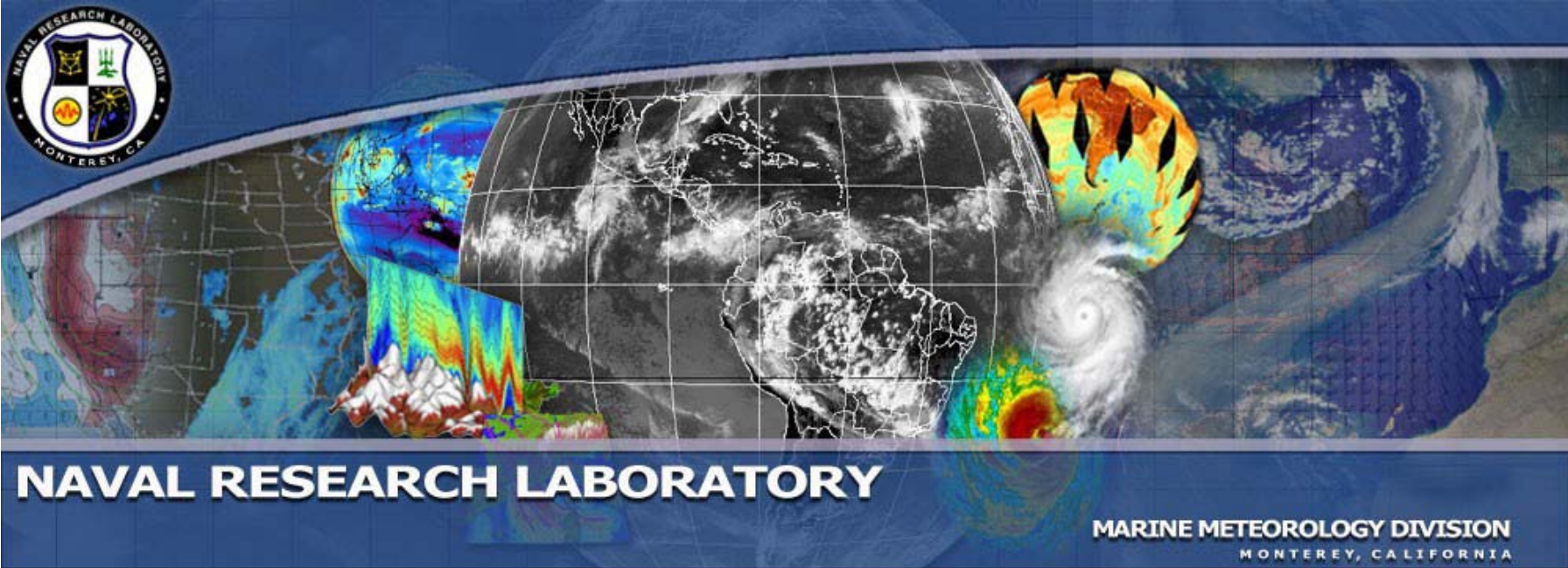




# Marine Meteorology Division Overview



*Nancy L. Baker*

*Head, Data Assimilation Section*

*Marine Meteorology Division*

*Naval Research Laboratory*

*Monterey, CA*

<http://www.nrlmry.navy.mil/>

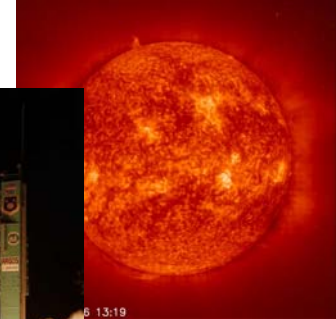
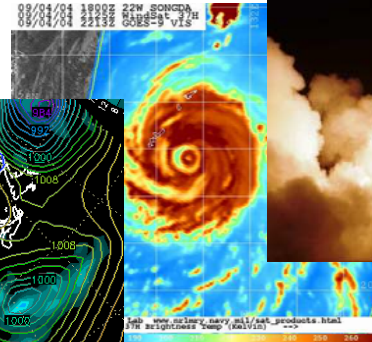
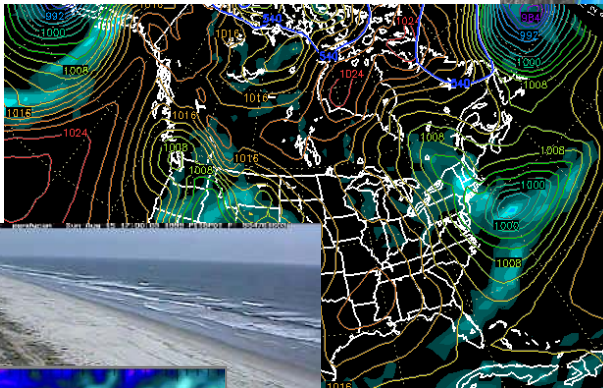
*NRL Marine Meteorology Division*



# Ocean and Atmospheric Science and Technology Directorate

Six Divisions performing scientific and technological innovation, research and development from the bottom of the sea floor to the top of the atmosphere and into space.

*This Directorate was formed in 1992, when meteorology and oceanography were integrated into NRL with the merger of smaller labs in CA and MS with NRL DC.*



Space Sciences (DC)

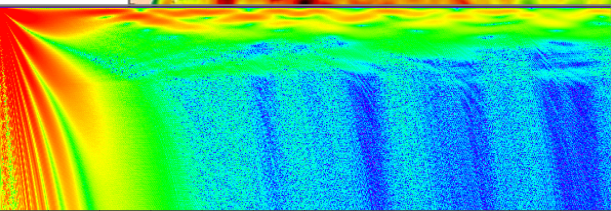
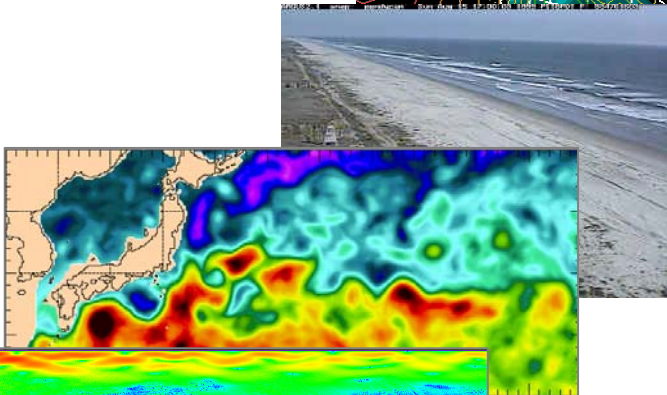
Remote Sensing (DC)

Marine Meteorology (CA)

Oceanography (MS)

Acoustics (DC & MS)

Marine Geosciences (MS)



view





# Naval Research Laboratory (NRL)

- ***Monterey – Marine Meteorology Division***
  - Research and development of global, mesoscale and shipboard atmospheric analysis and prediction systems
  - Coupled atmosphere-ocean modeling
  - Development of forecaster aids and automated weather interpretation system
- ***Washington, D.C. – Remote Sensing and Space Sciences Divisions***
  - Design and build satellites (POAM II/III, WindSat, MIS)
  - Stratospheric and mesospheric assimilation (GPS, ozone, MLS, SABER assimilation)
  - NOGAPS – ALPHA (Advanced Level Physics High Altitude)
- ***Stennis Space Center, MS – Ocean Division***
  - Ocean data assimilation and modeling



