Answers to the referee 1 23-Jun-2017

Thank you very much for your competent and creative comments. Please find below your comments repeated again and our answers. With the help of your advices, we have prepared a new version of our manuscript.

Main comments:

1.a) More literature research should have been done to discuss on physical mechanisms behind statistically identified teleconnections. This discussion should include how AO/NAO are dependent, and therefore to some degree redundant, and the role of PDO, SCA, and PEU. For example, some studies (cf. Vihma et al. 2014; Uotila et al. 2015) have found that PDO and SCA, in addition to AO/NAO, are important for the northern Baltic Sea temperature and for the maximum Baltic sea-ice extent. This appears to contradict the author's argument that only AO/NAO are important circulation modes in the Baltic Sea region.

To avoid the redundancy, after the first comparison with AO and NAO, we concentrate our subsequent analysis on AO only, which shows in our analysis larger impact than NAO. In discussion paragraph we added some discussion about the AO and the NAO dependency (based on Wallace, 2000; Budikova, 2012) and emphasised that although some investigations (Uotila et al., 2015; Ambaum et al., 2001; Bader et al., 2011) have been brought out that NAO is much more relevant and robust for the Northern Hemisphere variability than is the AO, still, we found like some other authors before us (Rinke et al., 2013; Balmaseda et al., 2010; Thompson and Wallace, 1998) that AO has larger impact to the teleconnections between the Artic and the mid-latitudes.

Our study and studies mentioned by the referee are investigating different connections. Vihma et al (2014) and Uotila et al (2015) investigated variability in the Baltic Sea region. We concentrated on the analysis of the teleconnection between the Eastern Baltic Sea region and the Arctic region. So, PDO and SCA are influencing more the Baltic Sea region variability than the Arctic and the Baltic Sea region covariability.

To expose the role of different teleconnection indices we reorganized the analysis of teleconnection indices as follows (based on the suggestions of our referees):

we explained our choices of indices based on geographical position of the centres of action of the teleconnection patterns in data paragraph (see the segment 1 beneath);

to show the impact of teleconnection indices we replaced the figure 4 (and left out the figure 3) with a table which contains the average of partial correlations of all relevant teleconnection indices between 1000 hPa temperature at TP and the Baffin Bay-Greenland region (20 – 80W; 55 – 80N). The region was chosen due to the results of analysis where this region showed most often significant correlation with the parameters of the Eastern Baltic Sea region. The first row shows the average of the regular Pearson correlation of 1000 hPa in the region. It has the most significant values during winter and spring. During these seasons is also the impact of AO and NAO most considerable. See the table 1 below;

we added to our discussion paragraph a new segment about the role of teleconnection indices, based on our analysis and literature: Uotila et al, 2015; Lim, 2015; Comas-Bru and McDermott, 2014; Vihma et al., 2014; Moore et al., 2013.

Segment 1 of new version:
"The teleconnection indices we applied in our analyses were chosen according to the possible influence due to the geographical position of the centres of action of the teleconnection patterns over the North-Atlantic-Eurasian region. The following indices were chosen: 1) The North Atlantic Oscillation (NAO), which is the dominant mode of atmospheric variability in the North Atlantic sector throughout the year (Barnston and Livezey, 1987); 2) The Arctic Oscillation (AO), which is usually defined as the first EOF of the mean sea level pressure field in the Northern Hemisphere (Ambaum et al., 2001); 3) The Scandinavian Pattern (SCA), which consists of a primary circulation centre over Scandinavia, with two other weaker centres of action with the opposite sign, one over the north eastern Atlantic and the other over central Siberia to the southwest of Lake Baikal (Bueh and Nakamura, 2007); 4) The East Atlantic Pattern (EA), which consists of a north-south dipole of anomaly centres spanning the North Atlantic from east to west (Barnston and Livezey, 1987); 5) The East Atlantic/West Russia Pattern (EA/WR), which consists of four main anomaly centres: Europe, northern China, central North Atlantic and north of the Caspian Sea; 6) The Polar/ Eurasia Pattern (PEU) consists of height anomalies over the polar region, and opposite anomalies over northern China and Mongolia.; 7) Additionally, Pacific Decadel Oscillation (PDO), which is the dominant year-round pattern of monthly North Pacific sea surface temperature (SST) variability was included. Although its geographical centres are far from the Baltic Sea region, Uotila et al (2015) found that PDO correlated significantly with the ice concentration and temperature of Baltic Sea. All indices were downloaded from the NOAA-CPC database (http://www.cpc.noaa.gov)."

