P2.1 VERTICAL TEMPERATURE PROFILE RADIOMETER BRIGHTNESS TEMPERATURE DATASET AND ITS STATISTICS

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1. INTRODUCTION

The Vertical Temperature Profile Radiometer (VTPR) was an operational 8-channel sounding system mounted on the NOAA-2 through NOAA-5 spacecrafts. The instrument made routine observations used to derive atmospheric temperature soundings. The measurements covered more than six years from November 1972 to February 1979.

The VTPR data were used in a number of reanalysis projects. The retrieved VTPR soundings with a horizontal resolution of approximately 600km were used in the reanalysis at National Center for Environmental Prediction / National Center for Atmospheric Research (Jenne, 2000). At the European Centre for Medium-range Weather Forecasts (ECMWF), the VTPR raw radiances and the VTPR-1c data with the observed resolution were directly assimilated into a 3-dimensional assimilation system in ERA-40 (Li, 2000).

Significant work was done at ECMWF to remove erroneous data in the original VTPR dataset. Rejection criteria were based on several factors including sum of the lengths of blocks and correctness of data record time and orbit starting time. The average error (rejected data) rate was 2.95% with most errors occurring mainly in three periods. The first was from November 1972 to April 1974, which was the initial operation of NOAA-2. The second was from January to August 1976, at the end of NOAA-4 operation. The third period was June through October 1978 of NOAA-5 data. During these three periods, the error rates often reached 8%. A large portion was recovered later by modifying the data processing code to handle block data better (Li, 2000). The average error rate was reduced from 2.95% to 0.88%.

In the original dataset, most pixels were not navigated. In an area with 8x23 (184) pixels, only three of them, the “principal points”, were earth-located. The horizontal resolution of the principal points was about 600km. The ITPP5.01 package was used at ECMWF to navigate all the pixels.

In order to make the VTPR data available to a broader research community, especially to the climate research community, the processed VTPR data were obtained from ECMWF. Descriptive statistics for the entire period of the VTPR data are presented.

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2. VTPR DESCRIPTION

A detailed description of the VTPR instrument has been provided by McMillin et al. (1973). The instrument scans perpendicular to the satellite motion, from left to right facing the direction of travel, in 23 discrete steps. Fields of view, scanning times, and apparent motion on the earth provide spot pixels which are contiguous both across and along the orbital track.

The VTPR sounder has a horizontal resolution of 55km x 57km at the nadir and 67km x 91km at the end of scan. Six of the eight channels are used to derive radiances in the 15 μm carbon dioxide band and are very similar to the subsequent High Resolution Infrared Radiation Sounder (HIRS) channels in the later NOAA satellite series. In addition to the sounding channels, there is one channel in the 11 μm atmospheric window region and another channel in the 18 μm water vapor absorption band. The VTPR channel spectrums are listed in Table 1.

Table 1. Nominal spectral intervals for VTPR filters.

Channel	Central Wave Length (μm)	Central Wave Number (cm^{-1})	Half-Power Width (cm^{-1})	Tenth-Power Width (cm^{-1})
1	14.96	668.5	3.5	10.5
2	14.77	677.5	10	20
3	14.38	695.0	10	20
4	14.12	708.0	10	20
5	13.79	725.0	10	20
6	13.38	747.0	10	20
7	18.69	535.0	18	20
8	11.97	833.0	10	16

As an example of VTPR orbit and coverage, Fig. 1 shows the NOAA-5 VTPR channel 8 measurement during a 6-hour period starting at 6 UTC, February 1, 1979. In this image, the orbits over Africa and Eurasia travel from north to south in descending orbits. The orbits over the Pacific Ocean are ascending orbits. Since channel 8 is in the atmospheric window region, the observation measures radiative emission from the surface. Large contrasts across land and ocean boundaries are shown. For example, the cold land and warm water at the United States west coast and the hot land and cool ocean water at the Africa south coast are seen in Fig. 1.

