Inferring Global Cloud Cover Properties and Trends from 30 years of HIRS Data

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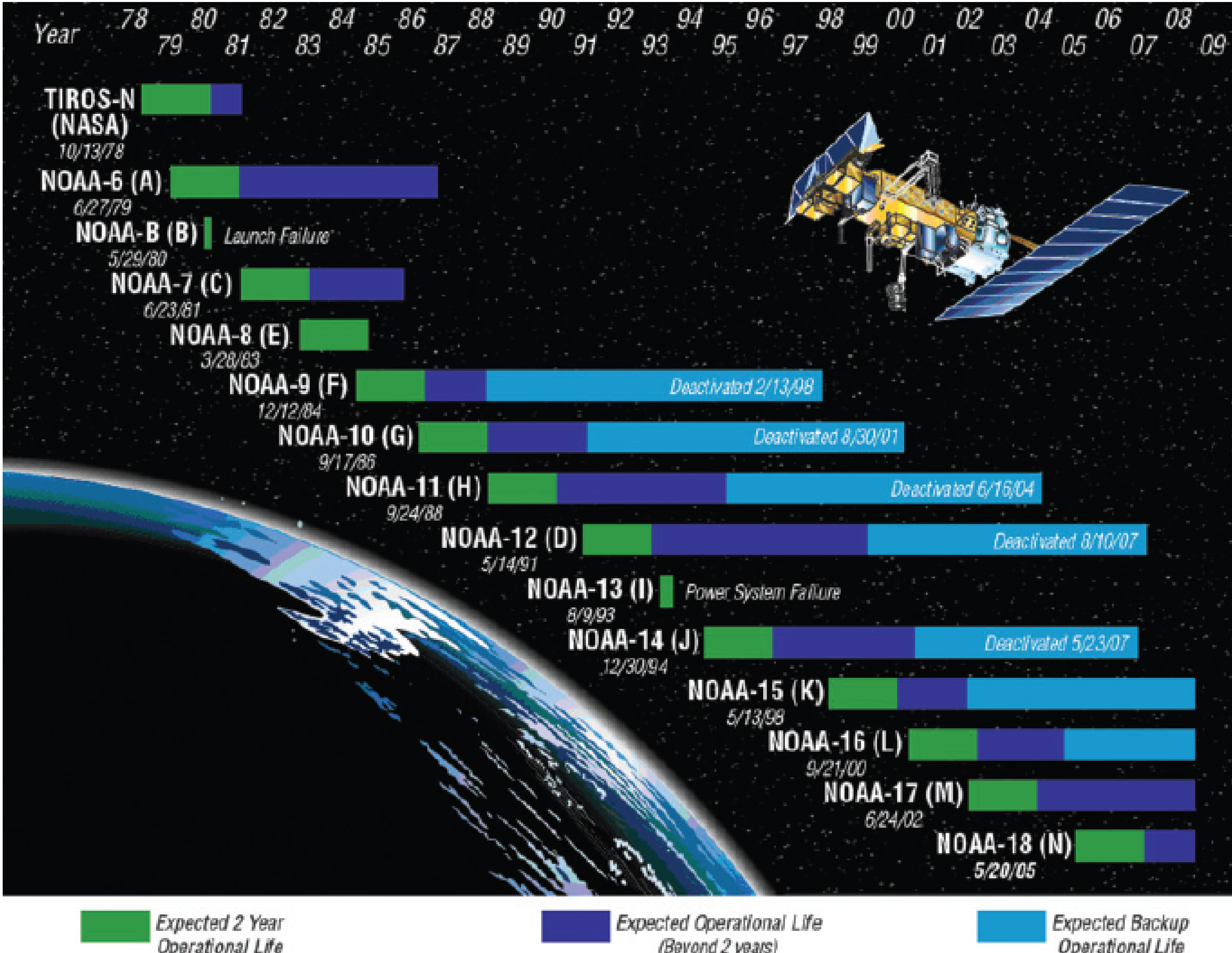
CO2 Slicing and the Wylie et al (2005) results
Algorithm Adjustments
Reprocessing HIRS CO2 Cloud Measurements
Trends from 1990s to 2000s
Combining Imager and Sounder Measurements
Conclusions

April 2010



Year
78
80
82
84
86
88
90
92
94
96
98
00
02
04
06
08
79
81
83
85
87
89
91
93
95
97
99
01
03
05
07
09
TIROS-N (NASA)
10/13/78
NOAA-6 (A)
6/27/79
NOAA-B (B)
Launch Failure
5/29/80
NOAA-7 (C)
6/23/81
NOAA-8 (E)
3/28/83
NOAA-9 (F)
Deactivated 2/13/98
12/12/84
NOAA-10 (G)
Deactivated 8/30/01
9/17/86
NOAA-11 (H)
Deactivated 6/16/04
9/24/88
NOAA-12 (D)
Deactivated 8/10/07
5/14/91
NOAA-13 (I)
Power System Failure
8/9/93
NOAA-14 (J)
Deactivated 5/23/07
12/30/94
NOAA-15 (K)
5/13/98
NOAA-16 (L)
9/21/00
NOAA-17 (M)
6/24/02
NOAA-18 (N)
5/20/05
Expected 2 Year Operational Life
Expected Operational Life (Beyond 2 years)
Expected Backup Operational Life

CTPs using CO2 Slicing

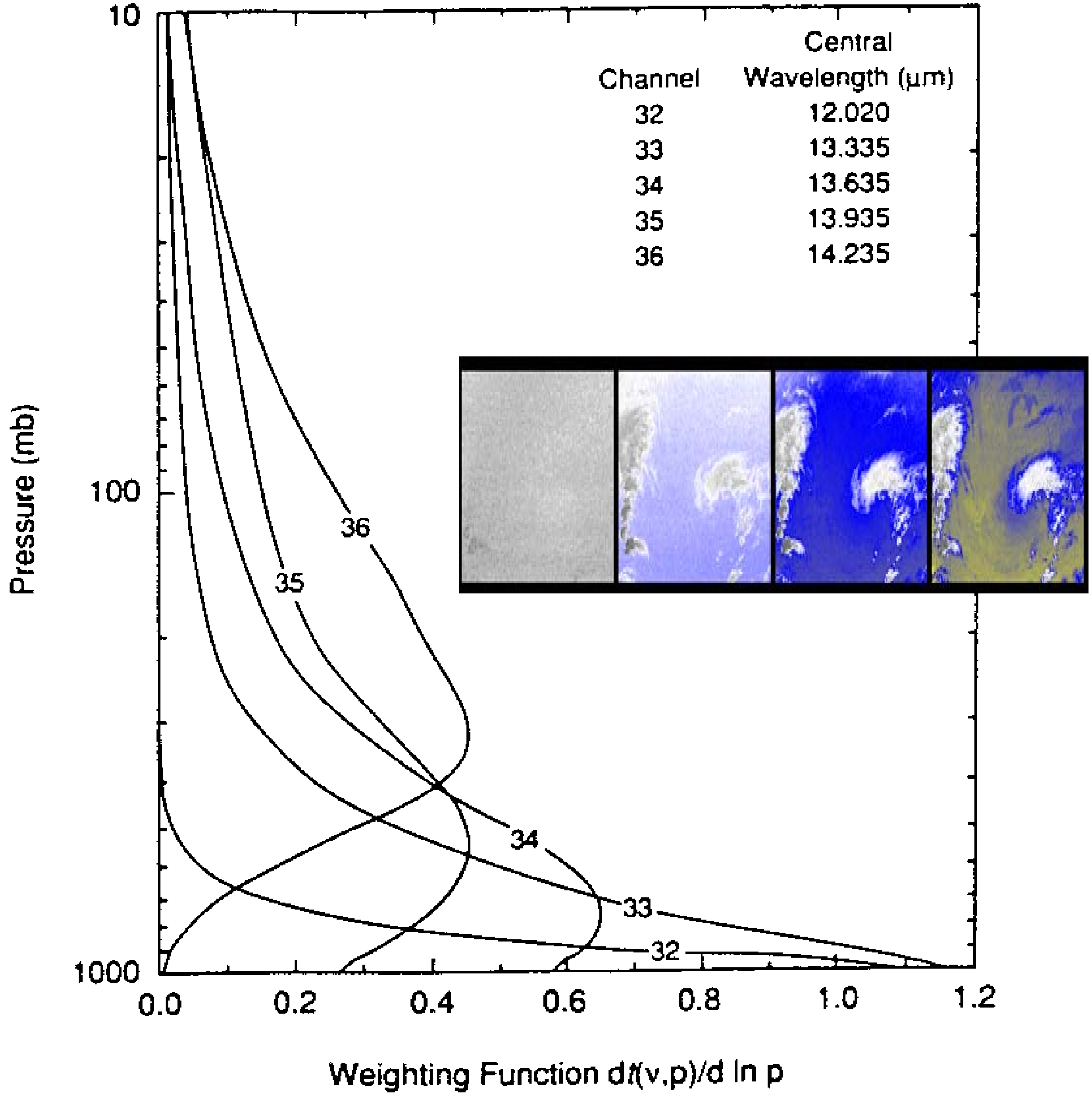
Different ratios reveal cloud properties at different levels

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

Meas   **Calc**

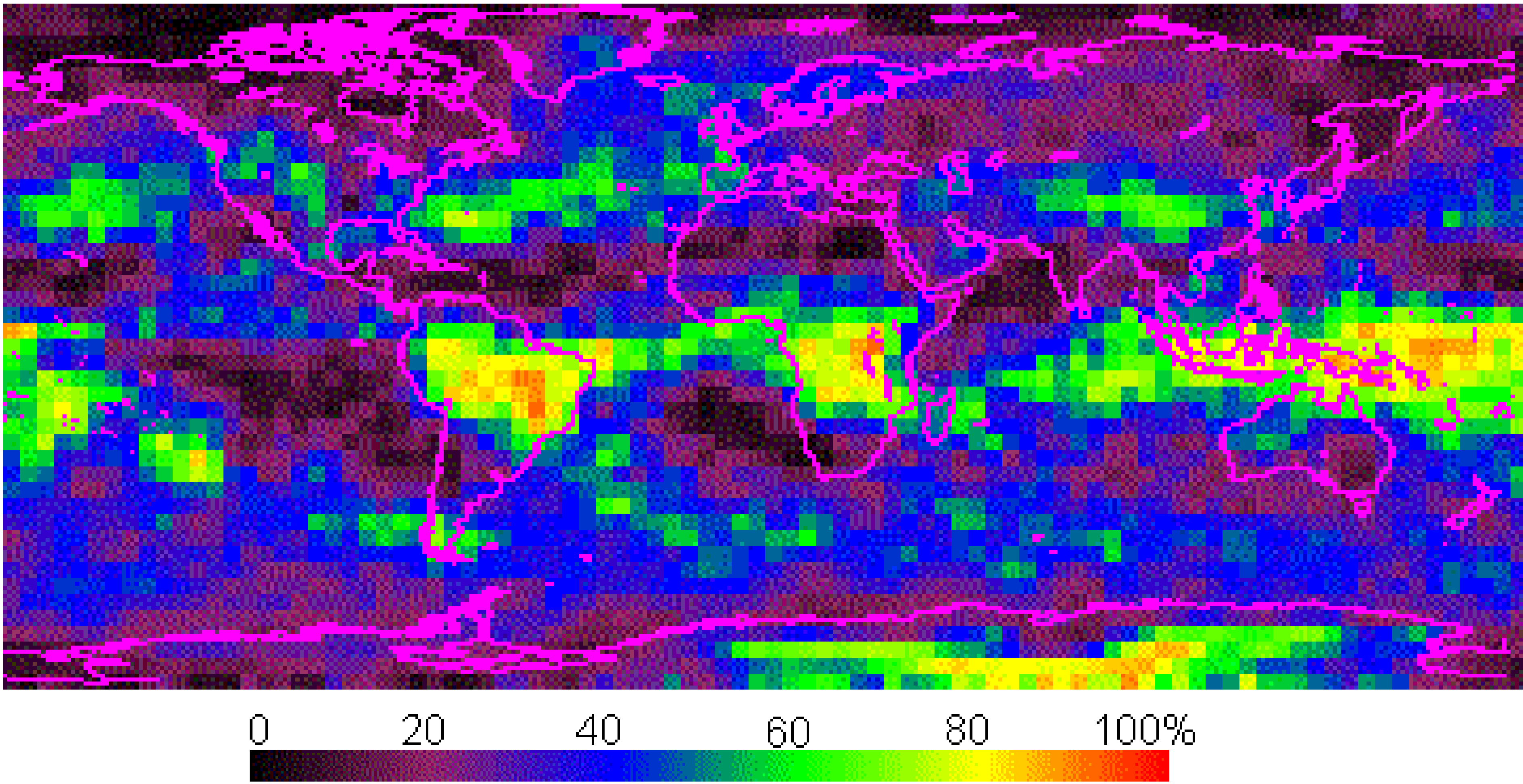
$$\frac{(I_{\lambda 1}-I_{\lambda 1}^{clr})}{(I_{\lambda 2}-I_{\lambda 2}^{clr})} = \frac{\eta\varepsilon_{\lambda 1}\int_{p_s}^{p_c}\tau_{\lambda 1}\, dB_{\lambda 1}}{\eta\varepsilon_{\lambda 2}\int_{p_s}^{p_c}\tau_{\lambda 2}\, dB_{\lambda 2}}$$