Table 1. *The partial correlations of teleconnection indices between 1000 hPa temperature at TP and the Baffin Bay-Greenland region (20-80W; 55 – 80). Smaller (than regular) values show higher impact of the index.*

index	**DJF**	**MAM**	**JJA**	**SON**
reg. correl.	*-0.41*	*-0.23*	*0.15*	*-0.02*
AO	**-0.07**	**-0.10**	0.19	0.08
NAO	**-0.10**	**-0.11**	0.23	0.04
PDO	-0.45	-0.26	0.06	-0.11
CAI	-0.41	-0.21	0.15	-0.01
PEU	-0.42	-0.18	0.19	-0.02
EA	-0.43	-0.27	0.06	0
EA/WR	-0.41	-0.22	0.12	-0.12
SCA	-0.25	-0.23	0.21	-0.01

1.b) Also, there are studies identifying possible physical mechanisms behind teleconnections. For example, Wu et al. (2013) found a linkage between the winter Baffin Bay sea-ice anomaly and northern European atmospheric circulation. Such discussion on mechanisms would assist the authors to find out which of the numerous correlation associations are likely to be physically sensible. Finally, by adding such a discussion the manuscript would better address the "Dynamics of the Earth system" subject area of the ESD journal.

We added to the Introduction paragraph the following segment to summarise possible physical mechanisms behind teleconnection (Segment 2):

Segment 2 of new version:
"The relationship between AA and weather extremes and/or persistent weather patterns in mid-latitudes are mostly explained with Arctic and North Atlantic anomalous circulation regimes, waviness and strength of jet stream (Vavrus et al., 2017; Francis and Skific, 2015; Overland et al., 2015; Barnes and Screen, 2015; Francis and Vavrus, 2015; Coumou et al., 2014; Tang et al., 2013; Petoukhov et al., 2013; Francis and Vavrus, 2012). Common supposition is that sea ice declines are primarily responsible for amplified Arctic tropospheric warming. This conjecture is central to a hypothesis in which Arctic sea ice loss forms the beginning link of a causal chain that includes weaker westerlies in mid latitudes, more persistent and amplified mid latitude waves, and more extreme weather (Perlwitz et al., 2015). On the other hand Sun et al. (2016) brought out that neither sea ice loss nor anthropogenic forcing overall yield the winter cold extremes and persistence in mid-latitudes. Arctic warming over the Barents–Kara Seas and its impacts on the mid-latitude circulations have been widely discussed (Jung et al., 2017; Dobricic et al., 2016; Semenov and Latif, 2015; Kug et al., 2015; Sato et al., 2014). Another particular regional warm core (Screen and Simmonds, 2010) is East Siberian–Chukchi Seas which is related to severe winters over North America (Kug et al., 2015; Lee et al., 2015). Screen and Simmonds (2010) brought out also the third particular regional warm core – northeast Canada and Greenland which has been less investigated. Wu et al., (2013) focused on winter SIC west of Greenland, including the Labrador Sea, Davis Strait, Baffin Bay, and Hudson Bay and found that winter SIC west of Greenland is a possible precursor for summer atmospheric circulation and rainfall anomalies over northern Eurasia. If we look at the regions in mid-latitudes then potential Arctic connections in Europe are less clear then with North America and Asia (Overland et al., 2015)."

