Observations and Research at Howard Beltsville Facility in Support of DISCOVER-AQ

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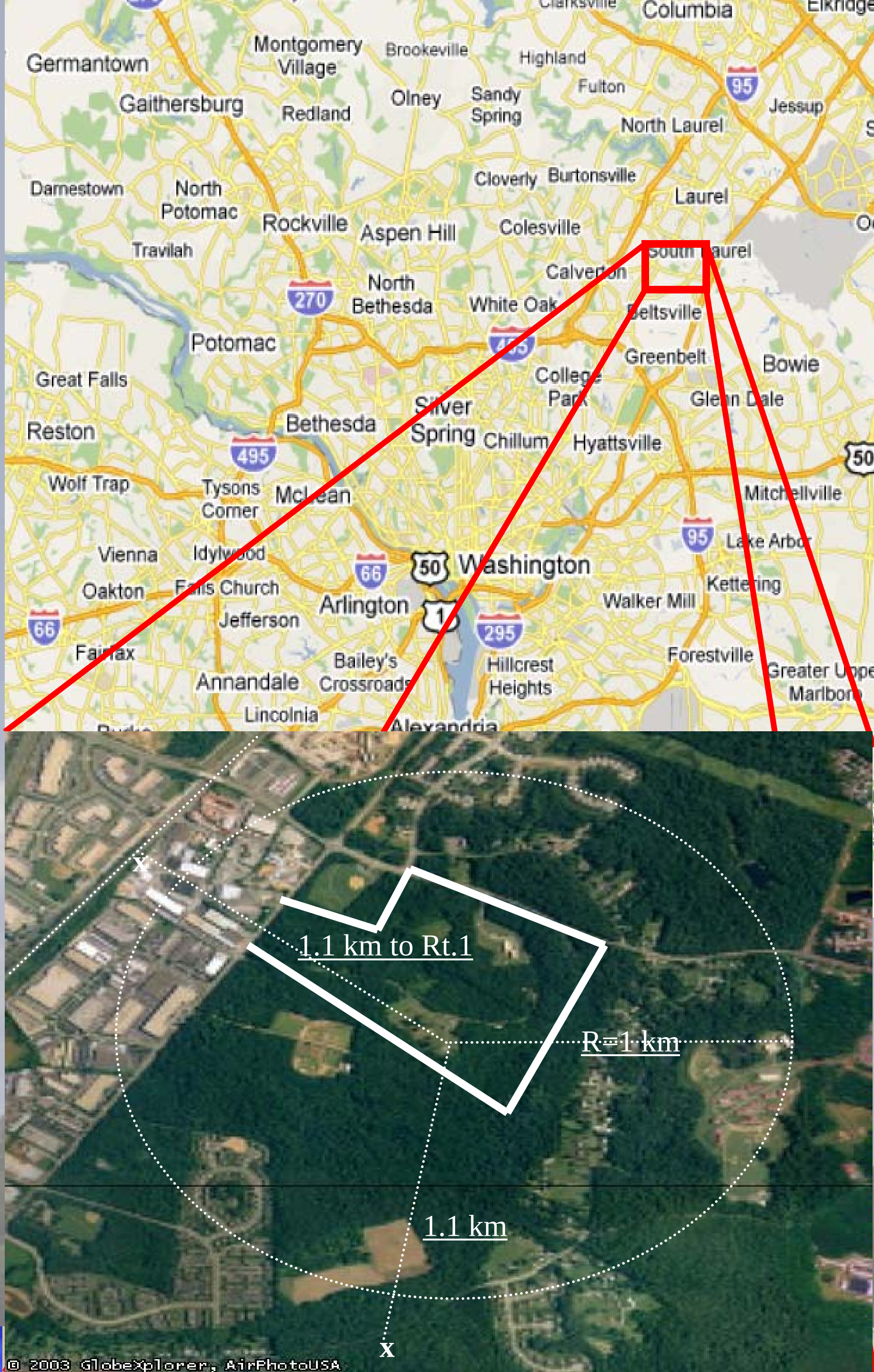
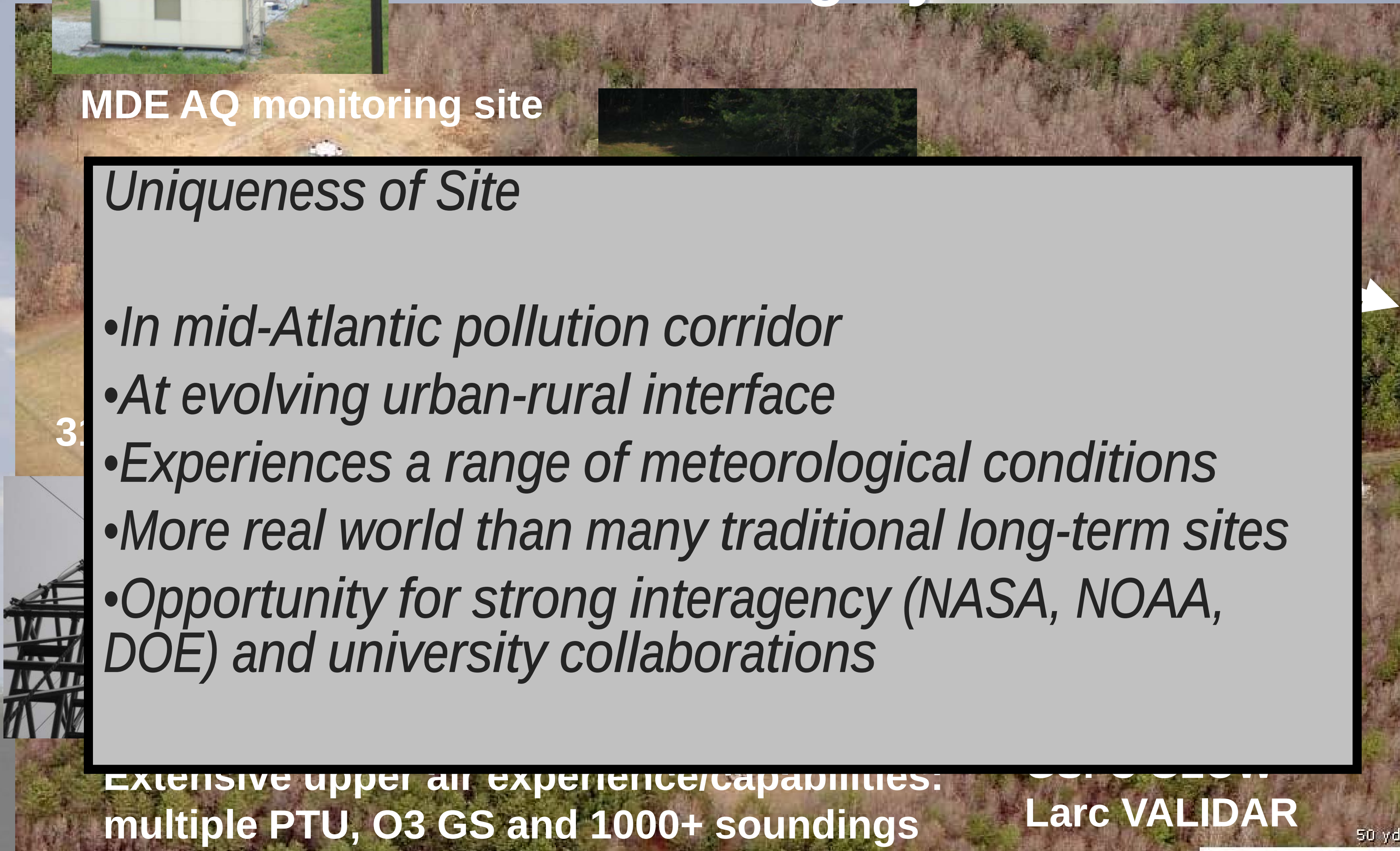
HU Beltsville Research

- Basic research to improve weather, climate, and air quality prediction through intensive and long-term atmospheric field experiments
- Student training with emphasis on understanding atmospheric processes through use of state-of-the-art atmospheric observing systems and analytical methods
- Contribute to national and international climate and environmental monitoring (SURFRAD, BSRN, DCNet GCOS, etc)



Comprehensive Set of In Situ Observing Systems

MDE AQ monitoring site



Uniqueness of Site

- *In mid-Atlantic pollution corridor*
- *At evolving urban-rural interface*
- *Experiences a range of meteorological conditions*
- *More real world than many traditional long-term sites*
- *Opportunity for strong interagency (NASA, NOAA, DOE) and university collaborations*

Extensive upper air experience/capabilities: multiple PTU, O3 GS and 1000+ soundings

