Progress Report on Reprocessing HIRS Cloud Measurements Nov 2010 to Apr 2011
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1. Mitigating Sensor to Sensor Differences

Sensor to sensor calibration differences are being investigated using HIRS simultaneous nadir overpasses (performed by Cao et al at STAR) and using AIRS as a calibration reference for HIRS (performed at SSEC). For the NOAA 14 through NOAA 17 HIRS sensors, results of the two approaches are being compared (Table 1). STAR has used the METOP HIRS sensor as a reference for the earlier NOAA HIRS sensors. SSEC has compared NOAA HIRS and Aqua AIRS measurements (convolved with the HIRS spectral response function) within 10 km and 10 minutes for cloud/clear and land/water.

Table 1: Spectral shifts suggested for the bands sensitive to CO2 (4, 5, 6, and 7) by inter-calibration with AIRS (the numbers of colocations is indicated for each sensor) and simultaneous nadir overpasses (SNOs) using METOP HIRS as initial reference.

			AIRS	SNO
For N14			(464 pts)	
Ch4	14.2 µm	704 cm-1	+2.25 cm-1	2.5 cm-1
Ch5	13.9	719	+2.5	2.5
Ch6	13.6	735	+2.25	0.0
Ch7	13.3	750	+1.0	0.0
For N15			(388 pts)	
Ch4	14.2	704	+1.25	0.15
Ch5	13.9	719	+0.0	0.45
Ch6	13.6	735	+0.75	0.0
Ch7	13.3	750	-1.0	1.9
For N16			(1000 pts)	
Ch4	14.2	704	+1.25	1.3
Ch5	13.9	719	+2.0	1.05
Ch6	13.6	735	+0.5	0.0
Ch7	13.3	750	+1.25	0.75
For N17			(1462 pts)	
Ch4	14.2	704 cm-1	+0.5	0.8
Ch5	13.9	719	+1.0	0.6
Ch6	13.6	735	+0.75	0.0
Ch7	13.3	750	+0.75	-0.25

The spectral shifts suggested from AIRS and SNOs mostly agree; where the disagreement is large the slope of the radiance change per spectral change is often small (Figure 1 shows an example for N14 Channel 6).

These comparisons give confidence that the SNO approach will help to mitigate sensor to sensor differences when AIRS or IASI are not available for high spectral resolution sensor intercalibrations.

Table 2 list the spectral shifts suggested by Cao et al for the CO2 and H2O sensitive spectral bands (channels 4, 5, 6, 7, and 12). The impacts of these shifts on clouds top pressures and on total precipitable water vapor are now being explored.

