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# *Interactive comment on* "Hindcasting the continuum of Dansgaard–Oeschger variability: mechanisms, patterns and timing" *by* L. Menviel et al.

**M. F. Sanchez Goñi (Referee)**

mf.sanchezgoni@epoc.u-bordeaux1.fr

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## General comments

The manuscript submitted to The Climate of the Past Discussions by Menviel et al. presents new LOVECLIM simulations for Dansgaard-Oeschger (D-O) and Heinrich events (HE). These simulations are designed in such a way that freshwater forcing in the North Atlantic Ocean generates changes in the Atlantic Meridional Overturning Circulation (AMOC) that produce realistic sea surface temperature changes (SST) when compared with alkenone-derived SST in the Iberian margin. The novelty of this contribution lies on the fact that these simulations are constrained by local observations.

Despite this weak constrain, the comparison between independent observations and the simulated climatic conditions (for example, the variability of temperature and hydro-climate in the eastern Mediterranean region, AMOC changes, Greenland temperature changes. . .) indicate a strong agreement. The authors conclude that this high level of agreement provides strong support for their initial hypothesis: "Heinrich events and DO variability during MIS 3 were caused by Northern Hemisphere ice sheet calving and freshwater discharges which subsequently influenced the strength of the AMOC, poleward heat transport and eventually global climate". This work deserves publication in The Climate of the Past. However, I have a number of concerns that the authors should address prior the manuscript be accepted by CP.

In the Introduction, it would be worth that the authors cite the main hypotheses put forward to explain D-O climatic variability and Heinrich events. Besides that, the key question (iii) "What sets the length of these events and their 'periodicity'?" should be rephrased. I do not understand if the authors address the length of the change itself or the length of the climatic phase produced by the change, I mean D-O warming/cooling versus Greenland Interstadial (GI)/Greenland Stadial (GS) and HE versus Heinrich Stadial (HS) and Heinrich layers (HL). The terms used by Menviel et al., are confusing, and the reader cannot easily follow author's arguments. HE are different from HS and HL (see discussion in Sanchez Goñi and Harrison, 2010, QSR).The titles of sections 3.5 and 3.7, "Abruptness of events" and "Timing and duration of events", respectively are now misleading because the authors discuss in 3.5 the duration of the event (D-O warming, i.e. a change) and in 3.7, as in Table 1, the duration of the climatic phase triggered by HE (recorded in the sediments by the presence of IRD that we call HL), i.e. HS. This part of the manuscript needs to be reorganized and clarified. In Table 1, it is really surprising to see that the authors discuss the duration of the HS based on terrestrial and ice paleoclimatic archives where there is no any direct tracer for HS, i.e. Ice Rafted Detritus (IRD). I suggest to the authors to look at the duration of HS based on the compilation of North Atlantic sequences by Elliot et al. (1998, 2001) (see discussion in Sanchez Goñi & Harrison, QSR, 2010).



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I am a little bit worried about the proxies used to perform the comparison between simulated and observed climatic variables. In particular, $\delta$18O and L* are not direct tracers for quantitative temperature and precipitations changes. I suggest to the authors to compare their simulations with pollen-derived quantitative temperature and precipitations estimations from the western Mediterranean region (Sanchez Goñi et al., 2002 Climate Dynamics).

The authors say that it is demonstrated that rainfall changes in the Arabian Sea track millennial-scale SST variations in the North Atlantic region. However, the age model uncertainties of North Atlantic marine records and the Arabian Sea record preclude demonstrating such a synchrony.

