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A climatology of rain-on-snow events for Norway

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Rain-on-snow (ROS) events and are complex extreme hydrometeorological phenomena requiring a combination of sufficient rainfall, snow depth, and snow cover – and each of these factors may not necessarily be extreme in themselves. They can have severe impacts, including floods and land slides, as well as loss of vegetation and wildlife, or permafrost changes, if the fallen rain subsequently forms ice layers (meaning that temperature is also a major factor). ROS events occur mainly in climates with a seasonal snow cover and the mixture of rain- and snowfall and sensitivity to the threshold temperature for snowmelt make them difficult to quantify. In addition, a sparse observational network, and the spatial scale mismatch between re-analysis products and real local events adds further uncertainty. Here we take advantage of the high-resolution seNorge hydrometeorological dataset for mainland Norway, gridded to 1km resolution (to properly represent Norway's rugged topography and complex drainage network). Station (climate) data are interpolated in space using Optimal Kriging Interpolation, and incorporate a snow module for estimates of snow variables. We use daily data spanning 1957-2016, and by choosing suitable thresholds for rain, snow water equivalent, and snow cover area, we construct a climatology for ROS events. Given Norway's diverse climate – ranging from the northern Arctic climate, to the southern maritime and Alpine climate – we find differing ROS characteristics and changes. Compared to our baseline 1961-1990 climate, we find that ROS events in our 1981-2010 climate decrease most in the South West winter season (where we postulate less snow persists in a warming climate), and increase most in the Northern and Alpine winter-spring season (where we postulate snow begins to fall as rain rather than snow in a warming climate). The occurrence of ROS events also broadly correlate with the North Atlantic Oscillation and the Arctic Oscillation, suggesting these circulation indices could help toward developing metrics to define ROS events in data-poor regions, and for projections of ROS characteristics under future climate change. Finally, we examine a case study of an extreme ROS event in May 2013 in the Alpine county of Oppland, which caused devastating flooding. By examining the interplay between rain, snow, and temperature, we gain better insight into the morphology of such extreme events – with a view to simulating ROS-generated runoff and flooding in future studies, and informing the LATICE project (www.mn.uio.no/latice/).