GLOBAL WARMING ESTIMATION FROM MSU

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ABSTRACT

In this study, we have developed time series of global temperature from 1980-97 based on the Microwave Sounding Unit (MSU) Ch 2 (53.74 GHz) observations taken from polar-orbiting NOAA operational satellites. In order to create these time series, systematic errors (~ 0.1 K) in the Ch 2 data arising from inter-satellite differences are removed objectively. On the other hand, smaller systematic errors (~0.03 K) in the data due to orbital drift of each satellite cannot be removed objectively. Such errors are expected to remain in the time series and leave an uncertainty in the inferred global temperature trend. With the help of a statistical method, the error in the MSU inferred global temperature trend resulting from orbital drifts and residual inter-satellite differences of all satellites is estimated to be 0.06 K decade^{-1}. Incorporating this error, our analysis shows that the global temperature increased at a rate of 0.13 ± 0.06 K decade^{-1} during 1980-97.

1. INTRODUCTION

The Microwave Sounding Unit (MSU) observations made in Ch 2 near 53.74 GHz indicate primarily the mid-tropospheric temperature. The MSU instrument has been flown on sequential sun-synchronous polar-orbiting NOAA operational satellites such that there is some overlap of observations during satellite transitions. Utilizing overlapping observations of successive satellites, it is possible to develop a time series of the global mid-tropospheric temperature from NOAA satellites. The potential to deduce the global temperature trend from such time series was first suggested by Spencer and Christy (1990) (SC). Following a procedure similar to that of SC, Christy, Spencer and Lobl (1998) (CSL) show that near nadir observations of MSU Ch 2 yield a weak global warming temperature trend (0.003 K decade^{-1}) between 1979-97. Another analysis of CSL that is not limited to near nadir data of MSU Ch 2 indicates a cooling trend (-0.046 K decade^{-1}) during that period.

The temperature trend indicated by the time series of CSL has distinct differences between the periods 1979-90 and 1991-97. During the first period, their time series shows a warming trend of about 0.09 K/decade. However, after 1990, CSL decrease the temperature at a rate of 0.06 K year^{-1} for three years to account for satellite orbital drift of NOAA 11. As a result of this correction, the global temperature trend for the entire period 1979-97 is decreased to -0.046 K decade^{-1}. Jones et al. (1997) and Hurrell and Trenberth (1998), in their studies, question the validity of this correction. For this reason, in this study we are analyzing the MSU data using an independent technique (see Prabhakara et al., 1998, from here after PIYD) to probe this drift-related correction made by CSL.

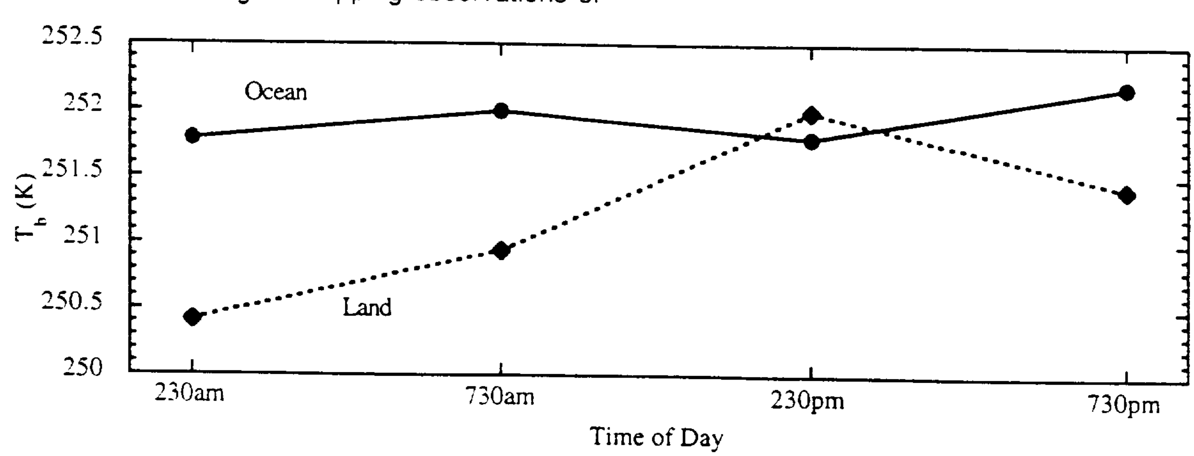

Figure 1. 1982 annual-mean diurnal cycle for global ocean and land.

