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Office of Naval Research Science & Technology

NRL Aerosol Forecasting Update Part 2: Research and Development

ICAP 9th Working Group Meeting

Lille, France

June 26-28, 2016

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2017 Navy Aerosol Community

Monterey (Marine Meteorology):

Anthony Bucholtz	Radiative measurements, tactical decision aids	**Elizabeth Reid**	Deployments and analysis
James Campbell	Lidar studies, cirrus radiation	**Jeffrey Reid**	Microphysics, radiation, observability
Edward Hyer	Satellite data quality, biomass burning	**Mindy Surratt**	Satellite and model output processing
Mayra Oyola (ASEE)	Dust radiation	**Annette Walker**	Dust sources, operational outreach
Jim Peak	Statistical post-processing	**Doug Westphal**	Emeritus
Dave Peterson	Meteorology, biomass burning, remote sensing	**Peng Xian**	Reanalysis, multi-model ensemble

Washington, DC (Remote Sensing):

Maggie Anguelova	Satellite retrievals
David Kuhl	Data assimilation for NWP, hybrid methods
Karl Hoppel	Data assimilation for NWP
Juli I. Rubin	Data assimilation and ensemble modeling
Peter Caffrey	Aerosol microphysics, modeling
Ivan Savelyev	Aerosol measurements

Extensive collaborations with our partners: Jianglong Zhang's group (UND), ONR funded MURI led by Steve Miller at CSU, Bob Holz and CIMSS (U of Wisconsin)…

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Navy Aerosol Modeling: From the global to the mesoscale

Overview of Navy Aerosol Prediction:

Global Modeling: Navy Aerosol Analysis Prediction System

- NAAPS Operational
  Data Assimilation: NAVDAS-AOD
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- ENAAPS
  Data Assimilation: EAKF
- ICAP Multi-Model Ensemble

Mesoscale Modeling: Coupled Ocean Atmosphere Mesoscale Prediction System

- COAMPS Operational Dust
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- MURI: Littoral Zone Prediction

Inline Aerosol Prediction: Navy Global Environment Model

- NAVGEM with aerosol

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Global Aerosol Prediction: The power in ensembles

Multi-Model Ensemble (Peng Xian's Talk)

ICAP MME

- Valuable collaboration between forecast centers
- Independence across ensemble members
- Top performer

Provides reliable forecast guidance and serves as a good reference dataset (e.g. TIGGE NWP)

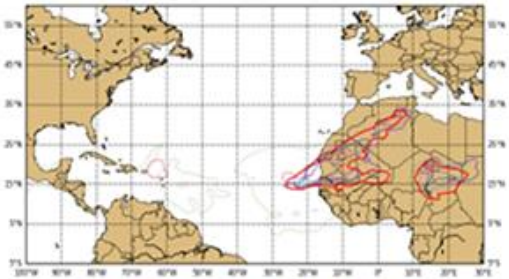
Single Model Ensemble

Ensemble NAAPS (ENAAPS)

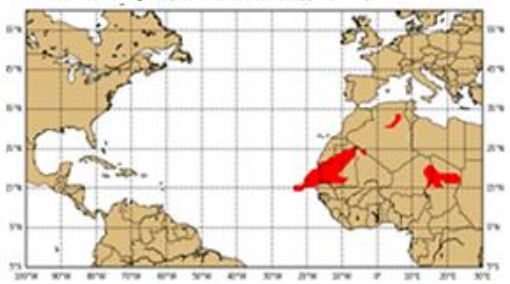
- 20-80 ensemble members
- EAKF data assimilation
- Moving towards operations.

Using observations more effectively for data assimilation

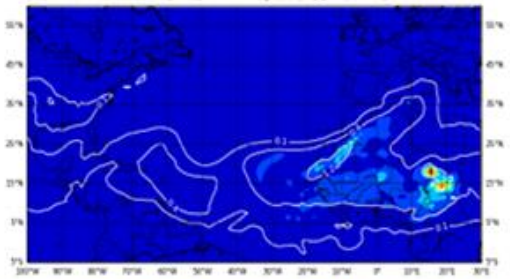
Probabilistic Products



AOT Contour (0.8)



Dust Warning



Ensemble Standard Deviation

Navy Global Aerosol Prediction: Ensemble NAAPS (ENAAPS)

