We would like to thank the editor and the three anonymous referees for their thorough evaluations with constructive comments that certainly will improve the manuscript. In the following, we will address the referees' comments point by point. We mark red the comments given by the referee, give our answers and comments in black and indicate how we addressed the amendments in the manuscript in green.

Comment on tc-2021-388

Anonymous Referee #2

Referee comment on "The impact of climate oscillations on the surface energy budget over the Greenland Ice Sheet in a changing climate" by Tiago Silva et al., The Cryosphere Discuss., https://doi.org/10.5194/tc-2021-388-RC2, 2022

This is an interesting novel study of the effects of the NAO and GBI and their combined influence on the Greenland Ice Sheet surface energy balance. The paper is fairly insightful and is reasonably well presented overall, although it would be useful to add an explanation of exactly how the NAG (influence of the North Atlantic over Greenland) time series was derived. It should also be clarified somewhere whether the reported correlation coefficients are based on detrended datasets. The analysis is based on an interesting and worthwhile hypothesis that the tilt within North Atlantic jet stream structures may have differing spatial (and temporal) effects on the near-surface impacts of jet-stream changes, and is best quantified by combining NAO and GBI rather than taking one of these measures in isolation.

We thank Referee #2 for the constructive review and the overall positive assessment of our study. We acknowledge that our methodological description of the derivation of NAG was apparently not clear enough in the initial submission. We will overcome this by reformulating the paragraph dedicated to the NAG explanation in Section 2.4.

Specific comments

Line 92 (P4): why not use the most recent (and best) ERA5 ECMWF reanalysis (which is available back to 1950) to force the RACMO for the whole time period?

Thanks, we complete LN92 with:

We used the latest version of RACMO2.3p2, which is forced by a combination of ERA reanalyses: ERA-40 (1958-1978), ERA-Interim (1979-1989) and ERA5 (1990-2020).

Line 97 (P4) "based on the lowest 5% albedo values between 2000 and 2015" – how many values/how frequent?

Thanks, we expand the mentioned sentence to: Bare ice albedo is estimated as the 5th percentile of the recorded albedo in each year by the 16-day MODIS product (MCD43A3) over the period 2000-2015. The resulting annual maps of MODIS-derived bare ice albedo are then averaged over the period 2000-2015 (Noël et al. 2018, 2019). The analysis of how many values/how frequent goes beyond our study scope.

L162 (P7) etc. – are the reported correlation coefficients based on de-trended data?

The reported correlations are not detrended, as none of the used variables are deterministic. Nevertheless, if we had assumed that the variables analyzed along L162 were linearly related, the correlation between detrended variables would be weaker but with the same sign. In order to overcome the linear relationship assumption, we do not use Pearson correlation coefficient but a non-parametric technique, namely Spearman correlation coefficient.

L183 (P8): how exactly is the NAG time series calculated?

As explained in the last paragraph in Section 2.4, the NAG is calculated by k-means clustering using NAO, GBI and GrIS IWV. We add: (see Section 2.4) to the text in L183. Additionally, we now name the clustering method before its description, as recommended by the Referee #3.

L187 (P8) "the influences exerted by NAO and GBI may differ" – this is an interesting result.

Thanks for this positive assessment! We find different regional changes with respect to the reference period by using only NAO or only GBI in most atmospheric variables (Fig. S10 and S11).

L190 (P8) "the 95$_{th}$ percentile of IWV is mainly connected to positive NAG phases in summer and winter": Fig. S3 suggests (dark circles) that high IWV is mainly associated with the neutral (grey) cluster then.

We improved Figure S3 (here Figure R1) in order to avoid confusion as pointed out by the referee.

