Using High-Resolution Atmospheric and Snow Modeling Tools to Define Pan-Arctic Spatial and Temporal Snow-Related Variations

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ABSTRACT

Our long-term goal is to understand the roles of snow in terrestrial Arctic systems. To accomplish this goal we have developed a collection of atmospheric and snow modeling tools used to define spatial and temporal variations in snow depth and properties. This collection of modeling tools includes SnowModel, a spatially-distributed snow-evolution modeling system designed for application in all landscapes, climates, and conditions where snow occurs. SnowModel is designed to run on grid increments of 1- to 200-m and temporal increments of 10-minutes to 1-day. It can be applied using much larger grid increments, if the inherent loss in high-resolution (subgrid) information is acceptable. Simulated processes include: snow accumulation; blowing-snow redistribution and sublimation; interception, unloading, and sublimation within forest canopies; snow-density evolution; and snowpack ripening and melt. Meteorological forcings required by SnowModel are provided by MicroMet, a physically-based, high-resolution (e.g., 1-m to 10-km horizontal grid increment), meteorological distribution model. MicroMet employs relationships between meteorological variables and the surrounding landscape to generate distributions of air temperature, relative humidity, wind speed and direction, incoming shortwave and longwave radiation, surface pressure, and precipitation to drive SnowModel. SnowModel also includes a snow data assimilation sub-model (SnowAssim) that is consistent with optimal interpolation techniques, where differences between observed and modeled snow values constrain modeled outputs. This assimilation approach is unique in that the correction is applied backwards in time to adjust variables prior to the assimilated observations.

There are also features in natural systems not considered in SnowModel. For example, the model assumes that vegetation cover in each model grid cell is uniform. Thus, the model is unable to appropriately simulate features like tree-wells, nor is it able to simulate snow drifts that accumulate behind individual shrubs, such as occurs throughout shrublands of the western United States and Arctic. To expand SnowModel's application, soil moisture, temperature, and runoff-routing sub-models could also be included. This would extend the model's use to a wider range of ecological and hydrologic applications.

In their current form, applying these modeling tools allows us to create distributions of numerous snow-related properties, including snow water equivalent (SWE), snow depth, mixed land-snow albedo (landscape albedo), snowpack layers, type of snow by layer, bulk thermal conductivity, hardness/penetration, mobility/trafficability indices, snow-ground interface temperature, snow-up and snow-melt timing, snow density and grain characteristics, snow characteristics changes in response to changes in atmospheric forcing (climate), snow changes in response to arctic vegetation changes (e.g., increased shrubs), and hydrologic potential (integrated basin peak SWE). Focus regions for our simulations and distributions include arctic Alaska, Greenland, Arctic North America, and the Pan-Arctic. As part of this presentation we will use the above collection of domains and variables to provide examples of our simulated snow-related distributions and variations.