Evaluating the Climatic and Energy Balance Controls on Snow Accumulation and Melt in Mountain Snowpacks

Keith Jennings, PhD candidate
Geography Department and INSTAAR, University of Colorado Boulder

Dissertation defense:
Tuesday 2018-08-21 at 2:00PM MDT
Sievers Conference Room, SEEC S228, East Campus

Snow is indispensible to the water resources and economy of the western United States, making it essential to accurately predict snowmelt volume, timing, and rate. However, uncertainties in snowpack processes, the effects of climate change, and spatial variability in rain-snow partitioning all complicate efforts to simulate snow accumulation and melt. With those issues in mind, this dissertation clarifies seasonal snow cover evolution in a changing climate by utilizing ground observations and validated output from a physics-based snow model.

The first project details how snowpacks develop cold content, the internal energy deficit that must be satisfied before snowmelt can begin. Using snow pit data and model output, I show that new snowfall exerts the primary control on cold content development in the snowpacks at an alpine and subalpine site in the Niwot Ridge LTER. Model output also indicates that cold content damps snowmelt rate and delays snowmelt onset at time scales less than 1 month.

The second project evaluates the physical processes controlling the response of the Niwot Ridge LTER snowpacks to increases in air temperature. Model simulations show that the increased sensitivity of the subalpine snowpack to climate warming is primarily a result of decreases to snowpack cold content and increases in positive energy fluxes.

The final project expands on the spatial scope of the first two by simulating snow accumulation and melt at sites in the western United States that span a climatic gradient from warm maritime to cold continental using different methods to partition precipitation into rainfall and snowfall. Results show that the selection of a precipitation phase method leads to the greatest divergence in seasonal snow cover evolution at the lower elevation maritime sites. Peak snow water equivalent and snowmelt timing simulated by the different methods varied by several hundred millimeters and over 1 month, respectively, at the warmest sites, and typically less than 20 mm and 1 week at the two coldest sites. Overall, this dissertation highlights how snow models and ground observations can be used to better understand snow accumulation and melt processes in a changing climate.