Reply to reviewer #2:

We thank the reviewer for the relevant comments and remarks which we believe considerably improved the quality of the paper. We answered all comments below and we prepared revised version of the manuscript in two supplement files, one file where all modifications (suppressions in red and addings in blue) are shown and a second one without track changes.

General comments:

1. **Referee:** A short overall presentation of the state of knowledge about ice wedge and sand-wedge formation, and their composite version often called composite wedges. Sand-ice wedges, as is the used type in this paper, are not a very used term in the periglacial literature to my knowledge. This should preferably also include the meteorological conditions controlling ice- and sand-wedge formation.
   Response: *Introduction has been rewritten and now describes the terms used (sand wedge, ice-sand wedge and ice wedge).*

2. **Referee:** The purpose of the paper is not clear to me. On p. 3629 line 12 an approach is suggested, which I think, but there is nothing on what is directly the purpose. And obviously this approach is to be tested in this paper.
   Response: *We agree, the purpose of the paper needs to be more clearly stated. The specificity of our approach consists in using multiparametric analyses (stable isotopes, total gas content, gas composition, crystallography, c-axes and sediments properties) in order to shed more light on the interpretation of the genetic and infilling processes of two specific ice wedges formed in contrasted environments (Holocene vs. Pleistocene), which cannot be fully understood with isotopic data only . The introduction has been adapted to clarify these main objectives. In a second step, after having shown the eligibility of using the co-isotopic data in a paleoclimatic perspective, we discuss the regional paleoclimatic context in terms of potential changes in moisture sources, combining our multiparametric results to the d-excess analysis.*

3. **Referee:** Too much use of glacial literature instead of periglacial literature as both background for the study e.g. p. 3629 line 3-6..old references to the periglacial literature mentioned and several glaciological references included despite this being about ice properties within ice wedges.
   Response: *The new introduction section refers to recent studies on ice wedges and on paleo-climatic interpretation of the studied area.*

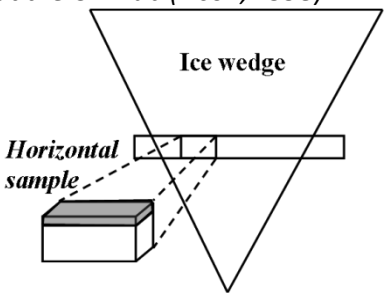
4. **Referee:** Introduction: The permafrost climate considerations are very overall, and have no details about the study area/region. Also there is nothing on ice-wedges specifically in this context, which would have been highly relevant, as one of the most ice-rich periglacial landforms.
   Response: *The revised introduction and discussion section now refers to recent studies on ice wedges and on the paleo-climatic interpretation of the studied area. We have kept the references from the glacial literature because we believe they can explain some of the specific and original observations made in the paper, with,to our best knowledge, no existing periglacial reference to these processes.*

5. **Referee:** Study area: There is nothing on the overall geomorphology of the study site. What landforms are the ice-wedges located in, and what is the overall Quaternary history ? Only the overall regional ? stratigraphy is outlined. Landscape development during ice-wedge /

sand-wedge formation is important to evaluate the results in the end in the discussion as well.
Response: *We agree. We added a scheme of the cliff structure enable to locate the two ice wedges and the general stratigraphy of the site. The geomorphology and the landforms history of this area is well documented in the Schirrmeister et al. 2008 paper and we now refer to it better in the manuscript. .*

6. **Referee:** There is nothing on the connection geographically between the two sampling sites. There is nothing on why exactly these two ice-wedges have been studied of out several ? in the area. There is nothing on why the sampling is done at the specific depths used.
Response: *We can now observe the cliff structure and the ice wedges location on Figure 2, and the text description has been slightly expanded. We also clearly specify why these two specific ice wedges were chosen for our detailed approach. The depth of sampling was chosen in order to: a) maximize the range of observations across the ice wedge, b) stay away from potential surface reworking and c) accessibility considerations. We have not changed the manuscript to limit size.*

7. **Referee:** Sampling and analytical methods: It would be nice with a better description of the sampling of horizontal sections from the chain sawed ice blocks sampled in the field.
Response: *We initially thought of including the following figure in the paper. We then decided to save space, given the already large number of existing figures. The text should reflect the content of the figure. The horizontal samples was recut using a diamond-wire saw available at the ULB lab (Tison, 1998)*



8. **Referee:** Why was the organic content not simply determined by burning in the end?
Response: *Our amount of sample was very limited. It is only at a later stage of the study that we felt the need for testing further hypotheses on our gas profiles. We therefore used the small amount of material that we had at its best, in order to at least obtain a qualitative check. This is now better specified in the "method" section.*

