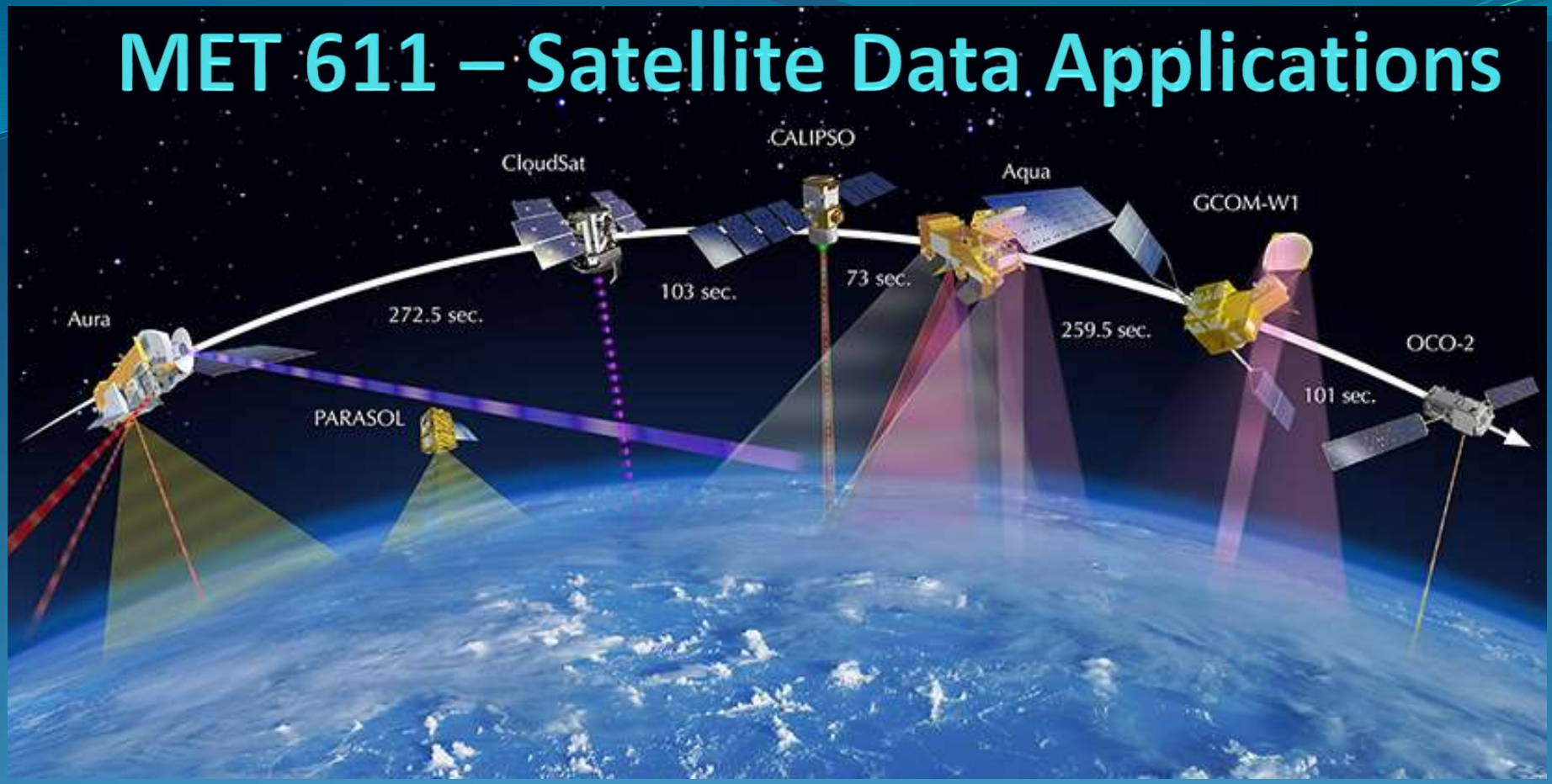
MET 611 – Satellite Data Applications

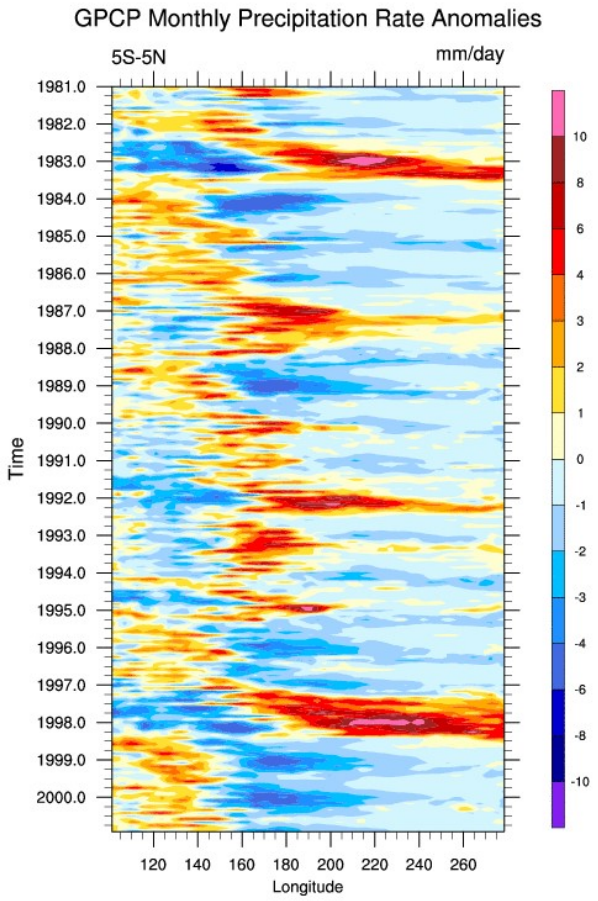


GPCP Introduction

Jennifer D. S. Griswold

Global Precipitation Climatology Project

- Organized in 1986
- http://www.gewex.org/gpcp.html
- http://precip.gsfc.nasa.gov/
- http://www.esrl.noaa.gov/psd/data/gridded/data.gpcp.html
- Component of the Global Energy and Water Cycle Experiment (**GEWEX**) of WCRP
- Objectives:
  - ➔ Improve understanding of **seasonal to inter-annual and longer term variability** of the global hydrological cycle
  - ➔ Determine the **atmospheric heating** needed for climate prediction models
  - ➔ Provide an **observational data set for model validation** and initialization and other hydrological applications



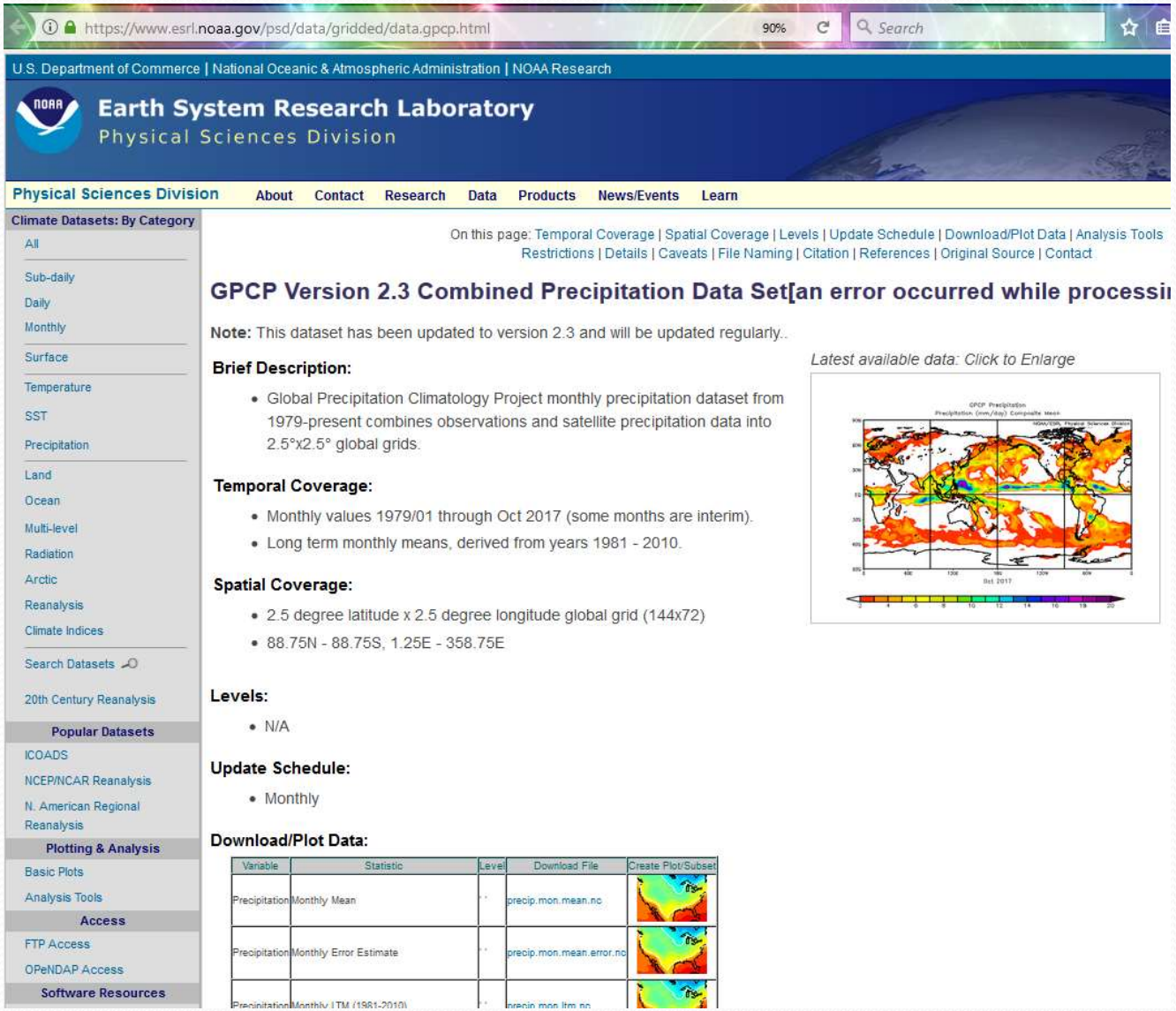
GPCP Strengths

- **Key Strengths:**
  - Provides **global coverage**
  - Is one of the **most-used** precipitation data sets for climate variability studies.
  - Provides **estimates of uncertainty** due to random errors (but not systematic errors).
  - **Regularly** updated.
  - Useful for **validation of global precipitation in climate models**, provided that care is taken to put the data on comparable grids using conservative re-gridding.

GPCP Limitations

- **Key Limitations:**
  - **Complex algorithms** are required to translate indirect and infrequent satellite measurements into high-resolution gridded precipitation estimates at regular time intervals.
  - **Debate about whether the global-mean precipitation amount is under-estimated**, due possibly to missing light rain over ocean (especially the Southern Ocean) and missing orographic precipitation over land.
  - Different satellites are used at different latitudes, leading to some **spatial heterogeneity**.

GPCP NOAA Data Website



- Notice Data is in **NetCDF** Format!
- **2.5 x 2.5 degree**
  - 144 x 72 grid
- Not -90 to 90 and -180 to 180!!
  - **You'll need new latitude and longitude files**
- **Data are Pacific Centered**
  - Need to change orientation to compare to MODIS

GPCP GEWEX Website

https://www.gewex.org/data-sets-global-precipitation-climatology-pro

ABOUT PANELS ACTIVITIES EVENTS

GEWEX

DATA SETS: GLOBAL PRECIPITATION CLIMATOLOGY PROJECT (GPCP)

The Global Precipitation Climatology Project (GPCP) was established by the World Climate Research Programme to quantify the distribution of precipitation around the globe over many years. In support of this work an international group of precipitation experts developed and produces the GPCP Version 2 monthly Satellite-Gauge (SG), Pentad, and One-Degree Daily (1DD) combined precipitation data sets. Check NCAR/UCAR's Climate Data Guide for more information on and access to these products. A backup FTP site for the Version 2 and 1DD products is located at NASA Goddard Space Flight Center (GSFC).

The 2.5-degree Version 2 monthly suite comprises a total of 27 products with the two primary products being the monthly satellite-gauge and associated precipitation error estimates. The Version 2 product covers the period January 1979 to the present, with a delay of two to three months for data reception and processing. Version 2 supersedes all previous versions of the GPCP monthly product, including Versions 1, 1b, 1c, and V2x79. The Pentad product provides precipitation estimates on a 2.5-degree grid over the entire globe at 5-day (pentad) intervals for the period January 1979 – present. The 1DD product provides precipitation estimates on a 1-degree grid over the entire globe at 1-day (daily) for the period October 1996 – present. Both the Pentad and 1DD products are consistent with the Version 2 monthly product in the sense that the Pentad and 1DD approximately sum to the monthly SG estimate. All three precipitation products are produced by optimally merging estimates computed from microwave, infrared, and sounder data observed by the international constellation of precipitation-related satellites, and precipitation gauge analyses.

DATA SETS: GLOBAL PRECIPITATION CLIMATOLOGY PROJECT (GPCP)

UPCOMING EVENTS

6-11 MAY 2018
2018 GEWEX CONFERENCE: WATER ON THE EDGE

26 FEB-6 MARCH 2018
2ND PAN-GASS MEETING

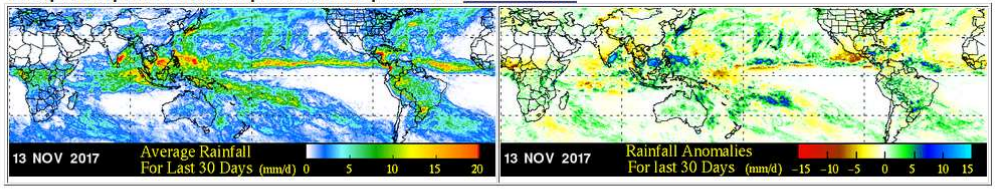
GPCP GSFC Website (V2.2)

https://precip.gsfc.nasa.gov

Global Precipitation Analysis

Mesoscale Atmospheric Processes Laboratory
NASA Goddard Space Flight Center

- **Microwave satellite overpass time history**
- **Global Real-Time 3-Hourly Precipitation Analysis of TRMM DATA**
- **Interactive Analysis and Display with TOVAS**
- **ENSO Precipitation Analyses (Research and Monitoring)**
- **Precipitation patterns in the tropics and subtropics for the last 12 months**



The precipitation research group in the Mesoscale Atmospheric Processes (Code 612) has constructed a number of data sets containing estimates of precipitation which are available at this site. Some estimates are sufficiently well developed that other researchers can find the data and associated products useful. Potential users are urged to pay careful attention to the differences among the data sets and to check back for updates to the data sets. Questions should be directed to the data set originators. All local binary data sets are held in Silicon Graphics (big endian) format.

NOTICE: GPCP V2.2 has been superseded by GPCP V2.3 which is now available at http://gpcp.umd.edu. GPCP V2.2 is still available on this page but it is recommended that users transition to GPCP V2.3. As the corresponding new 1DD V1.3 is still in beta test, 1DD V1.2 is still provided on this page. Users should note that 1DD V1.2 is not consistent with GPCP V2.3. Links to the GPCP Pentad data are preserved on this page. For questions regarding access to the GPCP V2.3 or the beta 1DD V1.3 please contact Bob Adler (radler@umd.edu) or JJ Wang (jjwang@umd.edu).

Global Precipitation Climatology Project (GPCP)

Monthly Data	Pentad Data	Daily Data	Climatology
Summary		Summary	Summary
Data	Data	Data	Data

UMD Website (V2.3)

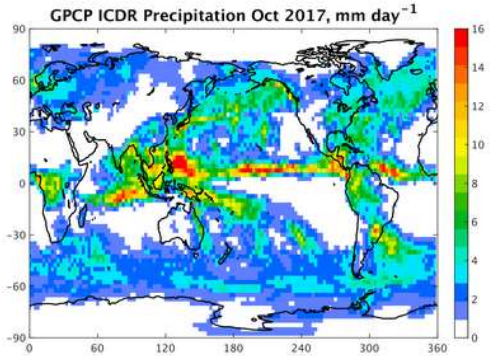
gpcp.umd.edu 90% Search

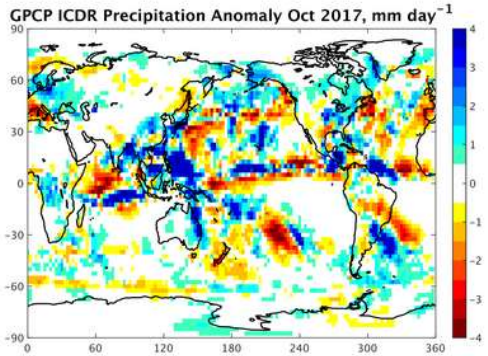
Global Precipitation Climatology Project (GPCP)

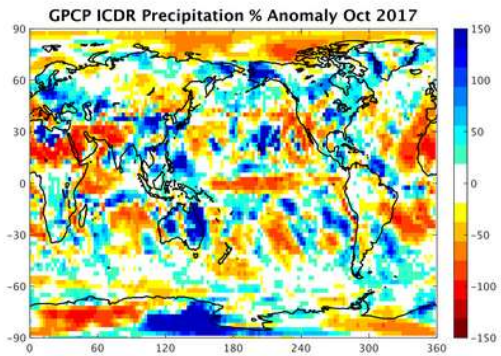
University of Maryland College Park
Earth System Science Interdisciplinary Center (ESSIC) and Cooperative Institute for Climate and Satellites (CICS)

GPCP Monthly Analysis (GPCP-Interim)--Latest Month

Interim GPCP estimates are provisional estimates of GPCP available ~10 days after the end of the month. They can be used for the most recent months for which GPCP is unavailable.







