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A new Bayesian hierarchical geostatistical model based on two spatial fields with case studies with short records of annual runoff in Norway

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We present a new Bayesian geostatistical hierarchical model that is particularly suitable for interpolation of hydrological data when the available dataset has short records, for including overlapping catchments consistently and for combining areal (runoff) and point (precipitation) observations. A key feature of the proposed framework is that several years of runoff are modeled simultaneously with two Gaussian random fields (GRFs): One that is common for all years under study and represents the runoff generation due to long-term climatic conditions, and one that is year specific. The framework is demonstrated by filling in missing values of annual runoff and by predicting mean annual runoff for about 200 catchments in Norway. The predictive performance is compared to Top-Kriging (interpolation method) and simple linear regression (method for exploiting short records). The results show that if the runoff is driven by weather patterns that are repeated over time, the value of including short records is large, and that we for partially gauged catchments perform better than comparable methods for both annual spatial interpolation and mean annual runoff. We also find that short records, even of length one year, can safely be included in the model.

In a smaller case study of ten years of annual runoff in Voss in Norway it is demonstrated that by combining runoff and precipitation data in the model framework that includes consistently modelling of overlapping catchments on average preforms better compared to using only one of the data sources. Further, the interaction between nested areal data and point data gives a geostatistical model that takes us beyond smoothing: The model can give predictions that are higher (or lower) than any of the observations.

A finding is that in Norway the climatic effects dominates over annual effects for annual runoff. Through a simulation study we demonstrate that in this case systematic under- and overestimation of runoff over time can be expected. On the other hand, a strong climate implies that short records of runoff from an otherwise ungauged catchment can lead to large improvements in the predictability of runoff.