MODIS Clear-sky Infrared Total Precipitable Water Vapor Product and its continuity with VIIRS and CrIS

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Outline

- The TPW retrieval algorithm
- MODIS vs VIIRS TPW Products
- Terra/MODIS calibration issue
- Aqua/MODIS data record / trends
- HIRS TPW data record
- Conclusion
- Future Plans

Algorithm Discussion

Clear radiance exiting the atmosphere for a MODIS IR band with wavelength λ:

$$I_\lambda = \varepsilon_\lambda^{sfc} B_\lambda(T_{sfc})\, \tau_\lambda(p_{sfc}) - \int_o^{p_{sfc}} B_\lambda(T(p))\, [\, d\tau_\lambda(p) / dp \,]\, dp\ .$$

I_λ is measured by MODIS for $\lambda = 4.4 - 14.2\mu m$ (I_{25}, I_{27}, … I_{36})

I_λ can be considered a nonlinear function of the atmospheric properties including T, q, ozone, surface pressure, skin temperature, and emissivity.

We can infer a statistical regression relationship using calculated radiances from a global set of radiosonde profiles and surface data.

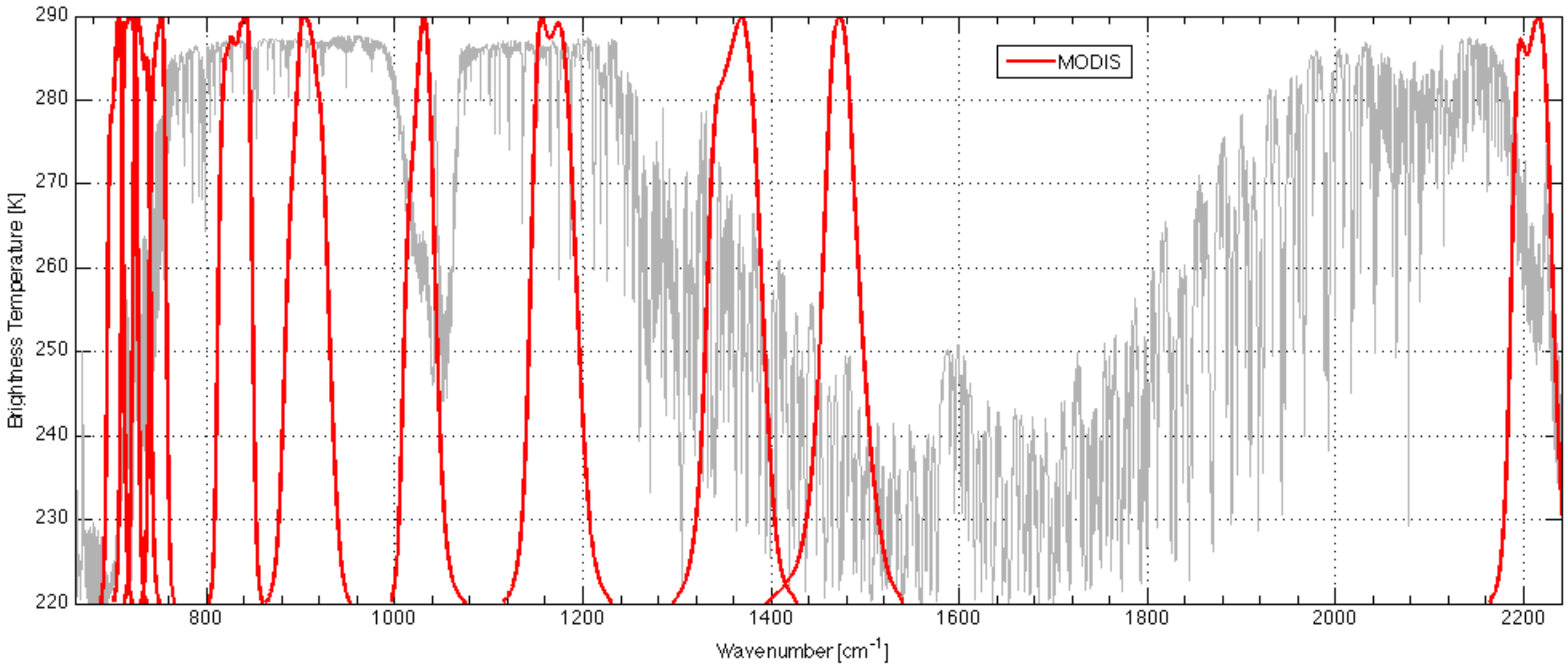
Relationship is inverted to retrieve atmospheric properties from observed MODIS radiances.

Algorithm Discussion

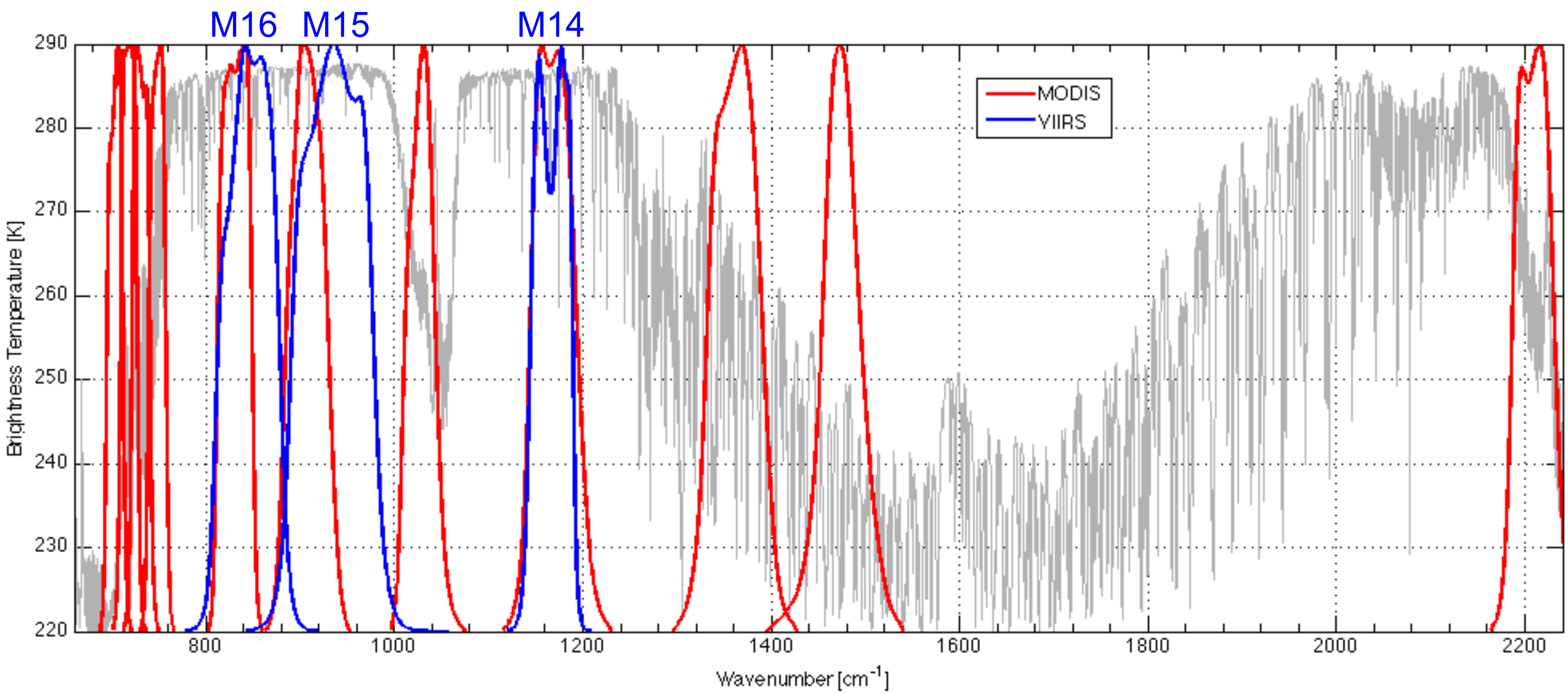
- **Global Training Dataset (SeeBor V5.0)**: data set drawn from NOAA-88, TIGR-3, ozonesondes, ECMWF analyses, desert radiosondes containing 15000+ global radiosonde profiles of temperature, moisture, and ozone used for training data set. The surface characteristics is assigned by using the UW Baseline Fit Global Land Surface Emissivity Database http://www.cimss.ssec.wisc.edu/iremis/).
- **RT model**: Radiance calculations for each training profile are made using a 101 pressure layer transmittance model (CRTM). Instrument noise is added to calculated spectral band radiances.
- In the regression retrieval algorithm, viewing angle, land/ocean and Brightness Temperature classifications were applied to build a better relationship for different atmospheric situations.

- **Uncertainty**: MOD07 TPW within 2 (4) mm rms for dry (wet) retrievals wrt Microwave Water Vapor Radiometer (at SGP Cart site)

Spectral Response Functions of Aqua/MODIS TIR bands used by the TPW algorithm



Spectral Response Functions of Aqua/MODIS TIR and VIIRS bands used by the TPW algorithm



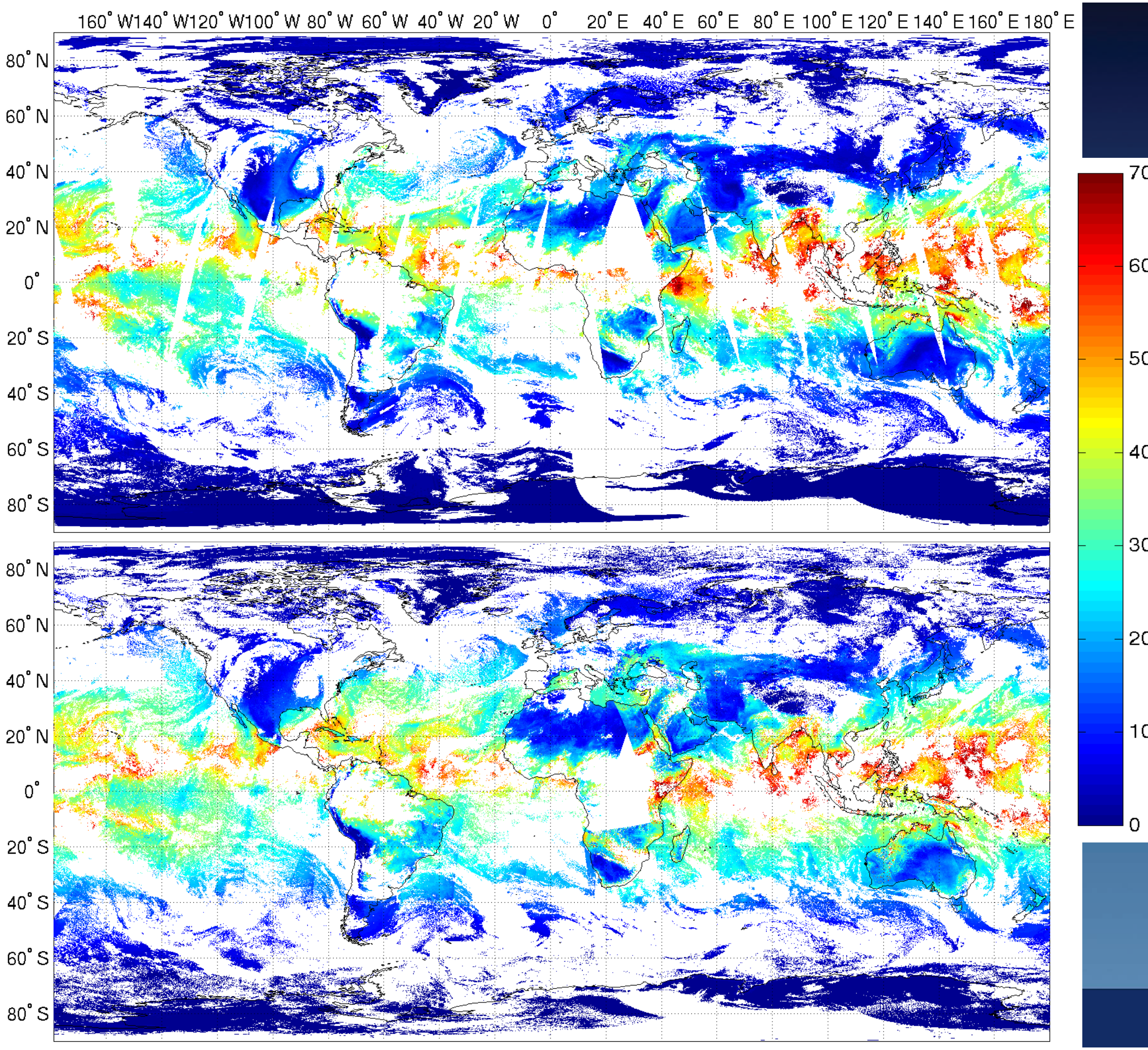
Comparison of the MODIS and the VIIRS TPW Products