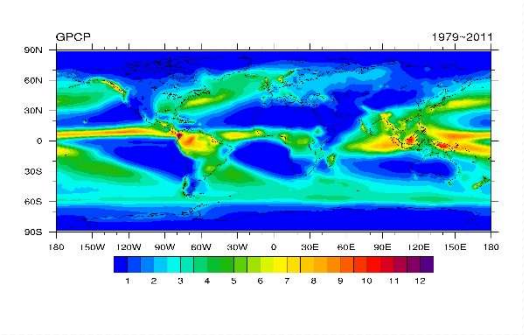
GPCP Background
Description

GPCP V2.3 Monthly
Description & Download

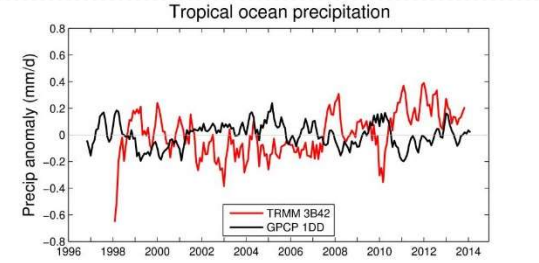
GPCP-Interim V2.3 Monthly
Description & Download

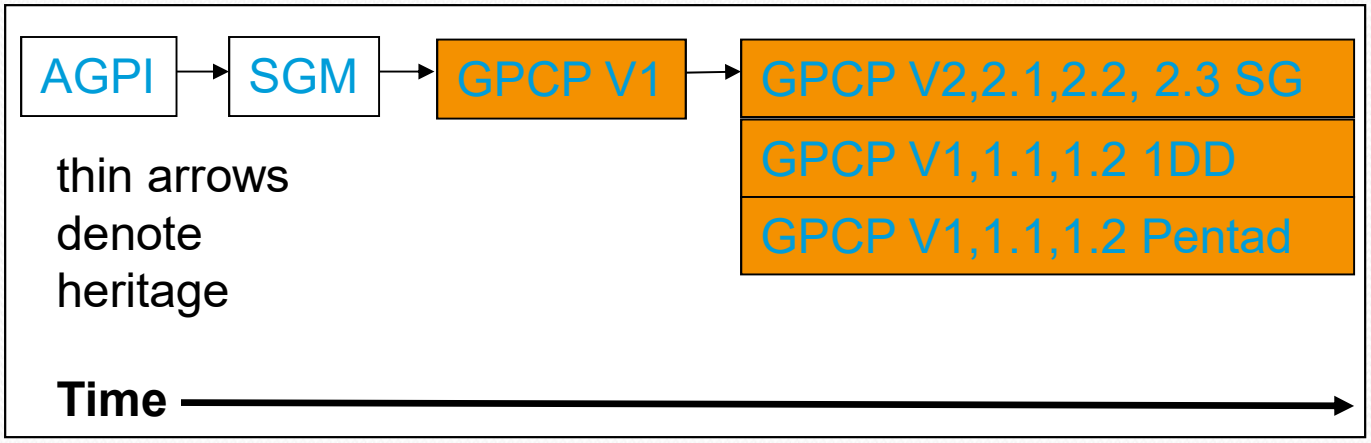
GPCP Heritage

- **GPCP Project**
  - Use then-new satellite passive microwave instruments to estimate "global" precipitation
  - Develop at 2.5deg climatology
  - Characterize El Niño Precipitation
  - Prior development work in Adler precip group quickly led to an operational data set



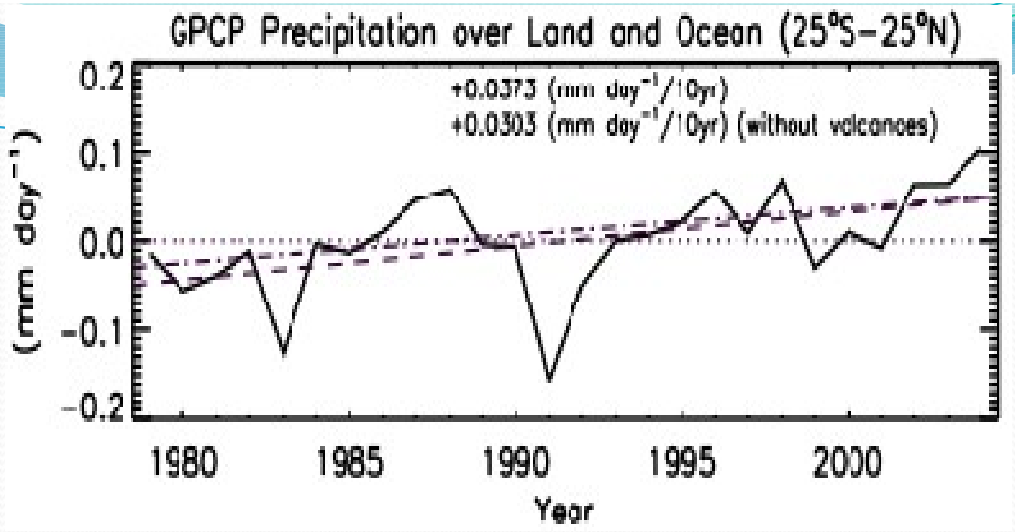
- **Subsequent development work made the product fully global on three different time scales**
  - Different algorithms, but, 1DD, Pentad forced to sum to the monthly mean.



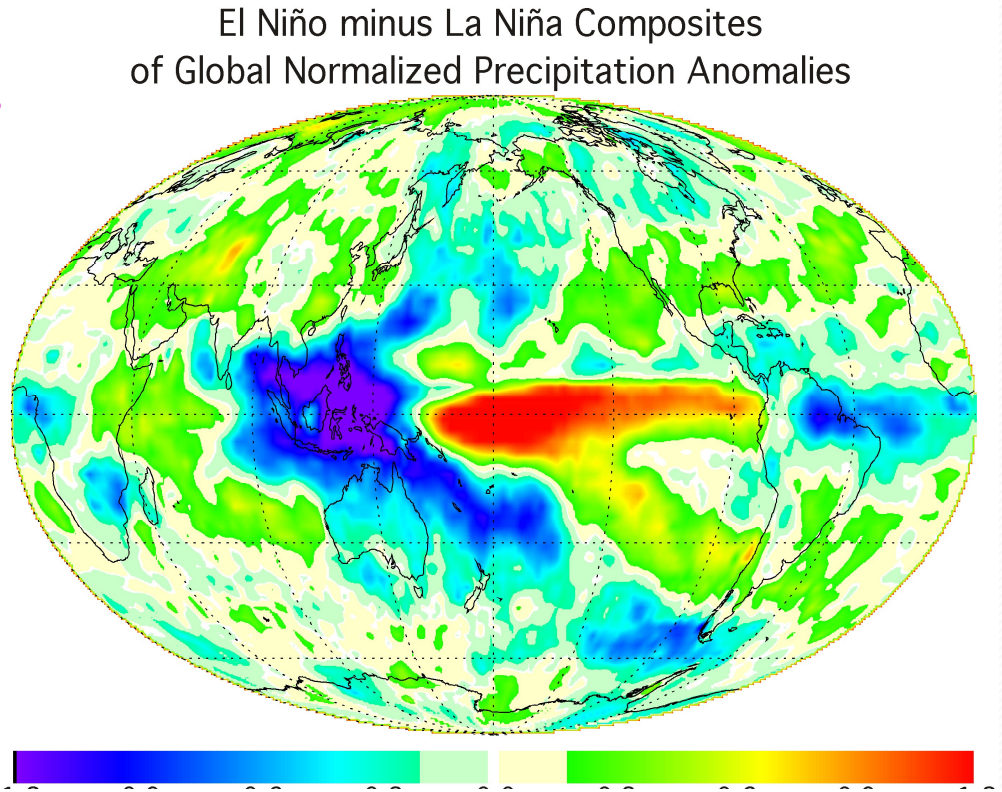


GPCP Objectives

A WMO/WCRP/GEWEX activity

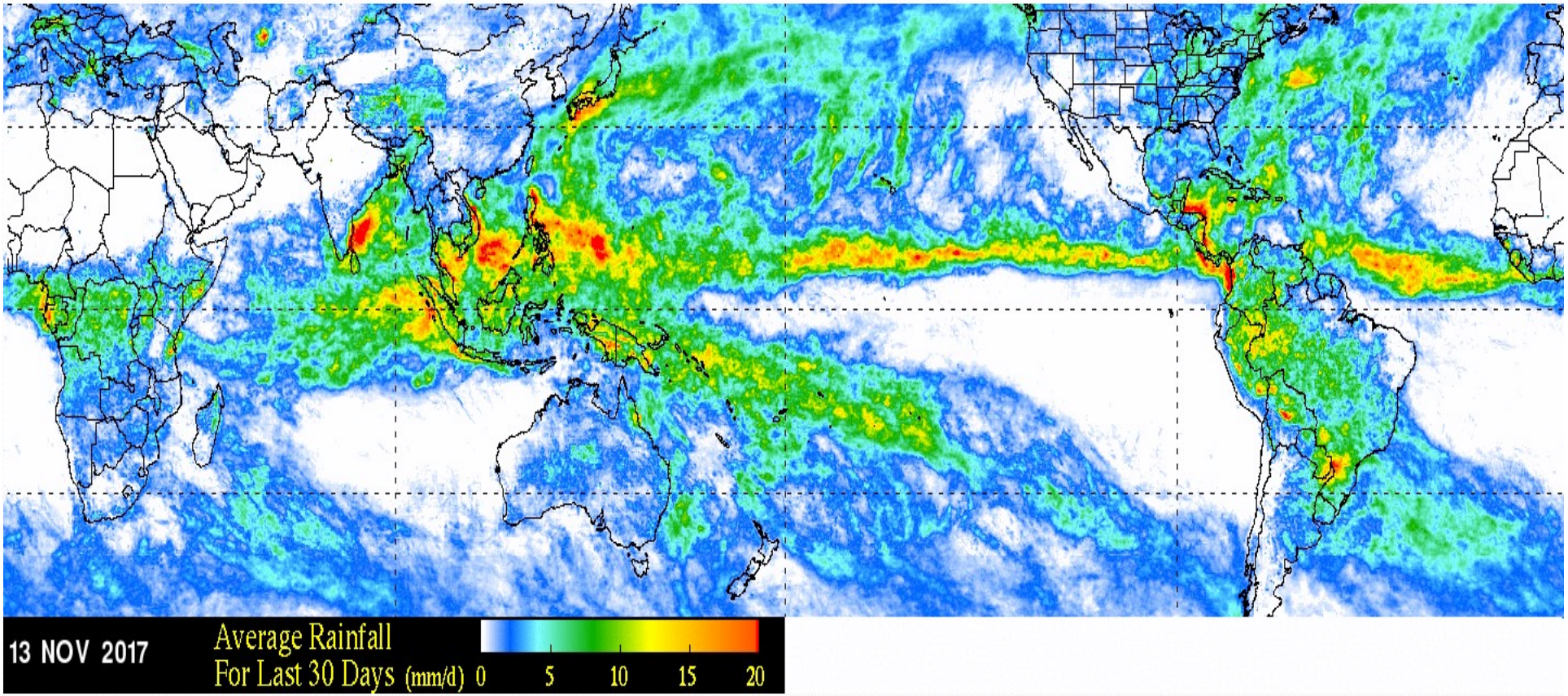


- Develop, produce **long-term, global precipitation analyses at monthly** and finer time scales for use in studies of weather and climate variations
- Characterize **quality of estimates**
- Improve the analyses by **incorporating new data**, improved analysis techniques, etc.
- Analyze the data sets – **precipitation alone or in combination** with other components of the hydrological cycle



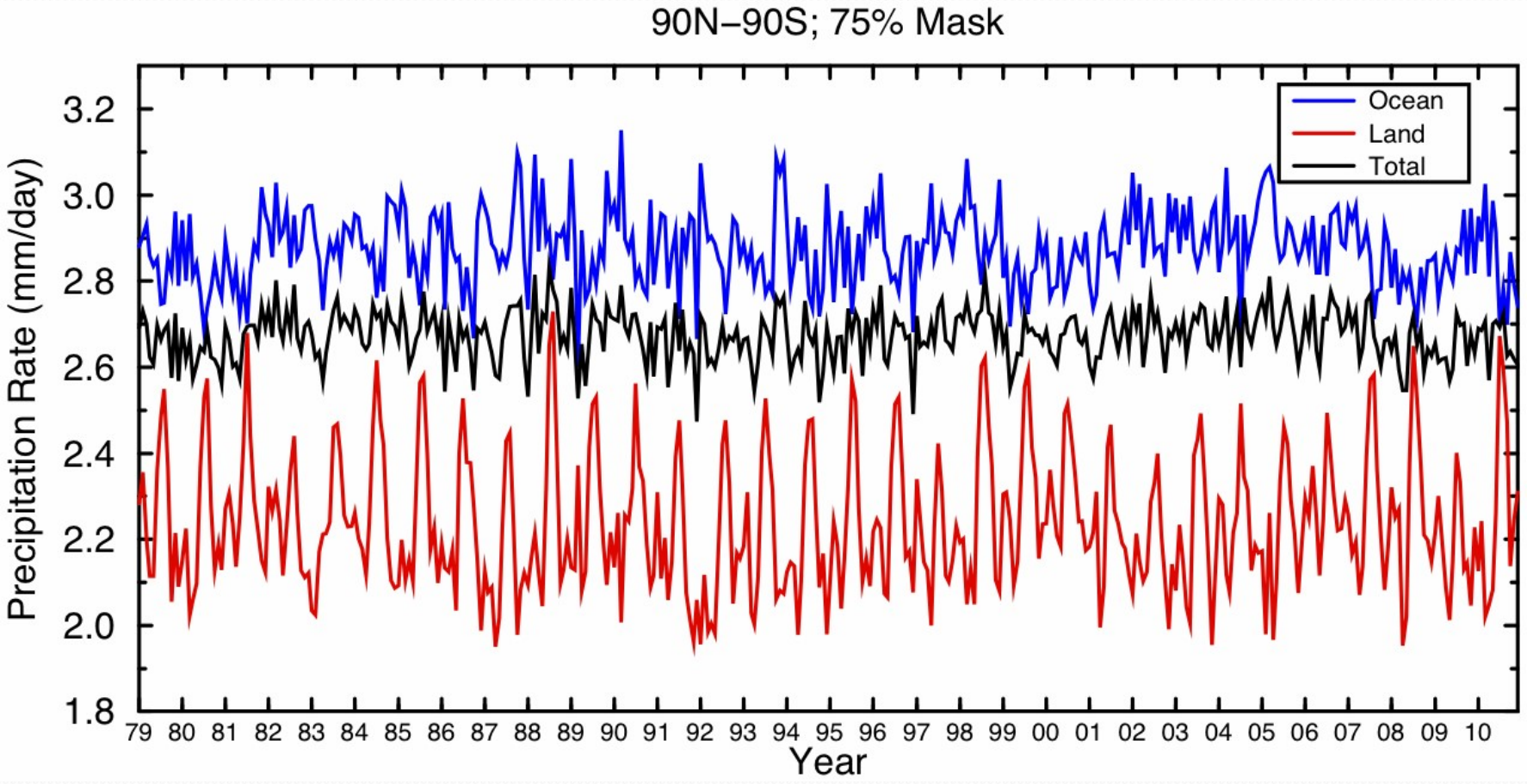
Success of Basic Objectives

- Yes, the long-term climatology validates well (more later)
  - Intelligent-guess fill-ins are no longer necessary
  - Highest latitudes still have issues (more later)



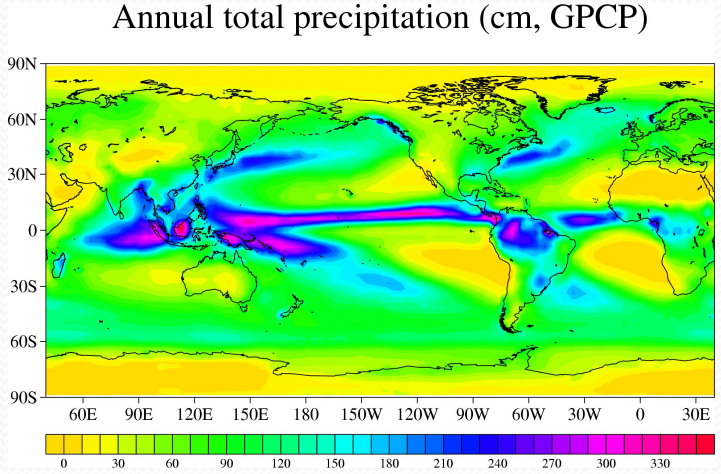
Success of Basic Objectives

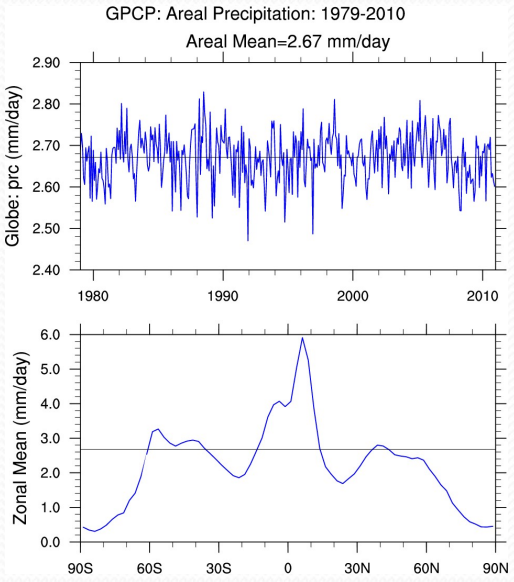
- Yes, we (quantitatively) see the annual cycle and ENSO events
  - Variations in the land and ocean time series largely offset each other



