Dear Editor and Reviewer,

We highly appreciate the further suggestion to improve our manuscript. Our response is written in italics below the comments.

Comments by the editor:

I would like to thank the authors for their revisions to the paper. The reviewer has suggested that some more evidence could be given to justify the choice of SOM array size. I agree that this would be useful information which would improve the paper, and that a further minor revision should be sufficient to include this. I look forward to seeing a revised version of this paper in due course.

Comments by the reviewer:

I very much appreciated the efforts made by the authors to improve the manuscript. In my view, I have only one minor comment which is related to the answer to my previous major comment (1).

I appreciate that the authors performed sensitivity tests with different domain sizes and different sizes of the SOM array. The authors claimed that they "made sensitivity tests with the array size (3x4, 4x5, 5x6), and based on these tests, 3x4 was found to be the most appropriate array size for this study." and that "the analysis is not very sensitive to the choice of region".

In my view, these statements are rather subjective. I recommend that the authors provide objective measures/metrics for the different SOM analyses which give more evidence for these statements.

Although the SOM technique provides an objective method for clustering, the choice of the SOM array size is always somewhat subjective (Alexander et al. 2010). Kohonen et al. (2014) (the first author being the developer of the SOM method) stated that the SOM array size must be determined by the trial-and-error method, after seeing the quality of the first guess. The subjectiveness of selection of SOM array size is widely recognized and accepted by the scientific community, and we have limited possibilities to overcome this feature of the method. The size of an optimal SOM array depends on the intended application and the size of the data space spanned by the input data (Cassano et al. 2006).

Impacts of SOM array size have been tested in various studies (e.g., Cassano et al. 2006, Cassano et al. 2007, Higgins and Cassano 2009, Liu et al. 2006, Nigro and Cassano 2014, Skific et al. 2009). These studies have provided qualitative assessments of array size, mostly based on visual inspection. They all agree that a larger number of nodes provides greater detail (of circulation types), while a smaller number of types represents the archetypical types with few details.

The reviewer recommended us to provide objective measures for the impacts of the array size and region size. According to our knowledge, purely objective measures for those do not exist. Cassano et al. (2015) estimated the effects of SOM array size by calculating Root-Mean-Square-Difference (RMSD) and twistedness index (TI) in different sized SOM arrays; however, also their approach included subjective assessement to select which characteristics of pressure patterns should be represented in the final SOM array and, in particular, what are the accepted/desired values of RMSD and TI as there are no subjective tresholds for those. Alexander et al. 2010 calculated sum of Root-Mean-Square Euclidean distances between the SOMs and the target dataset to find the smallest errors. Their final choice of SOM array was *a compromise between minimizing errors and providing sufficiently different synoptic patterns to be useful for a climate change study, thus also based on a subjective assessment.*

To compare the impacts of SOM array sizes, we show here the mean sea level pressure fields in 2x3, 3x4 and 4x5 sized SOMs in Figures R1–R3.

