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Climate of the Past Discussions

Interactive comment on "Abrupt cold events in the North Atlantic in a transient Holocene simulation" *by* Andrea Klus et al.

C. C. Raible (Referee)

raible@climate.unibe.ch

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Summary

The authors analyze two abrupt cold events in the North Atlantic Ocean (sea surface temperature) simulated in a transient orbital-forced simulation of the Holocene. Given the experimental design the cold events are generated by internal variability rather than external forcing. The triggering mechanism is the North Atlantic Oscillation which shows a prolonged positive phase starting earlier than the ocean response, mainly via changes in the momentum transfer to the ocean and a subsequent weakening if the sub polar gyre circulation. Interestingly, the Atlantic Meridional Overturning circulation is not involved in the processes leading to these cold events.

The manuscript is nicely written and well structured. More importantly it discusses an important scientific question, namely the role of internal variability in coupled climate system generating extreme events in the ocean. The authors suggest an interesting mechanism as the atmosphere seems to play the triggering process for a long lasting sea surface temperature anomaly. Thus this study is certainly important for the interpretation of past climate states and proxy records, so I recommend possible publication of this study in Climate of the Past after minor revisions (see below).

Still one mayor comment needs to be dealt with: The authors have a very long simulation so they can check how often a similar NAO period has occurred which directly can answer the question whether the NAO is really the trigger or not. Assume the authors find 10 other periods of prolonged positive phase of the NAO but no cold event, then it is questionable whether the NAO is the only trigger necessary for such an event.

Minor Comments

Title: I suggest to include ocean after Atlantic to make clear that the cold events discussed are mainly found in the sea surface temperature. p1,l16: Statistically significant?

Introduction: As the NAO plays an important role in the mechanism proposed the authors need to give a brief review of current NAO reconstructions and their problems, e.g., Ortega et al. (2015, A multi-proxy model-tested NAO reconstruction for the last millennium. Nature, 523 71-75),

P2,l11: I think that the authors need to mention the study of Lehner et al. (2013, Amplified inception of European Little Ice Age by sea ice-ocean-atmosphere feedbacks. J. Climate, 26, 7586-7602) as they show another important possible mechanism explaining cold events in the North Atlantic.

P3,l20-21: Please change to "The definition of oceanic regions used throughout the paper is shown in Fig. 1."

P3,l25: ”We define cold events as . . .”

P4,l22-24: Please change to “However, an increase in both SST and SSS is found northeast of Iceland, but a decline in sea ice concentration is detected there (event 1: warming of 1.6 °C, rise of 0.7 PSU, decline of -5 % in sea ice concentration; event 2: warming of 1.9 °C, rise of 0.9 PSU, decline of -11 % in sea ice concentration).”

P5,l8: I suggest to refer to Figure 8 here and add the 2 sigma range in Fig 8.

P6,l9: Please change to “They concluded . . .”

P6,l13: “The advection of salty and warm . . .”

P6,l21: “The transport from north to south is stronger towards . . . ” Otherwise I do not understand the sentence.

P6,l26: please add e.g. before the references as there are many more publications which highlight the tripole structure and dealing with the feedback process of SSTs and the atmospheric circulation.

P7,l13: “This is substantially more than . . .” P7,l16: please include a line break. Section 4.2: Given your mechanism I think it is necessary to discuss the differences to the mechanism described by Lehner et al 2013 as these authors suggest a mechanism which does not rely on the NAO. This is even more important as these authors use the same model though in different resolution.

Section 4.3: These oscillations are interesting but how model dependent are they? Is this behavior found also in other simulations with the same model? Is the reason mainly the coarse resolution and or the fact that the AMOC is rather weak and close to a threshold?

P8,l20: “who showed ”

Section 5: Given the fact that the model simulates to much sea ice how does this affect your proposed mechanism? Or in other words, is this mechanism only possible

because of the rather strong biases in sea ice distribution?

Fig. 1: Please start the caption with “Areas of ”

Fig.2: The reference period seems to be selected in a rather warm period and roughly 1000 years after the second extreme event – why? I suggest to use a longer ref period just between the two extreme events so from 4000-3200. Or just two ref periods before or after the extreme event to avoid any orbital forcing signal.

Fig.3: It remains unclear how the anomalies are calculated. I guess it is the difference between mean over the period of an event and reference. In this case I would call it a difference4 and not an anomaly (which is normally a deviation to a long-term mean, rather than a difference between independent periods). Please change this throughout the text

Fig. 6 and 9: see Fig.3

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