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Two Column Aerosol Project (TCAP) and Aerosol Mixing State

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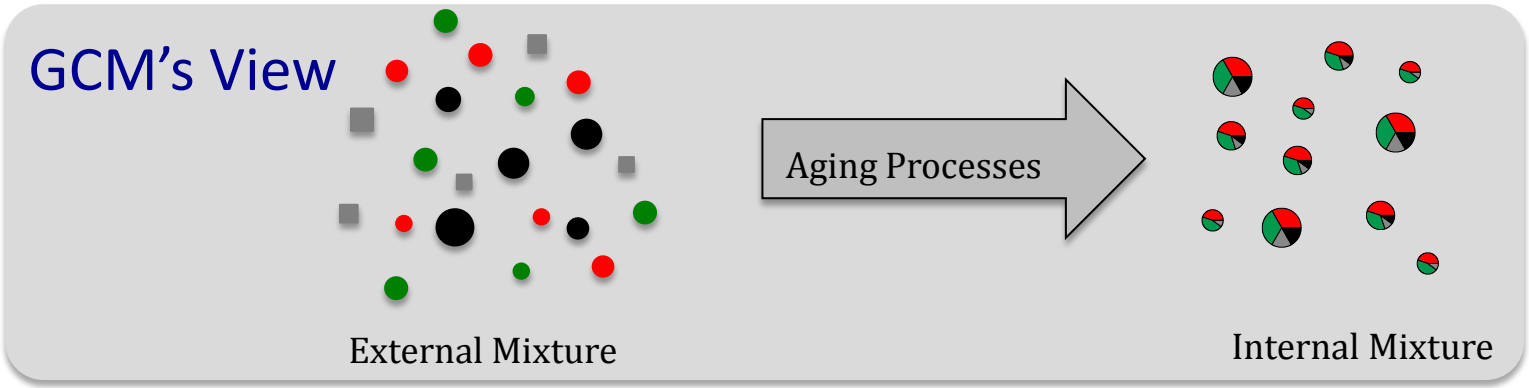
Mixing state: What do we mean?

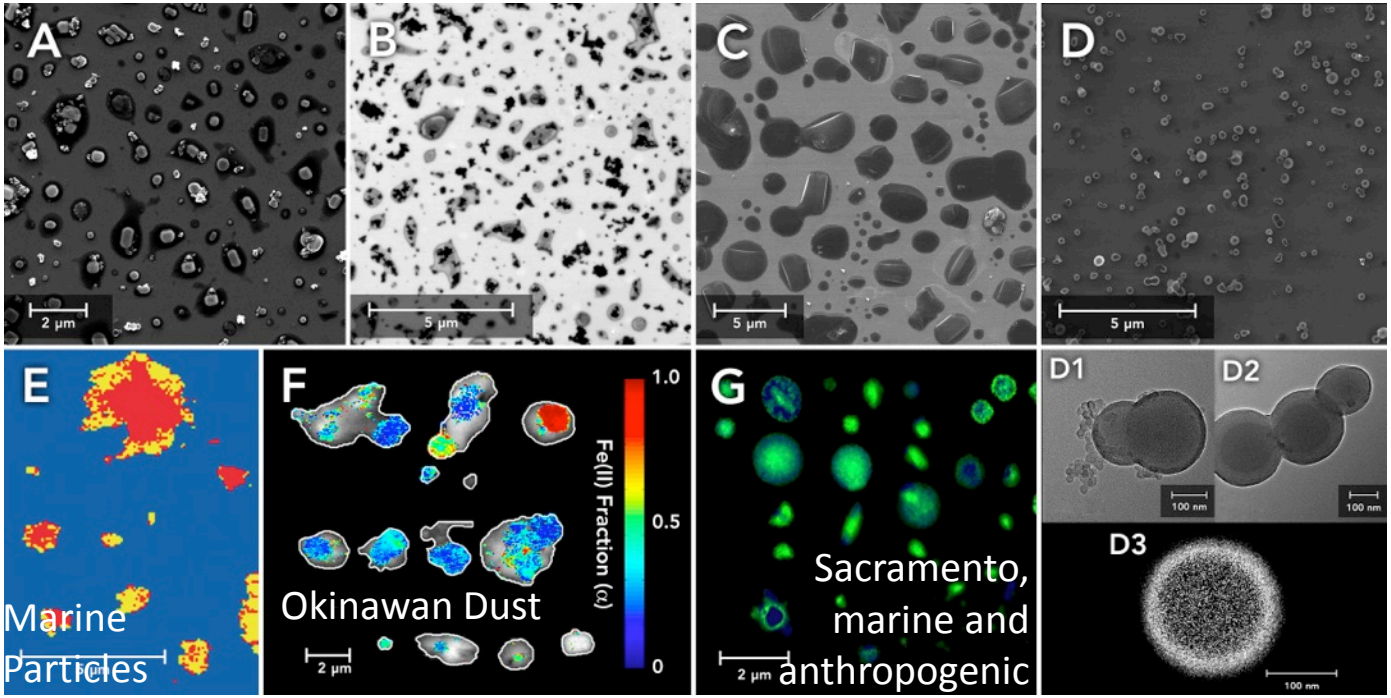


Mexico City: Inorganics coated with SOA

LA: BC coated with SOA

Internally mixed organics/sulfate

Biomass burning tar ball particles



Nature's View

A. Moffet et al. 2010
B. Wang et al. 2012
C. Zaveri et al. 2010
D. Hand et al. 2005
E. Liu et al. 2011
F. Moffet et al. 2012
G. Laskin et al. 2012

TCAP: A new field campaign

Two column, multi-season field study

- New instruments and multiple aircraft
- Year-long surface measurements

Designed to address a number of science questions:

- How do primary and secondary aerosol become internally mixed?
- What is the spectral dependence of aerosol optical properties?
- How critical is the particle chemical composition and mixing state in determining the CCN activity?
- What is the relative importance of aerosol indirect effects in maritime boundary-layer clouds?
- How do the aerosol chemical composition, mixing state, and optical properties vary seasonally?
- Can regional and global scale models accurately represent these aerosol properties?

Motivation: Space based aerosol climatology

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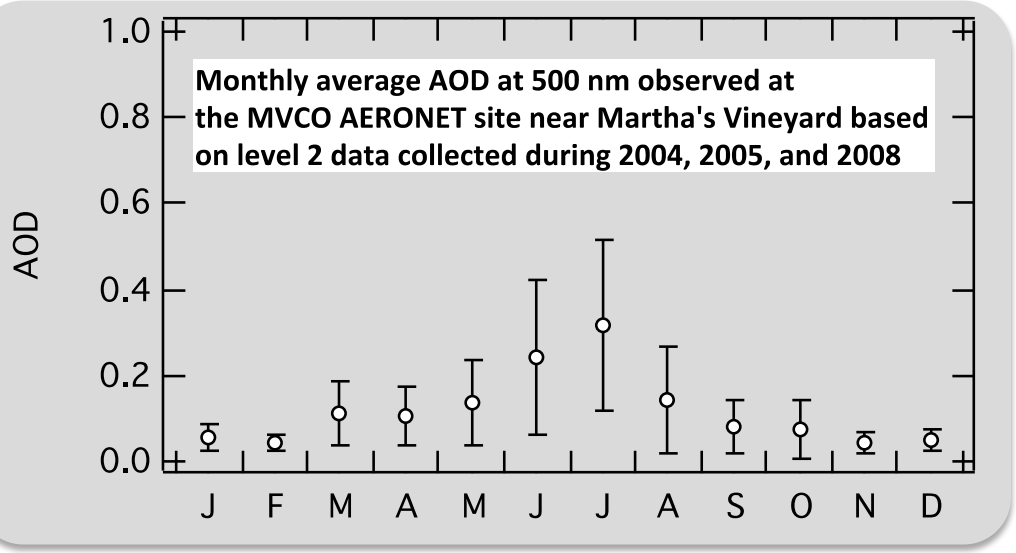
MODIS Terra Feb (2001-2010)

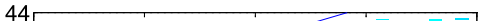
AOD
10:30

Mean AOD



Seasonal Differences

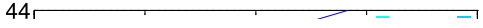
MODIS Terra Jul (2000-2010)



AOD
10:30

Mean AOD

MODIS Aqua Jul (2003-2010)



