Two Modes in the Recent Lower-Tropospheric Warming in the Northern Hemisphere

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1. INTRODUCTION

The greenhouse gases, i.e., CO2, CH4 etc., have steadily been increasing due to the human activity. The potential of the global warming due to the enhanced greenhouse effect has been noted particularly in recent years. The atmospheric GCM experiments with doubling CO2 concentration have suggested the considerable increase of tropospheric temperature particularly in the high latitudes (IPCC, 1990; 1992). The transient response experiments by some coupled atmosphere-ocean GCMs with increasing CO2 of the current rate have predicted the global surface temperature increase of 1 to 2 degrees in 2050. In the real climate system, the global and hemispheric surface air temperature have shown an apparent increasing trend in the past 100-year record, though the overall features in time change and spatial pattern of this increasing trend are somewhat different from those predicted by the GCM experiments.

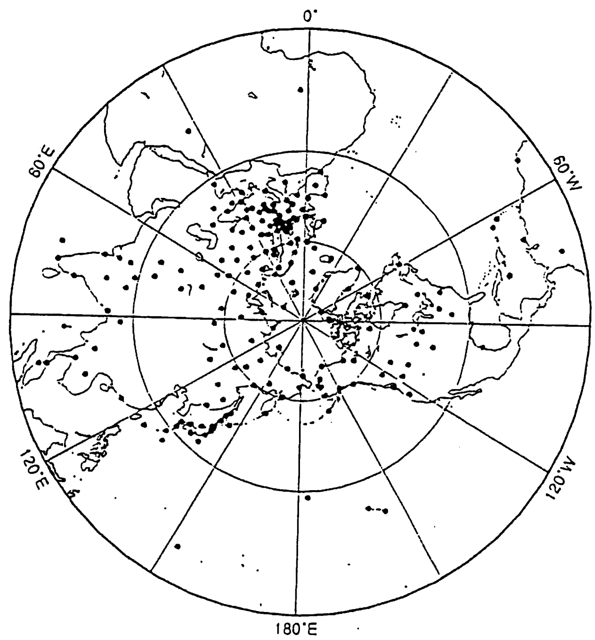

Figure 1. Distribution of radiosonde stations used for this study.

To detect the temperature increase due to the increasing greenhouse effect, the tropospheric temperature particularly in the lower part should be examined, rather than the surface air temperature. The surface air temperature, in addition, is more or less affected by local effects, e.g., urbanization, location changes of stations etc. However, few studies have so far attempted to detect the global or hemispheric temperature change in the troposphere due to smaller number of available stations with shorter-period data coverage compared to the surface temperature data (e.g., Angell et al., 1988; Oort and Liu, 1993). Very recently, Spencer and Cristy (1992) examined changes in the global as well as hemispheric mean tropospheric temperature averaged with homogeneously retrieved from the MSU micro-wave channels of Nimbus satellites. This satellite-derived temperature field has a great advantage in the spatial homogeneity for the whole globe, though the data covers relatively short period of the recent 15 years or so. This new data set has shown no remarkable trend except large interannual variability related basically to ENSO cycle.

