EXTENDING THE HIRS DATA STREAM TO CONTINUE MORE THAN THREE DECADES OF TRACKING GLOBAL CLOUD AND MOISTURE PROPERTIES

HIRS Recalibration
Mitigating Orbit Drift Effects
TPW and UTH
High and UT/LS Clouds
Continuation with IASI & CrIS
Conclusions

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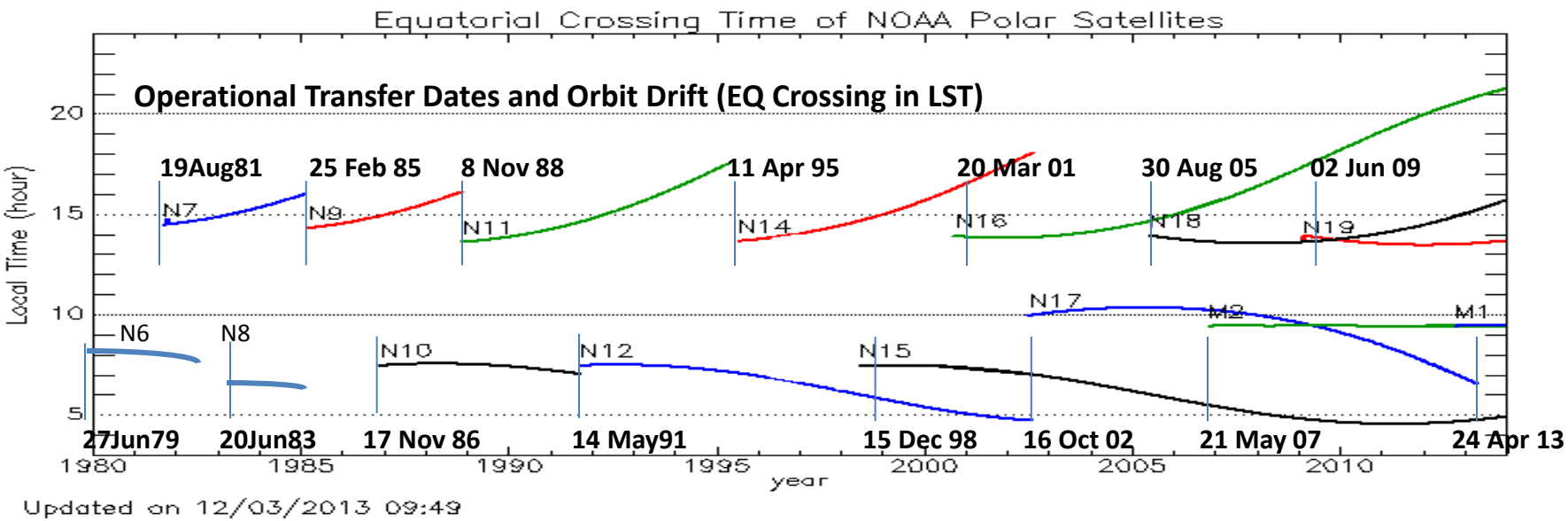
April 2016

Satellite	Launch Date	Operational Dates - Orbit	
TIROS-N	October 13, 1978	Oct 19, 1978-Jan 30, 1980	
NOAA-6	June 27, 1979	Jun 27, 1979-Mar 5, 1983 Jul 3, 1984-Nov 16, 1986	AM
NOAA-B	May 29, 1980	Failed to achieve orbit	
NOAA-7	June 23, 1981	Aug 19, 1981-Jun 7, 1986	PM
NOAA-8	March 28, 1983	Jun 20, 1983-Jun 12, 1984 Jul 1, 1985-Oct 31, 1985	AM
NOAA-9	December 12, 1984	Feb 25, 1985-Nov 7, 1988	PM
NOAA-10	September 17, 1986	Nov 17, 1986-Sep 16, 1991	AM
NOAA-11	September 24, 1988	Nov 8, 1988-Apr 11, 1995	PM
NOAA-12	May 14, 1991	May 14, 1991- Dec 14, 1998	AM
NOAA-13	August 9, 1993	Aug 9, 1993-Aug 21, 1993	
NOAA-14	December 30, 1994	Apr 11, 1995-Mar 19, 2001	PM
NOAA-15	May 13, 1998	Dec 15, 1998-Oct 15, 2002	AM
NOAA-16	September 21, 2000	Mar 20, 2001-Aug 29, 2005	PM
NOAA-17	June 24, 2002	Oct 16, 2002- May 21, 2007	AM
NOAA-18	May 20, 2005	Aug 30, 2005-Jun 01, 2009	PM
NOAA-19	February 06, 2009	Jun 02, 2009- July 2013	PM
MeTop-A	October 19, 2006	May 21, 2007-Apr 23 2013	AM
MeTop-B	September 17, 2012	Apr 24, 2013	AM

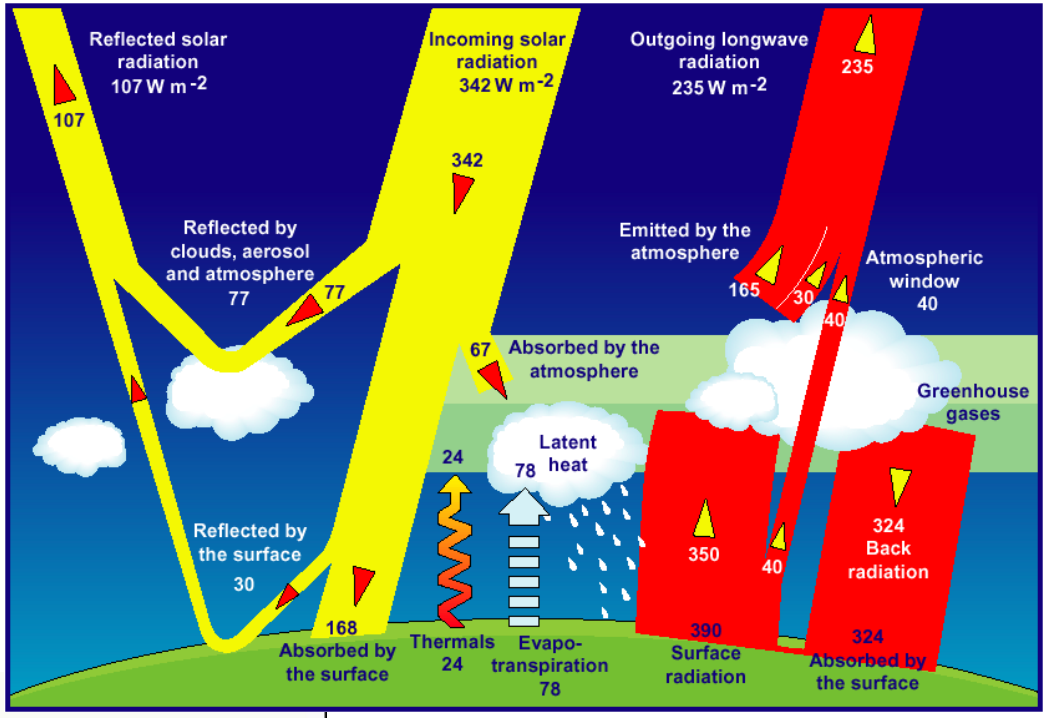
16 HIRS sensors used for 35+ year moisture study

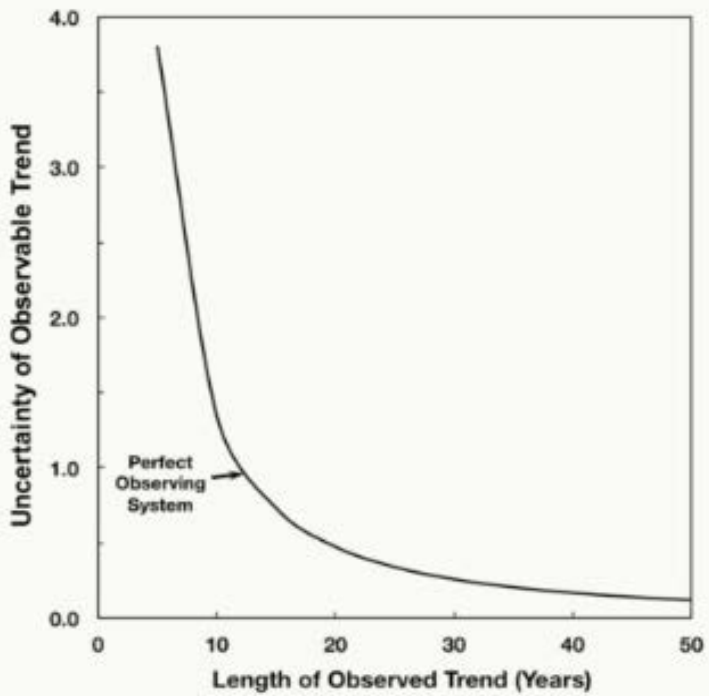
morning (8 am Desc Node)	night (2 am Desc Node)
NOAA 6 HIRS/2 – 6/1979	NOAA 5 HIRS – 10/1978
NOAA 8 HIRS/2 – 3/1983	NOAA 7 HIRS/2 – 6/1981
NOAA 10 HIRS/2 – 9/1986	NOAA 9 HIRS/2 – 12/1984
NOAA 12 HIRS/2 – 5/1991	NOAA 11 HIRS/2I* - 9/1988
NOAA 15 HIRS/3 – 5/1998	NOAA 14 HIRS/2I* - 12/1994
NOAA 17 HIRS/3 – 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.



Climate System Energy Balance

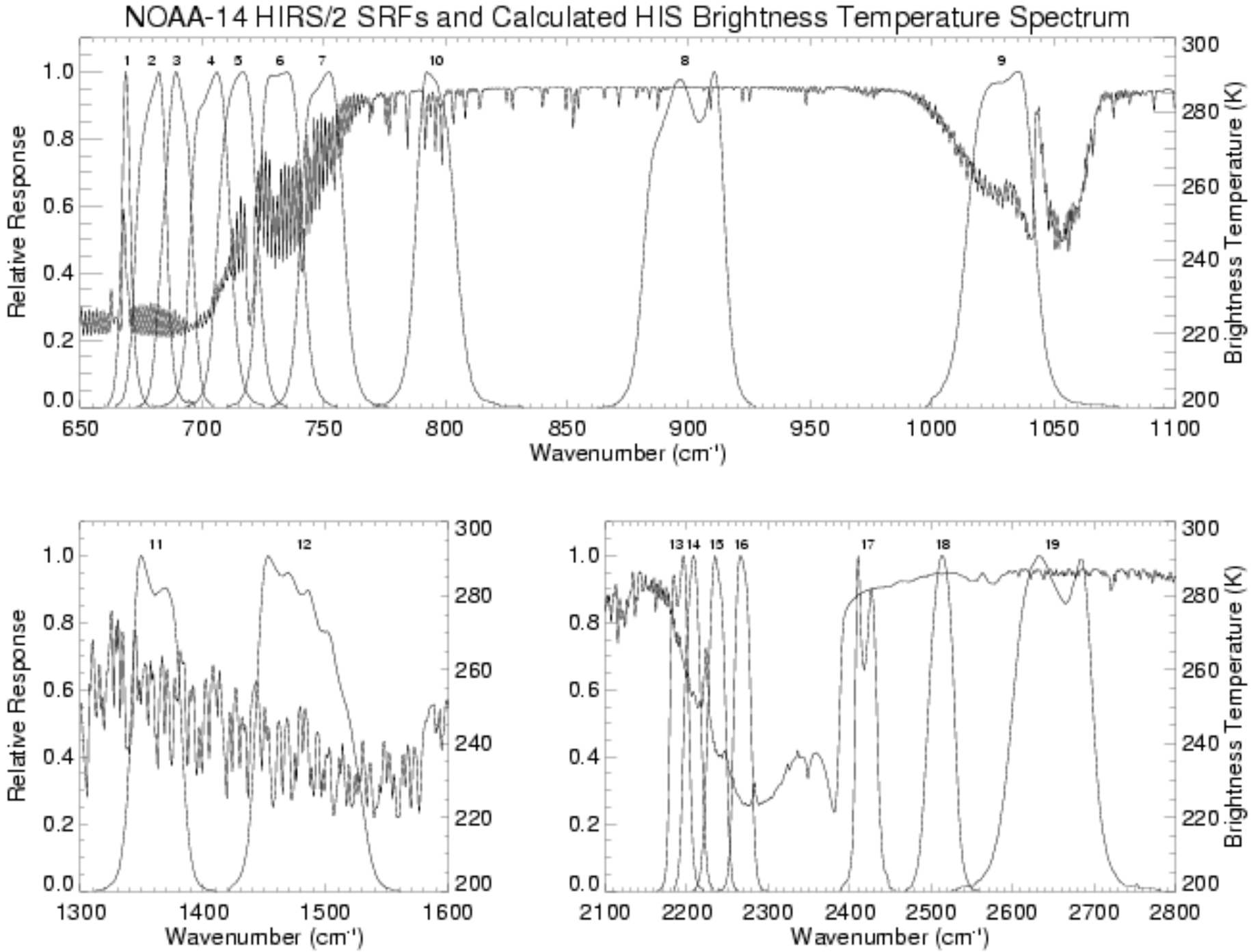




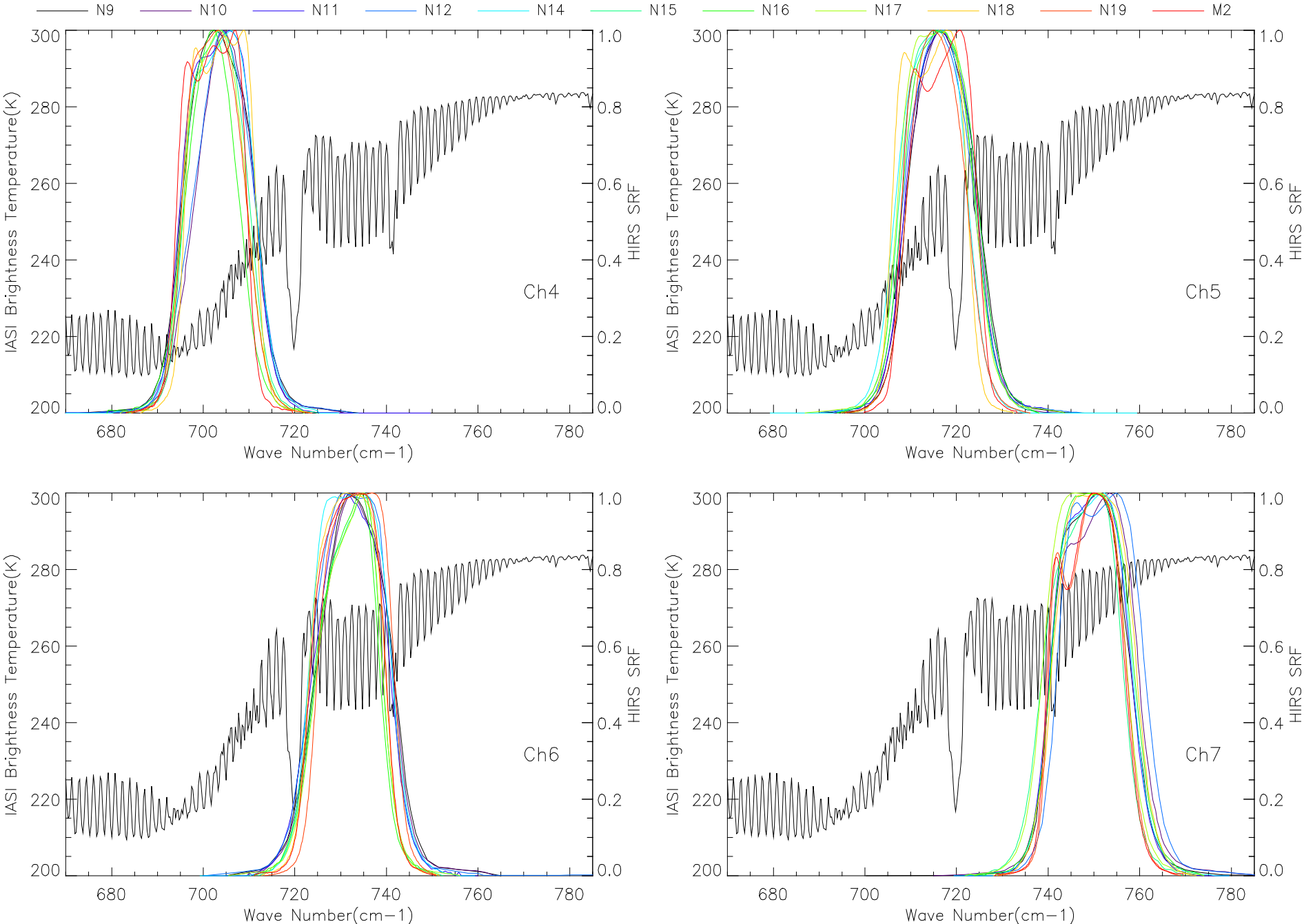
The length of time required to detect a climate trend caused by human activities is determined by:

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

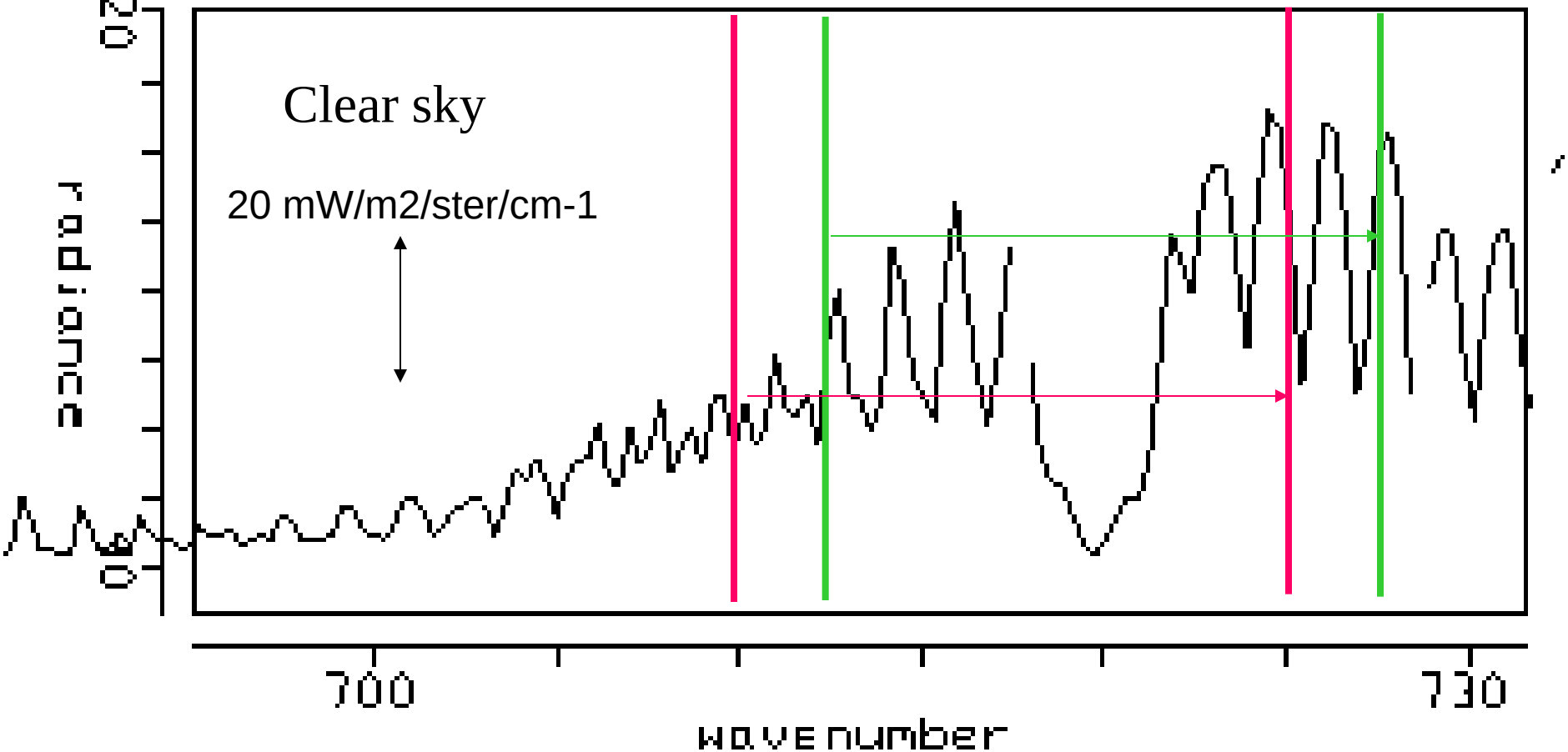
Accuracy Requirements of the Climate Observing System


NOAA-14 HIRS/2 SRFs and Calculated HIS Brightness Temperature Spectrum
Relative Response
Brightness Temperature (K)
Wavenumber (cm⁻¹)
1 2 3 4 5 6 7 10 8 9
11 12
13 14 15 16 17 18 19

SRFs of CO2 channels for NOAA/Metop satellites

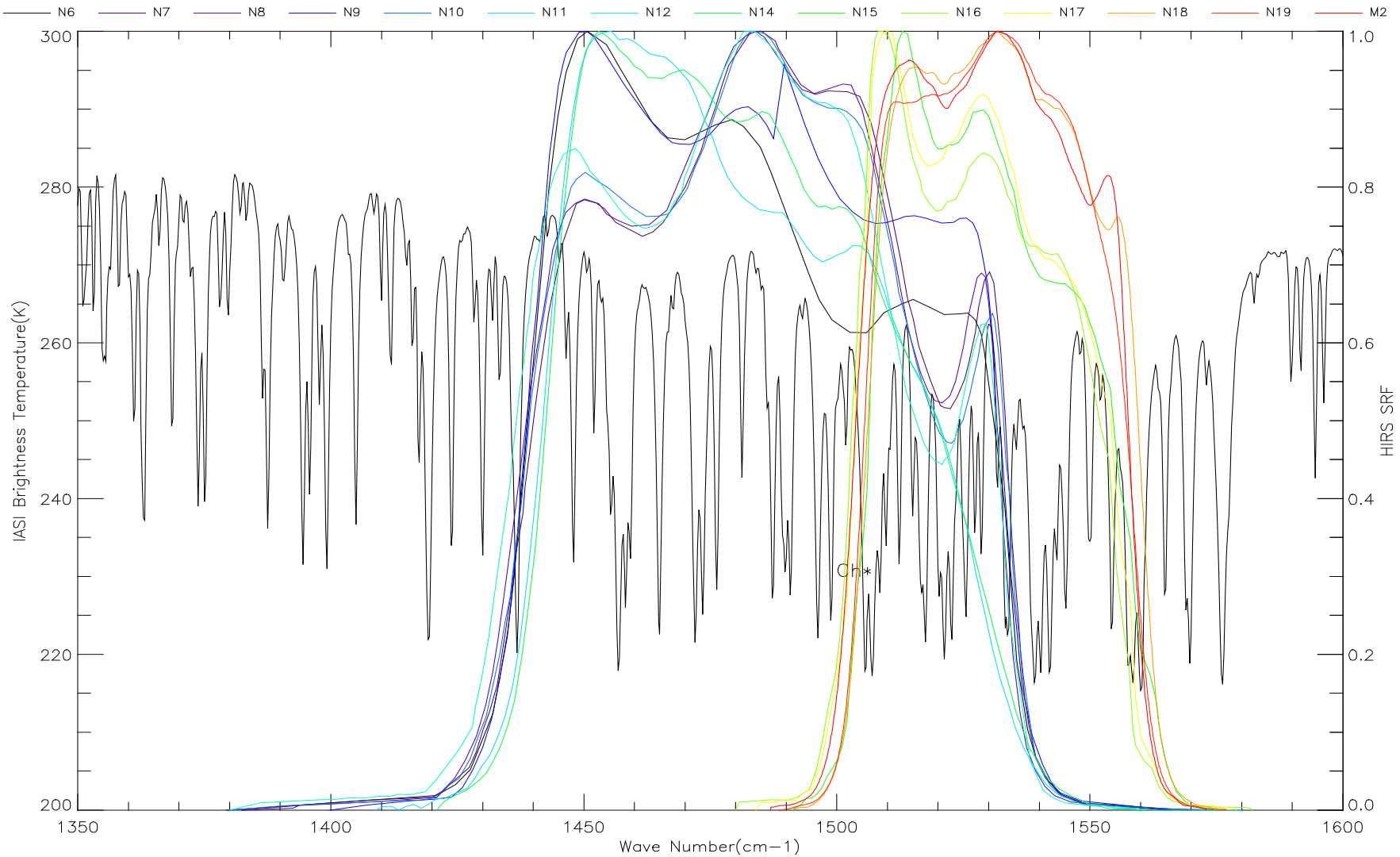


Adjusting the HIRS SRF



* Bandwidth ~ 15 cm-1
* If shift of 2.5 cm-1, ΔTb ~ +5 K, ΔR ~6 mW/m2/ster/cm-1
* Then calculation of clear sky radiance obs would be off by ΔR which would affect determination of Pc
* Warmer clear sky calculation introduces higher CTH estimation

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 – 14.2µm

Ch5 – 13.9µm

HIRS BT
minus
IASI BT

After optimal SRF shifting

Original BT difference

Ch7 – 13.3µm

Ch12 – 6.5µm

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 – 700 cm^{-1}

Ch5 – 720 cm^{-1}

Ch7 – 750 cm^{-1}

-1.16 cm^{-1}

-0.48 cm^{-1}

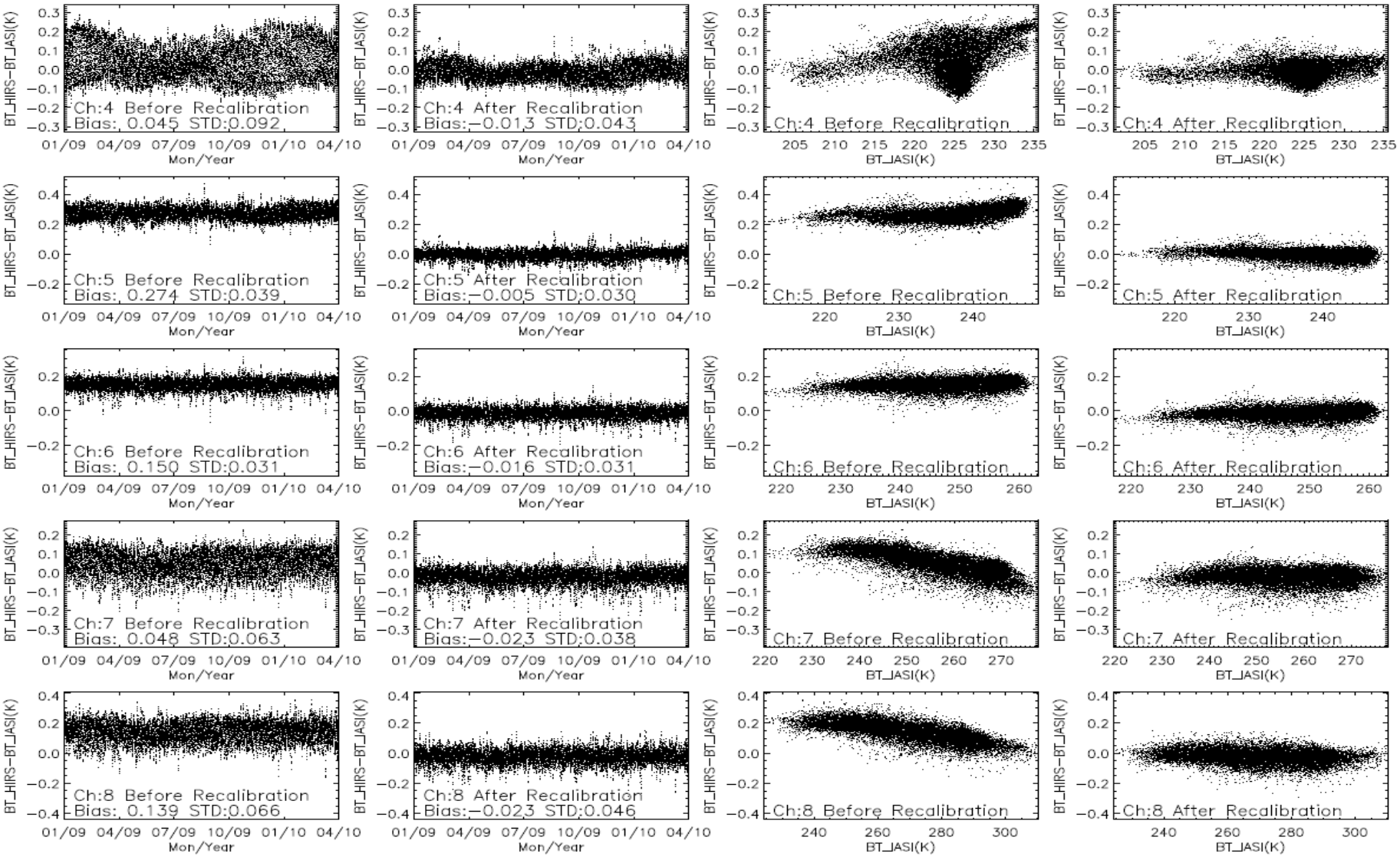
-0.52 cm^{-1}

Ch12 – 1530 cm^{-1}

-2 cm^{-1}

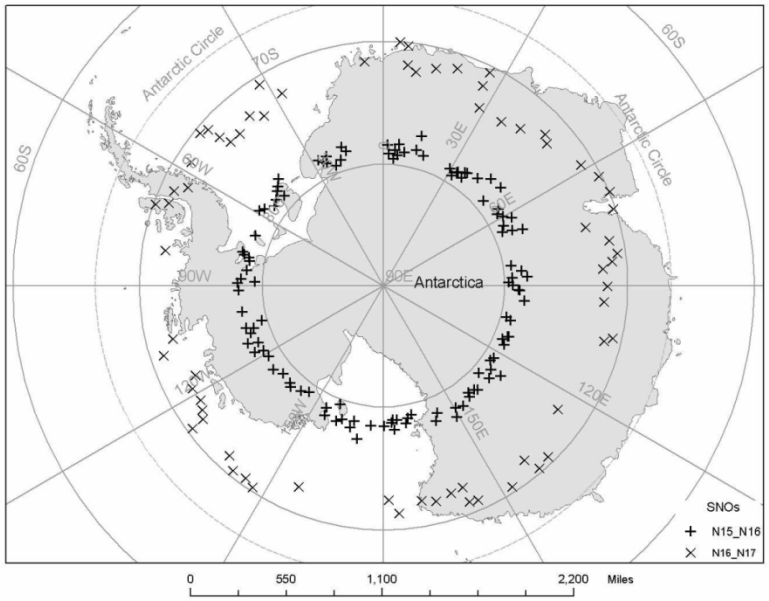
Between -5 and 5 wavenumber shifting, the orbital variance does not decrease significantly for channel 12.

