Recent Developments in Global Aerosol Forecasting at NRL

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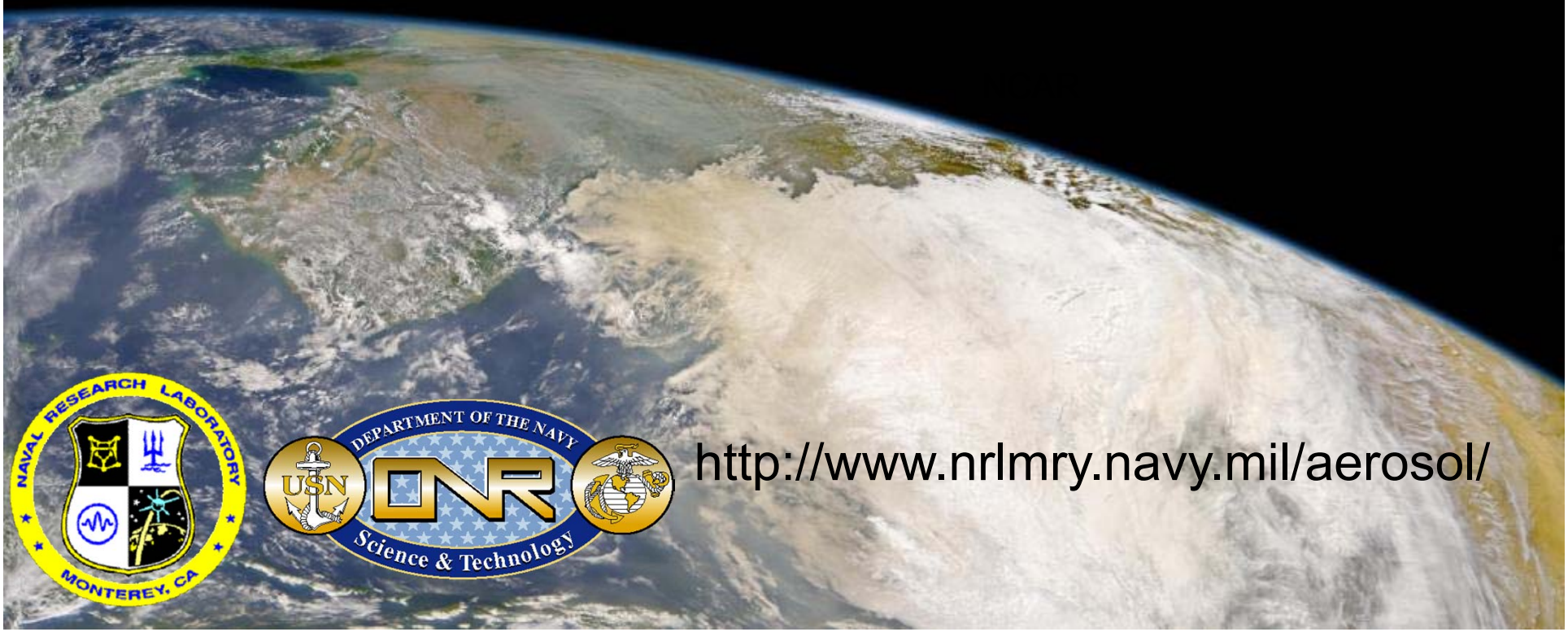
May, 2012



http://www.nrlmry.navy.mil/aerosol/

Updates

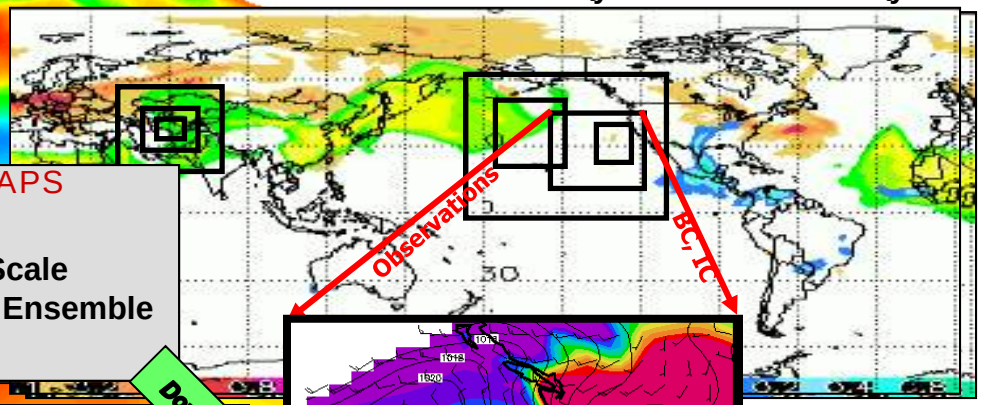
- Modeling Overview
- Data Assimilation
- Satellite Data Assessment and Climatology
- Lidars

- Later: Sessions leads discussion on the ICAP Multi-model ensemble and CLIPER

Naval METOC Enterprise
Telescoping NWP Strategy

Navy Operational Global Atmospheric Prediction System

NRL Aerosol Analysis and Prediction System



NRL Atmospheric Variational Data Assimilation System

Data Assimilation

NOGAPS/EFS &NAAPS
- *Global Coverage
- *Meso- to Synoptic Scale
- *1-7d Guidance/ 10d Ensemble
- * Weather, Aerosols

NAVDAS/ NAVDAS-AR
- *3DVAR / 4DVAR
- *Radiance Assimilation
- *Global to Meso- Scale

Down-Scale Nesting

COAMPS®
- *Nested Regional Coverage
- *Nonhydrostatic Scale
- *Routine areas, 0-72h Guidance
- *Weather, Ocean, and Aerosols

NWP

Through-the-Sensor Obs

Satellite

UAV

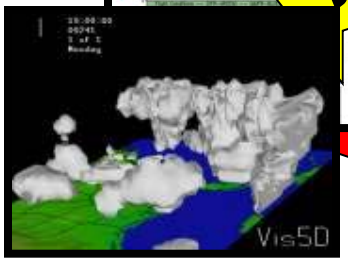
Coupled Ocean/ Atmosphere Mesoscale Prediction System

COAMPS-OS®
- *Nested Local Coverage
- *Tactical Scales, tailored products
- *0-?h Guidance, started on-demand
- *Ingest localized data for DA

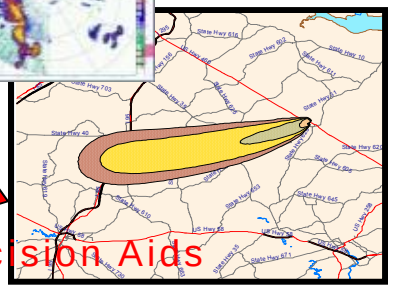
Data Fusion

Radar

NOWCAST
- *Rapid Environmental Assessment
- *Warfighter Time & Space Scales
- *0-6h Guidance, Rapid Update Cycle
- *Real-time, Automatic, Data Fusion



Decision Aids

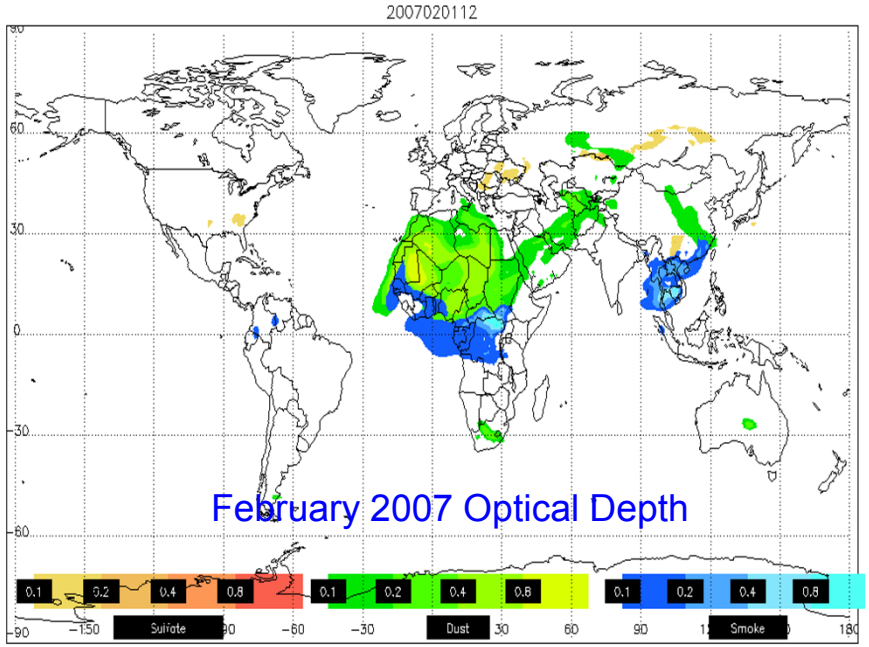


Navy Aerosol Modeling

http://www.nrlmry.navy.mil/aerosol/

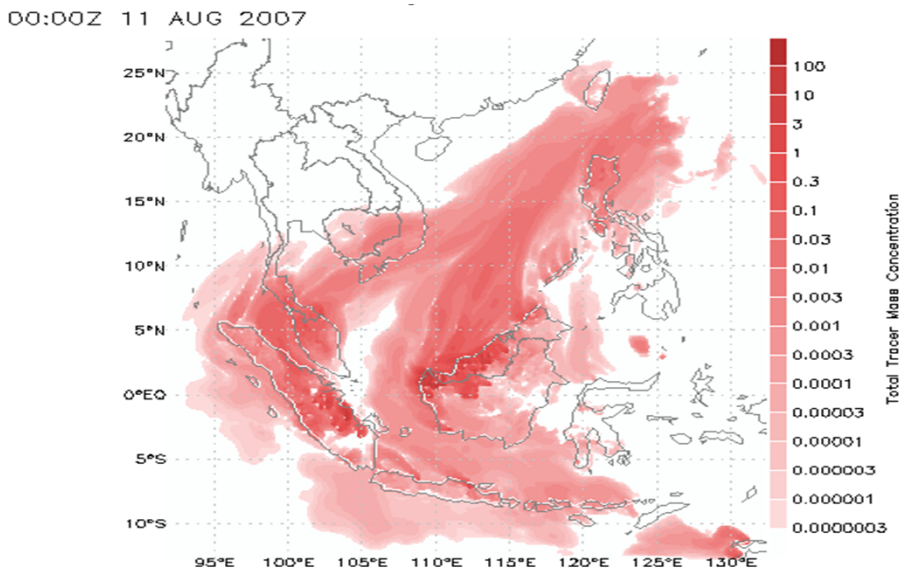
Global Modeling: Navy Aerosol Analysis and Predication System (NAAPS)

