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CLIMATE ANALYSIS WITH THE 21-YR HIRS PATHFINDER RADIANCE CLEAR-SKY DATA SET

Darren L. Jackson*
Cooperative Institute for Research in Environmental Sciences, Boulder, CO

John J. Bates
NOAA/ERL Environmental Technology Laboratory, Boulder, CO

1. INTRODUCTION

The TOVS 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 21-yr HIRS clear-sky radiance data set has been constructed as a part of the TOVS Radiance Pathfinder project and provides the science community its first clear-sky radiance data set with a consistent quality control and cloud detection method throughout the entire HIRS period. These data will be beneficial for observational climate change studies and climate model/reanalysis validation studies.

2. METHOD

HIRS 1b data were first calibrated and converted to brightness temperature using the ITPP and AAPP packages from the University of Wisconsin and EUMETSAT respectively. Cloud detection was first described in Jackson and Bates (2000) and a brief overview is given here. The cloud/clear conditions were ascertained using the HIRS channel 8 surface channel. A limb correction was first applied to channel 8 to eliminate water vapor effects seen in tropical profiles. Surface temperature information was constructed by binning the maximum value all-sky channel 8 observations onto a 0.5 degree grid for each 6-hour period for each day. Each observation is compared to nearby grids, both in space and time, to determine if the observation was colder than the expected surface temperature. Pre-defined thresholds decide whether an observation is cold enough to be considered cloudy. The remaining clear-sky swath data were saved at the original resolution of the satellite observation. These swath data provide a unique high-resolution clear-sky data set that can be used to compose grid data at various time (daily, pentad, monthly) and spatial (1.0, 2.5 degree) resolutions. Other data products include all-sky brightness temperature statistics for each orbit, channel, and satellite. Table 1 highlights the data products currently available at NOAA ETL.

* *Corresponding author address*: Darren L. Jackson, NOAA/CIRES/ETL, 325 Broadway R/ET7, Boulder, CO 80303-3328; e-mail: Darren.L.Jackson@noaa.gov

Table 1: Description of HIRS clear-sky data products.

Type	Size (Gb)	Description
Orbit	0.26	All-sky orbit statistics (mean, standard deviation, max, and min Tb) for each channel, satellite and orbit.
Grid	6.7	Monthly grids of mean, standard deviation and number of observations for each satellite and channel.
Swath	60	Original resolution with data records containing time, lat., lon., solar zenith, line number, scan position, altitude, reflectance, Tb.

3. RESULTS

Figure 1 gives a time series of the number of observations processed for each satellite and the number of remaining clear-sky observations after processing. Each satellite provides approximately $7x10^5$ observations per day and most of 21-yr period has coverage from two satellites collecting observations at four separate local times over the globe. Spikes indicate short periods where the data overlap between old and new satellites. The first nine years have several periods with coverage from only one satellite. The largest of these periods occurs in 1985-86 when the premature failure of NOAA-8 caused a significant gap in the morning satellite data. An extended period in 1997-98 where three satellites provide data is due to NOAA-11 satellite being reactivated after NOAA-12 HIRS data became suspect after May 1997 due to a filter wheel anomaly.

A significant diurnal drift in NOAA-11 resulted in this satellite moving into the NOAA-12 morning position. The clear-sky data time series indicates nearly a 90% reduction in data from the all-sky data. Clear-sky comparisons with ISCCP/AVHRR data indicate a good agreement with only 2% of the Pathfinder clear-sky observations residing in ISCCP assigned cloud