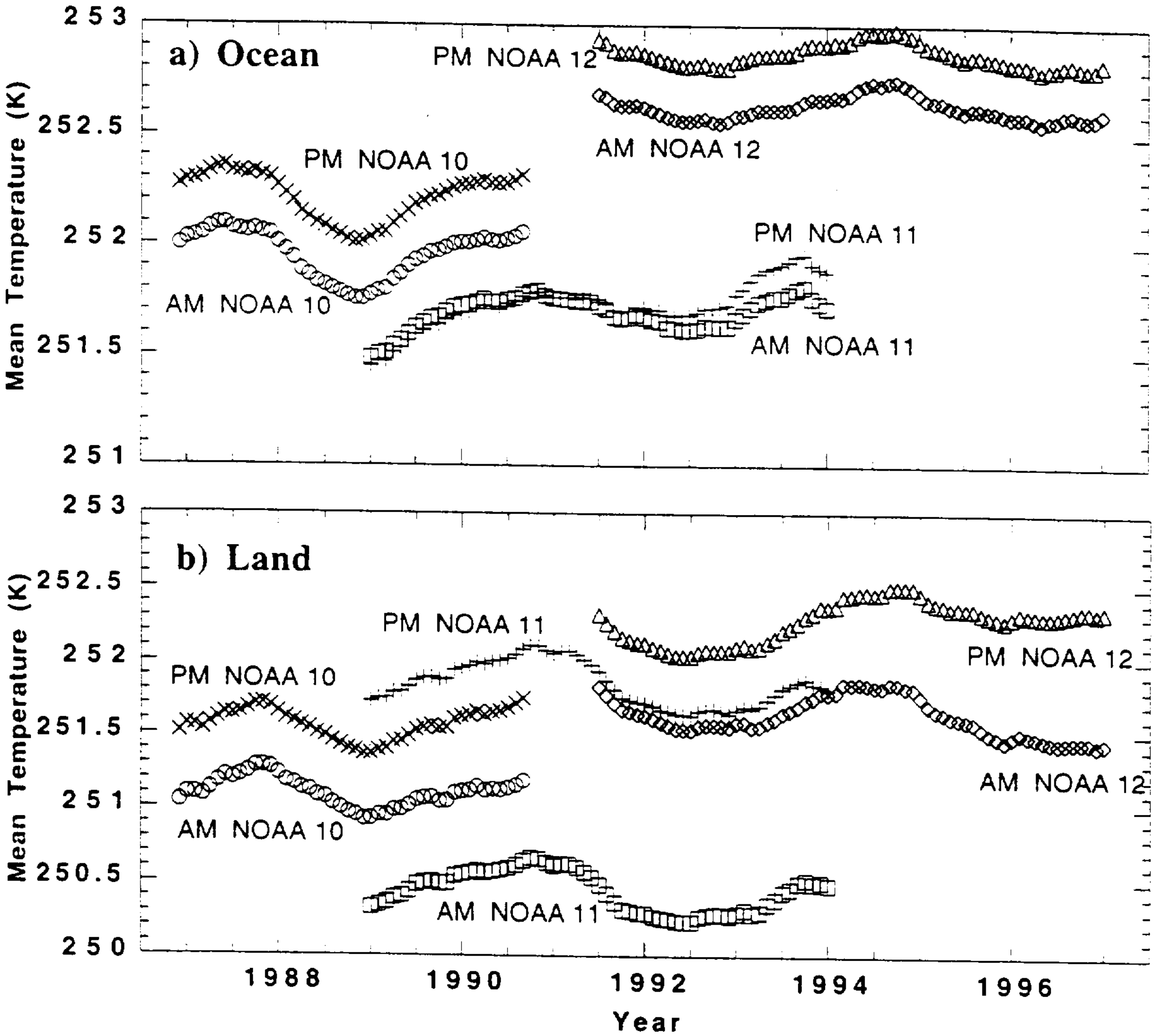

Figure 2. MSU Ch 2 12-month running mean of T_{am} and T_{pm} deduced from NOAA 10, 11, and 12 for **a)** global ocean and **b)** global land.

2. METHOD OF ANALYSIS AND RESULTS

In PIYD's analysis method, MSU data is partitioned into global land/ocean sets and each one of these sets is further divided into am/pm subsets based on the local equatorial crossing time (LECT). Because of this partitioning, we can assess objectively the inter-satellite error in the am and pm data subsets resulting from a transition of one satellite to the next. In addition this partitioning also enables us to probe into the nature of error introduced by orbital drift during the life of a satellite. However, we cannot objectively estimate the drift-related errors.

