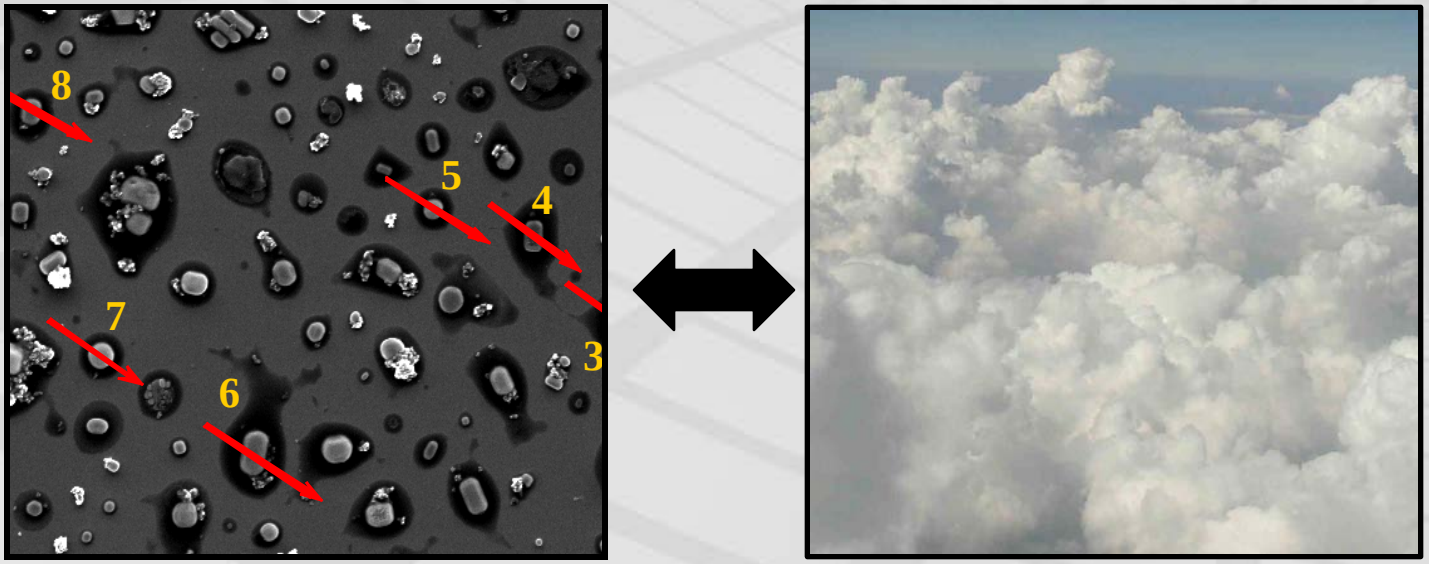
The Aerosol (and Cloud) Modeling Testbed:

A Community Tool to Objectively Evaluate Aerosol Process Modules



Jerome Fast, William Gustafson Jr., Elaine Chapman,
Richard Easter, Jeremy Rishel

ARM Science Team Meeting, Louisville KY, March 31, 2009

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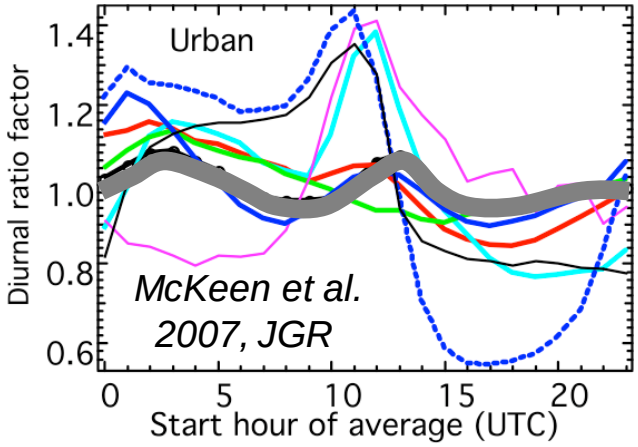
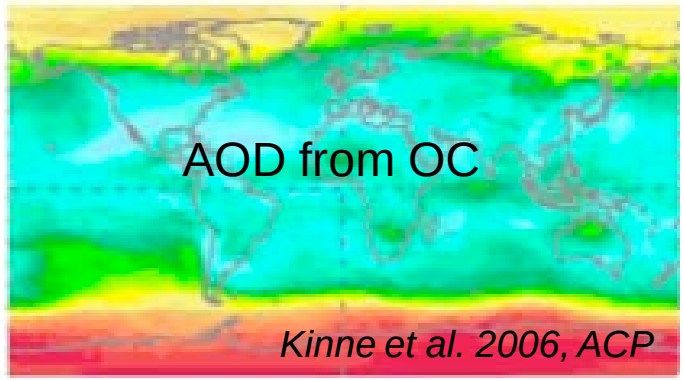
What is the Problem?

- Current aerosol modeling paradigm is haphazard and slow
  - *Differences among predictions arise from **many sources** (emissions, meteorology, chemistry, configuration) rather than aerosol treatments*
  - *Traditional model comparisons that quantify range of uncertainty contain **little insight on how to improve** predictions*

Range of Regional Model Predictions



Range of Global Model Predictions



- Thus, it is difficult to improve predictions of direct and indirect forcing in a timely manner

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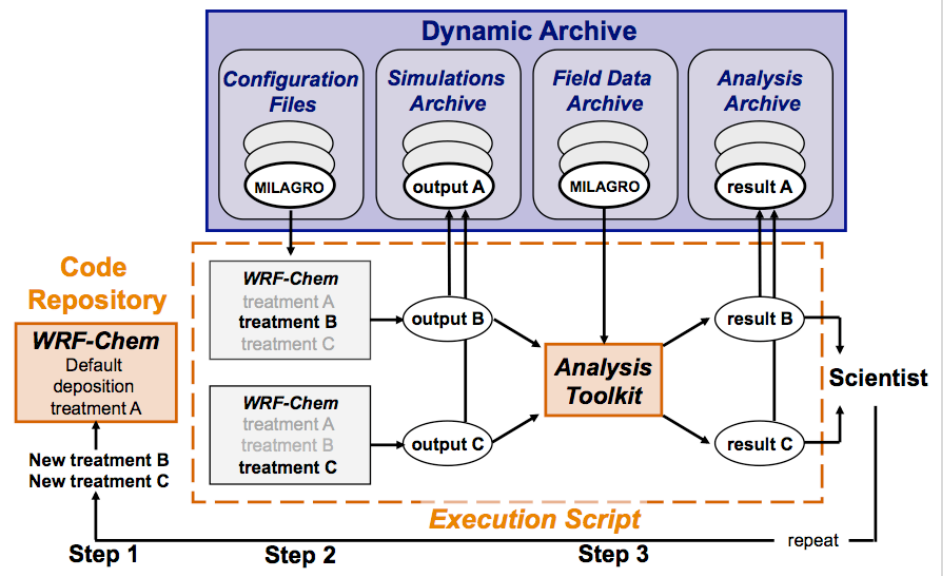
What Are We Trying to Accomplish?

