Geophysical Research Abstracts
Vol. 15, EGU2013-8965, 2013
EGU General Assembly 2013

The Impact of Sahara desertification on Arctic cooling during the Holocene

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The Holocene is clearly defined by an early thermal maximum, followed by a steadily declining global temperature that persists up until the recent anthropogenically induced warming. This gradual cooling is accredited to the Milankovitch theory of orbitally induced climate change. However, over the course of the Holocene the Sahara region has undergone a dramatic change, from a humid environment (Green Sahara) to a hyper-arid environment (Desert Sahara). This is likely to have had profound effects upon the regional and global climate, due to the change in surface albedo and moisture content of the atmosphere in this region. In this study we have looked at how desertification in the Sahara between 9 and 0ka contributed to cooling on a global scale, but most noticeably in the Arctic.

Using LOVECLIM, a global climate model, we show that the desertification of the Sahara during the Holocene was responsible for a significant degree of cooling, not only in the Saharan region, but also in the high-latitudes through a teleconnection involving both the atmosphere and ocean. The change in vegetation type from predominantly grass to desert, lowers the surface albedo in the Sahara region, which reduces local temperatures, increases surface pressure and decreases the wind strength in the equatorial Atlantic. This reduces the pressure gradient between the northern and equatorial Atlantic, resulting in weaker westerly winds and therefore a reduction in the transport of heat and energy to the high northern latitudes. As a result temperatures in the Arctic cool.

The overall Arctic cooling from 9 to 0ka, due to orbital and greenhouse gases, ranges from 3-4°C. We show that 1-2°C of this cooling is the result of a long-distance impact from the Sahara desertification, with the remaining cooling due to the localised effects of insolation changes. However, the localised response is clearly delayed from summer to autumn, due to a combination of processes, including the sea-ice insulation, snow-albedo and taiga-tundra feedbacks.

By comparing our results with an idealised simulation (i.e. the difference between 100% grass covered and 100% desert covered Sahara) we were able to determine an upper estimate of 2.5-3°C for the maximum Arctic cooling due to Sahara desertification. This is useful as an upper limit because in transient simulations LOVECLIM underestimates the greening of the Sahara, implying that the impact of Sahara desertification on Arctic cooling over the Holocene could have been larger in reality.

We conclude that interglacial climate is sensitive to changes in Saharan vegetation type. With the potential for both future greening and aridification of the Sahara being projected by climate models, these results form an important observation in both the palaeo and future climate debate.

Acknowledgements: We would like to thank Francesco Muschitiello (Stockholm University) for fruitful discussions on the effect of Sahara desertification on Holocene climate change.