5A.9 FALL WARMING EVENTS ON THE ARCTIC SLOPE OF ALASKA

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1. INTRODUCTION

The Arctic Slope of Alaska, is generally defined as that portion of Alaska north of the crest of the Brooks Range. This region, with an area over 230,000 km^2, is one of the least-understood climatic regions of the United States and is certainly the most sparsely populated. At the same time, the production of petroleum along Alaska's Arctic coast is a multi-billion dollar-per-year industry.

Olsson et. al. (2001) conducted a climatology of five years (1994-1998) of continuous surface meteorological data taken along a transect from near Prudhoe Bay on the Arctic Coast to the foothills of the Brooks Range. These unmanned remote sites, operated as part of the NSF LAII/ATLAS program made possible one of the first studies to analyze contemporary multi-year cold season measurements in upland as well as coastal plain locations and to include both wind speed and direction measurements throughout the period of record.

Meteorological stations at five research sites were located in a north-south transect on Alaska's Arctic Slope along the Dalton Highway. The southernmost site was in the foothills of the Philip Smith Mountains (Brooks Range) and the northernmost site was near Betty Pingo within the Prudhoe Bay Oil Field on the Arctic Coastal Plain near the Beaufort Sea Coast.

From this study, a picture emerges of the Arctic Slope as a region dominated by subfreezing temperatures for most of the annual cycle, the brief warm and snow-free season in June, July and August even shorter than that of Arctic Alaska south of the Brooks Range. Figure 1 shows the averaged and temporally-smoothed annual cycle of temperatures at each of the sites. To intercompare specific meteorological events, it is instructive to consider an unsmoothed time series of daily mean temperatures for a particular season. Figure 2 shows such a plot for the period from Oct. 97 through Jan. 98. With the notable exception of the southernmost site in the Brooks Range foothills[1] (dashed line) from December onward, the temperature trends to first order are generally quite similar,

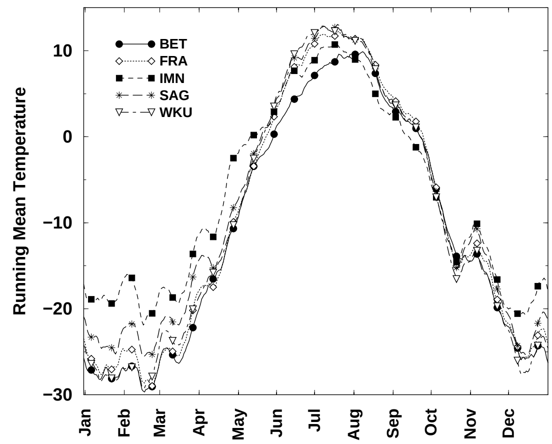

Fig. 1. Eleven-day running average mean daily temperature for the five sites over the annual cycle.

suggesting that the individual synoptic events that bring substantive temperature changes in this period occur across the entire network. These figures suggest that the five sites, while exhibiting some degree of variation from what might considered an "Arctic-Slope wide" climatology, still show a good deal of similarity in both seasonal variation and to meteorological forcing on a time scale of a few days.

2. FALL WARMING PERIODS

One of the most notable features in Fig. 2 is the dramatic warm-up at all sites seen in the second week of November. All of the non-coastal sites experienced warming to above freezing daily mean temperatures with the coastal site showing a weaker, but still discernible warming as well. From the context of the cold season snow cover, this is a significant event producing a melt crust that has important structural, mechanical and thermodynamic implications as the snow cover accumulates and evolves through the next six months. Further investigation shows that similar, if not as spectacular, thawing events occur during late October and November at most sites for each

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1. As discussed in Olsson et al. (2001) this higher elevation site becomes largely decoupled dynamically and thermodynamically from the Coastal Plains sites during the highly stable cold season

