

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 09
 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

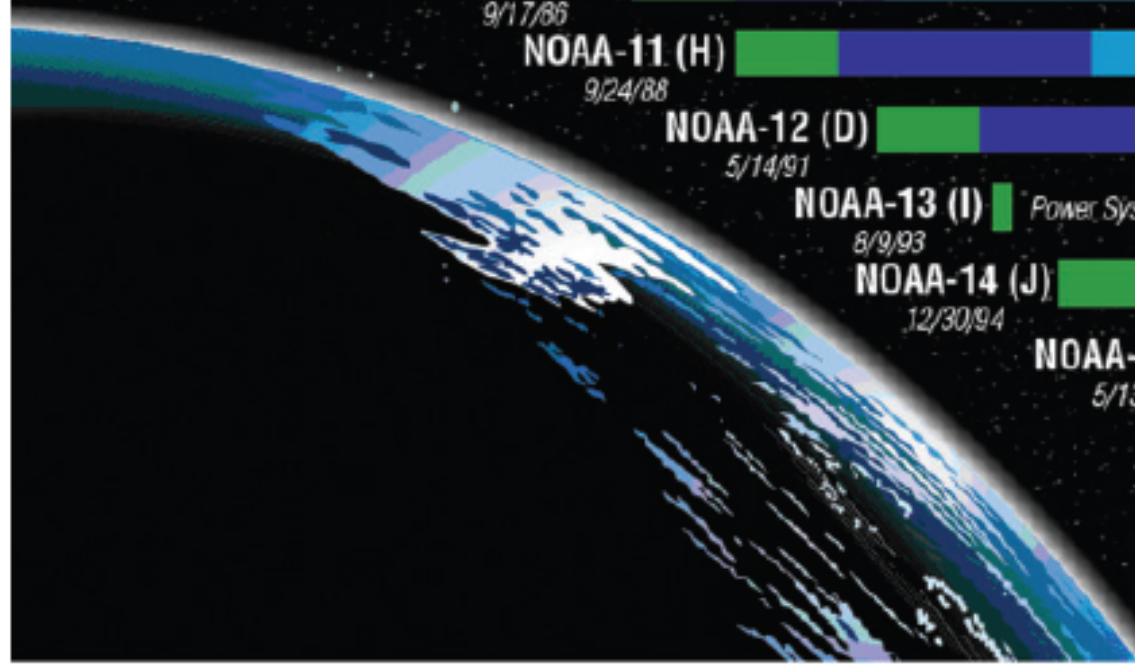
NOAA-14 (J) *Deactivated 5/23/07*
 12/30/94

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

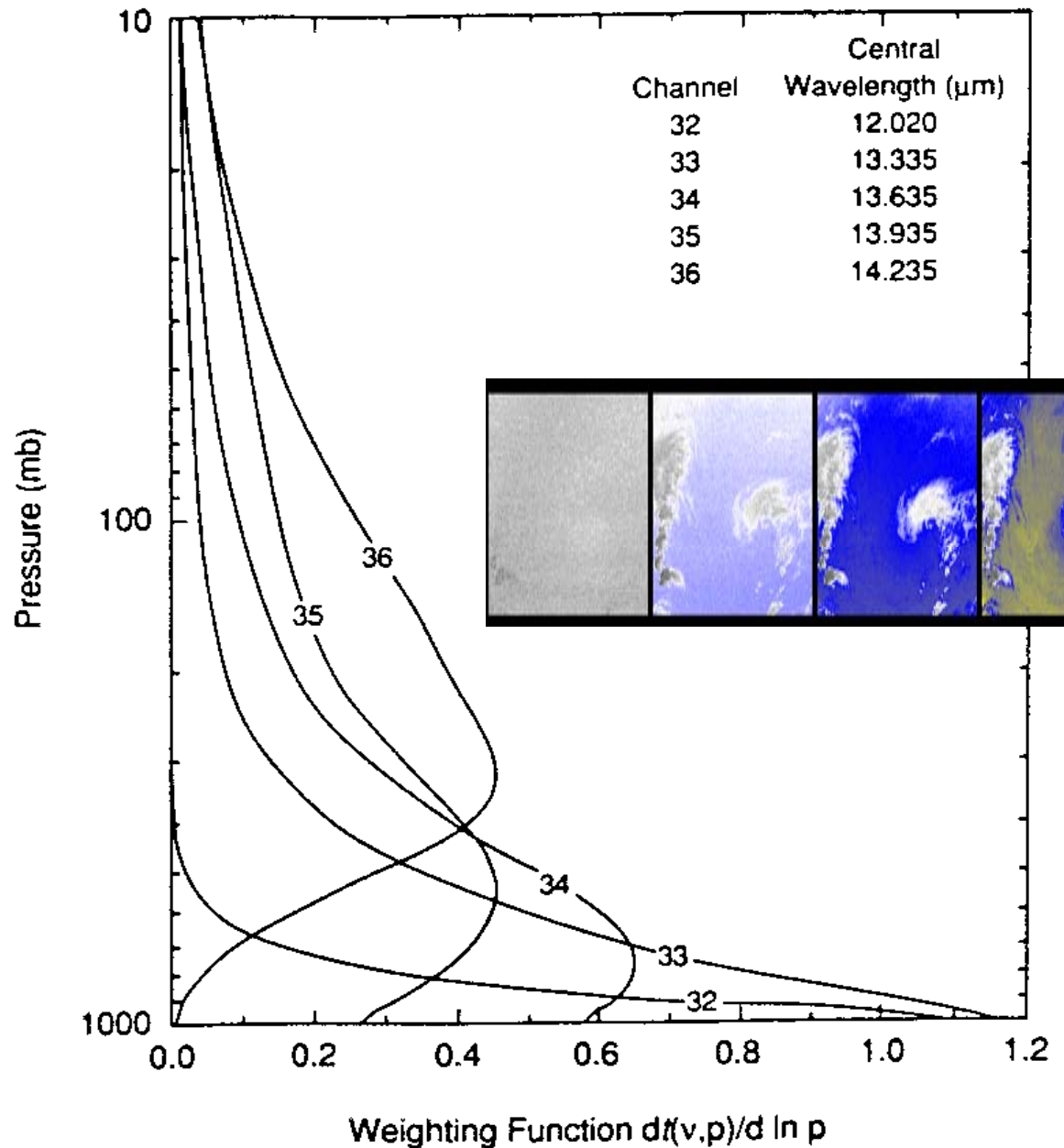
Meas

Calc

$$\frac{(I_{\lambda_1} - I_{\lambda_1}^{clr})}{p_s} = \frac{\eta \epsilon_{\lambda_1} \int \tau_{\lambda_1} dB_{\lambda_1} p_c}{p_s}$$

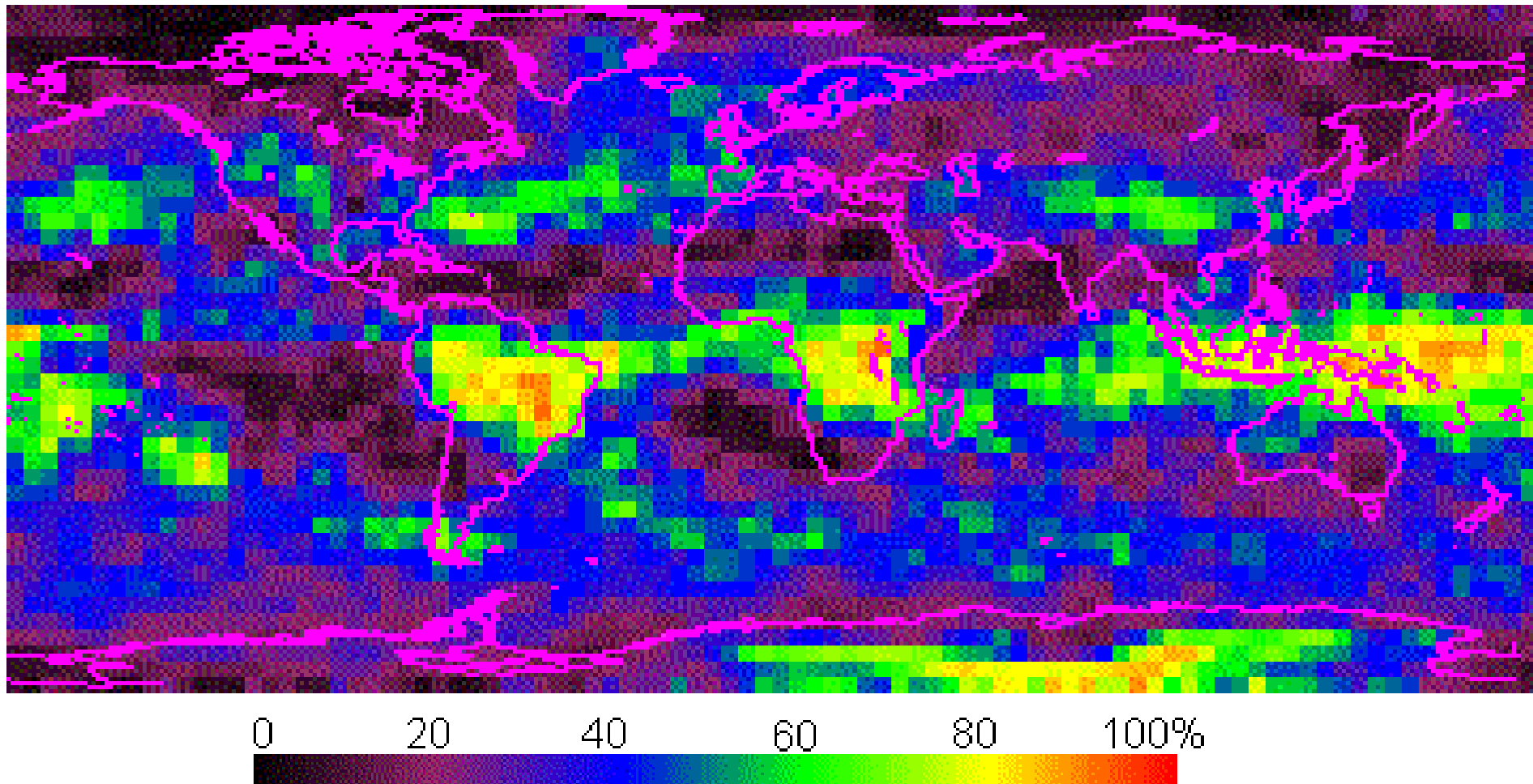
$$\frac{(I_{\lambda_2} - I_{\lambda_2}^{clr})}{p_s} = \frac{\eta \epsilon_{\lambda_2} \int \tau_{\lambda_2} dB_{\lambda_2} p_c}{p_s}$$

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

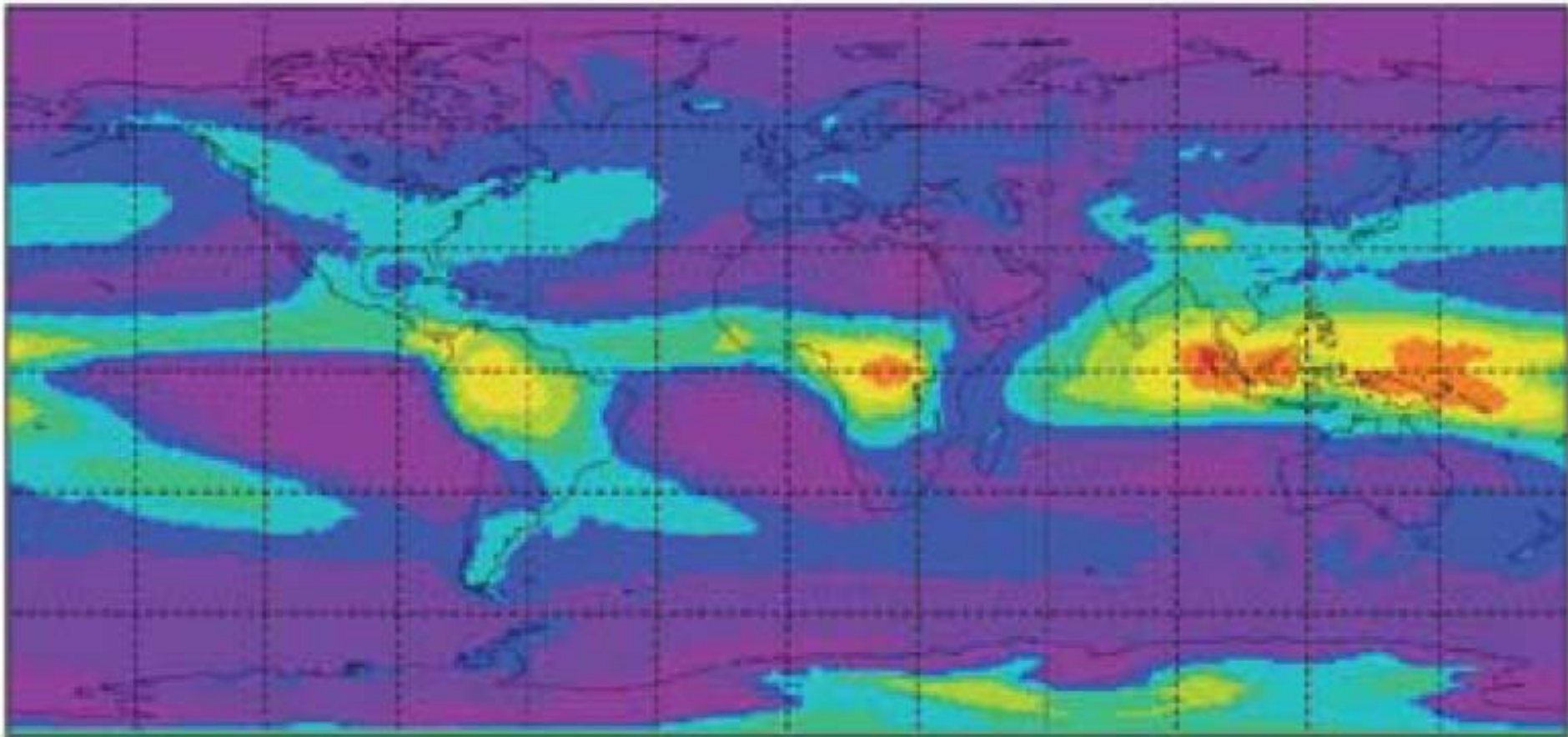


HIRS Results in Wylie et al (2005)

