The Connection between Trends of Mean Temperature and Circulation at the Surface: Part III. Spring and Autumn

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ABSTRACT

The sign of the weighted temperature change over two periods (1950–64, 1942–72) for 15°–80°N was determined by the change in the polar region in spring and autumn, as it was in winter but not in summer. Each of the four seasons shows a different distribution of zonally averaged temperature changes.

1. Introduction

The temperature trends at the surface over the Northern Hemisphere have been discussed for the winter and summer seasons by van Loon and Williams (1976a and 1976b; after this referred to as vLWa and vLWb). In the winter local temperature trends were connected with changes in the circulation at sea level on the scale of long waves, and zonally averaged trends were several times larger in high latitudes than in middle and low latitudes. In summer the local temperature trends were not so clearly associated with changes in advection as those in winter. Also in contrast with winter, the convergence of sensible heat transported by the mean waves in summer apparently bore little relation to the zonally averaged temperature trends, and the largest zonally averaged trends were in the middle latitudes rather than in the Arctic.

In this paper we examine the trends of surface mean temperature in spring (March, April, May) and autumn (September, October, November) for 1900–41, 1942–72 and 1950–64. The trend is defined as the slope of the linear trend line, fitted by least squares, for the period chosen. The data are from the same sources as in vLWa.

2. The trend of temperature in spring and autumn

Figs. 1 and 2 show the distribution of the temperature trends in spring and autumn for the period 1900–41. The trend, over most areas for which data were available, was upward in both seasons, a feature which was noted for winter and summer, too. The local temperature trends in spring and autumn were smaller than those found for summer and winter; in particular the large trends in winter in polar latitudes (up to 0.18°C year^{-1}) had no equivalent in the transition seasons for the period 1900–41.

The trends for the second period (1942–72) which was a period of hemispheric cooling according to Mitchell (1961) are shown in Figs. 3 and 4 for spring and autumn, respectively. In spring the temperature trend was downward in polar and middle latitudes, with areas of warming over Japan, the Middle East and the Pacific Ocean. In autumn the temperature trend was also downward in polar and middle latitudes, but a belt of warming is clear over the low-latitude Pacific and Atlantic Oceans and much of the low-latitude continental area.

For the period 1942–72, the zonally averaged temperature changes could be computed using the method described by vLWa. These changes are illustrated in Fig. 5 for all four seasons. Table 1 lists the average change in 1942–72 between 15° and 80°N in each season; the values are weighted by area as explained in vLWa. The temperature decrease was larger in spring than in the other seasons, and the curve in Fig. 5 shows that this is a result of zero or negative temperature changes at all latitudes. The increase of temperature in low latitudes in autumn was counteracted by a large decrease in polar latitudes to give an average change of −0.29°C, which was larger than in winter and summer.

The sign of the *global* trend is, of course, not necessarily the same as the one between 15° and 80°N. Comparatively small rises over the rest of the tropics and in the Southern Hemisphere would offset the negative changes found for 15° to 80°N. The values in Table 1 combined give an annual temperature change for the period 1942–72 of −0.26°C, but a rise of 0.15°C over the regions between 15°N and the

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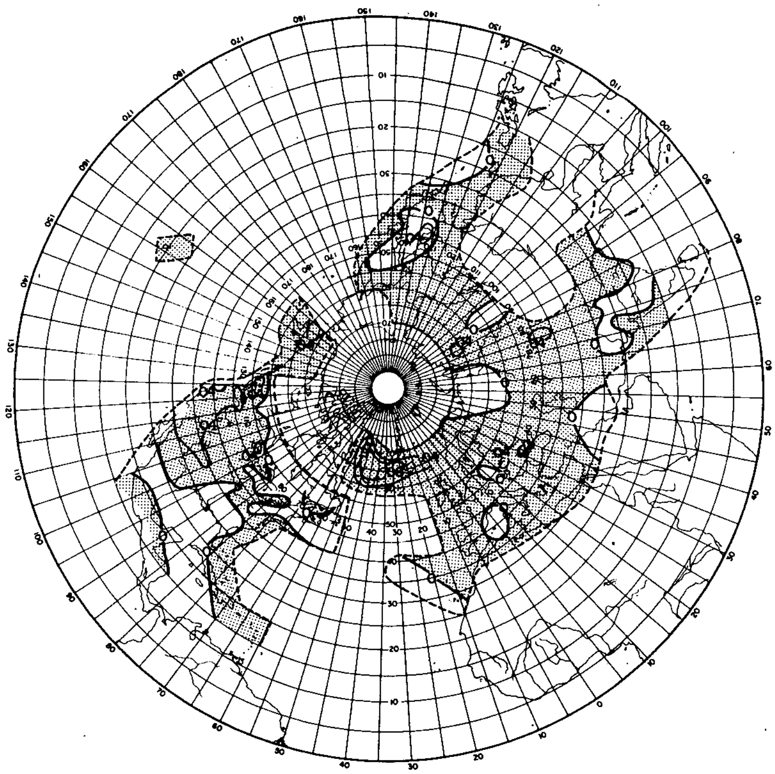