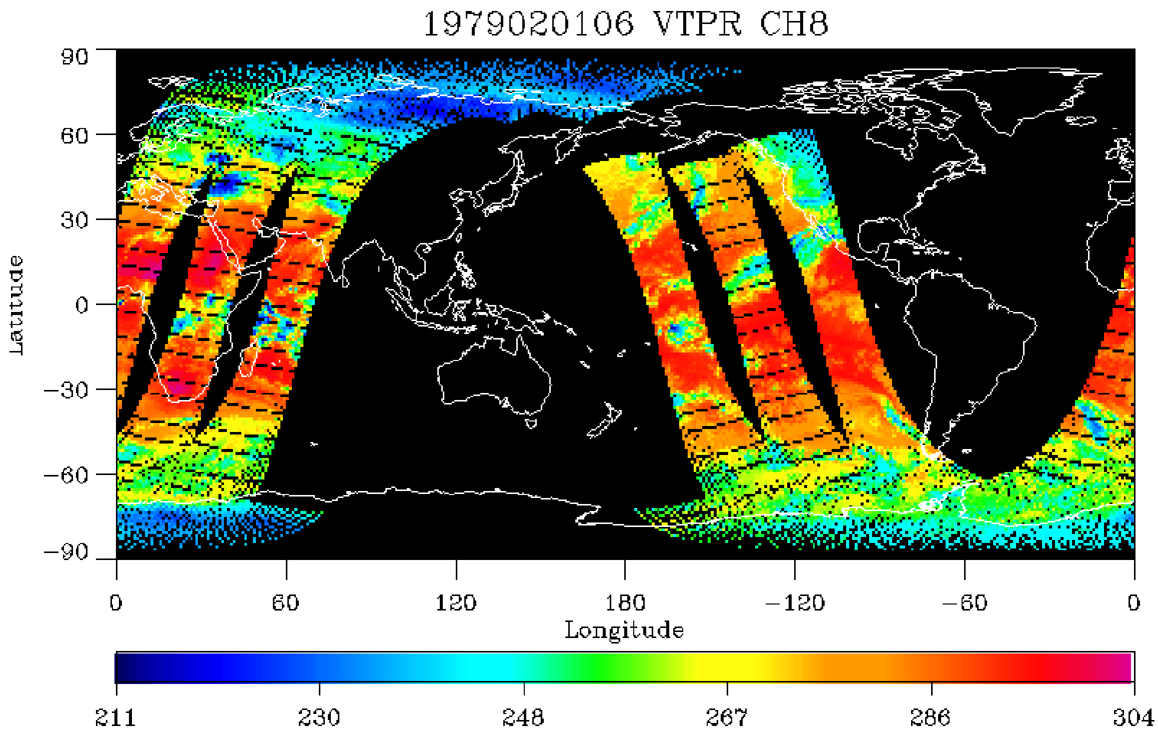

Fig. 1. An example of VTPR channel 8 measurement taken from NOAA-5 during a 6-hour period starting at 6 UTC, February 1, 1979.

The VTPR had two different operational modes with two different sets of filter functions. During the VTPR operation, one of the modes was switched on. In the VTPR data files, the satellite name and VTPR filter function are linked to each pixel measurement in terms of satellite identification and sensor identification. Other associated data include scan line, field of view, time, latitude, longitude, satellite height, satellite zenith, etc.

3. STATISTICS OF VTPR DATA

Each of the VTPR files contains six hours of data. The total number, standard deviation, mean, minimum, and maximum values for each of these six-hour files are computed. As an example, Figs. 2-6 plot these descriptive statistics for July 1978. The measurements are taken from the eight VTPR channels on NOAA-5. In general, the total number of pixels in 6-hour intervals is close to 40,000 (Fig. 2). July 1978 is within one of the three major periods of erroneous data. Large amounts of erroneous data have been removed by the ECMWF data processing package. The removal of data can be seen in Fig. 2 as significantly reduced number of pixels, on July 1, 5, 6, and 15-17.

The VTPR channels are designed to sense different levels of the atmosphere. Channel 8 is a surface window channel. Channels 1-6 are in the 15 µm CO_2 band for sensing atmospheric temperatures. Channel 6 is a near-surface channel. The weighting function of channel 5 peaks at mid-troposphere. Channel 4 peaks near the tropopause. Channels 3, 2, and 1 are stratospheric channels. Channel 7 is a water vapor channel.

