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James Hansen, S. Lebedeff

Institutions: Goddard Space Flight Center

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GLOBAL SURFACE AIR TEMPERATURES: UPDATE THROUGH 1987

James Hansen and Sergej Lebedeff

NASA Goddard Space Flight Center, Institute for Space Studies, New York

Abstract. Data from meteorological stations show that surface air temperatures in the 1980s are the warmest in the history of instrumental records. The four warmest years on record are all in the 1980s, with the warmest years in our analysis being 1981 and 1987. The rate of warming between the mid 1960s and the present is higher than that which occurred in the previous period of rapid warming between the 1880s and 1940.

Introduction

Global surface air temperature change is a primary meassure of global climate change. Current temperature trends are of special interest because of the expectation that increasing abundances of infrared-absorbing trace gases in the earth's atmosphere will cause a global warming.

Several studies of global surface air temperature change have been made recently, for example by Jones et al. [1986] and Hansen and Lebedeff [1987]. References to other work are given there and in a review by Wigley et al. [1985].

In our present note we update the results of Hansen and Lebedeff [1987], hereafter referred to as paper 1, through December 1987. Although this represents only two years of additional data, the results are of interest because 1987 is approximately as warm as 1981, the warmest previous year in the record. We present global-mean annual-mean results and then successively finer temporal and spatial resolutions. The higher resolution graphically illustrates regional climate fluctuations and helps identify the source of global trends.

Data Sources

Our present analysis is based on monthly surface air temperature records from three sources which we abbreviate as NCAR, MCDW and NOAA. The three sources all contain data from meteorological stations (mostly the same stations); they differ in period of coverage, station density, quality control, and near real time availability. NCAR refers to the data tape available from Roy Jenne of the National Center for Atmospheric Research; it contains digitized MCDW records and additional data [Spangler and Jenne, 1980]; the number of stations increases from about 300 in 1900 to about 1800 in 1960, decreasing to about 1000 in the 1970s and 1980s, with global coverage illustrated in paper 1; we employ an NCAR tape with data through December 1983. MCDW (Monthly Climatic Data of the World) refers to printed monthly mean records published by NOAA National Climatic Data Center in Asheville, North Carolina; we have digitized these data from January 1984 through August 1987, during which time there were approximately 600 stations. NOAA refers to monthly mean station records available via telecommunication a few days after the end of each month from the NOAA Climate Analysis Center; this record contains about 6000 stations, about 1200 of which are the same as an NCAR or MCDW station and thus were usable in our analysis, we have these data from April 1985 through December 1987

We found significant differences between the near real time NOAA data, which is not designed for climatological studies, and the other records for the same station and time Averaged over all stations, the NOAA data is about 0 2°C warmer than the other records. However, global year to year temperature changes in the NOAA data agree with those from the other data sets within 0.03°C, consistent with an assumption that reporting procedures (rounding, diurnal averaging, etc.) were similar in successive years. We used the NOAA data to obtain temperature change in 1987 only by differencing with earlier NOAA data and combining this change with longer NCAR/MCDW records. A more quantitative description of the data set characteristics will be published elsewhere.

We combined the NCAR, MCDW and NOAA records based on station number, name and latitude/longitude This process provided improved coverage in the 1980s, compared to paper 1, and disclosed several bad data points. However, the effect of these changes on analyzed temperatures was small, as discussed below.

Analyzed Temperature Change

The analysis was carried out as in paper 1, using stations with 20 or more years of data. The resulting global temperature change during the past century is shown in Figure 1, including uncertainty bars (95% confidence limits) derived as described in paper 1; this error analysis accounts only for