Larc VALIDAR

50 yds

Major Projects at HU Beltsville

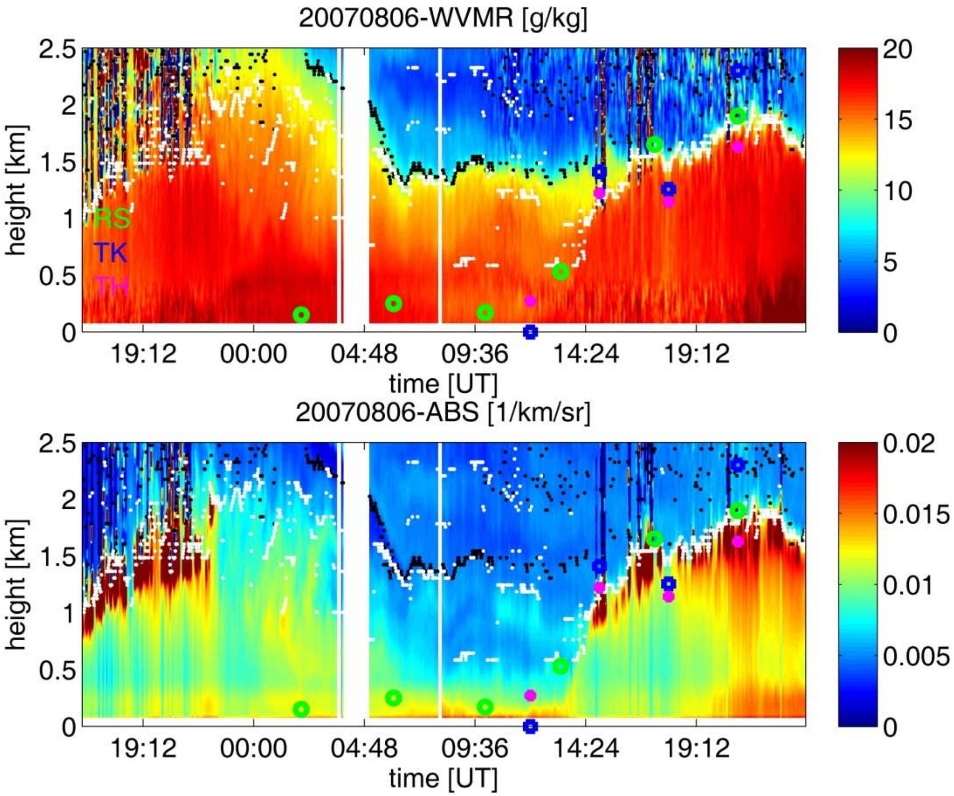
- NOAA Center for Atmospheric Sciences (NCAS) – a NOAA/CSC
- NASA/Howard Beltsville Center for Climate System Observations (BCCSO) – a NASA URC
- Water Vapor Variability Experiment – Satellite/Sondes (WAVES; AURA Cal/Val)
- Network for the Detection of Atmospheric Composition Change (NDACC)
- Maryland Department of the Environment – (PAMS, Speciation, Toxics networks)
- GCOS Reference Upper Air Network
- Goddard LIDAR Observatory for Winds (GLOW)

NCAS Example

Hicks
Adam
Robjhon

PTU soundings supporting development of PBL products from HURL and together verification of PBL parameterizations in numerical models

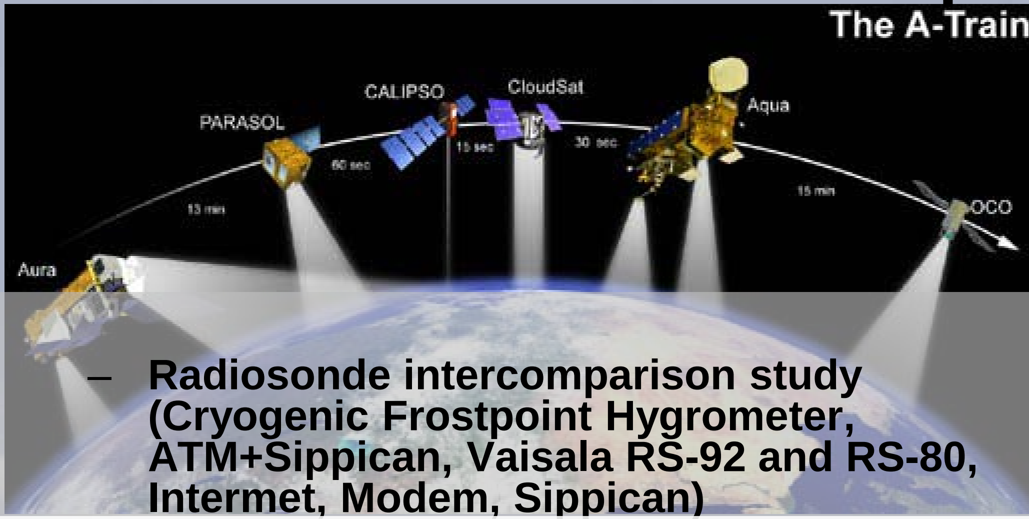
- *Important for improving accuracy of AQ, dispersion (Homeland Security), and mesoscale weather forecast.*
- *Aug 6-7 Case*
  - *HURL PBL height derived from the aerosol backscatter (white dot) shows a good agreement with that from radiosonde (green); Hicks and Adam have developed improved product*
- *Model (MYJ and TKE) produced too deep PBL height with respect to that from the HU lidar (white) and radiosonde (green)*
- *MYJ Theta PBL (magenta) heights were closer to observations*



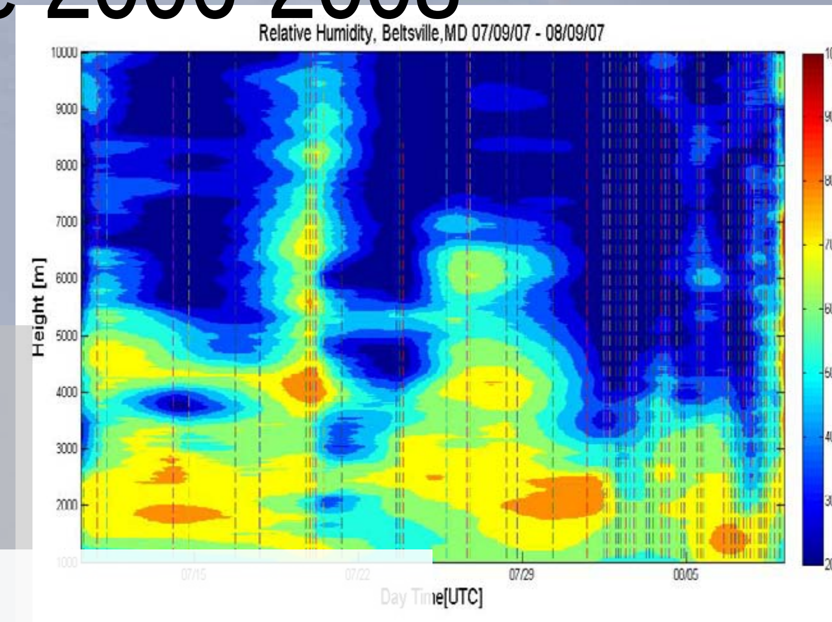
Time-height plot of water vapor mixing ratio (top) and aerosol backscatter (bottom) derived from the HU lidar from August 6 – 7, 2007

Overlayed are PBL heights from radiosonde (green), MYJ TKE PBL (model; blue), and MYJ Theta profile (magenta)

WAVES Example 2006-2008



- Radiosonde intercomparison study (Cryogenic Frostpoint Hygrometer, ATM+Sippican, Vaisala RS-92 and RS-80, Intermet, Modem, Sippican)



Summer 2007 preliminary RH time series at Beltsville, MD

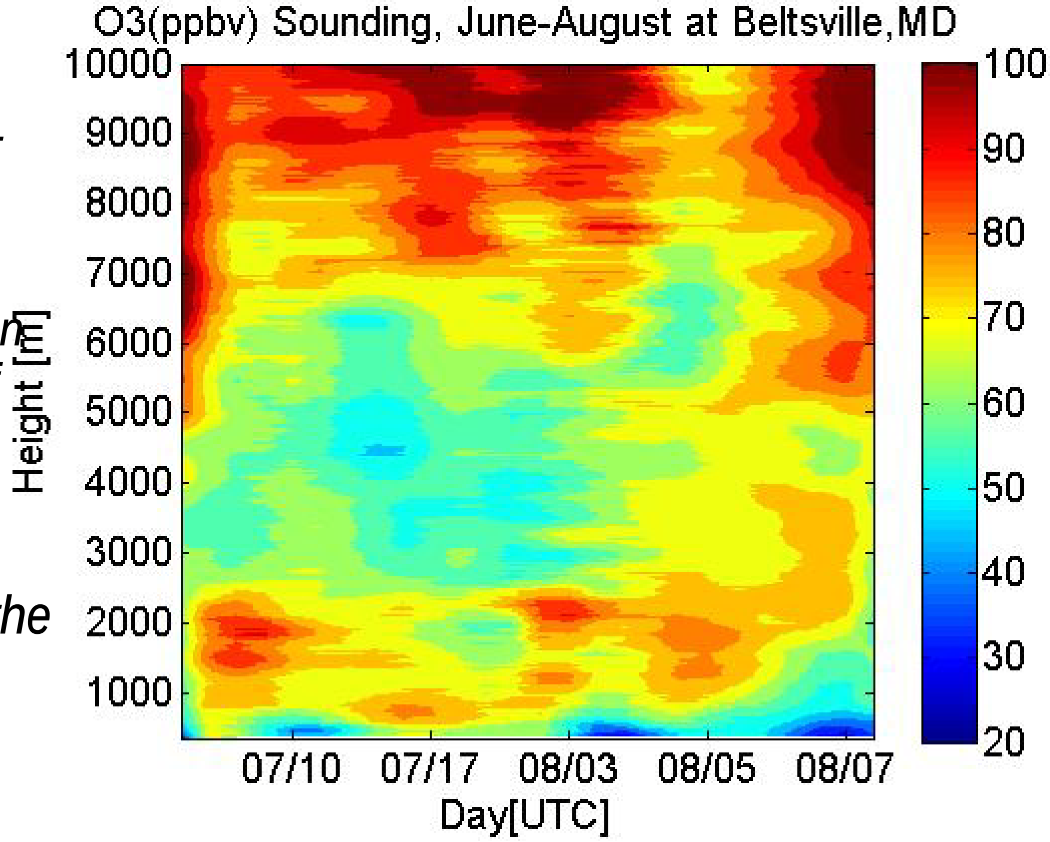
5 papers from JGR special section use WAVES data

