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Incorporation of a two-direction freeze-thaw algorithm into a spatially-distributed hydrologic model

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In the arctic environment, the active layer (the thin layer of soil above the permafrost, which annually thaws and freezes) is the zone where most hydrologic, biologic, ecologic, and geomorphic processes occur. The active layer is a dynamic region where soil properties (both hydraulic and thermal) rapidly change from the onset of snow melt through the freeze-back period. The rate of soil thaw is dependent upon a number of factors including soil material, soil moisture, and ice content. As these factors are variable with space and time, the position of the active layer is also both spatially and temporally variable. Knowing the condition of the soil (frozen, thawed, and position of the freeze/thaw interface) is fundamental to understanding and predicting the spatial and temporal energy and water fluxes. In this study, we incorporate a modified two-directional freeze-thaw algorithm into a spatially-distributed, process-based hydrologic model called TopoFlow. Written in IDL, TopoFlow was designed to handle the rapidly changing thermal and hydraulic soil properties that are ubiquitous throughout the Arctic. TopoFlow currently is able to simulate the major components of the water balance (precipitation, snow melt, evapotranspiration, groundwater flow, overland/channel flow) as well as some storage processes. The two-directional freeze-thaw algorithm is based upon the Stefan's equation. Physical properties of the soil (bulk density, porosity, mineral and organic content, water content) are specified as input variables. The algorithm is driven by the surface temperature and temperature at a specified depth. The incorporated algorithm is tested in a small high-arctic watershed (Bayelva) located close to Ny-Alesund, Svalbard. Comparisons of simulated freeze/thaw interface (0° C isotherm), snow melt, evapotranspiration, and soil moisture content with field measurements will be presented.