summer of 2012 and include aircraft-based observations from the Spectrometer for Sky-Scanning, Sun-Tracking Atmospheric Research (4STAR). The 4STAR aims to provide improved retrievals of aerosol optical and microphysical properties using the sun-tracking ability of the current 14-Channel NASA Ames Airborne Tracking Sunphotometer and the sky-scanning ability of the ground-based AERONET sun/sky photometers combined into one compact airborne instrument. Driven by requirements to have a low-profile compact head for airborne operation, the 4STAR entrance optics are considerably shorter than those of the ground-based AERONET instruments. As a result, an artificial enhancement of sky radiance can occur in the 4STAR data at small scattering angles (closer than 6 degrees from the sun). The main objective of this work is to quantify the potential impact of such artificially enhanced sky radiance on 4STAR-based aerosol retrievals during TCAP. To do that, we selected representative cases (both summertime and wintertime) that could be potentially observed during TCAP. We selected cases from the multi-year AERONET climatology at the MVCO AERONET site near Martha’s Vineyard.

Aerosol size distribution and calculated light-scattering efficiency in the Sacramento plume during CARES

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In this study we consider aerosol light scattering, using aircraft data collected upwind, above, and downwind of Sacramento, California during the DOE-sponsored Carbonaceous Aerosol and Radiative Effects Study (CARES) field campaign. As found in other urban studies, aerosol concentration normalized to a conservative tracer such as CO increased downwind of Sacramento, primarily from secondary organic aerosol (SOA) formation. Optical and radiative effects depend on whether the newly formed aerosol mass is added to small or large particles. The size range and wavelengths of interest intersect the Rayleigh regime in which scattering is proportional to DP6, and scattering efficiency (scattering per unit mass or volume) is proportional to DP3. The emission or formation of small particles in an urban environment could cause a competition for condensables, thereby reducing the aerosol mass that becomes an effective scatterer. Aerosol size distributions measured with a UHSAS (60–1000 nm) showed accumulation mode(s) with DP < 500 nm and a coarse mode with DP > 650 nm. Although the coarse mode can dominate scattering, particularly at long wavelengths, it is not of primary interest in the CARES campaign as it is unlikely to be associated with anthropogenic emissions, though it could be a function of land use. In the accumulation mode size range it was common for there to be two modes with geometric mean diameters of approximately 100 and 250 nm. There were flight transects where one or the other mode dominated and other transects where the two modes made roughly equal contributions to accumulation mode volume. Scattering efficiency has been calculated for transects upwind, over, and downwind of Sacramento. We consider the 14 flights with SW flow. For dry particles in the boundary layer, the scattering efficiency of aerosol smaller than 500 nm at a wavelength of 550 nm averaged 3.8 and 3.1 Mm-1 per um3/cm3 for the morning and afternoon, respectively. Trends from upwind to downwind locations were small. Day to day, the scattering efficiency, averaged over individual transects, varied between 1 and 8, according to whether the accumulation size range was dominated by the small or large mode. Taking the morning measurements as a starting point, we consider the dependence of scattering on growth conditions, specifically the size-dependent sink for condensables. Radiative effects are in the process of being calculated, with consideration of upscatter fraction, RH dependence of size, and aerosol layer depth.

Application of singular-value decomposition and linear programming to analysis of aerosol mass spectra taken during the MILAGRO campaign

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Aerosols are known to have significant impact on climate. Many of their most important properties, such as potential to serve as cloud condensation sites and scatter light, depend on mixing state. Aerosol composition measurements were obtained using an Aerodyne mass spectrometer during flights aboard a G-1 aircraft. Results from three flights under very different field conditions were analyzed for the present study. Analysis method: Principal components analysis (PCA) and singular-value decomposition (SVD) were used for data analysis and compression and to study the evolution of aerosol mixing state as particles age downwind in the Mexico mega-city plume. The principal components define a vector space of low dimensionality and spanned by orthogonal basis vectors onto which the mass spectra are projected. Taking just three dimensions provides a resolution of any given spectrum into three orthogonal components with circa 99% variance of the projected data set explained. Building on these conventional statistical methods (PCA and SVD), we add a new analytic approach: convex polyhedral boundaries of the projected spectral data sets are obtained using linear programming methods. Uniquely defined “simplex factors” (vertices of the convex polyhedral feasible set) are analyzed and compared and contrasted with factors obtained from positive matrix factorization (PMF). In addition to their uniqueness, we show in the context of aerosol composition analysis that the simplex factors are imbued with physical and mathematical optimization properties that make them ideal factors for the representation of aerosol mixing state.

Atmospheric aging of internally mixed sea salt and organic particles: surprising reactivity of NaCl with weak organic acids

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Mary Gilles, Lawrence Berkeley National Laboratory
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Composition of internally mixed sea salt—organic particles collected on board the G-1 research aircraft during the Carbonaceous Aerosol and Radiative Effects Study (CARES)—was performed using complementary electron microscopy and X-ray spectro-microscopy techniques. Substantial chloride depletion in individual sea salt particles is reported that could not be accounted by the presumed reactivity of sea salt with atmospheric inorganic nitric and sulfuric acids. We present field evidence that sea salt components in deliquesced atmospheric particles may effectively react with dissolved organic acids, releasing HCl gas to the atmosphere and leaving particles enriched in the corresponding organic salts. Formation of the organic salts products is not thermodynamically favored in the aqueous phase. However, the surprising shift of the reaction equilibrium in the aerosolized particles is driven by high volatility of the HCl product and its efficient evaporation from particles. Similar observations were also corroborated in a set of laboratory experiments where NaCl particles mixed with organic acids were found depleted in chloride. Formation of organic salts in the aged particles of marine origin will modify their hygroscopic and optical properties and impact their subsequent atmospheric reactions, hydration behavior, and propensity to act as cloud condensation and ice nuclei.

Atmospheric implications for mixed stochastic-singular models of ice nucleation

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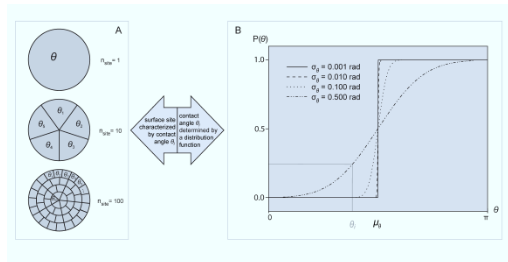
Susan Hartmann, Leibniz Institute for Tropospheric Research
Frank Stratmann, Leibniz Institute for Tropospheric Research
Heike Wex, Leibniz Institute for Tropospheric Research

Evidence exists that heterogeneous ice nucleation can be described by mixed stochastic-singular models. Recently, for example, our group introduced a “soccer-ball model” that envisions particles made up of surface sites or patches with different nucleation barriers. The key assumption is that classical nucleation theory applies on each patch. The number of patches on a particle and the distribution of nucleation barriers (parameterized through the contact angle) can be varied independently, and therefore the model can describe the transition from purely stochastic behavior to nearly idealized singular behavior. We review some recently published measurements in the context of the soccer-ball model and consider the degree to which model parameters can be fitted unambiguously. This, in turn, allows us to consider some general implications of extending laboratory measurements to the atmosphere, especially when those measurements are interpreted in the stochastic or singular limits.



In the soccer-ball model each ice nucleating particle is envisioned to have a surface divided into a number of surface patches or sites (panel A). Each surface site is associated with a nucleation energy barrier, represented through the contact angle. Contact angles are drawn from a distribution function that holds for the ensemble of particles (panel B). The mean and standard deviation of the contact angle distribution can be inferred from measurements.

Black carbon: ambient intercomparisons of physical and optical properties

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Kyle Gorkowski, Los Alamos National Laboratory
Manvendra Dubey, Los Alamos National Laboratory

Currently, absorbing aerosols are thought to be the most uncertain factor in atmospheric climate models (~0.4–1.2 W/m2), and potentially the second most important factor after CO2 in global warming (1.6 W/m2; Ramanathan and Carmichael, Nature Geoscience, 2008; Myhre, Science, 2009). While most well-recognized atmospheric aerosols, e.g., sulfate from power plants, have a cooling effect on the atmosphere by scattering solar radiation, black carbon (BC or "soot") absorbs sunlight strongly, which results in a warming of the atmosphere. Direct online measurements of BC are made with the Single Particle Soot Photometer (SP2), which detects BC by incandescence from individual particles. 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 to determine wavelength-dependent mass absorption coefficients (MACs) and absorption angstrom exponents (AAEs), among other optical properties. Ambient measurements of different BC types were collected during three different campaigns. (1) High mass concentrations of biomass burning were sampled during the Las Conchas fire, the largest wildfire in New Mexico history that started in the Jemez Mountains in Northern New Mexico and burned over 100,000 acres during the summer of 2011. (2) Low mass concentrations of aged transported "background" pollution were sampled during BEACHON-RoMBAS (Bio-hydro-atmosphere interactions of Energy, Aerosols, Carbon, H2O, Organics & Nitrogen – Rocky Mountain Biogenic Aerosol Study), a field campaign that was located in the Manitou Forest Observatory near Colorado Springs, Colorado, in summer 2011. (3) Fresh highway, aged outflow, and wood-burning BC types were sampled during the ClearfLo (Clean Air for London) campaign in Detling, England, during winter 2012. Optical properties are compared from these different BC types and compared with laboratory measurements, and size-resolved information is used to predict the absorptive effects of these climate-relevant aerosols on our atmosphere.

Climate forcing by carbonaceous aerosols: measurements (ARM) enhancing models (CESM)

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Carbonaceous aerosols—black carbon and organic (secondary and primary)—have been identified as key sources of uncertainty in estimates of radiative forcing of climate change. Recent significant advances in measurement techniques and laboratory and field observations (e.g., by ARM) have identified gaps in model treatments of these aerosols. For example, most models underestimate organic carbon, their light absorption at short wavelengths, and the effect of coatings on absorption by black carbon. Most IPCC AR5 models (e.g., CESM) now use size-resolved and speciated treatments of carbonaceous aerosols with first principles calculations of optical properties from refractive indices, size distribution, composition, and mixing state. Some IPCC AR5 simulate an anthropogenic direct aerosol radiative forcing of 0.0 to -0.1 W/m2, which is substantially more positive than most estimates (-0.5 W/m2) by IPCC AR4 models. We will analyze recent laboratory and field observations that have observed (or constrained) size distributions, optical properties, black carbon mass, and even organic composition, and use them to evaluate the treatments of carbonaceous aerosols in CESM, GISS, and ECHAM models. We hypothesize that improved treatments of carbonaceous aerosols in models to better match observations is the reason why the direct forcing aerosol forcing by AR5 models has increased to 0 to -0.1 W/m2 from -0.5 W/m2 for AR4 models. Our paper will test this hypothesis.

Deliquescence, efflorescence, and phase miscibility of mixed particles of aqueous ammonium sulfate and isoprene-derived secondary organic material

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Mackenzie Smith, Harvard University
Allan Bertram, University of British Columbia

The hygroscopic phase transitions of particles composed of laboratory-generated secondary organic material and ammonium sulfate were investigated using a dual-arm tandem differential mobility analyzer. Organic material was generated via isoprene photooxidation at organic mass concentrations of 20 to 30 μg m-3 and oxygen-to-carbon ratios of 0.67 to 0.74. We show that the organic material produced by isoprene photooxidation exerts a measurable influence on the hygroscopic properties of ammonium sulfate. For particles of high organic volume fraction, both the efflorescence and deliquescence relative humidity (ERH and DRH, respectively) of mixed particles decreased by greater than 20% relative humidity compared to pure ammonium sulfate values. The partial dissolution of ammonium sulfate was also induced at relative humidities less than the final DRH. The implication is that isoprene photooxidation products are miscible with the aqueous inorganic phase and are therefore able to alter the hygroscopic behavior of ammonium sulfate. This implication is consistent with a parameterization predicting phase separation as a function of organic material oxygen-to-carbon ratio. In the context of previous work, these results show that the influence of secondary organic material on the hygroscopic properties of ammonium sulfate varies with organic composition and confirm that the degree of oxygenation of the organic material, including complex organic materials, is an important variable influencing the hygroscopic properties of mixed organic-inorganic particles.

Determination of and evidence for non-core-shell structure of particles containing black carbon using the single particle soot photometer (SP2)

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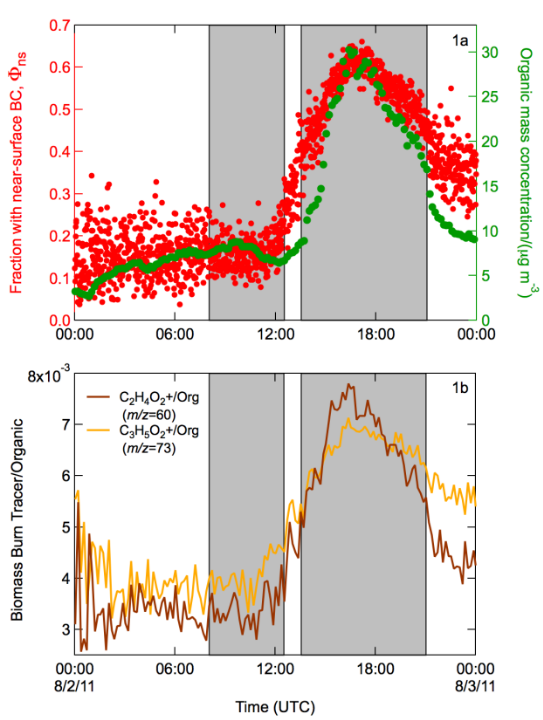
The large uncertainty associated with black carbon (BC) direct forcing is due, in part, to the dependence of light absorption of BC-containing particles on the position of the BC within the particle. It is predicted that this absorption will be greatest for an idealized core-shell configuration in which the BC is a sphere at the center of the particle whereas much less absorption should be observed for particles in which the BC is located near or on the surface. However, such microphysical information on BC-containing particles has previously been provided only by labor-intensive microscopy techniques, thus requiring assumptions for radiative transfer calculations (e.g., Lorenz-Lorentz mixing rule or core-shell model). The present poster describes a novel analysis method that utilizes the temporal behavior of the scattering and incandescence signals from individual particles containing refractory BC (rBC) measured by the single particle soot photometer (SP2) to distinguish particles with rBC near the surface from those that have structures more closely resembling the core-shell configuration. This approach permits collection of a high-time-resolution data set along with better counting statistics regarding the fraction of rBC-containing particles with rBC near the surface, Φns. Application of this method on a plume containing organic aerosol markers for biomass burn reveals that over 60% of the rBC-containing particles have rBC near the surface. Such a data set will not only provide previously unavailable information to the climate modeling community, allowing greater accuracy in calculating rBC radiative forcing, but also will yield insight into aerosol processes and life cycle.



(1a): Fraction of near-surface rBC-containing particles, Φns (red dots), and organic aerosol mass concentration determined by HR-ToF-AMS (green dots). (1b) The ratio of the mass concentrations of C2H4O2+ (m/z=60) and C3H5O2+ (m/z=73) to total organic aerosol determined by HR-ToF-AMS. In both panels shaded regions delineate plumes A and B.

Flux-induced growth of atmospheric nano-particles by organic vapors

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Atmospheric aerosols strongly influence climate by changing the reflectivity and lifetime of clouds. Model simulations show that nearly half of the global cloud condensation nuclei in the atmospheric boundary layer may be formed through new particle formation. New particle formation consists of formation of thermodynamically stable clusters from trace gas molecules (homogeneous nucleation) followed by growth of these clusters to a detectable size (~3 nm). While many studies indicate that organics enhance the initial growth of the clusters and therefore new particle formation, it is suggested that the strong increase of surface equilibrium vapor concentration due to cluster curvature (Kelvin effect) may prevent ambient organics from condensing on these small clusters. Here, particle number flux due to heterogeneous nucleation, in which organic molecules condense on cluster surfaces to form critical embryos, is examined. We find that the flux induced by heterogeneous nucleation of organic vapors can effectively grow clusters substantially smaller than the Kelvin diameter, traditionally considered as the minimum particle size that can be grown through condensation. Including this flux leads to a factor of up to 300 increase in the predicted rates of new particle formation and the subsequent production of cloud condensation nuclei.

Formation and growth of atmospheric aerosol particles from methanesulfonic acid, amines, and water

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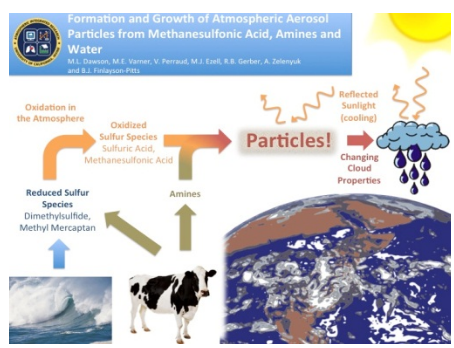
Mychel Varner, University of California, Irvine
Veronique Perraud, University of California
Michael Ezell, University of California
R. Gerber, University of California, Irvine
Alla Zelenyuk, Pacific Northwest National Laboratory
Barbara Finlayson-Pitts, University of California



Atmospheric aerosols impact visibility and affect human health and climate. Current climate models underestimate aerosol particles formed from the interaction of gas phase species in the atmosphere. An as-yet-unaccounted-for source of these particles is from methane sulfonic acid (CH3SO3H, MSA) and amines. MSA is an atmospheric oxidation product of a variety of organosulfur compounds, which are emitted in large quantities, particularly from the ocean. Amines have a variety of both biogenic and anthropogenic sources and have been shown to play an important role in particle formation with other gas-phase acids, particularly sulfuric acid. While nucleation from sulfuric acid accounts for the bulk of new particles formed in the atmosphere, particles formed from MSA and amines may help close the gap between measured and modeled atmospheric aerosols. Here we report results from laboratory studies of particle formation from the gas phase reactions of MSA with several amines. Experiments were performed in a unique, slow-flow, large-volume aerosol flow-tube reactor at 295 K and 1 atm, under conditions of varying relative humidity. Further experiments exploring the composition of particles formed from this source are underway using the SPLAT-II mass spectrometer. Experimental results are compared to an ab initio model describing cluster formation between MSA and the amines. The results of this comparison indicate an important role for water in the gas phase reaction of MSA and the amines to form particles. Atmospheric implications from this new source of particles are discussed.

Implementation of a sectional aerosol package with comprehensive SOA formation into CAM5

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Properties of atmospheric aerosols and aerosol-cloud interactions depend strongly on aerosol size distribution, composition, and mixing state. These microphysical characteristics underlie the major role of aerosols in radiative forcing of climate. However, both existing chemistry-aerosol modules (i.e., “bulk” and “modal”) in CAM5 do not resolve the detailed aerosol size distribution, and they oversimplify the formation of secondary organic aerosols (SOAs) that make up a significant portion of global aerosol burden. To address these issues, we implemented a sectional aerosol package into CAM5 (CAM5/Sect) that integrated the MOZART (Model of Ozone and Related Tracers) gas chemistry with MADRID (Model of Aerosol Dynamics, Reaction, Ionization, and Dissolution) aerosol microphysics to precisely link precursor gases to aerosol formation and size distribution. The new chemistry-aerosol package contains a total of 210 reactions, including 10 reactions for SOA chemistry to produce condensable semi-volatile organic gas species. Formation of SOAs is simulated from 4 anthropogenic and 14 biogenic organic aerosol precursors. We modified the land model in CAM5 to enable the interactive biogenic emissions of 15 volatile organic carbon (VOC) compounds, which is essential for the representation of tropospheric chemistry. Emissions of VOCs are based on an online biogenic emission system, MEGAN (Model of Emissions of Gases and Aerosols from Nature). In additional to SOAs, other aerosol types simulated include sodium, sulfate, ammonium, nitrate, chloride, dust, primary black carbon, and organic carbon. These prognostic size-resolved aerosols are subsequently coupled to photolysis, heterogeneous, and aqueous phase chemical reactions. A new treatment for aerosol/cloud interactions has been introduced into CAM5/Sect to account for the dependency of droplet formation on aerosol size and composition in each sectional bin. We started with 2-degree resolution and 8 size bins (0.02–10 micron in diameter) and are gradually moving toward our target resolution of 0.5-degree and 16 bins for intensive periods during field campaigns. The number of constituents carried in CAM5/Sect is 335, as compared to 25 for the standard version and 105 for MOZART. Preliminary results from CAM5/Sect will be presented.

Inter-comparison of aerosol hygroscopic properties as measured by several instruments in the summer 2011 Aerosol Lifecycle IOP

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The Aerosol Lifecycle IOP at Brookhaven National Laboratory deployed three instruments that measured various hygroscopic properties of ambient aerosols. The first instrument is an HT-DMA (Humidified Tandem Differential Mobility Analyzer), which measures the growth in aerosol size when subjected to 90% relative humidity. The second is a Humidigraph, or f(r), which measures the change in aerosol optical scattering due to a change in humidity. The third is a CCN (Cloud Condensation Nuclei Counter), which measures the ability of aerosol particles to form cloud condensation nuclei. These hygroscopic properties are important in assessing the effect of aerosols on global change. The HT-DMA (Brechtel Manufacturing, Inc.) and Humidigraph (Pacific Northwest National Laboratory) are newly developed instruments being deployed for the first time in the aerosol observing systems (AOS) of the second ARM Mobile Facility, Tropical Western Pacific site, and Mobile AOS-A (MAOS-A). The Aerosol Lifecycle field campaign occurred from June 15 to August 15, 2011. One of the more interesting days was the period of August 2–3, when two subsequent atmospheric plumes were sampled. These plumes (A and B) differed in organic aerosol content, source region (plume B from biomass burning region in Canada), percentage of aged aerosol, and number concentration. These two plumes also differed in aerosol hygroscopicity, which makes for an interesting inter-comparison between the three “hygroscopicity” instruments. The inter-comparison makes use of data from an SMPS (Scanning Mobility Particle Sizer), a CPC (Condensation Particle Counter), and a UHSAS (Ultra=High Sensitivity Aerosol Spectrometer), all of which were also deployed during the IOP.

Laboratory studies of carbonaceous aerosols: characterization and atmospheric processing

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David Croasdale, Boston College
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Alex Martin, Boston College
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Douglas Worsnop, Aerodyne Research, Inc.
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Paul Davidovits, Boston College

Carbonaceous aerosols, including black carbon and/or organic material derived from energy-related processes, can affect climate by direct or indirect processes. In the direct process, aerosols alter the atmospheric radiation budget by either absorbing or scattering incoming light depending on their composition and morphology. The indirect effects of aerosols occur through changes in cloud properties controlled by the ability of particles to act as cloud condensation nuclei (CCN). The uncertainty in the climatic effects of carbonaceous particles is driven in part by several important factors: poorly understood formation (e.g., secondary organic aerosol (SOA) generation), poorly quantified atmospheric processing (e.g., hydrophobic into hydrophilic), and limited information on the UV-VIS-IR optical properties. These uncertainties are complicated by the lack of measurement techniques that can unambiguously measure (isolate) carbonaceous particles' properties. Our current work involves testing and applying new, high-oxidant, wall-less flow tube reactor techniques for generating SOA from the gas-phase oxidation of volatile and intermediate volatility organic compounds and oxidized primary organic aerosol (OPOA) from heterogeneous oxidation of atmospherically relevant primary aerosols by OH radicals. Specifically, we are using a photochemical system originally developed to provide a measure of the "potential aerosol mass" of an airmass (i.e., PAM, developed by Brune et al. at PSU) in the laboratory as a complementary approach to conventional environmental chambers. The resulting particles are characterized using a suite of online particle instruments (including aerosol mass spectrometers, low pressure impactors for particle bounce, and CCN instruments) and offline, filter-based techniques. Our goals are to identify correlations between the chemical, physical, and optical properties of laboratory-generated SOA and OPOA that may help explain field measurements and enable more accurate climate modeling from hours to days of equivalent atmospheric aging. We will present results from our investigations covering a range of atmospherically relevant anthropogenic and biogenic precursors that provide insights into SOA oxidation pathways and that correlate chemical properties of laboratory-generated OPOA and SOA with their corresponding phase state, CCN activity, and optical properties.

Laboratory to cloud modeling: investigating sensitivity of ice nucleation parameterizations

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Xiaohong Liu, Pacific Northwest National Laboratory
Mikhail Ovchinnikov, Pacific Northwest National Laboratory

Ice nucleating properties of mineral dust particles are investigated in the laboratory. The laboratory data was parameterized using Classical Nucleation Theory (CNT), and the sensitivity of cloud properties to two different representations of CNT was investigated in the cloud-resolving model (CRM). The onset contact angle CNT representation is based on two sets of laboratory deposition ice nucleation measurements: Arizona test dust (ATD) particles of 100, 300, and 500 nm sizes; and 400 nm ATD and Kaolinite dust species. Relative humidity with respect to ice (RHice) required to activate 1% of dust particles as ice nuclei (IN) was used to calculate the onset single contact angles. The mean and standard deviation parameters of PDF representation were determined by fitting the CNT-predicted activated fraction to the measurements at different RHice. Results show that onset single contact angles are not much different between experiments, while the PDF parameters are sensitive to temperature and dust size. The CRM simulations show that cloud properties (ice number concentration, ice water content, and cloud initiation times) are sensitive to onset single contact angles and PDF distribution parameters, particularly to the mean value. The comparison of our experimental results with other studies shows that under similar measurement conditions the onset single contact angles are consistent within ± 2.0 degrees, while our derived PDF parameters have large discrepancies. The study implies that modeled cloud properties are sensitive to the ice nucleation parameterization representations derived from CNT. IN measurements including coating studies on aerosol particles of natural and biological sources are needed to simplify the role of aerosol substrate in the parameterizations as well as to improve the existing parameterization treatments.

Modeling water content and solute activities of atmospheric aerosols

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

Multilayer adsorption isotherm models describe a lattice adsorption of a solvent (e.g., water) molecule on to sites on a substrate (e.g., an electrolyte). In this work, statistical mechanics is used to modify the seminal Brunauer-Emmett-Teller (BET) adsorption isotherm to include distinct energies of adsorption of the solvent on to n layers in the hydration shell surrounding the solute molecule. 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 at water activities (aw, equivalent to the equilibrium relative humidity) as high as 0.9 to 0.95. Even further extension of the isotherm to the aw = 1 limit can be achieved through incorporating electrostatic limiting law behavior. The model is shown to be consistent with the Zdanovskii-Stokes-Robinson (ZSR) mixing model, which is 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 Internet.

http://www.aim.env.uea.ac.uk/aim/aim.php

On factors controlling marine boundary-layer aerosol optical depth based on ARM Azores measurements and satellite measurements

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Zhien Wang, University of Wyoming

Sea spray aerosol is one of the largest natural contributors to the global aerosol loading and thus plays an important role in the global radiative budget through both direct and indirect effects. Many previous studies have shown either strong or weak relationships between marine boundary-layer (MBL) aerosol optical depth (AOD) and near-surface wind speed because marine aerosol is influenced by a wide range of factors. This study attempts to examine extra contributing factors beyond wind to better characterize MBL AOD variations by using multiple satellite data and ARM surface data from the Azores. MBL AOD and aerosol layer structure were retrieved from CALIPSO and CloudSat satellite data, and only cloud-free and single aerosol layer conditions were considered. Daily surface wind speed data and sea surface temperature were obtained from the AMSR-E. Large-scale meteorological conditions were obtained from ECMWF. Detailed data analyses were carried out over nine regions representing different areas of the global oceans based on the two-year (2007–2008) satellite measurements. The results show that among the selected factors, surface wind speed and MBL depth are found to be the two most important factors determining MBL AOD. This suggests that not only mechanical production of sea-spray particles driven by near-surface wind processes but also vertical re-distribution driven by turbulent and shallow convective mixing in the MBL controls MBL AOD variations. A new relationship of between AOD and those two factors was derived based on satellite results and was further evaluated with ARM measurements from the Azores. Numerical simulations using WRF model and ARM data from the Azores are conducted to show the potential improvements in radiation computation.

Online molecular characterization of organic aerosol in field and chamber studies using a MOVI-CI-HTOF-MS

Joel Thornton, University of Washington

We report on the continued development and application of a novel approach to the molecular speciation of oxygenated organic compounds in gas and particle phases. A temperature-controlled Micro-Orifice Volatilization Impactor (MOVI) is coupled to a high-resolution time-of-flight mass spectrometer (HTOF-MS) employing a switchable suite of chemical ionization approaches. We demonstrate the capability of the approach to characterize the detailed elemental composition and volatility of a broad class of oxygenated organic compounds using results from both a smog chamber study of alkane oxidation and recent field deployments in Seattle and as part of the Clearflo/Aeroflo project from January–February 2012. In the smog chamber data our approach tracks the successive oxidation of alkanes into highly oxygenated intermediates that are present in both the particle and gas-phases simultaneously. A positive matrix factorization of our high resolution spectra results in a condensed set of factors that illustrate the successive oxidation with time and the time series of which agree remarkably well with an independent PMF analysis of data from the Aerosol Mass Spectrometer. Such highly controlled process studies form the basis for our ongoing interpretation of data obtained as part of the Clearflo/Aeroflo project. We operated the instrument in four different modes: two ionization schemes—carboxylic acid detection using acetate ion chemistry and oxygenated hydrocarbon detection using protonated water clusters—with two different collision-induced ion declustering regimes. These modes, together with the gas and particle separation and the volatility information, are providing an unprecedented characterization of the evolution of organic compounds in aged polluted air. Statistical analyses are ongoing to provide insights into the connections between wintertime VOC processing, SOA, and aerosol optical and physical properties.

On the synergetic relation between SOA and hydrophobic organics: SOA formation yield, evaporation kinetics, phase, morphology, diffusivity, viscosity, and coalescence rates

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Dan Imre, Imre Consulting
Josef Beranek, Pacific Northwest National Laboratory
Evan Abramson, University of Washington
Manishkumar Shrivastava, Pacific Northwest National Laboratory

Secondary organic aerosols (SOA) comprise the largest and least understood fraction of atmospheric aerosols. Recent studies by our group demonstrated that these particles are in quasi-solid phase and that their evaporation rates are orders of magnitude slower than predicted. Similar measurements on ambient SOA particles mixed with small amount of sulfate reveal nearly identical results, providing direct evidence that SOA evaporation in the ambient atmosphere is negligible. These results demonstrate that assumptions used by current models that SOA can be treated as liquid and modeled with parameterized Raoult's law, while assuming gas-particle equilibrium at all times, need to be significantly changed. In the atmosphere, SOA often forms in the presence of hydrophobic organics. We explore the interaction between hydrophobic organics and SOA by condensing SOA on particles composed of hydrophobic organics and coating SOA particles with the same, and find that hydrophobic organics and SOA form separate phases. When SOA is condensed on liquid hydrophobic organic particles, the SOA coating prevents the core from evaporating. When the same hydrophobic liquid organic is used to coat SOA particles, it evaporated rapidly. In both cases, particles remain spherical throughout the evaporation process. When solid hydrophobic organics, like polyaromatic hydrocarbons, are deposited on top of pure SOA particles, we find that the coated particles are aspherical and the hydrophobic organic rapidly evaporates, regenerating spherical SOA particles and leaving no trace of hydrophobic organics behind. However, SOA particles formed in the presence of the vapors of hydrophobic organics incorporate these organics into their bulk, where they become trapped for days. Independent of the hydrophobic organic, these particles are spherical and contain significant amounts of hydrophobic organics. Vapors of hydrophobic organics increase SOA formation yield by a factor of 1.6. The evaporation rates of SOA particles with trapped hydrophobic organics are significantly lower, and slow down more with aging. We have successfully generated SOA particles from a number of precursors in the presence of different hydrophobic organics, measured evaporation rates of fresh and aged SOA particles, characterized the morphological distribution of the organics trapped inside the SOA particles, and measured their diffusion rates through SOA, from which we calculate SOA viscosity and particle coalescence rates.

Optical properties of atmospheric aerosols over the Ganges Valley Aerosol Experiment site, ARIES, Nainital

Umesh Dumka, Aryabhatta Research Institute of Observational Sciences

The Atmospheric Radiation Measurement (ARM) first Mobile Facility (AMF1) has been operating at the Aryabhatta Research Institute of Observational Sciences (ARIES), Nainital, under the GVAX (Ganges Valley Aerosol Experiment) field campaign since June 2011. Under this project, the aerosol observing system (AOS) that comprises a set of instruments designed primarily for the continuous measurements of optical and microphysical properties of atmospheric aerosol at the surface is in operation. The principal measurements are those of the aerosol absorption and scattering coefficients, backscattered radiation, concentration, cloud condensation nuclei, particle number concentration, and particle size distribution as a function of the particle size and radiation wavelength. These measurements are used for calculating the aerosol single-scattering albedo (SSA), asymmetry parameter (g), and hygroscopic growth factor, and those are used for radiative forcing estimation. Generally, the low values of light scattering and hemispheric backscattering coefficients are observed during the Indian summer monsoon period, and it showed increasing trend after the monsoon. Total scattering and hemispheric back scatter coefficients at 450 and 700 nm are about 80% of the value at 550 nm respectively, and most of the particle concentration ranges from 200 to 5000 cm-3 during the study period. Such values are typical for a high-altitude site. The light scattering coefficients have strong positive correlation with hemispheric backscattering coefficients. The hemispheric backscatter ratio ranged from 0.1 to 0.15 during the period under study. The estimated Ångström exponent (indicates about the size of particles) ranges from 0.8 to 1.5, indicating the dominance of fine particles over the site. The single-scattering albedo obtained during this period ranged from 0.7 to 0.9. Detailed discussion will be made during the presentation.

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

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

Relative humidity (RH) affects the water content of an aerosol, altering its scattering and absorption of light, which is important for aerosol effects on climate and visibility. This project involves in situ prediction and measurement studies of aerosol optical properties including absorption, scattering, and extinction at three visible wavelengths (467, 530, and 660 nm) for organic carbon (OC) generated by pyrolysis of biomass, ammonium sulfate, and sodium chloride, and their mixtures at controlled RH conditions. Novel components of this project include investigation of: (1) Changes in all three of these optical properties at scanned RH conditions; (2) optical properties at RH values up to 95%, which are usually extrapolated instead of measured; and (3) examination of aerosols generated by the pyrolysis of wood, which is representative of primary atmospheric organic carbon, and its mixture with inorganic aerosol. Scattering and extinction values were used to determine light absorption by difference and single-scattering albedo values. The single-scattering albedo value for dry absorbing polystyrene microsphere benchmark agreed within 0.02 (absolute value) with independently published results at 530 nm. Light absorption by the nigrosin benchmark increased by a factor of 1.24+/-0.06 at all wavelengths as RH increased from 38 to 95%. Absorption by biomass OC aerosol increased by a factor of 2.2+/-0.7 and 2.7+/-1.2 between 32 and 95% RH at 467 nm and 530 nm, but there was no detectable absorption at 660 nm. Additionally, the spectral dependence of absorption by OC that was observed with filter measurements was confirmed qualitatively in situ at 467 and 530 nm. Mixing the biomass OC aerosol with select mass fractions of ammonium sulfate ranging from 22 to 48% and sodium chloride ranging from 16 to 39% resulted in an increase in light scattering and extinction with RH and inorganic mass fraction. However, the mixed aerosol showed no detectable difference in light absorption behavior in comparison to pure biomass OC. The main finding of this research is a measured increase in absorption with increasing RH, which is currently not represented in radiative transfer models even though biomass burning produces most of the primary OC aerosol in the atmosphere. A new DOE ASR-sponsored project will study the effect of chemical aging with ultraviolet light and ozone on the optical and cloud-nucleating properties of the biomass OC aerosol at controlled RH conditions.

Particle size distributions following condensational growth in continuous flow aerosol reactors as derived from residence time distributions

Scot Martin, Harvard University

Condensational growth in continuous flow reactors, such as continuously mixed flow reactors (CMFRs) and flow tube reactors, is widely employed in the field of aerosol science and technology to produce particles for industrial use and scientific research. The development of analytical equations for the number-diameter distribution n(d) of the particles in the outflow from these reactors is advantageous both for the inversion of data sets to obtain thermodynamic and kinetic parameters as well as for the rational design of experiments. In this study, equations are derived that relate the number-diameter distribution n(d) to the probability density function p(t) of particle residence time. Specifically, the condensational growth rate is used to derive n(d) based on p(t). Analytical equations are developed for CMFRs, laminar-flow reactors, and dispersive plug-flow reactors, with a focus on CMFRs. The CMFR equation accurately describes data sets collected for α-pinene and β-caryophyllene ozonolysis in the Harvard Environmental Chamber. The interpretation is that condensational growth can be considered as the principal mechanism for change in particle diameter in these experiments.

A real-time secondary organic aerosol formation tool: development, characterization, and application in field studies

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Amber Ortega, University of Colorado at Boulder
Reddy Yatavelli, University of Colorado at Boulder
Douglas Day, University of Colorado at Boulder
Brett Palm, University of Colorado

Recent field studies reveal large formation of secondary organic aerosol (SOA) under urban polluted ambient conditions, and there are indications of strong synergy between anthropogenic pollution and biogenic VOCs in increasing SOA formation. SOA formation in biomass burning smoke appears to be variable but sometimes substantial. Previous field studies depend on assumptions about mixing and air flow in order to relate the evolution of those SOA and its precursors, which limits the scientific insights under many conditions. To directly study SOA formation in ambient air in real-time, our group has deployed a Potential Aerosol Mass (PAM) photooxidation flow reactor in conjunction with an Aerodyne High Resolution Time-of-Flight Aerosol Mass Spectrometer, a Scanning Mobility Particle Sizer (SMPS) and a Proton Transfer Reaction-Mass Spectrometer (PTRMS). We have used this system to characterize SOA formation in (a) urban air during CalNex-LA-2010 in the Los Angeles area of California, (b) forest air at the USFS Manitou Forest in Colorado during BEACHON-RoMBAS-2011, and (c) biomass smoke in at the USFS Fire Science Lab in Missoula, Montana, during FLAME-3. The PAM reactor uses mercury lamps to create OH concentrations up to x10000 ambient levels. High oxidant concentrations accelerate the processing of volatile organic compounds and inorganic gases and their growth into the aerosol phase. PAM photochemical processing can represent up to approximately 20 days of equivalent atmospheric aging in the span of 4 minutes of residence time in the reactor, and PAM-processed aerosols have shown similar aging signatures and sulfate and SOA yields when compared to aging ambient aerosols. In some campaigns we used a gas-phase denuder to study heterogeneous OH processing of the pre-existing aerosol or injected O3 or N2O5 in PAM without lights to investigate SOA formation from O3 or NO3 oxidation. In all cases PAM OH photoxidation enhances SOA at intermediate exposure but results in net loss of OA at very long exposures. SOA formation greatly exceeds that calculated from the measured precursors in urban air, but differences are smaller in forest air. PAM oxidation also results in a similar slope in the Van Krevelen diagram than ambient oxidation. Lab experiments are ongoing to obtain SOA yields for the key precursors of the above campaigns under the same PAM conditions used in the field, and also to study SOA formation under conditions simulating the 2010 Gulf of Mexico oil spill.

The role of temperature in cloud droplet activation

Sara Christensen, North Carolina State University
Markus Petters, North Carolina State University
Paul Ziemann, University of California
Sonia Kreidenweis, Colorado State University

Organic aerosols in the atmosphere are composed of a wide variety of species, reflecting the multitude of sources and growth processes of these particles. Especially challenging is predicting how these particles may act as cloud condensation nuclei (CCN). Köhler theory relates the particle's dry diameter to its critical supersaturation. A hygroscopicity parameter, kappa, parameterizes this relationship in terms of the particle's chemical composition. Previous studies have characterized kappa values for pure and mixed compounds at laboratory temperatures, but did not account for a potential dependence of the relationship between critical supersaturation and particle dry diameter on temperature. Here we characterize the temperature dependence of kappa derived from CCN measurements for a variety of organic compounds in the laboratory. Single-compound organic aerosol and secondary organic aerosol from the reaction of alpha-pinene and O3 were generated in the laboratory, and activation properties were analyzed using size-resolved CCN analysis. The CCN instrument was placed inside a temperature-controlled enclosure. During the experiment the temperature inside the enclosure was ramped down from approximately 40° to 0°C over a period of approximately six hours. Size-selected sample aerosol was brought into the enclosure and was allowed to thermally equilibrate before entering the CCN instrument. Between the CCN instrument inlet and the point of activation, the sample was warmed again by ~3–4°C, which was necessary to establish the supersaturation inside the instrument. Activation data were collected by alternating diameter scans between organic aerosol and ammonium sulfate aerosol for calibration. Three possible outcomes were observed as temperature decreased: activation diameters of the organic compounds increased, remained constant, or decreased relative to the activation diameters of ammonium sulfate. The latter two observations can be explained by a weak dependence of water activity on temperature and a moderate dependence of solubility in water on temperature. We anticipate that our results will help to guide input and parameterization choices in models that rely on theory to extrapolate laboratory and ambient data to temperatures that are different than those during data collection. The objective is to better constrain droplet activation in mid- and high-level clouds and to ultimately decrease the uncertainty surrounding the aerosol indirect effect.