# A bit of history

- First satellite Sputnik Oct 4, 1957
- First U.S. Satellite Explorer I, Jan 31, 1958 (provided evidence for the Van Allen radiation belt)
- Naval Research Laboratory-
  - First U.S. Satellite program – Vanguard (1955-1959)
  - NRL Constructed the first complete launch facility at Cape Canaveral in 1957
  - Vanguard I launched March 17, 1958 (temperature sensor; still in orbit)
  - Vanguard II, Feb 17, 1959 (mission to observe cloud cover; still in orbit)
  - Part of U.S. participation in the International Geophysical Year (July 1957- Dec 1958)
  - NASA formed July 29, 1958 – with 200 NRL scientists forming the core

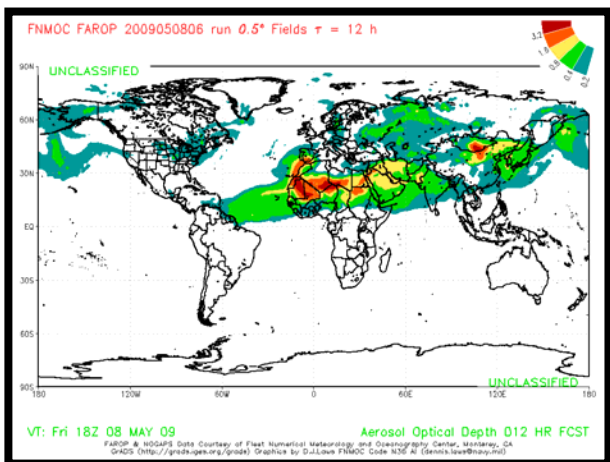


# Navy Operational METOC Activities

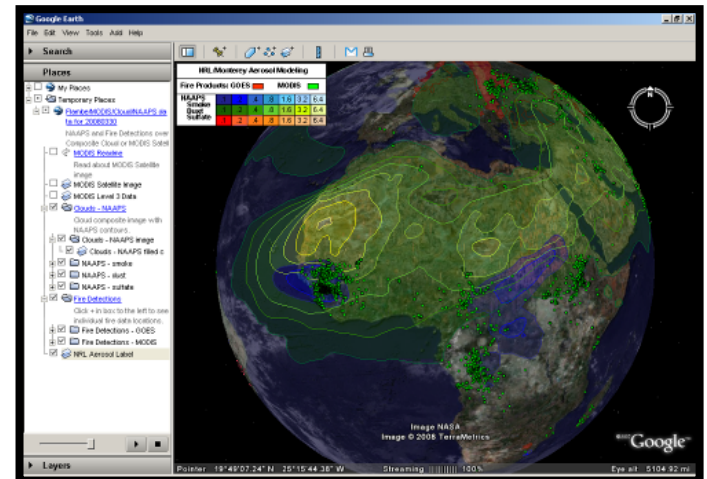
## Introduction

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

⚡ 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.



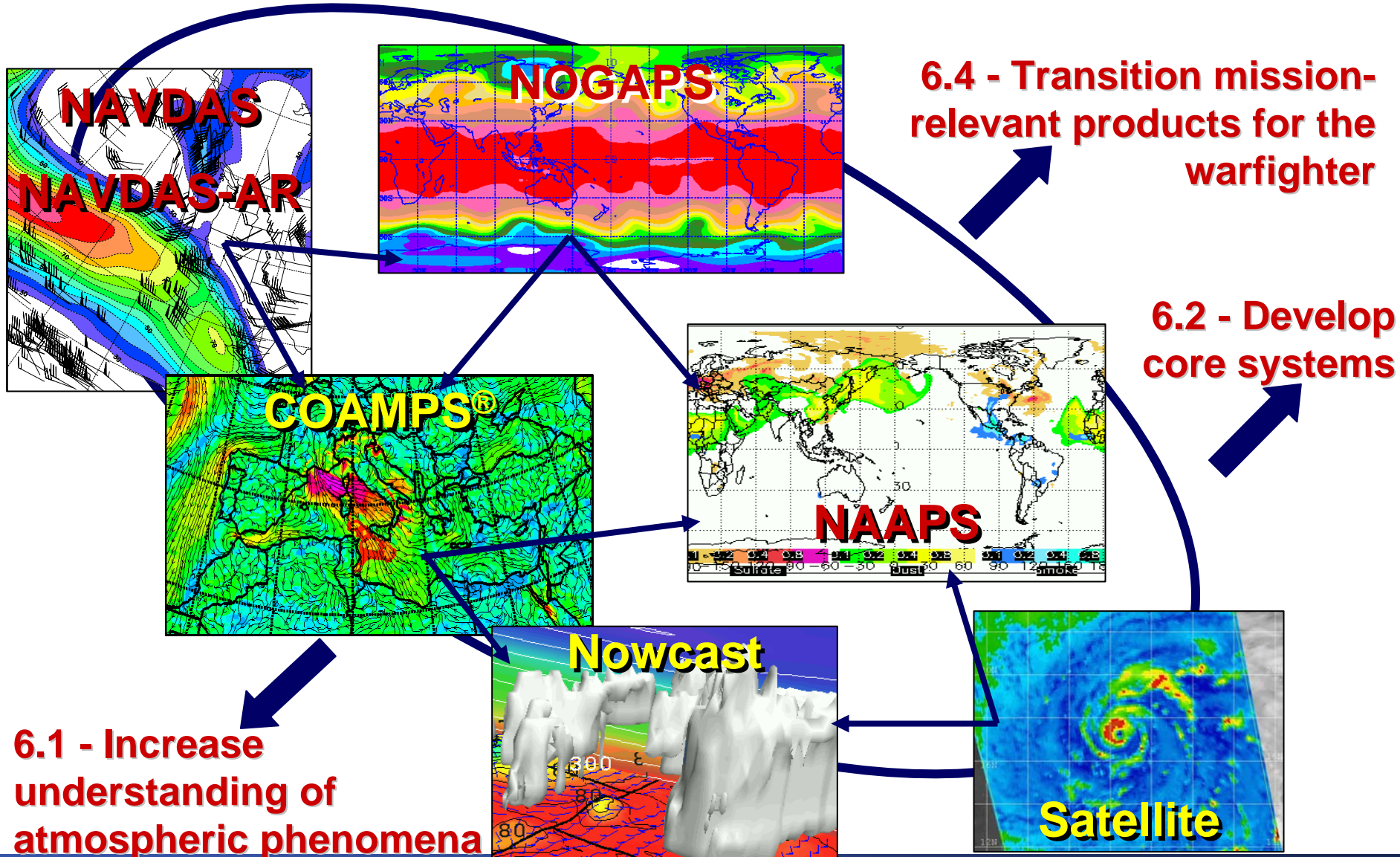
\* 40+ years in the business of NWP







# NRL Marine Meteorology Division Core Systems





# NRL/FNMOC Global Forecast Suite

- NOGAPS - Navy Operational Global Atmospheric Prediction System
  - Spectral T239L42 with effective model top at 0.04 hPa
  - Provides input/boundary conditions for
    - mesoscale, ocean, wave and ice prediction models,
    - ensemble forecasting system (T119L30)
    - aircraft and ship routing programs
    - tropical cyclone forecast model (GFDN)
  - Used for basic research predictability studies, adjoint sensitivity studies, adaptive observation-targeting

## ☀️ COAMPS®

- Coupled Ocean/Atmosphere Mesoscale Prediction System
- Includes fully embedded aerosol model
- Includes coupled ocean and wave models / assimilation systems

