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Scale dependent evaluation of process model performance

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Mathematical models of processes in soil science are often used to test our understanding of these processes, highlight where this is wanting and identify new hypotheses. Process models are also practically useful, for example, a soil process model can predict how the soil system will respond to changes in management or environment. They can therefore be used to help managers make decisions, or to help government predict the effects of new policy, trends in land use or climate change. Models are therefore needed to make predictions at different scales, scales which are often different from the scale at which the model was developed, or the scale at which information on model inputs is available.
Soil process models are typically developed at a particular spatial scale, depending on the processes described, experimental setup or measurements used to construct the model, and this scale is typically at that of a soil core or small field plot. This scale does often not correspond to the scale at which the model application scale or for which input information is available. When this happens, the model and its inputs require aggregation or disaggregation to the application scale, and this is a complex problem. The problem of disaggregation depends on the variability of the inputs, and on the mathematical structure of the model. Whether model output can be simply aggregated to the required scale depends on whether the model describes the key processes that determine the process outcome at that target scale.
We present a diagnostic framework which evaluates whether a model is appropriate for use at one or more target spatial scales. This evaluation is based on the performance of the predictions of variations at those target scales and also in the requirements for disaggregation of the inputs. We show that spatially nested analysis of the covariance of predictions with measured process outcomes is an efficient way to determine this performance.
From the spatially nested analysis of covariance, we identified the component correlations as the diagnostic with which to evaluate model behaviour. The concordance correlation is a measure of agreement between two variables which reflects both their linear correlation and the extent to which they agree with respect to their mean and variance. These correlations show how well the model emulates components of spatial variation of the target process at the scales of the sampling scheme. In the case only the model is used to predict, and the most useful diagnostic is the concordance aggregate correlation.

Aggregate correlations were identified as the most pertinent to evaluate models for prediction at particular scales since they measure how well aggregated predictions at some scale correlate with aggregated values of the measured outcome. The aggregate correlations are computed from the aggregated covariance matrices. In this case model predictions are assimilated with observations which should correct bias in the prediction, and errors in the variance; the aggregate correlations would be the most suitable diagnostic.

This diagnostic framework is demonstrated using a set of models of the soil processes associated to ammonia volatilization from urea.