Development of the Ensemble Navy Aerosol Analysis Prediction System and its application of the Data Assimilation Research Testbed in Support of Aerosol Forecasting

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NATIONAL RESEARCH COUNCIL
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Collaborators:

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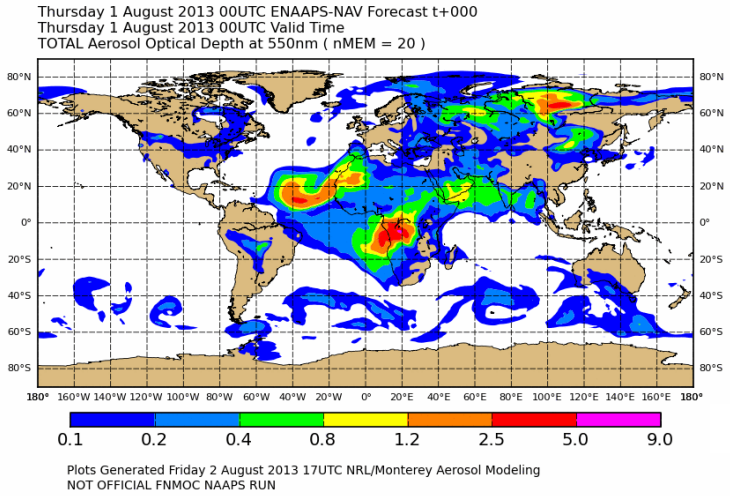
[3]CSC Inc, Monterey, CA

Ensemble NAAPS (ENAAPS)

- Built on 20 member NAVGEM meteorology
- Current ENAAPS forecast initialized with NAVDAS-AOD

1.



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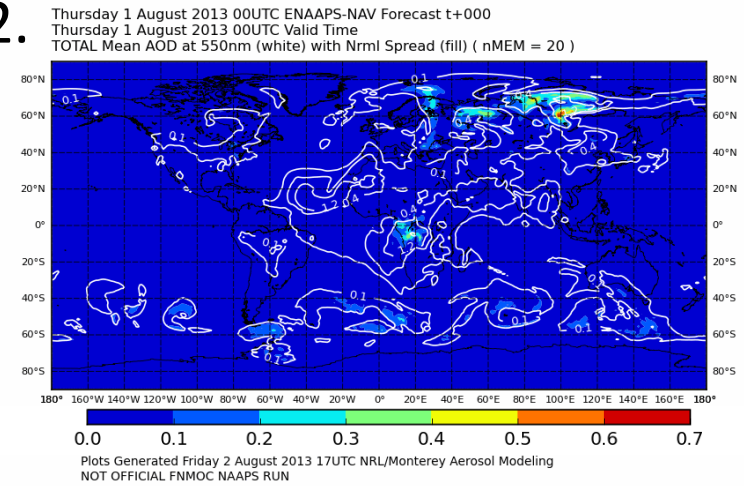

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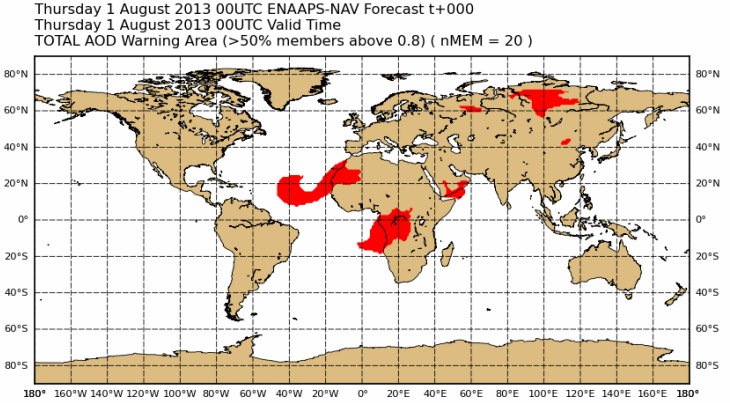
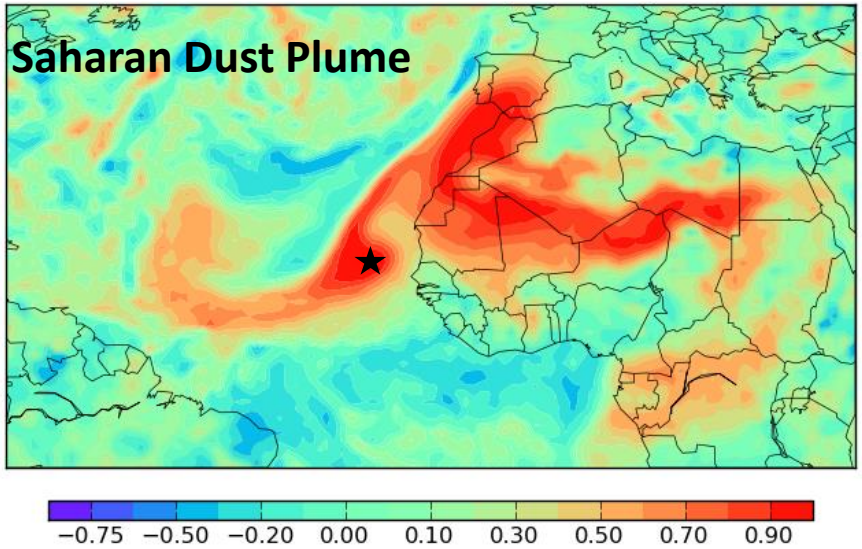


1. Ensemble Mean Forecast
2. Forecast Uncertainty (ie. Ensemble Spread)
3. Probability Information

ENAAPS and Ensemble Kalman Filter

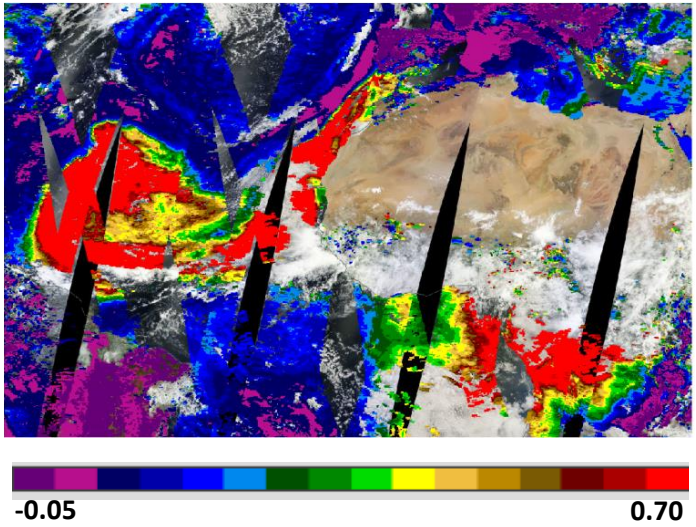
- Take full advantage of ensembles
- Replace variational NAVDAS-AOD with an EnKF system (DART)

Ensemble Correlation Fields



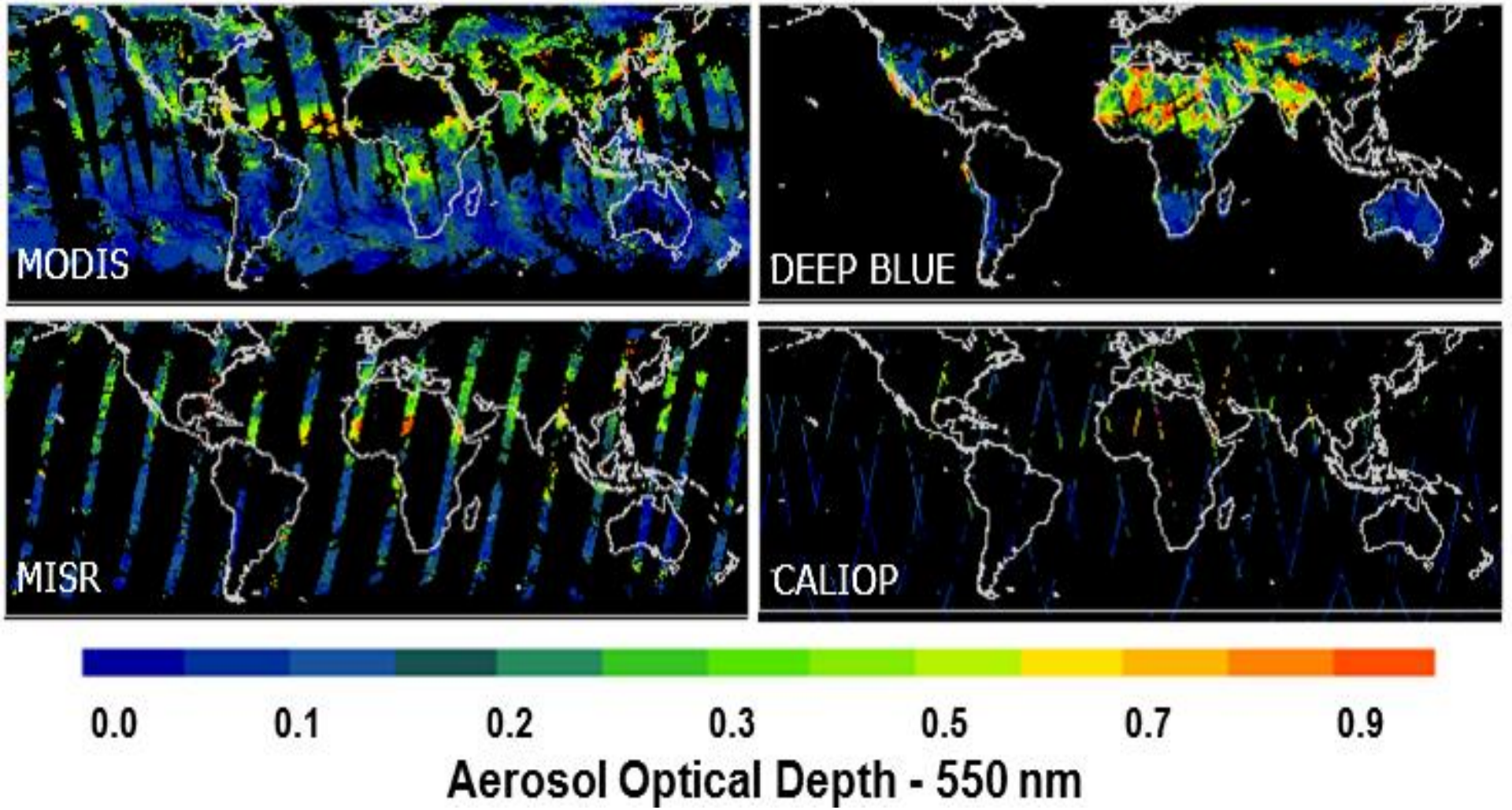
+

MODIS AOT Retrieval



→ Flow-Dependent Corrections to the model state fields

Observation Density of Aerosol-Related Satellite Products



ENAAPS-DART optimization

- July through August, 2013 (SEAC^{4}RS)
- Ensemble type (source, meteorology, combined)