Aerosol Modeling Testbed

A computational framework that streamlines the process of testing and evaluating aerosol process modules over a range of spatial / temporal scales



- ***Systematically and objectively*** evaluate aerosol process modules
- Provide ***tools*** that facilitate science by minimizing redundant tasks
- ***Document*** performance and computational expense
- Better ***quantify uncertainties*** by targeting specific processes

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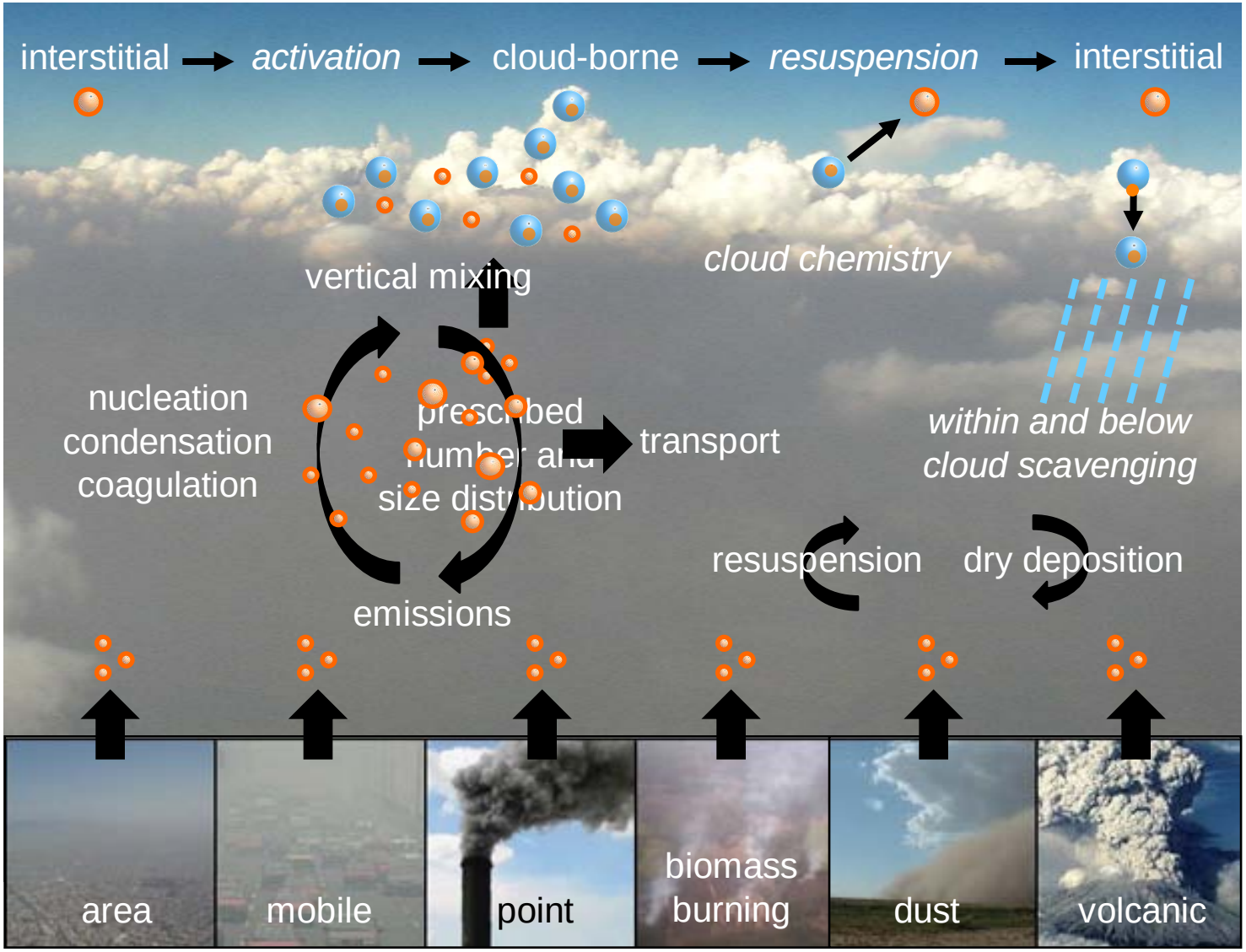
What is Our Approach ?

Model that Treats Aerosol Life Cycle



Simple Aerosols

- Ignores aerosol evolution
- Computationally efficient

Complex Aerosols

- Represents key aerosol processes
- Computationally expensive

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Two Primary Components

Use **Weather Research and Forecasting (WRF)** model as the foundation of computational framework

- Fully-coupled aerosol-radiation-cloud-chemistry interactions
- Handles multiple spatial scales (LES – CRM – regional – global)
- Increasing use of WRF to simulate aerosols
- Community model facilitates distribution of process modules

Create a **community tool** in which aerosol process modules are evaluated systematically and objectively

- Provide transparent **code control**
- Enable targeting of **specific processes** - modularity is critical
- Assess performance by fully-utilizing DOE **field campaign datasets**
- Maintain **long-term archive** of model output
- Customizable by users, but largely **automatic**

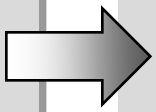
Evaluation Protocol

Software that Enables Scientific Analysis

- Parallel data structure for data and model output
  - *Focus on **field campaigns** with extensive measurements*
  - *Multiple cases to evaluate process modules over **range of conditions***
- Programs that extract model output at measurement sites and times, creates plots, and performs statistical calculations
- Extracts everything available by default, but customizable

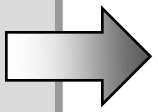
Extraction Programs:

- ***Fixed-Site Time Series***
- ***Aircraft Flight Simulator***
- ***Lidar Simulator***
- ***Satellite Simulator*** ***(FY 09)***
- ***Radar Simulator*** ***(FY 09)***



Analysis Programs:

- ***Graphics:*** "quick-look" plots using freeware (cross-platform)
- ***Statistics:*** mean, bias, correlation, meas-square-error, percentiles, etc.



