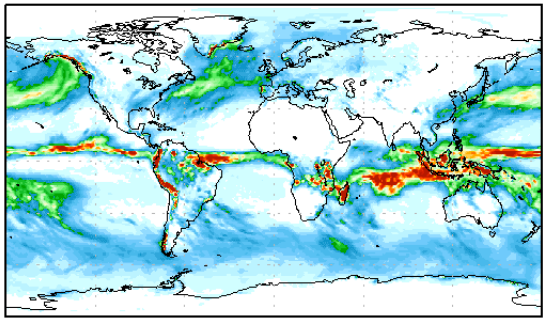
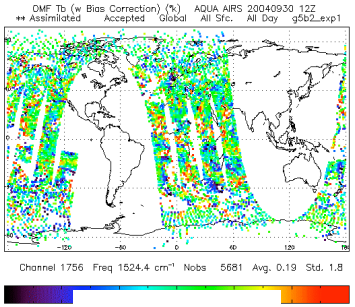


GEOS-5: A status report



Michele Rienecker

Max Suarez, Ron Gelaro, Julio Bacmeister, Ricardo Todling

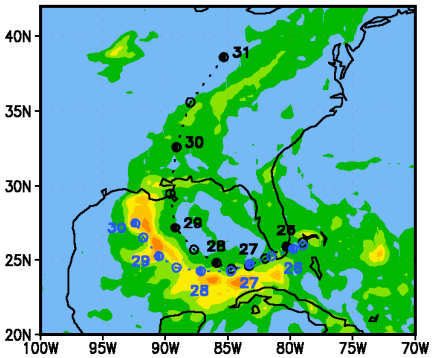
Larry Takacs, Steven Pawson, Arlindo da Silva

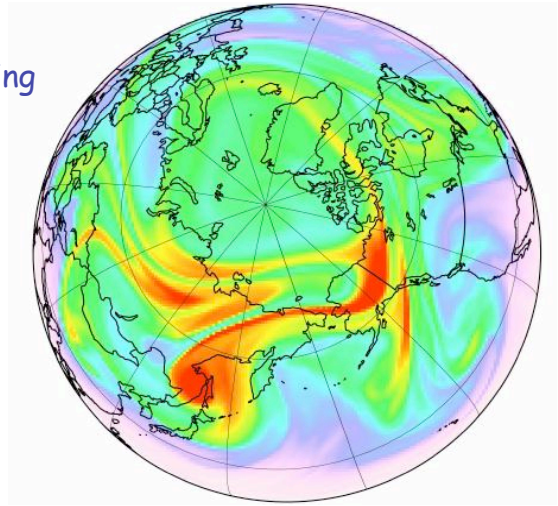
Emily Liu, Ivanka Stajner, Meta Sienkiewicz

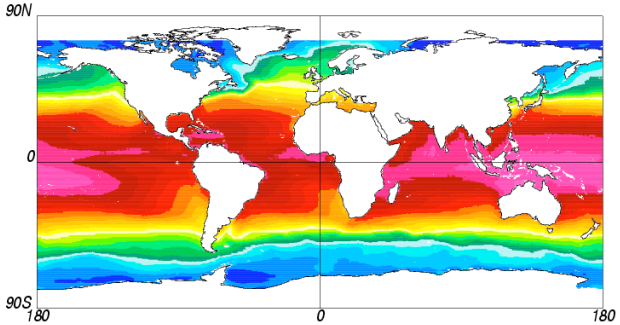
and GMAO

Global Modeling and Assimilation Office (GMAO)

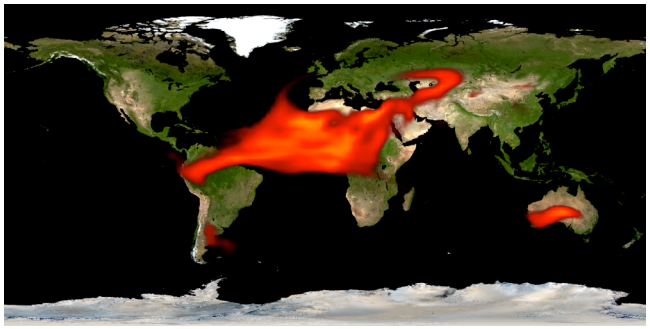
NASA/Goddard Space Flight Center







MAP Science Team Meeting
March 7-9, 2007



GEOS-5 SYSTEMS

AGCM

- Climate simulations
- Weather (MAP05 and MAP06)
- Tuning & Validation
  - Using satellite observations
  - Using SCM & GCE
- Development plans

Other components

- Atmospheric Chemistry
- Aerosols
- Ocean

ADAS

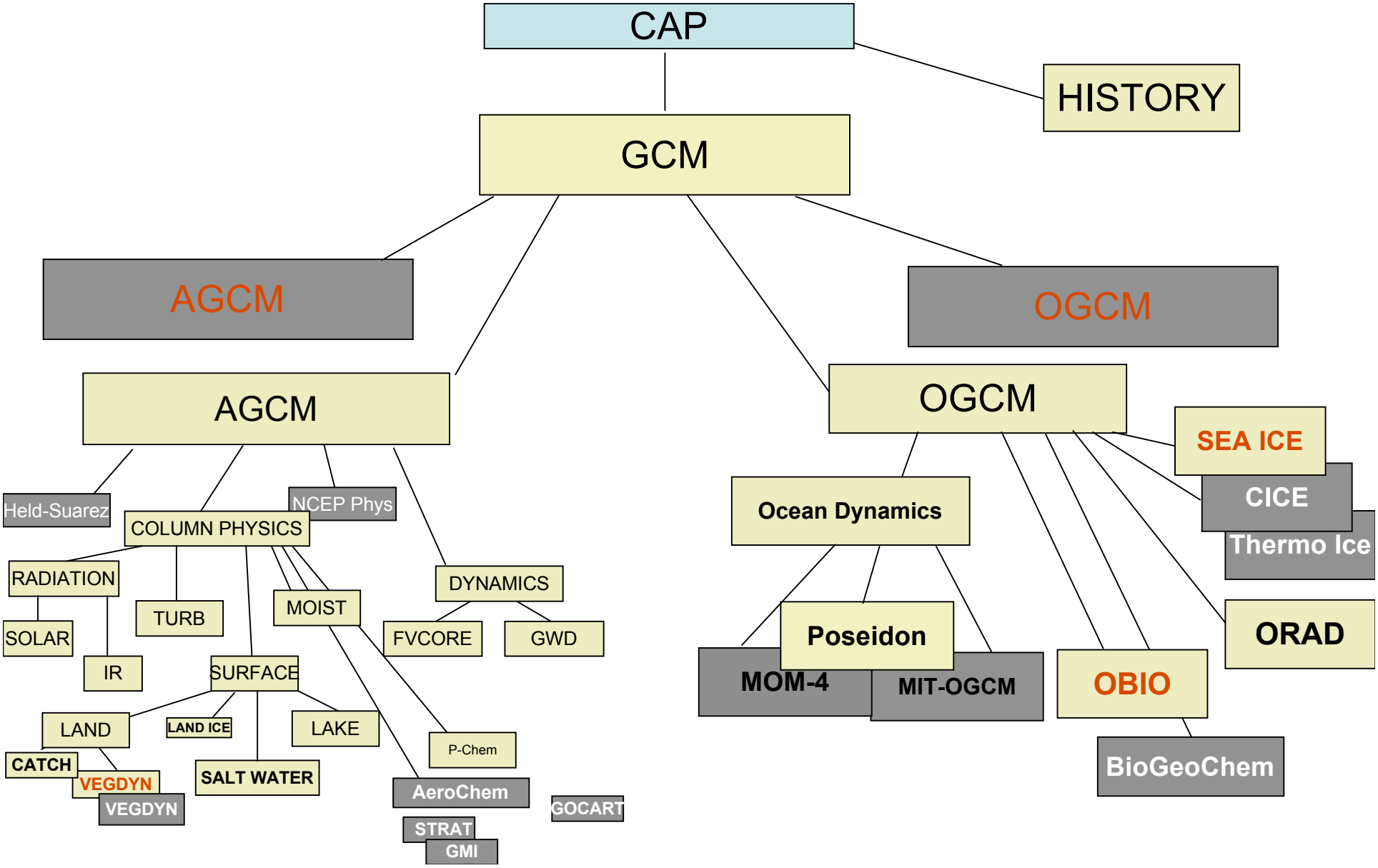
- The GSI Analysis
- Performance of 1/2° system
- Observation Impacts
- 4D-VAR development

What I don't have time to show…..

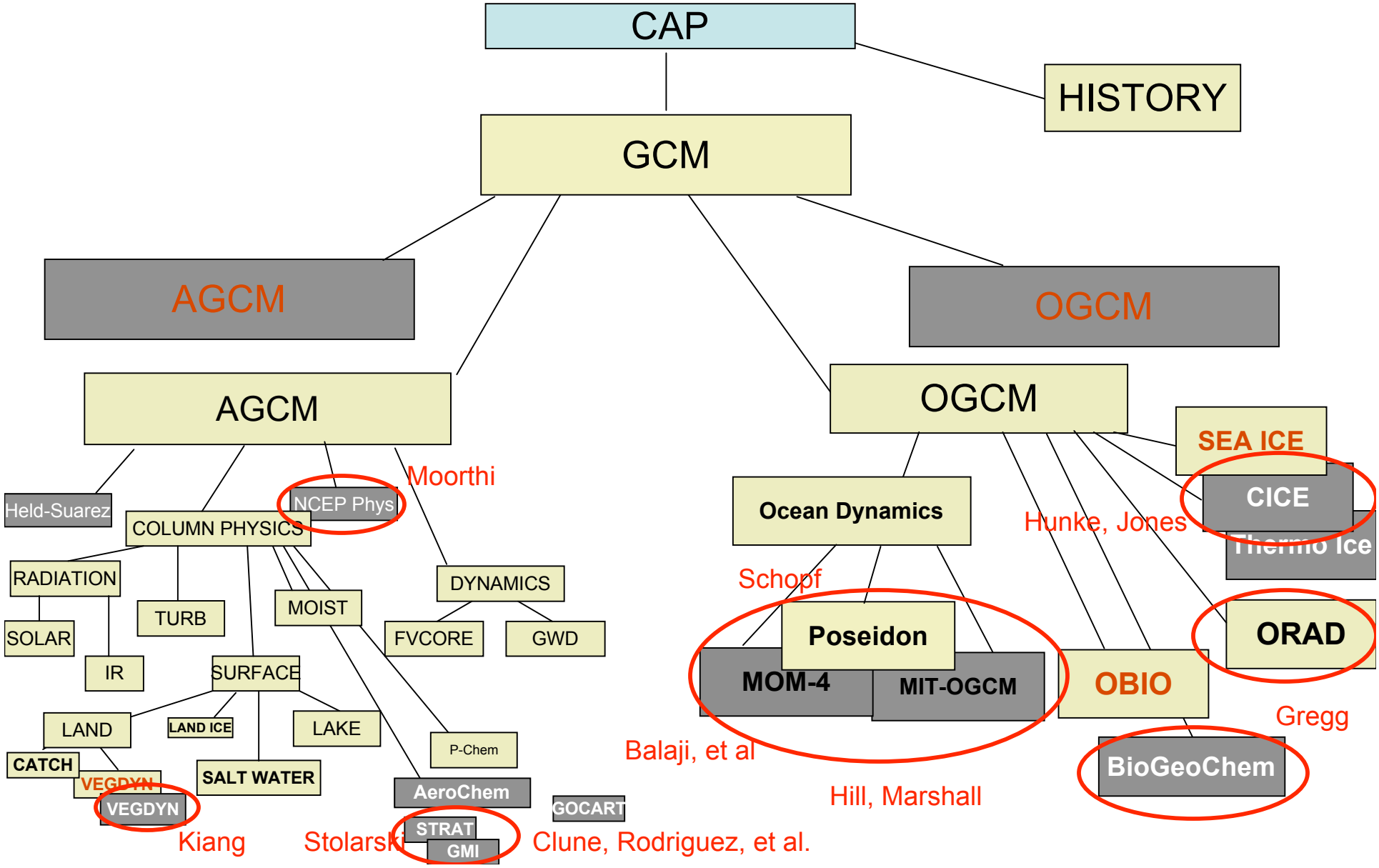
- The Catchment LSM
- The ODAS
- The Ocean biology model and ocean color assimilation system
- Carbon data assimilation
- The subseasonal/seasonal climate variability and prediction investigations
- Lots of science
- MERRA (Modern Era Retrospective-analysis for Research and Applications)
- MAPL