AOD
13:30

Mean AOD

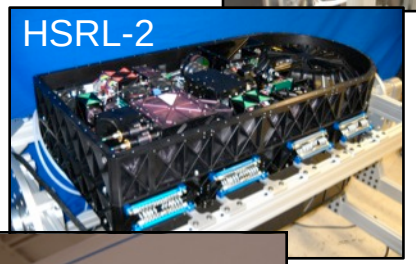
Diurnal Differences

TCAP: Design

- Sample in two columns near the eastern edge of North America
  - First column fixed over Cape Cod—12 month deployment of DOE Atmospheric Radiation Measurement (ARM) Mobile Facility (AMF)
  - Second column moveable over the Atlantic—2 DOE ARM Aerial Facility deployments, 1 NASA deployment

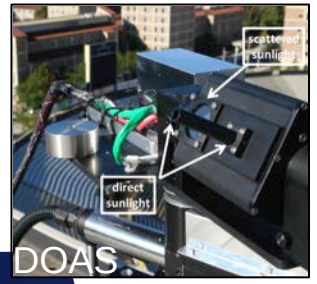
New airborne instruments provide insight

- TCAP was the first science deployment for a number of new instruments
  - Mini-SPLAT—single particle size and composition
  - NASA Spectrometers for Sky-Scanning, Sun-Tracking Atmospheric Research (4STAR)—AERONET-like capability
  - NASA High Spectral Resolution Lidar (HSRL-2)—Aerosol backscatter, extinction, depolarization, AOD (532 nm); aerosol backscatter, depolarization (1064 nm)
- Plus additional state-of-the-art instruments
  - Aerosol Mass Spectrometer—Aerosol composition
  - SP2—BC
  - PILS—Aerosol composition
  - Aerosol optical properties [scattering, absorption, f(RH)]
  - Aerosol size distribution
  - CCN
  - Research Scanning Polarimeter (RSP)
- CVI inlet



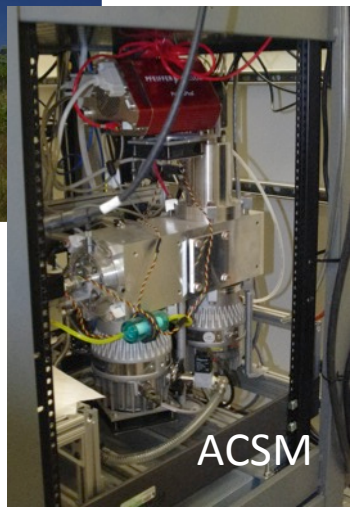
New surface instruments provide insight

- TCAP was the first science deployment for a number of new instruments
  - CU 2D GMAX-DOAS—Aerosol extinction, trace gases (summer)
  - MIT CCN-CVI-AMS—Composition of particles that form CCN (winter)
- Plus additional MAOS instruments
  - Aerosol Chemical Speciation Monitor (ACSM)—Aerosol composition
  - SP2—BC
  - Photo-acoustic—BC
  - PILS—Aerosol composition
  - PTRMS
  - Particle size distribution
  - CCN
  - Trace gases
  - Radiation, both broad band and spectrally resolved



DOAS


MAOS


ACSM

TCAP flights

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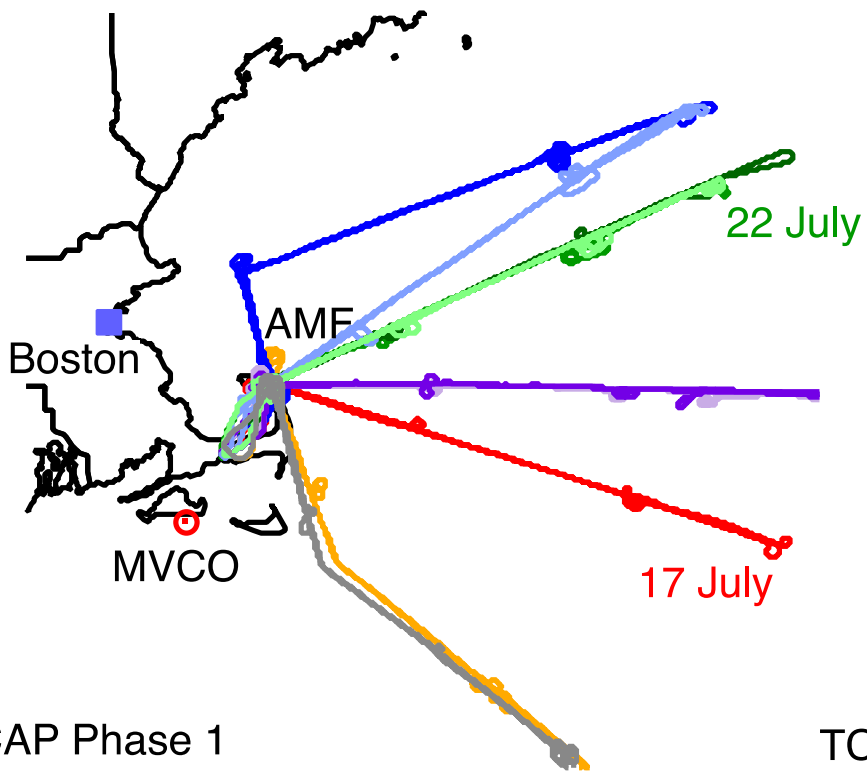
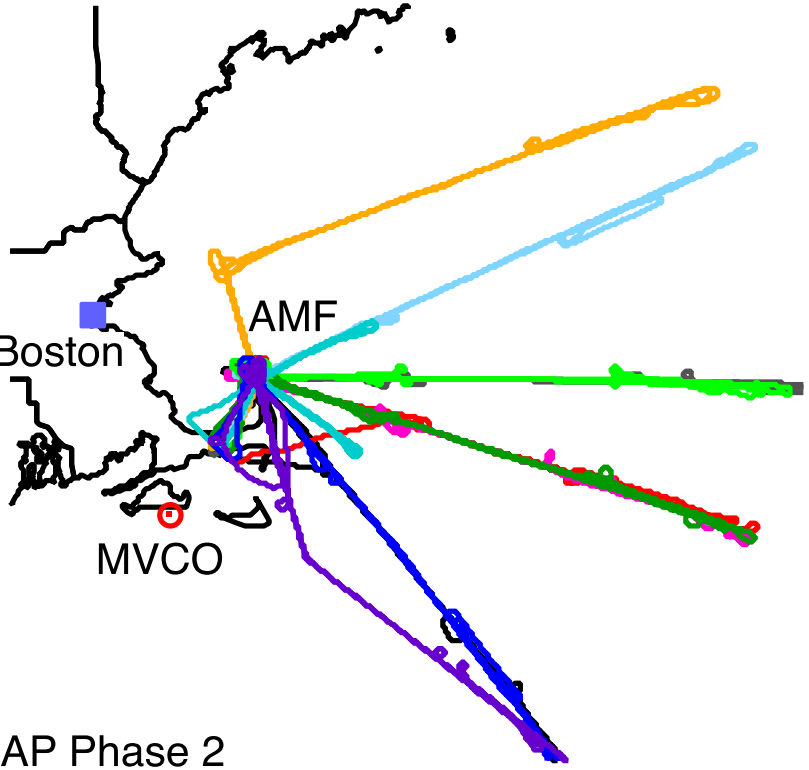
Clear air flights



