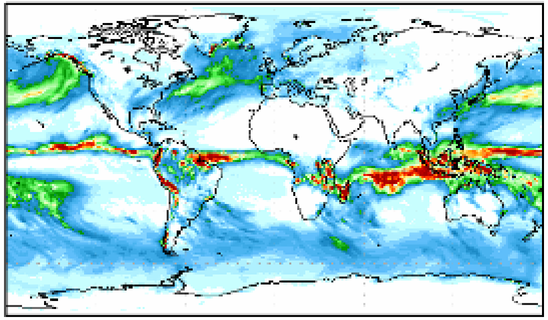
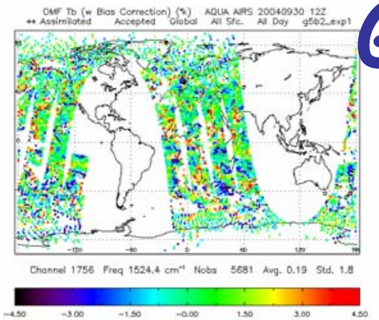




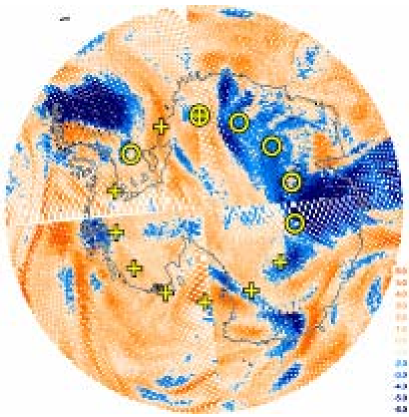
GMAO Satellite Data Assimilation

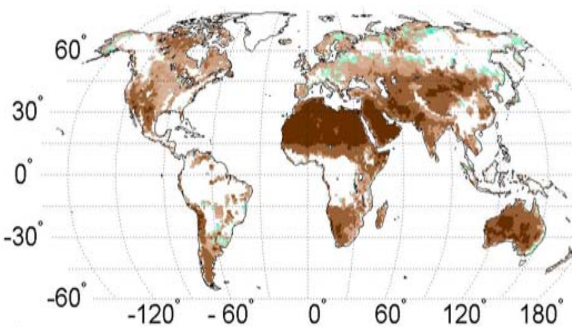
Michele Rienecker

Max Suarez, Ron Gelaro, Ricardo Todling, Emily Liu

Yanqiu Zhu, Ivanka Stajner, Meta Sienkiewicz, Rolf Reichle

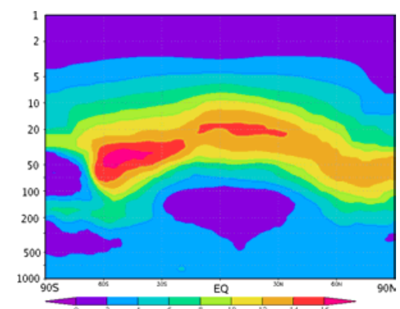
Christian Keppenne, Robin Kovach

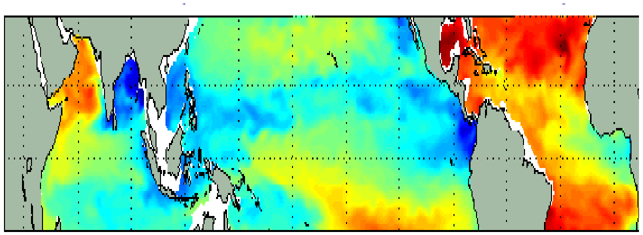




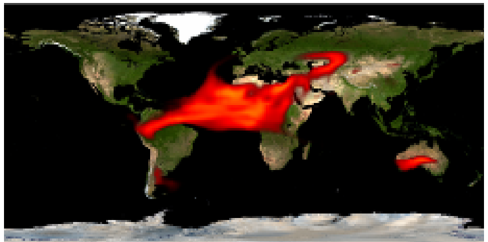
Global Modeling and Assimilation Office (GMAO)

NASA/Goddard Space Flight Center





JCSDA SSC Meeting
May 30-31, 2007



Global Modeling & Assimilation Office

http://gmao.gsfc.nasa.gov

- Atmospheric Assimilation:
  - NCEP's GSI
  - AIRS
  - Data impacts - Adjoint tools
  - MLS Ozone
- Land Surface: EnKF
- Ocean: EnKF
- Ocean Color: SEIK

GEOS-5 Atmospheric Data Assimilation System

Ricardo Todling, Max Suarez, Larry Takacs, Emily Liu

❖ AGCM

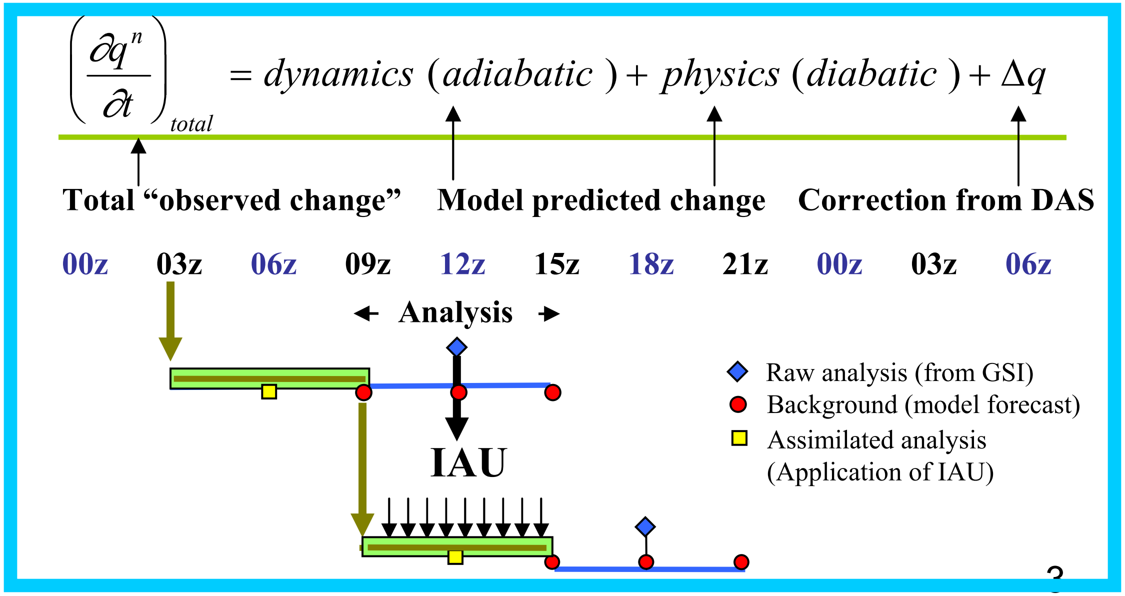
- ❖ Finite-volume dynamic core
- ❖ Bacmeister moist physics
- ❖ Physics integrated under the Earth System Modeling Framework (ESMF)
- ❖ Catchment land surface model
- ❖ Prescribed aerosols
- ❖ Interactive ozone

