Joint Center for Satellite Data Assimilation

Jim Yoe, NWS/NCEP
Chief Administrative Officer for JCDSA
Background & Introduction

JCSDA Modes of Operation

- Directed Research
  - Directed by JCSDA affiliated scientists
  - Example of DRT between NESDIS and NWS
  - Carried out by the partners
  - Mixture of new and leveraged funding
  - Short-term ROI expected
  - Grants and/or contracts awarded
  - Administered alternately by NOAA, NASA with contribution from DoD
  - Open to the broader research community
  - Funding awarded competitively
  - Near-term ROI expected

- External Research
  - Great way to initiate/strengthen involvement with JCSCA
  - Open to scientists from everywhere
  - Short-term (a few weeks/months)
  - Requires to identify host at partner institution; work on JCSDA-relevant topic
  - Mid-term ROI expected

- Visiting Scientist Program (VSP)
  - Research undertaken independently by partners, overlapping with JCSDA priorities
  - Results/deliverable are made available and shared with/between partners
  - JCSDA mainly coordinates

- In-Kind Research
  - Offers O2R environment
  - Open to External scientists, even not funded by JCSDA
  - Goal: funnel efforts toward helping the JCSDA partners (incl. NOAA)
  - Carrot is access to HPC & operational systems in R&D
  - S4 and JIBB

- O2R Facilitation
  - Grants and/or contracts awarded
  - Administered alternately by NOAA, NASA with contribution from DoD
  - Open to the broader research community
  - Funding awarded competitively
  - Near-term ROI expected

April 14, 2015
Testbed-Proving Ground Workshop
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

Approved by the Science Steering Committee
## Selection of Base Projects

<table>
<thead>
<tr>
<th>Category</th>
<th>Activity</th>
<th>Outcome</th>
<th>Beneficiaries</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Science &amp; Advanced Data Assimilation</strong></td>
<td>- Scientific/technical Support to CRTM</td>
<td>- Improved CRTM</td>
<td>All (inc. NWS, NESDIS)</td>
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<td></td>
<td>- Spectroscopy Improvements (including LBL modernization)</td>
<td>- Modern LBL model (in progress)</td>
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<td></td>
<td>- Cloudy radiance assimilation</td>
<td>- ATMS, AMSU, MHS, SSMIS</td>
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<td></td>
<td>- Optimize DA of microwave sounders and imagers (ATMS, SSMIS, AMSU, MHS,..)</td>
<td>- GPM, AMSR2, Imaging channels</td>
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<td></td>
<td>- Land Data Assimilation</td>
<td>- SMAP</td>
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<td></td>
<td>- Ocean data Assimilation</td>
<td>- AHVRR/MODIS/VIIRS GVF</td>
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<td>- Jason-2/3</td>
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<tr>
<td><strong>Tools</strong></td>
<td>- Multi-Platform QC and Pre-Processing Tool (MIIDAPS)</td>
<td>- Universal QC tool and Pre-processor for all satellite data</td>
<td>All partners (inc. NESDIS, NWS)</td>
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<tr>
<td></td>
<td>- Community Multi-Formatting Tool (CMFT)</td>
<td>- For BUFrizing all sat. data</td>
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<td>All (esp. academia and ext. research partners)</td>
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<td></td>
<td>- Community Sampling Thinning &amp; Representativeness Optimization Tool (CSTROT)</td>
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<td><strong>New Sensors</strong></td>
<td>- Geo DA: <strong>Himawari-8 Assimilation</strong>, <strong>GOES-R ABI Readiness</strong></td>
<td>- On-going effort.</td>
<td>NESDIS - NWS</td>
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<td></td>
<td>- Microwave sensors: <strong>GPM</strong> GMI, GCOM-W AMSR-2</td>
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<tr>
<td><strong>O2R Environment Extension</strong></td>
<td>- <strong>Extend O2R to GDAS T1534, 4DHybrid</strong></td>
<td>- Allow Science activities to be using the most up to date version</td>
<td>NWS - NESDIS</td>
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<td></td>
<td>- Extend O2R to HWRF, etc</td>
<td>- Allow more systems to be improved</td>
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<td>- Helps the R2O process</td>
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<td>- Increase ROI of NESDIS projects</td>
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</table>
## HDRA 2013 (Sandy) JCSDA Activities

