Authors' response to comments on paper:
How does sea ice influence $\delta^{18}O$ of Arctic precipitation?

Anne-Katrine Faber et al.

We thank the referees and the editor for their comments made to our manuscript. We appreciate the constructive feedback on our manuscript and have made substantial changes to the manuscript.

Response to anonymous referee # 1:

1.1 Abstract misleading - Focus on Greenland

Question:
The abstract emphazing the influence of sea ice on δ 18O of Arctic precipitation except on central Greenland is misleading

Changes in manuscript:
Changes in sea ice and sea surface temperatures have different impact in Greenland and the rest of the Arctic. The simulated changes in central Arctic sea ice does not influence $\delta^{18} O$ of Greenland precipitation, only anomalies of Baffin Bay sea ice. However, this does not exclude that simulations based on other sea ice and sea surface temperature distributions might yield changes in Greenland $\delta^{18} O$ of precipitation.

Question:
Same in the conclusion. e.g. l 317-320: "significant changes", but it should be emphasized that they are mainly local, not where most of the ice cores are.

Changes in manuscript:
Conclusion:
The geographical variations in the $\delta ^{18} O$ response to changes in Arctic sea surface conditions show that the isotopic composition of Arctic precipitation is sensitive to the spatial distribution of the sea ice and SST changes, however not at Greenland
….
The isotopic composition of Greenland precipitation are unaffected by the imposed changes in central Arctic sea ice cover in all experiments. Only conditions near Baffin Bay influence Greenland.

Question:
L313: relatively -> completely?
Changed.

1.2 Need for model evaluation in the Arctic.

Question:
Before using a model, some evaluation of this model is necessary. Can you add a figure showing the distribution of precipitation δ 18O in the Artic compared to precipitation data wherever they are available? (GNIP, snow samples, ice cores...)

Changes in manuscript:
A figure is added where data from ice cores and coastal Greenland GNIP stations are compared to the CTRL run

Question:
If the model features some biases what are the consequences on the conclusions. For example, is the absence of large-scale isotopic response specific to this model, and can it be linked to the representation of the large-sale circulation or of boundary layer processes?

Comments:
The model is positive biases producing to enriched d18O over Greenland as many other models.
To answer whether the absence of a large-scale isotopic response is specific to this model would require model-intercomparison study. Currently no model-intercomparison studies of isotope-enabled GCM are published for Arctic conditions.

1.3 Sea surface conditions rather than sea ice cover
Request:
Use the term sea surface conditions rather than sea ice cover

Changes to manuscript
This is changed through out the paper. Either sea ice cover and sea surface temperatures are used together, or the term sea surface conditions is used the describe both.

1.4 Questions on precipitation weighting.
Changes to manuscript
All d18O values from model output are shown as precipitation weighted. This is now corrected in the manuscript.

1.5 d18O-Temperature relationships.
Comments:
Reviewer 1 discusses the importance in the differences in the intercept values for the different experiments. In the previous version of figure 5, the plot ”All experiments” where each experiment were plotted with different colors. Therefore due to the plotting routine the differences in intercepts for each experiment incorrectly looked more pronounced. Therefore the plot “All experiments” in fig. 5 now plots all values with the same color. However, the differences in the intercepts values, especially for experiments ”2012” is now added to the manuscript

The reviewer disagrees with the implications for the interpretation of the d18O p signal. This part is now only briefly mentioned in the paper, and the manuscript now only mentions that the slope of $\delta ^{18} O_{p}$-temperature relationship is found to be insensitive to changes in the perturbations of sea ice.

No further analysis on this topic is conducted as the focus on this manuscript is directed towards a discussion on the causes of changes in the isotopic response.

Changes in the manuscript

In this study, the slope of $\delta ^{18} O_{p}$-temperature relationship is found to be insensitive to changes in the perturbations of sea ice. Differences in the intercept values of the regression is noted, most pronounced for the experiment "2012" where the offset of $\Delta \delta ^{18} O_{p}$ is $-0.39 \permil$.

1.6 The link with vapor origin is not clear
& 1.7 Clarify the link with large-scale circulation

Comments:

We clearly agree with the reviewer on this comment. Further analysis has been made and the results and discussion sections have been rewritten in order to improve this link.

Changes in the manuscript

To clarify the influence of the observed simulated change in d18O and the connection to either change in air mass origin or local temperature then analysis of the vertical distribution of T and d18O have been made. The zonal cross sections at latitude band 77 N have been added to the manuscript (fig 8 and fig 9). The given latitude has been selected to match the nearest grid point to the location of the ice core drilling site NEEM at Greenland. NEEM is selected rather than central Greenland due to several reasons. First, because the latitude band 77N covers a circumpolar band with regions of large sea ice changes all over the Arctic. Second, recent observations from Steen-Larsen 2011 find a connection between the isotopic signal at NEEM and Baffin Bay sea ice extent.

Furthermore spatial fields of d18Ov are added to the appendix. These show d18Ov at two different pressure levels, 950hPa and 700 hPa (thus representing different layers in the vertical) and show that clear surface based signal is found all over the Arctic and not just at the given selected 77 N latitude band as shown in the cross section plot.

In short we find that anomalies of d18Ov are surface based and connected to grid points of changes in sea ice. But changes are also seen for temperature near the surface.
We cannot separate the effect of temperature and changes in moisture source in this study due to the lack of moisture tracking. Therefore the discussion in this paper is now treating the possibilities of either changes in moisture source or temperature – but no conclusion is made.

Structural changes have been made to the manuscript in order to separate the findings from this set of model experiments and speculations based on findings from other studies.

2. Miscellaneous.

L18: Add more references, including key historical ones
<u>Changes in the manuscript</u>
Since the pioneering work by Dansgaard (1964), the understanding of stable water isotopes as a proxy for temperature has significantly advanced. It has become clear that the isotopic composition of precipitation is a complex signal, influenced by both local and regional climate conditions (Vinther et al., 2010; Steen-Larsen et al., 2011; Sjolte et al., 2011; Sodemann et al., 2008b; White et al., 1997; Johnsen et al., 1989)

L32: Demonstrate -> suggest OK
L64: Citations are wrong for isoCAM3:
<u>Comments:</u>
A model release paper does not exist for isoCAM3 thus it chosen to refer to Noone and Sturm 2010 as also done by other studies.
<u>Changes in the manuscript</u>
More details of isoCAM3 can be found in Noone and Sturm (2010)

L67: What is third generation isotope scheme?
This is now removed as this is not relevant

L156 – precipitation weighted d18Opwgt,
Corrected
Fig 3 and figure 4 caption – are these annual means?
Yes, corrected

L205 – latent heat flux as a proxy for evaporation

<u>Changes in the manuscript</u>

Changes in local evaporation are here investigated based on the surface latent heat flux

Figure 8 (now figure 10).
Additional statistical information required for this analysis.
<u>Changes in the manuscript</u>
The number of grid points of reduced sea ice is as follows; 1980: 217, 1996: 444, 2007:1148, and 2012: 2116. And the number of grid points of increased sea ice; 1980: 1508, 1996: 1024, 2007:554, 2012: 437.

L246 Weakening of the jet stream for separate years…
<u>Comments:</u>
Investigating the differences in the variability within the weakening of the Jetstream could yield information on the control of the sea surface conditions on jet stream variability. However given the model setup in this experiments with artificially constructed ocean data sets consisting of an Arctic section and a non-semi Arctic mean values section (as described in L109-L116) it is found not favorable to focus on Jetstream conditions as it is uncertain whether the potential artificially introduced SST gradients near 37 N in the Atlantic might alter the representation of the jetstream