A Diagnostic Study of the Tropospheric Sudden Warming over Alaska during Winter Seasons

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1. INTRODUCTION

In winter seasons, drastic temperature rise exceeding 30K within 10 days sometimes occurs over Alaska. These phenomena are not only confined to near the surface but also extended throughout the troposphere, so we may call it "tropospheric sudden warming". The horizontal scale of the sudden warming extends several thousand kilometers, and vertically it extends throughout the troposphere.

In the case of a winter 1988/89 (see Fig.1), minimum surface air temperature (227K) was recorded in late January, then temperature increased rapidly to the maximum (274K) 12 days later. At the same time, strong blocking high was formed, and large-scale circulation had changed due to the blocking high dominated at the North Pacific. An intense surface anticyclone developed over Alaska associated with the blocking high. The principal forcing in the anticyclogenesis is the vorticity advection and the differential thermal advection (Tan and Curry, 1993).

A heat budget analysis for this episode indicates that a strong adiabatic warming due to large-scale descending motion occurs in the early stage of the sudden warming. After that, the warm advection associated with the formation of blocking takes place over Alaska (Tanaka and Milkovich, 1990). According to the investigation of the same episode using an isentropic Ertel's potential vorticity, Hayasaki (1994) suggests that the sudden warming is related to the explosive cyclogenesis deepening over the east offshore of Japan.

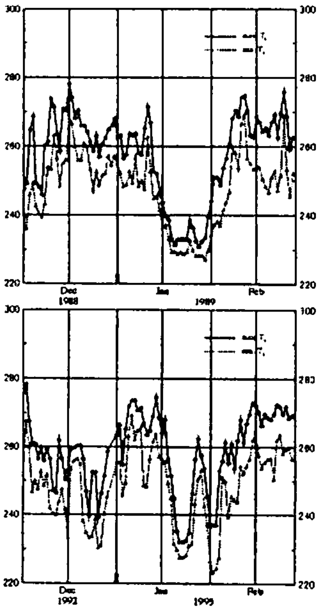

Figure 1: Time series of daily maximum (solid line) and minimum (dashed line) temperatures in Fairbanks (64.8°N,147.9°W). Periods are 1 December 1988 through 28 February 1989 (top) and 1 December 1992 through 28 February 1993 (bottom).

The primary purpose of this study is to find other sudden warming events over Alaska and to investigate the characteristics of the mechanisms about tropospheric sudden warming.

2. DATA AND METHODOLOGY

We obtained the ECMWF-TOGA grid-point global analysis data for December 1985 through February 1994 from National Center for Atmospheric Research (NCAR). The dataset contains twice-daily (0000 and 1200UTC) meteorological variables of horizontal wind, vertical p-velocity (ω), temperature, and geopotential height on the 2.5°×2.5° grids at all standard levels from 1000hPa to 50hPa.

The surface air temperature data is obtained from Alaska Climate Research Center. This data consists of the time series of daily maximum and minimum temperatures in Fairbanks (147.8°W, 64.7°N, station height is 138m) from January 1940 through December 1994. We define a daily mean temperature as an average of the maximum and minimum temperatures. We define a tropospheric sudden warming event as a temperature increase more than 30K within 10 days using the daily mean temperature.

3. RESULTS

The intensity of sudden warming and its seasonal variability is shown in Fig. 2. There are 52 cases in which the surface air temperature increased more than 30K within 10 days in Fairbanks during last 55 years (from 1940 to 1994). The warming frequently occurs from late November through April, particularly during the winter (DJF). The ratio of sudden warming events during DJF period exceed 86 % in the all cases.