TCAP Phase 1

10 Flights

Mixture of clear air and cloudy flights
Clear: 5 Cloudy: 9

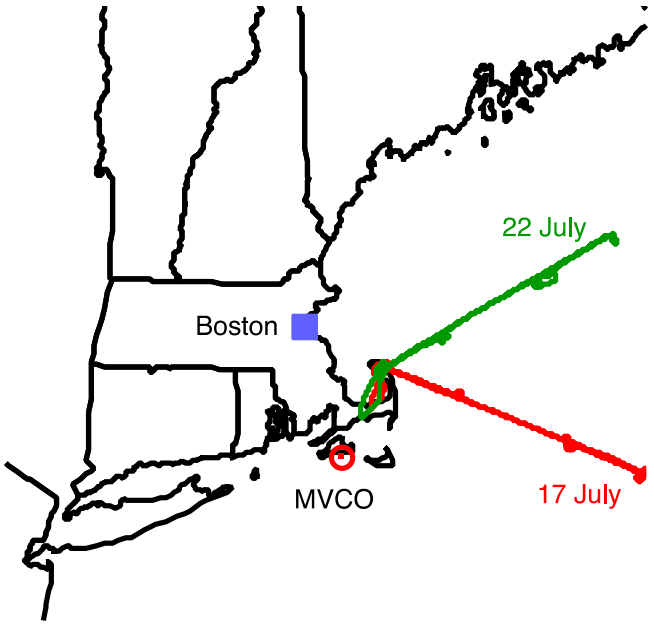


TCAP Phase 2

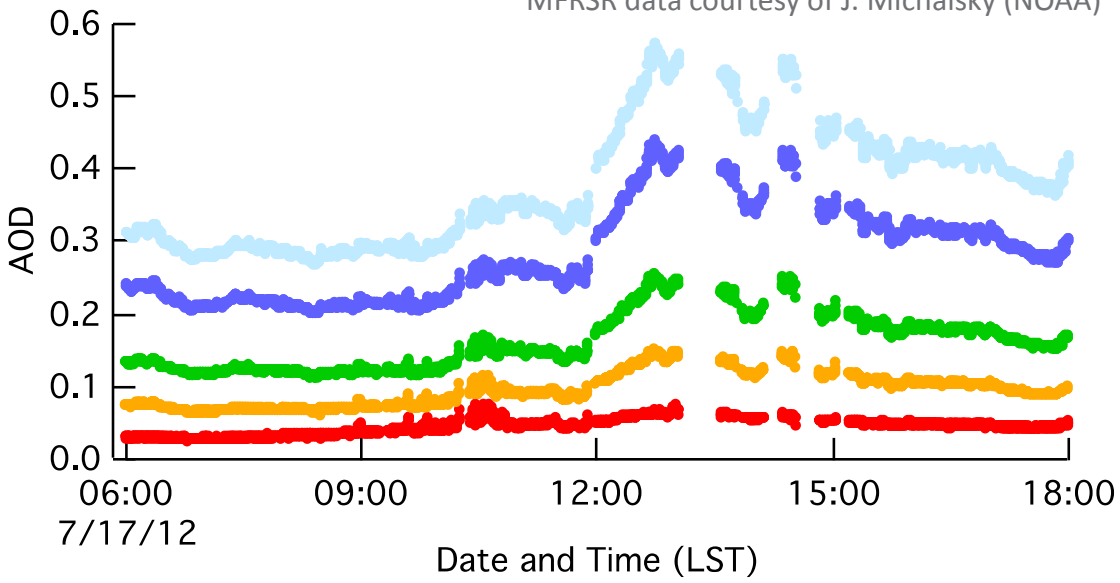
14 Flights

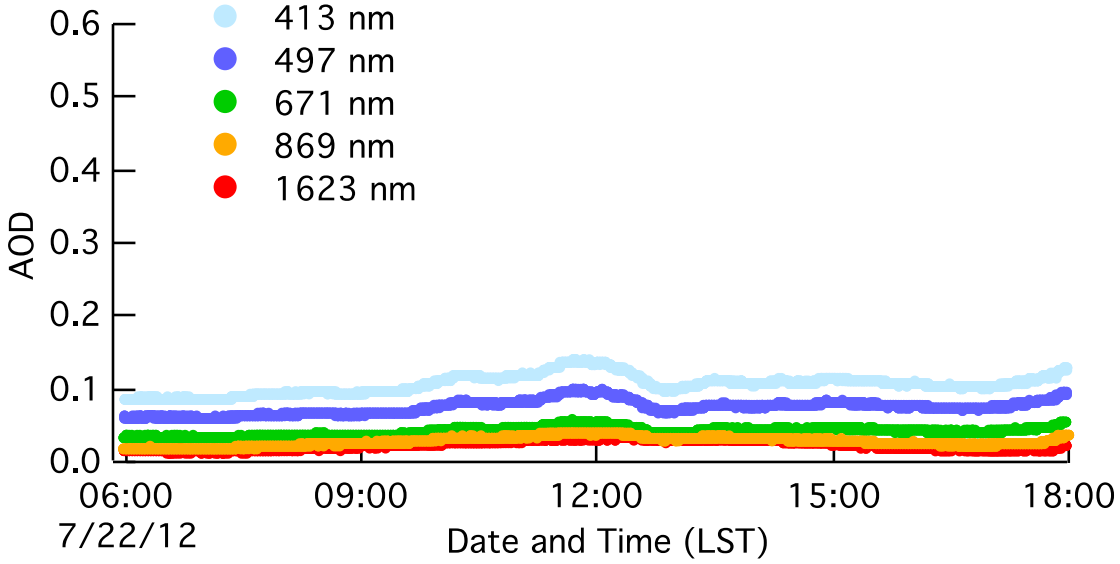
A tale of two days

- Two clear days were selected (no clouds over the AMF site)
- Much larger AOD on 7/17 than 7/22
  - Differences in aerosol loading or other aerosol properties?



MFRSR data courtesy of J. Michalsky (NOAA)





Aerosol loading

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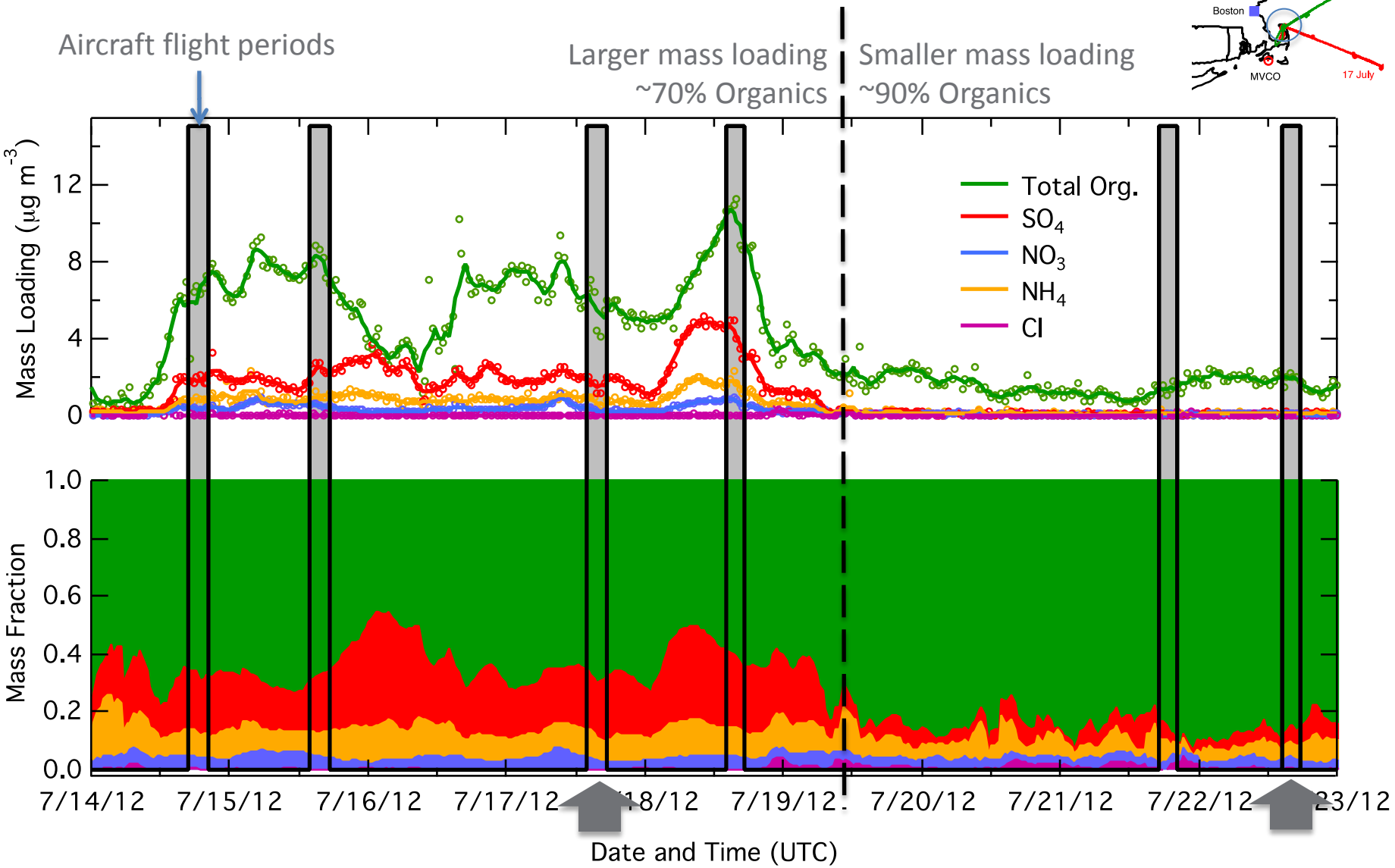
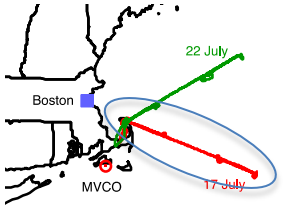
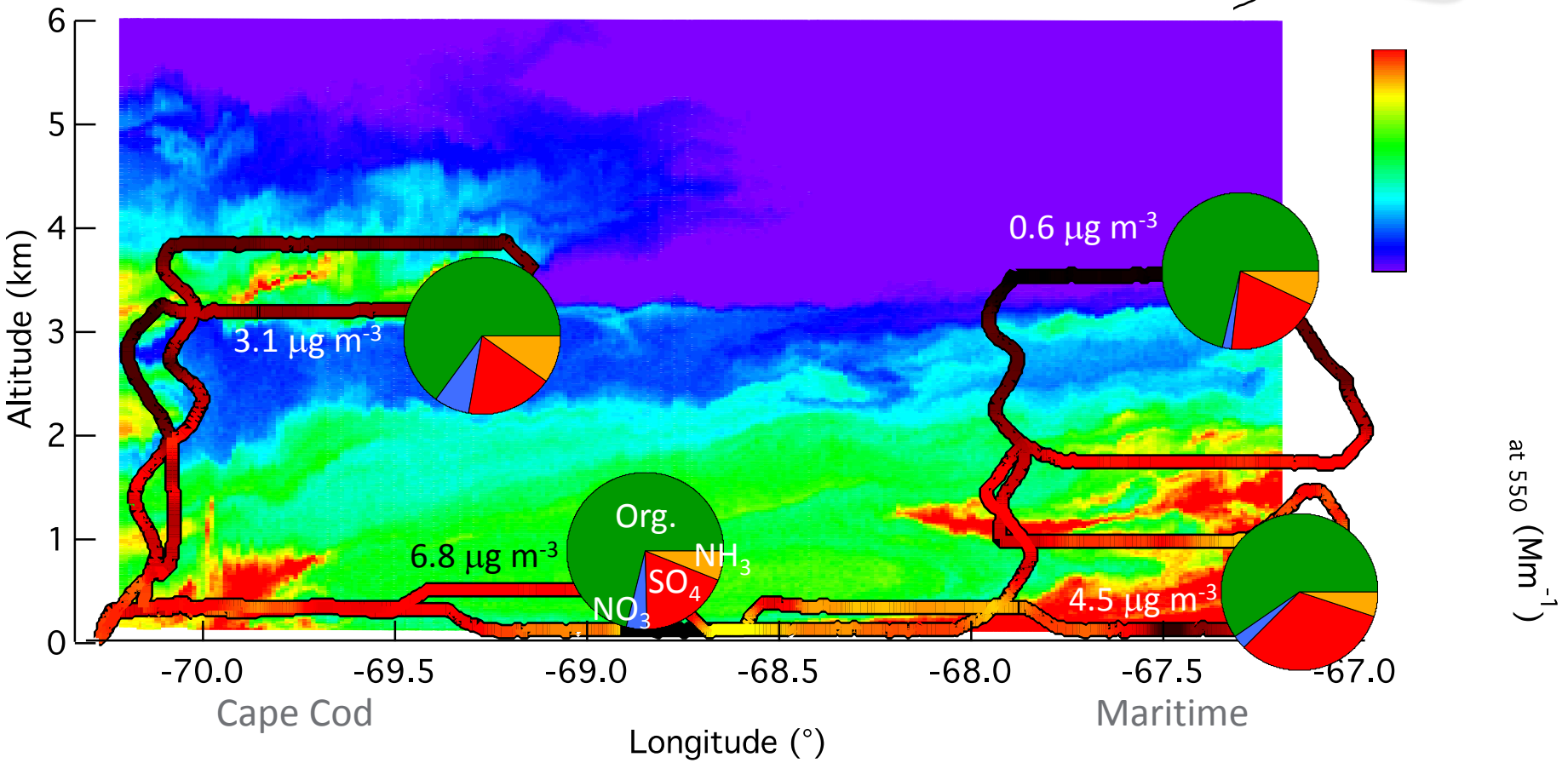
- Measurements from Aerosol Chemical Speciation Monitor