= *emissions for aerosol species i* in grid cell *(x,y)*
= random gaussian perturbation factor for species *i*, ensemble *n* (25% uncertainty)
= perturbed source for species *i*, ensemble *n*

- Constant vs Adaptive Inflation [Anderson, 2007]
- Ensemble size
- 1000 km localization

Covariance Inflation
=
=ensemble member *n*
= ensemble mean
=inflation factor

Ensemble Experiment Summary

Experiment Name	Ensembles	Inflation
Source, const	Source, 20 member	10% Constant Covariance Inflation
Source, adaptive	Source, 20 member	Adaptive Inflation
Meteorology, adaptive	Meteorology Only, 20 member	Adaptive Inflation
Met+Source, adaptive	Meteorology + Source, 20 member	Adaptive Inflation
Met+Source, 80	Meteorology + Source, 80 member	Adaptive Inflation

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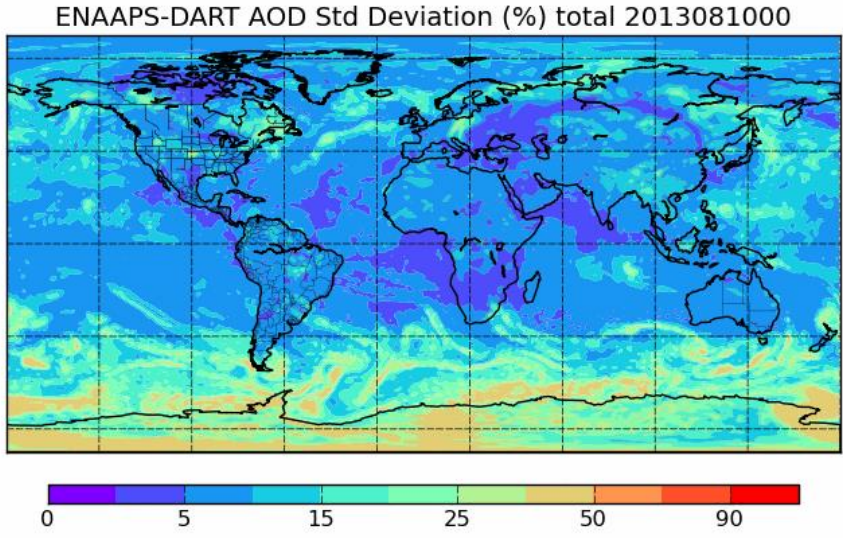
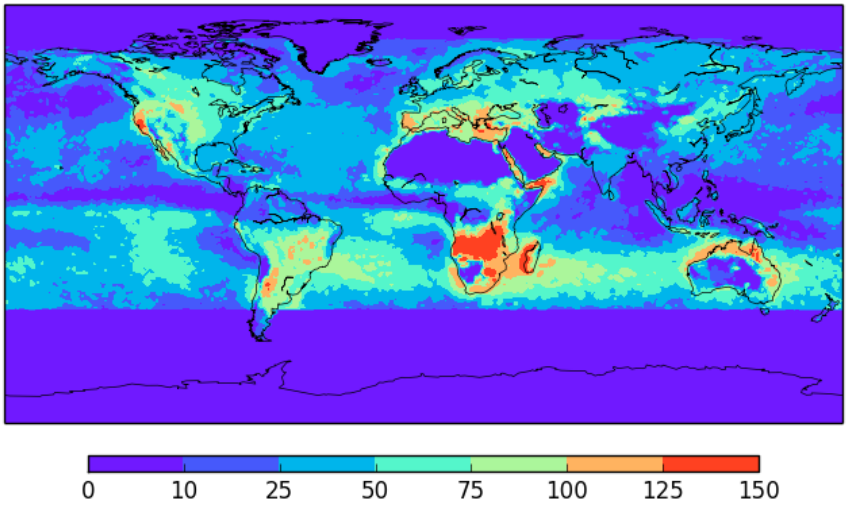
Impact of Configuration on Ensemble Spread

a. Source, constant inflation



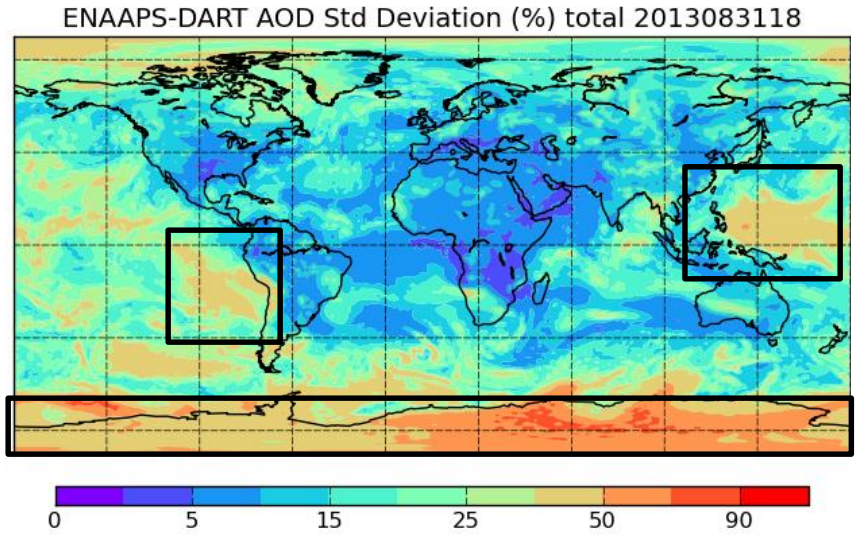
Assimilated MODIS Obs Count



Ensemble AOT Standard Deviation/Mean (%)

Impact of Configuration on Ensemble Spread

a. Source, constant inflation



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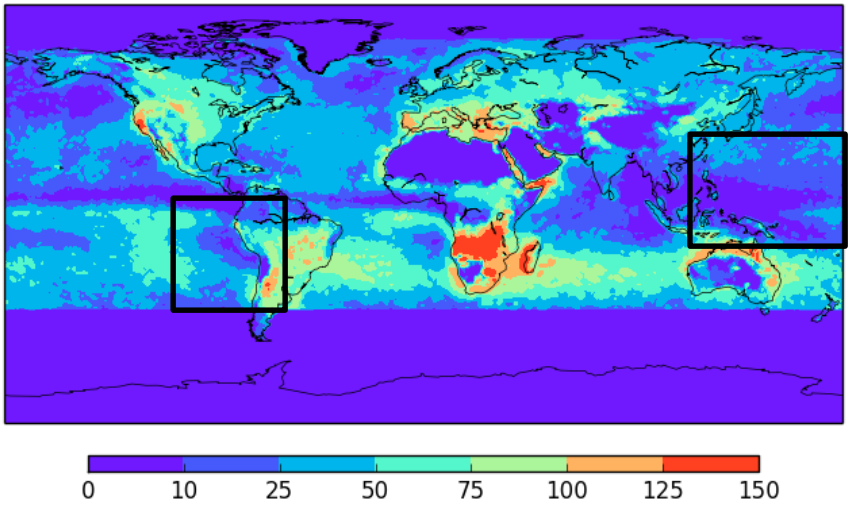

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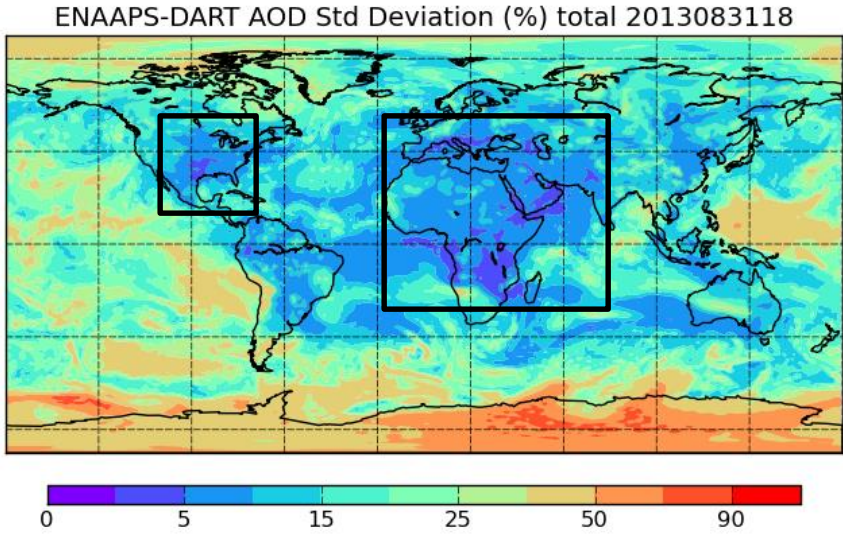

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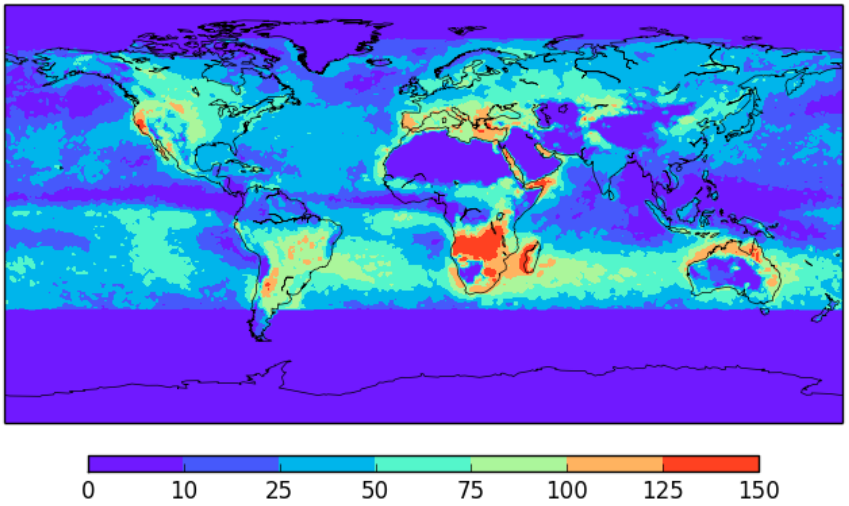
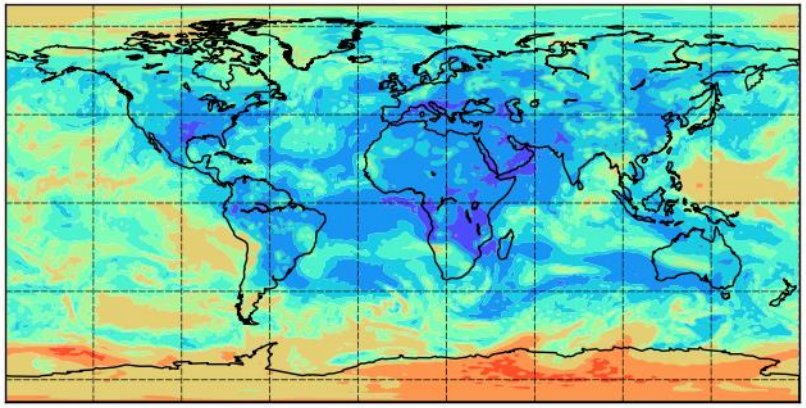