9. **Referee:** Results: In the ice texture and fabrics part it seems like you mention results from ISW on Fig. 5 yet there is not such legend on Fig. 5..probably you have forgotten.
Response: *Figure 5 has now been adapted to better underline the boundary between ISW-28 and IW-28 in the diagram.*

10. **Referee:** Concerning gas properties you highlight the low gas content compared to the glacial environment. Why is this a highlight ? The periglacial environment is very different from the glacial environment: : :and ice-wedge growth is not about simple snow compaction (this is also why I suggest you identify the relevant periglacial processes responsible for ice-wedge formation as background for this paper).
Response: *We made this comparison to use ice resulting from dry snow compaction as a reference for 0% of liquid water influence in the ice formation and on the total gas content (an original quantitative contribution of this paper). There is indeed a considerable amount of discussions and some inconsistencies in the existing literature on ice wedge formation*

processes including on the liquid water contribution and freezing processes. Very recently, St-Jean et al. 2011 have also identified the influence of variable liquid water contents on ice wedge formation. We have updated our manuscript in that respect and compared our results to this recent study. The introduction has also been adapted to give a brief reminder on ice wedges formation processes.

11. **Referee:** The section of sediment properties is strange. It ends with a sentence which is not making any sense..must be a part missing ? And it starts with a sentence repeating the method section on this. Otherwise the results reported here are not very detailed. What about real sediment information such as grain size data?
    Response: *Effectively, there was a misprint in the last sentence. As explained in response 8, we had very few sediment samples, too small to be dedicated to a proper granulometry spectrum. We used the amount of available sediments to produce a qualitative test on the hypothesis raised in by the gas behaviour..*

12. **Referee:** Discussion 5.1 most of this section is about comparison to the glacial environment and using results/interpretations from there to assume ice-wedge formation. Particularly the 'ribbon-like' structure is interpreted this way. And then it end up with saying that liquid water was present during ice-sand wedge formation. This is rather obvious again if one consider normal theory for ice-wedge formation. So I find this entire section very speculative, and less convincing in terms of understanding ice-wedge / composite wedge formation.
    Response: *As mentioned before, the discussion has been reorganized in two sections: in section 5.1 we use our multiparametric data to improve our understanding of ice wedges infilling processes in contrasted climatic environments and in the second section (5.2) we discuss the implications for the paleo-climatic history (changes in moisture sources and ice wedge response) of the area.*
    We use the comparison of the ribbon structure with what has been observed in other glaciated environments simply because we have not found any similar description in the permafrost literature. We also give our argumentation to show that there are similarities in the hydrodynamic conditions of formation for that facies both in periglacial and glacial environments.

13. **Referee:** 5.2 Again I think there is a problem with understanding the ice-wedge morphology and how ice-wedges work when discussing the apex above the crack. I assume you mean the trough? Mainly there seem to be a missing understanding of how ice forms in ice-wedges and which ice types are dominant in ice wedges. Ice veins in ice-wedge typically do not form due to a firnification process of snow.
    Response: *We adapted the Introduction and the discussion (5.1 section) along those lines. The ambiguous sentence discussed above has been removed.*

14. **Referee:** Page 3638 line 24 you mention bulk refreezing of a mixture of snow and interstitial water as the process of ice formation in IW-28.This is to my knowledge not the traditional understanding of ice vein formation in ice-wedges. Why include several measurement possibilities that do not work?
    Response: *As we explain in the text, our multiparametric data set indeed evidences bulk refreezing of a snow-water mixture (small granular crystals, spherical bubbles, no isotopic fractionation at the sampling level, total gas content half of dry firn content). The referee did not expand on why they think this is against the "traditional understanding" of ice vein formation (the snow-water mix?, the bulk refreezing?). Nevertheless, our conclusions are globally coherent with the recent studies on those processes (e.g. St-Jean et al., 2011), that also show refreezing of a snow and water matrix in various amounts...the details of the refreezing process might indeed be further refined in the future*

15. **Referee:** 5.3 page 2 3640 line 12-13. You already differentiated the three facies of the ice-wedges when presenting the site. Spell out LMWL line 23.
Response: *We wanted to insist on all the parameters which enable to differentiate the three facies. This comparison shows that texture, gas content, gas composition and isotopes are linked. The text is anyway amended in the new version of the manuscript.*

16. **Referee:** Page 3641 line 16-17. Why '..' on these processes ?
Response: *Ok. Changed.*

