Review of “Brief communication: Arctic sea ice thickness internal variability and its changes under historical and anthropogenic forcing” by Van Achter et al.

This brief communication looks at the temporal and spatial variability of Arctic sea ice volume and thickness (respectively) using the CESM large ensemble over three multi-decadal to multi-centennial periods (pre-industrial, historical, and future). A wavelet analysis was used to explore the peak modes of variability in SIV whereas the authors used an EOF analysis to explore the spatial modes of variability in each period. The key findings of the study are that there are two peak modes of SIV variability in the pre-industrial and historical time periods centered on 8- and 16-year periods. The first of these temporal modes is shown to be related to the first spatial mode of SIT variability, which shows a strong AO signature. The relationship between the first mode of SIT and the temporal mode of SIV is made more certain by a wavelet analysis performed on the first principal component of SIT, which is found to also have a peak at 8 years. The other key finding is that both temporal modes basically vanish after 2050 when SIV reduces by 50% in winter.

The results of the analysis are original in that the temporal and spatial analyses are brought together for the first time in this way. Overall, I rate the study in terms of originality, scientific quality, significance, and presentation as fair to good.

General comments:

- The EOF analysis is informative, but have the authors considered identifying spatial modes of variability by correlating the wavelet time series associated with the peak periods for SIV with sea ice thickness? It could be interesting to see if the SIT spatial patterns agree with the EOFs, especially since the EOFs are constrained by orthogonality.

Specific comments:

L20-25:
-Labe et al., 2018 did an EOF analysis comparison with PIOMAS and CESM LE monthly ice thickness that should be referenced here.

Labe, Z., G. Magnusdottir, and H. Stern, 2018: Variability of Arctic Sea Ice Thickness Using PIOMAS and the CESM Large Ensemble. *J. Climate,* **31**, 3233–3247, https://doi.org/10.1175/JCLI-D-17-0436.1

-The Singarayer and Bamber study didn't look at sea ice thickness, just concentration.
-historical - should state that these studies all used model-based thickness reconstructions.
- the EOF mode variance numbers cited were only from the Lindsay and Zhang study, so should state this. Also could note that the spatial structures of these modes and the amount of variance they explain can be sensitive to whether (and how) the SIT time series are detrended prior to

performing the EOF or K-cluster analyses, the season and the time period considered, and the model.

L60-654:

- It needs to be clarified whether the analysis is being performed on a single ensemble member from the large ensemble or the full ensemble. If the former was done, then I would suggest at least commenting on how robust the analysis is if performed on other ensemble members. Ideally though, the full ensemble would be used. For instance, the wavelet analysis could be performed on each ensemble member and then the results of the wavelet analysis could be averaged together. It's not immediately clear to me how one would do this for EOF analysis, perhaps by appending the ensemble members to one another.
- One of the advantages of the large ensemble is that the externally-forced signal can be removed from the ensemble by subtracting the ensemble mean from each ensemble member. This makes detrending by fitting to a polynomial unnecessary and actually inferior since it requires an assumption about the functional form of the response to the forced signal.

L70:

-Should offer some more details on how the wavelet analysis was performed [software used, wavelet function (ah I now see it says in Fig. 1 caption, but should say it here), and whether any normalization was used.]

L100:

-There is still overlap though between the occurence of each peak so it's maybe not very accurate to say they don't occur at the same time.

L110:

-It might be the contouring but I'm having a hard time seeing a significant area at the 5-year period during the 2010-2025 period.

Figure 1:

-I recommend changing the units on the vertical axis from months to years since these are the units used in the text.

-What is the yellow contour representing? Presumably it's statistical significance, but if it is then I think it would be easier to see if it were colored red as in the time integrated plots. It should also be stated.

-What are the areas of white on the contour plot representing?

L120:

-Do the authors have any idea why the leading EOF mode over the historical period explains much less variance than that found in Labe et al., even though the spatial pattern looks the same? Could it be that it's due to the use of all ensemble members in Labe et al.?

-Relatedly, I'm surprised that the variance explained by the first three modes doesn't sum to a higher number. For instance, looking at Lindsay and Zhang study, the first three modes identified in their study sum closer to 60-70%.

L140:

-Why was the first mode of SIT variability only compared with ice velocity and the second mode only compared with temperature? Why not compare each mode with both ice velocity and temperature?

L155:

-I'm not sure it's accurate to say that the air temperatures are causing the variability in SIT from this analysis. They appear to be associated with each other, but this doesn't imply causation. For instance, a thermodynamic response from the ice thickness variability is just as plausible. Nonetheless it is at least consistent with Olonscheck et al. (as stated though, they looked at ice area not thickness).

Technical comments:

L85:

-I would suggest separating this sentence into two; it’s currently a run-on (the two uses of the word “by”)