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Dominant role of the global monsoon intensity on large-scale Holocene vegetation transitions

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We give an overview on the global change in mid-to late Holocene vegetation pattern derived from a transient MPI-ESM1.2 simulation and discuss the vegetation trend in the context of the simulated Holocene climate change. The model captures the main trends found in reconstructions. Most prominent are the southward retreat of the northern treeline, coinciding the strong reduction of forest cover in the high northern latitudes during the Holocene, and the vast increase of the Sahara desert that is embedded in a general decrease and equator-ward retreat of the vegetation in the northern hemispheric monsoon margin regions. In contrast, large parts of the extratropical North American continent experience a greening during the Holocene, caused by an increase in forest and grass cover.

While the broad forest decline in the high northern latitudes can mainly be explained by the cooling of the warm season climate, precipitation is the driving factor for the tropical and extratropical vegetation trends on the northern hemisphere south of 60°N. The model indicates that most of the changes in rainfall can be related to the weakening of the northern hemispheric monsoon systems and the response of the global atmospheric circulation to this weakening.

The southern hemisphere is less affected by changes in total vegetation cover during the last 8000 years, but the monsoon related increase in precipitation and the insolation-induced cooling of the winter climate lead to shifts in the vegetation composition, mainly in between the woody plant functional types (PFTs).

The simulated large-scale global vegetation pattern almost linearly follow the subtle, approximately linear orbital forcing. Non-linear and more rapid changes in vegetation cover occur only on a regional level. The most striking area is the western Sahel-Sahara domain that experiences a rapid vegetation decline to a rather desertic state, in line with a strong decrease in moisture availability. The model also indicates rapid shifts in the vegetation composition in some regions in the high northern latitudes, in South Asia and in the monsoon margins of the southern hemisphere. These rapid transitions are mainly triggered by changes in the winter temperatures, which go into, or move out of, the bioclimatic tolerance range of the individual PFTs defined in the

model and therefore have to be interpreted differently.

In summary, our model results identify the global monsoon system as the key player in Holocene climate and vegetation history and point to a far greater importance of the monsoon systems on the extra-monsoonal regions than previously assumed.