The text in **BLACK color** is the **comments** from the reviewers, and the text in **BLUE color** is our **revisions and explanations**.

COMMENTS FROM EDITORS AND REVIEWERS:

Comments from Reviewers:

RC#1

This manuscript used GNIP station observations and several indices as well as re- analysis data to describe the correlation between precipitation stable isotopes and temperature, precipitation amount, moisture back-trajectories and several indices, and try to conclude the temperature effect and moisture source effect on precipitation stable isotopes.

The critical defect of this study is that the necessity of this study is not well elaborated. Honestly, it seems that the author found these data and analyzed purposeless, so the data analysis cannot provide enough evidences for the conclusion. Many similar studied have been done decades ago, and it is hard to see any advances in this study.

Done

Thanks to the reviewer for the great comments. We revised the introduction and elaborated the necessity of this study in details.

Please see the revisions in P4-5, L82-103:

However, modern meteorological monitoring networks and paleoclimatic research are relatively scarce in Siberia and Central Asia in comparison with other regions worldwide, and the explanation of paleoclimate proxies in different archives are controversial (Aizen et al., 2005; Blyakharchuk et al., 2007; Opel et al., 2010; Butzin et al., 2014). For example, the stalagmite $\delta^{18}O$ in the south of the Uralmountains (Baker et al., 2017) and the permafrost ice wedge $\delta^{18}O$ in central Eurasia (Meyer et al., 2015) are considered as indicators of winter temperature, recording the warming trend during the Holocene. The ice core $\delta^{18}O$ in the Belukha plateau (Aizen et al., 2016) and the alpine peat a-cellulose $\delta^{13}C$ (Rao et al., 2019a) in the Altai mountains, as indicators of the warm season temperature, also shown the trend of Holocene warming. The stalagmite $\delta^{18}O$ in central Asia is considered as an indicator of winter and spring precipitation (Wolff et al., 2016). The $\delta^{18}O$ records in Kesang Cave in western China and Tonnel'naya Cave in Uzbekistan are considered to be records of precipitation in Central Asia, which is closely related to the Asian monsoon (Cheng et al., 2016). However, Cai et al. (2017) interpreted Kesang $\delta^{18}O$ as the change of water vapor source, while (Rao et al., 2019b) believed that Kesang $\delta^{18}O$ should be the same as the ice core $\delta^{18}O$ in the surrounding area, which is an indicator of temperature change. In addition, stalagmite records in the Altai mountains of Siberia show that $\delta^{18}O$ is related to the intensity change of the Siberian high (Chen et al., 2019; Ye et al., 2019). Since the $\delta^{18}O$ in the paleoclimate records is mainly inherited from the atmospheric precipitation, it is of great significance to clarify the climatic significance of the $\delta^{18}O_P$ for the interpretation of the paleoclimate archives in central Asia.

At first, we chose Siberia and central Asia as study areas because of the centers of continents are especially sensitive to climatic changes. Secondly, our research is based on the results of previous research. Based on the limited data, we have carried out a more detailed analysis of the $\delta^{18}O_P$ characteristics of the study area and made a reasonable explanation. Finally, we have modified the structure and diagrams of this article, which will make our conclusions more obvious.

The text is not fairly organized, is lack of systematical discussion and full of hypothesis (e.g. P3, L50-51; P10, L215-216) given the available data. Authors need to present their work with better clarity. The authors speculate unwarranted conclusion based on correlation analysis.

Done

P3, L50-51: This sentence belongs to the abstract, so we do not give out the details. We have a systematical discussion to support this sentence in text of the MS.

Please see that in P18, L373-382:

The North Atlantic Oscillation (NAO) is one of the most important mode for the variabilities of atmospheric circulation in the northern hemisphere. During the positive NAO state, the surface pressure south of 55 °N is higher than normal, while a broad region of low pressure throughout the Arctic and Subarctic. This leads a strengthening of subpolar westerlies, bringing moisture with lower $\delta^{18}O$ from the high-latitude ocean inland through the British Isles (Clarke and Rendell, 2006). During the negative NAO state, both the Icelandic low and the Azores high-pressure are weaker than normal, which leads to the weakness of the mid-latitude westerlies (Hurrell, 2004). The weakening of the Azores anticyclone allows the westerlies to bring rain across the Iberian Peninsula into the Mediterranean and eventually to eastern Europe and Siberia and resulting in higher $\delta^{18}O$ values there.

P10, L215-216: We deleted this sentence and revised this part to make it more accurate and clearer. Please see lines 226-230:

We used the δD and $\delta^{18}O_P$ data from monthly precipitation observations collected at each GNIP site to obtain the LMWL equations given in Table 2. The LMWL slopes were generally lower than the GMWL slope at most stations (11/15) (except for Novosibirsk, Irkutsk, Enisejsk and Perm) (Table 2). Since the deuterium component is much less sensitive to kinetic effects than the O^{18} component, the evaporation during the precipitation period in the inland region led to equations for atmospheric precipitation with a lower slope at most monitoring sites (Dansgaard, 1964; Stewart, 1975; Peng et al., 2005; Yamanaka et al., 2007; Pang et al., 2011; Chen et al., 2015).