To have a more focused paper we reduced the number of parameters, for that we made a general table of correlations with all our parameters and then chose only 3 for subsequent analysis: temperature, SLP and we added geopotential heights. We separated cold and warm winters (based on Baffin Bay region), similar to Sato et al, (2014); and added following analysis to reveal possible physical mechanisms why the Baltic Sea and the BB winters are in opposite phase relying on 1000 hPa temperature. We look atmospheric circulation differences using SLP, 700 hPa and 500 hPa geopotential height differences between warm and cold winters. We added also a cross-section of geopotential heights (up to 100 hPa) along the 60W vertical slice and plots of annual evolution of 500-hPa height differences at 60N, 70N and 75N (similar to Wu et al., 2013). See figures below:

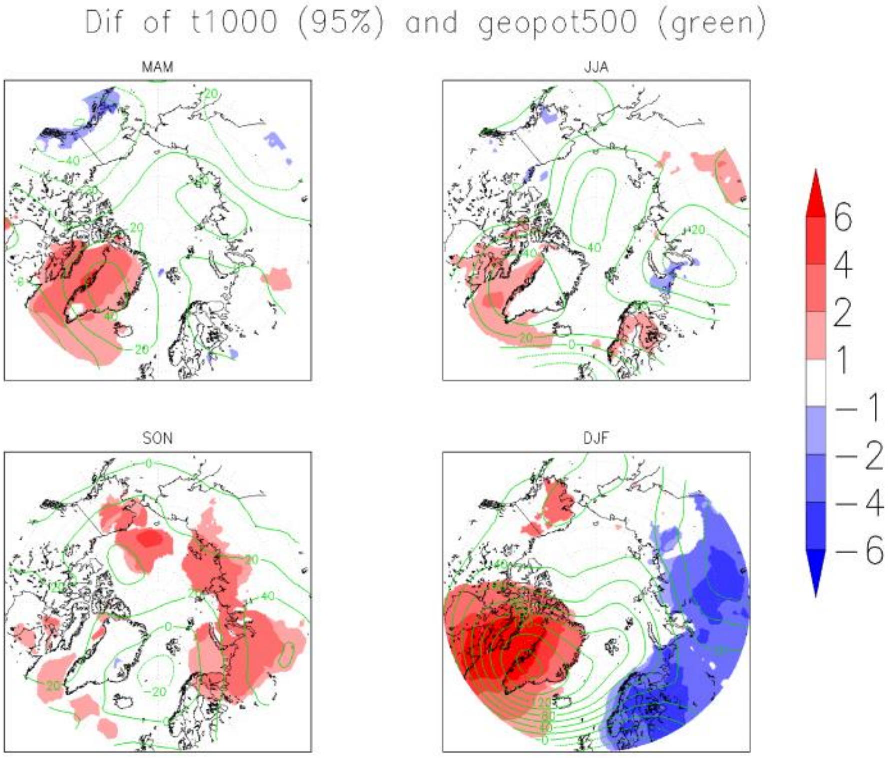

Figure 1. Seasonal difference maps (years with mild winters years with cold winters) in air temperature at 1000 hPa level (shading with confidence level of 95%), and (b) geopotential height at 500hPa level (contours).

