Transition from Research to Operations in the Joint Center for Satellite Data Assimilation

Lars Peter Riishojgaard, JCSDA Director
Overview

- R2O motivation (societal impact of NWP)
  - Why satellite data?
- Introduction to JCSDA
  - Background, structure, accomplishments, sample activities
- JCSDA Computing
- Summary and conclusions
Weather Prediction and the US Economy; A Macroscopic View

- Department of Commerce: “20% of overall US economy is weather sensitive”: ~$3 trillion/year
  - Impact to air and surface transportation, agriculture, construction, energy production and distribution, etc.
- Assume that half of this is “forecast sensitive”: $1.5 trillion/year
- Assume that the potential savings due to weather forecasting amount to 5% of the “forecast sensitive total”: ~$75B/year
• Assume that the savings are distributed linearly over the achieved forecast range for the global NWP system:
  – 0 h useful forecast range => $0 in savings
  – 336 h useful forecast (two weeks maximum predictability) range => $75B in savings

• This implies that the value to the United States economy of weather observations, dissemination, forecast products and services is $\geq 200M$ per hour of forecast range per year!
NWP requirements for upper-air data coverage

Hence the need for a global observing system, irrespective of target location of forecast!
Impact of GOS components on 24-h ECMWF Global Forecast skill
(courtesy of Erik Andersson, ECMWF)

Satellite data now account for most of the skill.
Growing importance of research data.
J CSDA History

- NASA/NOAA collaboration (Uccellini, Einaudi, Purdom, McDonald) initiated in 2000
  - Concern about US leadership in satellite data technology and instrumentation not replicated in user 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 J CSDA starting in 2002
- First permanent Director hired in 2004 (John Le Marshall)
- Memorandum of Agreement signed May 2008
**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.
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 (Edwards)
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)
J CSDA 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
J CSDA Mode of operation

- Directed research
  - Carried out by the partners
  - Mixture of new and leveraged funding
    - NOAA appropriation comes through NESDIS/STAR
  - J CSDA plays a coordinating role

- External research
  - Grants or contracts awarded to by one of the J CSDA parent agencies on a rotating basis
  - Open to the broader research community
  - Funding awarded competitively, based on peer-reviewed proposals

- Visiting Scientist program
J CSDA 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
JCSDA accomplishments (II)

- OSSE capability in support of COSMIC-2, JPSS, GOES-R, Decadal Survey and other missions
- Comprehensive suite of data impact experiments for all major observing systems using NCEP GFS
- Supercomputer at GSFC (jointly funded by NASA and NOAA, installed and operated by NASA for the Joint Center)
- Part of NOAA/NESDIS-funded supercomputer (S4) located at UW Madison available for JCSDA investigators
- Hand-off to NCEP of ATMS data assimilation capability (collaboration between EMC, NESDIS, NASA, JCSDA); implemented in operations on May 22 2012
Impact of COSMIC methodology update

- 500 hPa height AC scores as a function of the forecast for the 500 hPa heights in the Southern Hemisphere
- 40-day experiments:
  - expx (NO COSMIC)
  - cnt (old RO assimilation code - with COSMIC)
  - exp (updated RO assimilation code - with COSMIC)

COSMIC provides 8 hours of gain in model forecast skill starting at day 4

November 6-7 2013

Courtesy of Cuccurul, NCEP/EMC
Example of data impact study (CRTM v. 1 to v. 2 upgrade)

500 hPa geopotential height anomaly correction from 01/09/2008-02/22/2008

New implementation meets basic “do no harm” criterion

Large impact in the SH (more sensitive to satellite data)

Courtesy of Fuzhong Weng, NESDIS/STAR
OSCAT Experiments in JCSDA with the NCEP GFS

Slide courtesy of Li Bi

850hPa WIND
Global

500hPa WIND
Global
Current Polar Constellation

Slide courtesy of Kevin Garrett

Note that currently not all satellites are assimilated (no need given the redundancy)