- * only near nadir observations from pm orbits processed
- * clear sky radiance calculated from NCEP re-analysis
- * orbit drift (adjusted to 2 pm)
- * constant CO₂ (adjusted for 2% less high clouds in 335 ppm vs 380 ppm)



HIRS High Cloud detection over 20 years



0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9

AIRS High Cloud detection over 6 years

Reprocessing HIRS CO2 Cloud Measurements

Adjustments to HIRS Cloud Processing

Done

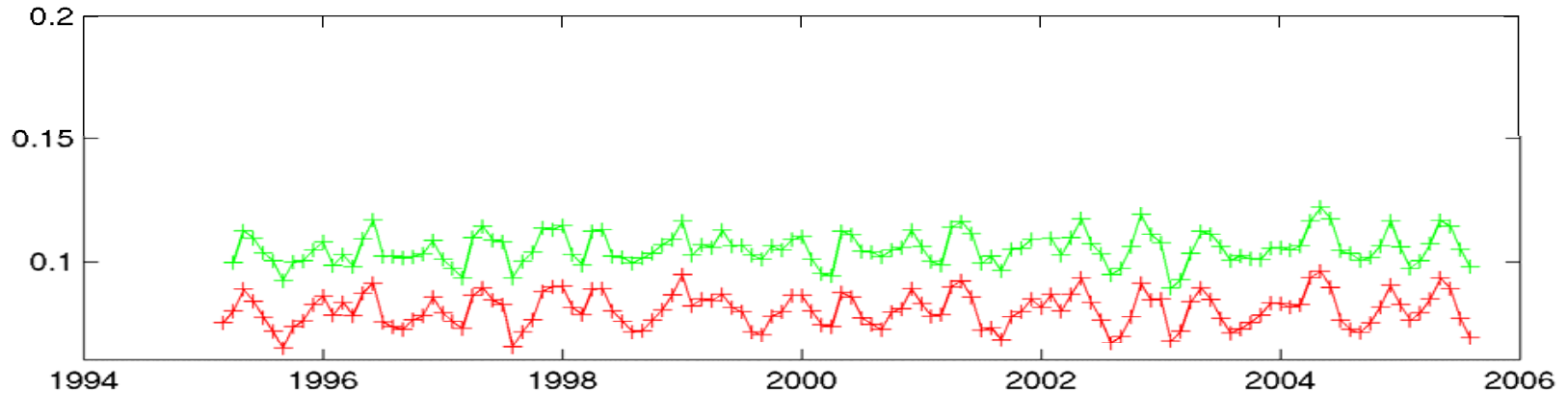
- Use "top-down" method where most opaque channel pair seeing cloud derives CTP
- **Lower the "noise" thresholds** (clear minus cloudy radiances required to indicate cloud presence in CO₂ bands) to force more CO₂ slicing solutions for high thin clouds.
- Adjust ozone profile between 10 and 100 hPa to 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

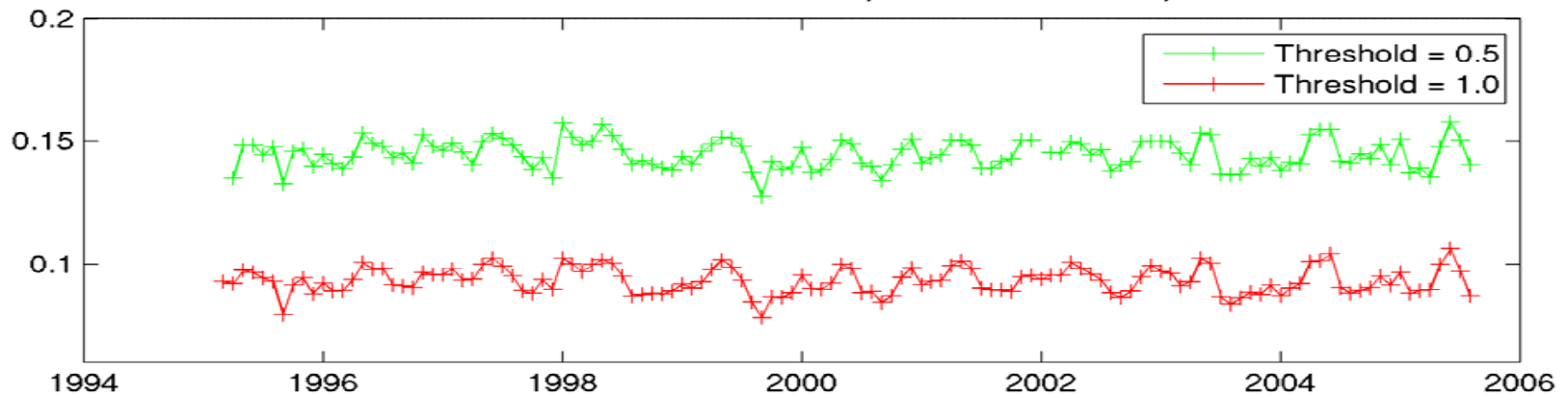
- Prohibit CO₂ slicing solutions for water clouds; use only IRW solution. Avoid IRW solutions for ice clouds; use CO₂ slicing whenever possible.
- Restrict CO₂ channel pair solutions to appropriate portion of troposphere (determined by their weighting functions).
- Add marine stratus improvement (constant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

Changing Cloud Detection Threshold

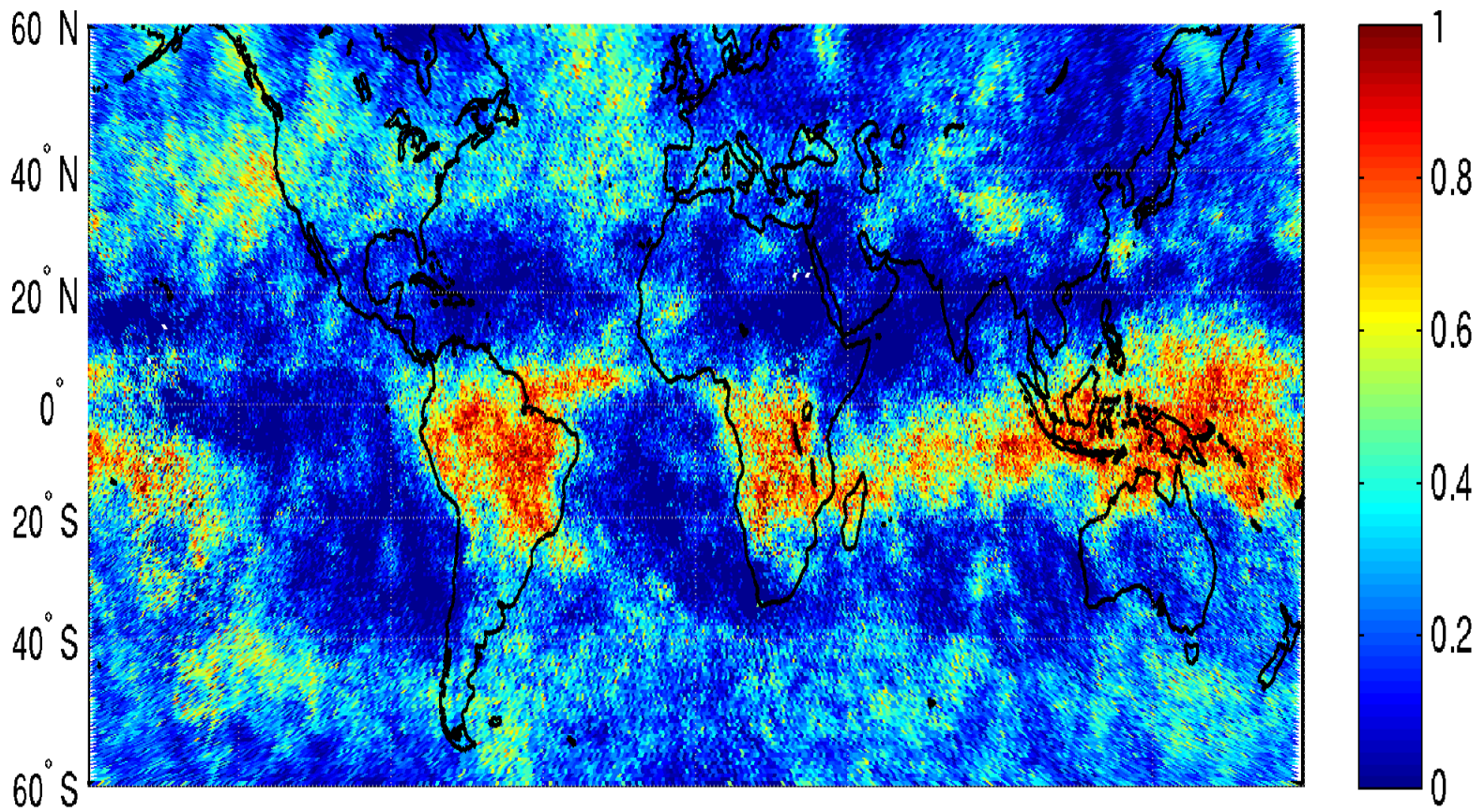
Thin clouds above 440 mb, -60 to 60 lat, Land



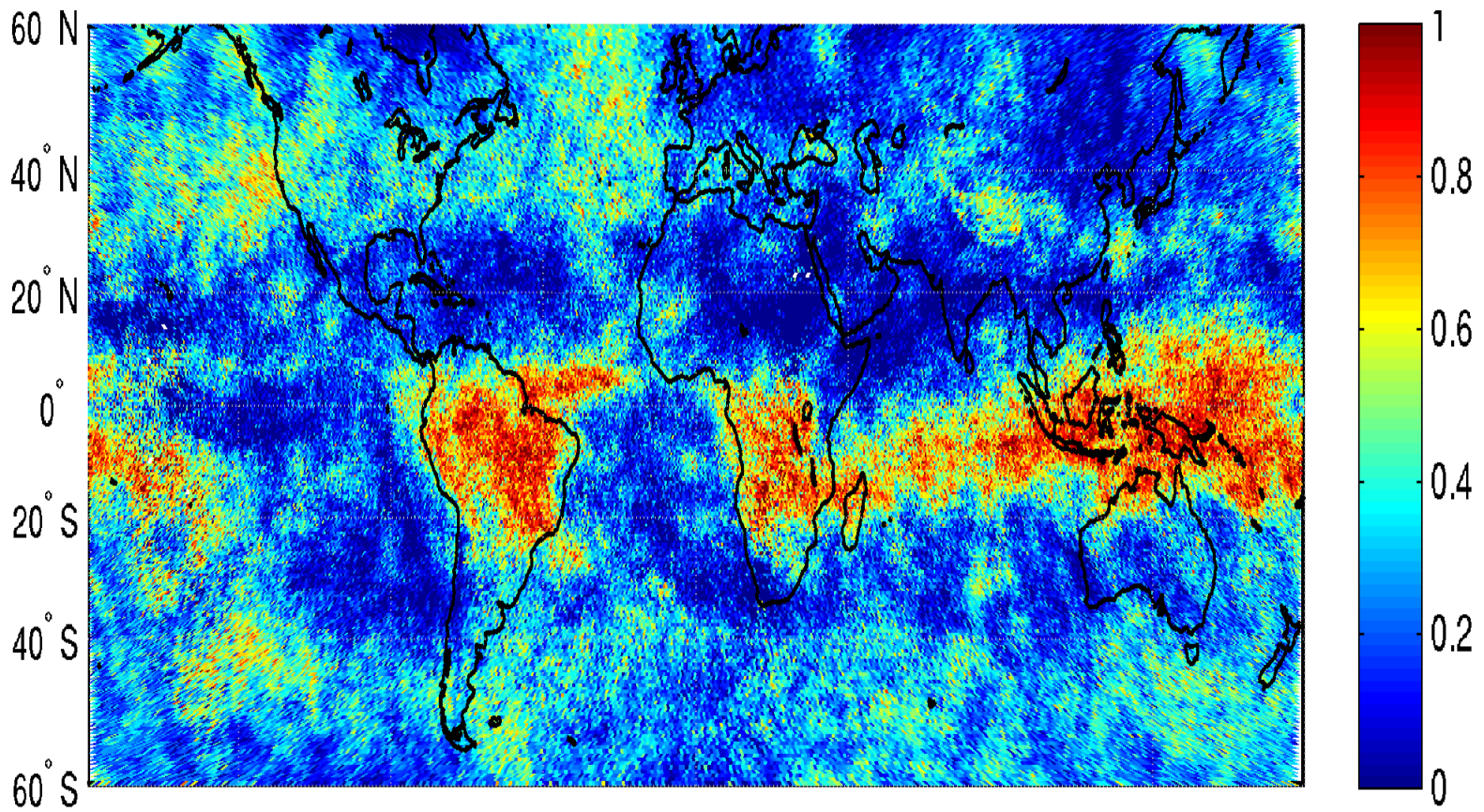
Thin clouds above 440 mb, -60 to 60 lat, Ocean