## ☀️ COAMPS-TC

- COAMPS-Tropical Cyclone Model
- Coupled with wave and ocean model

## ☀️ COAMPS-OS® (On-Scene)

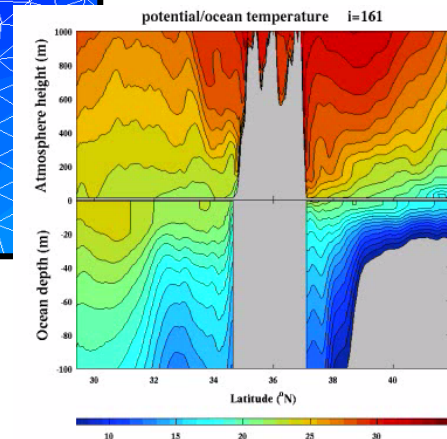
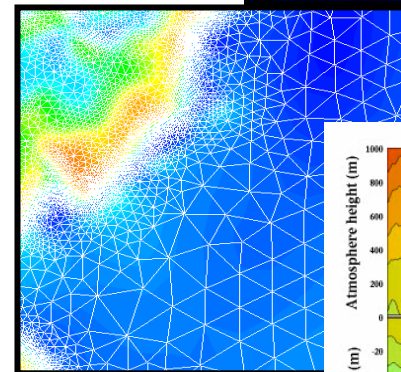
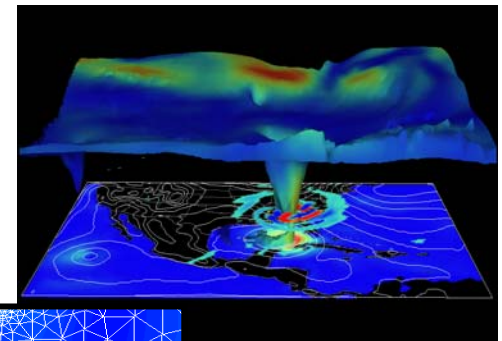
- COAMPS run via a customizable GUI

## ☀️ COAMPS-NG

- Next-Generation Mesoscale Model

## ☀️ COUPLED ENSEMBLE

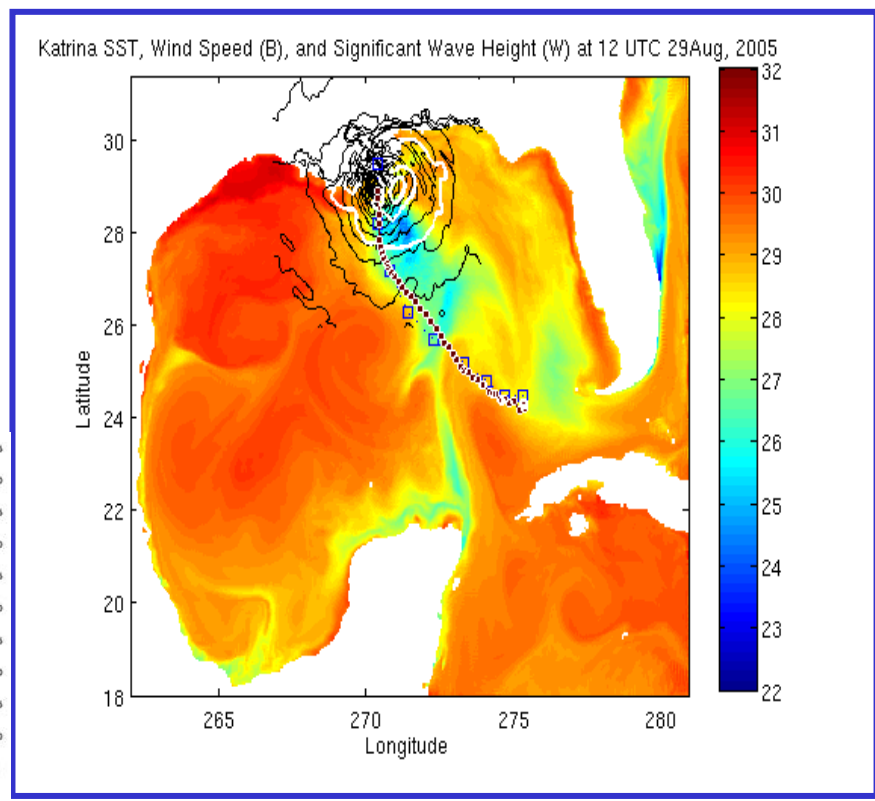
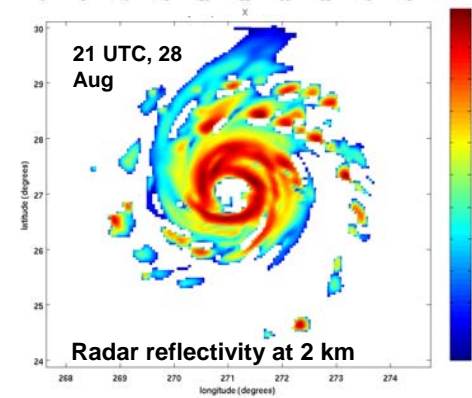
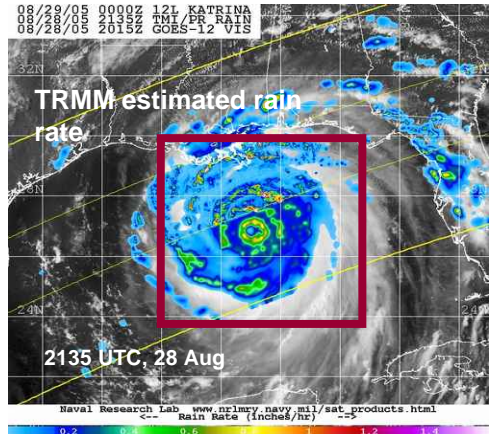
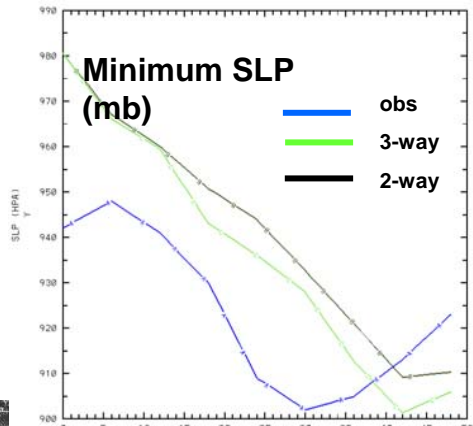
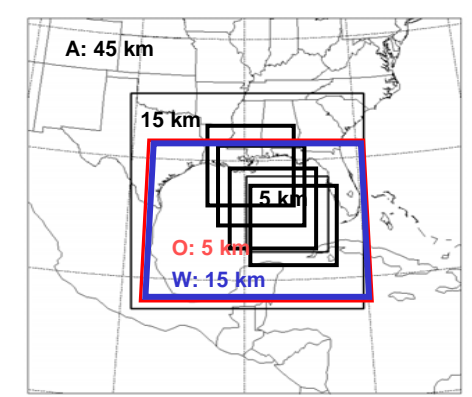
- Tested various perturbation methods, including ET





# 3-Way Coupled Simulation

## COAMPS/NAVDAS + NCOM/NCODA + SWAN



- Enhanced asymmetric convective structure after the formation of the trailing cold ocean wake
- Increased surface current speed to the right of the Katrina track due to wind-current coupling effect
- Increased wave growth on the northern quadrant of the hurricane due to wind-wave-current coupling effect



# Navy's Data Assimilation Tools



Red for Operational Systems

**NCODA**

## **NRL Coupled Ocean Data Assimilation System**

*Multivariate Analysis of ocean  $u,v,T,s,ice,SSH,SWH$ .  
Global, Regional, Local Ocean Data Assimilation.*

