

# ***Interactive comment on “A new high-resolution pollen sequence at Lake Van, Turkey: Insights into penultimate interglacial-glacial climate change on vegetation history” by Nadine Pickarski and Thomas Litt***

## **Anonymous Referee #1**

Thank you for the opportunity to comment on this manuscript. It concerns a sound data set of great value to the palaeoecological community as it comes from a region where such data for this period are scarce. Overall, I think the work is good and should be published in CPD but there are a number of important details that need to be considered and corrected first. In many instances these are related to terminology, definition of terms and ambiguity or circularity in the phrasing. One important example of this is the use of the term "steppe forest" without definition or explanation. Another is the use of marine isotope stage names to refer directly to intervals identified in the pollen record with no explanation for how that equivalence was established (even once an explanation is given, MIS terms should not be used directly for terrestrial intervals - see further details below). There is occasional circularity and a lack of clarity as to what was used to infer what but this is usually a question of the phrasing, and not a fundamental problem with the argument (examples below). I think that to make a convincing argument, the basis of both the stratigraphy and the chronology should be outlined in more detail (even if they are described elsewhere) so that the paper can stand alone. Without this, it is difficult to assess the validity of statements about the relative timing of events in the Lake Van pollen record and global scale climatic events. The vegetation reconstructions/inferences (particularly those involving trees) I think need to be more clearly described and the basis for the inferences better founded (e.g. with reference to modern pollen-vegetation studies, where possible). Also, I think there is succession where the authors have suggested there is not... this could do with some more consideration. These issues are detailed below along with suggestions for grammatical corrections. In addition there are numerous minor grammatical errors (especially plural/singular, tenses) (not all are listed below).

## **Page Line Comment**

**1 11** “effective moisture” needs some qualification (high, low?) otherwise the meaning is not clear  
We added ‘high’ to classify the phrases ‘effective moisture’.

**1 12** “forest” ought probably to be qualified with “open” since this is “steppe forest”  
We rewrote the sentence as follows: ‘Integration of all available proxies shows three intervals of high effective moisture availability, evidenced by the predominance of steppe-forested landscapes (oak steppe-forest),...’ (now line 11-12).

**1 12** I think the conventional term for the biome is “wooded steppe” (e.g. Allen et al. 1999, Nature 400, 740 – 743). If “steppe forest” means something other than this, then it must be defined (and in any case, a reference is needed).

According to Zohary (1973), the southern mountain slopes are covered by the Kurdo-Zagrosian oak steppe-forest belt, containing *Quercus brantii*, *Q. ithaburensis*, *Q. libani*, *Q. robur*, *Q. petraea*, *Juniperus excelsa*, and *Pistacia atlantica*. This oak steppe-forest has also been described as ‘mixed formation of cold-deciduous broad-leaved montane woodland and xeromorphic dwarf-shrublands’ by Frey and Kürschner (1989). Furthermore, several previous vegetation studies at Lake Van used the term ‘oak steppe-forest’, see also Zohary (1973); van Zeist and Bottema (1991); van Zeist and Woldring (1978); Wick et al. (2003). We added the definition of oak steppe-forest in the section ‘Site description’.

**1 13** “The warmest stage: : :” The previous sentence suggests moisture is the main limiting factor. If temperature is important too, then need to make it clear that both are involved throughout the text (i.e. avoid summarising warmer/wetter as “warmer”).

Changed in: The warmest/wettest stage as indicated by... (now line 15).

**1 13** “in terms of” I think this should read “as indicated by”

Changed.

**1 13** “amplitude” Double check – do you mean amplitude, or duration (or both)? Please clarify this.

In this context, I was referring to the amplitude of the penultimate interglacial, which was lower than during the next interstadial (MIS 7c).

**1 14** Insert “: : : the tree population maximum associated with: : :” before “MIS 7”

Done.

**1 17** Clarify presence or absence of trees in this instance of “steppe”

We replaced the term ‘steppe landscape’ by ‘...periods of treeless vegetation...’.

**1 19** Replace “more” with “higher”

Changed.

**1 21** The mild conditions inferred here are also in agreement with pollen records from elsewhere in southern Europe.

We added the agreement with other pollen records from southern Europe within this sentence. Now it reads: ‘In contrast, the occurrence of higher temperate tree percentages throughout MIS 7b points to relatively mild conditions, which is in agreement with other pollen sequences in southern Europe.’ (now line 22-25)

**1 25** Insert after “subdued oscillations”: “: : : as in other records of this interval from southern Europe.” E.g. MD01-2444 and I-284.

Done.

