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RECENT SECULAR TRENDS OF SURFACE AIR TEMPERATURES IN HIGH LATITUDES OF THE NORTHERN HEMISPHERE

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Abstract: CLINO (Climatological Normals) 1931–1960 and CLINO 1951–1980 compiled by the Japan Meteorological Agency are used to detect seasonal and annual secular trends in the north polar regions. World Weather Record series by U. S. Weather Bureau and NOAA are also used to analyze the interannual variation of surface air temperatures in this region.

The results are as follows: 1) There is a prevailing cooling trend in the latter period during 1931–1980. Remarkable negative temperature anomalies are observed especially over Arctic west Siberia near the Kara Sea. 2) A decreasing trend of surface air temperature at Ostrov Dikson near the Kara Sea is remarkable. The temperature has not recovered to the level of the 1940s in recent years. 3) It is important to remove the impact of rapid urbanization from the the temperature record, especially south of 60°N, because we must understand real atmospheric temperature difference between low and high latitudes, and detect the impact on atmospheric circulation of the so-called greenhouse effect.

1. Introduction

HANSEN and LEBEDEFF (1987, 1988) indicated a global warming of about 0.5–0.7°C in the past century and a strong warming trend between 1965 and 1980 in northern latitudes. They also showed that surface air temperatures in the 1980s are the warmest in the history of instrumental records. They associated the warming with the effect of greenhouse gases. However, the data sets they used include some urban heat island biases.

JONES *et al.* (1986) indicated that the period 1921–1984 was about 0.4°C warmer than the period 1851–1920 in the Northern Hemisphere. They attributed the warming partly to the effect of urban warming on the Northern Hemisphere average surface air temperature (JONES *et al.*, 1989; KARL and JONES, 1989). Their results indicate that in the United States the two global land-based temperature data sets have an urban warming bias between +0.1°C and +0.4°C over the twentieth century (1901–1984). They assessed the urban warming effect using estimates by KARL *et al.* (1988). JONES *et al.* (1989) concluded that the Northern Hemisphere landmass average compiled by JONES *et al.* (1986) may contain a spurious warming trend which is, at the maximum, 0.1°C over the first eight decades of the twentieth century.

WOOD (1988) commented that there is still the possibility of significant urban warming bias. BALLING and IDSO (1989) detected urban warming in several small urban centers and suggested that we may not yet have a proper measure of global climatic change.

ANGELL (1988) used a network of 63 well-distributed radiosonde stations which have less urban bias to estimate global mean annual temperature variations during 1958–1987. The results indicate an increase in year-average global temperature at the surface and in the tropospheric 850–300 mb layer of 0.08°C 10 yr^{-1} and 0.09°C 10 yr^{-1}, respectively, and a slight decrease in the troposphere of the north polar and north temperate zones. This implies an increase in the meridional temperature gradient between low and high latitudes. He concluded "it is premature to state categorically that a greenhouse effect is already being observed".

Thus, regional trends of air temperature are not so clear, especially in the polar regions. We not only need to consider urban bias but also to do analyses based on data with as little station movement (discussed below) as possible to obtain the secular trend of surface air temperature and a global or hemispheric scale.

In this paper, CLINO (Climatological Normals) 1931–1960 and CLINO 1951–1980 compiled by the JAPAN METEOROLOGICAL AGENCY (1967, 1987) are used to detect seasonal and annual secular trends in the north polar regions. Data of CLINOs are mostly prepared by WMO authorities. World Weather Record series by the U. S. WEATHER BUREAU AND NOAA (1959–1987) are also used to analyze the interannual variation of surface air temperatures in the specified region.

2. Results

Fifty-six stations are selected as areal representative climatic stations during 1931–1980 north of about 45°N (Fig. 1). The locations of these stations have not changed or have only slightly changed. According to station histories in World Weather Record Series, locations of many major stations have changed, especially in the U.S.A. and Canada, because many city stations moved to airport stations. Data of these stations were excluded in these analyses. Figures 2–6 show the surface air temperature differences of selected stations between the CLINO 1951–1980 and the CLINO 1931–1960 in winter, spring, summer, autumn and annual means, respectively.