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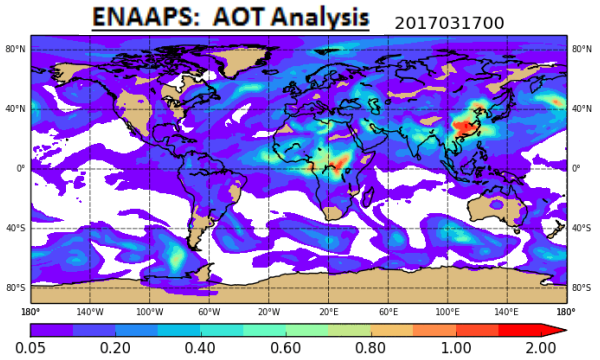
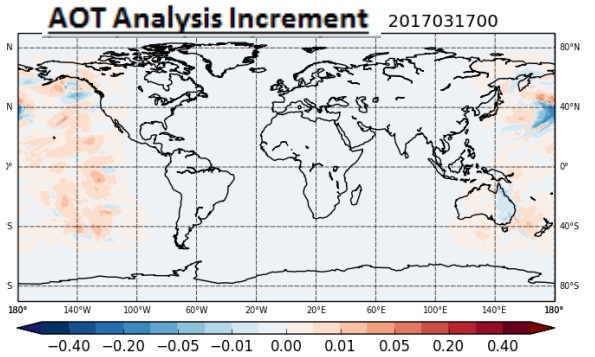
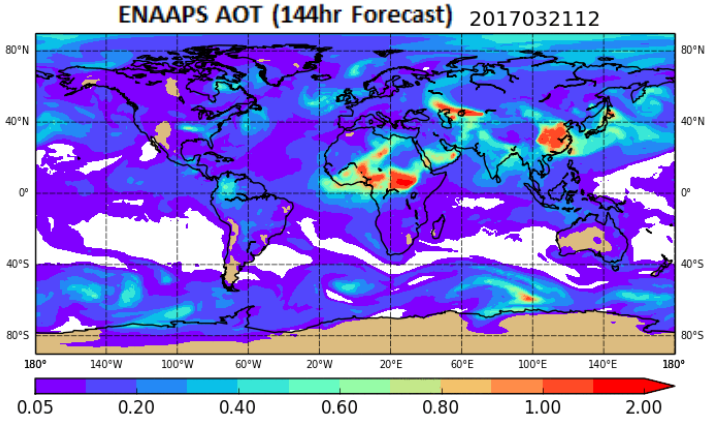
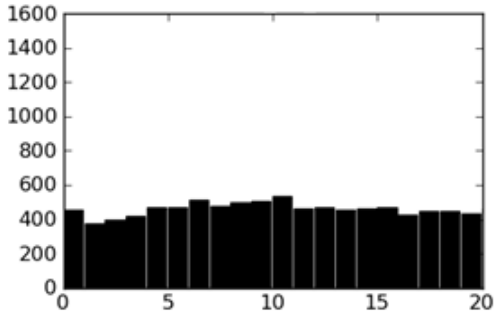
Recent Developments:

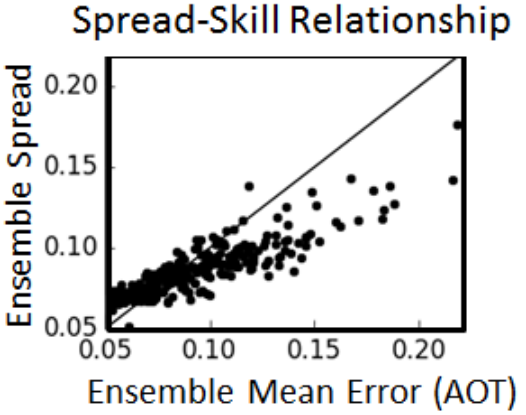
- ENAAPS-DART is moving towards operational implementation.
- Near real time cycling on Navy DSRC machines.
- Cycles with 80 ensemble members for assimilation
- Forecasts use 20 member subset.
- Ongoing efforts include ensemble verification, ensemble distribution/spread.











