**First of all we would like thanks a lot our Referee 1 for great work and for the very constructive comments and remarks.**

## Answers on Referee 1 comments

General comments:

1. A proxy, by definition, is some measurable characteristic that can stand in for an unmeasurable characteristic. The authors refer to the biological parameters that they measured in the Belukha ice core as "proxies", however, they never discuss what specifically they are proxies for. It is not clear whether the authors assume that the biomarkers in the ice core are proxies, or whether they are actually testing the idea that biological parameters can be proxies. This is a major deficiency in the framing of the story and should be clearly explained from the beginning of the paper. Further, if the former is true, then the authors need to be explicit with regards to what exactly their data are proxies for. Once this point is made clearly in the introduction, it should be carried through the entire paper, and discussed explicitly as part of the conclusions. Overall, my best guess is that author's goal was to define the ECM, connect those patterns to the deposition of the biological "proxies", and then determine whether the sources indicated by their analyses match those linked to the previously analyzed chemical species in the ice core, which is a test of the potential utility of biological markers as proxies. This needs to be made clear, so I do not have to guess.

**Answer:** The biological species (parameters) in an ice core of inland glaciers as the biological species in a sediment cores of lakes are proxies for the paleo climatic changes at the adjacent territories (first of all they reflect a change of climatic zones). The high resolution of the ice core layers (up to one year) can provide additional possibility to use the biological species as proxies for estimation of other atmospheric characteristics. Glaciers located on the boundary between contrasting climatic and vegetation zones are of most interest in this context. The main goal of our work was to show that changes of concentrations of the biological objects in the layers of the Belukha ice core can reflect the changes in the structure of precipitation in Altai region (i.e. can reflect changes of the contribution of different EMC's to annual precipitation). In this case the biological objects (species) in the Belukha ice core can be the proxies for the changes in the structure of precipitation in Altai region. The second goal of our work was to identify the sources of biological objects discovered in the Belukha ice core. Additionally, results of our work can be used for the different aspects of the transboundary atmospheric transport of substances.

The main position based for our article was the thesis that the vast majority of aerosols (about 80% of the total) fall out to the ground surface with precipitation and only near 20 % of aerosols fall out through dry depositions [Croft et al., 2010]. The biological objects transported for a long distance as other aerosols being the nucleus of atmospheric moisture condensation can easy involve in precipitation. Therefore we can assume that the biological objects as a component of aerosols mainly enter to the glacier surface with precipitation and not through dry depositions.

We will change introduction and other parts of our paper following the above explanations and will prepare the revised version of the paper taking into account your comments. Maybe in this case it will be better to rename our paper as "Biological objects recorded in a Belukha ice core (Russian Altai) as proxies for atmospheric regional processes".

2. The paper lacks clear description of the methods. After some laboring through what methods they do describe, and through the references list, I think I determined that the ECM's were not determined by the authors of this study, but rather came from another paper and were used to interpret biological data in this ice core. The authors should say this clearly, and discuss only the ECM's relevant to their story. The paper also lacks description of the statistics used to match the biological data with precipitation patterns. Correlation statistics are presented, but we have no idea how they were calculated (Pearson? Spearman? Were data transformed? etc.). It is also not

clear what the ECM data that they used in the correlation even are – are they numbers? An index of some sort? The readers re left to simply trust the p-values that are given, but has no way to vet the data for themselves. All of the methods need to be described clearly.
**Answer:** The methodology used for performing the main goal of our work was the following (step by step):

