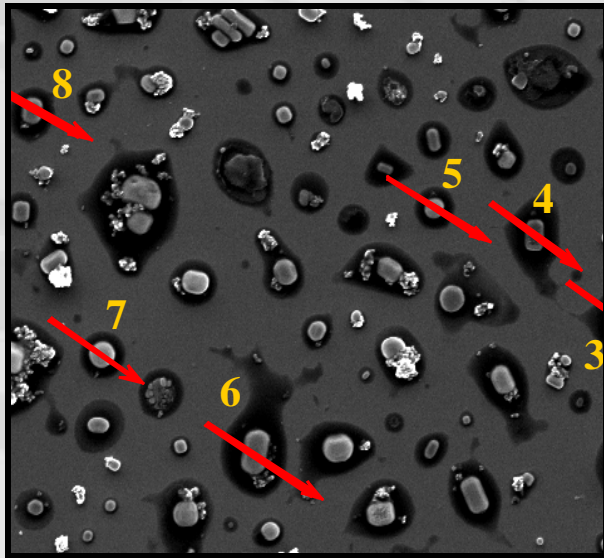


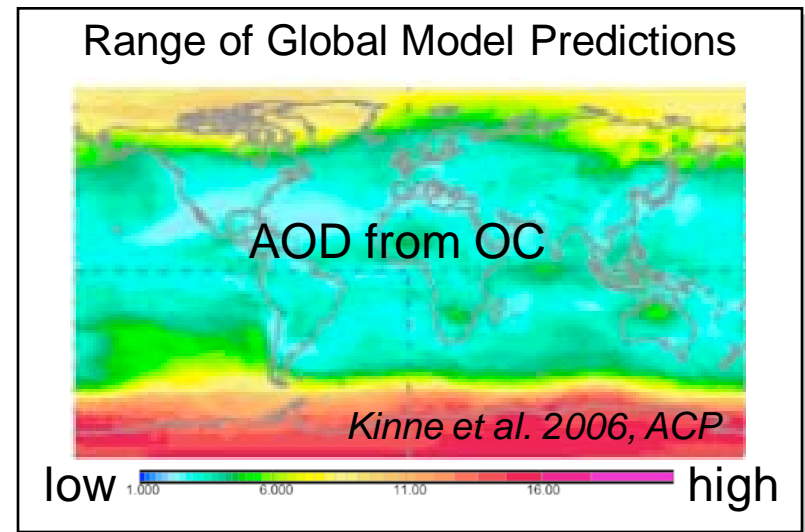
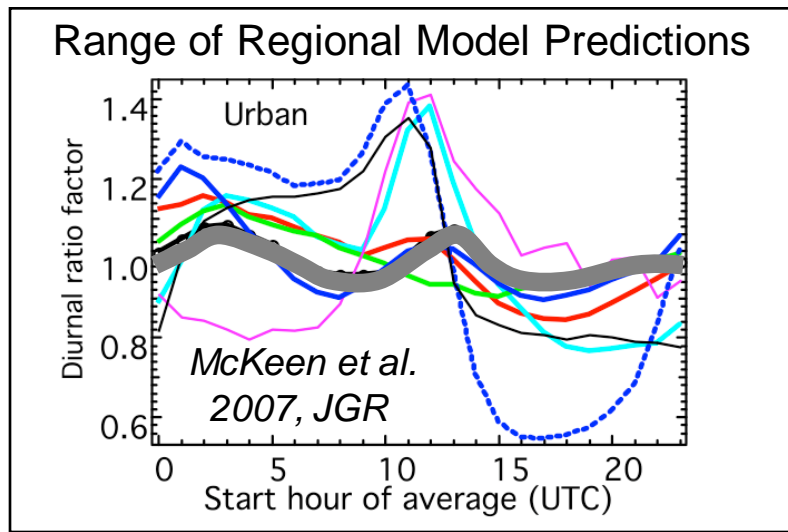
The Aerosol (and Cloud) Modeling Testbed: A Community Tool to Objectively Evaluate Aerosol Process Modules



Jerome Fast, William Gustafson Jr., Elaine Chapman,
Richard Easter, Jeremy Rishel
ARM Science Team Meeting, Louisville KY, March 31, 2009

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

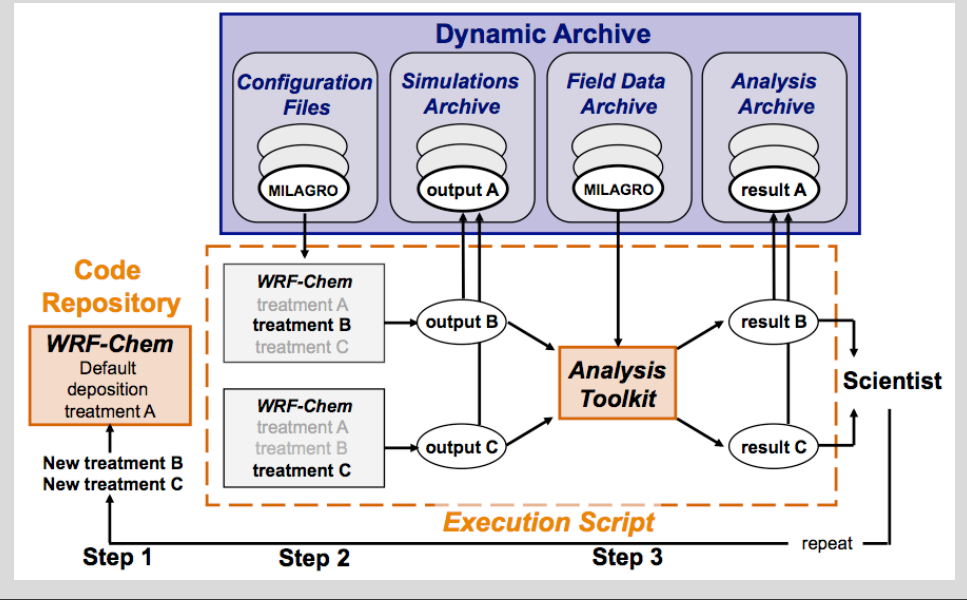


- Thus, it is difficult to improve predictions of direct and indirect forcing in a timely manner

