The UW SSEC/CIMSS Global Clear Sky IR Moisture Products derived from HIRS data

University of Wisconsin-Madison

Space Science and Engineering Center (SSEC)

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Recalibrating HIRS Sensors to Produce a 30 year Record of Radiance Measurements Useful for Moisture Trend Analysis

Recalibrating HIRS
Accommodating Orbit Drift
TPW and UTH Trends

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HIRS Recalibration

Mitigating sensor to sensor differences

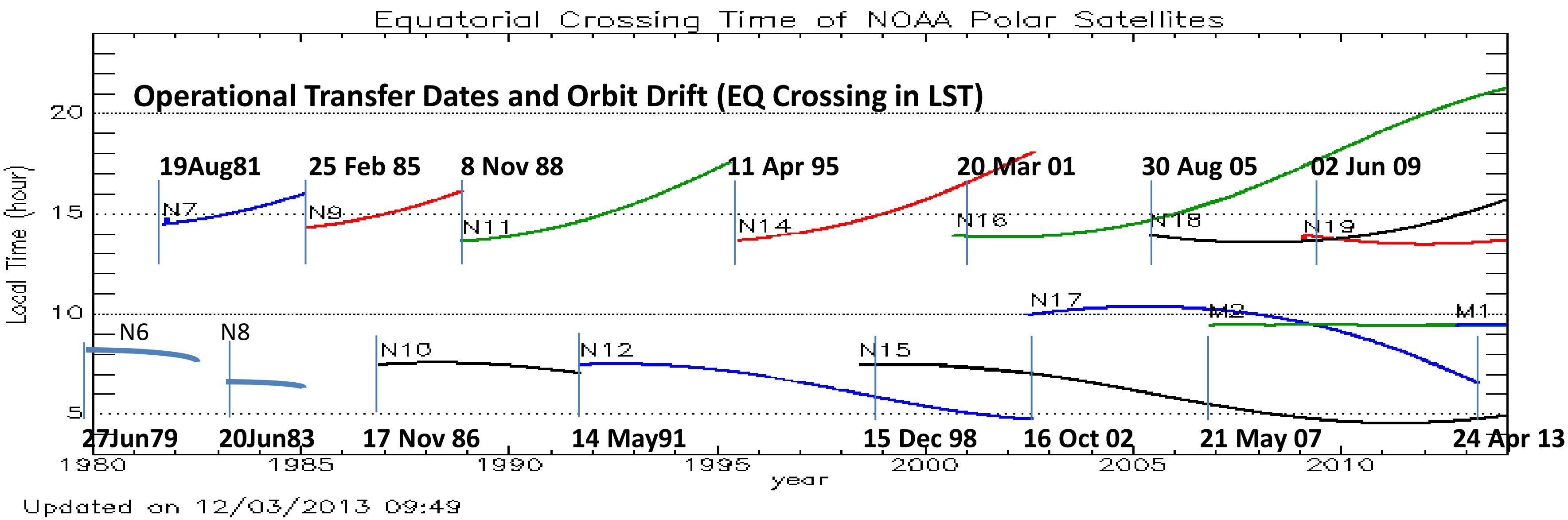
Recalibrating Metop HIRS using IASI

Recalibrating all prior HIRS
using Metop HIRS or IASI as a reference
(at Simultaneous Nadir Overpasses adjust for radiance differences
beyond those caused by known SRF differences)

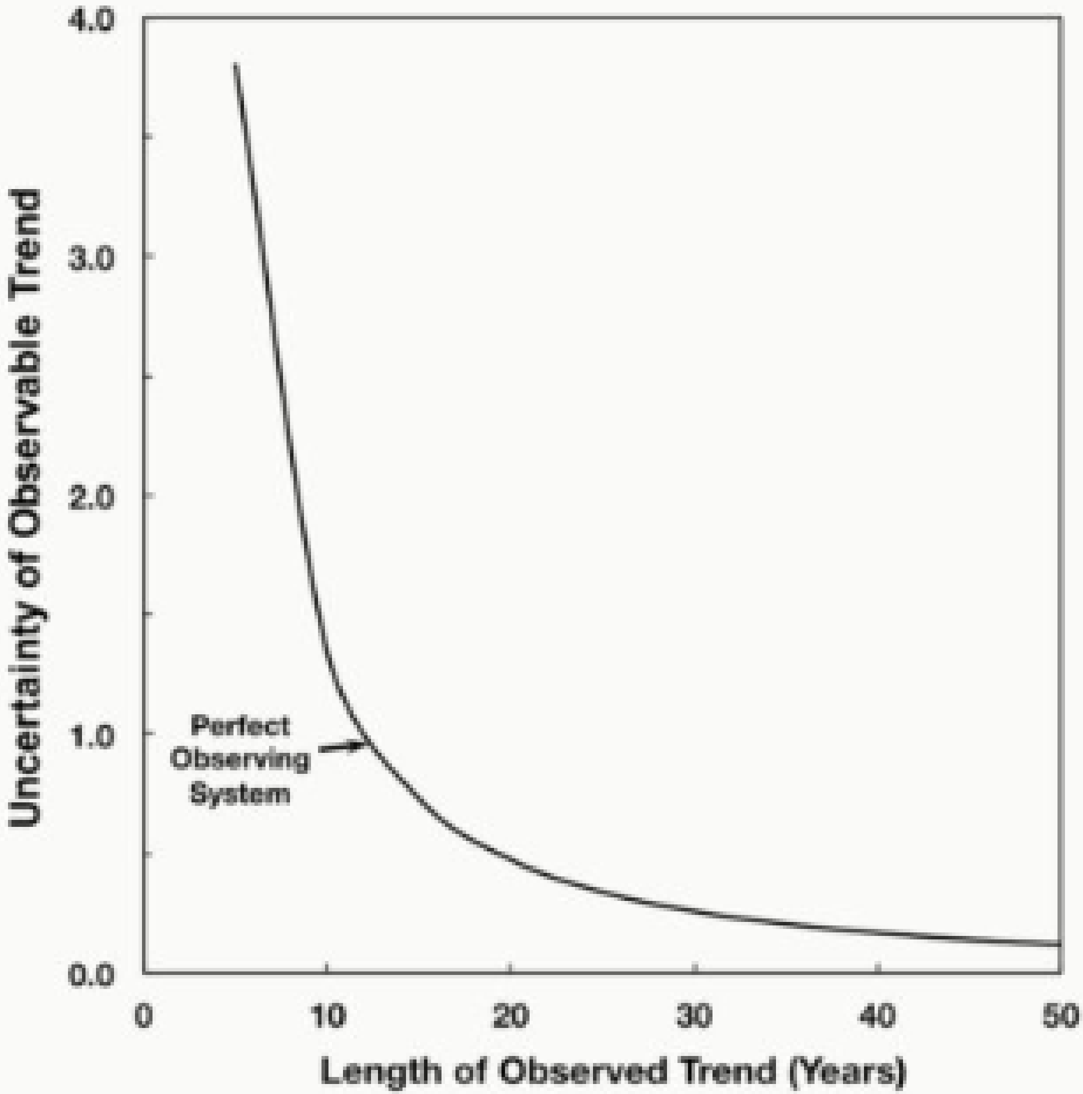
16 HIRS sensors used for 35+ year moisture study

morning (8 am Desc Node)	**night (2 am Desc Node)**
NOAA 6 HIRS/2 – 6/1979	NOAA 5 HIRS – 10/1978
NOAA 8 HIRS/2 – 3/1983	NOAA 7 HIRS/2 – 6/1981
NOAA 10 HIRS/2 – 9/1986	NOAA 9 HIRS/2 – 12/1984
NOAA 12 HIRS/2 – 5/1991	NOAA 11 HIRS/2I* - 9/1988
NOAA 15 HIRS/3 – 5/1998	NOAA 14 HIRS/2I* - 12/1994
NOAA 17 HIRS/3 – 6/2002	NOAA 16 HIRS/3 – 9/2000
METOP-A HIRS/4 – 10/2006	NOAA 18 HIRS/4 – 5/2005
METOP-B HIRS/4 – 9/2012	NOAA 19 HIRS/4 – 2/2009

Split window change: HIRS & HIRS/2 ch 10 is 8.6 um and HIRS/2I, /3, & /4 is 12.5 um .
Orbit Drift: Asterisk (*) indicates drift from 14 to 18 UTC over 5 years of operational use.
S/N improved in HIRS/3. FOV improved to 10 km FOV for HIRS/4 (previously 20 km FOV).
HIRS coverage: More than 100 satellite years in HIRS data set.



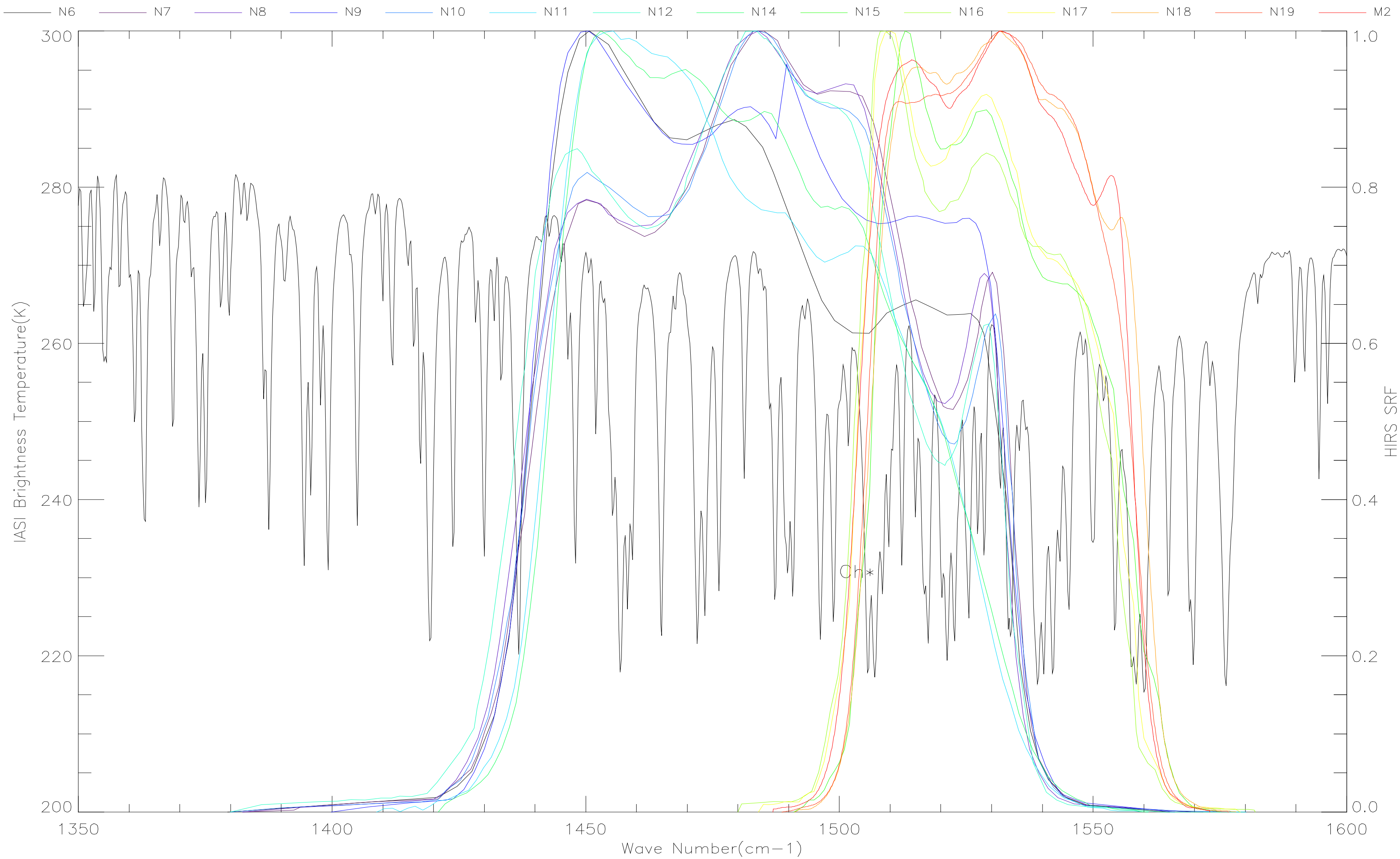
Accuracy Requirements of the Climate Observing System