FIG. 1. Isopleths of the slope of the trend line of spring mean temperature for 1900–41 (°C year^{-1}).

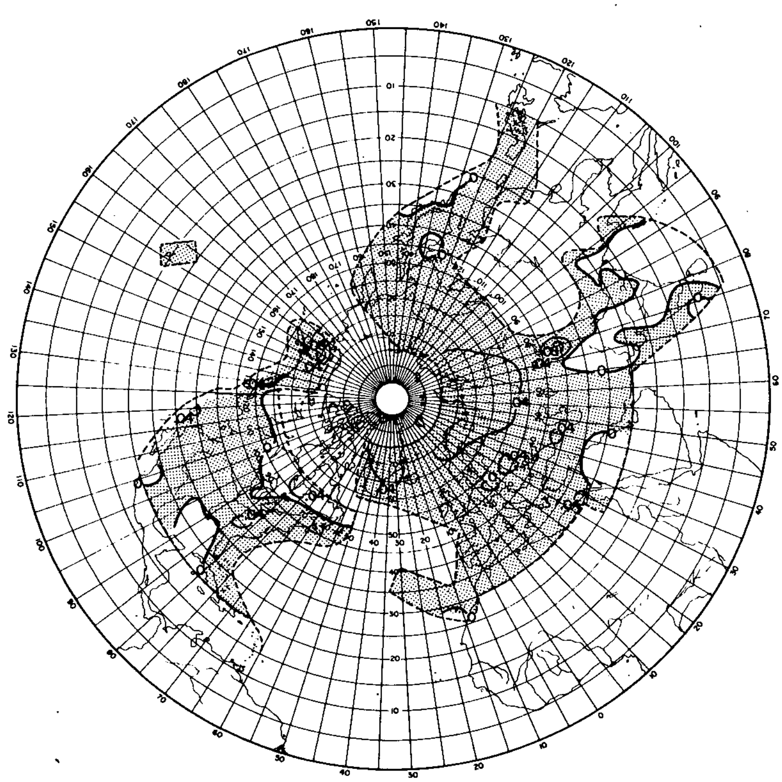

FIG. 2. As in Fig. 1 except for autumn.