**NAVDAS**

## **NRL Atmospheric Variational Data Assimilation System**

*3D Variational Analysis, Observation Space.  
Global, Regional, or Local Application.*

**NAVDAS-AR**

## **NAVDAS Accelerated Representer**

*4D Variational Analysis, Weak Constraint, Model Space.  
Global or Regional Application. High Altitude DA.*

**ADJOINTS**

## **NAVDAS—Adjoints** of 3D & 4D Data Assimilation Systems.

**NOGAPS—TLM**; Moist Adjoint  
**COAMPS®--TLM**; Moist Adjoint, *including explicit moist physics*

**NAVOBS**

## **NAVDAS-Adjoint Observation Monitoring System** (web-based)

*Real-time monitoring of all data assimilated.  
Identification of observation quality problems.  
Real-time data selection and data targeting.*

**EnKF**

## **Ensemble Kalman Filter Algorithm**

*Testing for COAMPS using real observations.  
EnKF/4DVAR Hybrid for the NAVDAS-AR framework.*



# NRL/FNMOC Analysis Systems

## NAVDAS-AR – NRL Atmospheric Variational Data Assimilation System-Accelerated Representer

- Full 4D-VAR algorithm solved in observation space using representer approach
- Weak constraint formulation allows inclusion of model error
- T239L42, model top at 0.04 hPa
- More effective use of asynoptic and single-level data
- More computationally efficient than NAVDAS for large # of obs
- Adjoint developed for observation impact with real-time web monitoring capability
- Operational implementation September 23, 2010



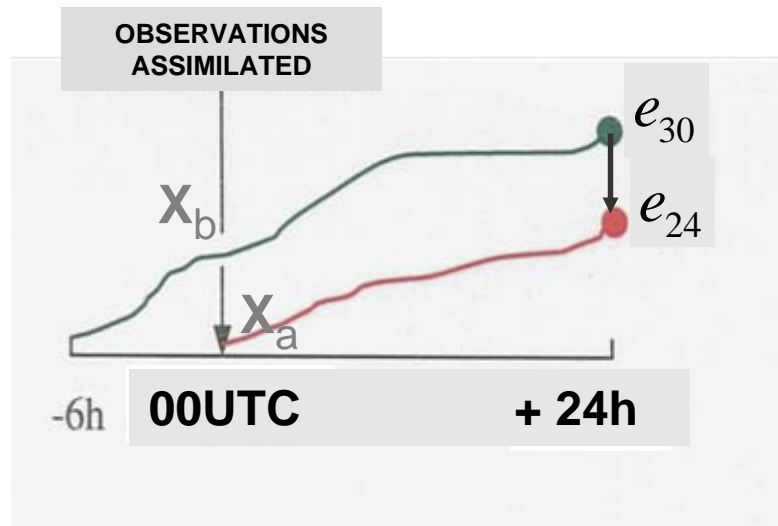


# Observation Impact Methodology

- New mathematical technique using NAVDAS and NOGAPS adjoint models
- Observation impact products generated 4x per day at 00, 06, 12 & 18 UTC
- Uses operational analysis fields and operational innovation vectors from NAVDAS / NOGAPS (NAVDAS-AR/NOGAPS)
- Results are used to
  - evaluate observation quality
  - tune observation reject lists
  - modify assimilation procedures
  - select satellite channels for assimilation



## Observations, model trajectories & forecast error



Observations move the model state from the “**background**” trajectory to the new “**analysis**” trajectory

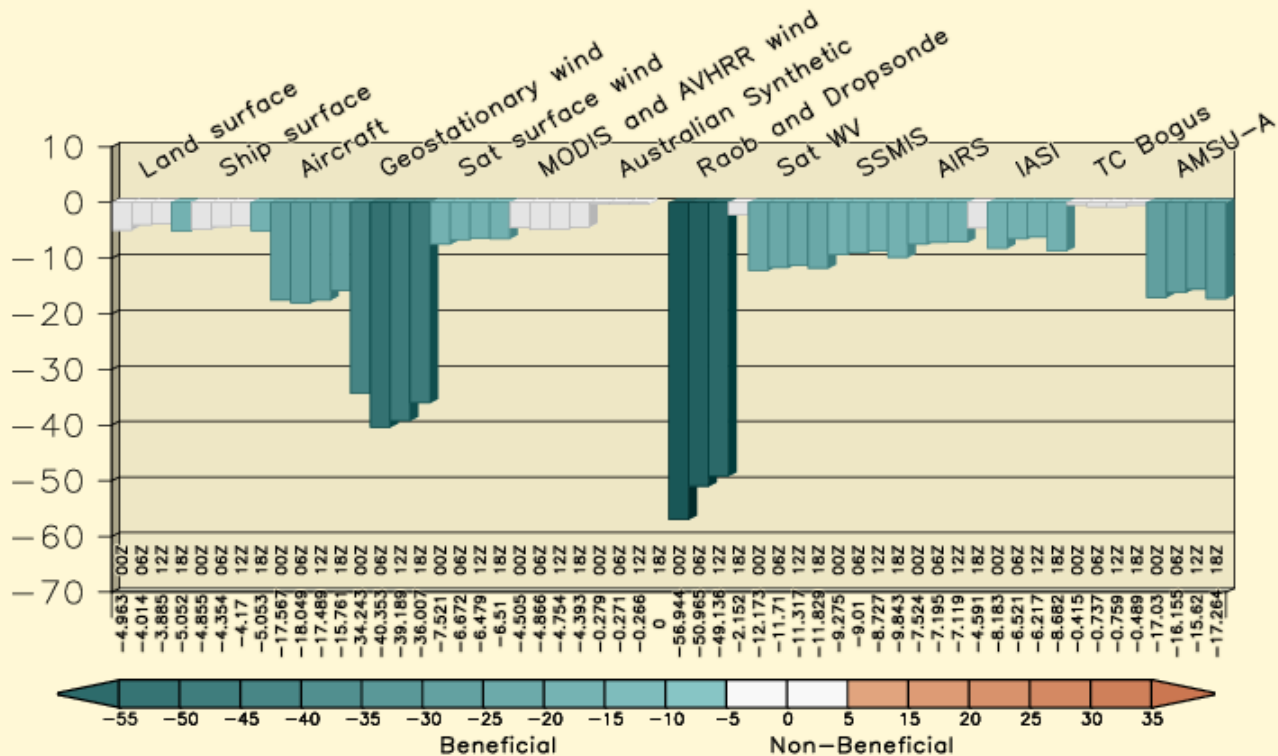
The forecast error difference,  $e_{24} - e_{30}$ , is due to the combined impact of all observations assimilated at 00UTC



# NAVDAS-AR Observation Impact

## FNMOG NAVDAS-AR Each Z Impact Sum by Instrument Type

Impact of 00UTC observations on 24h global forecast error – moist total energy norm ( $J\ kg^{-1}$ )  
for 30 days ending 12 Apr 2010