- **World's first operational global aerosol model and is based on NOGAPS fields.**
- **Utilizes world's first operational aerosol data assimilation & fire data streams.**
- **Used for forecasting as well as process studies and EO climatology.**



Mesoscale Modeling: Coupled Ocean Atmosphere Mesoscale Prediction System (COAMPS®)

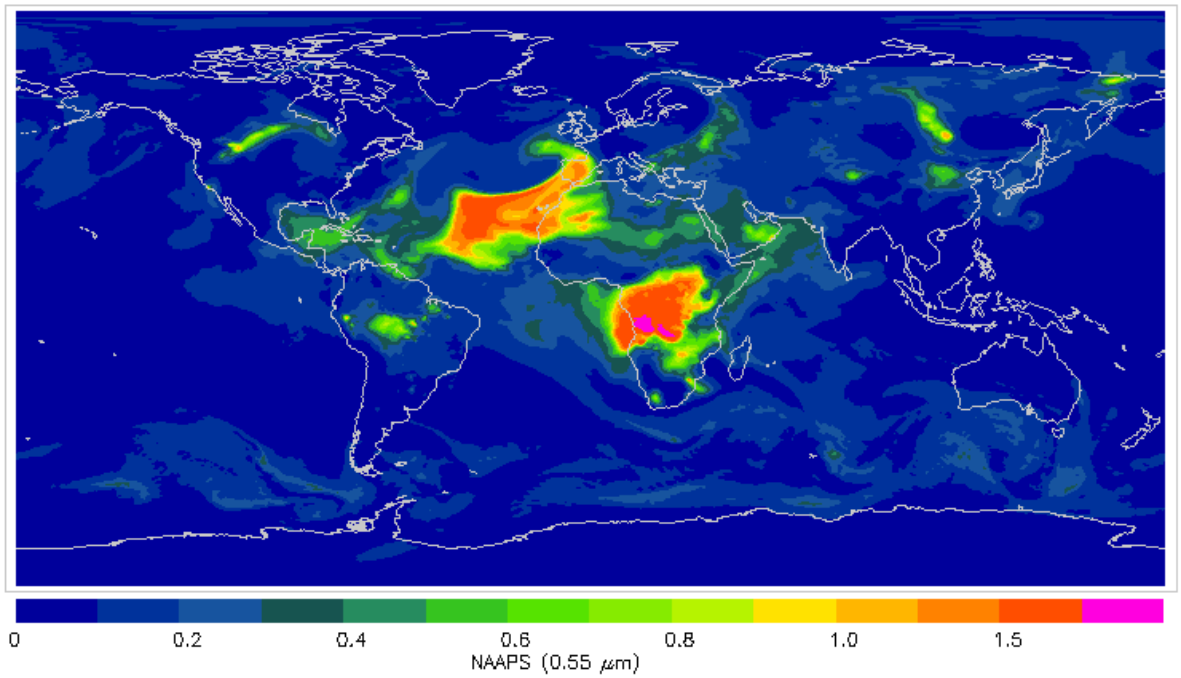
- **COAMPS® is mesoscale model fully coupled with the ocean.**
- **Dust forecasts operational at FNMOC and Currently adding aerosol species fully coupled with the model.**
- **Can be used to study complicated coastal flows where aerosol particles, winds, and water vapor covary.**



NAAPS Modeling Headlines

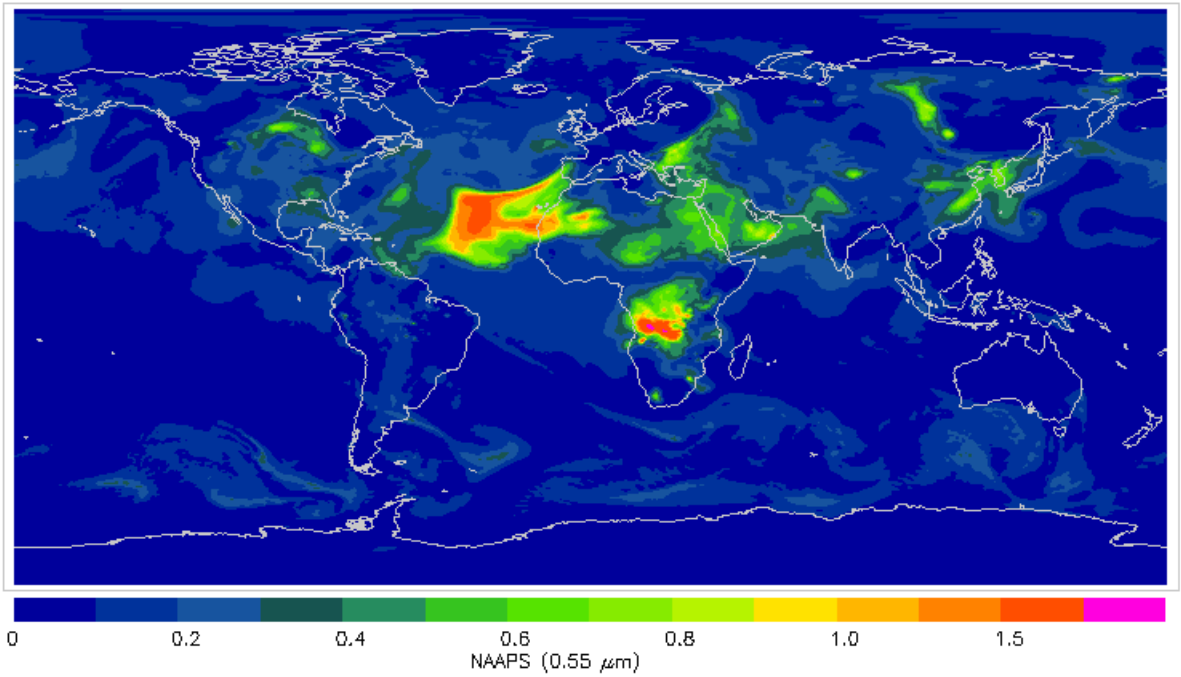
- February 2012: MODIS over land AOD data assimilation goes operational.
- NAAPS-development now at 0.5x0.5
- Very first attempt of Data Assimilation Research Testbed (DART) EnKF.
- Enhanced NAAPS ensemble.
- Published 2D/3D var CALIOP assimilation paper.
- Performing initial assessment on NPP VIIRS and AVHRR products
- DA grade MISR and Deep Blue products created (Zhang's UND shop).

Congrats to Jianglong Zhang for winning the David Johnson Award!



Demonstration of ½ degree NAVDAS-AOD

2007073118
Half-degree
Without data assimilation (free-running model)



2007073118
Half-degree
With data assimilation every 6 hours

Bottom line: Does not really improve scores as the meteorology has been at ½ degree for the last few years

The International Cooperative for Aerosol Prediction (ICAP) Multi-Model Ensemble-Walter Wednesday

ICAP Multimodel Ensemble

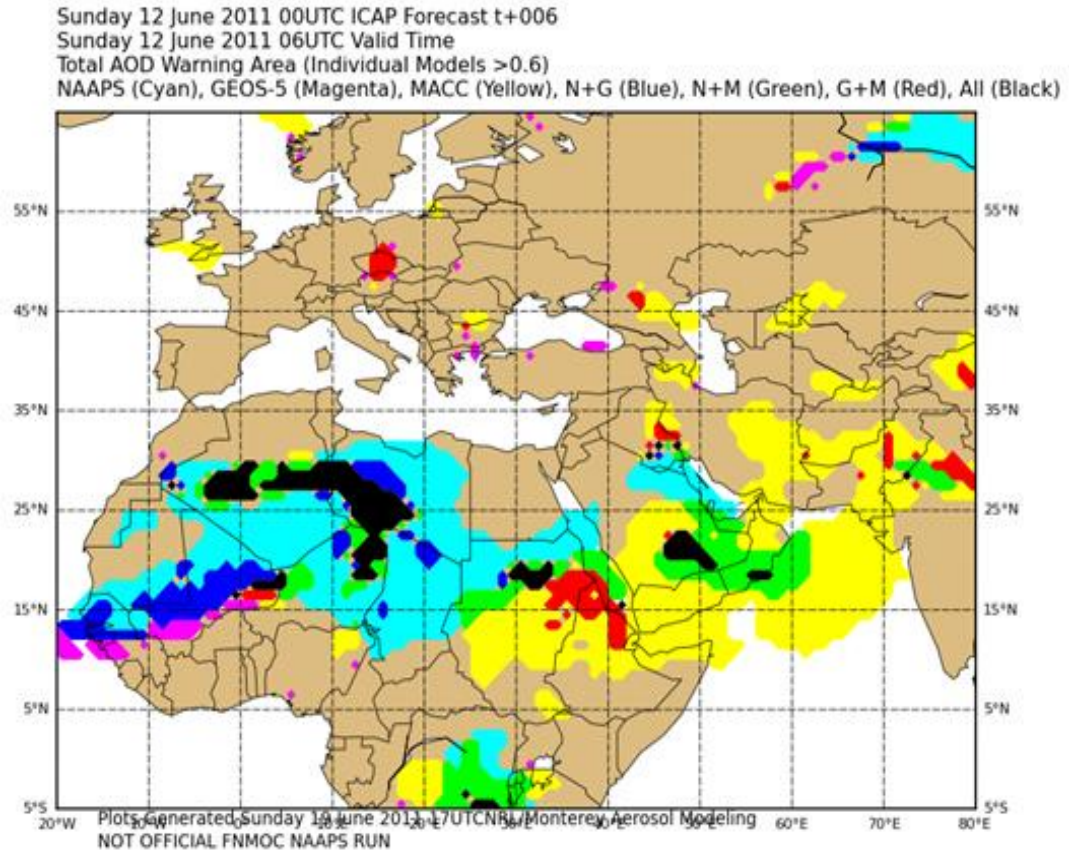
- Five centers active:
  - ECMWF (MACC)
  - GSFC (GEOS-5)
  - JMA (MASINGAR)
  - NCEP (GOCART Dust)
  - NRL-MRY (NAAPS and eNAAPS)

- Running pseudo-operationally, one day behind

- Current VV efforts AERONET based.

