NASA Water Vapor Project – MEaSUREs (NVAP-M) Global Water Vapor Dataset: Latest Results

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STC - METSAT

Science and Technology Corporation - Metsat Division, Fort Collins CO

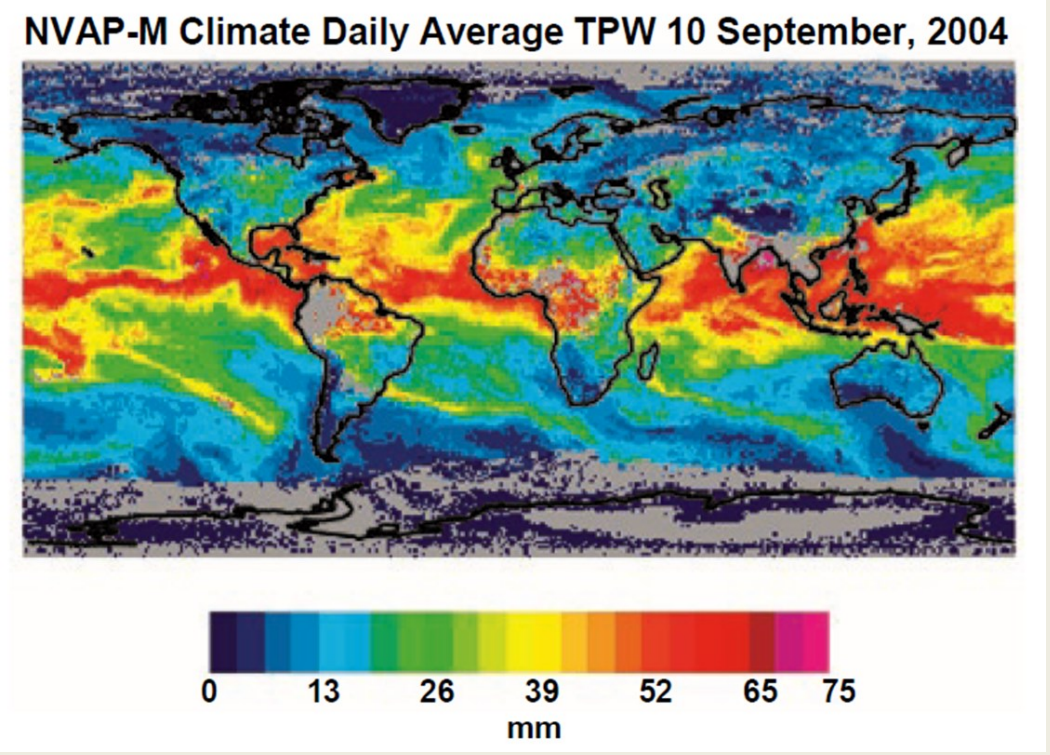
NVAP-M (NVAP (NASA Water Vapor Project) – MEaSUREs)

Produced under NASA MEaSUREs Program: Making Earth System Data Records for Use in Research Environments
G-VAP Workshop, Berlin, October 9-10, 2014

NASA Water Vapor Project – MEaSUREs

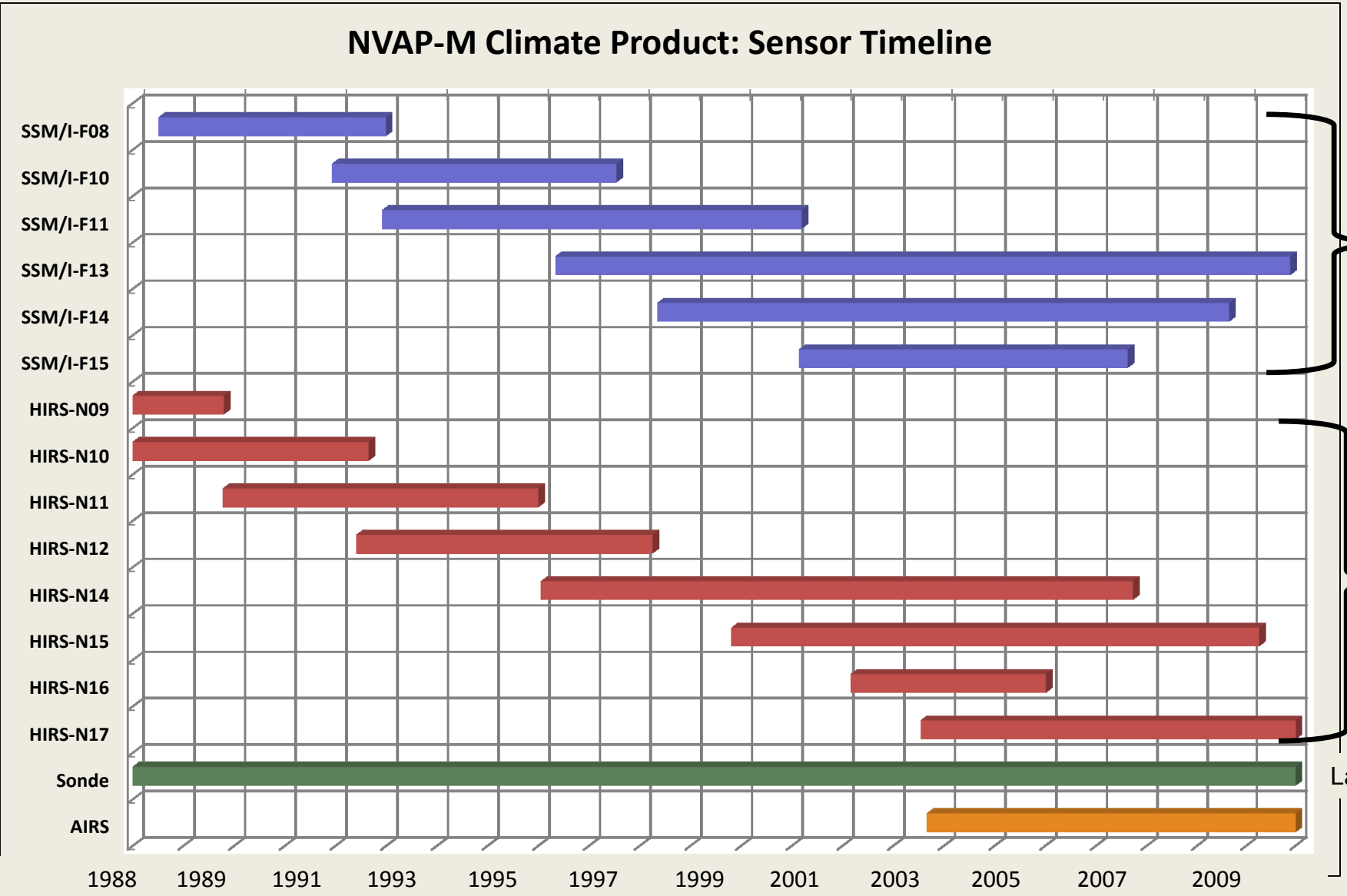
- **Reanalysis**, **extension** (1988-2009) **and replacement** of the heritage NVAP (1988-2001) dataset
- **Global** (land and ocean) data designed for weather, climate and hydrology users
- Total (TPW) and layered (LPW) precipitable water
- **Removes time-dependent biases** caused by dataset and algorithm changes incurred during multi-phase processing.
  - Focus on **consistent data inputs and peer reviewed processing algorithms** through time.
- **Back-propagation of modern observations** through the entire data period.
  - Collaboration with AIRS water vapor project at NASA JPL. (E. Fetzer et al.)
- Highly model-independent
- **Available at NASA Langley Atmospheric Science Data Center (ASDC):** https://eosweb.larc.nasa.gov/project/nvap/nvap-m_table

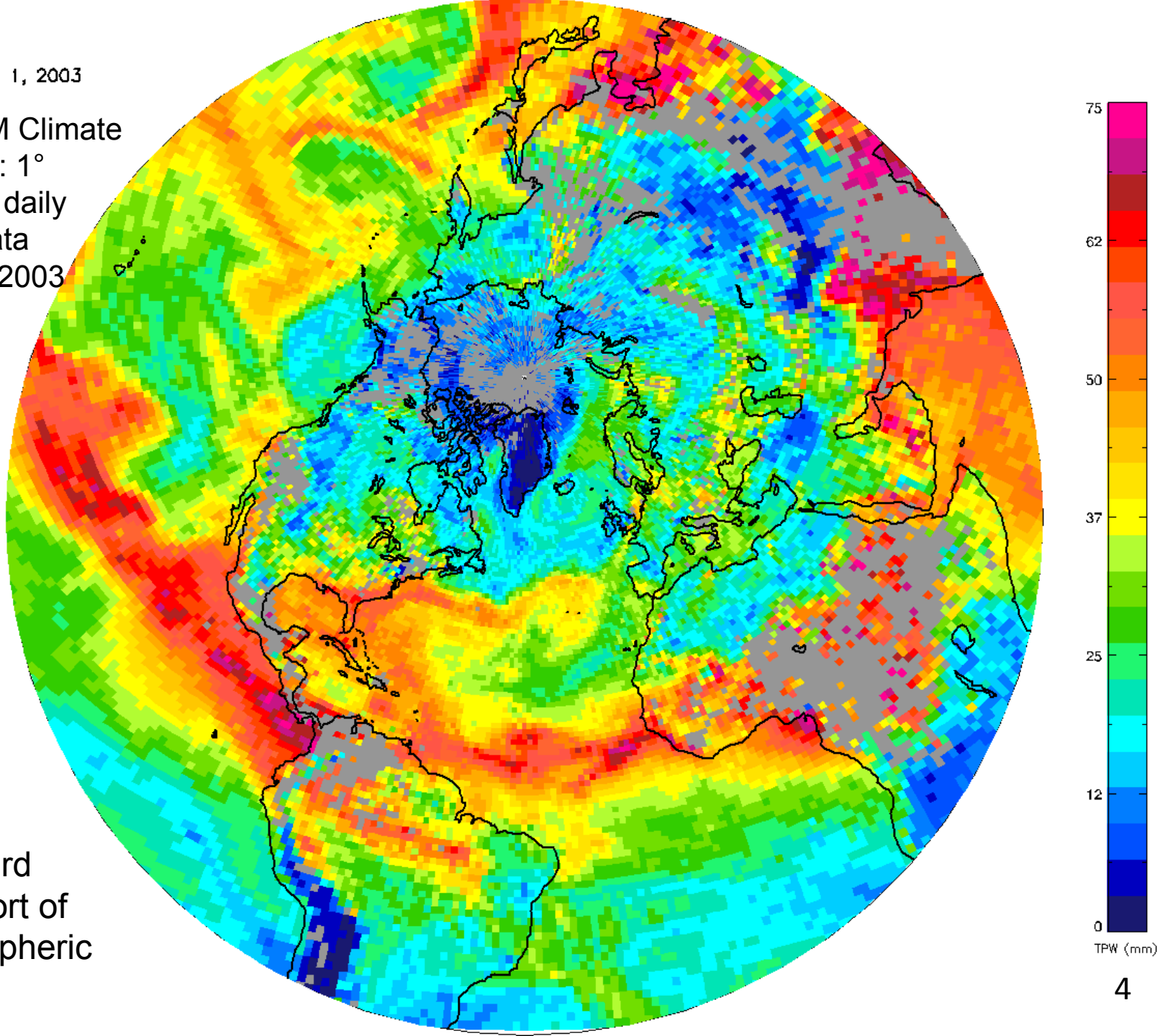
Similar in concept to GPCP, ISCCP, but with three products: Climate, Weather, Ocean.



Vonder Haar et al. 2012: Weather and climate analyses using improved global water vapor observations. *Geophys. Res. Lett.*, **39**, L15802. doi:10.1029/2012GL052094.

"NVAP-M" refers to the new NVAP-MEaSUREs data set. "Heritage NVAP" refers to the existing dataset described by Randel et al., 1996


NVAP-M Climate Product: Sensor Timeline
SSM/I-F08
SSM/I-F10
SSM/I-F11
SSM/I-F13
SSM/I-F14
SSM/I-F15
HIRS-N09
HIRS-N10
HIRS-N11
HIRS-N12
HIRS-N14
HIRS-N15
HIRS-N16
HIRS-N17
Sonde
AIRS
1988
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
Ocean only
Clear sky only
Land only



NVAP-M Climate Dataset: 1° gridded daily TPW data August 2003

Notice poleward transport of "atmospheric rivers"

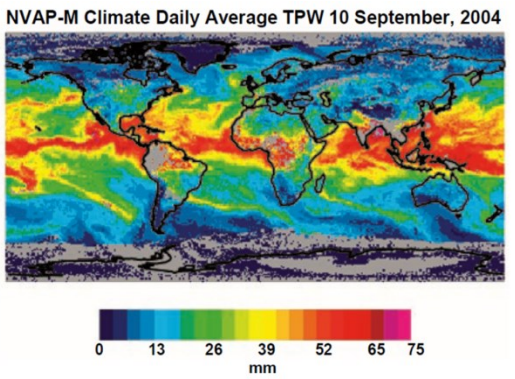
NVAP-M: A Three-Tiered Product Approach

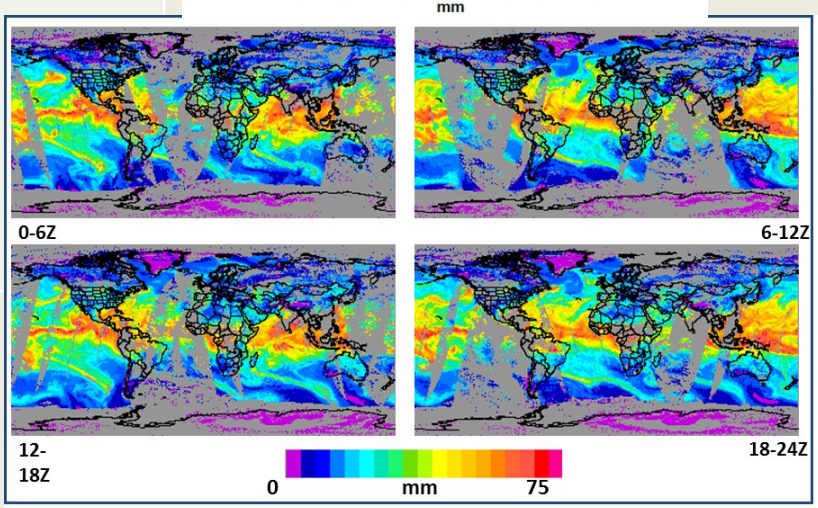
Heritage NVAP begun in early 1990's was "one size fits all" approach.