1. M. Shephard et. al., Comparison of Tropospheric Emission Spectrometer (TES) Water Vapor Retrievals with In Situ Measurements
2. R. Herman et. al, Validation of Tropospheric Emission Spectrometer Temperature Retrievals with Aircraft and Sondes
3. H. Vömel et. al., Validation of Aura/MLS Water Vapor by Balloon Borne Cryogenic Frostpoint Hygrometer Measurements
4. R. Nassar et. al., Validation of Tropospheric Emission Spectrometer (TES) Nadir Ozone Profiles Using Ozonesonde Measurements
5. B. Nardi et. al., Initial Validation of Ozone Measurements from the High Resolution Dynamic Limb Sounder (HIRDLS)
6. +More

RASL on a Dynamic Aviation King Air (Bridgewater, VA)

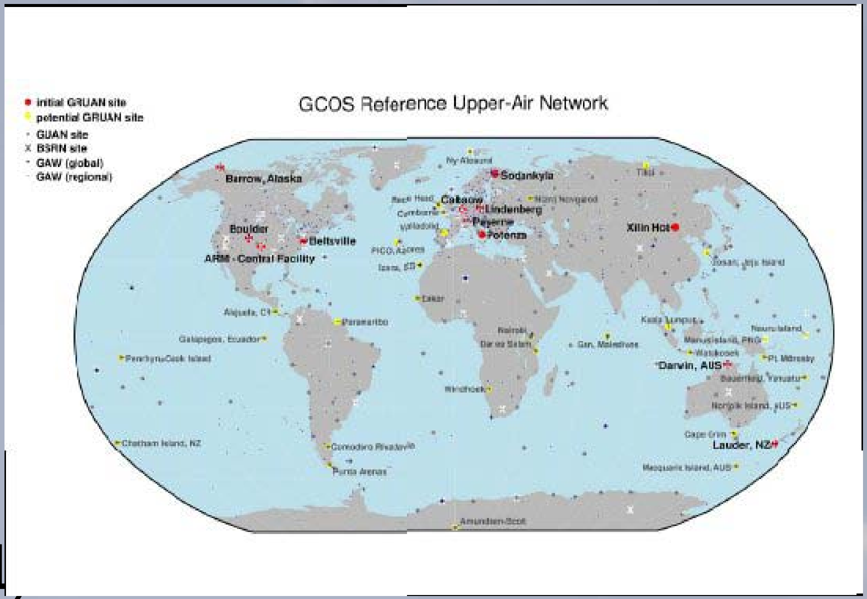
NCAS/MDE/WAVES Example

1. *The Mid-Atlantic Nocturnal Low-Level Jet: Transport and Turbulent Mixing of O3 and Precursors and Implications for Air Quality*
   - *Contribute to AQ model verification and development; development of regional control strategies*
2. *Yorks et al. The Variability of Free Tropospheric Ozone Budgets over Beltsville, Maryland (39N, 77W) in the Summers 2004-2007 (submitted)*
   - *Potentially important results for understanding Midlad strat/trop exchange, regional transport, etc processes within context of sat cal/val and AQ model/National Air Quality Forecast System (NAQFS)*



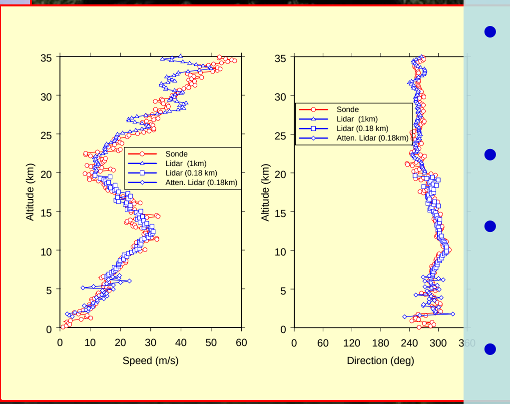
Plot shows O3 time-heights WAVES 07:
Several poor air quality episodes 7/9-11, 7/14-17, and 8/4-5
Stratospheric intrusion are also apparent

GCOS Reference Upper Air Network (GRUAN)



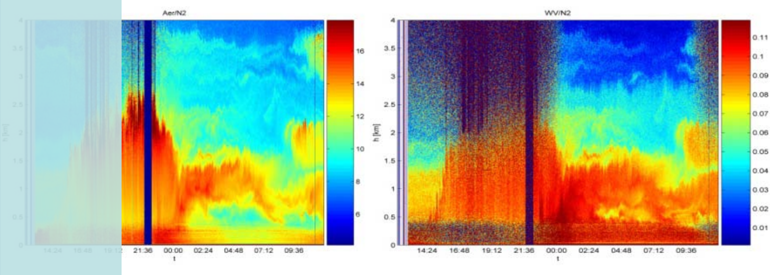
- WMO initiative (GCOS-112, GCOS-121)
- Establish an initial set of 12 stations globally (4 in U.S.)
  - "start small, but start"
  - 1x weekly production radiosonde with the best technology currently available at the site
  - monthly UT/LS sounding, multiple package launches, periodic intercomparisons of large range of sondes, regular daily 00 and 12 LST launches of best available technology
- Develop a reference radiosonde suitable for climate monitoring
- Regular GRUAN operations at Beltsville to began in 2009

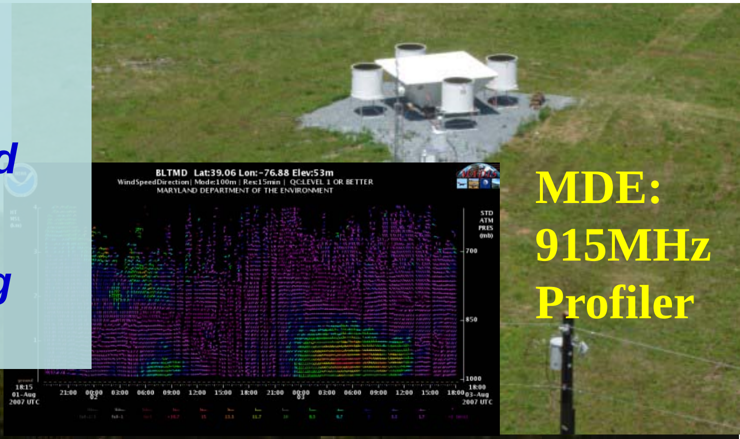
WIND IOP at Beltsville

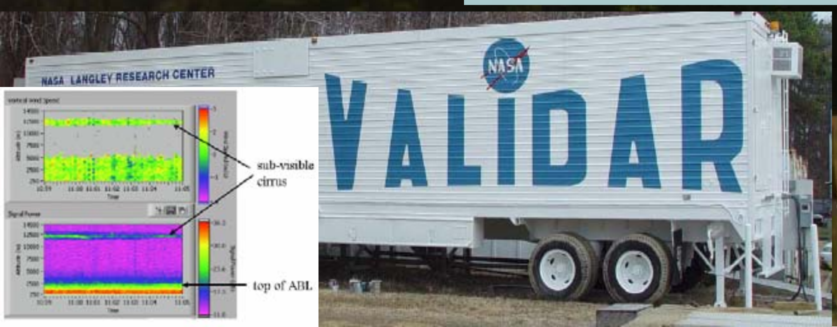


Summary of Objectives

- *Seasonal statistics wind lidar performance*
- *Performance in different aerosol/RH (via-HURL)*
- *Performance in cirrus clouds*
- *Synergy vis-à-vis other current/planned sensors*
- *Intercomparison of coherent and direct detection lidars*
- *Provide educational and training opportunities to students*







BCCSO

NASA Science Mission Directorate Questions

1) How is the global Earth system changing?
2) What are the primary causes of change in the Earth system?
3) How does the Earth system respond to natural and human-induced changes?
4) What are the consequences for human civilization?
5) How will the Earth system change in the future?