The number of stations should be explained more clearly. 13? 14? Or 20? Why the different number of stations are used for analysis? Some important and necessary information are missing, for instance, the advance of the study beyond previous studies, the different background of stations. . . The "trend" and "pattern" are not definition acceptably for the seasonal and annual variations.

Done

There are total of 29 sites in this paper, among which 15 sites (indicated by red triangles in Fig.1, Table 1-2) are located in Siberia and central Asia as defined by us, and other 14 (in purple) sites are used for comparative analysis. In the correlation analysis between $\delta^{18}O$ and temperature, precipitation and zonal circulation index on the monthly scale (Table 3-5), we used

13 stations with continuous data more than one year in the study area (Omsk and Irkutsk stations were abandoned due to continuous data less than one year). When discussing the relationship between δ^{18}O and temperature, precipitation, and NAO on an interannual scale, we used 20 sites with more than five years of data from these 29 sites (Table 4).

We added a new figure 2 to describe the climate background for each of the sites:

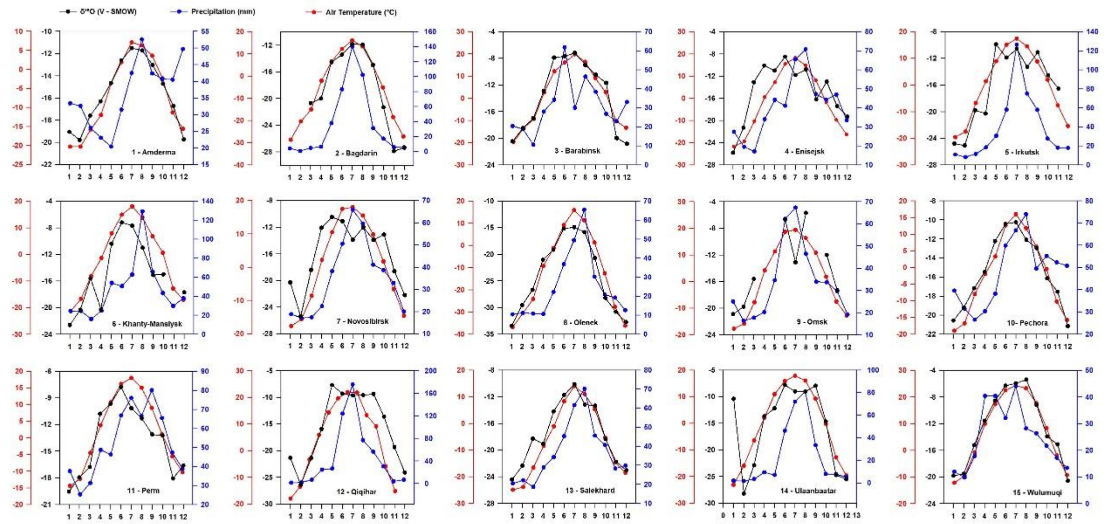

Fig.2 Basic climate background for the 15 GNIP meteorological stations in the Siberia and central Asia region referred in this study, including monthly mean precipitation (blue curve and axis in mm/month), monthly mean air temperature (red curve and axis in °C) and δ^{18}O of monthly precipitation (black curve and axis in ‰, V-SMOW). X-axes (1-12) denote months (January – December). Although the elevation, geographic location, moisture sources and precipitation seasonality may be quite different, the positive correlations between temperature and δ^{18}O are broadly similar in the Siberia and central Asia region.

The relationships between isotopes and NAO, EZCI, ZI are described in the text, but the significances and relevance of such analysis are not clear in the text.

Done

We changed the structure of the paper and hope that such changes will make our paper easy to read and understand. The section about the relationships between isotopes and NAO, EZCI looks more clear (Chapter 5.1-5.3).

Please see the revised sentences in L333-339:

The North Atlantic Oscillation (NAO) is the name given to the apparent dipolar nature of the weather between Greenland and Europe; the zonal index (ZI) is the name given to the changes in the zonally averaged zonal wind. In fact, they are just aspects of the same phenomenon (Hurrell, 1995). However, since the zonal circulation index ignores the north-south oscillation of the westerly, we mainly consider the relationship between $\delta^{18}O_P$ *and NAO rather than the Eurasian zonal circulation index (EZCI) on the interannual scale.*

P18, L372-378:

The correlation coefficient between NAO and annual weighted $\delta^{18}O_P$ *(*$\delta^{18}O_W$*) is not completely consistent with the correlation coefficient between temperature and* $\delta^{18}O_W$ *(Fig. 6), and changes with longitude, indicating that the influence of NAO on precipitation isotopes in different regions is not exactly the same (Fig. 6C). NAO mainly affects the* $\delta^{18}O_P$ *indirectly by affecting temperature in Europe (Baldini et al., 2008; Field, 2010; Sidorova et al., 2010; Wassenburg et al., 2016). From the Ural Mountains (60°E) to the east, there are different response of precipitation isotopes to NAO (Fig. 6C). During the negative NAO state, both the Icelandic low and the Azores high-pressure are weaker than normal, which leads to the weakness of the mid-*

latitude westerlies (Hurrell, 2004). The weakening of the Azores anticyclone allows the westerlies to bring rain across the Iberian Peninsula into the Mediterranean and eventually to eastern Europe and Siberia and resulting in higher $\delta^{18}O$ values.

