Modelling trends in climatic time series using the state space approach

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A typical feature of climatic time series is that they are not stationary but exhibit both slowly varying and abrupt changes in their distributional properties. These are caused irregular natural variability and by external forcing such as changes in the solar activity or volcanic eruptions. Further, the data sampling is often nonuniform, there are gaps in observations, and the uncertainty of the observations varies. When the observations are combined from various sources there will be instrument and retrieval method related biases.

Dynamic regression with state space representation of the underlying processes provides flexible tools for these challenges in the analysis. By explicitly allowing for variability in the regression coefficients we let the system properties change in time and this change can be modelled and estimated, also. Furthermore, the use of unobservable state variables allows modelling of the processes driving the observed variability, such as seasonality or external forcing, and we can explicitly allow for some modelling error.

The state space approach provides a well-defined hierarchical statistical model for assessing trends defined as long term background changes in the time series. The modelling assumptions can be evaluated and the method provides realistic uncertainty estimates for the model based statements on the quantities of interest. We show that a linear dynamic model (DLM) provides very flexible tool for trend and change point analysis. Given the structural parameters of the model, the Kalman filter and Kalman smoother formulas can be used to estimate the model states. Further, we provide an efficient way to account for the structural parameter uncertainty by using adaptive Markov chain Monte Carlo (MCMC) algorithm. This allows full Bayesian estimation of trend related statistics by simulating realizations of the estimated processes.

This presentation will provide a practical solution to the methodological challenges. It is illustrated by two case studies in trend and trend change point analyses. First, analysis of the recovery of stratospheric ozone using time series constructed from three different satellite instruments spanning the years 1984–2012. Second, a study of global warming trends in monthly mean temperature records in Finland using homogenized station values from the years 1847–2012.

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