- But…. see other presentations and the posters

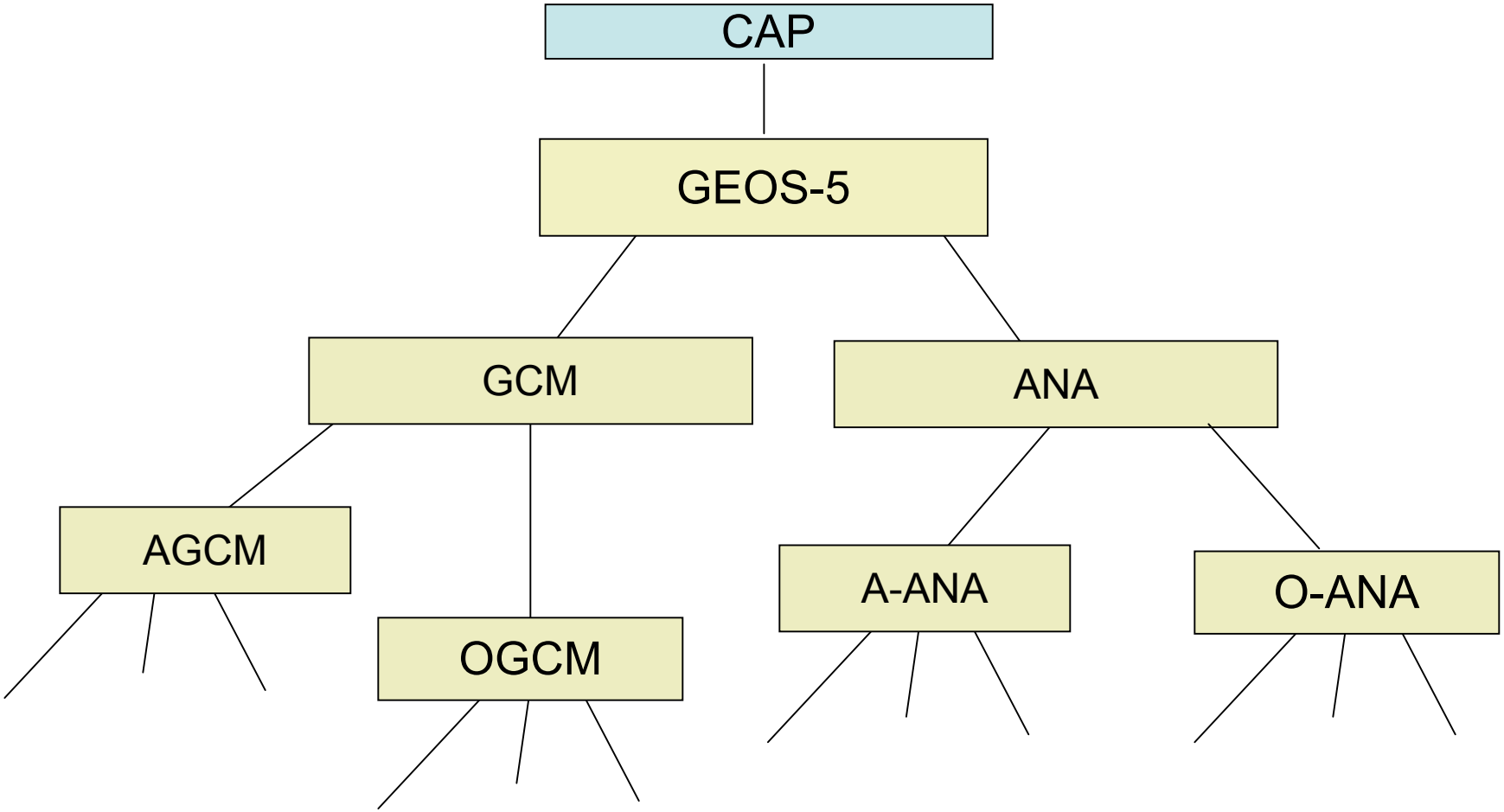
GEOS-5 GCM STRUCTURE



GEOS-5 GCM STRUCTURE



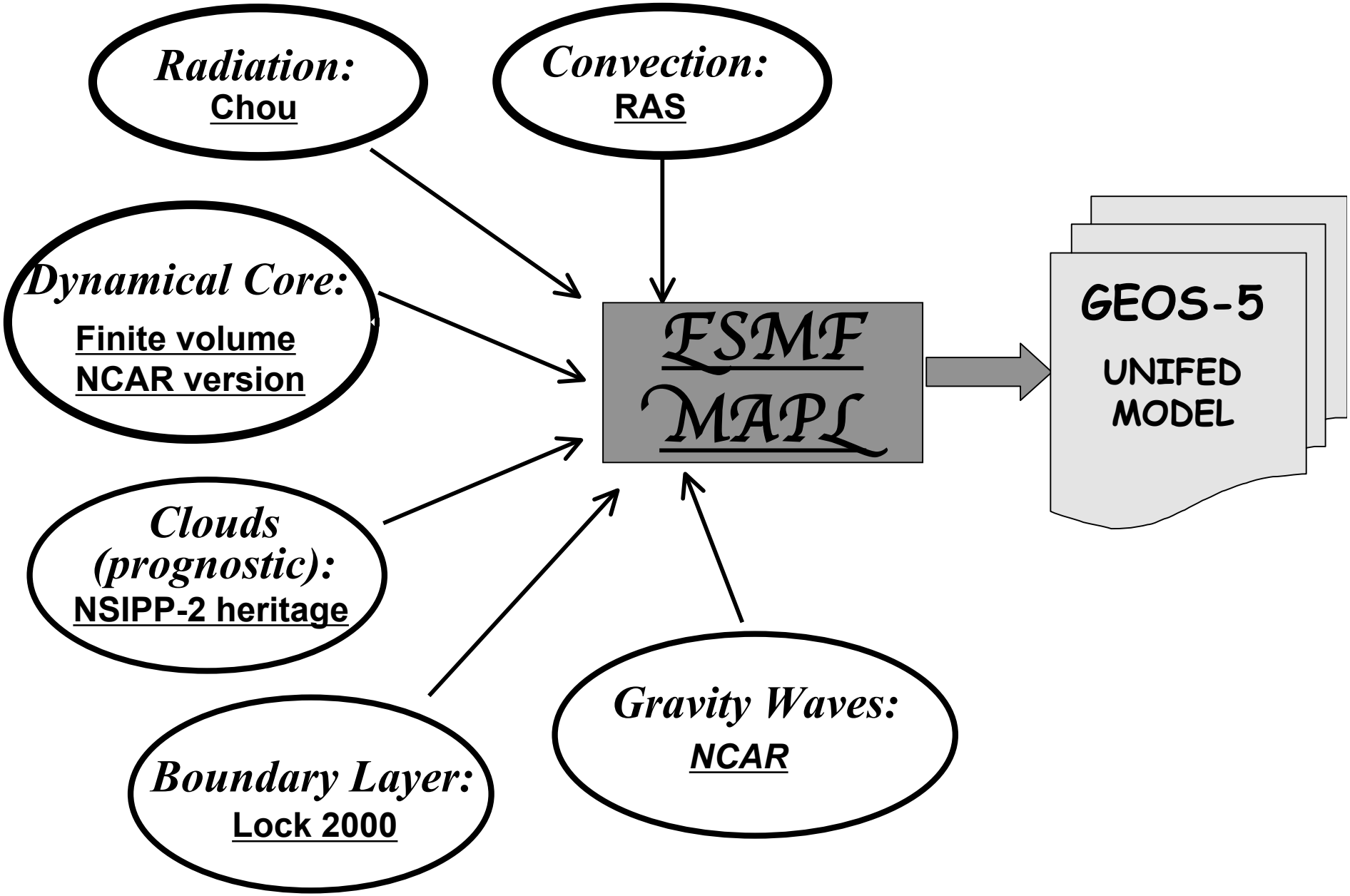
GEOS-5 DAS Structure



THE AGCM

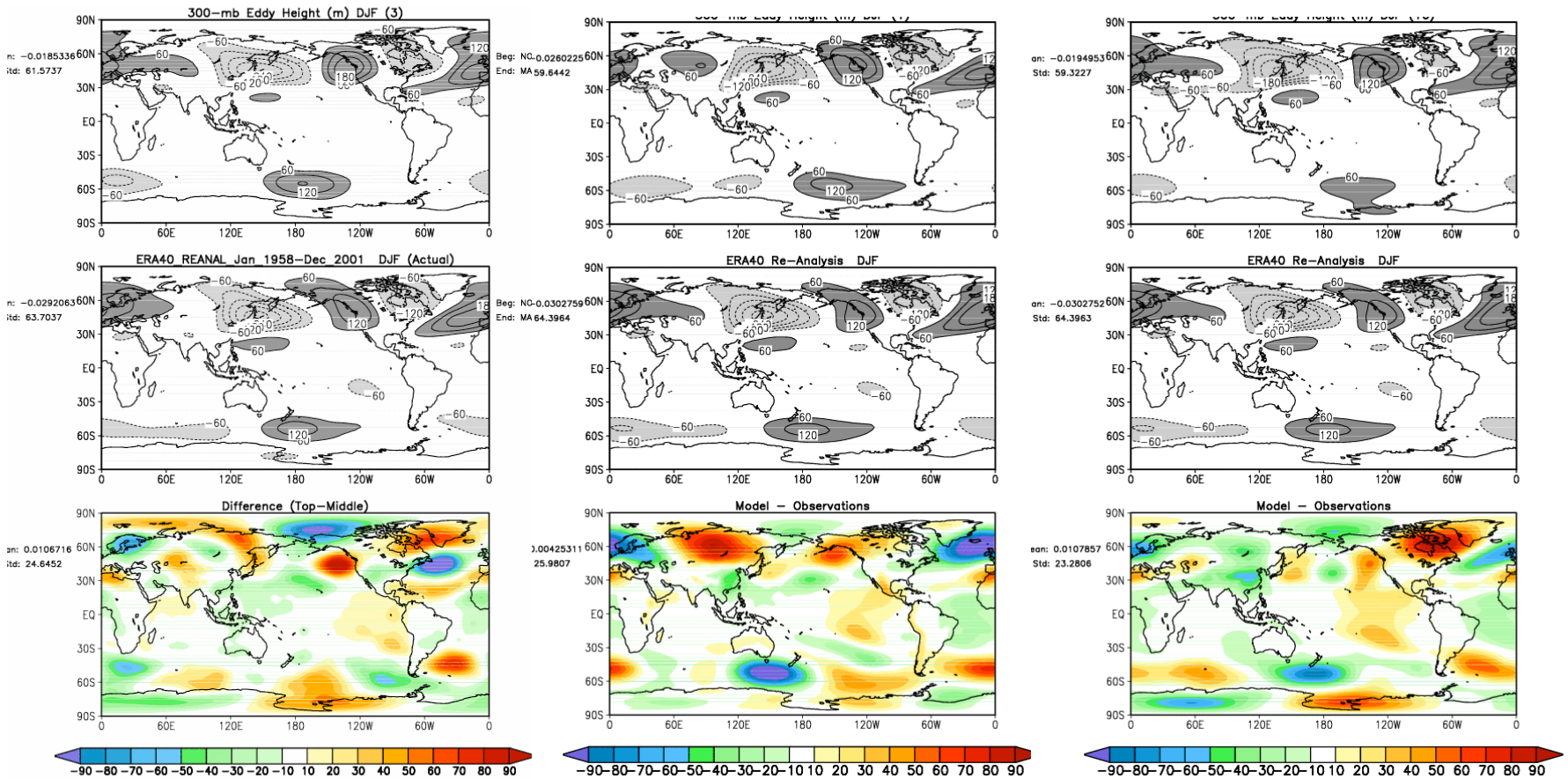
- A weather-climate model
  - Simulations (and predictions) in climate mode (1°)
  - Weather analysis and forecasts, reanalysis (1/2°)
  - Weather mode - hurricane prediction (1/4°)
- Development and validation focus is on moist processes
  - Using satellite data for tuning, validation, development
  - Using Single Column Model (SCM) to test physics parameterizations

    GEOS-5 SCM and full AGCM are the <u>same</u> code
- Development plans


Radiation:
Chou
Convection:
RAS
Dynamical Core:
Finite volume
NCAR version
FSMF
MAPL
GEOS-5
UNIFED
MODEL
Clouds
(prognostic):
NSIPP-2 heritage
Gravity Waves:
NCAR
Boundary Layer:
Lock 2000

