Ten Year Time Series of High Cloud Frequencies from HIRS and MODIS

Richard Frey[a], W. Paul Menzel[a], Nick Bearson[a], Andy Heidinger[b], Bryan Baum[a]

a Space Science and Engineering Center, University of Wisconsin -Madison, Madison, WI
b Calibration Branch, STAR, NESDIS, College Park, MD

Compare NOAA-18 HIRS (UW), Aqua MODIS (MOD06) Cloud Properties
Use MODIS Algorithm on HIRS Input Radiances
Cloud Top Pressure, High Cloud Frequency

6 March, 2014
Cloud Retrieval Evaluation Workshop-4
Grainau, DE

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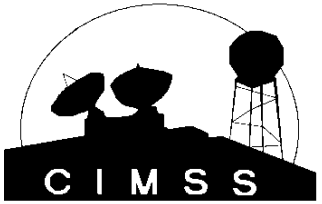
MODIS Collection 6 Reprocessing Not Complete
Use 2008 Only
Compare NOAA-18 HIRS (UW), C6 Aqua MODIS (MOD06) High Clouds
Use MODIS CTP Algorithm on HIRS Input Radiances
Cloud Top Pressure, High Cloud Frequency



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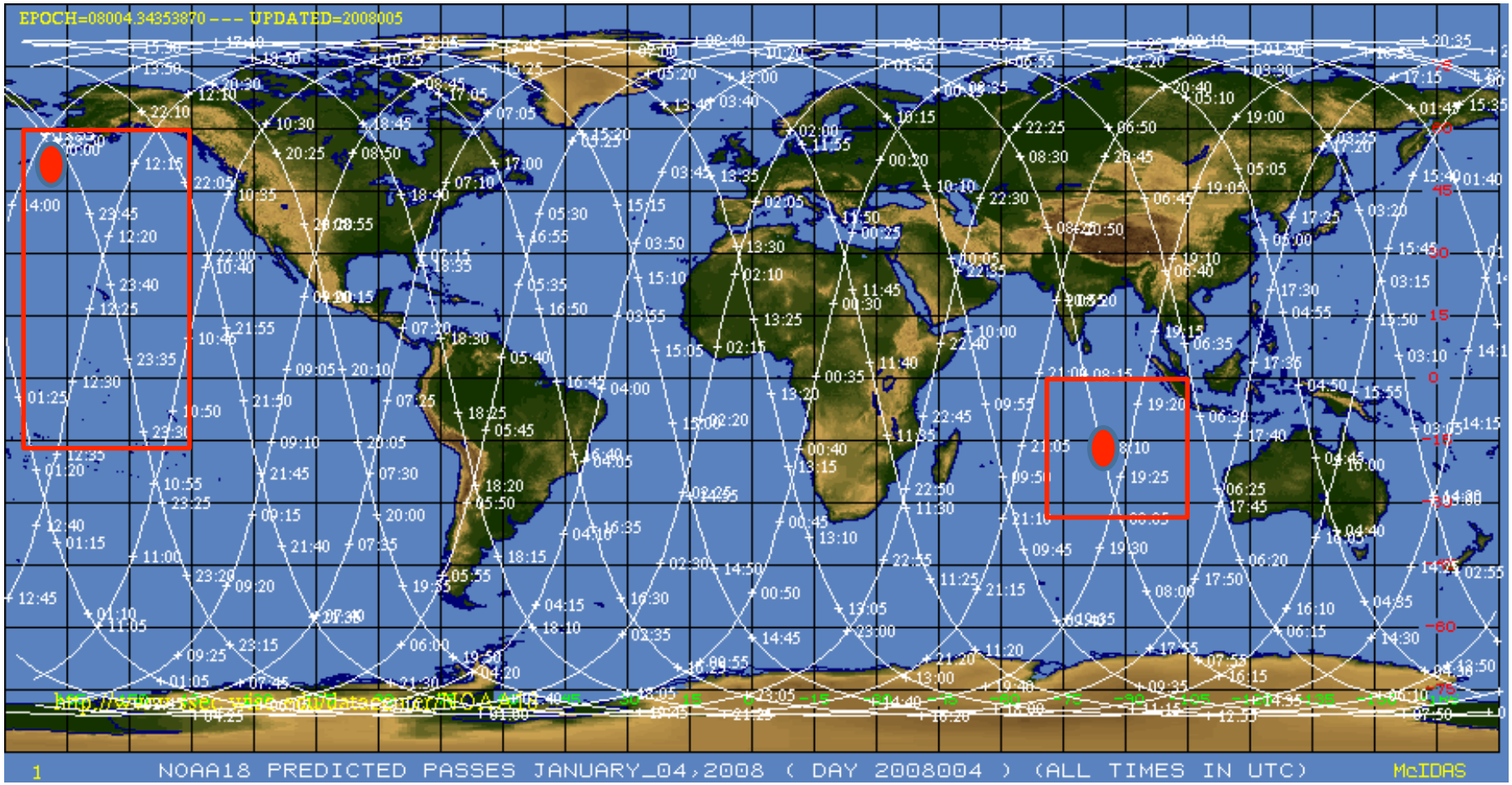
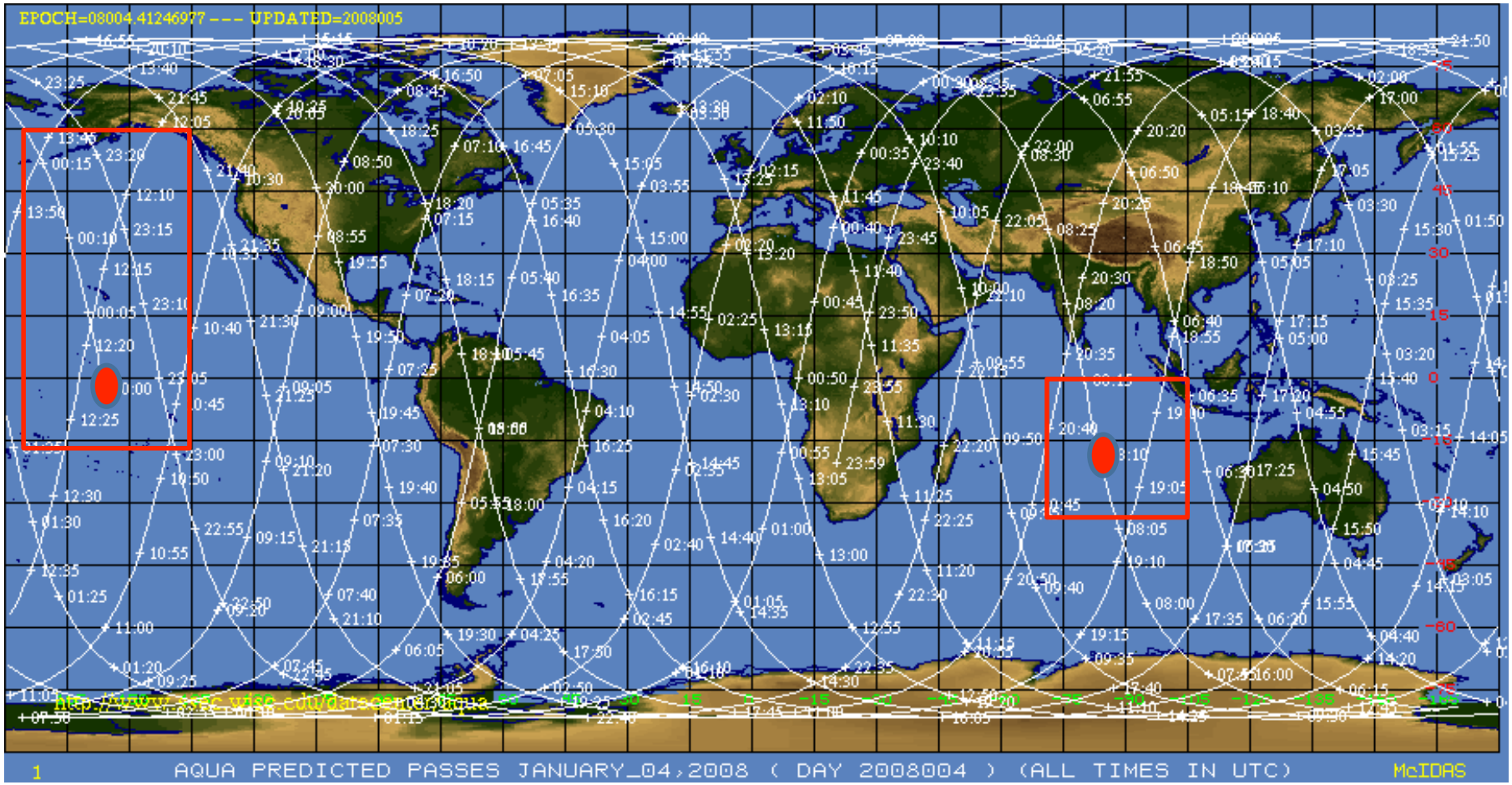
NOAA-18 and Aqua MODIS in Similar Orbits
Daytime Ascending Node/Nighttime Descending Node
Approximately 1 pm and 1am Local Overpass Time



NOAA-18 Nadir Overpass Locations on 04 January 2008

On this day, nearly simultaneous observations
Generally, observation time differences < 1 hour



Aqua MODIS Nadir Overpass Locations on 04 January 2008

CTPs using CO2 Slicing

Common HIRS and MODIS algorithm uses three ratios of CO_2 absorbing bands:

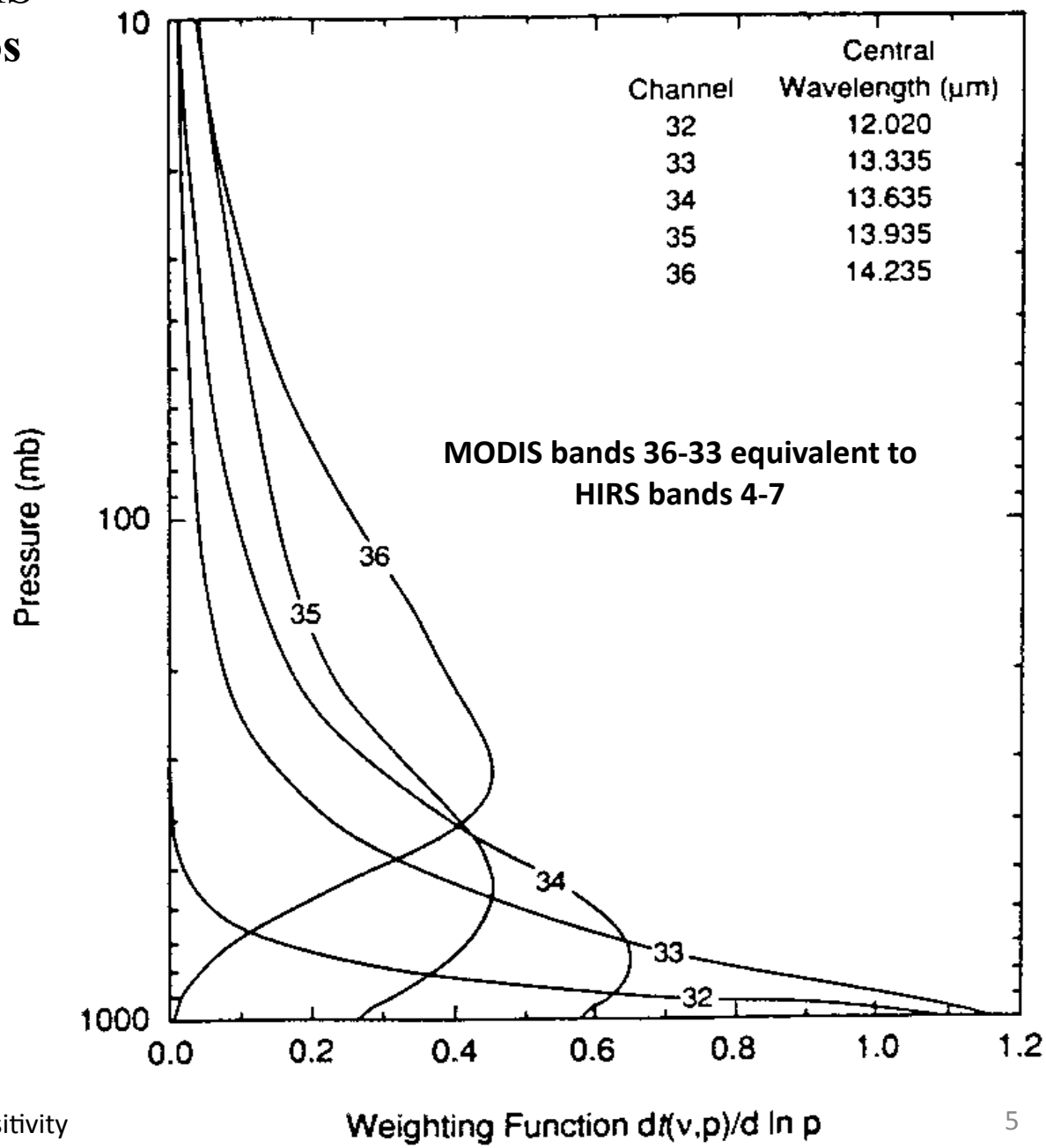
14.2/13.9
13.9/13.6
13.6/13.3

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

Use to adjust algorithm sensitivity



CO_2-slicing Algorithm Inputs

Radiances

MODIS 5x5 averages of 1-km cloudy pixels

HIRS NOAA-18 IFOVs are 10-km at nadir

Ancillary

Vertical profiles of atmospheric P, T, RH, O_3

- MODIS uses GDAS (1^o), HIRS uses CFSR (0.5^o)
- Global Data Assimilation System, Climate Forecast System Reanalysis
- Interpolated to 101 levels