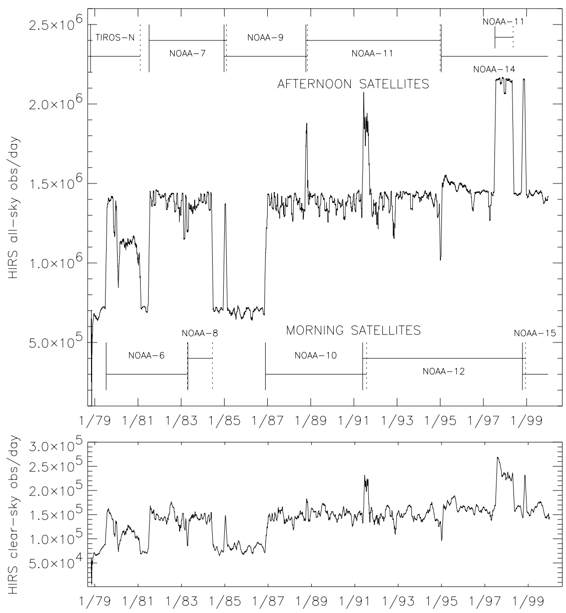

Figure 1: Time series of number of HIRS all-sky and clear-sky observations.

regions. However, the Pathfinder cloud detection uses a conservative approach that results in 13% of the ISCCP clear regions to be assigned cloudy.

Time series of 30N-30S brightness temperatures for channels 2 (14.70 μm), 4 (14.20 μm), 8 (11.10 μm) and 12 (6.70 μm) are presented in figure 2. Time series are shown from afternoon and morning satellites but from only two passes - the afternoon (15 LST) and evening (20 LST) passes. Channel 2 is a lower stratospheric temperature channel, channel 4 is an upper tropospheric temperature channel, channel 8 is a surface sensing temperature channel, and channel 12 is an upper tropospheric water vapor channel. Channel 2 results indicate an annual cycle with amplitude ~1.5 K and negative temperature trend for most of the record for both afternoon and evening passes. The direction and amplitude of the trend agrees well with the known cooling of the lower stratosphere detected by other satellites and ground-based instruments (Ramaswamy et al., 2001). Channel 4 time series indicates intersatellite bias of several degrees between the 10 satellites. This bias presumably is caused by small changes in the filter response functions and the central frequencies between the various satellites. Since this channel along with channels 5, 6 and 7 reside on edge of strong CO2 absorption region at 15 microns, the mean channel temperature is sensitive to small changes in these two parameters. The afternoon time series shows an artificial jump in 1985 caused by the transition from NOAA-7 to NOAA-9. Likewise, for the evening orbit in 1998 during the transition from NOAA-11 to NOAA-15. Channel 8 shows a noticeable decrease for both passes in 1991 following the eruption of Mt. Pinatubo. The afternoon pass shows a steady decrease from 1990 to 1995 demonstrating the drift of NOAA-11 from the afternoon to morning position. The large jump in January 1995 indicates the transition of afternoon satellites from NOAA-11 to NOAA-14. The afternoon data are warmer at all time periods since local observations near 15 LST result in the warmest temperatures over the desert regions. Channel 12 time series has high frequency variations and very little annual cycle for this domain. Intersatellite bias is most evident during the transition between NOAA-9 and NOAA-11 in the afternoon data in 1988.

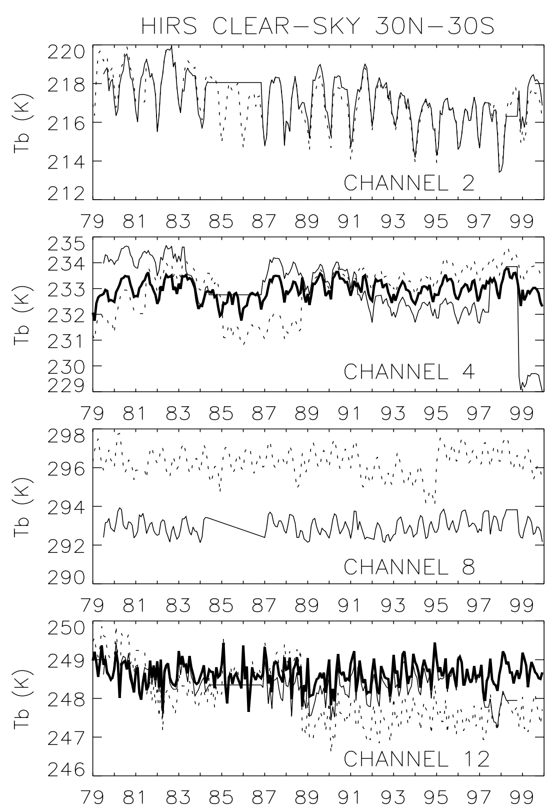

Figure 2: HIRS zonal mean time series of afternoon pass (dotted), evening pass (solid), and EDF-adjusted (thick curve) brightness temperatures for HIRS channels 2, 4, 8, and 12.