Generally, to find the inter-satellite error, we take overlap data of a morning satellite (LECT 7:30 am/7:30 pm) and an afternoon satellite (LECT 2:30 am/2:30 pm). As shown in PIYD, with the help of the partitioned data from such overlaps we can construct the diurnal cycle of the Ch 2 temperature. In Fig. 1, we show the Ch 2 diurnal temperature cycle over land and ocean deduced from the data of NOAA 6 and 7. The temperature maximum on land around 2:30 pm shown in the figure is reasonable, but the minimum on ocean around 2:30 pm is not. This indicates that there are, in addition to diurnal effects, some systematic errors in the MSU data that are related to calibration change of the instrument due to exposure to sun light. These inter-satellite differences of the order

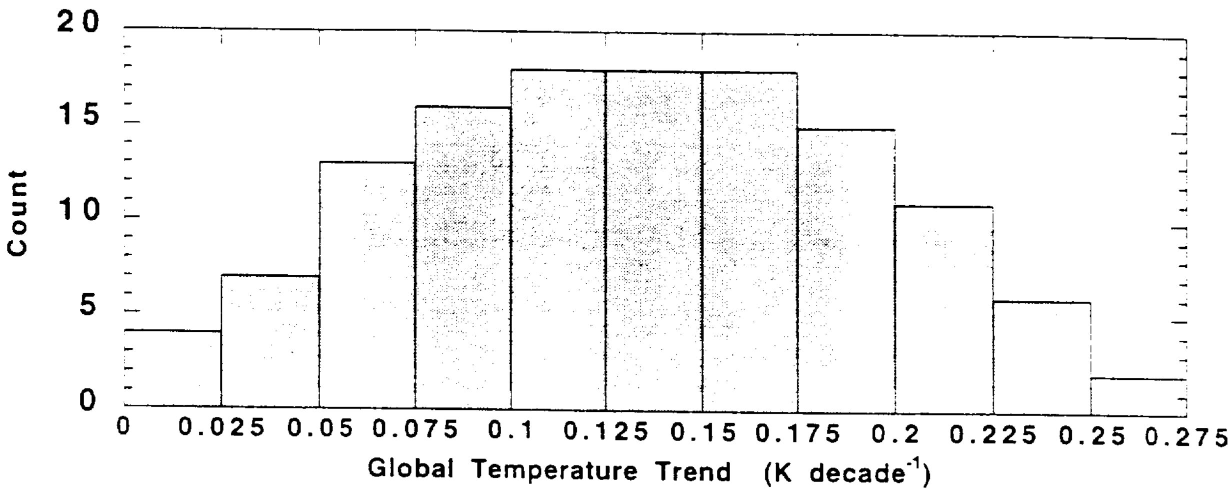

Figure 3. Frequency distribution of the trend in global temperature deduced from 128 different MSU Ch 2 time series formed from am/pm observations of seven NOAA satellites, NOAA 6 to 14. The mean global temperature trend is 0.13 K decade^{-1} with a RMS error of 0.06K decade^{-1}.

of 0.1 K are removable to an accuracy of about 0.02 K.

The drift-related errors in the data of each satellite can be appreciated from an analysis shown in Figs. 2a and b. As an example, we show in this figure the am and pm 12-month running-mean temperature observed by NOAA 10, 11 and 12 satellites over ocean and land. We may note NOAA 10 and 12 are morning satellites while NOAA 11 is an afternoon satellite. The running mean removes the annual cycle in the data and enables us to follow the temperature trend easily. We note from the figure that the am and pm temperatures from each satellite track one another closely. The behavior of the NOAA 11 am and pm data over ocean differs from that of the other two satellites because of calibration errors. Similarly, the behavior of the NOAA 12 am and pm data over land differs from the other two satellites because of diurnal effects. Now, if we assume that the diurnal amplitude of temperature over global land and ocean remains the same, and the onboard calibration procedure does not have systematic errors, then the difference between the pm and am brightness temperatures (T_{pm}- T_{am}) from each satellite over land or ocean should be nearly independent of time. However, from Figs 2a and b we find this is not so because of drift-related errors. We find the value of (T_{pm}- T_{am}) changes by about 0.05 K year^{-1} during the life of a satellite. This suggests there is a relative error of about 0.03 K year^{-1} in the am or pm data of each satellite. We note from Figs 2a and b that all satellites, morning and afternoon, have drift-related errors, and these errors cannot be removed objectively. This conclusion differs from that of CSL, who contend only afternoon satellites have drift-related error.

From the above discussion, when a time series of MSU Ch 2 temperature over the globe (land+ocean) is constructed, we infer that there could be some small residuals on the order of ~ 0.03 K left in the time series from inter-satellite adjustments and from drift-related problems. These errors do not necessarily compensate for one another. In order to estimate the total effect of these errors in time series generated from the seven NOAA satellites, NOAA 6 to 14, we have developed a statistical method. The am or pm MSU Ch 2 global temperature data of a given satellite can be used interchangeably in creating a time series. Thus, from seven satellites we can get 2^7 or 128 independent time series of Ch 2 global temperature. These independent time series can be analyzed to give 128 estimates of the global temperature trend. In Fig. 3, we show the frequency distribution of these trends as a function of the trend value. This distribution mimics that of a Gaussian type with a mean value of 0.13 K/decade. The root mean square of the distribution is 0.06 K. Thus, we deduce from our analysis of the MSU data from 1980-97 that the global temperature warmed at a rate of 0.13 $\pm$ 0.06 K decade^{-1}.

In Fig. 4a, we compare the time series of the temperature anomalies deduced from our study with that of CSL for the period 1980-97. In Fig. 4b, the difference between these time series is illustrated. The salient point of these figures is to indicate that both of our analyses agree reasonably well until the end of 1990. After that, CSL make a drift-related correction which has the effect of reducing the trend for the entire period 1980-97. Unlike CSL, we contend that the drift-related errors cannot be removed objectively, and that the total error in the time series has to be assessed in a statistical manner. For this reason, the global warming trend 0.13 $\pm$ 0.06 K decade^{-1} deduced here differs from that of CSL.

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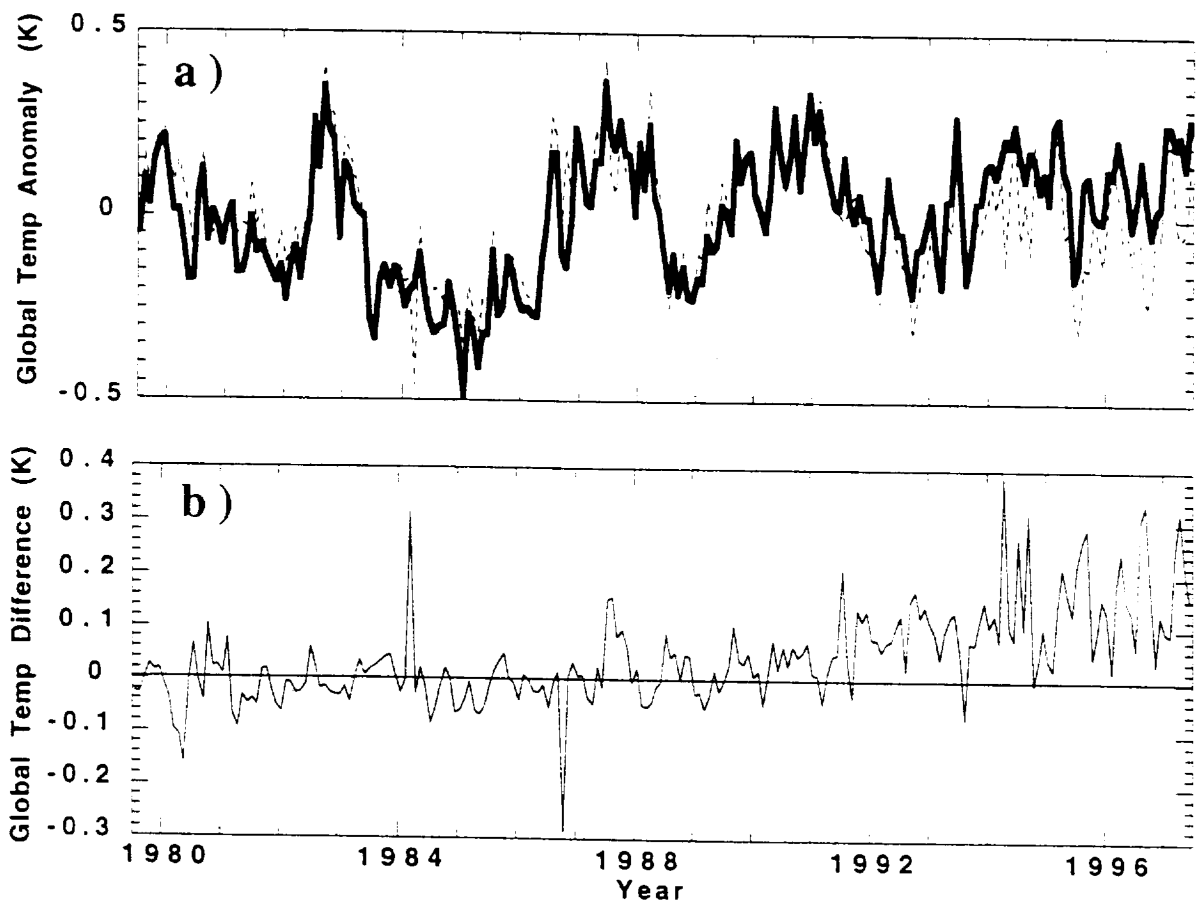

Figure 4. a) Comparison of global temperature anomalies deduced in this study (heavy solid line) vs. that deduced in the study of Christy et al. (1998) (dashed line).
b) The difference between the time series shown in Figure 4a.