The length of time required to detect a climate trend caused by human activities is determined by:

- *Natural variability*
- *The magnitude of human driven climate change*
- *The accuracy of the observing system*

SRF of water vapor channel for NOAA/MetOp satellites



- SRF of HIRS ch12 for NOAA/MetOp satellites (left axis), an IASI spectra (right axis)
- Differences can be seen between HIRS/2, HIRS/3, and HIRS/4

BT Bias Change with SRF shift

METOP-B 08/01/2013

Ch4

Ch5

HIRS BT
minus
IASI BT

After optimal SRF shifting

Original BT difference

Ch7

Ch12

Optimal shift
not clear

Scan line number

Color represents different wavenumber shifting

Orbital Variance as a function of SRF shift

METOP-B 08/01/2013

Ch4

Ch5

Ch7

-1.16 cm^{-1}

-0.48 cm^{-1}

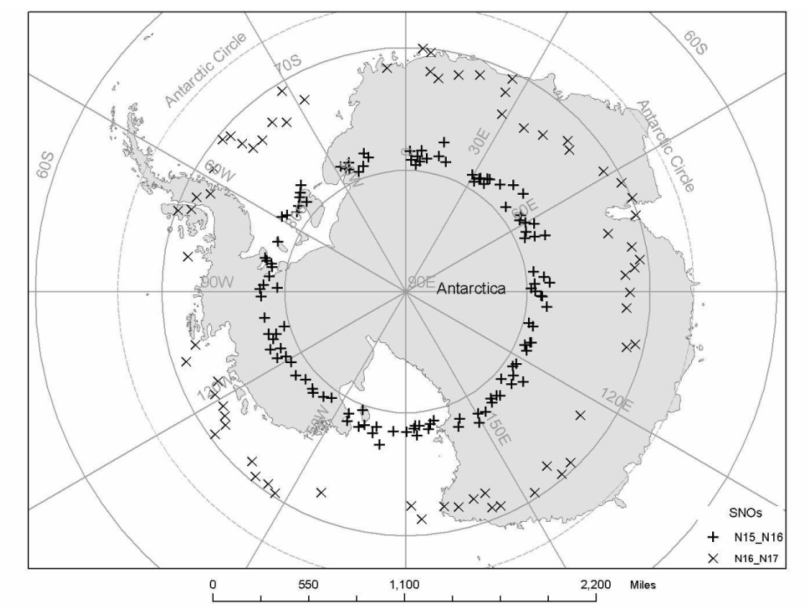
-0.52 cm^{-1}

Ch12

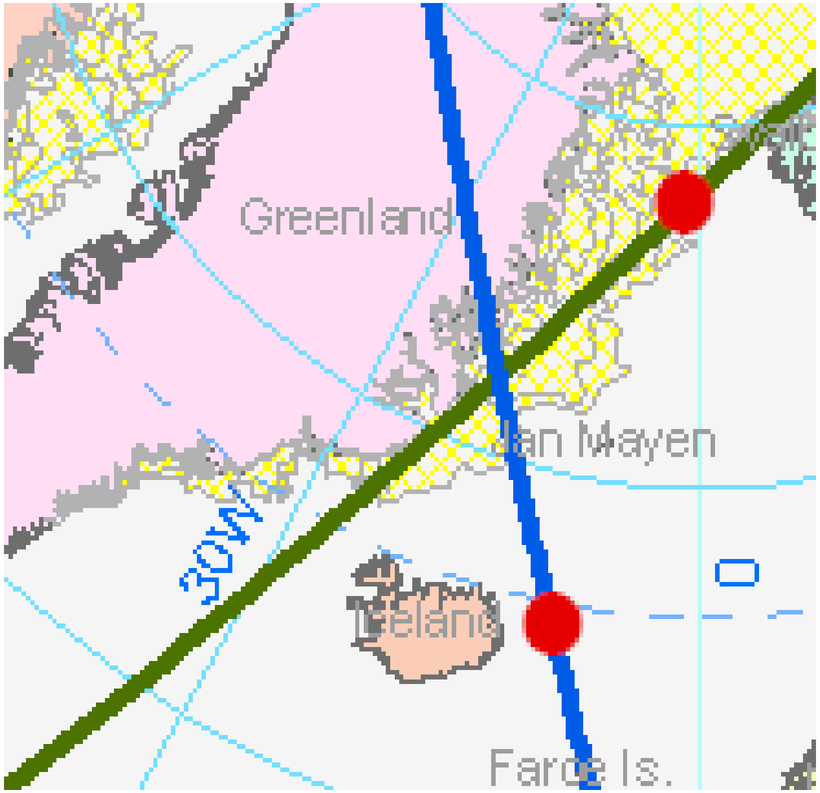
-2 cm^{-1}

Between -5 and 5 wavenumber shifting, the orbital variance does not decrease significantly for channel 12.

Toward an Integrated System for Intersatellite Calibration of POES using the SNO Method



N15 & N16 (+) and
N16 & N17 (X)
SNO locations
from 2000 to 2003



SNO: Simultaneous Nadir Overpass

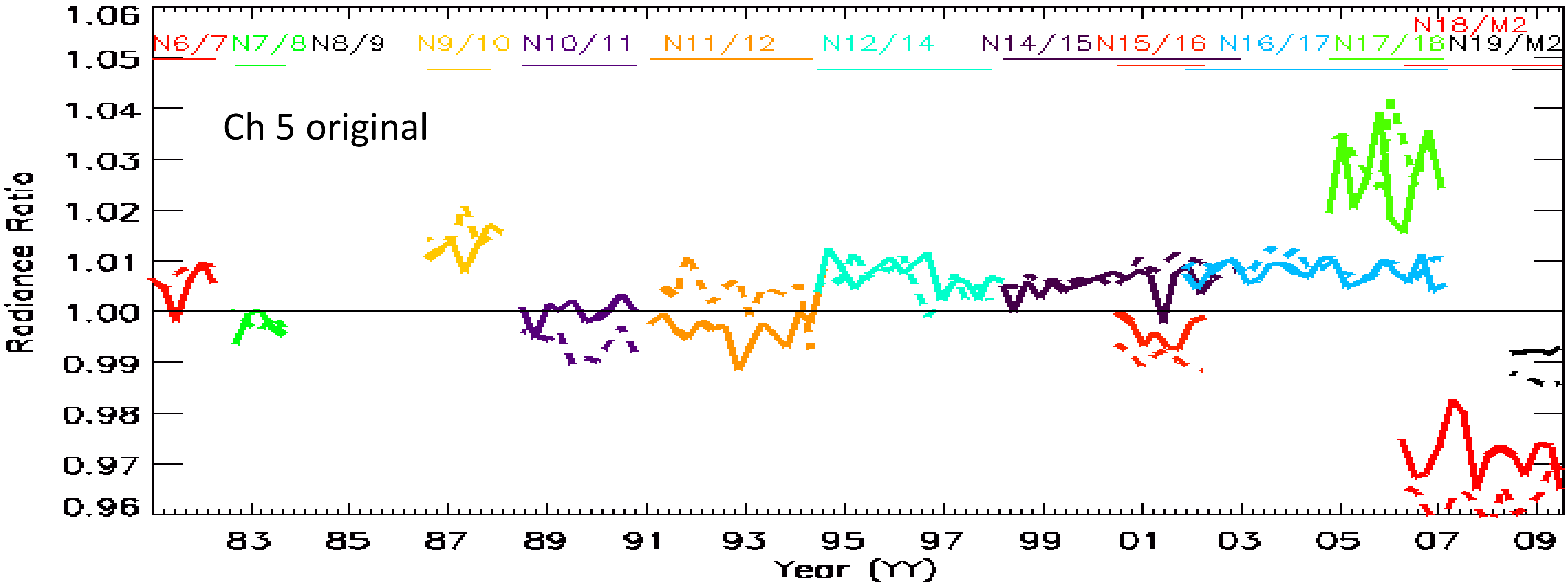
Using Metop-A IASI-HIRS data to estimate SRF shifts implied by HIRS-HIRS SNOs