NVAP-Weather	NVAP-Climate	NVAP-Ocean
Used for weather case studies on timescales of days to weeks	Used for studies of climate change and interannual variability	SSM/I-only.
•SSM/I Level 1 C intercalibrated radiances •HIRS cloud cleared radiances •Radiosonde, GPS since 1997 •AIRS Level 3 TPW and Layered PW	•SSM/I Level 1 C intercalibrated radiances •HIRS cloud cleared radiances, + AIRS since 2002 • Radiosonde	
•Maximizes spatial and temporal coverage •Not driven by reduction of time-dependent biases	•Consistent inputs through time. •Consistent, high quality retrievals. •Less emphasis on spatial and temporal coverage	
•4x daily •½ degree resolution • TPW and layered precipitable water •surface to 700 hPa •700 to 500 hPa •500 to 300 hPa • < 300 hPa.	•Daily •1-degree resolution •TPW • layered precipitable water •surface to 700 hPa • 700 to 500 hPa • 500 to 300 hPa • < 300 hPa	

Supplemental Fields

•Data source code (DSC) map, indicating the sources used in each grid box .





Current Status

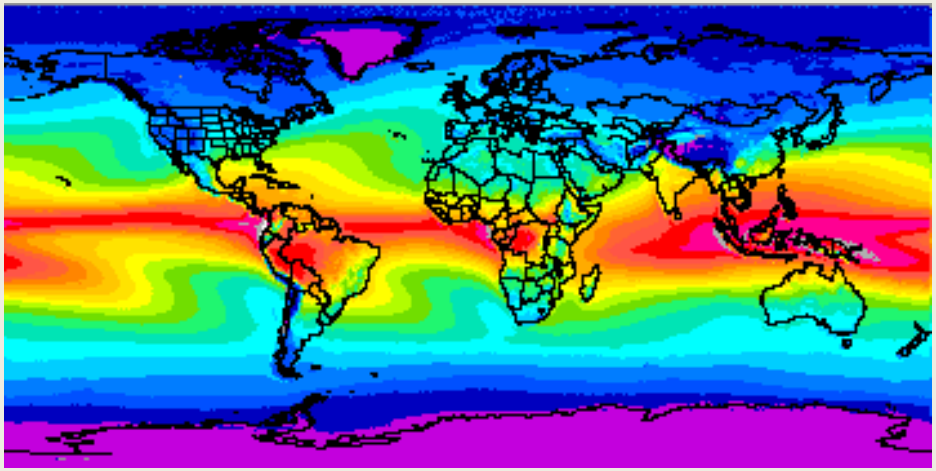
- Over 170 users worldwide have withdrawn the data since spring 2013.
- Most of our analysis has been on the total precipitable water vapor, not the four layers from sonde and AIRS / HIRS.
- A research focus is: What is the effect of time-dependent sampling (land / ocean, clear / cloudy) on global trend results?
- Our group is currently not funded by NASA for follow-on science.

Climatology of NVAP-M

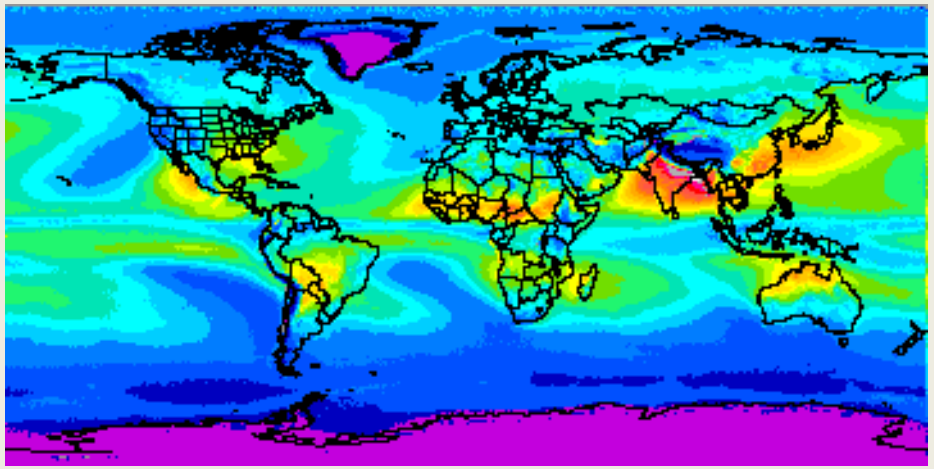
Global mean Total Precipitable Water Vapor (TPW) from the new NVAP-M Climate Dataset:

25.3 mm

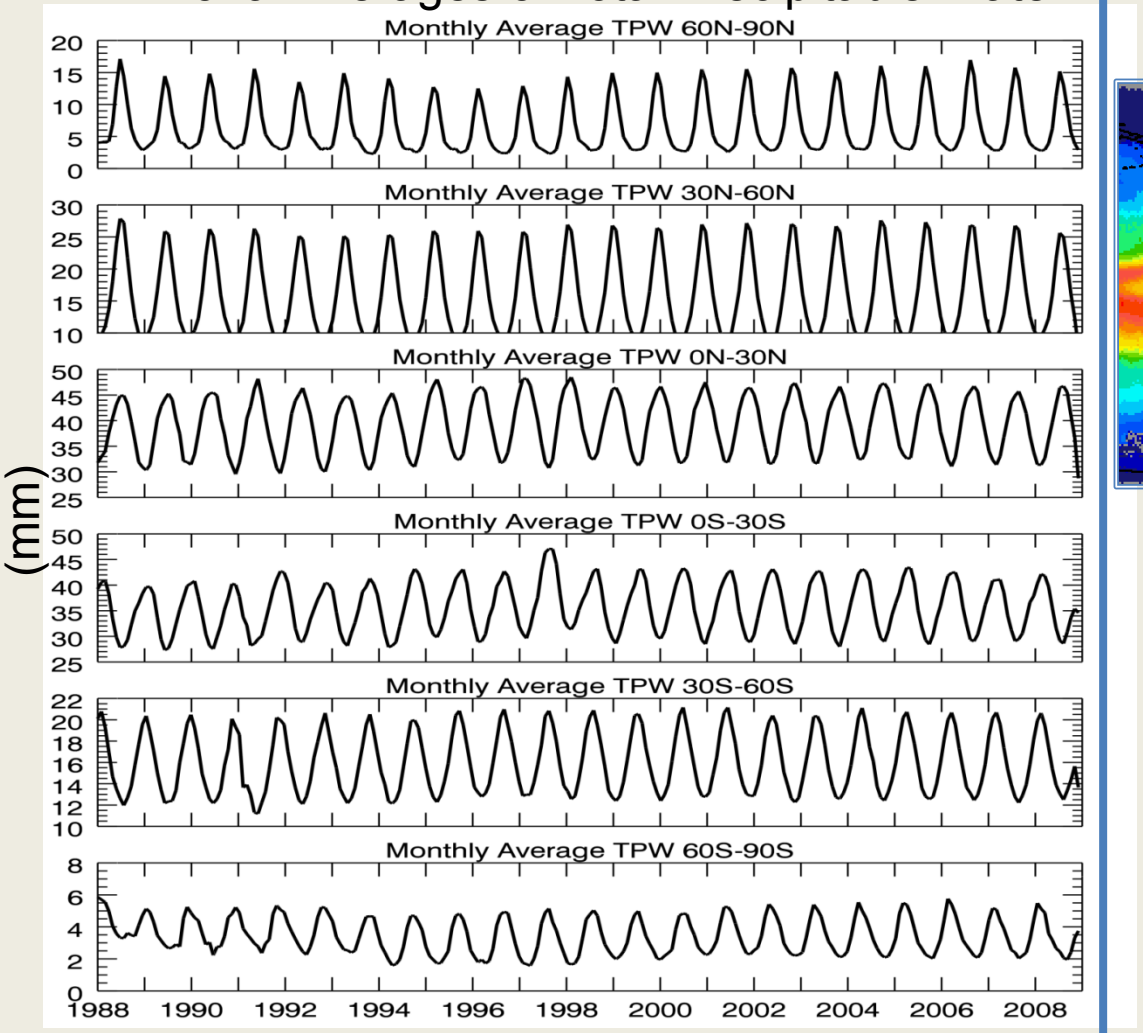
NVAP-M Climate Average TPW 1988-2009



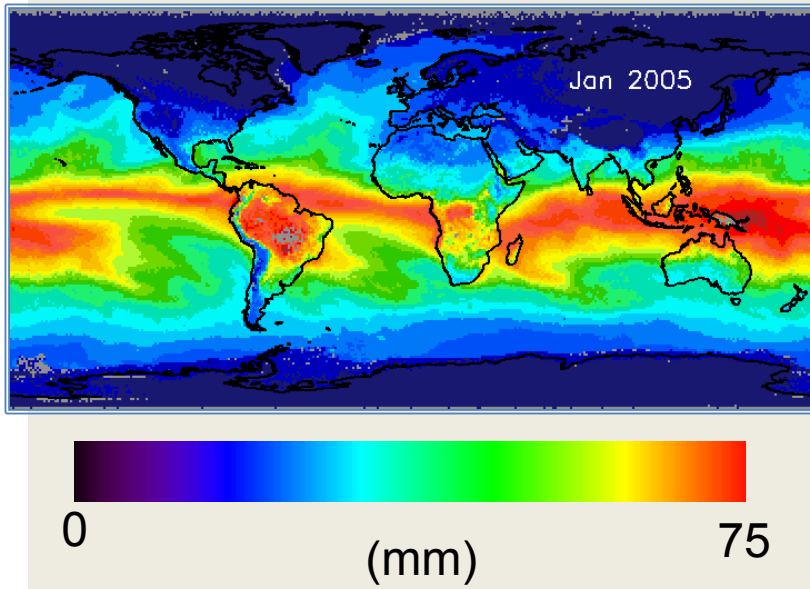
NVAP-M Climate TPW Standard Deviation 1988-2009



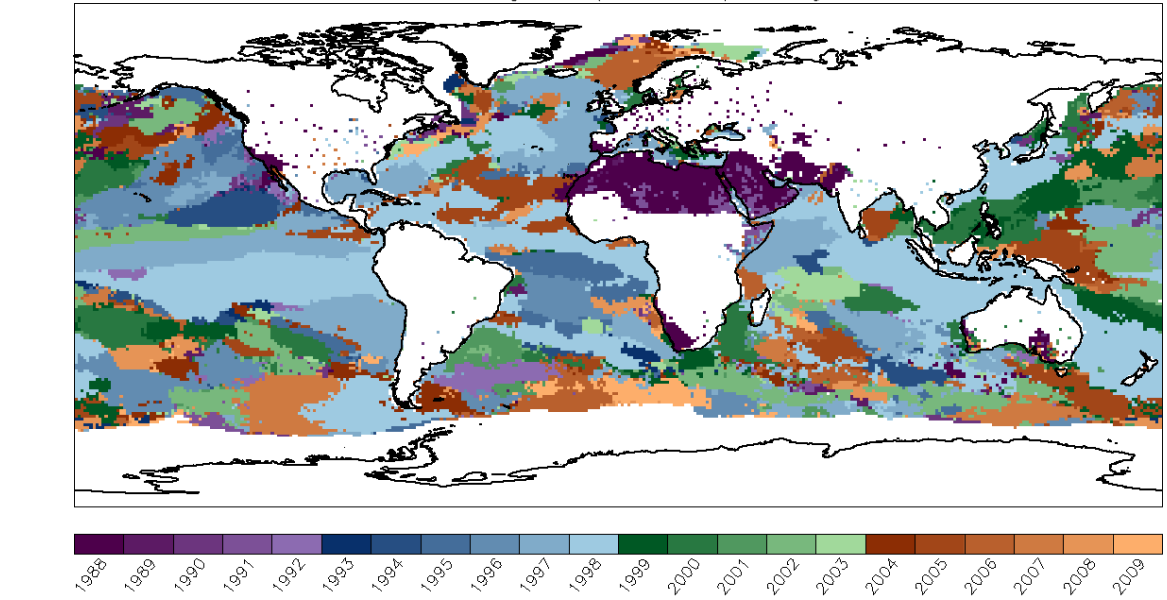
Zonal Averages of Total Precipitable Water



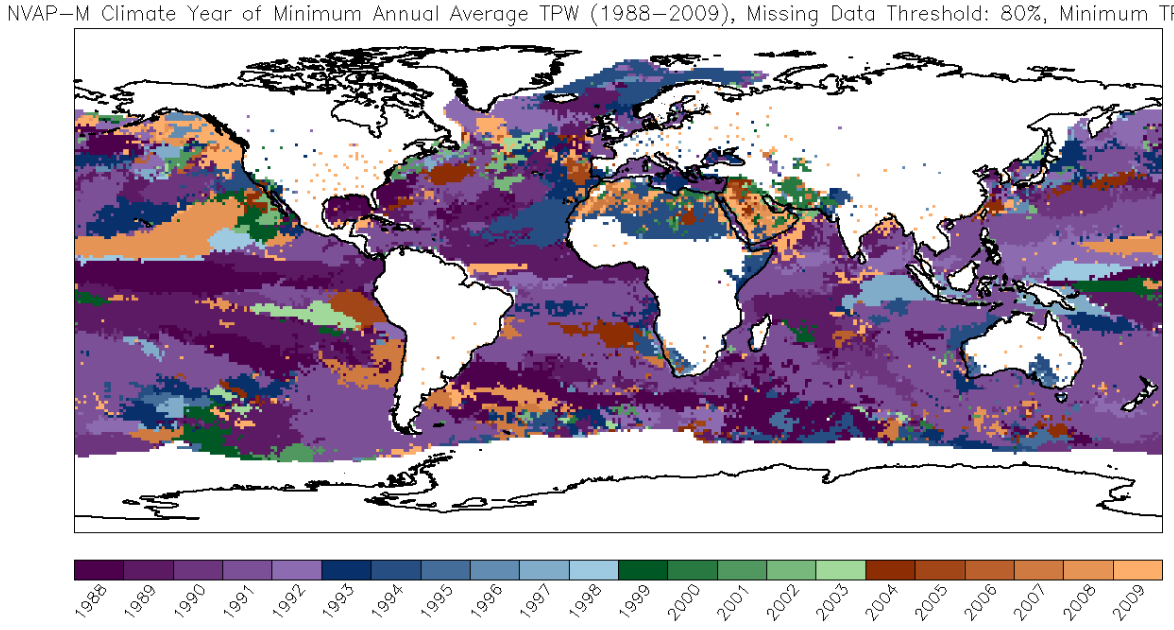
Monthly Mean TPW (mm) from NVAP-M Climate for 2005