URC Atmospheric Composition Thrust

URC Weather Thrust

Research teams (fac, collab, students) organized by these 5 sub-areas/questions

- **Quantifying aerosol variability and Impacts on Climate**
- **Monitoring climate variability with reference tropospheric (T and q)**
- **Quantification of free tropospheric O3 budget**
- **Precipitation variability within an urban-rural climate regimes**
- **Proof of concept space-based lidar measurements of winds**

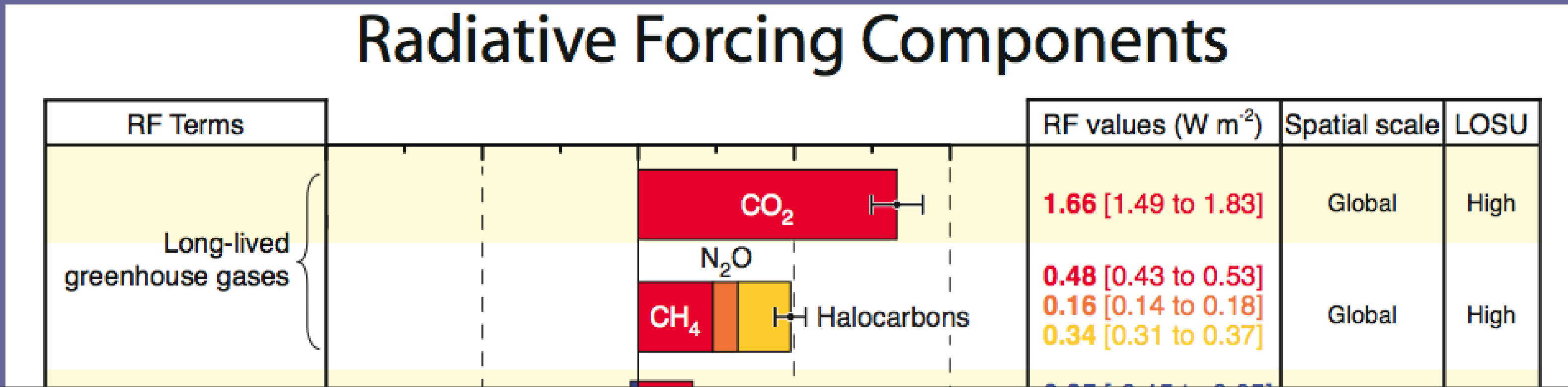
5 sub-areas derive from more specific science questions

Atmospheric Composition Thrust
Specific Science Questions

- How are aerosols changing, and how is that change impacting climate – specifically focusing on the aerosol indirect effects on clouds and precipitation in an evolving urban-rural climate environment?
- What are the long-term trends of relative humidity and temperature in the troposphere and what do those trends reveal about the changing climate?
- What is the short-term and long-term variability of tropospheric ozone, and what are the meteorological factors that control that variability?

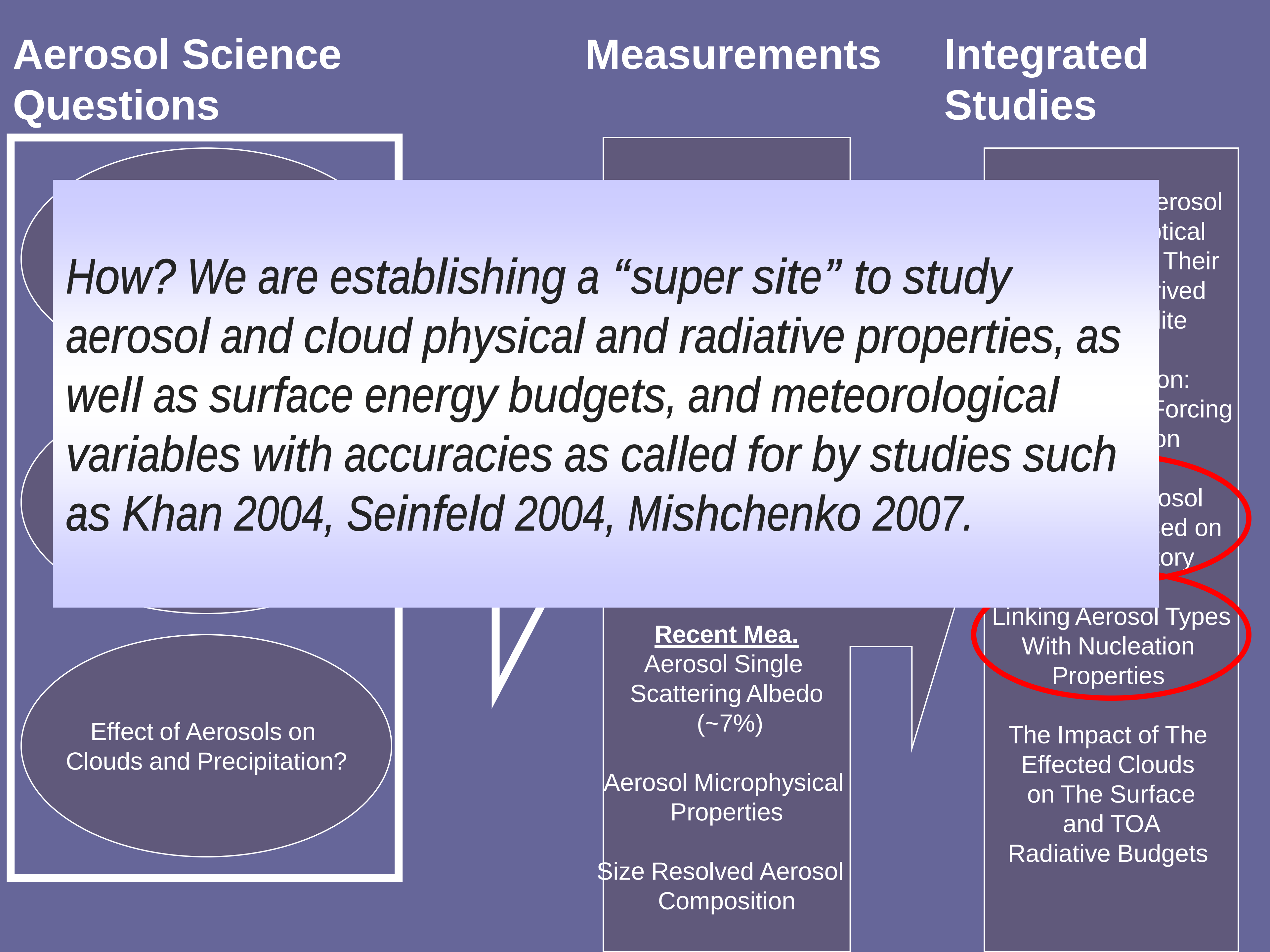
- The answer to these questions are central to efforts to "*understand and improve predictive capability for changes in climate forcing, and air quality associated with changes in atmospheric composition*"

(IPCC Report 2007) Atmos Change 1850 - Present



Comprehensive and accurate observations on a regional scale of aerosol chemical and physical properties and their influences on cloud microphysical properties and surface and top of the atmosphere radiative balances are needed to provide sufficient constraints for more thorough assessment by numerical models (Diner 2004; Seinfeld 2004; and Mishchenko 2007).

The second challenge is how to upscale observed microphysics and chemical processes of aerosols and clouds from laboratory or ambient environments to satellite and the model scales.



