P1.8 THE HIRS PATHFINDER RADIANCE DATA SET (1979-2001)

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1. INTRODUCTION

The HIRS satellite sounding data provide the longest and most extensive global record of temperature and moisture profiles for the earth's atmosphere. Version 1 of the HIRS Pathfinder radiance data (Jackson and Bates, 2001) provided the first clear-sky radiance data set with a consistent quality control and cloud detection method throughout the entire HIRS period. Version 2 introduces a longer data record with an improved cloud detection method, radiance data for both clear and cloudy observations, and cloud height retrievals using the CO_2 slicing method (Wylie and Menzel, 1999). These additions to the Pathfinder radiance data provide an opportunity to analyze cloud height and frequency in the context of climate variability.

2. CLOUD DETECTION

The technique used to compute the clear-sky data (Jackson and Bates, 2000) is similar to the ISCCP cloud clearing approach where observed window channel brightness temperatures at 11.1 μm are compared spatially and temporally to an estimated clear-sky value and rejected as cloudy if the observation is too cold. An enhancement to the cloud detection method was added to version 2. An additional threshold was added to test for HIRS channel 8 (11.1 μm) observations below freezing in the tropics (15N-15S) to further reduce the number of persistent cloudy observations from the clear-sky data. Improvements in computing the long-term clear-sky statistics for HIRS channel 8 enabled smoother transitions in the clear-sky climatological fields. This change eliminated erroneous cloud detection results at the end of leap years seen in version 1. Figure 1 gives one example of the difference between the version 1 and version 2 cloud detection.
Channel 5 (14.0 μm) observations are of middle tropospheric temperature at ~600 hPa, so they generally do not detect radiation from the surface. Version 1 gave a broad region of relatively cold brightness temperatures in the interior of South America south of the equator. Persistent cloud cover regions resulted in accepting some cloudy observations when compiling the clear-sky climatology in the Tropics.
Version 2 eliminates most of these cloudy observations and gives a larger region of missing data in the regions of persistent cloudiness. Other improvements to the clear-sky data include an updated limb correction and inclusion of observations over high terrain and polar regions. Even though a more stringent cloud detection method reduces the number of clear-sky observation, when combined with these other changes the number of clear-sky observations for the version 2 data set increased by ~25%.

3. CLOUD RETRIEVALS

A new step was added to the processing method that includes the CO_2 slicing method to compute cloud statistics. Three parameters are produced from the cloud retrieval scheme: cloud top pressure, cloud top temperature and effective emissivity, the latter being the product of the cloud fraction and the cloud emissivity.
Two significant changes from those cloud height data constructed previously in Wylie and Menzel (1999) were accomplished for the Pathfinder data. First, we used the NCEP reanalysis temperature and water vapor profiles to compute the clear-sky radiance. Second, we utilized the NCEP fast radiative transfer model (McMillin et al. 1995; Van Delst et al., 2002) for the forward brightness temperature calculations. These changes allowed for a more consistent surface temperature, and sampling the diurnal cycle provided a more accurate surface temperature that allowed cloud retrievals to be performed for morning satellites over land. The NCEP model required ozone profiles that we computed from the zonally averaged 19-level monthly climatology of Fortuin and Kelder (1998). The angle dependent model radiance were compiled every 12 hours on a 2.5^{o} grid and matched to the nearest HIRS observation. The observed clear-sky Pathfinder observations were used

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to bias-adjust the model radiance so not to introduce bias between the observed cloudy and computed clear-sky radiance in the cloud height calculation. The cloud height data were computed using the difference between the expected clear-sky and observed radiance and were archived at each HIRS footprint for observations at scan angles less than 49 degrees from nadir. All-sky HIRS radiance were archived for a select set of HIRS temperature and water vapor channels. Preliminary results for long-term high cloud statistics derived from these data are given in Wylie et al. (2003)

4. ORBIT STATISTICS

Orbit statistics provided statistical information on the radiance data for each orbit. These data, used primarily for quality control of the radiance data, were modified to include the higher order statistics of skewness and kurtosis. Orbit statistics can be used to identify orbits containing spuriously bad data or anomalies in the radiance data due to sudden problems with the instrument. Figure 2 shows a time series of the statistics compiled from NOAA-12. This case shows

