MERRA & US Reanalysis Plans & Activities

Michele Rienecker
Max Suarez, Ricardo Todling
Ron Gelaro, Julio Bacmeister
Siegfried Schubert, Michael Bosilovich
Global Modeling and Assimilation Office, NASA/GSFC

Phil Arkin, ESSIC, University of Maryland

Overview

- National Perspective
  - Past and ongoing re-analyses
  - Potential projects
  - CCSP deliverable
- MERRA
  - GEOS-5 System
  - Processing Plans
  - Status

Atmospheric Reanalyses

- NASA Data Assimilation Office
  - Early 1985 – 1993 reanalysis, GEOS-1
  - Not much impact - NCAR/NCEP product came out soon after
- NCAR/NCEP Reanalysis 1 and 2
  - Covered 1948 – present; v2 corrects a few significant problems
  - T62, 28 levels
  - Products disseminated effectively; huge impact
- North American Regional Reanalysis
  - Based on operational regional eta model – 32km
  - Covered 1979 – 2003; dissemination underway

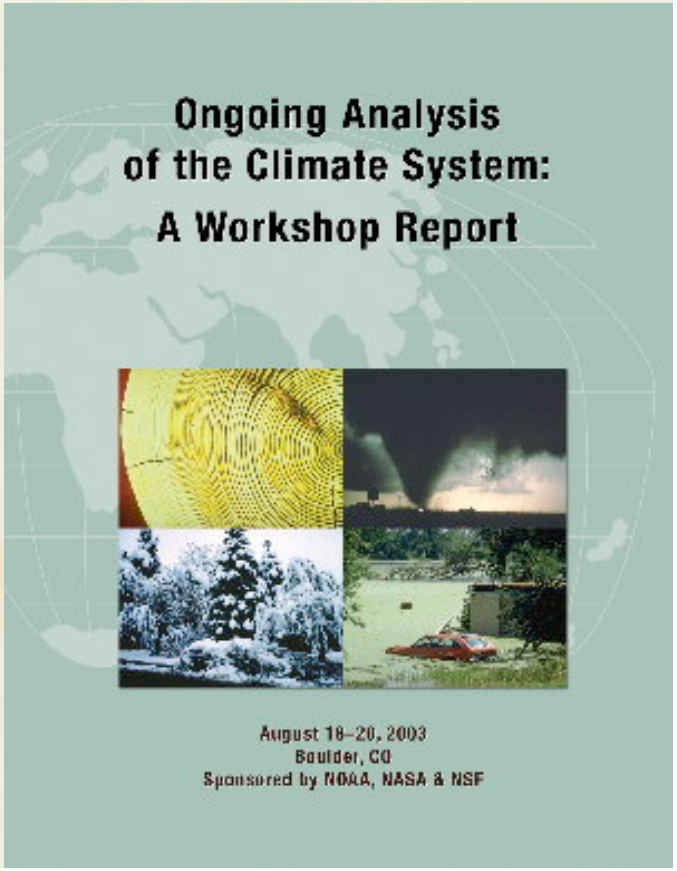
Ongoing Atmospheric Reanalyses

- Climate Data Assimilation System - CDAS
  - Extension in real time of NCAR/NCEP global reanalysis
  - Still useful, although coarse and outdated
  - Current operational analysis beginning to be used for many purposes
- Regional Climate Data Assimilation System – R-CDAS
  - Extension in real time of North American Regional Reanalysis
  - Eta being superseded by WRF model?
- What's the problem (all circa 2002 or so)?
  - All of these, while extremely valuable, had/have serious flaws
  - No overall National coordination/oversight
  - No coherent NOAA program

Workshop on Ongoing Analysis of the Climate System
18-20 August 2003, Boulder, Colorado

The Workshop concluded that the U.S. must establish a National Program for Ongoing (Iterative) Analysis of the Climate System to provide a retrospective and ongoing physically consistent synthesis of earth observations in order to:

- Design and guide operation of observing systems
- Produce and sustain the growing climate record
- Reconcile disparate climate observations and characterize analysis uncertainty
- Establish initial conditions for climate prediction
- Validate prediction and projection models on all time scales
- Provide long time series of global and regional (North American) climatic analyses for all types of prediction and projection verification



• Workshop report distributed (Arkin et al. 2003)
• See workshop web site (http://www.joss.ucar.edu/joss_psg/meetings/climatesystem/) for pdf version of report and background information from the workshop.

Elements of a Comprehensive Ongoing Analysis

- **Enhancing and managing the observational database**
  - Archeology, new sensors, continuity and feedback
- **Ongoing analysis**
  - Document impact of continuing observing system changes
  - Provide feedback to observing system developers/operators
- **Periodic reanalyses**
  - R1979 -- Post 1979 -- goal of continuous climate record, improved hydrological cycle
  - R1950 -- Post 1950 -- emphasis on continuity and low-frequency signal, interannual-to-decadal variability
  - R1850 -- Post 1850 -- best and longest consistent analysis, surface NH oriented, climate change
  - Continental-scale regional reanalysis at very high spatial resolution
- **Stewardship and dissemination**
  - Ensure that the products are useable
- **Research**
  - Develop improved methods and products
  - Intended to solve problems identified within program

Planned and Potential Reanalysis Activities in the U.S.

- **Modern Era Reanalysis for Research and Applications (MERRA)**
  - Funded NASA GMAO effort
- **Surface Input Reanalysis for Climate Assessment (SIRCA)**
  - Initial testing underway; funding needed [Gil Compo]
- **NCEP/EMC is interested in a reanalysis to support its Climate Forecast System**
  - Focused on satellite era
  - No real funding or progress so far
- **Integrated Earth System Analysis Project**
  - Evolved from proposed US Ongoing Analysis Project
  - Proposed by Randy Dole/Anjuli Bamzai to Climate Change Science Program [CCSP]
  - Presented to NRC Climate Research Committee
  - Tepid reception by CCSP so far
- **Analysis of Record proposed by NWS – overlap with NARR**
- **Arctic System Reanalysis**
  - Proposal for IPY -- coupled atmosphere-sea-ice-ocean-terrestrial-30km, north of 45°N

CCSP Deliverable

CCSP Implementation Plan SWG
Chairs: Siegfried Schubert and Marty Hoerling

A state-of-science synthesis report that:

(a) Summarizes the present status of current reanalysis efforts.

