Year 1 Report on Reprocessing HIRS Cloud Measurements
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1. Mitigating Sensor to Sensor Differences

Sensor to sensor calibration differences have been difficult to overcome; however AIRS is providing a reliable calibration reference for HIRS. Based on the approach of Tobin et al. (2006), AIRS measurements were convolved to the HIRS spectral response functions and compared with collocated (within 10 minutes and 10 km) HIRS measurements. Differences were noted between HIRS on NOAA-14, -15, and -16 and AIRS in clear and cloudy scenes for CO_2 sensitive spectral bands 4 (704 cm^{-1}, 14.2 μm), 5 (715 cm^{-1}, 14.0 μm), 6 (732 cm^{-1}, 13.7 μm), and 7 (750 cm^{-1}, 13.3 μm); mitigation was accomplished with a modest shift of the HIRS spectral bands. For NOAA-14, based on 338 comparisons made with July 2003 measurements, spectral shifts of 2.0, 2.5, 3.0, and 1.5 cm^{-1} to higher wavenumbers were suggested for bands 4, 5, 6, and 7 respectively. No spectral shifts were found to be necessary for NOAA-15 and -16. This brought the high and all cloud detection from the HIRS/2 sensor on NOAA 14 in family with the HIRS/3 sensors on NOAA 15 and 16. Figure 1 shows the results after implementing algorithm changes suggested by MODIS-CALIPSO cloud tests and shifting the NOAA 14 spectral bands as described above.

2. GEWEX HIRS Cloud Data Set

Cloud amounts and cloud top pressures derived from HIRS CO2 and IRW measurements were delivered to the GEWEX Cloud Team. Table 1 indicates the complete year data sets for am and pm orbits; ascending and descending orbits were processed separately. HIRS view angles less than 32 degrees from nadir were considered to mitigate cloud edge effects. Contiguous fovs from 60N to 60S were processed. The cloud mask was based on spatial and temporal variances of IRW plus CO2 screening of thin cirrus. Clear radiances were based on forward radiance calculation with bias correction interpolated from neighboring fovs (using NCEP/NCAR Reanalysis).

If a CO2 slicing radiance ratio cannot be calculated reliably for any of the possible band pairs because the clear minus cloudy radiance measurement for a given spectral band is less than 0.5 mW/m2/ster/cm-1 (approximately the instrument noise level) or none of the cloud top pressure solutions were in the appropriate range for that band pair, then an opaque cloud top pressure is calculated directly from the IRW (assuming it has a brightness temperature colder than the surface temperature by 3 C over ocean and 10 C over land where Tsfc is time interpolated from the NCEP Reanalysis). All clouds are assigned a cloud top pressure either by CO2 or IRW calculations. It should be noted that low clouds below 950 hPa or over barren land are assumed to be incorrect and designated as clear; below 950 hPa the thermal contrast is not reliable and over barren land (as identified in the IGBP ecosystem maps - Defries et al (1995)) where the surface temperature is not tracked well in the NCEP Reanalysis.

Table 2 summarizes the HIRS GEWEX data set characteristics.

3. Recoding the HIRS Cloud Algorithm

The MODIS algorithm software has been adapted to process HIRS data files. Early testing results are shown in Figure 2; it is noted that no cloud screening was applied and clear skies are included as low clouds. Also, no radiance bias corrections were implemented; these will be estimated when the cloud mask from the PATMOSX is incorporated into the HIRS reprocessing.

4. Investigating HIRS Stratospheric Cloud Trends

The presence of stratospheric clouds is based on the assumption that they occur when a more opaque spectral band sensitive to H_2O in the atmosphere produces a brightness temperature warmer than a nearly transparent infrared window spectral band. Observations from NOAA-14 spanning 1995 through 2005 show increases in stratospheric cloud occurrence until 2001 with a decrease thereafter; correlations with SST have also been studied. See Figure 3.

5. Remaining Work

5.1 Use SNOs to recalibrate HIRS sensors preceding NOAA 14; this will be done in collaboration with Cao et al. Assure that sensor to sensor transitions do not introduce spurious trends.