Aerosol layers: 17 July

- Deep residual layer over the ocean
- Some elevated layers aloft near Cape Cod





BC mixing state and the SP2

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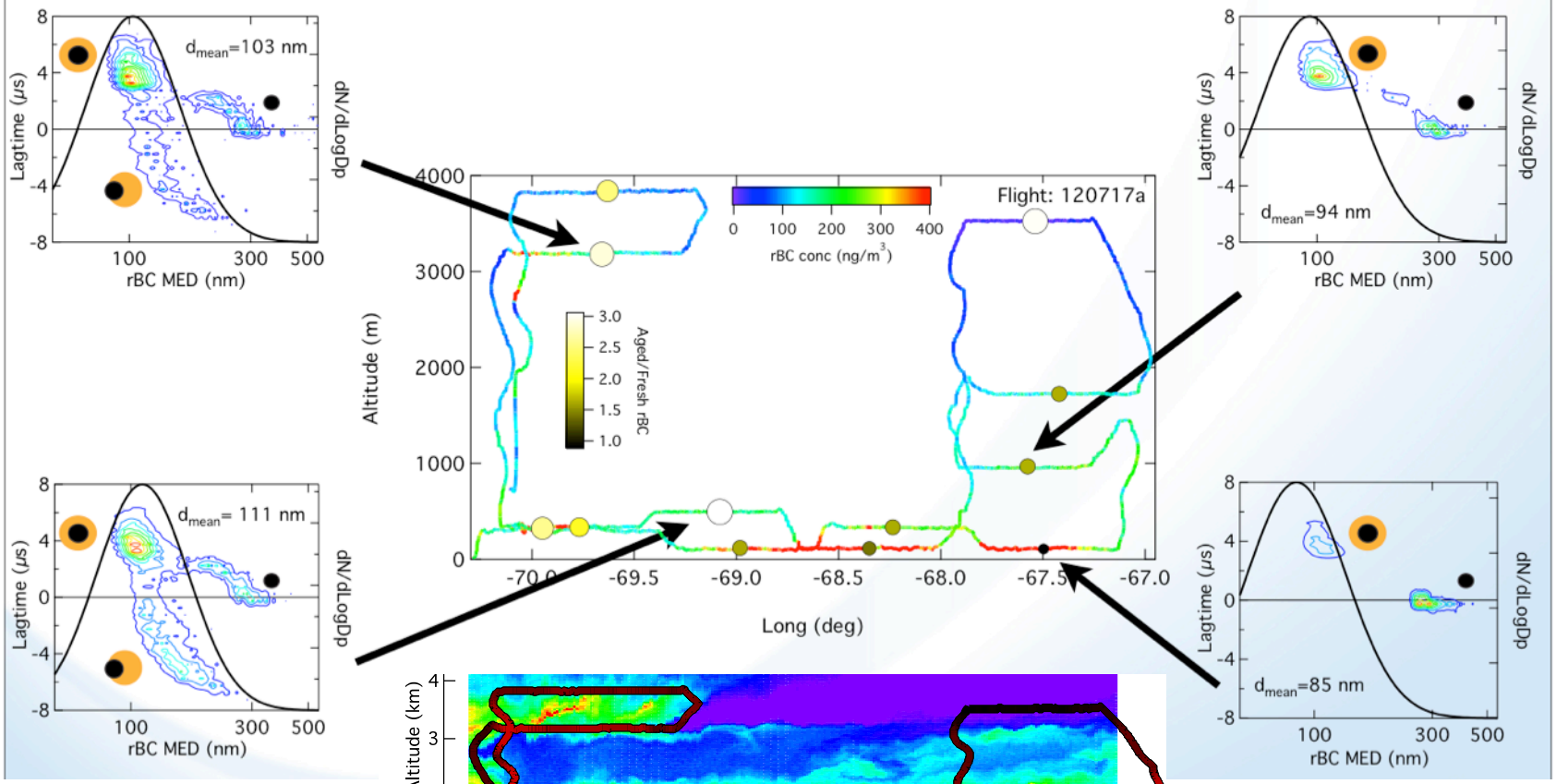
BC Fingerprints

SP2 Lagtime analysis suggests significant variations in rBC-particle morphology.
Variations in particle morphology accompanied by differing size distributions