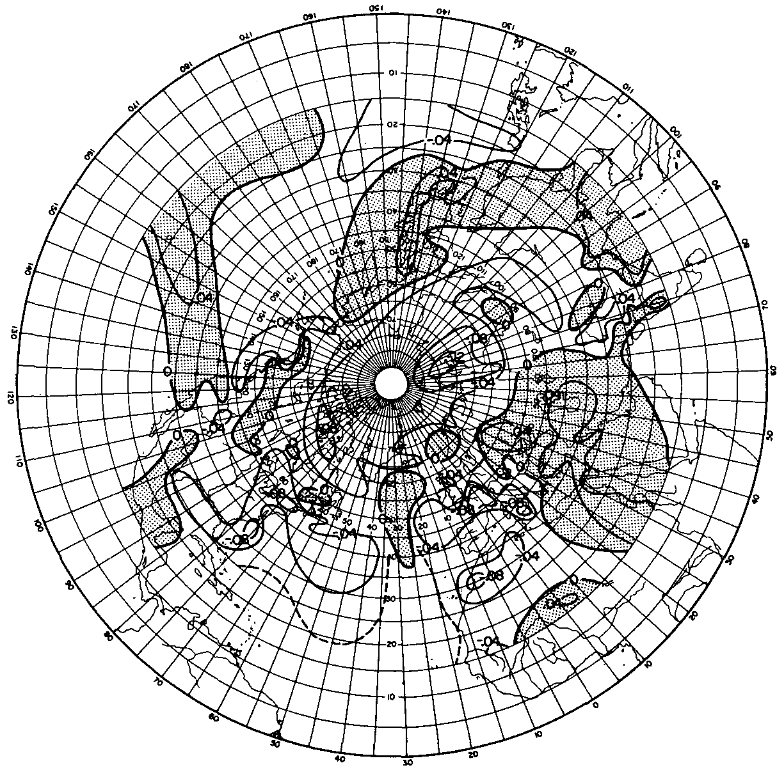

FIG. 3. As in Fig. 1 except for 1942–72.

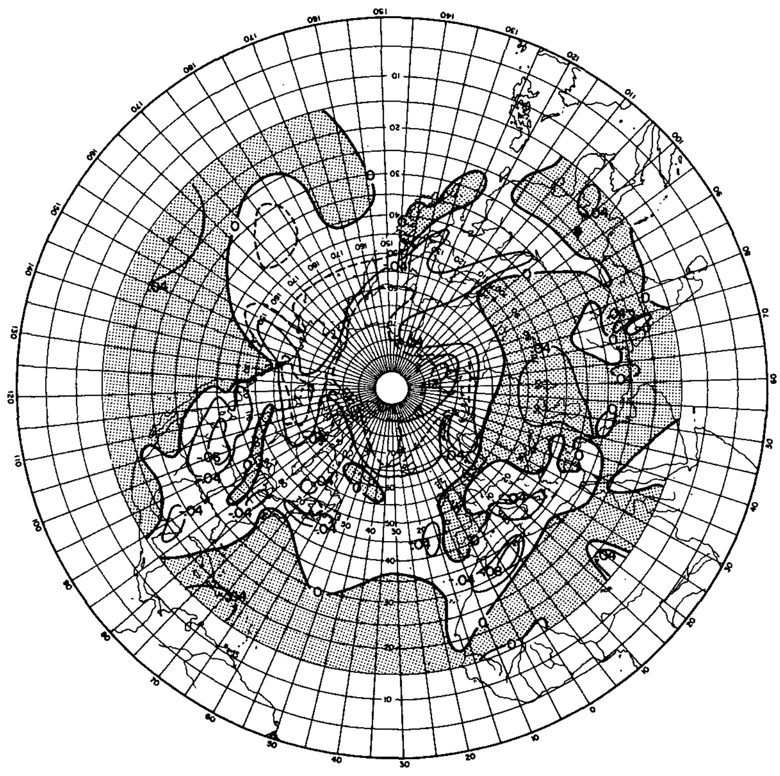

FIG. 4. As in Fig. 1 except for autumn 1942–72.

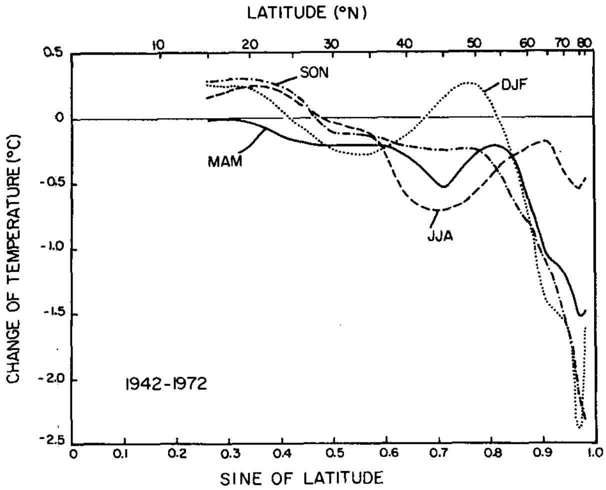

FIG. 5. Meridional profile of the change in each season from 1942 to 1972 of zonal mean temperature (°C) in 31 years. Computed from Figs. 3 and 5 and from van Loon and Williams (1976a, b).