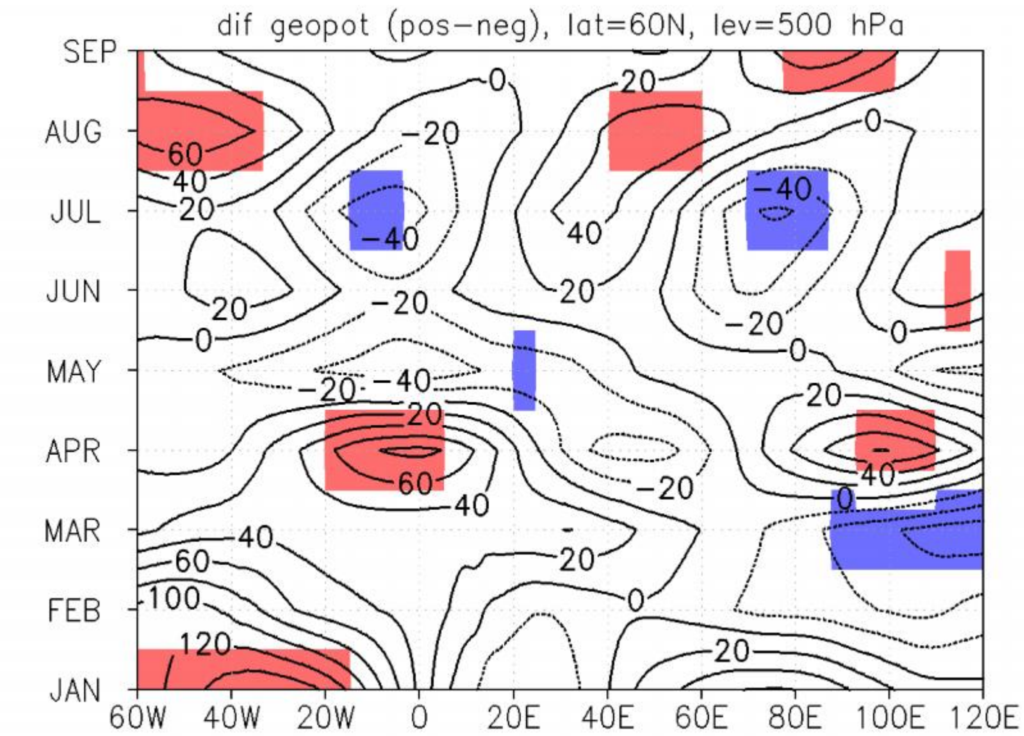

Figure 2. Evolution of 500-hPa height differences between mild and cold winters at 60N; red and blue shading indicates differences at the 95% significance levels for positive and negative height, respectively.

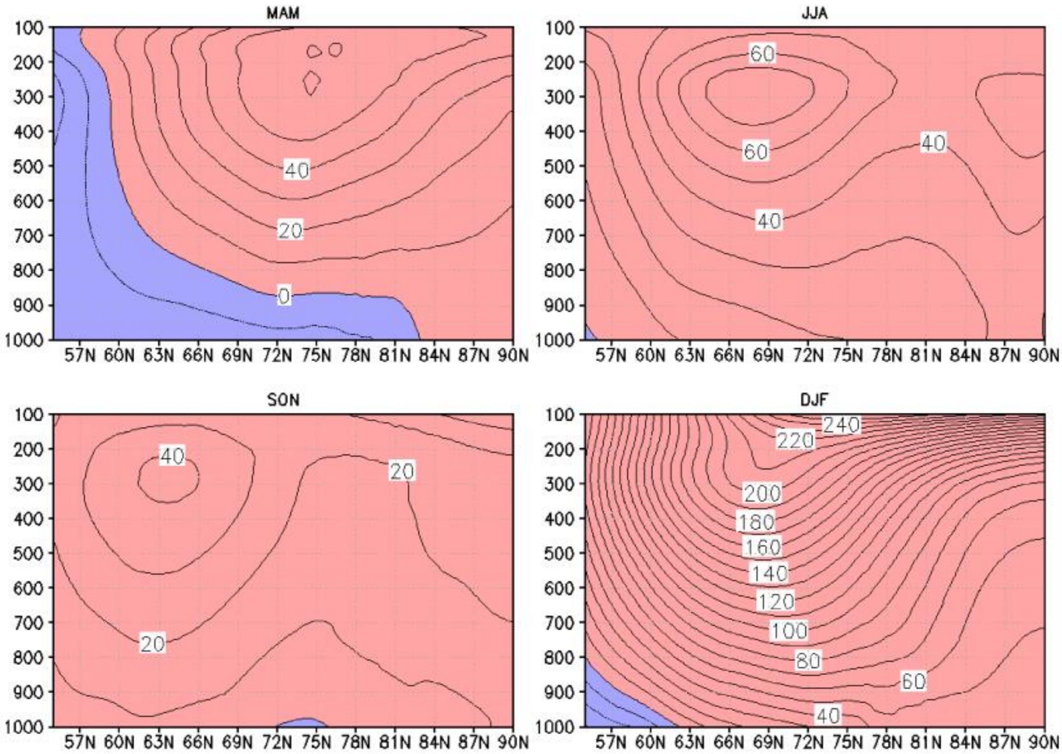

Figure 3. Differences in the mean heights between mild and cold winters along the 60W vertical slice. Contour intervals are 10 gpm; blue represent negative height differences and red positive height differences.