❖ Analysis

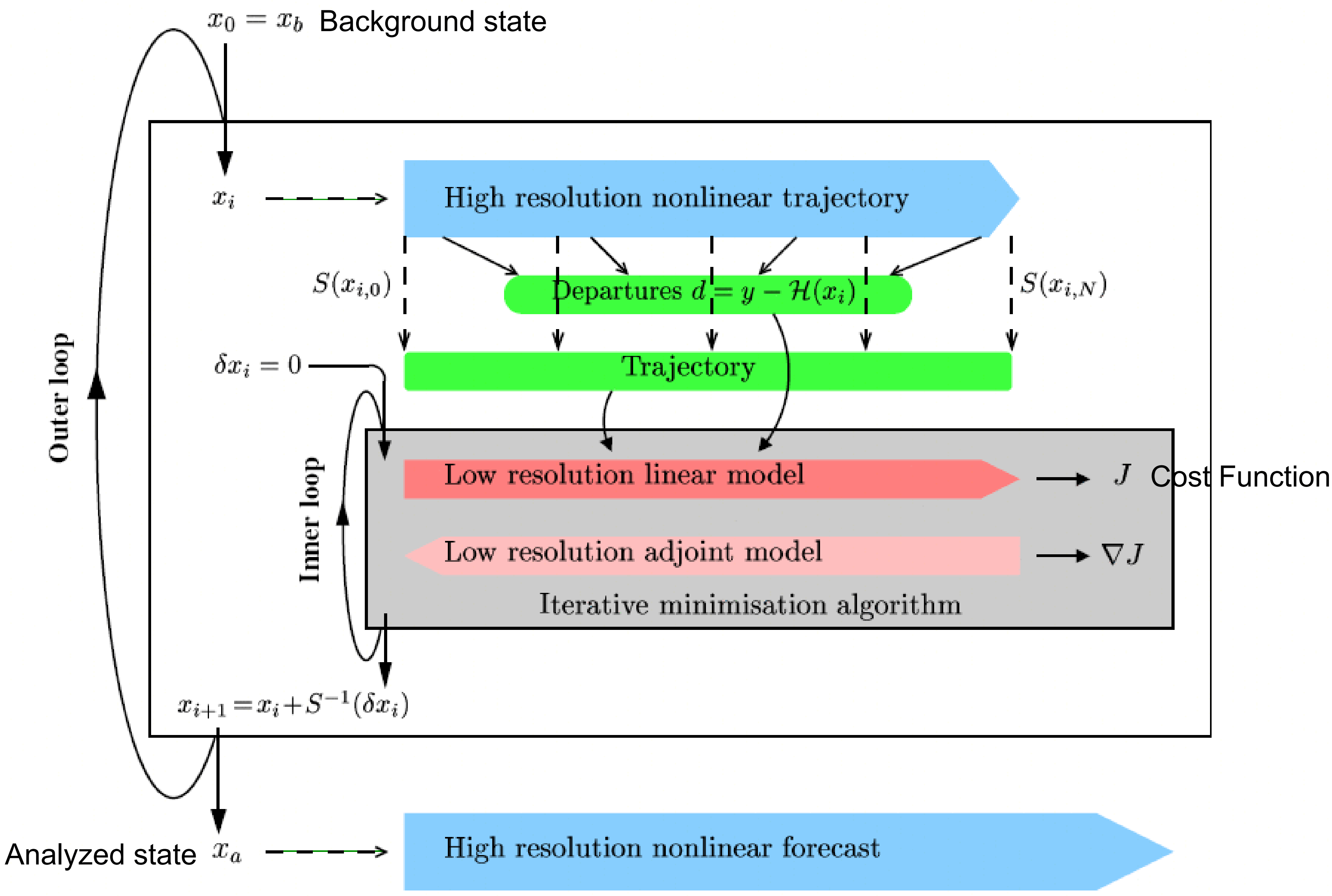
- ❖ Grid Point Statistical Interpolation (GSI)
- ❖ Direct assimilation of satellite radiance data
- ❖ JCSDA Community Radiative Transfer Model (CRTM) for most current instruments in space
- ❖ GLATOVS for TOVS (HIRS2, MSU, SSU) on board of TIROS-N, NOAA-06,…, NOAA-12
- ❖ Variational bias correction for radiances

❖ Assimilation

- ❖ Apply Incremental Analysis Increments (IAU) to reduce shock of data insertion
- ❖ IAU gradually forces the model integration throughout the 6 hour period



The next System - 4D-VAR



Progress in 4D-VAR Development (Tremolet & Todling)

1. **Trajectory Model: GEOS-5 with full physics**

2. **Model Adjoint: FV core with simple physics**

3. **Extension of GSI components for 4D-VAR**

   - Observation windowing flexibility
   - Observation handling (higher temporal-resolution bins)
   - Computation of time-dependent departures (OmF's)
   - Preliminary version of model-analysis interface
   - Options for minimization algorithm

4. **Fine ⇔ Coarse mappings: ESMF**

MERRA

http://gmao.gsfc.nasa.gov/merra/

MERRA System

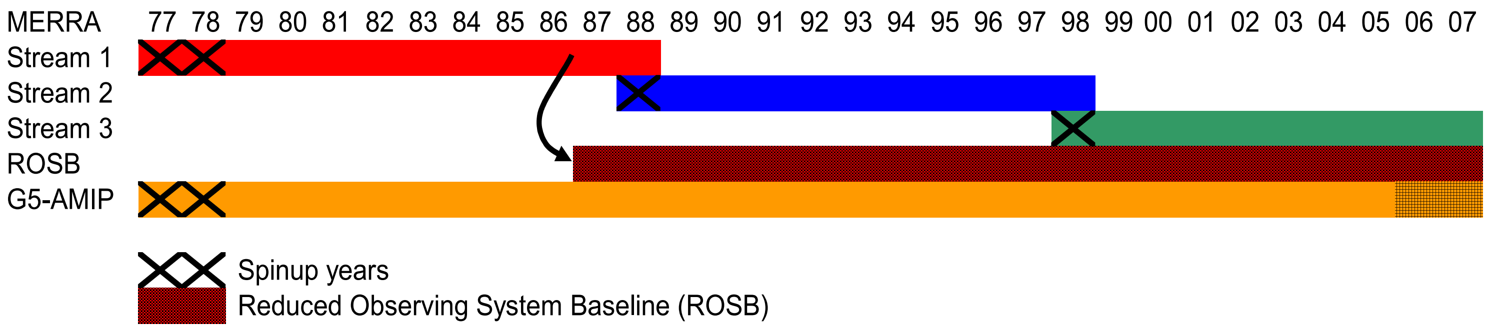
1/2° × 2/3° × 72L to .01 mb
1979-present
GSI Analysis with IAU
Parallel AMIP run

