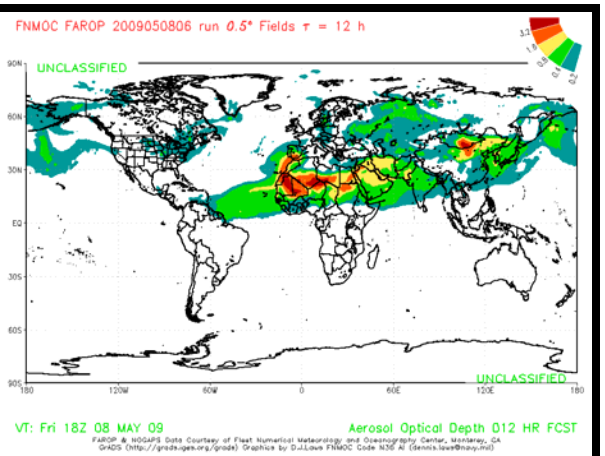
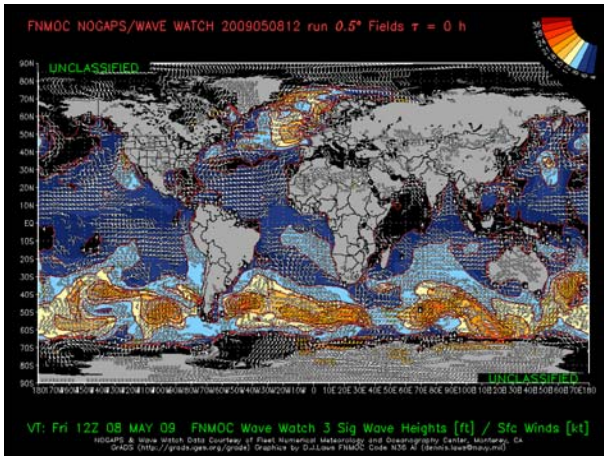
Navy Data Assimilation Activities
Introduction

- **Naval Research Laboratory (NRL) functions as the R&D performer and the transition agent for Navy atmosphere and ocean data assimilation efforts.**

- **Fleet Numerical Meteorology and Oceanography Center (FNMOC) and the Naval Oceanographic Office (NAVO) are the Navy's operational production centers, who run and produce the operational NWP and synoptic oceanography products.**



Dr. Craig Bishop
Naval Research Laboratory
Marine Meteorology Division
Monterey, CA



NAVY MODEL SUITE SUPPORTED

Active Development Areas

NOWCASTING & RAPID ENV. ASSESSMENT

MIDDLE ATMOSPHERE PREDICTION

ATMOS. ACOUSTICS

OCEAN COLOR / BIOLOGICAL MODELS

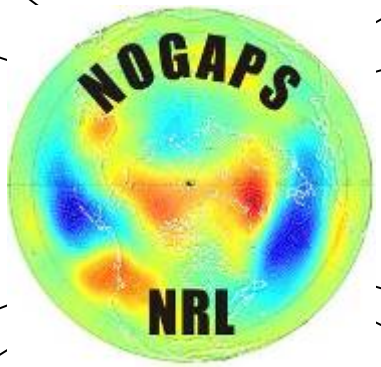
COUPLED AIR/OCEAN/ WAVE/SURF MODELS

LAND SURFACE MODEL

AF CLOUD MODEL

BALLISTIC WIND MODELS

EM / CLUTTER MODELS



SURF MODELS

STORM SURGE MODELS

WAVE MODELS

ENSEMBLE PREDICTIONS

MESOSCALE WEATHER MODELS

AEROSOL MODELS & OPTICAL / EO PRODUCTS

TROPICAL CYCLONE MODELS

GLOBAL & REGIONAL OCEAN MODELS

ICE MODEL

NUCL/CHEM/BIO MODELS

ACOUSTIC MODELS

OPERATIONAL IMPACTS

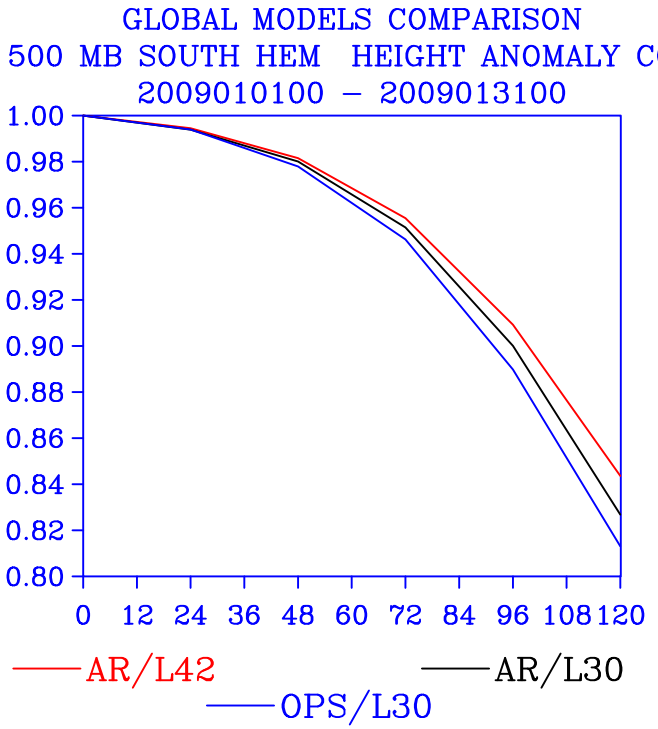
Overview of Satellite DA Activities Related to Recent or Upcoming Transitions

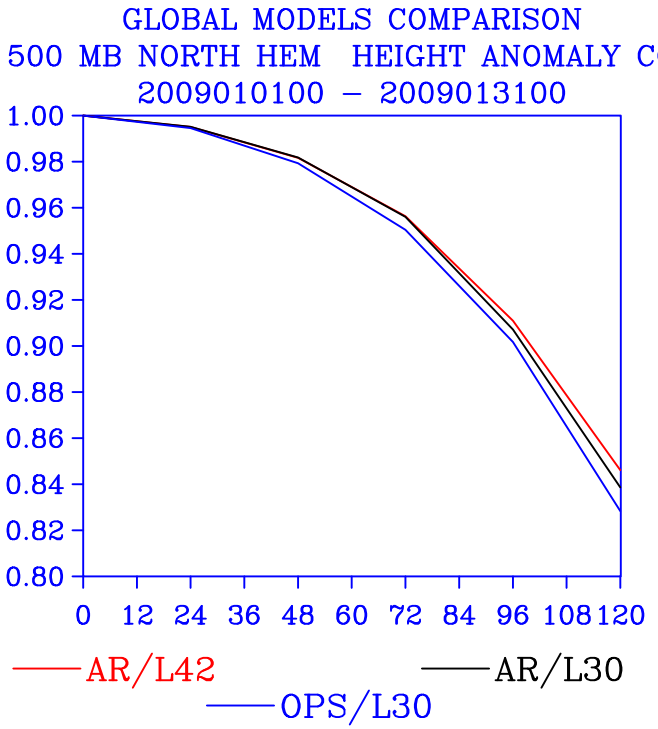
- Global 4DVAR with NAVDAS-AR (Xu et al.)
- Ob Impact / Channel Selection (Langland et al.)
- NPOESS Readiness Special Topics (Baker et al.)
- Advanced Sounders (IASI, ATMS, CrIS, Ruston et al.)
- Ozone Assimilation (SMUV/2, MLS, OMPS, Campbell et al.)
- SSMIS Unified PreProcessor/Assimilation (Swadley et al.)
- GPS Assimilation (COSMIC, GRAS, Hoppel et al.)
- Ocean SWH Assimilation (Jason 1,2, Envisat, Cummings)
- Aerosol Assimilation (MODIS, MISR, VIIRS, Reid et al.)
- Overview of some basic research activities if time permits

➢*Examples will be shown for topics in blue.*

OPSTEST of GLOBAL NAVDAS-AR
500 mb Height Anomaly Correlation

Transition of NAVDAS-AR system will include hyperspectral sounders





Comparison of NAVDAS (OPS/L30), NAVDAS-AR with 30 vertical levels (AR/L30) and NAVDAS-AR with 42 vertical levels and model top of 0.04 hPa

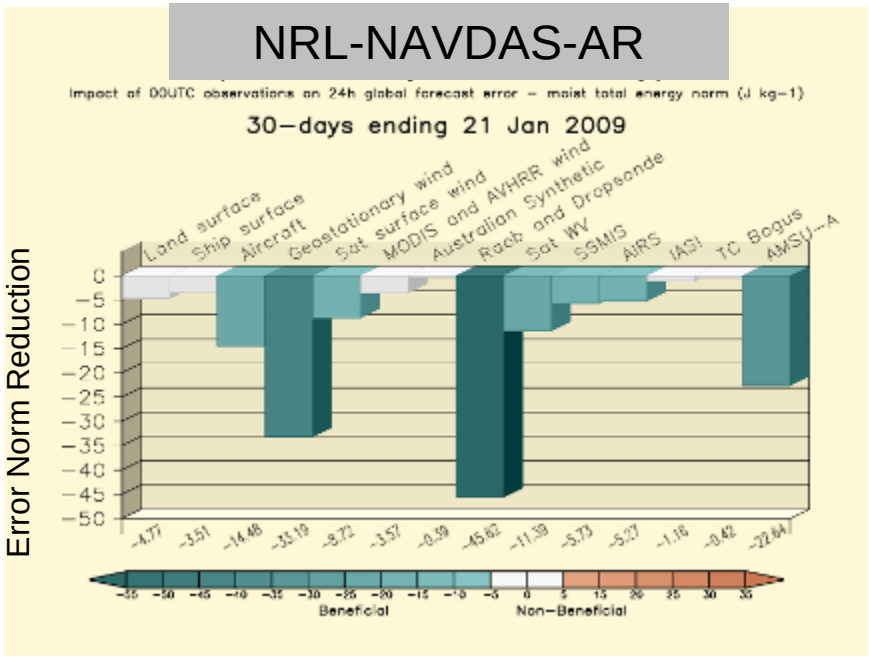
The higher model top makes more effective use of the satellite data.