Aerosol Science Questions
Measurements
Integrated Studies
How? We are establishing a "super site" to study aerosol and cloud physical and radiative properties, as well as surface energy budgets, and meteorological variables with accuracies as called for by studies such as Khan 2004, Seinfeld 2004, Mishchenko 2007.
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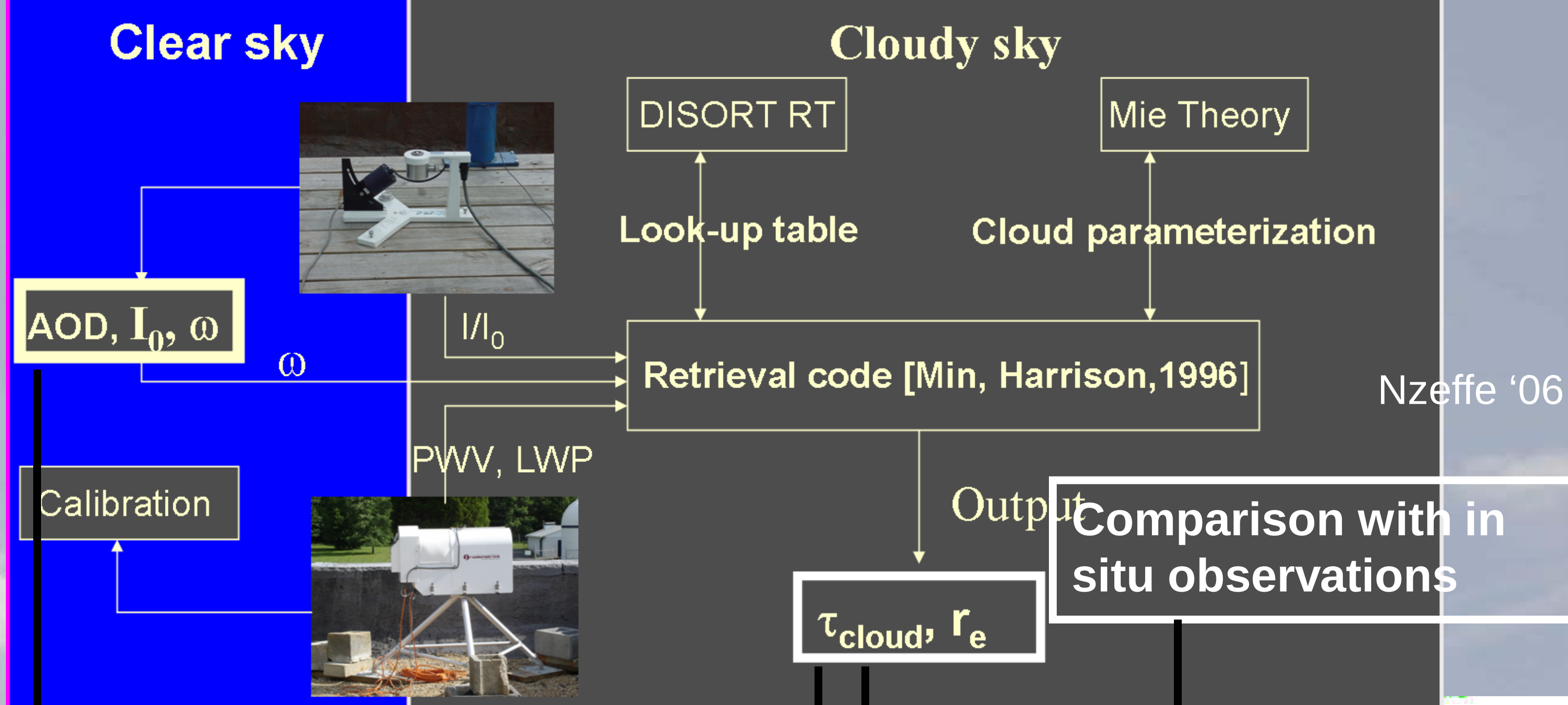
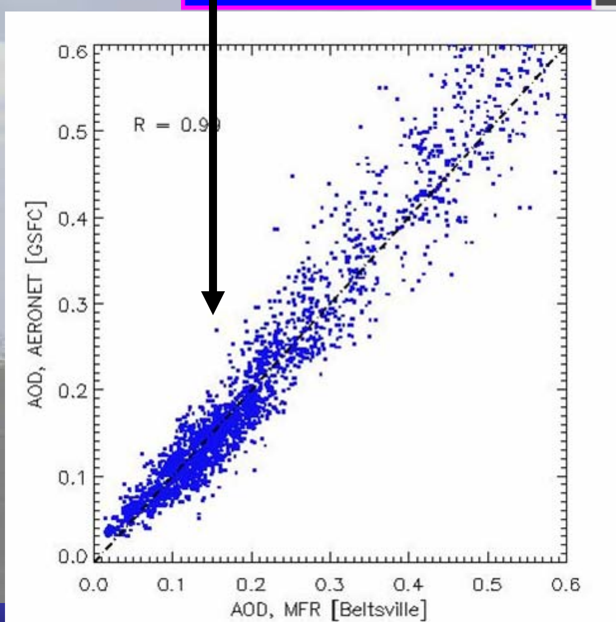
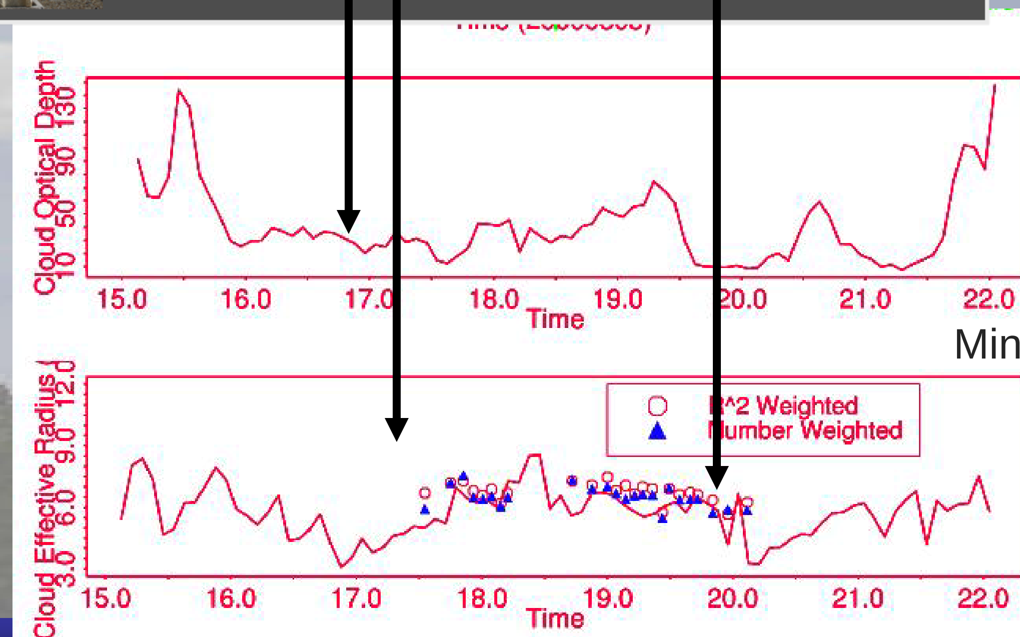
Linking Aerosol Types With Nucleation Properties
Recent Mea.
Aerosol Single Scattering Albedo (~7%)
Aerosol Microphysical Properties
Size Resolved Aerosol Composition
Effect of Aerosols on Clouds and Precipitation?
The Impact of The Effected Clouds on The Surface and TOA Radiative Budgets

