The Russian Surface Temperature Data Set

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ABSTRACT

A Russian group, under the initial leadership of M. I. Budyko, has produced the first comprehensive analysis of monthly average surface temperature (January 1891 through May 1980) for the Northern Hemisphere on a 5° × 10° latitude-longitude grid. This data set and the magnetic tape of the data are described. Other collections of surface temperature data are also described and compared on the bases of temporal and spatial coverage, and analysis methods.

1. Introduction

When Budyko (1969) published his energy-balance climate model in English, Western scientists became aware of the availability of a Russian surface temperature data set. His Fig. 1 [reproduced here in Fig. 1, as updated by Vinnikov *et al.* (1980)] shows "the secular variation of annual temperature in the northern hemisphere that was calculated from the maps of temperature anomalies for each month for the period of 1881 to 1960 which were compiled at the Main Geophysical Observatory." (Budyko, 1969) This unique data collection was produced with a tremendous manpower effort, and is now available, updated through May 1980, as monthly averaged surface temperature anomalies on a 5° × 10° latitude-longitude grid in digital form on magnetic tape. Through the activities of the US-USSR Bilateral on Environmental Protection,[1] I have had an opportunity to visit and work with Soviet scientists who have analyzed these data. My personal contacts with Drs. Vinnikov, Budyko and Gruza, together with my reading of several Russian publications describing the data set, have allowed me to become familiar with the way it was produced and how it is presented on the tape. In this paper I will describe the Russian surface temperature data set, and compare it to other collections of surface temperature data.

[1] The US-USSR Bilateral on Environmental Protection is administered by the Environmental Protection Agency and involves the active participation of the National Science Foundation, National Oceanic and Atmospheric Administration and the Department of Energy. Under this agreement there are a number of working groups in climate studies. The results presented in this paper represent a significant benefit of the scientific and data exchanges with the Soviets.

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2. The data sources

The maps upon which the data set is based come from two sources. The data from 1881 to 1960 come from maps (Sharova, 1960–67) of monthly mean surface temperature anomalies which were prepared at the Main Geophysical Observatory in Leningrad when Budyko was the director. They were prepared for the purpose of monthly and seasonal forecasting, with a goal of finding patterns in the monthly average departures from normal. The maps (Sharova, 1960–67) are hand-drawn, smooth, synoptic-type analyses of the data. The Introduction to the atlases[2] contains information on the number of stations used when constructing the maps. For example, in 1881 there were 246 continental stations; in 1913, 753; in 1940, 976; and at the end of the period ~2000 stations. The Introduction also contains a description of the data over the oceans and the principles and methods of analyzing the maps. According to Vinnikov (personal communication, 1981), experienced climatologists used great care in the analysis of the maps. Considerations such as station locations, breaks in the record, and errors in the data were made. He feels that they were very well done, but does not know the details of the analysis. The maps themselves contain only smooth isopleths and not the locations of the stations or the raw data upon which the analyses are based.

The data for the period 1961 to the present are based on maps appearing in the Synoptic Bulletin (1961–) of the State Hydrometeorological Committee (their equivalent of NOAA). These maps are drawn

[2] Dr. Joseph Fletcher, NOAA/ERL, Boulder, has a copy of these atlases.

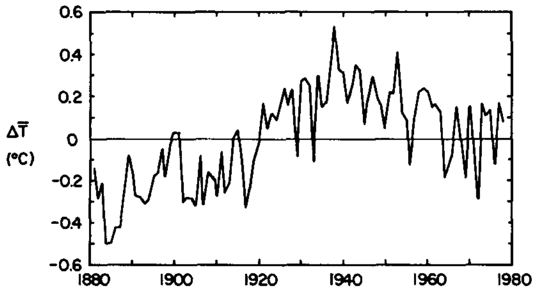

FIG. 1. Annual average surface temperature, 1881–1978, for the "Northern Hemisphere" (17.5°N–87.5°N) from Vinnikov *et al.* (1980).

based on data received in real time from the worldwide synoptic network, and are not processed by climatologists. Vinnikov feels that these analyses are not of as high a quality as those from 1960 and before. I do not know of anyone in the United States who has copies of these maps, but the data should be the same as those available to us in the *Monthly Climatic Data for the World.*

3. The nature of the data

The data on the tape are anomalies of surface air temperature. The anomalies were calculated, as shown in Table 1, relative to different sets of normals for different periods, so caution must be exercised when combining them to produce a homogeneous time series for climatic studies. Borzenkova *et al.* (1976) describe a procedure for producing such a homogeneous series. Vinnikov *et al.* (1980) suggest a modified procedure for the corrections and show results of applying this procedure to the data on the tape to produce zonal averages. I have corrected the anomalies so that they are all with respect to the 1881–1975 normals, using correction procedure B as described by Vinnikov *et al.* (1980), and have included this file on the tape.