About 5 % of low opaque clouds are correctly defined as high thin clouds when $[R_{clear} - R_{cloud}] > NEDR$ threshold is changed from 1.0 to 0.5 $mW/m^2/ster/cm^{-1}$



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

$m = 1.5 \text{ ppmv} / 365$

$b = 337.5 \text{ ppmv}$

$a = 3 \text{ ppmv}$

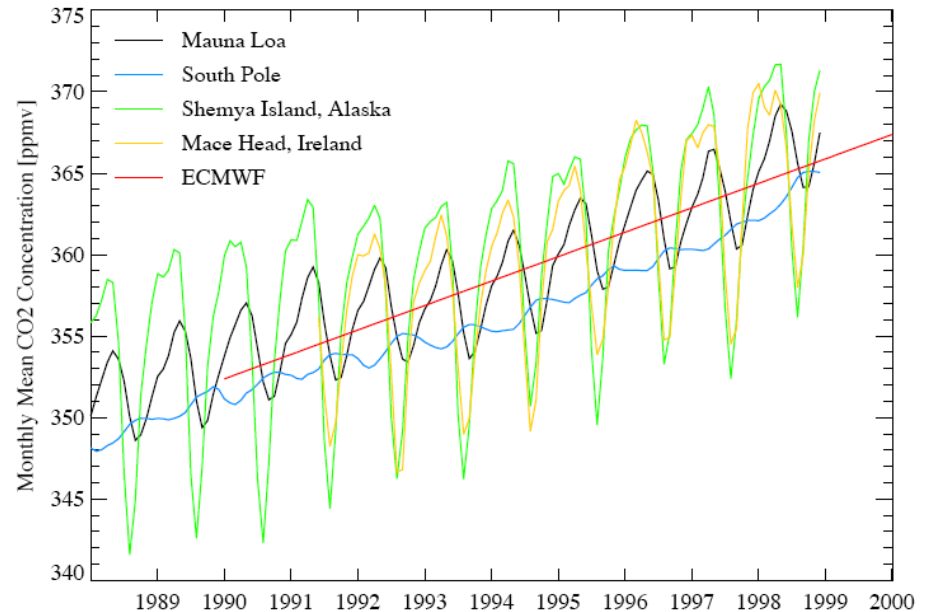
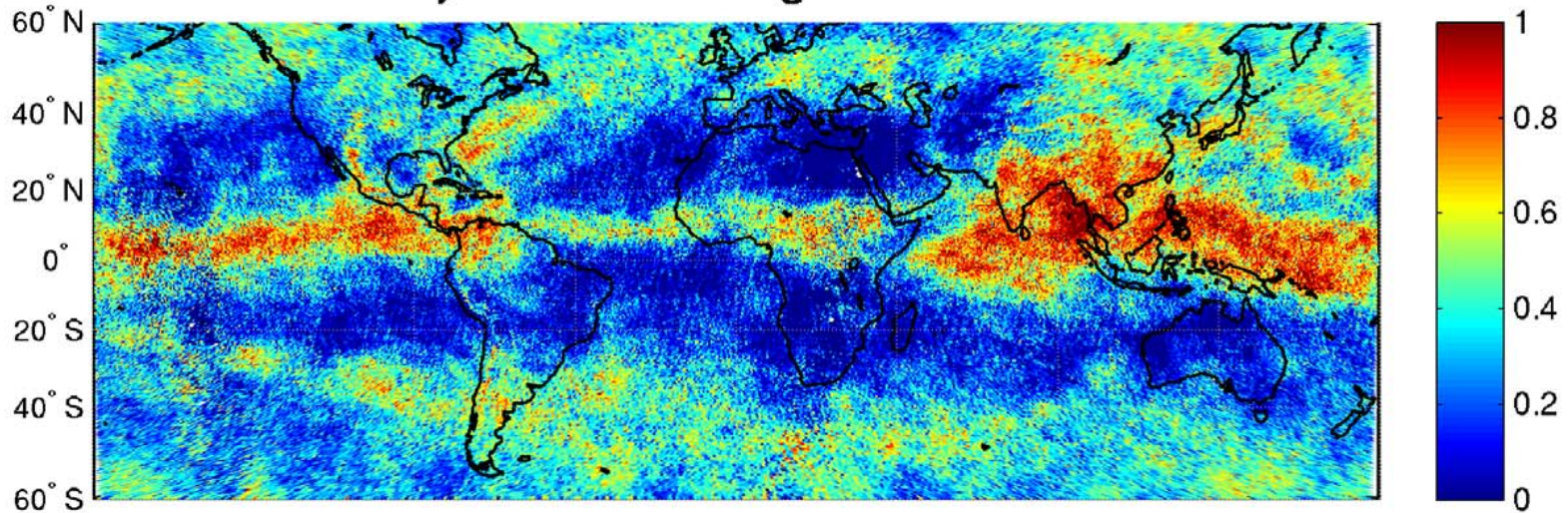


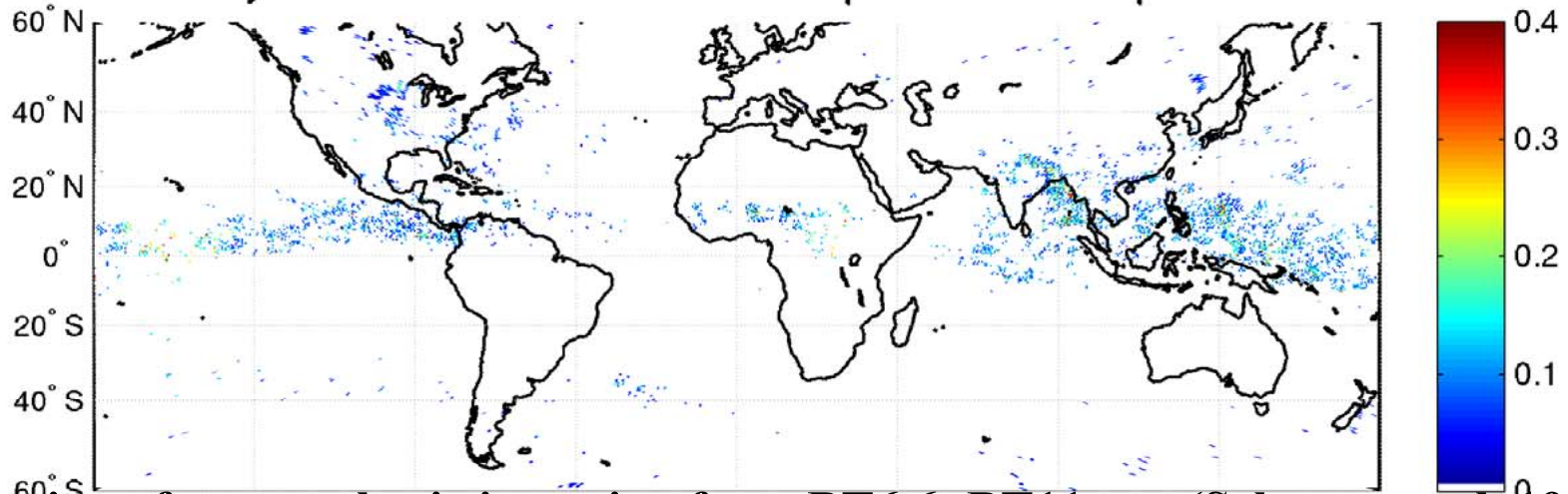
Figure 1. Time series of monthly mean surface CO₂ volume mixing ratios for 4 flask stations. The red line represents the values used by ECMWF. From Engelen et al (2001)

Stratospheric Cloud Identification

July 1997 % of High Cloud Obs

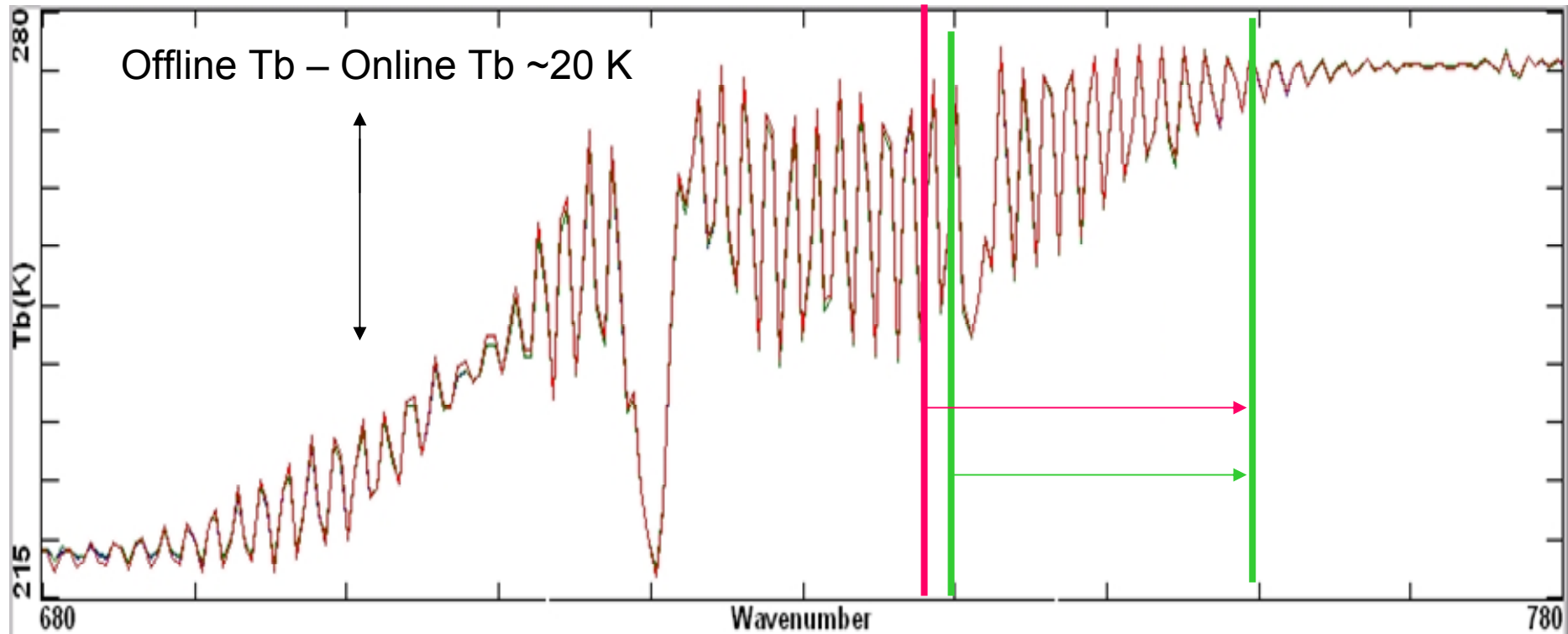


July 1997 % of Obs with $6.6 \mu\text{m BT} > 11 \mu\text{m BT}$



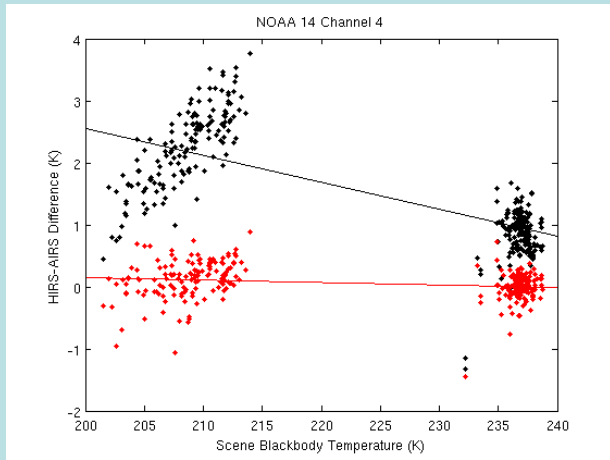
**Detection of stratospheric intrusion from $\text{BT}_{6.6} > \text{BT}_{11}$ test (Schmetz et al, 1997)
will help improve high cloud determination**