The standard deviation plots of these channels are shown in Fig. 3. The standard deviation values are largest for the surface channel, at around 20 K, followed by the near-surface channel and the water vapor channel, at around 15 K. The standard deviations for the mid to upper troposphere and stratosphere channels are much smaller. The several elevated values in the standard deviation plots correspond to the reduction in the numbers of pixels.

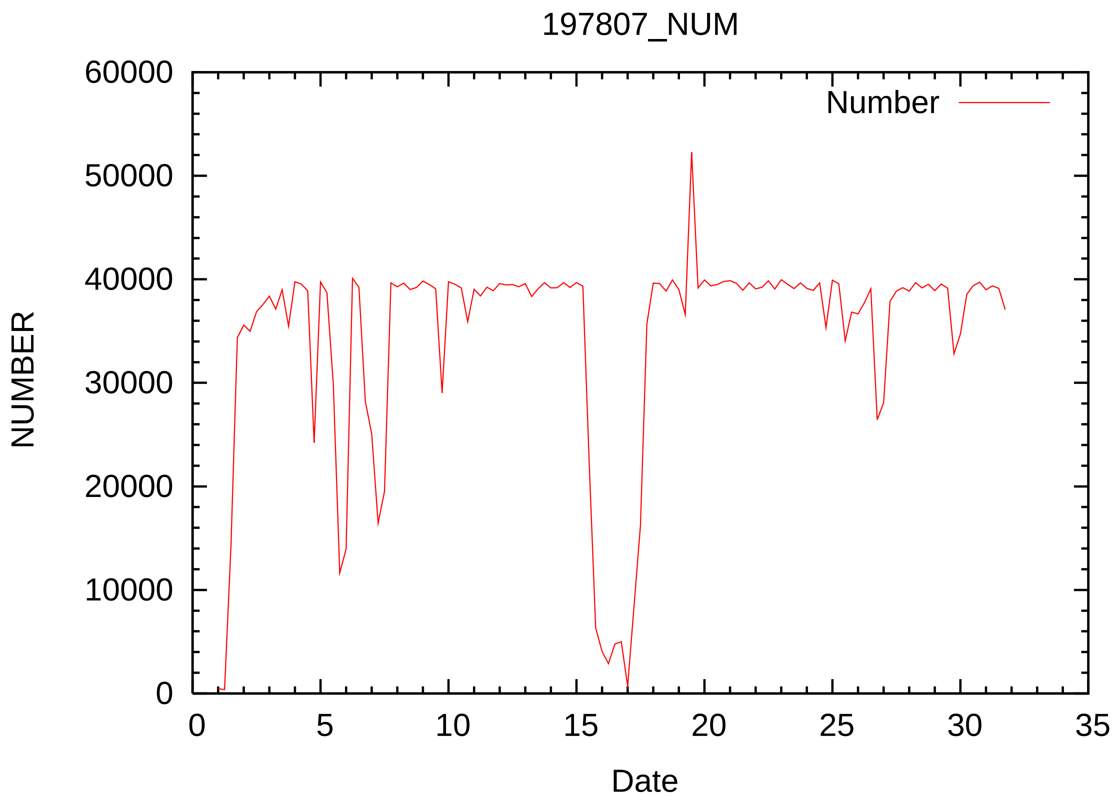

Fig. 2. VTPR total number of pixels for July 1978 from NOAA-5.