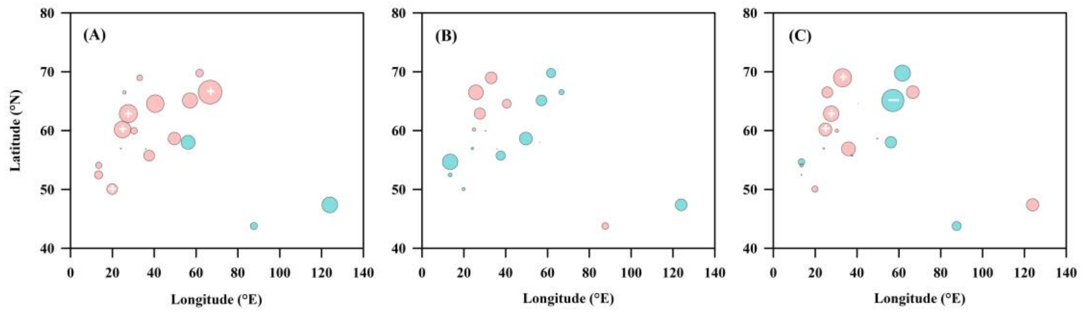

Fig. 6. *Distribution of the correlation coefficients between annual average temperature (A), annual precipitation (B), NAO (C) and $\delta^{18}O_W$, respectively. Pink means positive correlation and cyan means negative correlation. The size of the circle indicates the absolute value of the correlation coefficient. Values significant at 0.05 levels are marked by a plus/minus sign.*

The explanation of weak temperature effect in summer is wrong in L239-243.

Done

Thanks to the reviewer for the comments. We checked this part and revised it, making it more clear and easy to understand.

Please see the revised sentences in L248-255:

……This result may be attributed to the strong surface water evaporation in summer, during which more than 80% of precipitation in Eurasia originates from snowmelt and subsequent evaporation of soil moisture, leading to the weak correlation between $\delta^{18}O_P$ and temperature

in the summer season. Previous researches have suggested that recycled water from the land surface carrying the isotopic imprint of winter precipitation could significantly influence on the isotopic composition of regional precipitation, counterbalancing the positive coupling between temperature and $\delta^{18}O_P$ (Numaguti, 1999; Kurita, 2003; Kurita et al., 2004; Henderson et al., 2006).

More analysis should be offered to provide the related variations of isotopes with the shifts of westerlies.

Done

We selected the typical year of NAO to supplement and found that the effect of NAO phase changes on the westerly path is common (Fig. R1). Based on this, we analyzed the mechanisms about the NAO——atmospheric circulations——westerlies——$\delta^{18}O_P$.

Please see lines 382-392:

The North Atlantic Oscillation (NAO) is one of the most important modes of variabilities in the northern hemisphere atmospheric circulation. During the positive NAO state, the surface pressures south of 55 °N is higher than normal while a broad region of low pressure throughout the Arctic and Subarctic. This leads a strengthening of subpolar westerlies (Hurrell, 1995), bringing moisture from the high-latitude ocean inland through the British Isles. During the negative NAO state, both the Icelandic low and the Azores high-pressure are weaker than normal, which leads to the weakness of the mid-latitude westerlies (Hurrell, 2004). The weakening of the Azores anticyclone allows the westerlies to bring rain across the Iberian Peninsula into the Mediterranean and eventually to eastern Europe and Siberia (Hurrell, 1995).

We give out a figure in this response letter to support the analyses.