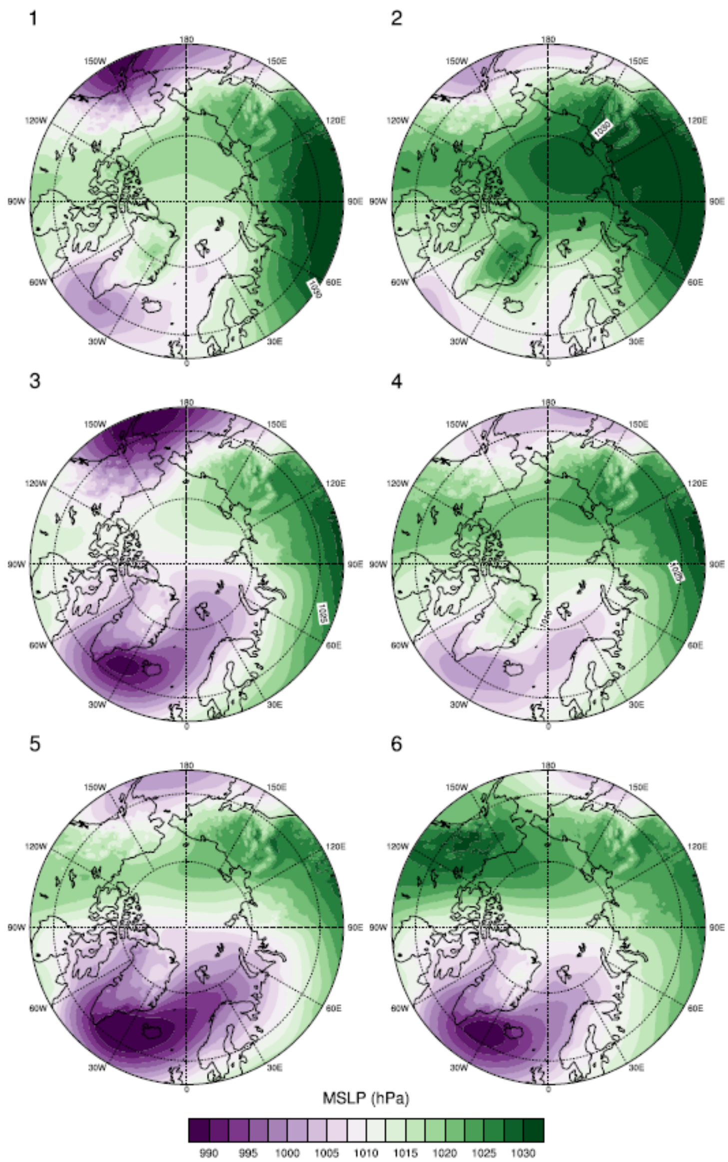

Figure R1. Mean sea level pressure fields in 2x3 SOM