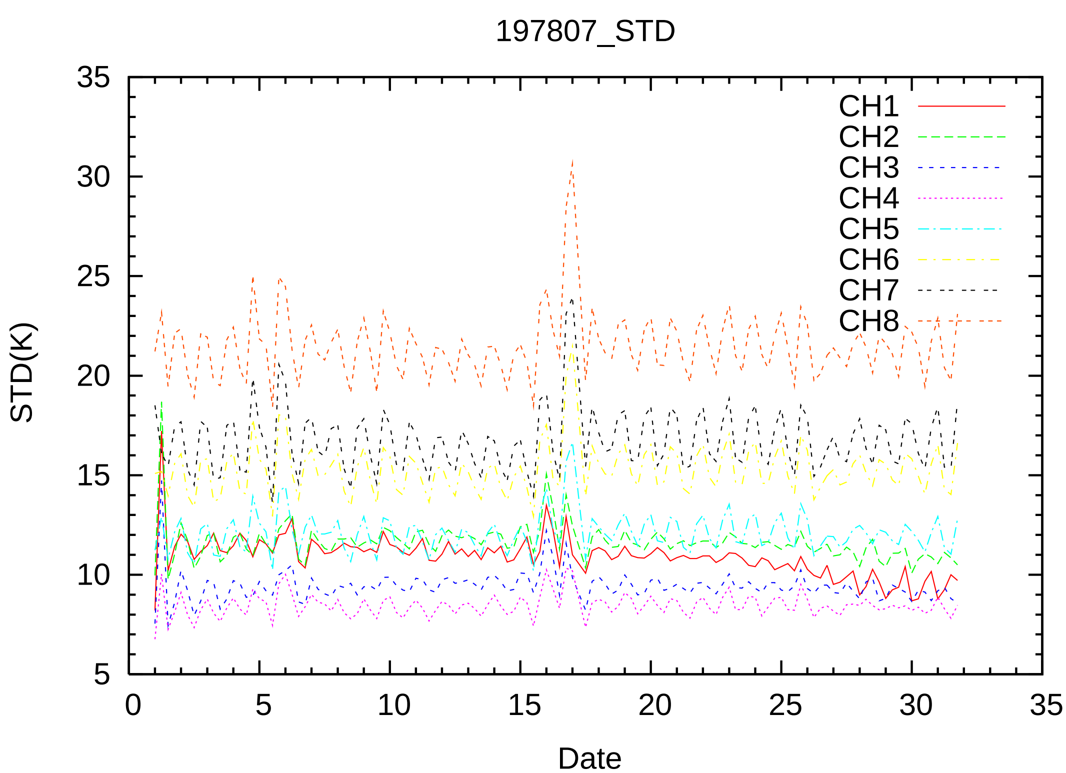

Fig. 3. VTPR standard deviation for July 1978 from NOAA-5.

