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Evolution of the climate in the next million years: A reduced-complexity model for glacial cycles and impact of fossil fuel CO2

Stefanie Talento and Andrey Ganopolski
Potsdam Institute for Climate Impact Research, Potsdam, Germany (talento@pik-potsdam.de)

We propose a reduced-complexity process-based model for the long-term evolution of the global ice volume, atmospheric CO_2 concentration and global mean temperature. The model only external forcings are the orbital forcing and anthropogenic CO_2 cumulative emissions. The model consists of a system of three coupled non-linear differential equations, representing physical mechanisms relevant for the evolution of the climate – ice sheets – Carbon cycle system in timescales longer than thousands of years. The model is successful in reproducing the glacial-interglacial fluctuations of the last 800 kyr, in good agreement with paleorecords both in terms of timing and amplitude, with a correlation between modelled and paleo global ice volume of up to 0.86.

Using different model realisations, we generate a probabilistic forecast of the evolution of the Earth system over the next 1 million years under natural and several fossil-fuel CO_2 release scenarios. In the natural scenario, the model assigns high probability of occurrence of long interglacials in the periods between present and 50 kyr after present, and between 400 kyr and 500 kyr after present. The next full glacial conditions are most likely to occur 90 kyr after present. The model shows that even already achieved cumulative CO_2 anthropogenic emissions (500 PgC) are capable of affecting the climate evolution for up to half million years, indicating that the beginning of the next glaciation is highly unlikely in the next 150 kyr. If cumulative fossil-fuel CO_2 emissions reach 3000 PgC, or higher, the model predicts with high probability ice-free Northern Hemisphere landmass conditions will prevail in the next half million years, postponing the natural occurrence of the next glacial inception to 600 kyr after present.