

NASA Contributions to the JCSDA GMAO & Hydrological Sciences Branch

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NASA/Goddard Space Flight Center



JCSDA Advisory Board Presentation
January 27, 2009

NASA Participation in the JCSDA

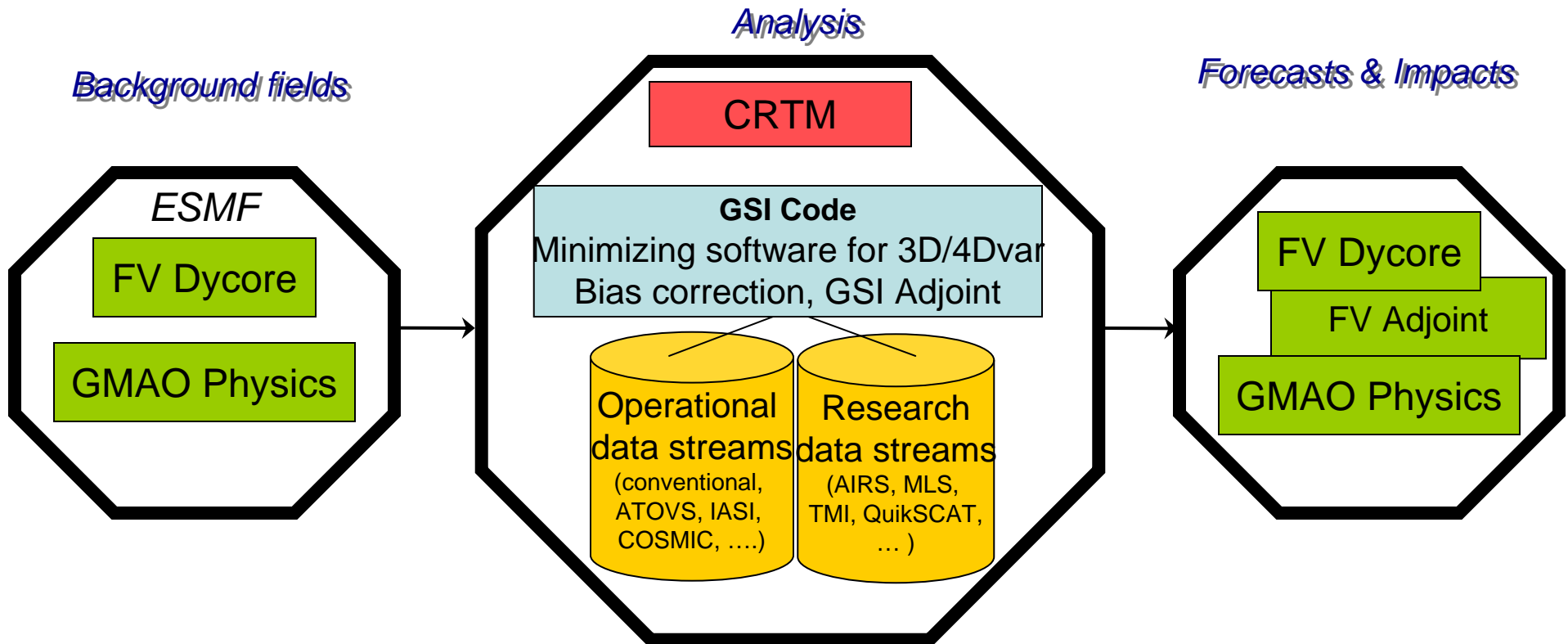
Research Partner

- ✓ **HQ supports the JCSDA FFO**
- ✓ **Global Modeling & Assimilation Office**
 - ❑ Joint atmospheric data assimilation system development with NCEP
 - ❑ Contributing to transition of NASA's research data into operations – our focus: AIRS, MLS T and O₃ retrievals
 - ❑ Collaborating in preparations for NPP/NPOESS – our focus: OMPS
 - ❑ Transitioning GOCART to GFS for air quality analysis and prediction
 - ❑ Ocean data assimilation collaboration with NCEP and with JCSDA science team
- ✓ **Hydrological Sciences Branch**
 - ❑ Implementation of Land Information System (LIS) in NCEP's GFS
 - ❑ Facilitating land data assimilation via LIS (with GMAO) for Noah LSM
 - ❑ Contributing LIS to the JCSDA science team

A few highlights....

- GMAO-NCEP coordination on atmospheric data assimilation
- MLS Temperature & Quick-look MLS product tests
- System update – 4DDA system - Observing system impacts
with Adjoint tools
- LIS and Land data assimilation
- MOM4 and Ocean data assimilation

