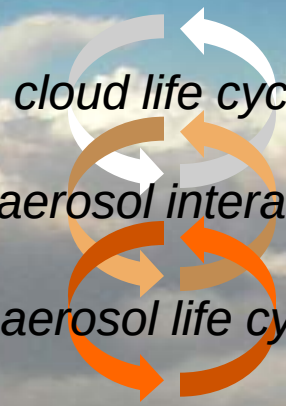
Applying the Aerosol and Cloud Modeling Testbed



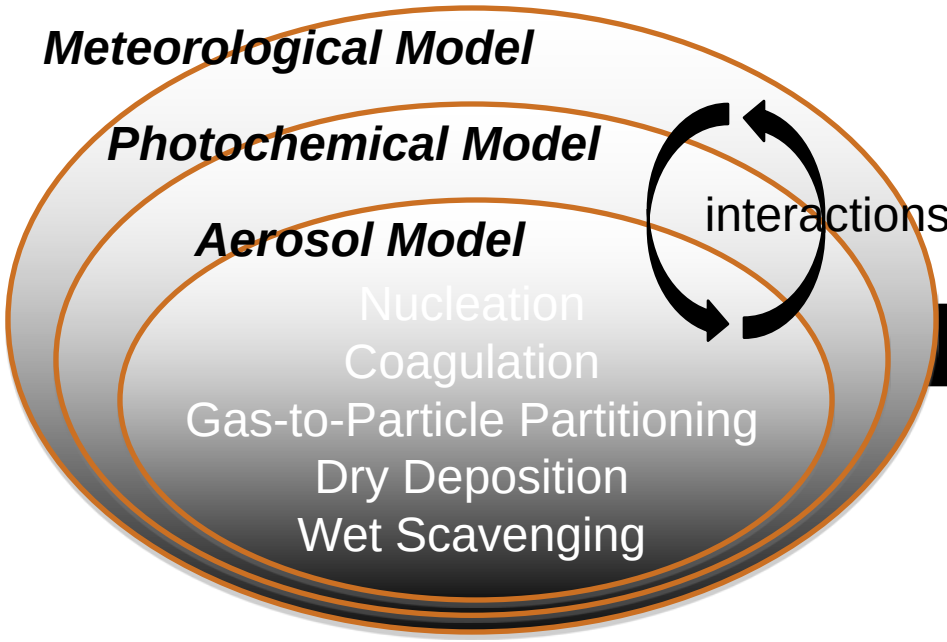
to Assess the Performance of Simulated Particle Properties and Radiative Forcing from Different Process Modules

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

ARM Aerosol Working Group Meeting, Boulder, CO, October 1, 2009

Pacific Northwest
NATIONAL LABORATORY

What is the Problem?



Traditional Modeling Paradigm
processes tightly coupled within aerosol model & other components of atmospheric model

applied to specific case

- Current 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

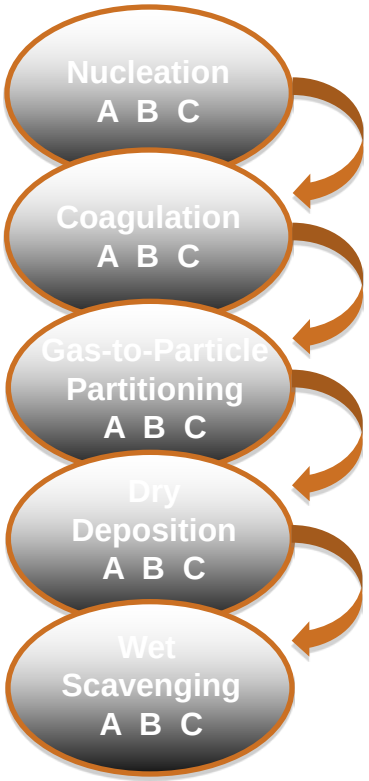
Pacific Northwest
NATIONAL LABORATORY

What Are We Trying to Accomplish?

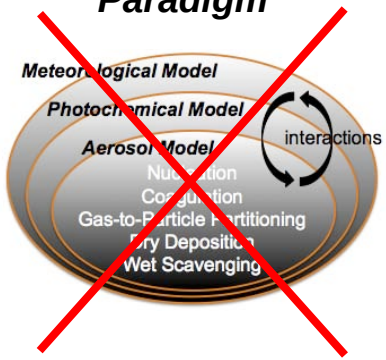
Aerosol and Cloud Testbed: A computational framework that streamlines the process of testing and evaluating aerosol and clouds process modules over a range of spatial / temporal scales

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

New Modeling Paradigm



Traditional Modeling Paradigm



Pacific Northwest
NATIONAL LABORATORY

ACT in Relation to Other DOE Activities

ACT Aerosol and Cloud Testbed
CAPT CCPP ARM Parameterization Testbed
FPT Fast-Physics Testbed

} ***What are the similarities and differences ?***

	ACT	CAPT	FPT
Model	WRF	CAM	multiple (WRF, CAM)
Spatial Scale	LES to mesoscale	global / single column	single-column, LES to global
Primary Processes Addressed	aerosols, cloud-aerosol interactions, cloud properties, trace gases	cloud properties	cloud properties, some cloud-aerosol interactions
Data Used for Evaluation	field campaign + operational data	operational + field campaign data	operational + field campaign data

How could they interact?

Assessment of how new cloud parameterizations perform in the presence of predicted aerosols

New / improved parameterizations of cloud properties

Example

Comparing Two Models in the Testbed

	MADE/SORGAM	MOSAIC
size distribution	modal (3 modes)	sectional (8 bins)
# of prognostic species	38 (76 with clouds)	104 (192 with clouds)

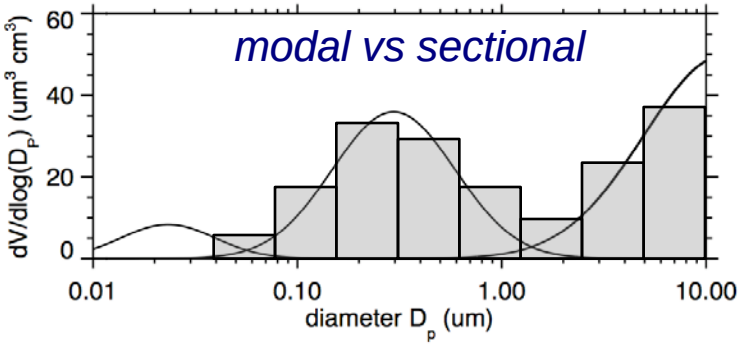
~ 2.7

Identical:

- *Anthropogenic, biomass burning, online sea-salt & dust emissions*
- *Boundary conditions from global chemistry model (MOZART)*
- *Photochemistry (CBM-Z)*
- *SOA turned off*
- *Aerosol optical properties*
- *Cloud-aerosol-radiation interactions*
- *Dry deposition*

Differences:

- *Nucleation & coagulation*
- *Gas-to-particle partitioning: (equilibrium vs dynamic)*
- *Size distribution*



- *MOSAIC is ~ 1.85 times more computationally expensive*

Testbed Case Development

Weather Research and Forecasting community model

configuring model domain, emissions, boundary conditions, etc.

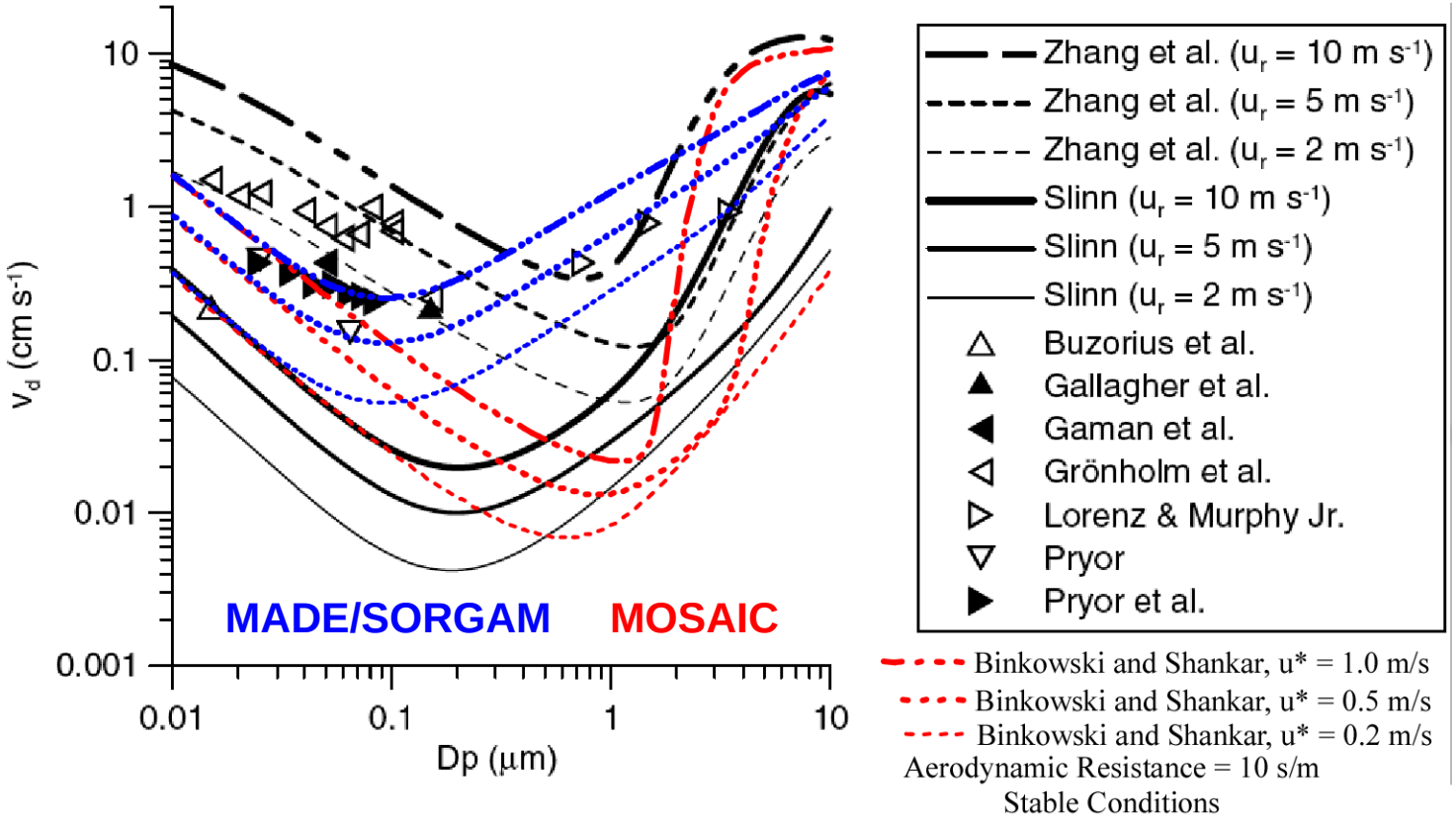
Analysis Toolkit Software

Simulators	Metrics
time series, profiles, aircraft, lidar, satellite	statistics graphics