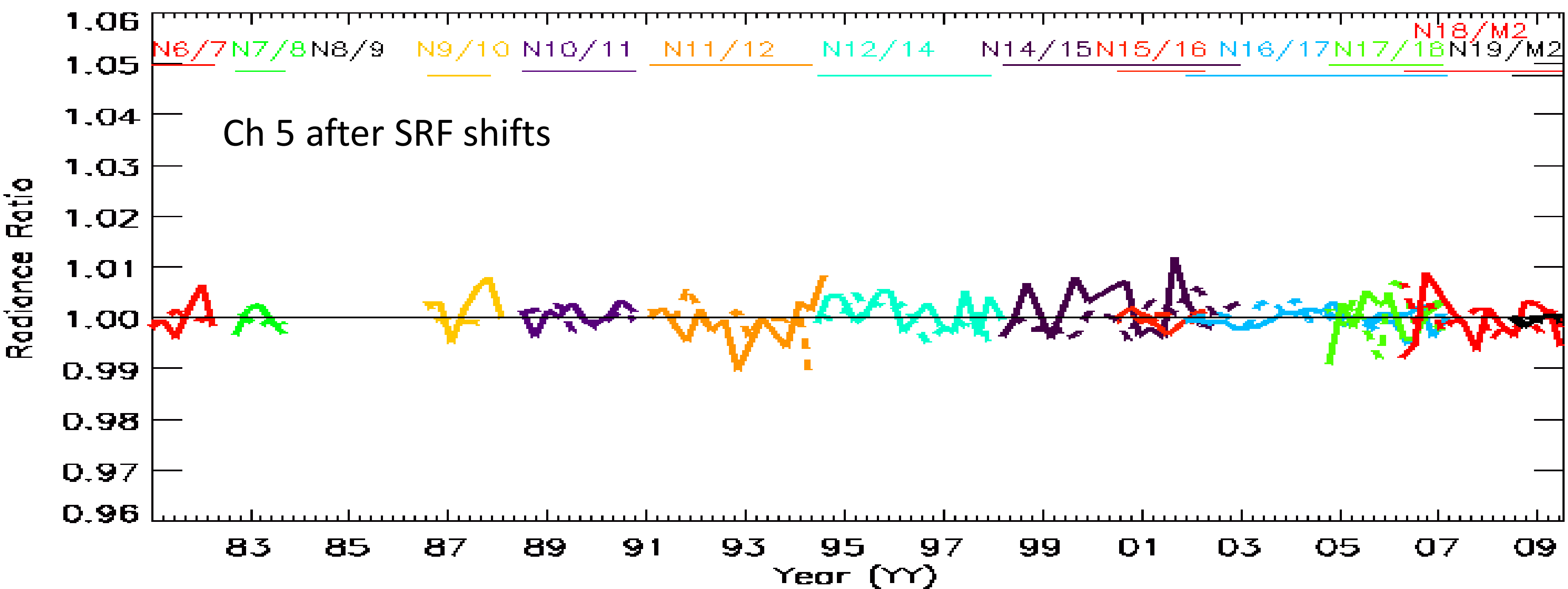
Impact of spectral shift on inter-satellite radiance (or BT) difference depends on atmospheric state at time of measurements

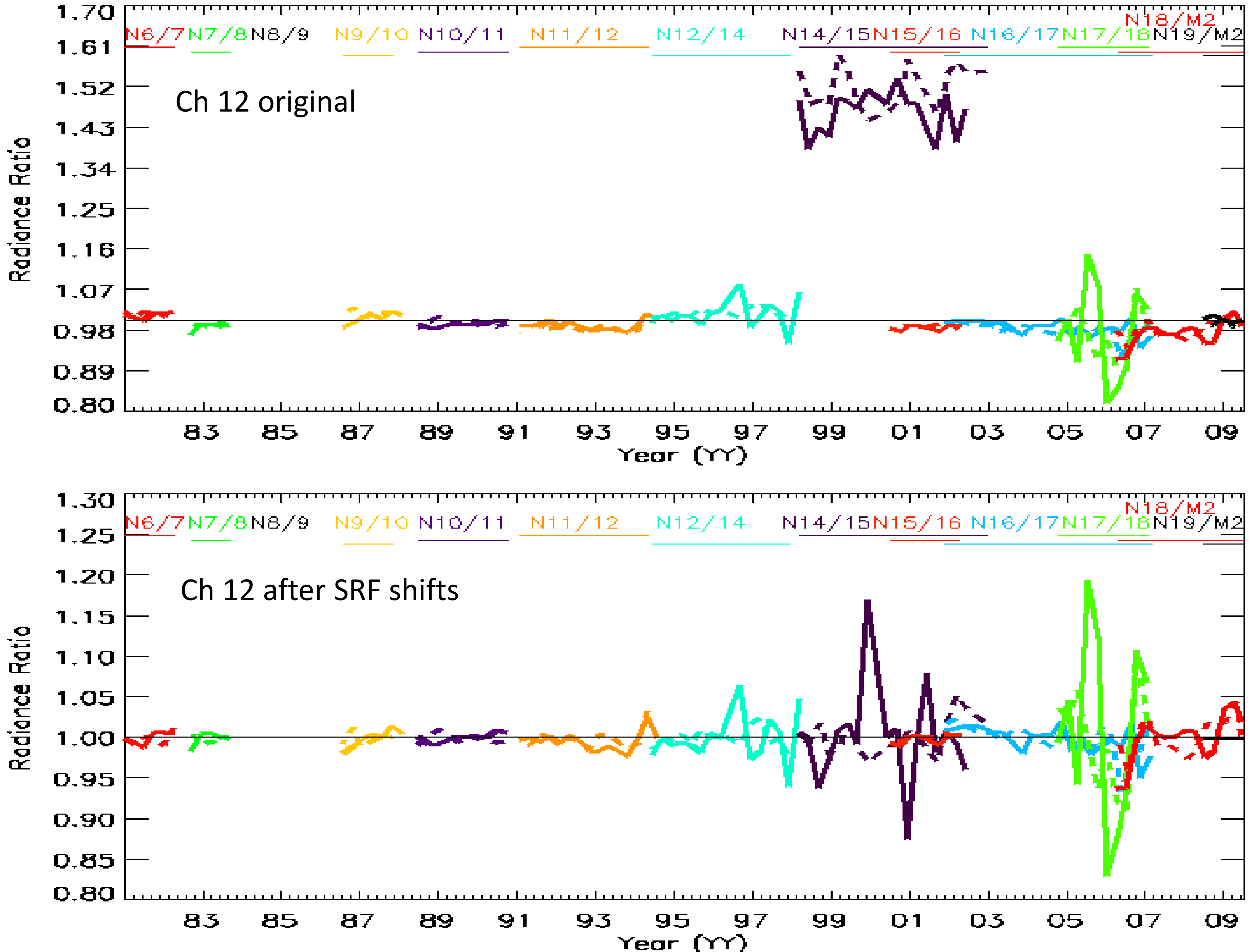
IASI-simulated HIRS data are used to develop linear models to estimate impacts of SRF shifts (and differences) on inter-satellite radiance differences for various atmospheric conditions;

For channel *i* and satellite *m* a shift of *ΔSRF* will produce a radiance change $\Delta R_{im} = \Delta SRF\ [\Sigma_j\ a_{ijm}\ R_{jm} + c_{im}]$

where *j* sums the HIRS CO2 channels 2 – 7, IRW channel 8, and H2O channel 12 (these are used to estimate the atmospheric state for a given SNO)


N6/7 N7/8 N8/9 N9/10 N10/11 N11/12 N12/14 N14/15 N15/16 N16/17 N17/18 N18/M2 N19/M2
Ch 5 original
Radiance Ratio
1.06
1.05
1.04
1.03
1.02
1.01
1.00
0.99
0.98
0.97
0.96
83 85 87 89 91 93 95 97 99 01 03 05 07 09
Year (YY)


N6/7 N7/8 N8/9 N9/10 N10/11 N11/12 N12/14 N14/15 N15/16 N16/17 N17/18 N18/M2 N19/M2
Ch 5 after SRF shifts
Radiance Ratio
1.06
1.05
1.04
1.03
1.02
1.01
1.00
0.99
0.98
0.97
0.96
83 85 87 89 91 93 95 97 99 01 03 05 07 09
Year (YY)



Ch 12 original
Radiance Ratio
1.70
1.61
1.52
1.43
1.34
1.25
1.16
1.07
0.98
0.89
0.80
N6/7 N7/8 N8/9 N9/10 N10/11 N11/12 N12/14 N14/15 N15/16 N16/17 N17/18 N18/M2 N19/M2
83 85 87 89 91 93 95 97 99 01 03 05 07 09
Year (YY)
Ch 12 after SRF shifts
Radiance Ratio
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0.95
0.90
0.85
0.80
N6/7 N7/8 N8/9 N9/10 N10/11 N11/12 N12/14 N14/15 N15/16 N16/17 N17/18 N18/M2 N19/M2
83 85 87 89 91 93 95 97 99 01 03 05 07 09
Year (YY)

CO_2 and H_2O HIRS spectral shifts

	Ch4(14.2)	Ch5(13.9)	Ch7(13.3)	Ch12(6.7)
Hirs2n06 V	0.31	0.7	0.7	1.1
Hirs2n07 V	-0.18	0.1	1.2	-0.46
Hirs2n09 H	0.43	2.66	-0.48	1.1
Hirs2n10 H	0.95	1.56	-0.93	3.0
Hirs2n11 H	1.72	2.05	0.15	4.2
Hirs2n12 H	0.47	2.23	-2.06	4.1
Hirs2n14 H	1.97	3.13	1.22	4.1
Hirs3n15 I	-0.21	0.27	1.01	0.6
Hirs3n16 I	0.22	0.62	0.47	0.8
Hirs3n17 I	0.54	0.72	0.44	-0.3
Hirs4n18 I	-0.71	-0.37	-0.49	3.3
Hirs4n19 I	-0.00	-0.12	0.10	0.7
Hirs4moa I	-0.15	0.10	-0.15	2.2
Hirs4mob I	-1.21	-0.43	-0.54	0.0