Slide presented by Art Sedlacek at TCAP Breakout

Aerosol mixing state: July 17

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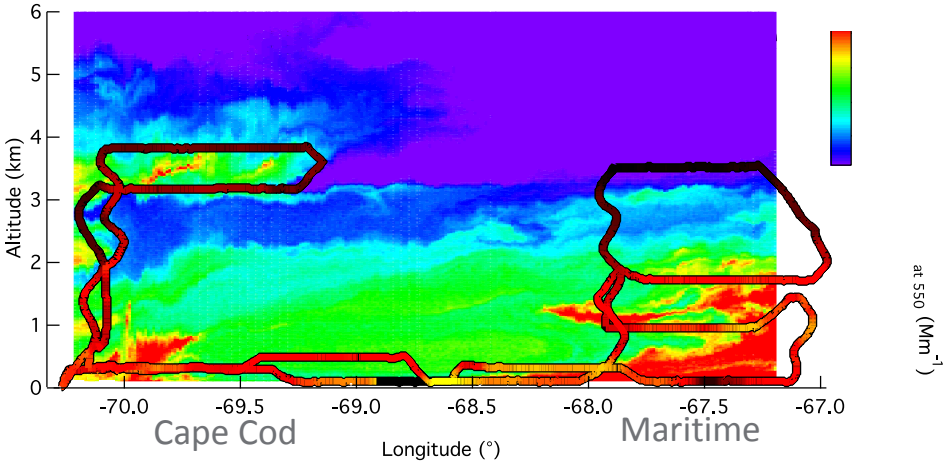
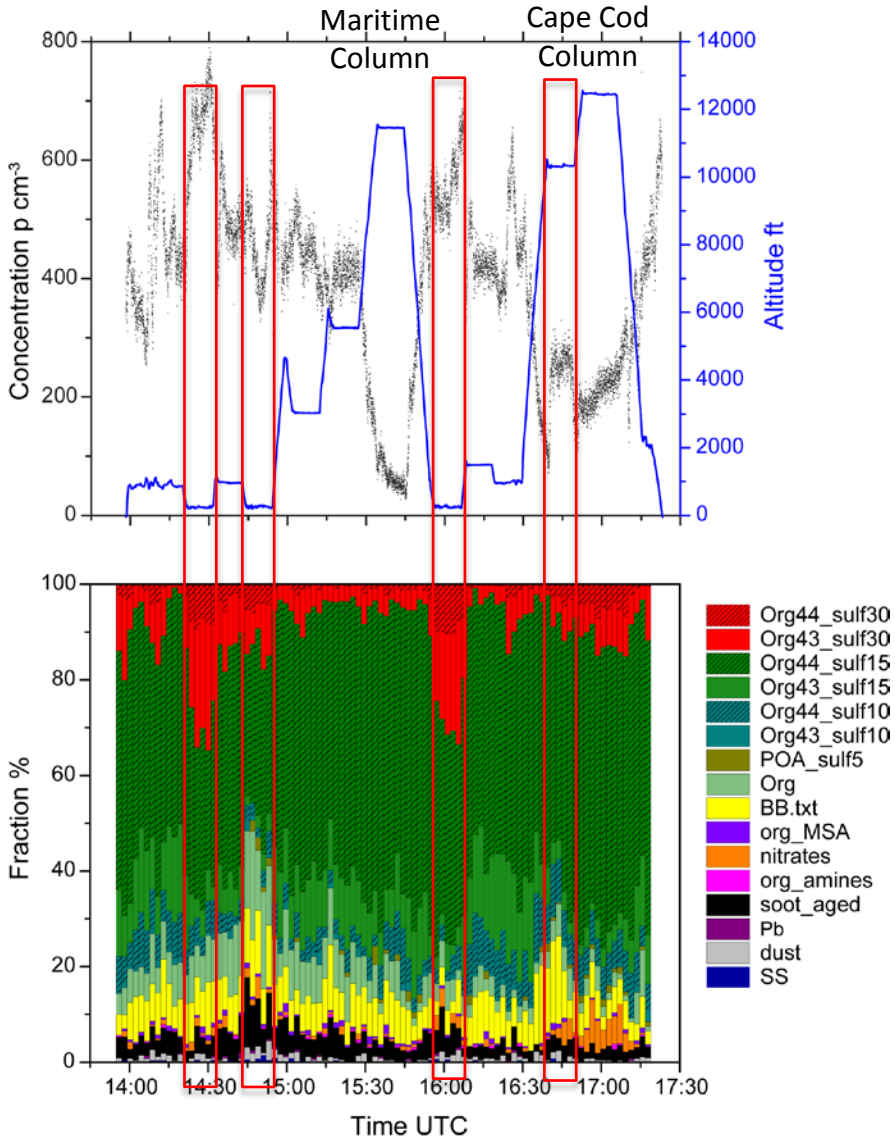
SPLAT

- Lower altitudes have larger fraction of sulfate mixed with the organics
- More aged soot in maritime column—consistent with SP2 measurements
- Elevated layer over over the AMF has increased biomass





WRF back trajectories

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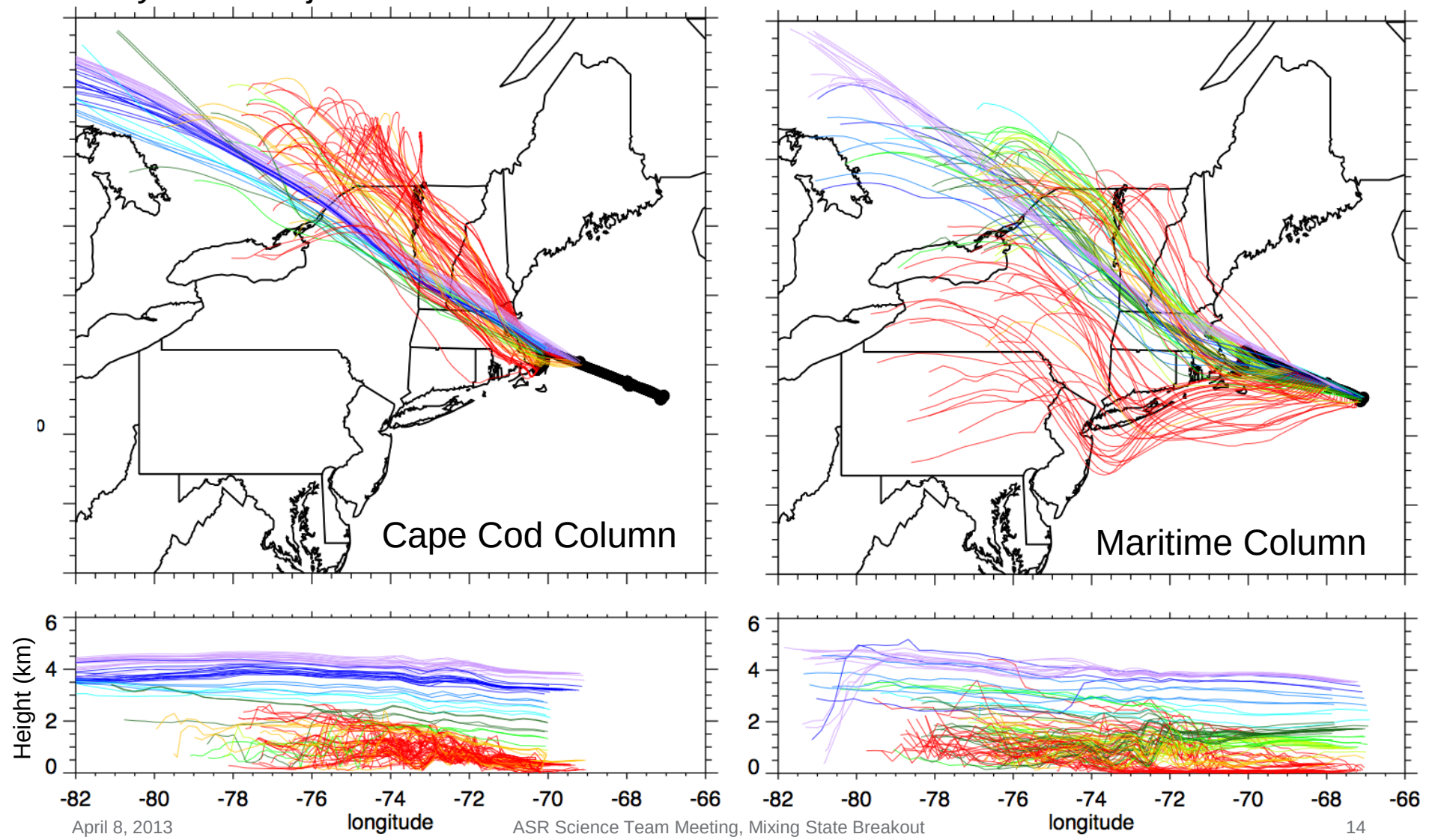
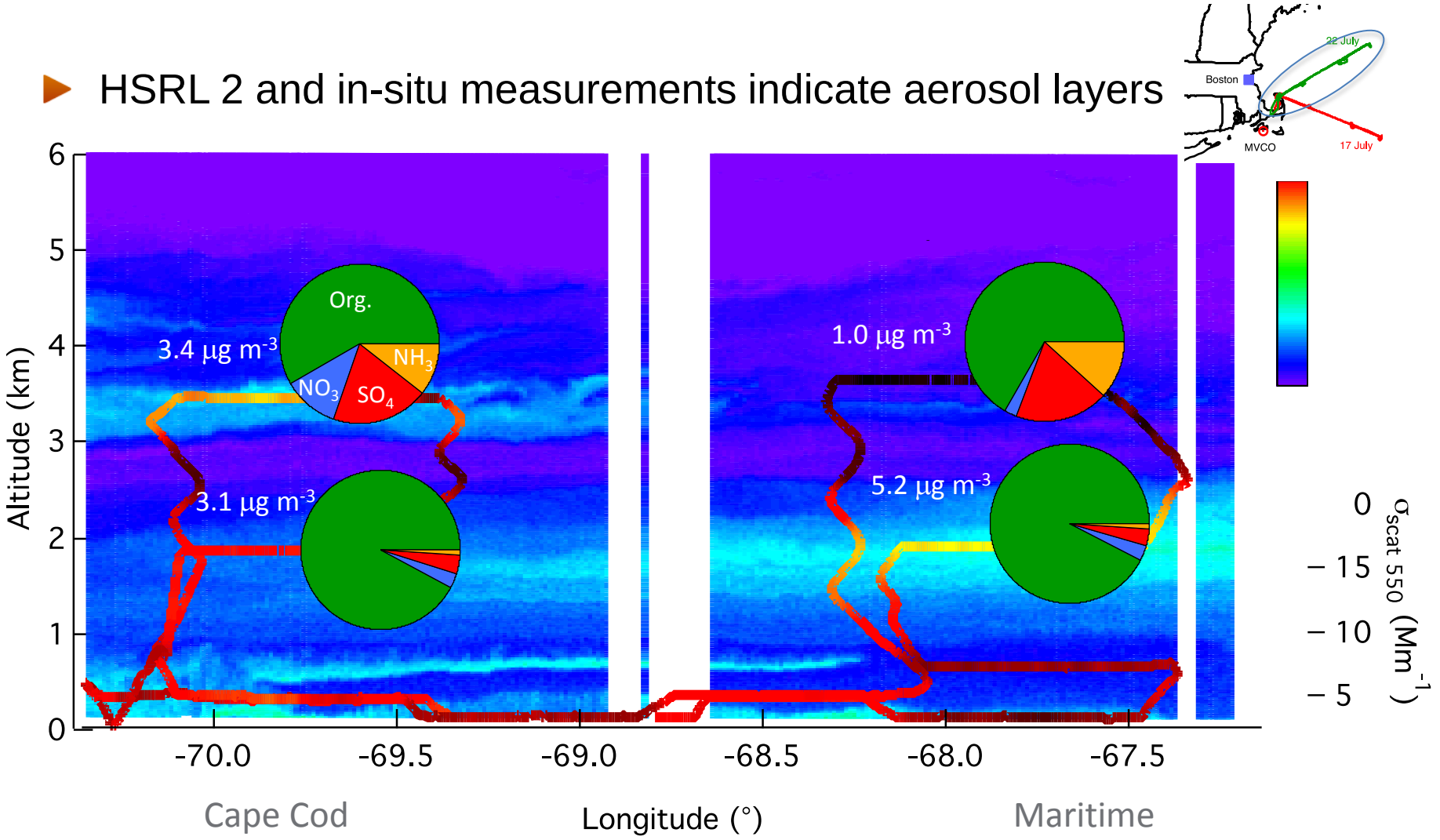
2-Day Back Trajectories