Seasonal variations of aerosol optical properties, vertical distribution, and associated radiative effects in the Yangtze delta region of China

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Zhanqing Li, University of Maryland
Youfei Zheng, Nanjing University of Information Science and Technology
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Maureen Cribb, University of Maryland

Four years of columnar aerosol optical properties and a one-year vertical profile of aerosol particle extinction coefficient at 527 nm are analyzed at Taihu in the central Yangtze River delta region in eastern China. Seasonal variations of aerosol optical properties, vertical distribution, and influence on shortwave radiation and heating rates were investigated. Multi-year variations of aerosol optical depths (AOD), Ångstrom exponents, single-scattering albedo (SSA), and asymmetry factor (ASY) are analyzed, together with the vertical profile of aerosol extinction. AOD is largest in summer and smallest in winter. SSAs exhibit weak seasonal variation with the smallest values occurring during winter and the largest during summer. The vast majority of aerosol particles are below 2 km, and about 62%, 67%, 67%, and 83% are confined to below 1 km in spring, summer, autumn, and winter, respectively. Five-day back trajectory analyses show that some aerosols aloft are traced back to northern/northwestern China, as far as Mongolia and Siberia, in spring, autumn, and winter. The presence of dust aerosols was identified based on the linear depolarization measurements together with other information (i.e., back trajectory, precipitation, aerosol index). Dust strongly impacts the vertical particle distribution in spring and autumn, with much smaller effects in winter. The annual mean aerosol direct shortwave radiative forcing (efficiency) at the bottom, top, and within the atmosphere is -34.8±9.1 (-54.4±5.3), -8.2±4.8 (-13.1±1.5), and 26.7±9.4 (41.3±4.6) W/m2 (Wm-2τ-1), respectively. The mean reduction in direct and diffuse radiation reaching surface amounts to 109.2±49.4 and 66.8±33.3 W/m2, respectively. Aerosols significantly alter the vertical profile of solar heating, with great implications for atmospheric stability and dynamics within the lower troposphere.

Secondary organic aerosol formation from alkane oxidation

John Seinfeld, California Institute of Technology

Long-chain alkanes represent an important class of precursors to atmospheric secondary organic aerosol (SOA) and therefore as contributing to the global burden of organic aerosol. Alkanes are the dominant component of the Unresolved Complex Mixture, which is thought to represent a large part of the unaccounted-for source of ambient SOA. We report here on comprehensive laboratory chamber experiments aimed at understanding both the detailed chemistry of formation and aging of alkane SOA as well as the overall yield of aerosol and its dependence on alkane structure. The chamber experiments were carried out for a 36-hour duration, thus capturing several generations of oxidation. Simultaneous measurements with a Chemical Ionization Mass Spectrometer and an Aerodyne High-Resolution Aerosol Mass Spectrometer afford an unprecedented view of gas- and aerosol-phase chemistry that leads to the multi-functional, low volatility compounds characteristic of SOA. The experiments reported here focus on the C12 alkanes, under both high- and low-NOx conditions, characteristic of strongly anthropogenically influenced air masses and relatively pristine environments, respectively.

Size-resolved growth rates of freshly nucleated particles acquired from size distributions down to 1 nanometer

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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 (CCN). New particle formation (NPF) by photochemical reactions of gas-phase precursors greatly increases the number concentrations of atmospheric aerosols and is often followed by rapid growth to a CCN-active size, leading to a significant enhancement of the global CCN population. This rapid growth, often two to fifty times that of the growth assuming the condensation of sulfuric acid alone, is not well understood or represented in global models, limiting the ability to accurately assess the impact of NPF on the global surface CCN population and the aerosol indirect effect. Understanding this rapid particle growth and representing it in models requires direct measurements of the particle growth rate, especially immediately following nucleation, at which stage freshly nucleated particles are most vulnerable to scavenging by existing particles. Recently, size distribution measurements of freshly nucleated 1–6 nm particles were acquired during an intensive field campaign in Boulder, Colorado, using a diethylene glycol-based ultrafine condensation particle counter optimized for detection of 1-nm condensation nuclei as a detector in a scanning mobility particle spectrometer. These measurements provide one of the first direct measurements of size- and time-dependent particle growth rates of freshly nucleated particles. Observed growth rates for 1–6 nm particles were found to range from 1–30 times that assuming only sulfuric acid condensation, with these growth rate enhancements increasing approximately linearly with diameter below 3 nm.

Sources of organic aerosols in the southeastern Pacific during 2008 VOCALS-REX

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Jian Wang, Brookhaven National Laboratory
Gunnar Senum, Brookhaven National Laboratory
John Jayne, Aerodyne Research, Inc.
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Peter Daum, Brookhaven National Laboratory

Concentrations of organic aerosol along with that of sulfate and ammonium over the northern Chilean coastal waters of the southeastern Pacific were determined using an Aerodyne cToF-AMS outfitted on the DOE G-1 aircraft during the 2008 VOCALS-REX campaign. Sea-salt aerosol (SSA, as NaCl) and nitrate were determined using the PILS-IC technique. Although all of the aerosol components except SSA exhibited a prominent east-west concentration gradient decreasing with distance from the shore consistent with their terrestrial origins, sulfate as well as nitrate decreased much faster than organics, suggesting additional organic sources toward the open ocean compared to near shore regions. Because the terrestrial emissions impacting the coastal marine boundary layer were transported by a fairly uniform south-southeasterly wind after land contact, the observed concentrations on the G-1 along a narrow latitude band (~19 S) upward of ~78 W are expected to reflect a distributed terrestrial source region that shifted progressively from north to south as offshore distance increases. While an increased organic relative to sulfate source from north to south is consistent with additional biogenic sources south of ~30 S where the Atacama desert to the north ends, other potential contributions such as ocean emissions and entrainment from free troposphere may also be appreciable and should be considered. Despite the low organic aerosol loadings observed on the G-1 during VOCALS (i.e., max < 1 μg m-3, median < 0.3 μg m-3), we attempt to determine their sources using the PMF technique; three factors resembling HOA, OOA, and BBOA are tentatively assigned. The validity and relative importance of these different sources are examined in term of their relationships to (1) sulfate, ammonium, and nitrate, which are anthropogenic from the land, (2) CO, which is advected from the land but can also be entrained into the marine boundary layer from the free troposphere, and (3) SSA, which is produced from ocean surfaces mainly by wind stress. Evidence for the purported marine originated small organic aerosol particles (D < 0.1 μm) generated either by bubble film bursting and/or by oceanic SOA precursors is also investigated.

Study of SOA growth mechanism: kinetic uptake of organic nitrates from the oxidation of monoterpenes

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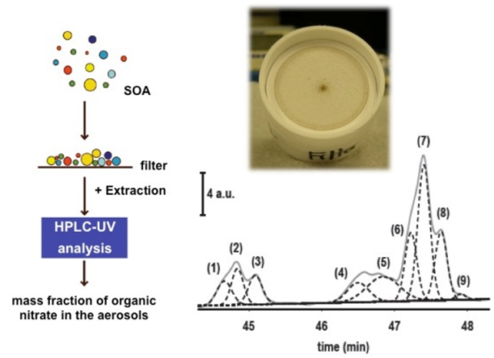
Matthew Dawson, University of California, Irvine
Barbara Finlayson-Pitts, University of California

Secondary organic aerosol (SOA), generated from the oxidation of volatile organic compounds (VOCs), contributes to a large proportion of the total organic aerosol mass encountered in the atmosphere. Understanding and quantifying the processes that lead to SOA formation and growth are critical, as SOA has adverse impacts on visibility, human health, and climate. The mechanism for SOA growth is currently described in most atmospheric models by an instantaneous thermodynamic equilibrium partitioning of semi-volatile organic compounds (SVOCs) into liquid pre-existing organic particles. However, there have been substantial discrepancies between model-predicted and field-measured SOA concentrations. There is increasing evidence that a significant part of the discrepancy may lie in model assumptions, especially that equilibrium between the gas phase and particles is achieved on very short time scales. There are a number of recent observations in both laboratory systems and field campaigns that indicate that some SOA may be much more viscous and less “liquid-like” than initially assumed. Thus, the diffusion coefficients would be smaller than assumed, resulting in longer times to reach equilibrium. A recent study from our group showed that in the case of simultaneous oxidation of α-pinene by ozone and nitrate radicals, the uptake of semi-volatile organic nitrate products into the SOA that is generated does not follow thermodynamic equilibrium partitioning. However, the data are consistent with a kinetically limited/condensation growth mechanism. We report here a series of new experiments performed using a large-volume slow flow aerosol flow tube system to measure the partitioning of organic nitrates into SOA formed under the same experimental conditions from a series of atmospherically relevant monoterpene precursors. Implications for model treatment of SOA growth will be discussed.

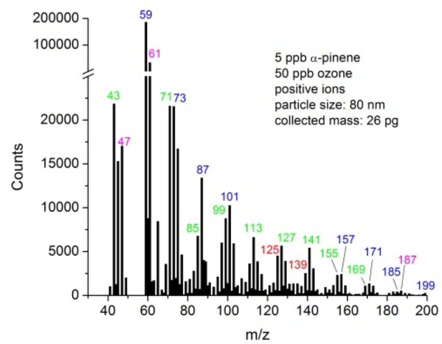


A typical LC-UV chromatogram of particles collected on a quartz-fiber filter from the simultaneous oxidation of alpha-pinene by ozone and nitrate radicals.

Understanding the biogenic species responsible for atmospheric new particle growth

Paul Winkler, National Center for Atmospheric Research
John Ortega, National Center for Atmospheric Research
Hans Friedli, University Corporation for Atmospheric Research
Jim Smith, National Center for Atmospheric Research

The chemical composition of secondary organic sub-50 nm diameter particles (nanoparticles) is among the key measurements required for understanding the processes responsible for atmospheric nucleation and subsequent growth. While aerosol mass spectrometry has typically been restricted to particle sizes greater than 50 nm due to sampling challenges, few techniques exist for investigating particle composition in a size range close to where nucleation and growth by organic vapours takes place. With the newly developed high-resolution time-of-flight (HTOF) Thermal Desorption Chemical Ionization Mass Spectrometer (TDCIMS, e.g., Voisin et al. 2003), we now can directly measure chemical compounds of freshly nucleated particles as small as 10 nm. In this study we investigated biogenic nanoparticles in the atmosphere and laboratory. During summer 2011 we participated in the Bio-hydro-atmosphere interactions of Energy, Aerosols, Carbon, H2O, Organics and Nitrogen - Rocky Mountain Biogenic Aerosol Study (BEACHON-RoMBAS) field campaign at the Manitou Forest Observatory (MFO) near Woodland Park, Colorado. The site is located in a ponderosa pine-dominated forest at an elevation of roughly 2400 meters above sea level. The remote location relatively far from direct emission sources typically provides clean conditions with substantial monoterpene and sesquiterpene concentrations. New particle formation events starting around noon were observed frequently, and particle diameters around 10–15 nm were found at the low end of the size distribution. Correspondingly, we focused on 20-nm particles as the smallest size for the HTOF-TDCIMS measurements. At this size ambient nanoparticles contained detectable levels of inorganic species such as sulphate, nitrate, and ammonium. In addition, several organic substances were found in significant amounts. The high mass resolution of the HTOF-TDCIMS allows for the identification of the molecular formulae of detected ions. In order to be able to attribute the organic signals observed at MFO to corresponding precursor gases, we conducted laboratory SOA formation studies using both the NCAR biogenic aerosol chamber as well as a flow tube. Different kinds of monoterpenes and sesquiterpenes representative for MFO conditions were oxidized by ozone under dark conditions. Little difference was found between the particle compositions in the chamber and flow tube experiments, respectively, although reaction rates varied considerably. Current work is focused on identifying these ions and ultimately the precursors and mechanisms responsible for the observed growth.



Typical mass spectrum of positive ions obtained from 80-nm particles formed from the oxidation of a-pinene in the NCAR biogenic aerosol chamber. As can be seen a series of peaks separated by m/z, differences of typically 14 amu are observed. While many species as well as a similar pattern were found from the ambient measurements, it is likely that compounds from other precursor gases contribute to the ambient signal as well.

Understanding the chemical processes that affect growth rates of freshly nucleated particles

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Mari Titcombe, University of Minnesota
Jun Zhao, University of Minnesota
David Hanson, Augsburg College
Peter McMurry, University of Minnesota

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 our recent work that contributes 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 the use of these data to quantify size-dependent growth rates down to 1 nm. During the summer of 2010 chamber experiments were carried out at the University of Minnesota to study nucleation and growth following the photochemical formation of sulfuric acid from sulfur dioxide in the presence of amines. Size dependent growth rates of 1-3 nm particles were measured and found to increase with size and to be less than values that could be explained by collision-limited uptake of sulfuric acid. This contrasts with measurements in the atmosphere, where 1-3 nm particles grow faster than can be explained by sulfuric acid condensation, presumably because other compounds also contribute to growth. Although these observations do not explain why atmospheric growth rates are so fast, they do show one way in which chamber studies may not accurately reflect all of the processes that are important in the atmosphere. Another interesting observation in the chamber studies was the strong effect of amines on sub-10-nm size distributions. When amines were not intentionally added to the chamber, nucleation occurred in a short burst. When amines were added, however, high nucleation rates persisted for the duration of the experiment. Without amine addition, sub 10-nm number distributions decreased sharply with increasing size after the initial nucleation burst. In the presence of amines, number distributions decreased much more gradually with increasing size, due to the high rates at which stable nuclei were produced and grew. The chamber studies also showed that amines were always present at levels of 10-100 ppt, no matter how much effort was made to clean the chamber. The AmPMS, developed by David Hanson and coworkers, allowed measurements of amines for the first time in chamber studies. We think it is likely that amines have always been present in chamber studies.

Value-added product highlights from the Aerosol Life Cycle working group

Connor Flynn, Pacific Northwest National Laboratory
Jerome Fast, Pacific Northwest National Laboratory
Duli Chand, Pacific Northwest National Laboratory
Evgueni Kassianov, Pacific Northwest National Laboratory
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Timothy Shippert, Pacific Northwest National Laboratory
Manishkumar Shrivastava, Pacific Northwest National Laboratory

The Aerosol Life Cycle working group (ALWG) occupies a central role within ASR and ARM as the organizing body responsible for furthering our understanding of basic aerosol properties. These basic properties cover a wide scope, including both extensive and intensive aerosol optical properties, aerosol size distribution, temporal and spatial distribution, response to humidity and characterization near clouds, and life cycle processes including formation (primary and secondary), evolution, scavenging, and dry/wet deposition. The ALWG translator team and developers within the ARM infrastructure are focused on meeting the needs of the broader science community and specifically on facilitating ASR science through the processing of aerosol instrumentation datastreams and development of value-added processing to calibration, qualify, and improve the measurements and to provide quantities that are difficult or impossible to obtain directly. We present an overview of ALWG value-added products and highlight results from several current efforts including the MFRSR AOD retrievals from AMF deployments, Aerosol Intensive Properties, Aerosol Best-Estimate, Organic Aerosol Composition, and analyses of aerosol-related field campaigns (CARES).

Abstracts

Atmospheric State & Surface

A decadal climatology of atmospheric state at SGP

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

Parameterizations in models attempt to statistically relate large-scale atmospheric variables such as temperature, humidity, and winds with variables that change on scales too small to resolve, such as cloud properties. We seek to study the observed relationships between such large- and small-scale variables through the creation of a set of atmospheric states and associated distributions of small-scale variables. We use an iterative clustering technique developed by Marchand et al. (2006, 2009) to define a set of atmospheric states for a region surrounding the ARM Southern Great Plains (SGP) site. Atmospheric state in this context can be thought of as a frequently occurring regional weather pattern. We use 13 years of dynamic and thermodynamic variables from the ERA-Interim reanalysis as the input to a clustering algorithm to define the states and cloud occurrence data from the vertically pointing millimeter wavelength cloud radar at the SGP site to validate the statistical significance of each state. Once the states are defined, we classify the state of the atmosphere every six hours for the duration of the study, creating a time series of atmospheric state. This time series can be used as a basis for compositing cotemporaneous observations of interest and creating distributions of small-scale variables associated with each of the states. Distributions of both ground-based observations from the SGP site such as cloud occurrence, precipitation, liquid water path, and radiative fluxes as well as satellite-derived equivalents can be created in this fashion. Further, the long time series of state allows us to investigate the interannual variability of the occurrence of states, their duration, diurnal cycles of states, and the probability of any one state transitioning to another state. We present here a selection of the states, distributions, and cycles we find most interesting.

Estimation of a non-flux component of atmospheric moisture flux divergence and its relation to SGP CLASIC clouds and rainfall

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Peter Lamb, University of Oklahoma
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). The conventional form of the moisture budget equation with negligible atmospheric storage is E-P = MFD = HA+HD where E is evapotranspiration, P is precipitation, and MFD is moisture flux divergence with components HA (horizontal moisture advection) and HD (horizontal velocity divergence in the presence of moisture). If MFD ~0, one might assume that all P is derived from E. We demonstrated in an earlier study that the fraction of P derived from E is provided by the inflow (IF/A) across the region's boundary that encloses area A, i.e., E/(IF/A + E). Through application of Green's theorem along the region's boundaries, MFD also is the net flux at these boundaries (OF/A – IF/A) where OF/A denotes the outflow. In our present work, we examine a new variable, HA-HD, and mathematically show that it is equal to the non-flux (maybe non-linear) terms over the region for the one-dimensional case. Cross-spectral analysis with daily data reveals that this variable has a close association with P with a periodicity of ~ 7 days. It also has a connection with cloud cover as illustrated by Figure 1, which is a plot of daily HA-HD, HA, and HD with respect to solar radiation (SR) over the study region for all eight study months. Except for moderately low SR (mostly cloudy), the opposing contributions of HA and HD tend to maximize the HA-HD variable over the SGP. For 2007 (CLASIC), both HA and HD were of negative sign for the most cloudy category. These opposing roles of HA and HD were not evident in our earlier moisture budget study over the Midwestern U.S. and therefore may indicate some uniqueness of the cloud-generating environment of the SGP site. Results will include further analysis of HA-HD associations, including modeled cloud estimates.

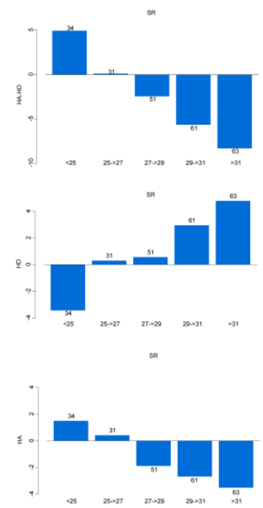

Figure 1. Mean daily values of HA-HD (top), HD (middle), and HA (bottom) when the mean daily solar radiation (SR) was in one of five categories shown. The abbreviations for these variables are defined in the text. The daily values are areal averages over our study region from all eight study months. The numbers on the top of the bars indicate the number of days that were included in that SR category. SR is in MJ m-2 day-1 with all other variables having units of mm day-1.

The first year of Raman lidar observations at Darwin

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David Turner, NOAA
Rob Newsom, Pacific Northwest National Laboratory
John Goldsmith, Sandia National Laboratories
Richard Ferrare, NASA Langley Research Center

The ARM Tropical Western Pacific (TWP) site in Darwin, Australia, provides a unique set of climate regimes. Darwin experiences three distinct climate patterns annually, consisting of (1) a dry continental regime from May to September, (2) a wet monsoon season from December to March, and (3) transition periods in April and October/November. The warmest sea surface temperatures associated with the Pacific warm pool are also observed in the TWP region. The dynamic and thermodynamic forcings associated with the Pacific warm pool significantly affect the atmosphere's general circulation. Thus, the TWP region plays a major role in the global inter-annual climate variability. Funding from the American Recovery and Reinvestment Act enabled the installation of a new Raman lidar at the TWP site in Darwin. The Raman lidar (RL) is a laser-based active remote sensing instrument that provides continuous vertical profiles of water vapor mixing ratio and several other cloud- and aerosol-related quantities at high vertical and temporal resolution. Hence, RL data provide important climatological information for better characterization of atmospheric conditions around the TWP region. The RL at the Darwin site has been operational since December 2010 with occasional downtimes resulting from instrument issues. This poster will provide an overview of the first year of TWP RL data. This will include comparisons of RL water vapor profiles with radiosondes, as well as evaluation of aerosol extinction and backscatter, cloud depolarization, and other variables. An initial climatology of water vapor mixing ratio, relative humidity, and aerosol will also be presented.

High-resolution profiles of atmospheric state: the Merged sounding, Interpolated sounding, and humidity-corrected sounding value-added products

David Troyan, Brookhaven National Laboratory
Michael Jensen, Brookhaven National Laboratory

Brookhaven National Laboratory has been producing radiosonde-related value-added products (VAP) for a significant time. The products that are currently available are (1) Mergesonde version 1, (2) Mergesonde version 2, (3) Sonde_Adjust, and (4) Interpolated_sonde. This poster highlights the scientific basis, the functionality, and the status of each of these VAPS. The high-time-resolution thermodynamic profiles—including both Mergesonde versions and Interpolated_sonde—serve as inputs into various other VAPS such as MICROBASE, BBHRP, RIPBE, and KAZR-ARSCL. Sonde_Adjust corrects well-known humidity problems found in the Vaisala RS-80, RS-90, and RS-92 radiosondes. Data from this VAP is used in Mergesonde version 2. The two merged sounding VAPs produce one-minute temporal resolution profiles of atmospheric state including thermodynamic and wind quantities. Version 1 creates profiles to 20 km above mean sea level, whereas version 2 achieves heights of 60 km above mean sea level. Each version uses available ECMWF output fields to augment the data from radiosondes, surface meteorology instrumentation, and the microwave radiometer (MWR). Interpolated_sonde uses data from the radiosonde, surface meteorology, and MWR to produce near-real-time profiles of atmospheric state parameters, but does not incorporate the ECMWF fields. This product was developed to quicken the processing of the new KAZR-ARSCL and scanning radar VAPs where high resolution profiles of winds and water vapor are needed for attenuation correction and velocity de-aliasing algorithms.

A method for estimating planetary boundary-layer heights and its application over the ARM Southern Great Plains site

Paul Schmid, Purdue University
Dev Niyogi, Purdue University

A new objective method to determine the height of the planetary boundary layer (PBL) was developed using afternoon and evening radio soundings from the ARM Southern Great Plains (SGP) site. The SGP site was well suited for this task as heights could be compared with those measured by lidar, also at the site. Heights were computed using the statistical variance and kurtosis of dewpoint and virtual potential temperature differences measured from radio soundings in the early and late afternoon. Values compared favorably with the ARM lidar measurements, gridded model data from the North American Reanalysis, and previous studies measuring PBL height in the region. Boundary-layer heights were compared with measured heat fluxes and soil moisture to measure the degree of coupling between the surface and the free atmosphere. Heights were also compared with aerosol optical depth and cloud cover to measure the coupling between the boundary layer and convection. A climatology of mean afternoon PBL heights from 2002 to 2011 was prepared over the site and compared with a concurrent climatology of aerosols and cloud cover to measure the possible impacts of land-use change or aerosol loading on the PBL depth and surface energy exchange.

http://landsurface.org

Observed diurnal cycle climatology of PBLH and CWRF sensitivity to PBL schemes

Shuyan Liu, University of Maryland
Xin-Zhong Liang, University of Maryland

The first observed climatology of the planetary boundary layer height (PBLH) diurnal cycle is provided. PBLHs are diagnosed rom fine-resolution sounding data collected in many major field campaigns across the world over various surface types. An objective algorithm determining PBLH from sounding profiles is first developed and then verified by available lidar and sodar retrievals. The algorithm is robust and produces realistic PBLH as validated by visual examination of several thousand additional soundings. This data set provides a unique observational data base for critical model evaluation on the PBLH diurnal cycle and its temporal/spatial variability. As the state-of-the-art regional climate model (RCM), CWRF (Climate extension of Weather Research Forecasting model) was developed, incorporating numerous improvements that are crucial to climate scales, thus providing the best platform for PBL schemes evaluation. CWRF-simulated PBLH diurnal cycles with various PBL schemes (MYJ, QNSE, UW, ACM, CAM, YSU) are compared against the best diagnostic climatology at the Southern Great Plains site (97°30'W, 36°36'N) of the Atmospheric Radiation Measurement (ARM) Climate Research Facility. All TKE-based schemes (MYJ, QNSE, UW) substantially underestimate convective or residual PBL heights from noon toward evening, while others (ACM, CAM, YSU) well capture the observed diurnal cycle except for the GFS with systematic overestimation. These differences among the schemes are representative over most areas of the domain, suggesting systematic behaviors of the parameterizations. Lower PBL heights simulated by the QNSE and MYJ are consistent with their smaller Bowen ratios and heavier rainfalls, while higher PBL tops by the GFS correspond to warmer surface temperatures.

Raman lidar retrievals of mixed-layer heights

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Marian Clayton, Science Systems and Applications, Inc./NASA Langley Research Center
David Turner, NOAA
Rob Newsom, Pacific Northwest National Laboratory
Amy Scarino, Science Systems and Applications, Inc./NASA Langley Research Center
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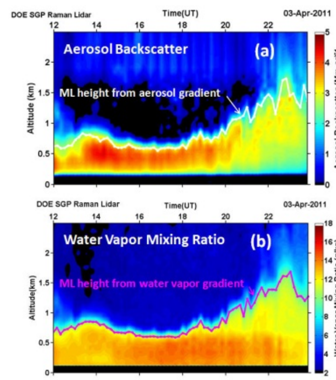
John Hair, NASA Langley Research Center
Michael Obland, NASA Langley Research Center
Raymond Rogers, NASA Langley Research Center

Accurate determination of the atmospheric mixing-layer (ML) height is important for modeling the transport of aerosols and aerosol precursors and forecasting air quality. Aerosol and water vapor profiles measured by the DOE ARM SGP and TWP (Darwin) ground-based Raman lidars provide direct measurements of the vertical structure of the ML. We have developed automated algorithms that use Haar wavelet covariance transforms to identify sharp gradients in aerosols and water vapor at the top of the ML and use these algorithms to derive ML heights during 2009–2011, including the period of the Midlatitude Continental Convective Clouds Experiment (MC3E). Since recent modifications to these lidars permit continuous temperature profiling, we also compute ML heights using potential temperature profiles derived from the Raman lidar temperature profiles. The Raman lidar ML heights are compared with ML heights derived from coincident radiosonde profiles and from coincident aerosol backscatter profiles measured by the NASA Langley airborne High Spectral Resolution Lidar (HSRL) in June 2009 during the Routine AAF CLOWD Optical Radiative Observations (RACORO) field campaign. We use the Raman lidar aerosol and water vapor profiles and ML heights to derive the fractions of total column precipitable water vapor and aerosol optical thickness within and above the ML and show how the ML heights and these fractions vary with time of day and season.



(a) SGP Raman lidar aerosol backscatter (355 nm) measurements on April 3, 2011. A preliminary indication of the mixing layer (ML) height as determined from the gradient in aerosol backscatter is shown by the white line. (b) Same except for SGP Raman lidar measurements of water vapor mixing ratio.

Retrieved temperature and humidity profiles from the AERI during MC3E

David Turner, NOAA

Four atmospheric emitted radiance interferometers (AERIs) were deployed at the SGP site close to the Central Facility to provide profiles of water vapor and temperature at high temporal resolution in the inner domain of the Midlatitude Continental Convective Clouds Experiment (MC3E). The typical spacing between the AERI systems was on the order of 15–20 km. Profiles were retrieved using an optimal estimation-based physical retrieval, thereby providing a full error covariance matrix for the solution, which reveals how the uncertainties at different levels in both temperature and humidity are correlated with each other. The influence of other trace gases on the retrieval was examined. The utility of these observations to investigate the role of small-scale horizontal inhomogeneities is examined using a couple of case studies, including a case on 29 May where a thermodynamic frontal boundary stalled directly over the domain before propagating northward as a warm front.

Routine planetary boundary layer (PBL) height value-added product (VAP) development using radiosonde measurements

Chitra Sivaraman, Pacific Northwest National Laboratory
Sally McFarlane, Pacific Northwest National Laboratory
Tami Toto, Brookhaven National Laboratory
Michael Jensen, Brookhaven National Laboratory

Planetary boundary-layer (PBL) depth is important to a wide range of atmospheric processes including cloud formation, aerosol mixing and transport, and chemical mixing and transport. Errors in the determination of the PBL height in models can significantly impact the formation and maintenance of low-level clouds. Therefore the Cloud-Aerosol-Precipitation Interactions (CAPI) working group has approved development of a PBL Height value-added product (VAP). Numerous instruments and algorithms have been used for PBL height detection, each with their own strengths and weaknesses. The PBL Height VAP will be developed in a phased approach in which we start with relatively simple algorithms and successively add new instruments and algorithms. In the first phase, development will focus on implementation of methods for PBL height detection using radiosondes, ceilometers, and micropulse lidars, as these instruments exist at all ARM sites. The poster will present results of PBL height determination from radiosonde measurements using several techniques, including examination of potential temperature gradients and critical thresholds of the bulk Richardson number. Additionally, the results from the Liu and Lang (2010) method of identifying the status (convective, stable, and residual) of the boundary layer will also be presented.

A stochastic method to evaluate carbon cycle and atmospheric transport models using atmospheric observations

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Atmospheric observations provide important constraints on the carbon cycle, but challenges arise when interpreting differences between surface fluxes inferred from observational inverse methods and those predicted by carbon cycle models. This work develops a test of the atmospheric transport models used to infer surface fluxes from concentration measurements by comparing decay rates of observed and simulated fluctuations in boundary-layer concentration gradients. This stochastic method follows an analytical solution to the conservation equation and can successfully diagnose the boundary layer-free troposphere vertical mass exchange in data from the ARM Climate Research Facility's Southern Great Plains site. The results motivate a stochastic-dynamical model to help identify sources of error in atmospheric inverse methods in terms of joint probability distributions for surface fluxes and vertical mass exchanges. This work is part of the LBNL/ARM Carbon Project measuring and modeling land-atmosphere interactions in the Southern Great Plains and North Slope of Alaska, supported by the DOE ARM, ASR, and Terrestrial Ecosystem Science (TES) programs.

Abstracts

Cloud Properties

3D tool supporting the FASTER multi-scale visualization and evaluation system

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Andrew Vogelmann, Brookhaven National Laboratory
Pavlos Kollias, McGill University
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As part of the FAst-physics System TEstbed and Research (FASTER) project, a web-deployed 3D data visualization and analysis tool is being developed to fulfill the need for easy-to-use, dynamic interactivity with large volumes of 3D data at a range of scales. The JAVA/JOGL-based open-source application is designed for easy, platform-independent installation and single-click load of 3D-gridded netCDF data. The simplified graphical user interface allows the simultaneous visualizations of a 3D volume of points and a user-selected 2D data slice. Plots and value statistics are automatically updated on screen as the user interacts with the 3D volume or 2D data slice. A data extraction utility is included that enables the export of subsets of input data and output statistics to netCDF format. Further development plans include visualization and analysis tools for collocated data sets such as aircraft trajectories and integration with the FASTER web-based testbed. Poster presentation includes an interactive and real-time demonstration of the product using ARM scanning radar data. Product release is planned for 2012 for the FASTER and Atmospheric System Research community.

Characteristics of low-cloud variability over the Azores

David Mechem, University of Kansas
Sandra Yuter, North Carolina State University
Simon de Szoeke, Oregon State University

Marine boundary-layer (MBL) clouds over the northeast Atlantic exhibit substantial differences compared to MBL cloud systems over the eastern subtropical Pacific basins. The ARM Mobile Facility (AMF) was deployed for a year and a half on Graciosa Island in the Azores in order to sample MBL and cloud system properties. In contrast with the other stratocumulus regimes, the northeast Atlantic is frequently influenced by intrusions of synoptic systems, even during the summer months. Data from the AMF deployment indicate a wide variety of MBL thermodynamic and cloud system configurations that at times differ greatly from the classical model of the stratocumulus-topped boundary layer. We focus on joint distributions of liquid water path, CCN concentration, large-scale vertical motion, and stability in order to establish the range of the parameter space that the cloud systems inhabit. These observational analyses serve as a guide to constrain initial numerical model sensitivity experiments to establish the most important factors governing cloud-system variability over the northeast Atlantic.

Characterizing convective and stratiform precipitation regimes observed during MC3E using C-SAPR radar

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Michael Jensen, Brookhaven National Laboratory
Scott Collis, Argonne National Laboratory

Observations gathered from the new Recovery Act-funded, C-band (5.6 GHz) scanning ARM precipitation radar (C-SAPR) during the MC3E campaign are used to partition precipitation events into convective cloud and widespread stratiform precipitating regions. For this effort, we combine newer ARM polarimetric radar insights with conventional radar segregation methods to classify bulk precipitation types. Identifying convective precipitation cores with radar is accomplished by evaluating 3D properties of the reflectivity factor Z field that are associated with storm intensity and spatial (texture, decay) properties. A challenge for C-SAPR and shorter radar wavelength-based classification methods is that conventional Z-based techniques are less robust for intense storms where attenuation of Z in rain is an important source of radar bias. C-SAPR dual-polarization radar measurements including the specific differential phase (KDP) are immune to partial attenuation in rain and are explored as means to improve convective/stratiform partitioning in attenuating conditions. Results of the precipitation mask partitioning are compared with those from nonattenuating radar references including profiling radars with vertical velocity insights. Partitioning is also compared with collocated surface-based video disdrometer records to reveal multiparameter bulk drop size distribution and rainfall properties linked to the assigned radar-based regimes.

Climatology of aerosol and cloud properties at the ARM SGP, TWP, and NSA sites

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Bangsheng Yin, State University of New York at Albany
Siwei Li, State University of New York at Albany
Minzheng Duan, Institute of Atmospheric Physics, Chinese Academy of Science

Long-term multifilter rotating shadowband radiometer (MFRSR) measurements at the ARM SGP, TWP, and NSA sites have been processed for aerosol and cloud optical properties. Combined with other active and passive measurements, the climatology of aerosol and cloud properties has been established. The diurnal, seasonal, and interannual variability of aerosol and cloud properties at each site has been analyzed. The comparison of aerosol and cloud properties among those sites illustrates distinct climatology in terms of large-scale circulation, aerosol-cloud interaction, and surface-atmosphere interaction. The long-term data set of aerosol and cloud properties is very useful for evaluation of climate models.

Cloud, precipitation, vertical motion, and turbulence properties from radar, lidar, and radiometer measurements in cirrus, snow, and stratocumulus clouds

Gerald Mace, University of Utah
Steven Cooper, University of Utah
Derek Posselt, Colorado State University

The cycling of water through cloud systems is intimately linked to processes that are modulated by turbulent motions in the atmosphere. Understanding these coupled processes requires measurements that can constrain them. The measurements routinely collected by the ARM Climate Research Facility have been specifically tailored to provide these measurement constraints. We have been working to develop an algorithm that can provide simultaneous estimates of cloud, precipitation, vertical motion, and turbulence properties using routine ARM measurements in ice, mixed, and liquid-phase precipitating cloud systems. We will describe the algorithm, provide validation using in situ aircraft data collected during ARM-sponsored field campaigns, and discuss directions for future work.

A comparison of cirrus radiative and mass properties between the SPARTICUS and MACPEX flight campaigns

Michael Schwartz, University of Utah
Gerald Mace, University of Utah
Paul Lawson, SPEC Inc.

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. The NASA Midlatitude Airborne Cirrus Properties Experiment (MACPEX) collected similar measurements during April 2011. During both campaigns, distributions of cirrus particle size, cross-sectional area, and mass were reported from measurements made via the 2D Stereo Probe (2D-S). These distributions, particularly those of particle cross-sectional area, relate to the radiative properties of cirrus clouds, and comparisons of these measurements between the two flight campaigns are made. This poster furthermore demonstrates use of these data to construct empirical relationships between particle maximum dimension and both particle cross-sectional area and particle mass. The resulting relationships are compared between the two flight campaigns. As such relationships are frequently used as part of cirrus property retrieval algorithms, an analysis of the uncertainty in one such algorithm due to uncertainty in these relationships is also demonstrated.

Comparison of factors modulating marine stratocumulus in the northeast Atlantic and southeast Pacific

Sandra Yuter, North Carolina State University
Matthew Miller, North Carolina State University
Simon de Szoeke, Oregon State University
David Mechem, University of Kansas

Marine low clouds are important sources of cooling within the Earth's radiation budget. The relative importance of environmental factors that modulate low cloud fraction is fundamental to improving the representation of these clouds within climate models. We use satellite and surface-based data sets from CAP-MBL and several ship cruises to the southeast Pacific to differentiate factors that are common to both stratocumulus regimes versus those that are unique to a particular geographic area. Our initial work uses geosynchronous IR data to obtain cloud fraction, height, area, and mesoscale organization for the two regions. We then examine the more detailed surface-based observations in terms of that larger scale context.

Convective cloud activity and associated lightning during the five large-scale Darwin wet season regimes

Vickal Kumar, Monash University

A two-wet-season data set from the Darwin C-band polarimetric radar and the World Wide Lightning Location Network is analysed to investigate the diurnal variability of convective cloud-top heights and associated lightning. The analysis is performed separately for five identified large-scale Darwin wet season regimes and for the three underlying surfaces: oceanic, coastal, and continental. The convective cloud occurrences are derived using two methods: the Steiner algorithm and the Thunderstorm Identification, Tracking, Analysis and Nowcasting (TITAN) system. We find that during their early growth phase, convective clouds are shallow with a peak occurrence height of approximately 9 km (and volume less than 30 km^3), and these, within few hours, grow into deeper convective towers with a peak occurrence height of approximately 14 km. For the coastal and continental regions, a majority of convective clouds develop in the afternoon, initiated by the sea breeze convergence, except during the active monsoon regime. In the active monsoon regime, convective cloud activity exhibits oceanic characteristics with a relatively low (approximately 11 km) peak occurrence height, smaller than average convective cloud volumes (36 km^3) and electrically least active convective cells. The "shallow westerly" regime is found to be electrically most active and produces the highest convective towers; this is believed to be caused by a higher amount of low-level wind convergence. The main conclusions of our study are that: (a) convective cell size depends on the large-scale atmospheric regime, the nature of the underlying surface, and the local time; (b) the cell kinematics (speed, lifetime, and direction of propagation) are mainly dependent on the large-scale atmospheric regime, and (c) the cell initiation mechanisms depend mainly on local time and the nature of underlying surface.