GEOS-5 ADAS



Analysis Component

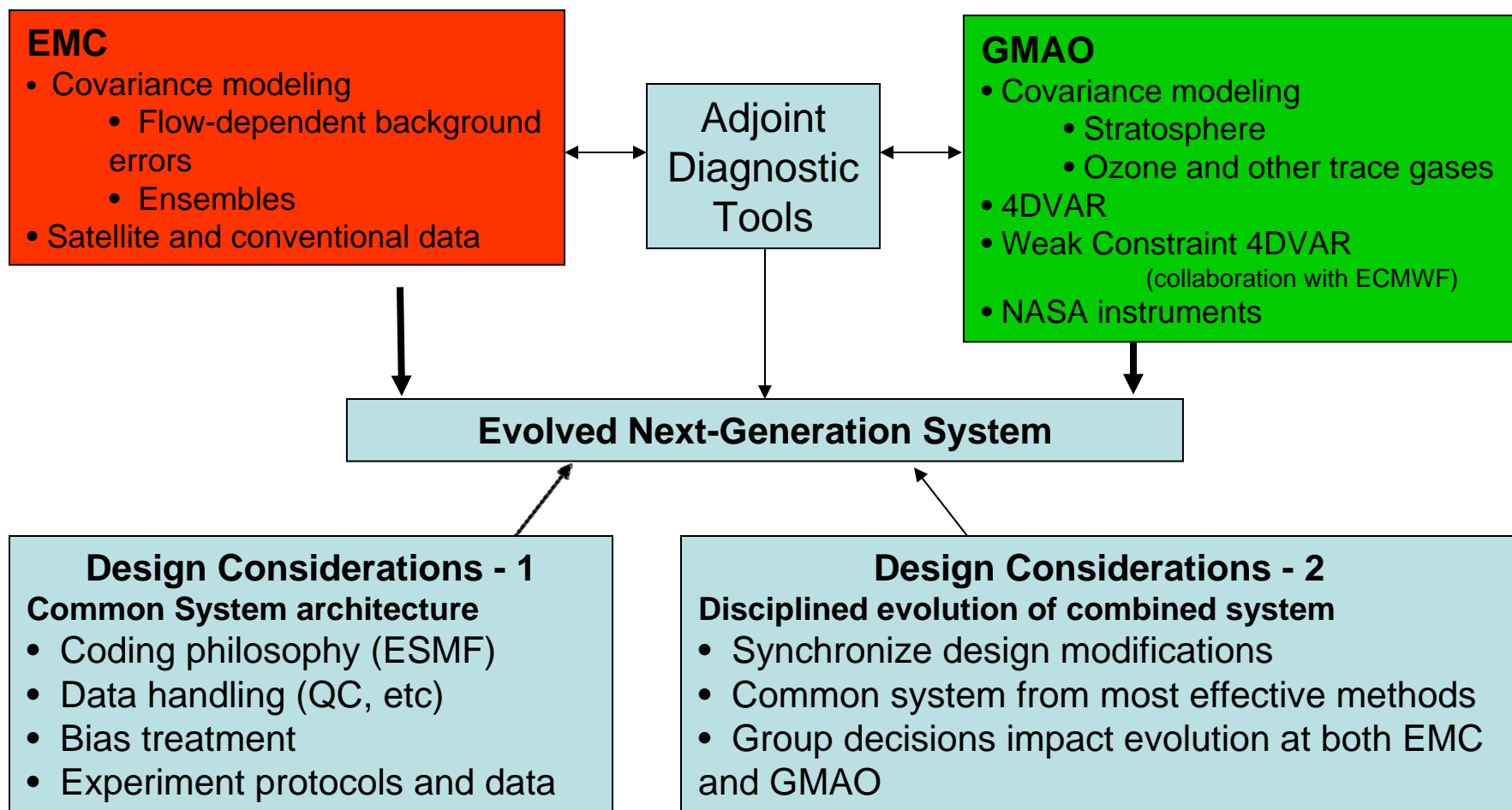
- ❑ NCEP-GMAO Gridpoint Statistical Interpolation (GSI)
- ❑ **JCSDA** Community Radiative Transfer Model (CRTM)
- ❑ Adjoints for 4D-Var, data impact studies