In discussion paragraph we added:

The large scale atmospheric circulation pattern in Figure 1 shows that the geopotential heights of 500 hPa are more than 100 gpm higher in mild winters than in cold ones, and the maximum of this height anomaly is centred over the maximum of the 1000 hPa temperature difference. It means that the whole column (up to 500 hPa) of the air in the Baffin Bay region is warmer than at cold years. Coming down to the lower surfaces (700 hPa, not shown), the maximum height anomaly is shifted to the east, what could be due to warmer sea surface of the Northern Atlantic compared to the regions that lay to west of it. The positive temperature anomaly (with the 500-hPa height anomalies) shifts towards east during the next seasons, reaching to Scandinavia/Baltic Sea region in summer (Figure 2). By Wu et al (2013) proposed mechanism, that associates the summer atmospheric circulation anomalies in the northern Eurasia with the previous winter ice conditions west of Greenland, supports our idea.

Figure 3 exhibit baroclinic structure of spring atmosphere north of 55N due to positive height anomalies in the lower troposphere below the 850 hPa and with further higher the negative ones. Similarly to Wu et al (2013) the vertical distribution of spring height anomalies differs from that of the previous winter when height anomalies show dominantly quasi-barotropic structure (not shown). With regression analysis they show the validity of their hypothesis of eastward propagation of the 500 hPa height anomalies. The same could be followed from Figure 2, where the evolution of 500 hPa height differences between mild and cold winters at 60 N is presented. Also at 65 N the similar pattern is present. At higher latitudes (70N and 75 N) this kind of signal propagation is missing.

2) Title is misleading. TP is a location in Southern Estonia and is not representing the entire Baltic Sea region. I base this claim on findings of previous studies mentioned above. I suggest to change the title to 'Atmospheric teleconnections between the Arctic and Southern Estonia'.

We generally agree with the reviewer. One point is not representative for the whole Baltic Sea region. But the representativeness depends very much on spatial autocorrelation of the studied parameter. To reduce the number of correlations we made a general table with all our parameters and then chose only 3 for subsequent analysis (temperature, SLP and we added height of geopotentials). According to Figure 1 in our manuscript and figure 4 in this document (see the figure 4 below) we presume that TP represents well the Eastern Baltic Sea region. Therefore we renamed the title as the 'Atmospheric teleconnections between the Arctic and the Eastern Baltic Sea regions'.

