# NASA's Modern Era Retrospective-analysis for Research and Applications: Validation

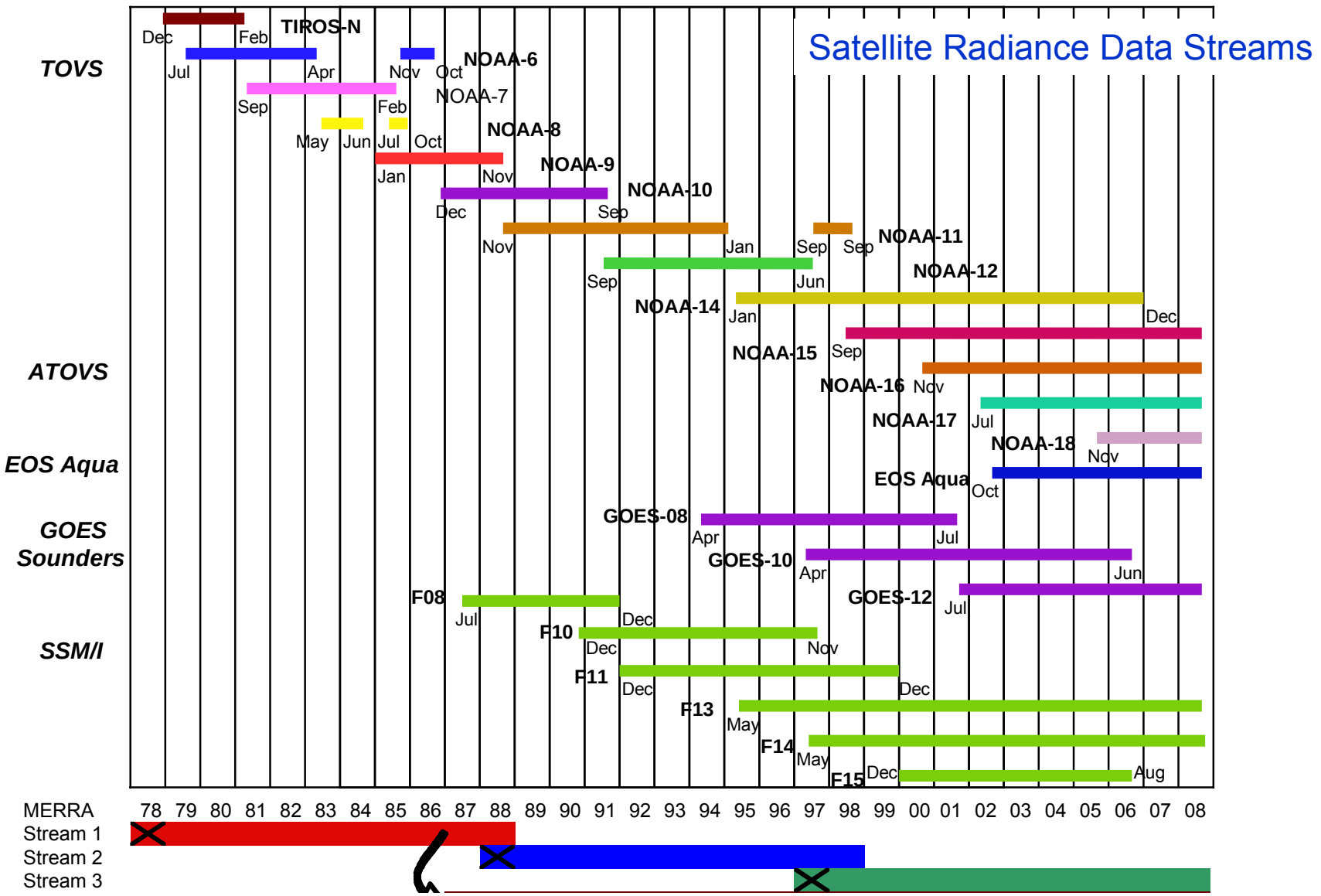
## Global Modeling and Assimilation Office

- Overview and Status
- Some early results
- Monitoring

Presented by Michael Bosilovich, MERRA Short Course, AMS Annual Meeting, Phoenix AZ, January 11, 2009

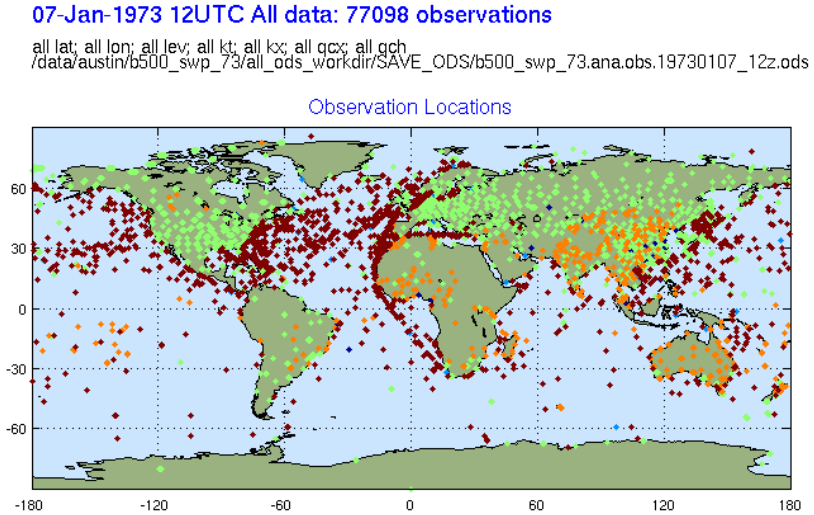
# NASA's Modern Era Retrospective-analysis for Research and Applications (MERRA)

- Retrospective-analyses use a fixed Global Atmospheric Model and Data Assimilation System to analyze the historical satellite and conventional data records into a continuous global gridded data set including a multitude of ancillary weather and climate diagnostics
- MERRA uses the latest release of the GMAO Global Earth Observing System Data Assimilation System (GEOS-5) and will analyze the period from 1979 – present, assimilating satellite radiances and conventional observations
- A NASA contribution to CCSP Synthesis and Assessment Product 1.3: Re-analyses of historical climate data for key atmospheric features. Implications for attribution of causes of observed change.

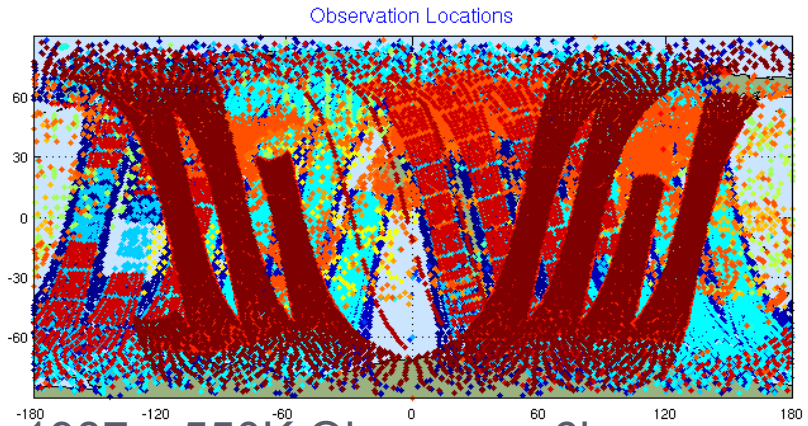



MERRA will analyze radiances from these satellites, and also several satellite retrieved data products as well as conventional observations (e.g. sondes)

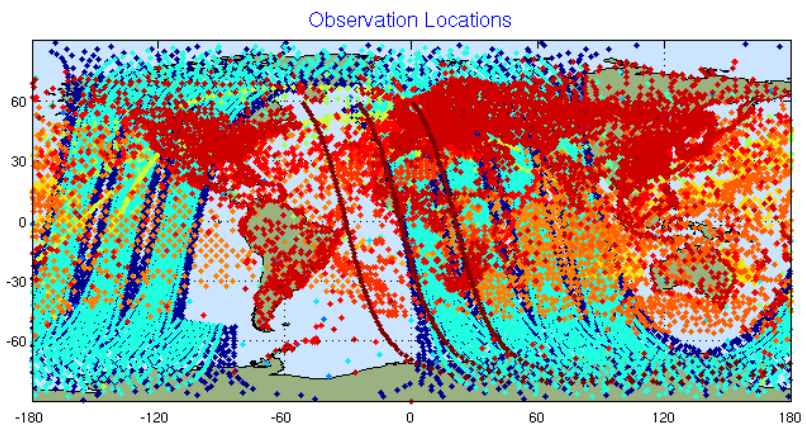
# The Changing Observing System



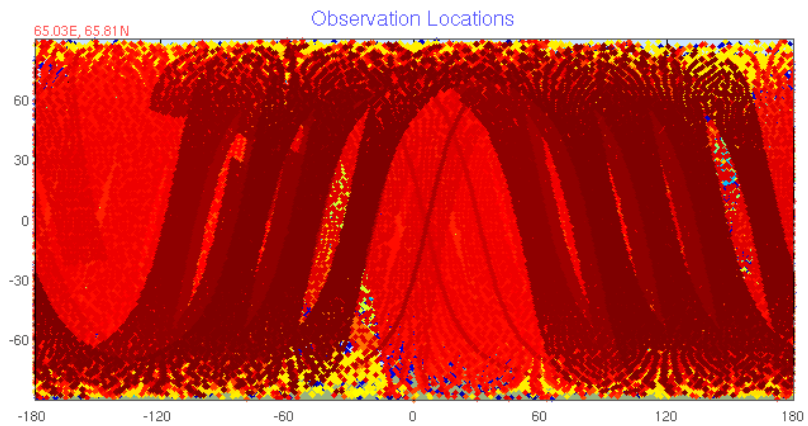

1973 – 77K Obs every 6hrs




1987 – 550K Obs every 6hrs




1979 – 325K Obs every 6hrs



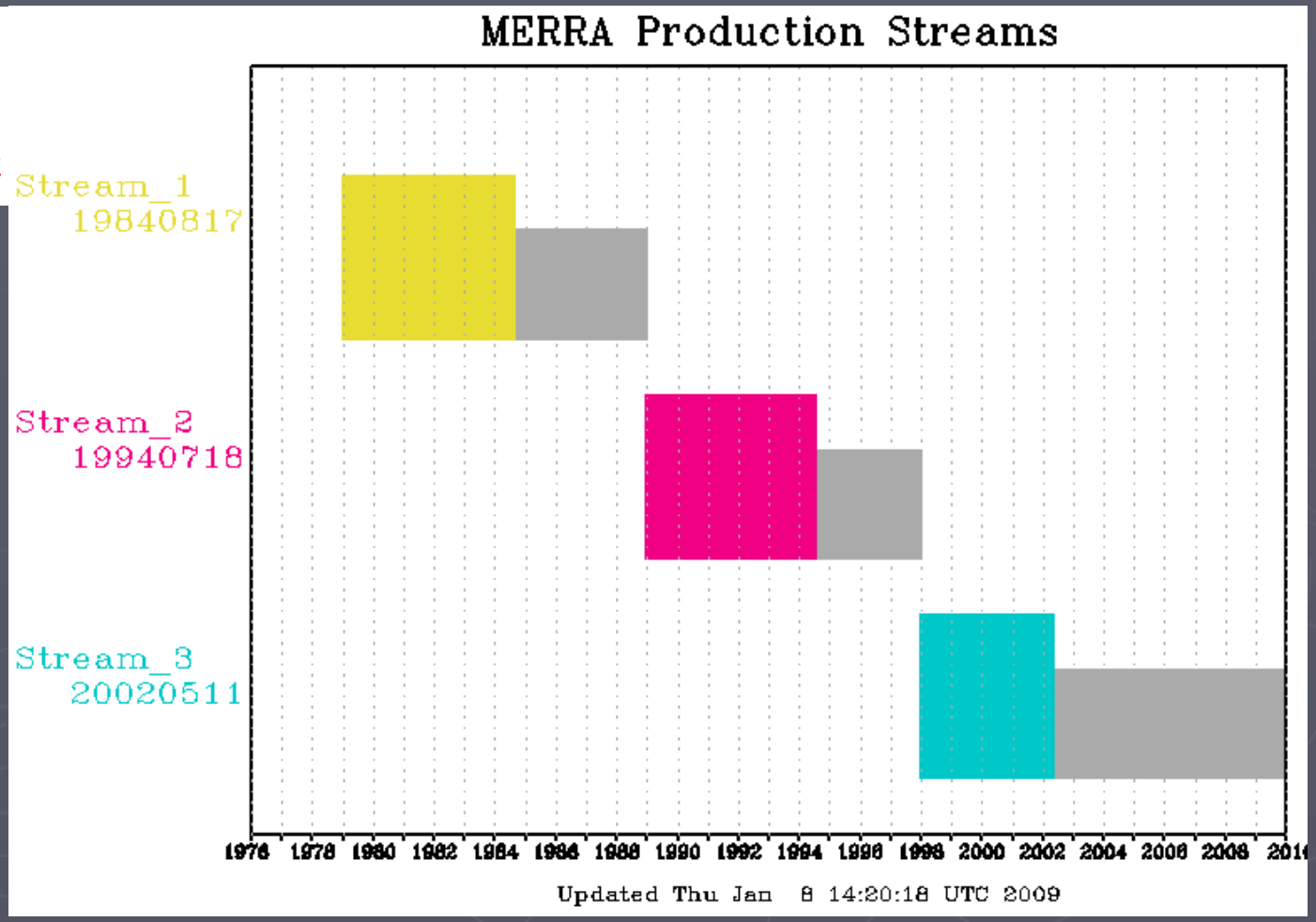

2006 – 4.2M Obs every 6hrs

# NASA's Modern Era Retrospective-analysis for Research and Applications (MERRA)

- Objective: To improve the water cycle representation in reanalyses, and support NASA Earth science and application activities
- 1979-present (continuing as it is feasible)
- ½° horizontal resolution (72 model levels, sfc-strat)
- 1 hourly surface and 2D diagnostic data
- 6 hourly 3-Dimensional atmospheric analysis
- >150 Tbs online storage, many portals
- Production Began May 2008 (complete Fall-2009)
- Home - http://gmao.gsfc.nasa.gov/merra/
- Data - http://disc.sci.gsfc.nasa.gov/MDISC/
- Discussion - http://merra-reanalysis.blogspot.com/