Detection of planetary boundary-layer height with ARM ceilometers

Victor Morris, Pacific Northwest National Laboratory

The height of the planetary boundary layer (PBL) is an important parameter for characterizing many atmospheric processes, including the dispersion of air pollutants and the formation of clouds. PBL depth is usually inferred from radiosonde measurements. However, at the ARM Climate Research Facility sites, balloon soundings occur only a few times per day and sometimes coincide with times that the PBL is rapidly developing. To improve the modeling of low-level clouds, an accurate measure of PBL height with higher temporal resolution is desired. As part of the American Recovery and Reinvestment Act, an integrated Boundary Layer Cloud System was deployed in 2010 at each of the ARM Facility sites that comprises a suite of instruments including a laser ceilometer. The new Vaisala ceilometers have the capability of continuous monitoring of the aerosol structure within the PBL. Vaisala has developed an algorithm that uses an enhanced gradient method for robust, all-weather retrieval of PBL depth. A brief test of new software that applies the algorithm was conducted at the Southern Great Plains site in June 2011. An evaluation of the measurement of PBL height from the ceilometer, compared to that from the balloon-borne sounding system, will be presented.

http://www.arm.gov/instruments/vceil

Determining conditions for stratocumulus clouds at the Azores

Simon de Szoeke, Oregon State University
Sandra Yuter, North Carolina State University
David Mechem, University of Kansas

High-albedo stratocumulus clouds cover a wide region of the world's oceans. Despite observations and models that have improved our understanding of marine stratocumulus, numerical weather prediction models rarely predict cloud occurrence better than diagnosis based on lower tropospheric stability (LTS, Klein and Hartmann 1993). Using marine-cloud observations from the two June–August seasons from the DOE ARM Mobile Facility deployment at the Azores, we diagnose cloud-emergent properties (e.g., fraction, height, and liquid water path) and their internal states (cloud drop number concentration, turbulence, and decoupling) as a function of external forcing parameters. A pair of closely related parameters is LTS and subsidence. We diagnose which of these is a better predictor of cloud fraction and how these large-scale forcings are related to cloud-top turbulence. Controlling for variability explained by the lower-tropospheric soundings, we explore whether observed changes in aerosol concentration measurably affect cloud amount, liquid water path, and cloud optical properties.

Diagnosis and reduction of biases in cloud amount simulated by the NCEP/GFS using satellite and ground-based measurements

Hyelim Yoo, University of Maryland

Cloud properties and their vertical structure are important for meteorological studies due to their impact on both the Earth's radiation budget and adiabatic heating. Furthermore, persistent marine stratus clouds over the eastern tropical oceans have not yet been resolved well in most climate and weather forecast models. The objectives of this study are to diagnose the performance of National Centers for Environmental Prediction (NCEP) Global Forecast System (GFS) model cloud simulations and to identify possible causes of the discrepancies in cloud fields using different types of satellite retrievals and ground-based measurements. Mistreatment of such marine stratocumulus clouds in the GFS model leads to an overestimation of upward longwave flux and an underestimation of upward shortwave flux at the top-of-atmosphere. With respect to input data biases, the temperature field from the GFS is comparable to that obtained from both satellite retrievals and ground-based measurements, but the GFS relative humidity field shows a wet bias in lower atmosphere. To improve simulations of low-level clouds, an experiment is performed by using the GFS model's original atmospheric fields with a different cloud parameterization scheme. The new scheme generates a large quantity of marine stratocumulus clouds over the eastern tropical oceans as well as low cloud amounts in the other regions around the world. Such results are expected to help improve the inherent problems of the GFS cloud parameterization scheme and to gain insights into the method in determining cloud fraction.

Dominant ice nucleation modes in synoptic and anvil cirrus clouds and their effect on ice morphology and fall speeds

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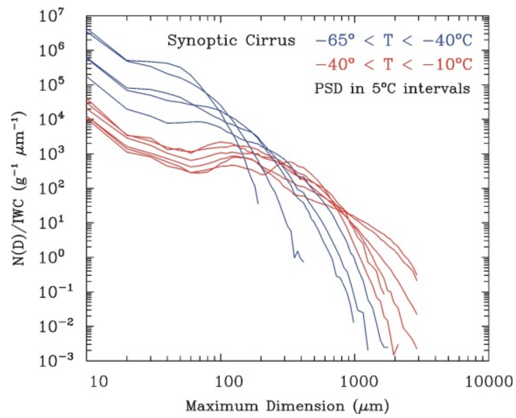
Observational studies on the relative roles of heterogeneous and homogeneous ice nucleation have yielded conflicting results regarding which process dominates at temperatures T < -40°C. This may at least partially be due to limitations of the probes used to measure the ice particle size distribution (PSD), where ice particles shatter upon entering the probe inlet tube. The resulting swarm of small ice crystal artifacts will obscure the natural concentration of small ice crystals, veiling useful information relating to ice nucleation. The TC4 and SPARTICUS field campaigns measured PSD using the 2D-S probe that was designed to minimize ice particle shattering, greatly reducing the veil of ice artifacts. Comparisons against traditional probe measurements show small ice crystal concentrations from the 2D-S are generally lower by a factor of 10 to 100 or more. Cirrus clouds during SPARTICUS were classified as either synoptic or anvil cirrus clouds while all TC4 cirrus were anvil cirrus. Synoptic cirrus clouds were discriminated from anvil cirrus via flight notes and satellite imagery of the sampled cirrus. The 174 PSD from 13 cirrus clouds consisted of 1–2 minute samples of microphysically stable regions of cloud that contained no liquid water. Going from warmer to colder T, the PSD analysis revealed the following abrupt changes near the onset T of homogeneous freezing nucleation (-38°C): (1) a change in PSD shape from bimodal to unimodal, (2) an increase in mass-normalized number concentration, (3) a decrease in mean and effective size, (4) a change in ice particle shape, and (5) a decrease in ice fall speed. All changes are consistent with homogeneous freezing nucleation dominating ice production for T < -40°C. In addition, these results agree with the T dependence of effective size and fall speed derived recently from satellite measurements of cirrus clouds. Results for anvil cirrus during TC4 and SPARTICUS were similar to the synoptic results, although the noted changes near -40°C were less abrupt with the exception of PSD shape. The results imply that cirrus cloud lifetime and coverage (through the ice fall speed) and optical properties (through crystal size and shape changes) are sensitive to the nucleation mode. These observations provide clear constraints for modeling ice nucleation processes and morphology, which in turn affect the effective size and fall speed, in GCMs and RCMs. Work is underway in applying these results to CAM5.



Temperature dependence of mass-normalized (N(D)/total IWC) synoptic cirrus PSD during SPARTICUS. PSD were averaged over 5-degree C intervals, and PSD measured at temperatures below -40 degrees C are in blue. The higher concentrations of small ice crystals in the blue PSD are consistent with homogeneous nucleation that occurs at T < -38 degrees C. The bimodality of warmer (red) PSD may be due to aggregation and lower ice nucleation rates associated with heterogeneous nucleation processes.

Evaluation of parameterizations of the vertical fluxes induced by boundary-layer clouds using ARM observations and high resolution simulations

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Boundary-layer clouds are intimately involved in the redistribution of enthalpy, moisture, and momentum in the lowest layers of the atmosphere and the transport and processing of aerosols. Thus, cloud parameterization must realistically determine the vertical fluxes induced by moist convection associated with clouds. However, not all information of vertical fluxes induced by clouds can be directly measured with the available instrumentation. To provide a comprehensive evaluation of the flux parameterization of clouds, ARM cloud observations must be incorporated with high resolution numerical simulations that explicitly resolve moist convection. In this study, the vertical flux parameterizations of shallow cumuli and stratocumulus clouds commonly used in climate models are evaluated using the case studies selected from ARM observations. We show that the advanced ARM Doppler cloud radars, such as the millimeter-wavelength cloud radar and the W-band ARM cloud radar, and the Doppler lidar provide a unique data set that can be combined with high resolution cloud simulations to provide critical evaluations of the parameterized vertical fluxes, particularly the vertical mass flux in both cloud layer and sub-cloud layer. Issues associated with vertical flux parameterizations of shallow cumuli and stratocumulus clouds are also discussed based on the evaluations performed in this study.

Evaluation of potential biases in CloudSat hydrometeor frequency of occurrence using ARM and Lindenberg cloud radar observations

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Stuart Young, The Commonwealth Scientific and Industrial Research Organisation

The CloudSat-CALIPSO radar-lidar combination is currently the best way to characterize the vertical distribution of hydrometeor frequency of occurrence on a global scale. Nevertheless, some characteristics of the instruments onboard those satellites imply that probably not all clouds are sampled by this combination. One particular difficult situation is that of low-level clouds near the oceanic or continental surface, because the lidar signal generally will be extinguished rapidly inside these water clouds, and the CloudSat radar signal may not have the required sensitivity to detect the often small-sized droplets they contain. Also the CloudSat cloud signal could be mixed with ground clutter, making the detection of these clouds difficult. The objective of this study is to characterize the errors associated with these spaceborne instrumental limitations on the hydrometeor frequency of occurrence. The underlying motivation is also to provide error bars for crucial quantitative studies ongoing with the CloudSat radar (such as the radiative budget calculations, the derivation of cloud climatologies, and the evaluation of large-scale models). In order to quantify these errors, we compare the mean vertical profiles of hydrometeor frequency of occurrence as derived over cloud radar sites at three different latitude bands (Barrow, Alaska; Lindenberg, Germany; Darwin, Australia) with the same profiles derived from extractions of CloudSat-CALIPSO observations within a 200-kilometer range from these sites.

Hole-punch clouds over Helsinki, Finland

Ewan O'Connor, University of Reading

Several hole-punch clouds were observed simultaneously over Helsinki, Finland, on November 5, 2011, in a supercooled liquid layer at an altitude of 7.5 km. The temperature of this layer was about -32Â°C. Formation of these circular holes is a result of glaciation; under certain conditions, the presence of ice nuclei in a supercooled liquid layer can produce large numbers of ice crystals that grow rapidly by deposition of water vapour in the supersaturated (with respect to ice) conditions. This rapid growth of ice crystals is maintained at the expense of evaporation of liquid droplets, causing a gap to form in the cloud, and the larger and heavier ice crystals falling in a visible streak below the liquid layer. However, ice nuclei are not normally present in high enough concentrations in the atmosphere to cause such glaciation. The mechanism responsible for glaciation is usually thought to be that ice nuclei originate via rapid freezing of water when an aircraft passes through the liquid layer. Here, we posit another mechanism that can also provide ice nuclei in sufficient quantities under certain conditions: intermittent fallstreaks from a higher cirrus layer, analogous to the seeder-feeder mechanism for enhanced orographic precipitation. This is based on observations by a collocated vertically pointing Doppler cloud radar (Metek 36) and Doppler lidar (Halo Photonics), situated on the roof of the Finnish Meteorological Institute in Helsinki, together with scans from the prototype C-band weather radar (Vaisala) on the roof of the University of Helsinki and photos from human observers. Interaction between a higher cirrus layer (8â€“11 km) and a lower mixed-phase layer 1-km deep (supercooled layer at 7.5 km with ice falling up to 1 km below) was noted in the cloud radar Doppler velocity spectra, where the velocity distribution of the falling ice from the cirrus layer broadened, then shifted to higher falling velocities after encountering the supercooled liquid layer. No aircraft were flying in this region at the altitude of the hole-punch cloud events.

How would cloud types affect the differences in multilayer cloud amounts retrieved from satellite and ARM ARSCL data?

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Mandana Khaiyer, Science Systems and Applications, Inc.
J Ayers, NASA Langley Research Center/Science Systems and Applications, Inc.

Representation of the vertical structure of cloud amount is one of the central issues driving uncertainties in cloud modeling for weather predictions and climate simulations. The measurement of the cloud vertical representation requires large data volumes of spatial and temporal cloud observation data. In order to deliver improved cloud data, and therefore improved cloud modeling, it is important to evaluate large-scale multilayered overlapping cloud amount data that have been derived from available satellite and ground-based measurements. To this end, we examined two different multilayered overlapping cloud products that are retrieved separately from (1) space-borne U.S. Geostationary Operational Environmental Satellite (GOES) imager data and (2) ground-based U.S. DOE ARM active lidar and radar observations. This examination involved an innovative method developed by the authors for retrieving multilayer cloud properties using the GOES passive satellite data as well as MODIS data. It integrates the measurements from the CO2-absorption channel with other atmospheric window channels to quantitatively determine the overlapping cloud properties on a pixel-by-pixel basis. The ARM active lidar/radar data utilized in this study is the Active Remote Sensing of Clouds (ARSCL) cloud vertical mask data product. The resulting GOES multilayered cloud properties were analyzed over the ARM SGP Central Facility site for multiple years and are compared to temporal and spatially matched ARSCL data. It was found that generally good agreement exists between the two for well-defined multilayer cloud profiles. However, significant differences exist for various multilayered conditions. For instance, in some cases, the GOES method would miss multiple layered clouds that did not possess a sufficient layer altitude separation. For other cases, the ARSCL method would miss upper-level thin cirrus clouds that were above optically thick lower clouds. A summary report of agreement and differences will be discussed for different cloud types based on their physical and optical properties.

Ice clouds microphysical retrieval using millimeter-wavelength Doppler radar observations

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A retrieval algorithm designed to estimate the ice cloud microphysical parameters from millimeter-wavelength cloud radar is presented. It uses combined information of radar reflectivity and Doppler velocity supplemented by temperature. The retrieval technique based on the optimal estimation (OE) method provides estimates of the mean mass-weighted diameter of ice particle size distribution and of ice water content. The algorithm follows the new microphysical approach in which the relations that govern the forward model within the OE framework as described in Szyrmer et al. (2012) are developed. The OE iterative technique allows a quantitative evaluation of the uncertainty of the retrieved quantities and is applied separately for a few selected sets of microphysical parameters. The final solution is the one that is most consistent with the radar observables. A sensitivity analysis of the proposed retrieval technique was performed using the cloud radar measurements collected during the SPARTICUS field campaign over the ARM Southern Great Plains site between January and June 2010.

KAZR-ARSCL: the new ARSCL VAP for the Ka-band ARM zenith-pointing radar

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With the installation of the new Ka-band ARM zenith-pointing radars (KAZRs) comes the need for a new value-added product (VAP) to make their measurements more readily usable by the scientific community. For over a decade, the ARSCL (Active Remote Sensing of Clouds) product has filled this need with respect to the previous generation of 35-GHz radars, the millimeter-wavelength cloud radars (MMCRs). Now that the MMCRs have been retired, the original ARSCL VAP will be retired following the completion of all historical processing. As in the original ARSCL product, the KAZR-ARSCL VAP combines data from several active sensors that provide complementary measurements: the KAZR (with its various operating modes), the Vaisala ceilometer, and the micropulse lidar, via the micropulse lidar cloud mask VAP. In addition, it will incorporate rain gauge and radiosonde observations. The KAZRs, installed at all of ARM's fixed sites as well as the second ARM Mobile Facility, are collecting observations with improved sensitivity, higher spatial and temporal resolution, and a more robust polarization mode. Taking advantage of these improvements, the new KAZR-ARSCL VAP has increased resolution relative to the original ARSCL, with 4-second time resolution and 30-meter height resolution. KAZR-ARSCL applies a correction for water vapor attenuation (which the original ARSCL did not), employs an improved mean Doppler velocity dealiasing technique, and offers greater accuracy in radar clutter detection. The KAZR-ARSCL VAP is expected to run autonomously, without the need for human intervention and corrections. This should result in far more timely data processing than was possible with the original ARSCL. KAZR-ARSCL will produce two primary datastreams: the complete data set with time-dependent cloud boundaries and best-estimate cloud bases as well as time-height fields of best-estimate radar moments, and a smaller datastream, consisting only of cloud boundaries and best-estimate cloud base.

A method for extraction of cloud microphysical properties using a continuous wavelet transform of cloud radar spectra

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Eugene Clothiaux, The Pennsylvania State University
Giovanni Botta, The Pennsylvania State University
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Andrew Ackerman, NASA Goddard Institute for Space Studies
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Stratiform clouds across the globe frequently contain both liquid- and ice-water particles in the same volume; that is, they are often mixed-phase clouds. Millimeter-wavelength cloud radar data are an important source of information on the microphysical properties and dynamical processes within these clouds. However, retrieving and quantifying the climatological radiatively important liquid-phase particles within these clouds remains a challenge because the radar signal is frequently dominated by the returns from the ice particles within these volumes. The ice masks the small reflectivity contribution from the liquid phase. Here, we present a technique that extracts the weak cloud-liquid drop contributions to millimeter-wavelength cloud radar (MMCR)/Ka-band ARM zenith radar (KAZR) Doppler-velocity spectra in which ice-particle returns dominate. In this approach spectra are first decomposed using a continuous wavelet transform. The resulting coefficients are then used to identify regions in the spectra where cloud drops contribute; Gaussian distributions are subsequently fit to these regions. Our preliminary results indicate this approach is capable of separating the cloud- and ice-particle contributions to the Doppler-velocity spectra. In the process the volume air motion and its turbulent broadening are also extracted. We will present results derived from synthetic spectra based on hydrometeor size distributions produced by state-of-the-art cloud-resolving model (CRM) simulations of Arctic mixed-phase clouds. The retrieval of the liquid- and ice-water contributions will be evaluated against the microphysical parameters extracted from the CRM and used to generate the synthetic spectra. We will also present the comparison between the retrievals based on the radar observation data from the Mixed-Phase Arctic Cloud Experiment (M-PACE) and the other in situ observations.

Mixed-phase cloud properties retrieval using MODIS reflectances and ARM NSA ground-based data

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Zhien Wang, University of Wyoming

The Arctic region is characterized by the high occurrence of low-level boundary-layer clouds and mid-level clouds, which often consist of complex three phase cloud systems of liquid, ice, and mixed phase. The coexistence of the different phases of cloud particles within a cloud layer often results in large uncertainties in the retrieved cloud microphysical properties by assuming a single phase (either liquid or ice) cloud layer because of the different refractive indices, particle sizes, and concentrations of ice and water particles. The current MODIS operational retrievals of effective radius (re) and optical depth assume a single water/ice phase clouds. The collocated MODIS retrievals and ARM NSA ground-based measurements show that MODIS-retrieved liquid water paths (LWPs) are systematically higher than ground-based measurements, especially at temperatures colder than -15°C. With ground-based retrievals as truths, we developed a two-layer mixed-phase cloud model (ice layer below water layer) to estimate the liquid phase re and optical depth with MODIS reflectances at 1.24 and 2.13 micrometers and ground-based measured ice properties. The Discrete Ordinate Radiative Transfer (DISORT) model is used to develop a look-up table for reflection function for mixed-phase clouds with different values of liquid water re and optical depth. Ice cloud properties, including effective particle size (Dge) and ice water content (IWC), calculated from measurements at the ARM NSA site are incorporated into radiative transfer calculations to estimate re and optical depth. Retrieved liquid water re and optical depth are validated against the ground-based measurements at the ARM NSA site and show significant improvements. The application of this new mixed-phase cloud retrieval algorithm to global MODIS measurements will be discussed too.

Modeling the growth of ice from the vapor: approximations, problems, and possible improvements

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Ice crystal vapor growth is a physical process that is critical for the evolution of the vast majority of atmospheric clouds. Despite its importance, numerical cloud models have primarily used a single method for approximating growing ice from the vapor, that being the capacitance analogy. In this analogy, a crystal is assumed to have vapor fields that can be approximated as the electrostatic potential surrounding a capacitor. This approximation is typically combined with mass-size relations derived from in situ cloud data to close the growth equations. These two approximations (capacitance and mass-size relations) are not only used in cloud models but are also routinely used to interpret laboratory measurements. Nevertheless, these approximations can produce large inaccuracies in the modeling of ice crystal growth, particularly at certain temperatures and supersaturations, even for idealized crystal shapes. One of the major shortcomings of this method is that the surface boundary condition requires the vapor density to be constant, which leads to an aspect ratio that does not vary in time. We use a combination of prior laboratory data, theoretical analysis, and detailed ice growth models to expose the temperature and supersaturations where these approximations are appropriate, where they break down and why, and possible methods to correct for the inaccuracies. Our analysis leads to a unified ice growth model that provides improved growth estimates for simple crystal shapes and can be used to interpret laboratory data and for growing ice in cloud models.

A new approach for entrainment rate estimation in cumulus clouds

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Shengjie Niu, Nanjing University of Information Science and Technology
Satoshi Endo, Brookhaven National Laboratory

A new approach is presented to estimate entrainment rate in cumulus clouds with aircraft measurements. The new approach is directly derived from the definition of fractional entrainment rate and relates it to cloud-clear air mixing fraction and height above cloud base. The results derived from the new approach compare favorably with those obtained with a commonly used approach and have smaller uncertainties (Figure 1). This new approach has several advantages: it eliminates the need for in-cloud measurements of temperature and water vapor content, which are often problematic in current aircraft observations; it has the potential for straightforwardly connecting the estimation of entrainment rate and the microphysical effects of entrainment-mixing processes; and it also has the potential for developing a remote sensing technique to infer entrainment rate.

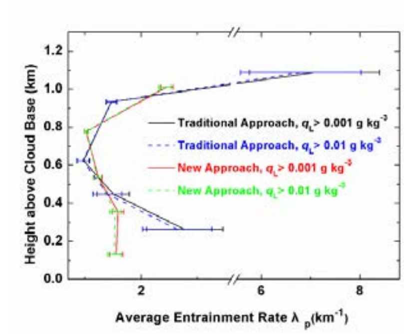


Figure 1. Comparison of the vertical profile of entrainment rate (λp) obtained using the new approach and the result from a traditional approach with different liquid water mixing ratio thresholds. The uncertainties are also shown.

Observationally based evaluation of NWP reanalyses on cloud vertical properties and their link to atmospheric radiation estimation over the Southern Great Plains

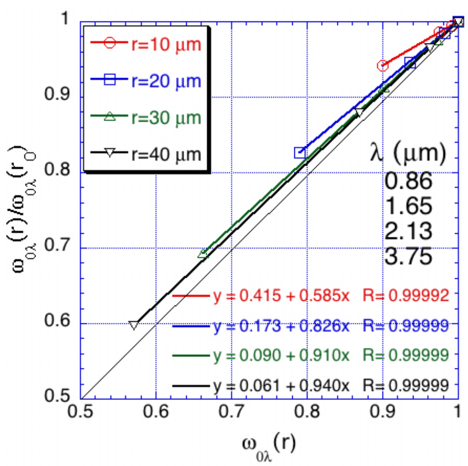
Wei Wu, Brookhaven National Laboratory

Cloud vertical properties (e.g., cloud top/base height) are critical to the estimation of atmospheric radiation. For understanding the linkage between model biases on cloud vertical properties and model biases on estimated atmospheric radiation, we use available reanalyses (e.g., ERA-Interim, NCEP/NCAR Reanalysis I, NCEP/DOE Reanalysis II, MERRA, and NARR) to first investigate the model biases on the cloud properties and estimated atmospheric radiation, by using the observations from the U. S. Atmospheric Radiation Measurement (ARM) Climate Research Facility Southern Great Plains (SGP) site. After that, the relationships between the model biases are examined. Connections to the common meteorological variables (e.g., temperature and relative humidity) are also discussed.

On spectral invariance of single scattering albedo for weakly absorbing wavelengths

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

The single scattering albedo ω0λ in atmospheric radiative transfer is the ratio of the scattering coefficient to the total extinction coefficient. For cloud water droplets both the scattering and absorption coefficients, and thus the single scattering albedo, are functions of wavelength λ and droplet size r. We show that for water droplets at weakly absorbing wavelengths, the ratio ω0λ(r)/ω0λ(r0) of two single scattering albedo spectra for two different droplet sizes is a linear function of ω0λ(r). The slope and intercept of the linear function are wavelength-independent and sum to unity. This relationship allows for a representation of the spectral variation of single scattering albedo ω0λ(r) for any droplet size using the spectral variation for just one size. We provide a simple physical explanation of the discovered relationship. Similar linear relationships characterize the single scattering albedo of non-spherical ice crystals.



The ratio of ω0λ(r)/ω0λ(r0) plotted against ω0λ(r) for four wavelengths λ=0.86, 1.65, 2.13, and 3.75 μm. Single scattering albedos ω0λ(r) are calculated using Mie theory. Droplet effective radius r=10, 20, 30, and 40 μm; r0=5 μm. Droplet sizes are assumed to follow a gamma distribution with effective variance v=0.1.

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
Hugh Morrison, National Center for Atmospheric Research

Arctic mixed-phase clouds are ubiquitous for much of the year, and the persistence of supercooled liquid in these clouds is not well understood. Most prior studies of mixed-phase clouds suggest that ice concentration plays the strongest role in controlling the structure, phase partitioning, and lifetime of these clouds. However, these prior studies assumed spherical particles or simple shapes that led to an over-estimate of mixed-phase cloud lifetime. These methods lack the ability to accurately evolve particle shape by adjusting particle growth parameters approximated off of in situ data. We show that this method is inconsistent with the vapor growth equations. To improve ice prediction, we present a new parameterization to proficiently predict single-particle or bulk-averaged aspect ratio evolution with a historical tracking parameter. The method is implemented into a two-dimensional Kinematic model and into the Weather Research and Forecasting model. Initial studies show that predicting ice habits have strong effects on cloud and water phase partitioning. Cloud dynamics modify these results as vertical motions can support the simultaneous growth of both liquid and ice. Dynamics extend cloud lifetime when ice concentrations are low, and ice crystals grow at temperatures that promote isometric growth (around -10°C). Temperatures where growth is highly non-spherical (-15°C and -6°C) require higher vertical motions and lower ice concentrations to maintain the liquid phase. Our results suggest a strong temperature dependency as well as varying degrees of microphysical and macrophysical dependencies to supercooled liquid maintenance in Arctic clouds.

Potential of using scanning polarimetric cloud radar measurements for identifying habits of ice hydrometeors and estimating their shapes

Sergey Matrosov, CIRES, University of Colorado/NOAA Earth System Research Laboratory
Gerald Mace, University of Utah
Roger Marchand, University of Washington
Matthew Shupe, University of Colorado
Gannet Hallar, Storm Peak Laboratory Desert Research Institute
Ian McCubbin, Desert Research Institute

The ARM Mobile Facility 2 was deployed during the winter of 2010–11 near Steamboat Springs, Colorado for the Storm Peak Lab Cloud Property Validation Experiment (STORMVEX). This presentation deals with the preliminary analysis of the scanning W-band ARM cloud radar (SWACR) data, which were promising for identification of ice hydrometeor habits (e.g., planar crystals versus columnar crystals) and estimation of their shapes (e.g., mean aspect ratios). A slant 45-degree linear polarization was used with the SWACR during STORMVEX, and the slant linear depolarization ratio (SLDR) was the measured polarimetric radar parameter exhibiting sensitivity to particle habits/shapes. The range-height indicator (RHI) scans were used for habit/shape recognitions. The in situ particle observations, collocated with radar measurements, were conducted at the Storm Peak Lab, located at an altitude of 450 m and at a range of 2.4 km from the radar. Observed ice hydrometeor habits ranged from pristine and rimed dendrites/stellars to aggregates, irregulars, graupel, columns, plates and particle mixtures. SLDR trends as a function of the radar elevation angle were indicative of the predominant hydrometeor habit/shape. For planar particles, SLDRs increase from values near the cross-talk of -21.8 dB at zenith viewing to maximum values at slant viewing. These maximum values depend primarily on predominant aspect ratio and bulk density of hydrometeors. The highest observed SLDRs at slant viewing were about -8 dB for pristine dendrites, which had the smallest aspect ratio among observed planar crystals. The maximum SLDRs at slant viewing gradually decrease as planar particle mean aspect ratios increase (i.e., particles become more spherical) due to riming or/and aggregation. Unlike planar hydrometeors, columnar particles (e.g., columns, needles) did not exhibit pronounced SLDR trends with the elevation angle. A difference in SLDRs between zenith and slant viewing can be used for inferring predominant aspect ratios of planar hydrometeors if an assumption about bulk density is made. For columnar particles, SLDR offsets from the cross-talk value are indicative of aspect ratios. Collected data are also indicative of particles being oriented preferably with their major dimensions in the horizontal plane. Relatively simple oblate (for planar crystals) or prolate (for columnar crystals) spheroidal particle models were able to approximate SLDR changes with the elevation angle.

Predicting ice habit evolution by riming for cloud models

Anders Jensen, The Pennsylvania State University
Jerry Harrington, The Pennsylvania State University
Hugh Morrison, National Center for Atmospheric Research

The growth of ice crystal in clouds is a challenging problem given the variety of crystals that can occur. Prior methods for growing ice crystals have depended on the use of mass-size relationships as a way to close the growth equations and evolve particle sizes. In many applications, this has led to the definition of multiple particle classes (small ice, snow, graupel, etc.) and transfer functions between them based on somewhat arbitrary boundaries. In this work we extend the more recent trend towards predicting particle properties to habit evolution through riming. Recently, a method to capture habit evolution in mixed-phase bulk cloud models has been developed (e.g., Sulia and Harrington 2011; Harrington, Sulia, and Morrison 2012). This method captures the evolution of ice aspect ratio avoiding the need for multiple ice and snow classes. Following prior work this model is extended to include the impacts of riming on mass, size, and aspect ratio evolution of the ice habits. We show that the method produces a more natural evolution from more pristine ice classes with very large, or small, aspect ratios towards graupel-like particles with aspect ratios near unity.

Preliminary retrievals of cloud and drizzle properties in the Azores using optimal estimation theory

Edward Luke, Brookhaven National Laboratory
Wanda Szyrmer, McGill University
Aleksandra Tatarevic, McGill University
Pavlos Kollias, McGill University

Advancing our understanding of the cloud-scale physical processes that affect cloud lifetime requires high-resolution measurements in clouds. One area of great interest is the separation of cloud and drizzle microphysics and turbulence in warm clouds to shed light on precipitation initiation, evolution, and the influence of aerosols and dynamics. Here, observations from the 21-month long ARM Mobile Facility (AMF) deployment in the Azores, as part of the Clouds, Aerosol, and Precipitation in the Marine Boundary Layer (CAP-MBL) field campaign, are used to develop an optimal estimation theory retrieval algorithm that aims to separate cloud and drizzle properties. The measurement vector includes the W-band radar Doppler spectrum profiles, liquid water path measurements from the microwave radiometer, cloud base height measurements from the ceilometer, and thermodynamics information from the nearest sounding. The output variables include the particle size distributions and liquid water content of drizzle and cloud populations, as well as vertical air motion, eddy dissipation rate, and liquid water flux. Furthermore, the methodology implicitly generates uncertainty estimates for all retrieved variables. In this presentation, we show preliminary results that extend our recent cloud/drizzle retrieval capabilities from light drizzle to all drizzling conditions through application of the optimal estimation algorithm. A preliminary assessment of retrieval quality is made using the coherency of retrieved fields in time and space and through comparisons of retrieved drizzle parameters at the cloud base with those from the O'Connor radar/lidar technique.

Satellite cloud retrievals for ARM sites and field experiments

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Christopher Yost, Science Systems and Applications, Inc.
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Fu-Lung Chang, Science Systems and Applications, Inc.
Thad Chee, Science Systems and Applications, Inc.
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Gang Hong, NASA
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Kris Bedka, NASA
Mandana Khaiyer, Science Systems and Applications, Inc.

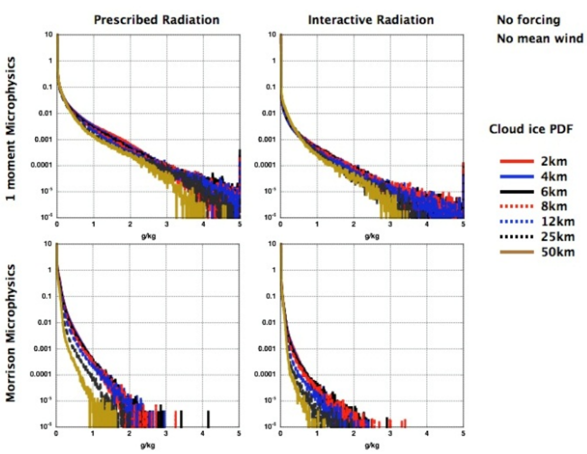
NASA Langley is regularly providing cloud properties and top-of-atmosphere broadband longwave and shortwave fluxes derived from satellite data over large areas for ARM and its associated field programs. Both geostationary and polar-orbiting satellite imager data are analyzed to detect clouds and retrieve their microphysical properties. The algorithms and satellite data used to produce the cloud and radiative products are often updated as new approaches and calibrations become available. This paper discusses the currently available data sets and recent improvements that have been implemented in the data processing. For example, new rough ice crystal scattering models are now employed in retrievals of ice cloud microphysical properties, cloud detection near the terminator has been improved with a new statistical method, new calibrations using the latest MODIS data have been brought into play, and a new GOES-West satellite has replaced GOES-11 with a slightly changed imager channel complement. All of these changes affect the retrieved properties. These and other changes are discussed using before-and-after examples. We have also been providing satellite support for many ARM field experiments. The resulting data sets and a few comparisons with ARM measurements are presented. Expected changes in future editions of the retrievals are also discussed.

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

Sensitivity of the statistics of simulated convective cloud systems to horizontal resolution

David Randall, Colorado State University
Donald Dazlich, Colorado State University
Todd Jones, Colorado State University

We will present an analysis of the sensitivity of simulated convection and cloud statistics to horizontal resolution, with grid spacings in the range from 0.5 km to 50 km. The three-dimensional non-hydrostatic numerical model is SAM, the System for Atmospheric Modeling, developed by Marat Khairoutdinov. We study both radiative-convective equilibrium and time-dependent advective forcing based on GATE. We include cases with prescribed radiative cooling and others with computed radiation based on RRTM. We use both one-moment and two-moment microphysics parameterizations. The results show that the key statistics of convective cloud systems are well simulated with grid spacings of 4 km or finer, but not with coarser grids.



Probability density functions for the cloud ice mixing ratio, in grams per kilogram, for each member of an ensemble of radiative-convective equilibrium simulations. The horizontal grid spacings used range from 2 km to 50 km and are distinguished by color, as shown in the legend. The top two plots show results obtained with the one-moment microphysics of Lin et al., while the bottom two plots are for simulations with the Morrison microphysics. The two simulations on the left use prescribed radiation, while those on the right use interactive radiation.

Studies of cloud microphysics in Arctic mixed-phase cloud: long ARM observational time-series take us beyond case studies

Lynn Russell, Scripps Institution of Oceanography
Johannes Muelmenstaedt, Center for Atmospheric Sciences and Physical Oceanography
Dan Lubin, National Science Foundation
Andrew Vogelmann, Brookhaven National Laboratory

Mixed-phase clouds occur in the Arctic for a large part of the year. Because the partitioning between ice and liquid water in these clouds—and hence their radiative properties—can vary widely, their correct representation in climate models is an urgent problem. The North Slope of Alaska (NSA) site of the ARM Climate Research Facility in Barrow, Alaska, has collected well over a decade of cloud property and radiation measurements with the aim of testing and refining climate model parameterizations of mixed-phase Arctic cloud. In this work, we classify the existing observations into four major meteorological regimes in two ways: (1) inspection of NCEP reanalysis data, and (2) k-means clustering on surface meteorological data. We show that cloud properties, as derived from radiometry, lidar, radar, and balloon-borne sensors, differ significantly between the four meteorological regimes. These regimes can therefore serve as ensembles of test cases for cloud properties that can be used to robustly test climate model parameterizations, exposing models to physically relevant atmospheric states spanning the full range of meteorological variability found in nature. 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. To illustrate the utility of this approach, we use over a decade of ARM observations to show that model success differs significantly between meteorological regimes in comparisons between observed and modeled cloud properties in a single-column and a regional climate model with a variety of microphysical parameterizations, ranging from strong underprediction of cloud optical thickness when high pressure to the north prevails to strong overprediction during low-pressure systems to the south.

Thermodynamic and radiative structure of stratocumulus-topped boundary layer

Virendra Ghate, Rutgers University
Mark Miller, Rutgers University
Bruce Albrecht, University of Miami

Boundary-layer stratocumulus clouds cool the surface underneath them by reflecting greater incoming shortwave radiation compared to the underneath surface, while emitting longwave radiation comparable to the underneath surface. The turbulence within a stratocumulus-topped boundary layer is thought to be maintained primarily through the cloud-top radiative cooling. Since the same parameterization is used in global climate models (GCM) to represent stratocumulus clouds and their linkage to the boundary-layer turbulence both over land and over the oceans, it is important to highlight the similarities and the differences between the two. In this study, we have analyzed the thermodynamic and radiative structure of stratocumulus-topped boundary layer using 166 soundings launched at the Southern Great Plains (SGP) site, 202 soundings launched during the ARM Mobile Facility (AMF)'s deployment at the island of Graciosa, Azores, and 158 soundings launched during cruises conducted in the South-East Pacific region. In addition to the general thermodynamic properties like Convective Available Potential Energy (CAPE), Convective Inhibition (CIN), inversion strength, etc., the associated cloud macro-physical properties like cloud boundaries, liquid water path, and surface turbulent fluxes are also quantified. The associated radiative fluxes and radiative heating rates were estimated using the Rapid Radiative Transfer Model (RRTM) at a 20-meter resolution within the boundary layer and at a 500-meter resolution above that. Profiles of thermodynamic and radiative properties will be presented using a height scale normalized by the inversion base height. The soundings will be further classified into coupled (well-mixed) and decoupled soundings using the difference between the cloud base height and lifting condensation level (LCL). The differences between the structure of coupled and decoupled boundary layer will be quantified, and an attempt will be made to explore the causes of these differences.

Turbulence profiles and cloud-surface coupling in Arctic stratiform clouds

Matthew Shupe, University of Colorado
Ola Persson, CIRES, University of Colorado/NOAA Earth System Research Laboratory
Amy Solomon, NOAA Earth System Research Laboratory Physical Sciences Division
Ian Brooks, University of Leeds
Guylaine Canut, University of Leeds

Stratiform clouds play a key role in Arctic climate through their high frequency of occurrence, persistence, variability of phase composition, and impacts on radiation and hydrology. Many of the key mechanisms that characterize these clouds are poorly understood due to complexities associated with a three-phase water system that is sensitive to aerosol properties and intricately tied to the atmospheric structure. Observations suggest that these clouds are at times thermodynamically coupled to the surface while at other times they are decoupled by an intervening stable layer. In this study we examine the coupling state of mixed-phase stratiform clouds during the fall and spring transition seasons at Barrow, Alaska. Characteristic signatures of the coupling state can be derived from ground-based remote sensors such as Doppler cloud radar. For example, radar-derived turbulent dissipation rates that are quasi-constant in height from the cloud layer down to the surface suggest that both the cloud and surface contribute to the turbulence affecting the cloud layer. On the other hand, a decrease in dissipation rates below the cloud suggest that the cloud itself is primarily responsible for generating its own turbulence without much influence from the surface. Retrievals of the dissipation rate are first evaluated using independent measures from aircraft and tethered-balloon systems, demonstrating that the radar estimates are able to reasonably represent the dissipation rates and their vertical distribution. We then explore the impact that the coupling state has on a number of cloud properties such as depth, height, microphysical properties, and temporal variability. For example, it is generally found that surface-coupled clouds tend to have larger liquid water paths and stronger vertical motions than those that are decoupled. Overall, the cloud-surface coupling state can have significant impacts on the cloud structure and lifetime as it controls the balance of heat, moisture, and aerosols to the cloud from below and above.

Uncertainty analysis of cloud properties retrieved from MICROBASE

Chuanfeng Zhao, Lawrence Livermore National Laboratory
Shaocheng Xie, Lawrence Livermore National Laboratory
Maureen Dunn, Brookhaven National Laboratory
Michael Jensen, Brookhaven National Laboratory

Quantification of uncertainty in cloud retrievals is important for cloud modeling studies. In this study, we perform an uncertainty analysis on the cloud properties retrieved from MICROBASE, the ARM baseline retrieval. Two types of uncertainties are studied. One is associated with uncertainties in defining those parameters that are used in the MICROBASE retrievals. The other one is related to uncertainties in the input data that are required to run the MICROBASE. The analysis is done by randomly perturbing several key parameters and required quantities within a range constrained by observations. In this poster, we will show preliminary results of this study based on ARM Southern Great Plains March 2000 data.

What controls the fractional cloudiness of fair-weather cumuli in a tropical marine environment?