Characteristics of the GPCP Data Set

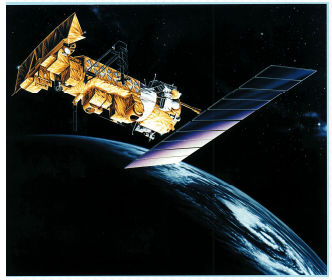
- **Global** Complete **Monthly** Precipitation Analysis
- **January 1979 to Present**
- **2.5° latitude by 2.5° longitude**
- **Input data**
  - Satellite Infrared (geostationaryo
  - Microwave (from mid-1987)
  - Gauge data (Global Precipitation Climatology
  - Center (GPCC) operated by the DWD
- **Output Data**
  - Satellite only
  - Merged gauge and satellite
  - Monthly, pentad, daily





Remote Sensing Estimates used in GPCP

- **Infra –red**
  - **GOES**
    - Rain Rate linearly related to fractional pixels Tcld < 235K
    - Most effective for deep convective clouds, used only in 40N,S zone
    - High spatial and temporal resolution
    - false signatures, insensitive to warm top rain



  - **TOVS**
    - TIROS Operational Vertical Sounder
    - Regression between cloud parameters and rain gauges
    - Used in high latitudes where MW and GPI techniques is poor
  - **OPI**
    - OLR precipitation Index
    - http://rain.atmos.colostate.edu/CRDC/datasets/NCEP_OPI.html

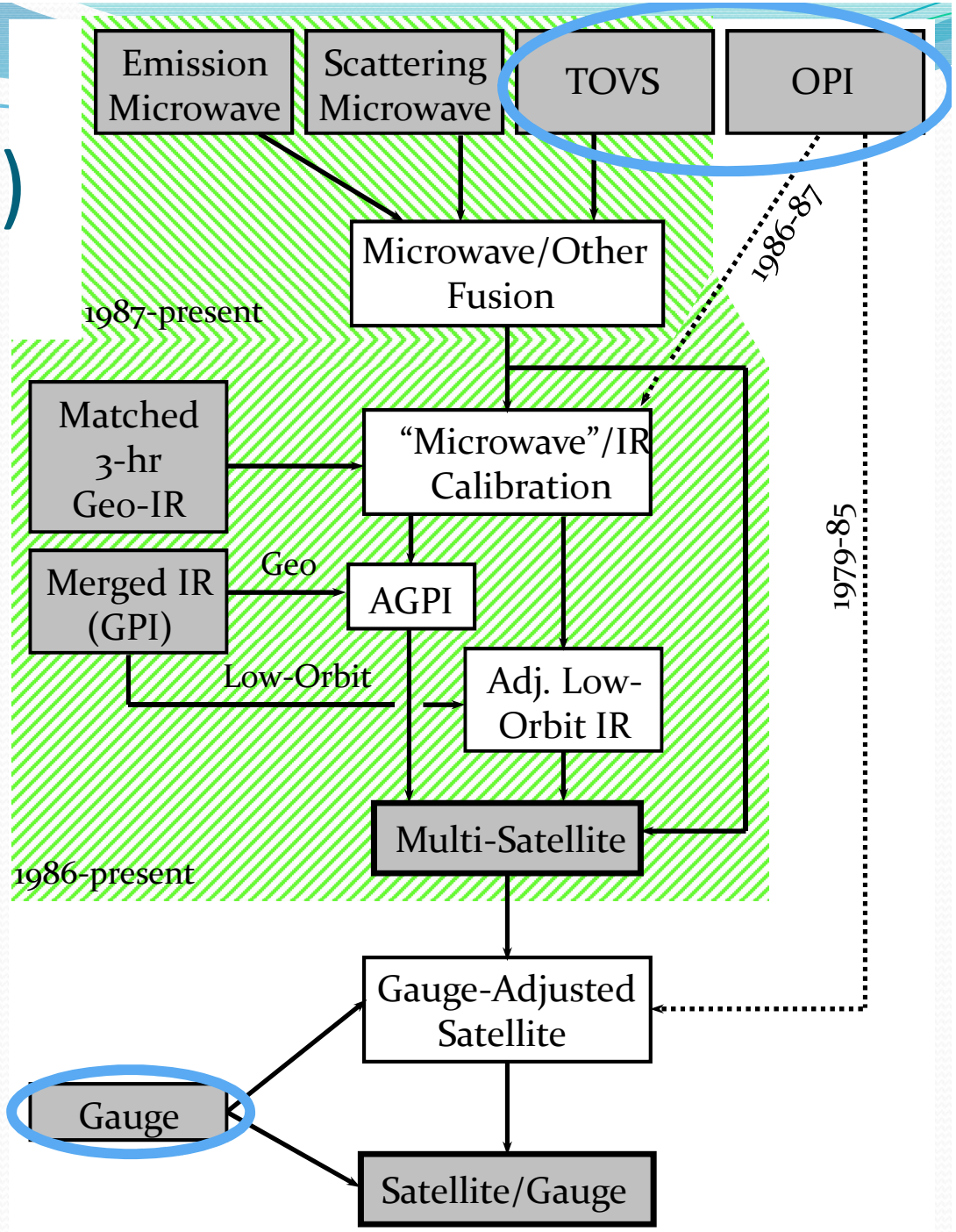
- **Microwave (SSM/I)**
  - Closely related to hydrometeors
  - Emission from cloud drops (29 GHz).
  - Most effective over water surfaces (Tsfc <<Tcld)
  - Scattering by ice particles over land over land (89, Tcld< Ta)
  - only ice clouds over land, low resolution, no estimate over snow and ice

Global Precipitation Climatology Project

Version 2 Monthly Satellite-Gauge (SC)

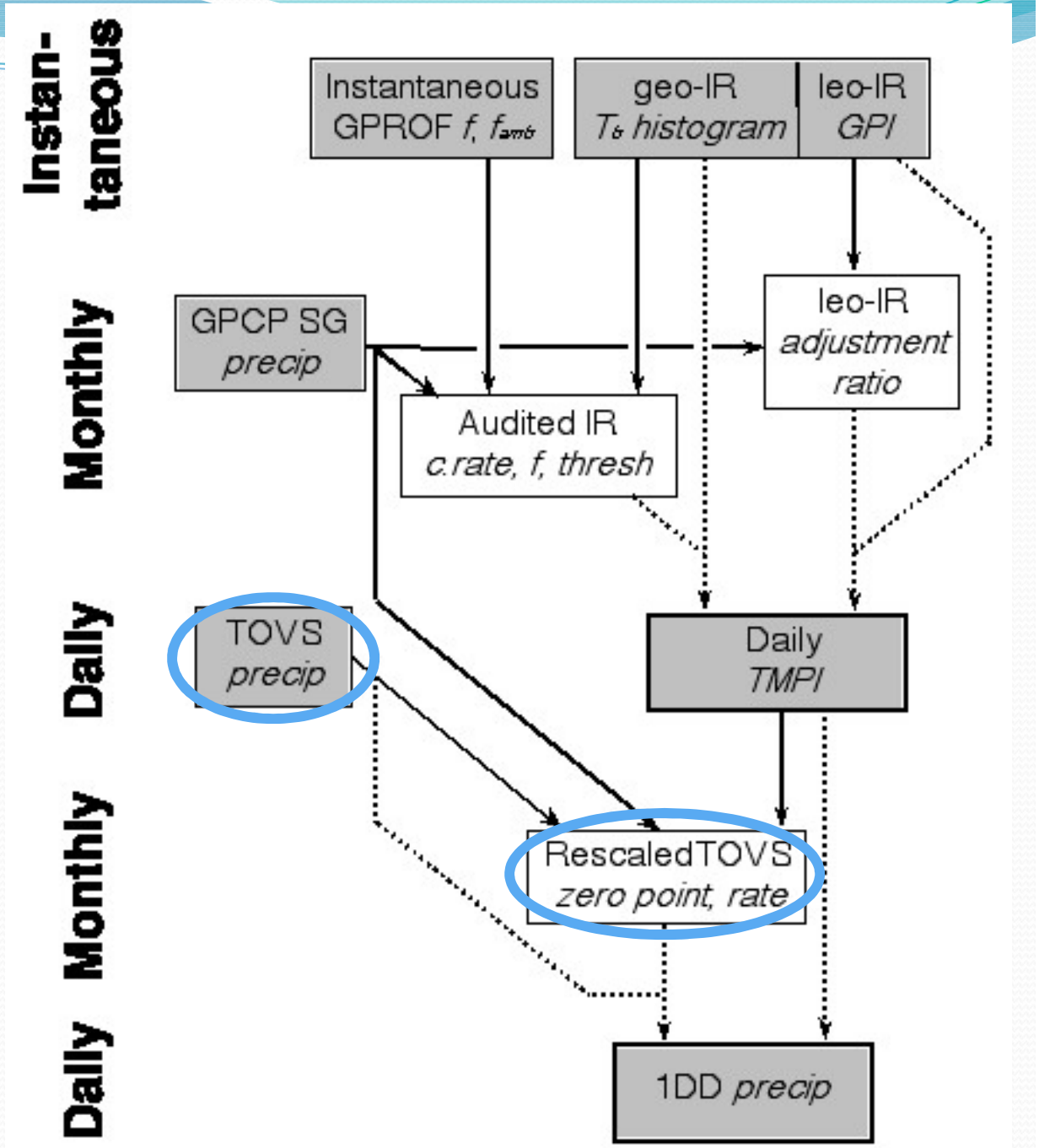
- Various input data depending on **era**
- **Sequential calibration** and combination of input data

- High-latitude and cold-season precipitation estimates provided by gauge, TOVS, OPI



One Degree Daily (1DD)

- 1DD Algorithm
- Similar input data
- Treated Differently
- High-latitude and cold-season precipitation estimates provided by TOVS, scaled by SG



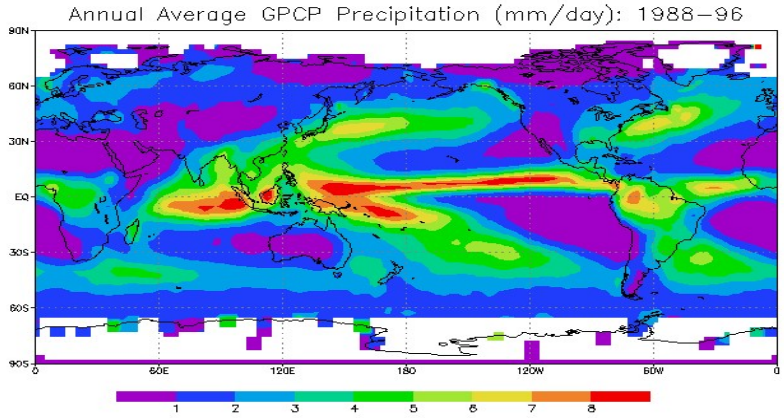
Monthly Mean Analysis Procedures

All products sum to monthly means

- **Monthly, 2.5° Merged Analysis**
  - 1979-present (Oct 2017)
  - *Adler et al. (2003)*
  - stepwise bias corrections; i.e., IR, adjusted to MW, satellite, adjusted to gauges, final blending uses inverse error weighting (Huffman, et al 1995 and Huffman et al, 1997)

- **Pentad, 2.5° Merged Analysis**
  - 1979-present (Oct 2017)
  - *Xie et al. (2003)*
  - combines satellite estimates by maximum likelihood estimates, then bias removal by solving a Poisson equation with gauges as boundary conditions. (Xie and Arkin, 1996,1997)

- **Daily, 1° Merged Analysis**
  - 1997-present (Oct 2017)
  - *Huffman et al. (2001)*



IMPORTANT POINT

Algorithms are designed for liquid precipitation

Gauges Used to produce a gridded analysis, ***incorporates water equivalent of solid precipitation***

Final GPCP Precipitation Field satellite estimates adjusted to large scale gauge analysis (***water equivalent of solid precipitation incorporated in this stage***)

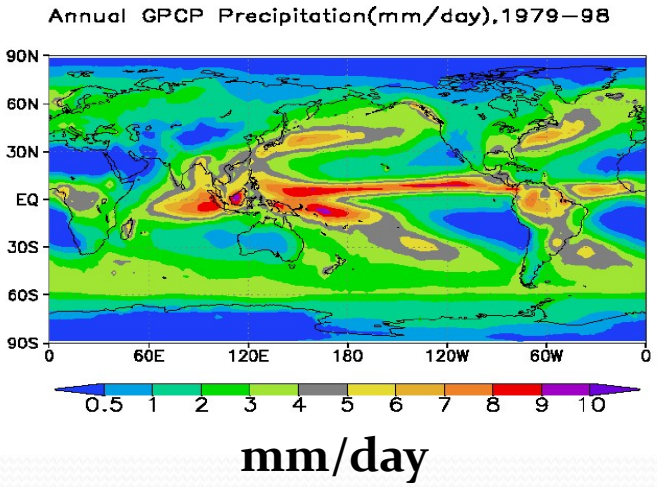
http://www.esrl.noaa.gov/psd/data/gridded/data.gpcp.html

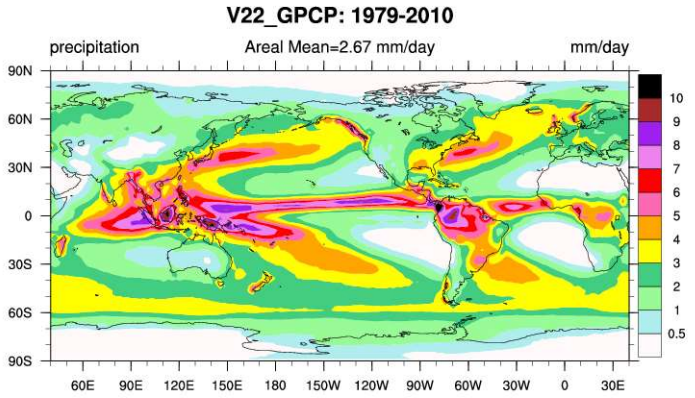
GPCP Version 2.3 (initiated in April l2016)

- **New version of GPCP V2.3 monthly**
  - Working with NOAA to streamline the multi-organization data streams, processing procedures and associated computer code to make the current GPCP Version 2 (V2.3) part of NOAA's Climate data Record [now Reference Environmental Data Record] program.
  - Small changes and shifts (decreases) in mean precipitation were noted for the post-2003 period over oceans that did not seem natural.
    - These were determined to be related to subtle shifts in input satellite precipitation estimates due to transitioning from one satellite to the next using inadequate overlap and cross calibration procedures.
  - New cross calibration procedures were developed, tested and applied to correct the problems and have been incorporated into the new V 2.3, which will become part of the NOAA program
  - In addition to changes in satellite inputs, new sets of gauge analyses became available from the Global Precipitation Climatology Center which were also integrated into the analysis record.

Climatology - Annual Mean Precipitation

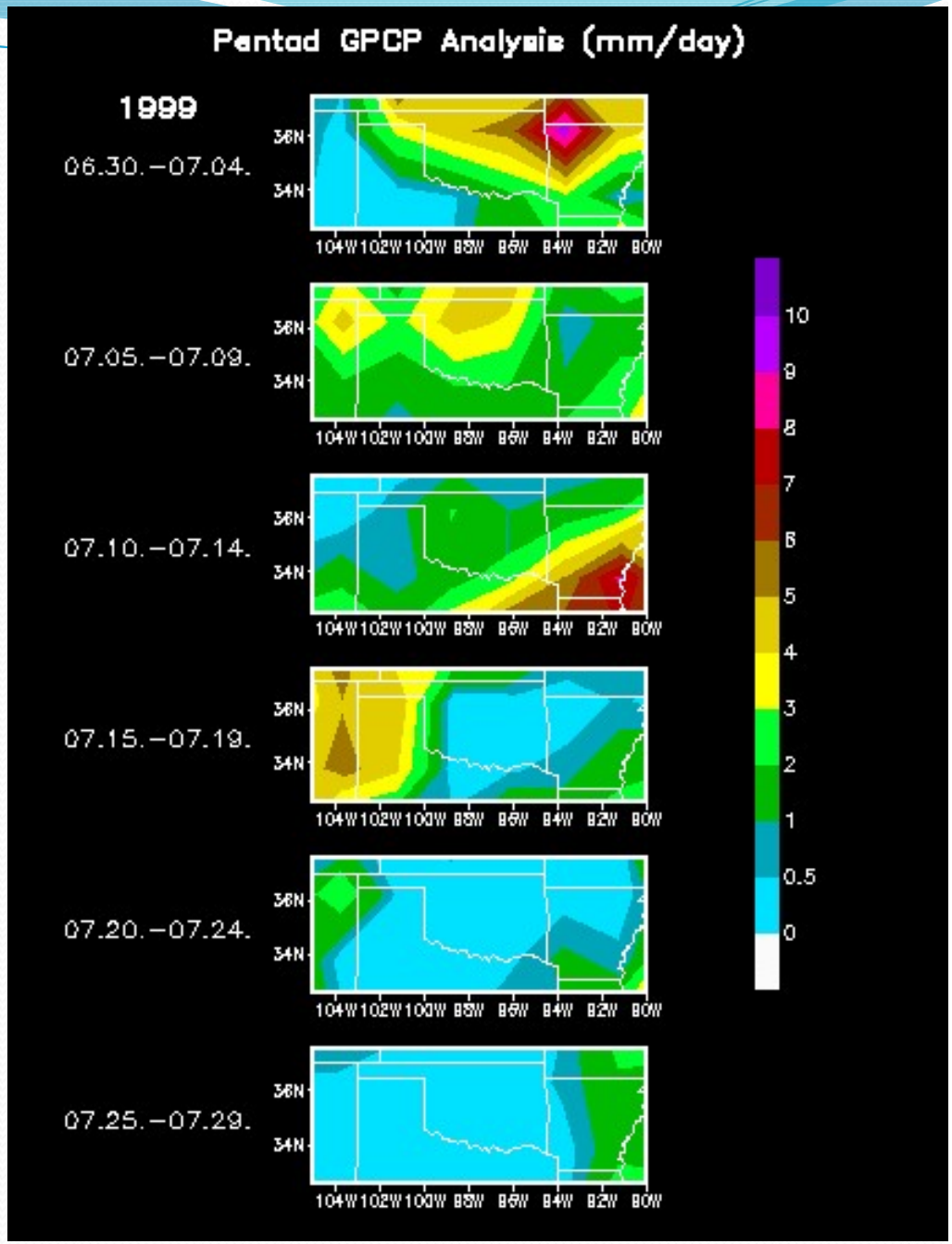
- **All available months** in the period January 1981--December 2010 are used to compute monthly climatological values.
- The data set archive consists of **unformatted REAL*4 binary files**. Each file occupies about 40 KB, and the whole data set contains about 486 KB.
- The grid on which each field of values is presented is a **2.5°x2.5° latitude--longitude** (Cylindrical Equal Distance) global array of points. It is size 144x72, with X (longitude) incrementing most rapidly West to East from the Prime Meridian, and then Y (latitude) incrementing North to South.