Figure 2 shows the winter trend. Positive anomalies are seen over the 50°N zone while remarkable negative anomalies are seen over the region between 60°N and the Arctic Ocean on the Eurasian continent. The temperature gradient with latitude along 90°E is intensified.

Figure 3 shows the spring trend. The pattern is similar to that of the winter trend but it shows a weaker anomaly. Figure 4 shows the summer trend. There is a widespread negative region in the north polar zone except Alaska. Figure 5 shows the autumn trend. There is a widespread negative region centrered over Arctic west Siberia, and a zonal positive region over the Urals. Figure 6 shows the annual mean trend. There are widespread negative anomalies over land regions near the Arctic Ocean.

Figure 7 shows year-to-year temperature variations at Arhangel'sk near the Barents Sea and Ostrov Dikson in Arctic west Siberia near the Kara Sea in summer and winter based on World Weather Record series. There are general decreasing

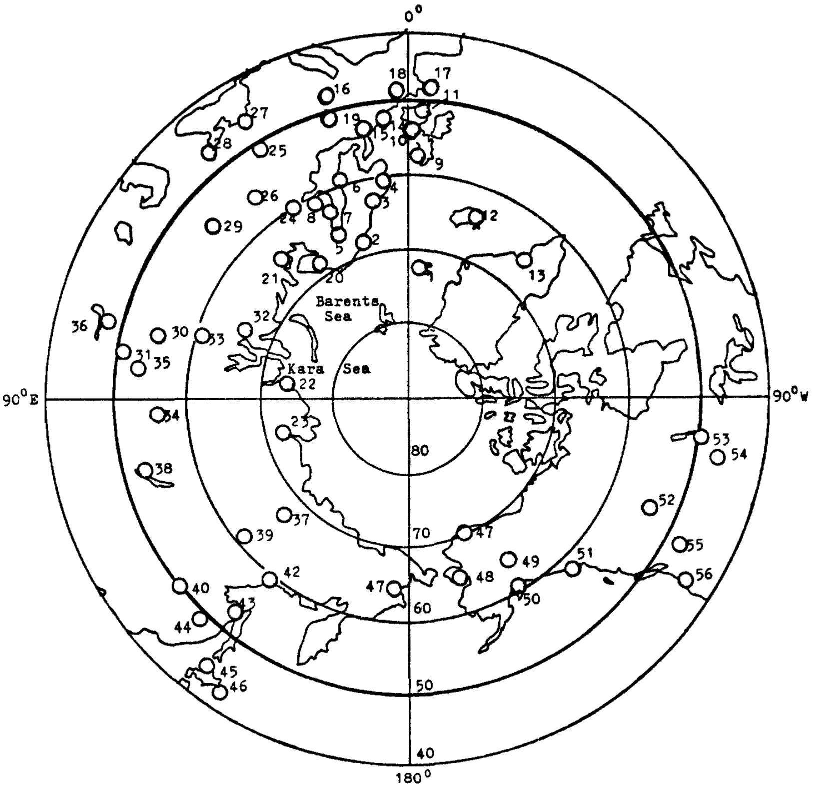

Fig. 1. Station map. Stations are 1 Jan Mayen, 2 Bodo, 3 Trondheim, 4 Bergen, 5 Haparanda, 6 Stockholm, 7 Vaasa, 8 Helsinki, 9 Aberdeen, 10 Manchester, 11 Plymouth, 12 Reykjavik, 13 Angmagssalik, 14 De Bilt, 15 Hamburg, 16 Wien, 17 Brest, 18 Paris, 19 Praha, 20 Murmansk, 21 Arhangel'sk, 22 Ostrov Dikson, 23 Hatanga, 24 Leningrad, 25 Kiev, 26 Moskva, 27 Odessa, 28 Rostov Na Donu, 29 Kazan, 30 Omsk, 31 