Ensemble AOT Standard Deviation/Mean (%)

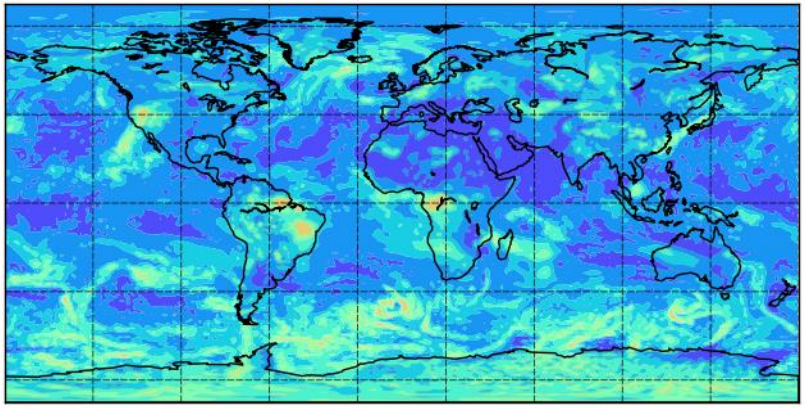
Impact of Configuration on Ensemble Spread

Ensemble Spread 20130831 18Z, end of optimization experiments

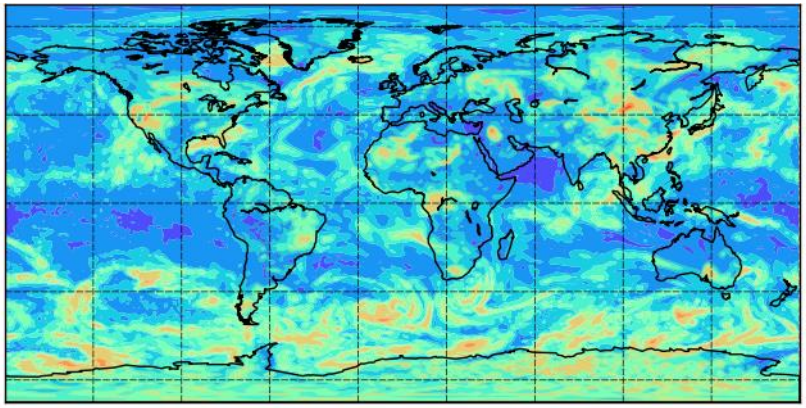
a. Source, constant inflation



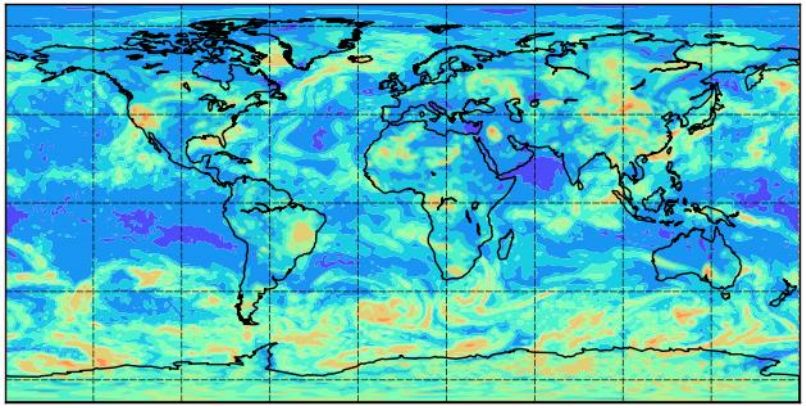
b. Source, adaptive inflation

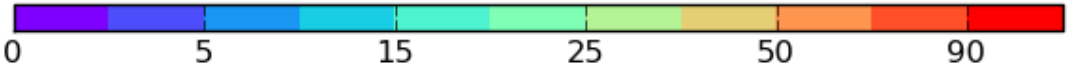


c. Meteorology, adaptive inflation



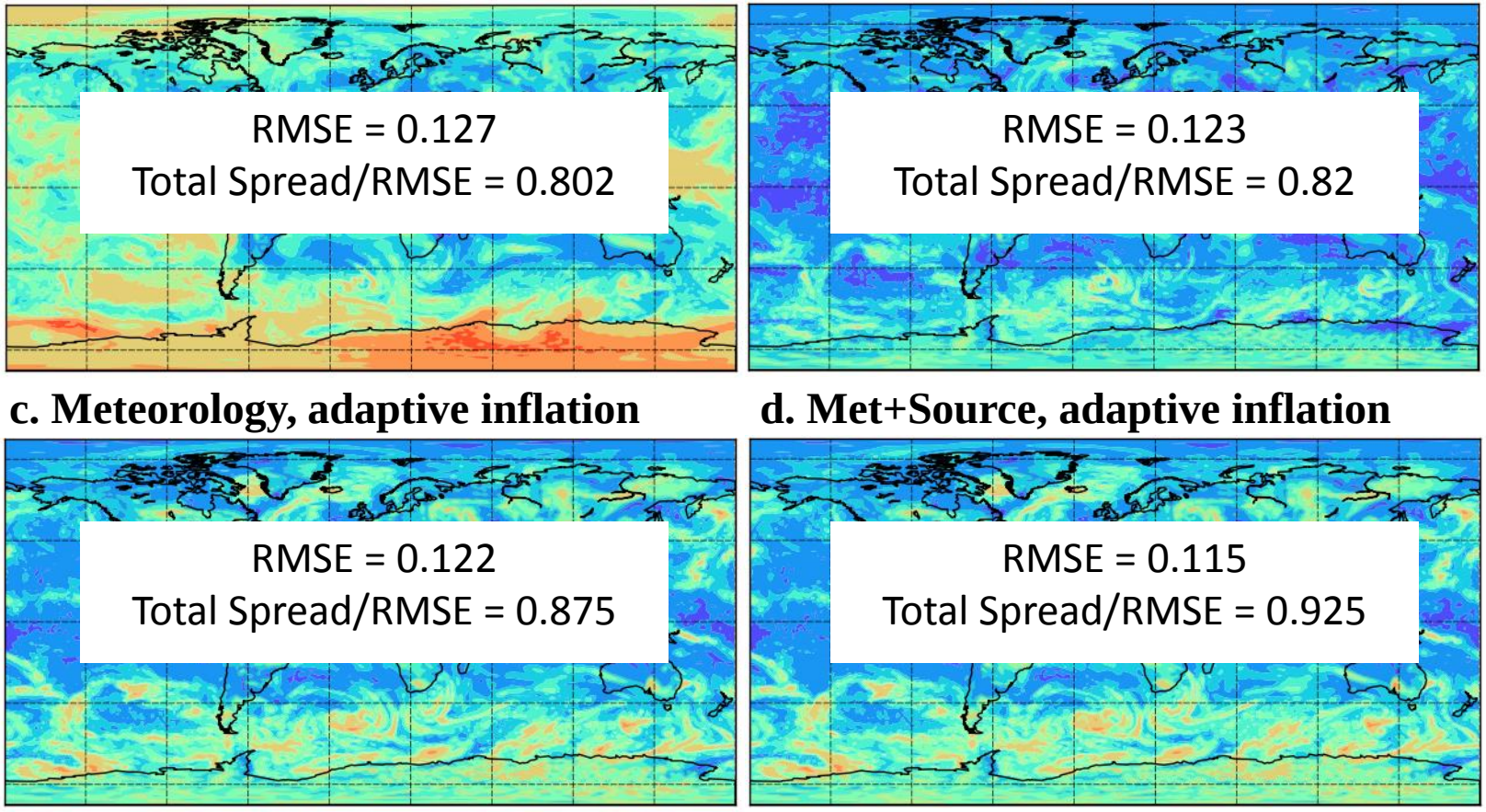
d. Met+Source, adaptive inflation





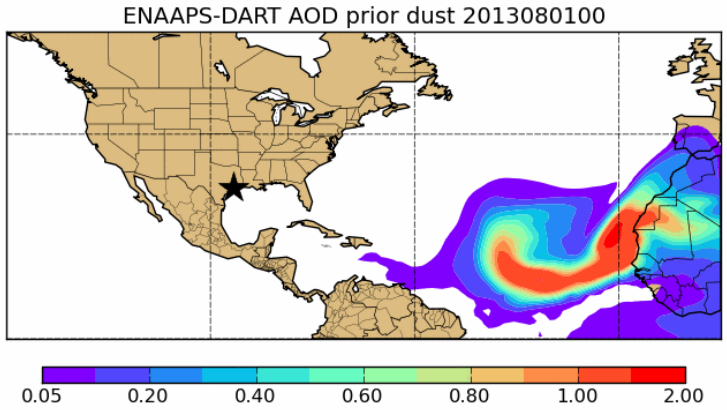
Ensemble AOT Standard Deviation/Mean (%)