Interoperability: Dry Deposition

Deposition Velocity for Evergreen Needleleaf Forest

from Pryor et al., Tellus, 2008

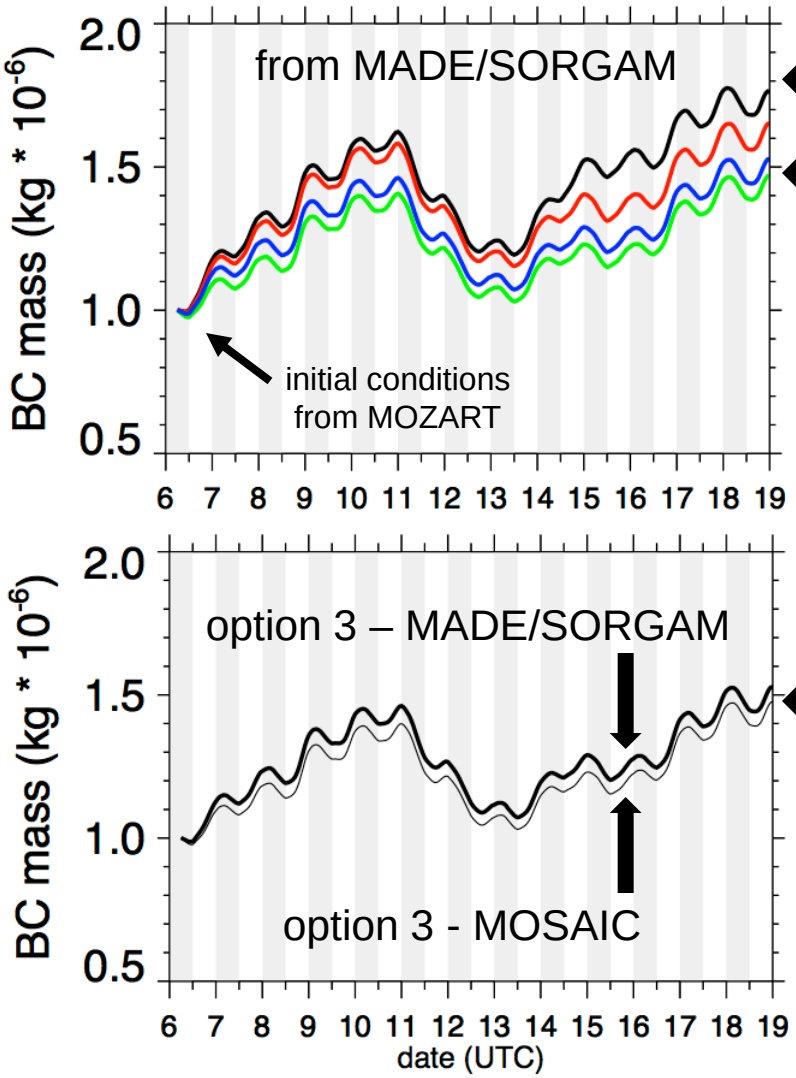


- v_d **varies greatly** among dry deposition treatments
- treatments based on **limited data** for specific vegetation types

Dry Deposition Uncertainties in Testbed Case

Black Carbon Mass

throughout entire model domain



models identical when deposition off

differences of ~12% among treatments

black = dry deposition off
option 1 (from MADE/SORGAM)
option 2 (from MOSAIC)
option 3 (from Zhang et al., 2001)

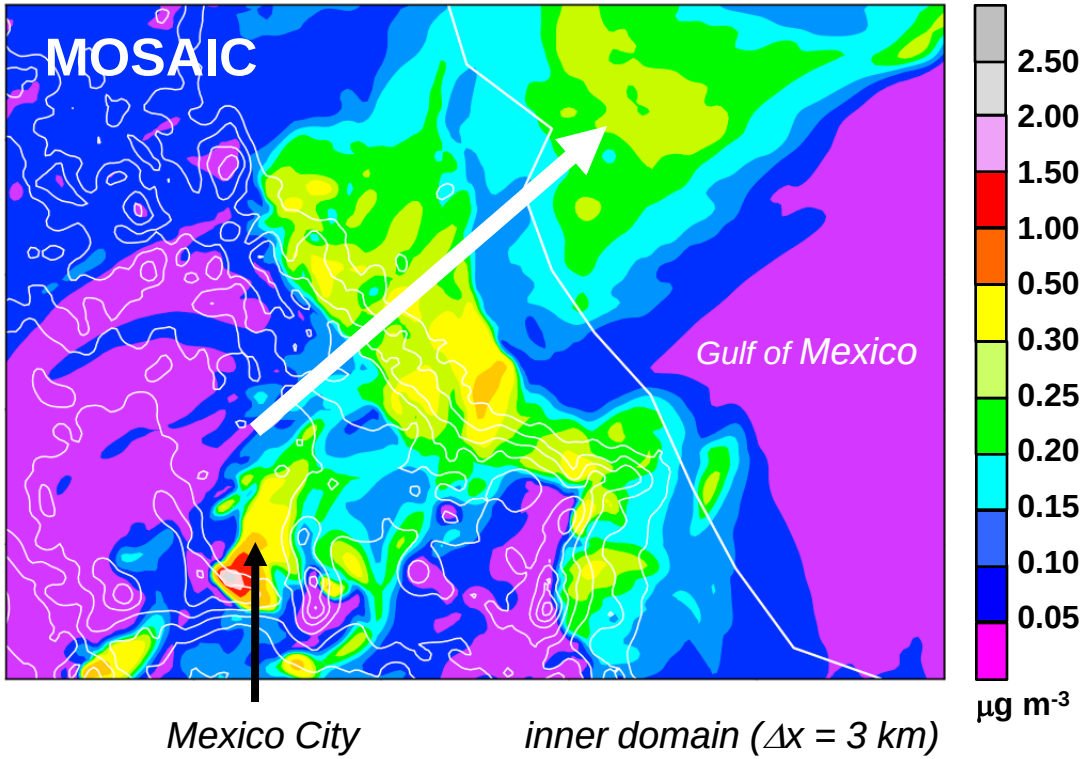
] interoperable

differences in size distribution produce differences of ~3%

Carbonaceous Aerosols

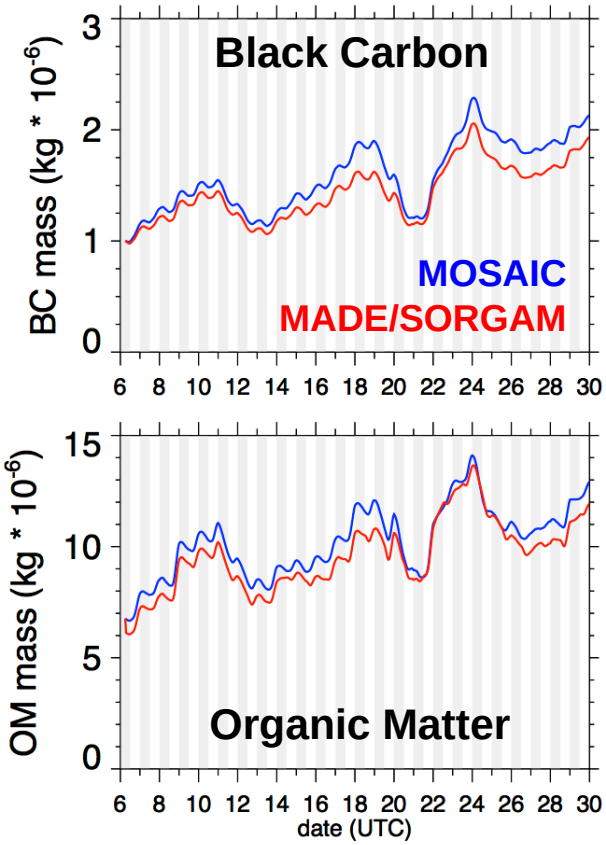
Black Carbon Concentrations ~1 km AGL

21 UTC March 20 – Strong Ambient SW Winds



Mass within Outer Domain

dry deposition option 1

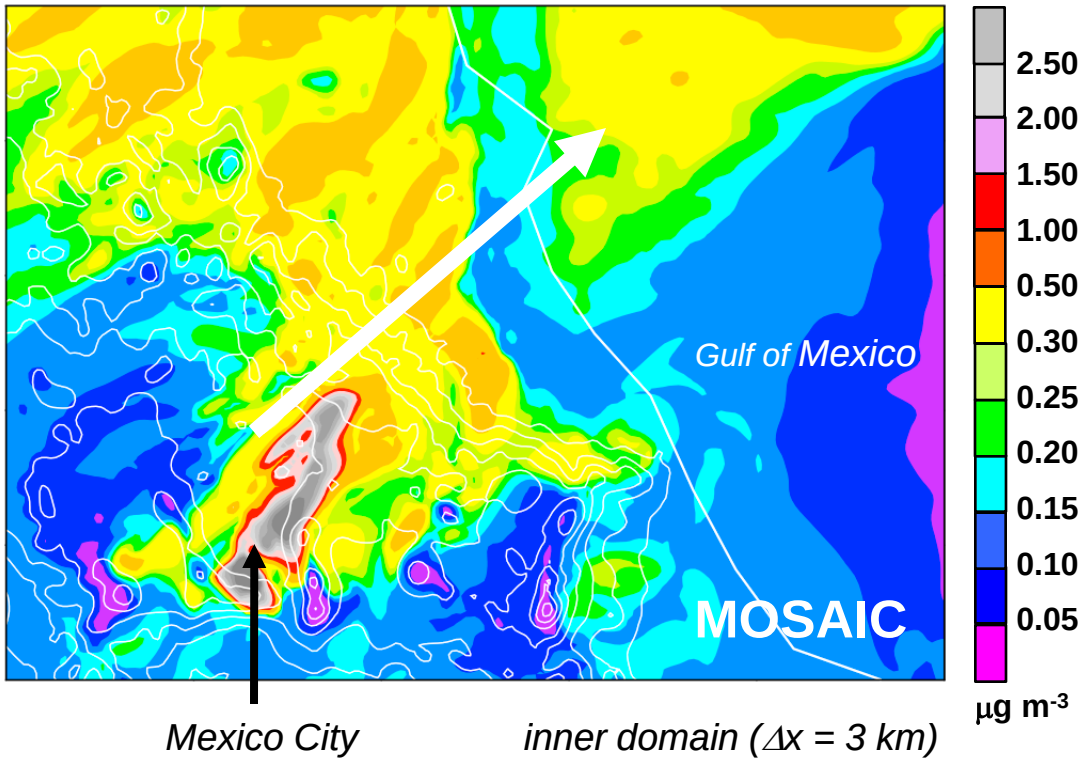


- Since BC and OM treated as a scalars with no chemistry (*SOA turned off*), differences due solely to **size distribution** in dry deposition and wet scavenging