MetOp-A HIRS Recalibration Using IASI

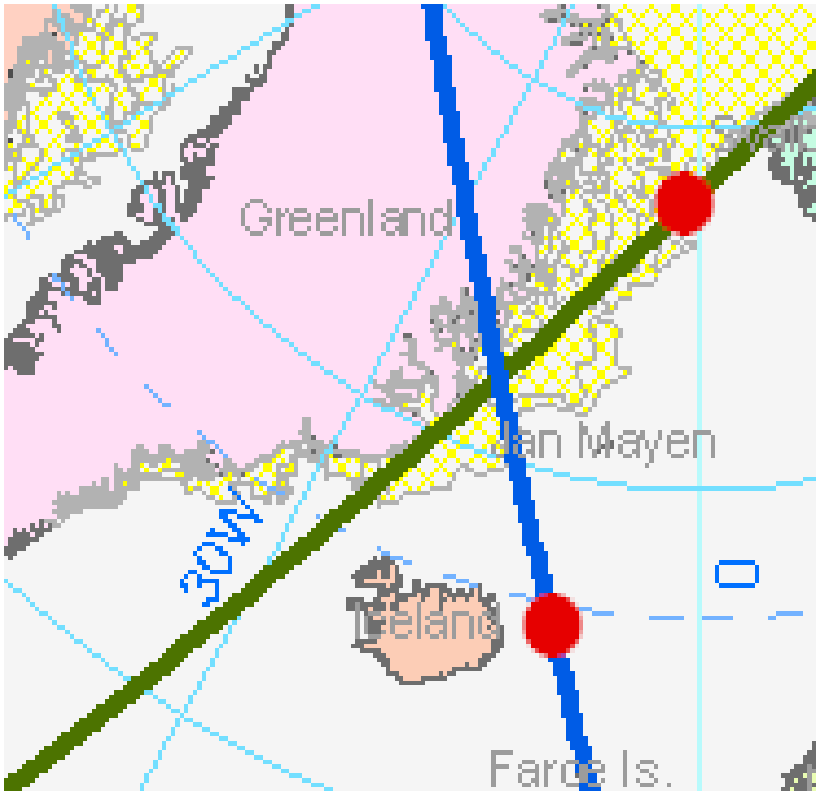


- Corrected of blackbody bias (0.14 K), SRFs (shifted -0.13, 0.09, -0.15 cm-1 for Ch 4, 5, and 7), and calibration non-linearity term.
- Validated with 16 months sampled MetOp data (the fifth orbit of each day)
- Both mean bias and bias variation (both T- and non T-dependent) are significantly reduced (< 0.1K)

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

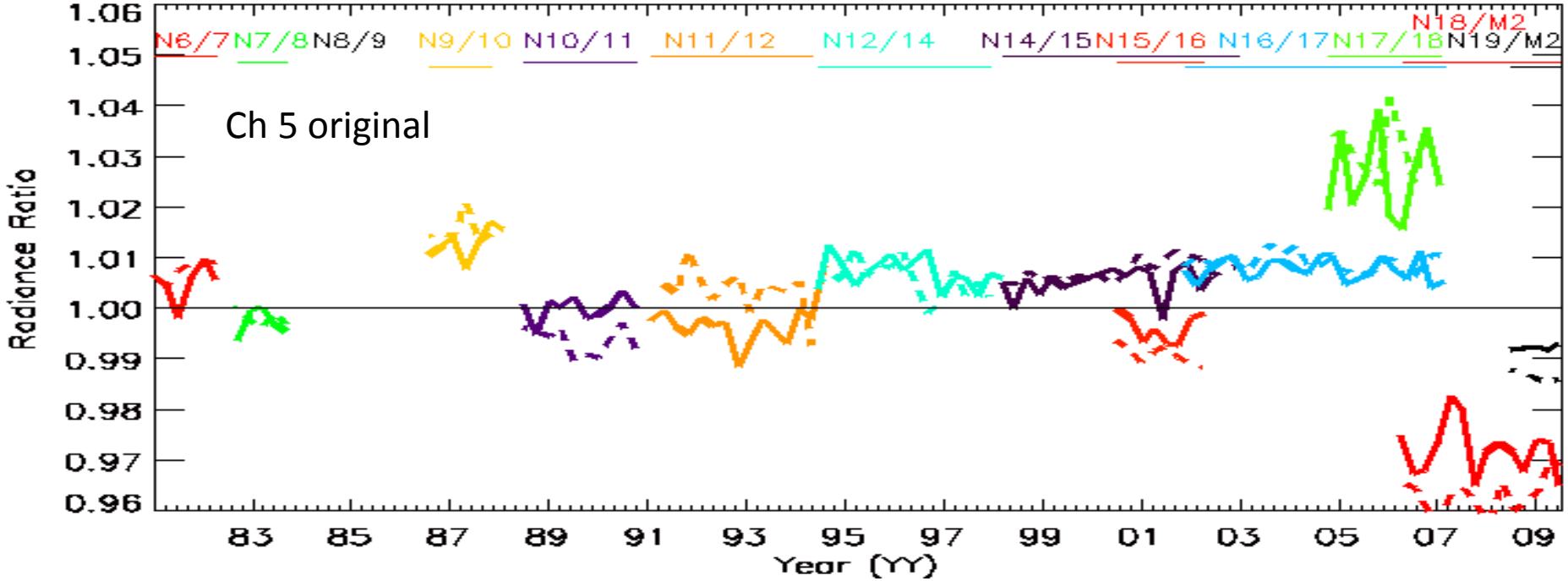
Using Metop-A IASI-HIRS data to estimate SRF shifts implied by HIRS-HIRS SNOs

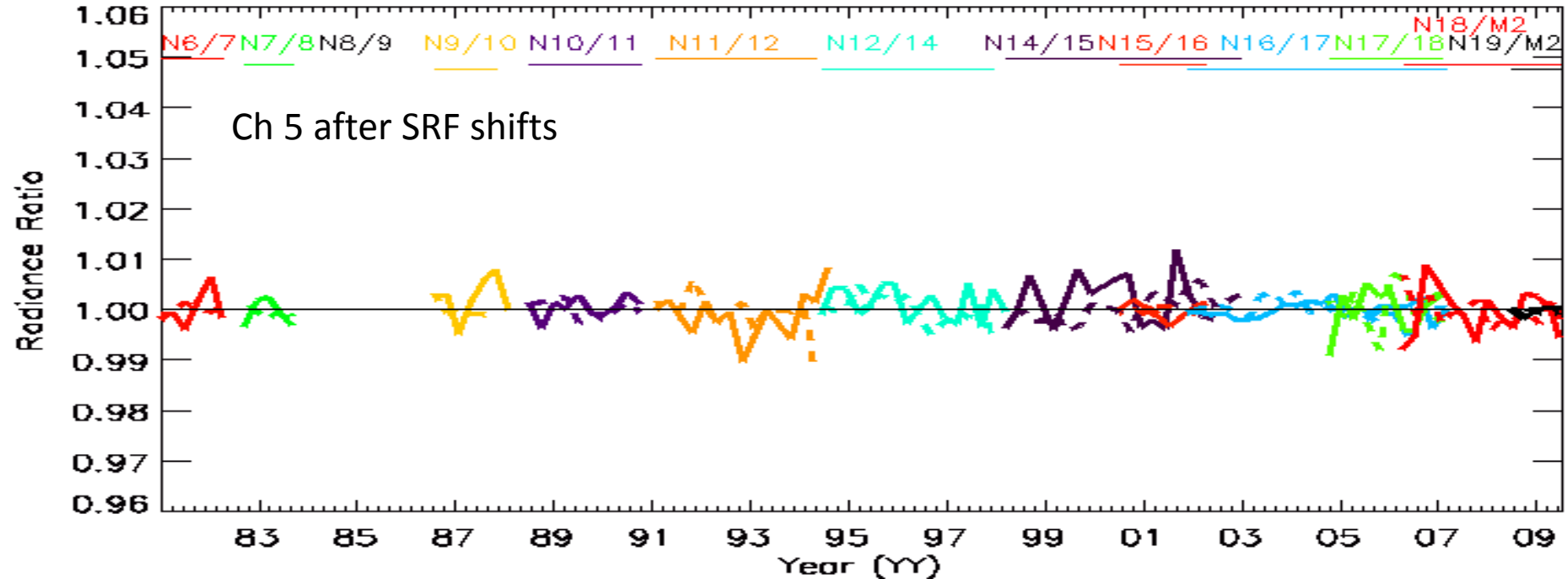
Impact of spectral shift on inter-satellite radiance (or BT) difference depends on atmospheric state at time of measurements

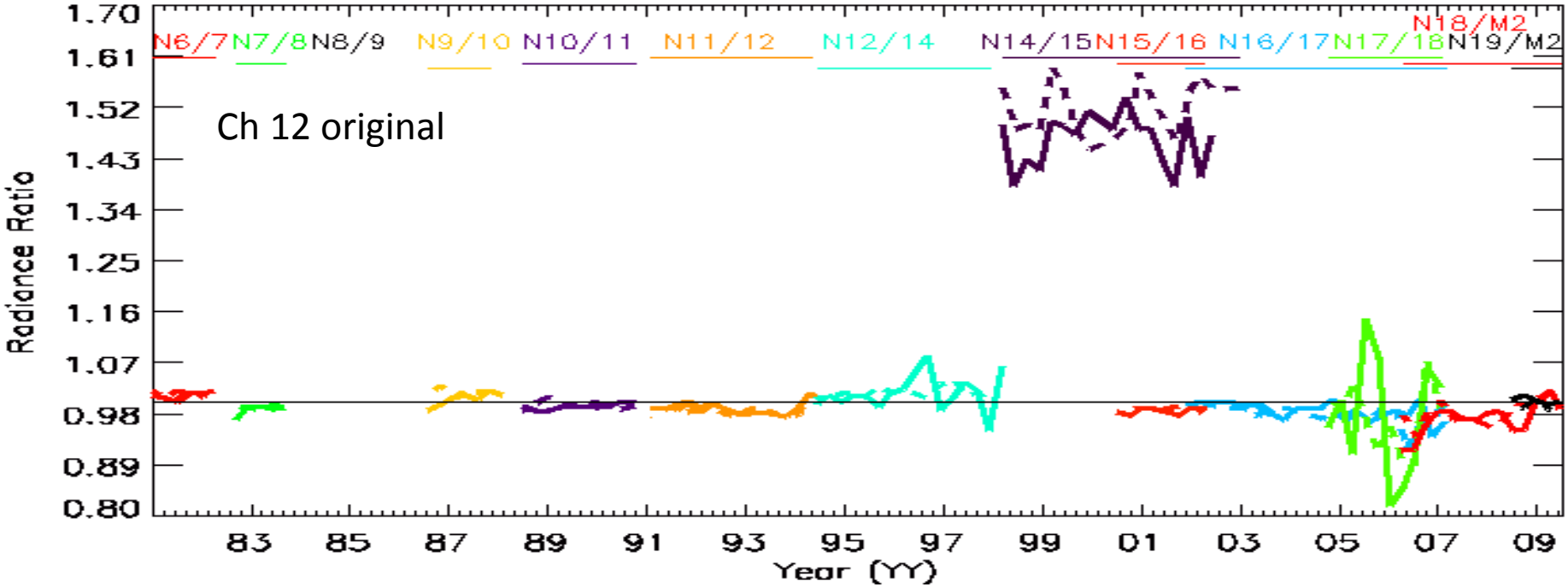
IASI-simulated HIRS data are used to develop linear models to estimate impacts of SRF shifts (and differences) on inter-satellite radiance differences for various atmospheric conditions;

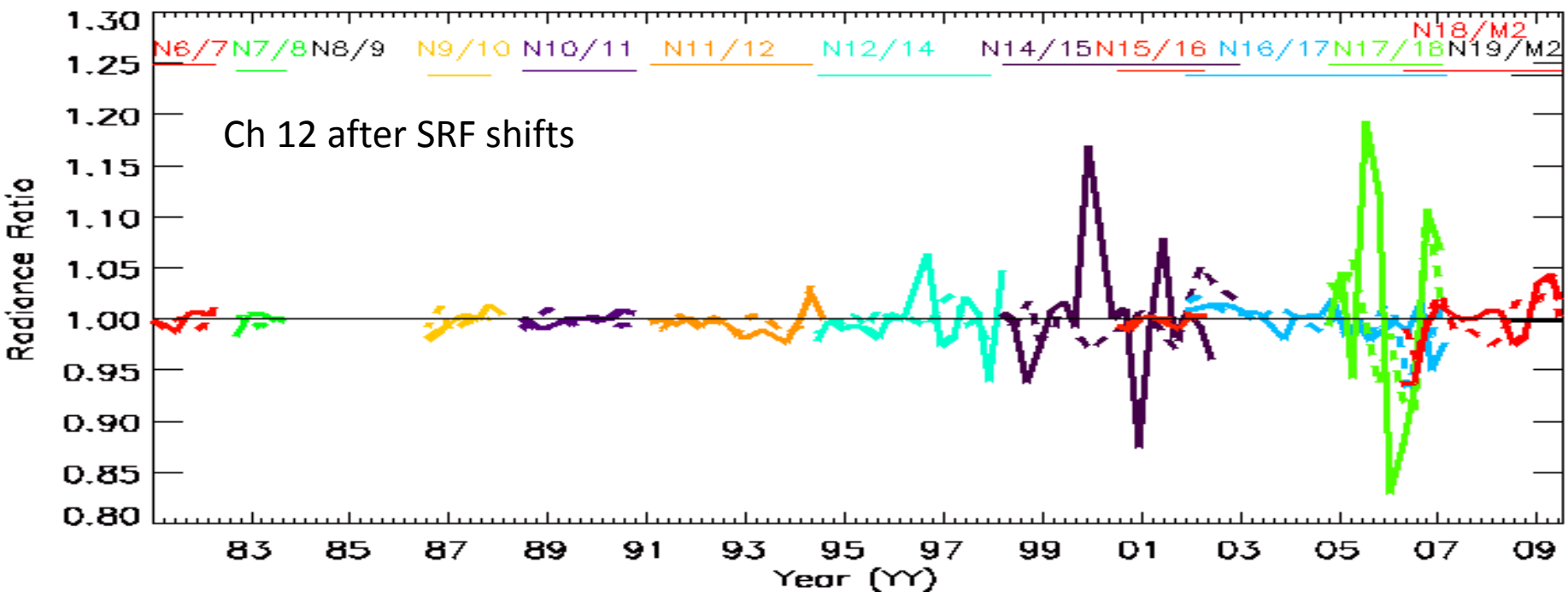
For channel *i* and satellite *m* a shift of ΔSRF will produce a radiance change $\Delta R_{im} = \Delta SRF\ [\Sigma_j\ a_{ijm}\ R_{jm} + c_{im}]$

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)


Ch 5 original
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
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 5 after SRF shifts
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
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
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
Radiance Ratio
1.70
1.61
1.52
1.43
1.34
1.25
1.16
1.07
0.98
0.89
0.80
83
85
87
89
91
93
95
97
99
01
03
05
07
09
Year (YY)


Ch 12 after SRF shifts
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
Radiance Ratio
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0.95
0.90
0.85
0.80
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 (Chen et al, 2013)

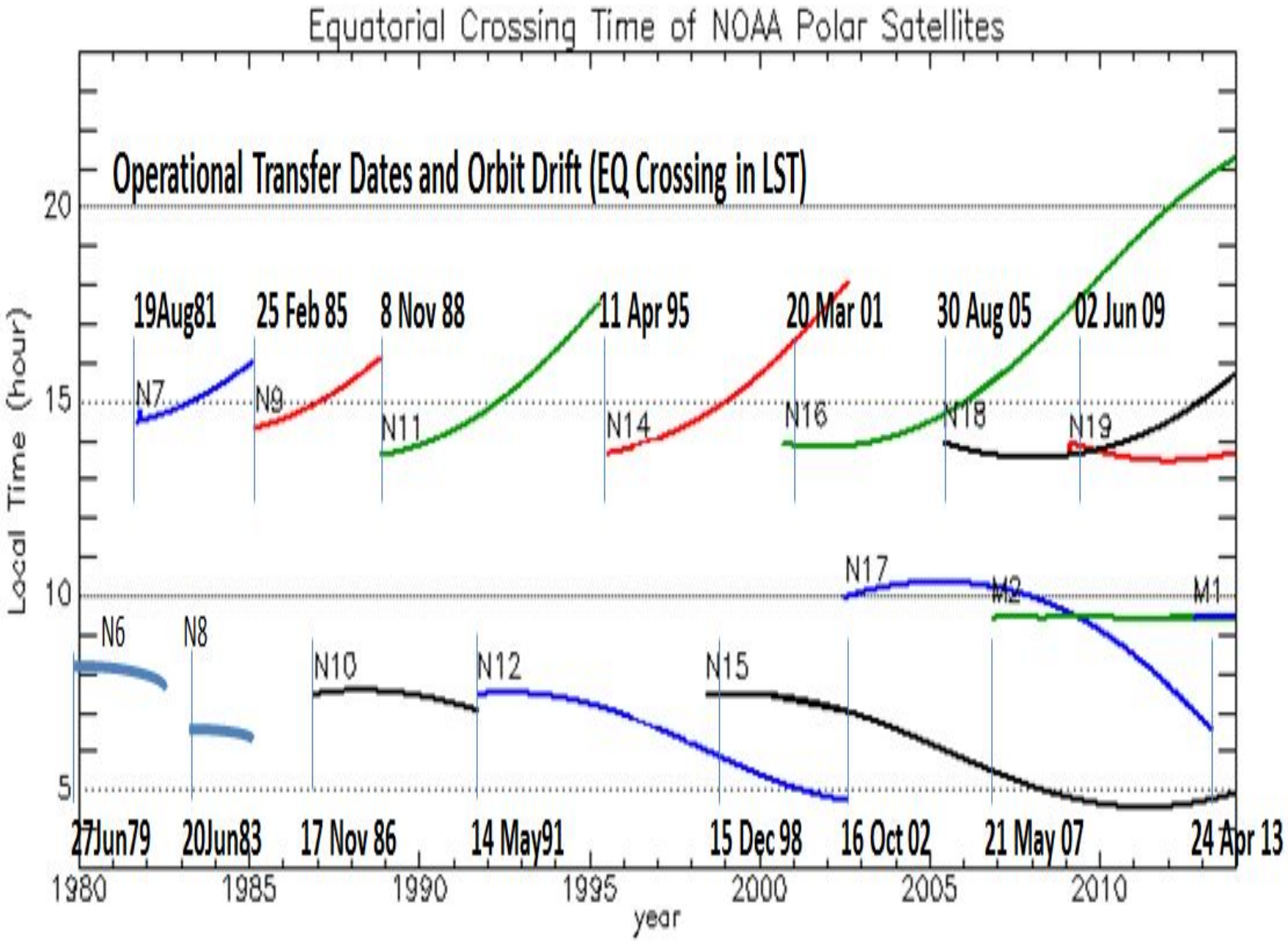
Mitigating effects of Orbit Drift

Confining trend analysis to operational dates for each POES

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

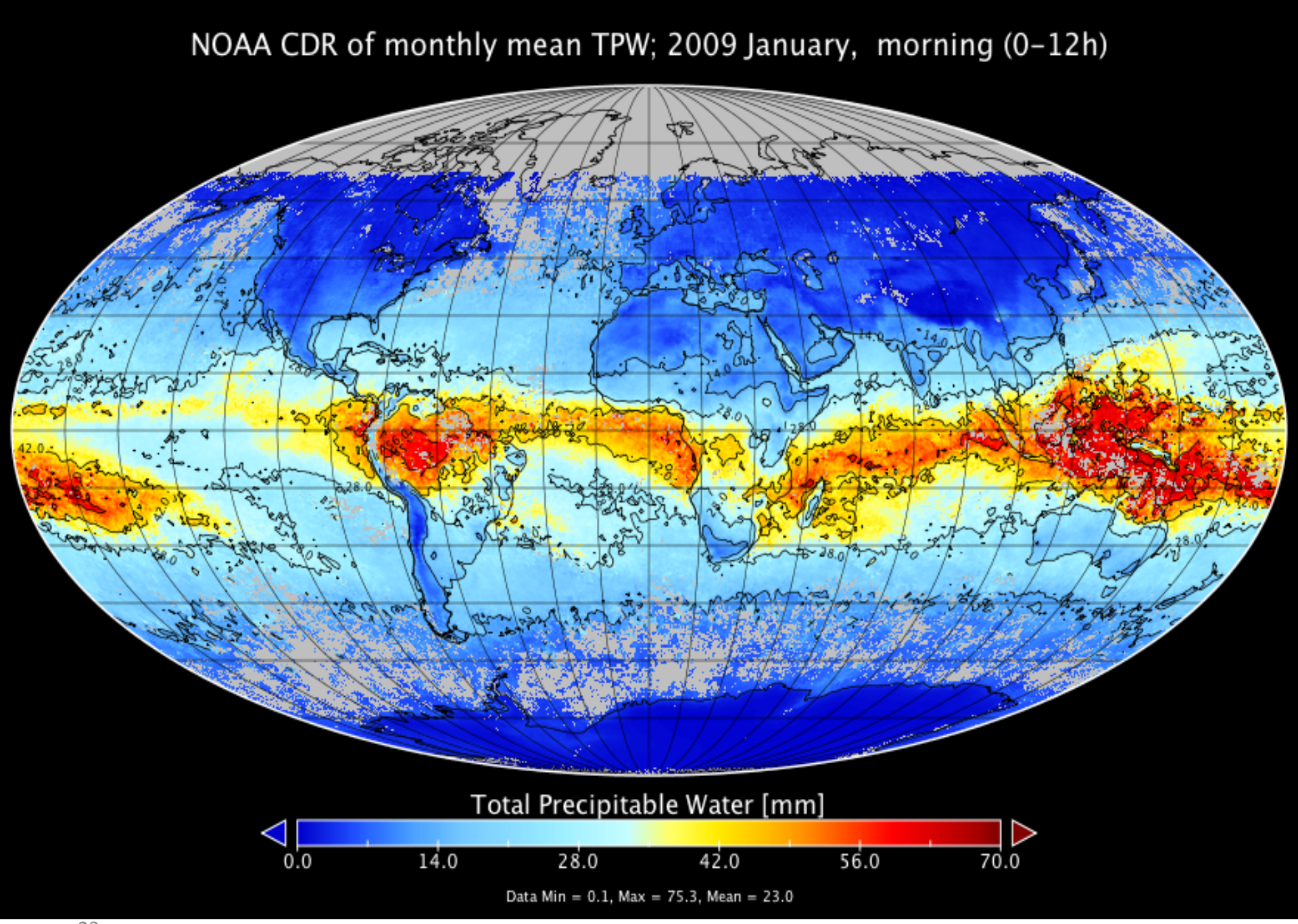
Morning SZA <= 85° and Local Time Before Noon

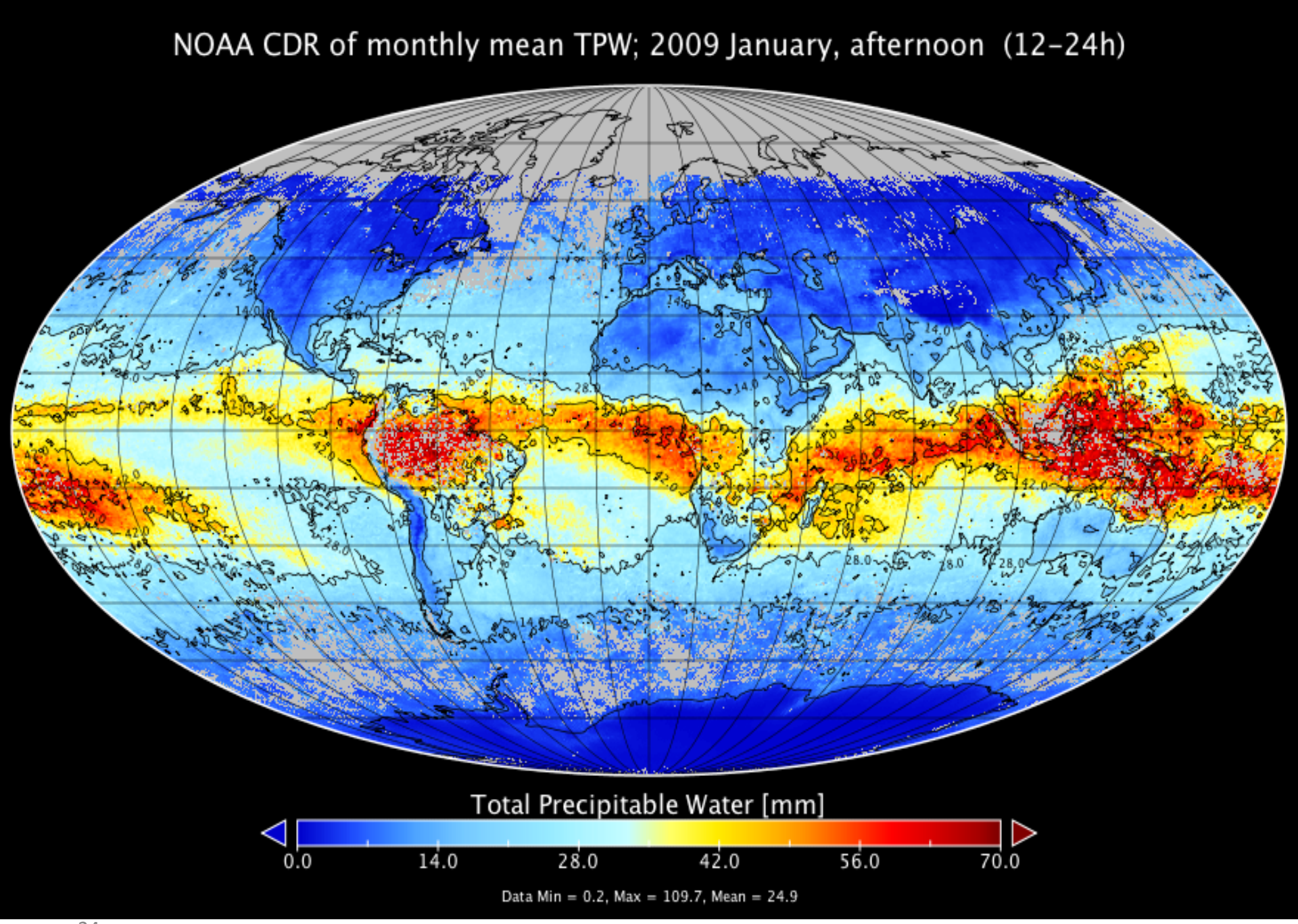
Afternoon SZA <= 85° and Local Time After Noon

Evening SZA > 85° and Local Time Before Midnight

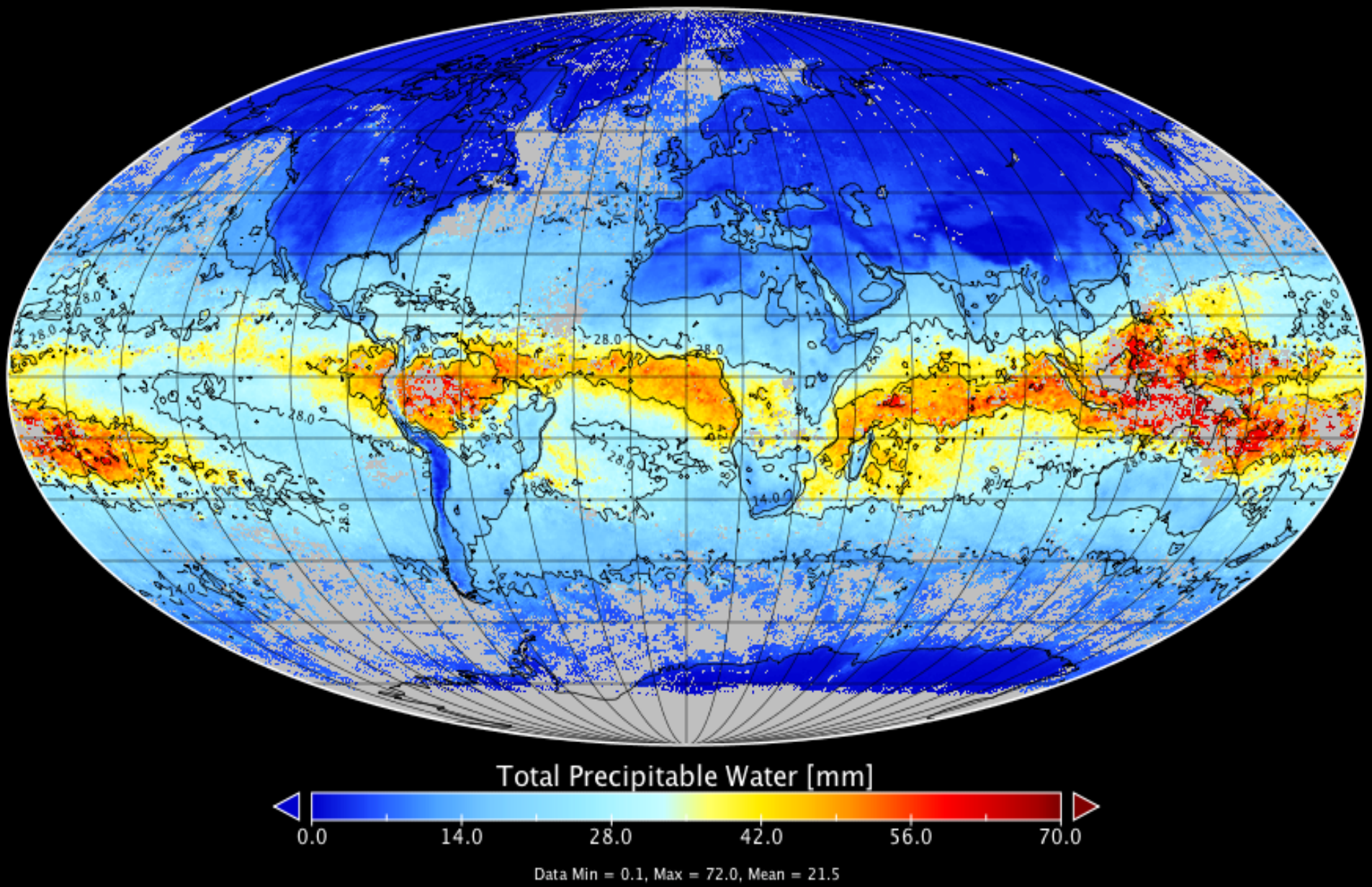
Night SZA > 85° and Local Time After Midnight

