

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

### **Anonymous Referee #1**

Received and published: 22 May 2016

This is a mostly well written manuscript with interesting new results identifying a stratospheric mechanism impacting the Atlantic Meridional Oscillation. Therefore, it is potentially suitable for publication in the Earth System Dynamics journal. I have, however, a few concerns which I would like the authors to address before I can recommend the publication.

My major concerns are:

1. What would be the impact of aerosols? Your model does not include aerosol interactions, you just simply reduce the solar radiation. This seems a critical simplification to me. You should at least discuss how aerosol interactions would modify the AMOC response if taken into account in your model.
2. I think in reality the salt rejection from the sea-ice growth is rather small and mainly

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occurs north from the regions of deep convection. Therefore it has only a minor importance to the deep convection and the AMOC compared to the heat loss and possibly the net precipitation (precipitation minus evaporation) at the ocean surface. At the moment, the reader is led to understand that the salt rejection is at least as important as the heat loss. The increase of the sea-surface salinity could also be due to a decreased net precipitation related to changing storm tracks, for example. To better support the salt rejection argument, you need to quantify the salt rejection to the surface density and compare it to other factors. Can you check the ocean surface fluxes from your model output and their relation to the T and S, not only density, anomalies? How realistic these modelled fluxes then are, depend on your model skill and are related to your model configuration, such as the sea-ice salinity scheme.

3. I have a problem when you treat the AO and NAO identically. Although the AO and NAO correlate, they are not identical, not even from the AMOC perspective. I agree that the AO behaves largely like the NAO in winter. If, instead of the AO, you based your analysis on the NAO, how would the results look like? What would be their significance after taking into account the possible year-to-year autocorrelation?

Minor comments:

- Page 1, line 16. I would rather say that 'surface currents transport water into the northern North Atlantic' rather than to 'Northern high latitudes' which sounds more like to the Arctic Ocean.
- Page 2, line 7. I don't think the AO is the hemispheric equivalent of the NAO. The NAO is a regional index and correlates with the AO, but their definitions differ substantially.
- Page 2, lines 18. '... by increasing SSTs and enhancing freshwater input ...'
- Page 2, line 32. As you focus on the AO in this paper, would be clearer not to talk about the NAO, but the AO, after Page 2, line 7.
- Page 3, line 19. '... uses temperature data ...'

- Page 4, line 3. You provide very little details on the model configuration. For example, what was the time step you used? How about the sea-ice salinity, was it constant? Or what sea-ice thermodynamics scheme was deployed? This information is important to assess how realistically the sea-ice salt rejection was modelled.
- Page 4, line 20. You should mention here how long model simulations continued after the 30 year SSR period.
- Page 4, line 27. Explain the acronym TSI.
- Page 4, line 32. Explain more in detail how the AO index was calculated and provide references. For example, a common way to calculate the AO is based on the PC1 of 1000 mb pressure height anomaly data north of 20N. Your method seem to differ from that. Why? How robust your results are based on the AO calculation method?
- Page 5, line 18. '... are related ...'
- Page 5, lines 21-22. This sentence is hard to understand. How is the slight initial reduction of the global mean temperature related to the initial conditions of the ocean when the ocean initial conditions are from a 1300 year long simulation? Why rather not related to the atmospheric initial conditions which presumably started from an observation based, physically less consistent initial state?
- Page 5, line 31. 'during the second half'
- Page 6, line 7. Do you mean that sea-ice patterns look similar but their anomalies are (presumably) weaker in the S1 experiments?
- Page 6, line 13. Is the reduction in precipitation related to a shift in the main storm track and, as a result, a colder and dryer atmosphere?
- Page 6, lines 15-16. I think you need to verify the significance of the salt rejection to the surface density. It is typically small compared to the cooling effect. Also, not much freezing occurs at the eastern side of Greenland, but the Arctic ice flows south and

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melts along the eastern boundary of the East Greenland Current.

- Page 6, lines 26-27. You should mention that these density and mixed layer depth anomalies are not reflected in the AMOC.
- Page 6, line 30. '... the North Atlantic (Fig. 3a).'
- Page 6, lines 33-34. You must mean 'the central North Atlantic' here.
- Page 7, line 2. The 'dominance' is based on very speculative assumptions. Just say 'Salinity changes, nevertheless ...'
- Page 8, line 1. Add a literature reference that proofs the linkage between the downward propagating wind anomalies and the AO phases.
- Page 8, lines 13-14. You don't show this in Fig. 6, which should be mentioned, or plot CTRL\_NOCHEM in Fig. 6.
- Page 8, line 16. '... which affects the wind ...'
- Page 8, line 29. '... the AO phase has a long lasting effect ...'
- Page 8, line 33. This should be '... the weakening of the Northern polar vortex ..', right?
- Page 8, lines 34-35. I suggest you to write '... dynamical changes decrease the density of the surface ocean waters South of Greenland, ...'
- Page 9, lines 11-13. Don't these citations analyse the impact of the increase in GHGs? Seems like you are cutting corners here. Wouldn't it be more correct to say e.g. '... Swingedouw et al., 2011). Related to increasing global greenhouse gas concentrations and associated surface warming, it is also one of the dominant ...'
- Page 9, line 17. '... may reduce the projected 21st century ...'
- Page 9, line 18. '... stronger than in the late 21st century than [today?], when a grand ...'

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- Page 9, line 23. '... the AMOC by anomalous ...'
- Page 9, lines 23-25. This sentence is not clear to me. I suggest rewriting 'The dynamical effect is enabled by chemistry climate interactions, which result in amplified stratospheric temperature responses.'
- Page 9, lines 28-29. The literature you cite here include three studies analysing NAO and only one analysing AO. This indicates to me, that NAO would have been a more appropriate index for this study as well, although its relation to the polar vortex is not as clear as the one of the AO.
- Page 9, line 31. 'the modelled response of the AMOC ...'
- Page 10, line 5. '... weakening of the AMOC with climatic ...'
- Page 10, line 10. What do you mean by 'Future studies'. Be more explicit. Are you planning to do this work?
- Figure 1. Write out the TSI acronym in the figure caption. As you used t-test for significance, did you check the autocorrelation or did you just treat each year as an independent variable? If years correlate, it affects your significance estimates. Explain more in detail what you did.
- Figures 2-4, 7, S1, S3, S5. Dots are not dark grey, but black. Better to say 'Black dots denote non-significant ...'
- Figure 2. More correct to say 'The sea-level pressure contour interval is ...'
- Figure S2. Indicate latitude and longitude locations of these T & S profiles.

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