Using AIRS to Adjust HIRS SRF

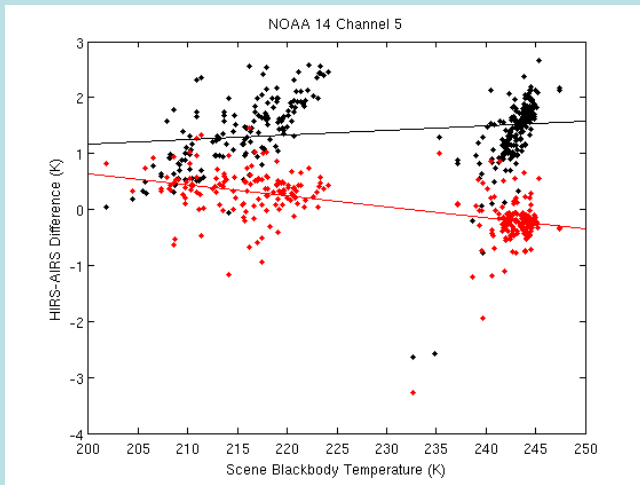


- * Bandwidth $\sim 20 \text{ cm}^{-1}$ includes roughly 12 peaks and 12 valleys
- * Including extra peak implies $\Delta T_b \sim +2 \text{ K}$ or $\Delta R \sim +1 \text{ mW/m}^2/\text{ster/cm}^{-1}$
- * Then calculation of clear sky radiance obs would be off by ΔR
which would affect determination of P_c
- * Warmer clear sky calculation introduces extra false cloud detection

N14 Channel 4



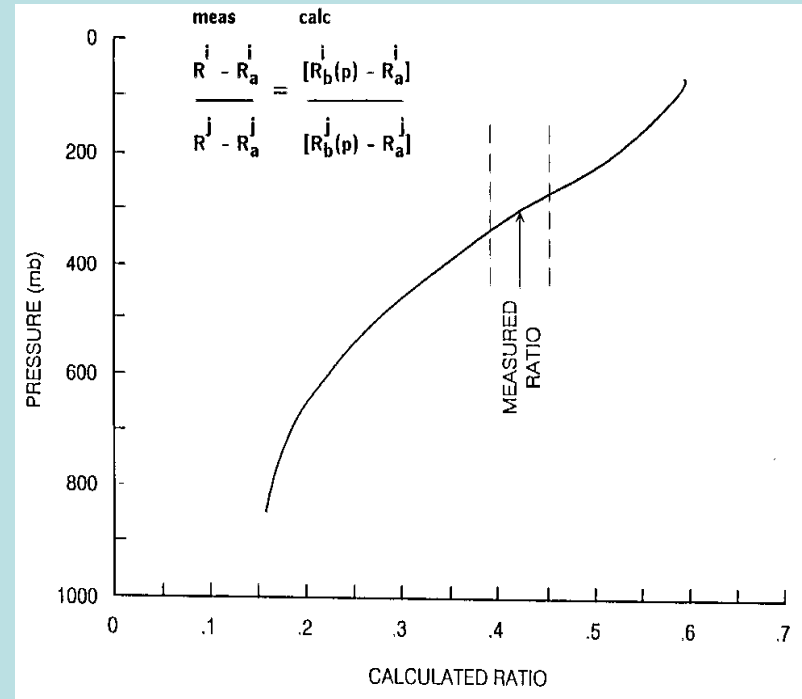
N14 Channel 5



$(I_4^{clr} - I_4)$ 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



$$(I_{\lambda_1}^{clr} - I_{\lambda_1}) \frac{p_c}{p_s} \eta \epsilon_{\lambda_1} \int \tau_{\lambda_1} dB_{\lambda_1}$$

$$(I_{\lambda_2}^{clr} - I_{\lambda_2}) \frac{p_c}{p_s} \eta \epsilon_{\lambda_2} \int \tau_{\lambda_2} dB_{\lambda_2}$$

as ratio increases, p_c decreases

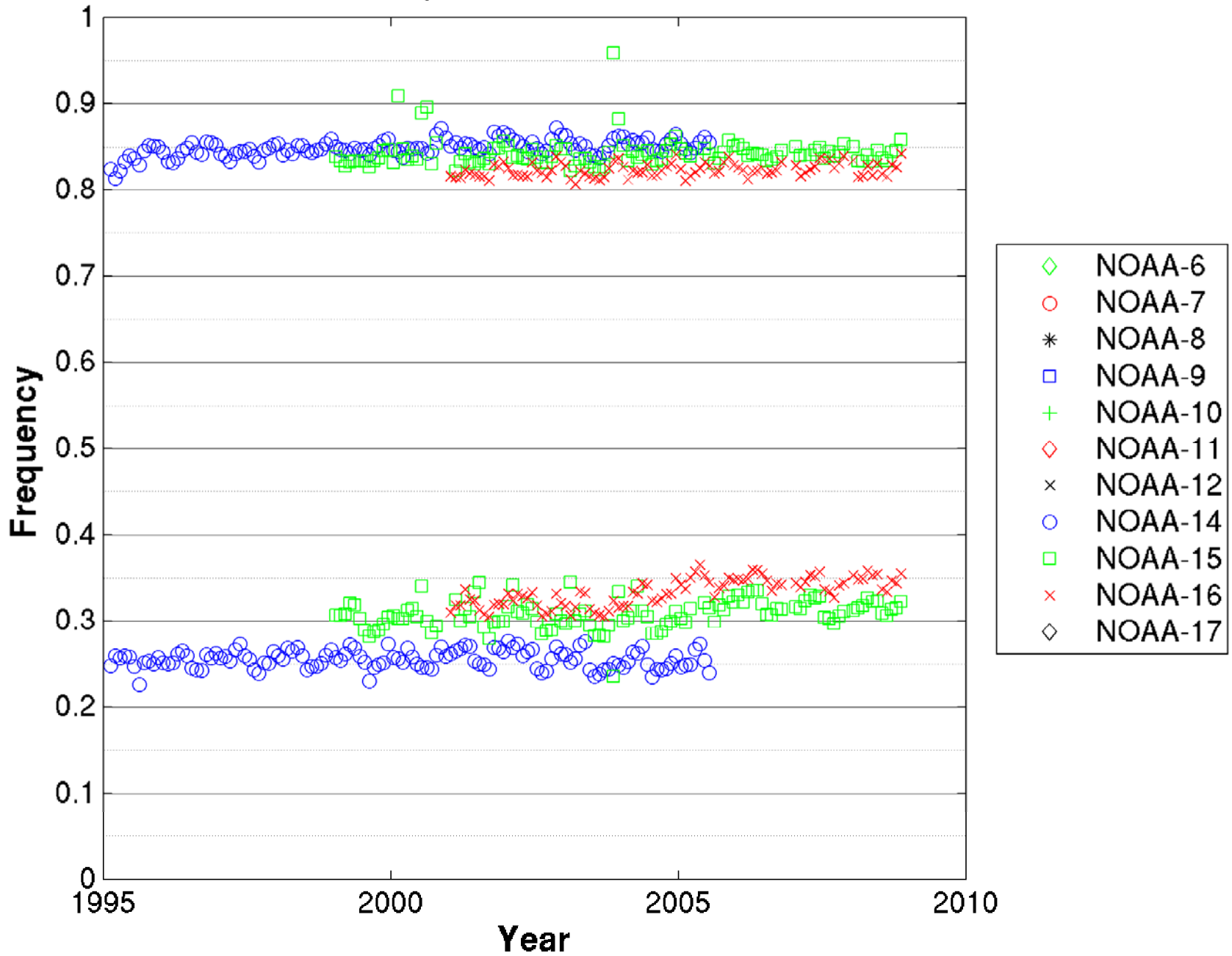
Spectral Shifts used for N14

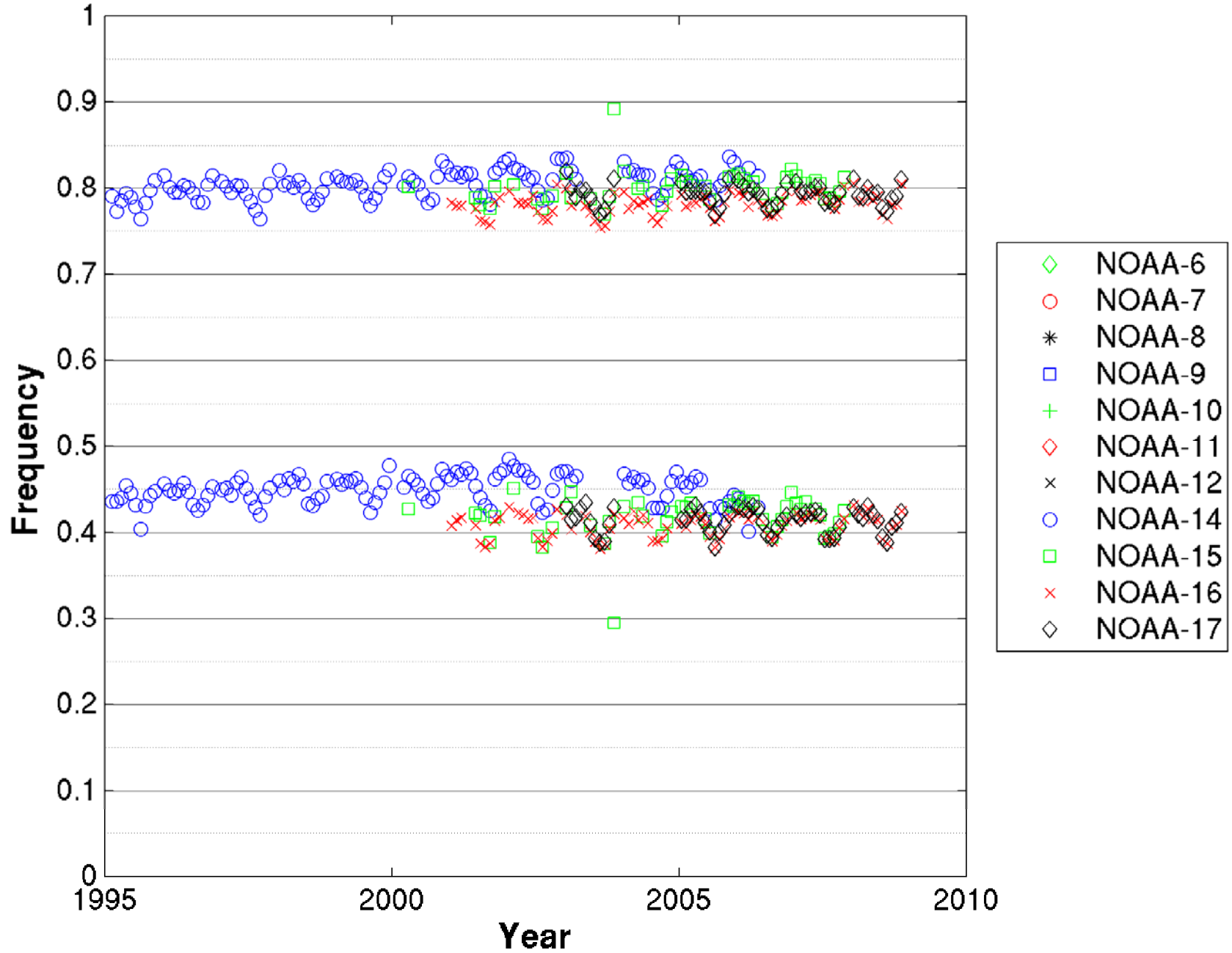
Ch4	14.2um	704 cm-1	+2.0 cm-1
Ch5	13.9	719	+2.5
Ch6	13.6	735	+3.0
Ch7	13.3	750	+1.5