Characteristics	MODIS (MOD07)	VIIRS (+CrIS)
Spectral Bands	IR only using CO_2, H_2O and IRW bands; between 4.5 and 14.5 µm (11 bands)	Band M14, M15, M16 TPW derived from CrIS/ATMS
Spatial Resolution	5km : 5x5 1km average	5km: 7x7 750m average
Spatial Coverage	Global (clear sky)	Global (clear sky)
Cloud Mask	MOD35 Cloud Mask	MVCM (750m)
Ancillary Data	GDAS (1^0x1^0 res)	CFSR(0.5^0x0.5^0 res)
Time periods	Morning (SZA <= 85^0 and Local Time Before Noon) Afternoon (SZA <= 85^0 and Local Time After Noon) Evening (SZA > 85^0 and Local Time Before Midnight) Night (SZA > 85^0 and Local Time After Midnight)	
Outputs	Total Precipitable Water (TPW) Hi and Low Integrated WV Skin Temperature Temperature, Mixing Ratio Profile Total Ozone Stability indices (LI, K, TT)	TPW Skin Temperature
Time Coverage	2000-	2012-

10.15.2014
AM

MYD07

VIIRS-only
Single Pixel



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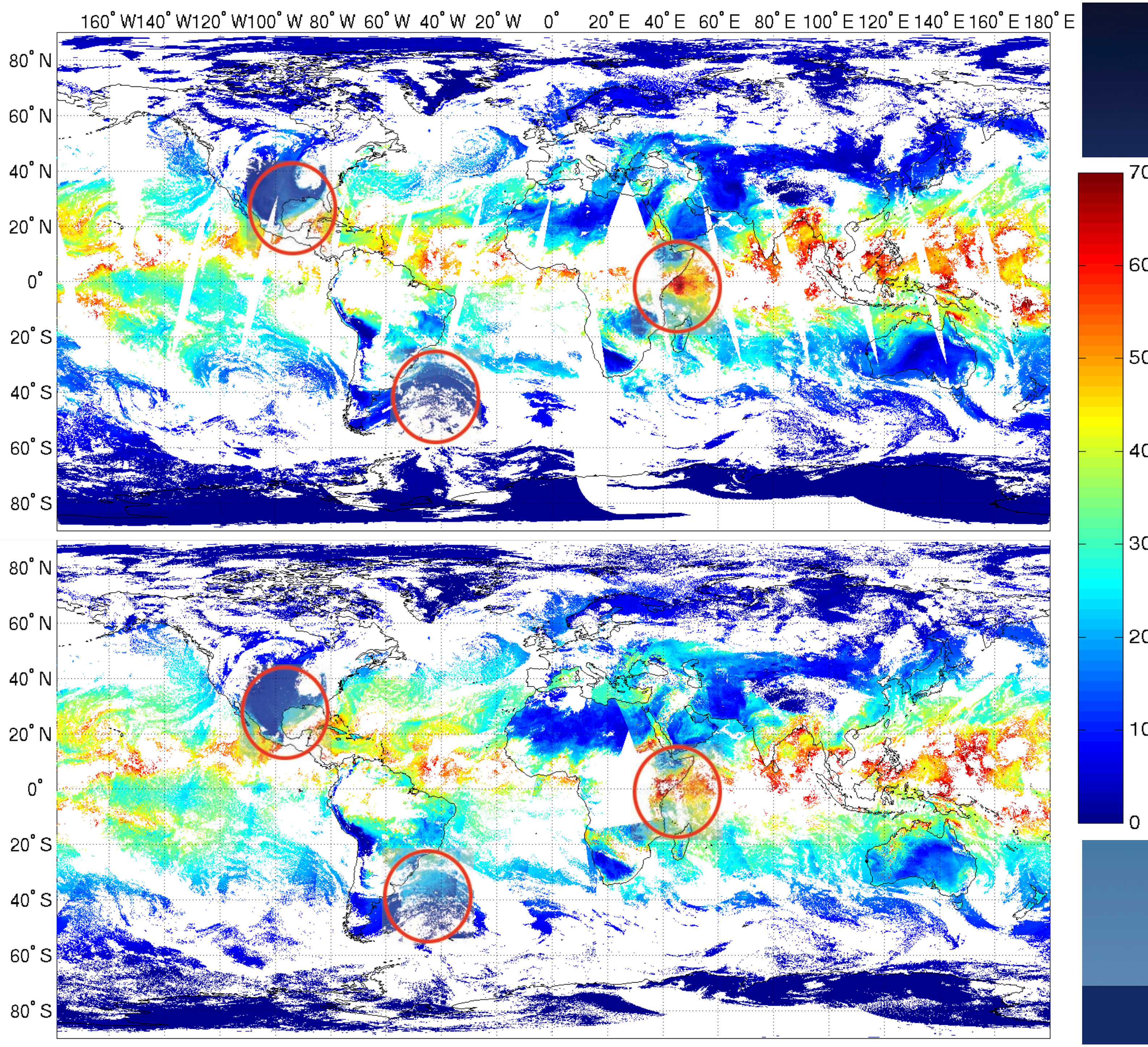
MYD07

VIIRS-only
Single Pixel



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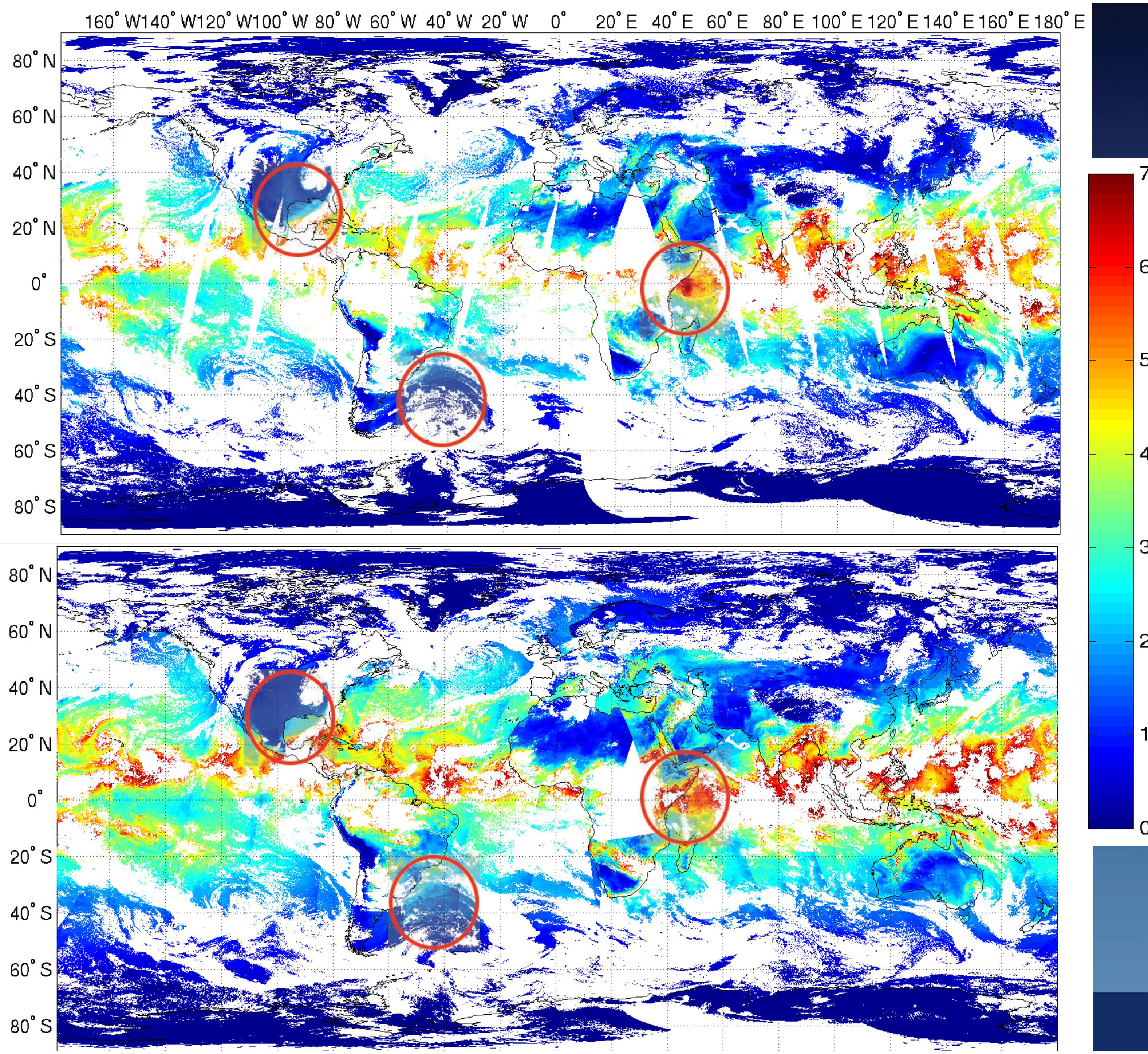
MYD07