Pentad (5-day) Data

- An analysis of global **pentad (5-day)** precipitation has been constructed for the Global Precipitation Climatology Project (GPCP).
- The **pentad analysis** is a companion to the V 2.3 product of the GPCP global monthly precipitation analysis.
- Users are recommended to use this pentad data set only for studies where **sub-monthly** and **intra-seasonal phenomena** are involved.

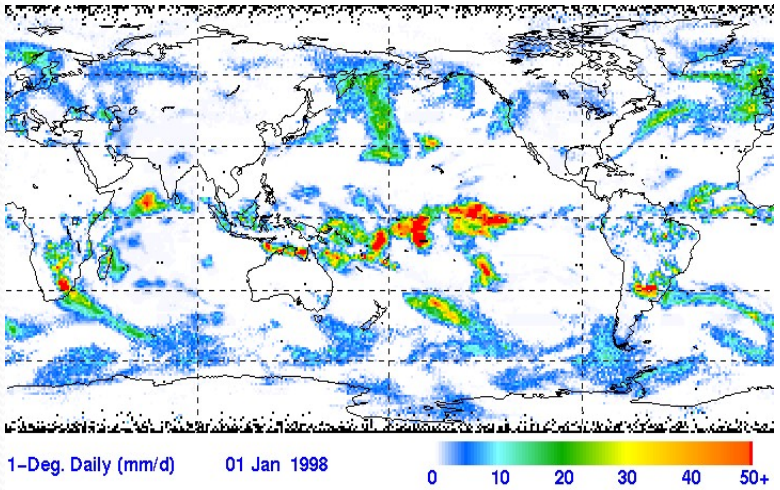


1-Degree Daily Data

- The 1DD uses the "best" quasi-global observational estimators of underlying statistics to adjust quasi-global observational datasets that have desirable time/space coverage. Specifically:
  - **Special Sensor Microwave Imager and SSMI Sounder (SSMI, SSMIS)**
    - 0.5°x0.5° by orbit & GPROF algorithm
    - Provides fractional occurrence of precipitation
  - **GPCP V2.3 Satellite-Gauge (SG) combination** (2.5 by 2.5 monthly) accumulation of precipitation to algorithms applied to:
    - **Geosynchronous-orbit IR** (geo-IR) T_b histograms (geo-IR) T_b histograms (1°x1° grid in the band 40°N-40°S, 3-hourly)
    - **Low-orbit IR (LEO-IR) Goes Precipitation Index** (GPI; same time/space grid as geo-IR)
    - TIROS Operational Vertical Sounder and Atmospheric Infrared Sounders (**TOVS**, **AIRS**; 1°x1° on daily nodes, Susskind algorithm)

1 x 1 degree, daily precipitation

January 1, 1998

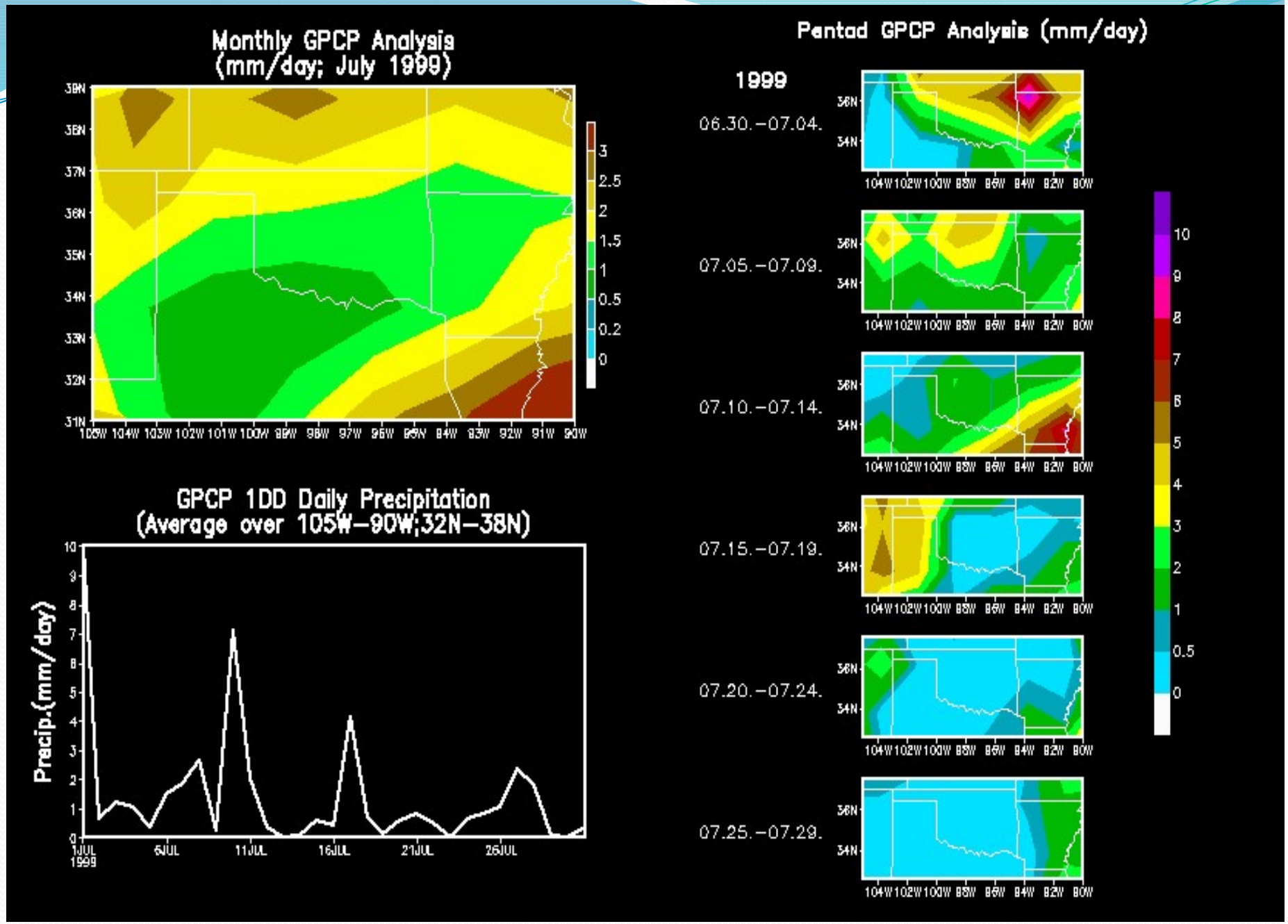


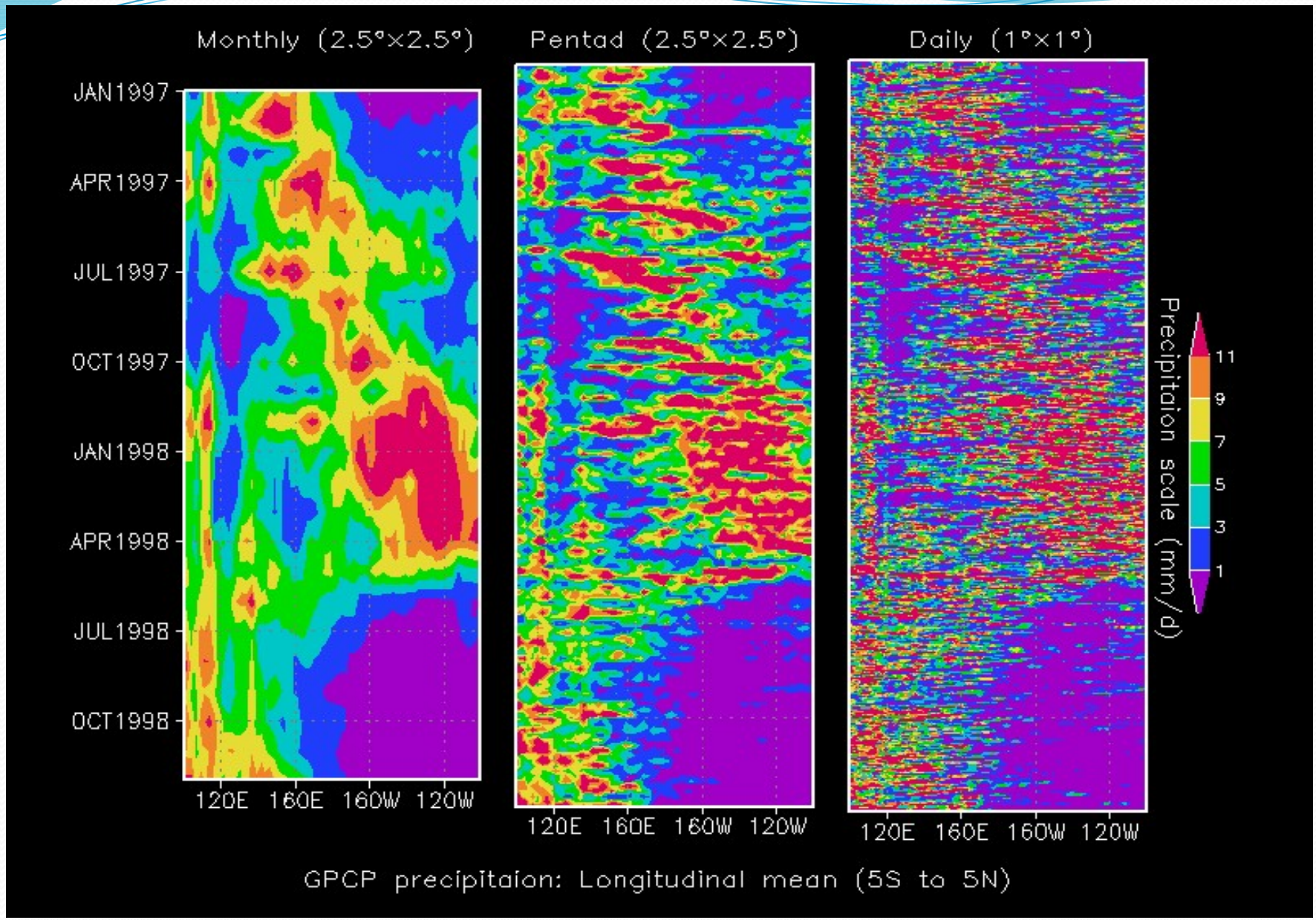
mm/day

http://precip.gsfc.nasa.gov/gpcp_daily_comb.html

Although microwave precipitation estimates and gauge analyses are not explicitly used due to sampling limitations, the calibration of the 1DD to the monthly Version 2.2 SG ensures that they do have a strong influence on the overall scaling.

The differences between the IR and TOVS (AIRS) datasets required that the 1DD be formulated in two parts, with smoothing over the latitude band 40° to 50° in each hemisphere to patch the data boundary.


Monthly GPCP Analysis
(mm/day; July 1999)
GPCP 1DD Daily Precipitation
(Average over 105W–90W;32N–38N)
Precip.(mm/day)
1JUL 1999
6JUL
11JUL
16JUL
21JUL
26JUL
Pentad GPCP Analysis (mm/day)
1999
06.30.–07.04.
07.05.–07.09.
07.10.–07.14.
07.15.–07.19.
07.20.–07.24.
07.25.–07.29.


Monthly (2.5°×2.5°)
Pentad (2.5°×2.5°)
Daily (1°×1°)
JAN1997
APR1997
JUL1997
OCT1997
JAN1998
APR1998
JUL1998
OCT1998
120E 160E 160W 120W
120E 160E 160W 120W
120E 160E 160W 120W
Precipitaion scale (mm/d)
11
9
7
5
3
1
GPCP precipitaion: Longitudinal mean (5S to 5N)

Validation

- Even though the **limited applicability of prior datasets** prevents complete global validation of the SG precipitation product, it is possible to make some quantitative comparisons.

- The **GPCP Surface Reference Data Center (SRDC)** at the National Climatic Data Center (NCDC) has constructed monthly area average precipitation for fifteen 2.5° x 2.5° cells located in five test site areas (Fig. 9) during the period July 1987-December 1991.

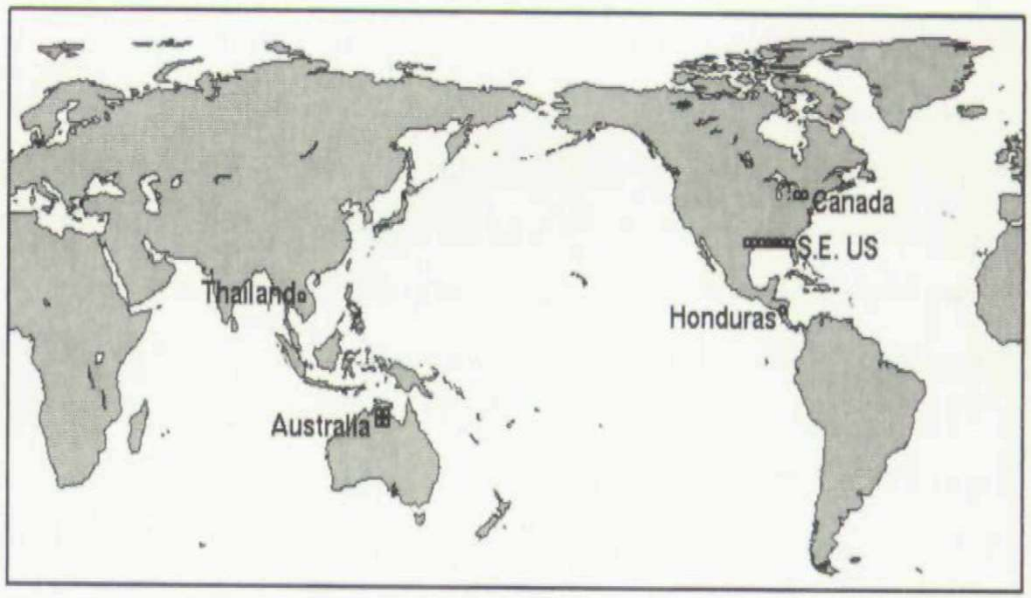
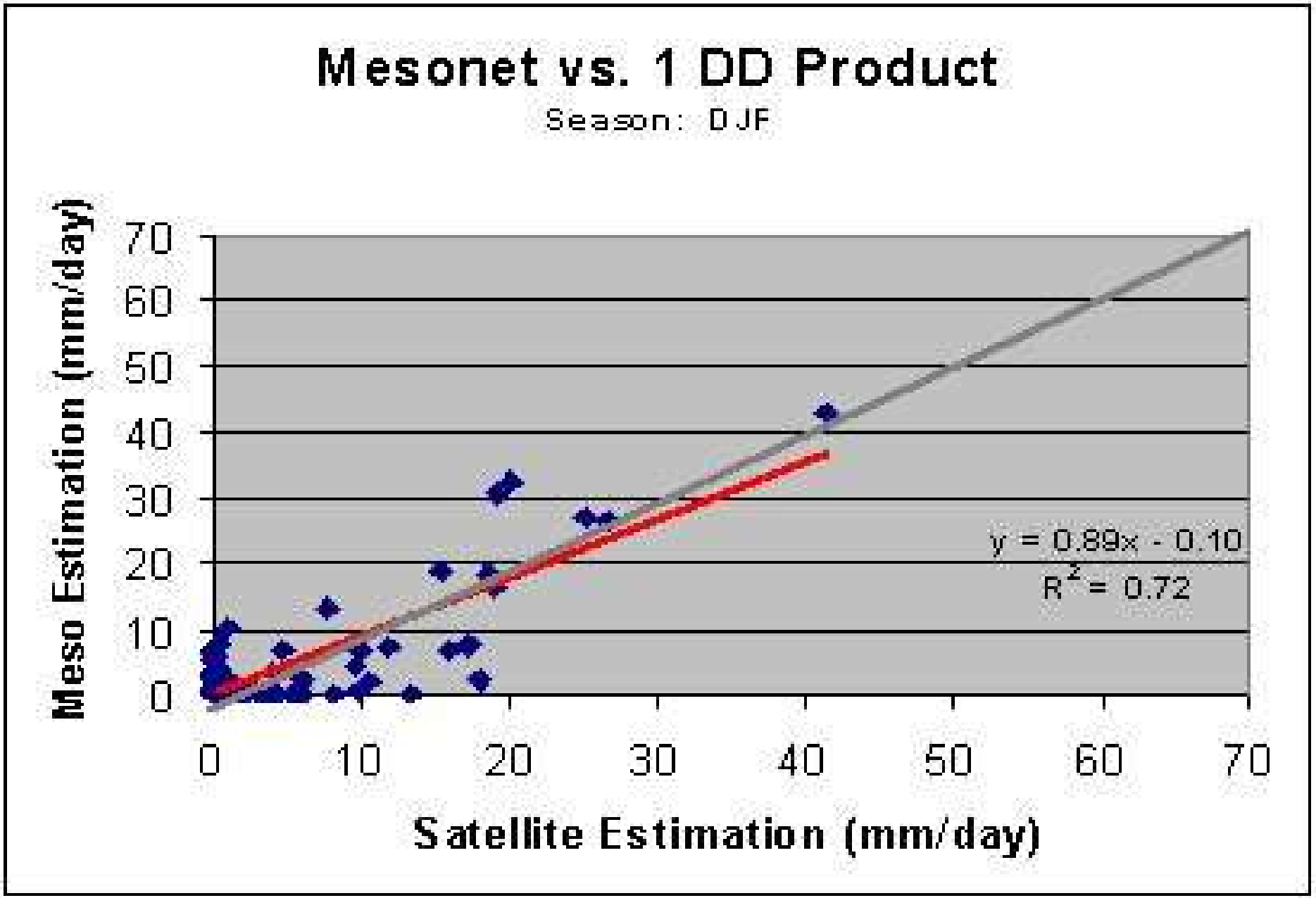


FIG. 9. Locations of SRDC test site cells.