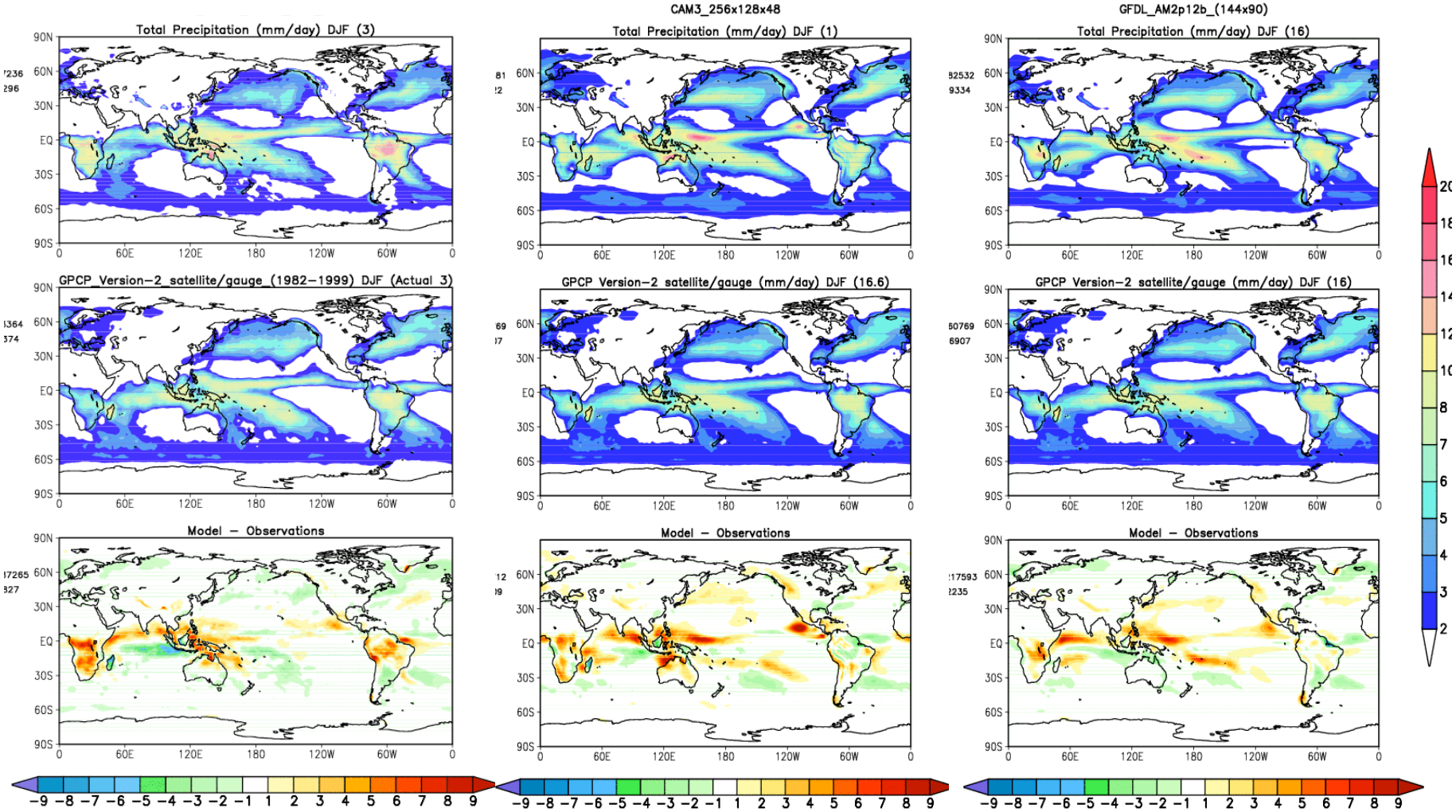
DJF 300 MB Eddy Height vs ERA-40

GEOS-5/EROS	NCAR/CAM-3	GFDL/AM-2
0.01 / 24.6	0.00 / 26.0	0.00 / 23.3



DJF Precipitation vs GPCP

GEOS-5/EROS	NCAR/CAM-3	GFDL/AM-2
.04 / 1.53	.40 / 1.44	.22 / 1.22

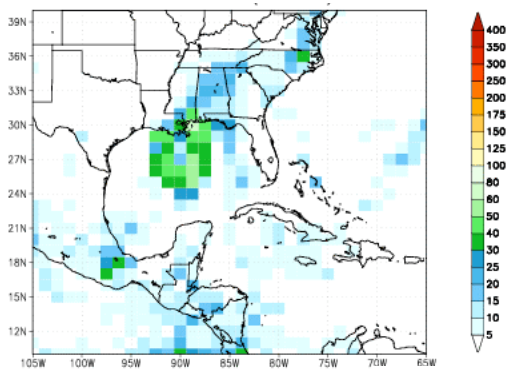


GEOS5: Realizing the power of Columbia

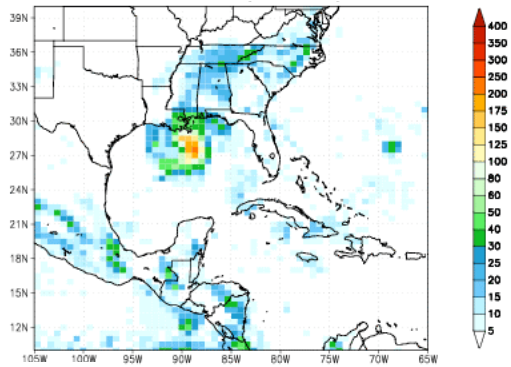
Precipitation Rate

Precipitation Rate (mm/day) (Initialized: 2005 Aug 27, 12z)
00Z29AUG2005

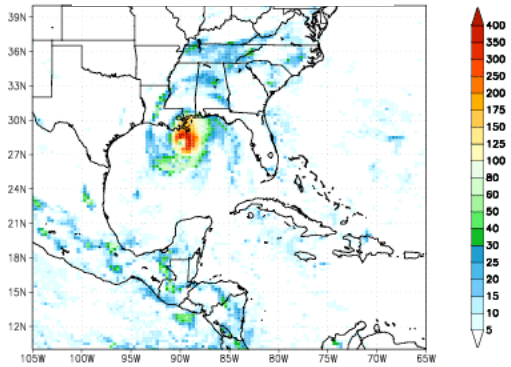
1 degree resolution



0.5 degree resolution



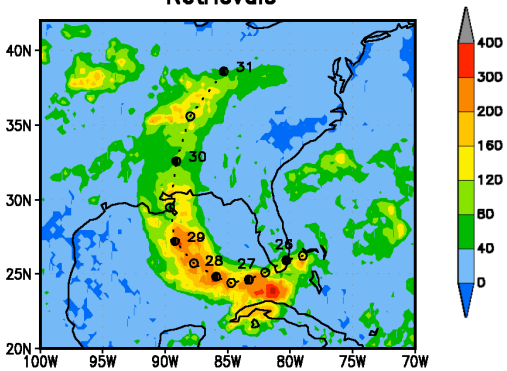
0.25 degree resolution



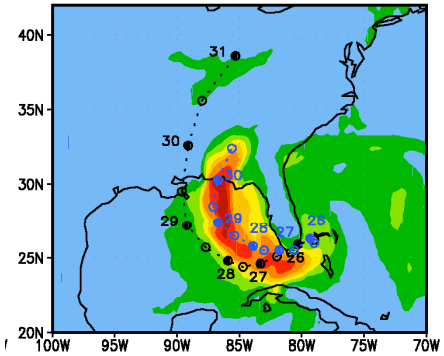
Hurricane Katrina (Aug 2005)

Accumulated rainfall (mm)

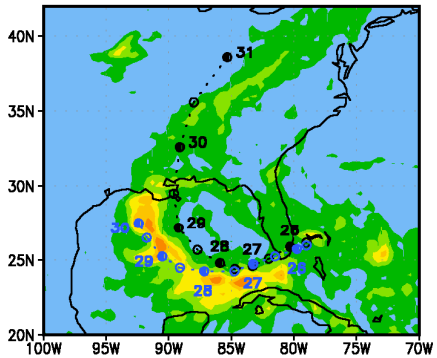
Retrievals



ECMWF forecast



GEOS-5: 1/4 degree forecast

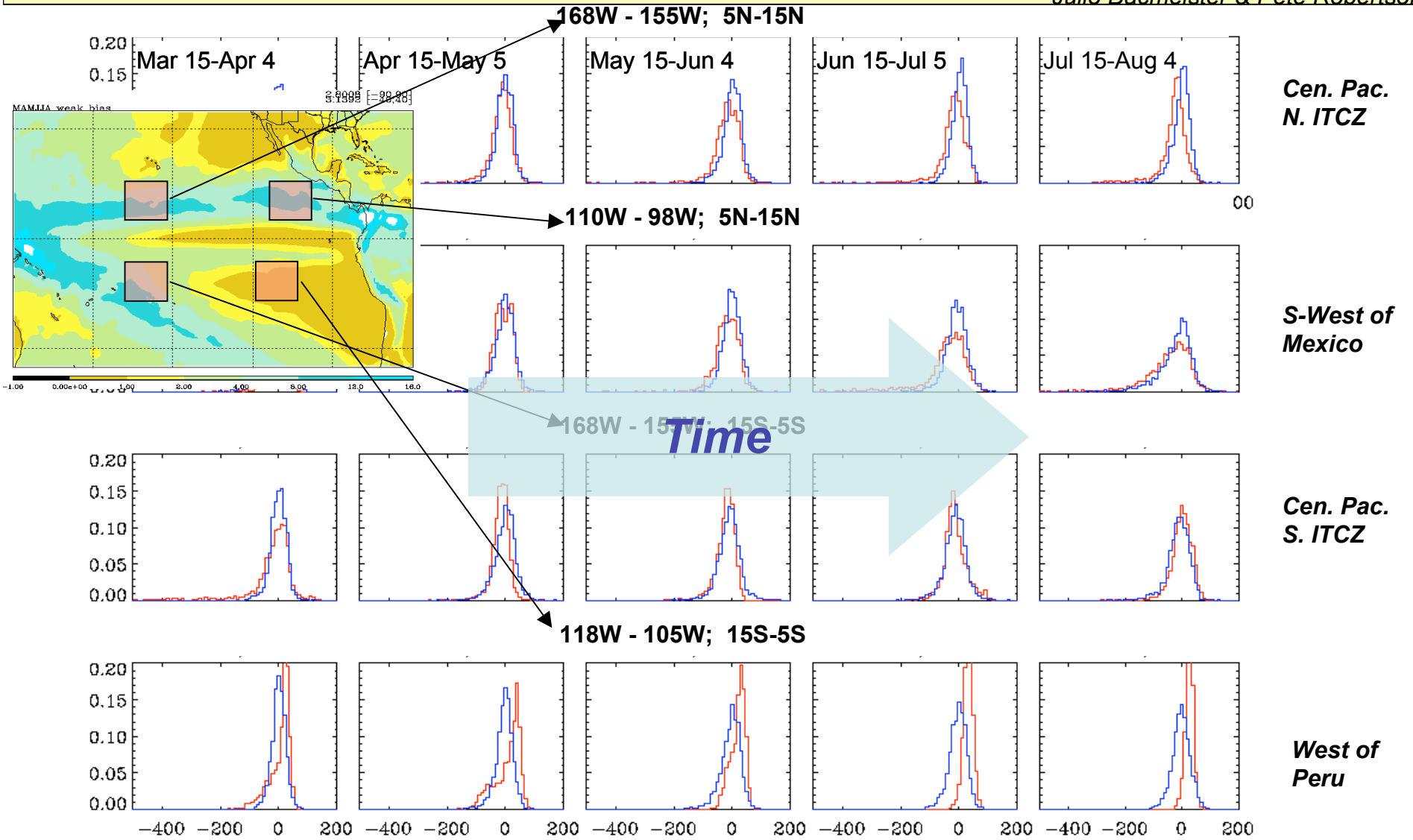


MAP'05
2-day Katrina forecasts
Increasing resolution improves realism of forecasts of the details in nature

Satellite data for model development and validation:

PDFs of ω_{850} from GEOS-5 compared with SSMI surface divergence

Julio Bacmeister & Pete Robertson



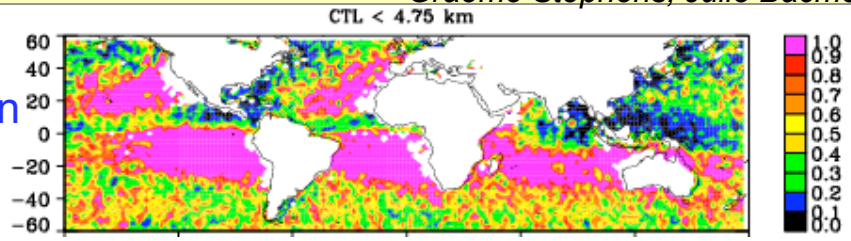
red – PDFs for standard GEOS5

Blue – PDFs for *scaled* SSMI surface divergence

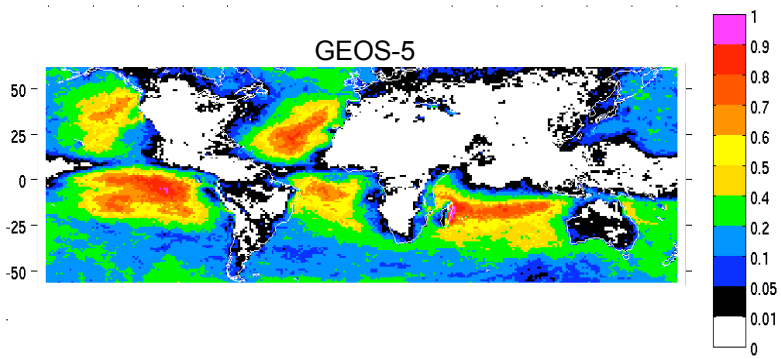
Satellite data for model development and validation: How to best use CloudSat data?

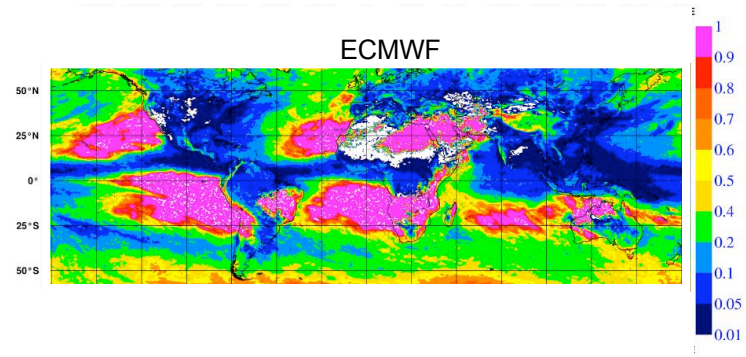
Graeme Stephens, Julio Bacmeister, Peter Norris, Angela Benedetti

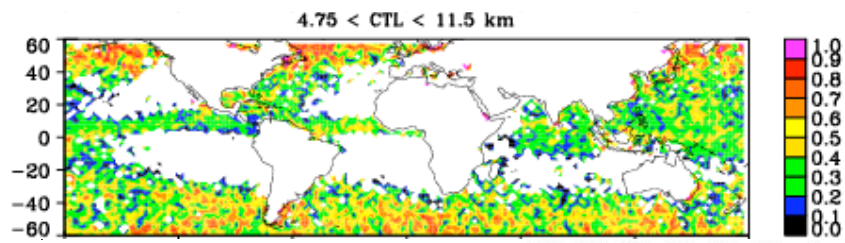
Fraction of precipitating profiles with cloud top within specified height ranges



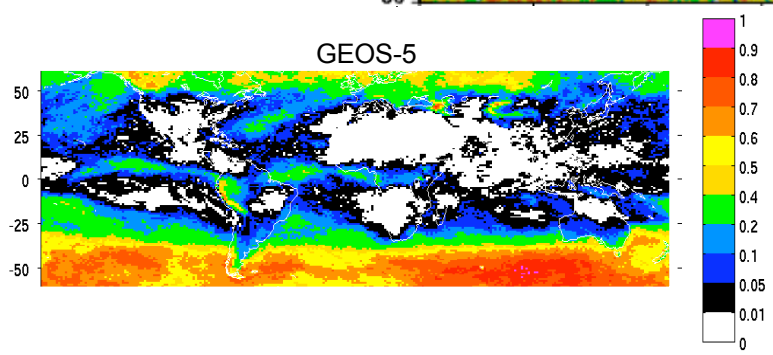
Low (< 4.75 km)

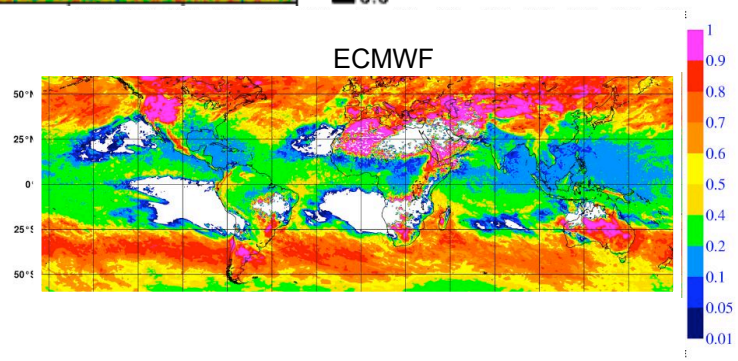






Mid (4.75 - 11 km)