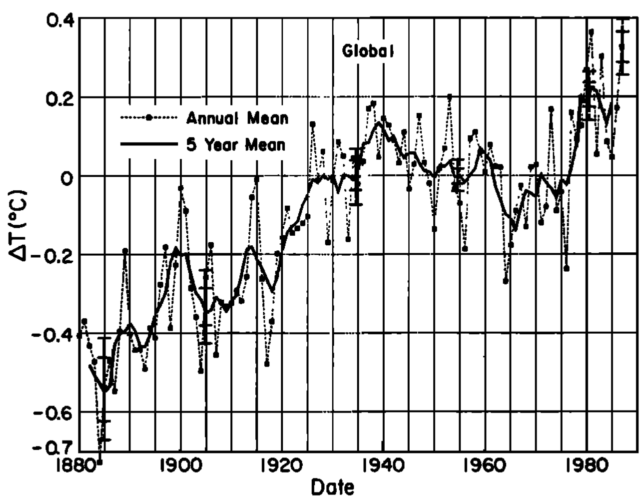

Fig. 1. Global surface air temperature change. The 5-year running mean is the average of the 5 years centered on the plotted year. Uncertainty bars (95% confidence limits) are based on an error analysis as described in paper 1; inner bars refer to the 5-year mean and outer bars to the annual mean

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the incomplete global coverage of stations. The uncertainty is smallest in the 1950s and 1960s; it is larger in 1987 than in the early 1980s, because of poor coverage at high latitudes in the Southern Hemisphere in the near real time data.

Figure 1 shows that 1987 was approximately as warm as 1981, the warmest previous year in the record. The 1980s are the warmest decade in the history of instrumental records, with the four warmest years on record all occurring in the 1980s. The rate of global warming between the mid-1960s and 1987 is greater than that in the previous period of rapid warming between the 1880s and 1940.

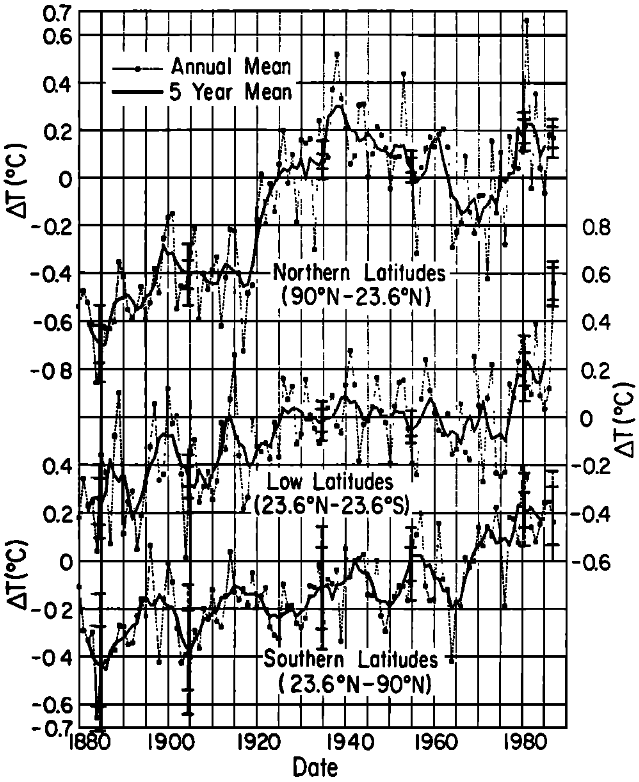

Fig 2. Surface air temperature change for three regions. Graphical details as in Figure 1.