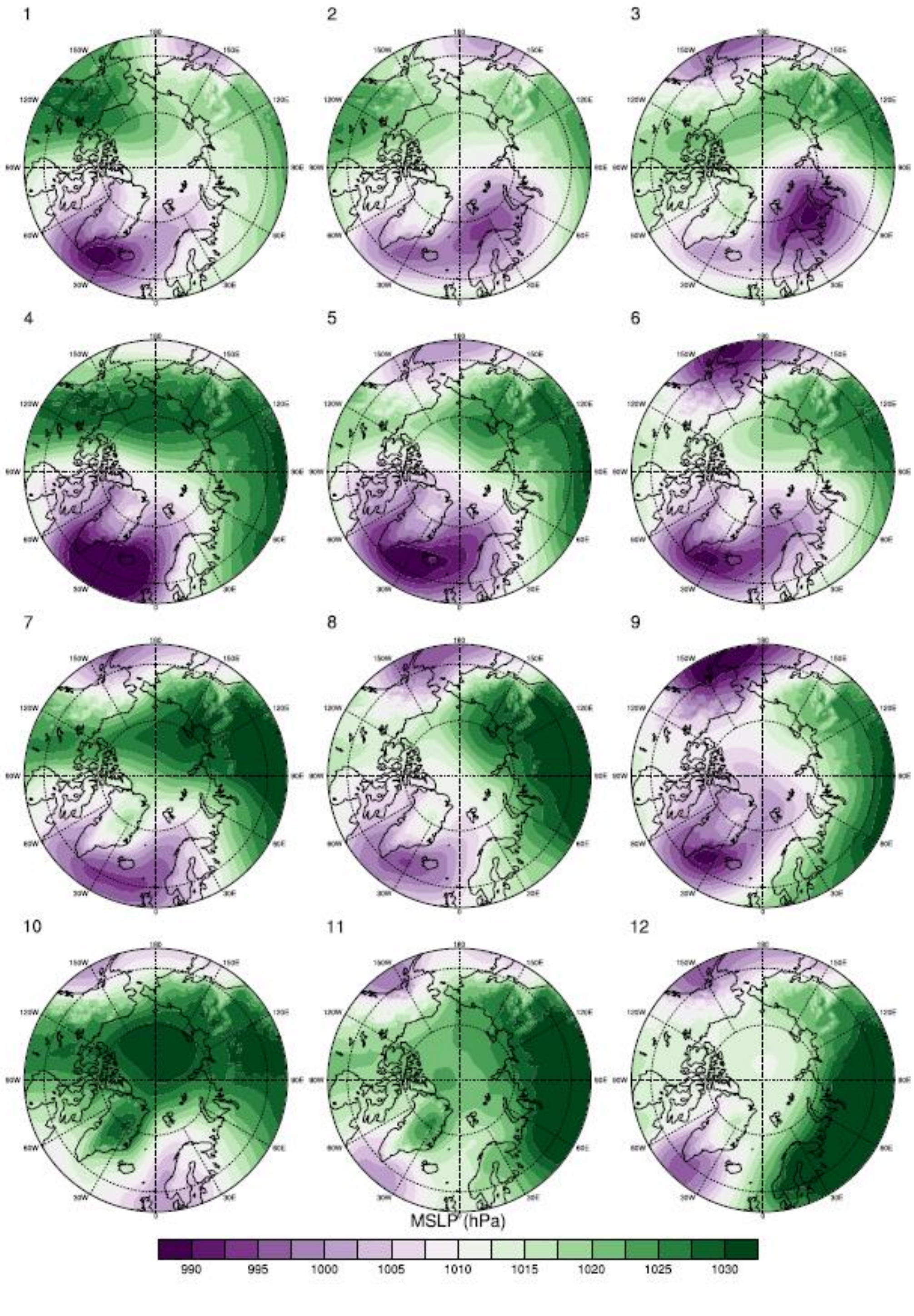

Figure R2. Mean sea level pressure fields in 3x4 SOM (which was used in the manuscript)