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

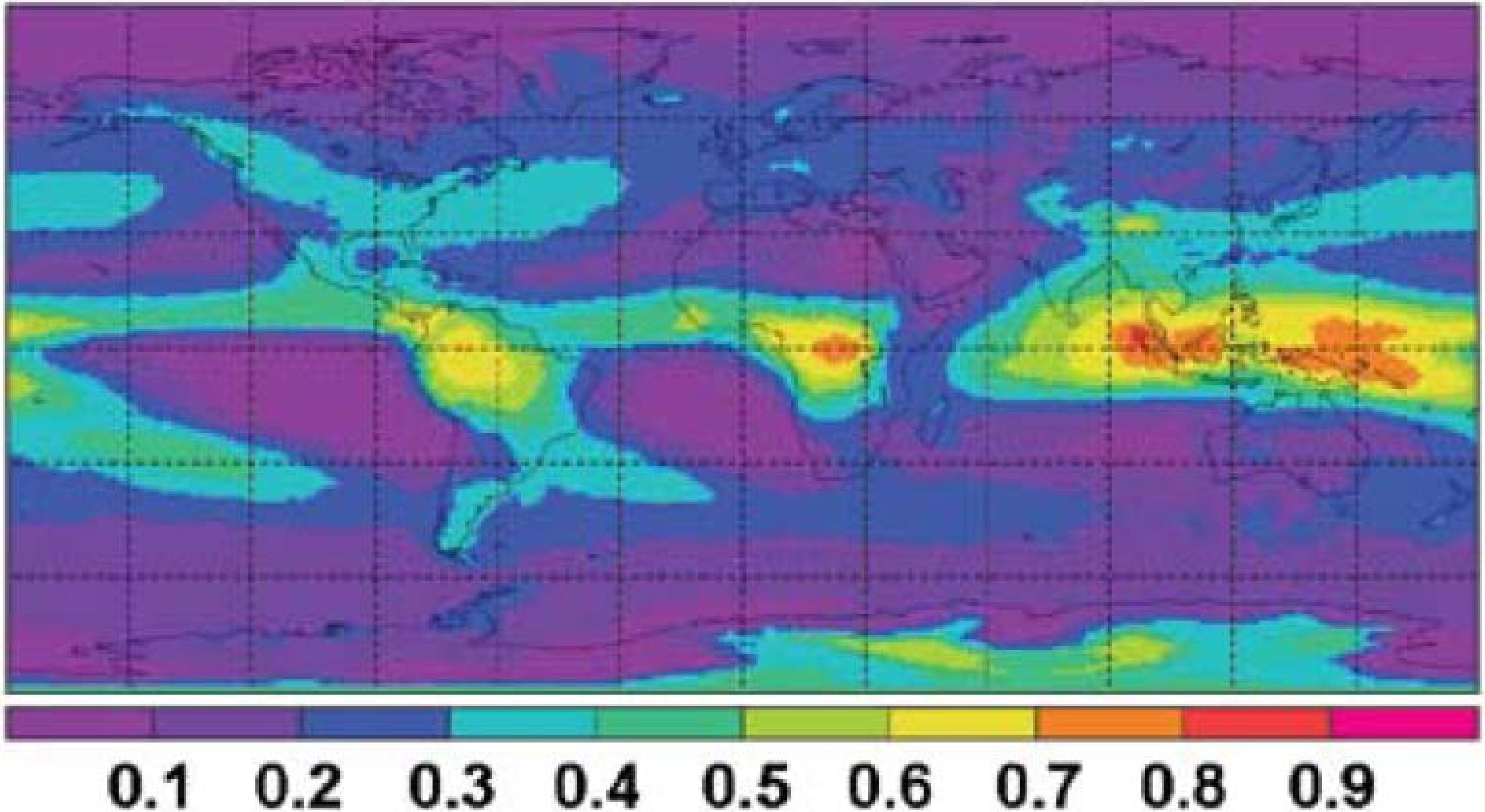


HIRS Results in Wylie et al (2005)

* only near nadir observations from pm orbits processed
* clear sky radiance calculated from NCEP re-analysis
* orbit drift (adjusted to 2 pm)
* constant CO_2 (adjusted for 2% less high clouds in 335 ppm vs 380 ppm)



HIRS High Cloud detection over 20 years



AIRS High Cloud detection over 6 years

Reprocessing HIRS CO2 Cloud Measurements

Adjustments to HIRS Cloud Processing

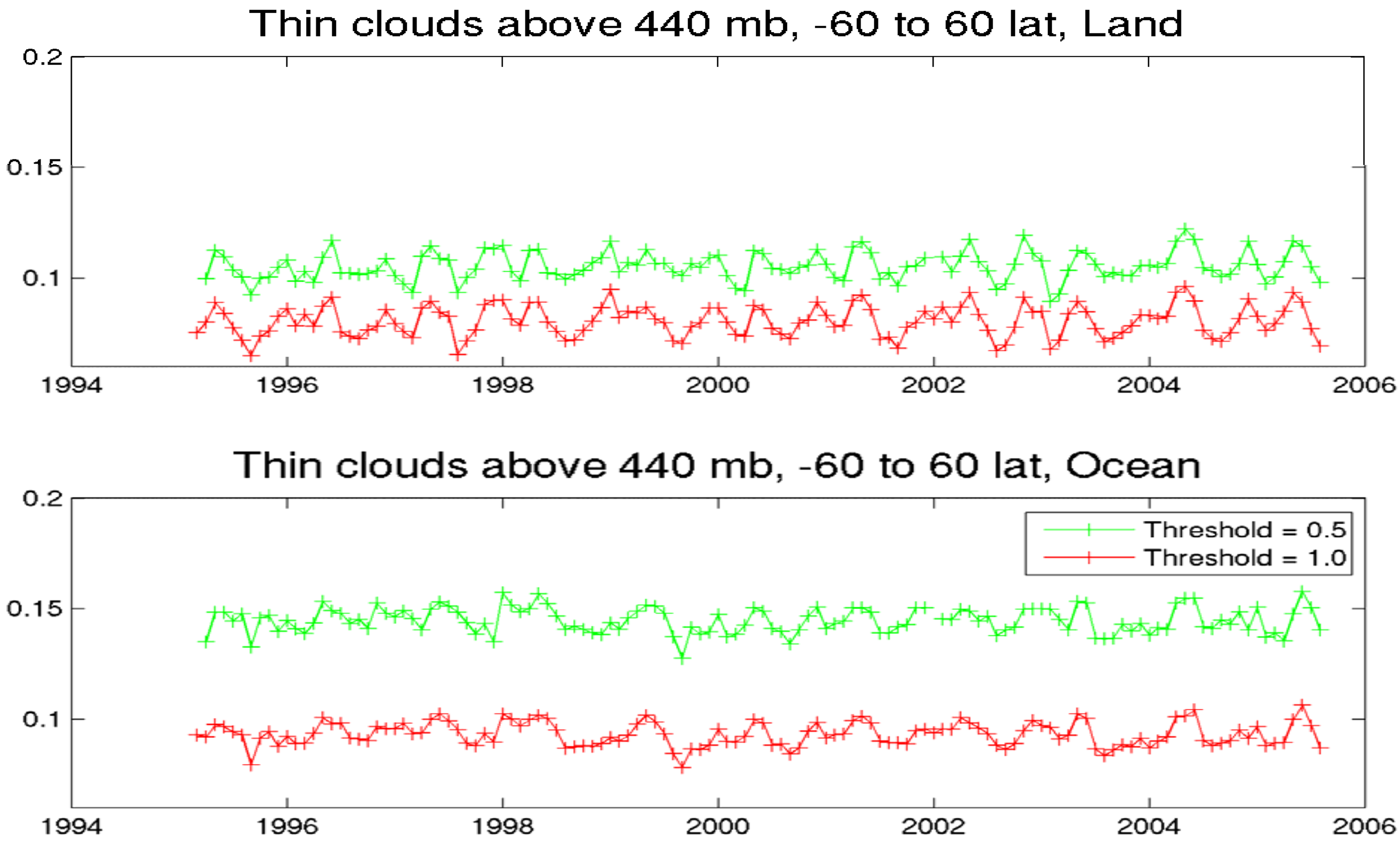
Done

- Use "top-down” method where most opaque channel pair seeing cloud derives CTP
- **Lower the "noise" thresholds** (clear minus cloudy radiances required to indicate cloud presence in CO2 bands) to force more CO2 slicing solutions for high thin clouds.
- Adjust ozone profile between 10 and 100 hPa to GDAS values instead of using climatology (so that CO2 radiances influenced by O3 profiles are calculated correctly).
- **Implement CO2 spectral band shifts** suggested by comparisons with AIRS
- **Identify stratospheric clouds** when opaque band is warmer than less opaque band
- **Incorporate sinusoidal CO2 increase**

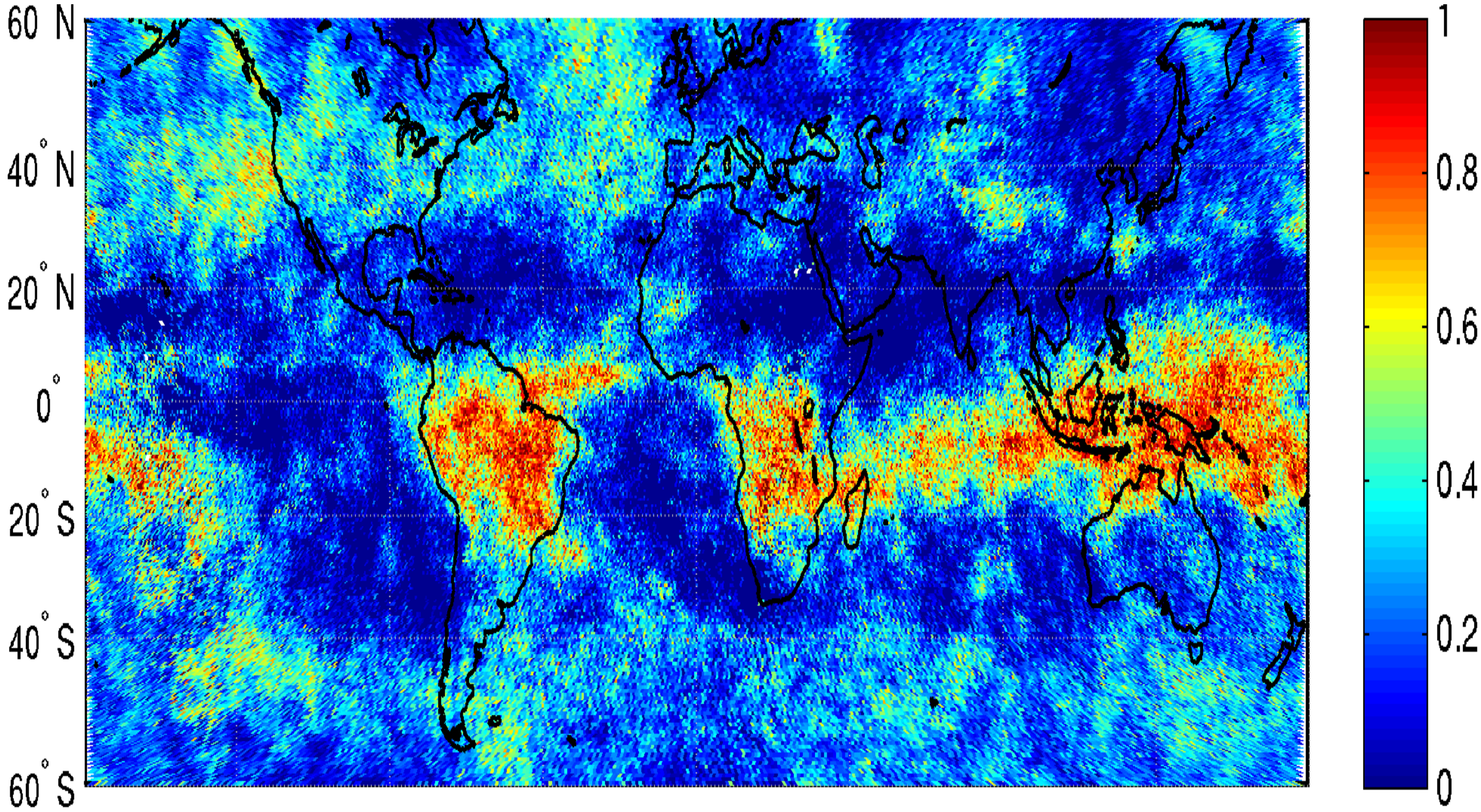
Pending

- Prohibit CO2 slicing solutions for water clouds; use only IRW solution. Avoid IRW solutions for ice clouds; use CO2 slicing whenever possible.
- Restrict CO2 channel pair solutions to appropriate portion of troposphere (determined by their weighting functions).
- Add marine stratus improvement (constant lapse rate in low level inversions)

