

Review of submission entitled “Declining Sea Ice and Its Relationship with Arctic Cyclones in the Current and Future Climate Part I: Current Climatology in CMIP6 Models” by Valkonen et al.

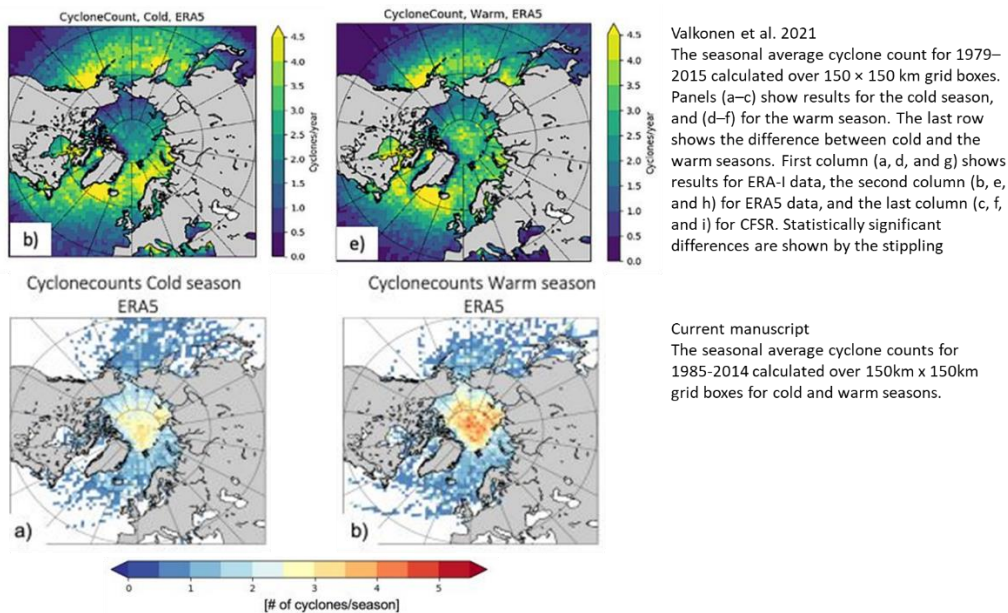
Overall recommendation: Reject

This manuscript aims to assemble a seasonal climatology (1985-2014) from ERA5 reanalysis and output from six coupled CMIP6 models on Arctic cyclone metrics that include cyclone count, minimum central pressure, depth, duration, pressure gradient, cyclone area, and accumulated cyclone energy (or ACE). A cyclone tracker algorithm based mean sea level pressure is applied to each dataset to compute the cyclone metrics, where cyclone area is used to obtain sea-ice concentration (SIC) when the cyclone circulation is co-located with the sea ice. Time series and trends of cyclone metrics and SIC from ERA5 are used to evaluate the same metrics from CMIP6 models. The authors’ also refer to a relationship between Arctic cyclones and SIC, which is implicitly established through co-positioning of cyclone area and SIC. While I find the statistical analysis presented on cyclone metrics, ERA5 vs. CMIP6 models, interesting, I do have major concerns with the manuscript in its current form, in particular (1) the described relationship between the cyclone metrics and SIC and (2) the accuracy of the spatial patterns in cyclone counts as shown in Fig. 2. As discussed in the comments below, I believe much of the results presented in the manuscript rest on these concerns and therefore I cannot recommend this study be published in *Weather and Climate Dynamics* at this time. I do think the authors could improve the manuscript and resubmit after extensive revisions. My overall recommendation is to reject the manuscript at this time.

Major Comments:

1. A relationship between Arctic cyclones and sea ice has been shown by a number of previous studies, many of which are cited by the authors in this manuscript. However, the key details that comprise this relationship and its complexity (e.g., specific cyclone related processes that impose dynamic or thermodynamic impacts on the sea ice) are not well presented in the introduction such that the authors can build upon them with their results and discussion. Analysis of cyclone metrics and their seasonal year-to-year variability against co-located SIC is interesting, but it does not well explain the physical processes between the two. For example, the authors state that cyclone counts and cyclogenesis trends increase from the late 1990s onward in the cold season which is attributed to SIC decline in the warm season. Is the increase in cyclones a function of more available low-level baroclinicity in the autumn-winter months and/or other local processes? No evidence related to the physical drivers is shown. Perhaps the low-level baroclinicity could be computed in cyclone areas that would help explain or corroborate increased cyclone counts and genesis. Perhaps a noncyclone database could be constructed (i.e., see noncyclone methodology described in Finocchio et al. 2020 and Schreiber and Serreze 2020) to further support the statistical relationships. Having SIC stratified by cyclone and noncyclone would give a more robust understanding of whether SIC changes are cyclone related or not.

