The Two-Column Aerosol Project (TCAP) Breakout Session

**Agenda**
1. Review of preliminary Research
2. Science questions
3. Status of instruments
4. Review logistics and flight plans
Preliminary Research: Why Cape Cod?

True-color Sea-viewing Wide Field-of-view Sensor (SeaWiFS) image from 4 May 2001
Image courtesy of the NASA EOS Project Science Office
Preliminary Research: Why Cape Cod?

True-color MODIS Aqua Image from 31 May 2010
Image courtesy of the NASA EOS Project Science Office

Boston haze on 5/31/2010. Photo courtesy of www.wbur.org (Boston local news)
Preliminary Research: Why Cape Cod?

- Large variations in the magnitude of predicted aerosol forcing.
Large variation in the magnitude of predicted aerosol forcing

Graph showing the largest variation among models is in the northern hemisphere mid-latitudes. The graph plots RF [W m^-2] against Latitude [°] for various models such as UMI, UIO_CTM, LOA, LSCE, MPI_HAM, GISS, UIO_GCM, and SPRINTARS, with a significant variation observed at mid-latitudes.
Preliminary Research: Aerosol Climatology-July

- Horizontal gradients in AOD
  - Larger in the morning
- Diurnal variations in AOD

Mean AOD (Jul 2000-2010)

~10:30 EST

~13:30 EST

Work led by Duli Chand
Smaller aerosol loading

- Changes in emissions and photochemistry
- Small changes in PM
Deployment Details

- One-year deployment of ARM Mobile Facility (AMF) and Mobile Aerosol Observing System (MAOS) starting in the summer of 2012

- Two aircraft intensive observation periods (IOPs)
  - July 7-30, 2012
  - Feb. 4-28, 2013

AOD from MVCO AERONET site
TCAP Science Goals

- Cloud Condensation Nuclei (CCN) studies
  - Does size or composition matter
- Local and Columnar radiation closure study
  - AOD will be measured with a range of different instruments
- Cloud-aerosol interactions
  - Long time series with detailed information about particles
- High resolution modeling
- Climate modeling
  - How well does a climate model represent horizontal and vertical variability of anthropogenic aerosols and their impact on scattering and absorption?
  - What are the important factors?
New cloud radars

- Scanning cloud radars provide unprecedented information about the spatial distribution of clouds
- Example from AMF deployment in the Azores
Aircraft Measurements

- Measurements complement those made on the ground
  - Aerosol optical properties
  - Particle size distributions
  - Cloud properties
  - Solar radiation

- Airborne remote sensing
  - High Spectral Resolution Lidar (HSRL)
    - Aerosol backscatter, extinction, AOD
  - Research Scanning Polarimeter (RSP)
    - Aerosol optical properties
    - Information about particle size distribution
Instrument Status

- SPLAT II — Alla
- 4STAR — Connor
- HSRL and RSP — Rich
Plans are being developed for both the G-1 and King Air.
AMF 1 Instruments

- Precision Spectral Pyranometer (PSP) x 2
- Precision Infrared Radiometer (PIR) x 2
- Shaded Black & White Pyranometer (B/W)
- Shaded Precision Infrared Pyrgeometer (PIR)
- Normal Incidence Pyrheliometer (NIP)
- Infrared Thermometer (IRT) x 2
- Multi-Filter Rotating Shadowband Radiometer (MFRSR)
- Narrow Field of View Zenith Radiometer (NFOV)
- Optical Rain Gauge (ORG)
- Anemometers (WND)
- Temperature/Relative Humidity Sensor (T/RH)
- Barometer (BAR)
- Present Weather Detector (PWD)
- Eddy Correlation Flux Measurement System (ECOR)
- Shortwave Array Spectrometer (SAS-He, SAS-Ze)
- Microwave Radiometer (MWR)
- Microwave Radiometer Profiler (MWRP)
- Microwave Radiometer 90/150 (MWR-HF)
- Doppler Lidar (DL)
- Ceilometer (CEIL)
- Balloon Borne Sounding System (BBSS)
- W-band ARM Cloud Radar - 95GHz (WACR)
- Ka-W Scanning ARM Cloud Radar (SACR)
- Atmospheric Emitted Radiance Interferometer (AERI)
- Total Sky Imager (TSI)
- Aerosol Observation System (AOS)
  - CCNC
  - PSAP
  - Nephelometers X 2
- Radar Wind Profiler – 1290MHz (RWP)
- Cimel Sunphotometer (CSPHOT)
Mobile Aerosol Observing System (MAOS) – 2 x 20’ sea containers (MAOS-A & MAOS-C)

