# The Joint Center for Satellite Data Assimilation

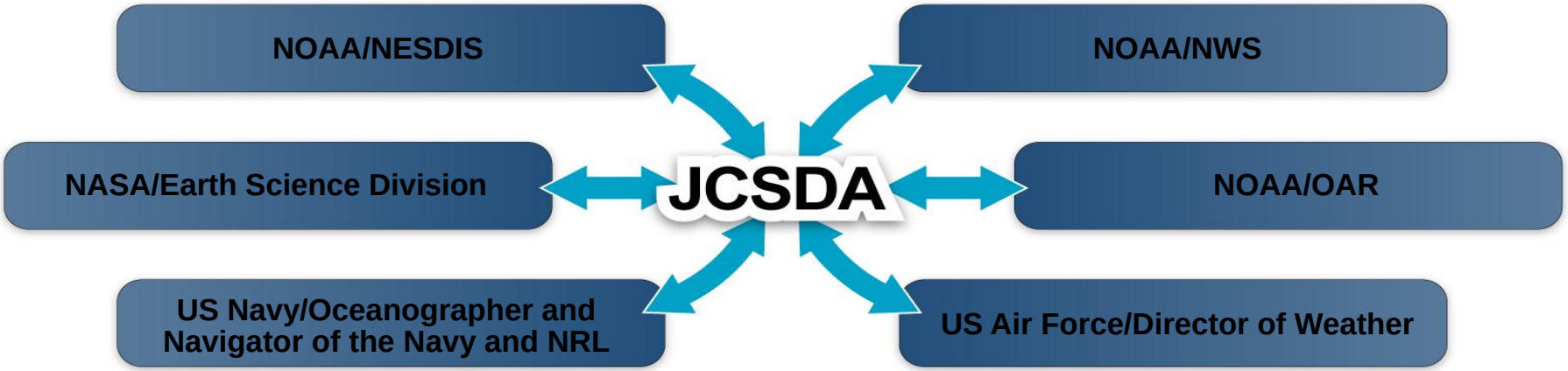
***Overview of activities***

Lars Peter Riishojgaard, Director

# Overview

- Current activities of the JCSDA partners; highlights
- Joint Center computing
- Future Plans
  - External Research, Workshops, Summer Colloquium,…

# JCSDA Partners, Vision, Mission




**Vision:**

*An interagency partnership working to become a world leader in applying satellite data and research to operational goals in environmental analysis and prediction*

**Mission:**

*…to accelerate and improve the quantitative use of research and operational satellite data in weather, ocean, climate and environmental analysis and prediction models.*

# Contributions to the JCSDA

**GMAO**

- *Atmospheric Data Assimilation*
  - Preparation for NPP – OMPS/LP (*see Philippe Xu's poster*)
  - Preparation for NPP – working with NESDIS and CRTM group to prepare GSI for ATMS and CrIS (*Will McCarty*)
  - OSSEs to prepare for Aeolus (*Will McCarty, see Ron Errico's presentation*)
  - Developing a real-time MLS radiance assimilation for the GSI (*Kris Wargan*)
  - Observing System Impact with Adjoint Tools (*Ron Gelaro*)

- *Aerosol Model and Assimilation* (*see Arlindo da Silva's presentation*)
  - Transitioned GOCART to NCEP/GFS
  - Testing assimilation of MODIS AOT with GEOS-5

- *Land data assimilation* – soil moisture (SMAP), Land surface temperature, snow, terrestrial water storage ( *see Rolf Reichle's presentation*)

**LIS** (Hydrological Sciences Branch, collaboration with AFWA, NOAA/NCEP, GMAO)

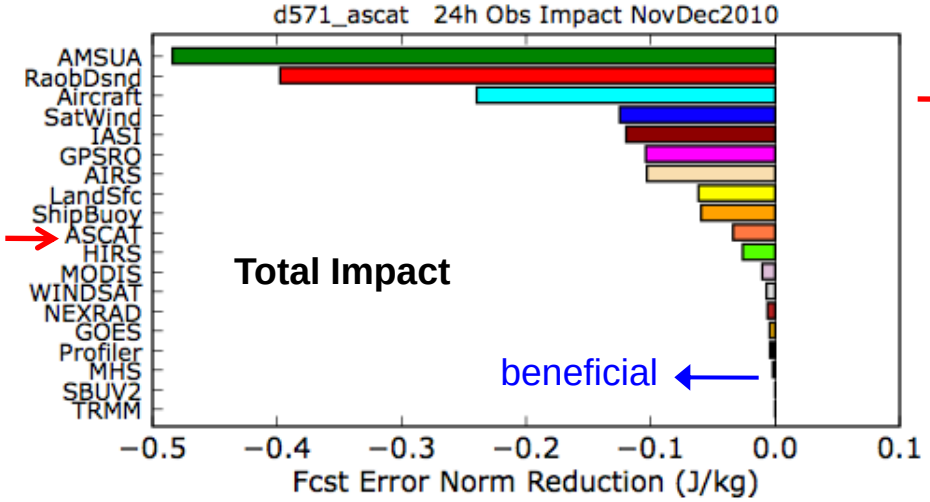
- Land Information System (*see Christa Peters-Lidard's presentation*)
  - Coupling with CRTM to improve satellite data assimilation for the atmosphere
  - Assimilation of multi-sensor snow (*see Sujay Kumar's presentation*)