GMAO- NCEP/EMC

Collaborating on Data Assimilation Development

Latest code merger is 4DVar-capable

Complementary Development Focus
Common Architecture

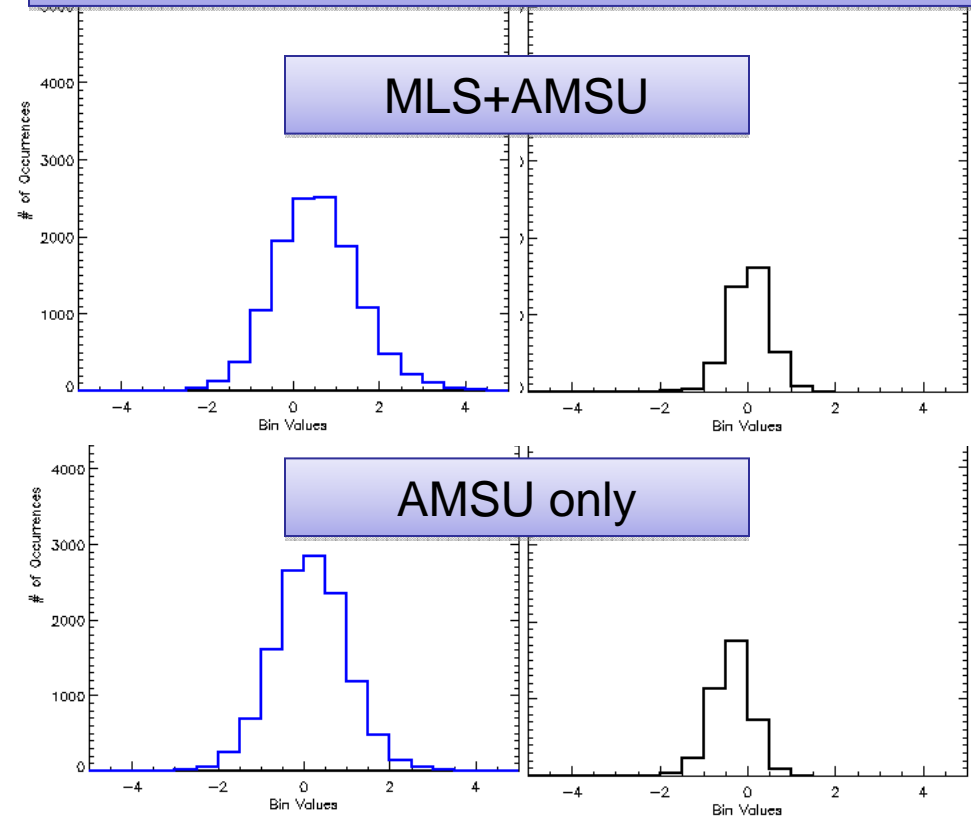
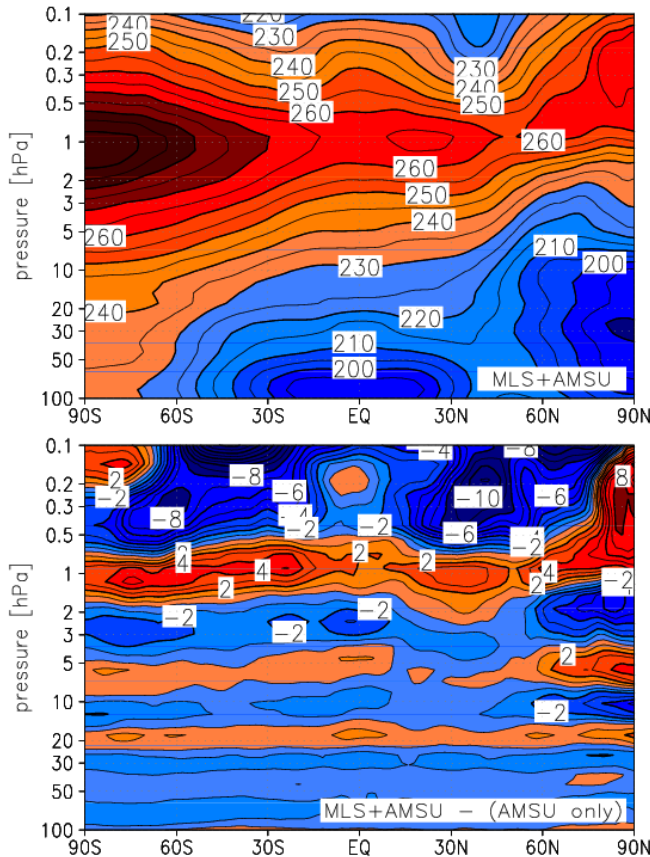


Assimilation of MLS Temperature

Impact on other data

The zonal-mean temperature, Jan 1 2005
AMSU only c.f. MLS+AMSU

Observed minus analyzed (O-A) of brightness temperatures: N-15 AMSU-A Ch 14 (assimilated) and AIRS Ch 74 (passive). Both channels peak in the upper stratosphere.



Stratospheric layering may be an MLS issue

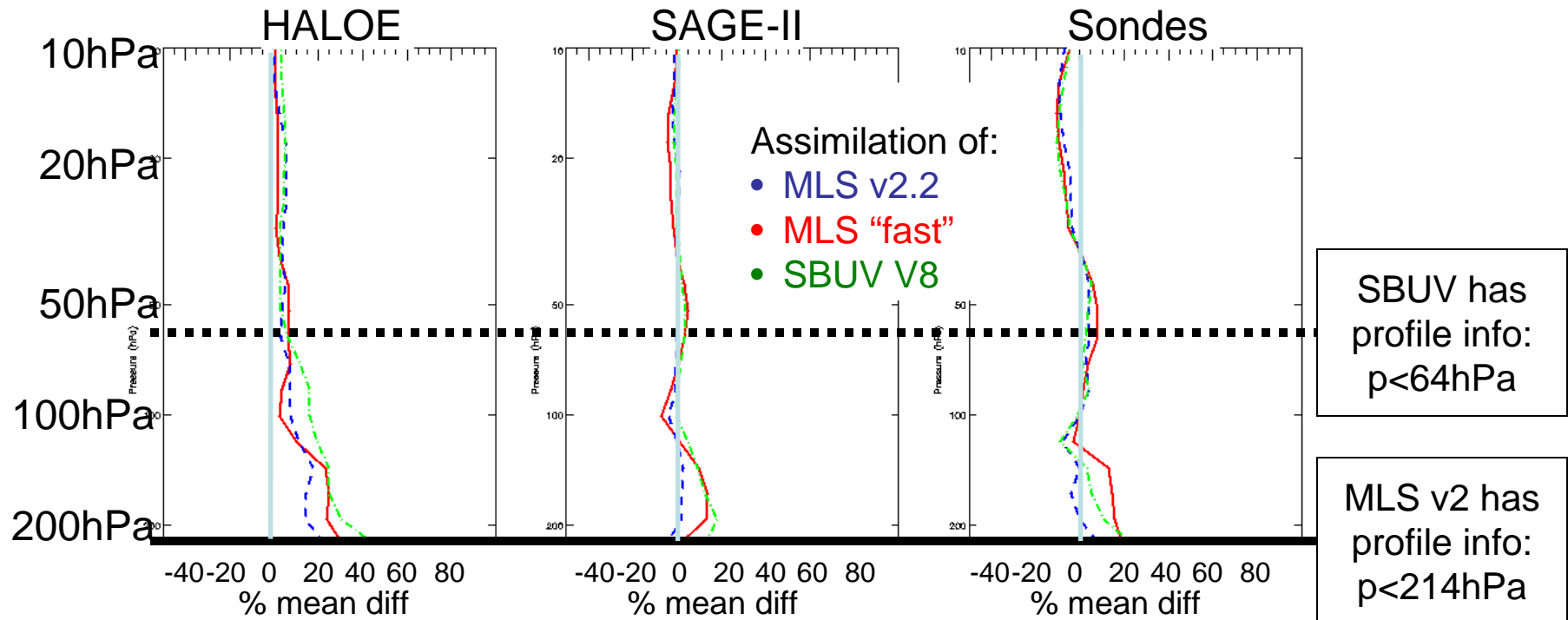
From comparison with lidar and HALOE data:
Assimilating MLS temperatures leads to improved structure esp. stratopause and lower mesosphere

