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Climate of the Past Discussions

Interactive comment on "Information on the early Holocene climate constrains the summer sea ice projections for the 21st century" *by* H. Goosse et al.

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The discussion paper shows that paleoclimatic data can help testing the ability of models to simulate climate under conditions that are outside the range of modern observation. The confidence level of sea-ice projections for the 21st century can thus be improved by validation using records from the past. The early Holocene constitutes a relatively recent "warm" interval, probably a most appropriate one for such an exercise. This point is clearly made in the paper. However, the model-data comparison that should be an important aspect of the discussion is rather elusive here. It is true that sea-ice data for the early Holocene are sparse and that model-data comparison is not a

simple matter. Nevertheless, data permitting the identification of sea-ice parameters do exist and should prove useful for comparison without biases due to over-interpretation. Thus, based on what is available in the literature, I think that the data-model comparison could be more informative than what is presented in the paper. Most of the comment below is therefore dealing with the use of sea-ice proxies for model-data comparison, with a few suggestions for future similar exercises.

When modelling sea-ice, the usual output from simulation is the extent of sea-ice expressed in km2 (cf. Tables 1-2, figures 3-4 of the discussion paper). In contrary to modelled results, reconstructions of past sea-ice cover are made locally from the analyses of marine cores and can not provide information on the areal extent of sea-ice, without large scale extrapolation that could results in biases. Extrapolations from a few data points are not a straightforward exercise in the Arctic and subarctic areas, because of heterogeneities in the spatial distribution of sea-ice in time and space. For example, the few available Holocene records suggest opposite sea-ice trends in the western vs. eastern Arctic (e.g., Fisher et al., 2006). Moreover, the reconstructed sea-ice parameter is not the same depending upon the proxy that is considered. Most proxies permit inferences in terms of presence vs. absence of sea-ice (e.g., ice-rafted debris, presence of fossil taxa associated with sea-ice or occurrence of taxa intolerant to sea-ice and freezing conditions). A few proxies may allow inference in terms of concentration or seasonal duration of sea ice (e.g., dinocysts; cf. de Vernal and Hillaire-Marcel, 2000). However, proxy data for perennial sea-ice (i.e., summer sea-ice) do not really exist because the inference of permanent sea-ice cover is usually based on the negative evidence such as the absence of microfossils suggesting nil productivity. Therefore, the "summer sea-ice extent" or perennial sea-ice is not the best parameter for comparing paleoclimate model simulations and paleoclimate data records. Nevertheless, even if the minimum sea-ice extent is of limited use for model-data comparisons, the distribution pattern of sea-ice, including the limits of both its maximum and minimum cover and its concentrations or seasonal extent could be useful. From this point of view, figure 2a is interesting but could be complemented with a figure showing the maximum limit

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of sea-ice and the anomalies (8 ka - modern) in term of mean annual concentrations. Such figures would help comparing model outputs with available paleoceanographical data reporting sea-ice cover estimates during the early Holocene. As a matter of fact, around 8 ka, sea-ice had a distribution pattern very different than at present, with positive anomalies (more sea-ice) in Chukchi Sea (cf. de Vernal et al., 2005) and along the eastern Greenland margins (cf. Solignac et al., 2006), whereas negative anomalies (less extended sea-ice) characterized the Baffin Bay, southern and eastern Labrador Sea (de Vernal and Hillaire-Marcel, 2006).

As mentioned in the discussion paper, early Holocene data from the Chukchi Sea, in the western Arctic, indicate a relatively dense sea-ice cover and thus permit to discard the simulation performed with parameter set E5. In addition, data from northernmost Baffin Bay (Levac et al., 2001), which indicate much reduced sea-ice during the early Holocene, and reconstructions from the Barents Sea (Voronina et al., 2001), which show similar sea-ice conditions, both suggest that the parameter sets E1 and E2 lead to significant overestimation of sea-ice cover in summer, at least regionally. Thus, the only parameter sets possibly yielding simulations consistent with data, are E3 and E4, but this has to be verified from fields providing maximum sea-ice cover or anomalies in its concentration. Alternatively, the ability of LOVECLIM to reproduce regional patterns should be questioned.

Although the information on the early Holocene climate is sparse and lacks accuracy, as stated by the authors, it nonetheless provides a means to evaluate models that are used in climate projection for the 21st century. From this point of view the manuscript of Goosse et al., which provides an illustration of such an approach, is a useful contribution. The strength of the conclusion, however, could be improved by a deeper deeper examination of paleoclimate data.

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