Secondary Aerosols

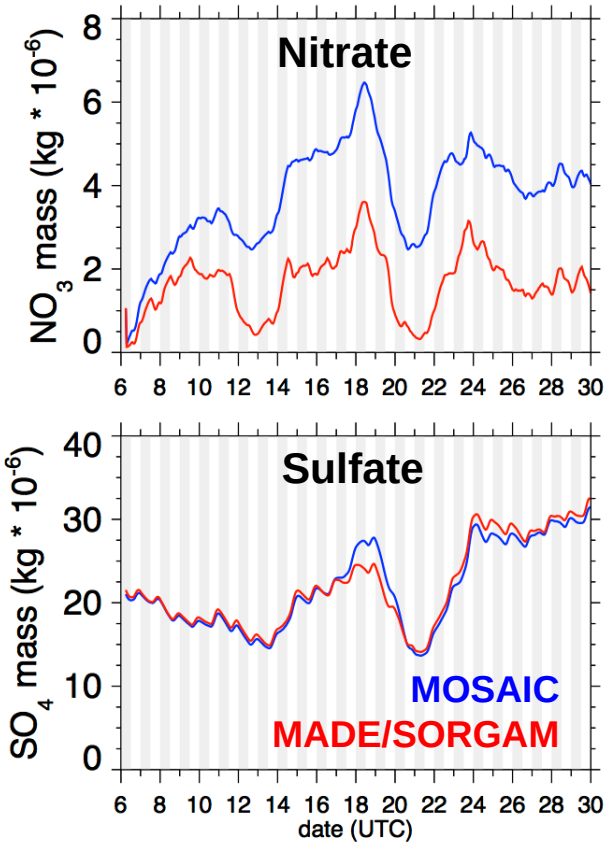
Nitrate Concentrations ~1 km AGL

21 UTC March 20 – Strong Ambient SW Winds



Mass within Outer Domain

dry deposition option 1

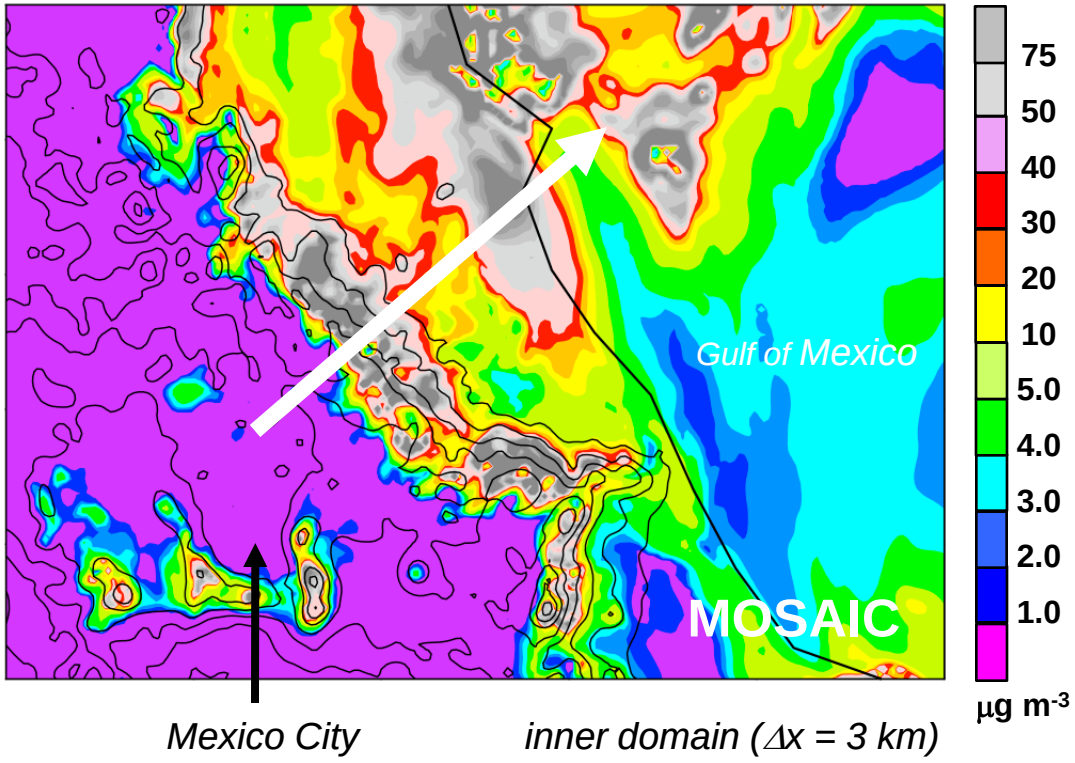


- Removal contributes to differences in secondary aerosols too, but different **gas-to-particle partitioning** treatments largely responsible
- HNO_3 + dust ⟶ NO_3 included in MOSAIC, but not MADE/SORGAM

Aerosol Water

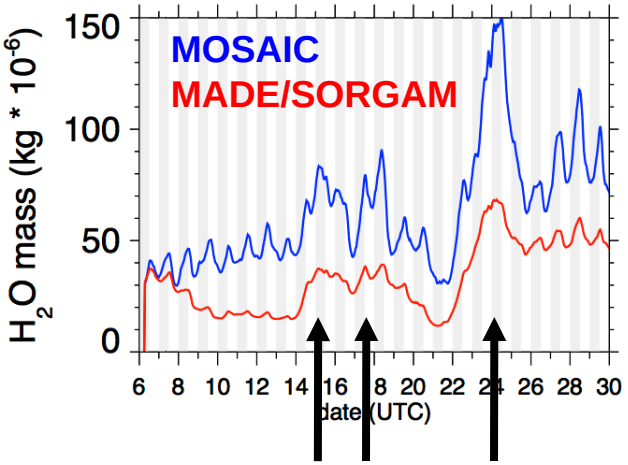
Aerosol Water ~1 km AGL

21 UTC March 20 – Strong Ambient SW Winds



H_2O within Outer Domain

dry deposition option 1

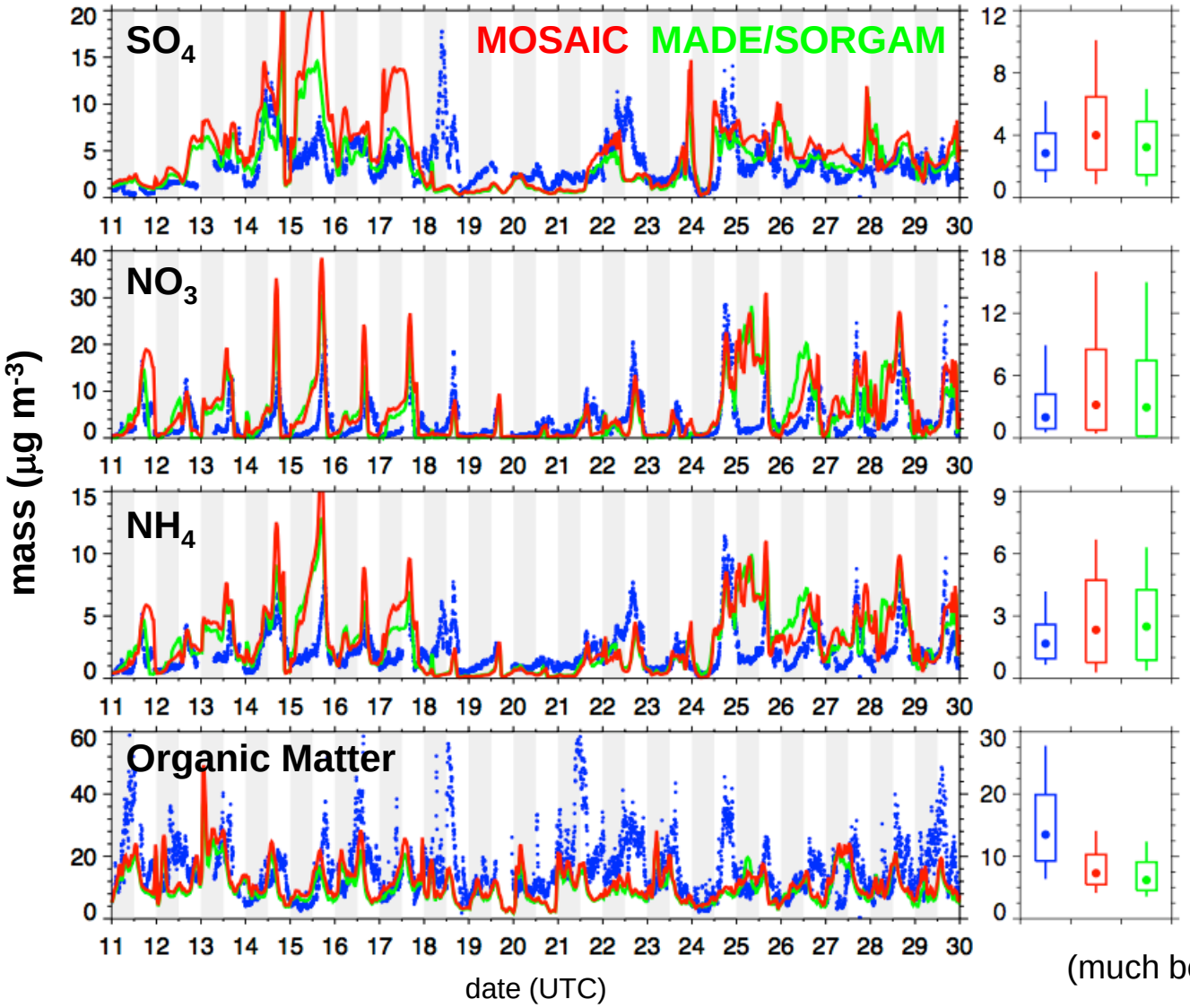


cold surges – higher RH

- Differences due to treatment of **gas-to-particle partitioning** and varying amounts of hydrophilic and hydrophobic aerosols

Aerosol Composition over Mexico City

AMS Observations at T0 Site



r	IA	b
0.38	0.51	1.58
0.36	0.51	0.35

r	IA	b
0.55	0.65	2.40
0.46	0.63	1.59

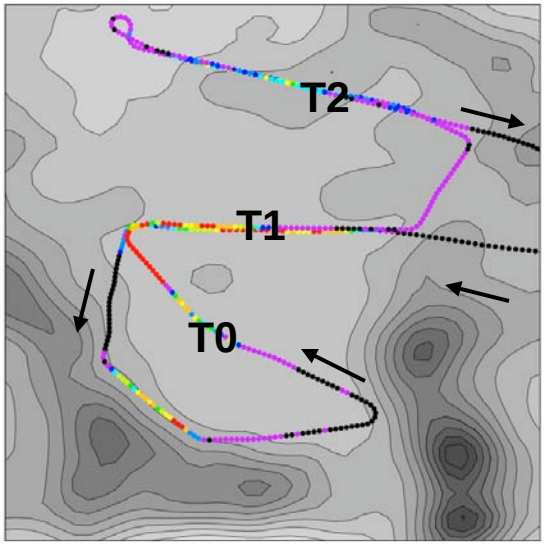
r	IA	b
0.49	0.61	0.98
0.46	0.61	0.77

r	IA	b
0.28	0.47	-7.40
0.28	0.47	-8.59

(much better agreement with HOA)