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

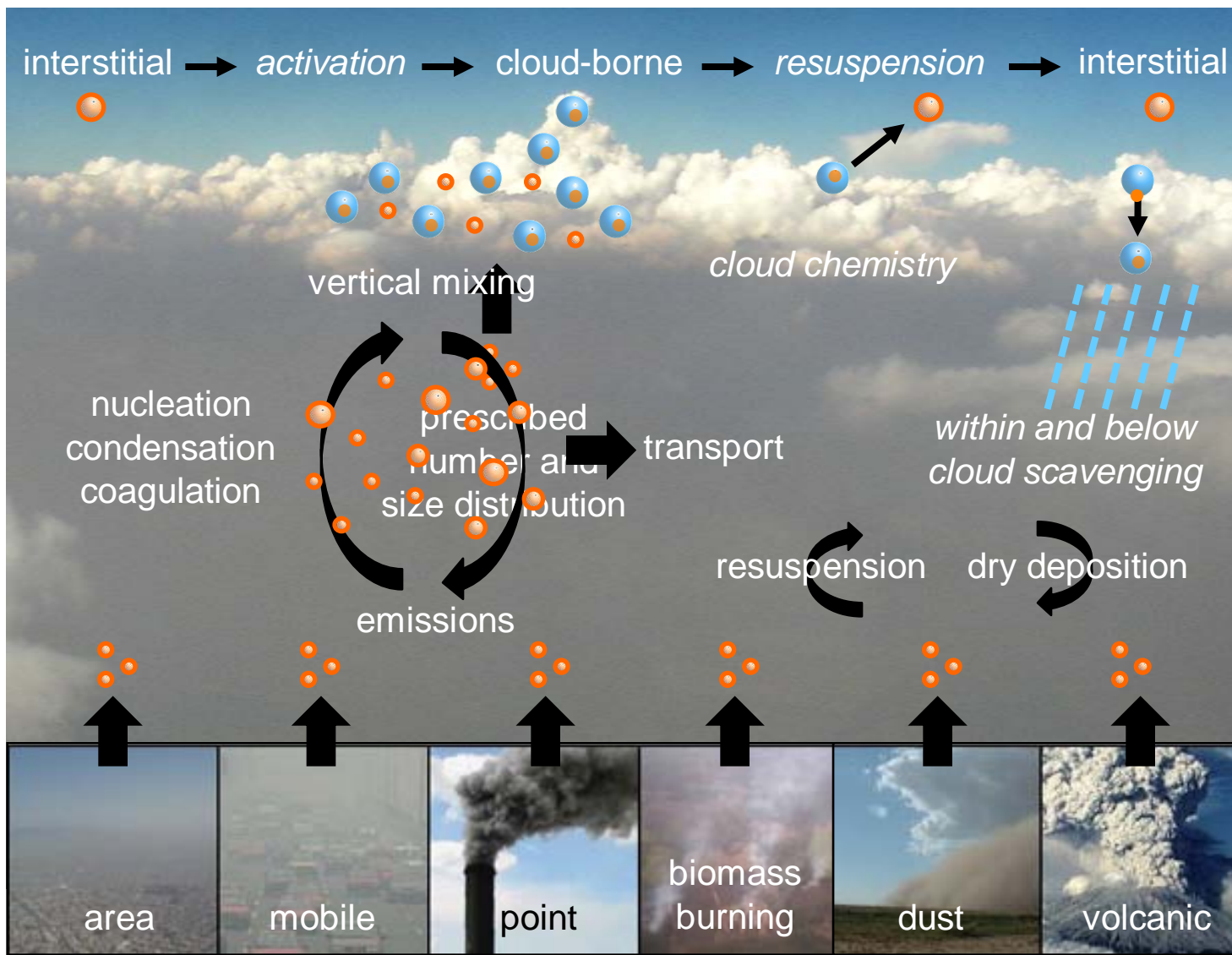


- **Systematically and objectively** evaluate aerosol process modules
- Provide **tools** that facilitate science by minimizing redundant tasks
- **Document** performance and computational expense
- Better **quantify uncertainties** by targeting specific processes

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

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**

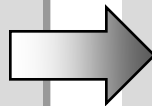
Evaluation Protocol

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

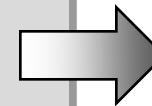
Extraction Programs:

- **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.

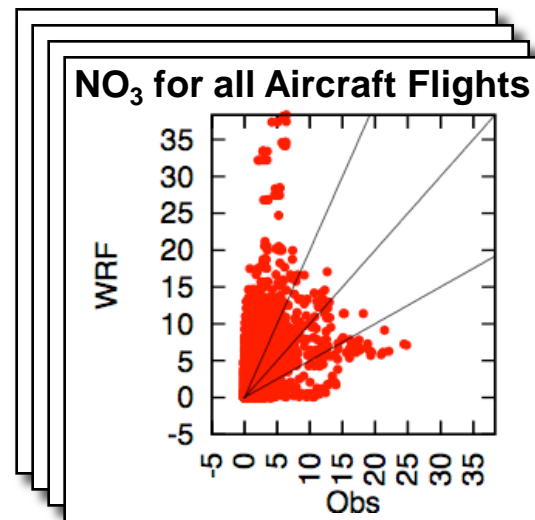
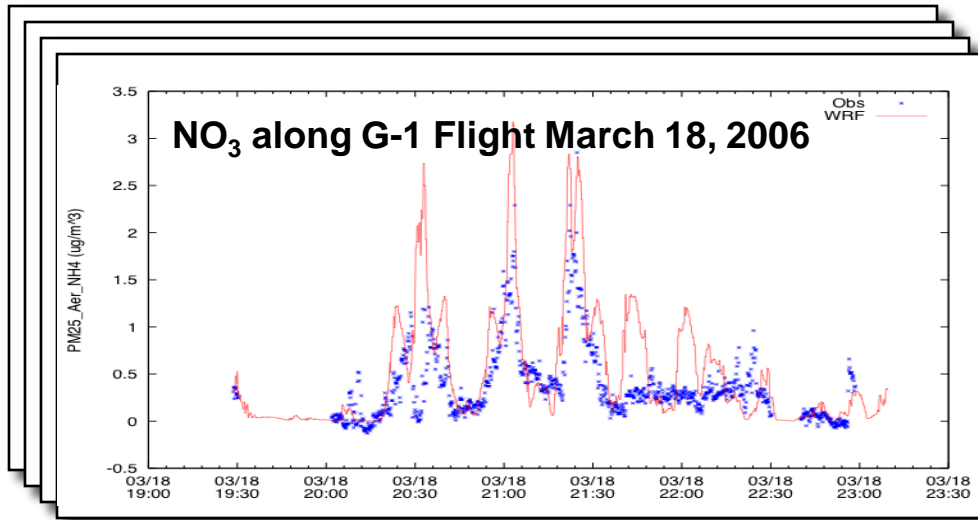