Impact of Configuration on Ensemble Spread

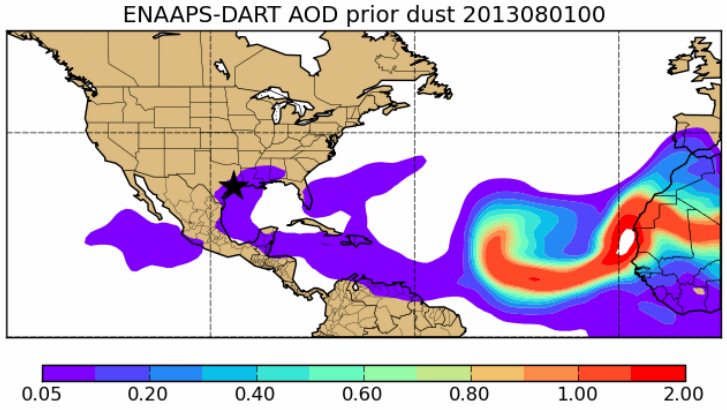


Importance of Met Ensemble for Long-Range Transport

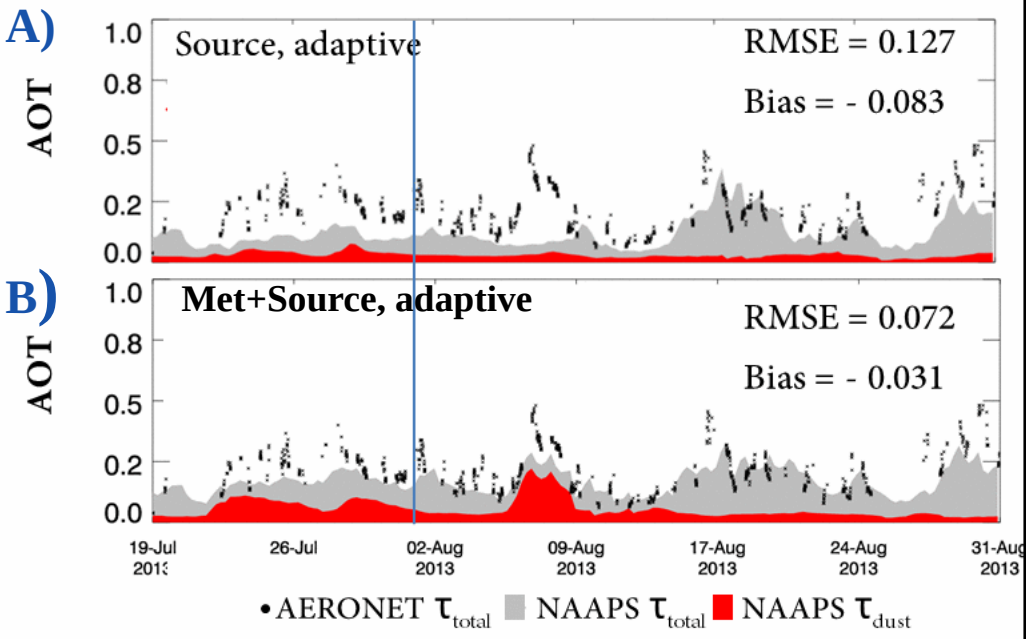
A) Source, adaptive inflation



B) Met+Source, adaptive inflation



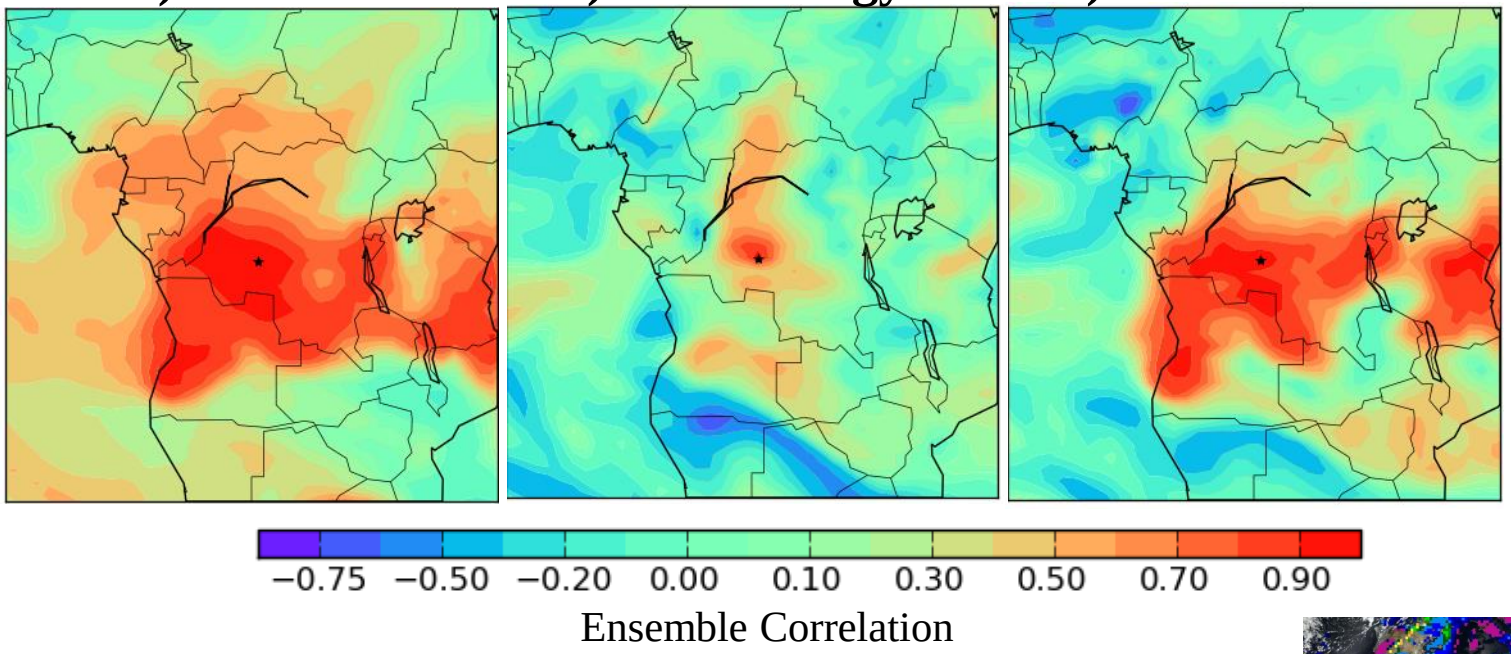
University of Houston AERONET site



*** Long-range transport of dust completely missed with source-only ensemble**

Impact of Source Ensemble

South African Smoke

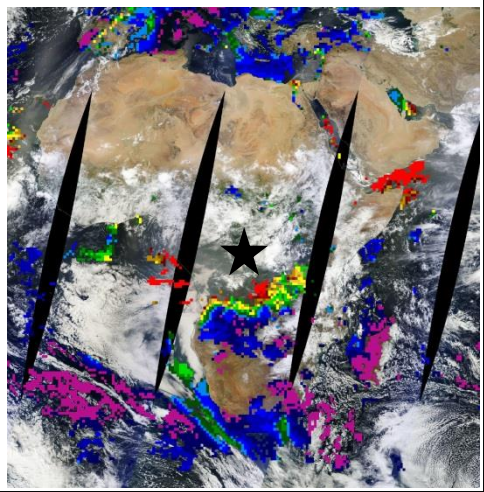


6 Hour Forecast relative to MODIS AOT:

A) Source RMSE = 0.133

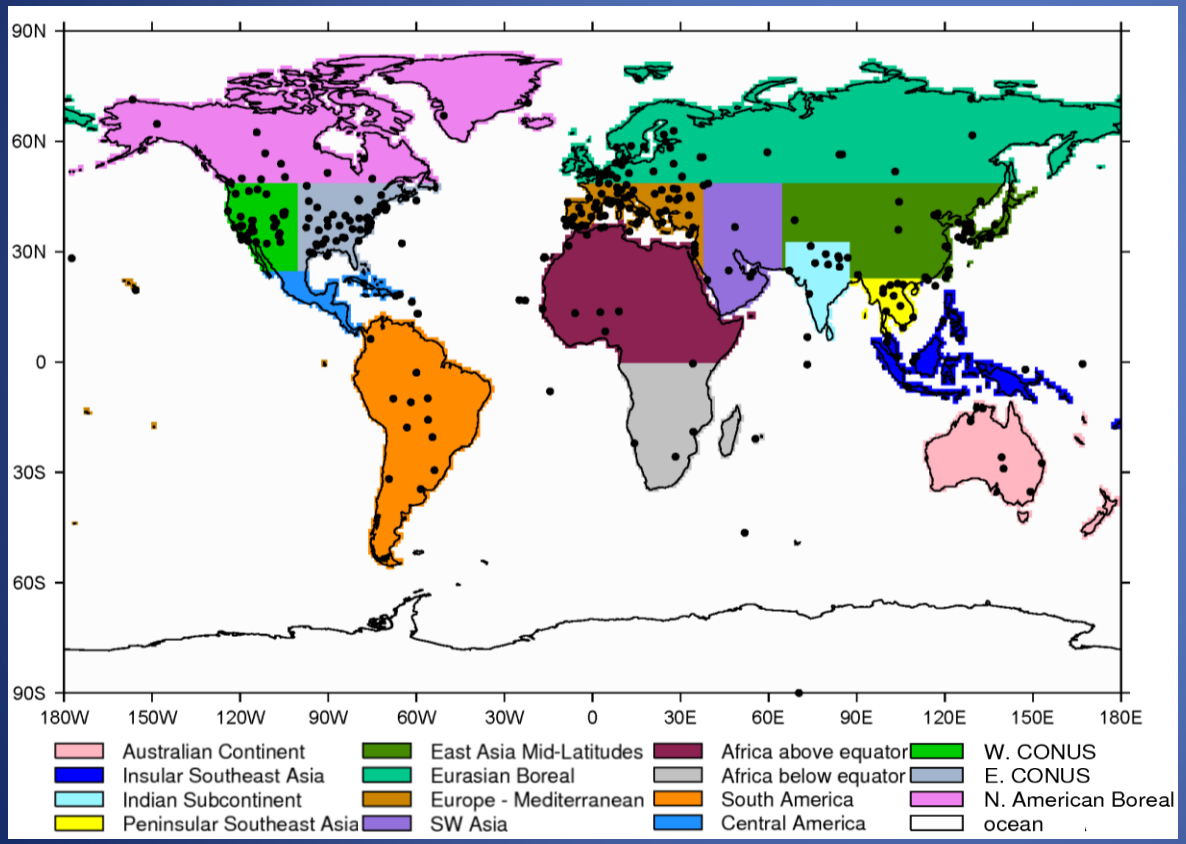
B) Meteorology RMSE = 0.14

C) Met+Source RMSE = 0.124



Verification Against AERONET

AERONET Sites by Region (2013)