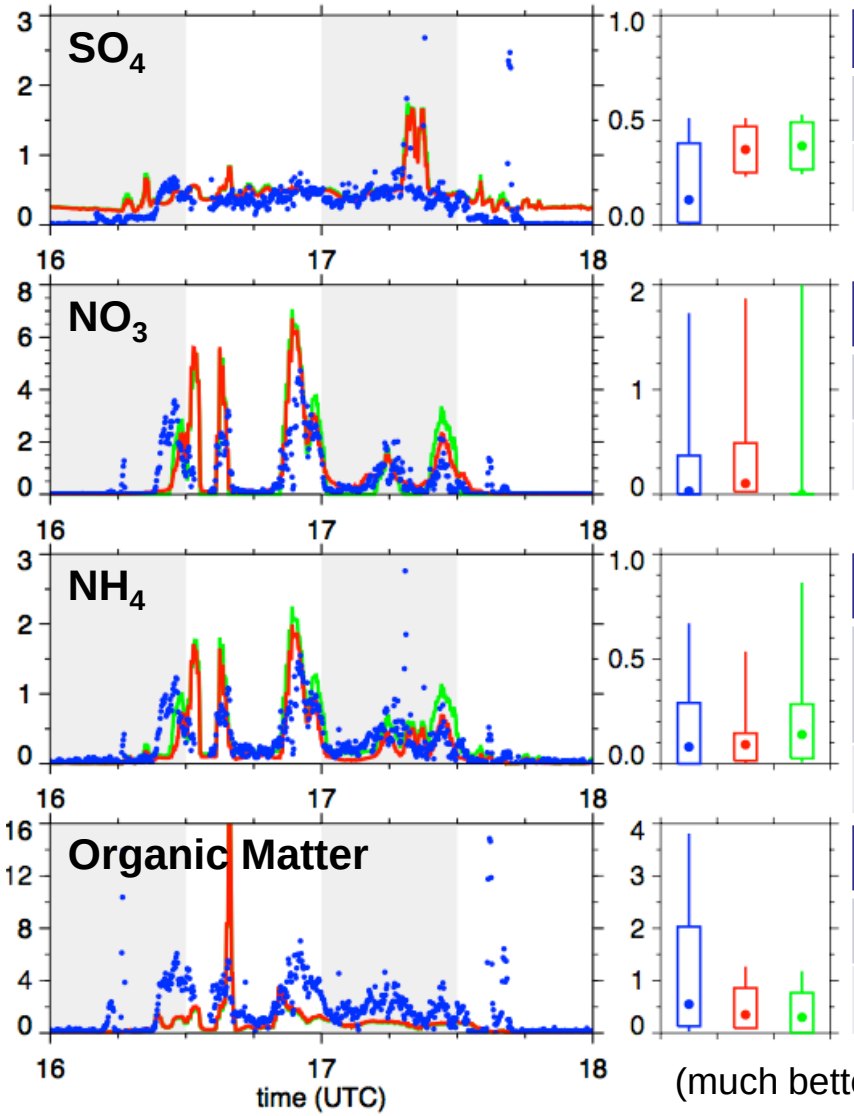
Aerosol Composition around Mexico City

NO_3 along G-1 Flight Path March 20



red = highest concentrations

AMS Observations MOSAIC MADE/SORGAM



r	IA	b
0.31	0.24	0.12
0.35	0.28	0.13

r	IA	b
0.69	0.80	0.13
0.70	0.79	0.09

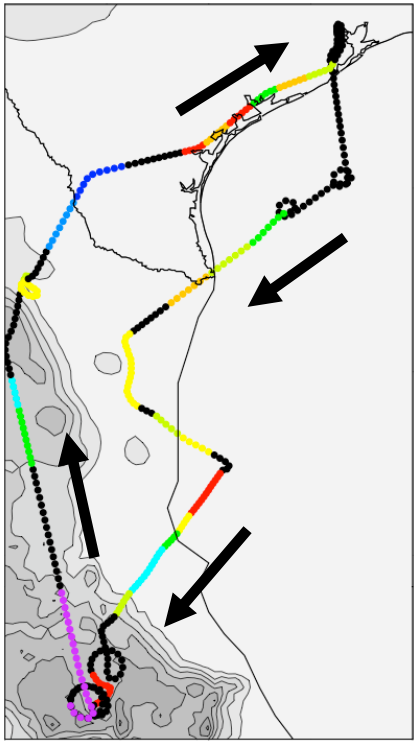
r	IA	b
0.62	0.78	-0.03
0.67	0.79	0.06

r	IA	b
0.28	0.49	-0.73
0.28	0.48	-0.79

(much better agreement with HOA)

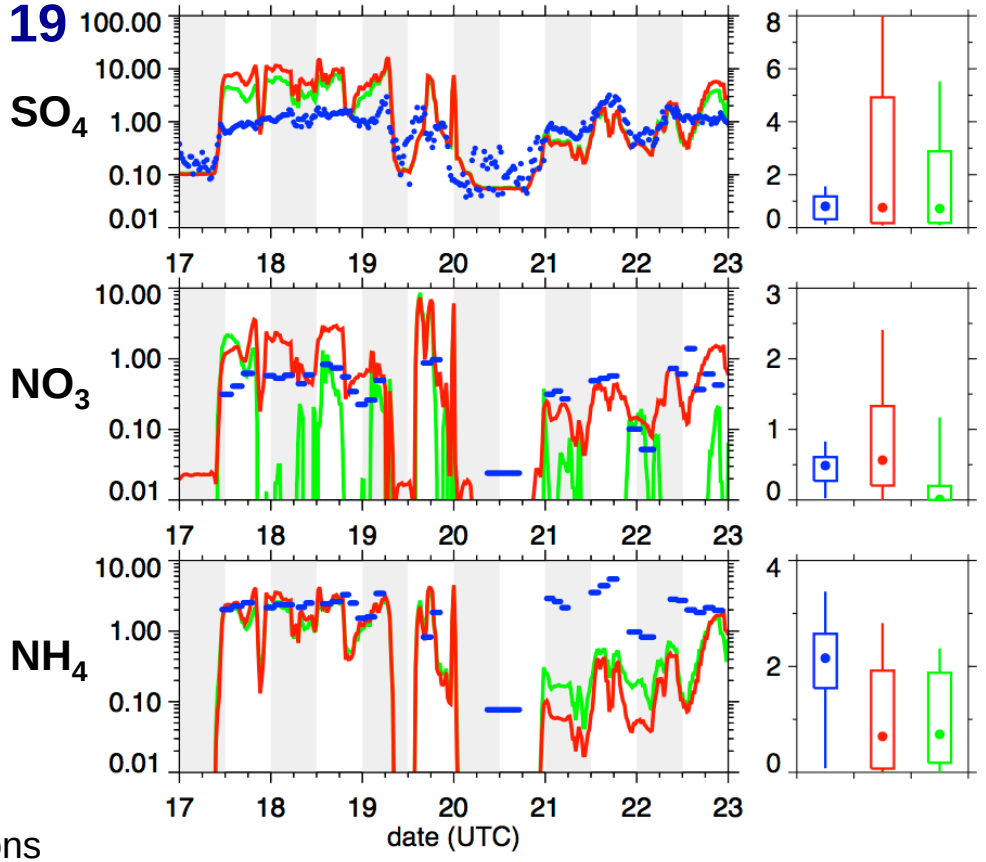
Aerosol Composition Downwind of Mexico City

NO_3 along DC-8 Flight Path March 19



red = highest concentrations

PILS Observations MOSAIC MADE/SORGAM



r	IA	b
0.42	0.22	1.80
0.46	0.34	1.01

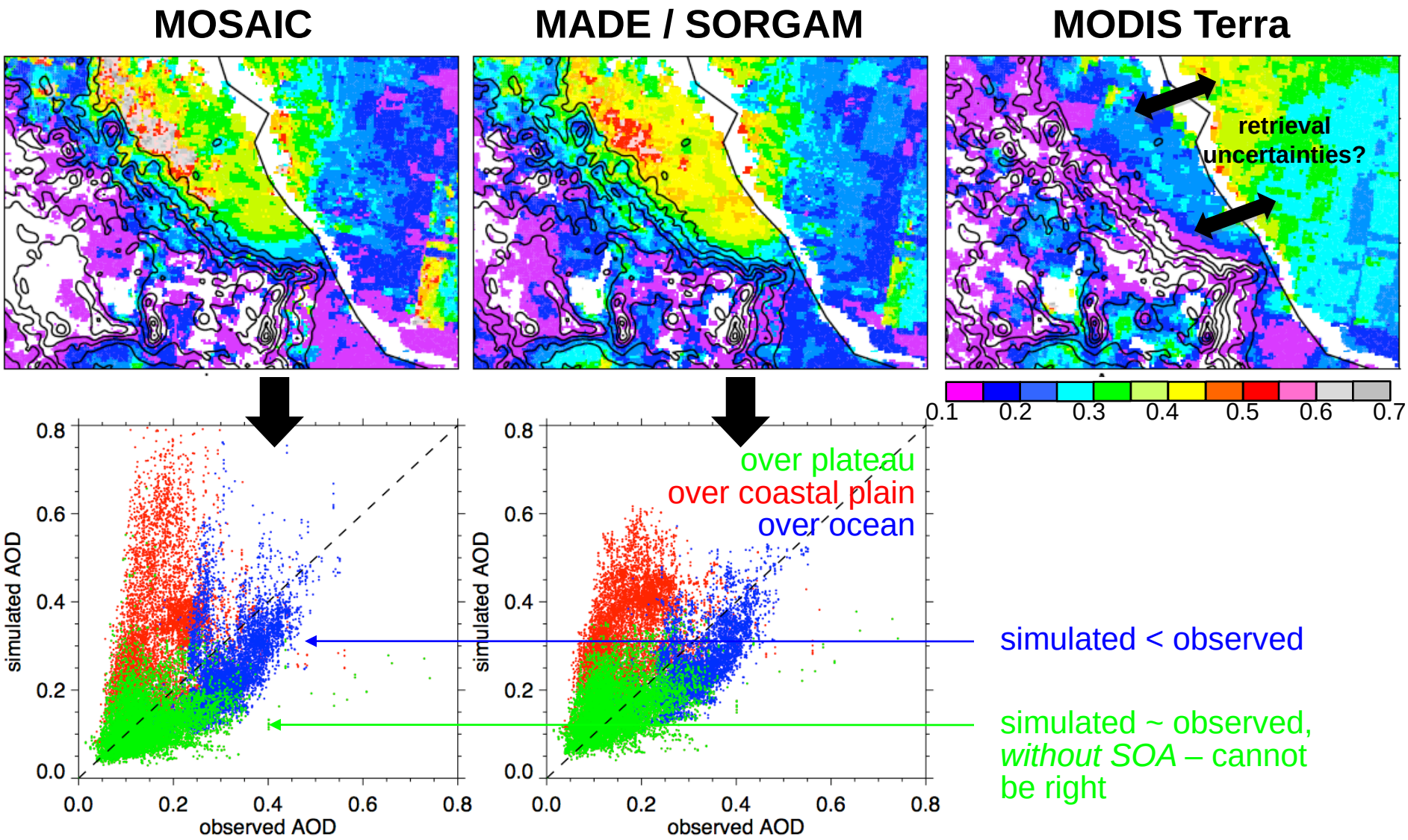
r	IA	b
0.46	0.37	0.46
0.22	0.38	-0.13

r	IA	b
0.14	0.49	-0.99
0.18	0.50	-1.10

- Meteorological errors contribute to plume displacements over Gulf?
- MOSAIC somewhat better in predicting NO_3 downwind

