University of Cologne

Cologne, 14 May 2024

Institute for Geophysics and Meteorology

MSc. Andreas Walbröl

Phone: +49 (0)221 470-3678

E-mail: a.walbroel@uni-koeln.de

Pohligstr. 3

50969 Cologne

Germany

Author's response:

Dear ACP editorial team,

we have revised the manuscript "Unusual atmospheric and sea ice conditions in the North Atlantic sector of the Arctic during the HALO-(AC)³ campaign" according to the comments of the reviewers (see line by line response below). As suggested by the reviewer, we changed the title with the intention to highlight the contrast between the warm and cold conditions: "Contrasting extreme warm and long-lasting cold air anomalies in the North Atlantic sector of the Arctic during the HALO-(AC)³ campaign".

We also analyzed the agreement of ERA5 with the dropsonde measurements. The results (integrated as a new figure) show an excellent agreement in accordance with the assimilation as more than 50 % of the dropsondes into ERA5. As suggested, we added a figure on radar measurements showing the bright band during one of the Atmospheric River (AR) events to stress that liquid precipitation was indeed observed over sea ice at this time of the year. An Arctic-wide synoptic map showing the average pressure and geopotential height conditions over the warm and the cold period has been added to the appendix to support the chapters focussing on AR events and marine cold air outbreaks.

Neither this manuscript or substantial parts of it have been published elsewhere in English or any other language, nor is it presently under consideration for publication by any other journal.

Sincerely,

Andreas Walbröl

Reviewer reply:

We thank the reviewer for the supportive review of the manuscript. The comments helped us to refine some of the analyses by adding supportive visualizations. Below, we repeat the reviewer's comments in black and write our responses in blue. The line numbers in the line-by-line responses are valid for the revised manuscript.

The manuscript flows well now and I like the figures. I remain puzzled why a manuscript focused on the HAO-AC3 field campaign contains absolutely no analysis of the HALO data. We see the dropsonde locations in Fig. 1, then on line 175 are told how scarce the measurements are and diverted to reanalysis. Why not use all the dropsondes to assess if ERA5 indeed possesses a moisture deficit, for example? It seems like a relatively easy assessment and something society funds field campaigns to do. So I feel that I am missing something - maybe the ERA5 assessment using HALO dropsonde data is a dedicated project someone else is undertaking?

- We were reluctant to show this as more than half of the sondes were assimilated into ERA5. However, we agree with the reviewer that the comparison is important for the reader. Therefore, we added a figure in Sect. 3.2, which shows excellent agreement of dropsondes and ERA5.

I like the focus on the extremely warm AR event, it is something to organize the paper around and the authors have done that by and large. I wonder if AR1 and AR2 couldn't simply be grouped together - although the Guan/Waliser discrimination identifies two, I don't see the meteorology as being different and in practice they are grouped together. Just calling AR1+AR2, AR1, could simplify the writing.

- We understand the idea of merging the two AR events for simplification. However, as they were connected to different pressure systems, we prefer to keep them separated.

The new title is an improvement in that it sounds like less of a report, but 'Unusual' sounds vague to me - why not try to summarize what is the unusual condition? I believe that is the AR, as the MCAOs aren't all that extreme - the domain is still warmer in the mean after all. Thus I suggest the authors reconsider the title (or defend their current choice further), to focus more on the anomalous warmth of the conditions sampled during HALO-AC3.

- Thank you for the comment on the title. It motivated us to change it to " Contrasting extreme warm and long-lasting cold air anomalies in the North Atlantic sector of the Arctic during the HALO-(AC)^3 campaign", which now stresses the contrast of the warm and cold conditions that both occurred during the campaign.

Another recommendation is to highlight the large-scale circulation features further. An SLP high over Scandinavia and SLP low over Greenland flip, around March 20. A map of the entire Arctic, showing the baroclinic wave structure for the 2 regimes, would be of interest. Of further interest of course is whether the atmospheric blocking is more pronounced than climatology, to help explain the AR, if that can be done.