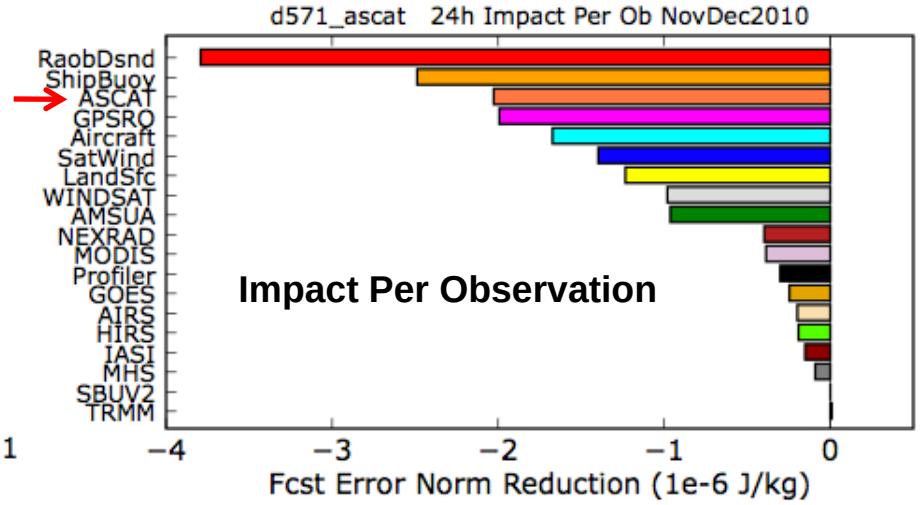
# Measuring the impact of ASCAT

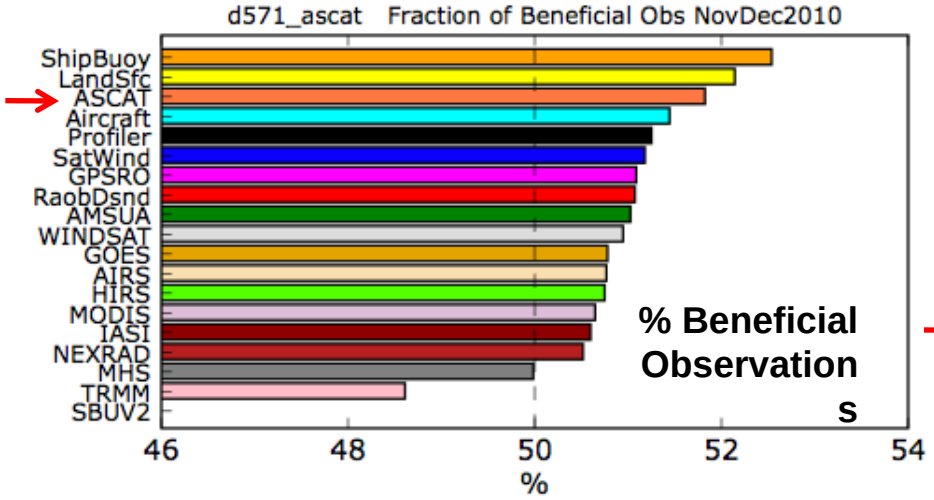
0z Average Observation Impact Statistics from GEOS-5 Forecasts

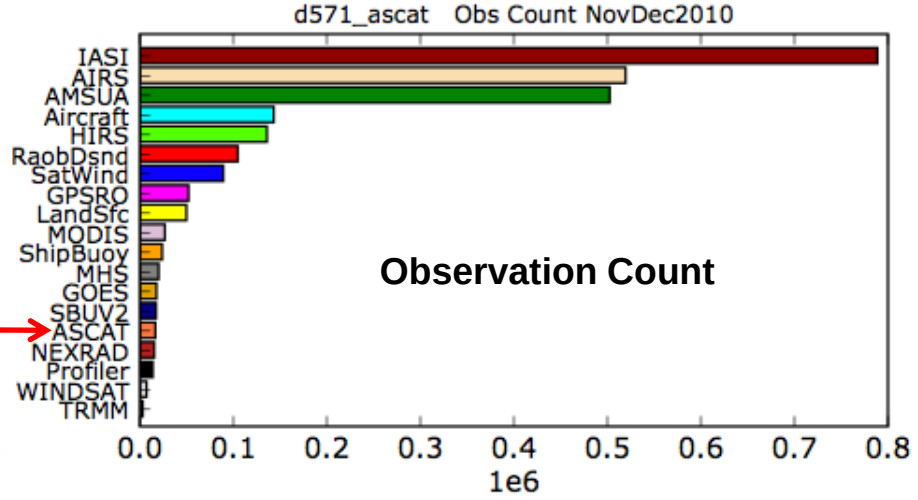
10 Nov 2010 – 02 Jan 2011

*Ron Gelaro*



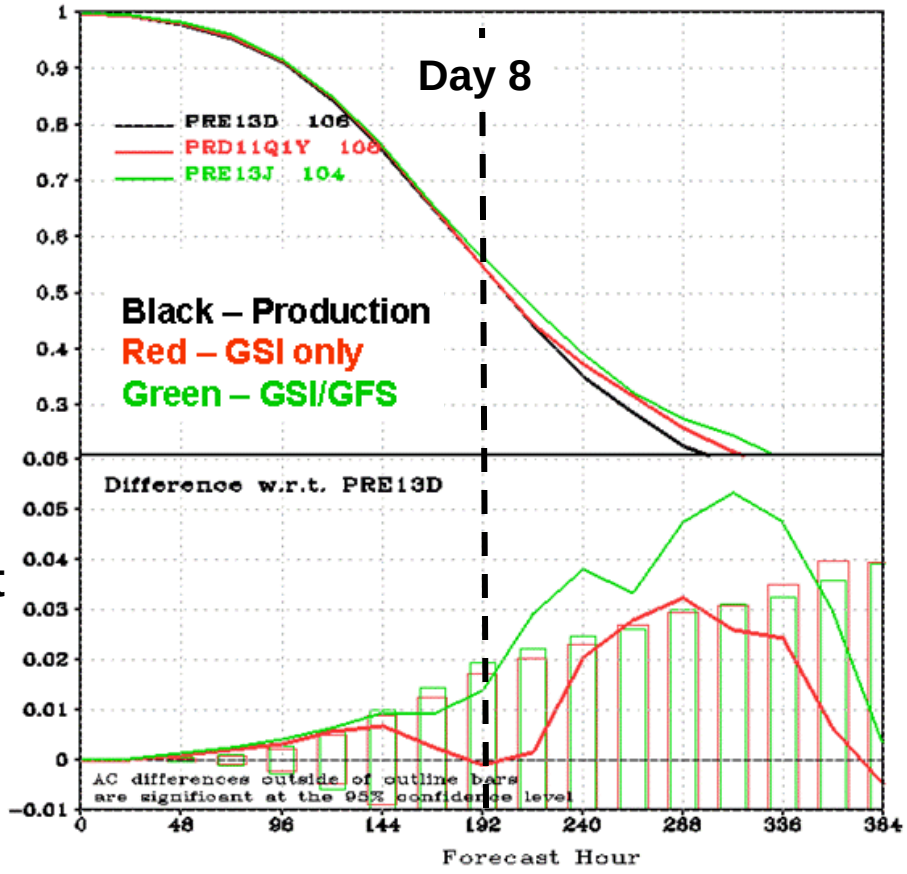




Adjoint-based estimate of 24-hr global forecast error reduction in wind, temperature and surface pressure combined as energy (J/kg), from sfc-150 hPa

# NOAA/NCEP
# Global Data Assimilation System
## Upgrade Implemented 9 May 2011

- **Analysis Changes**
  - Recomputed background errors
  - New version of CRTM 2.0.2
  - Improved Field of View calculation
  - Updates for thinning and collocation calculations
  - QC and obs. error and data handling updates for
    - OMI
    - AMSU-A (channel 5)
    - ASCAT
    - SBUV/2 ozone
    - Ocean buoys
  - New analysis options (useful for next round of development)
- **Model Changes**
  - Thermal roughness length upgrade (X. Zeng, U. Arizona)
  - Stratospheric tuning