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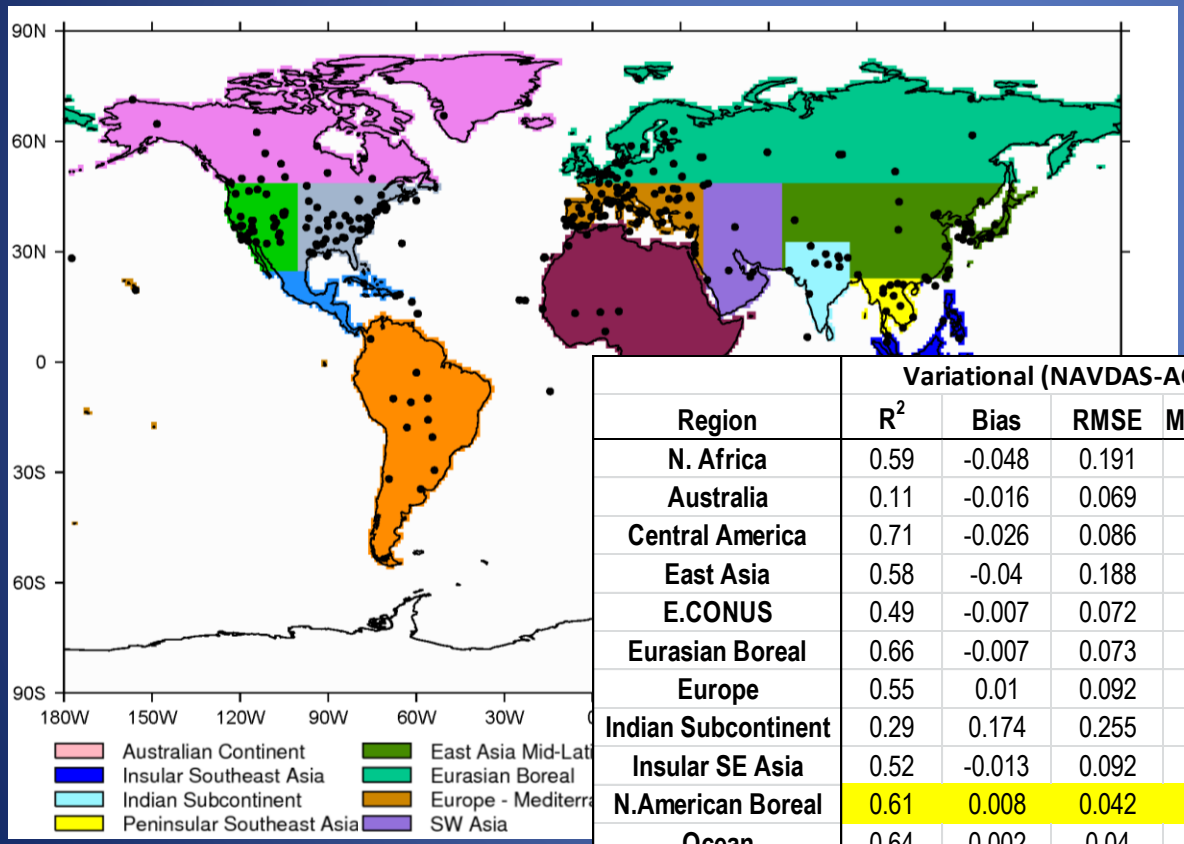
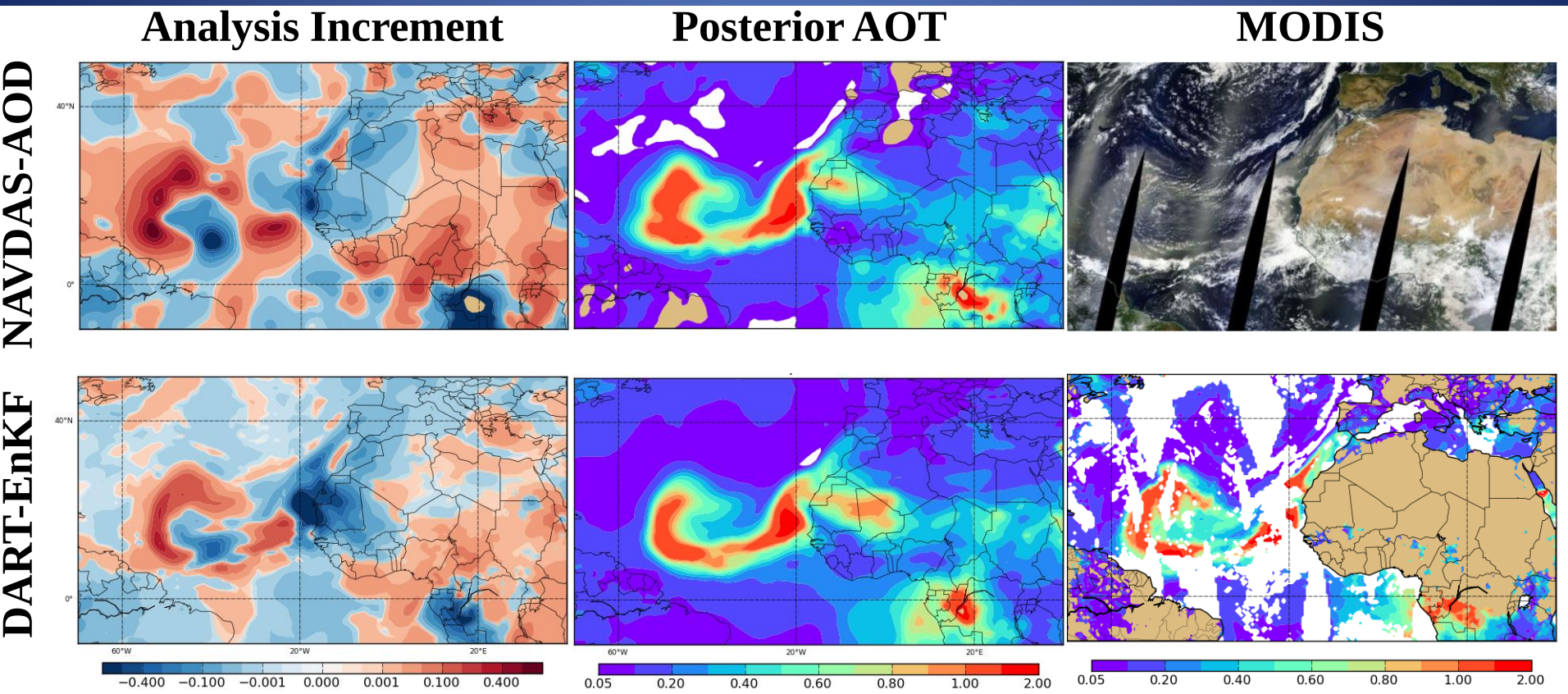


Based on 6 month simulations (April – September, 2013)

	Variational (NAVDAS-AOD)				EnKF (ENAAPS-DART)				AERONET
Region	R^2	Bias	RMSE	Mean AOT	R^2	Bias	RMSE	Mean AOT	Mean AOT
N. Africa	0.59	-0.048	0.191	0.348	0.63	0.003	0.188	0.399	0.396
Australia	0.11	-0.016	0.069	0.048	0.08	-0.001	0.064	0.063	0.063
Central America	0.71	-0.026	0.086	0.2	0.76	-0.03	0.085	0.196	0.226
East Asia	0.58	-0.04	0.188	0.326	0.53	-0.035	0.2	0.331	0.366
E.CONUS	0.49	-0.007	0.072	0.154	0.44	0.01	0.075	0.171	0.161
Eurasian Boreal	0.66	-0.007	0.073	0.144	0.61	-0.006	0.079	0.146	0.152
Europe	0.55	0.01	0.092	0.166	0.49	0.011	0.097	0.167	0.156
Indian Subcontinent	0.29	0.174	0.255	0.374	0.67	0.077	0.15	0.277	0.2
Insular SE Asia	0.52	-0.013	0.092	0.127	0.52	0.013	0.094	0.153	0.14
N.American Boreal	0.61	0.008	0.042	0.102	0.38	0.019	0.052	0.113	0.094
Ocean	0.64	0.002	0.04	0.092	0.63	0.008	0.04	0.098	0.09
Peninsular SE Asia	0.59	-0.016	0.208	0.345	0.68	-0.031	0.183	0.329	0.36
South America	0.02	0.022	0.054	0.067	0.48	0.005	0.029	0.05	0.045
SW Asia	0.67	-0.015	0.117	0.254	0.62	-0.027	0.125	0.242	0.269
W.CONUS	0.26	0.037	0.08	0.124	0.26	0.026	0.073	0.113	0.087

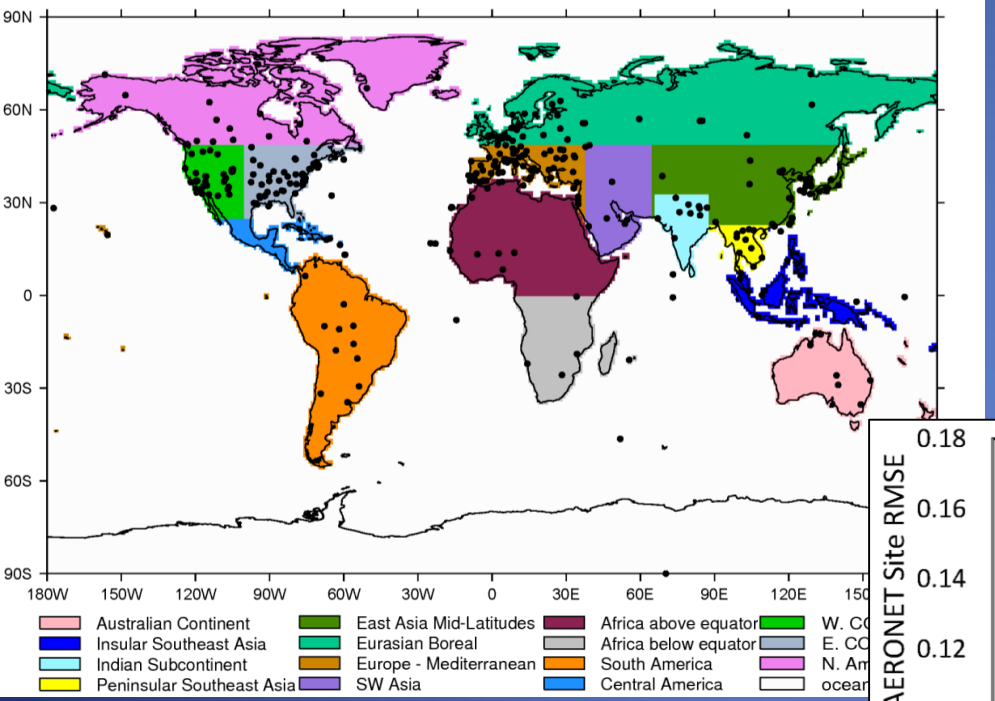
Spatial Impact of Assimilation Methodology

