Quantifying uncertainties in paleoclimate reconstruction: A case study over the past 800 kyr.

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Abstract

Our understanding of the paleoclimate is based on proxy data taken from climate archives, and models of the climate that mathematically formulate hypotheses of long-term climate dynamics. Utilizing these sources of information is non-trivial. Proxy data are sampled at a sequence of depths that must be converted into ages through the use of an age model, and the climate models need to be calibrated using suitable proxy data. Each of these undertakings involves numerous sources of uncertainty, such as uncertainties in the age and parameter estimates, discrepancies between models and real-world system dynamics, and in how proxy measurements relate to the state of the system. Accurately quantifying these uncertainties, and in particular propagating uncertainties through the entire analysis, is essential if we are to trust in the inferences from these investigations. Performing these investigations in two distinct stages of analysis can make this difficult, particularly when strong dependencies exist between stages. In this talk we demonstrate that Bayesian methodology is now sufficiently advanced for a single joint analysis to be undertaken, which characterizes each of these sources of uncertainty.

Our motivating example is the glacial-interglacial cycle over the past 800 kyr. Over this period the climate exhibits oscillations between cold periods in which glaciers extended, and warm periods in which the glaciers retreated. This is clear in, for example, benthic records of 18O, which is a measurement of the ratio between 18O and 16O taken from calcite shells embedded in deep-sea sediment cores, and is primarily a function of global temperature and ice volume at the time the calcite shell was deposited. Models of the glacial-interglacial cycle are frequently characterized as either ODEs or SDEs that explicitly model only several climate variables. These are termed phenomenological models, as they are consistent with the underlying dynamics of the system, but not derived from the physical processes. The tasks we aim to undertake are fitting an age model to the sediment cores (age estimation), reconstructing components of the climate over time (climate reconstruction), estimating the parameters of a phenomenological model (model calibration), and determining which models are more supported by the data (model comparison).