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Soil Moisture Network Design using Advanced Numerical Weather Prediction modelling and Data Mining technology for Hydrological applications

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Soil moisture plays an important role in the partitioning of rainfall into evapotranspiration, infiltration and runoff, hence a vital state variable in the hydrological modelling. However, due to the heterogeneity of soil moisture in space most existing in-situ observation networks rarely provide sufficient coverage to capture the catchment-scale soil moisture variations. Clearly, there is a need to develop a systematic approach for soil moisture network design, so that with the minimal number of sensors the catchment spatial soil moisture information could be captured accurately. In this study, a simple and low-data requirement method is proposed. It is based on the Principal Component Analysis (PCA) and Elbow curve for the determination of the optimal number of soil moisture sensors; and K-means Cluster Analysis (CA) and a selection of statistical criteria for the identification of the sensor placements. Furthermore, the long-term (10-year) soil moisture datasets estimated through the advanced Weather Research and Forecasting (WRF) model are used as the network design inputs. In the case of the Emilia Romagna catchment, the results show the proposed network is very efficient in estimating the catchment-scale soil moisture (i.e., with NSE and r at 0.995 and 0.999, respectively for the areal mean estimation; and 0.973 and 0.990, respectively for the areal standard deviation estimation). To retain 90% variance, a total of 50 sensors in a 22,124 km^2 catchment is needed, which in comparison with the original number of WRF grids (828 grids), the designed network requires significantly fewer sensors. However, refinements and investigations are needed to further improve the design scheme which are also discussed in the paper.