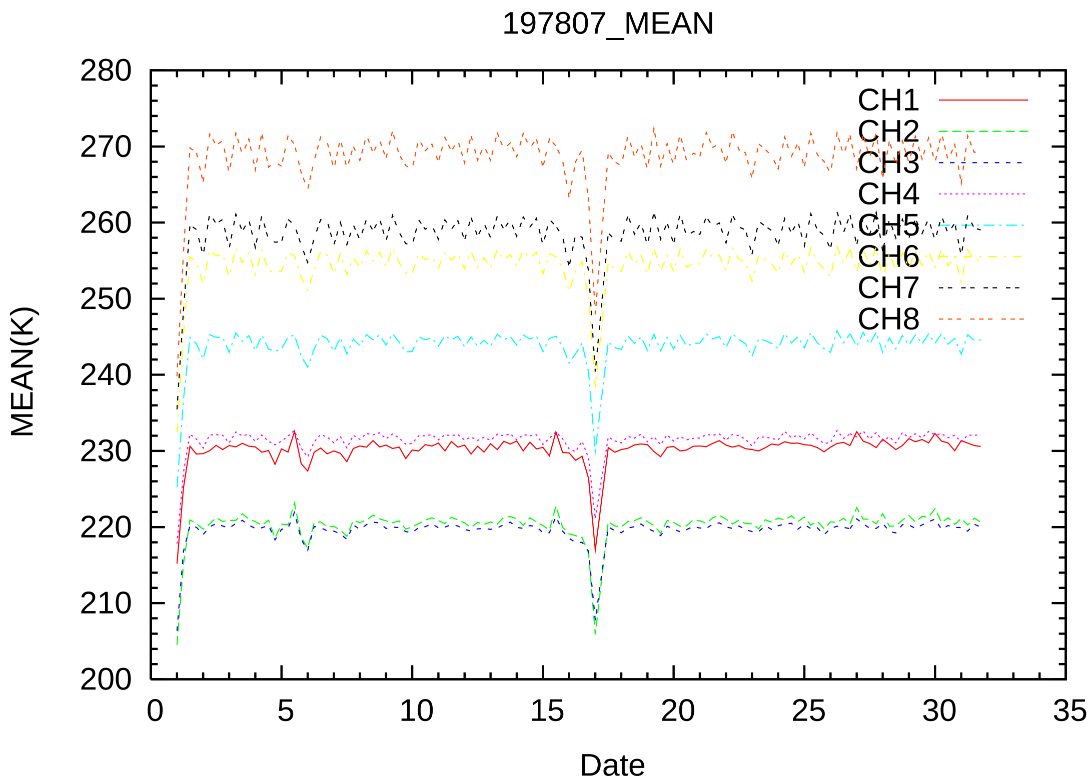

Fig. 4. VTPR mean values for July 1978 from NOAA-5.

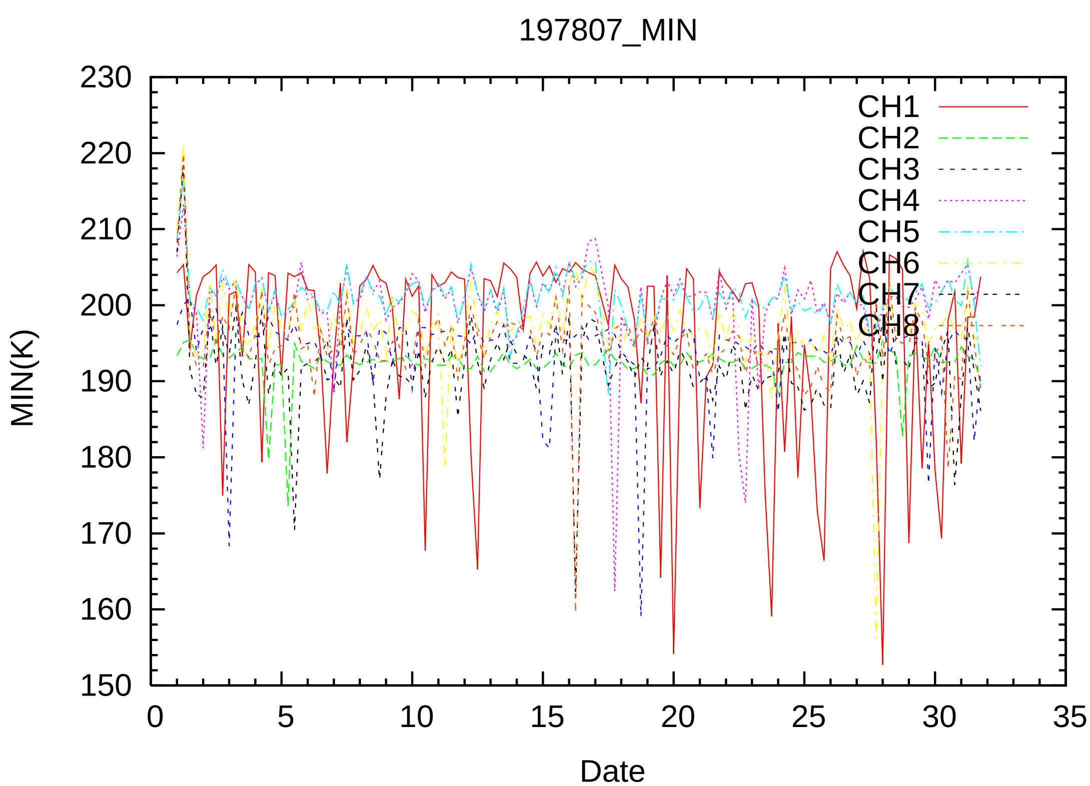

Fig. 5. VTPR minimum values for July 1978 from NOAA-5.