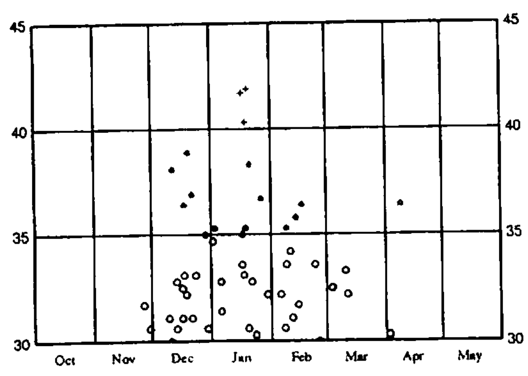

Figure 2: The intensity of the observed sudden warming represented by its temperature increase of 30 ∼ 35K : ∘, 35 ∼ 40K : •, 40K ≥ : +, within 10 days

Table. 1 lists the sudden warming events which are detected by the temperature time series in Fairbanks during the last decade. There are few cases in which no sudden warming occurs throughout a year. Namely, sudden warming event is not necessarily observed in Fairbanks every years.

year	date	ΔT (K)	periods (days)
86	—	—	—
87	87.01.19	30.6	7
88	—	—	—
89	88.12.16	31.1	9
	89.02.08	33.6	9
90	—	—	—
91	90.12.21	31.1	5
	91.01.20	38.3	6
	91.02.14	31.7	7
92	—	—	—
93	93.01.05	32.8	10
	93.02.11	31.1	9
94	—	—	—

Table 1: The date of the sudden warming (when the maximum temperature is recorded) and its magnitude. Values of ΔT indicate the difference between minimum and maximum temperatures. Periods show the terms of days from the minimum to the maximum.

The time-height section of potential temperature over Alaska in winter 1993 is illustrated in Fig. 3. It is shown that the temperature increases at the surface when the surface of 300K isentrope drops from 300hPa to 600hPa. In a high latitude, the tropopause is located at about 300hPa. So, the vertical scale of the sudden warming extends from the surface to nearly the tropopause level.

Figure. 4 represents the distribution of difference of minimum and maximum temperatures at the 700hPa level within 15 days at the beginning of February 1993. The horizontal extension of the +10K contour encloses an area of 50–80°N and 160°E–120°W.

The time-height section of the vertical p-velocity (ω) over Alaska during 15 January

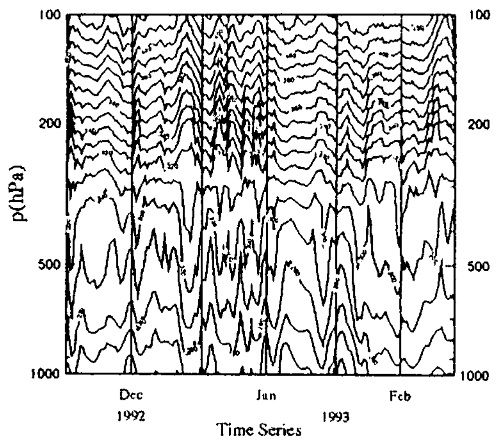

Figure 3: Time-height section of potential temperature over Alaska during 1 December 1992 through 28 February 1993.

through 16 February 1993 are illustrated in Fig. 5. It is shown that ω is negative throughout the troposphere before the occurrence of the minimum temperature (2 February) recorded at the surface. Then ω becomes positive soon after the minimum value is recorded. The maximum positive ω appears at the 400 $\sim$ 500hPa level, and the strong descending motion continues for 2 days (3 $\sim$ 4 February). After that, noticeable features of ω profiles are not find. These ω variation are also found in other sudden warming events (not shown).

Figure. 6 exhibits the distribution of strong descending motion at the 500hPa level during late January through early February in 1993. As can be seen in Fig. 6, the area of strong descending motion moves eastward from east offshore of Japan toward North Pacific. The maximum value reaches 0.6Pas^{-1}, and its area moves to interior Alaska. At the same time, the surface air temperature increases rapidly.

4. SUMMARY AND CONCLUSION

The drastic air temperature increase at the surface is often observed over Alaska during winter seasons. We find 52 cases by using time series of the daily minimum and maximum temperatures in Fairbanks. The drastic temperature changes occur mostly in winter (DJF). But

Figure 4: Distribution of temperature difference at the 700hPa level between the 5-day means for 30 January through 3 February (before the temperature increase) and 14-18 February (after the temperature increased) in 1993. The contour interval is 2K.

these phenomena are not observed every year.