MLS temperature results in a slight degradation - a positive bias and a wider pdf.

MLS temperature removes a slight negative brightness temperature bias.

Developing Real-time MLS

Impacts of Quick-Look MLS O₃ in GEOS-5



Mean difference (%) of assimilation minus validation data: 30°-60°N, Jan 2005

- MLS V2.2 is closest to all validation data types in lower stratosphere
- "Fast" processed MLS does not perform better than SBUV in this region

Presently iterating with MLS team to improve on this "fast" product

The 4DDA System

Ricardo Todling & Yannick Trémolet
Ron Gelaro

Impacts from Adjoint Tools
4DVar prototype experiments

Just completed merge with latest NCEP GSI
Provides Adjoint tools to NCEP (need model adjoint)

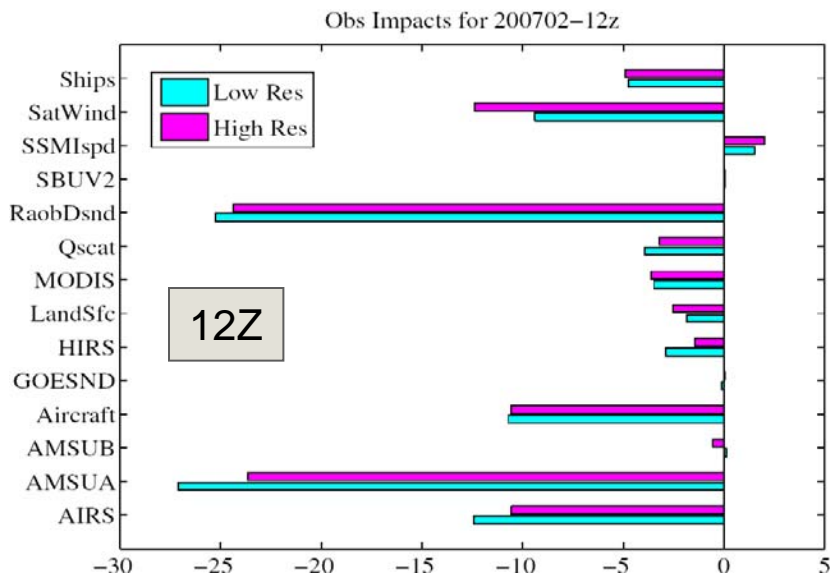
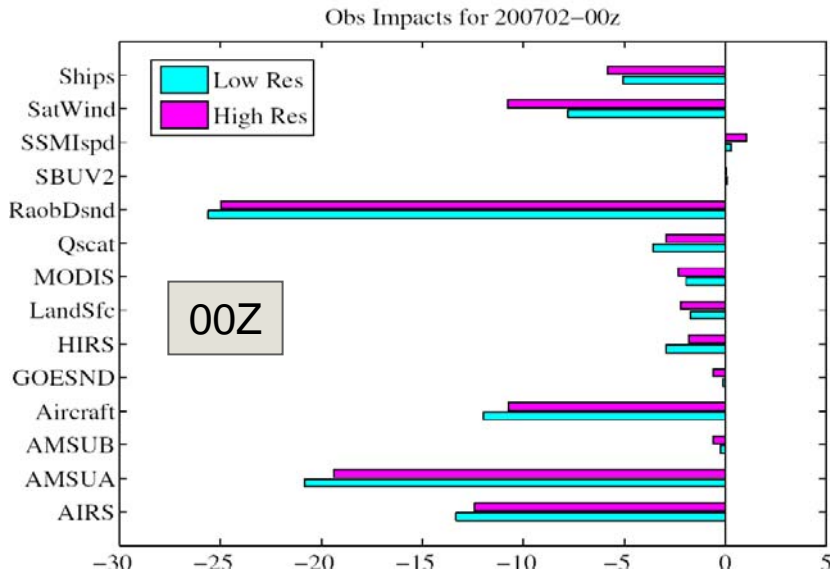
Summary of 4DVar Progress at GMAO

- Prototype NASA GEOS DAS 4DVAR now available
- Encouraging preliminary results with prototype 6-hr and 12-hr cycle 4DVAR
- Various adjoint-based diagnostic tools now available in GEOS DAS: forecast sensitivities, singular vectors, analysis sensitivity, and observations impact.
- Folded into latest code merge with NCEP
- Much work ahead:
 - Update TLM/ADM with cubed-sphere-based dynamical core
 - Adjoint of physics modules
 - Bring prototype 4DVAR to Operational-readiness status
 - Work on weak constraint 4DVAR formulation

The implementations done thus far benefited greatly from the original infrastructure of EMC-GMAO GSI and from 1-year visit by Yannick Trémolet from ECMWF

Observation impacts on 24-hr forecasts from GEOS-5 3Dvar for February 2007.