Atmospheric transmittance from forward model

- PFAAST (UW)
- Pressure-Layer Fast Algorithm for Atmospheric Transmittances

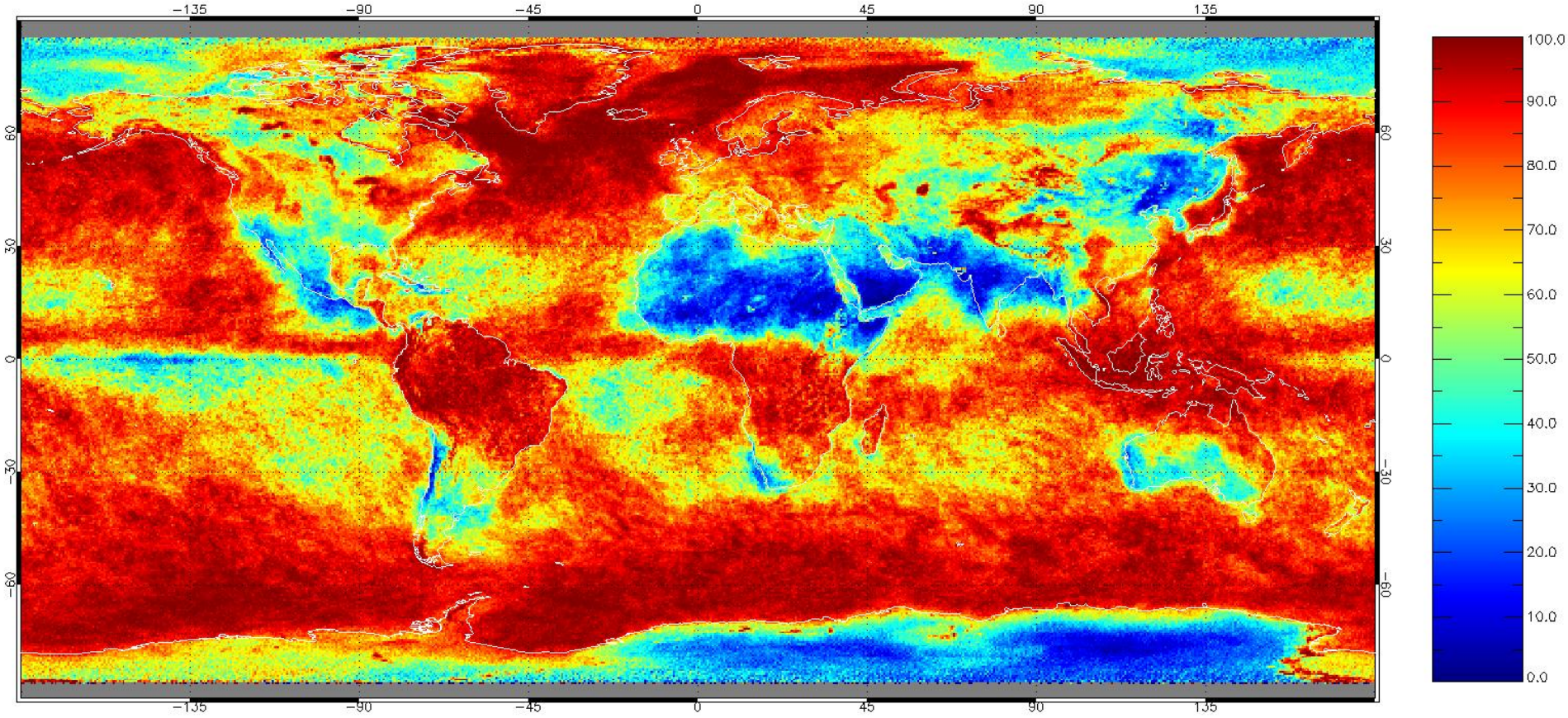
Cloud mask

- MOD35 1-km w/in 5x5s, PATMOS-x AVHRR GAC w/in HIRS FOVs
- MOD35 thresholding alg. using fuzzy logic, PATMOS-x is naïve Bayesian approach

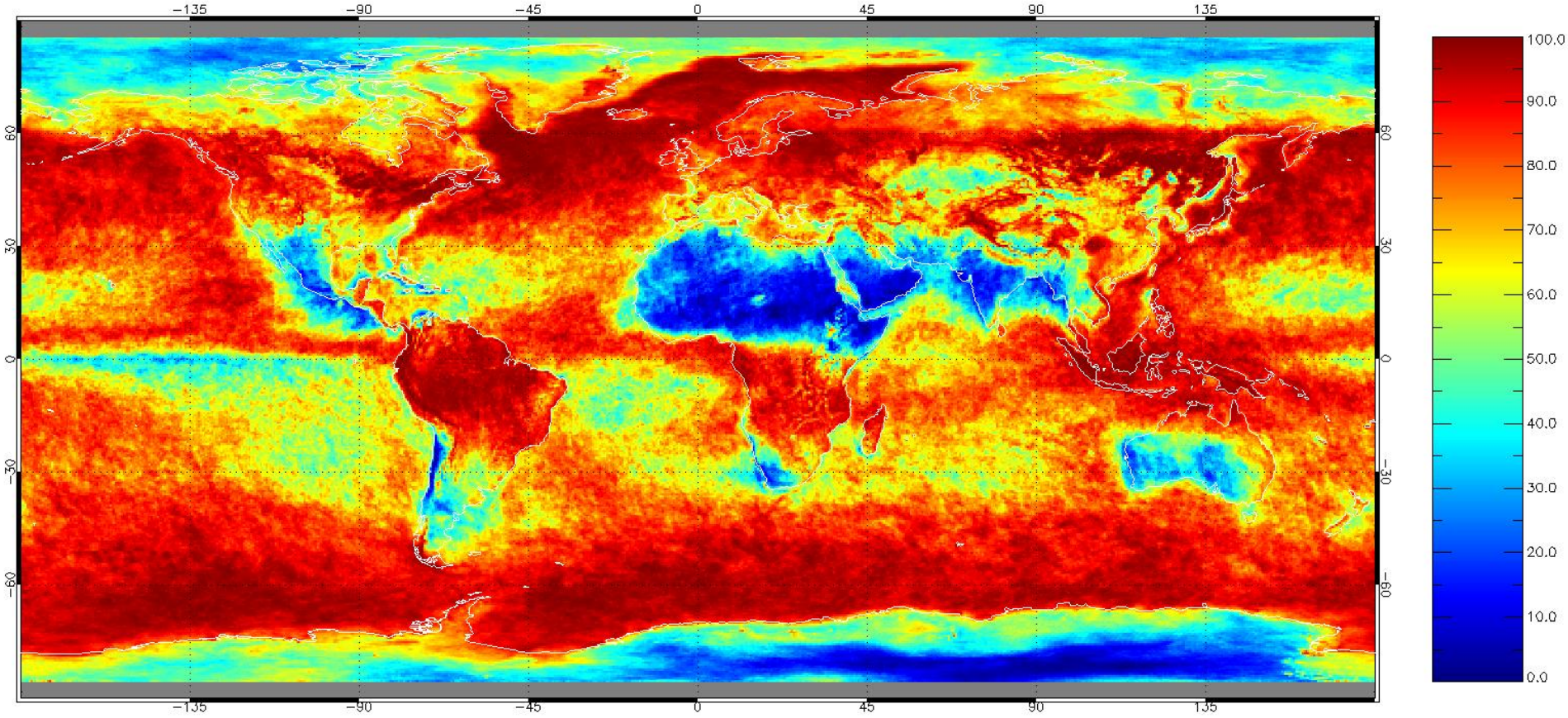
Clear-sky radiance bias (observed minus modeled)

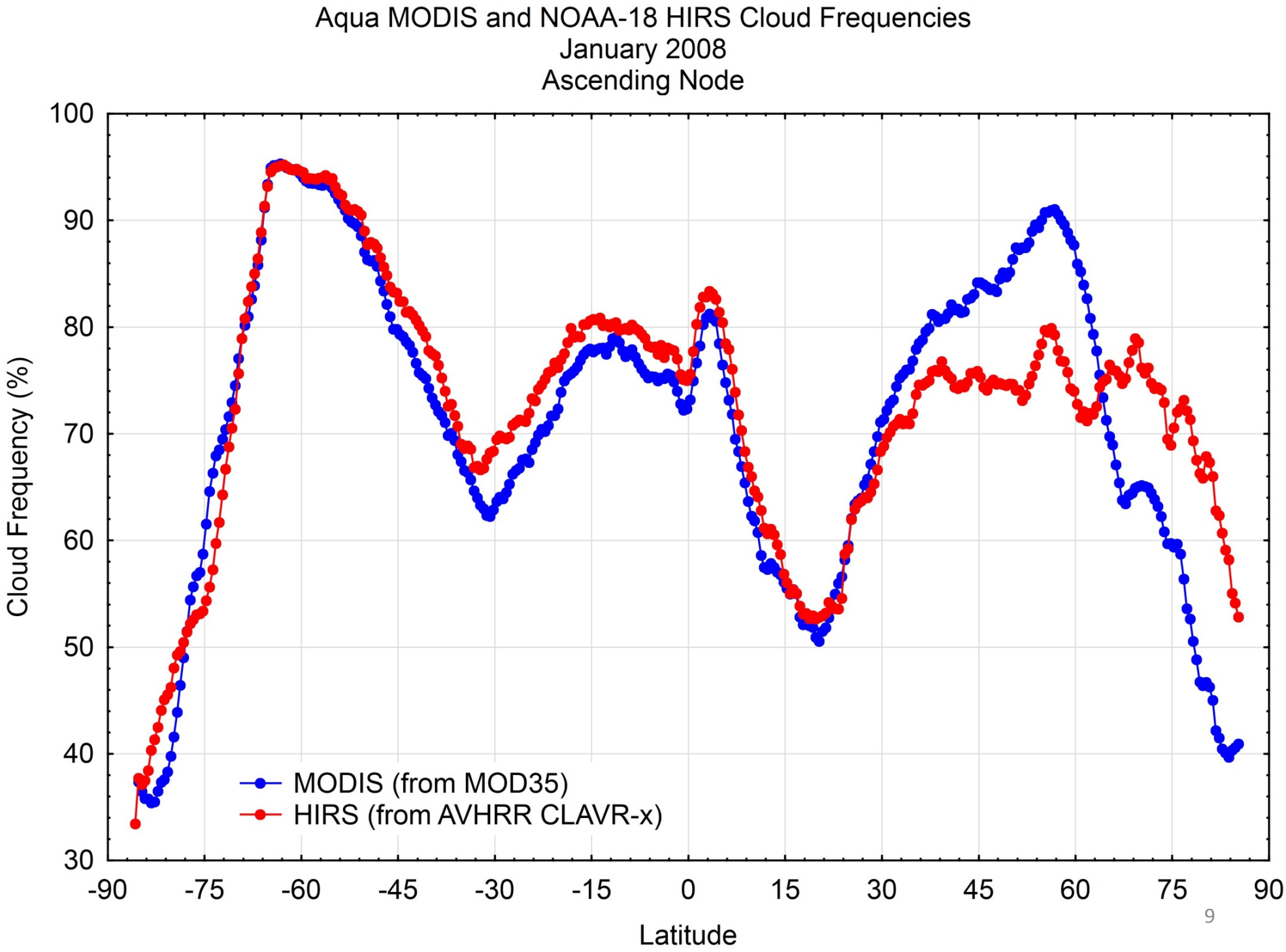
- Zonal means of monthly (HIRS) or 8-day (MODIS) regional means

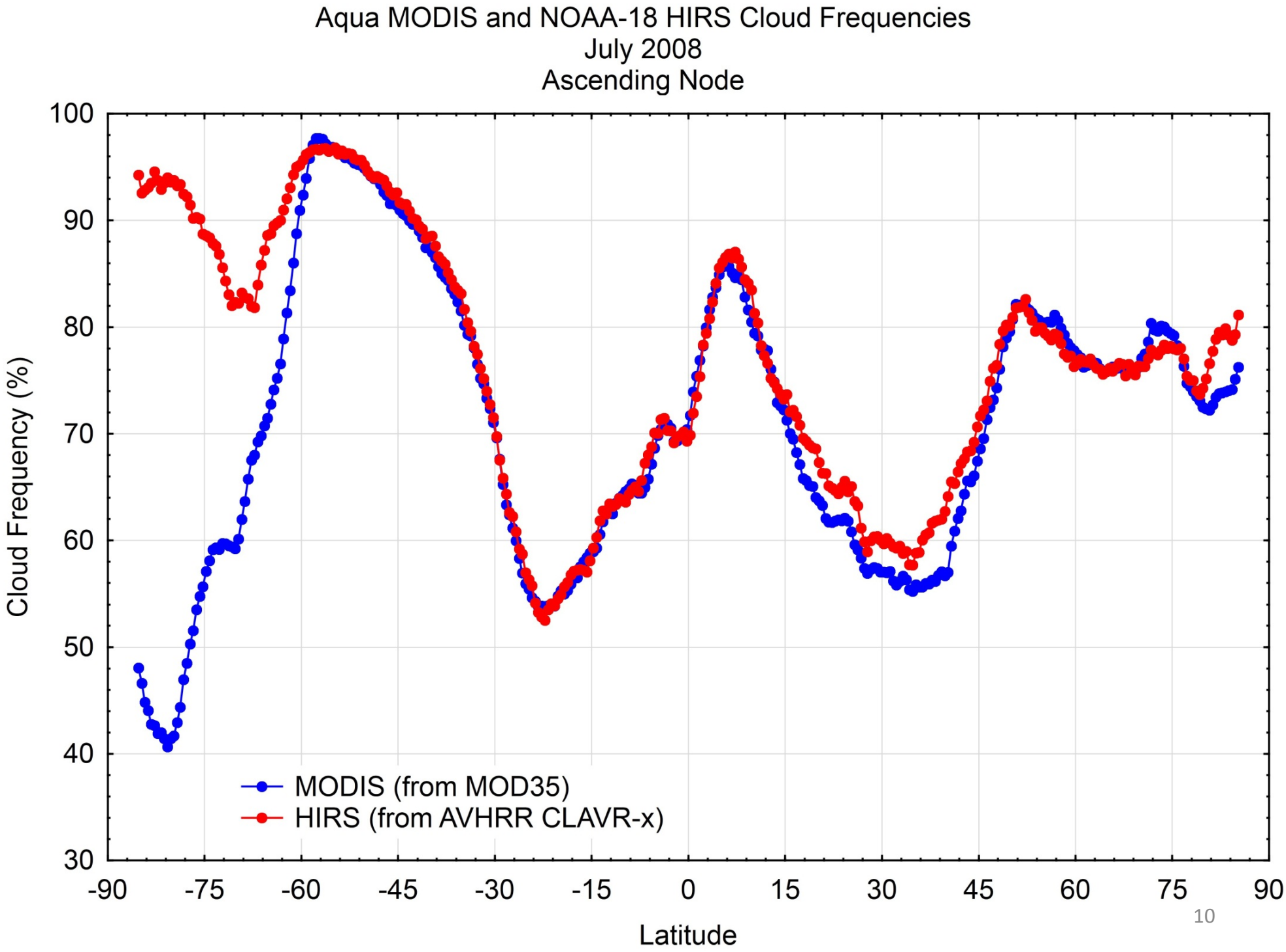
HIRS DJF 2008 AN (60S-60N Day) Cloud Frequency
PATMOS-x from Collocated AVHRR GAC