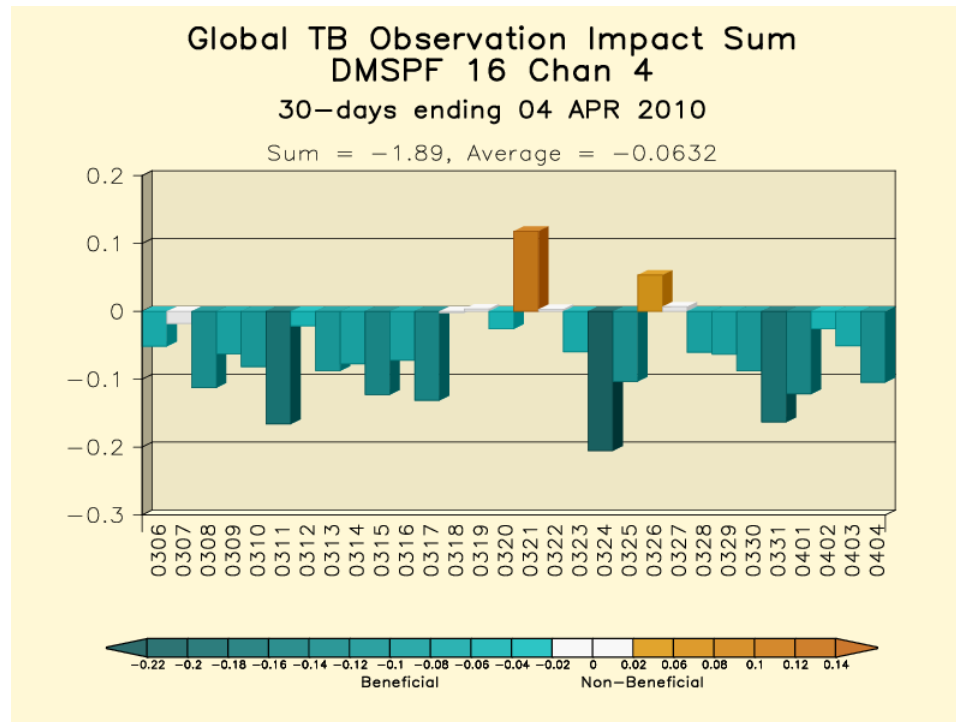
<http://www.nrlmry.navy.mil/obsens/>





# NAVDAS-AR Observation Impact

## Assimilation issues related to change in SALDAG



Observation impact as a function of date (abscissa) for DMSPF F16 Ch 4. These results indicate a non-beneficial impact starting around March 18, 2010, and continuing through the period in question.



# Atmos. Characterization for Oceanography

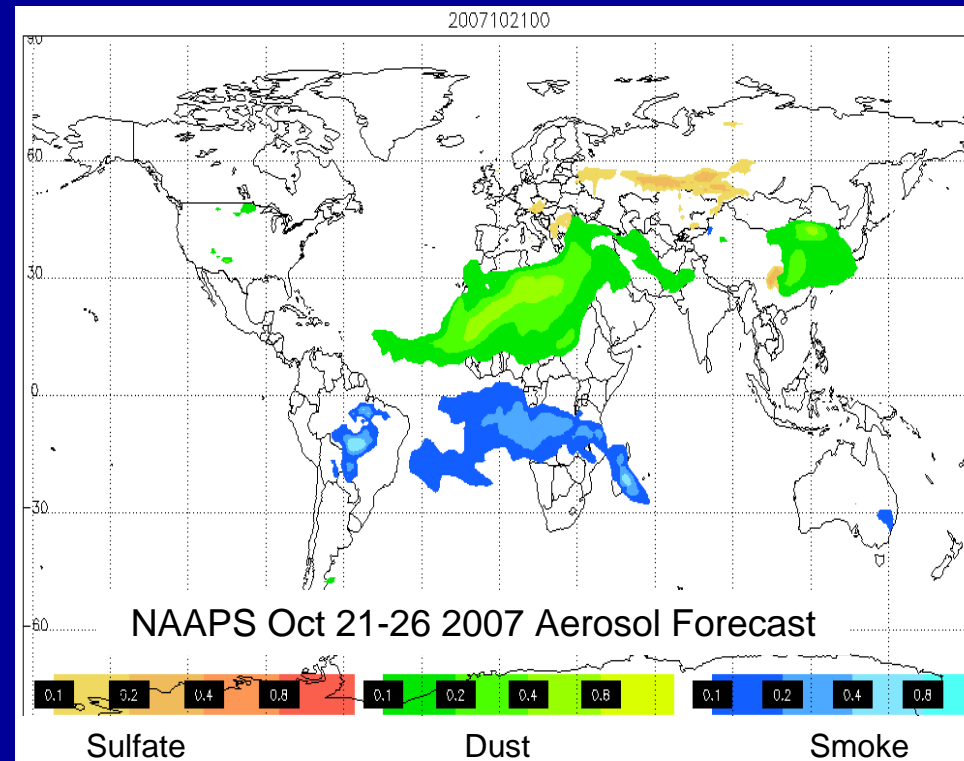
## Evaluate NAAPS Analyses



### NAAPS: Global aerosol analysis and forecast model

- Operational, FNMOC
- 6-day forecasts of aerosol concentrations, EO propagation
- Input: NOGAPS, NAAPS, FLAMBE, NAVDAS-AOD\*
- Output:
  - 6-hourly, 3-D analysis of:
    - dust, smoke,
    - sulfate, SO<sub>2</sub>,
    - sea salt
  - Horiz. res.: 1 degree,
  - Vert. res.: 200 m below 2 km,  
1 km above

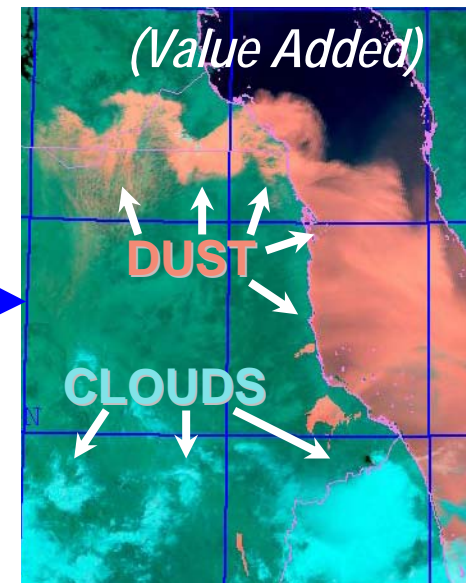
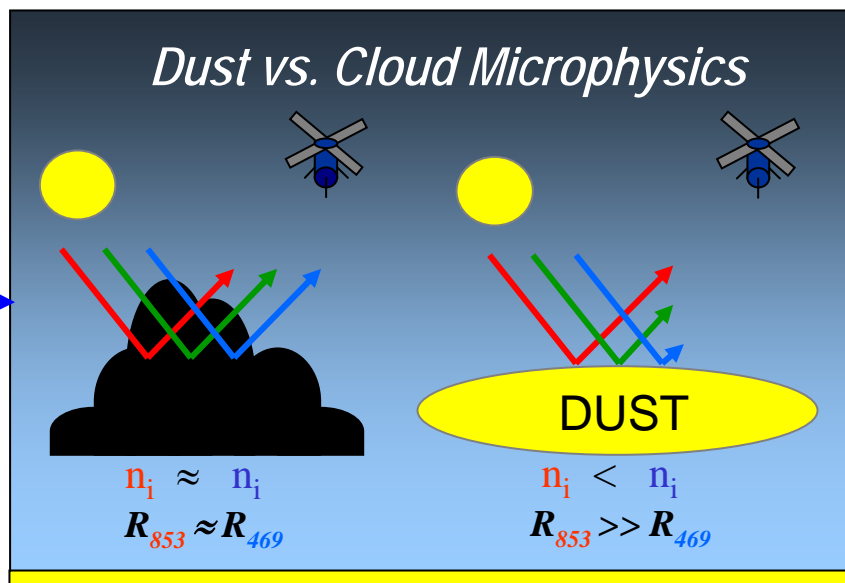
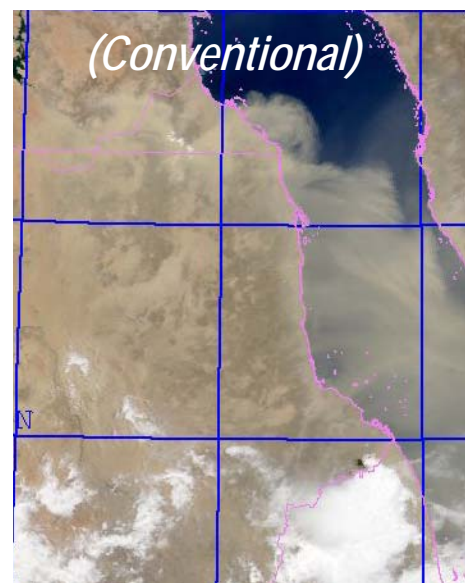
\* Operational by September 2009





