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Data-driven modeling of the Middle Pleistocene transition

Dmitry Mukhin (1), Andrey Gavrilov (1), Evgeny Loskutov (1), Juergen Kurths (2), and Alexander Feigin (1)
(1) Institute of Applied Physics of the Russian Academy of Sciences, Nizhny Novgorod, Russian Federation, (2) Potsdam Institute for Climate Impact Research, Potsdam, Germany

Many conceptual models of the Pleistocene dynamics have been suggested showing a variety of relevant dynamical mechanisms leading to the Middle Pleistocene transition (MPT), but so far there is no consensus about the most preferred one. Hear we suggest a data-driven modeling approach for inferring the MPT mechanisms from the widely used LR04 stack based on benthic d18O records. We use Bayesian data analysis for revealing the model that is minimal but enough for describing data. Mathematically, such a model provides highest probability to produce the proxy records we have, and hence, yields statistically justified inferences. Thus, a model so obtained is fully independent of any physical conception and can be used for verification of different climatological theories trying to explain the observed phenomena.

We construct the data-driven model in the form of stochastic nonlinear evolution operator parameterized via a universal approximator (artificial neural network) and forced by the insolation signals at different latitudes. The model also contains adjusting explicit dependence on time reflecting the secular cooling (and decreasing CO_2) trend that was permanent during the Pleistocene. The stochastic state-dependent term in the model reflects shorter-scale (millennial and centennial) processes which are under temporal resolution of data we use.

We find that the MPT was generated due to a long-term trend in climate leading to a noise-induced strongly nonlinear (sawtooth) oscillation build-up. It is very important that such post-MPT sawtooth oscillations cannot arise in our model without shorter-scale (millennial and centennial) forcing treated as stochastic process in the model; also, the model detects the increasing power of such processes in colder climate. Possibilities of more detailed studying of the interaction between such processes and the glacial cycles by inclusion of a millennial-scale model in the procedure are discussed. Regarding the external forcing, our finding is that the Earth's obliquity 41 kyr oscillations have dominant impact on climate variability during the whole Pleistocene via the insolation meridional gradient. The obliquity oscillations both amplify the glacial-interglacial cycles and phase-lock the major deglaciations in the post-MPT climate.