Scientist

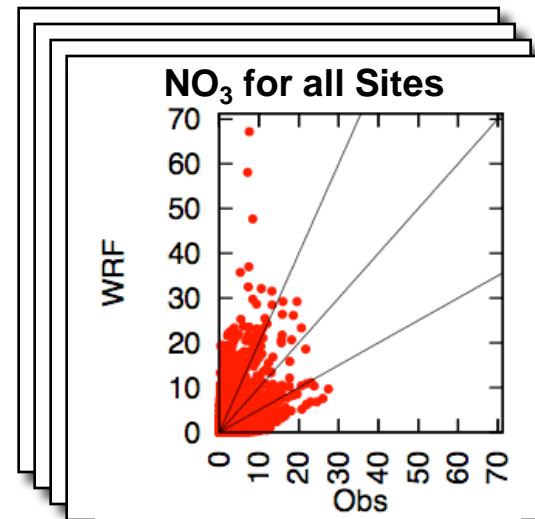
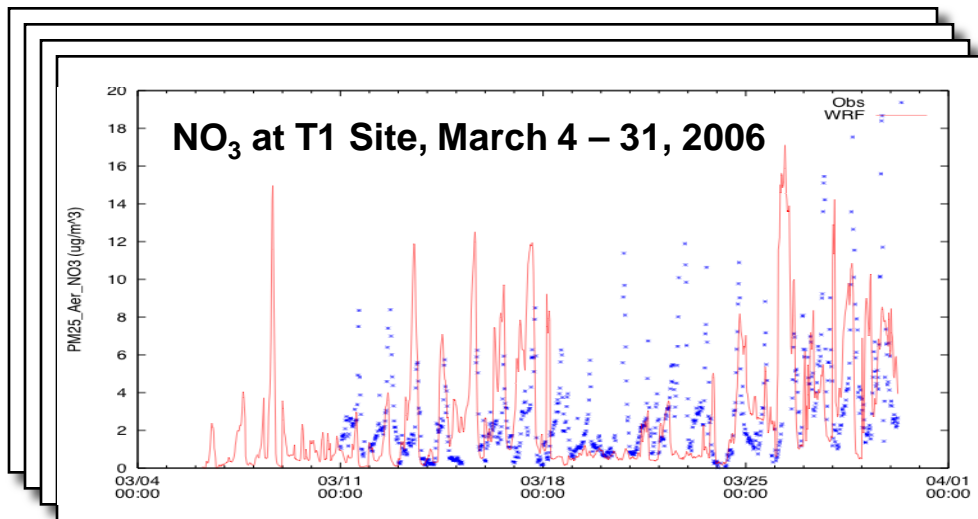