MODIS DJF 2008 AN (60S-60N Day) Cloud Frequency
MOD35 from 1-km MODIS Pixels

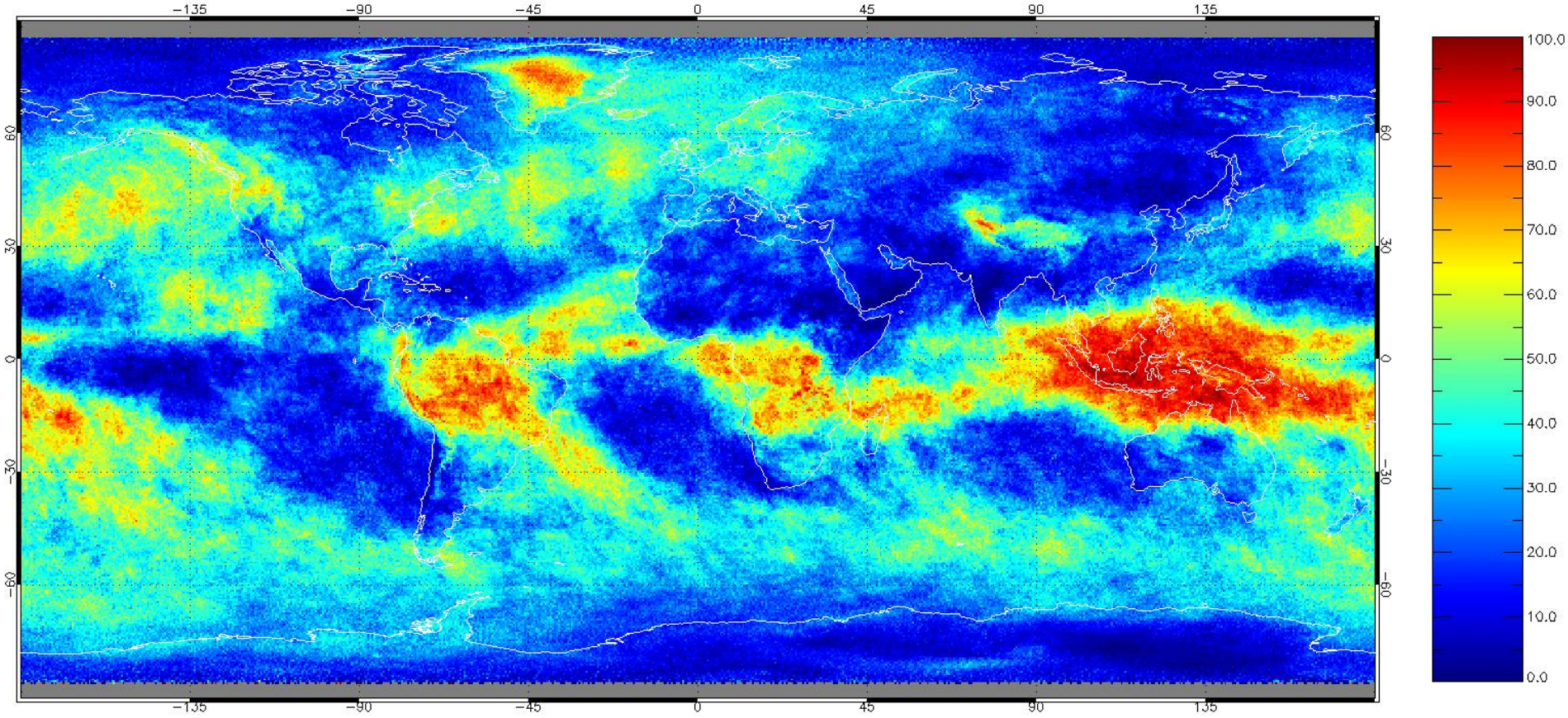



Aqua MODIS and NOAA-18 HIRS Cloud Frequencies
January 2008
Ascending Node
Cloud Frequency (%)
100
90
80
70
60
50
40
30
-90
-75
-60
-45
-30
-15
0
15
30
45
60
75
90
Latitude
MODIS (from MOD35)
HIRS (from AVHRR CLAVR-x)


Aqua MODIS and NOAA-18 HIRS Cloud Frequencies
July 2008
Ascending Node
Cloud Frequency (%)
100
90
80
70
60
50
40
30
-90
-75
-60
-45
-30
-15
0
15
30
45
60
75
90
Latitude
MODIS (from MOD35)
HIRS (from AVHRR CLAVR-x)

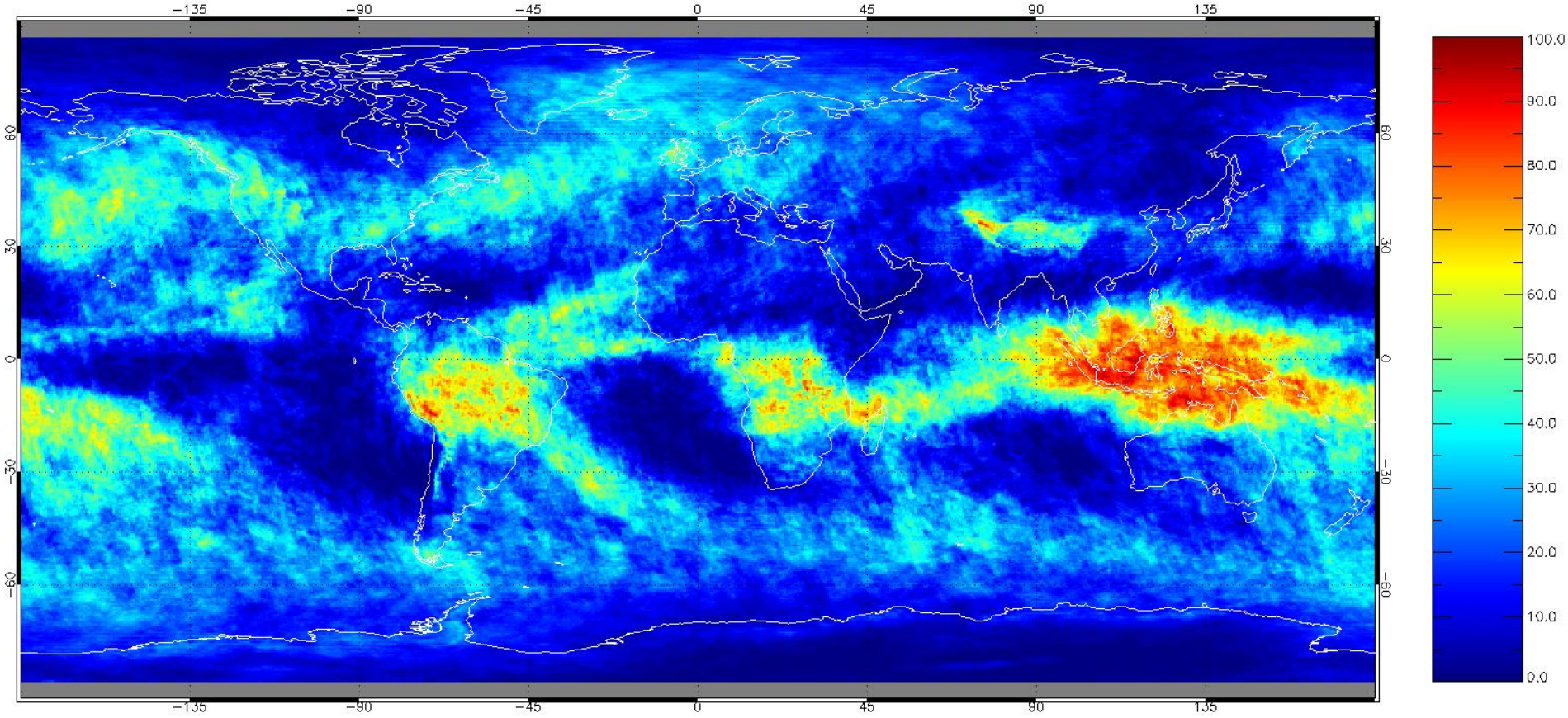
HIRS DJF 2008 AN (60S-60N Day) High Cloud Frequency