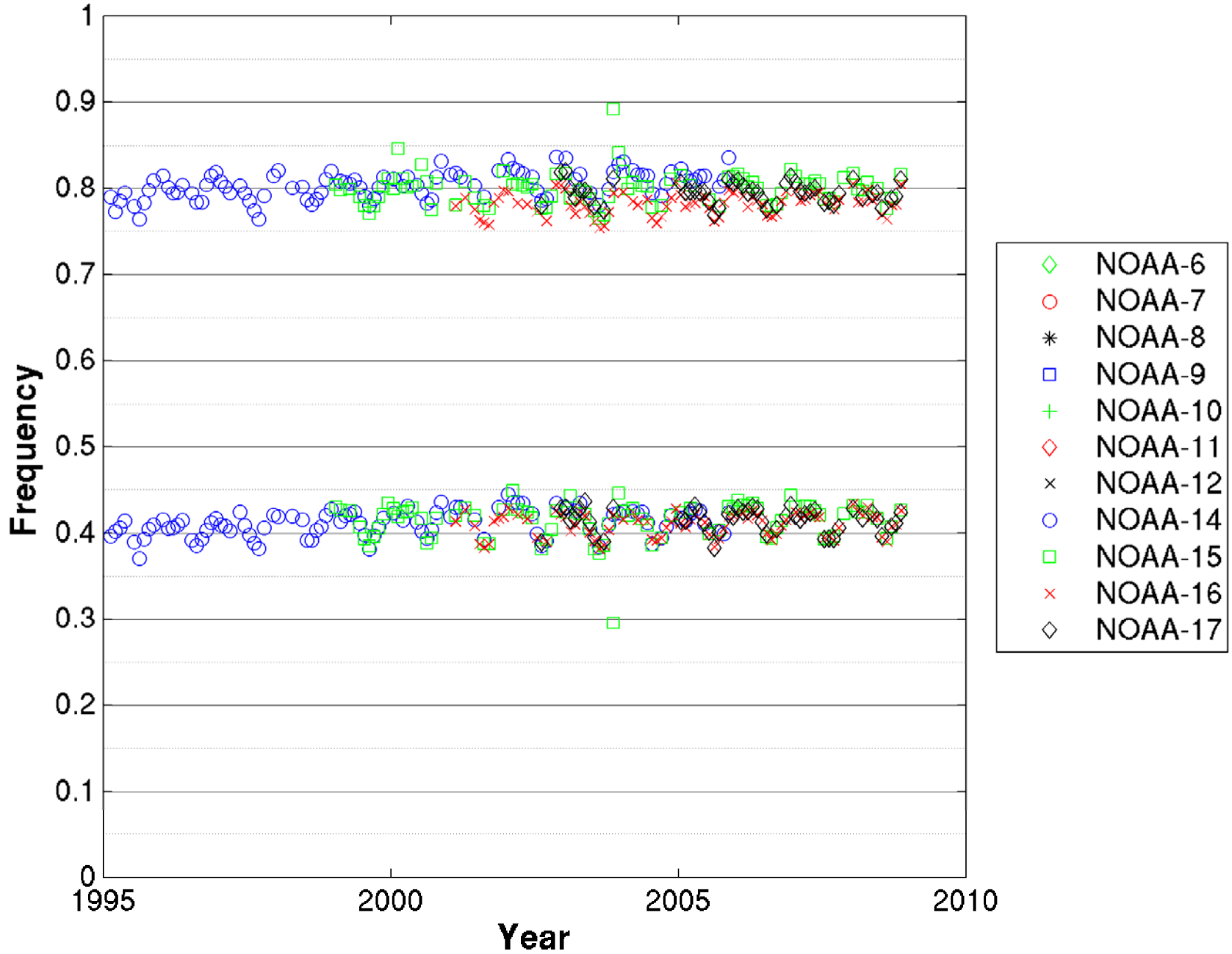
Spectral Shifts used for N15 & N16

none

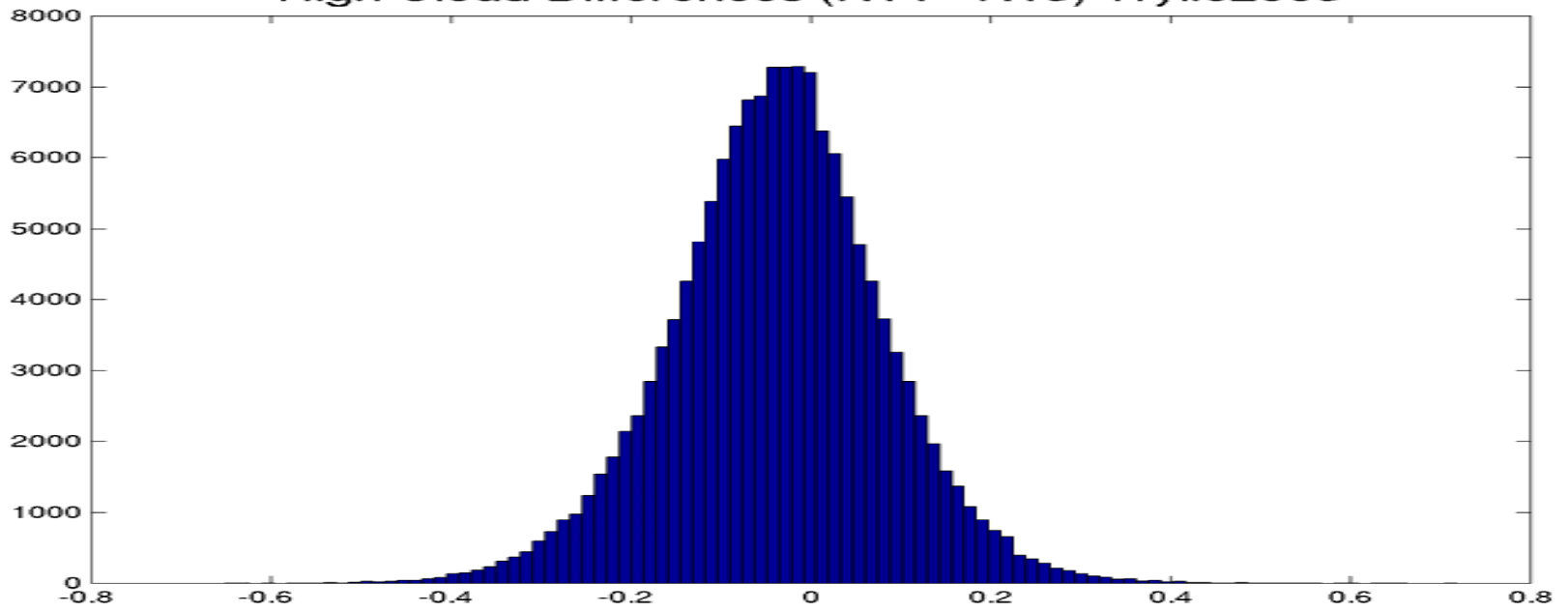
HIRS Reprocessing Results





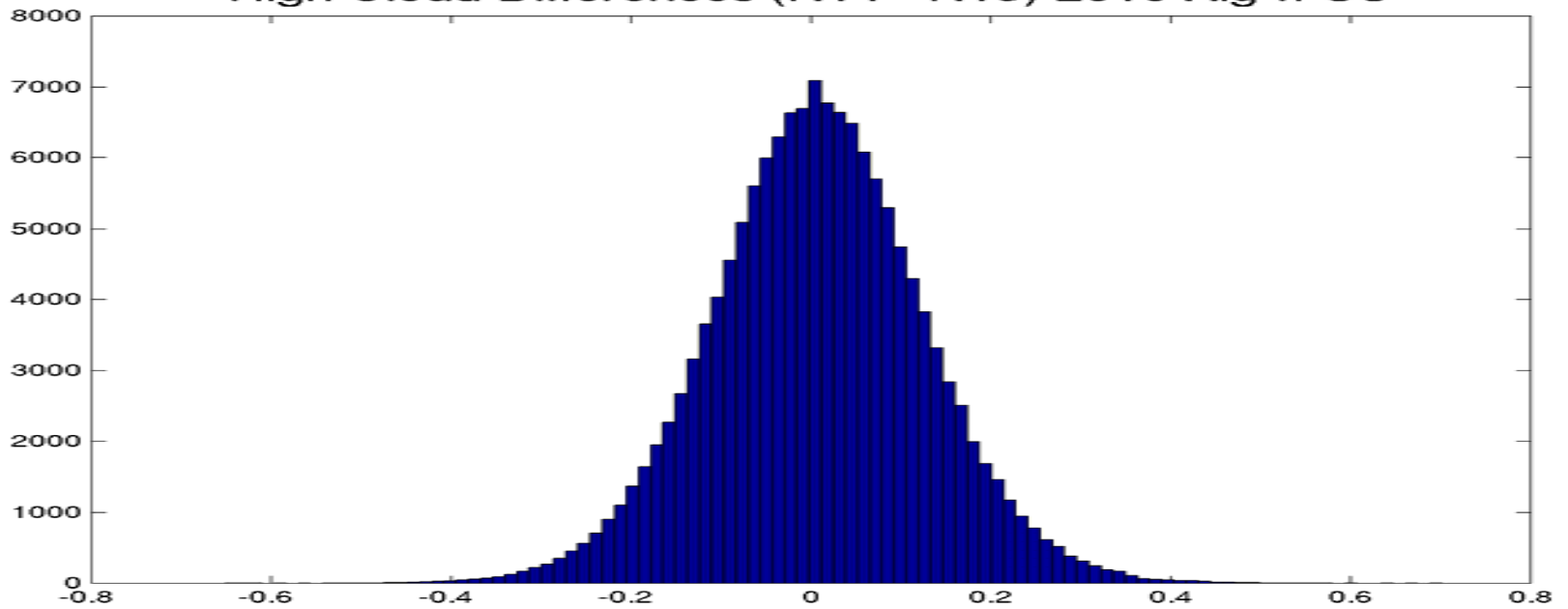


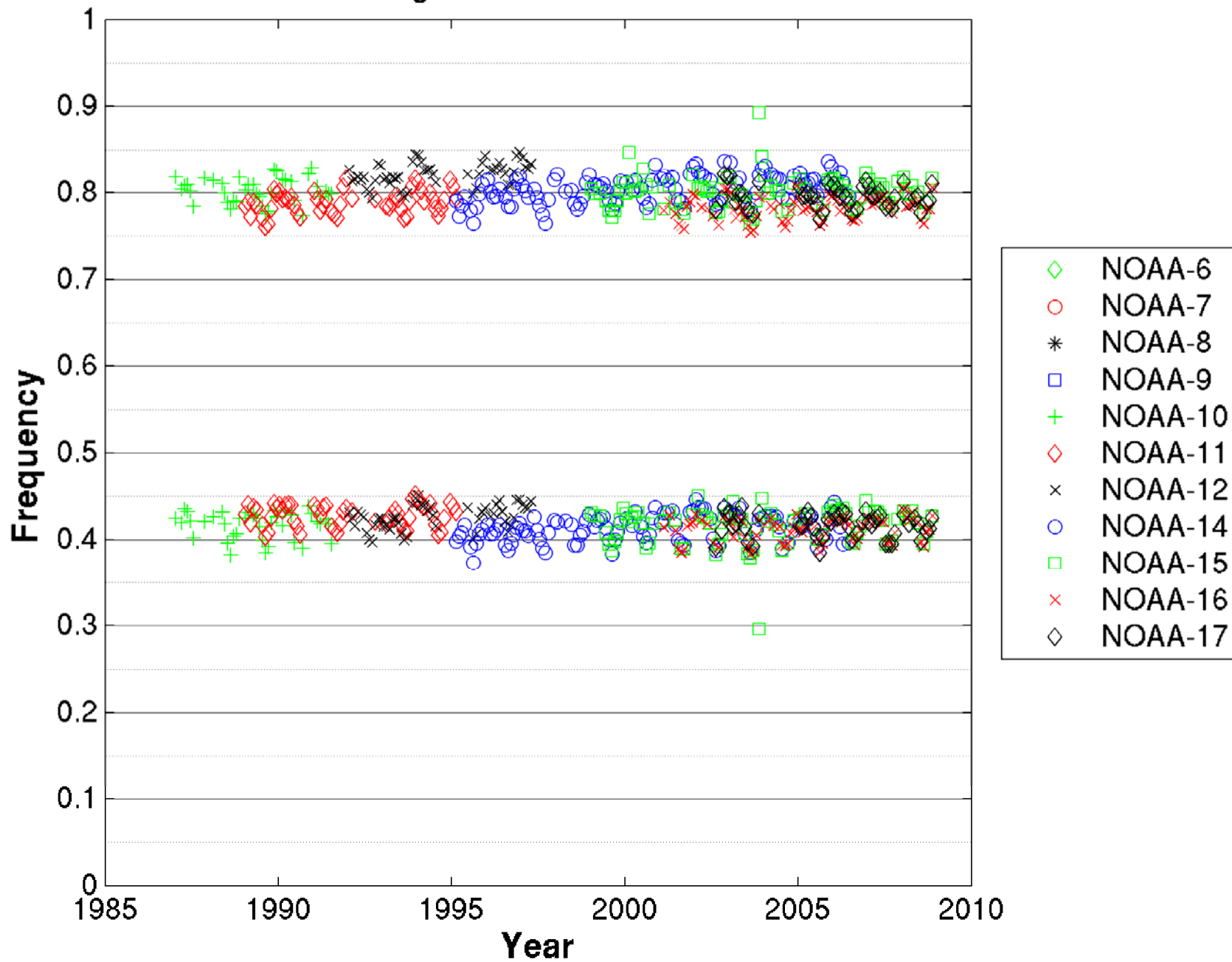
High Cloud Differences (N14 - N15) Wylie2005