“Quick-Look” Plots

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

MILAGRO Testbed Case Example



Aerosols – NOT clouds

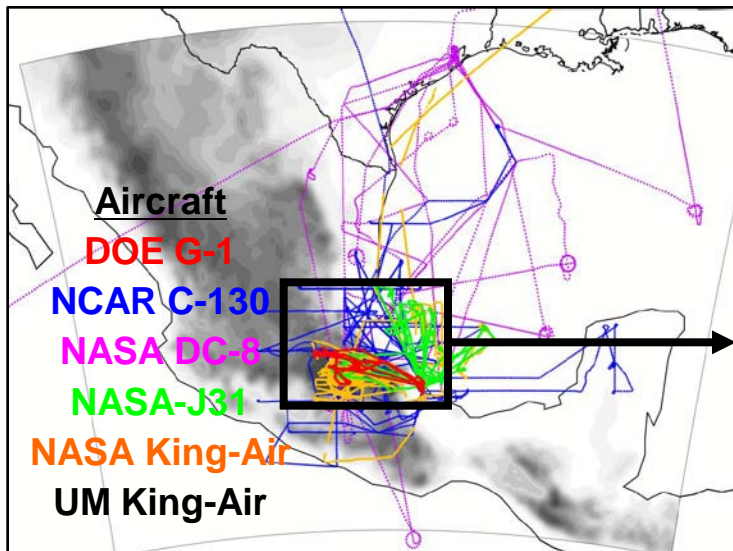
photo from NASA DC-8

Simulate aerosol transformation processes from urban to synoptic scales

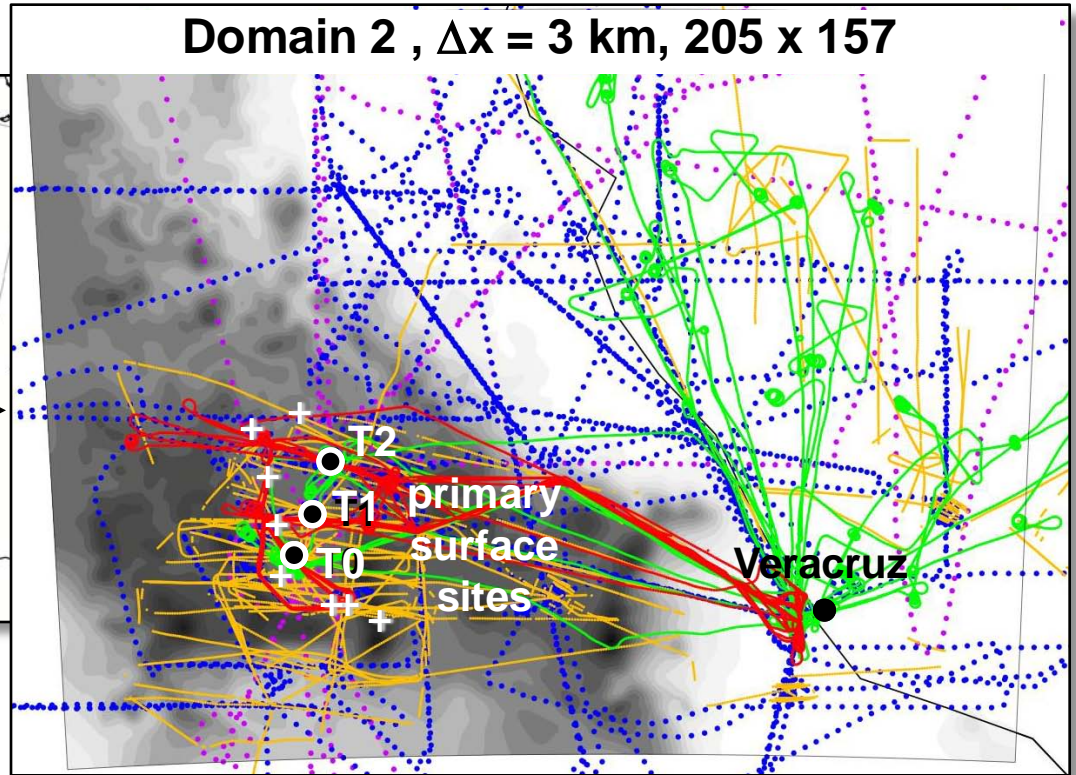
Testbed Case Configuration

Extensive Meteorological, Chemical, and Particulate Measurements

Domain 1, $\Delta x = 12$ km, 200 x 150



Domain 2, $\Delta x = 3$ km, 205 x 157



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

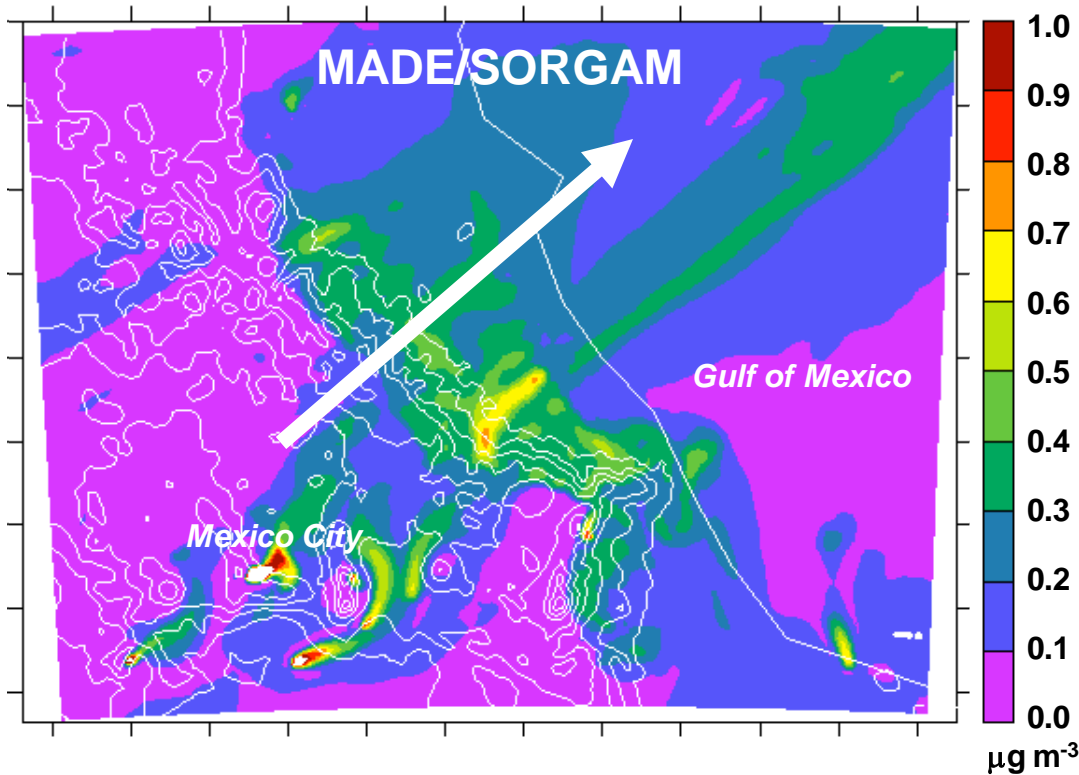
Comparing predictions in the **AMT:**