VIIRS-only
5km



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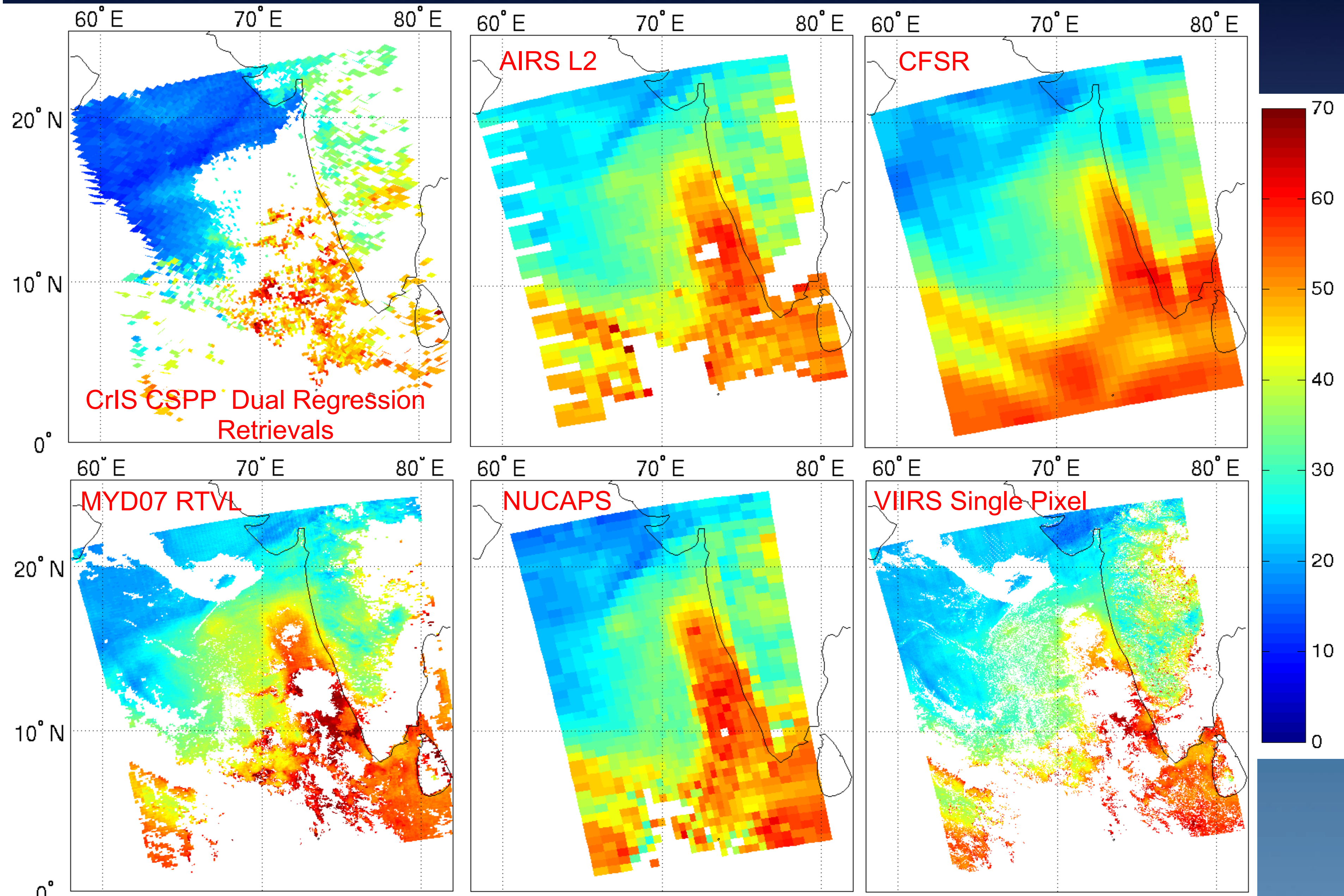
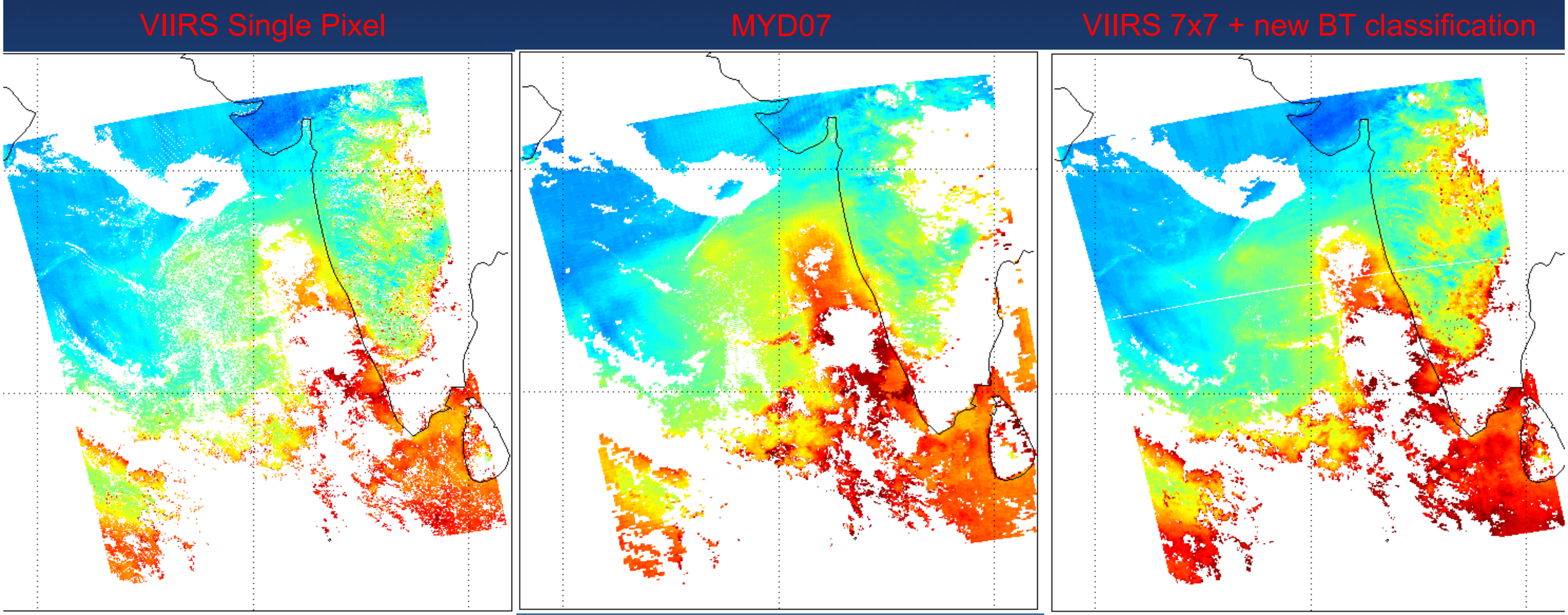
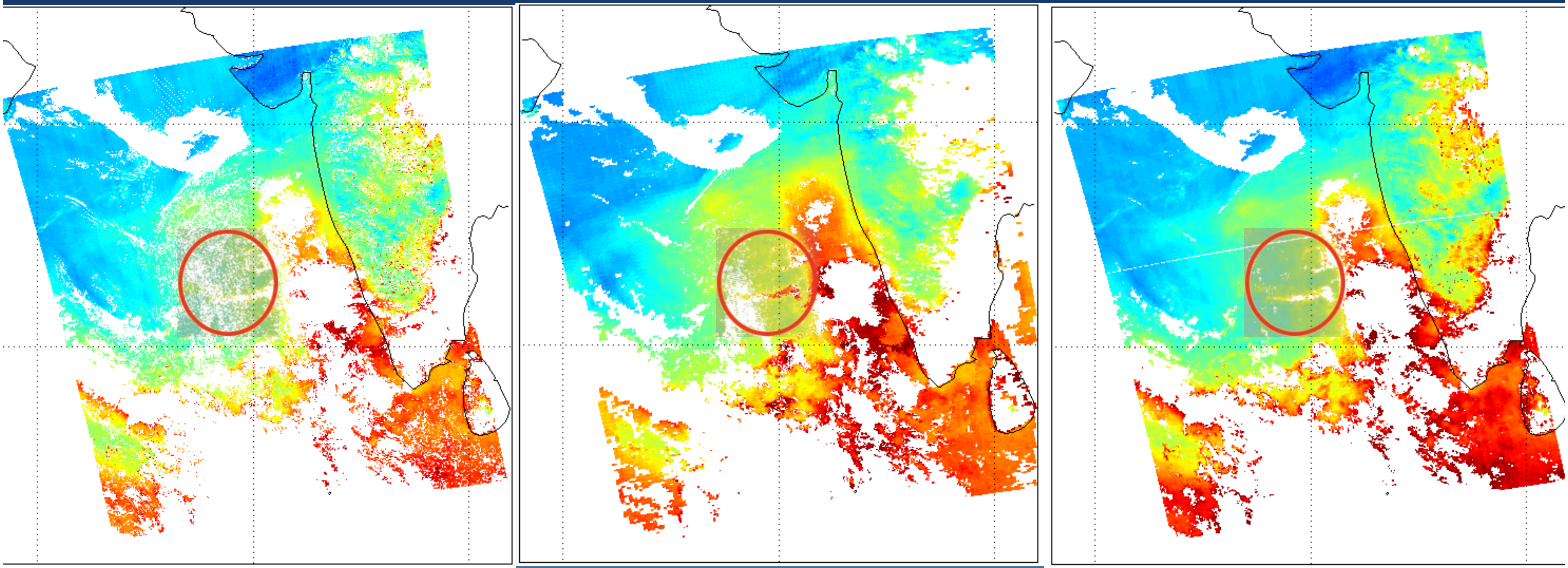
TPW fields for a selected Granule at 8:40 UTC, Oct 15, 2014