In this paper, the seasonal (3-month) mean

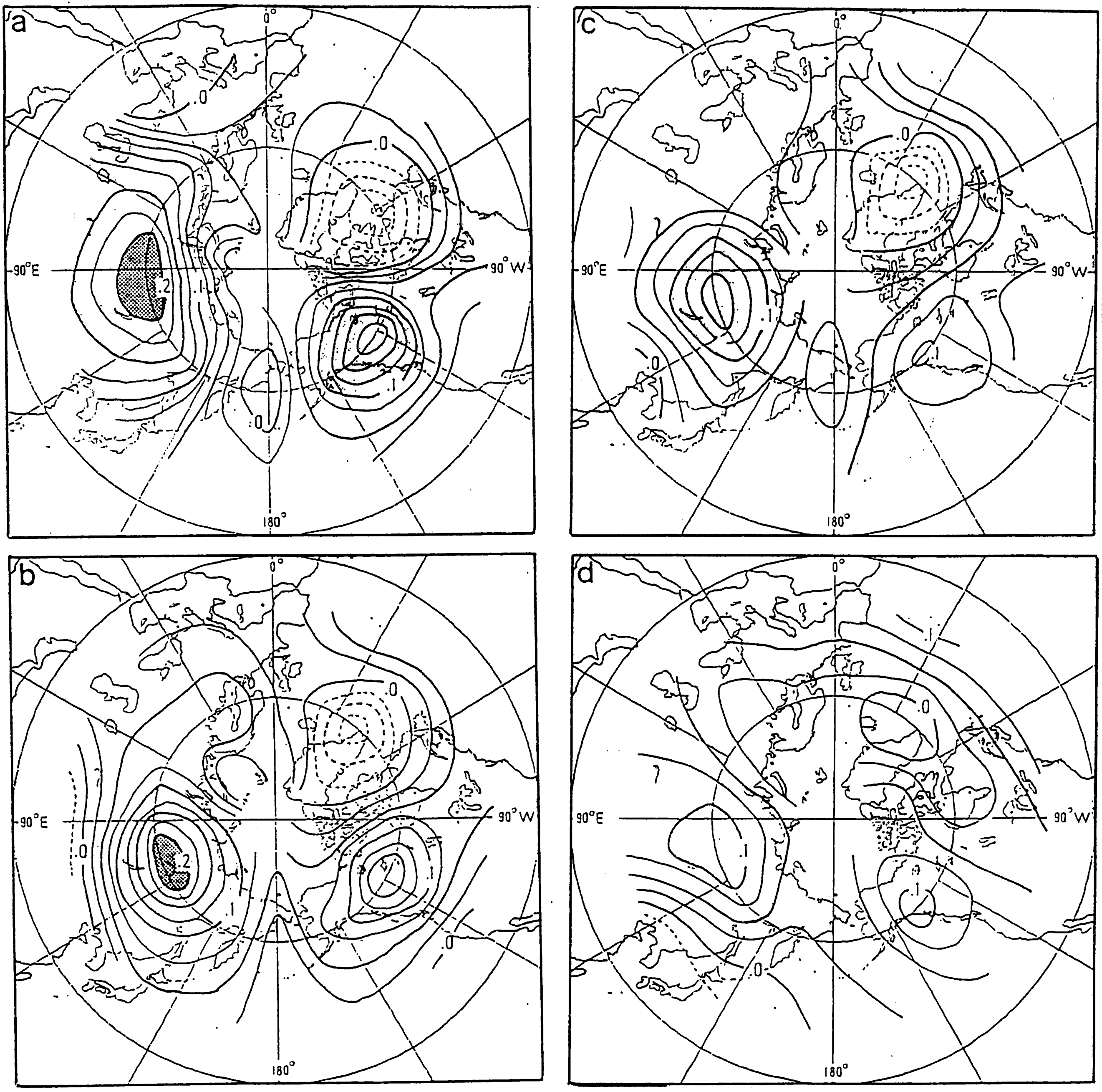

Figure 2. Spatial pattern (eigen vectors) of each vertical level (a-d: surface, 850, 700, and 500 hPa) for the first component of the EOF analysis. (Yasunari and Mito, 1995)

air temperature in the lower troposphere (850, 700, 500 hPa) in the Northern Hemisphere were analyzed from the upper air station data for the 30 years (1964-1993) to detect the recent temperature trend and/or interdecadal-scale variations. The vertical as well as spatial structure of temperature variations are scrutinized, which might explain possible forcing factors of these trends and variations.

2. DATA

The monthly mean temperature at 850, 700, and 500 hPa level were selected from the monthly rawinsonde observation data (RAOB) in the Northern Hemisphere to cover the recent 30 years from 1964 to 1993 as continuously as possible with few missing data. Finally, 181