Navy Global Aerosol Prediction: Ensemble NAAPS (ENAAPS)

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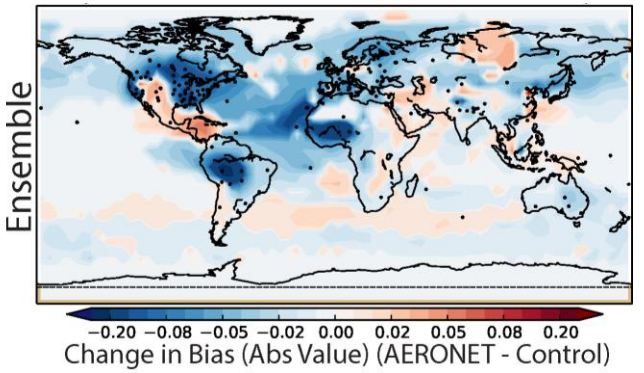
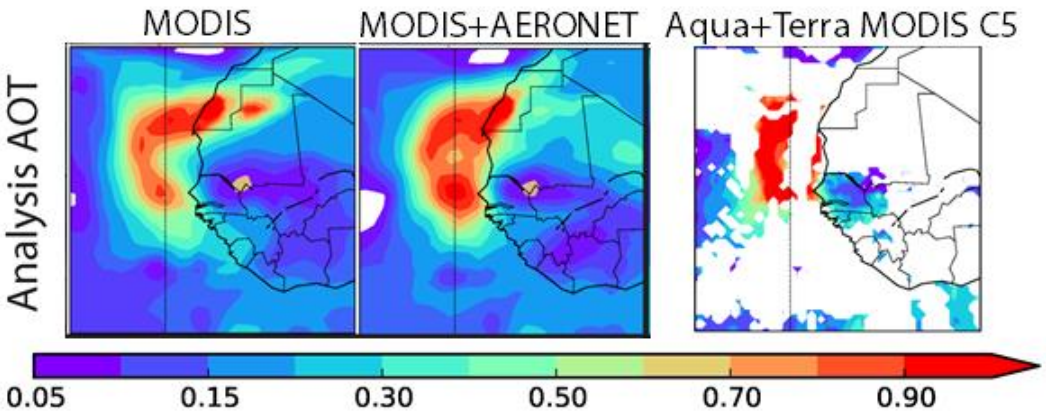
Improved Data Assimilation Capability:

- Flow-dependent corrections.
- Ideal for assimilating sparse aerosol information (e.g. in-situ, LIDAR).
- AERONET is helpful for capturing extreme aerosol events.

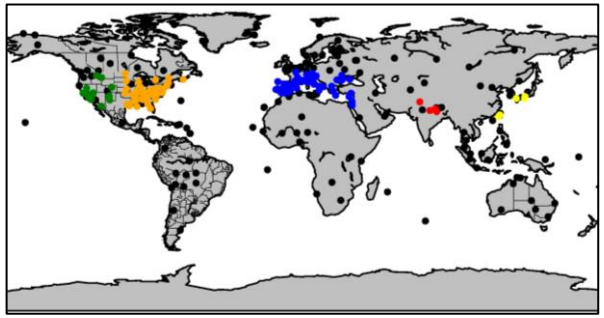
Error reductions relative to a no DA control for AERONET assimilation.

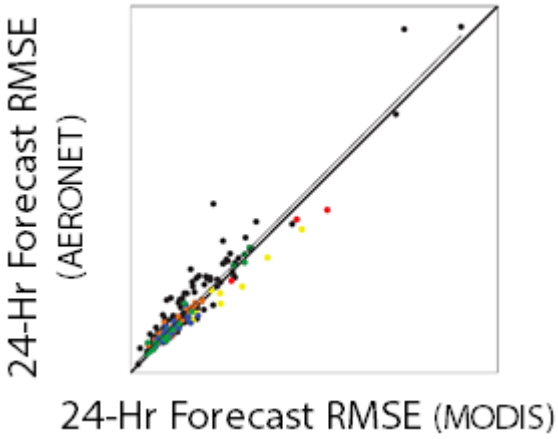




Near Real Time AERONET (v3, L1.5) will be needed.

- AERONET may serve as a useful back-up network for assimilation.





