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Climate of the Past
Discussions

Interactive comment on "A new age model for the Pliocene of the Southern North Sea Basin: evidence for asynchronous shifts of marine and terrestrial climate" *by* Emily Dearing Crampton-Flood et al.

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A comment to MIS M2 in the southern North Sea Basin: A hiatus in sedimentation during MIS M2 was already suggested in papers that deal with the stratigraphy of the southern North Sea Basin. Studies by Head (1998), De Schepper et al. (2009, Geological Magazine) and Louwye et al. (2004, 2010, Geological Magazine) place the Belgian (Kattendijk, Lillo, Poederlee Fm) and English (Coralline Crag, Red Crag) Pliocene formations into one coherent stratigraphy. In De Schepper et al. (2009) and Louwye et al. (2010), MIS M2 is identiïňĄed as a sequence boundary, de facto a hiatus,

in the southern North Sea Basin. These papers have not been taken into account, but would mostly support the conclusions here. See also the stratigraphic summary of De Schepper and Mangerud (2018, Norwegian Journal of Geology, Figure 7), which compares the northern North Sea Utsira Formation with Pliocene deposits in Iceland, England and Belgium.

Author reply: We thank Stijn de Schepper for the suggestions of the literature to be taken into consideration when discussing the MIS M2 in the revised manuscript. We will incorporate references to the relevant publications in the revised manuscript, particularly with reference to the base of the Poederlee Formation in Belgium which correlates with a sequence boundary Pia1 at approximately 3.21 Ma (De Schepper et al., 2009; Louwye et al., 2010; Geological Mag.). We agree that this would strengthen the interpretation of a hiatus taking place at the Hank site over the dramatic interval of MIS M2. We will add the appropriate references to the reference list.

For L440: Rather than comparing with the Norwegian Sea record, it would be more relevant to compare here with records from the southern North Sea Basin (England, Belgium).

Author reply: Thank you for the comment. We agree that comparing the discussion in section 4.1.2 with records more adjacent to the Hank site in England and Belgium is a good idea, and will adjust our discussion in the revised manuscript accordingly.

A comment to the mPWP in the southern North Sea Basin: The Poederlee and Lillo Formation correspond to the interval 3.2–2.7 Ma. The paleoenvironmental information from those formations (De Schepper et al. 2009; Louwye et al. (2010) would be a valuable addition to the interpretations from the Hank core and be a major step forward towards a comprehensive summary of the climate and environmental evolution of the North Sea Basin during the mPWP and Late Pliocene.

Author reply: We agree with Dr. de Schepper that a more detailed comparison of the environmental conditions during deposition of the Poederlee and Lillo formations in

Belgium to the records in the Hank core would be a valuable addition to the paper. We will therefore incorporate and discuss the paleoenvironmental interpretations that are proposed in the above two manuscripts into the discussion of our revised manuscript and figures where appropriate.

A comment to the inïňĆuence of the NAC in the North Sea: The inïňĆuence of the NAC in the Hank record is not convincing. Observing comparable SST variability is no proof for a causal relation (L40, L655 onwards). The common factor between the North Atlantic and the North Sea may be via the atmosphere (i.e. NAO). Note that while the SST variability in the eastern North Atlantic and Norwegian Sea correspond to the NAC (Naafs, Bachem, Lawrence), the cited SST variability in the Iceland Sea is related to the EGC (Clotten et al. 2018) (L655–659). Furthermore, most water from the North Atlantic ïňĆows into the North Sea Basin from the north. But in the manuscript, it is claimed that the NAC has a direct inïňĆuence on the southern North Sea Basin through the shallow connection in the south (Channel/Dover) (L622-624). While an open connection after MIS M2 is possible, it remains speculative. Certainly because the presence of O. centrocarpum (sensu Wall and Dale 1966) in the Hank core is considered as evidence for the NAC inïňĆuence in the North Sea. This does not have to be the case, and most likely it is not - this is a cosmopolitan species. It is true that in the modern North Atlantic, O centrocarpum sensu Wall and Dale (1966) (aka. cysts of Protoceratium reticulatum) can be considered as good indicator for the NAC (e.g. Harland et al. 2016 in Helyon and refs therein). It has been used as an indicator for the NAC in the Pliocene eastern North Atlantic, in the region where the NAC ïňĆows (e.g. De Schepper et al. 2009 Paleoceanography, 2013 PLoS One, Hennissen et al. 2014 Paleoceanography). But today, when the Channel is open, it is not a common species in the North Sea (Marret et al. 2003 RPP, Zonneveld et al. 2013 RPP). Given that O centrocarpum (sensu Wall and Dale 1966) is foremost a cosmopolitan species, tolerant to wide range of SST, SSS, nutrients, etc., its occurrence in the North Sea may not be a simple function of North Atlantic water inïňĆow.