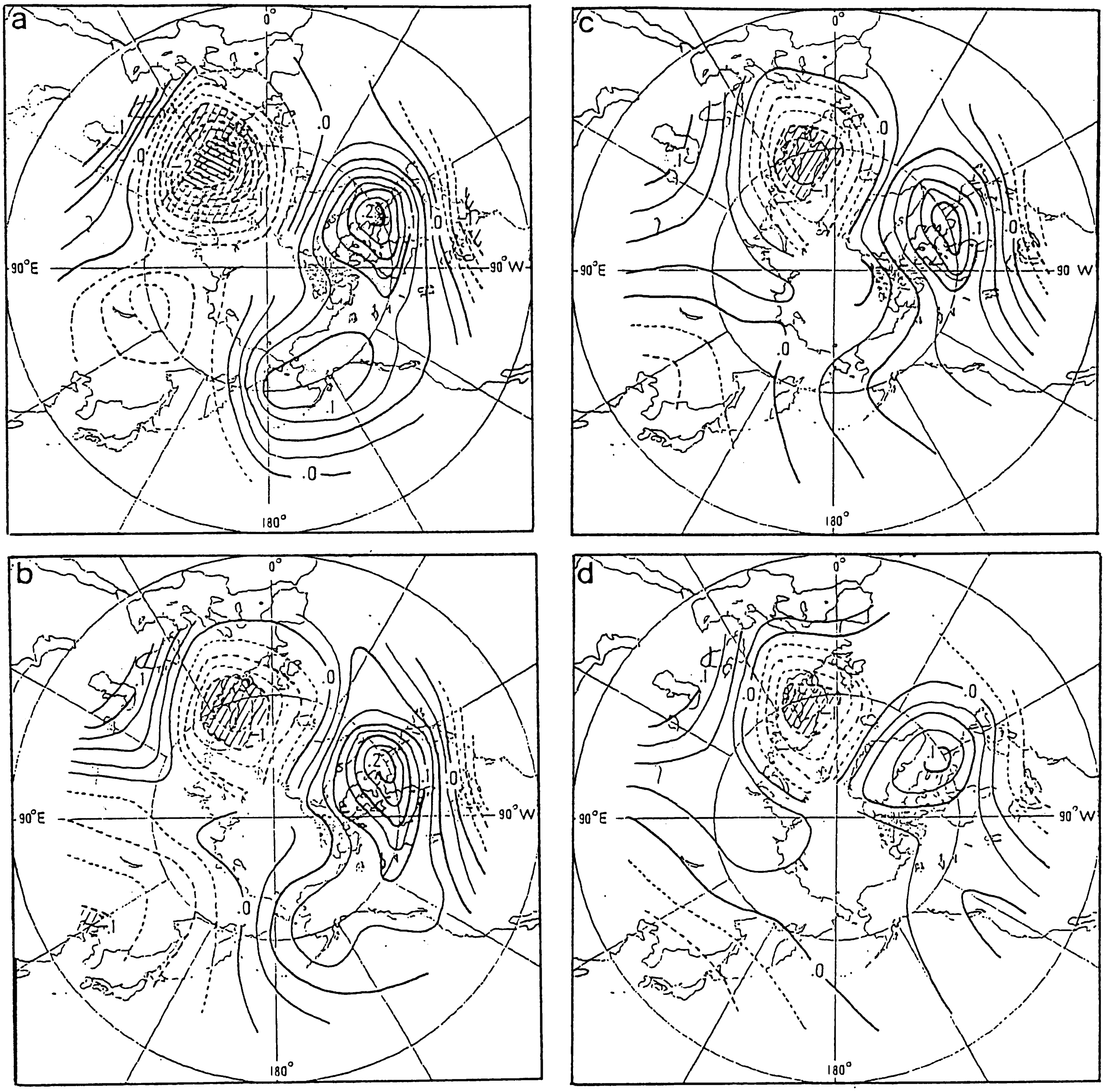

Figure 3. Same as Fig. 2, but for the second component of the EOF analysis.

stations were selected which satisfied this condition. The land-based gridded monthly surface air temperature compiled by Jones (1993) was also used. These data sets were adopted mainly from the GEDEX CD-ROM (the year 1992 version) produced at NASA, and additionally from Monthly Climatic Data for the World. The monthly mean data were averaged to seasonal (3 month) mean value for each season of the year. The distribution of stations used in this study is shown in Figure 1.

3. THREE-DIMENSIONAL MODES OF TREND AND DECADAL-SCALE FLUCTUATION

To deduce dominant modes of trend and decadal-scale temperature fluctuation with their vertical structures, the EOF (Empirical Orthogonal Function) analysis is applied to the the three-dimensional gridded temperature at the four vertical levels between 30°N to 80°N. To focus on the decadal-scale fluctuation or longer, the original data was low-pass filtered by operating 5-year moving average. The gridded data was produced by interpolating the original station data to every 20°x 20°latitude/ longitude grids. The grids where the original station data are sparse (i.e., ocean areas) are not included in this analysis. As a total, 42 gridded data was obtained at one level for each year, distributed mainly over the continents.