(b) Discusses key research findings on the strengths and limitations of the current reanalysis products for:

(1) Describing past climate variations and trends

[reducing uncertainties; improving models used for climate projections]

(2) Attributing causes of climate variations and trends

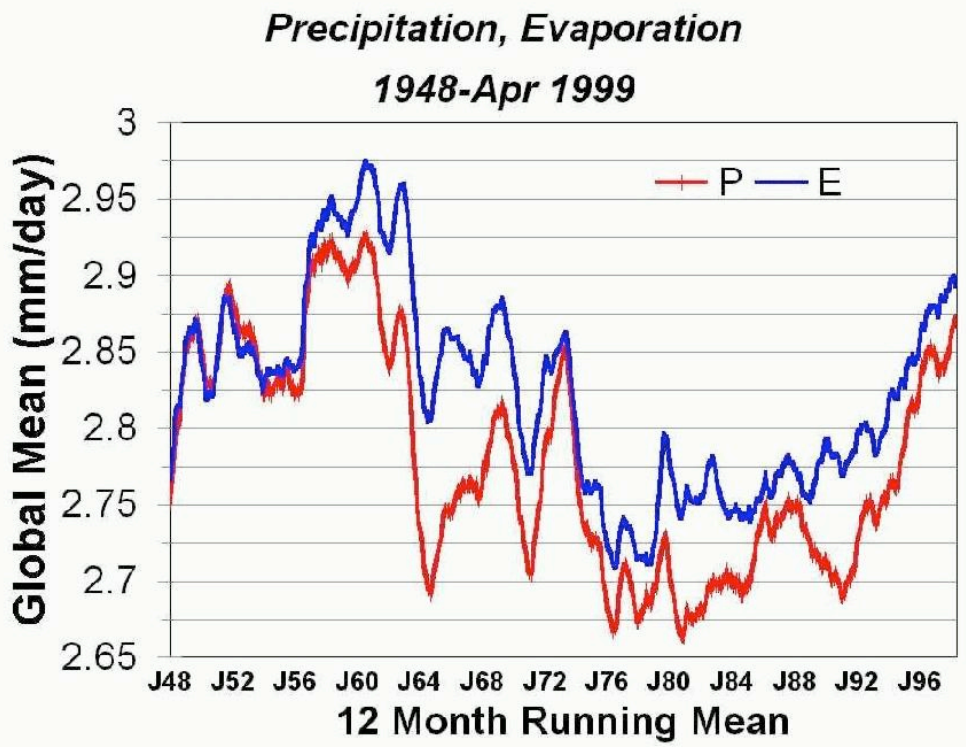
[regional climate variations; high-impact climate events events; rapid climate shifts; signature of external forcing]

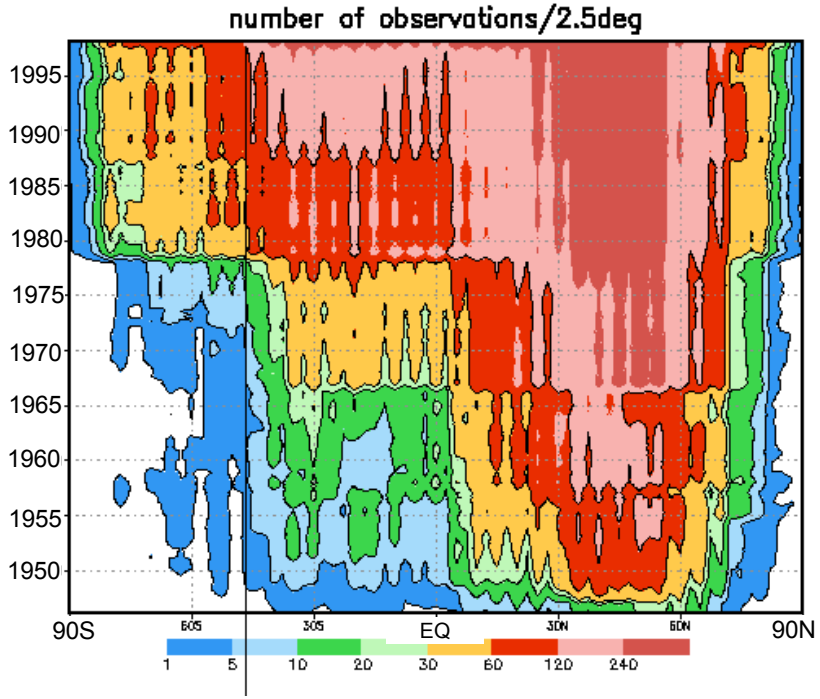
The temporal focus: 1948-present.

- ***Proposed lead agency:*** **NOAA**
- ***Supporting agencies:*** **NASA, DOE, (NSF)**

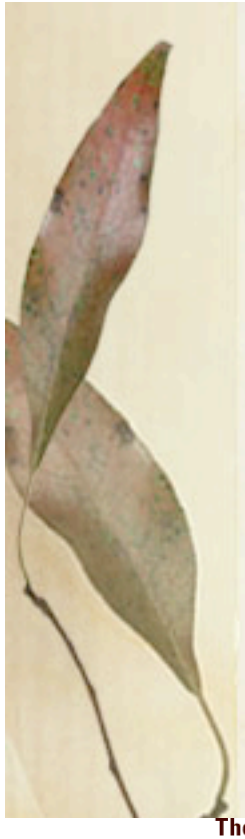
Long-term Trends in the NCEP/NCAR Reanalysis

Glenn H. White
EMC/NCEP/NWS/NOAA

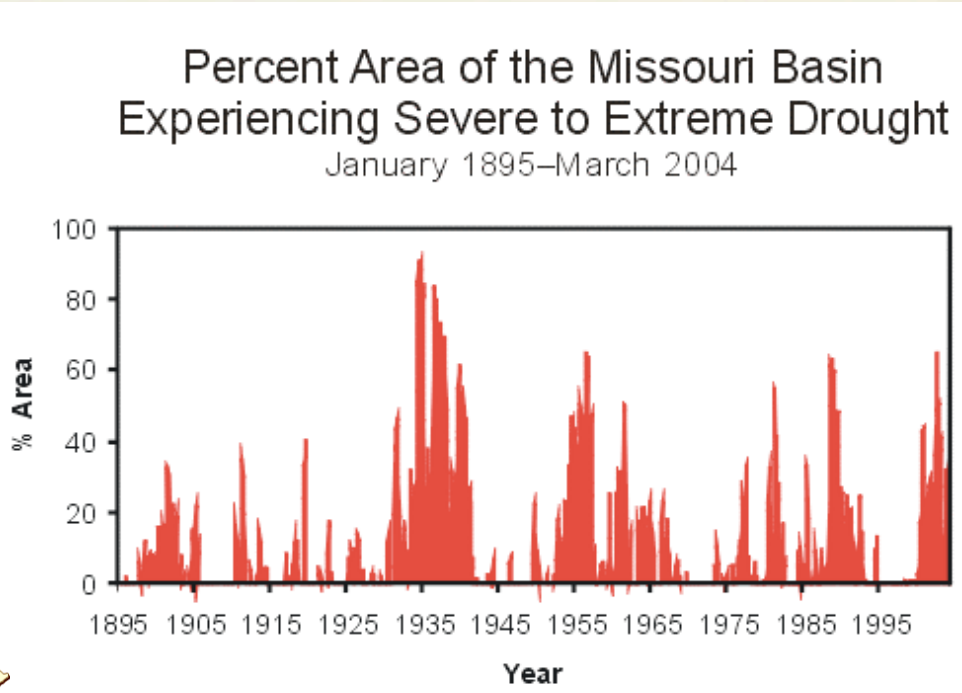


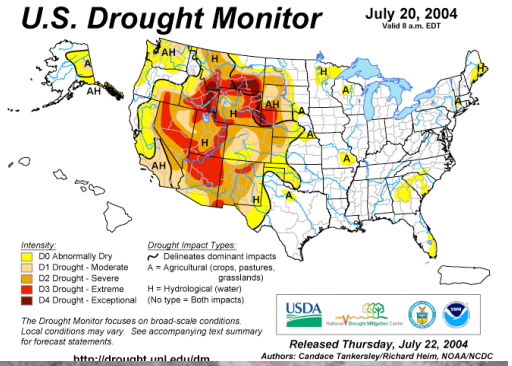


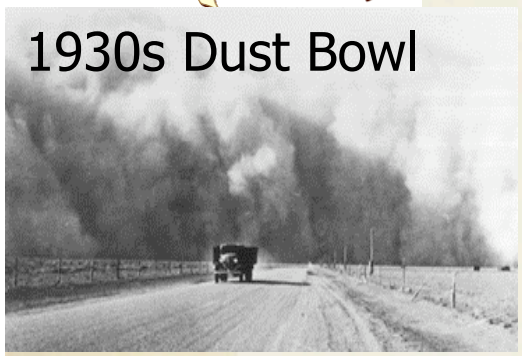
What causes major drought in the United States? What can we expect in the future?