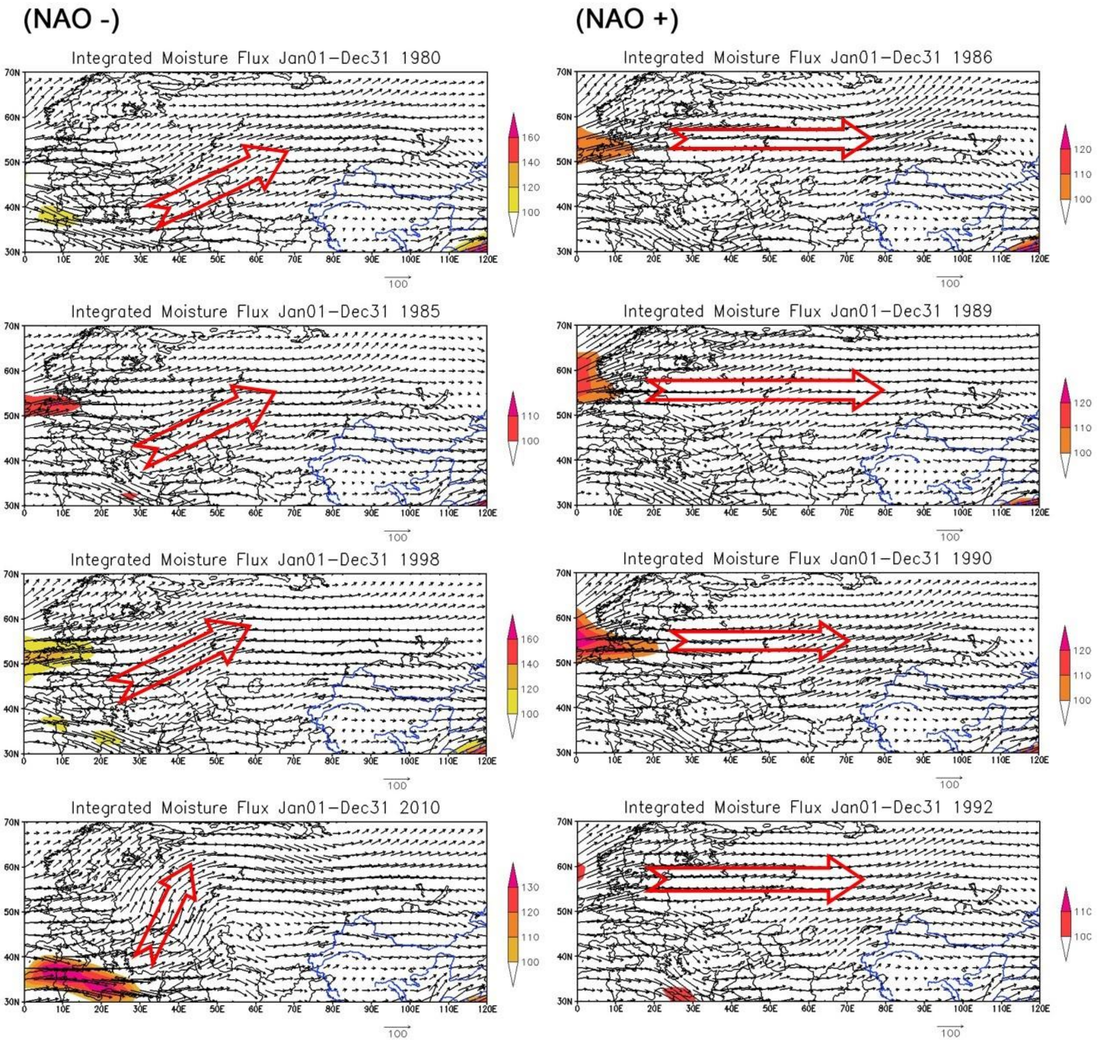

*Fig. R1 The average atmospheric moisture transport fluxes in different NAO phases (shadow & vectors; unit: kg/ (m*s)). 1980 NAOI = -0.14, 1985 NAOI = -0.18, 1998 NAOI= -0.48, 2010 NAOI = -1.15, 1986 NAOI = + 0.50, 1989 NAOI = + 0.70, 1990 NAOI = + 0.59, 1992 NAOI = + 0.58. During the positive NAO state, the westerlies bring moisture from the high-latitude ocean inland through the British Isles. During the negative NAO state, the westerlies bring moisture across the Iberian Peninsula into the Mediterranean and eventually to eastern Europe and Siberia.*

The meaning of amount effect analysis should be clarified. If it related with the moisture source? Or shifts of westerlies? What is the authors' point on this analysis?

Done

The questions raised by the reviewers are well worth exploring. The "amount effect" is a negative correlation between $\delta^{18}O$ and the amount of monthly precipitation (low $\delta^{18}O$ in rainy months and high $\delta^{18}O$ in months with spare rain). This "amount effect" is found all the year round at most tropical stations, and in the summer time at mid-latitudes (Dansgaard, 1964). At high latitudes, the temperature effect is the dominating factor while the "amount effect" is almost negligible. We believe that the variations of precipitation $\delta^{18}O$ at all the sites was controlled by temperature effect rather than "amount effect" (Fig. 4 and Table 3-4). Theoretically, $\delta^{18}O_P$ is also sensitive to changes in moisture source, continental recycling, condensation of vapor, and rain out during the transport of air mass from source to precipitation site. At present, based on the GNIP data and our analyses, we believe that temperature and changes in moisture source (resulted by NAO——atmospheric circulation——westerlies track——moisture sources (relative north Atlantic or relative south Atlantic, Mediterranean and Black Sea)——temperature and isotopes composition) is the dominate factor for the annual changes of precipitation isotopes in Siberia and central Asia.

