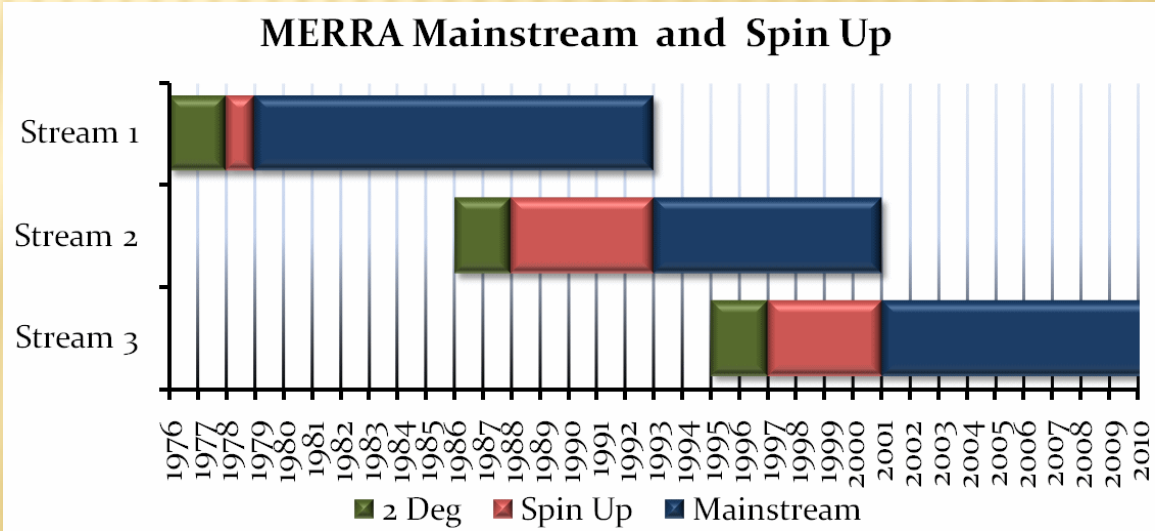
AN OVERVIEW OF MERRA: VALIDATION AND CHALLENGES FOR FUTURE REANALYSES

Presented by Michael Bosilovich

with contributions from many in the GMAO

NASA'S MODERN ERA RETROSPECTIVE-ANALYSIS FOR RESEARCH AND APPLICATIONS (MERRA)

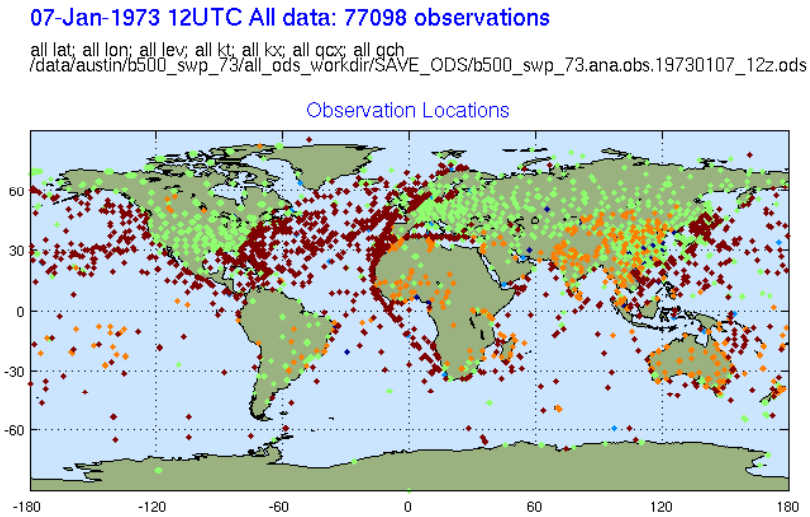
- 2002 Proposed Objective: Improving the water and energy cycle representation in a reanalysis
- GEOS5 system development including NASA global climate model with NCEP GSI data assimilation
- Nov 2007 – External User Review Group endorses the Validation Review of GEOS5 for MERRA
- Production began in May 2008
- Provisional release of 9 yrs. data in Dec 2008
- Began realtime pro-duction in Apr 2010
- Currently 1979 through May '10 are available



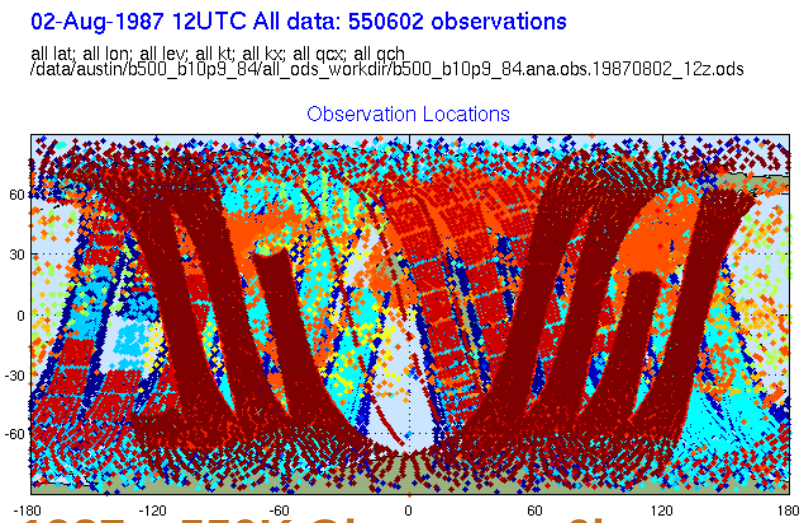
NASA'S MODERN ERA RETROSPECTIVE-ANALYSIS FOR RESEARCH AND APPLICATIONS (MERRA)

- 1979-present (continuing as it is feasible)
- ½° horizontal resolution (72 model levels, sfc-strat)
- 1 hourly surface and 2D diagnostic data
  - Including complete budgets and extensive meteorology, lowest model level states
- 6 hourly 3-Dimensional atmospheric analysis
- 3 hourly 3-D model background including diagnostics, coarse resolution
- >70 Tbs online storage, many portals (incl. subsetter) up to realtime processing > 31 years of data

