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Impact of vegetation cover on interglacial climates

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Quaternary interglacials show varying amplitudes and different patterns of changes in climate and vegetation cover. A better understanding of these changes requires deeper insight into the mechanisms by which climate and vegetation interact. Using the Earth system model CESM1.2, the present study assesses the role of Northern Hemisphere vegetation changes in shaping the global climate for different interglacial warm intervals: the mid Holocene (MH; 6 ka), the Last Interglacial (LIG; 127 ka), and Marine Isotope Stage 11 (MIS 11; 409 ka). The model allows the prognostic and interactive simulation of leaf and stem area indices and vegetation height, while the vegetation biogeography is fixed ("semi-dynamic vegetation"). In accordance with previous studies, we find that the simulated interglacial climates turn out to be too cold compared to reconstructions. Relative to the pre-industrial (PI) control run, the annual global mean surface air temperature (SAT) is 0.3 K colder in the MH, 0.1 K colder at the LIG and unchanged at the MIS 11 time slice. Strongest warming is found above the Arctic Ocean, where the model simulates a mean annual SAT increase by up to 3 K for the MH, up to 7 K for the LIG, and up to 6 K for MIS 11. Applying changes in the vegetation cover, which more realistically represent the biogeography of the interglacial time slices (including expansion of vegetation over North Africa and in the northern hemisphere mid and high latitudes), has crucial impact on the global interglacial climates. Over Siberia, annual mean SAT increases by 2-3 K in all interglacial experiments compared to PI. Globally, the MH becomes 0.4 K warmer, the LIG becomes 0.6 K warmer, and the MIS 11 becomes 0.8 K warmer relative to PI. Polar amplification is much more pronounced after applying the vegetation changes, with an annual mean warming of 5-6 K over the Arctic Ocean at the MH, up to 9 K at the LIG, and 7-8 K at MIS 11. The large polar temperature changes during the LIG are associated with a seasonally ice-free Arctic Ocean. The vegetation changes also impact the interglacial atmospheric water cycles, most pronounced in Northern Hemisphere monsoon regions. In particular, the West African monsoon is substantially amplified in response to the expansion of vegetation. Physical processes causing these changes are analyzed. In summary, the results suggest that the intricate interplay between climate and vegetation stands as one of the fundamental mechanisms shaping the dynamics of past interglacials, which needs to be more carefully addressed in future model studies.