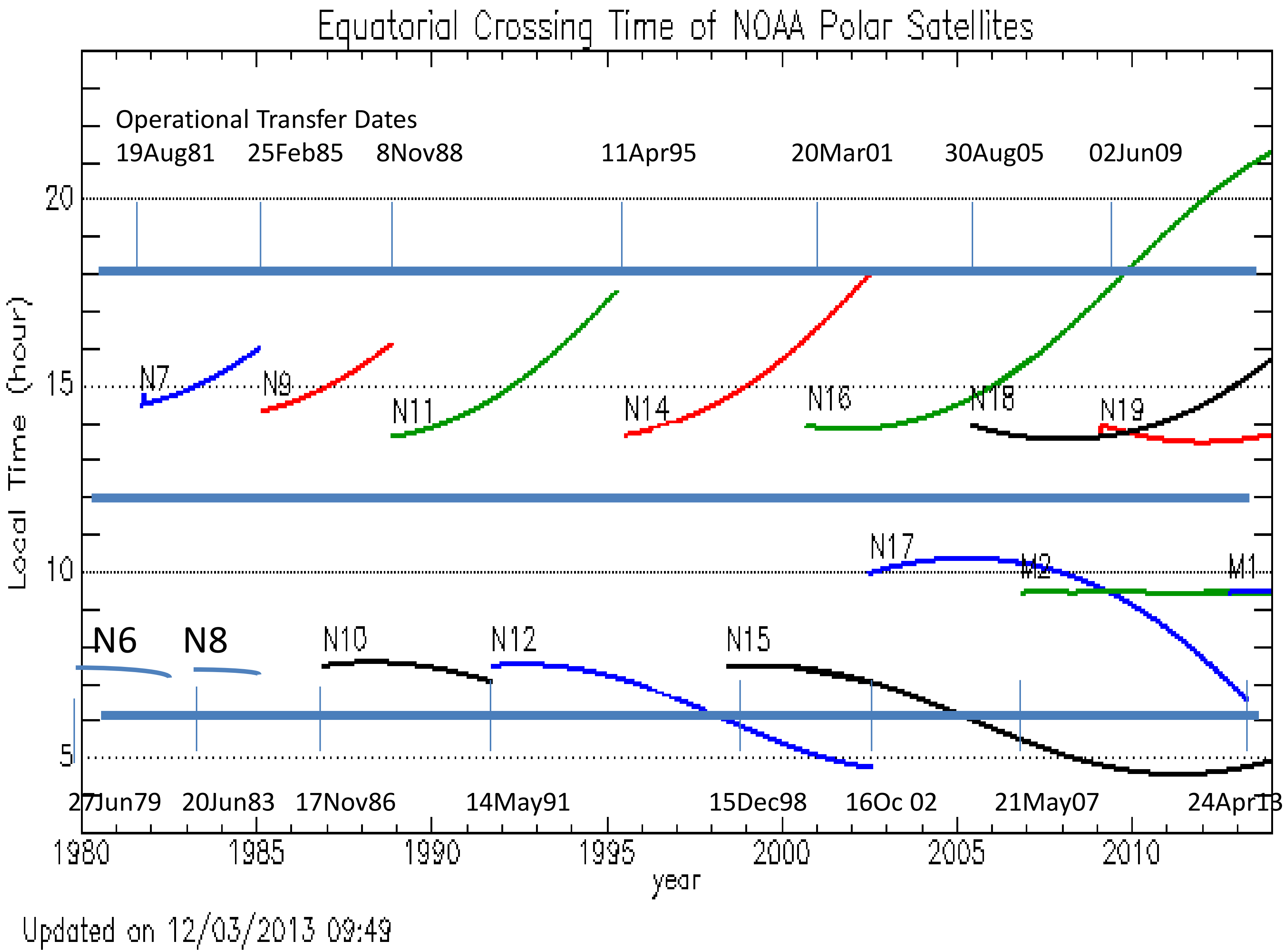
V indicates intercal with VAS, H with later HIRS, and I with IASI directly

Accommodating Orbit Drift

Dividing the day into four segments

(with sunlight before and after noon; without sunlight before and after midnight)

Equatorial Crossing Times / Operational Transfer Dates for NOAA



Dividing the Day into 4 Time Periods

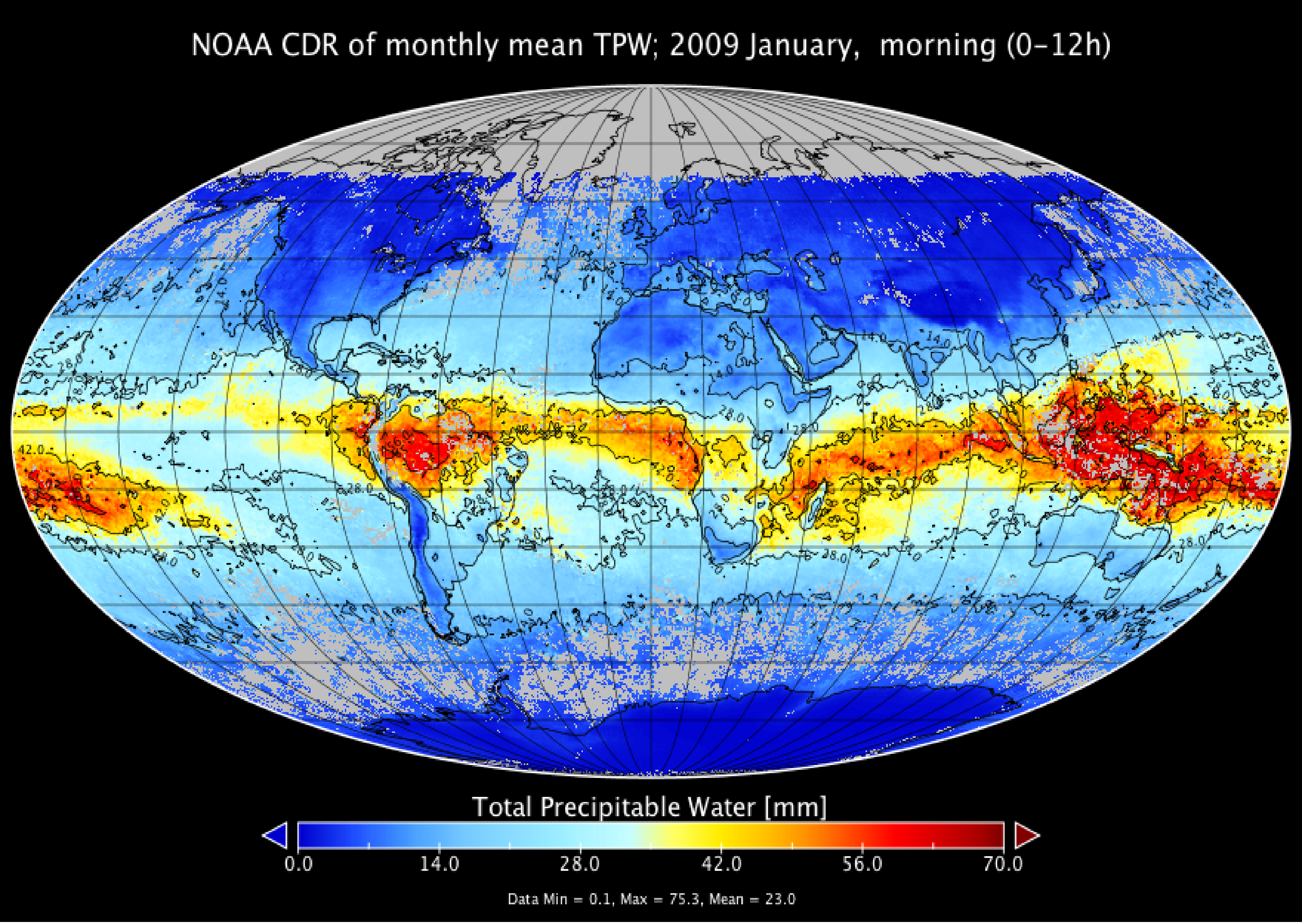
Morning SZA <= 85^{o} and Local Time Before Noon

Afternoon SZA <= 85^{o} and Local Time After Noon

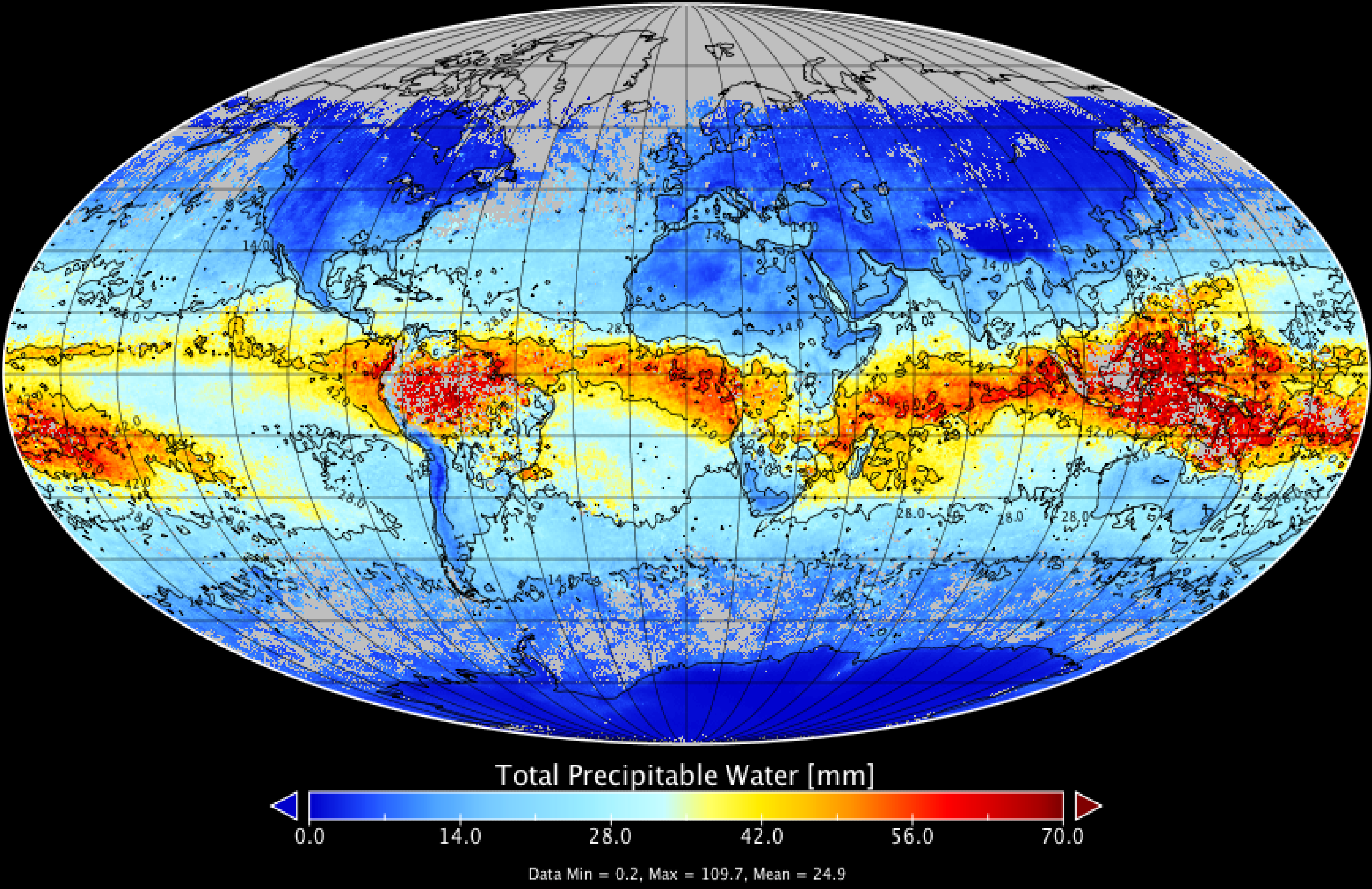
Evening SZA > 85^{o} and Local Time Before Midnight

