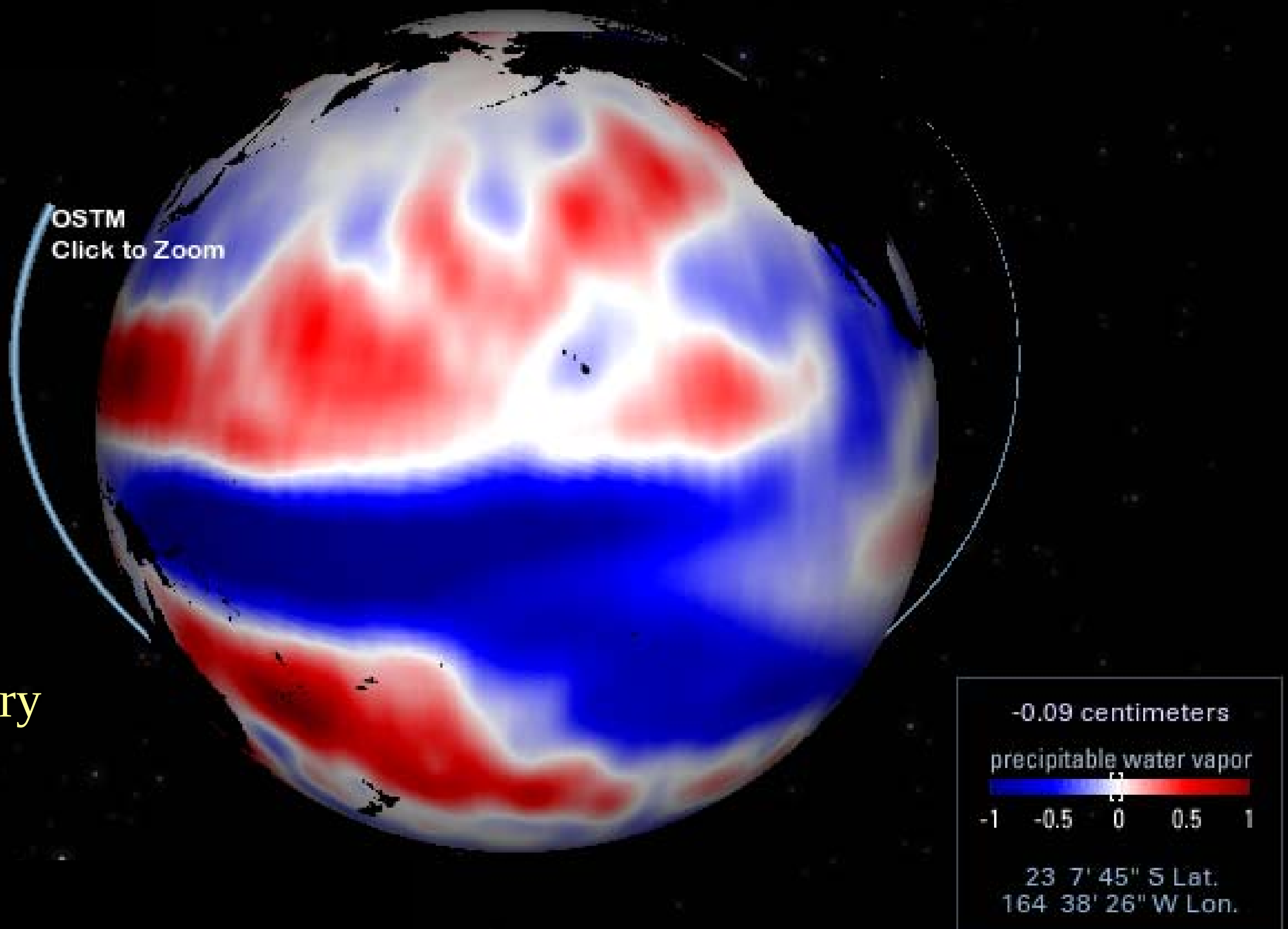
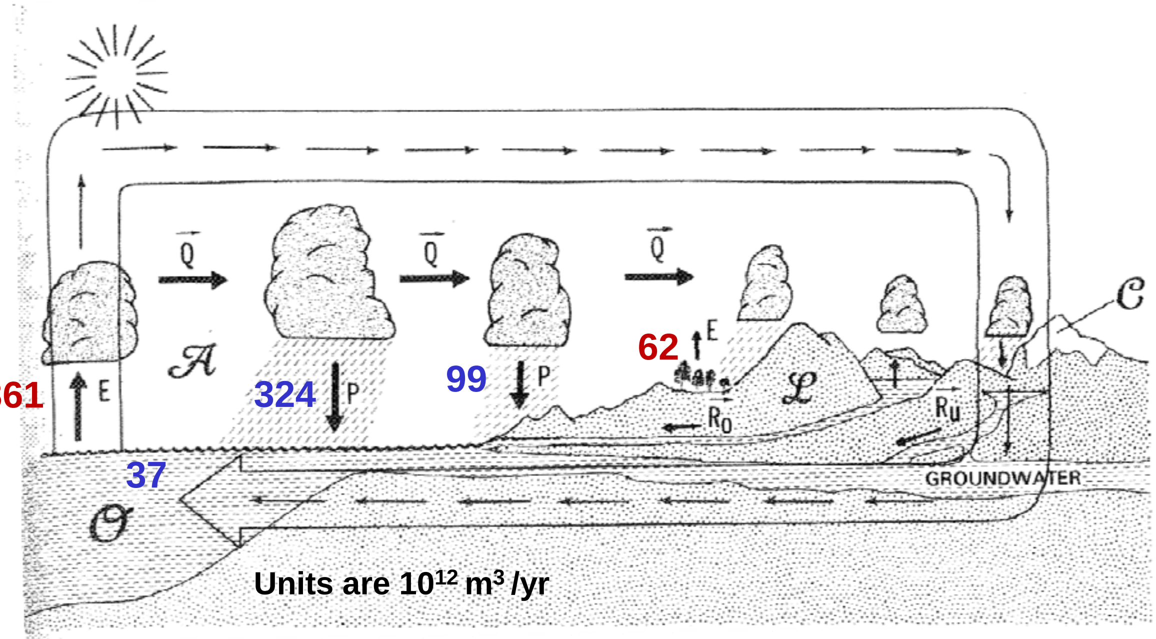
Tracking Water Above the Oceans: A 19-year Water Vapor and Cloud Water Climatology from the Altimeter Radiometers



Shannon Brown
Jet Propulsion Laboratory
10/20/2011

Hydrologic Cycle

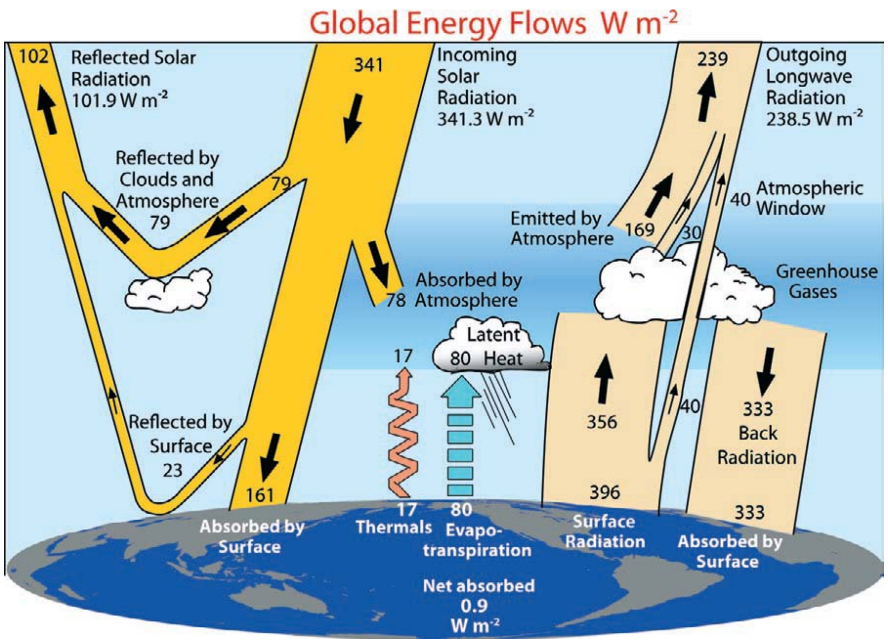
Water Storage on Earth	
Oceans	97.39 %
Ice	2.01 %
Ground water	0.58 %
Lakes/rivers	0.02 %
Atmosphere	0.001 %



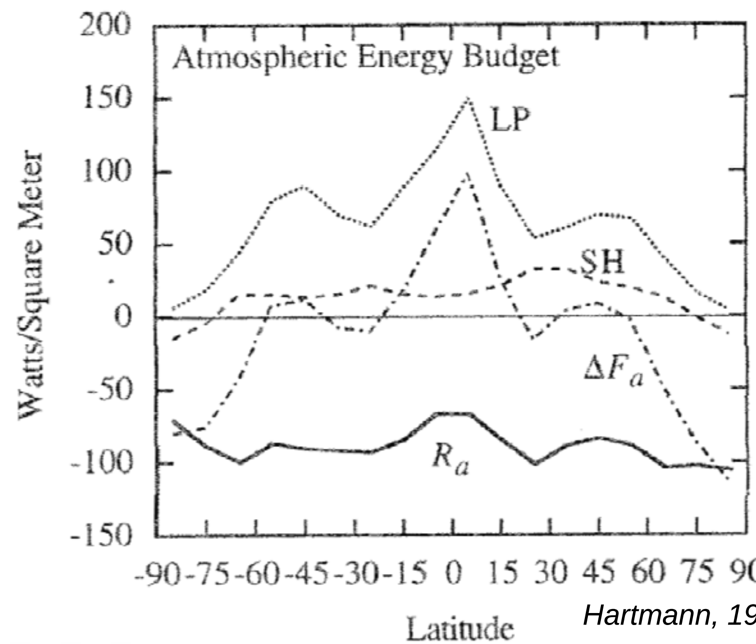
Peixoto and Oort, 1991

Only 0.001% of water on Earth resides in the atmosphere, but this small amount has a profound impact on Earth's weather and climate