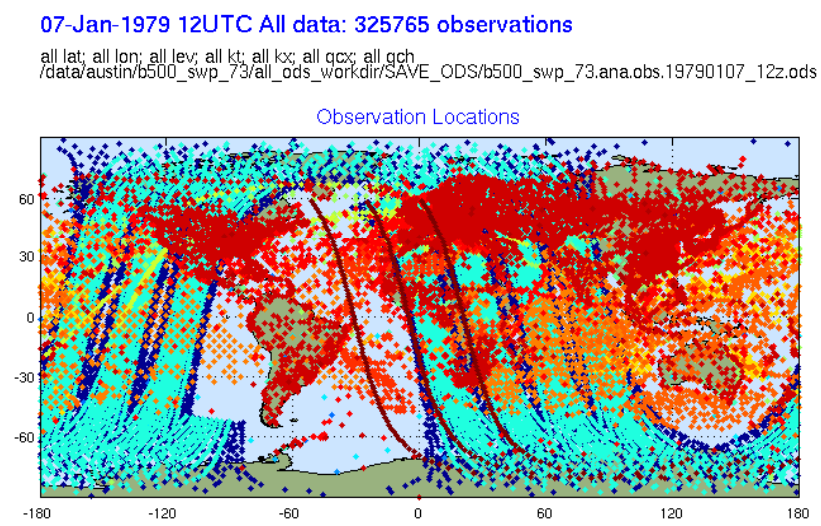
CHALLENGE AND ADVANTAGE OF REANALYSIS



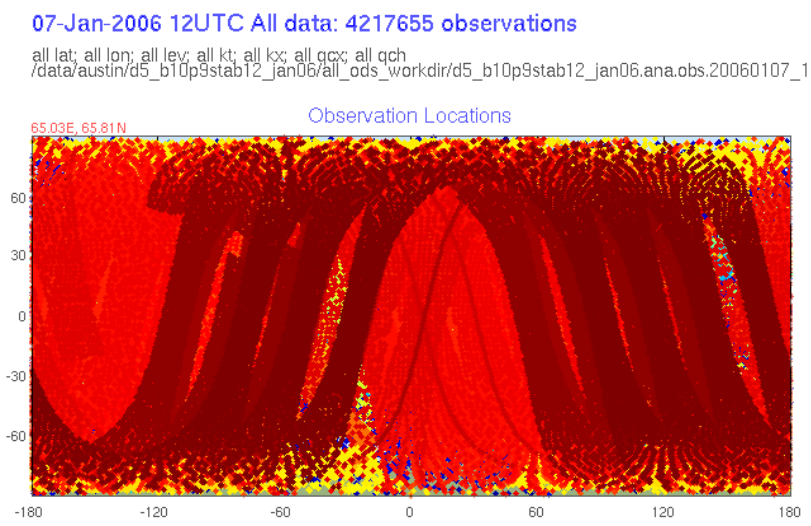
1973 – 77K Obs every 6hrs



1987 – 550K Obs every 6hrs



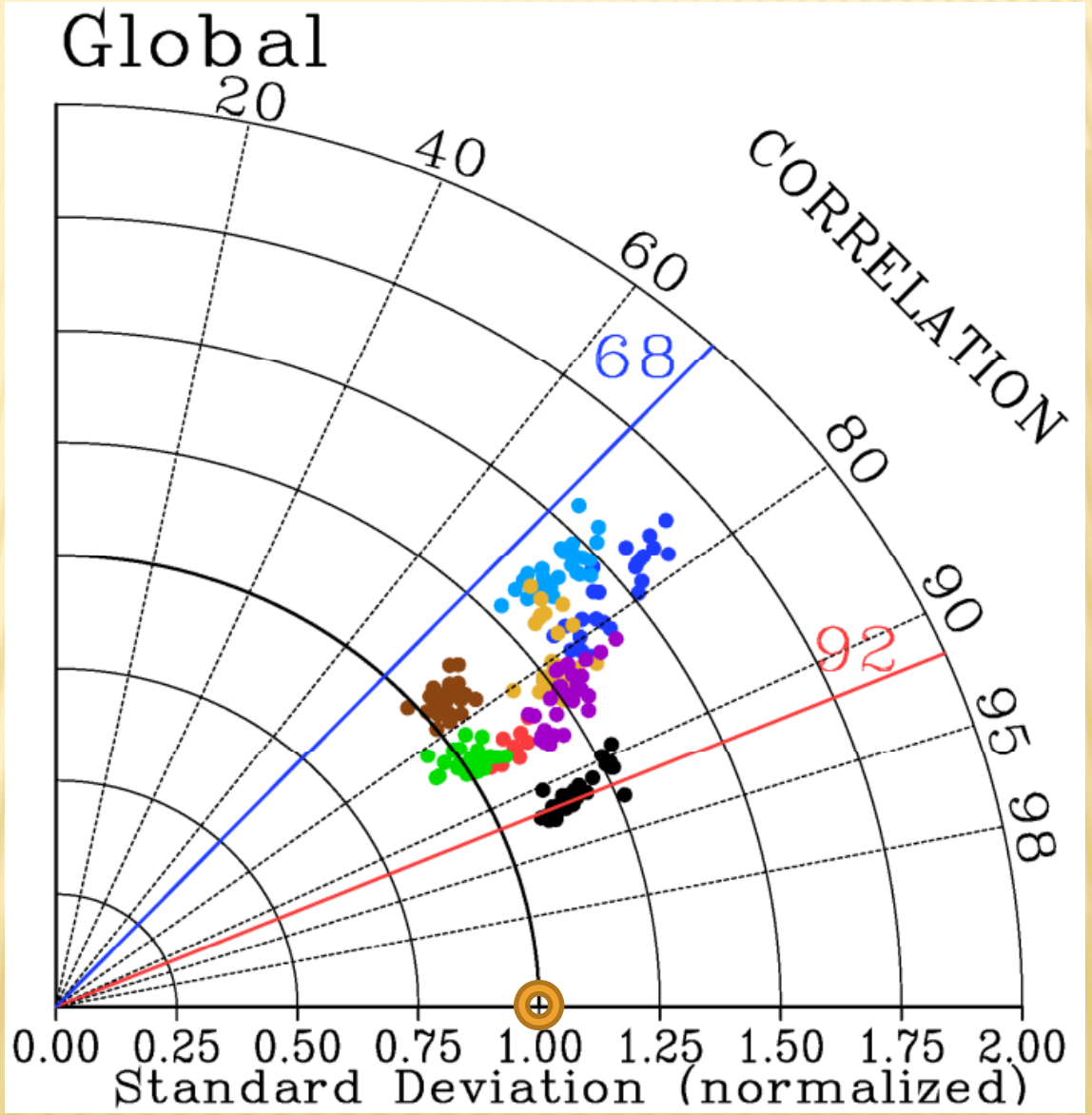
1979 – 325K Obs every 6hrs



2006 – 4.2M Obs every 6hrs

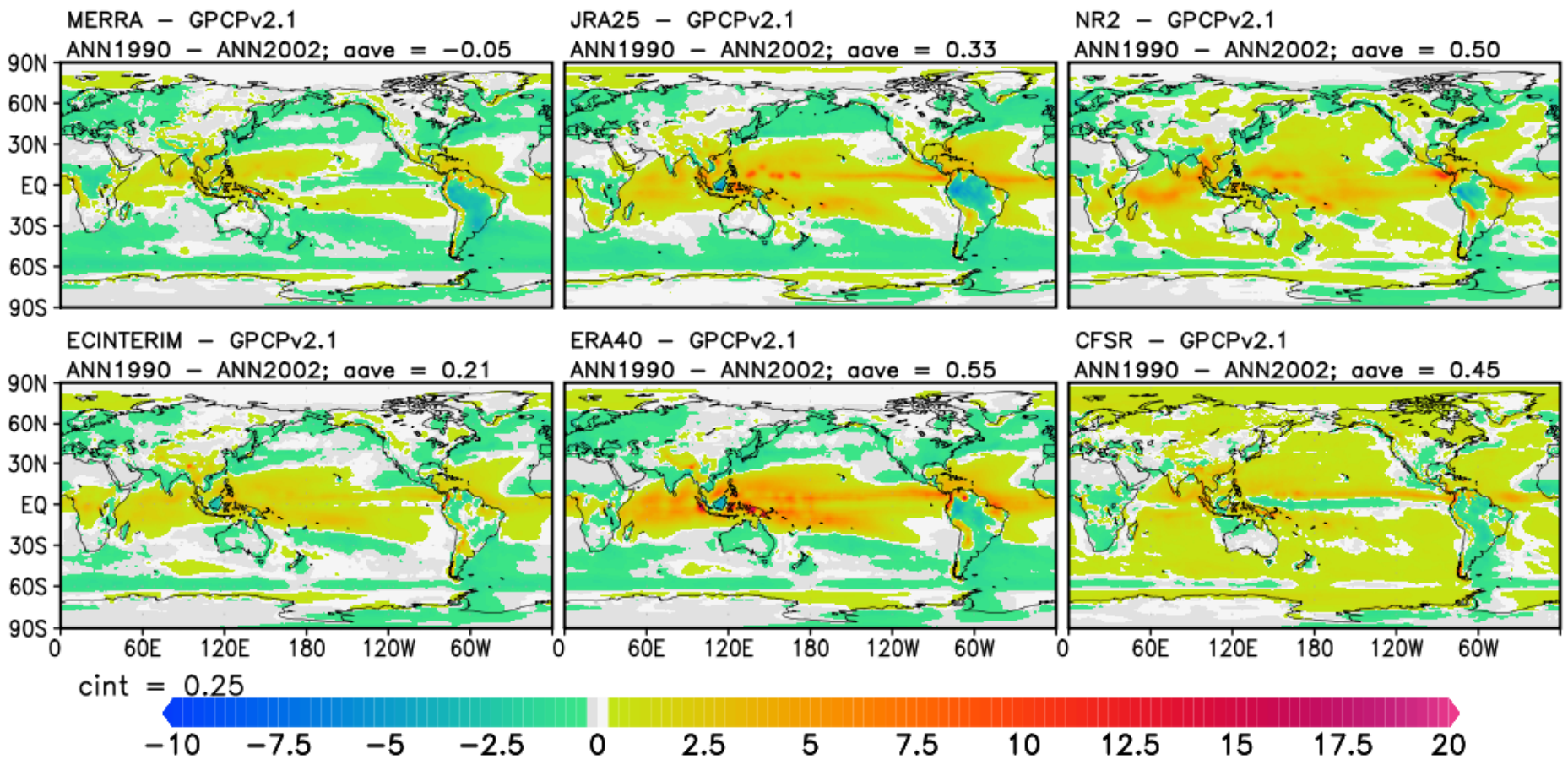
ASSESSING PRECIPITATION SKILL

CMAP
ERA40
NR1
NR2
JRA25
INTERIM
CFSR
MERRA



Taylor Diagram of Global Annual precipitation skill of existing reanalyses e.g. Bosilovich et al (2008)