- Strong annual cycle is found in all latitude zones
- ENSO of 1997-1998 most apparent in 0-30° S



Year of Maximum Annual Average TPW

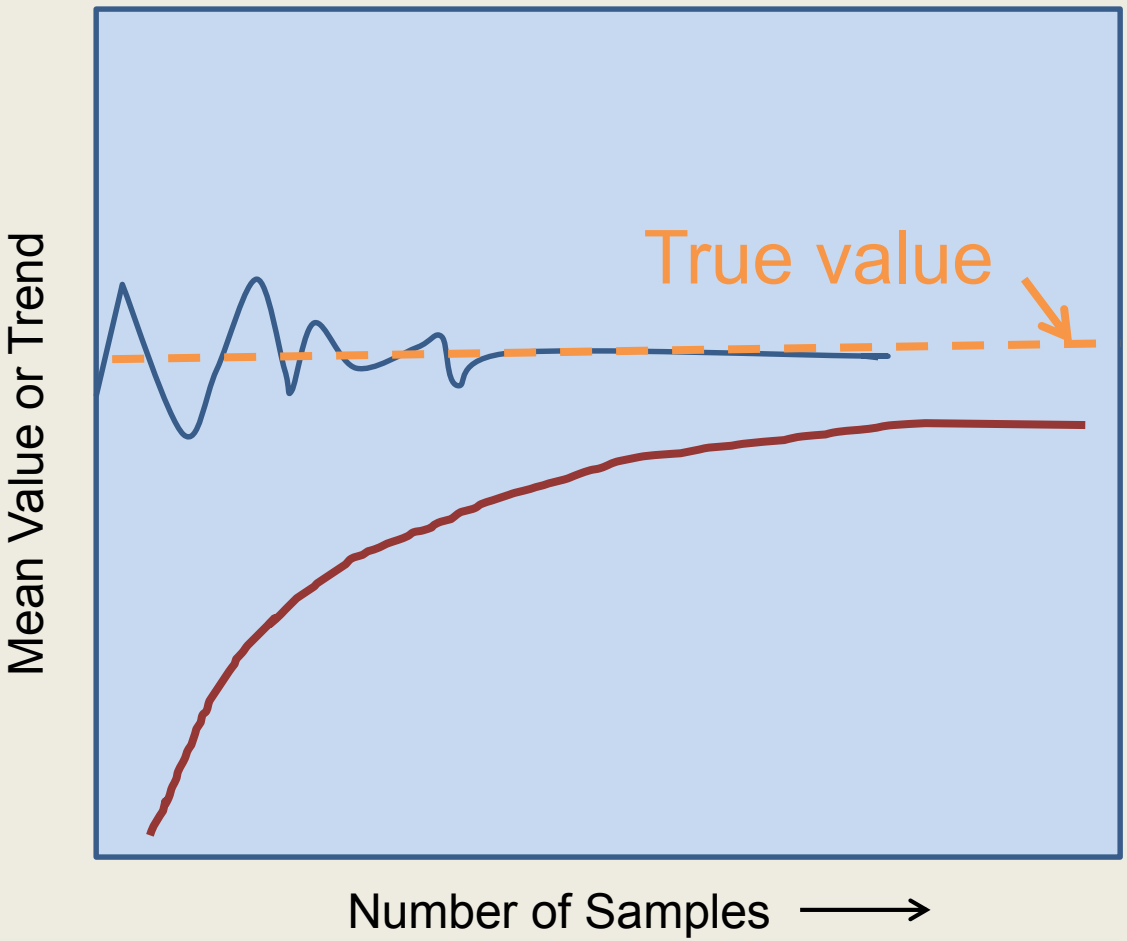


Year of Minimum Annual Average TPW

The Challenge of Time-Dependent Sampling

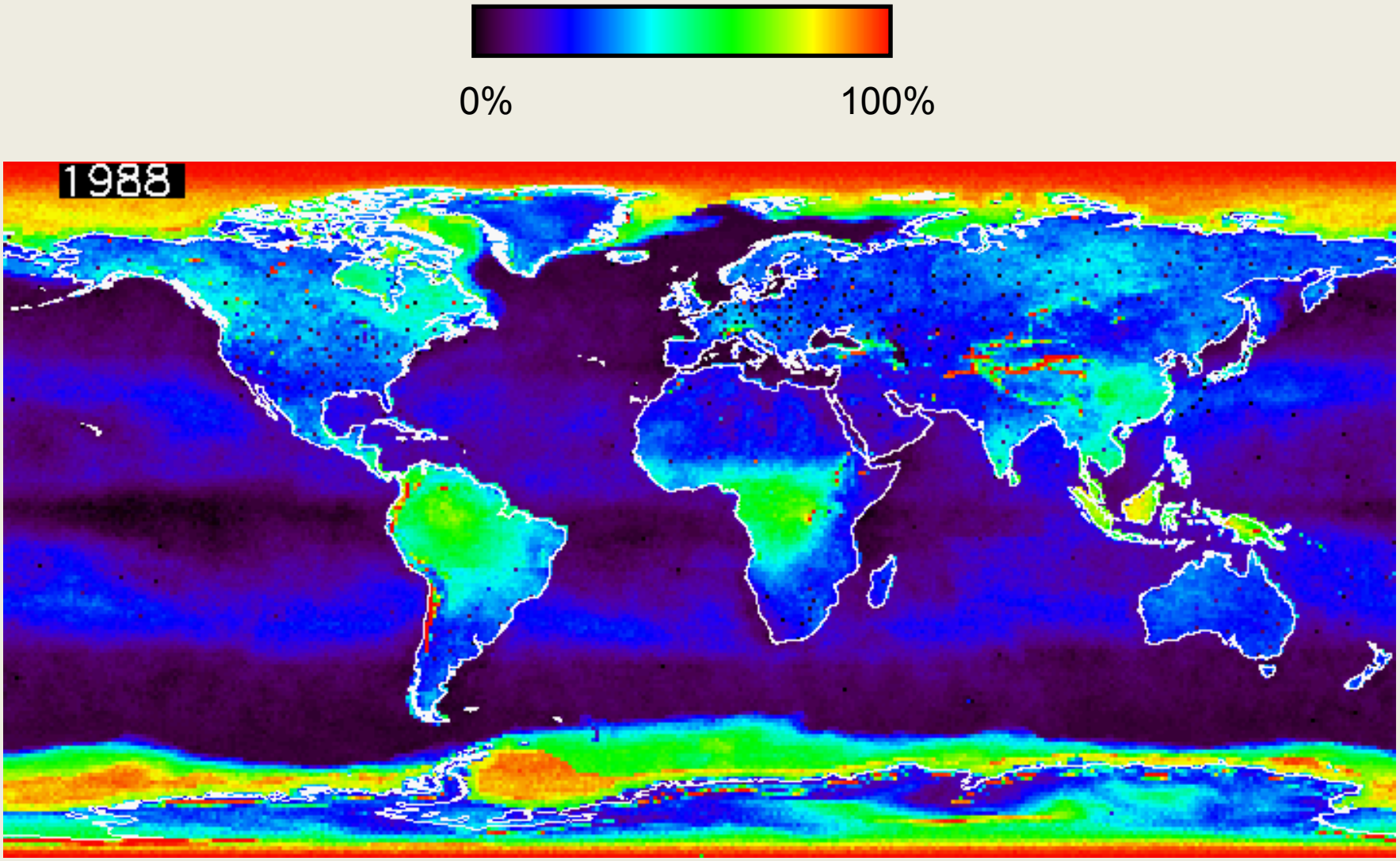
- Especially in the study of global and regional trends

Conceptual Diagram

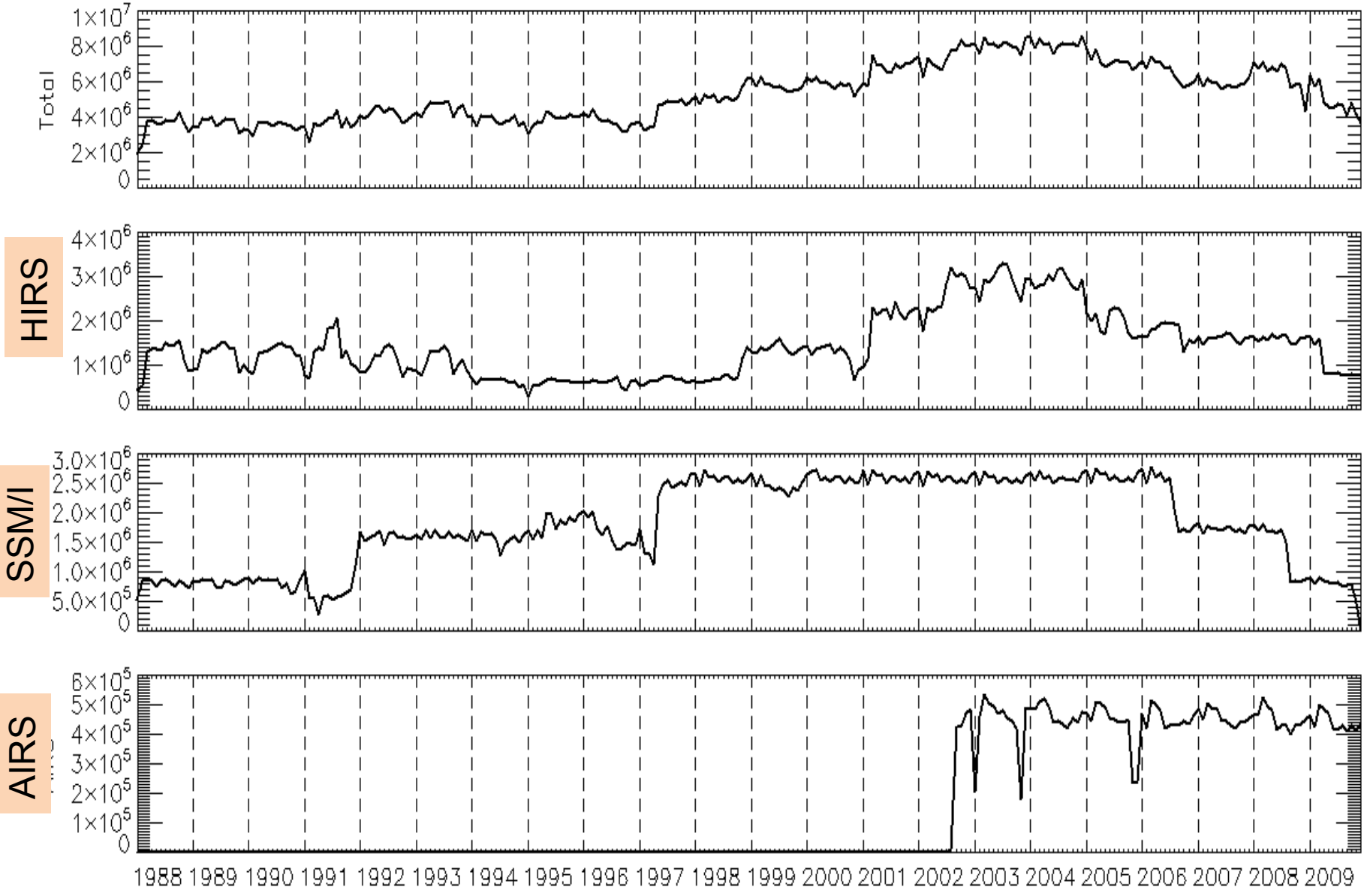


How are our estimates influenced by sampling (clear / cloudy, land / ocean…) ?

Percentage of Time TPW Missing from NVAP-M Climate (1988-2009)

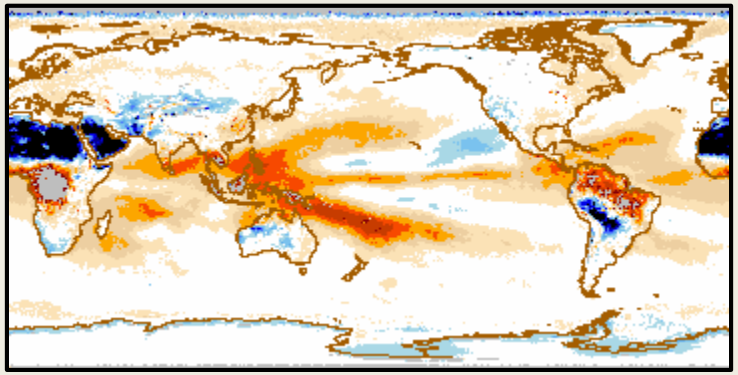


Number of grid boxes in NVAP-M Climate using each data type

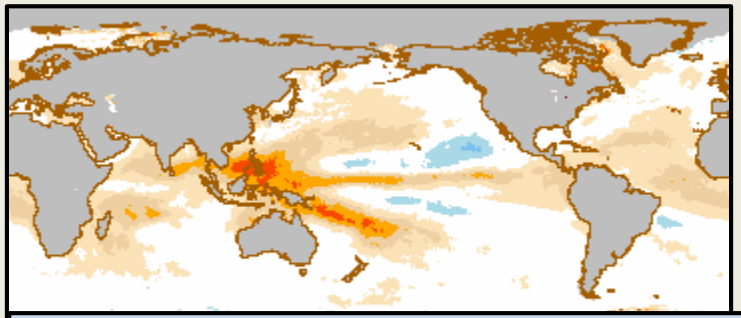


How do these changes affect results?