EMPHASIS ON WATER CYCLE

- Global Precipitation, Evaporation, Land Hydrology, Cloud parameters and TPW

GLOBAL HEAT AND WATER BUDGETS FOR ALL PROCESSES

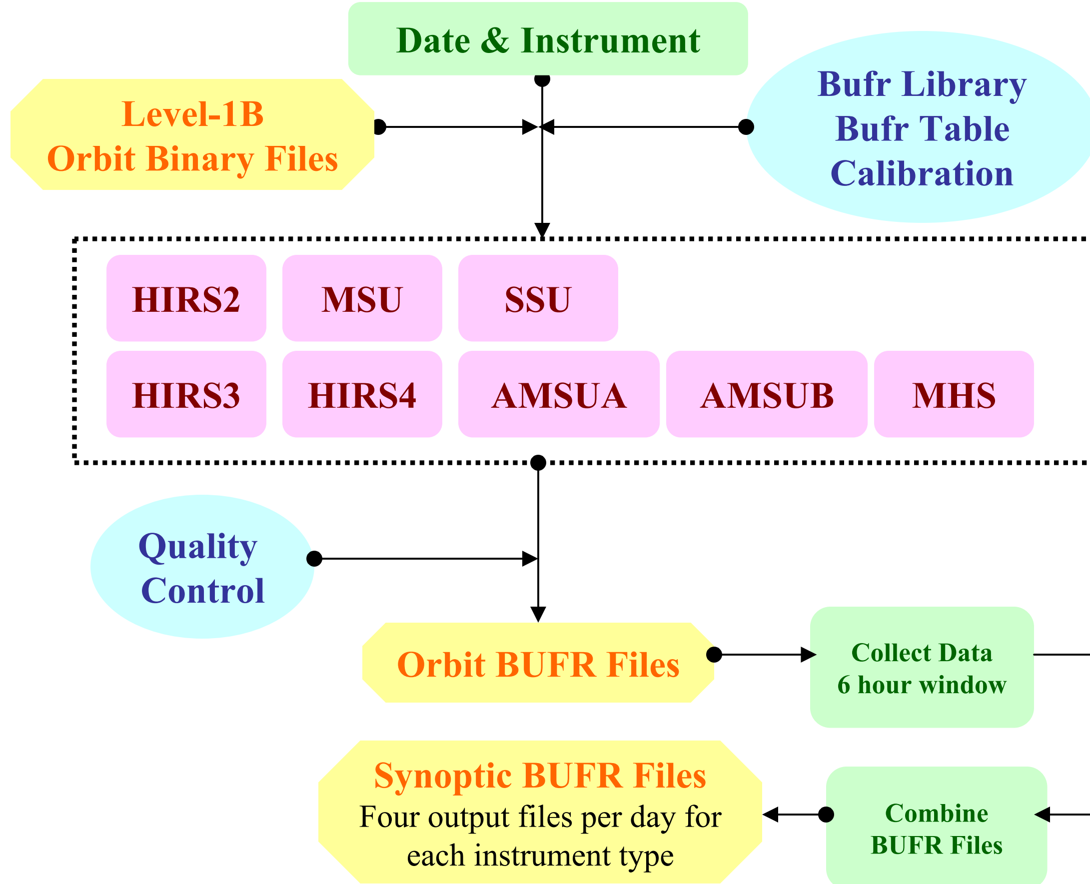
DIURNAL CYCLE FROM HOURLY 2-D FIELDS



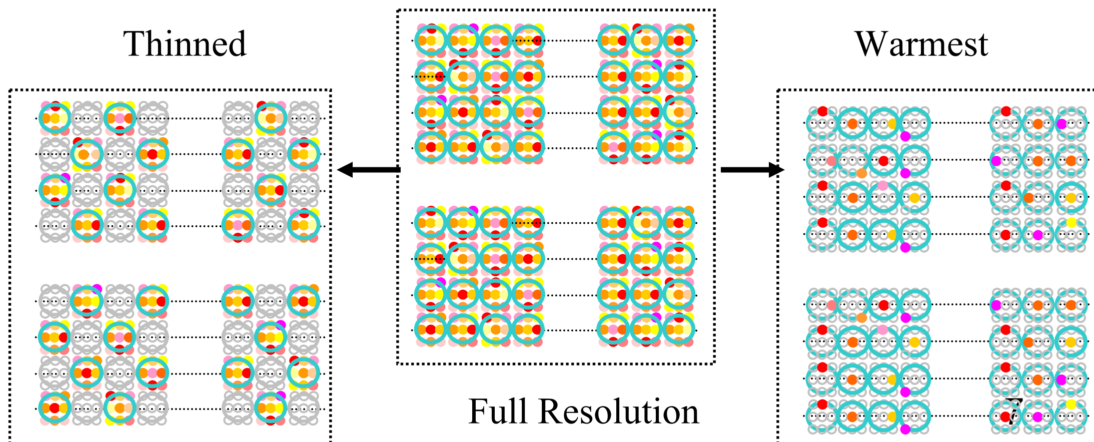
In-house Radiance Data Processing

Emily Liu

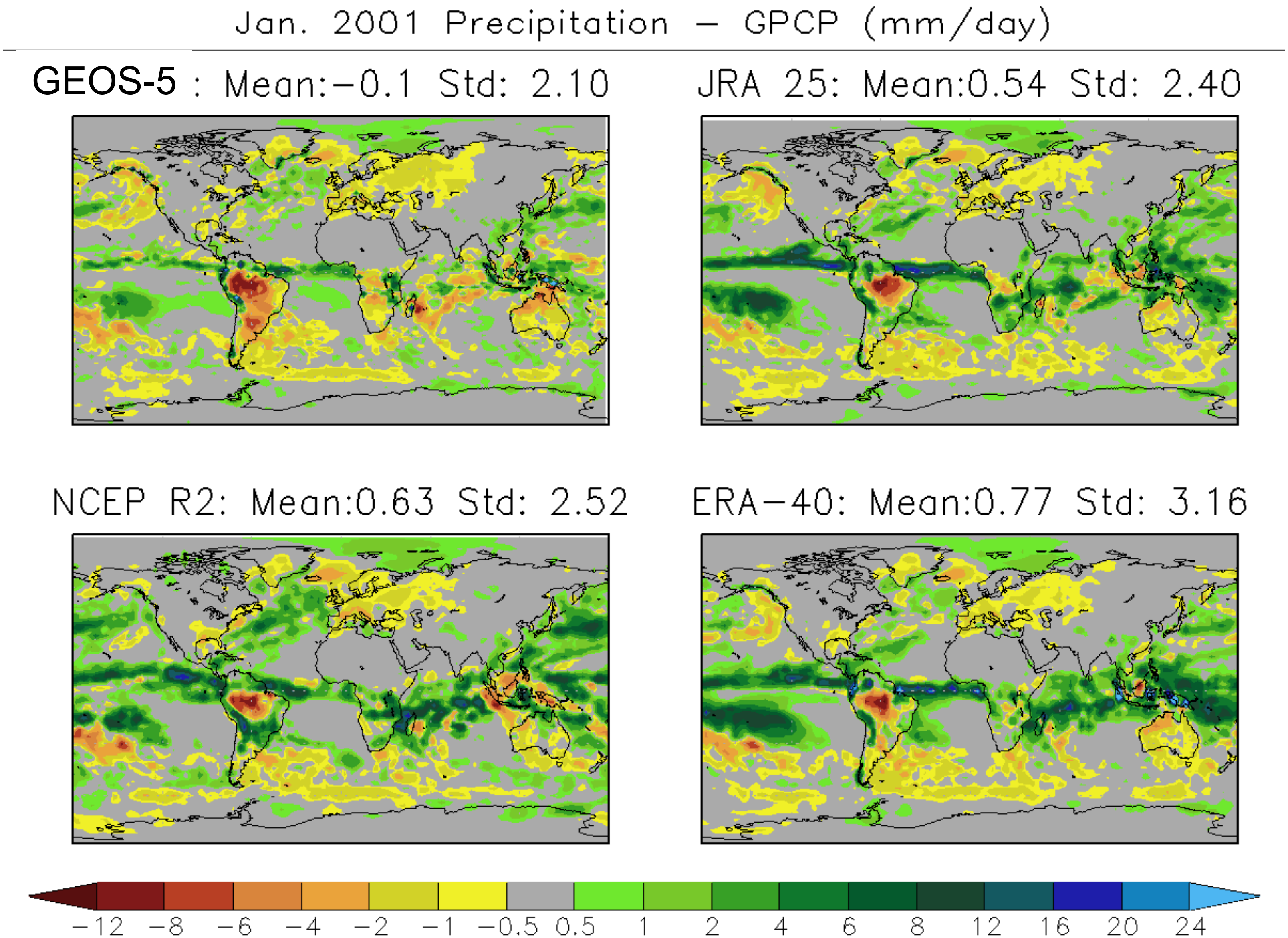
- ❖ In house data processing to support Modern Era Retrospective-analysis for Research and Applications (MERRA)
- ❖ Level-1b TOVS/ATOVS radiance data were converted to calibrated radiance in BUFR format with appropriate quality controls
- ❖ Data available from 1979 to present
- ❖ Data blacklists from ECMWF ERA40, JMA25 reanalysis, and GMAO GEOS-4 reanalysis (CERES) for further data screening
- ❖ Can reprocess the radiance data if calibration coefficients can be estimated from a better technique such as SNO (simultaneous nadir overpass)