<table>
<thead>
<tr>
<th>Category</th>
<th>Activity</th>
<th>Outcome</th>
<th>Beneficiaries</th>
<th>Comments</th>
</tr>
</thead>
</table>
| **Science & Advanced Data Assimilation** | - AMV Data Assimilation Improvement  
- Cloudy Radiance Data Assimilation  
- Geostationary Radiance Assimilation Improvement  
- SSMIS Data Assimilation Optimization  
- Land Data Assimilation  
- Ocean data Assimilation | - Improved CRTM  
- Modern LBL model (in progress)  
- Assimilation of: ATMS, AMSU, MHS, SSMIS, GPM, AMSR2, Imaging channels, SMAP, AHVRR/MODIS/VIIRS GVF, Jason-2/3 (on going effort)  
- Mitigate the effect of the potential loss of the PM orbit (on going) | - All (inc. NWS, NESDIS) |          |
| **New Sensors & OSSE**            | - OSSE Activities (Geo Hyperspectral, Radio Occultation) | -On-going effort.  
- Assess future sensors configuration (Radio Occultation sensors, Hyperspectral Sensor on Geo) | -NESDIS  
-NWS  
-OAR |          |
| **O2R Environment Extension**     | - Upgrade/extend the JIBB and S4 supercomputers | -Double capacity of the JCSDA HPC  
- Allow highest resolutions systems to be worked on | - NWS  
-NESDIS  
-OAR |          |
# Selection of External Research

## Selected Projects through the NOAA Federally-Funded Opportunity (FFO) –FY13

<table>
<thead>
<tr>
<th>Project #</th>
<th>Proposal Number(s)</th>
<th>Title</th>
<th>Institution</th>
<th>PI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12,10</td>
<td>Modernization of the Community line-by-line models and CRTM-OSS Implementation</td>
<td>Atmospheric &amp; Environmental Research (AER)</td>
<td>Jean-Luc Moncet, PI Eli Mlawer, co-PI</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>Improvement and validation of JCSDA’s Community Radiative Transfer Model (CRTM) Optical Properties</td>
<td>Texas A&amp;M University</td>
<td>Ping Yang, PI</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>Evaluation and Improvement of Land Surface States and Parameters to Increase Assimilation of Surface-Sensitive Channels and Improve Operational Forecast Skill</td>
<td>University Corporation for Atmospheric Research</td>
<td>Michael Barlage, PI Xubin Zeng, co-PI</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>Assimilation of All-Sky Microwave and Infrared Satellite radiances: from research to Operations</td>
<td>National Center for Atmospheric Research University of Wisconsin, Cooperative Institute for Meteorological Satellite Studies</td>
<td>Thomas Auligne, PI</td>
</tr>
</tbody>
</table>

The FY15 External Research Opportunity:
- **Selection in progress.**
- **Target Start date: August 2015.**

The upcoming JCSDA newsletter will highlight all JCSDA external research projects, pre-faced by T. Lee (NASA) and S. Boukabara (NOAA)
## Selection of Visiting Scientists at JCSDA-NOAA (FY14 Cycle)

<table>
<thead>
<tr>
<th>Visit (Title)</th>
<th>Host Institution (Beneficiary)</th>
<th>Area of benefit</th>
<th>V. Scientist Parent Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Migration of a wind-wave data assimilation scheme to NOAA systems</td>
<td>NWS</td>
<td>Ocean Data Assimilation</td>
<td>Naval Service, Argentina</td>
</tr>
<tr>
<td>HYBRID data assimilation for the Indian Ocean</td>
<td>NWS</td>
<td>Ocean Data Assimilation</td>
<td>Indian Met. Service (India)</td>
</tr>
<tr>
<td>Exploring Mathematical cutting edge techniques in satellite data assimilation</td>
<td>NESDIS</td>
<td>CRTM &amp; Inversion In Cloudy/Precipitating Conditions</td>
<td>Georgetown University (US)</td>
</tr>
</tbody>
</table>
GMI Data Assimilation

(Preliminary but Encouraging Results)

- JCSDA began optimizing the assimilation of GMI data in GDAS.
  - A new QC subroutine has been developed to filter out cloud and precipitation contaminated observations from GMI data for clear sky data assimilation.
  - Bias correction, observation errors, and QC routines continue to be optimized, and forecast impacts are being assessed.

