3.11 THE CLIMATE CHANGE IN THE WESTERN ARCTIC DURING THE LAST TWO DECADES

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1. INTRODUCTION

Much of the recent work on Arctic climate variability has focused on the winter period (Thompson and Wallace 1998; Monahan et al. 2000). But at least in the western Arctic, here defined as the region extending from eastern Siberia across Alaska to northern Canada, many striking changes in surface conditions have occurred in the spring. Based on NCEP/NCAR Reanalysis, supplemented by the TOVS Path-P data set, this warming is shown as a recent increase in the frequency of warm months at 925 hPa, compared to the previous four decades. The primary difference between four notably warm springs in the 1990s and four cold springs in the 1980s was the sense of the horizontal advection term in a lower-tropospheric heat budget for northern Alaska/southern Beaufort Sea. While the horizontal advection of heat was highly episodic, it was related to changes in the mean circulation at low-levels, in particular a shift from anomalous northeasterly flow in the 1980s to anomalous southwesterly flow in the 1990s during March and April. This change in the low-level circulation was coincident with cooling in the lower stratosphere and strengthening of the polar vortex, in association with a systematic shift in the Arctic Oscillation (AO) near the end of the 1980s. This shift in the AO had its greatest amplitude at the end of winter in March, and had its greatest impact on lower-tropospheric temperatures over the western Arctic in April. While there were substantial decadal differences, there was also considerable month to month and year to year variability within the last two decades.

2. DATA SETS

We make use of two hemispheric data sets. The first is the NCEP/NCAR Reanalysis, which provides a full suite of atmospheric parameters on a 2.5-degree grid from 1948 to present. There is good coverage of rawinsonde data along the Arctic coast for assimilation into the Reanalysis. The second is the TOVS Path-P data set, which provides temperature and humidity analyses north of 60°N on a 100 x 100 km^2 grid for the period 1979 –1998. The TOVS Path-P data set is based on satellite-measured radiances that provide relatively good horizontal resolution in the central Arctic, but with some uncertainties in calibration. We adjusted the TOVS temperature data at each level for each satellite period before 1986 when there are no corrected DELTAs calculated in a conservative manner. The end result is that TOVS Path-P temperature is consistent with those from the Reanalysis, which indicates that diagnostic calculations from the Reanalysis for the Arctic are reasonably robust.

3. RESULTS

The decadal-scale variability in western Arctic temperatures is illustrated in Fig. 1 using data from the Reanalysis at grid points near Barrow, Alaska (72.5°N, 157.5°W) and Eureka, Canada (80°N, 85°W). Values are anomalies from the 1948–1999 monthly means. Our base decade is 1989–1998 because of a prominent shift in the Arctic Oscillation in 1989, so that 1989 groups with the 1990s. The bottom panels show the decadal averaged temperature anomalies for each month at the 925 hPa level for the 1950s through the 1990s. The top panels show their counterparts at the 200 hPa level in the lower stratosphere. Values at 200 hPa are qualitatively similar to other stratospheric levels. Values at 925 hPa are similar, but stronger than anomalies at higher tropospheric levels.

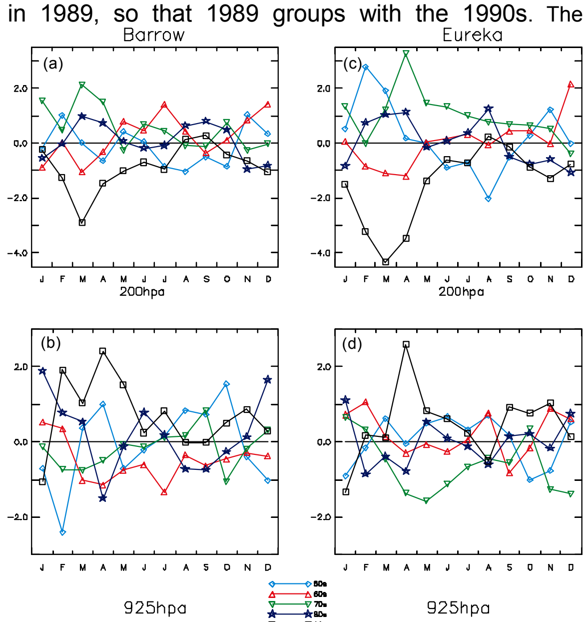

Fig. 1 The monthly temperature anomaly averaged over each decade from 1950s to 1990s at the closest grid point from Barrow, Alaska (a and b), and Eureka, Canada (c and d) based on NCEP/NCAR reanalysis at 200 hPa (top) and at 925 hPa (bottom).

At the 925 hPa level, prominent warm anomalies occurred during the 1990s at Barrow through the entire spring and at Eureka during April. The magnitudes of these anomalies for April in the 1990s are greater than the magnitude of the anomalies in any other month of any other decade.