Energy Balance in the Atmosphere



Trenberth et al., 2009



Hartmann, 1994

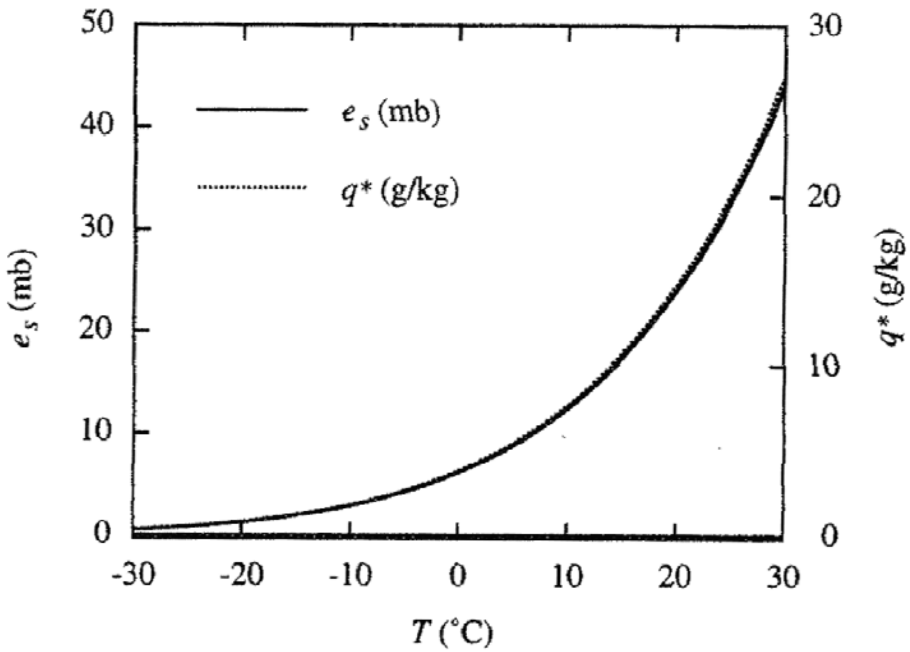
Water vapor is the most potent green house gas, contributing 60% of the net long wave radiative forcing of the atmosphere

The release of latent heat from clouds and precipitation is largely responsible for the zonal redistribution of heat in the atmosphere

Longwave Radiative Forcing	
H_2O	60 %
CO_2	26 %
O_3	8 %
CH_4+N_2O+trace	6 %

Water Vapor Climate Feedback

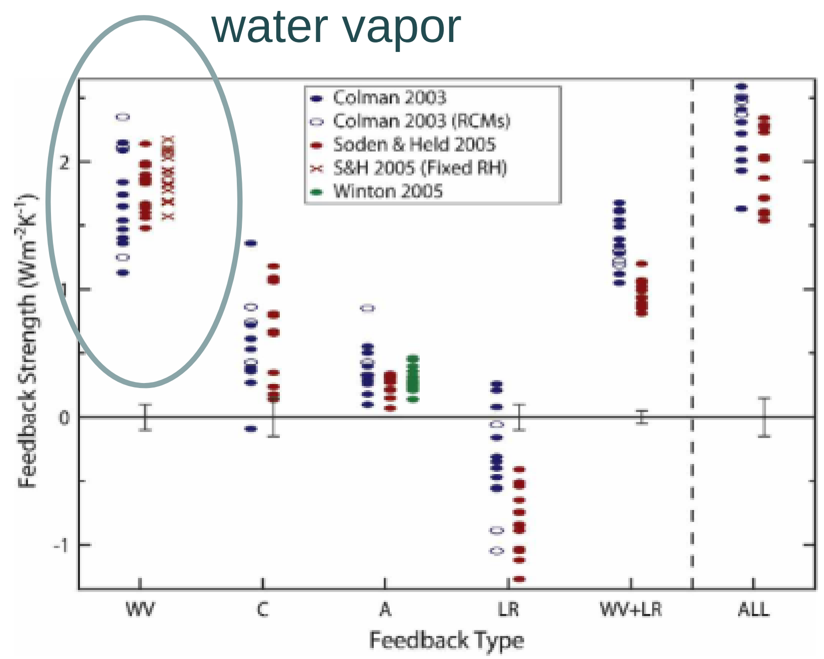
- Water vapor has a positive climate feedback as described by the Clausius-Clapeyron relation
  - *Predicts a 7%/K change in precipitable water vapor assuming constant relative humidity*
- Constant relative humidity is generally a robust feature of climate predictions



$$e_s \cong 6.11 \bullet \exp\left\{ \frac{L}{R_V} \left(\frac{1}{273} - \frac{1}{T} \right) \right\}$$

Water Vapor Climate Feedback in Models

- Climate models show that water vapor is the strongest climate feedback mechanism
  - Consistent with constant relative humidity assumption
- Significant disagreement in the magnitude of the water vapor feed back exists between models
- Clouds also have a significant climate feedback and show the largest differences in the estimated magnitude between models
- Climate observations of water vapor and clouds critical for validating models



Climate feedback parameters (Bony et al. 2006)

Radiometers on Altimeter Missions

The primary job of the microwave radiometers on-board Topex/Jason-1 and Jason-2 is to provide range correction for the altimeter due to tropospheric water vapor

The radiometers also provide retrievals of precipitable water vapor and integrated cloud liquid water, which are important observations

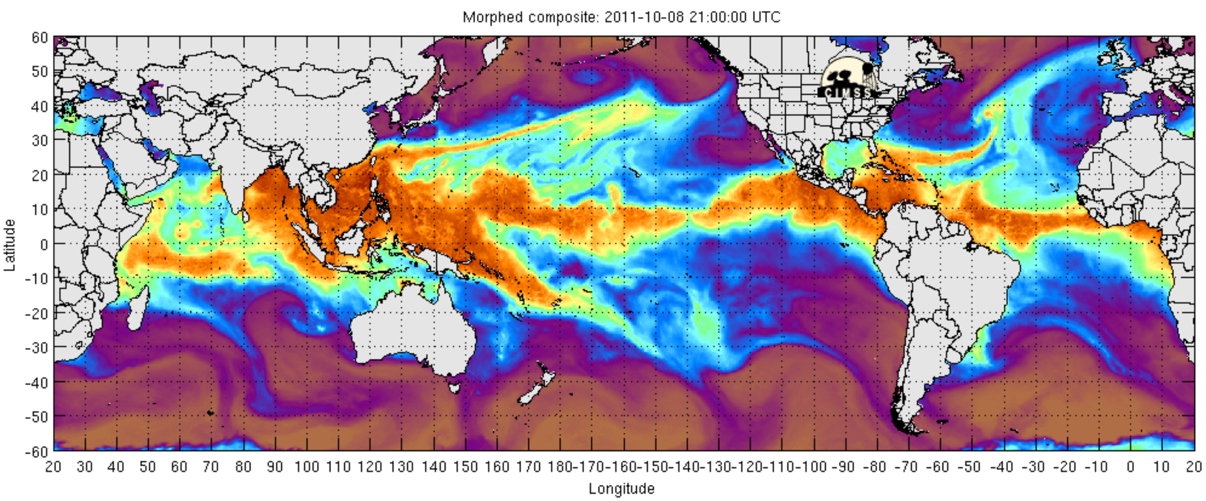
The significant effort in ensuring the long term stability of the radiometer calibration for GMSL studies enables the use of these observations for climate studies

- Complementary to existing records – different error sources
- Complete sampling of diurnal cycle