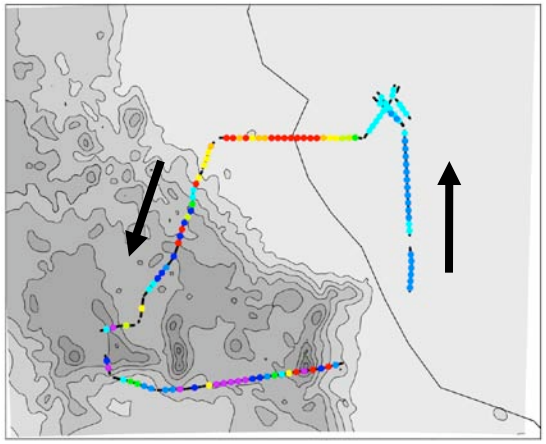
Satellite Simulator

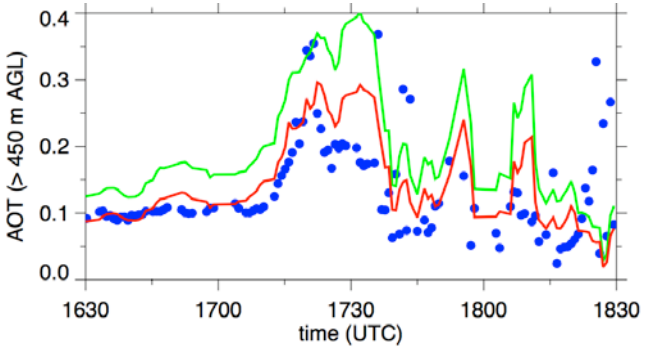
Average AOD between March 6 and 29



Lidar Simulator

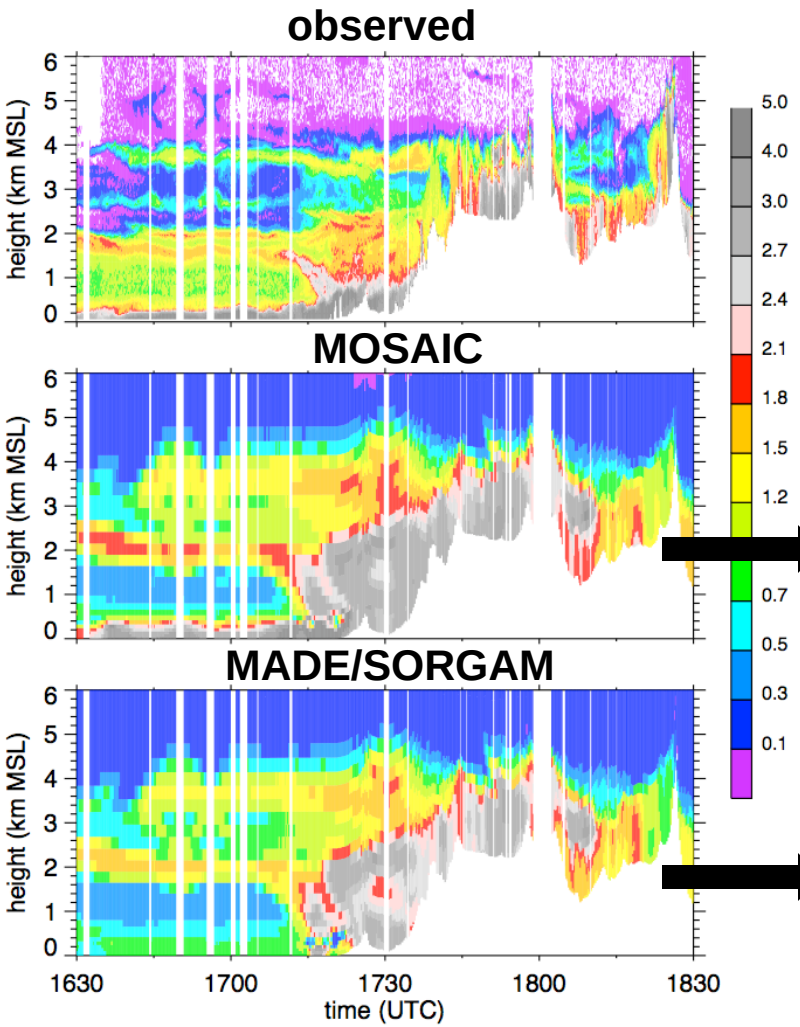
AOT along B-200 Flight Path March 12



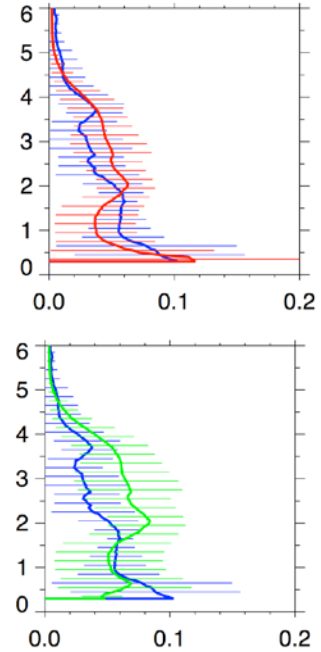


observed
MOSAIC
MADE/SORGAM

HRSL Backscatter Profiles



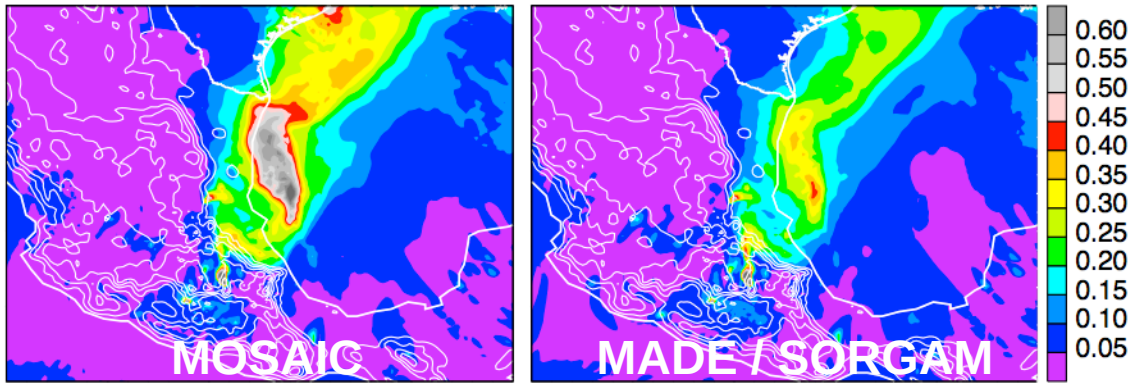
Mean and σ of extinction



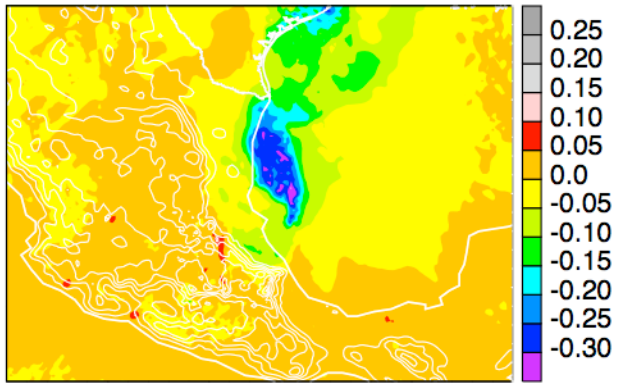
What is impact on heating rates?

