Reply to Reviewer#2

We are grateful to reviewer#2 for the time in reading our manuscript, as well as critical suggestions and encouragements. As described below, we will take all of the comments raised by the reviewer into account in the revised manuscript. Below, our responses are shown in blue, and the comments by the reviewer is shown in black. Again, thank you so much for your time in reviewing our paper!

General Comments.
This paper presents results from a series of hosing simulations. There's a long history to these type of simulations and we can learn things about the climate system from them. However, the link between arbitrarily dumping freshwater into the North Atlantic and climate events is still not clear (Barker et al 2015). Since this paper is so clearly aimed at understanding actual climate events, DO events, there needs to be more in the Introduction about how to link the hosing simulations to real events. Ultimately, as is stated in the Discussion, the results presented here show how the climate system responds to the cessation of an external forcing. This needs to be made clear not just at the end of the paper.
We agree to the reviewer's concern that the link between the hosing experiment and actual climate events needs to be clarified in the Introduction. We will clearly state in the Introduction of the revised manuscript that

- There is a large debate on the role of freshwater hosing in DO cycles (Barker et al. 2015), and other modeling studies show a intrinsic variability that resembles DO cycles (Vettoreti and Peltier 2016, Brown and Galbraith 2016, Klockmann et al. 2018).
- We will be focusing on the situation how the climate system responds to the cessation of an external forcing through hosing experiments.
- While the cause triggering AMOC variability in hosing experiments differs from that in intrinsic oscillations, there are some similarities in the recovery process (see our reply to the next comment). Hence, there is a possibility that the outcome of the study can be applied to those obtained via intrinsic oscillations of the AMOC.

There are a number of climate models which can now simulate DO like events without the need for external forcing. It would be useful to describe these in a bit more detail in the Introduction. There are 2 reasons for this: first to show that external forcing is not the only way to change the AMOC; second, and more importantly, to give some context for how the results presented in this manuscript might apply to those simulations. For example Vetoretti and Peltier (2016/2014) describe the balance between sea ice/salinity/AMOC that is at play in their oscillations. This will clearly be modulated by the processes shown in this study. If you can link your study with that of e.g. Vetoretti and Peltier, you can make a much stronger case that the results presented here can apply far more generally than just in the case of external forced AMOC shutdowns. This Reviewer, who is a hosing sceptic, would find this much more satisfying. In the last paragraph of the Discussion this idea is mentioned. I would encourage you to expand this to make the links between this study and the others clearer. Doing this should make make this study much more applicable to interpreting the coupled oscillations not just hosing type runs.
Thank you for the encouragement! As pointed out by the reviewer, there is a similarity in the recovery process described by Vetoretti and Peltier (2016) and MIS3-5aiceH. For example, their study showed that the gradual warming at the subsurface ocean over the Irminger Sea and its balance with sea ice thickness and sea surface salinity during stadial caused the formation of deepwater. We also see a similar process operating in our hosing experiment that the gradual warming of subsurface ocean at Irminger Sea induces a deepwater formation when the sea ice is sufficiently thin and sea surface salinity is sufficiently high. We will point out this similarity in the Discussion to link our hosing studies with studies describing the mechanism of intrinsic oscillations of the AMOC.
Furthermore, as in the reply to the previous comment, we will clarify in the revised Introduction that there is a large debate on the role of freshwater hosing in DO cycles (Barker et al. 2015), and other

modeling studies show a intrinsic variability that resembles DO cycles (Vettoreti and Peltier 2016, Brown and Galbraith 2016, Klockmann et al. 2018).

Figure 8 shows that the state of the climate at the end of the hosing is quite different in MIS3H and MIS3-5iceH. Could it not be the case that the different response time of the AMOC in the 2 experiments is a result of the different state from which the AMOC is recovering? The partially coupled experiments show that wind affects the response time from the MIS3 weak state, but this does not necessarily imply that this is also the cause of the altered response time in MIS3-5aice. I think that the discussion about the winds suggests that the different sea ice and salinity distributions shown in Fig 8 can be linked to the winds but it would help a reader to be explicit about this. Fig 8 is, to this reviewer, the key figure in this paper. All of the other discussion is around trying to explain it. It would therefore help to come back to it at the end of the PC experiments to apply what you have shown.
As the reviewer pointed out, the different sea ice and salinity distributions at the end of hosing between MIS3H and MIS3-5aiceH are linked to the differences in surface winds. Ultimately, these differences in sea ice and salinity cause the different recovery time among the two. Following the reviewer's suggestion, we will explicitly explain this after the PC experiments by including more description regarding Fig. 8 in the first paragraph of the Discussion of the original manuscript.