PRECIPITATION ANOMALIES

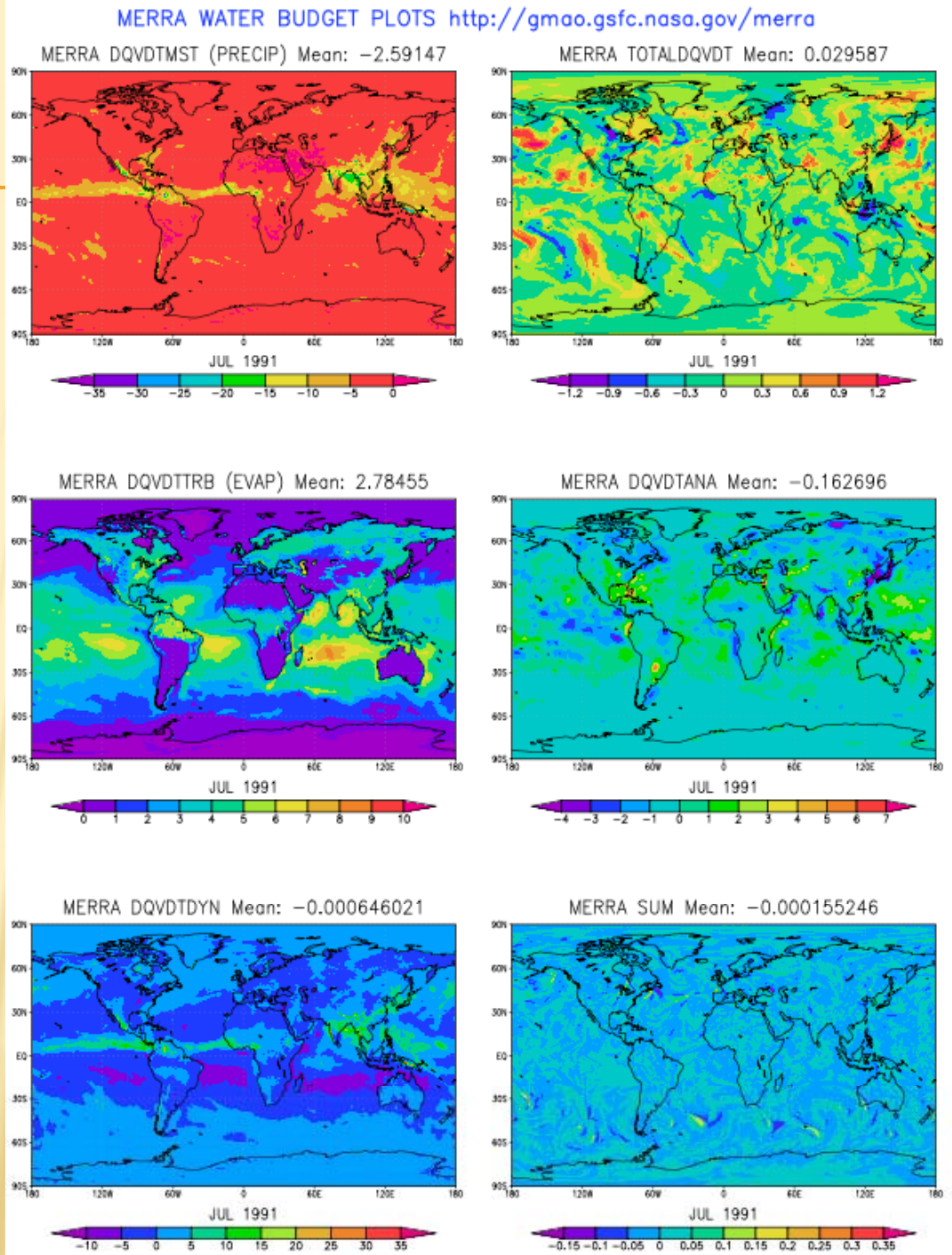


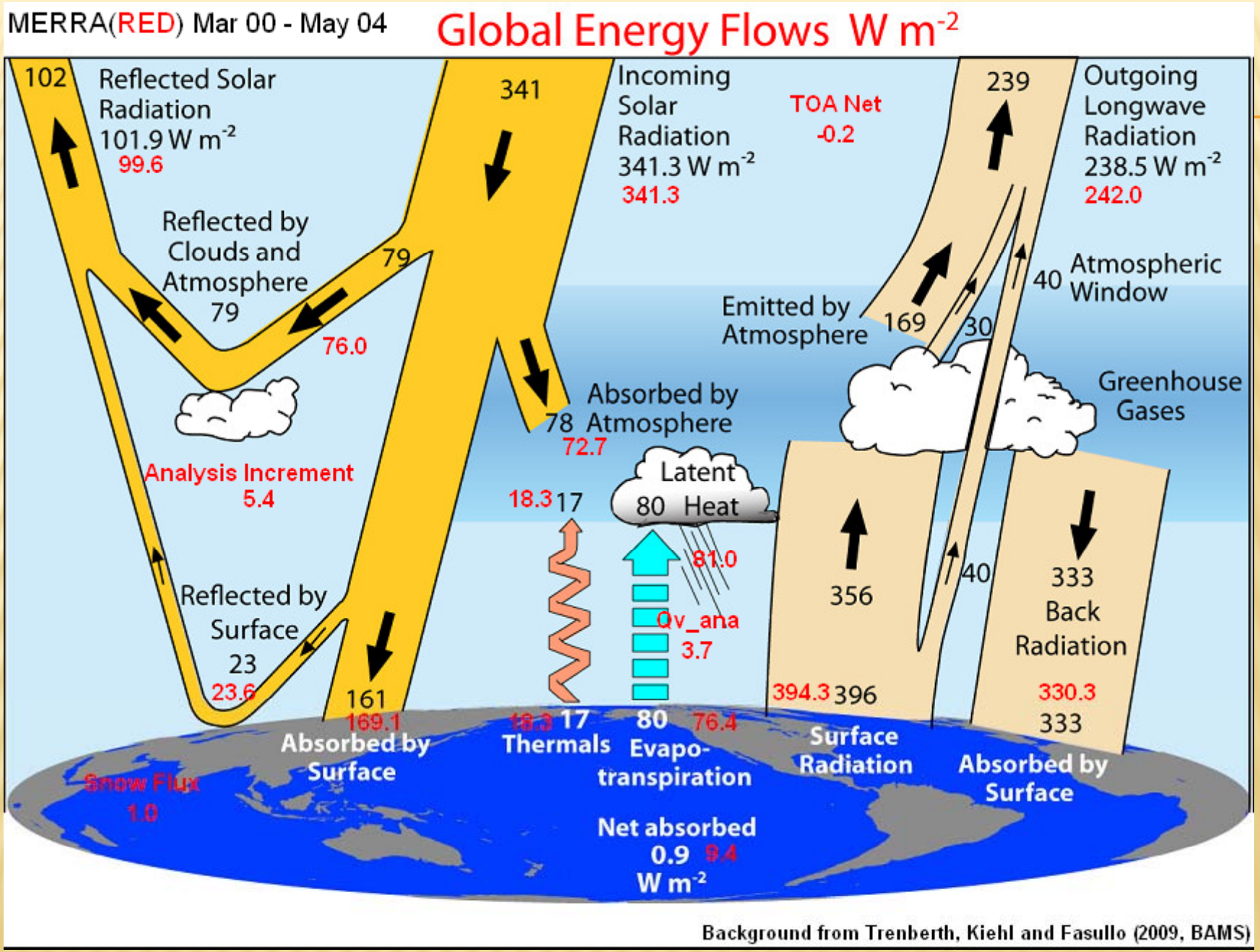
- http://gmao.gsfc.nasa.gov/ref/merra/atlas/

Calculating Budgets

$$\frac{\partial qv}{\partial t} = E - P - \nabla \cdot qv + \frac{\partial qv}{\partial t}_{ANA}$$

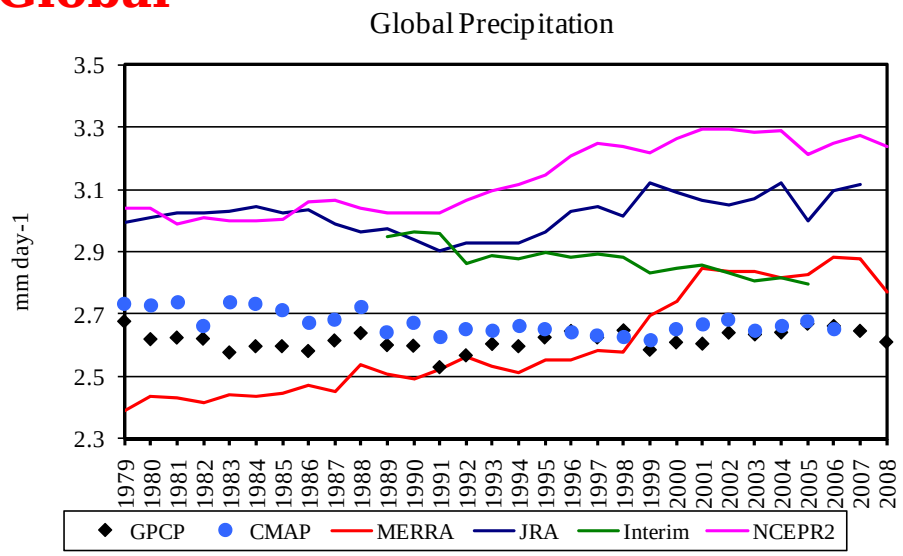
- Complete budgets are available including all tendencies and analysis increments
- Water (all phases), Ozone, KE, Enthalpy, Included
- Also, land-only budgets
- Tremendous effort by Max Suarez, Larry Takacs and Randy Koster



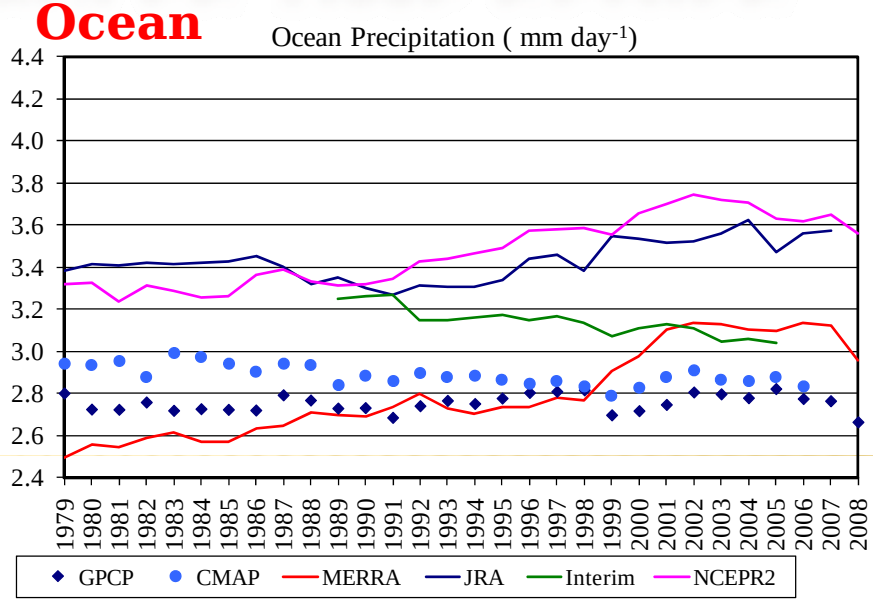

MERRA(RED) Mar 00 - May 04
Global Energy Flows W m-2
102
Reflected Solar Radiation 101.9 W m-2
99.6
341
Incoming Solar Radiation 341.3 W m-2
341.3
TOA Net
-0.2
239
Outgoing Longwave Radiation 238.5 W m-2
242.0
Reflected by Clouds and Atmosphere
79
79
76.0
40 Atmospheric Window
Emitted by Atmosphere
169
30
Greenhouse Gases
Absorbed by Atmosphere
78
72.7
Analysis Increment
5.4
18.3 17
Latent 80 Heat
81.0
Qv_ana
3.7
356
40
333 Back Radiation
330.3
333
Reflected by Surface
23
23.6
161
169.1
394.3 396
18.3 17
Thermals
80
Evapo-transpiration
76.4
Absorbed by Surface
Surface Radiation
Absorbed by Surface
Snow Flux
1.0
Net absorbed
0.9 0.4
W m-2
Background from Trenberth, Kiehl and Fasullo (2009, BAMS)

WATER AND ENERGY CYCLES TIME SERIES

Global

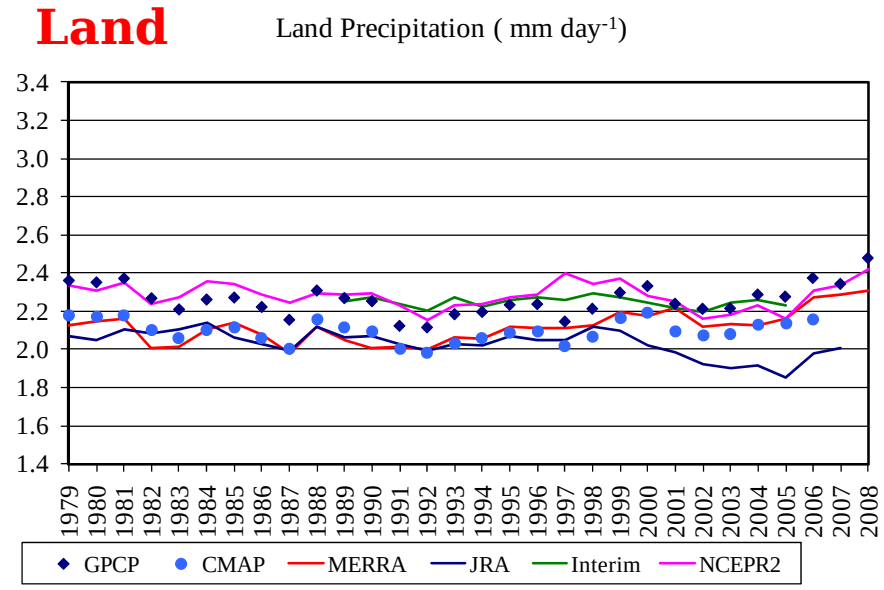


Ocean



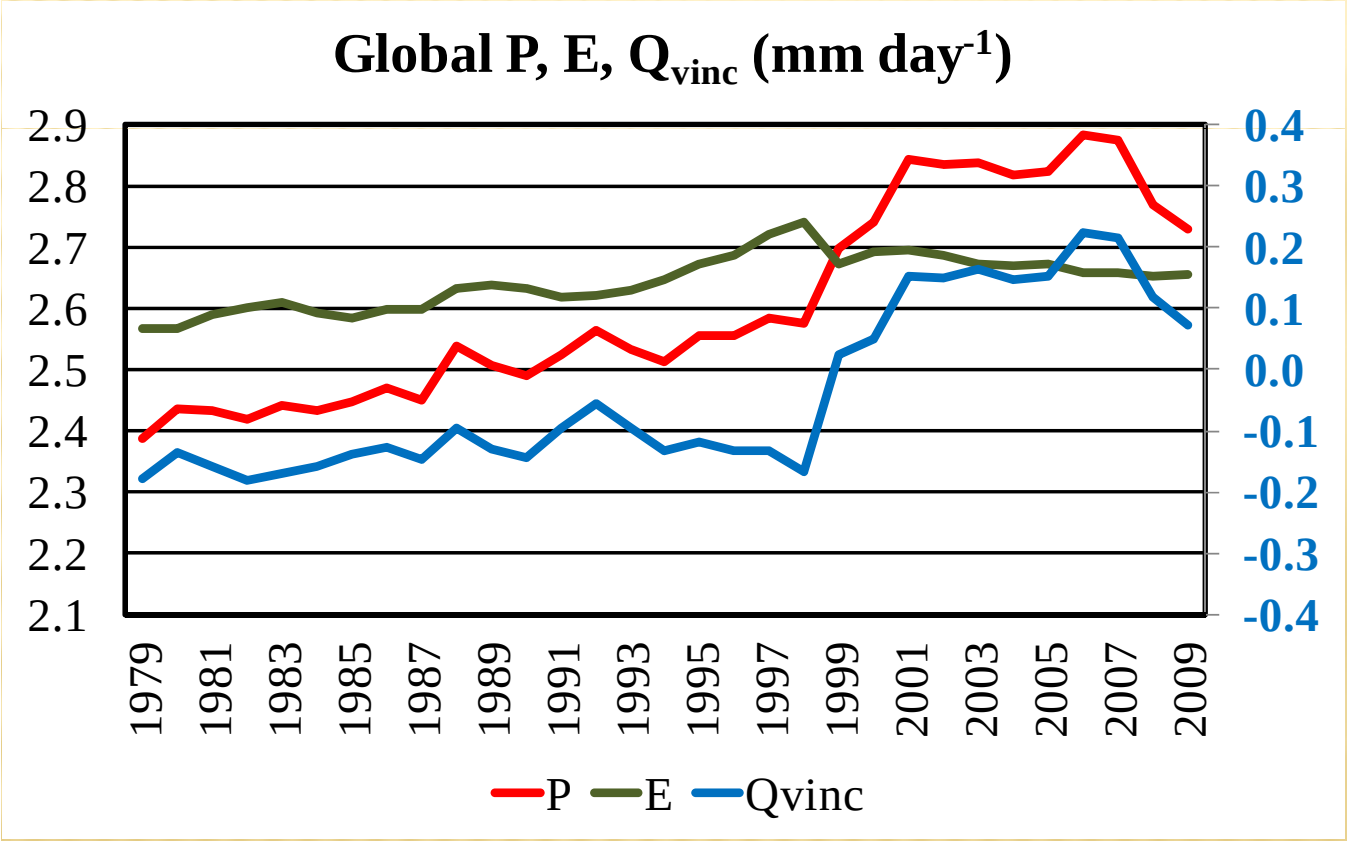
- Global P trend mostly over Ocean
- Land, taken together, are comparable with little apparent trend

