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Systemic change increases model projection uncertainty

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Most spatio-temporal models are based on the assumption that the relationship between system state change and its explanatory processes is stationary. This means that model structure and parameterization are usually kept constant over time, ignoring potential systemic changes in this relationship resulting from e.g., climatic or societal changes, thereby overlooking a source of uncertainty. We define systemic change as a change in the system indicated by a system state change that cannot be simulated using a constant model structure. We have developed a method to detect systemic change, using a Bayesian data assimilation technique, the particle filter. The particle filter was used to update the prior knowledge about the model structure. In contrast to the traditional particle filter approach (e.g., Verstegen et al., 2014), we apply the filter separately for each point in time for which observations are available, obtaining the optimal model structure for each of the time periods in between. This allows us to create a time series of the evolution of the model structure. The Runs test (Wald and Wolfowitz, 1940), a stationarity test, is used to check whether variation in this time series can be attributed to randomness or not. If not, this indicates systemic change. The uncertainty that the systemic change adds to the existing model projection uncertainty can be determined by comparing model outcomes of a model with a stationary model structure and a model with a model structure changing according to the variation found in the time series.

To test the systemic change detection methodology, we apply it to a land use change cellular automaton (CA) (Verstegen et al., 2012) and use observations of real land use from all years from 2004 to 2012 and associated uncertainty as observational data in the particle filter. A systemic change was detected for the period 2006 to 2008. In this period the influence on the location of sugar cane expansion of the driver sugar cane in the neighbourhood doubled, while the influence of slope and potential yield decreased by 75% and 25% respectively. Allowing these systemic changes to occur in our CA in the future (up to 2022) resulted in an increase in model projection uncertainty by a factor two compared to the assumption of a stationary system. This means that the assumption of a constant model structure is not adequate and largely underestimates uncertainty in the projection.

References

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