Specific Comments

The title "Does a difference in ice sheets between Marine Isotope Stages 3 and 5a affect the duration of stadials?" is very snappy but ultimately in the experiments presented what determines the duration of the stadial period is how long the freshwater forcing is applied. A slightly more conservative "Does a difference in ice sheets between Marine Isotope Stages 3 and 5a affect the time it takes for the AMOC to recover from a weakening?" or similar would be a little more accurate.
We agree to the reviewer's concern that the current title is bit ambitious. On the other hand, we also feel it's quite attractive. We haven't made up our mind at this point, but at least we came up with a possible alternative title,"Does a difference in ice sheets between Marine Isotope Stages 3 and 5a affect the duration of stadials?: results from hosing experiments". We will report our plan in the revised manuscript.

Paragraphs beginning Line 246/269 – It would help to expand the description of the resumption of the AMOC in these paragraph. This would make it easier to understand the rest of the paper as a reader would better understand the set of processes (ice, salinity, convection) that lead from weak AMOC to strong. The summary sentences at the end of these paragraphs are very helpful.
We will expand the description of these two paragraphs and make the explanation of the recovery clearer in the revised manuscript.

Line 256 - "Four hundred years after the cessation of hosing, the surface salinity and sea ice thickness reached a quasi-equilibrium state, whereas the subsurface temperature continuously increased" how about: "an apparently steady state, however subsurface is still warming…." As it's not a quasi-eqm state.
Thanks for the suggestion! We will fix it as suggested.

Line 275 - "Because the surface salinity was sufficiently high in the weak phase of the AMOC, deepwater could form continuously." This suggests that deep water formation was happening during the weak AMOC phase, which I don't think is the case?
"Deepwater formation region in MIS3H" this can be seen in Fig. 5(b) correct? If so refer a reader to this figure for ease of comparison.
Some deepwater formation occurs at Irminger Sea after the cessation of hosing. This is shown in Fig. 8b, but it was not mentioned in the original manuscript, which caused some confusion. In the revised manuscript we will modify the sentence as follow to make our explanation clearer.
"Because the surface salinity was sufficiently high in the weak phase of the AMOC (Fig. 8e), deepwater could form continuously at Irminger Sea (Fig. 8b)."

Also Figure 5b shows the spatial map of convection area at the last 100 years of the hosing period. During the hosing, no deepwater formed, however, after the hosing had stopped, some convection formed over the Irminger Sea, without causing a drastic change in AMOC, but only a gradual increase in AMOC strength. We will clarify that Fig. 5b is showing the last 100 years of the hosing in the revised manuscript.

Line 290 - "With the southward-shifted westerly wind and strong northerly wind over the western North Atlantic, less sea ice was transported to the deepwater formation region in MIS3H" – worth saying this weakens the westerly wind formerly moving the sea ice. Confusing otherwise.
Following the reviewer's suggestion, we will modify the sentence as follows;
"The southward-shifted westerly wind and strong northerly wind over the western North Atlantic weaken the eastward sea ice transport to the deepwater formation region in MIS3H"

Line 291 "Therefore, even though the atmosphere was colder, less sea ice existed over the deepwater formation region." How do we know that the atmosphere was colder? You should show it.
Following the reviewer's suggestion, we will add the Fig. A5 in the revised figure. The figure, indeed, shows a colder temperature in MIS3H compared to MIS3-5aiceH.

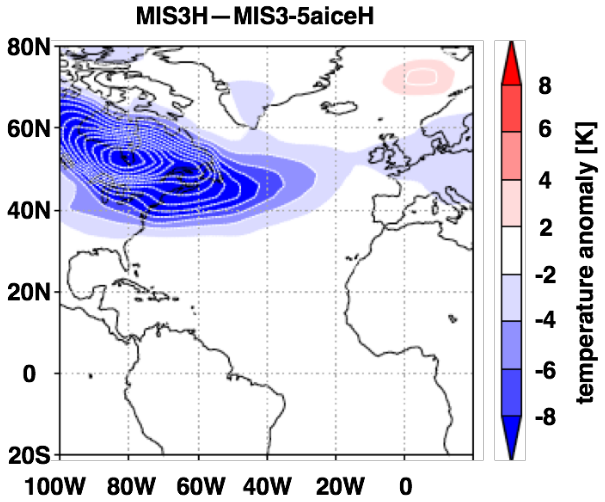

Fig. A5 Annual mean surface air temperature differences between MIS3H and MIS3-5aiceH at the last 100 years of the hosing.