Rubin et al. 2017, JGR

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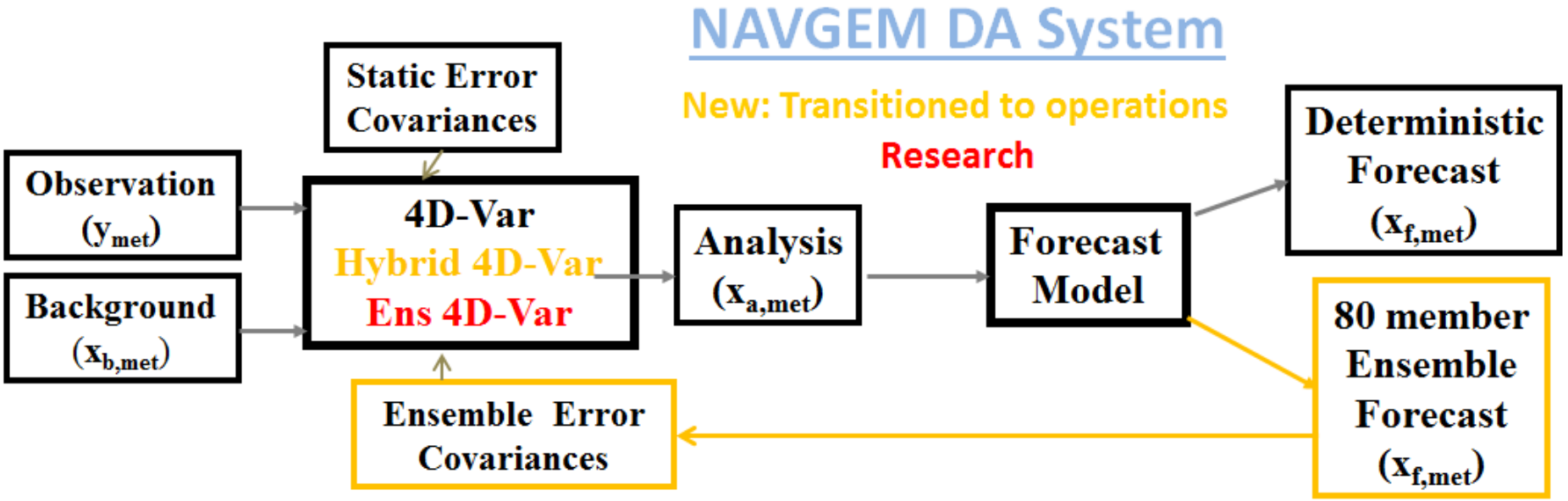
ENAAPS and Numerical Weather Prediction



- Hybrid 4D-Var Data Assimilation has transitioned to operations as part of NAVGEM 1.4.
- Having an operational 80 member NAVGEM forecast is key for getting ENAAPS to operations.
- There is ongoing research into an Ens 4D-Var (no TLM/adjoint) that is a joint effort between NRL Monterey and DC.

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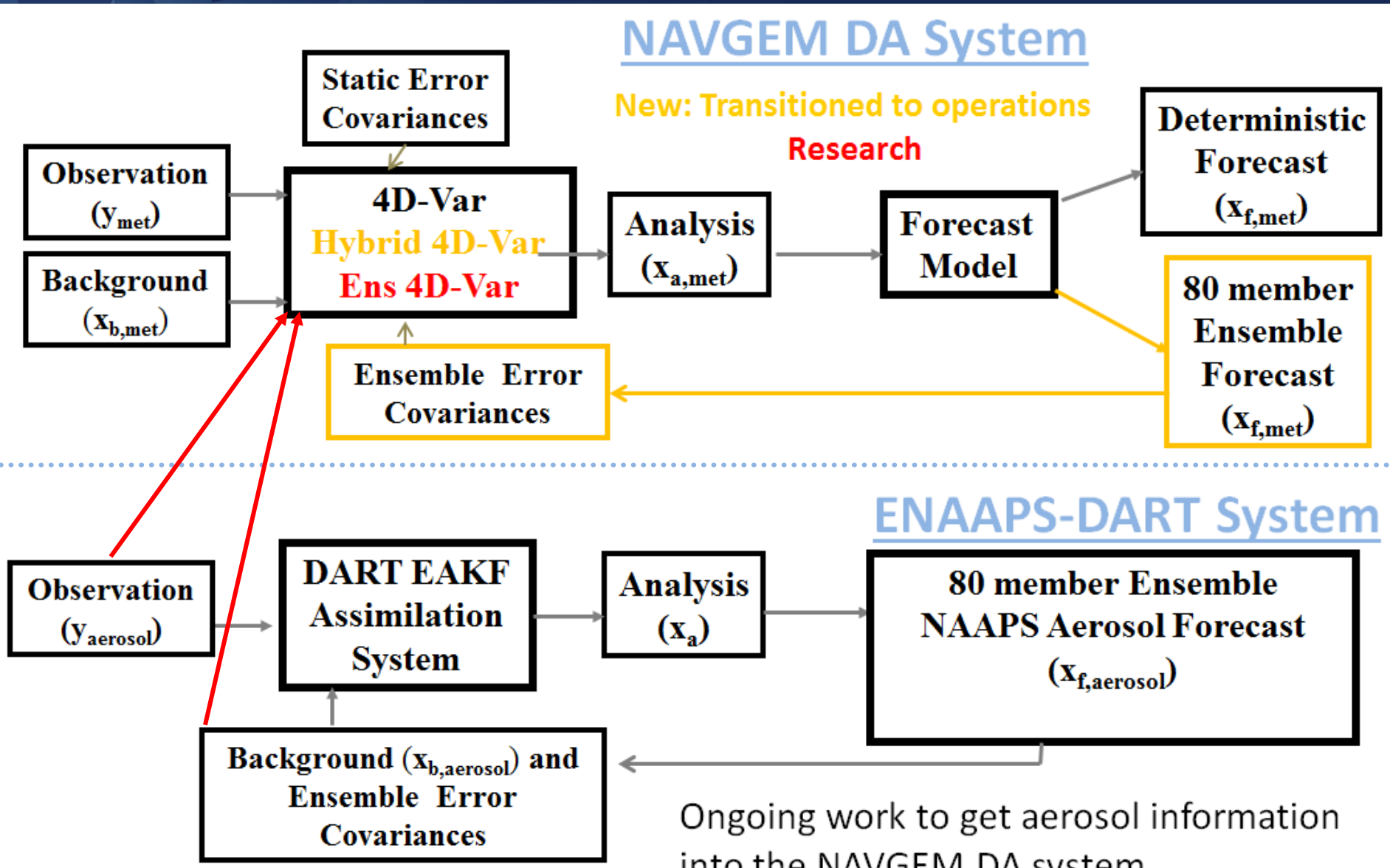
ENAAPS and Numerical Weather Prediction