Real-Time Observation Impact Monitoring

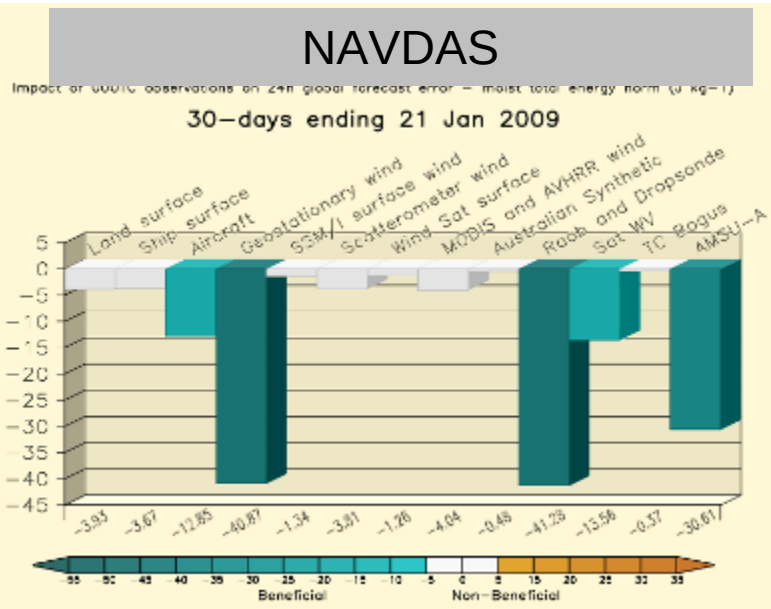
www.nrlmry.navy.mil/obsens/dev/

Capability to directly compare impact of observations in different assimilation systems

NRL-NAVDAS-AR



NAVDAS

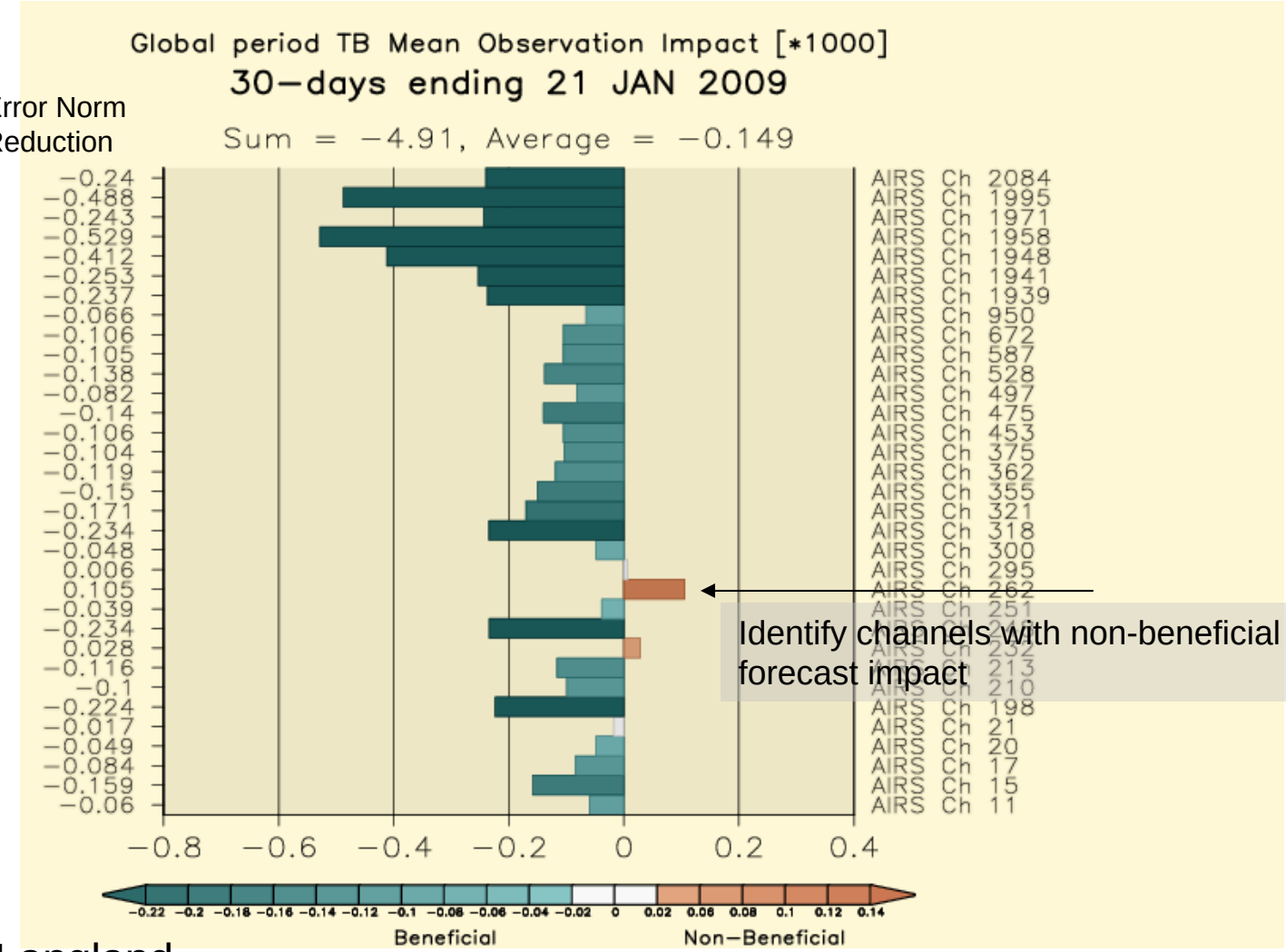


Web-page software developed at NRL can be used to display results from other JCSDA partners on the same page – or we can transition the software for direct use at other centers .

Ask Rolf Langland

Diagnostics for improved use of satellite observations by NRL and other JCSDA partners