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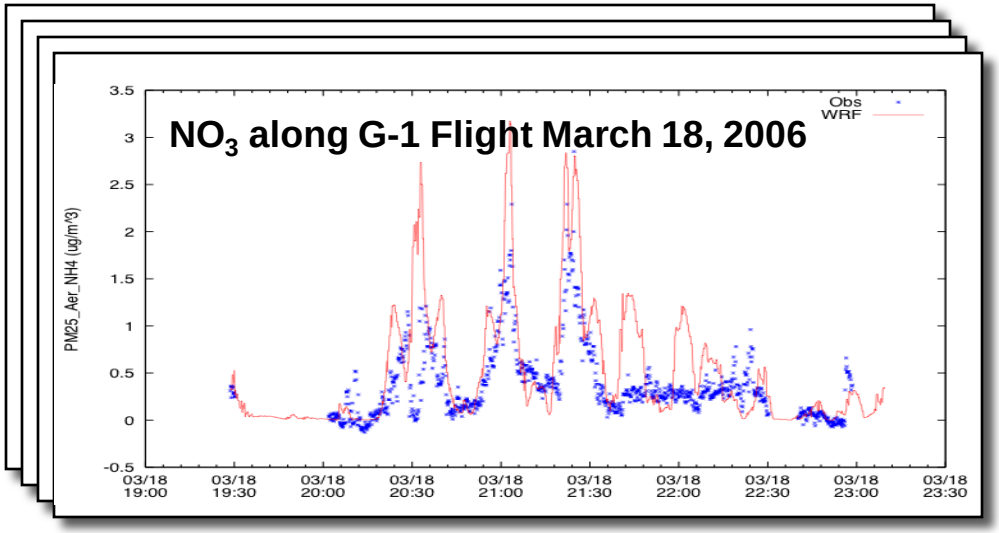
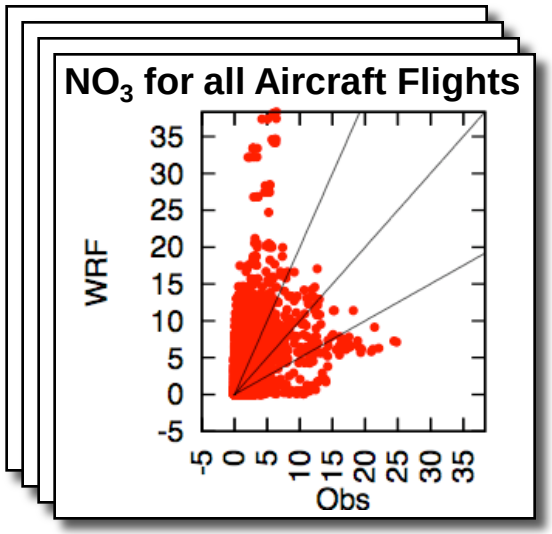
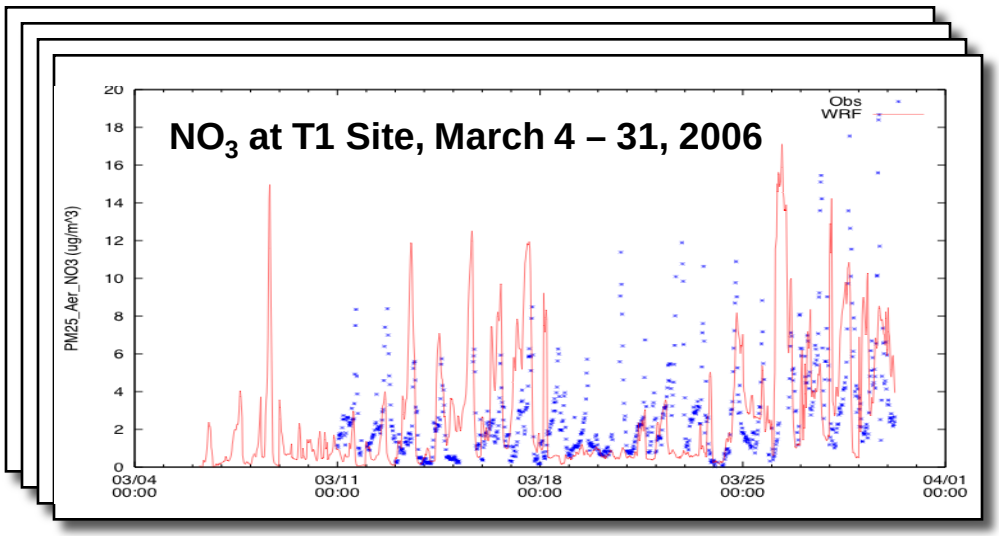
“Quick-Look” Plots

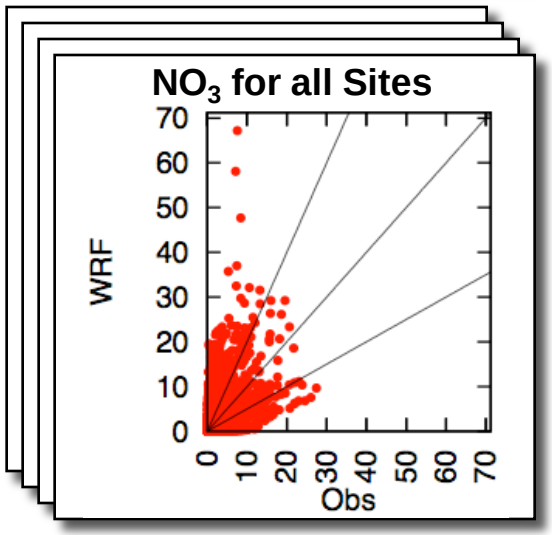
Thousands of Plots Generated: Meteorology, Trace Gases, Aerosols, Others
to browse model performance





Aircraft





Surface

AMT in Relation to CAPT and AeroCom

AMT Aerosol Modeling Testbed
CAPT CCPP ARM Parameterization Testbed
AeroCom Aerosol Comparisons between Observations and Models

	AMT	CAPT	AeroCom
Model	WRF	CAM	multiple models
Spatial Scale	LES / CRM / mesoscale	global / single column	global
Simulation Period	days - month	~ month	~ year
Primary Processes Addressed	aerosols, cloud-aerosol interactions, trace gases	cloud properties	aerosols
Data Used for Evaluation	field campaign + operational data	operational + field campaign data (e.g. ARM)	operational data (e.g. satellite, AERONET, surface PM)

niche ?