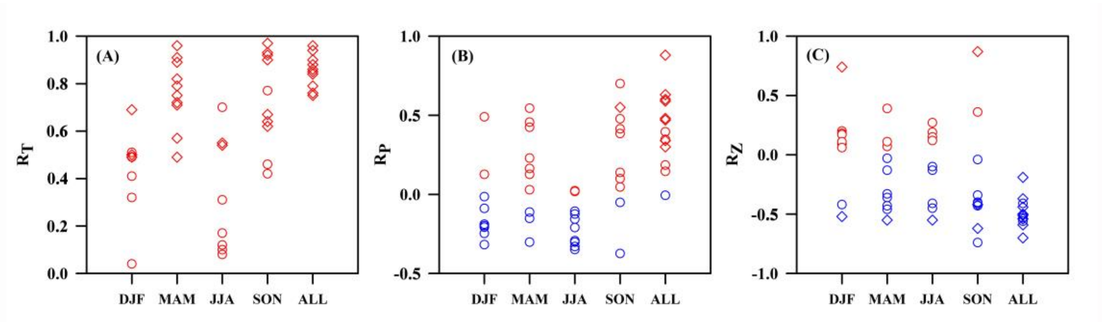

Fig. 4. *Linear correlation coefficient (R_T, R_P and R_Z) between air temperature, precipitation, EZCI and $\delta^{18}O$ (calculated for every two consecutive years for GNIP stations with records longer than 2 years) plotted in different seasons and all year round (DJF, MAM, JJA, SON and ALL). The diamonds represents correlation coefficients that are significant smaller than 0.05 (i.e., higher significance) and circles represent insignificant correlations greater than 0.05. Red means positive correlation and blue means negative correlation.*

Table 3. Correlation coefficients between $\delta^{18}O_P$ and temperature based on monthly data (R_T)

Site	DJF	MAM	JJA	SON	ALL	n
Amderma	0.32	0.49*	0.08	0.62**	0.75**	72
Bagdarin	——	0.82*	0.17	0.92**	0.90**	34
Barabinsk	0.49	0.96**	0.70	0.97**	0.96**	28
Enisejsk	——	——	——	——	0.88**	12
Khanty-Mansiysk	——	——	——	——	——	13
Novosibirsk	——	——	——	——	0.88**	12
Olenek	——	——	——	——	——	35
Pechora	0.50*	0.57**	0.55*	0.64**	0.85**	79
Perm	0.49*	0.79**	0.31	0.42	0.79**	79
Qiqihar	0.51	0.75**	0.17	0.46	0.76**	50
Salekhard	——	——	——	——	——	58
Ulaanbaatar	0.41	0.89*	0.10	0.93**	0.84**	44
Wulumuqi	——	0.71**	0.08	0.67**	0.86**	123

** Denotes a statistically significant relationship at $p<0.05$.*
*** Denotes a statistically significant relationship at $p<0.01$.*
DJF: December-January-February; MAM: March-April-May; JJA: June-July-August; SON: September-October-November; All: the entire year

Table 4 Correlation coefficients between $\delta^{18}O_P$ and the rainfall amount based on monthly

data (R_P)

Site	DJF	MAM	JJA	SON	ALL	n
Amderma	0.13	-0.30	-0.16	-0.05	-0.01	72
Bagdarin	——	0.42	-0.33	0.38	0.48**	34
Barabinsk	-0.20	0.23	0.02	0.41	0.35	28
Enisejsk	——	——	——	——	0.59*	12
Khanty-Mansiysk	——	——	——	——	0.88**	13
Novosibirsk	——	——	——	——	0.40	12
Olenek	-0.19	0.54	0.02	0.14	0.60**	36
Pechora	-0.21	0.13	-0.13	-0.37	0.19	79
Perm	-0.09	-0.15	-0.35	0.55*	0.15	79
Qiqihar	-0.25	0.16	-0.11	0.48	0.47**	50
Salekhard	-0.32	-0.11	-0.29	0.05	0.30*	58
Ulaanbaatar	0.49	0.46	-0.21	0.70*	0.63**	25
Wulumuqi	-0.02	0.03	-0.30	0.10	0.34**	123

** Denotes a statistically significant relationship at $p < 0.05$.*

*** Denotes a statistically significant relationship at $p < 0.01$.*

DJF: December-January-February; MAM: March-April-May; JJA: June-July-August; SON: September-October-November; All: the entire year

The description in L415-416 is wrong, opposite with the westerly transport. The English should be improved by the native speaker.

Done

Thanks to the reviewer for the comments. The description in L415-416 is ambiguous, we revised it as follows.

Please see lines 406-408:

……the westerly wind (from ~ 45 °N – 55 °N) blows to the western Europe and turn northeast at ~30 °E (Fig.8A), bringing warmer water vapor from the southwest to the northeast of Eurasia and resulting in higher $\delta^{18}O_W$ values.