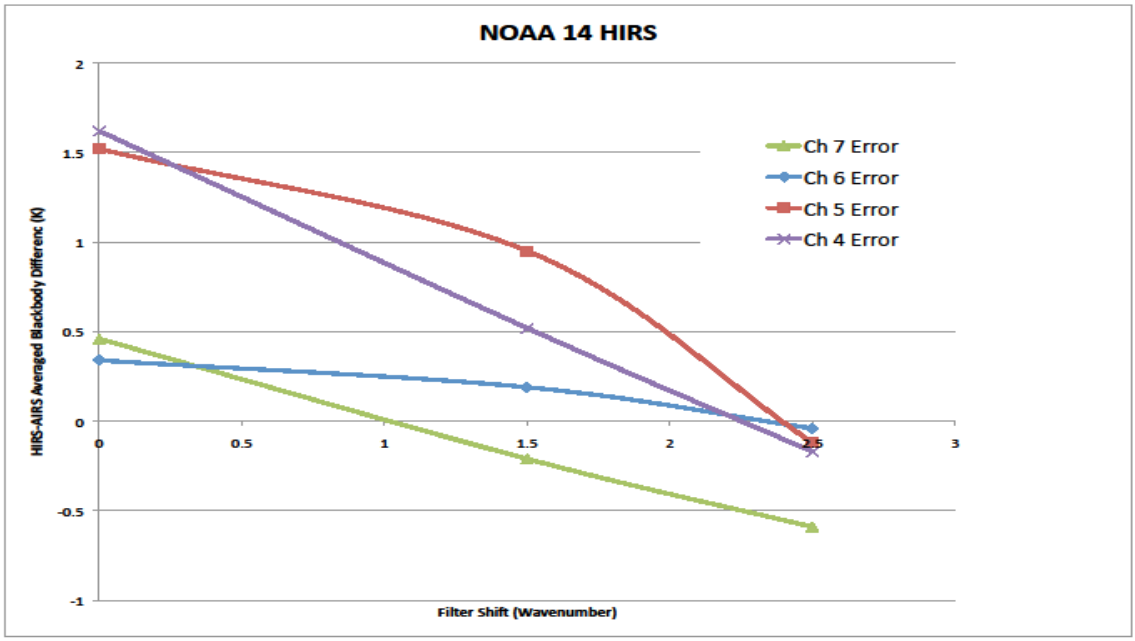

Figure 1: NOAA 14 HIRS minus AIRS brightness temperature differences as a function of spectral shift for channels 4 through 7.

Table 2: 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)
N9	1.1 cm-1	-0.1	0.1	8.1
N10	1.4	0.7	-1.1	2.9
N11	2.0	0.2	0.1	11.7
N12	1.05	0.7	-2.3	12.0
N14	2.5	2.5	0.0	11.8
N15	0.15	0.45	1.9	5.6
N16	1.3	1.05	0.75	8.9
N17	0.8	0.6	-0.3	4.7
N18	-0.3	-0.2	-1.0	2.5
N19	-0.8	0.05	-0.45	0.3
M2				2.2

Ch6 (13.6) shifts were not deemed necessary

2. *GEWEX HIRS Cloud Data Set*

The data set delivery to the GEWEX Cloud Team was corrected for some labeling errors and extra data sets of cloud amounts and cloud top pressures derived from HIRS CO2 and IRW

measurements were processed (Table 3 indicates the revised data delivery). Descriptions of the algorithm, assumptions made, and error characteristics were submitted.

Table 3: 66 HIRS cloud data sets delivered to GEWEX. Missing years had missing months caused by missing data, problems with the clear sky composite used in calculating the radiance bias adjustment, or other spurious issues still to be determined. Each data set included cloud emissivity E (all, high, mid, and low), effective cloud amount NE (all, high, mid, and low), cloud top temperature (high, mid, low, plus all histogram for 150 to 320 K), cloud amount N (all, high, mid, and low), relative cloud amount (high, mid, low divided by total cloud amount), and cloud pressure (histogram of all for 100 to 1100 hPa)

Year	730 am	130 pm
1986		N9
1987	N10	N9
1988		
1989	N10	N11
1990	N10	
1991		N11
1992	N12	N11
1993	N12	N11
1994	N12	N11
1995	N12	N14
1996	N12	N14
1997		N14
1998		N14
1999	N15	N14
2000		N14
2001		N14
2002	N15	N14
2003	N15	N14
2004	N15	N16
2005	N15	
2006	N15	N16
2007		
2008	N15	

3. Recoding the HIRS Cloud Algorithm

Software has been written to convert HIRS 1B files into hdf.

The MODIS algorithm software is being adapted to process HIRS hdf data files - MOD06 for clouds and MOD07 for moisture.

Testing on the MOD06 cloud algorithm adapted to HIRS continues. Impact of using the NCEP reanalysis instead of the Global Data Assimilation System was characterized (see example for 1 January 2007 in Figure 2); more clear sky (indicated as very low clouds) are found with the reanalysis data set (it should be noted that no cloud screening was applied so that clear skies are included as low clouds). Radiance bias corrections remain to be implemented. PATMOSX is being incorporated into the HIRS reprocessing to provide a sub-HIRS-pixel cloud mask.

