Interactive comment on:

"The impact of Sahara desertification on Arctic cooling during the Holocene".

By: F.J. Davies, H. Renssen, M. Blaschek, and F. Muschitiello

This study investigates the potential impact of Saharan desertification – or expansion – on Arctic temperatures during the last 9 kyr. The authors apply the LOVECLIM model to isolate the climatic effects of changes in Saharan vegetation during the Holocene based on transient and equilibrium climate simulations. The authors conclude that the expansion of the Saharan desert, and associated changes in surface albedo, contributed significantly to decreasing temperatures in the Arctic during the Holocene. According to the model simulations, as much as 42% of the Holocene Arctic cooling can be attributed to the expansion/desertification of Sahara.

This interesting study highlights the importance of land-atmosphere teleconnections for understanding climate change, and the topic is highly appropriate for *Climate of the Past*. As such, this contribution may serve as an ideal starting point for a discussion of this important aspect of Holocene climate change. In general, however, I feel the authors are somewhat uncritical with respect to potential shortcomings of the model approach and results. The paper would benefit from a more thorough discussion of these aspects as well as a brief discussion of how the model results compare to actual reconstructions of Arctic climate change during the Holocene, an aspect that is entirely lacking.

Contribution from Saharan expansion to Arctic cooling

The impact of desertification in Sahara on Arctic cooling is quantified through a set of equilibrium experiments. However, the LIS and GIS melt-water fluxes were not included in the OGSIS equilibrium simulations, but including them "would result in constant freshening of the ocean" - preventing the oceans from reaching a quasi-equilibrium state. The authors state that "neglecting the melt fluxes likely resulted in a marginally warm early Holocene climate" (L5-13, P. 1657). However, this constant freshening of the ocean is likely to have slowed down the AMOC significantly, which would have contributed to Arctic cooling throughout parts of the Holocene. In general, the numbers quantifying the impact of Saharan desertification must be very uncertain considering the processes omitted in the equilibrium simulations. The paper would benefit considerably from a brief discussion of these aspects, which would place the impact of the Saharan desertification in a more realistic context.

To place an upper limit on the potential impact of desertification in Sahara, the authors "simulate extreme early (9 ka and late (0 ka) Holocene environments". These simulations, which were carried out with the OG model that disregards the ice sheets and melt-water fluxes, are based on extreme vegetation changes that exceed those estimated from pollen and macrofossil data (Joly et al., 1998). Therefore, to state that "the modeling results indicate that up to 42% of the cooling in the Arctic over the period 9ka – 0ka was a direct result of the desertification in Sahara" (L5, p 1654) appears a little misleading – and highly uncertain - considering the limitations of the approach. Here, the authors seem to uncritically accept the model results without any discussion of the context and assumptions involved. *(NOTE: It is a bit unclear how the number "42%" is computed – the authors refer to a temperature decrease of 4.0 C (Fig. 2d), but it doesn't look like the average temp difference north of 66.5N is 4.0 C. Guess it refers to the difference between the first and last row in table 2, but it is unclear to me how the 1.7C contribution due to 100% desertification is obtained?). Also, I don't understand why the Arctic appears colder in Fig. 2a compared to Fig. 2d, which was computed with extreme differences in vegetation?*

Another limitation in the model approach concerns the prescription of clouds in the LOVECLIM model – as explained by the authors in the paper. To address this problem, the authors carry out sensitivity tests with a cloud cover over Sahara at 9 ka that resemble the modern cloud cover prescribed for the Amazon region in the LOVECLIM model. This is a reasonable first-order test that takes into account changes in the radiation balance, but it seems to ignore related changes in precipitation and the hydrological cycle in general. It is unclear if the hydrological cycle is allowed to vary accordingly or if it is decoupled from the cloud cover. These aspects are important to assess the validity of the model results and should be discussed in more detail. *(The discussion of how the prescription of a modern Amazon-like cloud cover at 9 ka influences Arctic cooling is quite confusing (L 10-20, P. 1661) – it is somewhat unclear whether the discussed changes refer to changes between 9ka and 0 ka, or changes relative to those obtained with a modern Saharan cloud cover throughout the Holocene).*

Comparisons to climate reconstructions

Given the limitations of the model approach, it is really hard to assess the degree to which the model correctly captures the dominant processes as well as the actual climatic changes that took place during the Holocene. It would have been informative to include comparisons to proxy-based reconstructions of changes in Arctic climate during the Holocene – as well as changes in Saharan climate, but I acknowledge that such reconstructions are sparse. Several studies discuss Holocene changes in Arctic climate (e.g. Wanner et al., QSR, 2008; Vinther et al., JGR, 2005; Kaufman et al., QSR, 2004) and this study would benefit from placing the model results into such a context. For instance, do the proxy-based reconstructions show any notable change when the vegetation changes supposedly accelerated, or was the change too gradual?

A more in-depth assessment of the model limitations and a discussion of how the model results link up with reconstructed changes in Arctic climate would increase the relevance and impact of this study. However, the study represents an excellent starting point for a discussion of land-atmosphere teleconnections as well as the factors contributing to Arctic cooling during the Holocene.