**1 27** Clarify what it is that indicates cooler and wetter conditions (it’s not the identification of MIS 6e!)

We clarify the indication of cooler/wetter climate conditions. Now it reads: ‘Furthermore, we are able to identify the MIS 6e event (c. 179-159 ka BP) as described in marine pollen records, which reveals clear climate variability due to rapid alternation in the vegetation cover.’ (now line 32-34).

**2 36** Could you say what the resolution was in that study?

Done. Now it reads: ‘Based on millennial-scale time resolution (between c. 1-4 ka), the 600,000 year old record already shows...’ (now line 42).

**2 41** Replace “allow” with “have allowed”

Changed.

**2 45** Replace “is not being” with “has not been”

Changed.

**2 49** Replace “already available” with “existing”

Changed.

**2 57** Replace “this presented study” with “our”

Changed.

**2 57** Delete “want to”

Done.

**2 58** Change to past tense  
Done.

**2 61** Change to past tense  
Done.

**3 67** “meter” should be plural  
Done.

**3 77** “latitudes” should be singular  
Done.

**3 88** It would be helpful to know whether these forest and shrub formations represent the “natural” state of the vegetation versus the result of human impacts (e.g. pastoralism).  
In line 82-83, now in line 88-89: We already mentioned in the sentence above, that the present-day vegetation cover around Lake Van was and is the results of agriculture and pastoralism.

**4 99** “those” is ambiguous: : : can you say what “those” refers to? (Existing pollen data?)  
We rewrote the sentence as follows: ‘In this section, we combine new pollen and isotope data with the already existing low-resolution pollen record published by Litt et al. (2014) and oxygen isotopes data derived from bulk sediments ( $\delta^{18}\text{O}_{\text{bulk}}$ ) analyzed by Kwiecien et al. (2014).’ (now line 105-107).

**4 101** Chronology section – perhaps the explanation of how (at least this part of) the Lake Van sequence has been aligned to the marine isotope stratigraphy belongs here?  
Thank you very much for this advice. We added the following section: ‘Marine isotope stage (MIS) boundaries follow Lisiecki and Raymo (2004). ... For the climatostratigraphic alignment of the presented Lake Van sequence, the proxy records were visually synchronized to the speleothem-based synthetic Greenland record ( $\text{GL}_{\text{T-syn}}$  from 116 to 400 ka BP; Barker et al., 2011) (now line 117-119).

**4 114** How were the age control points identified – in which proxy record?  
We added further information about the ‘age control points’. Now it reads: ‘The identifications of TOC-rich sediments containing high Ca/K intensities and increased AP values at the onset of interstadials/interglacials were aligned to the interstadials/interglacial onsets of the synthetic Greenland record by using ‘age control points’. Here, the correlation points of the Lake Van sedimentary record have been mainly defined by abiotic proxies (i.e., TOC) caused by a higher time resolution of this data set in comparison to the pollen samples available during that time.’ (now line 119-124).

**5 127** Insert “group” after “taxonomic”  
Done.

**5 131** “percentages” should be singular  
Done.

**5 133** Should be “lake surface”?  
Changed to ‘...to evaluate lake surface conditions, ...’.

**5 137** Replace “was” with “were”  
Done.

**5 142** Insert “were made” after “measurements”  
Done.

**5 157** “deciduous forested”: : : I think you need to specify whether this is closed or open forest because the implication of following this with “open steppic landscapes” is that the forest was closed canopy which, given the low AP%, is unlikely. Which leads to the next comment: : :

At Lake Van, the AP maxima do not exceed 50-60%, suggesting that ‘closed’ forest conditions were never established in eastern Anatolia. It is always an ‘open’ oak steppes-forest, similar to the potential present-day vegetation cover at the southern shore of Lake Van. It is a cold-deciduous broad-leaved montane woodland and xeromorphic dwarf-shrublands (Frey and Kürschner, 1989).

Here, we replace ‘forest’ with ‘open deciduous oak steppe-forest. Now it reads: ‘The pollen diagram provides a broad view of alternation between regional open deciduous oak steppe-forest and treeless desert-steppe vegetation.’ (now line 177-178).

**5 159** With low AP % values, I’m not sure “forested” gives the right impression. It sounds a bit too, well, “forested”! Is there an alternative term that would be a better representation of the open landscape with few trees that the pollen data seem to represent? Ideally, this would have its basis in modern pollen-vegetation work.

See reply above. Now it reads: ‘We were able to recognize three main phases (PAZ Va1, Va3, Vc2, and Vc3), where total arboreal pollen percentages reach above 30%.’ (now line 178-179).

Regarding a modern pollen-vegetation work at Lake Van, at present there is only one monthly resolved pollen study available (Huguet et al., 2012), which was obtained from a sediment trap in the lake basin. However, this study does not reflect the mosaic-like vegetation at Lake Van.