TMR:1992 - 2005

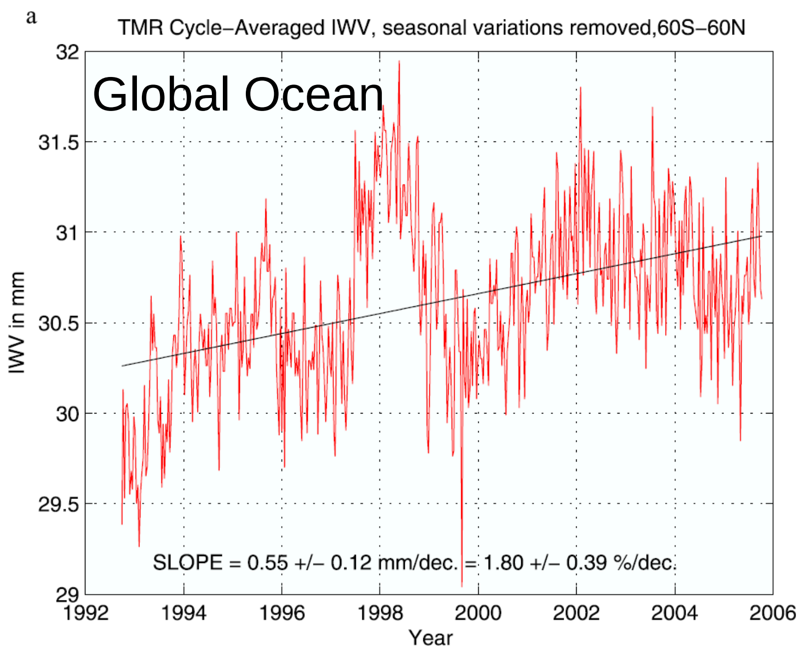
JMR: 2002 -

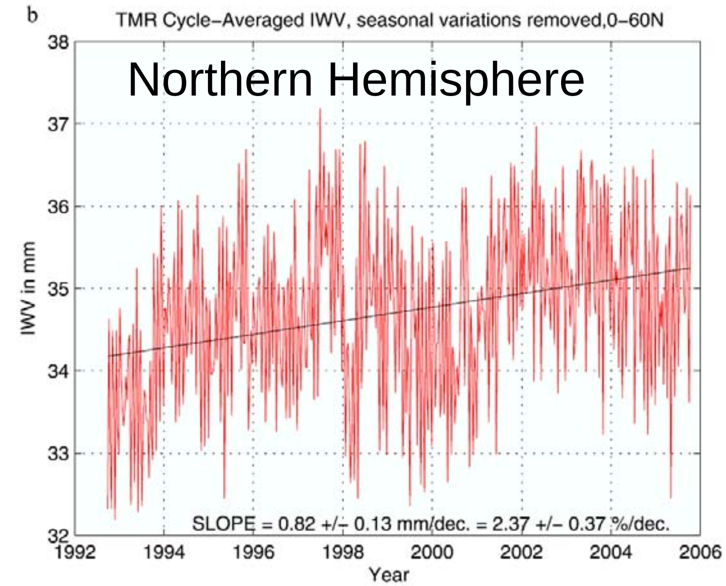
AMR: 2008 -



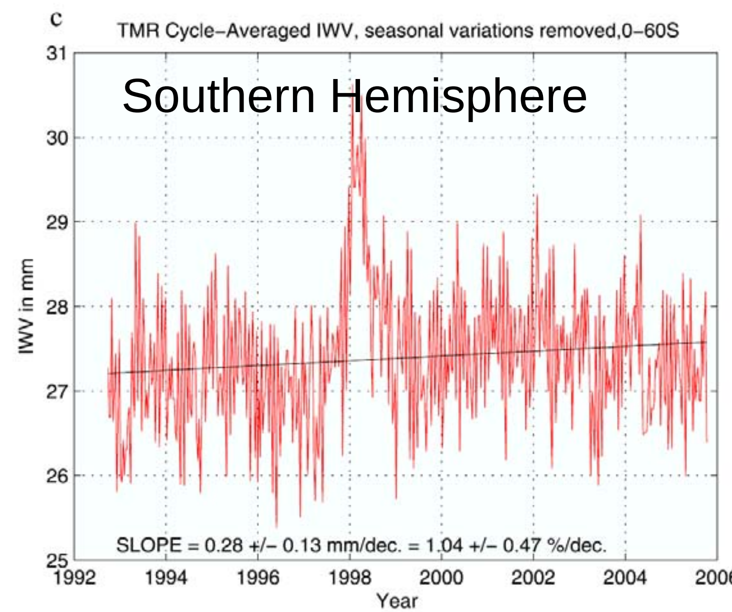
Courtesy of CMISS Univ of Wisc.

Observed PWV Trends from TMR



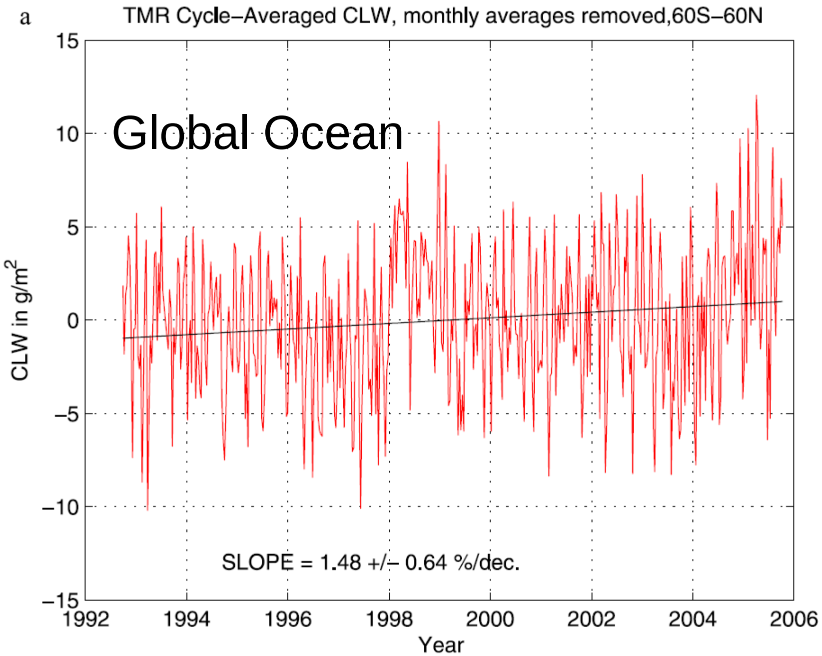


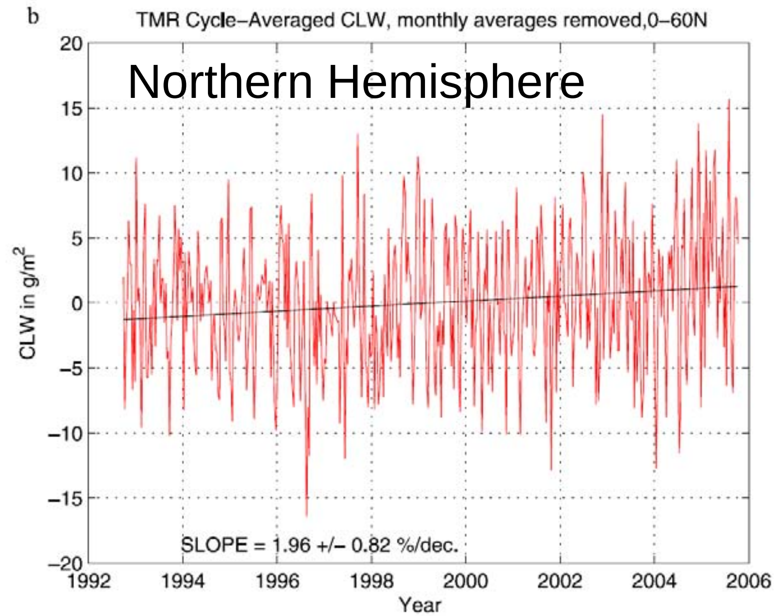
TMR Precipitable Water Vapor Trends 1992-2005		
Global	0.55 mm/dec	1.8 %/dec
NH	0.82 mm/dec	2.37 %/dec
SH	0.28 mm/dec	1.04 %/dec



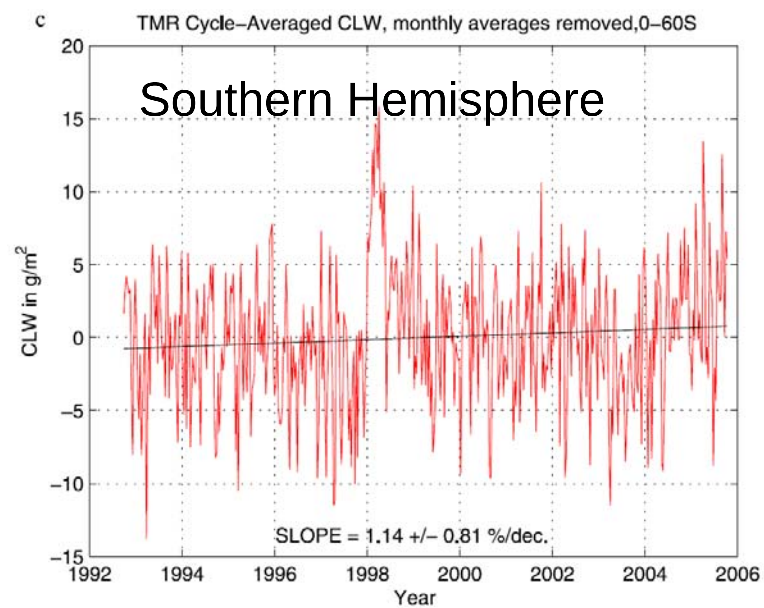
Keihm et al., 2009; "Ocean water vapor and cloud liquid water trends from 1992-2005 TOPEX microwave radiometer data", JGR

Observed CLW Trends from TMR



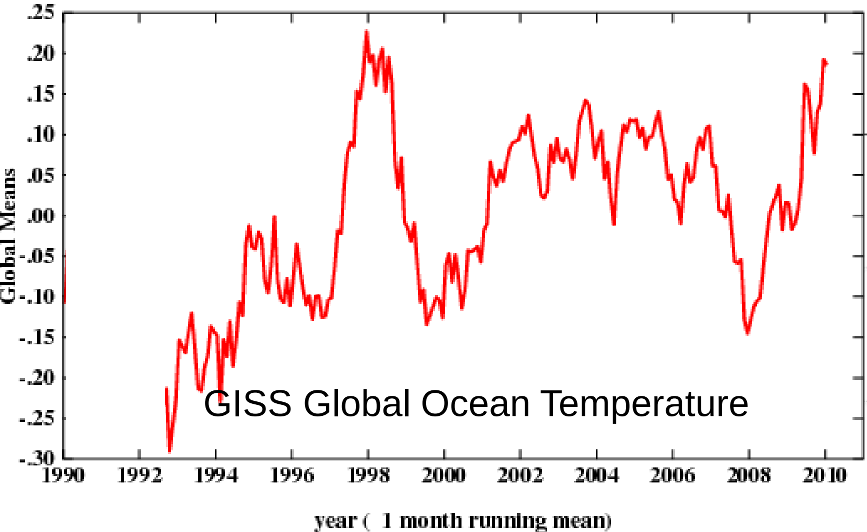


TMR Cloud Liquid Water Trends 1992-2005	
Global	1.48 %/dec
NH	1.96 %/dec
SH	1.14 %/dec

