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The role of Saharan dust in modulating monsoon response in MPI-ESM mid-Holocene simulations

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In mid-Holocene (ca. 6,000 years ago) different orbital conditions caused more summer insolation in the Northern Hemisphere than at present-day. This had lead to a dramatic increase in the vegetation cover in North Africa and a strengthening of the West African Monsoon (WAM). Since the Sahara was mainly covered by grassland and savanna, the atmospheric burden of Saharan dust was substantially lower than today. It is typically difficult to fully reproduce the WAM behaviours in mid-Holocene from proxy reconstructions with climate models, if they do not account for accurate changes in vegetation and dust aerosol. While many models have implemented interactive vegetation in Earth System Models, dust aerosol is often prescribed with a climatology and not interactively calculated in paleo-simulations, e.g., due to the computationally expensive aerosol schemes. Here, we present results from mid-Holocene simulations performed with the Max Planck Institute Earth System Model (MPI-ESM). The prescribed distribution of dust aerosol and its optical properties are derived from an aerosol-climate simulation with ECHAM6-HAM (Egerer et al., 2016), that has the same atmospheric model as MPI-ESM. Our results show that accounting for Saharan dust reduction substantially warms mid-Holocene summers both locally in the Sahara and even globally, with a global mean warming of about +1.2 K relative to the control simulation, based on pre-industrial dust. The regional hydrological cycle changes substantially. Evaporation increases in the region between 10°N - 20°N of the ascending branch of the Hadley circulation, leading to a dramatic change in the P-E balance there. The net effect of this response is an about 14% weaker and narrower WAM compared to the simulation with the pre-industrial dust aerosol. These changes are an improvement of the model performance in comparison to the proxy reconstructions in deep tropics (5°N - 10°N) and in the Sahel region (15°N - 20°N). Our results point to the importance of desert-dust aerosol for simulating global and regional climates.