Land



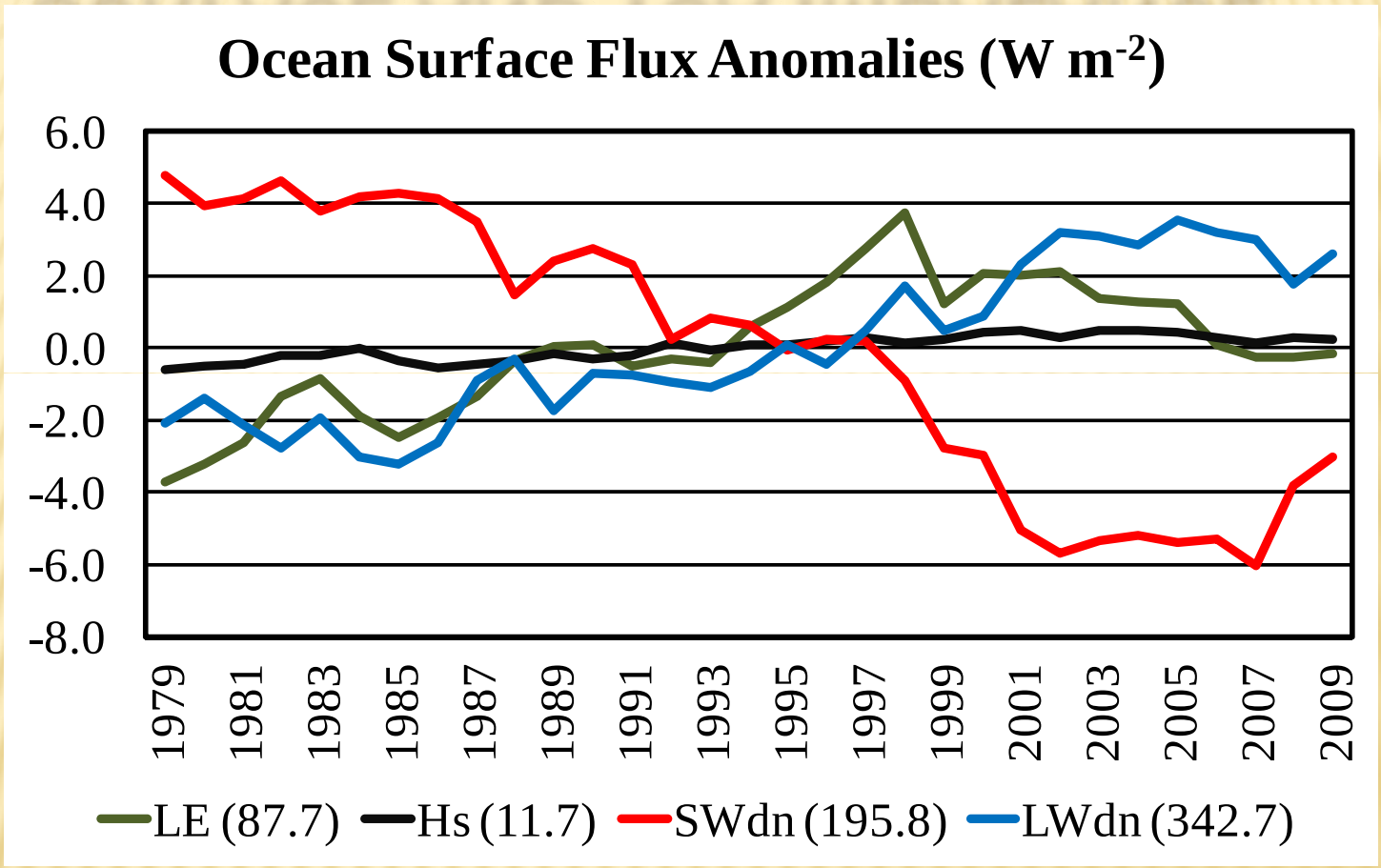
GLOBAL WATER BALANCE

$$\frac{\partial \overline{w}}{\partial t} = -\nabla \cdot \left(\overline{\vec{v}w}\right) + E - P + \left[\frac{\partial \overline{w}}{\partial t}\right]_{ANA} + F$$



- Nov98 NOAA15
- Jul99 QSCAT
- Jan01 NOAA16
- Aug02 NOAA17
- Oct02 AIRS
- Nov05 NOAA18

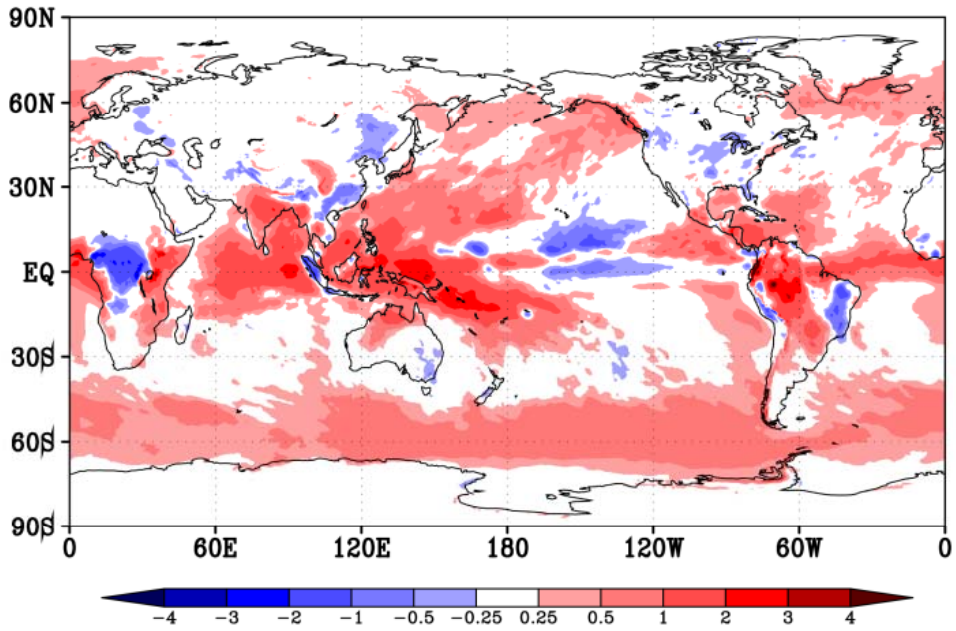
NET SURFACE AND TOA IMBALANCE



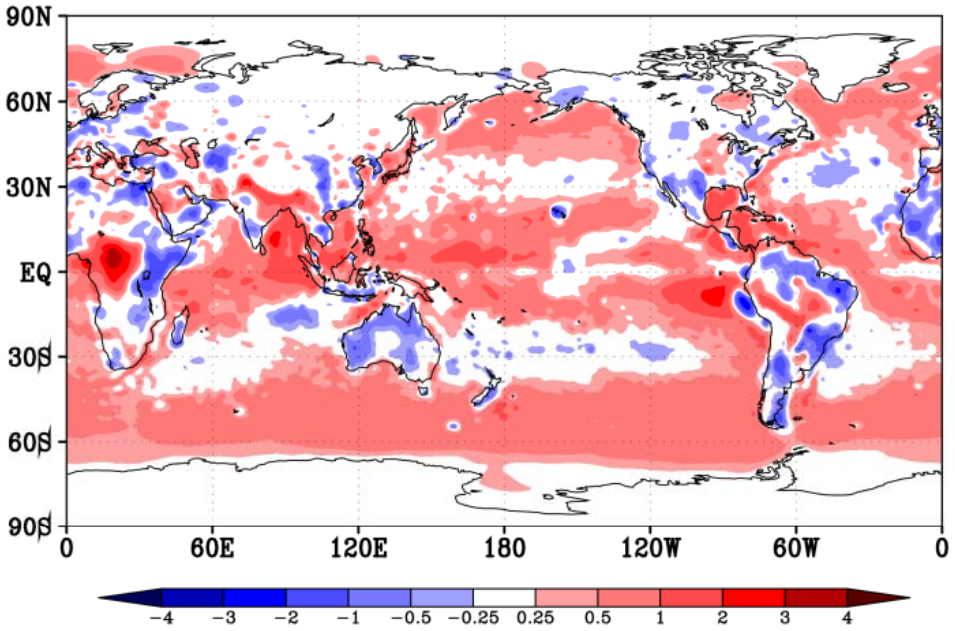
- Global surface net imbalance is improving in time, mostly changing over Ocean
- The Ocean net imbalance is decreasing in incoming SW radiation and increasing LE