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

The fractional coverage of fair-weather cumuli in marine environments has an important impact on Earth's surface radiation budget, since these clouds are the most prevalent cloud type over the oceans. Here we make use of ARM observations made from Nauru Island (0.5°S, 167°E) from 1999–2000 during a prolonged period of suppressed conditions at the island. Non-precipitating fair-weather cumuli were the dominant cloud type, and little precipitation was observed. Monthly averages of fractional cloudiness obtained from the ceilometer vary from about 10 to 20% on a seasonal time scale during this period. The fractional cloudiness has a negative correlation (r=-0.84) with the sea surface temperature and the large-scale low-level boundary-layer temperature advection (from NCEP Re-analysis). In this study we examine the processes and parameters responsible for this negative correlation. The cumulus cloud-base mass flux and fractional area coverage of active updrafts are obtained from MMCR Doppler velocity measurements. A mixed-layer model of the subcloud layer based on monthly averaged surface and near-surface temperature and moisture measurements and cloud base height from a ceilometer provides estimates of the convective velocity scale w*. Thermodynamic soundings are used to estimate the static stability in the lower troposphere, the convective inhibition (CIN) at cloud base, and the relative humidity in the cloud layer. These parameters are used to establish the role of various physical processes in regulating the fractional cloudiness of fair-weather cumuli in a marine tropical environment.

Zenith/nadir-pointing cloud radars: linear or circular polarization?

Michele Galletti, Brookhaven National Laboratory
Dong Huang, Brookhaven National Laboratory
Pavlos Kollias, McGill University

In this paper we consider scatterers with azimuthal symmetry and explore the effects of transmit polarization (either linear or circular) on the retrieved polarimetric variables: reflectivity, depolarization ratio, cross-polar coherence, and degree of polarization. The results are relevant to the interpretation of signatures from millimeter-wavelength zenith-pointing cloud radars, like the KAZR (Ka-band zenith-pointing radar), MMCR (millimeter-wavelength cloud radar) and WACR (W-band ARM cloud radar) systems in use at the Atmospheric Radiation Measurement (ARM) Climate Research Facility operated by the U.S. Department of Energy, as well as for nadir-pointing precipitation and cloud radars onboard NASA (National Aeronautics and Space Administration) and ESA (European Space Agency) satellite missions. It is found that, for scatterers with azimuthal symmetry, reflectivity is maximized at linear polarization transmit (therefore preferable for single-polarization systems), whereas the depolarization ratio dynamic range is maximized at circular polarization transmit (probably preferable for dual-polarization systems). The physical meaning of the cross-polar coherence is revisited in terms of scattering symmetries, and use of the degree of polarization to extend the depolarization ratio dynamic range below the cross-polar isolation level of the antenna is illustrated. Two practical applications emerge from this theoretical analysis. First, at Ka-band (wavelength is 8 mm), the circular depolarization ratio (CDR) of rain displays a large dynamic range due to non-axisymmetric drop oscillations. Since drop oscillations map monotonically to raindrop size, CDR also maps monotonically to raindrop size, and we exploit this dependence to derive a rain-rate estimator at Ka-band. Experimental data from MMCR are compared with Mishchenko T-matrix code to substantiate the result. Second, the polarimetric analysis conducted for scatterers with azimuth symmetry outlines a powerful two-dimensional classification scheme making use of Huynen parameters. Given the stunning variability of ice crystal habits (pristine dendrites, stellars, columns, needles, plates + the processes that transform them: riming and aggregation), it is necessary to develop a model-free classification scheme that identifies some “shape parameter” independently of any assumed model. In our scheme, cloud of spheres and cloud of dipoles can be uniquely identified in the classification plane, thus providing an indication to how “sphere-like” or how “needle-like” the scatterers are.

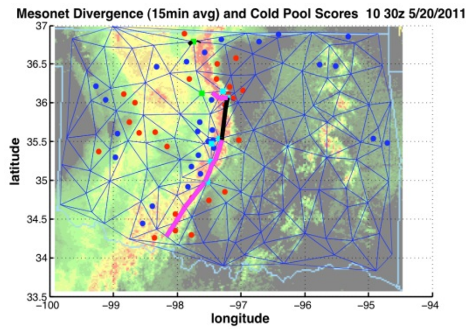
Abstracts

Dynamics/Vertical Motion

Analysis of convectively generated cold pools and fronts from Mesonet data

Andrew Lesage, University of Utah
Steven Krueger, University of Utah

The Oklahoma Mesonet includes over 100 stations throughout Oklahoma and has been collecting observations for over 15 years at 5-minute intervals. Surface observations of temperature, pressure, and wind speed were used in this study to identify frontal passages and cold pools for the JJA 1997 period and the 15 April–31 May 2011 period, which coincided with the Midlatitude Continental Convective Clouds Experiment (MC3E). The Mesonet stations, minus those located in the panhandle, were used to construct a grid using the Delaunay Triangulation method. A unitless variable, termed a "cold pool score", based on pressure rises and temperature falls at a station over 30-minute intervals, was used to determine the location of fronts associated with convectively generated cold pools as they progressed across the Mesonet. The frontal analysis was able to identify the fronts accurately in a variety of cases as well as to provide statistics for the frequency and strength of fronts. Western Oklahoma had the highest frequency of fronts during JJA 1997, and Eastern Oklahoma during the MC3E period. The temperature and pressure change values during the frontal passages had near-zero correlation in the JJA 1997 period and a correlation of -0.21 for the MC3E period. This suggests that there is high variability in the vertical structure of temperature perturbations in the cold pools. Strong convergence typically occurred ahead of a front, with strong divergence behind. Cold pools were identified by requiring a frontal passage across a Mesonet triangle to have occurred as well as strong divergence. This set of requirements appears to be capable of capturing convectively generated cold pools reasonably well. It also filters out the cases of frontal passages that do not have cold pools, such as the dry frontal passages. This method of identifying fronts and cold pools should prove to be useful for evaluating cumulus parameterizations. Additional research was performed to calculate an estimate of evaporation of precipitation assuming it was responsible for the entire pressure change during the frontal passage. These results may help constrain microphysical parameterizations of raindrop break-up.



Example of frontal analysis based on Mesonet station time series. Red dots indicate triangles with strong convergence. Dark blue dots indicate triangles with strong divergence. Green squares are cold pool scores >3 and <5, while cyan squares are cold pool scores of > 5. (Radar image from the UCAR image archive.)

Anomalous heating distributions and the MJO in CAM4

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

Vertical and horizontal heating distributions are critical in determining the strength, location, and duration of the Madden-Julian Oscillation (MJO). Implementing a technique we developed to add either idealized or realistic heating distributions to CCSM4.0, we showed in our previous work that correctly simulating the horizontal distribution of tropical heating is critical for accurate modeling of the MJO. We also showed the importance of the heat and moisture exchanges that take place at the ocean-atmosphere interface. In this current work, we employ the same technique to look at tilted heating distributions, both idealized and observed. We use idealized distributions of heating that are tilted to mimic the east-west progression of shallow convective, deep convective, and stratiform clouds that is observed to pass during an MJO event. We also do a run in which we add observed heating distributions that include the components from shallow and radiative heating. For the idealized cases, 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 control runs done with little or no horizontally varying heating. We perform sensitivity studies on the strength and location of heating, as well as the angle to which the tilting occurs. Preliminary results show that the addition of the shallow convective component is more important than the upper-level radiative component. We also show that the most robust MJO occurs when the tilting angle between the stratiform and mid-level convection is steeper than that of the tilting angle between the shallow and mid-level convection. A stronger MJO signal is also evident when the added heating moves southward as the MJO advances to its later phases.

Development of multi-scale large-scale forcing data sets for MC3E cloud modeling studies

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Yunyan Zhang, Lawrence Livermore National Laboratory
Renata McCoy, Lawrence Livermore National Laboratory
Minghua Zhang, State University of New York at Stony Brook

The large-scale forcing fields (e.g., vertical velocity and horizontal advective tendencies) are required to run single-column and cloud-resolving models (SCMs/CRMs), which are the two key modeling frameworks widely used to link field data to climate model developments. In this study, we use an advanced objective analysis approach to derive the required forcing data from the soundings collected by the Midlatitude Continental Convective Cloud Experiment (MC3E) in support of its cloud modeling studies. MC3E was a major field campaign conducted during the period 22 April 2011 to 06 June 2011 in south-central Oklahoma through a joint effort between the DOE ARM Climate Research Facility and the NASA Global Precipitation Measurement Program. One of its primary goals is to provide a comprehensive data set that can be used to describe the large-scale environment of convective cloud systems and evaluate model cumulus parameterizations. The objective analysis used in this study is the constrained variational analysis method. A unique feature of this approach is the use of domain-averaged surface and top-of-the atmosphere (TOA) observations (e.g., precipitation and radiative and turbulent fluxes) as constraints to adjust atmospheric state variables from soundings by the smallest possible amount to conserve column-integrated mass, moisture, and static energy so that the final analysis data is dynamically and thermodynamically consistent. To support modeling studies on various scale convective systems, the large-scale forcing data were created over three domains with the size of 300 km x 300 km, 150 km x 150 km, and 75 km x 75 km, respectively. This poster provides more details about the forcing development and shows preliminary analysis results on the characteristics of the large-scale forcing structures for several selected convective systems observed during MC3E.

A Doppler-radar-based cloud-scale dynamics climatology of cirrus

Pavlos Kollias, McGill University
Heike Kalesse, McGill University
Matthew Gruber, University of Alaska

Cirrus microphysical properties are strongly controlled by vertical air velocities and their mesoscale variability (Kärcher and Ström 2003). It has been argued that adequate parameterization of cirrus in global climate models requires cloud-scale vertical velocity probability density functions (Kärcher and Lohmann 2002). Dynamical properties of cirrus can only be directly determined through the use of Doppler measurements from cloud radars at ground-based profiling sites or using aircraft penetrations. Here, probability density functions of vertical velocity as well as turbulence and updraft fractions are presented. The study is based on 15 years (1997–2011) ground-based cirrus cloud observations from the profiling millimeter-wavelength radar at the Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) climate research facility in Oklahoma, USA. In addition, the Doppler measurements are used to detect gravity waves whose correlation with cirrus microphysical properties is investigated. ECMWF re-analysis model output is used to relate the cirrus clouds dynamics to large-scale meteorology.

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The effective beam of ARM scanning radars and the shear contribution to radar-measured spectrum width

Ming Fang, University of Miami
Bruce Albrecht, University of Miami

Different from the vertically pointing cloud radar that fixes its radar beam in the vertical direction, ARM W-, X-, and Ka-band scanning cloud radars scan their beams in vertical planes with predetermined azimuth angles and provide the capability to obtain cloud volume data within a few minutes. The radar-measured spectrum width is often used to retrieve turbulence in clouds. However, other than turbulence, radar antenna motion and shear can also contribute to the measured spectrum width, and they need to be removed before the retrial of turbulence. In fact, an analytical expression that can be used to calculate spectrum width due to antenna motion alone, like that for azimuthally scanning radar, does not exist. Furthermore, using stationary beam width can cause the shear contribution to be seriously underestimated due to two reasons. One is that the vertical shear of horizontal wind is much larger than its shear in the horizontal plane; another is that radar antenna motion combined with signal processing creates an effective beam width that is significantly broader than its stationary counterpart. But the analytical expression of an effective beam pattern for a beam scanning in a vertical plane does not exist either. Starting from the correlation function of radar signals, this study derives the analytical expressions of the effective beam pattern that can be approximated by a Gaussian function under certain circumferences. The general relation between normalized effective beam width and antenna rotation rate and dwell time is plotted. This curve is even applicable to a beam scanning in the azimuth direction with a zero degree elevation angle. This study also derives analytical spectrum width equations due to beam scanning in a vertical plane and the vertical shear of horizontal wind. All expressions are given in the spherical coordinate system that is a better choice for processing radar observations. It has been shown that for the ARM Ka-band scanning cloud radar, the effective beam width is about 1.4 times broader than the stationary beam. The results obtained in this study will help to classify some confusion or mistakes in the literature and will be applied to the data collected by ARM scanning cloud radars.

Impact of vertical and temporal error covariances on the vertical velocity and advective tendencies in the ARM constrained variational analysis

Minghua Zhang, State University of New York at Stony Brook
Jun Huang, State University of New York at Stony Brook
Shaocheng Xie, Lawrence Livermore National Laboratory

Deriving the atmospheric vertical velocity and advective tendencies accurately from the ARM field campaigns is essential to force and evaluate models against measurements, especially measurements of clouds and precipitation. In the current ARM analysis, a variational algorithm is used to derive these physical quantities. The magnitudes of the variational adjustments depend on the specified error covariance matrix in the definition of the minimization cost function. If the specified error is large for a variable at a particular level, the adjustment to that variable at that location will be large. At present, errors for all atmospheric state variables are specified using instrument errors from manufacturers and aliasing errors from temporal variation of the variables, but they are assumed to be independent in time and in space. In this presentation, we show the structure of the error covariance matrix in the TWP-ICE field campaign and quantify its impact on the analyzed products. Simulations from a high-resolution model (WRF) are used to verify the implementation of the algorithms and results.

Low-level divergence measurements during MC3E

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

Observations of low-level divergence/convergence areas in the planetary boundary layer (PBL) can be used to document fronts, deep convection, gust front outflow, drylines, and gravity waves. The detection of such areas has been accomplished in the past using Mesonet and Doppler radar observations. Here we take advantage of the heterogeneous distributed radar network deployed for the Midlatitude Continental Convective Clouds Experiment (MC3E) to document PBL divergence. The technique used is based on the use of insects as tracers of the horizontal wind and the combination of Doppler velocity measurements from the X- and C-band radars. Examples of the evolution of the PBL dynamics from clear sky to shallow cumulus initiation over the Southern Great Plains site are analyzed. In addition, cloud and precipitation statistics associated with these features are presented.

Validation of multiple-Doppler analysis of convective clouds using the ARM precipitation radar network during MC3E

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

Convective processes play an important role in Earth's energy balance through the redistribution of heat and moisture in the atmosphere. In particular, vertical motions associated with these processes are inherently linked to the life cycle of cloud systems and are therefore directly tied to the energetic impacts of these systems. Despite their importance, the spatial and temporal scales of these vertical motions are poorly understood, adding significant uncertainty to convective parameterization. A radar data assimilation tool based on a 3-dimensional variational technique has been developed to enhance our understanding of these vertical motions within convective clouds. However, in order to trust the output of this tool, its sensitivities and accuracies need to be characterized. Scanning precipitation radars located at the ARM Southern Great Plains (SGP) site are used in the assimilation process to retrieve vertical motions for selected convective cases during the Midlatitude Continental Convective Clouds Experiment (MC3E). Using a statistical approach, the veracity of the retrievals is evaluated by comparing them with observations from the radar wind profiler network located at SGP.

WRF simulations of convectively generated gravity waves during TWP-ICE

Mai Nguyen, Monash University
Michael Reeder, Monash University
Todd Lane, University of Melbourne

All convective clouds emit gravity waves (GWs). As they propagate, the GWs emitted by clouds displace air parcels vertically, possibly producing further cloud. 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 GWs 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 GWs simulated by high resolution simulations using WRF for the period during the Tropical Warm Pool-International Cloud Experiment (TWP-ICE). Characteristics of the high-frequency GWs simulated by WRF simulations are consistent with our previous reports using radiosonde observations. During the break monsoon period, the diurnal variation of activity of the high-frequency GWs in the stratosphere shows a clear peak in the late afternoon. This peak is pronounced over land, consistent with the afternoon continental convection. In comparison, the peak wave activity over water has significantly lower magnitude and occurs in the early morning hours. This characteristic is consistent with shallower maritime convection. Furthermore, spectral characteristics of the high-frequency GWs, which were not resolved accurately by radiosonde observations, can be derived from model simulations and will be presented here.

Abstracts

Field Campaigns

3D cloud field variation associated with MJO cycle from the AMIE field campaign

Min Deng, University of Wyoming
Chuck Long, Pacific Northwest National Laboratory
Sally McFarlane, Pacific Northwest National Laboratory
Gerald Mace, University of Utah

The Madden-Julian Oscillation (MJO) is an intraseasonal fluctuation in the global tropics with a cycle of 30–60 days (Madden and Julian 1971, 1972). It is characterized by eastward propagation of regions of enhanced and suppressed tropical rainfall, associated with distinct patterns of lower and upper atmospheric circulation anomalies in the tropics. However, the processes responsible for the onset of heavy precipitation and its propagation are still poorly understood. The mechanism by which convection organizes into mesoscale cloud field is little-known. DYNAMO/CINDY2011/AMIE (ARM MJO Investigation Experiment) afford the opportunity to study MJO initiation and evolution. Deployed multiple wavelength precipitation and cloud radars such as C-POL, SWACR, KAZR, and NCAR S-band dual-polarized (S-Pol) radar and ARM long-term observations at the Manus site offer vertical distribution of cloud fields and allow testing of several of the current hypotheses related to MJO initiation and evolution. We study the convection spectral broadening and heavy precipitation initiation with the composite cloud fields in a function of MJO cycle. These data coupled with simulation studies will provide a basis to improve the representation of the MJO in large-scale climate and weather forecast models.

Aerosol composition at a rural site southeast of London measured by high resolution mass spectrometry

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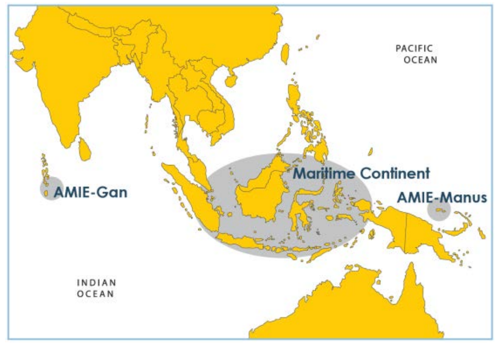
Lu Xu, Georgia Institute of Technology
Matthew Kollman, Georgia Institute of Technology
John Jayne, Aerodyne Research, Inc.
Scott Herndon, Aerodyne Research, Inc.
William Brooks, Aerodyne Research, Inc.
Leah Williams, Aerodyne Research, Inc.
Paola Massoli, Aerodyne Research, Inc.
Ed Fortner, Aerodyne Research, Inc.
Puneet Chhabra, Aerodyne Research, Inc.
Timothy Onasch, Aerodyne Research, Inc.
Douglas Worsnop, Aerodyne Research, Inc.

A High Resolution Time-of-Flight Aerosol Mass Spectrometer (HR-ToF-AMS) and complementary instrumentation were deployed at a rural site in Detling (southeast of London) during the Clear Air for London (ClearfLo) campaign from January–February 2012. ClearfLo is a collaborative multidisciplinary project to study boundary-layer pollution across London. The HR-ToF-AMS provides quantitative measurement of non-refractory submicron aerosol composition and size distribution with high time resolution. Total mass concentrations and diurnal trends of organics, nitrate, sulfate, ammonium, and chloride at the Detling sampling site are reported. As increasing distance from an urban center is often correlated with increasing photochemical aging, the aerosol mass spectrometry data at the Detling site provide insights into composition of a more oxidized air mass and the evolution of organic aerosols (OA) in the atmosphere. Elemental analyses are performed to determine elemental composition of the bulk OA, including oxygen/carbon (O/C), hydrogen/carbon (H/C), and nitrogen/carbon (N/C) ratios. Positive matrix factorization (PMF) is used to deconvolve the OA into different components, reflecting OA of different sources and/or photochemical processing. Preliminary PMF results are presented to show the relative importance of hydrocarbon-like organic aerosols (HOA) and oxygenated organic aerosols (OOA), which are surrogates of primary and secondary OA, respectively. Other OA components resolved by PMF analysis will also be discussed.

AMIE: A two-pronged campaign to study the MJO in collaboration with DYNAMO and CINDY2011

Chuck Long, Pacific Northwest National Laboratory
Sally McFarlane, Pacific Northwest National Laboratory
Brad Orr, Argonne National Laboratory
Michael Ritsche, Argonne National Laboratory
Paul Ortega, Los Alamos National Laboratory
Troy Culgan, Bureau of Meteorology

A large, international field campaign focused on the Madden-Julian Oscillation (MJO) has been organized starting October 1, 2011. The DOE Atmospheric Radiation Measurement (ARM) Climate Research Facility is conducting the ARM MJO Investigation Experiment (AMIE) in collaboration with the DYNAMO (Dynamics of the Madden-Julian Oscillation) and CINDY2011 (Cooperative Indian Ocean experiment on intraseasonal variability in the Year 2011) campaigns as part of the over-arching MJO study. AMIE has two components, one located on the Addu Atoll, Maldives in the Indian Ocean, with the main site on Gan Island where the second ARM Mobile Facility (AMF2) is deployed (the AMIE-Gan campaign). The other component is located at the ARM Tropical Western Pacific (TWP) site on Manus Island, Papua New Guinea (AMIE-Manus). Data gathered at these two sites will allow studies of the initiation, propagation, and evolution of convective clouds within the framework of the MJO, including comparisons of characteristics between the newly formed and more mature phases experienced at the two locations. The AMIE campaigns run six months, from October 1, 2011, through March 31, 2012. Both the AMIE-Gan and AMIE-Manus sites feature a full suite of atmospheric instruments including surface radiation and meteorological measurements, as well as measurements of atmospheric state and cloud and precipitation characterization. In particular, a continuous 8-per-day series of radiosondes will be launched throughout the entire six months at both sites. In this presentation, we will give a brief overview of the AMIE campaign, including examples of atmospheric state, radiation, and cloud macrophysical results, and preliminary comparisons of these variables between the two sites.



Area map showing the two AMIE campaign sites of Gan Island in the Maldives, Indian Ocean, and the ARM TWP Manus site, Papua New Guinea, plus the intervening Maritime Continent area.

http://campaign.arm.gov/amie/

Analysis of long-term and real-time aerosol optical properties near the New England coast: preparation for the Two-Column Aerosol Project (TCAP) field campaign

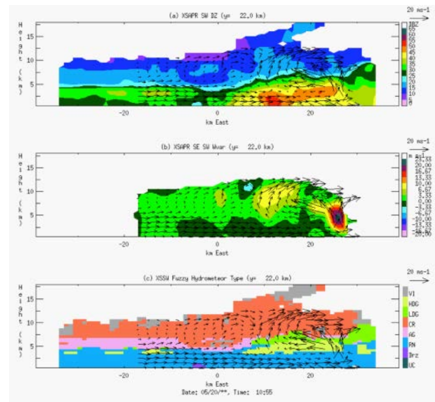
Duli Chand, Pacific Northwest National Laboratory
Carl Berkowitz, Pacific Northwest National Laboratory
Larry Berg, Pacific Northwest National Laboratory
Elaine Chapman, Pacific Northwest National Laboratory
Evgueni Kassianov, Pacific Northwest National Laboratory

One of the key objectives of the U.S. Department of Energy's Two-Column Aerosol Project (TCAP) is to provide observations with which to evaluate the uncertainty in model simulations of aerosol optical depth (AOD) and their relation to estimates of aerosol radiative forcing, and hence, to climate. The objectives are met by having detailed ground-based aerosol measurements via deployment of the ARM Mobile Facility (AMF) and the Mobile Aerosol Observing System (MAOS) at Cape Cod, Massachusetts, for a 12-month period starting in the summer of 2012. These measurements will be supported by two scheduled aircraft campaigns using the ARM Aerial Facility's (AAF) G-1 aircraft and NASA's B-200 aircraft in July 2012 and again in February 2013. Each campaign will include sampling within two atmospheric columns using the two aircraft; one column will be located directly over, or very close to the AMF located on Cape Cod, while the second will be over a relatively remote maritime location. The pre-campaign study presented here is designed to help select the optimal location of the second, remote maritime atmospheric column using the mean and standard deviation of previously observed AODs from surface and space. The optimal site for the maritime location will have a high degree of variability so that the observations made here will stress model capabilities to capture both the temporal and spatial changes to AOD. In this study, we present regional climatological values of (1) AOD from the Moderate Resolution Imaging Spectrometer (MODIS) on Terra and Aqua satellite platforms; (2) the vertical distribution of aerosol layers from the Cloud Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) satellite; and (3) the long-term aerosol optical properties from the Aerosol Robotic Network (AERONET) surface sunphotometer at Martha's Vineyard, Massachusetts. Seasonal and geographical variations in these quantities are analyzed and tentative explanations sought based on historical records of regional meteorology and emissions. In addition to the climatology of aerosol optical properties, we also discuss the potential use of near real-time MODIS satellite images and simulations from the Navy Aerosol Analysis and Prediction System (NAAPS) in planning and implementation of the TCAP field campaign.

Analysis of X-SAPR and C-SAPR data from MC3E

Steven Rutledge, Colorado State University
Angela Rowe, Colorado State University
Brenda Dolan, Colorado State University

We will report on various analyses of X-SAPR and C-SAPR data collected during the joint DOE/NASA field project MC3E (Midlatitude Continental Convective Clouds Experiment) carried out during May–June 2011 at the DOE ARM site near Lamont, Oklahoma. We have developed an attenuation correction for the X-SAPR data based on the differential phase method. Corrected X-SPAR reflectivity fields compare favorably to nearby KVNX NEXRAD data, except for areas where hail is identified. This underpins the difficulties of retrieving meaningful X-band data in hail regions. We will also report on new activities involving a dual-wavelength (X-and C-band) Hydrometeor Identification algorithm. Also, we will report on results from a so-called blended rainfall algorithm using specific differential phase data at both X- and C-bands. Dual-Doppler derived air motion statistics along with hydrometeor types will be shown, aimed at developing suitable formats for comparing to ASR modeling efforts.



Cross-sections of reflectivity and airflow (top panel), vertical motion and airflow (middle panel), and hydrometeor type and airflow (bottom panel) for the 20 May MCS observed in MC3E.

The dependence of arctic mixed-phase stratus ice cloud microphysics on aerosol concentration using observations acquired during ISDAC

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Robert Jackson, University of Illinois
Alexei Korolev, Environment Canada
Michael Earle, Environment Canada
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Data acquired by the National Research Council of Canada (NRC) Convair-580 equipped with cloud and aerosol probes during five sorties through single-layer arctic stratocumulus on 8, 18, and 26 April 2008 during the Indirect and Semi-Direct Aerosol Campaign (ISDAC) were used to test three aerosol indirect effects hypothesized to act in mixed-phase clouds: the riming indirect effect, the glaciation indirect effect, and the cold second indirect effect. The data showed a correlation of R2 = 0.75 between liquid drop number concentration Nl inside cloud and ambient aerosol number concentration NPCASP below cloud. This, combined with an increase of liquid water content LWC with height above cloud base and the nearly constant profile of Nl, showed that liquid drops were likely nucleated from aerosol at cloud base. No strong evidence of a riming indirect effect was observed for the ISDAC single-layer stratus. A strong correlation of R2 = 0.69 between ice crystal number concentration Ni and NPCASP above cloud was noted for ISDAC. Increases in ice nuclei (IN) concentration with NPCASP above cloud combined with the subadiabatic LWC profiles suggest possible mixing of aerosol and IN from cloud top consistent with the glaciation indirect effect for ISDAC. The higher Ni and lower rel observed for the more polluted ISDAC cases compared to the cleaner M-PACE cases is consistent with the operation of the cold second indirect effect.

Effect of land surface interactions on low-level jet development and cloud convection processes: a mesoscale modeling study using the ARM CLASIC 2007 and IHOP 2002 field observations

Umarporn Charusambot, Purdue University
Dev Niyogi, Purdue University
Mark Miller, Rutgers University
Fei Chen, National Center for Atmospheric Research

This study focuses on the analysis of vegetation and land surface feedbacks on three cases: the evolution of an early morning low-level jet (LLJ), drought conditions, and cloud processes during deep and shallow convection over the U.S. Southern Great Plains. A number of numerical experiments were conducted with the Weather Research Forecasting (WRF) – Advanced Research Version (ARW ver. 3). The study utilized observations for a LLJ event that observed on 3 June 2002, severe drought during 11–19 June 2006, and deep and shallow convection during 10-13 June 2007. Detailed, high resolution of soil moisture and temperature conditions were developed using an offline Land Data Assimilation System (LDAS) with a 3-km grid spacing for the innermost domain. Experiments were conducted to investigate the impact of different land surface processes related to soil moisture/temperature, vegetation representations, and heterogeneity on the atmospheric processes. Results were compared with CLASIC (Cloud and Land Surface Interaction Campaign); IHOP (International H20 Project); and ARM energy flux, dropsonde, and radiosonde data. Diagnosis of the surface variables; low-level jet occurrence; rainfall distribution; and moisture transport, heating rate, and cloud processes showed that soil moisture and vegetation transpiration played an important role on each of the events studied: LLJ evolution and nocturnal rainfall, drought conditions, and deep and shallow convection events. The coupled models with high resolution soil moisture conditions (WRF-LDAS) and vegetation transpiration (WRF-GEM) improved prediction in speed and abrupt changes of wind direction over the region and predict more accurate energy balance and soil moisture during the drought conditions and cumulus convection . The changing land surface heterogeneity and decreasing plant stomatal resistance also modified the LLJ speed, and the strong gradients of fluxes and temperature initialized more convection in the region. The study provides one of the first results highlighting that land surface-vegetation-soil moisture feedbacks are important not only for daytime processes but also for improved simulation of early morning and nocturnal events, especially during drought conditions and cumulus convection.

http://landsurface.org

Enhanced SOA formation from mixtures of biogenic and anthropogenic emissions during the CARES campaign

John Shilling, Pacific Northwest National Laboratory

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. Over the course of the campaign, PTR-MS data showed that biogenic volatile organic compounds (VOCs), particularly isoprene, dominate the region with anthropogenic VOCs, such as benzene and toluene, observed in smaller concentrations. Overall, the AMS showed that the particle phase is dominated by organic material (81% on average) with smaller concentrations of sulfate (10%), nitrate (6%), and ammonium (4%) nitrate observed. Comparison of organic aerosol (OA) concentrations on flight days with different prevailing meteorological conditions will be presented to elucidate the role of anthropogenic and biogenic emissions on OA formation. The data show that airmasses predominantly influenced by only anthropogenic or biogenic emissions contained relatively small concentrations of OA, even when other photochemical conditions were favorable. However, OA levels are dramatically enhanced when isoprene-rich air from the foothills is mixed with the Sacramento urban plume, suggesting both anthropogenic and biogenic emissions are key in producing elevated OA concentrations.

Evolution of aerosol composition and optical properties during the 2010 CARES campaign

Rahul Zaveri, Pacific Northwest National Laboratory
Pat Arnott, University of Nevada
Dean Atkinson, Portland State University
James Barnard, Pacific Northwest National Laboratory
Josef Beranek, Pacific Northwest National Laboratory
Jack Cahill, Universtiy of California, San Diego
Chris Cappa, University of California, Davis
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Kyle Gorkowski, Los Alamos National Laboratory
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Larry Kleinman, Brookhaven National Laboratory
Walter Knighton, Montana State University
Nels Laulainen, Pacific Northwest National Laboratory
Claudio Mazzoleni, Michigan Technological University
Mikhail Pekour, Pacific Northwest National Laboratory
Kimberly Prather, Scripps Institution of Oceanography
Jimmy Radney, Portland State University
William Shaw, Pacific Northwest National Laboratory
John Shilling, Pacific Northwest National Laboratory
Stephen Springston, Brookhaven National Laboratory
R. Subramanian, Droplet Measurement Technologies
Arthur Sedlacek, Brookhaven National Laboratory
Ari Setyan, University of California, Davis
Chen Song, Pacific Northwest National Laboratory
Kaitlyn Suski, Universtiy of California, San Diego
Will Wallace, Washington State University
Xiao-Ying Yu, Pacific Northwest National Laboratory
Alla Zelenyuk, Pacific Northwest National Laboratory
Qi Zhang, University of California, Davis

Atmospheric black carbon (BC) particles readily absorb both upwelling and downwelling broadband radiation and are thought to be second only to CO2 in contributing to global warming. However, large uncertainties still exist in the global estimates of BC radiative forcing, which depend not only on our ability to accurately simulate the global loading and distribution of BC, but also on the precise knowledge of the mixing state and morphology of BC particles due to ageing. To this end, one of the objectives of the Carbonaceous Aerosol and Radiative Effects Study (CARES) conducted in Sacramento, California, during June 2010 was to investigate the evolution of urban BC particles and the associated optical properties, with the overarching goal of improving their process-level model representations. The daytime Sacramento urban plume was routinely transported to the northeast into the Sierra Nevada foothills area rich in biogenic emissions, and the aged aerosols were often recirculated back into the urban area the next morning. The CARES campaign observational strategy was designed to take advantage of this flow pattern by setting up two observation supersites—one located within the Sacramento urban area and another located about 24 km to the northeast in Cool, California, a small town in the rural foothills area. The DOE G-1 aircraft was also deployed in the morning and afternoon on selected days to characterize the evolution of urban and biogenic aerosols and their optical properties. In this study, we present the analysis of the measurements made at the two ground sites and onboard the aircraft to illustrate the evolution of aerosol composition and optical properties due to ageing. Results indicate up to 30% enhancement in BC mass absorption efficiency (at 532 nm wavelength) due to BC ageing. Angstrom exponents for absorption were found to be appreciably greater than unity at low aerosol loadings, suggesting presence of “brown carbon” in background air. Single-particle mass spectrometer data onboard the G-1 and at the ground sites indicate that biomass burning particles were present in appreciable amounts, which could at least partially explain the source of brown carbon. Sensitivity of the predicted optical properties with the core/shell Mie code to model assumptions of particle mixing state will be discussed.

HSRL data from STORMVEX

Edwin Eloranta, University of Wisconsin

HSRL data acquired during STORMVEX will be presented along with an evaluation of instrument performance and preliminary data analysis.

http://liar.ssec.wisc.edu

Instrument and scientific capabilities in the ARM Aerial Facility

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Jason Tomlinson, Pacific Northwest National Laboratory
John Hubbe, Pacific Northwest National Laboratory
Celine Kluzek, Pacific Northwest National Laboratory
Duli Chand, Pacific Northwest National Laboratory
Mikhail Pekour, Pacific Northwest National Laboratory
Beat Schmid, Pacific Northwest National Laboratory

The Atmospheric Radiation Measurement (ARM) Climate Research Facility's Aerial Facility (AAF) deploys aircraft-based instruments for understanding aerosol, cloud, and radiative processes in the atmosphere. Airborne measurements enhance the long-term ground-based ARM measurements by supplying a means for evaluating and improving remote sensing retrieval algorithms, detailed information in situ not easily measured remotely, and data sets for testing and evaluating model simulations. Through the American Recovery and Reinvestment Act, ARM acquired a number of new capabilities for observing atmospheric processes. A detailed list is found at http://www.arm.gov/sites/aaf/instruments. Characterization of these instruments provides insight into their scientific capabilities. We will highlight several new instrument capabilities for measuring aerosol, cloud, and radiative properties through our analysis of instrument performance characteristics during recent ARM field campaigns. Standardization of AAF data formats, such as ICARTT and IWGADTS, used to promote airborne measurements usage throughout the scientific community will also be discussed.

Large-scale atmospheric state and cloud/precipitation characteristics during MC3E

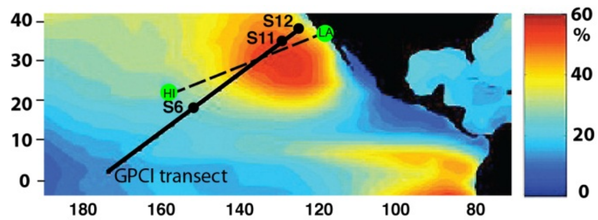
Michael Jensen, Brookhaven National Laboratory
Pavlos Kollias, McGill University
Scott Giangrande, Brookhaven National Laboratory
Scott Collis, Argonne National Laboratory
Walter Petersen, NASA Marshall Space Flight Center
Shaocheng Xie, Lawrence Livermore National Laboratory
Heike Kalesse, McGill University

The Midlatitude Continental Convective Clouds Experiment (MC3E), a joint field campaign of the DOE Atmospheric Radiation Measurement (ARM) Climate Research Facility and NASA's Global Precipitation Measurement (GPM) Mission, took place at the ARM Southern Great Plains site between April 22 and June 6, 2011. The major objective of this campaign was the collection of a comprehensive data set for the study of a variety of convective cloud/storm conditions targeting processes important for the parameterization of convection in large-scale models and the retrieval of precipitation from space-borne sensors over land. This poster will present initial analysis of relationships between large-scale atmospheric state derived from the MC3E sounding network (e.g., VARANAL, CAPE, CIN) and the cloud and precipitation characteristics observed by the MC3E instrumentation.

MAGIC: ARM's first shipboard deployment

Ernie Lewis, Brookhaven National Laboratory
Warren Wiscombe, Brookhaven National Laboratory
R Reynolds, Remote Measurements & Research Company
Bruce Albrecht, University of Miami
Geoffrey Bland, NASA
Charles Flagg, State University of New York at Stony Brook
Stephen Klein, Lawrence Livermore National Laboratory
Pavlos Kollias, McGill University
Stephen Schwartz, Brookhaven National Laboratory
A Siebesma, Royal Netherlands Delft University of Technology
Joao Teixeira, NASA
Robert Wood, University of Washington
Minghua Zhang, State University of New York at Stony Brook

The MAGIC project involves deployment of the second ARM Mobile Facility (AMF2) aboard a Horizon Lines cargo ship traversing a route between Los Angeles and Hawaii over a full year starting in October, 2012, to measure properties of clouds and precipitation, aerosols, and atmospheric radiation. MAGIC is the first true marine deployment of AMF2 and is a unique collaboration between ARM and Horizon Lines, LLC, the largest container shipping company operating under the Jones Act. The transect between Los Angeles and Hawaii is very near the line used by several modeling intercomparisons, specifically GPCI, EUCLIPSE, and CGILS. Along this transect, cloud properties change from a low stratocumulus deck with high aerial coverage near the west coast of the U.S. to high puffy cumulus with low aerial coverage near Hawaii (Figure 1), with important consequences for Earth's climate and energy budget. Climate models have a difficult time accurately representing this transition. By collecting data over a full seasonal cycle, MAGIC will provide validation for these modeling efforts and aid in understanding and representing this transition. The principal objectives of MAGIC are to improve the transition of the Sc-to-Cu transition in climate models by characterizing the essential properties of this transition, and to produce the observed statistics of these Sc-to-Cu characteristics corresponding to the deployment period along these transects. To realize these objectives, MAGIC will measure properties of clouds and precipitation (specifically cloud type, fractional coverage, base height, physical thickness, liquid water path, optical depth, and drizzle and precipitation frequency, amount, and extent), atmospheric conditions (specifically temperature, relative humidity, wind speed and direction, and the vertical profiles of these quantities), oceanic conditions (specifically sea state and sea surface temperature and salinity), properties of aerosols (specifically size distribution, light-scattering behavior, hygroscopic behavior, cloud condensation nuclei behavior, and composition), and spectral and broadband shortwave and longwave radiation and their interaction with clouds and aerosols (specifically broadband and narrow-channel direct and diffuse fluxes; downwelling and upwelling spectral radiances; and cloud and aerosol spectral optical thicknesses).



Annual average low-level cloud cover with MAGIC transect (dashed line) and GPCI transect (solid line) with postions of CGILS intercomparison locations (dots).

http://www.ecd.bnl.gov/MAGIC.html

A novel back-trajectory analysis of the origin of black carbon transported to the Himalayas and Tibetan Plateau during 1996−2010

Zifeng Lu, Argonne National Laboratory
David Streets, Argonne National Laboratory

Black carbon (BC) deposited on snow and ice can reduce the surface albedo and consequently accelerate glacier melting. Surrounded by the world's two largest BC-generating regions (South Asia and East Asia), the Himalayas and Tibetan Plateau (HTP, also known as Earth's "third pole") is encountering a rapid climate change and glacier retreat since 1990s, for which BC transported to the HTP was reported to be the major reason. In support of the Ganges Valley Aerosol Experiment (GVAX), a novel back-trajectory approach that takes into account all the atmospheric processes related to BC (e.g., emissions, hydrophilic-to-hydrophobic conversion, and dry/wet deposition) is developed on the basis of the framework of the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model to evaluate the BC origin reaching the HTP during 1996−2010. The results indicate that BC received by the HTP increased by 41% from 1996 to 2010 with a linear annual growth rate of 2.5%, implying that the BC problem is accelerating in the HTP region. BC sources that influence the HTP vary with seasons. On an annual basis, South Asia and East Asia are the main source regions, accounting for 67% and 17% of BC transported to the HTP, followed by Former USSR (~8%), Middle East (~4%), Europe (~2%), and Northern Africa (~1%). Although annual BC emission in China is at least 80% higher than that in India, its contribution to BC on the HTP is smaller. Examining the sectoral distributions, the contributions of residential, industry, land transportation, and agricultural waste burning to the EEI are 60±5%, 17±3%, 15±5%, and 6±3%, respectively. Open forest burning has significant interannual and seasonal variability, accounting for 11% of the BC transported to the HTP in 1999 when extensive forest burning occurred. Showing significant monthly variations, BC reaching the HTP is high in winter and low in summer, which is attributed to the effective wet scavenging of BC during the summer monsoon season. We show the seasonal spatial distribution of BC sources directly on a 0.5º x 0.5º grid, and it directly identifies the hotspots of sources (e.g., the Indo-Gangetic Plain of India and the Sichuan Basin of China) and provides information to policymakers about the best target areas for mitigating the climate changes and other effects on the HTP.