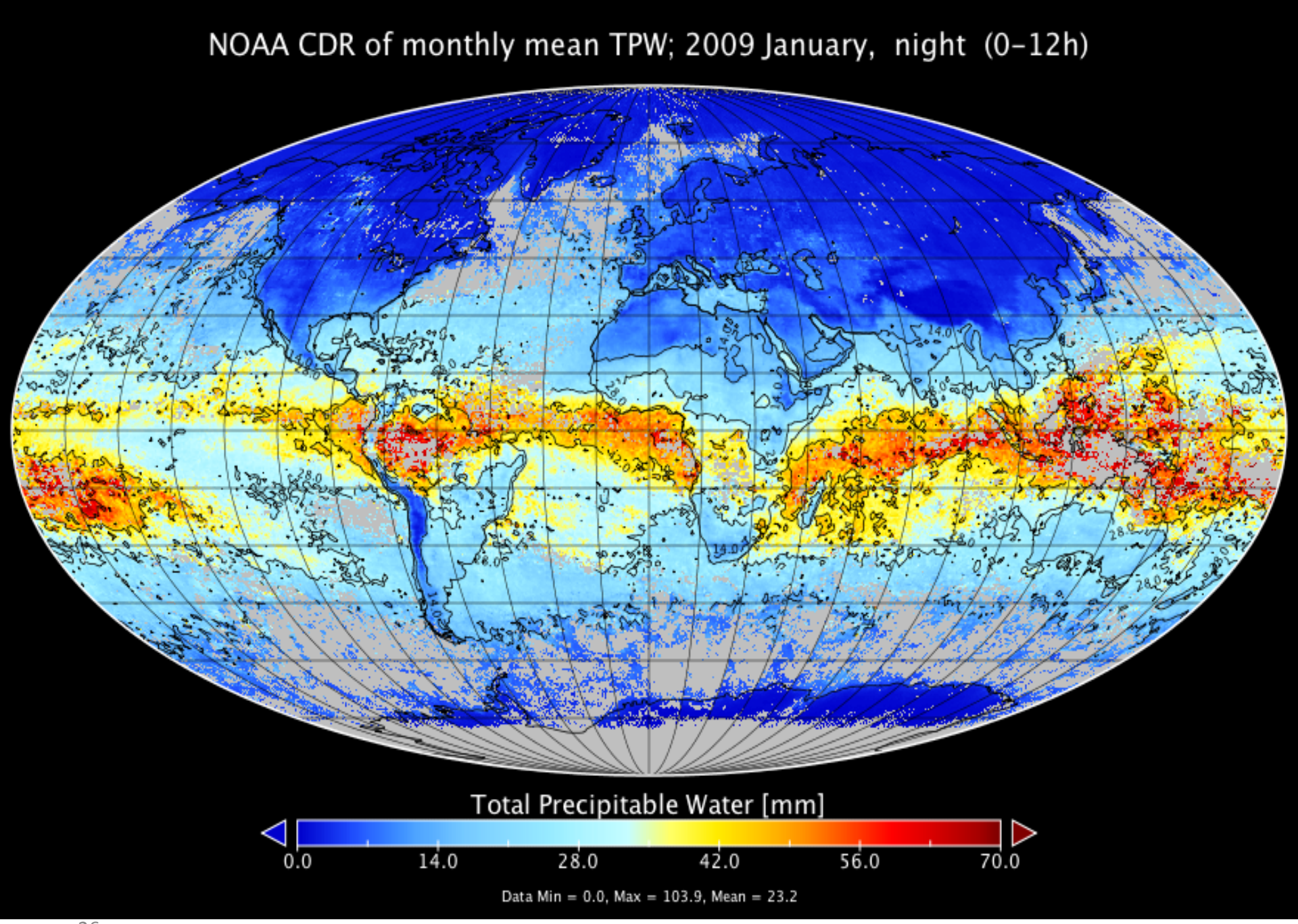
Accounting for and taking advantage of orbit drift


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)
Total Precipitable Water [mm]
0.0
14.0
28.0
42.0
56.0
70.0
Data Min = 0.2, Max = 109.7, Mean = 24.9

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



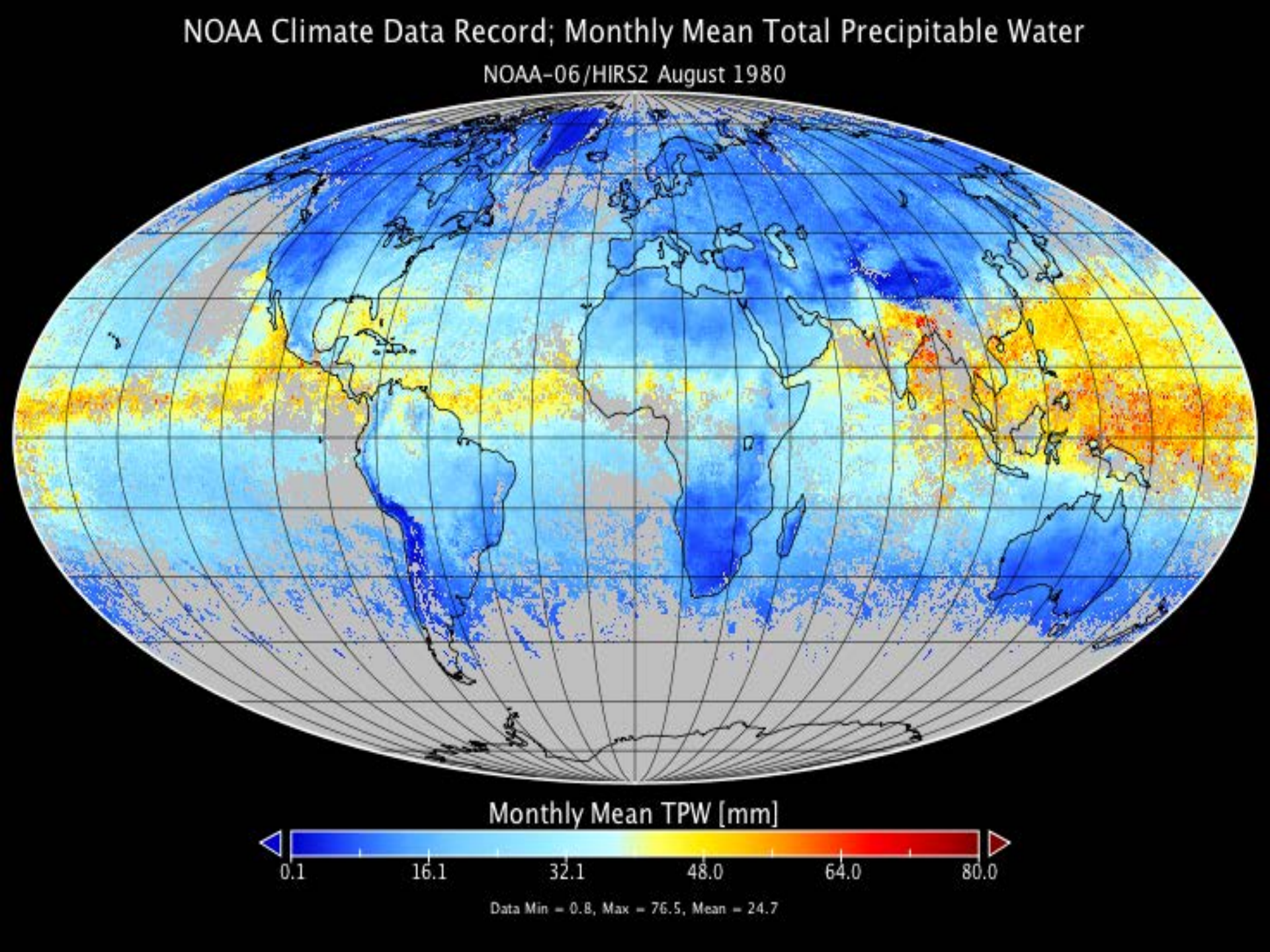

NOAA CDR of monthly mean TPW; 2009 January, night (0-12h)
Total Precipitable Water [mm]
0.0
14.0
28.0
42.0
56.0
70.0
Data Min = 0.0, Max = 103.9, Mean = 23.2

HIRS TPW and UTH Trends

Comparing with Aqua MODIS

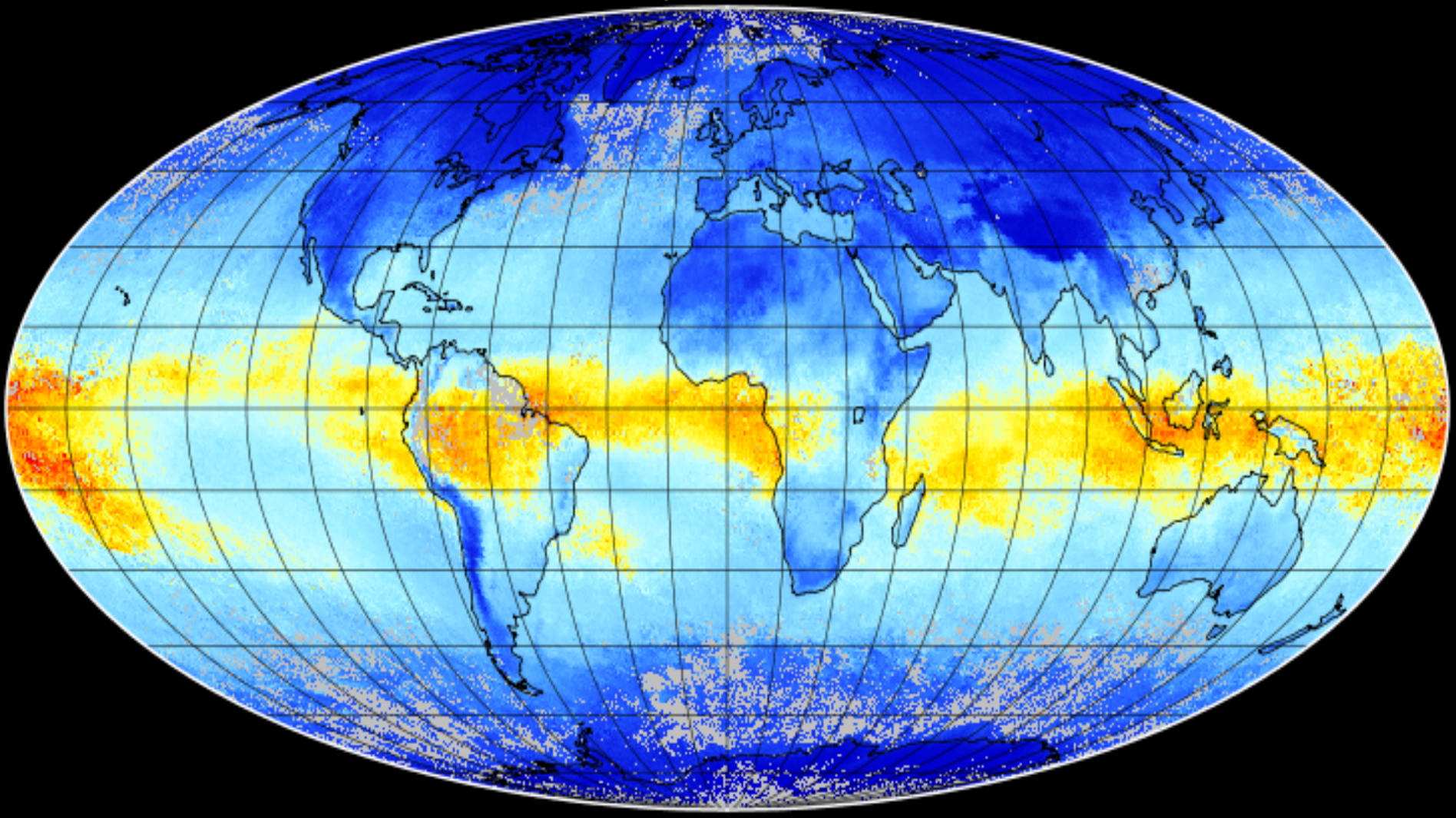
HIRS TPW and UTH

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 & UTH 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 AVHRR based PATMOS-x cloud mask is used to characterize HIRS sub-pixel cloud cover.


NOAA Climate Data Record; Monthly Mean Total Precipitable Water
NOAA-06/HIRS2 August 1980
Monthly Mean TPW [mm]
0.1
16.1
32.1
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 - Morning

METOP-B/HIRS4 March 2015

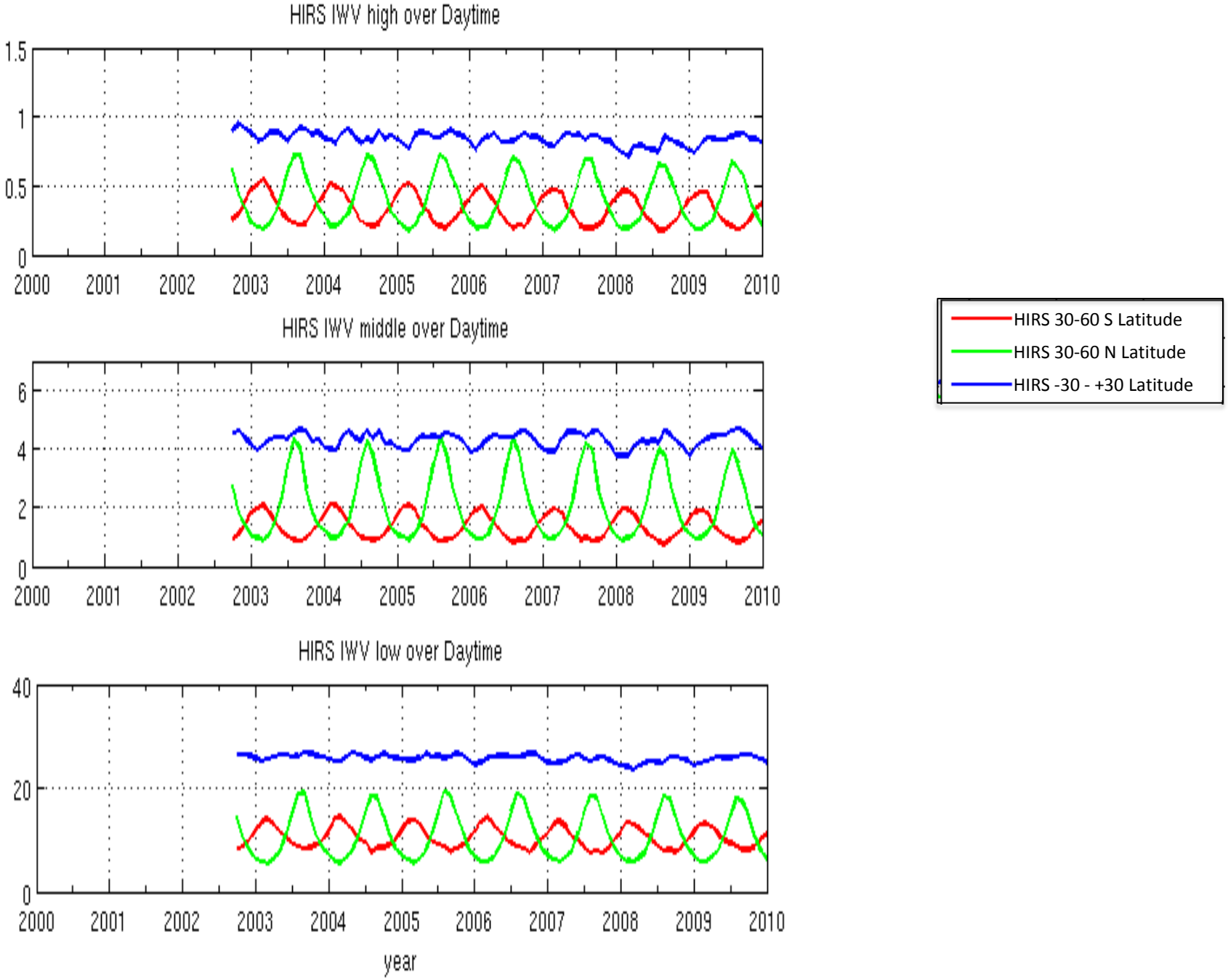


Monthly Mean TPW [mm]

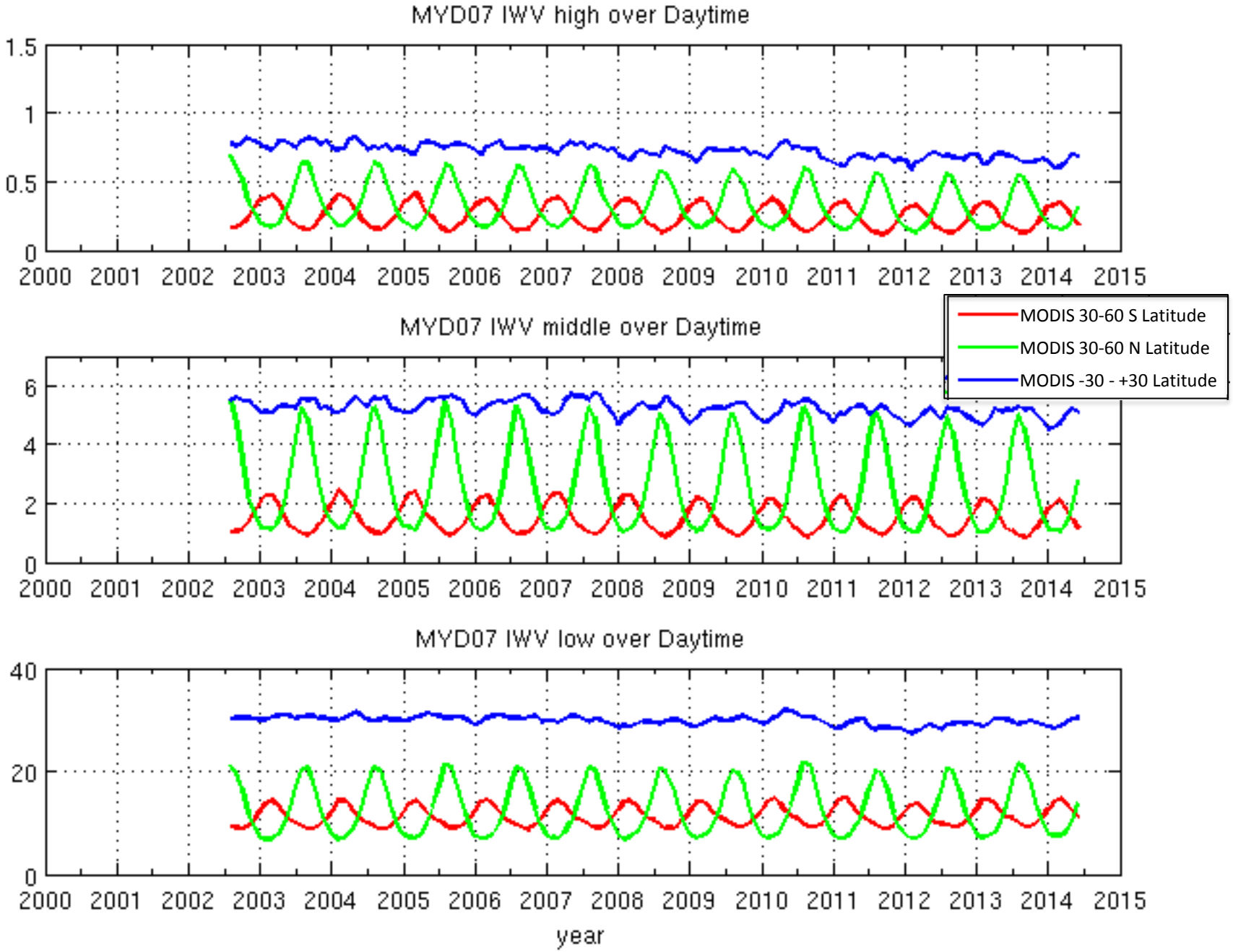
0.1 16.1 32.1 48.0 64.0 80.0

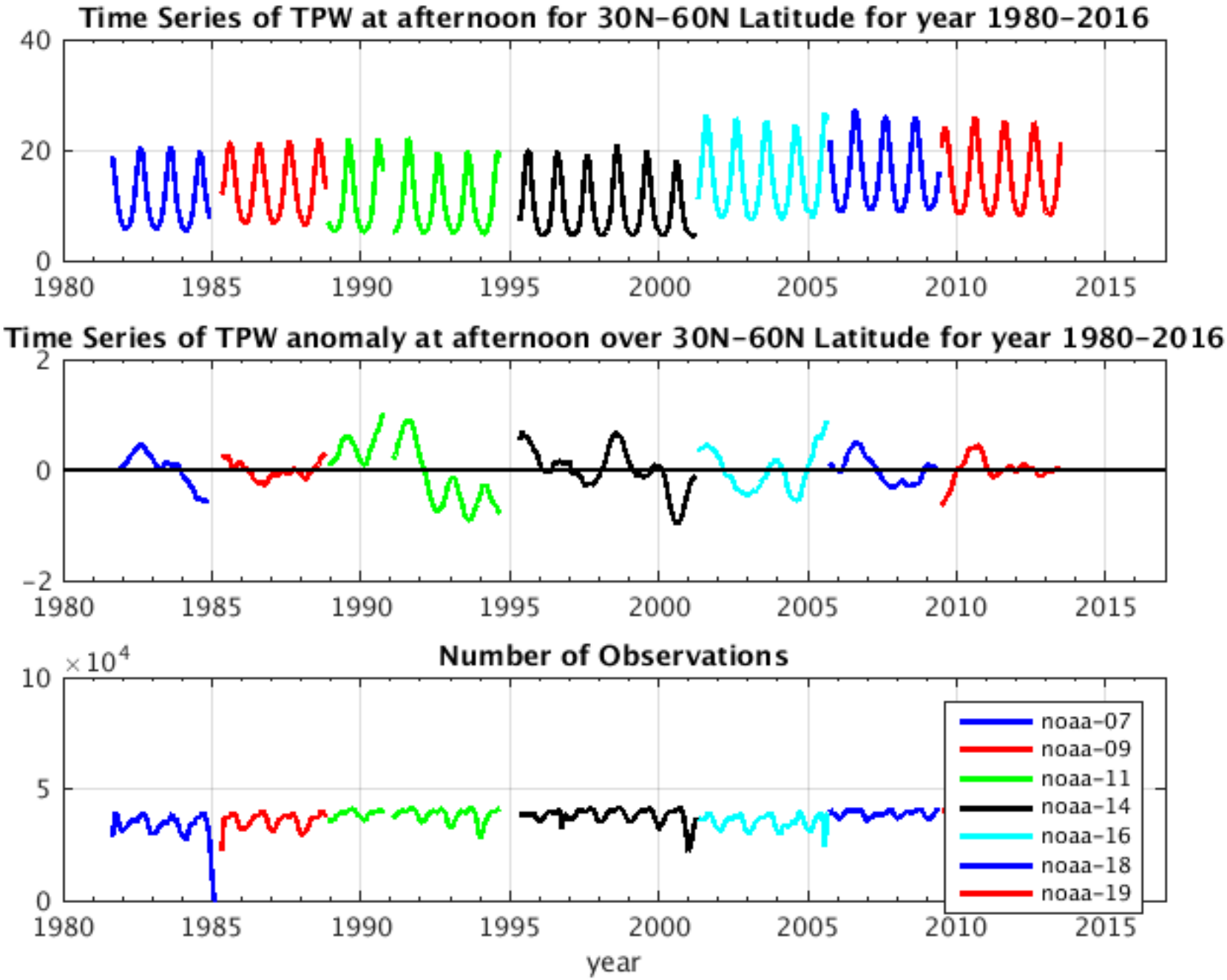
Data Min = 0.1, Max = 71.5, Mean = 23.1

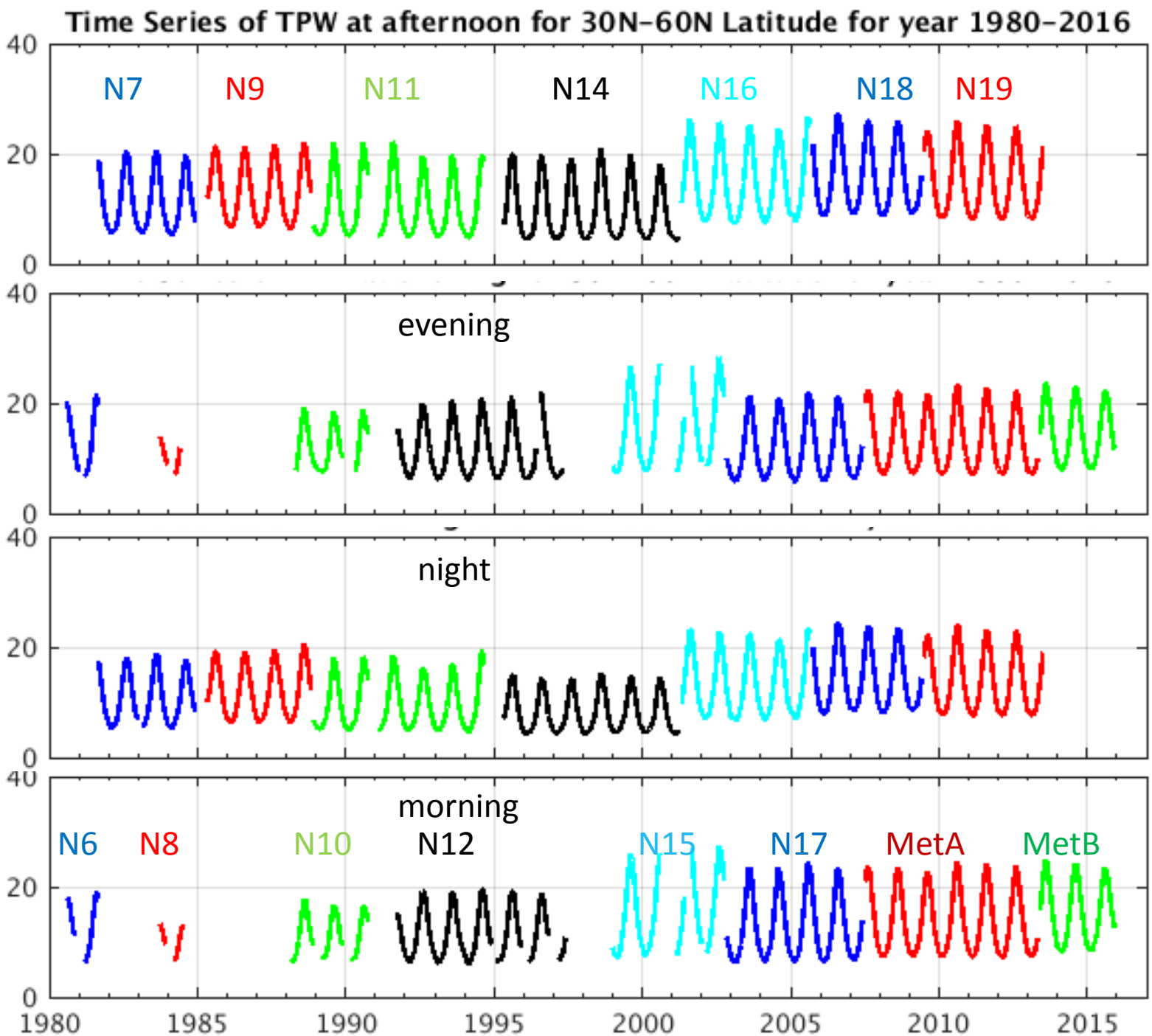
Time series of N17/HIRS IWV high, middle and low over Daytime

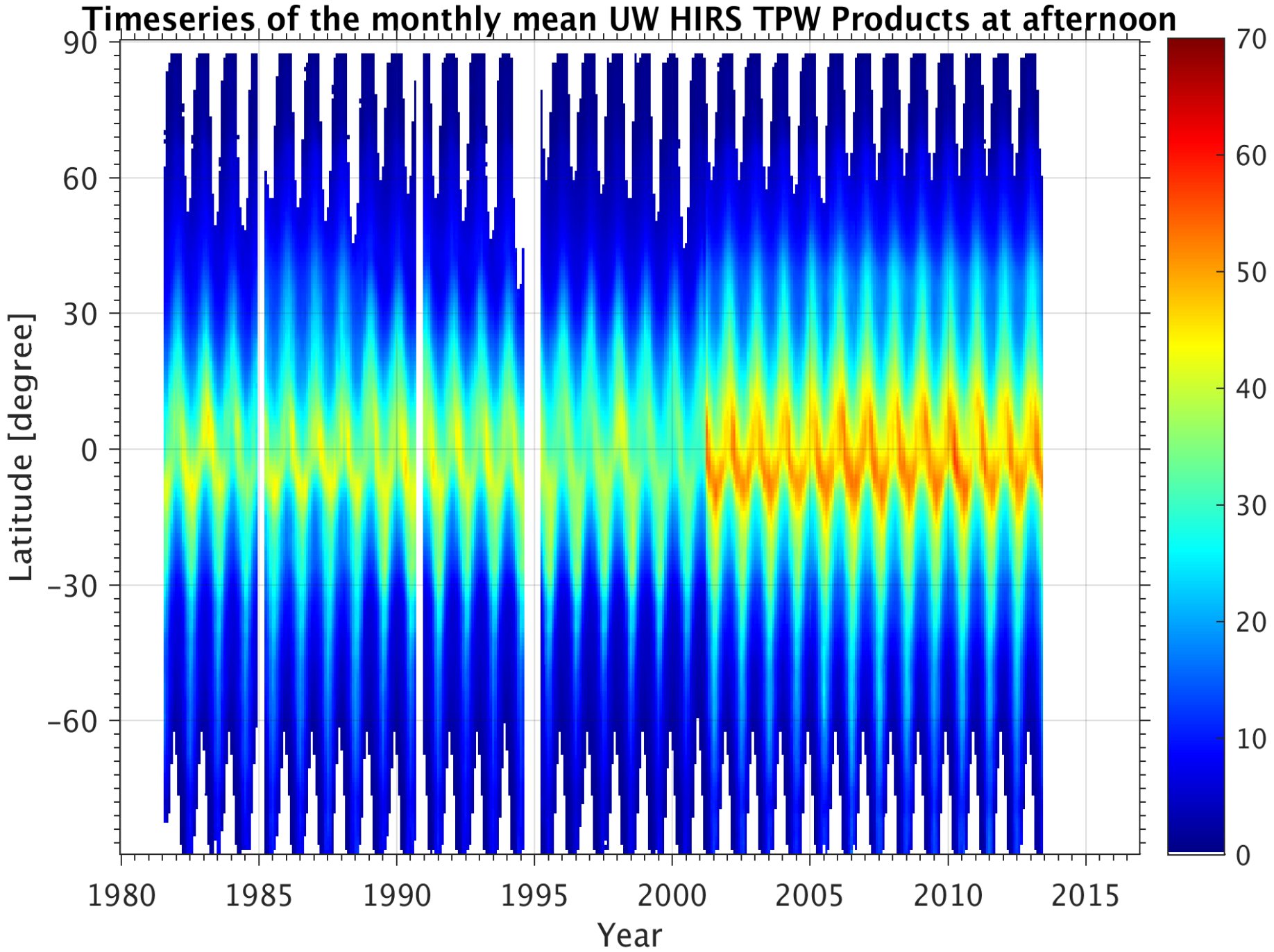


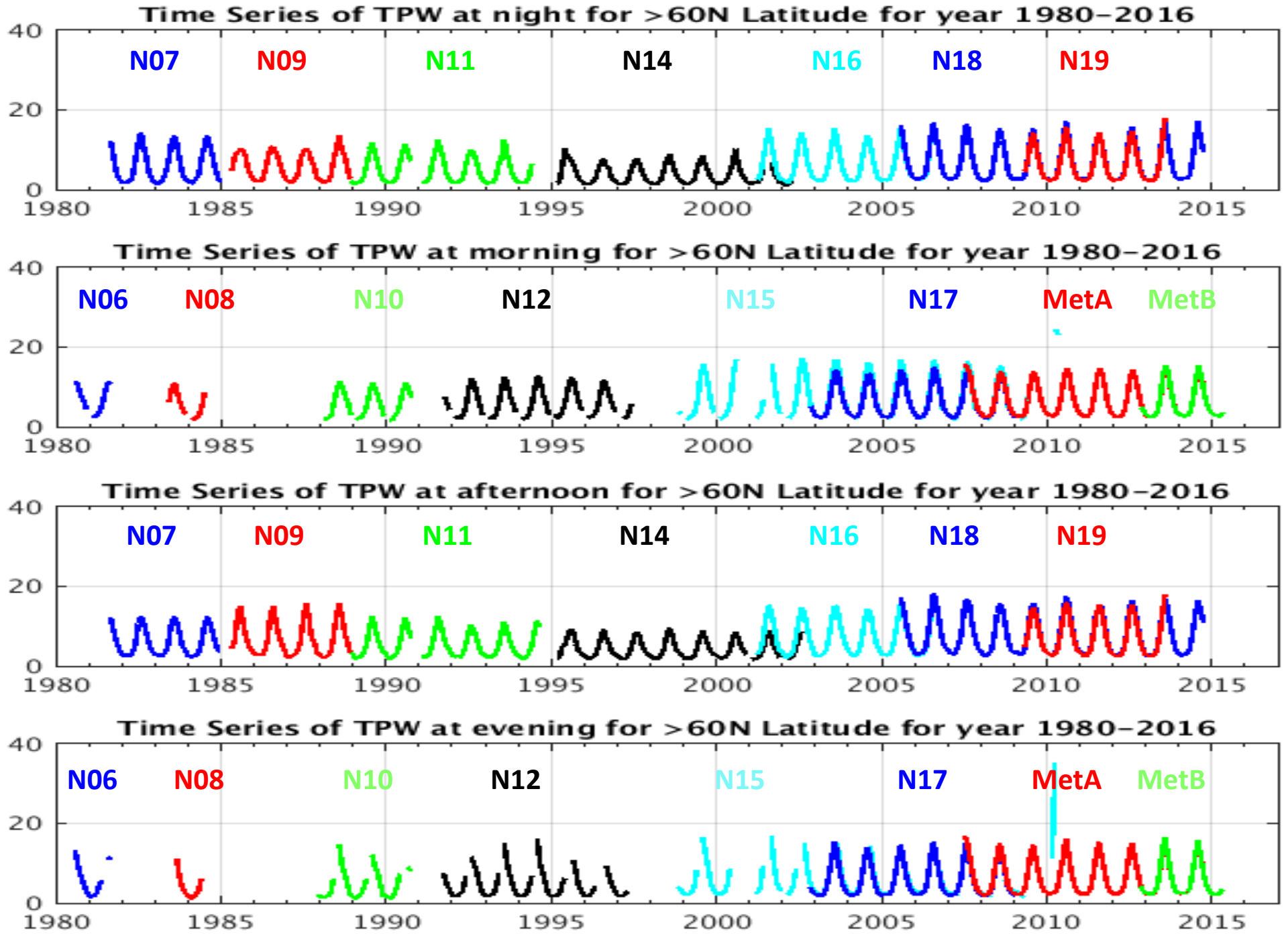
Time series of MYD07 IWV high, middle and low over Daytime