17. **Referee:** Line 26 Tsite = the air temp of the site ? Tsource = snow temp or ground temp ? I think the interpretations of the isotopic values are too much dependent of the overall global/regional (again mainly glacial !) environmental conditions and too little on the local periglacial conditions. The local conditions are very speculative: : :assuming a thinner snow cover or an earlier crack opening enabling particles to be blown/entrained into cracks. What is this based on ? And is this really likely in the arctic environment ? Why couldn't it simply be aeolian sediment in the snowpack, which is transported with the snow meltwater into the cracks during spring/summer ? Likewise with the increase in albedo due to thin snow cover suggestion leading to more meltwater. When would this happen ? During which parts of the year and in which air temperatures typically in Siberia ?
Response: *Tsource has been explained before in the text. It refers to the temperature at the source of the moisture (evaporation site). We totally agree that the local conditions play a role on the filling process of the ice wedges. In this case, the properties are quite contrasted between ISW-28 and IW-28. We show that the isotopic contrast cannot be explained by local phase changes and that we can use the d-excess as a paleoclimatic indicator. The sharp contrast in d-excess therefore suggests a major shift in moisture source. The other properties also, show considerable changes in the wedge filling process (for ISW-28: less snow availability, episods of water refreezing, larger relative inputs of sediments reorganized at single crystal layers limits...) with important contrasts in local processes.*
We cannot judge with the data at hands if the origin of the relocated sediments is "more snow entrainment" or larger contribution of the surface material due to proximity of the limit of the wedge combined to low snow input in the wedge during the winter. We have modified the sentence in section 5.1 (ISW-28) in this regard.
We cannot provide summer temperature at the time with our data set, but we can say from present day observations at higher latitudes (or altitudes) that summer melting is not unlikely, even in a colder glacial environment.

18. **Referee:** Conclusion: First sentence is over simple - delete.
Response: *Ok, changed*

19. **Referee:** Then it is claimed that the analyses has improved the ice-wedge process understanding. This I cannot see, as most of what is stated is assumptions, which has not been documented in any detail. But rather we have got lots of comparisons with how the glacial world works, which might not be directly relevant for ice-wedge formation.
Response: *The discussion structure has now been modified to clarify the links between our data set and the ice wedge formation processes.*

Detailed comments:

20. **Referee:** Figures: Generally the figure texts are not very informative. Do not assume that the reader directly go into the text and find all relevant details. These should be included in the figure texts.
    Response: *Most of figure captions have been extended.*

21. **Referee:** Fig. 1. Why not photo of the sampled section or the overall stratigraphy of the study site and then have this overview map as a small insert.
    Response: *A scheme of the structure and the stratigraphy of the sampling area has been added in Figure 2.*

22. **Referee:** Fig. 2. No good scale on either of the photos. Not easy to see the extent of the ice-wedges. Boxes are grey not black on my file here.
    Response: *The sampling area extension has been added in the figure caption and the box color has been corrected.*

23. **Referee:** Fig. 3. Plots too small. Make wider and make use of the full width of the page to improve readability. Unit on x axis on a) and b) should be width not sample no. also to improve direct comparison with figure 7.
    Response: *Figure size has been modified by the editing process, the source file was larger. We now have distances equivalency on the x-axes*

24. **Referee:** Fig. 4. Start with a real text, such as Thin section photographs of the textural properties of the ice-wedges.
    Response*: Ok, corrected*

25. **Referee:** Fig. 5. Why no ISW-28 ?and not indication of where this is on the fig like on Fig. 3 and 7.
    Response*: IW-26, ISW-28 and IW-28 location have been added.*

26. **Referee:** Fig. 6. n = ?
    Response: *Each value of n is specified in the figure caption.*

27. **Referee:** Fig. 7. Larger plots to full width of the page to increase readability. What are O and N in lower most d) part of the figure, should be explained directly on the figure.
    Response: *Initial file uploaded in the submission process was a full width page. We do not have these letters in our version of the figure (?)*

28. **Referee:** Fig. 8 The text is not sufficient. Make it at real text explaining that this is: : :and do not write see text for details ! Thanks.
    Response: *Now Figure 9, the figure caption has been modified*.

29. **Referee:** A temperature is never warm or cold, but high or low (page 3640 line 4)
    Response: *Ok, the text has been modified*

30. **Referee:** Always present the figure in increasing order, not Fig. 4 before fig. 3 (page 3630 line 29).
    Response: *Ok, done.*

31. **Referee:** Typically we use ice-wedges in periglacial literature, you mainly use ice wedges, but in some places ice-wedges.
    Response: *Both are in literature, here we used the terms ice wedge and ice-sand wedge. Manuscript has been standardized*

32. **Referee:** Always include all references used in the text in the ref. list. I found all on page 3640 line 19 not included.
    Response: *This mistake has been corrected.*

33. **Referee:** The English language could be improved to also improve the understanding of your argumentations in several parts of the paper. This is particularly necessary on page 3642 lower half.
    Response: *The text has been partly re-written to improve the language and the understanding (especially the introduction and discussion sections).We will also ask to be able to take advantage of the free "copy-editing" new facilities of the Journal, if the editor agrees.*