Example: impact of AIRS channels on NOGAPS 24hr forecast error



Ask Rolf Langland

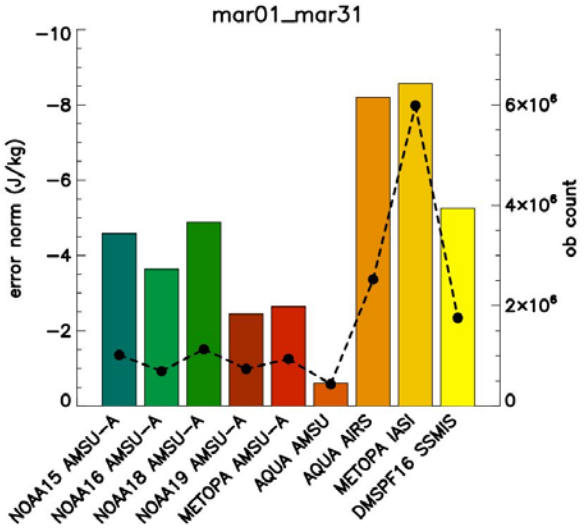
Advanced Sounders

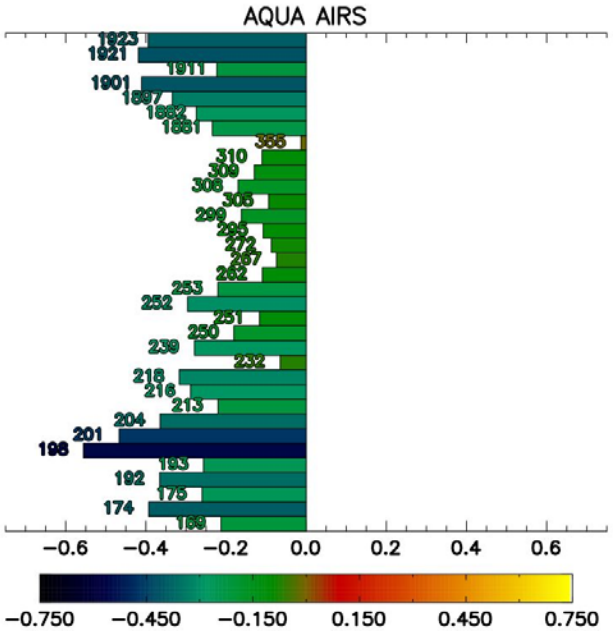
Ask Ben Ruston

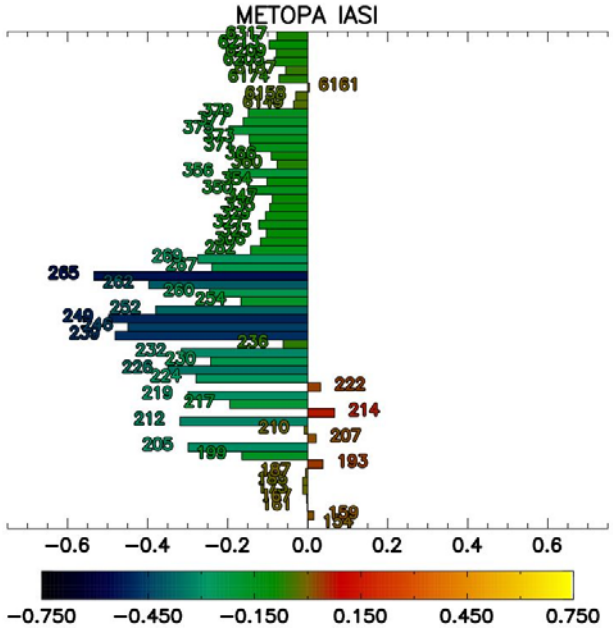
Observation Sensitivity

Hyperspectral sounders contribute:
- large volume of data
- large reduction in forecast error norm

Complex channel interactions; ob-sensitivity powerful tool discriminating impacts of additional channels







Advanced Sounders

Ask Ben Ruston

Routine Monitoring

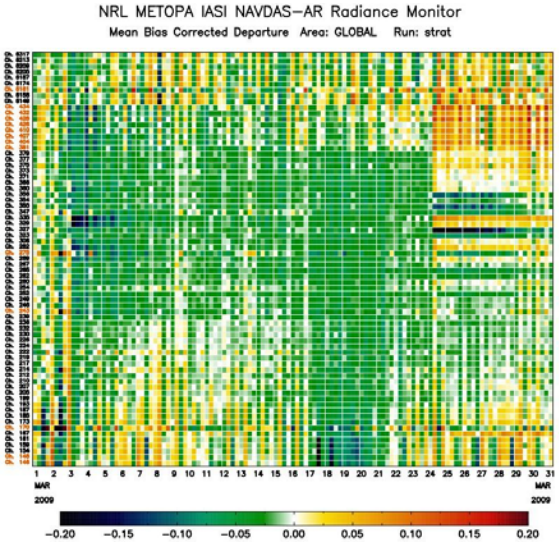
follow day-to-day sensor health

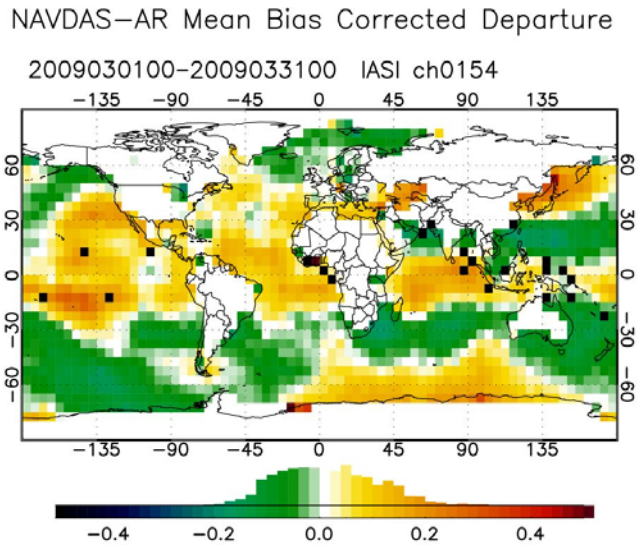
highly sensitive to changes in entire system
{other sensors, fcst model, …}

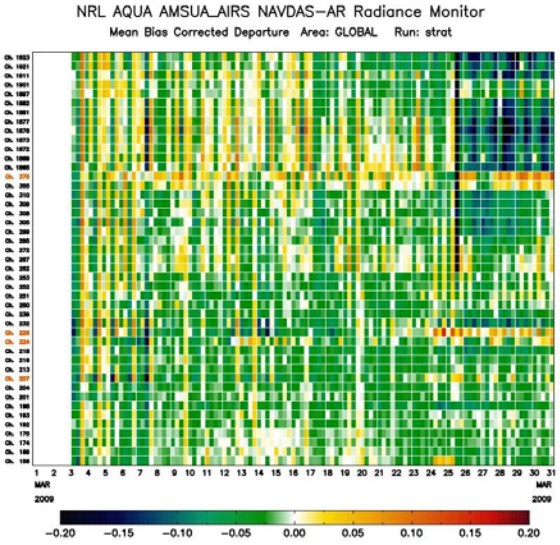
used to monitor channel "*drift*" over time

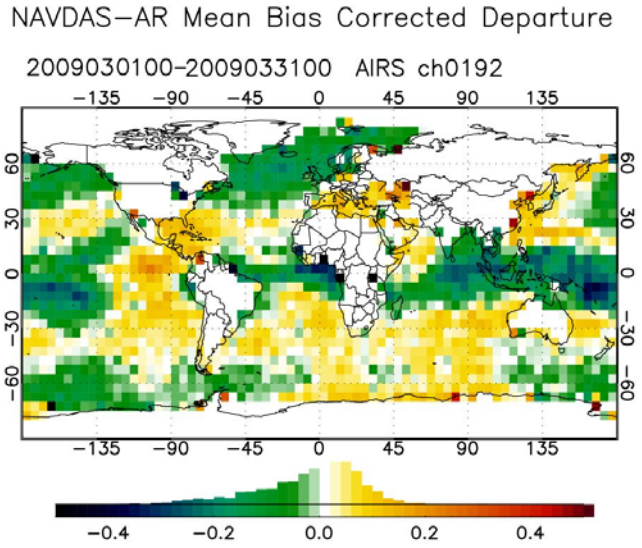
monitor spatial biases in channel departures

monitor changes relative to meteorological events









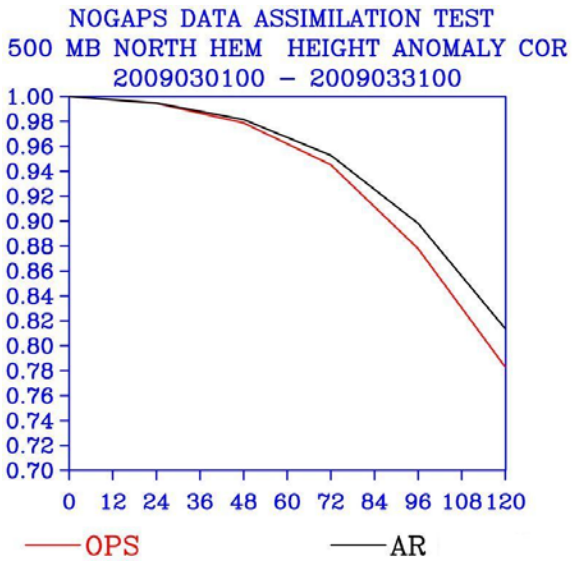
Advanced Sounders

- **Objective:**

  Ask Ben Ruston

  Test, evaluate, and implement combined microwave and infrared satellite assimilation targeting improved analysis and forecasting of temperature and humidity fields in operational weather models.