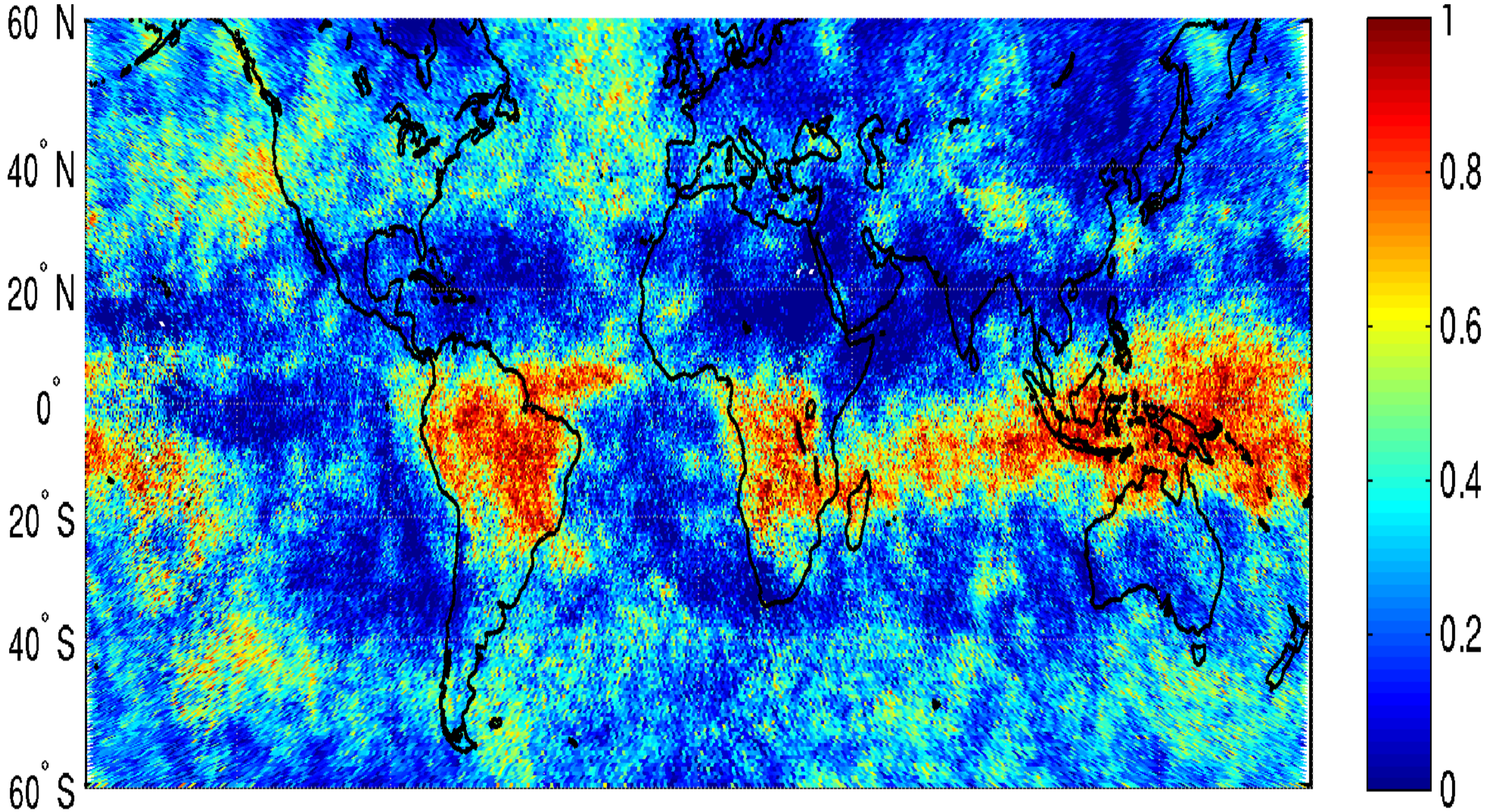
Changing Cloud Detection Threshold



About 5 % of low opaque clouds are correctly defined as high thin clouds when [Rclear – Rcloud] > NEDR threshold is changed from 1.0 to 0.5 mW/m2/ster/cm-1



January 1997 NOAA-14 % of High Cloud Observations NEDR=1.0



January 1997 NOAA-14 % of High Cloud Observations NEDR=0.5

CO2 Ramp

$$F(x) = [\, m\, x + a*\sin(2\pi x/365)] + b$$

where

x = # days since 1 Jan 1980

m = 1.5 ppmv / 365

b = 337.5 ppmv

a = 3 ppmv

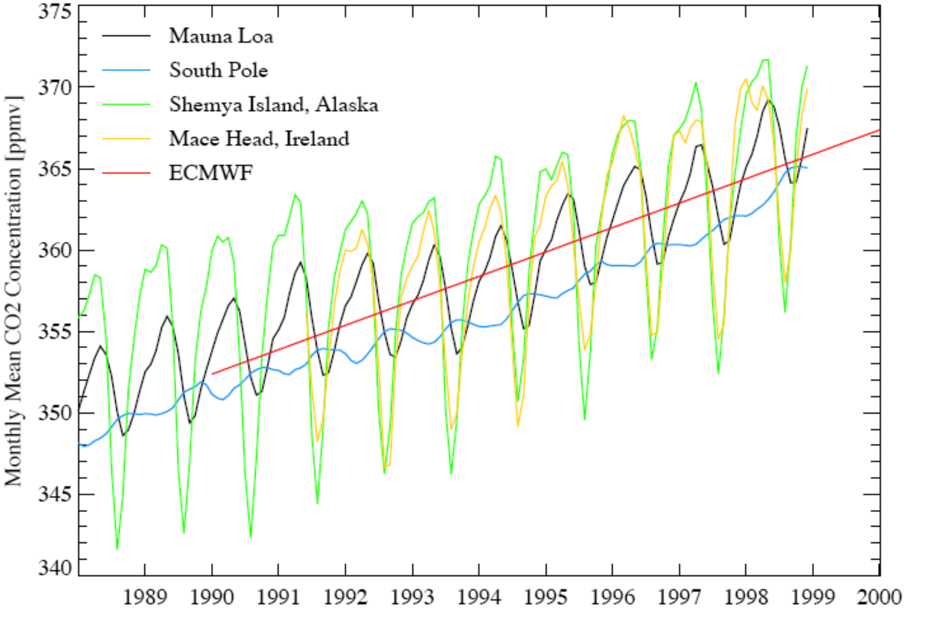
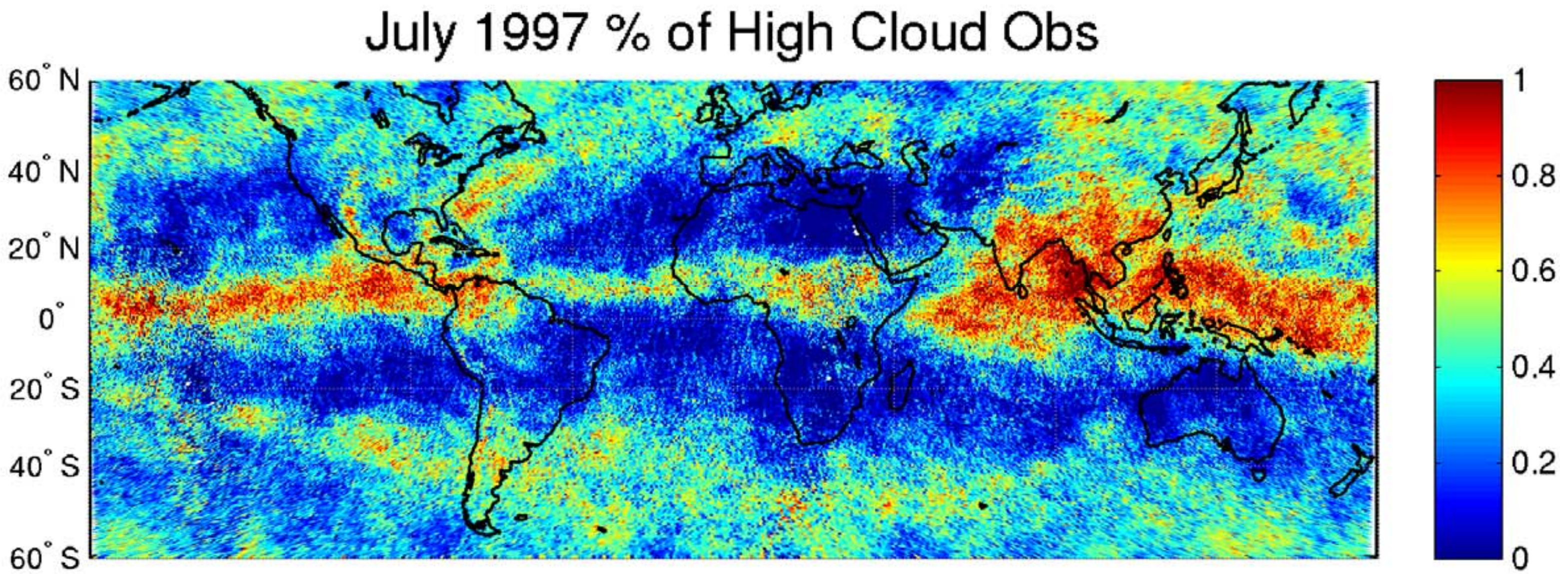
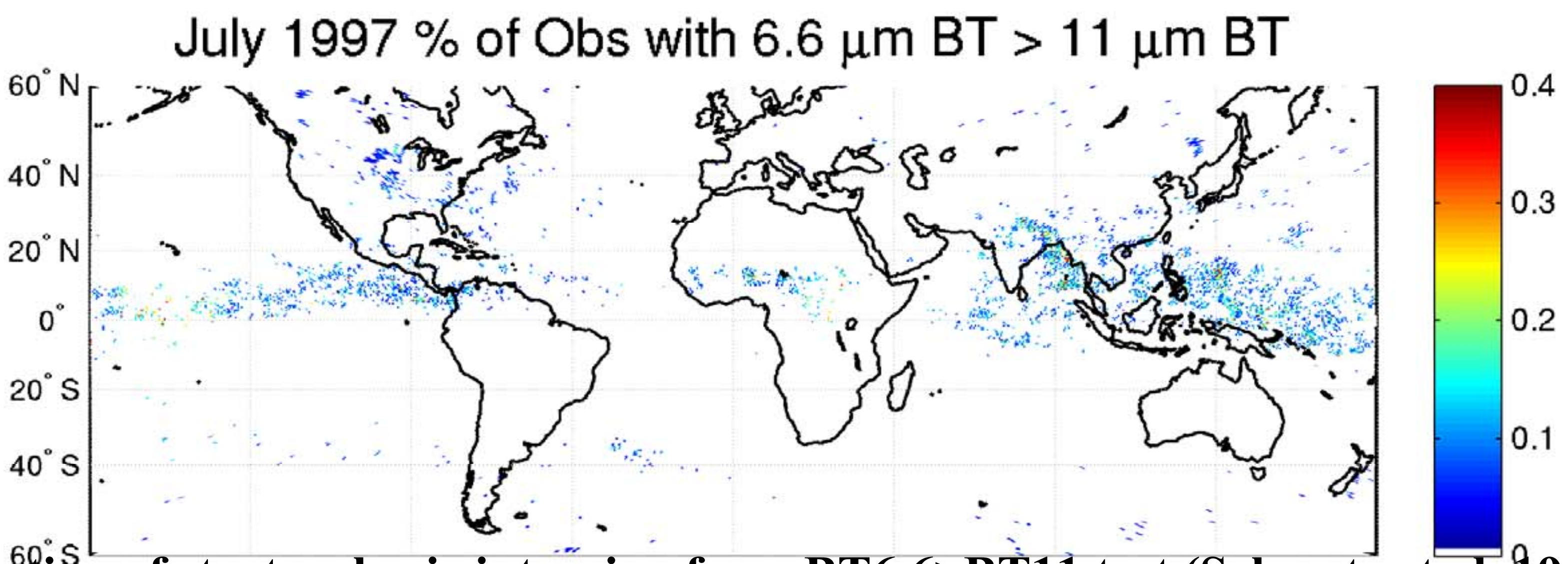


Figure 1. Time series of monthly mean surface CO_2 volume mixing ratios for 4 flask stations. The red line represents the values used by ECMWF. From Engelen et al (2001)