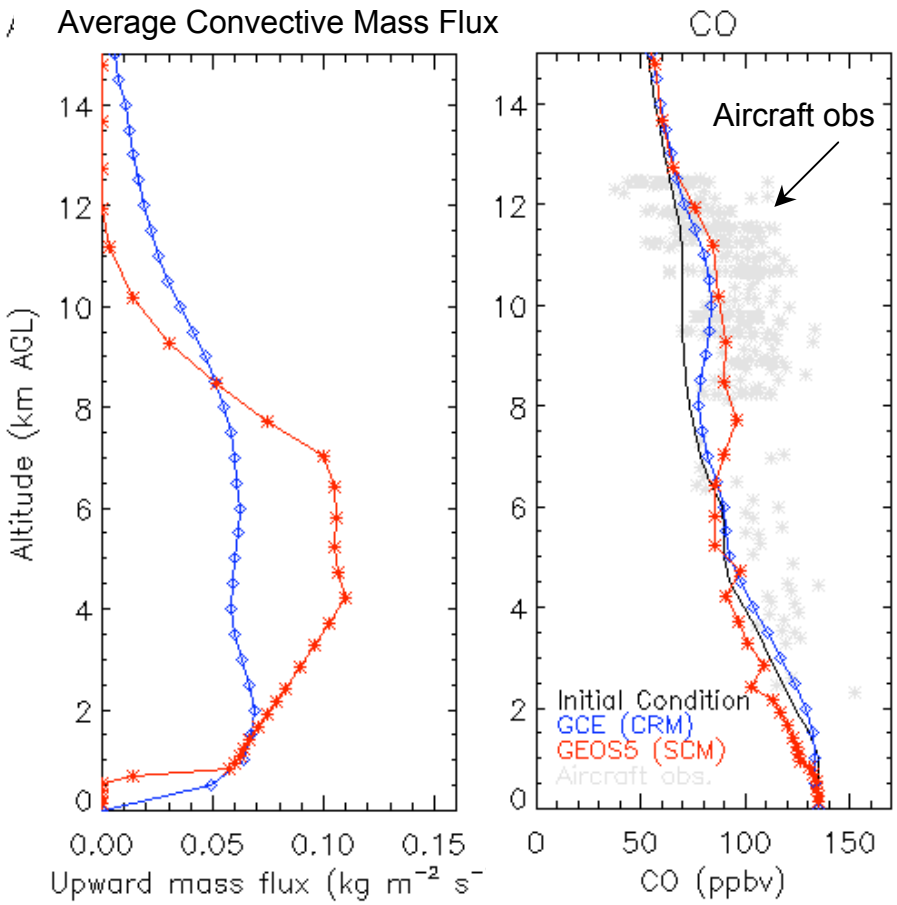




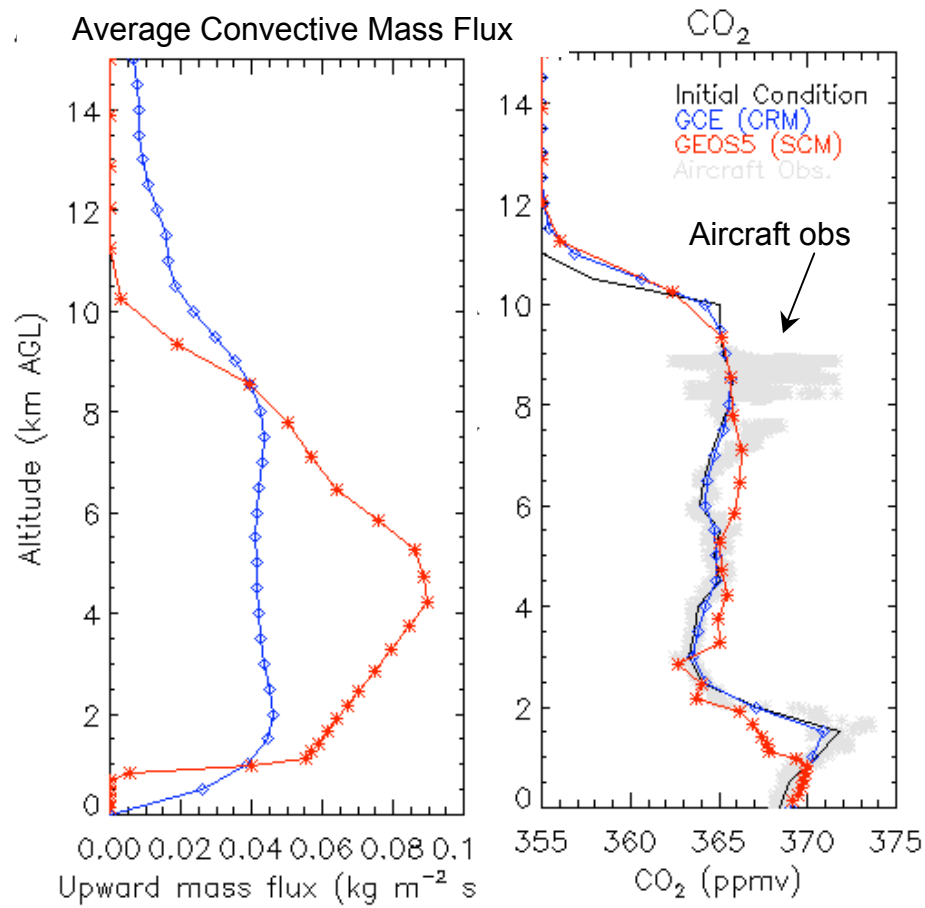
GEOS-5 - Testing Parameterizations with the SCM and GCE

Lesley Ott, Julio Bacmeister, Steven Pawson

Convective mass flux in the July 10 1996 STERAO storm



Convective mass flux in the July 21 1998 EULINOX storm



Planned Pathway for Model Dynamics

Fvcore

- *Single repository (GSFC, NCAR, NCEP, GFDL?)*
- *Hydrostatic cubed sphere*
- *Nonhydrostatic cubed sphere*

Development Plans for Model Physics

Focus is on parameterizations for high resolution

Single column model framework (SCM) a platform for development and testing

Use of *GCE CRM* (*with W. K. Tao)* to improve cloud geometry (and PDFs) - updrafts, mass fluxes, cloud properties

Improving RAS - broadening the input to entrainment by including prior cloud pdfs (*with Brian Mapes)*

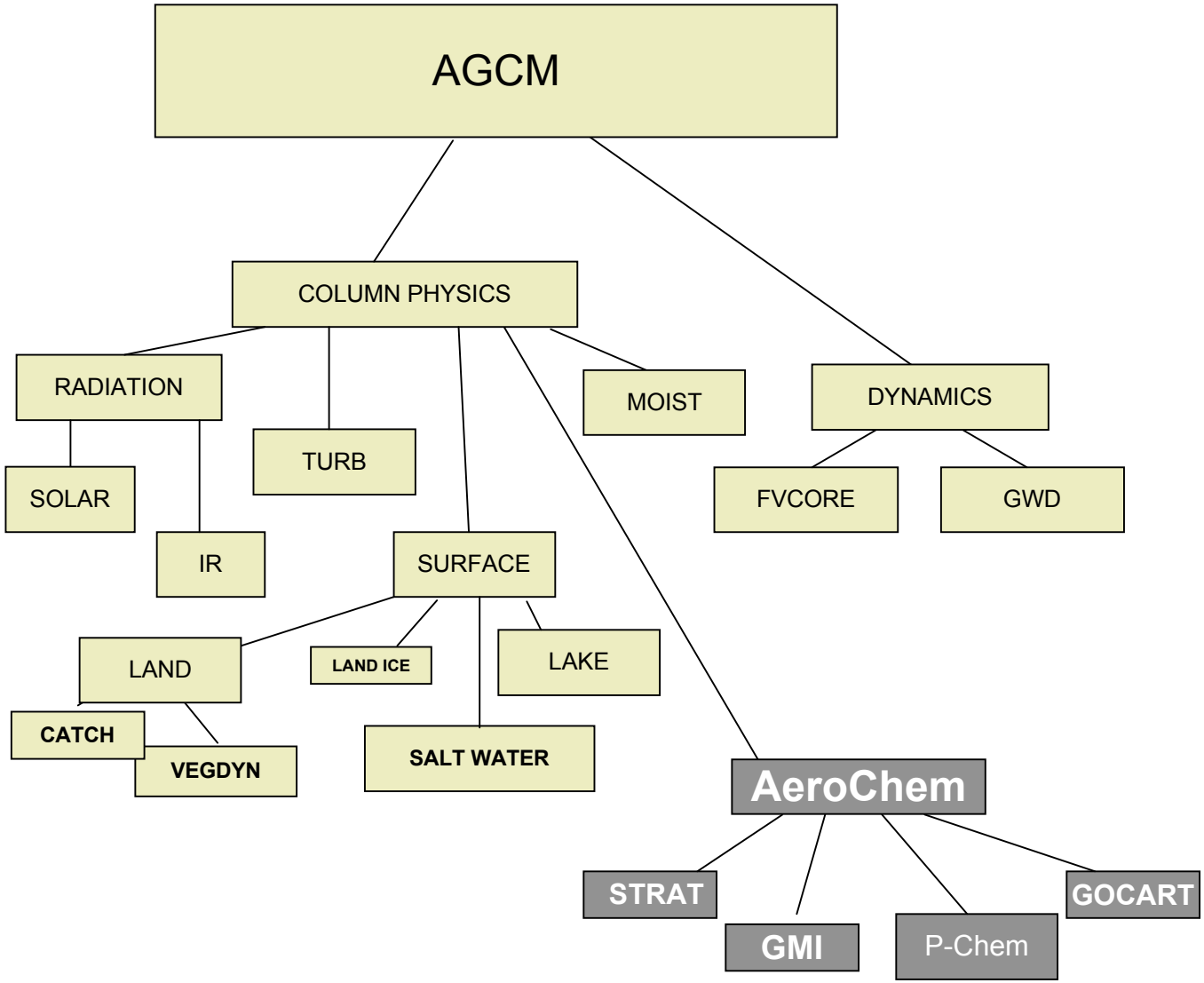
"Parameterization Swaps"*, e.g., McRAS (Sud and Walker), RAS2 (Moorthi); NCEP physics*

Gravity Wave Drag Parameterizations (orographic and non-orographic) (*with Jadwiga Richter, Fabrizio Sassi, Steve Eckermann*)

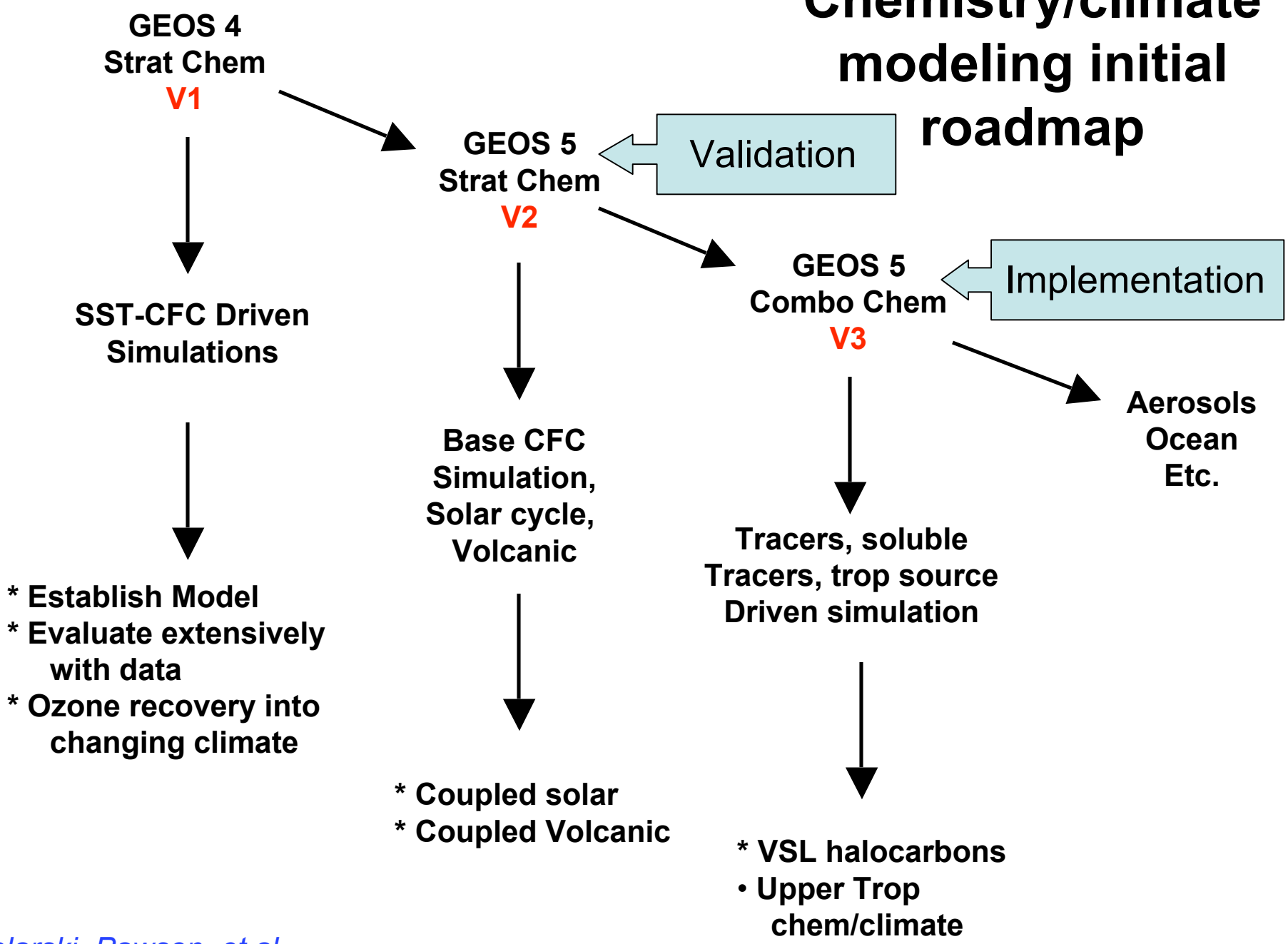
Other components

- Coupled chemistry-climate/circulation simulations
- Aerosols
- Coupled AOGCM
  - testing the ogcm under GEOS-5

GEOS-5 GCM STRUCTURE



Chemistry/climate modeling initial roadmap



Stolarski, Pawson, et al

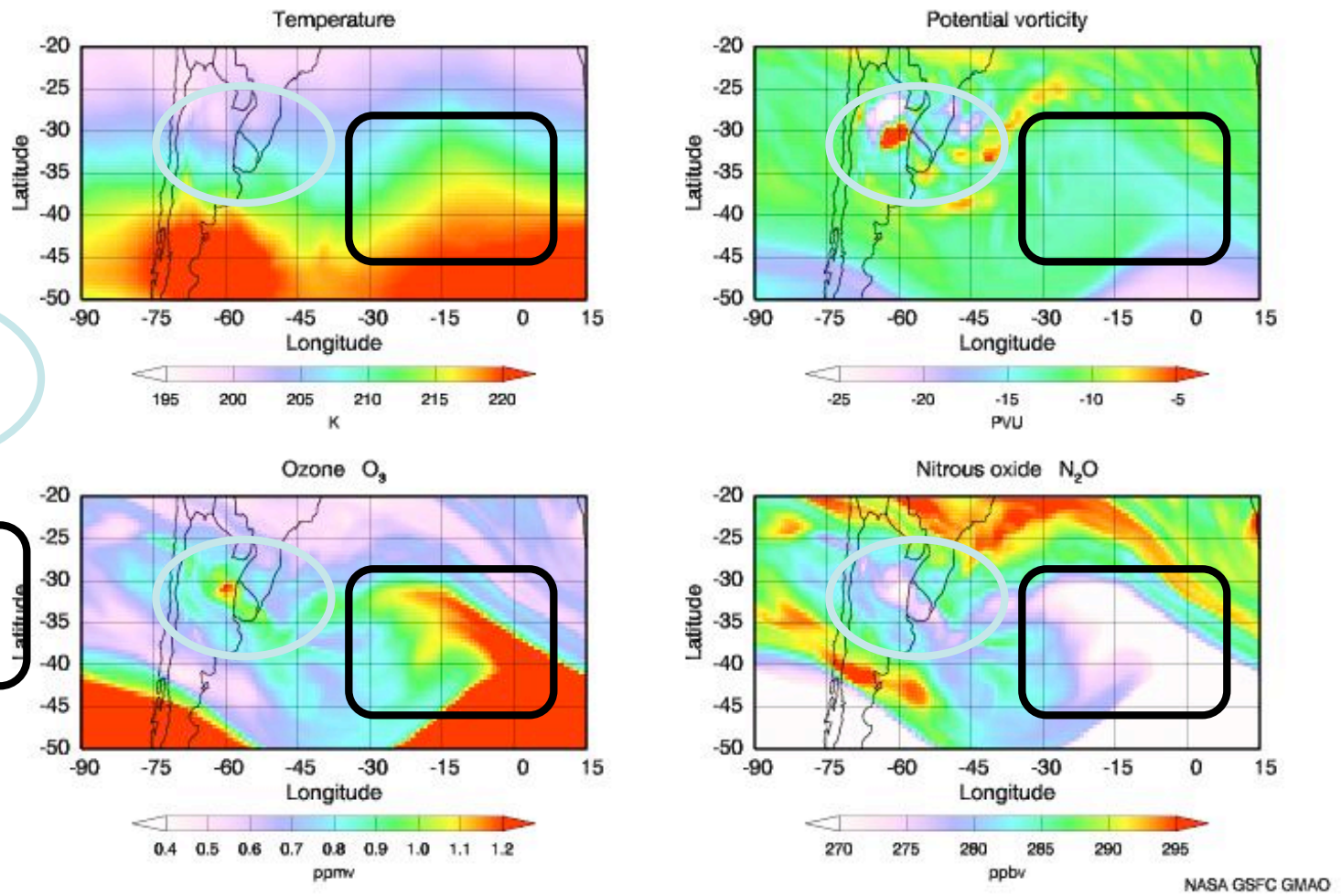
GEOS-5 AGCM with Stratospheric chemistry module from GSFC/ACD