Jan 2003

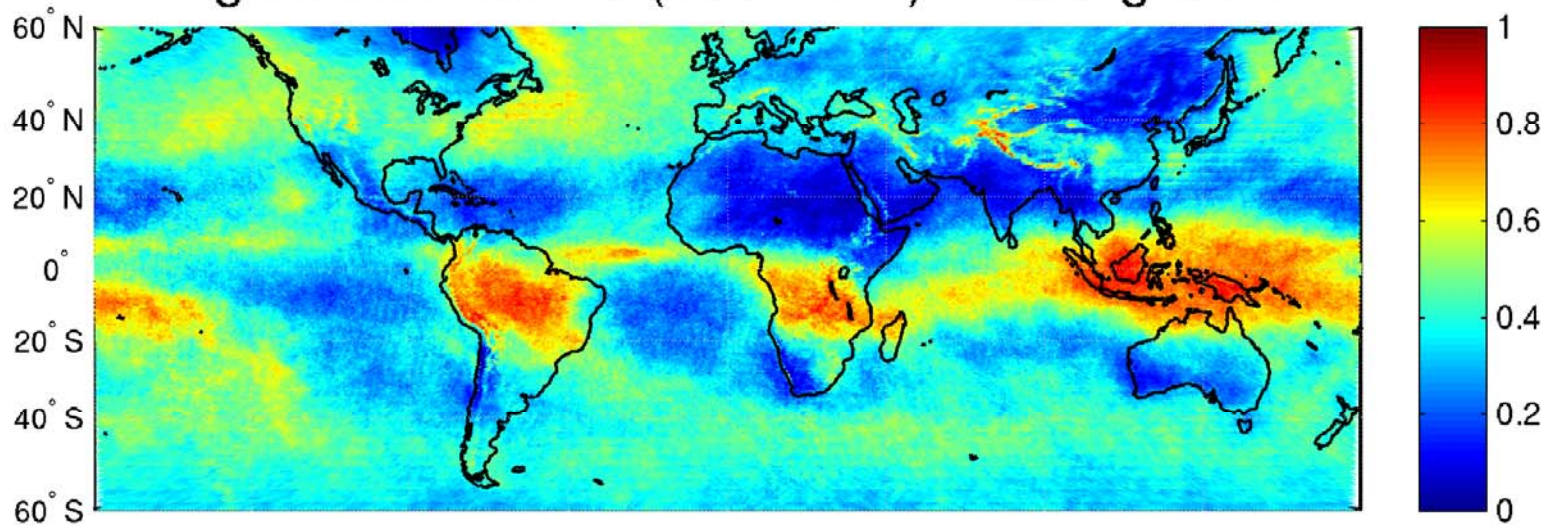
High Cloud Differences (N14 - N15) 2010 Alg w SS



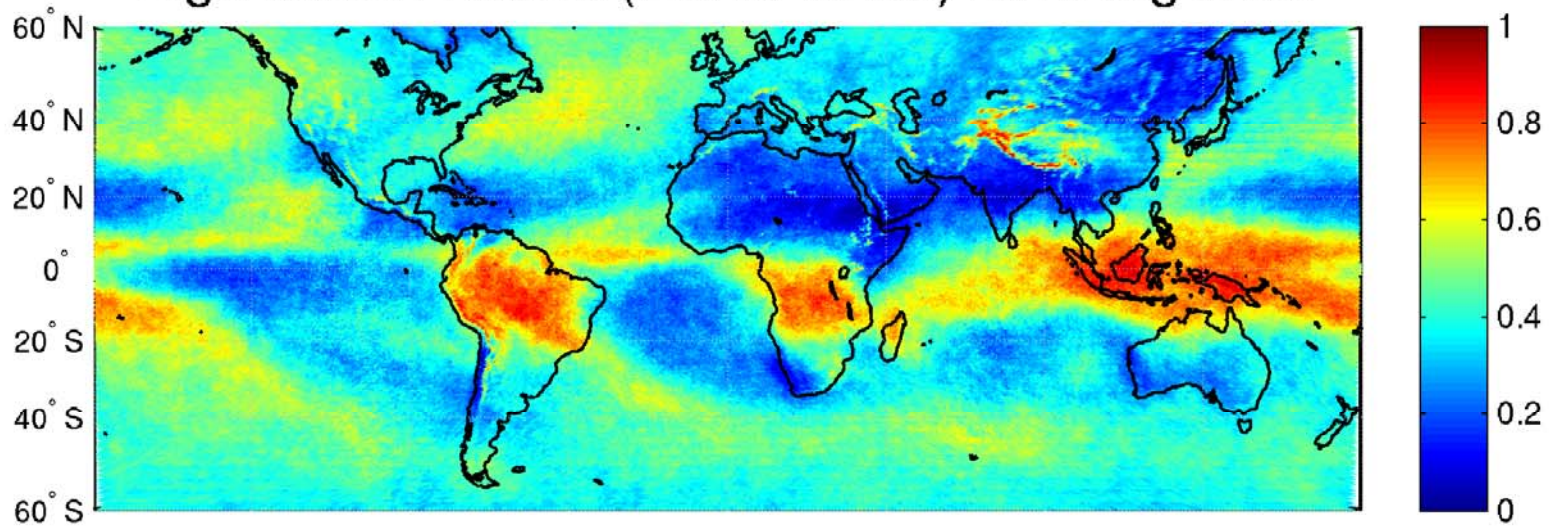


Changes from the 1990s to the 2000s

High Cloud Fraction (90s winter) 2010 Alg w SS

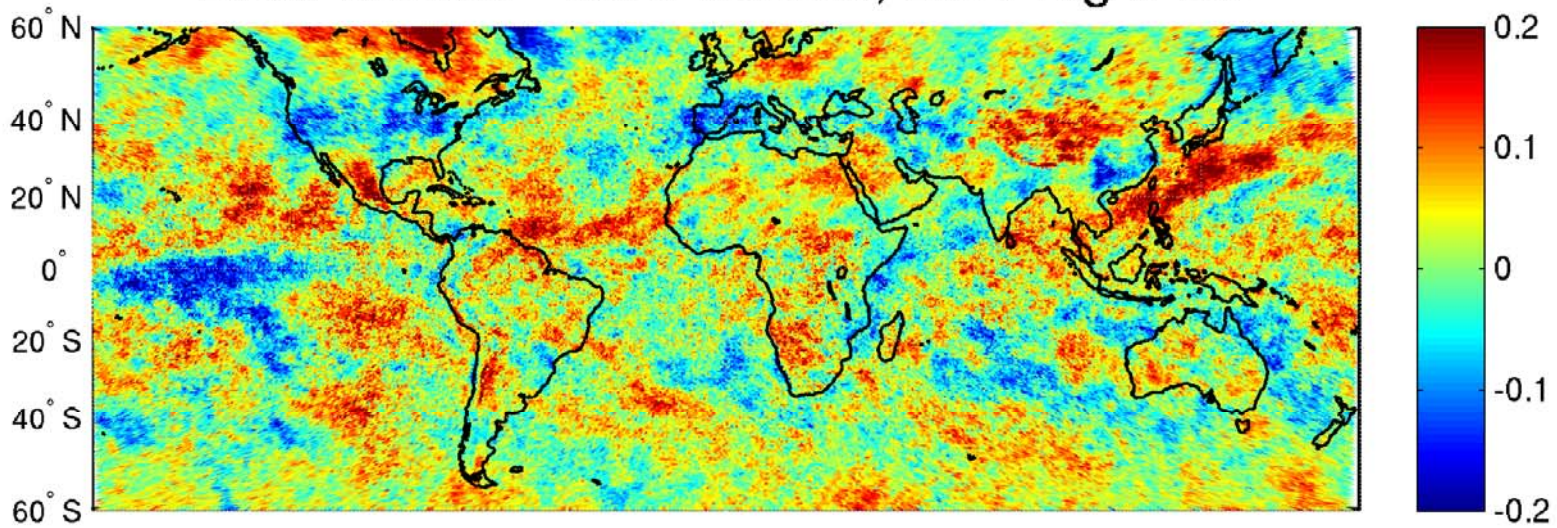


High Cloud Fraction (2000s winter) 2010 Alg w SS



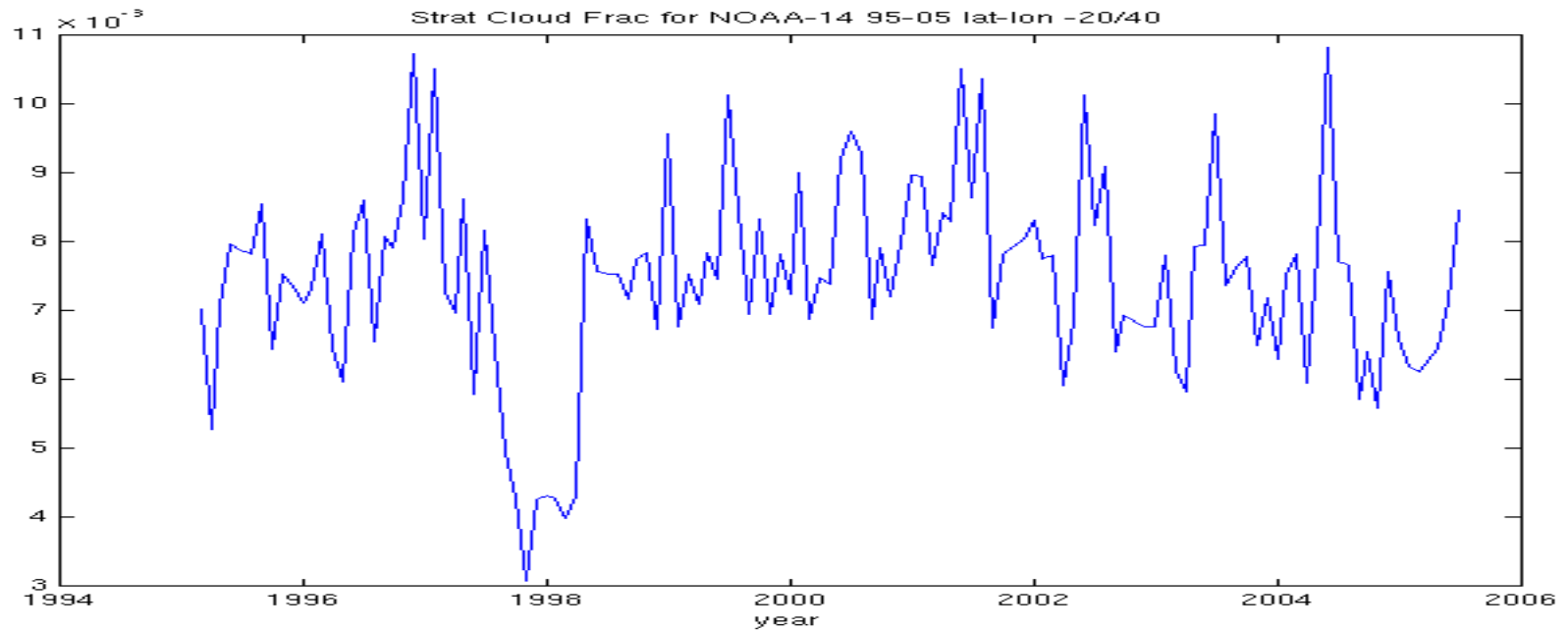
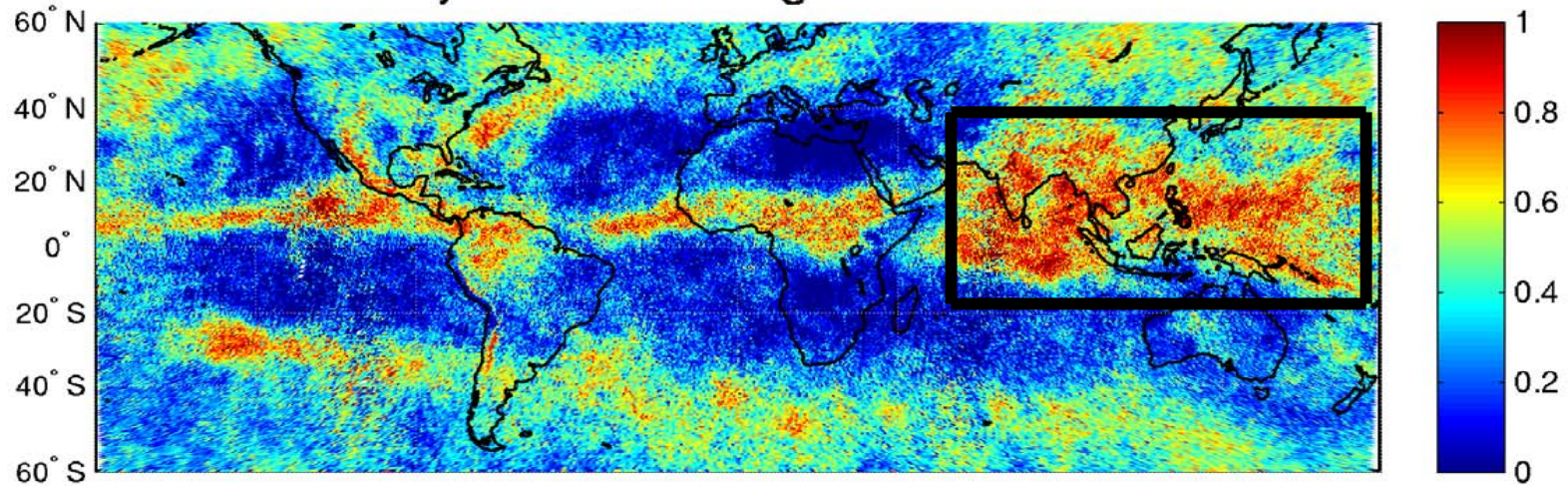
High Cloud Winter Changes