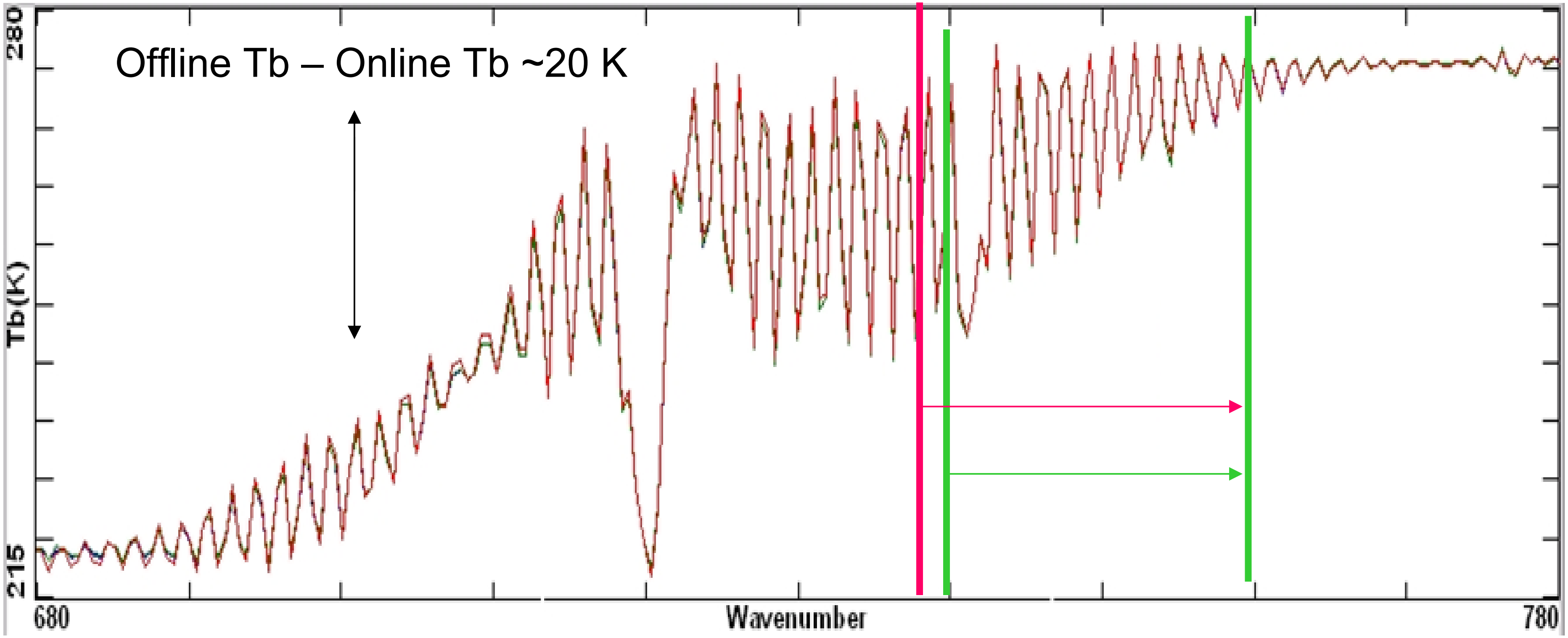
Stratospheric Cloud Identification





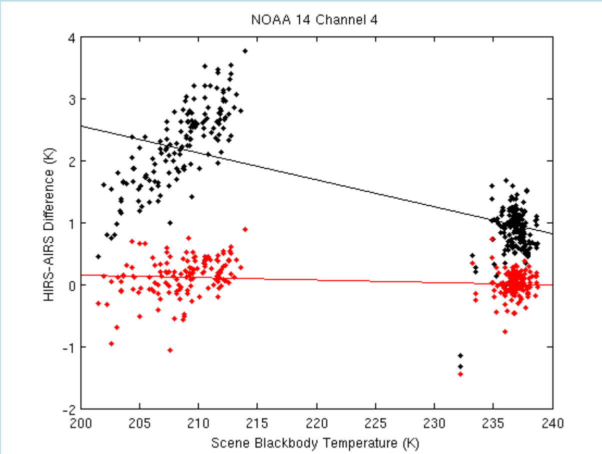
Detection of stratospheric intrusion from BT6.6>BT11 test (Schmetz et al, 1997) will help improve high cloud determination

Using AIRS to Adjust HIRS SRF

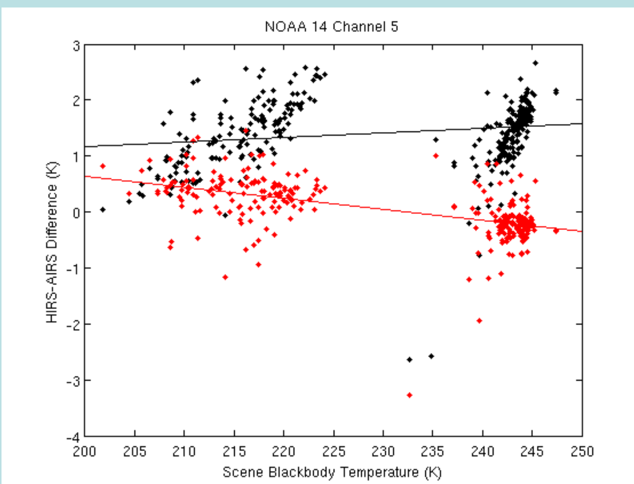


* Bandwidth ~ 20 cm-1 includes roughly 12 peaks and 12 valleys
* Including extra peak implies ΔTb ~ +2 K or ΔR ~ +1 mW/m2/ster/cm-1
* Then calculation of clear sky radiance obs would be off by ΔR
  which would affect determination of Pc
* Warmer clear sky calculation introduces extra false cloud detection

N14 Channel 4



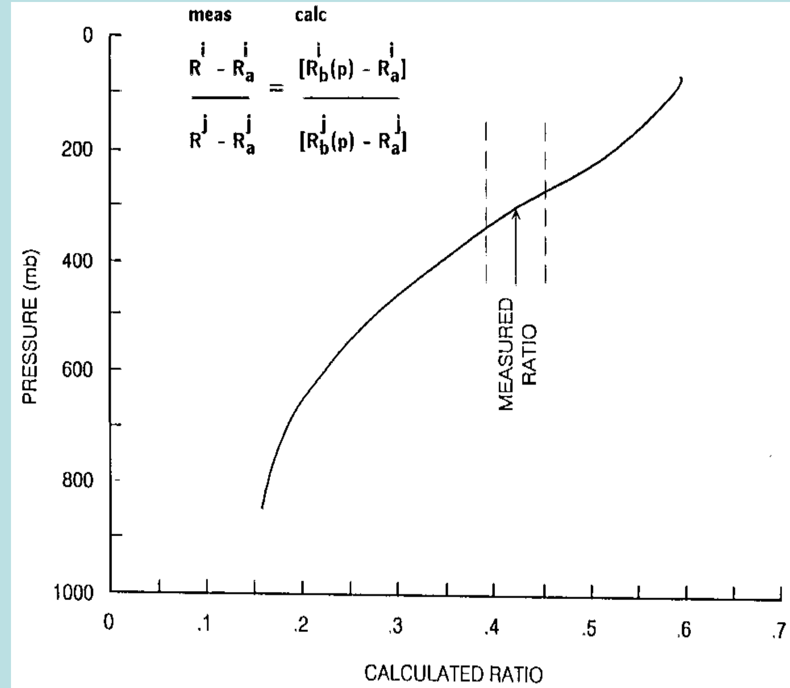
N14 Channel 5



$(I_4^{clr}-I_4)$ is too small (wrt to AIRS)

$(I_5^{clr}-I_5)$ is too large (wrt to AIRS)

So cloud forcing ratio 4/5 is too small



$$\frac{(I_{\lambda1}^{clr} - I_{\lambda1})}{(I_{\lambda2}^{clr} - I_{\lambda2})} = \frac{\eta\varepsilon_{\lambda1} \int_{p_s}^{p_c} \tau_{\lambda1}\, dB_{\lambda1}}{\eta\varepsilon_{\lambda2} \int_{p_s}^{p_c} \tau_{\lambda2}\, dB_{\lambda2}}$$

as ratio increases, p_c decreases

Spectral Shifts used for N14

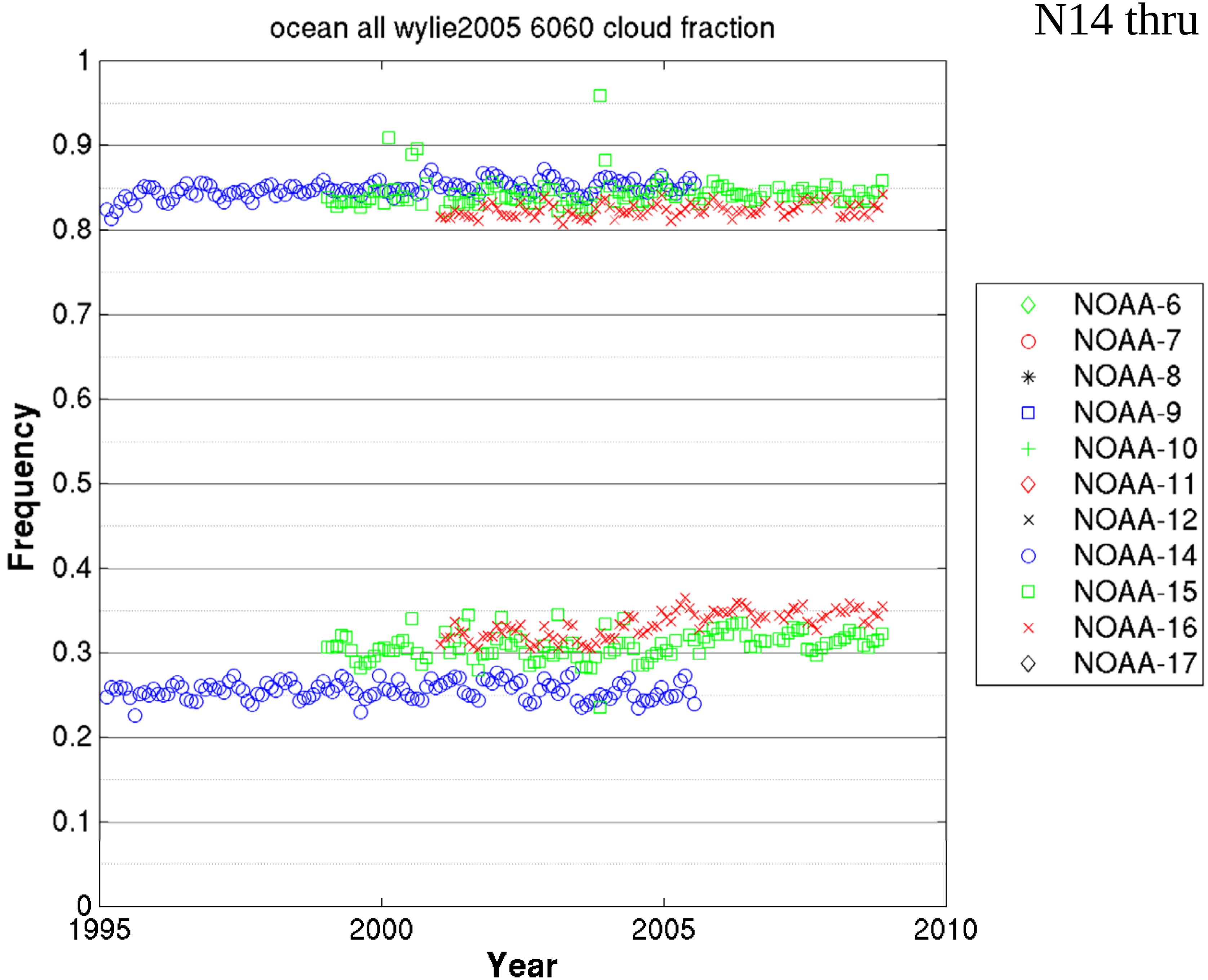
Ch4	14.2um	704 cm-1	+2.0 cm-1
Ch5	13.9	719	+2.5
Ch6	13.6	735	+3.0
Ch7	13.3	750	+1.5