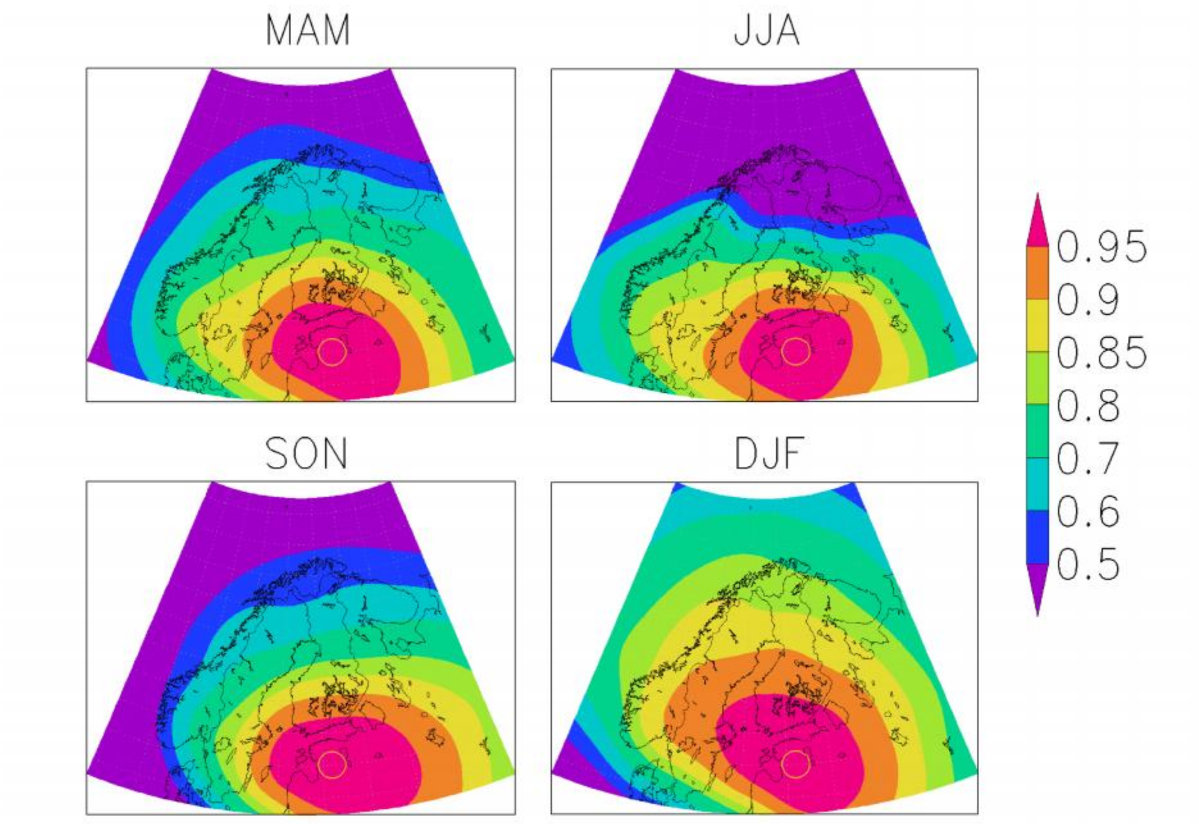

Figure 4. Correlation maps of SLP for the testing point in the Eastern Baltic Sea region.

3) Results section needs to be more focussed, now the large number of details confuses the reader. As a result, the reader is left wondering which correlation links are important which are not. Here, a summary table listing the most significant and physically relevant linkages would help the reader. Such a table would then support discussion.

To reduce the number of correlations we made a general table with all our parameters and then chose only 3 for subsequent analysis (temperature, SLP and we added height of geopotentials). We took the maximum value of the correlation between the Baffin Bay region and the testing point in the East Baltic Sea region during one season.

4) The analysis is based on only one reanalysis, although it is known that reanalyses have significant biases in the Arctic. To ensure the robustness of results, would be good to check main results with another reanalysis. I was also wondering why CFSR was picked of all available products? I suggest carrying out the analysis with an ECMWF one, such as ERA-Interim.

We repeated all the analysis with ERA-Interim. The results were resembled sufficiently in main points, although there were some discrepancies during summer season in the Central Arctic region. The dissimilarities are mentioned in the manuscript.

5) Methods have not been adequately explained. In particular, the partial correlation method needs to be explained and a reference to literature added.

We have used only well-known statistical methods in our analyses. For partial correlation, we could cite for example H. Cramer, Mathematical methods of statistics, Princeton Mathematical Series, no. 9. (Princeton University Press, Prinston, 1946), but it is in most statistical textbooks anyway. Still, we added formulas we used to the manuscript:

Detrending: $Y_i = X_i - (k \cdot ye \quad + b - X_a \quad)$.

Partial correlation: $R_{AB|C} = \dfrac{R_{AB} - R_{AC} \cdot R_{BC}}{\sqrt{(1 - R_{AC}{}^2) \cdot (1 - R_{BC}{}^2)}}$

6) Statistical terminology is misleading at places. For example, I would not say that correlation is strong when r is 0.5-0.7. Such a correlation range explains only 25-50% of variance.

By the meaning of "how much one parameter variance is controlled by the other one", 25-50% is indeed not very strong. At the same time, by the meaning of "how certain we can be that there is connection between two parameters", the probabilities for 0.5 and 0.7 are 99.8% and 99.998% correspondingly, that is quite strong. Even correlations exceeding ±0.32 are significant at 95% confidence level, so for correlation above ±0.5 we needed stronger name than "significant".

7) Although the manuscript is generally clearly written, some sentences are difficult to understand (please see minor comments for details).

We improved our manuscript as suggested in minor comments:

- lines 27-28. mention what could be the mechanism linking the Arctic to the outside Arctic environment. For example, does the air advection from mid-latitudes to the Arctic change?

We added the assumption about southerly warm advection based on Sato et al., 2014.

- line 32. ’all kinds of heat conservation changes’ is obscure, be more specific.

As the energy budget of the Arctic is highly dependent on energy exchange with lower latitudes, then the changes in atmospheric and oceanic circulation play an important role in all kinds of heat conservation changes in the Arctic, most prominently expressed in sea ice volume variations.

