Progress Report on Reprocessing HIRS Cloud Measurements
Nov 2011 to Apr 2012
Principle Investigator: W. Paul Menzel
Date: May 2012

1. Mitigating Sensor to Sensor Differences

Sensor to sensor calibration differences continue to be studied in collaboration with the STAR calibration team. The approach has been to estimate the radiance change for a specific channel due to Spectral Response Function (SRF) difference and uncertainty. To do this a linear model has been developed to correlate the radiance change in a selected channel with the spectral radiances in selected HIRS channels. The hyper-spectral measurements from the Infrared Atmospheric Sounding Interferometer (IASI) on the MetOp satellite are used to simulate HIRS observations and to estimate the parameters in the linear models. The linear models are applied to the NOAA and MetOp HIRS data at SNO locations to estimate the inter-satellite radiance differences due to the SRF differences and uncertainties. The inter-satellite mean radiance biases are minimized towards zero with residual maximum uncertainty less than 1% after the impacts of SRF differences and uncertainties are taken out. Using the MetOp HIRS as a reference, the optimized SRFs for every NOAA HIRS are found by minimizing the root-mean-square values of inter-satellite radiance difference. Compared with pre-launch SRF measurements, the optimized shifts of the SRF can be as large as 3.3 cm-1. The comparisons between MetOp IASI and NOAA HIRS measurements from satellites after NOAA-15 at SNO locations show the optimized SRF significantly improves the consistencies of NOAA HIRS radiances relative to those of MetOp IASI.

The spectral shifts for the carbon dioxide sensitive channels have been determined in this way. Some work remains on refining the water vapor channel spectral shifts; it appears that the spectral shifts will need to be accompanied by an adjustment in the calibration algorithm offset (space view term).

Table 1: SNO suggested spectral shifts for bands sensitive to CO2 (4, 5, 6, and 7) and H2O (12) on NOAA 9 and thereafter.

	Ch4 (14.2)	Ch5 (13.9)	Ch7 (13.3)	Ch12 (6.7)
N09	-0.69	1.80	-1.15	-0.49
N10	-0.07	0.34	-1.78	1.42
N11	0.68	0.67	-0.57	2.60
N12	-0.47	1.36	-2.76	2.73
N14	0.97	2.11	1.14	3.26
N15	-0.92	-0.73	1.00	-0.56
N16	-0.46	-0.52	0.38	TBD
N17	-0.27	-0.59	-0.09	TBD
N18	-0.97	-1.43	-0.39	TBD
N19	-0.31	-0.73	0.13	TBD
MOA	-0.15	0.10	-0.15	2.20

Ch6 (13.6) shifts were not deemed necessary

2. *Reprocessing the HIRS Cloud Data Set*

The HIRS data from NOAA-6 onwards have been re-processed using the original HIRS algorithm software with adjustments suggested by the MODIS experience and the spectral shifts suggested by using Metop HIRS as a reference. Figure 1 shows a comparison of the afternoon high cloud trends over ocean before and after the spectral shift. Sensor to sensor differences are found to have been largely mitigated and some modest trends have been changed. Winter and summer high cloud differences remain constant at roughly 6 %; winter high clouds remain relatively constant showing no trend. A paper summarizing the impact of the spectral shifts and the results from this re-processing has been drafted; submission to the Journal of Oceanic and Atmospheric Technology is planned.

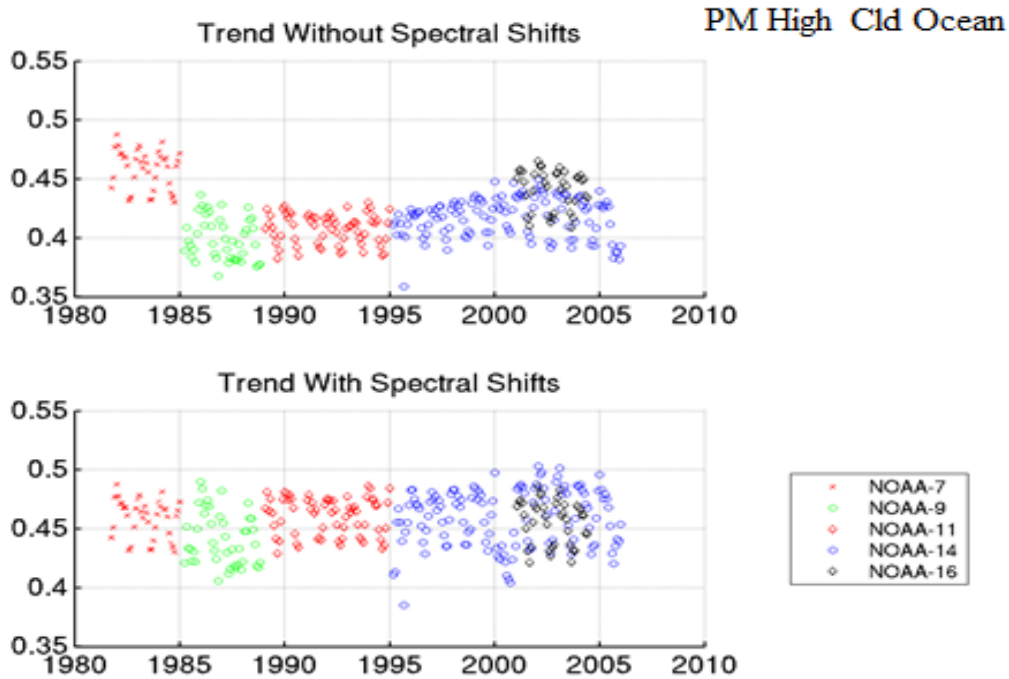


Figure 1. Afternoon high (CTP<440 hPa) cloud over ocean trends from 1981 through 2009 given in fraction of total HIRS observations before spectral shift (top) and after spectral shift (bottom).

3. *CREW-3*

SSEC hosted the third Cloud Retrieval Evaluation Workshops (CREW) wherein international satellite-based cloud retrieval teams share their experience with state-of-art cloud parameter retrievals from passive imaging satellite observations. CREW provides a path towards optimizing these retrievals for both climate monitoring research as well for climate and weather model analysis. In addition to focusing on instantaneous cloud parameter retrievals, CREW also seeks to observe and understand methods that are used to prepare daily and monthly cloud parameter climatologies. Particular attention is given to increase the traceability and uniformity of different long-term and homogeneous records of cloud parameters. As a result of past CREW recommendations, a common

database was built to organize cloud property retrievals from different algorithms for passive imagers (MSG, MODIS, AVHRR, POLDER and AIRS), complemented with cloud measurements that serve as a reference (CLOUDSAT, CALIPSO, AMSU, MISR) for a number of "golden days." Three working groups provided specific recommendations.

The Working Group on Cloud Vertical Placement suggested complementing the cloud height and temperature retrievals with information on the cloud type i.e.: opaque, semi-transparent, or multiple-layer clouds. In addition, this group strongly supported the recent developments towards better detection of multiple-layer clouds in an atmospheric column. The Working Group on Cloud Physical Properties discussed in detail the differences between cloud property retrievals from infrared (IR) observations, and the microphysical properties of ice cloud models that should be used to retrieve ice cloud parameters from visible (VIS) and shortwave infrared (SWIR) observations. They concluded that IR-only cloud optical thickness retrievals appear to have better skill than VIS/SWIR techniques for clouds with optical thicknesses smaller than 3. Based on comparisons between active sensor (CALIOP; Cloud-Aerosol Lidar with Orthogonal Polarization), VIS/SWIR, polarized measurements from PARASOL (Polarization and Anisotropy of Reflectances for Atmospheric Sciences coupled with Observations from a Lidar), and IR-only retrievals of optical thickness, the retrievals for ice cloud seem to match best with nature when roughened particles are assumed. Finally, the Working Group on Cloud Climatologies discussed ways forward to accommodate a common approach for generating global gridded (Level 3) cloud climatologies with respect to methods used for spatial sampling and methods for calculating uncertainty information. Moreover, the need was stressed for uniformity among the cloud parameter datasets.

The next CREW meeting is being planned for 2013.

4 Recoding the HIRS Cloud Algorithm

The MODIS cloud algorithm software adaptation to HIRS continues. Past progress includes (1) using HIRS hdf radiance and geolocation input data files with MODIS-like (Collection 6) algorithms for clouds and moisture, (2) incorporating collocated AVHRR cloud mask data from PATMOS-X into the HIRS reprocessing to provide a sub-HIRS-pixel cloud mask (a HIRS FOV must be at least 15% cloudy to be processed as a cloudy FOV), (3) using the PATMOS-X cloud mask to initialize the clear versus cloudy FOV identification necessary for radiance bias adjustments, (4) testing the spectral shifts suggested by STAR, and (5) measuring the quality of the resulting cloud and TPW fields through inter-comparisons with CALIOP and AIRS.

Comparison of collocated HIRS 18 and CALIOP cloud top heights for August 2008 is shown in Figure 2; CALIOP data were processed at 1 km resolution and compared with the HIRS cloud results that have a 10 km FOV at nadir FOV (HIRS spectral shifts have not been introduced in these results). It is anticipated that some scatter in the comparison will be reduced when CALIOP data are averaged at 5 km resolution. Nonetheless, most of the HIRS-CALIOP CTHs are found to have a bias of -0.7 km with a standard deviation

of 3.4 km; there are very few outliers with disagreement beyond 5 km. Results with the HIRS spectral shifts incorporated will be processed and compared to study the impact.