Aerosol layers: 22 July

- HSRL 2 and in-situ measurements indicate aerosol layers

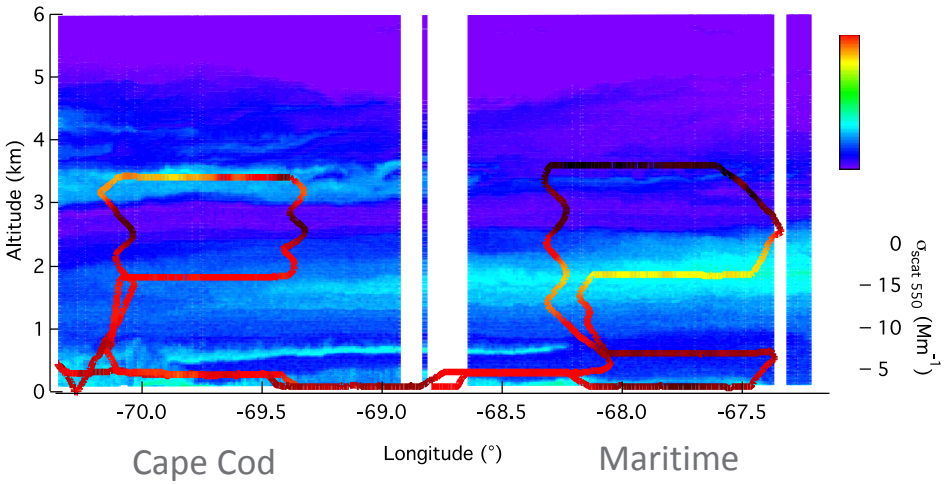


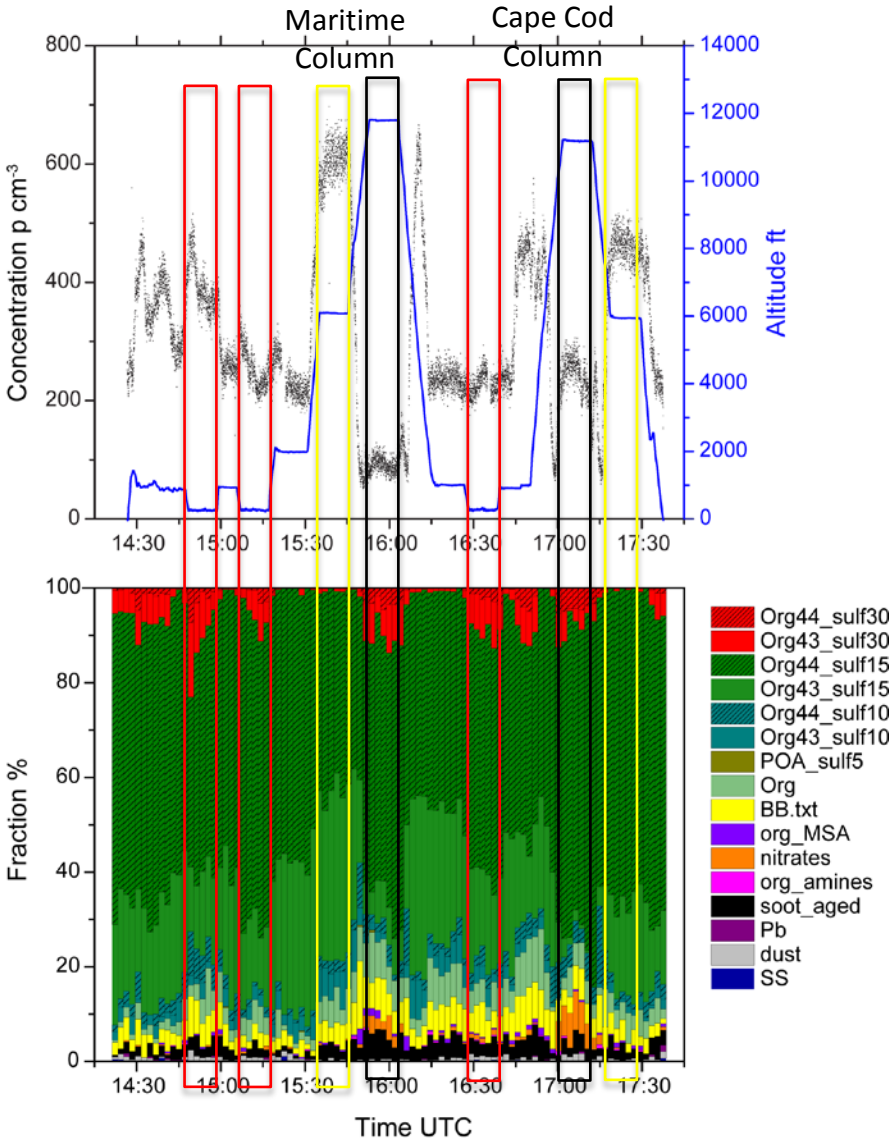
- AMS shows changes in chemical composition

