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Uncertainties in climate sensitivity and residual carbon emissions permit for a hothouse climate ahead

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Given the large 'very likely' range of equilibrium climate sensitivity (ECS, 2 to 5 K), as reported by the Intergovernmental Panel on Climate Change (IPCC) and additional carbon cycle feedbacks, we investigate whether the current Earth system has the potential to significantly deviate from pre-industrial levels in the long-term towards a "hothouse" state. We use the fast Earth system model CLIMBER-X to generate an ensemble of simulations for the next millennium with interactive CO_2 and CH_4 for ECS values between 2 and 5 K, and force our simulations using the extended low-to-intermediate emission scenarios of SSP1-2.6, SSP4-3.4, and SSP2-4.5. These scenarios are normally associated with peak global warming levels of 1.5, 2, and 3°C respectively for a standard ECS of approximately 3 K.

In simulations using an ECS of 5 K, we observe that the global mean temperature increase would more than double compared to the standard ECS of 3 K. Roughly half of this warming is propelled by positive carbon cycle feedbacks in the different scenarios, with equal contributions from both CO_2 and CH_4. In the SSP2-4.5 "middle of the road" scenario, we find that a high ECS could see global mean temperatures which exceed 7 °C within the next millennium, with some regions experiencing temperature increases up to 20 °C via polar amplification. If we consider unavoidable residual carbon emissions of less than 10% of our present-day value, we find that the CO_2 concentration in the atmosphere can be sustained, thereby resulting in a continuous temperature rise until the year 3000 A.D. unless carbon is sequestered. Prolonged periods of high temperatures, as seen in this study, could lead to the breaching of critical thresholds within the Earth system, like the stability of the Greenland and Antarctic ice sheets for example. As high ECS values cannot be disregarded as implausible at the present time, these results hint hint that we could be on track towards an extreme "hothouse" climate in the long-term if there is no carbon removal.