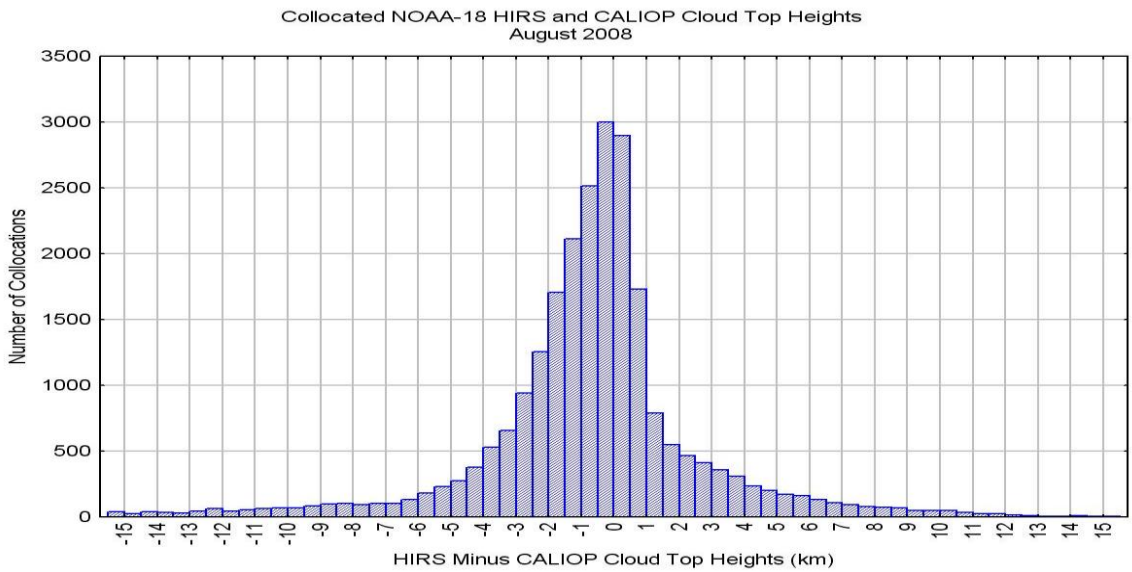


Figure 2. HIRS minus CALIOP 1-km cloud top heights for August 2008. HIRS values were generated with the recoded MODIS-like algorithm. Scatter will be reduced on the positive side of the difference distribution when 5-km CALIOP output is available.

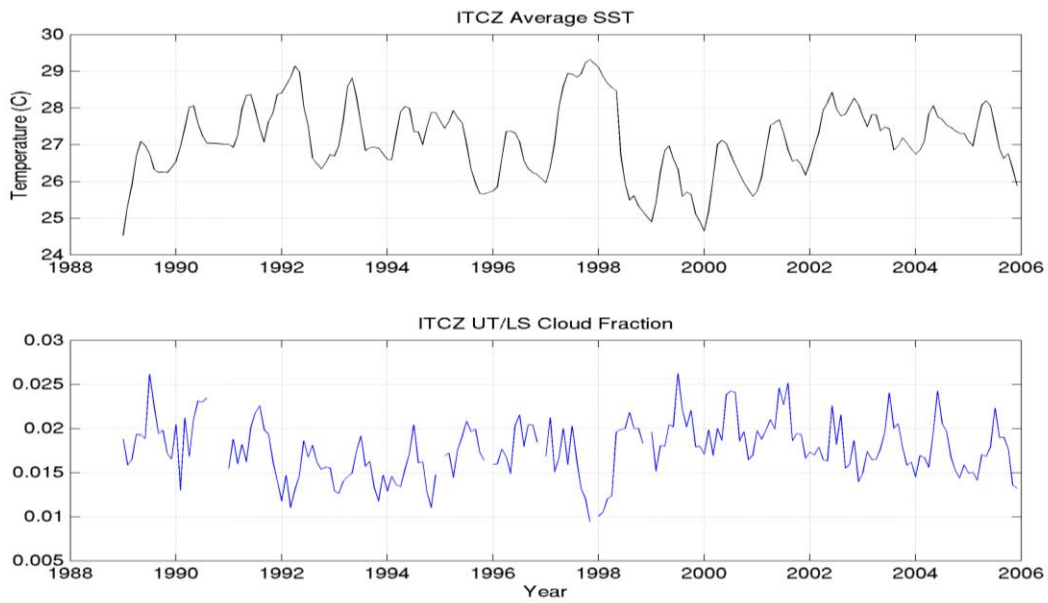
Conversion of MOD07 to retrieve HIRS moisture layers (high. middle, and low) and total column moisture continues. The synthetic regression coefficients for the statistical retrieval have been derived using a fast radiative transfer model; atmospheric characterization is achieved with a global set of atmospheric temperature, moisture, and ozone profiles. The radiative transfer calculation of the HIRS spectral band radiances have been performed without spectral shifts for the training profiles using the JCSDA Community Radiative Transfer Model; we are working with the CRTM team to recalculate the transmittance coefficients with the spectral shifts suggested by the STAR calibration team. The HIRS instrument noise was added into the calculated spectral band radiances, and the resulting temperature-moisture-ozone profile / HIRS radiance pairs are used to establish a statistical regression. Ancillary data (geo-location, cloud mask, surface emissivity) has been incorporated in the processing. Expansion of processing to all view angles (beyond the current limit of less than 32 degrees from nadir) and corrections for cloud contamination in partly cloudy pixels are now being tested.

5. Investigating HIRS Stratospheric Cloud Trends

The presence of upper tropospheric / lower stratospheric (UT/LS) clouds has been estimated at the pixel level on the assumption that positive lapse rates above the tropopause imply that the more opaque spectral band sensitive to CO2 or H2O in the atmosphere produces a brightness temperature warmer than a less opaque or nearly transparent infrared window spectral band. UT/LS cloud detection trends using measurements sensitive to CO2 (BT13.9 > BT13.3) were compared with those using measurements sensitive to H2O (BT6.7 > BT11). CO2 detection is more prevalent and

somewhat out of phase with H2O detection; H2O presence in the UT/LS is variable while CO2 presence is relatively constant. In NOAA-14 data spanning 1995 through 2005, there are indications of UT/LS clouds in 0.7 % of the observations from 60˚N to 60˚S using CO2 absorption bands; however, in the region of the International Tropical Convergence Zone this increases to 2.5%. Monthly trends show increases in UT/LS cloud detection until 2001 with a decrease thereafter. Strong inverse correlations between UT/LS clouds and tropical sea surface temperature trends are also found. A paper has been submitted to JAMC.

(a)



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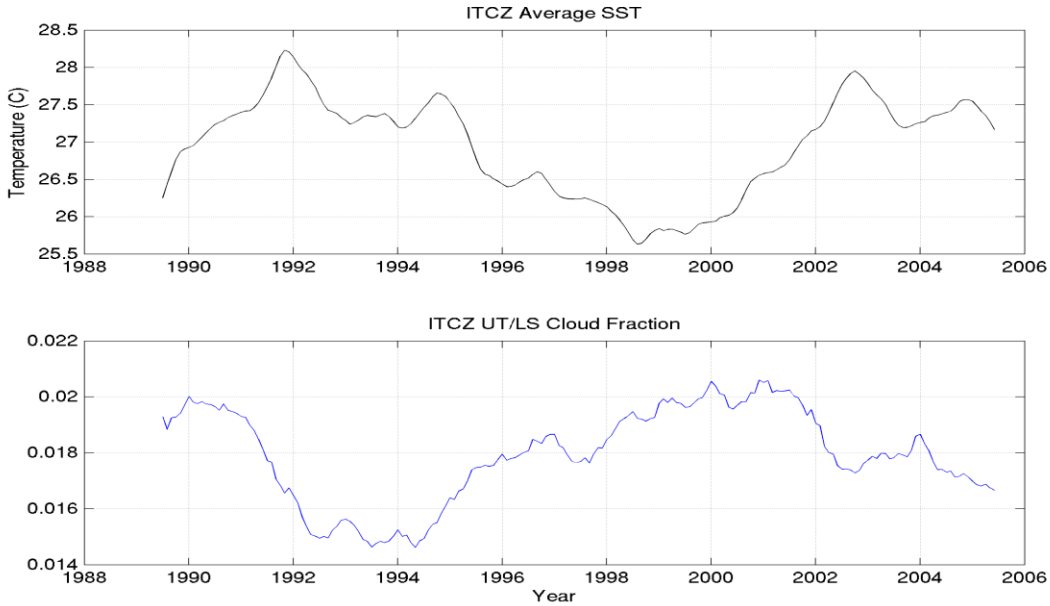

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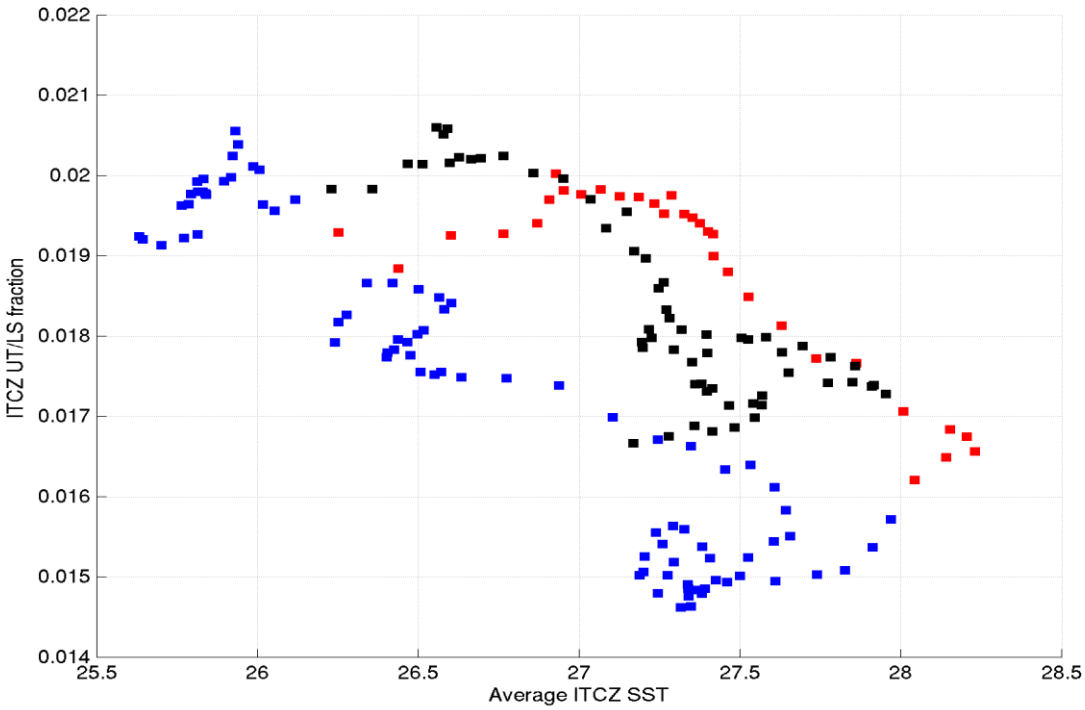

Figure 3. (a) Monthly SSTs over the Nino 3.4 area and UT/LS cloud fraction detected by HIRS over the ITCZ (20 S – 40 N; 45 -180 E) from 1989 to 2005. (b) Multiyear trend of same with a sliding average that includes the six months of data both before and after each month. (c) Scatter plot of monthly sliding average values (omitting mid-1997 to mid-1998) with UT/LS fraction on y-axis and SST on x-axis; correlation coefficient is 0.61. The three sections of the time series are shown in different colors with Aug 1989 – Aug 1992 in red, Sep 1992 - Dec 2000 in blue, and Jan 2001 through Apr 2005 in black.