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

As stated elsewhere, the ultimate goal is to establish a near real-time compendium of monthly average global cloud properties that will be presented in the context of cloud trends and patterns from the past thirty years. This global climatology of cloud parameters will include cloud fraction, cloud-top pressure, and cloud emissivity; algorithm strengths, weaknesses, and inherent errors for each parameter will be clearly stated and documented. Detection of changes in cloud properties, either regionally or globally, would be identified and the magnitude of the change would be characterized as extraordinary or not and as reliable or not (depending on the bounds inherent with the error sources of the data set).

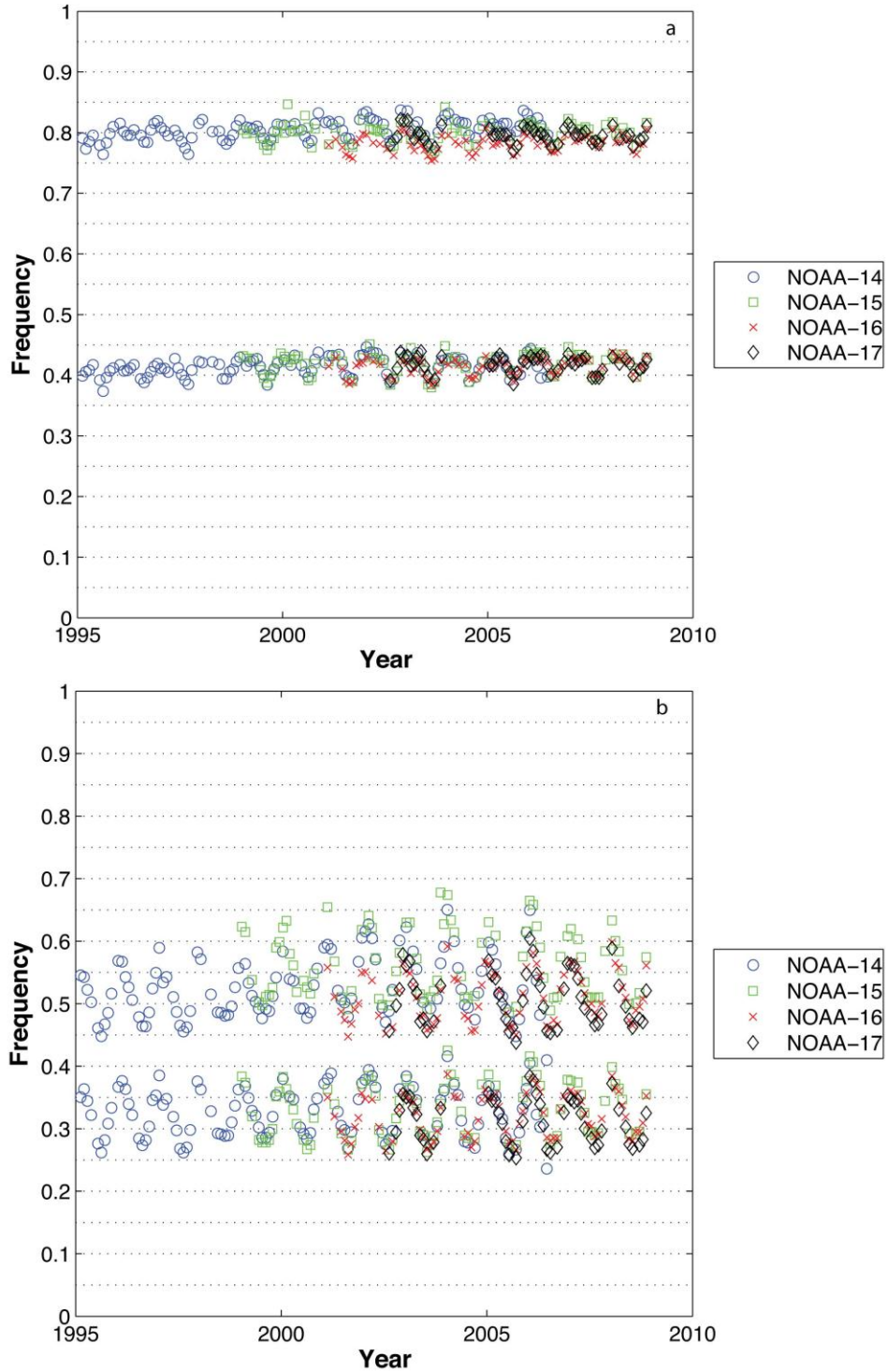

Figure 1: Results of adjusted algorithm using changes suggested by the MODIS work, including the spectral shift. The percentage of HIRS observations since 1995 that found "all" and "high" (CTP less than 440 hPa) clouds from 60˚N to 60˚S (a) over oceans and (b) over land.