- Working on ICAP universal benchmarks

PRODUCTS	INDIVIDUAL ICAP MODELS - REGIONS									
	GLOBAL	NIOSEA	BYZANTIUM	EASTASIA	SUBTROPATL	PACIFIC	CONUS	SATLANTIC	SIOAUS	NPOLAR
ALL MODELS AOD 2012 02 06	sulfate dust smoke seasalt total	sulfate dust smoke seasalt total	sulfate dust smoke seasalt total	sulfate dust smoke seasalt total	sulfate dust smoke seasalt total	sulfate dust smoke seasalt total	sulfate dust smoke seasalt total	sulfate dust smoke seasalt total	sulfate dust smoke seasalt total	sulfate dust smoke seasalt total
MULTI-MODEL ENSEMBLE 2012 02 06	sulfate dust smoke seasalt total	sulfate dust smoke seasalt total	sulfate dust smoke seasalt total	sulfate dust smoke seasalt total	sulfate dust smoke seasalt total	sulfate dust smoke seasalt total	sulfate dust smoke seasalt total	sulfate dust smoke seasalt total	sulfate dust smoke seasalt total	sulfate dust smoke seasalt total



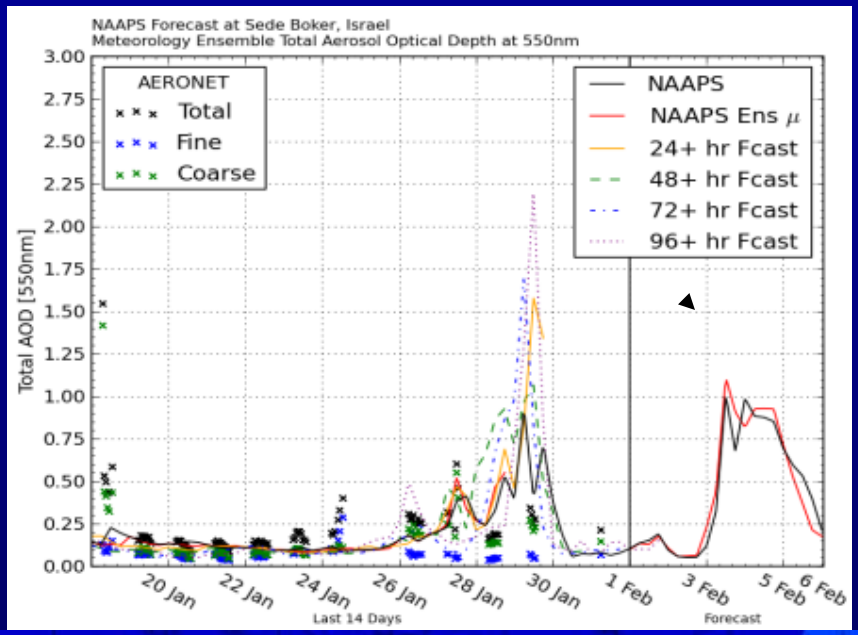
Developed New Information Spread and Verification Infrastructure

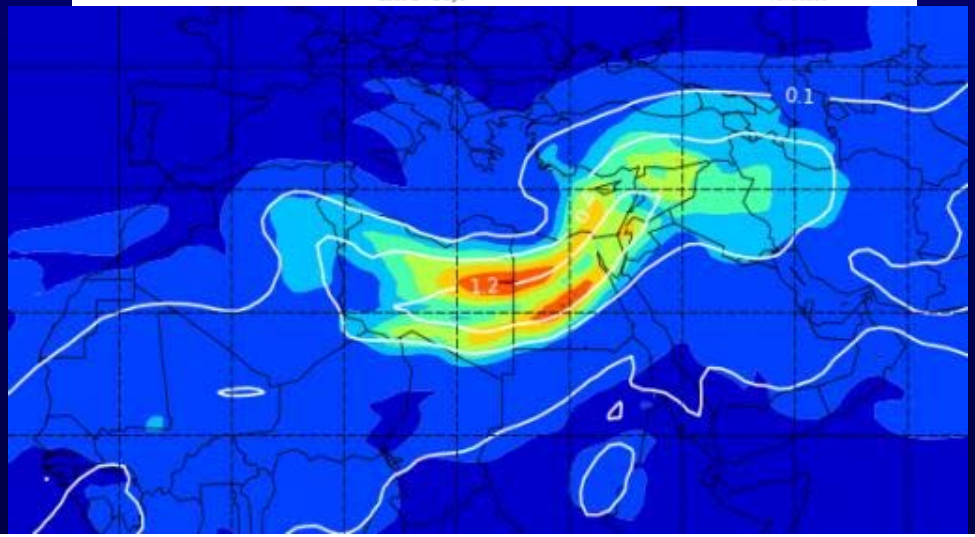
Ensemble NAAPS (eNAAPS) created early last year.

eNAAPS is based on 20 member NOGAPS ensemble. Still investigating source function draws.

New near real-time mean spread plots, spaghetti plots, ensemble meteograms, rank diagrams etc... To help understand forecast uncertainty.

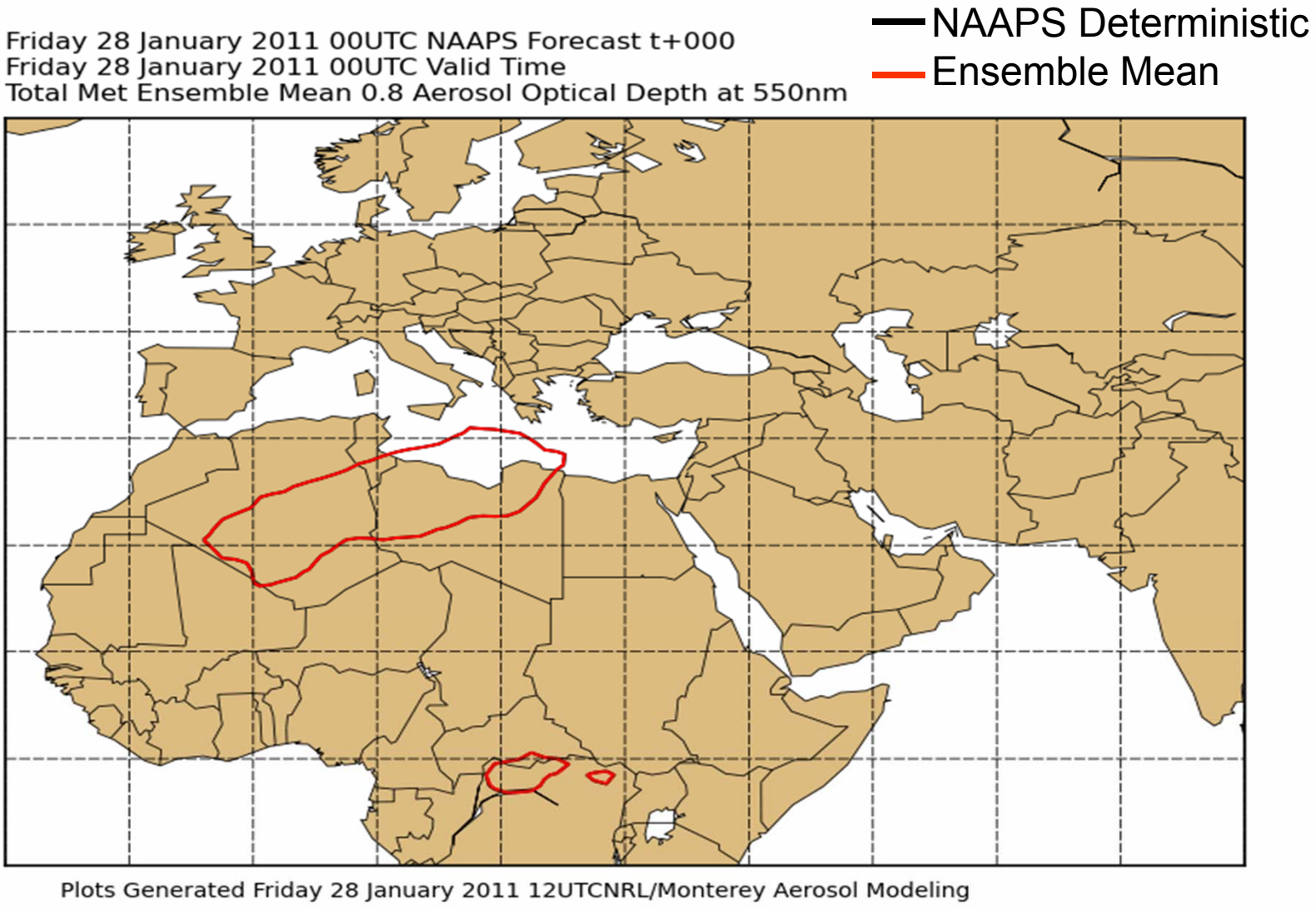
These tools help us determine where to scrutinize observations





