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A smoothing algorithm for estimating time dependent parameters: application to a simple climate model

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The structure of environmental models is rarely good enough to predict the deterministic behaviour of the environmental system at the level of precision of modern measurement devices. This leads to invalidation of a basic statistical assumption that is often used for statistical inference of model parameter values: the assumption that measurements are independently and identically distributed around deterministic model results.

Systematic deviations of model results from measurements are a fundamental problem in the estimation of parameters and their uncertainties.

This situation leads to a demand for statistical techniques that can be used to detect and diagnose model deficits using detailed measurements, and to include systematic deviations of assumed random origin into uncertainty estimates of model parameters and predictions.

To constructively diagnose model deficits, it is not sufficient to merely identify systematic deviations of model results from data. Rather, it is much more useful to identify model adaptations that would lead to improved model fit.

We suggest that this can be done by considering parameters as stochastic processes and using the data to identify their time-dependent states as well as the parameters of the stochastic process itself.

An analysis of the identified temporal behaviour can then lead to the search for causes

of this behaviour. If the variables describing these causes can be modelled deterministically, then the model structure can be extended to represent the newly identified cause-effect relationships.

On the other hand, if the variables describing these causes vary randomly, or if it seems more realistic to describe the variation by a random process, then this random process can be included in the model, thus giving more realistic estimates of uncertainty in model predictions.

We present a Markov Chain Monte Carlo algorithm to perform Bayesian parameter estimation for time dependent parameters.

The time dependent parameters are supposed to follow a mean reverting Ornstein-Uhlenbeck process. The hyper-parameters of the stochastic process are selected by means of a Bayesian cross validation criterion.

An application of the techniques to a simple 1-dimensional upwelling-diffusion climate model is presented.