# MERRA Production Status

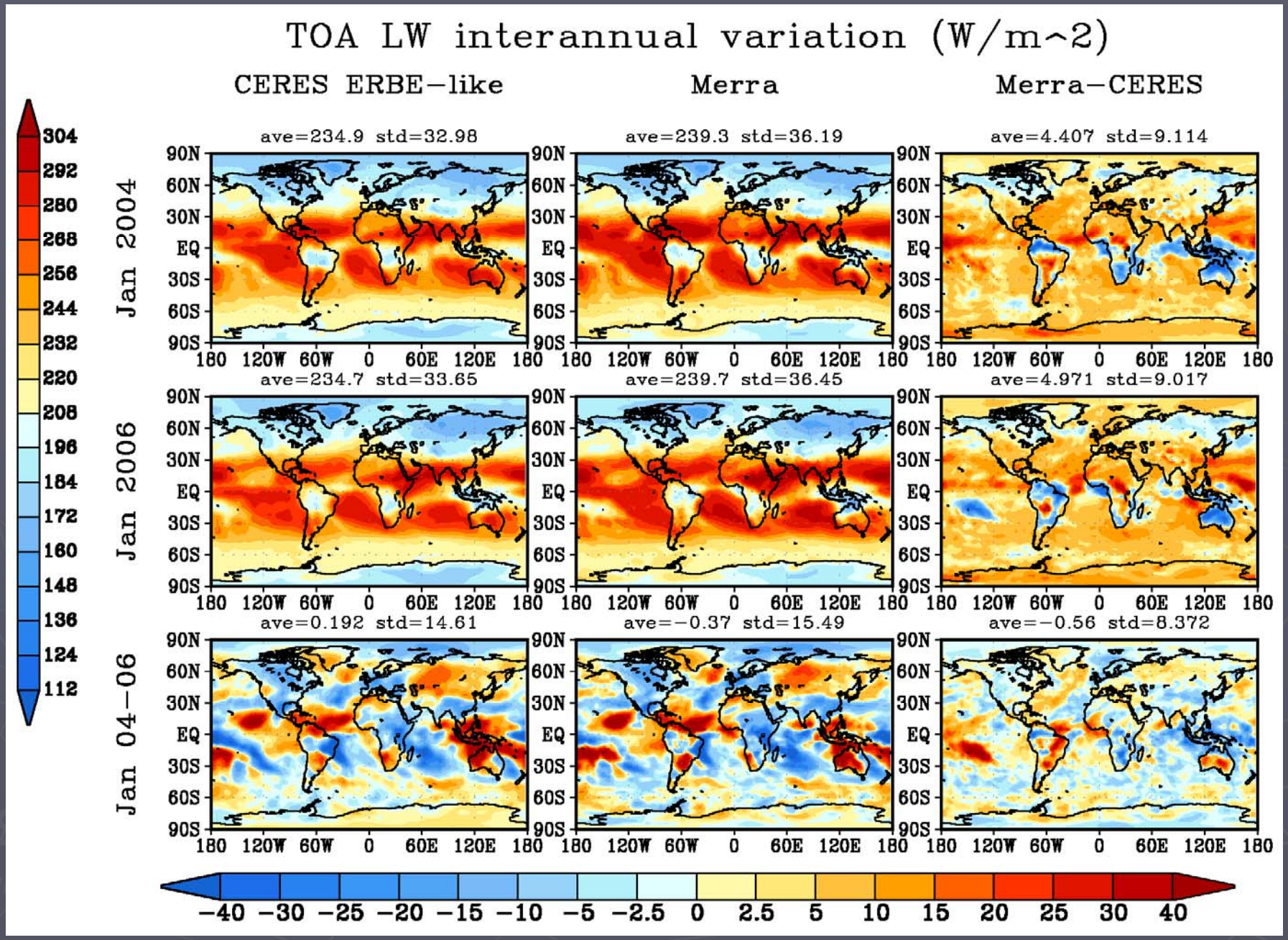
Nearly 17 years complete and shipped to DISC



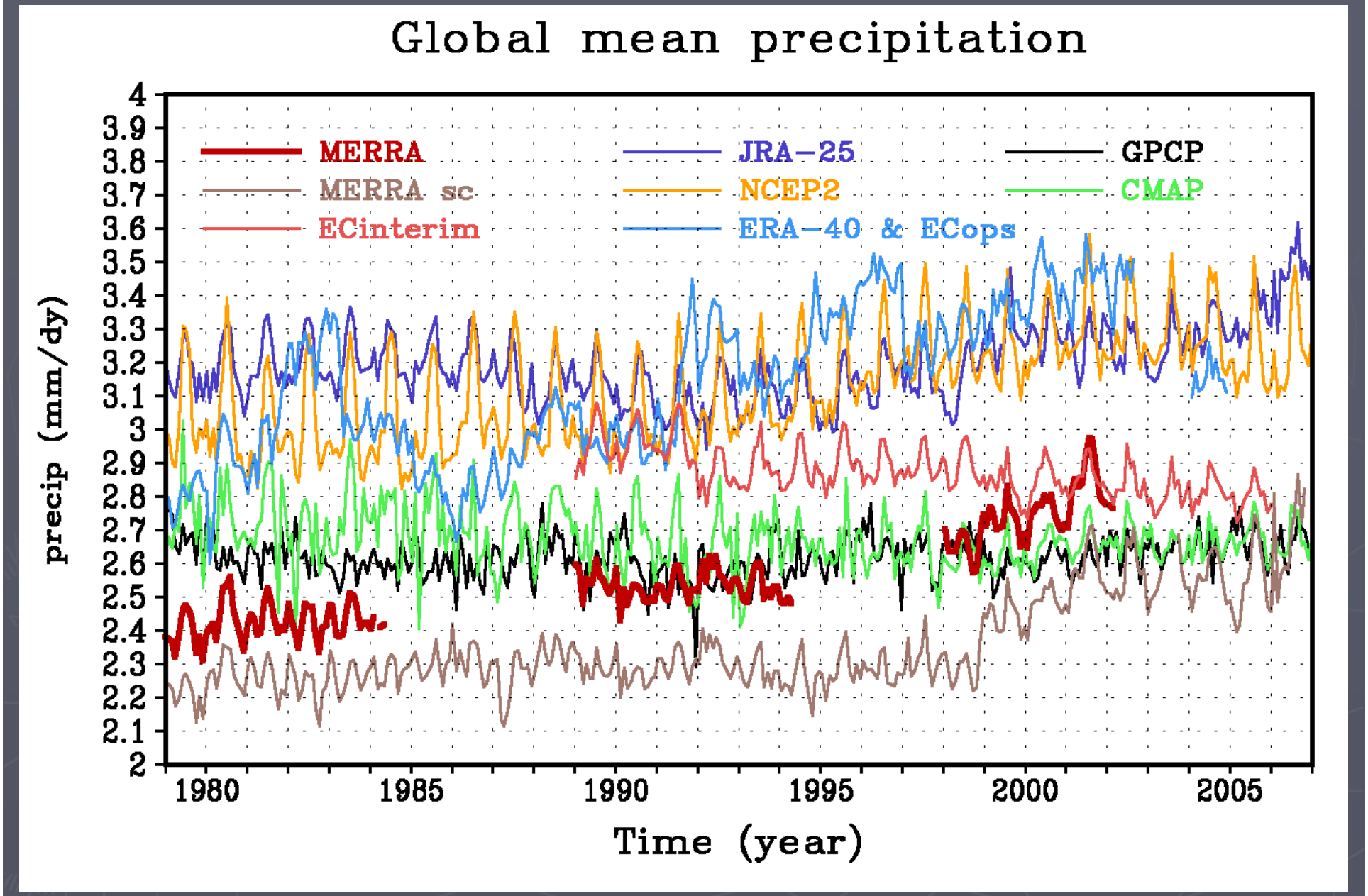

- This figure is updated regularly at: http://gmao.gsfc.nasa.gov/research/merra/progress-events.php

# MERRA Validation

- Experiment Review, Nov 2007
- Included Short Experiments at native resolution (9 months was the longest)
  - Long experiment with coarse resolution (Scout)
- Radiation, clouds, precipitation, surface temperature, UTH, general circulation
- Data sources: SRB, CERES, MODIS, GPCP existing reanalyses
- Increments (e.g. P-E), Indian Monsoon