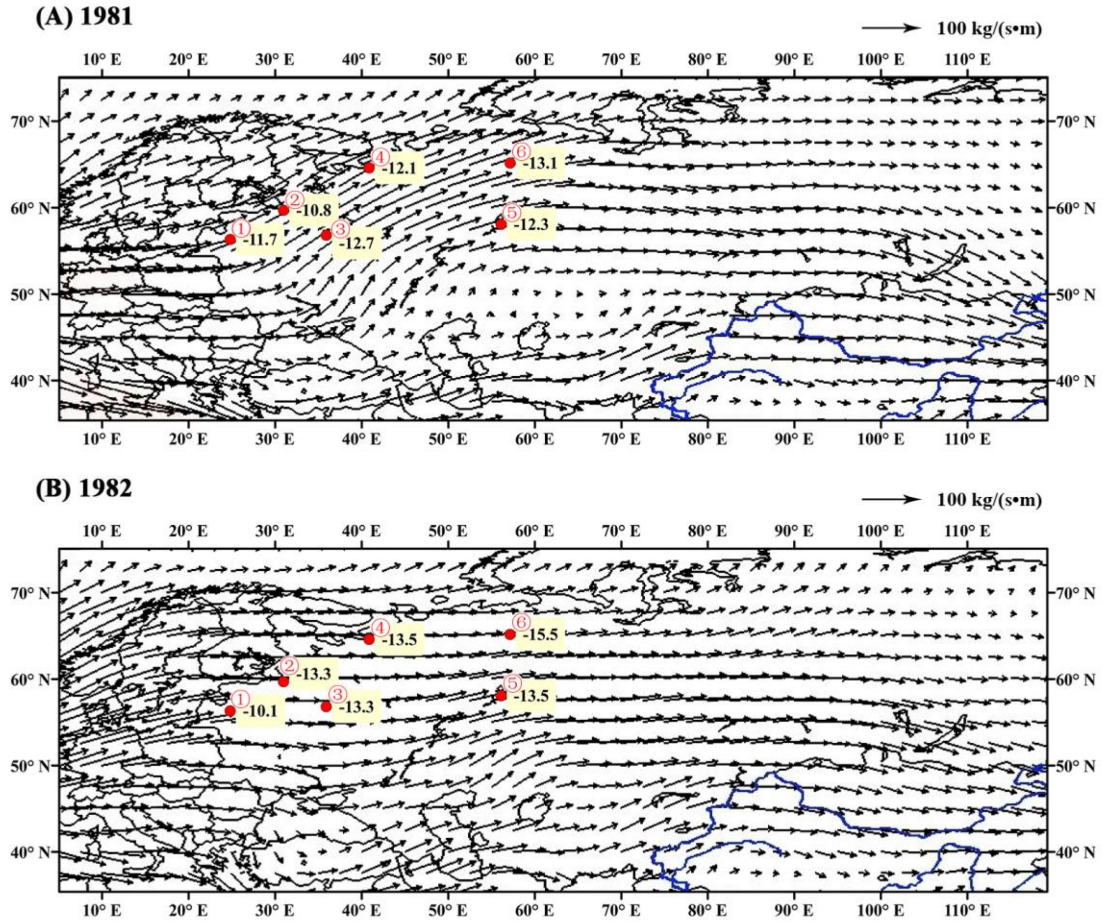

*__Fig. 8.__ Spatial distribution of $\delta^{18}O_W$ values in the precipitation at the GNIP stations in different NAO phases. The circled numbers (1–6) indicate ① Riga, ② St. Petersburg, ③ Kalinin, ④ Arkhangelsk, ⑤ Perm, and ⑥ Pechora. The average atmospheric moisture transport moisture fluxes (vectors; unit: kg/ (m*s)) in different NAO phases are indicated: __(A)__ 1981 (NAOI= -0.21) and __(B)__ 1982 (NAOI= 0.43). The $\delta^{18}O_W$ values change due to different water vapor transport sources in different NAO phases.*

By considering these issues, I do not think this manuscript is good enough to be published in any high-quality journals. I would recommend the editor reject the manuscript at present and encourage the author to resubmit after improvement.

Done. We responded to each of the comments seriously and revised the paper carefully as above. We will invite a professional person to improve the final version of the MS before it be re-submitted to the journal.

RC#2

The manuscript by TaoWang et al. presents the correlation analysis between the GNIP data in Siberia and Central Asia and the circulation patterns. This analysis is very important for the understanding of the precipitation isotopic composition formation as well as for the atmospheric circulation modeling. However, there are two major critical points that should be improved before the paper can be accepted for the publication.

We appreciated the reviewer for his/her recognition for the value of this study. We respect to every comments of the reviewer and revised the manuscript carefully. Please see our point to point response as follows.

Firstly, the dataset chosen for the analysis is rather poor. The datasets from the Siberian stations (Table 1) contain less than 30 points which is not enough for the proper correlation analysis. Many stations provide data for less than five years which is also not enough for the analysis of the seasonal cycle. Moreover, the datasets from the GNIP were not quality-checked. For instance, in the study of Butzin (Butzin et al., 2014) et al. (2014) several stations and data points were excluded from the analysis because of their unrealistic values.

Done

First of all, we agree with the reviewer that the data of GNIP site in the research area is scarce; we only found 15 sites within the research area defined in this paper. The scarcity of GNIP data in this region is a reality that cannot be changed at present. Secondly, we checked the data of Amderma Khanty-mansiysk, Olenek and Salekhard discarded by Butzin et al. (2014) as the reviewer mentioned. We agree with the reviewer and thanks for this great comments. There are some problems about the monthly mean temperature for Khanty-Mansiysk (K-M), Olenek and Salekhard. We revised our discussion about these stations, not discuss the relationship between precipitation isotopic compositions and questionable temperature values. Finally, we focused on the relationship between $\delta^{18}O_P$ and meteorological elements at monthly timescale, but not seasonal cycles.