- SOnic Detection And Ranging (SODAR) System (1000 to 4000 Hz)
- Ultra-High Sensitivity Aerosol Spectrometer (enhanced)
- Dual Column Cloud Condensation Nuclei Counter (CCN)
- Single Particle Soot Photometer (SP2)
- Scanning Mobility Particle Sizer (SMPS)
- Photo-Acoustic Soot Spectrometer (PASS), 3 Wavelength
- Humidigraph (3 Relative Humidities with 3 single wavelength nephelometers)
- Humidigraph (Scanning Relative Humidity with 3 single wavelength nephelometers)
- Trace Gas Instrument System (Research-Grade)
- Particle Into Liquid Sampler-Ion Chromatography-Water Soluble Organic Carbon (PILS-IC-WSOC)
- Particle Soot Absorption Photometer (PSAP), 3 Wavelength
- Nephelometer, 3 Wavelength
- Condensation Particle Counter (CPC), 10 nm to >3000 nm particle size range
- Condensation Particle Counter (CPC), 2.5 nm to >3000 nm particle size range
- Hygroscopic Tandem Differential Mobility Analyzer (HTDMA)
- Proton Transfer Mass Spectrometer (PTRMS)
- 7-Wavelength Aethelometer
- Weather Transmitter (WXT-520)
- Aerosol Chemistry Speciation Monitor (ACSM)
What Are Atmospheric Aerosols?

- **Not** chemicals released from a spray can!
- Particles that occur in the atmosphere
  - Wide range of sources, some natural some man-made (anthropogenic)
  - Particle range in size from nm to μm and larger
    - Particle sizes less than 2.5 and 10.0 μm are regulated

The diameter of a human hair ranges between 17 and 180 μm

Berkowitz et al. 2011
Atmospheric Aerosol—Images from Space

- Aerosol is ubiquitous
  - Both natural and anthropogenic

Haze over the East China Sea. Image courtesy of NASA

Arnica Fire (Yellowstone National Park), Sept. 2009. Image courtesy of NASA
Why Do We Care?

- Aerosol impacts climate
  - Absorb/scatter sunlight
    - Direct impact on radiative forcing
    - Function of particle size and chemical composition
  - Impact on cloud microphysics
    - Indirect impact on radiative forcing associated with changes in cloud properties (including cloud fraction)
    - Function of particle size distribution and chemical composition
  - High amount of uncertainty
The Two-Column Aerosol Project (TCAP)

Overarching Goal: To understand the processes responsible for producing and maintaining aerosol distributions and associated radiative and cloud forcings off the coast of North America

True-color Sea-viewing Wide Field-of-view Sensor (SeaWiFS) image from 4 May 2001
Image courtesy of the NASA EOS Project Science Office
Science Goal 4: High Resolution Modeling

- Models that treat meteorology and chemistry
  - Evolution of aerosols and its effect on CCN, cloud/aerosol interactions
  - Emphasis on how radiative forcing within the two TCAP columns were affected by particle formation, mixing state, and grid resolution

- Detailed chemistry models
  - Recently developed model (Zaveri et al. 2010)

Particle reflectivity at ~1 km

AOD

WRF-Chem predictions: NEAQS
The Two-Column Aerosol Project (TCAP): Measurements

True-color Sea-viewing Wide Field-of-view Sensor (SeaWiFS) image from 4 May 2001
Image courtesy of the NASA EOS Project Science Office
Mobile Aerosol Observing System (MAOS)