Table 1: 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. All data preceding N14 will have to be recalibrated using the SNOs established by Cao et al.

Year	730 am	130 pm
1984		N7
1985		
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	N12	N14
1998	N12	N14
1999	N15	N14
2000	N15	N14
2001	N15	N14
2002	N15	N14
2003	N15	N14
2004	N15	N14
2005	N15	N14
2006	N15	N16
2007	N15	N16
2008	N15	N16

Table 2: Characteristics of HIRS NOAA GEWEX Data Set

Spectral bands used – IR only using CO2 and IRW bands (see Table 1)
Orbits processed - Both ascending and descending for 730 am and 130 pm (only one satellite per orbit)
Coverage - Contiguous FOVS (20 km resolution at nadir) over whole globe within 32° from nadir
Cloud mask - Spatial and temporal variances of window channel data plus CO2 channel screening of thin cirrus
Clear radiance estimate - Explicit forward radiance calculation (based on NCEP/NCAR Reanalysis) with calculated minus measured radiance bias adjustment
Cloud parameters processed – effective cloud amount and cloud top pressure
Strengths - good detection of high thin clouds even in partly cloudy FOVs
Weaknesses – thermal contrast for low clouds is suspect (low cloud with CTP> 950 hPa or with 3 (5) deg C of SST (LST) or over barren land is assumed to be clear sky); polar clouds

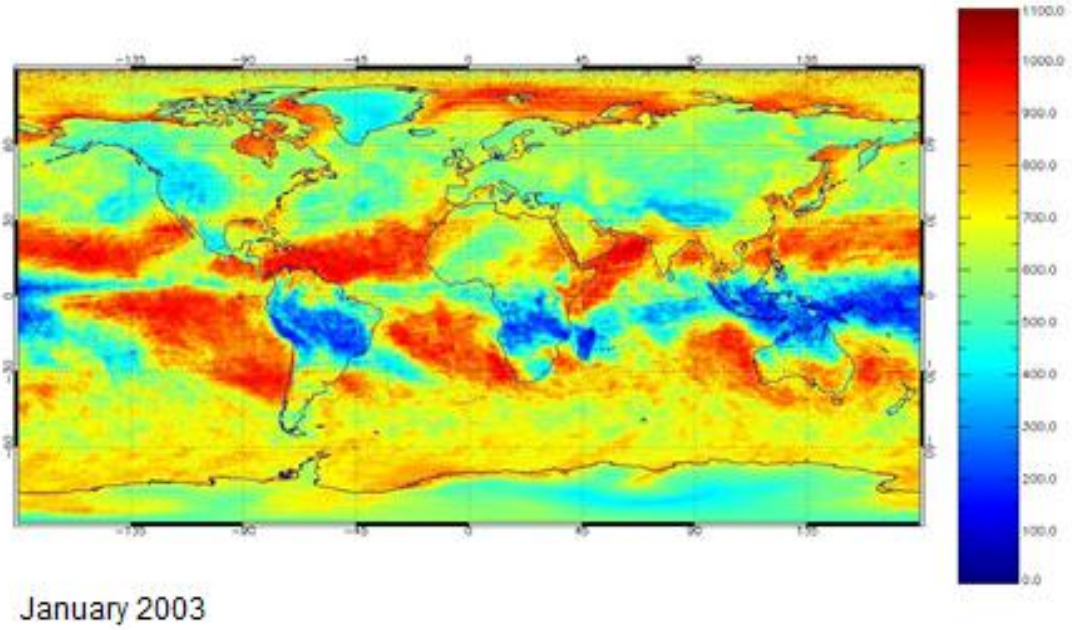

Figure 2: NOAA-15 monthly mean ascending node CTPs for January 2003 (0.5-degree equal-angle bins). Data is average of daily means. Notice the slantwise anomalies seen just west of S. America and in the southern Indian Ocean. These are due to calibration stripes (no radiance data) falling in more or less the same locations on many days of the month. The horizontal and vertical striping (e.g., Sea of Okhotsk) are 2.5 degrees wide, indicating observed vs. modeled (NCEP Reanalysis 1 profiles) atmospheric temperature and moisture discrepancies.