Ongoing work to get aerosol information into the NAVGEM DA system.

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Navy Mesoscale Aerosol Prediction: MURI Ensemble Data Assimilation

Multidisciplinary University Research Initiatives (MURI) program funded by ONR:

Improve forecasting of aerosol in the complex littoral environment (CSU)

Goal: Produce high resolution 3D analysis of aerosol fields/uncertainty.

Approach: Coupled atmosphere-aerosol-chemistry ensemble DA.

Models: WRF-Chem, CSU RAMS.

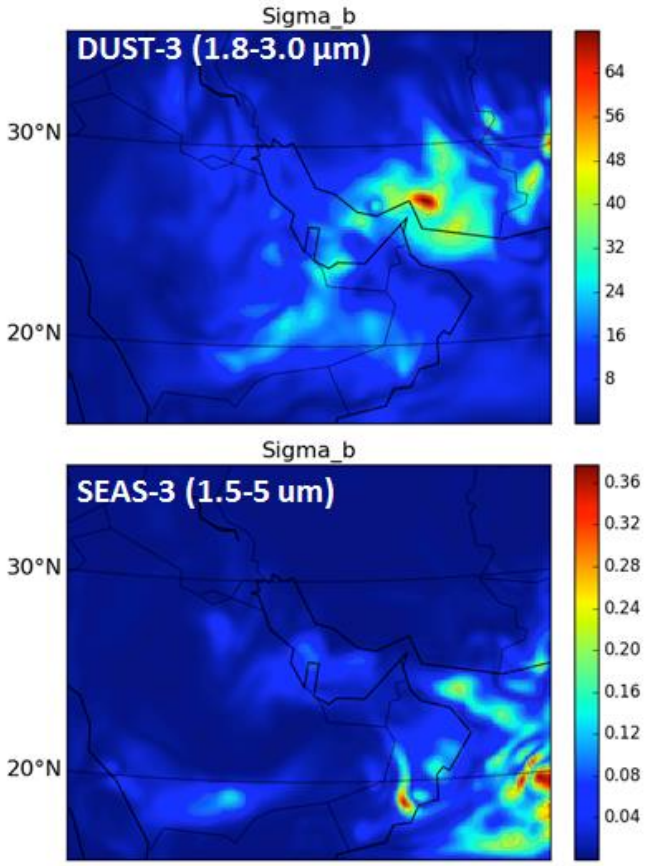
DA: EnKF (Maximum Likelihood Ensemble Filter)

Challenge: Can data assimilation exploit environmental parameter correlations to overcome observational shortfalls and provide a high-resolution 3D analysis of aerosol fields?