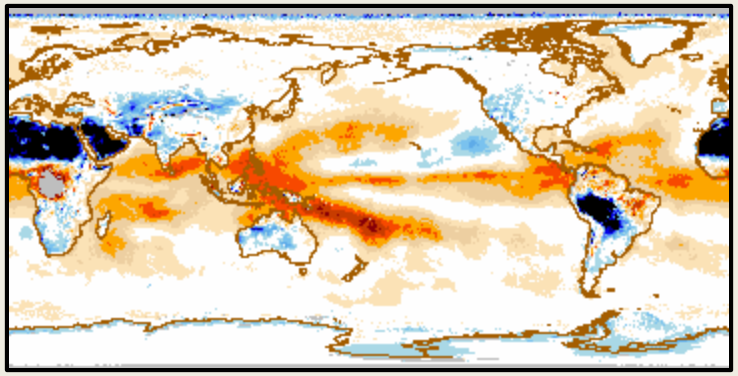
1988 – 2009 Trends with Data Witholding



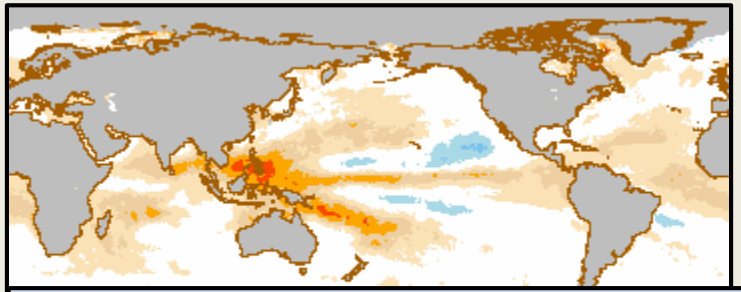
Unfiltered NVAP-M
+ 0.51 mm / decade



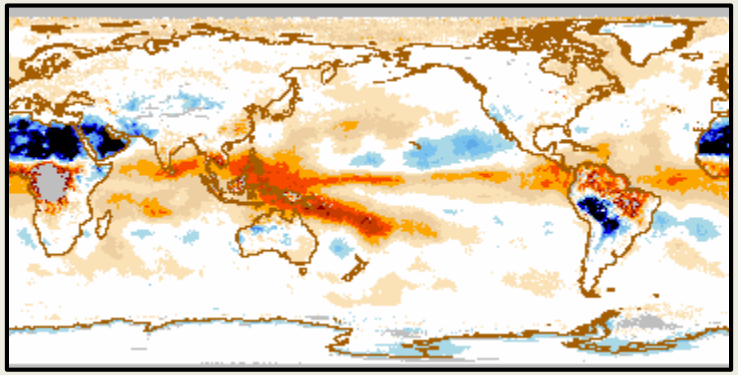
NVAP-Ocean Unfiltered +0.53 mm / decade



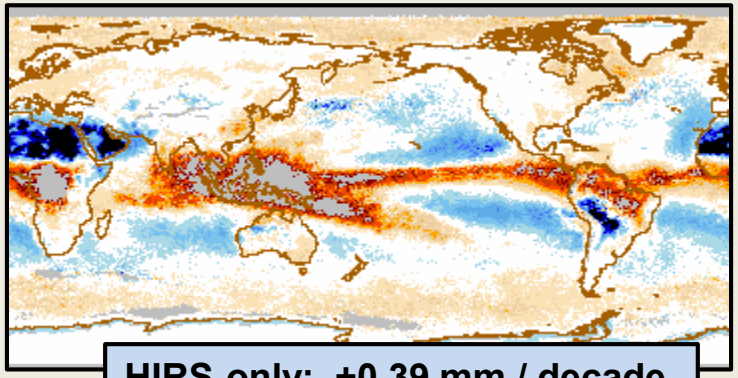
Two infrared, one SSM/I per day, no sondes
+ 0.45 mm / decade



NVAP-Ocean: One SSM/I per day +0.51 mm / decade



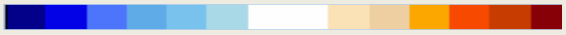
Two infrared, one SSM/I per day, No AIRS
+ 0.48 mm / decade



HIRS-only: +0.39 mm / decade

Insufficient data

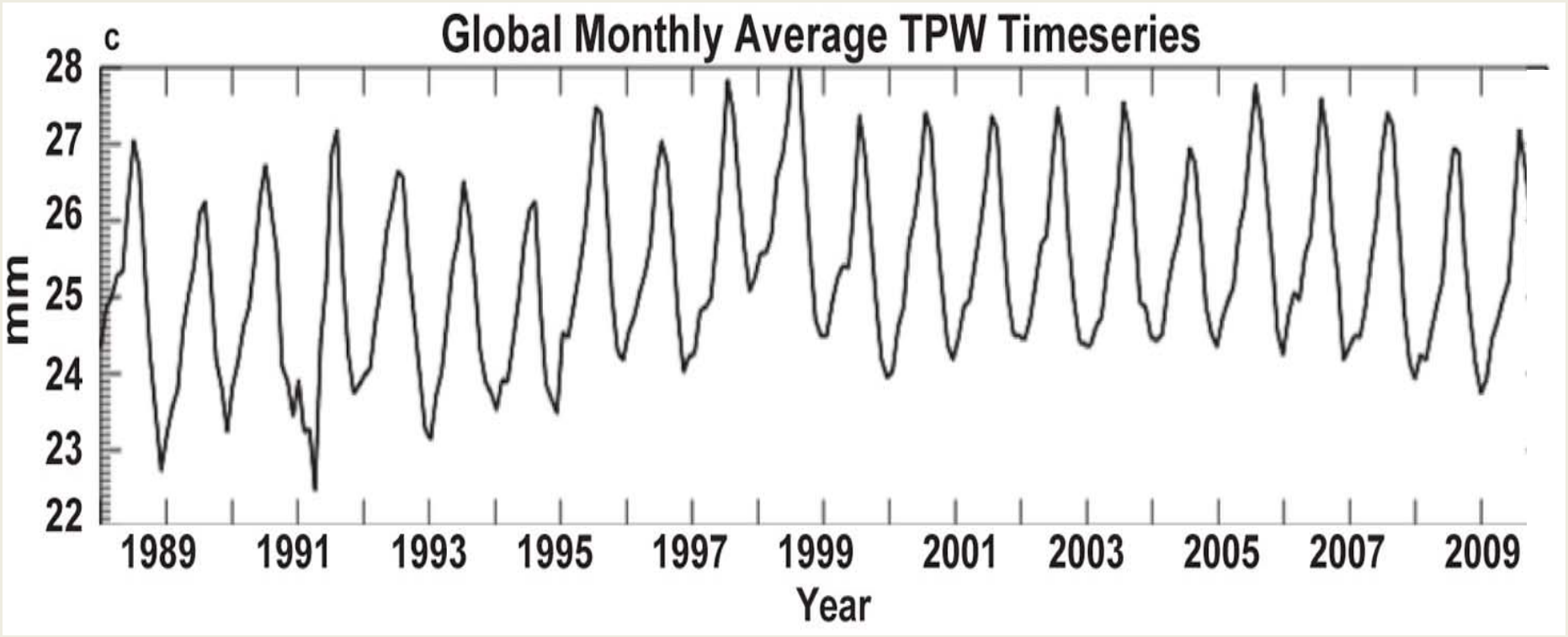
-3.5



+3.5

(mm / decade)

At this time
- due to time-varying sampling effects currently under study -
we can neither prove nor disprove a robust trend in the global water vapor data from the NVAP-M Climate data set (over land and ocean)



Journal Acronyms for Total Water Vapor in a Column (July 2013 search)

Acronym	AMS Journals	J. Geophy Res.
TPW	131	36
IPW	13	6
PWAT	23	10
IWV	33	67
TCWV	36	13
PWV	89	103
TWV	12	3
PWC	21	11
IPWV	4	1
PWAV	0	0
VIM	7	0
WVP	27	9
TPWV	2	0
WVPA	0	0
PRW	5	6
LPW (layered)	5	

At least 15 different acronyms

An Aside:

Can we agree on and recommend standardized terminology?

From AMS Glossary of Meteorology:
The total precipitable water is that contained in a column of unit cross section extending all of the way from the earth's surface to the "top" of the atmosphere. Mathematically, if $x(p)$ is the mixing ratio at the pressure level, p, then the precipitable water vapor, W, contained in a layer bounded by pressures p_1 and p_2 is given by

$$W = \frac{1}{g} \int_{p_1}^{p_2} x\,dp,$$

Summary

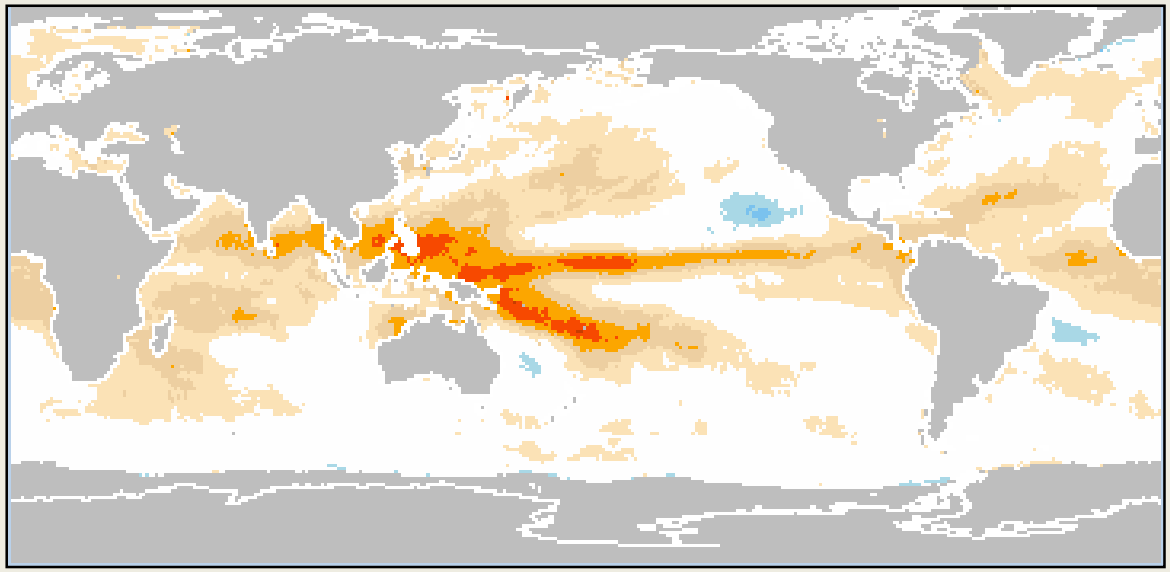
- NVAP-MEaSUREs reprocesses, extends and replaces the original NVAP dataset. Consistency of input datasets and algorithms with time is a main focus of NVAP-M.
- Data is available at the NASA Langley ASDC.
- Changes in satellite sampling with time continue to hinder the ability to claim a significant robust global trend in TPW.
- Multisensor records of water vapor are challenging, but allow a global depiction of water vapor. The concept of creating different processing paths (Climate, Ocean, Weather) has proven useful for meeting the needs of diverse users.
- Dataset ends in 2009, a future reprocessing and extension (possibly including other sensors) is envisioned.

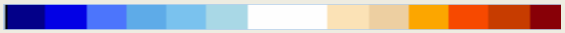
We acknowledge the support of the NOAA NEAT Program (Fuzhong Weng technical lead) and the NASA MEaSURES program

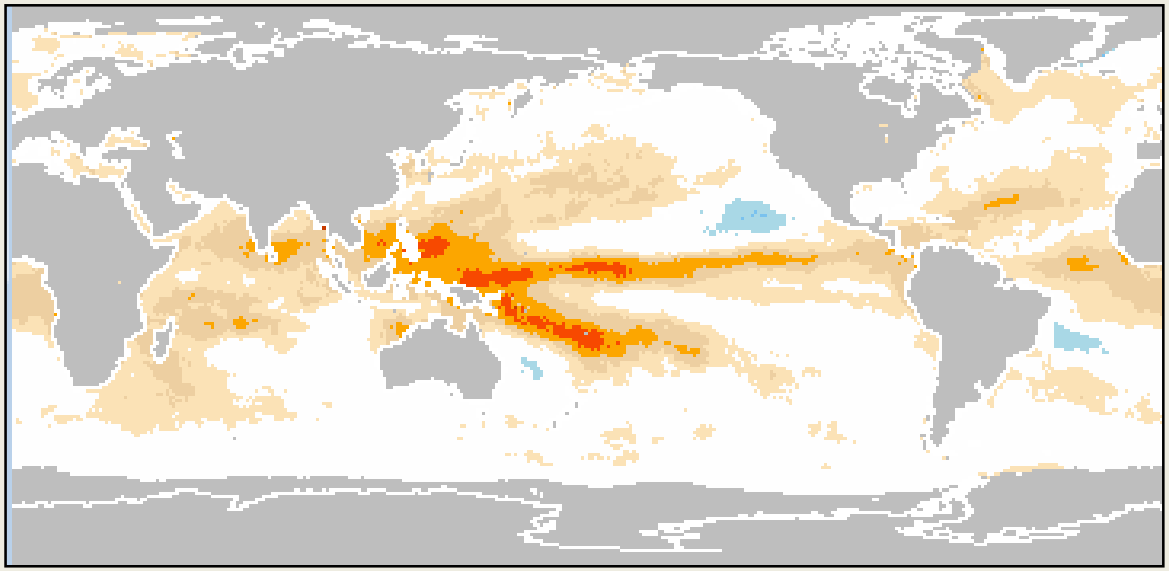
Backup Slides

Preliminary Trend Analysis

New intercalibrated SSM/I-only data over ocean are shown with two trend estimators