- lines 33-34. I found this argument rather weak. So far, it has been very difficult to show that the observed Arctic warming has actually had impact on mid-latitutes.

We added a segment to our Introduction to reveal the background of Arctic – mid latitude linkages (Segment 3) and to summarise possible physical mechanisms behind teleconnections (Segment 2).

Segment 3
“Several studies have demonstrated relationships between warming and/or ice decline, and mid-latitude weather and climate extremes (Handorf et al., 2015; Coumou et al., 2014; Tang et al., 2013; Petoukhov et al., 2013; Francis and Vavrus, 2012; Petoukhov and Semenov, 2010). Others have analysed whether these associations are statistically and/or physically robust (Hassanzadeh et al., 2014; Screen et al 2014; Barnes et al 2014; Screen and Simmonds 2013, 2014; Barnes 2013), while some investigations suggest that the apparent associations may have their origin, in part, in remote influences (Perlwitz et al., 2015; Sato et al., 2014; Peings and Magnusdottir 2014; Screen et al., 2012; Petoukhov and Semenov 2010).”

- line 36. ’patterns of high pressure’?

Actually we meant by the ’large-scale patterns of pressure anomalies’ both high and low pressures. To be clearer we replaced the phrase as follows: ’large scale patterns of high and low pressure’.

- line 69. ’One of the reasons for incomplete understanding ...’

Corrected

- line 71. ’... vice versa due to their close proximity.’

Corrected

- line 71. Where does ’Therefore’ point to?

Therefore may-be redundant in this sentence and we decided to remove it.

- line 100. Which correlation coefficient? Spearman?

We use through the work only Pearson correlation, we have clarified this in the manuscript.

- line 102. Why was the Arctic defined as north of 55N. Why not north of the Arctic circle?

We added a sentence: "We define the Arctic region here as the region northward of 55 N. Larger region than usual (Arctic cap from polar circle or 70N; July 10 °C isotherm) helps to analyse results that lay partly outside the usually defined Arctic region.”

- lines 155-160. When explaining your correlation findings, it would help if figure subpanels are cited more frequently to specifically indicate where you see the regions. Some geographic regions mentioned are rather local and many readers may not know where they are (e.g. the Gulf of Alaska).

We added citations of figures.

- line 156. ’the AO index as the controlling factor’, better?

Corrected

- line 171. ’change in one parameter due to climate change’?

We added to the brackets (e.g. due to climate change).

- line 176. ’... partial correlations, controlled ...’

Corrected

- line 180. I can’t find negative correlation in winter above Greenland and the East Siberian Sea in Figure 6.

Thank you for pointing this out. There has been really some misunderstanding and the sentence is incorrect. We deleted this statement.

- line 184. Positive correlation around Greenland in winter looks rather weak and not clear.

It is indeed quite weak so we deleted this statement.

- line 188. Change to ’It means that climatic conditions’. Weather is chaotic with no memory beyond two weeks.

Corrected

-line190-191. This sentence is unclear. Do you mean’... during the following spring?’

We added …’during the following spring and summer’… to clarify the sentence.

- line 195. How can you say that ’whole Eurasian average spring temperature is highly controlled’ based on your analysis?

Our idea based on both lag=0 and lag=3 strong correlation between TP and Eurasia in spring. We tested this by changing the TP in several locations in Eurasia and it turned out that this statement is incorrect, so we deleted it.

- line 198. You can call the region between Greenland and Svalbard the Fram Strait.

Corrected.

- line 209-210. I don’t understand this sentence.

We rephrase the sentence as follows:
The reason why summer season differs from other seasons may-be caused by a less effective large-scale circulation.

- line 220-221. What do you mean by ’AO/NAO paradigm’?

We rephrase the sentence as follows:
The study of Ambaum et al. (2001) suggests also that because of the physical background of NAO, it may be more relevant and robust for the Northern Hemisphere variability than is the AO.

- line 253. 'previous season's climate conditions'.

Corrected

- Table 1. Add information on the sample size, N=36?

Corrected

Thank you once more for your trouble and professionalism!

Sincerely yours,

Liisi Jakobson
Erko Jakobson
Piia Post
Jaak Jaagus

References (If we use in our answers references that were already given in our article then we will not give the reference here again):

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