The relative impacts of the various observing systems does not change significantly when resolution changes \Rightarrow low-resolution experiments can be used effectively for quick looks at the impact of new data types



$2^\circ \times 2.5^\circ \times L72$

$0.5^\circ \times 0.625^\circ \times L72$

Observation sensitivity and impact studies require the adjoint of the underlying data assimilation system:

Model adjoint: forecast sensitivity

Analysis adjoint: observation sensitivity

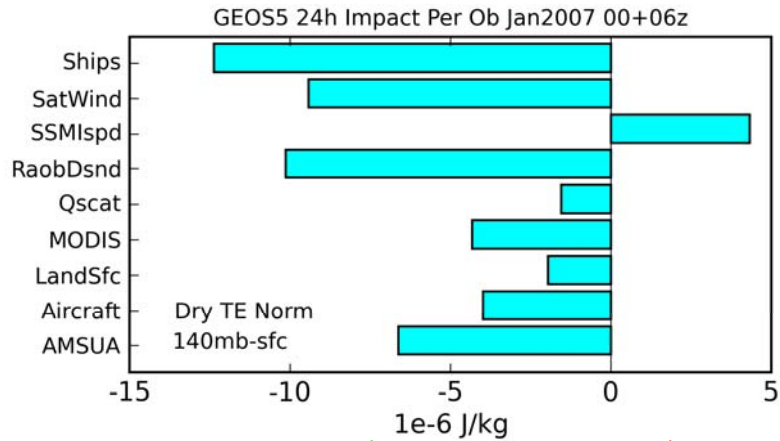
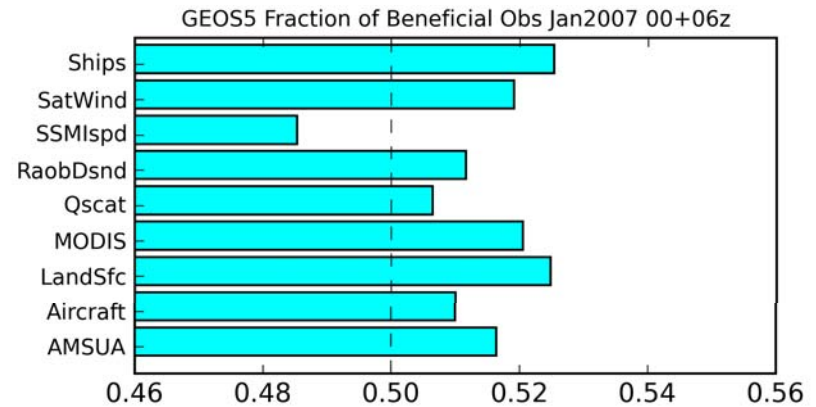
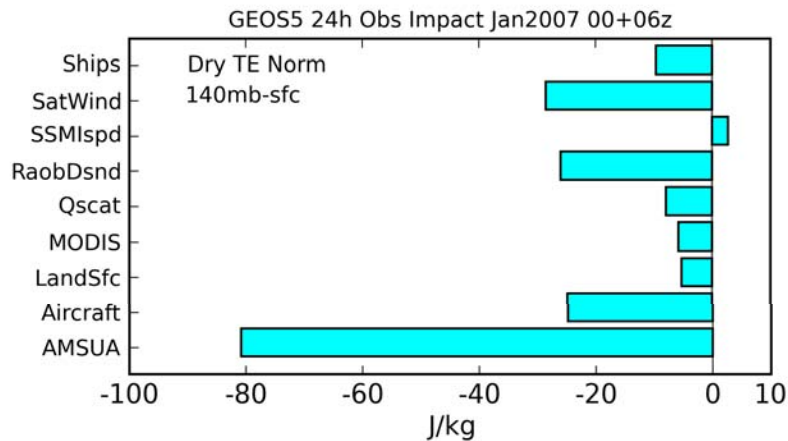
Trémolet (2008) developed the “automatic” calculation of the analysis adjoint within the assimilation system.