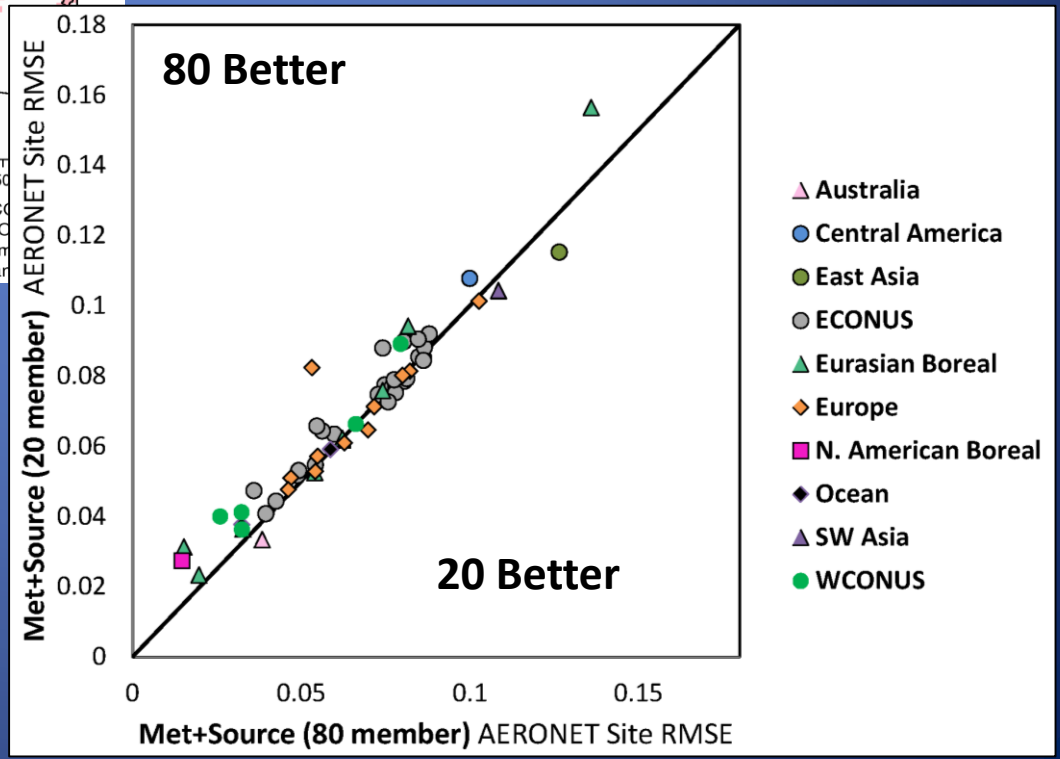


*** Can capture sharper gradients in aerosol features with EnKF**

Impact of Number of Ensembles

AERONET Sites by Region (2013)





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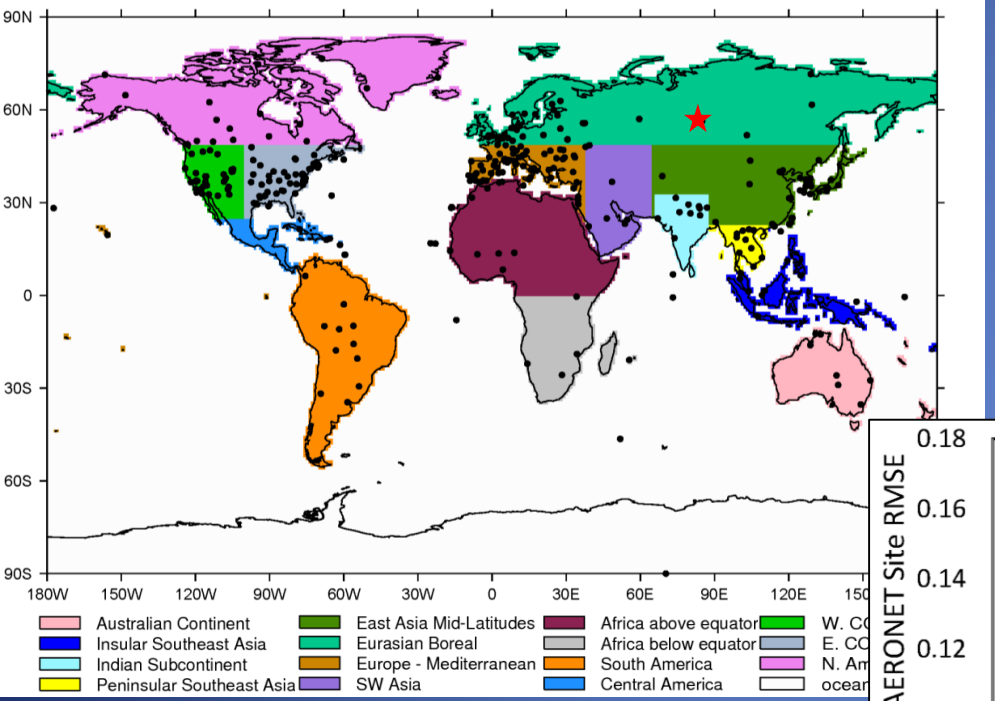
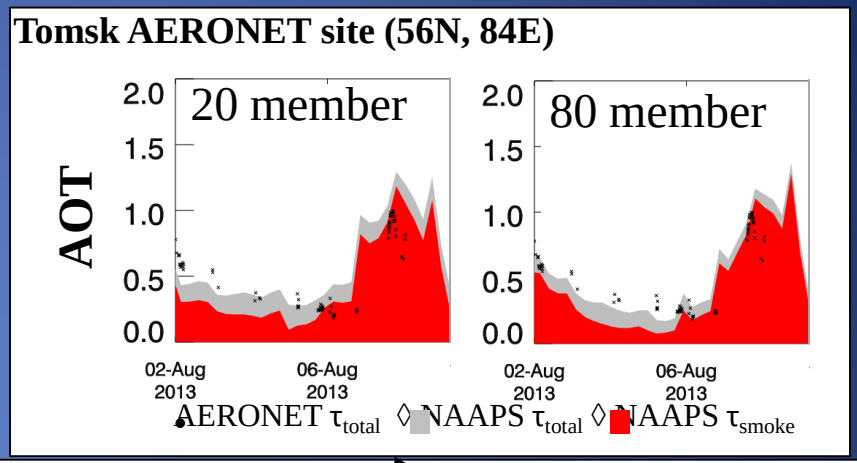
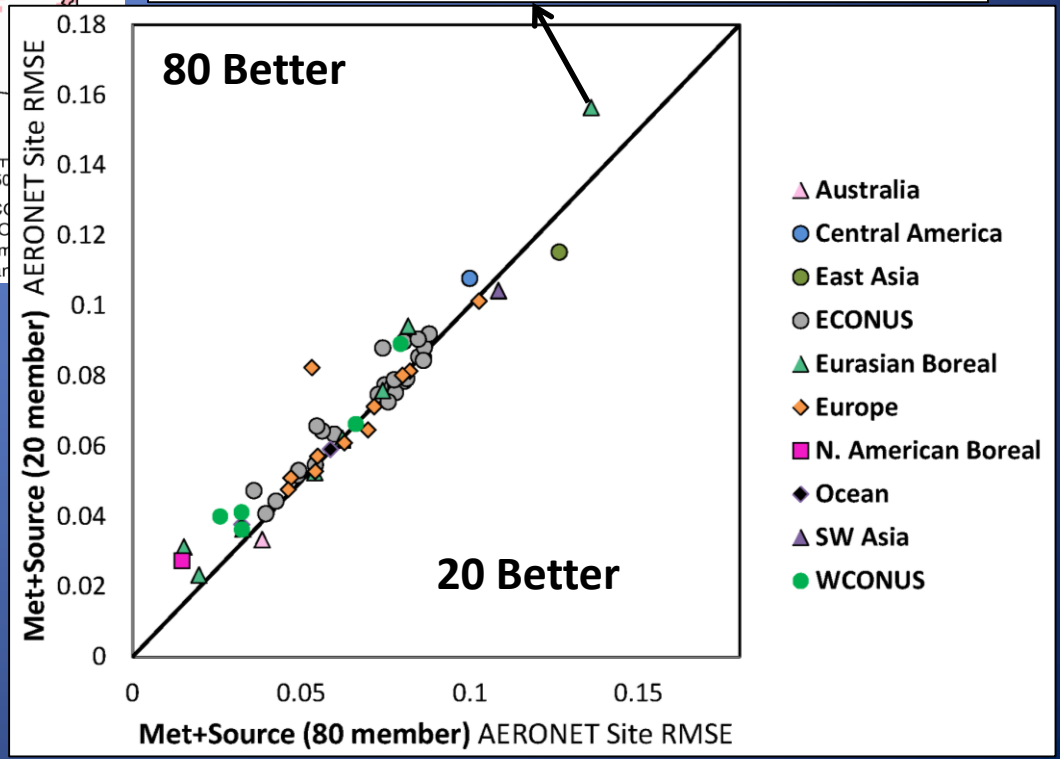
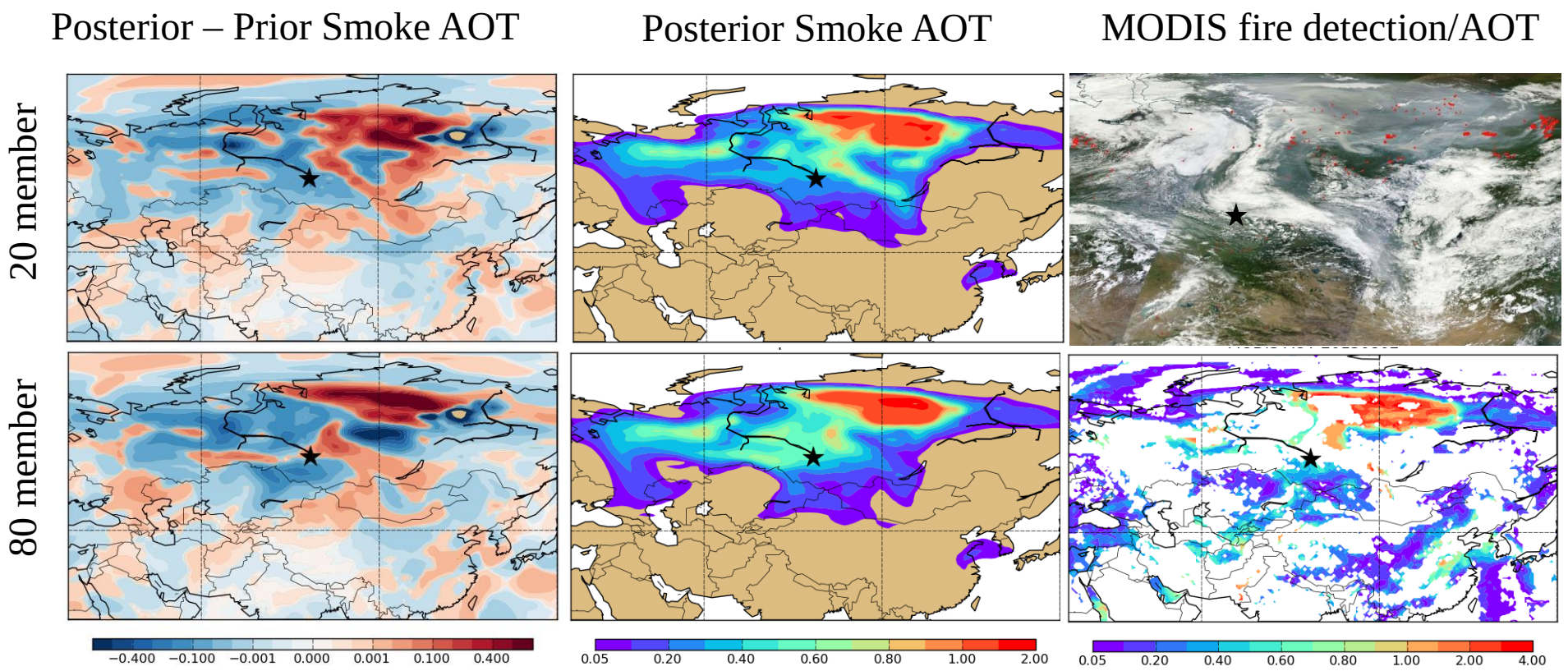






