The Processing and Radiative Properties of Aerosols over the Western North Atlantic Ocean at Bermuda

Principal Investigators

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Scientific Motivation

Atmospheric aerosols are *major factors* limiting our diagnostic and prognostic understanding of global climate change (CGER, 2001; IPCC, 2001).

To reduce uncertainties, the National Aerosol Climate Interaction Program (NACIP) recommends:

1. Establishment of **aerosol observatories** **at** **strategic locations** to support systematic measurements of aerosol sources, distributions, and properties.

2. Application of these measurements to develop realistic treatment of aerosols, including their chemical and microphysical evolution and their interaction with radiation in climate models.

There is a widely recognized need for long-term regionally representative observations (eg., NACIP, SOLAS, etc.)

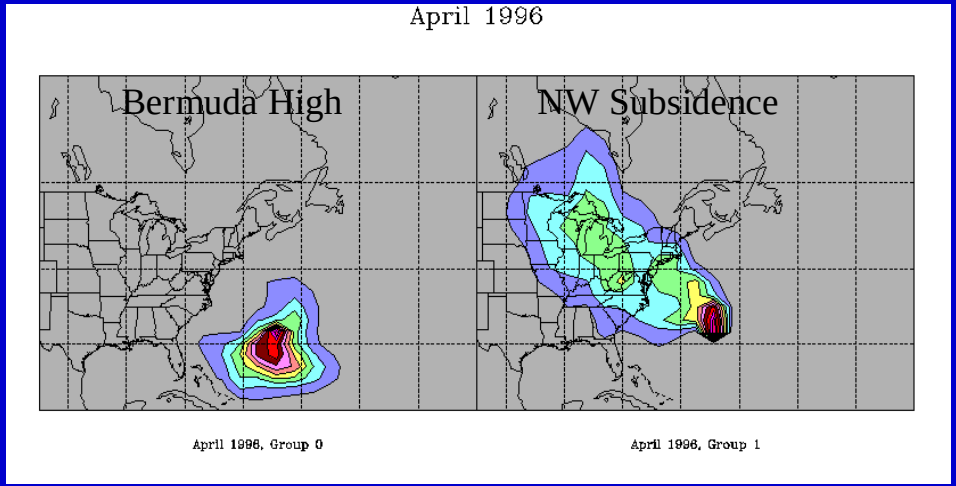
Aerosol Observatories are the only reliable way to meet the fundamental NACIP objective of linking aerosol radiative forcing to aerosol sources, composition, and physiochemical processing.

NACIP also specifically identifies the effects of BC and OC among the *"Big Five"* issues requiring particular emphasis.

Why Bermuda?

Unique location influenced by

- N. American outflow
- Saharan dust
- Clean marine air



Opportunity to extend and augment existing long-term data records

Excellent facilities supported by both NSF and BBSR

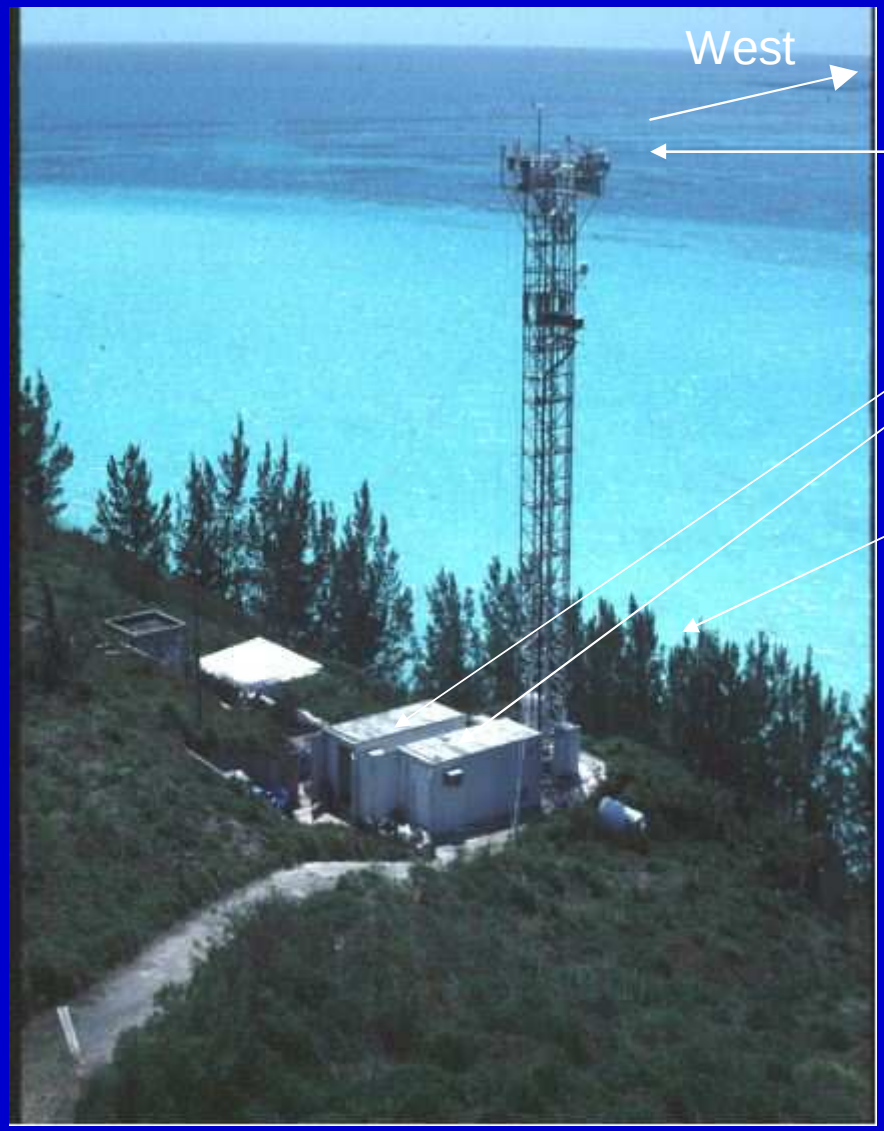
Relevant ancillary oceanographic data (BBSR)