It is also important to know that although the anomalies are for *surface* temperature, the normals were computed for *sea level* temperature, to eliminate altitude effects in the normals maps. In order to correct the anomalies to the same reference set of normals, it is not necessary to use the actual normals, but in order to reconstruct the actual surface temperature fields it is. In this case, it is also necessary to realize that the "sea level" normal maps were created from station normals by assuming an artificial lapse rate of temperature, and that different lapse rates were used for different normal periods. For 1881–1935(40) and 1881–1960, 5°C km^{-1} was used, and for 1931–1960, 6°C km^{-1} was used, as shown in Table 1. The details, and procedures for correcting for these factors are given in Borzenkova *et al.* (1976).

4. Russian analyses of the data

Several Russian papers have been published which present analyses of surface temperature change over the last 100 years based on this data set. Budyko (1969) presented a graph of "Northern Hemisphere" annual average temperature from 1881 to 1960. It turns out that few data were available for this period south of 20°N and near the North Pole, so it was not really a hemispheric average. Still, this was the first publication of annual average temperatures for the Northern Hemisphere and has been used for comparison with model results in many studies of climate change.

Borzenkova *et al.* (1976) present a detailed analysis of the data as annual averages from 1881 to 1975 from 17.5 to 87.5°N in broad latitude bands. Although the data extend to the North Pole for all years, and to the Equator after 1960, the analysis was confined to this latitude band due to the lack of tropical data before 1960. They gave a detailed description of the data and the procedures they used for constructing a homogeneous time series. All the results were presented as zonal averages. Rubinshteyn (1977) criticized this paper by suggesting various sources of error in the analysis, but Vinnikov (1977) quite convincingly defended the analysis procedure, giving further details about the considerations of urban effect, breaks in the record and other possible problems.

A book of maps of the data and computer printouts of various averages was published by Gruza and Ran'kova (1979). They considered the data from 1891 to 1976—the same data which are on the first version of a magnetic tape which they produced. (Copies of this tape, called the METEOR tape, exist in the United States at the National Climatic Center and the National Center for Atmospheric Research (NCAR). The version of the METEOR tape we received, however, does not include complete coverage of the Northern Hemisphere. The tape being described in this paper is more recent, and contains complete Northern Hemispheric coverage.) The book contains for each month maps of means, gradients and various statistical moments of these quantities. There are also latitude vs. month graphs of zonal

TABLE 1. Temperature normals and lapse rates used to calculate anomalies for different periods of the record.

Anomalies for the period	Computed relative to normal for the period	Temperature lapse rate
1881–1940 and 1961–1969	1881–1935 (most stations) 1881–1940 (some stations)	5°C km^{-1}
1941–1960	1881–1960	5°C km^{-1}
1970–1980	1931–1960	6°C km^{-1}

averages. In addition, computer tables and graphs are provided of time series of various averages of the data for different months and latitude and longitude bands.

Vinnikov *et al.* (1980) updates the paper of Borzenkova *et al.* (1976) by extending the analysis through 1978 and by showing the effects of trying different systems of corrections to the data to account for the different normals periods. Again, zonal averages are presented, and the paper contains a table of annual average temperature for the extra-equatorial part of the Northern Hemisphere (17.5–87.5°N, plotted in Fig. 1). The final correction system used is almost the same as that of Borzenkova *et al.* (1976), but uses long-term means over the oceans rather than self-consistent grid values.

5. The tape

A magnetic tape[3] has been produced by the Russians, under the direction of G. V. Gruza at the World Data Center in Obninsk, and contains surface temperature data from January 1891 through May 1980. The tape now contains seven data files, all but one of which are in units of degrees Celsius and contain data on a 5° × 10° latitude-longitude grid from 0 to 90°N. The files are described in detail in the documentation accompanying the tape, but will briefly be described here. There are two files which contain the uncorrected surface temperature anomalies, to the nearest tenth of a degree Celsius, organized in different latitude-longitude order. One file contains the monthly mean sea level norms for 1881–1935, one contains the sea level norms for 1881–1960, and one contains the difference between these norms. One file contains grid-point altitudes for use in converting between surface temperatures and sea level temperatures. The last file, which I added, contains anomalies of surface temperature for each month corrected so that the anomalies are all with respect to the same normal (1881–1975). I also corrected the anomalies for February 1974, which are in error on the other files. [A copy of the tape was sent to Phil Jones who, in comparing with his data (Jones and Wigley, 1980a–d), discovered that the Russian data for February 1974, were wrong. I contacted Drs. Vinnikov and Gruza who supplied me with the correct data for this month.]

6. Other surface temperature analyses

There have been many compilations of Northern Hemisphere surface temperature series, as shown in Table 2. These compilations differ because of their temporal coverage, their spatial coverage, the choice of stations, and the averaging methods, particularly the choice of method to deal with data-sparse regions. The attempted temporal and spatial coverages are listed in the table. The papers are grouped because some of them are updates or expansions of previous work. Here I will point out some distinguishing features of particular papers.