**6 166-7** “The highest concentration peaks occur during forest intervals”. Please rephrase this to remove the circularity. (How do we know these were forested intervals? Partly, because of the high pollen concentration!).

We revised this sentence in: ‘During PAZ IV1-6, Va2, Vb, and VI, the pollen concentration is dominated mainly by steppic herbaceous pollen species (between 5,000 and 52,000 grains cm<sup>-3</sup>), whereas PAZ IIIc 6, Va1, Va3, and Vc2-3 consist of tree and shrubs taxa (all above c. 5,000 grains cm<sup>-3</sup>).’ (now line 188-190).

**6 171** Add a brief comparison with the pollen record here (to be consistent with the next sentences about *Pediastrum* which are compared with the pollen).

To be consistent with the rest of this section, we revised the sentences. Now it reads: ‘In total, six green algae taxa were identified in the Lake Van sediments. Fig. 2a presents only the most important *Pseudopediastrum* species. The density of the thermophilic taxa *Pseudopediastrum boryanum* reaches maxima values (c. 5,500 coenobia cm<sup>-3</sup>) combined with high arboreal percentages especially during PAZ Vc2. In contrast, the cold-tolerant species *Pseudopediastrum kawraiskyi* occur during the treeless phases (PAZ IV4-2, max. values c. 2,000 coenobia cm<sup>-3</sup>).’ (now line 191-195).

**6 181** Is the amplitude exceptionally high? This phrasing suggests you have made comparisons with other records: : : if so, please indicate broadly which records (or kinds of records) it is high relative to.

We have not made any comparison with other records in this case. The Lake Van isotope composition shows a high-frequency oscillation. We replaced ‘high amplitude’ by ‘high-frequency oscillation’ (now line 207-208).

**7 197** Please say how you define stadial and interstadial here OR avoid using these terms here and make the correlation between particular peaks in the isotope curve and particular stadial-interstadial transitions (defined in other records) later on. I think the same applies for Termination III (since you haven’t yet clearly justified the identification of TIII in the lake Van record).

Thank you very much for your good advice. We added a new section ‘Boundary definition and biostratigraphy’, where we defined Terminations, interglacials, interstadial/stadial stages, and the correlation to the Marine Isotope Stages (now line 227-248).

**7 204** This should read “marked” not “remarkable”

Done.

**7 205** Does “here” refer to this study? If so, the “generally considered” does not make sense. Please clarify.

We rephrase this section. Now it reads: ‘According to Litt et al. (2014), the three-marked temperate arboreal pollen peaks (PAS Vc, Va) can be described as an interglacial complex. This general pattern of triplicate warm phases interrupted by two stadials (PAS Vb, PAZ Va2) is characteristic both in marine and ice-core records (MIS 7e, 7c, 7a after Lisiecki and Raymo, 2004), as well as for continental pollen sequences in southern Europe correlated and synchronized by Tzedakis et al. (2001).’ (now line 250-254).

**7 206** The sentence starting “This general pattern: :” is ungrammatical. The warm phases alternate with the cold phases. Please rephrase. Also, it is interesting that you do not mention changes in moisture availability here. There either needs to be a justification for that (deliberate?) omission, or both climatic parameters need to be considered.

Rephrased. See reply above.

**7 207** There is something odd about the line of reasoning here. On what basis did you establish the equivalence between the phases with more trees and MIS 7e, 7c and 7a if not by comparison of the pollen record with a marine isotope record (such as that used in the stratigraphy of Martinson et al. 1987) directly or indirectly? (I.e. “comparable with the marine classification by Martinson: :” does not make sense). Also, take care with using the language of marine isotope stratigraphy to directly refer to intervals recorded by the pollen record – it is not strictly correct to do that (though of course we all do it informally). Ideally, wooded intervals in the AP% curve should not be directly aligned with the (apparently) equivalent MIS stages; there are significant offsets (and uncertainties) in the timing of the beginning and end of forest intervals on land relative to the beginning and end of warm marine isotope stages. Marine pollen records, from the Iberian margin and elsewhere, which combine marine isotope stratigraphy with a terrestrial vegetation signal are the only records in which the relative timing can be established directly (and these show significant offsets).

In agreement with Tzedakis (2007), the onset of terrestrial temperate intervals corresponds broadly with the Mid-June insolation maximum. Here, the length of the delay depending on local conditions keeping moisture availability below the tolerance threshold for tree growth.

However, we explained the basis how we aligned arboreal pollen record (as part of an independent proxy record) with the MIS stages in section ‘Chronology’ and ‘Boundary definition and biostratigraphy’ (See reply above). For the synchronization, we used the independent XRF and TOC proxy records that showed more or less no offsets in the timing of the beginning and end of warm Marine Isotope Stages. Therefore, we were able to combine the terrestrial vegetation signal, which documents (of course) offsets with the beginning and end of warm phases, with the MIS stratigraphy (See also reply **10 315**).