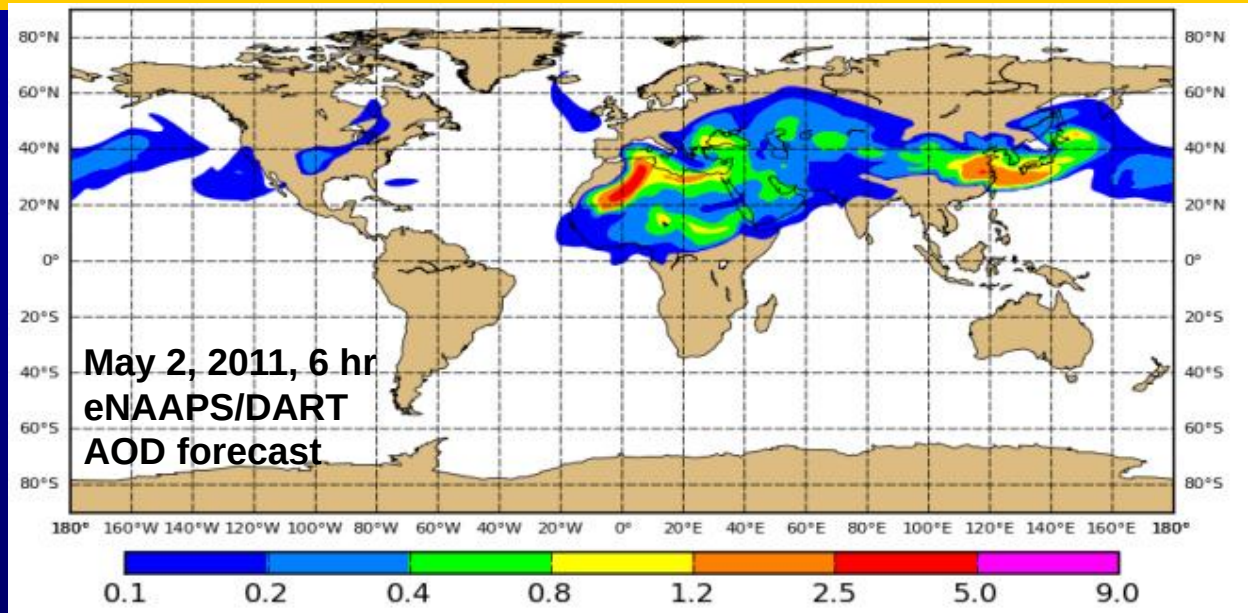
NAAPS Ensemble

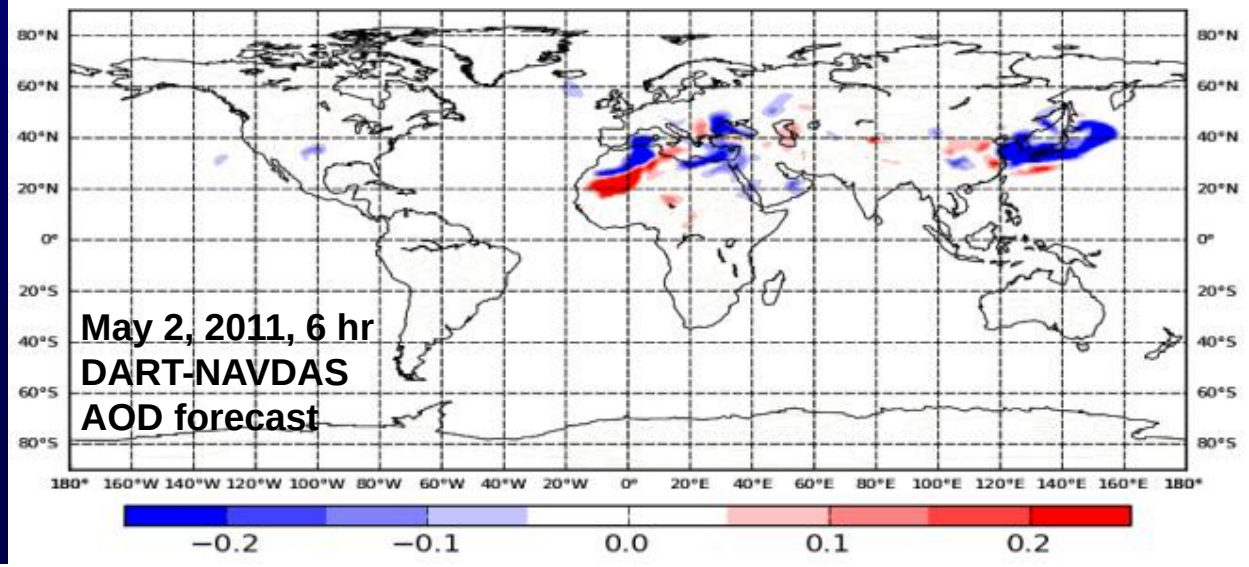
Developmental version of NAAPS
20 members from NOGAPS Ensemble.



Data Assimilation Research Testbed
Ensemble Kalman Filter (EnKF) Data Assimilation

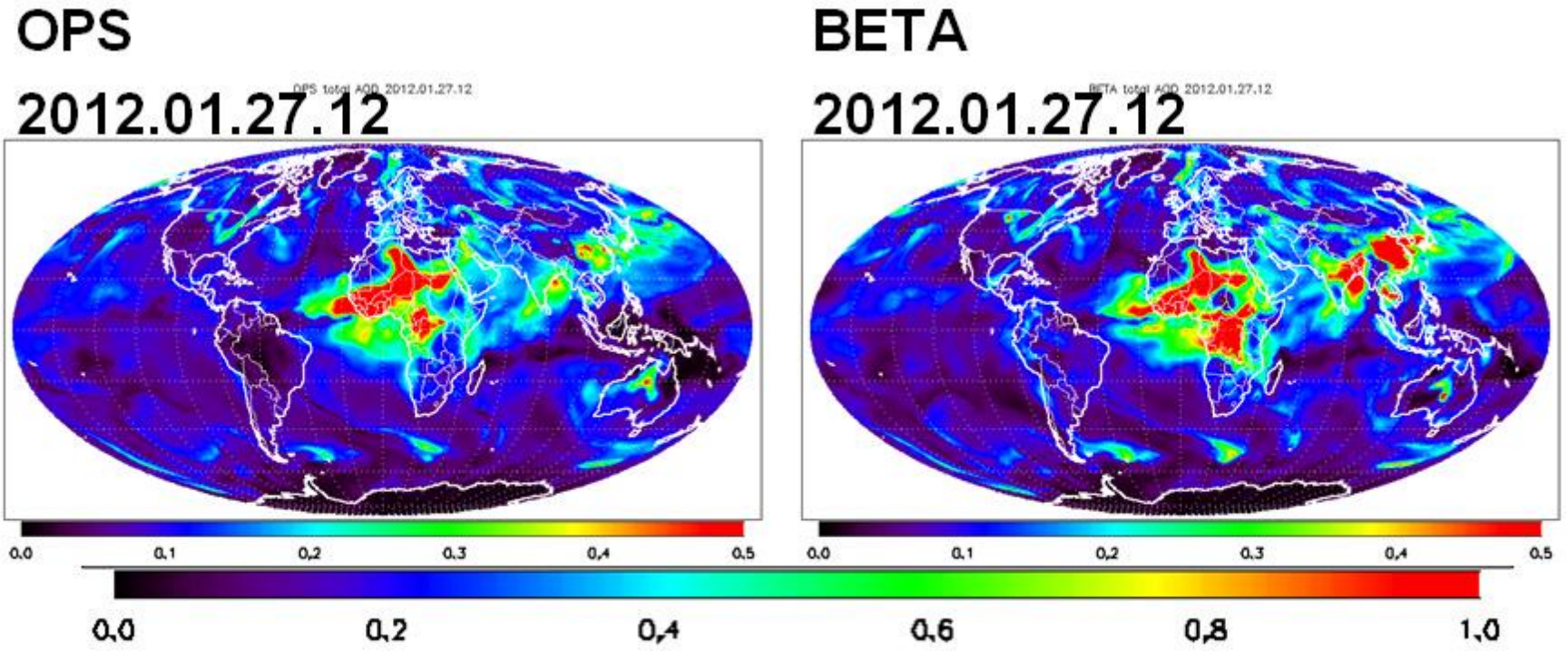
- DART has very recently been ported to eNAAPS.
- Test runs completed.
- In areas with plentiful observations DART and NAVDAS-AOD give similar results.
- Large differences exit in regions with few AOD observations.
- Lots of work ahead, including localization





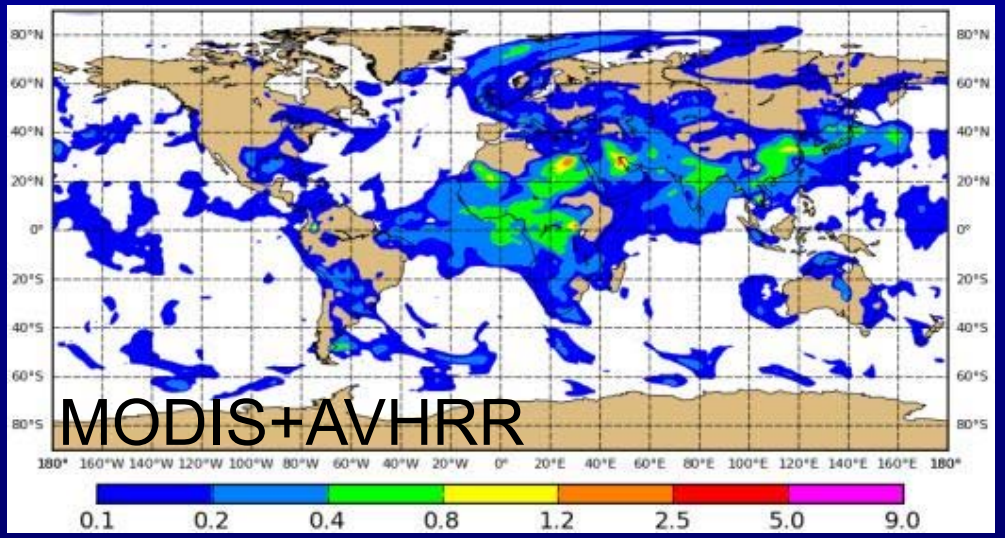
Over-land AOD Data Assimilation in Operations

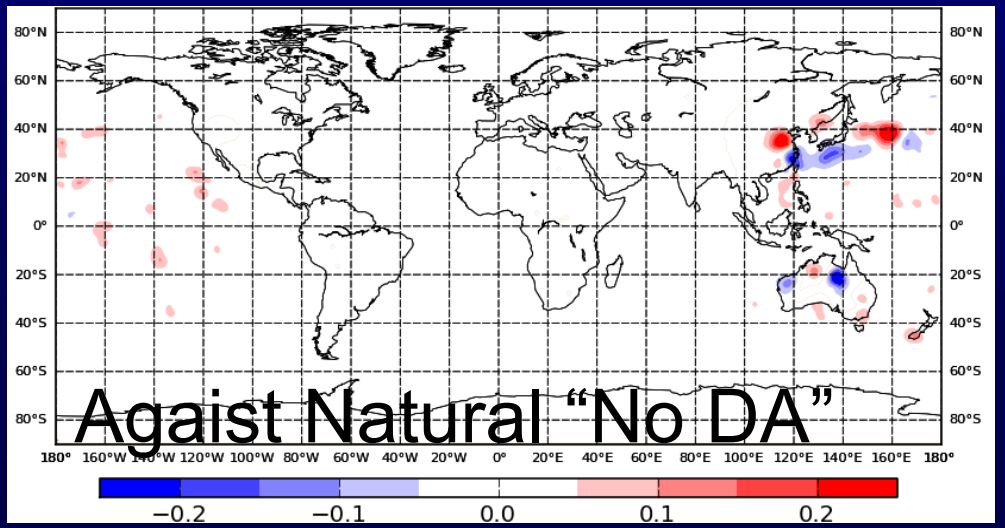
- VTR for Dec 24 2011 – Jan 27, 2012
- Largest impacts are over or near land sources
- Operational Feb, 2012



Verification: Model configuration and satellite observation impact

- Ensemble methods can be used to study a variety of model and observation questions.
- This work unit developed the tools for analyzing impact of AVHRR and NPP Multiple models are run against our most advanced deterministic run and natural/no DA run to assess impact.