1. We provide a high-resolution analysis of biological species in the Belukha ice core with annual resolution and get the records of the biological object concentration changes in the Belukha ice core for the period 1964-2000. The methods used for getting these results were described in section 3 "Methods" (in subsections 3.1 "Sampling" (unfortunately this subsection was wrongly named as "Methods" in our paper), 3.2 "Dating", and 3.3 "Analyses of diatoms, spores, and pollen").
2. Using the daily data on the frequency of synoptic patterns (daily calendar of successive change of ECMs - elementary circulating mechanisms) observed in the Northern Hemisphere [Kononova, 2009] and instrumental data of daily precipitation from the Kara-Tyurek weather station (located close to Belukha glacier) we calculated the contribution (in %) of each from 41 EMCs in annual precipitation in the study area for the period 1964-2000 (for each year and for period in whole). In other words, we calculated how much precipitation fall down in the Altai region at different types of ECMs during a year, and then calculated the percentages relatively the total annual precipitation.
3. To determine the atmospheric processes that contribute to the deposition of biological objects at the Belukha glacier in the period 1964-2000, we compared the changes in the amount of precipitation in the Altai region at different types of ECMs for years with maximum and minimum concentrations of biological proxies in the ice core. For this purpose for years with the highest concentration of biological proxies, we identified the types of atmospheric circulation pattern providing in the period of flowering and sporulation the higher amount of precipitation relatively to the average of these types for the corresponding circulation period. For years with the minimum concentration of biological proxies, we identified the types of atmospheric circulation pattern providing the less amount of precipitation relatively to the average of these types.
4. If for years with the highest and the minimal concentrations of biological proxies we determined the same types of ECMs then it meant that these ECMs can define the deposition of biological objects at the Belukha glacier. For these ECMs we calculated pearson's correlation coefficient between concentrations of biological objects in the layers of the Belukha ice core and contribution (in %) of EMC in annual precipitation.

We understand that in our paper the description of the used methods is not satisfying (all three Referees have pointed it), so we will completely revise the description of methods (especially for general methodology of the study and the Classification of circulation mechanisms by Dzerdzeevskii) at the revised version of the paper.

3. There are far too many tables in this paper, and they are difficult to read. With a little thought, many of them could be either combined or deleted, and made more informative and useful. Some of the figures could be combined (i.e. figures 4 and 5 go together and could be joined into figure 4 a and b). The introduction to the paper is rambling and jumps between topics.
**Answer:** We will revise all tables and figures

4. The paper lacks discussion. Jumping from Results to Conclusions is insufficient. The Introduction and Results should be streamlined in favor of including meaningful discussion of the data in the context of overall ideas about biological proxies.
**Answer:** We will add the discussions of the results to the revised version of the paper.

Specific Comments:

Text P2590 L1: It is not clear to me, in this particular article, what these biological signatures are to be proxies for. The climatic data presented seems to be used to track the sources of the biological agents - so, the climatic data is already a given as far as I can tell. So, what is the biology a proxy for?
**Answer:** the answer has been done in the general comments

P2590 L17: Nice thesis statement. Direct and to the point.
**Answer:** the answer has been done in the general comments.

P2590 L24: This statement begs the question, "Why do we need an additional tool? What is missing with the current tools?"
**Answer:** The period of instrumental observation of climatic parameters is short (maximum about 150 years). This is shortage of current tools. Unlike to it, pollen and other biological proxies from natural archives such as glaciers, peat and lake's deposits can cover periods of hundreds and thousands years. Our research shows that these biological proxies can be interpreted not only in terms of vegetation and landscape changes, but also in terms of predominant types of atmospheric circulations. It gives new tool for investigation of atmospheric circulation in pre instrumental era.

P2591 L1: I think there should be a citation, or some further discussion here, as I would argue that deposition with precipitation should be higher than dry deposition, but not that there is no dry deposition of biological agents on glaciers. Can't things be attached to dust particles?
**Answer:** the answer has been done in the general comments

P2591 L4: This seems to be the main point of the paper, but it is kind of buried here and unclear. "Insight" is not a specific enough term.
**Answer:** the answer has been done in the general comments.

P2591 L6: What do you mean by?
**Answer:** in this context "typical" means "a typical representative of inland glaciers"

P2591 L22-23: "proxy records of biological species for the Altai region and northern Eurasia as a whole" – this statement seems to be just thrown in here, as nothing in the preceding sentences prepares the reader for this idea. A clearer connection needs to be made here.
**Answer:** agree; in whole the answer has been done in the general comments.