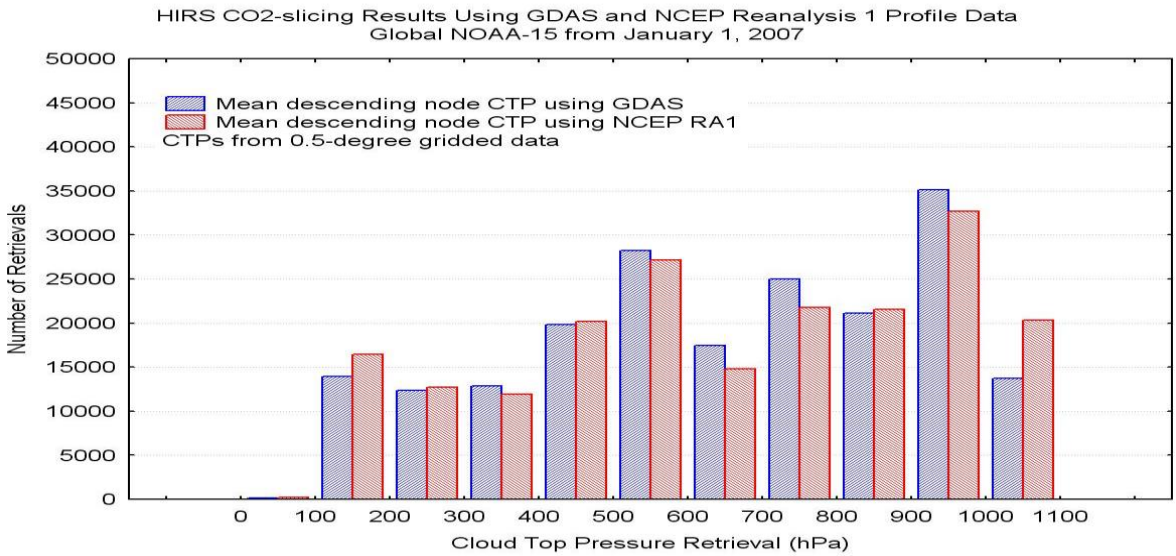

Figure 2: Distribution of CTPs for 1 January 2007 using GDAS (blue bars) and NCEP RA1 (red) input profiles (descending node).

Conversion of MOD07 has begun in order to retrieve HIRS moisture layers (high. middle, and low) and total column moisture. The algorithm for determining the regression coefficients has been staged. The synthetic regression coefficients for the statistical retrieval are derived using a fast radiative transfer model with atmospheric characteristics taken from a dataset of 15,704 global profiles of atmospheric temperature, moisture, and ozone profiles. The radiative transfer calculation of the HIRS spectral band radiances is performed for each training profile using JCSDA Community Radiative Transfer Model (CRTM V 1.2). The HIRS instrument noise is added into the calculated spectral band radiances, and these radiative transfer calculations provide a temperature-moisture-ozone profile / HIRS radiance pair for use in the statistical regression analysis. The CRTM coefficients for shifted HIRS spectral response function have been requested and provided by the CRTM developing team (special thanks to Paul van Delst and Yong Chen). Preparation has also begun for collection of the necessary input data (geolocation, cloud mask, and ancillary data).

In addition, efforts are underway to to transition the automated International ATOVS Processing Package (IAPP) from a 32-bit to a 64-bit environment. The goal of this transition is to be able to obtain retrieval coefficients that incorporate the SeeBor surface emissivity database into the IAPP.

4. Investigating HIRS Stratospheric Cloud Trends

Detecting the presence of stratospheric clouds is based on the assumption that a more opaque spectral band produces a brightness temperature warmer than a less opaque spectral band. Stratospheric cloud detection trends using measurements sensitive to CO2 (BT13.9 > BT13.3) were compared with those using measurements sensitive to H2O (BT6.7 > BT11) from NOAA-14 spanning 1995 through 2005. CO2 detection seems to out of phase with H2O detection, perhaps because H2O presence in the stratosphere is variable while CO2 presence is relatively constant.