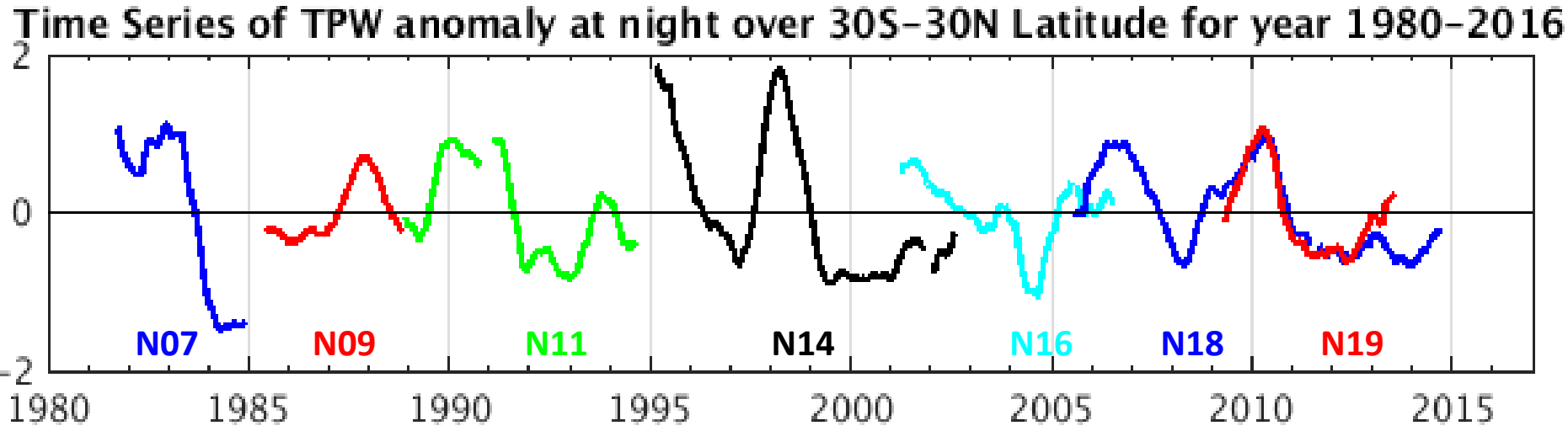


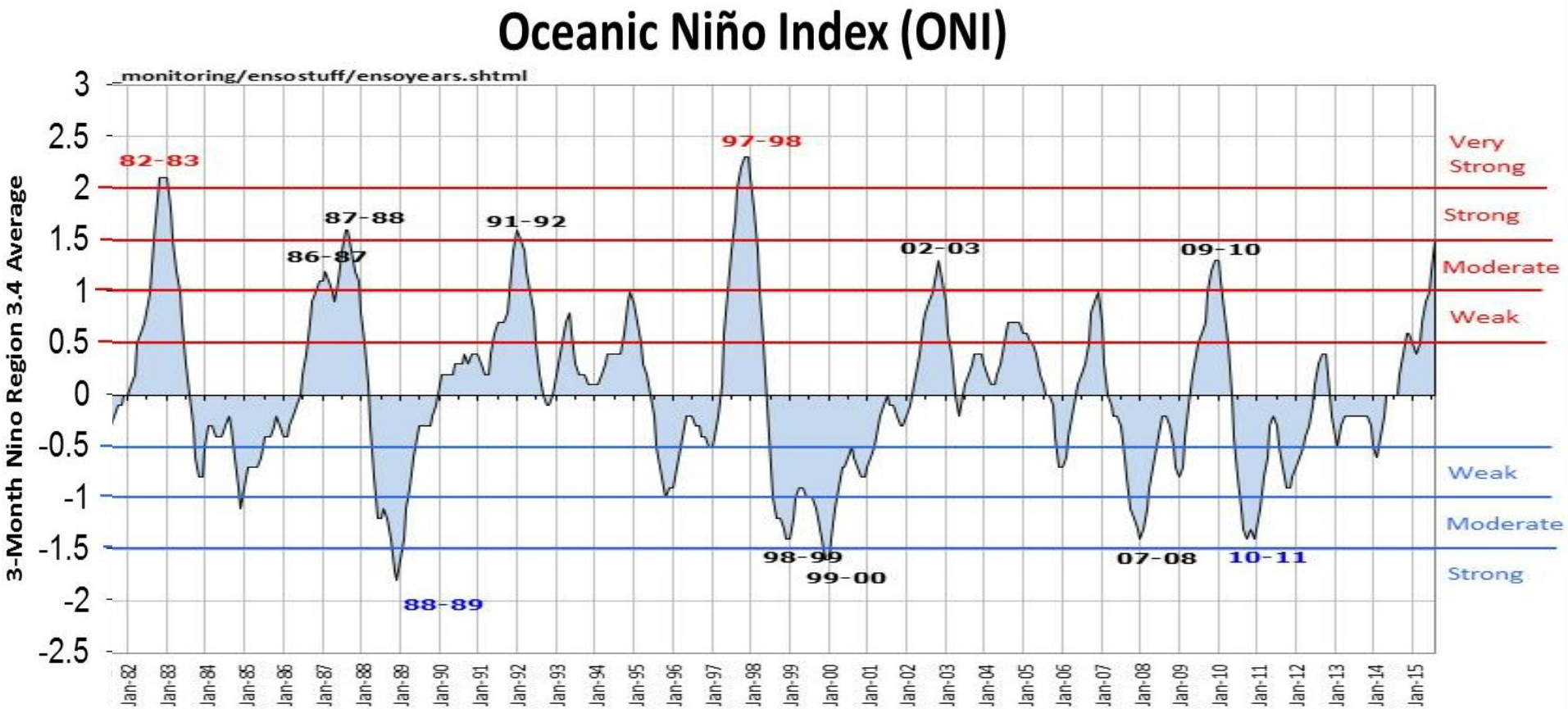

Time Series of TPW at afternoon for 30N-60N Latitude for year 1980-2016
40
20
0
1980
1985
1990
1995
2000
2005
2010
2015
Time Series of TPW anomaly at afternoon over 30N-60N Latitude for year 1980-2016
2
0
-2
1980
1985
1990
1995
2000
2005
2010
2015
Number of Observations
×10^4
10
5
0
1980
1985
1990
1995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

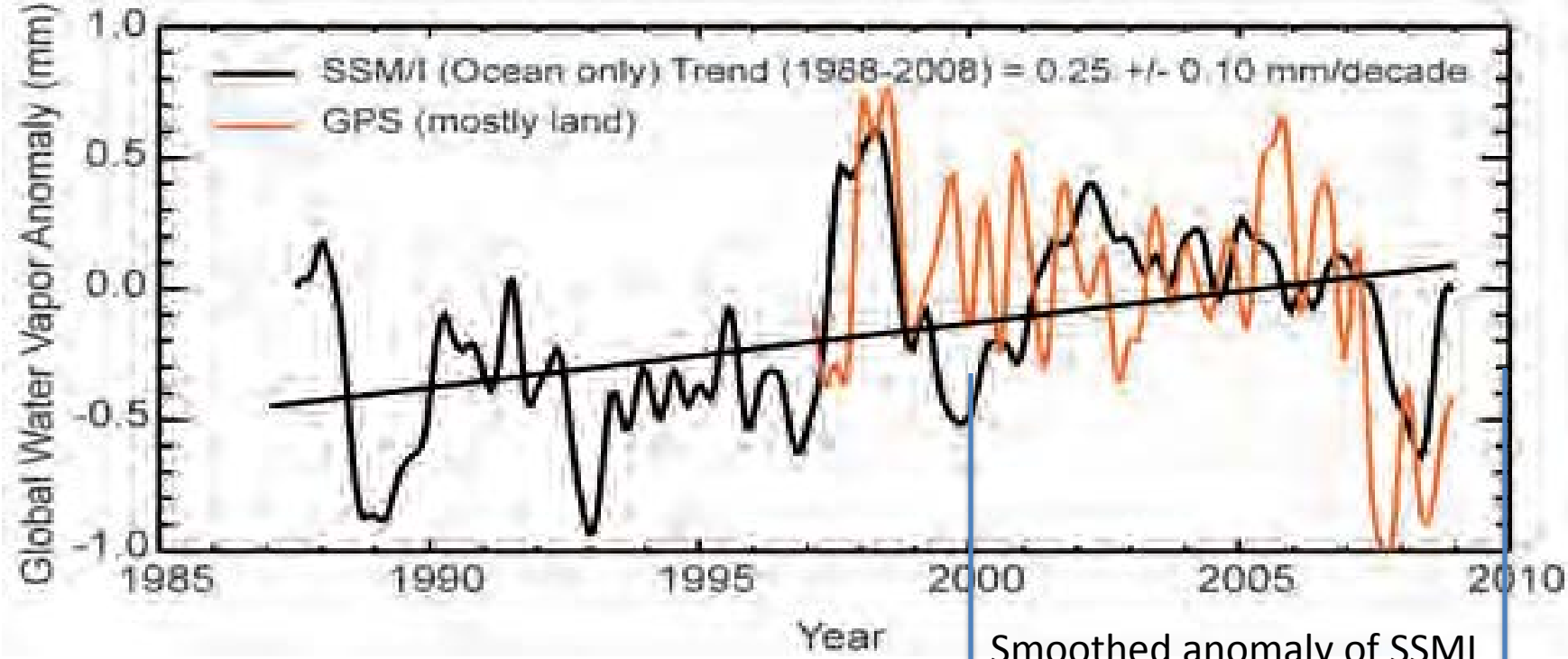

Time Series of TPW at afternoon for 30N-60N Latitude for year 1980-2016
N7
N9
N11
N14
N16
N18
N19
evening
night
morning
N6
N8
N10
N12
N15
N17
MetA
MetB
40
20
0
1980
1985
1990
1995
2000
2005
2010
2015


Timeseries of the monthly mean UW HIRS TPW Products at afternoon
Latitude [degree]
90
60
30
0
−30
−60
1980
1985
1990
1995
2000
2005
2010
2015
Year
70
60
50
40
30
20
10
0

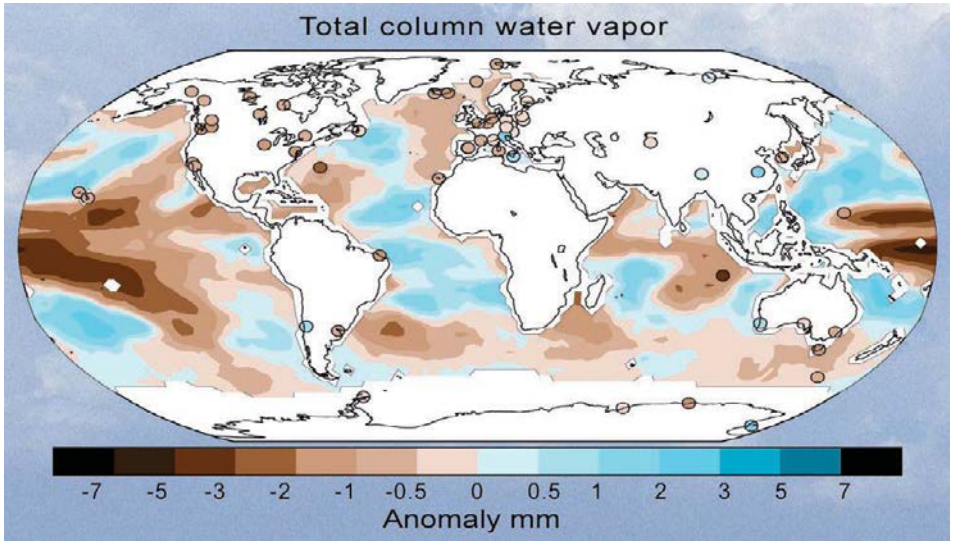

Time Series of TPW at night for >60N Latitude for year 1980–2016
N07
N09
N11
N14
N16
N18
N19
Time Series of TPW at morning for >60N Latitude for year 1980–2016
N06
N08
N10
N12
N15
N17
MetA
MetB
Time Series of TPW at afternoon for >60N Latitude for year 1980–2016
N07
N09
N11
N14
N16
N18
N19
Time Series of TPW at evening for >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

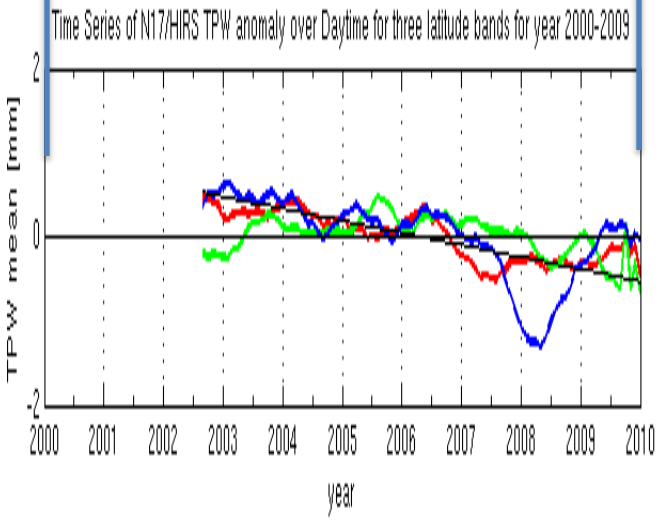

Time Series of TPW anomaly at night over 30S-30N Latitude for year 1980-2016
2
0
-2
N07
N09
N11
N14
N16
N18
N19
1980
1985
1990
1995
2000
2005
2010
2015


Oceanic Niño Index (ONI)
_monitoring/ensostuff/ensoyears.shtml
3-Month Nino Region 3.4 Average
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
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
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15



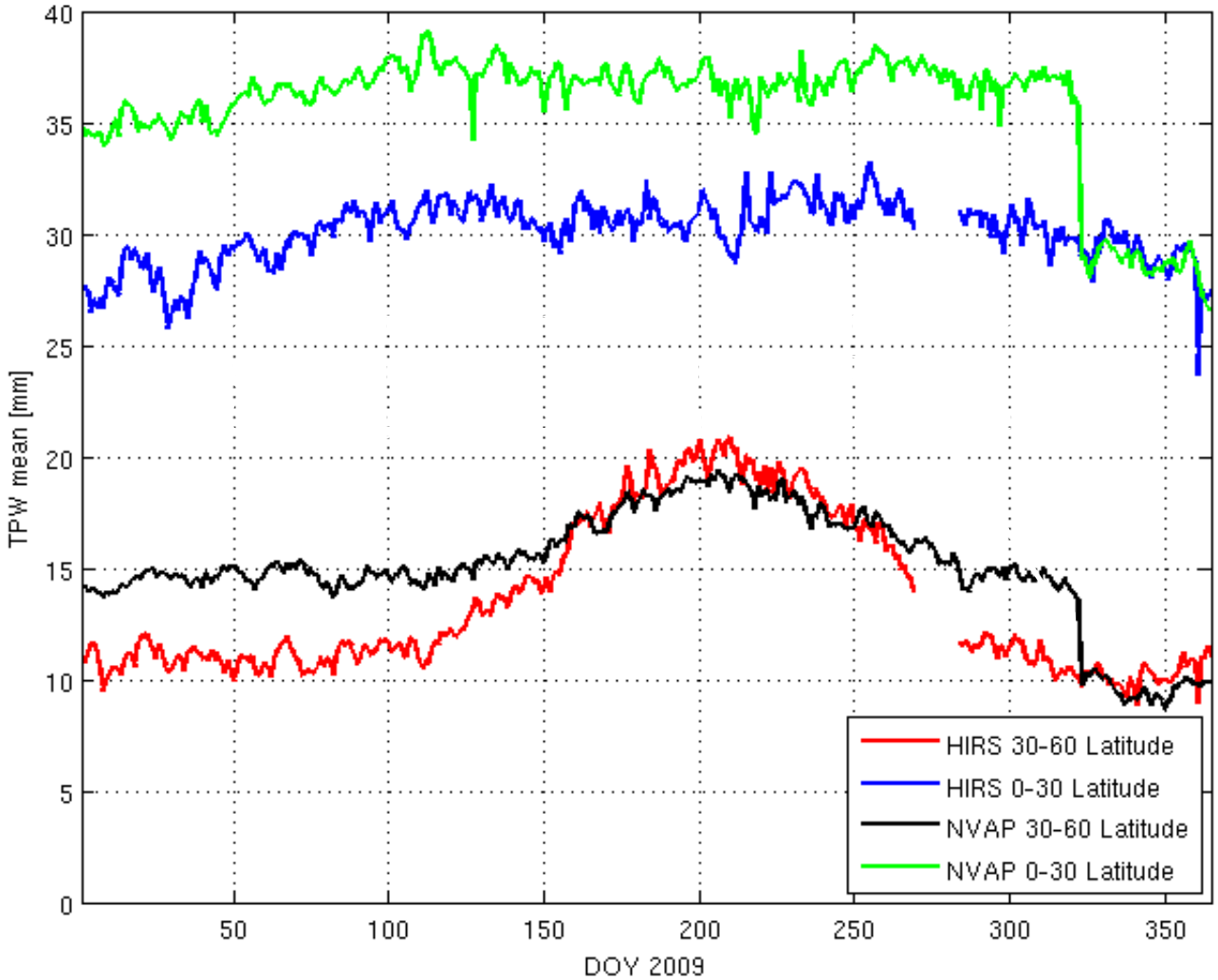
Smoothed anomaly of SSMI and HIRS TPW





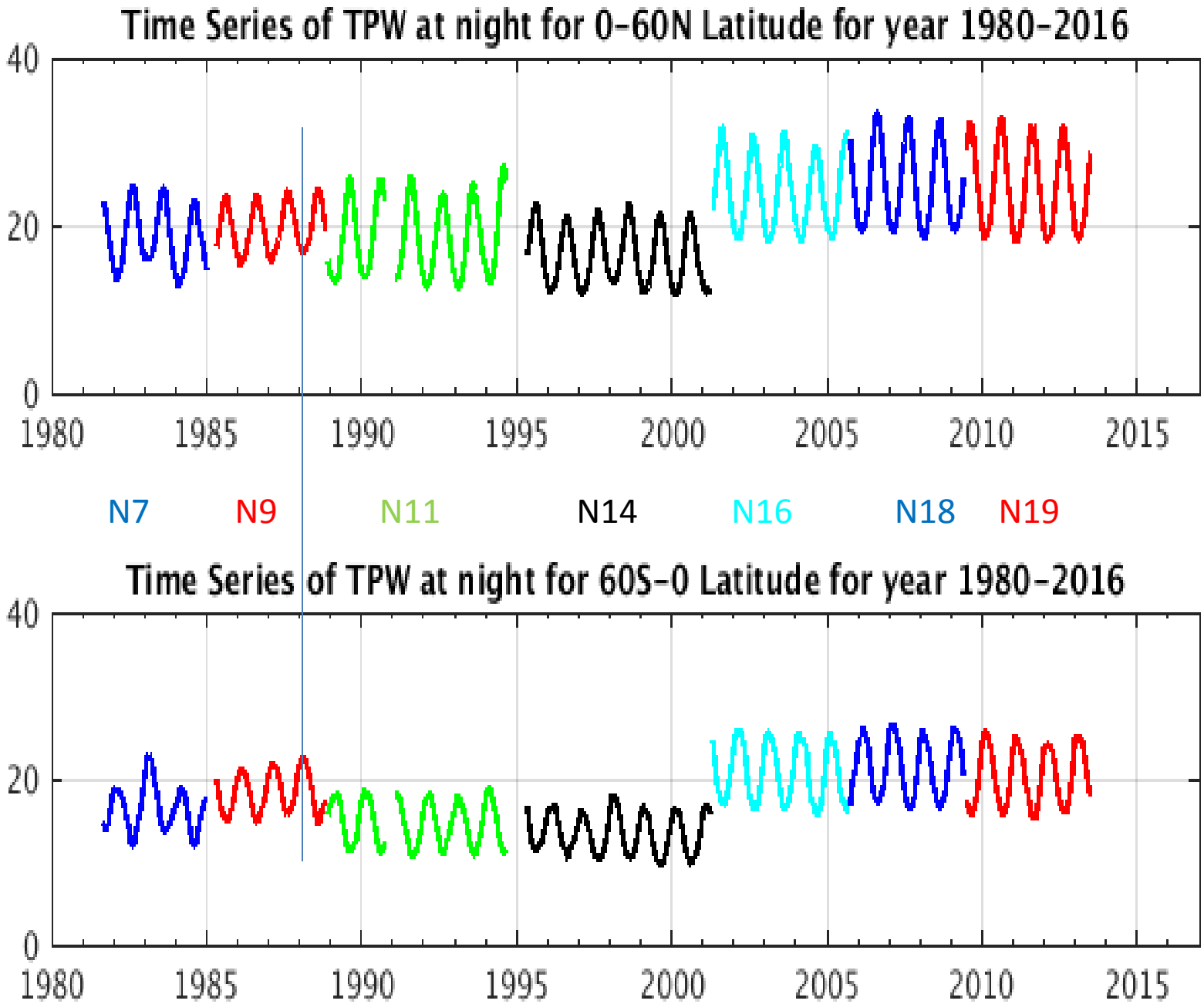
2008 La Nina Water Vapor 10 yr Anomaly

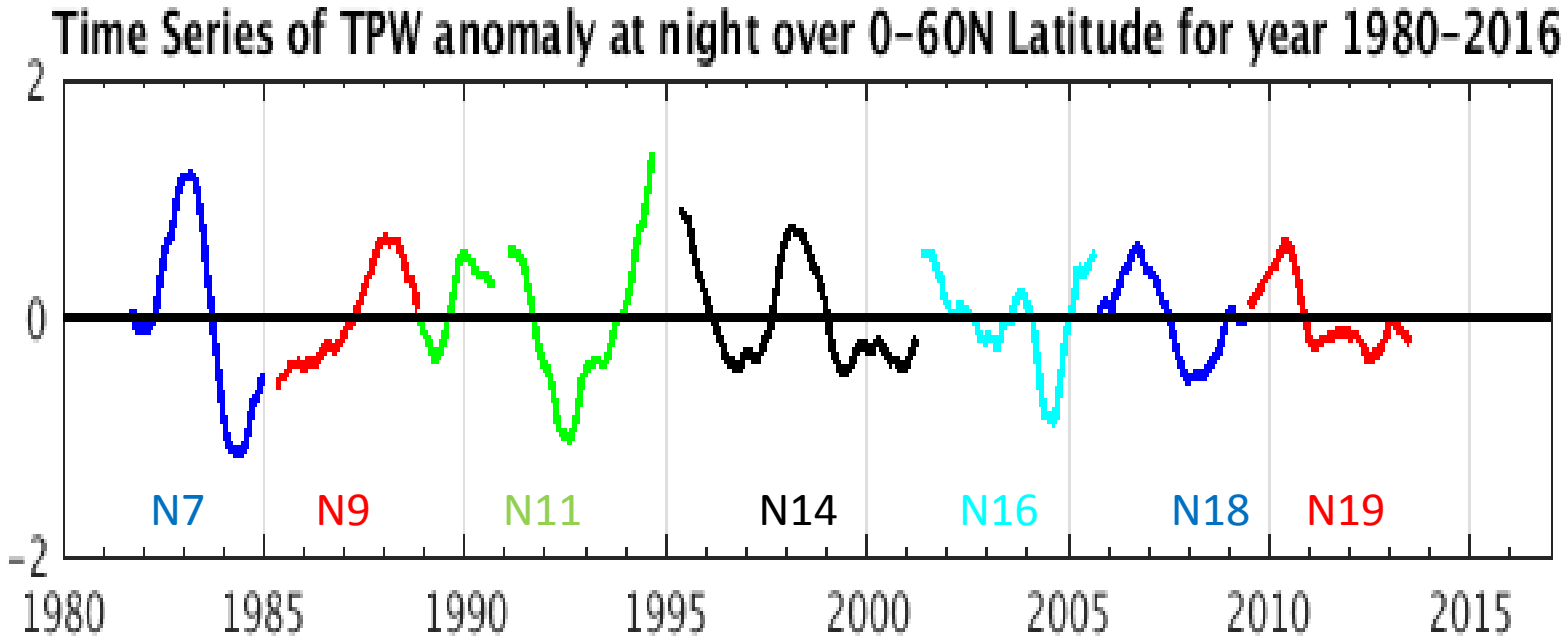
METOP-A/HIRS4 TPW (mm) compared to NASA NVAP Product for 2009

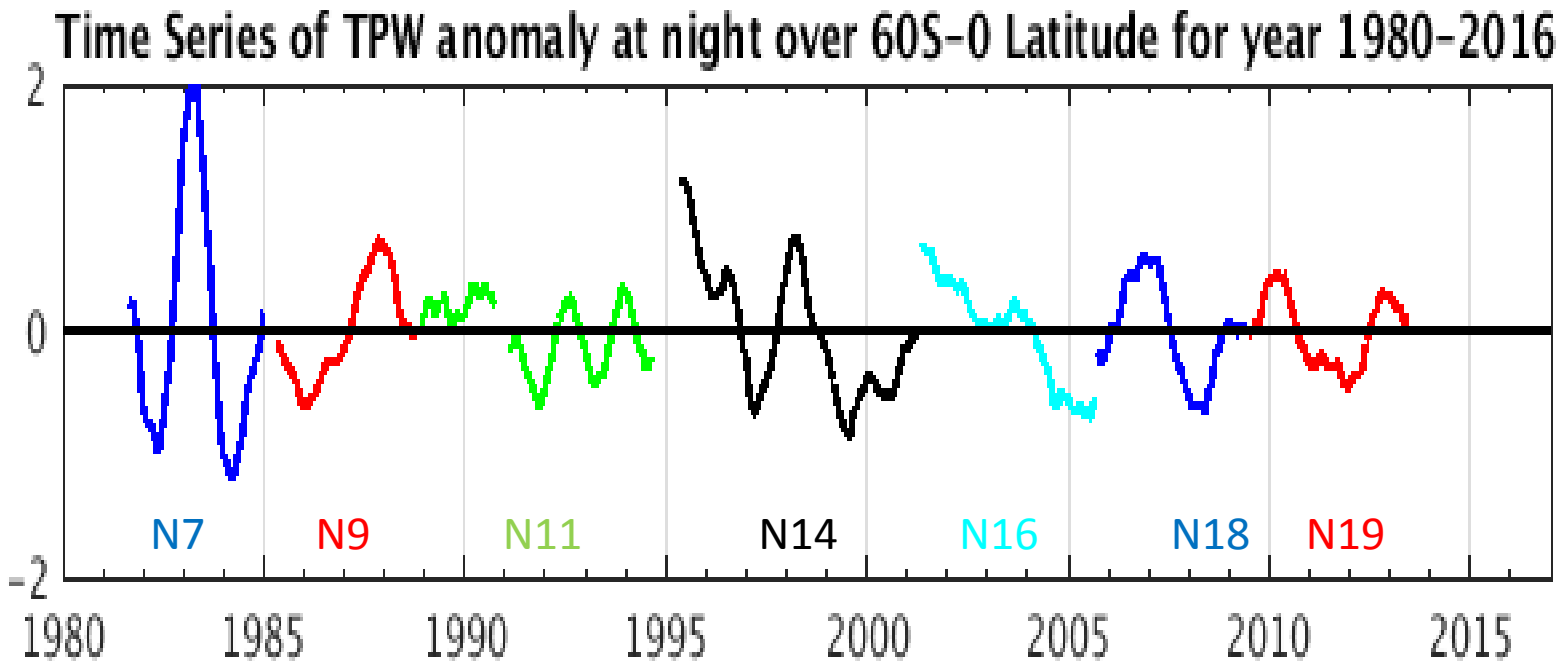


NVAP-M: Vonder Haar et al. 2012, JGR

Hemispheric Balance?