Semipalatinsk, 32 Salehard, 33 Surgut, 34 Krasnoyarsk, 35 Barnaul, 36 Balkhash, 37 Verhojansk, 38 Irkutsk, 39 Jakutsk, 40 Blagovescensk, 41 Anadyr, 42 Ohotsk, 43 Nikolaevsk Na Amure, 44 Habarovsk, 45 Wakkanai, 46 Nemuro, 47 Barrow, 48 Nome, 49 Fairbanks, 50 Anchorage, 51 Juneau, 52 Edmonton, 53 Winnipeg, 54 Bismarck, 55 Spokane and 56 Portland.

trends during 1931–1980; extremely low temperatures have been recorded during the later part of this period. The trends in the late 1980s are not shown; however, temperatures at Osatrov Dikson have not recovered to the level of the 1940s according to recent data from Monthly Climatic Data for the World series by NOAA. Correlation analyses between Arhangel'sk and Ostrov Dikson show 0.247 and 80% significant level in summer, 0.379 and 95% significant level in winter, and 0.463 and 99% significant level in averaged over the year. The temperature trend at Ostrov Dikson is nearly same as that at Arhangel'sk, namely the trend over the Atlantic Arctic.

3. Discussion

Many studies using climate models of global warming induced by increasing greenhouse gases demonstrate the greatest warming in the polar regions (*i.e.*, Manabe and Wetherald, 1980). Recently, Stouffer *et al.* (1989) showed greater warming in

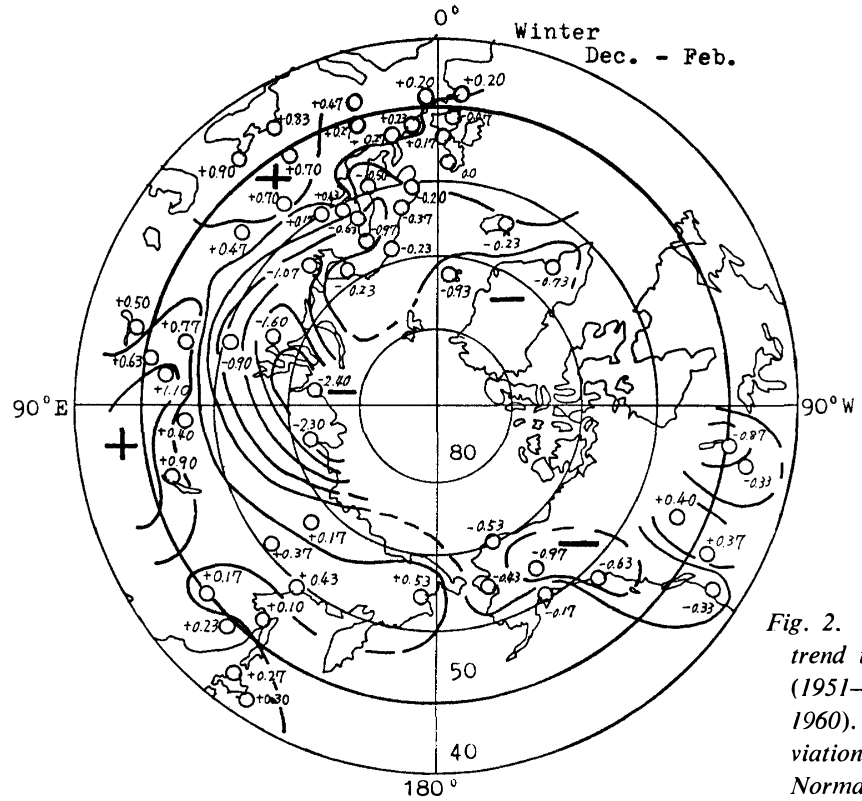

Fig. 2. Surface air temperature trend in winter (°C). CLINO (1951–1980) – CLINO (1931–1960). "CLINO" is an abbreviation for "Climatological Normals".