Preliminary assessment shows the assimilation of GMI data changing forecast hurricane tracks and the skill scores of forecast variables.

- Results are mixed, sample sizes thus far have been small.
- Work is ongoing to isolate and qualify forecast impacts.
SNPP ATMS Assimilation Optimization

**Current Assimilation**
- S-NPP ATMS assimilated operationally at NCEP since May 2012 GDAS/GFS upgrade (L+6 months)
- Next generation MW sounder should have some positive impact on NWP forecast.
  - Additional channels (1 51 GHz, 2 183 GHz)
  - Scan geometry (Nyquist sampling, wider swath)

**Assimilation Improvements**
- Enhance data thinning/data selection from coarse (skip 5 out of every 6 FOVs) to intelligent thinning (CSTROT).
- Optimize spatial averaging (maintain high resolution for sounding/water vapor channels).
- Implement dedicated ATMS Quality Control routine based on 1DVAR preprocessor to increase the number and quality of assimilated observations.

**Optimization Results**
- **10% more observations per sounding channel, per cycle, with new QC**
- **Statistically significant increase in SH Anomaly Correlation (500 mb). Neutral NH.**

Forecasts with ATMS (and no AMSU) show similar performance to forecasts with no ATMS (with AMSU)

Reduction in Tropical Cyclone Track Forecast Error

April 14, 2015

Testbed-Proving Ground Workshop
• DMSP SSMI/S on-board 4 platforms (F16, F17, F18, F19) in early morning polar orbit
  ▪ F16 sounding channels failed
  ▪ F19 available Q1 FY15
• 2015 NCEP GDAS/GFS upgrade will assimilate temperature sounding channels
  ▪ No imaging/water vapor channels assimilated
• Forecast impact from SSMI/S is neutral
• Work in progress to extend to DMSP F19

SSMI/S Assimilation Optimization

Optimization Approach (2016 GDAS/GFS Upgrade)

New liquid and ice cloud retrieval algorithms, and removal of precipitation pre-screening.

Current SSMIS 19 GHz O-B

Just 500 observations over ocean passing QC but not assimilated for imaging 19 GHz

New SSMIS 55 GHz O-B

Better QC leads to more middle/upper tropospheric observations being assimilated (400 more obs for this cycle)

Current SSMIS 55 GHz O-B

Characterize SSMIS imaging channel bias and error for application in GSI

April 14, 2015
Testbed-Proving Ground Workshop
AMV Data Assimilation Optimization

- Compare difference between NCEP and NAVY (NRL) impact of AMVs on data assimilation systems.
  - Data volume differences
  - Observation error
  - Filtering (thinning versus superobbing/averaging)
  - Blacklisting/QC of data types assimilated

JDCA satellite winds working group established between partnering agencies (NESDIS/JCSDA, NCEP/EMC, NAVY/NRL, NASA/GMAO, U.Wisc/CIMMS) to leverage earlier work and to improve AMV assimilation across the board.

GDAS analysis is improved with respect to ECMWF analysis in the region of the Tropical Easterly Jet (TEJ).

Plans: Continue optimization of AMV observation errors, filtering, data usage and investigate regional and global analysis and forecast skill within the GSI/GFS.
Assessment of AHI H8 sample data

*(GOES-R Readiness)*

- BUFR observations (courtesy of W. Wolf, NESDIS, Y. Song, IMSG) from JMA’s 2015-01-25 full disk sample is thinned by selecting every 10\textsuperscript{th} point ~ 20km spacing between 2km pixels.