The Dust Bowl







R1979

Focus: the best comprehensive, consistent, high-resolution global data with a strong emphasis on **improving the hydrological cycle** and related physical processes.

Utilize latest state-of-the-art data assimilation system
Link 4DDA and model development

- Improve/assess model performance esp. hydrological cycle
- Extend assimilation techniques (e.g. precip/cloud) to use historical data
- Improve ocean surface fluxes
- Develop DAS techniques that are “moisture friendly”
- Improve stratosphere, assimilate constituents, aerosols
- Support efforts to “clean-up” satellite radiance data
- Assess impact of resolution in model and analysis

New R1979 Efforts in the U.S.

- **NOAA/NCEP NARR completed**
  - http://wwwt.emc.ncep.noaa.gov/mmb/rreanl/
  - 1979-2003
  - Available from NCDC and JOSS
- **NASA/MERRA production starts fall 2006**
  - http://gmao.gsfc.nasa.gov/merra.php
  - 1979-present

Modern Era Reanalysis for Research and Applications (MERRA)

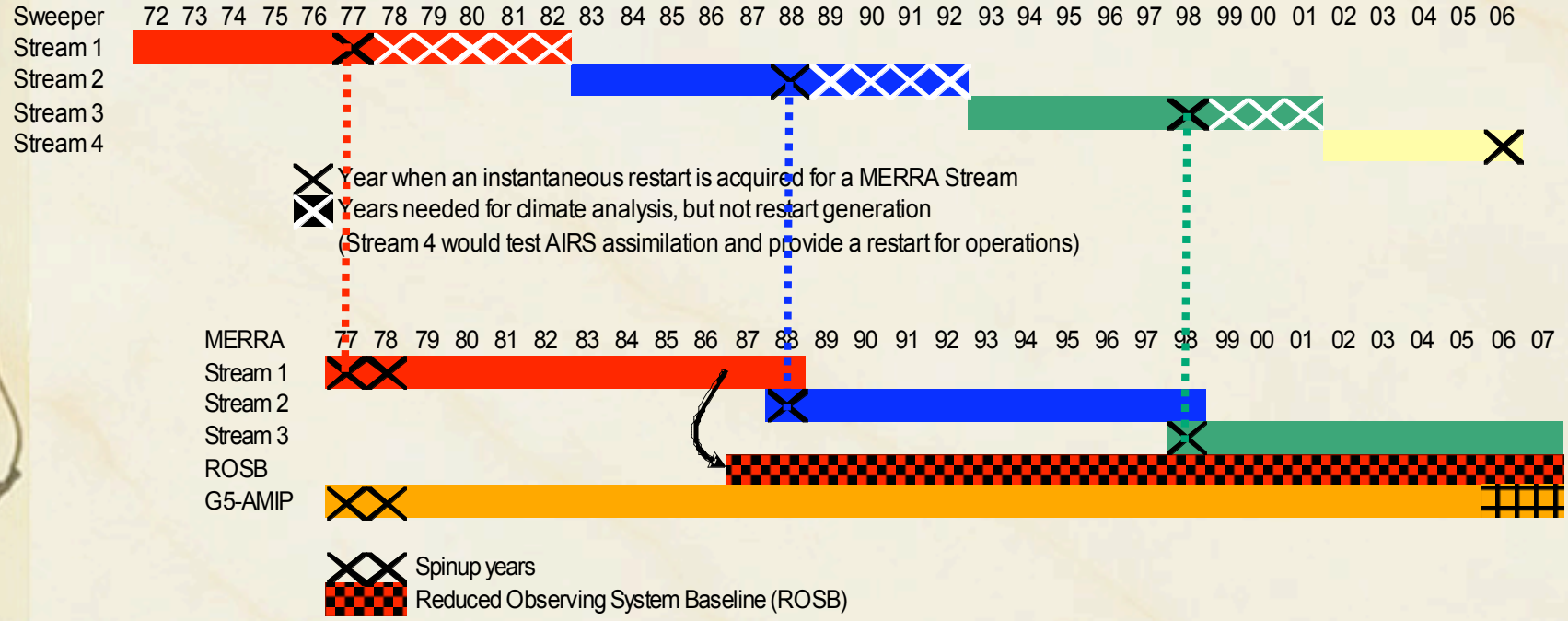
GMAO

System Configuration

- Satellite Era, 1979 – Present
- 1/2° × 2/3° × 72L
- Top: 1 Pa
- NASA GEOS-5 GCM
- Finite Volume Dynamical Core
- Physics integrated under the Earth System Modeling Framework (ESMF)
- Catchment Land Surface
- NCEP/GMAO Gridpoint Statistical Interpolation (GSI)
- Prescribed aerosols; assimilated, interactive ozone
- Assimilation of GPROF rain-rate from SSM/I and TMI

MERRA Processing Streams

ICs from 2° Sweeper



- Two ways to handle 77 – Conventional obs from early 70s, or climate IC from 77-82
- Minimum 15 years then for Sweeper to provide land ICs

