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New estimation of critical orbital forcing – CO_2 relationship for triggering of glacial inception

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Glacial inception represents a bifurcation transition between interglacial and glacial states and is governed by the non-linear dynamics of the climate-cryosphere system. It has been previously proposed that to trigger glacial inception, the orbital forcing defined as the maximum of summer insolation at 65^{o}N and determined by Earth's orbital parameters must be lower than a critical level. This critical level depends on the atmospheric CO_2 concentration. While paleoclimatic data do not constrain the critical dependence, its accurate estimation is of fundamental importance for predicting future glaciations and the effect that anthropogenic CO_2 emissions might have on them.

In this study we use the new Earth system model of intermediate complexity CLIMBER-X (which includes modules for atmosphere, ocean, land surface, sea ice and the new version of the 3-D polythermal ice sheet model SICOPOLIS) to estimate the critical orbital forcing - CO_2 relationship for triggering glacial inception. We perform a series of experiments in which different combinations of orbital forcing and atmospheric CO_2 concentration are maintained constant in time. Each model simulation is run for 1 million years using an acceleration technique with asynchronous coupling between the climate and ice sheet model components. SICOPOLIS is applied only to the Northern Hemisphere with a 40 km horizontal resolution.

We analyse for which combinations of orbital forcing and CO_2 glacial inception occurs and trace the critical relationship between them, separating conditions under which glacial inception is possible from those where glacial inception is not materialised. We study how adequate it is to use the maximum summer insolation at 65°N as a single metric for orbital forcing, as well as consider the differential effect each one of Earth's orbital parameters might have. In addition, we investigate the spatial and temporal patterns of ice cover during glacial inception under different orbital forcings.