

Interactive comment on “Response of the AMOC to reduced solar radiation – the modulating role of atmospheric-chemistry” by S. Muthers et al.

Anonymous Referee #3

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The paper by Muthers and coauthors assesses the potential impact of atmospheric chemistry on the Atlantic meridional overturning circulation (AMOC) in two scenarios of reduced solar incoming radiation. The analysis is performed in ensembles of simulations in which interactive atmospheric chemistry is switched on and off. This allows the authors to detect two competing mechanisms that act toward strengthening and weakening the AMOC: the former as a result of thermally driven changes in upper ocean densities; the latter as a response of a dominating Arctic Oscillation negative phase, which in turn results from changes in the stratospheric circulation. Muthers et al. therefore conclude that the inclusion of atmospheric chemistry in climate models could be essential for a correct representation of solar-driven AMOC changes. These results could be of great relevance for the community and, hence, worth publishing. However, my main concern about this paper relates the fact that the Introduction, as it

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is written now, does not allow us to clearly see the novelty behind this investigation, or whether this is relevant at all. The Introduction lacks a clear description – which, on the other hand, does not have to be too long – of previous works on the same or similar fields, so that we can identify from the very beginning what is the “hole in our current knowledge” the authors aim to address. I must admit that this is partly done in the last paragraphs in the Conclusion section; however, it is here too late and must appear earlier in the paper. This task could actually be done at cost of the initial description of the AMOC, which is supplementary (my guess is that any one approaching this paper will already have a clear idea of what the AMOC looks like). The Introduction might thus be kept relatively short. I encourage the authors to revise the Introduction to clarify this aspect. For this reason, I recommend major revisions before considering this work for publications

Other major points

The experiments A small comment of why control simulations were simulated under 1600 CE conditions is recommendable, as CMIP5, for example, suggested using 1850 CE conditions. Also, why were the simulations run only 30 years? Is there any particular reason?

Results Could the authors also show the pattern of AMOC anomalies as a result of reduced incoming solar radiation? I think an index alone is not sufficient, and AMOC anomalies might be of different signs on different sites. This might indeed be interesting to show and comment.

Discussion Discussion might be enriched by putting this work’s results into the context, for example, of some solar minima in the recent past, like the Maunder Minimum. Also, it might be interesting to discuss the changes one might expect if solar variability changes were indeed of smaller magnitude, as some reconstruction suggest. Would the authors expect a similar response in the AMOC/climate?

Minor Comments

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Page 1 L4. SRR acronyms is not used in Abstract L18 . . . upwelling processes that bring the water back . . . L19 please, rephrase “this Atlantic circulation” L20 I think, there is no need to bring the Atlantic Meridional Oscillation into the discussion if this is not going to be used any further

Page 2 L4-5 Upper salinity also increases due to net evaporation in the tropical North Atlantic L22 Please, remove comma after management L23 GHG has not been defined

Page 3 L5 “different mechanisms, how” please, rephrase L9 add comma after chemistry

Page 4 L27 Do experiments here mean simulations? I suggest reviewing the use of these two terms throughout the manuscript, as sometimes one feels they are interchanged. L32-33 there is no need to indicate that AO index is multiplied by -1

Page 5 L2 “near-surface (2 m) air temperature” L2-end I wonder why common acronyms are not used throughout the text, such as, SAT, SST, etc. L2-end In many instances it is written: “reduction in temperatures”. This can be perfectly replaced by “cooling” L7-11 This is a topic for the Discussion. It is nonetheless of little relevance for this paper. L18 “are related”

Page 6 L4-5 It is not clear in which run the larger cooling is found L5-6 do temperatures and sea ice anomalies here refer to the value or the pattern? Please, clarify. Besides, it is said that they are similar, but not to what. Does it mean similar to those in S2? L12 add comma after “sea ice formation” L15 Here I wonder how relevant it is for the sea ice increase the advective contribution from a stronger AMOC. L17 Replace everywhere in the text Nordic Sea for Nordic Seas, as it stands for Greenland, Norwegian, Iceland seas, and sometime also the Barents Sea. L23 please, rephrase “. . . but the significance is reduced” L24 add comma before while L28 This sentence is probably too long. It could be divided into two. L30 please, clarify or rephrase “in other parts of the North Atlantic” L30 remove comma after period L33 remove comma after convection L35 rephrase “Similar to the Nordic Seas” (for example, “As in the Nordic Seas.”)

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Page 7 L6 add comma after forcing L7 Split the sentence into two. “in comparison to S2_NOCHEM. Similar differences ... “ L11 This statement might need a citation L17 add comm after forcing L21 add comma before a reduction L23 add comma after Furthermore L25 It is interesting to notice that changes in the polar vortex do not seem to go linearly with the reduction in the solar forcing. One should not expect linearity in the response, of course, but it is interesting in any case.

Page 8 L9 add comma after response; change phenomena for phenomenon L10 add comma after AO index L12-14 I do not necessarily agree with the authors on some of the interpretations they make from Figure 6 regarding the AO index, which are in these lines exposed. For example, changes in the S1 experiments are mostly nonsignificant, and, although in CHEM there is a shift toward more negative values, in NOCHEM the change is more like a broadening of the distribution, rather than a change to more negative phases. Also, it should be stated here that the AO index in S2_NOCHEM features a first half of mostly negative values, followed by a positive trend towards more positive. This might even be investigated further, as an extra. L16 affects L25 Here a statement connecting changes in temperature and salinity with those in density might be help connect ideas. L27 Could you explain shortly or cite in the literature why this instantaneous AMOC response to the AO? Is it due to wind forcing? If it were due to heat-driven changes in the convection, as those found during positive or negative phases of the NAO, I would assume some delay in the response of the AMOC L33 Add comma after As a consequence, L34-35 Isn't it a reduction in the density? Otherwise, one should not expect a reduction in the convection, but an intensification

Page 9 Conclusions: I'd call this section Conclusions and Discussion. L6 please, remove comma after chemistry L12 the sentence about the projected future weakening of the AMOC should be connected with the next paragraph. L15 It would be recommendable to compare the magnitude of the projected minimum with that of those implemented in this study, as well as its duration. If the magnitude of this future minimum were much smaller, we might then expect negligible changes in the AMOC strength

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L20 please, rephrase. For example, adding after effect “when atmospheric chemistry is taken into account” L25 Many of the elements? L26 on various time scales. Also, it would be recommendable to indicate which scales in particular the authors refer here L25-30 In this paragraph, three different verb tenses are used to talk about results from previous studies. I suggest using only one, maybe past simple? L31 remove comma after for the first time

Page 10 L2 when chemistry-climate interactions. . . this, I think, is already indicate at the beginning of the sentence L4 remove comma after GHGs L7 add comma after In this case,

FIGURES Would it be recommendable to add some of the Supplementary Figures to the main text? In particular those that are most referred in the text. There are indeed more Supplementary Figures than main ones. Fig. 1 Please, clarify whether the Student’s t-test done after or before smoothing? The gray vertical lines indicating the SRR period are black Fig. 2. Please, clarify why climatologies in panels e and g, and in f and h are different, if they derive from the same control simulation, CHEM and NOCHEM respectively? Figs. 5 and 6 Gray vertical lines are again black Fig. 7 Readjust text to match the panels Fig. 8 Could you please increase the font size of the smallest text? Fig. S4. What are the shading and contours respectively?

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