Aerosol mixing state

miniSPLAT

- Lower altitudes have higher fraction of sulfate mixed with the organics
- Elevated layer over over the AMF has increased biomass burning aerosol and nitrate





BC mixing state and the SP2

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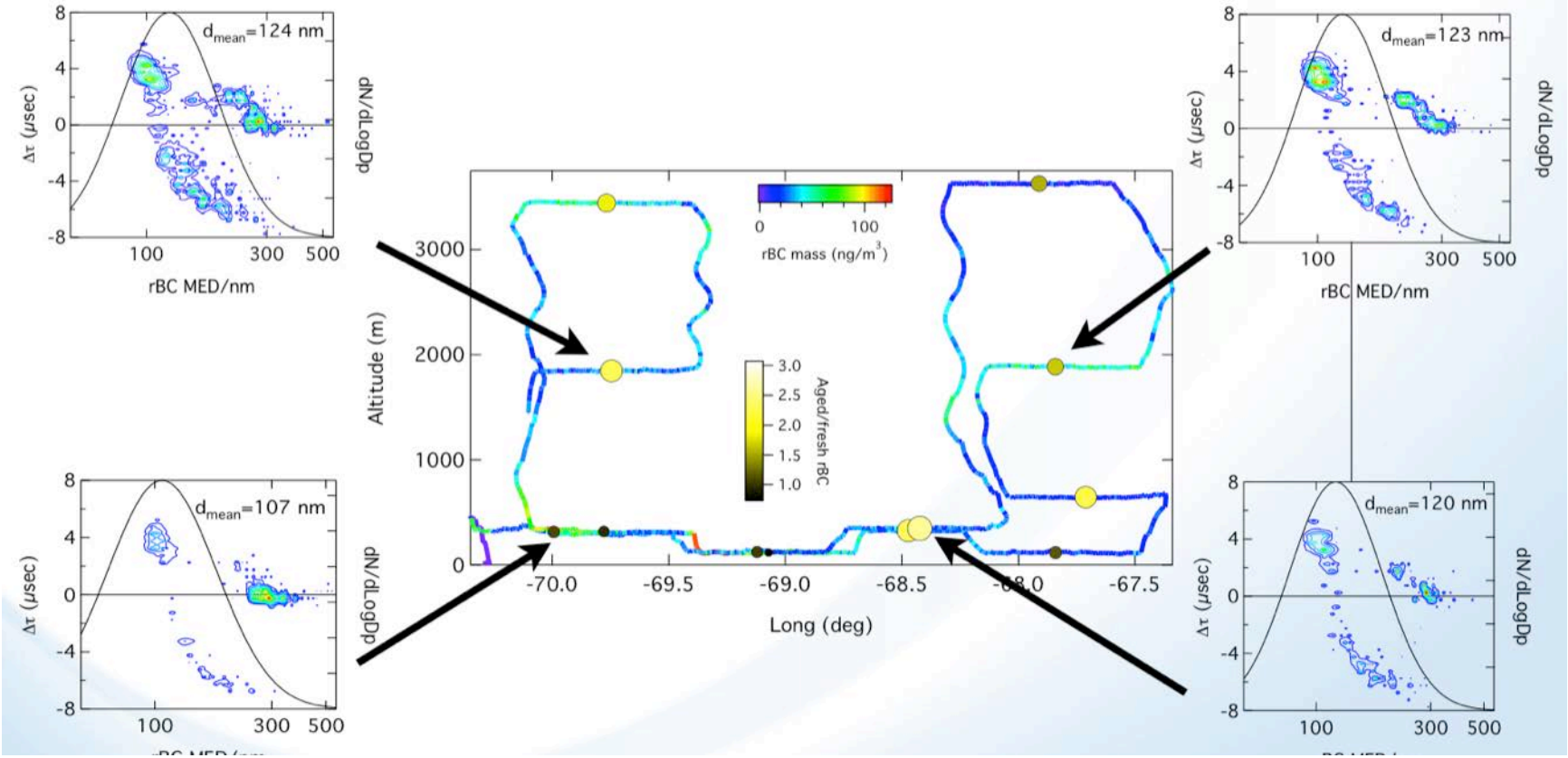
Variation in rBC-particle morphology appears to be less than than observed on July 17.



Slide presented by Art Sedlacek at TCAP Breakout

Conclusions and future Work

- A high quality set of in situ and remote sensing data were and are being collected
  - Both IOPs have been completed
  - A wide range of aerosol loading was observed
- Case study of periods with clean and dirty conditions show a change in aerosol loading, chemical composition, mixing state, and arrangement of rBC
  - Ideal test cases for intercomparison of active and passive remote sensing techniques
  - Rigorous tests of a range of 3-D and box models
- Data analysis is ongoing—radiative and CCN closure studies
- Evaluating regional and global scale models
- Analysis of Phase 2 has just started

Acknowledgements: This work has been supported by the US Department of Energy via the Atmospheric Science Research (ASR) and Atmospheric Radiation Measurement (ARM) programs. Special thanks to the individuals associated with the ARM Climate Research Facility's Aerial and Mobile components.

Thank you

TCAP Website—http://campaign.arm.gov/tcap/
ARM Data Archive—http://www.archive.arm.gov/

BC Mixing State: 17 July

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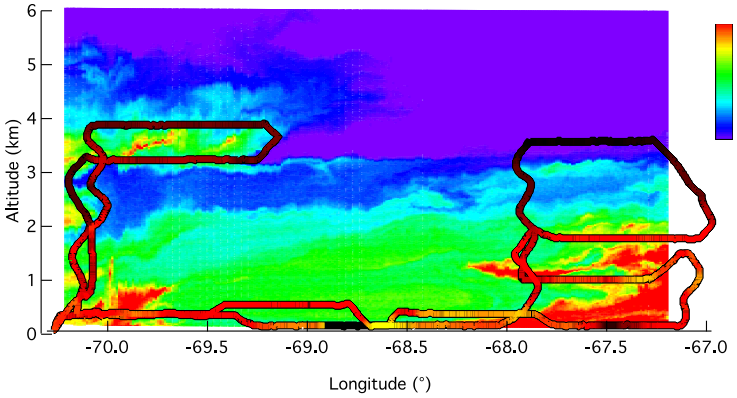
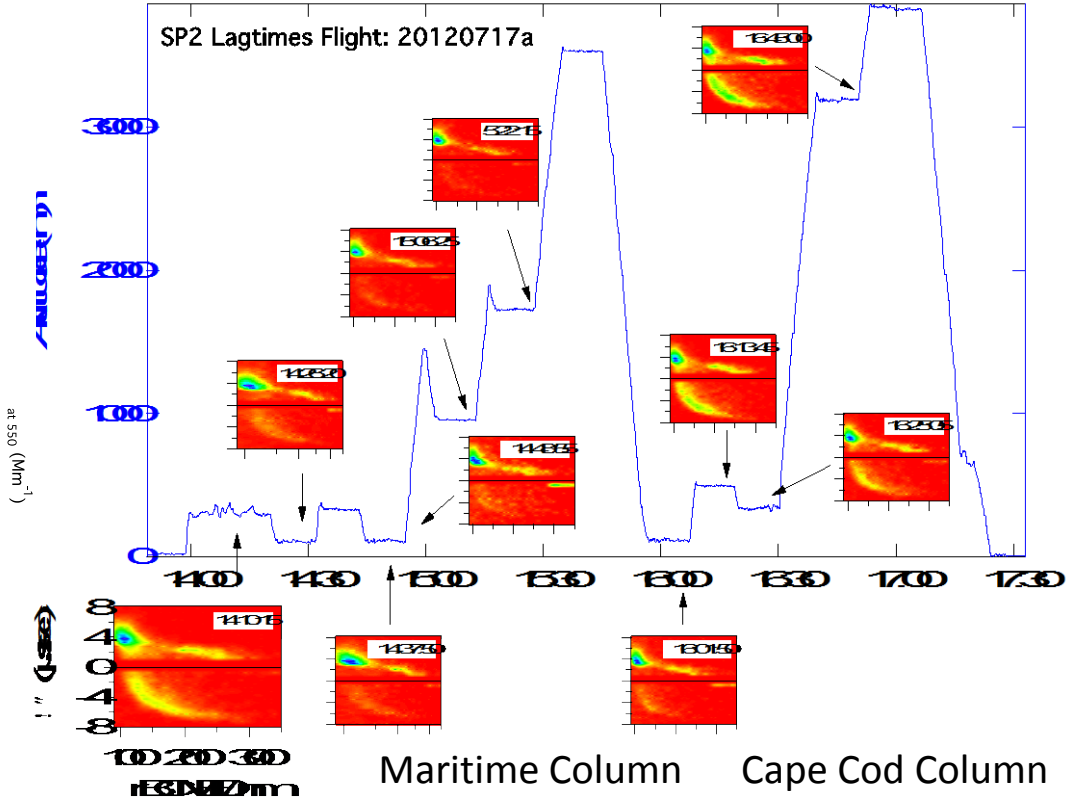
SP2