Strategy:

1. Use probabilistic forecasts to get aerosol vertical distribution since AOT is 2D.
2. For adequate high-resolution aerosol data assimilation need additional information about vertical distribution.
3. Assimilate MW all-sky satellite radiance observations
4. All-sky primarily impacts clouds, but through coupled atmosphere-aerosol ensemble forecast error correlation it also impacts aerosol 3D fields.

6-hour Forecast Uncertainty at 850 hPa
WRF-Chem + GOCART (32 ensembles)
Valid 0600 UTC on 4 Aug 2016



Results from Milija Zupanski-CIRA

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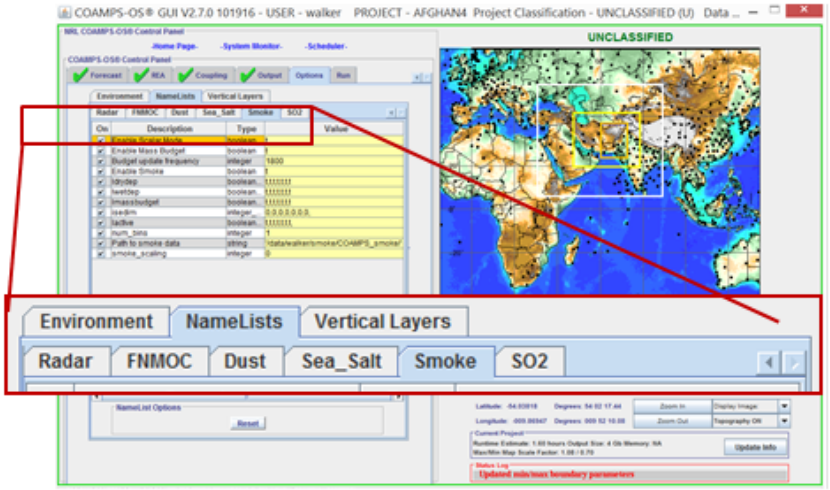
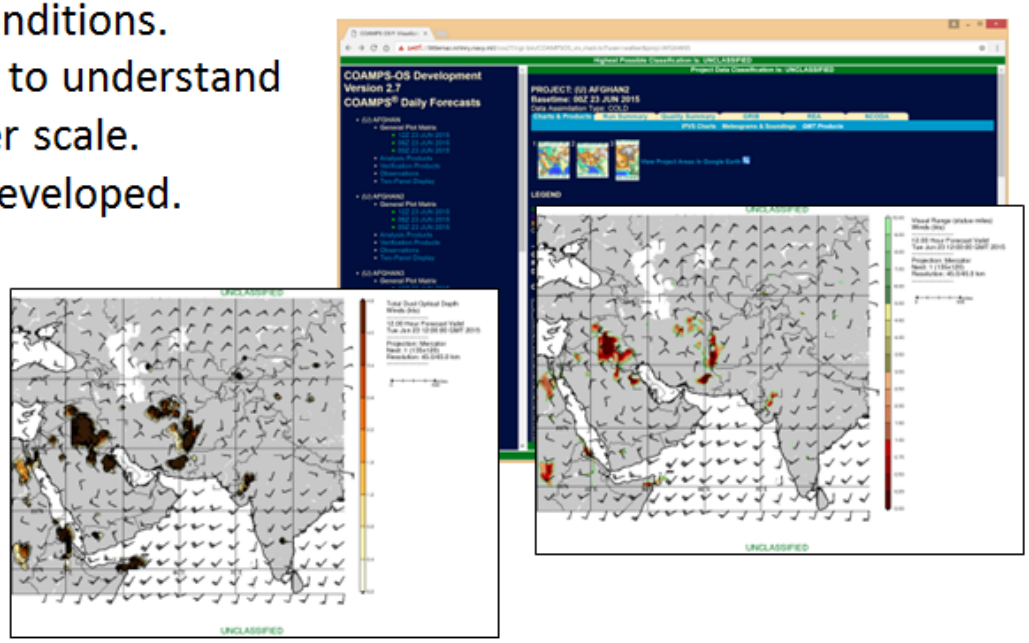
COAMPS with NAAPS Aerosol Species

Support for new COAMPS v5.6 aerosol prediction module in COAMPS-OS

- COAMPS with dust, operational since 2001.
- COAMPS now supports all 4 NAAPS aerosol species (dust, smoke, sea salt, SO_2).
- Allows for NAAPS as COAMPS boundary conditions.
- NAAPS and COAMPS can be used together to understand aerosol from the large scale to a much finer scale.
- New aerosol visualization products were developed.