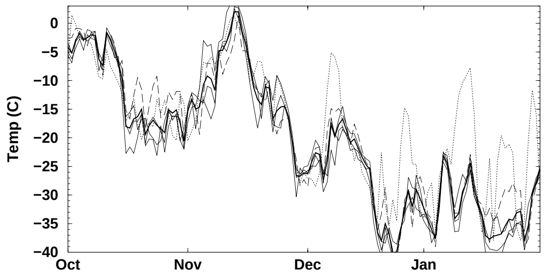

Fig. 2. Daily mean temperatures at the five sites for the period Oct. 1997 through Jan. 1998. The bold line represents the average temperature of the four northernmost sites, The dotted line is the foothills site.

of the years in the record. The timing of this warm-up, sometime between julian day 303-323 (last week in October to third week in November), is consistent enough and strong enough to appear clearly in Fig. 1 having survived both the multiple year and running average operations.

To clarify the occurrence of these events on an annual basis it is useful to consider a specific meteorological station. The SAG site was established on a hilltop near the Sagwon Bluffs (69° 25' N, 148° 45' W) approximately 100 km south of Prudhoe Bay. This site is located in a transitional zone between coastal plain and the foothills at an elevation of 370 m.

Figure 3 shows time series of daily mean temperature during the period of interest at SAG for each of the five years of record. All years show one, and sometimes two, strong warming events, with many lasting for several days. Though 1994 does not show a daily mean temperature that exceeds freezing there were several hours spanning two days that the temperature was within two degrees of freezing. The fact that many nearby locations had experienced above freezing temperatures was attested to by the widespread very hard and distinct snow stratum still quite evident at the onset of the melt season (Olsson et al. 2000).

3. SPECIFIC WARMING EVENTS

Figure 4 shows a "snapshot" of the surface and lower-tropospheric characteristics of the major warming events for the years 1995-1998 while Fig. 5 shows midtropospheric fields for the same periods. Unlike Olsson et al. (2001) which used analysis fields on a 45 km grid from the NCEP ETA forecast model for the 1997 event, the gridded data used in this study is 2.5°×2.5° NCEP Reanalysis data as the ETA fields were not available for the earlier years.

Not surprisingly, all episodes show a low-level thermal (850-1000 mb thickness) ridge and southerly flow over much of Alaska. (Thickness, rather than surface temperature is used here because it is a more robust thermal in the spatially coarse reanalysis data sets).

3.1 Oct. 30 — Nov. 1, 1995

This three day period was the earliest of the warming events in the five years of record, with 1994's very brief warming event occurring just after this time. As is common during this time of year, the surface pressure pattern is dominated by low pressure over the Bering and Chukchi Seas and a cold-core high over northern British Colombia and the Yukon, both acting in concert to provide a strong pressure gradient over western Alaska. A 500 mb ridge axis sits over eastern Alaska, extending into the Gulf. This pattern was one of the more progressive of the warming events. Cold advection is apparent at 700 mb to the surface over and south of the Aleutian Islands, acting to both weaken the ridge and propagate it eastward.