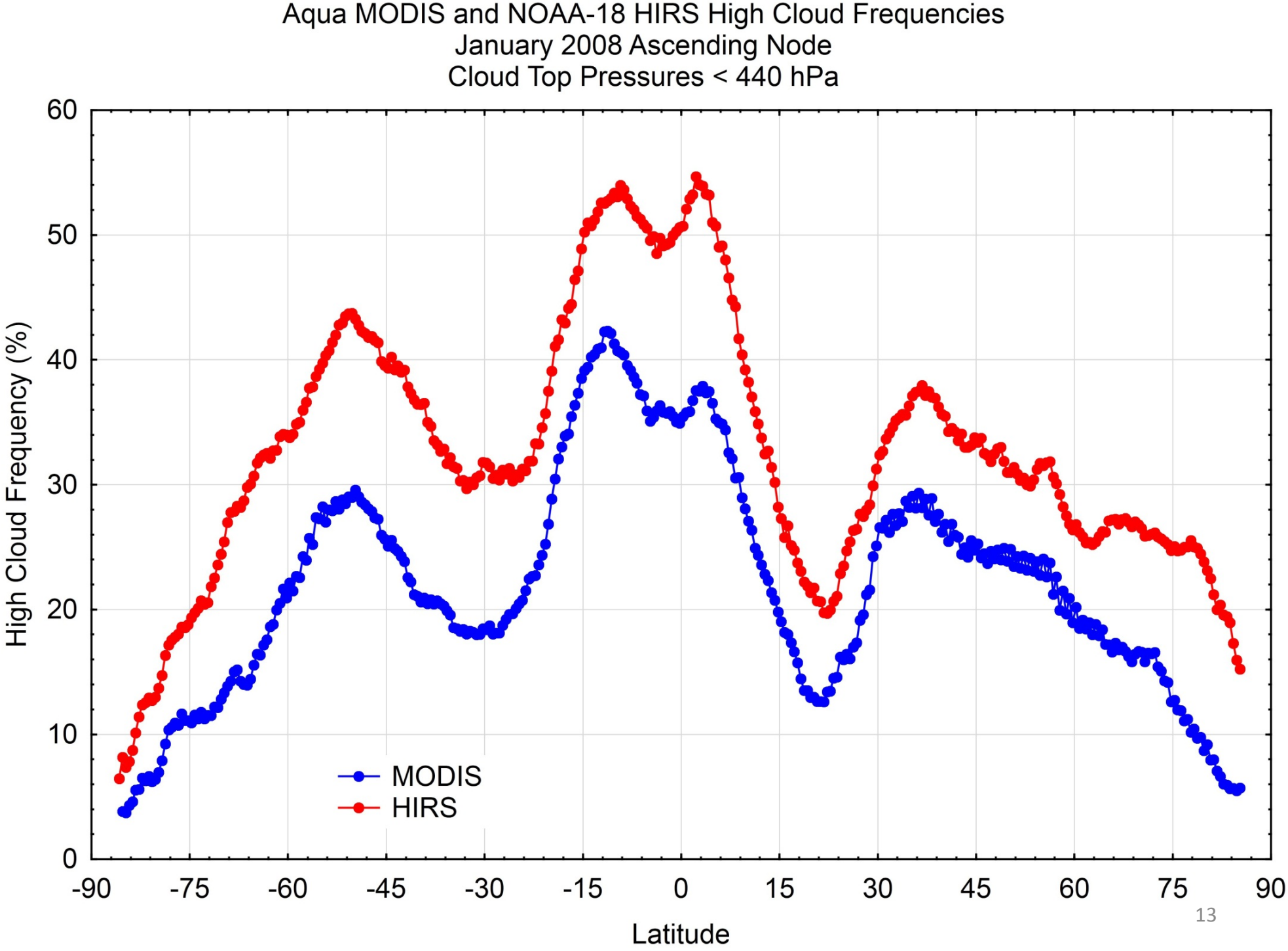
CTP < 440 hPa

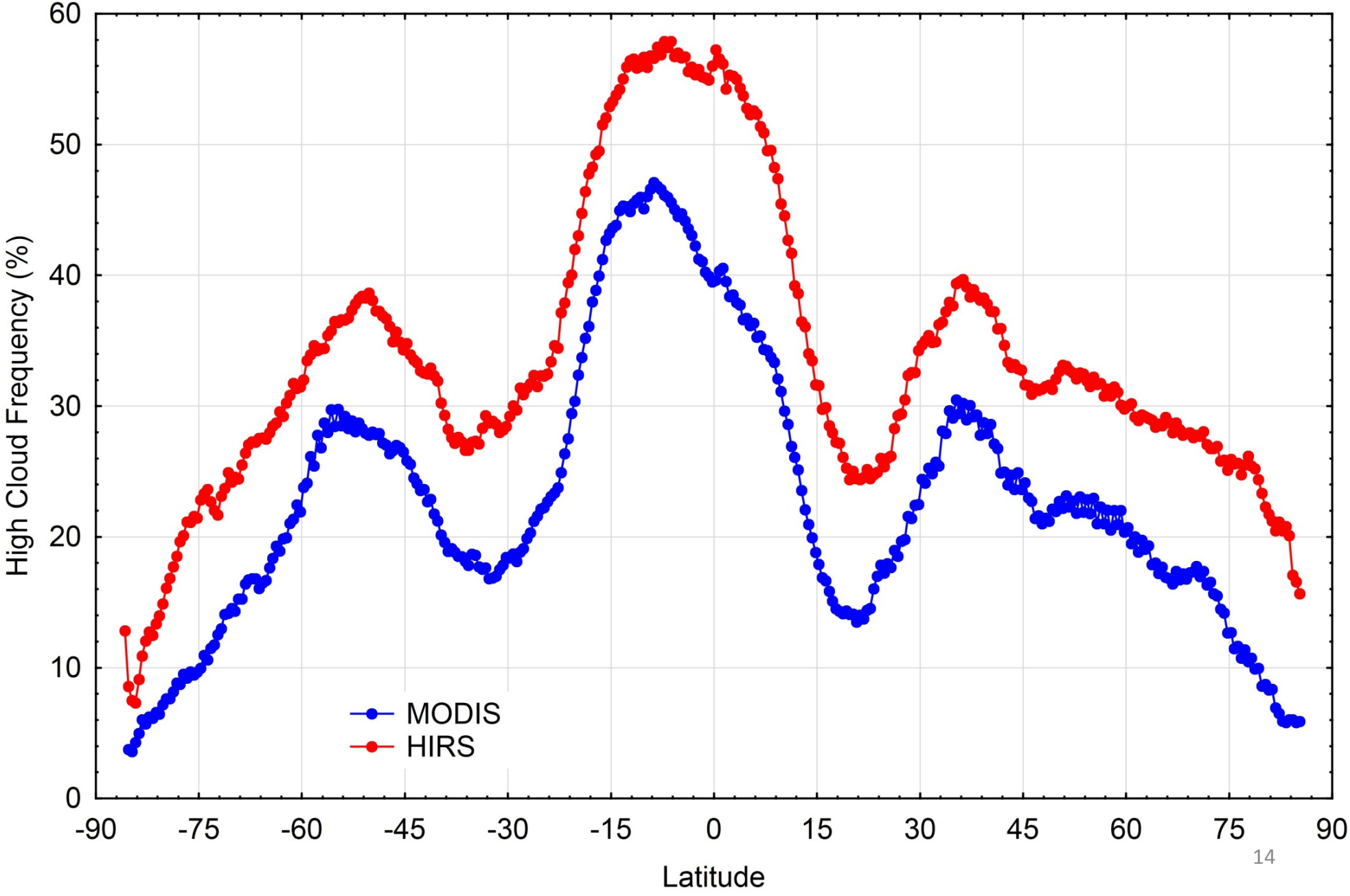


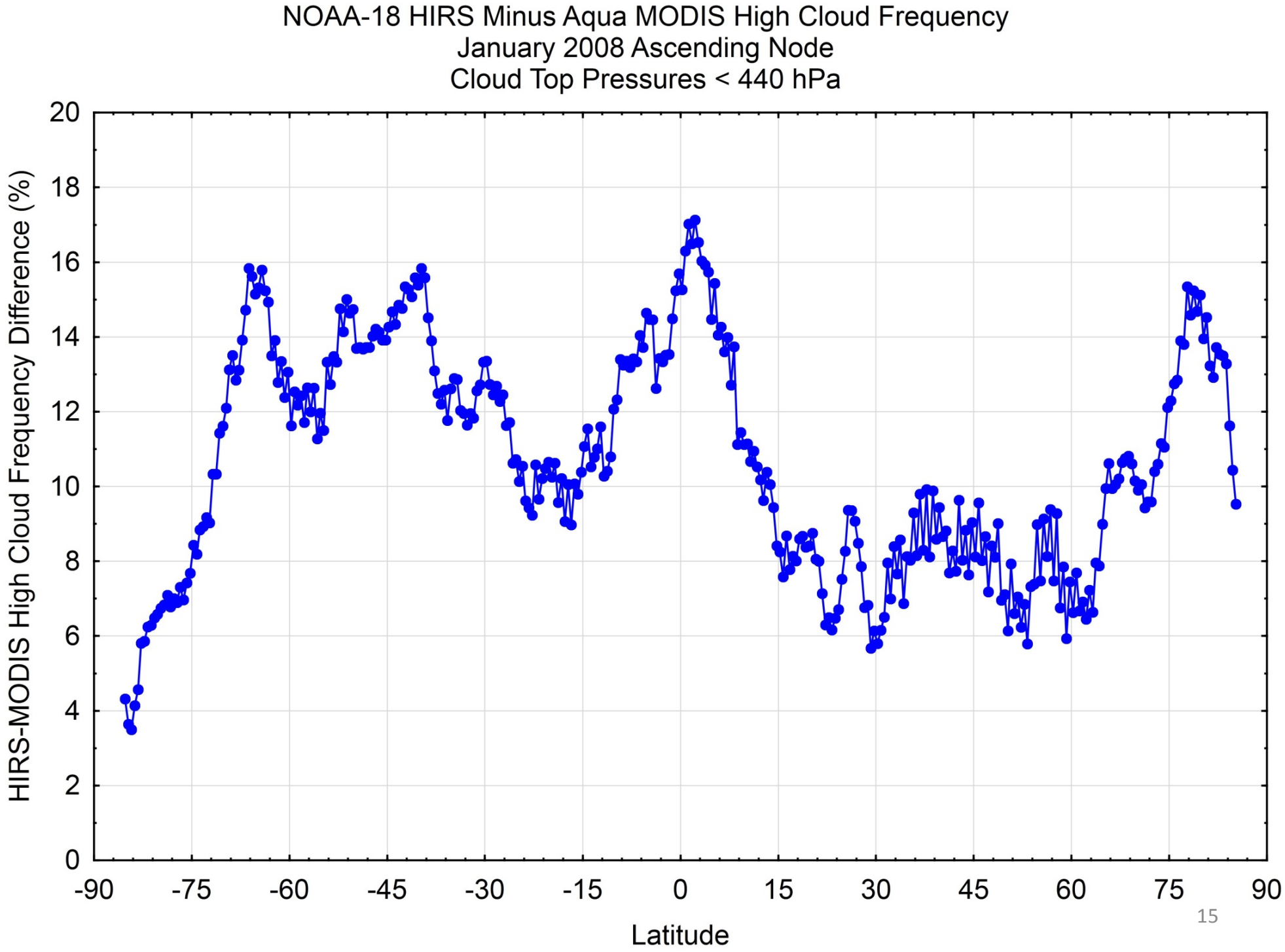
MODIS DJF 2008 AN (60S-60N Day) High Cloud Frequency

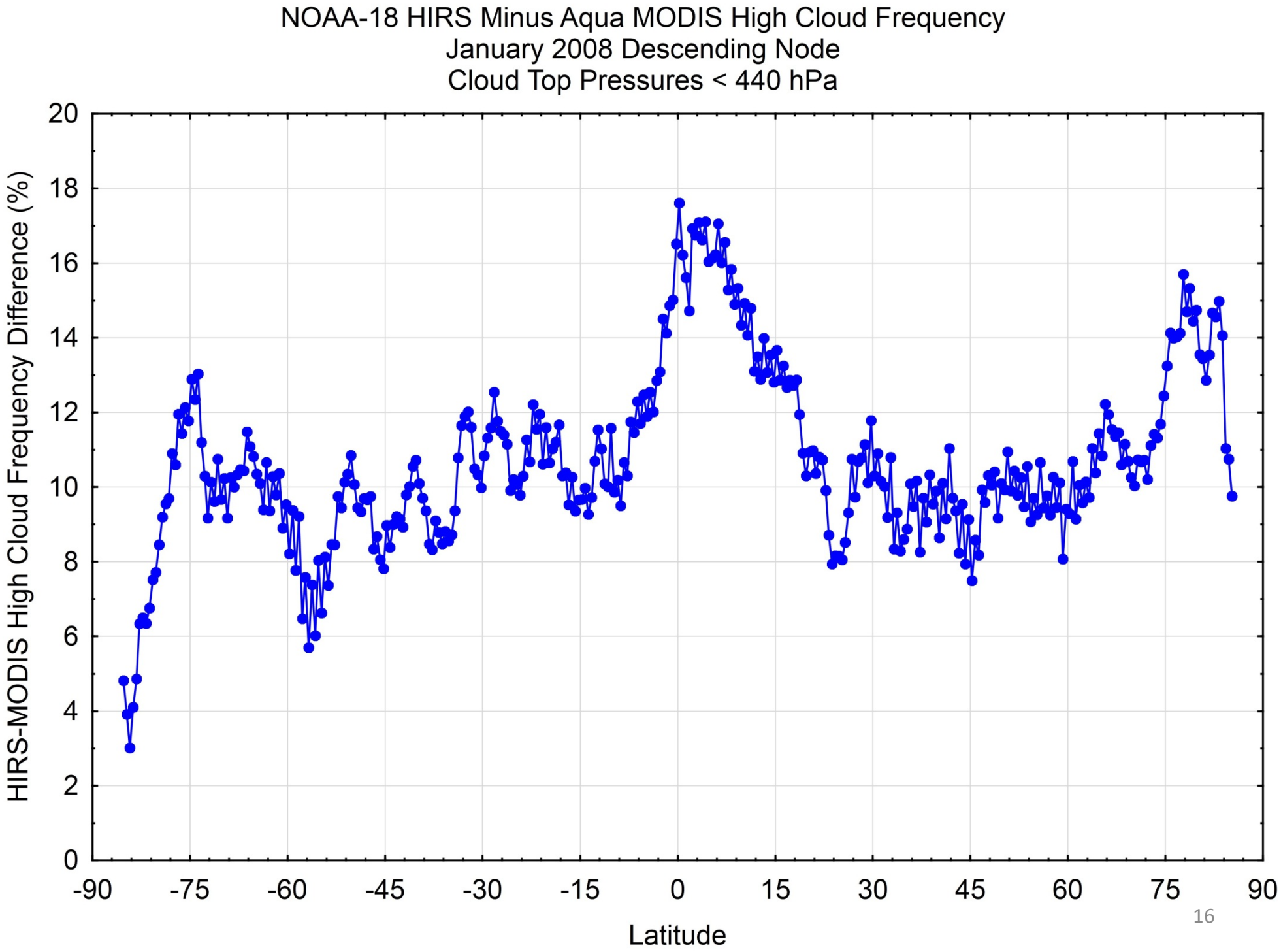
CTP < 440 hPa




Aqua MODIS and NOAA-18 HIRS High Cloud Frequencies
January 2008 Ascending Node
Cloud Top Pressures < 440 hPa
High Cloud Frequency (%)
0
10
20
30
40
50
60
-90
-75
-60
-45
-30
-15
0
15
30
45
60
75
90
Latitude
MODIS
HIRS


Aqua MODIS and NOAA-18 HIRS High Cloud Frequencies
January 2008 Descending Node
Cloud Top Pressures < 440 hPa
High Cloud Frequency (%)
60
50
40
30
20
10
0
-90
-75
-60
-45
-30
-15
0
15
30
45
60
75
90
Latitude
MODIS
HIRS


NOAA-18 HIRS Minus Aqua MODIS High Cloud Frequency
January 2008 Ascending Node
Cloud Top Pressures < 440 hPa
HIRS-MODIS High Cloud Frequency Difference (%)
0
2
4
6
8
10
12
14
16
18
20
-90
-75
-60
-45
-30
-15
0
15
30
45
60
75
90
Latitude

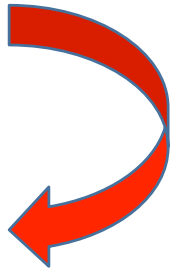

NOAA-18 HIRS Minus Aqua MODIS High Cloud Frequency
January 2008 Descending Node
Cloud Top Pressures < 440 hPa
HIRS-MODIS High Cloud Frequency Difference (%)
0
2
4
6
8
10
12
14
16
18
20
-90
-75
-60
-45
-30
-15
0
15
30
45
60
75
90
Latitude

NOAA-18 HIRS and Aqua MODIS CTP/ECA Table

60N-60S AN and DN Nodes from January 2008

HIRS in red, MODIS in blue

CTP (hPa)	Effective Cloud Amount (%) <25	25-50	50-75	75-95	>95	Totals
< 440	15.45	10.77	10.05	9.41	2.60	48.28
	5.69	7.53	8.34	8.97	3.91	34.44
680-440	1.50	2.86	3.12	2.86	2.28	12.62
	0.37	1.16	2.68	2.69	5.59	12.49
> 680	2.04	5.09	4.10	3.43	24.45	39.11
	4.20	7.24	7.12	7.55	26.95	53.06



Values are %s relative to ***all clouds*** and sum to 100%.

Number valid retrievals:	6939640	267133019
Percentage CO2-slicing retrievals:	58.91	40.46

We've consistently found more high clouds with HIRS. Why?

CO_2-slicing Algorithm Differences

Low Cloud Filters

HIRS uses PATMOS-x (AVHRR) cloud phase

more than 75% water clouds in a HIRS IFOV not permitted

MODIS uses emissivity 11/12 µm "beta" ratios

beta < 0.95 not permitted

HIRS "second chance" high clouds

A HIRS-detected high cloud overrides PATMOS-x clear sky designation

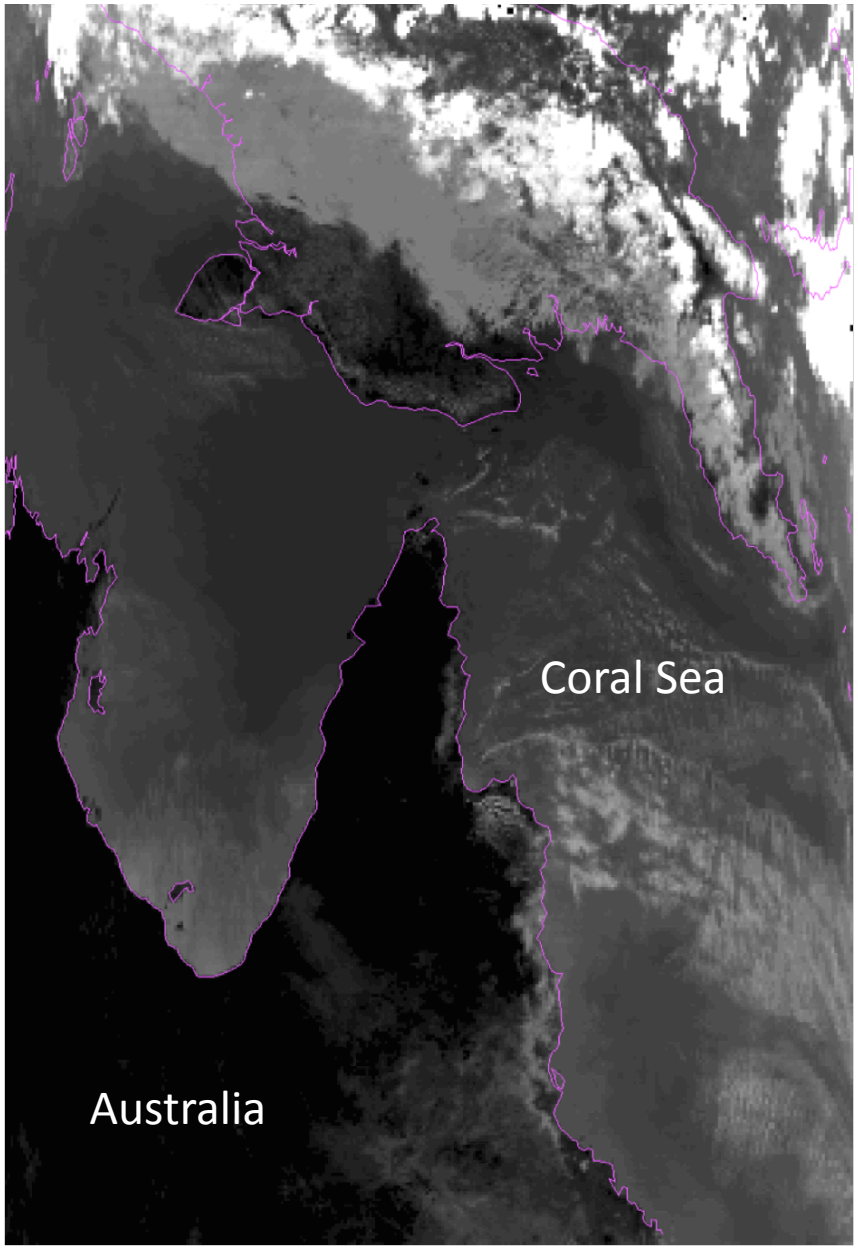
Nothing similar exists in the MODIS algorithm