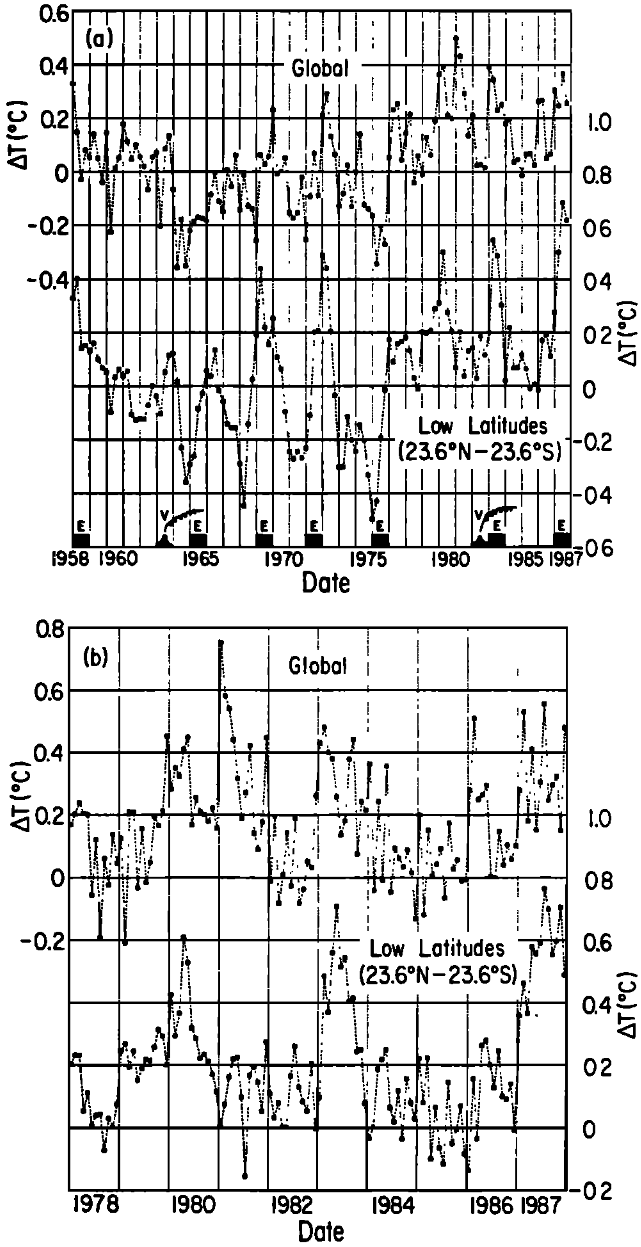

Fig. 3. Surface air temperature change (*a*) at seasonal resolution for the past 30 years, and (*b*) at monthly resolution for the past decade. E and V mark the years of major El Niño events and volcanic eruptions, respectively.

Figure 2 divides the globe into three regions. Low latitudes, between about 23.6°N and 23.6°S, cover exactly 40% of the globe, being the 32 boxes illustrated in Figure 2 of paper 1. The global warming in 1987 is entirely the result of a large jump in temperature, more than 0.4°C, at low latitudes. Northern latitudes, covering 30% of the globe, were 0.5°C colder in 1987 than in 1981, their year of peak warmth. Southern latitudes were 0.2°C colder than their peak warmth of 1980–1981.

Global and low latitude temperatures are shown with higher temporal resolution in Figure 3: (*a*) is the past 30 years at seasonal resolution, and (*b*) is the past 10 years at monthly resolution. Dates of major volcanic eruptions and El Niño events [Rasmusson, 1985] are marked in part (*a*). The period displayed here is too short for empirical study of volcanic aerosol effects on climate, but from longer records Mass and Schneider [1977], Self et al. [1981], and Angell and Korshover [1985] found statistical evidence for global cooling of 0.1–0.2°C during the 2–3 years following large eruptions. A clearer correlation exists between El Niño events and warm low latitude (23.6°N–23.6°S) surface air temperature, as previously found by Angell and Korshover [1985].

The 1987 warmth is unusual in its sustained level of high temperature at low latitudes (Figure 3*b*). The temperatures are greater at low latitudes than in 1983, despite the 1983 El Niño being the strongest of the century [Rasmusson, 1985]

Color maps of surface air temperature are shown in Figure 4 for calendar years 1986 and 1987, and for the four seasons beginning December 1, 1986. These maps illustrate that the warmth of 1987 at low latitudes was not limited to the principal region of El Niño warming in the eastern Pacific; it was warm through almost the entire low latitude region in all four seasons. It was also remarkably warm in the northern half of North America, especially in the winter and spring, and cold in Europe in the same seasons; in both regions the difference from climatology was about 2σ, where σ is the