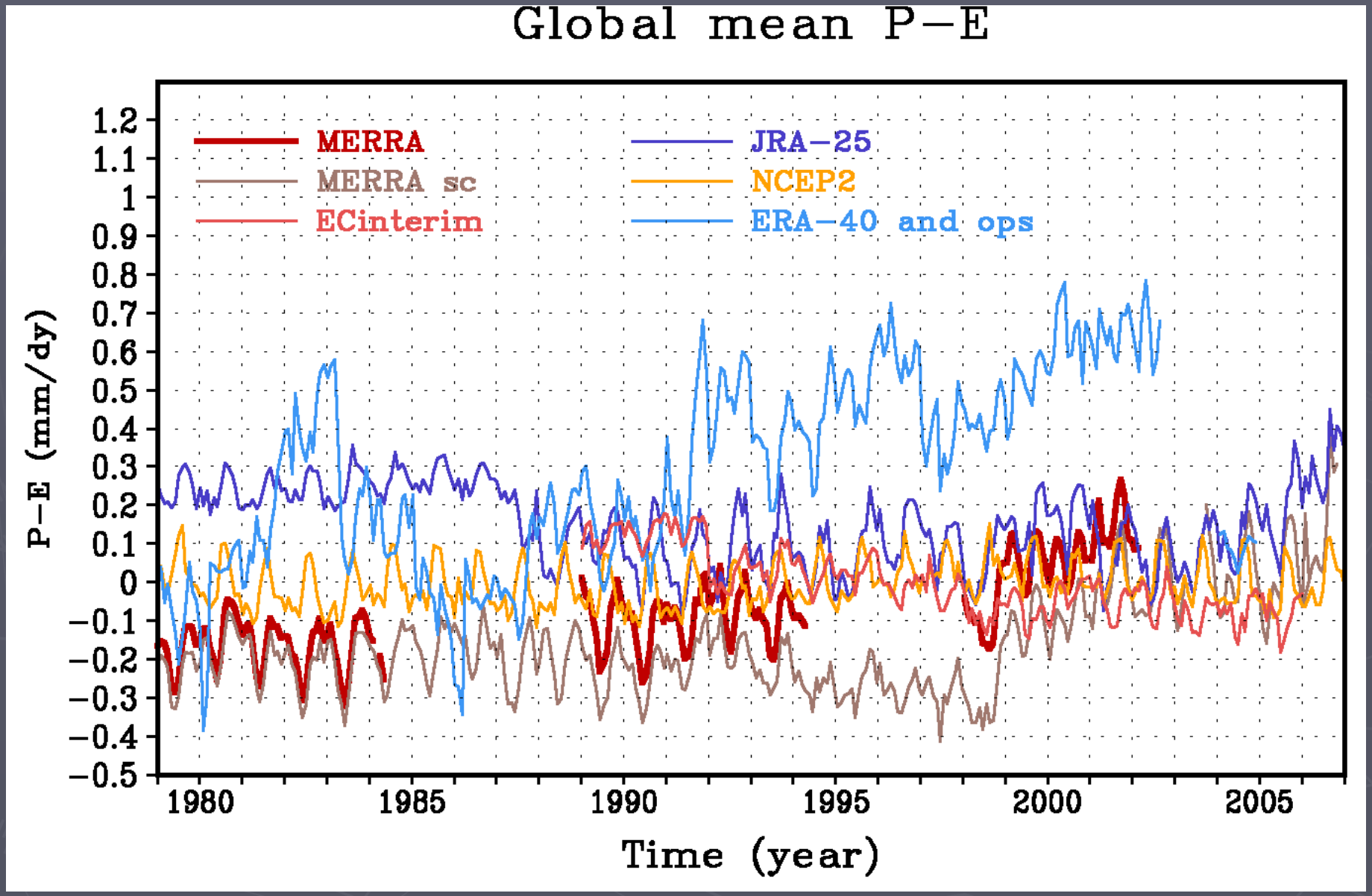


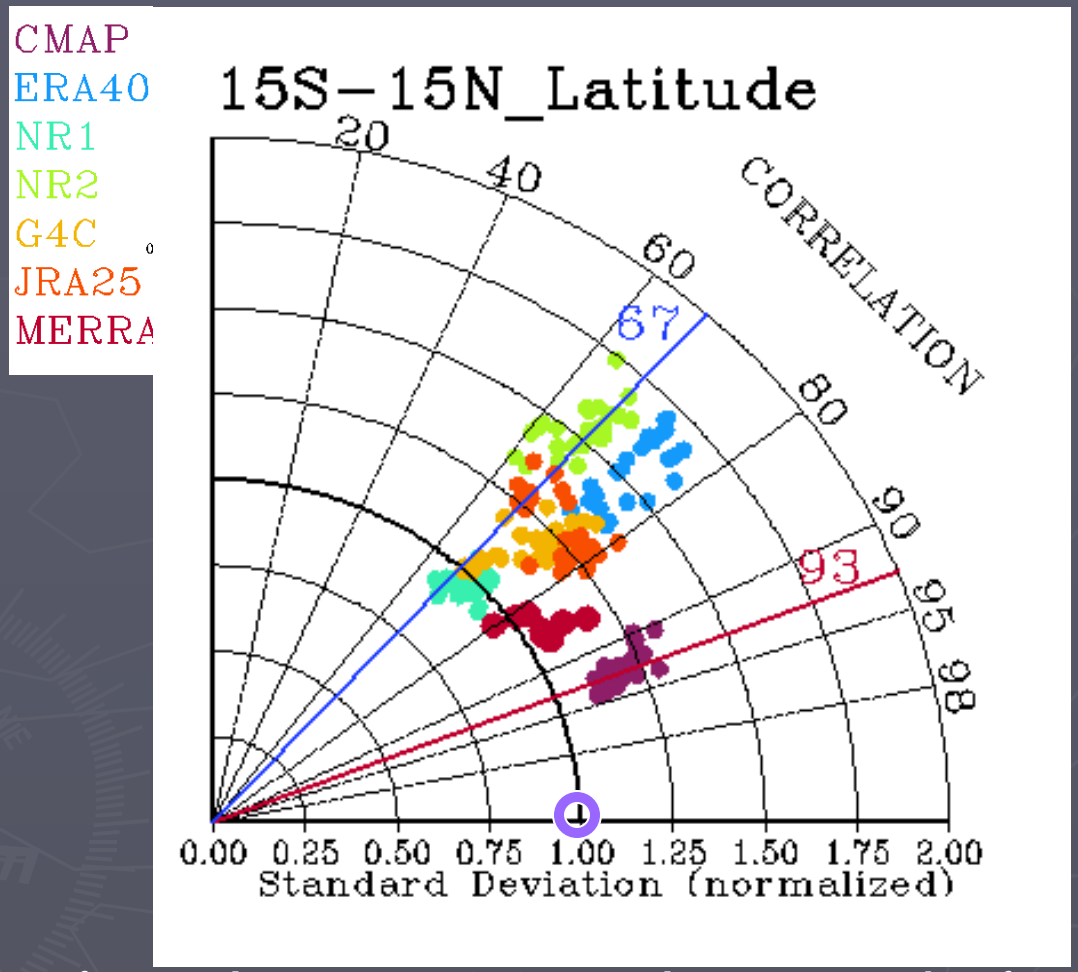

See also S. Schubert presentation provided in the Docs folder of the flash drive




← Will go over this or something like it

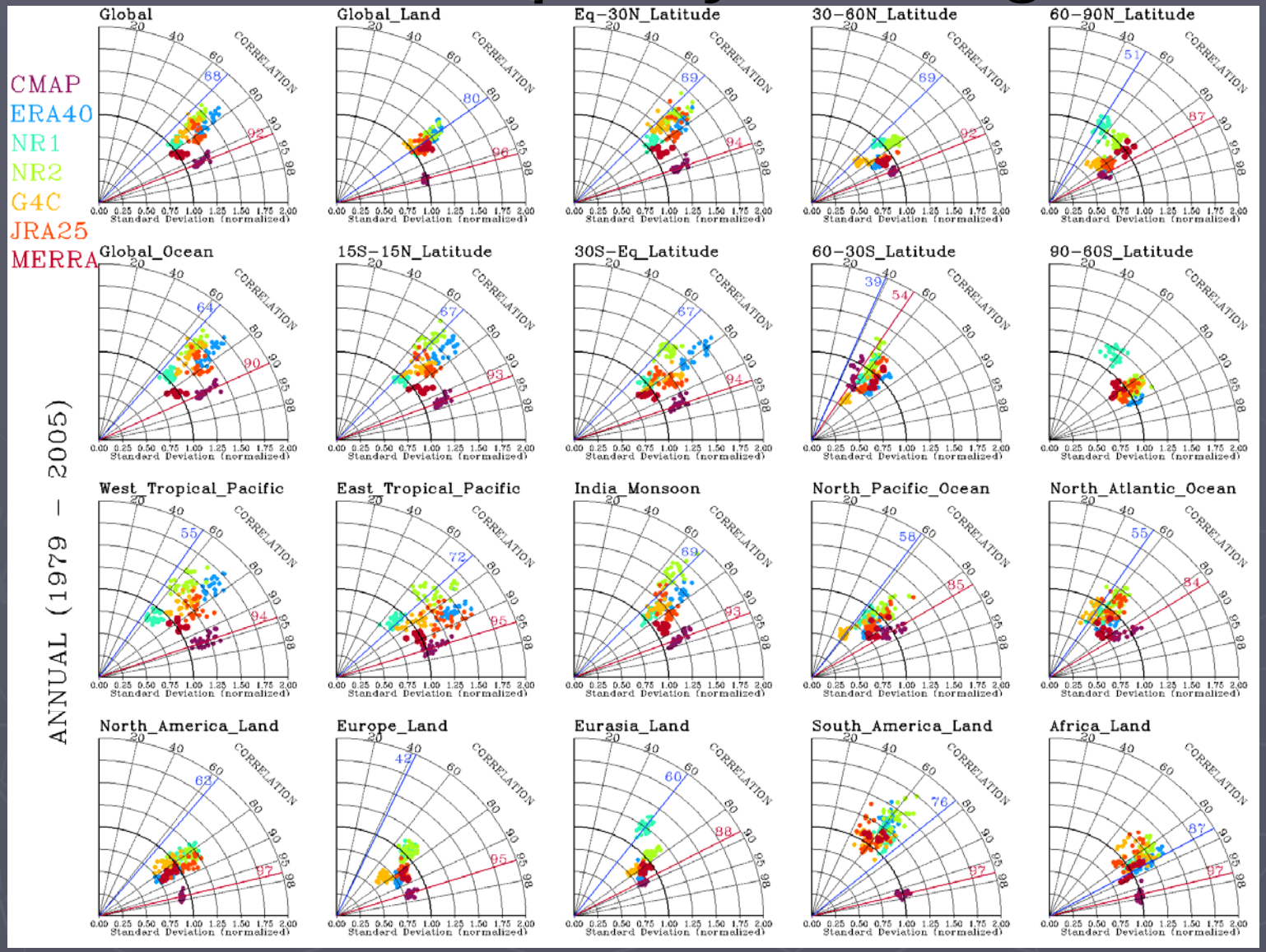
# Effect of Water Vapor Analysis





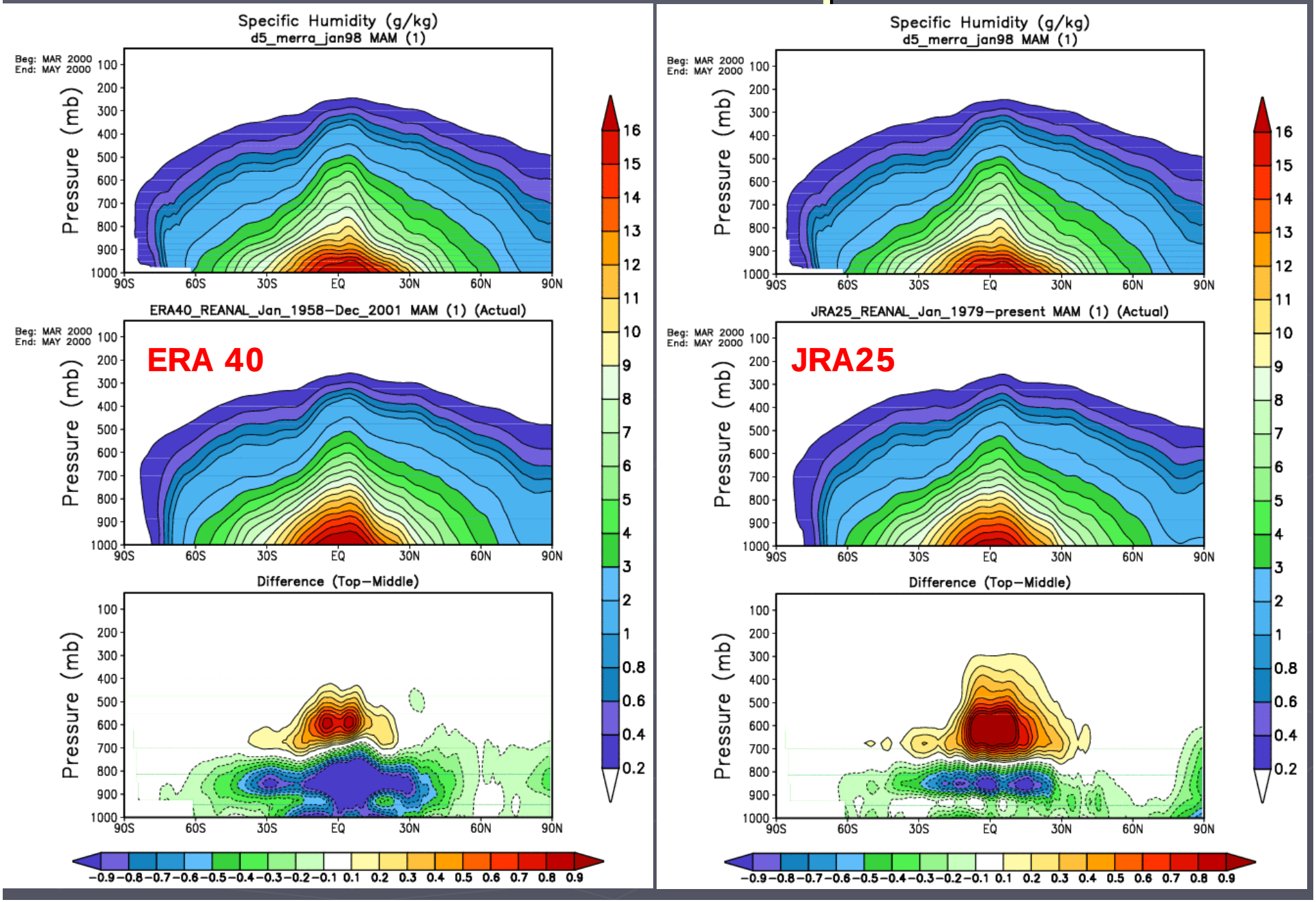

Taylor diagrams for tropical precipitation. GPCP merged precipitation is the reference data set. The diagrams compare spatial correlation (to GPCP) of the analysis to standard deviation normalized by the reference data set. If a field exactly duplicated GPCP, it would be at the 1,1 point. Linear distance to the 1,1 point is a measure of skill in reproducing the reference data set (annual 1979-2005).

# MERRA Precip Taylor Diagrams

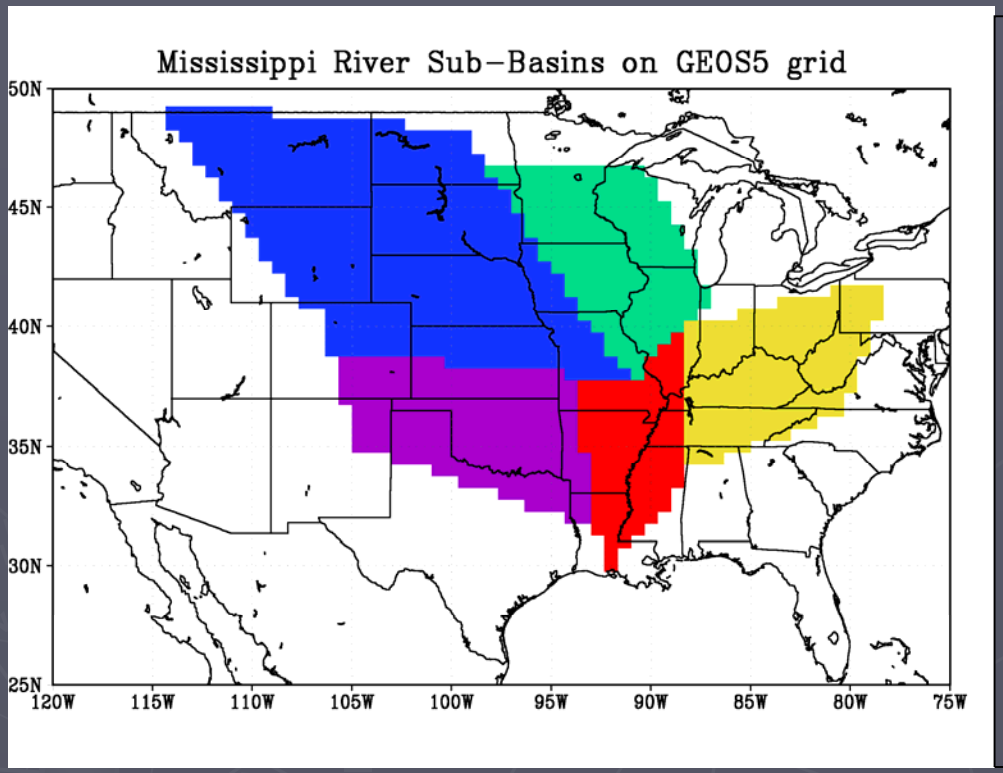



- See also: Bosilovich et al (2008, JAMC)

# General Circulation: Tropical Moisture

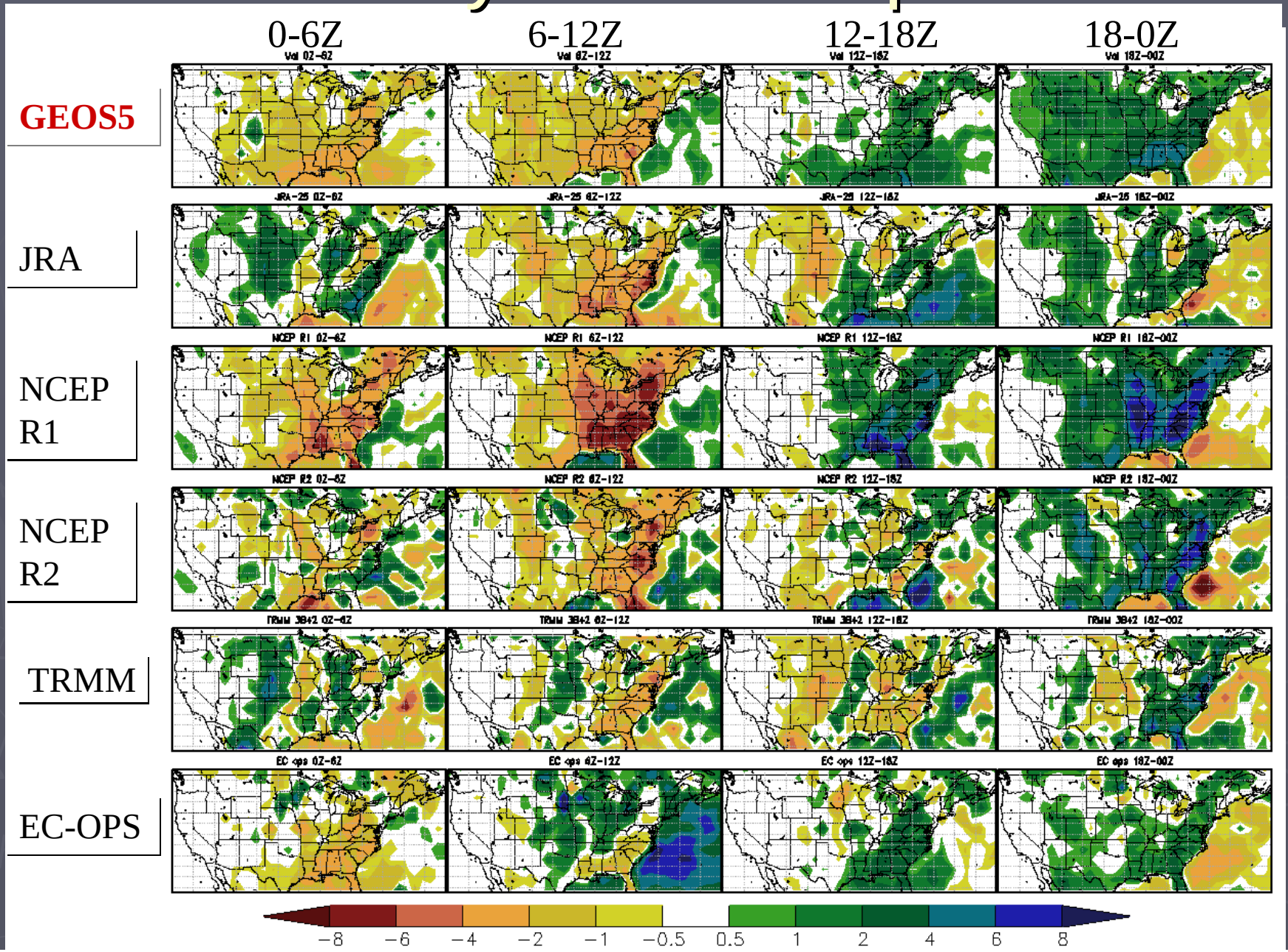


# Basin-scale Precipitation




- CPC US ¼ gridded gauge data
- Daily, Jan 1 – Sep 30 2004
- Consider all of the Mississippi River Basin domain
- Comparison with CEOP Multi-Models in Poster session

