Geophysical Research Abstracts
Vol. 15, EGU2013-7856-1, 2013
EGU General Assembly 2013

Parameter estimation in slow fast models: a palaeoclimate application

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Ice ages have paced climate for about 3 million years. They are characterised by a succession of glacial and interglacial eras, the latest interglacial era having begun approximately 11,000 years ago. There is debate about the timing of the next glacial era, although this is only one of many possible questions about the dynamics of ice ages. Our focus is on how to express these questions in a statistically coherent framework. Even leaving aside chronological uncertainties, the problem is challenging, and we show why.
The ice volume oscillations have been modelled by using a non-linear stochastic differential equation with a drift function involving astronomical forcing and a Wiener process as a noise term. Additionally, the observation measure through a proxy is considered as contaminated by another independent noise. The deterministic version of this model has potentially complex dynamics, which can be connected to the theory of strange non-chaotic attractors. The challenge we are facing with the calibration of this model is partly related to the complexity of its dynamics. For estimating the parameters of the model based on observations, two strategies are considered, one by extending the space of the unobserved variables for including the parameters, and the other by approximating the integral over the unobserved variables in order to obtain the marginal likelihood. Both for the estimation in the extended model and for the numerical integration, an unscented Kalman filter and a particle filter are used and compared.