Aerosol-Radiation Effects: No Dust

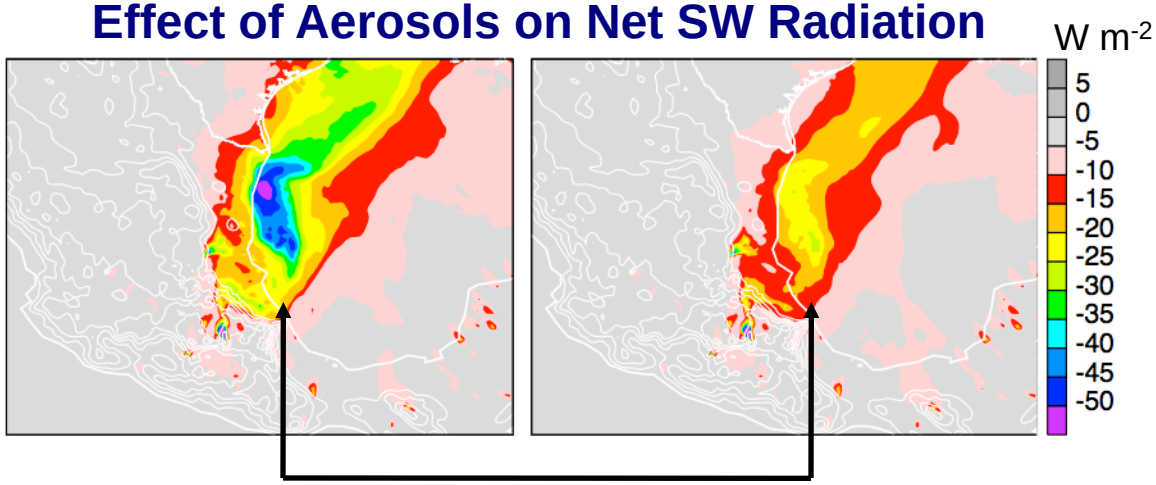
400 nm AOD 19 UTC March 19

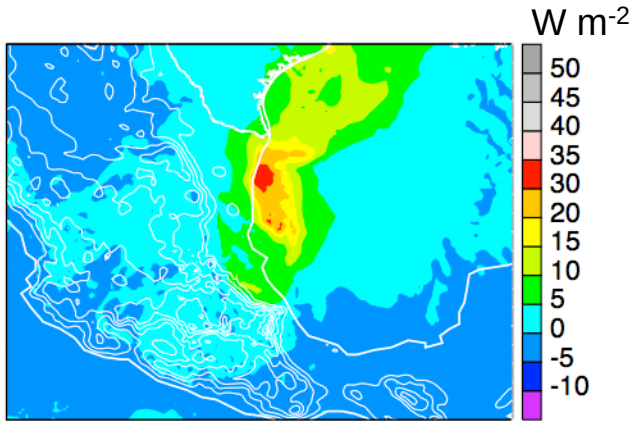


MADE / SORGAM - MOSAIC



Effect of Aerosols on Net SW Radiation

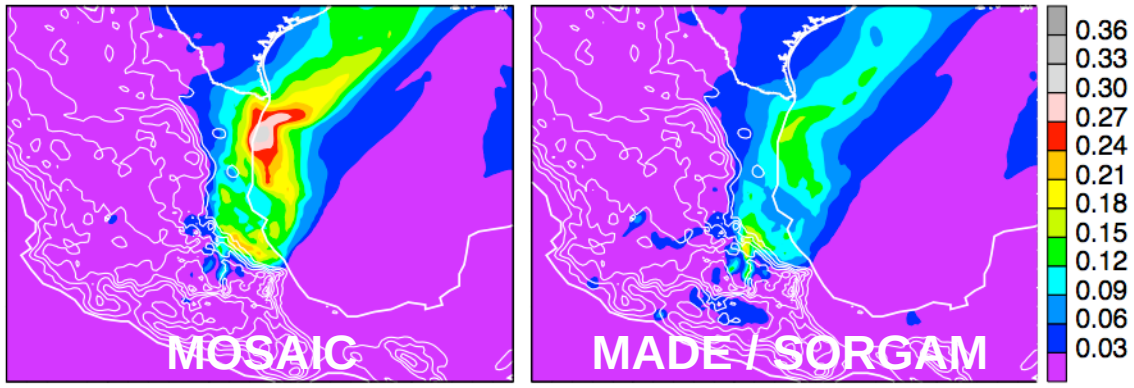




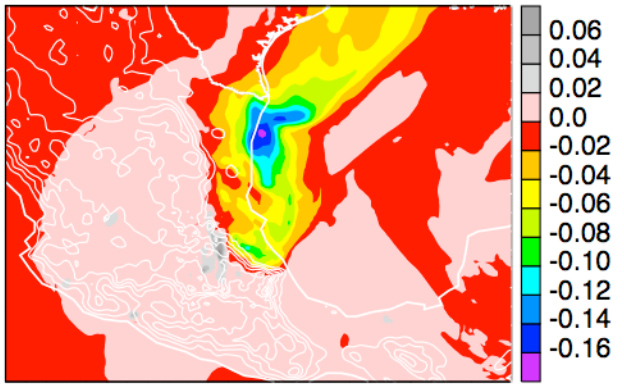
MOSAIC has greater impact

Aerosol-Radiation Effects: SO_4 + NO_3 + NH_4

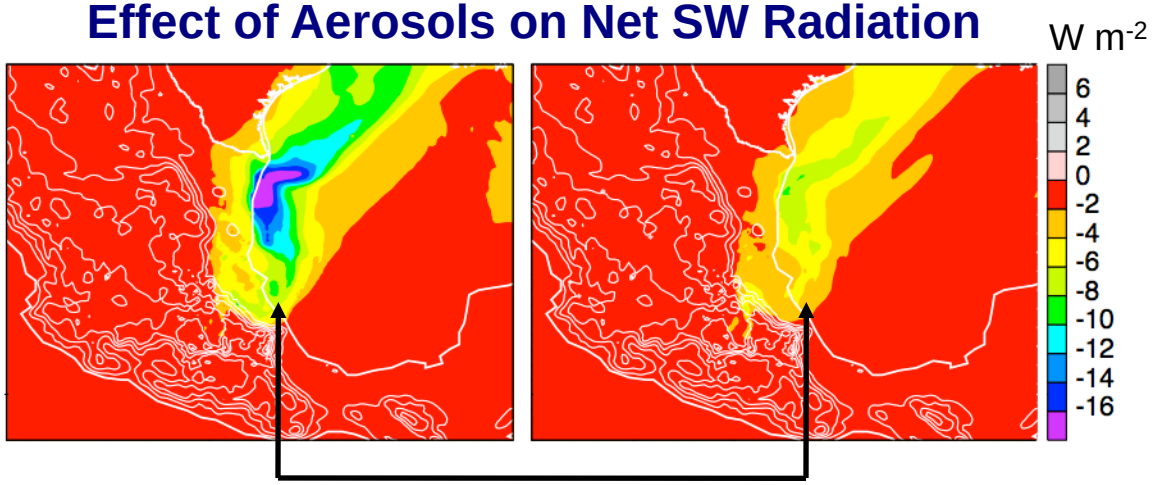
400 nm AOD 19 UTC March 19

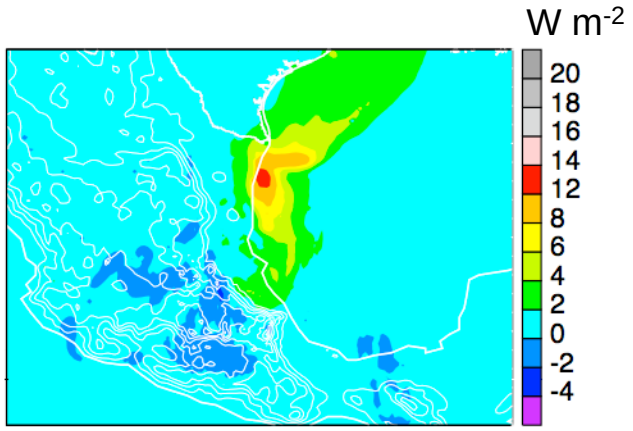


MADE / SORGAM - MOSAIC



Effect of Aerosols on Net SW Radiation

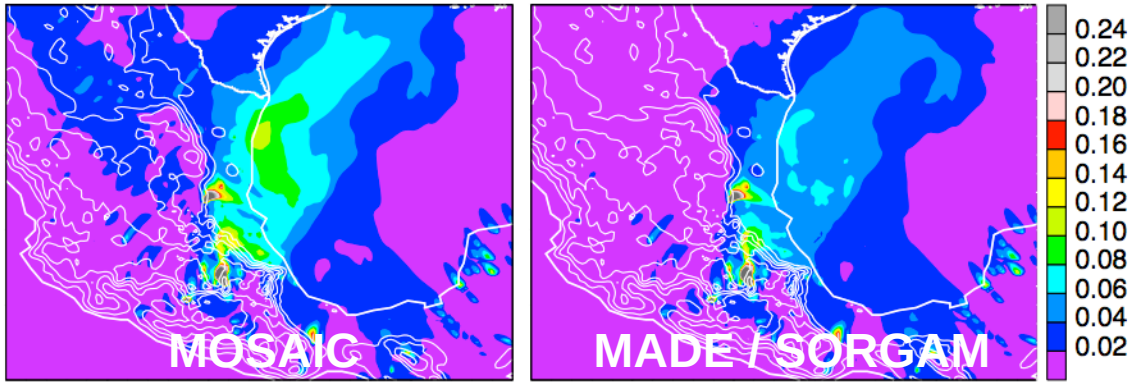




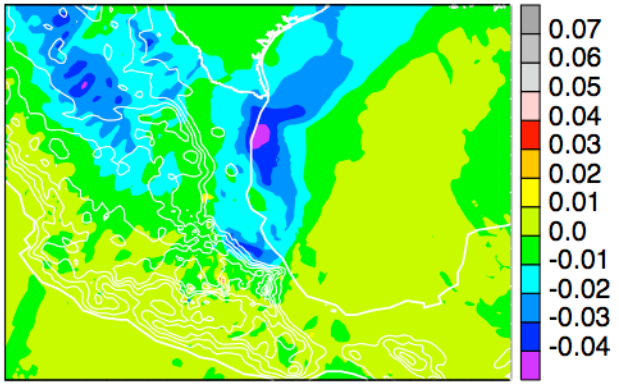
MOSAIC has greater impact

Aerosol-Radiation Effects: Carbonaceous

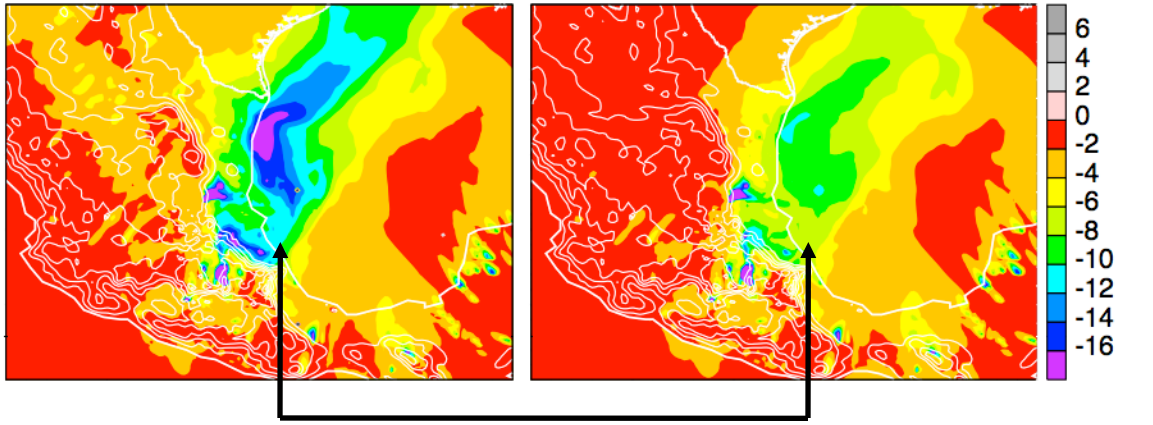
400 nm AOD 19 UTC March 19

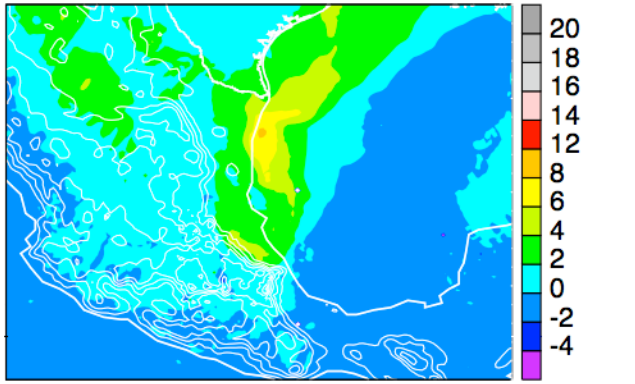


MADE / SORGAM - MOSAIC



Effect of Aerosols on Net SW Radiation

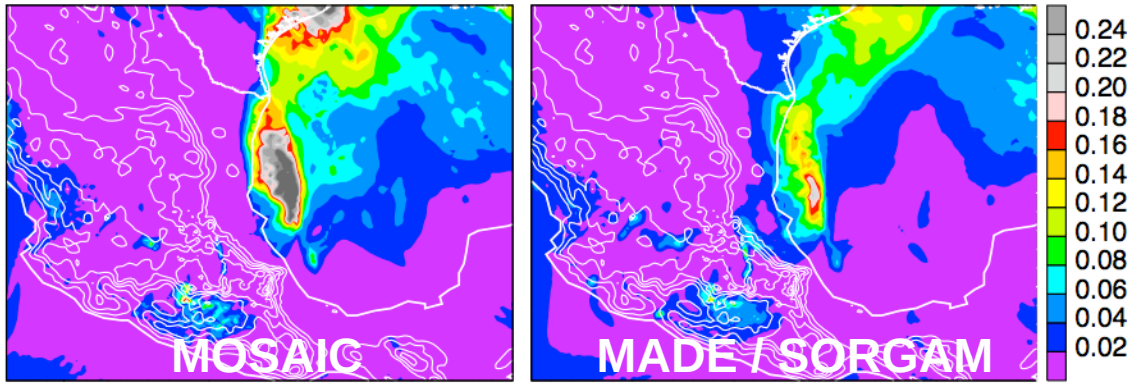




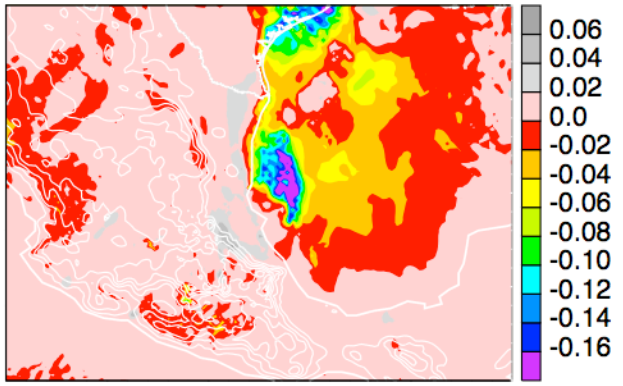
MOSAIC has greater impact

Aerosol-Radiation Effects: H_2O

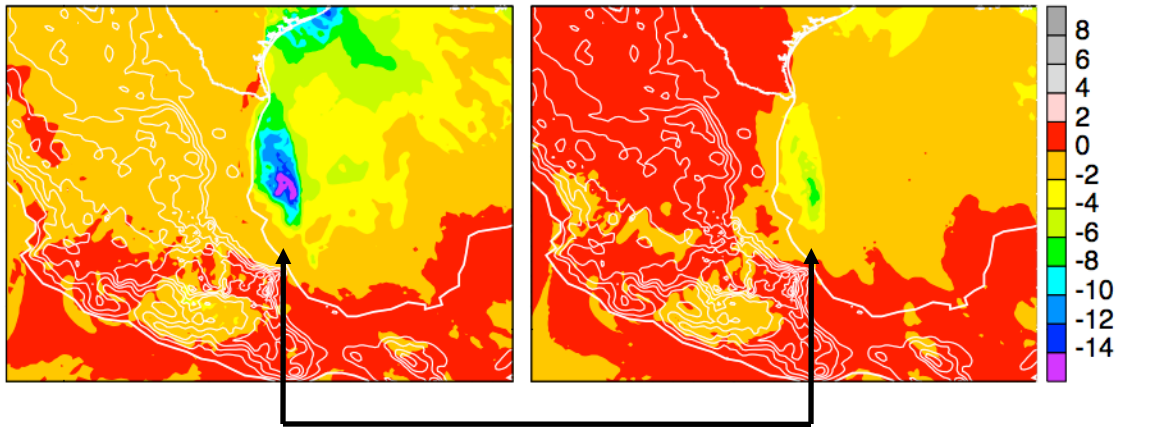
400 nm AOD 19 UTC March 19

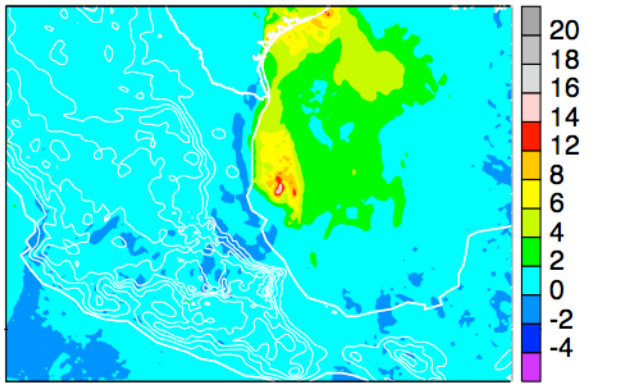


MADE / SORGAM - MOSAIC



Effect of Aerosols on Net SW Radiation

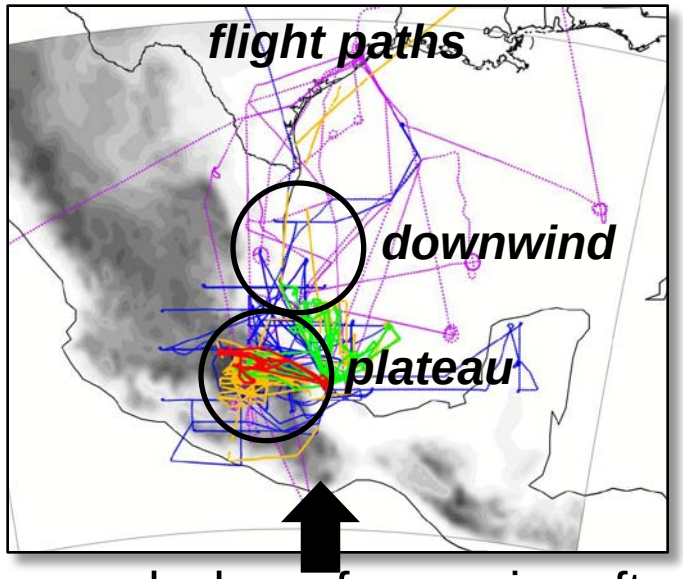




MOSAIC has greater impact

Summary

- Models are **similar over the plateau**, close to the anthropogenic emission sources, but ..
- MOSAIC's NO_3 and H_2O **higher downwind**
- Some differences in **dry deposition via size distribution** produce differences in mass