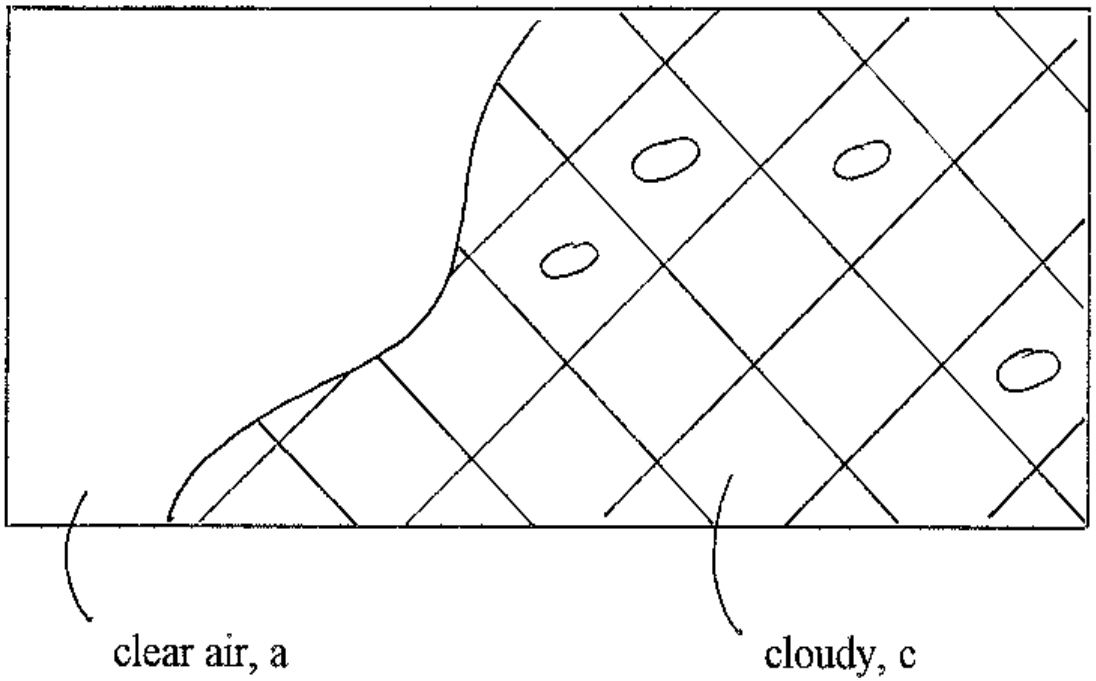

Time Series of TPW at night for 0-60N Latitude for year 1980-2016
40
20
0
1980
1985
1990
1995
2000
2005
2010
2015
N7
N9
N11
N14
N16
N18
N19
Time Series of TPW at night for 60S-0 Latitude for year 1980-2016
40
20
0
1980
1985
1990
1995
2000
2005
2010
2015


Time Series of TPW anomaly at night over 0-60N Latitude for year 1980-2016
2
0
-2
N7
N9
N11
N14
N16
N18
N19
1980
1985
1990
1995
2000
2005
2010
2015


Time Series of TPW anomaly at night over 60S-0 Latitude for year 1980-2016
2
0
-2
N7
N9
N11
N14
N16
N18
N19
1980
1985
1990
1995
2000
2005
2010
2015

HIRS High Cloud Detection

Radiance from a partly cloudy FOV



$$R=[1-N\varepsilon]R_{\text{clear air}} + N\varepsilon\, R_{\text{opq cld}}\,(P_c)$$

Two unknowns, $N\varepsilon$ and P_c , require two measurements

CTPs using CO2 Slicing

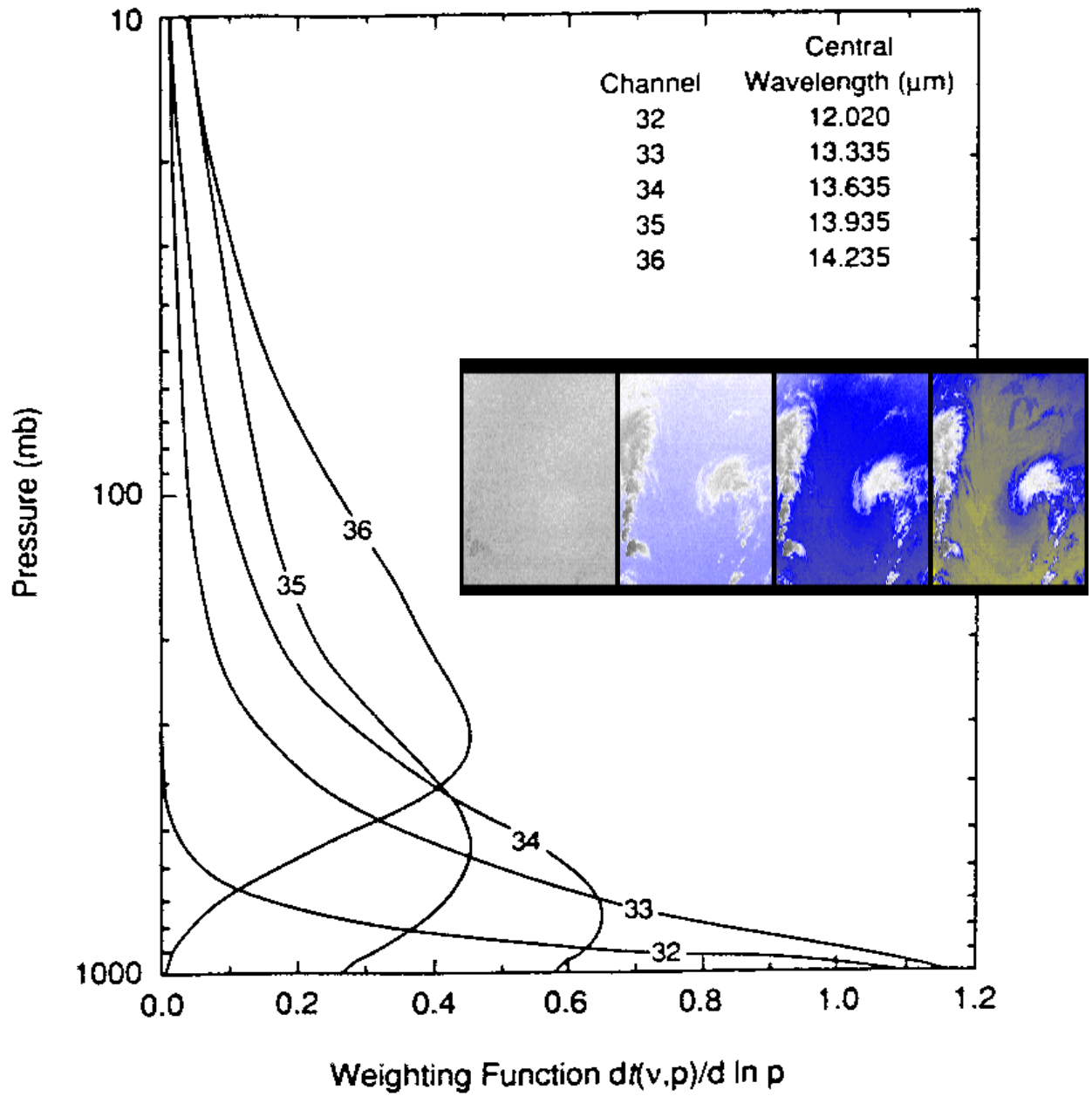
Different ratios reveal cloud properties at different levels

hi - 14.2/13.9
mid - 13.9/13.6
low - 13.6/13.3

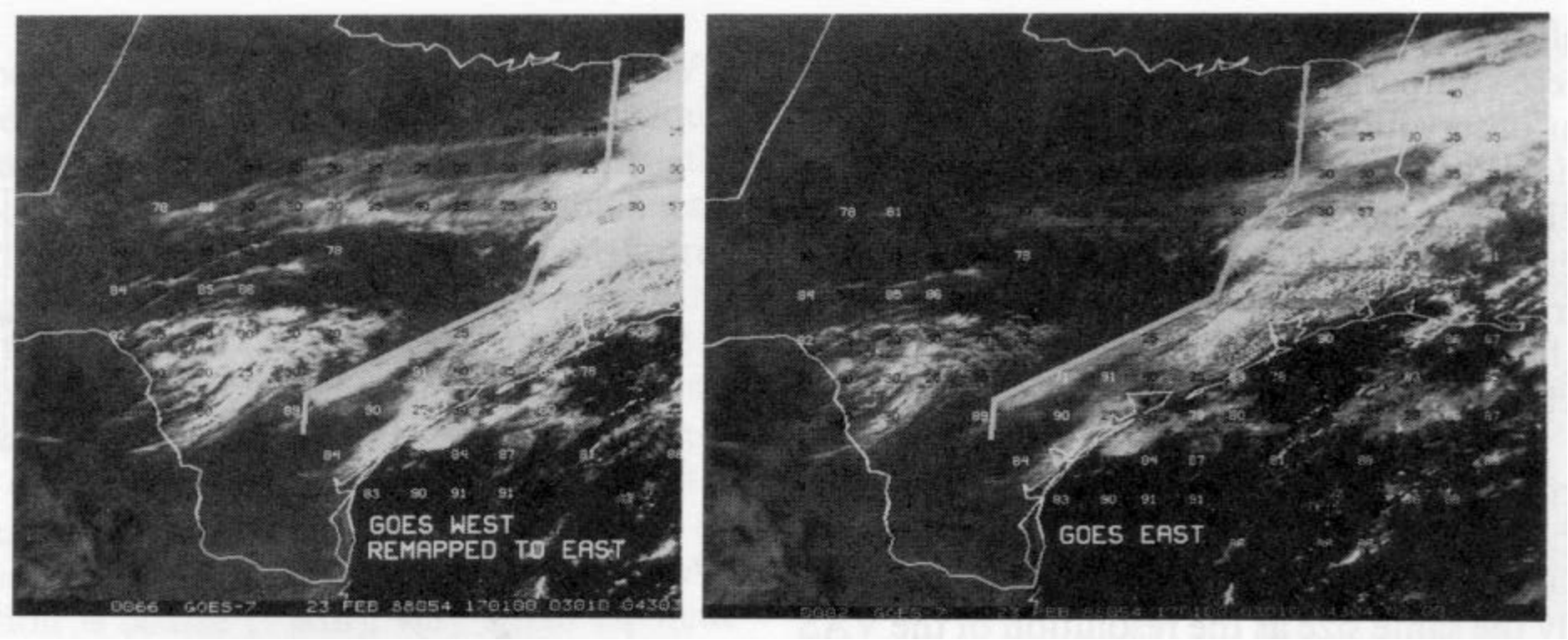
Meas **Calc**

$$\frac{(I_{\lambda 1}-I_{\lambda 1}^{clr})}{(I_{\lambda 2}-I_{\lambda 2}^{clr})} = \frac{\eta\varepsilon_{\lambda 1}\int_{p_s}^{p_c}\tau_{\lambda 1}\,dB_{\lambda 1}}{\eta\varepsilon_{\lambda 2}\int_{p_s}^{p_c}\tau_{\lambda 2}\,dB_{\lambda 2}}$$

if $(I_\lambda^{clr} - I_\lambda) < \Delta$
then IRW is used

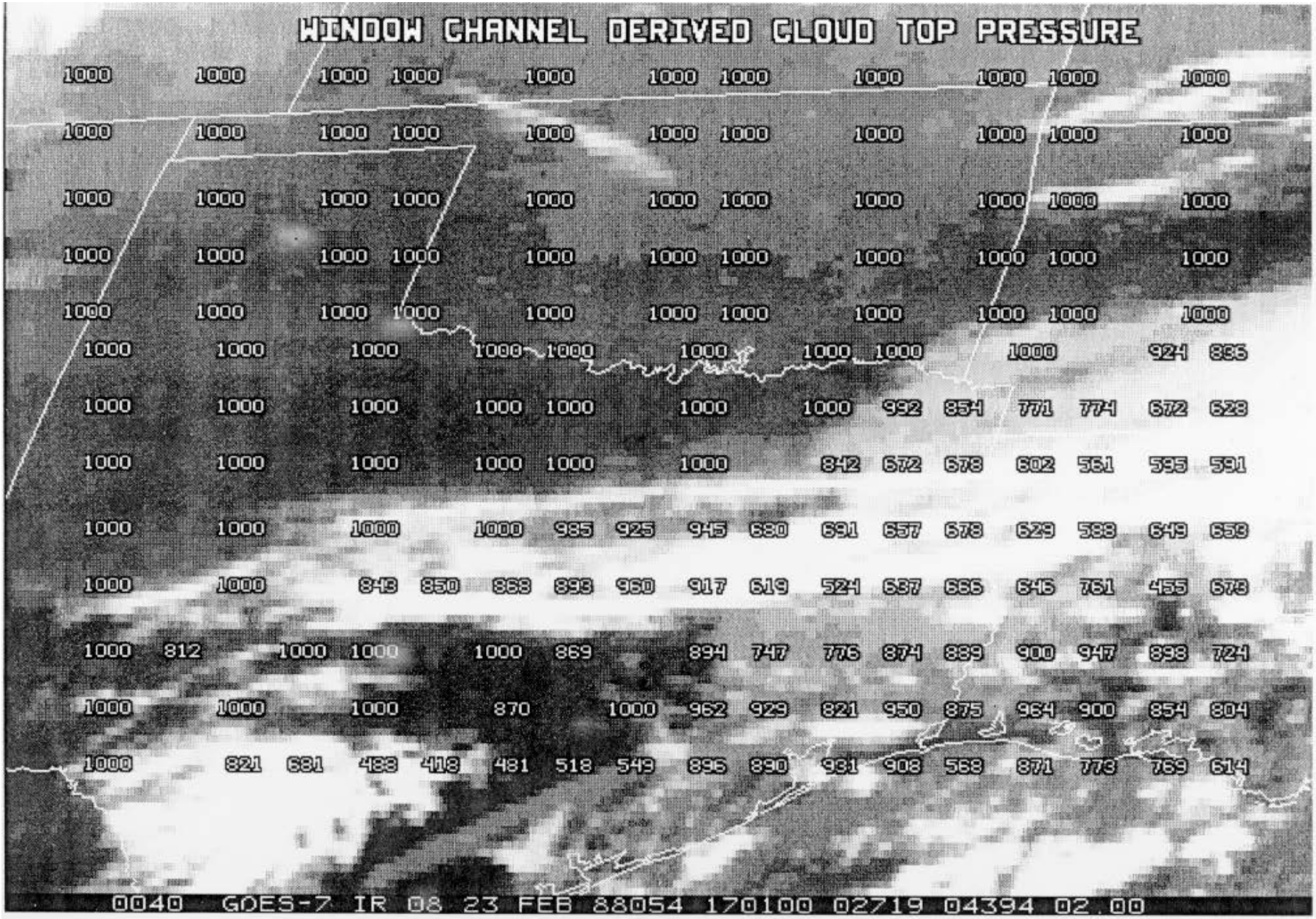


Cirrus detection has been elusive in the visible bands

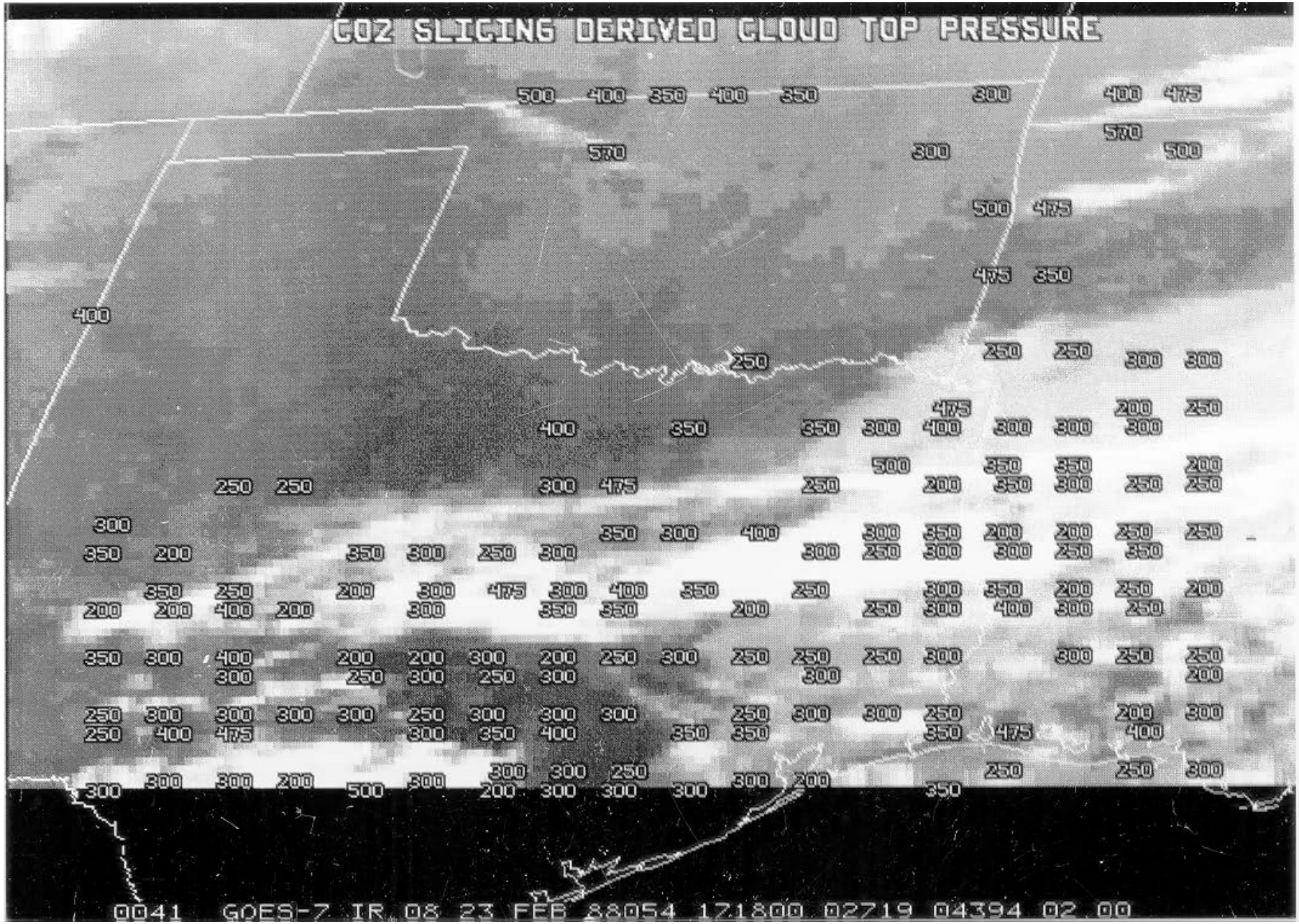


Depending on view angle GOES sees or misses Texas cirrus

IR window sees cirrus but cannot place height correctly



CO2 slicing corrects for semi-transparency of cirrus

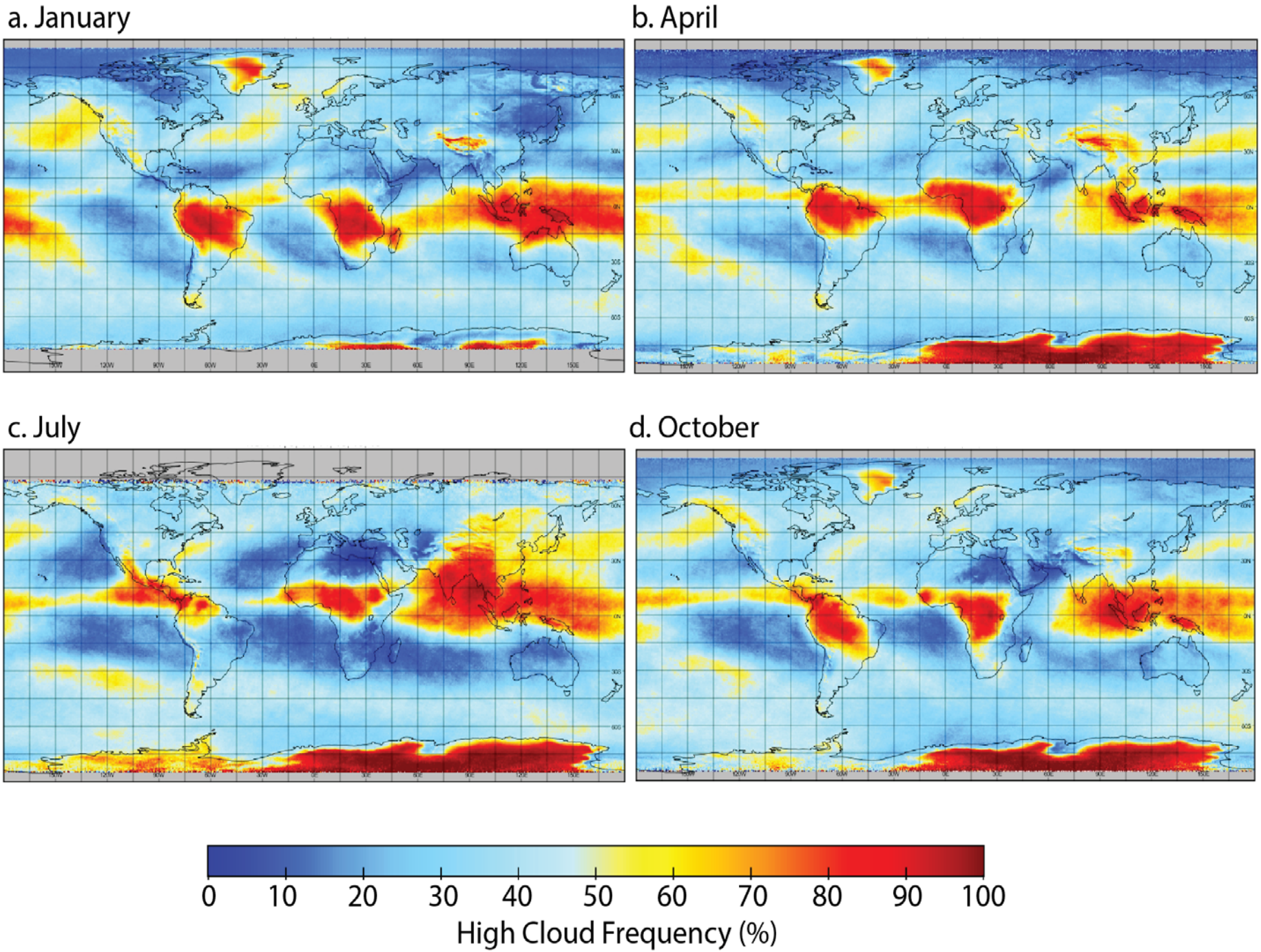


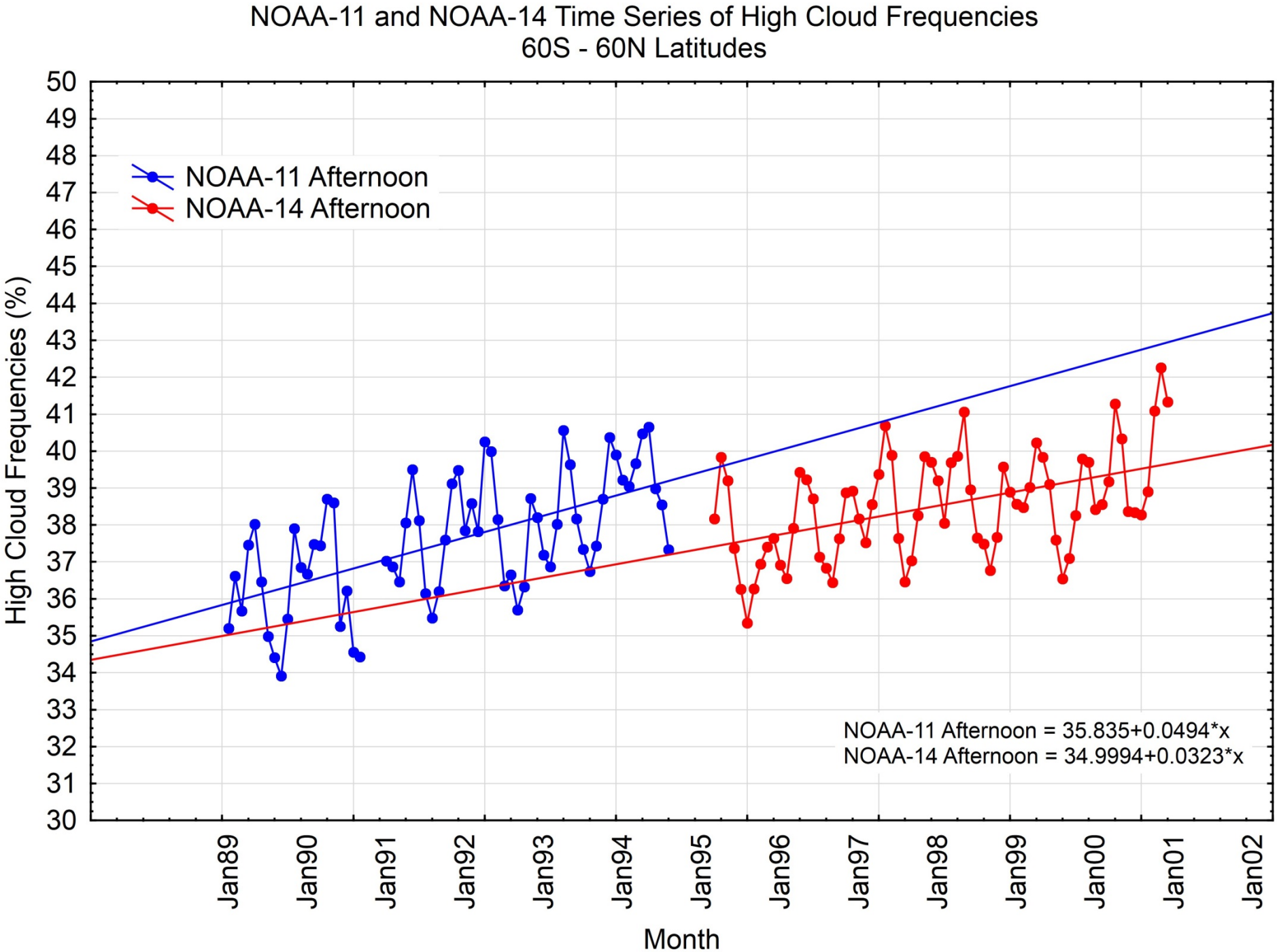
HIRS High Clouds

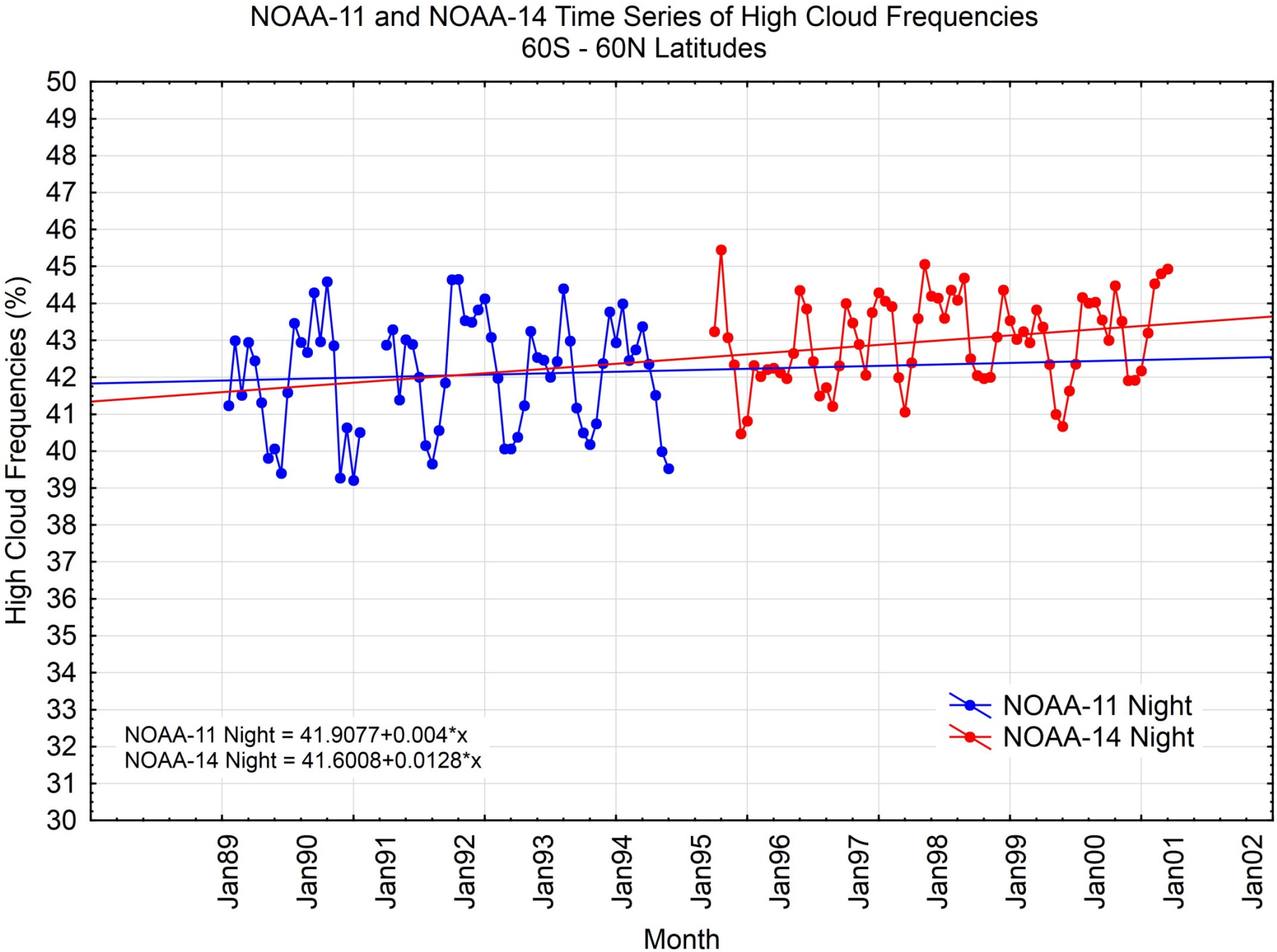
HIRS high clouds are determined using CO2 slicing to estimate cloud top pressure for HIRS FOVs within 32 deg of nadir over land and ocean both day and night. The retrieval approach is borrowed from MODIS (Menzel et al., 2008). High, mid, and low clouds are separated into thin, thick, and opaque categories. There is strong reliance on radiances from 13.3 to 14.2 µm. The AVHRR based PATMOS-x cloud mask is used to characterize HIRS sub-pixel cloud cover.