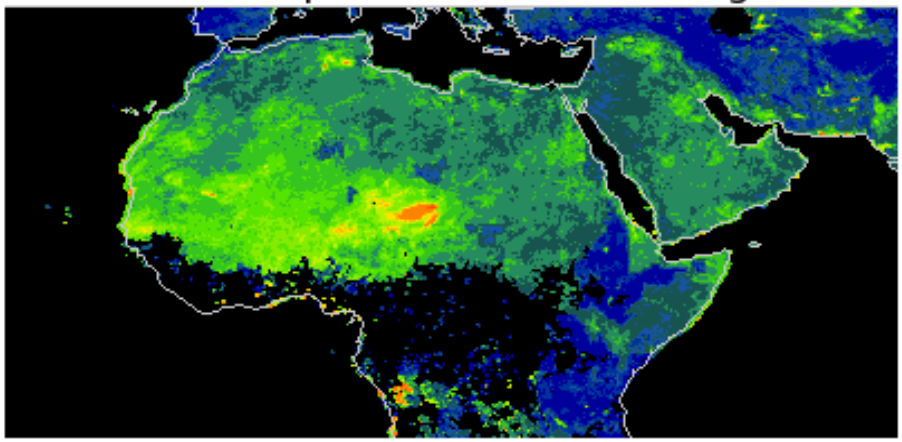




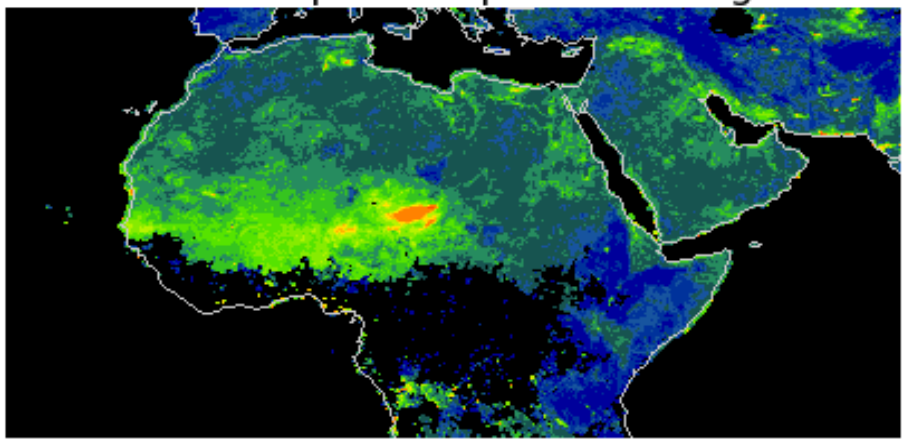
DA Quality MODIS Deep Blue product for Africa

(Yingxi Shi, submitted)

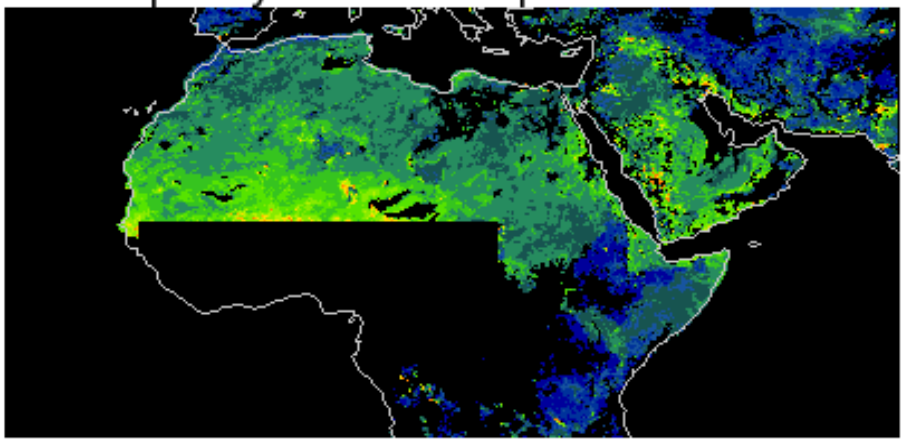
MODIS DeepBlue Terra 2007 Original



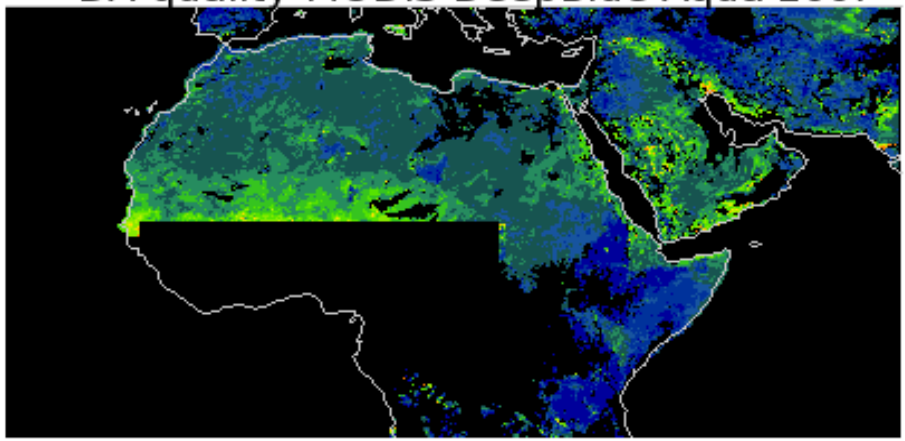
MODIS DeepBlue Aqua 2007 Original

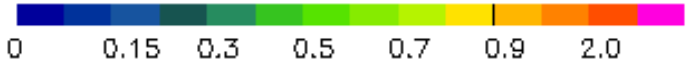


DA-quality MODIS DeepBlue Terra 2007



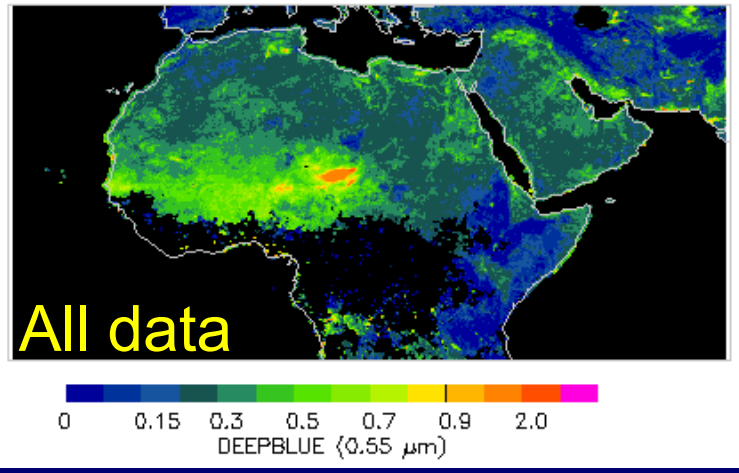
DA-quality MODIS DeepBlue Aqua 2007

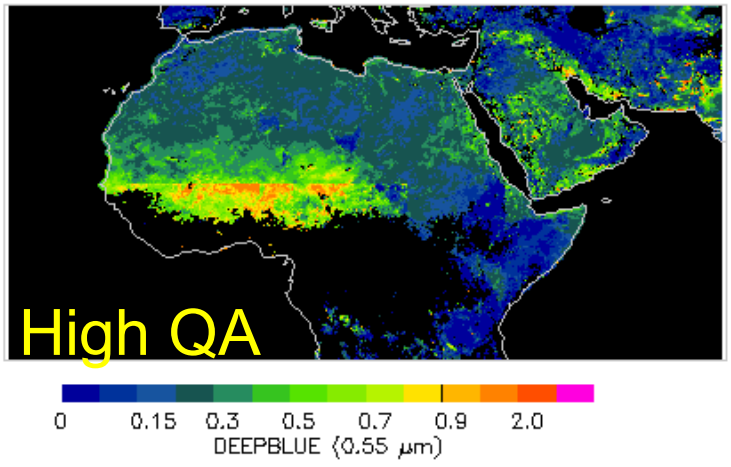


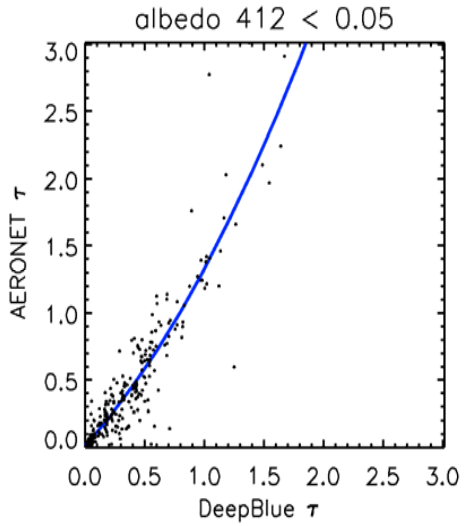


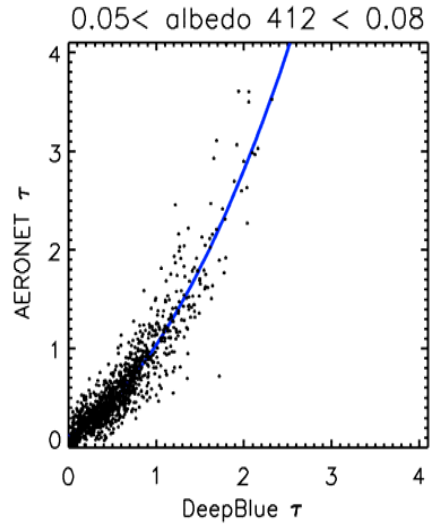
Aerosol Optical Depth (0.55 micron)

