Long-term measurements of direct aerosol climate forcing

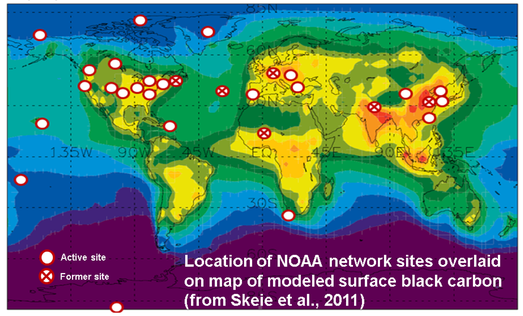
John A. Ogren, Aerosol Group Chief

Scientists	Technical Support
Elisabeth Andrews	Robert Albee
Anne Jefferson	Derek Hageman
Patrick J. Sheridan	Jim Wendell

Aerosol Forcing 101 (the primer)

Our goal is to characterize the means, variabilities, and trends of climate-forcing properties of different types of aerosols, and to understand the factors that control these properties.

What do we need to know?	WHY?
AEROSOL AMOUNT	Correlated with forcing
AEROSOL 'DARKNESS'	Determines the cooling/warming potential of particles
AEROSOL SIZE	•Anthropogenic aerosol contribution •Amount of incoming radiation lost to space
AEROSOL TYPE	Source identification/contribution
LOCATION	Aerosol forcing depends on the underlying surface and whether they are above or below clouds.



Location of NOAA network sites overlaid on map of modeled surface black carbon (from Skeie et al., 2011)

Motivation and Strategy

Long-term aerosol measurements can be used to:

→Derive direct aerosol radiative forcing
→Evaluate/constrain models
→Evaluate/calibrate remote-sensing measurements (satellite and ground-based)

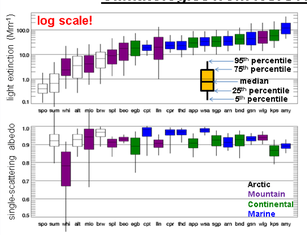
Our approach:

→Standardized suite of measurements and protocols
→Globally distributed network (pristine and polluted sites)
→Long-term fixed and shorter-term "mobile" measurements
→NOAA resources leveraged to support collaborators

Climatology and Trends

Long-term network observations demonstrate spatial, temporal and compositional differences and can be used to identify trends.

Climatologies from NOAA Aerosol Network



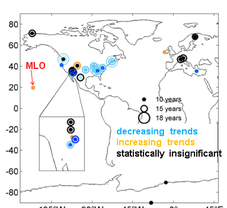
Wide variety of aerosol types and environments

Large variation in aerosol amount (light extinction)

No relationship between amount and "nature" of aerosol

→Important to measure regionally representative air masses
→Short field campaigns cannot capture climatological variability.

Long-term trends in aerosol properties



(Figure from Coen Collaud et al., 2013)

Trends not spatially homogenous
→complex processes including emissions changes, transport, and transformation of aerosol particles.

Aerosol optical properties have changed significantly over last two decades

US aerosol scattering is decreasing
→due to air pollution control laws?
→MLO's positive trend may be due to increased Asian emissions.

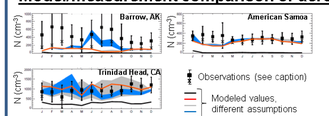
Where do we go from here?

- Maintain and expand long-term measurement network through partnerships
- Continue to analyze data in terms of climate forcing and climate relevant parameters, trends, correlations and variabilities

Model Evaluation

Representation of aerosols is a large area of model uncertainty.
→need to increase confidence in simulation of current and past trends
→need to properly model aerosol sources, sinks and processing

Model/measurement comparison of aerosol number concentration



■ = observed monthly mean
x = observed monthly median
I = standard deviation of the observed monthly mean

(From Spracklen et al., 2010)

→Models must include secondary formation processes (e.g., nucleation) to correctly represent aerosol number concentrations.

→Models must correctly parameterize aerosol microphysics in order to properly simulate cloud formation and, hence, indirect forcing by aerosols.

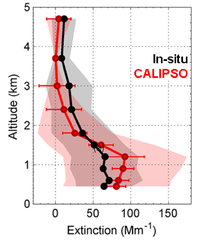
Where do we go from here?