New option tabs in COAMPS GUI for each aerosol species:
Dust, Smoke, Sea Salt, SO_2



AOT and visual range are the primary graphics products.

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Ongoing Efforts in Global Modeling

Working towards efficient processing:

Forecast Efficiency with Inter-dependent Tasks

Satellite and Model Output/Input

Workflow Management with Cylc

Setup	Obs Processing	Data Assimilation
Forecast	Ensemble	Post-Processing
Obs Sensitivity		Cleanup

NAVGEM flow

https://cylc.github.io/cylc

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Ongoing Efforts in Global Modeling

Working towards efficient processing:

Forecast Efficiency with Inter-dependent Tasks

Satellite and Model Output/Input

Geo-located Information Processing System (GeoIPS™)

A new Python-based system for Operational and R&D processing of data with latitudes and longitudes

Generalized: *The same code can be applied for all datasets (model and satellite datasets).*
Extendable: *Addition of new datasets, products, and sensors is straightforward.*
Easy to Use: *Can run without knowledge of the code.*

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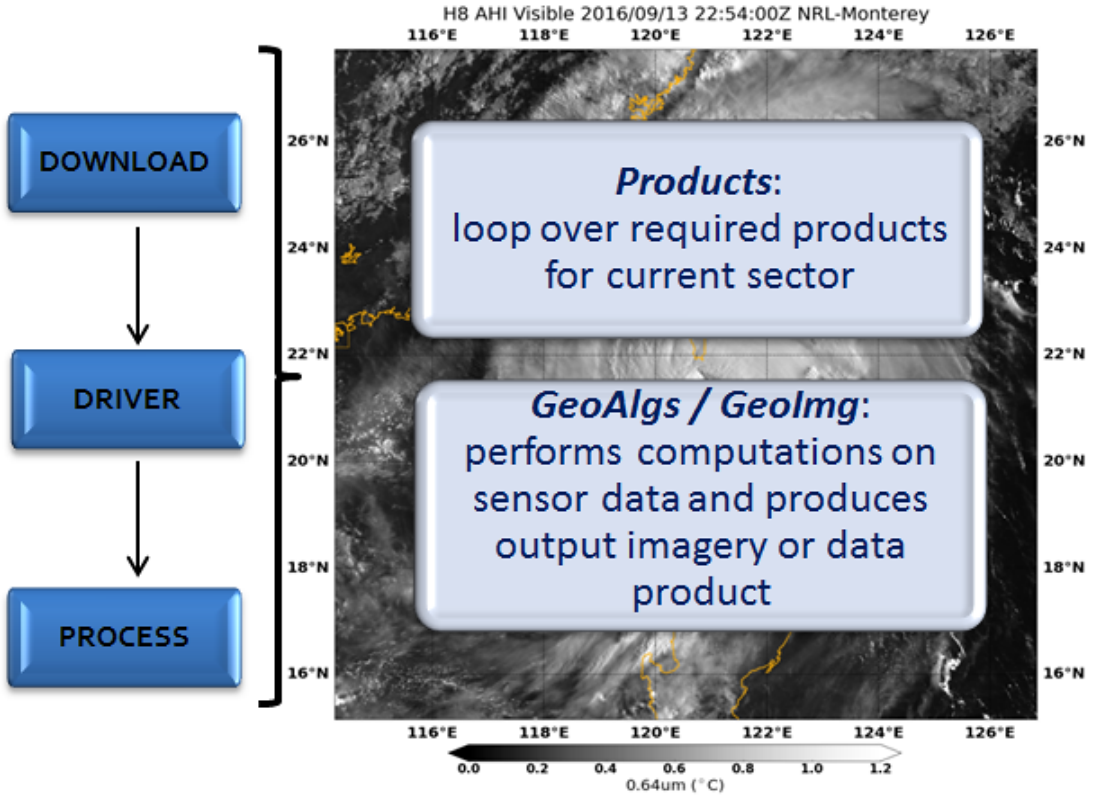
Geo-located Information Processing System (GeoIPS™)

A new Python-based system for Operational and R&D processing of data with latitudes and longitudes

New features/versions in development:

1. **Open-source release:** *Facilitates collaboration across organizations.*
2. **Data fusion:** *combine multiple datasets into a single product.*
3. **Quantitative data output:** *currently imagery-based output. New capabilities will be used for data ingestion into models/data assimilation*

