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Stochastic Climate Forcing for Ice-Sheet Models

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Climate oscillations from glacial periods, with large parts of the continents covered with ice, to warm interglacials like the present one, are observed in various paleoclimatic records over the past few million years. According to Milankovitch theory, which is commonly assumed, these glacial cycles are linked to changes in insolation due to periodic changes of external earth-orbital forcing. However, this relationship is far from understood, because the insolation variations are so small that enhancing feedbacks must be at play. Moreover, there are several shortcomings in the Milankovitch theory: first, the duration of the glacial cycles changed at the so-called Mid-Pleistocene transition from 41,000 years to approximately 100,000 years and second, the interglacial of 400,000 years ago should not have happened. Thus, the current phasing and magnitude of the glacial cycles are far from being well understood and the external perturbation might only play a minor role in comparison to internal stochastic variations or internal oscillations.

Although modern Ice-Sheet Models (ISM) are able to simulate evolution of ice-sheets at the entire glacial or interglacial time scales, the state-of-the-art Earth System Models (ESM) are too computationally expensive for such long integrations. Therefore, a constant climate forcing is usually used in the ice-sheet models. However, this approach does not take into account the stochastic nature of climate. At the same time, ESM models provide valuable information on natural climate variability, which then can be used for building stochastic climate models able to generate both continuous and discrete climate variables with stochastic atmospheric processes. In this study, we present a stochastic climate model, built from large sets of Community Earth System Model (CESM) integrations with both internal and external climate forcing, and able to generate synthetic climate forcing (such as temperature and precipitation fields) of any length. The stochastic model is based on Empirical Orthogonal Functions (EOFs) technique with regression models for Principal Components (PCs) and generates seasonal climate patterns. It is also conditioned on large-scale atmospheric and oceanic circulations and inherits statistical properties of climate from the CESM model runs. The stochastic model output will be further used in ISM model for investigating ice age hypotheses.