SPATIAL EFFECT OF AMSU (ESTIMATED) ON MERRA

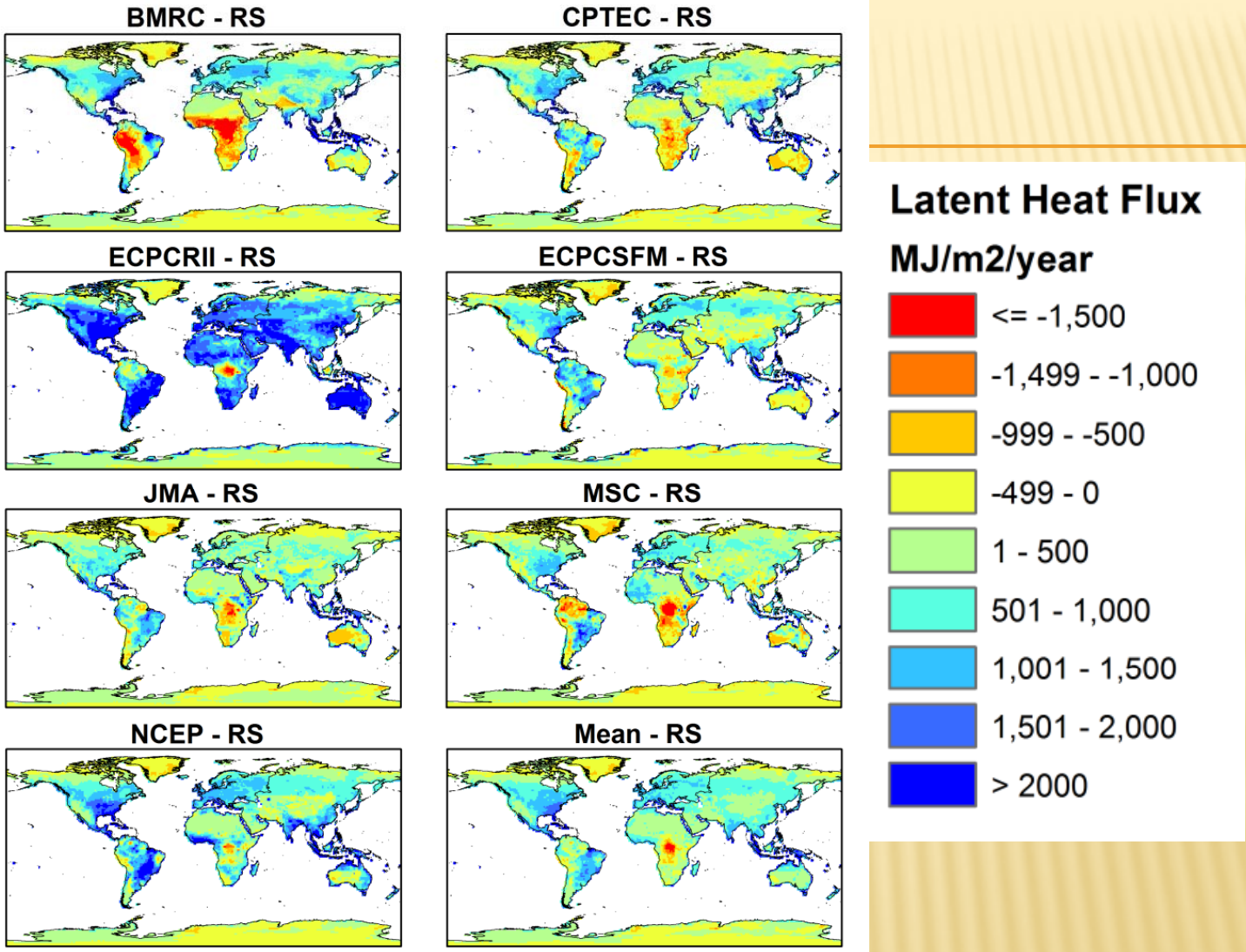
Precipitation Change (mm day^{-1})
2000-08 minus 1990-97



Increment Change (mm day^{-1})
2000-08 minus 1990-97

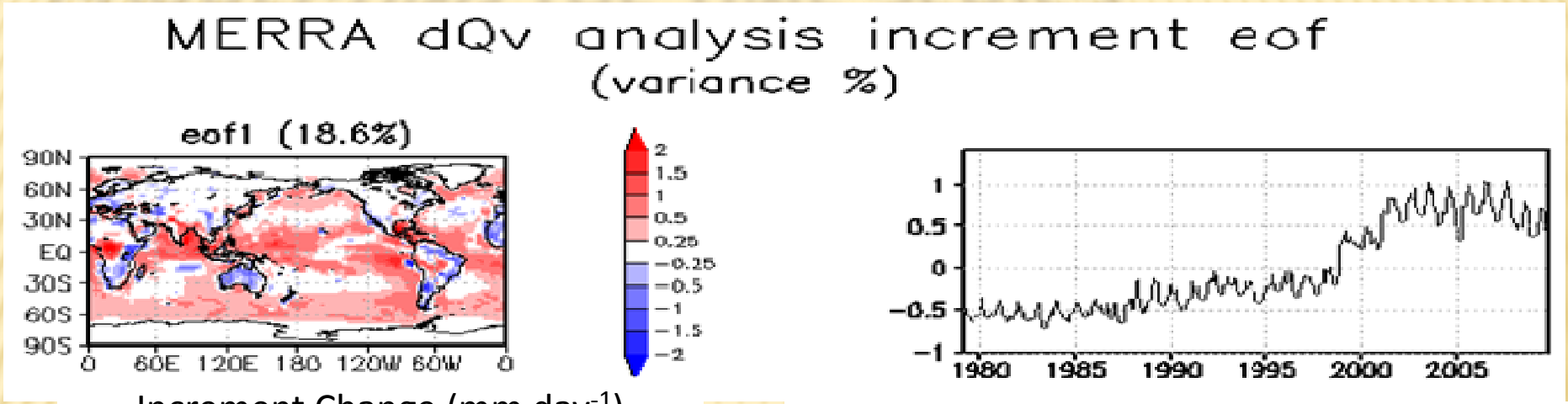


- Increases in SH midlatitude and Indian Ocean
- SPCZ increase is also related to moist convergence
- African decrease needed more attention

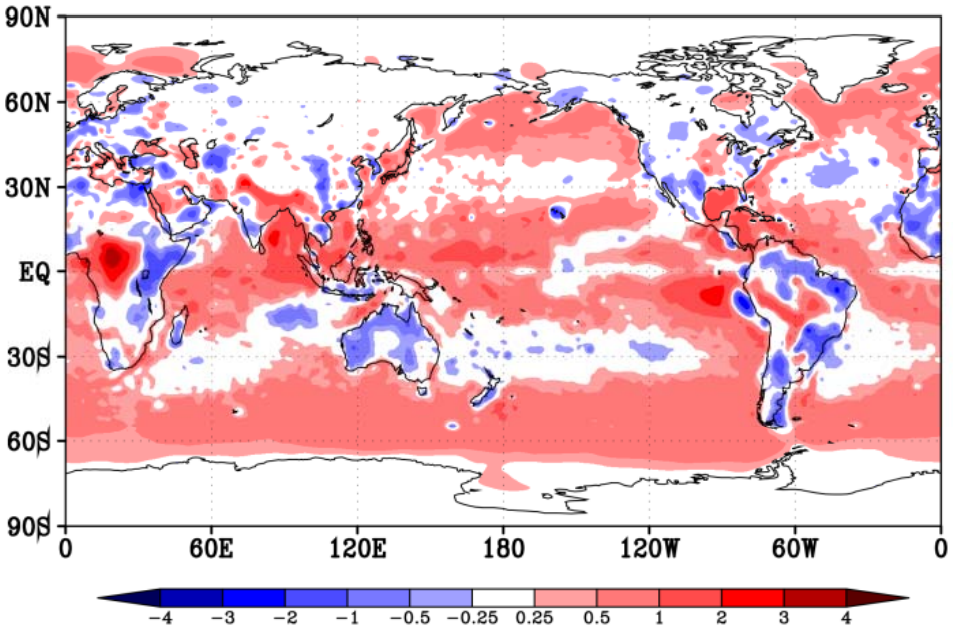


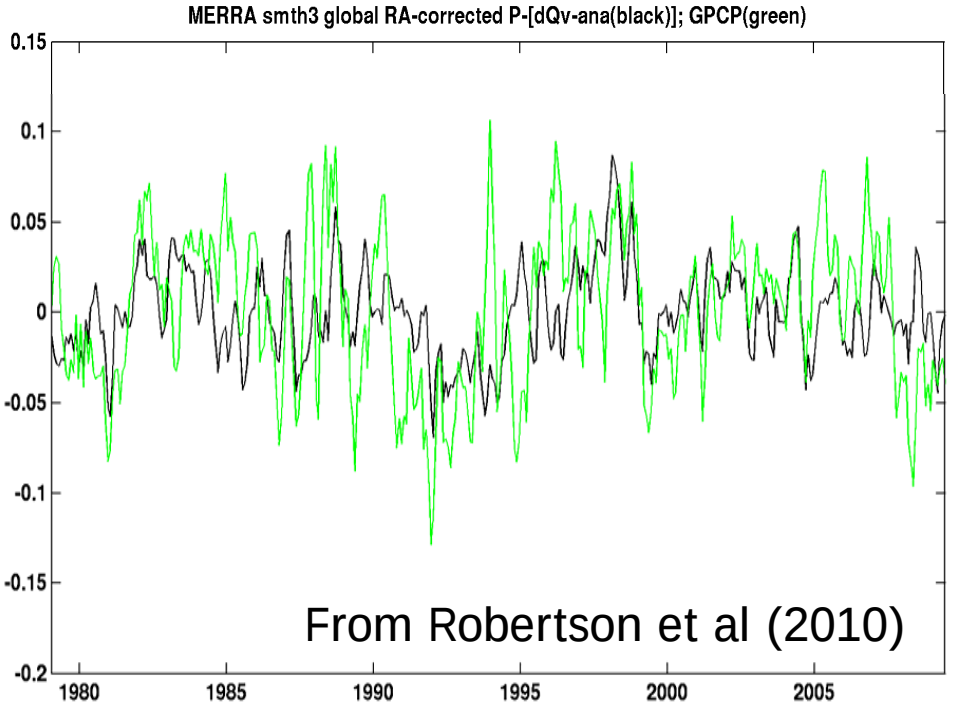
- Many analyses can help understanding/validation/development
- 2003-2004 LH Flux Difference from a Remotely Sensed estimate (Vinukollu et al 2010)

CORRECTING THE TIME SERIES



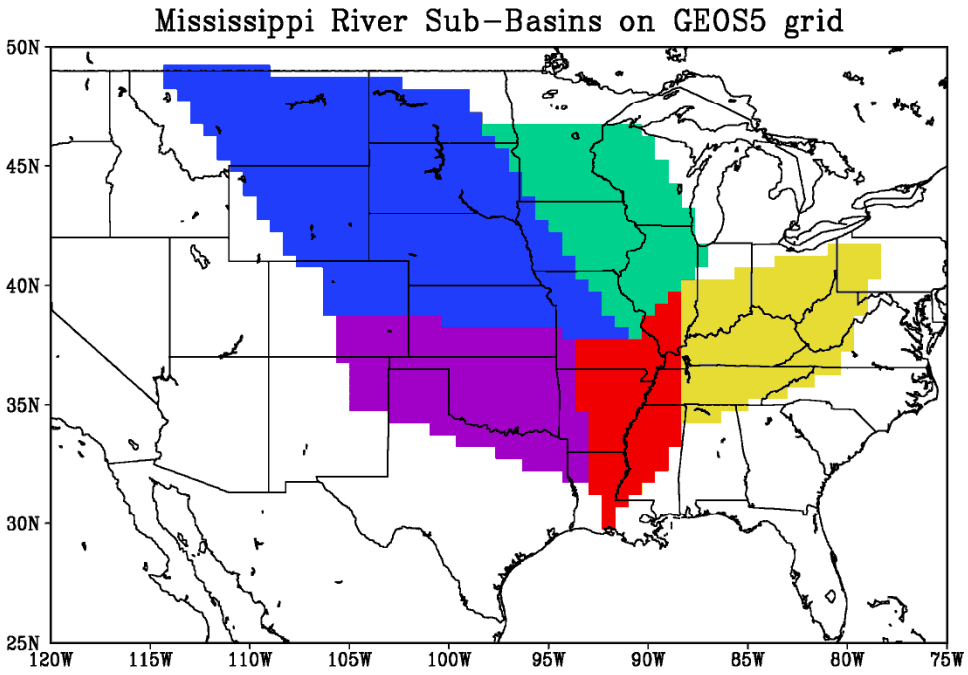
Increment Change (mm day^{-1})
2000-08 minus 1990-97