other cloud-working groups at CRM and regional scales

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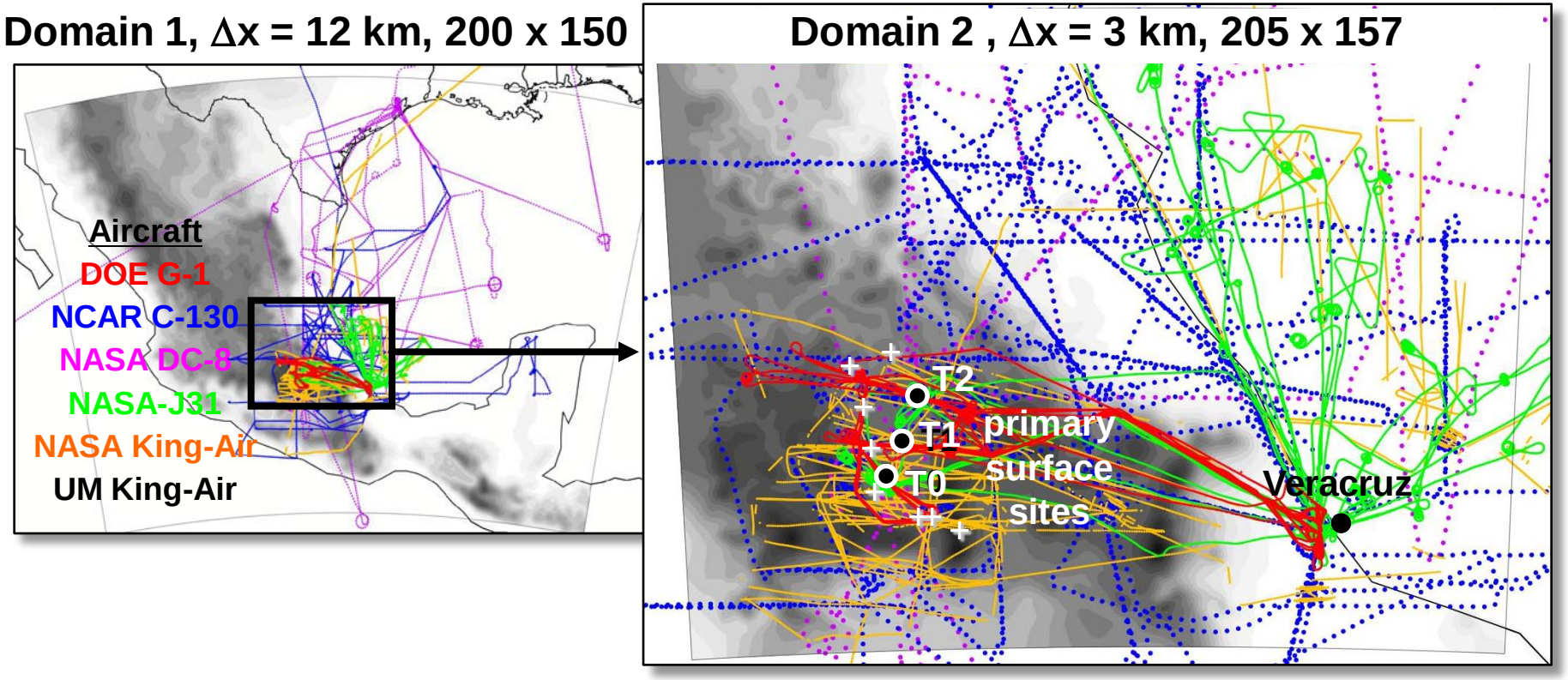
MILAGRO Testbed Case Example

Simulate aerosol transformation processes from urban to synoptic scales

Testbed Case Configuration

Extensive Meteorological, Chemical, and Particulate Measurements



Data Sources

DOE, NSF, NOAA, NASA, operational, etc.

collect into format suitable for models

~5 Gb

~20,000 files

Aerosol Modeling Testbed

dataset available for download and data-mining

Compare Two Aerosol Models

- **MADE/SORGAM:** "simple"
  - *modal size distribution (3 modes),*
  - *38 prognostic species*
- **MOSAIC**: "complex"
  - *sectional size distribution (8 size bins)*
  - *(8 size bins), 104 prognostic species*

Different treatments for: nucleation, coagulation, gas-to-particle partitioning, and deposition

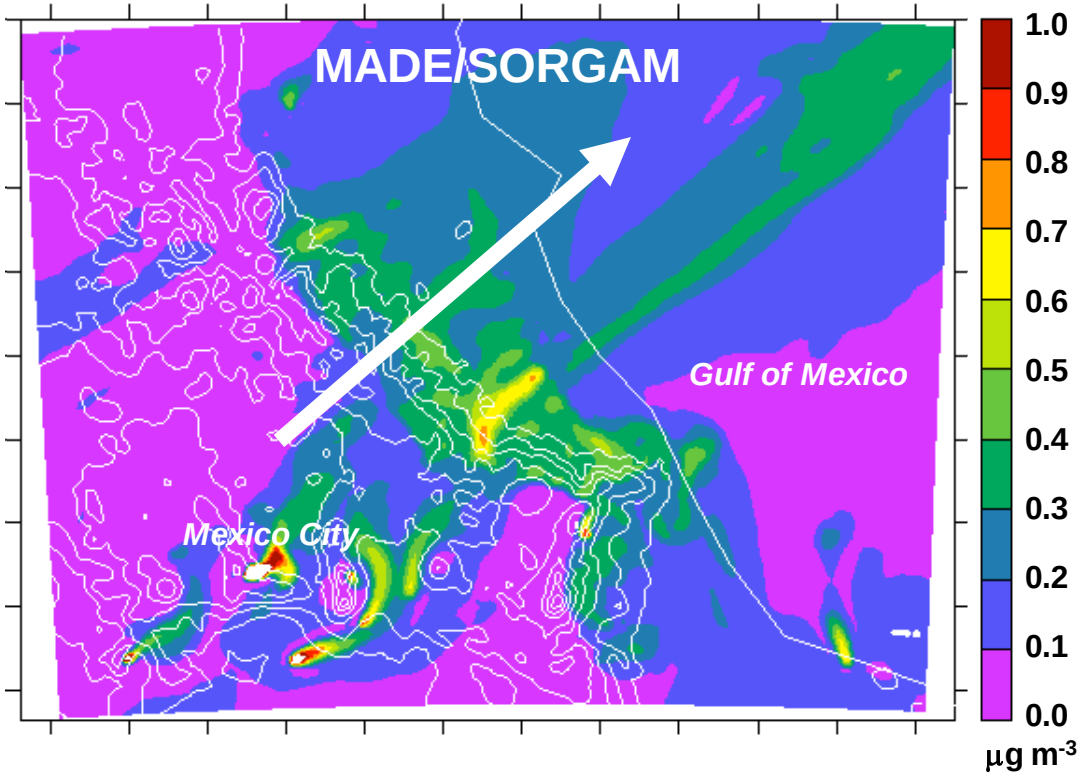
Comparing predictions in the **AMT:**

- Here, **MADE/SORGAM** and **MOSAIC** have identical:
  - *Anthropogenic, biomass burning, online sea-salt & dust emissions*
  - *Boundary conditions from global chemistry model (MOZART)*
  - *Photochemistry (CBM-Z)*
  - *Aerosol optical properties*
  - *Cloud-aerosol-radiation interactions*