# Accomplishments/Achievements

## NRL Dust Enhancement



1) Begin with conventional datasets (MODIS)

2) Apply physics to identify and isolate parameters of interest in a complex scene

3) Communicate information effectively

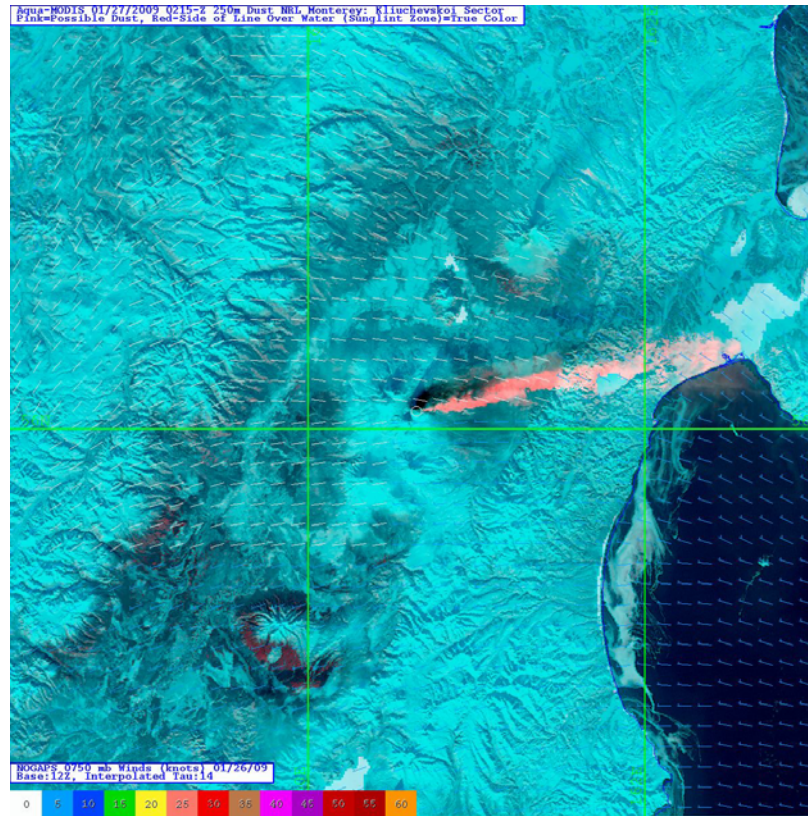
→ Provides continuous enhancement across the land/water algorithm interface





# Accomplishments/Achievements

## Volcanic Ash Detection



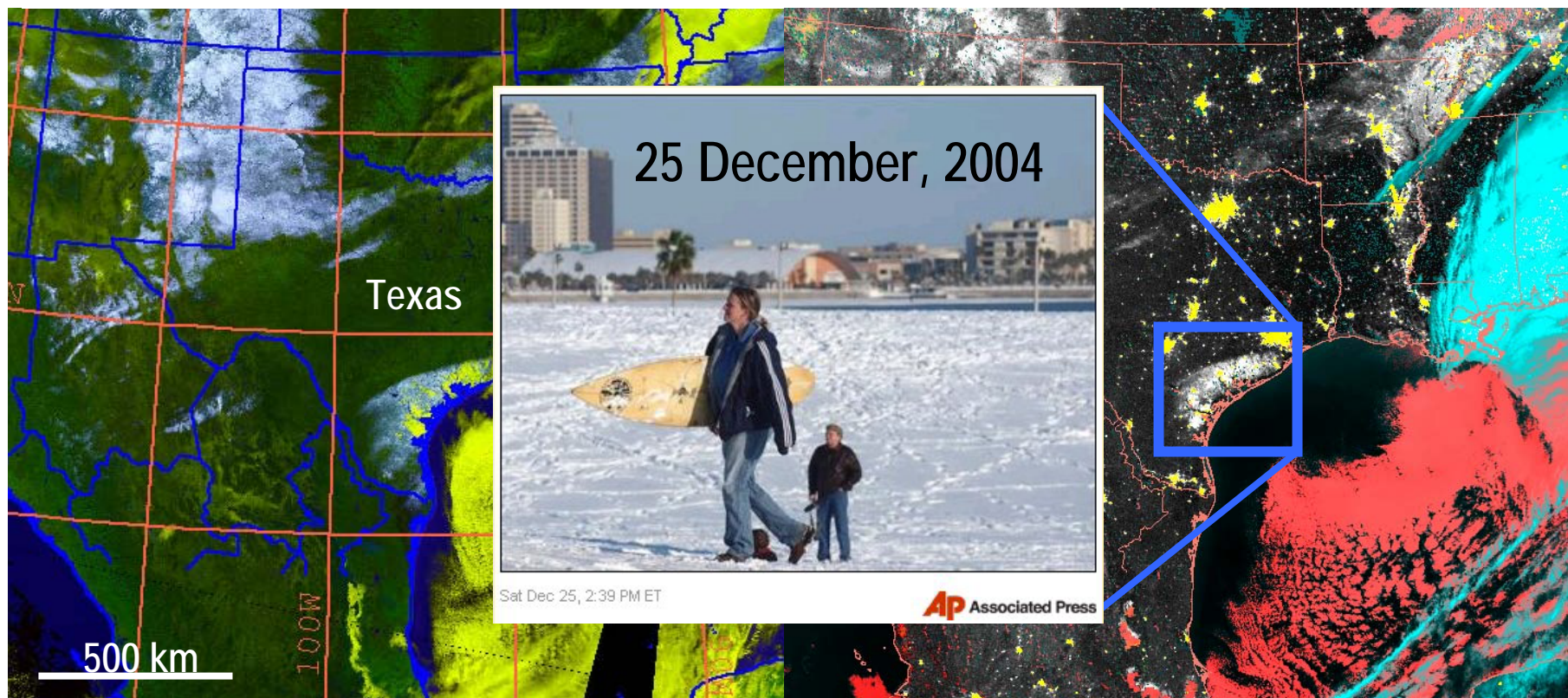
Kliuchevskoi Volcano  
Kamchatka Peninsula  
27 January 2009

Volcanic 'glass' particles melt/damage turbine engines. Physics of detection completely analogous to dust enhancement. *Note: doesn't work for all volcanic ash types.*