Aerosol Sampling Sites on Bermuda

- Bermuda Biological Station for Research
- David's Head Sampling Site
- Sampling sector: 25° through east to 180°.

- Tudor Hill Atmospheric Observatory
- Sampling sector: 180° through 330°.

Tudor Hill Atmospheric Observatory, Bermuda



- 23 m high aluminum walk-up tower.
- Two air-conditioned converted 20 ft cargo containers.
- Located on steep slope with tower base 28 m above sea level.

Past long-term atmospheric data records for Bermuda

1980 – 1982 **Global Precipitation Chemistry Project (GPCP)**

Wet-deposition fluxes of major ionic species (event)

1882 – 1987 **Western Atlantic Ocean Experiment (WATOX)**

Wet-deposition fluxes of major ions and trace metals (event)

1987 – 1995 **Atmosphere-Ocean Chemistry Experiment (AEROCE) I&II**

Ionic composition of bulk aerosol (daily)

Trace-element composition of bulk aerosol (daily)

Wet-deposition fluxes of major ionic species (daily)

Wet-deposition fluxes of trace metals (daily)

^{210}Pb, ^{7}Be (daily)

O_3 (continuous)

Transport climatology (twice daily)

Past long-term atmospheric data records at Bermuda – Cont.

1995 – 1999 **AEROCE III**

Ionic composition of bulk aerosol (daily)
Physical and optical properties of aerosols (continuous)
Radiation (continuous)
Trace-element composition of bulk aerosol (daily)
^{210}Pb, ^{7}Be (daily)
Wet-deposition fluxes of major ionic species (daily)
Optical properties of scavenged insoluble aerosols (daily)
CO (continuous)
O_3 (continuous)
Transport climatology (twice daily)

Rationale for Resuming and Augmenting Observations at Bermuda

- Enhance value of both existing and **new** data
  - Chemical and climate models
  - Remotely sensed data
- Improve resolution in evaluating long-term trends.
- New techniques and approaches enhance utility of all data
  - Discrete evaluation of super- and sub-µm size fractions
  - EC/OC
  - Spectrally resolved absorption
  - Sun photometer
  - Micro-pulse Lidar
  - Trajectories coupled with satellite imagery (GOES IR, specific humidity, aerosol products, AIRS CO, etc.)
- Interpret in conjunction with emerging North American and global emissions inventories

Research Objectives

1. To **characterize major processes** controlling the chemical, physical, and optical properties of near-surface aerosols, including elemental and organic carbon (EC/OC), over the western North Atlantic Ocean.

2. To quantify long-term trends in aerosol concentrations and fluxes and assess their influences on direct climate forcing over the western North Atlantic Ocean.

3. To provide data for and to collaborate with investigators in

   - the modeling community to develop reliable predictive capabilities for direct climate forcing by aerosols and

   - the remote sensing community to improve the accuracy of algorithms used to retrieve atmospheric and oceanic information from satellite and ground/ship based instruments.

Summary of Research Plan

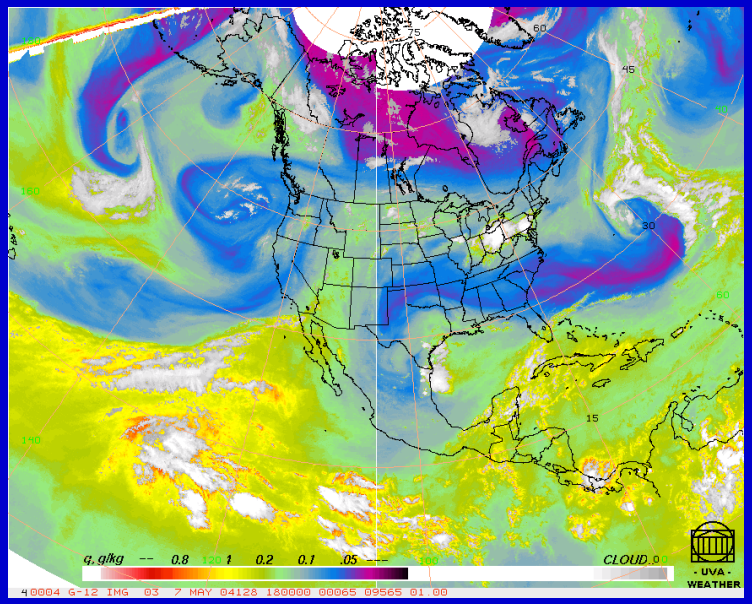
- Sample super- and sub-µm aerosol size fractions daily with high-flow MOUDI impactors and analyze for
  - EC/OC
  - Spectrally resolved absorption
  - Major ions
  - Mineral aerosol mass