In parts of the manuscript the link between the winds and the ice and salinity is a bit unclear. This is likely because different aspects of the overall wind change affect ice and salinity differently. So, for example, at Line 340 "It was found that the difference in surface wind played a role in causing the difference between MIS3H and MIS3-5aiceH. The cyclonic surface wind at mid-high latitudes was stronger in MIS3H than in MIS3-5aiceH. In addition, a strong northerly wind anomaly was induced over the western North Atlantic. As a result, the wind-driven transport of salt to the deepwater formation region was larger and wind-driven sea ice transport smaller in MIS3H compared with MIS3-5aiceH." It would help a reader to spell out which of the northerly anomaly and the stronger cyclonic surface wind affects sea ice and which affects salinity.
We agree to the reviewer's point. We will clarify the relation of local surface wind and salt and sea ice transport in the revised manuscript as follows;
"It was found that the difference in surface wind played a role in causing the difference between MIS3H and MIS3-5aiceH. The cyclonic surface wind at mid-high latitudes was stronger in MIS3H than in MIS3-5aiceH. As a result, the wind-driven transport of salt to the deepwater formation was stronger in MIS3H. In addition, a strong northerly wind anomaly was induced over the western North Atlantic in MIS3H. Together with the southward shift of westerly wind, this caused a reduction of wind-driven transport of sea ice to the deepwater formation region over Irminger Sea. The higher surface salinity and thinner sea ice thickness over the deepwater formation region then increased

the probability of the recovery of the AMOC. Thus, the changes in the surface wind caused by the glacial ice sheet could contribute to a shorter stadial during MIS3 compared with MIS5."

Line 318 – state that the MIS3 heat flux should lead to cooler temperatures. You say it later but a reader may already be confused.
We will fix this following reviewer's suggestion.

Line 320 – "This long stadial state was caused by the very thick sea ice over the deepwater formation region, associated with stronger surface cooling by the MIS3 ice sheet (Fig 12b,d)" this is confusing, because this seems to suggest that the change in sea ice in _windwater is due to a different mechanism, surface cooling, than _wind, advection. Which is not the case? Also Fig 12b,d doesn't show stronger surface cooling in any of its plots. It would, however, be very helpful to show this.
Following the reviewer's comment, we will modify the sentence as follows to clarify that the same mechanism causes the increase in sea ice in both experiments;
"The long stadial states observed in these two experiments were caused by the very thick sea ice over the deepwater formation region (green and blue lines compared to red line in Fig 12b and Fig. 12d), associated with stronger surface cooling induced by the larger MIS3 ice sheet (Fig. A5)"
We will also add Fig. A5 or a similar figure to show the stronger surface cooling by the ice sheet.

Line 332 – "Therefore, the larger (smaller) MIS3 (MIS5a) ice sheet reduced (increased) the recovery time of the AMOC by reducing (increasing) the input of atmospheric freshwater flux over the deepwater formation region." Do not try and compress 2 sentences into 1 using brackets. It is totally unintelligible. Just write out:" Therefore, the larger MIS3 ice sheet reduced the recovery time of the AMOC by reducing the input of atmospheric freshwater flux over the deepwater formation region when compared to MIS5a."
Thank you for the comment! We agree it is easier to read. We will fix this following the reviewer's suggestion.

Line 340 – add reference to Fig 10 – for a reader who comes in halfway through.
We will fix this following reviewer's suggestion.

Figures
All time series plots need to have marks to show where the hosing is or it not occurring. E.g. Fig 8. Put some hatching over the time 0-500 to show that hosing happens here.
Thanks for the suggestion. We will fix this.

Fig 10. Show the deep water formation areas to allow a comparison. It's important to know where one is looking for the changes in surface fields.
In the last 100 years of hosing, no deepwater forms in MIS3H and MIS3-5aiceH. In fact, the figure of deepwater formation is presented in Fig. 5 d-f. However, after the cessation of hosing, some deepwater forms at Irminger Sea in both experiments before the AMOC starts to recover abruptly, which is shown in the time series figure of Fig. 8 (b,c,h,i). To make the explanation clearer, we will specify the area used for the time series analysis in Fig. 5. Hope this modification fixes the problem.