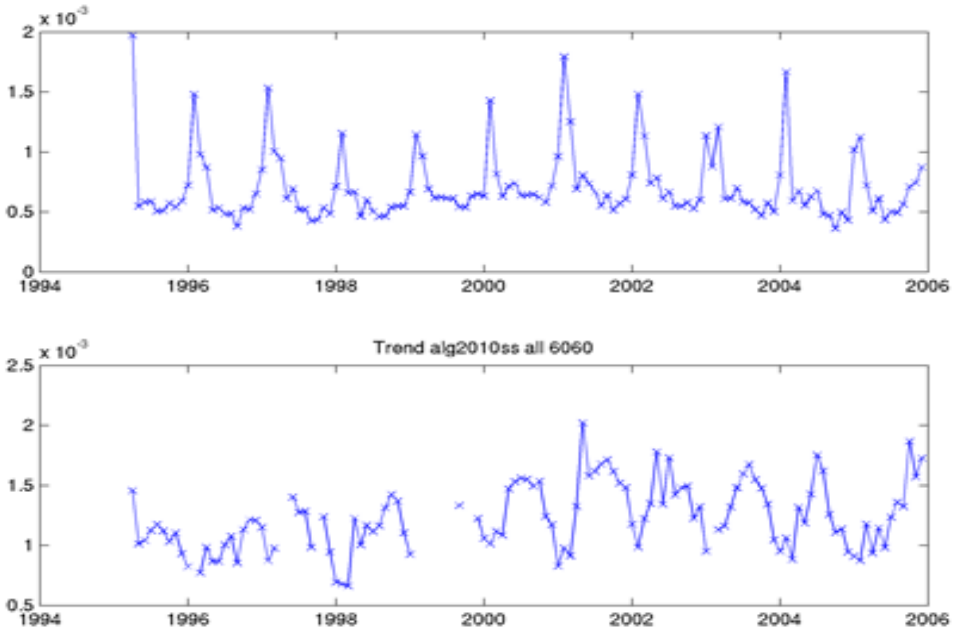

Figure 3: NOAA-14 1995 through 2005 from 60 N to 60 S stratospheric cloud detection trends (top) using measurements sensitive to H2O (BT6.7 > BT11) and (bottom) using measurements sensitive to CO2 (BT13.9 > BT13.3).

5. Remaining Work

5.1 Investigate the impact of SNO recalibration of HIRS sensors on cloud and moisture product trends; this is being done in collaboration with Cao et al.

5.2 Fill in some of the missing months (years) in the GEWEX HIRS data set.

5.3 Incorporate PATMOSX cloud fields to initialize the clear-cloud identification necessary for radiance bias adjustments in the HIRS CO2 slicing calculations. Test the new software on several seasons (years) of data. Validate results with CALIPSO where possible. Prepare the software for transfer to NCDC.

5.4 Continue to test CO2 detection of stratospheric clouds to complement the H2O detection; publish a paper describing the results.

Progress Report on Reprocessing HIRS Cloud Measurements May 2011 to Oct 2011
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Date: Oct 2011

1. Mitigating Sensor to Sensor Differences

Sensor to sensor calibration differences continue to be studied. The Metop HIRS has been re-calibrated using the many simultaneous IASI measurements. The other HIRS sensors are being referenced to the Metop HIRS using simultaneous nadir overpasses. Initially the focus was on reducing the scatter of the SNO radiances comparisons; more recently the emphasis has shifted to reducing the bias from one senor to the next. This work is being performed by Chanyong Cao and Ruyie Cheng at STAR). Table 1 summarizes the spectral shifts that have resulted from these efforts and that are now being used in the HIRS cloud property re-processing.

Work continues on refining the water vapor channel spectral shifts; the calibration algorithm offset (space view term) remains to be adjusted.