- ❖ Receiving full spatial resolution AIRS and AMSU-A data from NESDIS
- ❖ Processing full resolution data set into thinned and warmest data sets in BUFR format



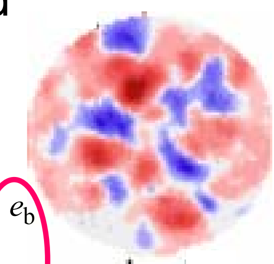
The GEOS-5 ADAS Validation: Precipitation

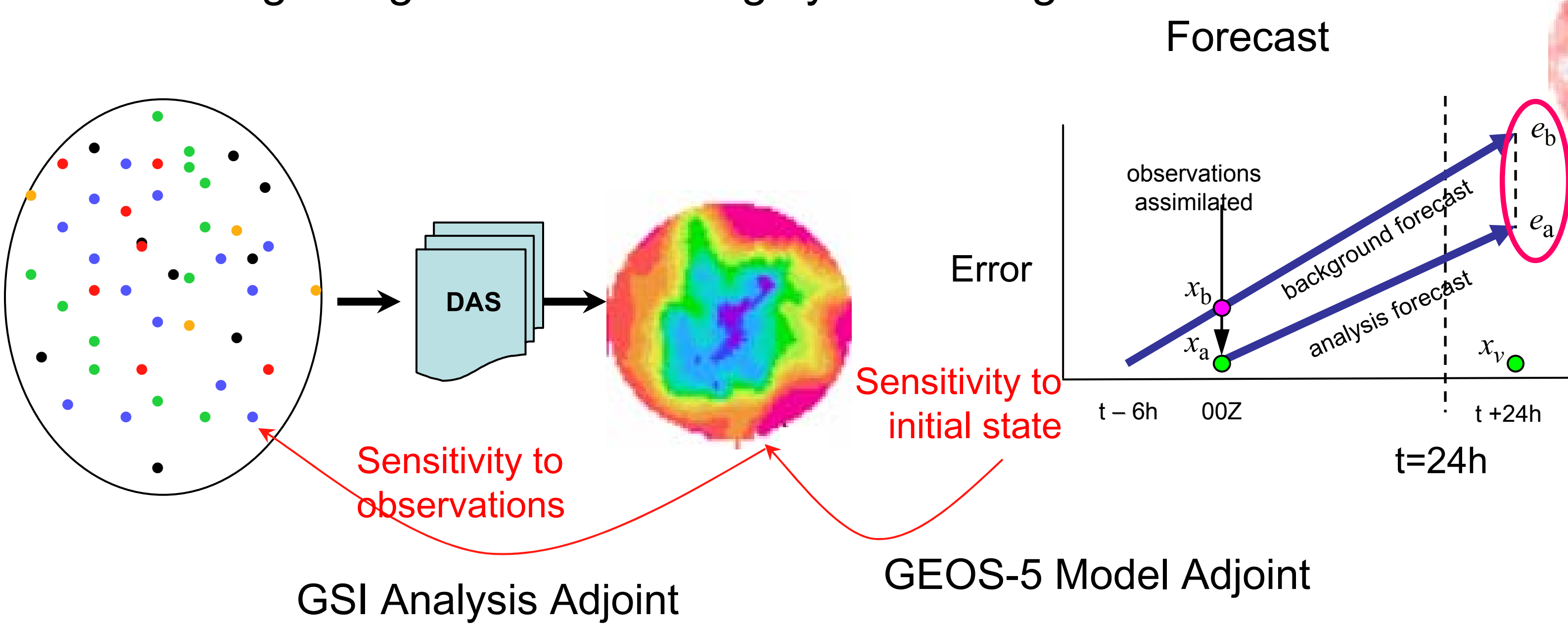


Adjoint tools for Observation Impact Studies

Ron Gelaro

- Efficient estimation of sources of forecast error and observation sensitivity (observation impact)
  - determined with respect to observational data, background fields or assimilation parameters, all computed simultaneously
  - useful for designing intelligent data selection strategies and guiding future observing system design

