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Surface energy budget and turbulent fluxes at Arctic terrestrial sites

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Determination of the surface energy budget (SEB) and all SEB components at the air-surface interface are required in a wide variety of applications including atmosphere-land/snow simulations and validation of the surface fluxes predicted by numerical models over different spatial and temporal scales. Here, comparisons of net surface energy budgets at two Arctic sites are made using long-term near-continuous measurements of hourly averaged surface fluxes (turbulent, radiation, and soil conduction). One site, Eureka (80.0 N; Nunavut, Canada), is located in complex topography near a fjord about 200 km from the Arctic Ocean. The other site, Tiksi (71.6 N; Russian East Siberia), is located on a relatively flat coastal plain less than 1 km from the shore of Tiksi Bay, a branch of the Arctic Ocean. We first analyzed diurnal and annual cycles of basic meteorological parameters and key SEB components at these locations. Although Eureka and Tiksi are located on different continents and at different latitudes, the annual course of the surface meteorology and SEB components are qualitatively similar. Surface energy balance closure is a formulation of the conservation of energy principle. Our direct measurements of energy balance for both Arctic sites show that the sum of the turbulent sensible and latent heat fluxes and the ground (conductive) heat flux systematically underestimate the net radiation by about 25-30%. This lack of energy balance closure is a fundamental and pervasive problem in micrometeorology. We discuss a variety of factors which may be responsible for the lack of SEB closure. In particular, various storage terms (e.g., air column energy storage due to radiative and/or sensible heat flux divergence, ground heat storage above the soil flux plate, energy used in photosynthesis, canopy biomass heat storage). For example, our observations show that the photosynthesis storage term is relatively small (about 1-2% of the net radiation), but about 8-12% of the imbalance magnitude. All turbulent fluxes are highly correlated with net radiation because this balance between solar and longwave radiation is the principal energy source for daytime surface warming, evaporation, and photosynthesis. We find that turbulent fluxes of carbon dioxide and sensible heat are closely linked and, on average, change sign synchronously during the diurnal and annual cycles. The work is supported by the NOAA Climate Program Office, the U.S. National Science Foundation (NSF) with award ARC 11-07428, and by the U.S. Civilian Research & Development Foundation (CRDF) with award RUG1-2976-ST-10.