# Diurnal Cycle of Precipitation

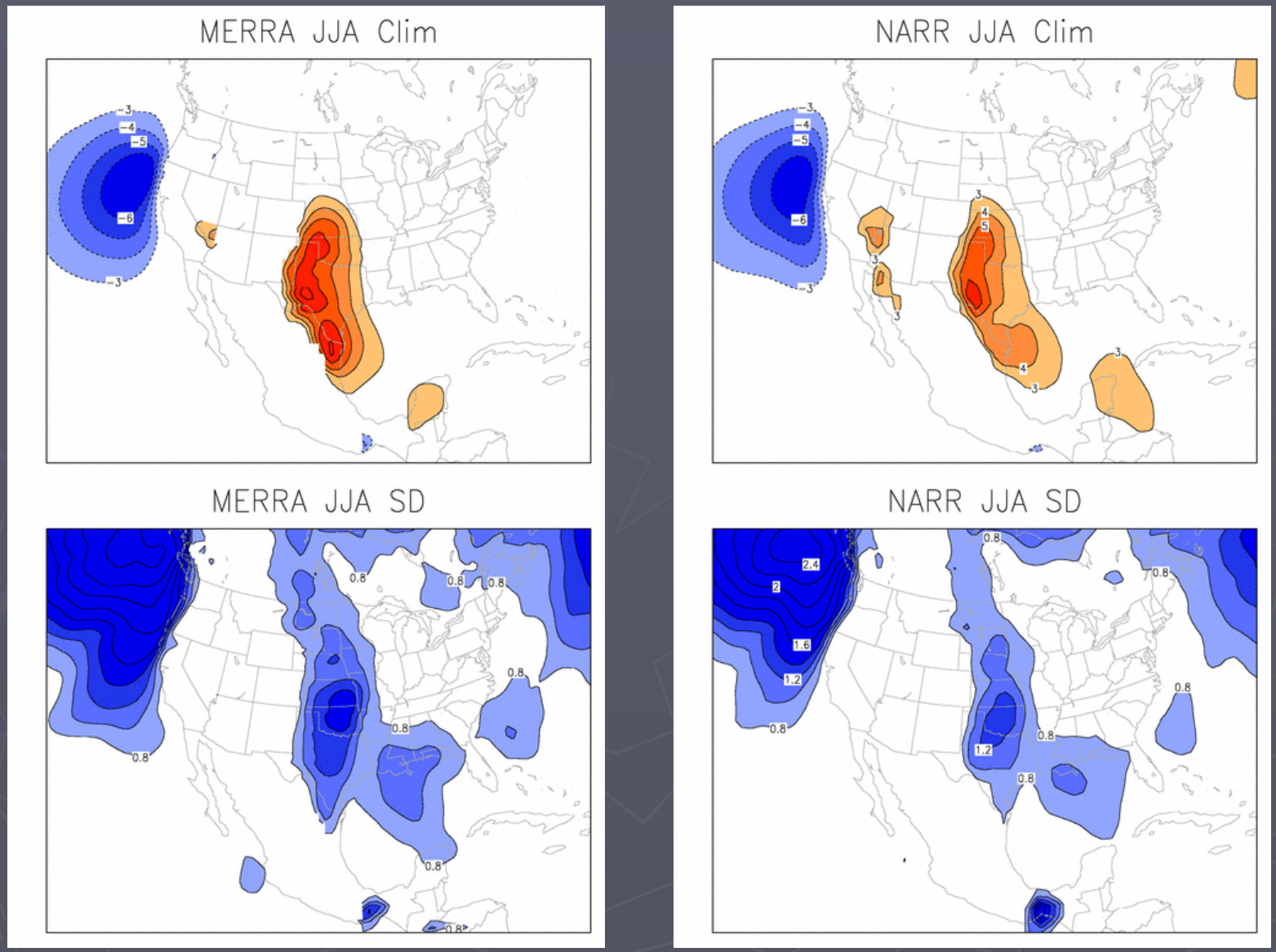


# JJA v-wind at 850mb (9-yrs)

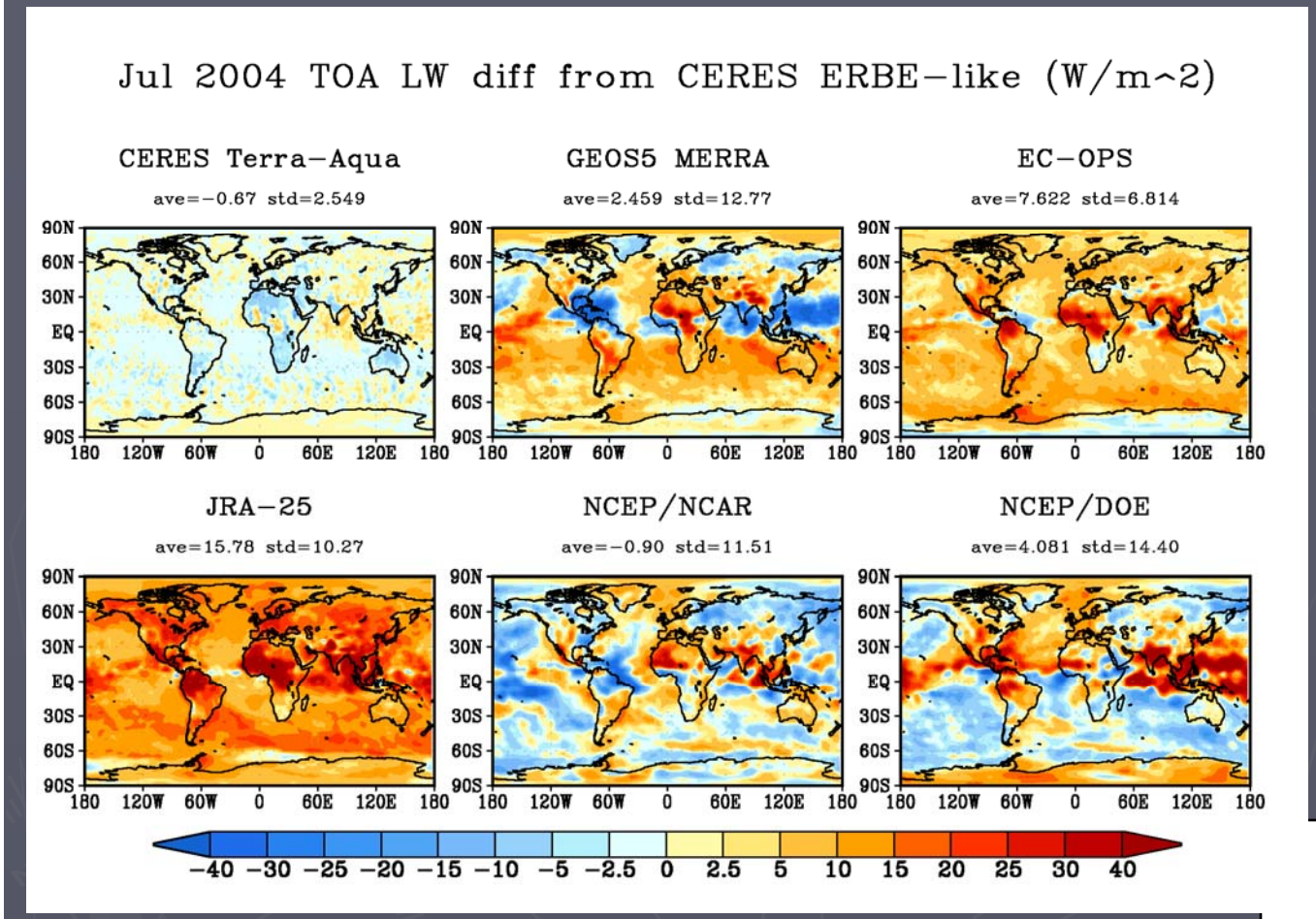
MERRA | NARR

Mean

Std



# TOA LW comparison of reanalyses

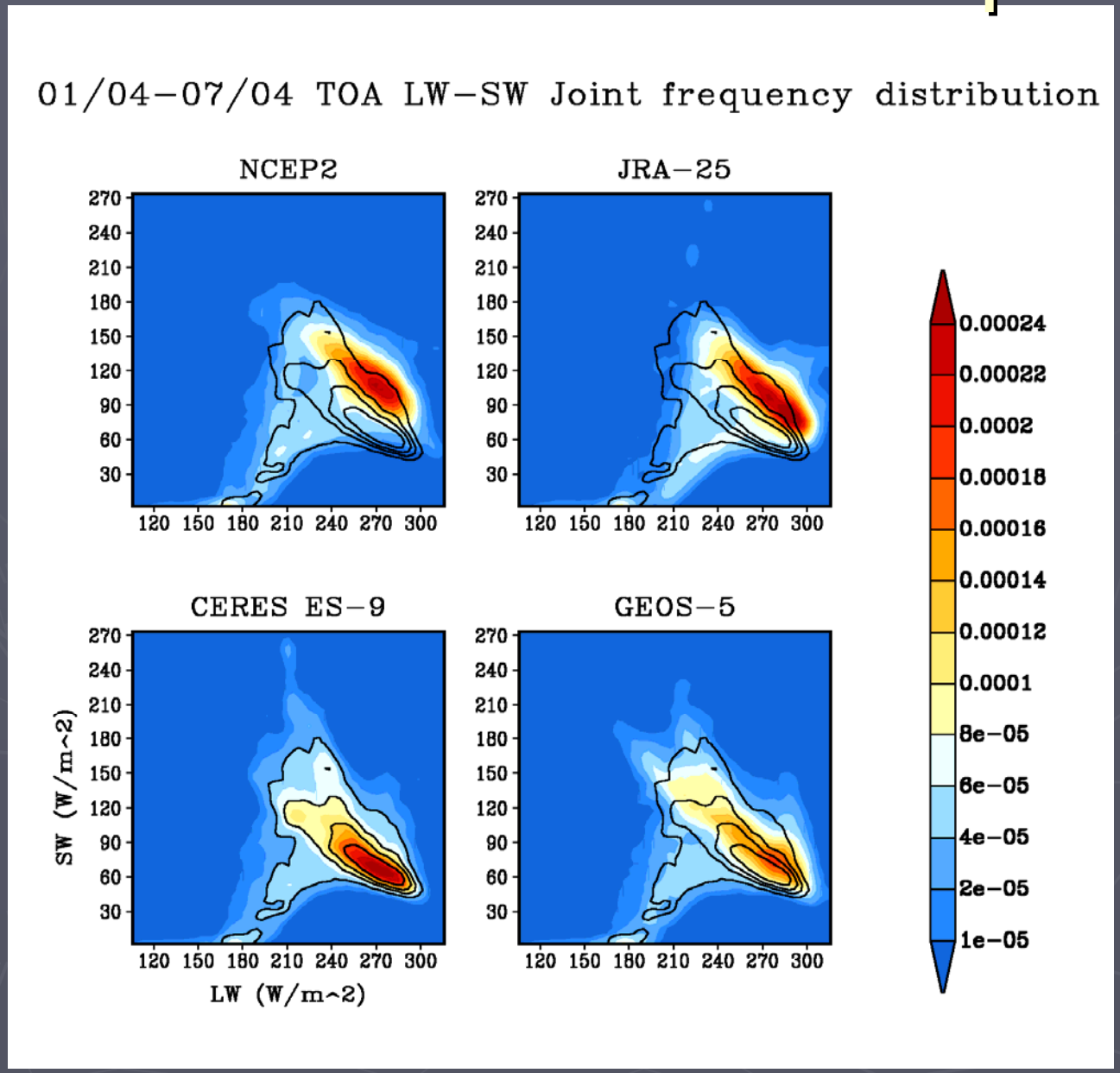



| TOA LW difference ($W/m^2$) | Jan, 2004 | | Jul, 2004 | |
|---|---|---|---|---|
| | Ave | STD | Ave | STD |
| CERES Terra - Aqua | -0.8 | 2.4 | -0.7 | 2.5 |
| MERRA - CERES | 5.4 | 9.1 | 2.5 | 12.8 |
| ECOPS - CERES | 8.9 | 7.3 | 7.6 | 6.8 |
| JRA25 - CERES | 16.2 | 9.0 | 15.8 | 10.3 |
| NCEP1 - CERES | -0.5 | 11.4 | -0.9 | 11.5 |
| NCEP2 - CERES | 4.6 | 14.4 | 4.1 | 14.4 |

- All reanalyses get similar patterns as observation.
- The difference between observations can be a reference for the uncertainty in reanalyses.
- For all reanalyses, strongest error happens over tropical convective regions.
- MERRA TOA LW flux bias mean and standard deviation are moderate among reanalyses.

