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Geostatistical modelling with 3D+T data: soil moisture, temperature, and electrical conductivity at the field scale

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Dynamic soil data collected using automated sensor networks can facilitate our understanding of soil processes, but highly dimensional data may be difficult to analyze in a manner that incorporates correlation in properties through 3-dimensions and time (3D+T). We demonstrate two approaches to making continuous predictions of dynamic soil properties from fixed point observations. For this analysis, we used the Cook Farm data set, which includes hourly measurements of soil volumetric water content, temperature, and electrical conductivity at 42 points and five depths, collected over five years. We compare performance of two modeling frameworks. In the first framework we used random forest algorithms to fit a 3D+T regression model to make predictions of all three soil variables from 2- and 3-dimensional, temporal, and spatio-temporal covariates. In the second framework we developed a 3D+T kriging model after detrending the observations for depth-dependent seasonal effects. The results show that both models accurately predicted soil temperature, but the kriging model outperformed the regression model according to cross-validation; it explained 37%, 96%, and 16% of the variability in water content, temperature, and electrical conductivity respectively versus 34%, 93%, and 4% explained by the random forest model. The full random forest regression model had high goodness-of-fit for all variables, which was reduced in cross-validation. Temporal model components (i.e. day of the year) explained most of the variability in observations. The seamless predictions of 3D+T data produced from this analysis can assist in understanding soil processes and how they change through a season, under different land management scenarios, and how they relate to other environmental processes.