Algorithm Sensitivity -> $(I_\lambda^{clr} - I_\lambda) > \Delta$

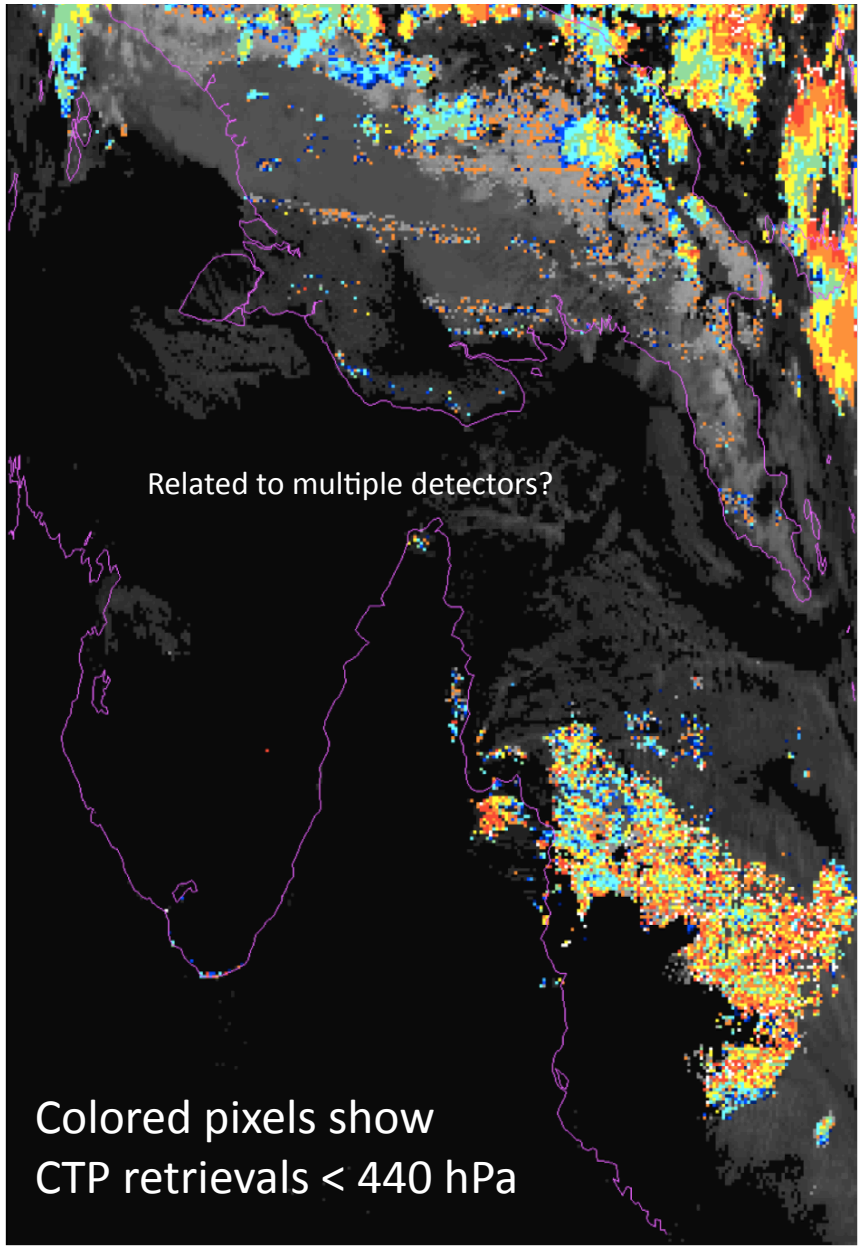
HIRS clear minus cloudy radiance difference threshold is 0.5 $W/m^2*str*cm^{-1}$