**5-Day 500MB NH AC**
**00Z Cycles 16 June-29 Sept 2010**



# Planned Upgrade of NOAA/NCEP GDAS

## Target Implementation is Q2FY12

### Aggressively developing a Hybrid EnKF-3DVar system

- Joint Project: NOAA (ESRL, NCEP), NASA GMAO, Univ OK
- Others plan to support regional/hurricane applications—AOML, PSU
- Extensive development testing on ESRL Boulder machine
- System ported back to NCEP for pre-implementation testing (summer 2011)
- Implementation will require creative computational resource planning

### Candidate Components in Upgrade Include:

- GPS RO bending angle rather than refractivity
- Inclusion of compressibility factors for atmosphere
- Retune SBUV observation errors
- Update radiance usage flags
- Prepare for NPP and Metop-B
- Add GOES-13 data
- Add Severi CSBT radiance product
- Modification of Radiance bias correction
- Satellite monitoring stats code included in Ops.
- Improved moisture analysis and add more IASI and AIRS moisture channels
- New Sat wind data and QC
- NSST analysis in GSI

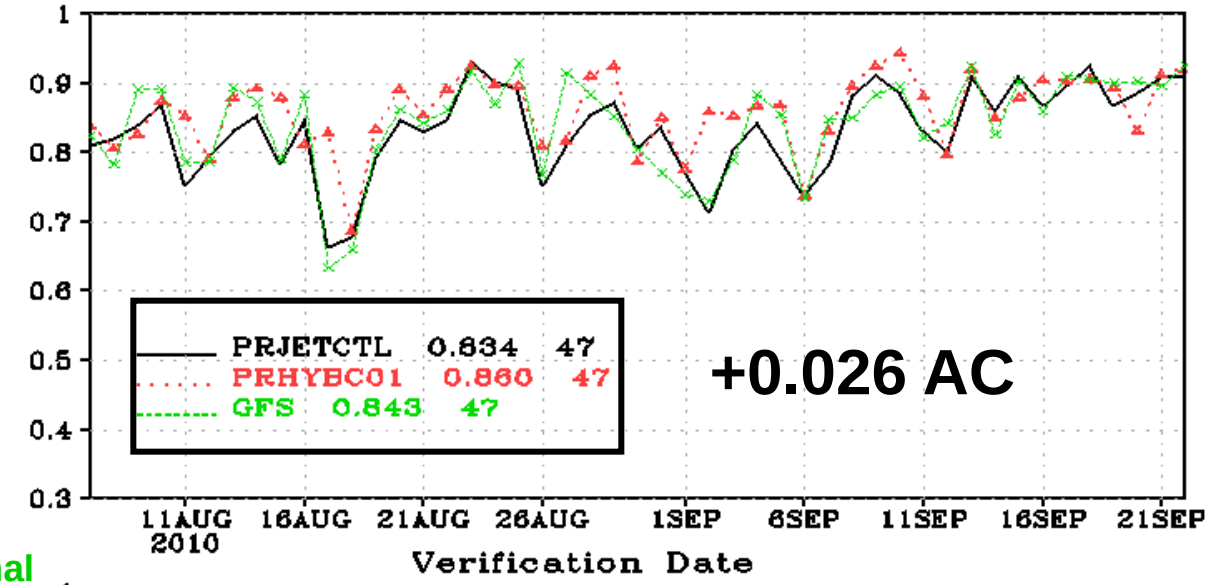
# Development of GSI Hybrid Var-EnKF

- Test Period: 01 Aug to 22 September 2010
- Deterministic Forecasts: Operational GFS @ T574L64
- Ensemble Configuration:
  - 80 ensemble members
  - GSI for observation operators
  - T254L64 operational GFS
- Initialized 00 UTC 15 July 2010 from interpolated GEFS members
  - allowed over 2 weeks spin-up
- Assimilate all operational observations
  - Includes early (GFS) and late (GDAS/cycled) cycles
  - Operational prepbufr files (no prep/additional qc)
- Dual-resolution/Coupled
  - High resolution control/deterministic component
  - Includes TC Relocation on guess
  - Ensemble is recentered every cycle about hybrid analysis
  - Throw out EnKF analyis mean
- Bias correction (satellite) coefficients come from GSI/VAR
- Minimal tuning done for hybrid
  - 1/3 static B, 2/3 ensemble