Night SZA > 85^{o} and Local Time After Midnight

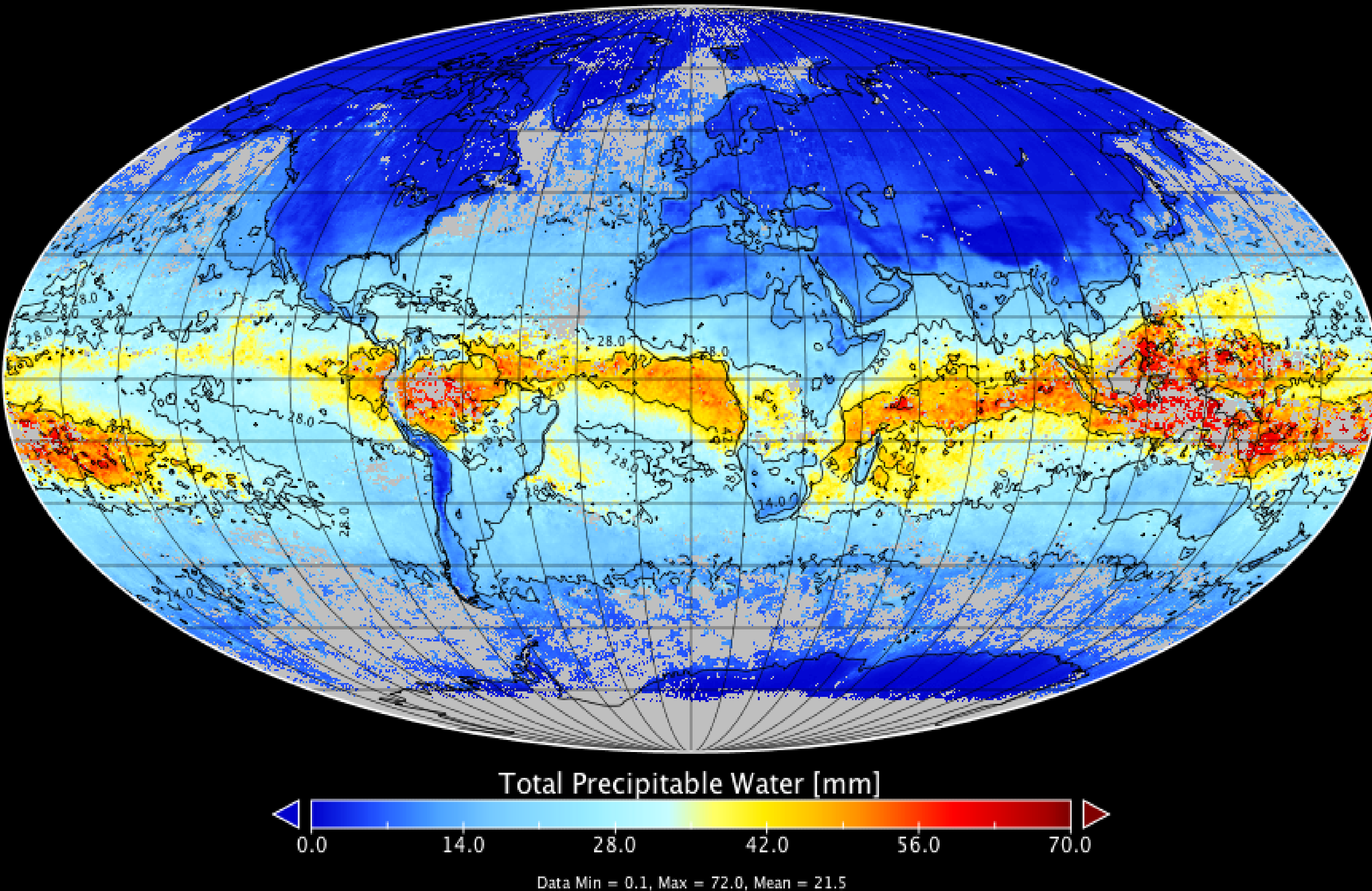
Accounting for and taking advantage of orbit drift

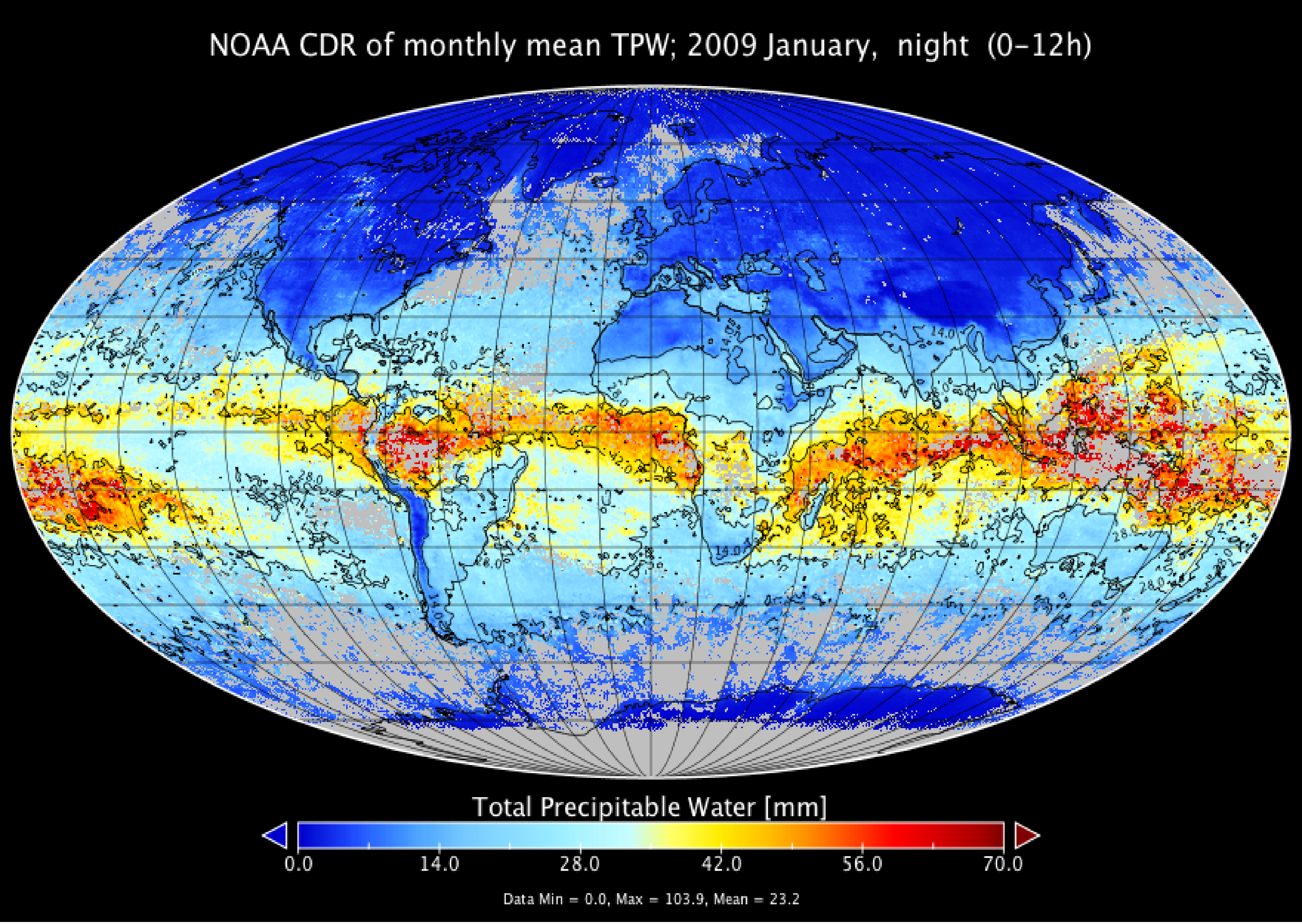

NOAA CDR of monthly mean TPW; 2009 January, morning (0-12h)
Total Precipitable Water [mm]
0.0
14.0
28.0
42.0
56.0
70.0
Data Min = 0.1, Max = 75.3, Mean = 23.0

NOAA CDR of monthly mean TPW; 2009 January, afternoon (12-24h)



NOAA CDR of monthly mean TPW; 2009 January, evening (12-24h)



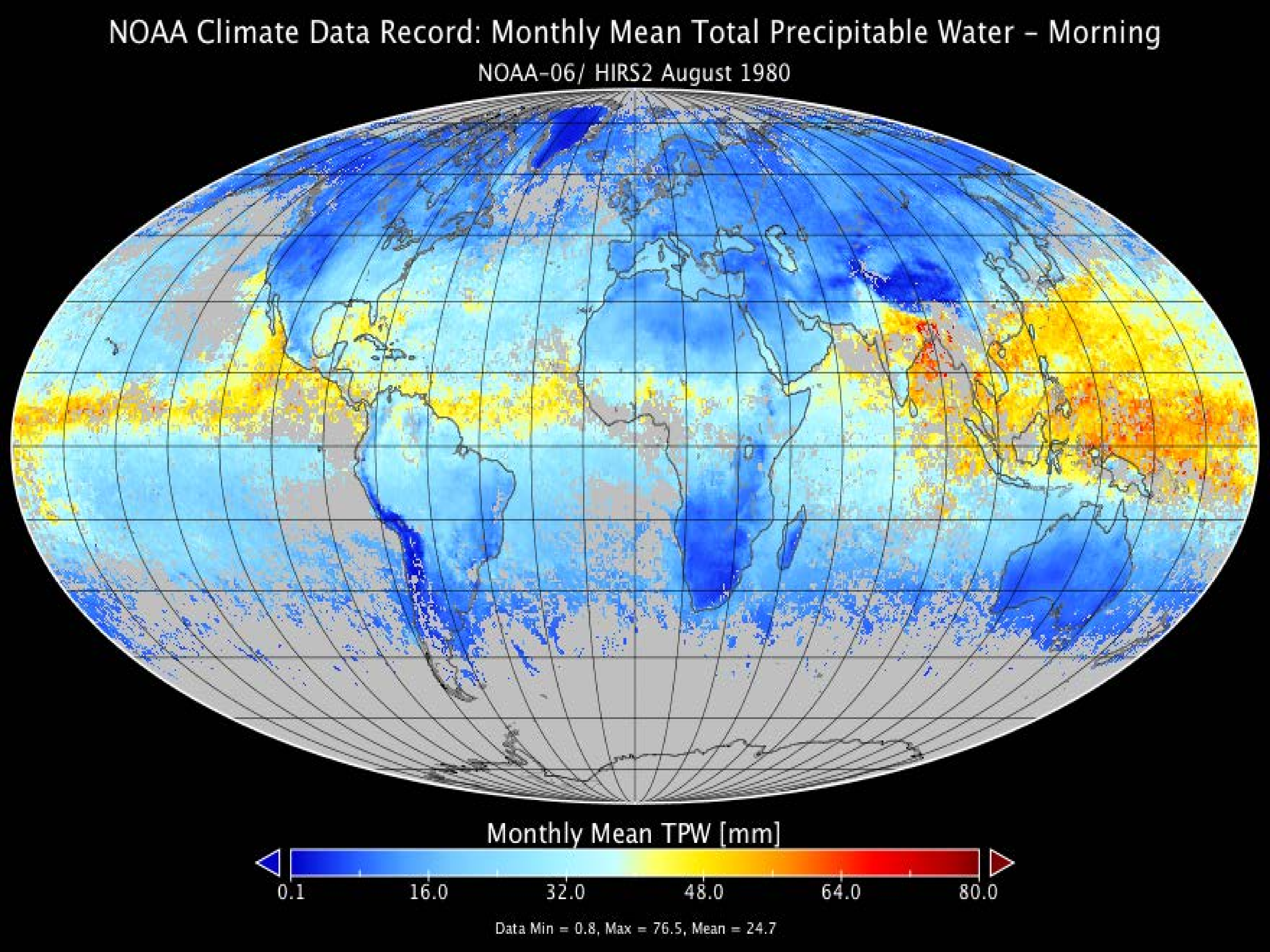

NOAA CDR of monthly mean TPW; 2009 January, night (0-12h)
Total Precipitable Water [mm]
0.0
14.0
28.0
42.0
56.0
70.0
Data Min = 0.0, Max = 103.9, Mean = 23.2