6. Remaining Work

6.1 Test the new software and spectral shifts on several seasons (years) of data. Continue validation of results against CALIPSO where possible. Compare against Aqua L3 for a month where CALIPSO is available and then a month early in the MODIS mission to test consistency.

6.2 Prepare paper on re-processed HIRS cloud detection trends.

6.3 Finish preparations to process HIRS moisture fields in clear and partially cloudy skies.

6.4 Prepare the software for transfer to NCDC.

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1. Mitigating Sensor to Sensor Differences

Sensor to sensor calibration differences continue to be studied in collaboration with the STAR calibration team. The approach is to estimate radiance changes for a specific channel due to Spectral Response Function (SRF) modifications and related uncertainty. A linear model correlates the radiance change in a selected channel with the spectral radiances in selected HIRS channels. The hyper-spectral measurements from the Infrared Atmospheric Sounding Interferometer (IASI) on the MetOp satellite are used to simulate HIRS observations and to estimate the parameters in the linear models. The linear models are applied to the NOAA and MetOp HIRS data at Simultaneous Nadir Overpass (SNO) locations to estimate the inter-satellite radiance differences. The inter-satellite mean radiance biases are minimized with residual maximum uncertainty less than 1% after the impacts of SRF differences and uncertainties are taken out. With use of the MetOp HIRS as a reference, the optimized SRFs for every NOAA HIRS are found by minimizing the root-mean-square values of inter-satellite radiance difference.

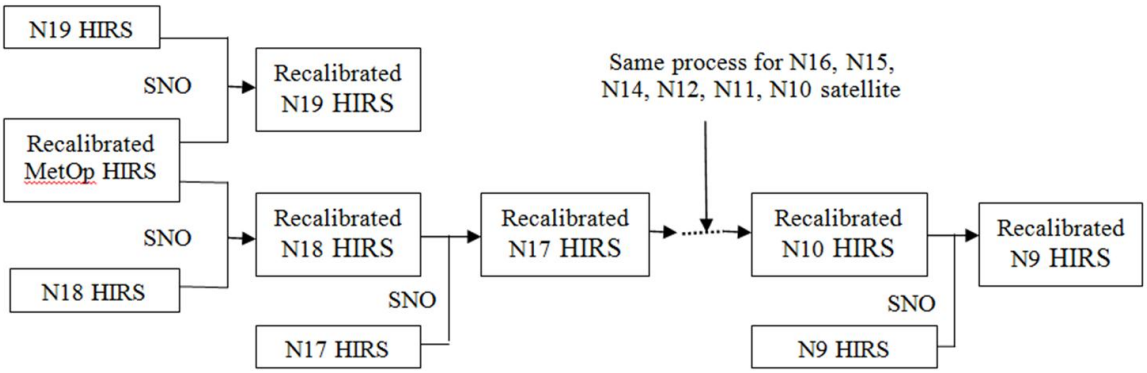


Figure 1: Schematic of the recalibration process using Metop IASI and SNOs

After another re-calibration wherein the H_2O channel shifts were finalized, the optimized shifts of the SRF are found to be as large as 2.8 cm-1 for the CO2 channels and 7.1 cm-1 for the H_2O channels. In some cases large differences in the SNO recalibration from the south pole were found with respect to those from the north pole; these are still being investigated especially for NOAA-11 channel 5. Note that each time a SRF is changed, several years of data need to be processed again to assess the results from the SRF change. That is, the ability to assess changes that result from simple SRF modifications relies on a significant amount of data reduction.

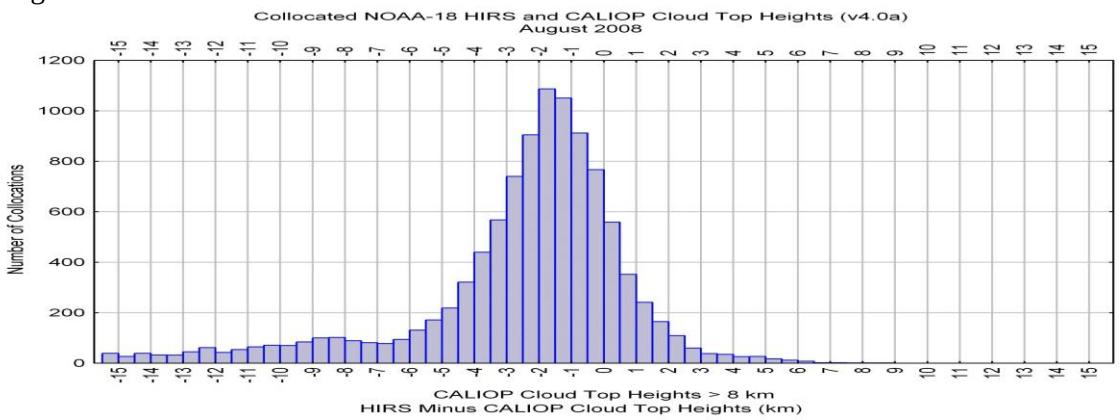
Table 1: SNO suggested spectral shifts for bands sensitive to CO2 (4, 5, 6, and 7) and H2O (12) on NOAA 9 and thereafter. Ch6 (13.6) shifts were not deemed necessary.

	Ch4 (14.2)	Ch5 (13.9)	Ch7 (13.3)	Ch12 (6.7)
N09	-0.69	1.80	-1.15	3.2
N10	-0.07	0.34	-1.78	5.7
N11	0.68	0.67	-0.57	6.9
N12	-0.47	1.36	-2.76	7.0
N14	0.97	2.11	1.14	7.1
N15	-0.92	-0.73	1.00	3.4
N16	-0.46	-0.52	0.38	5.5
N17	-0.27	-0.59	-0.09	-0.2
N18	-0.97	-1.43	-0.39	6.0
N19	-0.31	-0.73	0.13	3.0
MOA	-0.15	0.10	-0.15	2.20

2. *Comparison with CALIOP*

Effects of the recalibration on cloud top heights were studied using CALIOP as a reference. High cloud determinations from NOAA-18 shifted to a better comparison with CALIOP determinations for August 2008 (see Figure 2).

Original SRFs



Shifted SRFs

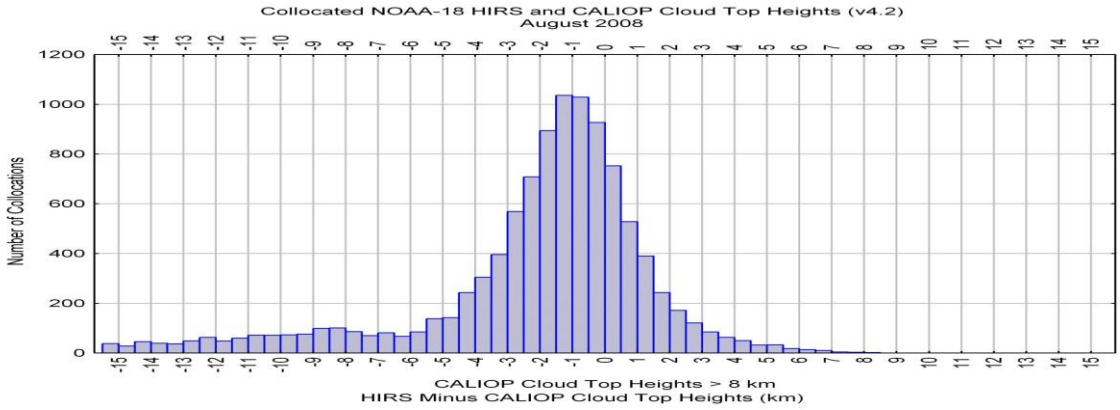


Figure 2: HIRS minus CALIOP high cloud heights for NOAA-18 with and without SRF shifts in August 2008

3. *Reprocessing the HIRS Cloud Data Set*

The HIRS data from NOAA-6 onwards have been re-processed using the original HIRS algorithm software with adjustments suggested by the MODIS experience and the spectral shifts suggested using Metop HIRS as a reference. Figure 3 shows the afternoon and morning high cloud trends over ocean after the spectral shifts. Sensor to sensor differences in the high cloud products are found to have been largely mitigated, except for NOAA-11 where large differences in the north and south pole SNO recalibrations were noted for channel 5. Further study into NOAA-11 (and possibly NOAA-16) is planned.