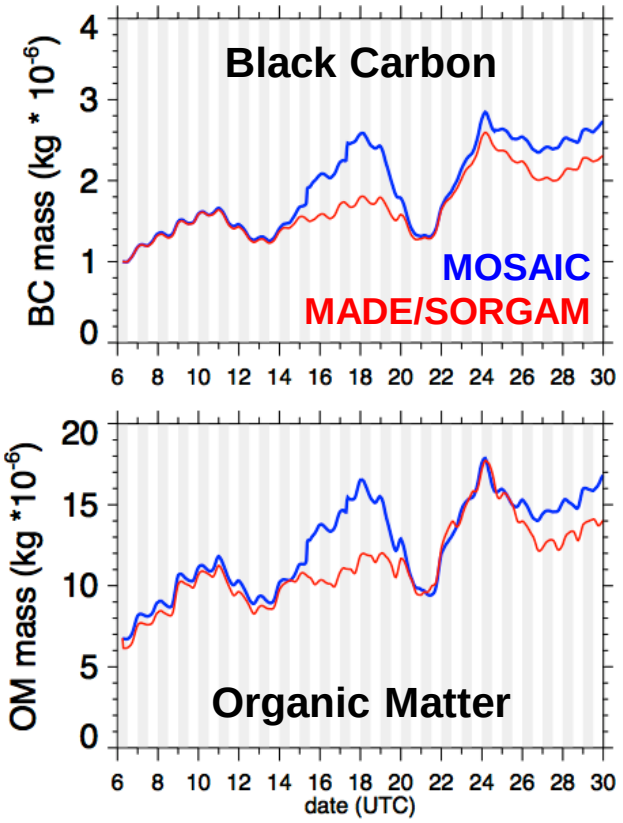
Carbonaceous Aerosols

Black Carbon Concentrations ~0.5 km AGL

21 UTC March 20 – Strong Ambient SW Winds



Mass within Domain 1 over 3-Week Period

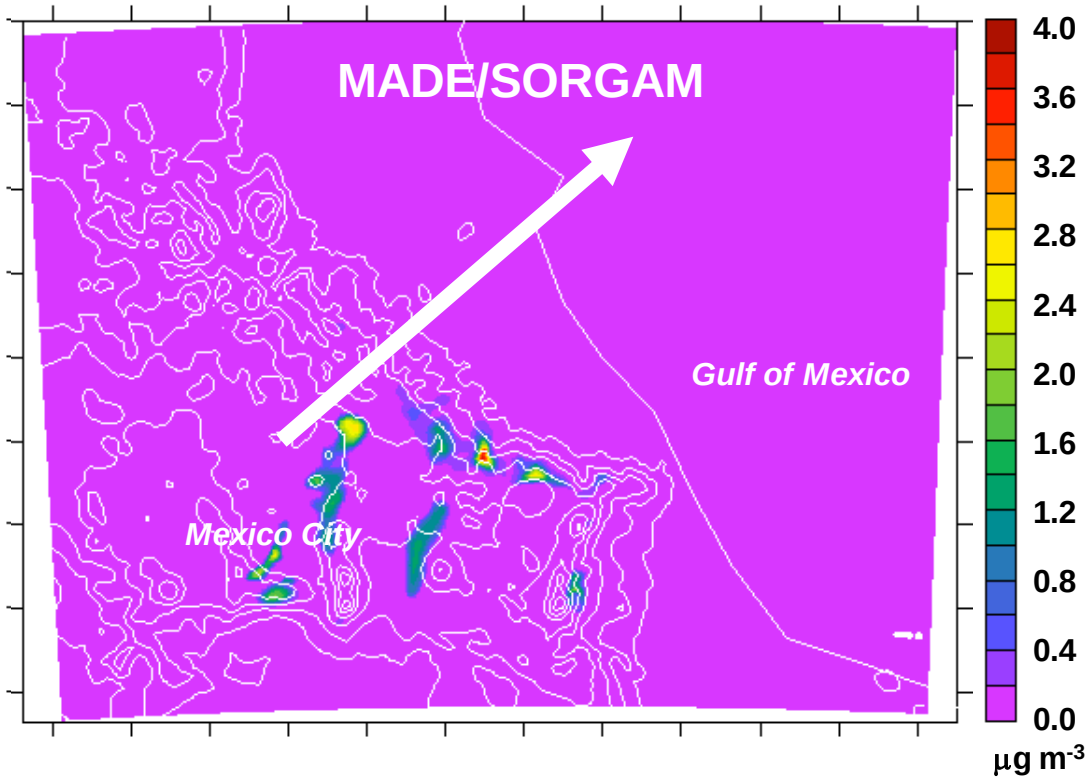


- Since BC and OM treated as a scalars with no chemistry (*SOA turned off*), differences due solely to treatments of **deposition**
- Modular and interoperable deposition 'driver' will be implemented soon

