Rain on snow responses to climate warming in the Pyrenees.

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Climate warming is changing the quantity, timing and spatial patterns of mountain snowpacks. Due to the increase of the rainfall/snowfall ratio, one of the main expected changes in snow-related hazards are rain-on-snow (ROS) events. Here, we perform a climate sensitivity analysis to analyze the shifts in the frequency and intensity of the ROS events in a mid-latitude mountain range, the Pyrenees, by focusing in the ROS spatial, elevation and seasonality patterns. ROS events climate sensitivity is analyzed for low (1500), mid (1800) and high (2400 m) elevation sectors, by forcing a physical-based snow model (FSM2) with long-term climate reanalysis data (1980 – 2019), assuming an increase of temperature (from 1ºC to 4ºC, by increments of 1ºC) and precipitation (from -10% to 10%, by increments of 10%). The results expose significant differences in the ROS climate sensitivity depending on the elevation and season of the year. In a warmer climate, ROS events decreases (increases) at low and mid (high) elevations during winter, whereas increases at high elevations during spring. Maximum ROS climate sensitivities are found in southern and eastern slopes of the range. Here, an increase of 1ºC causes ROS frequency increases by up to 30% over the baseline scenario, enhancing snow runoff and provoking flash flood events. ROS sensitivity is mainly explained by changes in precipitation type instead of mean annual temperature or snow cover duration. Results suggest similar ROS climate sensitivities in other mid-latitude mountain ranges, and anticipate an increase of hazards triggered by ROS events in the shoulders of the season.