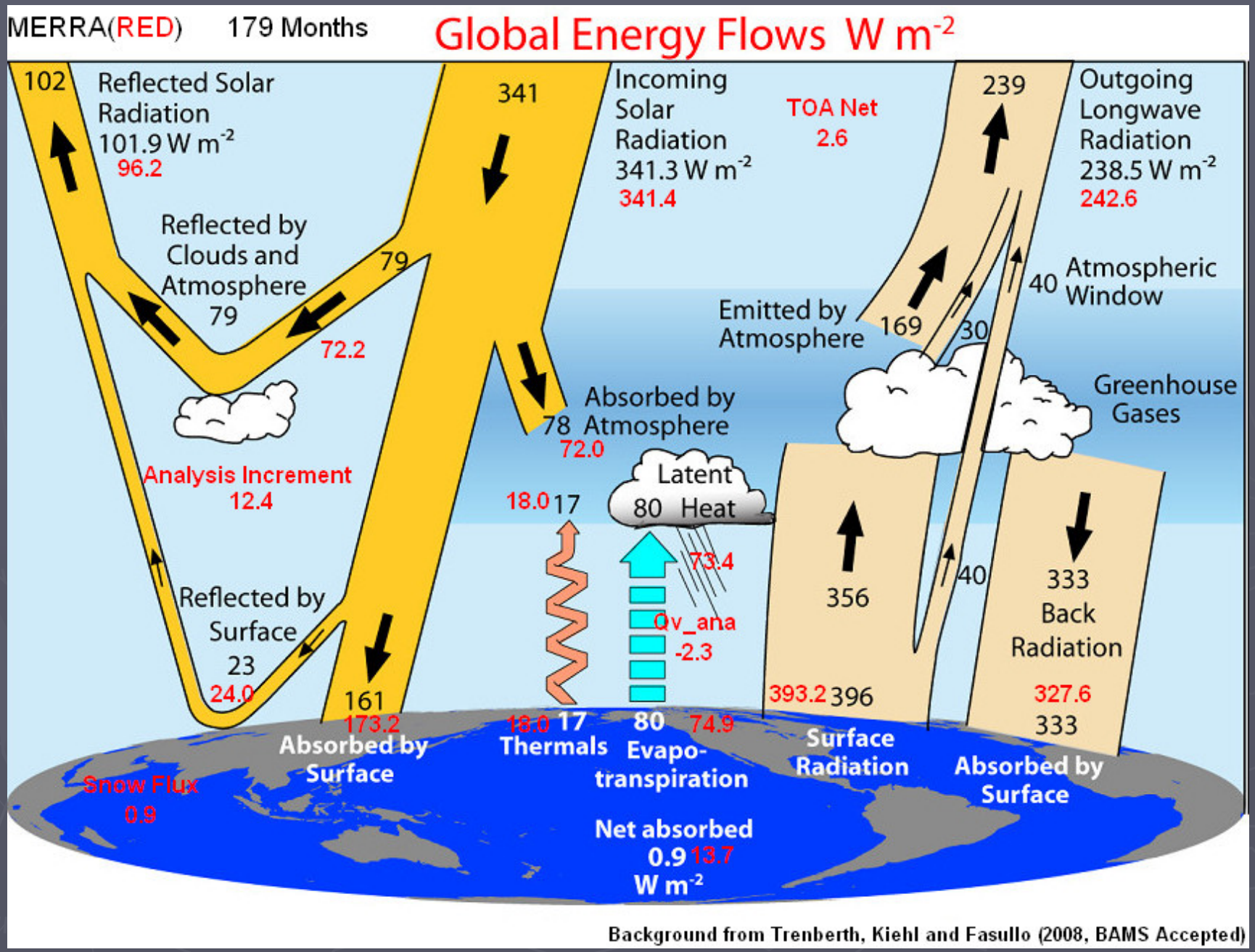
From Junye Chen

# TOA LW-SW Joint Freq. Distribution

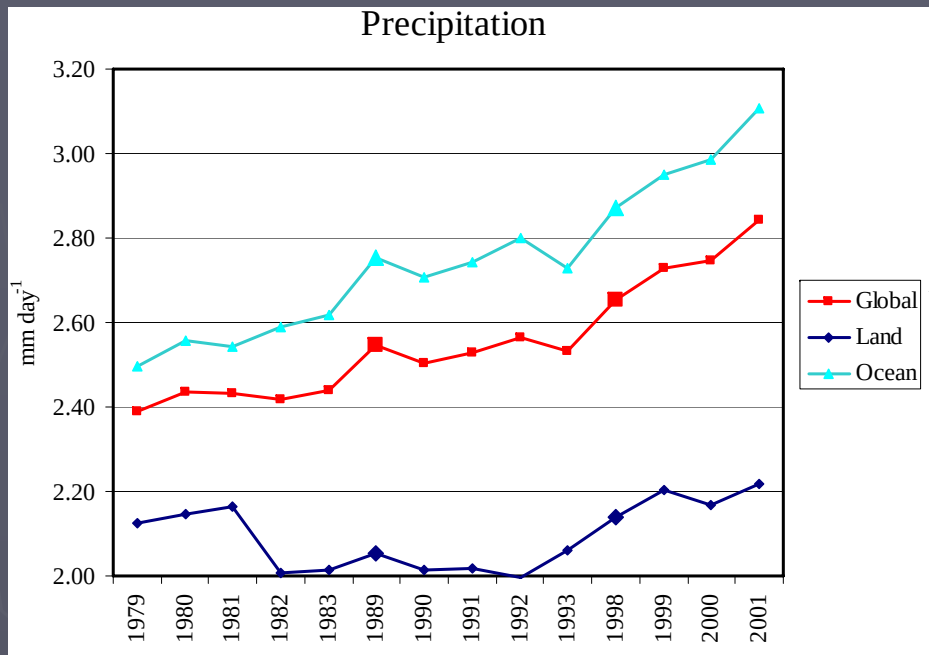


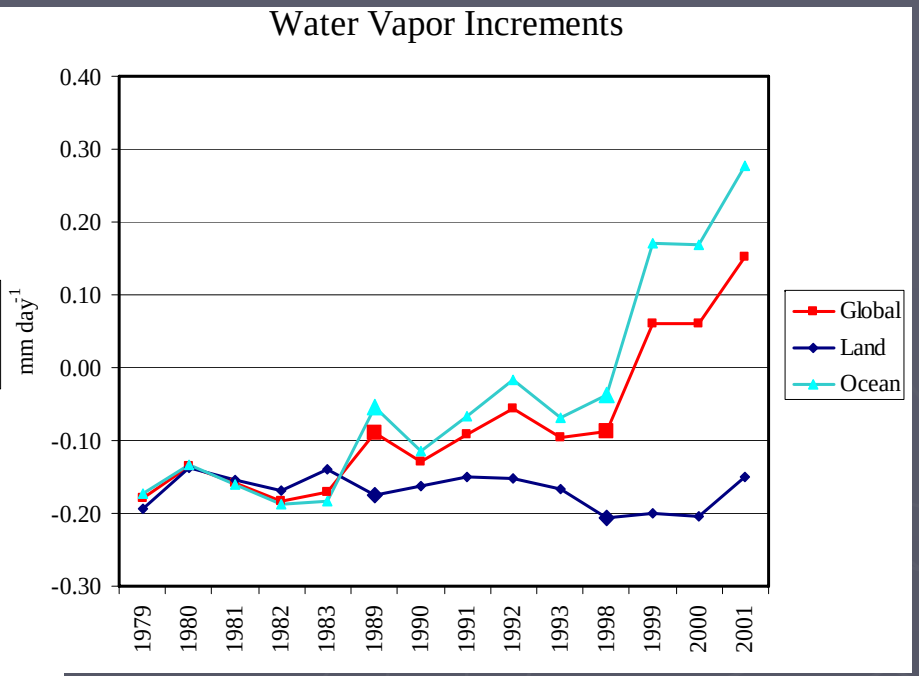

- LW-SW Joint Frequency Distribution (JFD) shows the relationship of LW and SW under different atmospheric states.
- The shape and location of MERRA LW-SW JFD is closer to CERES observation, while the MERRA pattern is a little stretched.

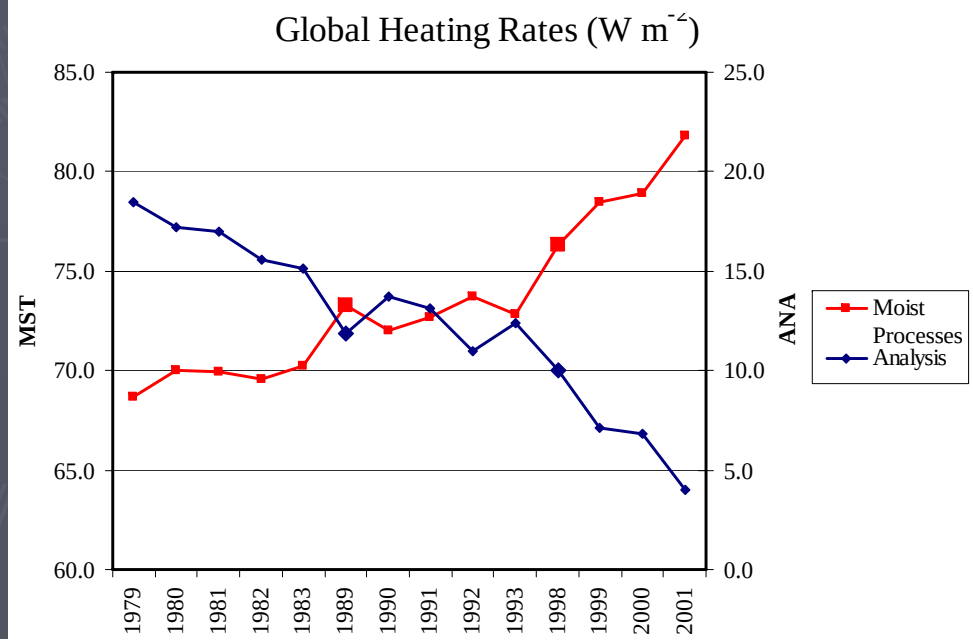
- From Junye Chen


MERRA(RED) 179 Months
Global Energy Flows W m-2
102
Reflected Solar Radiation 101.9 W m-2
96.2
341
Incoming Solar Radiation 341.3 W m-2
341.4
TOA Net
2.6
239
Outgoing Longwave Radiation 238.5 W m-2
242.6
Reflected by Clouds and Atmosphere
79
79
72.2
40
Atmospheric Window
Emitted by Atmosphere
169
30
Greenhouse Gases
Absorbed by Atmosphere
78
72.0
Analysis Increment
12.4
Latent Heat
80
18.0
17
73.4
Qv_ana
-2.3
356
40
333
Back Radiation
Reflected by Surface
23
24.0
161
173.2
393.2
396
327.6
333
18.0
17
Thermals
80
74.9
Evapo-transpiration
Absorbed by Surface
Surface Radiation
Absorbed by Surface
Snow Flux
0.9
Net absorbed
0.9
13.7
W m-2
Background from Trenberth, Kiehl and Fasullo (2008, BAMS Accepted)

# Trends in the Water and Energy Cycles

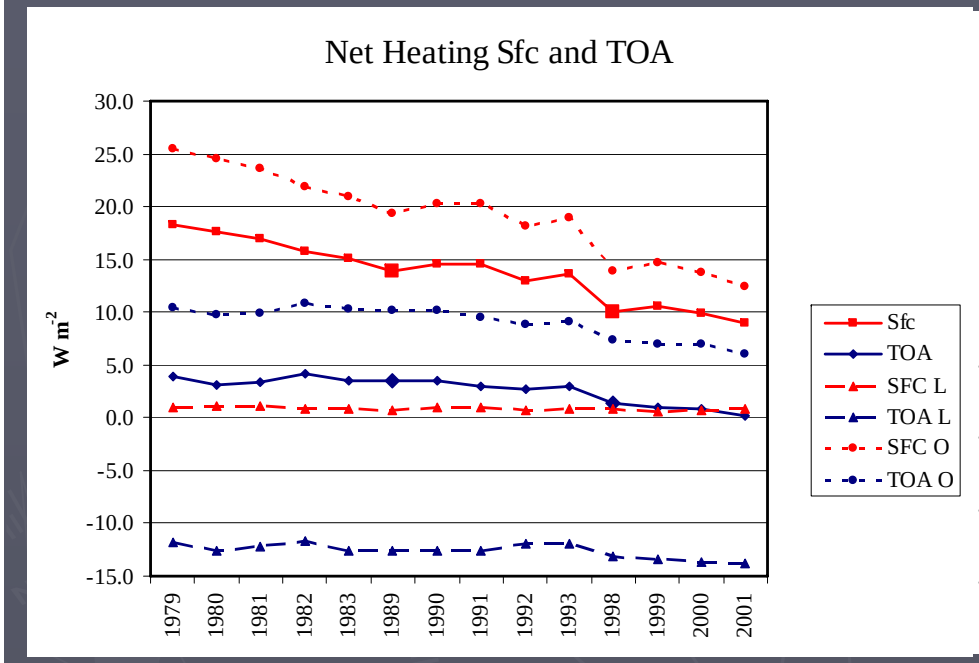


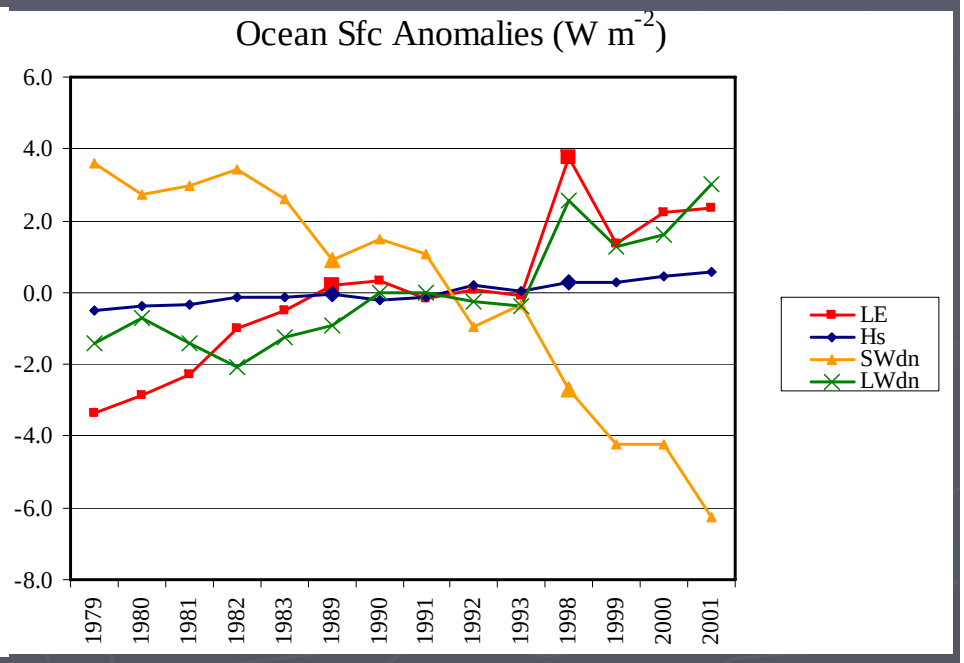




- Global P trend mostly over Ocean, and corresponds to Qv Increments
- Atm Latent heating variations anti-correlated to heating increments

# Net Surface and TOA Imbalance



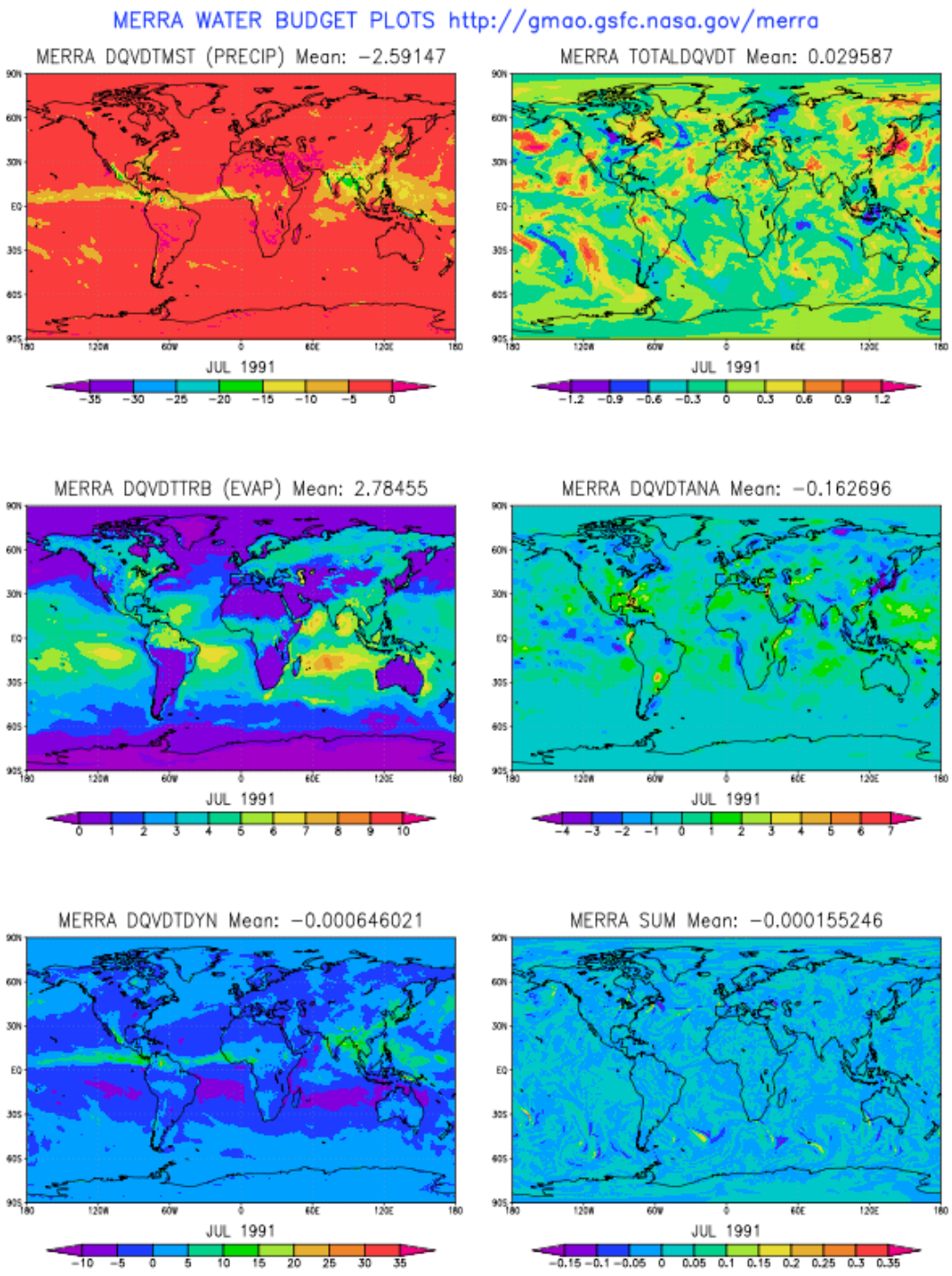




- Global surface net imbalance is improving in time, mostly changing over Ocean
- The Ocean net imbalance is decreasing in incoming SW radiation and increasing LE