In the winter seasons during the last decade of December 1985 through February 1994, we find 8 cases in which temperature has increased more than 30K within 10 days. In this study, we have focussed on these cases using ECMWF global analysis.

The time-height section of potential temperature over Alaska exhibits that the descending isentropes in the upper troposphere and the temperature increased at the surface occurs simultaneously. Therefore, the vertical scale of the warming extends over the entire troposphere.

The horizontal temperature change indicates that these phenomena are not confined within a local scale. The horizontal extension reaches several thousand kilometers. Therefore, these phenomena are not explained only by the local Foehn.

The time-height section of ω and its horizontal distribution indicate that the temperature change at the early stage seems to have caused by a strong descending motion. This re-

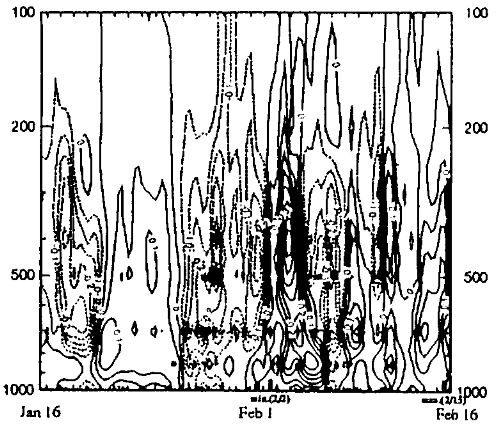

Figure 5: Time-height section of vertical p-velocity (ω) over Alaska (contour interval : $0.05 \mathrm{Pas}^{-1}$) in 1993. Positive numbers (solid line) denote descending motion and negative (dashed line) numbers denote ascending motion.

sult is similar to that in the winter 1989 and other several cases. As a matter of course, warm advection associated with the southerly flow also contributed to the drastic temperature increase (Colucci, 1985). But descending motion plays an important role in the increase of surface air temperature at the early phase.

The blocking anticyclones occur frequently in high latitudes near Alaska and the North Atlantic. In this study, we have focussed only the region around Alaska. More investigation is necessary for other sudden warming events at other places to understand the mechanisms of the tropospheric sudden warming.

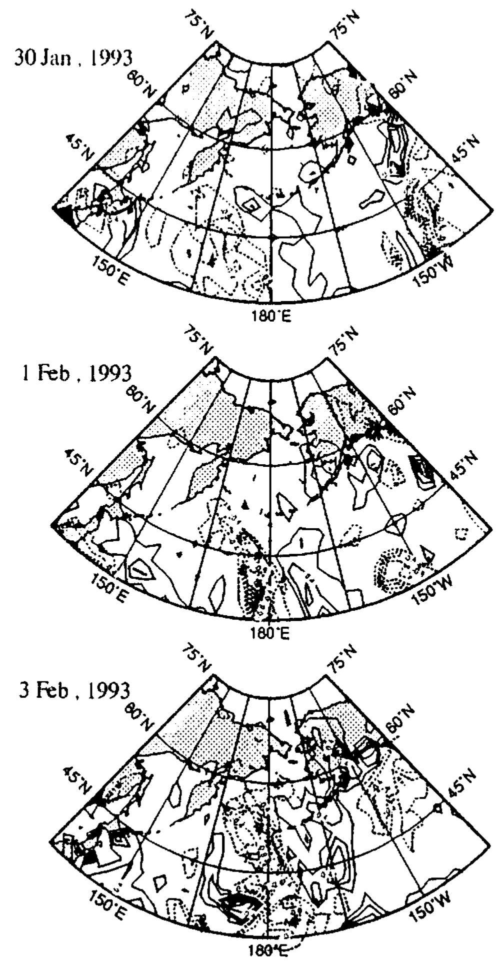

Figure 6: Distributions of 500hPa vertical p-velocities (ω) (contour interval : $0.2 \mathrm{Pas}^{-1}$). Dashed contours correspond to negative numbers and solid contours positive.

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