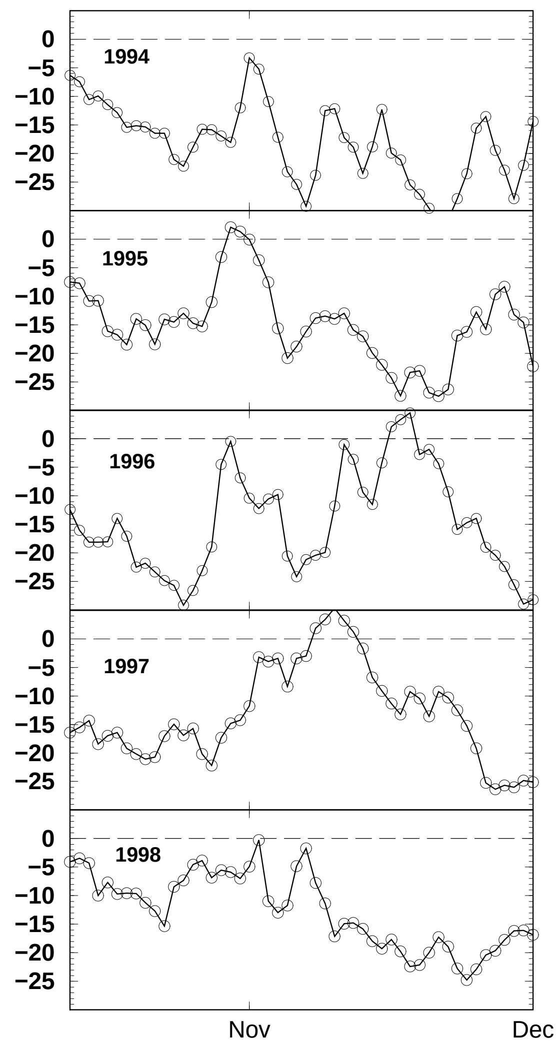

Fig. 3. Daily mean temperatures at SAG for all five years of record during the latter half of EC, showing warming/thawing events (note 0° C isotherm). Temperatures are degrees C.

3.2 Nov. 15—Nov. 18, 1996

This longer-lived event was, along with 1997, one of the stronger warming periods as well. Here the environment is more barotropic with anticyclonic circulation at low levels over all of Interior Alaska. An impressive high-amplitude ridge at 500 mb is centered over the state can with 700 mb temperatures near freezing and very little thermal advection at any level. It is interesting to note that the large-scale thermal pattern existed for a few days after temperatures dropped below freezing at SAG, a factor which emphasizes the significance of surface radiational cooling and weak winds at these latitudes to the surface thermal energy balance.

3.3 Nov. 8—Nov. 12, 1997

This was also a long-lived event. As in 1995, this synoptic situation involved a deep low in the general vicinity of the Bering Sea. In contrast to the other cases considered here however a strong gradient exists along the Alaska-Canada border. This enabled a “back-door” delivery of warm air around and over the eastern end of the Brooks Range after warm advection weakened. As in 1994 (not shown), this resulted in a strong southerly downslope wind component over SAG— factors that contributed to the strength and longevity of the observed surface warming. The midtropospheric pressure and thermal patterns in this event also closely resemble the 1995 case.

3.4 Nov 1, 1998

In this brief event, the lower tropospheric environment was more baroclinic, with a cool air tongue (lower thickness values) extending well south of the western Aleutian chain. The remnants of the surface pressure pattern responsible for the warm advection over western Alaska, again a low pressure center in the Bering Sea, is apparent in Fig. 4. By this time however, a rapidly propagating and deepening low over the

