Some Characteristics of the Climate on the North Slope of Alaska

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Introduction

The North Slope of Alaska is one of three sites of the U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Program. A major ARM objective is to study the impact of clouds on radiative transfer in the atmosphere. The meteorological characteristics near the surface have a significant influence on radiative fluxes and cloud formation. Therefore, investigations of the near-surface climatology, in terms of snow cover and air temperature, have the potential to enhance our understanding of atmospheric radiative transfer processes and, thereby, the surface energy balance.

Climatic conditions on the North Slope of Alaska are not well understood due to the sparsity of meteorological stations and the discontinuity of the observations. The objective of this study is to describe the present-day climatic conditions on the North Slope of Alaska using currently available field measurements.

The data used in this study include air temperature, precipitation, snowfall and seasonal snow cover for stations and sites shown in Figure 1. The data were taken from the National Climate Data Center (1994), the Natural Resources Conservation Service of the U.S. Department of Agriculture (1994), and from research projects (sponsored by the DOE and the National Science Foundation) carried out in recent years on the North Slope of Alaska (Zhang 1989, 1993; Zhang and Osterkamp 1991). Air temperature data used in this study includes the period from 1987 through 1992, while precipitation, snowfall, and seasonal snow cover are for the period from 1976 through 1994 for all stations and sites on the North Slope of Alaska as shown on Figure 1.

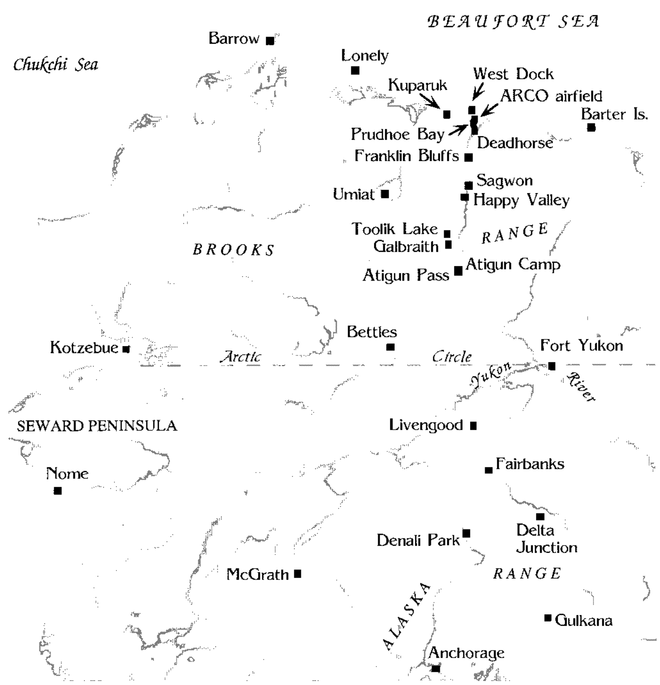

Figure 1. Alaska stations and sites where data used in this study were collected.

Results

Air Temperature

The mean annual air temperature (MAAT) at stations and sites within about 120 km of the Beaufort Sea coast and with an elevation lower than 250 m averaged about -12.4 ± 0.3°C for the period from 1987 to 1992. Moving southward and to higher elevations, the mean annual air temperature increased from -12.7°C at Umiat to about -8.0°C at Toolik Lake with average gradients of about 0.08°C km^{-1} with distance (north-south) and 6.7°C km^{-1} with elevation. The annual amplitude increased rapidly from 16°C to over 20°C within 20 km from the coast with the amplitude ranging from 19.5°C at Deadhorse to about 21.5°C at Umiat. Southward and at higher elevation, the annual amplitude of the air temperature decreased to about 17.5°C at Toolik Lake.

Freezing and thawing indices are the summation of daily mean temperature below and above 0°C during a year, respectively. The thawing index increased almost linearly from about 250°C/day along the coast to over 1000°C/day inland, which indicates that the thawing season was short and cool along the coast and longer and warmer inland. The thawing index then decreased slightly going into the foothills of the Brooks Range. The freezing index increased from 4800°C/day along the coast to over 5300°C/day inland, which illustrates that the freezing season was relatively warmer along the coast and colder inland, although the freezing season along the coast was longer than inland. The freezing index dropped significantly from 4800°C/day inland to about 3800°C/day over the foothills of the Brooks Range, which indicates much warmer winter months over the foothills.

Correlation analysis show that changes in MAAT were mainly controlled by the variation of winter temperatures. Colder years had lower winter temperatures and a higher freeze index and (i.e., vice versa) for warmer years. The impact of summer air temperature on MAAT is not significant in this region. This implies that proxy data, which are related to the summer air temperatures, may produce errors when used to reconstruct the MAAT in the arctic region.

Precipitation

Measuring precipitation in a wind-swept region, especially where the total quantity is small and more than 50% of that comes as snow, is a difficult task. Currently, there are two systems used to measure precipitation in northern Alaska for the period from 1976 through 1994: a standard 8-inch pan precipitation gauge with no shield used by the National Weather Service (NWS) and a Wyoming Gauge with shield used by the Natural Resources Conservation Service (1994).

The results (Zhang et al. 1996) indicate that the NWS 8-inch pans have underestimated precipitation, on average, by about 75%, ranging from 20% to 180%. Precipitation values measured by the two methods are well correlated with each other.

