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A statistical framework for modelling the spatial distribution and intensity of orographic precipitation

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Most precipitation in mid-latitudes is attributable to convective clouds and frontal systems. Although their development is not induced by the underlying terrain, the orography can play a substantial role in altering their features. A potential consequence is the modification of the precipitation spatial distribution at the ground, which likely exhibits a highly segmented nature in both space and time. Its accurate assessment is crucial for water management, especially over mountainous regions downstream of which human activities may be strongly impacted. Observed precipitation data are in general too coarse in space to be representative of topographic variations in the "true" precipitation field. Aiming at describing the spatial distribution and intensity of precipitation over complex terrain, we specify a statistical model which does not solely rely on observed data but also incorporates established analytical descriptions of physical processes involved.

A 2-dimensional advection equation for the column integrated cloud water density was derived, reducing the quasi-analytical upslope model designed by Smith (2003). The equation represents processes causing cloud water production due to forced uplift of moist air, downwind drift of cloud water and its conversion to precipitation. Discretizing the advection equation and perturbing it by means of a stochastic noise, we specify a simultaneous autoregressive model for a spatial gaussian field representing a latent potential of precipitation to convert in both precipitation occurrence and intensity. Its moments depend on both physical quantities and unknown parameters estimated from observed precipitation data, and can be nested in a numerical model producing a spatial, physically informed, grid refinement, yet combining information carried in observed data. Large-scale fraction of precipitation or convective cores are included in an extension of the model. Idealized experiments show model features and limitations as well as its sensitivity to the unknown parameters and environmental conditions. Real case applications over the Coast Range and Sierra Nevada, in California, US, show a good agreement with observation and a good reproduction of different precipitation-regimes.

Furthermore, the model constitutes the basic-brick for a predictive downscaling method, achieved adding a further level and linking the unknown parameters in the model to upper-air variables and weather regimes.