- 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*

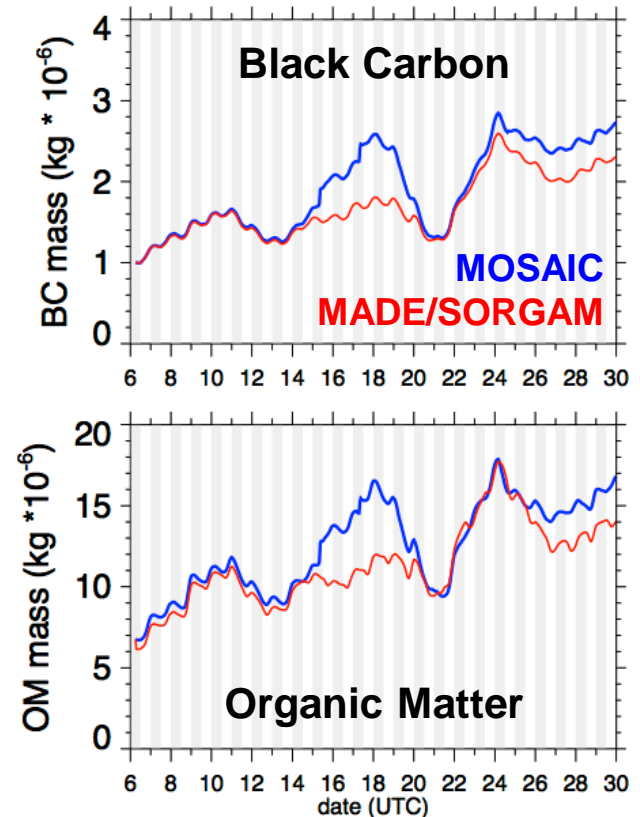
Carbonaceous Aerosols

Black Carbon Concentrations ~0.5 km AGL

21 UTC March 20 – Strong Ambient SW Winds



Mass within Domain 1 over 3-Week Period

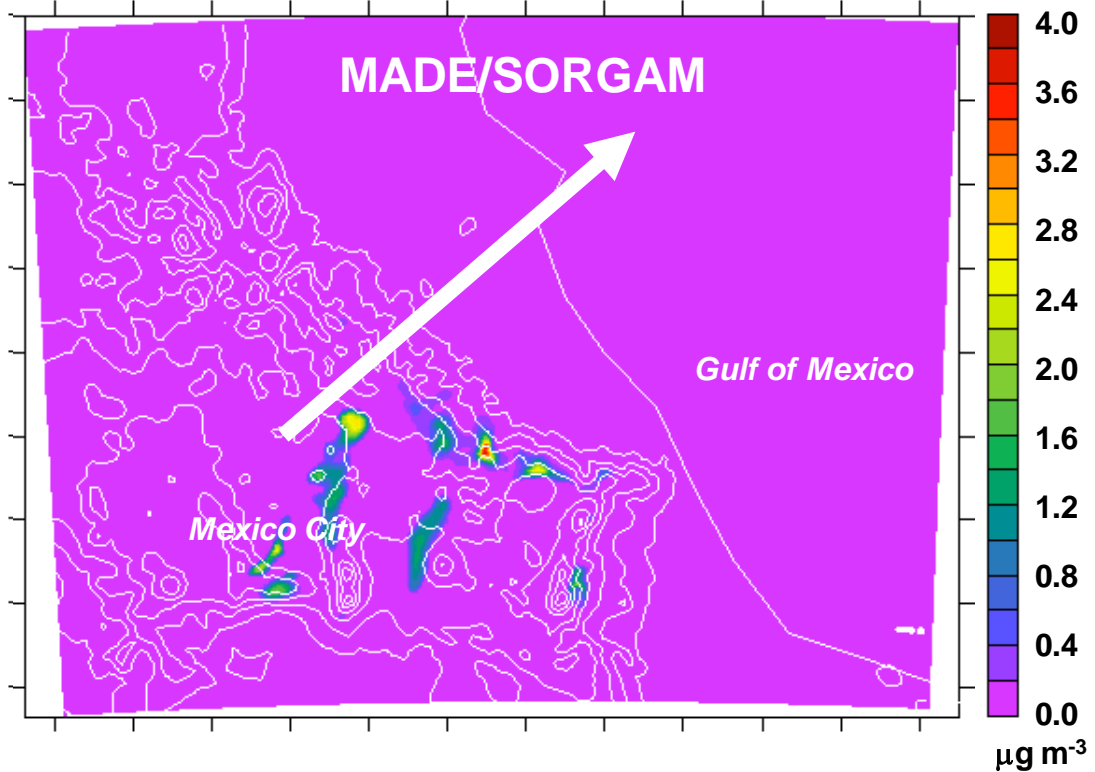


- Since BC and OM treated as scalars with no chemistry (*SOA turned off*), differences due solely to treatments of **deposition**
- Modular and interoperable deposition 'driver' will be implemented soon

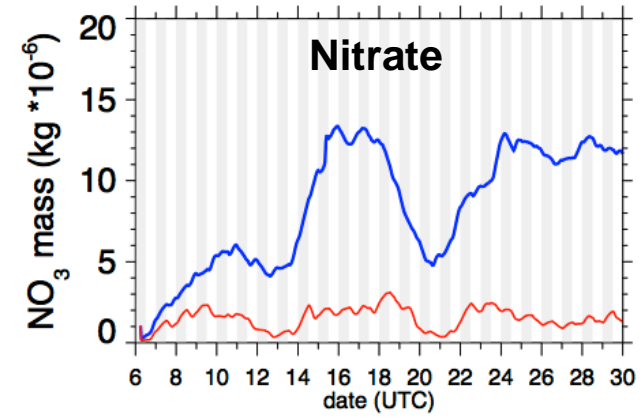
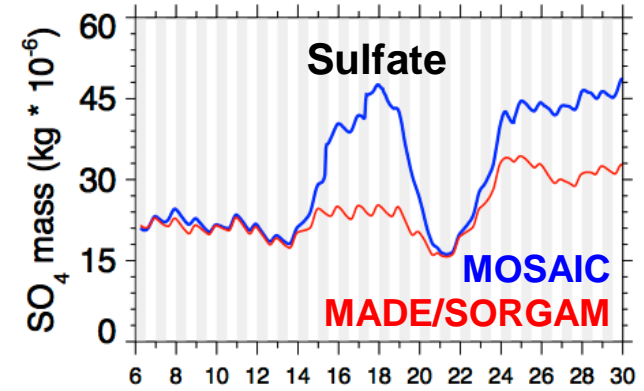
Secondary Aerosols