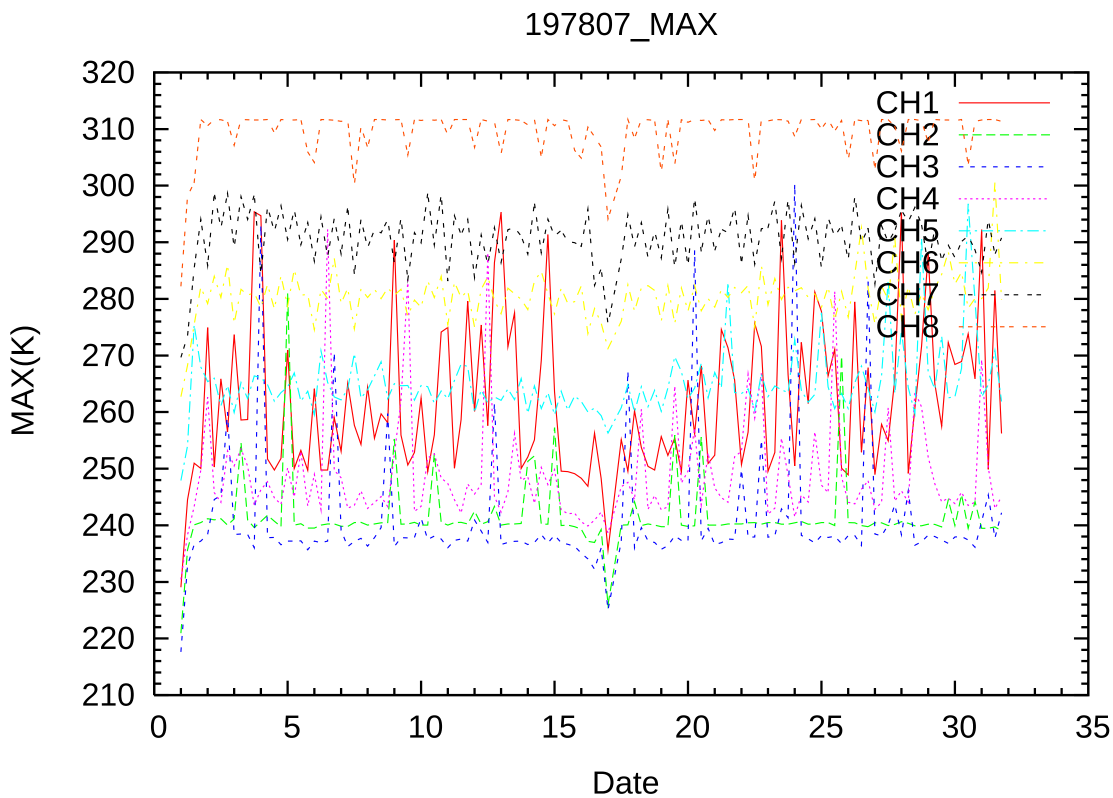

Fig. 6. VTPR maximum values for July 1978 from NOAA-5.

The mean values of the VTPR channels are shown in Fig. 4. The plots show that the mean brightness temperature values are largest at the surface (channel 8), the mean temperature decrease with height, as measured by channels 6, 5, 4, and 3, from the troposphere to the lower stratosphere. The mean temperature then increases with higher altitude in higher levels, as measured by channels 2 and 1. Several large departures of the mean values occur on the days when there are less total numbers of pixels. Figs. 5 and 6 show the minimum and maximum values of the channels, respectively. Diurnal variations are clearly exhibited by the plots. The maximum value of channel 8 saturates at 311.70 K.

Through the entire VTPR records from November 1972 to February 1979, the standard deviations of the eight channels are shown in Fig. 7. The time series display large annual variations. The sensors are generally stable through the entire period.

4. SUMMARY AND DISCUSSION

The entire time series of VTPR dataset is available at the National Climatic Data Center. The dataset covers the VTPR records from the NOAA-2 through NOAA-5 spacecrafts from November 1972 to February 1979.

Each file of the dataset contains six hours of VTPR measurement. To facilitate the understanding of each file's coverage and general data characteristics, descriptive statistics associated with each file are computed. Time series of the statistical plots are produced. The plots show the number of pixels in each file, the standard deviation of the channel brightness temperatures, and the mean, minimum, and maximum values. As each of the eight VTPR channels sense different levels of the atmosphere, significantly different statistical characteristics are displayed at each channel. The mean and maximum brightness temperature values resemble the pattern of the global mean temperature profile, which show decreasing temperature with height in the troposphere and increasing temperature in the stratosphere. The standard variation plots exhibit largest values in the surface and near-surface levels.