- Simulations at 0.666°× 0.5° with 72 layers
- Year is defined only by boundary conditions (SST, ice, chemical emissions)
- Example: Sept 26 “2004” at 425K

Steven Pawson, Eric Nielsen, Rich Stolarski

Lee of Andes

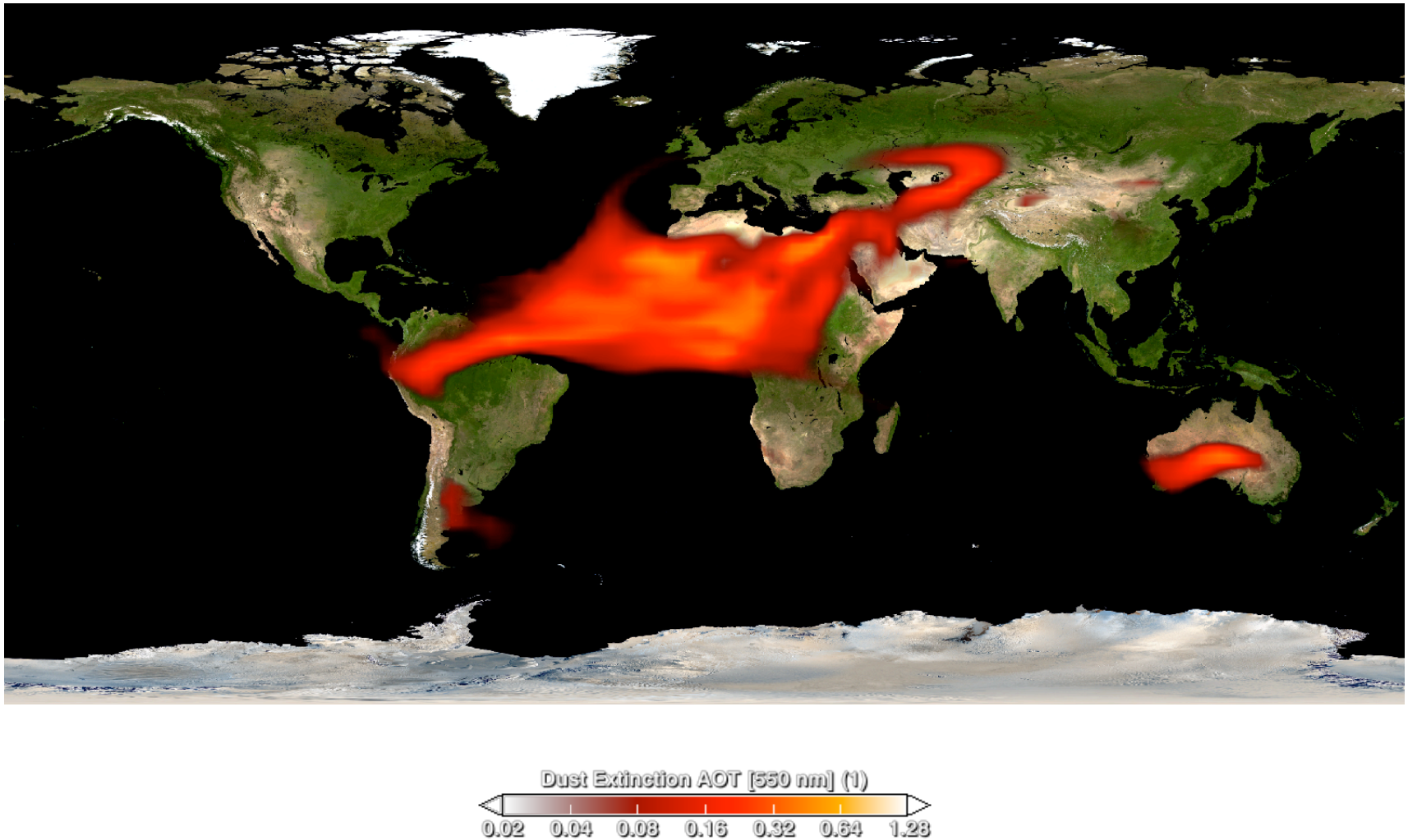
Edge of Vortex



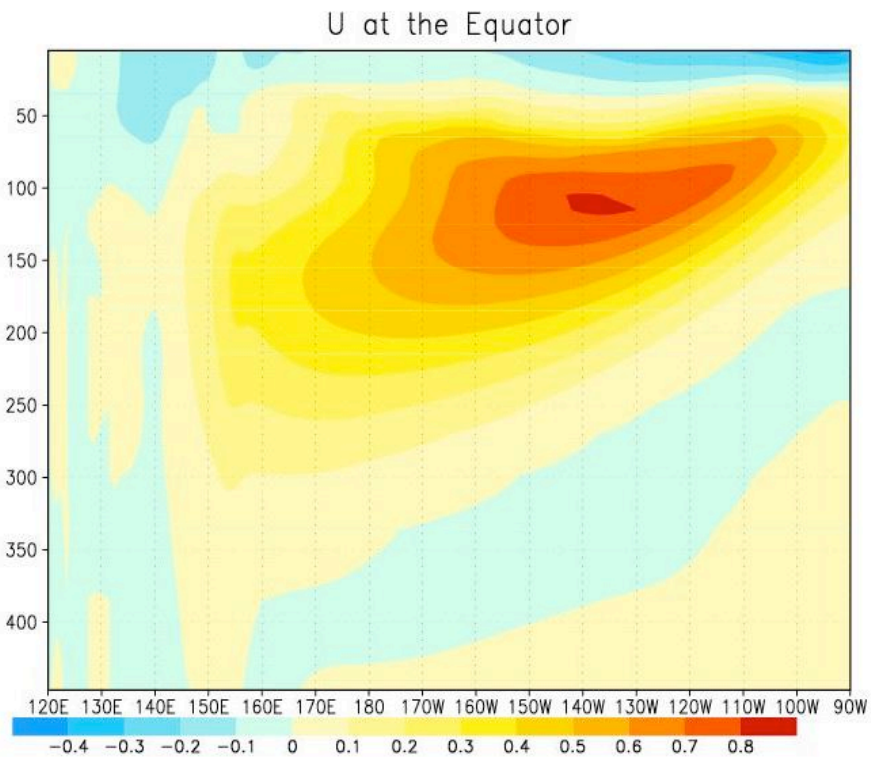
See the simulations on the hyperwall!

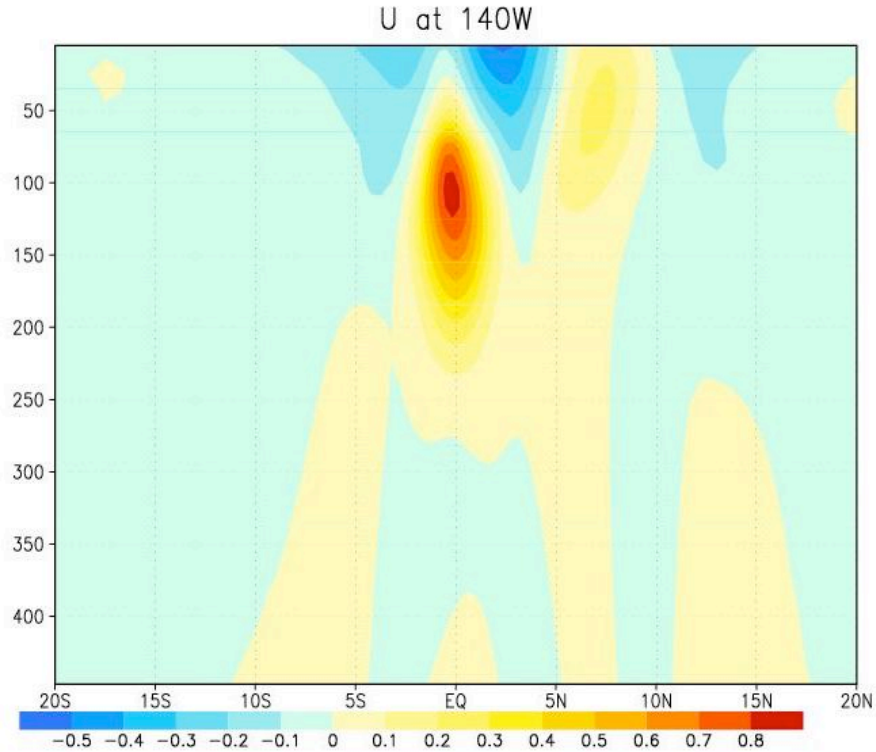
GEOS-5 AGCM with Aerochem/GOCART from GSFC/ACD

- Simulations at 2.5°× 2° with 72 layers
- Snapshot after 20-day simulation

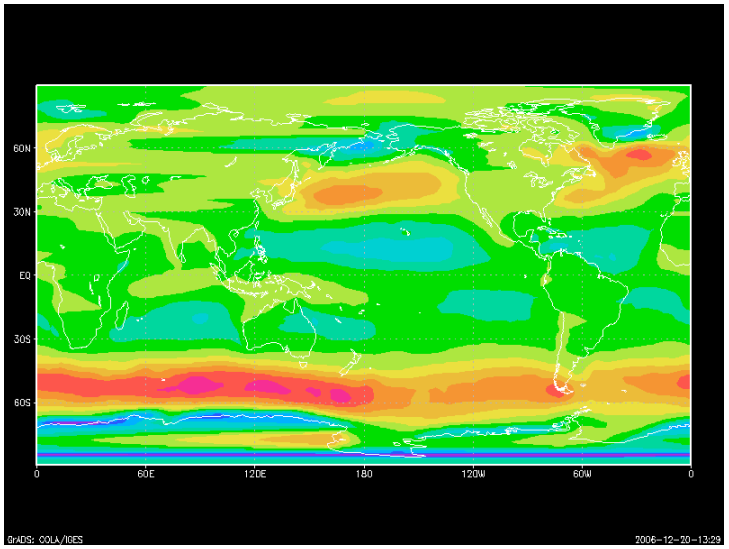


15-year integration of MOM4 under GEOS-5 structure completed (with dataAGCM) -- test of coupler for tripolar grids

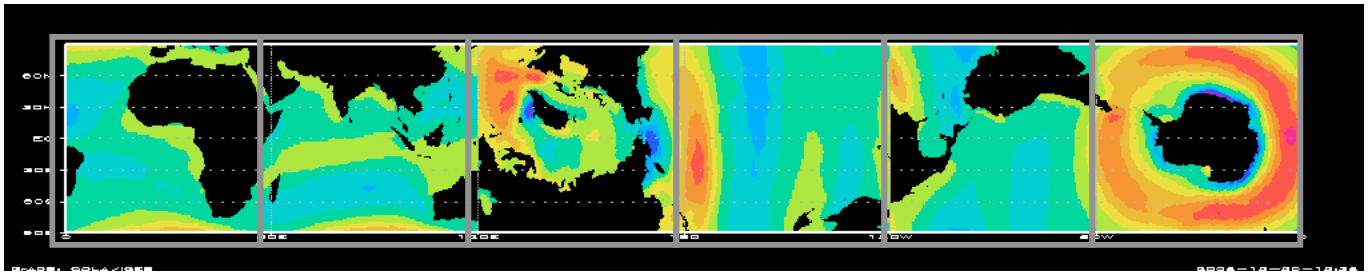




Interface completed for communications test for GEOS-5 AGCM - MITogcm (cubed sphere) coupling



Zonal stress seen by 1 degree atmosphere



Zonal stress "seen†" by MIT CS510 ocean

•Cube face

† *ocean really sees rotated stress.*

From Chris Hill, MIT

Next steps

- Coupled AOGCM tests with MOM4
  - will be basis for (sub) seasonal forecast investigations [contributing to NOAA's Climate Test Bed]
  - advancing chemistry-climate feedback studies to an interactive ocean
  - including ocean biology
  - including and evaluating sea-ice models

- Coupled Chemistry-circulation
  - GMI COMBO chemistry-climate
  - Harvard tropospheric chemistry for air pollution transport studies

- Aerosols
  - Prognostic aerosols using GOCART
  - Inclusion of Indirect effects

- LSM with dynamic vegetation
  - prognostic phenology
  - carbon-nitrogen fluxes

The Atmospheric Data Assimilation System (ADAS)

NCEP/GMAO GSI + GEOS-5 AGCM

1/2° x 72L resolution for NRT production and MERRA (1979-present)

- Reprocessed August 2004 - December 2006 for AURA
- AURA system is continuing in production mode
- Ops stream will include 5-day forecast
- Updated system now in validation (2001, 2004)
- Metrics have focused on MERRA (hydrological cycle)

- The GSI Analysis
- Performance of 1/2° system
- Observation Impacts
- 4D-VAR development