1988-2007 NVAP-Ocean Trend

TPW Trend from least squares linear regression

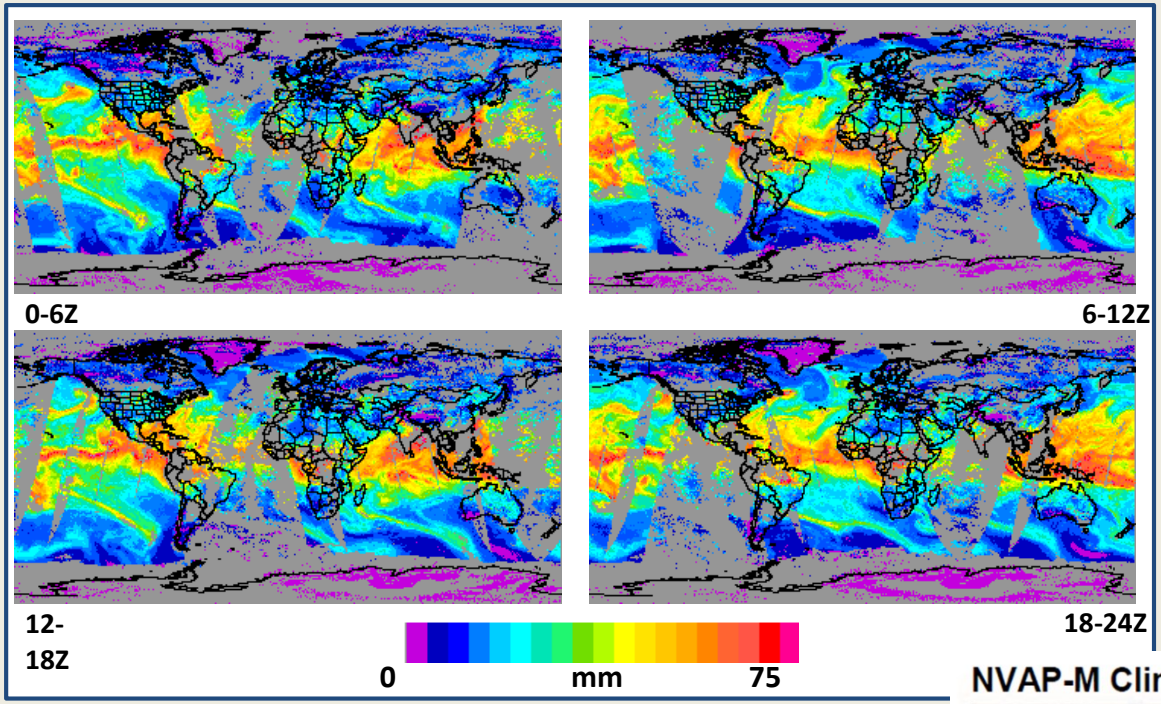
Ocean mean +0.61 mm / decade

TPW Trend from Theil-Sen slope estimator

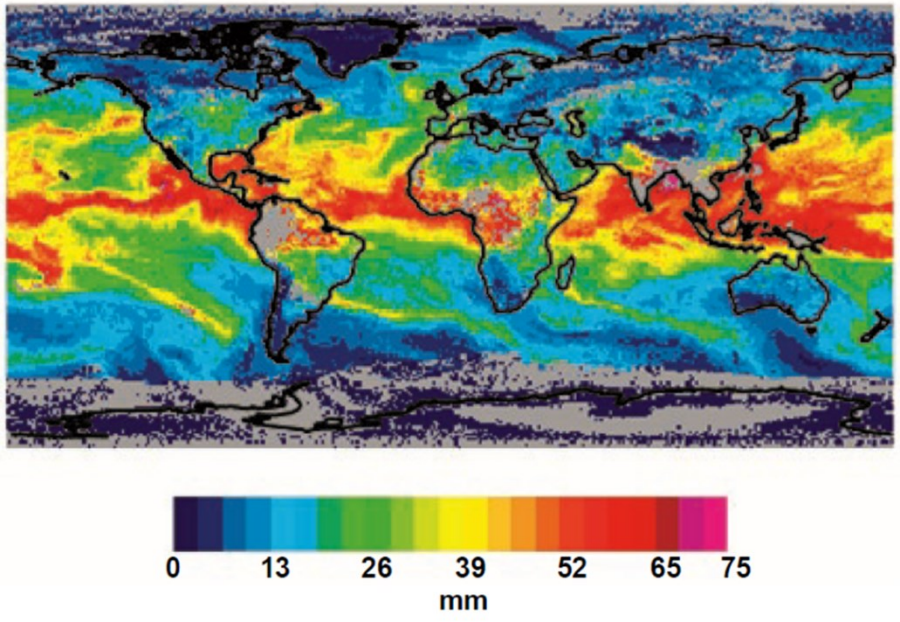
- less sensitive to extreme values
- slight reduction in ENSO region

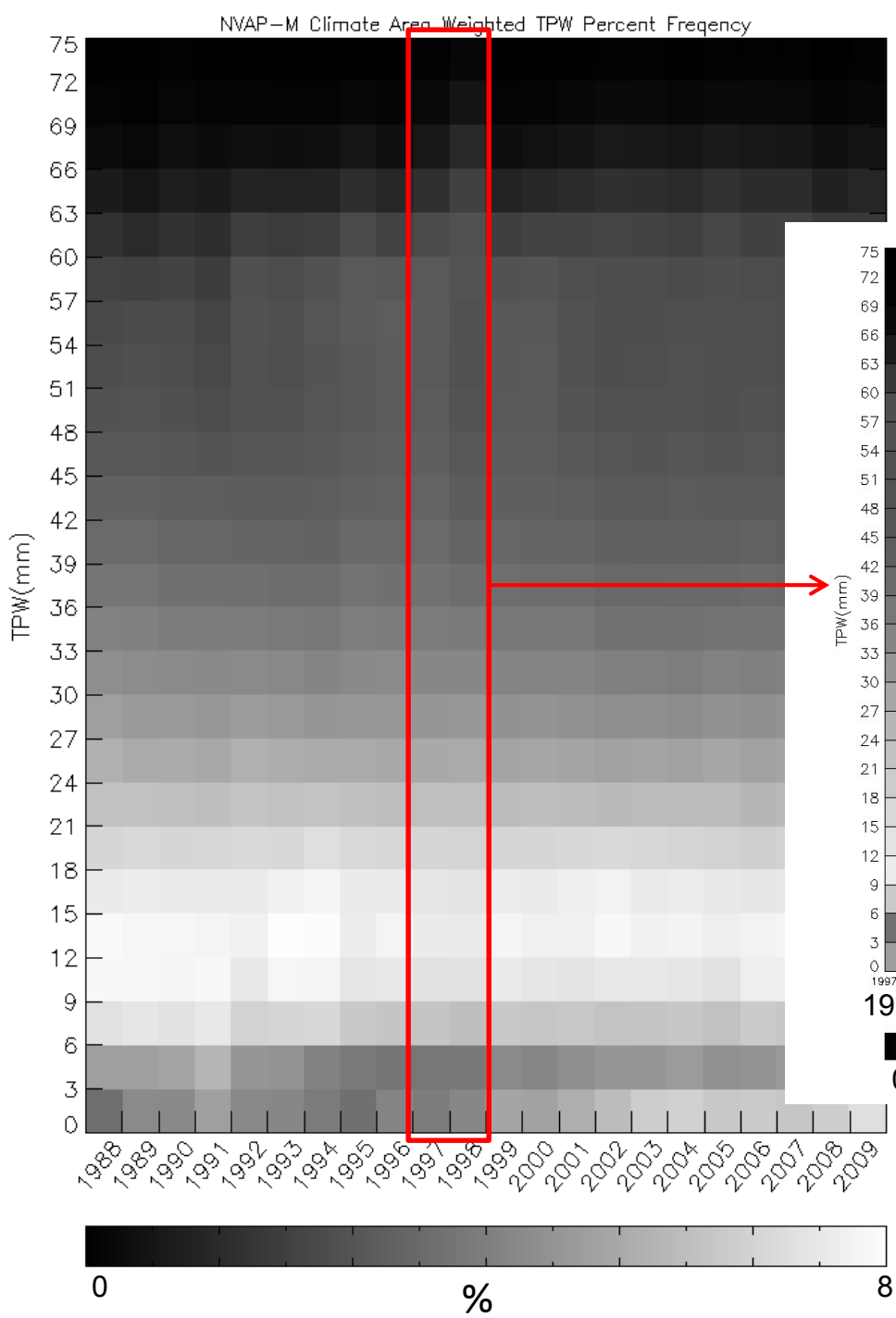
Ocean mean +0.61 mm / decade

NVAP-M Weather vs. Climate Product

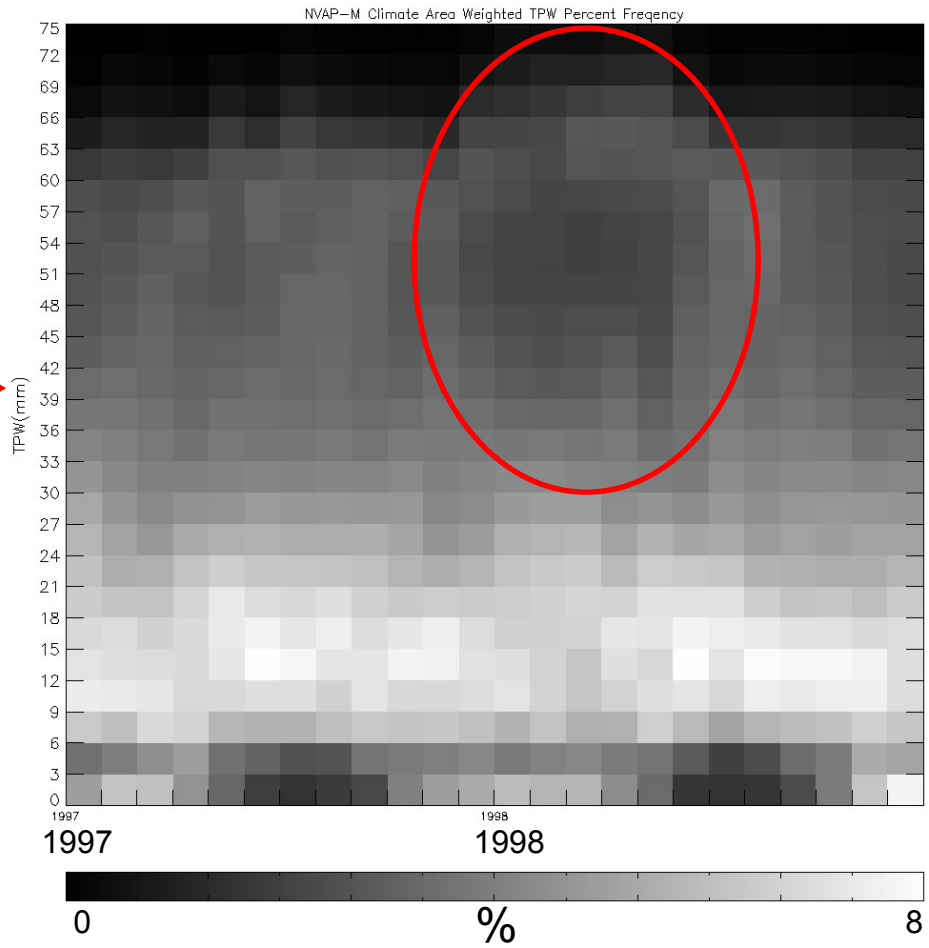


NVAP-M Climate Daily Average TPW 10 September, 2004



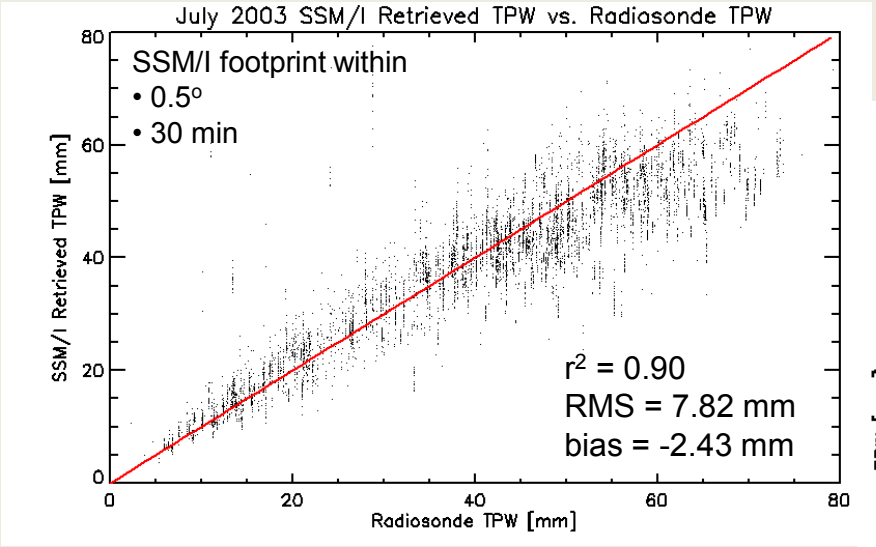


- NVAP-M Climate Dataset
- Annual frequency
- 3mm bins
- Area-weighted bin count

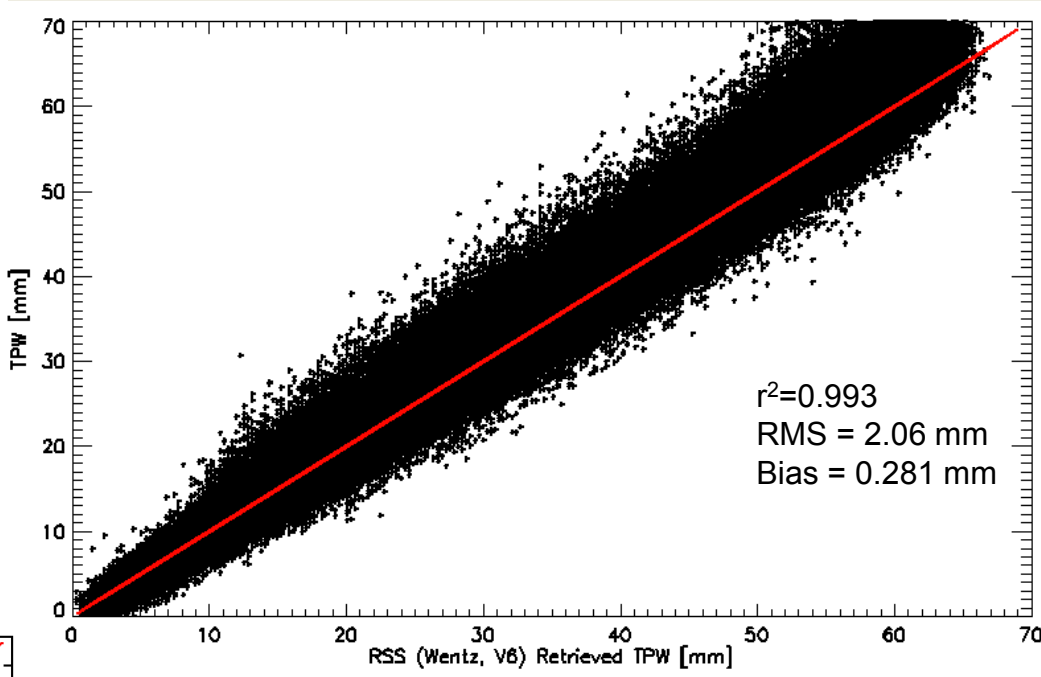


- El Niño caused a higher frequency of high TPW values and a lower frequency of mid-level TPW values as compared to surrounding years