Precipitation measured by Wyoming Gauges varied significantly with the distance from the Arctic Coast and elevation. Along the Arctic Coast and the Coastal Plain with elevations below 200 m, the annual total precipitation varied from 200 mm to about 240 mm. Southward and at higher elevation (over 800 m), precipitation increased to 330 mm. At Atigun Pass, where the elevation is above 1,400 m, precipitation increased to 640 mm. More than 50% of the annual precipitation fell as snow along the coast; inland, the amount of snowfall decreased from 47% of the annual precipitation at Sagwon to about 40% at Toolik Lake. In the Brooks Range where elevation is over 1000 m above sea level, snowfall increased to over 50% of the annual precipitation.

Seasonal Snow Cover

The NWS records at Barrow and Barter Island indicate that snowfall occurred throughout the year. During the summer months (June through August), snowfall was relatively light and constituted less than 10% of the total annual snowfall. Snow usually stayed a few days on the ground and then disappeared right away (i.e., instantaneous snow cover). From October through May, precipitation fell entirely as snow. The maximum monthly snowfall occurred in October, and more than 50% of the annual snowfall occurred from September through November.

On the average, snow covered the ground surface for more than eight months at both Barrow and Barter Island, ranging from 6.5 to about 10 months. At Umiat, the average duration of the snow cover was slightly less than eight months, varying from six to nine months. Thickness of the seasonal snow cover was about the same at Barrow and Barter Island, with the average maximum thickness less than 30 cm. At Umiat, the average maximum thickness was about 40 cm.

Climatic Zones

The currently available data suggest differentiation of the North Slope of Alaska into three major climate zones as summarized in Table 1: Arctic Foothills, Arctic Inland, and Arctic Coastal.

Overall, the climate on the North Slope of Alaska is strongly influenced by the continental and marine environments. During the summer seasons, the Arctic Coastal zone experienced more frequent cloudiness and fog, and the prevailing northeast winds or sea breezes off the ocean kept the average summer air temperatures within a few degrees of freezing. Inland, clear skies were more prevalent,

Table 1. Three major climate zones of North Slope of Alaska.	
Climate Zone	Description
Arctic Coastal	This zone includes areas that extend inland about 20 km from the ocean. Cool summers and relatively warm winters prevail with low continentality index (Zhang et al. 1996) due to the presence of the ocean and sea ice. Both diurnal and annual amplitudes of air temperature were relatively small compared with the values in the Arctic Inland zone. Precipitation was lowest in this region, and more than about 50% of it fell as snow. Snow covered the ground for eight to ten months per year.
Arctic Inland	This zone is located south of the Arctic Coastal zone and extends about 100 km along the Haul Road from the Arctic Coast. This extension could be more than 200 km to the West due to its low elevation. This zone experienced the same mean annual air temperature as in the Arctic Coastal zone, but had extremely cold winters and relatively warm summers with the highest continentality index in the region. Freezing and thawing indices were also the highest in the region. Both diurnal and annual amplitudes of air temperature increased significantly compared with the Arctic Coastal zone. Precipitation was slightly higher than in the Arctic Coastal zone but lower than in the Arctic Foothills zone to the south. The average duration of the seasonal snow cover was less than eight months. Marine influence was reduced significantly due to the zone's distance from the ocean.
Arctic Foothills	This zone includes the stations and sites from Galbraith to Sagwon. Differentiation of this zone from the Arctic Coastal and Arctic Inland zones to the north is based upon its higher elevation and greater distance from the ocean. Mean annual air temperature in this zone was about 2 to 4°C warmer than the two zones to the north. Summer temperatures were warmer than in the Arctic Coastal zone but slightly cooler than in the Arctic Inland zone, while winter temperatures were much higher due to the impact of the atmospheric inversion in this region, which also makes the continentality index the lowest among all three zones. Precipitation was the highest in the region with about 40% falling as snow.

wind directions more variable, and average air temperature higher. Although the ocean off the western and northern shores of Alaska is covered with seasonal and multi-year sea ice, it is still a significant heat source for the atmosphere.

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References

National Climate Data Center, 1994: Climatological data, Alaska, 80.

National Climatic Data Center, 1994: Local climatological data, Barrow, 1921-1994, U.S. Department of Commerce, Weather Bureau.

National Climatic Data Center, 1994: Local climatological data, Barter Island, 1948-1988, U.S. Department of Commerce, Weather Bureau.

National Resources Conservation Service, 1994: Alaska annual data summary, water year 1994. U.S. Department of Agriculture, Soil Conservation Service.

Zhang, T., 1989: Thermal regime of permafrost within the depth of annual temperature variation at Prudhoe Bay, Alaska, M.S. Thesis, Geophysical Institute, University of Alaska Fairbanks, pp. 145.

Zhang, T., 1993: Climate, seasonal snow cover and permafrost temperatures in Alaska north of the Brooks Range, Ph.D. Dissertation, Geophysical Institute, University of Alaska Fairbanks, pp. 232.

Zhang, T., and T. E. Osterkamp, 1991: Analysis of the climatic history at Barrow and Barter Island, Alaska, *Proceedings of the 42nd Arctic Science Conference*, University of Alaska Fairbanks, May, 1991.

Zhang, T., T. E. Osterkamp, and K. Stamnes, 1996: Some Characteristics of the climate in Northern Alaska, submitted to *Arctic and Alpine Research*.