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)
N9	1.05 cm-1	2.4	-0.9	8.1
N10	1.3	1.25	-1.4	2.9
N11	1.85	1.0	0.1	11.7
N12	0.8	1.7	-3.7	12.0
N14	2.35	2.5	1.5	11.8
N15	-0.15	0.3	1.6	5.6
N16	0.8	1.0	1.25	8.9
N17	0.45	0.5	-0.1	4.7
N18	-0.2	-0.4	-0.75	2.5
N19	-0.6	0.15	-0.25	0.3
M2	-0.15	0.1	-0.15	2.2

Ch6 (13.6) shifts were not deemed necessary

2. Reprocessing the HIRS Cloud Data Set

The HIRS data set from NOAA-6 onwards has 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 one shows the resulting HIRS cloud observations over ocean from 60 N to 60 S for the past 30 years. No long term trends are evident; annual increase of high clouds observations from summer to winter by 6% persists in the 1990s. When the data are separated by equator crossing time into morning and afternoon orbits, sensor to sensor differences are found to have been largely mitigated. A paper summarizing the results from this re-processing has been prepared for submission to the Journal of Oceanic and Atmospheric Technology.

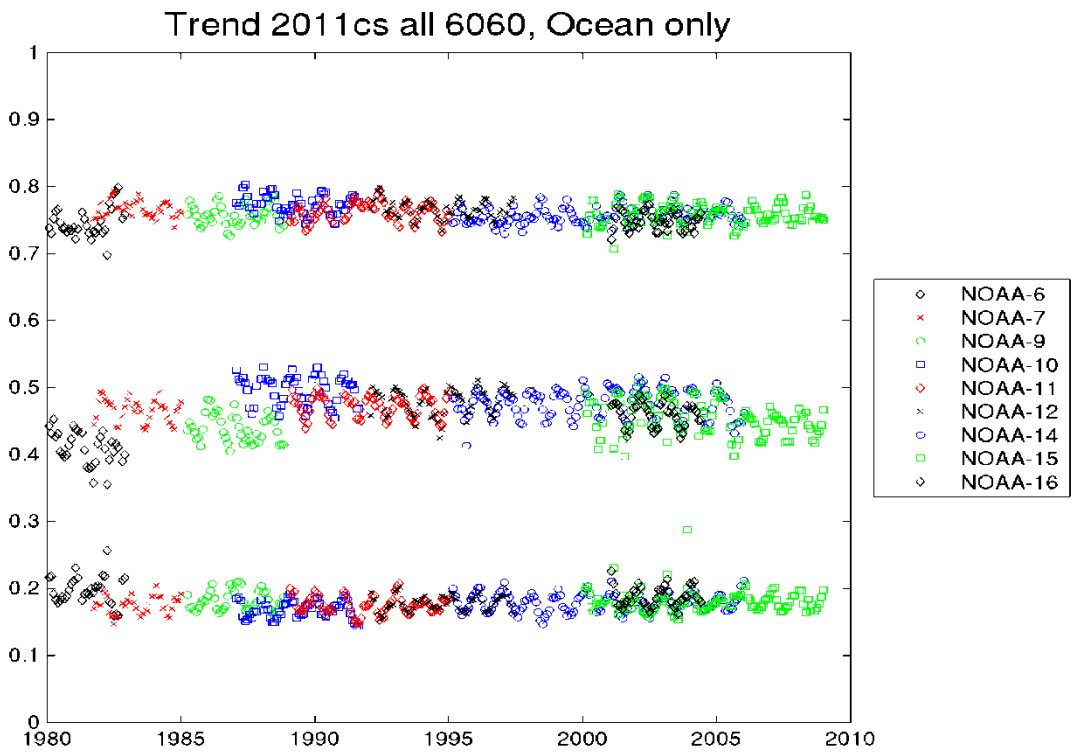


Figure 1. All cloud observation (top), high (CTP<440 hPa) cloud observation (middle), and uncertain clear or cloudy (bottom) trends from 1981 through 2009 given in percentage of total HIRS observations. Uncertain clear or cloudy results primarily for low clouds where surface emissivity effects and low thermal contrast leave room for doubt when a low cloud has been identified.

3. GEWEX HIRS Cloud Data Set

The Assessment of Global Cloud Data Sets from Satellites was drafted by the GEWEX Cloud Team. The summary of comparison results (which include ISCCP, PATMOS-X, HIRS, TOVS, AIRS, MISR, MODIS, POLDER, CALIPSO, SAGE, ATSR0 was reviewed and modifications were suggested. The paper is expected to be released late 2011.

