Atmospheric Field Measurements and Development of Climate Models

The atmospheric scientists of the Environmental Science (EVS) Division at Argonne National Laboratory are collecting, evaluating, and assimilating information on characteristics of aerosols and other atmospheric parameters, then using the data in development of advanced global- and regional-scale climate models.

Problem/Opportunity

Improving understanding of climate change requires new approaches for collecting, analyzing, and assimilating field data sets into atmospheric and climate models. Collecting relevant climate and process-scale data sets and making them suitable for evaluation and further development in climate models is a highly complex task; spatial data coverage ranges from local points to regions, and new methodologies enable data collection for a given volume of atmosphere, either directly or from satellite platforms. EVS is meeting the challenge to develop integrated data sets that represent process interactions, then applying the data sets in models to reduce process-related uncertainty and benefit the development of high-resolution climate models.

Atmospheric Instrumentation and Measurements

EVS staff members provide expert support for instruments that measure key climate variables at three ACRF sites and two AmeriFlux sites. (ACRF is the U.S. Department of Energy Atmospheric Radiation Measurement [ARM] Climate Research Facility.) ARM focuses on obtaining continuous field measurements — from routine surface observations and cloud and radiative properties to advanced remote sensing of aerosol distributions in the atmospheric boundary layer. A primary ARM goal is improving understanding of the fundamental physics related to interactions between clouds and radiative feedback processes in the atmosphere, in order to promote the advancement of climate models.

EVS-supported ACRF instruments include the following:

- *Active remote sensors* to characterize the location and evolution of cloud, aerosol, and thermodynamic profiles above the deployment site.

Collecting Atmospheric Field Measurements

- *Cloud radar* to determine cloud location, reflectivity, particle vertical velocity, and velocity distribution above the facility.
- *Micropulse lidar and laser ceilometer* to measure aerosol structure in the sub-cloud layer.
- *Radiosondes* to measure optical cloud base height.
- *Microwave radiometer* to quantify the vertical thermodynamic structure and measure precipitable liquid water and water vapor.
- *Boundary layer wind profiler* to continuously measure wind profiles and refractive index structure above land sites.

Instrumented facilities supported by EVS include the second ARM Mobile Facility (AMF2), a laboratory designed to collect climate-related data during land- and ocean-based deployments typically lasting six to twelve months. The AMF2 will also be deployed in extreme climate conditions such as the Arctic, including possibly on an ice sheet above the Arctic Circle. Primary objectives of AMF2 deployments are data on clouds, cloud radiative properties, and effects of aerosols on clouds. The AMF2 includes a full complement of radiometers to measure upwelling and downwelling radiation — to be stabilized for ocean deployments. Surface latent, sensible, and CO_2 fluxes are measured, along with standard surface meteorological variables. The AMF2 is also equipped with instrumentation that enables research on aerosol-cloud relationships. Measurements of light absorption by aerosols and cloud nucleating properties are made routinely.

ARM Mobile Facility 2 (AMF2) Laboratory

Impact of Atmospheric Aerosols on Climate

An EVS project uses DOE Atmospheric System Research field measurements in urban and regional-scale air masses to evaluate various microphysics models of aerosol formation, transport, and removal. This work will benefit climate change studies and foster both development of suitable aerosol process models for use in global-scale climate change models and the independent development of regional-scale climate models. The focus is on processes affecting the production of organic aerosols from chemical precursors, particularly aerosols with radiative characteristics that can affect climate. Also studied are spatial and temporal distributions, atmospheric lifetimes, secondary aerosol production, urban contributions to the regional aerosol background, and effects of aging on aerosol properties. Models used range from 0-D box models to 3-D global chemical-transport models employed to evaluate process-scale and 3-D models.

This research is addressing the following technical issues:

- Uncertainties in emissions of primary aerosols and aerosol precursor gases, through use of a novel model inversion method for aerosol precursor gases.
- Emission uncertainties that affect the calculated atmospheric burdens of primary and secondary aerosols, through further development of the EaKF data assimilation procedures for aerosols already implemented by EVS for trace gases in a regional-scale aerosol-atmospheric dynamics model.
- Data set assimilation with the GEOS-CHEM model.
- Uncertainties in aerosol process model parameters, through use of an Argonne-developed parameter sweep procedure for the 1-D aerosol chemistry-planetary boundary layer dynamics model.
- Past and possible future regional-scale trends in anthropogenic and natural aerosol emissions.
- Use of GEOS-CHEM to estimate impacts of aerosol trends on calculated aerosol optical depth and radiative forcing.

DMCP: Data Domain to Model Domain Conversion Package

EVS is developing a single methodology for use with data collected at the widely distributed ACRF or AmeriFlux sites to derive suitable grid average or column mean values of measured variables for model evaluation and data assimilation in climate models. The latest available statistical modeling tools and relevant physical and chemical process are used to generate error estimates of the mean quantities — averaged from the observation grid to the model grid — as well as correlations in errors across space and time. The software tools generated will be documented and distributed as the DMCP.

Crop Model for Climate Model Simulations

EVS is integrating agricultural factors into the Community Land Model (CLM) to simulate changes in above- and below-ground carbon storage when naturally vegetated land is converted to agriculture. Methods from earlier land surface models (such as Agro-IBIS and LPJ-mL) are incorporated into the carbon-nitrogen version of CLM to model the growth of crop systems including corn, soybean, and wheat. Also evaluated are the impacts on soil carbon of a variety of residue management and fertilization farming practices. Estimates of economically driven land use changes drive various land use scenarios. Also being incorporated into the model are other management practices, crop types (including cellulosic biofuel crops such as switchgrass and *Miscanthus*), finer resolution, and climate impacts on agriculture. This project supports the integrated assessment model development project CIM-EARTH (http://cimearth.org/) — a collaboration between Argonne and the University Chicago.

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