Figure 2 shows the spatial pattern (eigen vectors) of each vertical level for the first component, which occupies about 42% of the total variance. A center of anomalous heating in winter at the surface and the lower troposphere has been found to be located over eastern Siberia (Lena River basin). Another center of the anomalous heating is likely to exist over the northern Pacific and the northwestern part of North America, with the maximum amplitude in the mid troposphere (700-500 hPa).

Figure 3 shows the spatial pattern of each vertical level for the second component, which occupies about 28% of the total variance. This pattern shows a dipole pattern over the western hemisphere with a positive center over northeast North America and a negative center over Greenland/northernmost Atlantic region. The spatial pattern of each vertical level shows a very similar feature with nearly the same amplitudes, which strongly suggests that this component exhibits a barotropic mode of temperature fluctuation in the troposphere.

The time series (scores) of these two components are shown in Figure 4. The first component shows a remarkable increasing trend with some minor decadal-scale undulation, which implies that the tropospheric temperature over the area of positive anomalies (as shown in Fig. 2) centered over Siberia has been more or less monotonously increasing throughout the recent 30 years, with larger amplitudes at the surface and the lower troposphere.

The second component, by contrast, shows

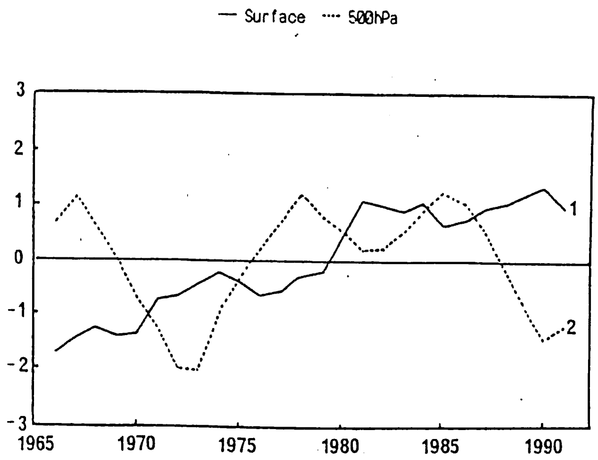

Figure 4. Time series of the two components.

a interdecadal scale fluctuation with a rapid increasing phase in late 1970's and a decreasing phase after late 1980's. This implies that the temperature particularly over north America through the north Atlantic region has considerably been modulated by this interdecadal scale fluctuation throughout the troposphere, with relatively high (low) anomalies in late 1970's through 1980's over Alaska/Arctic Canada (Greenland/north Atlantic).

4. POSSIBLE FORCING FACTORS OF THE DOMINANT MODES

These two modes might be related to the different feedback processes in the climate system. The first mode shows more or less monotonously increasing trend, which suggests us to be more closely related to the effect of the anthropogenic greenhouse gas increase, with some feedbacks in the cryosphere (snow cover and/or permafrost), as has been suggested by Groisman et al. (1994). The snow cover fluctuation over the Northern Hemisphere and Eurasia, in fact, shows a close association to the first component. The other mode is likely to be more directly associated with a atmospheric response of the decadal-scale sea surface temperature changes in the equatorial Pacific (Nitta and Yamada, 1989). A similar association has been noted in the decadal scale SST change and the second component.

5. CONCLUSIONS

The three-dimensional EOF analysis was conducted for the lower tropospheric temperature in the Northern Hemisphere for 30 years from 1964 to 1993, to detect the long-term fluctuation of tropospheric temperature, including the trend and decadal-scale fluctuation. The result for 5-year moving average data has shown that the most dominant mode is a monotonously increasing trend centered over Siberia. This mode has largest amplitude at and near surface level. Another mode is also found which has an interdecadal scale fluctuation, with a dipole structure over north America through the north Atlantic sector. These two modes are suggested to be associated with the recent cryosphere change over the continents and SST change in the equatorial Pacific/Indian Oceans. Further details will be discussed in Yasunari et al. (1995)

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