- While mass loading is similar, the **impact of dust on radiation is different** as a result of fine mode size distribution



- Largest differences between the two models occurred where fewer aircraft measurements were obtained (expect large differences everywhere when testing SOA treatments) – useful to know model differences **prior to** field campaign design and deployment
- Need to test **modal-MOSAIC** to isolate gas-to-particle partitioning
- Need to test **other aerosol representations** (QMOM, etc.)
- Impact of size distribution on **cloud-aerosol interactions** not yet examined

Pacific Northwest
NATIONAL LABORATORY

What's Next?

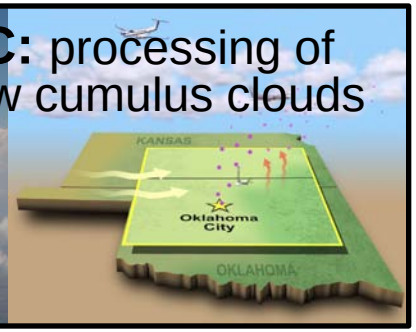
Pacific Northwest
NATIONAL LABORATORY

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*

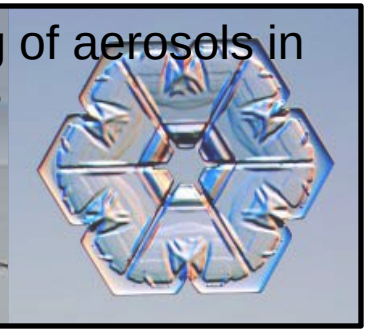
- **CHAPS/CLASIC:** processing of aerosols in shallow cumulus clouds

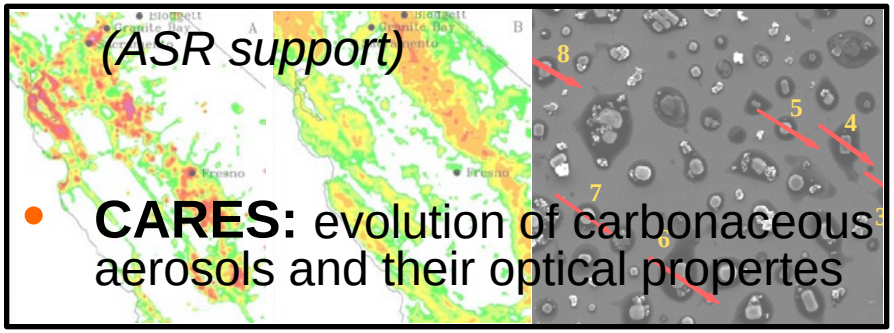
(ASR support)



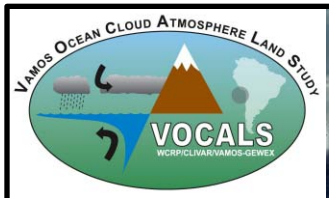
- **ISDAC:** processing of aerosols in mixed-phase clouds

(CCPP support)





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



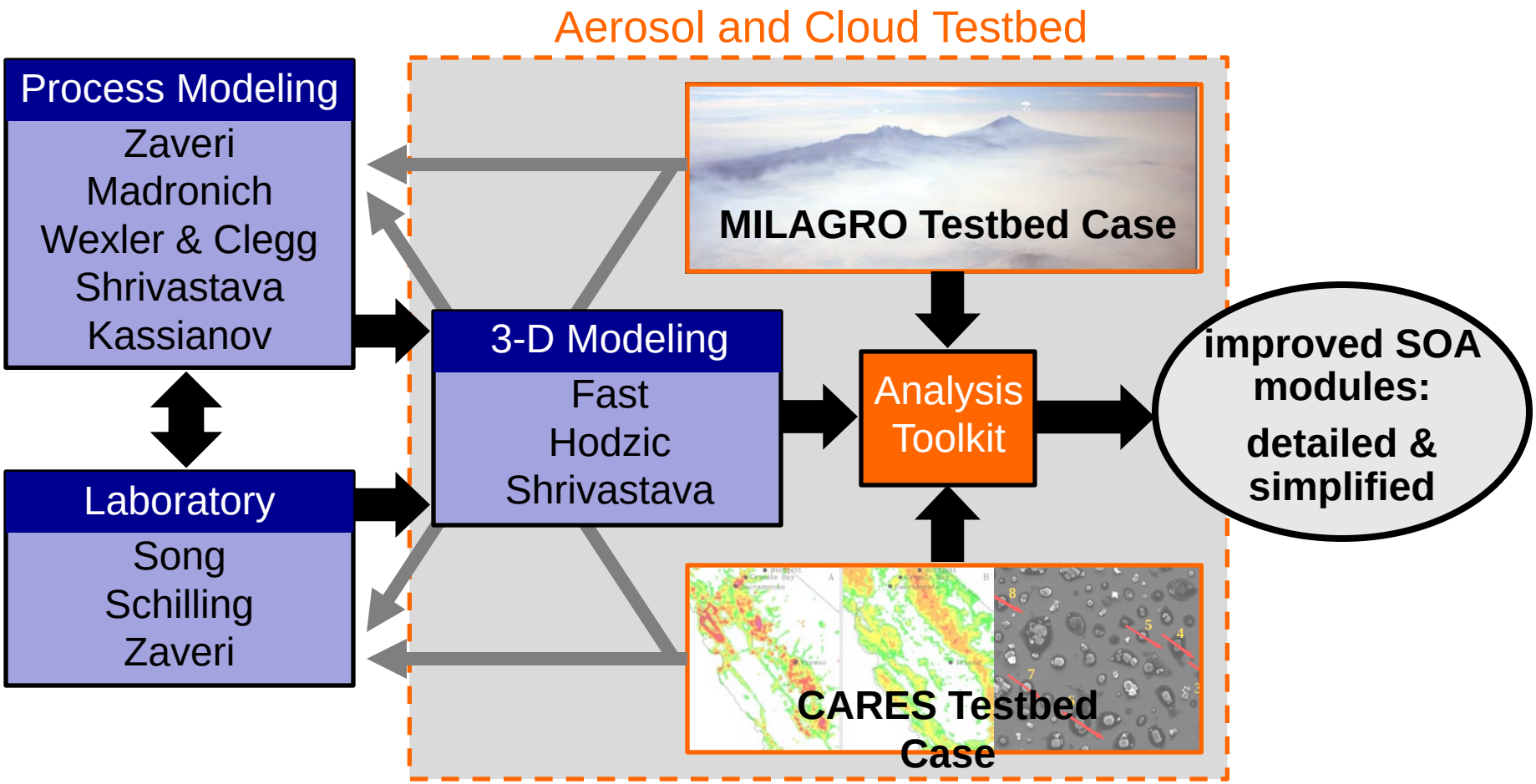
- **VOCALS:** aerosol processing in marine stratocumulus clouds

- **Users are free to develop their own cases for all to use**
- **International Field Campaigns ?**

Pacific Northwest
NATIONAL LABORATORY

SOA Working Group

How will Field, Laboratory, and Modeling Scientists Work Together?