TPW fields for a selected Granule at 8:40 UTC, Oct 15, 2014

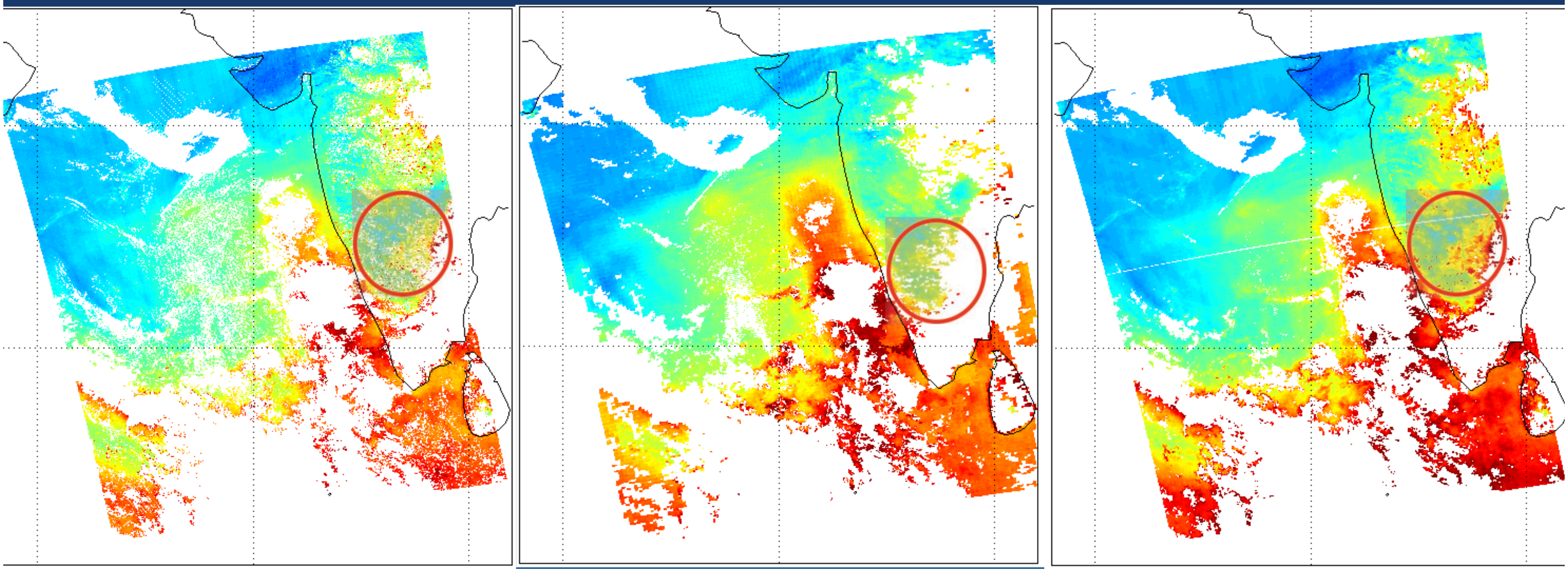


TPW fields for a selected Granule at 8:40 UTC, Oct 15, 2014



TPW fields for a selected Granule at 8:40 UTC, Oct 15, 2014

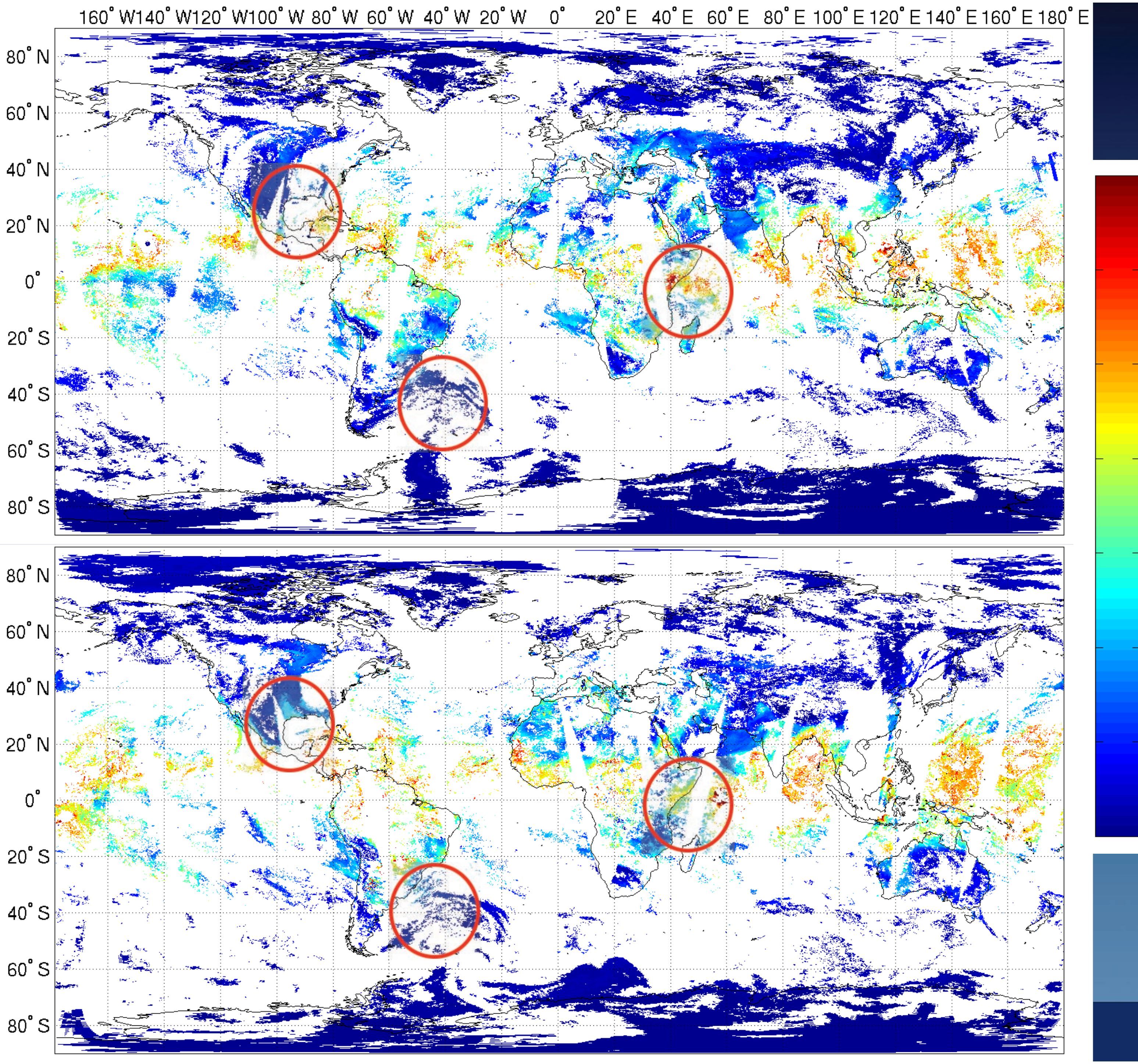
VIIRS Single Pixel | MYD07 | VIIRS 7x7 + new BT classification