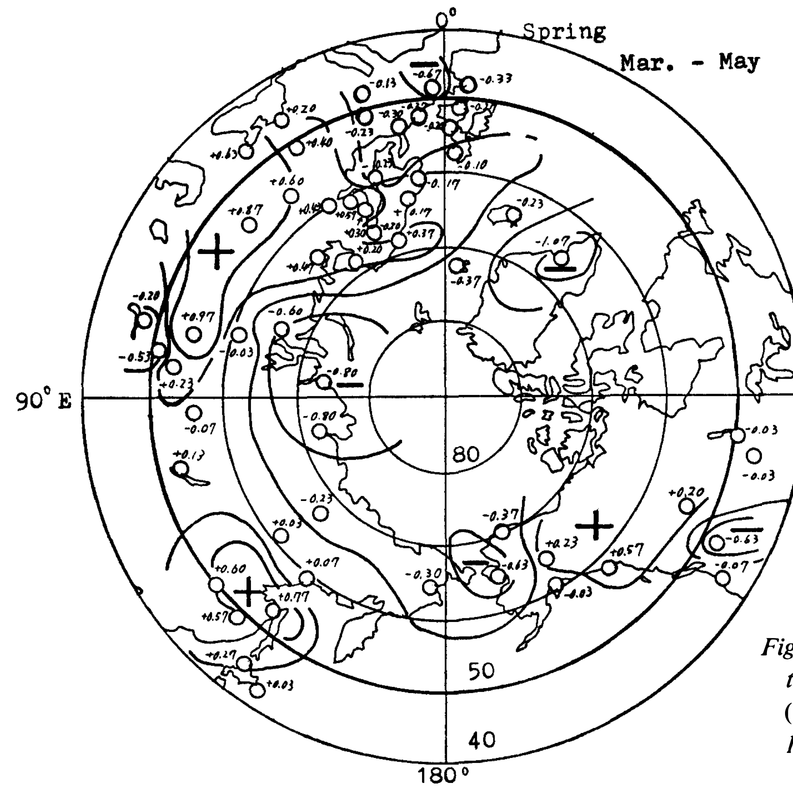

Fig. 3. Surface air temperature trend in spring (°C). CLINO (1951–1980) – CLINO (1931–1960).