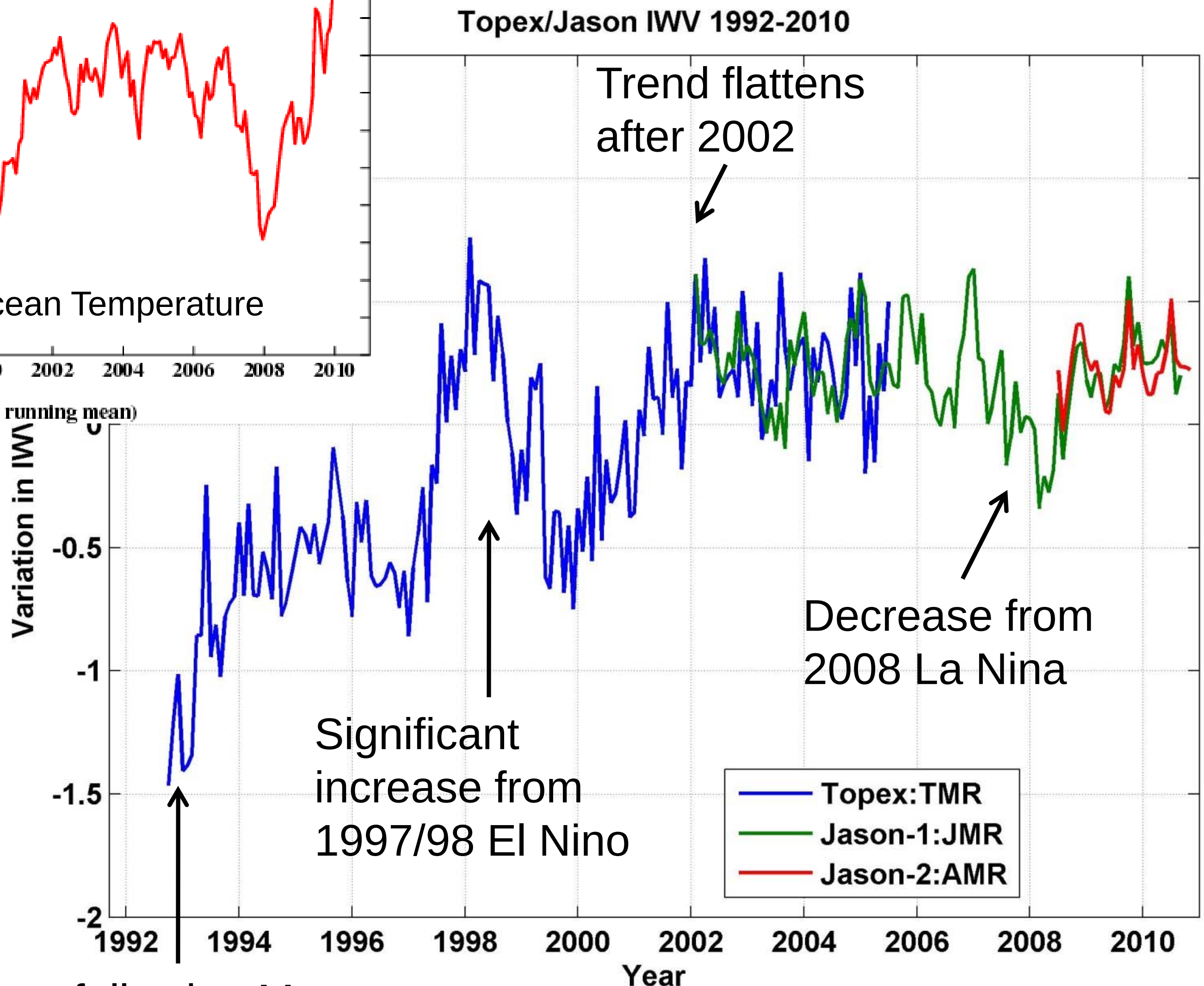


Keihm et al., 2009; "Ocean water vapor and cloud liquid water trends from 1992-2005 TOPEX microwave radiometer data", JGR

19-Year Inter-calibrated PWV Record

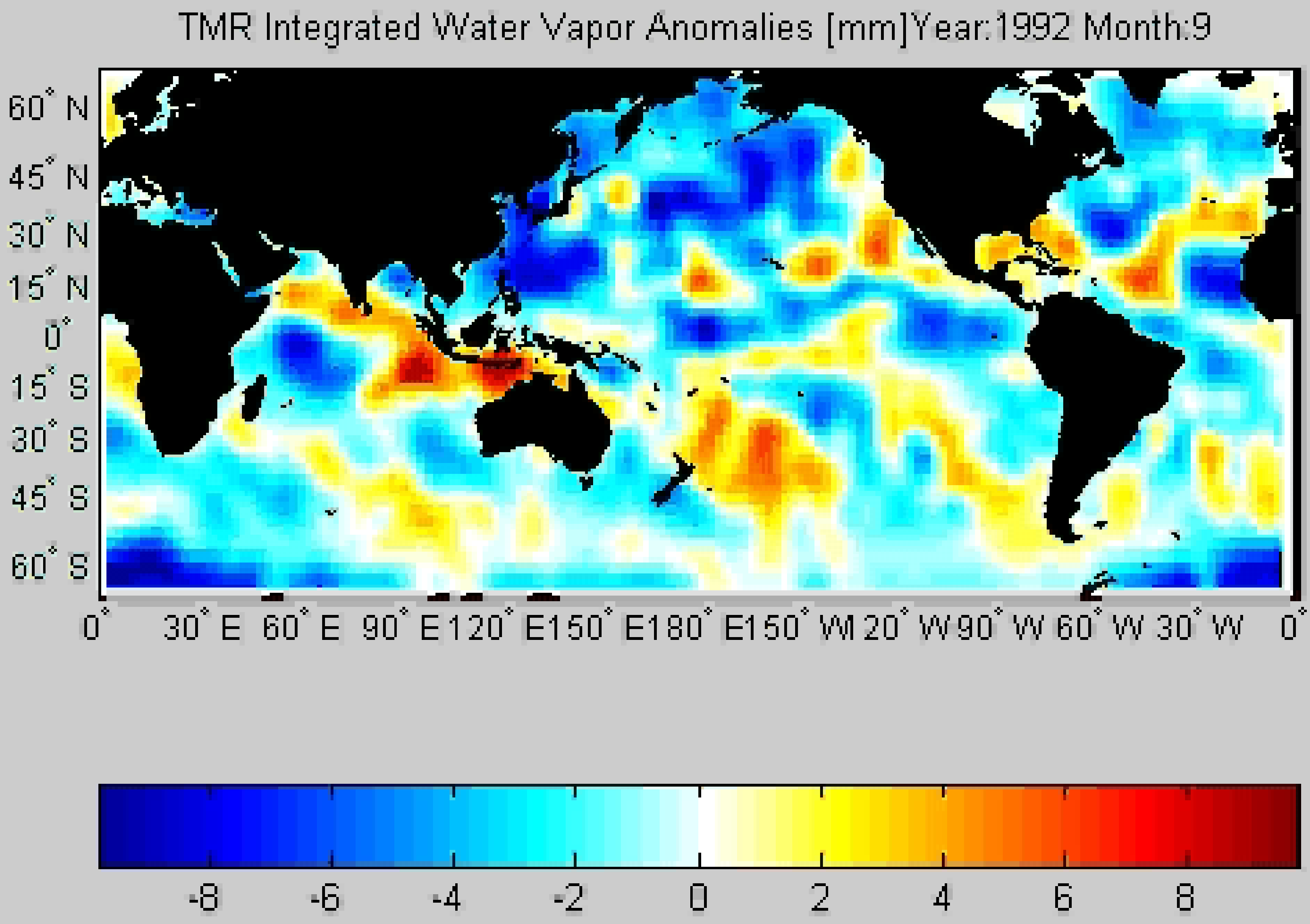


Tacks overall global temperature trend



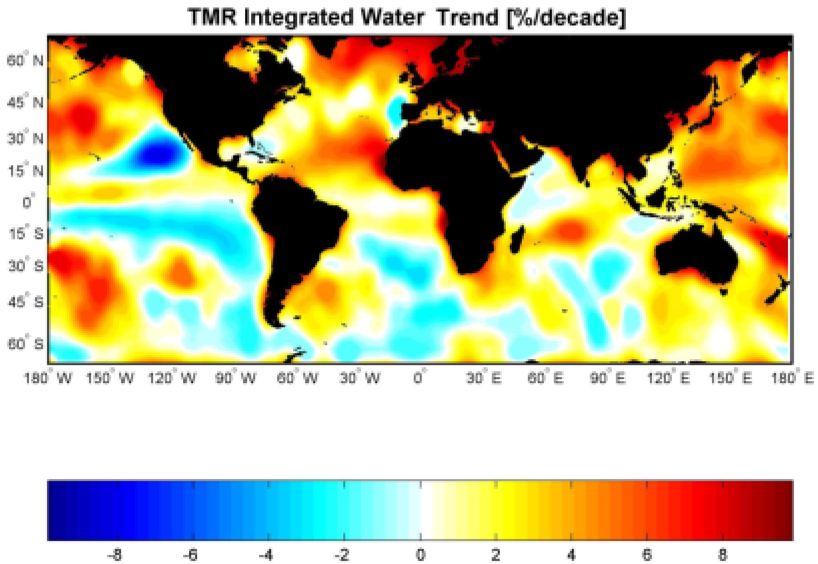
Decrease following Mt. Pinatubo eruption