Author reply: Thanks for the constructive comment, insight, and relevant literature concerning the presence of O centrocarpum (sensu Wall and Dale, 1966) and its modern and Pliocene occurrences. We refer to the author response to reviewer #2 who raised a similar concern, and also questions whether the influence of the NAC can be recorded in the North Sea using O. centrocarpum. We agree that there is scarce evidence for an open channel from the North Sea to the Atlantic via the English Channel, and that based on the evidence presented here by Stijn de Schepper, there may be little evidence to connect the trends in O. centrocarpum in the Hank record with influence of the NAC. Therefore, we will rewrite the discussion that links the occurrence of O. centrocarpum to the NAC in the revised version, making sure to refer to key literature and explain the reasons why using this strategy may be problematic in this North Sea setting. Regarding the high SST variability observed in the Hank record, we believe that the similarities between the high variability recorded at the Hank site and other nearby records should be mentioned in the discussion, and the possible causes for high variability in the other records be outlined. However, as the link between the NAC and SST variability is too speculative and cannot be fully constrained, we will be more cautious in section 5.2 of the revised manuscript with regards to attributing the SST variability at the Hank site to any one specific factor, such as influence of the NAC.

Minor comments L127, L621: It is not impossible, but it remains speculation whether a connection was established after MIS M2. The connection was likely only temporarily opened during the Pliocene when SL was high (e.g. see more recent papers by Van Vliet-Lanoë et al. 2002; Gibbard and Lewin 2016, Geologica Belgica).

Author reply: Thanks for this addition and references. We will definitely consider this in the revised version, and add more recent references when referring to the circulation and openings in the North Sea during the Pliocene.

L317–318: Barssidinium is not the best example for a (sub)tropical taxon, as it occurs in Iceland in the Pleistocene (e.g. Verhoeven et al. 2011, Paleo-3).

Author reply: We will remove the reference to '(sub)tropical' in the sentence. We will also add the following sentence afterwards: '(Sub)tropical species like Lingulodinium machaerophorum, Operculodinium israelianum, Spiniferites mirabilis, Tectatodinium pellitum and Tuberculodinium vancampoae are missing at this depth.'.

L625–630: O. centrocarpum (sensu Wall and Dale 1966) is foremost a cosmopolitan species recorded from different environments and tolerant to wide range of SST, SSS, nutrients, etc. Its occurrence in the North Sea shelf environment is thus not necessarily evidence for NAC inïňĆuence.

Author reply: As per our reply to the major comment raised above, we will rewrite the discussion to tentatively connect the presence and trends in O. centrocarpum in the Hank record to the strength of the NAC in the revised manuscript. We do see an interesting feature in the O. centrocarpum record insofar as a large abundance (∼40 %) that occurs at 305 m, directly after the high abundance of Osmunda spores and % Cold Dinocysts at 306 m. We interpret this increase in O centrocarpum as a possible restoration of (mostly) marine conditions at the Hank site after sea level drawdown which we interpret at 306 m. This period also correlated with low mean annual air temperatures ($\sim$ 6 °C), and decreased abundance of Taxodium-type pollen species (Fig. 6). We are not sure how best to interpret this, the best possible explanation we have at this stage is to connect the high abundance of O centrocarpum with the inflow of Atlantic Water when sea levels rose after the M2 event. We believe that the revised manuscript could benefit from some discussion on this observed feature in Section 5, we will make sure to refer to literature presented here about O centrocarpum in order to provide a more tentative and speculative explanation of this link.

L629: Boessenkool et al. (2001) studied surface sediments offshore SE Greenland. The study does not provide evidence for a relationship between O.centrocarpum and the NAC. Please use more appropriate references.

Author reply: We will remove the references that tie the presence of O. centrocarpum

to the NAC (see above) in the revised manuscript, thus the reference of Boessenkool et al. (2001) will also be deleted (and removed from the reference list).

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