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A spatial Bayesian assimilation scheme for snow coverage observations into a gridded snow model

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A spatial probability distribution of variables in a snow cover model is developed, tailored to the assimilation of satellite snow cover data into the mass balance state of a gridded hydrological model. The assimilation is based on Bayes' theorem, and uses the developed distribution as its prior. The spatial approach limits the uniqueness in each cell's updating, and forces similarity between neighbouring cells as well as among cells with similar altitude. Representing spatial dependencies in the prior distribution strongly improves the performance of the assimilation scheme in terms of reduced variance, compared to a non-spatial prior previously reported.

In each of the model's grid cells, the sub-grid variability in snow storage is described by a parametric snow depletion curve with three seasonally static parameters and one dynamic argument. The method assumes that the model has a gridded structure, a temperature index snowmelt equation, and that elevation gradients are substantial sources of inter-cell variation. Based on these assumptions, the four cell-specific variables are transformed into three global and four gridded variables, to which the joint prior distribution is applied. A spatial covariance structure is applied to two of the gridded variables. The transformation enables the prior distribution in each simulation unit to be constructed from simple, yet realistic error models, in particular because the surfaces for variables with a spatial covariance structure are simplified by isolating global effects.

Three assimilation experiments are run in a 2400 km2 mountainous region in central Norway (61°N, 9°E) using two Landsat 7 ETM+ images separately and together. Averaged over the region, updating reduces the prior uncertainty (variance) by 20-80 percent, varying among variables and dependent on the situation at image acquisition

date. Global (spatially constant) variables, and gridded variables with a spatial prior covariance structure achieve larger variance reductions than variables with no a priori spatial dependency.