# Vertically-Integrated Water Vapor Budget for July 1991

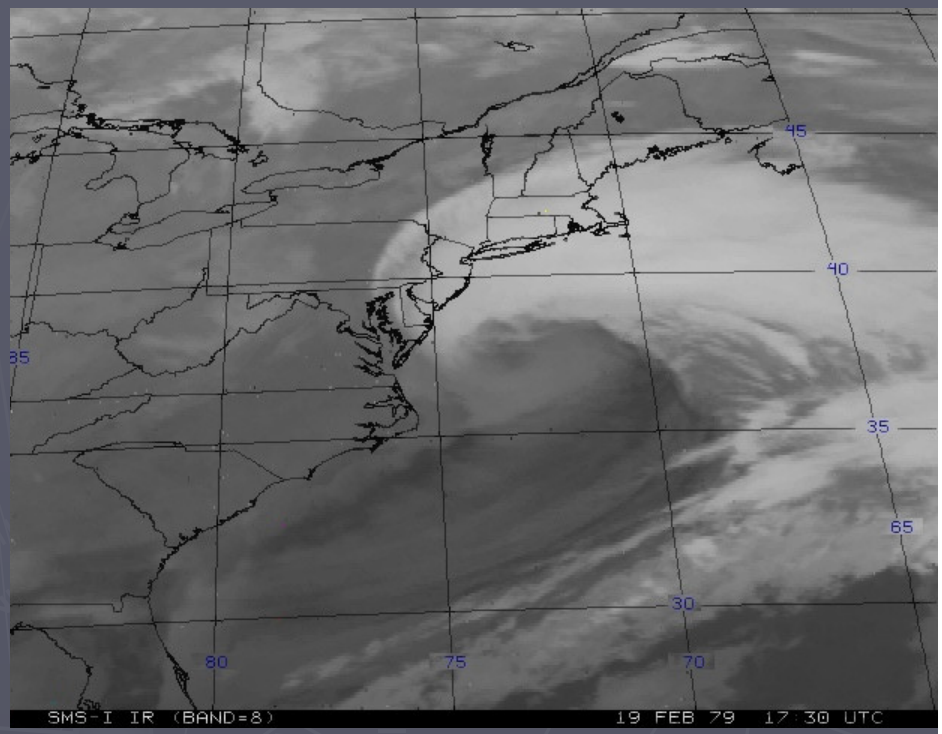
$$\frac{\partial qv}{\partial t} = E - P - \nabla \cdot qv + \frac{\partial qv}{\partial t}_{ANA}$$

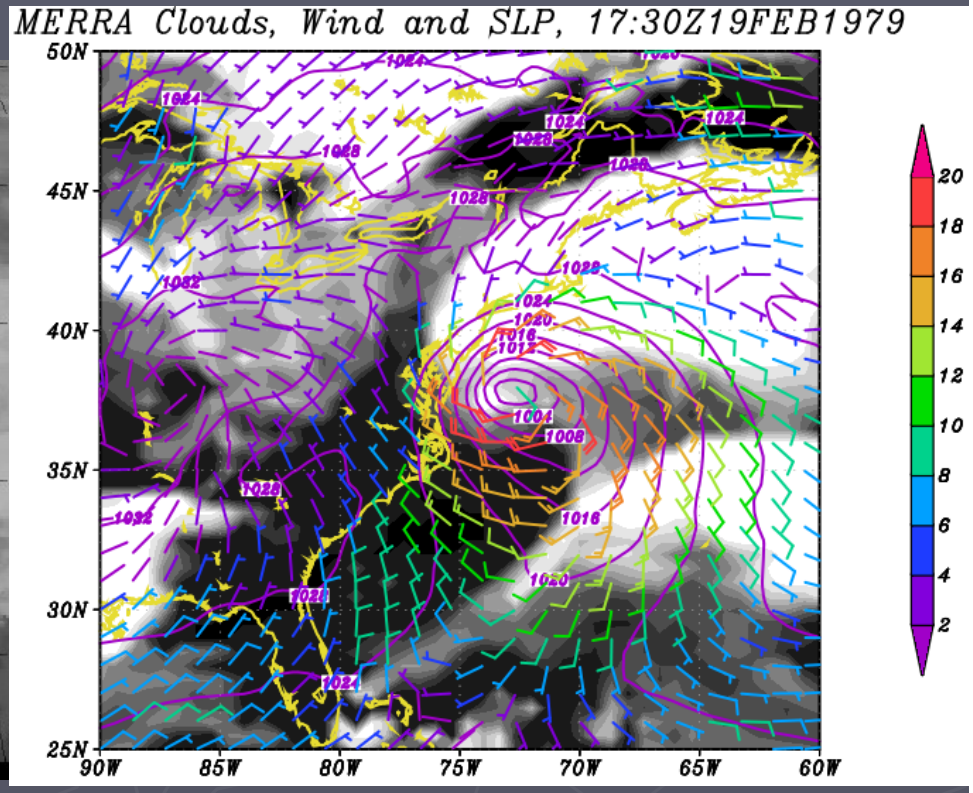
- Complete budgets are available including all tendencies and analysis increments
- Water (all phases), Ozone, KE, Enthalpy, Included
- Also, land-only budgets
- Tremendous effort by Max Suarez, Larry Takacs and Randy Koster



# Presidents Day Snow Feb 19, 1979

*GOES IR 17:30Z19FEB1979*

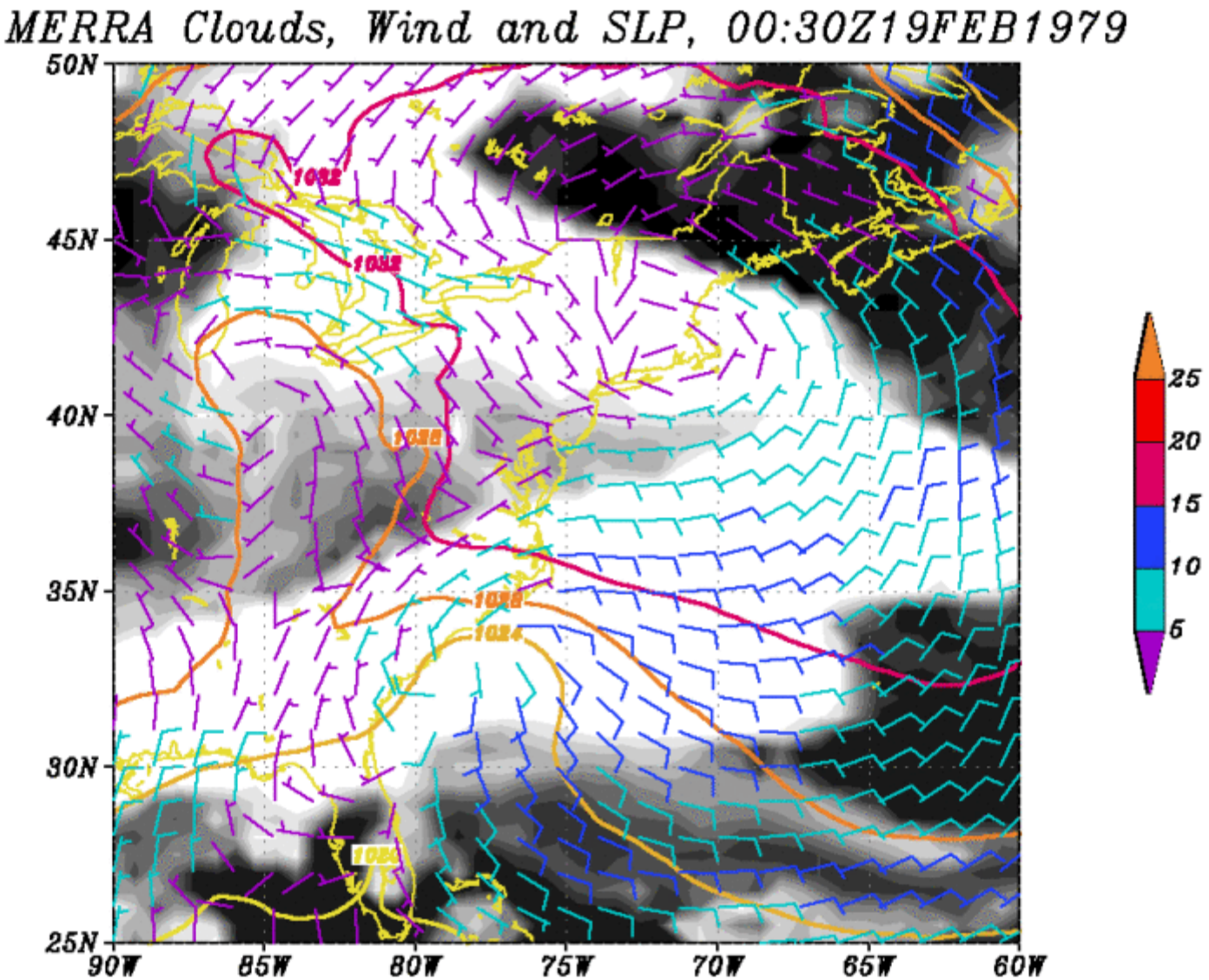



(Barbs every other grid space)

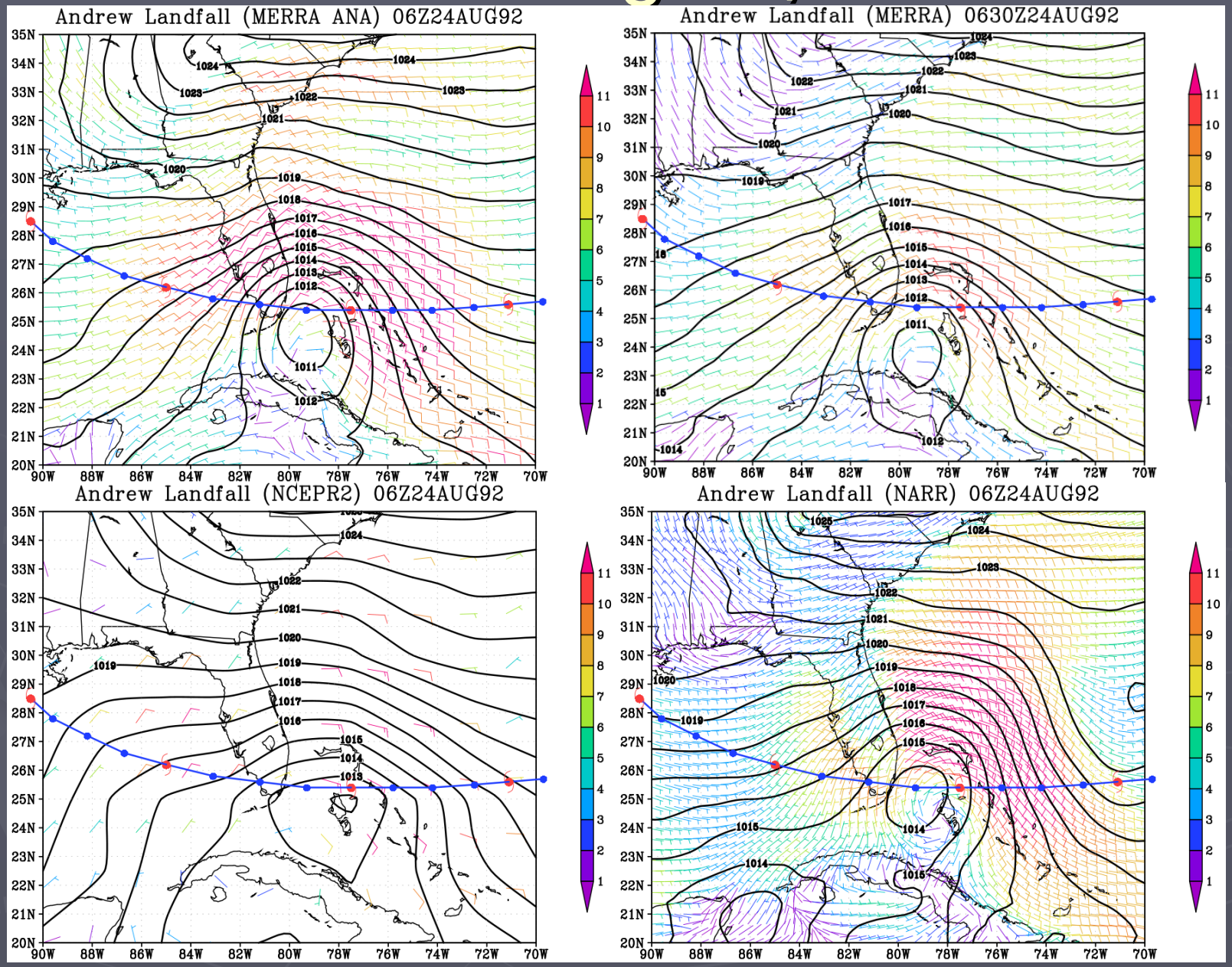
- Much fewer observations early in the record, still weather can be reasonable