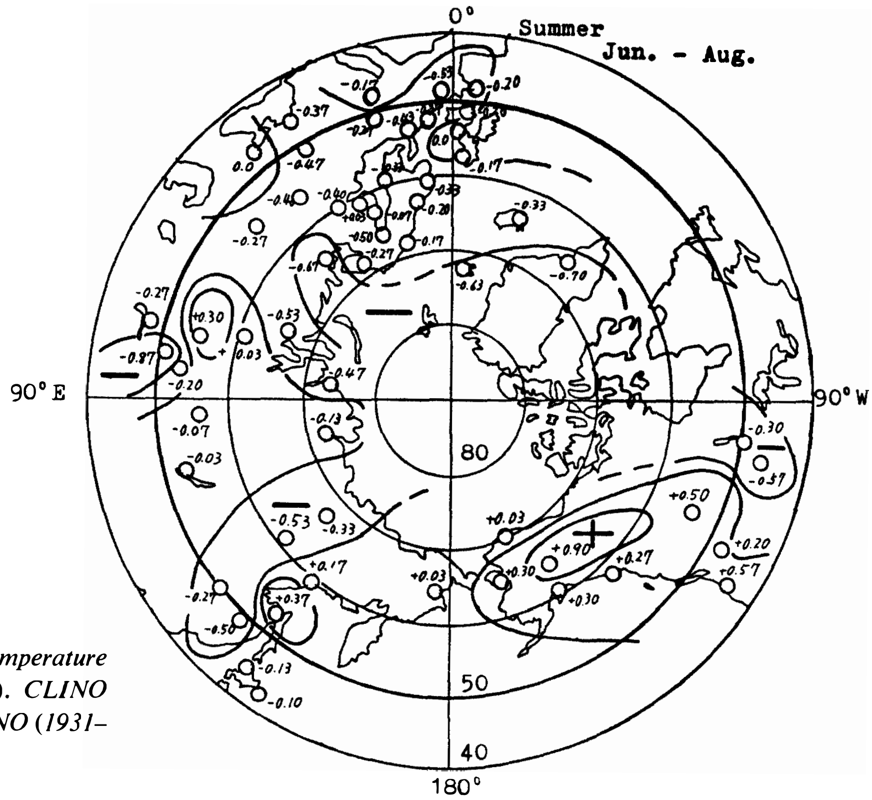

Fig. 4. Surface air temperature trend in summer (°C). CLINO (1951–1980) – CLINO (1931–1960).

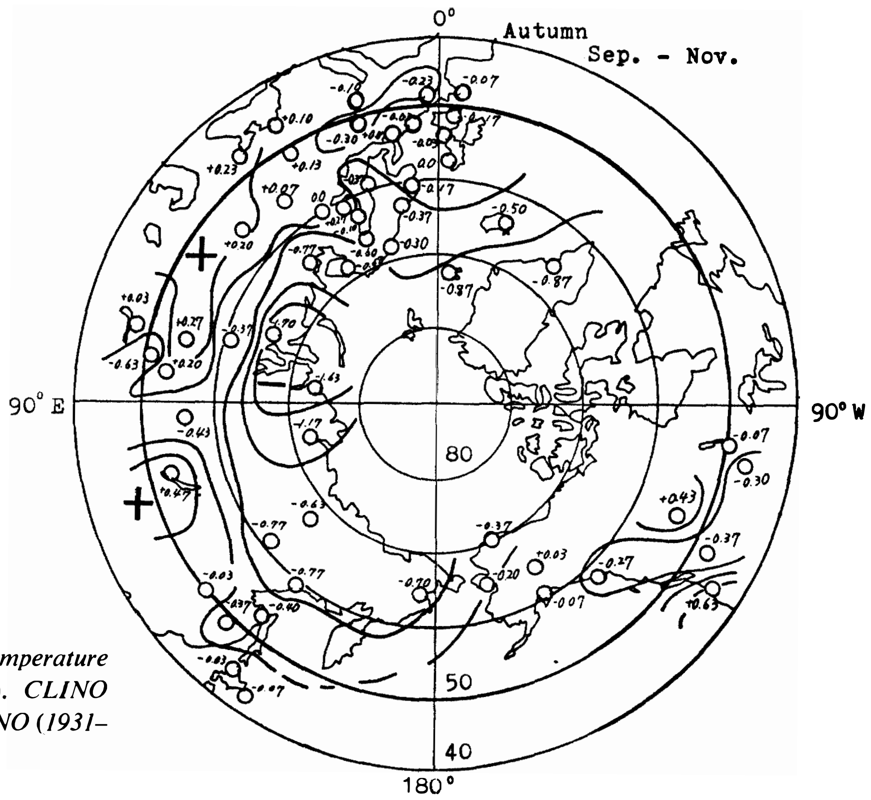

Fig. 5. Surface air temperature trend in autumn (°C). CLINO (1951–1980) – CLINO (1931–1960).