# 500 hPa SH AC Time Series

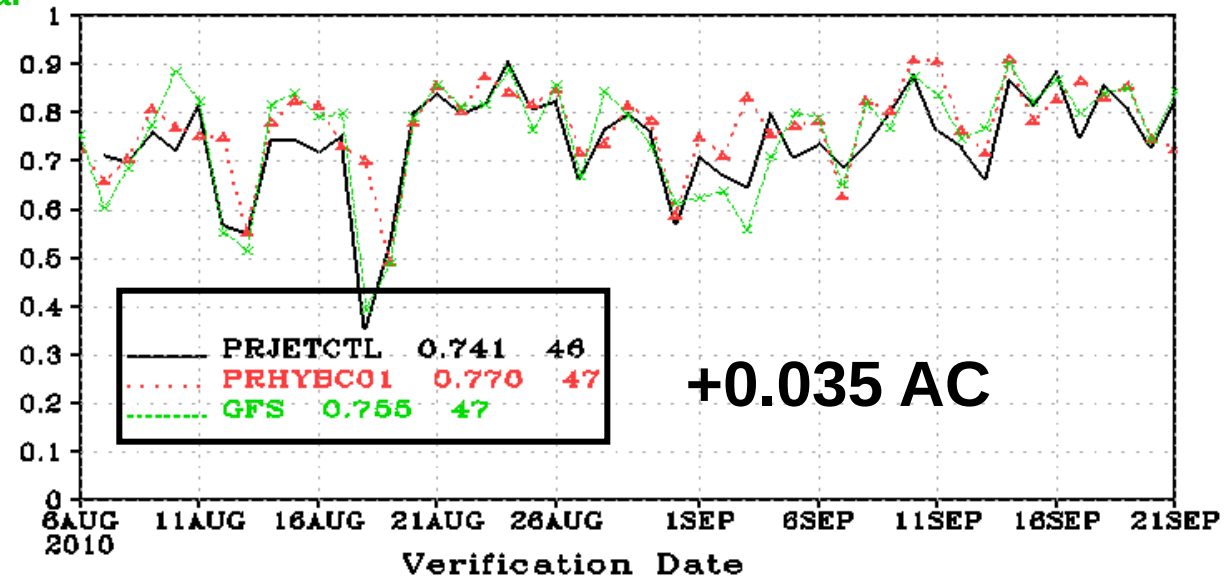
## Test Period: 6 Aug to 21 Sept 2011

**Day 5**



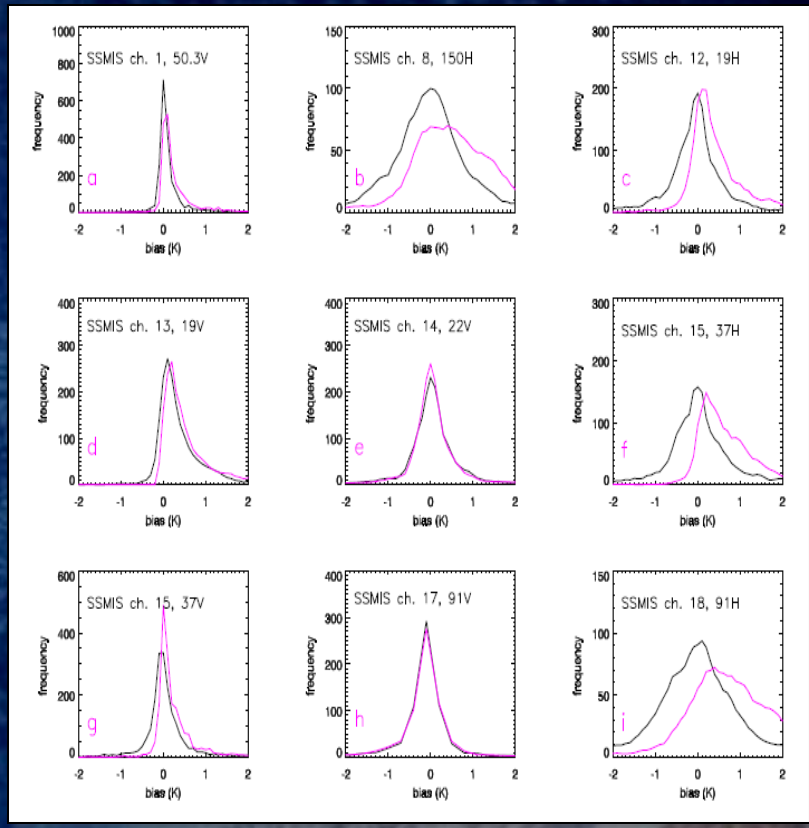

**Black – Control**
**Red – Hybrid**
**Green – Operational**

**Day 6**



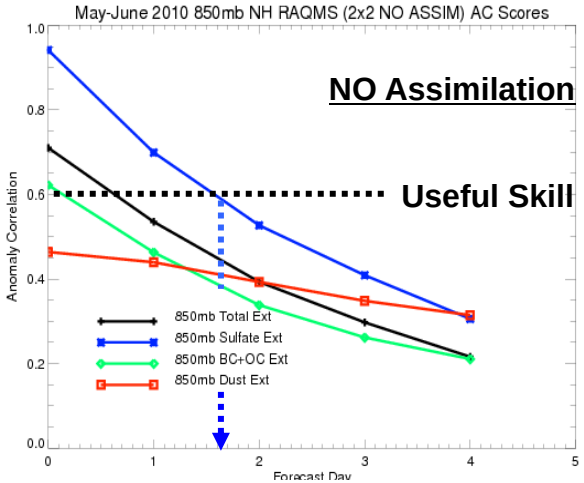
# Overview of NESDIS Satellite Data Assimilation Activities (1/2)

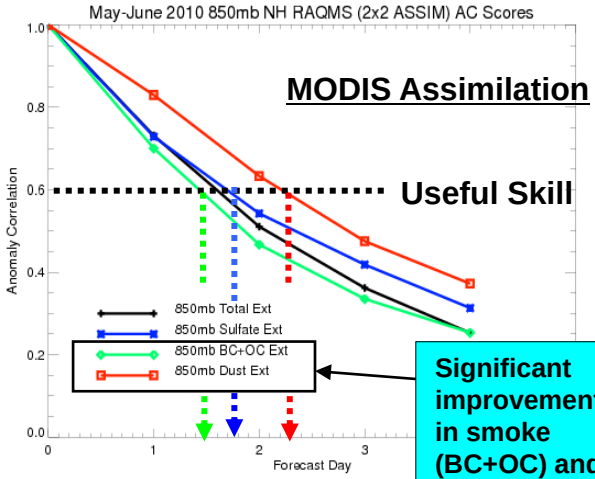
- **CRTM Science Activities – [Han et al].**
  - ✓NLTE implementation (non-local thermodynamic equilibrium)
  - ✓Improved Ocean Microwave Emissivity Model (FASTEM4)
  - ✓Aerosol optical depth module for air quality forecasting (not released yet)
  - ✓Extension of CRTM for visible channels, including imager of GOES-11, -12, -13, -14, -15, mt2, VIIRS and foreign sensors.
- **NPP/JPSS Readiness. Proxy Data (in BUFR format ) available to NWP centers- [Wolf et al.]**
  - ✓CrIS, ATMS, VIIRS and OMPS
- **GFS/GSI AIRS V5 Temperature Retrieval Assimilation Experiments – [Pierce et al.]**
- **IR Hyperspectral cloud-cleared radiances (AIRS, IASI) – [Barnet et al.]**
- **Microwave cloudy radiance data in non-precipitating clouds (AMSU-A) - [Kim et al.]**




Histograms of the differences between CRTM-simulated and observed brightness temperatures for six SSMIS channels. Red curve – CRTM with FASTEM-3;
black curve – CRTM with FASTEM-4

# Overview of NESDIS Satellite Data Assimilation Activities (2/2)




Significant improvements in smoke (BC+OC) and dust aerosol forecasts

- MiRS 1DVAR Science Activities– [Boukabara et al.]
  - ✓Potential to be used as QC and/or pre-processor for DA
  - ✓Applicable to NOAA/METOP AMSU, MHS, SSMIS, TRMM/TMI, ATMS
- NAM-CMAQ GOES Column Ozone Assimilation – [Pierce et al.]
- Contributions to GOES aerosol assimilation into air quality forecasting model – [Kondragunta et al.]
- Assessment of Global Aerosol Forecast Skill (MODIS AOD Assimilation) of RAQMS – [Pierce et al.]
- Use of Global Biomass Burning Emissions from Geo Satellites in GFS-GOCART – [Kondragunta et al.]
- Water Vapor Data Assimilation in GDAS – [Jung et al.]
- Soil moisture Assimil. in GFS using Kalman Filter–[Zhan et al.]
- NPP/JPSS & GOES-R cal/val readiness and OSSE Simulations - [Weng et al.]