- Thank you for the suggestion. We added synoptic maps averaged over the warm and the cold period in the appendix to give a wider perspective for interested people. The plot also supports the atmospheric blocking remark in chapter 4 and can explain the longevity of the cold air outbreak conditions in chapter 5. Regarding the last point: The unusual strength of the blocking can be, although implicitly, inferred from the strength of the pressure anomalies. Such a statement has been integrated into the discussion. A detailed analysis of the blocking strength, for which no clear definition exists, would be beyond the scope of the manuscript.

Line 175 'scarcity of measurements' is a strange phrase here. Can this be stated in a more nuanced fashion, for example by referencing some of the genuine measurement papers?

- We speficied this statement and added that there are no permanent radiosonde stations north of 82.5°N (Rinke et al., 2019) to support the scarcity of measurements in the Arctic: "Given the scarcity of measurements, e.g., no radiosonde stations north of 82.5° N (Rinke et al., 2019), reanalysis data are used to characterize the conditions over the whole study domain. " (lines 175-176)

Line 187: is the typical Arctic SLP established elsewhere in the manuscript?

- Good point. We have not yet mentioned what the typical Arctic sea level pressure is for this season. Thus, we have added a sentence that refers to a climatological pressure field of the Arctic: "The high MSLP of the central Arctic agrees well with the climatological pressure shown for April in Fig. 4.8 of Serreze and Barry (2014)." (lines 201-202)

Line 14 in abstract: mention the maxima values are in the ERA5 record (and not measurements)

- We made it more clear that these maxima were indeed measurements: "These warm and moist air masses caused the highest measured 2 m temperatures (5.5 °C) and daily precipitation rates (42 mm day-1) at Ny-Alesund for March since the beginning of the record (1993)." (lines 13-14)

Line 228: can ARs can start in the arctic? That seems strange.

- The formulation was indeed a bit imprecise. To be more precise, we changed it to: "The number of strong AR events decreases meridionally (Fig. 7) because of two effects: Firstly, along their northward propagation, ARs generally decline in intensity. Secondly, within the Arctic circle, the likelihood of new AR formation strongly decays, as the moisture uptake from the ocean is substantially reduced (Papritz et al., 2022)." (lines 243-246)

Line 252: why not treat the reader to a radar image of the brightband here? Also include mention of whatever retrieved precipitation values are available from the HALO datasets, I would think some preliminary values at least are available, after 2 years?

- We agree that it is a good idea to visualize the bright band. Therefore, we added a plot showing the bright band, which is best captured in the radar linear depolarization ratio

observations: "Liquid precipitation at high latitudes over sea ice was also observed by the cloud radar onboard HALO as we detected a distinct bright band in the linear depolarization ratio at about 0.5-1 km height on 13 March (Fig. 10)." (lines 266-267).
We often observed high LDR values close to the surface, which suggests the presence of tumbling particles. As high LDR values indicate the presence of complex melting particles, no simple relation between reflectivity and rain rate can be applied.

Line 281: a 19 day mcao cant just be one strong cyclone passage, and it's also hard to see the 19day extent in Fig. 4. An Arctic wide 500 hPa Geopotential height analysis, averaged over the warm and cold periods, might help bring this out.

- We agree that the average pressure over the cold period can illustrate the potential longevity of MCAO conditions. However, as we did not want to disrupt the current flow of the paper, we only added the figure to the appendix and related the pressure constellation to the longevity of MCAO conditions in one sentence in the main text: "The longevity of the MCAO conditions can be explained by the persistence of low pressure over Scandinavia, the Barents Sea and Russia, and high pressure over Greenland and the central Arctic during the cold period (Fig. B1b in Appendix B)." (lines 298-300)
  We also rearranged the paragraph to make it more clear that this 19 day MCAO event consists of multiple waves of changing MCAO conditions related to the presence of cyclones near Svalbard.

Overall the figures are nice, Fig 7, 9, 10 in particular . Within Fig. 4, the white contour lines indicating the SLP can be a little faint. Suggest thickening a few key lines, and including 'L' and 'H' to indicate pronounced closed circulations. Done.