Monthly PWV Anomalies

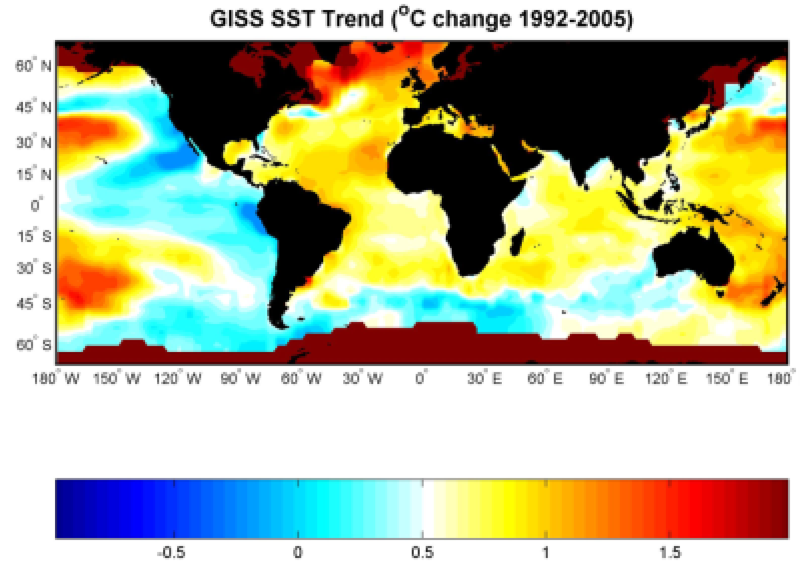


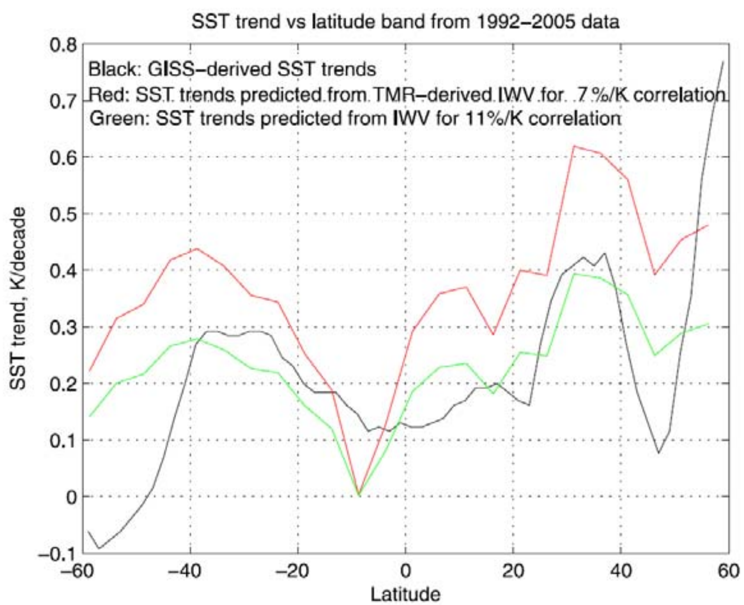
Regional Trends and SST

TMR PWV trends



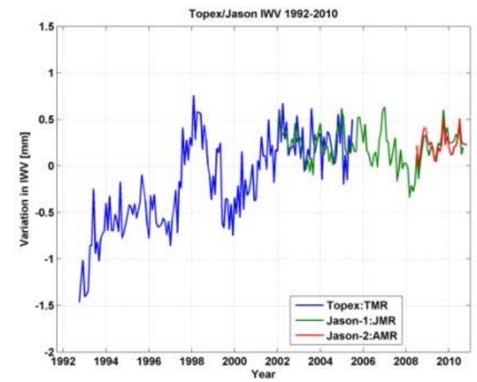
GISS SST trends

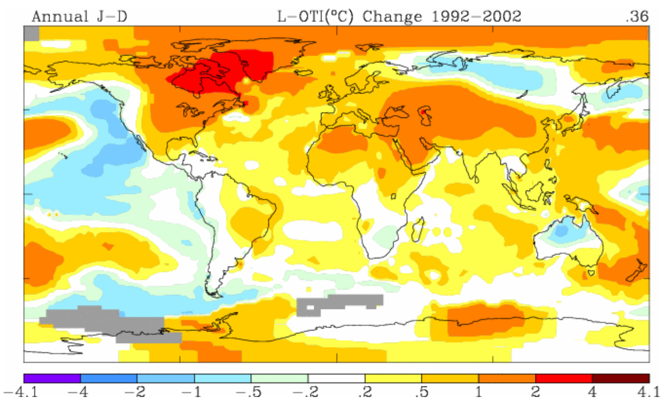


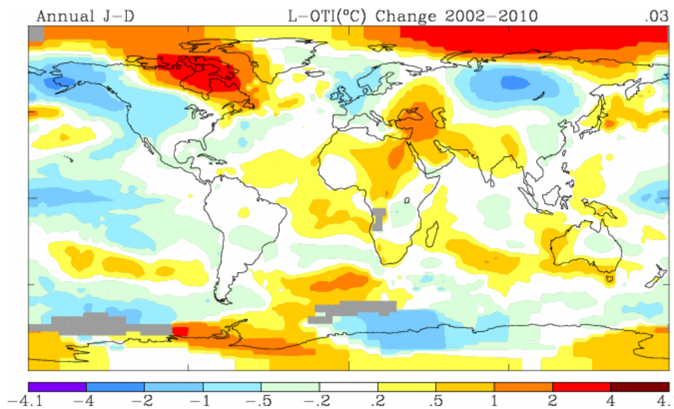


Regional Changes

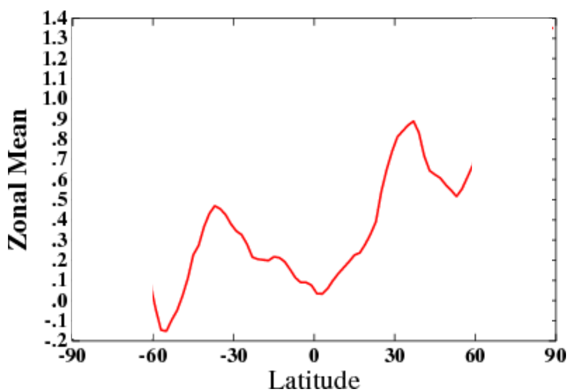
- GISS temperature trends show consistency with PWV trends
  - Larger trend from 1992-2002 and little trend from 2002-2010
  - Larger trends in NH than SH over 1992-2002 period

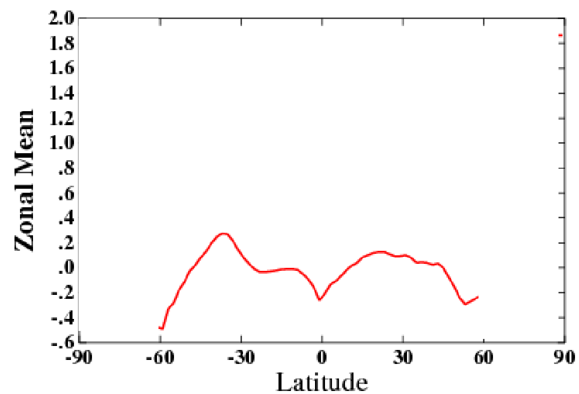






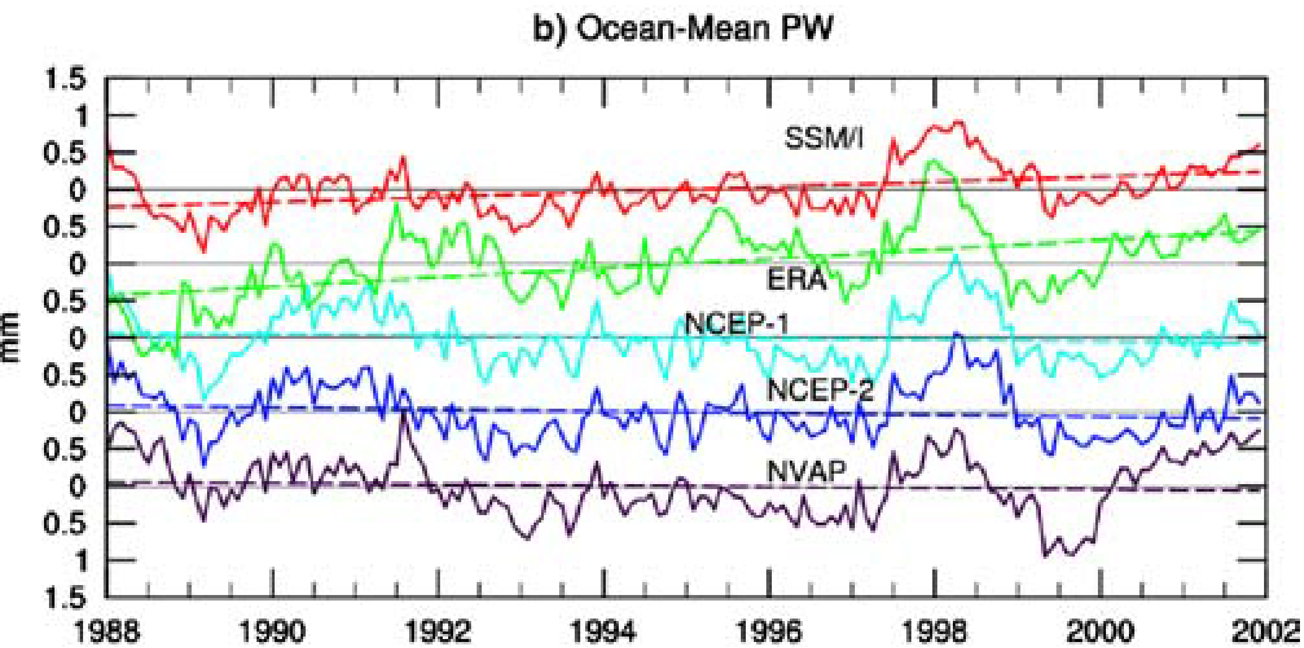
TMR Precipitable Water Vapor Trends 1992-2005	
Global	0.55 mm/dec
NH	0.82 mm/dec
SH	0.28 mm/dec