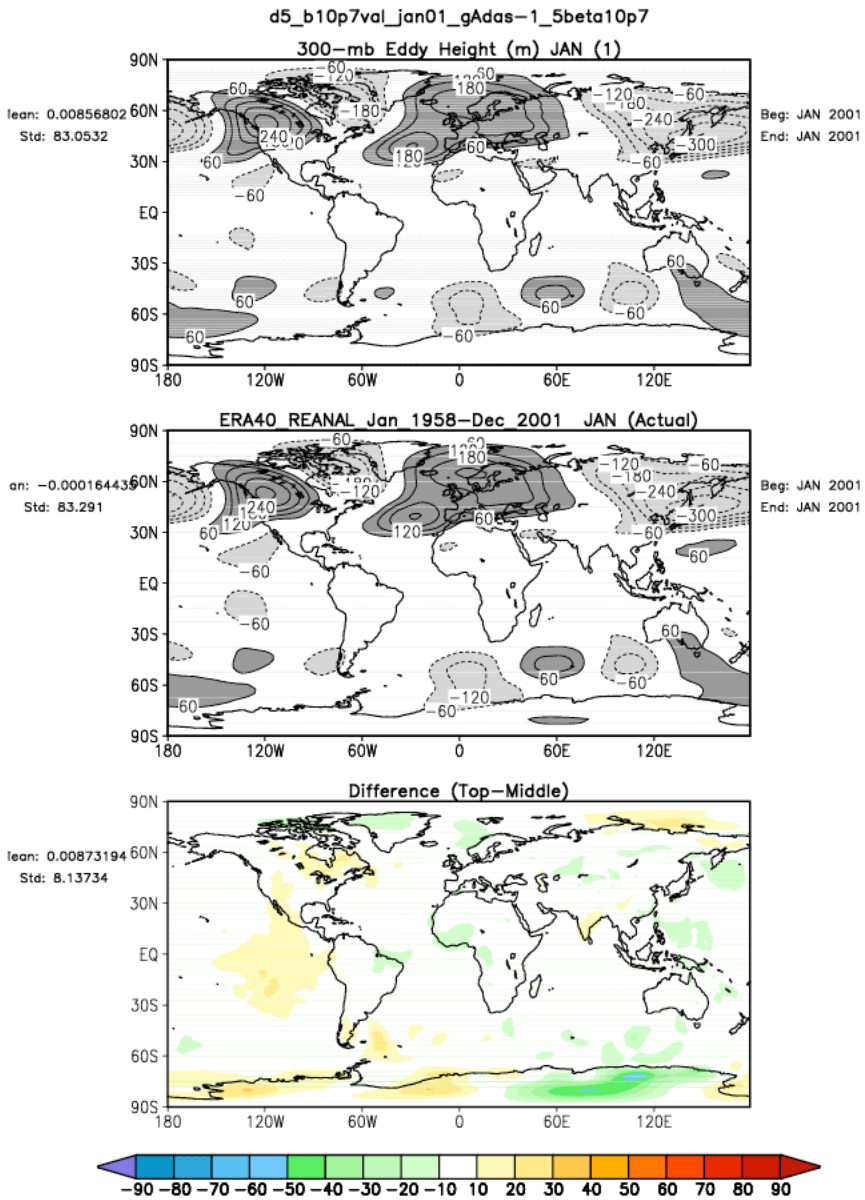
The GSI Analysis

- Developed by NCEP

- Radiance-based assimilation
- Allows for inhomogeneous and anisotropic background error covariance formulation
- Allows distinguishing land-sea, tropics-midlatitudes, etc
- Easy to use in both global and regional applications
- Uses the JCSDA Community Radiative Transfer Model (CRTM)
- Online observational (and model) bias correction

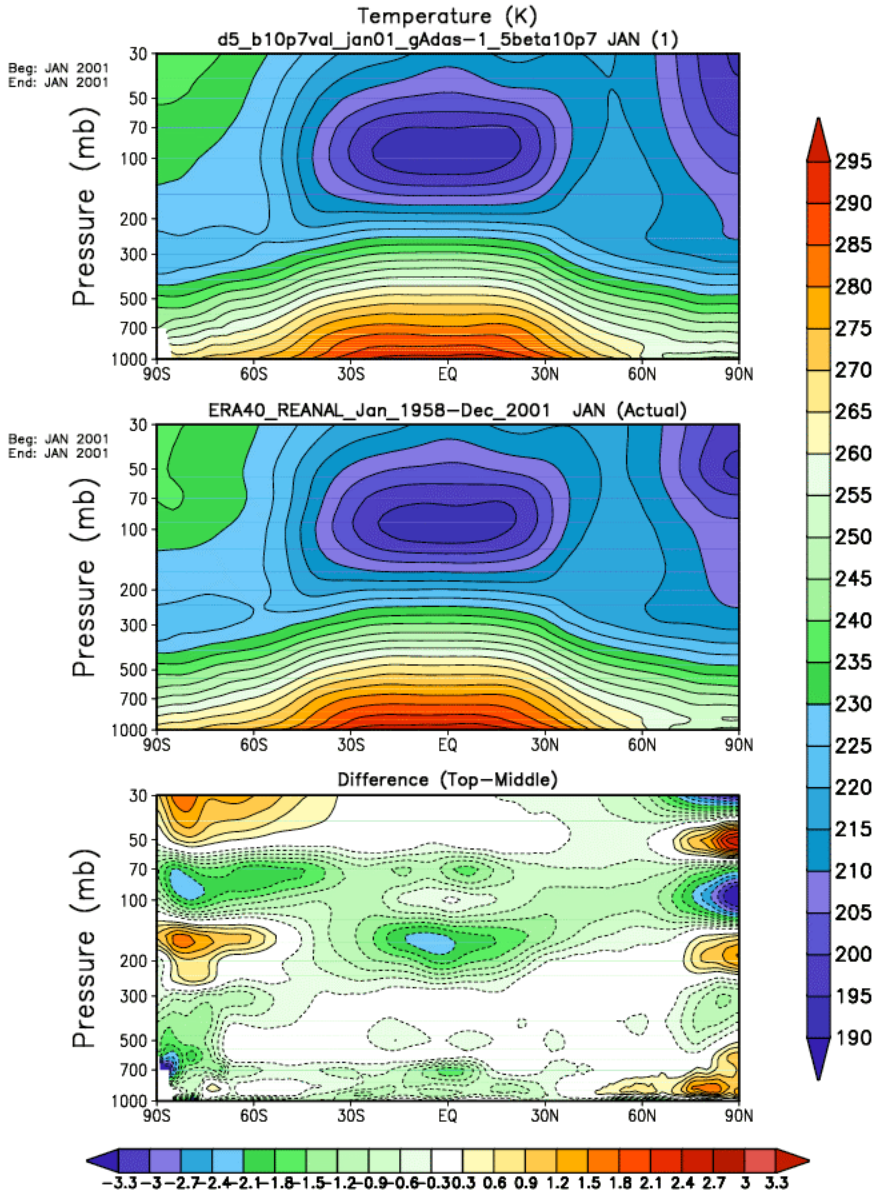
- Now NCEP-GMAO joint development -- shared repository