Impact of Number of Ensembles

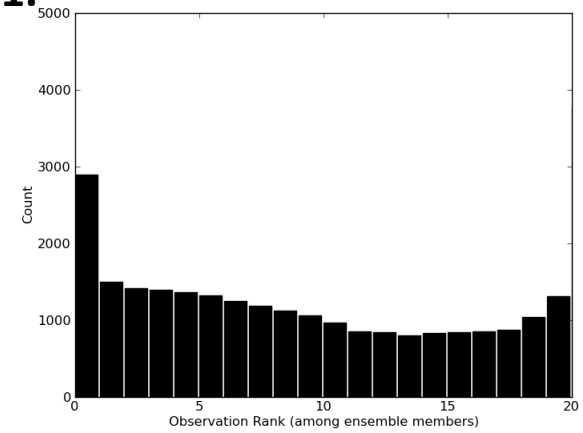
Tomsk AERONET site (56N, 84E) 2013080206



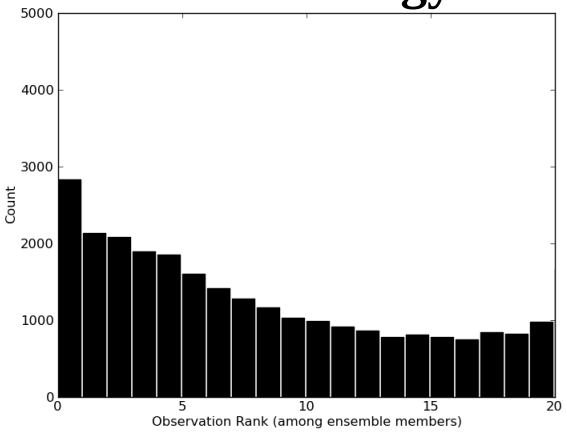
Smoke Emissions

Rank Histograms of AOT (North American Boreal)

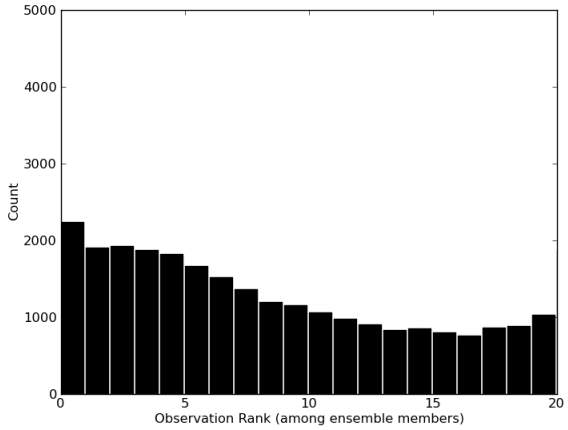
1. Source



2. Meteorology



Met+Source



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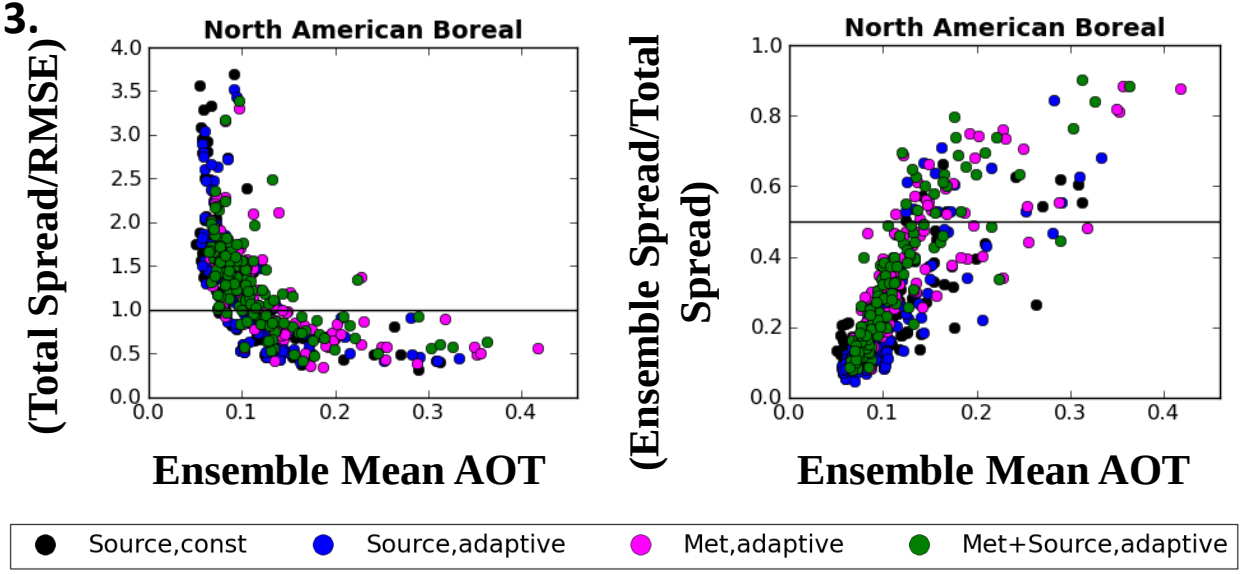
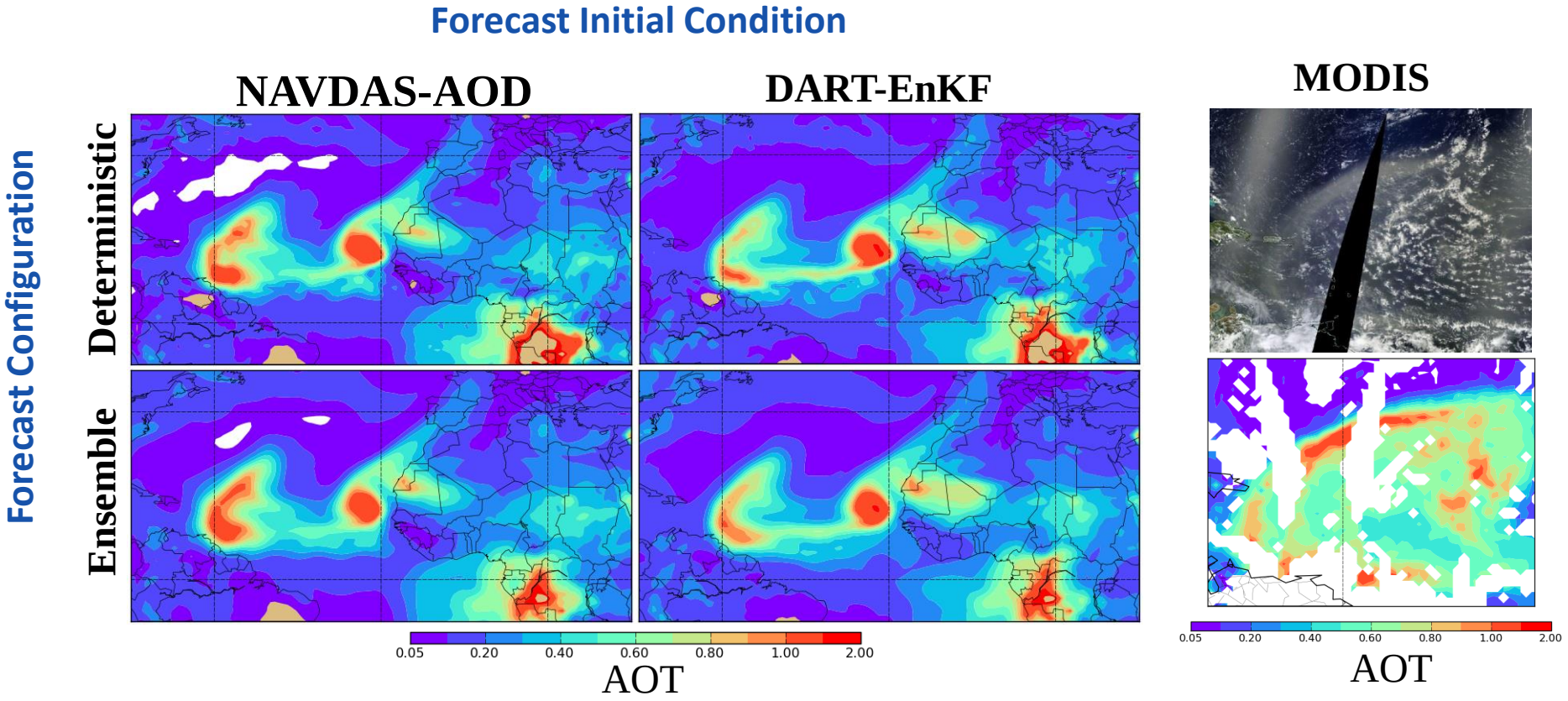


1. Bias in smoke dominated regions.
2. Meteorology ensemble helps (increase in ensemble spread), but bias still present.
3. Smoke dominated regions not well-tuned.