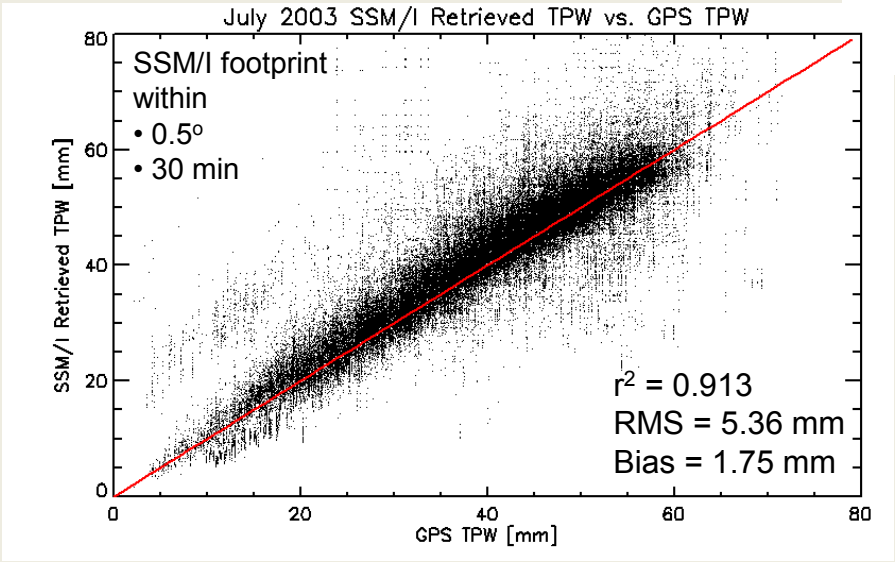
SSM/I Retrieved TPW



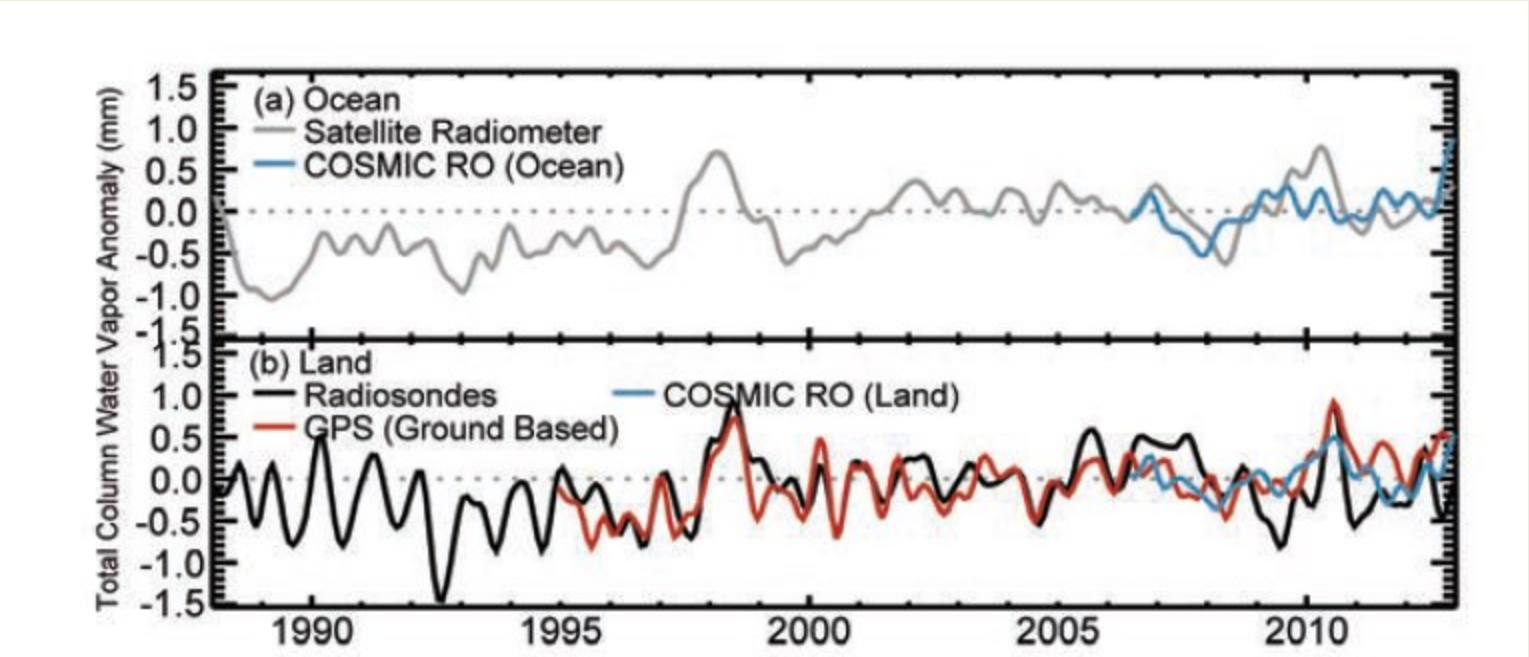
Radiosonde



Remote Sensing Systems V6



GPS Islands / Coastal



BAMS State of Climate 2012

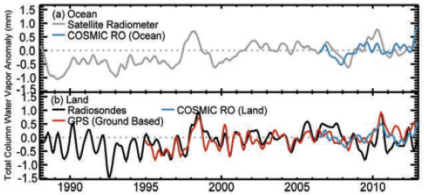
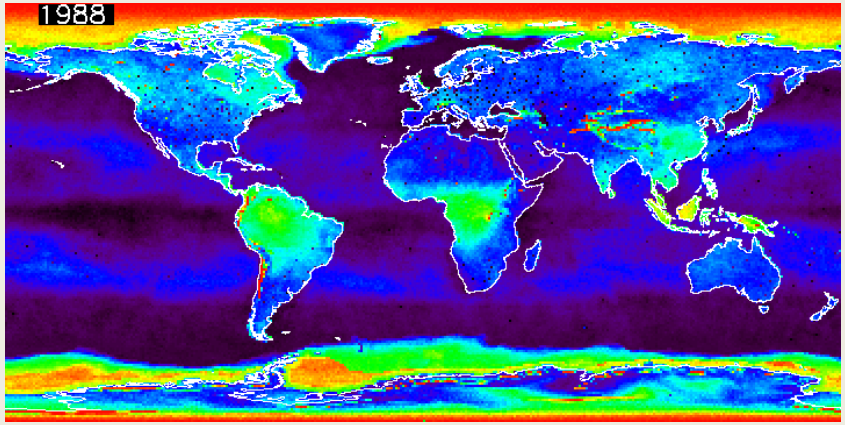
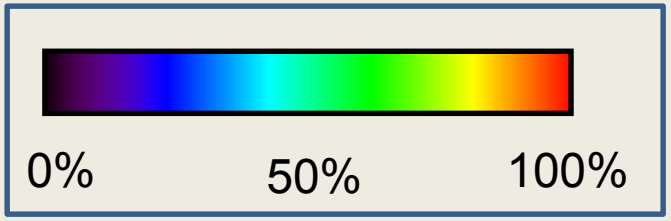


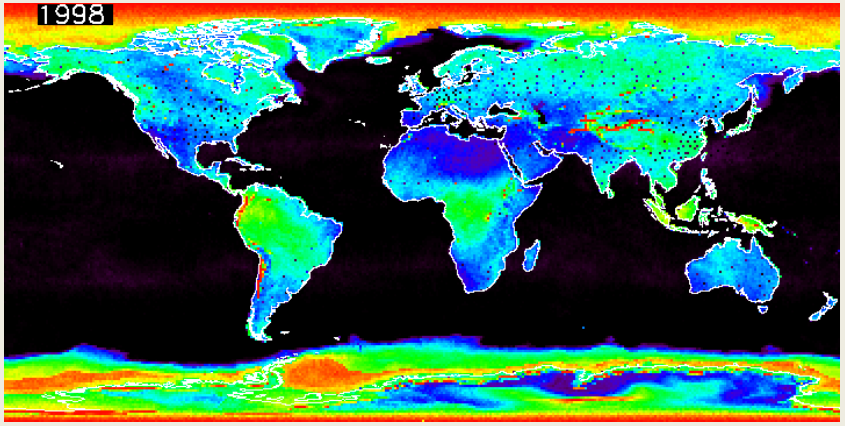
FIG. 2.11. (a) Anomaly time series of TCWV over ocean from satellite-borne microwave radiometers and COSMIC. The reference period for both measurements is 2007–12. (b) Anomaly time series of TCWV over land from radiosondes, ground-based GPS, and COSMIC. Except for COSMIC, the reference period is 1997–2012. The COSMIC land anomalies are calculated relative to a 2007–12 COSMIC land climatology. For (a) and (b) the time series have been smoothed to remove variability on time scales shorter than 6 months.

Percentage of Time Data Missing from NVAP-M Climate TPW

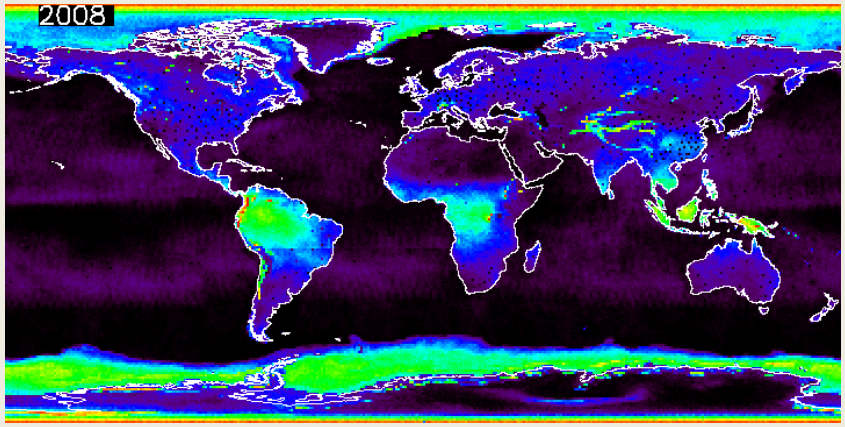


1988





1998

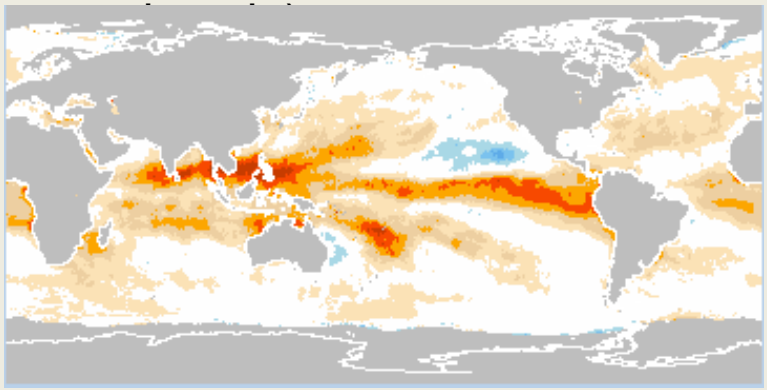


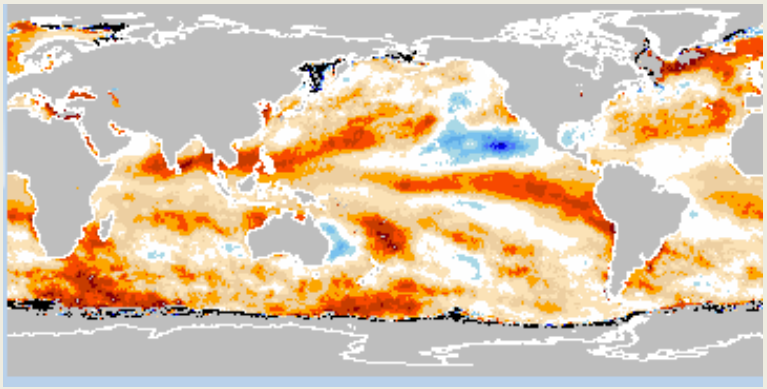
2008

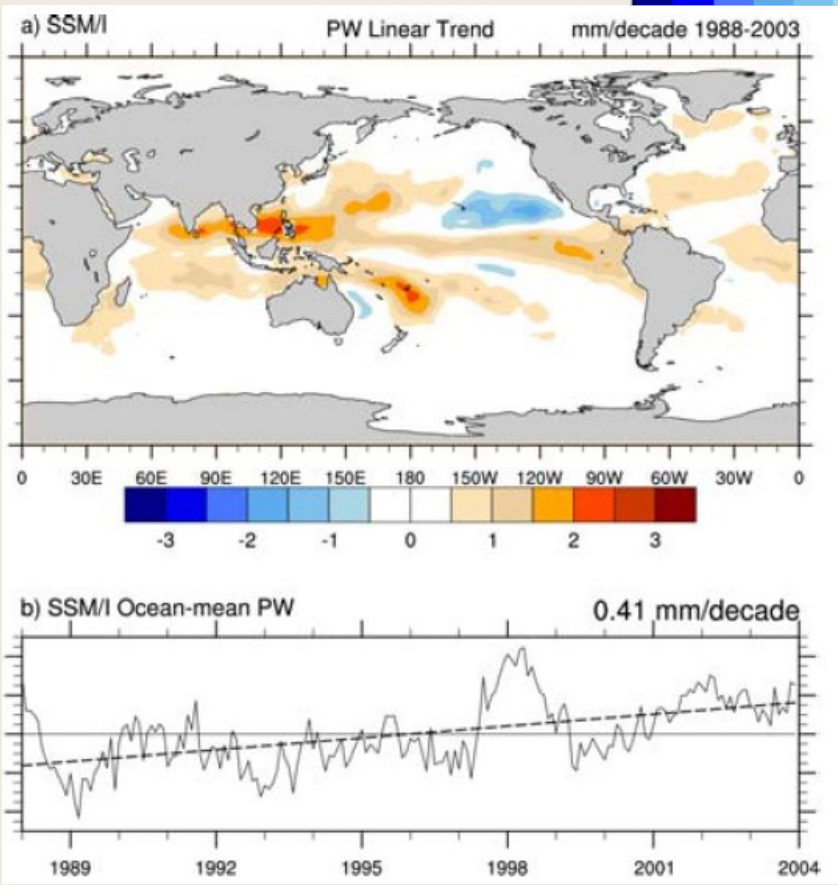
1988-2003 data (Latest – new missing data)