4 Recoding the HIRS Cloud Algorithm

The MODIS algorithm software has been adapted to process HIRS hdf data files - MOD06 for clouds and MOD07 for moisture. The MOD06 cloud algorithm was adapted to use the NCEP reanalysis (instead of the Global Data Assimilation System) as reported last time. PATMOSX was incorporated into the HIRS reprocessing to provide a sub-HIRS-pixel cloud mask (a HIRS FOV must have at least 15% cloudy to be processed as a cloudy FOV). Radiance bias corrections based on using Metop HIRS as the reference were implemented. Table 2 shows NOAA-15 HIRS results for one month January 2003; the spectral shifts have increased the number of CO2 slicing cloud retrievals, especially for thin high clouds. The cloud top pressure changes caused by the algorithm adjustments are now being studied through inter-comparisons with CALIOP.

Table 2. January 2003 NOAA-15 HIRS Cloud Observations separated in hi, mid and lo as well cloud effective emissivity quarters and opaque.

(a) Using PATMOS-X cloud mask but with holding radiance bias adjustment

CTP	0-25	25-50	50-75	75-95	>95
< 440	5.85	8.80	7.56	6.52	1.63
680-440	1.15	2.95	4.06	9.49	9.24
> 680	2.94	6.18	6.15	7.08	20.38

Percentages are relative to all clouds
Number valid retrievals: 9064511
Percentage CO2-slicing retrievals: 51.10
For IRW solutions, CEE = cloud fraction

(b) Using PATMOS-X cloud mask along with radiance bias adjustment for spectrally shifted CO2 bands

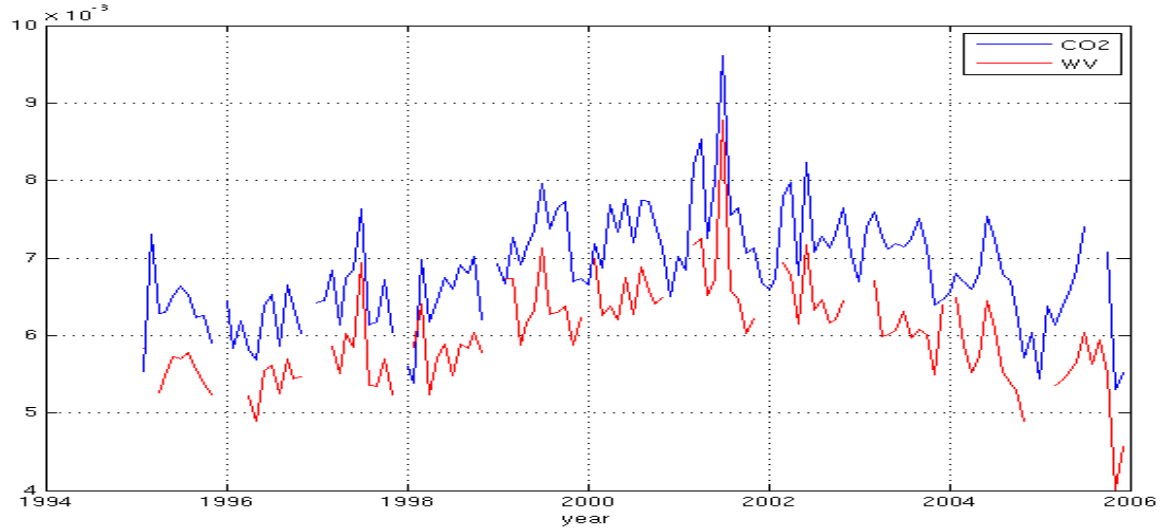
CTP	0-25	25-50	50-75	75-95	>95
< 440	7.95	8.93	8.36	6.63	2.92
680-440	2.76	6.03	6.87	6.11	9.52
> 680	2.69	5.45	5.13	5.68	14.97

Percentages are relative to all clouds
Number valid retrievals: 9064511
Percentage CO2-slicing retrievals: 56.85
For IRW solutions, CEE = cloud fraction