# Presidents Day Snow Feb 19, 1979



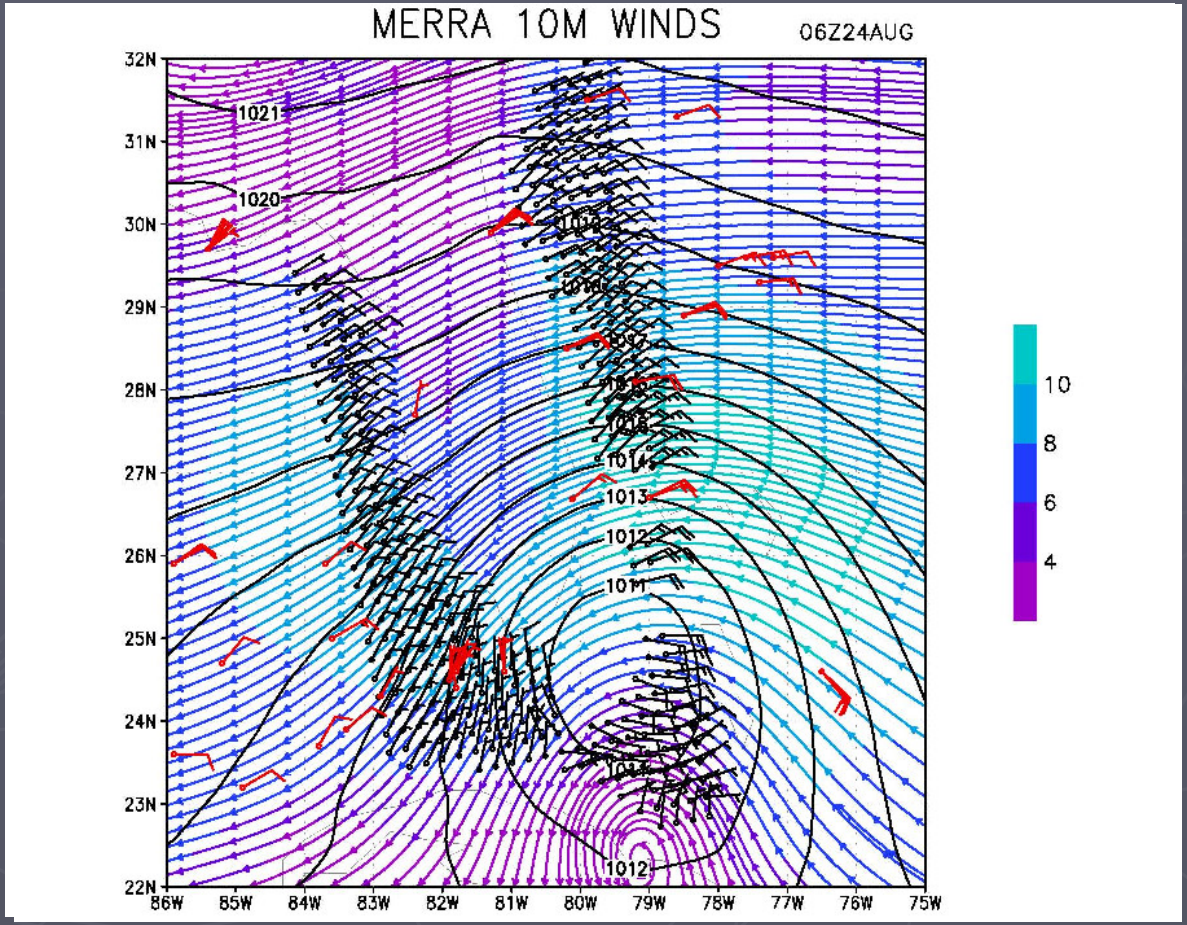

Routine for this animation at \Source\Feb1979

# Andrew Aug 24, 1992

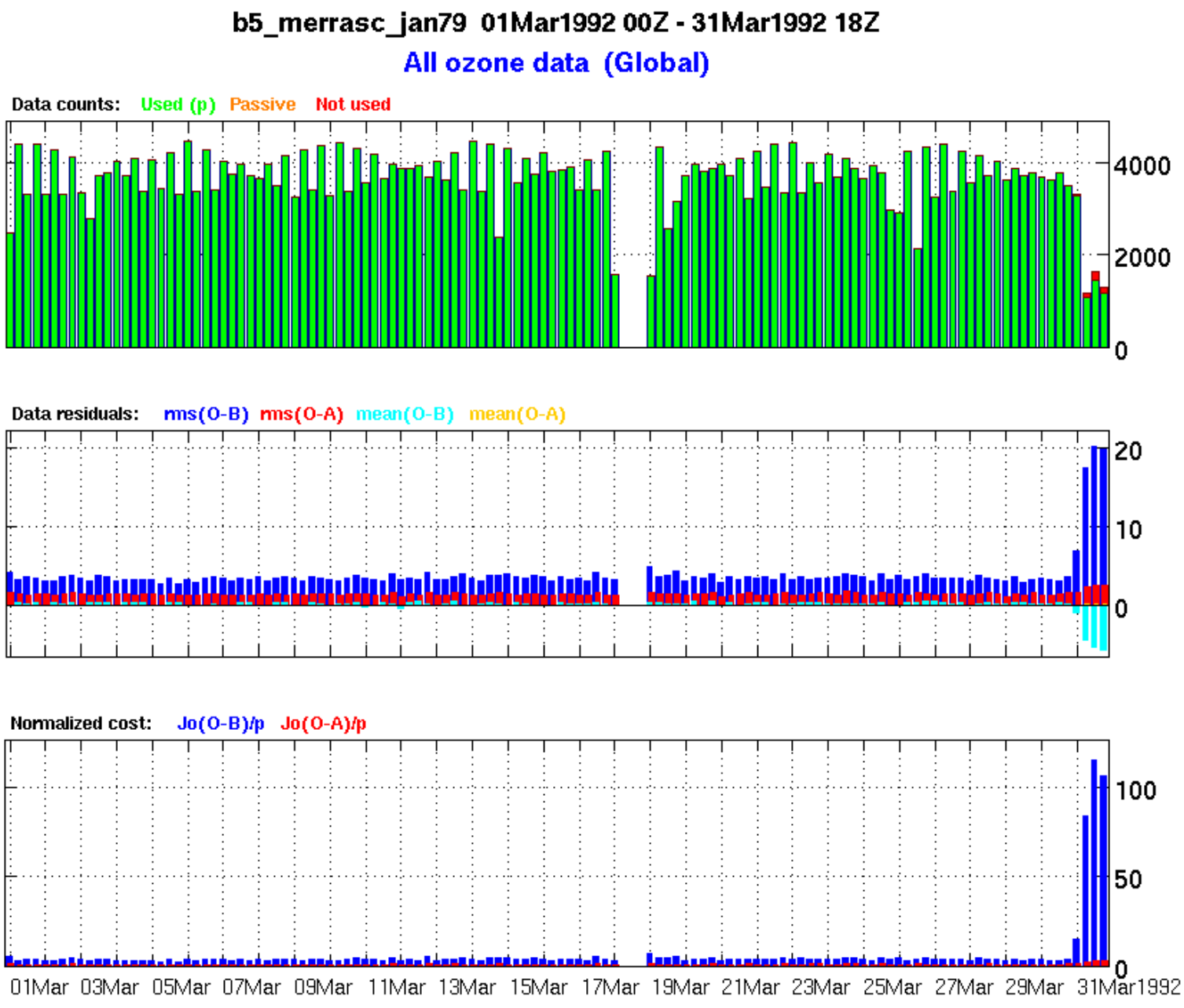



- All from GDS; Scripts on disc at /Source/Andrew

# Andrew Aug 24, 1992



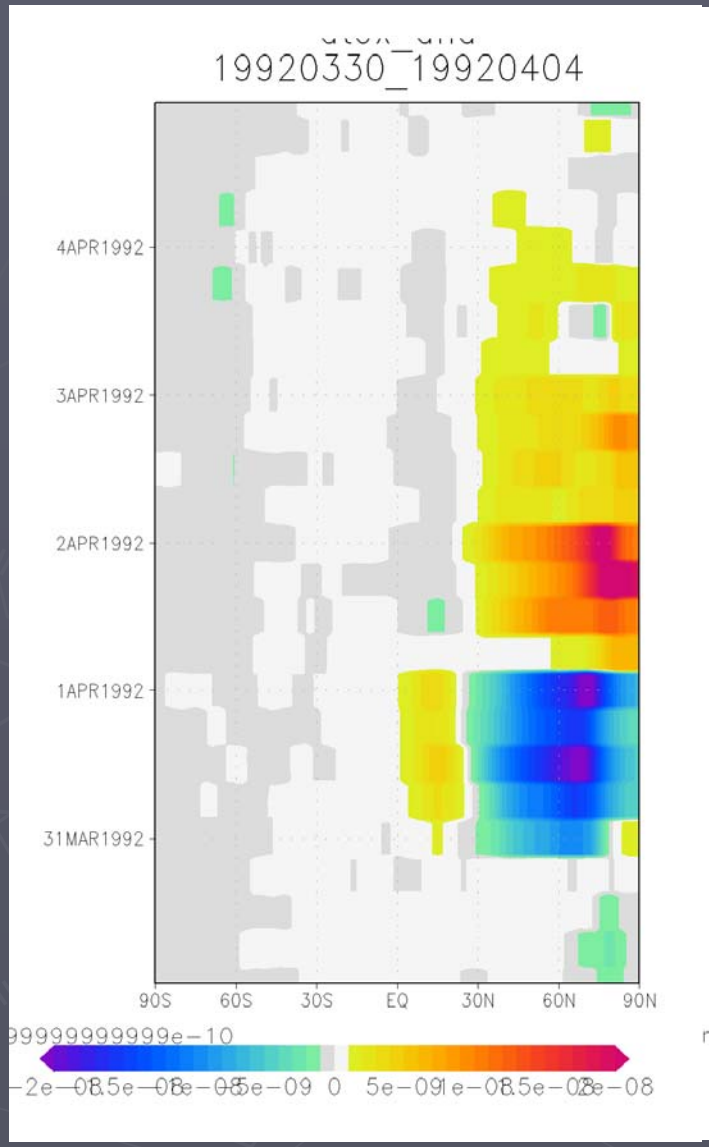

- Contaminated ERS1 data is used
- Resolution still too coarse for small TCs



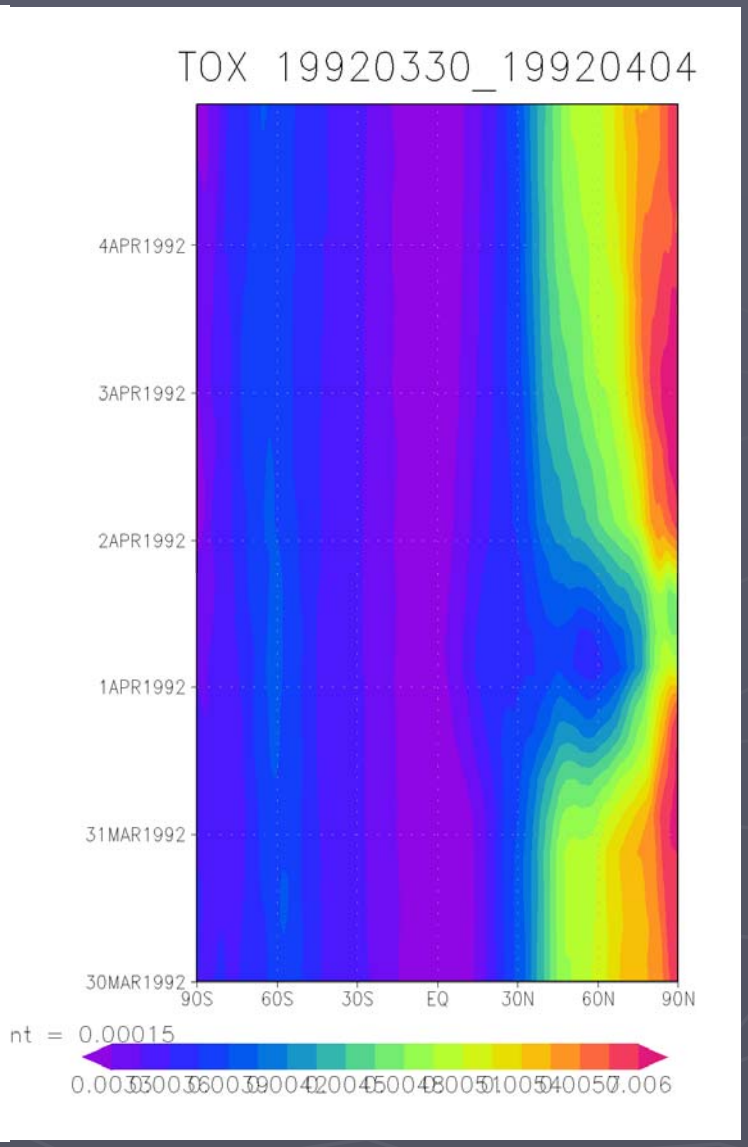

Scout SBUV Assimilation Statistics, Mar 1992

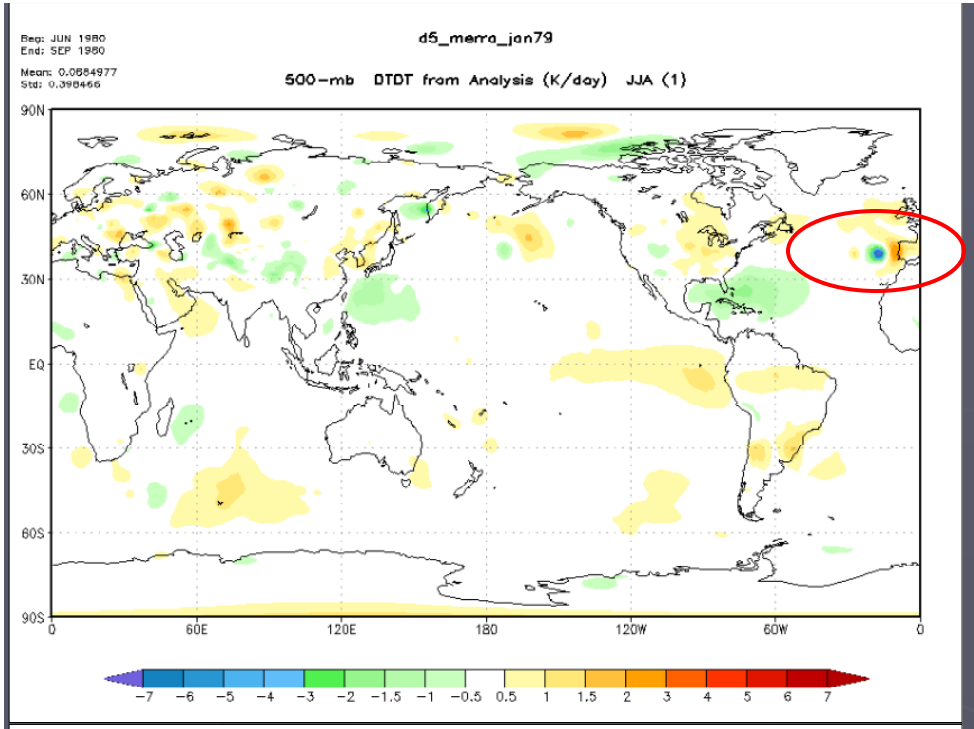
# Ozone response to questionable data

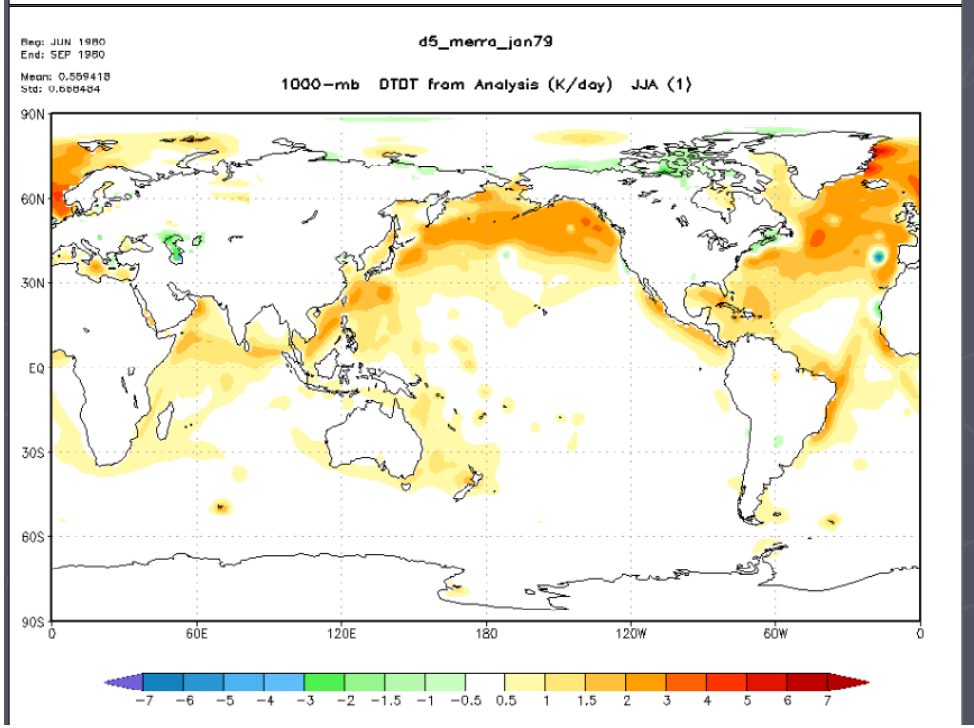
## Increments




## Ozone



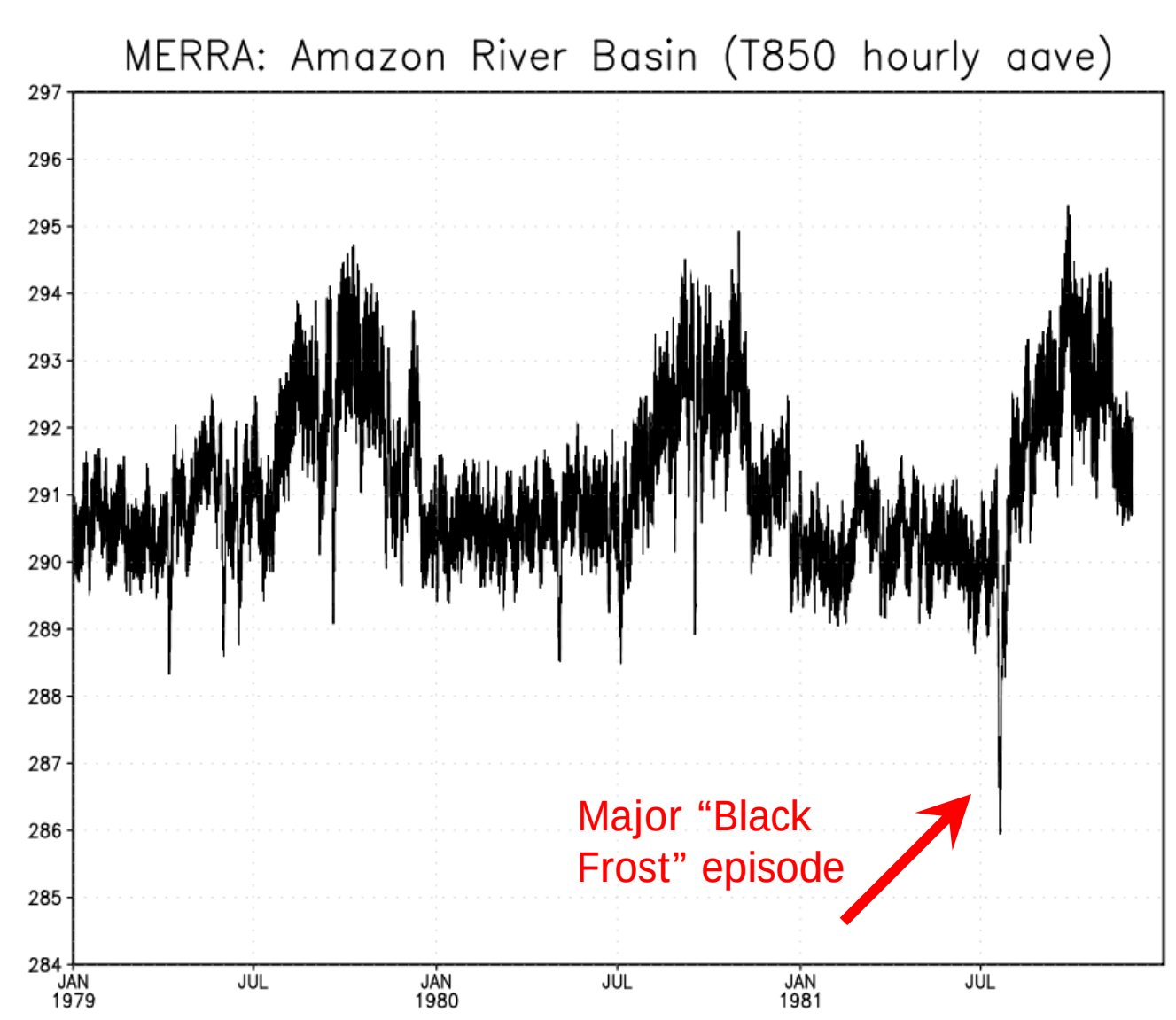


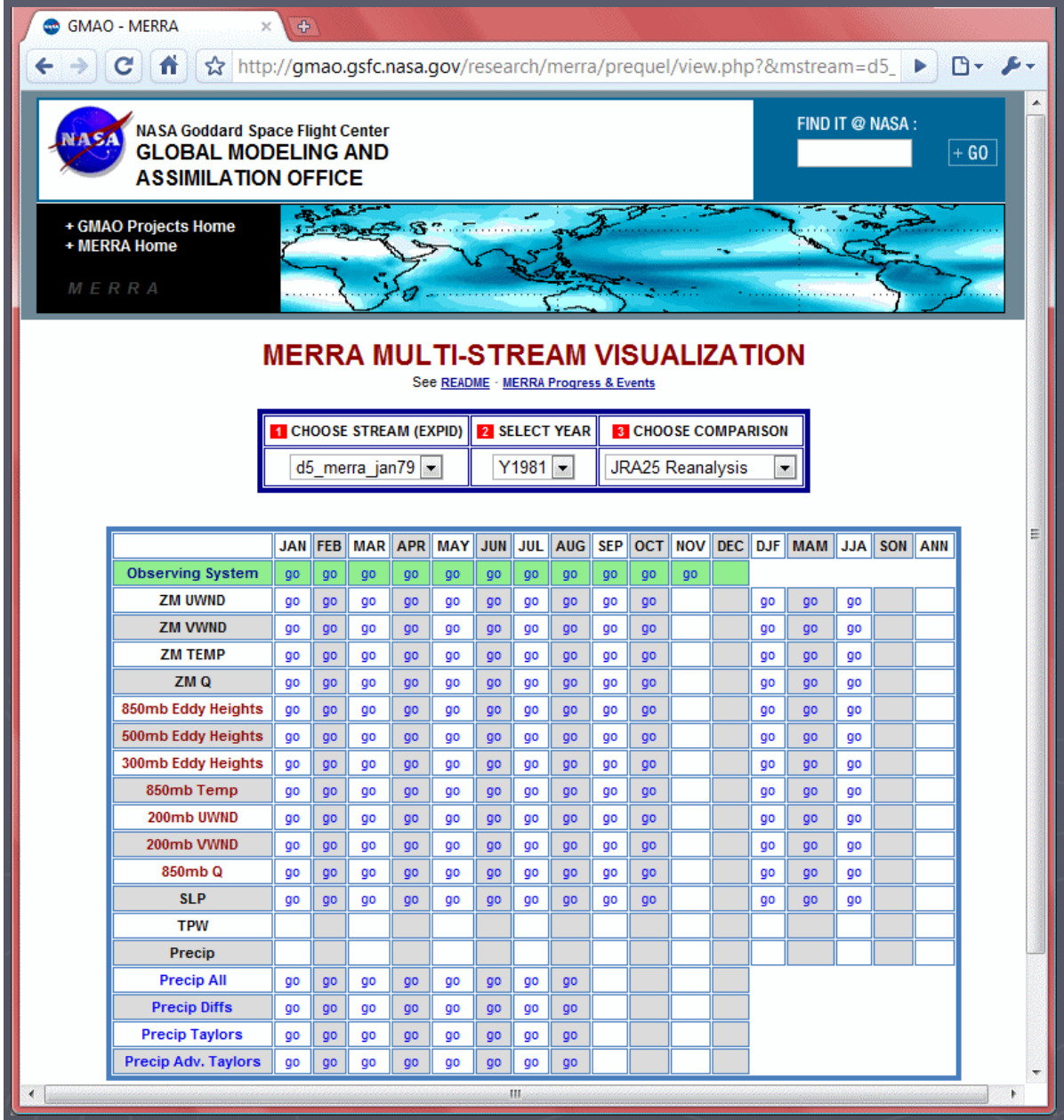

# Flawed sounding: Azores

- 1979-1980: A persistent sounding west of Portugal is very different from others nearby
- The result is a persistent counter-increment that affects energetics and moisture budgets

# MERRA Hourly Basin Average



# MERRA On-Line Atlas



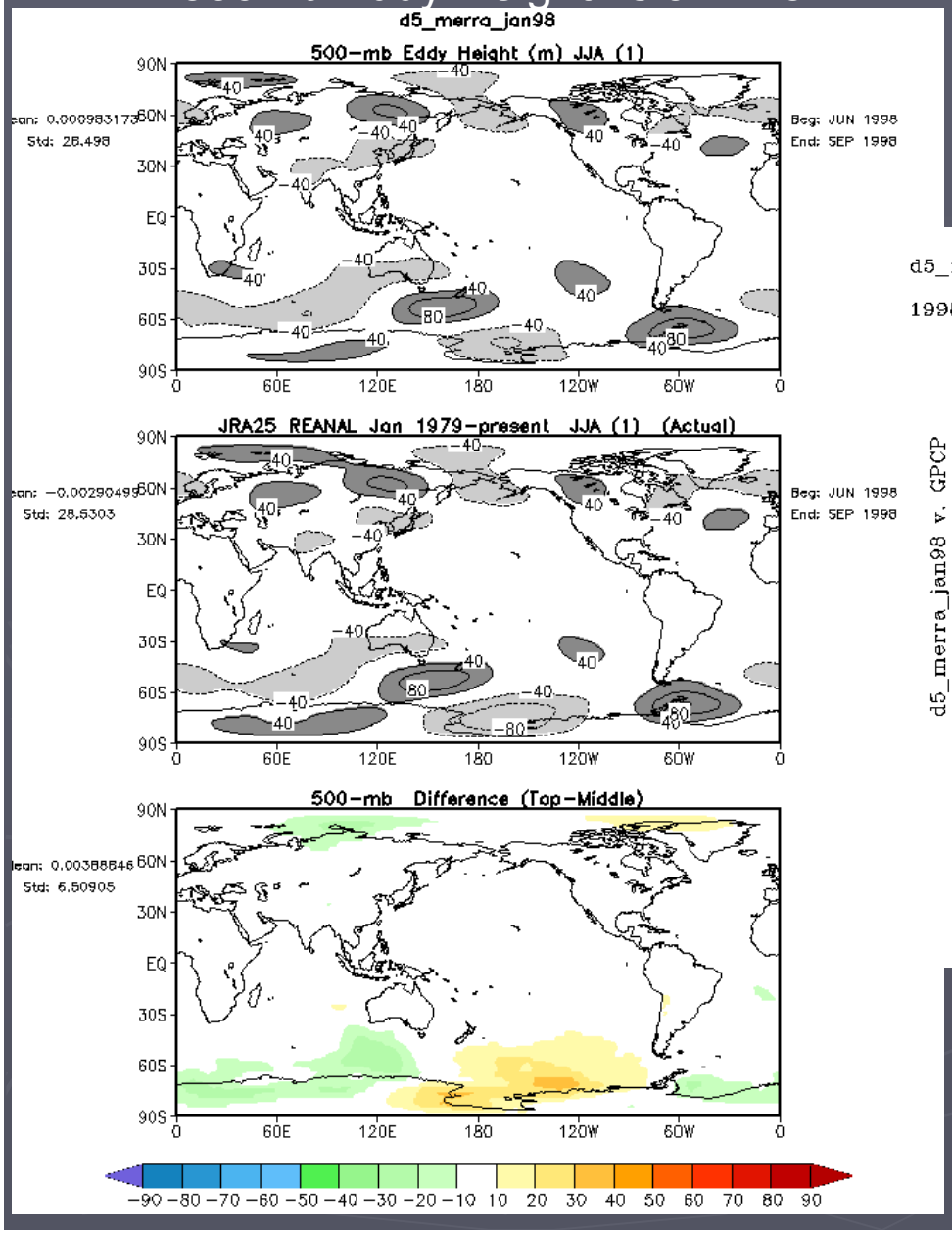

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | DJF | MAM | JJA | SON | ANN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observing System | go | go | go | go | go | go | go | go | go | go | go | | | | | | |
| ZM UWND | go | go | go | go | go | go | go | go | go | go | | | go | go | go | | |
| ZM VWND | go | go | go | go | go | go | go | go | go | go | | | go | go | go | | |
| ZM TEMP | go | go | go | go | go | go | go | go | go | go | | | go | go | go | | |
| ZM Q | go | go | go | go | go | go | go | go | go | go | | | go | go | go | | |
| 850mb Eddy Heights | go | go | go | go | go | go | go | go | go | go | | | go | go | go | | |