- Clear-sky filtering using a threshold of 1.25K in the difference between a split-window simulated regression SST and NWP (ECMWF) SST.
  - Viewing angle restricted to be within 55° of nadir.
  - Roughly 10\% of thinned pixels over ocean are determined to be clear; however, some residual cloud remains.
Objective of CSTROT:
- Develop a new thinning scheme to optimize satellite data usage in GSI data assimilation for both global and regional modeling systems.

CSTROT Functions:
- **Thinning options:**
  - using Standard Deviation
  - using regression
  - by skipping points
- **Representation options:**
  - Random points
  - Closest point
  - Averaging
- **Nested domain options:**
  - by target regions
  - by domain size

CSTROT is an “intelligent” thinning tool to optimize satellite data selection in DA.

April 14, 2015
Testbed-Proving Ground Workshop
OSSE Activities
Hypothetical Sensors

• **Sponsor-funded OSSE activities were undertaken in JCSDA:**
  – Wind Lidar OSSE effort funded by NASA
  – Hyperspectral Geo sensor OSSE funded by NESDIS
  – DoD-requested OSSE in support of DMSP-follow on decision making (DWSS)

• **OSSE activity has been initiated in NOAA. JCSDA in leading role**
  – In support of H. Sandy funded *data gap mitigation strategy*
  – Goals to achieve:
    – (1) set up the next generation OSSE tool (newest data assimilation system, higher spatial resolution, new NR, etc)
    – (2) Provide authoritative evaluations on the impact of Geo-based hyperspectral sensors and Radio Occultation sensors (multiple commercial options), Geo-based MW sensor on NOAA systems

• **Effort is well coordinated with QOSAP initiative**
  – Main focus of JCSDA is global experiments
  – Coordination ongoing with AOML, ESRL, CIMMS, etc
Impact Assessment of JPSS Data Gap

The launch of JPSS-1 will occur past the design life of heritage passive microwave and infrared atmospheric sounders on the current POES and Suomi-NPP platforms.

A new set of “Data Denial” experiments are being run to assess the expected forecast impact if no Afternoon, polar-orbiting satellite data is available due to the data gap.

The “Control” experiment establishes baseline performance of the current satellite observing system capability.

The “3polar” experiment removes the redundancy of observations but maintains platforms flying in early-morning, mid-morning, and afternoon polar orbits.

The “2polar” experiment removes the redundancy of observations plus all platforms flying in the afternoon polar orbit (the data gap).

The “1polar” experiment removes the redundancy of observations plus both the early-morning and afternoon polar orbits (leaving only mid-morning observations).

April 14, 2015
Impact Assessment of JPSS Data Gap

Experiments

• Current operational GDAS/GFS (T574/T1534 resolution)
• 1 Season: May 15, 2014 - July 31, 2014
• 4 experiments:
  – Control run
  – 3 polar
  – 2 polar (data gap)
  – 1 polar

Status

• All experiments processed May 15 – July 3, 2014.
• Preliminary results are showing expected degradation of forecast performance from Control to 3polar to 2polar experiments.
• Degradation from Control to 3polar suggests current observing system is not completely redundant.
• We will extend the experiments to independently verify impact of Individual Obs Systems
# Planned FY15 Priorities

