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Bayesian distributed calibration of snow cover parameters

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Calibration and validation of distributed precipitation-runoff models is notoriously in lack of data, in particular at high altitude. In mountainous regions with seasonal snow coverage, the relation between snow cover mass balance and fractional snow covered area (SCA) may be sufficiently stable to take advantage of remote sensing snow cover data. If this is the case, SCA information can be used to condition grid cell specific snow model parameters, thus augmenting traditional runoff measurements in the calibration process. The challenge is, however, that the SCA at a specific location and time depends on several unknown variables, all candidates for re-estimation by the single observation. In this work, we allow prior information to govern the different variables' adjustment to the SCA observations by using Bayes' theorem. We also apply spatial and temporal dependencies to the prior distribution, in order to reduce the dimensionality of the estimation problem relative to the observed information.

The presented approach requires that the precipitation-runoff model employs grid cell specific snow depletion curves (SDCs), describing the relation between local snow coverage to local snow mass balance. The inter-annual stability of the local SDCs is analysed by estimating each year's posterior expectation maps of three SDC parameters, using time series of MODIS snow cover images at 1 km resolution. This is repeated for six years of data, with between 8 and 15 images of fractional snow coverage per melt season. Calibrated parameter maps are then averaged over five years and compared to the remaining year's map, for all six perturbations.

Comparing each 5-year calibrated map to the independent year's posterior expecta-

tion, all six experiments show positive correspondence for the sub-grid coefficient of variation in snow depth. Removing a few outliers and normalising for elevation, the same is the case for a local snow storage multiplier, and a pre-melt bare ground fraction. However, two spatio-temporally global elevation gradients (in air temperature and mean snow storage, respectively) take posterior expectations which are a priori unlikely, in particular causing an unrealistic elevation dependency of mean snow storage. We argue that this is due to the different in strength among the components in the prior, where the single-term prior of the two gradients are almost non-informative set up against $\sim 10^5$ observations, compared to the priors involving a term per grid cell. The conclusion is that in high-dimensional Bayesian estimation, harmonising the dimensionality among prior components can be more important than the subjective specification of each prior component.