Measurement System for Aerosol and Cloud Properties



Nzeffe '06





Min et al

Sector Analysis

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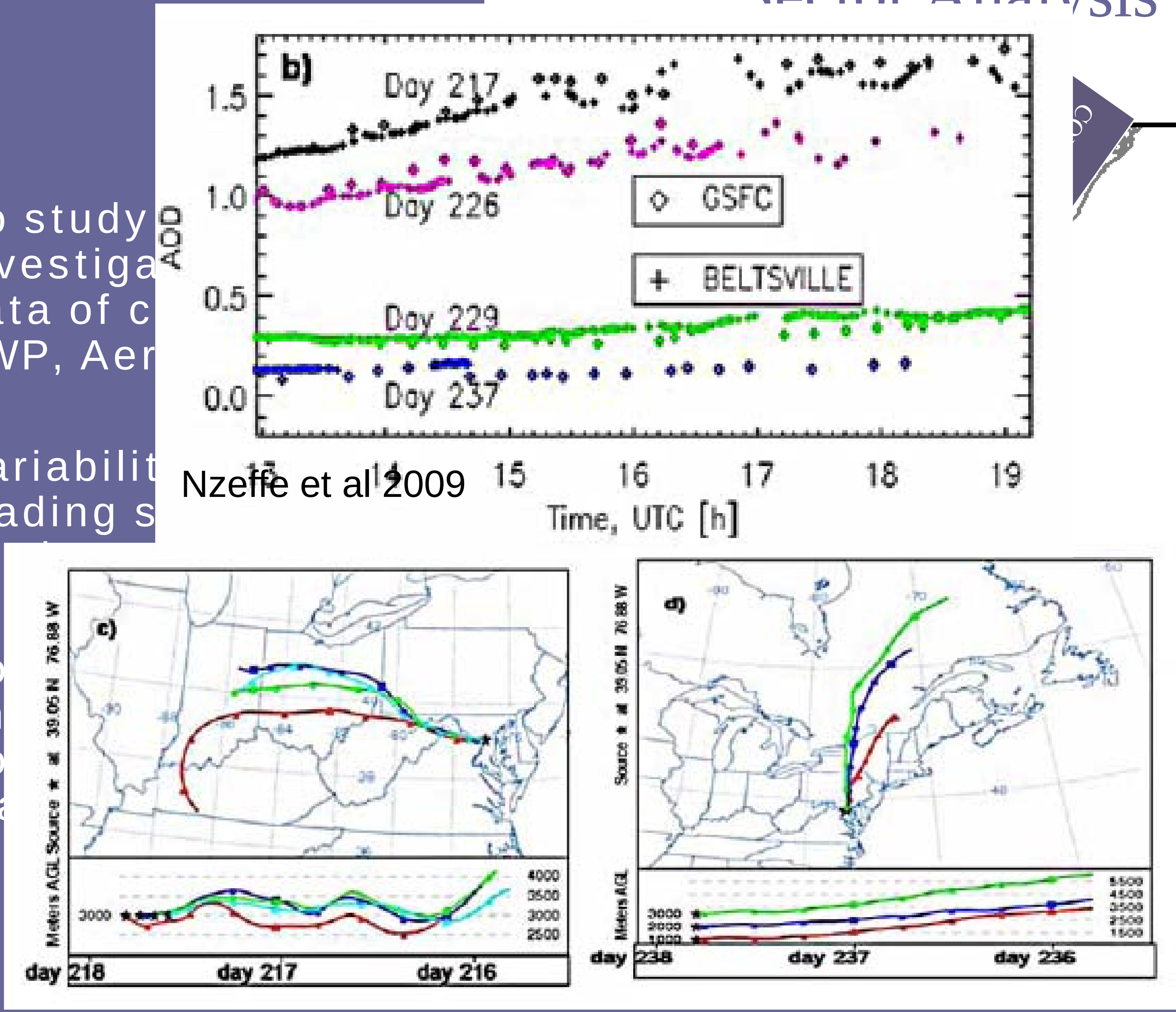
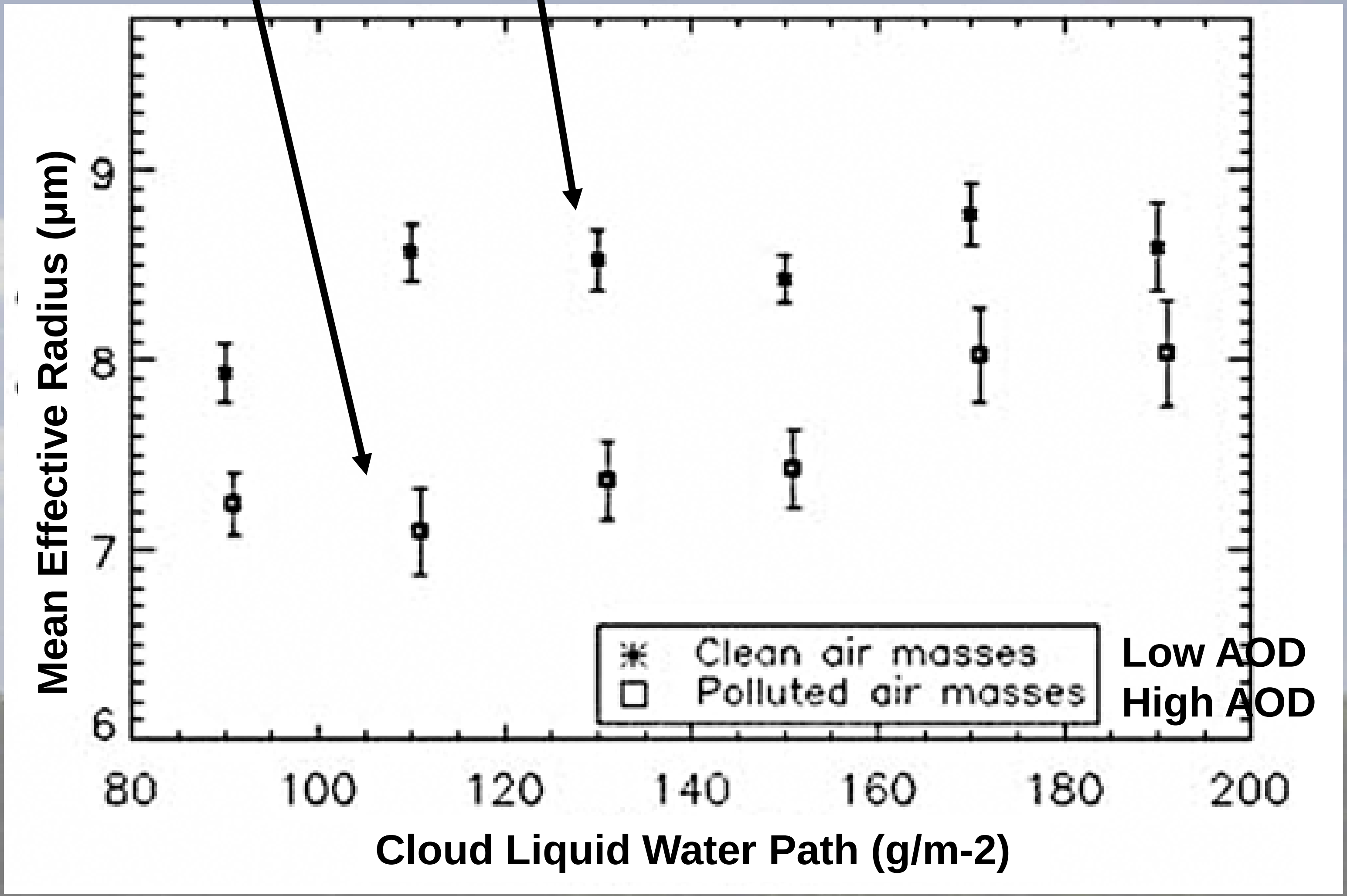
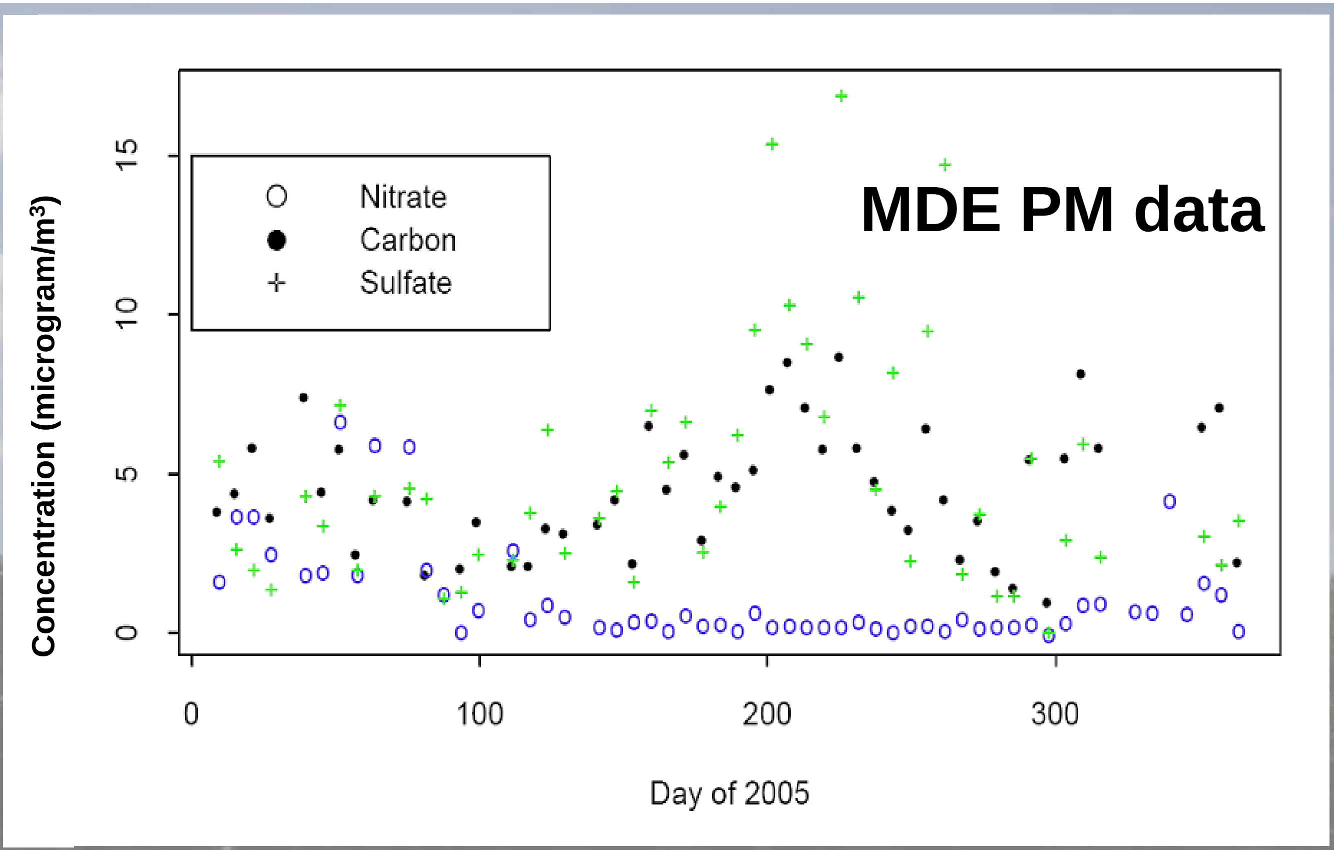


Nzeffe et al 2009

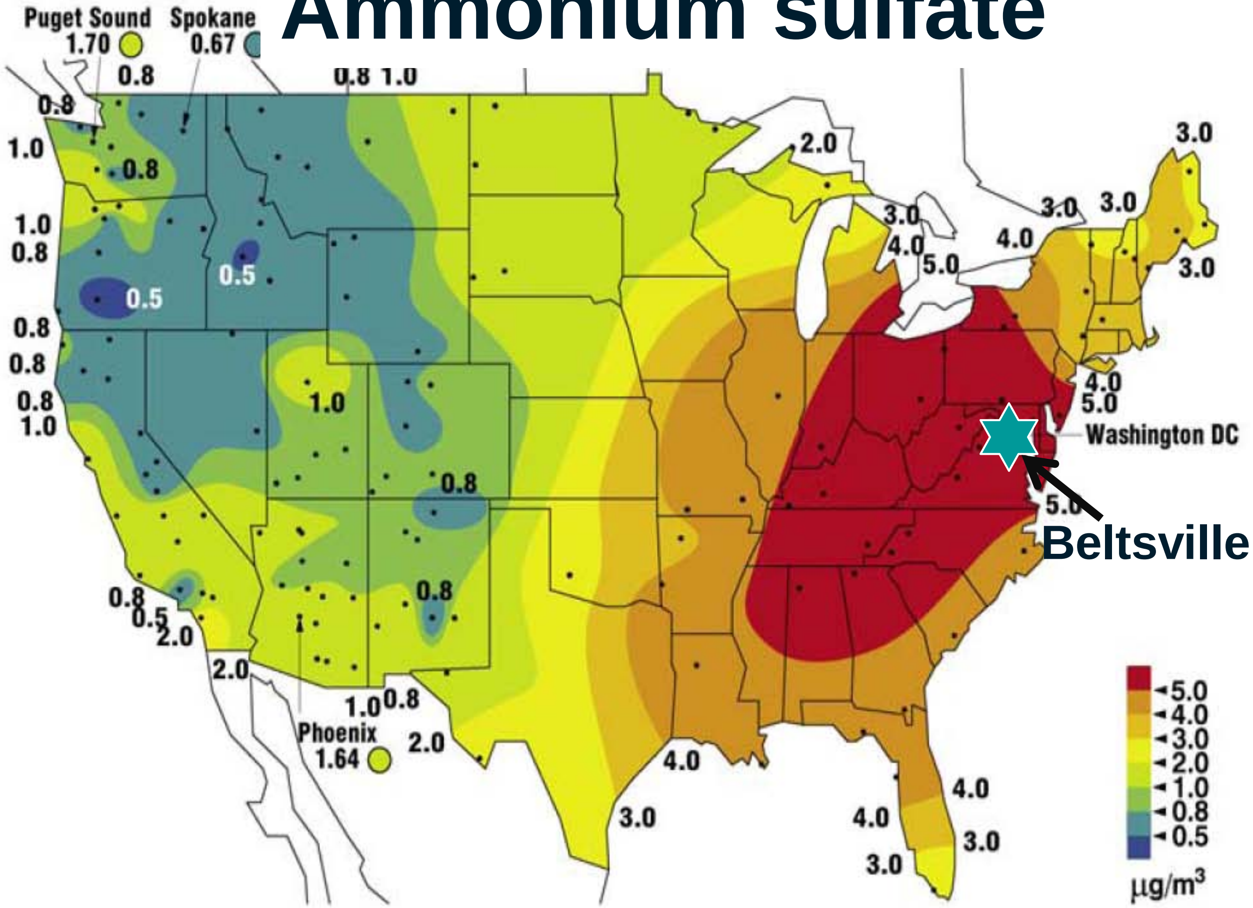
- Preliminary analysis of cloud effective radius under conditions of high and low AOD (Zneffe et al 2009) – polluted/pristine air masses
- Re (high AOD air) < Re (low AOD air), especially for low LWP
- Results consistent with Twomey (1974) concept