<table>
<thead>
<tr>
<th>Category</th>
<th>Planned FY15 Activities</th>
<th>Expected Outcome</th>
<th>Availability of Resources</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Priority Baseline Activities</td>
<td>- CRTM</td>
<td>- Improved CRTM</td>
<td>- Yes (Base)</td>
<td>- This is the main directed research program in JCSDA</td>
</tr>
<tr>
<td></td>
<td>- Passive Microwave Sounders DA</td>
<td>- ATMS, AMSU, MHS, SSMIS</td>
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<td>- Hard choices must be made to accommodate other priorities</td>
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<tr>
<td></td>
<td>- Passive Microwave Imagers DA</td>
<td>- GPM, AMSR2, Imaging channels</td>
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<td>- Reduction of support expected</td>
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<td>- Radio Occultation</td>
<td>- SMAP</td>
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<td></td>
<td>- Land Data Assimilation</td>
<td>- Jason-2/3</td>
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<td>- Ocean data Assimilation</td>
<td>- SNPP VIIRS</td>
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<td>- Aerosols DA</td>
<td>- SNPP OMPS</td>
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<td>- Ozone DA</td>
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<td>New Sensors</td>
<td>- Megha-Tropiques SAPHIR</td>
<td>- Improvement in Upper WV skills (Meteo-France info., see EUMETSAT conf.)</td>
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<td></td>
<td>- HIMAWARI – AHI8</td>
<td>- Increase readiness <strong>GOES-R ABI</strong></td>
<td>- No (best effort to fold it under passive microwave DA efforts)</td>
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<td></td>
<td>- OCO-2</td>
<td>- Explore use of Sfc Pressure globally</td>
<td>- Yes (H. Sandy effort)</td>
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<td></td>
<td>- ISS-RapiSCAT</td>
<td>- Surface Wind speed</td>
<td>- No (best effort to fold it under IR DA efforts)</td>
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<td></td>
<td>- Yes (under active sensors DA)</td>
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<td>Impact Assessments</td>
<td>- Initial implementation of <strong>JosASC</strong> Initiative</td>
<td>- Ability to assess impact of GOS in hurricane conditions and at global scale</td>
<td>- No but funds to be carved out from JCSDA and QOSAP to seed-fund it</td>
<td>- This would be at the expense of other baseline activities</td>
</tr>
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<td></td>
<td>- Data Gap Impact assessment &amp; mitigation effort impact assessment</td>
<td>- Better readiness for a data gap situation. Evaluate the impact of the added value.</td>
<td>- Yes (H. Sandy)</td>
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<td>- Would require sustained HPC and funding for future years</td>
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<tr>
<td>Support the Data Gap Mitigation effort (H. Sandy funding)</td>
<td>- AMV Data Assimilation (cont’d)</td>
<td>- Mitigate the impact of losing the PM orbit</td>
<td>- Yes (H. Sandy)</td>
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<td></td>
<td>- Cloudy Radiance assimilation</td>
<td>- Evaluate options for future instruments</td>
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<td>- Geo radiance data assimil.</td>
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<td></td>
<td>- OSSE experiments</td>
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April 14, 2015

Testbed-Proving Ground Workshop
Aerosols Data Assimilation Coordination

Improving NCEP global aerosol forecasts using JPSS S-NPP VIIRS aerosol products

**The Scope of the Project**

**NOAA Model**
- NEMS GFS Aerosol Component (NGAC)

**Satellite Observations**
- Aerosol observations from S-NPP VIIRS

**NOAA DA System**
- The hybrid EnKF-GSI system
- **New Capability** to assimilate aerosol optical depth (AOD) observations

**NOAA Products**
- **New Product:** Aerosol analysis for multi-species

**Proposed approach:**

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Institutes</th>
<th>Resources (FTE)</th>
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<tbody>
<tr>
<td>Aerosol data assimilation algorithm</td>
<td>GSFC</td>
<td>-- (Leveraging aerosol development at GMAO)</td>
</tr>
<tr>
<td>VIIRS observation processing</td>
<td>STAR</td>
<td>0.2</td>
</tr>
<tr>
<td>Implementation and testing</td>
<td>NCEP</td>
<td>0.8</td>
</tr>
</tbody>
</table>

- Improve real-time NGAC aerosol forecasts
- Enhance aerosol capability in Next-Generation Global Prediction System (NGGPS)
Ocean Data Assimilation Coordination

(POCs: NESDIS Eric Bayler - NWS Avichal Mehra)

Objective:
Implement NCODA (Navy’s Coupled Ocean Data Assimilation) for NCEP ocean forecasting operations

Sensors/Data:
- SST: NOAA & METOP GAC/LAC (AVHRR); VIIRS; COMS; GOES, MTSAT, MSG;
  - Microwave: AMSR-E, AATSR, WindSat
- SSS: Aquarius, SMOS
- Sea Ice concentration and temperature: AMSR-E, SSMI
- Altimeter SSH: Jason-2, SARAL/AltiKa, CryoSat
- T, S and Velocity profiles from in situ platforms: ARGO, ships, buoys, variety of other profilers