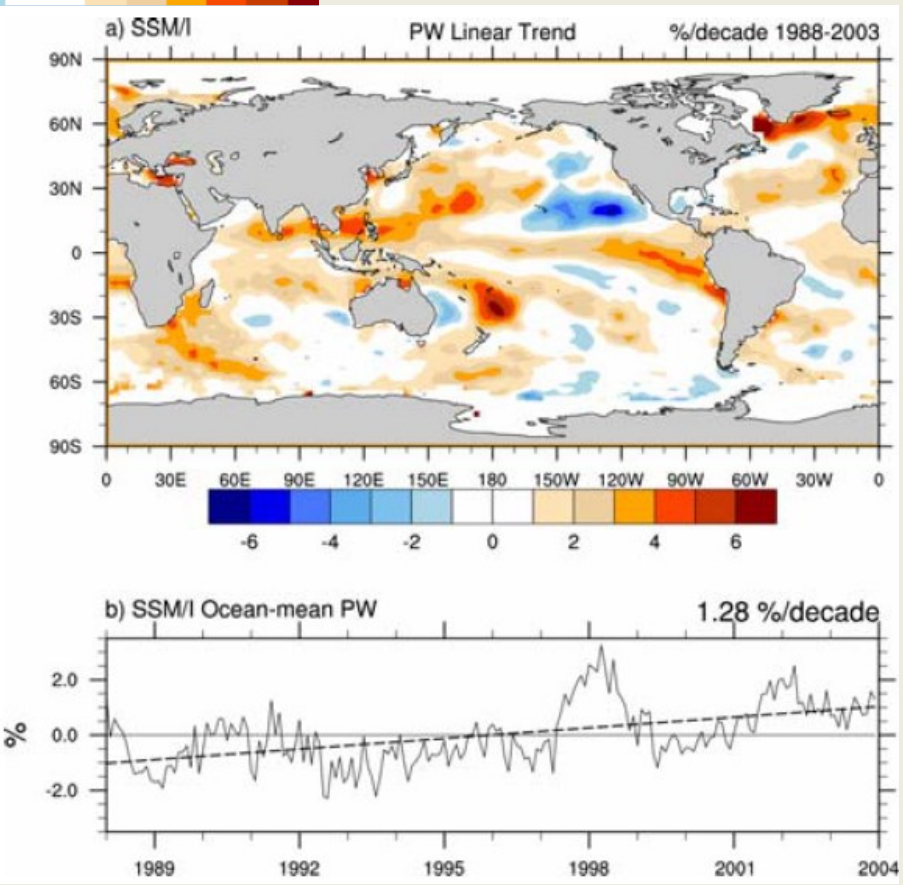
Trend (mm /

Trend (% / decade)







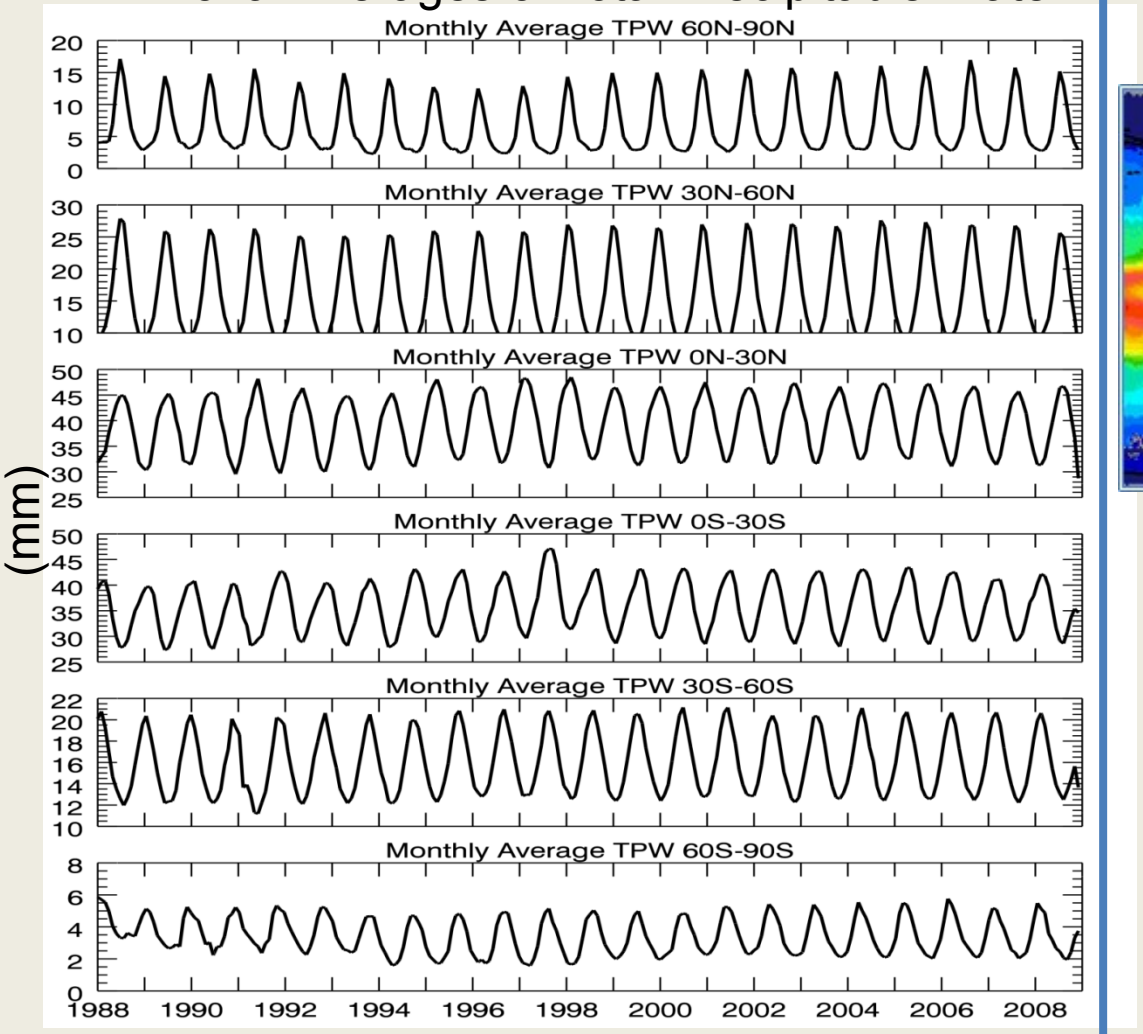


Review of TPW Trend Results

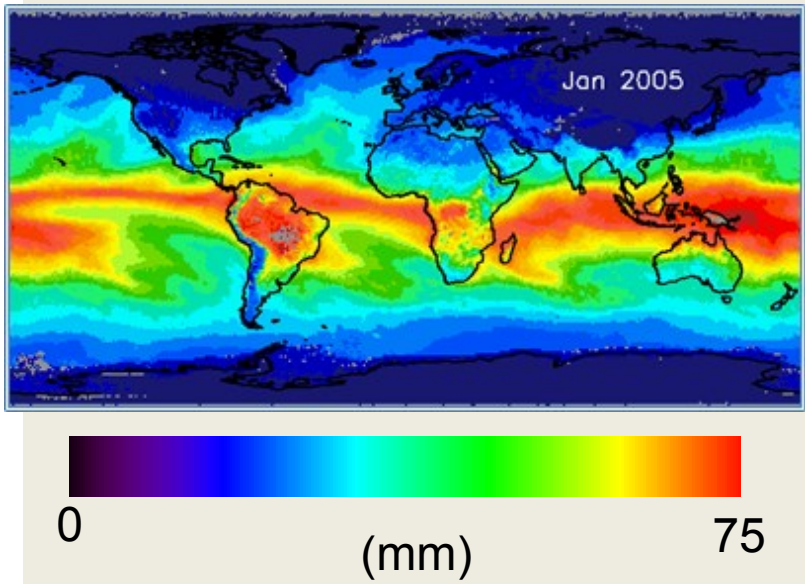
Paper	Trend	Time Period	Data	Technique
Wentz and Schnabel (2000)	+1.9 % / decade (20 N – 60 N) +2.1 % / decade (20 S – 20 N) +1.0 % / decade (60 S – 20 S)	1987-1998	RSS SSM/I	Deseasonalized fit. 90 day half-width Gaussian smoother. Least squares fit. Wilks Lag-1 autocorrelation test. Mean is 12 year mean for the zone.
Wentz et al. (2007)	Mean 28.5 mm 0.35 ± 0.114 mm / decade (or 1.2 % ± 0.4 % / decade); Global ocean.	July 1987 – August 2006.	RSS SSM/I	"Seasonal variability removed"/ Low pass filter with ± 4 month half-width Gaussian smoother.
Goldberg et al (2011)	0.63 mm / decade or 1.4 % / decade (20 N – 20 S). 1.35 mm / decade without SNO intercalibration.	1991 – 2006	Raw SSM/I and Alishouse regression algorithm. No use of F8.	
Trenberth et al (2005)	0.4 mm ± 0.09 mm / decade, or 1.3 % ± 3 % / decade	1988 – 2003 (for IPCC AR4, added 2004, changed to 1.2 % / decade	RSS SSM/I	*Local monthly mean averaged to get area mean. 1-3-4-3-1 filter applied. Includes maps of trends and EOF analysis, a strong ENSO signal.
AMS State of Climate (2012)	Not quoted, graph provided	1997-2010 base	RSS SSM/I, AMSR-E and WindSat	Six month smoothing filter.

*Two significance approaches: 1) Select 10000 annual means at random, 99.67 % significant [how?]. 2) Combine different mixes of SSM/I, trend ranges from +0.38 to + 0.43 mm / decade. Combine these two results to get quoted uncertainty.

Zonal Averages of Total Precipitable Water

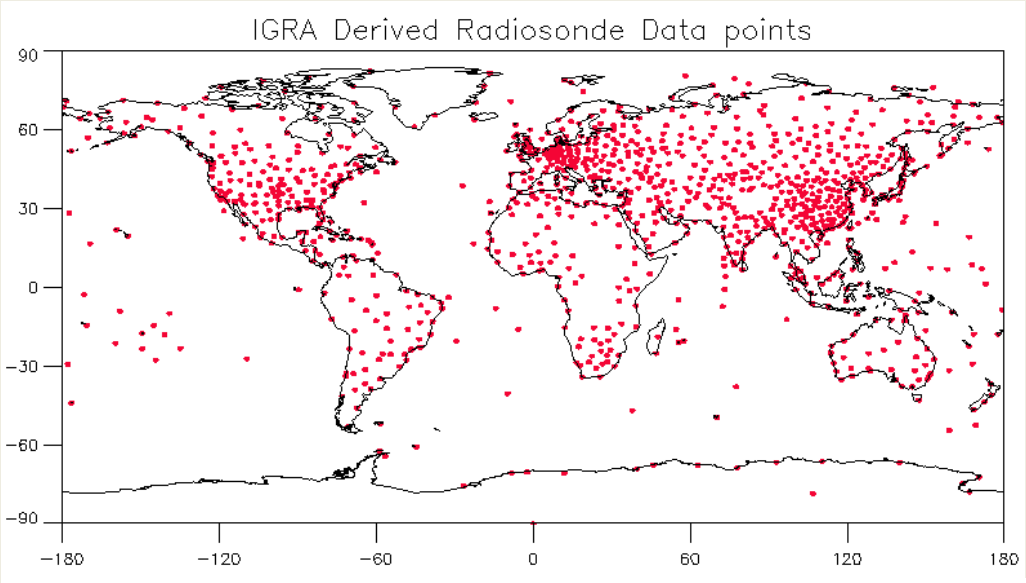


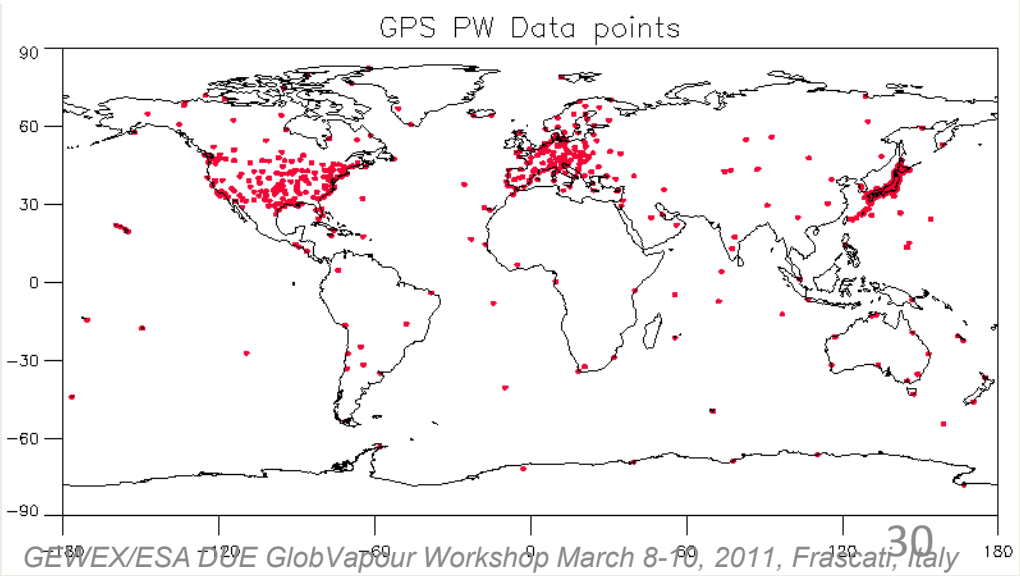
Monthly Mean TPW (mm) from NVAP-M Climate for 2005



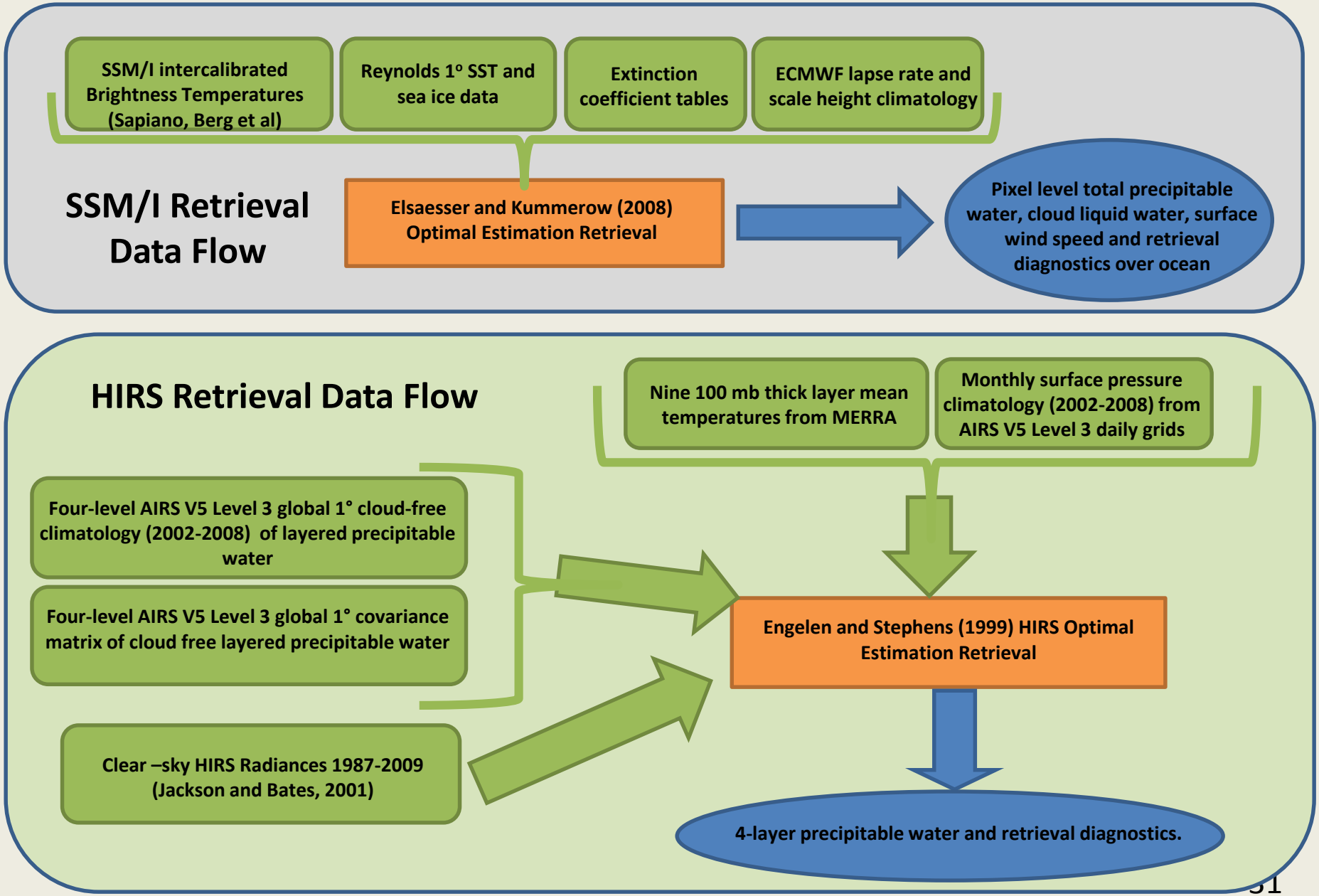
- Strong annual cycle is found in all latitude zones
- ENSO of 1997-1998 most apparent in 0-30° S