Aqua MODIS is 1.0 – 4.0 $W/m^2*str*cm^{-1}$

Aqua MODIS from 29 July 2008

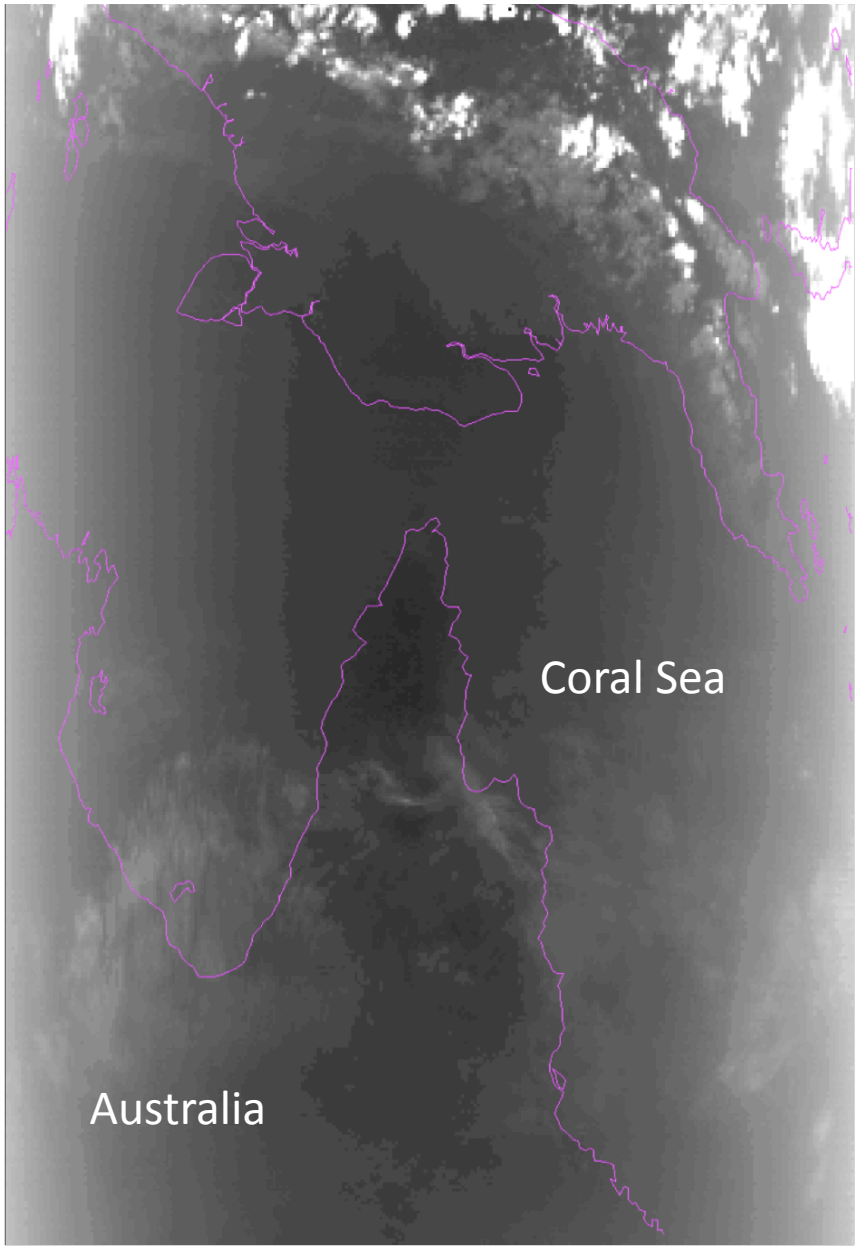


MODIS Band 31 BT

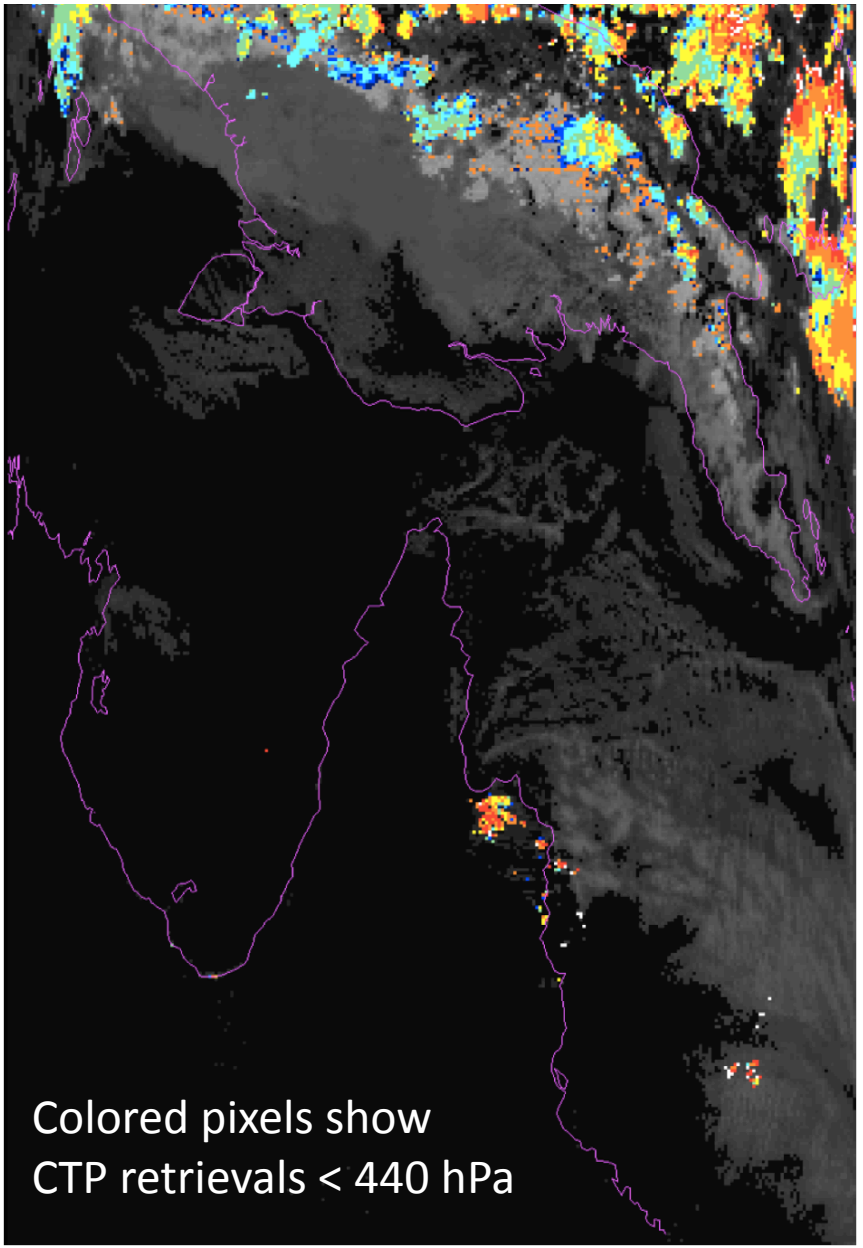


MODIS High Cloud Retrievals

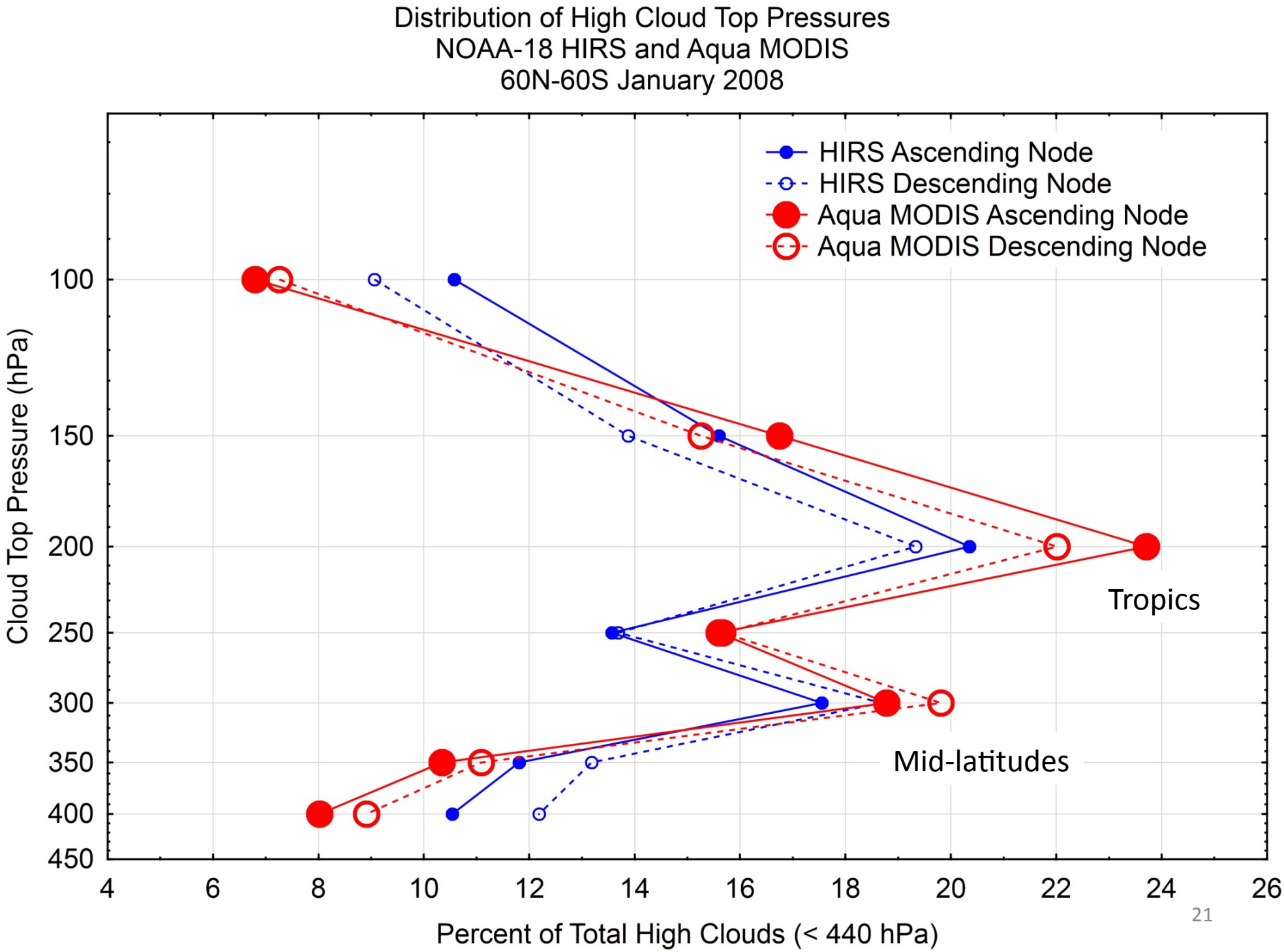
Aqua MODIS from 29 July 2008

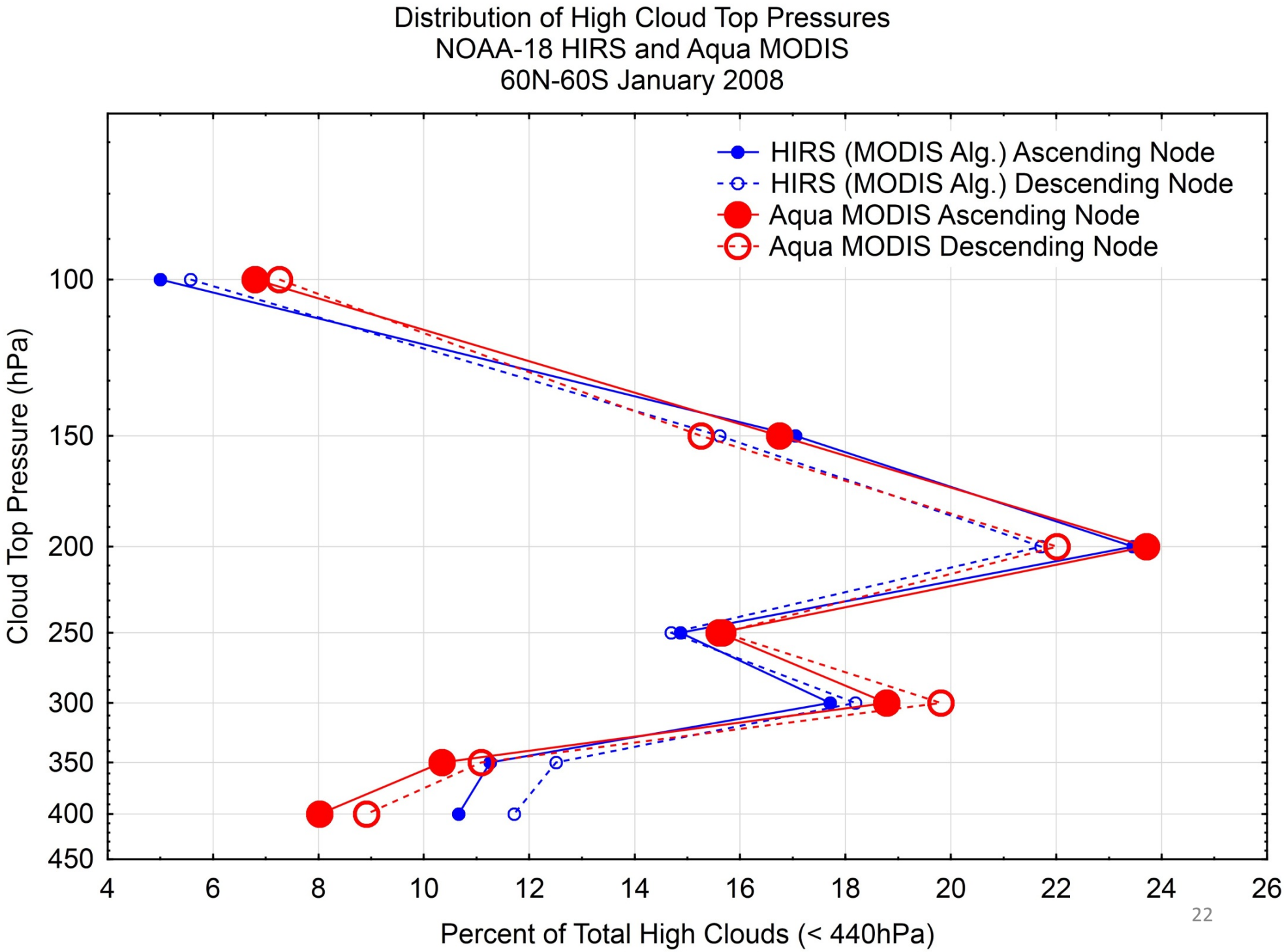


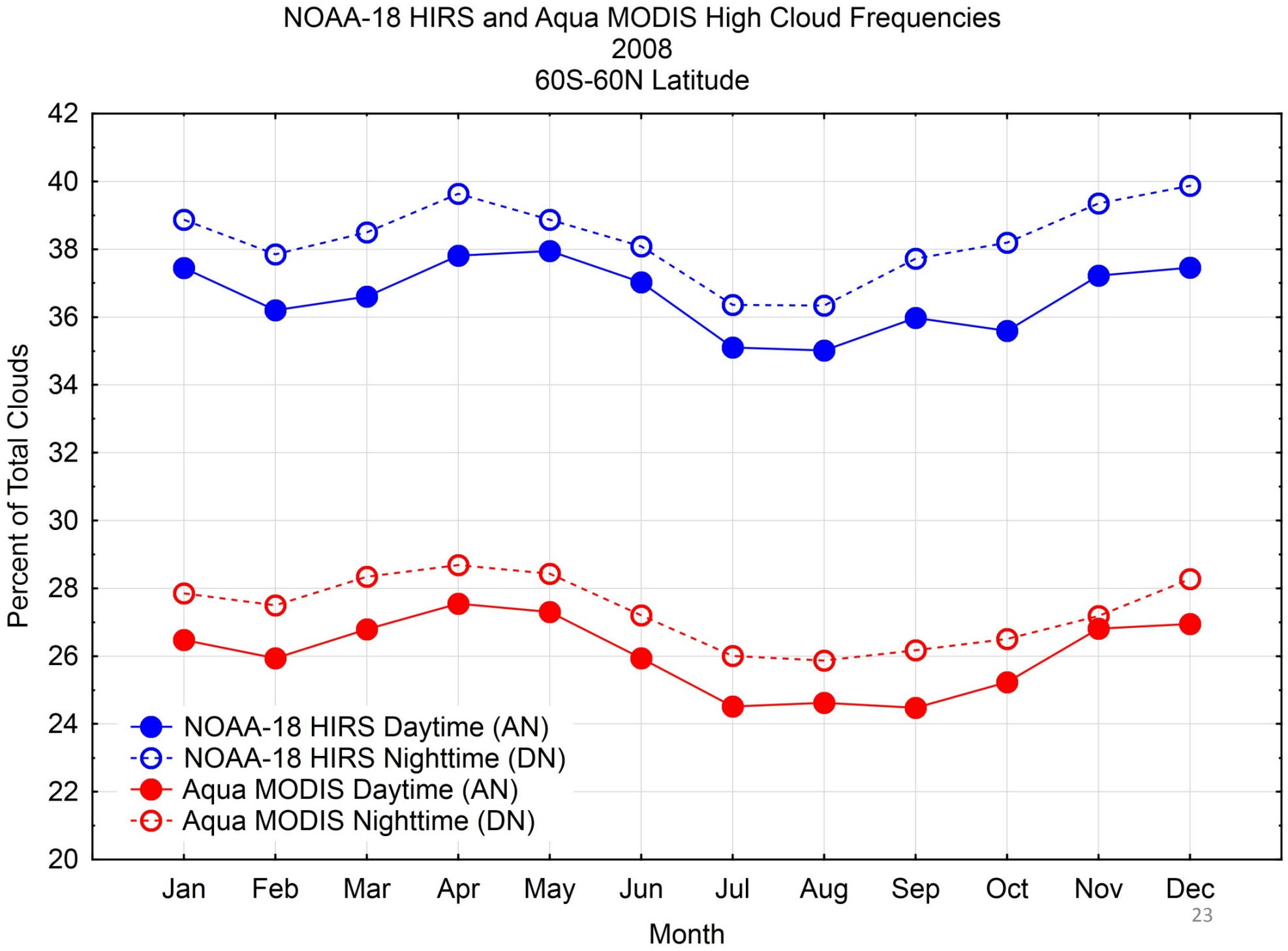
MODIS Band 35 BT



MODIS C6 High Cloud Retrievals


Distribution of High Cloud Top Pressures
NOAA-18 HIRS and Aqua MODIS
60N-60S January 2008
HIRS Ascending Node
HIRS Descending Node
Aqua MODIS Ascending Node
Aqua MODIS Descending Node
Tropics
Mid-latitudes
Cloud Top Pressure (hPa)
100
150
200
250
300
350
400
450
4
6
8
10
12
14
16
18
20
22
24
26
Percent of Total High Clouds (< 440 hPa)


Distribution of High Cloud Top Pressures
NOAA-18 HIRS and Aqua MODIS
60N-60S January 2008
HIRS (MODIS Alg.) Ascending Node
HIRS (MODIS Alg.) Descending Node
Aqua MODIS Ascending Node
Aqua MODIS Descending Node
Cloud Top Pressure (hPa)
100
150
200
250
300
350
400
450
4
6
8
10
12
14
16
18
20
22
24
26
Percent of Total High Clouds (< 440hPa)


NOAA-18 HIRS and Aqua MODIS High Cloud Frequencies
2008
60S-60N Latitude
Percent of Total Clouds
42
40
38
36
34
32
30
28
26
24
22
20
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
NOAA-18 HIRS Daytime (AN)
NOAA-18 HIRS Nighttime (DN)
Aqua MODIS Daytime (AN)
Aqua MODIS Nighttime (DN)

Main Points

HIRS radiance data is being processed with MODIS CO_2-slicing algorithm

A one-year comparison between HIRS and Aqua MODIS shows high cloud frequency distribution is geographically very similar but with a consistent bias of about +12% HIRS relative to MODIS; a little higher in the tropics

More high transmissive clouds detected by HIRS relative to Aqua MODIS due to necessary decreased sensitivity thresholds (higher ΔR) for MODIS; may point to multiple detector issues on MODIS

*Aqua MODIS cloud data is well characterized by comparisons to CALIOP lidar (A-train); hence, confidence in HIRS results (30+ years) is increased if HIRS and MODIS compare well

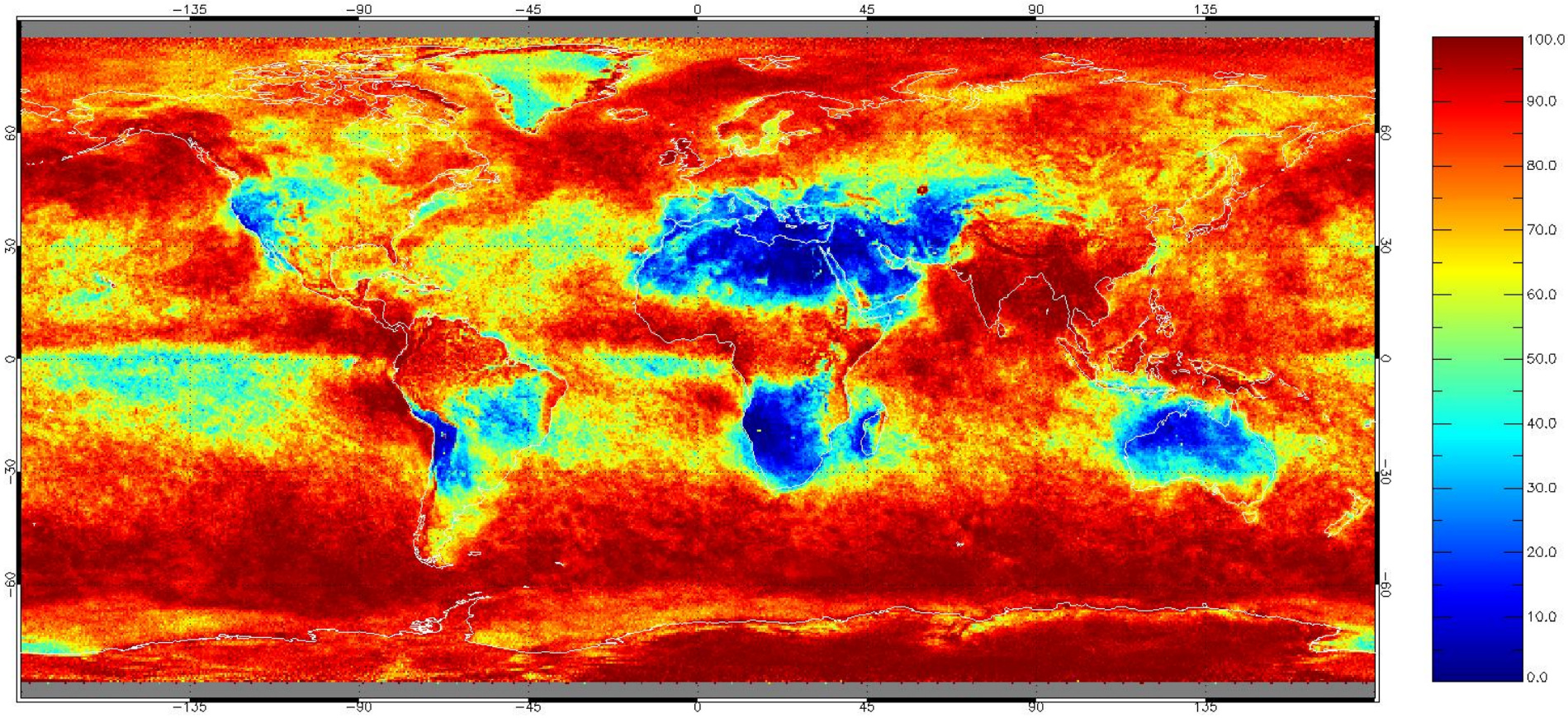
Future work:

Process 10 years of HIRS data and compare with 10 years of MODIS; do HIRS and MODIS time series of high cloud distributions match?

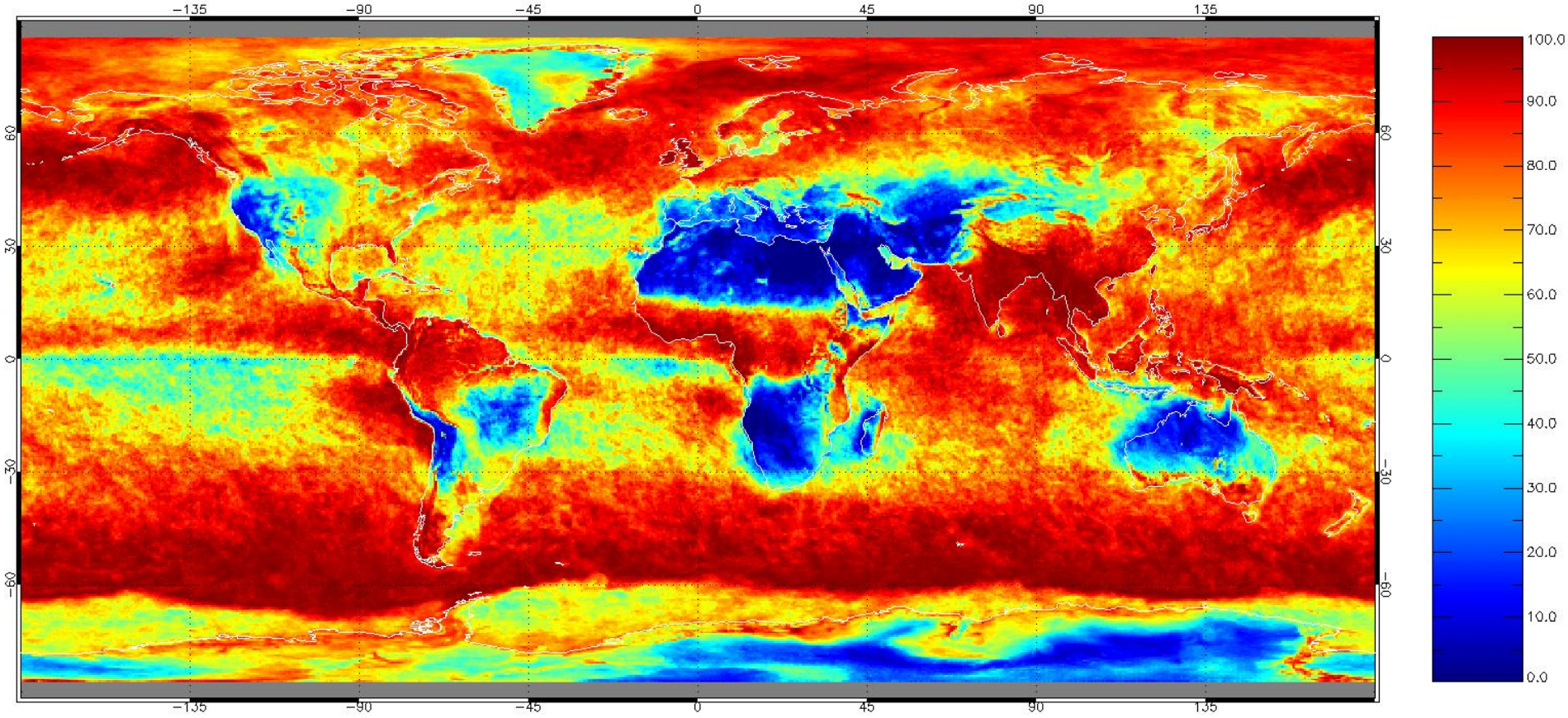
Process 30 years of HIRS data with MODIS algorithm; look for high cloud trends or changes

Compare CALIOP vs. HIRS and CALIOP vs. Aqua MODIS for 2008; does lower HIRS ΔR yield false high clouds?