- Measures scattering and incandescence from individual particles
- Lag time ($\Delta\tau$) — time difference between peak in scattering and incandescence
  - Negative values: BC near surface



Cape Cod Column

Maritime Column



Maritime Column

Cape Cod Column

Maritime column has fewer negative values of $\Delta\tau$

2-Line Header for New PNNL PowerPoint Presentation Template

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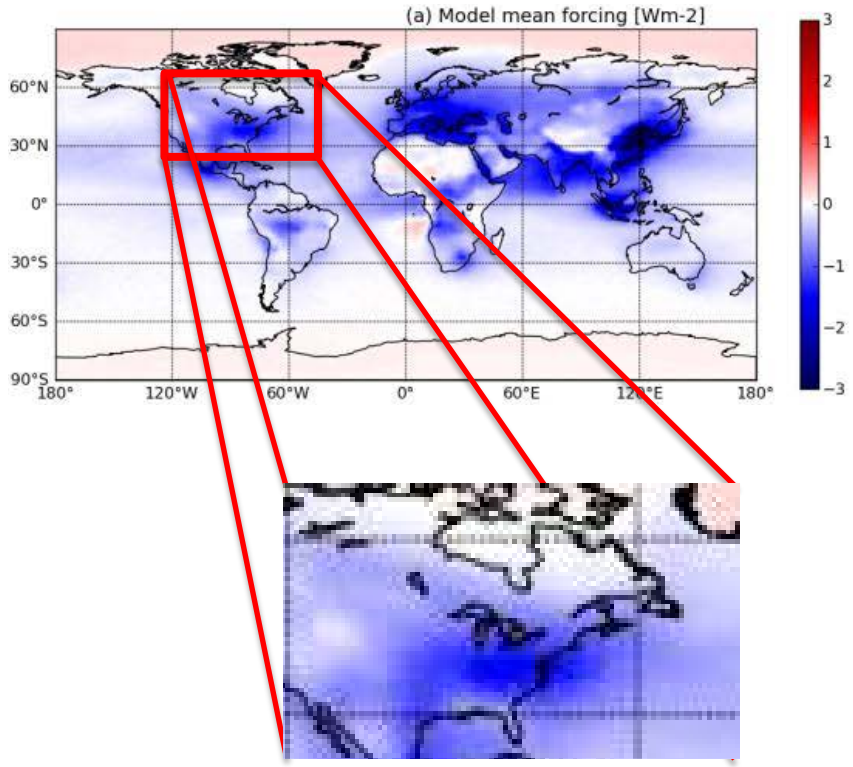
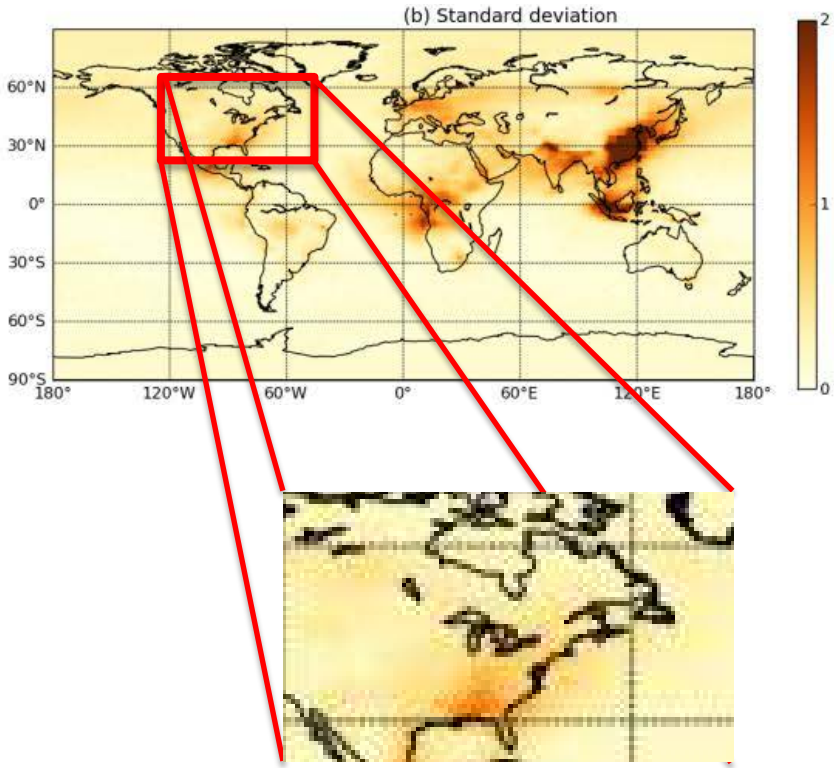
Motivation for TCAP

- Global models show a large gradient and standard deviation of AOD along the coast (e.g. AeroCom II)
- Large Standard deviation between models

Myhre et al. 2012

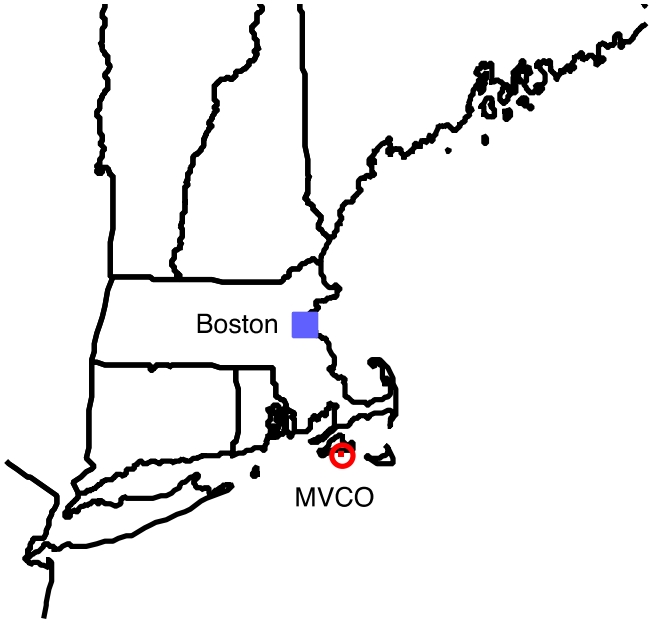


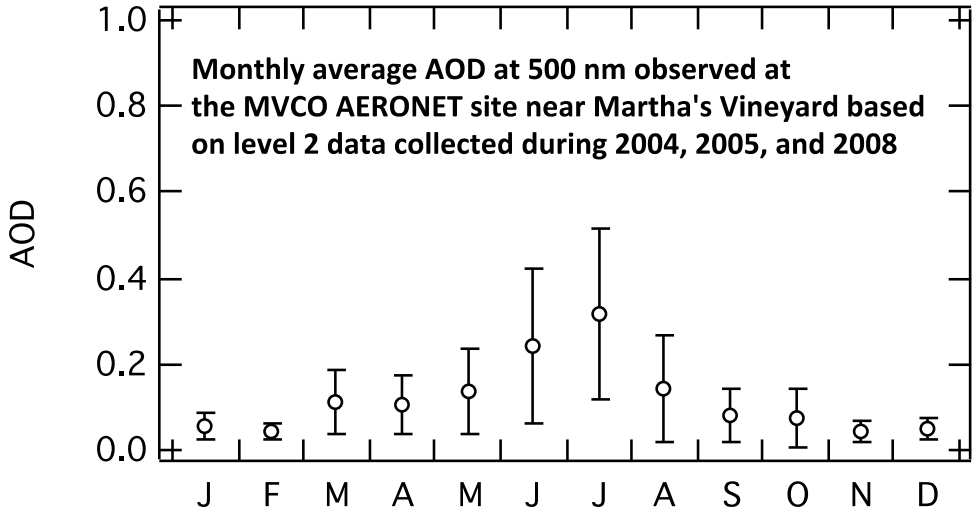


Research Need: Data to constrain models

Motivation: Surface based aerosol climatology

- AOD has a seasonal cycle
  - Related to emissions (both natural and anthropogenic) and available sunlight
- Role of near-surface vs. elevated aerosol in AOD





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