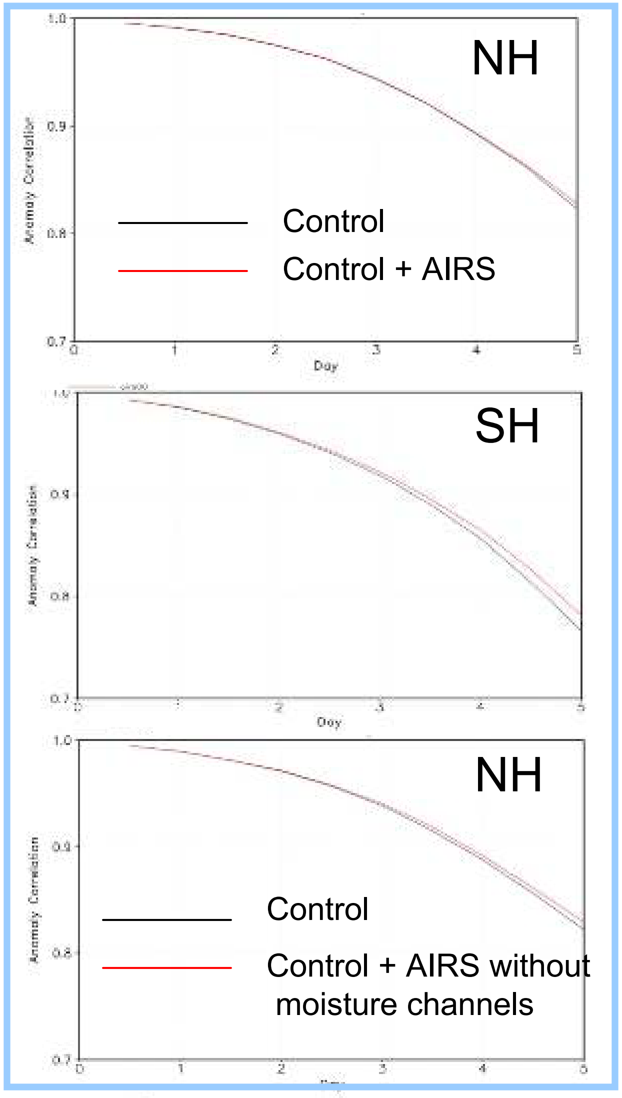


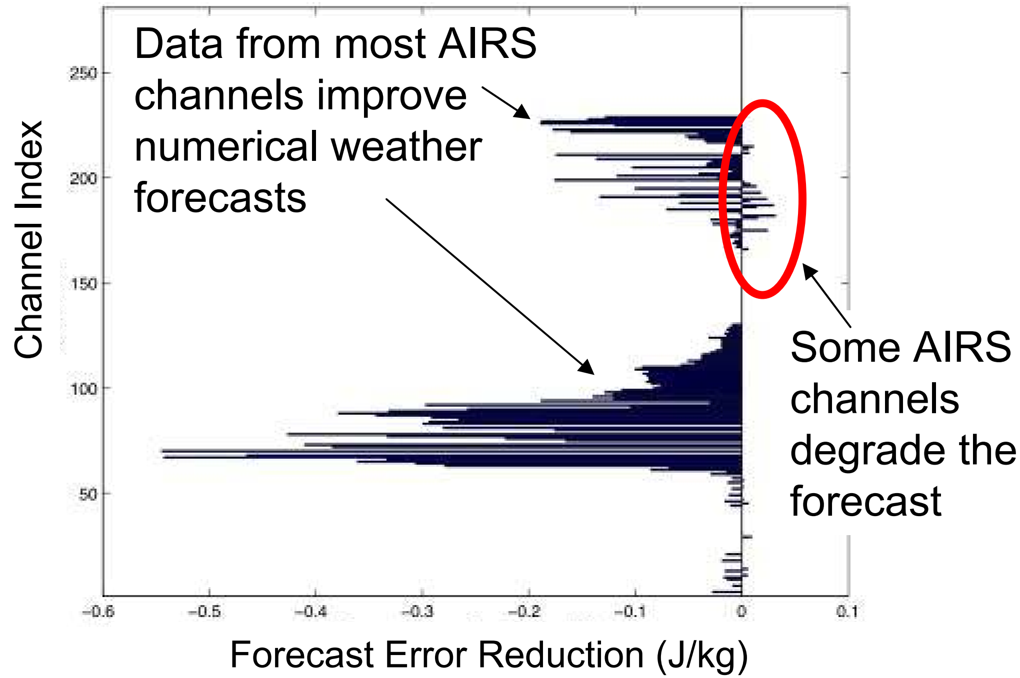


GEOS-5 used to Evaluate Impact of AIRS in NWP

Emily Liu, Ron Gelaro, Yanqiu Zhu

Forecast Skill vs. Time

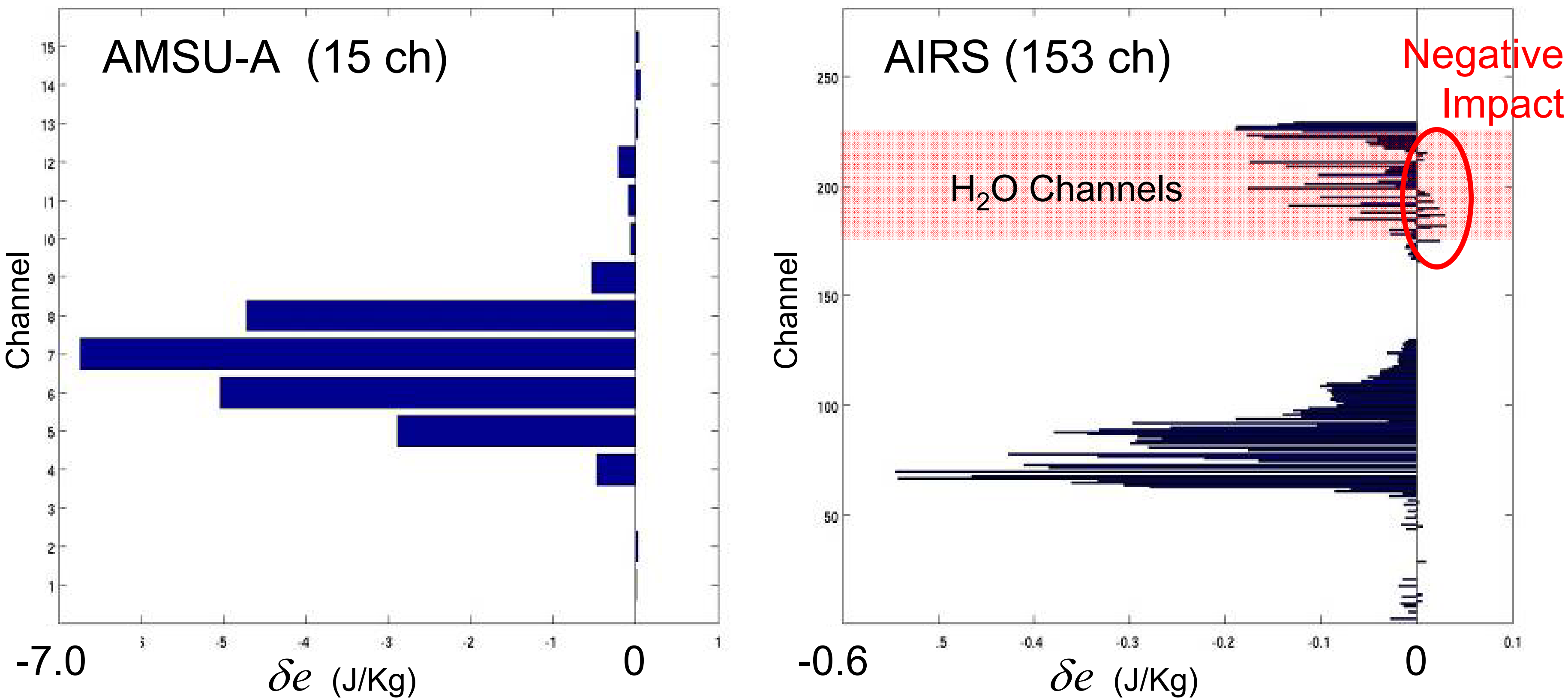




AIRS brings slightly positive impact on forecast skill in Northern Hemisphere; clear positive impact in Southern Hemisphere. But forecast skills are increased when moisture channels from AIRS are not included

Diagnosing impact of hyper-spectral observing systems

GEOS-5 July 2005 00z Totals



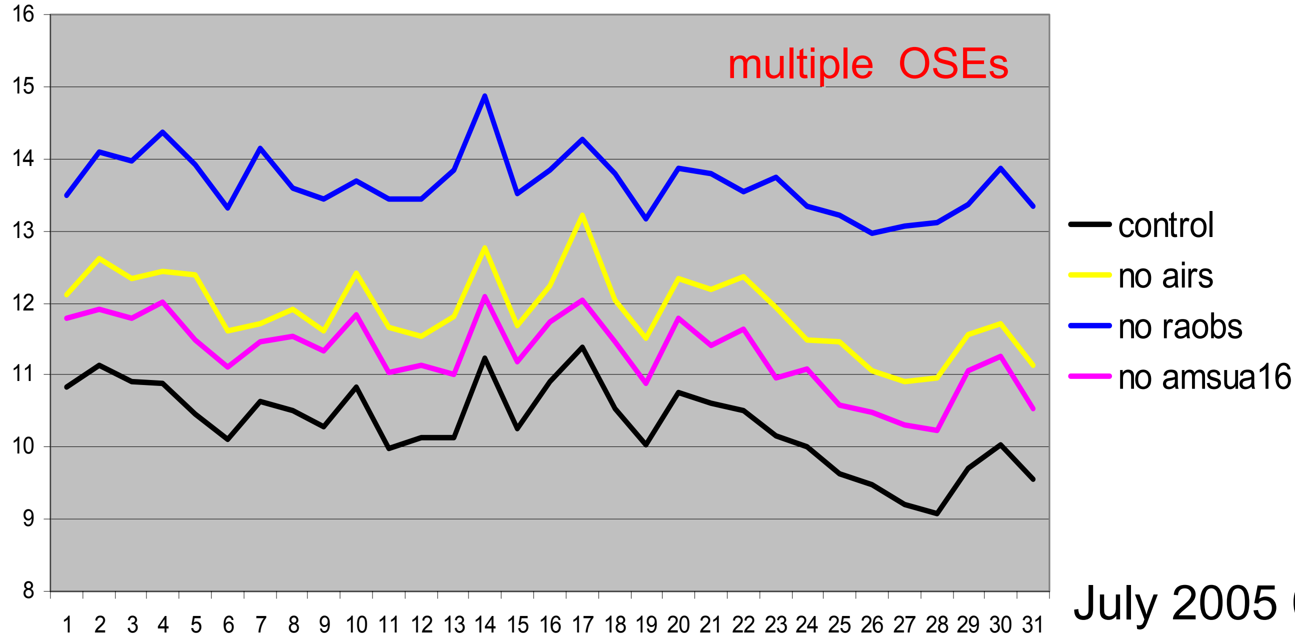
…several AIRS water vapor channels currently degrade the 24h forecast in GEOS-5…

