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Predicting long-term catchment nutrient export: the use of nonlinear time series models

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After the Second World War the nitrate concentrations in European water bodies changed significantly as the result of increased nitrogen fertilizer use and changes in land use. However, in the last decades, as a consequence of the implementation of nitrate-reducing measures in Europe, the nitrate concentrations in water bodies slowly decrease. This causes that the mean and variance of the observed time series also changes with time (nonstationarity and heteroscedascity). In order to detect changes and properly describe the behaviour of such time series by time series analysis, linear models (such as autoregressive (AR), moving average (MA) and autoregressive moving average models (ARMA)), are no more suitable. Time series with sudden changes in statistical characteristics can cause various problems in the calibration of traditional water quality models and thus give biased predictions.

Proper statistical analysis of these non-stationary and heteroscedastic time series with the aim of detecting and subsequently explaining the variations in their statistical characteristics requires the use of nonlinear time series models. This information can be then used to improve the model building and calibration of conceptual water quality model or to select right calibration periods in order to produce reliable predictions.

The objective of this contribution is to analyze two long time series of nitrate concentrations of the rivers Ouse and Stour with advanced nonlinear statistical modelling techniques and compare their performance with traditional linear models of the ARMA class in order to identify changes in the time series characteristics. The time series were analysed with nonlinear models with multiple regimes represented by self-exciting threshold autoregressive (SETAR) and Markov-switching models (MSW).

The analysis showed that, based on the value of residual sum of squares (RSS) in both datasets, SETAR and MSW models described the time-series better than models of the ARMA class. In most cases the relative improvement of SETAR models against AR models of first order was low ranging between 1% and 4% with the exception of the three-regime model for the River Stour time-series where the improvement was 48.9%. In comparison, the relative improvement of MSW models was between 44.6% and 52.5 for two-regime and from 60.4% to 75% for three-regime models. However, the visual assessment of models plotted against original datasets showed that despite a high value of RSS, some ARMA models could describe the analyzed time-series better than AR, MA and SETAR models with lower values of RSS. In both datasets MSW models provided a very good visual fit describing most of the extreme values.