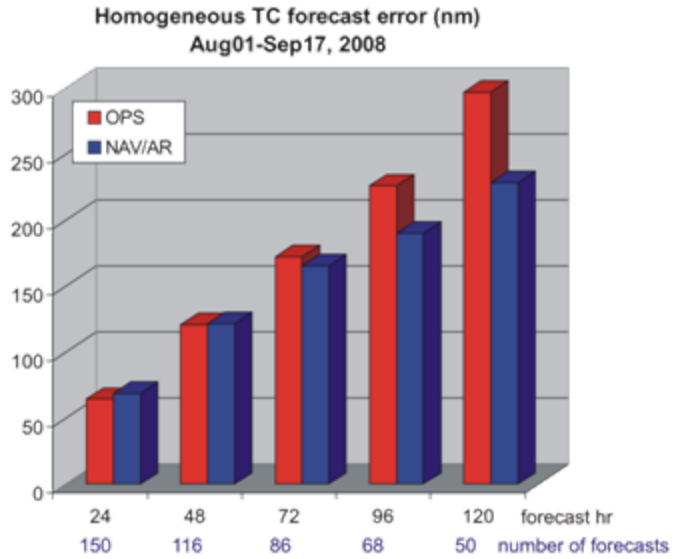
- **Accomplishments:**
  - ✓ AIRS/IASI cloud-free assimilation in NAVDAS-AR
    - ✓ Watts-McNally adaptive QC
  - ✓ Observation Sensitivity channel selection
  - ✓ Combined monitoring of AMSU, SSMIS, IASI, AIRS
  - ✓ Increased effective model top and channels assimilated



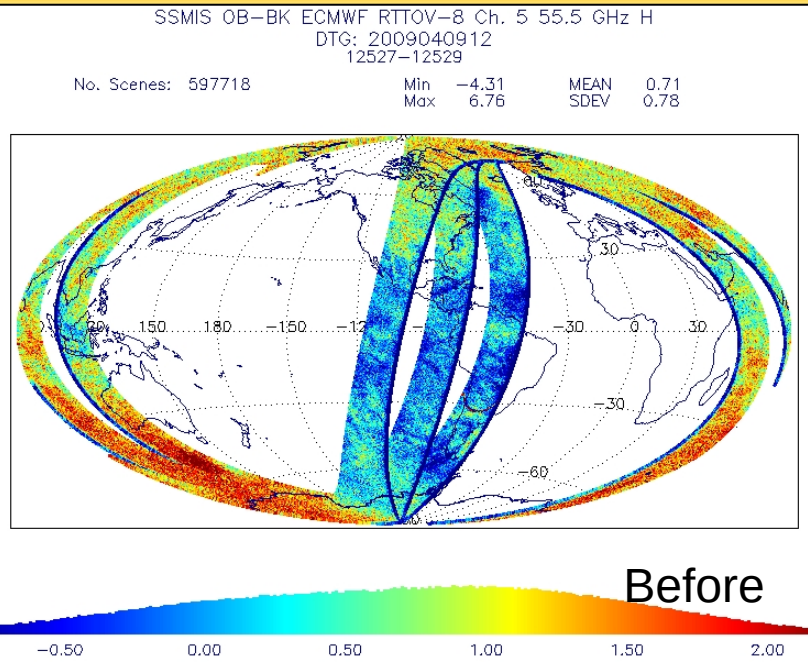
Positive impact in both hemispheres

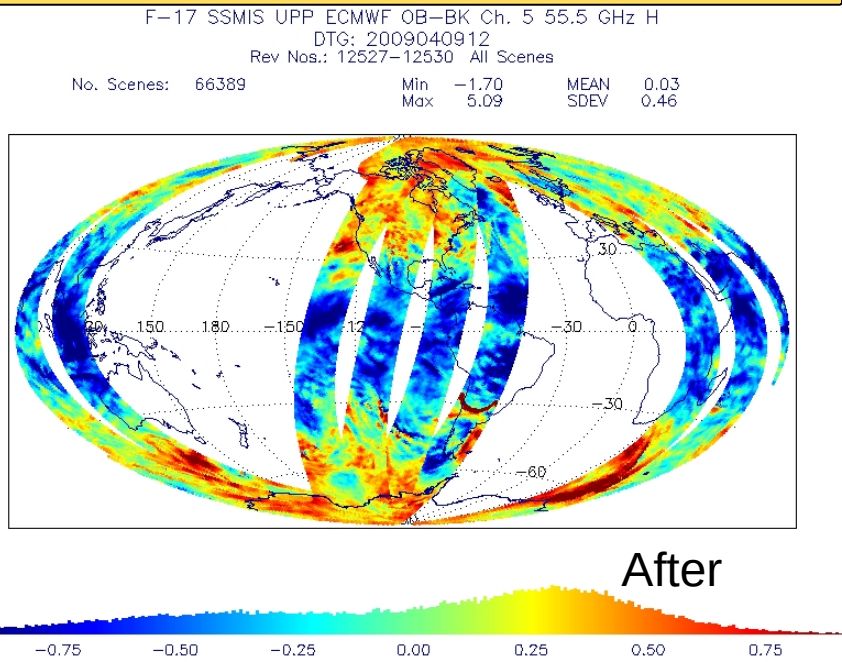
Consistently better than ops for past 6 months

Consistently better TC tracks



SSMIS Unified Pre-Processor
Updated





UPP V2 includes

Ask Steve Swadley

- Reflector Emission Corrections
- Spatial Averaging to reduce NEΔT to 0.1 K level
- Uses Operational NGES Fourier Filtered Gain Files to Correct Gain Anomalies
- Produces ASCII and BUFR TDR output files at reduced resolution
- Performs Scan Non-uniformity corrections
- SSMIS UPP V2 Operational at FNMOC July 2008 for F16
- F17 UPP V2.1 OPS at FNMOC May 11, 2009.
- FNMOC distributes UPP data to NESDIS for use by the NWP Community

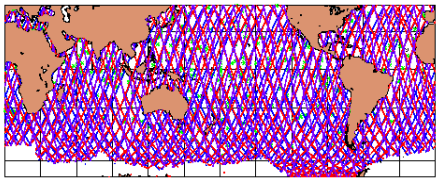
Operational at FNMOC, UKMO, ECMWF; Testing underway at AFWA and NCEP.

NCODA Ocean Data Assimilated

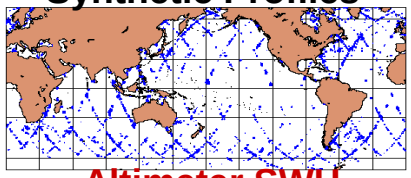
To Analyze T, S, u, v, SSH, SST, Ice Conc., SWH

Jason
GFO
ENVISAT

Altimeter SSH



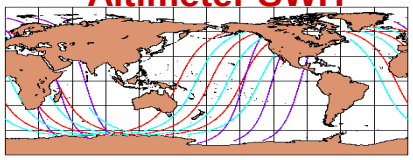
Synthetic Profiles

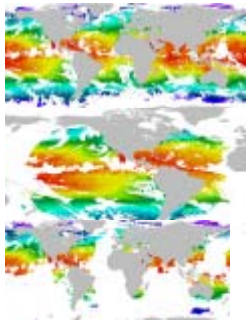


Ask Jim Cummings

Jason-1
Jason-2
ENVISAT

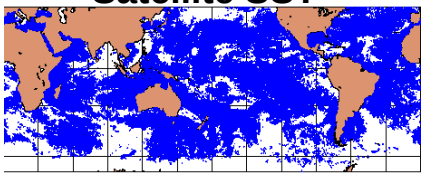
Altimeter SWH





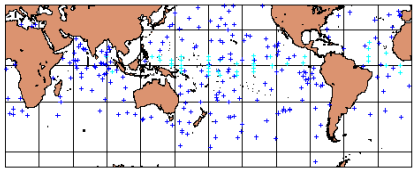
NOAA/METOP
AVHRR (GAC/LAC)
GOES, MSG
AMSR-E, AATSR

Satellite SST



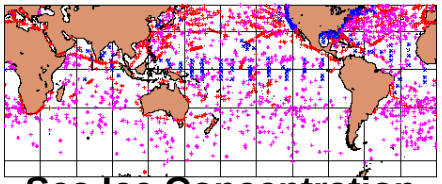
XBT, CTD
Fixed/Drifting Buoys
Argo Floats, Gliders

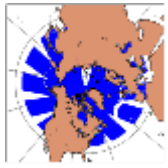
***In Situ* Profiles**



Ship (ERI, Bucket ,Hull)
Fixed/Drifting Buoys
CMAN Stations

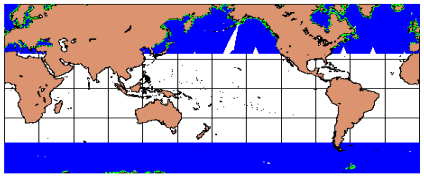
***In Situ* SST**



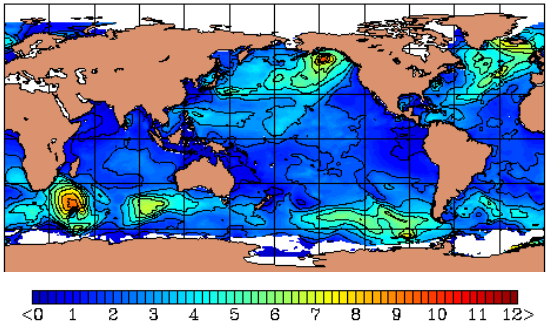


DMSP SSM/I
F13, F15, F16

Sea Ice Concentration

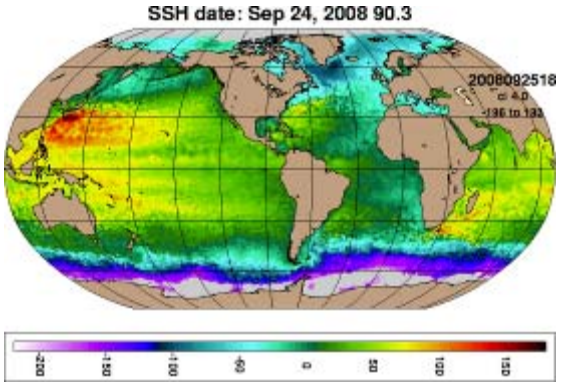


NCODA



WW3 SWH (m)