Group I was the first attempt to describe the temperature variations of the past 100 years. It was started by H. C. Willett with the collaboration of J. M. Mitchell as a graduate student. The first time series to result with proper latitudinal weighting were the updated versions of Mitchell (1961). Callendar (Group II) calculated averages of continents and oceanic regions, as well as zonal bands. Group III, the Russian data, are described in Section 4 above. In the Japanese analyses (Group IV) the 1975 and 1977 papers used cubic spline fits to get values in data-sparse regions, and the 1979 papers used optimum interpolation. When using optimum interpolation, values of 0°C were assumed in regions with no data, so the resulting averages probably underestimate the actual variations. Angell and Korshover (1977, 1978), Group V, used a sparse network of evenly spaced stations, and so sacrificed detail for even coverage. Barnett (1978), Group VI, used empirical orthogonal function to analyze air temperature data over land combined with sea surface temperature data over part of the ocean, and pointed out that Angell and Korshover's stations may not be located in the regions of maximum variability. Still, the Angell and Korshover time series agree with those of Yamamoto *et al.* (1975) in the same latitude range, as they pointed out (Angell and Korshover, 1977). The Climatic Research Unit of the University of East Anglia (Group VII) and NASA/GISS (Group VIII) are both attempting to produce the same type of analysis as the Russians. [Hansen *et al.* (1981) use the GISS data but do not describe the analysis in detail.] They are, however, using objective, rather than subjective, methods for analyzing the spatial fields to grid points. Damon and Kunen (1976), Group IX, analyzed Southern Hemisphere data, but did not properly area-weight the averages. Dronia (Group X) calculated the magnitude of the urban influence, which is one important consideration in the interpretation of any of these data collections.

7. Summary

A Russian group, under the initial leadership of M. I. Budyko, has produced the first analysis of monthly average surface temperatures for the Northern Hemisphere on a 5° × 10° latitude-longitude grid. This data set and the magnetic tape of the data are described in this report. The Russian data set is the

[3] Copies of the tape are available from Roy Jenne at NCAR, P.O. Box 3000, Boulder, Colorado 80307.

TABLE 2. Global surface temperature data sets.

	Minimum averaging period	Period	Latitude
I. Willett (1950)	5 years (annual, winter)	1845–1939	world
Mitchell (1961)	5 years (annual, winter)	1845–1959	60°S–80°N
Mitchell (1963)	5 years (annual, winter)	1880–1959	60°S–80°N
Reitan (1974)	monthly	1955–1969	0°–80°N
Brinkmann (1976)	3 years (all seasons)	1969–1973	0°–80°N
II. Callendar (1961)	5 years (annual, summer)	1871–1950	50°S–73°N
III. Budkyo (1969)	annual	1881–1960	"NH"
Borzenkova *et al.* (1976) [Rubinshteyn (1977)]	annual	1881–1975	17.5–87.5°N
Vinnikov (1977)	annual	1881–1975	17.5–87.5°N
Gruza and Ran'kova (1979)	monthly	1891–1976	17.5–87.5°N
Vinnikov *et al.* (1980)	annual	1881–1975	17.5–87.5°N
IV. Asakura (1975)	annual	1960–1968	"NH"
Yamamoto *et al.* (1975)	3 months	1951–1972	"NH"
Yamamoto *et al.* (1977)	7 months	1957–1972	global
Yamamoto and Hoshiai (1979a)	12 months	1951–1977	25°S–90°N
Yamamoto and Hoshiai (1979b)	3 months	1876–1975	25°S–90°N
V. Angell and Korshover (1977)	annual	1958–1975	global
Angell and Korshover (1978)	seasonal	1958–1977	global
VI. Barnett (1978)	winter, annual	1950–1977	20°N–80°N
VII. Jones and Wigley (1980a–d)	seasonal	1881–1980	0–90°N
Jones *et al.* (1982)	monthly	1881–1981	0–90°N
Kelly *et al.* (1982)	seasonal	1881–1980	60°–90°N
VIII. Hansen *et al.* (1981)	annual	1880–1979	global
IX. Damon and Kunen (1976)	5 years	1943–1974	90°S–0°
X. Dronia (1967)	10 years	1871–1960	global

first and only available digitized, gridded collection of monthly average Northern Hemisphere surface temperature data. The quality of the data over land, especially for recent periods, should be excellent and useful for many studies of climate. The quality of the data over oceans is questionable, and, unfortunately, it will not be possible to objectively determine the quality by a reanalysis. I would recommend to someone interested in data over the oceans, to either acquire data based on ship measurements (e.g., Paltridge and Woodruff, 1981) or wait for the analyses of the Climatic Research Unit or GISS. These later analyses will be able to include an analysis of the quality of the data over the oceans, and the dependence of the results on the analysis technique used. I expect the analyses of the Russians over land to be very similar to those of these other two groups. Other collections of surface temperature data are also described, and compared on the bases of temporal and spatial coverage, and analysis methods.

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