P 2592 L4 to end of paragraph: This sentence is very confusing. If understanding the atmospheric patterns is important, what are the biological markers proxies for? What is the interpretation?
**Answer:** the answer has been done in the general comments.

P2592 L12: Describes the results from another study, where the biological record actually was used as a proxy for something. Similar interpretation is totally lacking in the current manuscript.
**Answer:** Beginning from mid of $20^{th}$ century a micro and macro remnants of plants (pollen, spores, sells, preserved organs and tissues, charcoal) and animals (Protozoa and Invertebrata) buried in lake's and peat sediments are wide using as proxies in investigation of past vegetation and climate changes (Birks, 1981; Faegri and Iversen, 1989; Roberts, 1998; Webb, 1985; Warner, 1988; Holmes, 1992; Bennett et al., 1990). Palynological study of the continental ice cores are not numerous enough compared to investigations of the Arctic and Antarctic glaciers [Liu et al., 1998; Liu et al., 2005; Yang et al., 2010; Reese et al., 2013]. At the same time the

continental glaciers, in contrast to the glaciers of the polar and subpolar latitudes, are located within the close proximity to the plant communities and have a high accumulation rate and high resolution of palynological analysis [Mikhalenko, 2009]. For example, studies of snow pits and an ice core in the Russian Altai demonstrated the potential of high resolution of pollen taxa in the small quantity of samples (near 10 ml) [Nakazawa et al 2004, 2005, 2011, 2012]. Pollen and charcoal have been investigated also in Belukha glacier for estimation of biogenic emissions from Siberian boreal forests [Eicher et al., 2011].

P2592 L20: The description of the circulation mechanisms and the precipitation is out of place here. It should be described clearly in the Methods, as it is difficult to determine exactly how the circulation patterns responsible for highest precipitation were identified.
**Answer:** the answer has been done in the general comments.

P2592 L24-25: The section ends with the statement that the analysis of the results allowed the authors to identify the main sources of the biological signatures deposited on the glacier, but does not tell the reader WHY they were identifying the sources. What is the goal here? This would be a great time to make that clear.
**Answer:** the answer has been done in the general comments.

P2594 L7: State what types of spores were being looked at. Bacteria also form spores, and this is an important distinction, which is not made clearly until later in the paper.
**Answer:** Spores of ferns and mosses (Bryophyta, Sphagnum), as well as cysts of Chrysophycean algae have been calculated. We did not look bacterial spores. Spores of inferior plants and bacteria perhaps are similar but the size of the first ones are larger than the second ones. So, we can't say that it was a spores of bacteria. In the other side, algae cysts and spores of inferior plants look alike too – spherical without any specific components on their surface. We can't recognize them in the light microscope. We can do it only with SEM and X-RAY analysis.

P2594 L9: Decontamination procedures should be described clearly, or at least cited.
**Answer:** Decontamination procedures have not been used. Decontamination uses for removing of the organic matter covered the frustules of diatoms as it is an usual practice when diatoms are prepared for diatom analysis of condensed matters (bed and peat sediments). But here we didn't do it, because in our case this procedure can destroy diatoms themselves.

P2594 L25: Describe "standard hydrobiological methods".
**Answer:** standard hydrobiological methods - procedures for preparation of biological objects were described in section 3 "Methods".

P2595 L4: So, what was on the filter was resuspended in Milli Q water? It is not clear to me how the samples were processed.
**Answer:** Ice was melted–filtered–particles from the filter were washed in small volume of water–counted with light microscope in the counting chamber "Nazhotta".

P2595 L5: What is "Nazhotta"?
**Answer:** It is a special counting chamber for count cells, pollen grains, etc. under light microscope. It looks like a counting chamber of Goryaeva which used in clinic laboratories for count of blood elements.