- **More cases needed to further characterize AIE**
- **What is temporal variability (--less conclusive in winter composition and dynamics?)?**
- **What is forcing/heating on TOA surface energy budgets**
- **Use more in situ – based studies of detailed microphysics, composition and nucleation**

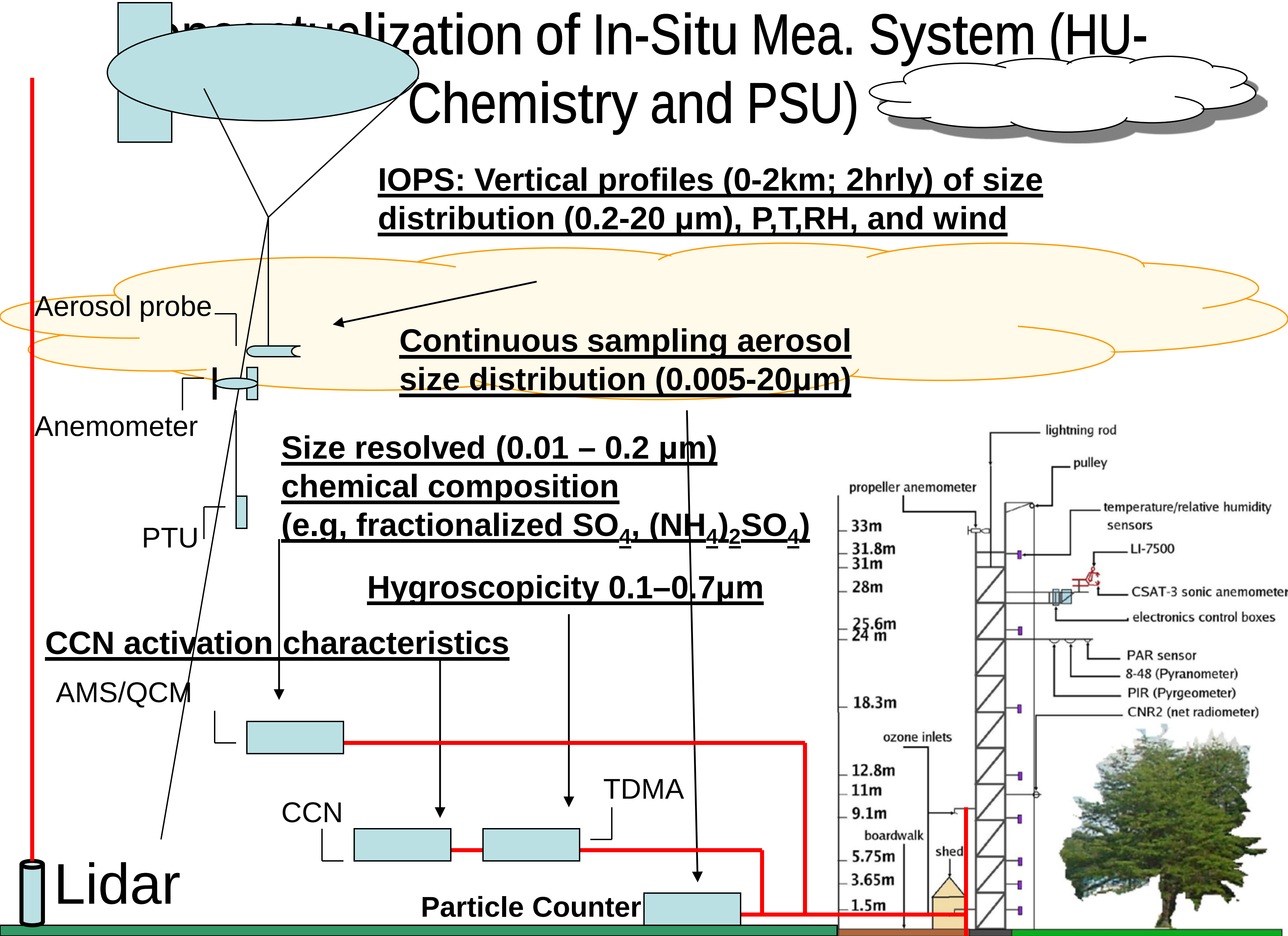


Ammonium sulfate



Malm et al. (2004)

Conceptualization of In-Situ Mea. System (HU-Chemistry and PSU)



Gas Phase and Size Resolved Concentrations

Beltsville IOP 2010

Gas Analyzers

Aerosol Counters and CCN

Size Resolved Composition

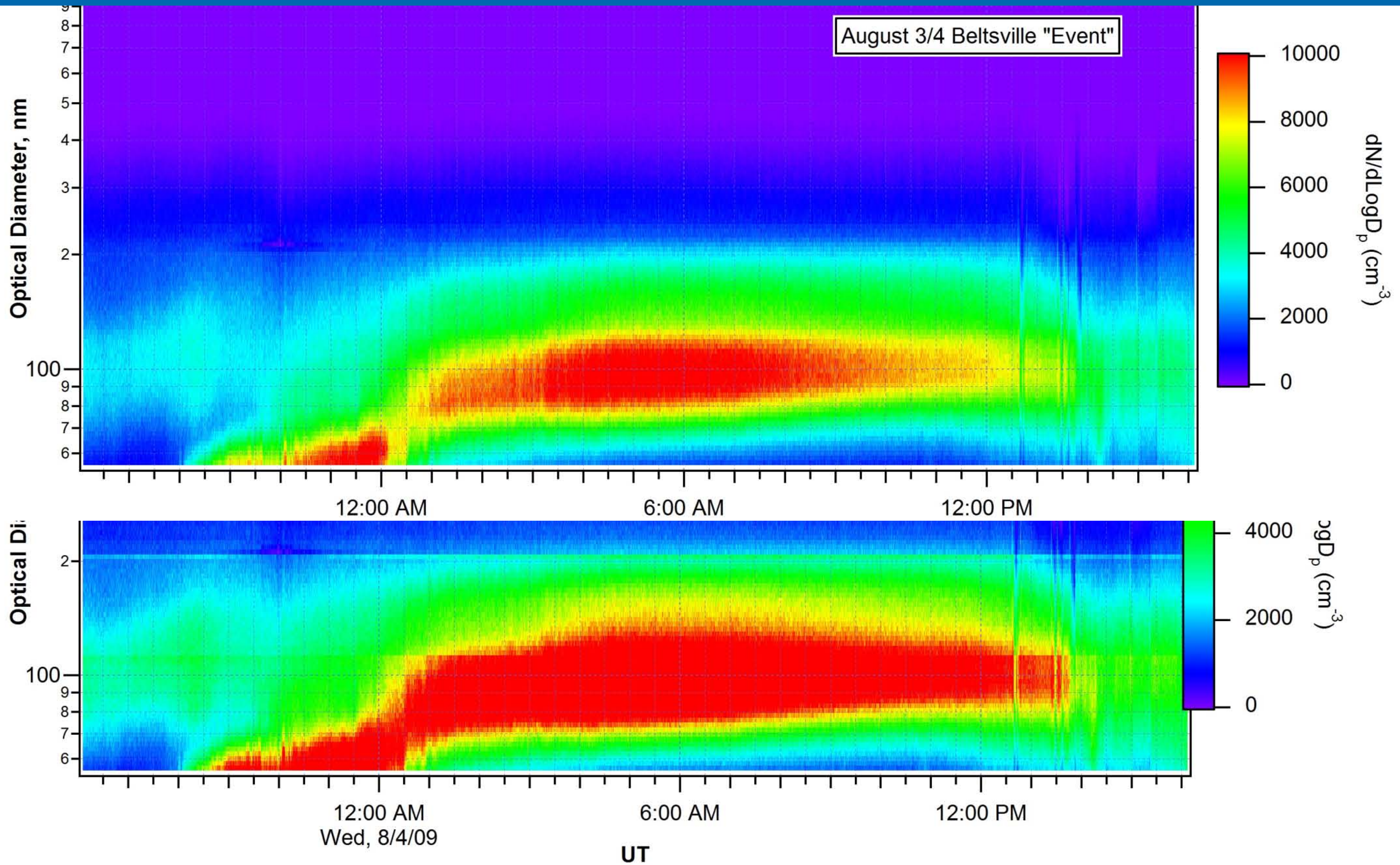
Beltsville IOP 2009

Ultra-high Sensitivity Aerosol Spectrometer (UHSAS)

Aerosol Mass Spectrometer (AMS)

