Response to reviewer #2

I am very grateful for the thoughtful and constructive comments of the reviewer on the first version of our manuscript. We addressed all the mentioned problems in the revised version of the paper and the response is attached bellow.

The authors correlate temperature in southern Greenland reconstructed from ice cores with several blocking indices, with the aim to extend the time series of blocking in Greenland by means of ice core data. The paper is generally well-written, but below I identify several major issues that need to be addressed in a revised version of the paper.

1. North Atlantic blocking and the NAO are known to be inversely correlated (Scherrer et al., 2006, Croci-Maspoli et al., 2007). The authors mention that Greenland temperatures are known to be correlated with the NAO, but do not talk about the known relationship with blocking.
However, since it is known that the NAO and blocking are inversely correlated, then using a temperature time series that has been used to reconstruct the NAO for creating a time series of blocking is trivial and does not justify a separate publication. You should address this severe issue in the introduction an provide some justification as to what your study is contributing in addition to making use of these known facts. In the discussion of the results I also miss an attempt to separate or distinguish the influence of the NAO and blocking.

The relationship between NAO and blocking is discussed in the revised paper. Indeed a large part of blocking variability from the North Atlantic region is related to NAO variability. However, what we analyse in our paper is that part of blocking variability that is related with SW Greenland temperature. Therefore we investigate the relationship between this part of blocking variability as captured by a blocking index and the NAO.
In order to find the patterns of SW Greenland temperature (T), blocking (B) and NAO we performed an EOF analysis of T, B and NAO indices. The dominant pattern (EOF1), which describes 73% of the variance, captures the out of phase variability of T and B with NAO, which is the relationship often mentioned in the literature. We show that the winter pattern associated to this mode is the NAO. The second pattern (EOF2), describing 19% of the variance, captures out of phase variations of T and B with NAO almost in neutral phase (the NAO weight is close to zero). The seasonal pattern associated to this mode is a dipole located in the western part of the North Atlantic. Finally, the third pattern (EOF3), explaining 8% of the variance, captures in-phase variability of T, B and NAO. Therefore our blocking index variability is not totally dependent on the NAO. The index contains information about all three patterns mentioned and not only about NAO.

2. If a Greenland temperature record from ice cores should be used as a proxy for blocking, I would expect some explanation of the physical mechanisms by which the actual measured quantity in the ice cores, i.e. stable isotopes, are influenced by blocking. I do not see this relationship established in the paper, instead the ice core temperature

signal is used almost as a thermometer record. A helpful reference in this context may be Sodemann et al., 2008. If the blocking-isotope relationship is not established on a physical basis, there is no guarantee that the correlation remains equally valid throughout time.

As suggested, we mentioned some possible relationships between atmospheric circulation variability and stable isotope variability from Greenland ice cores (Sodemann et al. 2008). However it is not the goal of the paper to enter into details of physical mechanisms that explain the relationship between atmospheric circulation variability and stable isotope variability.

3. The authors use several different blocking indices throughout their paper, some based on Z500 and one based on SLP. The different indices should be directly compared based on the same dataset, and the difficulties and limitations of an SLP-based blocking index discussed.

In this version we have used a long (101 years) daily 500 mb geopotential height from the 20th century reanalysis project (Compo et al. 2009) for the period 1908-1947 merged with daily 500 mb geopotential height from the reanalysis project for the period 1948-2008 (Kalnay et al. 1996). Therefore, we did not used the SLP blocking index as in the first version of our manuscript.

4. A separate Discussion section which addresses the uncertainty of the reconstruction and the similarities or differences to the NAO should be added. Such a section could also contain more discussion of the blocking variability during past periods as promised in the Introduction.

We present a detailed discussion of our blocking reconstruction and NAO reconstructions. As suggested we enlarged our discussion related to the role of blocking in generating extreme phenomena during several past periods with focus on Late Mounder Minimum (LMM).

L. 18: A direct relation would require a physical explanation, which is not given in the paper.

As we mentioned, it is not the main goal of our paper to give detailed explanations on possible mechanisms related to the relationship of blocking and stable isotope variability. We just establish statistical relationships between blocking parameters (frequency and spatial distribution) and SW Greenland temperature observations and proxy data. We referred to the paper of Sodemann et al. 2008 for a possible physically based connection of atmospheric circulation and stable isotope records from Greenland ice cores.

L. 23: The blocking variability during past periods is not really discussed in this paper.

As suggested, we enlarge the discussion about blocking variability during the last millenium as it appears in our reconstruction as well as in other published reconstructions (Barriopedro et al. 2008; Casty et al. 2005; Slonosky et al. 2000.etc).

Pg. 2414
L11: How does the linear detrending affect the results? How is the detrending justified?
LI
We construct the patterns based both on original and linearly detrended data. The patterns remain qualitatively the same.

L. 23: A discussion of why this blocking index is used is required. There several other, more recent blocking indices available (see references in Scherrer et al., 2006)

We mentioned other blocking indices published in the literature (Pelly and Hoskins, 2003; Scherrer et al. 2006 and the references therein). We have considered two largely used indices based on G500 field (Tibaldi and Molteni, 1990; Scherrer et al. 2006). The first reason was that we can compare our results with those already published in the literature. The second is that we are interested in long term variation of blocking frequency and only long-term daily G500 field (101 years) are available from 20th Century Reanalysis Project (Compo et al. 2009) and NCEP/NCAR reanalysis project (Kalnay et al. 2006).