GEOS-5 DAS & MERRA - status

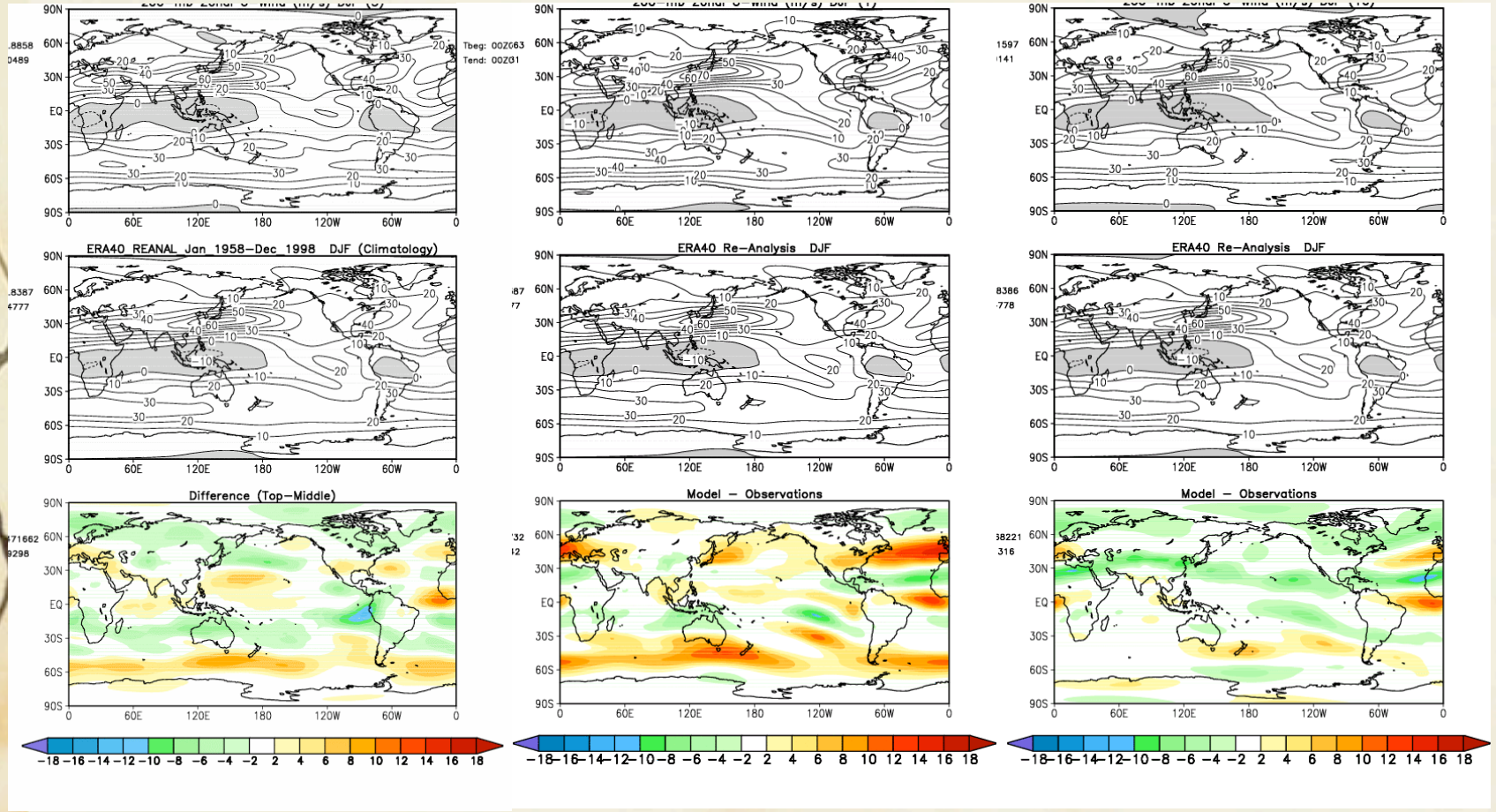
- Incremental Analysis Update (IAU)
  - reduces shock of data insertion
- Moist physics model development and tuning in DAS mode
- Data sets assembled and pre-processed as required
- Background error statistics generated and tuned for GEOS-5 (vs GFS)
- Tuning balance constraint statistics
- Currently undertaking a data-sweep
- 1/2° system in parallel test phase; 2º system used for 2001 tests
- External User Group will evaluate validation data sets (2001; 2004)