Validation Gauges

TABLE 1. Monthly numbers of gauges used in the SRDC and gauge analyses for each test-site area box.

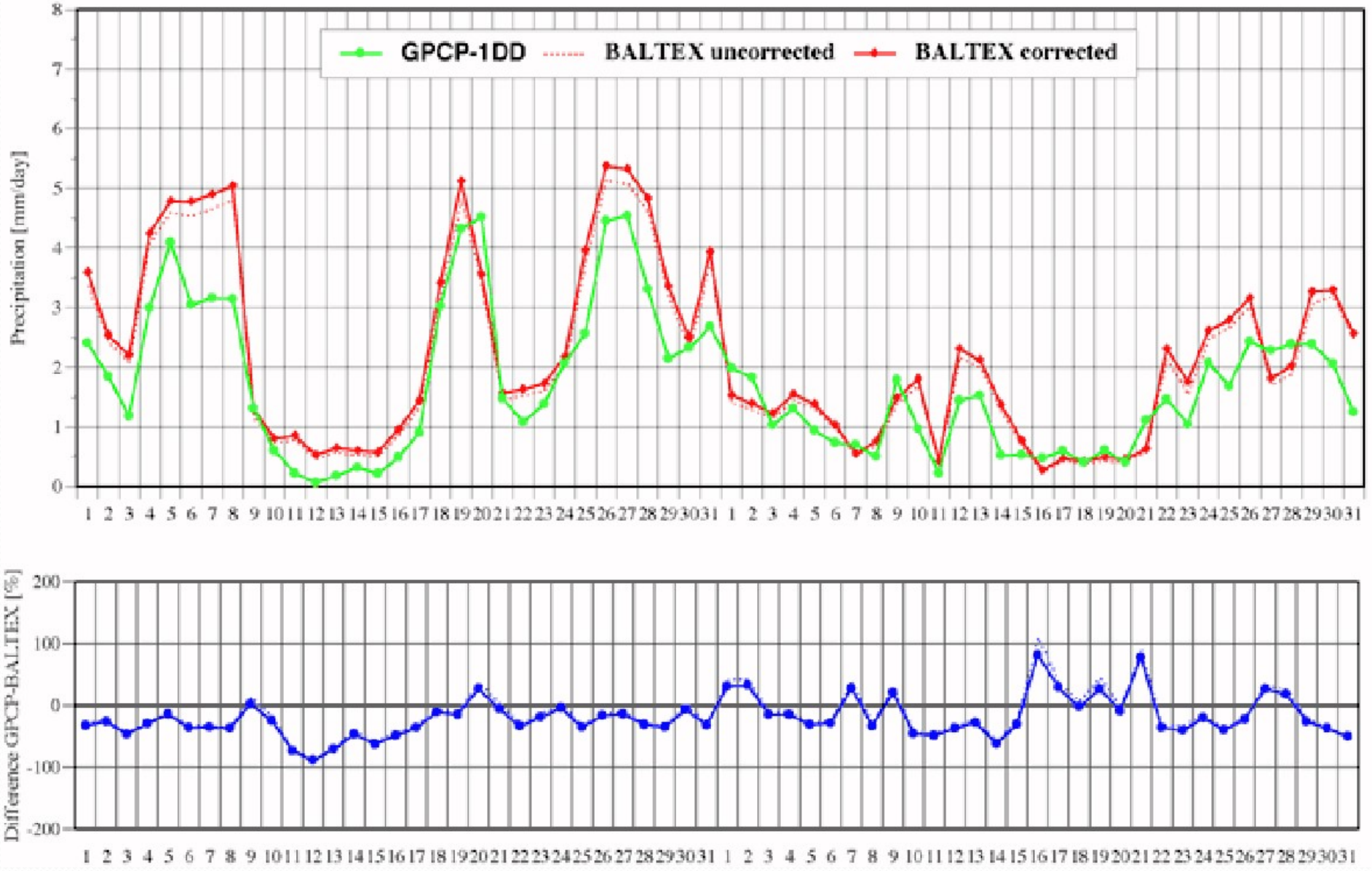
Site	SRDC			GPCC		
	25th percentile	50th percentile	75th percentile	25th percentile	50th percentile	75th percentile
Australia	10	14	32	0	1	2
Canada	70	96	104	2	3	5
Honduras	13	13	14	3	3	3
Southeastern United States	35	50	65	3	4	5
Thailand	80	80	82	8	8	8


Mesonet vs. 1 DD Product
Season: DJF
Meso Estimation (mm/day)
Satellite Estimation (mm/day)
0
10
20
30
40
50
60
70
y = 0.89x - 0.10
R2 = 0.72

GPCP-1DD Precipitation Composit vs. High Resolution Precipitation Analysis

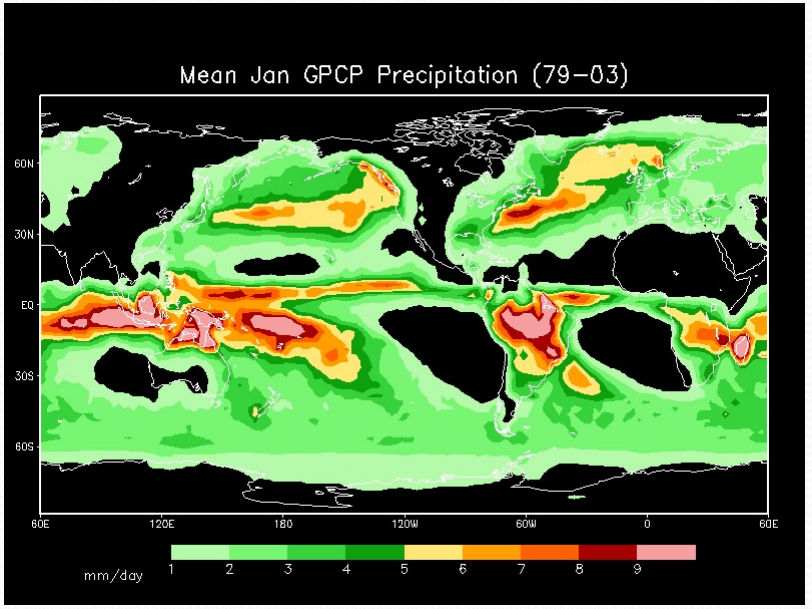
form BALTEX rain gauge networks (corrected)

July 1 - August 31, 1997



Applications and GPCP Contributions

- **Examples:**
  - Estimates of global precipitation patterns
  - Estimated mean global rainfall rates
  - Zonal Mean Precipitation



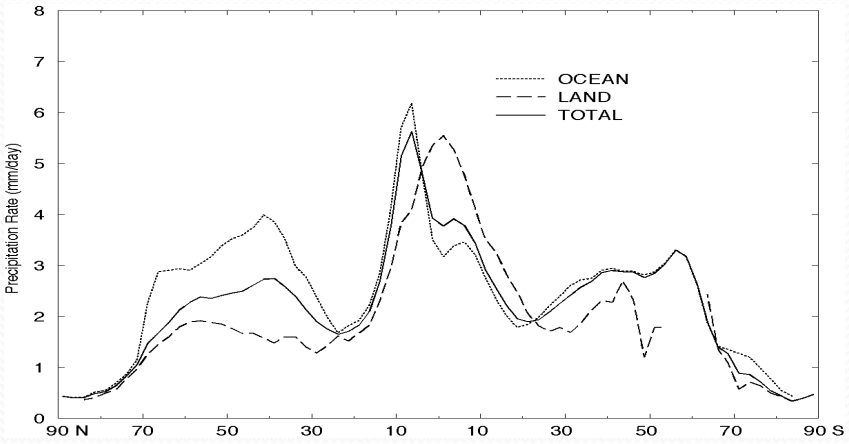
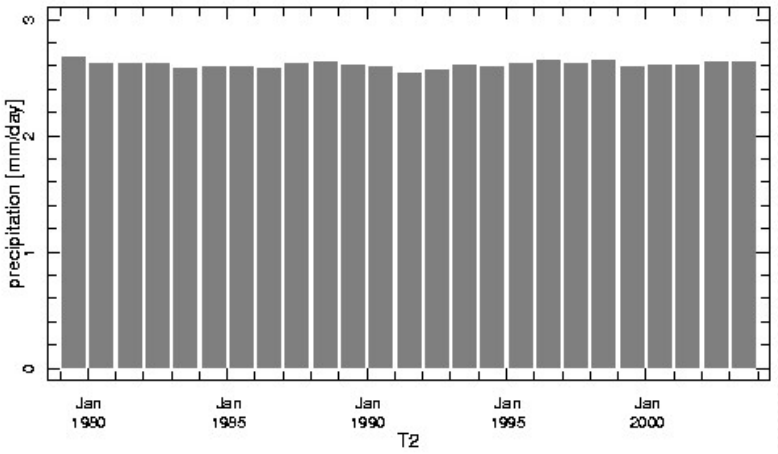
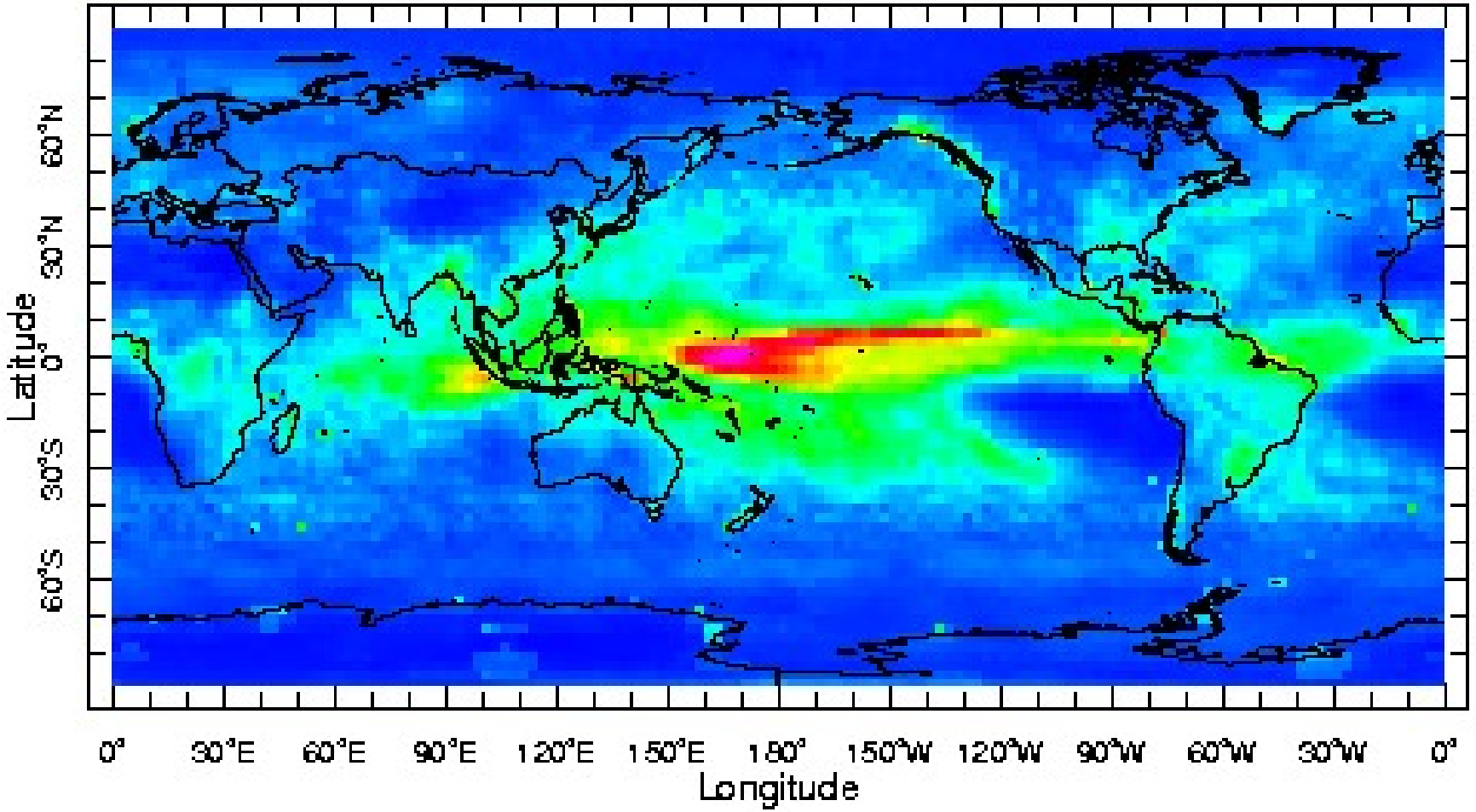


Figure 1a. Zonal mean precipitation, land versus ocean, 1979-2003, after Adler et al, (2003)



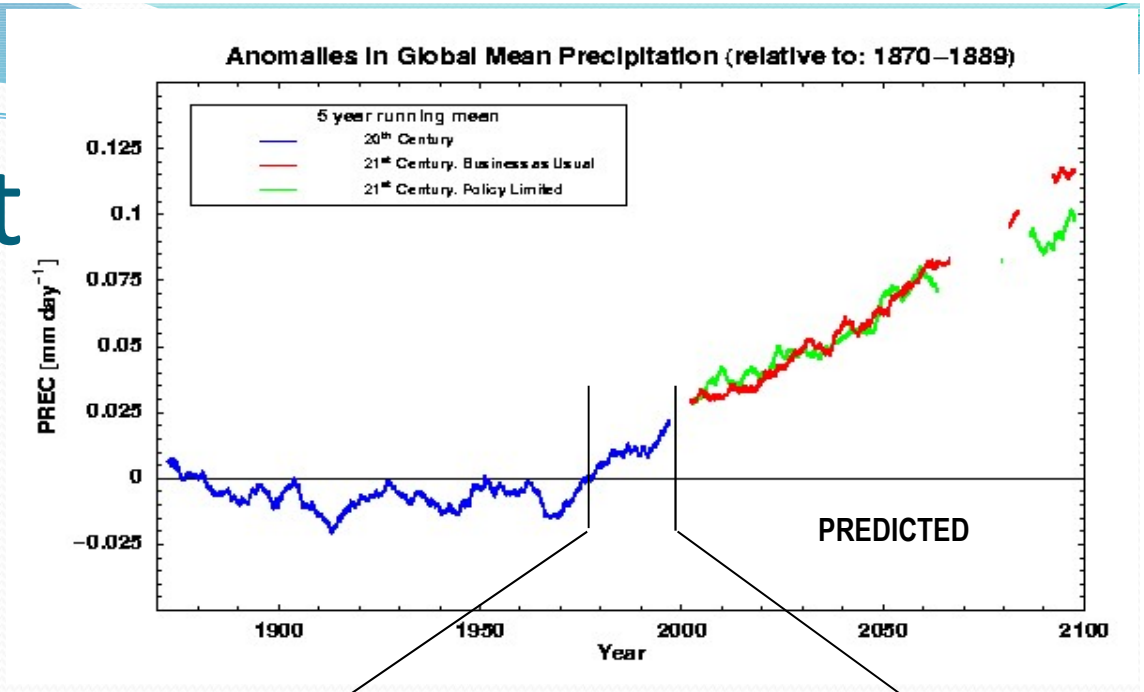
P estimated a 2.61 mm/day
Yearly Standard Deviation 0.03mm/day