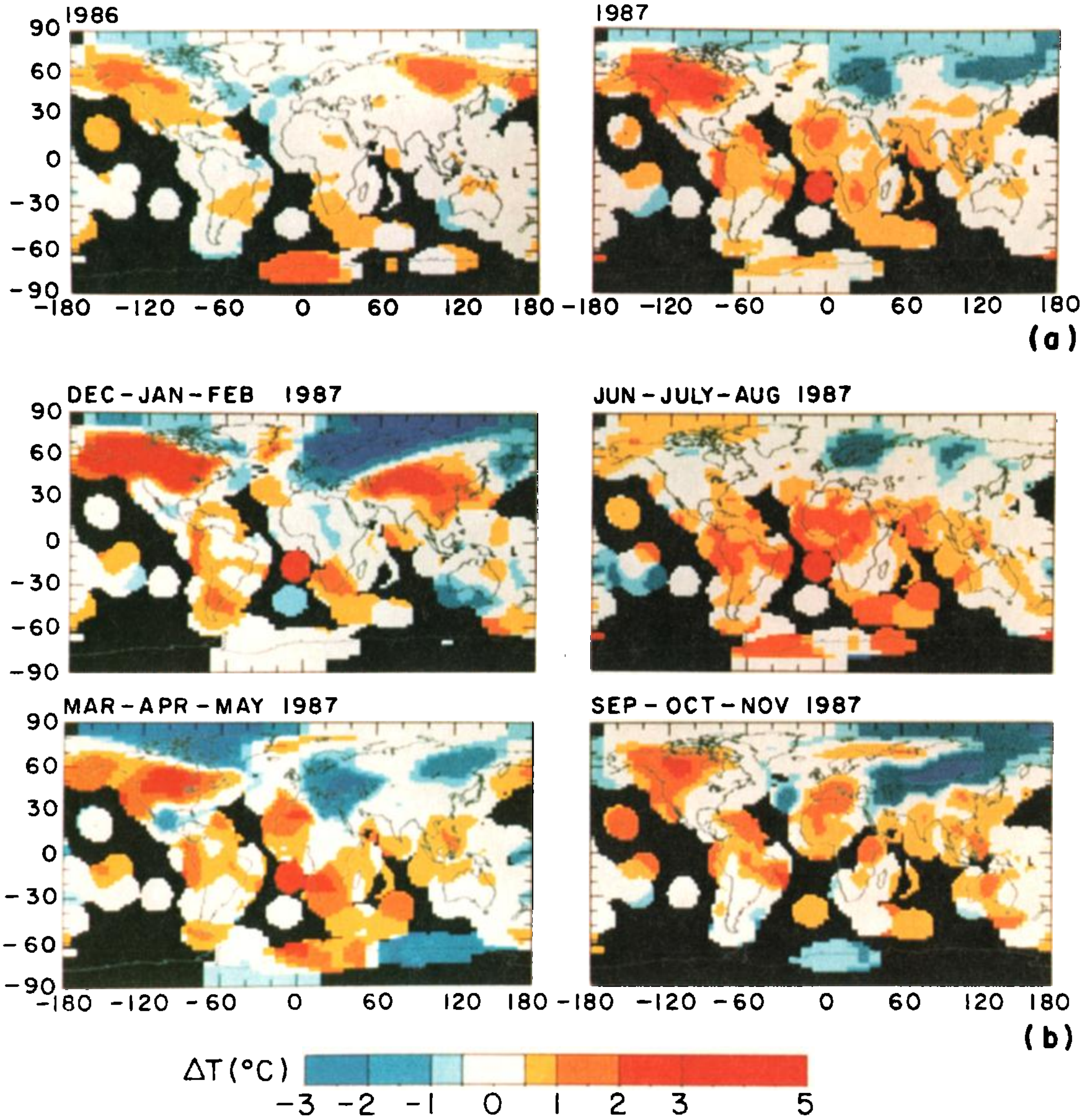

Fig 4. Surface air temperature (*a*) in 1986 and 1987, and (*b*) in the four 1987 seasons; Dec-Jan-Feb 1987 begins December 1, 1986. The zero point for each period and location is the 1951–1980 mean.

interannual variability of seasonal mean temperature (plate 5 of paper 1). Other extratropical regions with exceptional warmth in 1987 included large parts of southern Asia, southern South America, and southern Africa. Siberia was unusually cool in the spring, summer and fall.

