

## Recent Changes in Summer Greenland blocking captured by none of the CMIP5 models

Edward Hanna, Xavier Fettweis, Richard J. Hall

### Summary

This paper presents timeseries of atmospheric blocking and temperature over the Greenland ice sheet simulated by global climate models from the Coupled Model Intercomparison Project 5 (CMIP5) for the period (1950-2100) and compares the modeled timeseries for the period 1950-2017 with the same fields from climate reanalysis data. Atmospheric blocking and temperature patterns are quantified using a modified form of the Greenland Blocking Index (GBI), which is based on 500 hPa geopotential height anomalies over the area containing the Greenland ice sheet, and a temperature index derived for the same region. The comparison indicates that none of the 36 global models examined are able to capture recent anomalous increases in GBI and temperature over Greenland relative to other areas in the same latitude band. Nor do the models capture the magnitude of the recent positive anomalies.

### General Comments

The paper documents an important difference between reanalysis datasets and global climate model outputs, highlighting that the climate models do not capture recent changes over Greenland that are believed to play a strong role in recent accelerating mass loss. The paper is therefore highly relevant and of interest to the cryospheric and larger scientific community, and is well written. The main question for the authors concerns whether the reanalysis data can really be established to be outside of internal model variability:

- Are the CMIP5 results averages of a set of ensemble members, or one realization from an ensemble? If they are averages, wouldn't ensemble members show more variability, placing the reanalysis results within the internal model variability, making them consistent with a possible realization of some of the models? If available, ensemble members should be included to evaluate this possibility.

### Specific Comments

1. P. 2, Lines 10-11: Suggest changing "climate model" to "global climate model" for clarity.
2. P. 2, Lines 27-31: Please provide some more detail about the CMIP5 outputs. Are these ensemble members or an average of ensemble members? Briefly, what is the forcing applied to the historical simulations and future projections shown in Figs. 1 and 2.
3. P. 2, Line 29: Please explain how the 20-year running mean was applied at the start and end of the timeseries
4. P. 4, Lines 7-14: The disparities between TA2 and GB2 anomalies are much smaller for the other reanalysis products, especially for the period after 2000. This should be mentioned here. Could this be because the NCEP reanalysis assimilates soundings as mentioned earlier, and therefore incorporate a process missing in the models? Perhaps this could also help explain why the CMIP5 models do not appear to capture this relationship either.
5. P. 4, Line 11: Would it be possible to show a plot of this ratio, perhaps in the supplementary material?

6. P. 4, Lines 17-18: The future projections show larger negative anomalies. Please clarify that positive anomalies are being referred to. Also, it is hard to distinguish individual model lines, but it seems possible that comparable changes in the indices might be possible for a given 20-year period from some of the models (i.e. from a negative to a neutral state).
7. P. 5, Line 13: Are there other reasons, besides the large magnitude of the change, for the view that these are not due to internal variability?
8. P. 5, Lines 4-24: Can the authors suggest some possible mechanisms for what could cause errors in model representations of blocking?
9. Figure 1: It is hard to tell where the GB1 index is plotted in Figure 1. It would be helpful if an additional entry were added to the legend and the GB1 index were mentioned at the start of the caption instead of at the end.
10. Figure 2: Note in the caption that values are normalized to the reference period.

#### **Technical Corrections**

1. P. 1, Line 19: Change "(Francis et al. (2015)) suggests" to "(Francis et al., 2015) suggest"
2. P. 2, Line 2: Change (e.g. Hanna et al. (2018)) to (e.g. Hanna et al., 2018).
3. P. 4, Line 3: Add reference to Figures S1 and S2 in the supplementary material.
4. P. 5, Line 16: Perhaps change "how realistic is model representation" to "how realistically models represent"