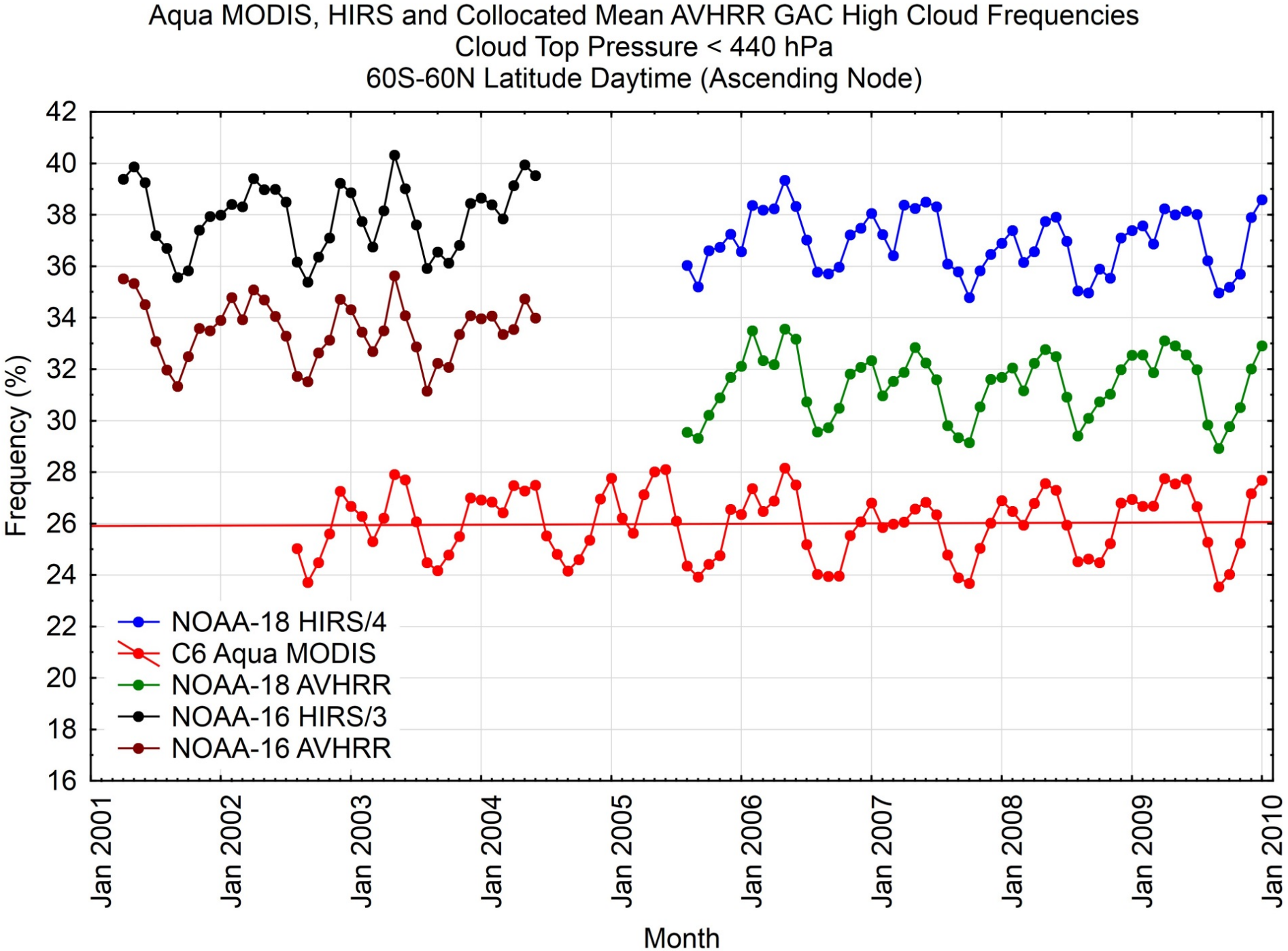
	Thin (εf<0.5)	Thick	Opaque (εf>0.95)	Total
High (CTP<440 hPa)	19.7±1.2	13.3±1.0	2.8±0.4	35.8
Mid	4.0±0.3	5.5±0.6	1.9±0.3	11.4
Low (CTP>660 hPa)	6.8±0.7	6.4±0.5	13.9±1.2	27.1

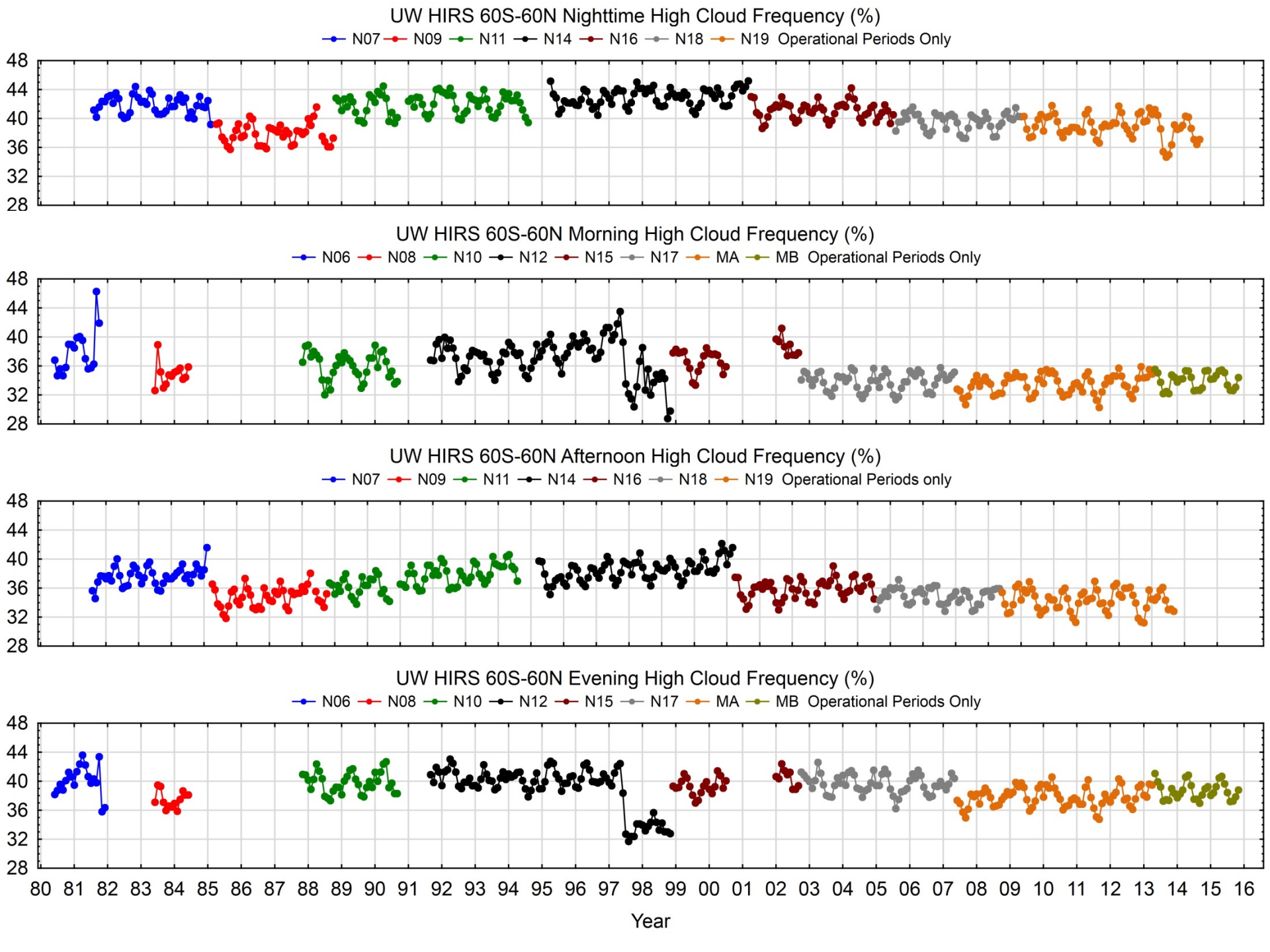
Percentage of all near nadir (view angle < 32 deg) HIRS observations that found clouds from 60°N to 60°S (24.7% found clear skies) for Dec-Jan-Feb 2009. Scatter (rms) about mean values is also indicated.

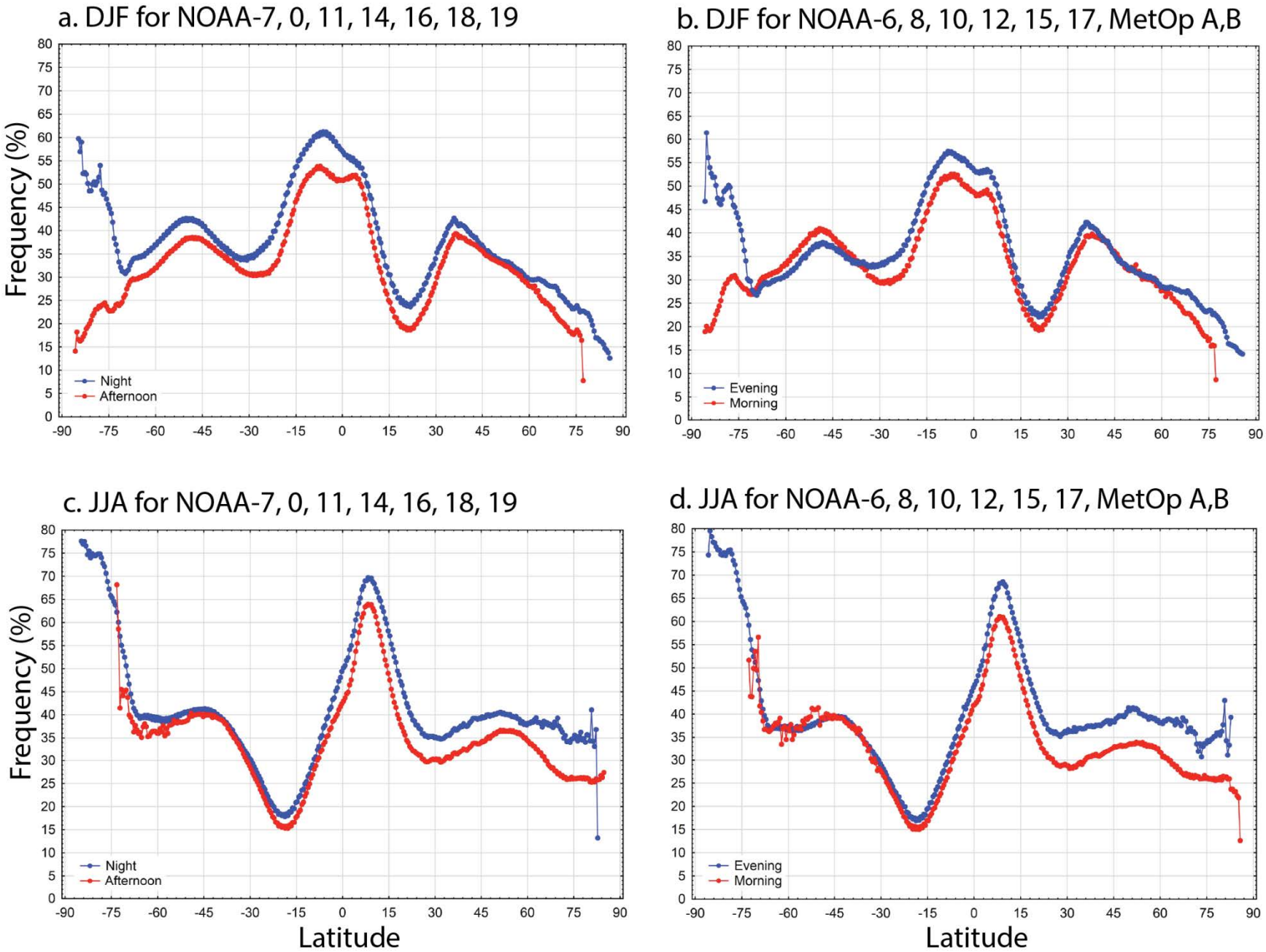

a. January
b. April
c. July
d. October
0
10
20
30
40
50
60
70
80
90
100
High Cloud Frequency (%)

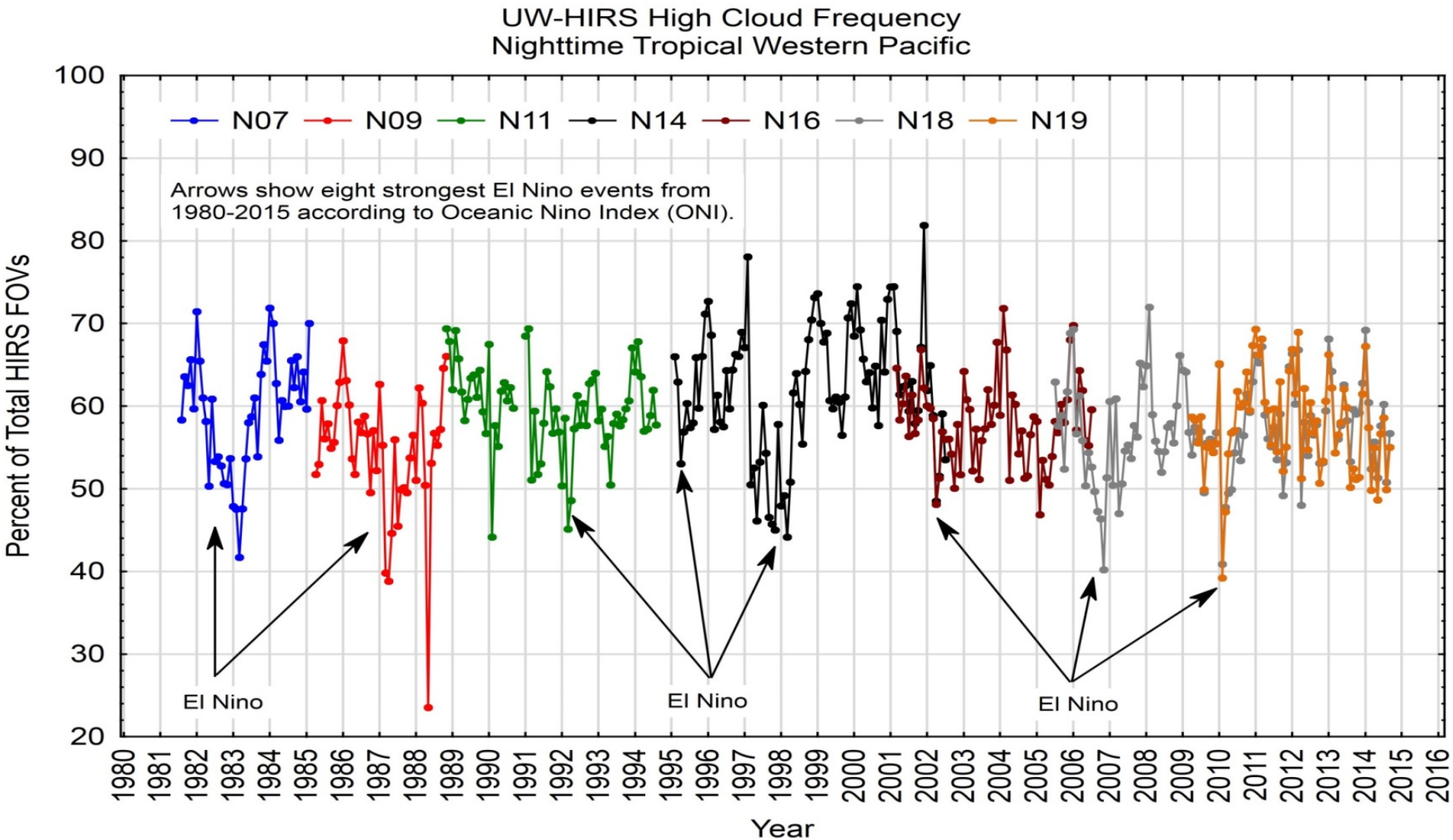

NOAA-11 and NOAA-14 Time Series of High Cloud Frequencies
60S - 60N Latitudes
NOAA-11 Afternoon
NOAA-14 Afternoon
High Cloud Frequencies (%)
50
49
48
47
46
45
44
43
42
41
40
39
38
37
36
35
34
33
32
31
30
NOAA-11 Afternoon = 35.835+0.0494*x
NOAA-14 Afternoon = 34.9994+0.0323*x
Jan89
Jan90
Jan91
Jan92
Jan93
Jan94
Jan95
Jan96
Jan97
Jan98
Jan99
Jan00
Jan01
Jan02
Month


NOAA-11 and NOAA-14 Time Series of High Cloud Frequencies
60S - 60N Latitudes
High Cloud Frequencies (%)
50
49
48
47
46
45
44
43
42
41
40
39
38
37
36
35
34
33
32
31
30
Jan89
Jan90
Jan91
Jan92
Jan93
Jan94
Jan95
Jan96
Jan97
Jan98
Jan99
Jan00
Jan01
Jan02
Month
NOAA-11 Night = 41.9077+0.004*x
NOAA-14 Night = 41.6008+0.0128*x
NOAA-11 Night
NOAA-14 Night


Aqua MODIS, HIRS and Collocated Mean AVHRR GAC High Cloud Frequencies
Cloud Top Pressure < 440 hPa
60S-60N Latitude Daytime (Ascending Node)
Frequency (%)
42
40
38
36
34
32
30
28
26
24
22
20
18
16
NOAA-18 HIRS/4
C6 Aqua MODIS
NOAA-18 AVHRR
NOAA-16 HIRS/3
NOAA-16 AVHRR
Jan 2001
Jan 2002
Jan 2003
Jan 2004
Jan 2005
Jan 2006
Jan 2007
Jan 2008
Jan 2009
Jan 2010
Month

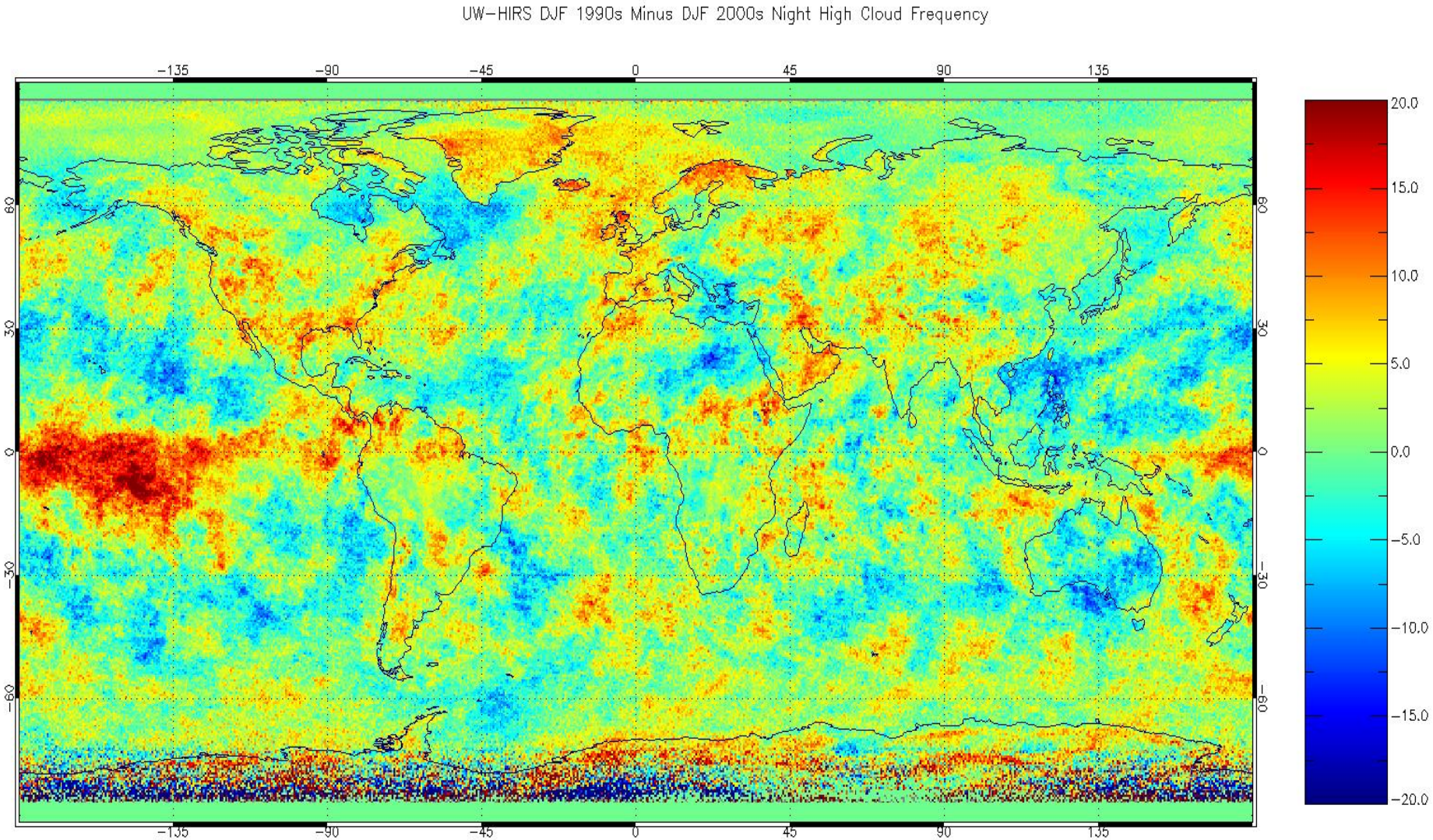

UW HIRS 60S-60N Nighttime High Cloud Frequency (%)
N07 N09 N11 N14 N16 N18 N19 Operational Periods Only
UW HIRS 60S-60N Morning High Cloud Frequency (%)
N06 N08 N10 N12 N15 N17 MA MB Operational Periods Only
UW HIRS 60S-60N Afternoon High Cloud Frequency (%)
N07 N09 N11 N14 N16 N18 N19 Operational Periods only
UW HIRS 60S-60N Evening High Cloud Frequency (%)
N06 N08 N10 N12 N15 N17 MA MB Operational Periods Only
48 44 40 36 32 28
80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16
Year


a. DJF for NOAA-7, 0, 11, 14, 16, 18, 19
b. DJF for NOAA-6, 8, 10, 12, 15, 17, MetOp A,B
c. JJA for NOAA-7, 0, 11, 14, 16, 18, 19
d. JJA for NOAA-6, 8, 10, 12, 15, 17, MetOp A,B
Frequency (%)
Night
Afternoon
Evening
Morning
Latitude

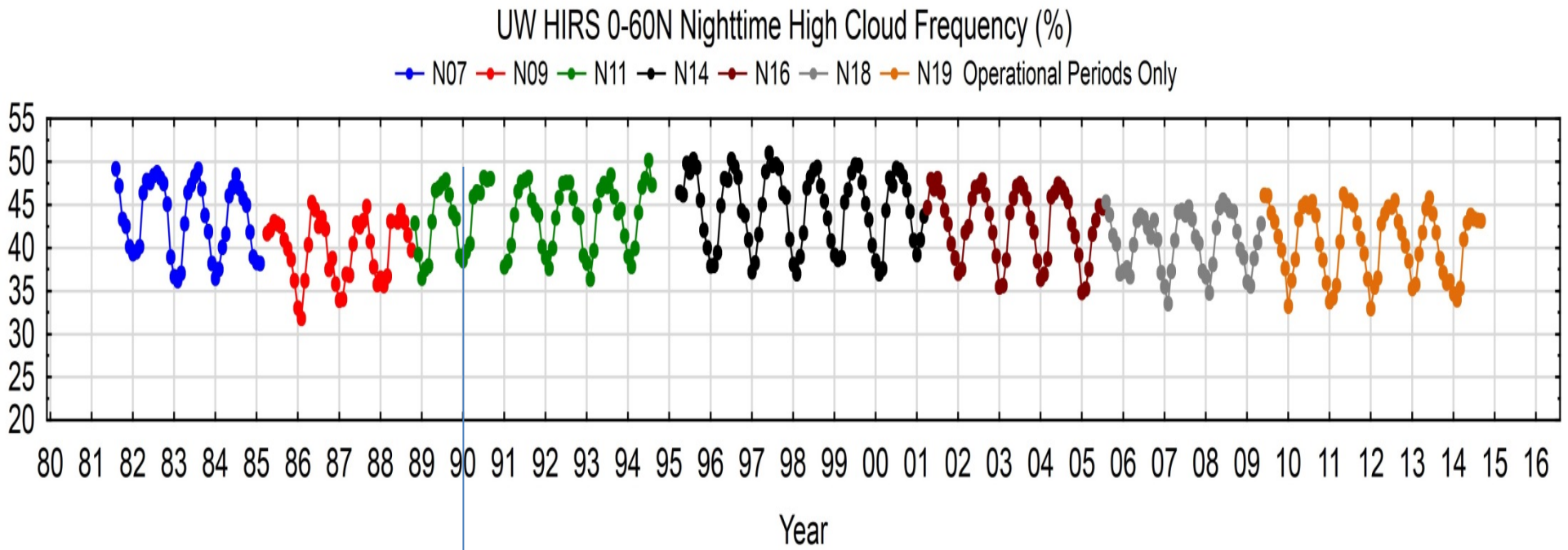


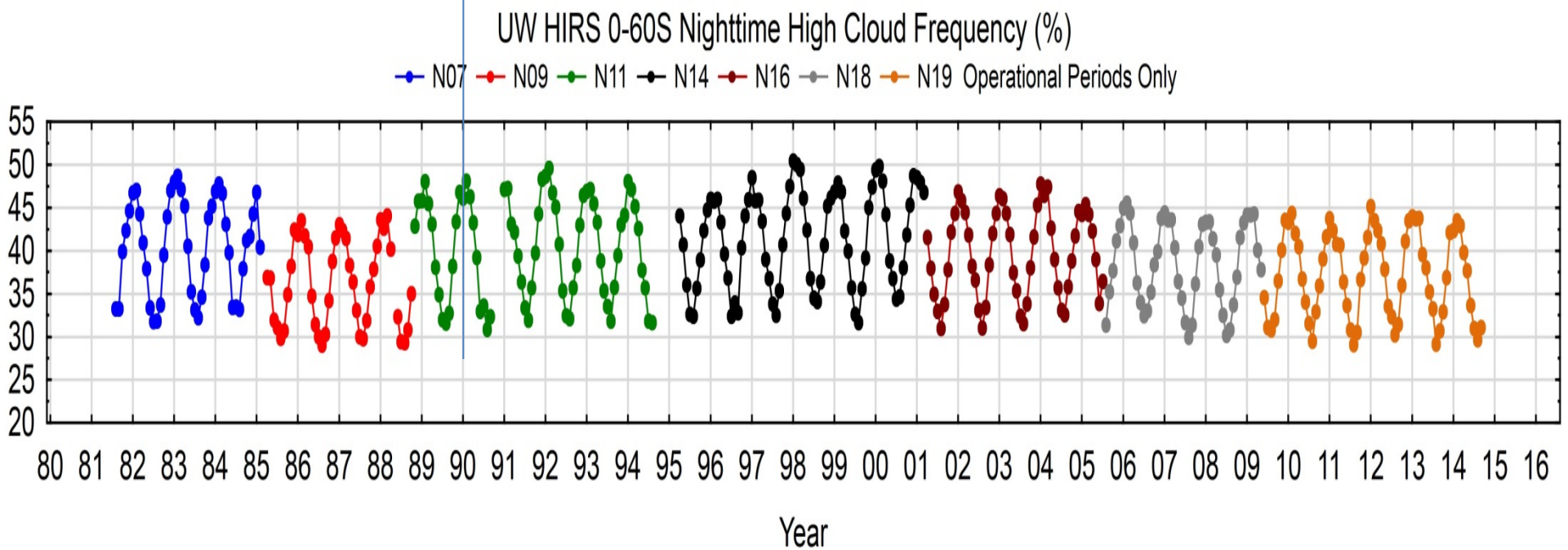
El Nino events seem correlated with decreased high cloud detection in Tropical Western Pacific region (23N-23S, 100-160E).