We checked the GNIP data and found some problems as the reviewer mentioned. Please see the figures as follow.

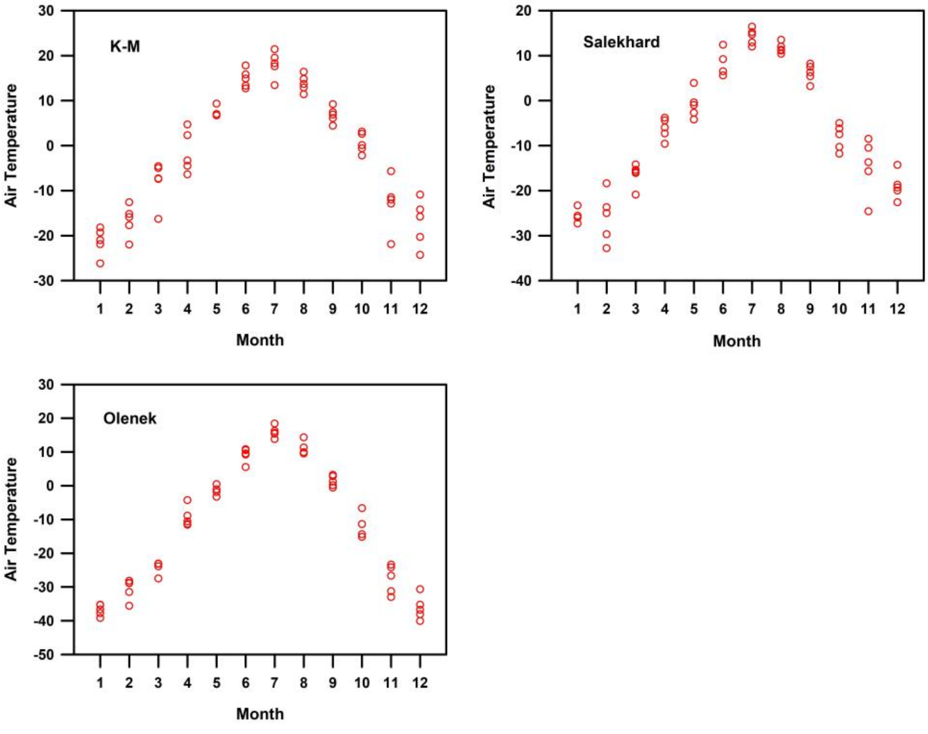

Fig. R2 Monthly mean temperatures of Khanty-Mansiysk (K-M), Olenek and Salekhard.

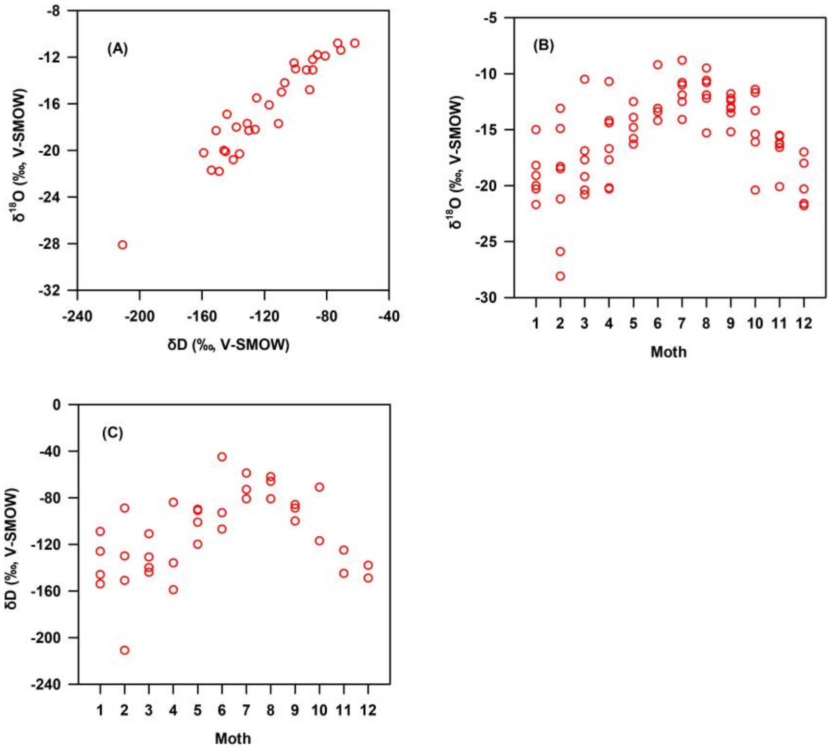

Fig. R3 Delta values of D and ^{18}O isotopes from Amderma. (A) $\delta^{18}O$ and δD values of precipitation (B) Annual variations in $\delta^{18}O$ (C) Annual variations in δD

Another point is the lack of new information in the study. Similar studies have already been conducted in Siberia and Central Asia. For example, Butzin et al. (2014) analyzed the GNIP data from the same monitoring sites combined with the ECHAM-wiso calculations and concluded that the precipitation isotopic composition depends mostly on the local temperature and on the NAO.