data from GISS

Observations and Models



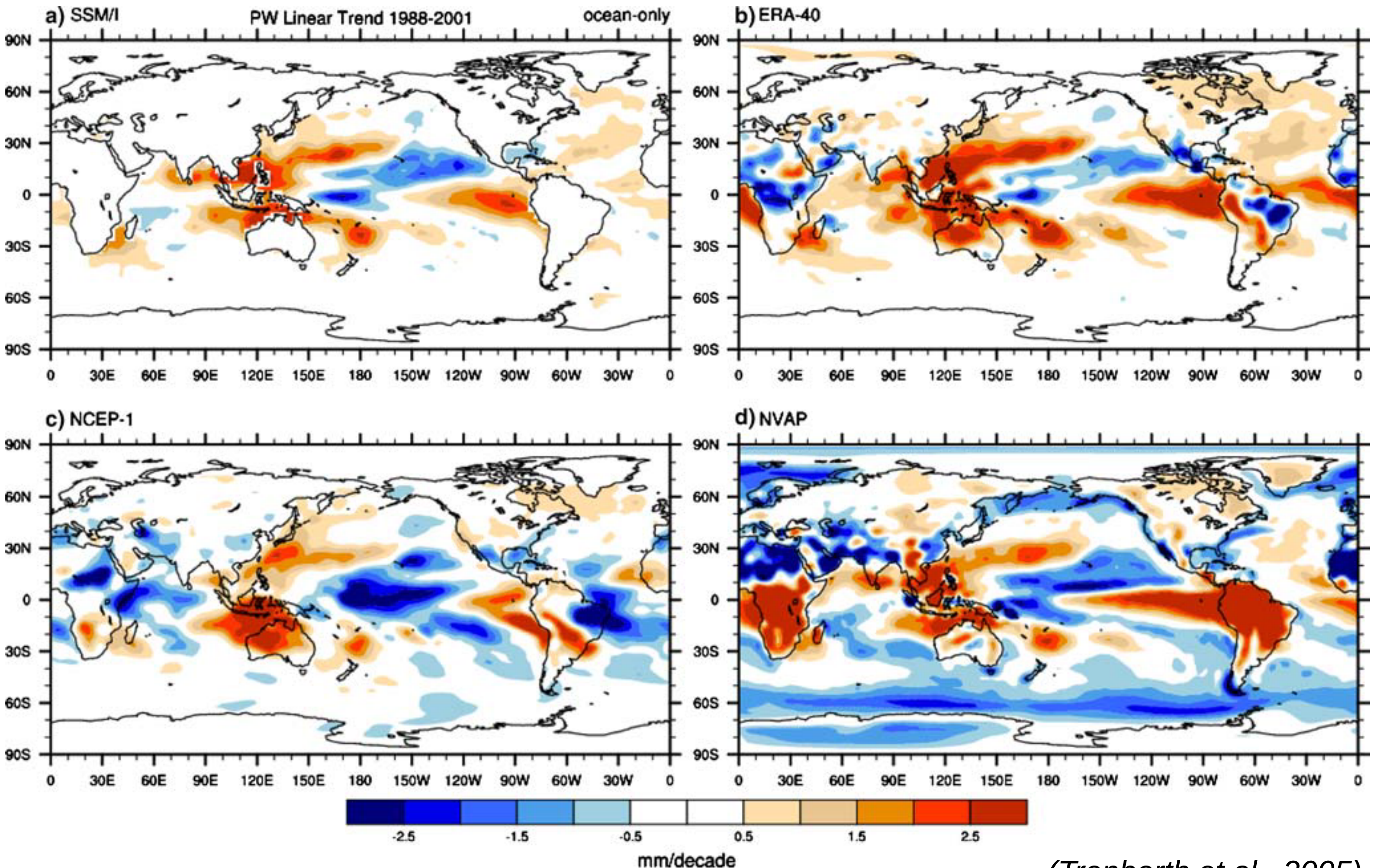
(Trenberth et al., 2005)

Previous studies have shown significant differences between models and observations of PWV on annual and decadal time scales

PWV Trends 1988-1992 *(Trenberth et al., 2005)*	
SSM/I (RSS)	0.4 mm/decade
NVAP	-0.1 mm/decade
NCEP-1	-0.1 mm/decade
ERA-40	0.7 mm/decade

Observations and Models

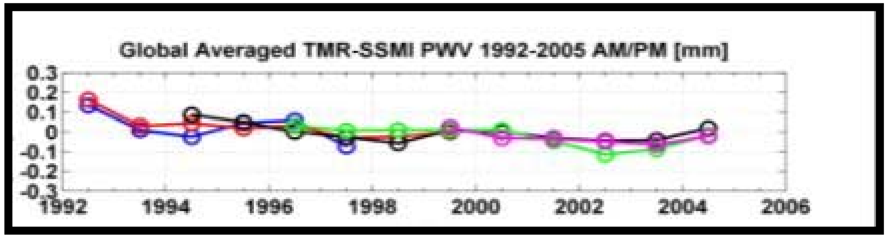
Differences between models and observations even more apparent in regional trends



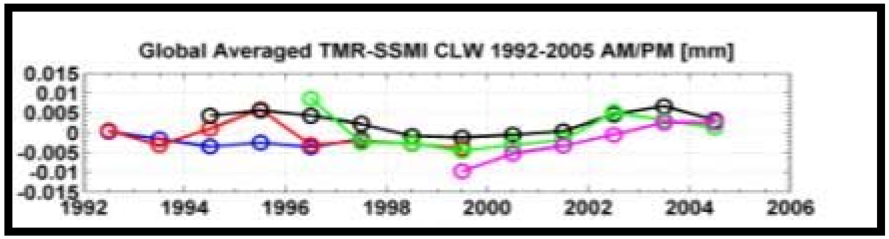
(Trenberth et al., 2005)

Inter-sensor Trends

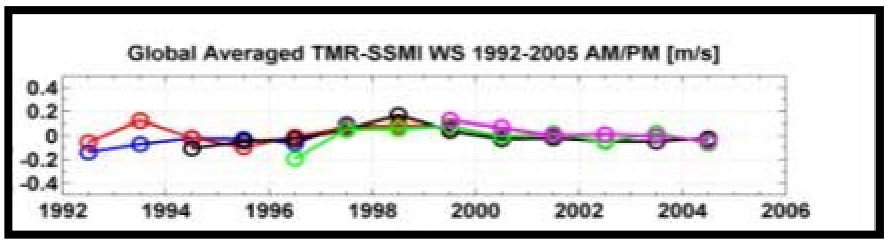
PWV [mm]



CLW [mm]

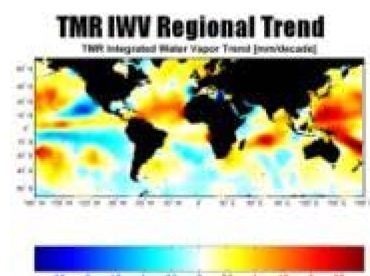


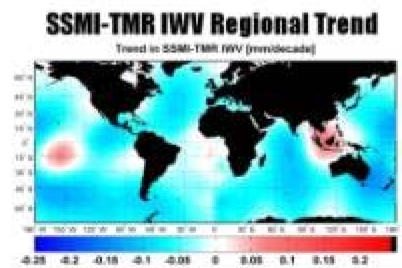
WS [m/s]

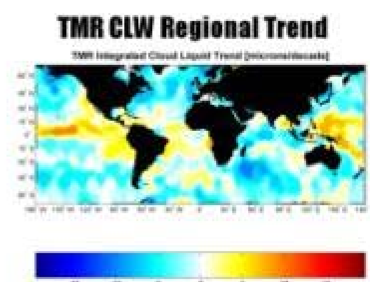


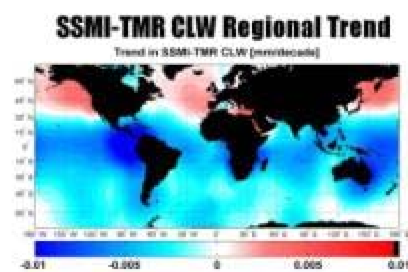
SSM/I products from RSS

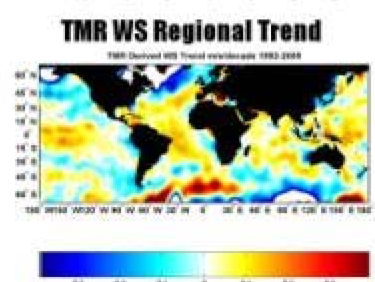
- Inter-sensor comparisons provide estimate of observational uncertainty in trends from the satellite pair

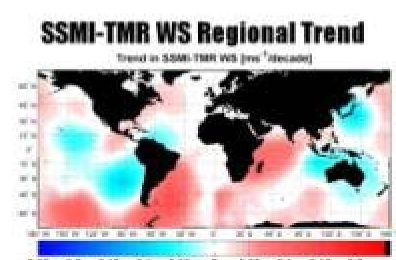










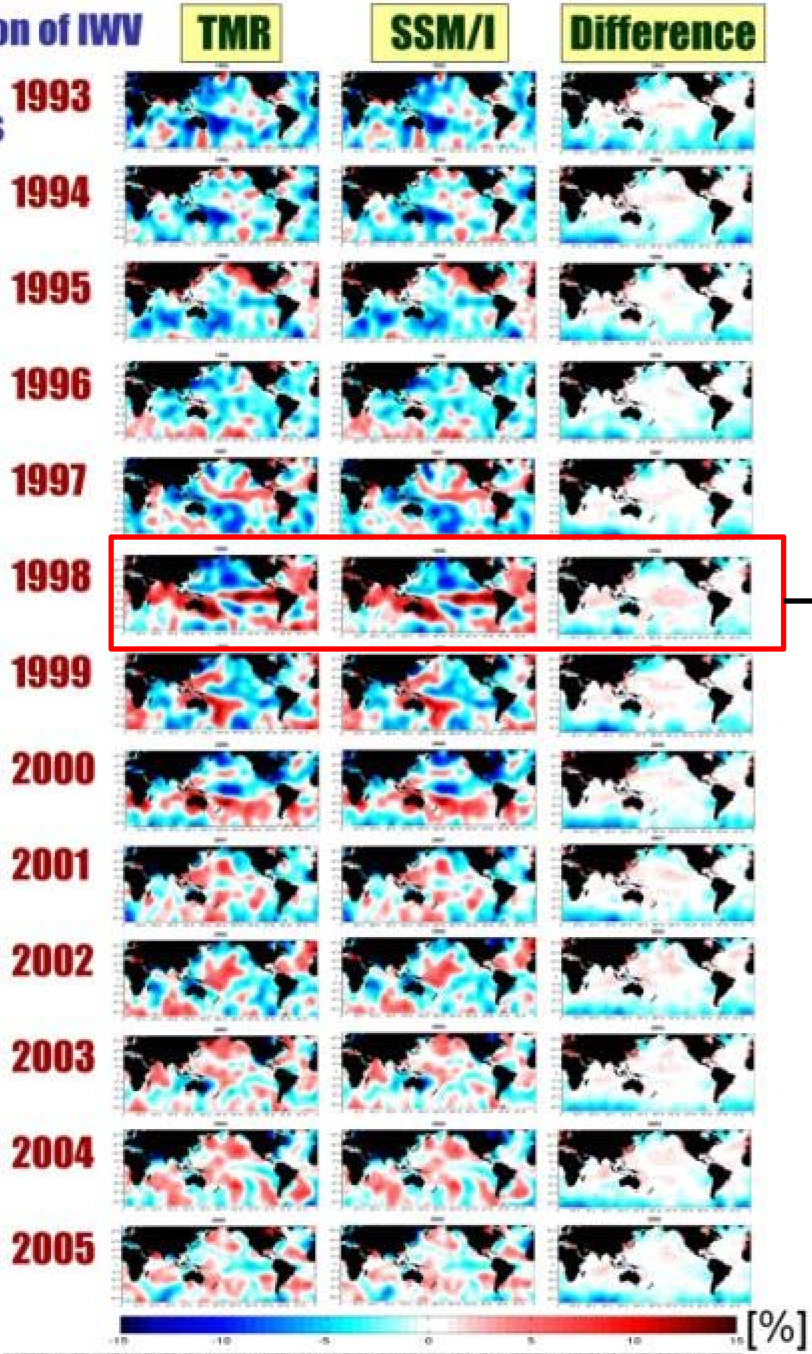


Means to ascertain the magnitude of sensor artifacts in the observed climate signals from both data records