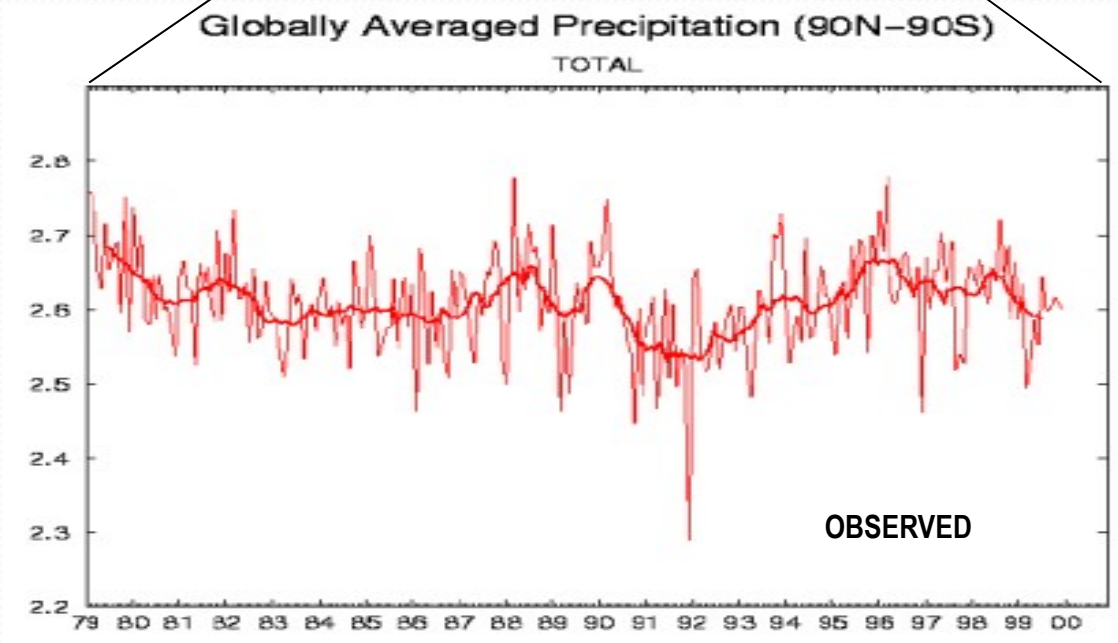
Standard Deviations of Annual Mean Precipitation



GPCP in a Climate Context

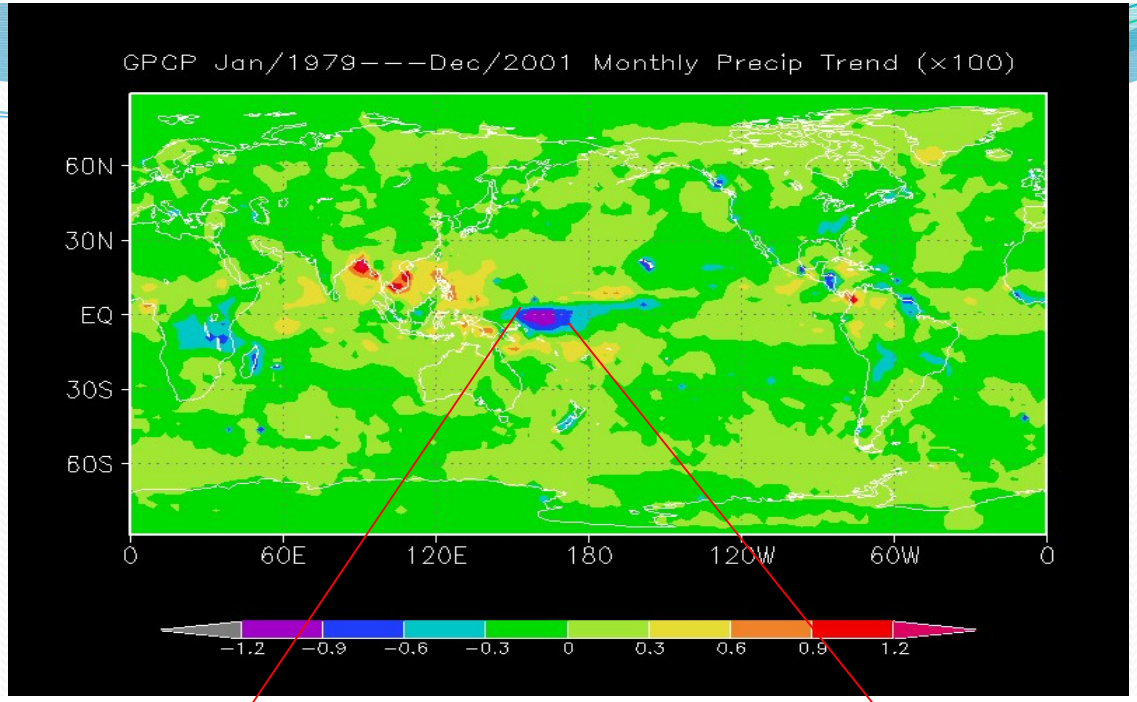
- Long Time Span!
- 1979-2017
- Perfect for comparing to Global Climate Models

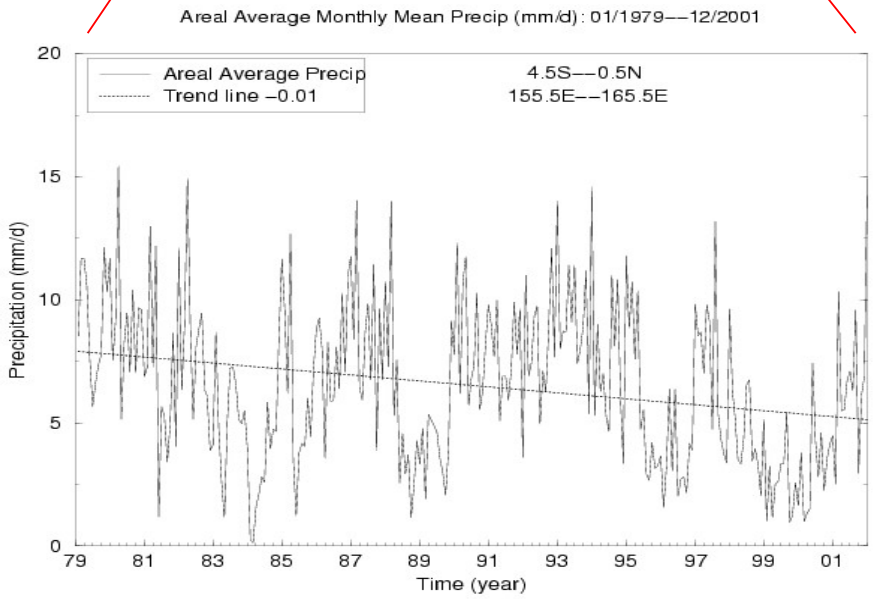


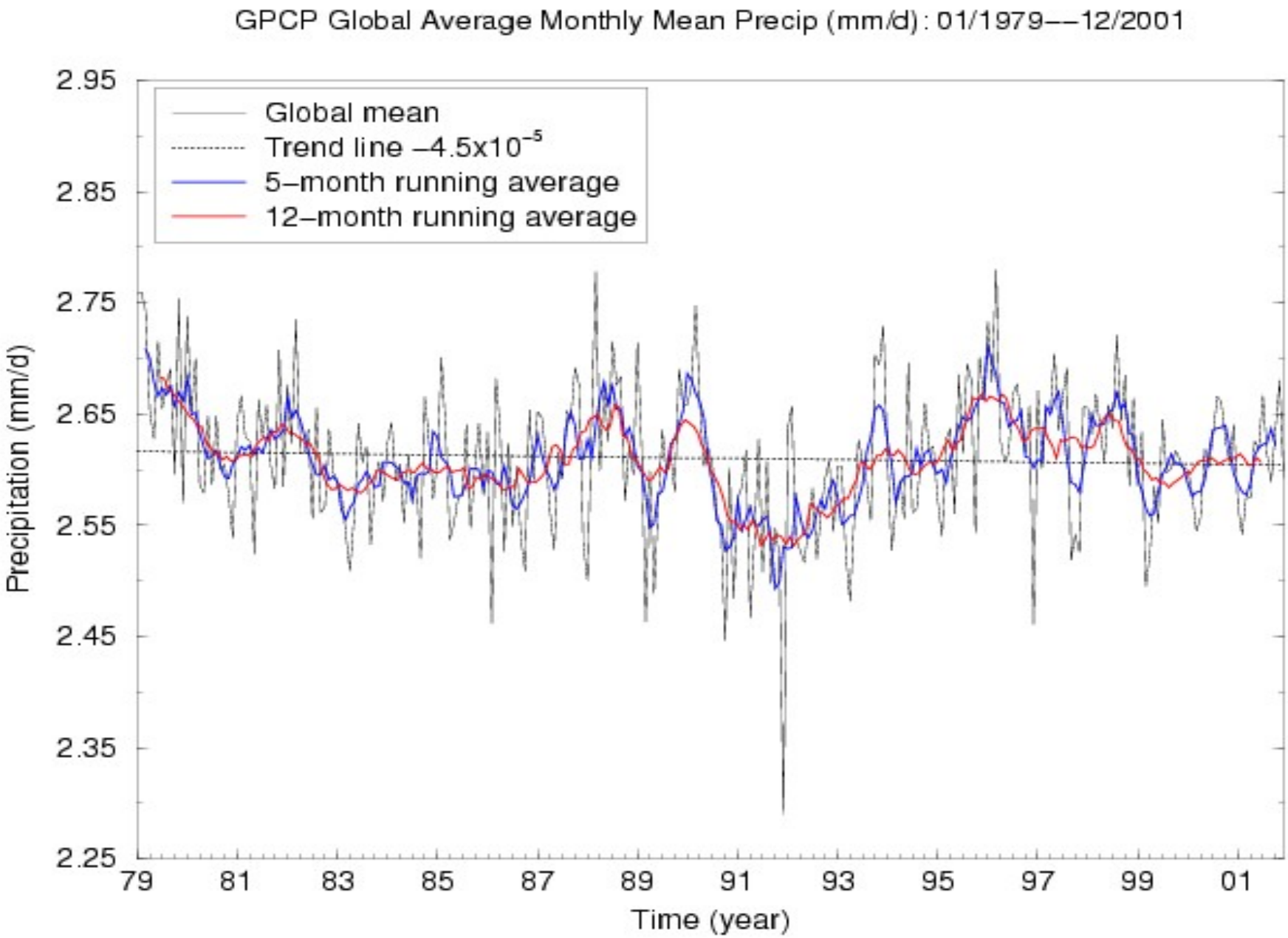


Trends

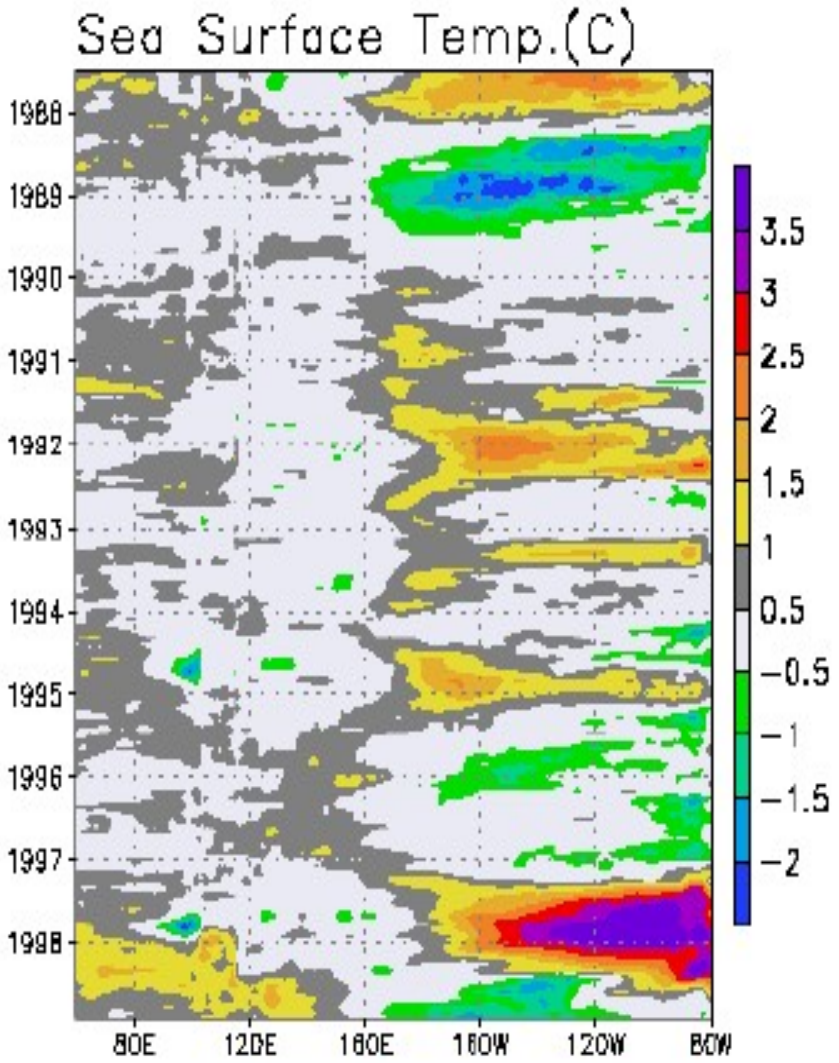
- Global Patterns of increasing and decreasing precipitation
- Can zoom in and look at trends in specific locations.
- Again, great for comparing to climate models (past & future prediction)

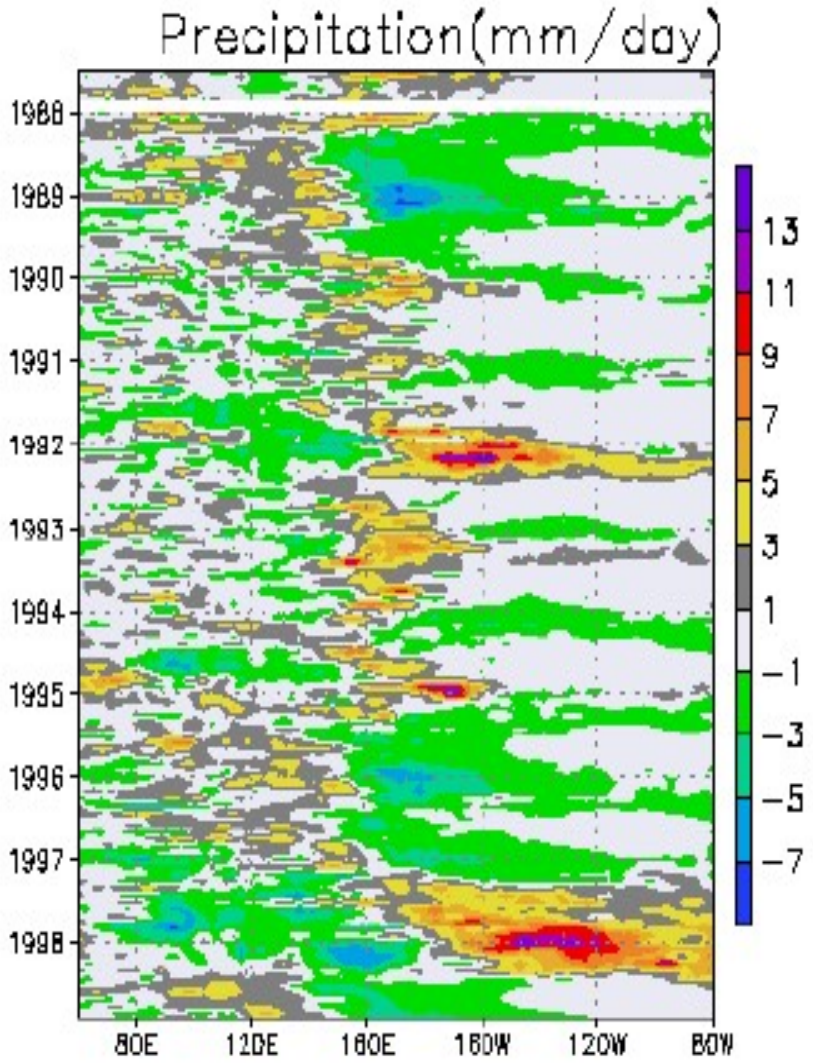





GPCP Global Average Monthly Mean Precip (mm/d): 01/1979--12/2001
Global mean
Trend line –4.5x10^{-5}
5–month running average
12–month running average
Precipitation (mm/d)
2.95
2.85
2.75
2.65
2.55
2.45
2.35
2.25
79
81
83
85
87
89
91
93
95
97
99
01
Time (year)

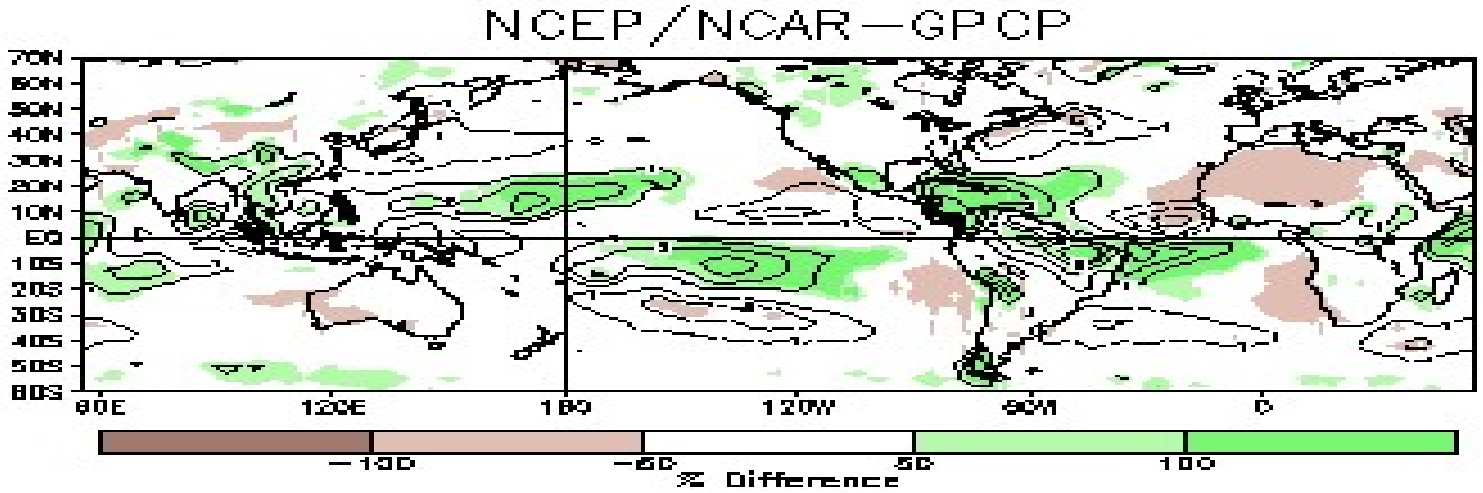
Hovmoller Diagrams
Monthly Anomaly (5N-5S)