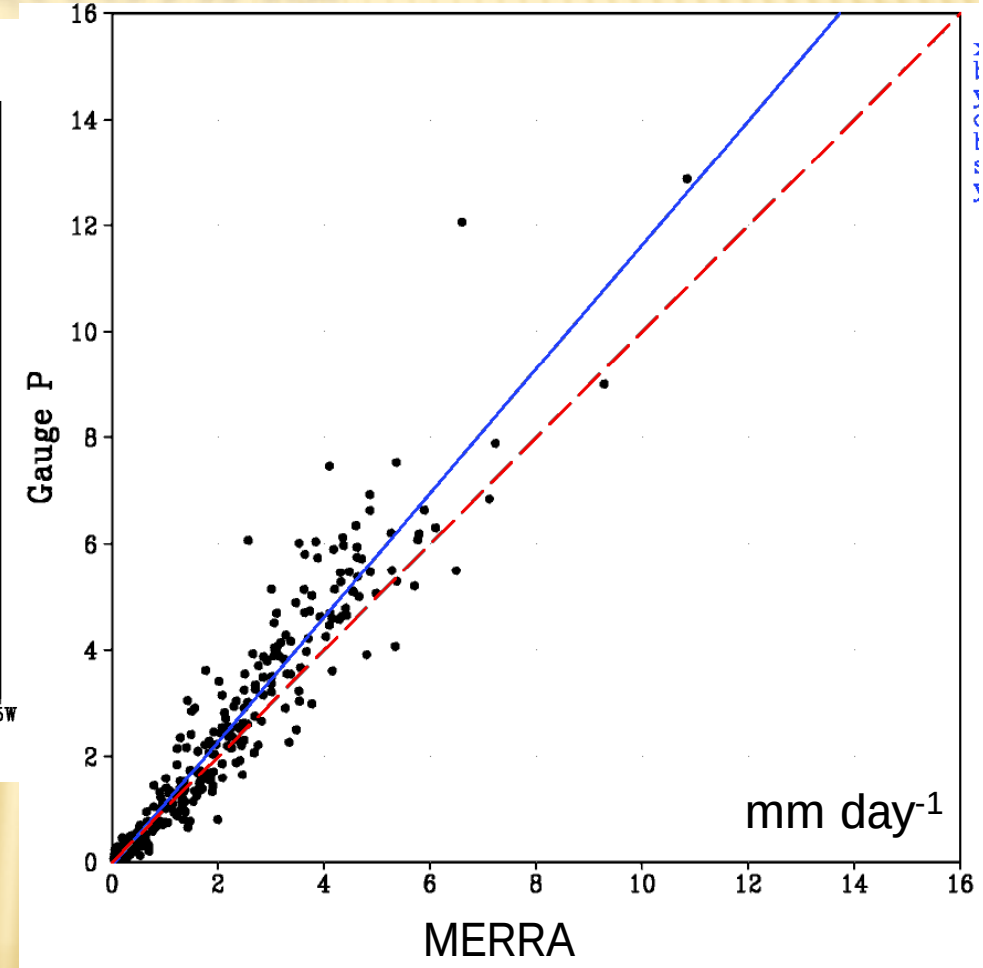




From Robertson et al (2010)

BASIN-SCALE PRECIPITATION





- CPC US ¼ gridded gauge data
- Daily, Jan 1 2003 – Dec 31 2004
- Area average over the Mississippi River Basin domain

TROPOPAUSE FOLD

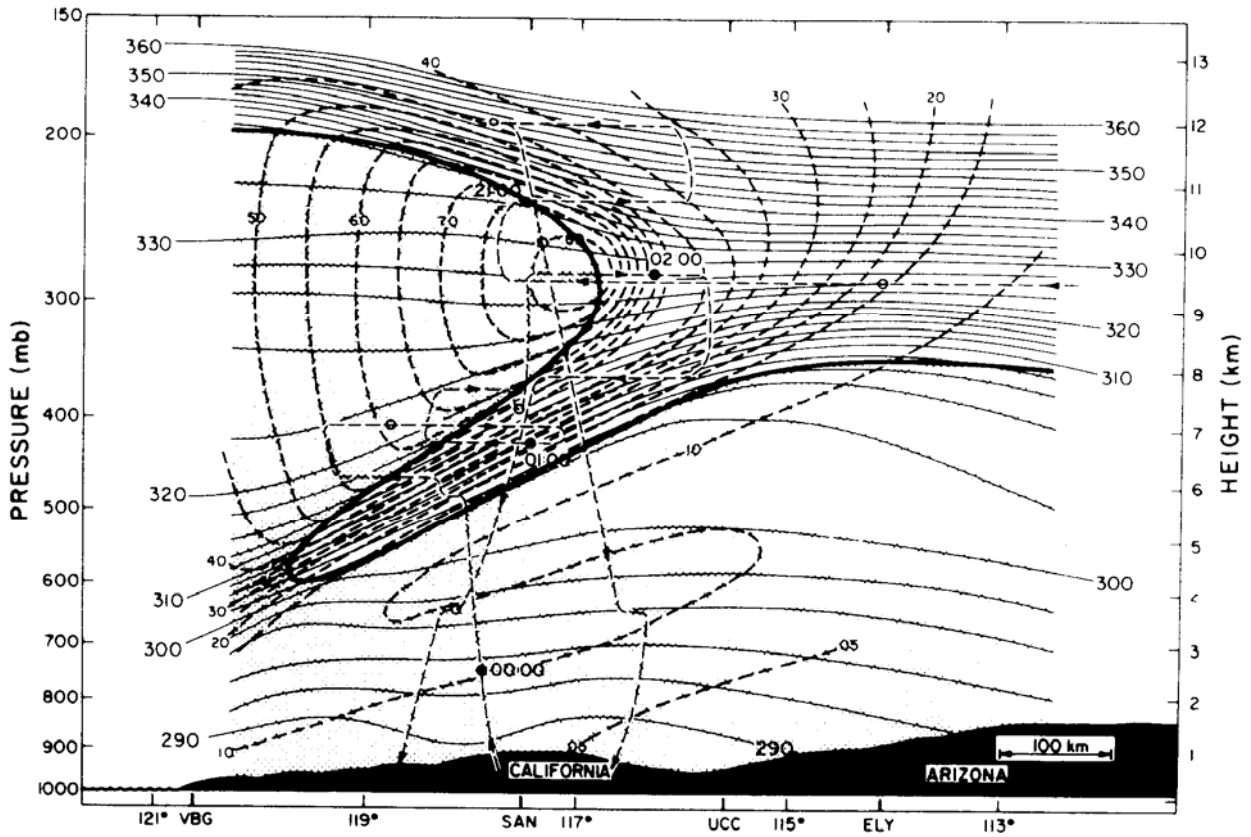
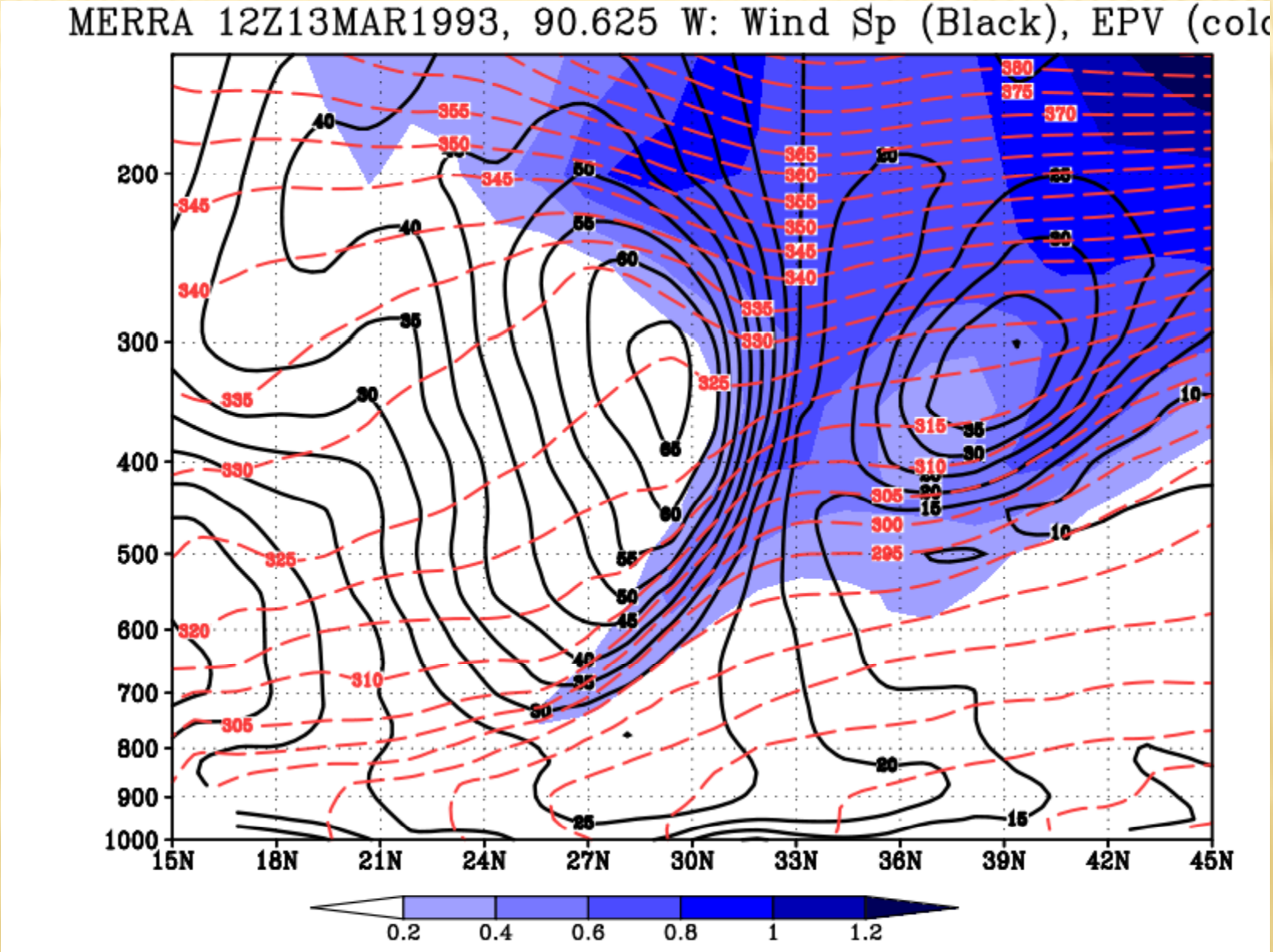
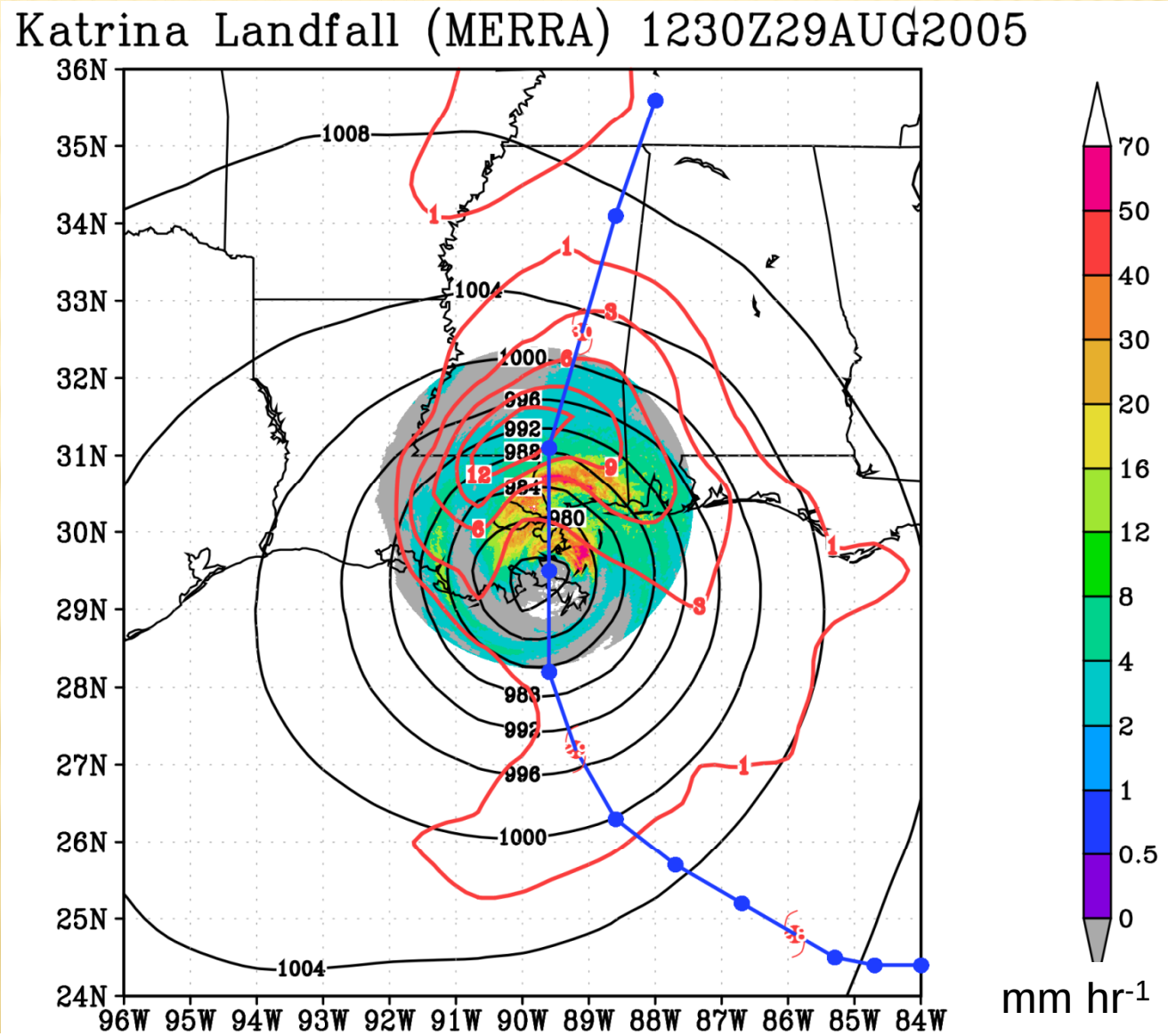