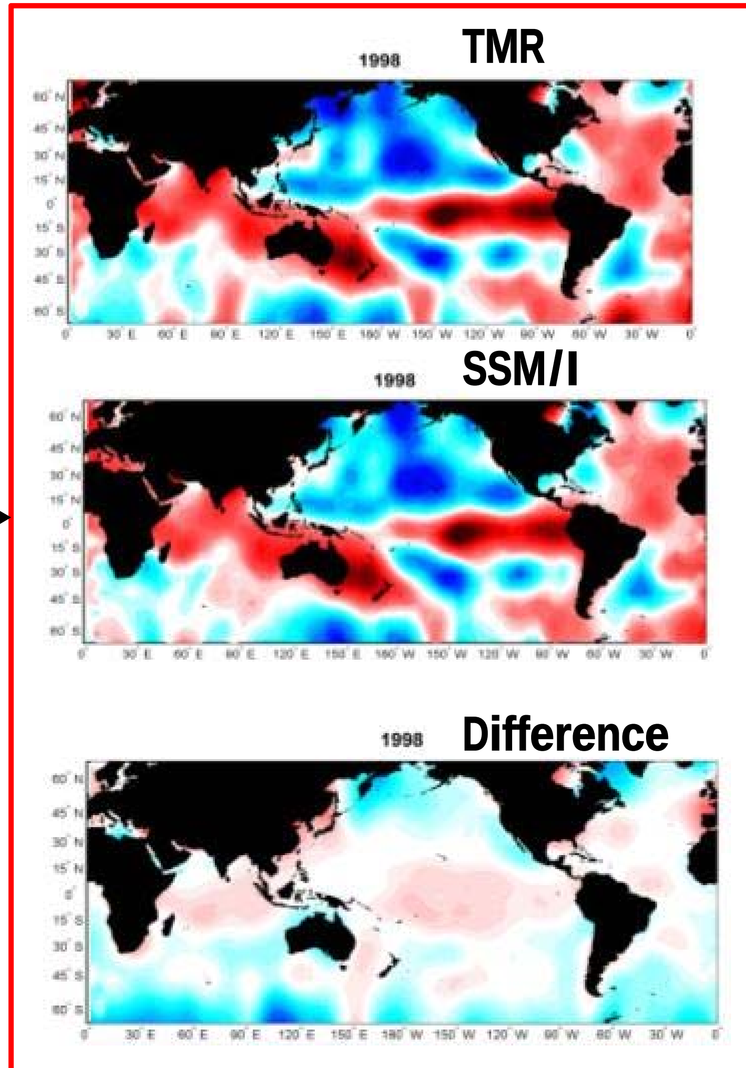
Validate inter-calibration of multi-sensor records

Assessing uncertainty in observations for model validation

Comparison of IWV Annual Anomalies

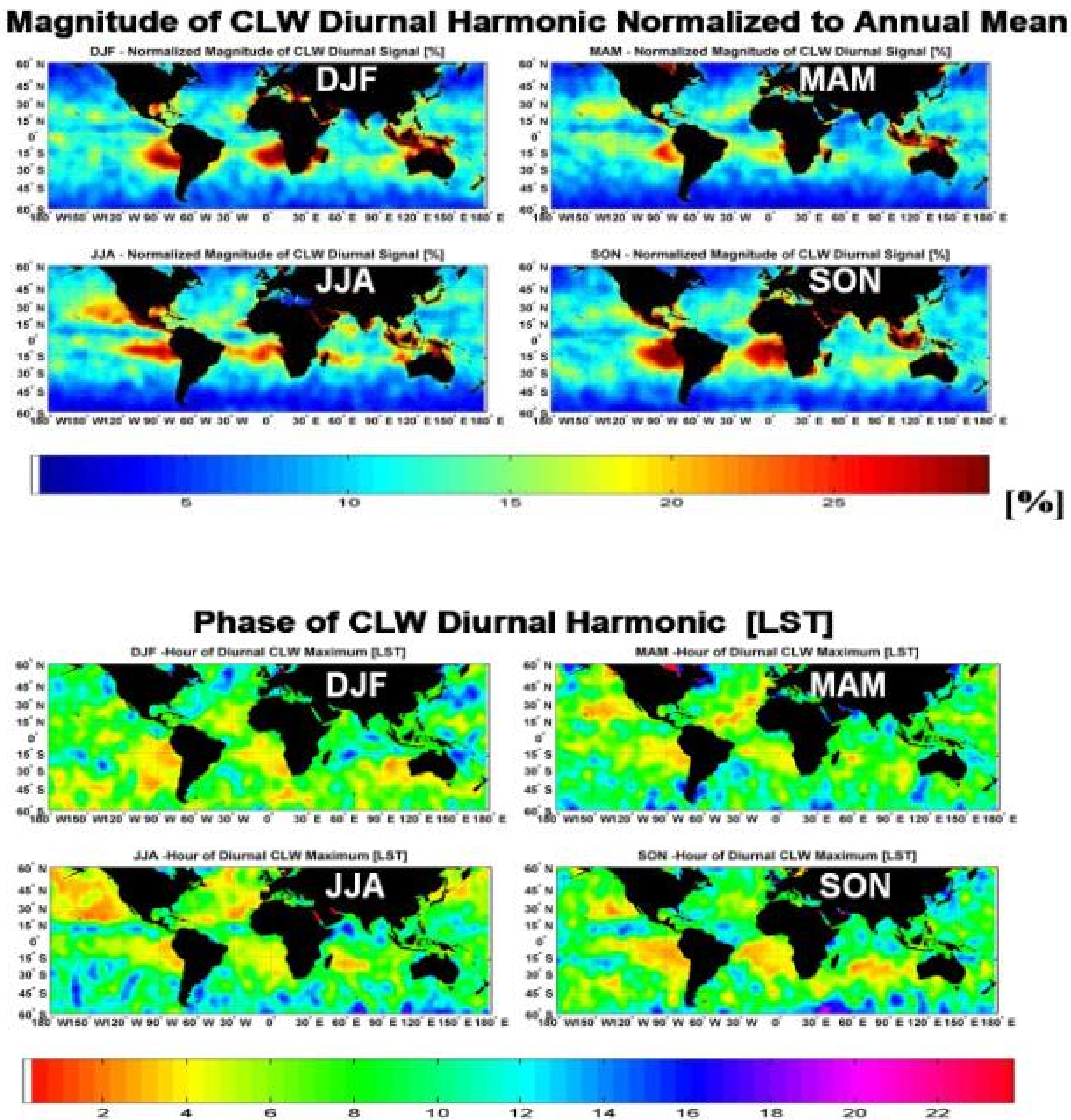


IWV annual anomalies from the 1992-2005 mean for TMR (left), SSM/I (center) and the TMR-SSM/I difference (left). The inter-satellite differences are small compared to the observed anomalies, providing realistic constraints for model validation.



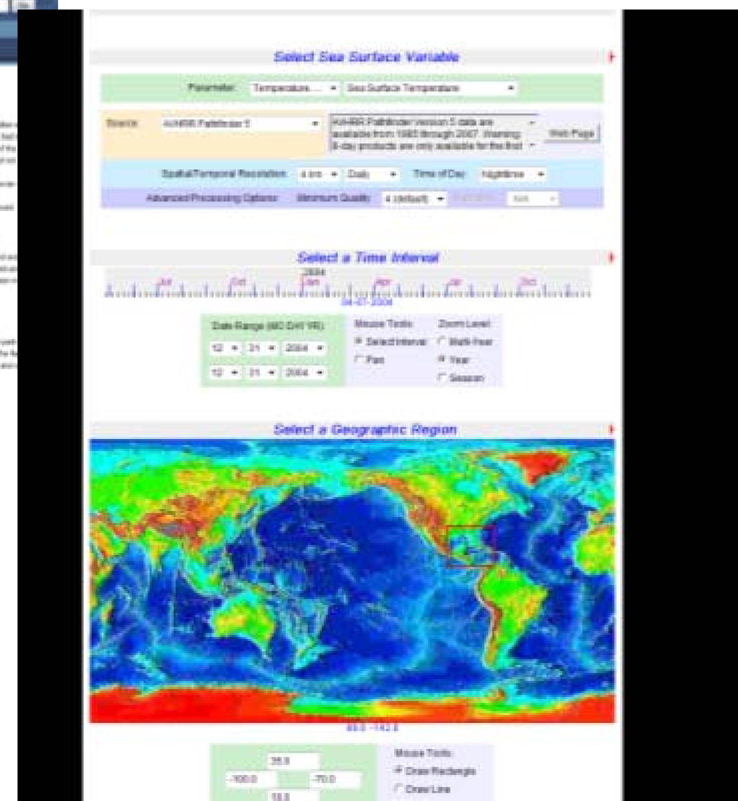
Diurnal Cycle

- Understanding diurnal cycle, particularly for clouds, is important for assessing climate feedback mechanisms
  - Diurnal cycle aliased in sun-synchronous sensors
  - As record grows, can study changes in diurnal cycle over time