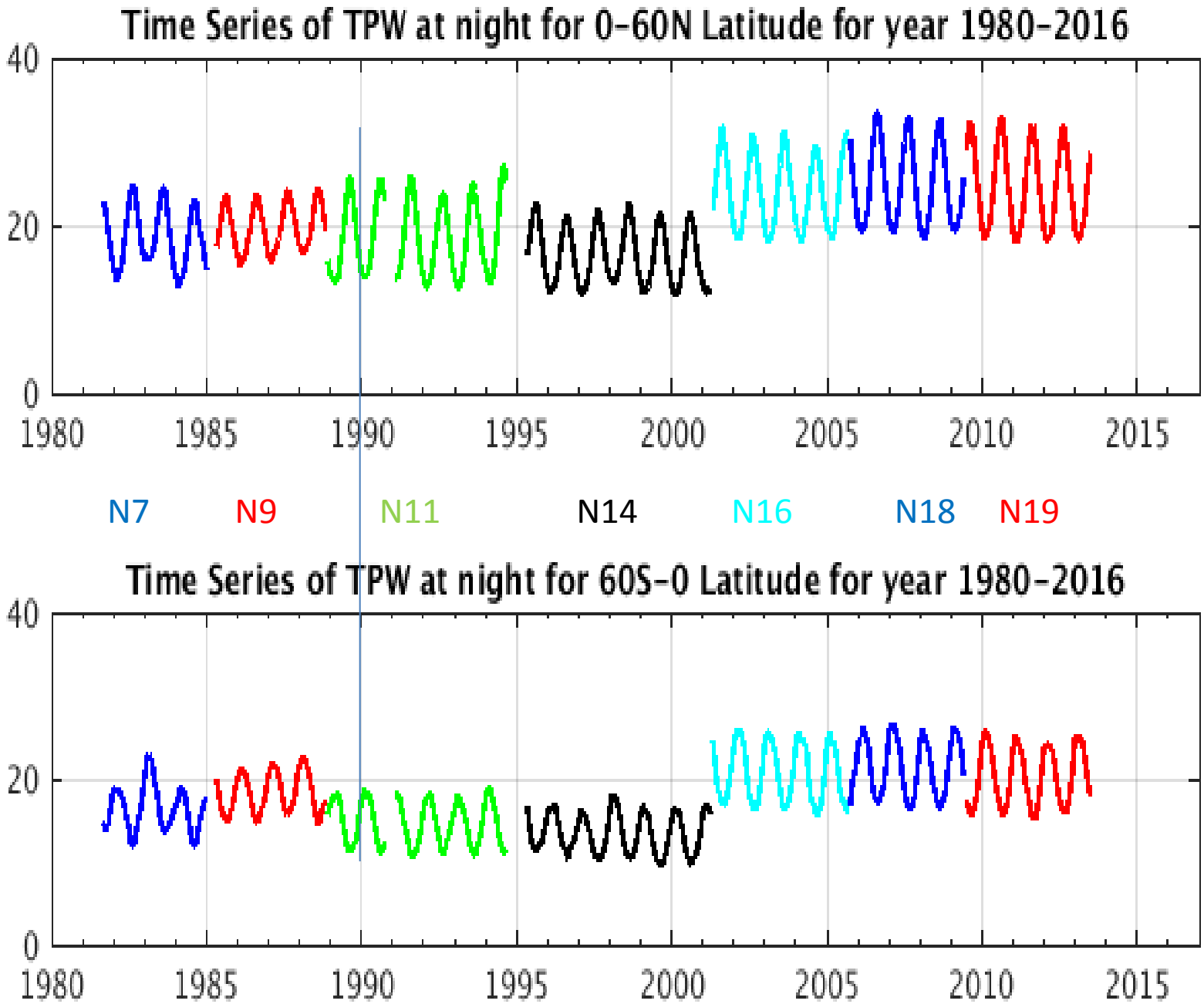
Decadal Changes – 1990s minus 2000s

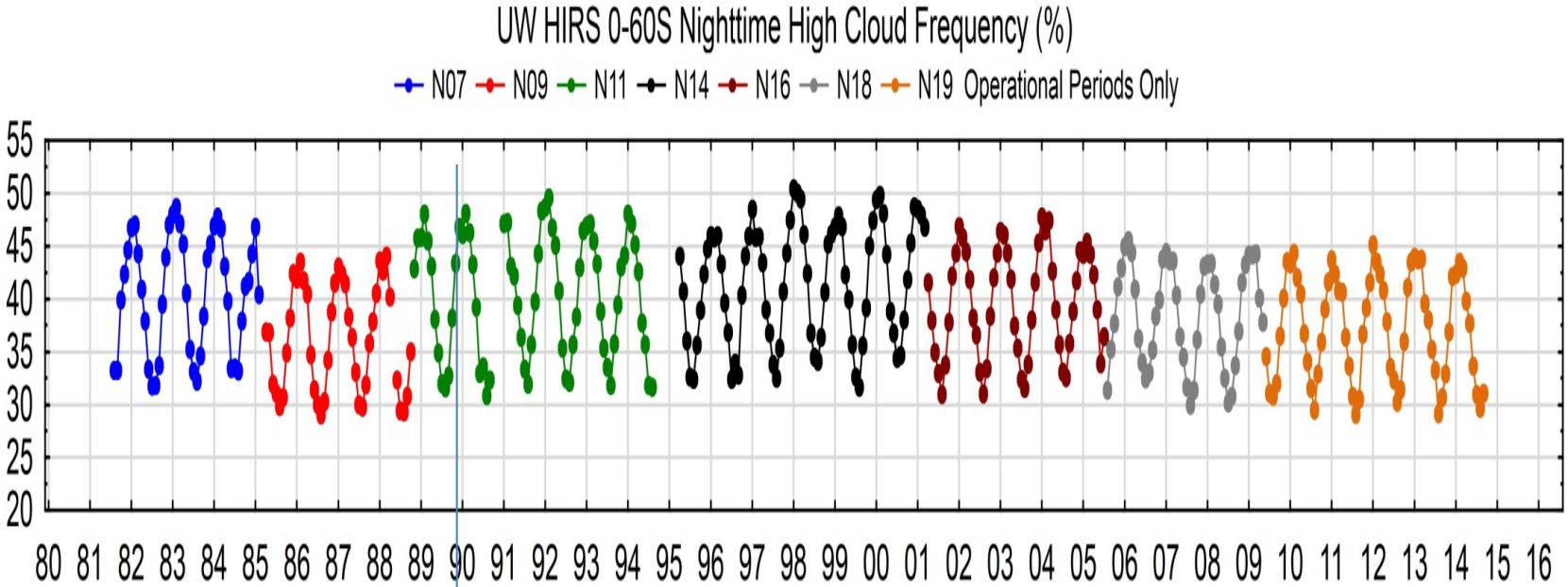


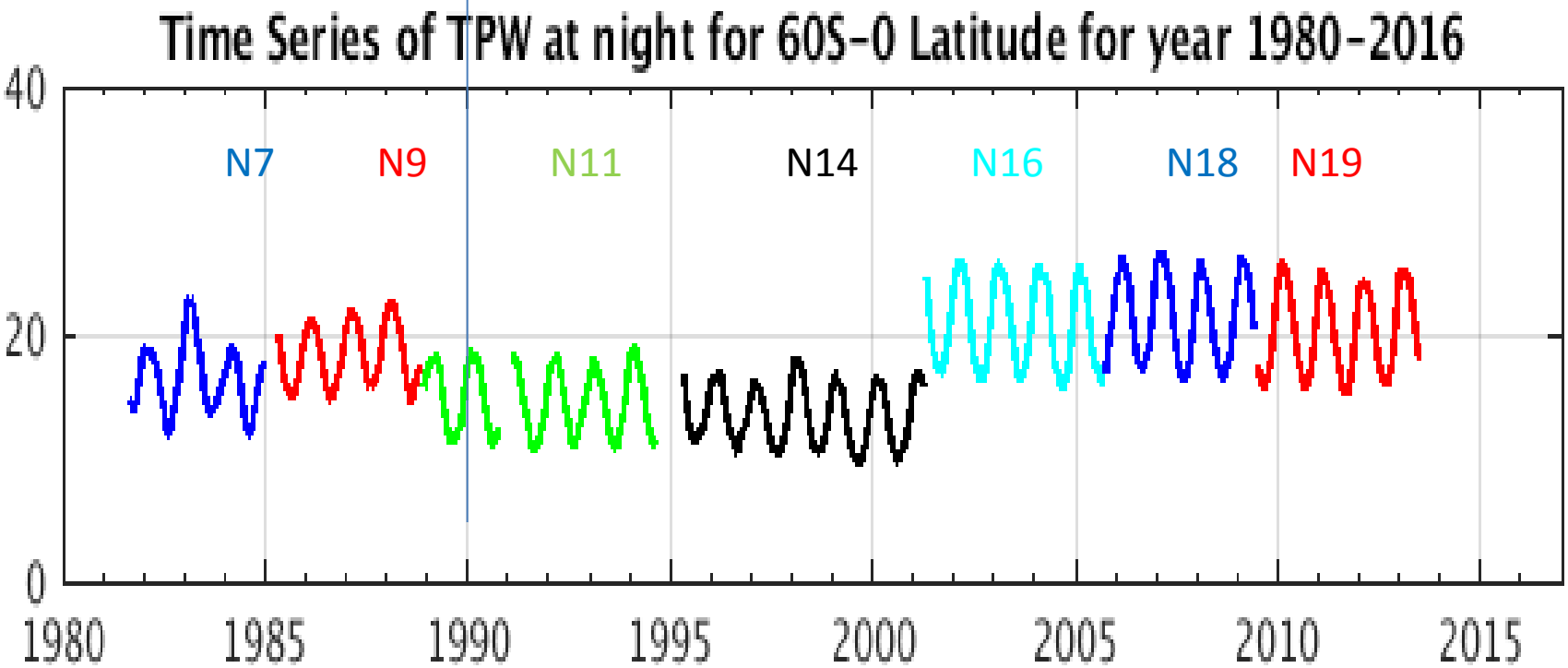
Hemispheric Balance?


UW HIRS 0-60N Nighttime High Cloud Frequency (%)
N07 N09 N11 N14 N16 N18 N19 Operational Periods Only
55
50
45
40
35
30
25
20
80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16
Year


UW HIRS 0-60S Nighttime High Cloud Frequency (%)
N07 N09 N11 N14 N16 N18 N19 Operational Periods Only
55
50
45
40
35
30
25
20
80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16
Year


Time Series of TPW at night for 0-60N Latitude for year 1980-2016
40
20
0
1980
1985
1990
1995
2000
2005
2010
2015
N7
N9
N11
N14
N16
N18
N19
Time Series of TPW at night for 60S-0 Latitude for year 1980-2016
40
20
0
1980
1985
1990
1995
2000
2005
2010
2015

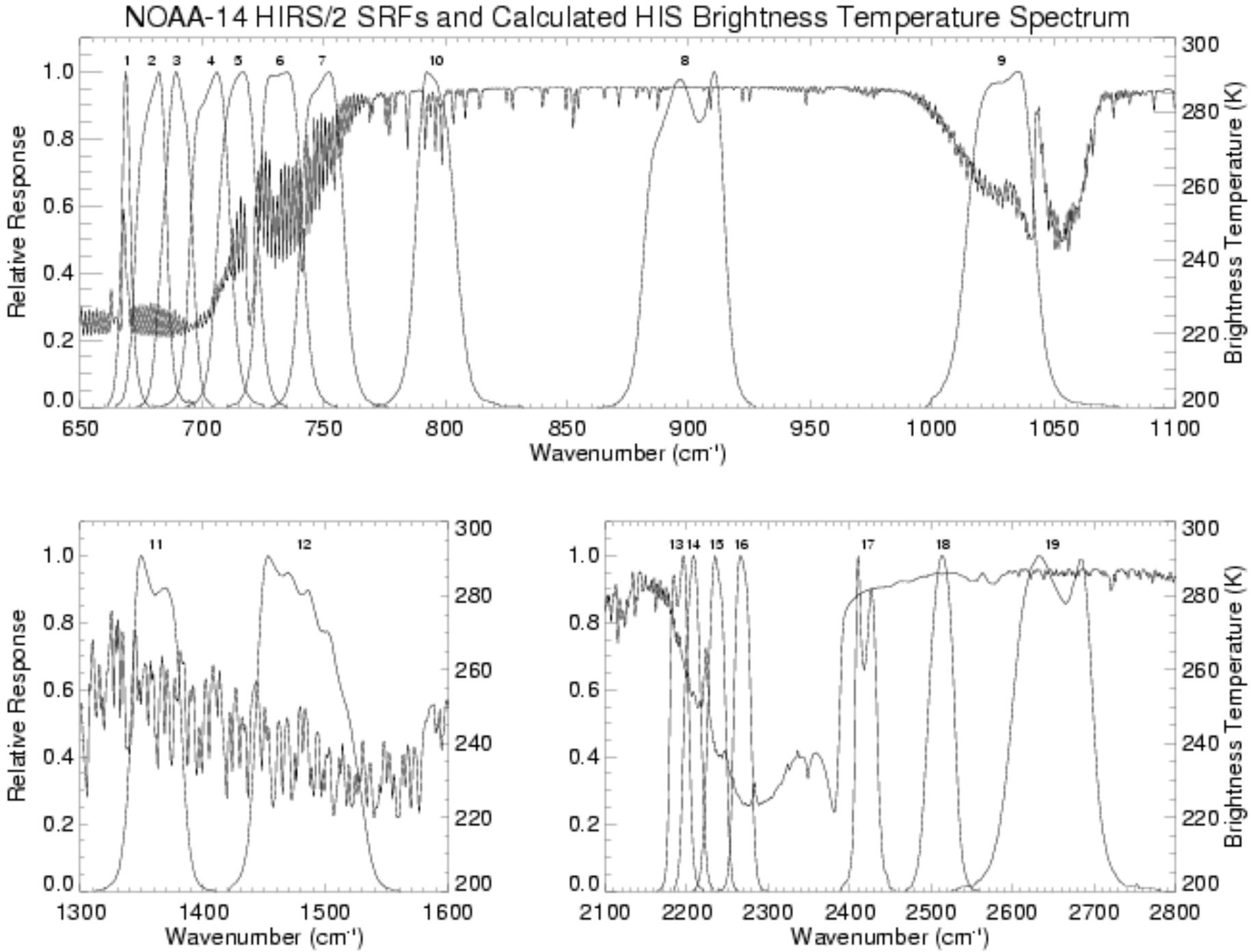

UW HIRS 0-60S Nighttime High Cloud Frequency (%)
N07 N09 N11 N14 N16 N18 N19 Operational Periods Only
55
50
45
40
35
30
25
20
80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16


Time Series of TPW at night for 60S-0 Latitude for year 1980-2016
N7
N9
N11
N14
N16
N18
N19
40
20
0
1980
1985
1990
1995
2000
2005
2010
2015

Continuing HIRS Products with IASI & CrIS

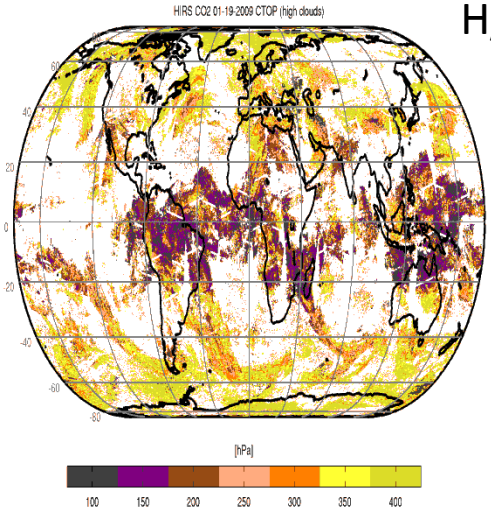
Using IASI & CrIS to continue HIRS products

- Builds on HIRS CO2 slicing cloud work and moisture regression algorithm
- High spectral resolution CrIS and IASI data are averaged to resemble HIRS broad band spectral coverage and to estimate cloud and moisture properties
- Co-located HIRS and IASI data are used initially to provide proof of concept. AVHRR PATMOS-x cloud mask is used to identify clear from cloudy HIRS measurements. NCEP ReAnalysis is used to establish clear sky radiance biases.

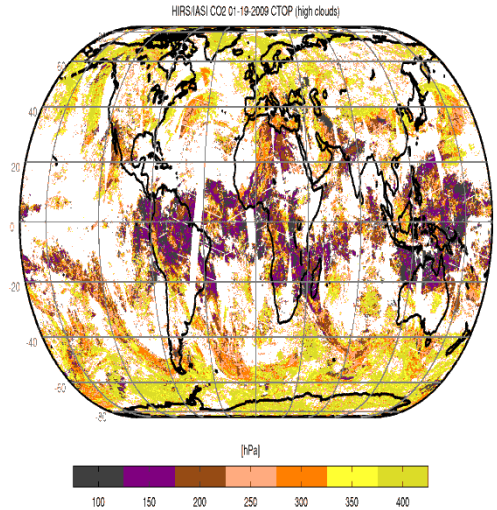

NOAA-14 HIRS/2 SRFs and Calculated HIS Brightness Temperature Spectrum
Relative Response
Brightness Temperature (K)
Wavenumber (cm⁻¹)
1 2 3 4 5 6 7 10 8 9
11 12
13 14 15 16 17 18 19

HIRS (H) & HIRS/IASI (H/I) Cloud Comparison 19 Jan 2009

H



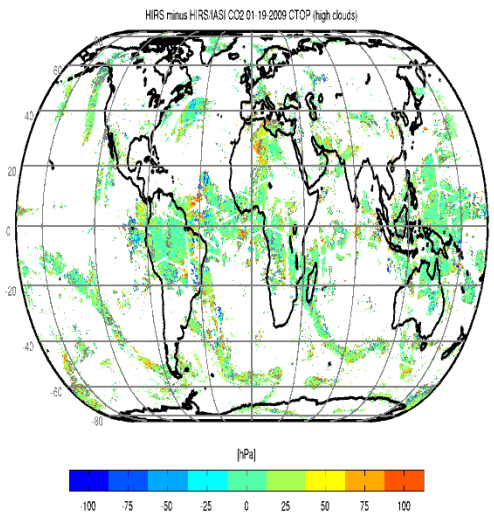
H/I



IASI has higher sampling density with larger footprint causing HIRS/4 to find fewer clouds than HIRS-IASI (especially non-opaque clouds)

On Metop, IASI samples four 12 km FOVs every 50 km while HIRS samples one 10 km FOV every 20 km cross-track and 40 km along track.

H-H/I

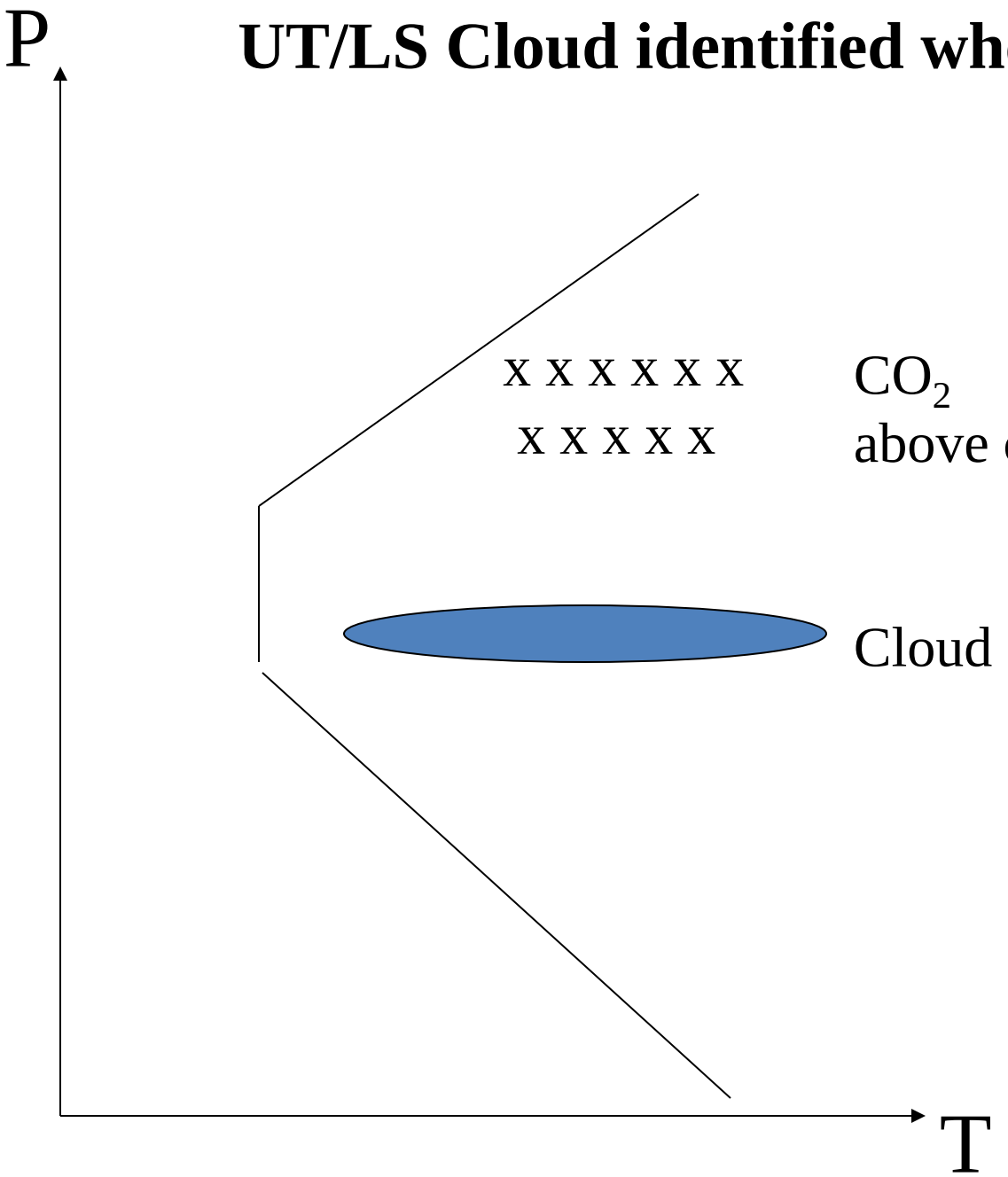


Distribution (% of all observations) of HIRS (H) & HIRS-IASI (H-I) cloud determinations 60N-60S								
	Thin		Thick		Opaque		Total	
	H	H-I	H	H-I	H	H-I	H	H-I
High	17	23	13	14	3	2	33	40
Mid	4	5	6	5	3	2	12	12
Low	4	6	7	9	18	10	29	25

HIRS/IASI results indicate that continuing the HIRS cloud record can be done with IASI and CrIS (CTPs within 25 hPa).

UT/LS Clouds

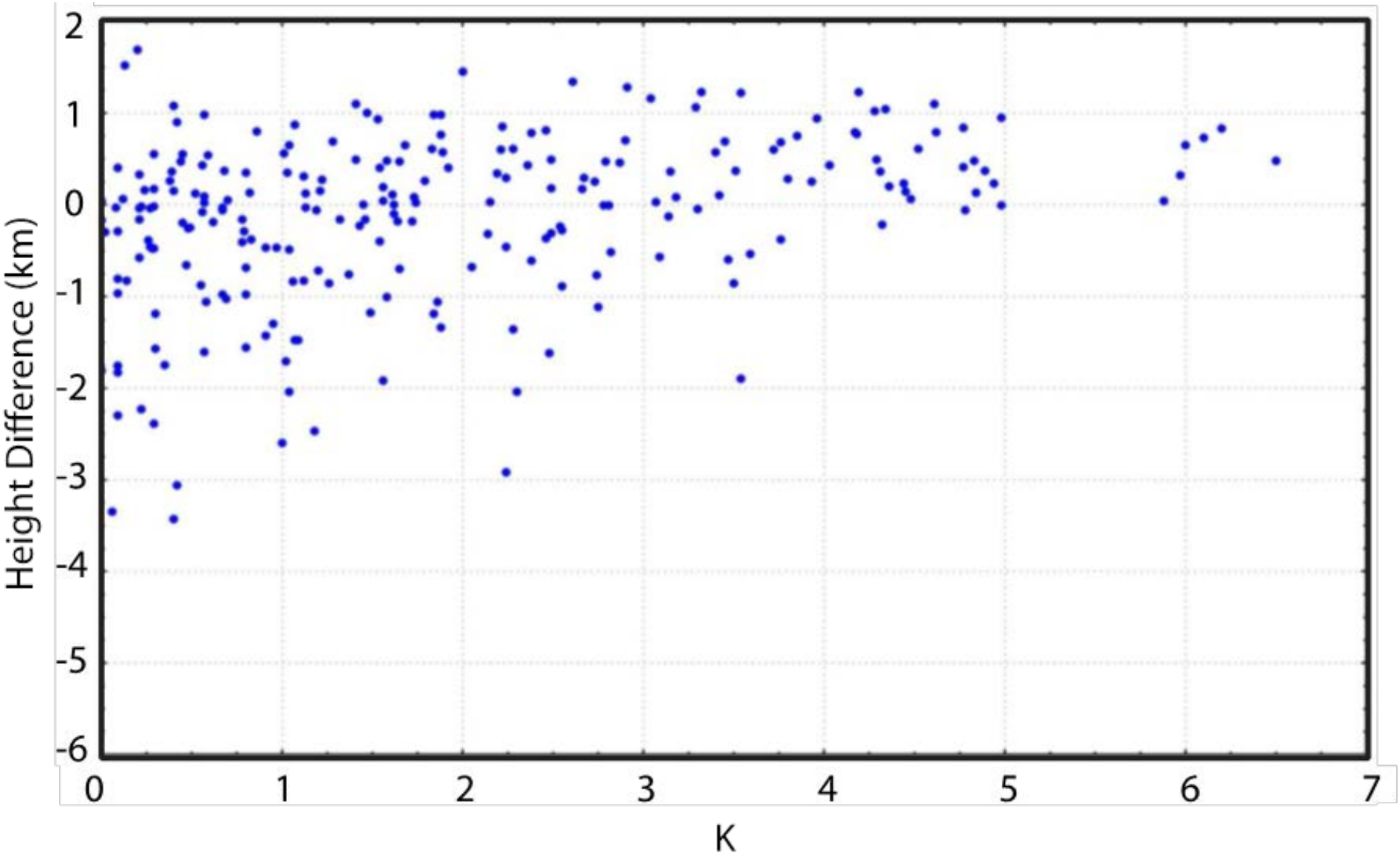
UT/LS Cloud identified when BT13.9>BT13.3



BT13.9

BT13.3

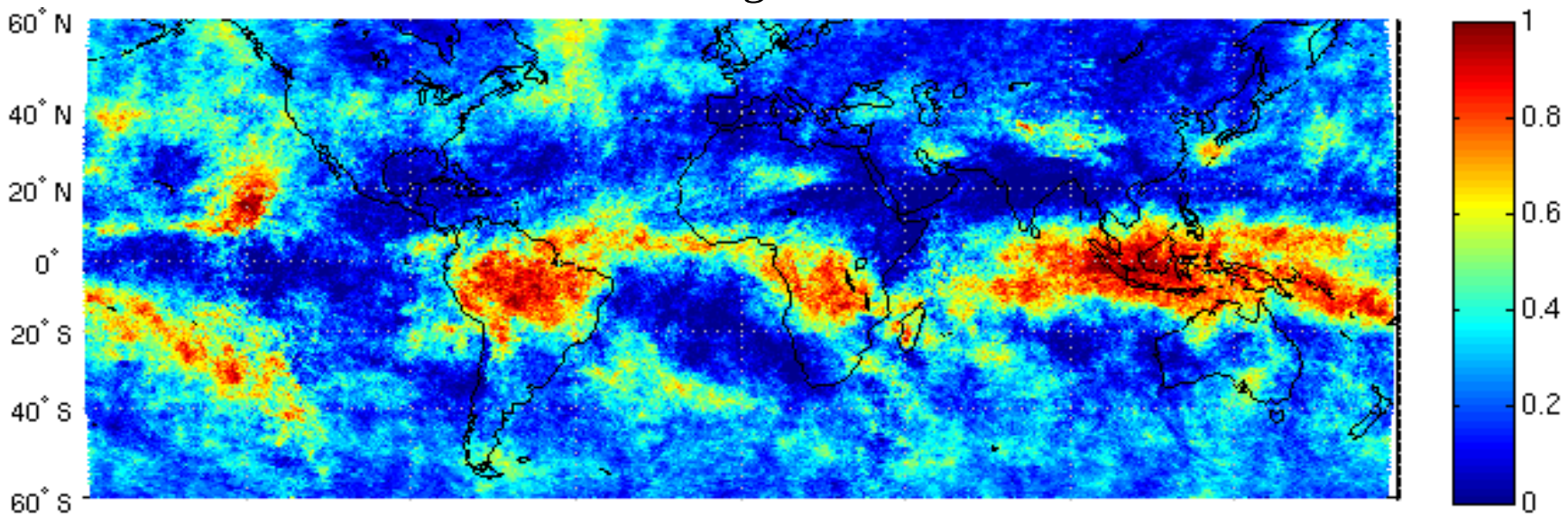
Can also use
WV above cloud when
BTWV>BTIRW



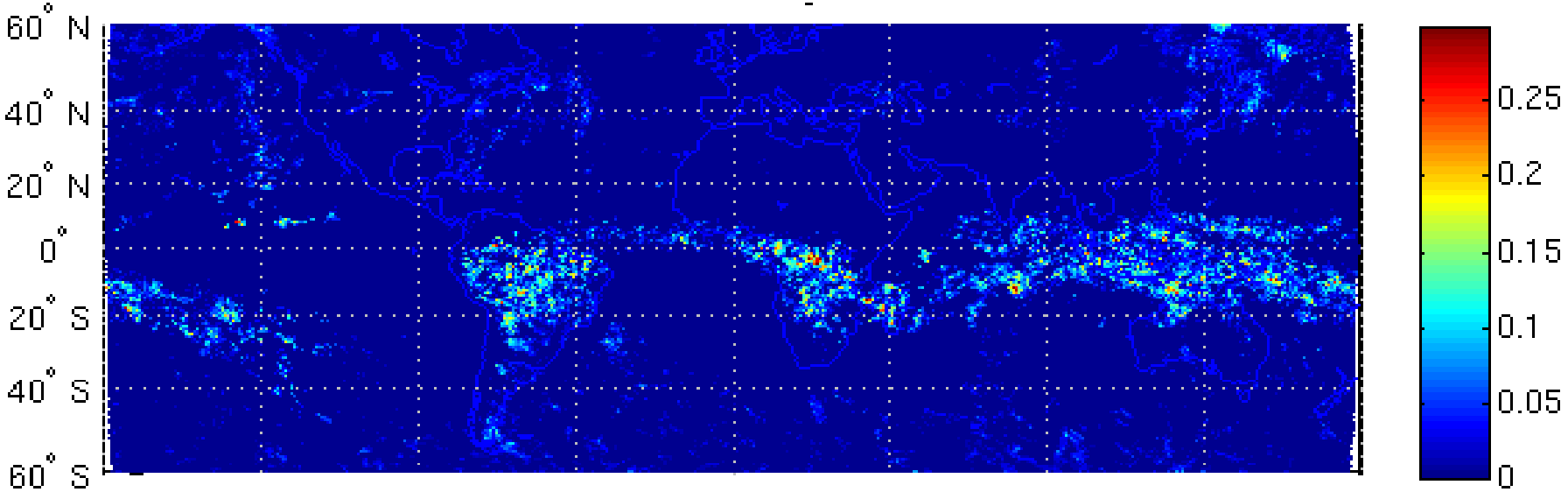
August 2008 NOAA-18 HIRS [BTD(14.0-13.3)>0] values (x-axis in deg K) versus CALIOP cloud top height minus tropopause height (y-axis in km). In 80% of HIRS FOVs where CO2 test indicated UT/LS cloud, CALIOP found cloud within 1.5 km of tropopause.