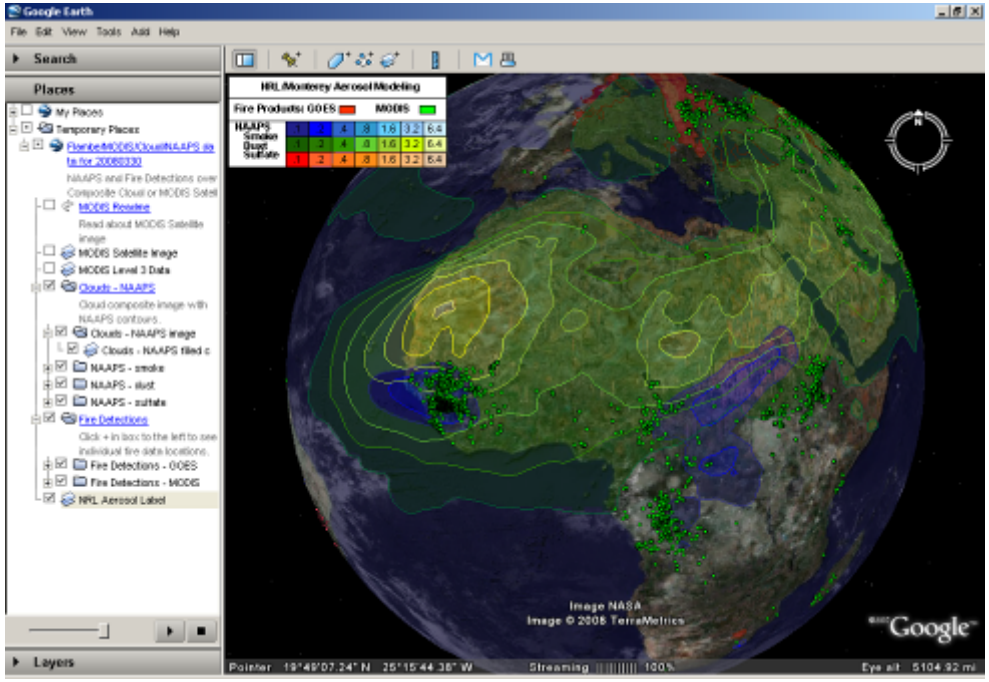
Community Models used/planned for Ops by Navy and NOAA



HYCOM SSH
Valid 24 Sep 2008

CURRENT STATUS
Navy Aerosol Data Assimilation

- **NAVDAS-AOT nearly operational at FNMOC for MODIS over water.**
- **Performed test runs with global MODIS products.**
- **Finalizing MODIS over-land QA procedures.**
- **Difficulty is not in the assimilation, but in understanding observation errors.**
- **Now performing error analysis for CALIPSO data to test suitability for assimilation (Ensemble Kalman filter?).**



Extensive real-time global and regional product suite and data available on-line at

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

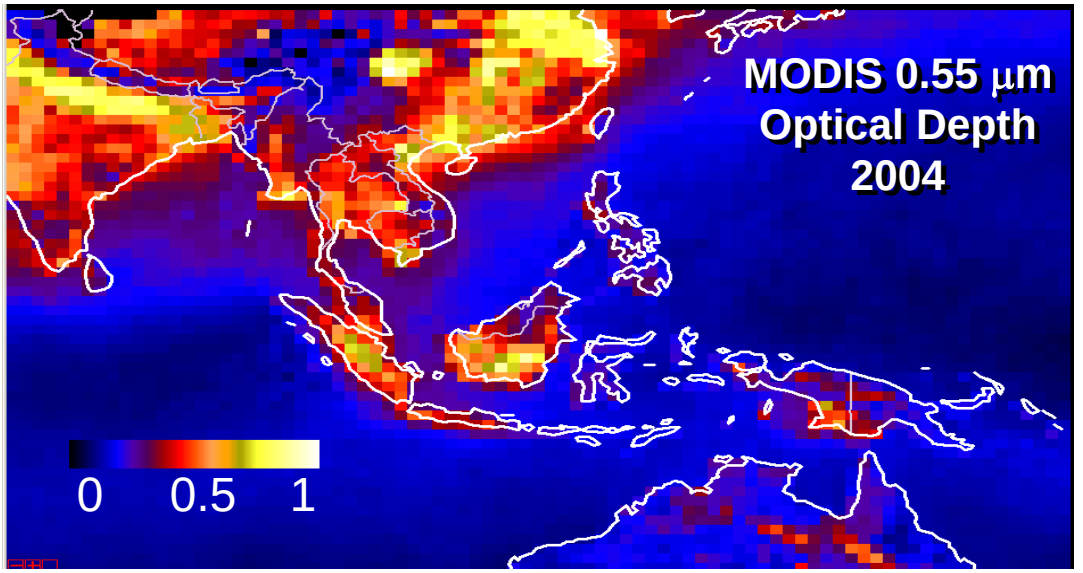
Ask Jeff Reid

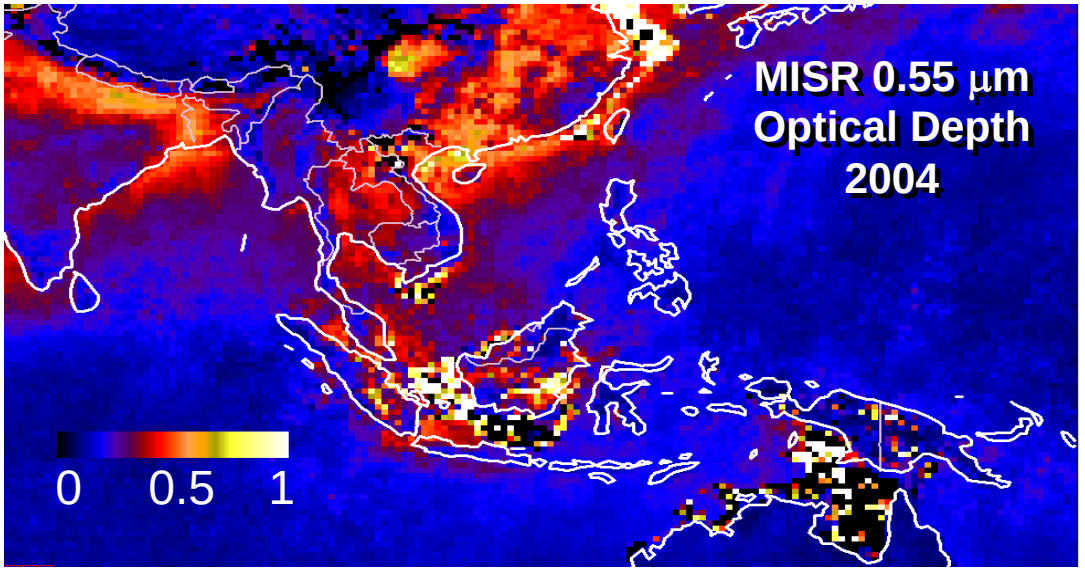
NRL has significant expertise and software that could be leveraged by partners.
Global to mesoscale source databases; quality control / bias removal techniques; post-processing; field measurement, Cal/Val & model validation capability.

Using MISR and MODIS
Issues for Data Assimilation

- Despite both the MODIS and MISR science teams claiming success, the products exhibit significant differences
- Even within a single product line, there are differences between land and ocean
- Assimilation of multiple data sources requires a thorough understanding of algorithm behavior and corrections

Ask Jeff Reid



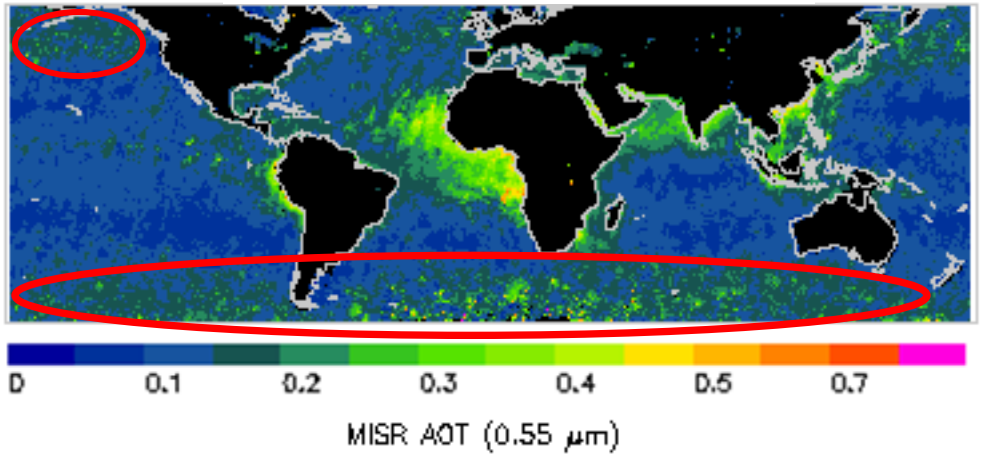


Impact of QC on Annual mean AOT (2005 Data)