Figure 10.30. Cross section through a tropopause fold for 0000 GMT, 13 March 1978. Potential temperature (K) is indicated by thin solid lines; wind speed (m s^{-1}) by thick dashed lines; Sabreliner flight track by thin dashed lines; tropopause defined in terms of potential vorticity (100×10^{-7} K mb^{-1} s^{-1}) by thick solid line. The troposphere is stippled. (From Shapiro, 1980.)

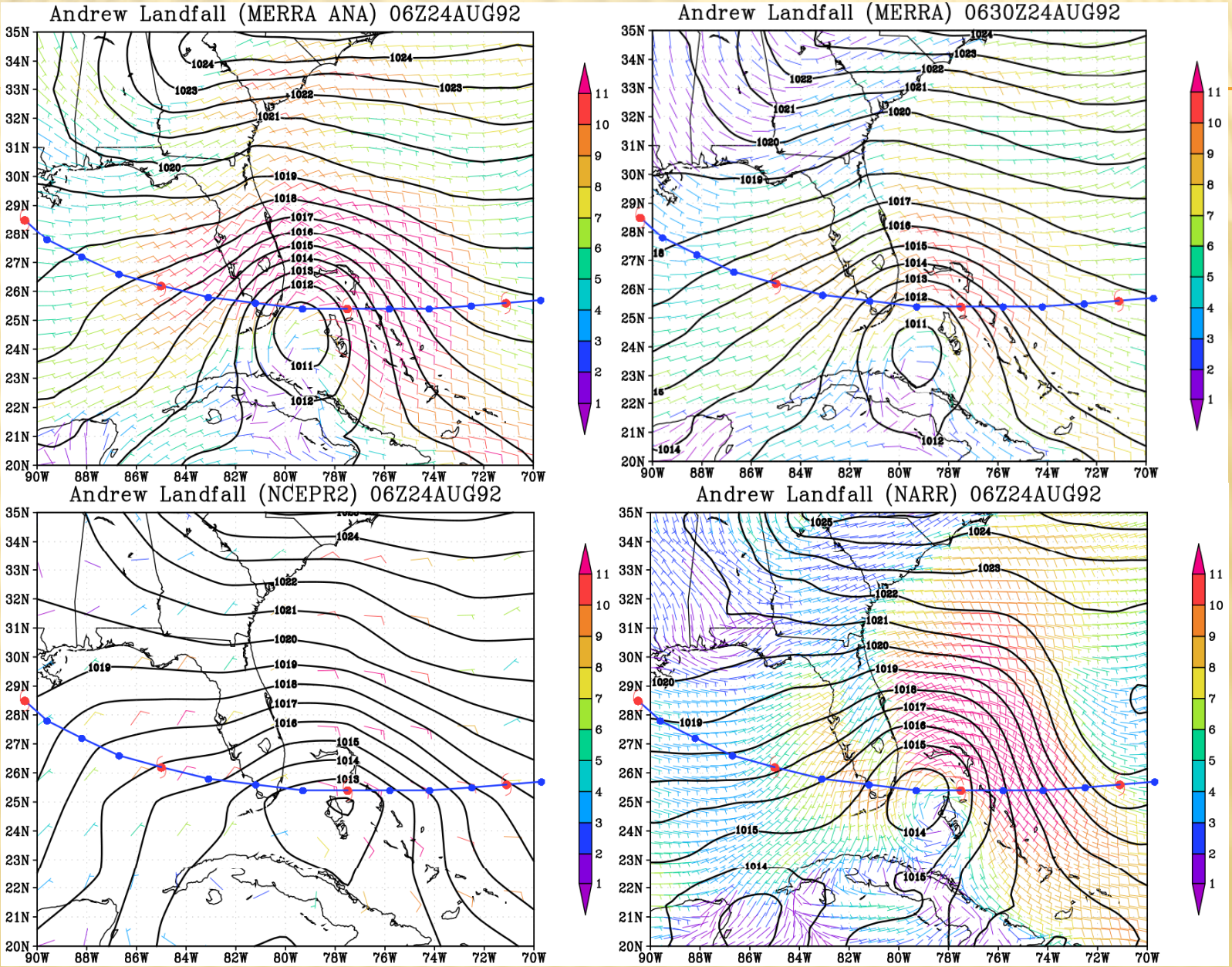
TROPOPAUSE FOLD



KATRINA AT LANDFALL



ANDREW AUG 24, 1992



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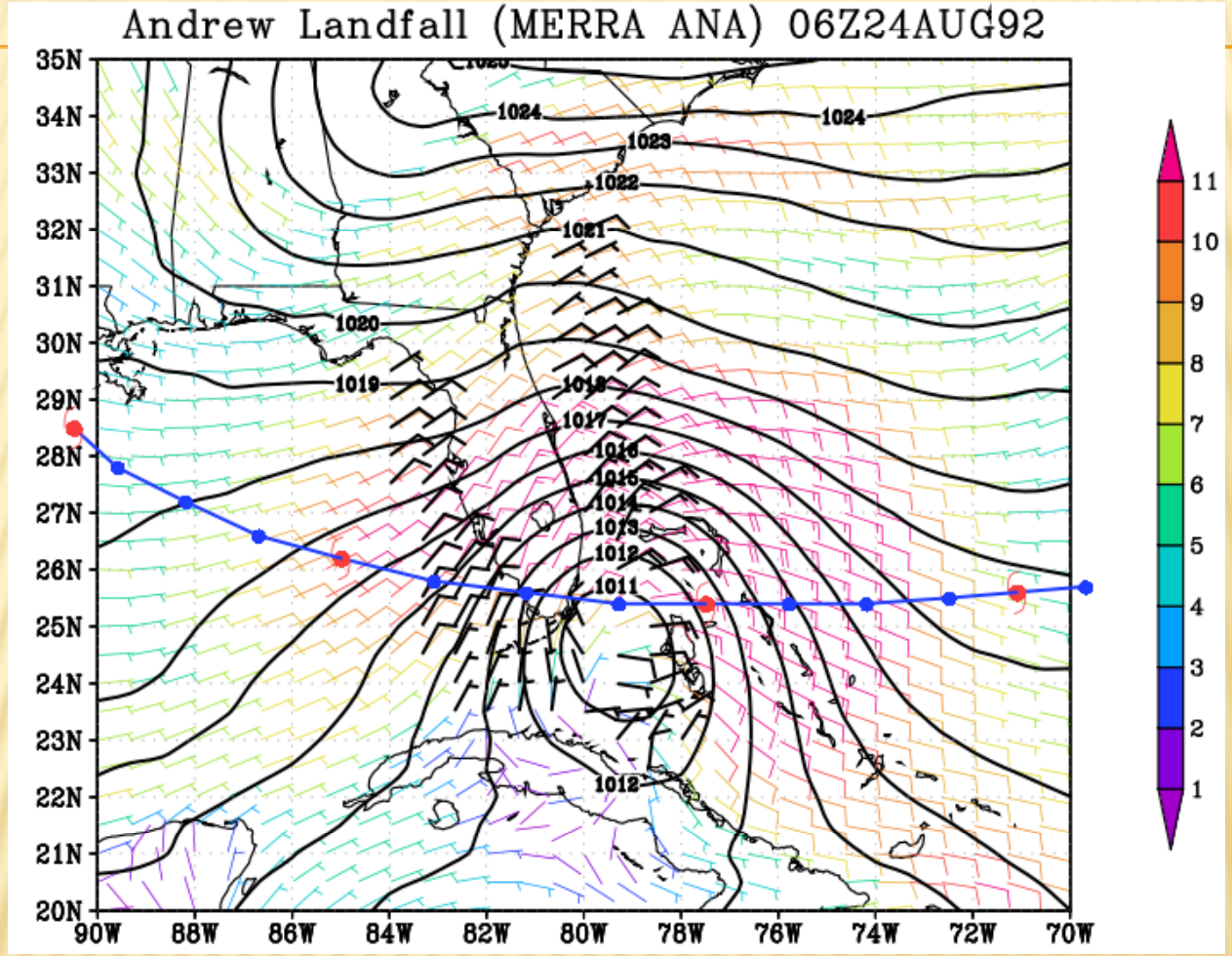
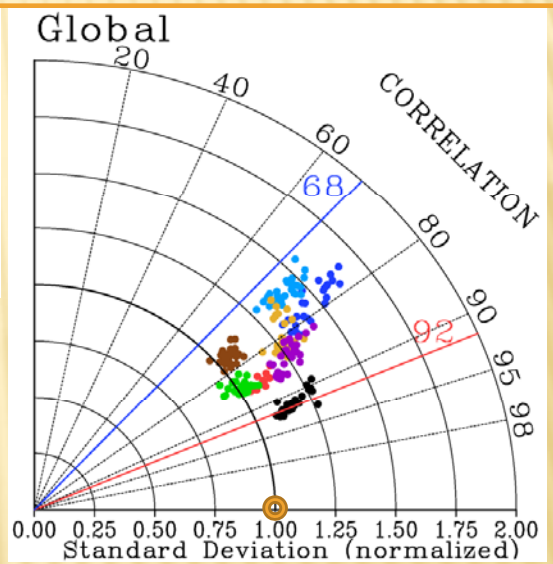
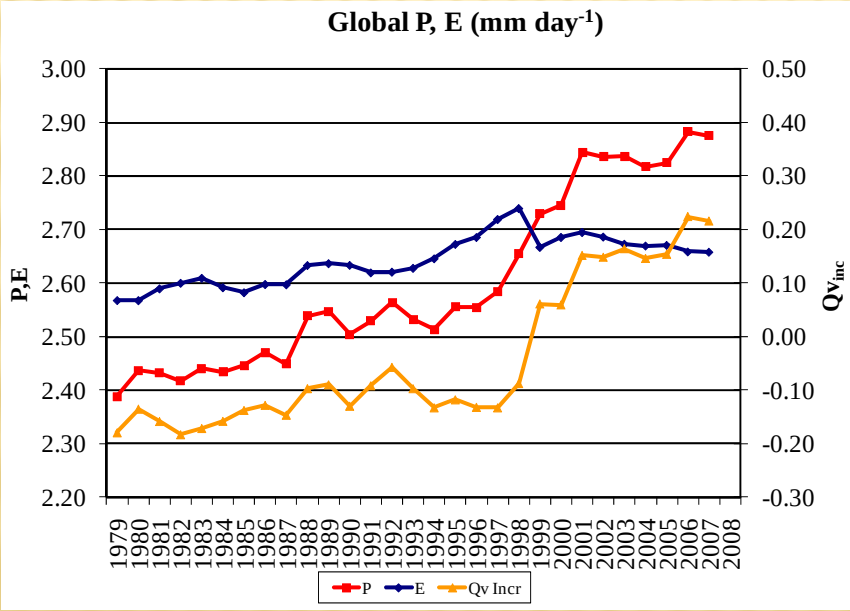