South Pole could counterbalance the −0.26°C. Since data for the Southern Hemisphere are sparse we cannot compute a hemispheric change.[3]

[3] There was warming in New Zealand (Salinger and Gunn, 1975), Australia (Tucker, 1975) and some of the Antarctic (Damon and Kunen, 1976) in recent decades, but cooling in other parts of the hemisphere.

TABLE 1. Average temperature change 15°–80°N during the period 1942–72

Winter	−0.21°C
Summer	−0.19°C
Spring	−0.36°C
Autumn	−0.29°C
Year	−0.26°C

As described in vLWa, we divided the temperature and pressure records into overlapping 15-year periods of which one, 1950–64, has been examined for the winter and summer seasons. Fig. 6 shows the distribution of the temperature trend for the period 1950–64 in spring. In general there was an upward trend in low latitudes and a downward trend in high latitudes. The largest changes were over arctic Canada, where the maximum was −0.5°C year^{-1} for the 15-year period. The trends in autumn for 1950–64 are shown in Fig. 7, they were much smaller than those in winter for the same period (cf. vLWa, Fig. 5).

The zonally averaged temperature changes for each season for 1950–64 are shown in Fig. 8. It is clear that the zonally averaged change during this 15-year period was different in the different seasons. Between 50° and 70°N the winter temperatures rose greatly, whereas temperatures in other seasons fell or showed only a small rise. Since for this period and latitude

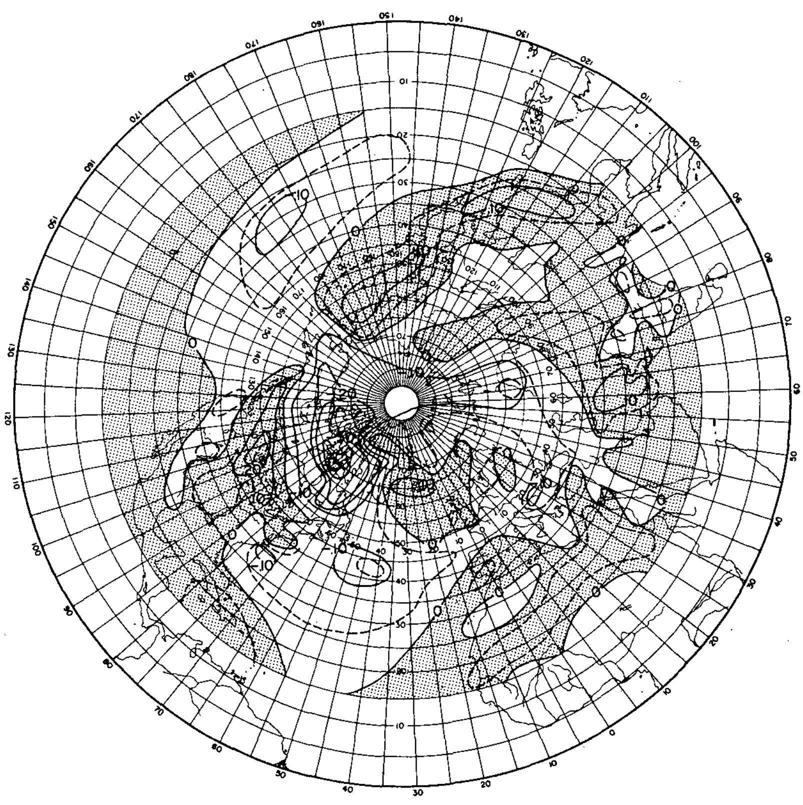

FIG. 6. As in Fig. 1 except for spring 1950–64.