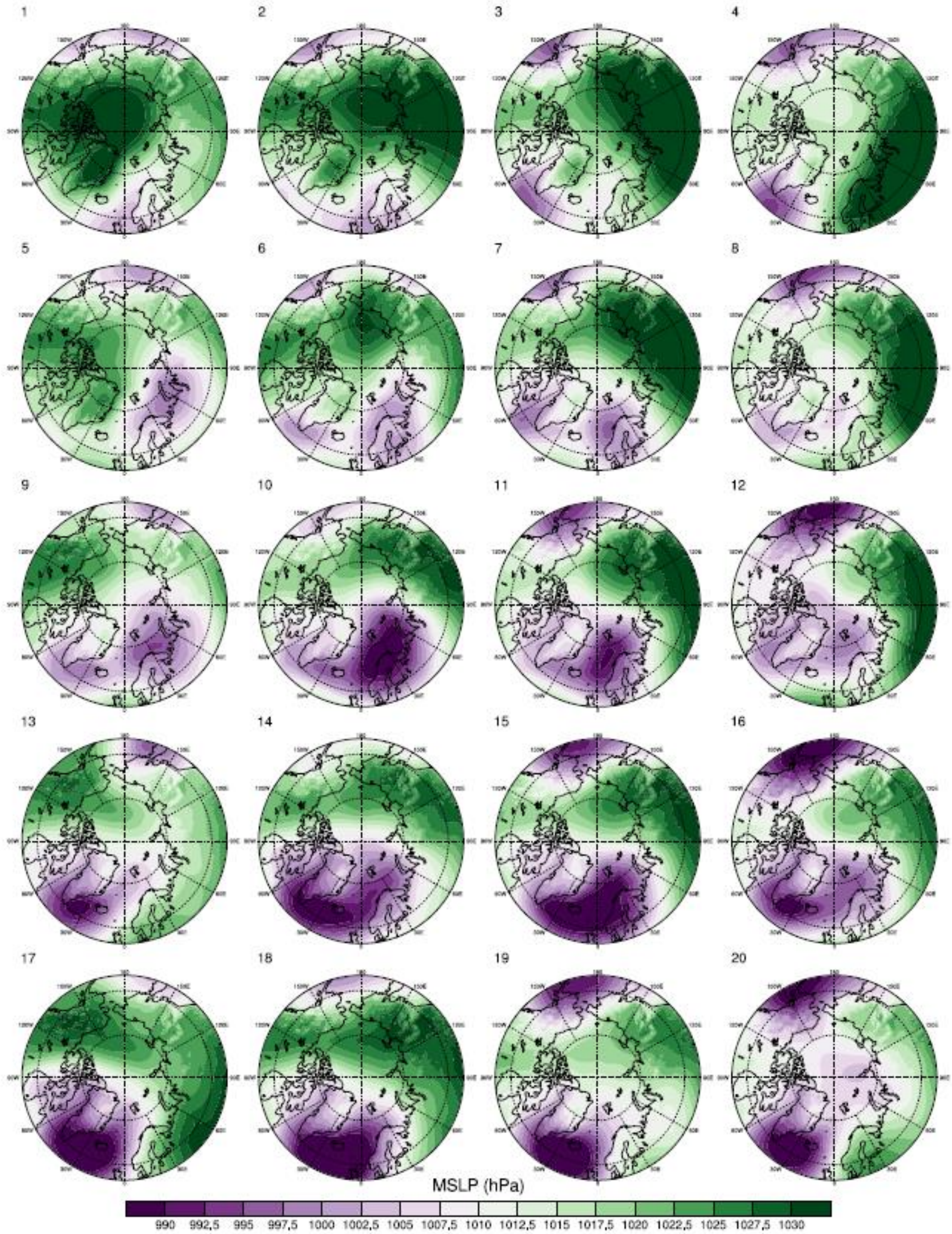

Figure R3. Mean sea level pressure fields in 4x5 SOM

Based on visual inspection, it is clear that 2x3 SOM (Figure R1) does not contain the needed level of details; it especially lacks circulation types (i) where North Atlantic low pressure has a very eastern location over the Barents Sea (this feature in present in types 2–3 in Figure R2 and types 5, 9, and 10 in Figure R3), and (ii) where the high pressure bridge between Russia and North America across the Central Arctic Ocean has broken up (this feature in present, i.e., the bridge is broken, in types 9 and 12 in Figure R2, types 4, 8, 12 and 20 in Figure R3). These circulation types, lacking in 2x3 SOM, are known to be very important for heat and moisture advection (Nygård, 2019).

As expected, 4x5 SOM (Figure R3) has more details than 3x4 SOM (Figure R3), but they essentially show the same kind of circulation patterns. Importantly, 4x5 SOM does not display circulation patterns or main characteristics of pressure fields that are totally missing in 3x4 SOM. Based on these subjective analyses, we concluded that the 3x4 array sufficiently captures the main circulation types in the Arctic in winter, and importantly, each circulation type has enough members (ranging from 147–461), being sufficient for further statistical analyses.

To include some metrics in selection of the size of SOM array, we have now calculated variances within each circulation type. Because we have used composites of real mean sea level pressure fields in the manuscript, instead of the "master SOM" directly produced by the SOM algorithm, comparison of variances within each circulation type is more meaningful for this study than comparing Root-Mean-Square Euclidean distances between the "master" SOM and the target dataset, as previoulsly done by Cassano et al. 2015 and Alexander et al. 2010. To evaluate how much variability in pressure there is within each circulation type, we calculated variance for each circulation type separately, and then averaged over all the circulation types.