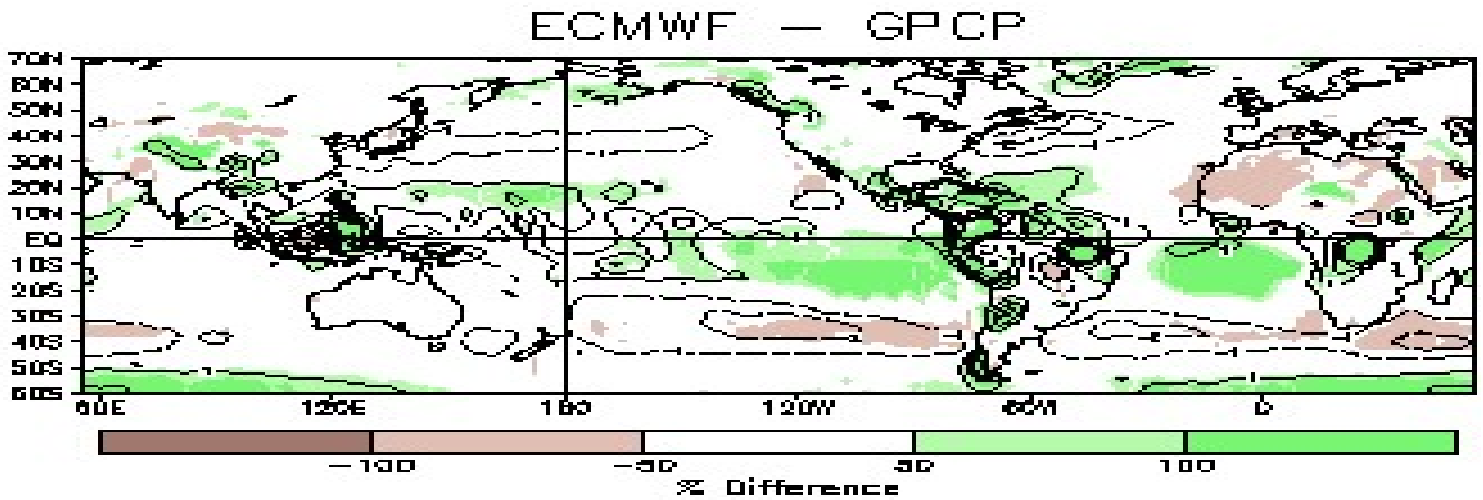




Comparisons with Reanalysis

Mean Annual Difference





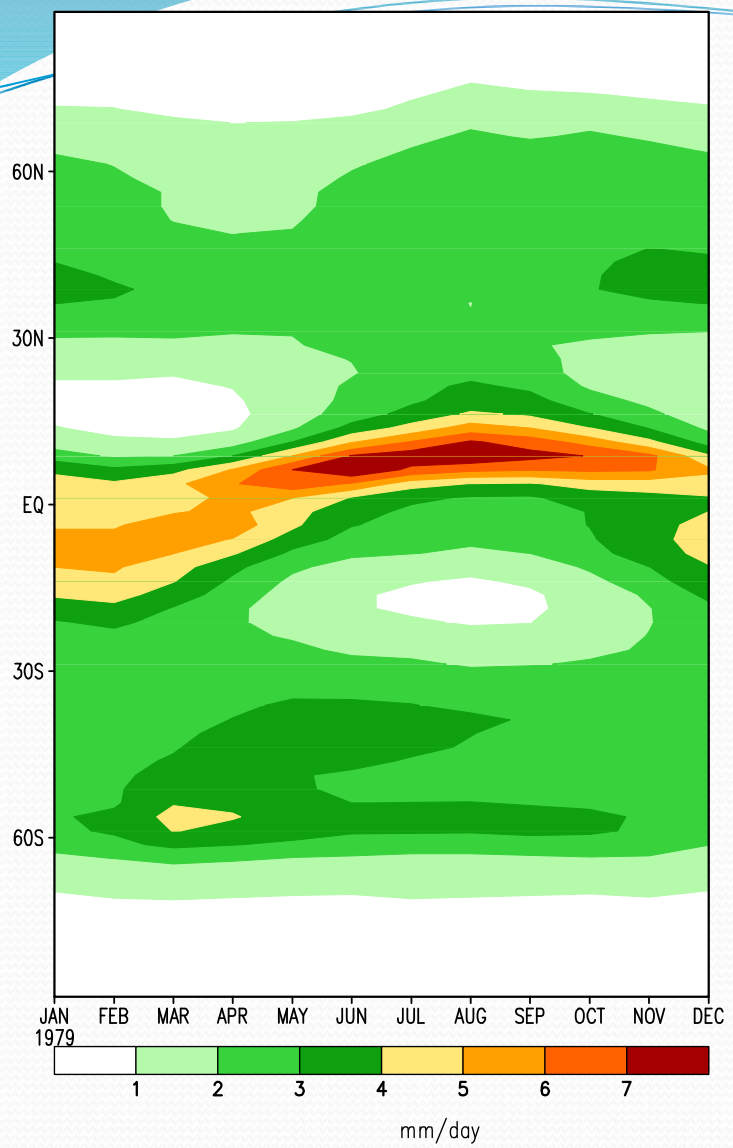
Future Outlook/Issues

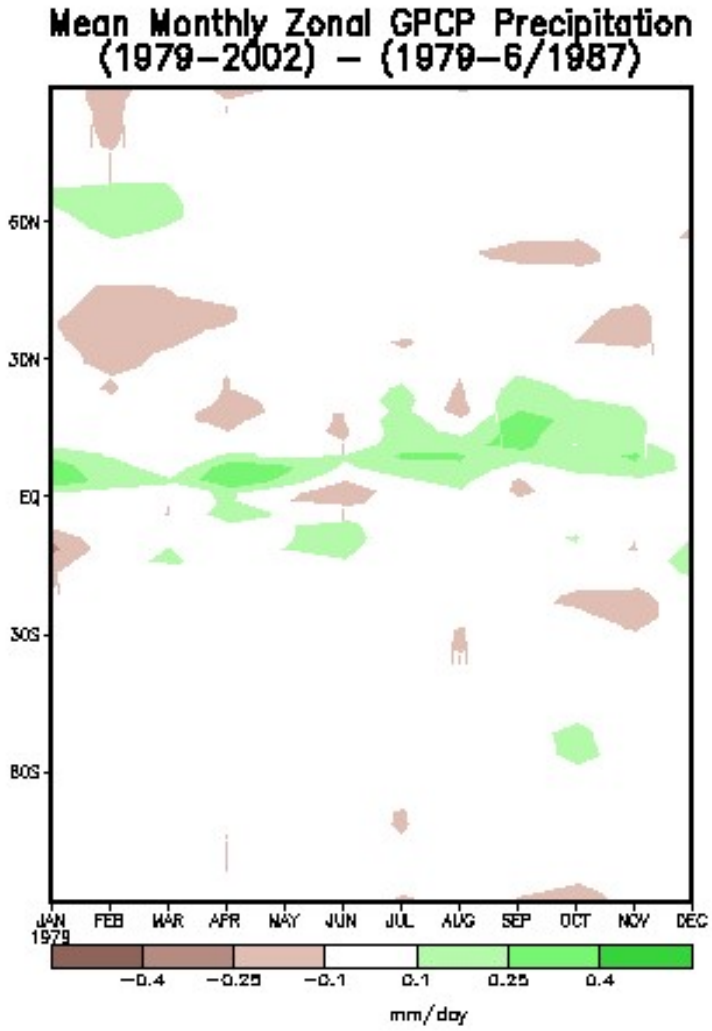
- **New Instruments/Improved Algorithms**
  - TRMM: a calibration source
  - AMSR: improved MW algorithm
  - Eventually GPM Since TRMM is dead
- **Use of Multiple Satellites**
  - Operational and research satellites e.g. multiple microwave observations from AMSU, AMSR, SSM/I, TRMM…. GPM
- **Solid precipitation**
  - Snow rate
- **Precipitation in complex terrain**
  - A challenge - microphysical cloud properties to detect “warm top rain”

Future Outlook/Issues

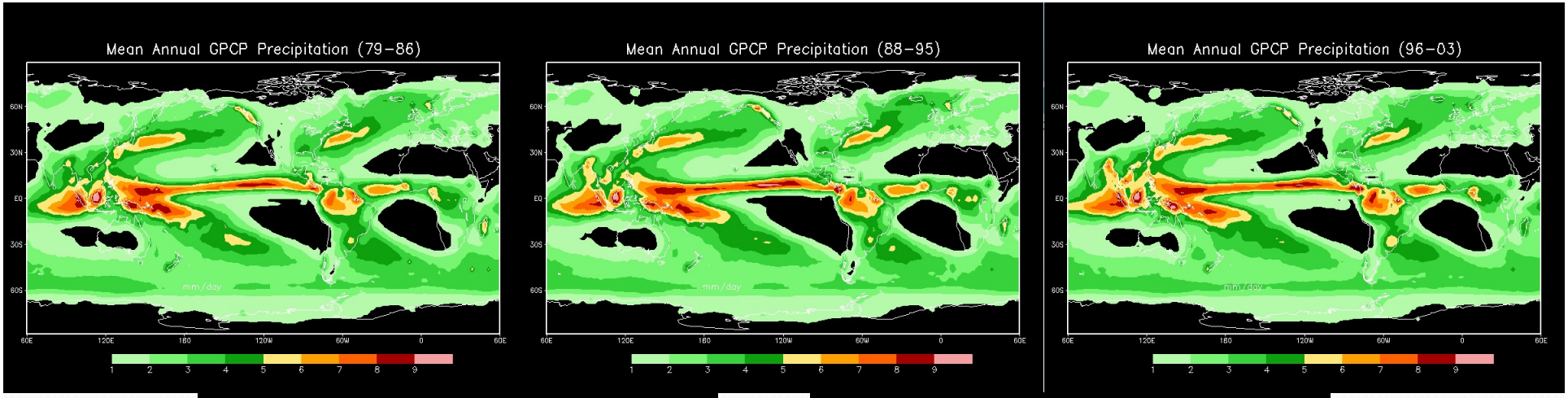
- **Use of Multiple Satellites**
  - Currently GPCP uses IR data from Geostationary and Polar orbiting data and MW data from one SSM/I. We now have MW data available from multiple SSM/I orbits, AMSU data, TRMM data and soon will have AMSR data. The challenge is to utilize these data effectively. They are proposing to utilize these data to develop a three hourly 1 x 1 degree product. This would be Version 3.

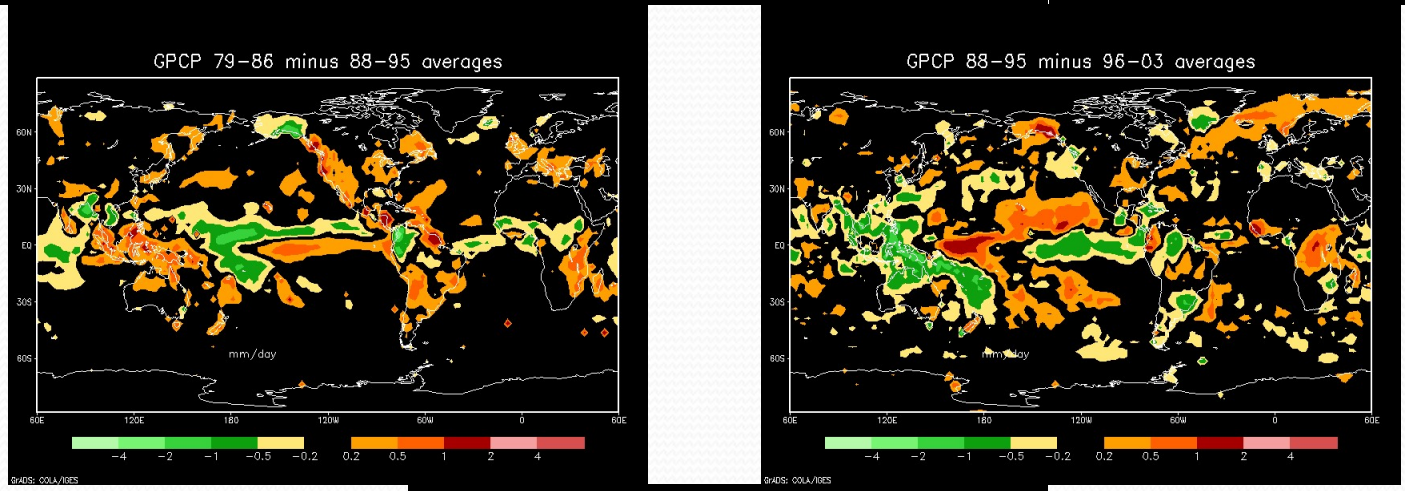
- **Solid Precipitation**
  - Solid precipitation is not measured explicitly but is included over land through use of gauges.
  - Liu and Curry have done some early work on solid precipitation over the oceans and recently Ferraro has been studying the use of AMSU 150 and 176 GHz data to help identify solid precipitation over land.

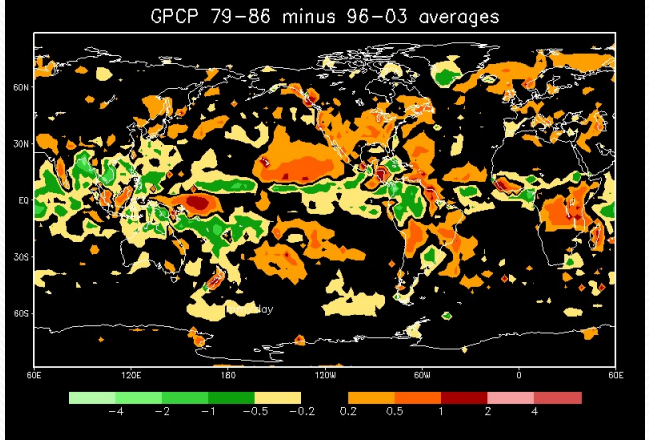




Annual cycle of zonal mean GPCP Precipitation (mm/day) and b) the difference between total period zonal mean 1979 – 2002 and 1979-86/87.







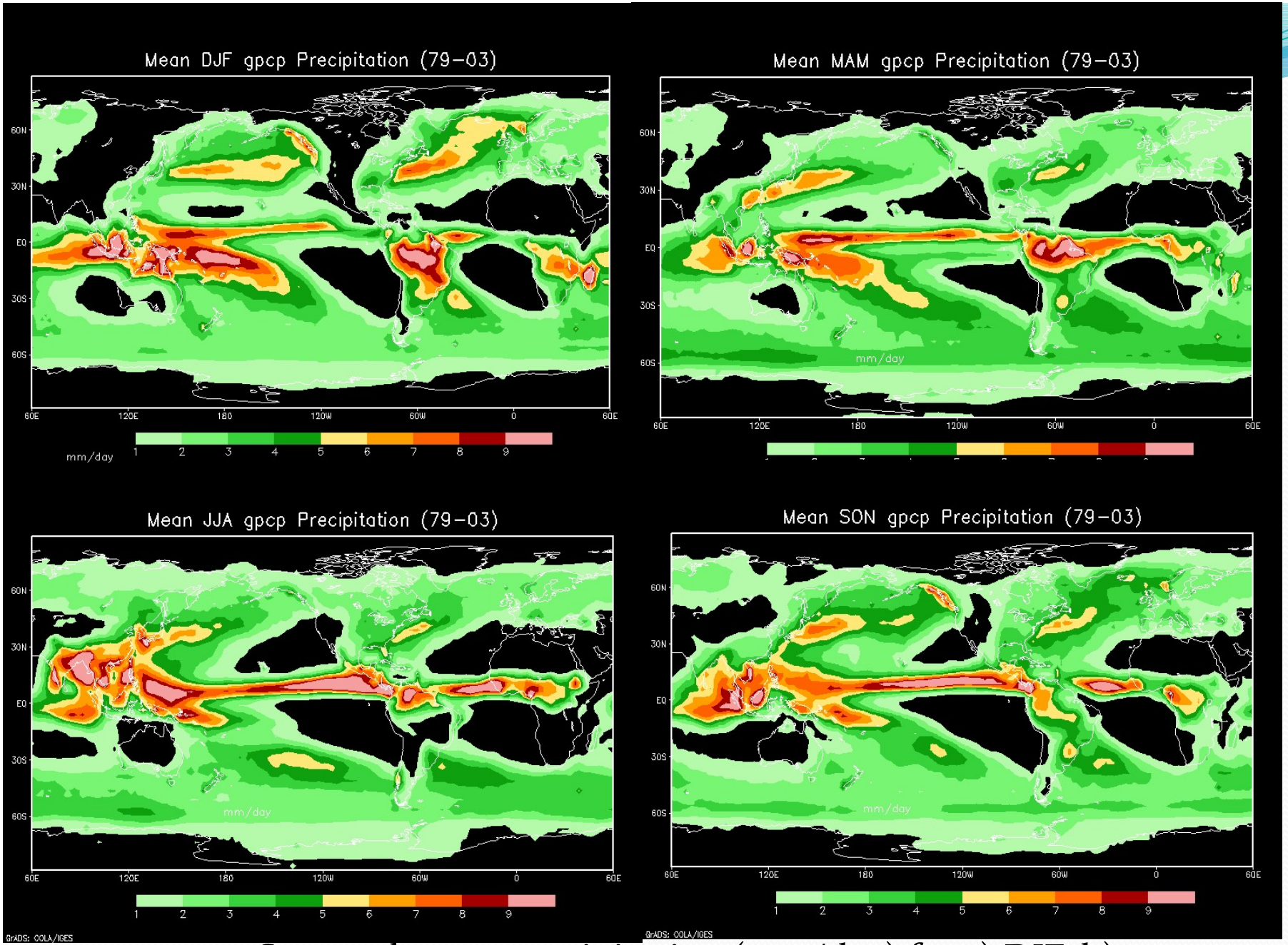
(top) Mean GPCP Precipitation
P1-1979-86 (left)
P2 -1988-95 (middle)
P3- 1996-2003 (right)

