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Underestimation of mid-Holocene Arctic warming in PMIP simulations

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Due to the orbital forcing, Arctic is warmer during mid-Holocene ($\sim$ 6 kyr BP) in summer because the region received more insolation and also warmer in winter because of strong feedbacks, leads to an annual mean temperature warming. Existing proxy reconstructions show that the Arctic can be two degrees warmer than pre-industrial. However, not all the climate models can capture the warming, and the amplitude is about 0.5 degree less than that seen from proxy data. One possible reason is that these simulations did not take into account a fact of 'Green Sahara', where the large area of Sahara region is covered by vegetation instead of desert as it is today.

By using a fully coupled climate model EC-Earth with about 100 km resolution, we have run a series of sensitivity experiments by changing the surface type, as well as accompanied change in dust emission over the northern Sahara. The results show that a green sahara not only results in local climate response such as the northward extension and strengthening of African monsoon, but also affect the large scale circulation and corresponding meridional heat transport. The combination of green sahara and reduced dust entails a general strengthening of the mid-latitude Westerlies, results in a change to more positive North Atlantic Oscillation-like conditions, and more heat transport from lower latitudes to high latitudes both in atmosphere and ocean, eventually leads to a shift towards warmer conditions over the North Atlantic and Arctic regions. This mechanism would explain the sign of rapid hydro-climatic perturbations recorded in several reconstructions from high northern latitudes after the termination of the African Humid Period around 5.5 - 5.0 kyr BP, suggesting that these regions are sensitive to changes in Saharan land cover during the present interglacial. This is central in the debate surrounding Arctic climate amplification and future projections for subtropical precipitation changes and related surface type changes. Our results also suggest that proper reconstruction of vegetation cover and dust emission are needed to paleoclimate modelling community in order to reproduce a more realistic mid-Holocene climate.