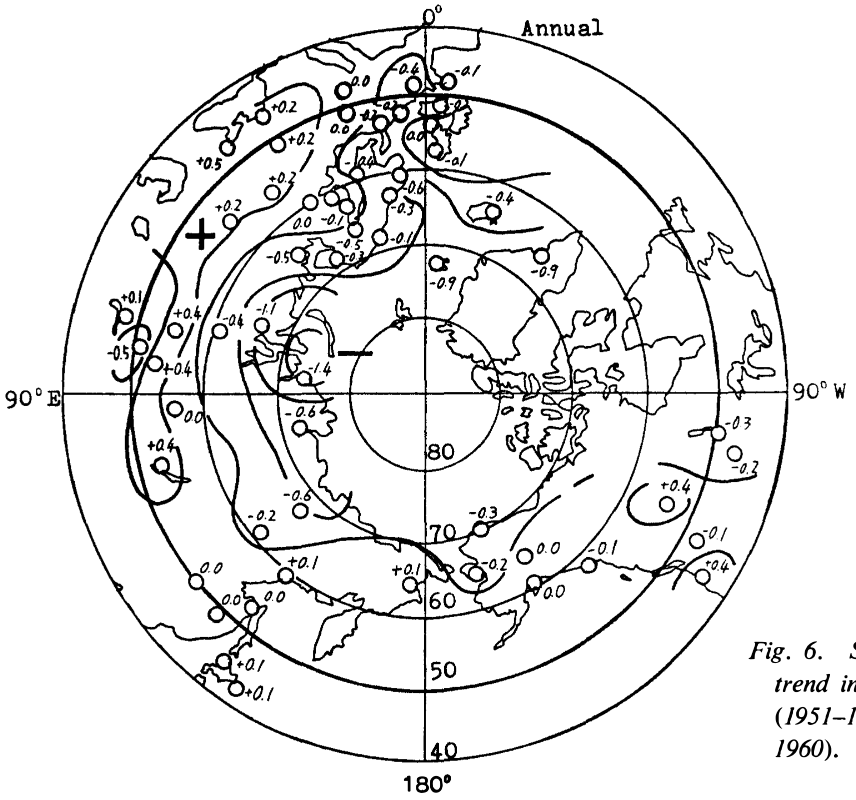

Fig. 6. Surface air temperature trend in annual (°C). CLINO (1951–1980) – CLINO (1931–1960).

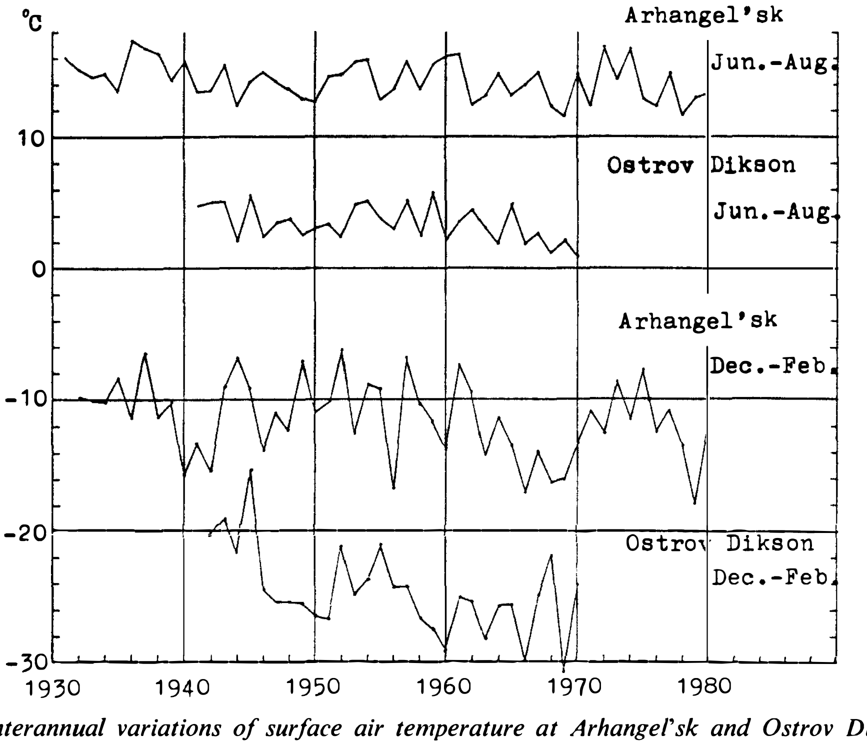

Fig. 7. Interannual variations of surface air temperature at Arhangel'sk and Ostrov Dikson in summer and winter.