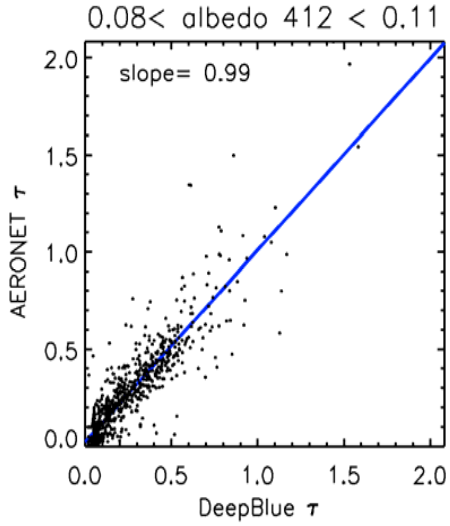
Deep Blue DA Version

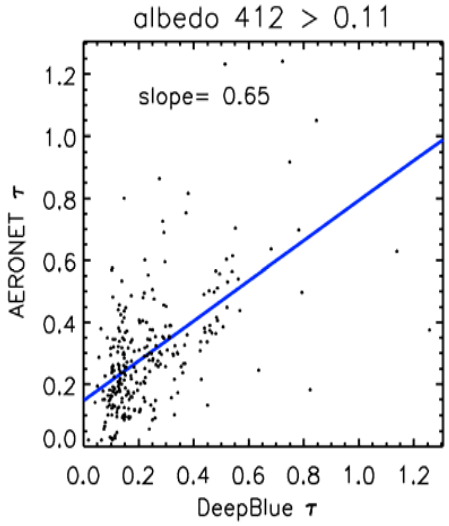




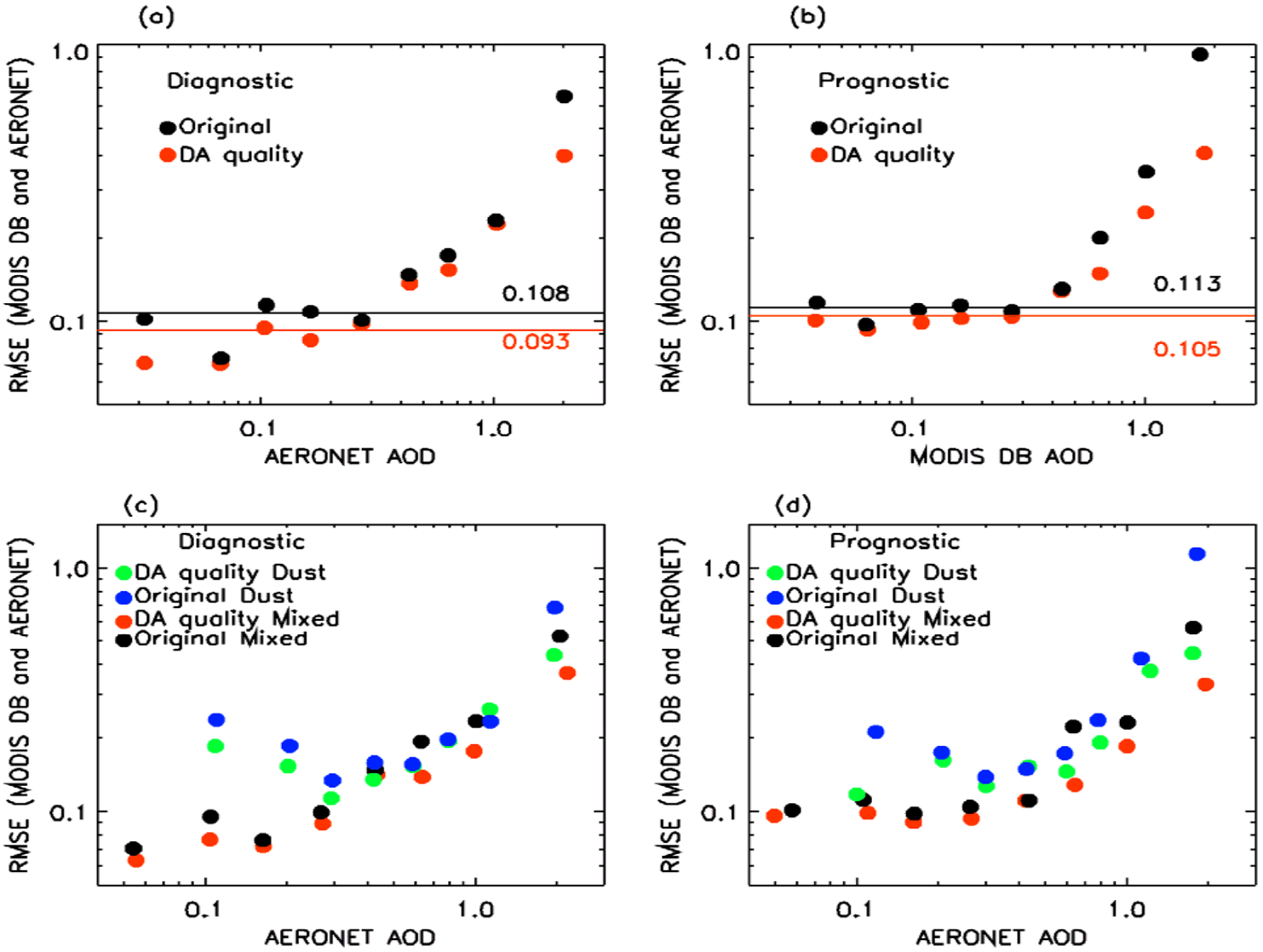




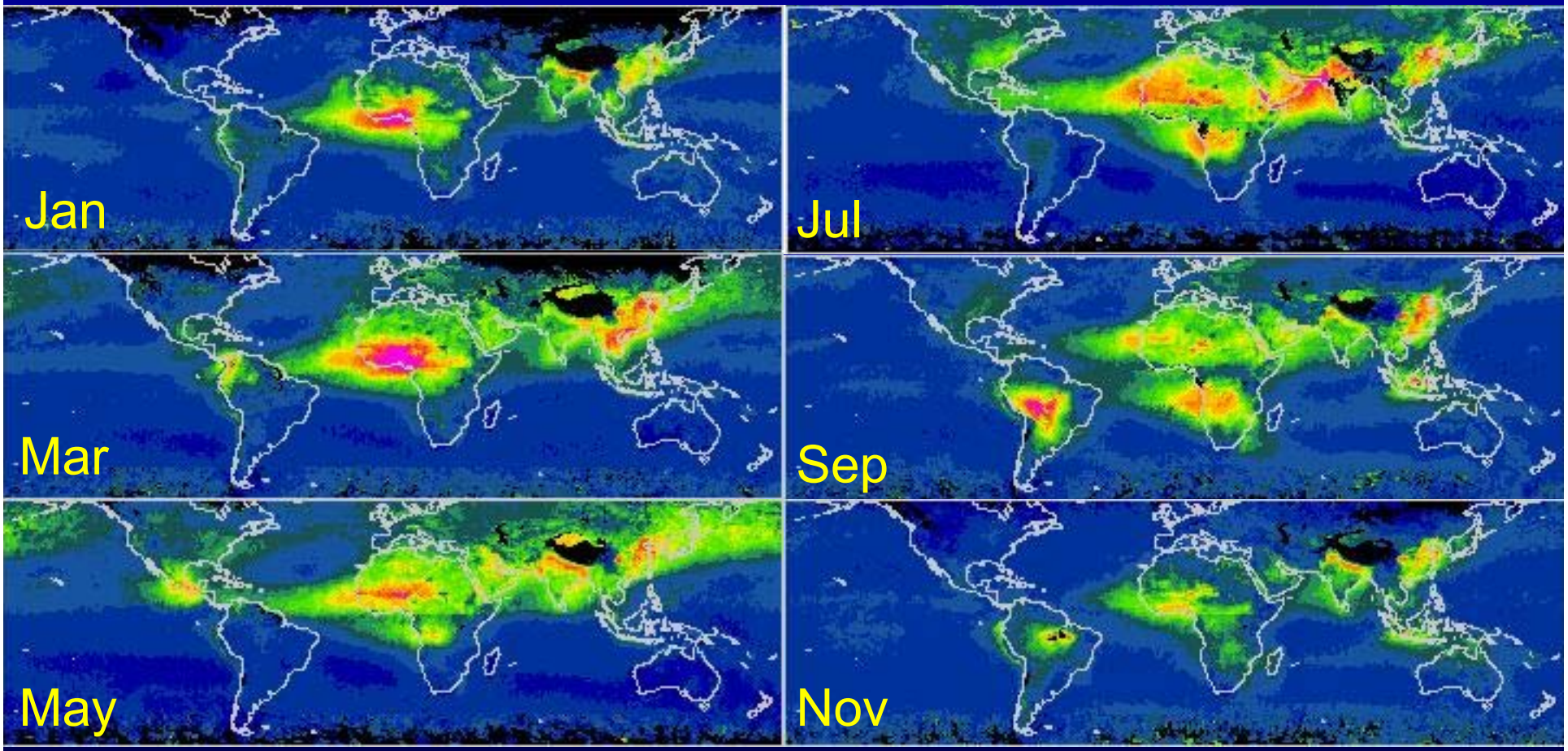




MODIS Aqua Deep Blue RMSEs

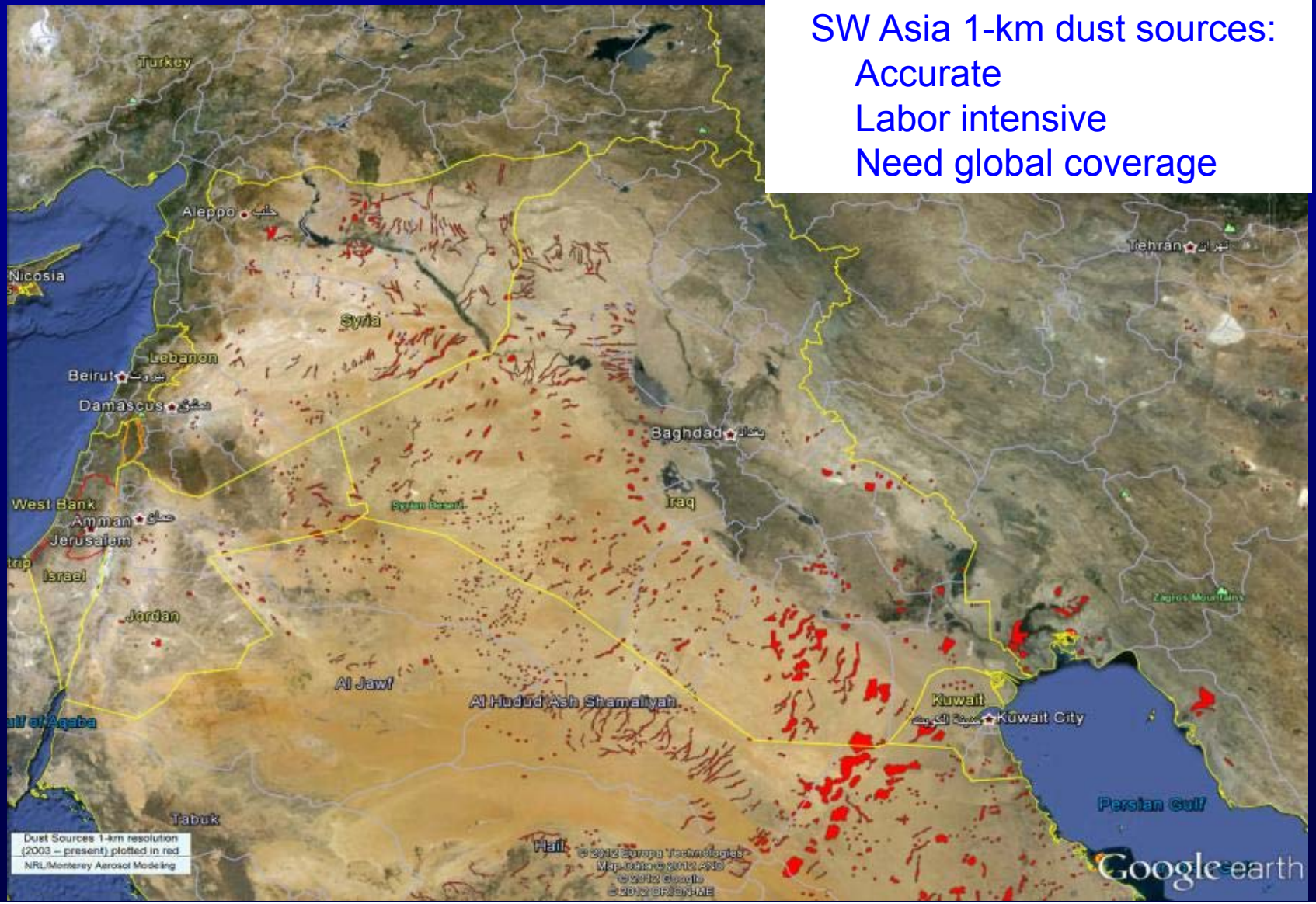


Baseline satellite climatology almost finished. Still some hotspots and fusion issues to work out.



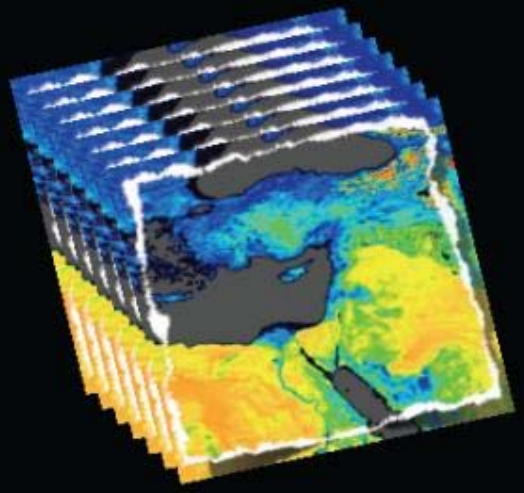
Further development of a global high-resolution dust source database. Need to expand globally.

SW Asia 1-km dust sources:
- Accurate
- Labor intensive
- Need global coverage

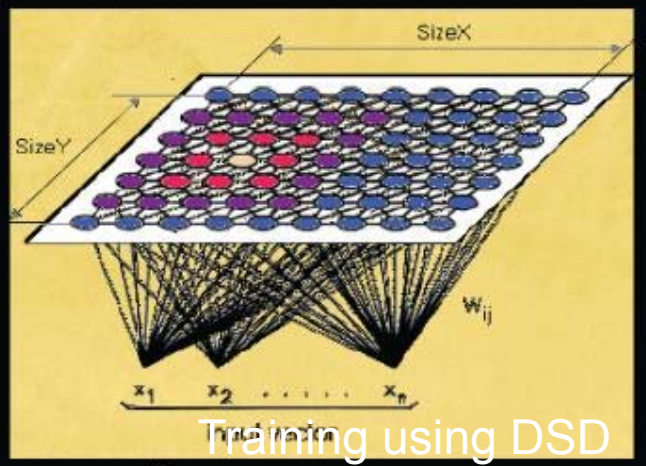


Global high-resolution dust source database from Self Organizing Map (SOM) Neural Network