Overview of ARM cloud and precipitation observations during AMIE

Sally McFarlane, Pacific Northwest National Laboratory
Chuck Long, Pacific Northwest National Laboratory
Jennifer Comstock, Pacific Northwest National Laboratory
Nitin Bharadwaj, Pacific Northwest National Laboratory
Chitra Sivaraman, Pacific Northwest National Laboratory
Karen Johnson, Brookhaven National Laboratory
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Brad Orr, Argonne National Laboratory

The Atmospheric Radiation Measurement (ARM) MJO Investigation Experiment (AMIE) occurred Oct 1, 2011–March 31, 2012 in association with the DYNAMO (Dynamics of the Madden-Julian Oscillation) and CINDY2011 (Cooperative Indian Ocean experiment on intraseasonal variability in the Year 2011) campaigns. The primary goal of these campaigns is to improve understanding of the roles that the interaction between environmental moisture and convection, the dynamic evolution of the cloud population, and air-sea interaction play in MJO initiation. The AMIE component of the campaign was focused on collecting measurements to address the first two questions. AMIE included measurements both with the second ARM mobile facility (AMF2) in the Maldives and at the permanent ARM site on Manus Island, Papua New Guinea. The dual-pronged nature of the AMIE experiment allowed observation of both MJO initiation in the Indian Ocean (at the Maldives site) and the mature phase of the MJO as it passed over the maritime continent (at the Manus site). In the Maldives, the AMF2 was located on Gan Island, at the Addu airport. The AMF2 consists of a full suite of atmospheric instrumentation including surface meteorological instruments, radiometers, vertically pointing ceilometer, cloud radar and lidar, and a 2D video disdrometer. As part of the AMF2 deployment, the dual-wavelength Scanning ARM Cloud Radar (SACR) was also deployed nine kilometers from the airport to document the 3D spatial characteristics of the cloud field. At Manus, a similar suite of instruments is available at the permanent ARM facility. In this presentation, we give an overview of the ARM cloud and precipitation observations during AMIE including data set availability, instrument performance, and some initial results.

Overview of ClearfLo: Study of Aerosol Sources and Processing at a Rural Site Southeast of London

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Andrew Freedman, Aerodyne Research, Inc.
William Brooks, Aerodyne Research, Inc.
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Felipe Lopez-Hilfiker, University of Washington
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Nga Lee Ng, Georgia Institute of Technology
Lu Xu, Georgia Institute of Technology
Matthew Kollman, Georgia Institute of Technology
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Manvendra Dubey, Los Alamos National Laboratory
Allison Aiken, Los Alamos National Laboratory
Kyle Gorkowski, Los Alamos National Laboratory
Timothy Martin, Argonne National Laboratory
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Air pollution generated by large urban areas poses threats to human health and the environment. ClearfLo is a large, multidisciplinary study of the London urban atmosphere aimed at understanding the relationships between surface meteorology, gas-phase composition, and particulate matter at a city street site, a city background site (away from local traffic sources), and at a rural location that samples the outflow from the London urban area. We have deployed a suite of instruments at a rural site southeast of London in Detling, UK, during January–February 2012. The wintertime studies also provide information on gas and particle emissions from home heating solid fuels. The project is coordinated by the UK National Centre for Atmospheric Science with support from the Natural Environment Research Council. Several research groups joined together to provide continuous, high-time-resolution measurements of aerosol chemistry and microphysics, measurements of gas-phase tracers and secondary organic aerosol (SOA) precursors, and radiative and meteorological measurements. Aerodyne Research, Inc. (ARI) and the Georgia Institute of Technology provided instruments to monitor aerosol chemical composition, including organics, inorganics, and black carbon, as well as extinction and single-scattering albedo. ARI also deployed instruments for state-of-the-art measurements of trace gas species. The University of Washington, Seattle, deployed a newly developed, high-sensitivity mass spectrometer system that is capable of near-real-time measurements of molecular level composition of both gas and particle-phase organics. Los Alamos National Laboratory (LANL) provided measurements of in situ aerosol optical properties and size distributions, and Argonne National Laboratory (ANL) provided remote sensing and meteorology measurements. Here we present an overview of preliminary results from the deployment.

Preliminary WRF/Chem model analyses for the BEACHON-ROMBAS 2011 field study

Alma Hodzic, National Center for Atmospheric Research
Jose-Luis Jimenez, University of Colorado

The scientific understanding of the formation and aging of organic aerosols in forest environments is still limited, especially in presence of anthropogenic pollutants. The Bio-hydro-atmosphere interactions of Energy, Aerosols, Carbon, H2O, Organics and Nitrogen (BEACHON) project was initiated by NCAR in 2008 to provide a detailed characterization of biosphere-hydrosphere-atmosphere interactions through combination of long-term field measurements, laboratory studies, and multi-scale modeling. The BEACHON-ROMBAS intensive aerosol study took place from 25 July to 25 August 2011 at the Manitou Observatory Forest in Colorado with the specific objective of characterizing the formation and growth of biogenic particles in the forest canopy and quantifying the perturbations that occur in presence of anthropogenic emissions. Here we will present the first results of the high-resolution simulations (4-km) that were performed over the Colorado mountains using the Weather Research and Forecasting model with chemistry (WRF/Chem) during summer 2011 and used to interpret and analyze the meteorological and chemical data collected during the campaign. The meteorological and passive tracer analyses were used to identify the main meteorological regimes and characterize the periods of a strong anthropogenic influence. Of particular interest were the periods featuring the transport of the front-range urban pollution or the Four Corners Power Plant plume over the forest site. For each of these periods the WRF/Chem model predictions of main organic aerosol components were assessed and compared with the AMS data. In addition, the sensitivity of the model results to changes and inaccuracies in the land use is discussed.

Radiatively active gases: ACME airborne observations in the U.S. Southern Great Plains

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William Riley, Lawrence Berkeley National Laboratory
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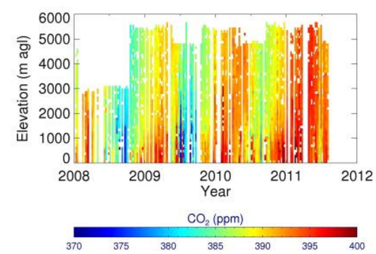
James Smith, Atmospheric Observing System

The vertical profile of atmospheric greenhouse gas mixing ratios is used in large-scale inversions of surface fluxes, as tracers of atmospheric transport, in characterization of climate-carbon cycle interactions, and in validation of satellites. The ARM Airborne Carbon Experiment (ARM-ACME) collects profiles semi-weekly from a small aircraft (Cessna 206) on a series of horizontal legs ranging from 17,500 feet down to 1,500 feet above sea level. Since November 2007, more than 300 continuous CO2 vertical profiles have been collected, along with NOAA/ESRL 12-flask (carbon cycle gases and isotopes) packages for validation and fingerprinting the source of CO2 anomalies. Currently these are the only semi-weekly atmospheric profiles collected in the United States, and the data are used in inversions, satellite validation, and other studies. We report here on three years of these airborne measurements. The continuous CO2 observations are measured using an Atmospheric Observing System, Inc. instrument. The analyzer has non-imaging optics, an NDIR core, and negligible sensitivity to motion of platform. Accuracy, including bias, is approximately 0.1 ppm of CO2 at 1 Hz. Comparison between the continuous and flask CO2 measurements indicates no systematic differences. In addition to the long-term trend in CO2 mixing ratio of about 2 ppm per year in the free troposphere, the seasonal cycle in mixing ratio spans more than 20 ppm within the boundary layer and 10 ppm in the free troposphere within a single year. We have discovered that the CO2 mixing ratio varies over the vertical profile by as much as 6 ppm on a single day, and the direction of the concentration gradient across the boundary layer reverses between spring and fall. This research is supported by the ARM AAF and TES programs.



Weekly average continuous CO2 concentrations collected in the U.S. Southern Great Plains since January 2008.

Science highlights from the CAP-MBL field campaign at Graciosa Island

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Robert Wood, University of Washington
Christopher Bretherton, University of Washington
Pavlos Kollias, McGill University
Mark Miller, Rutgers University
Jasmine Remillard, McGill University
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Virendra Ghate, Rutgers University
Anne Jefferson, NOAA ERSL Global Monitoring Division
Yanluan Lin, NOAA Geophysical Fluid Dynamics Laboratory
Cecile Hannay, National Center for Atmospheric Research
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The Clouds, Aerosol, and Precipitation in the Marine Boundary Layer (CAP-MBL) experiment used the comprehensive instruments of the ARM Mobile Facility deployment at Graciosa Island in the Azores from May 2009 to January 2011. This platform produced a rich set of coincident and continuous atmospheric measurements of meteorology, aerosols, clouds, precipitation, and radiation in a relatively remote maritime region. Here we highlight several research results from CAP-MBL. About half of all clouds observed in CAP-MBL had detectable precipitation falling below their bases, and 20–40% of measured precipitation accumulation originated from clouds with tops lower than 3 km. We show new methods that use the radar Doppler spectrum to characterize and separate precipitation drops from cloud droplets in low clouds. They reveal the cloud structures responsible for the initiation of precipitation in marine stratocumulus clouds. Cloud-forming aerosol concentrations at the Azores vary by over two orders of magnitude, from dirty air masses associated with continental pollution to ultra-clean collapsed marine boundary layers with some of the lowest CCN concentrations yet measured. The long duration of CAP-MBL allows us to explore the time evolution of aerosol concentrations and look for relationships between aerosol and cloud and precipitation processes. We also show how the CAP-MBL data can be used to locally test the GFDL AM3p9 and CAM5.1 climate models running in forecast mode and show the strengths and weaknesses of these models in simulating the marine boundary layer and aerosol and precipitation processes.

The Storm Peak Lab Cloud Property Validation Experiment: overview and emerging science

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Gannet Hallar, Storm Peak Laboratory Desert Research Institute
Ian McCubbin, Desert Research Institute
Matthew Shupe, University of Colorado
Sergey Matrosov, CIRES, University of Colorado/NOAA Earth System Research Laboratory
Arthur Sedlacek, Brookhaven National Laboratory
Chuck Long, Pacific Northwest National Laboratory
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From December 2010 through April 2011, the second ARM Mobile Facility was deployed to Steamboat Springs, Colorado, to take part in the Storm Peak Lab Cloud Property Validation Experiment (STORMVEX). In collaboration with assets supported by NSF in the Colorado Airborne Multiphase Cloud Study (CAMPS) and the Desert Research Institute's Storm Peak Laboratory, a full suite of aerosol, cloud, precipitation, radiation, and environmental data was collected that provides a unique long-term view of one of the snowiest seasons on record in the Central Rocky Mountains. The combination of mid-mountain remote sensing from AMF2 and operational cloud property measurements at Storm Peak Lab augmented by airborne data collected by the University of Wyoming King Air is proving invaluable in documenting the processes that result in the development of precipitation in mixed-phase clouds. Combined with this, having near-identical measurements of aerosol properties at two locations on the mountain is revealing new information on the nucleation of aerosols. In this paper, we will give a broad overview of the STORMVEX campaign, the data set, and emerging science made possible by STORMVEX.

The Two-Column Aerosol Project (TCAP)

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Daniel Cziczo, Massachusetts Institute of Technology
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Richard Ferrare, NASA Langley Research Center
Chris Hostetler, NASA Langley Research Center
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Michael Obland, NASA Langley Research Center
Jerome Fast, Pacific Northwest National Laboratory
Connor Flynn, Pacific Northwest National Laboratory
Philip Rasch, Pacific Northwest National Laboratory
Jens Redemann, NASA Ames Research Center
Phil Russell, NASA Ames Research Center
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Rahul Zaveri, Pacific Northwest National Laboratory
Alla Zelenyuk, Pacific Northwest National Laboratory

The Two-Column Aerosol Project (TCAP) is designed to provide observations of the distribution, chemical properties, and optical properties of aerosol within and between two columns of air along the eastern seaboard of the Atlantic Ocean. These columns will be separated by several hundred kilometers and be sampled during summer and winter intensive operations periods (IOPs). These two IOPs, in addition to a 12-month set of continuous surface observations, will provide a rich data set with which to test the veracity of cloud and radiative transfer models. TCAP will make use of the ARM Mobile Facility (AMF), the Mobile Aerosol Observing System (MAOS), and the ARM Aerial Facility (AAF) during the IOPs, the first of which is scheduled for July 2012 and the second for February 2013. The NASA B-200 aircraft will also participate during July 2012 and will deploy the NASA Langley Research Center High Spectral Resolution Lidar (HSRL) and the NASA Goddard Institute for Space Studies Research Scanning Polarimeter (RSP). Scientific questions to be addressed by observations from TCAP include: How do the mixing states of primary and secondary aerosol differ between air masses adjacent to the coast relative to those found over the open ocean? How do changes in mixing state affect aerosol optical properties? What is the spectral dependence of the aerosol optical properties? How do aerosol chemical composition, mixing state, and optical properties vary seasonally? How critical is the particle chemical composition and mixing state in determining the aerosol optical properties and CCN activity within and above the marine boundary layer? What is the relative importance of aerosol indirect effects in maritime boundary-layer clouds? Can regional- and global-scale atmospheric models accurately represent the aerosol optical properties, aerosol mixing state, and cloud-aerosol interactions and their seasonal variation near the eastern edge of North America? The TCAP Science Team is looking forward to working with others in the ASR community and to this end will present a review of the science goals and discuss preliminary flight patterns, deployment schedules, and other logistical details that may be of interest to other investigators.

Variability of aerosol properties and mixing-layer heights from airborne high spectral resolution lidar, ground-based measurements, and the WRF-Chem model during CARES and CalNex

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William Shaw, Pacific Northwest National Laboratory
Rahul Zaveri, Pacific Northwest National Laboratory
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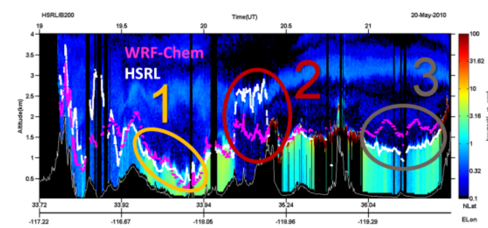

While WRF-Chem and HSRL PBL heights tend to agree (1), the algorithms can differ in low aerosol loading conditions (2), and other situations (3), perhaps related to temperature gradients. These discrepancies need to be understood and corrected for further comparisons. The image is a flight from CalNex; images showing comparisons from CARES flight will be included in this work.

The NASA Langley Research Center (LaRC) airborne High Spectral Resolution Lidar (HSRL) was deployed on board the NASA B200 aircraft for flights over California in May and June of 2010 to aid in characterizing aerosol properties during the CalNex and CARES field campaigns. Measurements of aerosol extinction (532 nm), backscatter (532 and 1064 nm), and depolarization (532 and 1064 nm) were made during nearly 100 flight hours on 31 science flights, many in coordination with other participating research aircraft (DOE G-1, CIRPAS Twin Otter, NOAA WP-3, and NOAA Twin Otter), satellites, and ground sites. The HSRL data are used to characterize the vertical and horizontal distribution of aerosols, provide the vertical context for the airborne in situ measurements acquired from these other aircraft, and to derive the height of the mixing layer (ML). Parameters derived from HSRL data are also used to infer aerosol types and determine the fraction of aerosol optical thickness (AOT) contributed by these types. This work examines the variability of the extensive (dependent on aerosol type and number density) and intensive (dependent on aerosol type only) aerosol properties to aid in describing the broader context of aerosol distributions within and near the Sacramento and Los Angeles regions. WRF-Chem model depictions of aerosol properties and types are compared with measured HSRL aerosol parameters and derived products including the aerosol types and mixing-layer heights. These measurements are examined to evaluate aerosol distributions and transport in the Sacramento region. ML heights derived from HSRL measurements are compared with those derived from radiosonde and ceilometer measurements and from WRF-Chem simulations. Initial comparisons show that the HSRL and radiosonde ML heights from CARES are highly correlated ($r^2>0.94$) with bias differences less than 40 m. Similar ML height comparisons using data from CalNex also show high correlation but also some large differences; potential explanations for such differences are explored.

http://science.larc.nasa.gov/hsrl/

Vertical profile retrievals of trace gases and aerosol optical properties by CU GMAX-DOAS

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Sunil Baidar, University of Colorado at Boulder

During the Two-Column Aerosol Project (TCAP) field campaign, the University of Colorado Ground based Multi AXis DOAS instrument (CU GMAX-DOAS) will be deployed at Cape Cod to provide simultaneous retrievals of aerosol optical properties and trace gas vertical profiles with a single portable instrument. CU GMAX-DOAS allows the study of horizontal and vertical aerosol gradients and decoupling of trace gas and aerosol vertical extinction profiles. A novel telescope was developed and is presented here. It collects solar stray light in any elevation/azimuth angle pair and is capable of direct sun tracking. The telescope aims to facilitate the determination of aerosol optical properties, i.e., asymmetry parameter and single-scattering albedo, along with the determination of absolute Raman scattering probability (RSP), i.e., the probability that an observed photon has undergone a rotational Raman scattering event, from recording both scattered light radiance spectra and direct sun spectra. Simultaneously, the vertical column density (VCD) of trace gases like nitrogen dioxide (NO2), nitrous acid (HONO), formaldehyde (HCHO), glyoxal (CHOCHO), bromine oxide (BrO), iodine oxide (IO), and oxygen dimers (O4) can be measured with the same instrument. The poster presents first tests of the novel telescope at the University of Colorado at Boulder that we plan to deploy during TCAP for the first extended field deployment. We plan to compare CU GMAX-DOAS with ARM instruments such as the Cimel sunphotometer and multifilter rotating shadowband radiometer (MFRSR), as well as in situ measurements, and possibly airborne instruments such as the high spectral resolution lidar (HSRL) and 4STAR during the intensive aircraft period. CU GMAX-DOAS adds trace gases to the extensive suite of aerosol measurements planned. In particular, the cloud processing of gases like glyoxal forms secondary organic aerosol (SOA) in clouds and aerosol water. Another aspect consists in exploring the capabilities for retrievals of aerosol optical properties in the presence of clouds.

Abstracts

Infrastructure & Outreach

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

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

The Atmospheric Radiation Measurement Climate Research Facility collects thousands of timestamp 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. 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.

AMF2 AMIE-Gan deployment at Addu City, Republic of Maldives

Michael Ritsche, Argonne National Laboratory
Brad Orr, Argonne National Laboratory
Nicki Hickmon, Argonne National Laboratory

The second ARM Mobile Facility (AMF2) deployed to Addu City, Republic of Maldives, in support of the ARM MJO Investigation Experiment (AMIE) beginning on August 15, 2011. The AMF2 and the AMIE campaign were also part of two other projects, CINDY2011 (Cooperative Indian Ocean experiment on intraseasonal variability in the year 2011) and DYNAMO (Dynamics of the Madden-Julian Oscillation), occurring at the same time. The AMIE campaign had two components, one located in the Maldives (AMIE-Gan) and another site located at the ARM Tropical Western Pacific (TWP) site on Manus Island, Papua New Guinea (AMIE-Manus). The science goals of AMIE-Gan required making measurements at two different geographical locations. The main site was located on Gan Island at the Gan International Airport directly adjacent the Maldive Meteorology Service Office. The second site was located on Hithadhoo Island on recently recovered land near the wharf. These two sites are approximately 9 kilometers apart by line of sight. The main site contained almost all of the AMF2 instrumentation, while the secondary (wharf) site contained the AMF2 scanning cloud radar. Local Maldivians were hired and trained to do the eight-per-day balloon launches required for the duration of the six-month deployment. An overview of the AMIE-Gan deployment and associated challenges for the AMF2's first foreign deployment will be presented.

AMF2 status update: engineering efforts for the MAGIC campaign

Brad Orr, Argonne National Laboratory
Michael Ritsche, Argonne National Laboratory

The original design of the AMF2 included the capability for deploying the core suite of ARM instrument systems on marine platforms, including ships. The significant influx of ARRA instrumentation has dramatically improved the measurement and scientific capabilities of the AMF2, but it has also nearly doubled the AMF2 footprint. This presents significant challenges when configuring and adapting the AMF2 for a particular ship installation. The Marine ARM GPCI Investigation of Clouds (MAGIC) campaign takes place on a commercial cargo ship sailing between Long Beach, California, and Honolulu, Hawaii. The AMF2 deployment will be on an upper bridge deck where space is fairly limited. This area is also not specifically designed to support large containers and will require modifications be made to the ship structure. There will only be space for three containers, which will necessitate a reconfiguration of the AMF2 to maximize use of that space and provide the measurements required to support MAGIC. An overview of the MAGIC deployment and associated engineering activities will be presented.

ARM Archive remodeling: streamlined user interfaces and new access features

Raymond McCord, Oak Ridge National Laboratory
Giri Palanisamy, Oak Ridge National Laboratory
Karen Gibson, Oak Ridge National Laboratory

The Archive home page and user interfaces are being streamlined and restructured to make the initial reaction to the ARM Data Archive less overwhelming. Changes will reduce the number of interfaces, improve the grouping of interfaces, and provide more emphasis on data discovery from a measurements perspective (versus instruments). The Archive home page is organized into: searching for data, visualizing data, and access to specialized data. Data searching is refocused on a measurement theme for users who are less familiar with the desired data. A "one-page" interface provides efficient access for users familiar with the desired data. Data visualization includes the Archive Thumbnail Browser (pre-computed plots) and NCVWeb (interactive plots). Access to specialized data includes pathways to field campaign data, showcase data, evaluation data, and PI data. Direct access to ARM data from user applications is being explored with THREDDS catalog technology and machine-readable DQR information (see poster by Sean Moore et al.).

http://www.archive.arm.gov

ARM facilities on the North Slope of Alaska: Barrow, Oliktok, and Atqasuk: update on changes and additions

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Fred Helsel, Sandia National Laboratories
Jeffrey Zirzow, Sandia National Laboratories
Valerie Sparks, Sandia National Laboratories
Johannes Verlinde, The Pennsylvania State University
Scott Richardson, The Pennsylvania State University
Martin Stuefer, University of Alaska Fairbanks
Christine Waigl, 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. In 2011, we completed the installation of new instruments and upgrades to existing instruments in Barrow. New instruments for a facility at Oliktok are under discussion along with ARM-funded support for Unmanned Aerial Systems operations in the Oliktok area. ARM operations in Atqasuk have been suspended, although infrastructure in Atqasuk is still available for Intensive Operating Periods. An update on ARM facilities in Barrow, Oliktok, and Atqasuk is provided on our poster.

X-band radar on Barrow Arctic Research Center and Vaisala autosonde balloon launcher at ARM's Barrow site.

ASR cloud modeling data development at Lawrence Livermore National Laboratory

Renata McCoy, Lawrence Livermore National Laboratory
Shaocheng Xie, Lawrence Livermore National Laboratory
Yunyan Zhang, Lawrence Livermore National Laboratory
Chuanfeng Zhao, Lawrence Livermore National Laboratory

This poster describes new additions, updates, and future plans of the cloud modeling value-added products (VAPs) being developed by the Lawrence Livermore National Laboratory (LLNL) ARM Infrastructure team. These include the ARM showcase Climate Modeling Best Estimate (CMBE) product, which was recently renamed “ARM Best Estimate” (ARMBE), the large-scale forcing data sets, and the ARM Cloud Retrieval Ensemble Dataset (ACRED). Specifically, ARMBE has been updated to the most recent 2011 data, and it contains new variables for the SGP site, such as latent and sensible heat fluxes from ECOR instruments and clear-sky fluxes that can be used to derive effective cloud albedo. The recent progress in the forcing data development includes multi-scale forcing data sets for MC3E and two previous ARM IOPs (summer 1997 and spring 2000) at SGP and forcing for AMF-China. For ACRED, we have produced high-frequency (1-minute) ACRED data consistent with the ARM Radiatively Important Parameters Best Estimate (RIPBE) VAP to facilitate the use of the ARM Broadband Heating Rate Profile (BBHRP) testbed in evaluating the retrieval products contained in ACRED. In addition to these products, we also highlight the progress we made to tie ARM data to the international climate modeling community through publishing ARMBE data in ESGF and making data available to the IPCC CMIP5. The future goals for all the LLNL ARM VAPs are also presented.

Automated use of data quality information currently stored in ARM Data Quality Reports

Sean Moore, Mission Research Corporation
Giri Palanisamy, Oak Ridge National Laboratory
Kenneth Kehoe, NOAA ESRL Global Monitoring Division
Raymond McCord, Oak Ridge National Laboratory
Randy Peppler, University of Oklahoma

The ARM Climate Research Facility strives to provide datastreams of quality suitable for scientific research. The Data Quality Office, Instrument Team, Site Scientists, and others within ARM regularly review and assess ARM's datastreams for problems. Any issues discovered and confirmed as problems are summarized in Data Quality Reports (DQRs) and delivered as text files to users ordering ARM data. While valuable, it is impractical to use such reports with the large amount of data processed by most users. To improve the usefulness of these reports, we are developing methods to simplify application of the DQR data quality status to affected data. The primary simplification will be to filter bad or suspect data before actually delivering it to the user. A custom netCDF file will be produced with data affected by a DQR marked as “missing.” Users will be able to decide if this should be done, and to what degree, during the ordering process. Simplified reordering procedures will ensure users can easily acquire and maintain data sets that incorporate the latest data quality information. We will also provide a mechanism for users to query on-demand the latest known issues affecting a measurement or derived quantity. This mechanism, implemented as a web service, can be incorporated into data processing codes in order to identify and eliminate problem data as needed. Detailed documentation and code samples will be provided to help users utilize this service. Feedback and suggestions for other methods to improve DQR dissemination are welcome.

www.dq.arm.gov

Citing ARM data using Digital Object identifiers (DOIs): how and why

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Raymond McCord, Oak Ridge National Laboratory
Karen Gibson, Oak Ridge National Laboratory
James Mather, Pacific Northwest National Laboratory
Jimmy Voyles, Pacific Northwest National Laboratory
Mark Martin, Oak Ridge National Laboratory
Rolanda Jundt, Pacific Northwest National Laboratory

To facilitate citing the ARM data sets in journals and articles, the ARM Data Archive, in collaboration with DOE Office of Scientific and Technical Information (OSTI), established a DOI service for the ARM data sets. This allows the users to more directly cite the exact ARM data that they have used in their research. This DOI service also allows the future data users and the ARM Facility to easily track the data used in various articles. The ARM DOIs are currently published on the ARM datastream web pages and in the Archive user interfaces. The relevant DOIs are sent as part of the data order notification email. Typically DOIs are assigned to individual objects (report or data table), but for ARM data sets, these DOIs are assigned at the ARM data product level, which eliminates the need for creating millions of DOIs for all the data files and also helps the users to cite ARM data with a few DOIs. To cite ARM data, users should include a combination of information in the citations: ARM DOIs, data collected location(ARM site and facility), date range of the data used in their study, and the date downloaded from the ARM Archive. The ARM infrastructure team is currently developing various citation strategies with DOIs and seeks input from the users to improve the strategies.

Development of an ARM-wide maintenance reporting capability

Brad Perkins, Los Alamos National Laboratory
Christine Waigl, University of Alaska Fairbanks
Martin Stuefer, Geophysical Institute, University of Alaska Fairbanks
Kathy Lazar, Brookhaven National Laboratory

The various ARM Site Operations offices have historically developed and maintained their own site-specific database for documenting instrument and infrastructure maintenance activity. These “Maintenance Databases” have traditionally served as the collection point for near-real-time maintenance documentation, which may provide metadata for ARM data products. These various databases also contain information that should be referenced or detailed in other ARM databases such as DQPR, DQR, OSS, BCR, and IMMS. ARM has long needed to enable communication between Site Operations maintenance databases and other ARM databases and automate the creation of links or shared content between those databases. While the existing maintenance databases serve similar purposes, the chosen (often proprietary) database technologies, database content and structure, and type and level of accessibility vary widely. A single program-wide, near-real-time view of recent or future maintenance activity is not available, and the existing maintenance database implementation differences have prevented ARM database integration. ARM has approved a proposal to develop a Common ARM-Wide Maintenance Capability. This effort will build upon recent development work by ARM North Slope of Alaska (NSA) Operations adopting an easy-to-use maintenance entry system. A single database will be established to store all ARM maintenance reports. This will solve the existing program-wide access limitation and provide a flexible reporting and notification structure. The database architecture will allow the development of an offline reporting tool for use when Internet is limited or unavailable. A capability to enter future planned maintenance will be developed, providing an Operations planning tool and visibility to upcoming maintenance that could affect data flow or quality. Having a single common database and database access architecture will ease integration with other ARM databases.

Improving quality control tools and procedures for ARM value-added products

Justin Monroe, University of Oklahoma
Kathy Lazar, Brookhaven National Laboratory
Sherman Beus, Pacific Northwest National Laboratory
Randy Peppler, University of Oklahoma

Recently, the development life cycle for ARM value-added products (VAPs) was updated to include a more efficient and well-defined set of procedures. As a result of these updates, the ARM Climate Research Facility Data Quality (DQ) Office now maintains a more active role in the quality control (QC) of these products. Due to the additional complexity often inherent in VAPs when compared to instrument-level products, the DQ Office developed new tools and procedures to more effectively handle this task. One of these tools is DQ Inspector, a command-line plotting utility that is very effective for reviewing VAPs in the evaluation stage prior to official release. Another new tool is DQ Explorer, a web application that incorporates several new features that greatly improve the ability of the DQ Office to perform routine QC assessment of production VAPs. Collaborations between the DQ Office and government labs within ARM have also led to useful updates to the ARM DQ Assessment system, which now allows users to quickly access relevant reports for VAP input datastreams.

Integrated Software Development Environment: Data Consolidation Tool and development framework

Krista Gaustad, Pacific Northwest National Laboratory

This poster describes functionality and benefits of ARM's Integrated Software Development Environment (ISDE) 1.0. In addition to automating the retrieval and storage of the data from and to netCDF files, this first version of the libraries widely available to the ARM user community also supports unit, data type, and coordinate dimension transformations, thus eliminating the need for most preprocessing tasks. Coordinate dimension transformations can be used to map variables' coordinate dimensions to static values, to the coordinate dimensions of another datastream, or to the smooth data. This first release includes also the Data Consolidation Tool which is an application that performs any retrieval process defined in ARM's Process Configuration Manager graphical interface, allowing data users to quickly construct netCDF files that meet their particular research needs. A code generation template is available to facilitate the development efforts of users who need to develop their own analysis modules and not simply transform or consolidate existing ARM data products.

Investigating Clouds and precipitation at the Jülich Observatory for Cloud Evolution

Susanne Crewell, University of Cologne
Kerstin Ebell, University of Cologne, Institute for Geophysics and Meteorology
Ulrich Loehnert, University of Cologne, Institute for Geophysics and Meteorology
Birger Bohn, Research Centre Juelich

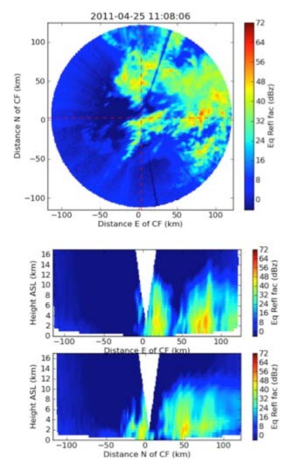
The Jülich Observatory for Cloud Evolution (JOYCE) is a unique site for investigating the processes leading to cloud formation and cloud evolution. To this end, various instruments have been set up at the Research Centre Jülich that continuously monitor water vapour, clouds, and precipitation over many years. JOYCE is operated jointly by the University of Cologne, the Research Centre Jülich, and the Transregional Collaborative Research Centre TR32 "Patterns in Soil-Vegetation-Atmosphere-Systems: Monitoring, Modelling and Data Assimilation." The area around Jülich (Germany) is arable land characterized by heteorogenous land surface conditions that are monitored by TR32. The core instruments of JOYCE are a scanning cloud radar, a micro rain radar, a ceilometer, a pulsed Doppler lidar, a scanning 14-channel microwave radiometer (MWR), an infrared spectrometer (AERI), a Doppler sodar, a total sky imager, and radiation sensors. These measurements are supplemented by the standard meteorological measurements from the 120-m measurement tower including eddy covariance and in situ aerosol measurements. In addition, the polarimetric weather radar of the Research Centre Jülich provides information about the spatial distribution of precipitation. Because aerosol and precipitation vary rapidly in the area of Jülich, the long-term data cover a broad atmospheric spectrum well-suited for process studies and statistical analysis. For the latter, synergetic products based on the integrated profiling techniques (Lohnert et al. 2008) are derived. In addition to the continuous monitoring of the atmospheric column, a 3D picture of water vapour and clouds is provided by the hemispheric scans of the cloud radar and MWR. The data of TR32 and JOYCE are used to investigate the influence of the land surface on surface on water vapour variations, the development of boundary clouds, cloud radiation interaction, and the precipitation formation.

http://www.geomet.uni-koeln.de/allgemein/forschung/joyce/

Moments to models: progress towards a suite of precipitation radar VAPs

Scott Collis, Argonne National Laboratory
Kirk North, McGill University
Scott Giangrande, Brookhaven National Laboratory
Nitin Bharadwaj, Pacific Northwest National Laboratory
Kevin Widener, Pacific Northwest National Laboratory
Adam Theisen, CIMMS/ARM Data Quality Office
Pavlos Kollias, McGill University

The newly installed X- and C-band scanning precipitation radars (SAPRs) are producing remotely sensed measurements of precipitating cloud systems. These radar moments need a large degree of correction and processing for geophysical retrievals to be performed. This presentation gives an overview of the end-to-end processing system for the ARM precipitation-sensitive radars. The system starts with raw data from the radars and produces value-added products (VAPs), which are readily comparable with cloud-resolving and single-column model output. As well as highlighting recently released evaluation products, the presentation will also outline future development plans.



Example data from the recently released MMCG VAP.

The new and improved Southern Great Plains

John Schatz, ARM Climate Research Facility
David Breedlove, ARM Climate Research Facility
David Swank, ARM Climate Research Facility
Daniel Hartsock, University of Oklahoma
Douglas Sisterson, Argonne National Laboratory

During the past several years the SGP has been undergoing a major configuration change that has resulted in new and exciting capabilities. The SGP instrumentation previously contained in 31 measurement sites in a 55,000-square-mile grid has shrunk to 21 sites and to a grid size less than 9000 square miles, for better alignment to current general circulation models. As new sites were located and installed in this smaller grid, SGP took advantage and made improvements in the layout, communication enclosure, and instrument stand design of these measurement sites. Sites not in the new domain were retired and remediated. Also, to meet new scientific emphasis and thanks to Recovery Act funds, the SGP installed three X-band radars and one C-band radar and relocated the three existing 915-MHz profilers, bringing them in closer to the Central Facility to support the new radars. These new capabilities proved very useful during the DOE/NASA collaboration campaign Midlatitude Continental Convective Clouds Experiment, or MC3E. This large-scale campaign was created to gather detailed information to answer questions about convective systems. The use of the SGP network of radars, NASA's aircraft, and a very active convective season created a winning combination and very successful campaign.

New ARM measurements: progress today with steps towards our future

Jimmy Voyles, Pacific Northwest National Laboratory
James Mather, Pacific Northwest National Laboratory

The DOE Atmospheric Radiation Measurement (ARM) Climate Research Facility has recently enhanced its observational capabilities at its fixed and mobile sites as well as its aerial facility. New capabilities include scanning radars, several types of lidars, an array of aerosol instruments, and in situ cloud probes. All ARM sites have been equipped with dual-frequency scanning cloud radars that will provide three-dimensional observations of cloud fields for analysis of cloud field evolution. Sites in Oklahoma, Alaska, and Papua New Guinea have also received scanning centimeter wavelength radars for observing precipitation fields. This combination of radars will provide the means to study the interaction of clouds and precipitation. New lidars include a Raman lidar in Darwin, Australia, and high spectral resolution lidars in Barrow and with the second ARM Mobile Facility. Each of these lidars will provide profiles of aerosol extinction while the Raman will also measure profiles of water vapor. ARM has also expanded its capabilities in the realm of aerosol observations. ARM is adding aerosol observing systems to its sites in Darwin and the second mobile facility. These aerosol systems principally provide measurements of aerosol optical properties. Additionally, a new mobile aerosol observing system has been developed that includes a variety of instruments to provide information about aerosol chemistry and size distributions. Many of these aerosol instruments are also available for the ARM Aerial Facility. The Aerial Facility also now includes a variety of cloud probes for measuring size distribution and water content. The new array of ARM instruments is intended to build upon the existing ARM capabilities to better study the interactions among aerosol, clouds, and precipitation. Data from these instruments are now available and development of advanced data products is underway.

NSA corrective maintenance reporting upgrade: a status report

Christine Waigl, University of Alaska Fairbanks
Martin Stuefer, University of Alaska Fairbanks
Brad Perkins, Los Alamos National Laboratory
Mark Ivey, Sandia National Laboratories
Jeffrey Zirzow, Sandia National Laboratories
Walter Brower, UIC Science Division/ARM Climate Research Facility
James Ivanoff, ARM Climate Research Facility
Cory Stuart, Argonne National Laboratory

The ARM North Slope of Alaska (NSA) Site Operations team has deployed a new corrective maintenance reporting (CMR) database. The aim of the new development is to increase the quality, completeness, and number of corrective maintenance reports after each intervention on any of the instrument or infrastructure systems at the ARM NSA facilities of Barrow, Atqasuk, and Oliktok. The application was built using common open-source components and a flexible and easy-to-manage data model with a view towards generalization to other ARM sites and interoperability with other program-wide reporting tools (OSS, DQPR, DQPR, weekly reports, IMMS). After two months of exclusive production use, the new database is well accepted. The transfer of maintenance information from the sites improved, and an increase in the number of CM reports has been noted. The new CMR database ensures improved consistency and completeness of reports with an easy-to-use, fast, and appealing user interface. Feedback from operators and other members of the ARM community has been decisive in considering trade-offs such as between the level of detail collected and the complexity of the task of filling in a CM reporting form. Characteristic features are more fine-grained notification subscription options, improved reporting capabilities, improved editing capabilities including the option to attach image files, import of legacy CM data, and easy search capabilities. At the same time, the new application is making operational tasks such as weekly status reporting or the linking of DQPR and OSS entries back to maintenance reports, noticeably easier. The distinction between optional, configurable, and required data fields facilitates the extension of the database system to other facilities in ARM.

https://nanuna.gi.alaska.edu/cm

The Organic Aerosol Composition (OACOMP) value-added product for the ARM Data Archive

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Alison Tilp, Brookhaven National Laboratory

Secondary organic aerosols (SOA) comprise a large fraction of the aerosol mass in the atmosphere at many locations; however, the formation of SOA is poorly understood and represented by atmospheric models. This deficiency represents a large source of uncertainty in quantification of aerosol effects on radiation and clouds and consequently the prediction of future climate. Evaluation and development of aerosol process modules require data products generated from field observations. Aerosol mass spectrometers (AMS) have been frequently used in DOE-supported field campaigns for characterizing aerosol composition and elucidating aerosol sources and processes. In addition, three units of Aerosol Chemical Speciation Monitor (ACSM) were recently added to the TWP and SGP long-term measurement sites and mobile aerosol observing system (MAOS). The ACSM is a “mini” version of the AMS developed for continuous, low-maintenance operation. The typical time resolution of AMS measurements is 2–5 minutes at fixed sites and 30 seconds or less on mobile platforms (e.g., aircraft), while the time resolution of ACSM is generally 30 minutes. Code is currently being adapted that takes measurements of total organic matter and other spectra information from the ACSM and derives the primary and secondary fractions of organic matter. The code will be run operationally within ARM’s Data Management Facility, and the new data product, called the Organic Aerosol Composition (OACOMP) value-added product, will eventually be made available on the ARM Data Archive. This presentation will describe the motivation for OACOMP, quality assurance (QA) procedures, how the organic aerosol components are derived, progress that has been made including preliminary results, as well as anticipated operational implementation. Information on the primary and secondary components will be valuable for modelers when evaluating new treatments of organic matter.