GEOS-5 Observation Impact: Comparison with OSEs

Ron Gelaro and Yanqiu Zhu

24h Forecast Error Energy

(J/Kg)

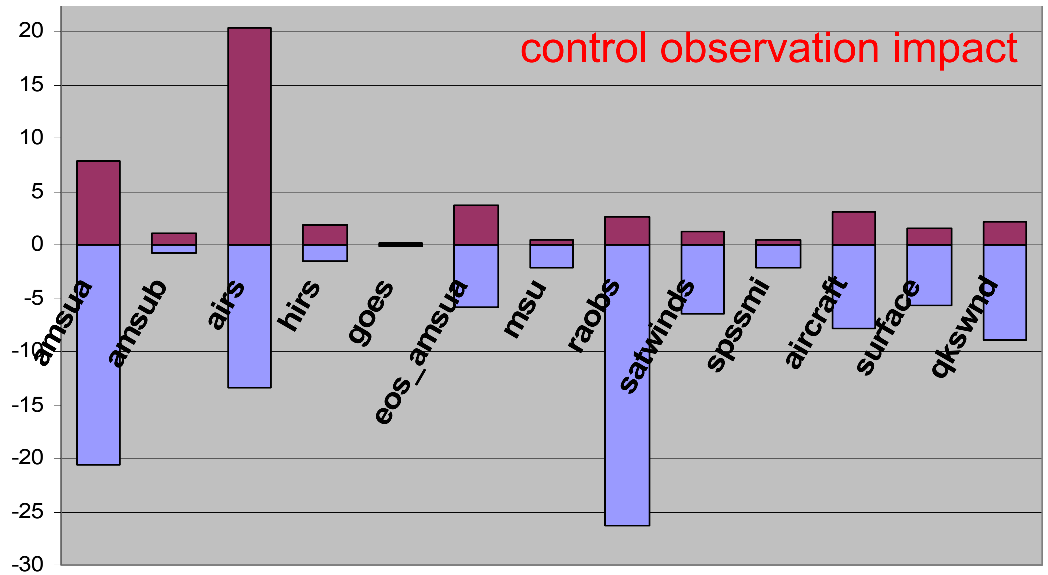


July 2005 00z

Observation Count (millions)

δe

(J/Kg)