Nitrate Concentrations ~0.5 km AGL

21 UTC March 20 – Strong Ambient SW Winds



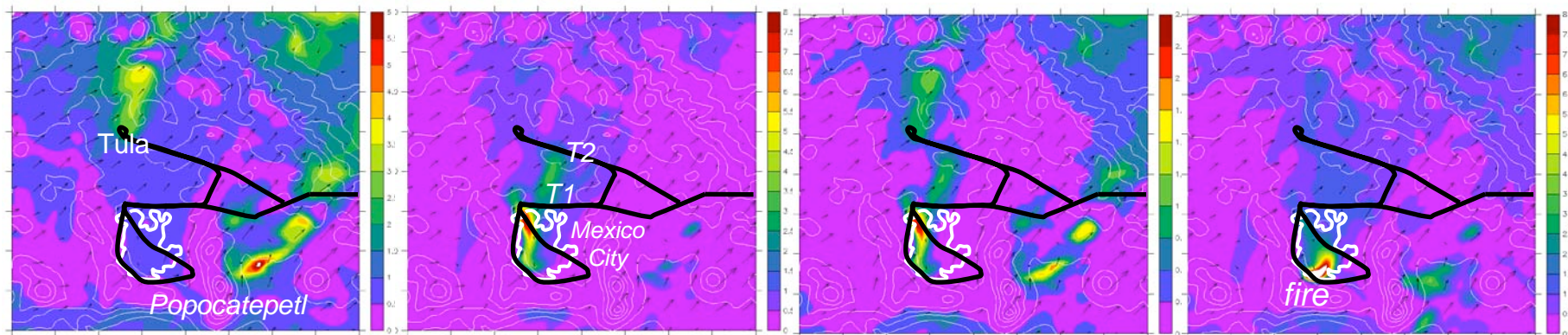
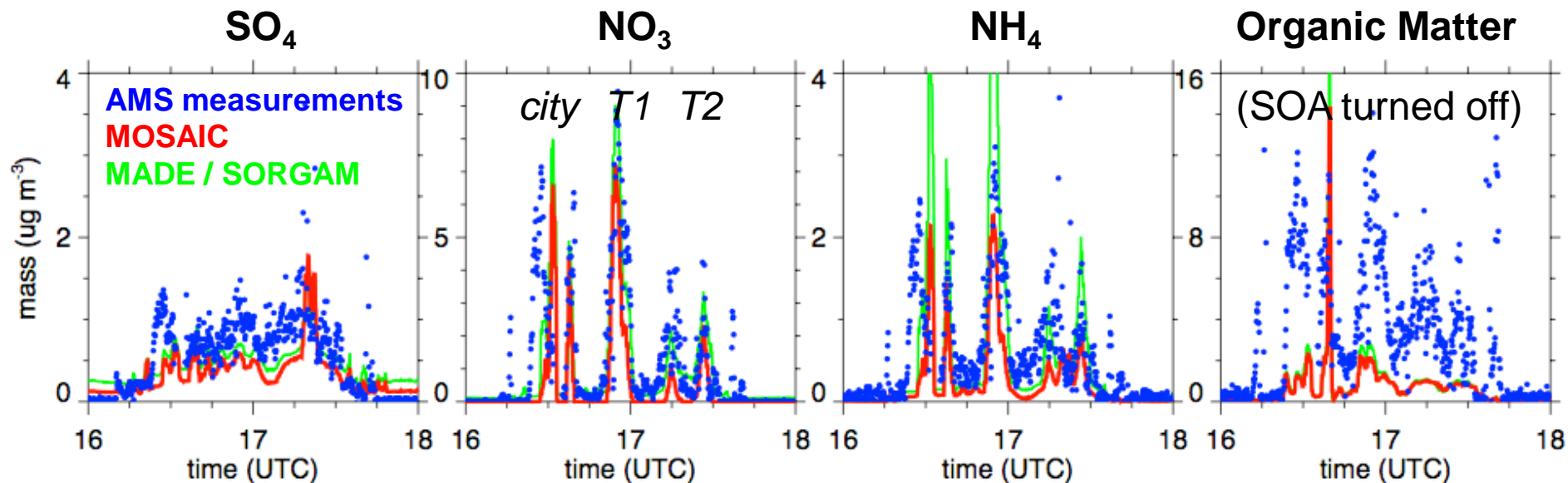
Mass within Domain 1 over 3-Week Period



- Deposition contributes to differences in secondary aerosols too, but different **gas-to-particle partitioning** treatments largely responsible
- $\text{HNO}_3 + \text{dust} \rightarrow \text{NO}_3$ 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?



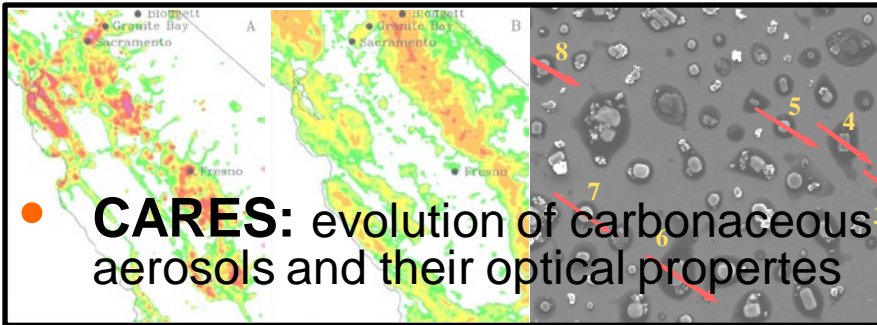
Pacific Northwest
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Future Testbed Cases

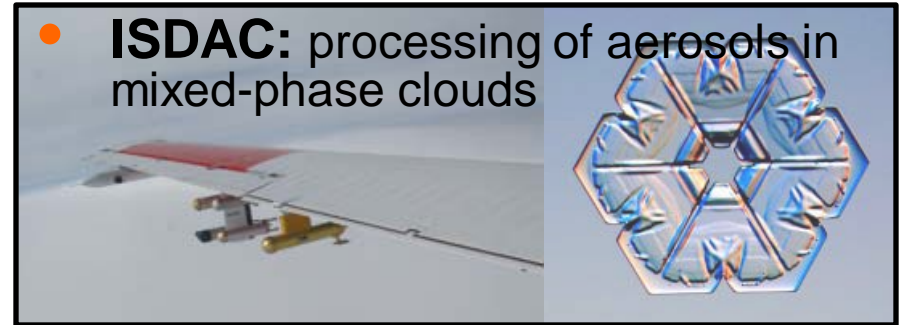
- **Multiple Testbed Cases Needed:**

- *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 properties

The image for CARES shows two maps of California (A and B) with color-coded regions, and a 3D visualization of aerosol particles with red arrows indicating their evolution and optical properties.

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

The image for ISDAC features a 3D rendering of an aircraft in flight and a large, complex, multi-faceted ice crystal structure.

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

The image for CHAPS/CLASIC shows a photograph of shallow cumulus clouds on the left and a 3D map of the Oklahoma region with a yellow box highlighting the study area around Oklahoma City.