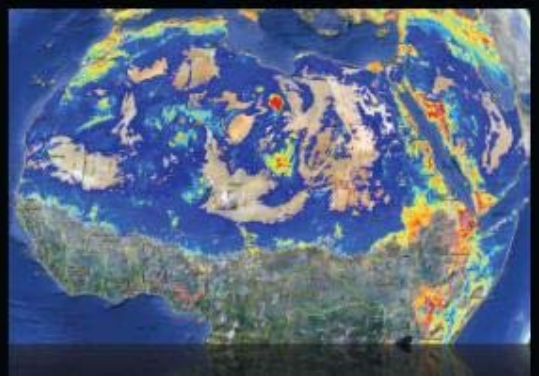
Self Organizing Map Classification



7 Bands
MODIS MCD43C3
bihemispherical reflectance
one year of data



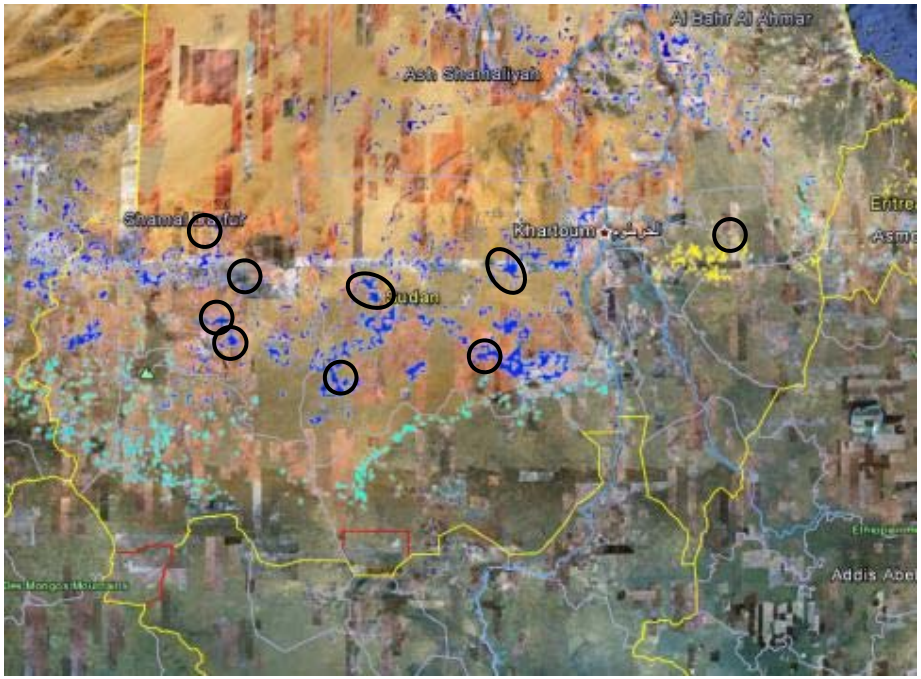
Training using DSD



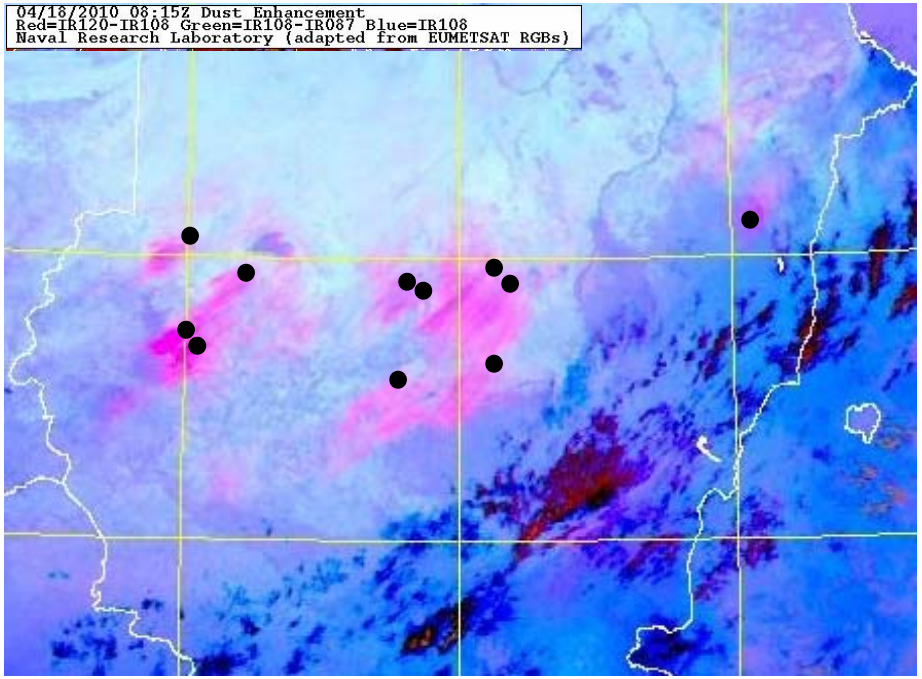
Global high-resolution DSD: Africa

Sudan Dust Event: April 18, 2010 0815Z

DSD V3.1



MSG RGB



- Verified over SW Asia and E. Asia
- Applied to N. Africa, N. America, S. America
- Final step: scaling studies at regional to global resolutions

→ SOM approach provides rapid global source identification

Getting deeper into lidar Campbell working on turn the crank assimilation and verification tools.