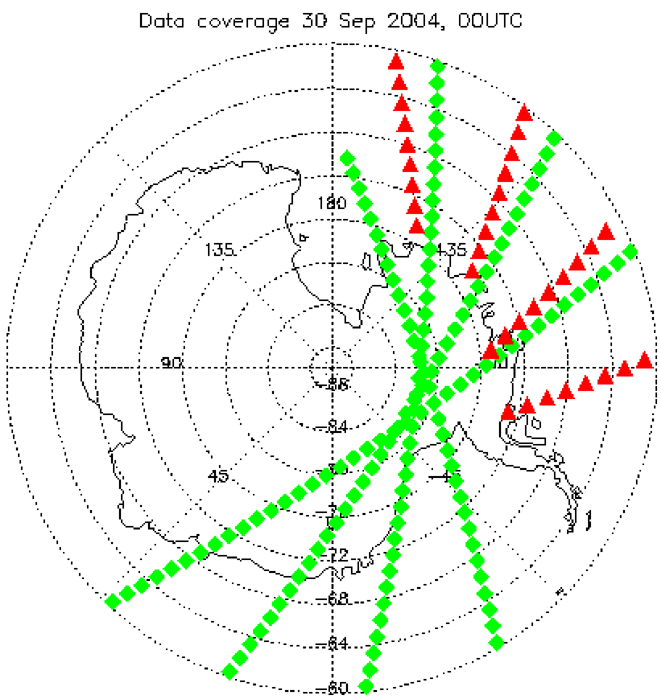


Assimilating AURA/MLS ozone

Meta Sienkiewicz and Ivanka Stajner

SBUV daytime only – no data near South Pole due to high solar zenith angle

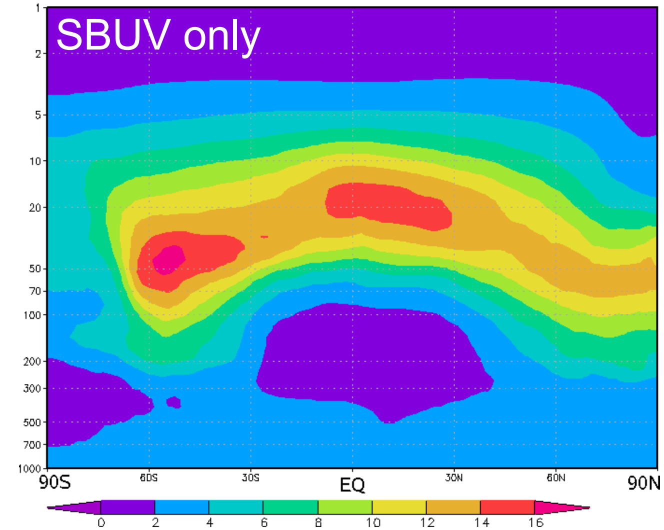
MLS orbital limit ±82º

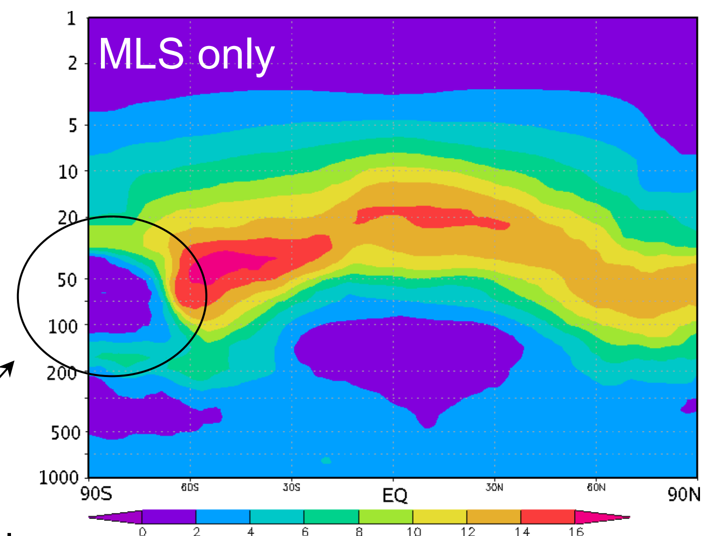


▲ NOAA 16 SBUV

◆ MLS

Zonal mean ozone 9/30/2004 00UTC



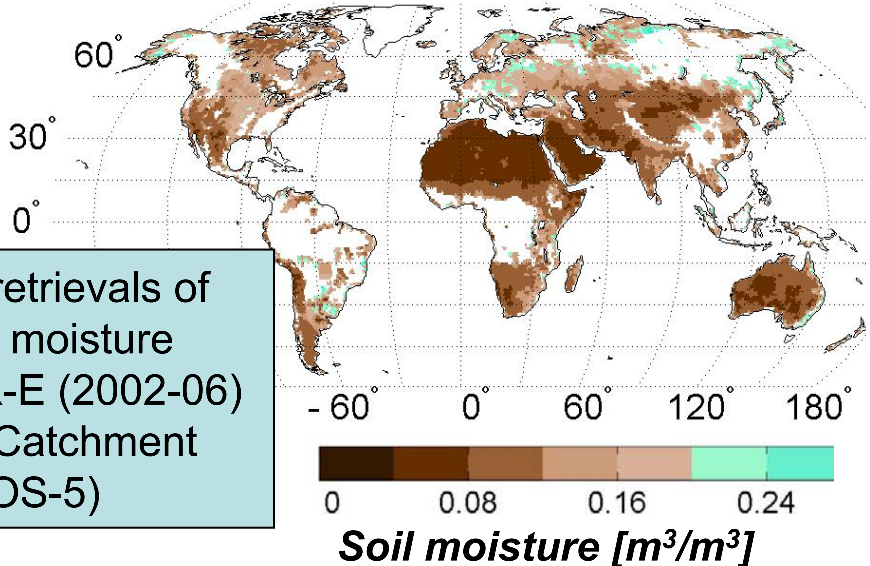


Ozone hole develops in MLS assimilation

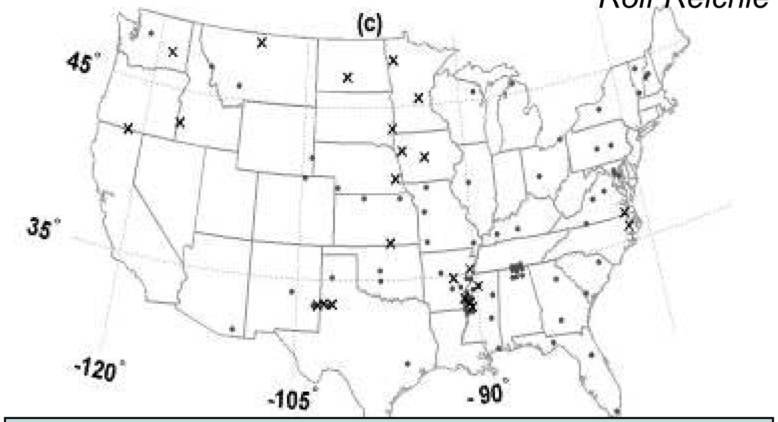
Ozone partial pressure (mPa)

Global assimilation of AMSR-E soil moisture retrievals

Rolf Reichle



Assimilate retrievals of surface soil moisture from AMSR-E (2002-06) into NASA Catchment model (GEOS-5)



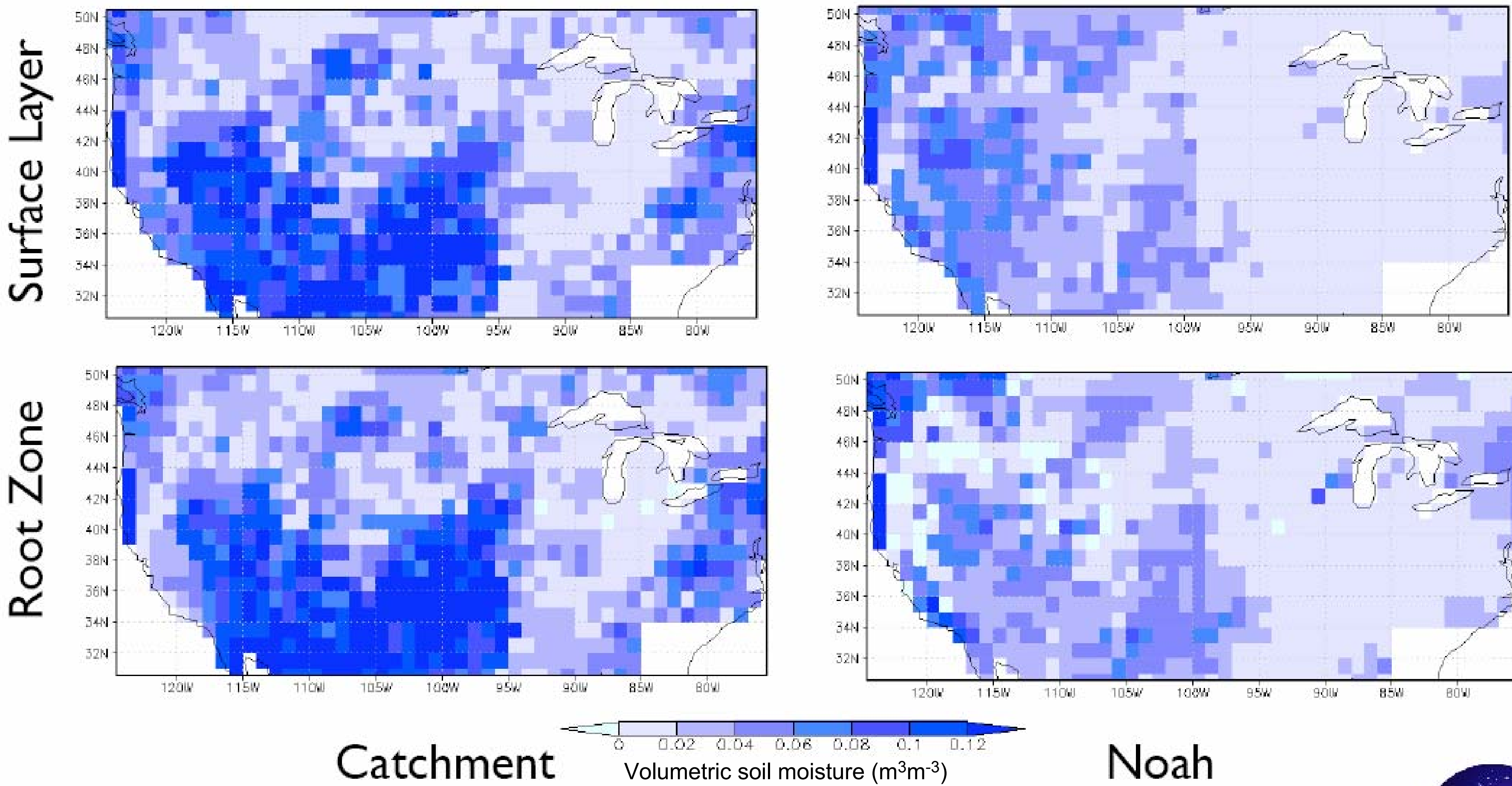
Validate with USDA SCAN stations (only 23 of 103 suitable for validation)

Reichle et al. *JGR*, **2007**		Anomaly time series correlation coeff. with in situ data [-] (with 95% confidence interval)			Confidence levels: Improvement of assimilation over	
	N	**Satellite**	**Model**	**Assim.**	**Satellite**	**Model**
Surface soil moisture	23	**.38±.02**	**.43±.02**	**.50±.02**	**>99.99%**	**>99.99%**
Root zone soil moisture	22	**n/a**	**.40±.02**	**.46±.02**	**n/a**	**>99.99%**

Assimilation product agrees better with ground data than satellite or model alone.

Modest increase may be close to maximum possible with *imperfect* in situ data.

Improvement Metric (RMSE(OpenLoop) - RMSE(EnKF)) for soil moisture OSSEs



Kumar, Reichle, et al. (2007), *Adv. Water Resources,* submitted.