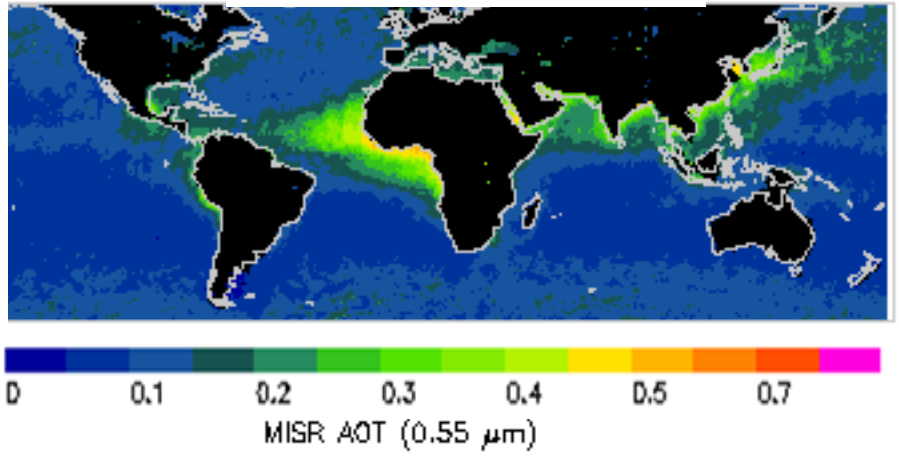
(Yingxi, Zhang, and Reid-AGU 2008)

Ask Jeff Reid

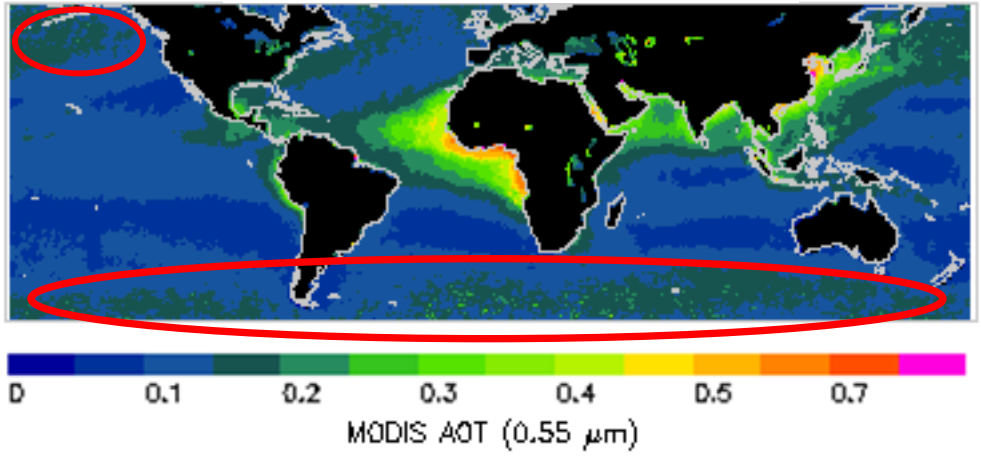
Original MISR AOT



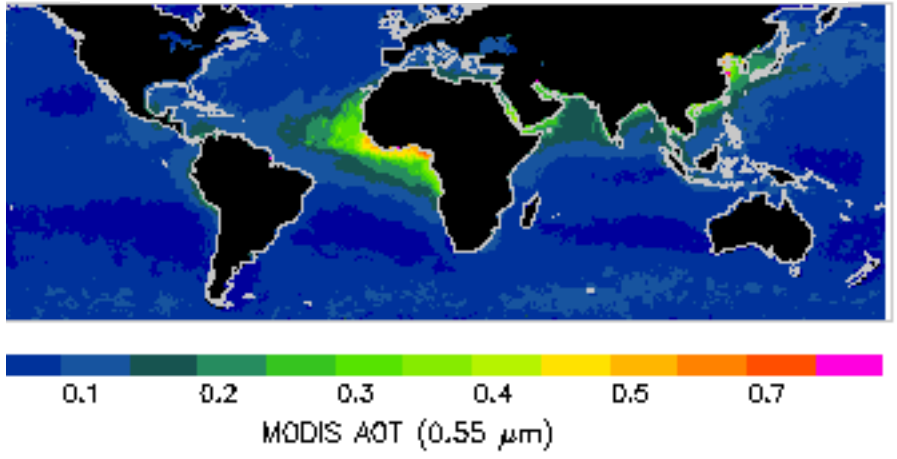
New MISR AOT



Original MODIS AOT



New MODIS AOT (9 months)

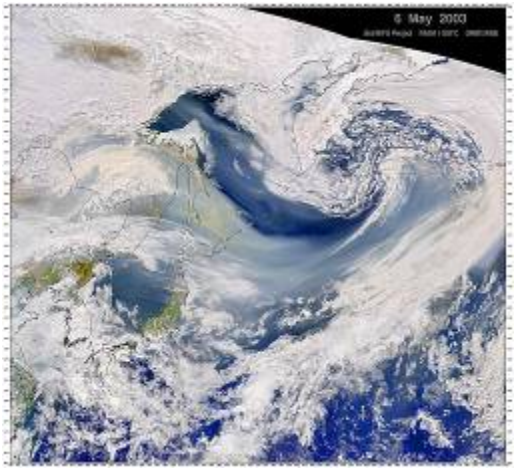


Features once presumed to be "real" have been shown to be artifacts.
NRL data QC algorithms for AOT can be utilized by others for aerosol DA.

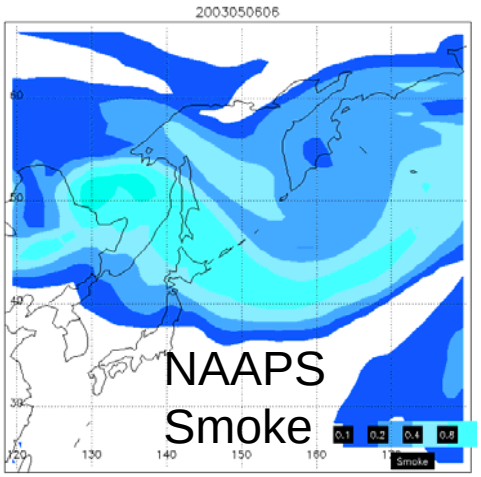
Global Aerosol DA & Prediction

NAAPS -- Navy Aerosol Analysis and Prediction System

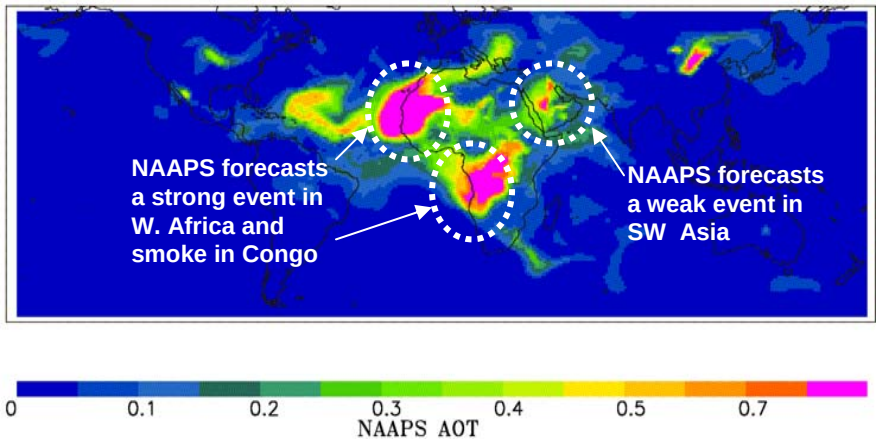
Ask Doug Westphal



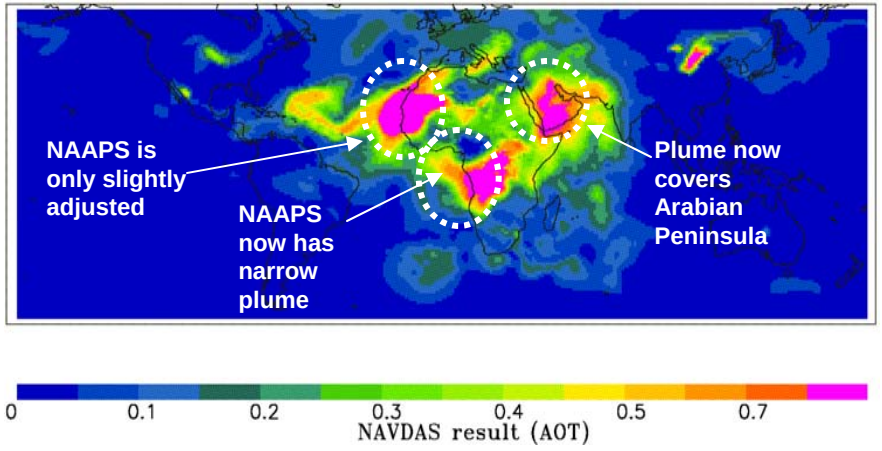
First global operational aerosol forecast system *(dust, smoke, sulfate, SO_2, sea salt, volcanic ash).*
Post-processed optical properties for military application.
Automated links to tri-service TAWS aviation decision aid.



