Review of “Greenland's annual and interannual mass variations from GRACE/GRACE-FO linked with climatic indices”

Summary: This paper seeks to understand how annual to decadal-scale variability in the mass change of the Greenland Ice Sheet is related to a set of climate indices and parameters. After decomposing the mass change time series into the top five principal components (PCs), numerous cross correlations are performed between the PCs and climate variables using a cross wavelet transform. The most significant relationships with the highest correlations are then discussed. The correlations for annual variability are summarized and some causal relationships investigated in previous studies are noted. I have some major concerns as to the design of the study, the lack of a clear and comprehensive connection to the peer-reviewed literature, and the quality of the writing. Until these major comments are addressed, it is difficult to evaluate many of the specifics of the study.

Major Comments:

1. The methods in this study have the potential to be part of an investigation into causal relationships between Greenland Ice Sheet mass loss and other climate processes (King et al., 2023). This study, however, uses correlations without a comprehensive literature or physics-based discussion of what is already known about these relationships. Though some previous work is mentioned, this paper lacks a clear discussion of the current understanding of the Greenland Ice Sheet in the context of the broader climate system. Such a literature review is important for guiding the reasoning behind which relationships are tested, at which lags, and for which frequencies. Some exploration is appropriate, but calculating a large set of correlations with only the confidence bounds as a guide can easily suggest false or misleading relationships. Such an approach, which is explicitly stated in the paper on lines 210-214, can be referred to as “p-hacking” (e.g., Nuzzo, 2014). This may not have been the intention of the authors; however, this is how the paper reads given that the question, methods, and discussion are not clearly guided by the existing peer-reviewed literature nor a physics-based understanding of the system. Without this guidance, it is unclear which findings are spurious and which may represent real, causal relationships between ice mass loss and climate variables. A hypothesis-driven study based on exploring a knowledge gap in the peer-reviewed literature, such as was done in King et al. (2023), could make for a compelling study, even when similar methods are used. Ideally the paper would add new insight into existing hypotheses or propose new hypotheses. As it is currently written, it is not clear what insight this paper adds that may not already be in the existing literature.

2. The writing, word choice, and tone need work. The writing lacks conciseness and clarity. The word choices include many casual, non-specific, and sometimes misleading words. This, in part, leads to a tone that is too casual, especially for some sections. See below for an example of how this shows up in a few paragraphs. I hope the example helps illuminate how the writing can be improved throughout the entire manuscript.

This example shows the types of edits I would provide throughout the entire paper. I hope that it is a helpful guide for future editing. In the following, <u>underlines indicate casual wording</u>, *italics indicate vague wording*, **bold indicates confusing or misleading wording**, and [comments are

inserted in square brackets]. This does not include grammar or punctuation issues or fine-combed editing for conciseness and clarity.

Section 5, Lines 280-312

"Our results **show interactions** [correlation is not causation] between ice mass variations and variations in climate indices or meteorological parameters. These **interactions** are more or less evident depending on the frequency with which we study the phenomenon, ***and they are often linked to each other***.

Among the three indices, the GBI shows the strongest correlation (-0.85 and -0.91) with mass variations. This is a logical result given that this index is specifically designed for Greenland. This contrasts with the **other two indices, such as the AMO**, [confusing wording] which only accounts for *a small portion* [be more specific] of the waters surrounding Greenland. Similarly, the NAO, although it focuses on atmospheric pressures like the GBI, is calculated for the entire dipole covering the North Atlantic rather than just Greenland. (Figure 3 and Table 1) [Something does not have to be local to have a strong impact. A stronger argument would be based on our physical understanding of the atmosphere and the ice sheet.]

To understand the complex mechanisms that affect the GIS, we start by examining which meteorological parameters ***can intervene on*** [do you mean "interact with" or "impact"?] the NAO, GBI, and AMO indices. The most obvious, temperature, is **linked** to NAO and AMO. [Linked also implies causation, which has not been shown here.] The latter **responds to** [this again implies causation] our TDT parameter both for the annual cycle and for the 11 years period. Surprisingly, the GBI index is only **sensitive** [also implies causation] to temperature for the annual frequency [cite?]. However, this index is *the most local of the three*, and it would seem normal that it is directly influenced by local weather parameters [cite]. ***Currently***, [current to what?] annual temperature variations dominate *the signal*, [which signal?] such that no *longer-term behavior* [what does long-term mean in this context?] is highlighted.

When we look at precipitation, it is correlated with the NAO and AMO only for periods of 4 years and 11 years. No **link** between them is visible with an annual periodicity. Only the GBI index is well anti-correlated to the precipitation **fall *following* the annual cycle** [what is "precipitation fall"? What does "following" imply in this context?]. This relationship is consistent with what was expected since the conditions favorable to precipitation are when the GBI decreases and vice versa [cite. Be clear about what are new findings versus what is already in the literature.].

The albedo is also **sensitive** to annual variations of the GBI but with a slight lag of one to two months. This **sensitivity** is indirectly related to the atmospheric pressure above Greenland, reflected by the GBI index [cite if there is literature on this]. **The control of atmospheric pressure, on the amount of precipitation and temperature, *positively or negatively influences* the reflective quality of the GIS surface, and with *more or less delay*, the time for the last precipitation to fall in winter or for the energy available for melting to cause the surface to darken in summer.** [confusingly worded and needs citations]

Finally, we would like to know what is *the force* that generates and maintains these periodic variations. Some are obvious, such as the annual, others are subtler, such as the period between 8 and 12 years, and finally, others are more complicated to explain, such as the 4 or 7 year periods and the at least 15 years long period. For this last one, we're [contractions are too casual] aware that it's based on a very strong hypothesis [explain and cite], ***that of the observed signal's periodicity***. The methodology used was chosen because it allows us to *highlight* common periods in our signals. It would take a much longer observation period to ascertain *this* [what does "this" refer to?], however, the results are realistic and consistent with known climatic phenomena [explain and cite].

We will start by discussing in more detail the two periods for which there are strong and **indisputable relationships** [significant correlations are not the same as indisputable relationships. More evidence is needed to back up this claim.] between ice mass, meteorological parameters, and climate indices: the 1 year period, and the period between 8 and 12 years. Then, we will **assess** [replace with the word "discuss"? No formal assessment is done.] the other periods visible in the signal studied, and we will finish by looking at the punctual **event** [two events were mentioned earlier] detected in M5 of the EOF decomposition."

References:

King, M.A., Lyu, K. & Zhang, X. Climate variability a key driver of recent Antarctic ice-mass change. *Nat. Geosci.* **16**, 1128–1135 (2023). https://doi.org/10.1038/s41561-023-01317-w

Nuzzo, R. Scientific method: Statistical errors. *Nature* **506**, 150–152 (2014). https://doi.org/10.1038/506150a