Target models & products:
- Global RTOFS: SSH; sea-Ice concentrations and drifts; T, S and velocity fields for full 3D ocean.
Land Data Assimilation Coordination

(POCs: NESDIS J. Zhan - NWS M. Ek)

JCSDA Applications of NASA SMAP Data

- Two NOAA SMAP Early Adopters will ingest and assimilation SMAP soil moisture and freeze/thaw data products to improve forecasts of daily rainfall, air temperature, humidity, root-zone soil moisture, skin temperature, runoff and in turn drought and river floods.
- NESDIS will ingest SMAP data through Soil Moisture Operational Product System (SMOPS) as inputs to NWS-NCEP models.
- NWS-NCEP has tested a GFS-EnKF coupled system to test impact of assimilating satellite soil moisture data on numerical weather prediction (NWP).
- NWS-NCEP and NESDIS-STAR will collaborate on the development of a GFS/GLDAS/LIS semi-coupled system for operational land data assimilation.
Backups
Accomplishments - CRTM

CRTM Mission
- Satellite radiance simulation and assimilation for passive MW, IR, & Visible sensors of NOAA, NASA, DoD satellites, and others (200 sensors)
- Simulation of clear/cloudy/precipitating scenes, globally

CRTM Applications
- Data assimilation in supporting of weather forecasting
- Physical retrieval algorithm for products
- Stability and accuracy monitoring of satellite observations
- Education and Research: reanalysis, climate studies, air quality forecasting, and a radiative tool for students

CRTM Future Development
- Aquarius, SMOS, SMAP,..
- CRTM for CMAQ
- CRTM unapodized capability
- CRTM for cloudy/rainy data assimilation

ATMS Ch. 4 (O-B) GDAS

(slide based on Q. Liu presentation)
O2R Environment
A pre-requisite for a successful R2O Transition

- This is a critical piece for a successful R2O. O2R involves:
  - Supercomputer(s): JIBB, S4, Zeus Allocation
  - Porting/benchmarking codes/systems/libraries
  - Documentation to help researchers navigate
  - User Support

- Status:
  - GSI, GFS implemented/benchmarked
  - HWRF implemented and benchmarked
  - Synchronization with T1534 completed
  - On-going porting of the 4D Hybrid
  - JCSDA secured an upgrade to its JIBB and S4 supercomputers to perform OSSEs/OSEs and to keep up with the newest resolution
  - JCSDA secured an increase to its NOAA R&D allocation for this year on Zeus (1million core hours) to allow contribution to the H. Sandy data gap mitigation effort. [yet to be implemented]

- In progress:
  - Extension of O2R to include Ocean DA (NCODA, HYCOM)
  - Extension of O2R to include Land Systems (LIS).

JIBB Utilization by Application
March 2014

More than ~ 50 users on both JIBB and S4 (total more than ~100). Mixture of NOAA and external Researchers

Scientific efforts in satellite DA in JCSDA (funded by GOES-R, JPSS, etc)

Scientific efforts in satellite DA in academia

Scientific efforts in satellite DA in NOAA

Products, techniques, improvements, with direct and immediate relevance to NOAA NWS Operational Models (both global and regional)
OSE Activities / Impact Assessment

(1) No Satellite / (2) No Conventional Data
15 Aug – 30 Sep 2010
500 hPa Anomaly Correlations

- An extensive assessment of the global observing system impact on NOAA forecast system has been undertaken.

- The impact assessment was done wrt satellite data (collectively & individually: microwave AMSU, MHS, GPS, hyperspectral IR, AMVs, etc) as well as conventional data.

- Satellite data as a group, had a very significant impact which surpasses the conventional data impact (by a wide margin), especially in the southern hemisphere.

- The impacts of individual classes of sensors did not add up to the significant impact above.

Results from the extensive data denials experiments performed in the JCSDA, aimed at assessing the impact of the global Plots courtesy of J. Jung.