Sampling design optimisation for rainfall prediction using a non-stationary geostatistical model

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The accuracy of spatial predictions of rainfall by merging rain gauge and radar data is partly determined by the sampling design of the rain gauge network. Optimising the locations of the rain gauges may increase the accuracy of the predictions. Existing spatial sampling optimisation methods are based on minimisation of the spatially averaged prediction error variance under the assumption of intrinsic stationarity. Over the past years, substantial progress has been made to deal with non-stationary spatial processes in kriging. Various well-documented geostatistical models relax the assumption of stationarity in the mean, while recent studies show the importance of considering non-stationarity in the variance for environmental processes occurring in complex landscapes. We optimised the sampling locations of rain gauges using an extension of the Kriging with External Drift (KED) model for prediction of rainfall fields. The model incorporates both non-stationarity in the mean and in the variance, which are modelled as functions of external covariates such as radar imagery, distance to radar station and radar beam blockage. Spatial predictions are made repeatedly over time, each time recalibrating the model and using the predictions from the previous time step as an additional covariate. The space-time averaged KED variance was minimised by Spatial Simulated Annealing (SSA). The methodology was tested using a case study predicting daily rainfall in the North of England for a one-year period. Results show that (i) the proposed non-stationary variance model outperforms the stationary variance model, and (ii) a small but significant decrease of the rainfall prediction error variance is obtained with the optimised rain gauge network. In particular, it pays off to place rain gauges at locations where the radar imagery is inaccurate, while keeping the distribution over the study area as uniform as possible.