Quality control techniques for scanning ARM radar

Adam Theisen, CIMMS/ARM Data Quality Office
Scott Collis, Argonne National Laboratory
Scott Giangrande, Brookhaven National Laboratory
Randy Peppler, University of Oklahoma

The introduction of the new precipitation radars procured through the American Recovery and Reinvestment Act has resulted in a need to develop innovative quality control methods to analyze the data in a timely and effective manner. Techniques have been employed to gather a subset of data from each radar volume in order to determine the general quality of the data. Some of these techniques include using point target reflectivities, vertical profiles of differential reflectivity, comparisons with vertical profiling instruments at the Southern Great Plains Central Facility, and comparison with precipitation instruments at the Central Facility. Comparing the precipitation estimates derived from the radar reflectivity to the precipitation instruments at the surface has led the Data Quality Office to additionally investigate the individual performance of each precipitation instrument. Data from each precipitation instrument were gathered over 2011 and analyzed. Each instrument was compared to a baseline instrument at each site, in most cases a MET tipping-bucket rain gauge. This analysis was able to provide an idea of how each instrument performed relative to one another in differing conditions.

Search, discovery, and accessibility of field campaign data: status update

Daniel Larkin, Brookhaven National Laboratory
Alice Cialella, Brookhaven National Laboratory
Richard Cederwall, Oak Ridge National Laboratory
Richard Wagener, Brookhaven National Laboratory
Kathy Lazar, Brookhaven National Laboratory
Karen Gibson, 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. In the summer of 2010 a significant portion of the field campaign data received metadata assignments. New instrument classes and primary measurement types were defined to pave the way for the influx of former ASP field campaign data. This summer all the former ASP field campaign data were assigned metadata. This required a formidable amount of effort to reorganize the ASP data to fit into the ARM FC data structure paradigm. By the end of the fiscal year, nearly 95% of all delivered FC data had been assigned. This is an unsurpassed level of completeness for the FC metadata assignments.

Value-added product highlights from the Cloud Life Cycle working group

Michael Jensen, Brookhaven National Laboratory
Shaocheng Xie, Lawrence Livermore National Laboratory
Scott Collis, Argonne National Laboratory

ARM value-added products (VAPs) provide an important translation between the measurements from ARM instrumentation and the geophysical quantities needed for scientific analysis, particularly model parameterization and development. VAPs are developed by the ARM infrastructure team (translators and developers) with guidance from each ASR science working group and individual science sponsors for each VAP. This poster will highlight the current status of ARM VAPs relevant to the ASR Cloud Life Cycle working group (CLWG) with an emphasis on new developments including precipitation and cloud radar-based VAPs, vertical velocity VAPs, and forcing data sets

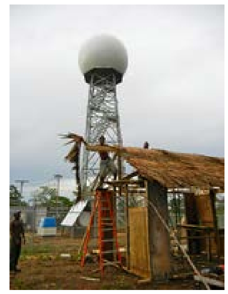
Abstracts

Instruments

ARM radars: status and near-term plans

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

ARM has gone from 5 Ka-band cloud radars to 25 cloud and precipitation radars this year. This poster presents a review of what has been accomplished and what still needs to be done in the near-term to bring the ARM radar network to full operational capacity.



C-band scanning ARM precipitation radar on Manus Island, Papua New Guinea.

Autosonde installation at ARM Climate Research Facility North Slope of Alaska site

Donna Holdridge, Argonne National Laboratory
Jenni Prell, Argonne National Laboratory
James Ivanoff, ARM Climate Research Facility
Walter Brower, UIC Science Division/ARM Climate Research Facility
Timothy Grove, ARM Climate Research Facility
Mark Ivey, Sandia National Laboratories

Installation of the Vaisala Autosonde at the ARM Climate Research Facility North Slope of Alaska (NSA) site took place in May 2011. The system was purchased with Recovery Act funding and will allow for an increased launch schedule with less burden on the local observers. Details and images of the Autosonde will be provided.

Cimel sunphotometers: updates on recent deployments and review of uncertainty estimates

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

We present a review of recent Cimel sunphotometer (CSPHOT) deployments and data availability. Since 2010, as part of the deployment of the Boundary Layer Cloud System, additional CSPHOTs were acquired. This allowed the expansion of ARM CSPHOTs deployments to all fixed sites and the two mobile facilities, including recent deployments to Ganges Valley, India, (AMF1) and Gan Island (AMF2). Also, in the summer of 2011, a CSPHOT was deployed as a part of the Aerosol Lifecycle campaign at Brookhaven National Laboratory to relate the very detailed in situ aerosol observations of the Mobile Aerosol Observing System (MAOS) to column-integrated aerosol properties derived from the CSPHOT measurements. To address the recently highlighted need to quantify ARM measurement uncertainties, we review the various sources of uncertainty in geophysical quantities derived from CSPHOT measurements and summarize overall uncertainty estimates from published instrument intercomparisons.

Comparison of in situ field measurements of water vapour and stable carbon isotopologues of carbon dioxide from laser spectroscopic instruments

Hope Michelsen, Sandia National Laboratories
Ray Bambha, Sandia National Laboratories
Paul Schrader, Sandia National Laboratories
Brian LaFranchi, Lawrence Livermore National Laboratory
Thom Rahn, Los Alamos National Laboratory
Thomas Guilderson, Lawrence Livermore National Laboratory
Anna Karion, Cooperative Institute for Research in Environmental Sciences
Colm Sweeney, NOAA Earth System Research Laboratory

Anthropogenic sources of carbon dioxide represent a significant portion of the global carbon budget, and attributing atmospheric CO2 abundances to their biogenic and anthropogenic sources will require accurate measurements of CO2 concentrations from multiple sensors. We conducted an intensive field campaign in fall 2010 to measure CO2 and several tracers for its sources using a new mobile laboratory. Two trucks carrying instruments for greenhouse gases were deployed along with a gas-calibration system. Air was drawn into both trucks from a 10-m tall mast. All measurements were made either from a common inlet or closely located inlets. We used four instruments to make high-frequency laser-spectroscopic measurements of abundances of CO2 and its stable isotopologue (13CO2). Each of these instruments simultaneously measured abundances of water vapor. Automated flask samplers collected whole air samples for offline analysis of CO2 abundances and δ13C-CO2. We obtained good agreement among CO2 measurements from these instruments following careful post-processing and calibrations. Good agreement was also demonstrated for water vapor measurements. Differences between δ13C-CO2 measured by two of these instruments, however, were larger than expected.

Comparison of vertical velocity observations between the ARM Doppler lidar and the 915 MHz radar during MC3E

Rob Newsom, Pacific Northwest National Laboratory
Richard Coulter, Argonne National Laboratory
Marc Fischer, Lawrence Berkeley National Laboratory
Edwin Campos, Argonne National Laboratory

This poster presents a comparison of vertical velocity measurements from a 915-MHz radar and a collocated coherent Doppler lidar. The comparison was conducted at the Atmospheric Radiation Measurement Climate Research Facility Southern Great Plains site during a three-month period spanning the Midlatitude Continental Convective Clouds Experiment (MC3E). The accuracy of the lidar measurements was also assessed by comparison with sonic anemometers at the 25- and 60-meter levels on a nearby meteorological tower. During this study, the radar was operated exclusively in its low-power, short-pulse mode and sampled only in the vertical direction. In this mode of operation, the radar provided vertical velocity measurements with a height resolution of 121 meters and a nominal temporal resolution of about 6 seconds. The low-power mode provided finer height resolution than the high-power mode but reduced sensitivity in clear-air. To compensate, the radar vertical velocities were reprocessed by averaging raw Doppler spectra over 60-second time intervals. The lidar, on the other hand, was operated with a pulse integration time of 1 second and a height resolution of 30 meters. To enable comparison, the lidar data were averaged and resampled to match the height and time resolution of the radar. The lidar-radar comparisons were restricted to periods with no precipitation and sorted by surface heat flux and friction velocity measurements as determined from sonic anemometer data. The comparisons were also restricted to heights below 2 kilometers AGL. Above that level, measurements from both systems were dominated by noise. As expected, the radar vertical velocities exhibited higher noise levels than the lidar measurements. Histograms of the difference between the radar and lidar vertical velocities show a tendency for the radar to be slightly negatively biased relative to the lidar in convective to neutral conditions. Under stable conditions the bias was essentially zero. When averaged over all stability conditions, the mean value of the radar vertical velocity was -9 cm s-1, compared to a mean of 0.04 cm s-1 for the lidar. For heights below 500 meters AGL, the correlation coefficients ranged from about 0.8 under convective conditions to 0.3 under stable conditions. A comparison between the lidar and sonic anemometers showed excellent agreement, with an overall RMS deviation of less than 50 cm s-1 and a linear correlation coefficient of greater than 0.95.

Development and control of a stable platform for shipborne measurements

Richard Coulter, Argonne National Laboratory
Timothy Martin, Argonne National Laboratory

Many of the second ARM Mobile Facility (AMF2) deployments are expected to be on research vessels or ships of opportunity. Some instruments should be isolated from ship motion as much as possible in order to make useful measurements. This includes most instruments requiring shading from the sun or trying to make direct measurements of solar radiation. It also includes instruments that purport to measure vertical velocities of air or cloud droplets, such as any ARM radar that does not have inertial compensation. The stable platform developed by AMF2 has been developed under significant cost restraints. Results from its maiden voyage in 2010 and subsequent improvements are presented. Anticipated use of a second, similar platform specifically for supporting radar measurements is also discussed.

The AMF2 stable platform at sea aboard the RV Connecticut during a three-day cruise out of Woods Hole. The MWR, MFRSR, and a tilt sensor are in place and operating on the platform, which includes a turntable to compensate for ship yaw.

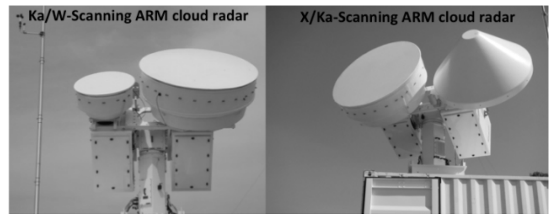
Evaluation of first data from the operational 3-channel microwave radiometers (MWR3C)

Maria Cadeddu, Argonne National Laboratory

Between October and December 2011 the new 3-channel microwave radiometers (MWR3C) have become operational at three ARM sites (Southern Great Plains, the second ARM Mobile Facility, and Tropical Western Pacific-Darwin). We present the new datastreams and a first evaluation of the data set. We compare the brightness temperature measurements with measurements from the 2-channel MWR, from the RPG 90/150 radiometer, and with model computations to assess overall accuracy of the calibration and stability of the instruments. We present the new retrieval algorithm for the real-time estimation of precipitable water vapor and liquid water path and compare the results with retrievals from the 2-channel MWR. The new data set and real-time retrievals are available from the ARM Data Archive. An assessment of the newly developed rain mitigation system and rain detection capability is also shown. The new MWR3C will become operational at the remaining ARM sites in the upcoming months.

First-generation operational modes for ARM radars

Nitin Bharadwaj, Pacific Northwest National Laboratory
Pavlos Kollias, McGill University
Kevin Widener, Pacific Northwest National Laboratory
Scott Collis, Argonne National Laboratory



ARM's scanning dual-polarization dual-frequency cloud radars.

The ARM profiling radars have been used to observe cloud systems for over a decade. The cloud profiling radars have provided valuable data sets for the study of clouds. However, the profiling radars were limited to observing cloud properties in a vertical column. Recently, the ARM Climate Research Facility has added scanning cloud and precipitations radars to its facilities. The primary purpose of these radars is for the three-dimensional observation of clouds and spatial-temporal mapping of cloud properties. The ARM radars are deployed at four fixed sites and on two mobile facilities (AMF1 and AMF2) for regional climate studies. The four fixed sites are Southern Great Plains (SGP) in Oklahoma, North Slope of Alaska (NSA) in Barrow, Tropical Western Pacific (TWP) Darwin in Australia and TWP Manus Island in Papua New Guinea. These radars will be located with the baseline instrument suites at the ARM sites for comparative measurements. Cloud systems have been observed at various scales and differing structures. The cloud systems classification is used as a guide to include the spatial scale and structure of the clouds to facilitate the design radar scan strategies. In addition to cloud structure and spatial scale, the geographical location of the radar must be taken into account while designing the scan strategy. The observation of cloud systems in three dimensions has not been done in a 24x7 operational environment. The first-generation scanning modes for the ARM radar are presented. The first-generation scan strategy is aimed to meet a few base-level objectives of the ARM Facility. The data from the first generation will provide data to evaluate the sampling strategies for the scanning ARM cloud radars (SACRs) and scanning ARM precipitation radars (SAPRs). In addition, the first-generation operating modes will provide a framework to build long-term operational scanning modes that are tailored for each of the radar sites, which cover a wide range of climatic regimes.

Ice nucleus counter for laboratory and field measurements

Greg Kok, Droplet Measurement Technologies

Ice clouds regulate a significant portion of precipitation formation and have major influence on cloud characteristics such as cloud dynamics and radiation. Modeling has been difficult with regard to these items, as the ice-nucleating properties of aerosols are complex to measure. Droplet Measurement Technologies is producing a commercial ice nucleus counter based on the parallel plate chamber design, coupled with a high-efficiency refrigeration system and a single-particle detector that uses depolarization of the scattered light to identify liquid or ice particles. The system is completely automated and designed for continuous, unattended operation. The refrigeration system can cool the cold wall to -70°C, and the warm wall can be cooled to -40°C. A new variable-speed DC-powered compressor is used, which provides rapid cooling and a high degree of temperature control. An optical particle counter has been designed specifically for the ice nucleus counter. The unit is designed to handle the entire flow from the IN chamber with a high degree of resolution for the particle size. Light is collected in side scatter, as the primary sizing detector. Backscattered light is passed through a polarizing prism, separating the scattered light into the S and P polarizations. The electronics provide for binning of the data as well as particle-by-particle recording of the signal intensity. Particle sizing is from 0.4 to 10 microns.

Introducing an Absolute Cavity Pyrgeometer for improving the atmospheric longwave irradiance measurement

Ibrahim Reda, National Renewable Energy Laboratory
Tom Stoffel, National Renewable Energy Laboratory

Advancing climate change research requires accurate and traceable measurement of the atmospheric longwave irradiance. Current measurement capabilities are limited to an estimated uncertainty of larger than ± 4 W/m2 using the interim World Infrared Standard Group (WISG). WISG is traceable to the Système international d'unités (SI) through blackbody calibrations. An Absolute Cavity Pyrgeometer (ACP) is being developed to measure absolute outdoor longwave irradiance with traceability to SI using the temperature scale (ITS-90) and the sky as the reference irradiance, instead of a blackbody. The ACP was optically characterized by the National Institute of Standards and Technology (NIST). Under clear-sky and stable conditions, the responsivity of the ACP is determined by lowering the temperature of the cavity and calculating the rate of change of the thermopile output voltage versus the changing net irradiance. The absolute atmospheric longwave irradiance is then calculated with an uncertainty of ±3.96 W/m2 with traceability to SI. The measured irradiance by the ACP was compared with the irradiance measured by two pyrgeometers calibrated by the World Radiation Center with traceability to the WISG. A total of 408 readings was collected over three different clear nights. The calculated irradiance measured by the ACP was 1.5 W/m2 lower than that measured by the two pyrgeometers that are traceable to WISG. Further development and characterization of the ACP might contribute to the effort of improving the uncertainty and traceability of WISG to the SI. Reference: Journal of Atmospheric and Solar-Terrestrial Physics, accepted for publication December 12, 2011.

MFRSR and MFR program and hardware changes

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

The Campbell CR1000 logger program that controls the operation of the majority of ARM multifilter rotating shadowband radiometers (MFRSR) is being upgraded. Most significantly, the upgrade will add functionality for operation at locations greater than +/- 50 degrees latitude. This will allow us to complete the transition of the NSA MFRSR to the same state as the fully upgraded systems that are currently operating at the SGP sites. Other logger program updates include: adding code for seamless deployments in the Southern hemisphere, improved reading of the Dallas instrument identity chip, expanded internal documentation of the program, and an overall streamlining of the code. Once completed, the only required end user input is the station's latitude and longitude; otherwise, system operation due to instrument location will be transparent to the end user. In addition to the above updates, we are also proposing additional changes that we believe will improve the primary measurements, as well as including unique QC parameters to better assess the stability of a given measurement set. By the time of the 2012 ASR Science Team Meeting, we will also have completed an upgrade of the SGP Central Facility (CF) multifilter radiometers (MFR). Those instruments are known as MFR10m and MFR25m. This will be a complete update of those systems, i.e., both will have fully refurbished sensors, and data will be collected with Campbell CR1000 data loggers. Where applicable, software updates to the MFRSR code will also be incorporated into the MFR logger program. In addition to the Central Facility MFR upgrades, we are also resurrecting the MFR that flies on the Cessna out of the Ponca City airport. This instrument will use the same code as the CF MFRs, and the instrument system will also include a GPS for time and location (latitude/longitude/altitude) information. The Cessna MFR should be functional no later than the Science Team Meeting. All of the above changes (planned and proposed) will be completely described in our poster.

Mobile Aerosol Observing System (MAOS): a new instrument suite for the Aerosol Lifecycle (ALC) IOP

Stephen Springston, Brookhaven National Laboratory
Arthur Sedlacek, Brookhaven National Laboratory

The Aerosol Lifecycle (ALC) Intensive Operations Period conducted during mid-June to mid-August 2011, in central Long Island, New York, achieved multiple objectives. Scientifically, the campaign focused on the evolution of aerosol optical properties and secondary organic aerosol formation and processing, as well as CCN formation during multiple, distinct air-flow patterns. The extensive suite of instrumentation within the Mobile Aerosol Observing System (MAOS) attracted collaborative participation by multiple academic, commercial research, DOE, and other government co-investigators. In addition to the MAOS instrument suite, the co-investigators contributed their own measurement capabilities, yielding a rich, combined data set. All instrument mentors were present for this maiden deployment of MAOS and used the opportunity to refine measurement strategies for future deployments. The operators were trained in day-to-day tasks and problem-solving. This training and lessons-learned served as the basis for an extensive Operating Procedures document. The data set (MAOS and Co-Investigators) from the ALC is being made available through the ARM External Data Center (XDC). Long Island and Cape Cod, Massachusetts, have similar environmental conditions, which make the ALC measurements representative of those expected for the Two-Column Aerosol Project (TCAP) to be held in the summer of 2012.

Observation and model comparison of the thermodynamic environment using the microwave radiometer profiler

Lynn DiPretore, Rutgers University
Mark Miller, Rutgers University
Virendra Ghate, Rutgers University

It is anticipated that the knowledge gained through analysis of ARM Mobile Facility (AMF) observations will be utilized by efforts to increase the accuracy of global climate models (GCMs) in under-sampled regions of interest. In pursuit of one such effort, the purpose of this study is to investigate the feasibility and utility of observation and model comparisons that employ thermodynamic profiles derived from the AMF’s 12-channel microwave radiometer profiler (MWRP) to assess the profiles generated by GCMs in the corresponding vertical column of grid cells. Although radiosondes are widely accepted as the preferred instrument for obtaining atmospheric profiles, they are not suitable for the present application because assimilation techniques are required to resolve the scales discordance between radiosonde launches and GCM time steps. Profiles with spatial and temporal characteristics that are appropriate for comparison with GCM output are available, however, from the MWRP. To demonstrate the accuracy and capability of radiometric retrievals for the present application, profiles obtained from the MWRP are compared with radiosonde soundings from the one-year AMF deployment in Niamey, Niger, in 2006. Key variables that characterize the thermodynamic environment are then used to assess the performance of four GCMs. Analyses of the links between clouds, precipitation, and the thermodynamic environment are explored and are found to have the potential to provide a unique and valuable opportunity to assess the performance of parameterized physics in GCMs.

Rapid scan dynamic humidity particle spectrometer

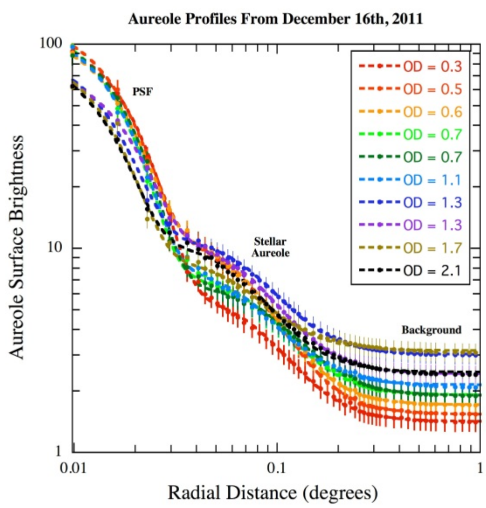
Athanasios Nenes, Georgia Institute of Technology
Richard Moore, Georgia Institute of Technology
Terry Lathem, Georgia Institute of Technology
Jack Lin, Georgia Institute of Technology
Tomi Raatikainen, Georgia Institute of Technology

The Continuous-Flow Streamwise Thermal-Gradient CCN counter (CFSTGC), which has been commercialized by Droplet Measurement Technologies (Roberts and Nenes, AST, 2005; Lance et al., AST, 2006), has proven to be reliable, robust, and relatively simple to operate for ground-based and airborne measurements. The supersaturation profile in the CFSTGC depends on pressure, flow rate, the streamwise temperature gradient, and to a lesser extent, the inlet temperature. Currently, the instrument is operated at a constant flow rate, and its supersaturation is adjusted by changing the column temperature gradient in the streamwise direction. Although a well-established and robust approach, this mode of operation provides CCN measurements at one supersaturation at a time. Switching supersaturations is slow, requiring 20–40 seconds for column temperatures to stabilize during a supersaturation change (occasionally even longer periods). Data collected during transient periods are often discarded, which is a problem if CCN measurements are done in rapidly changing environments (such as those encountered in aircraft studies). A new mode of operation, called “Scanning Flow CCN Analysis”, or SFCA (Moore and Nenes, AST, 2009), addresses these issues. SFCA involves changing the flow rate in the instrument over time, while maintaining a constant temperature gradient; this causes supersaturation to continuously change, allowing the measurement of a supersaturation spectrum (i.e., CCN concentrations between 0.1 and 1.0% supersaturation) over a flow cycle, which can be as short as 10 seconds (and without loss of data continuity). Another important aspect of SFCA is the minimization of CCN measurement biases from volatilization effects that could occur under the high temperature gradients typically associated with the conventional operation of the instrument. SFCA combines the simplicity and robustness of the DMT CCN counter with the dynamical range and temporal resolution of a CCN spectrometer. We present demonstrations of a prototype SFCA unit deployed in a number of airborne campaigns (CalNex, GRIP, IFEX) aboard the CIRPAS Twin Otter, NOAA WB-P3, and NASA DC-8 platforms. Apart from the important scientific results and successful data collected during these campaigns, we present “lessons” learned and discuss the ongoing efforts to improve the resolution and dynamic range of the technique.

Retrieving cirrus microphysical properties from stellar aureole images

John DeVore, Visidyne, Inc.
Joe Kristl, Visidyne, Inc.
Saul Rappaport, Massachusetts Institute of Technology

While climate change monitoring has improved significantly from routine, ground-based, sun photometer measurements of aerosols made at AERONET sites worldwide, the impacts of cirrus clouds remain much less certain because they occur high in the atmosphere and are more difficult to measure. We report on a Phase I SBIR project to retrieve microphysical properties of cirrus ice crystals using stellar aureole imaging. We have demonstrated that (1) we have clearly measured aureole profiles; (2) we can follow the aureole profiles out to about ~1/4 degree from stars (~1/2 degree from Jupiter); (3) the aureoles from cirrus have very distinctive profiles, being flat out to a critical angle, followed by a steep power-law decline with a slope of ~ -3; (4) the profiles are well modeled using gamma size distributions; and (5) the critical angle in the profiles is ~0.12 degrees, (6) indicating that the particle size distribution extends out to at least several hundred microns (based on particle averaged projected area).



The circles and error bars show profiles of the azimuthally averaged aureole radiance around the star Capella for a broad range of cirrus optical depths on the evening of December 16, 2011. The dashed curves show fits to a sum of three functions representing the instrument point spread function (PSF), cirrus ice crystal diffraction (Stellar Aureole), and city shine scattered from the Boston, Massachusetts area (Background).

Update on the performance and evaluation of the Total Precipitation Sensor in Alaska

Jessica Cherry, International Arctic Research Center
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The authors provide an update on the performance and evaluation 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 gages, but may not detect smaller-sized snow particles. Output from the TPS is being compared to that from the collocated NOAA Climate Reference Network (CRN) sites, snow particle counters, and changes from snow depth sensors. Additional data from wind tunnel experiments suggest that not only may the sensor fail to detect trace precipitation, but the asymmetry caused by the 'gooseneck' design must also be accounted for in the wind pumping portion of the sensor algorithm.

Abstracts

Modeling

Advancing models and evaluation of cumulus, climate, and aerosol interactions

Andrew Gettelman, National Center for Atmospheric Research
Lin Su, University of Colorado

We are developing consistent cloud microphysics and aerosol activation for cumulus and stratiform clouds with a more modular and flexible cloud microphysics module for the National Center for Atmospheric Research (NCAR) and Department of Energy (DOE) Community Atmosphere Model (CAM). We are developing a more robust single-column model framework that incorporates ARM field data sets and observation periods, including scripts for running CAM in forecast mode. We seek to improve the representation of convective clouds and aerosol-cloud interaction in convective clouds. We will evaluate the model with convective precipitation statistics (including intensity and extreme events) as well as aerosol-cloud interactions and their effect on cloud development such as the delay of precipitation, convection invigoration and extending cloud lifetime. We will eventually release our evaluation tools to the community. The project will tie together and link existing ASR efforts to release versions of the NCAR/DOE CAM. *Proposal Team: A. Gettelman, L. Su, J. Bacmeister, R. Neale, H. Morrison, S. Park, B. Eaton, J. Truesdale (NCAR), S. Xie, S. Klein (LLNL), G. Zhang (UCSD), Y. Liu, W. Lin (BNL), S. J. Ghan, X. Liu (PNNL)

Analysis of high-resolution cloud simulations using dynamical downscaling and data assimilation

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Yangang Liu, Brookhaven National Laboratory
Satoshi Endo, Brookhaven National Laboratory
Zhengqing Ye, NASA Jet Propulsion Laboratory
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Parametric representations of cloud/precipitation processes continue to be adopted in climate simulations with increasingly higher spatial resolution or with emerging adaptive mesh framework, and it is only becoming more critical that such parameterizations have to be scale-aware. Continuous cloud measurements at DOE's ARM sites have provided a strong observational basis for novel cloud parameterization research at various scales. Despite significant progress in our observational ability, there are important cloud-scale physical and dynamical quantities that are either not currently observable or insufficiently sampled. Outputs from cloud-resolving simulations are often used to provide such cloud-scale fields. To complement the ARM measurements, the cloud-resolving simulations have to be configured in realistic settings. This is achieved with 3D cloud-resolving dynamical downscaling using Weather Research and Forecasting (WRF) model and multi-domain nesting. However, there is no guarantee that simply cloud-resolving would produce high-confidence cloud-scale data. A number of factors may have important influence on the cloud-resolving simulations. These factors include, but are not limited to, domain size, spatial resolution, model top, forcing data set, model physics and the growth of model errors. In addition to sensitivity experiments to basic model configurations, a multi-scale data assimilation system is further adopted to minimize model errors and improve the simulation of cloud-scale physical and dynamical quantities. The hydrometeor advection that may play a significant role in hydrological process within the observational domain but is often lacking, and the limitations due to the constraint of domain-wide uniform forcing in conventional cloud system-resolving model simulations, are at least partly accounted for in our approach. The analysis focuses on the evaluation of both mean and probability distribution of macrophysical and microphysical properties, as well as eddy transports that are central to the parameterization of sub-grid processes in coarser-resolution models.

Building a multiscale aerosol data assimilation system for the FASTER project

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Investigation of aerosol-related issues such as evaluation of model-simulated aerosol indirect effects against ARM observations often requires a multiscale data set; however, measurements alone often cannot satisfy all the requirements. The objective of this research is to facilitate the aerosol-related tasks of the FASTER Project by developing an aerosol reanalysis product for the Routine AAF Clouds with Low Optical Water Depths (CLOWD) Optical Radiative Observations (RACORO) field campaign, using an advanced data assimilation scheme and both surface and aircraft aerosol measurements. The developed reanalysis product offers three-dimensional fields of aerosol concentrations and size distributions. We have set up a three-domain nested WRF/Chem for the SGP region that uses the MOSAIC aerosol scheme. The MOSAIC scheme here uses four size bins to represent size distributions and explicitly treats eight major species, including elemental/black carbon (EC/BC); organic carbon (OC); nitrate (NO3); sulfate (SO4); chloride (Cl); ammonium (NH4); sodium (Na); and the sum of other inorganic, inert mineral and metal species. A set of simulations have been carried out to characterize aerosol concentrations and size distributions, and the model performance was evaluated. We then implemented a 3DVAR data assimilation system with this WRF/Chem aerosol system. This 3DVAR scheme was formulated in an attempt to take full advantage of the MOSAIC scheme to provide analyses of comprehensive specie concentrations and size distributions. Preliminary results demonstrated that the assimilation of surface measurements, including PM2.5 and speciated concentrations, improved the model specie concentrations, which suggests that the model specie concentrations and size distributions should be improved by assimilating additional aircraft measurements during RACORO. Further development will integrate a multiscale scheme into this 3DVAR. The framework and products are useful for addressing other aerosol-related issues using ARM measurements in general.

http://www.bnl.gov/esm/

Cloud-Aerosol-Radiation ensemble modeling system (CAR): one application on aerosol climate effects

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The Cloud-Aerosol-Radiation (CAR) ensemble modeling system has recently been built to determine (via intercomparison across all schemes) or reduce (e.g., via the optimized ensemble integration) the range of the uncertainties caused by the likely cloud-aerosol-radiation interactions. In the CAR, cloud, aerosol, and radiation transfer have been separated; the radiative effects of cloud including cloud vertical overlap and aerosol including aerosol first indirect effects are explicitly treated. By using the climate model coupled with the CAR, the comprehensive studies on the different roles of the different cloud/aerosol/radiation factors in cloud-aerosol-radiation interactions and their feedback can be conducted. In this study, to show the complicated interactions among cloud, aerosol, and radiation, the influences of the following factors, such as cloud scheme combinations, cloud vertical overlap treatments, radiation transfer schemes, cloud droplet number schemes, and aerosol optical property schemes on aerosol direct effects and first indirect effects have been investigated both offline at the U.S. Southern Great Plains for the year 2000 and online over the U.S. by using CWRF/CAR (the regional Climate-Weather Research and Forecasting Model). Our preliminary results clearly show that all the above factors obviously affect aerosol direct and first indirect effects. The substantial model differences among different CAR cloud/aerosol/radiation scheme combinations suggest the limited physical descriptions of cloud-aerosol-radiation interactions in current models and the potential powerful application of CAR on cloud-aerosol-radiation interactions. Some results from CESM1.0/CAR are also shown.

Comparison of water budget between AMMA and TWP-ICE clouds

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Two field campaigns, AMMA (the African Monsoon Multidisciplinary Analysis) and TWP-ICE (Tropical Warm Pool-International Cloud Experiment), took place in 2006 near Niamey, Niger, and Darwin, Australia, providing extensive observations of mesoscale convective systems (MCSs) near a tropical coast and a desert, respectively. Under the constraint of their observations, three-dimensional cloud-resolving model simulations are carried out in the paper to replicate the basic characteristic of the observed MCSs. All of the modeled MCSs exhibit a clear structure with deep convective clouds accompanied by stratiform clouds and farther anvil clouds. In contrast to TWP-ICE ones, AMMA MCSs with a scale of ~400 km have been duplicated successfully. These modeled AMMA and TWP-ICE MCSs offer an opportunity to understand the structure and mechanism of MCSs, with their water budget that is represented in terms of horizontal water fluxes between convective, stratiform, and anvil cloud regions; vertical water fluxes between warm, mixed-phased and icy cloud layers; and water source/sink due to microphysical processes. The comparison in water budget between AMMA and TWP-ICE MCSs suggests that TWP-ICE convective clouds are stronger while the AMMA mesoscale ascent outside convective clouds is stronger. This result is consistent with the observed difference in convective and stratiform clouds between the two climatological regimes where the two campaigns resided. In addition, case comparison suggests that strong vertical wind shear in the upper troposphere brings about wide anvil clouds in TWP-ICE and high ice crystal concentration is one of the factors that contribute to large AMMA MCSs.

Constraining ice cloud microphysics parameterizations in Community Atmospheric Model version 5 using SPARTICUS measurements

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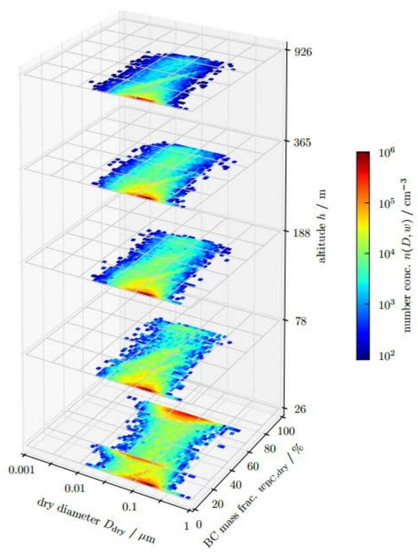
Jennifer Comstock, Pacific Northwest National Laboratory
David Mitchell, Desert Research Institute

Cirrus clouds composed of ice crystals play an important role in modifying the global radiative balance through scattering shortwave (SW) radiation and absorbing and emitting longwave (LW) terrestrial radiation. Cirrus clouds also modulate water vapor in the upper troposphere and lower stratosphere, which is an important greenhouse gas. Although cirrus clouds are an important player in the global climate system, there are still large uncertainties in the understanding of cirrus cloud properties and processes and their treatments in global climate models, due to the scarcity of cirrus measurements and instrument artifacts of in situ ice crystal number measurements. The Small Particles in Cirrus (SPARTICUS) campaign (http://campaign.arm.gov/sparticus/) measured routine number concentration and size distribution of small ice particles (i.e., < 50 µm diameter) over the DOE Atmospheric Radiation Measurement (ARM) South Great Plains (SGP) site from January to June 2010. With a new generation of probes designed to minimize artifacts due to shattering, SPARTICUS provides relatively long-term statistics (~150 hours of in situ data) of cirrus cloud measurements, including small ice particle concentrations. In this study we use the SPARTICUS observations to constrain cloud ice microphysics parameterizations in the Community Atmospheric Model version 5 (CAM5) for the ice crystal formation through ice nucleation and ice crystal growth through water vapor deposition and autoconversion of cloud ice to snow. This is achieved by comparing modeled ice crystal number concentration, ice effective radius, ice water content, and relative humidity inside and outside cirrus, and their covariance with temperature with the statistics from SPARTICUS observations. Model sensitivity tests are performed with different ice nucleation mechanisms (homogeneous versus heterogeneous nucleation) and different vapor deposition coefficients to reflect the parameter uncertainties in cirrus parameterizations. Our results indicate (1) homogeneous ice nucleation may play a dominant role in the ice formation compared to the heterogeneous nucleation in the midlatitude cirrus with temperature less than -40°C over the SGP site, (2) the threshold size of ~250 µm is the parameterization for the autoconversion of ice crystals to snow, and (3) the deposition coefficient of water vapor on ice crystals is between 0.05 and 0.1.

Coupling the stochastic particle-resolved aerosol model PartMC-MOSAIC with WRF

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

To assess the chemical reactivity, cloud condensation nuclei (CCN) activity, radiative properties, and health impacts of black-carbon-containing particles, an understanding of the aerosol mixing state is of crucial importance. The recently developed particle-resolved aerosol box model PartMC-MOSAIC has allowed new insight into this issue, as it resolves the evolution of the per-particle composition explicitly for a particle population undergoing coagulation, condensation, dilution, and emission. So far PartMC-MOSAIC has been used as a Lagrangian box model without resolving spatial variation. The work shown in this presentation is taking the model development to a new level by coupling PartMC-MOSAIC to a one-dimensional version of the community model WRF. We will present the newly developed, particle-based stochastic algorithm for turbulent diffusion and show results of code verification. We will also show, for the first time, the results of spatial- and particle-resolved simulations of black carbon aging in a polluted boundary layer that demonstrate the capabilities of the coupled WRF-PartMC-MOSAIC model system. These initial results indicate that while the bulk concentration of black carbon becomes well-mixed in the boundary layer during the day, fresh black carbon particles exist in only the lowest layers.



Two-dimensional particle size distribution quantifying the mixing state of black carbon at 5 selected levels in the boundary layer after 12 hours of simulation (1800 LST). The results indicate that over time a complex pattern of mixing states develops and that this depends on altitude. Fresh black-carbon-containing particles (high BC mass fraction) exist only in the lowest layers.

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

Vladimir Krasnopolsky, NOAA

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, NN ensemble is used to constitute a stochastic NN convection parameterization. The developed NN convection parameterization has been tested in a diagnostic CAM (CAM-NN) run versus the control CAM run. 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. The obtained results are encouraging. The final step and future plans of the project will include (a) preparation of a NN-convection paper in addition to our NCEP Office Note (No. 469) and (b) initiation of a new collaborative effort (that goes well beyond the current project and will require an adequate funding) with the DOE PNNL group dedicated to development of NN emulations for MMF and testing it in the PNNL CAM-MMF. 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.
Publication: Krasnopolsky, V, M Fox-Rabinovitz, A Belochitski, P Rasch, P Blossey, and Y Kogan. 2011. Development of neural network convection parameterizations for climate and NWP models using Cloud Resolving Model simulations. NCEP Office Note No. 469:

http://www.emc.ncep.noaa.gov/officenotes/newernotes/on469.pdf

Effect of coastline-driven organization on rain climatology of a GCM with two-plume organized convection scheme

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Brian Mapes, University of Miami

The mesoscale organization of precipitation convection is highly relevant to next-generation global numerical weather prediction models. An organized convection scheme is introduced and tested in the newest Community Atmosphere Model (CAM5.1) with a new unified shallow-deep convection scheme, a two-plume version of the University of Washington (UW scheme). The single variable org represents the roles of sub-grid evaporation and downdraft, sub-grid geography and breezes, shear rolls, deformation filaments, and other unknown stochastic components in the initiation and development of convection. The study is to investigate the effect of breeze-initiated organization on the precipitation climatology. Sea and land breezes (SLB) play a significant role in the initiation and organization of convection and do make an important contribution to the climatology of precipitation. It is needed to better represent the convective organization over complex land-sea terrains. In this two-plume organized convection scheme, the role of coastline is represented by a constant or semidiurnal variable, called “coast2org”, as one of the org sources. Experiments with and without coastline show some interesting but surprising results. Based on the effect of coastline-driven organization on the future precipitation, there are two different regions that we called normal regions and mystery regions. In normal regions like the African coastline, Indian coastline, eastern South American, and northeastern U.S. coastline, as might be expected, a positive feedback exists: the coastline makes the organization stronger, which favors the occurrence of deep convection and has more precipitation; then the larger precipitation rate generates the convective organization by the evaporation of downdraft (cold pool), and so on. However, there still exist some mystery regions like Indonesian maritime continents and the Gulf of Mexico Coast, etc., where the total precipitation is reduced with coastlines, although their convective organization becomes stronger. A stability study shows that when taking the coast-driven organization into account, the mean states in these mystery regions become significantly more stable and CAPE has a dominant importance to control the convection; the net stabilization effect defeats the evaporation positive effect. Further studies are needed to explore the mechanism for puzzling results.