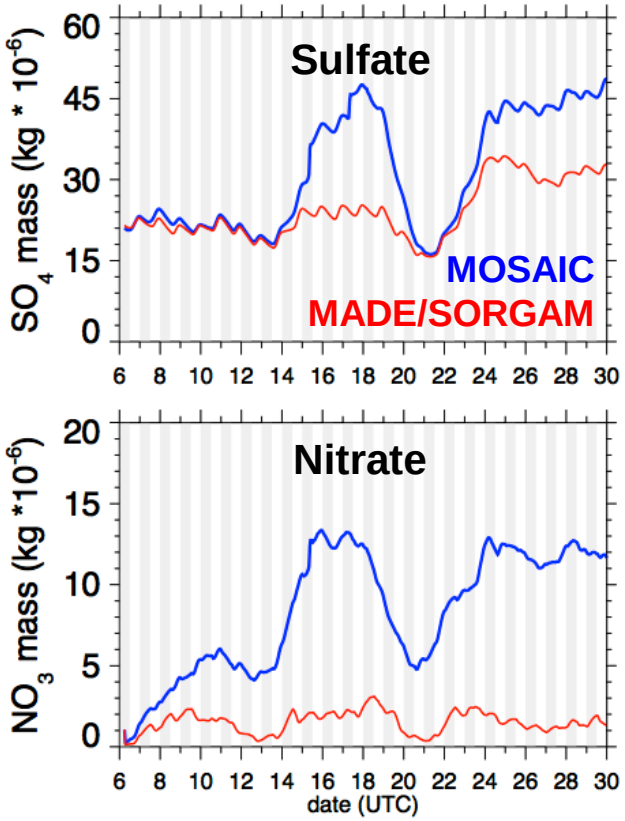
Secondary Aerosols

Nitrate Concentrations ~0.5 km AGL

21 UTC March 20 – Strong Ambient SW Winds



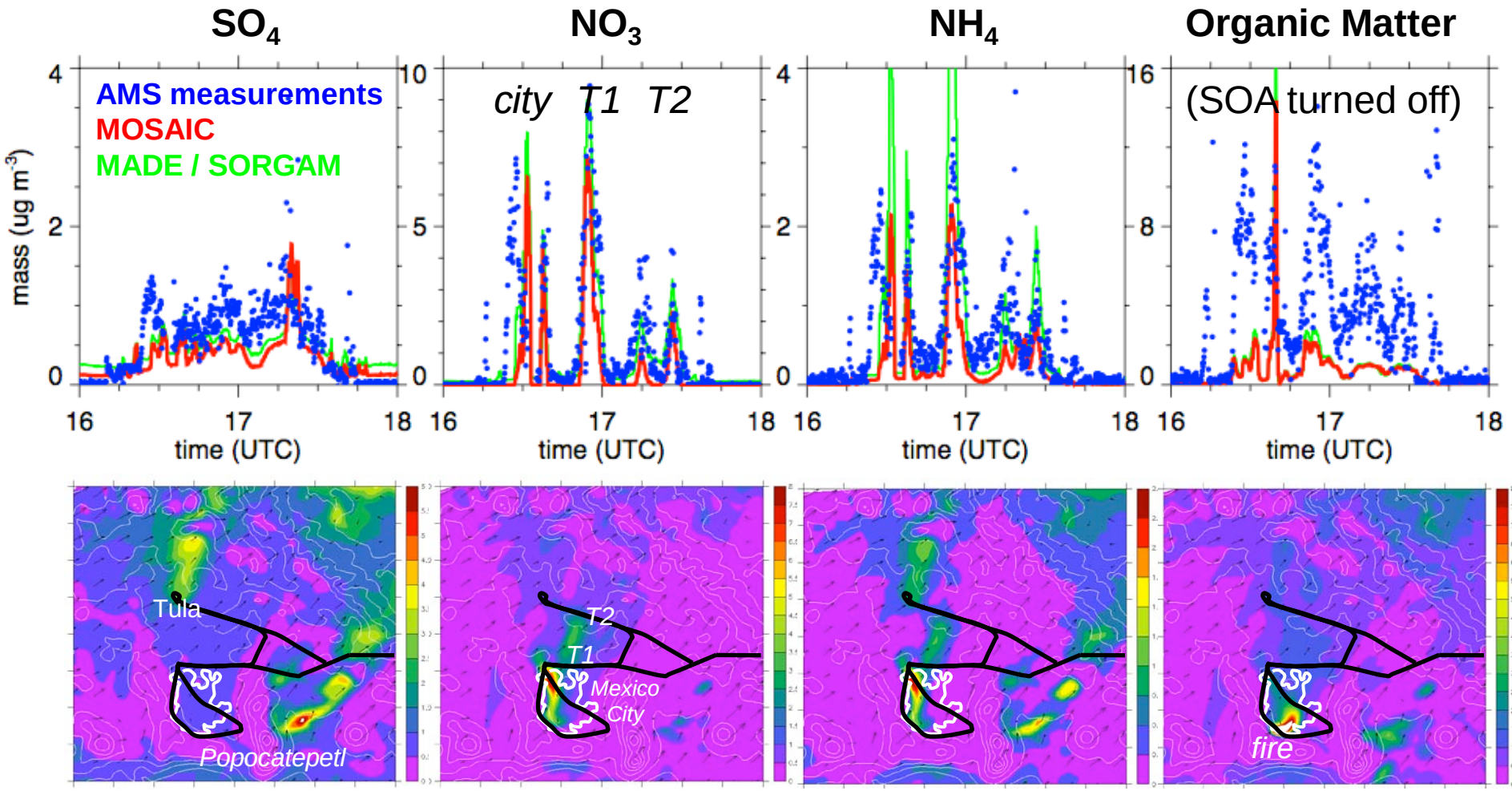
Mass within Domain 1 over 3-Week Period



- Deposition contributes to differences in secondary aerosols too, but different **gas-to-particle partitioning** treatments largely responsible
- HNO_3 + dust ⟶ NO_3 included in MOSAIC, but not MADE/SORGAM

Evaluation of Aerosol Composition

G-1 Aircraft March 20, 2006 – Strong Ambient SW Winds



horizontal cross section at 17 UTC and ~ 0.7 km AGL

What's Next?

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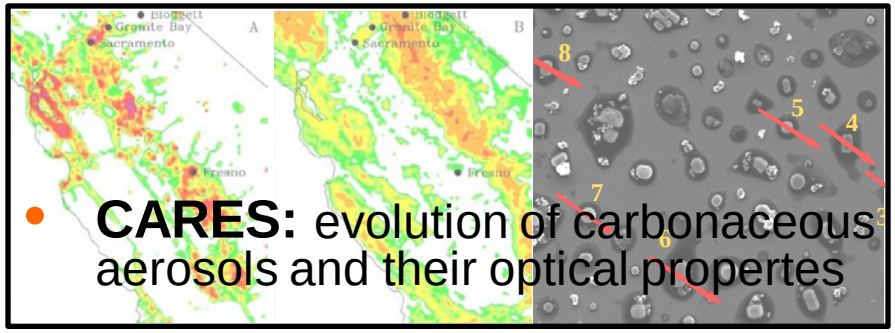
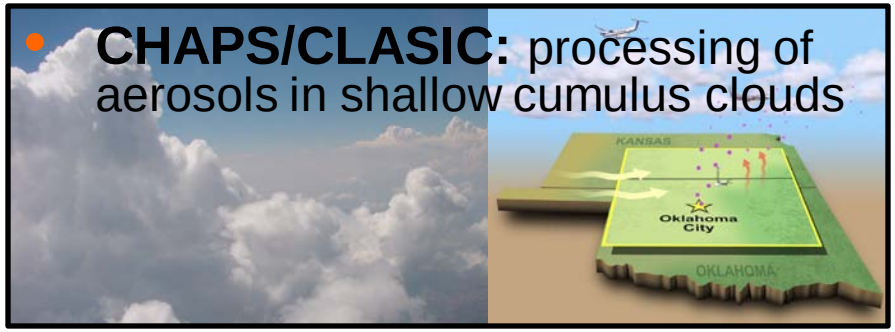
Future Testbed Cases