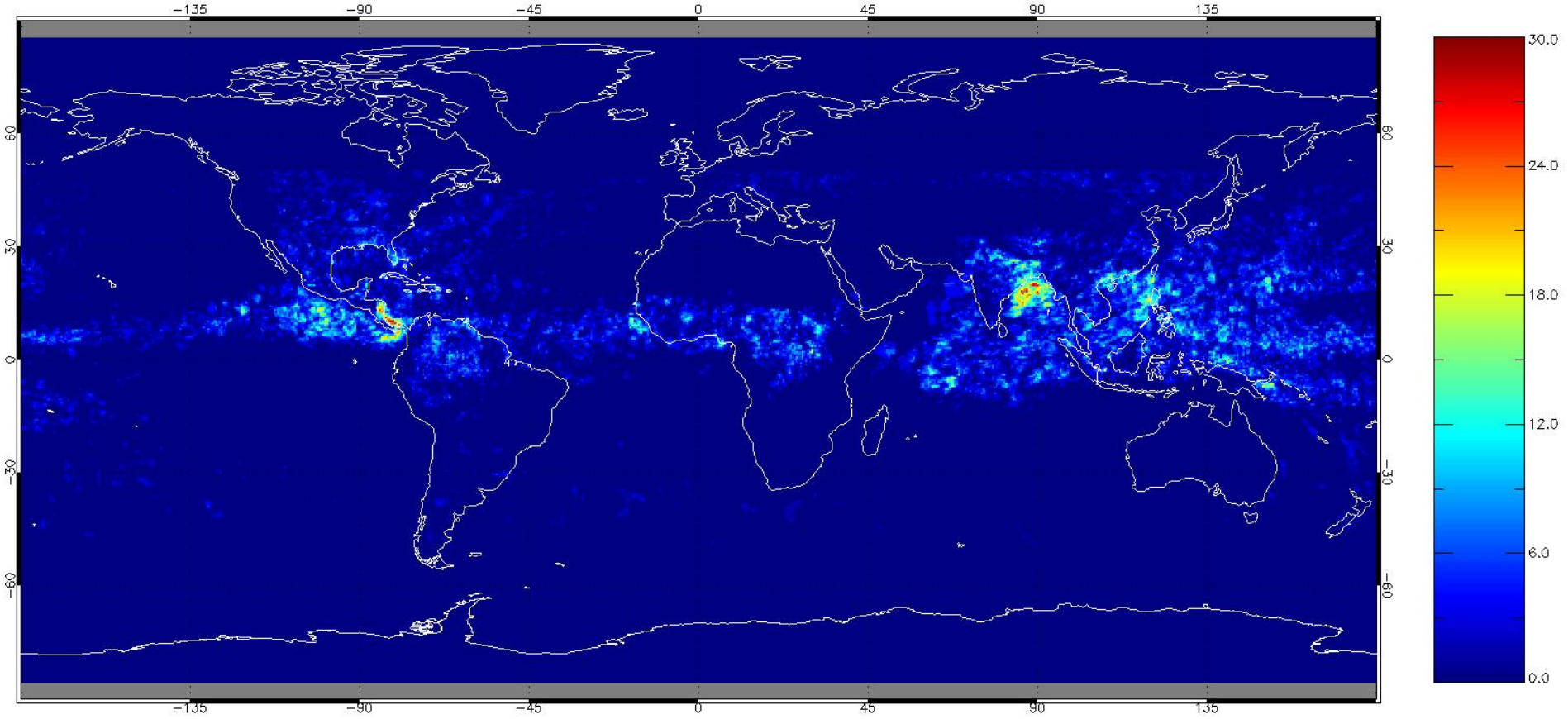
HIRS JJA 2008 AN (60S-60N Day) Cloud Frequency
PATMOS-x from Collocated AVHRR GAC



MODIS JJA 2008 AN (60S-60N Day) Cloud Frequency
MOD35 from 1-km MODIS Pixels

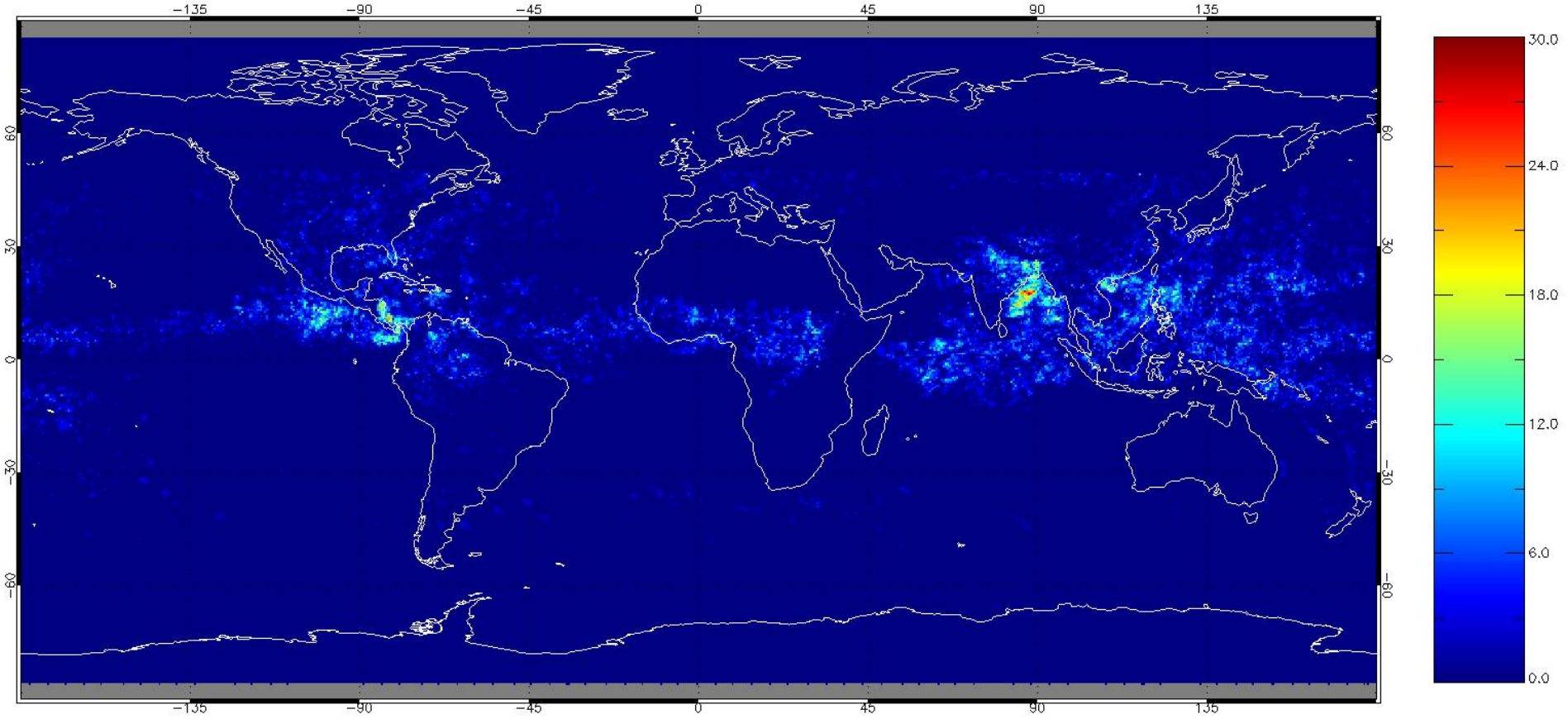


Aqua MODIS Daytime (AN) UTLS Cloud Frequency
JJA



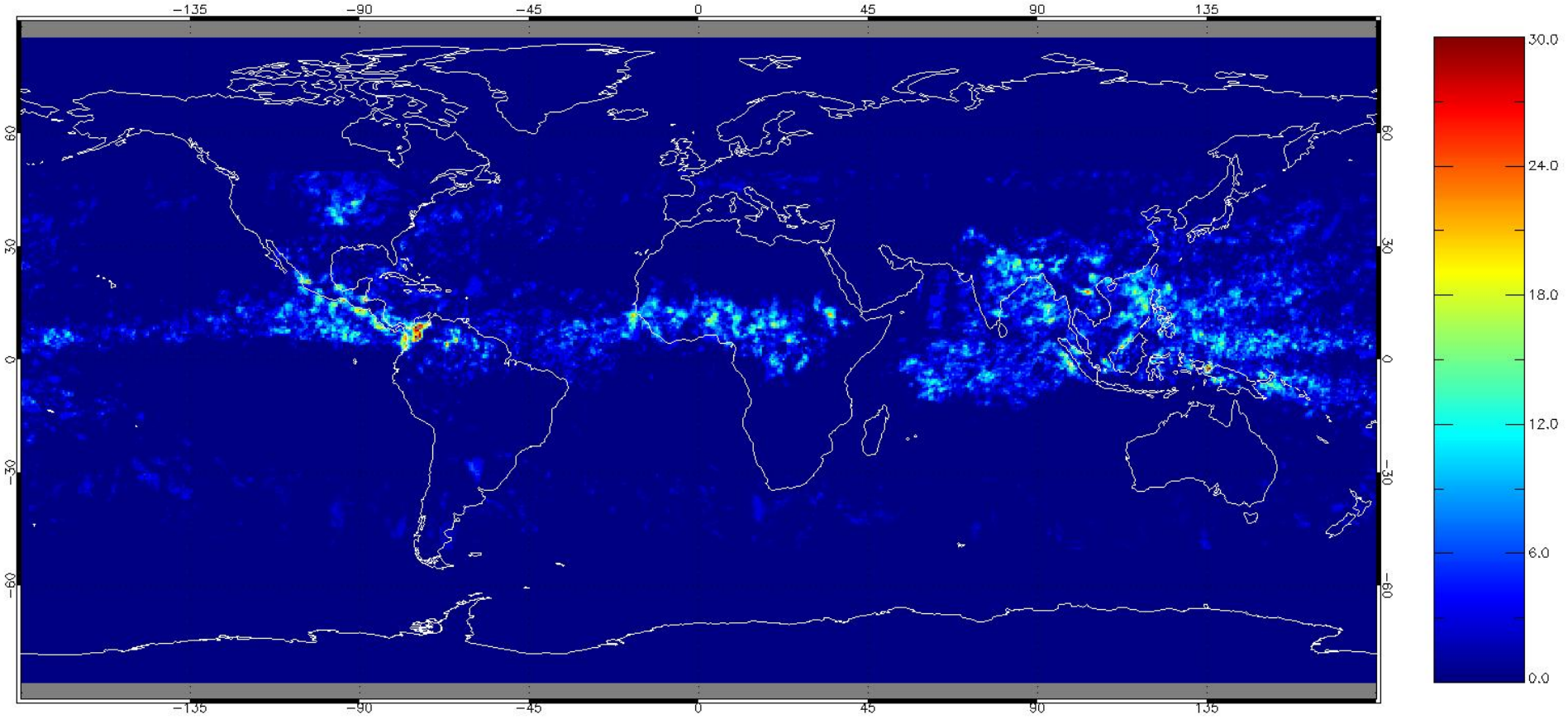
UTLS clouds where (13.9 µm BT – 13.3 µm BT) > 0.5K
50S-50N