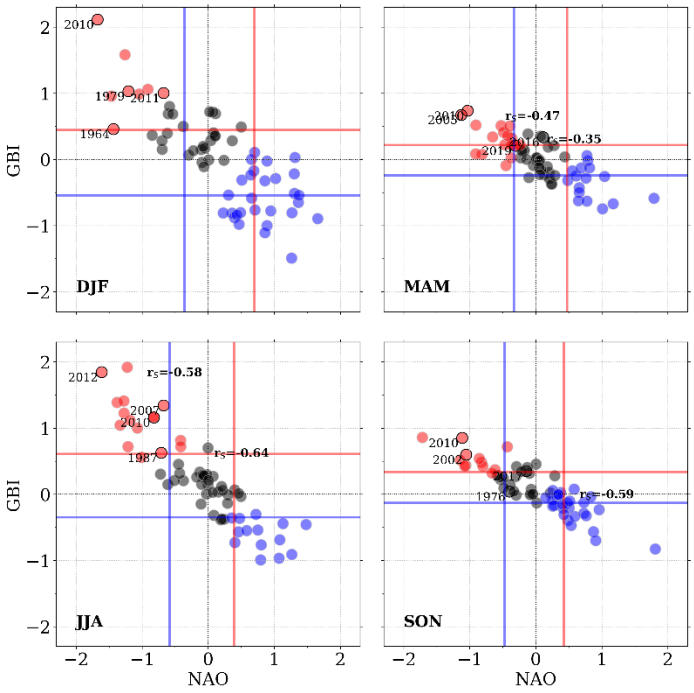

Figure R1- Improved Figure S3.

L198 (P8) "in winter +NAG frequently contributes the most to surface accumulation". What is the reason for this? If +NAG means more Greenland Blocking, this should be associated with fewer storms in south-east Greenland.

NAG is the combination of GBI, NAO and GrIS IWV. One seasonal +NAG phase does not necessarily indicate only one specific blocking situation centered over Greenland, but rather the influence of a series of high-pressure systems nearby Greenland interrupted by episodic cyclonic activity (e.g., Bjørk et al., 2018 and Hanna et al. 2018). We mentioned in the Introduction how wave breaks in the North Atlantic contribute to surface mass gains in the western part of Greenland (LN 21).

Fig. 3 (and elsewhere): are the reported correlation coefficients based on de-trended data?

Since we segregate the data by season and NAG phase, each sample is typically composed by assorted years. This means that the following value is not dependent on the previous value.

If we had assumed that the relationship among variables for the 62 years in the analysis were linear and deterministic, the detrended version would not change the results, but only attenuates the correlation coefficients. This attenuation makes a few weak detrended relationships weaker and not significant without changing the correlation coefficient ranks among significant correlations.

If we had assumed that the relationship among variables in analysis were non-linear and stochastic within the segregated data, we would be able to detrend the data by differencing. The resulting correlations would be strengthened in comparison with the raw data. However, both detrended methods strongly rely on subjective decisions which is why we present raw non-parametric correlations.

L238 (P12) "-NAG in winter promotes more IWP at the Northeast" – this seems unclear from Fig. 4(a).

We agree that this information cannot exclusively be seen in Fig 4a and in addition Figure S8d has to be taken into account. We add the reference to this figure in the revised version. Given the negative winter temperatures, the increase in cloud content over the Northern regions is entirely attributed to increases in IWP.

L240 (P12) "The RH2m…" – where is this shown? Should this refer to the q2m plots?

RH2m is not shown, and we now acknowledge that RH2m does not add much to the discussion. We will remove these details in the revised version.

References:

- Bjørk, A., Aagaard, S., Lütt, A., Khan, S., Box, J., Kjeldsen, K., Larsen, N., Korsgaard, N., Cappelen, J., Colgan, W., et al.: Changes in Greenland's peripheral glaciers linked to the North Atlantic Oscillation, Nature Climate Change, 8, 48–52, https://doi.org/10.1038/s41558-017-0029-1, 2018.
- Hanna, Edward, et al. "Greenland blocking index daily series 1851–2015: Analysis of changes in extremes and links with North Atlantic and UK climate variability and change." International Journal of Climatology 38.9 (2018): 3546-3564.
- Noël, Brice, et al. "Rapid ablation zone expansion amplifies north Greenland mass loss." Science Advances 5.9 (2019): eaaw0123.