- **Multiple Testbed Cases Needed:**
  - *Field campaigns usually focus on narrow set of processes*
  - *Evaluate aerosol process modules over wider range of conditions*
  - *Specific interests of modelers*



- **CARES:** evolution of carbonaceous aerosols and their optical propertes

- **ISDAC:** processing of aerosols in mixed-phase clouds



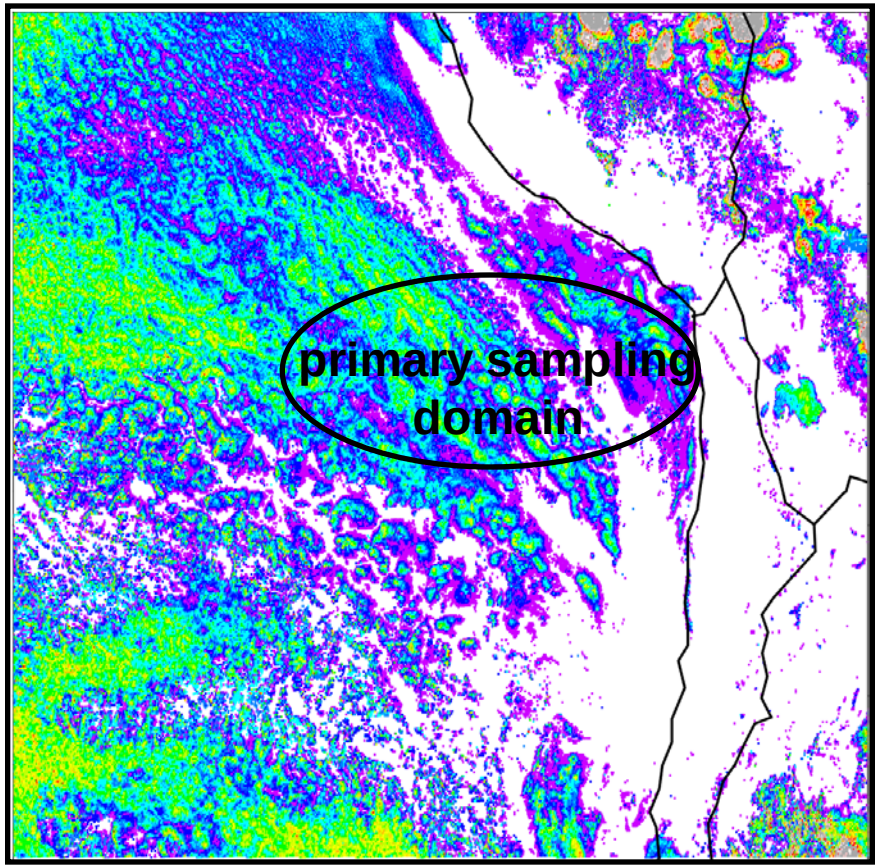
- **CHAPS/CLASIC:** processing of aerosols in shallow cumulus clouds

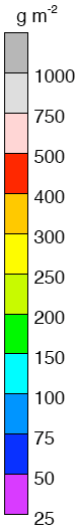
- **VOCALS:** aerosol processing in marine stratocumulus clouds