Electromagnetic modeling of pristine ice crystals with multiple mass-dimensional relationships

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Kultegin Aydin, The Pennsylvania State University
Johannes Verlinde, The Pennsylvania State University

Advances in electromagnetic scattering techniques for arbitrary objects (e.g., Draine and Flatau 1994, Xu 1995) have led to the creation of accurate models for complex ice particles such as pristine ice crystals (e.g., Liu 2008, Botta et al. 2011). These types of models have the potential to successfully constrain cloud models through comparisons with radar measurements, representing the missing link between the two (e.g., Avramov et al. 2011). Therefore particular care is necessary when approaching this modeling problem. A very common approach to complex electromagnetic modeling of pristine ice crystals consists in characterizing a particular type of crystal (e.g., stellar, dendrite, or planar) in terms of a single mass-dimensional (M-D) relationship (e.g., Liu 2008). However, the literature provides many different M-D relationships (e.g., Pruppacher and Klett 1997, Mitchell and Heymsfield 2005) for the same type of crystal, making the single M-D relationship approach substantially limited. An overview of the many M-D relationships available in the literature shows that a given class of crystals can cover a relatively big region in the M-D plane. Ideally, electromagnetic models of pristine ice crystals should be able to appropriately sample a significant set of points in this region in order to provide cloud modelers with appropriate scattering computations that match the desired microphysical parameters (i.e., the shape of the crystals and their M-D relationship). In an effort to close the gap between electromagnetic and cloud models, several electromagnetic models of different classes of pristine ice crystals (dendrites, plates, columns, etc.) were developed using the generalized multiparticle Mie (GMM) method for scattering computations (Xu 1995, Botta et al. 2011). These models were tailored to cover as much area of the M-D plane region defined by the multiple M-D relationships available for each class. Electromagnetic back-scattering computations at vertical and side incidence for pristine ice crystals modeled using this approach are presented.

Evaluating the diurnal cycle of convection and clouds over land simulated by NCAR CAM4 and CAM5 in a weather forecasting framework using ARM SGP data

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

It is very challenging for global climate models to simulate the correct diurnal cycle of convection and clouds over land. For the observed late-afternoon precipitation peak, models usually report a quicker onset around noon. Previous studies suggest that this model deficiency is usually due to the lack of an intermediate stage involving shallow convective clouds and their gradual moistening of free troposphere. Recently NCAR released its community atmospheric model (CAM) version 4 and 5 in which significant modification is made to the boundary-layer turbulence scheme and shallow convection scheme. It is worthwhile to evaluate the effects of these modifications focusing on two aspects: (1) the development of shallow cumulus clouds over land and (2) the diurnal evolution of late-afternoon deep convection over land. The models are run at 0.9° by 1.25° horizontal resolution with 26 vertical levels for June 2008 to March 2010 in the weather forecasting framework. We evaluate the second-day forecast by the models, which are initialized with ECMWF analysis data every day at 0 UTC and forecast for the six following days. This framework facilitates the identification of model parameterization deficiency in the short range forecast before other compensating errors could potentially mask such deficiency as they do in the long-term climate simulations (Phillips et al. 2004). Specifically, we compare model simulations with the observed diurnal cycle statistics we developed for different convection regimes: forced and active fair-weather shallow cumulus and the shallow cumulus that transits to late-afternoon deep convective clouds with heavy precipitation using ARM long-term observations (Zhang and Klein 2010, 2012). We also will work on a few case studies in the warm season of 2008 and 2009, targeting different convection regimes and will make detailed exploration of the parameterization performance of the two CAM versions in simulating clouds, precipitation, and convection-related variables. Such practice serves as a prelude to provide working directions for our following work, which is to set up typical-convection composite-cases over land based on ARM SGP observations for large-eddy simulations and single-column CAM so as to improve and develop cloud and convection parameterizations.

Evaluation of cloud microphysical parameterizations in cloud-resolving model simulations using the ARM observations

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Clouds modulate the distribution of energy and water within the atmosphere and regulate the hydrological cycle. Cloud microphysical parameterizations are critical for the representation of cloud microphysical properties in both cloud-resolving and climate models. In this study, we analyze the capabilities of a cloud-resolving model (CRM) with advanced bulk microphysics schemes to simulate the microphysical properties and evolution of convective clouds and anvil cirrus over the Southern Great Plains (SGP) site in the midlatitudes and Kwajalein Atoll in the tropics. To evaluate the simulated cloud properties, we use observations from the Atmospheric Radiation Measurement (ARM) Climate Research Facility 1997 Summer Intensive Observation Period at the SGP site and the Kwajalein Experiment (KWAJEX) field campaign. The CRM simulations are evaluated using, in particular, precipitation records, radiative fluxes, and radar reflectivity values from the ARM millimeter-wavelength cloud radar (MMCR) and the Kwajalein precipitation radar. Preliminary analysis of the ARM SGP case shows that precipitation events during this period are well captured by the model, but the outgoing longwave radiation (OLR) is considerably underestimated and the model generates too much high cloud when compared with the MMCR observations. We find that the excess cloud production is due in part to the microphysical parameterizations but that the periodic lateral boundary conditions of the CRM also play an important role. Compared to the cloud radar reflectivity histograms from the ARM MMCR observations, the simulated cloud radar reflectivity reproduces the shape and the mode of the reflectivity histograms at levels above 11 km. The agreement deteriorates at lower levels, presumably because more complicated microphysical processes are involved. In our study we focus especially on the causes of the overproduction of ice and high-level clouds in the CRM simulations. Improvements of the ice microphysics scheme and resulting impacts on the simulation are presented.

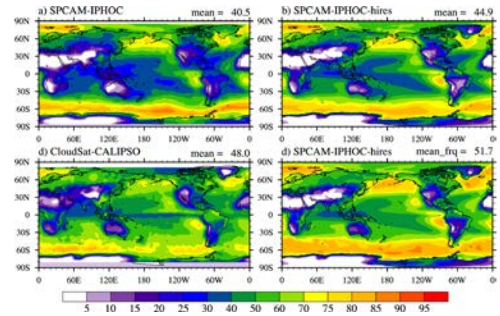
A global aerosol model to study the impact of anthropogenic activities on marine cloud condensation nuclei

Tianyi Fan, University of Colorado
Brian Toon, University of Colorado

A critical aspect of the uncertainty of aerosol indirect effects on climate is the contribution of anthropogenic sulfur emissions to CCN over the oceans, since the largest cloud forcing is from marine stratus. The production of sulfate aerosol from anthropogenic origins has to complete with natural aerosol sources. To take into account the complexity of the CCN forming processes in the marine boundary layer, processes that are essential for the marine aerosol system are introduced to construct a global sea salt/sulfate aerosol model based on a coupled climate and aerosol model CAM5/CARMA3. The processes include the emission of precursor gases from both anthropogenic and natural sources, the emission of sea salt and primary sulfate, gas-phase oxidation of DMS and SO2, nucleation, condensation, aqueous-phase oxidation of SO2, cloud droplet activation, cloud resuspension, and dry/wet removals. The model is capable of capturing the observed non-sea-salt sulfate mass concentration. The sulfate budget indicates that 55% of the sulfate particles are produced by gas-phase conversion, and 45% are produced by cloud processing. Although the number concentration is dominated by Aitken-mode aerosols (radius smaller than 0.1 µm) that are dominated by sulfate, only a small fraction of CCN are large coarse mode particles (radius larger than 1 µm), which is dominated by sea salt over the remote ocean. A test run is carried out with anthropogenic sulfate emission turned off to identify the anthropogenic effects of sulfate on global marine CCN.

Global climatology simulated from an upgraded multiscale modeling framework model

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



Global distribution of low-level cloud amount (with pressure greater than 700 hPa) from two MMF simulations with different vertical resolutions and the CloudSat/CALIPSO observations. Panel (d) is the frequency of cloud occurrence at GCM grid boxes regardless the amount of low clouds.

Multiscale modeling framework (MMF), which replaces traditional cloud parameterizations with a 2D cloud-resolving model (CRM) in each atmospheric column, is a promising approach to climate modeling. This approach represents convective processes well but not the boundary-layer turbulence and clouds. An upgrade on the CRM component with an advanced third-order turbulence closure has been made. In this study, two simulations are performed with a grid size of 1.9° x 2.5°, but they differ in the vertical resolution. The number of model levels below 700 hPa increases from 6 in one simulation (6L) to 12 in another (12L) to better resolve the vertically thin stratus clouds. This reconfiguration was first tested in CRM testing using large-eddy simulation as the benchmark. The testing confirmed that low-cloud simulation could be sufficiently improved with the doubling of the vertical resolution in the lower troposphere. The 12L MMF simulation is better not only in the global-mean low cloud amount that is 4.4% higher than the 6L simulation and is within 3.1% of that of CloudSat-CALIPSO observations, but also in the horizontal distributions and vertical structures that are more realistic in several ocean basins. Another significantly improved result of both simulations is the spatial patterns of tropical precipitation—in particular, a single intertropical convergence zone (ITCZ) in the Pacific, instead of double ITCZs in an earlier simulation with coarser horizontal resolution—and realistic intensity of South Pacific convergence zone and the ITCZ in the Atlantic. Many aspects of the global climatology from the ten-year 12L simulation agree with observations very well—in particular, a nearly balanced TOA radiative energy budget. In terms of spatial correlations and patterns in the tropical/subtropical regions, most surface/vertically integrated properties show greater improvement for increased horizontal resolution than for increased vertical resolution. The relationships among low cloud amount, lower-tropospheric stability, surface relative humidity, and planetary boundary-layer height are consistent with those observed in five low-cloud deck regions. An aspect for future improvement is related to the imbalance in surface energy budget.

High-resolution modeling of aerosol composition and optical properties associated with anthropogenic and biogenic precursor emissions during CARES

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Richard Ferrare, NASA Langley Research Center
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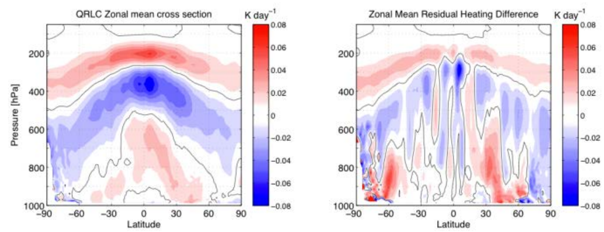
The WRF-Chem model is used with a grid spacing of 4 km to simulate the life cycle of aerosols in central California during the entire CARES campaign, conducted in June 2010. Measurements collected at the two surface sites and on the G-1 and B-200 aircraft are used to evaluate the simulation, particularly anthropogenic and biogenic trace gas precursors of aerosols and aerosol mass, composition (e.g., sulfate, nitrate, ammonium, chloride, black carbon, organic matter) and optical properties (e.g., aerosol optical depth, single-scattering albedo). Anthropogenic emissions are obtained from the California Air Resources Board, biogenic emissions are computed on-line using the MEGAN model, and the initial and lateral boundary conditions for meteorology and chemistry are based on the NAM and MOZART models, respectively. This simulation is meant to provide a benchmark for future simulations that will incorporate improved treatments of secondary organic aerosols and aerosol mixing state within the framework of the MOSAIC aerosol treatment in WRF-Chem. Observations show that the first part of the campaign was characterized by clean conditions with very low aerosol concentrations, but the meteorological conditions became more favorable for aerosol formation during the last week of June. Therefore, the ability of the model to simulate the diurnal and multiday variations in aerosols will be examined. Predicted spatial variations in aerosols associated with the Sacramento and Bay Area plumes will be compared with data from the G-1 aircraft as well as with profiles of backscatter and extinction measured by the High Spectral Resolution Lidar (HSRL) on the B-200 aircraft. Fast et al. (2011) found that the WRF model was able to simulate the meteorology and transport of carbon monoxide tracers reasonably well during the campaign and that local recirculation processes were likely responsible for observed aerosol layers over the Sacramento Valley in the morning. The simulation will therefore be analyzed to determine how recirculation affects aerosol aging in the vicinity of Sacramento. We will also identify the likely sources of model errors, such as uncertainties in emissions and the treatment of secondary organic aerosols, and describe how those errors affect how aerosols influence the local radiation budget.

Impact of RHUBC-I water vapor continuum absorption updates on climate simulations with CESM

Aronne Merrelli, University of Wisconsin
David Turner, NOAA
Daniel Vimont, University of Wisconsin-Madison
Eli Mlawer, Atmospheric & Environmental Research, Inc.



Zonal, annual average differences between the two CAM integrations: clear-sky longwave heating, introduced by the water vapor continuum absorption update (left); total heating, including shortwave, cloud forcing, and latent heating terms (right).

Water vapor is the dominant contributor to atmospheric absorption in infrared wavelengths. Thus, knowledge of longwave radiative heating and cooling and its connection to atmospheric dynamics is dependent on accurate knowledge of water vapor absorption properties. The total water vapor absorption is typically divided into a spectral absorption line component and a smoothly varying continuum absorption component. The ARM-supported Radiative Heating in Underexplored Bands Campaigns (RHUBC) were conducted to directly measure the water vapor absorption in dry conditions, in order to better constrain the continuum absorption model in far infrared (FIR) wavelengths (17–50 μm). Data collected during RHUBC-I led to an update in the water vapor continuum absorption model (MT-CKD v2.4). Compared to the previous version of the continuum model (CKD v2.4), the self and foreign model coefficients changed by up to 50%, which results in net longwave flux changes of up to 0.8 W/m^2. To investigate the climate impact of this change in longwave heating, we ran climate simulations with the Community Atmosphere Model (CAM) version 5, which is part of the NCAR Community Earth System Model (CESM). CAM 5 uses the RRTMg band model for the longwave radiative transfer, which contains the water vapor continuum model before the RHUBC-I updates (CKD v2.4). We modified the CAM 5 RRTMg code to use the RHUBC-I updated continuum model (MT-CKD v2.4) and ran the modified and unmodified CAM in parallel from the same starting condition. The change in longwave heating from the water vapor continuum update introduced small changes in the cloud amount, latent heating, temperature, and humidity. These thermodynamic changes produced diabatic heating that compensated the longwave heating change introduced by the water vapor continuum absorption change. No changes in the large-scale dynamical fields were observed.

Improved prediction of the impact of shallow cumuli using WRF

Larry Berg, Pacific Northwest National Laboratory
William Gustafson, Pacific Northwest National Laboratory
Evgueni Kassianov, Pacific Northwest National Laboratory

Recently, the Weather Research and Forecasting (WRF) model has been modified to improve the representation of shallow cumuli. Changes have been made to both the WRF cumulus and radiation parameterizations. In the cumulus parameterization, the trigger function applied in the standard Kain-Fritsch scheme has been improved to account for the sub-grid variability of temperature and humidity within the boundary layer. In the radiation parameterization, the cloud fraction computed in the cumulus parameterization is used to determine the radiative fluxes, rather than the standard cloud fraction formulation that is based on the grid box relative humidity. These changes improve the treatment of the radiative impacts of shallow convective clouds. Together, these modifications improve the prediction of shallow cumulus convection and the surface cloud effect, as is shown for three case studies that use data from the ARM Southern Great Plains site.

Improving and understanding convection and cloud simulation in the NCAR GCM using ARM observations

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

In an effort to improve the representation of convective processes in the NCAR GCM, we made several modifications to the convection scheme in the NCAR CAM3 and CAM5. These include closure, convection trigger, convective momentum transport, and convective cloud microphysics. These modifications significantly improved the model simulations of the mean climate and variability such as Madden-Julian Oscillation (MJO). To understand these improvements, we analyzed the heat and moisture budgets for MJO. It is found that lower troposphere moistening prior to deep convection, which is important for MJO initiation, is a combined result of vertical advection and shallow convection. Without shallow convection, the moistening is much slower. For the interaction between convection and large-scale clouds, the hydrometeor budgets are computed in the tropical and midlatitude convective regions. We found that different microphysical processes play different roles in convective and large-scale clouds. Cloud microphysical properties from the model are compared with ARM and other observations. In addition, with the inclusion of convective microphysics in the model, we will also explore the interaction of aerosol and convection using CAM5.

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

Anning Cheng, NASA Langley Research Center
Kuan-Man Xu, 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 atmospheric grid column, 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-cloud processes. This approach is shown to produce realistic global distribution of low clouds (see the companion poster by Xu and Cheng), 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 Community Atmosphere Model (CAM) at T42 resolution. The improved low-cloud simulation and the tremendous cost of the MMF motivates us to directly implement the HOC scheme in a GCM, i.e., bypassing the CRM component of the MMF. <p>The new approach will require simplifications and development of an optical approach from the HOC used in CRM because of the large difference in time-stepping and horizontal scales of subgrid variability between the CRM and GCM. We 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. Preliminary results from single-column model testing and recent progress of this project will be presented in this poster.

Improving cloud microphysics simulations for the SGP from four-dimensional variational data assimilation (4DVAR)

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

This study evaluates the improvements from a 4DVAR data assimilation of SGP surface and SGP Central Facility (CF) rawinsonde observations in simulating deep convection in eight WRF microphysics schemes, relative to control simulations without data assimilation (CNTRL), for the SGP warm-season heavy precipitation event of May 27–31, 2001. Because convection tends to develop in a region of high water vapor content, the 95 percent of maximum microphysics-simulated water vapor mixing ratio at 5.5 km (level of maximum observed cloud reflectivity) is used to identify objectively, through linear regression, the location and orientation of simulated convective cloud structure (Figure 1, top left) in the vicinity of the SGP CF. Ka-band cloud radar reflectivity was computed by using particle size distributions employed in the eight WRF cloud microphysics schemes. In-cloud thermodynamic parameters—such as saturated moist static energy, buoyancy, equivalent potential temperature (θe), convective available potential energy (CAPE), and convection inhibition (CIN)—were computed, and vertical transects across the SGP CF were compared with observations. To maximize the utility of the observed millimeter-wavelength cloud radar (MMCR) reflectivity, the analysis was performed for the three hours immediately preceding the intense convection at the SGP CF. During the intense convection period, the MMCR suffered severe attenuation (Figure 1). Compared with CNTRL, the 4DVAR experiments show marked improvement in the simulated Ka-band cloud radar reflectivity in the vicinity of the SGP CF (Figure 1e). This improvement is associated with enhanced lower- and mid-tropospheric buoyancy and higher near-surface and mid-tropospheric relative humidity of 4DVAR compared with CNTRL. Because of drier air at the top of a capping inversion in the 4DVAR simulations, the simulated CAPE values are lower than CNTRL. However, the CNTRL simulations have higher CIN compared with 4DVAR. Although all simulations under-predicted the observed high θe below 3 km at 0000 UTC 28 May, saturated moist static energy deviations from time-averaged reference profiles compared well with similarly computed rawinsonde counterparts, especially for the Thompson microphysics scheme.

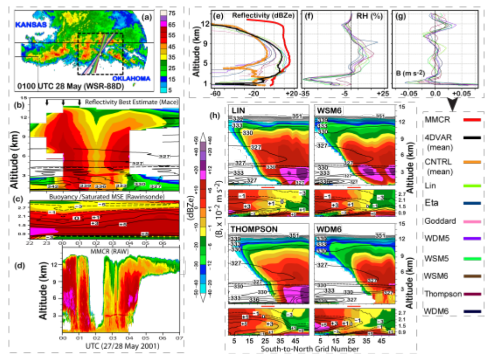


Figure 1. Observed (left) and simulated (right) reflectivity and thermodynamic structure for the SGP CF for 2300 UTC 27 May–0100 UTC 28 May 2001. (a) KVNX WSR-88D reflectivity, showing the nested WRF domain and the orientation of transects for eight microphysics schemes. (b) MMCR reflectivity (shading) and rawinsonde θe (contour, K). (c) Saturated moist static energy deviations (hs, contours, K) and buoyancy perturbations (B, shading) from time-averaged (TA) reference profiles (RP). (d) MMCR raw reflectivity, showing complete attenuation. (e) Observed and simulated Ka-band reflectivities for 4DVAR runs and their averages along with those for CNTRL. (f) RH differences between the 4DVAR and CNTRL simulations. (g) Same as (f) except for B. (h) Vertical transects along the lines in (a) of 4DVAR Ka-band reflectivities and θe for selected schemes (top and third rows), and transects of B (shading) from area-averaged RP, and hs (contours) from TARP (second and bottom rows). All vertical transects in (h) are 3-hr averages (arrows in b). Ka-band cloud radar reflectivities were computed according to the particle size distribution specifications of the eight microphysics schemes.

Improving numerics of the WRF model bulk microphysics schemes: time integration scheme impacts on precipitation

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Nancy Brown, Lawrence Berkeley National Laboratory
Surabi Menon, Lawrence Berkeley National Laboratory
Aditya Murthi, Lawrence Berkeley National Laboratory

Implementation of bulk cloud microphysics (BLK) parameterizations in atmospheric models of different scales has been of interest for the last two decades. From the perspective of cloud physics, time steps, on the order of a few seconds, used for the host model integration are justifiable. However, when BLK schemes are used in regional and global models with time steps on the order of hundreds and thousands of seconds, the numerics and the physics are often affected. This research analyzes the numerics used in BLK schemes and demonstrates analytically the time steps needed to maintain stability and positive definiteness of the time integration schemes for various cloud microphysics processes. In this study, we focus on warm clouds. The Eulerian forward-in-time integration scheme used in numerous BLK schemes, implemented in the Weather Research and Forecasting (WRF) model, is conditionally stable and not positive-definite. As a result, WRF BLK schemes might have improved performance at more refined spatial resolution when the time steps used to advance the microphysical finite-difference equations have an order of magnitude reduction from seconds to tenths of seconds. For coarser spatial resolution simulations, time steps are often increased from hundreds to thousands of seconds. This can lead to a degradation of performance of the WRF BLK schemes due to the application of corrective approaches such as “mass conservation” (for single-moment schemes) and additional “concentration adjustments” (for double-moment schemes). Our analysis, based on analytic stability and positive definiteness criteria, will assess the impact of Eulerian forward-in-time (EFTI), adaptive sub-stepping (ADSS), semi-implicit (SITI), and fully implicit (FITI) time integration techniques on precipitation formation processes in different BLK schemes implemented in the WRF model. We also analyze spatial and temporal distributions of accumulated precipitation obtained in idealized large-scale WRF simulations. Differences between the control simulation (Morrison-Curry-Khvorostyanov BLK scheme with EFTI) and simulations with ADSS, SITI, and FITI will be presented and discussed. This is the first step in a longer-term research effort, and future efforts will focus on examining the implications of these findings through regional and global simulations and analyses.

Improving the ECMWF model's representation of supercooled layers in arctic mixed-phase clouds

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

In November 2010, the ECMWF model's cloud scheme was extended to include additional prognostic variables for separate cloud liquid and ice species, as well as prognostic rain and snow variables. Instead of a diagnostic split for cloud water species dependent on temperature, this new cloud scheme provides the framework for co-existing cloud water species and an explicit treatment of conversion processes between phases. Clouds at the North Slope of Alaska (NSA) site are challenging to represent well in a global model due to complicated layer structures, often including supercooled liquid layers. The new cloud scheme is assessed for the Mixed-Phase Arctic Cloud Experiment (M-PACE) during the autumn of 2004. With the new cloud scheme, the model is now able to produce mixed-phase clouds topped by a liquid layer. In order to improve forecasts during weakly forced conditions, the generation terms for supercooled liquid water and the ice deposition rate near cloud top are modified to allow more supercooled liquid to form. ARM observations from NSA are used to validate these changes. The impact on liquid and ice water paths and surface radiation for sample cases from the M-PACE experiment are investigated. For the single-layer case (October 9–10, 2004, first intercomparison case), liquid and ice water paths are in good agreement with aircraft observations.

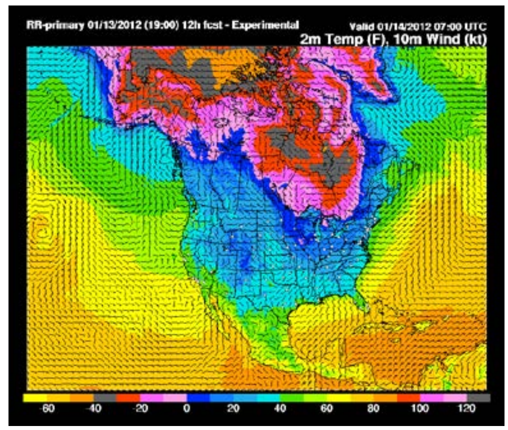
Intercomparisons of CAM physics with WRF physics options

Jimy Dudhia, National Center for Atmospheric Research

Collaboration with PNNL, with NCAR's part also funded by ASR, has enabled the inclusion of the latest CAM physics within the community-released version of WRF. This enables climate physics to be tested both in idealized and real-data cases for short-term weather and regional climate runs. The CAM physics released in Version 3.3 (April 2011) included the newest version of Zhang-McFarlane convection, the Bretherton-Park UW planetary boundary layer, and the Park-Bretherton UW shallow cumulus scheme. These were added alongside the previously available RRTMG radiation supplied by AER, which was also linked to WRF-Chem by PNNL and NOAA/ESRL last year. Work is ongoing to make available the final piece, which is the Morrison-Gettelman microphysics scheme, and results will be shown if possible. There are plans to release this later in 2012. With a complete set of CESM 1.0's CAM physics, WRF can be used as a testbed for intercomparisons with a multitude of other physics options designed for both weather and climate applications, as well as for interactions with chemistry via the variety of WRF-Chem options. Independent efforts exist to couple WRF with a regional ocean model (ROM) and the CLM land model via the CPL7 approach used in CESM.

An introduction to the NCEP Rapid Refresh model data: the next-generation replacement for RUC (Rapid Update Cycle)

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



Experimental RAP 12-h forecast: 2-m temperature, and 10-m wind.

The Rapid Update Cycle (RUC), developed by NOAA's Forecast Systems Laboratory and run operationally at the National Centers for Environmental Prediction (NCEP), is an atmospheric prediction system comprised primarily of a numerical forecast model and an analysis system to initialize that model. ARM, via the External Data Center, has collected and archived the hourly analysis data since 1994. Data are available to users in both Grib and netCDF formats. This data set in the ARM Data Archive is the only long-term archive of this model. It has attracted a large variety of users and applications, has found its way into a number of VAPs, and is one of the most requested ARM data sets. Here we want to alert the ARM community of the impending changes in progress at NCEP. In early 2012, the RUC model is expected to be replaced with the next-generation model called Rapid Refresh (RAP). This model is based on a rapidly refreshing configuration of the Weather Research and Forecasting (WRF) model. The RAP model output products differ from the RUC data in horizontal resolution, domain size, grid type, and variables. We welcome input from the ARM community on requirements for future ARM data products based on the RAP model output data, e.g., to minimize impact on RUC-dependent processes and analyses or to take full advantage of the new RAP features. Please send requirements or questions to xdc_oper@arm.gov. For more information on Rapid Refresh, see:

http://rapidrefresh.noaa.gov/

An ISDAC case for LES intercomparison: model setup and preliminary results

Mikhail Ovchinnikov, Pacific Northwest National Laboratory

In this presentation, we will describe a new intercomparison based on a shallow stratus cloud observed over the sea ice during Flight 31 of the Indirect and Semi-Direct Aerosol Campaign (ISDAC). The intercomparison is designed to investigate the origins for the diversity among large-eddy simulation results documented in previous studies of mixed-phase clouds. This study expands earlier work in two principal ways: through unification of some previously unconstrained aspects of models and via analysis of previously unexamined relationships among microphysics, radiation, and cloud dynamics. Specifically, mass-size and fall speed-size relationships are prescribed, so that the rates for depositional growth and sedimentation are constrained across different models. A simple parameterization for the longwave radiative cooling rate is also formulated to eliminate another potentially important source of inter-model variability. Preliminary results from simulations demonstrating the effect of increased ice number concentration on cloud structure will be presented.

Large-scale environment and transitions to deep convection in cloud-resolving simulations

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

Cloud-resolving model simulations and vector analysis are used to develop a method for evaluating the sensitivity of shallow to deep transitions to various large-scale environmental variables. Results of the CRM simulations over three tropical regions are used to cluster environmental conditions favorable and unfavorable for transition to deep convection. The relationship between large-scale deep heating and the projection of the profiles of the large-scale environmental fields to a vector connecting these two clusters is used to perform a quantitative comparative assessment of the roles of these fields in the transition to deep convection. This vector formulation represents a simple conceptual framework for evaluating and improving sensitivities in model cumulus parameterizations.

MC3E: post-mission simulations

Di Wu, NASA
Toshihisa Matsui, NASA Goddard Space Flight Center/ University of Maryland, Earth System Science Interdisciplinary Center
Wei-Kuo Tao, NASA Goddard Space Flight Center
Christa Peters-Lidard, NASA Goddard Space Flight Center
Arthur Hou, NASA Goddard Space Flight Center
Michele Rienecker, NASA Goddard Space Flight Center

The WRF-ARW model with high resolution was employed for the real-time forecast during the Midlatitude Continental Convective Clouds Experiment (MC3E) field campaign (April 22–June 6, 2011) over the SGP site. The model features new Goddard microphysics (Lang et al. 2011) and Goddard radiation schemes and runs twice a day with 00Z and 12Z forecast cycle. The objects for the post-mission simulations are: (1) improving WRF model simulations with different model configuration and input data resources, (2) validating model results with available observational data sets, and (3) investigating the effects of key physical processes (microphysics, radiation, surface fluxes, and terrain) on model simulations. In this poster, we will present the simulation results of three cases from MC3E: April 25–26, May 20, and May 23. A significant improvement in depicting the May 20 squall line event is found by coupling WRF with Land Information System (LIS), indicating the importance of a more realistic representation of land-surface processes on simulating midlatitude mesoscale convective systems. The simulation will be compared with ground-based radar observations and also will incorporate Goddard Satellite Simulator Unit (GSDSU) to compare with satellite products (TRMM PR and AMSR-E).

Modeling study of irrigation effects on land surface fluxes and water recycling in the Southern Great Plains

Yun Qian, Pacific Northwest National Laboratory
Maoyi Huang, Pacific Northwest National Laboratory
Ben Yang, Pacific Northwest National Laboratory
Larry Berg, Pacific Northwest National Laboratory

Remarkable changes in cultivation of farmland together with insufficient precipitation in the warm season have required the extensive irrigation to sustain crop growth in the Southern Great Plains (SGP). In this study, we incorporated an irrigation scheme into the NOAH land surface model utilized as part of WRF model, which is informed by satellite-measured potential irrigation area data. Daily irrigation is triggered in early morning when root-zone soil moisture availability is below a specific threshold over croplands or pastures during the growing season. We conducted four sets of regional simulations using the WRF model, with or without irrigation included, over the SGP for a typical dry and wet summer, respectively. The results show that irrigation reduces model bias in simulating the soil moisture, surface air temperature, latent heat (LH), and sensible heat (SH) fluxes, suggesting it is critical to include the irrigation process in modeling the land surface fluxes and land-air interaction. Irrigation brings additional water to the surface, leading to the increase of soil moisture. As a result, the evapotranspiration and corresponding LH increased at the land surface. The surface air cools because of the decreased SH, compensating with the increased LH. The experiment results in this study show the irrigation caused LH (SH) increase (decrease) by 5-15 W/m2, cooling the surface by 0.3–0.5°C and increasing the surface air specific humidity by 0.3–0.6 g/kg, averaged over the SGP domain during a drier warming season (2006). Those changes mainly occurred during daytime. We found that the irrigation-induced increase in evapotranspiration and decrease in surface temperature led to two competing processes affecting the evolution of convective clouds and precipitation. The increase in evapotranspiration resulted in the formation of unstable conditions associated with increased water vapor that could enhance convective cloud formation, and therefore increase the chance of larger amounts of precipitation. Meanwhile, the surface cooling reduced the convective available potential energy and created a more stable atmosphere acting to suppress convective cloud formation and decrease the chance of precipitation. As a result of these two opposite mechanisms, the spatial pattern of simulated precipitation change induced by irrigation is very inhomogeneous, and the averaged total precipitation over the SGP domain only slightly increased during irrigation season. The irrigation intensity and corresponding impact on the surface fluxes and precipitation is much smaller in a wetter year (2007). The model results also indicate the irrigation-caused soil memory from the previous period results in wetter and cooler surface air lasting for more than one month, suggesting the impact of irrigation on regional climate and water recycling could be at scales from intraseasonal to seasonal.

New regional modeling products for Alaska: focus on hydroclimatology

John Walsh, University of Illinois
Jessica Cherry, International Arctic Research Center
Mark Ivey, Sandia National Laboratories

The arctic hydrologic cycle is known to be changing quickly, as air temperatures increase, glaciers melt, and permafrost thaws. Because the region is data-sparse, climate models and reanalyses can be important tools for studying hydroclimatological change. Grid cell size and scale-dependent physics in climate models, however, impact the resolution of key hydroclimatological processes. An effort is described wherein several new regional models and reanalyses are compared to raw and bias-corrected observations for the Alaska domain for the period 2000–2008. This period corresponds to the DOE's observational record at Barrow. These model simulations include a 15-km run of the Weather Research and Forecasting model (WRF) laterally forced by the Community Atmospheric Model 3.1 (CAM3.1), a 15-km run of WRF laterally forced by the National Center for Environmental Prediction (NCEP) reanalysis, 1-degree CAM-HOMME (a newly developed dynamically core for CAM), a reconstructed precipitation product derived from the NASA Catchment Land Surface Model, the Arctic Regional Reanalysis, and station data.

Observational evaluation of cloud resolving simulations by WRF driven by the ARM continuous forcing at SGP

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

Cloud-resolving models have been applied to various atmospheric phenomena and recognized as an effective tool to evaluate and develop its parameterizations. We examine the cloud-resolving simulations performed by the Weather Research and Forecasting (WRF) model in conjunction with the forcing framework developed in the FAst-physics System TEstbed and Research (FASTER) project. The simulations are driven by time-varying, continuous large-scale and surface forcings derived from the observation during March 2000 Cloud IOP at the Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) site. The simulation is evaluated against cloud properties obtained through the ARM observations. Sensitivity studies to WRF's physics schemes and nudging strategies are also examined.

On the relationships of large to small scales in a convecting atmosphere in the real world and a CRM

Christian Jakob, Monash University
Laura Davies, Monash University
Vickal Kumar, Monash University
Peter May, Bureau of Meteorology
Alain Protat, Australian Bureau of Meteorology

Our previous research has elucidated relationships between large and small scales in tropical convection using data at the ARM Darwin site. In particular, we have shown that convective activity is more directly related to convergence—and hence the dynamical state of the tropical atmosphere—than to CAPE, and hence the thermodynamic state of the atmosphere. We also showed that the relationship to convergence is to first order one that controls the area that is convectively active, rather than the intensity of the convection. Here, we first refine our observational knowledge by extending our analysis to include the depth of the convective cells and investigating its relationship to the large-scale conditions with the aim to test the hypothesis that dry mid-tropospheric states lead to shallower clouds. C-POL radar data at Darwin are used to identify the depth of convective cells and form the backbone of this investigation. First attempts at using the radar data to retrieve vertical velocity in convective cells will also be shown. Following on from this we investigate how well a cloud-resolving model (CRM) can reproduce both the observed convective structures and their relationship to the state of the large-scale atmosphere. For this purpose the System for Atmospheric Modelling (SAM) CRM is run using forcing data derived from three wet seasons at the Darwin site. Model results are compared to the observed relationships derived from the C-POL observations.

Perturbed-parameter hindcasts of the MJO with CAM5

Jim Boyle, Lawrence Livermore National Laboratory
Stephen Klein, Lawrence Livermore National Laboratory
Richard Neale, NOAA/CIRES Climate Diagnostics Center

The Madden-Julian Oscillation (MJO) is a dominant source of intraseasonal variability precipitation and is a subject of strong interest to ARM and ASR. In an attempt to understand and improve the typically poor simulations of MJO by climate models, we have performed perturbed-parameter hindcasts with the fifth version of the Community Atmosphere Model. Our hindcasts are initialized with analysis data for a 2009-2010 strong MJO event that is a focus of the Years Of Tropical Convection project, and they were performed as part of Cloud-Associated Parameterization Testbed. With Latin Hypercube sampling of 16 parameters contained in the parameterizations of shallow convection, deep convection and large-scale clouds from a predetermined range of their acceptable values, we have performed 500 hindcasts of 20-day length. The initial analysis suggests that the MJO could be improved through greater evaporation of deep convective precipitation and less efficient autoconversion of deep convective condensate to precipitation. The initial analyses also suggest that making deep convective plumes less dilute by lowering the lateral entrainment rate would degrade the MJO hindcasts from the default version of CAM5, which already performs respectably in hindcasts of MJO forecast indices, if not precipitation.

Physical processes controlling the evolution of ice concentration in cirrus clouds

Eric Jensen, NASA Ames Research Center
Paul Lawson, SPEC Inc.

Several past studies have compared measured cirrus ice concentrations with calculations based on nucleation theory. However, such calculations only indicate the peak ice concentrations occurring just after nucleation events. Various cloud processes (e.g., differential sedimentation, entrainment, dispersion, and aggregation) conspire to reduce mean ice concentrations as the cloud evolves. Here, we use both a one-dimensional cloud model and a three-dimensional cloud-resolving model to evaluate the impact of these processes on the evolution of ice concentration through the life cycle of cirrus clouds. Results are compared statistically with airborne measurements of midlatitude cirrus ice concentration during the DOE SPARTICUS and NASA MACPEX campaigns. We will show that mean ice concentrations are reduced substantially by processes occurring after nucleation events, and this issue should be taken into consideration when comparing with observations that necessarily represent a range of cloud ages. We find that radiatively driven small-scale convection results in considerable variability in cirrus microphysical properties. In particular, frequency distributions of ice concentration are broader when three-dimensional effects are included than in equivalent one-dimensional simulations. Under some conditions, convective motions can considerably enhance ice concentrations in the lower parts of cirrus.

Retrieving 4-dimensional atmospheric boundary-layer structure from multi-time profiles over a single station

Zhaoxia Pu, University of Utah
Lei Zhang, University of Utah
Linbo Wei, University of Utah
Steven Krueger, University of Utah

Most routine measurements from climate study facilities, such as the Department of Energy's ARM Southern Great Plains site, come from individual sites over a long period of time. While single-station data is very useful for many studies, it is challenging to obtain 3-dimensional spatial structures of atmospheric boundary layers that include prominent signatures of deep convection from these data. This study examines the ability of modern data assimilation techniques in retrieving 4-dimensional (both spatial and temporal) atmospheric boundary-layer structures from multi-time profiling data at a single station. To demonstrate the idea, multi-time wind profiles from a single station are assimilated into the mesoscale community Weather Research and Forecasting (WRF) model using its four-dimensional variational data assimilation system. The impact of data on the numerical simulations of a warm season mesoscale convection system during IHOP_2002 is evaluated. Results indicate that the assimilation of high temporal and vertical resolution wind profiles have a significant influence on the numerical simulation of the convective initiation and evolution. Not only the wind fields but also the structure of moisture fields associated with the convective system are improved. Data assimilation has also resulted in more accurate prediction of the locations and timing of the convection initiations; as a consequence, the skill of quantitative precipitation forecasting is enhanced greatly. The method is now being applied to a recent convective case during the Midlatitude Continental Convective Clouds Experiment (MC3E). The impact of assimilating multi-time and multi-sensor soundings from the SGP site on the representation of convective properties of the selected convective case is examined. Detailed results and recent progress will be reported in the presentation. Reference: Zhang, L, and Z Pu. 2011. "Four-dimensional Assimilation of Multi-time Wind Profiles Over a Single Station and Numerical Simulation of a Mesoscale Convective System Observed During IHOP_2002." Monthly Weather Review 139, 3369–3388.