← Improves Forecast Degrades Forecast →

THORPEX: Observation Impact Intercomparison for January 2007

Gelaro, Langland, Cardinali

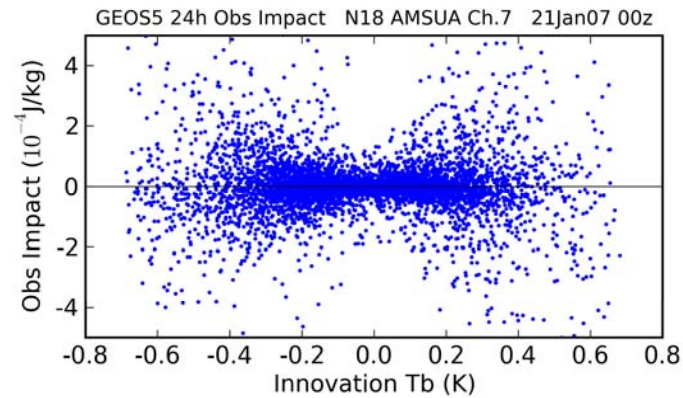
24-hour Forecast Impact
using GEOS-5 Adjoint tools



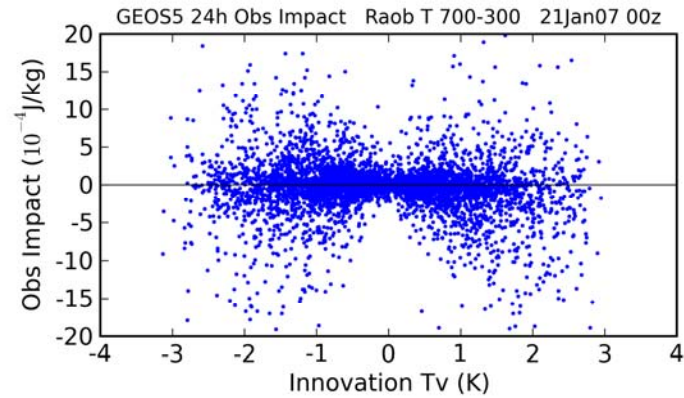
← Improves forecast → Degrades forecast

24-hour Forecast Impact using GEOS-5 Adjoint tools

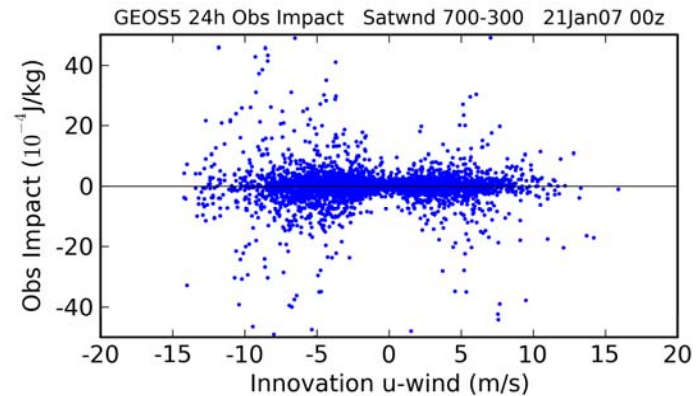
N-18 AMSU Ch 7



Radiosonde Temperature



Satellite winds

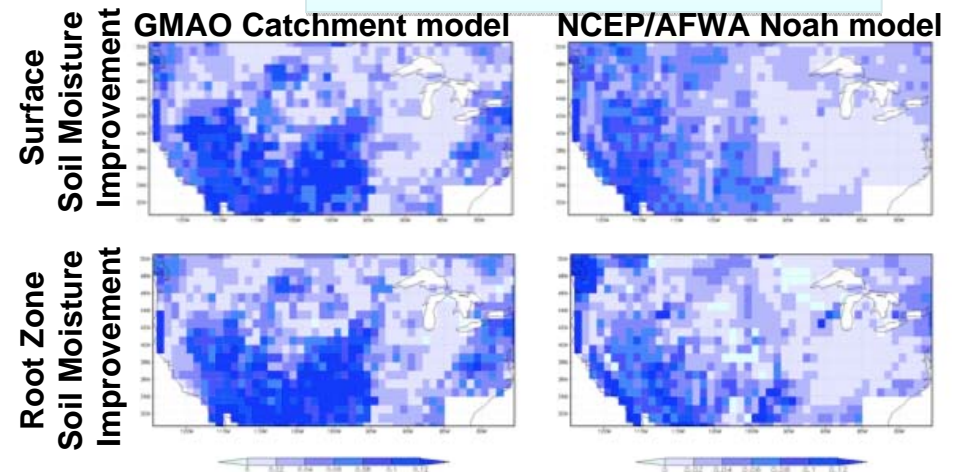


Land Information System

Provides a unified land data assimilation Framework for the JCSDA

S.V. Kumar, R.H. Reichle, C.D. Peters-Lidard, R.D. Koster, X. Zhan, J.B. Eylander, K. Mitchell
NASA – AFWA - NCEP