- ERS observations overlay
- MERRA Obs (including O-F and O-A) to be available for user access soon

BEGINNING RESEARCH

- MERRA Precipitation shows skill compared to GPCP, relative to other reanalyses
- Trends are on the order of other reanalyses, but the bias is much improved
- Energy balance smallest in the recent period, ~8Wm^{-2} imbalance





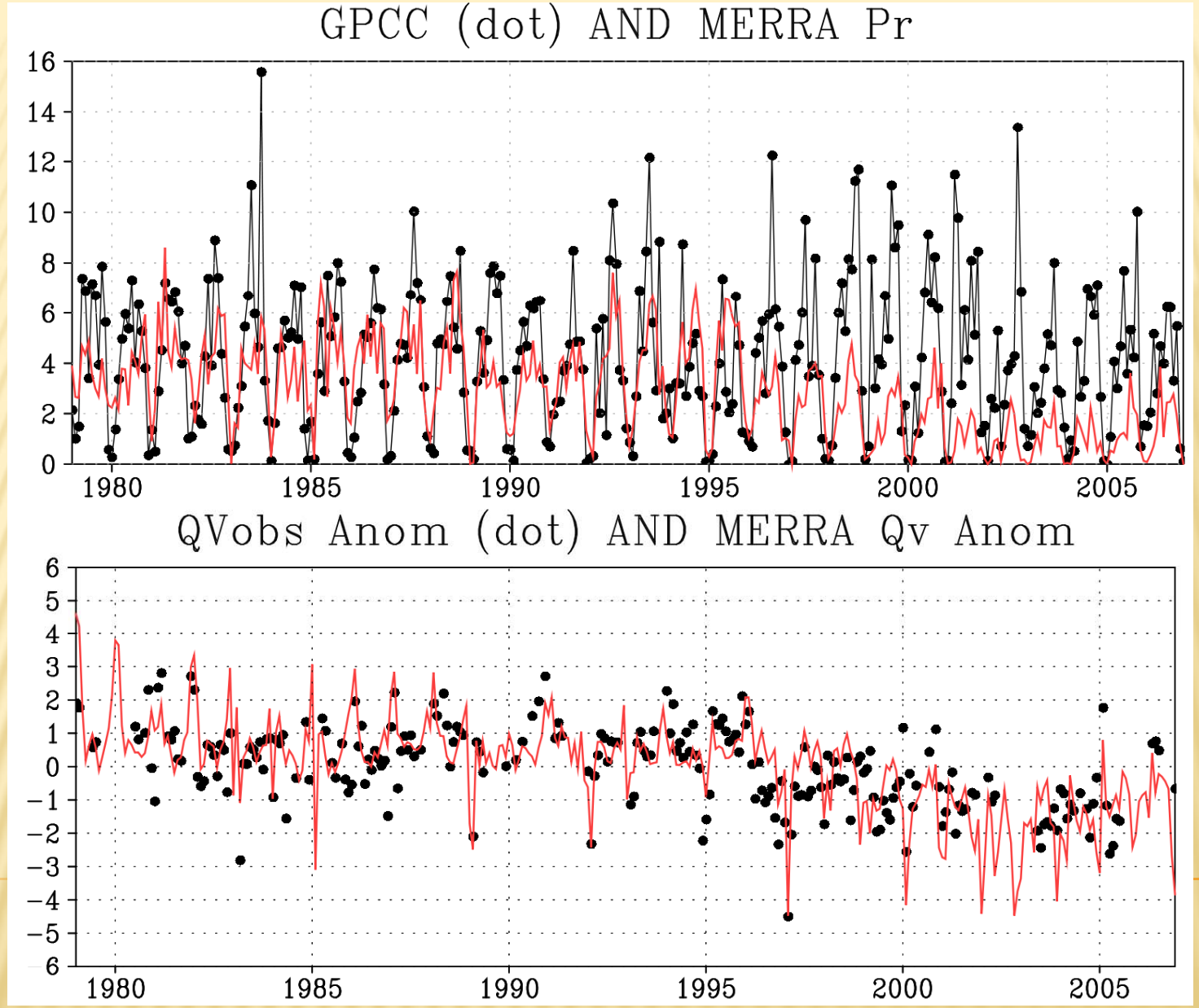
- Remaining issues in reanalyses: model bias appears as trends in conjunction with the changing observing system, can affect many aspects of the reanalysis
- Researchers must evaluate the processes important to their project; Analyzed observations should help

THANK YOU

- Home - http://gmao.gsfc.nasa.gov/merra/
- Data - http://disc.sci.gsfc.nasa.gov/MDISC/
- Atlas - http://gmao.gsfc.nasa.gov/ref/merra/atlas/
- Discussion –

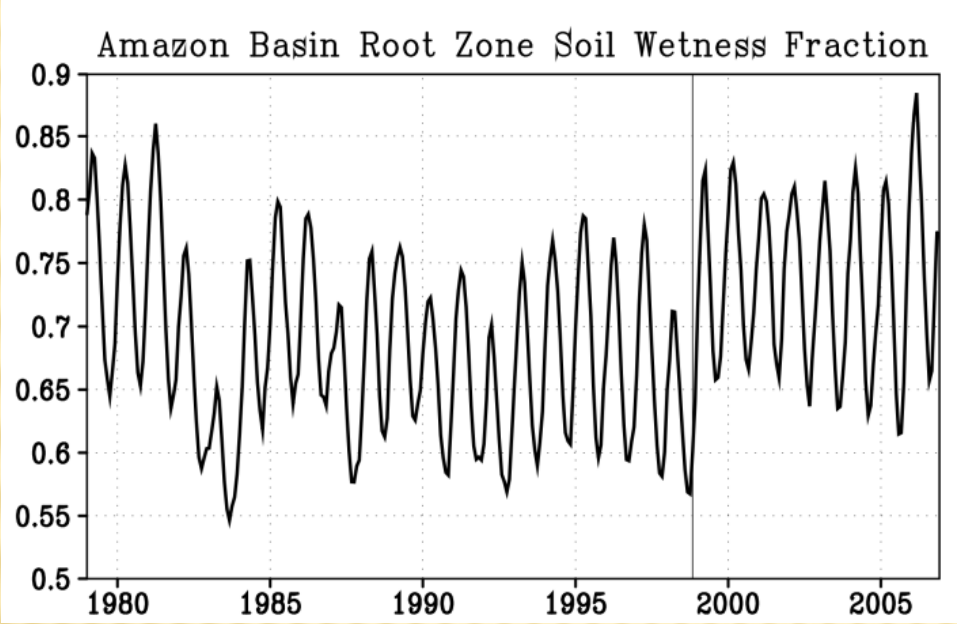
  http://merra-reanalysis.blogspot.com/

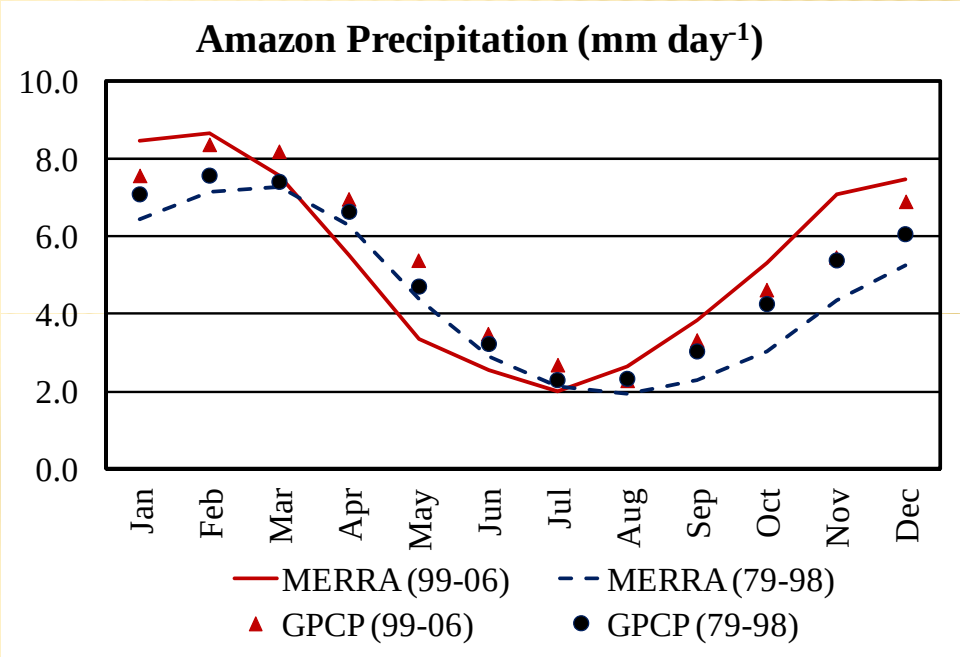
- merra-questions@listserv.gsfc.nasa.gov
- Michael.Bosilovich@nasa.gov



850mb specific humidity from Bangui (64650), compared to MERRA grid point, monthly mean anomalies

AMAZON TIME SERIES





- Amazon precipitation generally increases, but there is also a phase shift in the annual cycle
- More water in the soil, after AMSU assimilation

ATMOSPHERIC HEATING