2. The spatial pattern of ERA5 cyclone counts shown in Fig. 2 a and b seems much different from those shown Valkonen et al. (2021) Fig. b and e (see comparison in pasted graphic below). There is a modest difference in the years used in each climatology, i.e., 1984-2015 shown here versus 1979-2015 shown in Valkonen et al. (2021), but why is there such a discrepancy in the cyclone density patterns? For example, the North Atlantic storm track is a primary cyclone pathway into the Arctic during the cold season (Valkonen et al. 2021; Serreze and Barrett 2008; Zahn et al. 2018, and many others). Here, the cyclone counts are higher in the central Arctic than in the North Atlantic during the cold season? In the warm season, the spatial patterns of cyclone counts look more reasonable with higher counts in the central Arctic, but still not correct. In the warm season, for example, higher cyclone counts should also be found east of Greenland and along south-coast Alaska, but counts are lower in these locations than expected. I could be misunderstanding the color scale or the units, but shouldn't the cyclone density patterns be relatively consistent with Valkonen et al. 2021 and other studies? In addition, these discrepancies in cyclone counts prompt concern as a large portion of the subsequent statistical analysis links to the positioning of cyclone counts shown in Fig. 2.



3. The introduction, methods, and figure captions could benefit from additional and clearer description. For example, cyclone matrix is referenced but never defined. Even referring to Valkonen et al. (2021), I don't find a clear definition of cyclone matrix. I do find a section in Valkonen et al. (2021) paper entitled "cyclone matrix" but no explicit definition. Is it simply the regional boundary in Fig. 1 and cyclones metrics within, including the 24h duration requirement?

Specific comments:

Abstract: No discussion on the cyclone / sea ice relationship in the context of the main results.

Line 30: Perhaps a comma is missing or the following sentence needs to be rephrased.

“They found that the even though all 30 the models did depict a decline in the SIC, the models show a large spread in SIC results, partly due to large internal climate variability and were less consistent with the ERA-Interim results than the SAT”

Line 42: The complex relationship between cyclones and sea ice is not clearly described using previous studies.

“The complex relationship between cyclones and the changing sea ice, and cyclones’ important role in the Arctic now and in the future, make it critical to better understand the interactions between Arctic cyclones and sea ice, and how these interactions may change with a warming climate.”

Line 77: This sentence needs a citation.

“Studies have also been conducted to better understand how this relationship might change with changes in Arctic climate.”

Line 82: “Arctic cyclones and their relationship with Arctic SIC” needs to be unpacked in the introduction.

Line 84: “Arctic cyclone characteristics” would be good to list the characteristics here.

Line 90: Main goal #3. “To assess the CMIP6 models’ ability to represent observed relationships between Arctic cyclones and sea ice, and to accurately describe the causalities between the two”
The observed relationships between Arctic cyclones and sea ice are not clearly explained.

Line 116: Section 2.2 “Reanalysis data – ERA5” ERA5 is not a fully coupled model. All six CMIP6 models are fully coupled models. Does this have implications on the results? If so or not, this should be discussed

Line 141: “were cyclone”, where cyclones?

Line 146: “cyclone matrix” needs to be defined

Line 147: “recorder”, recorded?

Line 148: “SIC over the cyclone area”, SIC co-located with the cyclone area?

Line 150: “How intense each cyclone was (weak, normal strong , calculated based on the 25th lowest, interquartile and the top 25th percentile values of ACE over the whole study period), and the average SIC (less than 15%, more than 85%, or in between) were also noted in the cyclone matrix.”

Are these metrics used in the analysis or discussed in the results? I don’t recall where/how they were used?

Line 158: ACE metric. Is this average surface wind speed? Some additional explanation is needed.

Line 166: Hurrell and Deser (2009) is not in the reference list.

Figures:

The grey shading in the color bar in Figs. 1 and 2 conflicts with grey colored landmass.

Figure 3 shading is not explained. Same with Figs. 5, 6, and 9.

References

Finocchio, P. M., J. D. Doyle, D. P. Stern, and M. G. Fearon, 2020: Short-term Impacts of Arctic Summer Cyclones on Sea Ice Extent in the Marginal Ice Zone. *Geophys. Res. Lett.*, **47**, 1–9, <https://doi.org/10.1029/2020GL088338>.

Schreiber, E. A. P., and M. C. Serreze, 2020: Impacts of synoptic-scale cyclones on Arctic sea-ice concentration: A systematic analysis. *Ann. Glaciol.*, **61**, 139–153, <https://doi.org/10.1017/aog.2020.23>.

Serreze, M. C., and A. P. Barrett, 2008: The summer cyclone maximum over the central Arctic Ocean. *J. Clim.*, **21**, 1048–1065, <https://doi.org/10.1175/2007JCLI1810.1>.

Valkonen, E., J. Cassano, and E. Cassano, 2021: Arctic Cyclones and Their Interactions With the Declining Sea Ice: A Recent Climatology. *J. Geophys. Res. Atmos.*, **126**, 1–35, <https://doi.org/10.1029/2020JD034366>.