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A Simple Model for Glacial Cycles and Impact of fossil fuel CO2 emissions

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We propose a simple physically-based model of the coupled evolution of Northern Hemisphere (NH) landmass ice-volume, atmospheric CO_2 concentration and global mean temperature. The model only external forcings are the orbital forcing (maximum solar insolation at 65°N) and anthropogenic CO_2 emissions. The model consist of a system of 3 coupled non-linear differential equations, representing physical mechanisms relevant for the evolution of the climate system in time-scales longer than thousands of years.

When forced by the orbital forcing only, the model is successful in reproducing the natural glacial-interglacial cycles of the last 800kyr, in agreement with paleorecords and simulations performed with the CLIMBER-2 Earth System Model of intermediate complexity. The model is successful in reproducing both the timing and amplitude of the glacial-interglacial variations, producing a correlation with paleodata of 0.75 in terms of NH ice-volume.

For the next million years, we analyse the model results under different scenarios: the natural scenario (in which only orbital forcing is applied) and scenarios in which various magnitudes of fossil fuel CO_2 emissions are considered (in addition to the orbital forcing).

When anthropogenic emissions are included the model shows that even fairly low CO_2 anthropogenic emissions (100 Pg or larger) are capable of affecting the next glacial inception, expected to occur in 120kyr from now, delaying large NH ice formation by 50kyr. Considering total carbon releases ranging between 1000 and 5000 Pg (a reasonable expectation of fossil fuel CO_2 emissions to occur in the next few hundred years) the temporal evolution of the climate system could be significantly different from the natural progression. Emissions larger than 3000 Pg could have long-lasting effects, being natural conditions not resumed even after 1 Million years have passed. In addition, emissions larger than 4000 Pg prevent glacial cycles in the next half million years.