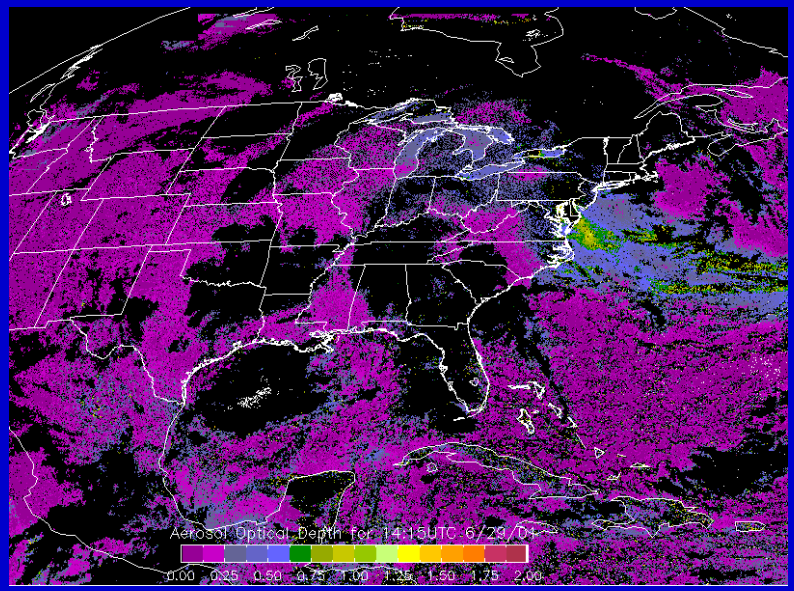
- Sample wet-only precipitation daily
  - Analyze all samples for major ions
  - Analyze subset of samples for DOC and insoluble particulate EC/OC

- Continuously measure
  - Total aerosol scattering
  - Aerosol optical depth (AERONET Sun Photometer; B. Holben, NASA)
  - Aerosol backscatter, extinction, and optical depth profiles and cloud heights (Micro-Pulse Lidar, J. Welton, NASA)
  - Downwelling broadband surface irradiance (E. Dutton, NOAA)
  - Ozone (S. Oltmans, NOAA)

Summary of Research Plan – cont.

- Calculate 3-D back trajectories 4x daily and cluster into major transport regimes
- Integrate results into a coupled chemical/radiative/transport climatology
- Evaluate variability in data ensemble during individual cases studies
- Collaborate with independently funded investigators in the modeling and remote-sensing communities to interpret results.





Current Status of Program

April 2006 – March 2009

- Duration of Phase I Funding
- Phase II contingent upon renewal proposal

July 2006

- Aerosol and precipitation sampling initiated

Early 2007

- Radiometer deployment scheduled

Summer 2007

- Lidar deployment scheduled

Recommendation

Coordinate Measurement Strategies at Bermuda and Cape Verde to the Extent Possible

- Facilitate direct comparability
- Maximize utility of combined data for
  - Modeling community
  - Remote-sensing community

Measurements to be made at Cape Verde in collaboration with the Reactive Halogens in the Marine Boundary Layer (RHaMBLe) intensive in May / June 2007 if funded under current NSF application

i) Soluble reactive trace gases every 2 hours or less (HCl, HNO_3, NH_3, HCOOH, and CH_3COOH; tandem mist chamber technique, [Keene et al., 2004]).

ii) Reactive Cl gases every 2 hours or less (HCl* - primarily HCl, Cl* - including Cl_2 and HOCl, and Cl_t - total volatile inorganic Cl; tandem mist chamber technique, [Pszenny et al., 2004]).

iii) Total volatile inorganic Br and I every 6 hours or less (filter pack, neutron activation analysis, [Pszenny et al., 2004]).

iv) Total particulate Br, I, Na, and Al in size-segregated aerosols every 12 hours or less (cascade impactor, neutron activation analysis, [Arimoto et al., 1997]).

v) Pending successful methods development, speciation of size-resolved particulate I every 12 hours or less (cascade impactor, chromatography).

vi) Size-resolved aerosol pH every 12 hours or less (thermodynamics of measured phase partitioning, [Keene et al., 2004]).

vii) Size-resolved aerosol LWC every 12 hours or less (hygroscopicity models [Keene et al., 2004]).

viii) Dry-deposition fluxes of size-resolved particulate species every 12 hours or less (following the modeling approach of Hummelshøv et al. [1992])

Coupled reactive gaseous halogen cycling through marine aerosol

Species in *italics* will be measured during the RHaMBLe Cape Verde intensive