- Operational during aircraft IOPs
- Particle chemical composition
  - Mass loading (NO$_3$, SO$_4$, NH$_4$, Cl, Organic)
  - Composition, anions, cations, water soluble OC
  - Black carbon
- Trace gases
  - CO/N$_2$O/H$_2$O, SO$_2$, NO/NO$_2$/NO$_Y$, O$_3$
  - VOC concentration (PTR-MS)

Aerodyne Research Aerosol Chemical Speciation Monitor

Deployment of MAOS at BNL

http://www.arm.gov/sites/amf/mobile-aos
Mobile Aerosol Observing System (MAOS)

- Aerosol optical properties
  - Absorption
  - Scattering
  - Black carbon
  - Hygroscopicity—how particles grow with increasing RH
    - Two techniques: Humidified Tandem Differential Mobility Analyzer
    - Humidified scattering measurements

- Aerosol-cloud interactions
  - Cloud Condensation Nuclei Counter

Deployment of MAOS at BNL

http://www.arm.gov/sites/amf/mobile-aos
Radiation Measurements

- Direct and diffuse shortwave radiation
  - Broadband and spectrally resolved
- Microwave Radiometer
  - Profiles of temperature and humidity
- Total Sky Imager
  - Cloud images

![Graph of irradiance over time](image)

Date and Time (UTC)

8/2/02 12:00 15:00 18:00 21:00 00:00 03:00 8/3/02

Irradiance (W m$^{-2}$)

0 100 200 300 400 500 600 700

Direct
Diffuse
NASA High Spectral Resolution Lidar (HSRL)

- Provides vertical context to G-1 in situ measurements
- Allows for determination of aerosol type and comparisons of AOD
- Remotely measures “curtains” of aerosol properties

Aerosol backscatter profiles and boundary layer heights in California
Collaboration

- Data collected during ARM deployments is freely available to the public
  - Approximately 6 months delay for some data
- Maximize data use
Summary

- ARM data is freely available to everyone
- TCAP is designed to improve our understanding of cloud-aerosol-radiation interactions
- A large number of instruments will be deployed
  - Surface site
    - Particle and trace gas chemistry
    - Particle size distributions
    - Downwelling radiation
    - Cloud properties (from radar)
  - Aircraft IOPs
    - Particle and trace gas chemistry
    - Particle size distributions
Questions

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Science Goal 1: CCN Chemical Closure Study

- Does size or composition matter?
- Single particle mass spectrometer
  - Details of the composition of individual particles, including mixing state
- CCN counter
- “Internal” pumped CVI (Pekour et al. 2008) downstream of CCN counter
  - Select particles that activate in the CCN counter
  - Has been applied in the lab—not yet on aircraft
Science Goal 2: Radiative Closure

► Local Closure

■ Slab AOD measured by Spectrometer for Sky-Scanning, Sun-Tracking Atmospheric Research (4STAR) will be compared to AOD estimates based on in situ aircraft measurements of:
  - scattering,
  - absorption,
  - size distribution and,
  - mixing state

► Columnar closure

■ Experiment 1: Integrate 4STAR AOD profiles & in situ profiles and compare to AMF MFRSR

■ Experiment 2: Determine column-integrated values of SSA to SSA derived from the MFRSR
Science Goal 3: Cloud-Aerosol Interactions

- Most past studies have been of short duration
  - AMF deployment to Azores is an exception
- Extend CHAPS analysis to observations from the AMF, MAOS and G-1
  - Long time series with detailed information about particles (MAOS) and sub-cloud and cloud vertical velocity

Aerosol loading

Cold air outbreak—1/26/07
Science Goal 5: Global Modeling

Two primary questions:

- How well does CAM5 represent the horizontal and vertical variability of anthropogenic aerosols and their impact on extinction and AOD?
- What are the primary factors that can be used to explain differences between CAM5 simulations of direct and indirect radiative forcing and the TCAP measurements?