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Impacts of land surface properties on Last Glacial Maximum climate

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Climate models tend to overestimate surface temperatures and precipitations at the Last Glacial Maximum (21,000 BP). Changes in vegetation cover at that period may possibly represent a non negligible feedback to improve model-data agreement. At the Last Glacial Maximum (LGM), grassland and desert ecosystems were more widespread than they are today, mainly at the expense of forest ecosystems. In general, vegetation cover was less dense. Such a change is expected to lead to an increase of surface albedos and a decrease of roughness lengths. Both effects may impinge on surface temperatures.

In this work, we have analysed the implications of changing land surface properties on the climate at the LGM. The Planet Simulator, an Earth system model of intermediate complexity (Fraedrich et al., 2005, Meteorol. Z. 14: 299-304 and 305-314) was used to carry out a series of sixteen simulation experiments, where we have assessed the effects from differences in (1) the vegetation cover (via surface albedos and roughness lengths), (2) ice-sheet cover, (3) orography and (4) the effect of reduced atmospheric carbon dioxide between a pre-industrial state and the LGM. The sixteen simulation experiments consider all possible perturbations of a given control run configuration by prescribing changes of these four parameters individually and combined.

The factor separation method of Stein and Alpert (U. Stein et P. Alpert, 1993, J. Atmos. Sci., vol. 50(14):2107-2115) was used to analyse the results from the sixteen simulation experiments in terms of the individual and combined contributions of the four applied modifications to the overall response of the climate system.

Vegetation changes between the pre-industrial and the LGM have been obtained from simulation experiments carried out with the dynamic vegetation model CARAIB (Otto et al., 2002, Global Planet. Change, vol. 33:117-138). These changes were then translated into corresponding changes of surface albedos and roughness lengths, which are required as boundary conditions in the Planet Simulator.

Our results witness of a global cooling due to the reduction of atmospheric CO2, a large and more localised cooling due to the ice cover change and of the strong influence of orography on atmospheric circulation and winds. They also emphasize the non negligible impact of vegetation cover change on climate. Indeed, we find that the vegetation cover change at the LGM leads to significant global cooling, with more pronounced local contrasts, together with a decrease in precipitations. Our analysis furthermore points out important non-linear effects when the combined effects are considered. We find that the change in the vegetation cover reinforces the cooling due to other surface cover changes, such as the ice-cover, when applied together with them.

The results from our simulation experiments emphasise that it is important to take the climate-vegetation interaction into account when using climate models to study past, present or future climate change.