north polar regions than in south polar regions. Although global warming in recent years based on recorded surface air temperatures has been indicated by many authors, there was no prevailing warming in the north polar regions during 1931–1980, as shown in Fig. 2.

KELLY *et al.* (1982) showed that certain regions are particularly sensitive to long-term variations, most notably northwest Greenland and around the Kara Sea. Warming began to effect the Arctic during the first half of 1970s, particularly in the Barents Sea and Kara Sea regions. This pattern of warming is similar to that which occurred during the 1920s. They suggested data for the northwest Greenland and Kara Sea regions may provide a good indicator of long-term trends over the whole hemisphere.

We can find remarkable anomalies at Ostrov Dikson and near the Kara Sea in Figs. 2–7, although selected data do not include data of northwest Greenland. This is not consistent with data of the 1920s and the first half of the 1970s, as mentioned by KELLY *et al.* (1982).

Warming in northern Europe is usually associated with an enhanced zonal circulation (LAMB and JOHNSON, 1959). We can use the pressure difference between the Azores and Iceland as an index of the North Atlantic Oscillation (NAO), a measure of the strength of the zonal circulation. A period of warming Arctic winters around 1920 was associated with a high NAO index. After the warmest winter of 1926–1944 since 1900 the NAO index decreased, the mean position of the Icelandic low shifted eastward and the warm period over the Atlantic sector ended (ROGERS, 1985). The NAO index decreased 0.5 mb between CLINO 1951–1980 and CLINO 1931–1960, and such decreasing trend explains a colder winter pattern in the Atlantic Arctic and Arctic west Siberia regions.

Another, very complicated problem is the urban wariming bias effect on surface air temperature. Although JONES *et al.* (1989) argued that the urban bias in their data should be no larger than 0.1°C over the twentieth century, on the basis of a detailed comparison of their data with the Historical Climate Network in the United States, data of other countries possibly have larger bias. For example, WOOD (1988) suggests that there is a significant urban warming bias in the hemispheric and global averages. He indicated that even small cities and towns may not be immune from urban warming.

The warming bias by urbanization is interpreted as follows on the basis of Brunt's night radiation cooling equation (from TAKEUCHI and KONDO, 1981)

$$\Delta T_s = 1.1\ R_{net} \sqrt{\frac{t}{C\rho\lambda}} \tag{1}$$

where ΔT_s is the range of night radiative cooling (°C), R_{net} is net radiation, t is time duration, C is specific heat, ρ is density and λ is thermal conductivity. Larger $C\rho\lambda$ thus means smaller cooling. In small towns and in airport areas, $C\rho\lambda$ has been increased in recent years by the replacement of natural soil by artificial materials such as asphalt. The C of asphalt is smaller than that of wet soil or water but the $C\rho\lambda$ of asphalt is nearly the same as that of water. Urbanized surfaces are easily warmed in sunny daytime but warmed asphalt surfaces are not easily cooled at night (TSUCHIYA, 1985). Urbanized surface impact on surface air temperature is larger in lower and midlatitudes than in high latitudes because of additional anthoropogenic heating.

We must exclude data with urban bias or correct for the urban bias in the study of average hemispheric or global surface air temperature. If global warming still remains in middle or low latitudes of the Northan Hemisphere after removing the urban bias we should recognize an increasing temperature gradient between low and high latitudes as mentioned by ANGELL (1988). An increasing temperature gradient is serious because it produce an activated atmospheric circulation regime as mentioned by TSUCHIYA (1990) and then some anomalous weather or large regional climatic anomalies are suggested before the widespread global warming induced by the greenhouse effect.