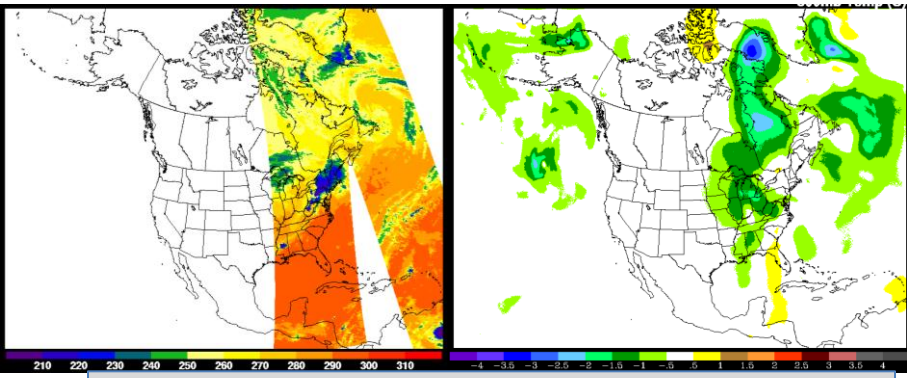
# Preliminary results on assimilation of AIRS radiance and retrieval data in the Rapid Refresh *(1h cycle, WRF/ARW, GSI)*


**Haidao Lin, Steve Weygandt, Ming Hu, Stan Benjamin**
***NOAA/ESRL/GSD Assimilation and Modeling Branch***

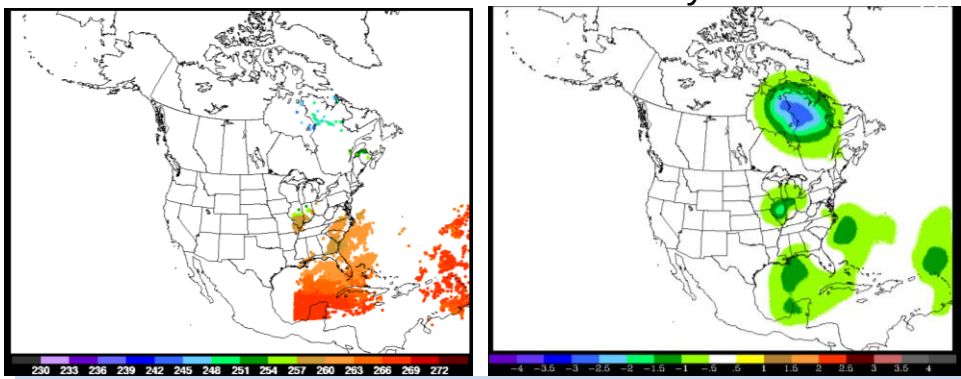
**Tim Schmit (*NOAA/NESDIS/STAR, Madison, WI*),**
**Jinlong Li, Jun Li (*CIMSS, University of Wisconsin-Madison***


**See Haidao Lin JCSDA poster**

**Radiance** Assimilation Results – 6z 8 May 2010

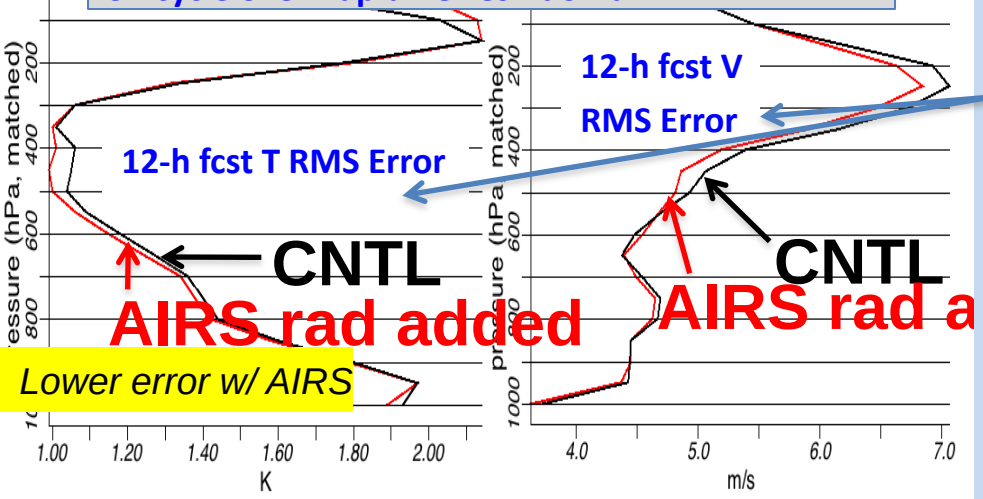



**Retrieval** Assimilation Results – 6z 8 May 2010




**9-day assimilation experiments – 8-16 May 2010**

**3h cycle over Rapid Refresh domain**



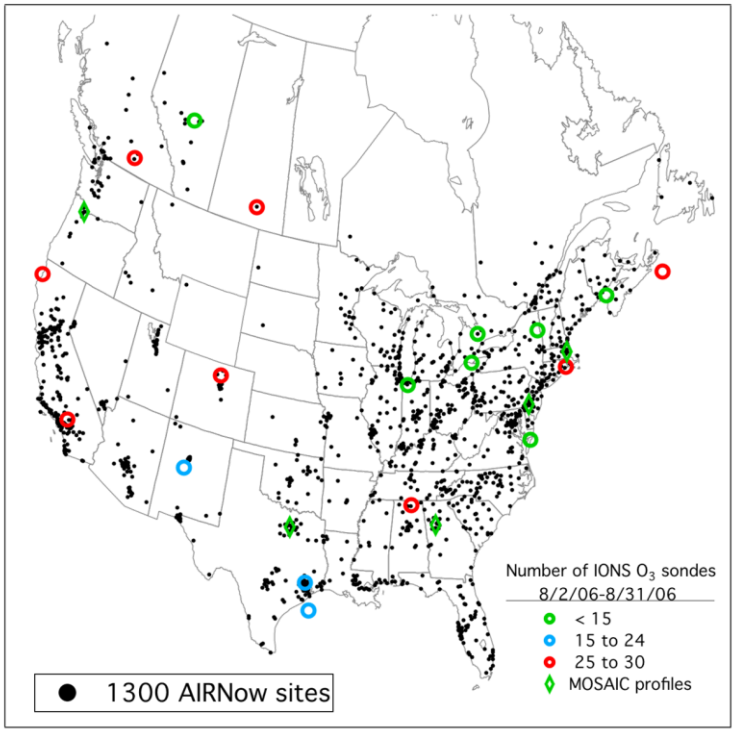

## SUMMARY AND FUTURE WORK

**Preliminary result:**

1. **AIRS data has slight positive impact for short-term predictions in 3h cycled Rapid Refresh, more for radiances.**
2. **Bias correction necessary for positive impact for radiances, not performed yet for retrievals.**
3. **Tuning of horizontal/vertical thinning necessary for retrieval assim.**