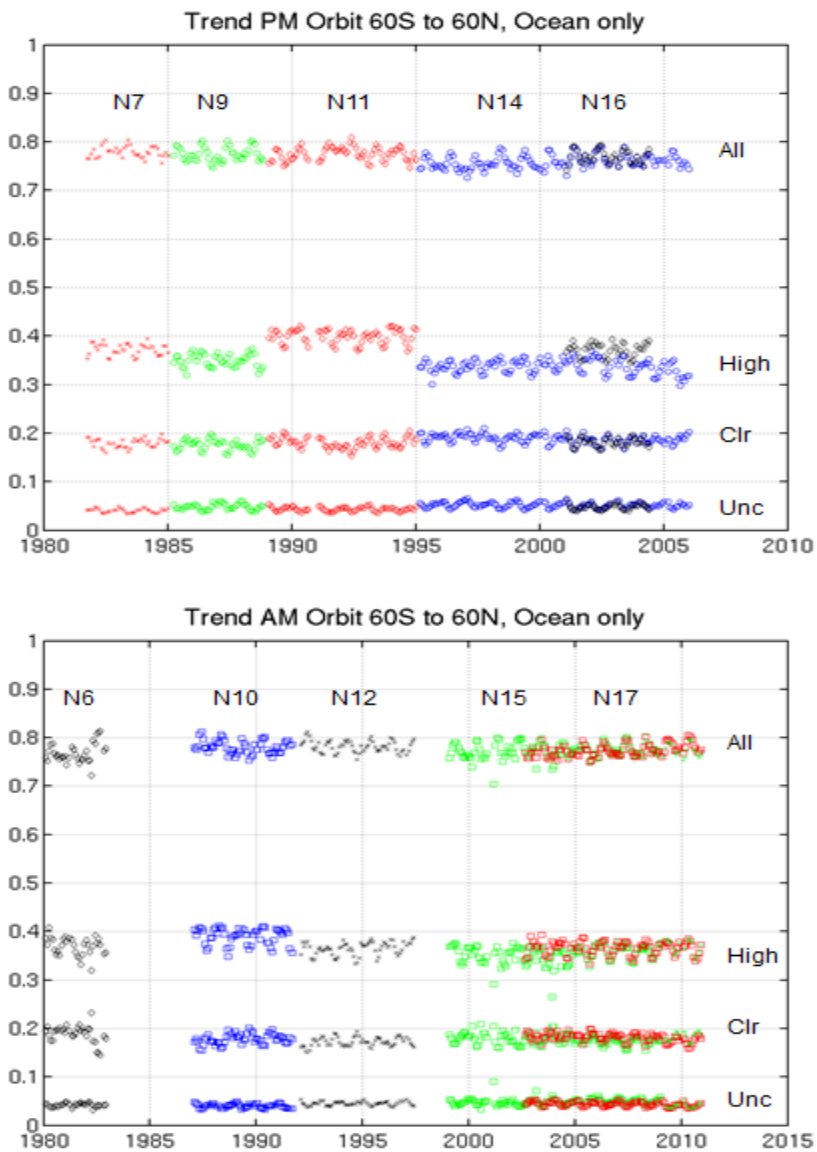


Figure 3: Afternoon and morning high (CTP<440 hPa) cloud over ocean trends from 1980 through 2009 given in fraction of total HIRS observations after the spectral shifts.

SSEC is developing software for converting HIRS Level 1b and higher level data files to NetCDF-4. The flat file (i.e., Level 1b) to NetCDF4 converter has been developed and now is being tested with scientists to assure that the output files are well organized. Transfer to NCDC is planned for Dec 2012.

The MODIS cloud algorithm software adaptation to HIRS continues. Past progress has included (1) using HIRS HDF-4 radiance and geo-location input data files with MODIS-like Collection 6 algorithms for clouds and moisture, (2) incorporating collocated AVHRR cloud mask data from PATMOS-X into the HIRS reprocessing to provide a sub-HIRS-pixel cloud mask - a HIRS FOV must be at least 15% cloudy to be processed as a cloudy FOV, (3) using the PATMOS-X cloud mask to initialize the clear versus cloudy FOV identification necessary for radiance bias adjustments, (4) testing the spectral shifts suggested by STAR, and (5) measuring the quality of the resulting cloud fields through comparison with CALIOP.

In the past six months the following accomplishments were added: (6) implemented and tested HIRS UT/LS algorithm with collocated CALIOP observations; (7) updated spectral shifts in HIRS forward model calculations that are used in clear-sky radiance bias and cloud top pressure routines – this led to significant improvements in modeled versus observed clear-sky radiance biases for the CO_2 bands; (8) changed cloudy versus clear-sky radiance threshold from 1.0 to 0.5 radiance units for the CO_2 bands thus adding sensitivity to thin high clouds; and (9) processed one year of NOAA-18 HIRS/4 data through to generation of cloud top pressures. As with MODIS, the SRF modifications improve our radiative transfer simulations of the upwelling radiances to the point where we greatly increase the sensitivity to optically thin cirrus.

Conversion of MODIS algorithm software to retrieve HIRS moisture layers (high. middle, and low level) and total column moisture continues. The synthetic regression coefficients for the statistical retrieval have been derived using a fast radiative transfer model; atmospheric characterization is achieved with a global set of atmospheric temperature, moisture, and ozone profiles. The radiative transfer calculations of the HIRS spectral band radiances have been performed with and without spectral shifts for the training profiles using the JCSDA Community Radiative Transfer Model. HIRS instrument noise was added into the calculated spectral band radiances, and the resulting temperature-moisture-ozone profile / HIRS radiances were used to establish a statistical regression. Ancillary data (geo-location, cloud mask, surface emissivity) have been incorporated. Processing has been expanded to all view angles (beyond the past limit of less than 32 degrees from nadir). Figure 4 shows an example result for one orbit on 13 August 2008. Incorporation of the surface emissivity and the H_2O channel spectral shifts is producing the best results in comparison with MODIS and GDAS TPW.

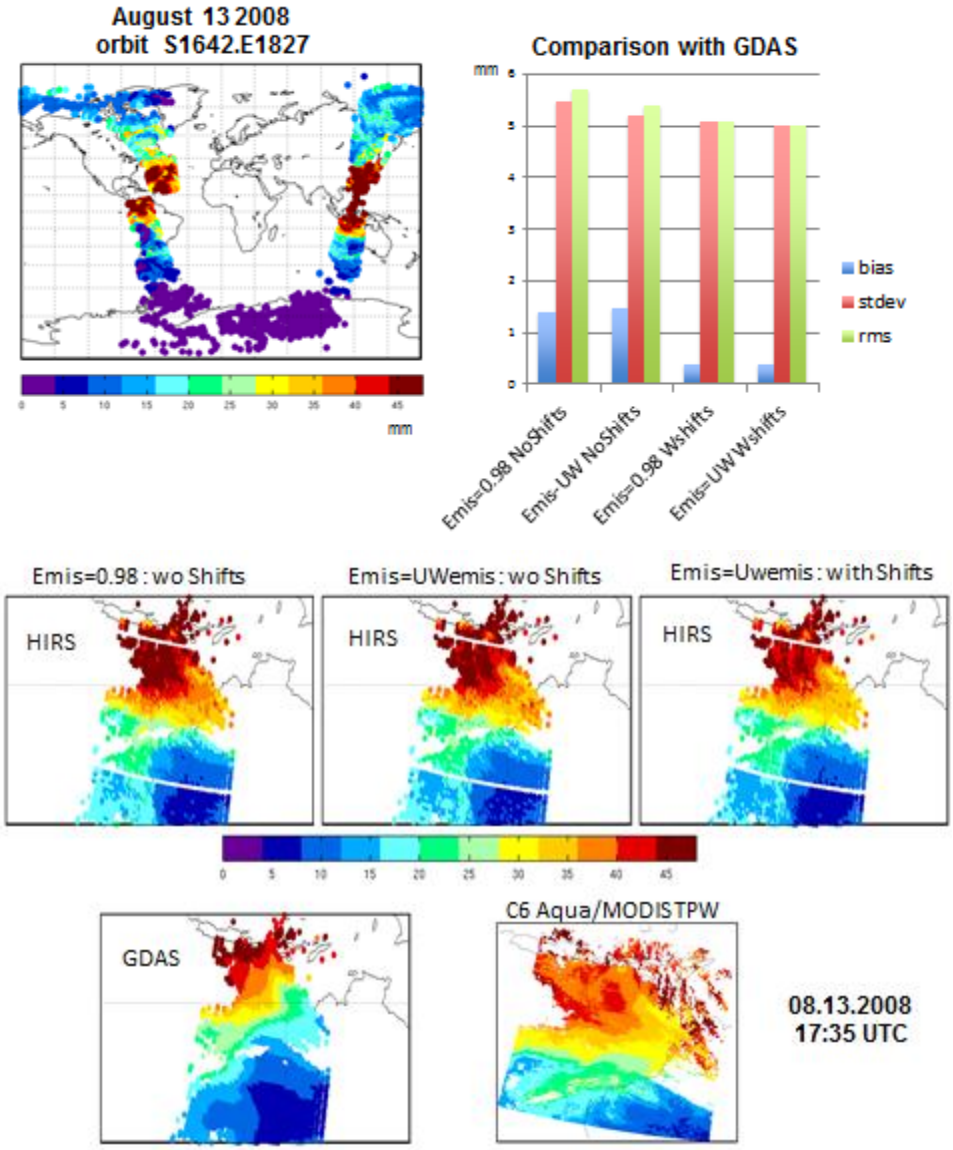


Figure 4: NOAA18/HIRS TPW compared to GDAS and Aqua/MODIS TPW

5. *Investigating HIRS Stratospheric Cloud Trends*

The presence of upper tropospheric / lower stratospheric (UT/LS) clouds has been estimated at the pixel level on the assumption that positive lapse rates above the tropopause imply that the more opaque spectral band sensitive to CO_2 or H_2O in the atmosphere produces a brightness temperature warmer than a less opaque or nearly transparent infrared window spectral band. UT/LS cloud detection trends using measurements sensitive to CO_2 (BT14 > BT13.3) were compared with those using measurements sensitive to H_2O (BT6.7 > BT11). CO_2 detection is more prevalent and somewhat out of phase with H_2O detection; H_2O presence in the UT/LS is variable while the CO_2 is relatively constant. In NOAA-14 data spanning 1995 through 2005, there are indications of UT/LS clouds in 0.7% of the observations from 60˚N to 60˚S using CO_2

absorption bands; however, in the region of the International Tropical Convergence Zone this increases to 2.5%. Expanding to all the HIRS sensors from NOAA-10 onwards, the UT/LS cloud detection maxima in the western Pacific region of the ITCZ shows a decreasing trend from 1987 to 1996, followed by an increasing trend from 1996 to 2001, and thereafter a decreasing trend resumes. The overall trend seems to be saying that deep convection in the tropics has been in a slight decrease for the past twenty years (see Figure 5). A paper on this work has been accepted for publication by JGR.