Mean Differences

P1 minus P2 left-middle

P2minus P3 rt-middle

P1 minus P3 bottom



Seasonal mean precipitation (mm/day) for a) DJF, b) MAM, c) JJA and d) SON

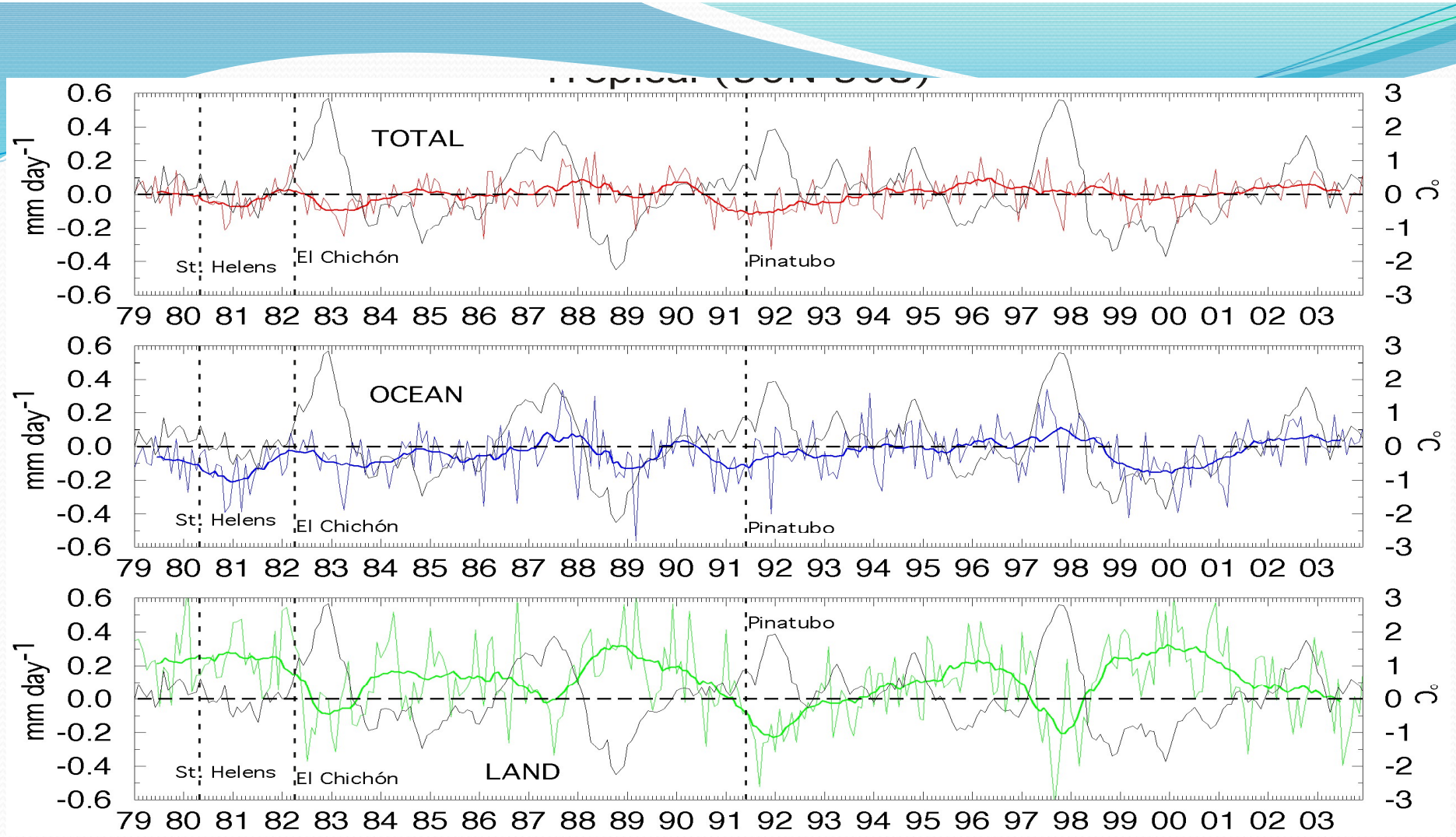


Fig. 9b) Tropical (30°N-30°S) averages of monthly precipitation anomalies (mm day^{-1}) for (top) total, (middle) ocean, and (bottom) land. Vertical dashed lines indicate the months of significant volcanic eruptions. The thin black curves indicate the Niño-3.4 SST index (°C). After Adler et al 2003.

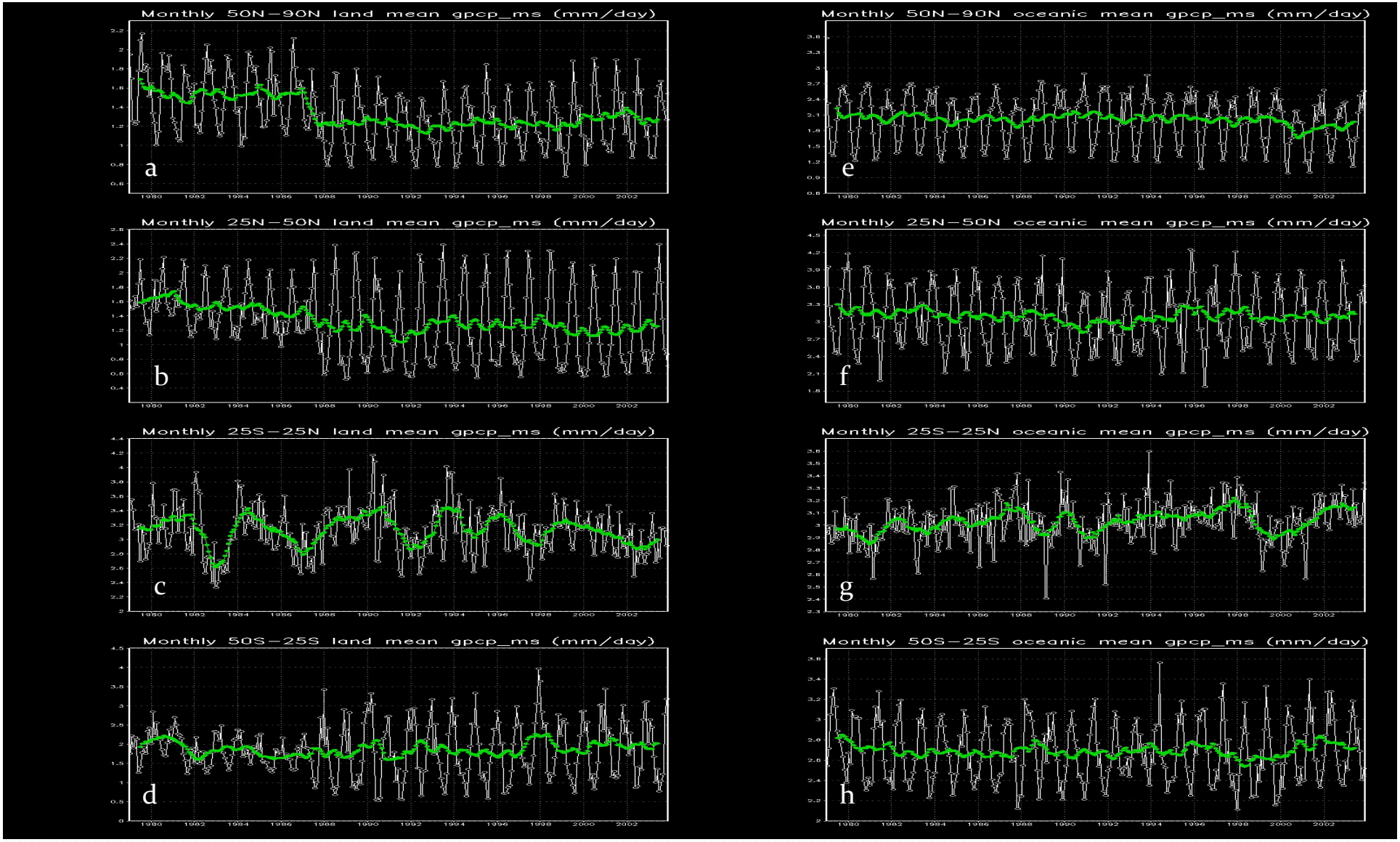


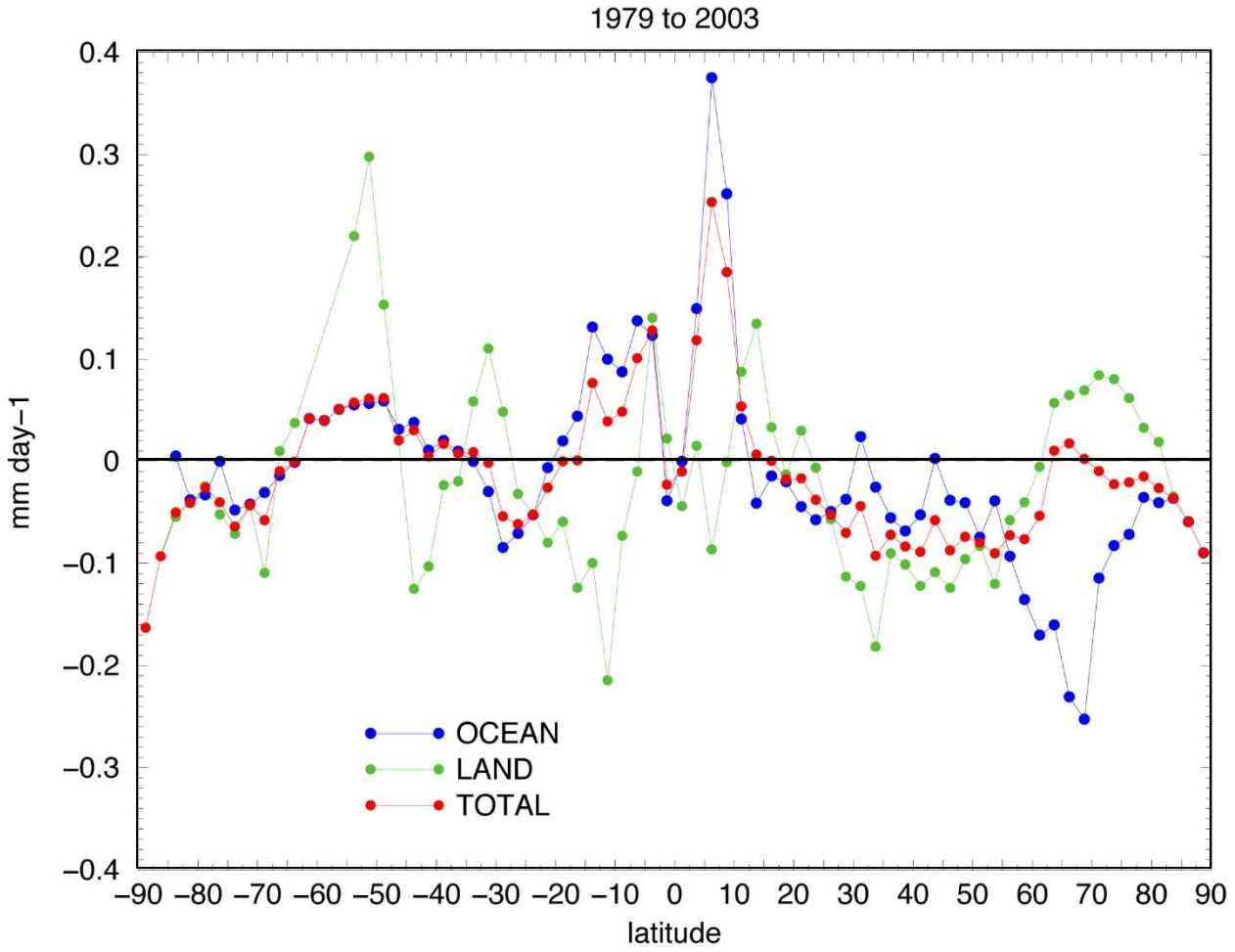
Fig 10. Time series of zonally averaged GPCP estimates over land (left hand panels) and over the ocean (right hand panels). Zonal averages are for 50N to 90N (a,e); 25N to 50N (b,f); 25S to 25N (c,g) and 50S to 25S (d,h). The introduction of microwave data in 1987 is evident for the data over land.

Linear Trend Fit – Zonal Average

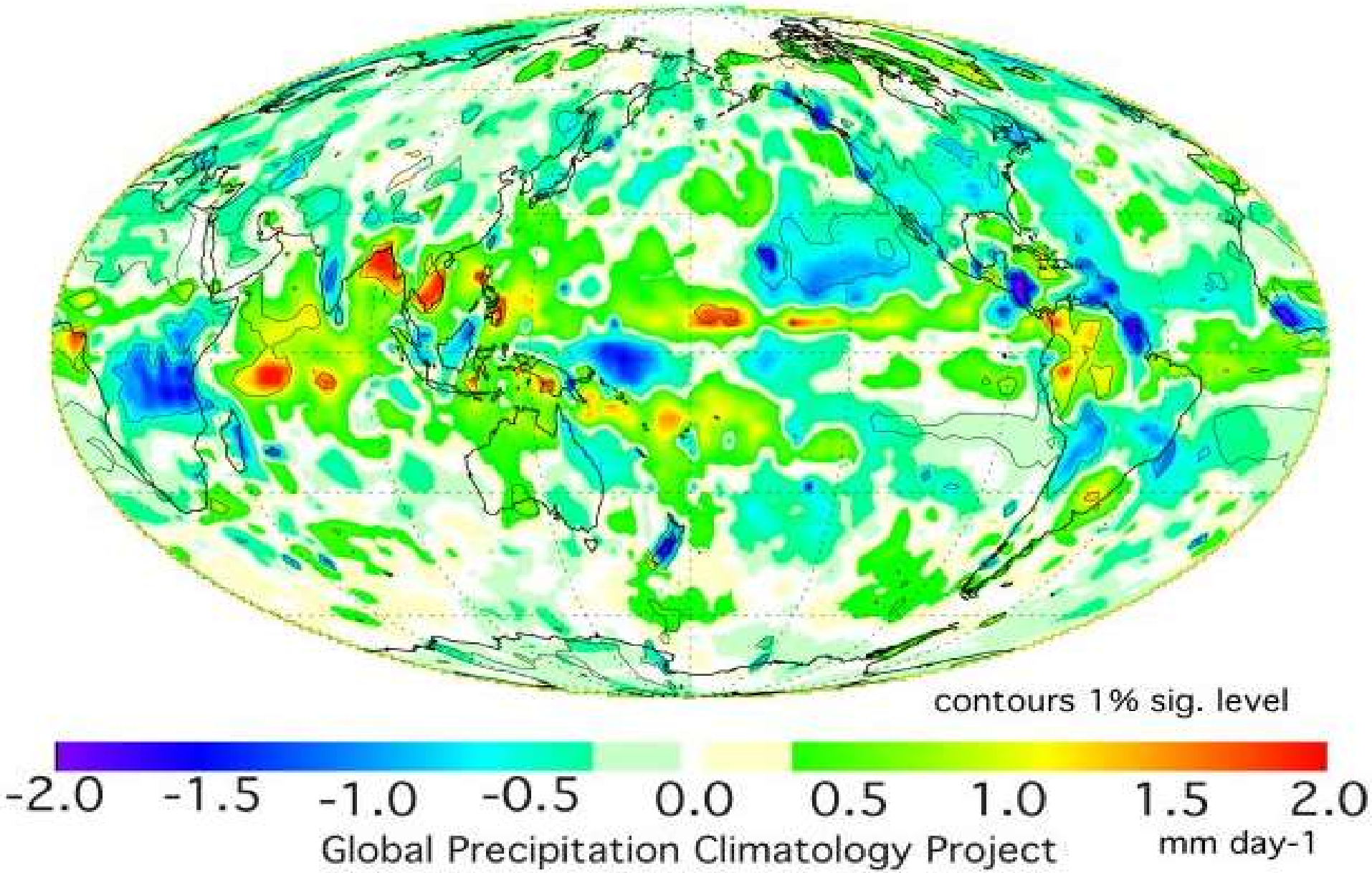
Zonal averages of 25-year linear trend show quite different trends in different lat. bands

Note **regional coherence**.

Land and Ocean are not uniformly related.



Linear trends in the zonally averaged GPCP estimated precipitation.



Map of linear changes in GPCP precipitation anomalies from January 1979 to December 2003. The thin black contour outlines the local 1% significance level.

Summary

- The GPCP Data provide (relatively) **consistent and complete global precipitation estimates** from (1979) to the present.
- These data identify features of the **large-scale precipitation fields** not (well) known before.
  - e.g. oceanic precipitation patterns, storm tracks, individual ENSO patterns
- Global precipitation **shows no significant trends over the period of record** … however regional "trends" are evident in the tropics.
  - These aren't easily untangled from instrumental differences and differences in ENSO in the record.
- **These are research data!!**
  - For real-time monitoring go to CAMS-OPI or other "operational" estimates such as CMORPH