Spectral Shifts used for N15 & N16

none

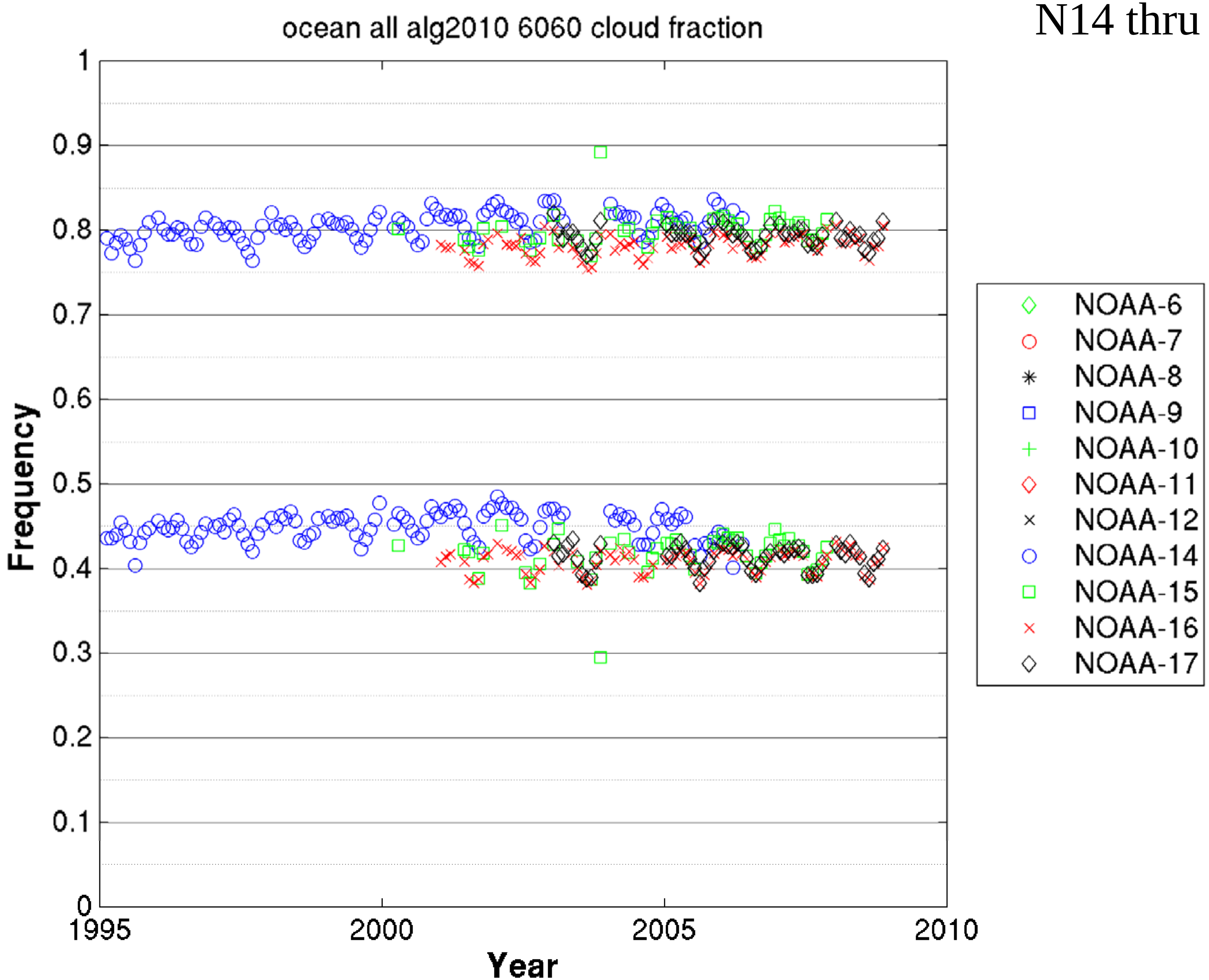
HIRS Reprocessing Results

N14 thru N16



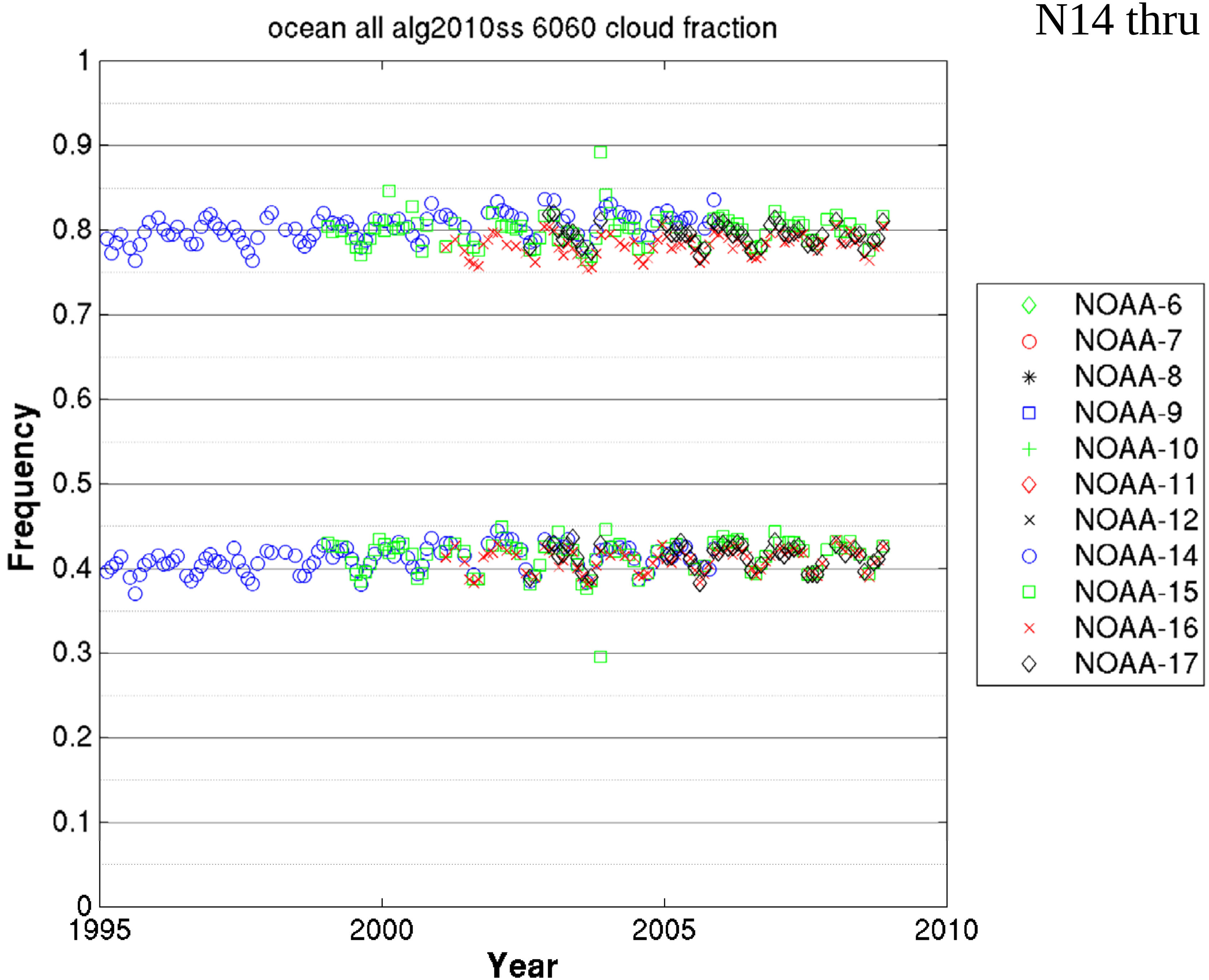
ocean all wylie2005 6060 cloud fraction
Frequency
Year
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1995
2000
2005
2010
NOAA-6
NOAA-7
NOAA-8
NOAA-9
NOAA-10
NOAA-11
NOAA-12
NOAA-14
NOAA-15
NOAA-16
NOAA-17

N14 thru N17

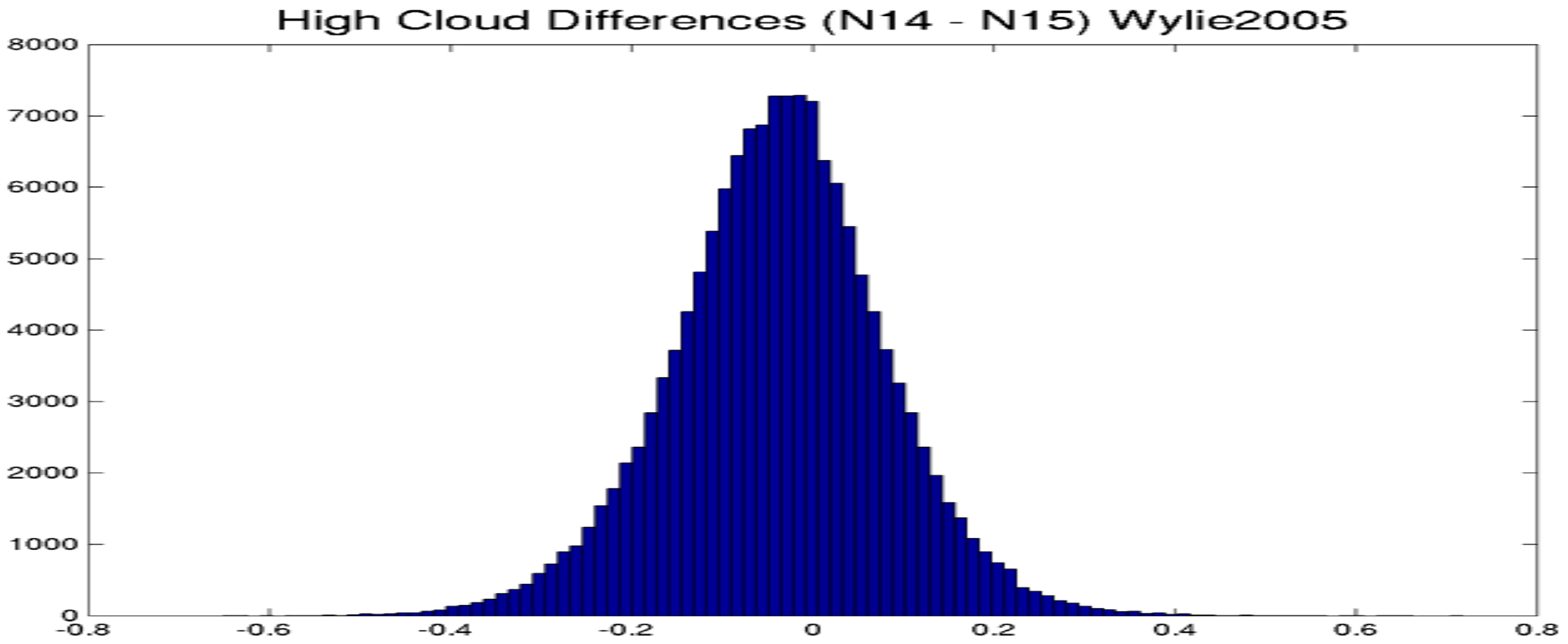


ocean all alg2010 6060 cloud fraction
Frequency
Year
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1995
2000
2005
2010
NOAA-6
NOAA-7
NOAA-8
NOAA-9
NOAA-10
NOAA-11
NOAA-12
NOAA-14
NOAA-15
NOAA-16
NOAA-17