The GEOS-5 ADAS Validation: 300mb Eddy Height

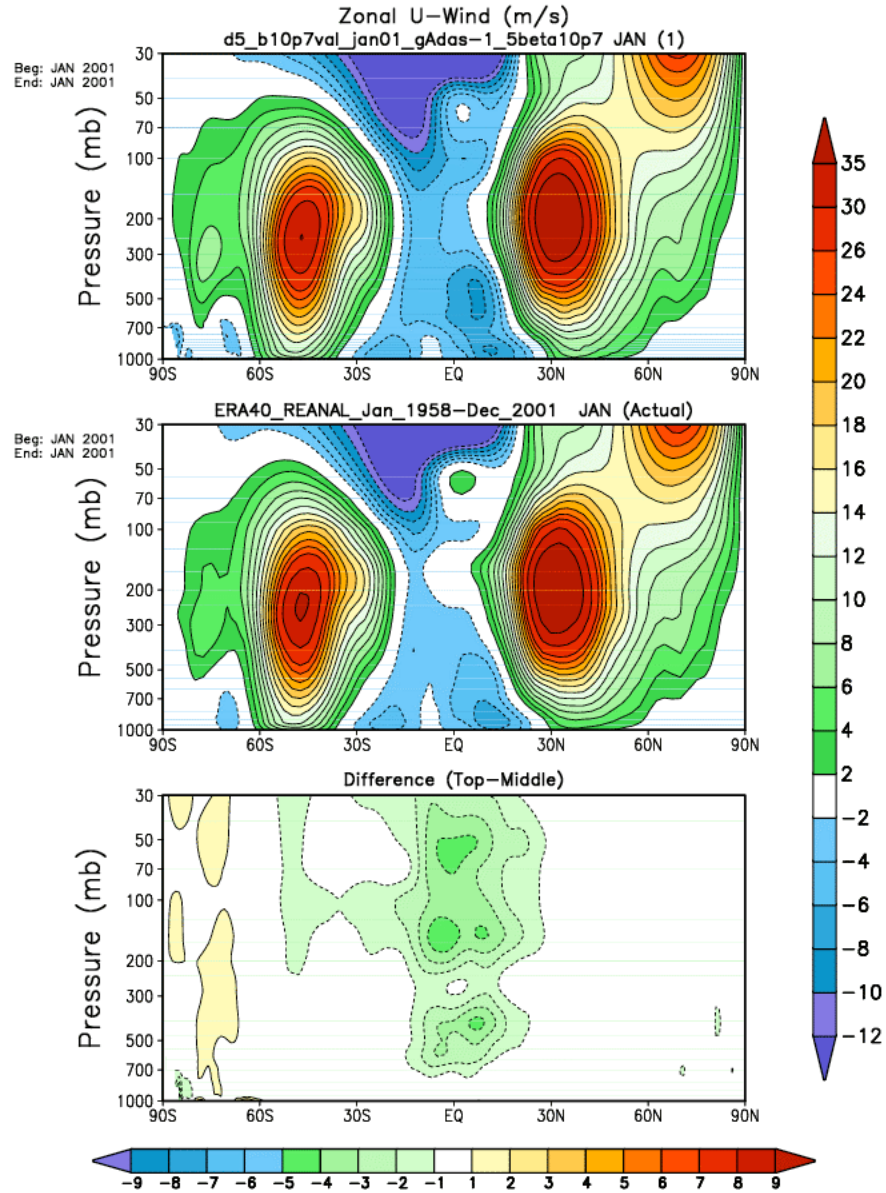


The GEOS-5 ADAS Validation

Zonal Mean Temperature

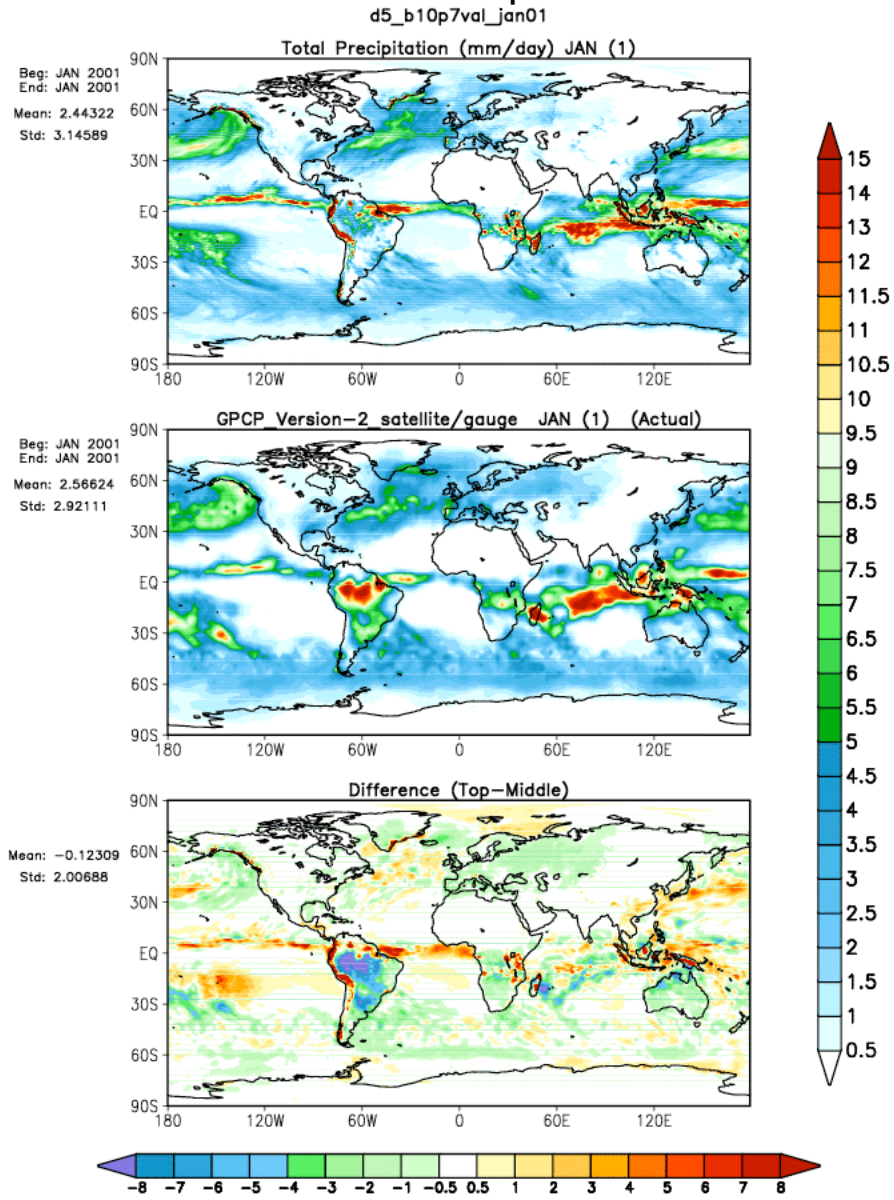


Zonal Mean u-wind

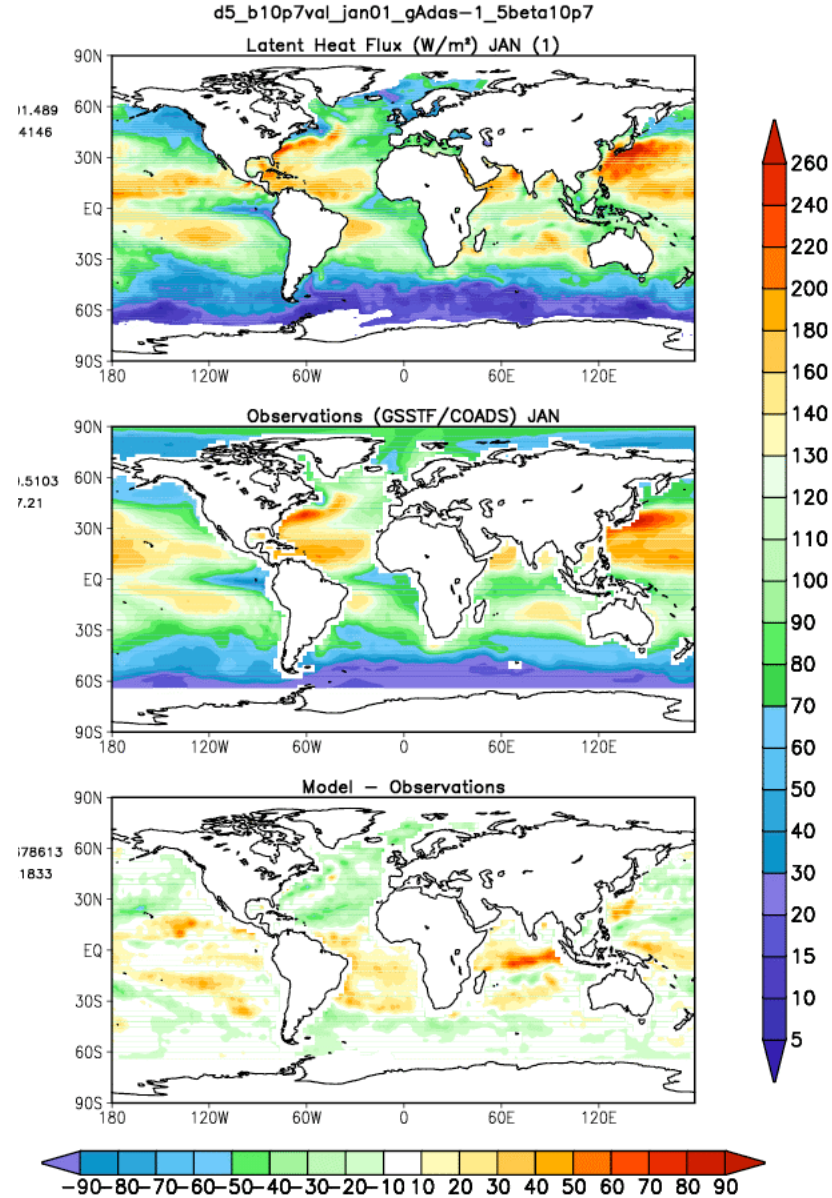


The GEOS-5 ADAS Validation

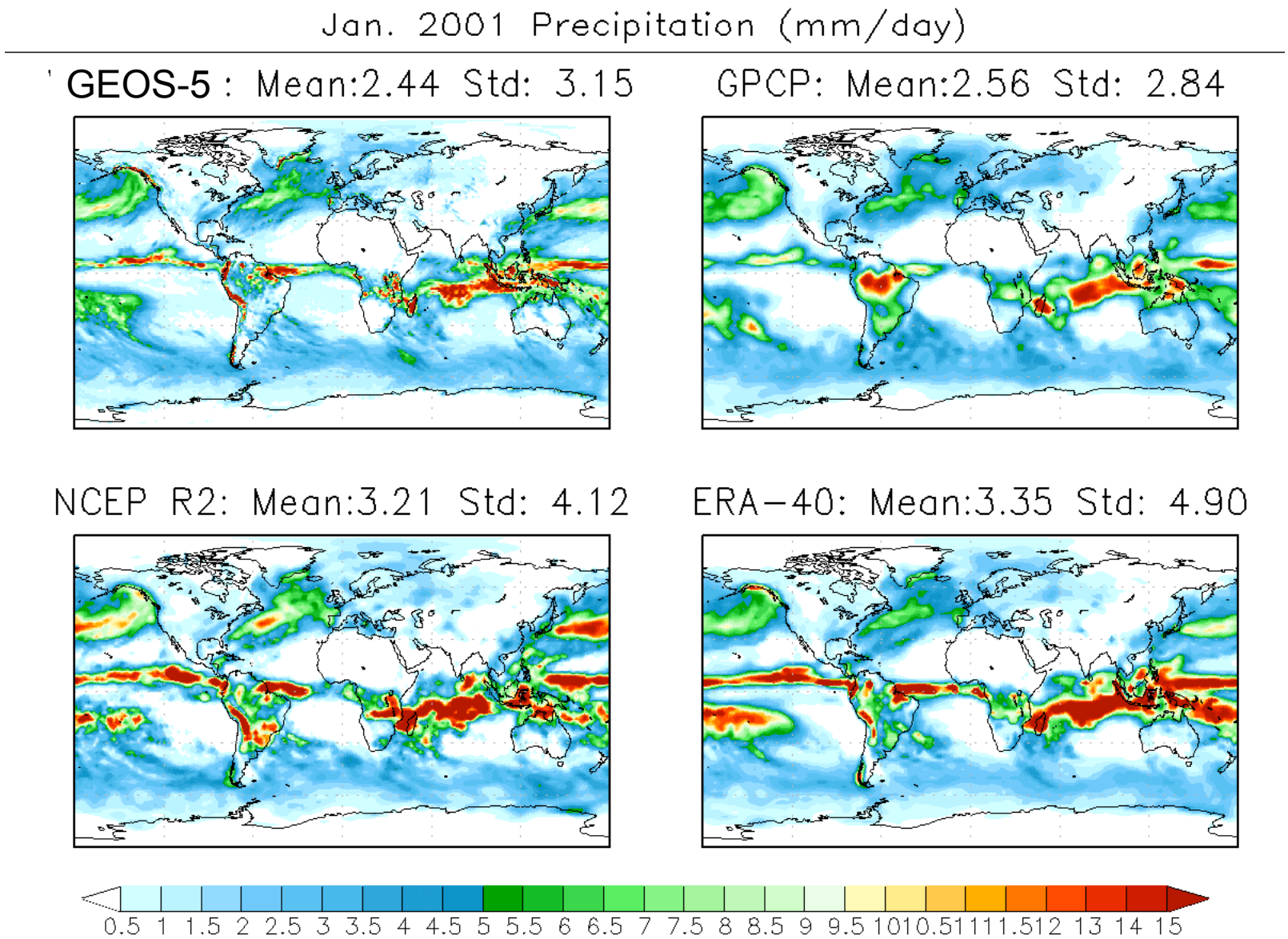
Total Precipitation



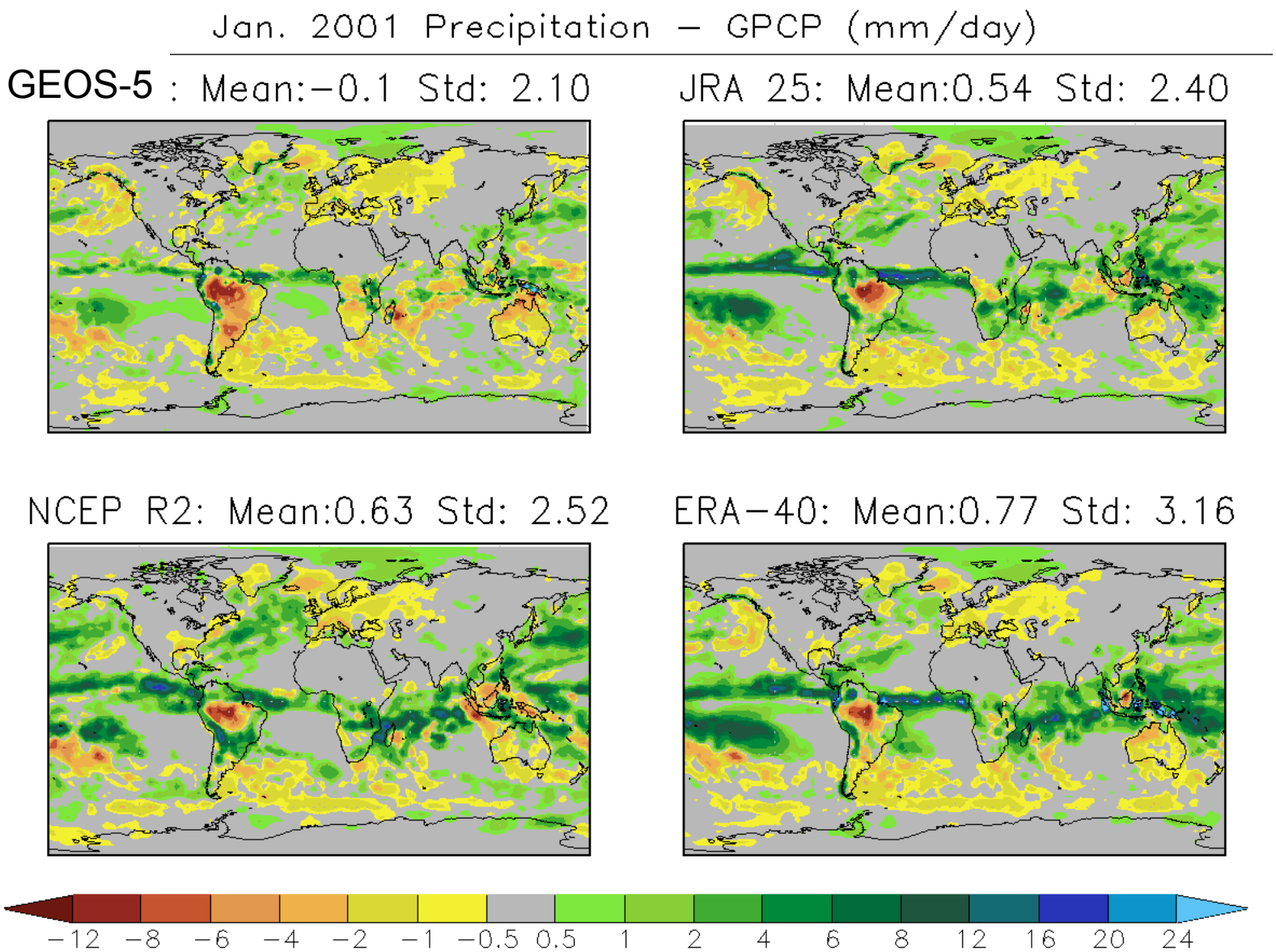
Surface Latent Heat Flux



The GEOS-5 ADAS Validation: Precipitation



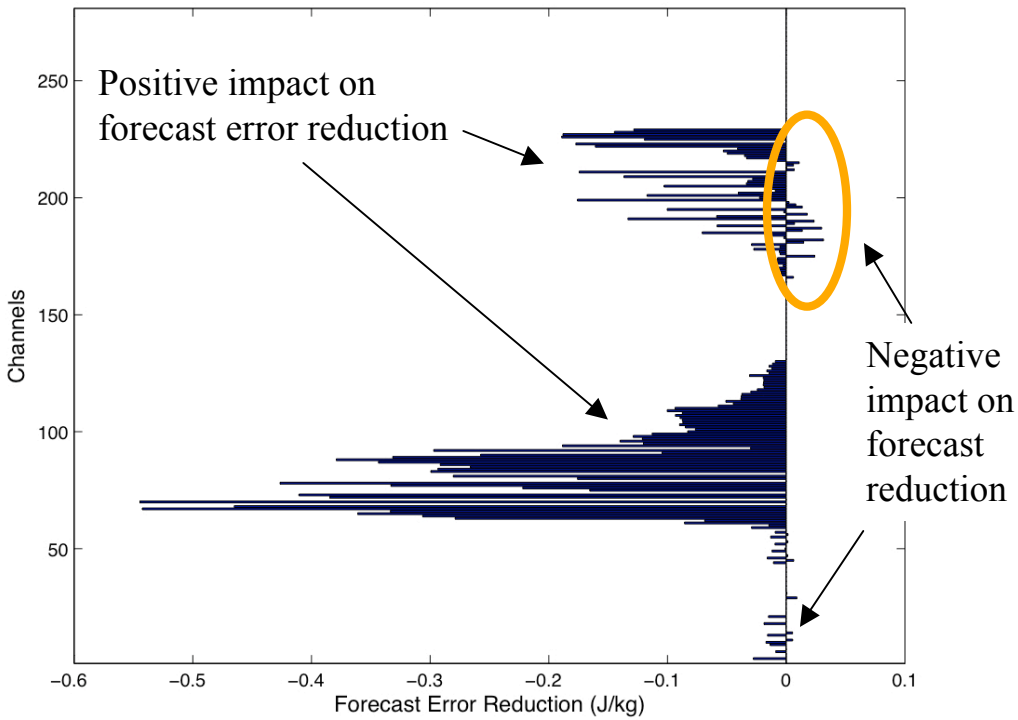
The GEOS-5 ADAS Validation: Precipitation

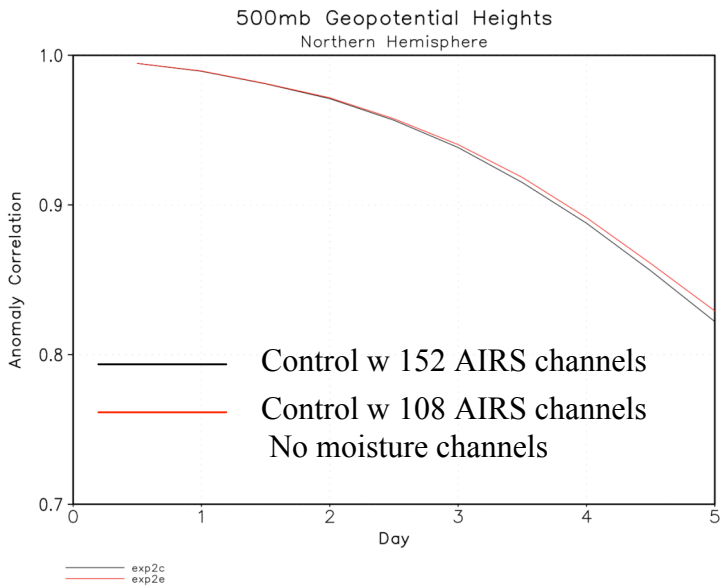


Observation Impact/Sensitivity Experiments

- AIRS
- Adjoint Tools
- AIRS Ozone and PSCs
- Ozone from Aura/MLS

The Impact of AIRS --- Moisture Channels

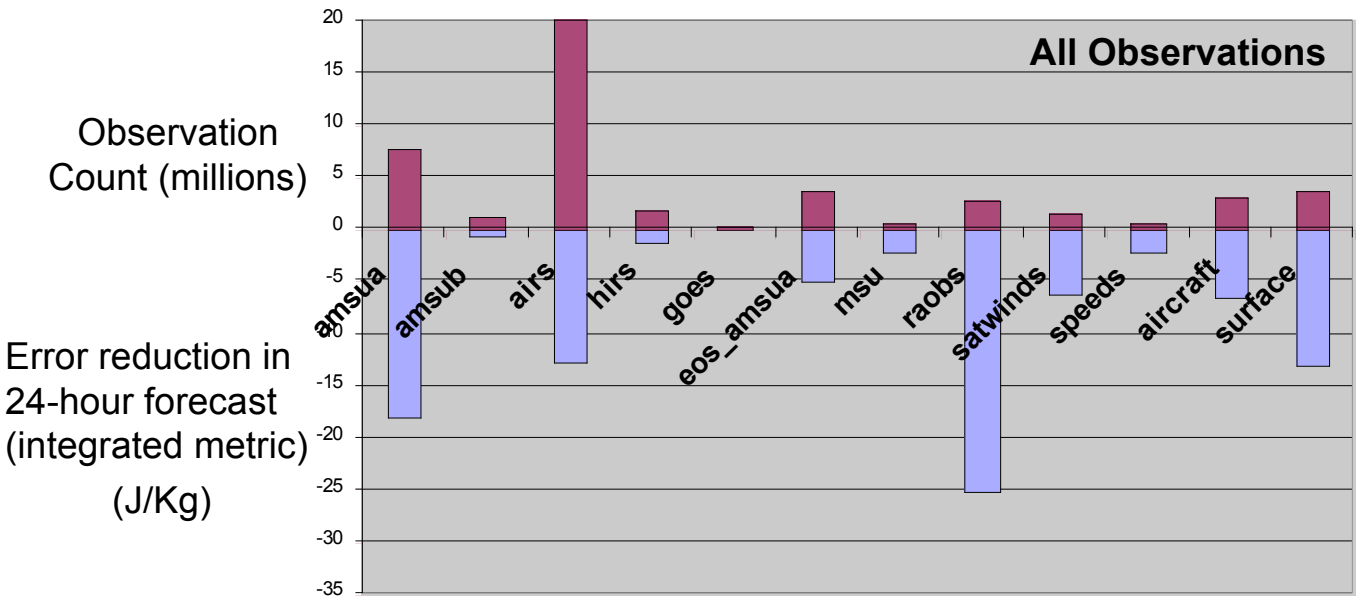




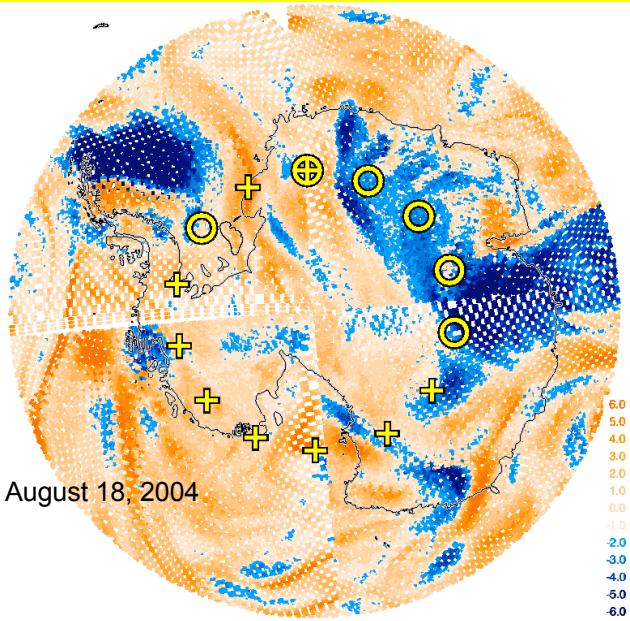
- The adjoint of the GSI developed at GMAO indicates that the some of the AIRS moisture channels have negative impact on the forecast skills