SNPP instruments fail before JPSS 1 is launched. No Polar PM data

Future satellite (high level confidence)

Constellation as of September 2012. Sources: NESDIS/OSO & CGMS/WMO pages

Mean Local Times at the Ascending Node (hh:mm)
Data Denial Setup

• Use May 2012 version of GDAS/GFS
  – GSI Hybrid 3DVar/EnKF
  – Resolution: T574 (analysis/forecast) and T382 for ensembles (operational resolution)
  – 2 seasons
    • Summer season – August 1-September 30, 2012
    • Winter season – January 1-February 28, 2013
    • 20 day spin-up time (experiments started 7/10/2012 for 1st season)
    • Summer season extended through November 4 to cover Hurricane Sandy case study
  – SSMI/S capability ported to S4 from GSI trunk for early morning polar coverage
  – All experiments are run on S4
## Data Denial Experiments

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*AIRS and MODIS IR winds are a proxy for SNPP CrIS and VIIRS*
500 hPa Anomaly Correlation

Anomaly Correl: HGT P500 G2 00Z, Day 5

Anomaly Correl: HGT P500 G2/NHX 00Z, Day 5

Anomaly Correl: HGT P500 G2/SHX 00Z, Day 5
Preparation for data from new sensors

- Goal is to have operational users ready to
  - assess data from new sensors from day 1
  - assimilate data from new sensors within one year from launch
- Current activities include
  - Suomi/NPP VIIRS, OMPS in close collaboration with NESDIS/STAR, NCEP/EMC
  - Aquarius
  - SMAP
  - GPM
  - GOES-R (ABI, GLM)
  - ...
Observing System Simulation Experiments (next talk by Sean Casey)

- OSSEs are designed to assess the impact of candidate future observing systems
  - Support for important programmatic decisions on satellite programs
  - Trade-studies during design and development
  - Learning tool for data assimilation experiments prior to launch
- Similar to data denial experiments, and yet fundamentally different
  - Everything (nature, reference observations, and candidate observations) is simulated
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

Some resources available on

NOAA R&D computer
- No projected growth for JCSDA

NASA made initial investment in JCSDA supercomputer to address this problem
- IBM Linux cluster; 576 Intel Westmere processors
- Immediately augmented by NOAA (GOES-R) to 3456 processors
- Located at Goddard, operated by NCCS for the Joint Center
- NOAA/NESDIS provides scientific software support
**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
System first open to J CSDA users 01/2011
As of 08/2013 ~50 J CSDA users; many J CSDA applications have been ported on to this system
  - GDAS porting completed late 2011
  - Hybrid DA system ported immediately after initial GDAS port
  - Code management plan between NCEP and J CSDA under development to facilitate two-way code transfers (“R2O and O2R”)
System currently in the process of being expanded (Hurricane Sandy Relief Bill)
  - Doubling of capacity (cycles and storage)
Next Steps

- New Operational satellites
  - JPSS (& more complete exploitation of S-NPP)
  - GOES-R
  - ...
- New Research Satellites
  - ADM/Aeolus Doppler Wind Lidar
  - GPM, SMAP
- New International Satellites/Sensors
  - ASCAT, OSCAT, COSMIC-2, GCOM-W, Himawari, JASON-3, FY-3, Korean, etc.
- 4D Hybrid Data Assimilation
- Full Earth Systems Modeling:
  - Land, Ocean, and Ice as well as Atmosphere
Summary

- JCSDA activities have had clear impact on operational activities in all partners
  - Joint systems and code (CRTM, GSI, LIS, …)
  - Additional sensors (AIRS, MODIS, COSMIC, IASI, SSMI/S,…)
  - Ongoing improvements to assimilation methodology and diagnostics (observation operators, adjoint sensitivity,…)
  - Major improvements in forecast skill result from adding large number of small improvements
- Several CICS staff involved in JCSDA R2O transition activities
- Synergy between research and operations critically important to success of JCSDA