10.15.2014
CrIS CSPP
Dual Regress

AM

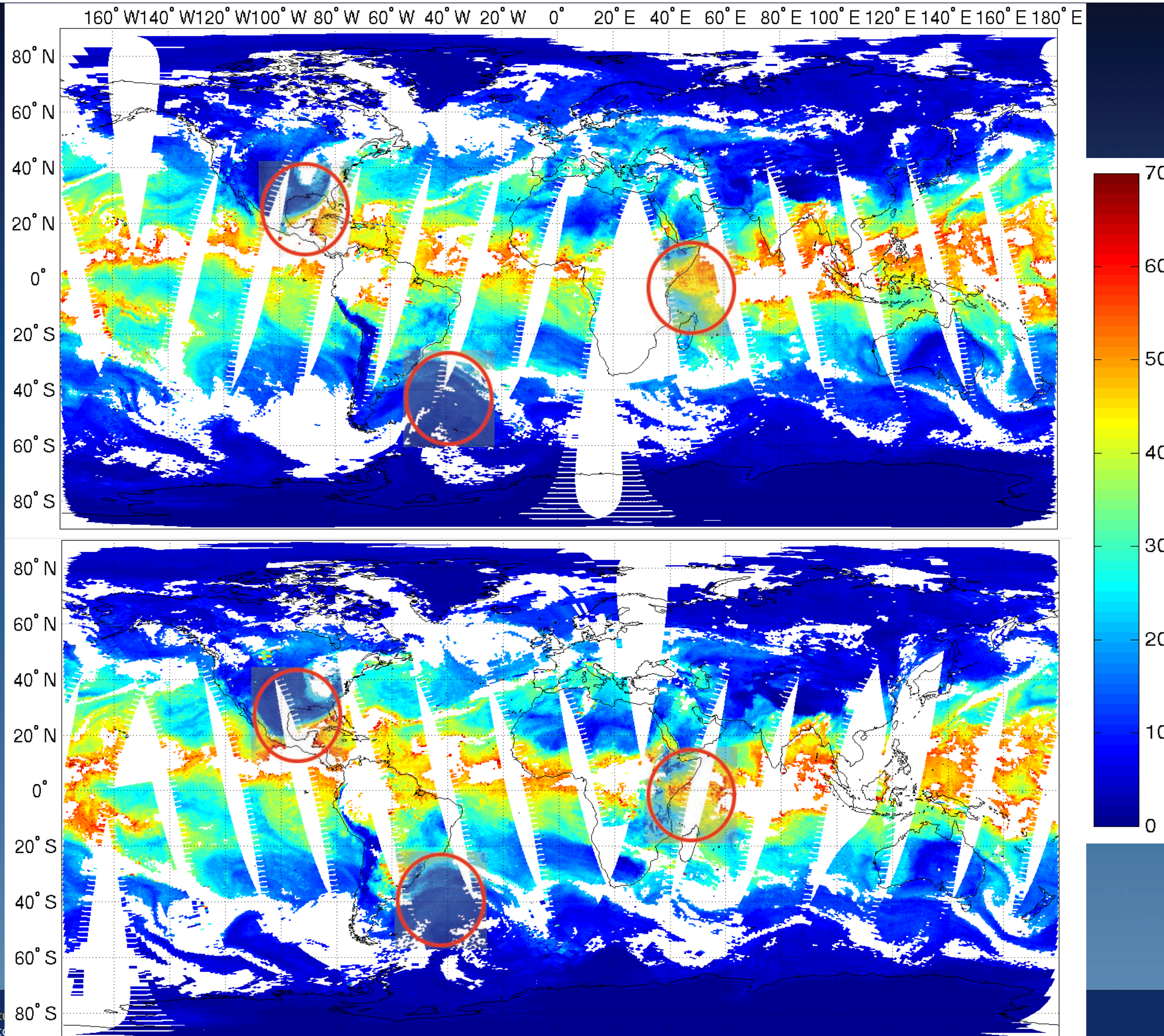
PM



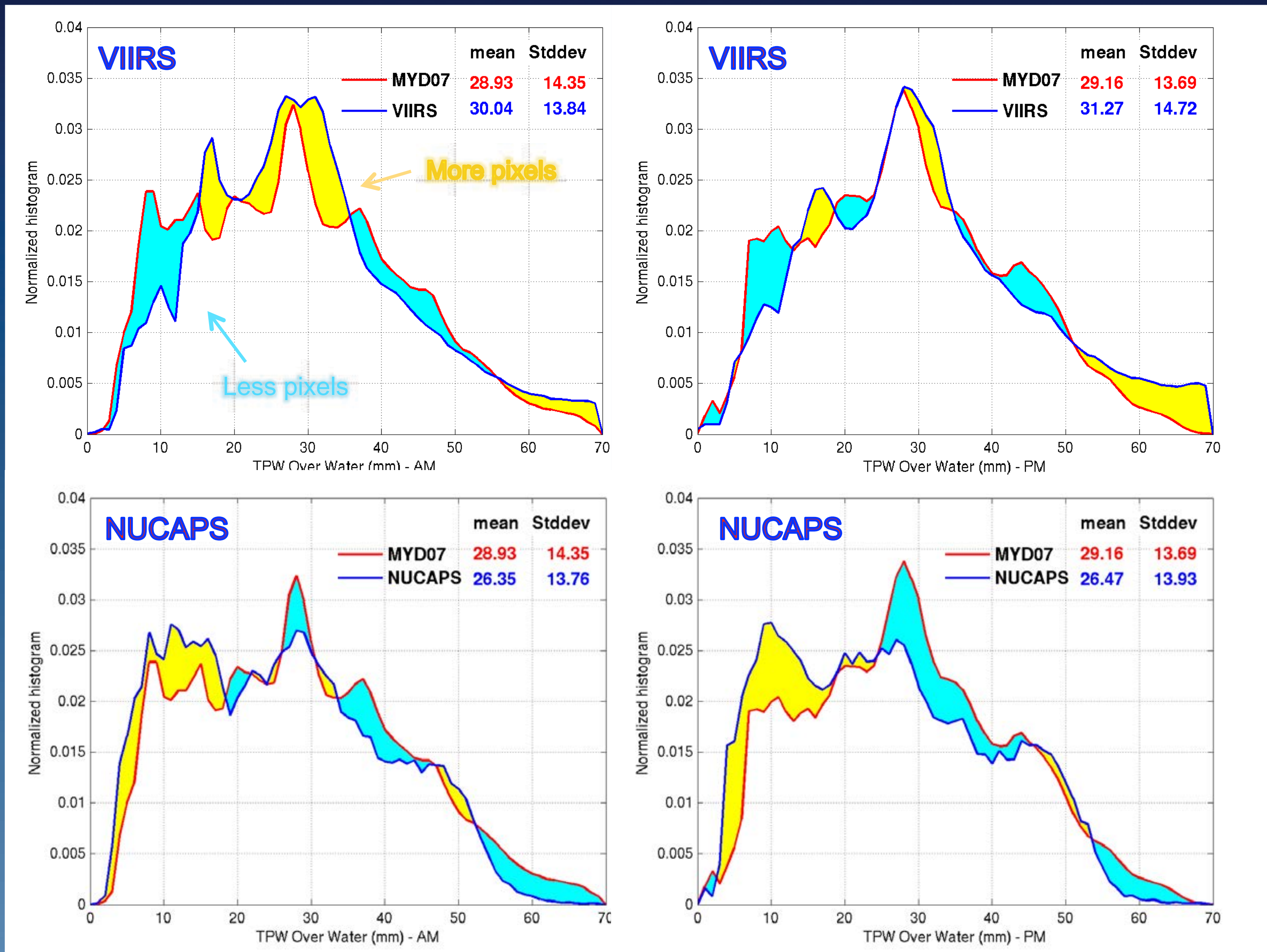
10.15.2014 CrIS+ATMS NUCAPS

AM

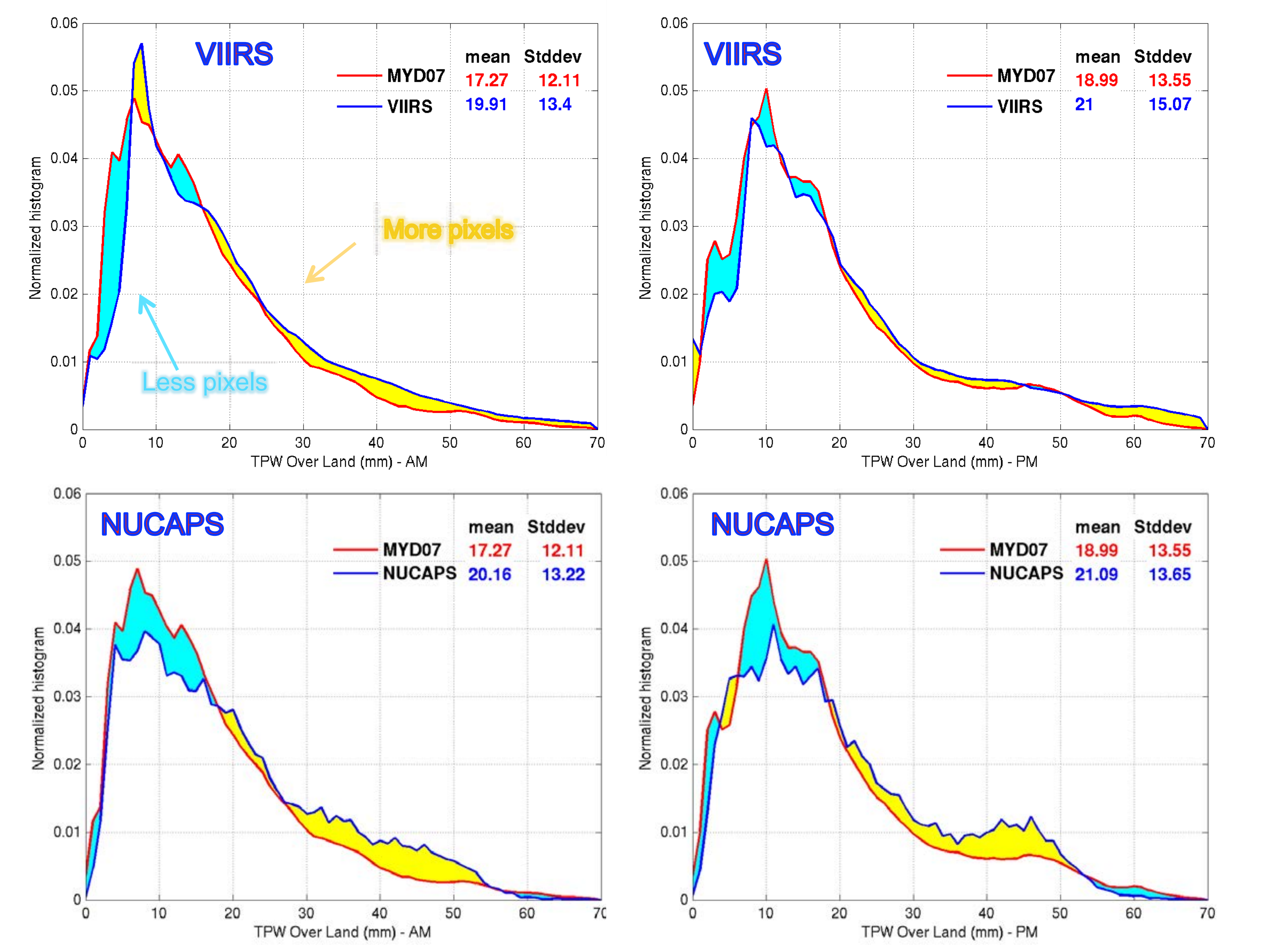
PM



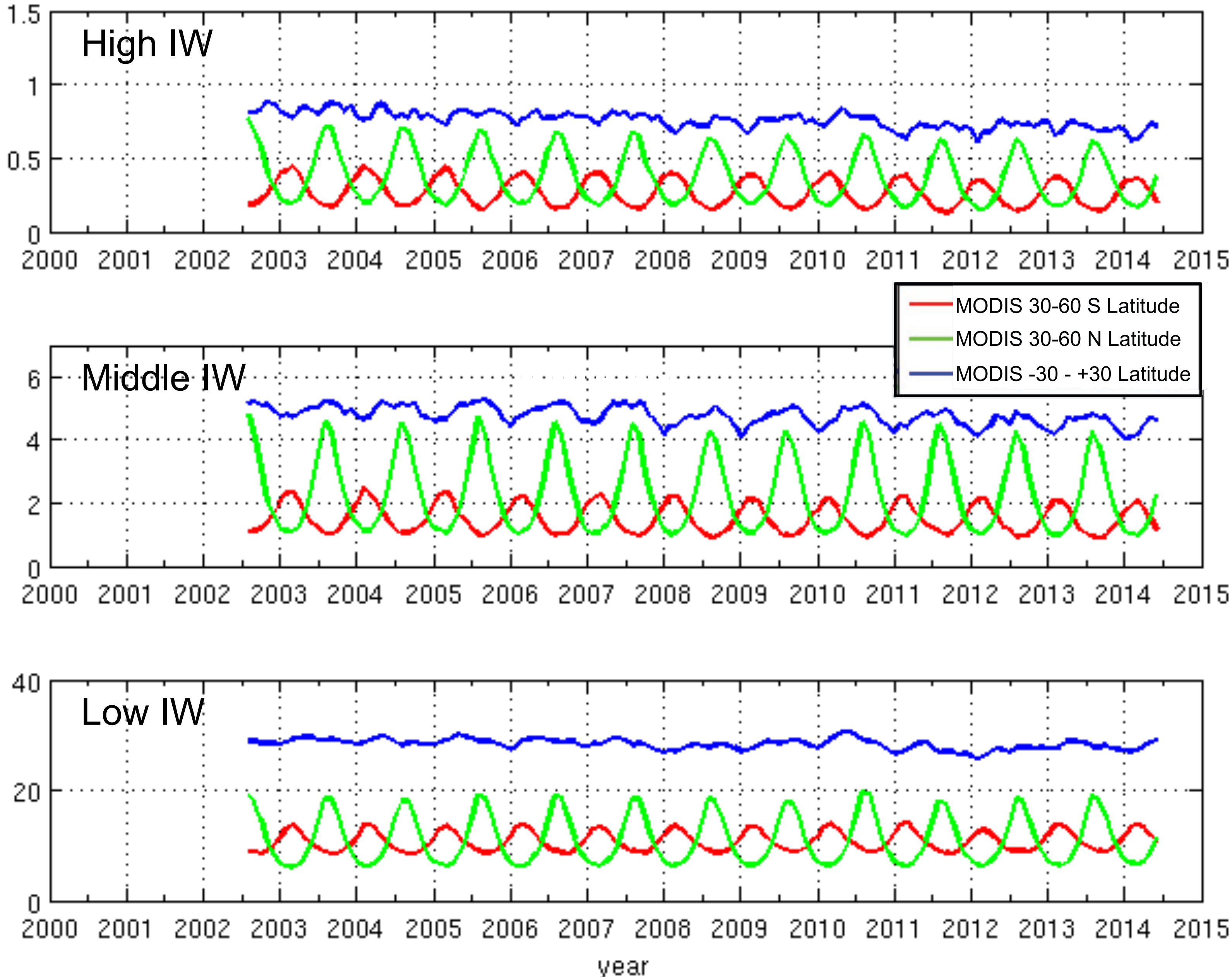
Normalized histogram of MYD07 vs VIIRS (5km) and NUCAPS TPW on Oct 14, 2014 over Water



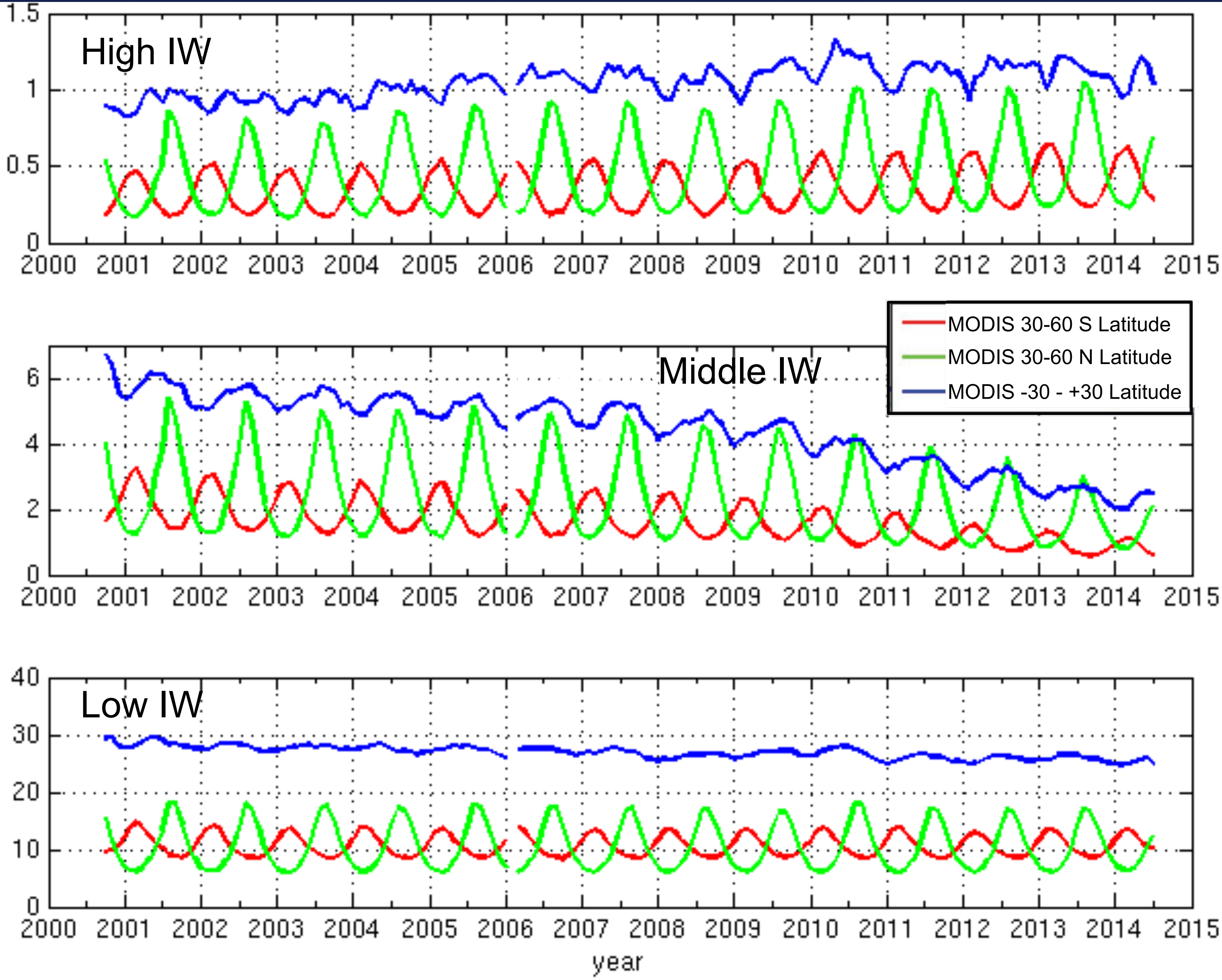
Normalized histogram of MYD07 vs VIIRS (5km) and NUCAPS TPW on Oct 14, 2014 over Land