6. Remaining Work

6.1 Transfer NetDF4 L1B HIRS software to NCDC (4Q12). (Note: this was not part of the original proposal but is being provided as a service)

6.2 Continue to test the new software and spectral shifts on several seasons (years) of data. Continue validation of cloud results against CALIPSO where possible. Compare TPW results globally against MODIS, AIRS, and GDAS for all season (1Q13).

6.3 Transfer cloud algorithm (CO2 slicing plus PATMOS-X cloud mask) with output in NetCDF4 format to NCDC (2Q13).

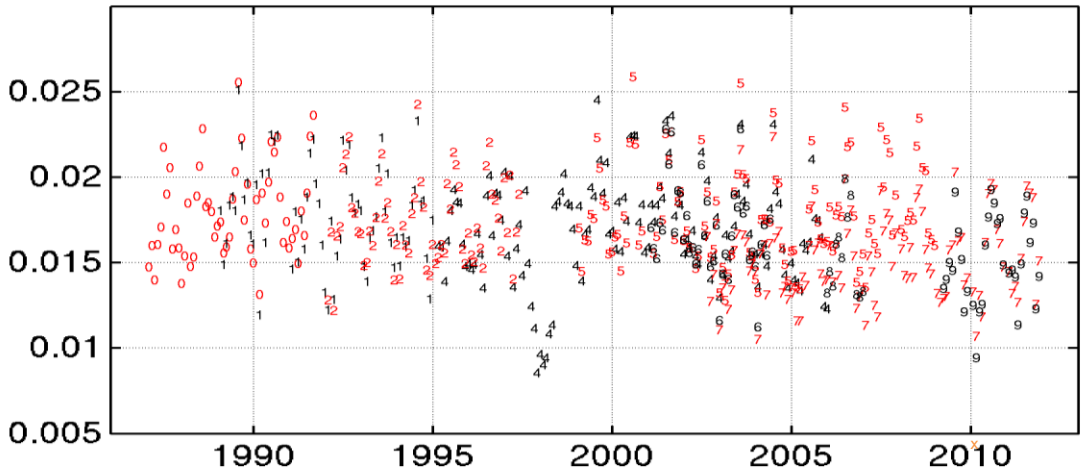
6.4 Transfer TPW algorithm (with surface emissivity enhancement) to NCDC (3Q13)

And pending the availability of modest additional resources:

6.5 Switch to CRTM (from PFAAST) in cloud algorithm (4Q13).

6.6 Transfer daily gridding L3 software to NCDC to facilitate intercomparisons (4Q13).

(a)



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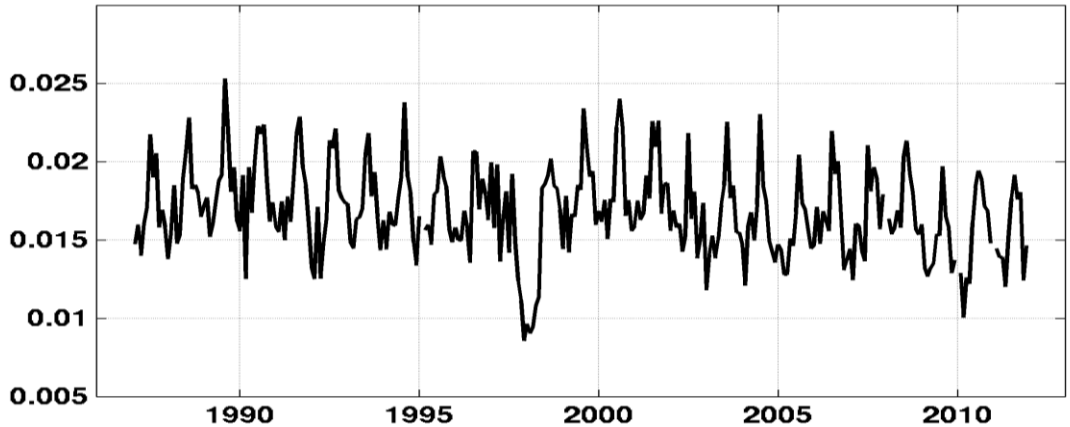

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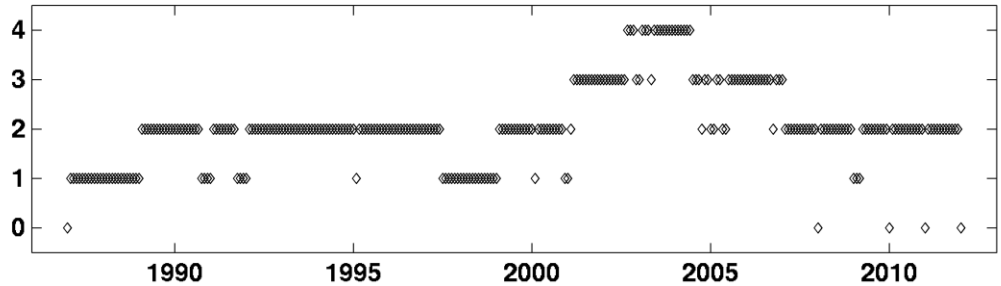

Figure 5: (a) Individual monthly UT/LS cloud fraction detected by each HIRS over the ITCZ (20S to 40N latitude; 45 to180 longitude) from Jan 1987 to Dec 2011. The number indicates the NOAA satellite (e.g. 0 for NOAA-10, 1 for NOAA-11, and so on) and the color indicates the orbit (red for descending morning and black for ascending afternoon). (b) Average monthly UT/LS cloud fraction detected by all HIRS on NOAA-10 through NOAA-19 over the ITCZ from Jan 1987 to Dec 2011. (c) The number of satellites used in each monthly average. If less than 20 days were processed for a given satellite for a given month, those data are not used in the trend analysis.

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1. *Mitigating Sensor to Sensor Differences*

Recalibration back to NOAA-9 has been completed for H2O and CO2 channels - issues with non-nadir views have been resolved. Recalibration from NOAA-15 onwards are from direct intercomparison with Metop-A IASI; those for NOAA-14 backwards are from SNOs. Recalibration of NOAA-6 through -8 is underway, now that the geo-sounder data from VAS (VISSR Atmospheric Sounder) has been staged and the double differencing recalibration can begin. This work has been published and the reference is Chen, R., C. Cao, and W. P. Menzel, 2013: Intersatellite calibration of NOAA HIRS CO2 channels for climate studies, J. Geophys. Res. Atmos., 118, doi:10.1002/jgrd.50447.

Table 1: Spectral shifts for bands sensitive to CO2 (4, 5, and 7) and H2O (12) suggested by direct comparison with IASI on NOAA 15 and thereafter and by HIRS sensor SNOs on NOAA 14 and earlier. Ch6 (13.6) shifts were not deemed necessary. (from Chen et al., 2013)

	Ch4(14.2)	Ch5(13.9)	Ch7(13.3)	Ch12(6.7)
hirs2n09	0.72	2.42	-0.67	1.1
hirs2n10	1.06	1.48	-1.12	3.0
hirs2n11	1.67	1.94	-0.04	4.2
hirs2n12	0.51	2.03	-2.25	4.1
hirs2n14	2.13	2.80	1.14	4.1
hirs3n15	-0.21	0.27	1.01	0.6
hirs3n16	0.22	0.62	0.47	0.8
hirs3n17	0.54	0.72	0.44	-0.3
hirs4n18	-0.71	-0.37	-0.49	3.3
hirs4n19	-0.00	-0.12	0.10	0.7
hirs4moa	-0.15	0.10	-0.15	2.2

2. *Transfer HIRS CTP software to NCDC*

The algorithm theoretical basis documentand the software for processing the HIRS cloud top propertieswere delivered to NCDC in June 2013. After discussions with NCDC, a one-month benchmark data set was delivered in August of the same year.

3. *Reprocessing the HIRS Cloud Data Set*

The HIRS data from NOAA-15 and -17 have been re-processed (a) using the original HIRS algorithm software with adjustments suggested by the MODIS experience, (b)

incorporating the spectral shifts suggested using Metop IASI as a reference, and (c) complementing the HIRS CO2 high cloud detection with the AVHRR PATMOS-x cloud mask (guiding clear versus cloudy HIRS FOV identification with the collocated AVHRR cloud mask is expected to improve the observed minus radiance bias correction that is applied in the CO2 slicing algorithm). Daily cloud properties on 0.5-degree grids were accumulated for each month (separated by ascending or descending orbit); output (emphasizing total column, high, mid, and low) includes

Cloud Amount - CA, CAH, CAM, CAL
(number of cloudy fovs detected / number of clear and cloudy fovs)
Effective Cloud Amount (weighted by cloud emissivity) - ECA, ECAH, ECAM, ECAL
(average ECA / number of cloudy fovs)
Cloud pressure - CP, CPH, CPM, CPL
(average cloud pressure)
Cloud temperature - CT
(average cloud top temperature, inferred from CPs converted to CTs)
UT/LS (Upper Tropospheric/Lower Stratospheric) Clouds Frequency of Occurrence
(number of fovs with UT/LS clouds detected /number of clear and cloudy fovs)

Where H denotes Pc < 440 hPa, M denotes 440 hPa < Pc < 680 hPa, and L denotes Pc > 680 hPa.