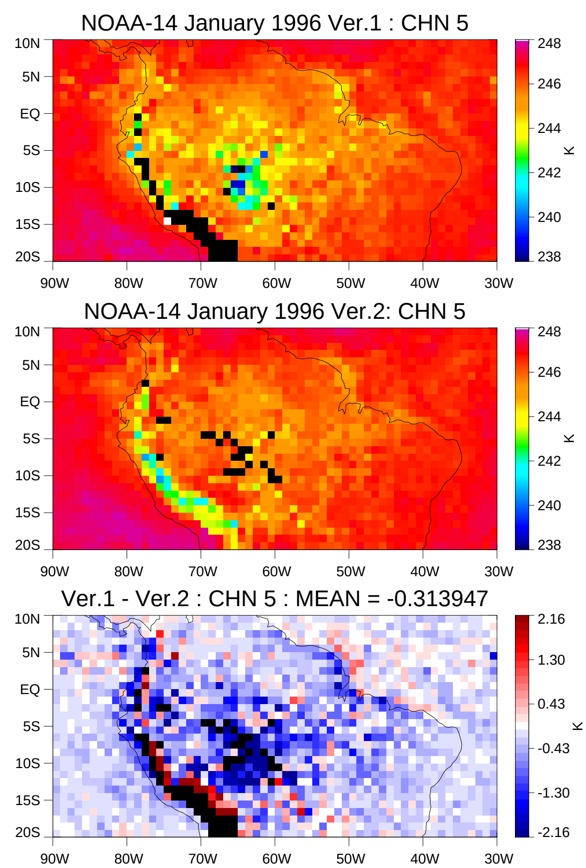

Figure 1: Comparison of version 1 and version 2 NOAA-14 channel 5 clear-sky brightness temperatures temperatures over South America.

large changes in the maximum and minimum brightness temperatures for channel 4 (14.2 μm) beginning in May 1997. It is at this time the HIRS filter wheel mechanism degraded causing large anomalies in HIRS radiance for several channels. Red dots indicate the individual orbit values that can be used to screen suspect data from the HIRS 1b time series.

5. INTERSATELLITE BIAS

Understanding bias in the HIRS radiance data is essential for application of these data to climate research. One of the greatest challenges in this data set is correcting intersatellite bias. Figure 3 gives time series of the 30N-30S clear-sky data for four HIRS channels. Channel 2 (14.7 μm) provides the best stability and generally shows a downward trend in lower stratospheric temperature over the 23-yr period. Channel 4 indicates a shift to colder observations from the HIRS/2 to HIRS/3 instrument starting in 1998 even though no change was made to spectral location of this channel. Temperature channels 4 and 8, and water vapor channel 12 show significant intersatellite bias, the amplitude of which can achieve several degrees K for the temperature channels.

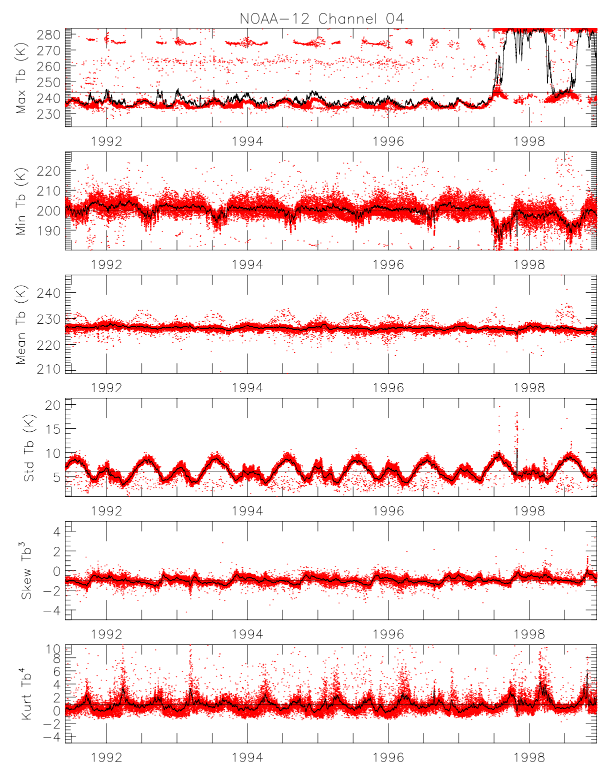

Figure 2: Time series of orbit statistics for NOAA-12. Red dots indicate individual orbit value, black curve is a 5-day running mean, and black line is the climatological mean. STD is standard deviation, Skew is skewness and Kurt is kurtosis.

Past efforts to remove this bias have been accomplished through an empirical adjustment process (Bates et. al., 1996) and bias adjustments were applied to version 1 data (Jackson and Bates, 2001). However, attempts to explain these biases from differences in the filter response have given mixed results that depend on satellite and channel. Our past efforts have not considered sampling differences between the modeled and observed radiance that might explain this mixed result, so a simple experiment is presented here to investigate this problem. Table 1 gives results from a comparison between NOAA-11 and NOAA-12 in January 1994. We used the NCEP reanalysis profiles and NCEP fast radiative transfer model to forward compute the brightness temperatures that directly match clear-sky observations from the Pathfinder data. This strategy allows us to remove bias that may be introduced through the diurnal cycle or spatial sampling differences. Previous results from using a separate radiative transfer model and atmospheric profiles that were not matched to the HIRS observations are also given in Table 1. The bias from the observations indicates NOAA-11 to be ~1 K warmer than NOAA-12 while two model results indicate this difference to be of the opposite sign. The NCEP model result holds true