In the Conclusion section, the authors conclude that Heinrich events and D-O variability during MIS 3 were caused by Northern Hemisphere ice sheet calving and freshwater discharges based on the strong agreement between simulated and observed paleoclimatic reconstructions. I think that this assertion is a circular reasoning because they have caused climatic changes by introducing freshwater fluxes into the model. Actually, what the authors demonstrate is that LOVECLIM is able to realistically simulate observed climatic changes in different regions of the Earth when it is forced by a particular amount of freshwater fluxes, constrained by local observations (SST in the Iberian margin), and a source located between 55°W-10°W, 50°N-65°N. Menviel et al. work's demonstrate that these particular freshwater fluxes explain the observed regional millennial-scale climatic variability of MIS 3. However, the question of the origin of freshwater fluxes remains: What is the cause of the iceberg pulses? Also in the conclusion, the paragraph dealing with Figure 11 is confusing. First, the colors of IRD and salinity curves in the figure do not coincide with those referred in the text. There is no salinity axis, and there is no record of AMOC changes to argue that AMOC strengthening leads to North Atlantic and Greenland warming as well northern North Atlantic sea-ice retreat. Actually, there is no record for sea-ice changes. Further, I wonder whether this paragraph is well placed in the conclusion section. I recommend



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to the authors to rewrite the Conclusion section.

Specific comments

Introduction

The duration of MIS 3 is slightly different, 59.4-27.8 ka, from that presented by Menviel et al., 60-24 ka. (see discussion in Sanchez Goñi and Harrison, QSR 2010). When referring to the large-scale drying of the northern tropics in response to HE, authors should add that there is actually a large-scale drying of the northern Eurasia as shown by the global compilation of pollen data (Harrison and Sanchez Goñi, 2010). Sections 3.3 and 3.4 Could the authors specify the direction of the changes in benthic $\delta$18O associated with the IRD pulse in the Greenland and Irminger Sea. Are these changes during C7 observed in the twin core MD95-2042 (cf. Shackleton et al., 2000)? The authors have obtained a comprehensive spatial view of the simulated D-O warming from an EOF analysis of global surface air temperatures and precipitations. It may be interesting to compare these maps with the pollen-derived temperature and precipitation reconstruction at D-O warming 8 ($\sim$38 ka) and 6 ($\sim$33 ka) (Harrison and Sanchez Goñi, 2010, QSR).

Section 3.7

The authors should refer to Grousset et al. (2000) regarding the HE 3. These authors conclude that HE 3, in contrast with the other HE, has a European origin. Figures and Tables In the legend of Figure 1 and in the Conclusion section, the authors refer to Alley (2000, PNAS) to illustrate Greenland quantitative temperature changes over MIS 3. However, Alley's paper only presents Greenland temperature changes between 16,000 and 10,000 years. I guess that the temperature profile presented in this figure derives from estimations by Huber et al, EPSL, 2006. In the same legend of Figure 1 and all over the text and figures, the authors should replace GIS with GI after Svensson et al., 2006, QSR. In the legend of Figure 3, what does NE mean?



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Typo mistakes

Page 4773, paragraph 20 – Add “of” in “. . .causing a weakening of the Atlantic Meridional Overturning Circulation. . .). Page 4773, paragraph 25 – Replace “a” with “an” in “. . .evidence of aninterhemispheric. . .”. Page 4774, paragraph 5 – Delete “is” in “. . .does not provide is an explanation. . .”

Additional references to discuss and include in the manuscript

Grousset, F. E., Pujol, C., Labeyrie, L., Auffret, G., and Boelaert, A. (2000). Were the North Atlantic Heinrich events triggered by the behavior of the European ice sheets? Geology 28, 123–126.

Harrison, S.P., Sanchez Goñi, M.F. (2010) Global patterns of vegetation response to millennial-scale variability and rapid climate change during the last glacial period. Quaternary Science Reviews 29: 2957-2980.

Shackleton, N.J., Hall, I., Vincent, E. (2000). Phase relationships between millennial-scale events 64,000-24,000 years ago. Paleoceanography 15, 565-569.

Sanchez Goñi, M.F., Cacho, I., Turon, J.-L., Guiot, J., Sierro, F.J. , Peypouquet, J.-P. , Grimalt, J. & Shackleton, N.J. (2002). Synchroneity between marine and terrestrial responses to millennial scale climatic variability during the last glacial period in the Mediterranean region. Climate Dynamics 19: 95-105

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