The springs of the 1960s through 1980s tended to be relatively cold at both stations. In particular, the 925 hPa temperature anomalies in the middle of winter (Dec. to Feb.), on the whole, were actually positive in the 1980s and near zero in the 1990s at Barrow.

Lower stratospheric temperatures, as indicated by the 200 hPa temperature anomalies in Fig. 1, were relatively cool during spring in the 1990s, especially in March. Spring temperatures were relatively warm in the 1970s, and to a lesser extent, in the 1980s. This time of year is also when the zonal winds at Barrow had their greatest positive (westerly) anomalies at 200 and 925 hPa during the 1990s (not shown) It is clear that spring, on the whole, was colder aloft and warmer near the surface in the 1990s than in previous decades. Our further study shows that the 1990s were cold as a whole in the lower stratosphere because of the increased frequency of cold years. Similarly, the warm period of the 1970s through the mid-1980s is largely due to a preponderance of warm years, rather than due to an increase in the magnitudes of the anomalies in the warm years. The interannual fluctuations at 925 hPa have the same nature as those aloft. In particular, in April during most years in the 1980s (1990s) the 925 hPa temperature anomalies were negative (positive).

The heat budget results for the Barrow region for the selected years in 1980s and 1990s show that the horizontal advection term acted to cool in the 1980s and to warm in the 1990s; this change was largely compensated for by changes in the vertical advection term and to a lesser extent, the residual term. The fundamental difference between cold and warm years relates to the sense, number, and intensity of episodic horizontal temperature advection events. The preponderance of cold advection events during the selected years in the 1980s versus warm advection events in the 1990s in the vicinity of Barrow can be attributed to differences in the mean circulation during the two periods. Fig. 2 shows the 925 hPa geopotential height anomaly maps for two groups of years during March/April. The 1980s (including 1980, 1982, 1984 & 1987) included anomalously high pressure centered over the Barents Sea extending across the eastern Arctic, and hence also anomalous northeasterly low-level flow around Barrow, while the 1990s (1990, 1993, 1995 & 1997) included relatively low pressures over the central Arctic and high pressures south of Bering Strait and hence a greater tendency for southwesterly low-level flow over Barrow.

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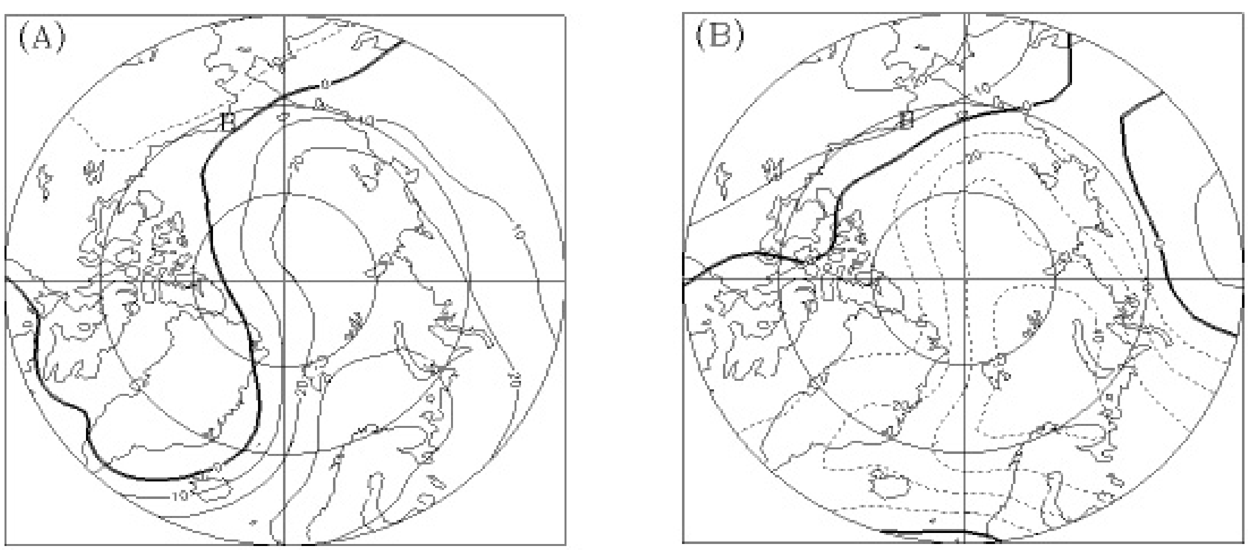

80s 90s

Fig. 2 The monthly mean geopotential height anomalies averaged over March and April from the composite 4 years: (A) 1980, 1982, 1984, and 1987, (B) 1990, 1993, 1995 and 1997. The data are from NCEP/NCAR reanalysis. Letter B inside figure indicates the location of Barrow, Alaska.