As Figure R4 shows, for the 2x3 SOM array the mean variance of mean sea level pressure within circulation types is 143.7 (variances in individual cirulation types ranging from 137.4 to 148.2). For 3x4 SOM, the mean variance of mean sea level pressure within circulation types is 123.5 (variances in individual cirulation types ranging from 108.7 to 143.5). For 4x5 SOM, the mean variance of mean sea level pressure within circulation types is 120.1 (variances in individual cirulation types ranging from 98.5 to 136.7). The mean variance of the whole input mean sea level pressure data is 178.2. From these results, we can conclude that the variance is much reduced in 3x4 SOM array compared to 2x3 SOM array, but as large drop in variance is not seen between 3x4 and 4x5 SOM arrays (Figure R4). This supports that 3x4 SOM array is a good choice for this study with its relatively low level of variance within the SOM circulation types.

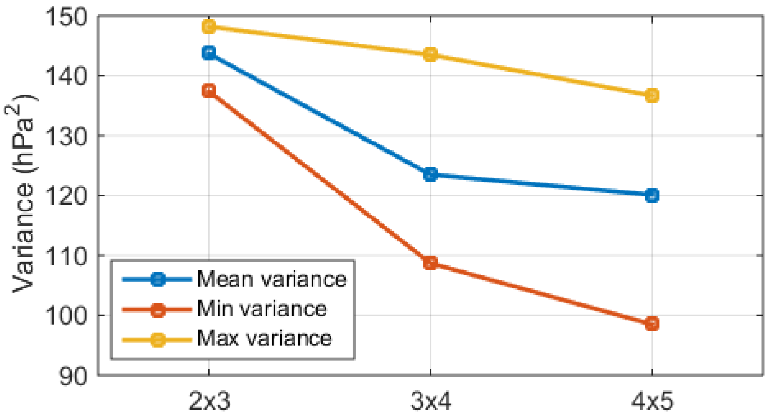

Figure R4. The mean, max and min variance of mean sea level pressure within circulation types in SOM arrays of 2x3, 3x4 and 4x5.

We have now included more text about the array size selection in the manuscript: ***"The size of the SOM array was subjectively selected to 3 x 4, to include the main features of regional circulation patterns and yet be sufficiently general to enable conceptualization of the results. In comparisons of 2 x 3, 3 x 4 and 4 x 5 SOM array sizes, it was clear that that 2 x 3 SOM does not contain the needed level of details; it especially lacks circulation types (i) where North Atlantic low pressure has a very eastern location over the Barents Sea, and (ii) where the high pressure bridge between Russia and North America across the Central Arctic Ocean has broken up. These circulation types, lacking in 2 x 3 SOM, are known to be very important for heat and moisture advection (Nygård, 2019). Instead, 4 x 5 SOM does not display circulation patterns or main characteristics of pressure fields that are totally missing in 3 x 4 SOM. We also calculated variances of MSLP within each circulation type. The mean variance within a circulation type is notably reduced in 3 x 4 SOM array (123 hPa^2) compared to 2x3 SOM array (144 hPa^2), but the mean variance does not decrease at the same rate towards the 4 x 5 SOM array (120 hPa^2)."***

The selected SOM domain should highlight the essential circulation characteristics that impact the features to be studied, and areas with high variability that are not relevant for the particular study should be excluded from the domain to avoid having those areas dominate the features included in SOM (Cassano et al. 2015). In our study, the SOM analysis was made for the region north of 50°N, while the cloud and thermodynamic analyses were made for the region north of 65°N. The SOM area was extended from 65°N to 50°N to capture the Icelandic low and a sufficient part of Aleutian Low, which both are very essential features in transporting heat and moisture to the Arctic. Due to this reason, the region north of 50°N is considered as the minimum domain size. Extension of the southern border from 50°N towards south decreases the weight of Arctic pressure patterns in the analysis, weakening detected anomalies in temperature and moisture in the Arctic. The text in Section 3.1 is modified to include these arguments for the domain size: ***"The SOM analysis was made for the region north of 50°N, while the cloud and thermodynamic analyses were made for the region north of 65°N. The SOM area was extended from 65°N to 50°N to capture the Icelandic low and a sufficient part of Aleutian Low, which both are very essential features in transporting heat and moisture to the Arctic (Nygård, 2019)."***

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