P2595 L21: Write "it is", not "it's".
**Answer:** agree

P2596 L1: Write "cyclones coming from the South (the Mediterranean, Black, and Aral Seas).

**Answer:** agree

P2596 L6-16: This is just Table 1, rewritten. Text should not merely re-state the tables.
**Answer:** we will delete Table 1 and will insert all need information in text. Whole Subsection 3.4 will be revised according remarks.

P2596 L18: I do not understand this sentence. Does it mean that the classification system was used from 1899 to 2000? Or that the data were from 1899-2000? Please clarify.
**Answer:** The classification of atmospheric circulation patterns covers the period 1899-2008. In our work we used data only for period 1980-2000.

P2596 L21: Delete “most”.
**Answer:** agree

P2597 L3: “contributed” instead of “contribute”
**Answer:** agree

P2597 L6-10: Again, it is not clear how exactly the circulation patterns with high precipitation were determined.
**Answer:** the answer has been done in the general comments

P2597 L12: No need to repeat “1964-2000” again.
**Answer:** agree

P2597 L24: “low biodiversity”, not “weak biodiversity”.
**Answer:** agree

P2597 L28: I’m not sure how you can say that they were "most often preserved". This implies equal rates of deposition, but differential rates of preservation, which I do not think is what you mean. Maybe you could say "were most frequently observed".
**Answer:** agree

P2598 L7: Write “that live”, not “living”, as they were not living there when you found them.
**Answer:** agree

P2598 L13: Instead of “and different species of”, write “and species-specific”.
**Answer:** agree

P2598 L15: “periods” not “period”.
**Answer:** agree

P2598 L27: I am not sure what the addition is for. Was the precip for each of the four ECM added together to be used in the correlation? It would seem that different diatoms could be related to different ECM, so it would make more sense to analyze each ECM individually. Either way, this math should be clarified.
**Answer:** the answer has been done in the general comments

P2600 L10: Why are algal cysts and fern and lichen spores combined in one category? Also, I think that the term “inferior plant” is somewhat outdated.
**Answer:** We put chrysophycean cysts, Algae, Bryophita and fungal spores in one group, because of their morphological similarity. Algal cysts and spores of inferior plants look alike – spherical without any specific components on their surface. We can’t recognize them in the light

microscope. You can do it only with SEM and X-RAY analysis. So, when you count in the counting chamber under the light microscope you can't say exactly "who is who".

P2600 L11-17: Needs rewording and proper punctuation. Additionally, the contention that "smooth" algae are more common in eutrophic water and shallow pools needs a citation. Finally, this information needs to be tied to information on local water sources in order for it to be relevant.
**Answer:** Before it was noted that smooth forms of stomatocysts are more typical for eutrophic water bodies as well as for shallow pools as well. In oligotrophic and deep pools stomatocysts with different elements on the surface usually prevailed, that provides their floating in the water column (Bazhenova et al., 2012). Similar diatoms cysts of chrysophycean algae and spores of inferior plants can be transported over hundreds to thousands kilometers

P2601 L5: Underlying surface of what?
**Answer:** Underlying ground surface

P2601 L11: "In the period of dominant zonal circulation (1981-2001)" is not needed in this sentence.
**Answer:** agree

P2602 L4: Again, there is no indication as to why we need this additional signal, or what environmental changes it might tell us about. After reading the paper, it seems that the authors needed a lot of pre-existing environmental data to make their conclusions, so it is not clear to me what environmental changes the data might serve as record of.
**Answer:** the answer has been done in the general comments

P2602 L21: "ECM" was already defined, and does not need to be defined again here.
**Answer:** agree

P2603 L4: As a closing statement, this sentence is very weak. It leaves the reader still not knowing what the point of the paper was, and reads more like good, supporting data that should have been integrated earlier in the story.
**Answer:** agree; the answer has been done in the general comments