# Accomplishments/Achievements

## Detecting Snow Cover at Night



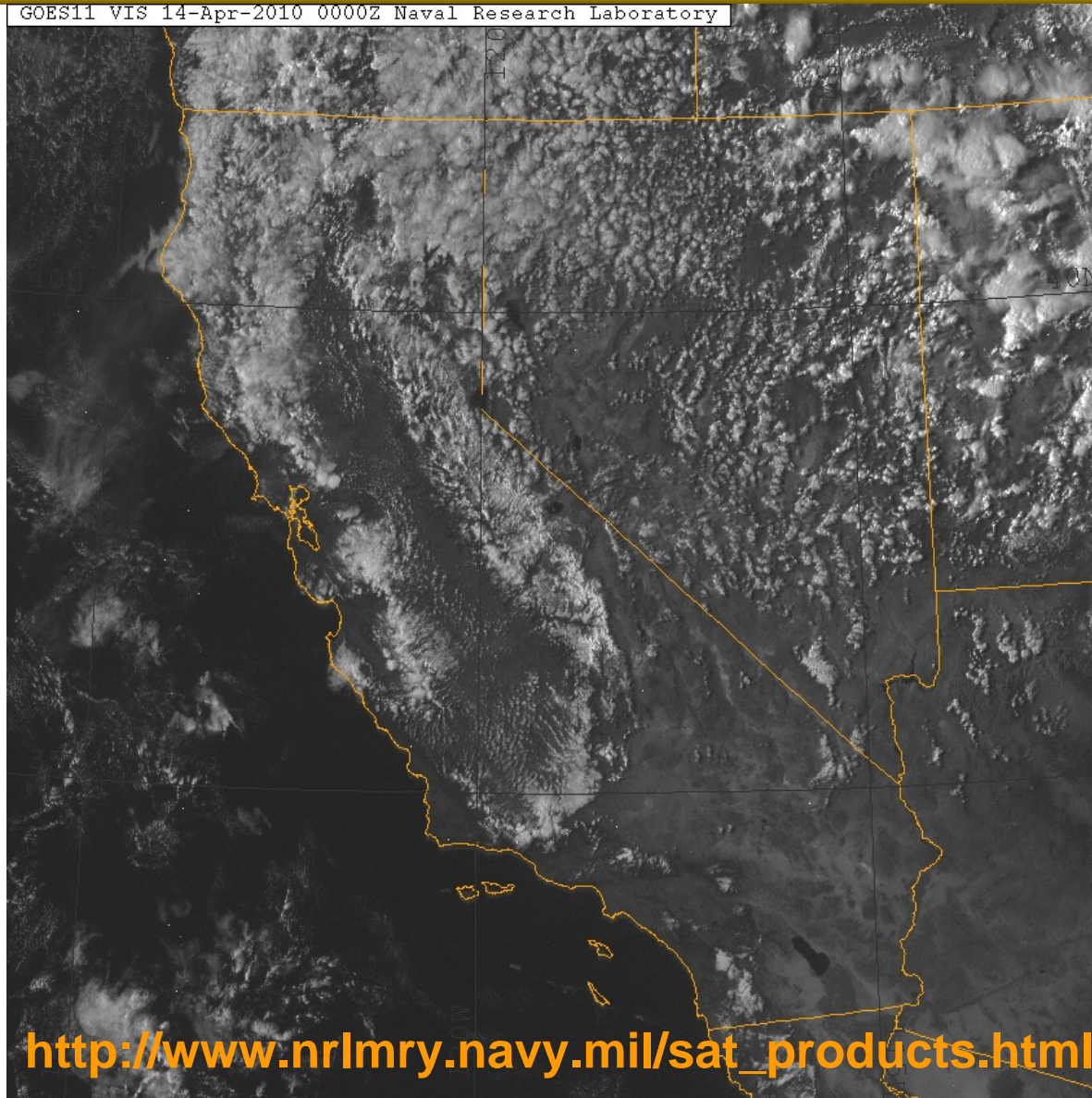
Use of moonlight reflection and thermal emission from blended satellite sensors (OLS DNB and GOES multi-spectral IR to simulate VIIRS capabilities) to decouple clouds and snow cover at night.





# Satellite Imagery

GOES11 VIS 14-Apr-2010 0000Z Naval Research Laboratory



[http://www.nrlmry.navy.mil/sat\\_products.html](http://www.nrlmry.navy.mil/sat_products.html)



Welcome to Monterey!





# NRL/FNMOC Analysis Systems

## NAVDAS – NRL Atmospheric Variational Data Assimilation System

- 3DVAR observation space algorithm
- Unified code for both global and mesoscale NWP systems
  - *Operational for NOGAPS on October 1, 2003*
  - *Operational for COAMPS® December, 2006*
  - *Operational for COAMPS-OS® (CAAPS) October 15, 2008*
- Designed to be precursor for our 4D-Var system, NAVDAS-AR, an accelerated representer assimilation system
- Groundbreaking development of the adjoint of NAVDAS is used for cost effective observation impact studies

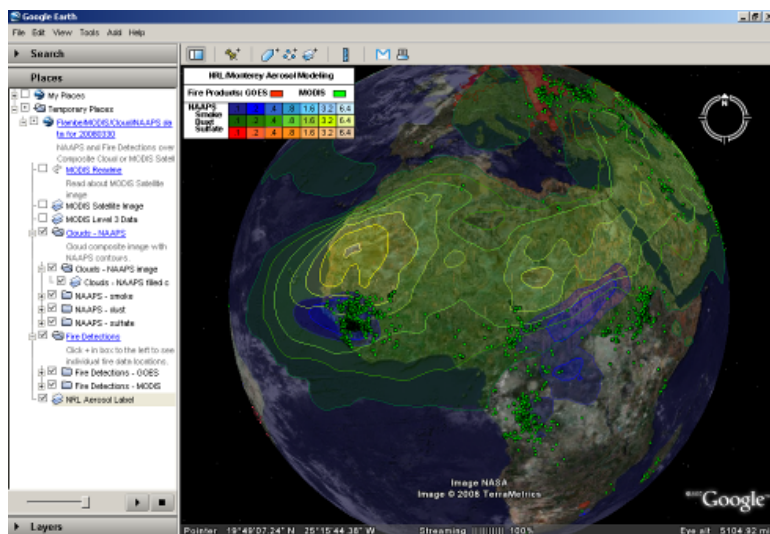


# Summary of Navy Aerosol and Visibility Prediction

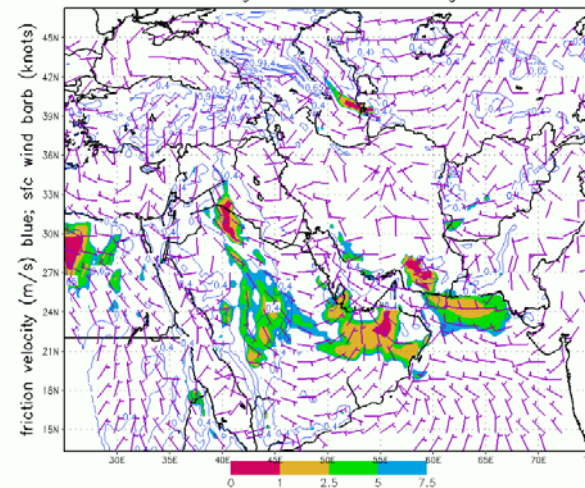


## NRL/FNMOC capabilities:

- **Operational three-dimensional, global and regional aerosol forecasting.**
- **Multiple species** (dust, smoke, sulfate, sea salt, volcanic ash).
- Global to regional-scale **source databases** and database development.
- Characterization of error properties of data / **quality control** / bias removal.
- **Aerosol variational data assimilation, developed as part of NAVDAS.**
- Post-processing software for **optical properties.**
- **Direct links to military tactical decision aids (TAWs)**
- **Field measurements** for science, model validation, and Cal/Val.
- Data distribution (WWW, Metcast, NIPRNET, SIPRNET, Google Earth).