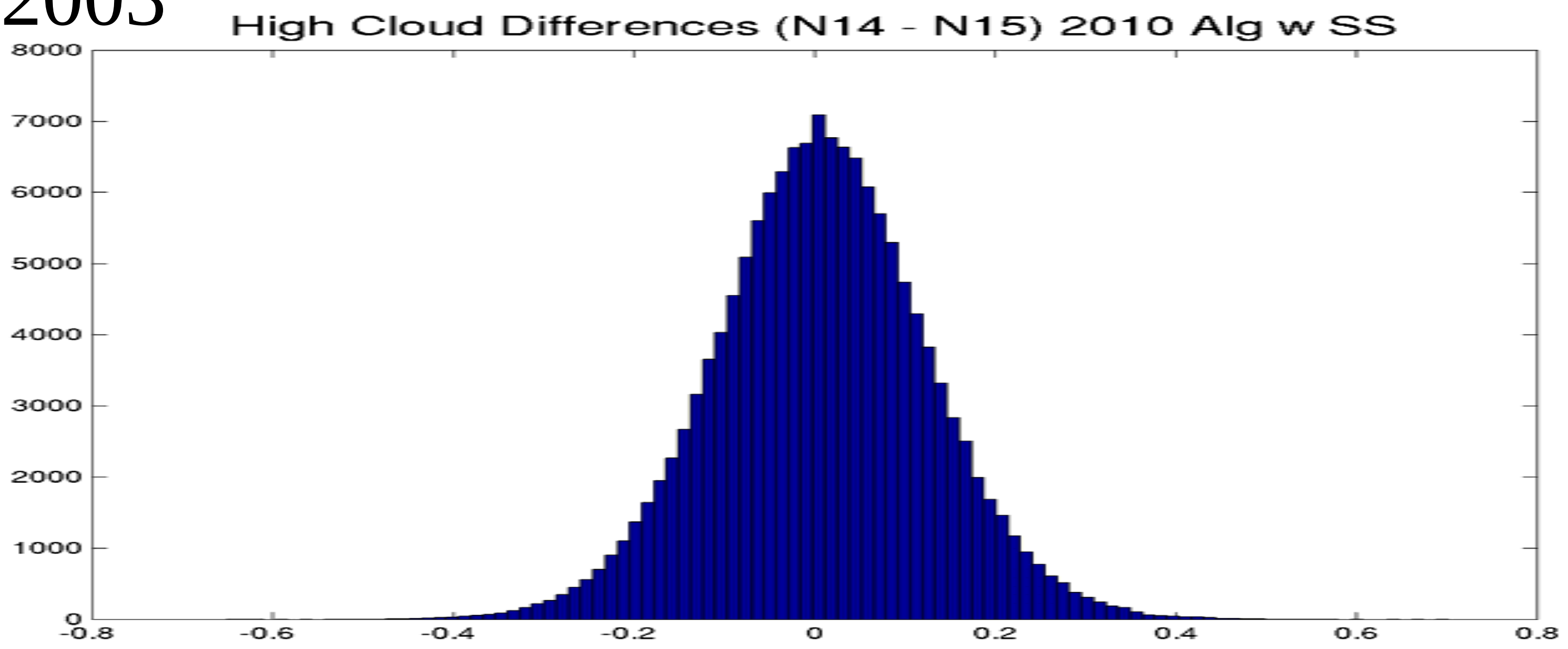
N14 thru N17



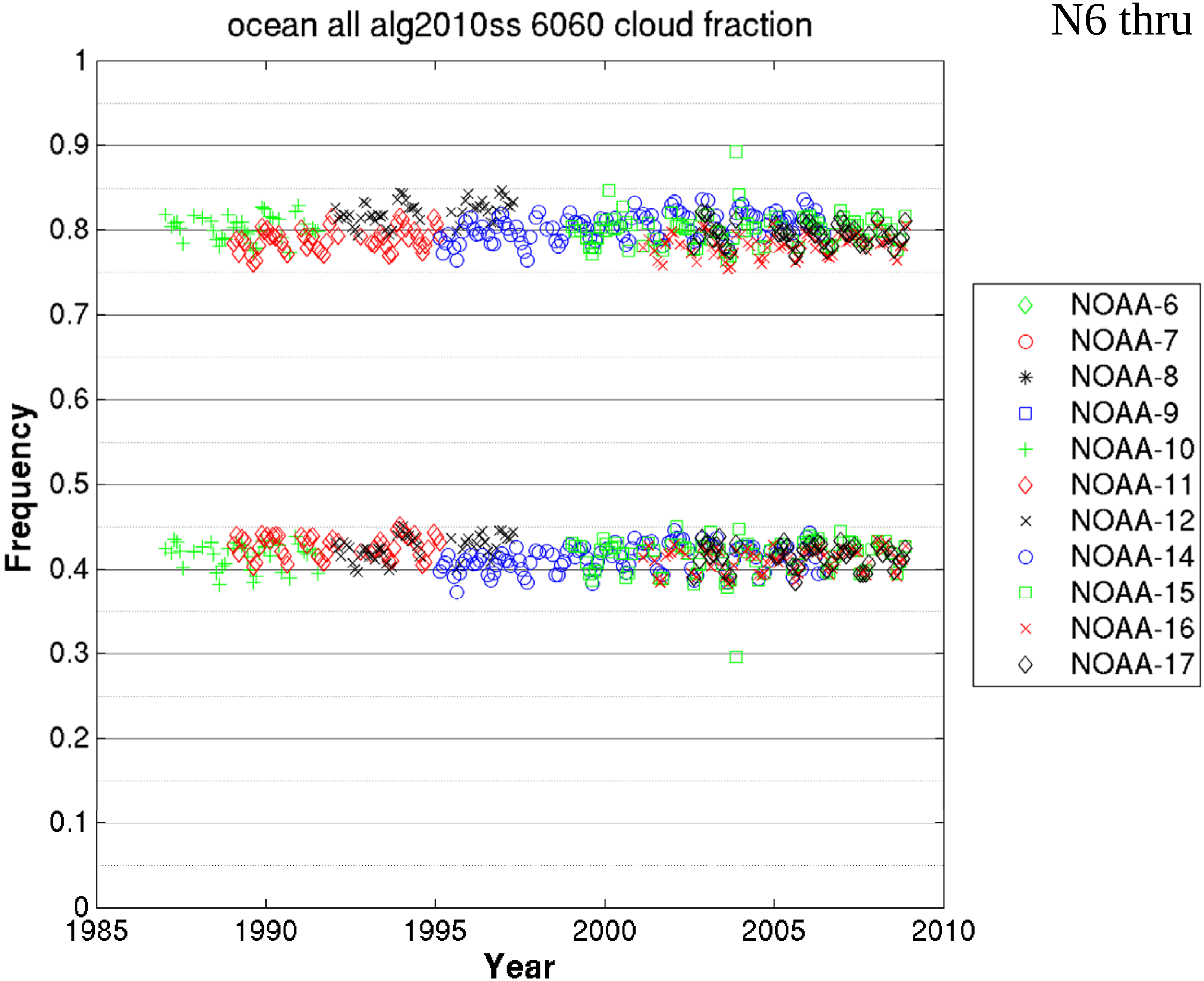
ocean all alg2010ss 6060 cloud fraction
Frequency
Year
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1995
2000
2005
2010
NOAA-6
NOAA-7
NOAA-8
NOAA-9
NOAA-10
NOAA-11
NOAA-12
NOAA-14
NOAA-15
NOAA-16
NOAA-17


High Cloud Differences (N14 - N15) Wylie2005
8000
7000
6000
5000
4000
3000
2000
1000
0
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8

Jan 2003

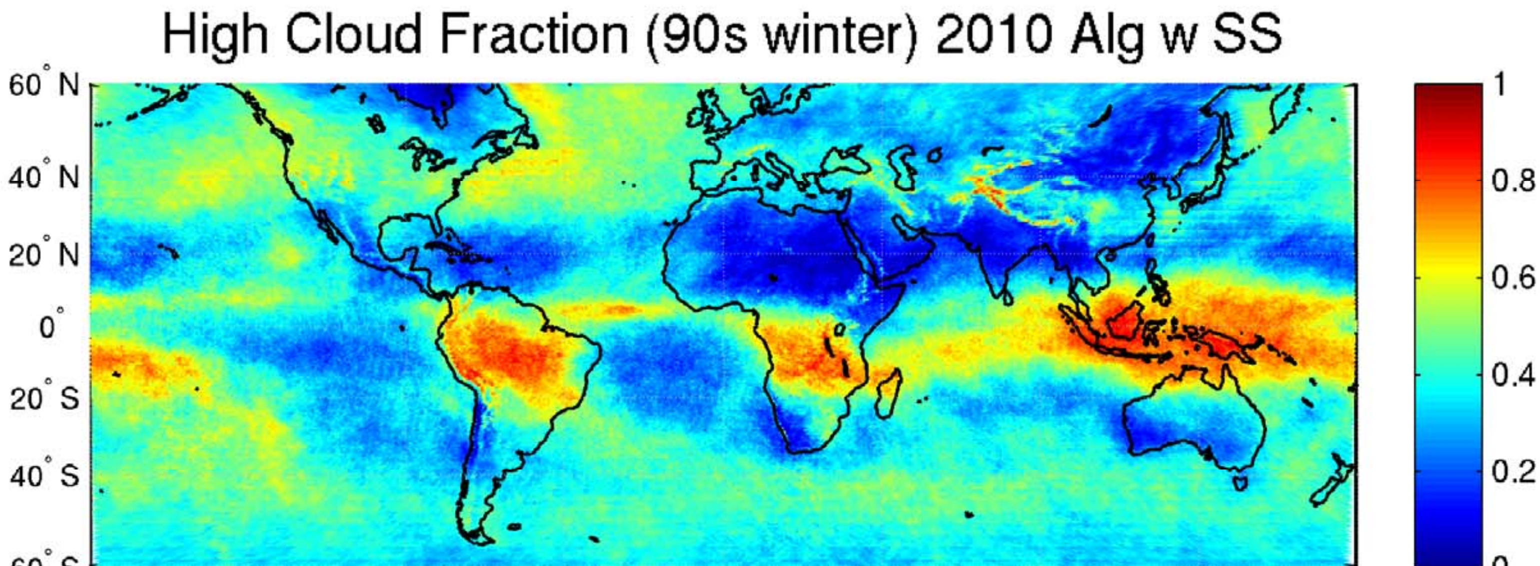

High Cloud Differences (N14 - N15) 2010 Alg w SS
8000
7000
6000
5000
4000
3000
2000
1000
0
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8

N6 thru N17

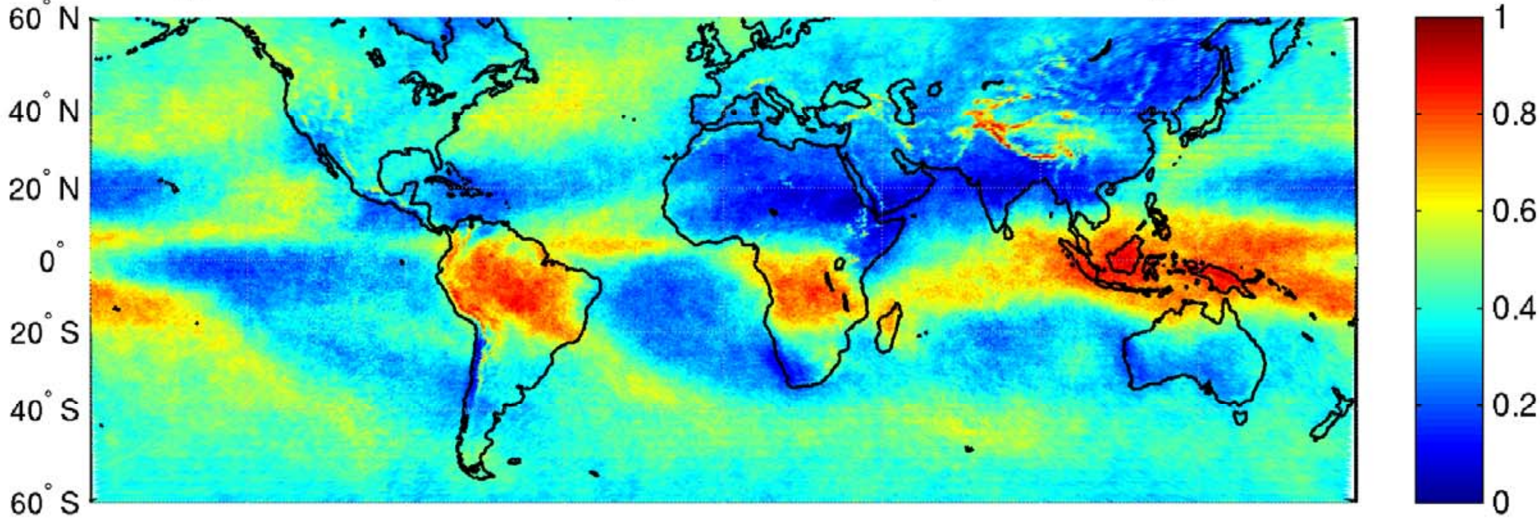


ocean all alg2010ss 6060 cloud fraction
Frequency
Year
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1985
1990
1995
2000
2005
2010
NOAA-6
NOAA-7
NOAA-8
NOAA-9
NOAA-10
NOAA-11
NOAA-12
NOAA-14
NOAA-15
NOAA-16
NOAA-17

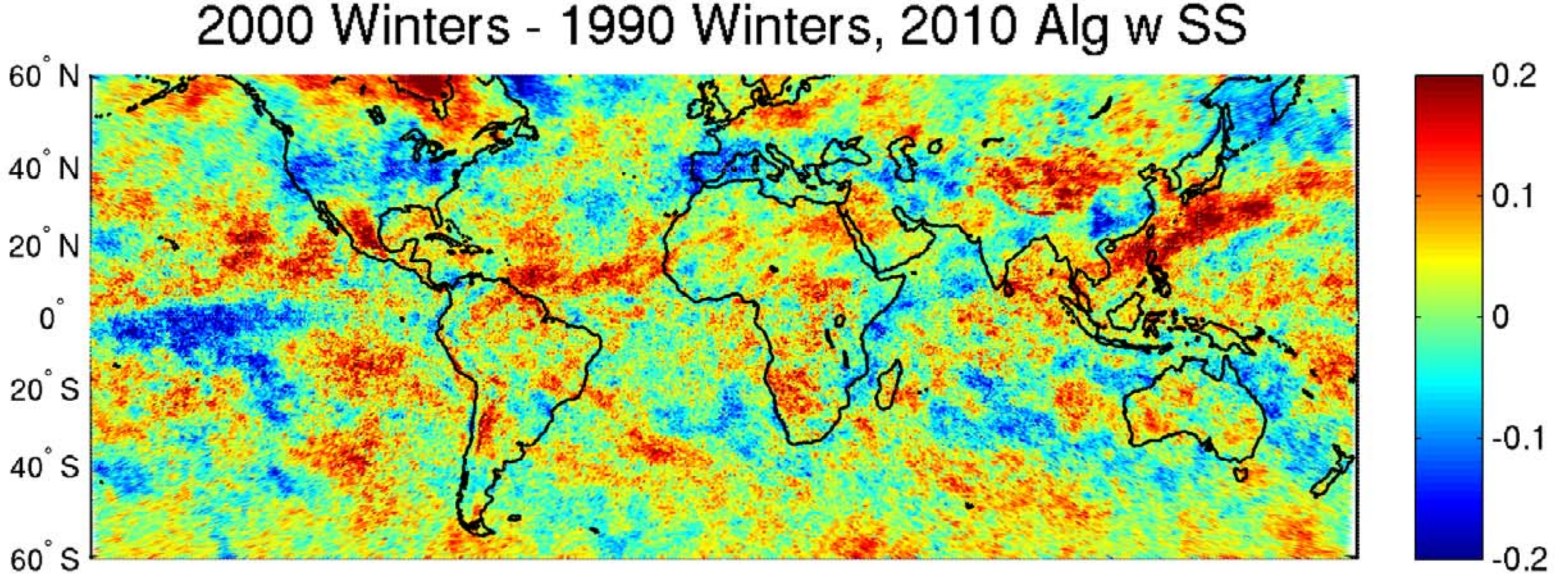
Changes from the 1990s to the 2000s


High Cloud Fraction (90s winter) 2010 Alg w SS
60° N
40° N
20° N
0°
20° S
40° S
60° S
1
0.8
0.6
0.4
0.2
0

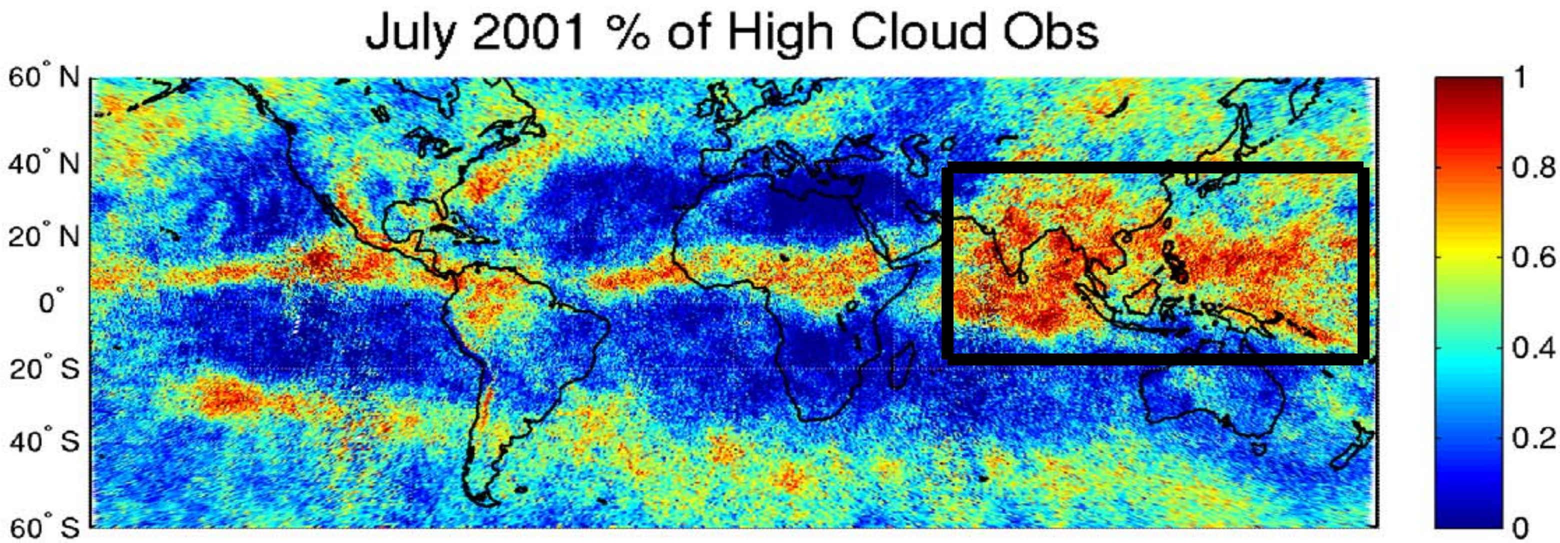
High Cloud Fraction (2000s winter) 2010 Alg w SS