- The observation system experiments also indicate that the forecast skills are increased when moisture channels from AIRS were not included

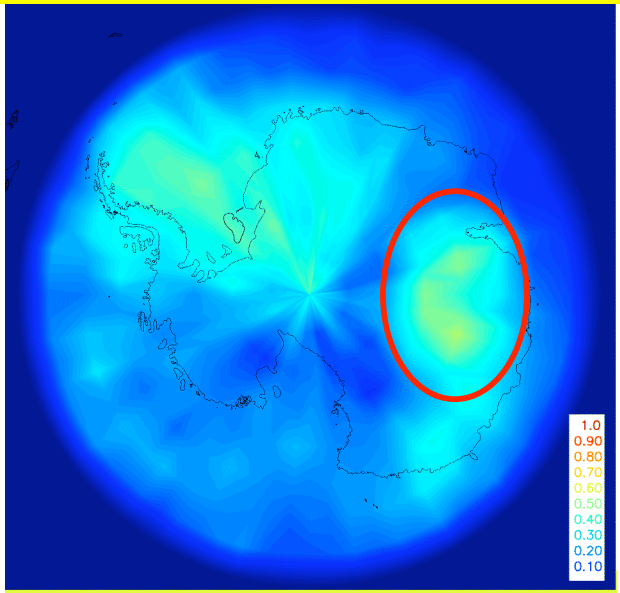
GEOS5 Observation Impact: July 2005 00z Totals



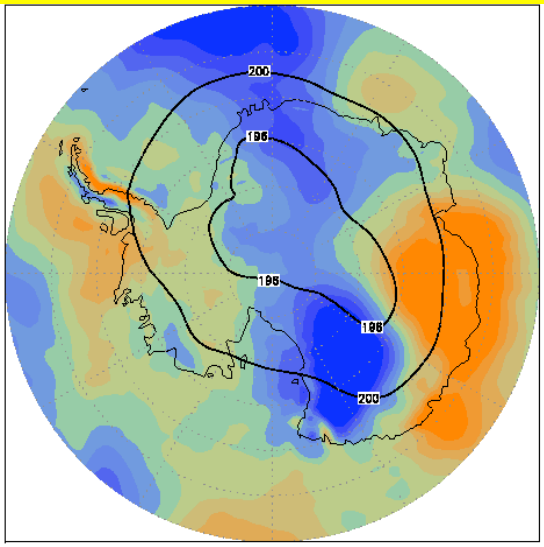
Ice Polar Stratospheric Clouds (PSCs) Detected from Assimilation of Atmospheric Infrared Sounder Data



AIRS observations-minus-**GEOS-5** forecast (O-Fs) for 6.79μm "moisture" channel. The forecast is computed assuming that clouds are not present. O-Fs lower than –2K (blue) typically coincide with locations where POAM III detected ice PSCs (◎).



High frequency of AIRS O-Fs lower than -2K indicates frequent ice PSCs in an unusual region during August 2004.



This is a cold region (temperature contours) with frequent upwelling (orange) during August 2004 at 200 hPa over Antarctica.

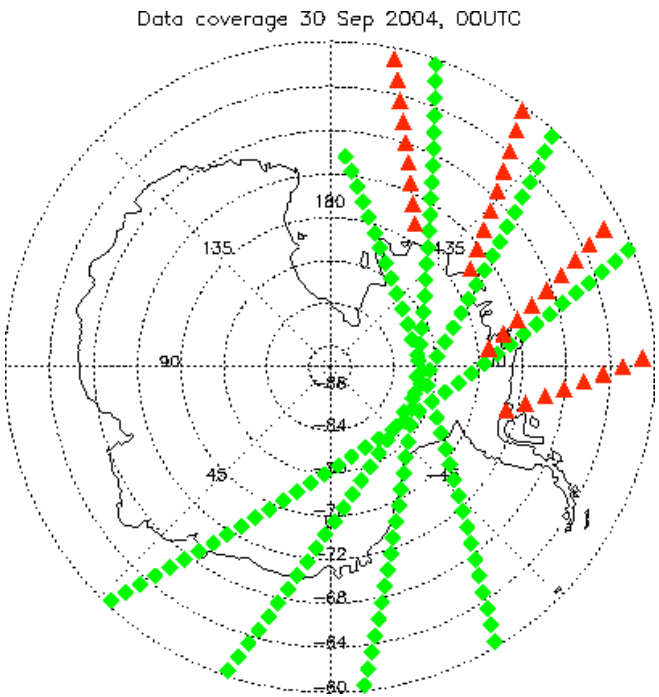
I. Stajner, C. Benson, H.-C. Liu, S. Pawson, N. Brubaker, L.-P. Chang, L. P. Riishojgaard and R. Todling (GMAO). Manuscript submitted to *Geophysical Research Letters*.

Contact: ivanka@gmao.gsfc.nasa.gov

Initial tests of assimilating AURA/MLS ozone

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

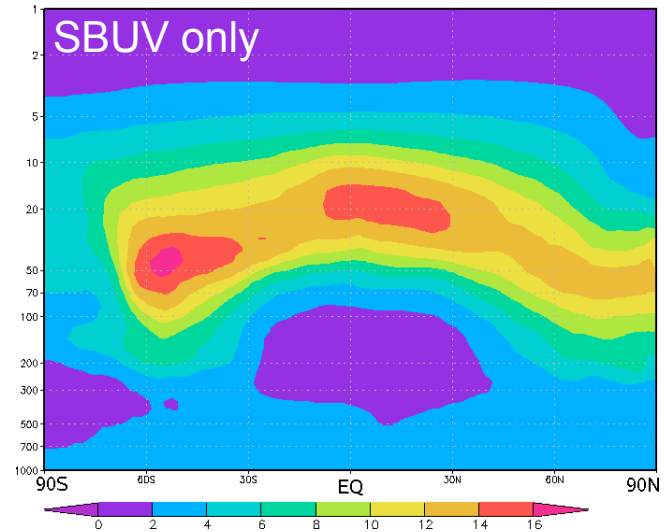
MLS orbital limit ±82º

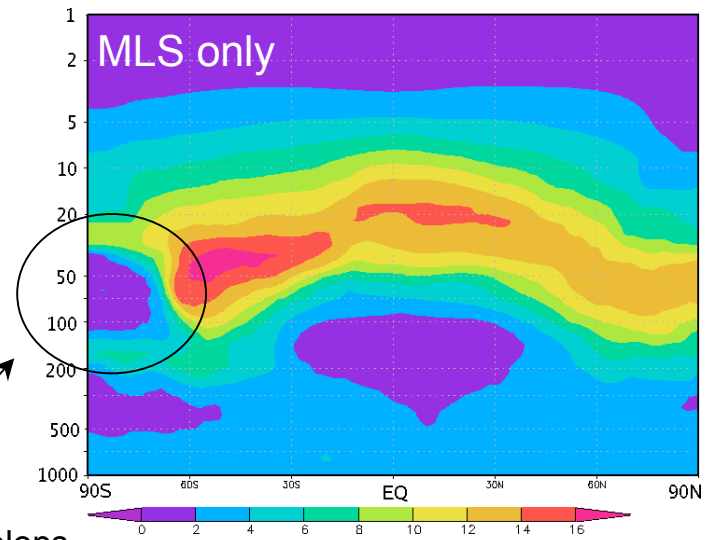


▲ NOAA 16 SBUV

◆ MLS

Zonal mean ozone 9/30/2004 00UTC

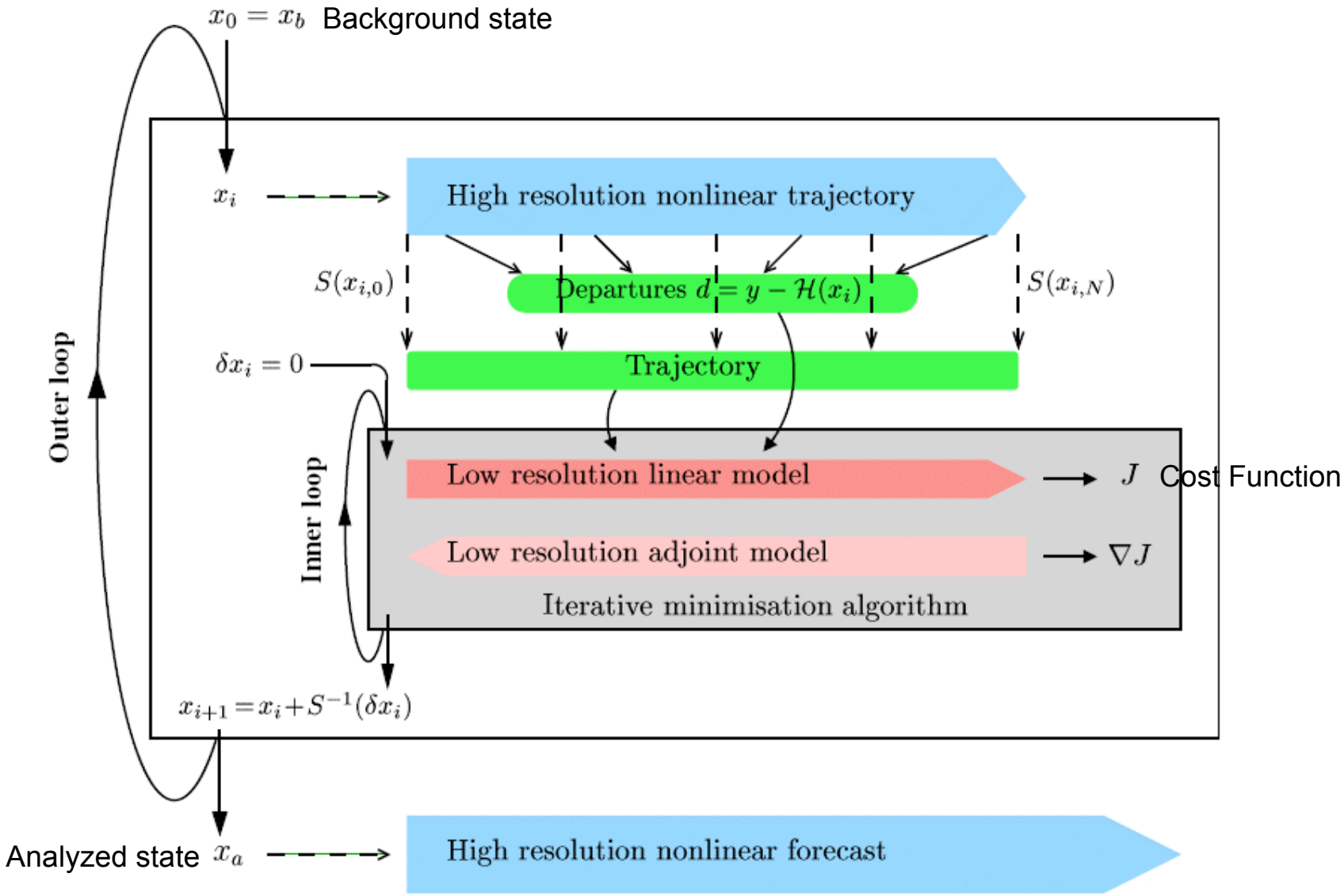




Ozone hole develops in MLS assimilation

Ozone partial pressure (mPa)

The 4D-VAR System



Progress in 4D-VAR Development

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

GMAO Systems: GEOS-5

http://gmao.gsfc.nasa.gov/systems/geos5/test.php

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GMAO Systems: GEOS-5

GEOS-5 System

GEOS-5 Home | GMAO Home | GEOS-5 Access | Architecture & Documentation | Results | Publications | Collaborations | Contacts

The Goddard Earth Observing System Model, Version 5 (GEOS-5) is a system of models integrated using the Earth System Modeling Framework (ESMF). The GEOS-5 DAS integrates the GEOS-5 AGCM with the Gridpoint Statistical Interpolation (GSI) atmospheric analysis developed jointly with NOAA/NCEP/EMC. The GEOS-5 systems are being developed in the GMAO to support NASA's earth science research in data analysis, observing system modeling and design, climate and weather prediction, and basic research.

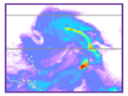
GEOS-5 is supported by NASA's Modeling Analysis and Prediction (MAP) Program.

What's New?

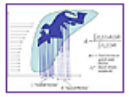
- ***1 November 2006.***

GEOS=5 Release 1.0 is now available from the MAP Software Repository. This is the first release of the GEOS-5 System. Climate simulations and DAS integrations have been undertaken with this release and some results are presented in the Results section of this page. See the Release notes for details of this release.

System Architecture and Documentation



Results



Publications and Presentations

Acknowledgement: GEOS-5 has been developed through the support of NASA's Modeling, Analysis and Prediction (MAP) Program.

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Web Designer/Curator: Robin M. Kovach (Email)

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