

Interactive comment on “The impact of Sahara desertification on Arctic cooling during the Holocene” by F. J. Davies et al.

Anonymous Referee #3

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The impact of Sahara desertification on Arctic cooling during the Holocene

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This paper presents a collection of sensitivity experiments using the Earth System Model of Intermediate Complexity (EMIC) LOVECLIM1.2. This model allows for a large number of sensitivity studies that would otherwise not be possible for this type of study. The main goal of the paper was to identify the variability in cooling in the Arctic associated with simulated desertification that occurred in the Sahara during the transition from the Holocene to modern. The expanding literature continues to recognize the importance of the role of land surface changes on Northern Hemisphere climate. Paleoenvironmental teleconnection modeling studies of this type form an important basis for understanding transient climate change, in connection with proxy data validation, and

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therefore are well suited to discussion in Climate of the Past.

Comments:

In the Experimental Design section the discussion of how the LIS and GIS meltwater fluxes are not included (P1657L8) should be discussed just after the OGGIS simulation is described or page 1656L14. So a reorganization of section 2.2 is necessary.

In the results section on from P1658L17 to P1659L11 there is some discussion of the possible atmospheric and ocean mechanisms involved in connecting changes in the Arctic with changes in the Sahara. I feel the ideas in this section need to be addressed in further detail with more thought put into where the model may accurately describe the dynamics and thermodynamics involved in the discussed mechanisms. Additionally, deficiencies in the model (not just clouds in the later sections) should also be addressed. There is a brief mention of the Azores high and Icelandic low that suggests some thought has gone into the connection with the variability of the North Atlantic Oscillation (NAO). Furthermore, there may be (long timescale) changes in this mode and other modes of climate variability such as the East Atlantic Mode (e.g. Barnston and Livezey 1987). This raises the question of the fidelity of the LOVECLIM model in reproducing the major modes of climate variability as compared with observation. There is no mention of this in the paper, and the description of LOVECLIM in Goosse et al 2010 does not seem to address the models ability in simulating these main models of variability (e.g. ENSO, NAO, AMO, PDO etc). Some discussion in the literature (Mairesse et al. 2013) suggest a more negative NAO during the 9-6 ka period in this model with a weaker meridional gradient and weaker westerlies. This seems to contradict the changes in winds observed between 9k0kEQ_ OG-9k9kEQ_ OG as the simulations transition towards modern. Although there seems to be no robust changes in the PMIP2 set of model with respect to this issue (e.g. Gladstone et al. 2005) these issues should be expanded up here.

In addition to changes in seasonality from orbital changes, changes in albedo from a

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darker more vegetated Sahara (9k-6k) to a contrasting dark ocean and bright desert (0k) are expected to impact the zonal circulation in the region and the downwelling of dry air over land from 9K to 0K. This should also be discussed more in context to the comments above. For changes in the meridional patterns the author can strengthen their discussions on changes in the Hadley circulation and shifts in the intertropical convergence zone (ITCZ). There is a body of literature emerging on the teleconnections between the position of the ITCZ and changes in the tropics and change in landcover in other areas (e.g. Liu et al 2014).

The change in atmospheric heat transport is briefly discussed (P1659L5-11). Is the heat transport in Fig 4 mainly from latent heat transport from transient eddies ($V'Q'$) or the total transport including sensible heat transport ($VQ+VT$) (This is not clear)? It is pointed out that the majority of the transport is from eddy latent heat transport, but on the other hand the Bjerknes compensation is mentioned where the relative balance operates on the total global atmospheric transport between land and ocean.

Equally critical to these sensitivity modeling studies is validation with proxy based climate data. The section from P1659L19 to P1660L3 does not adequately address the literature on the how the model performs in the transition from the Holocene optimum to present day.

There is a long section (compared to the rest of the paper) on pages 1660-1661 that addresses the issue on the prescription of modern clouds in the model and the impact of this on the sensitivity of the model. The section begins with a discussion that initially concludes that the surface of a cloudy and vegetated region can absorb the same amount of incoming solar radiation; I suppose to motivate the next set of sensitivity experiments. Considering the fact that the surface net longwave, sensible and latent heat balance will be completely different between vegetated and desert, the previous discussion seems a bit pointless. The authors might consider revising their motivation for this next set of sensitivity experiments. Even using the cloud cover based on the modeled Amazon distribution distribution seems like a highly speculative endeavor

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(e.g. many IPCC models show difficulty in obtaining the same modern precipitation regimes over the Amazon). There are only a couple of cloud simulations in the large set of sensitivity experiments, so these simulations could be reconsidered.

The ocean model components of EMICs are often the most sophisticated and resolved component of the coupled system, yet there is little discussion of the changes in ocean circulation through the Holocene to modern transition especially in the OGGIS simulations (e.g. the connection between changes in Sahara albedo, SSTs, deep water formation and sea ice distribution are probably quite important if there are any significant changes).

References:

Barnston and Livezey (1987) Classification, seasonality and persistence of low-frequency atmospheric circulation patterns. *Mon. Wea. Rev.*, 1083-1126

Mairesse, H. et al. (2013) Investigating the consistency between proxy-based reconstructions and climate models using data assimilation: a mid-Holocene case study. *Clim. Past*. doi:10.5194/cp-9-2741-2013

Gladstone, R et al. (2005) Mid-Holocene NAO: a PMIP2 model intercomparison, *Geophys. Res. Lett.*, 32, L16707, doi:10.1029/2005GL023596

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