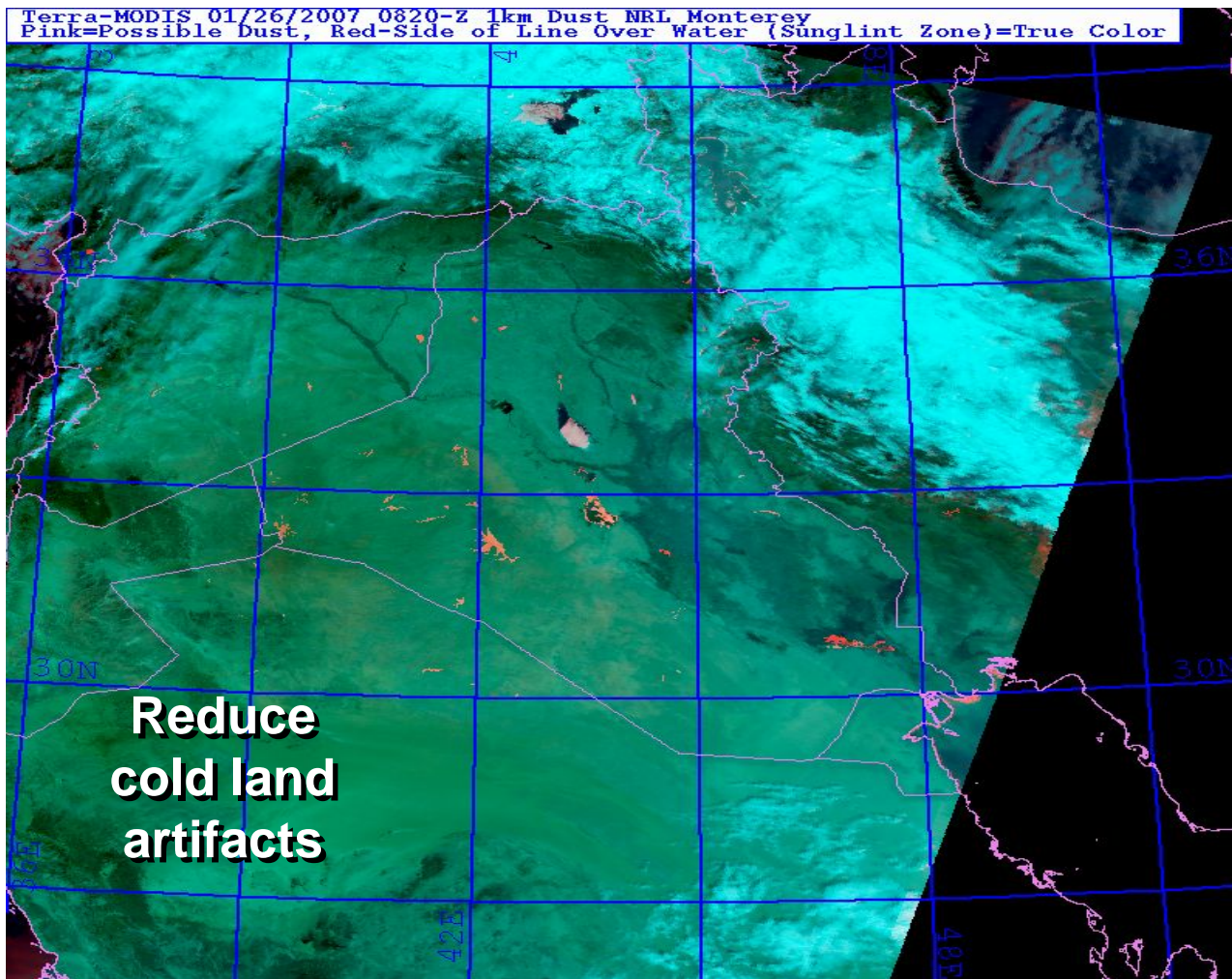
Surface dust visibility (nm) 03h fcast valid at 15Z28FEB2007  
COAMPS starting from 12Z28FEB2007 grid 18-km





# Accomplishments/Achievements

## Dust enhancement: Improvements for winter conditions

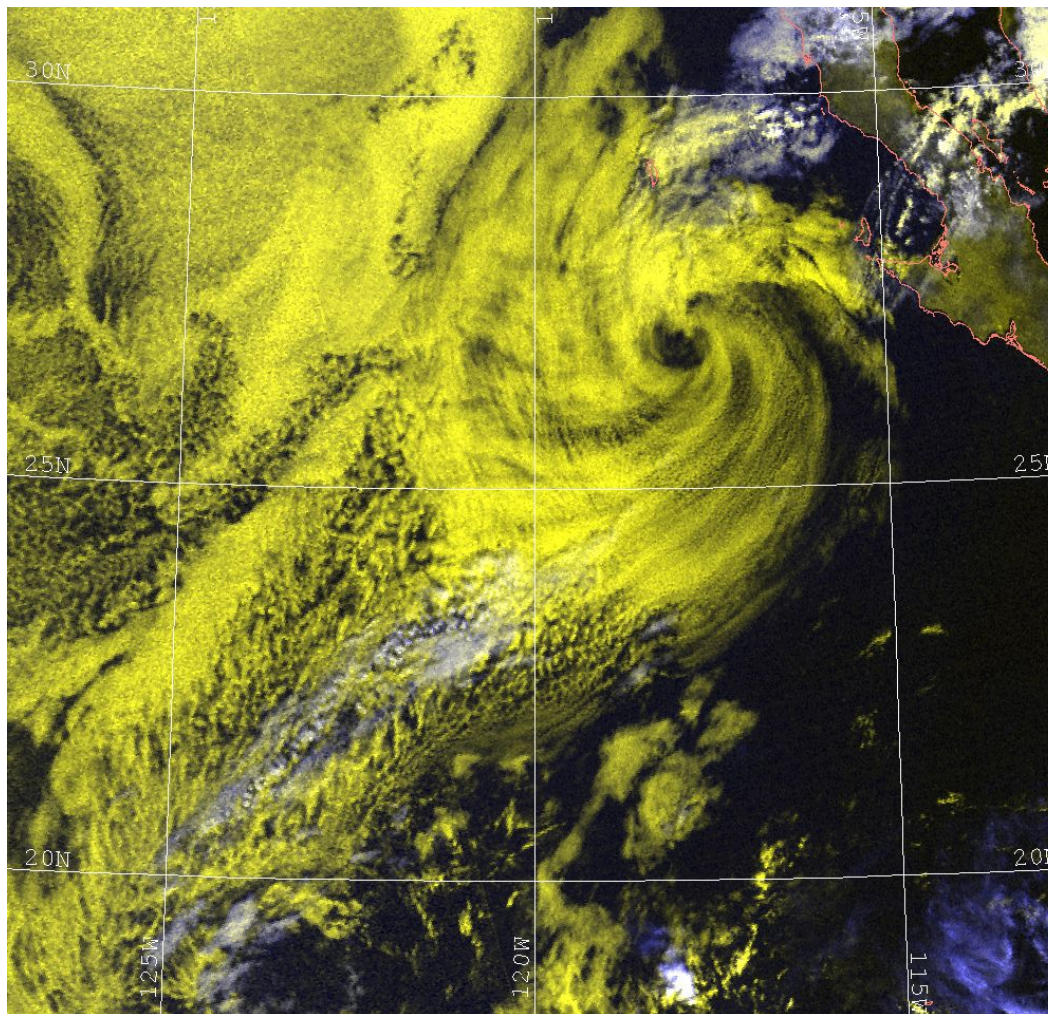






# Accomplishments/Achievements

## Low cloud detection at night



Lunar illumination readily depicts tropical system cloud field

Homogeneous IR scene unable to separate low level clouds from SST field