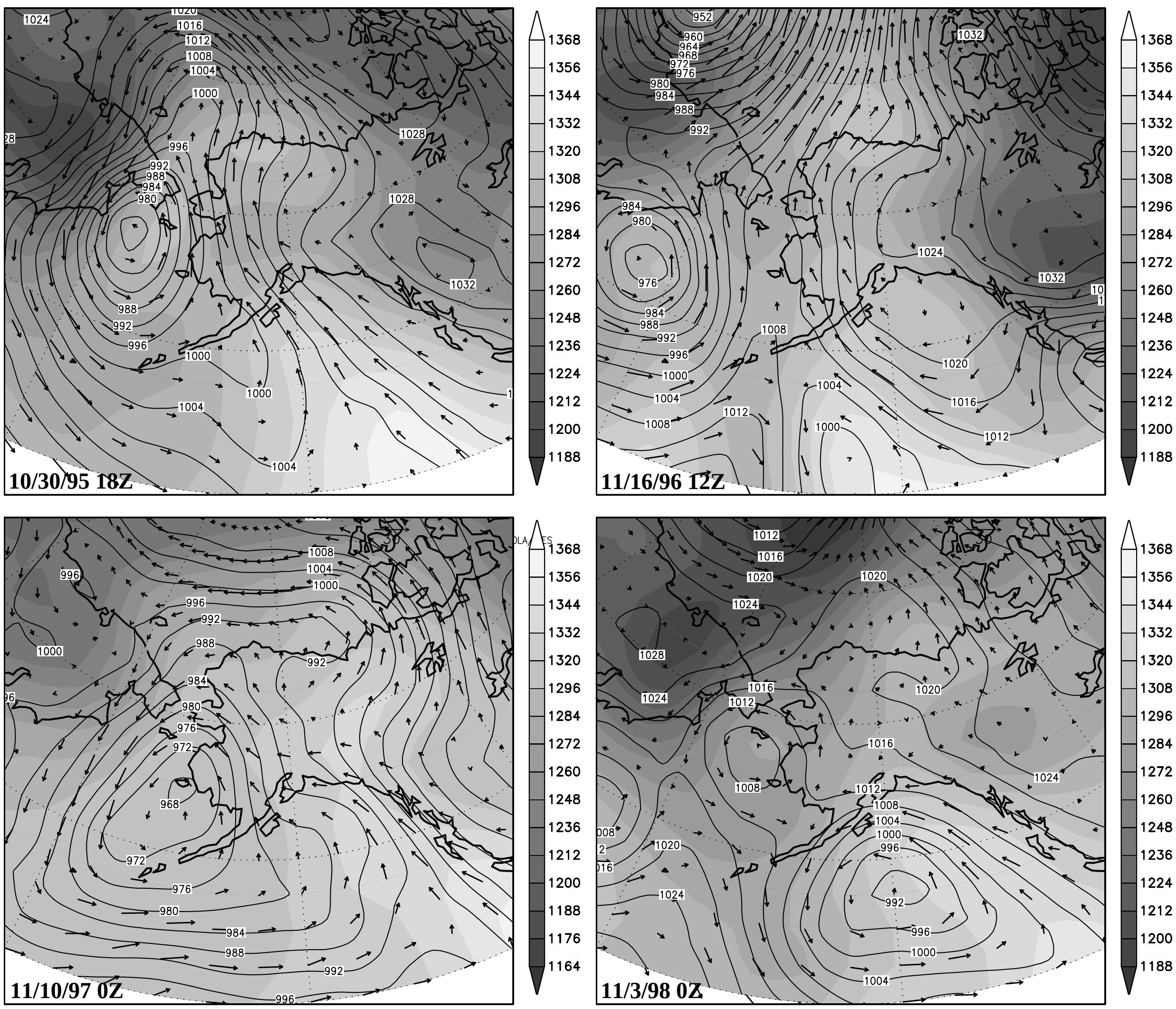

Fig. 4. Thickness of the layer between 850 mb and 1000 mb (m, shaded), mean sea-level pressure (mb, contoured) and mean wind vectors in the 850-1000 mb layer for the dates and times denoted in the panels.