AMIP: DJF 200 MB U vs ERA-40

GEOS-5
0.05 / 3.49

CAM-3
1.72 / 3.89

AM-2
-0.68 / 3.11

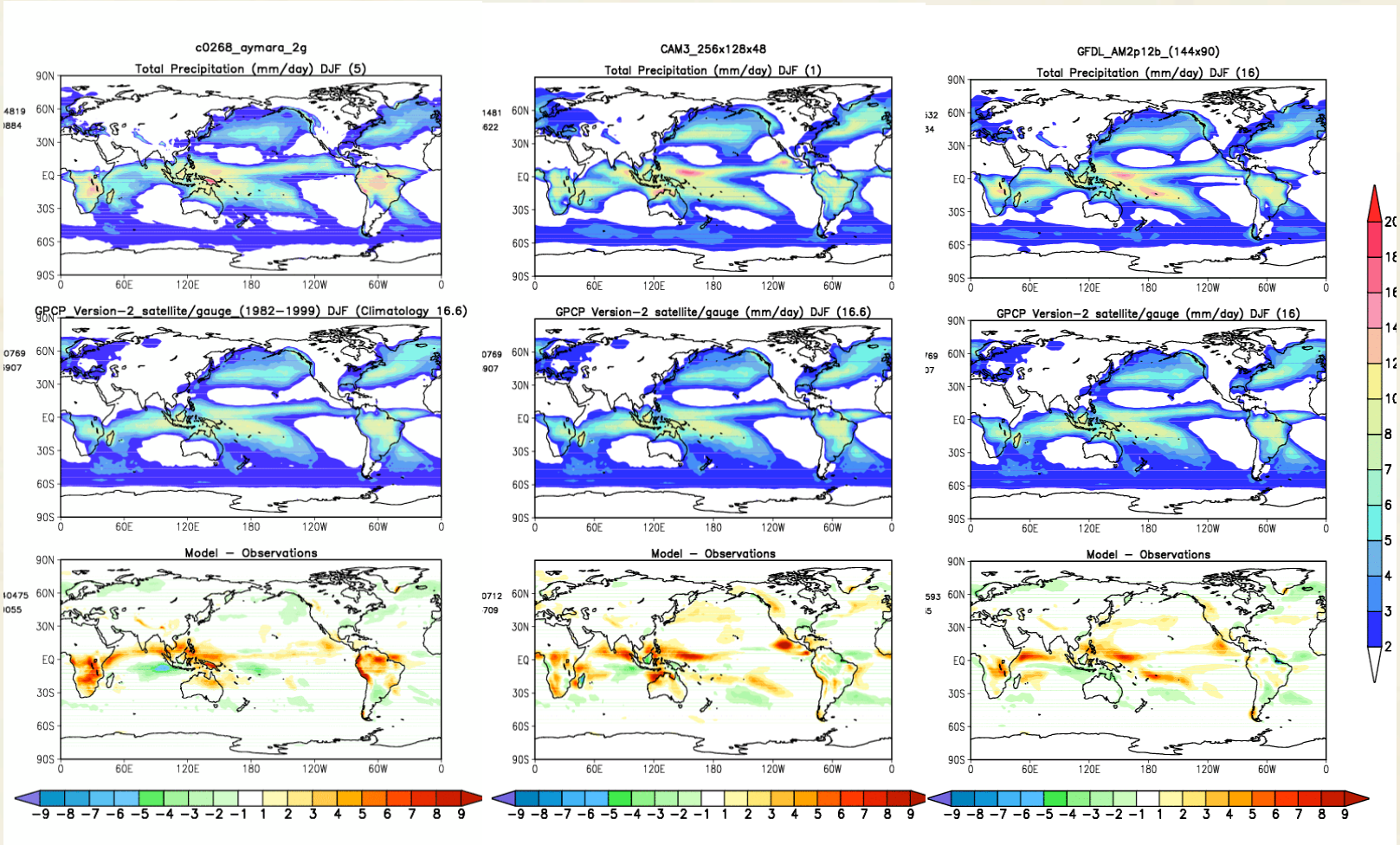


AMIP DJF PP vs GPCP

GEOS-5
.24 / 1.49

CAM-3
.40 / 1.44

AM-2
.22 / 1.22

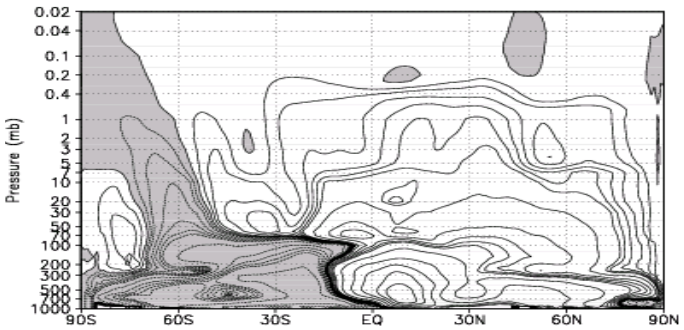


Residual Circulation

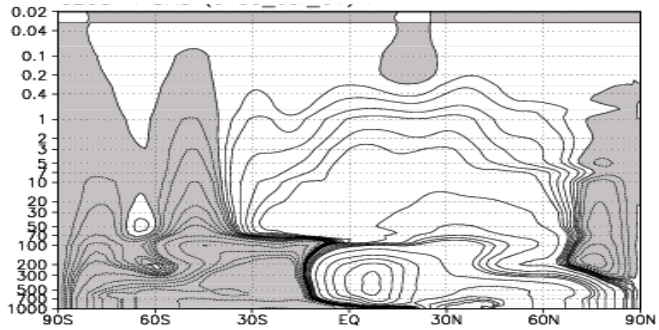
Impact of IAU

January Residual circulation streamfunction

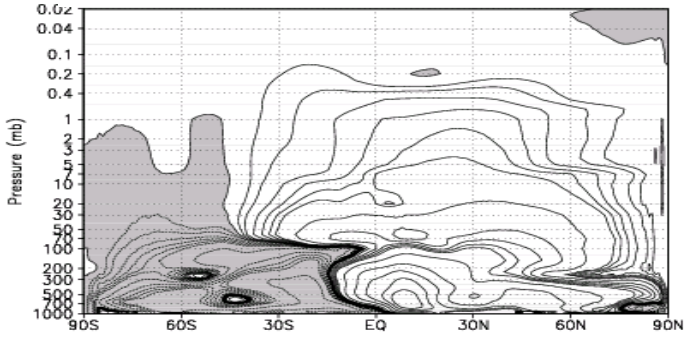