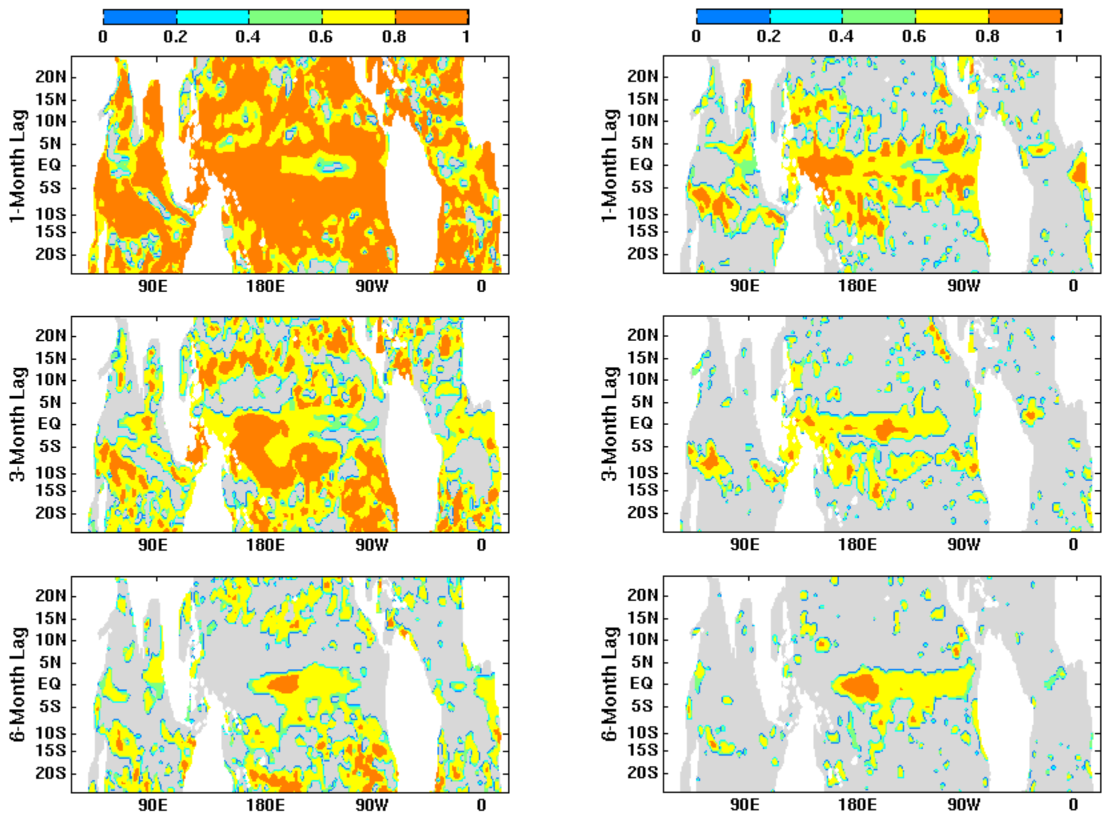
Forecast skill (ACC) from CGCMv1
Heat content anomaly in upper 300m
1993-2006

EnKF | OI-TS

1-month lead

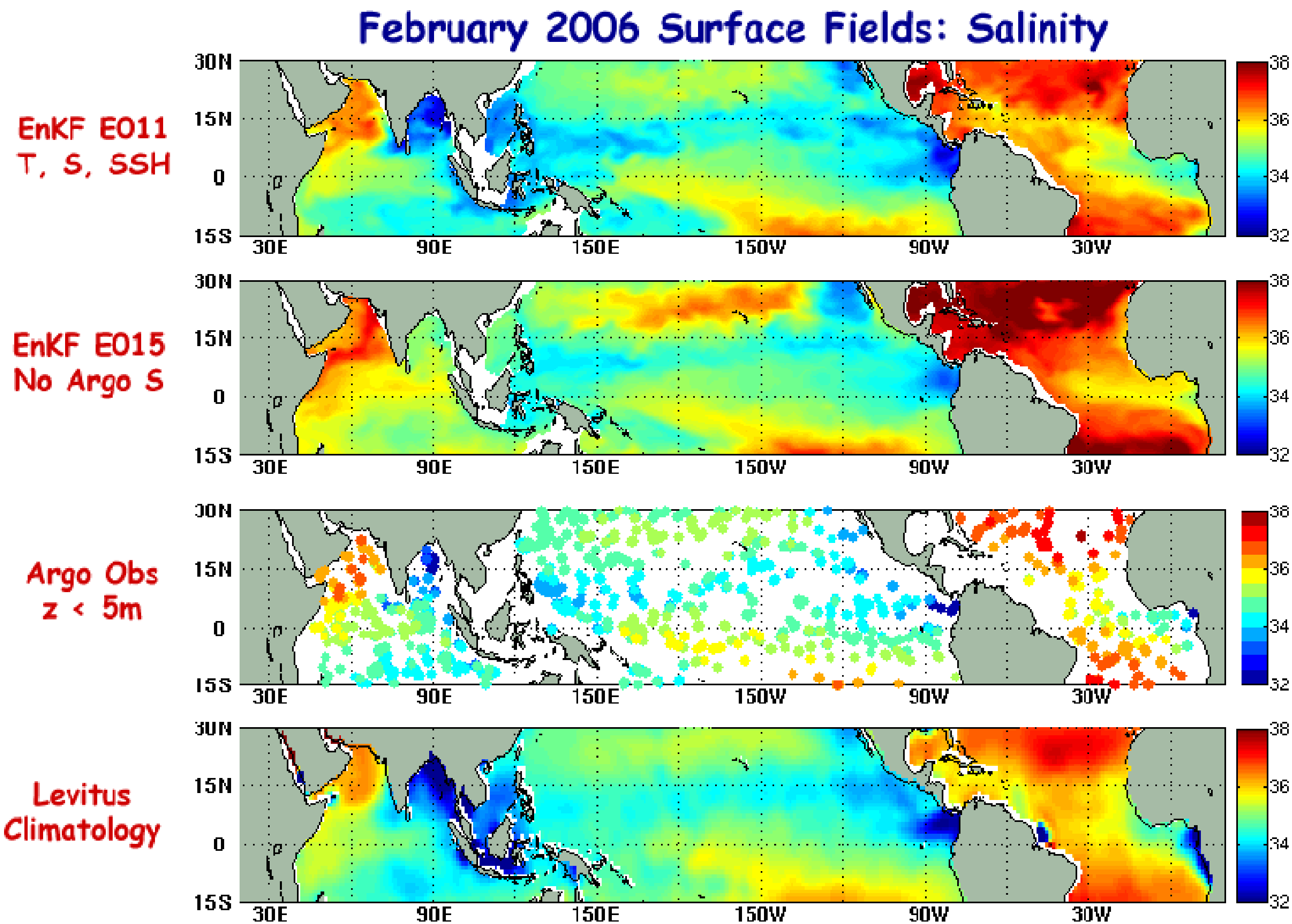
3-month lead

6-month lead



The impact of Argo - preparing for Aquarius

Christian Keppenne and Robin Kovach



GMAO's Collaborations with JCSDA Partners

- Atmosphere:-
  - GSI - NCEP
  - Adjoint tools - NRL
  - AIRS
  - Ozone
  - Aerosols
  - OSSEs (emerging) - NCEP, NESDIS, et al
- Land Surface:-
  - EnKF development
  - LIS implementation for Catchment and Noah LSMs
- Ocean:-
  - EnKF and MvOI development for MOM4 - NCEP
  - Altimetry with online-bias-estimation
  - Ocean color

GMAO - Near-term Plans

- Atmosphere:-
  - Development of 4Dvar
  - Contribute to OSSE capability
  - AIRS (QC) - IASI - CrIS
  - Ozone - GOME-2 - OMPS
  - Real-time MLS
  - MODIS Winds - VIIRS
  - CO, CO_2 (OCO)
- Land Surface:-
  - EnKF: Surface Temperature and Snow
  - LIS implementation for Catchment and Noah LSMs
- Ocean:-
  - MOM4: retrospective analysis for seasonal forecast
  - Surface Salinity
  - Ocean color: removing instrument biases