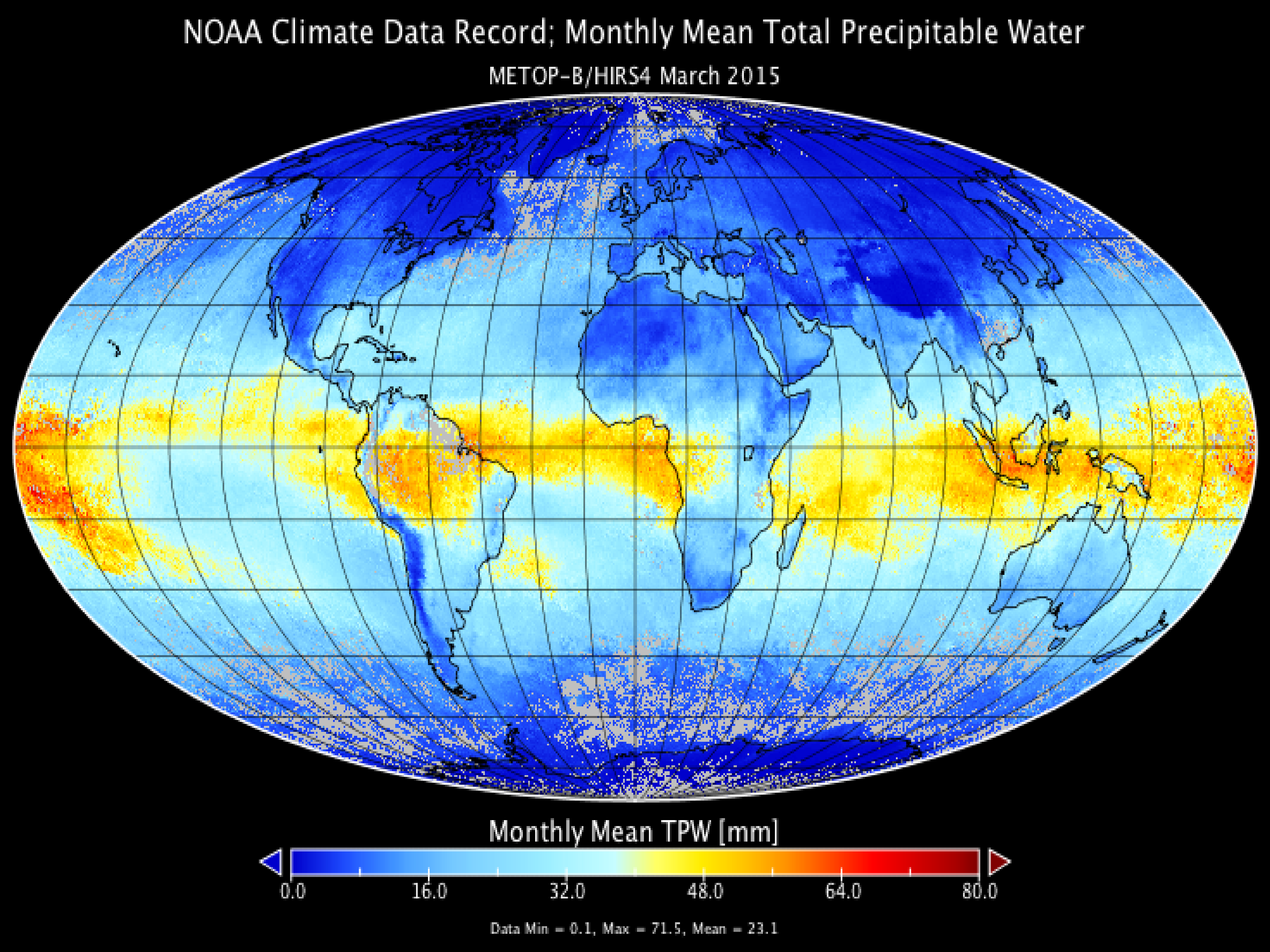
HIRS TPW and UTH Trends

Comparing with Aqua MODIS

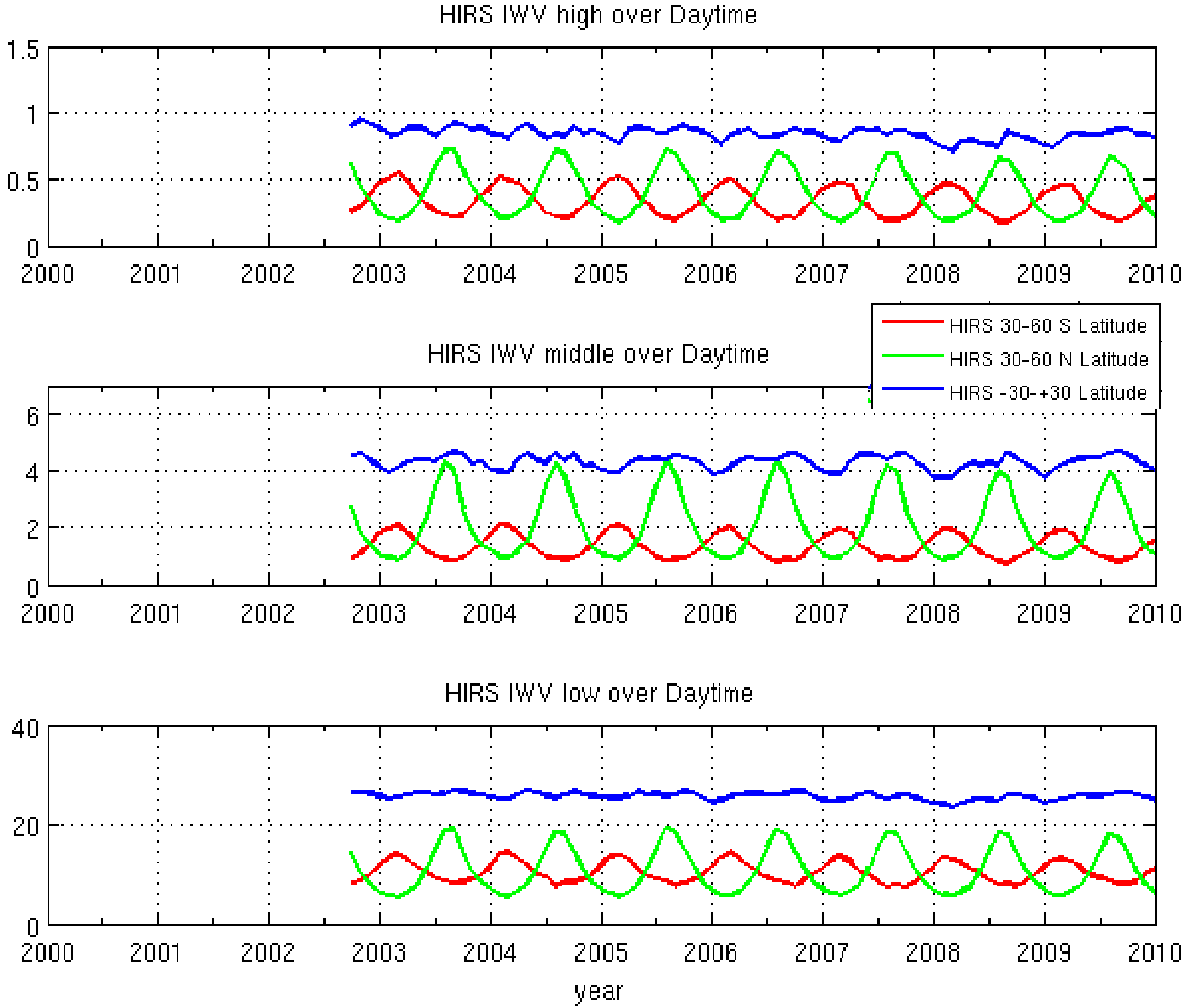
HIRS TPW and UTH

HIRS TPW and UTH is a statistical regression developed from the SeeBor data base (Borbas et al. 2005) that consists of geographically and seasonally distributed radiosonde, ozonesonde, and ECMWF ReAnalysis data. TPW are determined for clear sky radiances measured by HIRS over land and ocean both day and night. The retrieval approach is borrowed from MODIS (Seemann et al. 2003, Seemann et al. 2008). There is strong reliance on radiances from 6.5, 11, 12 μm. The PATMOS-x cloud mask is used to characterize HIRS sub-pixel cloud cover.