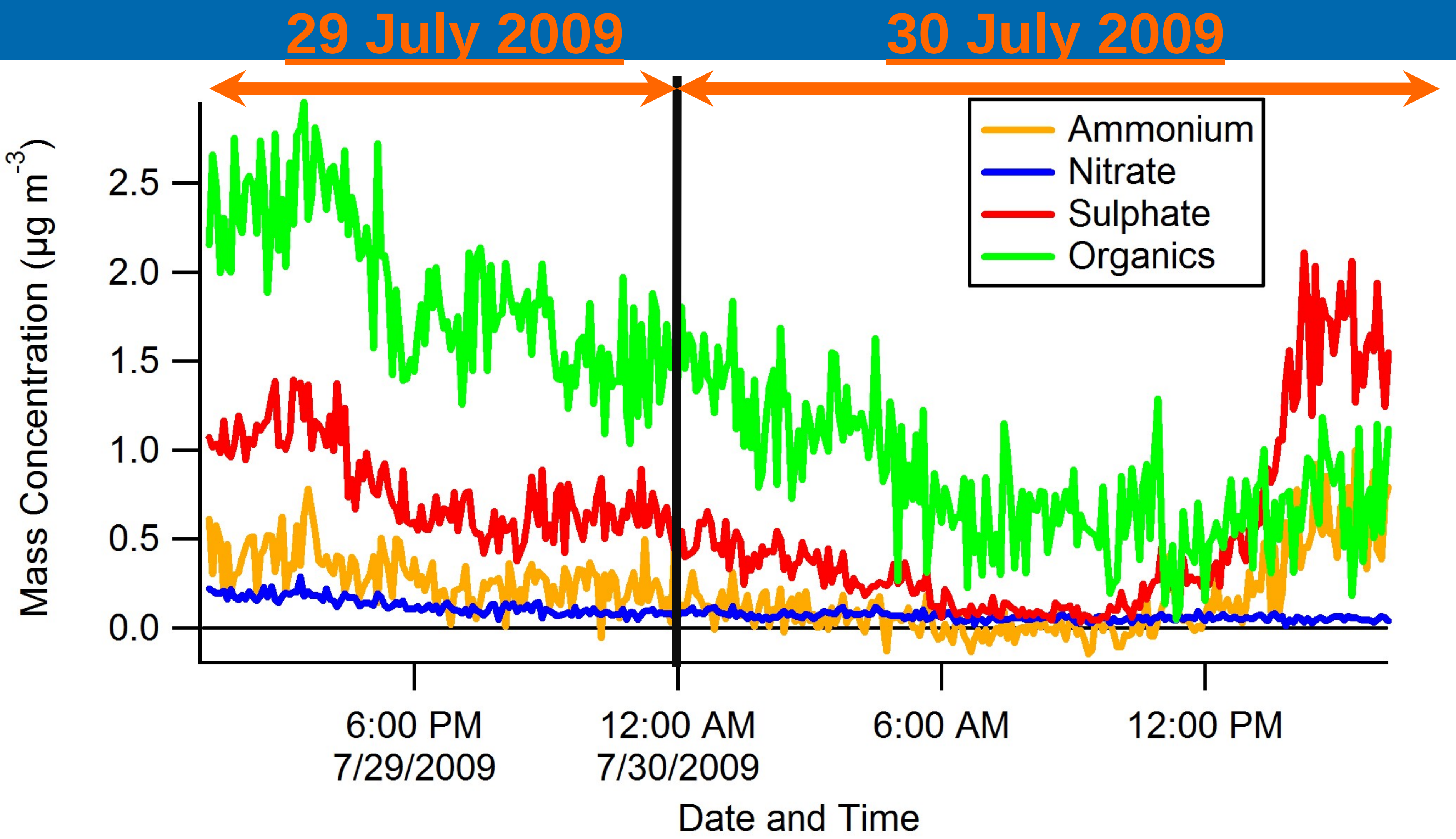
Particle growth events at Beltsville

IOP 2009; UHSAS Data



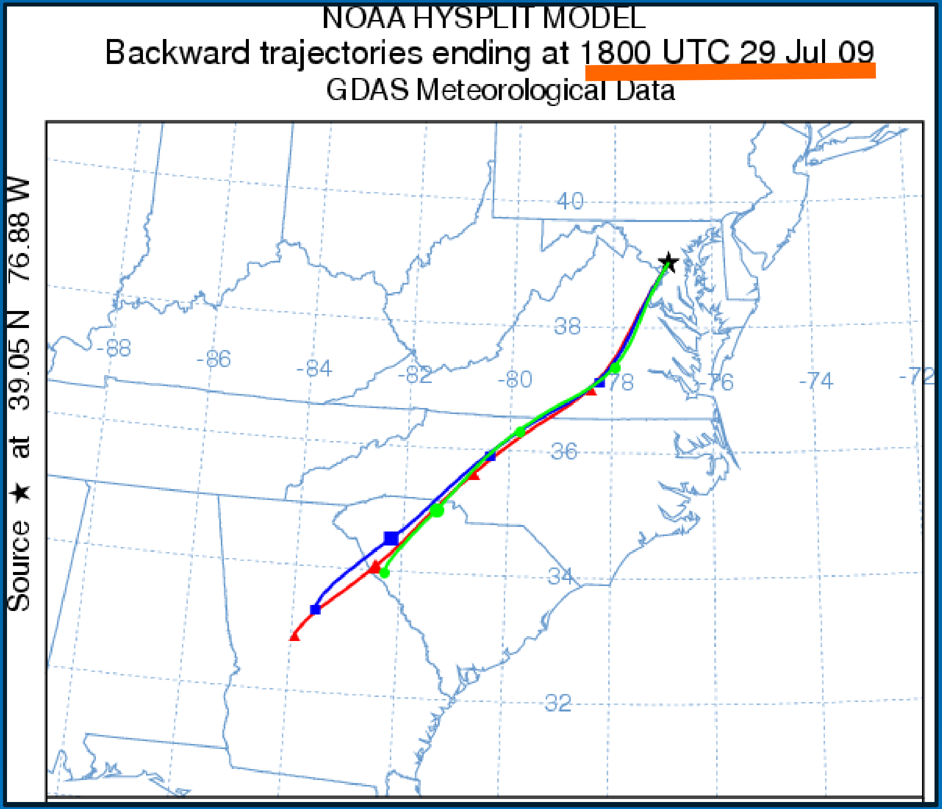
Particle chemical attributes at Beltsville

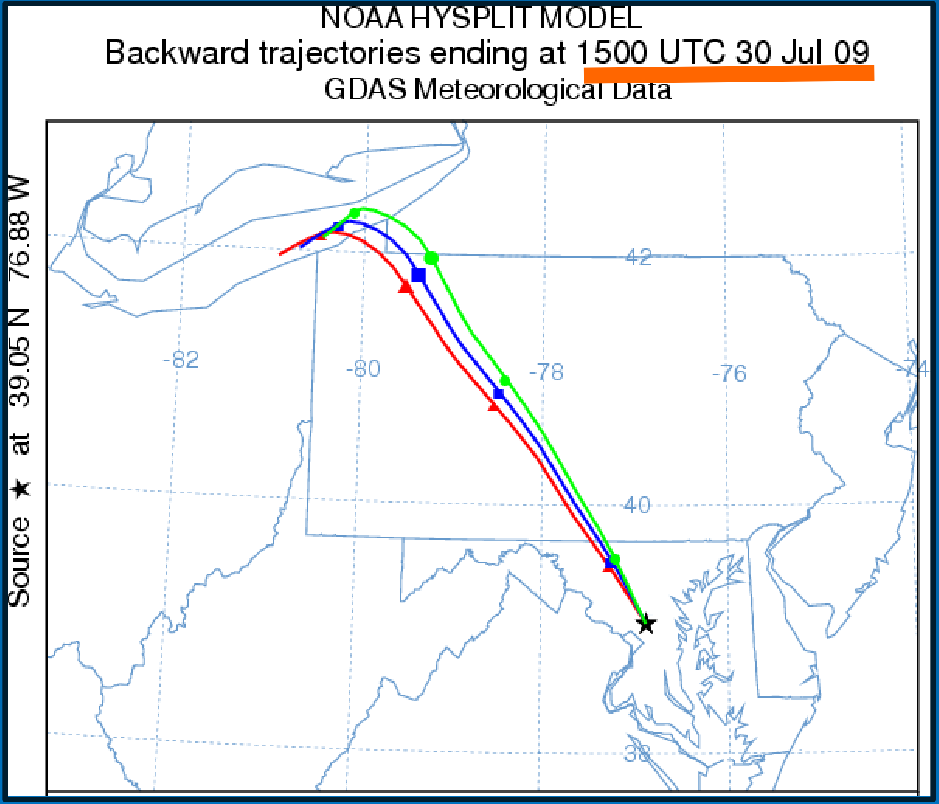
IOP 2009: Aerosol chemistry



Particle chemical attributes at Beltsville

IOP 2009: Air parcel trajectory





- See not only aerosol loading influenced by air mass but also composition
- Also see dominant presence of organic/biogenic aerosols in addition to sulfate
- Opportunity to further quantify role of phytogenic aerosols in climate

Summary

- **The variability of aerosol microphysics and composition and potential on climate are being studied and quantified**
- **Development of CCN nucleation based on linkages of aerosol types and their CCN attributes. These will be necessary to test and validate the fidelity of cloud resolving models – which can then be applied to study AIE**.
- **Results from the above will be used to constrain radiative transfer model calculations to estimate direct radiative forcing (IPCC need)**
- **Results will be up-scaled and applied to improve retrieval algorithms for space-based observations of aerosol physical and chemical properties (e.g., ASP)**
- **Vertical distribution of aerosol concentration and size distribution will be combined with Lidar-derived extinction profiles to develop Lidar based retrievals of aerosol properties (e.g., aerosol concentration)**