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Modeled impacts of changes in tundra snow thickness on ground thermal regime and heat flow to the atmosphere in Northernmost Alaska

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Seasonal snow covers the tundra surface for up to nine months of each year on the Alaskan North Slope. Variations in the snow thickness could strongly influence the thermal regime of the underlying soil and permafrost, and energy exchange between the land surface and the atmosphere. A one-dimensional heat-conduction model with phase change for thermal regime of snow and permafrost containing unfrozen water was developed and used to quantify the impact of changes in the tundra snow thickness on the snow surface temperature, ground thermal regime, and the conductive heat flow to the atmosphere. The model is driven through the surface energy balance. The baseline inputs for the numerical model are mean daily air temperature, dew point temperature, snow cover thickness, wind speed, atmospheric pressure measured at the National Weather Service (NWS) station at Barrow, Alaska, and the incident solar radiation and the surface albedo measured at the NOAA Climate Monitoring and Diagnostics Laboratory (CMDL) at the Barrow site from 1995 through 1999. Based on a study for the long term mean daily maximum and minimum snow thickness distributions at Barrow in the snow season of 1948 through 1997, a snow thickness factor was defined and five simulation cases were conducted by using the measured snow thickness data and by changing the actual snow thickness by 50% and 75% in the snow season of 1997-1998. The modeled results indicate that changes in snow thickness have significant impacts on ground thermal regimes and conductive heat flow to the atmosphere. A decrease in the snow thickness by 50% leads to the maximum ground temperature decreased at 0.01 m depth by 2.0^{o}C, at 0.29 m depth by 1.48^{o}C, at 1.0 m depth by 1.21^{o}C, and at 3.0 m depth by 0.72^{o}C. An increase in the snow thickness by

50% results in the maximum ground temperature increased at 0.01 m depth by 2.01^{o}C, at 0.29 m depth by 1.44^{o}C; at 1.0 m depth by 1.14^{o}C, and at 3.0 m depth by 0.66^{o}C. On an annual basis, variation in the snow thickness by 50%, the ground temperature variation of more than 0.25^{o}C occurs as deep as 8.0 m below the ground surface. Decreasing snow thickness by 50% and 75%, respectively, the magnitude of the mean conductive heat flow to the atmosphere for December increases from 5.87 to 10.17 and 14.58 W m^{-2}, while increasing snow thickness by 50% and 75%, the magnitude of the mean conductive heat flow to the atmosphere for December decreases from 5.87 to 4.30 and 3.77 W m^{-2}, respectively. The effect of changes in snow thickness on the snow surface temperature is very limited. Decreases and increases in snow thickness by 75%, the corresponding increase and decrease in the average snow surface temperature for the period before snowmelt from September 22, 1997 through March 10, 1998 are just 0.13^{o}C and 0.04^{o}C, respectively.