Table 1 updates results in paper 1 to include 1986 and 1987, and modifies some results in the period 1980–1985 The changes, generally less than 0.1°C, arise from improved station coverage and discovery of several errors in station records. The largest change of global temperature is a

TABLE 1. Surface Air Temperature Change for the Globe and Specified Regions.

				Zone								Box					
Year	Globe	NH	SH	1	2	3	4	5	6	7	8	6	7	9	10	15	16
1980	0.27	0.21	0.33	0.21	0.08	0.12	0.36	0.27	0.33	0.33	0.62	0.59	-0.12	-0.67	-0.03	0.52	0.03
1981	0.36	0.50	0.20	1.13	0.92	0.25	0.22	0.03	0.24	0.51	0.59	1.79	1.18	0.24	1.63	0.80	0.13
1982	0.05	0.03	0.09	-0.26	0.09	-0.08	0.16	0.03	0.14	0.21	0.05	-0.82	-0.88	0.39	0.84	-0.13	0.10
1983	0.30	0.37	0.22	0.13	0.74	0.11	0.39	0.39	0.09	0.16	0.00	0.53	-0.16	0.84	1.97	0.10	0.18
1984	0.09	0.08	0.10	0.25	0.03	-0.05	0.14	0.03	-0.05	0.18	0.83	0.43	-0.19	0.19	-0.30	0.04	0.11
1985	0.05	-0.02	0.13	0.21	-0.26	-0.04	0.04	0.02	0.20	0.39	0.54	-0.37	-0.15	-0.96	-0.26	-0.29	0.04
1986	0.17	0.17	0.17	0.08	0.30	0.11	0.14	0.09	0.16	0.31	1.10	0.80	-0.40	-0.16	0.20	0.72	0.38
1987	0.33	0.31	0.34	-0.36	0.16	0.39	0.57	0.55	0.17	0.36	0.06	2.02	0.63	-0.99	-0.26	0.42	0.39

decrease of 0.06°C in 1981. An updated computer data tape, including time series of analyzed temperature change at global, hemispheric, zonal and box resolution, and a program to produce maps of arbitrary resolution, is available from the authors or Roy Jenne of NCAR.

Discussion

The global temperature inferred from meteorological stations is 0.78°C warmer in 1987 than the 1880s mean. This result is not corrected for urban heat island effects, which we argue [paper 1] contribute a warming of 0.1–0.2°C in the past century. Thus we estimate that the 1987 global surface air temperature, corrected for urban effects, is 0.63 ± 0.2°C warmer than in the 1880s; the uncertainty range is a subjective estimate, combining errors due to incomplete global coverage, uncertainty in urban effects, and other factors.

The years 1981 and 1987 are the warmest in the period of instrumental records. The difference in the analyzed global temperatures for these two years is less than the uncertainty due to incomplete spatial coverage, so it is not possible to identify the single warmest year.

The global warming in 1987 occurred at low latitudes; southern and northern latitudes remained substantially cooler than the maxima obtained in 1980 and 1981. Low latitude temperature is likely to decline in 1988 or 1989, assuming termination of the current El Niño. But, considering the known increase of greenhouse forcing of the climate system, we do not expect temperatures necessarily to decline to the recent inter-El Niño values (Figure 3b). It has been argued elsewhere [Hansen et al., 1984] that recent global temperatures are probably out of equilibrium with current atmospheric composition, because of the climate system's thermal inertia and thus its finite response time. Perhaps a fluctuation to warmer temperatures can be maintained at least partially, especially at low latitudes where the ocean mixed layer is thin and exchange with the deeper ocean is inhibited by stable stratification.

What is the significance of recent global warming? The standard deviation of annual-mean global-mean temperature about the 30-year mean is 0.13°C for the period 1951–1980. Thus the 1987 global temperature of 0.33°C, relative to the 1951–1980 climatology, is a warming of between 2σ and 3σ. If a warming of 3σ is reached, it will represent a trend significant at the 99% confidence level. However, causal connection of the warming with the greenhouse effect requires examination of the expected climate system response to a slowly evolving climate forcing, a subject beyond the scope of this paper.

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