The VTPR measurement covers more than six years of observation. Seven of the eight channels are used to derive radiances in the 15 μm carbon dioxide band and in the atmospheric window region. They are very similar to the subsequent HIRS channels in the later NOAA satellite series. These observations provide a valuable dataset to significantly extend the HIRS sounding series which started in November 1978 and continues to the present.

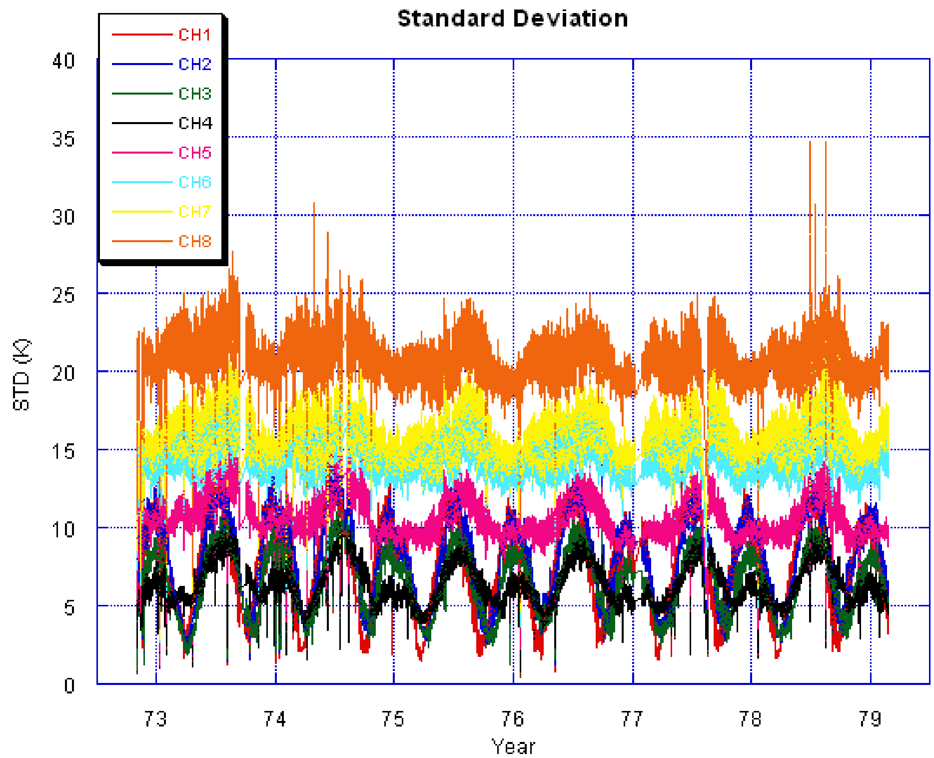

Fig. 7. The standard deviations of channel brightness temperatures for the entire VTPR records.

Previous studies have used HIRS data to examine inter-annual variability and trends of upper tropospheric water vapor in relationships with dynamical and thermo-dynamical processes (Bates et al., 1996; Bates and Jackson, 2001; Bates et al. 2001). The HIRS data in these studies covered one phase of the Pacific decadal oscillation. A longer time series would be required to see if the same relationships hold during the opposite phase. Since the warm phase of the Pacific decadal oscillation started in the late 1970s around the beginning of HIRS observation, the VTPR data can be particularly useful in revealing the atmospheric thermo-dynamical interactions in the cool phase before the HIRS records. To extend the knowledge in the variability of global temperature and water vapor in different levels of the atmosphere, we have recently derived temperature and water vapor profiles based on HIRS measurement from 1978 to 2004 (Shi and Bates, 2005). We plan to extend the time series back in time by incorporating the VTPR observation. Combined together, the VTPR and HIRS measurements provide a valuable source for assessing global climatic change in the past decades.

5. ACKNOWLEDGEMENT

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6. REFERENCES

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