GEOS-5 DAS



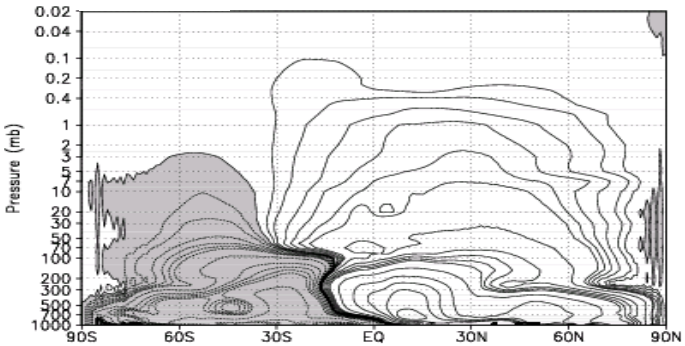
GEOS-4 DAS



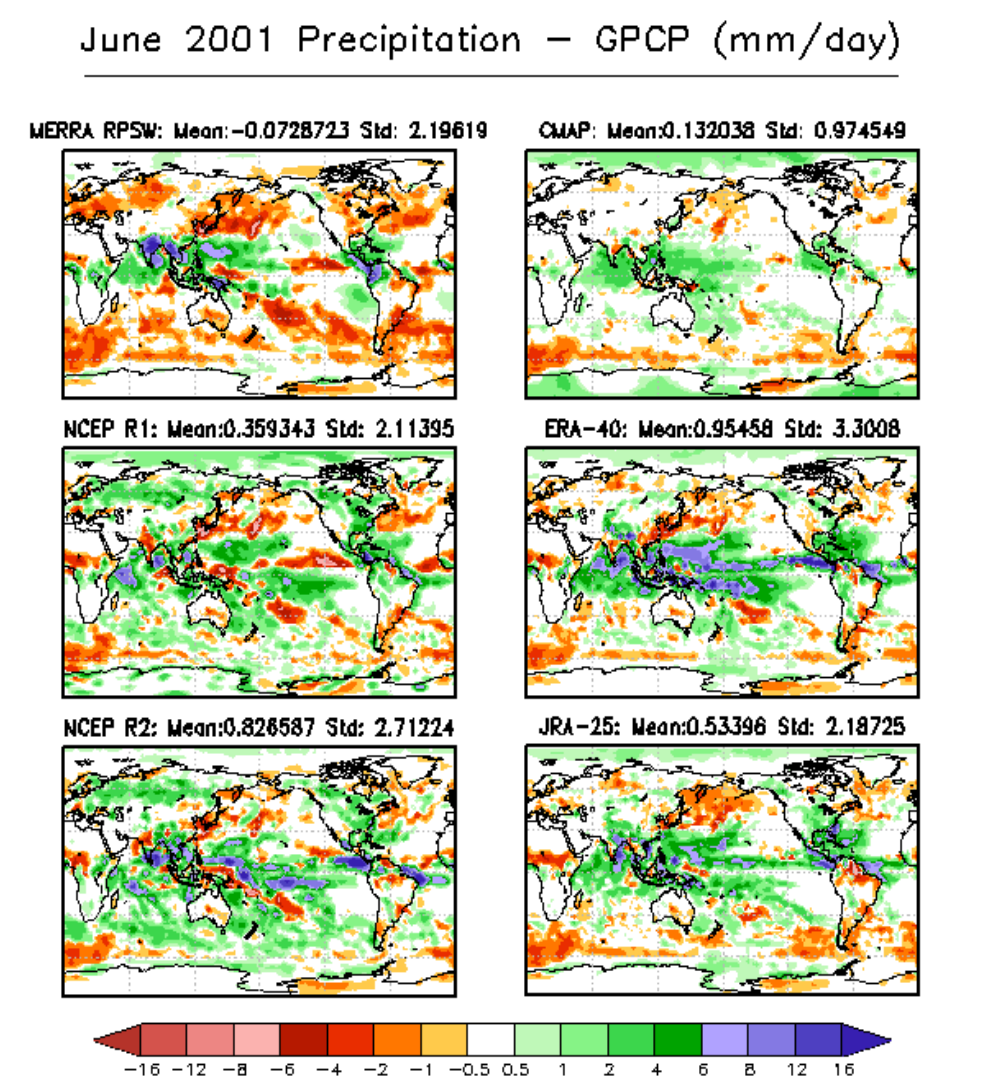
GEOS-5 IAU

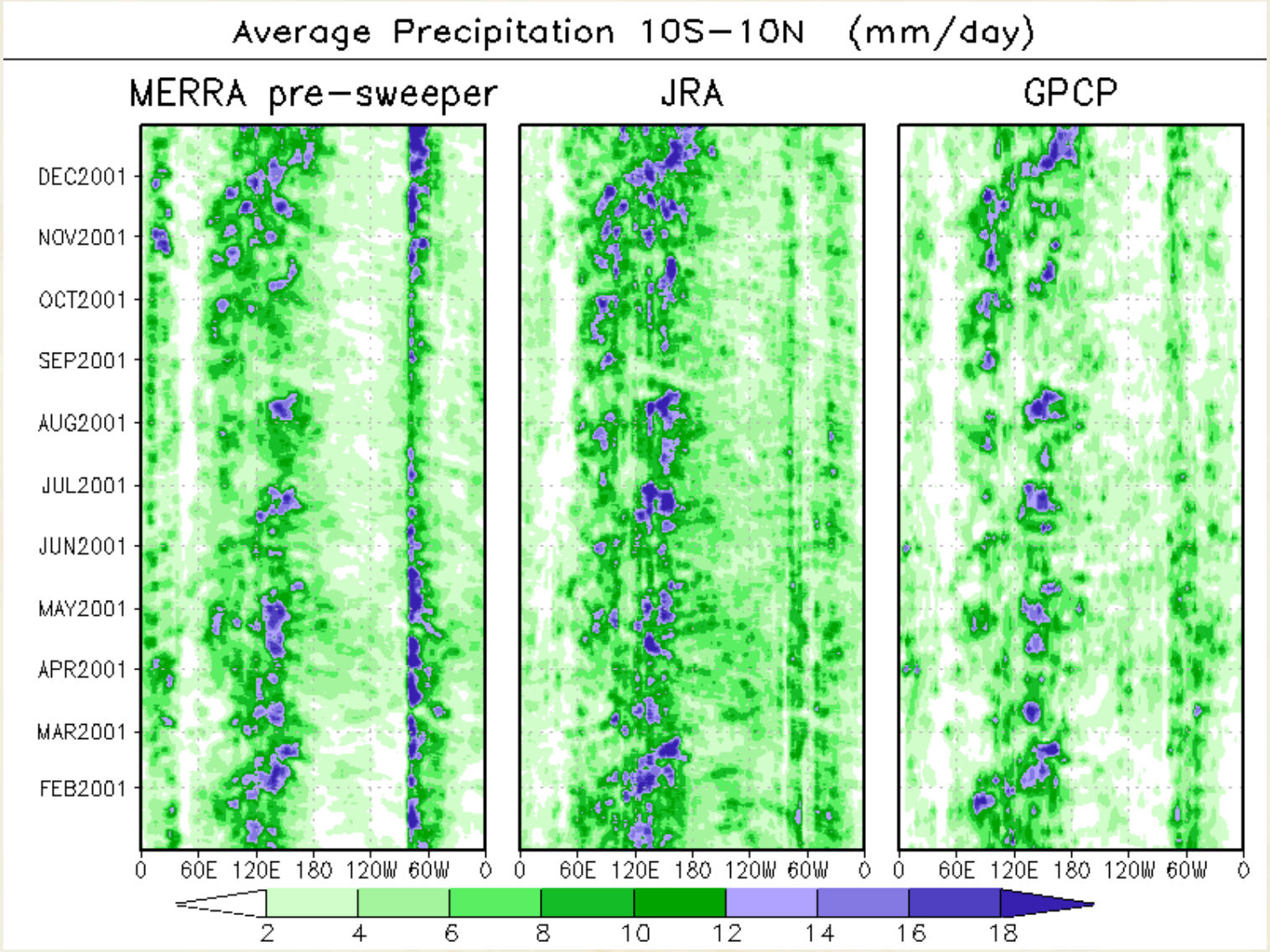


GCM



2° MERRA tests




Average Precipitation 10S–10N (mm/day)
MERRA pre–sweeper
JRA
GPCP
DEC2001
NOV2001
OCT2001
SEP2001
AUG2001
JUL2001
JUN2001
MAY2001
APR2001
MAR2001
FEB2001
0 60E 120E 180 120W 60W 0
2 4 6 8 10 12 14 16 18