NAAPS first guess of AOD (12-h forecast) for 12Z, July 19, 2005



NAAPS updated AOD analysis (NAVDAS innovation + first guess)

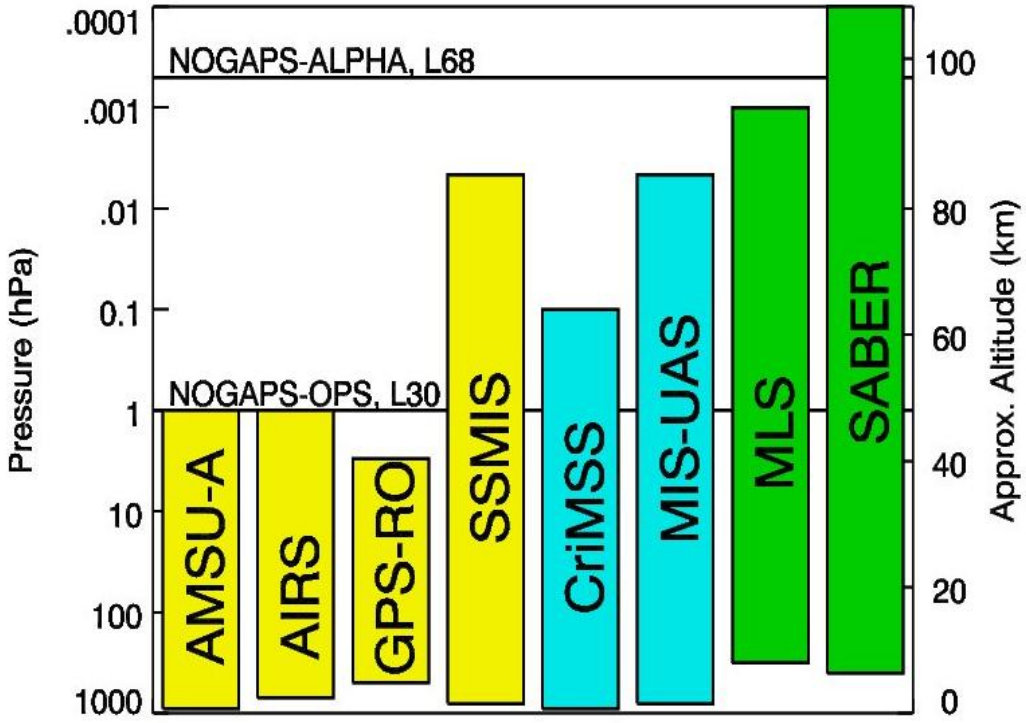


AEROSOL DATA ASSIMILATION capability -- Initial hand-off of 2DVAR assimilation of Aerosol Optical Depth (as an add-on to NAVDAS) made to FNMOC.

Overview of Basic Research and Exploratory Development Activities

- Middle Atmosphere Assimilation (MLS, Saber, Eckermann et al.)
- Ocean Skin SST Assimilation (Jason 1,2, Envisat, Cummings)
- Radiance space localization in EnKFs (Bishop,Campbell)

High Altitude Data Assimilation
Available Temperature Measurements



Operational (near-real time data)

Future operational (NPOESS)

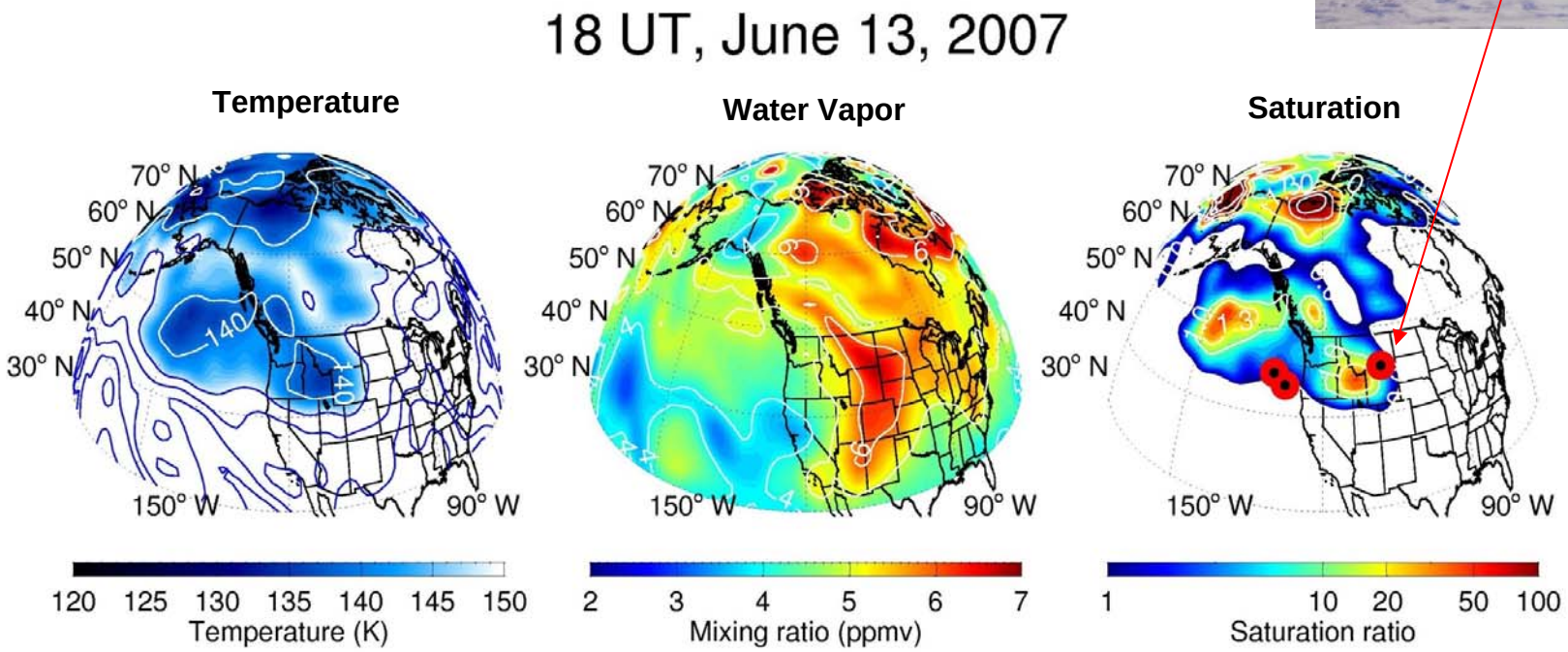
Current Research Instruments

(US satellite instruments)

AMSU-A:	Advanced Microwave Sounding Unit
AIRS:	Atmospheric Infrared Sounder
GPS-RO:	GPS Radio Occultation from the COSMIC constellation of receivers
SSMIS:	Special Sensor Microwave Imager/Sounder
CriMSS:	Cross-track Infrared Sounder + Advanced Technology Microwave Sounder
MIS-UAS	Microwave Imager/Sounder with Upper Air Sounding
MLS:	Microwave Limb Sounder on the AURA spacecraft
SABER:	Sounding of the Atmosphere using Broadband Emission Radiometry

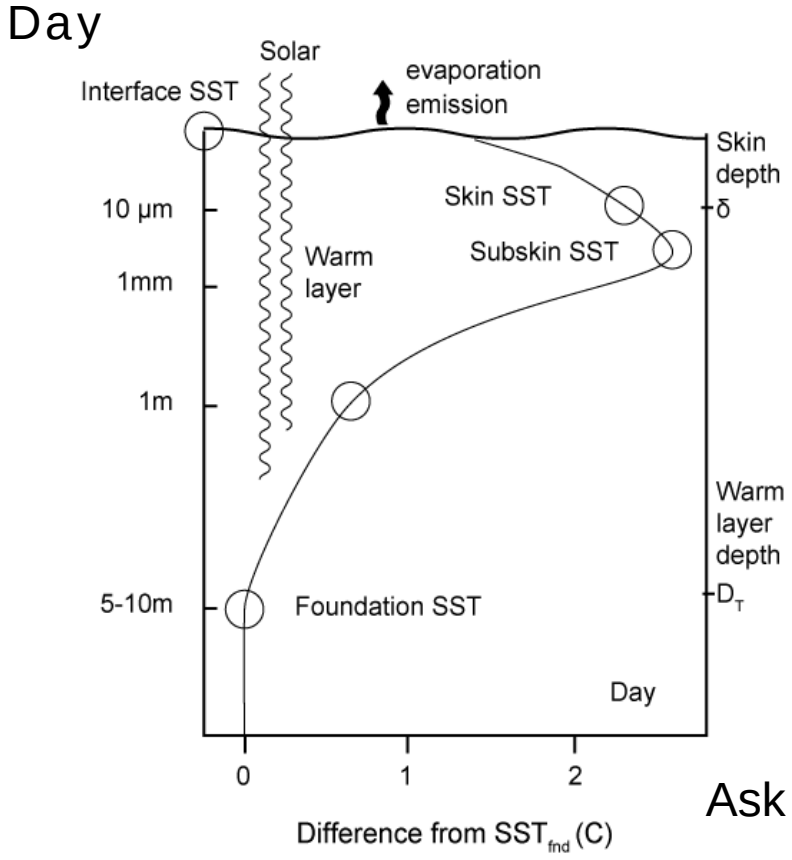
MLS/SABER assimilation for mesospheric science