Figure 1 shows the results for NOAA-15 and -17. There is still some evidence of sensor to sensor jumps in the cloud trends for the daytime orbits. Further study into remaining issues is underway (orbit drift, etc.).

4 Transfer HIRS TPW software to NCDC

The algorithm theoretical basis document, the software for processing the HIRS moisture column properties, and a one month benchmark data set were delivered to NCDC in September 2013. Daily moisture column properties on 1 degree grids were accumulated for each month (separated by ascending or descending orbit); output (emphasizing total column, high, mid, and low) includes

Latitude
Longitude
SatelliteZenithAngle
Land_Fraction
Cloud_Fraction (AVHRR determination of clear sky)
Scan Time
Day/Night Flag
Node Type (ascending or descending)
CTP_Retrieval_Flag (CO2 slicing confirmation of clear sky – no high thin cirrus)
NWPmodel_Surface_Pressure
NWPmodel_Total_Precipitable_Water
Radiances for 16 spectral channels used (16)

Brightness_Temperatures for 16 spectral channels used (16)
Retrieved_Surface_Skin_Temperature
Retrieved_Total_Precipitable_Water
Retrieved_Integrated_WaterVapor_H
Retrieved_Integrated_WaterVapor_M
Retrieved_Integrated_WaterVapor_L

Where H denotes Pc < 440 hPa, M, denotes 440 hPa < Pc < 680 hPa, and L denotes Pc > 680 hPa. The netcdf file size for one orbit is roughly 25 MB. The software provides level 3 daily and monthly mean products additional to the level 2 orbital products.

Figure 2 shows the benchmark data set for January 2009 of the average total column (TPW), high, mid, and low tropospheric moisture detected by HIRS on Metop A.

5. Investigating HIRS UT/LS Cloud Trends

Investigation of the Upper Tropospheric Lower Stratospheric cloud trends gleaned from 14 years of NOAA-11 and -14 data reveal a deseasonalized (deviation from monthly average) trend that matches the fluctuations of the Total Solar Irradiance (see Figure 3). More work is planned to investigate this.

6. Remaining Work (pending the availability of modest additional resources)

6.1 Provide python script for converting HIRS/2 Level-1B data to NetCDF. (1Q14)
6.2 Continue reprocessing to complete 10 years of HIRS cloud and TPW results. (2Q14)
6.3 Transfer STG L3 gridding software in Python, with associated documentation, to NCDC to facilitate intercomparisons. (2Q14)
6.4 Switch to CRTM (from PFAAST) in cloud algorithm (3Q14).
6.5 Switch to higher resolution Climate Forecast System ReAnalysis in cloud algorithm. (3Q14)
6.6 Add radiance bias adjustment dictated from the difference of observed and calculated radiance to the moisture column algorithm. (3Q14)
6.7 Provide 10-year HIRS data set to NCDC, both instantaneous Level 2 and gridded Level 3 products that adopt the changes above. (4Q14)

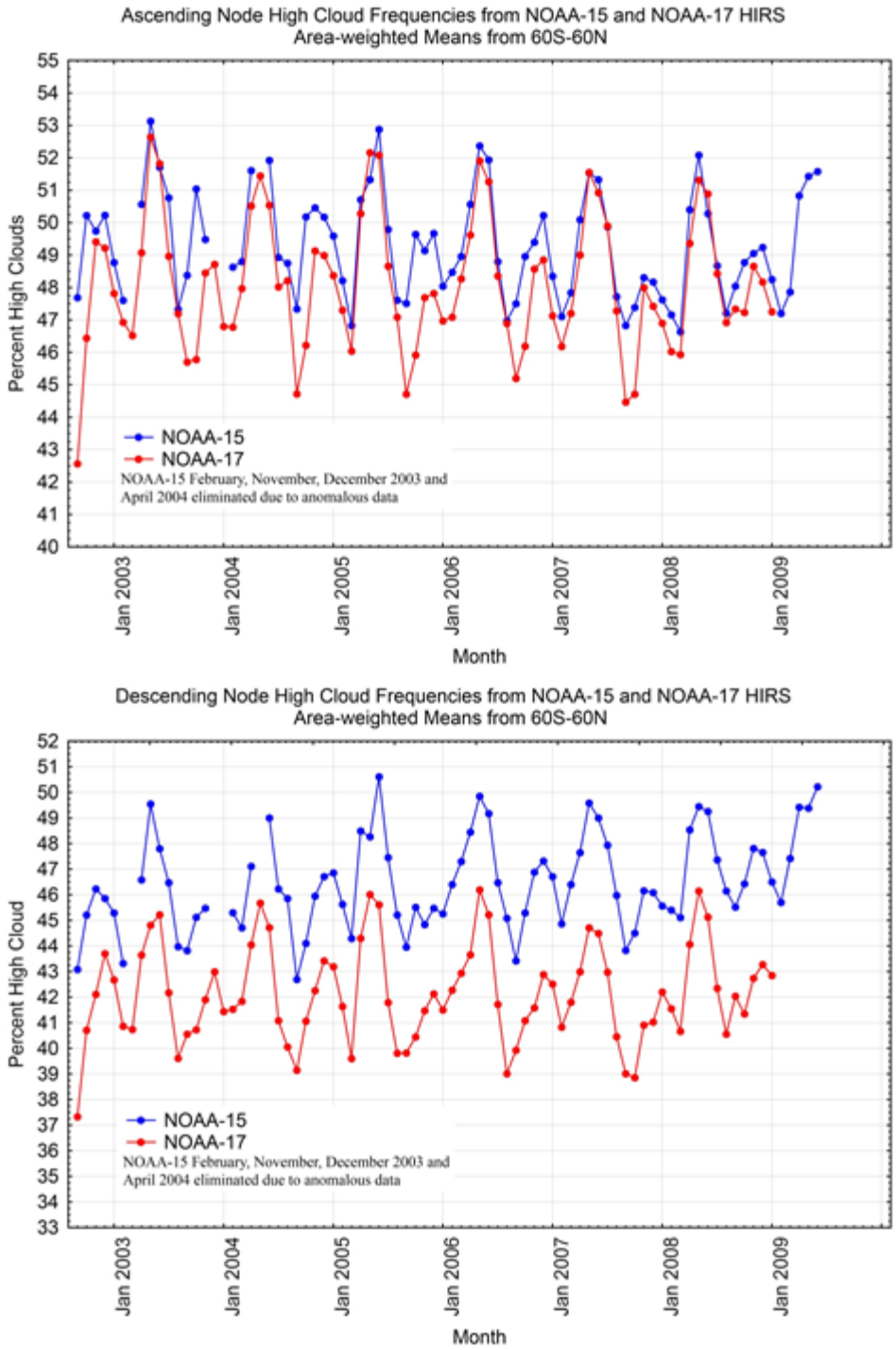

Figure 1: Ascending (top) and descending (bottom) node high cloud detection (percentage of all HIRS FOVS between 60N and 60S) for 2003 through 2009.

Ascending

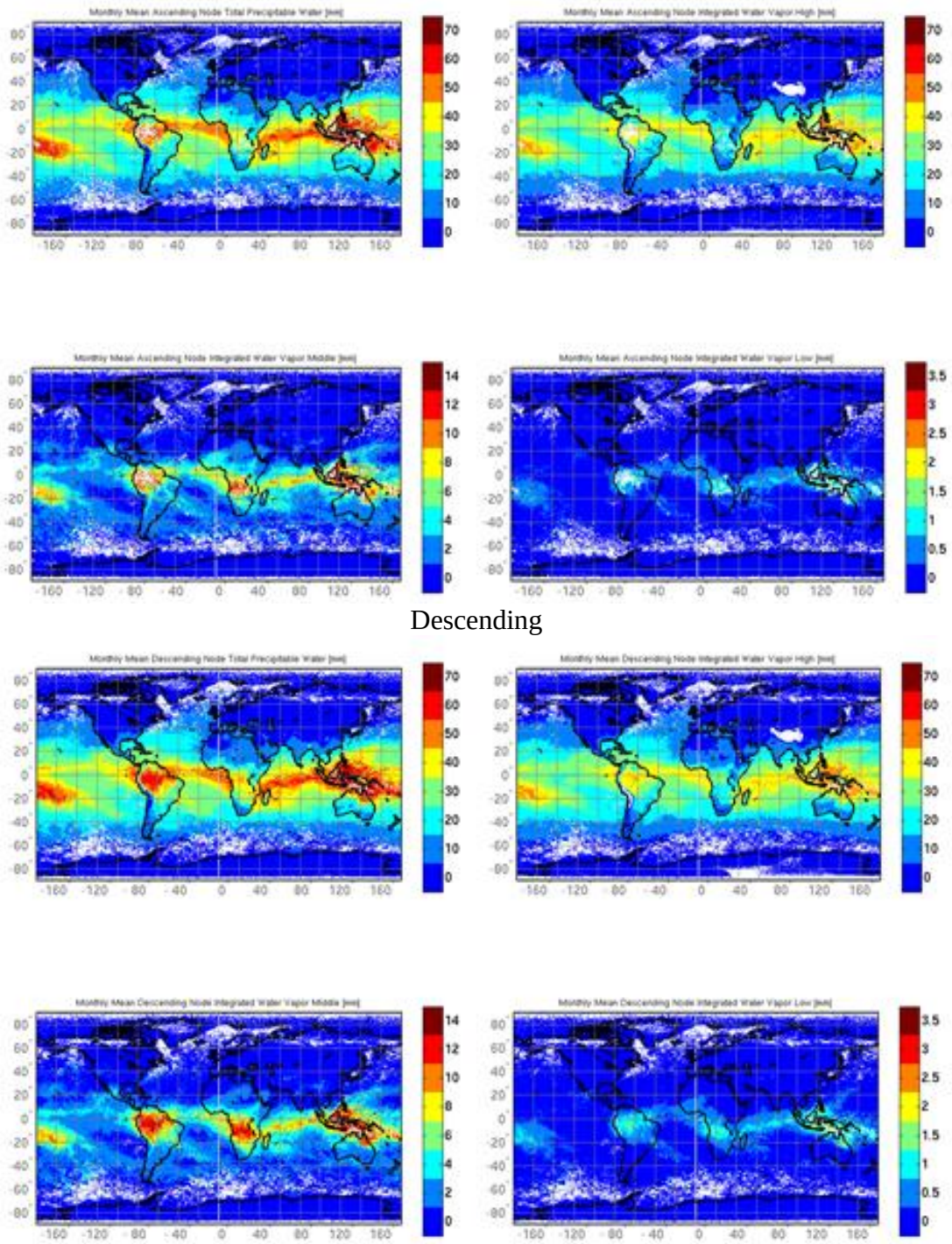

Figure 2: Ascending and Descending node mean total column (top left), low (top right), mid (bottom left), and high (bottom right) integrated column moisture detection for January 2009 from HIRS on Metop A.