**Plans:**

- **Continue evaluation of impact of AIRS radiance and retrieval data with new thinning & bias correction designs**
- **Investigate current cloud contamination detection**
- **Run 1-h cycle tests, test different AIRS time windows**
- **More cases ➔ operational use of AIRS data in RR@NCEP**



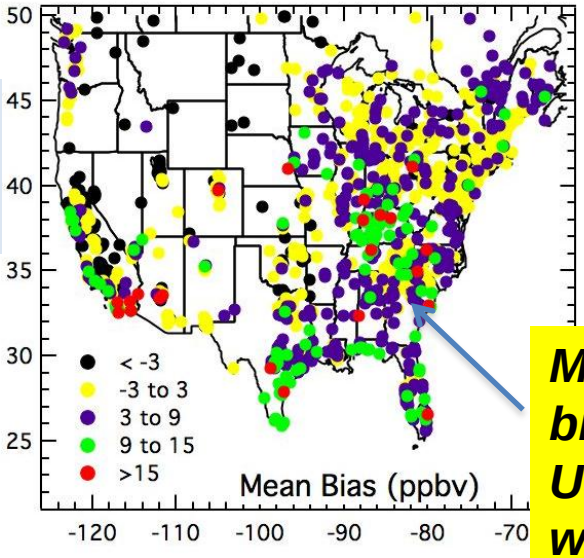

## $O_3$ and Particulate Matter Data Assimilation from Sfc Obs with WRF/Chem and GSI

-Mariusz Pagowski
(+ Grell, McKeen, Peckham, Devenyi) – NOAA-ESRL

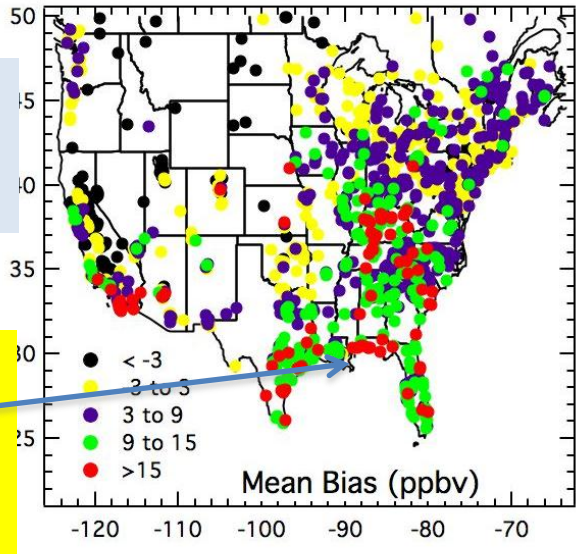
*Quart.J.Roy.Meteor.Soc*. – 2010 (Oct)

## $O_3$ bias (ppbv) – 24h (next day) forecast valid 00z – 2-31 Aug 2006

**With** assim of AIRNow $O_3$ obs in GSI



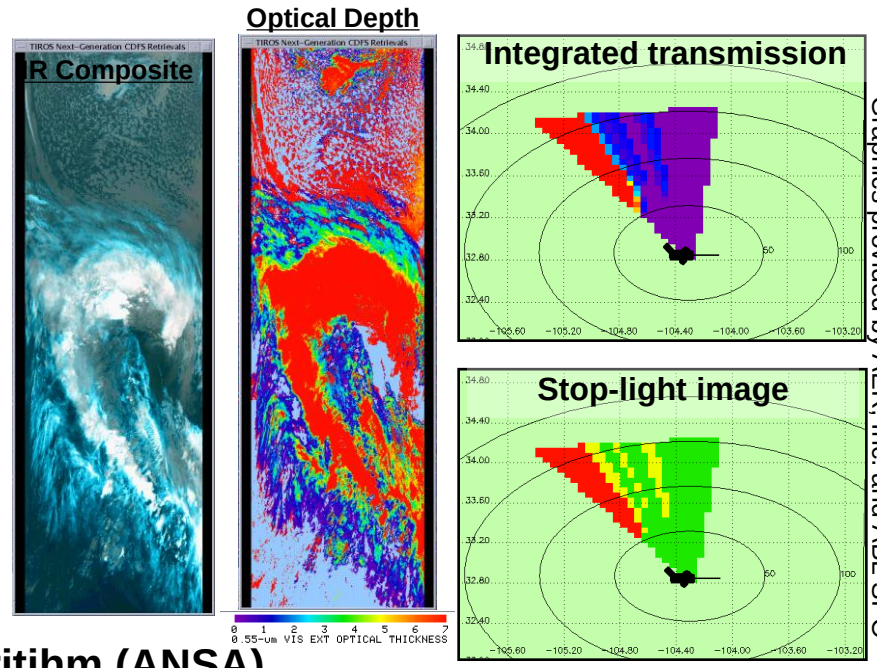

**CNTL**
**no** assim of $O_3$ obs




***Much lower $O_3$ bias, esp. in SE US w/ $O_3$ assim***

# Improved Satellite DA in Cloud and Land Surface Modeling

- **Integrating cloud optical properties into cloud analysis/forecasting models**
  - **Up to 13 channels used in algorithms**
  - **Superior cloud property outputs**
  - **Leveraged financial support from Airborne Laser Program**
  - **IOC fall 2011**
- **Improve Surface Characterization**
  - **Land Information System (LIS)**
  - **Higher resolution, more efficient computation, multi-grid configuration**
  - **Implementing AFWA-NASA Snow Algoritihm (ANSA) assimilating MODIS data**
  - **Leverages multi-agency investment**
  - **IOC summer 2011**