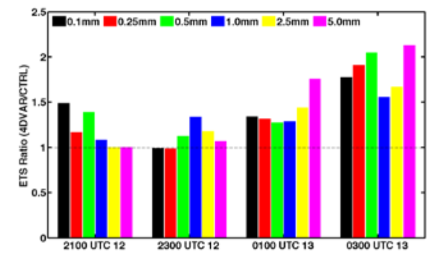


Figure 1. The ratio of equitable threat scores (ETS), defined as R=ERS4DVAR/ETSCTRL for 1-hour accumulated precipitation between CTRL (without assimilation of wind profiles) and 4DVAR (with assimilation of wind profiles) experiments with threshold of 0.1, 0.25, 1.0, 2.5, and 5.0 mm at 2100 UTC 12 June 2002, 2300 UTC 12 June 2002, 0100 UTC 13 June 2002, and 0300 UTC 13 June 2002. When ETS ratio is greater than 1, the QPF skill is improved by 4DVAR.

Sensitivity of precipitation forecasts to microphysical parameterization and grid-resolution at convective-allowing and cloud-allowing scales

Alexander Khain, The Hebrew University of Jerusalem

Twelve precipitation forecasts were compared during the 2010–11 winter rainy season over Israel using two versions of WRF: (a) with Single Moment Scheme (WSM6) bulk-parameterization and (b) with spectral bin microphysics (SBM). Forecasts were performed using 1.3-km and 4-km grid spacing. The results from 12 forecast cases showed no clear forecast improvement with decrease in grid spacing when WSM6 was used. The results show that the SBM forecasts were ranked higher than the forecasts using WSM6 at 1.3- or 4-km grid spacing, deterministic or ensemble. They were also better than forecasts obtained with other bulk microphysical schemes, when compared against station data at the Hermon Mountains for a single test case. This study suggests that the utilization of cloud-resolving scales (1.3 km) in forecast models should be accompanied by improvement in the microphysical description of cloud processes to realize the benefit of high resolution.

The Separate Physics and Dynamics Setup (SPADS) for analyzing scale dependency of physics

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At the previous ASR Science Team Meeting, this project presented the concept of using separate grids within an atmospheric model to investigate scaling behavior of physics parameterizations. Since then, this method has been further developed under the moniker "Separate Physics and Dynamics Setup" (SPADS). At this point, the SPADS technique has been coded into the Weather Research and Forecasting model for analyzing the behavior of cloud parameterizations across scales ranging from cloud-scale-resolving to the mesoscale, with the potential for analyzing larger scales as well. Preliminary results will be shown for cumulus and microphysical parameterizations showing how they behave very differently when presented with atmospheric states gridded at different resolutions. The results have implications for designing scale-aware parameterizations for next generation climate models that use multi-resolution grids, such as the High-Order Method Modeling Environment (HOMME) and Model for Prediction Across Scales (MPAS) cores in the Community Earth System Model.

http://www.pnnl.gov/atmospheric/staff/staff_info.asp?staff_num=5716

Simulating convection sensitivity to atmospheric state during AMIE-Gan

Anthony Del Genio, NASA
Audrey Wolf, NASA Goddard Institute for Space Studies

The relationship between moist convection and tropospheric humidity is thought to be central to the existence of the Madden-Julian Oscillation. The difficulty that many GCMs have in simulating the MJO may therefore be diagnostic of insufficient coupling between convection and humidity in their cumulus parameterizations, associated with weak entrainment and/or rain evaporation. The AMIE-Gan deployment of the second ARM Mobile Facility (AMF2) in the Maldives over the past fall and winter offers an unprecedented opportunity to observe the onset of the MJO and constrain cumulus parameterizations. Nature has cooperated by producing at least two, and perhaps three, MJO events during the first half of the six-month AMIE-Gan deployment. Eventually, a forcing data set will be created to drive SCMs and CRMs during the AMIE-Gan period. However, we need not wait for that product to test certain aspects of cumulus parameterizations. One of the highlights of AMIE-Gan is the presence of a long record of three-hourly radiosonde data. Over the first three months the soundings clearly show moistening of the lower troposphere by about 10% relative humidity in advance of MJO onset, followed by 20–30% humidity increases at upper levels after the disturbed phase begins. The temperature signal of the MJO is weaker, but for at least the second observed MJO in November 2011, there is a detectable 1 K warming of the lower troposphere before MJO onset and a 2 K upper troposphere warming thereafter. Since cumulus parameterizations require only a temperature and humidity profile to diagnose moist convection triggering and depth, we can use the available soundings directly in semi-prognostic SCM simulations that test the response of the parameterizations to the observed thermodynamic structure. We will use this approach to diagnose convection depth using several different versions of the GISS Model E2 SCM: the operational CMIP5 version, experimental versions with stronger entrainment and/or rain evaporation, and a new version that reduces entrainment only after convective downdrafts inject cold air into the boundary layer. ARM radar observations of convective depth during AMIE-Gan will be used to document the actual relationship of convection to thermodynamic structure in advance of MJO onset. We will also attempt to understand whether the previously observed large variance in precipitation and convective depth at intermediate values of column water vapor is due primarily to lapse rate or humidity profile variations.

Synoptic regime classification at the Azores site and the corresponding cloud microphysical properties

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The ARM Mobile Facility (AMF) Azores site was located at the southern tier of the North Atlantic storm alley, thus experiencing frequent transitions between midlatitude and subtropical synoptic regimes that are related to the zonal placement of the North Atlantic storm track. Given that poleward shifts in midlatitude storm tracks constitute a substantial source of cloud and rain climate feedbacks, the Azores site serves as a promising location to examine relevant cloud properties and processes at scales ranging from synoptic to microphysical and to evaluate the ability of a suite of models to simulate the primary system behaviors. Two different methods are used here to classify the synoptic regimes affecting the Azores site during the time of the AMF deployment. The first relies on a new climatology of midlatitude storminess that, in addition to locating the storm center, delineates the area of influence of a midlatitude storm. The second applies a clustering algorithm to Cloud Optical Thickness-Cloud Top Pressure histograms and derives the major weather states based on the morphology of the cloud field. Once the synoptic regimes derived by the two methods are identified and mapped and their relationship is examined, data from the AMF retrievals are compiled over regime-representative time periods for statistical evaluation of global model and large-eddy simulations. Preliminary analysis of output from GISS GCM current-climate simulations is performed to establish baseline model skill in simulating the observed regimes and the resulting cloud structures. In addition, recently derived microphysical retrievals of drizzle particle size distributions are statistically compared with existing regime-representative large-eddy simulations of low-lying marine clouds.

Using dynamic and thermodynamic profiler retrievals to improve the forecast of the May 24, 2011 outbreak: an observing systems simulation experiment

Sean Crowell, National Severe Storms Laboratory
David Turner, NOAA

In 2009, the National Research Council issued a report recommending a nationwide mesoscale network of ground-based instruments for measuring both momentum and thermodynamic variables within the atmospheric boundary layer. On May 24, 2011, during the Midlatitude Continental Convective Clouds Experiment, a line of severe storms passed through northern Texas, Oklahoma, and southern Kansas. A unique network of four atmospheric emitted radiance interferometers (AERIs) in the MC3E domain collected a high time resolution set of thermodynamic profiles during this event. With these observations, a unique opportunity exists to examine the impact a network of the thermodynamic instruments might have assisted forecasters in predicting the location and timing of convection initiation on May 24, as well as the storm motions that ensued. In this study, we perform an Observing Systems Simulation Experiment using a Weather Research and Forecasting (WRF) Model simulation at 1-kilometer resolution to serve as truth, and from which we generate observations to be assimilated into a coarser 4-kilometer resolution experimental run using a three dimensional variational (3DVar) framework, with different physics parameterization schemes to avoid the ``perfect model" scenario. The experiments performed vary observation densities and lead times before moving from analysis into forecasting mode. We compare the impacts of these factors on the location and timing of model-forecasted convection initiation against the true convection initiation, as well as differences in general storm motion.

Using SGP data to evaluate forecasts of central U.S. mesoscale convective systems in a GCM with explicit embedded convection

Richard Somerville, Scripps Institution of Oceanography

Using observations from the Southern Great Plains (SGP) site, we show that organized nocturnal eastward-propagating convection in the central U.S. can be captured in a prototype multi-scale global climate model (GCM). Such a model uses embedded cloud-resolving models (CRMs) in each GCM grid volume instead of statistical parameterizations to represent sub-grid convection. This approach is often called super-parameterization, and the model we use is a Super-Parameterized version of the Community Atmospheric Model (SPCAM). The ability to simulate these phenomena is a surprising result, because the CRM in SPCAM is idealized in two dimensions with periodic boundary conditions, which restricts fast-manifold storm propagation mechanisms to the horizontal scale of a GCM grid box and constrains CRM shear organization to a fixed horizontal plane. Nonetheless, these simulated storms are qualitatively characterized as having realistic propagation speeds and may result from slow-manifold pathways linking large-scale dynamics with a prognostic convective life cycle including CRM “memory.” However, limitations in the technique, such as a fixed CRM orientation, and apparent discrepancies in the simulated storm relative flow structure are unresolved issues requiring closer analysis. The Cloud-Associated Parameterizations Testbed (CAPT) approach to evaluating GCM error statistics in forecast mode is applied here to test the sensitivity of this result to CRM orientation and to quantitatively compare the simulations with well-observed storm systems that passed over high-value ground-based sensors at the SGP site. A Newtonian relaxation "nudging" technique has been developed to initialize both the GCM- and the CRM-resolved scales in SPCAM for forecast simulations. This nudging technique spins up the CRM while constraining the large-scale GCM fields with analyzed observations. Propagating storms are captured in SPCAM with any of three different CRM orientations (zonal, meridional, or diagonal). Although the basic convective phenomenon is captured in the model, detailed comparisons with observations reveal that some features of the storm location, thermodynamic structure, and condensate fields are not well simulated.

Using the ARM-SGP variational analysis to evaluate a PDF-based parameterization for boundary layers and clouds

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Single-column model (SCM) studies with a parameterization for boundary layers and associated clouds, based on multi-variate probability density functions including dynamics (MVD PDFs), have shown great promise in simulating cloud microphysics, macrophysics, and cloud-aerosol interactions. These studies have used Global Cloud System Study (GCSS) test cases for cumulus, stratocumulus, and mixed cloud types. In this study, we report on our tests of MVD PDFs using the ARM variational analysis for the SGP site. While the MVD PDFs simulate clouds when applied to the GCSS sounding and forcings, they do not do so when applied for corresponding periods to the ARM variational analysis. We examine the roles of the ARM-GCSS differences in surface fluxes, temperature and moisture advection, and initial soundings in explaining the behavior of the MVD PDFs. We will explore the possibility that horizontal averaging of vertical structures in the fields driving the MVD PDFs is responsible for the degraded performance of the MVD PDFs using the ARM analysis and the prospects for improving their performance using smaller-scale ARM observations.

Abstracts

Precipitation

ARM's disdrometer suite: capabilities and deployment

Mary Jane Bartholomew, Brookhaven National Laboratory

A disdrometer is an instrument used to measure the drop-size distribution and velocity of falling hydrometeors. Some disdrometers can distinguish between rain, graupel, and hail. ARM is primarily interested in their contribution to the understanding of precipitation processes, but disdrometers can also be used for traffic control, airport observation systems, and hydrology. The latest disdrometers employ microwave or laser technologies. 2D video disdrometers make the most detailed and complete observations of hydrometeor shape and fall velocity. Impact disdrometers of the Joss-Waldvogel design have been deployed since February 2006 at the Tropical Western Pacific (TWP) Darwin site and since April of 2006 at the Southern Great Plains (SGP) Central Facility. Each typically measures and counts 3.5 million drops annually and does so over the drop diameter range from 0.3 mm to 5 mm. Observations from the impact disdrometers can be found in the ‘disdrometer’ datastream. Five 2D video disdrometers were purchased by ARM with Recovery Act funds from Joanneum Research, and all were deployed in 2011. Four of them are assigned permanently to TWP Darwin, TWP Manus, the SGP Central Facility, and the second ARM Mobile Facility (AMF2). The fifth was used for the Midlatitude Continental Convective Clouds (MC3E) field campaign and is currently at the North Slope of Alaska site in Barrow, testing its ability to characterize snow particles and its performance in Artic cold. ARM’s video disdrometers are able to measure hydrometeor fall velocity, drop height, and drop width of each individual drop observed. Hence, oblateness for each drop can be determined as well. Data are available in the ‘vdis’ and the ‘vdisdrops’ datastreams. The video disdrometers have a measurement range from 0.2 mm to 10 mm. Lastly, ARM has purchased four Parsivel2 disdrometers made by OTT Hydromet. At the time of this abstract submission, their deployment location(s) had not yet been determined. They are 1D optical disdrometers with capabilities similar to their 2D cousins. They can be easily configured to include hydrometeor classification in the final data product.

Collocated UHF and Ka-band radar measurements for rain profile retrievals at ARM SGP facility

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The U.S. Department of Energy Atmospheric Radiation Measurement (ARM) Climate Research Facility sites host an unequalled number of active and passive collocated sensors. In this study, Ka-band (35-GHz) and UHF-band (0.915-GHz) Doppler radar observations of the atmospheric column are combined to characterise profiles of clouds and precipitation microphysics. Particular attention has been made to ensure that the 0.915-GHz wind profilers provide an accurate Rayleigh reflectivity profile reference. They were recently reconfigured in a vertically pointing mode for the observation of vertical velocities in convective clouds. Their sampling strategy cycles every 8 seconds through two interlaced modes: a long pulse mode with high sensitivity and a maximum range of 15 km and short pulse mode giving a high vertical resolution of 150 m up to 9 km. However, the real-time estimation of the signal-to-noise ratio (SNR) of the ARM wind profilers can lead to biases in the estimation of the radar reflectivity. Due to its large beam width, the measured spectra are very wide and can extend over the whole Nyquist interval in convective situations. In such conditions, the recovery of the hydrometeor signal from the background noise is troublesome and requires the estimation of the noise floor from clear air echoes. Furthermore, as a consequence of the high sensitivity of the long mode, the receiver can saturate at short ranges in case of heavy precipitation. Such saturated reflectivities have to be identified and replaced by short mode non-saturated measurements. Finally, the two modes can be merged to provide a full profile of reflectivity every 8 seconds. Then, our approach makes use of the resulting non-attenuated reference reflectivity of the wind profiler and of the attenuated reflectivity of the new Ka-band radar (KAZR), to estimate the attenuation caused by rain at Ka-band. Rainfall rate profiles are then retrieved by taking advantage of the nearly linear relation between specific attenuation and rainfall rate at Ka band. Particular care has been devoted to precisely calibrate the two systems and to match their beams. Several cases occurred during the Midlatitude Continental Convective Clouds Experiment (MC3E), which took place at the ARM Southern Great Plains (SGP) site in April–May 2011, are used to test this method and to compare the results with collocated disdrometer measurements.

Intercomparison of surface precipitation in seven SCMs against the ABRFC observation over the ARM SGP Site

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This study evaluates the overall performances of seven SCMs (NCAR CAM 3, 4, 5; GFDL AM2, 3; GISS, and ECMWF) by comparing simulated hourly surface precipitation with observations at the ARM SGP site from 01 January 1999 to 31 December 2001. Results show that most SCMs can reasonably well reproduce the observed total precipitation. The model performance is better in the nighttime than in the daytime. The frequency of precipitation, especially light precipitation, is higher in most SCMs than in the observation. The frequency of very strong precipitation (> 50 mm/day) is underestimated in all SCMs. For precipitation stronger than 10 mm/day in general, the frequency tends to be overestimated in the daytime but underestimated in the nighttime in most SCMs. The disparities in the convective/stratiform partitioning among the SCMs are further examined. It is also shown that most SCMs produce a spurious precipitation peak in the weak vertical motion regimes, while the observed precipitation is more tightly coupled to the large-scale vertical motions. Several extreme cases will be analyzed to further reveal the meteorological backgrounds against which the model underestimation/overestimation events may occur.

Merging Doppler velocity spectra in time and height to overcome mismatch in radar pulse volumes from collocated radars

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The DOE ARM Climate Research Facility has combined scanning cloud radars into dual-frequency configurations designed to sample the three dimensional structure of cloud systems. One radar configuration consists of W-band (95 GHz) and Ka-band (35 GHz) radars with matched beamwidth antennas mounted on a single steerable platform. This configuration allows both radars to simultaneously observe the same radar pulse volume. Since both radars are observing the same cloud particles, differences in measured reflectivity and Doppler velocity are due to non-Rayleigh scattering features of the cloud particles and can be used to retrieve cloud properties. Another radar configuration consists of Ka-band (35 GHz) and X-band (9.5 GHz) radars mounted on a steerable platform, but the X-band beamwidth is larger than the Ka-band beamwidth (1 vs. 0.3 degrees). Since both radars are not observing the same cloud particles, differences in measured reflectivity and Doppler velocity cannot be directly used to retrieve cloud properties. Observations from multiple scans and multiple range gates need to be combined to scale the mismatched radar observations to a common spatiotemporal resolution. This study addresses the pulse volume mismatch in collocated vertically pointing radar observations by combining Doppler velocity spectra over multiple profiles and multiple range gates forming statistically homogenous regions. The size of a homogenous region is determined by pre-defined correlation lengths. When studying precipitation features, the correlation lengths can be scaled to reflectivity (Z) and mass-weighted mean diameter (Dm). By setting Z and Dm tolerances, the uncertainty estimates of homogenous regions are consistent from region to region. Relaxing the tolerances generates larger spatiotemporal homogenous regions. The tolerance level is dictated by the scale of the modeling being performed. Since the initial data from collocated Ka- and X-band radar systems are still being collected, the upscaling procedure was validated using 35-GHz (KAZR) radar (0.5 degree and 1-s dwell) and 2.8-GHz (S-band) radar (2.5 degree and 7-s dwell) observations during the MC3E field campaign. During stratiform rain and using tolerances of 0.5 dBZ and 0.1 mm, homogenous regions were observed to extend over 21 seconds in time and 500 m in height. The analysis technique as well as the vertical and temporal structure of homogenous regions will be shown at the ASR Science Team Meeting.

Precipitation estimation from the ARM distributed radar network during the MC3E campaign

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Scott Collis, Argonne National Laboratory
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The ARM DOE-NASA Midlatitude Continental Convective Clouds Experiment (MC3E) was the first demonstration of the ARM Climate Research Facility scanning precipitation radar platforms. A goal for the MC3E field campaign at the Southern Great Plains (SGP) facility was to demonstrate the capabilities of ARM polarimetric radar systems for providing unique insights into deep convective storm evolution and microphysics. One practical application of interest for climate studies and the forcing of cloud resolving models is improved Quantitative Precipitation Estimates (QPE) from ARM radar systems positioned at SGP and Tropical Western Pacific (TWP) locations. This study presents the results of ARM radar-based precipitation estimates during the two-month MC3E campaign. Emphasis is on the usefulness of polarimetric C-band radar observations from the C-band scanning ARM precipitation radar (C-SAPR) for rainfall estimation to distances within 100 km of the Oklahoma SGP facility. Collocated ARM/NASA disdrometer resources, precipitation profiling radars, and nearby surface Oklahoma Mesonet gauge records are consulted to evaluate potential ARM radar-based rainfall products and optimal methods. Rainfall products are also evaluated against the regional NEXRAD-standard observations.

Retrieve rain/drizzle size distribution using dual-frequency millimeter-wave radars

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Differential measurements from a dual-frequency millimeter-wave radar, i.e., the difference between measurements at the two frequencies, provide a rich suite of information about both cloud and rain properties. Differential reflectivity is proportional to cloud liquid water content (LWC) if non-Rayleigh effects are negligible. When large drizzle drops or rain present, differential reflectivity, combined with vertical velocity and Doppler width measurements, enables unambiguous separation of non-Rayleigh effects and attenuation effects. These differential measurements have the following advantages: (1) they do not require absolute radar calibration, (2) they do not depend on air motion, and (3) they do not depend on turbulence broadening. Thus, this dual-frequency approach can provide accurate (unbiased) retrieval of cloud and rain properties. This approach is tested using observations from the Ka- and W-band cloud radars operated by the Atmospheric Radiation Measurement (ARM) Climate Research Facility.

Semi-diurnal variation of rainfall simulated by cloud-system-resolving model

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We studied the characteristics of rainfall over the tropics in the cloud-system-resolving model (Non-hydrostatic ICosahedral Atmospheric Model; NICAM). Semi-diurnal variation of surface rainfall was found over continental area such as Africa, India, and the Amazon. No semi-diurnal variation of rainfall is represented over the ocean such as the Pacific and Indian Oceans, while diurnal variation of rainfall is significant over the ocean area. Slight signal of semi-diurnal variation is seen near larger island over maritime continent. This semi-diurnal variation of rainfall over the continental area, with primary peak in the afternoon and secondary peak at early in the morning, is confirmed in TRMM/PR and TMI observation. The timing of the primary peak is almost same between TRMM observations and NICAM simulation, while the secondary peak in TRMM/PR and TMI observation is earlier than NICAM. Detailed analysis of semi-diurnal variation of rainfall over Africa by the METEOSAT infrared observations revealed that the afternoon peak is associated with the large number of small-size deep convection. This is consistent with the percentage of convective rainfall observed by TRMM/PR and TMI. Early morning peak of rainfall is rather corresponding to the smaller percentage of convective rain by TRMM/PR and TMI.

Targeted bulk microphysics scheme improvements through cloud-resolving and limited-area model intercomparison with observations

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Ping Zhu, Florida International University
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
Adrian Hill, UK Met Office
Ben Shipway, UK Met Office
Christopher Williams, University of Colorado at Boulder/NOAA Earth System Research Laboratory

Errors in cloud-resolving model (CRM) and limited-area model (LAM) simulations that result from various bulk microphysics scheme assumptions can be reduced by making scheme alterations guided by comparisons with each other and comparisons with available observations. This is the approach being used for a suite of CRM and LAM simulations of the 23–24 January 2006 mesoscale convective system (MCS) event during the Tropical Warm Pool-International Cloud Experiment (TWP-ICE). There are many differences between CRM and LAM simulations due to very different boundary conditions and forcing methodologies. For example, stratiform area is much lower in the LAM simulations than the CRM simulations. In terms of radar reflectivity and rainfall statistics, the CRM simulations perform better than the LAM simulations, which is not surprising because the CRM forcing is partly derived through radar-derived rain-rate observations. With the inclusion of analysis nudging in coarser domains, the LAM simulations are able, however, to generate cyclonic flow associated with the MCS whereas the CRMs inherently cannot. Despite these differences, there are many important similarities between CRM biases and LAM biases related to bulk microphysics assumptions. Across all simulations, convective area is too high, simulated convective radar reflectivity aloft is too high, and stratiform rain rates are too low. Despite this general agreement in bias, there still exists substantial spread in model output. Differences between simulations are highly correlated with differences in assumed hydrometeor size distribution properties and the number of prognostic moments of the hydrometeor size distributions. Specific scheme components that appear related to the biases and have possibilities for future improvement are the rain droplet breakup parameterization, the density (and hence fall speed) of rimed precipitating ice, the assumed mass-dimension relationship for snow, and the assumed gamma size distribution shape parameter for rain. These will be explored in upcoming sensitivity tests.

Abstracts

Radiation

2D radiative processes near cloud edges

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Because of the importance and complexity of dynamical, microphysical, and radiative processes taking place near cloud edges, the transition zone between clouds and cloud-free air has been the subject of intense research both in the ASR program and in the wider community. One challenge in this research is that the one-dimensional (1D) radiative models widely used in both remote sensing and dynamical simulations become less accurate near cloud edges. The large horizontal gradients in particle concentrations imply that accurate radiative calculations need to consider multi-dimensional radiative interactions among areas that have widely different optical properties. This study examines the way the importance of multidimensional shortwave radiative interactions changes as we approach cloud edges. For this, the study relies on radiative simulations performed for a multi-year data set of clouds observed over the NSA, SGP, and TWP sites. This data set is based on MICROBASE cloud profiles, as well as wind measurements and ARM cloud classification products. The study analyzes the way the difference between 1D and 2D simulation results increases near cloud edges. It considers both monochromatic radiances and broadband solar radiative heating, and it also examines the influence of factors such as cloud type and height and solar elevation. The results provide insights into the workings of radiative processes and may help better interpret radiance measurements and better estimate the radiative impacts of this critical region.

Energy flows in Earth's climate system

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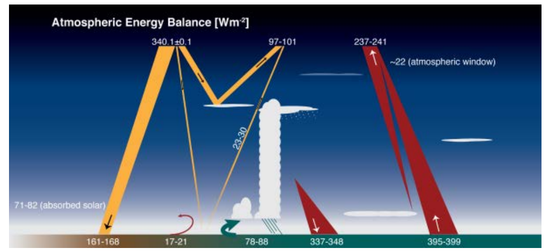

Earth's global and annual mean top-of-atmosphere and surface energy budget, subjectively determined based on literature review complemented by global simulations. Values are presented as a two-sigma range, i.e., roughly 68% likelihood that the actual value falls within the stated range.

Recent research in observing and modeling energy flows in Earth's climate system is reviewed with emphasis on Earth's energy balance and its susceptibility to perturbations, particularly the roles of clouds and aerosols. More accurate measurements of the total solar irradiance and the rate of change of ocean enthalpy help constrain the energy budget at the top of the atmosphere (TOA) to less than 4 W m-2. Earth reflects substantially less solar radiation and emits more terrestrial radiation than was believed even a decade ago. High precision measurements of the energy budget at the TOA provide new opportunities to track Earth's energy flows on timescales of days to years. The principal limitation in the estimate of secular trends now lies in the natural variability of the Earth system itself. The average planetary energy imbalance, central to interpretation of climate change over the industrial period, is estimated as 0.9 ± 0.3 W m-2 (one-sigma). Constraining the energy budget at the surface is much more difficult than at the TOA. Although satellite instruments afford the opportunity for reproducible measurements with global coverage and high spatial and temporal resolution, important quantities such as cloud fraction depend strongly on the measurement approach. Collocated measurements of cloud fraction by multiple approaches yield results that differ can differ profoundly at a single time, in monthly averages, and in the seasonal pattern; monthly anomalies in time series of cloudiness also show less sensitivity to measurement technique. Differences among measurement techniques make unambiguous determination of long-term trends difficult and potentially sensitive to observational inhomogeneities. Rapid responses (adjustments) of elements of the climate system are central to the definition of the forcing that results from a change in atmospheric composition. Uncertainty in this adjustment, in addition to uncertainty in the secular compositional perturbation, limits accurate determination of radiative forcing. Changes in clouds contribute importantly to this adjustment and thus contribute to uncertainty in estimates of both radiative forcing and climate system response. Advances in tracking Earth's energy flows and compositional changes on daily through decadal timescales are key to advancing model development and evaluation.

http://www.mpimet.mpg.de/fileadmin/staff/stevensbjorn/Documents/StevensSchwartz2012.pdf

High-resolution skin temperature derived from geostationary satellite top-of-atmosphere clear-sky infrared temperature retrievals

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Climate modelers rely on high-accuracy, high-resolution initial radiometric and surface conditions for effective evaluation of the global climate model. The ARM Climate Research Facility focuses on the development of products that continuously measure radiative feedback processes in order to support climate model advancement. One such product, the infrared thermometer (IRT), measures surface skin temperature at the Solar and Infrared Radiation Station (SIRS) located at the Southern Great Plains Central Facility. This parameter is a principal surface and radiometric element of the atmospheric radiation balance. NASA Langley provides cloud and clear-sky retrievals for ARM climate modelers derived from geostationary satellite imagery. Using these retrievals, an inverted correlated k-distribution method is applied to clear-pixel values of top-of-atmosphere infrared temperature to derive a large-area, high-resolution skin temperature data set. The high frequency of geostationary satellite observations allows for study of the diurnal variation of skin temperature. This spatial and temporal resolution, and the fact that only clear scenes are used, leads to a high-accuracy data set viable for comparison with ARM IRT measurements, with the latter used as validation. Once validated, these high-accuracy observations can lead to improved skin temperature measurements and more advanced global climate models.

Improved TOA broadband shortwave and longwave fluxes over various ARM domains

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Top-of-atmosphere broadband longwave and shortwave fluxes are essential for evaluating climate change and studying cloud radiative interactions. Geostationary satellites can be employed to monitor the rapidly changing fluxes over large areas such as the ARM Southern Great Plains (SGP) and Tropical Western Pacific (TWP) sites. The narrowband measurements from geostationary satellites are converted to broadband fluxes by using narrowband-to-broadband (NB-BB) conversion coefficients. Empirical NB-BB flux conversion fits have been derived by matching twice-daily coincident broadband fluxes from the CERES instrument aboard the Terra satellite (10:30 local crossing time). These NB-BB fits have been derived for distinct ARM domains and geostationary satellites. Separate fits have been derived using GOES-10/CERES Terra Ed2C for the Marine Stratus Radiation Aerosol and Drizzle (MASRAD) ARM Mobile Facility deployment from March–September 2005 and GOES-13/CERES Terra Ed3 for the Midlatitude Continental Convective Clouds Experiment (MC3E) campaign covering the Southern Great Plains (SGP) domain from April–June 2011. Recent coverage of the TWP domain with MTSAT-2/Terra CERES Ed3 is provided by fits derived from July–October 2010. The NASA/Langley VISST algorithm incorporates the new fits to derive TOA BB fluxes, as well as complete cloud and radiative property data sets. The fluxes are validated against CERES Terra/Aqua from various time periods.

Long-term radiance trends at the ARM Southern Great Plains Site

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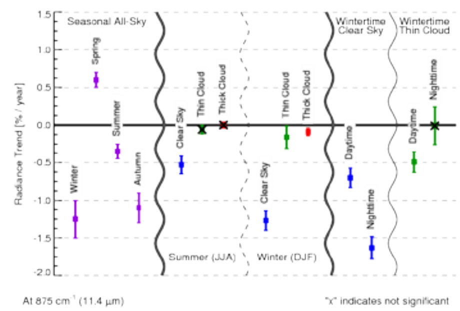
Over 14 years of downwelling spectral infrared radiation data have been collected by the atmospheric emitted radiance interferometer (AERI) at the Department of Energy's Atmospheric Radiation Measurement (ARM) site in north-central Oklahoma. The absolute calibration of each AERI spectrum is ensured to be better than 1% of the ambient radiance by the design of the instrument and its calibration subsystem. The measured infrared spectra, numbering more than 800,000, were classified as clear-sky, thin cloud, and thick cloud scenes using a neural network method and were further sorted by diurnal and seasonal cycles. Many significant long-term trends are obtained from the AERI radiance data set when looking at the data on annual, seasonal, and diurnal time scales. For example, the downwelling radiance is decreasing over this 14-year period in the winter, summer, and autumn seasons, but it is increasing in the spring; these trends are statistically significant and are primarily due to long-term change in the cloudiness above the site. The trend spectra reveal changes in cloud characteristics that may be attributed to changes in cloud height, temperature, and particle size. Given the decadal time span of the data set, natural variability needs to be considered when drawing broad conclusions. Nonetheless, these accurate spectral observations have high value since they can be used to infer possible mechanisms for any trends from the observations themselves, and they can be compared with global and regional climate models to evaluate their performance. Furthermore, this work provides a foundation for using global infrared radiance measurements from satellite instruments to ascertain climate trends and test general circulation models.



Radiance trends at 11.4 μm in all-sky scenes for different seasons (left); for different sky conditions in summer and winter (center); and for clear-sky and thin-cloud conditions in the winter for day and night (right). A black "X" on the symbol indicates that the trend is not statistically significant.

A one-year study of the diurnal cycle of clouds and radiation in the West African Sahel region

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The Sahel region of West Africa is thought to be particularly sensitive to global climate change due to its location on the tropical margin and its heavy dependence on yearly rainfall delivered by the West African Monsoon. This rainfall nurtures a precariously small and essential agricultural output in this region. To gain a better understanding of the role of clouds and other radiatively active forcing mechanisms, which contribute to the monsoon circulation in the Sahel, radiative fluxes and cloud properties, among other atmospheric quantities, were measured during the RADAGAST Campaign (Radiative Atmospheric Divergence using ARM Mobile Facility, GERB, and AMMA Stations) in Niamey, Niger, during 2006. Shortwave and longwave fluxes were measured at the top of the atmosphere every fifteen minutes using the Geostationary Earth Radiation Budget (GERB) instrument aboard the Meteosat-8 satellite. Coincidently, the ARM Mobile Facility (AMF) measured the radiative fluxes at the surface on a time scale of less than one minute, which enabled the calculation of the cross-atmosphere radiative flux divergence on a time scale of fifteen minutes. This divergence quantifies the net warming or cooling experienced by the atmospheric column above the Sahel. These high-temporal-resolution measurements are combined with high-resolution active remote sensor measurements of clouds and moisture, which are thought to partially control the radiative flux divergence. We use these unique measurements to define and quantify the diurnal cycle of clouds and radiation in the Sahel region and to determine how varying cloud conditions impact this cycle. Our data also demonstrate the power and utility of this measurement approach and its ability to evaluate global climate model simulations of the Sahel region.

On the determination of variance in modeled and observed surface irradiance

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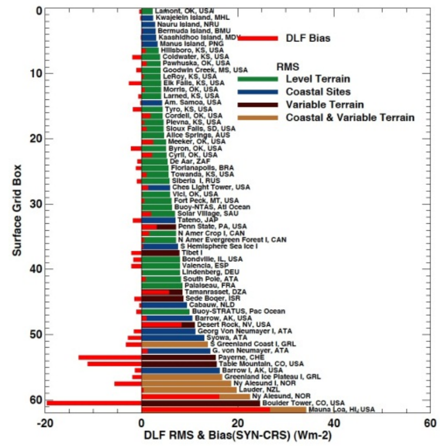
Satellites view the entire Earth over relatively short periods of time, allowing for reasonable observation of the Earth's radiation budget at the top of the atmosphere (TOA). At the Earth's surface, however, we are necessarily restricted to observations of irradiance at essentially a handful of sites located primarily over northern hemisphere continental regions. Hence, to determine the global budget of irradiance at the surface we must rely on radiative transfer models driven by 4-dimensional space/time re-analyses of the atmospheric state over time. Modeled and observed surface irradiances have been compared in many studies (e.g., Rossow and Zhang 1995, Rose et al. 2006, Charlock et al. 2006, Wang and Pinker 2009, Niu et al. 2010). The RMS difference between modeled and observed irradiances at surface sites can be used as a measure of uncertainty, though their relationship is complex. The noise of temporal and spatial mismatch between observed surface irradiances can dominate in the comparisons,



especially shortwave irradiances, and uncertainty might be overestimated if the surface site does not represent the grid box where the site is located. We separate the RMS difference of modeled minus observed irradiance into three components: r^2= r(s)^2+r(t)^2+r(m)^2 where r is the RMS difference computed with the difference between modeled gridded monthly mean irradiance and observed monthly mean irradiance. r(s) is the RMS difference due to variability of surface irradiance within the grid (spatial sampling), r(t) is the uncertainty due to temporal resolution of modeled irradiance, and r(m) is modeling error and the noise due to matching modeled irradiances with surface observations. The spatial RMS error r(s) arises because observations at a surface site measure the irradiance at one location that may not be representative of a larger area such as a global climate model grid box. Temporal uncertainty arises because model input is often based on observations that are typically limited to several times a day. Modeling error includes the error in the inputs and assumptions in the model. Using various satellite-based model calculations of surface downward irradiance at several different time and space scales, we attempt to determine the components of the above equation to quantify the uncertainty in such model versus observation comparisons.

Radiative heating rate profiles over the ARM TWP sites using inputs from multiple ground-based and satellite remote sensors

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The vertical distribution of radiative heating plays an important role in determining dynamic atmospheric processes. An accurate representation of heating rates in the atmosphere is limited by our ability to describe the thermodynamic state and cloud properties of the atmosphere. From a remote sensing perspective, a comprehensive view of the atmosphere requires that we combine remote sensing instruments according to their relative strengths. In this study we quantify radiative heating rate profiles using observations at the ARM Tropical Western Pacific (TWP) sites. The Pacific Northwest National Laboratory-combined remote sensor retrieval is used for cloud inputs, which uses the millimeter-wavelength cloud radar, micropulse lidar, and microwave radiometer to obtain cloud and precipitation properties for all sky conditions. While the ARM TWP sites provide a continuous set of observations, they are unable to describe the spatial variability of radiative heating in the atmosphere. Therefore we use heating rates derived using ground-based data to examine those derived using inputs from the A-train constellation of satellites. We make comparisons to an existing satellite heating rate data set, the CCCM data product. These comparisons provide insight into the advantages and disadvantages present in each data set and provide guidance on how such data sets might be improved to explore processes in the atmosphere dependent on radiative heating.

A space and time surface radiation climatology of the ARM Southern Great Plains site

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We are in the process of developing the surface radiation budget for the ARM Southern Great Plains (SGP) site using Solar and Infrared Radiation Station (SIRS) radiometers available at six extended facilities. Our goal is to derive a climatology of the monthly surface radiation budget from 1998 to the present. We currently are calculating the shortwave and longwave budgets and surface albedo for Pawhuska (EF12) as a prototype for the entire study. The SIRS data archive also contains data quality checks (QC) that we use to identify missing and questionable data. The automated QC began in 2002 and continues to the present. The years prior to 2002 require visual inspection. The procedure for developing a monthly budget is as follows. The upward and downward longwave radiation measurements are summed over the 1440 minutes in a day, beginning at local midnight, to obtain a daily total. Each daily budget then is summed for the month to obtain the monthly budget. A day for accumulating the shortwave radiation begins near sunrise, with the first minute that an upward or downward component of radiation is greater than zero, and ends near sunset, when the component again becomes negative. One estimate of global downward shortwave radiation is directly measured; a second estimate is computed from direct solar and diffuse sky measurements. There is but one estimate of the upward shortwave component. Each of the components is summed minute-by-minute throughout the course of the day to yield a daily sum in units of MJ/m**2. The same procedure is applied each day of the month to yield a monthly sum for each component. To date, we have developed for EF12 a monthly summary table for each month, along with time series plots of the daily and monthly components of shortwave and longwave radiation. We currently are visually inspecting all data flagged as ‘bad’ or missing because we have found cases in which neither condition is correct. The tables and time series will be finalized after we determine replacement values for bad and missing data. Thus, an associated goal is to assess the reliability and robustness of the data set across the 14+ years of records and make appropriate adjustments. Similar analyses will be applied to the remaining five extended facilities that were considered to have the most spatially homogeneous surface properties among all extended facilities.

The Stabilized Radiometer Platforms (STRAPs): description and planned upgrades

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Measurements of solar and infrared irradiance by instruments rigidly mounted to an aircraft have historically been plagued by the introduction of offsets and fluctuations into the data that are due solely to the pitch and roll movements of the aircraft. To address this problem, two STabilized RAdiometer Platforms (STRAPs) were developed through collaboration between the Naval Postgraduate School (NPS) Center for Interdisciplinary Remotely Piloted Aircraft Studies (CIRPAS), the Naval Research Laboratory (NRL), and Sandia National Laboratories (SNL). The platforms were designed and built through an Office of Naval Research (ONR) Small Business Innovation Research (SBIR) grant by L-3 Communications Sonoma EO (formerly Sonoma Design Group). Each STRAP is capable of being mounted on the top (or bottom) of an aircraft, and each utilizes a self-contained, coupled Inertial Navigation System-GPS pair to actively keep a set of uplooking (or downlooking) radiometers horizontally level to within ±0.020 degrees for aircraft pitch and roll angles of up to approximately ±10 degrees. The system update rate of 100 Hz is fast enough to allow the STRAPs to compensate for most pitch and roll changes experienced in normal flight and in turbulence. The STRAPs have been flown in a handful of field campaigns and test flights that have illustrated their ability to work extremely well, greatly increasing the accuracy and quantity of solar and IR irradiance measurements from aircraft. However, the STRAPs also experienced various failures during these flights that highlighted the need to increase their reliability. The DOE ARM Aerial Facility (AAF) is funding the maturation and hardening of the two currently existing STRAP instruments. Specifically, upgrades will be made to the navigational computer hardware components, the platform control software, and the operating system of each of the STRAPs. These upgrades will make the STRAPs more robust and better suited for use in field studies or routine flights and will provide the atmospheric science community with two valuable tools for accurately characterizing the radiative balance of the Earth's atmosphere for climate- and weather-related studies.

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