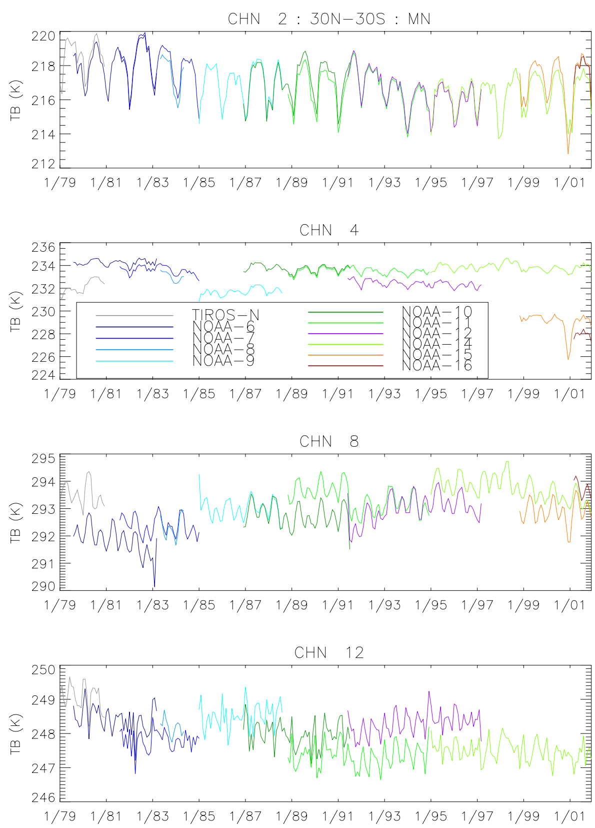

Figure 1: Clear-sky monthly mean brightness time series for channels 2, 4, 8, and 12 for all satellites. Each color represents one satellite.

for different observation times and latitude bands. The conclusion here is that sampling differences do not explain the intersatellite bias for these two satellites. Therefor, this unexplained difference between model and observations likely originates from one of two sources: differences between the published pre-launch instrument response function used by the models and response of the in-flight instrument or errors in the calibration coefficients provided with the 1b data.

Table 1: Comparison of observed and modeled channel 4 brightness temperatures for 30N-30S in January 1994. MODTRAN results were computed from TIGR-3 profiles.

	NOAA-11	NOAA-12	N11-N12
OBS.	232.45 K	231.33 K	1.12 K
NCEP	231.06 K	232.37 K	-1.31 K
MODTRAN	231.45 K	232.57 K	-1.12 K

6. CONCLUSIONS

Version 2 of the HIRS Pathfinder Radiance data now provides an improved clear-sky data set product and a new cloud data product that includes cloudy radiance and cloud parameters from the CO_2 slicing method. Three forms of HIRS Pathfinder radiance are available at the NOAA/OAR/Environmental Technology Laboratory and are described in further detail in Table 2. These data could be a valuable asset for GEWEX, CLIVAR and SPARC in their climate change and detection programs. These data are also beneficial for HIRS quality control efforts; for example, ECMWF has used the orbit statistics data to flag potentially bad HIRS observations for the ERA-40 project.

An example showing the difficulty of modeling the observed intersatellite bias demonstrates that sampling differences between model and observations does not explain the bias. Such bias might arise from two other sources: (1) erroneous calibration data in the 1b data or (2) inaccurate representation of the response function used by the model. Further study in these two areas is recommended to identify the source of the bias.

7. REFERENCES

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Table 2: Description of the version 2 HIRS Pathfinder radiance data sets.

Data Type	File Type	Size (Gb)	Description
Orbit	ASCII	0.3	All-sky statistics for each orbit (maximum, minimum, mean, standard deviation, skewness, and kurtosis of brightness temperature, number of good and missing observations) for each channel and satellite.
Clear Grid	Binary, INT*2	40	Monthly clear-sky brightness temperature grids of mean, standard deviation, and number of observations for each satellite and channel.
Cloud Swath	Binary, Mixed	360	Swath data exists at resolution of HIRS instrument with data records containing time, latitude, longitude, solar zenith, line number, scan position, altitude, reflectance, clear-sky flag, brightness temperature (channels 4-8,10,12), NCEP surface temperature, clear-sky radiance – cloud radiance difference (channels 4-7), cloud-top temperature and pressure, effective emissivity.
Clear Swath	Binary, Mixed	90	Swath data exists at resolution of HIRS instrument with data records containing time, latitude, longitude, line number, scan position, solar zenith, altitude, clear-sky flag, reflectance, brightness temperature (channels 1-19)