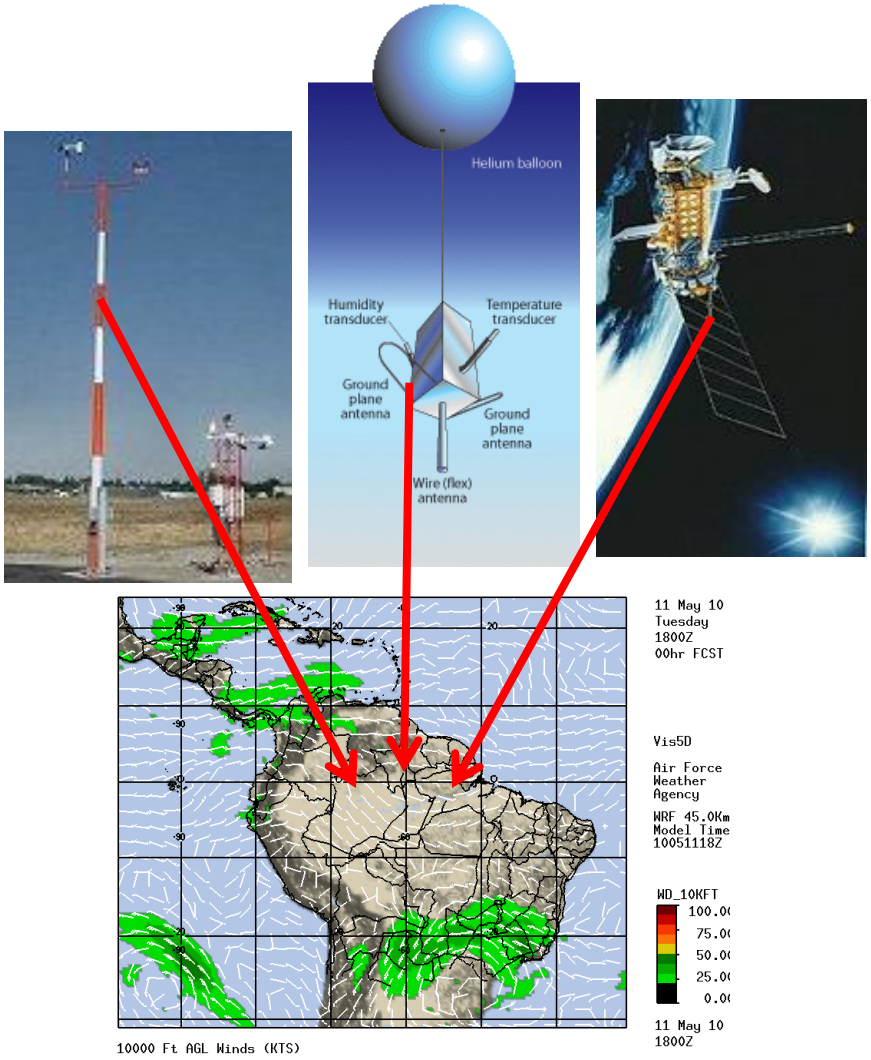

Graphics provided by AER, Inc. and ABL SPO

# WRF DA Initiatives

U.S. AIR FORCE

AIR FORCE WEATHER AGENCY

- Pursuing GSI Transition to replace WRFVAR (IOC spring 2012)
  - Leveraging mature 3DVAR assimilation system with advance satellite radiance assimilation capability
- Working receipt of satellite radiance data unique to GSI
- Pursue 4DVAR as enabler to assimilate “cloud-filled” properties vice only “cloud-free” satellite radiances
- Hybrid DA capability (ETKF with 3DVAR or 4DVAR) to leverage ensemble DA capabilities
- Investigate the utility of full Ensemble Kalman Filtering DA technique with respect to 4DVAR



# Recent Highlights of Navy Data Assimilation NAVDAS-AR (4D-Var)

## NAVDAS-AR *(strong constraint, CRTM)* Operational Sept, 2009

## New Satellite Data sources added or improved with NAVDAS-AR

- ✓ **IASI, AIRS** assimilation added, ***refined and skill improved***; NOAA-19 **AMSU-A**
- ✓ **DMSP F16, F17, F18 UPP** operational; ***Assimilating radiances, surface winds, TPW, ice***
- ✓ **ASCAT, WindSAT** ***(winds and TPW)***

## T319L42 NOGAPS/NAVDAS-AR Operational May, 2010

NOGAPS

## Subsequent sensors added to NAVDAS-AR

- ✓ **GPS RO** bending angle Operational Sept, 2010*
  - COSMIC, GRAS, GRACE-A, Terra SAR-X, SAC-C, C/NOFS
- ✓ **RARS** ATOVS retransmission data Operational Sept, 2010*
- ✓ **Combined LEO/GEO** atmospheric motion vectors (AMV) Operational Nov, 2010*
- ✓ **Hourly geostationary winds** (AMV) from MTSAT, Meteosat and GOES-W Operational Dec, 2010*
- ✓ **MHS** and **SSMIS** 183 GHz channel assimilation Operational Jan, 2011

## Sensors and enhancements to be added to NAVGEM

- ➢ Variational bias correction
- ➢ SBU/V and MLS **ozone**
- ➢ HIRS and Geostationary Clear-Sky Radiance
- ➢ Weak-constraint formulation
- ➢ Flow-dependent background errors

# Recent Highlights of Navy Data Assimilation NAVDAS (3D-Var)

## New Satellite Data Sources added to NAVDAS

- ✓ ASCAT scatterometer
- ✓ WindSat wind vectors and TPW, new WindSat retrieval algorithm (NRL DC)
- ✓ Mid-level Geostationary winds
- ✓ MODIS and AVHRR polar winds
- ✓ Combined LEO/GEO winds
- ✓ AMSU-A Satellite Radiances, including RARS

COAMPS®

## Sensors still to be added to NAVDAS

- ✓ **IASI, AIRS and SSMIS radiances**
- ✓ **MHS and SSMIS 183 GHz channel assimilation**

# JCSDA Computing

- Lack of JCSDA computing "major obstacle to success" (JCSDA Advisory Panel Jan 2009)
- Review of past JCSDA-funded external projects revealed lack of computer resources as significant limitation
- R2O requires O2R
  - Research community needs access to operational codes and adequate computer resources in order to help
- New resources made available on NOAA backup computer
  - However, no projected growth on NOAA R&D computer
- NASA has procured JCSDA supercomputer resource to test algorithms in the context of operational partner systems
  - IBM Linux cluster; 576 Intel Westmere processors; 200 Tb of storage
  - Located at GSFC and operated by NCCS for the Joint Center
  - *NOAA-funded expansion in progress!*

# JCSDA computer at GSFC

- Hostname jibb ("Joint Center in a Big Box")
- Open to all JCSDA projects, internal as well as external, with supercomputing needs
  - Plan is to support GDAS, GFS/GSI, WRF, GEOS-5, CRTM, MIRS and other applications relevant to JCSDA users *(see presentation by E-M. Devaliere)*
- Account request process relatively straightforward; approval within days
  - Request to E.-M. Devaliere or A. Pratt; approval by L. P. Riishojgaard, S. Boukabara or J. Yoe