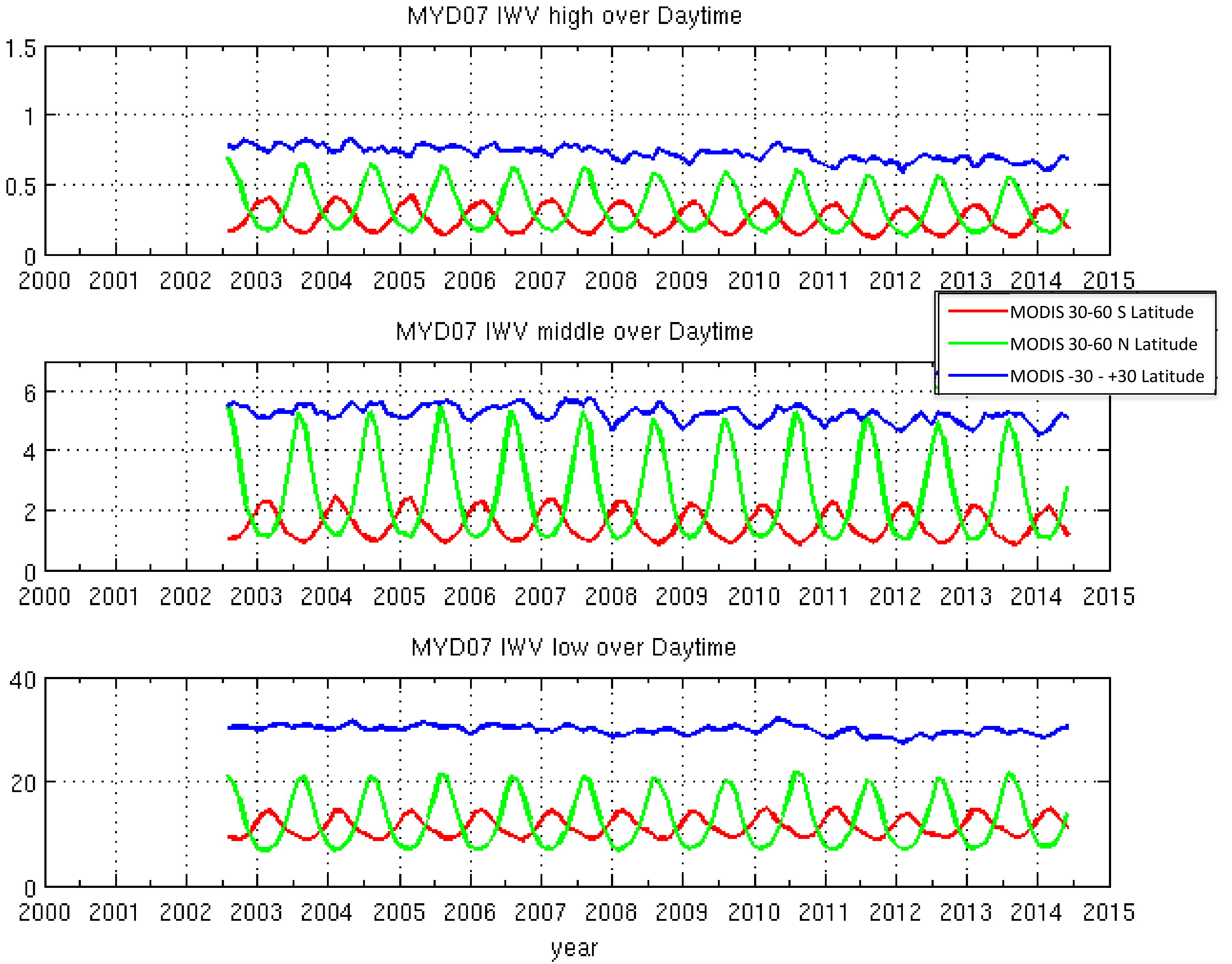

NOAA Climate Data Record: Monthly Mean Total Precipitable Water - Morning
NOAA-06/ HIRS2 August 1980
Monthly Mean TPW [mm]
0.1
16.0
32.0
48.0
64.0
80.0
Data Min = 0.8, Max = 76.5, Mean = 24.7

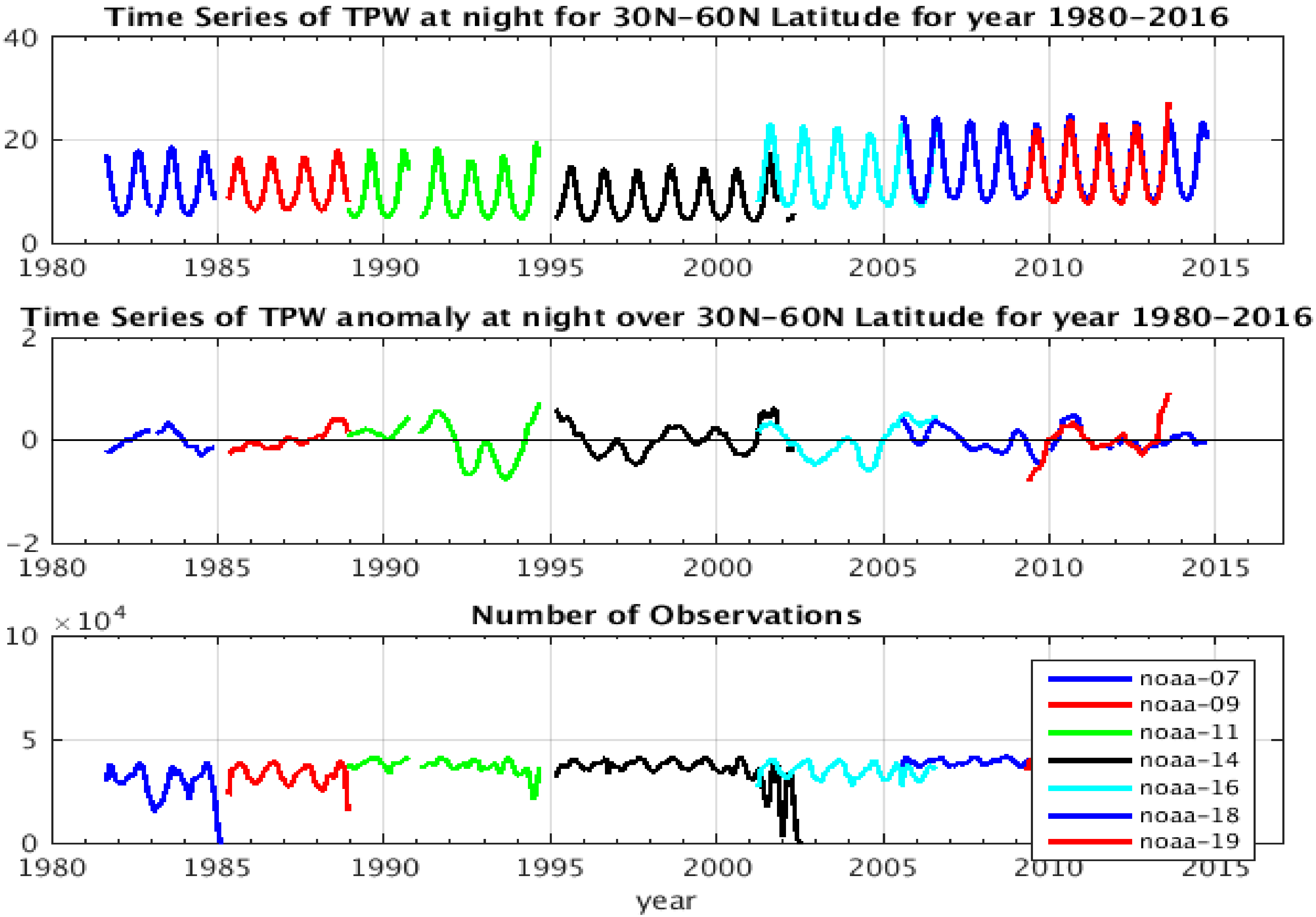

NOAA Climate Data Record; Monthly Mean Total Precipitable Water
METOP-B/HIRS4 March 2015
Monthly Mean TPW [mm]
0.0
16.0
32.0
48.0
64.0
80.0
Data Min = 0.1, Max = 71.5, Mean = 23.1