References

ANGELL, J. K. (1988): Variations and trends in tropospheric and stratospheric global temperatures, 1958–87. J. Clim., **1**, 1296–1313.

BALLING, R. C., Jr. and IDSO, S. B. (1989): Historical temperature trends in the United States and the effect of urban population growth. J. Geophys. Res., **94**, D3, 3359–3363.

HANSEN, J. and LEBEDEFF, S. (1987): Global trends of measured surface air temperature. J. Geophys. Res., **92**, D11, 13345–13372.

HANSEN, J. and LEBEDEFF, S. (1988): Global surface air temperature; Update through 1987. Geophys. Res. Let., **15**, 323–326.

JAPAN METEOROLOGICAL AGENCY (1967): Climatic Tables for the World (1931–1960). Technical Data Series, No. 31.

JAPAN METEOROLOGICAL AGENCY (1987): Climatic Tables for the World (1951–1980). Technical Data Series, No. 51.

JONES, P. D., RAPER, S. C. B., BRADLEY, R. S., DIAZ, H. F., KELLY, P. M. and WIGLEY, T. M. L. (1986): Northern Hemisphere surface air temperature variations; 1851–1984. J. Clim. Appl. Meteorol., **25**, 161–179.

JONES, P. D., KELLY, P. M., GOODESS, C. M. and KARL, T. (1989): The effect of urban warming on the Northern Hemisphere temperature average. J. Clim., **2**, 285–290.

KARL, T. R., DIAZ, H. F. and KUKLA, G. (1988): Urbanization; Its detection and effect in the United States climate record. J. Clim., **1**, 1099–1123.

KARL, T. R. and JONES, P. D. (1989): Urban bias in area-averaged surface air temperature trends. Bull. Am. Meteorol. Soc., **70**, 265–270.

KELLY, P. M., JONES, P. D., SEAR, C. B., CHERRY, B. S. G. and TAVAKOL, R. K. (1982): Variations in surface air temperatures; Part 2. Arctic regions, 1881–1980. Mon. Weather Rev., **110**, 71–83.

LAMB, H. H. and JOHNSON, A. I. (1959): Climatic variation and observed changes in the general circulation. Geogr. Ann., **2–3**, 94–134.

MANABE, S. and WETHERALD, R. T. (1980): On the distribution of climatic change resulting from an increase in CO_2 content of the atmosphere. J. Atmos. Sci., **37**, 99–118.

ROGERS, J. C. (1985): Atmospheric circulation changes associated with the warming over the northern North Atlantic in the 1920 s. J. Clim. Appl. Meteorol., **24**, 1303–1310.

STOUFFER, R. J., MANABE, S. and BRYAN, K. (1989): Interhemispheric asymmetry in climate response to a gradual increase of atmospheric CO_2. Nature, **342**, 660–662.

TAKEUCHI, K. and KONDO, J. (1981): Chihyo ni Chikai Taiki (Atmosphere near the Ground). Tokyo, Univ. Tokyo Press, 113–116.

TSUCHIYA, I. (1985): Landsat TM data ni yoru ikutsukano toshi no dojiteki netsu kankyo no hikaku (Some thermal features of several cities based on Landsat TM data series). 1985 nen Syunki Taikai Koen Yokosyu, Japan Meteorol. Soc., 118.

TSUCHIYA, I. (1990): Some comments on the recent studies of interannual fluctuations of Northern

Hemisphere snow and ice cover and climate. Proc. NIPR Symp. Polar Meteorol. Glaciol., **3**, 89–94.
U. S. Weather Bureau and NOAA (1959–1987): World Weather Record Series.
Wood, F. B. (1988): Comment; On the need for validation of the Jones *et al.* temperature trends with respect to urban warming. Clim. Change, **12**, 297–312.

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