# Jibb Initial System Capabilities

- Compute – IBM iDataPlex
  - 576 total cores; 6.3 TF Peak Computing
  - 48 Compute Nodes
    - Dual-socket, hex-core 2.8 GHz Intel Westmere with 24 GB of RAM
    - Quad Data Rate Infiniband Network (32 Gbps) in a 2-to-1 blocking fabric
- Storage
  - 8 IBM x3650 Storage Servers
  - 2 IBM DS3512 Storage Subsystems
  - 200 TB Total
  - IBM GPFS File System
- Ancillary Nodes
  - 2 Login Nodes
  - 2 Management Nodes

# Jibb Total System Capabilities (when fully built out via NOAA-funded expansion)

- Compute – IBM iDataPlex
  - 3,456 total cores; 37.8 TF Peak Computing
  - 288 Compute Nodes
    - Dual-socket, hex-core 2.8 GHz Intel Westmere with 24 GB of RAM
    - Quad Data Rate Infiniband Network (32 Gbps) in a 2-to-1 blocking fabric
- Storage
  - 8 IBM x3650 Storage Servers
  - 2 IBM DS3512 Storage Subsystems
  - 400 TB Total
  - IBM GPFS File System
- Ancillary Nodes
  - 2 Login Nodes
  - 2 Management Nodes

# Software Stack and Responsibilities

| | | |
|---|---|---|
| NASA/NOAA Applications | Applications – GEOS5, GFS | SIVO, GMAO, NOAA |
| User Libraries | Libraries – netcdf, baselibs (GMAO) | USG, SIVO |
| Commercial Software | IDL (4 seats), Matlab (not installed yet) | NCCS SAs, USG |
| Message Passing Libraries | Intel MPI, MVAPICH (os) | NCCS SAs, USG |
| Tools | gcc debugger (os), other? | NCCS SAs |
| Compilers | Intel Compilers, gcc (os) | NCCS SAs |
| Resource Management | Altair PBS Pro v. 10 | NCCS SAs |
| File System | IBM GPFS | NCCS SAs |
| Interconnect | OpenIB (os) | NCCS SAs |
| Operating System | Novell SLES Linux 11 (os) | NCCS SAs |
| Management Software | IBM xCAT (os) | NCCS SAs |

# Colloquium and Workshops

- ECMWF-JCSDA Workshop on Clouds and Precipitation
  - ECMWF, Reading June 2010
  - Follow-on to 2006 JCSDA Workshop
  - ~60 participants (20 from the US)
  - Important topic for NWP and data assimilation in terms of products, modeling and observations
  - Preparation of NWP users for future missions (e.g. GPM)
  - Recommendations in Workshop Summary (mostly model and data assimilation system development)
- JCSDA-HFIP Workshop on Satellite Data Assimilation for Hurricane Forecasting
  - AOML, Miami, Dec 2-3 2010
  - 50+ scientists from research and operations
    - Current data assimilation systems used for hurricane prediction
    - Various types of satellite data used for hurricane prediction
    - Future directions
  - Full Workshop Report (including recommendations) available at: http://www.jcsda.noaa.gov/meetings_JCSDA-HFIPWorkshop2010.php

# Outlook

- External Research
  - FY 2010: NOAA (FFO)
  - FY 2011: NASA (ROSES)
  - FY 2012: DoD (still in planning stages)
- Preparation for new sensors
  - NPP, ADM, SMAP, Aquarius, FY-3, …
- Summer Colloquium
  - Training event modeled on the 2009 Summer Colloquium
- Fifth *WMO Workshop on the Impact of Various Observing Systems on NWP*, late May 2012 in the US (venue still TBD)

# Backup slides

# JCSDA History

- NASA/NOAA collaboration (Uccellini, Einaudi, Purdom, McDonald) initiated in 2000
  - Concern about US leadership in satellite data technology and instrumentation not replicated in applications, e.g. NWP
  - GMAO (DAO), NCEP and STAR (ORA)
  - Emphasis on balanced approach involving
    - Modeling
    - Computing
    - Observational data
- Inclusion of DoD (NRL Monterey and AFWA) triggered by IPO sponsorship of JCSDA starting in 2002
- First permanent Director hired in 2004 (John Le Marshall)
- Memorandum of Agreement signed May 2008

# JCSDA Science Priorities

*Overarching goal: Help the operational services improve the quality of their prediction products via improved and accelerated use of satellite data and related research*

- Radiative Transfer Modeling (CRTM)
- Preparation for assimilation of data from new instruments
- Clouds and precipitation
- Assimilation of land surface observations
- Assimilation of ocean surface observations
- Atmospheric composition; chemistry and aerosol

*Driving the activities of the Joint Center since 2001, approved by the Science Steering Committee*

# JCSDA Management Structure


**Agency Executives**

NASA, NOAA, Department of the Navy, and Department of the Air Force

**Management Oversight Board**

NOAA / NWS / NCEP (Uccellini)

NASA/GSFC/Earth Sciences Division (Hildebrand)

NOAA / NESDIS / STAR (Powell)

NOAA / OAR (Atlas)

Department of the Air Force / Air Force Director of Weather (Egentovich)

Department of the Navy / N84 and NRL (Chang, Curry)

**JCSDA Executive Team**

Director (Riishojgaard)

Deputy Director (Boukabara)

Partner Associate Directors

(Lord, Rienecker, Phoebus, Zapotocny, Benjamin)

Advisory Panel

Co-chairs: Jim Purdom, Tom Vonder Haar, CSU

Science Steering Committee

(Chair: Craig Bishop, NRL)

# JCSDA Mode of operation

- Directed research
  - Carried out by the partners
  - Mixture of new and leveraged funding
  - JCSDA plays a coordinating role
- External research
  - Grants awarded following proposals submitted to Federal Funding Opportunity, administered by NOAA on behalf of all JCSDA partners
    - Option for contracts included for FY2011 (NASA ROSES)
  - Open to the broader research community
  - Funding awarded competitively, peer review process
- Visiting Scientist program

# JCSDA accomplishments

- Common assimilation infrastructure (EMC, GMAO, AFWA)
- Community radiative transfer model (all partners)
- Common NOAA/NASA land data assimilation system (EMC, GSFC, AFWA)
- Numerous new satellite data assimilated operationally, e.g. MODIS (winds and AOD), AIRS and IASI hyperspectral IR radiances, GPSRO sensors (COSMIC, GRAS, GRACE), SSMI/S, Windsat, Jason-2,…
- Advanced sensors tested for operational readiness, e.g. ASCAT, MLS, SEVIRI (radiances),…
- Ongoing methodology improvement for sensors already assimilated, e.g. AIRS, GPSRO, SSMI/S,…
- Improved physically based SST analysis
- Adjoint sensitivity diagnostics
- Emerging OSSE capability in support of COSMIC-2, JPSS, GOES-R, Decadal Survey and other missions