MPLNET Singapore

NAAPS 2d var

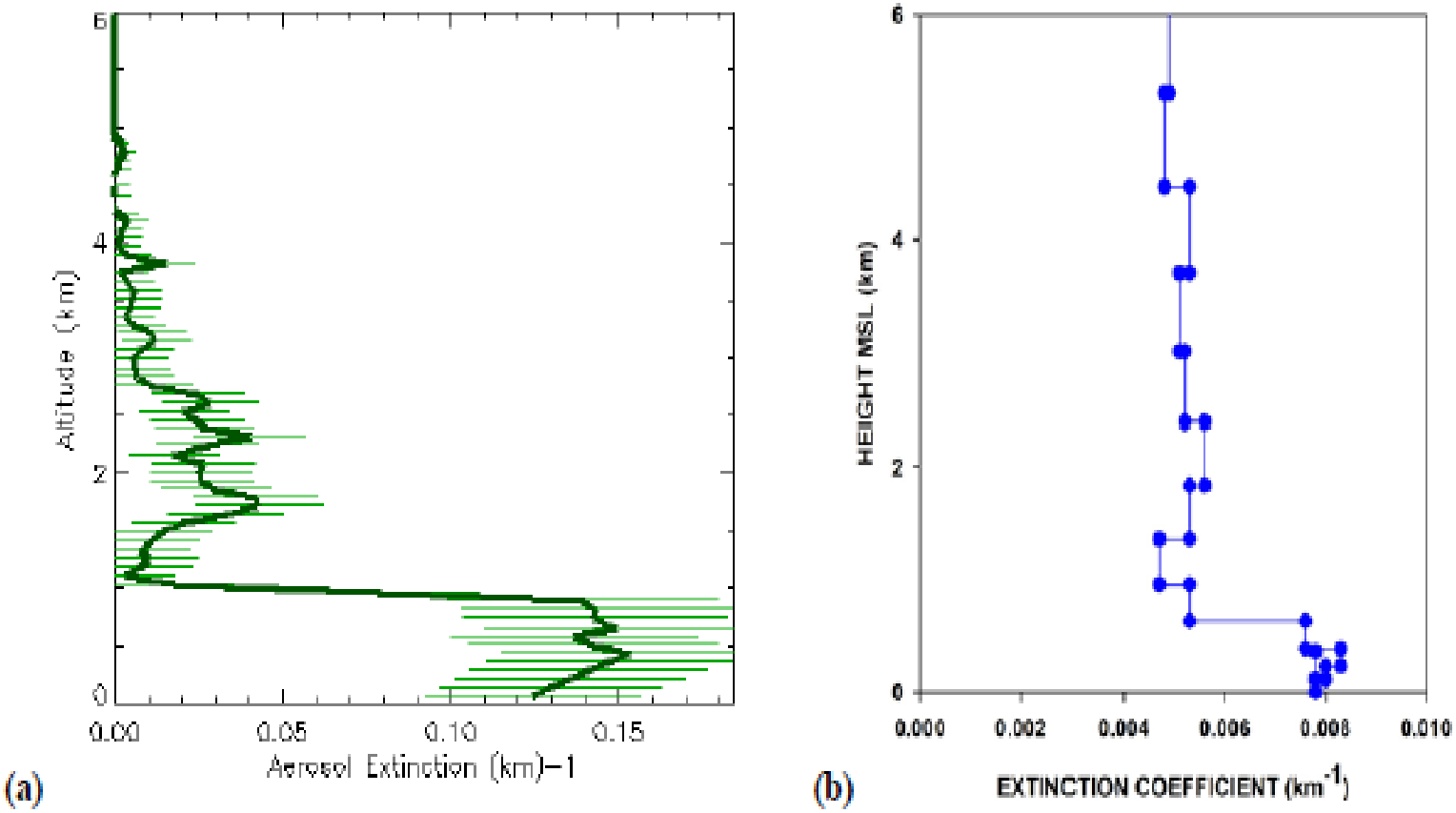
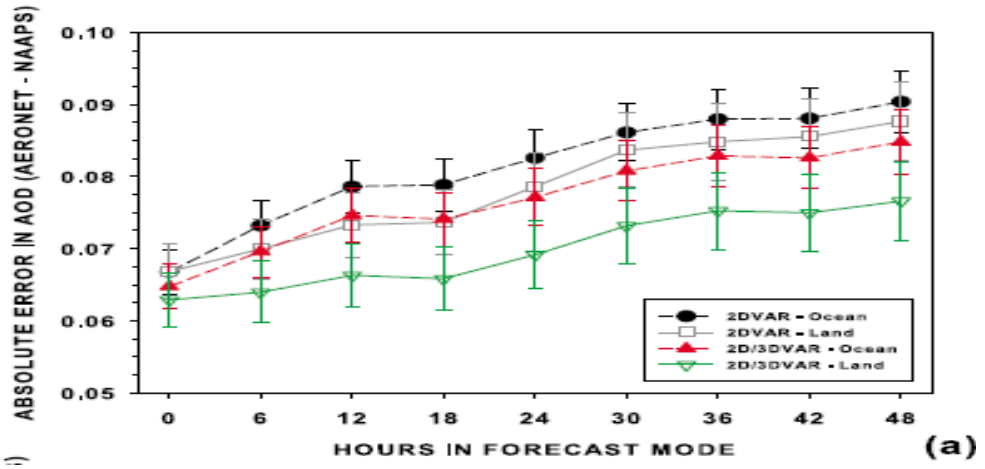


Figure 1. (a) MPLNET Level 2.0 532 nm aerosol extinction coefficient profile at Singapore, 0815 UTC 15 November 2009, solved at 75 m vertical resolution. (b) NAAPS model profile of 550 nm aerosol extinction coefficient for the Singapore 1° x 1° model grid point at 0600 UTC. Given the varying depth of the model levels used, vertical resolution varies.

Need to Assimilate Satellite Lidar Data:



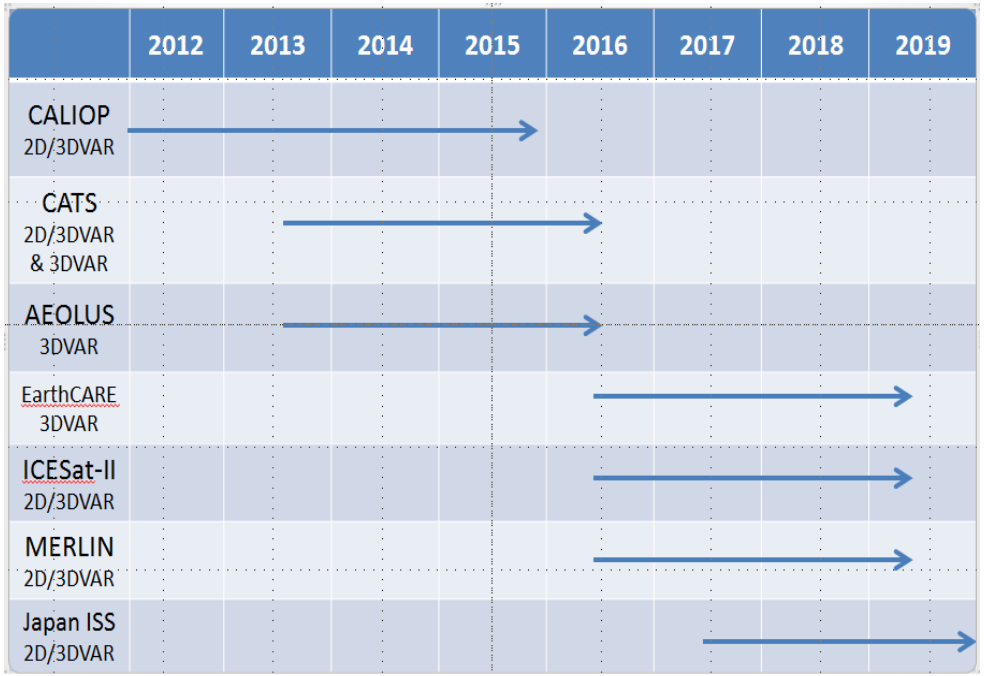
Navy Application

- 10-15% improvement in NAAPS AOD forecast accuracies out to 48 hr using CALIOP *(Zhang et al., GRL*, 2011)
- Assimilating satellite lidar data causes redistribution of aerosol particle extinction within NAAPS. This *directly* impacts:
  1. Visibility assessment
  2. Forecasts downwind
  3. Depiction of boundary layer
  4. Diabatic heating rates/radiative transfer calculations
  5. Radiance assimilation/atmospheric correction

Outlook

- Spaceborne lidars expected through 2025
- Expect to propose to CALIOP, CATS and ICESat-II
- Need to provide input on product design and operational use, advocating < 6 hr latency

Satellite-based Lidar Missions Current and Manifested



Conclusion: Our plans for the year ahead

- Implement 0.5 degree NAAPS operationally.
- Start FLAMBE2 quasi-operationally.
- Complete first cut on VIIRS DA product
- More modeling focus on COAMPS, particularly with the SEAC4RS field work.
- Preparation for CATS lidar data.
- Advancing development of EnKF aerosol DA to run quasi-operationally.
- Forward models for radiance assimilation.
- Start playing with the ICAP multi-model ensemble!

Southeast Asia Composition, Cloud Coupling Regional Study (SEAC4RS)

NRL 7544 Focus Areas:

6.1 Aerosol impacts radiative/microphysical impacts on clouds and warm rain processes.

6.2 Tropical aerosol observability and predictability.

6.2 Biomass burning emissions and transport forecasting.

7544 Participants

Bucholtz: Radiation

Campbell: Regional Lidar Network

Hyer: Biomass Burning

Lynch: Aerosol precipitation interaction

E. Reid: Radiation

J. Reid: Lead, Aerosol and Radiation as well as Ground Mission

Sessions: Ensembles and Lagrangian modeling

Walker: Forecasting

NRL Contributions

30 hrs each for DC8 & ER2

28 days at Sea on the Vasco (w/ CIRPAS)

Singapore and Nha Trang Supersites

Aircraft Radiometers

COAMPS-OS Forecasts

Lagrangian Modeling

Universal smoke source function for all modeling teams

Manage the ICAP multi model ensemble

Base Time: 00:00Z 11 AUG 2007

SEAC^{4}RS In a Nutshell

Aug-Sept 2012

NASA DC8 150 hrs

NASA ER2 150 hrs

NCAR GV 120 hrs

VASCO 28 d at sea

Maritime Aerosol Network Ferry

AERONET

AERONET Intensive.

Radiation Enhanced

Perm. Lidar

Leosphere Lidar

SHADOZ