Impact on 24 Hour Forecast

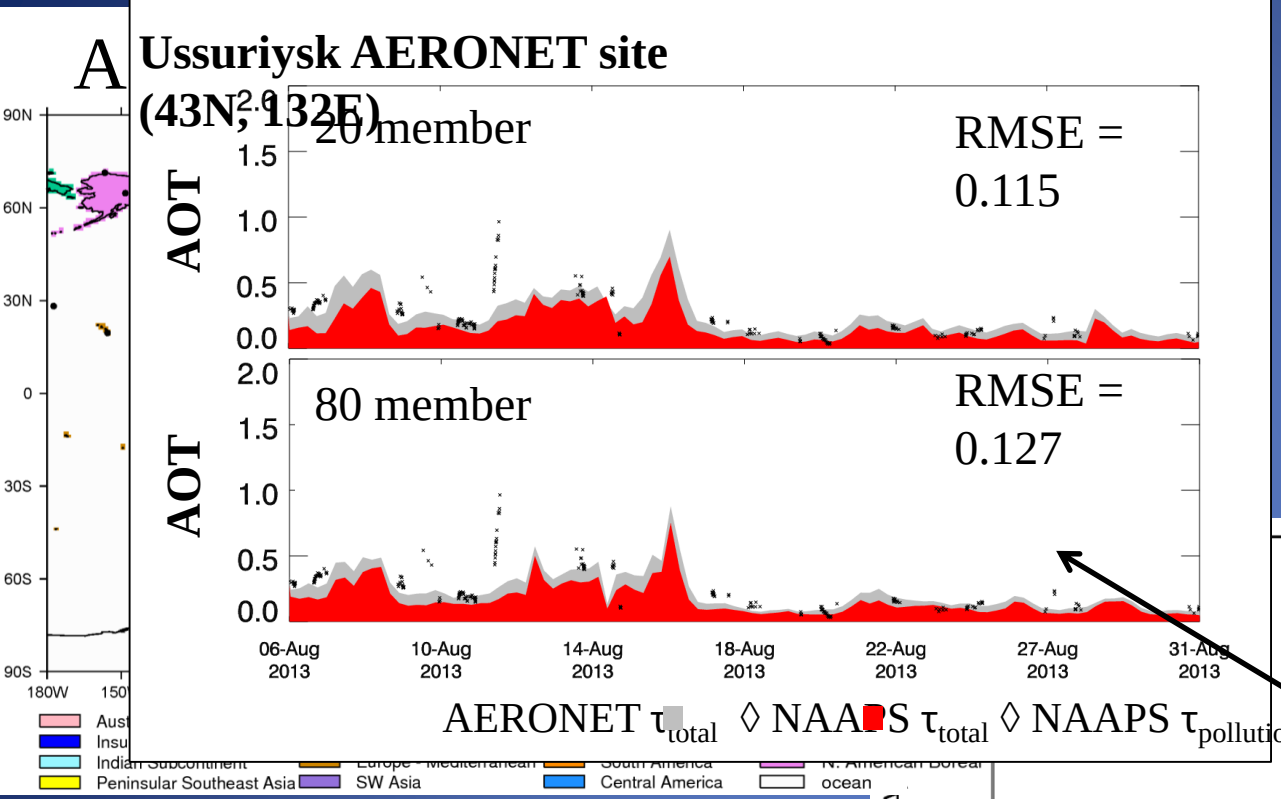


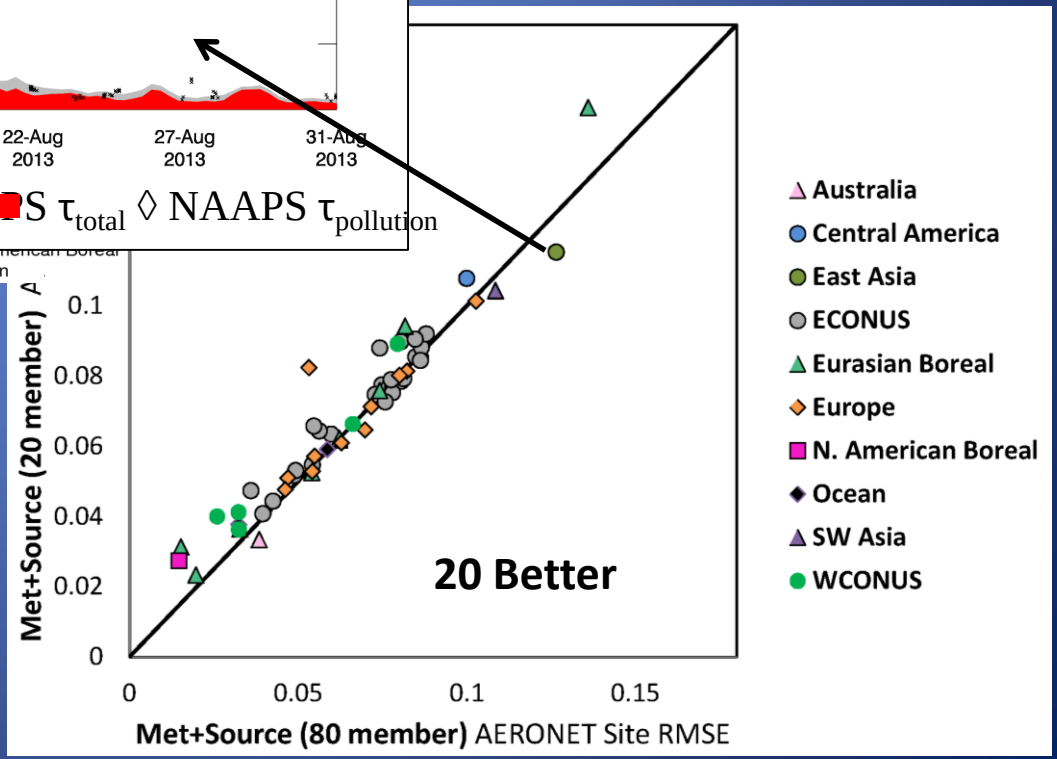
*Sharpness of dust front from EnKF data assimilation is propagated in the forecast.

Current state of the ensemble system….

- An ensemble aerosol system with EnKF data assimilation has been implemented.
- Bulk statistics at AERONET sites – performance is similar to current variational system in AOT space
- Capture sharper gradients with EnKF – allow for taking advantage of increases in model resolution
- This system will be used to incorporate additional aerosol products for assimilation and to tie in source functions to assimilation system.
- Contender for transition to operations using the 80 member NAVGEM ensemble for assimilation and 20 member for forecast.

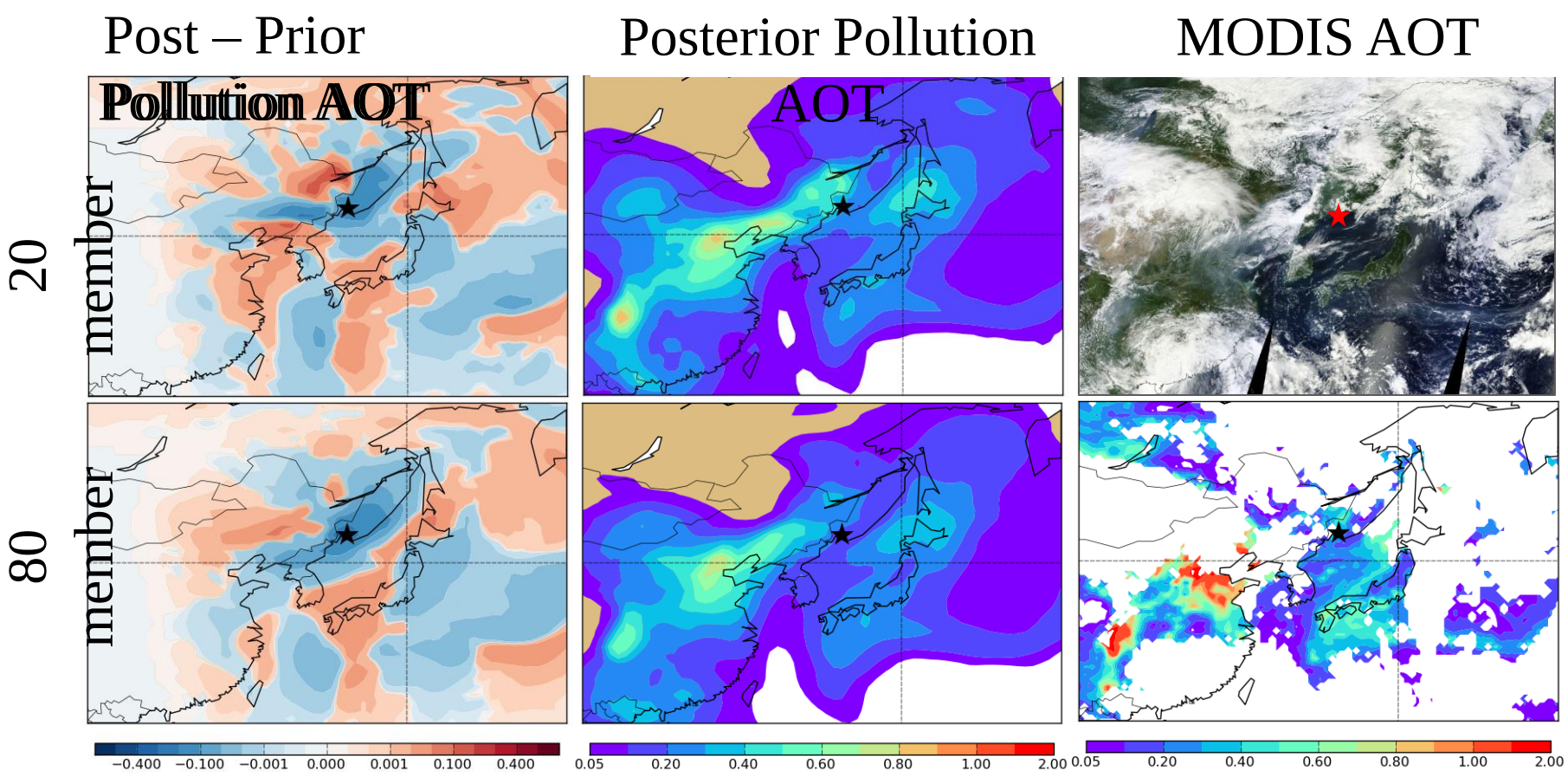
Impact of Number of Ensembles





Impact of Number of Ensembles

Ussuriysk AERONET site (43N, 132E)



Impact of Source Ensemble