UT/LS Cloud Identification

UT/LS and High Clds for Jan 2000

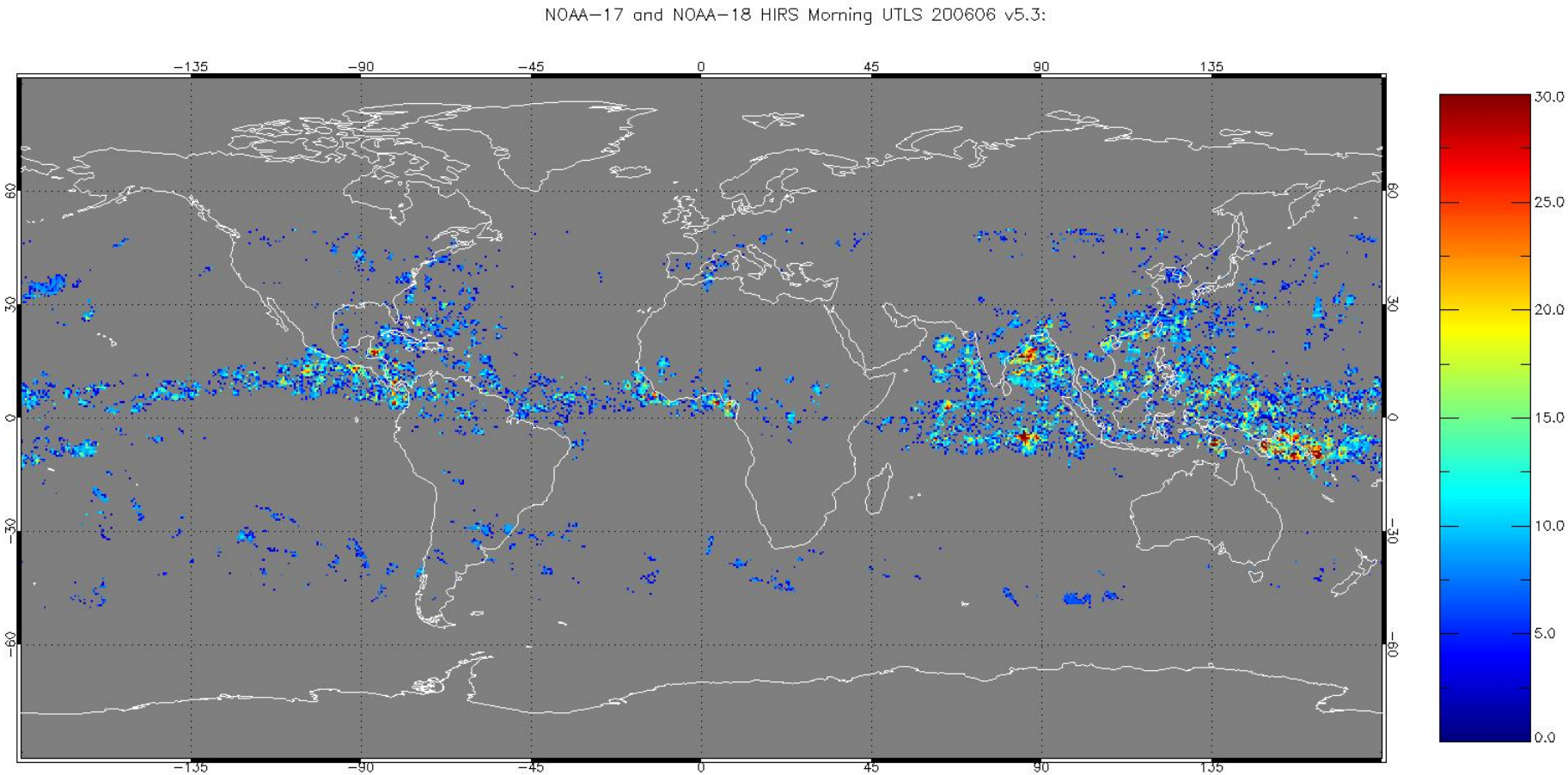


UT/LS Clds for Jan 2000



Detection of near stratospheric cloud from BT14>BT13.3 test

Upper Tropospheric/Lower Stratospheric (UTLS) Cloud Frequency



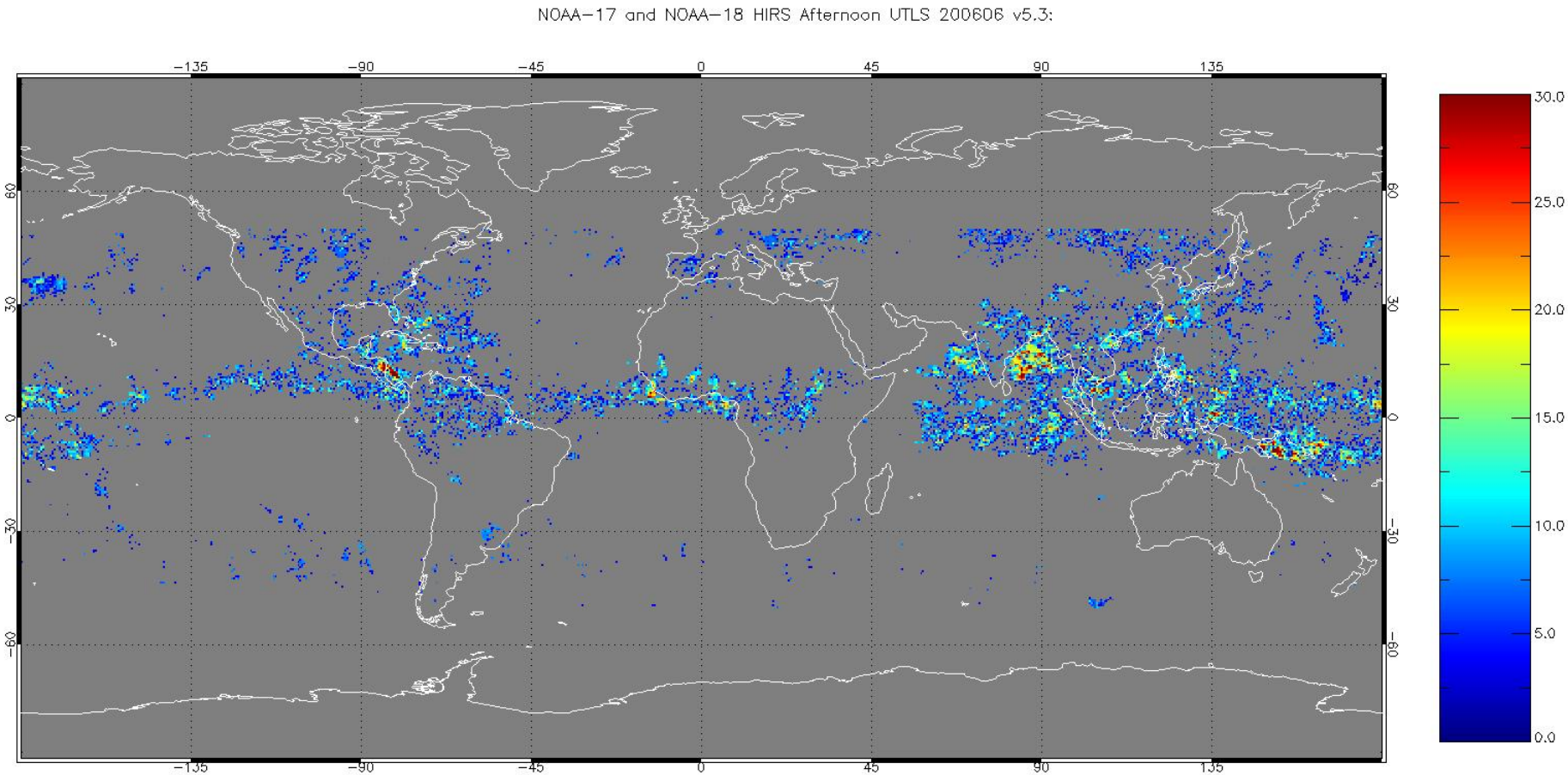
UTLS Frequency in Percent

Morning June 2006

SZA <= 85° and Local Time Before Noon

Spatial Resolution is 0.5^{o} Equal Angle

Upper Tropospheric/Lower Stratospheric (UTLS) Cloud Frequency



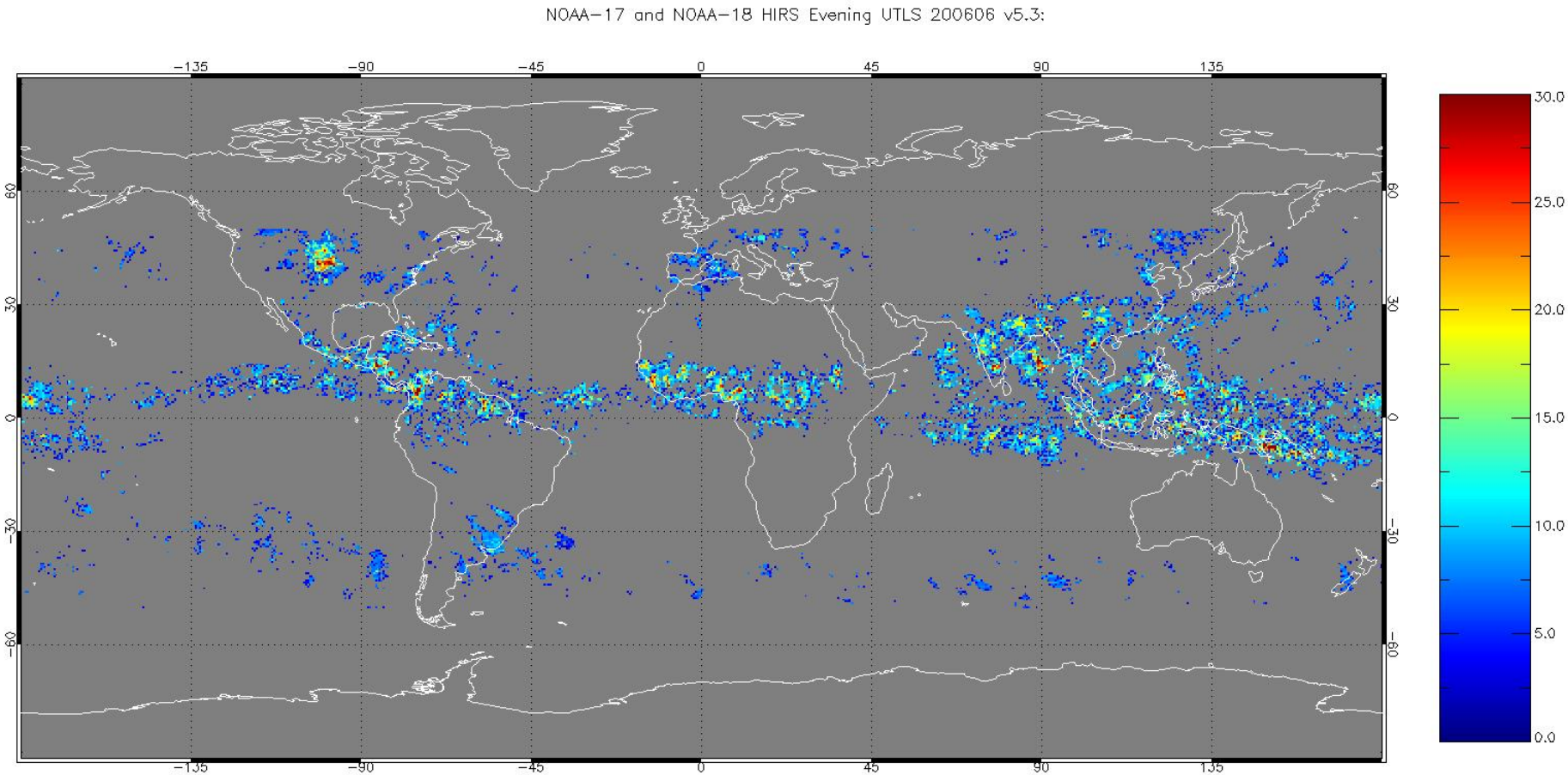
UTLS Frequency in Percent

Afternoon June 2006

SZA <= 85° and Local Time After Noon

Spatial Resolution is 0.5^{o} Equal Angle

Upper Tropospheric/Lower Stratospheric (UTLS) Cloud Frequency



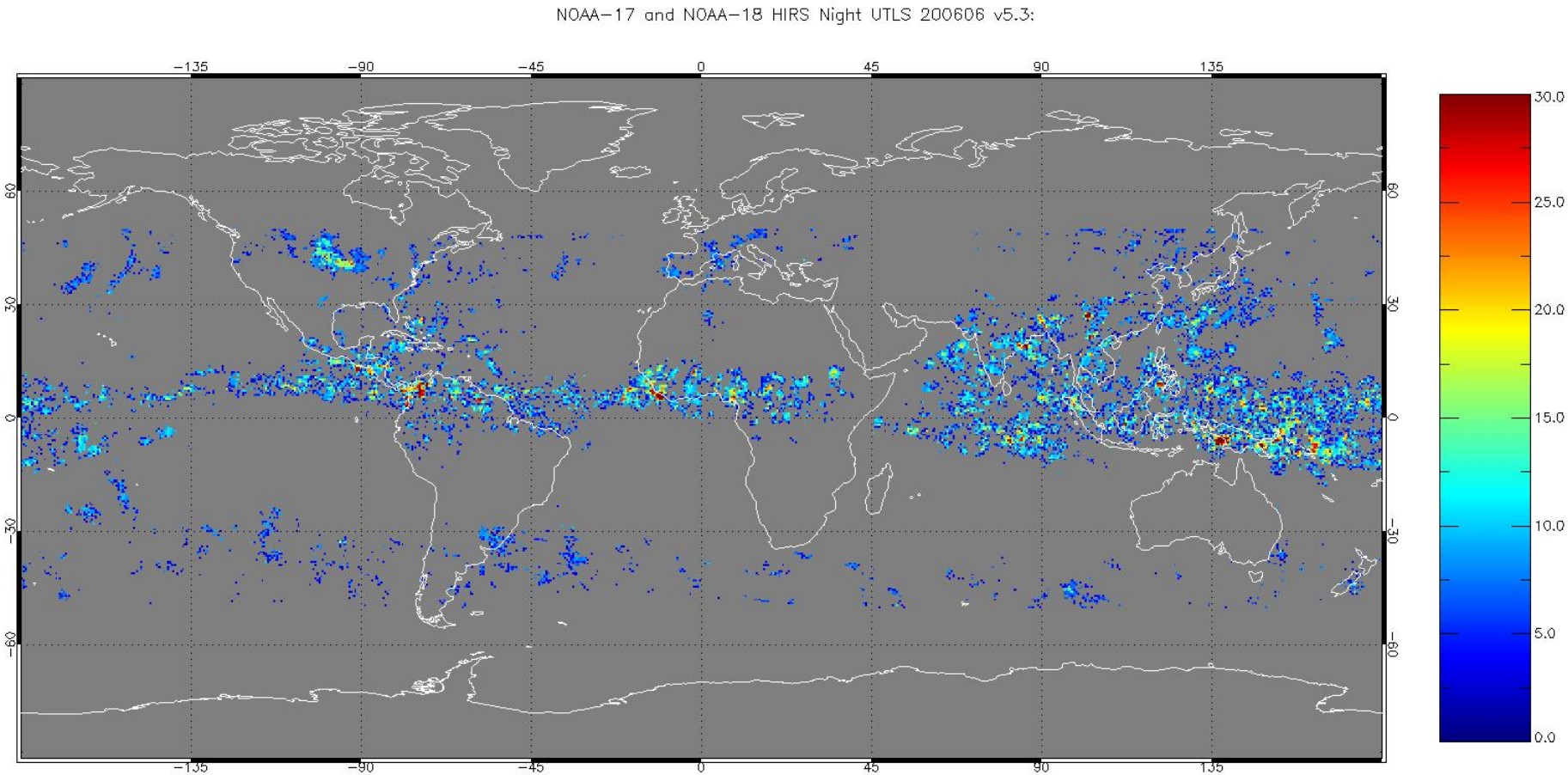
UTLS Frequency in Percent

Evening June 2006

SZA > 85° and Local Time Before Midnight

Spatial Resolution is 0.5^{o} Equal Angle

Upper Tropospheric/Lower Stratospheric (UTLS) Cloud Frequency

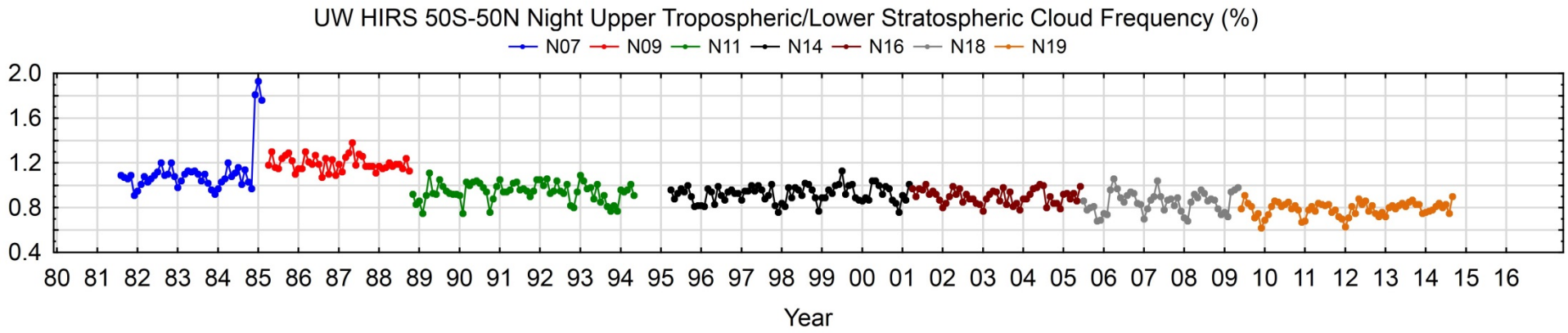


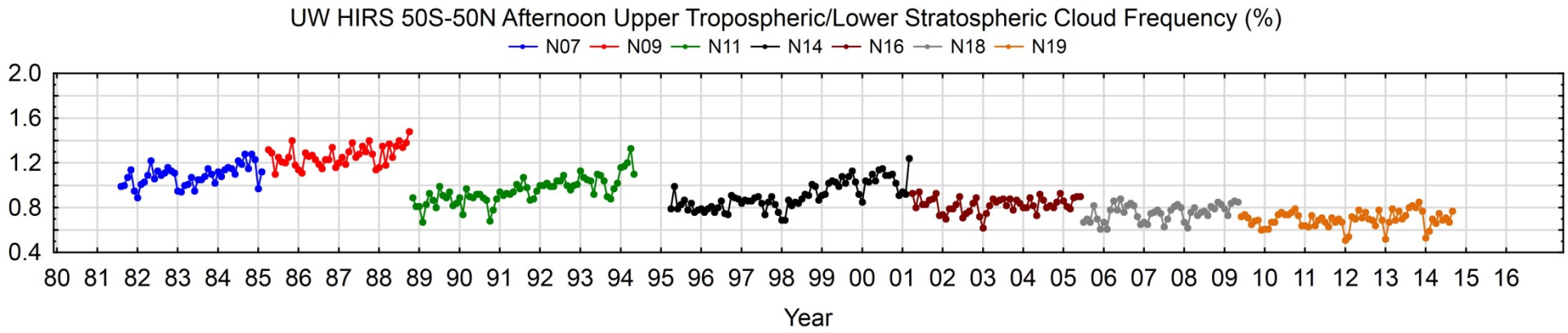
UTLS Frequency in Percent

Night June 2006

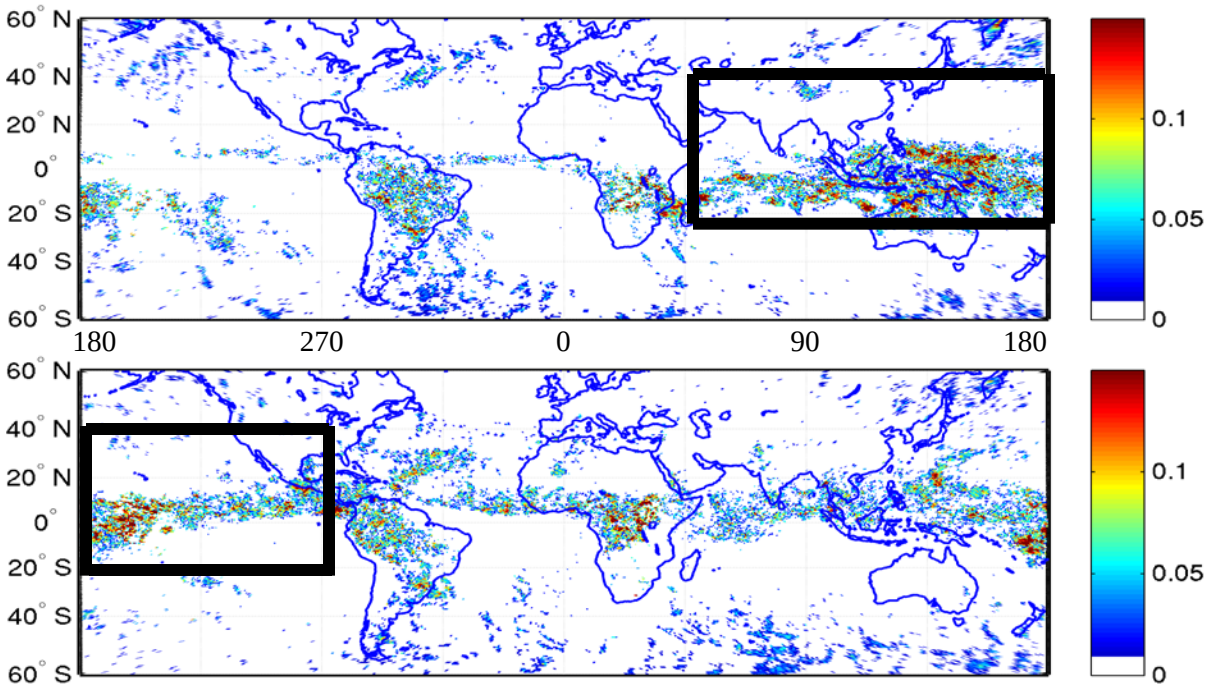
SZA > 85° and Local Time After Midnight

Spatial Resolution is 0.5^{o} Equal Angle


UW HIRS 50S-50N Night Upper Tropospheric/Lower Stratospheric Cloud Frequency (%)
N07 N09 N11 N14 N16 N18 N19
2.0
1.6
1.2
0.8
0.4
80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16
Year

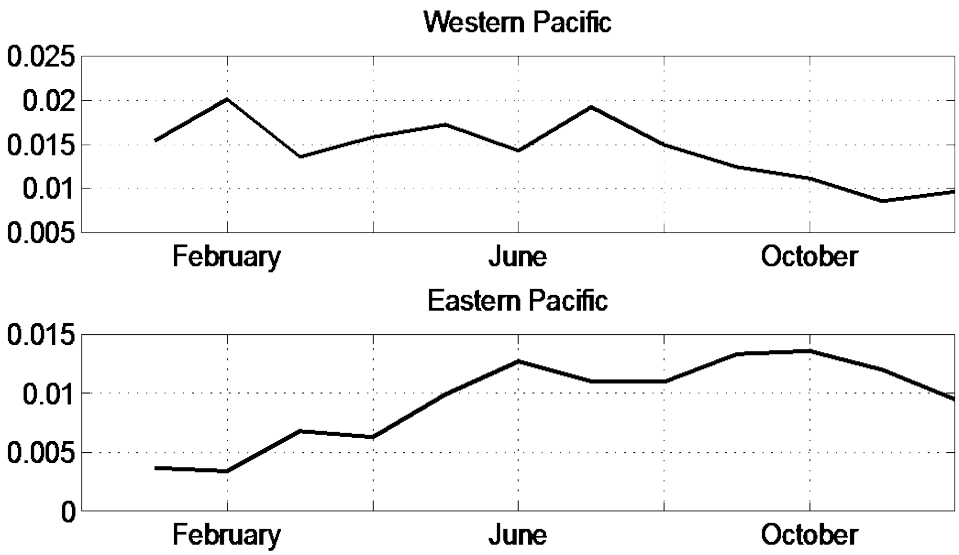

UW HIRS 50S-50N Afternoon Upper Tropospheric/Lower Stratospheric Cloud Frequency (%)
N07 N09 N11 N14 N16 N18 N19
2.0
1.6
1.2
0.8
0.4
80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16
Year

El Nino
Year
1997

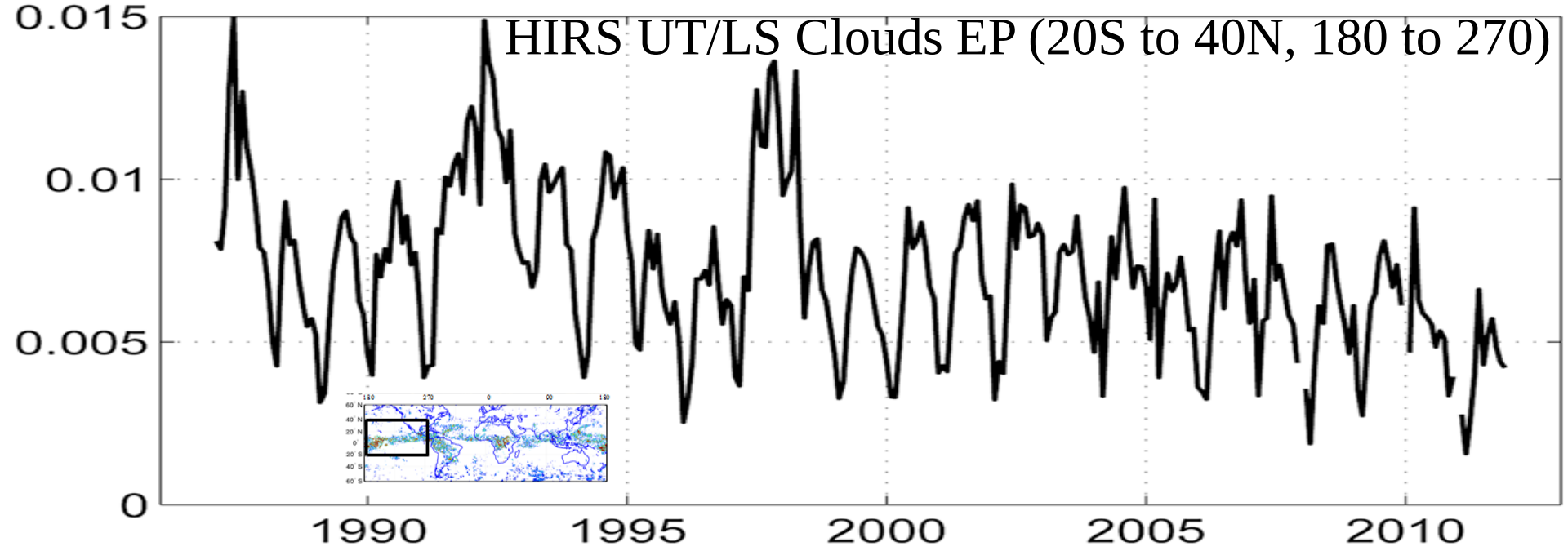


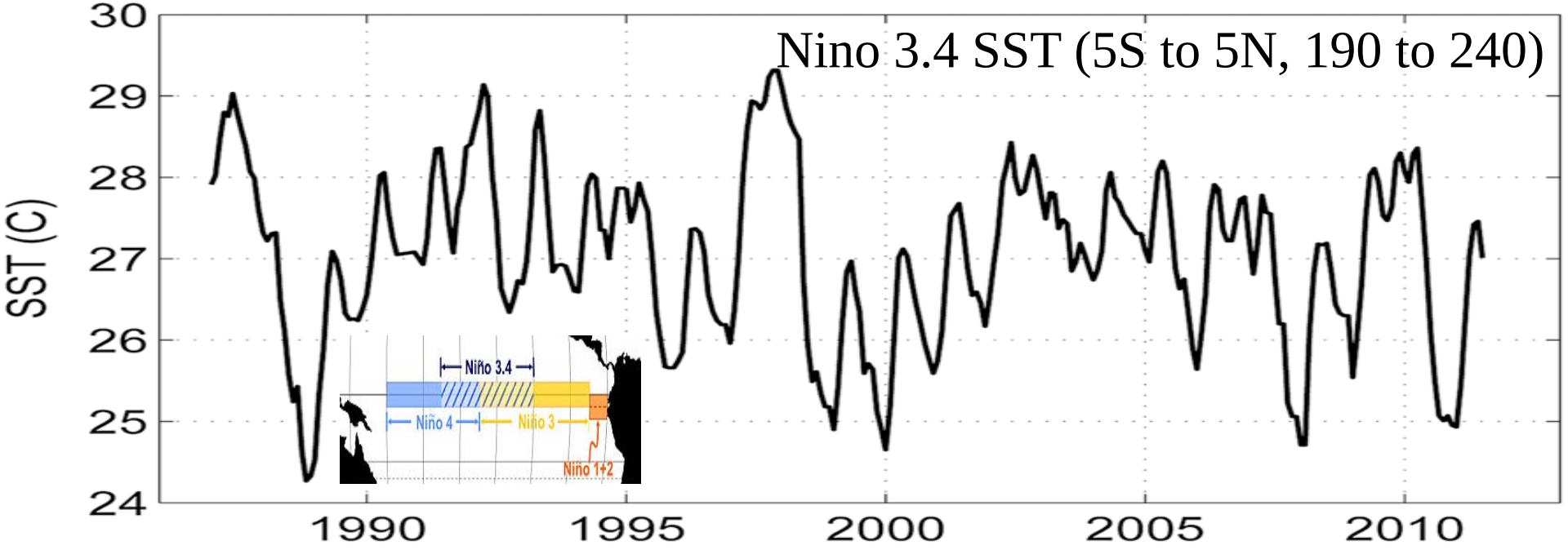
Feb

Oct



Western Pacific Region
(45 to 180 longitude)
Eastern Pacific Region
(180 to 270 longitude)
from 20S to 40N latitude


HIRS UT/LS Clouds EP (20S to 40N, 180 to 270)
0.015
0.01
0.005
0
1990
1995
2000
2005
2010


Nino 3.4 SST (5S to 5N, 190 to 240)
SST (C)
30
29
28
27
26
25
24
1990
1995
2000
2005
2010
Niño 3.4
Niño 4
Niño 3
Niño 1+2

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 day into 4 time periods mitigates effects of orbit drift somewhat

Regarding High Cloud Trends

* HIRS radiance data is being processed with MODIS CO2-slicing algorithm
* Afternoon cloud trends are affected by orbit drift
* Frequency of night time cloud is greater than that in day time (cloud mask??)
* 10 km FOV (HIRS4) sees fewer clouds than 20 km FOV (HIRS3 & HIRS2)
* Clouds are found in ~75% of HIRS observations over 60N-60S; hi clouds in ~35%
* NH and SH seasonal high clouds exactly out of phase (min-max matchup); seasonal fluctuation greater in SH than NH
* EPB UT/LS clouds show correlation with El Nino3.4 SSTs

Regarding H2O Trends

* HIRS radiance data is being processed with MODIS TPW / UTH algorithm
* Seasonal TPW cycle is strongest in northern mid-latitudes, weakest in tropics, stronger in the afternoon than at night
* NH and SH seasonal TPW exactly out of phase (min-max matchup)
* Hemispheric seasonal TPW and high clouds in phase
* Decrease in tropical TPW is evident during La Nina events
* Recalibrating IR split window needed to mitigate sensor to sensor TPW issues

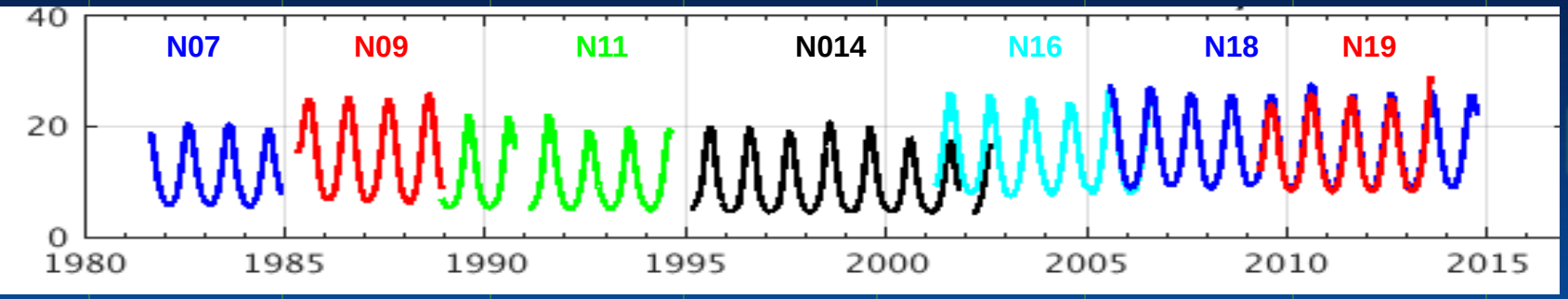
Overall

* HIRS data from 1978 onwards offers unique global cloud and moisture record

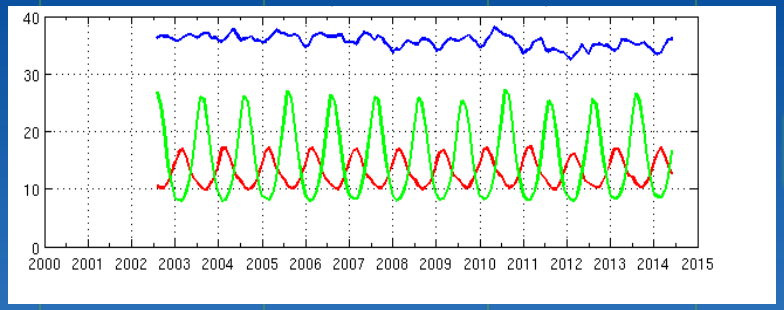
Timeline

1980 1990 2000 2010

AVHRR/HIRS Northern Mid latitude (30N-60N)



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



S-NPP/VIIRS/CrIS and Metop/AVHRR/IASI