- Continue to provide long-term aerosol measurements for use in evaluation of aerosol emissions, processing, and transport in models.
- Develop parameterizations of aerosol properties (e.g., systematic variability) that can be used to constrain/improve representation of aerosols in models.
- Use long-term aerosol measurements to assess the scales of spatial/temporal variability to minimize uncertainties in model/measurement comparisons.

Remote-sensing Validation

Remote-sensing retrieval products cannot be considered reliable until they have been independently validated
→ In-situ aerosol measurements can be related back to physical standards; remotely-sensed aerosol properties can not be.

'Proof-of-concept' satellite validation using in-situ aerosol profiles



Mean extinction profiles; the shaded areas are the standard deviations.
(From Sheridan et al., 2012)

Generally good agreement between in-situ (aircraft) and satellite-retrieved (CALIPSO) extinction.
However, CALIPSO often overestimated extinction in the PBL.
→Possible issues with CALIPSO's cloud screening algorithm

The extinction threshold for a 50% probability of detection by CALIPSO is 20–25 Mm⁻¹.
→These statistical data offer guidance on CALIPSO's ability to retrieve aerosol extinction at sites around the globe

Where do we go from here?

- Perform case studies to identify specific reasons for agreement/disagreement between in-situ and CALIPSO extinction
- Use long-term aerosol measurements to assess the scales of spatial/temporal variability to minimize uncertainties in satellite/measurement comparisons
- Work with NASA on airborne aerosol measurements platform

Conclusions/Outlook

The ESRL/GMD aerosol group provides long-term, quality-controlled data sets for use in climatologies and trend analyses, modeling and remote-sensing evaluations, and climate studies.

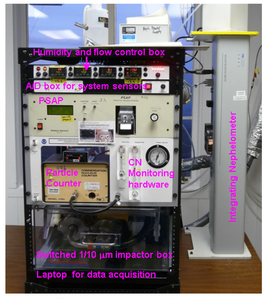
By enlisting partners we have been able to expand our measurements and research despite shrinking budgets.

Partners and collaborators enable us to expand both our measurement presence and our research efforts.

Aerosol Network Measurements

Measurement Systems

Aerosol systems are deployed at long-term surface measurement sites around the globe.
"Mobile" (moveable) and aircraft aerosol systems have been deployed for both short and multi-year campaigns.
Goal of measurements: characterize the aerosol properties that control direct radiative forcing.



Typical aerosol rack (MLO sampling system)

Basic Aerosol System Hardware

Aerosol Light Scattering
→Indicator of aerosol amount and related optical effects
→Instrument = Integrating nephelometer

Aerosol Light Backscattering
→Indicator of angular distribution of scattering light
→Instrument = Integrating nephelometer

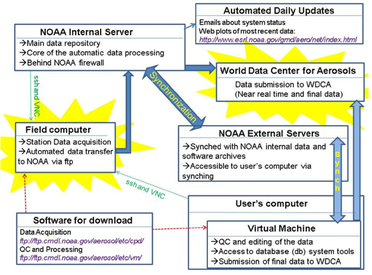
Aerosol Light Absorption
→Indicator of particle darkness, related to black carbon (BC)
→Instrument = Filter-based absorption photometer (e.g., PSAP)

Aerosol Number Concentration
→Precursor of cloud condensation nuclei; Indicator of local contamination
→Instrument = Condensation particle counter

Aerosol System Software

The ESRL/GMD Aerosol group has developed software for acquisition, processing, and archiving of data from instruments used in the NOAA-federated aerosol network.

This complete software package ensures data consistency among sites:
Field site → NOAA → Site Scientist → QC (data editing+corrections) → WMO World Data Center for Aerosols.



Schematic of aerosol system data flow

NOAA's Federated Aerosol Network

This network is a shared endeavor of NOAA and many collaborating organizations, including WMO GAW, U.S. DOE, and multiple U.S. and foreign universities and organizations.

NOAA/ESRL supplies…

- Site visit(s), design assistance
- Initial installation/calibration assistance
- Some peripheral equipment
- Training
- Data archiving and initial processing
- Software for QC and visualization
- Continued advice (e.g., troubleshooting)

Collaborator supplies…

- A commitment to long-term site operation
- Major instruments
- Station technicians
- Long-term station operation costs
- Data quality checking and editing

Result: A long-term, cooperative program with shared data access, making atmospheric measurements that are directly comparable with the other stations in the network and following established sampling protocols