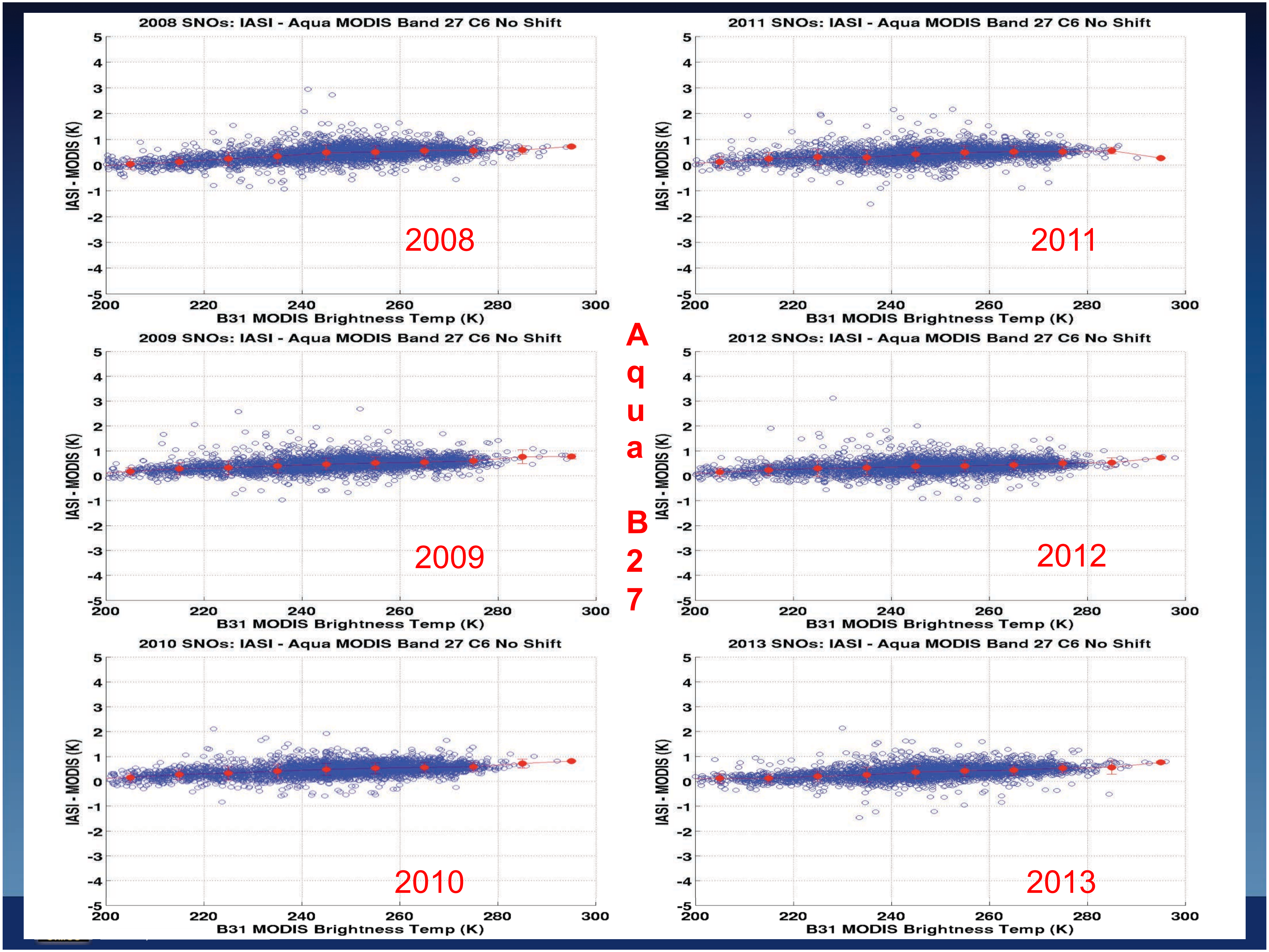


Time series of the Aqua MOD07 high, middle and low layer monthly mean integrated water vapor (IWV) for the mid-latitude North (30N to 60N), mid-latitude South ((30S-60S) and tropical latitude (30S to 30N) bands at nighttime

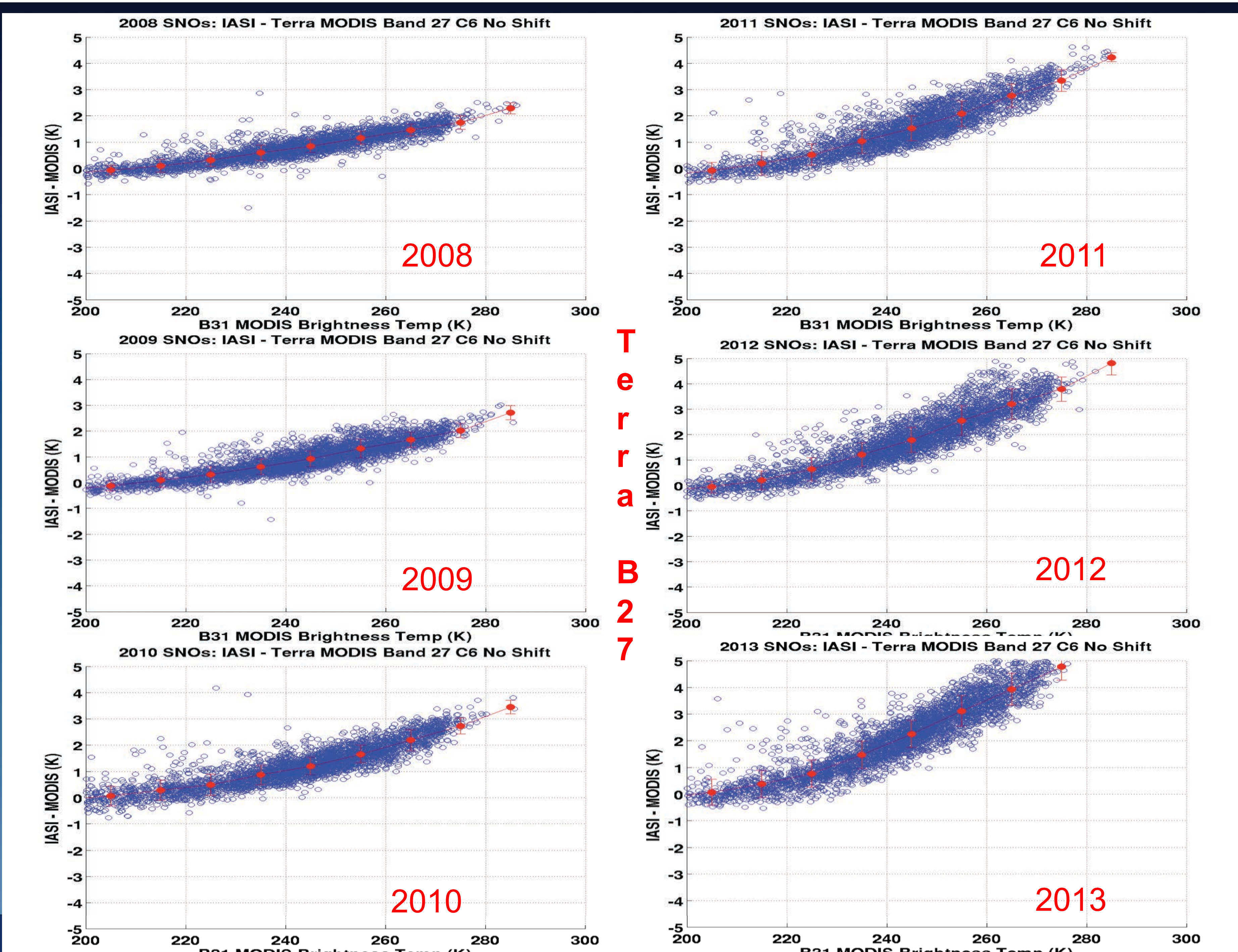


Time series of the Terra MYD07 high, middle and low layer monthly mean integrated water vapor (IWV) for the mid-latitude North (30N to 60N), mid-latitude South ((30S-60S) and tropical latitude (30S to 30N) bands at nighttime





2008 SNOs: IASI - Aqua MODIS Band 27 C6 No Shift
2008
2011 SNOs: IASI - Aqua MODIS Band 27 C6 No Shift
2011
2009 SNOs: IASI - Aqua MODIS Band 27 C6 No Shift
2009
2012 SNOs: IASI - Aqua MODIS Band 27 C6 No Shift
2012
2010 SNOs: IASI - Aqua MODIS Band 27 C6 No Shift
2010
2013 SNOs: IASI - Aqua MODIS Band 27 C6 No Shift
2013
IASI - MODIS (K)
B31 MODIS Brightness Temp (K)
Aqua B27



2008 SNOs: IASI - Terra MODIS Band 27 C6 No Shift
IASI - MODIS (K)
B31 MODIS Brightness Temp (K)
2008
2011 SNOs: IASI - Terra MODIS Band 27 C6 No Shift
IASI - MODIS (K)
B31 MODIS Brightness Temp (K)
2011
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IASI - MODIS (K)
B31 MODIS Brightness Temp (K)
2009
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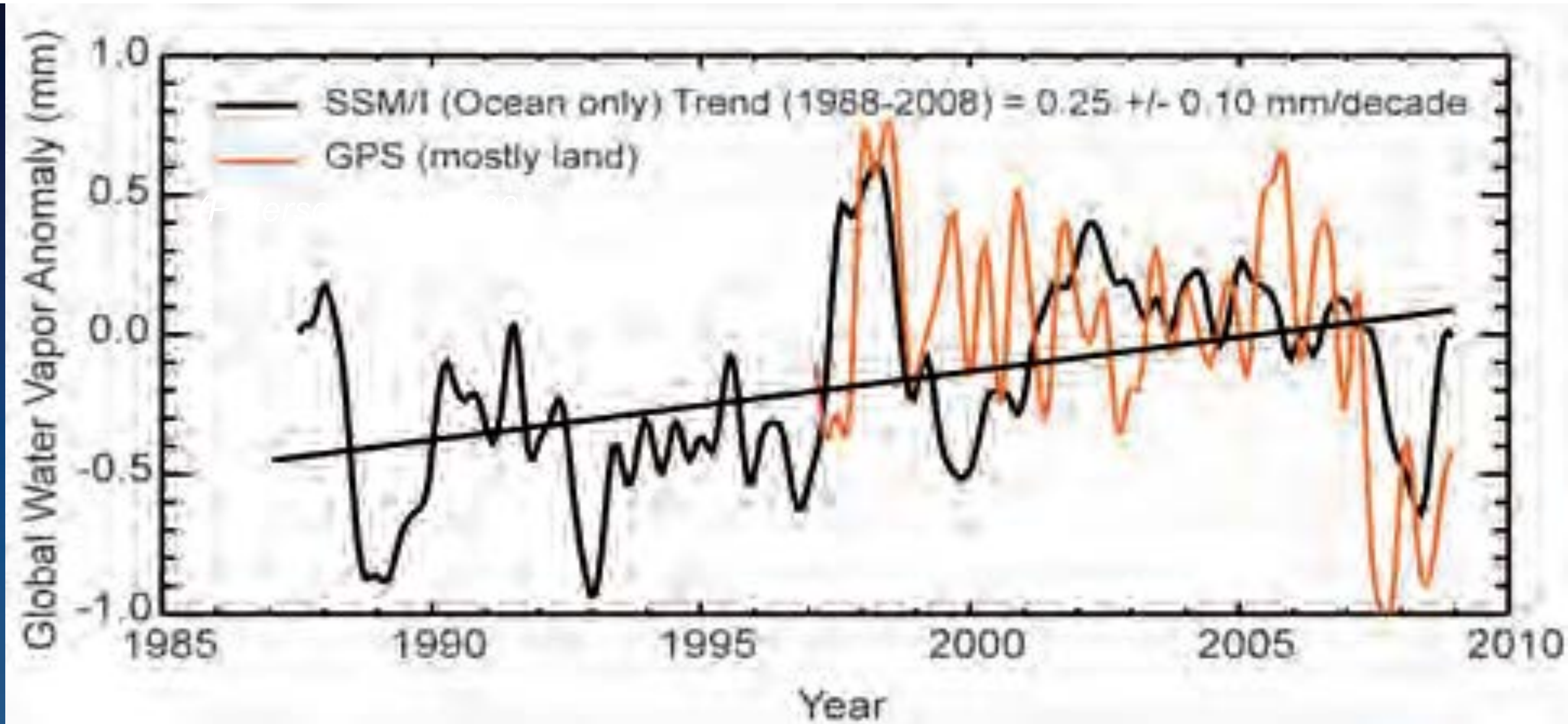
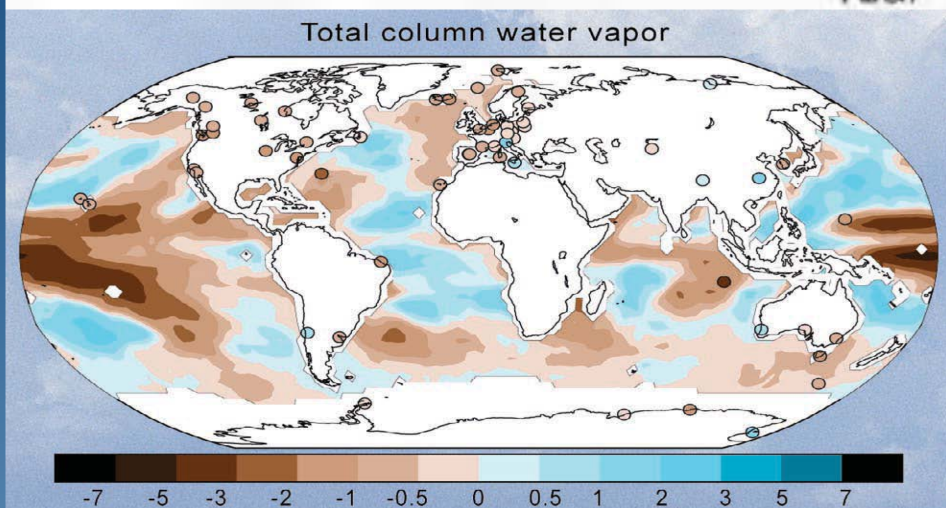
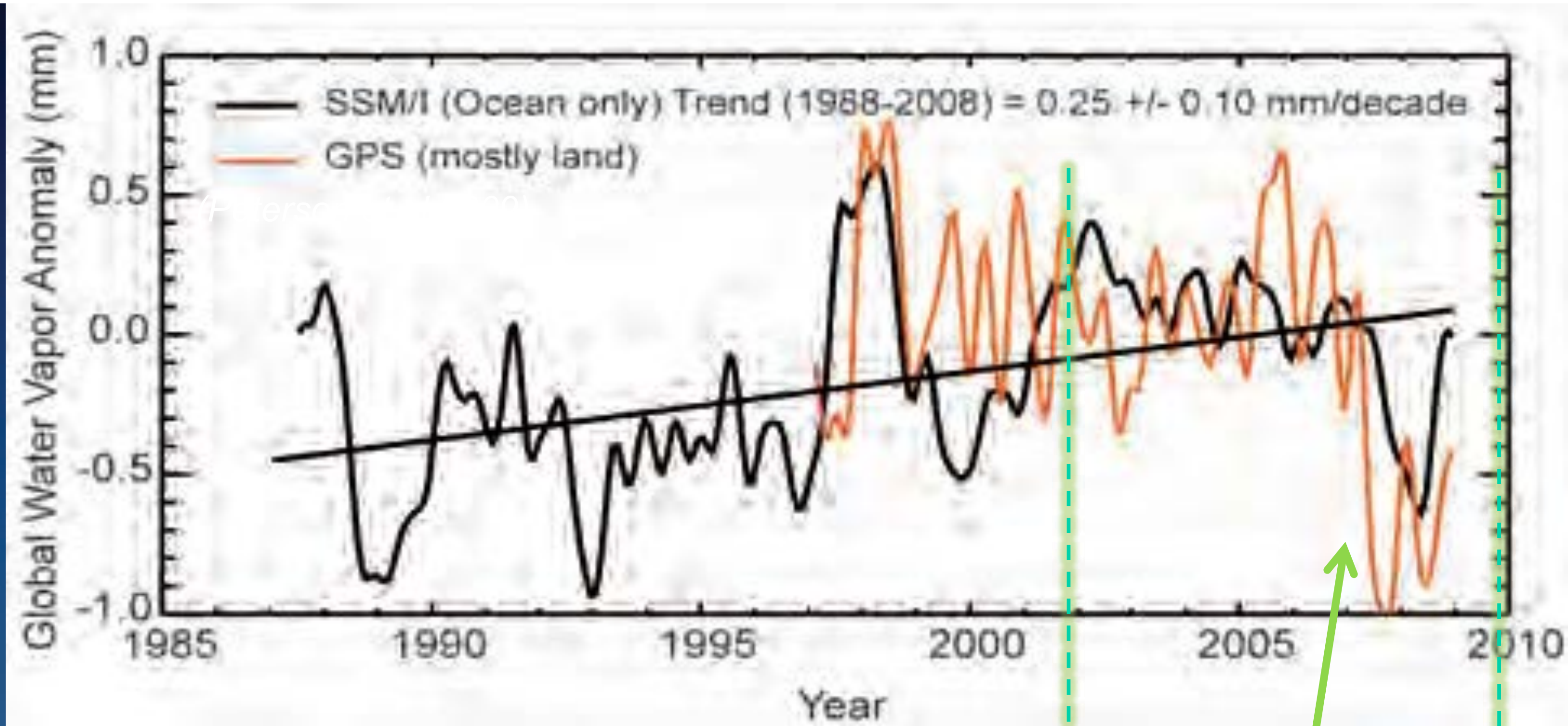
IASI - MODIS (K)
2012
2010 SNOs: IASI - Terra MODIS Band 27 C6 No Shift
IASI - MODIS (K)
B31 MODIS Brightness Temp (K)
2010
2013 SNOs: IASI - Terra MODIS Band 27 C6 No Shift
IASI - MODIS (K)
B31 MODIS Brightness Temp (K)
2013
Terra B27