Conversion of MOD07 is progressing in order to retrieve HIRS moisture layers (high. middle, and low) and total column moisture. The synthetic regression coefficients for the statistical retrieval have been derived using a fast radiative transfer model with atmospheric characteristics taken from a dataset of 15,704 global profiles of atmospheric temperature, moisture, and ozone profiles. The radiative transfer calculation of the HIRS spectral band radiances have been performed for each training profile using JCSDA Community Radiative Transfer Model (CRTM V 2.0). The HIRS instrument noise was added into the calculated spectral band radiances, and these radiative transfer calculations provide a temperature-moisture-ozone profile / HIRS radiance pair for use in the statistical regression analysis. Collection of the necessary input data (geolocation, cloud mask, and ancillary data) was completed. The SeeBor surface emissivity database has also been added to the processing. Initial results of clear sky retrievals appear reasonable but the coverage is limited; expansion of processing to all view angles (currently we limit it to less than 32 degrees from nadir) and corrections for cloud contamination in partly cloudy pixels are now being considered.

5. *Investigating HIRS Stratospheric Cloud Trends*

Detecting the presence of upper tropospheric / lower stratospheric (UT/LS) clouds is based on the assumption that a more opaque spectral band produces a brightness temperature warmer than a less opaque 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) from NOAA-14 spanning 1995 through 2005. 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. Figure 3 shows that deseasonalizing the data makes the trends correlate better. A paper is in preparation on this work.



(b)

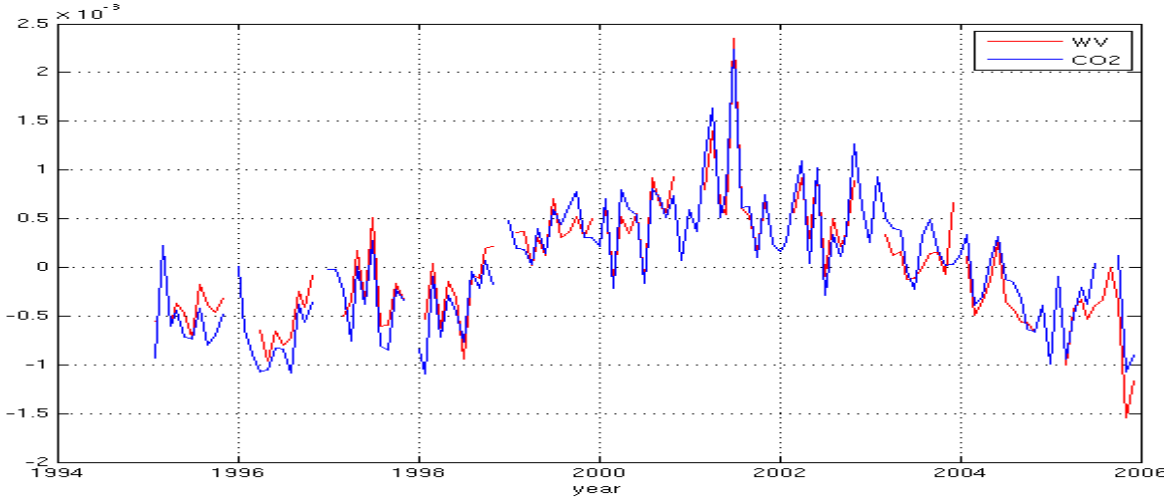


Figure 3. (a) UT/LS cloud fractions over 60 S – 60 N using NOAA-14 HIRS data over the years 1995 to 2005. Corr=0.89. (b) The same data de-seasonalized to emphasize the difference in the UT/LS trends before and after 2001. Corr=0.9491.

6. Remaining Work

6.1 After incorporating PATMOSX cloud fields to initialize the clear-cloud identification necessary for radiance bias adjustments in the HIRS CO2 slicing calculations, test the new software on several seasons (years) of data. Validate results with CALIPSO where possible.

6.2 Help hosting Cloud Retrieval Evaluations Workship in Madison in November 2011

6.3 Continue study of UT/LS cloud detection trends; publish a paper describing the results.

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

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

6.6 Prepare the software for transfer to NCDC.