

Interactive comment on “Anticyclonic atmospheric circulation as an analogue for the warm and dry mid-Holocene summer climate in central Scandinavia” by K. Antonsson et al.

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The manuscript presents an attempt to explain reconstructed climate trends in central Scandinavia during Holocene by using modern climate analogues. The authors demonstrated using several (both original and previously published) climate records for this region that maximum temperatures (either annual or summer) in this region were reached during mid-Holocene and that lake level at that time (i.e. 4–8 KyBP) was lower than at present. The authors compared their data with one transient Holocene simulation performed with a climate model of intermediate complexity forced by orbital variations and came to the conclusion that modelling results are inconsistent with

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their data. Therefore, they proposed an alternative explanation for "dry and warm" mid-Holocene climate in Scandinavia. Namely, they proposed that mid-Holocene climate change in Scandinavia would be better explained by "changing atmospheric circulation" with dominating summer-time anticyclonic circulation, something like Indian summer at present. While I have no problem with this hypothesis per se, I do have some problems with the paper and several issues require clarification or corrections.

Major comments

The first problem is the meaning of "alternative explanation". From the paper it sounds like "Indian summer" is an alternative to summer insolation change for the explanation of warm and dry mid-Holocene conditions. But if it is indeed an alternative, then why atmospheric circulation and likelihood of different weather regimes were different at mid-Holocene from the present one. If it was still due to different summer insolation than the word "alternative" does not sound appropriate. In this case, the word "additional" or "complementary" would be more appropriate because insolation alone (see below) also can explain warmer and drier mid-Holocene conditions in Scandinavia. But if it was not insolation change, than what? Do the authors believe that atmospheric circulation can experience significant variations on orbital time scale without any external (for the climate system) forcing?

The second problem is the meaning of "models failure" to simulate warmer and drier mid-Holocene conditions in Scandinavia. As far as I am aware, all models (simple and GCMs) simulate warmer (at least summer) mid-Holocene climate over the continents of the Northern Hemisphere in general and over Scandinavia in particular. The magnitude of this warming is quite comparable with that derived from reconstruction (1-2C). At the same time, the meaning of the term "drier" is ambiguous. In the manuscript it clearly means less precipitation. However, the lake level is controlled not only by precipitation but also by evaporation. The latter, in turn, is very sensitive to temperature. For example, 2 degrees warming (assuming no other changes) will increase evaporation by ca. 15%. Therefore warming alone, without any appreciable change in precipita-

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tion is sufficient to explain low lakes level during mid-Holocene and hence the fact that climate models do not produce large drop in precipitation during mid-Holocene does not necessarily mean that they are wrong. Renssen's results discussed in the paper do disagree with paleoclimate reconstructions in that they show monotonous summer temperature decline during the whole Holocene whilst data show thermal "optimum" (actually maximum) after 8 KyBP. But this discrepancy is not surprising at all because in Renssen's and similar transient experiments the presence of the Northern Hemisphere ice sheets (except for Greenland) and an additional freshwater flux into the ocean associated with ice sheets melting were not taken into account. The latter, in particular, can be an important factor affecting Scandinavian climate via strength of the Atlantic thermohaline circulation. Hence modelling results can be only compared with paleodata after the complete disappearance of the Northern Hemisphere ice sheets, i.e., strictly speaking, only after 7 KyBP and the lack of the temperature maximum during mid-Holocene cannot be considered as the arguments against predominantly insolation control of European climate change during mid- (but not early-) Holocene.

At last, concerning the use of modern analogues for explaining past climate change. In general this is a valuable approach. However, it has one serious problem: apparent similarity between climate pattern associated with a certain mode of present day climate variability (say El Nino, positive phase of NAO or Indian summer) and a certain period in the past, does not prove that the mechanisms behind short-term present day climate variability and long-term past climate variability are the same or even have something in common. The idea itself that certain aspects of past climate change recorded by proxies may be related not only to mean climate shifts but also to changes in short-term climate variability, such as increase of frequency of some types of meteorological conditions, is rather appealing. The question is how this specific hypothesis can be verified. I cannot imagine the type of paleoclimate proxies which can distinguish between summer warming caused by direct impact of insolation and a warming associated with the high frequency (or more persistent?) blocking events. If the authors have an idea how their hypothesis can be tested, I would suggest to share it with the

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readers.

Specific comments

Page 586, line 8 (also page 588, line 18 and other places) The term "insolation" stands for incoming solar radiation received at the Earth's surface and hence the word "solar" is not required in combination with "insolation".

Page 587, first line. What is "effective humidity"?

Page 594, lines 12/13. I am not sure I understand the meaning of "reconstructions show that major changes in summertime climate took place towards higher mid-summer temperatures..." Do you mean that summer temperatures continue to rise for some time after 8 KyBP?

Page 594, lines 17/23. This is very long and somewhat confusive sentence. Firstly, it is beyond any doubts that insolation was not "the only factor important to the climate" even during the late Holocene, not mentioning the early Holocene. Secondly, "ice sheets dynamics" was not taken into account at all in the cited publications. At last, the fact that a relatively simple climate model used in the study by Renssen et al. (2005) failed to correctly reproduce "observed" pattern of Holocene climate change in Scandinavia does not prove that this climate change cannot be explained by insolation change with more elaborated climate models and more comprehensive boundary conditions.

Page 598, line 8. Why "low solar output" is required to explain warm climate conditions in Scandinavia?

Page 598, line 10. In fact, the climate change discussed in the paper should be characterized as multi-millennial or, even, orbital-scale climate variability. And I am not aware about any mechanism in the atmosphere-ocean system which is capable to explain internal variability on such long time scales.

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