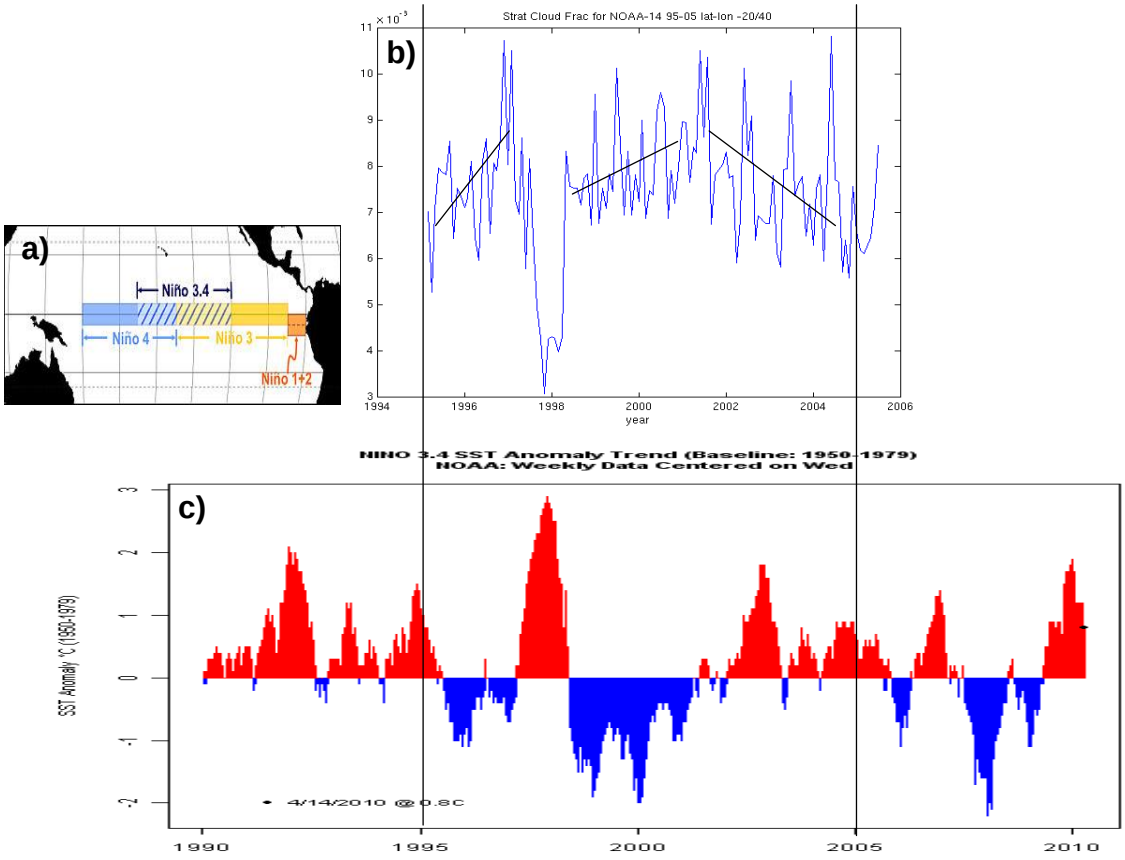

Figure 3: Weekly sea surface temperatures (SSTs) from 1990 to 2010 over the area illustrated in image (a) as the Niño 3.4 tropical region (blue and yellow lines) is shown in the bottom image (c) (National Climate Data Center-NCDC). Top image (b) shows the stratospheric cloud fractions over the ITCZ region (20ºS-40ºN; 45º-180ºE) for 1995-2005 with a linear fit superimposed.