Soil Moisture Assimilation

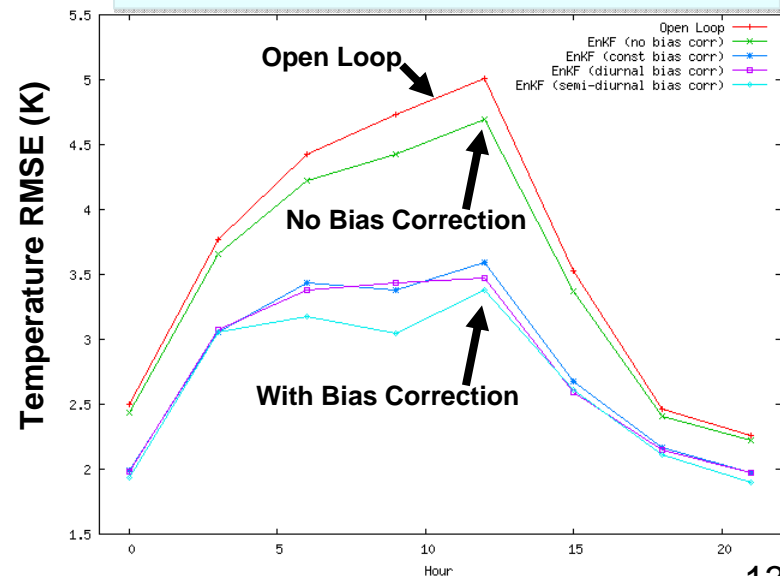


- LIS – integrating land surface models, assimilation algorithms, observational sources for users at NASA, AFWA, NCEP and JCSDA investigators – led by NASA/HSB (Peters-Lidard).

- GMAO-developed capabilities for land data assimilation have been implemented LIS

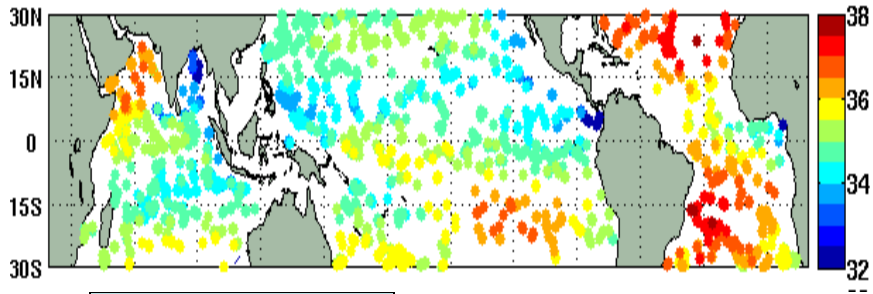
- Capabilities have been demonstrated for assimilating soil moisture, snow and skin temperature observations.

Skin Temperature Assimilation

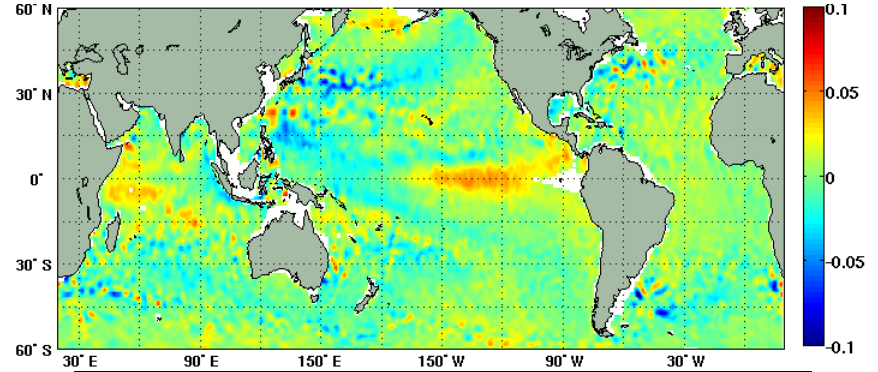


Kumar, et al., 2008. A Land Information System Data Assimilation Framework using the Land Information System, *Advances in Water Resources*, 31, 1419-1432.

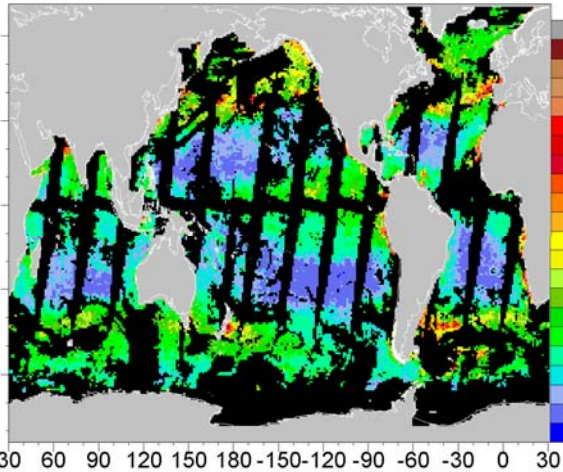
Ocean data assimilation in the GMAO



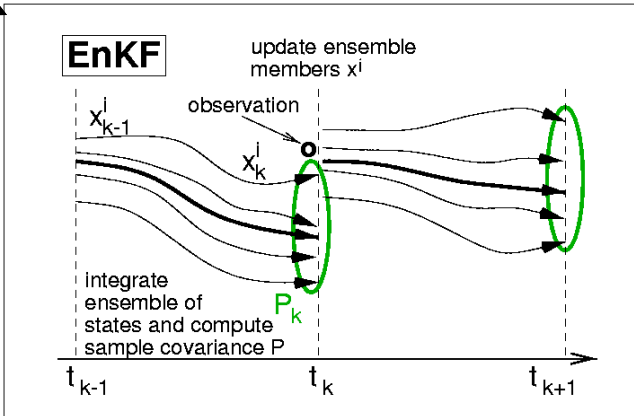
Temperature and salinity profiles from Argo floats



Sea Level anomalies (TOPEX/JASON)