Tables: There are far too many tables, and a lot of them can probably be consolidated, some maybe deleted. The descriptions for the tables should include a more explicit title so that the reader can easily see where tables fit in to the text. For example, Table 3 is about diatoms, but you don't get to that until you are almost through the description. Similarly, Table 4 also goes with the diatom analysis, but there is no indication of that whatsoever in the title, which is exactly the same as that for Table 6, save the ECM numbers. It might be possible to combine the "amount of precipitation" tables into a single table and the "characteristics of atmospheric processes" into another table, instead of having so many small tables.
Table 1: Out of the 41 types of ECM listed here, only 9 are actually related to the biological parameters discussed later in the text (based on a count of the ECM that appear in later tables). Presenting all 41 of them is confusing, and makes this table too busy. I recommend focusing on only the ECM that are important later in the paper. Also, it looks like none of the Southern meridional ECM ended up explaining the biological parameters, so space is wasted here describing them, and in Figure 2 showing the example of 13(s).
I do not think that the atmospheric pressure, blocking processes, and cyclone outlets are information that are integrated into the paper. It seems more important to know things like the main months of precipitation here - information that clutters later tables, but would be useful here. The table description should be able to stand alone, so I would define "ECM" here.

How the letters “a-d” correspond to blocking processes is not explained. Brackets are [], while parentheses are ().
Table 2: This is a nice summary table. Instances of the word “some” should be changed to something more quantitative, as I do not know what “some” means. I believe you mean “cosmopolitan” rather than “cosmopolite”. The word “spores” does not need to be capitalized, and this heading could be shortened “Cysts and spores” with a footnote describing them. Be consistent throughout the table – in the diatoms section, there is a small line between each species, but in the coniferous tree section, there is not.
Table 3: And all tables of this type – the Roman numerals for months are confusing and not particularly helpful in the table. Be consistent in naming columns in all of the tables. They should all read "minimal concentration" and "maximal concentration", not some abbreviated to max. and min. and some "maximal" and "absence". Also, standardize the font sizes. Put a line in between the sections for maximal and absence of diatoms, or a break in the line that is there, so that the separation is clear. As it is, I have to guess at whether 1984 goes with "maximal" or "absence". You do not need to list the name of the met station, as you already say it in the text and it is not necessary information for understanding the contents of the table. If you want to make it clear that it is met station data, you could put it in a footnote.
Table 4: What is “Zn”? What is “Trace”? What do you mean by "intensive" precipitation? Can you be more quantitative about this? Further, you probably do not need to dedicate a column in the table to this, as they are all "intensive". You could mention in the Table description that they are all periods of heavy precipitation instead. However, a description of the terminology is absolutely necessary, and should be at least in the Methods.
Table 6: Zn-Az should be defined. I was able to find Az in the text, but not Zn. They should both be defined in both places anyway.
Table 10: It is not clear to me why this and similar tables need to list the primary season. If this is needed, it should be made clearer in the text.
Figures: All labels written as units/l should be changed to superscript format.
Figure 1: All of the blues are too close in color, so we cannot tell lakes from glaciers.
Figure 2: There are far too many lines in this figure, rendering it nearly unreadable. Lightening the lat/long lines are removing some of them altogether would help. The figure is far too difficult to read and interpret as it is. Also, the final dynamic scheme is not used in the paper (as far as I can tell), so why show it?
Figure 3: Label the months as months, instead of Roman numerals. The biological object labels are too close to each other. The units on the axis should be in parentheses.
Figure 4: The legend should clearly state what the arrows indicate. Change “diatoms are not identified” to “no diatoms observed”. Figures that go together, such as 4 and 5, could be combined into a single, paneled figure.
Figure 5: The dynamic schemes should be described, not just depicted. Description belongs in the text, but possibly in the figure legend. I do not understand why you show the four “example” dynamic schemes in Figure 2, but then show different schemes of the same groups in the following figures. This is redundant, and I do not see why you cannot use the figures to serve both purposes at the same time.
**Answer:** All Tables and figures will be correct according to these comments.