Done

First, the study area of Butzin et al. (2014) is mainly concentrated in Western Siberia (55–90° E and 55–70° N), and our study area covers a larger range (55–125° E and 40–70° N). Secondly, by analyzing the influence of NAO on $\delta^{18}O$, we believe that $\delta^{18}O$ is affected by not only the temperature but also the strength and path of westerly wind, and the change of moisture source, which is different from previous studies.

P19, L411-416:

The NAO influences the changes in both $\delta^{18}O_P$ and $\delta^{18}O_W$ by affecting the intensity and pathway of the westerly (Hurrell, 1995; Field, 2010; Langebroek et al., 2011). Therefore, we speculate that over mid- to high-latitude regions throughout Eurasia, $\delta^{18}O_W$ is affected by both the NAO and the temperature. This joint influence is the main reason for the absence of a temperature effect in the variability of $\delta^{18}O_W$ at the interannual time scale.

And in the third of forth in the section of conclusions, Lines 432-439:

(3) The $\delta^{18}O_P$ values were negatively correlated with the EZCI at the monthly time scale. The zonal circulation results in changes in $\delta^{18}O_P$ throughout Eurasia by affecting the local temperature and water vapor source. The relationship among $\delta^{18}O_P$, the temperature and the EZCI varies seasonally and is influenced by changes in the source of water vapor in summer.

(4) The $\delta^{18}O_P$ values in the study region and the NAOI exhibit opposing trends at the interannual timescale. The NAO affects the source of water vapor transport by changing the pathways of the westerly, leading to changes in both $\delta^{18}O_P$ and $\delta^{18}O_W$.

The paper is not well structured. The study region is not defined; the borders of Siberia and Central Asia assumed in the study are not described. The results from the previous studies in the region are not used (e.g. Ala-aho et al., 2018a, 2018b; Butzin et al., 2014; Opel et al., 2010). The description of the calculation methods is missing. How was the correlation calculated? How was the significance estimated? Finally, the English language should be improved by a native speaker.

Done

We define the range of Siberia and Central Asia at 55-125°E, 40-70°N, with borders of the Arctic Ocean, the Tien Shan Mountains, the Ural Mountains and the Verkhoyansk Mountains. Please see the details in Lines 156 - 162:

The study region, which is located in the northern part of Eurasia, includes inland Siberia and the northern part of Central Asia (40 °N – 70 °N, 55 °E – 125 °E) (Fig. 1). The region of interest herein is a typical mid- to high-latitude continental area, extending from the Ural Mountains in the west to the Stanovoy Range in the east, from the Arctic Ocean in the north to a series of mountain ranges toward the south, namely, the mountains in northern Kazakhstan to the southwest, Urumqi in the south, and Qiqihar (northeastern China) to the southeast (Fig. 1).

We read and cited the relevant literatures provided by the reviewer.

Please see that in P3, L56-60:

Siberian permafrost constitutes one of the most important forms of tundra in the world and acts as an indicator of temperature change; accordingly, the greenhouse gases released through the melting of permafrost have important impacts on global climate change and carbon cycle processes (Dobinski, 2011; Schuur et al., 2015; Ala-aho et al., 2018a, 2018b; Raudina et al., 2018).

Literatures (Butzin et al., 2014; Opel et al., 2010) have been cited in lines 82-85:

However, modern meteorological monitoring networks and paleoclimatic research are relatively scarce and controversial in Siberia and northern Central Asia in comparison with other regions worldwide (Aizen et al., 2005; Blyakharchuk et al., 2007; Butzin et al., 2014; Opel et al., 2010)

We calculated the Pearson correlation coefficient as follows:

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \overline{x})(y_i - \overline{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \overline{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \overline{y})^2}}$$

The sample values of the factor x and y are x_i and y_i (i=1, 2, ..., n), and r_{xy} is the correlation coefficient between the factor x and y. $\overline{x}$ and $\overline{y}$ represent the average of the two feature sample values, respectively.

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \quad , \quad \bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i$$

We applied a Student's t test for the significance estimated.

To conclude, the paper at present cannot be published in ESD. I would recommend the editor rejects the manuscript.

Done

Thanks for the comments on our MS.

We have respected to each reviewer's comments and addressed the comments seriously. Thanks to the reviewers for their critical and constructive comments, which have improved the quality of the manuscript significantly. The revised manuscript has been checked and corrected for proper English language, grammar, punctuation, spelling, and overall style by one or more of the highly-qualified, native English-speaking editors. Now, we re-submit the revised MS to Earth System Dynamics, and we are looking forward a positive decision about the paper soon.

Best regards

Ting-Yong Li and Tao Wang

21th, May 2019

Supplied References

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