Radiosonde, GPS distribution

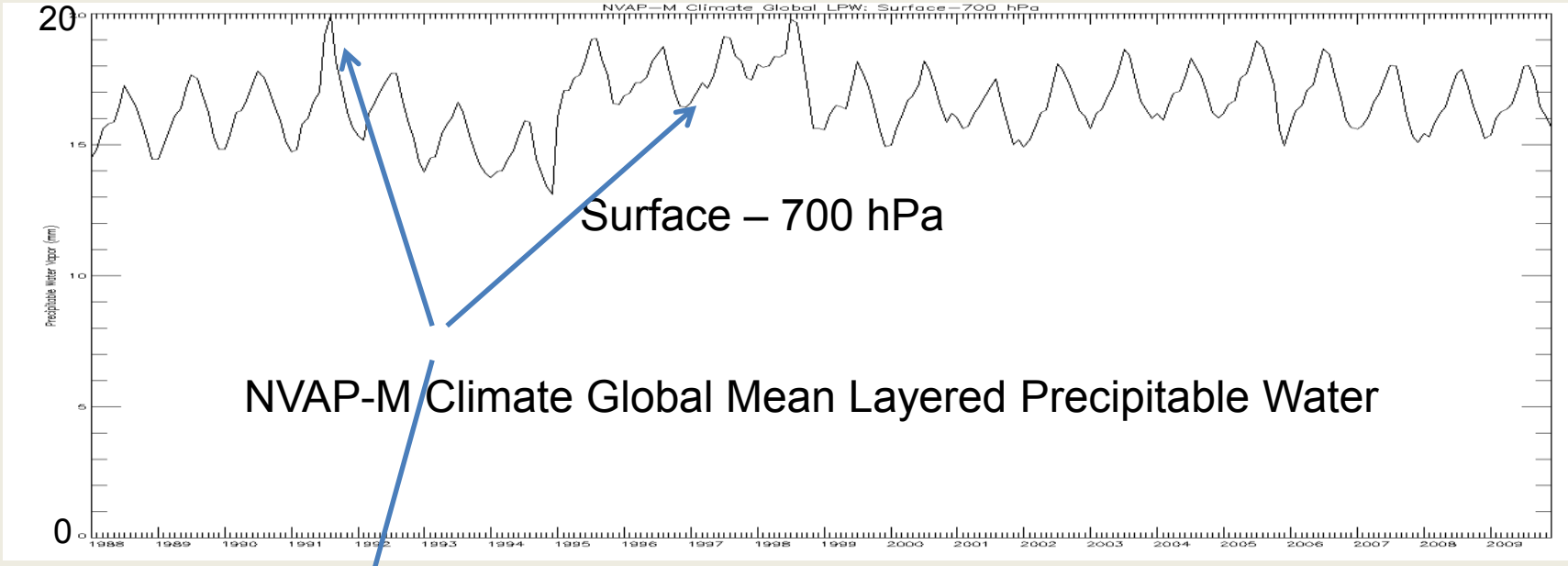




Dataset Construction: Algorithms

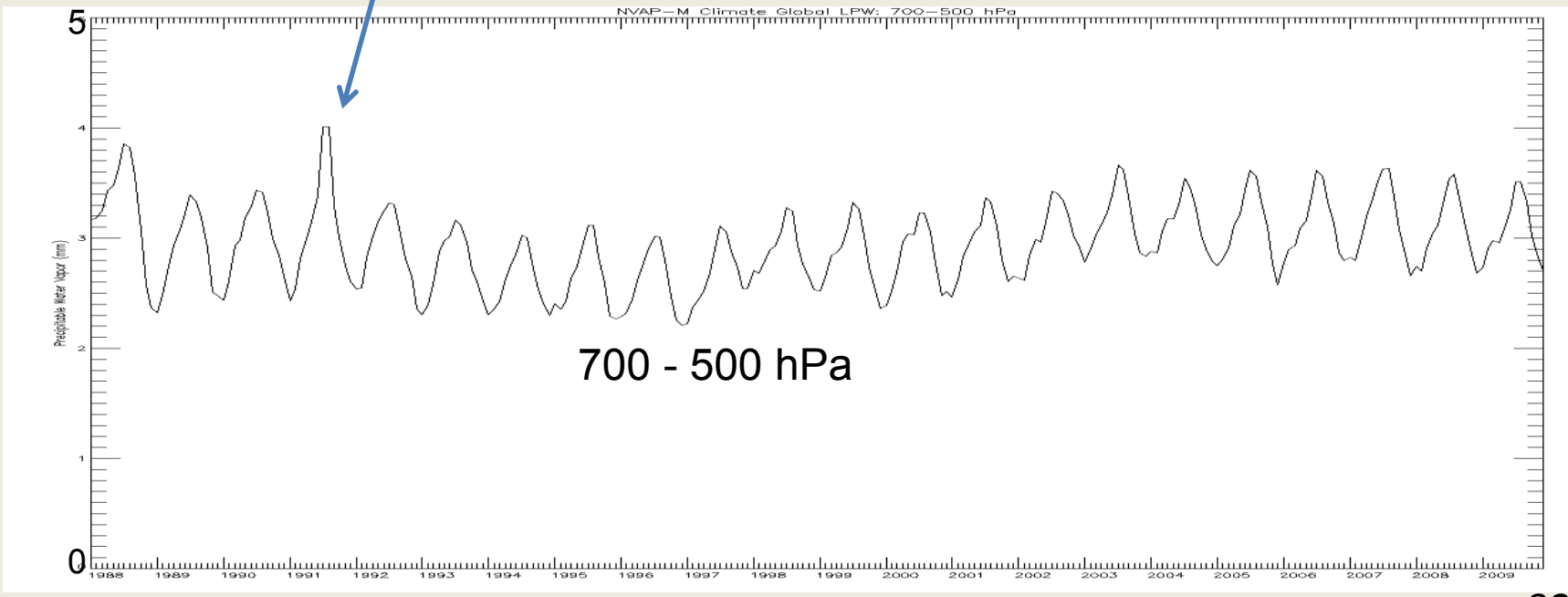


1988 2009



Surface – 700 hPa

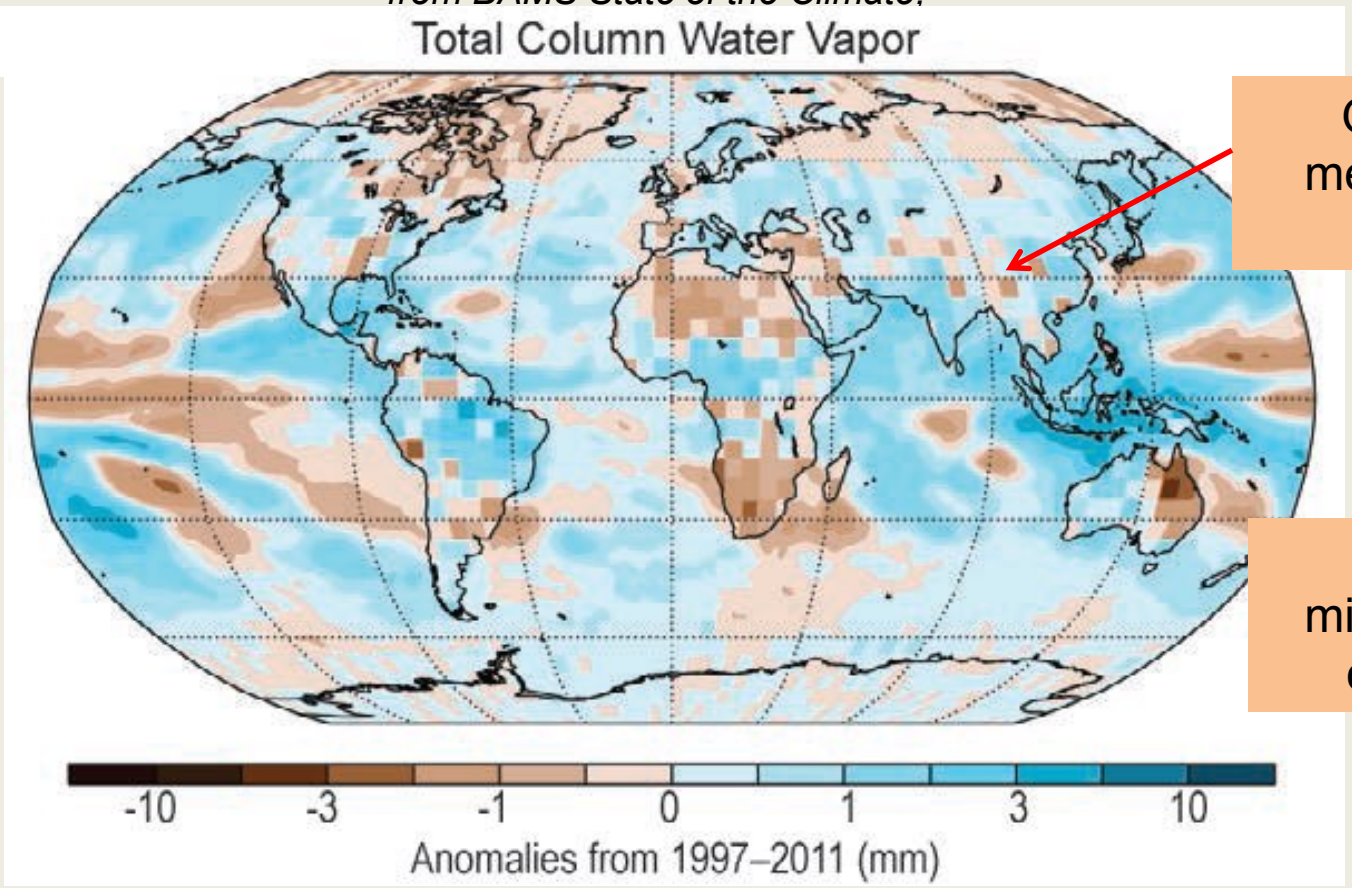
NVAP-M Climate Global Mean Layered Precipitable Water



700 - 500 hPa

Current global TPW products for climate use a limited subset of data

from BAMS State of the Climate.

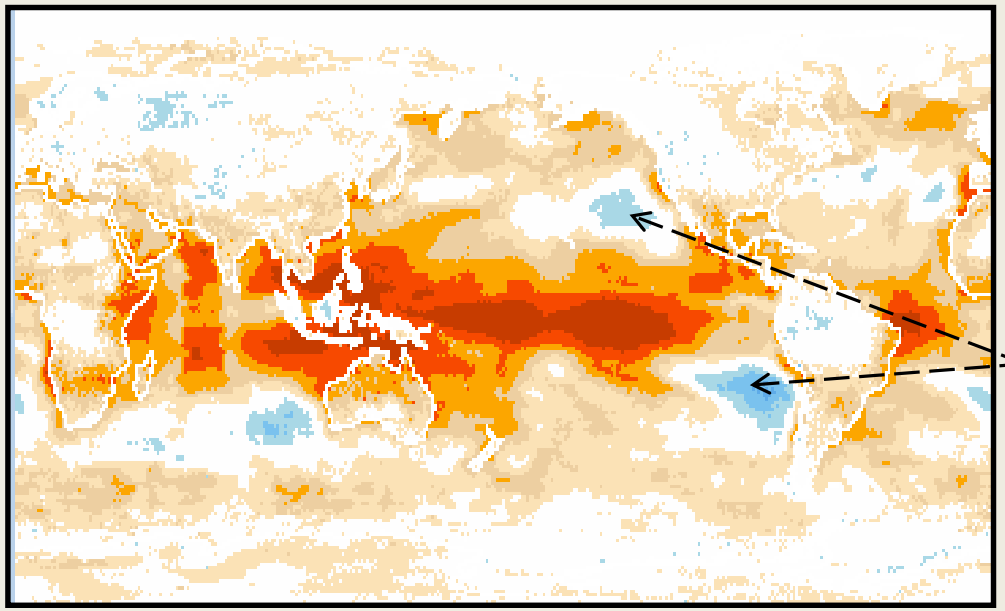


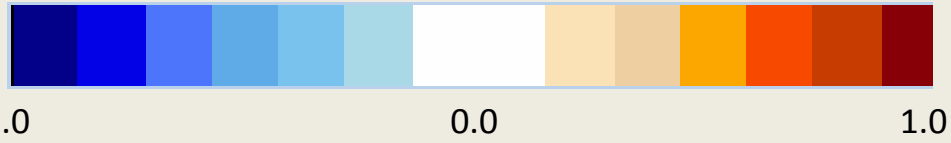
Only “point” COSMIC measurements over land (note blockiness)

Only conical scanning microwave measurements over ocean (No NOAA satellites)

Some Additional Thoughts

Correlation of ISCCP total cloud and NVAP-M total precipitable water vapor monthly anomalies (1988-2007)





Blue areas indicate cloud amount decreases as TPW increases

Illustrates the usefulness of comparing related data sets