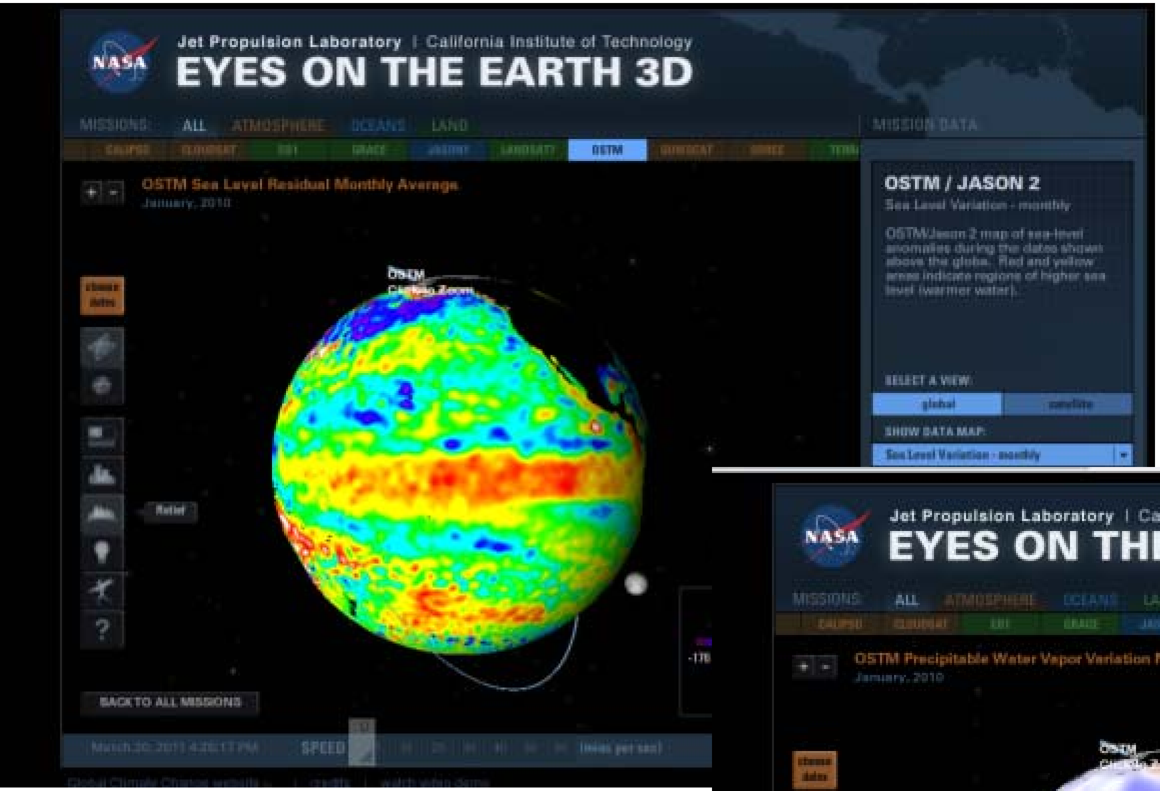


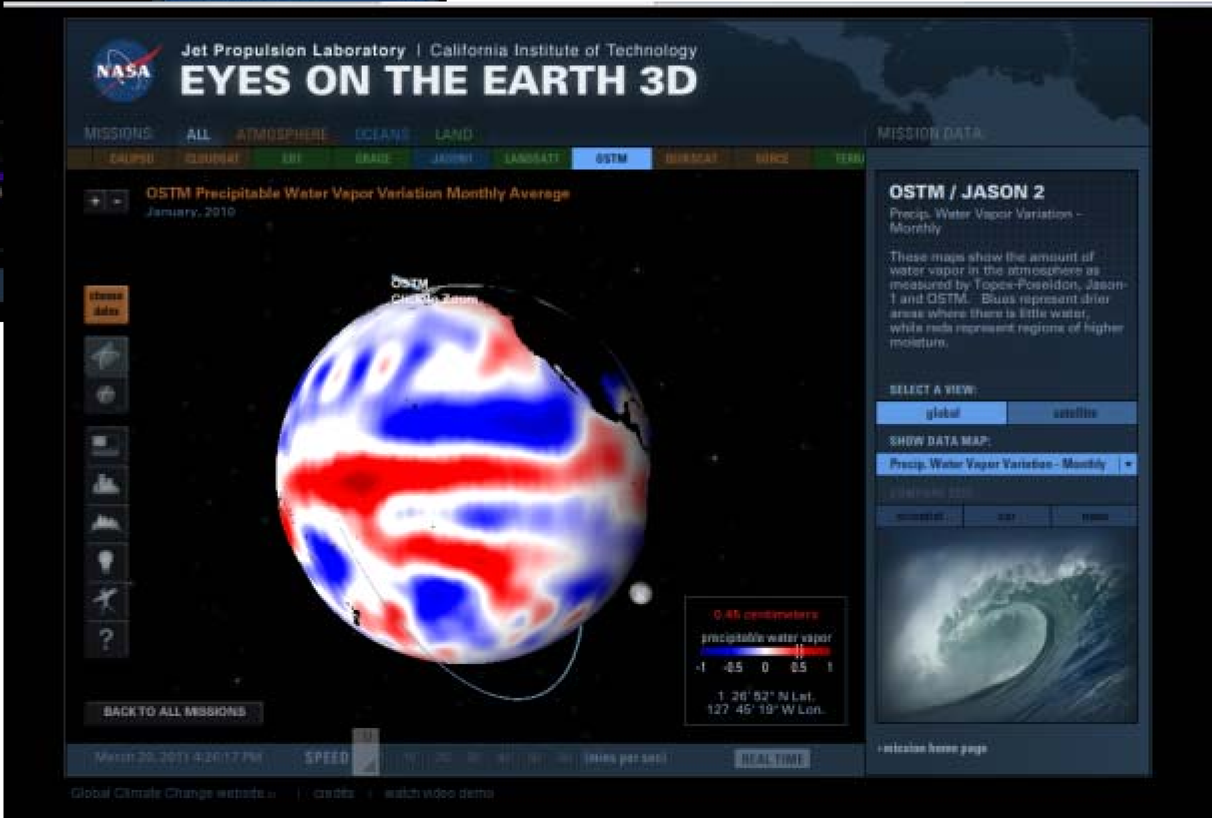
Distribution

- Working with PO.DAAC to offer data through new web portal
  - Access raw data records or higher level data
  - Includes ability to subset in time and space



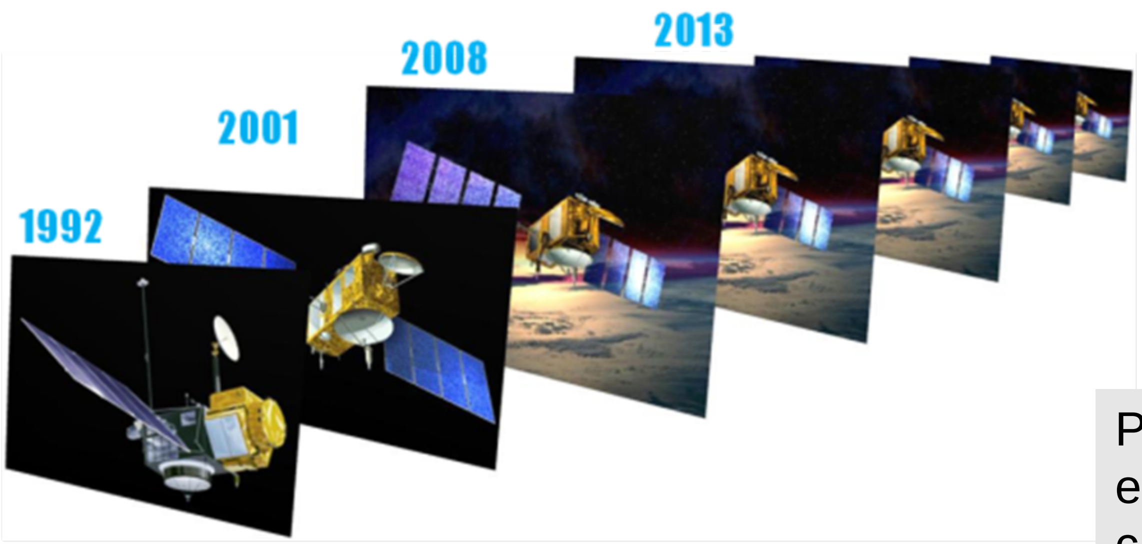
Outreach


Jet Propulsion Laboratory | California Institute of Technology
EYES ON THE EARTH 3D
MISSIONS: ALL ATMOSPHERE OCEANS LAND
MISSION DATA
OSTM Sea Level Residual Monthly Average
January, 2010
OSTM / JASON 2
Sea Level Variation - monthly
OSTM/Jason 2 map of sea-level anomalies during the dates shown above the globe. Red and yellow areas indicate regions of higher sea level (warmer water).
SELECT A VIEW:
global
satellite
SHOW DATA MAP:
Sea Level Variation - monthly
BACK TO ALL MISSIONS
SPEED


Jet Propulsion Laboratory | California Institute of Technology
EYES ON THE EARTH 3D
MISSIONS: ALL ATMOSPHERE OCEANS LAND
MISSION DATA
OSTM Precipitable Water Vapor Variation Monthly Average
January, 2010
OSTM / JASON 2
Precip. Water Vapor Variation - Monthly
These maps show the amount of water vapor in the atmosphere as measured by Topex-Poseidon, Jason-1 and OSTM. Blues represent drier areas where there is little water, while reds represent regions of higher moisture.
SELECT A VIEW:
global
satellite
SHOW DATA MAP:
Precip. Water Vapor Variation - Monthly
precipitable water vapor
-1 -0.5 0 0.5 1
BACK TO ALL MISSIONS
SPEED
REAL TIME
Global Climate Change website | credits | watch video demo

Summary

- Careful radiometer calibration yields almost 20-year climate data record of precipitable water vapor and cloud liquid water
  - Complementary to climate data records produced from other sensors
  - Complete sampling of diurnal cycle
  - Continuous record from well inter-calibrated instruments (i.e. tandem mission)
  - Record should extend at least into the next decade
  - *Keihm et al., 2009, JGR; Brown et al., 2009, TGRS*



Potential for Jason-CS to include enhanced radiometer suited for climate observations which will improve record