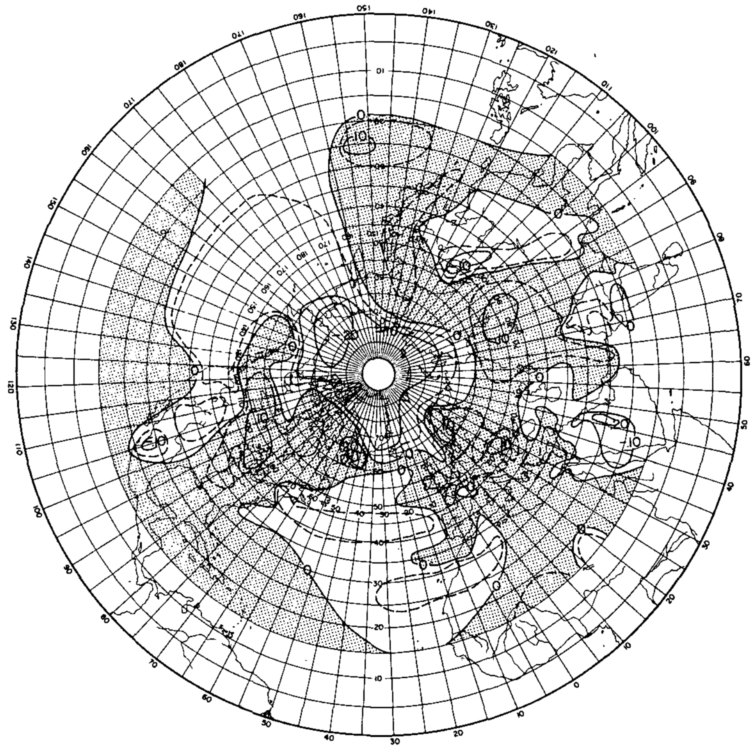

FIG. 7. As in Fig. 1 except for autumn 1950–64.

belt the data coverage is good, the different trends in the four seasons are well established.

The temperature changes for 1950–64 between 15° and 80°N are listed in Table 2; as in Table 1 the averages are area weighted. Winter, because of the marked warming between 50° and 70°N, had an average warming, whereas the other seasons had a temperature decrease. The values in Table 2 can be combined to give a change of the annual temperature for the period 1950–64 of +0.03°C. Such a small value is not likely to be accurate and can only be taken as an indication of little or no overall trend in annual temperature for the zone between 15° and 80°N during 1950–64.

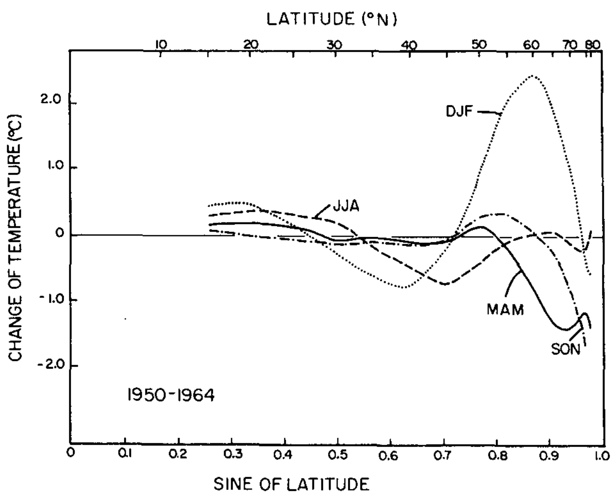

FIG. 8. As in Fig. 5 except for 1950–64.

3. The zonal harmonic waves

As in winter and summer there was no single wave or combination of waves in which the pressure pattern preferably changed. Within a 15-year period, the wave that explains most of the variance in the pressure trends differs between seasons. For example, in the period 1950–64, waves 1 and 4 explain most of the variance in the pressure trend in spring, wave 2 in summer, wave 2 in autumn and wave 3 in winter. The variance explained by wavenumbers >4 appears to be larger in spring and autumn than in winter. The mean waves themselves are smaller in the transition seasons than in winter; at 55°N the waves in spring and autumn are about one-half of their size in winter.

TABLE 2. Average temperature change 15°–80°N during the period 1950–64.

Winter	+0.39°C
Summer	−0.04°C
Spring	−0.22°C
Autumn	−0.10°C
Year	~0.0°C

4. Discussion

The temperature trends and their relation to circulation changes at the surface have now been examined for all four seasons. For the period 1900–41 the trend over most of the continents in the Northern Hemisphere was upward in all seasons. During the period 1942–72 spring and autumn had a characteristic in common with winter: the negative sign of the weighted temperature change for 15°–80°N was influenced mainly by the temperature change in high latitudes. Each of the four seasons had a different distribution of zonally averaged temperature change.

The *global* temperature trends remain uncertain because of lack of data in the tropics and Southern Hemisphere.

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