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Insights into precipitation orographic enhancement from snow-course data and their value for improved hydrologic predictions

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Precipitation enhancement along elevation gradients is the result of complex interactions between synoptic-circulation patterns and local topography. Since precipitation measurements at high elevation are often biased and sparse, predicting precipitation distribution in mountain regions is challenging, despite this being a key step of hydrologic-forecasting procedures and of water management in general. By acting as a natural precipitation gauge, the snowpack can provide useful information about precipitation orographic enhancement, but the information content of snow-course measurements in this regard has been generally underappreciated. We leveraged 70,000+ measurements upstream five reservoirs in Valle d'Aosta, Italy, to show how manual and radar snow courses can be used to estimate precipitation lapse rates and consequently improve predictions of hydrologic models. Snow Water Equivalent above 3000 m ASL can be more than 4-5 times cumulative seasonal precipitation below 1000 m ASL, with elevational gradients up to 1000 mm w.e. / km ASL. Enhancement factors estimated by blending precipitation-gauge and snow-course data are highly seasonal and spatially variable, with exponential or linear profiles with elevation depending on the year. Blended gauge - snow-course precipitation lapse rates can be used to infer precipitation in ungauged areas and compensate for elevation gradients in an iterative, two-step distribution procedure of precipitation based on modified Kriging. Coupling this precipitation-distribution procedure with a snow model (S3M) shows promising improvements in Snow Water Equivalent estimates at high elevations.