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Is snowmelt important for runoff during rain-on-snow floods over the Western U.S. mountains?

Nicholas Wayand and Jessica Lundquist

University of Washington, Seattle, United States (nicway@u.washington.edu)

Many case studies have shown the potential of rain-on-snow conditions to produce extreme snowmelt rates and increase flooding within snow-dominated basins along the Western U.S. mountain ranges. However, it is not well understood under what conditions and in which basins forecasters need to be concerned with the contribution from snowmelt. In this study, we follow a generalized approach to identify the main controls on the importance of snowmelt for flooding across a range of idealized basins and rain-on-snow events.

The Distributed Hydrological Soil and Vegetation Model was used to simulate multiple elevation bands spanning typical Western U.S. mountain temperature regimes. A range of idealized basins were simulated by adjusting the fraction of the total basin area within each elevation band as well as the vegetation type. For each ideal basin, a sensitivity study was performed to identify conditions for maximum melt (with unlimited and limited snow available) by adjusting the meteorological forcing data and parameters controlling the simulated turbulent heat fluxes. Because many previous studies have cited the important contribution of snowmelt from low to mid-elevations, the initial conditions of the snow water equivalent (SWE) prior to a given rain-on-snow event were also perturbed.

Results indicated that the fraction of a basin's area coincident with the level of maximum simulated snowmelt controlled the upper bound for the total basin input from snowmelt. This elevation range of maximum snowmelt is a function of the available SWE prior to the rain-on-snow event and the energy available for melt during the event. Perturbations to the initial conditions of SWE, by shifting pre-storm rain-snow transition, had the largest impact on the relative importance of snowmelt. The largest source of energy for melt depended on the elevation and vegetation type. Simulations of different vegetation structures during the rain-on-snow event found that in clearings, the sensible and latent heat fluxes dominated, while in forests, net-irradiance and advected heat from rainfall were more important for melt than the turbulent heat flux. The turbulent heat flux values responsible for the largest simulated melt rates were most sensitive to changes in wind speed, which in turn is controlled by the vegetation structure, snow surface roughness and complex terrain.

In short, high-risk basins for large snowmelt events are ones that are sparsely forested, with shallow elevation gradients within the transitional snow zone (where rain and snow occur equally as often during winter) and have a large fractional area coincident with the storm's elevation of maximum snowmelt. Under such conditions, simulated snowmelt may contribute as much as 30% of total basin input (rainfall plus snowmelt).