| 500mb Eddy Heights | go | go | go | go | go | go | go | go | go | go | | | go | go | go | | |
| 300mb Eddy Heights | go | go | go | go | go | go | go | go | go | go | | | go | go | go | | |
| 850mb Temp | go | go | go | go | go | go | go | go | go | go | | | go | go | go | | |
| 200mb UWND | go | go | go | go | go | go | go | go | go | go | | | go | go | go | | |
| 200mb VWND | go | go | go | go | go | go | go | go | go | go | | | go | go | go | | |
| 850mb Q | go | go | go | go | go | go | go | go | go | go | | | go | go | go | | |
| SLP | go | go | go | go | go | go | go | go | go | go | | | go | go | go | | |
| TPW | | | | | | | | | | | | | | | | | |
| Precip | | | | | | | | | | | | | | | | | |
| Precip All | go | go | go | go | go | go | go | go | | | | | | | | | |
| Precip Diffs | go | go | go | go | go | go | go | go | | | | | | | | | |
| Precip Taylors | go | go | go | go | go | go | go | go | | | | | | | | | |
| Precip Adv. Taylors | go | go | go | go | go | go | go | go | | | | | | | | | |

- Updated regularly with monthly comparisons versus existing reanalyses and some global observed data sets
- More comparisons being added and will be redone at the completion of MERRA
- Comments Welcome

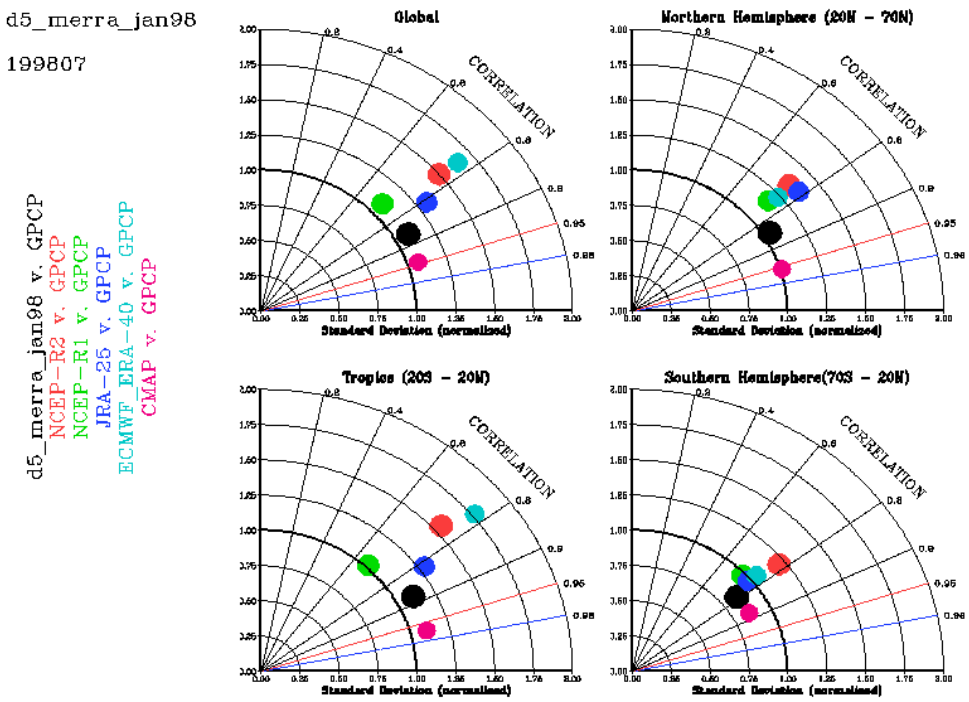
http://gmao.gsfc.nasa.gov/research/merra/prequel/view.php

# Example figures from the Atlas

500mb Eddy Height vs JRA25




Precipitation Taylor Diagram, All Reanalyses using GPCP as the reference



# MERRA Documentation

- GEOS5 Model and Assimilation Document, Rienecker et al.
- MERRA File Specification, Suarez et al. (Outlines the output data format, and information on variables)
- MERRA Validation, Bosilovich et al. (Results of the GEOS5 Validation Experiments, prior to beginning MERRA production)