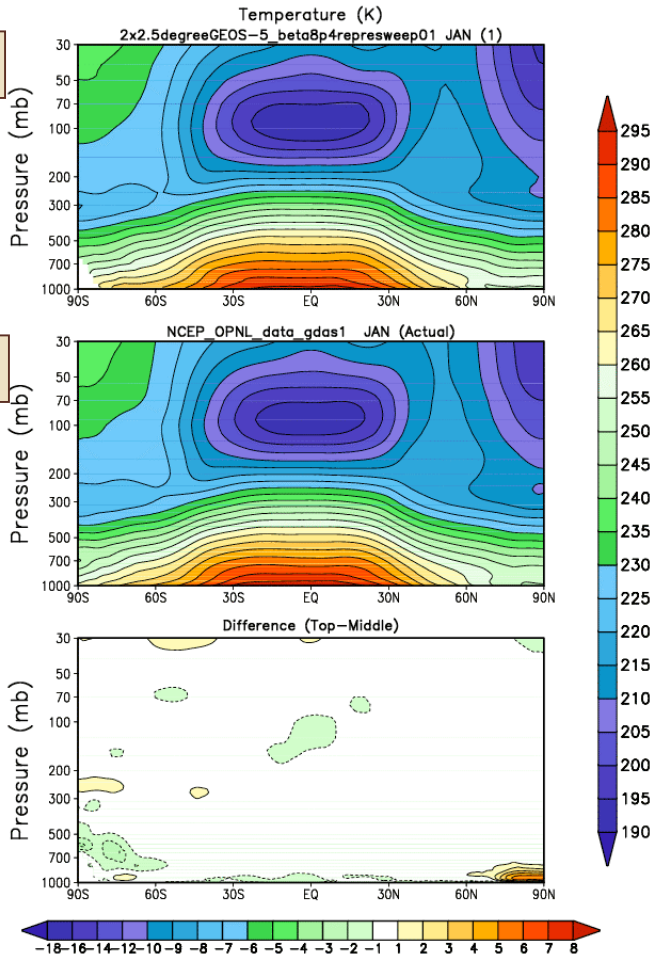
2° MERRA tests

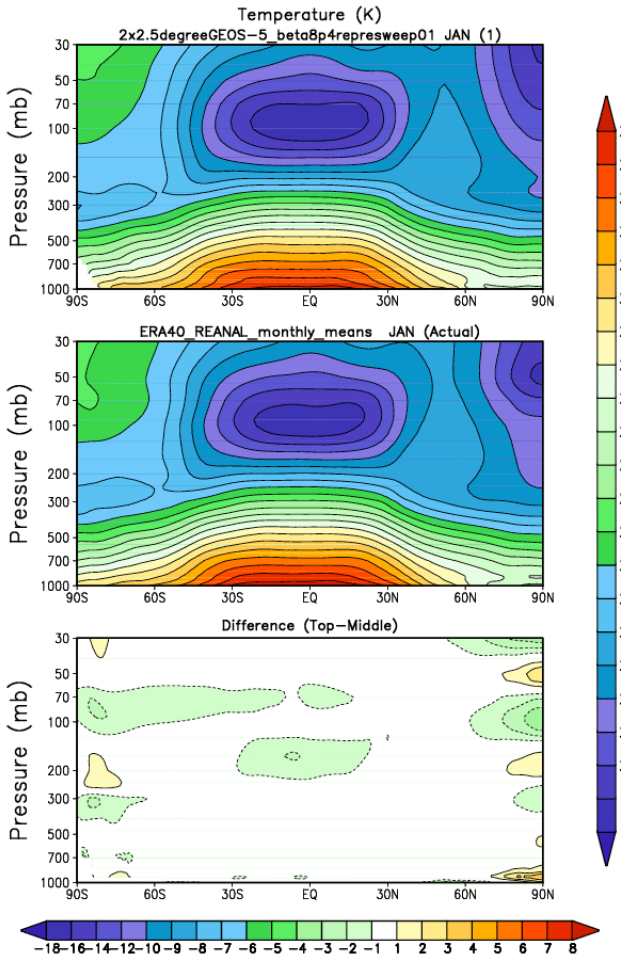
Zonal Mean Temperature for January 2001

GEOS-5

NCEP OPS

Δ





GEOS-5

ERA-40

Δ

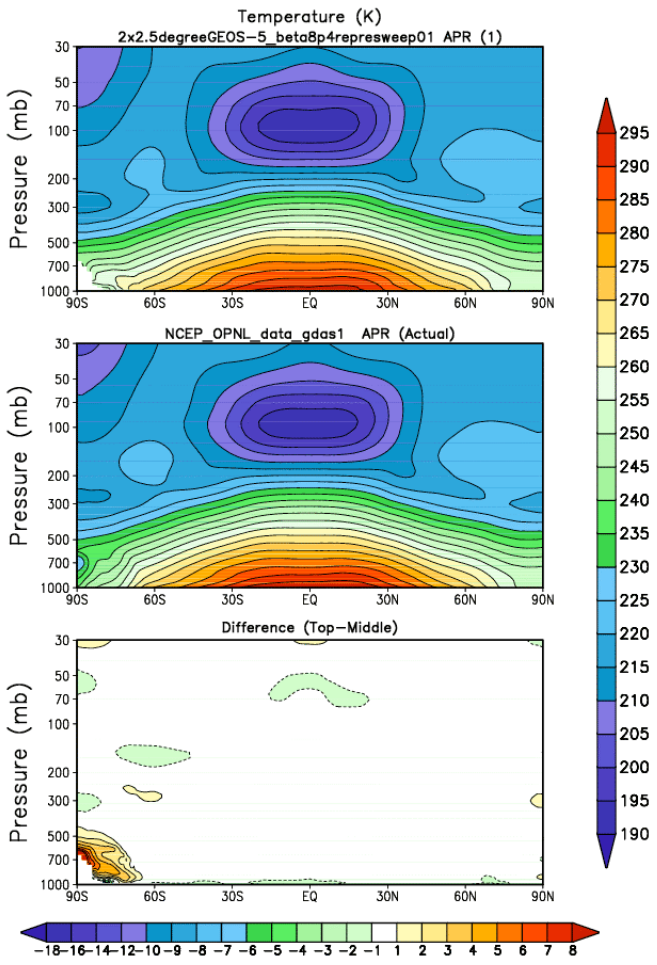
2° MERRA tests

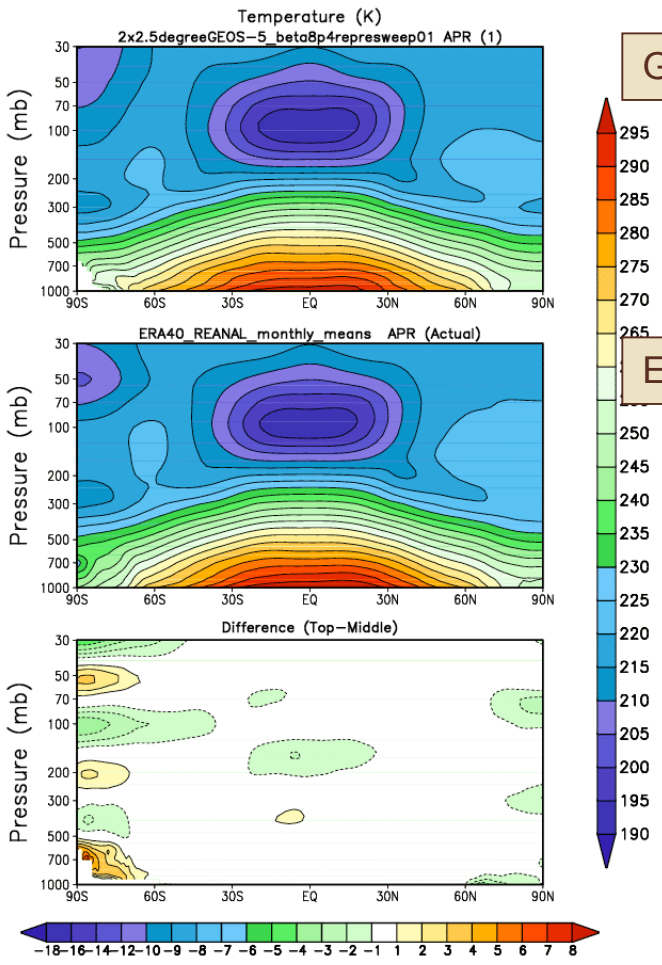
Zonal Mean Temperature for April 2001

GEOS-5

NCEP OPS

Δ





GEOS-5

ERA-40

Δ

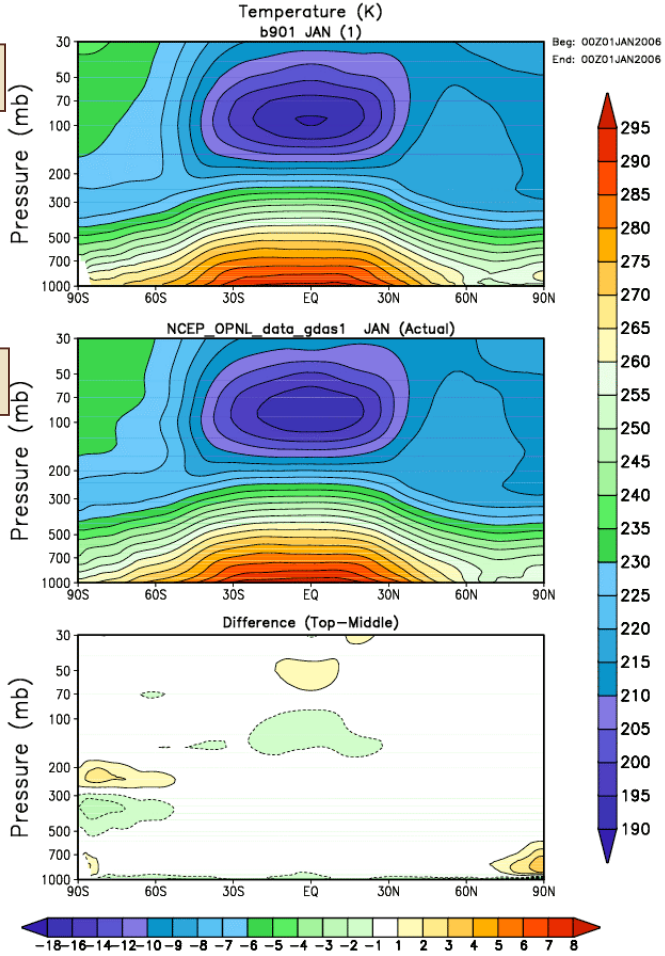
1/2° tests

Zonal Mean Temperature for January 2006

GEOS-5

NCEP OPS

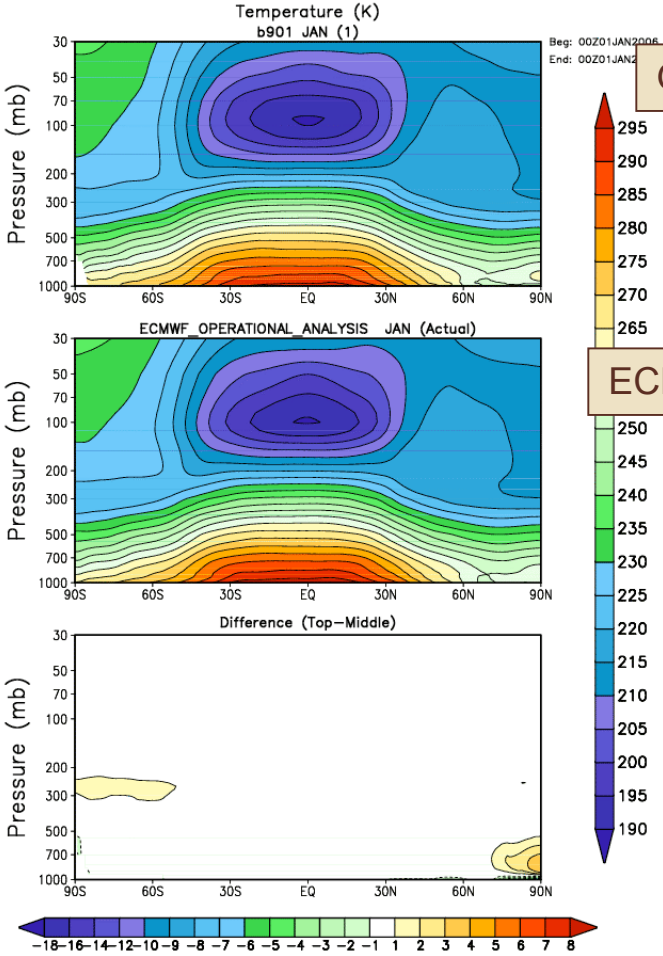
Δ



GEOS-5

ECMWF OPS

Δ



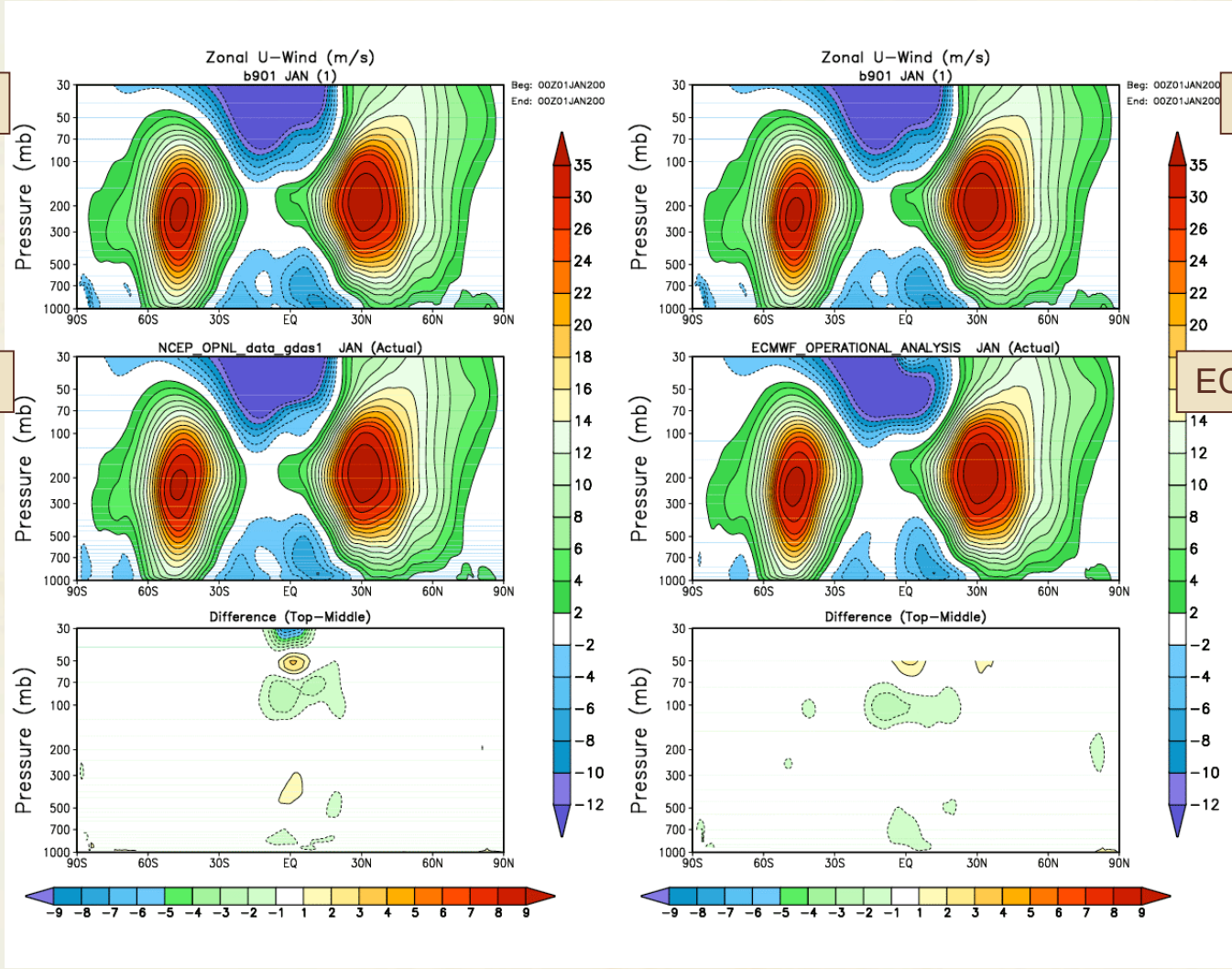
1/2° tests

Zonal Mean U for January 2006

GEOS-5

NCEP OPS

Δ



GEOS-5

ECMWF OPS

Δ

MERRA: Issues encountered

- CRTM does not support early satellite data or SSU -- RTTOVS not yet fully included -- workaround is to use GLATOVS
- Precipitation shock, online ozone assimilation, stratosphere and tracer applications led us to adopt IAU
- Calibration issues for SSM/I precipitation estimates (TMI merged product)
- Precipitation assimilation
- Need to tune the model physics in assimilation mode
- Super-ob'ing of non-radiance data
- SST - which product?

Schedule

- Production planned to begin Sept 2006
- 2-year duration for production