Time series of N17/HIRS IWV high, middle and low over Daytime

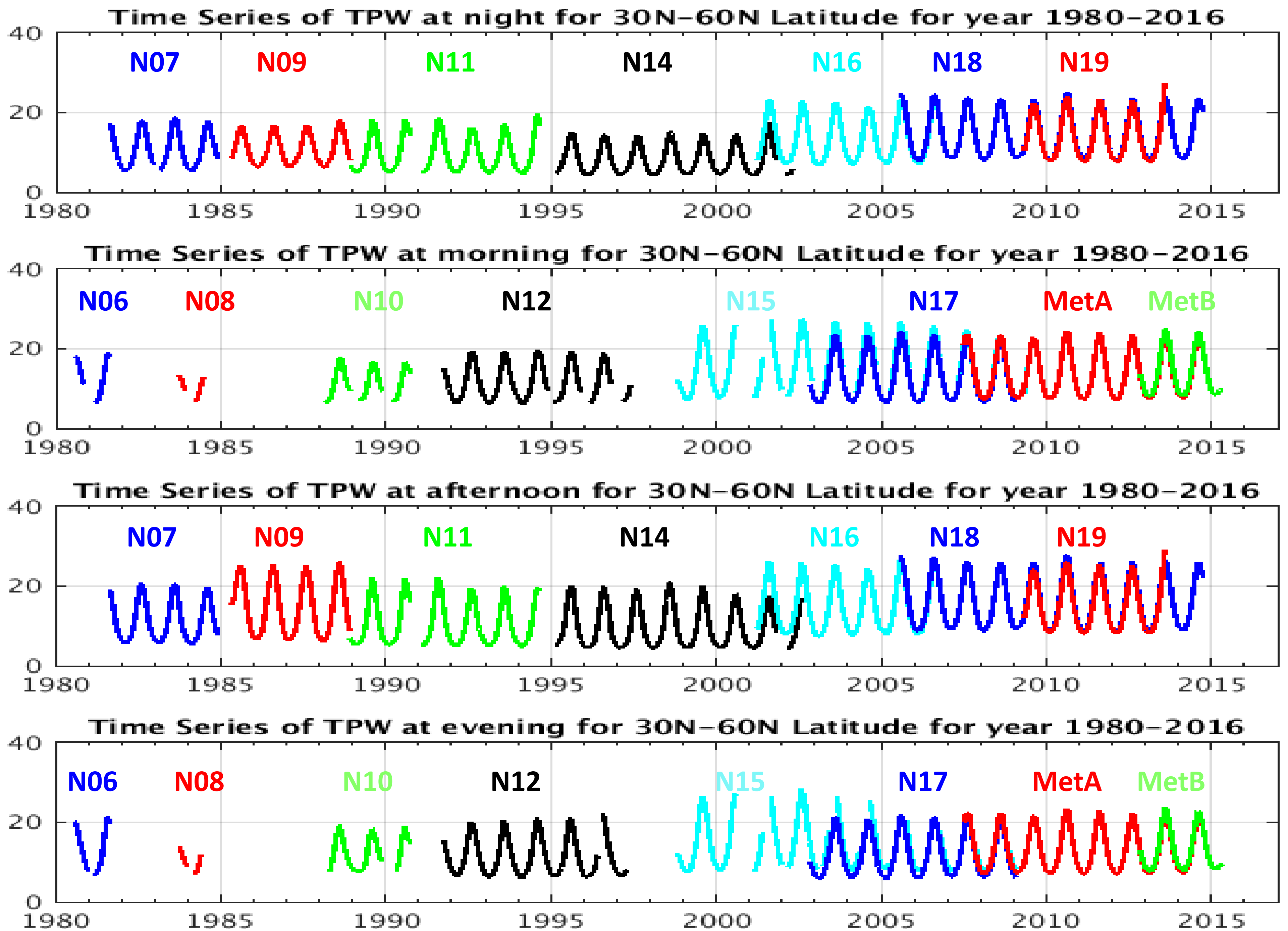


Time series of MYD07 IWV high, middle and low over Daytime

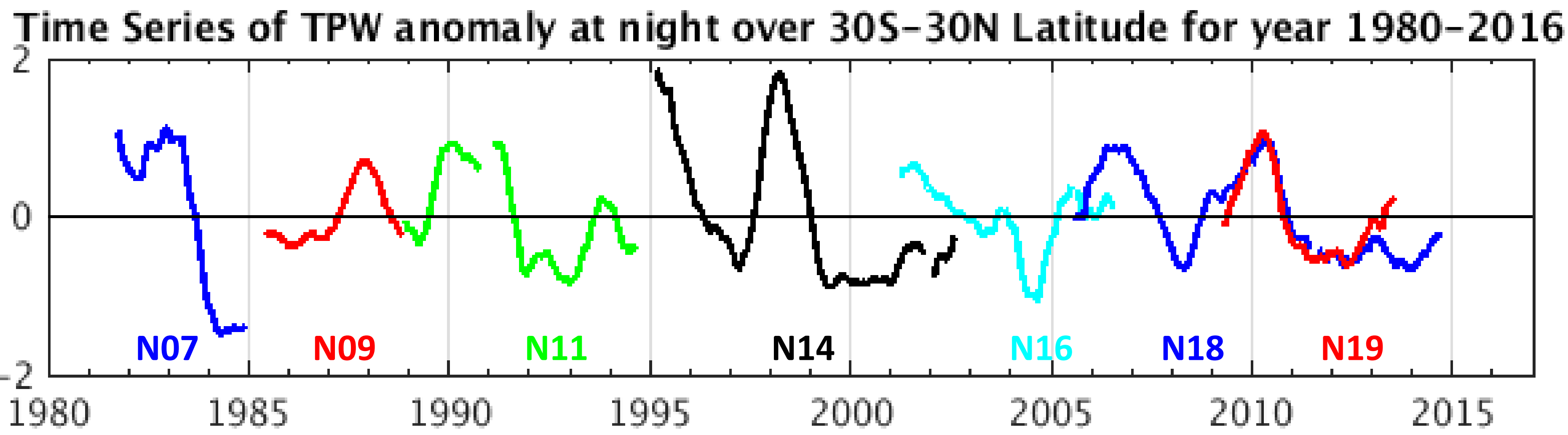


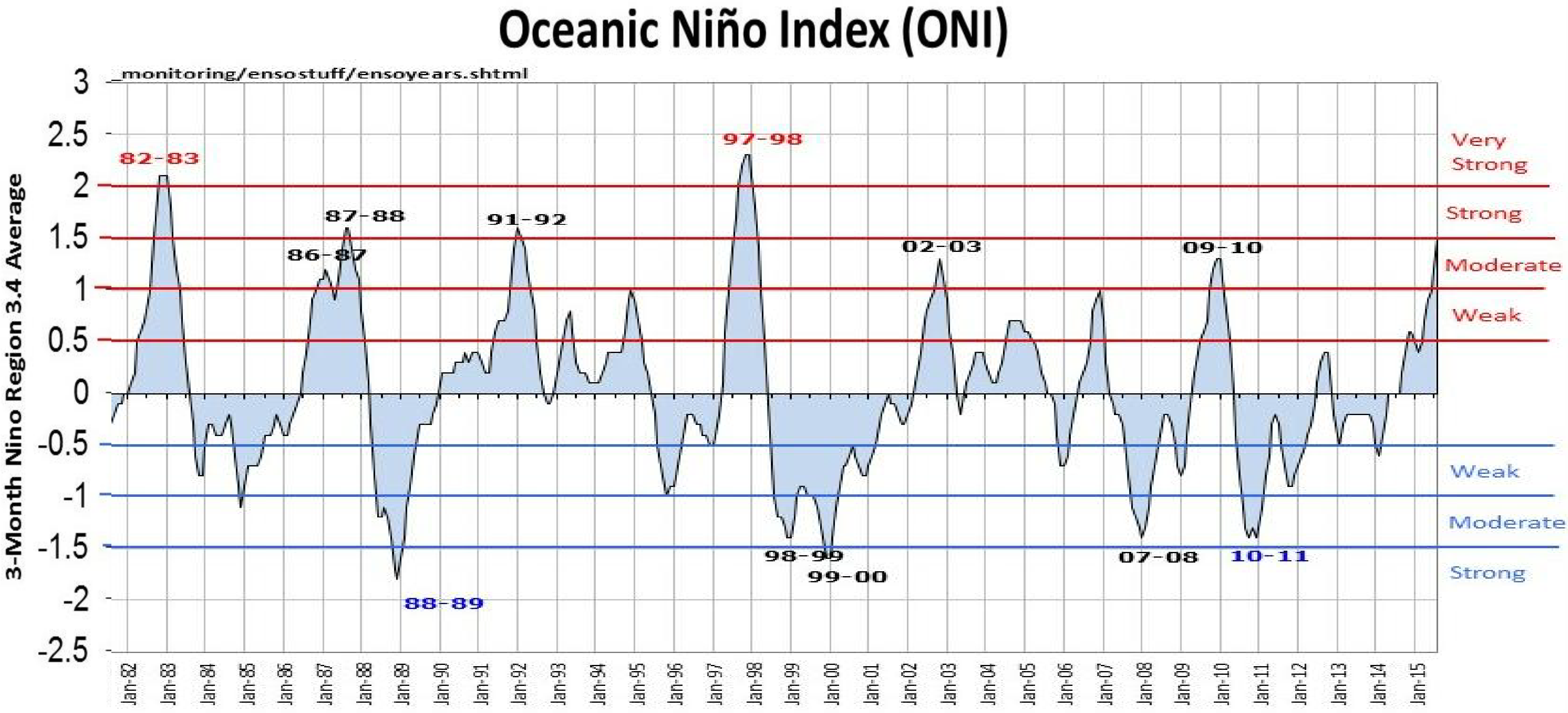


Time Series of TPW at night for 30N-60N Latitude for year 1980-2016
40
20
0
1980
1985
1990
1995
2000
2005
2010
2015
Time Series of TPW anomaly at night over 30N-60N Latitude for year 1980-2016
2
0
-2
Number of Observations
×10^4
10
5
noaa-07
noaa-09
noaa-11
noaa-14
noaa-16
noaa-18
noaa-19
year



Time Series of TPW at night for 30N-60N Latitude for year 1980-2016
N07
N09
N11
N14
N16
N18
N19
Time Series of TPW at morning for 30N-60N Latitude for year 1980-2016
N06
N08
N10
N12
N15
N17
MetA
MetB
Time Series of TPW at afternoon for 30N-60N Latitude for year 1980-2016
N07
N09
N11
N14
N16
N18
N19
Time Series of TPW at evening for 30N-60N Latitude for year 1980-2016
N06
N08
N10
N12
N15
N17
MetA
MetB
0
20
40
1980
1985
1990
1995
2000
2005
2010
2015


Time Series of TPW anomaly at night over 30S-30N Latitude for year 1980-2016
2
0
-2
1980
1985
1990
1995
2000
2005
2010
2015
N07
N09
N11
N14
N16
N18
N19


Oceanic Niño Index (ONI)
_monitoring/ensostuff/ensoyears.shtml
3-Month Nino Region 3.4 Average
82-83
86-87
87-88
88-89
91-92
97-98
98-99
99-00
02-03
07-08
09-10
10-11
Very Strong
Strong
Moderate
Weak
Weak
Moderate
Strong

Conclusions

Regarding Recalibration

* Metop HIRS recalibration using IASI offers best HIRS reference
* Recalibration against reference HIRS mitigates but does not eliminate sensor to sensor differences
* Dividing the day into 4 time periods mitigates but does not eliminate effects of orbit drift

Regarding H2O Trends

* Seasonal TPW cycle is strongest in northern mid-latitudes and weakest in tropics
* Seasonal TPW cycle is stronger in the afternoon than at night
* La Nina decrease in tropical TPW is evident
* Recalibrating IR split window needed to mitigate sensor to sensor TPW issues
* TPW decrease from 2002 to 2008 and increase after 2008 is suggested

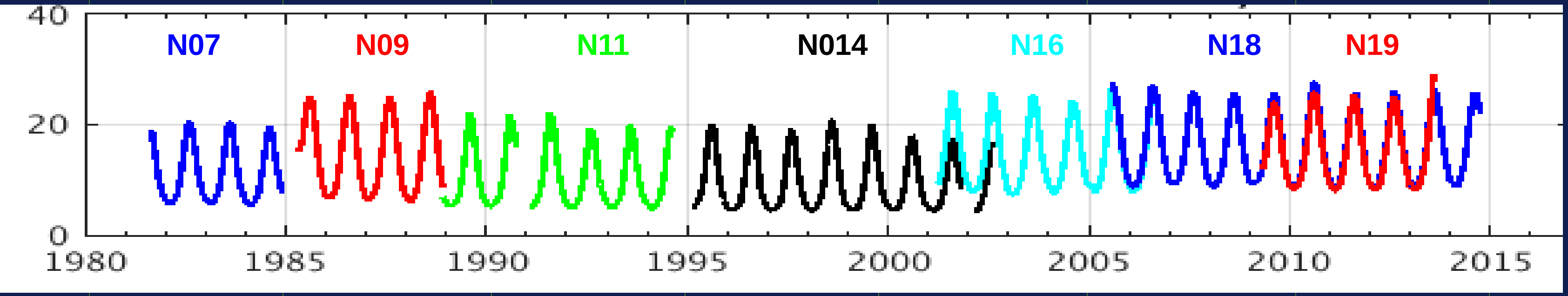
Overall

* Reprocessing whole HIRS record will reveal trends better

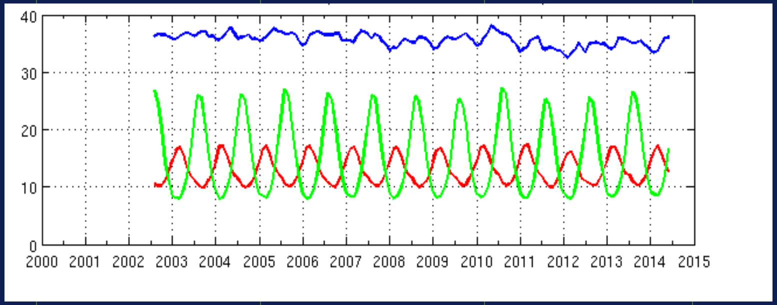
Timeline

1980 1990 2000 2010

HIRS Northern Mid latitude (30N-60N)



Aqua/MODIS Northern Mid latitude (30N-60N - green)



S-NPP/VIIRS