Pg. 2415

L. 27: a reference is needed here

We mentioned the paper of Trigo et al (2004) which presents the influence of blocking on temperature, in particular on Greenland temperature.

Pg. 2416
L. 1: Is this not one of the main hypotheses of this paper? Then this should be part of the introduction, and underpinned by more evidence than a claim without reference in the sentence before.

We modify this sentence as suggested.

L. 3: Mention what fraction of the temperature variance is explained by the PC-1 time series. What are the caveats and uncertainties of such an approach?

The correlation between PC1-D18O and observed SW temperature in winter is 0.75 (Vinther et al. 2003). Therefore, in the unfiltered data about 60% of PC1 ice core variability is linearly related to temperature variability. It increases to 70% for decadal time scales.

L. 16: Clarify that you use the TM blocking index here

We modify this sentence.

L. 20: Since you are separating into warm and cold Greenland temperatures, this is not really different from separating into negative and positive NAO phases. How is your approach different from previously published NAO reconstructions?

This part of the text was modified in the revised version of the manuscript. During the period 1908-2005 not all extreme Greenland temperature are also the years with extreme values of the NAO index. It is true, most of them, but not all. As we mentioned, there are two other patterns, that are related with SW Greenland temperature variability.

Pg. 2417

L. 9: clarify what you mean by "important"

We modified the text in this revised version.

L. 12: How does this result compare with the NAO time series and previously published time series of blocking (Croci-Maspoli et al., 2007)

As we mentioned, our blocking index was defined based on the difference between blocking frequency during warm and cold SW Greenland winters. Croci-Maspoli et al 2007 evaluated the relationship between the blocking in the entire Atlantic sector and the NAO. Therefore the connection of our blocking index with the NAO is a little bit different than that described in the paper of Croci-Maspoli et al. 2007.

L. 14: What is ultimately needed is a physical relation between blocking variability and how surface temperature is recorded in an ice core (see Sodemann et al., 2008). You should at least point this out as a requirement (or limitation)

We mentioned some possible relationships between atmospheric circulatiopn and stable isotope variability from Greenland and mentioned the paper of Sodemann et al. (2008) for a more detailed description of possible mechanisms of these relationships as revealed by statistical analysis.

L. 17: How extreme are the examples, e.g. in terms of standard deviations?

In the example considered here the values are higher (lower) than +-1.5 sigma.

Fig. 3 does not display a lot of useful information and should be removed.

We remove it as suggested.

L. 26: Clarify, is this a 2-dimensional TM index? How is it different to previously published indices, and can it be directly compared to the figures in Scherrer et al., 2006?

The map of this 2D index can be compared directly with that of Scherrer et al. 2006. We have used the same algorithm, the only differences are the data set and the period of analysis. However, the results are very similar to those reported by Scherrer et al. 2006.

Pg. 2418

L3: over THE North Sea
LI
We modify as suggested.

L. 4: How similar/different are the findings and why?

We discussed the similarity and differences from the Scherrer's results.

L. 29: A correlation of r=0.4 leaves quite a bit of unexplained variance, this should be discussed.

We mentioned that not only the blocking is responsible for temperature variability. Other processes can play an important role in summer temperature variability in SW Greenland.

Pg. 2419

L. 4: How good and reliable is this information, what are the uncertainties?

We compare our reconstruction with other reconstructions from the literature in order to establish the reliability of our reconstruction.

Fig. 10 does not display a lot of useful information and should be removed.

We remove it as suggested.

Sec. 4 has very little explanation or discussion in relation to the number of Figures shown. Their should be either more discussion or less figures.

As suggested, we reduced the number of Figures and added more text.

Sec. 5 should be renamed "Summary and conclusions". There is no actual discussion of the results in this section.

We discussed the blocking variability as derived from our reconstruction as well as from other published reconstructions.

Figs. 1 and 8: The area +/-1 sigma around the curves could be indicated by shading or error bars

We try to do this but the figures become less readable. We just mentioned that there are significant differences in the blocking frequency in the sector we chosed.

Figs. 2 and 9: Obvious differences and time lags between the two time series should be mentioned and discussed

A cross correlation analysis shows that the correlation is maximum at lag zero for winter. A delay of 3-5 years between temperature and blocking variations was discovered for summer. We mentioned the values of correlation coefficients in the text.

Figs. 6 and 13: Panel (a) could be removed, as the difference between panels (b) and

(c) is quite obvious.

We remove the panel a) from both figures as suggested.

Fig. 7: A separate panel with a zoom on the period where the two time series can be compared would be helpful to evaluate differences or correspondence.

We represented only the decadal component of the temperature variability so that the figure becomes more readable.

Fig. 14: The periods with large differences should be identified and discussed

We enlarged our comments related to the periods when blocking index and Greenland temperature are weakly connected.

References

Croci-Maspoli, Schwierz, Davies: Atmospheric blocking: space-time links to the NAO and PNA. Climate Dynamics (2007) vol. 29 pp. 713-725

Scherrer, Croci-Maspoli, Schwierz, Appenzeller: Two-dimensional indices of atmospheric blocking and their statistical relationship with winter climate patterns in the Euro-Atlantic region. Int. J. Climatol. (2006) vol. 26, pp. 233-249

Sodemann, Masson-Delmotte, Schwierz, Vinther, Wernli: Inter-annual variability of Greenland winter precipitation sources. Part II: Effects of North Atlantic Oscillation variability on stable isotopes in precipitation. J. Geophys. Res. (2008), vol. 113, D12111