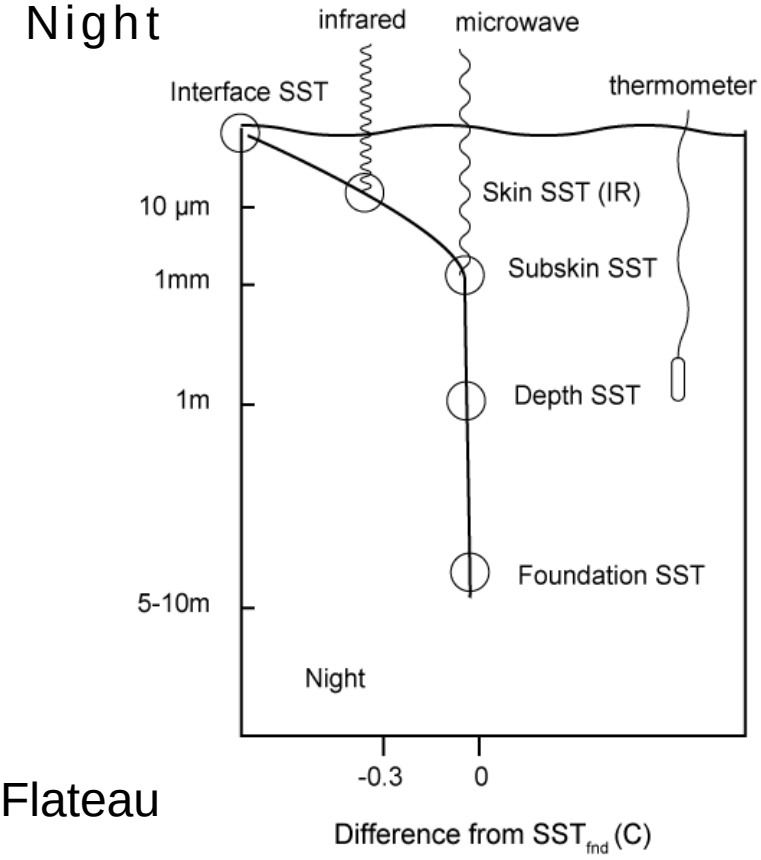
A cold pool moves over Pacific NW at 82 km altitude.
Ice clouds (PMCs) predicted and observed
by NRL SHIMMER instrument (on STPSat-1).



From Eckermann et al., "High-altitude data assimilation system experiments for the northern summer mesosphere season of 2007", *J. Atmos. Sol.-Terr. Physics*

NPOESS Readiness: Skin SST
Conceptual SST Day/Night Differences





Ask Piotr Flateau

- **Skin SST influences convection and mixing in atmospheric models**
- **Skin SST important in radiance assimilation for channels that “see” the surface**
- **Skin and sub-skin SST are directly measured by satellites (IR and MW)**
- **Existing SST retrievals are estimates of “bulk” SST at unknown depths**

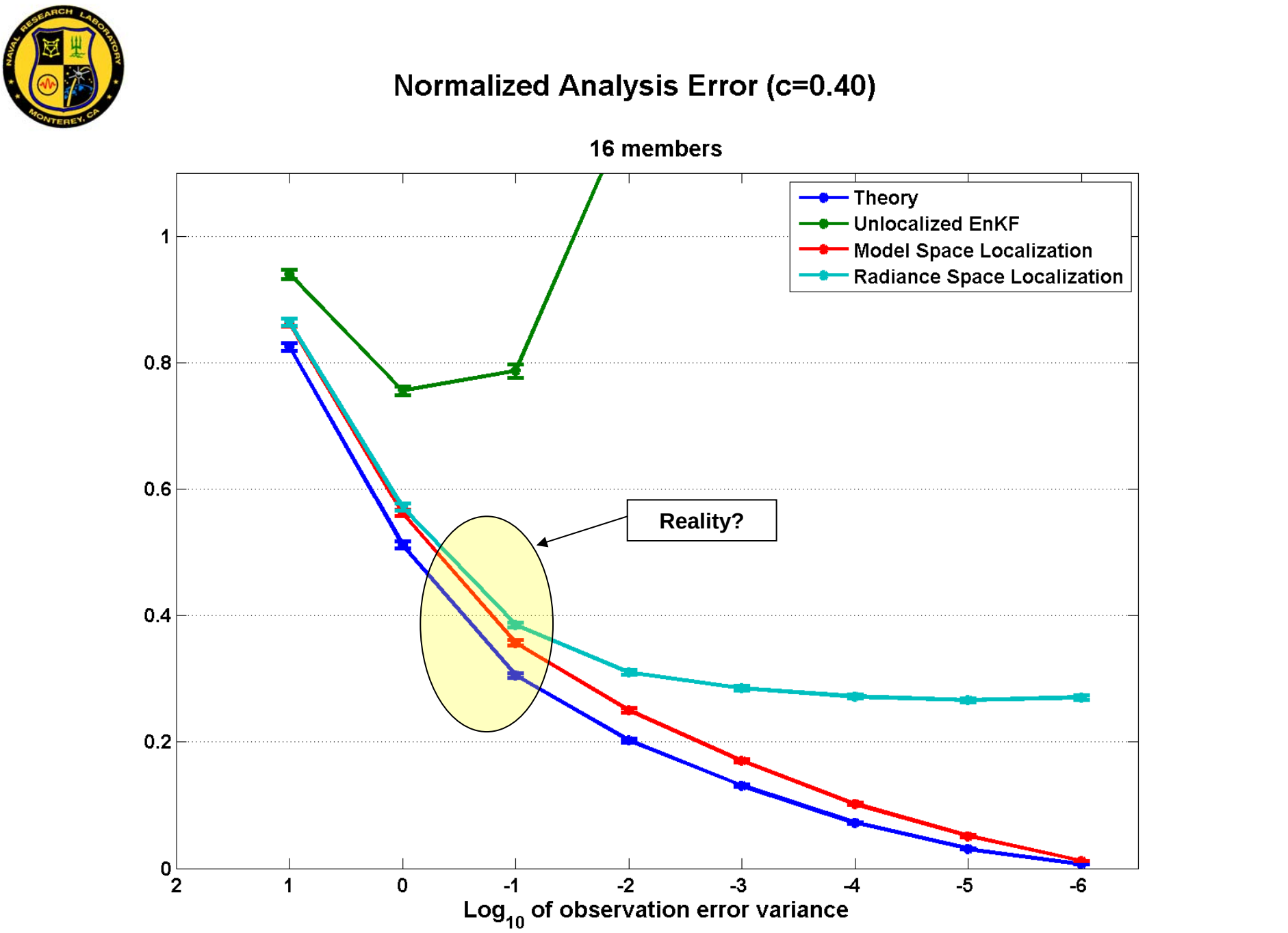
Covariance Localization for Satellite Radiances in Ensemble Kalman Filters

- Spurious correlations render unlocalized EnKFs useless. The sample error covariance can be localized in **model space**

$$\mathbf{K}_j \simeq \left[\left(\rho \circ \mathbf{P}_j^f\right)\mathbf{H}^T\right]\left[\mathbf{H}\left(\rho \circ \mathbf{P}_j^f\right)\mathbf{H}^T + \mathbf{R}\right]^{-1}$$

- or in **observation space**

$$\mathbf{K}_j \simeq \left[\rho \circ \left(\mathbf{P}_j^f \mathbf{H}^T\right)\right]\left[\rho \circ \left(\mathbf{H}\mathbf{P}_j^f \mathbf{H}^T\right) + \mathbf{R}\right]^{-1}$$


Normalized Analysis Error (c=0.40)
16 members
Theory
Unlocalized EnKF
Model Space Localization
Radiance Space Localization
Reality?
1
0.8
0.6
0.4
0.2
0
2
1
0
-1
-2
-3
-4
-5
-6
Log10 of observation error variance

Summary and Conclusions

- A simple physical reason that observation space localization is inappropriate for satellite radiances was shown: **correct correlations in radiance space are eliminated as spurious, regardless of how well the localization is tuned**
- 1D experiments showed **systematically worse analyses** for **observation space localization**
- **Lack of convergence** to zero analysis error in the presence of perfect observations is troubling
- We recommend that users weigh carefully the computational performance gains they expect relative to the drawbacks demonstrated here
- Paper in review for MWR

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