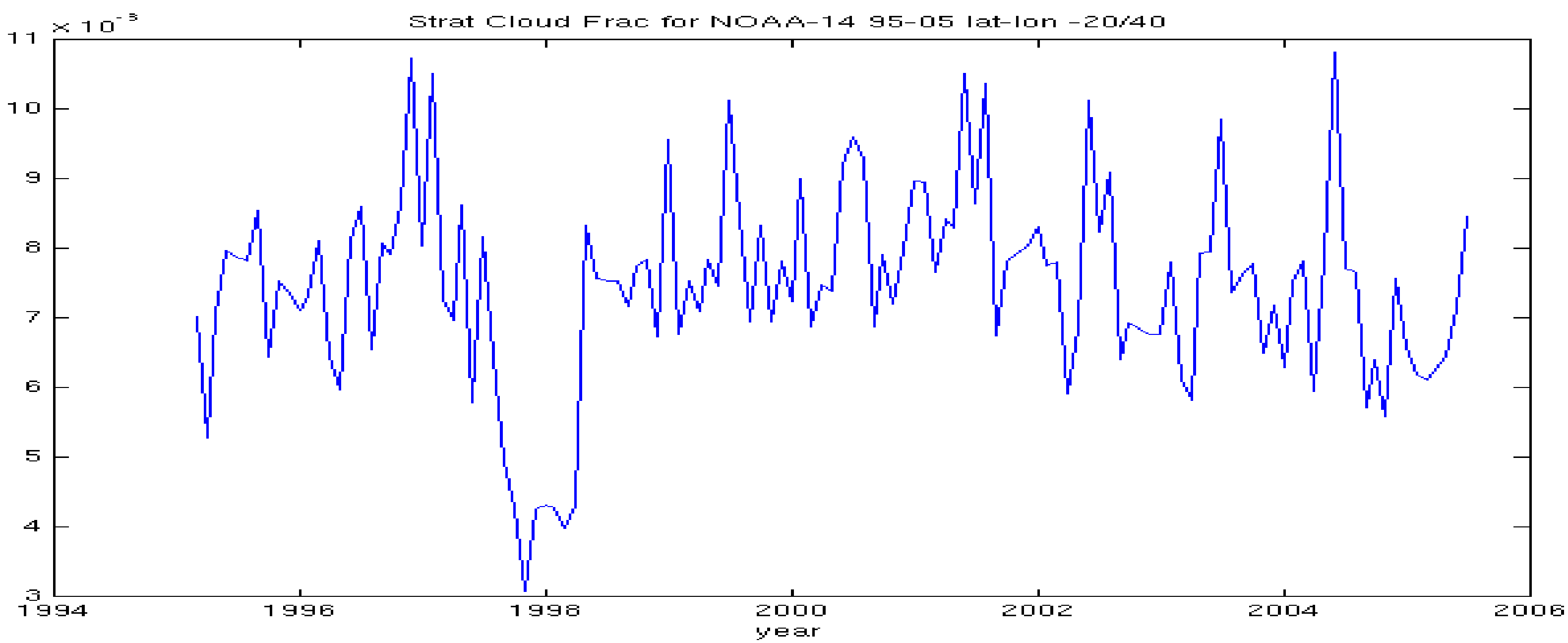


High Cloud Winter Changes

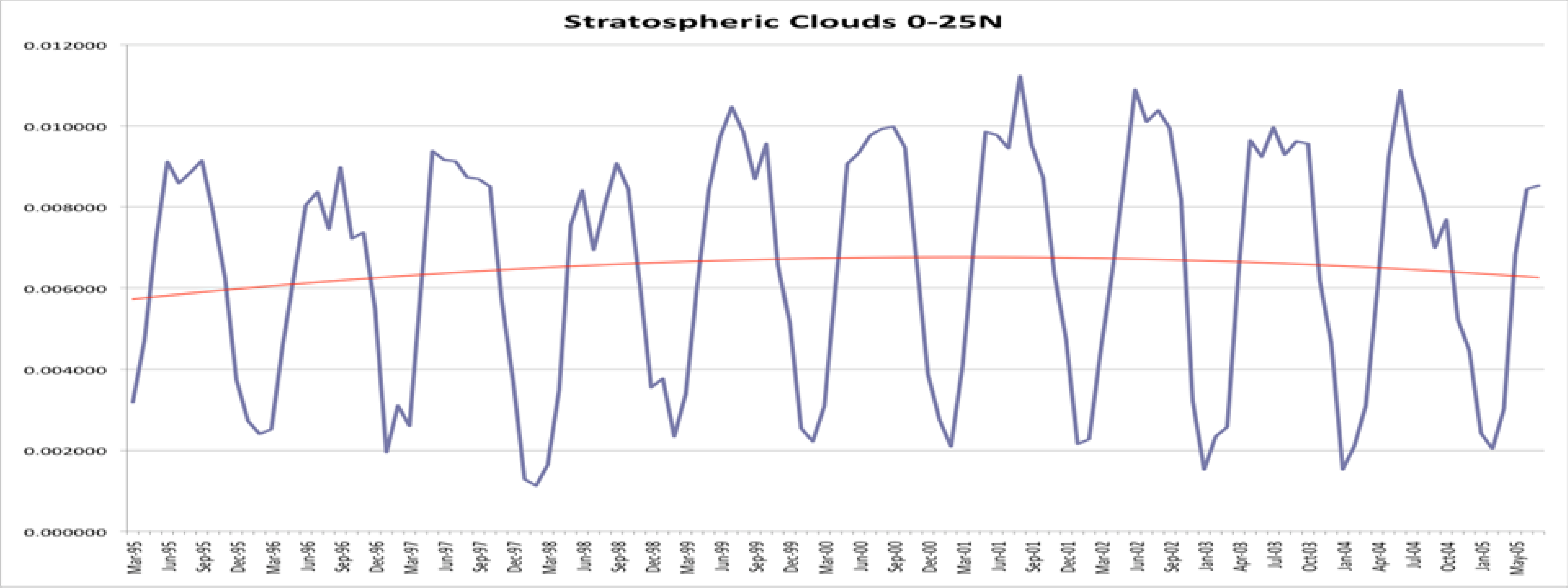


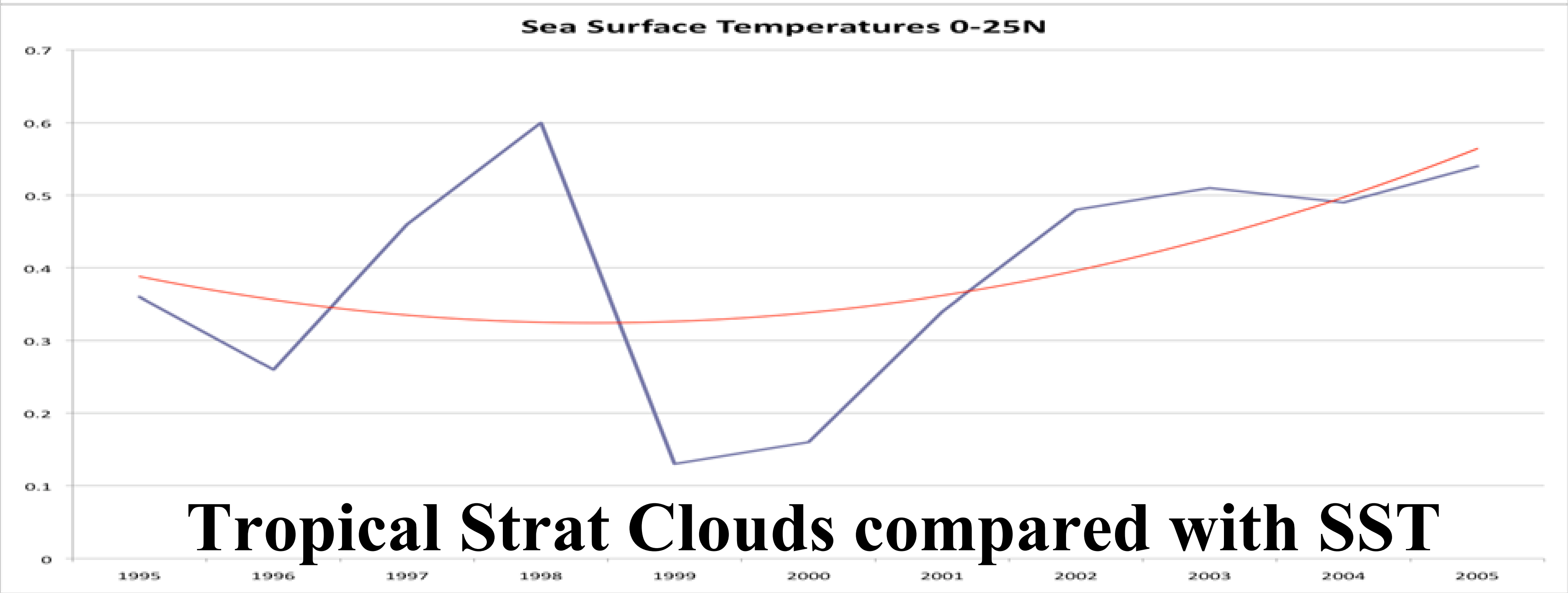
Trend of ITCZ DCCs is being studied – Kolat et al





