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Interactive comment on "Seasonal transition dates can reveal biases in Arctic sea ice simulations" *by* Abigail Smith et al.

Anonymous Referee #2

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General Comments

The manuscript suggests to evaluate CMIP6 sea ice simulations using ice seasonality metrics. The authors define a set of seasonal metrics based on sea ice concentration and surface temperature simulated by CMIP6 and CESM earth system models. A recent satellite database describing several ice seasonality metrics is also used to evaluate models.

A first part is focused on transition period between the different melt and freezing dates. They find an asymmetry between spring ice loss and fall ice growth in both satellite observations and model simulations. They also show that most models have a late freeze onset compared to observations.

In the second part the correlation between seasonal metrics and sea ice area and thickness is studied. The authors find a good correlation between freezing dates , sea ice area and thickness. These correlations allow to highlight sea ice biases in some models which are compensated by other processes. The authors give the example of CNRM model which has biases in melting and in sea ice thickness but which represent realistic sea ice area for the wrong reasons.

I found this paper very interesting. It includes newly observation database and suggests an interesting and novel approach to evaluate earth system models sea ice simulations. I stress the good work the authors made by analysing a large set of earth system models with several members besides satellite observations. I think that this work can make a great contribution to the literature after following comments are addressed in the context of a minor revision.

Specific Comments

P1 line 13 "the spread between climate model projections of sea ice has been on the order of millions of square kilometers in Coupled Model Intercomparison Project (CMIP)" . Can you specify about which parameter you are talking ? Sea ice coverage ?

P4 line 92 "(select figures using all available members are provided in the Supplement)." : Can you specify which figures ?

P9 to P17 : I think it would be beneficial to add maps of the four intra-seasonal periods (melt , freeze , seasonal loss-of-ice and seasonal gain-of-ice periods) and a table of spatial median (and standard deviation) for each model and observation as for table 4. Moreover, you look at the difference between the spatial of the metrics to describe the median of the intra-seasonal periods. But as median(A) - median (B) $\neq$ med(A -

B), calculating the intra-seasonal period for each pixel before doing the spatial median seems more appropriate.

P11 lines 205-207 "the model spread (May 15- June 3) " : Is it really June 3 or is it June 13 here?

P14 line 228 : What do you mean by "internal variability of the satellite data" ?

p20 line 302 " (Supplementary Table S3)" : I guess you mean Table S4.

p22 line 320 "This lack of relationship is a strong indication that the spatial coverage of break-up dates is not sufficient for describing pan-Arctic sea ice feedbacks. " : I wonder if the lack of relationship between March mean ice thickness and break up date can be explained by the inverse relation between ice growth and thickness which explains that the thinner the ice, the more efficient the growth. This relation should temper the delay in break up (see Bitz & Roe, 2004 and Lebrun et al. 2019).

Bitz, C. M., Holland, M. M., Hunke, E. C. and Moritz, R. E.: Maintenance of the Sea-Ice Edge, J. Climate, 18(15), 2903?2921, doi:10.1175/JCLI3428.1, 2005.

Lebrun, M., Vancoppenolle, M., Madec, G. and Massonnet, F.: Arctic sea-ice-free season projected to extend into autumn, The Cryosphere, 13(1), 79?96, doi:https://doi.org/10.5194/tc-13-79-2019, 2019.

p22 line 247 " indicating that the impact of seasonal transition biases can be be large" : you should remove a "be"

Figure 2 : This figure seems not describe in detail in the main text. You should move it in supplementary.

Figures 3 and 6: Can you remind the definition criteria for melt and freeze onset dates in both caption as you did for fig 4,5,7 and 8 ?

Table 3 : What do you mean by "spread" ?

Table 3 - Table 4 : Can you also add a spatial standard deviation for each model and observation?

Table 6 or Table S4 : Caption for both tables are exactly the same. I guess it is a mistake you should fix.