In light of the significant intersatellite bias in

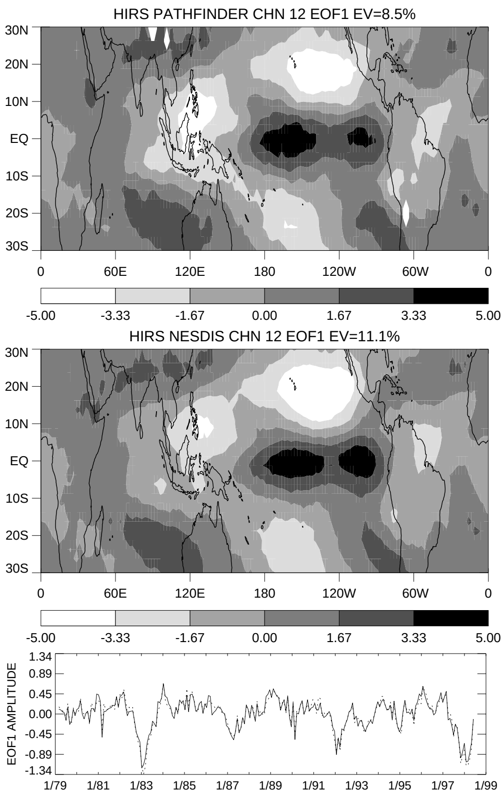

Figure 3: Leading EOF of clear-sky HIRS channel 12 data for the Pathfinder and NESDIS Operational. Time series of leading mode for Pathfinder (solid) and NESDIS (dotted) is given in bottom figure.

channels 4 and 12, an empirical dynamic function (EDF) analysis was applied to the data to eliminate intersatellite bias. This approach uses cumulative histograms of the interannual anomaly fields from the four local overpass periods and adjusts the results to a reference (evening) overpass time. Details of this technique are outlined in Bates et al. (1996). The EDF-adjusted brightness temperatures are shown by the thick curves for channel 4 and channel 12. The adjusted time series eliminate the artificial shifts created during satellite transitions. A physically based approach for explaining the intersatellite bias could not explain all of these transitions. This is likely due to inaccurate information about the instrument filter response or central frequency.

A comparison with NESDIS operational sounding data indicates HIRS channel 12 compares favorably for both the spatial variance and the time amplitude. The first EOF for channel 12 is given in figure 3. HIRS channel 12 indicates ENSO as the dominant mode of variability. The time series indicates this leading mode has its largest amplitude during El Niño events of 1983, 1987, 1992, and 1998. The moisture pattern indicates increased tropical moisture in the Central and Eastern tropical Pacific associated with tropical convection and significant dry regions over parts of Indonesia and the subtropical Eastern Pacific in the Northern Hemisphere.

4. CONCLUSIONS

Clear-sky HIRS data from the TOVS Pathfinder radiance project for the period from October 1978 to December 1999 indicate the temperature channels relate well with known changes in the temperature field for the lower stratosphere and lower troposphere. Middle and upper tropospheric channels suffer the largest intersatellite bias, but these biases were reduced using an empirical-based EDF approach for eliminating jumps between satellite periods. EOF Comparison with the NESDIS operational data products indicates good agreement for the moisture field and temperature fields (not shown).

Applications of these data include investigating the role of water vapor climatologies for GEWEX water vapor project, analysis of the role of water vapor in the monsoon/desert system for CLIVAR-GOALS, studies of upper tropospheric/lower stratospheric water vapor for SPARC and climate model/observation studies with AMIP-II. Future improvements to these data include providing all-sky data products, including cloud height and densities using the CO_2 cloud slicing method (Wylie and Menzel, 1999), and making these data available for users in a standard data format at a data center.

5. REFERENCES

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