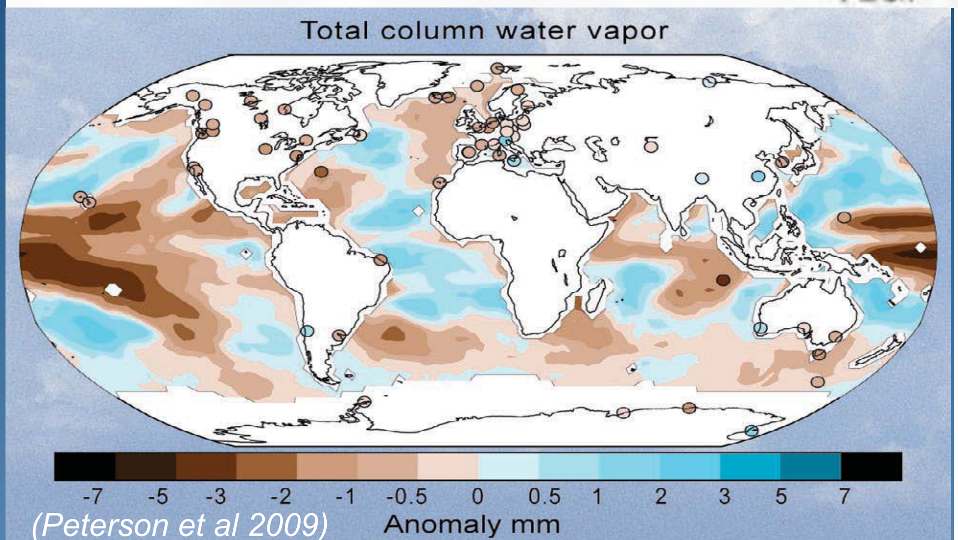


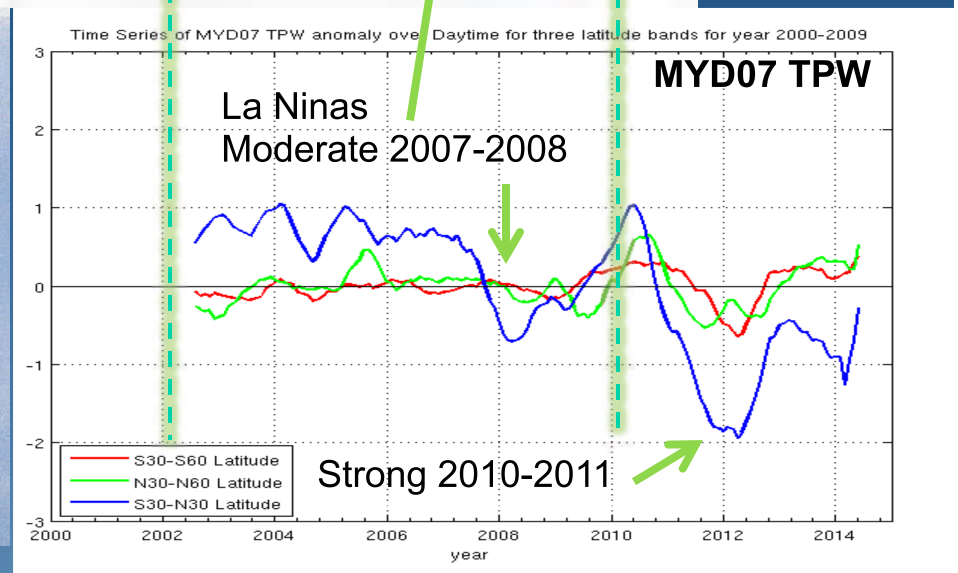


(Peterson et al 2009)