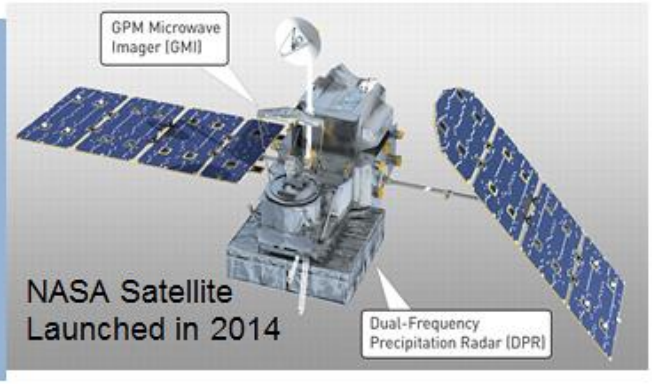


Super Typhoon Meranti

Satellite Retrievals of Aerosol Relevant Parameters

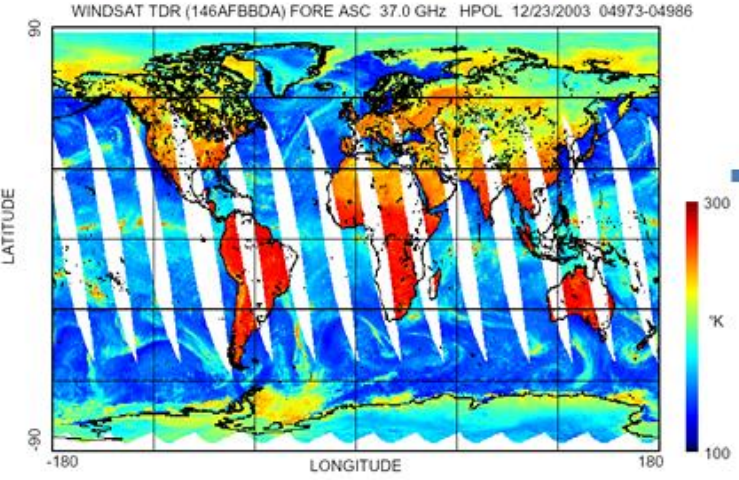
WindSat

- Developed by NRL Remote Sensing Division
- 11+ years and counting archive of global brightness temperatures

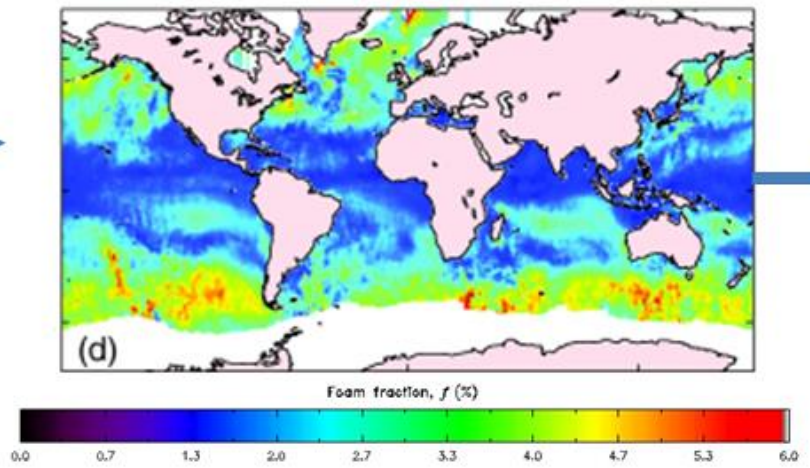


WindSat and GMI combined to improve spatial coverage, retrievals were calibrated to remove bias.

Brightness Temperature, T_B [K]



Whitecap Fraction



Sea Salt Emissions, Monahan Source Function

Anguelova et al., 2013

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Navy Aerosol Summary

- There are several lines of development/research for Navy aerosol prediction from the global (NAAPS/ENAAPS) to the mesoscale (COAMPS/MURI).
- We see ensembles as an important part of aerosol prediction moving forward, in the continued collaboration through the ICAP-MME and also through ENAAPS development and ongoing littoral zone work.
- ENAAPS is moving towards operations, is now capable of NRT forecasts.
- Forecast efficiency in the runs themselves, I/O, and visualization are an important focus (Cylc implementation, Netcdf, GeoIPS processing).
- Expansion of the Navy aerosol community to DC, Remote Sensing division and other university partners has enabled new research and development with remote sensing products and data assimilation for aerosol/NWP.