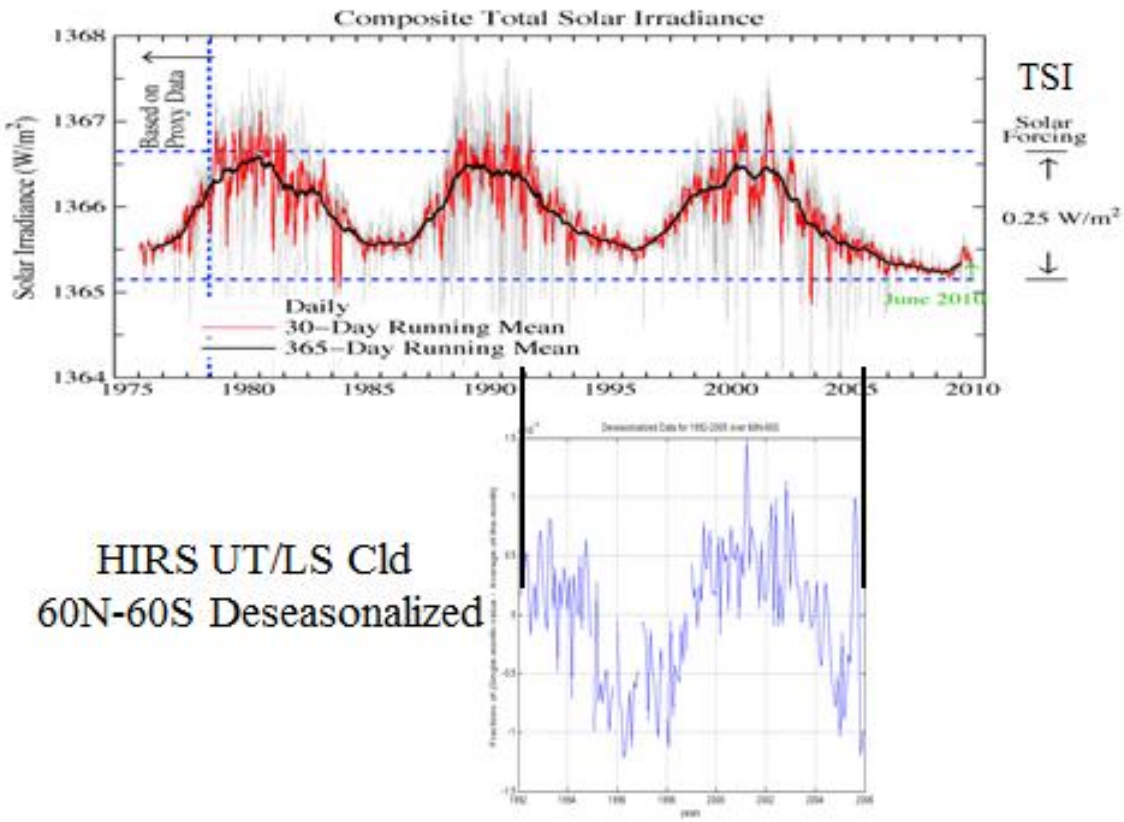

Figure 3: HIRS UT/LS cloud detection (deseasonalized by month) compared with the Total Solar Irradiance for 1991 to 2005.

Progress Report on Reprocessing HIRS Cloud and Moisture Measurements
Nov 2013 to Apr 2014
Principle Investigator: W. Paul Menzel
Date: May 2014

1. Mitigating Sensor to Sensor Differences

Recalibration back to NOAA-7 is progressing. NOAA-7 and -9 HIRS were compared at selected validation sites for channels 4, 5, and 7. The approach uses stable sites to quantify the differences between the two satellites. The annual cycles are reduced by taking the radiance ratio between the satellite observations and an empirical model. Results indicate that the bias for channel 4 is larger than that for channels 5 and 7. Over ocean, the diurnal and annual cycles are very small. Also, channel 7 sees near the surface. Separately, GOES 6 data have been compared with NOAA-7 and -9; the geo-sounder data from VAS (VISSR Atmospheric Sounder) has been staged and the double differencing recalibration accomplished. Similar bias patterns were found for the channels discussed above. Figure 1 shows the results for Channel 5.

2. Transfer HIRS CTP and TPW software to NCDC

Python script for converting HIRS/2 Level-1B data to NetCDF was provided. The algorithm theoretical basis documents for Cloud Top Properties (CTP) and Total Precipitable Water-Vapor (TPW) were reviewed and revised as recommended. The software for processing both was tested at NCDC. After several telecoms with NCDC, the one-month benchmark data sets were successfully read and meta-data documented. Software modifications to the CTP code that are necessary for processing the entire HIRS swath were delivered in December 2013. The changes are needed so that the Level-2 CTP output may be used as input to the TPW process. Comments on the Level-3 (daily, monthly) CTP output files have been received and work is ongoing to conform the metadata fields to NCDC standards. Ten year (2000-2009) data sets are in preparation for delivery in June 2014.

3. Reprocessing the HIRS Cloud and Moisture Data Sets

The HIRS data from NOAA-15 and -17 have been re-processed (a) using the original HIRS algorithm software with adjustments suggested by the MODIS experience, (b) incorporating the spectral shifts suggested using Metop IASI as a reference, and (c) complementing the HIRS processing with the AVHRR PATMOS-x cloud mask. Figure 2 shows the NOAA 15 and 17 results for TPW and UTH trends for 2000 to 2009. Figure 3 shows NOAA 15 and 17 high cloud frequencies and Upper Tropospheric/Lower Stratospheric (UTLS) cloud frequencies for 2000-2009.

4. Remaining Work (pending the availability of modest additional resources)

4.1 Continue reprocessing to complete 10 years of HIRS cloud and TPW results. (2Q14)

4.2 Provide 10-year HIRS data set to NCDC, both instantaneous Level 2 and gridded Level 3 products that adopt the changes above. (2Q14)
4.3 Transfer STG L3 gridding software in Python, with associated documentation, to NCDC to facilitate intercomparisons. (3Q14)
4.4 Switch to CRTM (from PFAAST) in cloud algorithm (3Q14).
4.5 Switch to higher resolution Climate Forecast System ReAnalysis in cloud algorithm. (3Q14)
4.6 Add radiance bias adjustment dictated from the difference of observed and calculated radiance to the moisture column algorithm. (4Q14)

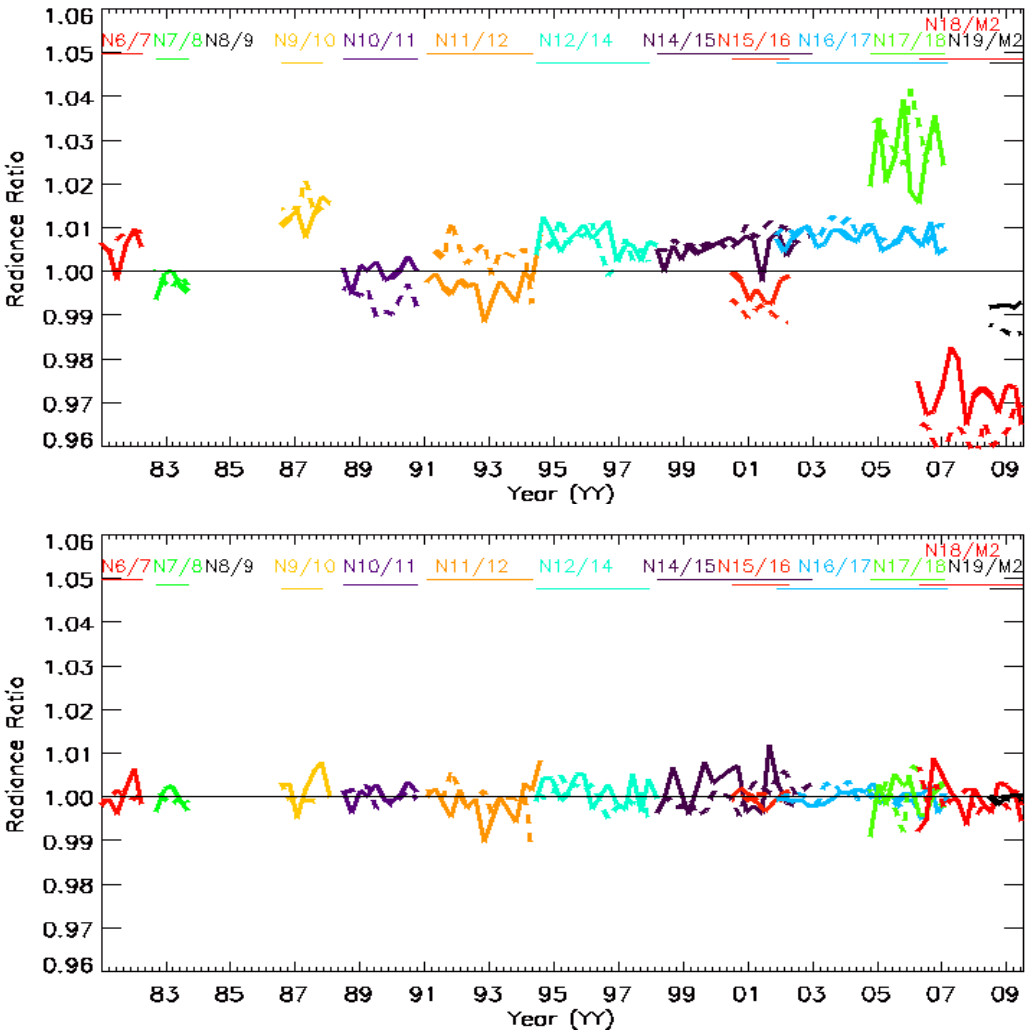

Figure 1: Radiance ratios for NOAA 6 through Metop 2 for Channel 5. (top) Without recalibration. (bottom) After applying the spectral shifts for N6 of 0.7 cm-1 and for N7 of 0.1 cm-1.