- **International Field Campaigns ?**

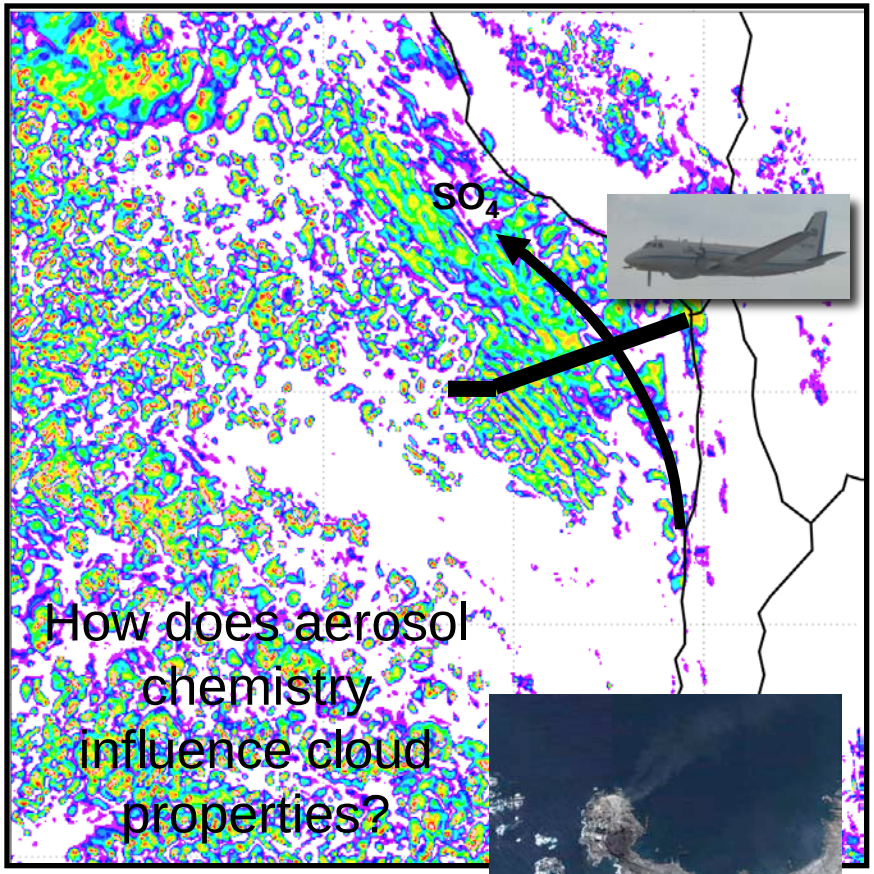
VOCALS

GOES LWP, 13 UTC October 25





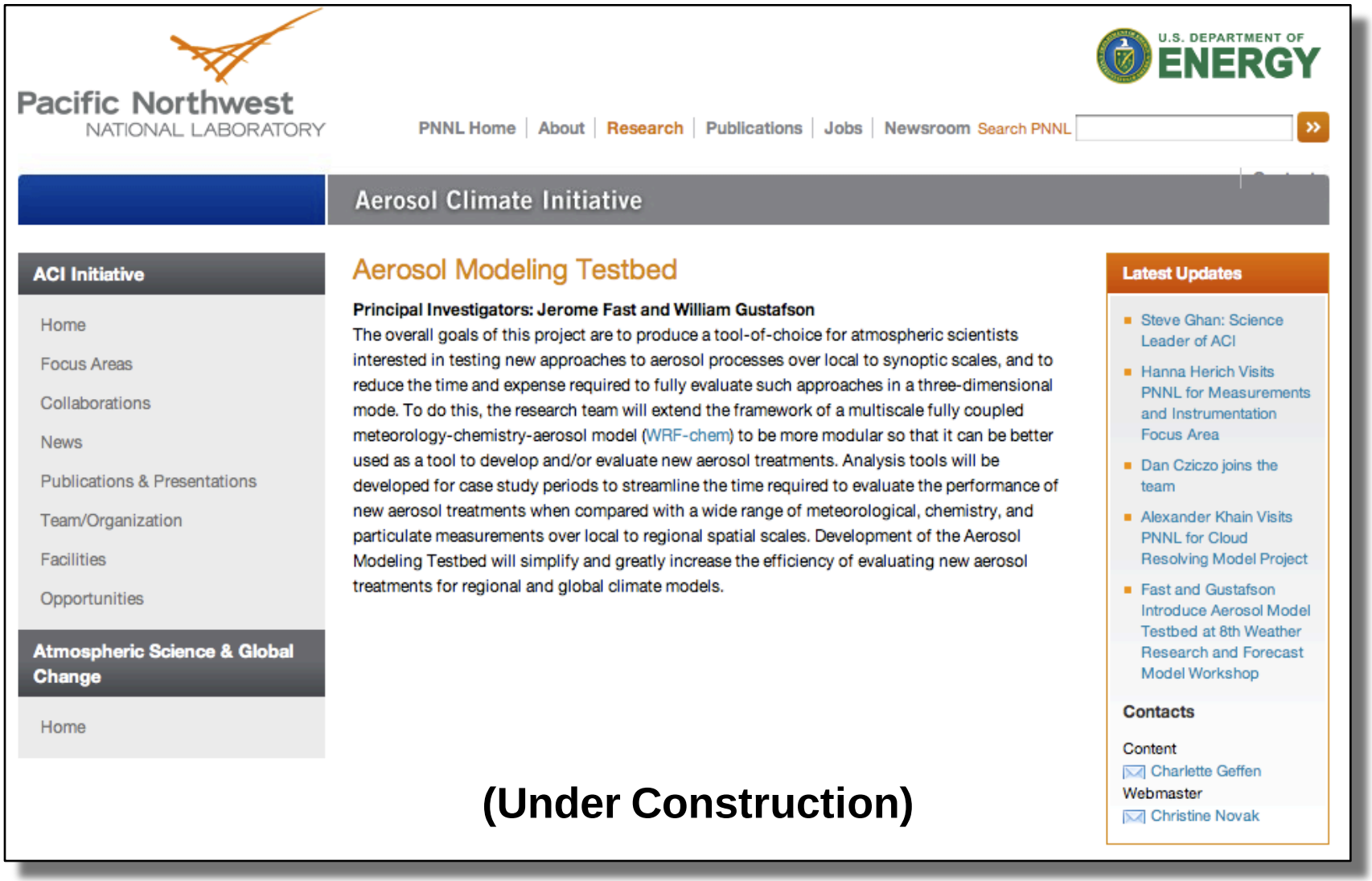
WRF LWP, Δx = 4 km



Challenge: Evaluation needs to help unravel dynamics versus aerosol effects

How Will User's Access the AMT ?

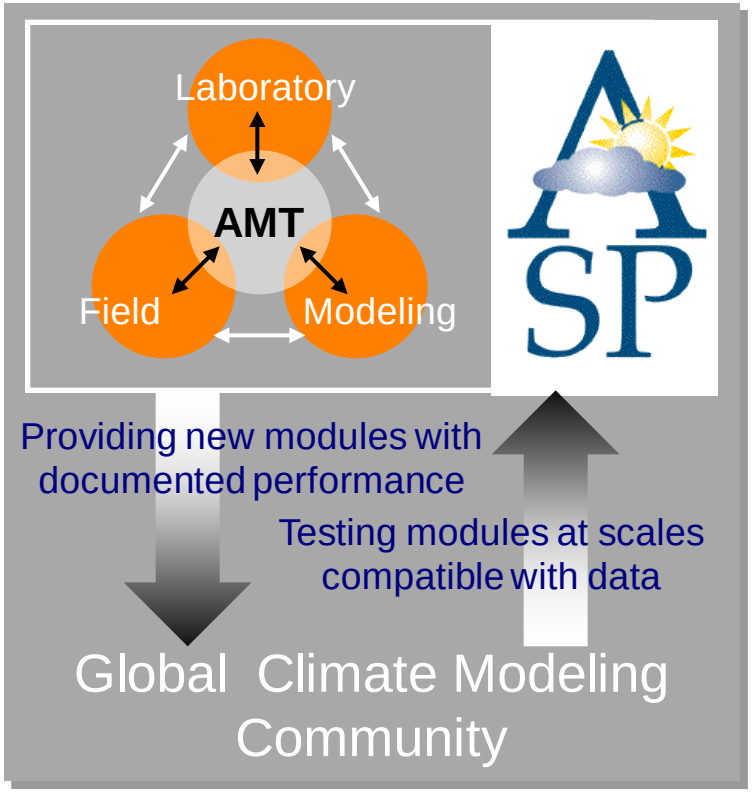
http://www.pnl.gov/atmospheric/research/aci/aci_proj_testbed.stm



(Under Construction)

Expected Outcomes

- **Community tool** to facilitate systematic and objective evaluation of aerosol process modules for real-world conditions
- **Enhance research** capabilities of DOE research (ASP, ARM, SciDAC) and its visibility in the scientific community
- **Long-Term Vision:**
  - ***New paradigm*** *for aerosol science community that increases collaboration*
  - ***Reducing uncertainties*** *in aerosol aging, cloud-aerosol interactions, and consqueantly aerosol radiative forcing in regional and global models*



with support from: