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A note on hemispheric and global temperature changes

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RESUMEN

El presente trabajo discute un registro de baja a media temperatura troposférica, obtenida de un satélite micro-wave sounder (MSU) usando el canal 2R. El registro que da temperaturas medias mensuales para los 18 años desde 1979 a 1996, inclusive, y para los dos hemisferios y el Globo, son analizados con el propósito de encontrar tendencias a largo plazo. Se hizo una comparación con los registros de temperatura usando datos entándares.

ABSTRACT

The paper discusses a lower to middle tropospheric temperature record obtained from a satellite micro-wave sounder (MSU) using channel 2R. The temperature record, giving monthly mean temperatures for the 18 years from 1979 to 1996, inclusive, and for the two hemispheres and the Globe, are analysed with the purpose of finding long term trends. A comparison is made with temperature records using standard data.

1. Introduction

Long term local surface air temperature records are available for a number of locations, especially in Europe. Manley (1974) has collected a series of monthly mean temperatures for Central England for the years 1659 to 1973. Attmannspacher (1981) has published 200 years, 1781 to 1980, of meteorological observations for Hohenpeissenberg. Pfister (1988) has described the climate history of Switzerland from 1525 to 1860. Weber (1994) has collected long-term temperature records for a number of cities in Austria, Czechoslovakia, England, Germany, Holland, Hungary, Norway, Poland, Russia, Scotland, Sweden and Switzerland. On the larger scale Groveman and Landsberg (1979) has attempted to reconstruct the northern hemispheric temperature for the years: 1579 to 1880. The various reports from the International Panel on Climate Change

(IPCC, 1995) contain estimates of both the Northern and the Southern Hemisphere temperatures based on papers such as Jones *et al.* (1986).

It is very difficult to make hemispheric and global data sets using the standard meteorological data for long time intervals and for climatic purposes. The reason is naturally that a reasonable global coverage using surface and upper air observations can be obtained for limited time intervals only. While the surface data may be adequate for relatively large continental areas, it has always been difficult to cover the oceanic areas with a sufficient number of observing stations. In addition, some surface data need to be corrected for urban heat effects. With regard to upper air data we note that they do not permit hemispheric and global coverage for more than about 50 years before the present. During the last couple of decades satellite observations have provided an additional data source. As a matter of fact these observations are providing a more and more essential data source for hemispheric and global analyses.

Satellite observations are of course not *in situ* observations, and the processing of the data to provide estimates of, for example, the temperature requires extended calculations. It is not the purpose of this paper to review the data processing procedures required for data from the various channels on the sensors of the satellites. It will be sufficient to note that the data processing procedures have been improved and tested to provide data of excellent quality. Nevertheless, the lengths of the records of hemispheric and global data sets are small compared with the time scales that are important to a description of the climate of the atmosphere and its changes.

Some years ago it was attempted to investigate changes of the atmospheric global temperatures (Wiin-Nielsen, 1991a and 1991b) from the global analyses at a number of tropospheric and stratospheric pressure levels obtained from the European Centre for Medium-Range Weather Forecasts (ECMWF). The data covered 7 years only. The goal was to use global analyses of good quality. Other collections of regional, hemispheric and global analyses have been produced for example by the Institute of Meteorology, Free University of Berlin by publishing "Annual Hemispheric Climate Reports" and by Karl (1988). The IPCC (1995) uses tropospheric and stratospheric temperatures based on radiosonde data, produced by Angell (1988), as well as the MSU data mentioned below.

A new record of hemispheric and globally averaged temperatures have recently been produced based on the micro-wave sounder (MSU). These data are provided as hemispheric and global mean temperatures, and they may be considered as mean temperatures for the tropospheric layer from the surface to ca. 9 km. In this paper we shall consider this data set. Some of the temperature data has been treated and validated for the troposphere and the lower stratosphere by Spencer and Christy (1992a, 1992b, 1993). The data used in this study has kindly been provided by Dr. G.-R. Weber.

2. Results from the MSU data set

The data set covers the period from January 1, 1979 to December 31, 1996. During this period there has been some few days where it has been impossible for technical reasons to produce the temperature records. In the present treatment we shall use the monthly mean data for each of the months, 216 in all. The data are the hemispheric averages for the Northern and the Southern hemispheres. The global average is easily obtained as the mean of the hemispheric averages. As said above we may consider each temperature as representing the vertical mean for the layer from the surface of the Earth to about 9 km.

The MSU data are given as deviations from a decadal mean covering the interval 1982-1991, incl. The data as given are reproduced in Figures 1, 2 and 3 for the Northern and Southern hemispheres and for entire Earth, respectively. In additon to the noisy changes from month to month we notice also changes on a larger time scale. The well known temperature increases in the Northern Hemisphere (Fig. 1) in the late 1980's are well represented as well as the increases in 1994 and 1995. These increases are also seen in the global mean temperatures (Fig. 3). A comparison between Figure 1 and Figure 2 shows that the changes in the Southern and the Northern hemispheres agree reasonable well with each other on the larger time scales with respect to the times at which the maxima and minima occur, but differences in magnitudes are observed.

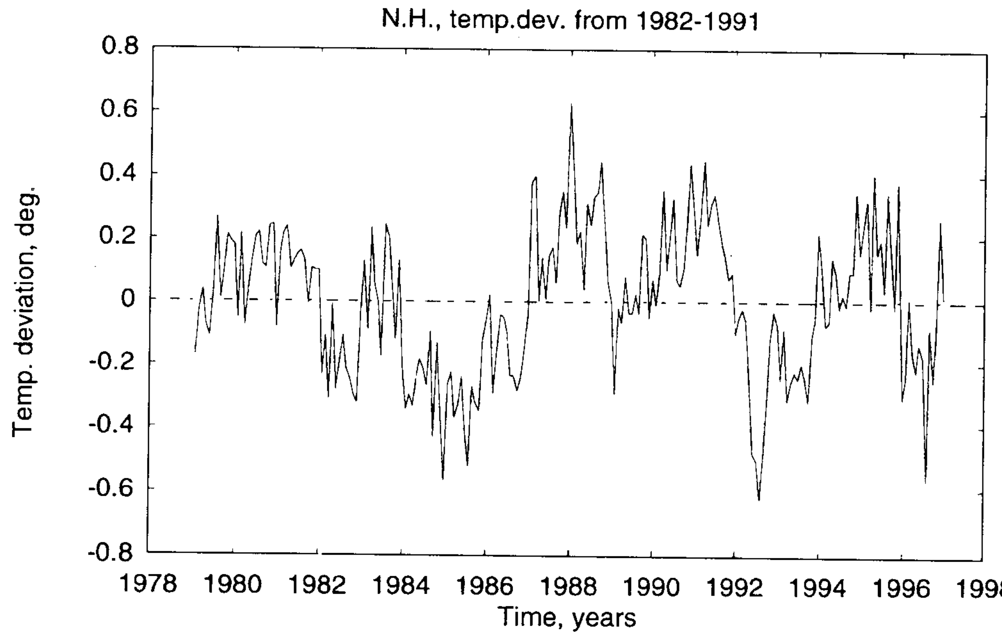

Fig. 1. Temperature deviations from the reference state (monthly averages for the years 1982-1991) for each of the 216 months. Northern Hemisphere.

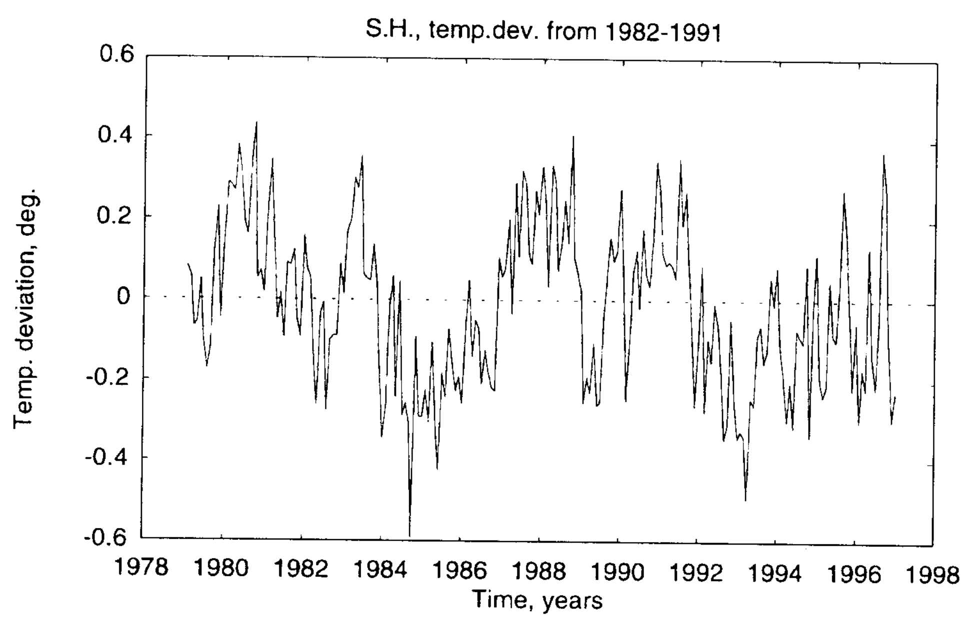

Fig. 2. As Figure 1, but for the Southern Hemisphere.

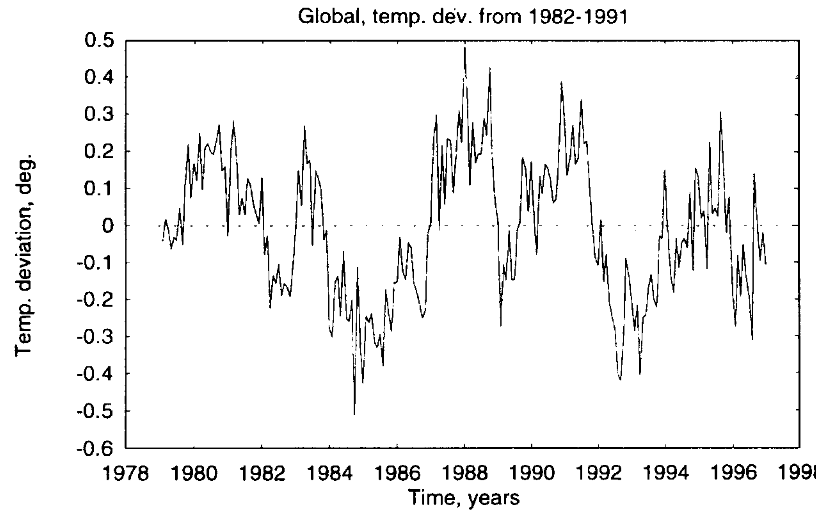

Fig. 3. As Figure 1, but for the Globe.

To obtain a better picture of the changes on the larger time scales 12 months running means were calculated from the original data. These curves are represented in Figures 4, 5 and 6 for the Northern and the Southern hemispheres and for the Globe, respectively. The features mentioned above are now seen more clearly. The magnitudes of the deviations from the 1982-1991 averages are confined to the interval from -0.4 to 0.4 degrees with slightly larger variations in the Northern Hemisphere. Figure 7 shows the three curves in Figures 4 to 6 on the same diagram. It is seen that the changes in the two hemispheres are closely related to each other indicating that they may be caused by the same physical processes. The oscillating changes of the temperature deviations indicate that the averaged change should be small. For the Northern Hemisphere the mean change is -0.0039 and for the Southern Hemisphere it is -0.0151. For the global changes one finds consequently a mean change of only -0.0095. If the last number were to be significantly different from zero, it would correspond to a temperature decrease of about 0.05 per century.

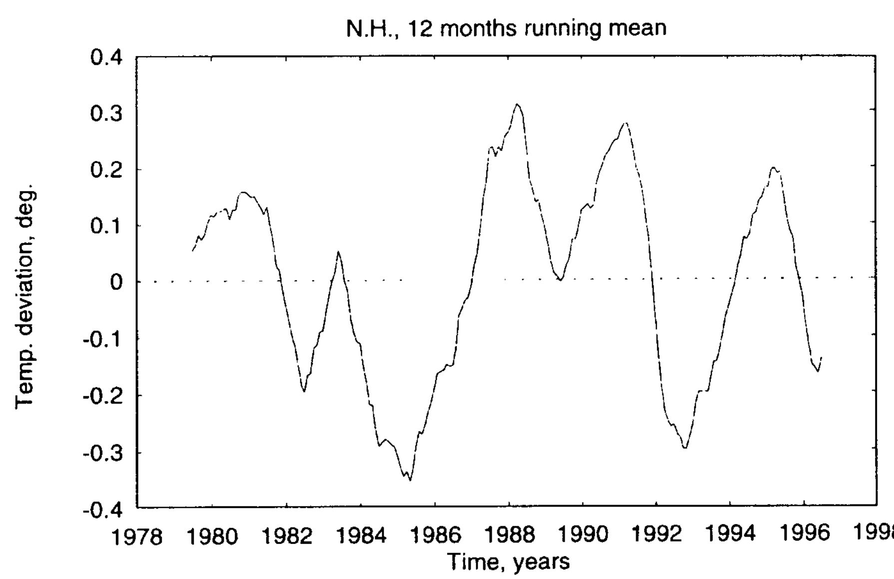

Fig. 4. Twelve month running average for the data in Figure 1. Northern Hemisphere.

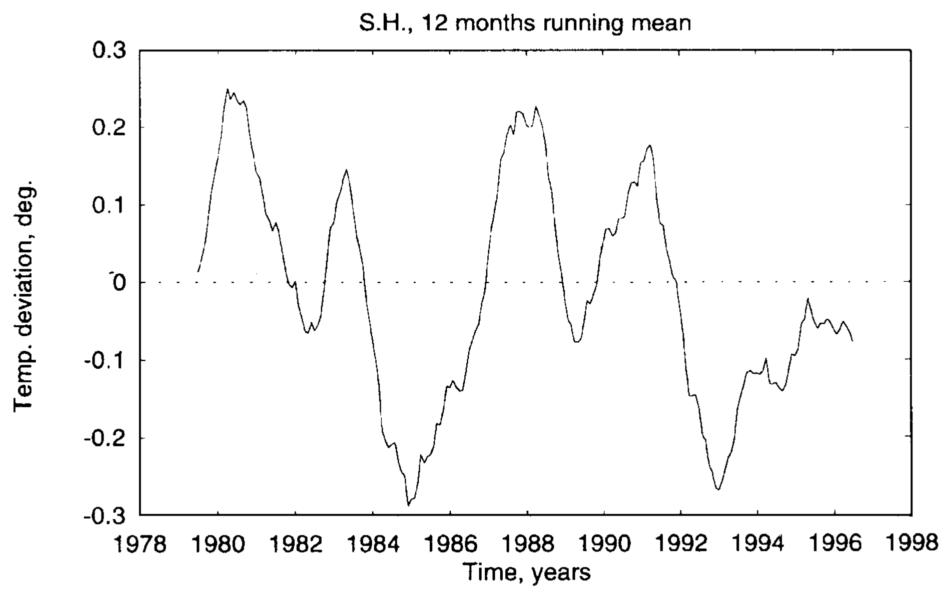

Fig. 5. Twelve month running average for the data in Figure 2. Southern Hemisphere.

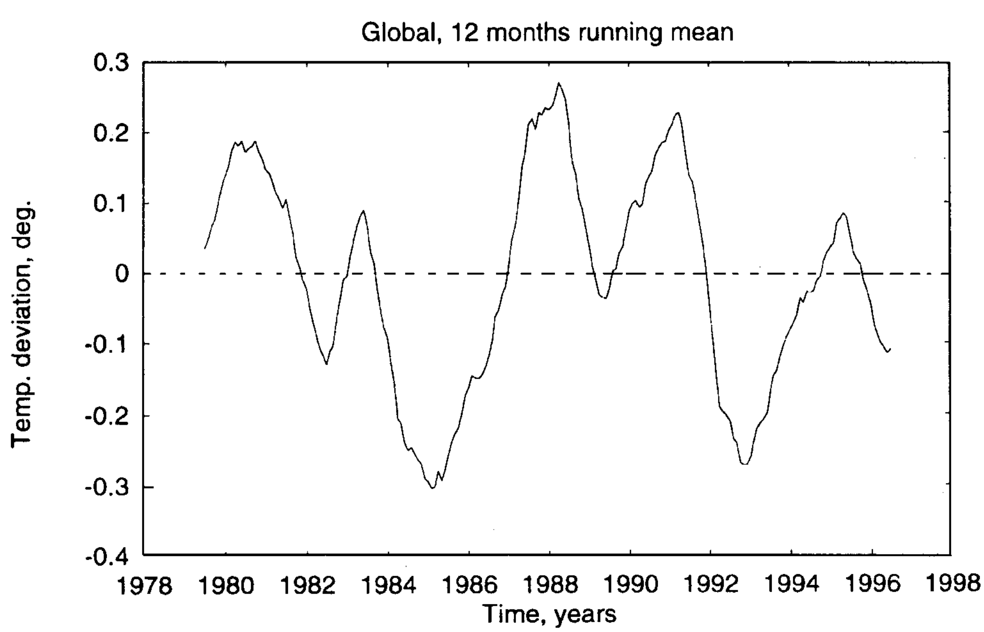

Fig. 6. Twelve month running average for the data in Figure 3. The Globe.

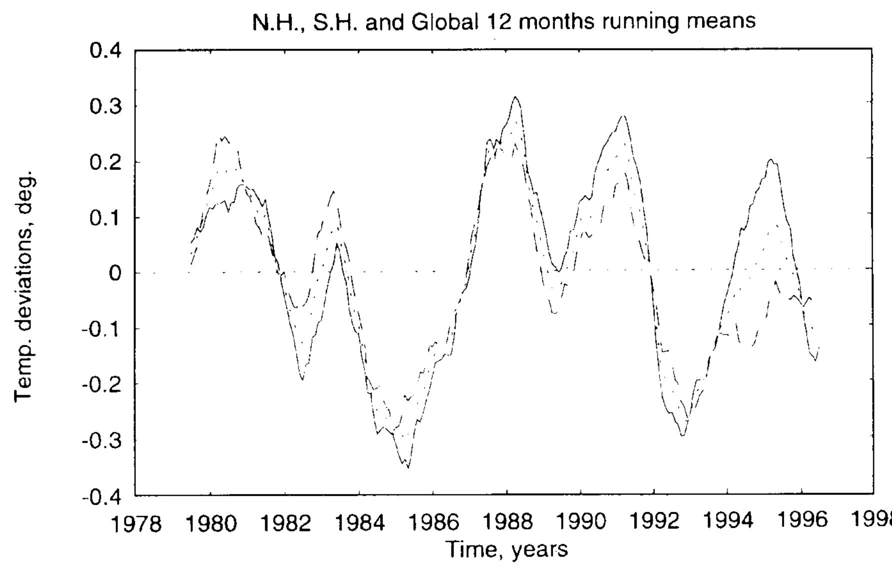

Fig. 7. The curves from Figure 4, 5 and 6 on the same diagram.

One may ask if the above negative mean values are significantly different from zero. To answer this question we have estimated the real mean by using the formula:

$$M_r = M \pm \frac{1}{(n_{\max} - 1)^{1/2}} \sigma \qquad (1)$$

where M_r is the estimated real mean, M the mean from the data set and s the standard deviation. We find the following results:

$$N.\ H.: -3.95 \times 10^{-3} \pm 1.58 \times 10^{-2}$$
$$S.H: -1.5 \times 10^{-2} \pm 1.37 \times 10^{-2} \qquad (2)$$
$$GLOBE: -9.50 \times 10^{-3} \pm 1.29 \times 10^{-2}$$

which would indicate that only the mean change for the Southern Hemisphere is barely significantly different from zero.

3. Comparison with global analyses

The MSU data for the interval 1979-1995, incl., have been compared with the temperatures obtained from radiosondes for the same period (IPCC, 1995, see page 148). Deviations amounting to 0.3 degrees are found between the two data sets. It appears that the variations in the tropospheric temperatures from the usual data are somewhat larger than in the MSU data, but the two data sets appear to be close to each other in the changes on a larger time scale.

The data employed in the present study so far relies entirely on the data from the MSU. Other researchers are presently in the process of comparing the MSU data with other available data sets based on hemispheric and/or global analyses using radiosonde data (Weber, *personal communication*). In this study we shall compare with the ECMWF global analyses carried out routinely four times per day as part of the daily production of the medium-range forecasts. The global analyses for the years 1982-1988, incl., were used in the studies described by Wiin-Nielsen (1991a and 1991b). At the moment the re-analysis project is being carried out at ECMWF. In the not too distant future it will thus be possible to compare the MSU data with the global mean values for the re-analysis data. For the moment and as a preliminary comparison we shall be satisfied by using the 1982-1988 data, located within the time interval covered by the MSU-data.

The original ECMWF data set has been reprocessed to bring it into the same form as the MSU data. For this purpose the entire time interval from 1982 to 1988 has been used as the reference data set. The first step was therefore to average the data set for each of the twelve months GLOBE of the year provide. The second step was to calculate the differences between the individual months and the averaged value for that month in the reference set. The temperature averages for each month is shown in Figure 8, where 250 K has been subtracted from each averaged temperature. The lowest temperatures appear in November and the highest in July.

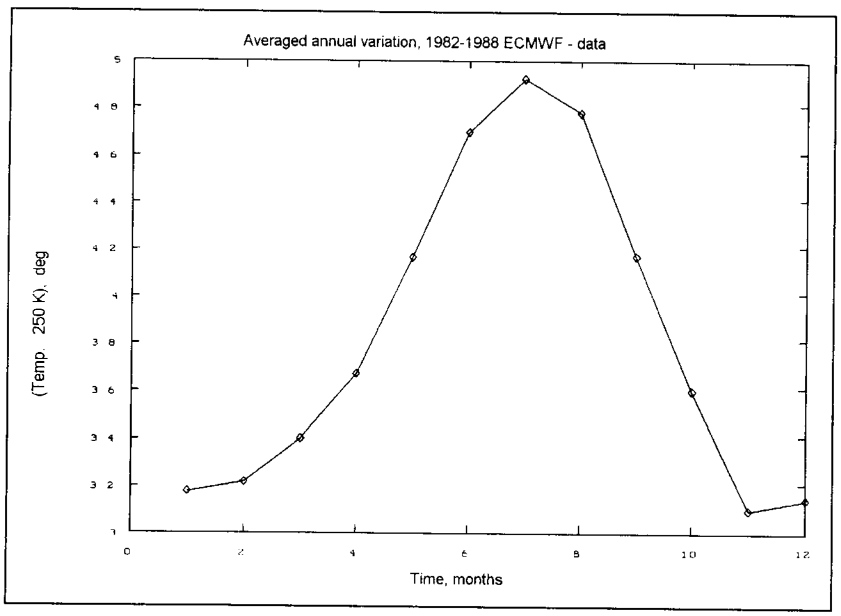

Fig. 8. The monthly averaged temperatures for the ECMWF data set (1982-1988). Global and vertical averages. The temperature in K is obtained by adding 250 K.

The deviations from the reference data are shown in Figure 9 which should be compared with Figure 3, while the 12 month running mean for the ECMWF data appear in Figure 10 which should be compared with Figure 6. To ease the comparison Figure 11, containing both the MSU and the ECMWF data for the common time interval 1982-1988, has been prepared. We notice that the two curves begin at about the same level and also finish in good agreement in 1988. The largest difference appears over the period from the early part of 1984 to the early part of 1986. In this time span the MSU data show larger negative deviations than the ECMWF data by 0.2 degrees. The difference is smaller than the largest differences found in the comparison contained in IPCC (1995). It may be real, but it should be pointed out that the reference state for the two data set are not the same (1982-1991 for the MSU data and 1982-1988 for the ECMWF data), and that the ECMWF data are the well defined vertical mean for the layer 250 to 1000 hpa, while the layer to which the MSU data refer is more uncertain. The fact that the ECMWF data show a smaller deviation is most probably related to changes in the analysis procedure and to changes in the prediction model used at ECMWF at the time. The record from ECMWF shows that a number of major changes were introduced in december 1983 with further corrections made during the next couple of years. These changes may collectively account for the large decrease seen on Figure 9 in December, 1983 and for the differences between the ECMWF and the MSU curves from this time to the middle of 1986 (Fig. 11).

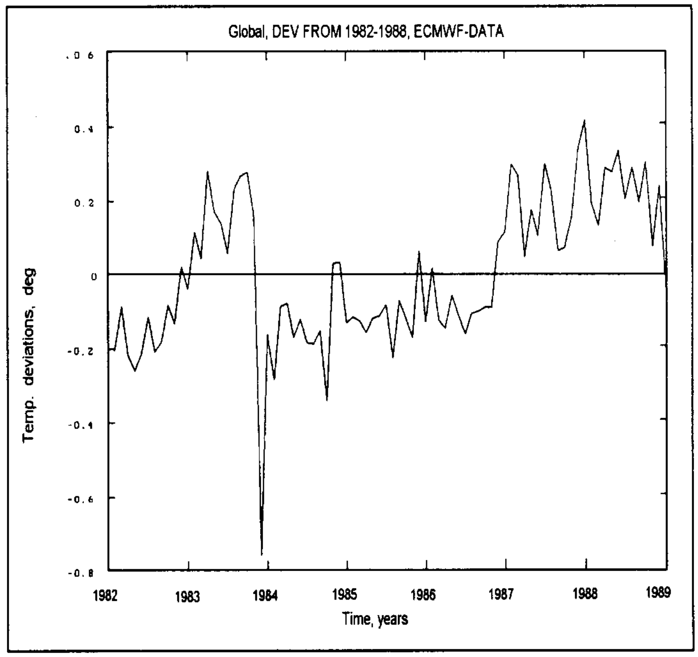

Fig. 9. Deviations from the reference state (1982-1988) for the global ECMWF data.

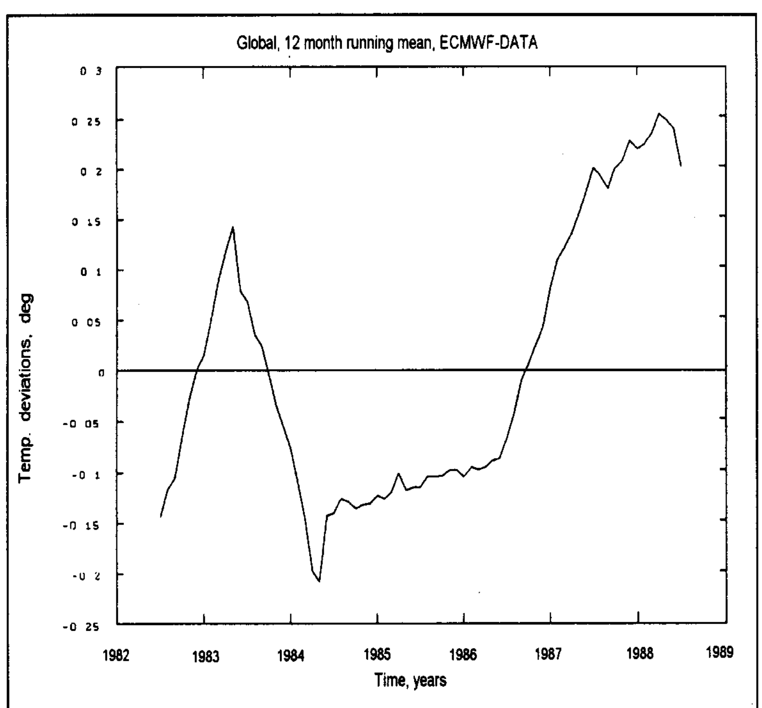

Fig. 10. The twelve month running average for the ECMWF global data.

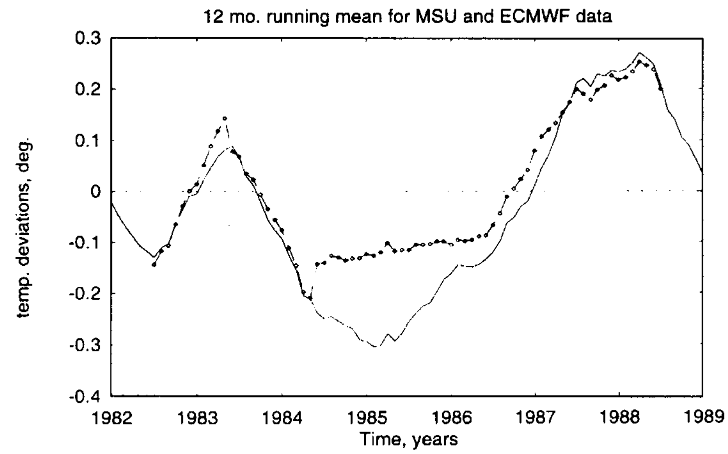

Fig. 11. The twelve month running mean of the temperature deviations for the MSU and the ECMWF data sets for the years 1982-1988, inclusive.

The ECMWF data indicates a mean change of the temperature of -0.01 degrees over the total period. This mean is not significantly different from zero. Treating the data in the same way as the MSU data we arrive at the relation:

$$GLOBE: -0.01 \pm 0.0627 \quad (3)$$

Figure 12 displays the monthly averages calculated as averages for the total MSU data set (1979-1996). It appears from the figure that cooling takes place in the first seven months of the year and heating in the remaining months. However, these values may not be significant due to the small averaged changes for the whole global data set.

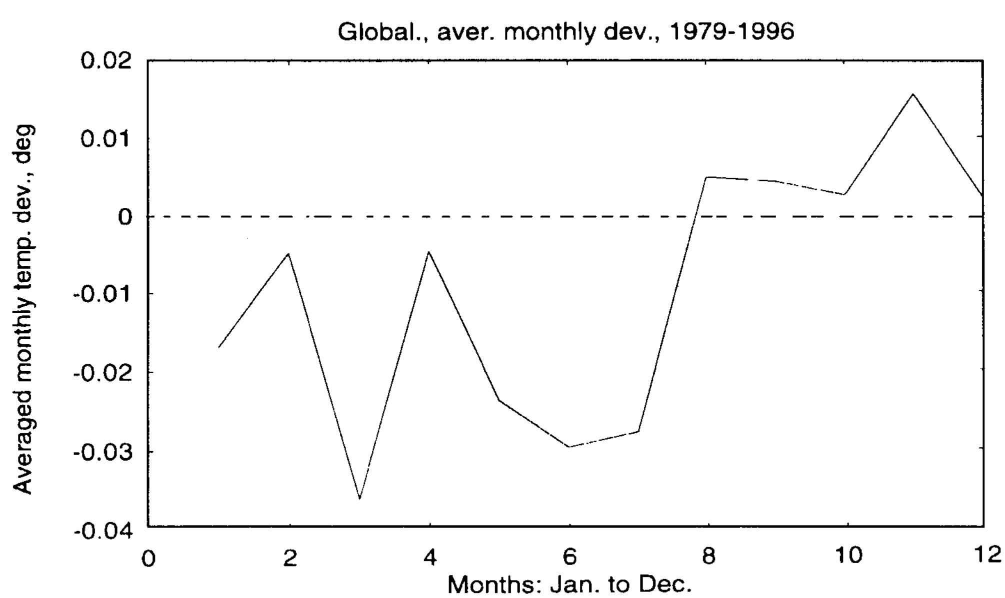

Fig. 12. The globally averaged monthly deviations from the MSU reference state (1982-1991).

4. Concluding remarks

The data sets considered in this note cover a too small time interval to be significant for longer term climate changes. The comparison between the MSU data and the ECMWF data indicate that middle tropospheric temperature deviations show a satisfactory agreement between the two data sources. The satellite data will thus provide a very important data source for monitoring climate changes in the future.

For the two data sets we may say that none of them indicate any systematic change of the middle and lower tropospheric temperatures.

5. Acknowledgements

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