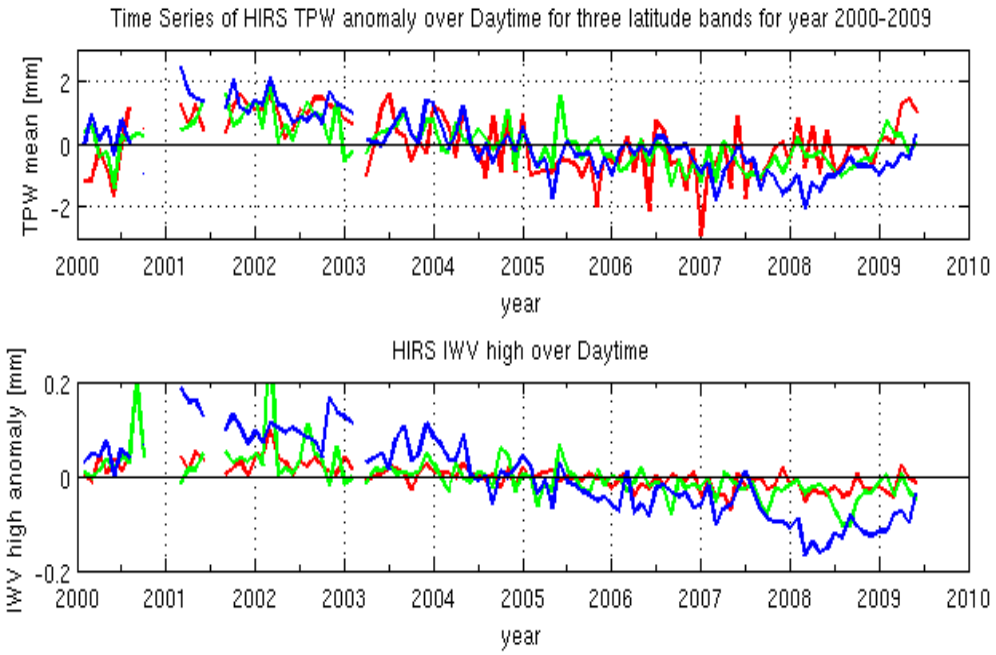

Figure 2a: NOAA 15 daytime (descending orbit) TPW and UTH (IWV high for high Integrated Water Vapor) monthly anomalies for 2000 to 20009, where red is for 30-60 S latitude, green 30-60 N, and blue 30N to 30S.

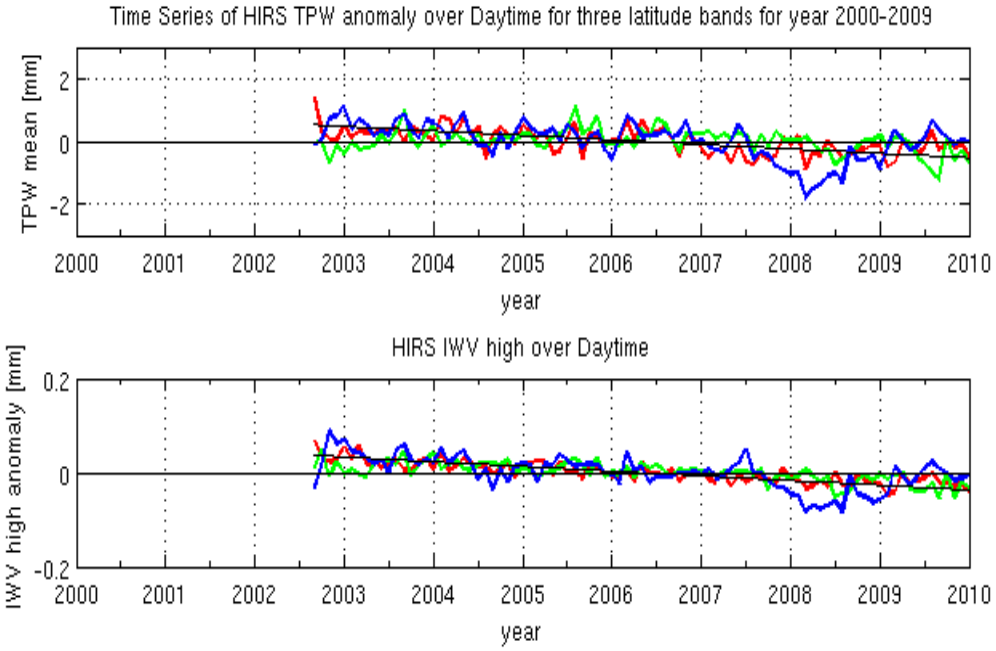

Figure 2b. Same for NOAA 17 for 2002 to 2009.

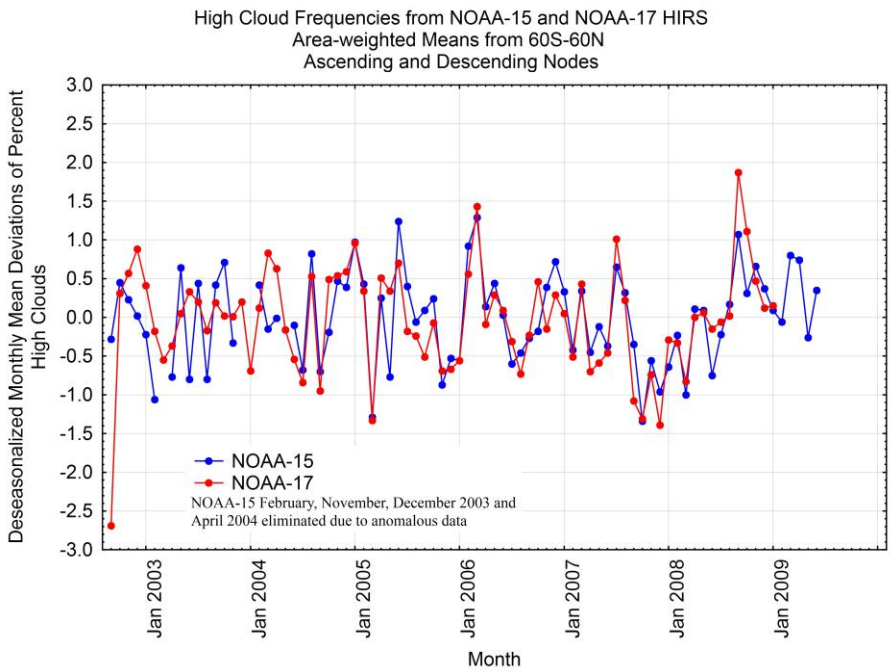

Figure 3a. Deseasonalized NOAA 15 and 17 high cloud frequencies for 2002-2010.

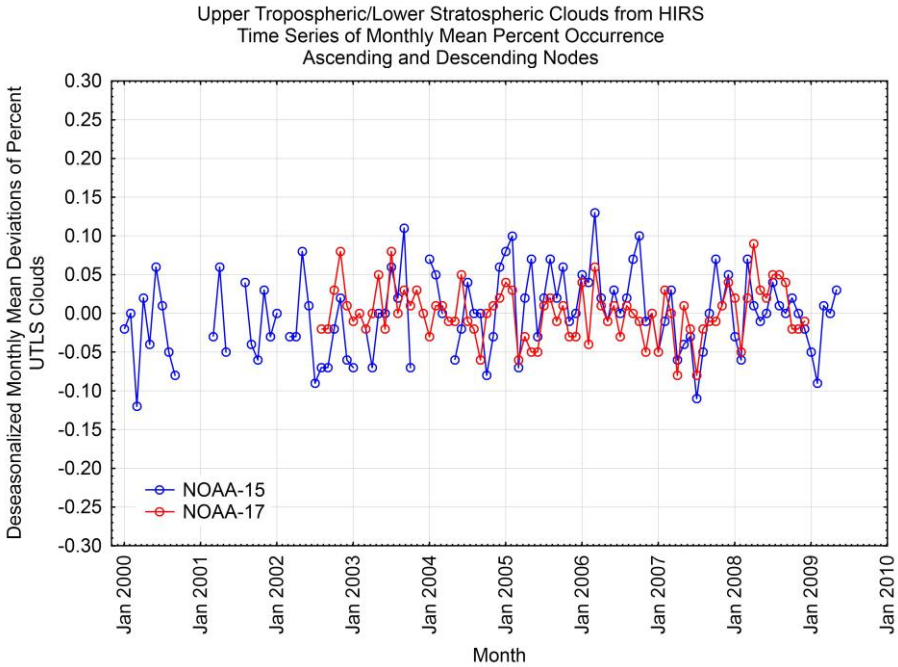

Figure 3b. Deseasonalized NOAA 15 and 17 UTLS cloud frequencies for 2000-2010.