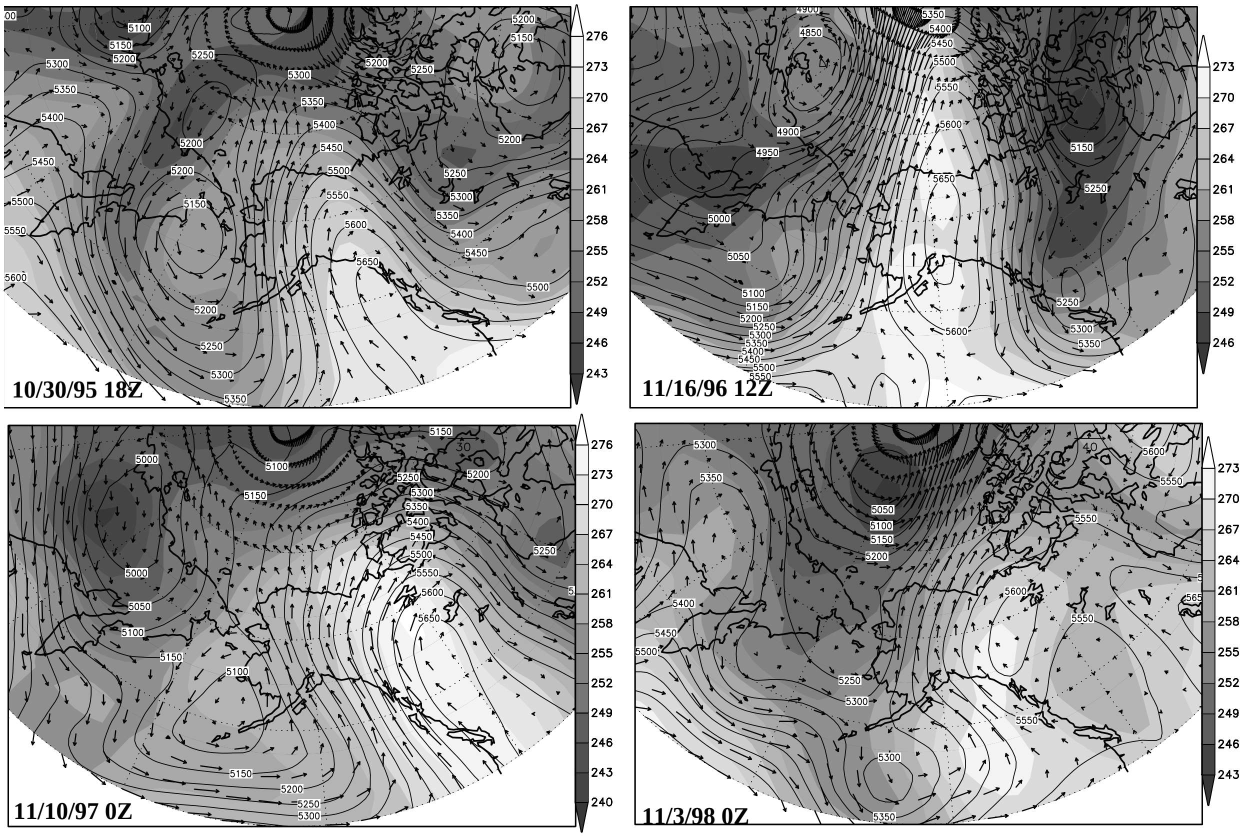

Fig. 5. Midtropospheric characteristics of the atmosphere during the early cold season for 1995-1998: 700 mb temperatures (degrees K shaded), 700 mb winds (vectors) and 500 mb geopotential heights (m, contoured). Times and dates are coincident with panels in Fig. 4

Gulf of Alaska dominated the circulation at lower levels. The NE surface flow over the Alaska Peninsula at this time was bringing cooler air south, effectively cutting off the southerly import of warm extra-tropical marine air that drives these warming events. Evidence of the more baroclinic nature of this case is also evident at higher levels with a cold core cutoff low at 500 mb and accompanying strong cold advection at 700 mb.

4. CONCLUDING REMARKS

The warming events examined here were seen to have several similar distinguishing characteristics, most notably warm low-level advection over western Alaska resulting from a low centered generally in the Bering Sea region. This occurs at a time of year where surface temperatures on the Arctic Coast are increasingly influenced by infrared radiation from the snow-covered surface in the increasingly long winter night.

Other regional factors besides horizontal advection and radiation contribute to surface temperatures in this region, in particular compressional warming in descending downslope flow off of the Brooks Range, a phenomena favored by the wind /pressure regime that brings the warm air from the south.

While not discussed in this study evidence also suggests that these events are important in transferring water substance into the Arctic Basin and advecting ice in the Beaufort Sea away from the Arctic Coast in the ensuing southerly flow.

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REFERENCES

Olsson, P., M. Sturm, G. Liston, C. Racine, and J. Holmgren, Significant weather events producing North Slope snow cover: Understanding episodic change in a remote and transient landscape. 2000 *LAII-NSF Workshop, Seattle, WA, (preprint volume in press)*, 2000.

Olsson, P.Q., L.D. Hinzman, M. Sturm, G.E. Liston, and D.L. Kane, 2001: A surface climatology of The Kuparuk Basin on the Arctic Slope of Alaska. Submitted to *J. Geophys. Res.*