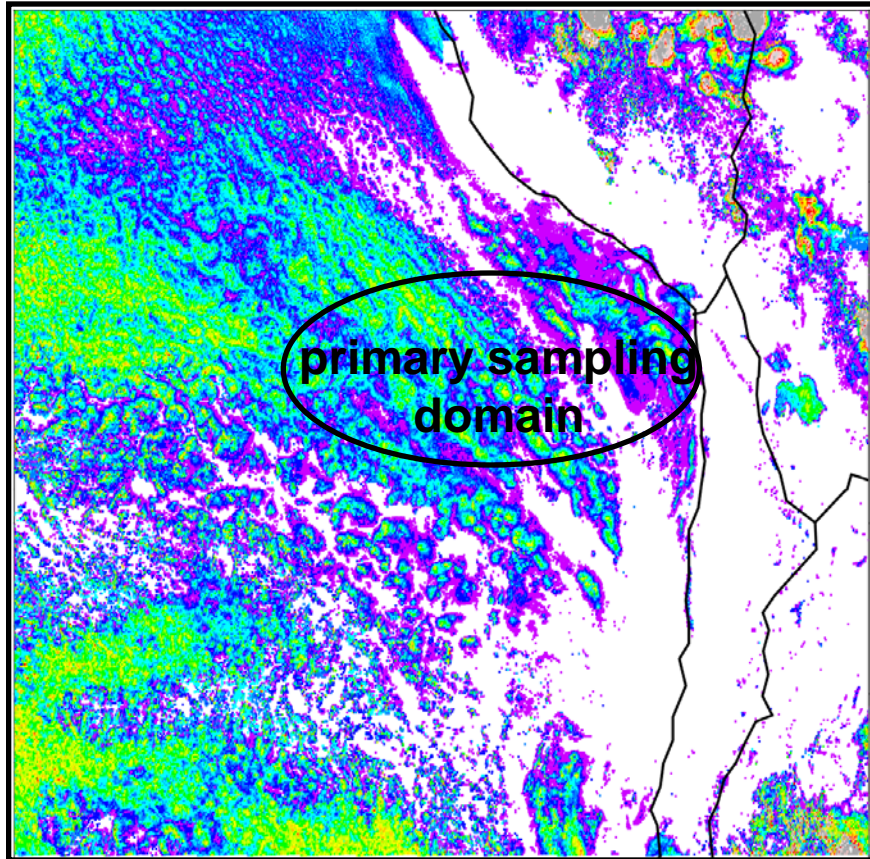
- **VOCALS:** aerosol processing in marine stratocumulus clouds

The image for VOCALS includes the logo for the VAMOS OCEAN CLOUD ATMOSPHERE LAND STUDY (VOCALS) and a photograph of marine stratocumulus clouds over the ocean.