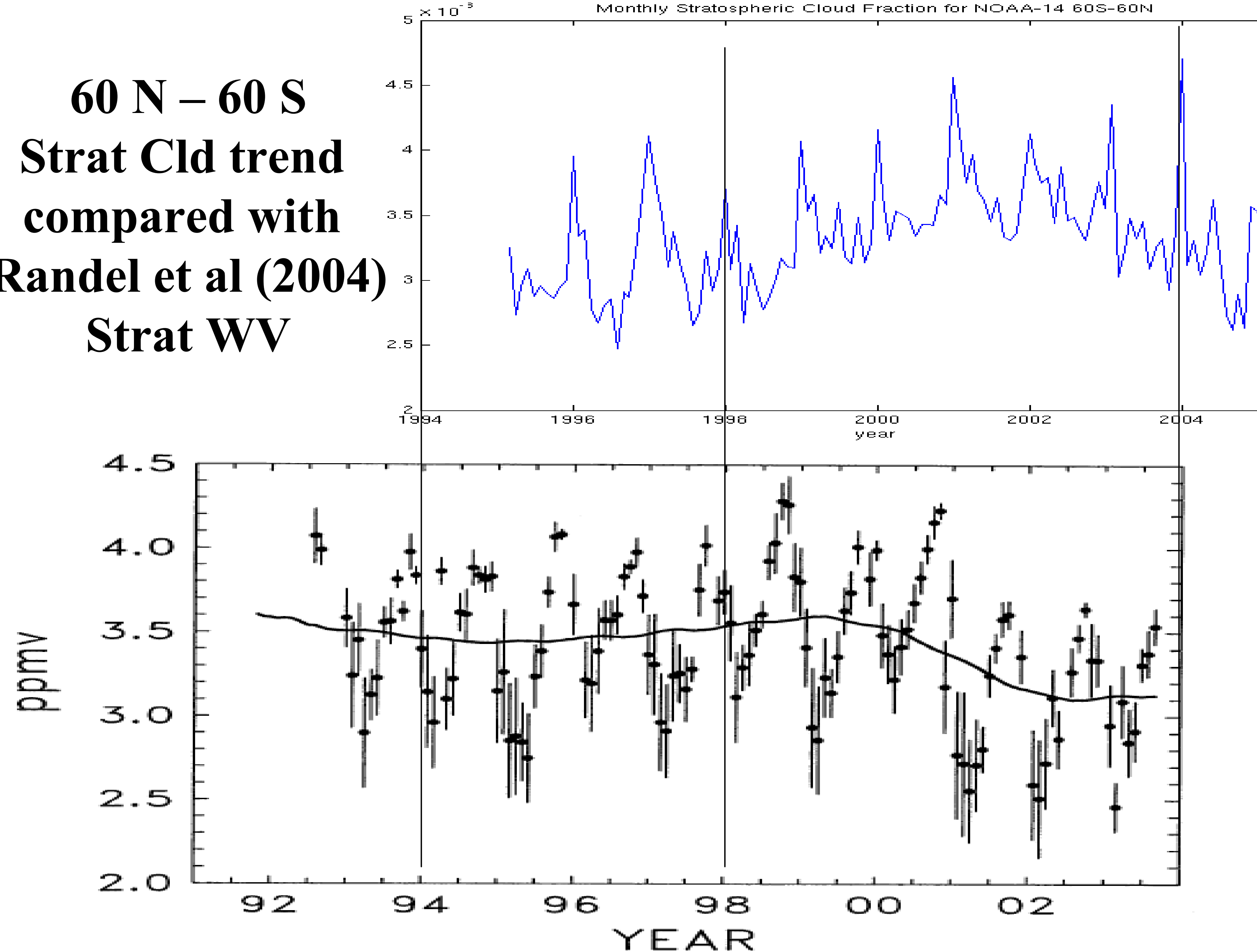
Olsen, Baum, Kolat, Wylie, & Menzel



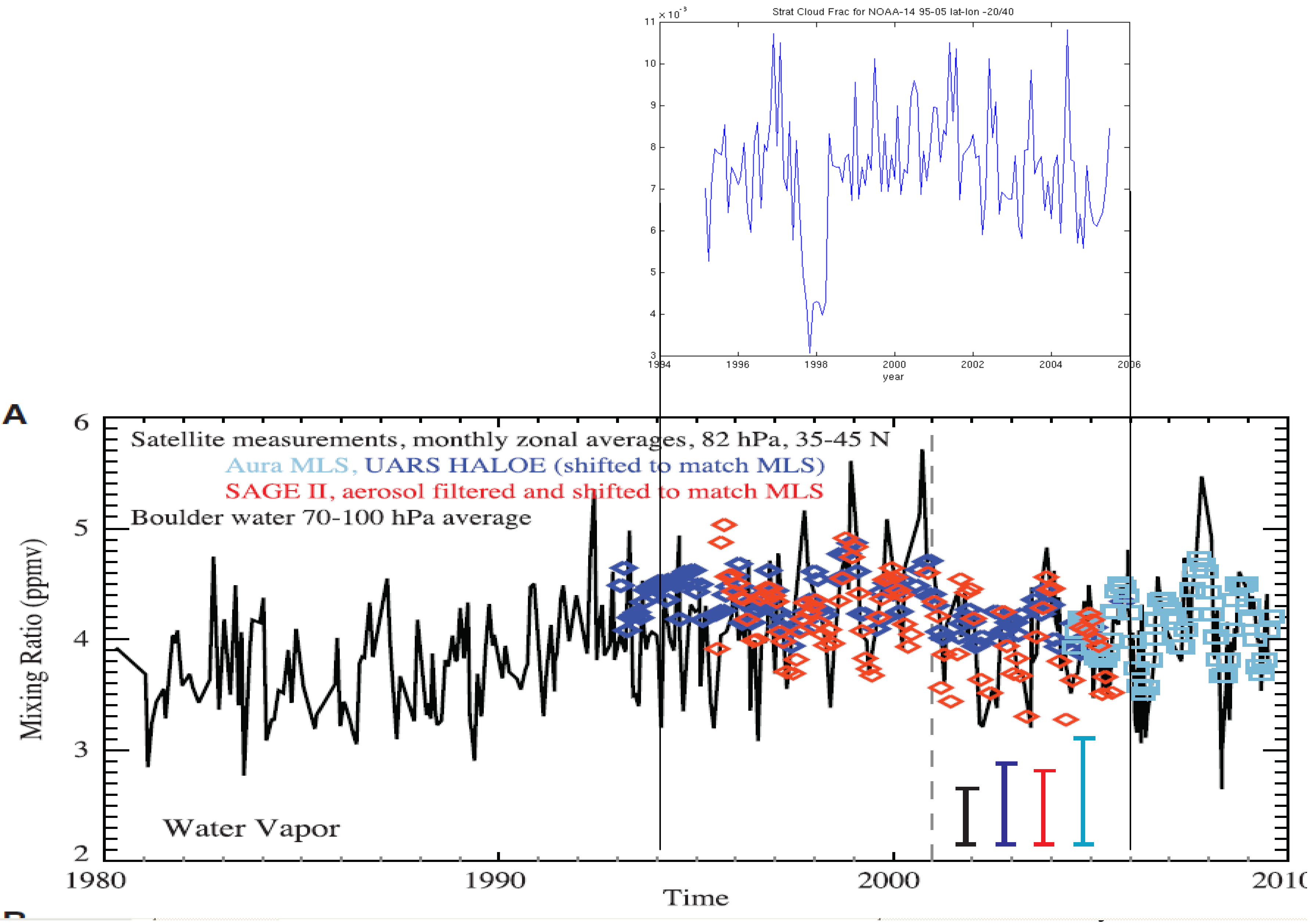


Tropical Strat Clouds compared with SST

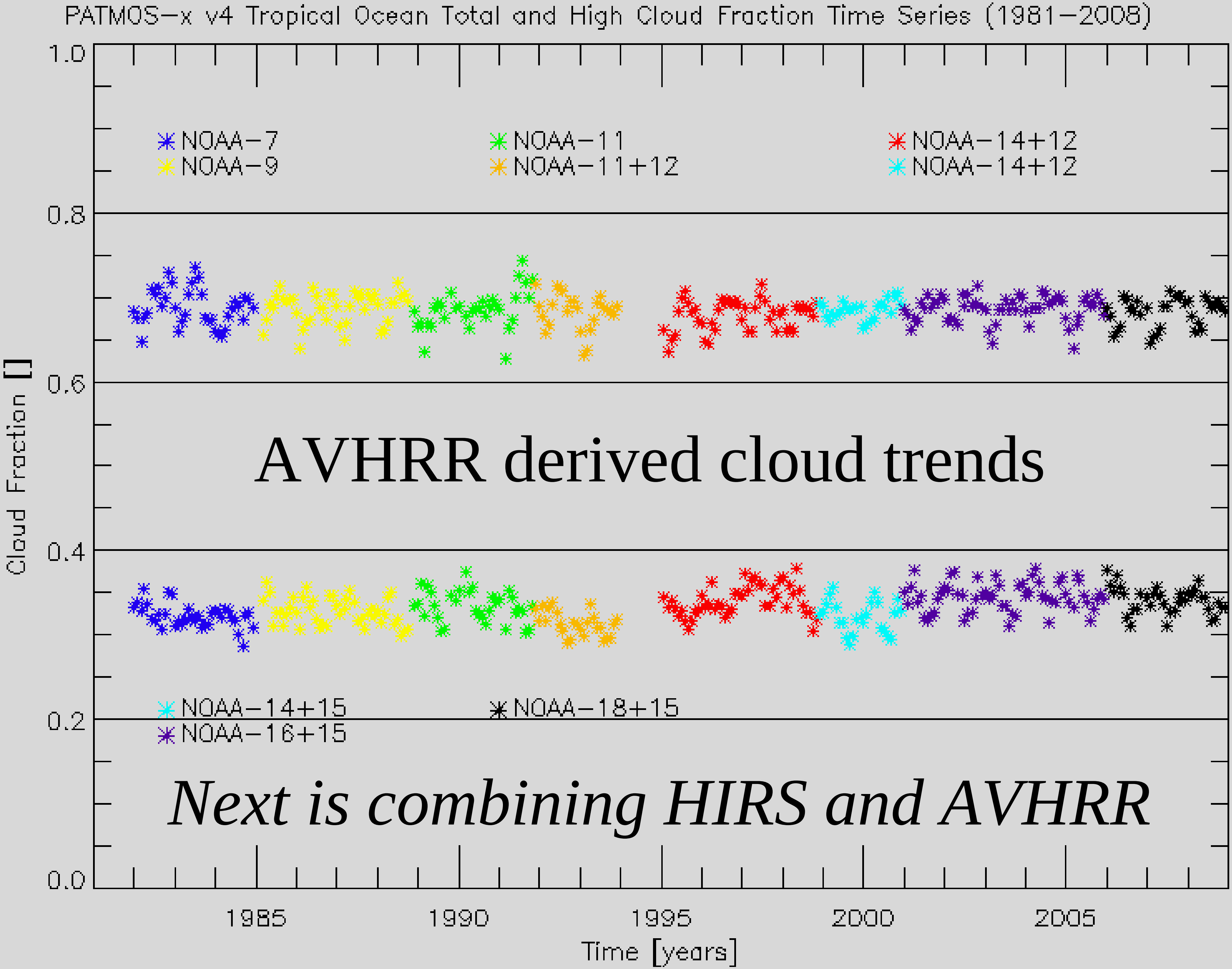
60 N – 60 S Strat Cld trend compared with Randel et al (2004) Strat WV



ITCZ Strat Cld trend compared with Solomon et al

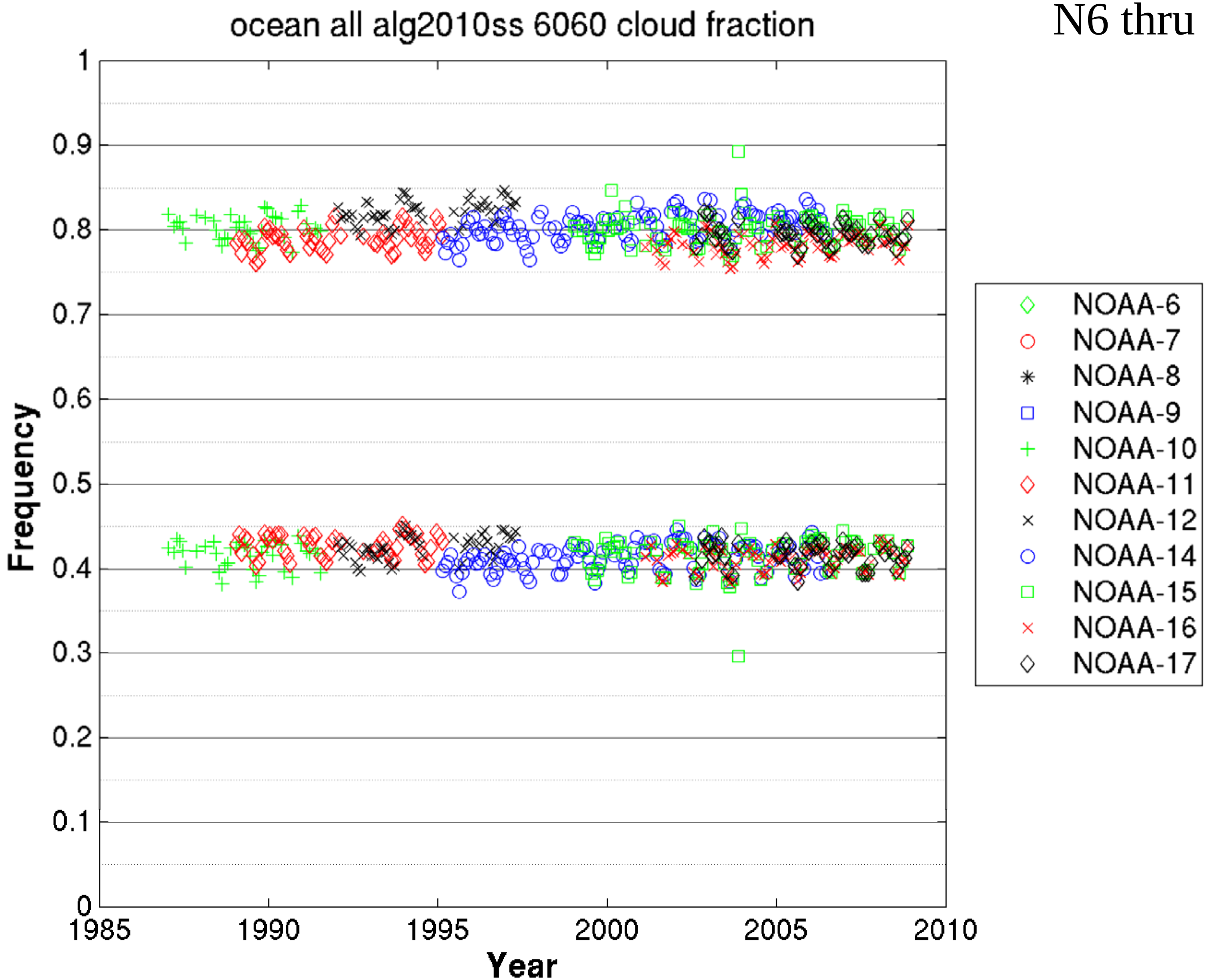


Combining Imager and Sounder Measurements



PATMOS-x v4 Tropical Ocean Total and High Cloud Fraction Time Series (1981-2008)
NOAA-7
NOAA-9
NOAA-11
NOAA-11+12
NOAA-14+12
NOAA-14+12
AVHRR derived cloud trends
NOAA-14+15
NOAA-16+15
NOAA-18+15
Next is combining HIRS and AVHRR
Cloud Fraction []
Time [years]
0.0
0.2
0.4
0.6
0.8
1.0
1985
1990
1995
2000
2005

N6 thru N17



ocean all alg2010ss 6060 cloud fraction
Frequency
Year
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1985
1990
1995
2000
2005
2010
NOAA-6
NOAA-7
NOAA-8
NOAA-9
NOAA-10
NOAA-11
NOAA-12
NOAA-14
NOAA-15
NOAA-16
NOAA-17

Conclusions

* algorithm adjustments tested with MODIS, halving CO2 slicing threshold, spectral shifts suggested by AIRS, CO2 ramp, stratospheric intrusions,… are producing consistent results
* clouds were found in ~80% (55%) of HIRS observations over ocean (land) since 1995; hi clouds were found in ~40% (33%) over ocean (land)
* DJF clouds (all as well as high) over ocean increase about 0.5% per year from 1995 to 2003 and decrease at the same rate from 2003 to 2009; JJA clouds (all as well as high) remain constant 1995 to 2009.
* Interesting correlations between strat clouds vs SST and strat WV are emerging
* reprocessing of complete HIRS archive using SNOs with adjusted algorithm is underway; merging with AVHRR planned
* the best cloud top property retrievals from high spatial and high spectral radiance measurements remain to be achieved