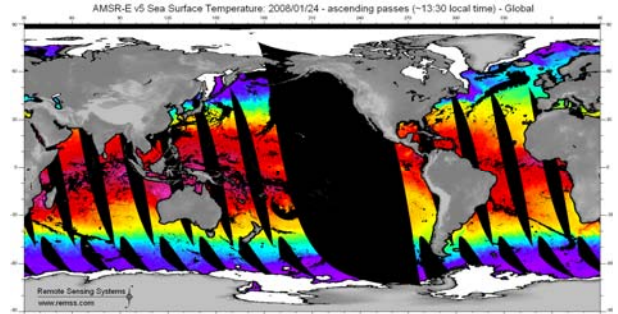


Surface chlorophyll (CZCS, SeaWiFS, MODIS)

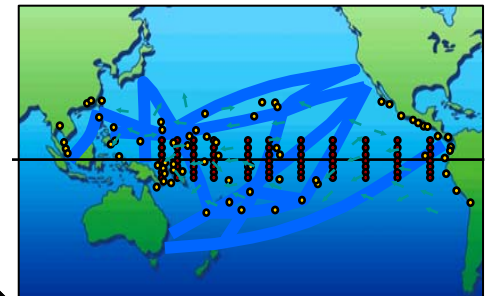


Ensemble-based ocean data assimilation system

Ocean state estimates for climate analysis and for short-term climate forecasts



SST (AMSR-E; MODIS)



In situ temperature profiles (TAO/PIRATA moorings, XBTs)

Keppenne

Ocean data assimilation in the GMAO

GEOS-5/ODAS2.....

- GMAO has implemented MOM4 in collaboration with GFDL, adopting NCEP's configuration
 - Assimilation system for MOM4 implemented with ESMF under GEOS-5; Multivariate analyses for altimeter assimilation under test.
 - Facilitates collaboration with NCEP - both assimilate altimeter data but use of different techniques
 - Helps JCSDA to contribute to operational transition of Aquarius data assimilation and future mission planning (Jason-3, SWOT)
 - Collaborating with ocean efforts from the FFO:
 - A. Kaplan, M. Cane, N. Arnold: Models for Remotely-Sensed Sea Surface Heights and Temperatures in Ocean Data Assimilation
 - R.N. Miller: Estimating Representation Error of Satellite and *in situ* Data for Data Assimilation into Ocean Climate Models
- MvOI and EnKF in a hybrid mode – to supplement low-dimensional ensemble
- Implemented UKMO *in situ* data QC – supplemented with tests from our existing system
- Using UKMO corrected XBT data set for climate analysis

Summary

- GMAO's JCSDA efforts are focused towards improving the use of AIRS, MLS and OMI data and preparing for NPP/OMPS
- GMAO contributing to CRTM WG (identifying issues, evaluation of performance)
- Data assimilation adjoint - efficient tool for observation impact studies
 - Complements traditional OSEs
 - Comparisons of impacts - clarify deficiencies in data quality vs. assimilation methodology (GMAO and NRL; also ECMWF)
 - Can be applied to OSSEs for the Decadal Survey Missions
- 4DVar development maturing - important to extract information from satellite data
- Aerosol and carbon species included with real-time system - GSFC is collaborating with NCEP to bring GOCART to NCEP's system
- Emerging collaboration on ocean data assimilation - Jason-1, OSTM, Aquarius
- Strong collaboration with NCEP and AFWA on land information system

- *GMAO and NCEP collaboration -- research to and from operations*
 - NASA now has improved system that delivers products to support:
 - NASA instrument teams (Aura, CERES, MODIS, CALIPSO) and field campaigns
 - NASA science (e.g., MERRA, seasonal forecast, atmospheric composition...)
 - Planning of Decadal Survey Missions

JCSDA Oceans & Satellite Data

- Currently assimilating:
 - SST retrievals
 - sea-ice concentration
 - sea-surface height anomalies (from altimetry)
 - significant wave height (from altimetry).
- Preparing for sea-surface salinity (SMOS and Aquarius)

- Models:
 - HYCOM: NCEP (Real-time Ocean Forecast) and NRL
 - WW3: NCEP and NRL
 - MOM4: NCEP GODAS (climate) and GMAO

- Assimilation Methods:
 - NRL: NCODA MVOI is operational at FNMOC and NAVO, and runs in R&D with HYCOM
 - NCEP: univariate 3Dvar with MOM4; OI, 2Dvar with HYCOM
 - GMAO: MvOI and EnKF with MOM4

JCSDA Oceans Project Team Objectives

- ✓ Coordinate efforts on the processing of altimeter data to improve the consistency between different data sources, and the estimates of tides, the geoid and mean ocean dynamic topography.
- ✓ Coordinate efforts to develop improved assimilation of altimetry data.
- ✓ Construct and conduct experiments that contribute to design considerations and justification for Jason-3 and SWOT.
- Coordinate efforts to develop more sophisticated and physically-based assimilation methods for mean and spectral satellite observations of surface wind waves, especially from SAR wave data.
- ✓ Coordinate efforts aimed at assimilating satellite sea-surface salinity (SSS) data.
- Coordinate experiments that document the impact of data types identified by the Project Team.

JCSDA Ocean Projects Team

Jim Cummings, NRL (co-chair)
Hendrik Tolman, NCEP (co-chair)
Laury Miller, NESDIS
Eric Bayler, NESDIS
Guillaume Vernieres, GMAO

Expect to bring in FFO scientists
Michele Riencker
Dave Behringer