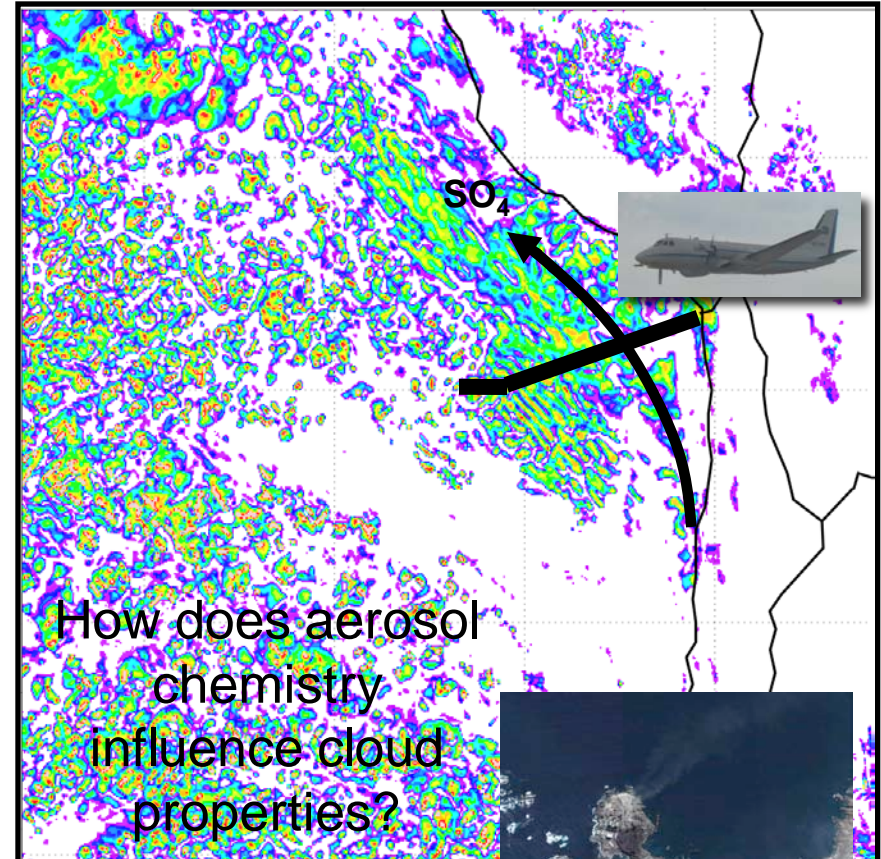
- **International Field Campaigns ?**

VOCALS

GOES LWP, 13 UTC October 25



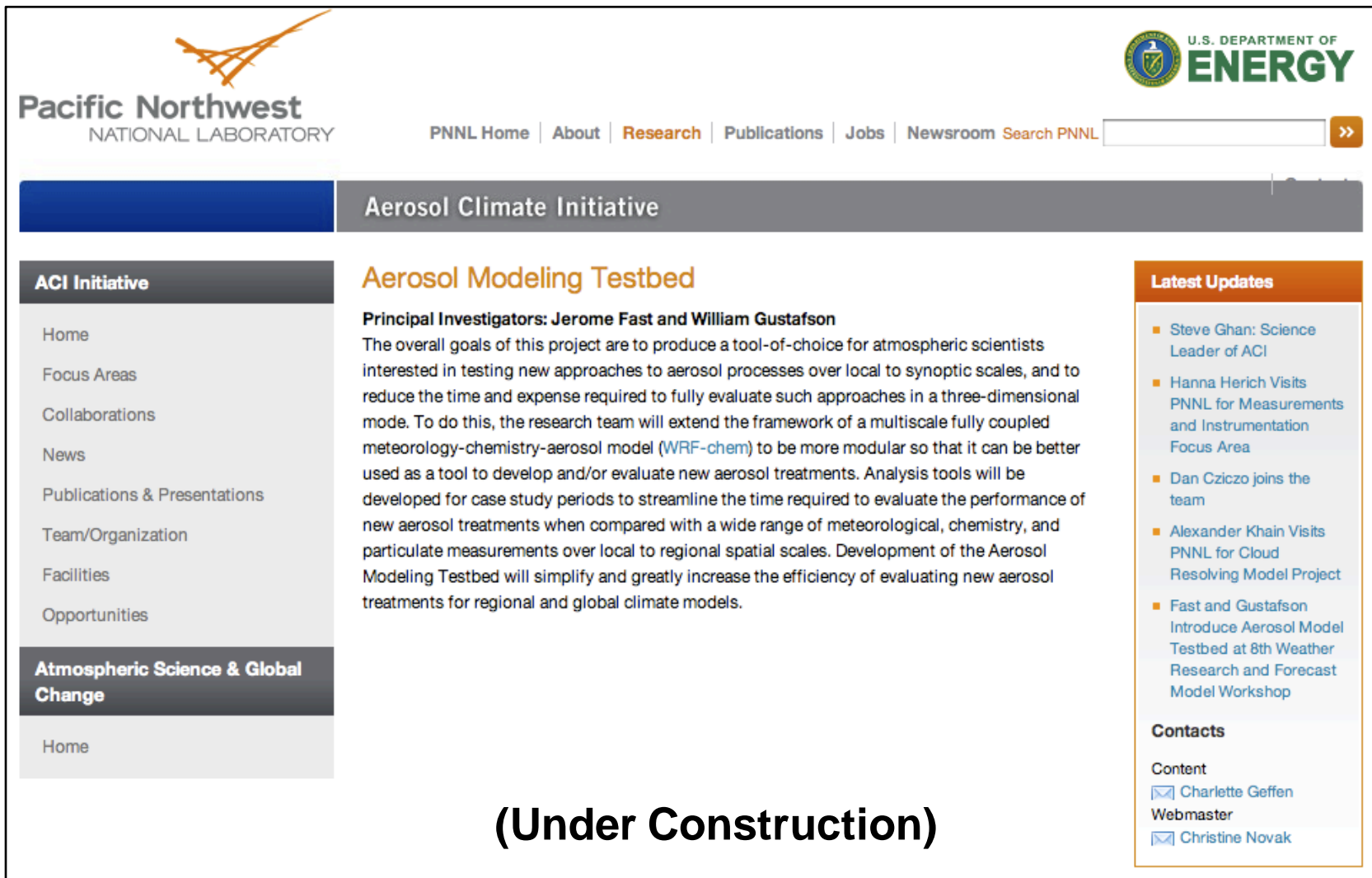
WRF LWP, $\Delta x = 4$ km



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



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Aerosol Climate Initiative

ACI Initiative

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Aerosol Modeling Testbed

Principal Investigators: Jerome Fast and William Gustafson

The overall goals of this project are to produce a tool-of-choice for atmospheric scientists interested in testing new approaches to aerosol processes over local to synoptic scales, and to reduce the time and expense required to fully evaluate such approaches in a three-dimensional mode. To do this, the research team will extend the framework of a multiscale fully coupled meteorology-chemistry-aerosol model (*WRF-chem*) to be more modular so that it can be better used as a tool to develop and/or evaluate new aerosol treatments. Analysis tools will be developed for case study periods to streamline the time required to evaluate the performance of new aerosol treatments when compared with a wide range of meteorological, chemistry, and particulate measurements over local to regional spatial scales. Development of the Aerosol Modeling Testbed will simplify and greatly increase the efficiency of evaluating new aerosol treatments for regional and global climate models.

Latest Updates

- Steve Ghan: Science Leader of ACI
- Hanna Herich Visits PNNL for Measurements and Instrumentation Focus Area
- Dan Cziczo joins the team
- Alexander Khain Visits PNNL for Cloud Resolving Model Project
- Fast and Gustafson Introduce Aerosol Model Testbed at 8th Weather Research and Forecast Model Workshop

Contacts

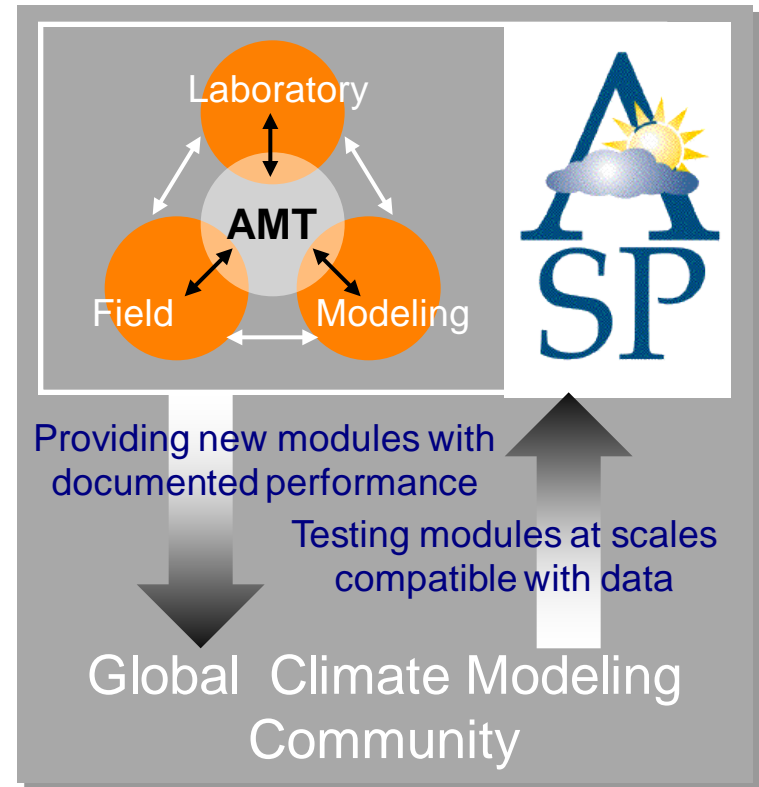
Content

- Charlette Geffen Webmaster
- Christine Novak

(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 consequently aerosol radiative forcing in regional and global models



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