NOAA-18 HIRS Daytime (AN) UTLS Cloud Frequency
JJA



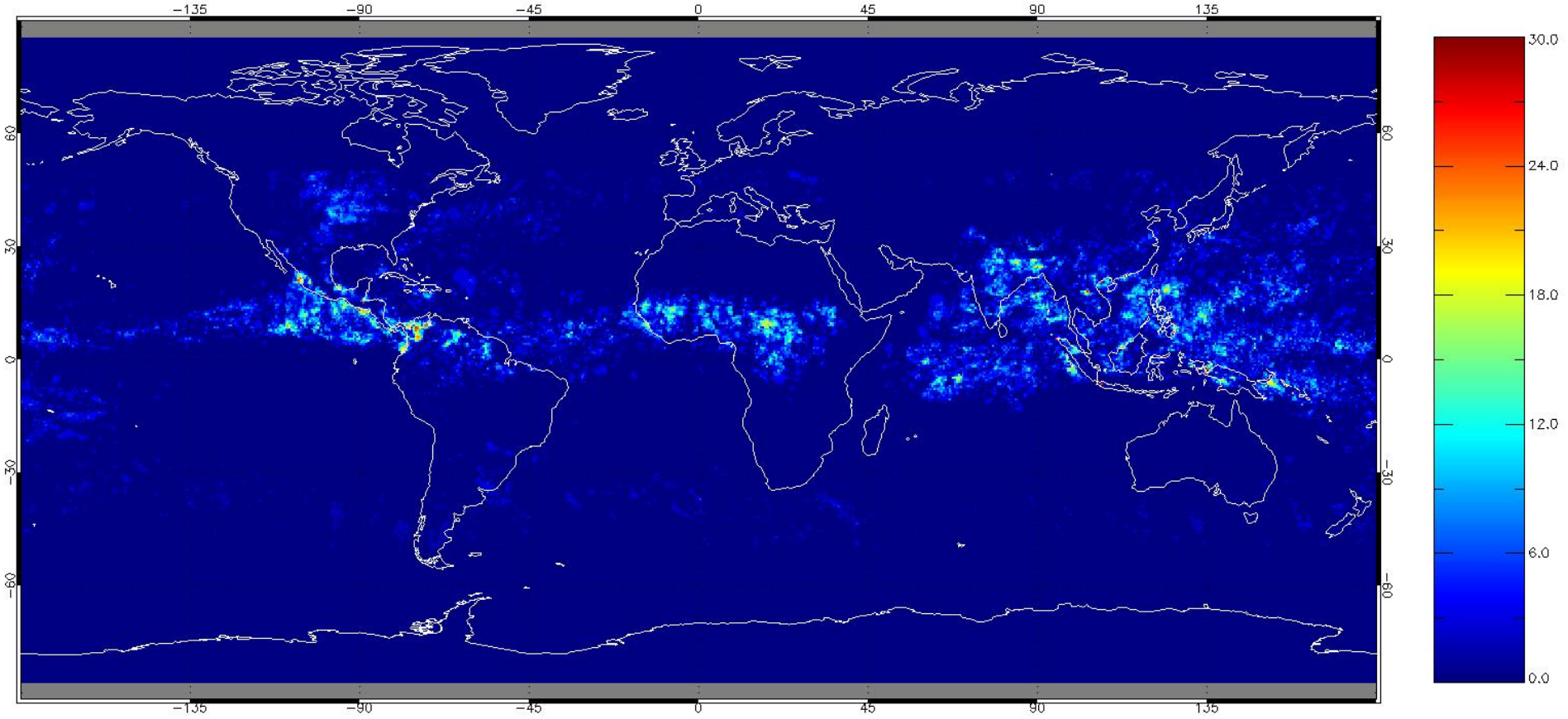
UTLS clouds where (13.9 µm BT – 13.3 µm BT) > 0.5K
50S-50N

Aqua MODIS Nighttime (DN) UTLS Cloud Frequency
JJA

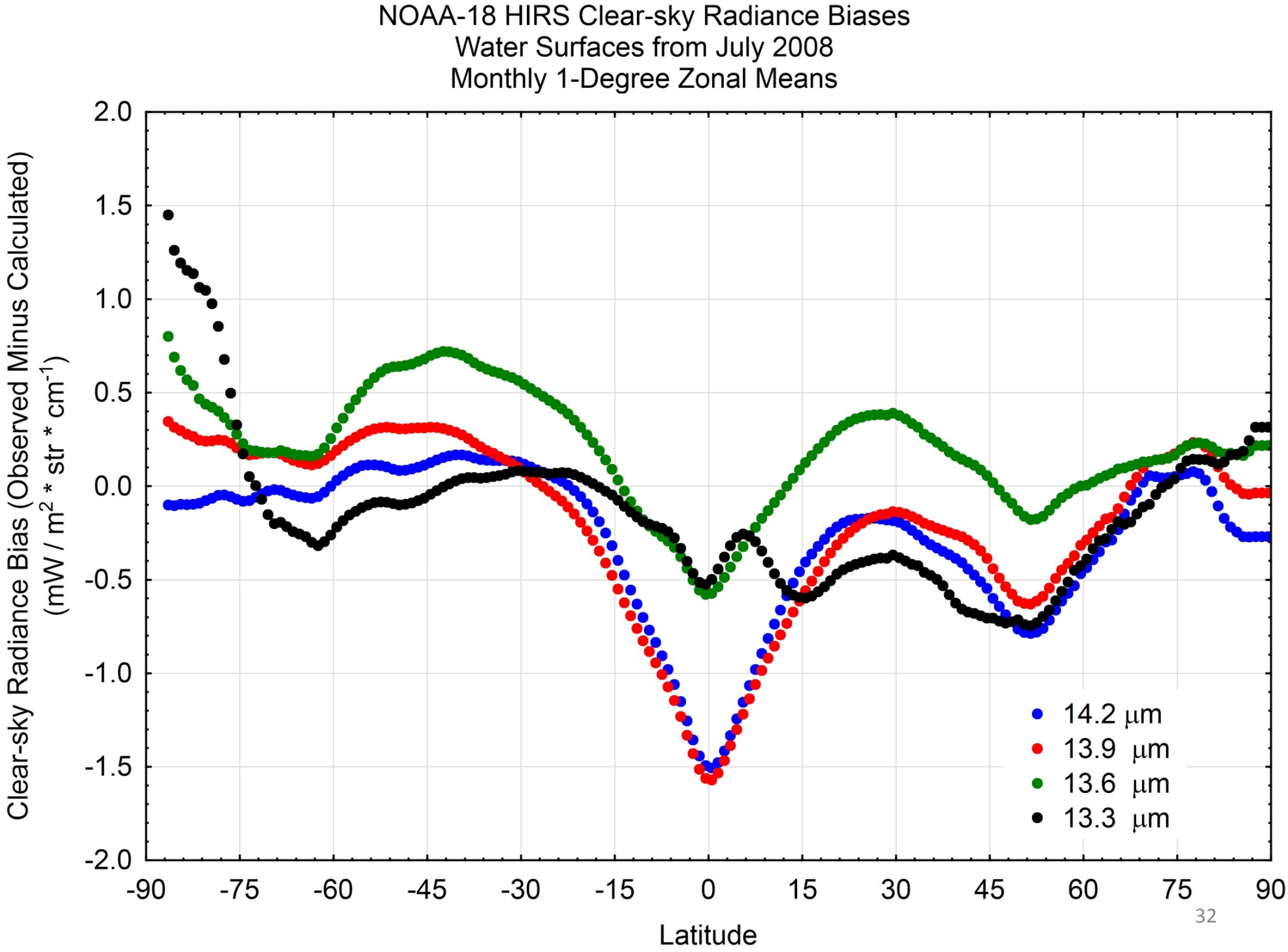


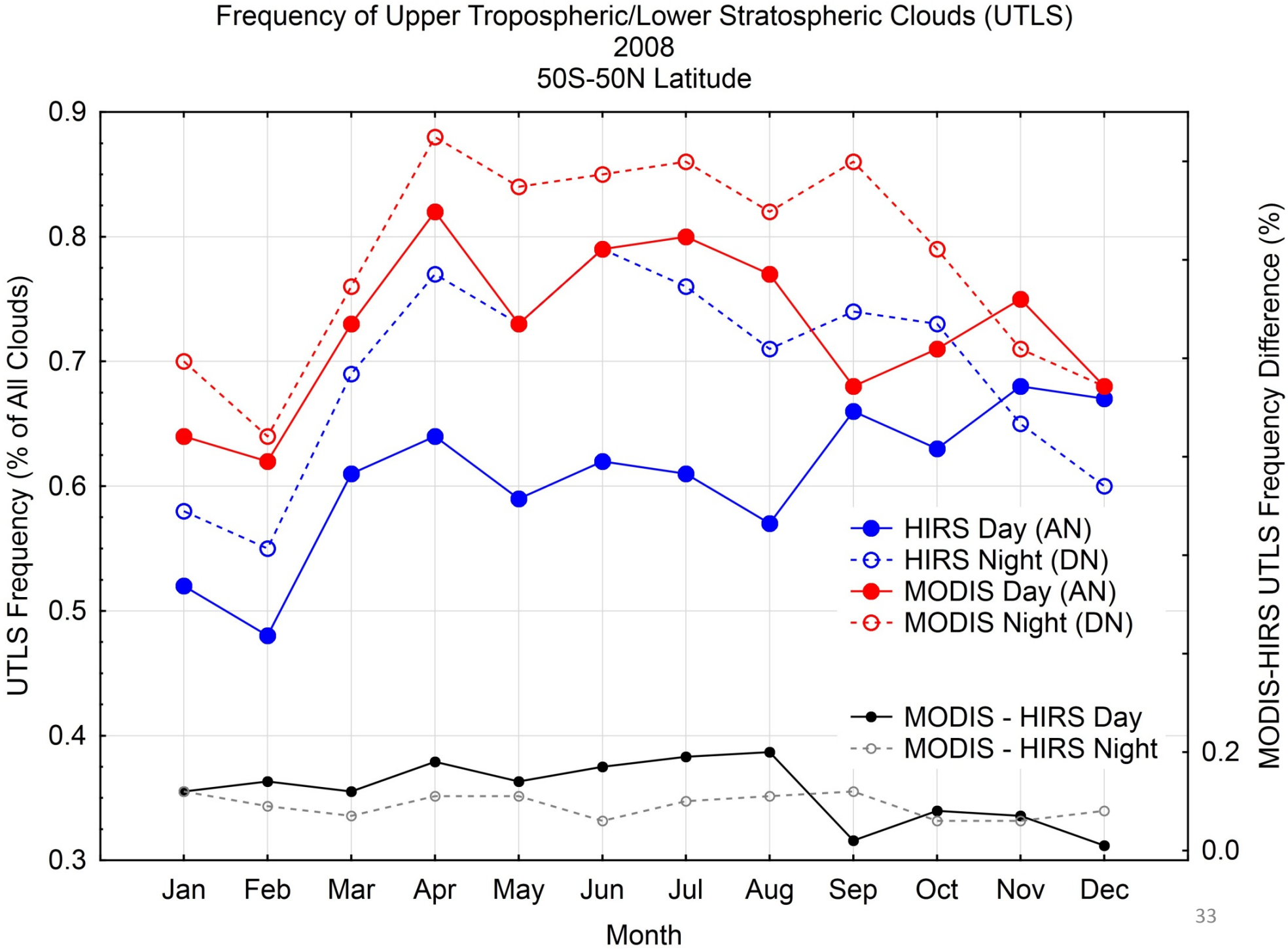
UTLS clouds where (13.9 µm BT – 13.3 µm BT) > 0.5K
50S-50N

NOAA-18 HIRS Nighttime (DN) UTLS Cloud Frequency
JJA

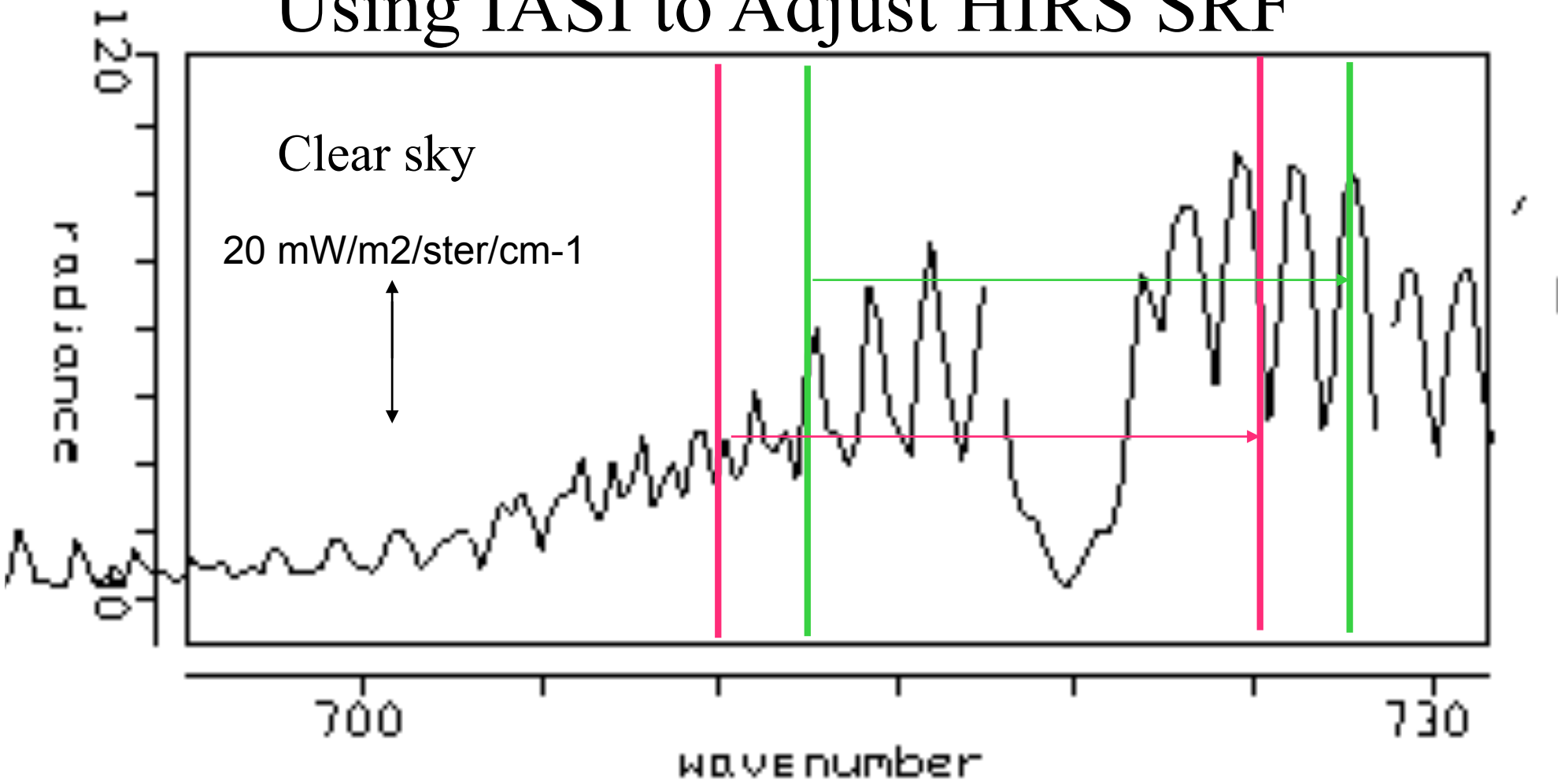


UTLS clouds where (13.9 µm BT – 13.3 µm BT) > 0.5K
50S-50N


NOAA-18 HIRS Clear-sky Radiance Biases
Water Surfaces from July 2008
Monthly 1-Degree Zonal Means
Clear-sky Radiance Bias (Observed Minus Calculated)
(mW / m2 * str * cm-1)
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-90
-75
-60
-45
-30
-15
0
15
30
45
60
75
90
Latitude
14.2 μm
13.9 μm
13.6 μm
13.3 μm


Frequency of Upper Tropospheric/Lower Stratospheric Clouds (UTLS)
2008
50S-50N Latitude
UTLS Frequency (% of All Clouds)
MODIS-HIRS UTLS Frequency Difference (%)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
HIRS Day (AN)
HIRS Night (DN)
MODIS Day (AN)
MODIS Night (DN)
MODIS - HIRS Day
MODIS - HIRS Night

Using IASI to Adjust HIRS SRF



* Bandwidth ~ 15 cm-1
* Shift of 2.5 cm-1, ΔTb ~ 2 K, ΔR ~3 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 extra cloud detection

See Chen et. al., JGR, vol. 118, June 2013