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Magnitude of anthropogenic CO_2 emissions and pre-industrial carbon cycle state as key factors which determine timing of the next glacial period

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Due to the exceptionally long atmospheric lifetime of anthropogenic CO_2, anthropogenic emissions are expected to affect the timing of the next glacial cycle. This is because glacial inception depends not only on changes in solar insolation, but also on CO_2 concentration. Using the fast Earth system model CLIMBER-X, we conduct long-term transient coupled climate–carbon cycle–ice sheet simulations to explore how different levels of cumulative emissions influence the predicted timing of the next glacial inception. Our results show that assumptions about the pre-industrial state of the carbon cycle and the magnitude of cumulative emissions profoundly impact the predicted timing of inception. We find that historical carbon emissions are insufficient to delay the next glacial period, which would naturally occur around 50 kyr AP (kiloyears after present). Cumulative emissions exceeding 1000 PgC are likely to postpone glacial inception until 100 kyr AP, while emissions up to 5000 PgC would still lead to glacial inception within the next 200 kyr. Millennial-scale AMOC variability, particularly its weakening into Stadial conditions, is also shown to play a critical role in the exact timing of the onset of the next glaciation. Despite this, the simulated timing of glacial inception aligns reasonably well with the predicted timing, which was found using the critical insolation–CO_2 relation and a dedicated set of coupled climate–carbon cycle experiments. In these experiments, the predicted timing was identified as the point when the simulated atmospheric CO_2 concentration drops below the critical threshold required to trigger glacial inception, given a specific value of maximum summer insolation at 65°N. Our study underscores the long-term impact of anthropogenic CO_2 emissions on the Earth's climate, and offers new insights on the inherent predictability of glacial cycles.