2008 La Nina Water Vapor 10 yr Anomaly

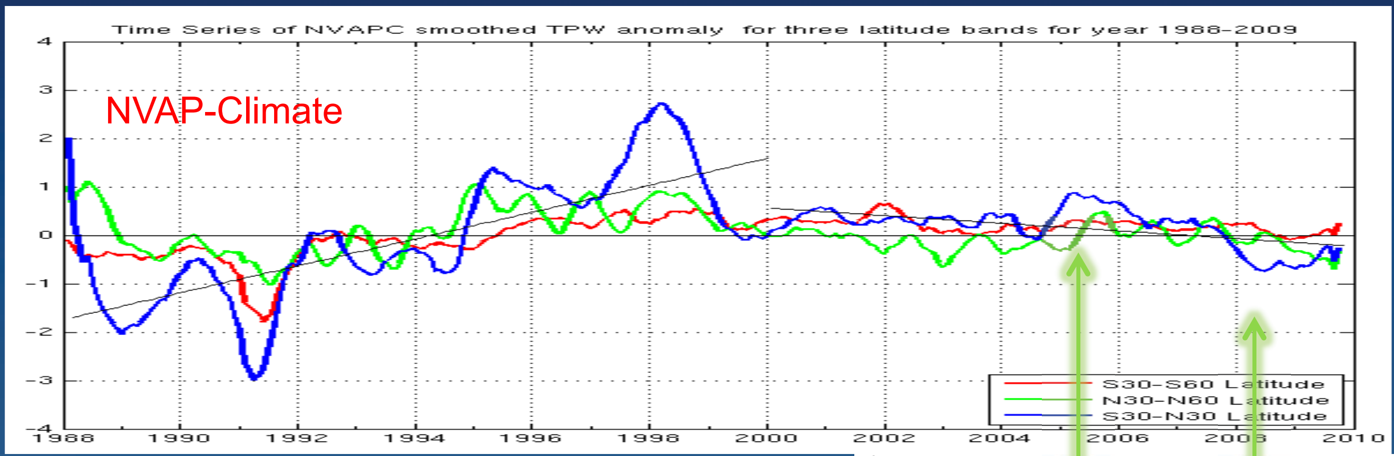


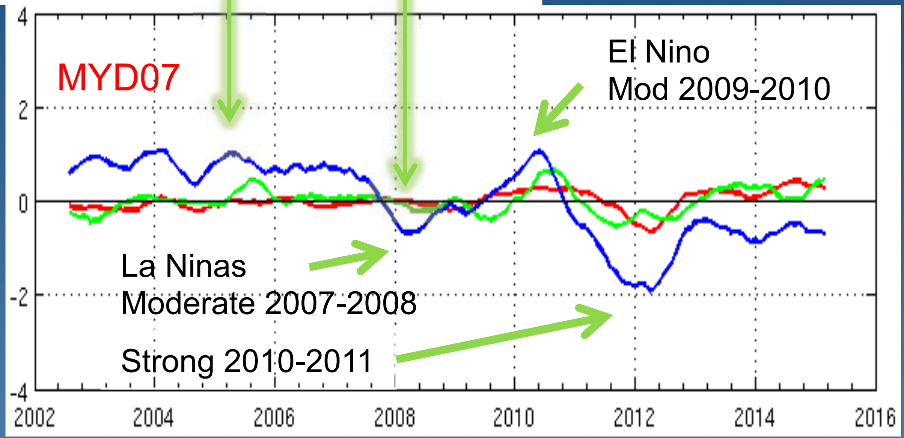




2008 La Nina Water Vapor 10 yr Anomaly

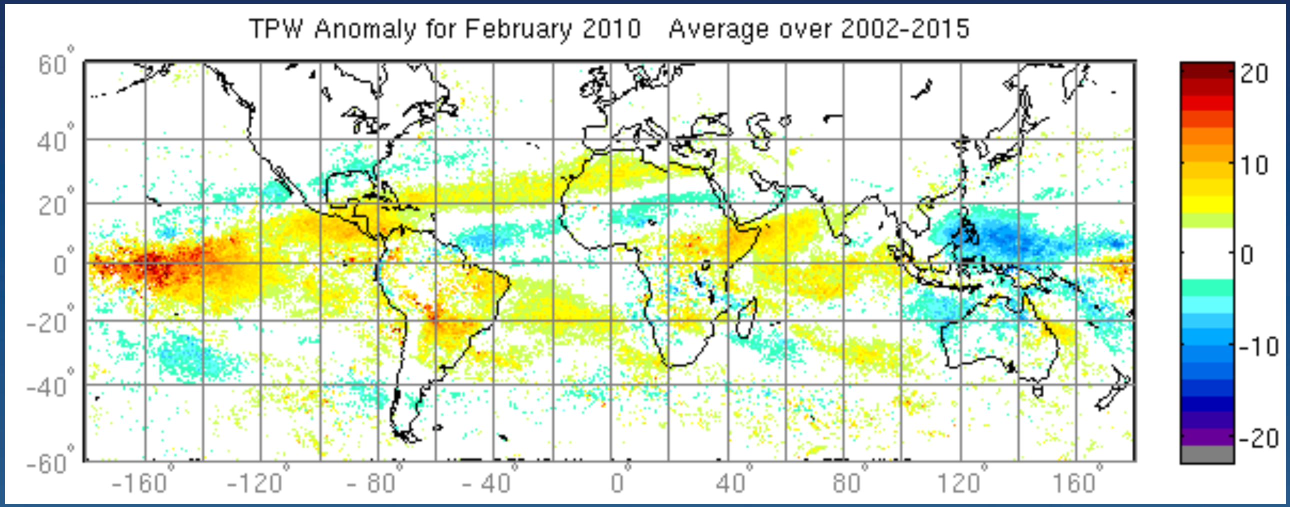
NVAP and MYD07 TPW trends



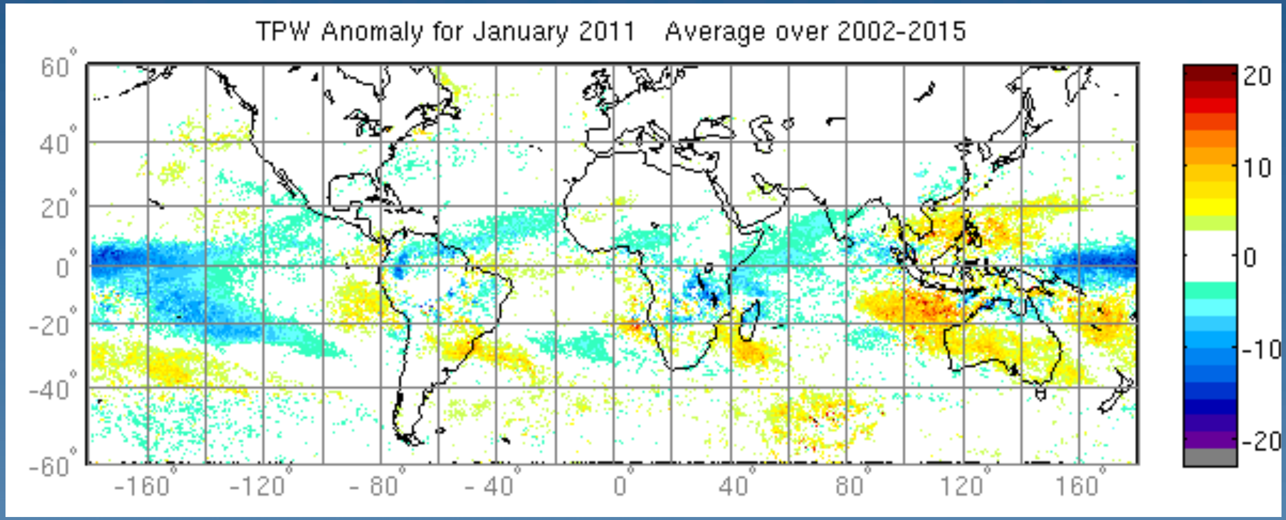


MYD07 TPW 12y anomaly

2009-2010
Moderate El Nino

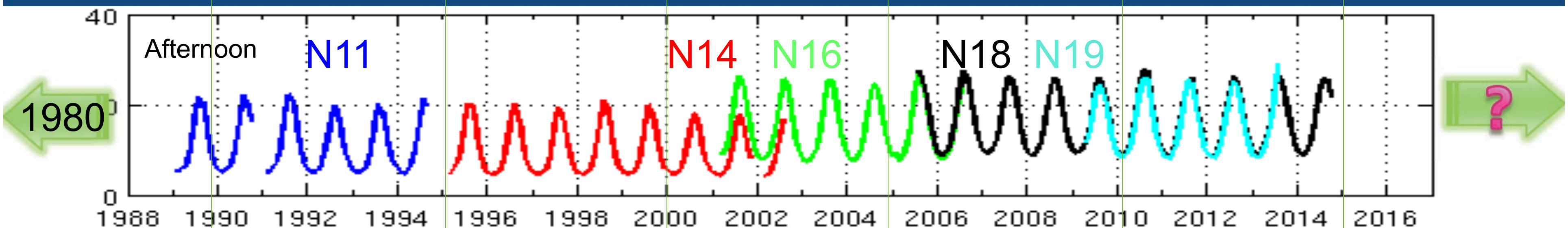


2010-2011
Strong La Nina

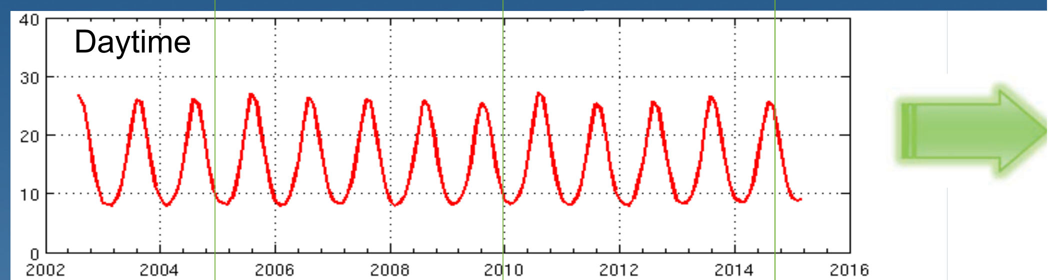


GOAL: Processing HIRS, MODIS, and VIIRS+ with the same algorithm will create a TPW record that can reveal trends over more than 4 decades

HIRS Northern Mid latitude (30N-60N)



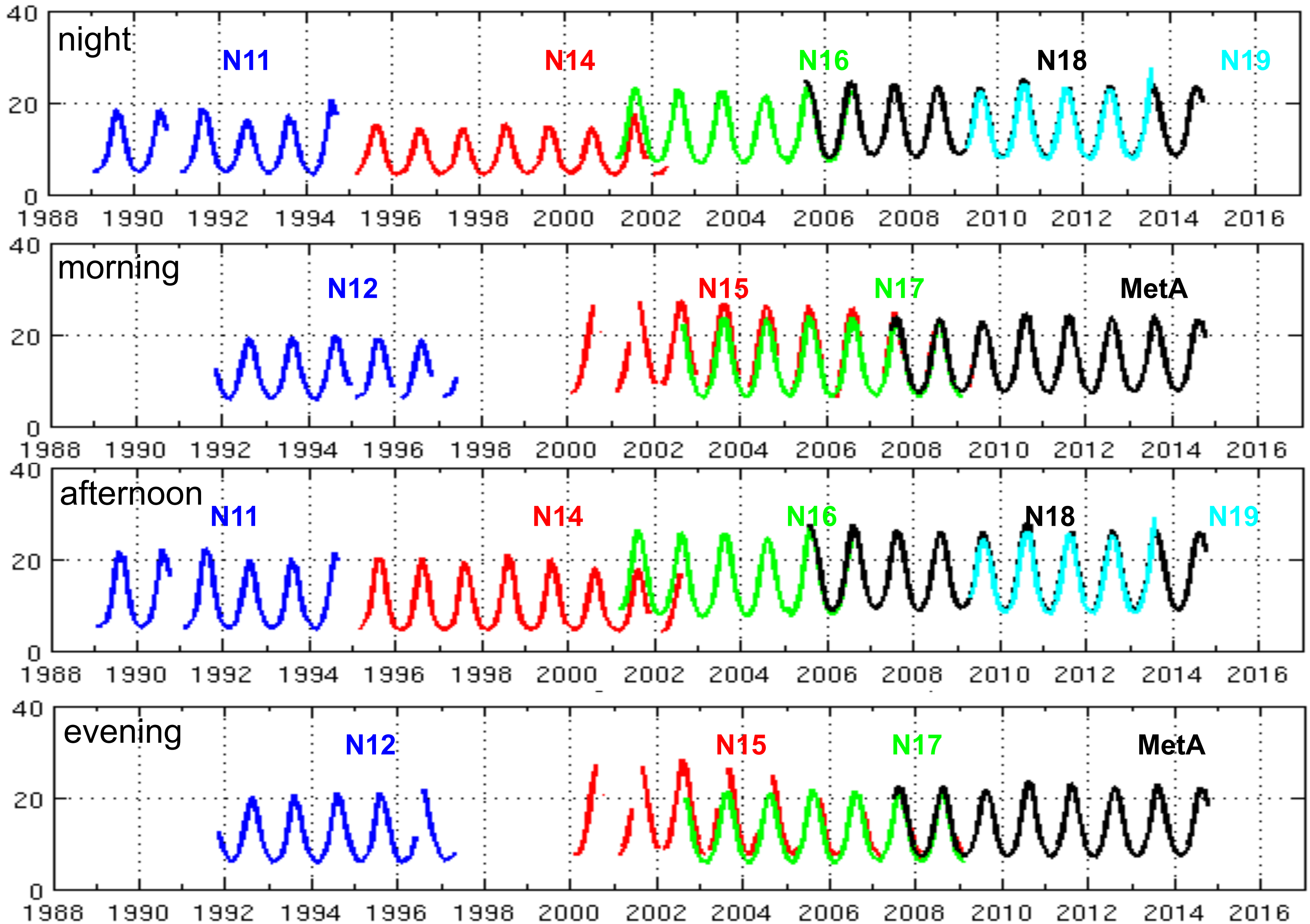
Aqua/MODIS Northern Mid latitude



S-NPP/VIIRS Northern Mid latitude

Time series of HIRS TPW for Northern Mid-latitudes 1989 - 2015

HIRS/2 ← HIRS/3 → HIRS/4



Conclusions (MODIS and HIRS trends)

- Seasonal MODIS, HIRS and NVAP TPW cycle is strongest in northern mid-lats and weakest in tropics
- Aqua MODIS and NVAP (& HIRS –see on poster) water vapor trends are in good agreement; Terra MODIS water vapor is out of family due to Ch 27 cross-talk calibration drift
- TPW does not show significant diurnal changes
- TPW decrease in 2008 and 2012 is evident in Aqua MODIS, N15 & N17 HIRS and NVAP-Climate data record. Those agree with the La-Nina events at the Tropic.
- Increase in tropical TPW in 2015 is suggested

Conclusions (VIIRS TPW)

- VIIRS split window enables 750 m resolution TPW maps with moderate ability to depict moisture gradients – very wet and very dry conditions are not captured very well
- VIIRS TPW over land requires careful attention to the surface emissivity, sea/land and BT classifications, and clear determination
- NUCAPS show moisture gradients at 50 km resolution even in the presence of non-precipitating clouds
- VIIRS + NUCAPS shows promise for continuing the moisture records established by HIRS and MODIS

Plans for VIIRS + NUCAPS TPW Products

- Check sea-land and BT training data distributions
- Increase the viewing angle categories
- Supplement VIIRS split window with NUCAPS to better capture very dry and wet conditions

Plans for MODIS TPW Products

- Characterize Terra B27 crosstalk and reprocess if possible

Plans for HIRS TPW Products

- Recalibrate split window bands against IASI and reprocess complete record

The End

MODIS spectral shifts applied

Terra		Aqua
Band 27: +4.0 cm-1	H_2O	Band 27: +5.0 cm-1
Band 28: +2.0 cm-1	H_2O	Band 28: +2.0 cm-1
Band 30: +1.0 cm-1	O_3	Band 30: +0.0 cm-1
Band 34: +0.8 cm-1	CO_2	Band 34: +0.8 cm-1
Band 35: +0.8 cm-1	CO_2	Band 35: +0.8 cm-1
Band 36: +1.0 cm-1	CO_2	Band 36: +1.0 cm-1

Based on AIRS/IASI-MODIS Brightness Temperature differences over a selected year 2009. (Tobin et al, 2006, Quinn et al, 2010)