2000 Winters - 1990 Winters, 2010 Alg w SS

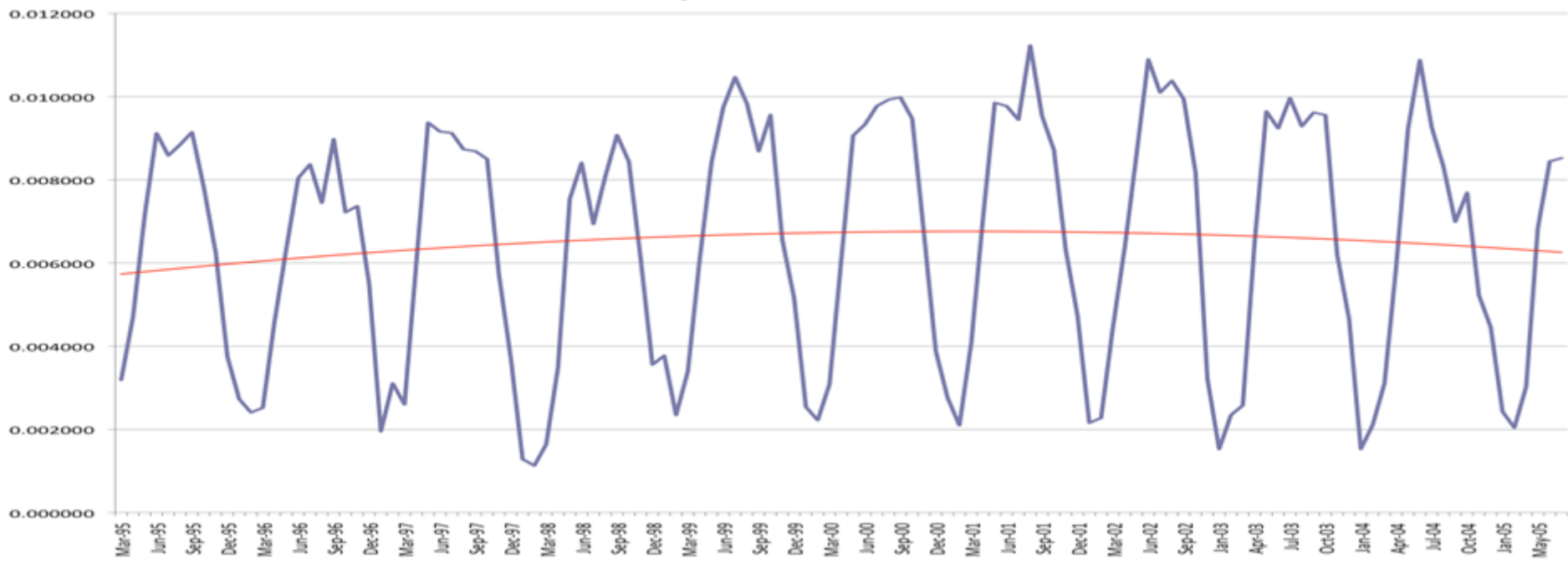


Trend of ITCZ DCCs is being studied – Kolat et al

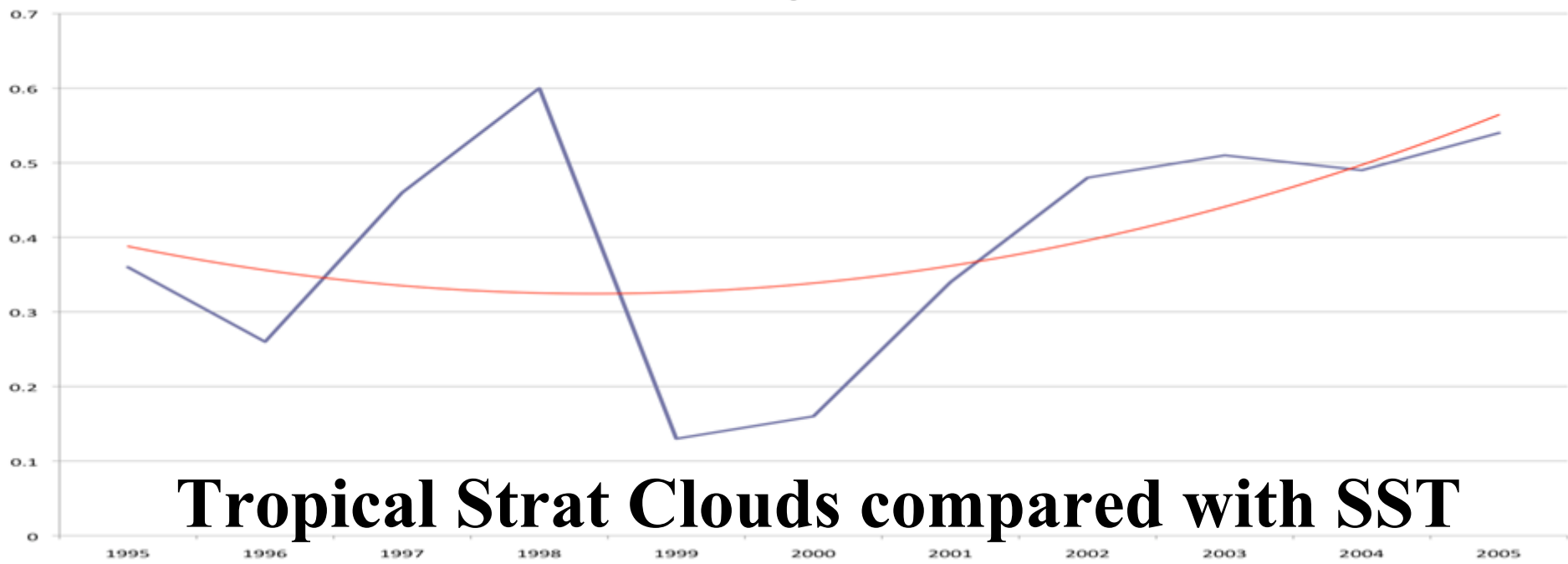
July 2001 % of High Cloud Obs



Stratospheric Clouds 0-25N

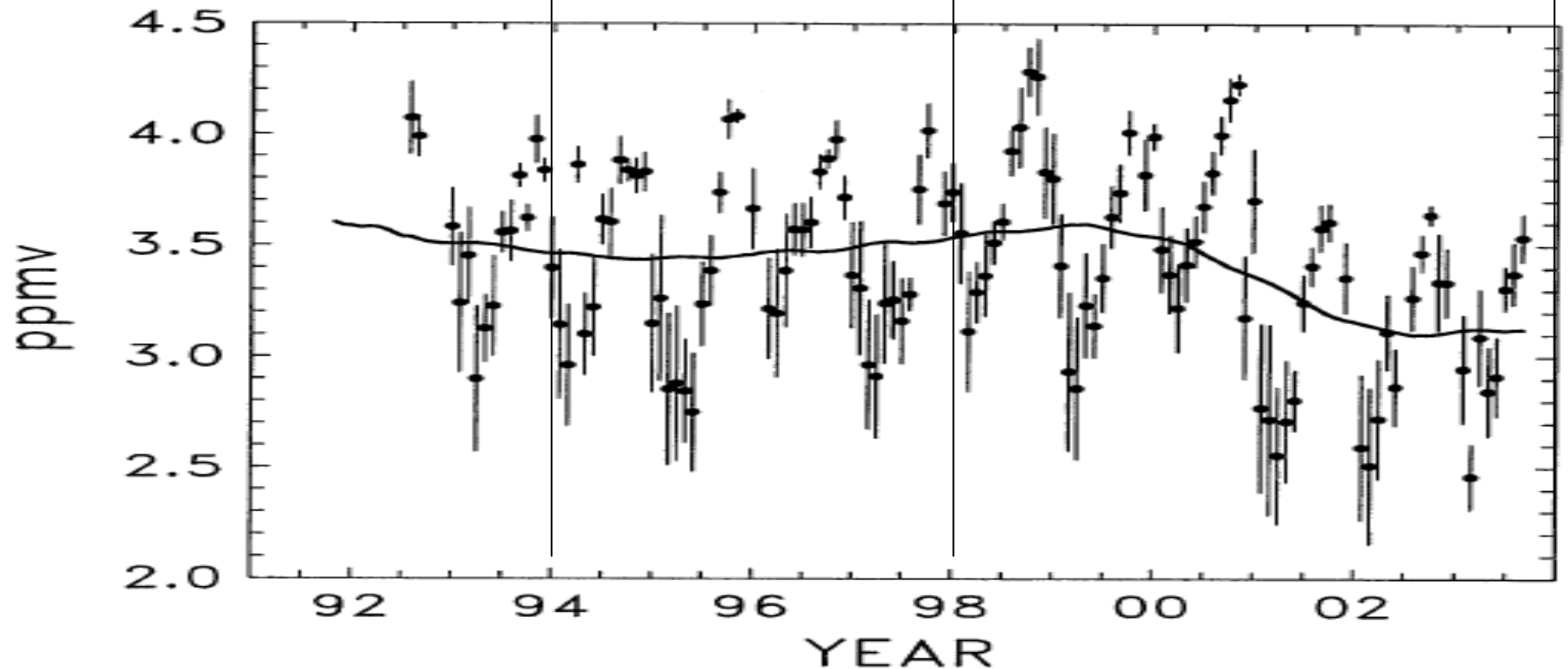
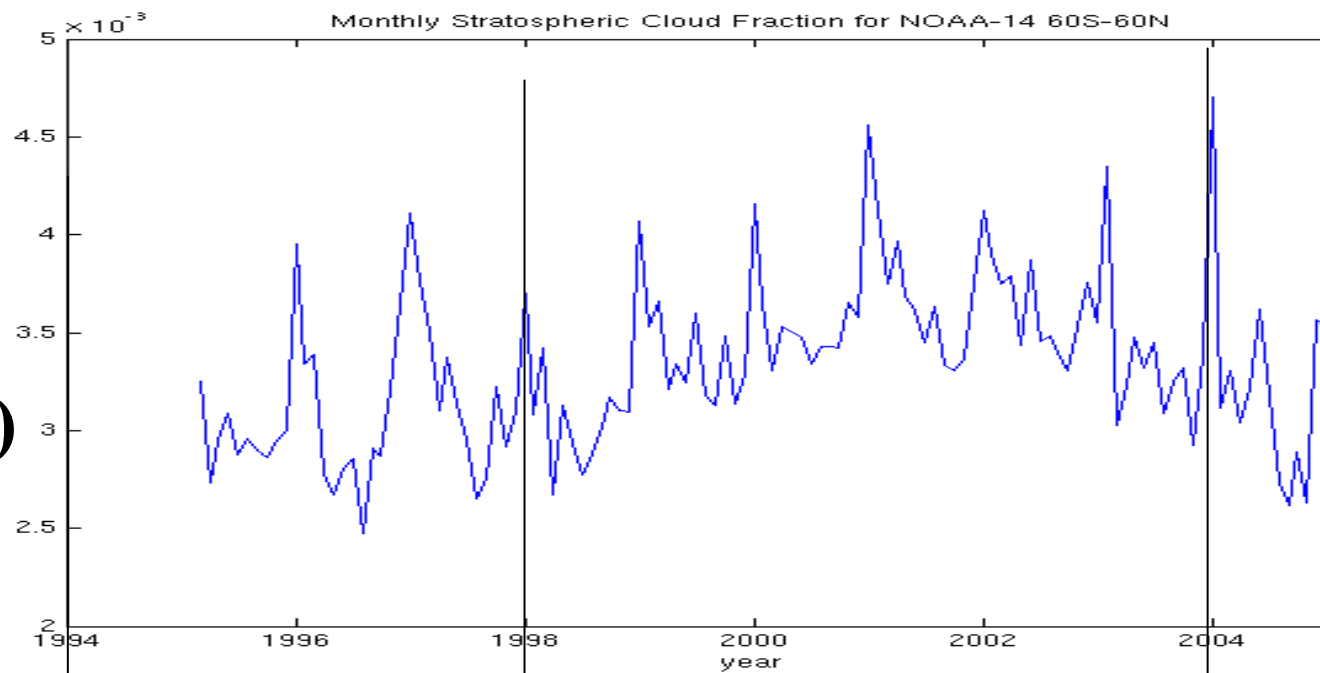