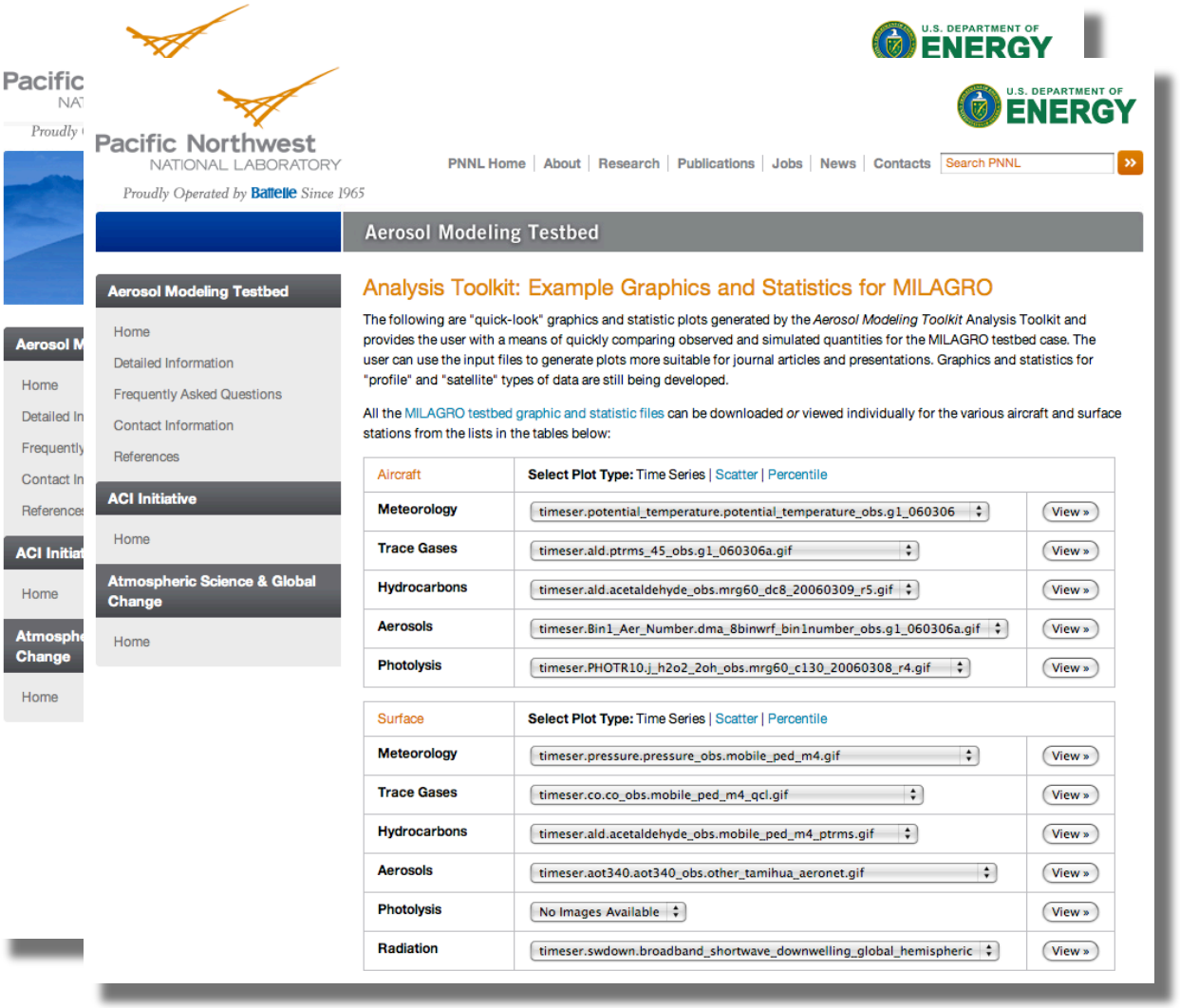


- Invite other ASR scientists to work with us
- Working groups that target other specific processes could be established

How Will User's Access the ACT ?

Beta Testbed Web Site – Software and Testbed Case Now Available

http://www.pnl.gov/atmospheric/research/aci/amt

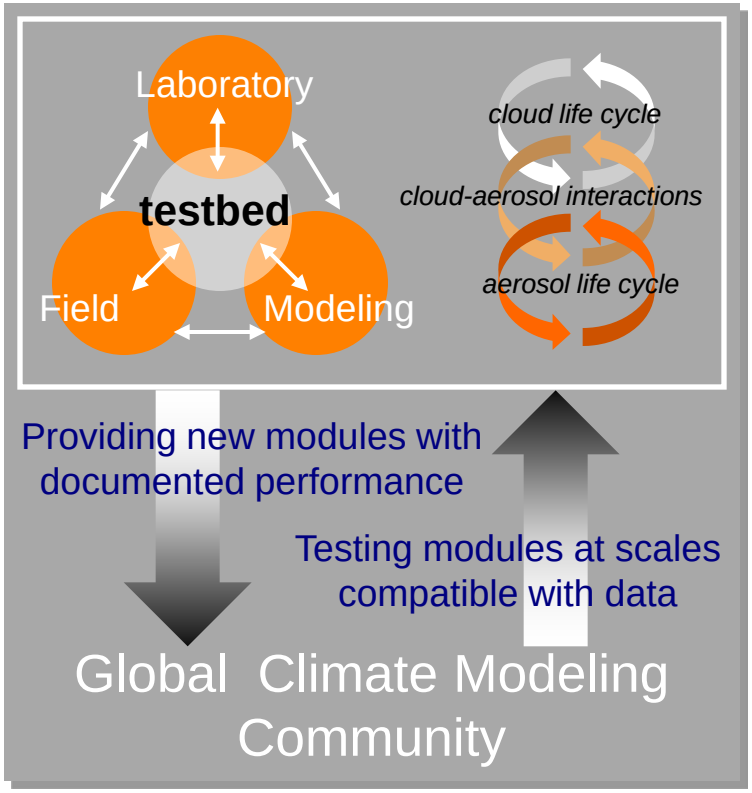


- Basic overview
- Documentation describing how Analysis Toolkit software is run
- Example graphics and statistics
- How software and testbed cases can be downloaded

Pacific Northwest NATIONAL LABORATORY

Vision

- **Community tool** to facilitate systematic and objective evaluation of aerosol process modules for real-world conditions
- **Enhance research** capabilities of DOE research (e.g. ASR) 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*



Acknowledgements:

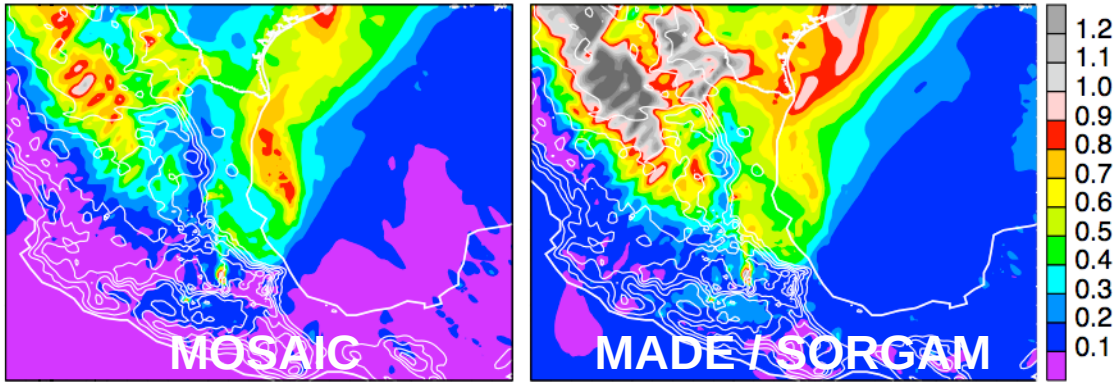
- Support from PNNL LDRD Aerosol Climate Initiative
- Thanks to hundreds of scientists contributing to data used by testbed cases and development of WRF

Pacific Northwest
NATIONAL LABORATORY

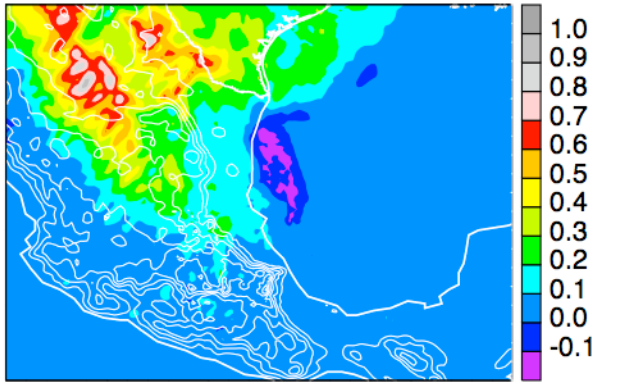
Extra Slides

Aerosol-Radiation Effects

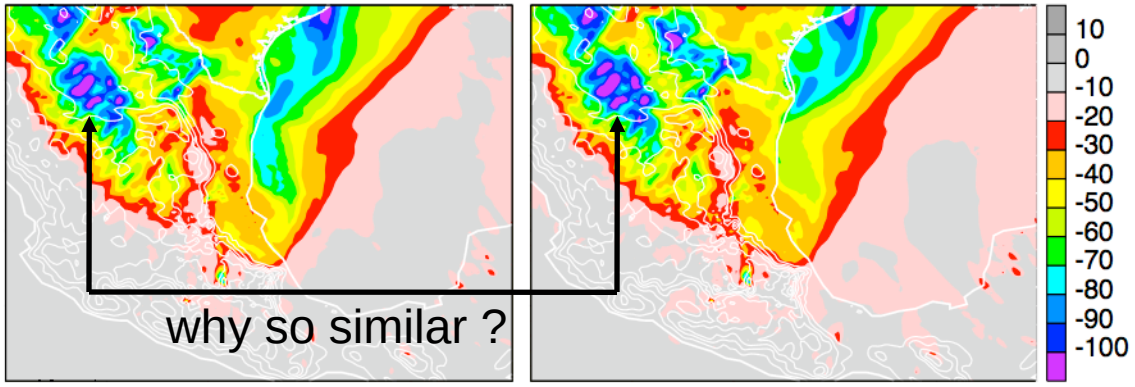
400 nm AOD 19 UTC March 19

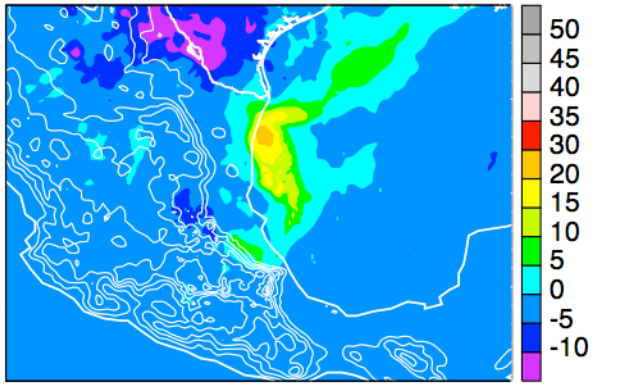


MADE / SORGAM - MOSAIC



Effect of Aerosols on Net SW Radiation





ω_o different – offsetting effects

↑ more direct ↓ less diffuse ↓ less direct ↑ more diffuse

differences as large as ~20 W m^{-2}