Accounting for Snow in Regional and Global Atmospheric Models

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ABSTRACT

The objective of this presentation is to outline a modeling methodology which is able to account for relevant aspects of seasonal snow within the context of weather and climate models. This methodology specifically accounts for subgrid snow-distribution variability, and its two-way interactions with atmospheric, hydrologic, and other features of the surrounding landscape. To develop this methodology, a combination of physically-based modeling, field-measurement programs, and remote-sensing products are being used. The problem of realistically representing seasonal snow in regional and global atmospheric and hydrologic models is made complex because of the numerous snow-related features that display considerable spatial variability at scales below those resolved by the models. As an example of this variability, over the winter landscape in middle- and high-latitudes, the interactions between wind, vegetation, topography, precipitation, solar radiation, and snowfall produce snowcovers of nonuniform depth and density (Liston and Sturm 1998). The wind-transport effects are particularly important in prairie, alpine, and Arctic environments. In addition, the snow distribution at scales of interest to atmospheric models is strongly dependent upon subgrid temperature and precipitation distributions (Liston et al., 1998). During the melt of these snowcovers, the snow-depth variation leads to a patchy mosaic of vegetation and snowcover that evolves as the snow melts. This mix of snow and vegetation strongly influences the energy fluxes returned to the atmosphere, and the associated feedbacks that accelerate the melt of remaining snow-covered areas. From the perspective of a surface energy balance, the interactions between the land and atmosphere are particularly complex during this melt period (Liston 1995). In spite of this complexity, Liston (1995) concludes that, in order to account for the first-order influences of subgrid snow distributions within an atmospheric model, the fraction of each atmospheric model grid cell that is covered by snow must be known. It is then appropriate to perform one energy balance over the snow-covered fraction, and one energy balance over the vegetation-covered fraction, assuming both fractions see the same atmosphere, and then weight the resulting fluxes according to the respective fractional areas.

This importance of snow-covered fraction is supported by both field observations and modeling studies. They suggest that within the context of local, regional, and global atmospheric, hydrologic, and ecologic models used to simulate weather, climate, land-surface moisture, and vegetation processes, three fundamental subgrid-scale features are required to describe the three-dimensional evolution of seasonal snowcover from the end-of-winter

through spring melt. These three features are: 1) the melt rate, 2) the depletion of snow-covered area, and 3) the end-of-winter snow-water-equivalent distribution (see attached figure) (Liston 1998a). These features are strongly interrelated and knowledge of any two of them allows the generation of the third.

In addition to subgrid variations in snow distribution, there are regional differences between the snowcovers located in different climate regimes, such as maritime, boreal forests, tundra, and prairie regions. Each of these regions have their own characteristic snow densities (and thus thermal properties), grain size distributions (important for remote sensing applications), and stratigraphic profiles. These variations can be handled using the methodology outlined by Sturm et al. (1995).

A primary conclusion of this presentation is that in order to realistically represent seasonal snow within the context of atmospheric models used to simulate weather and climate, the fractional snow-covered area within each atmospheric model grid cell must be known. This can be determined through knowledge of the subgrid snow distribution, and the computed snow-melt rates (Liston 1998a). In addition, this presentation indicates that improvements in atmospheric model simulations will be made by changing how the horizontal distribution of snow is accounted for, and that this is more important than possible improvements in the snow model's vertical resolution (Liston 1998b). The suggested changes in the representation of spatial snow distributions are expected to improve the model simulation of season snow and the associated interactions with the atmosphere.

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Three fundamental features must be accounted for to realistically represent snowcover in atmospheric models. These are:

1) The snow in a grid cell has some distribution

2) At some point that snow experiences melting

3) Eventually that snow disappears completely

** Any one of these curves can be obtained from knowledge of the other two. **