Sea Surface Temperatures 0-25N

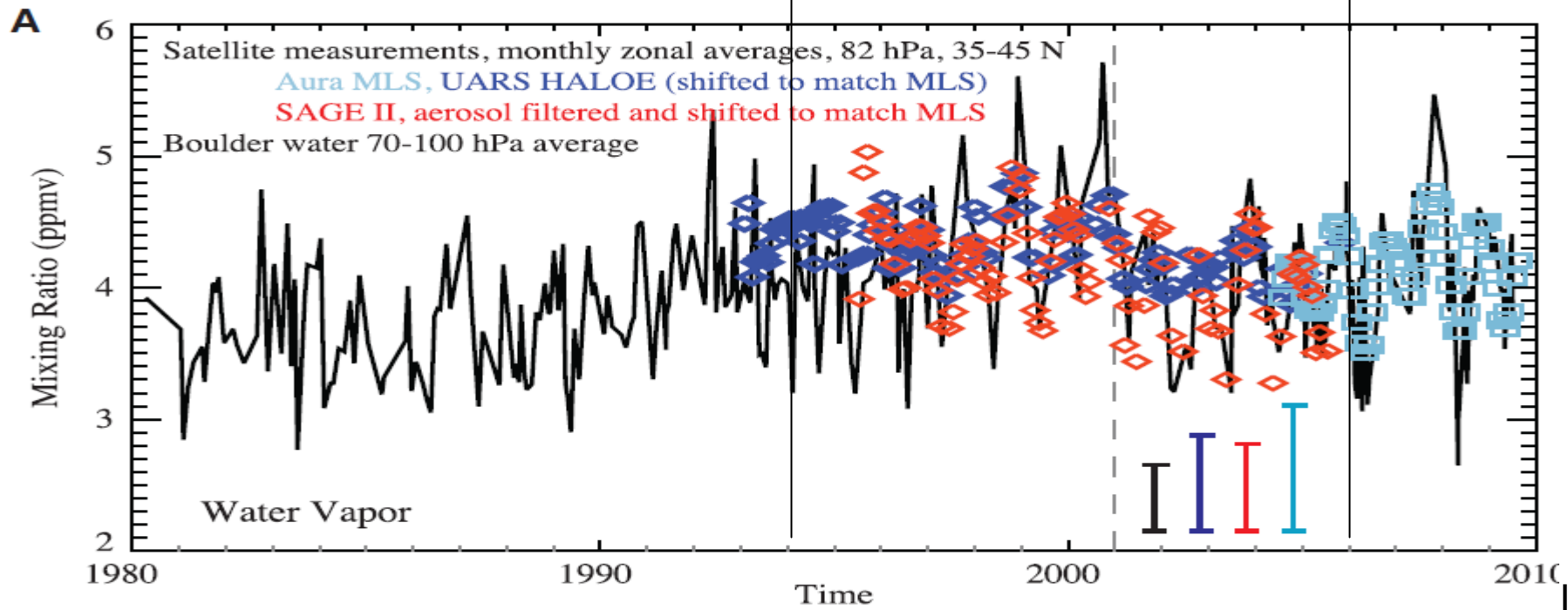
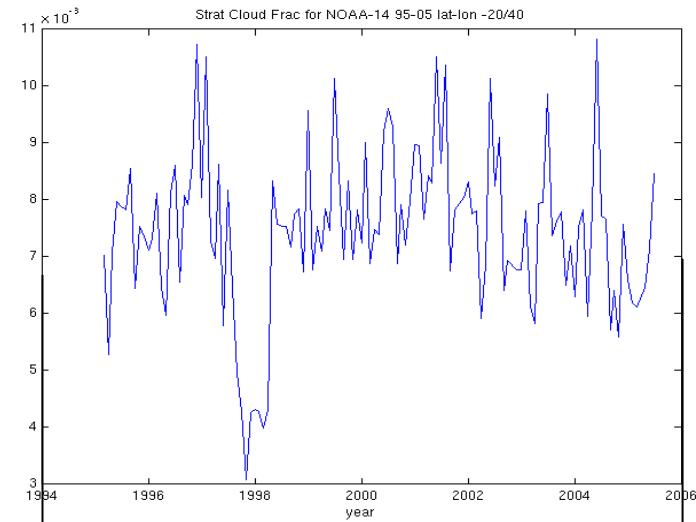


Tropical Strat Clouds compared with SST

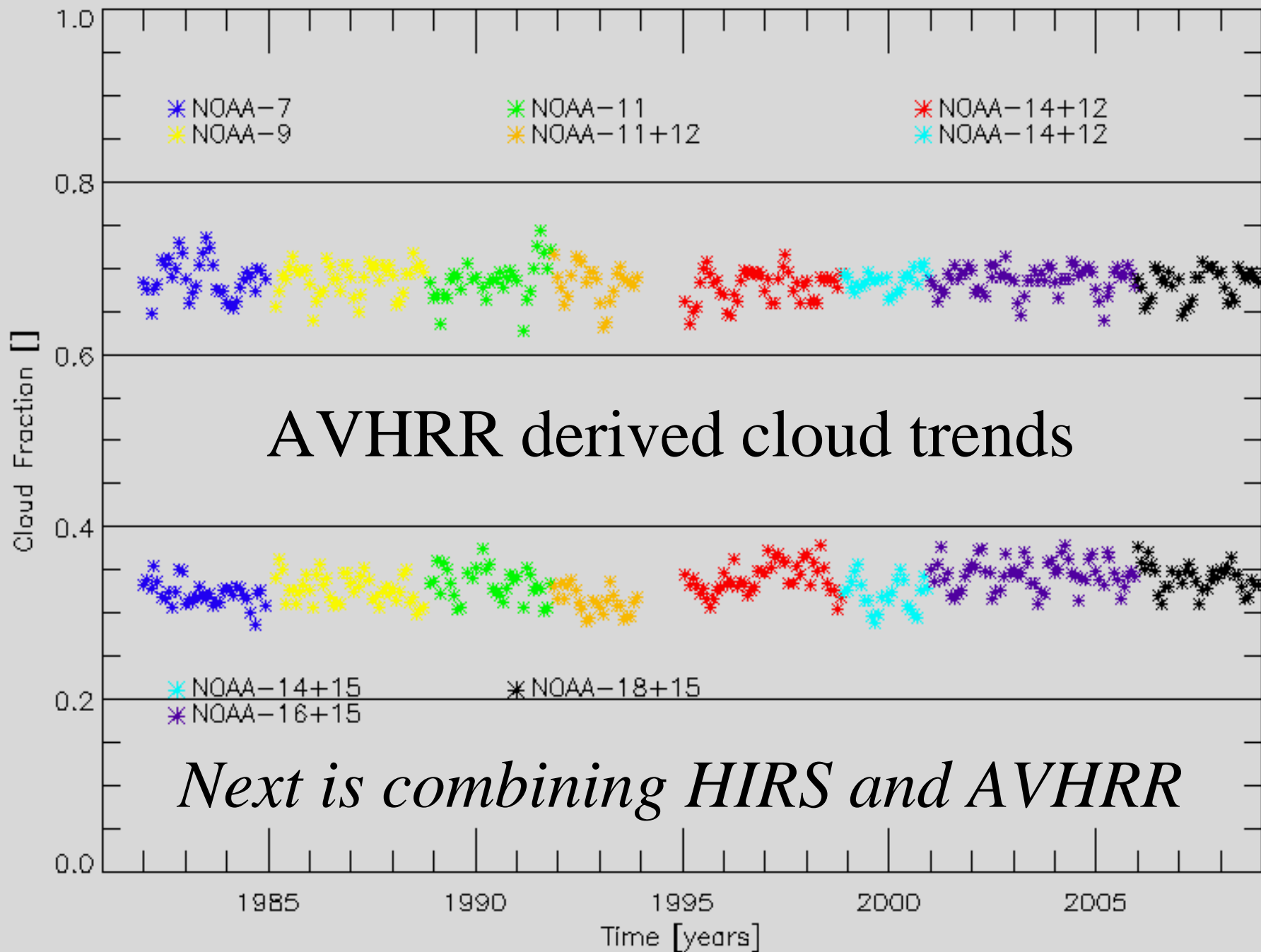
60 N – 60 S
Strat Cld trend
compared with
Randel et al (2004)
Strat WV

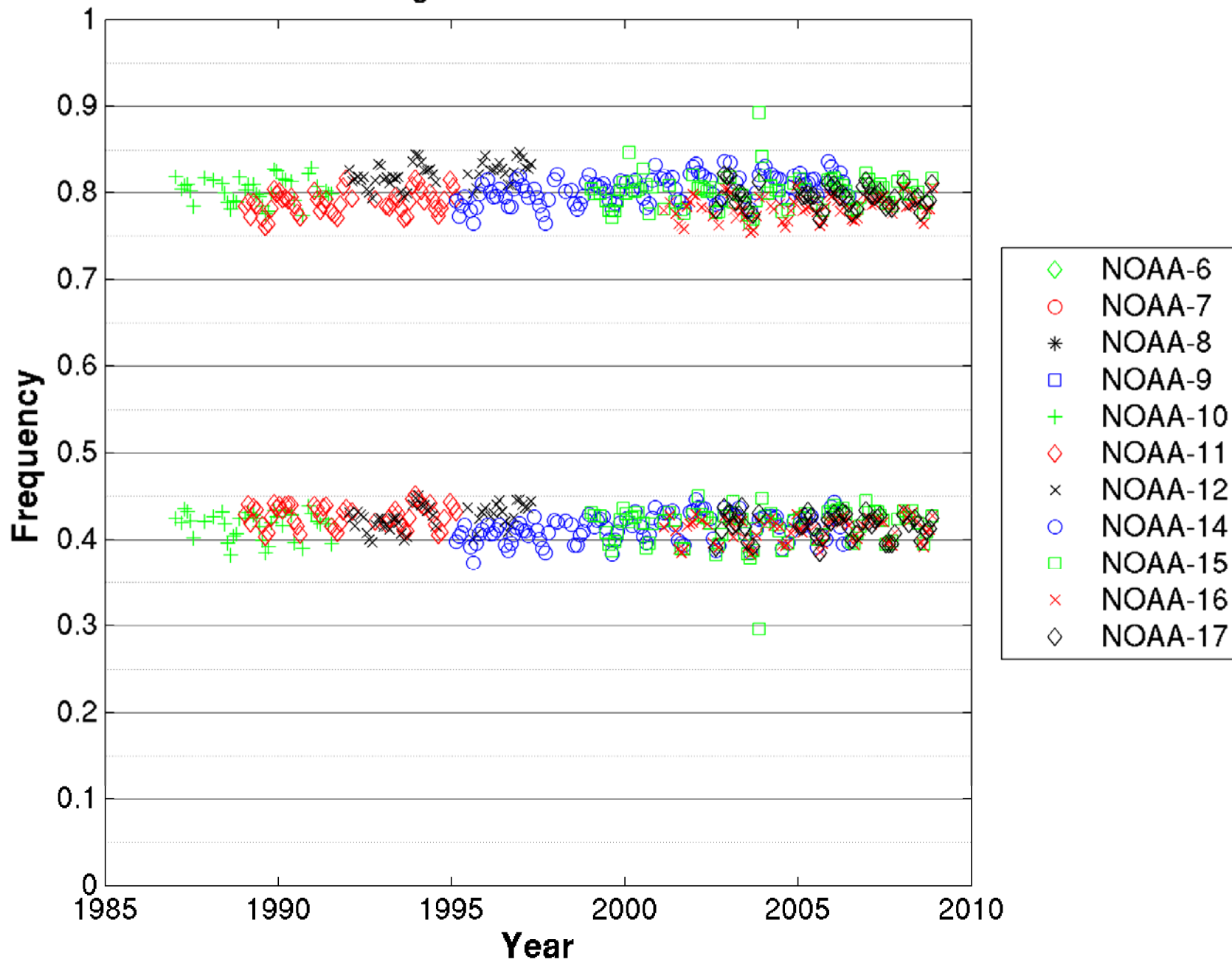


ITCZ Strat Cld trend compared with Solomon et al



Combining Imager and Sounder Measurements





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

International TOVS Study Conference, 17th, ITSC-17, Monterey, CA, 14-20 April 2010.
Madison, WI, University of Wisconsin-Madison, Space Science and Engineering Center,
Cooperative Institute for Meteorological Satellite Studies, 2011.