**7 214** Should “abrupt” be “brief”? In this context, “abrupt” doesn’t really make sense.

Removed.

**7 217** Rephrase: link the sentence starting “It is clear: :” to the previous one and remove “it”, which is unclear.

Due to the general improvements of this section, the sentences is now revised as follows: ‘...fire activity rose at the beginning of each warm phase when global temperature increased and the vegetation communities changed from warm-productive grasslands to more steppe-forested environments. Increased fire frequency is clear visible by high charcoal concentration up to 3,000 particles cm<sup>-3</sup>...’ (now line 271-274).

**7 217** “: : vegetation communities changed.” State what kind/direction of changes this refers to.

See reply above.

**7 219** When discussing events in the past, not stratigraphy, the terminology is “start” not “base”  
Changed.

**7 222-3** The inference of “oak steppe-forests where summer-green *Quercus* rises consistently above 20%” needs a few words of explanation and justification, and a reference.

We already define the term ‘oak steppe-forest’ in the section ‘Site description’. See also reply to comment **1 12**.

**8 233** “this” should be “their” as in “their hypothesis”, but it would also be helpful to have a brief re-statement of that hypothesis here.

For the better understanding, we added some additional information about the hypothesis from Kwiecien et al. (2014). Now it reads:

‘Furthermore, Kwiecien et al. (2014) described the relation between soil erosion processes and the vegetation cover in the catchment area. They define interglacial conditions related to increased precipitation indicated by higher amount of arboreal pollen and lower detrital input. Our new high-resolution pollen record validates their hypothesis with high authigenic carbonate concentration (high Ca/K ratio; low terrestrial input) along with the increased terrestrial vegetation cover density (high AP percentages above 50%) during the climate optimum (c. 240-237 ka BP; Fig. 3).’ (now line 289-294).

**8 241** I think there needs to be a clear statement of how these records were aligned – i.e. how do you know that the vegetation changes (that you interpret to represent cooling/drying) recorded in the Lake Van sequences occurred BEFORE “: : : ice accumulation is evident: : : in MD01: : : “?

We removed this section.

**8 241** The linking phrase (“In light of these insights: : :”) does not work because the insights just described are not what suggests a shift from temperate to coniferous taxa.

We removed this phrase due to general modifications of the text.

**8 248** Why “re-expansion” not just “expansion” (implies a second expansion)?

Changed.

**8 253** The persistence of relatively large tree populations through the period equivalent to MIS 7b was noted at Lac du Bouchet and at Ioannina; please cite this work here.

Done.

**8 263** MIS 7c is not an interstadial: : : unless you want to define it as such at Lake Van (but then this must be explained and justified).

We improved the section ‘forested periods’ and added some more information/comments about the penultimate interglacial complex MIS7, including MIS 7c and MIS 7a as an interglacial stage.

**9 263-266** All good reasons listed here for not calling MIS 7c an interstadial.

You are completely right. It was a misunderstanding. MIS 7e, 7c, and 7a are, of course, interglacial stages.

**9 273** Which other tree taxa are missing, besides *Pistacia*, from the succession: : : I couldn’t see any others. If only *Pistacia* is missing from the wooded interval equivalent to MIS 7c, this is not sufficient to say there is no succession. I think there is: as in the “7e” interval the “7c” tree population expansions begin with *Betula*, continue with *Quercus* and this is followed by expansion of *Pinus* populations.

Good remark! We rewrite the complete section ‘forested periods’. See reply above.

**9 275** Ensure the phrasing reflects the fact that you are describing conditions in the region of lake Van and that the same conclusions may not apply elsewhere (i.e. include reference to the region to which your conclusion applies).

We removed this sentence.

**9 277** Don’t need BP with ka, conventionally.

Done.



**9 277** Along with the intervals that have more trees, the open (treeless) intervals also need to have their equivalence to the marine isotope stratigraphy justified. To repeat – it is not good practice to refer directly to intervals identified in a terrestrial pollen record with the MIS nomenclature (you need to demonstrate the basis for the correlation, and even then, I would still say “the interval broadly equivalent to MIS: : :” or similar wording).

See also reply line **7 207**.

**9 277** Related to the comment above, replace “MIS 7d” with “pollen record between : : : and : : : ka” or use zone names. There are numerous other places in the manuscript where MIS terminology is used where it is not appropriate.

We replace MIS 7d with: ‘The two periods between the three temperate forested intervals, PAZ Vb (227-221 ka, 109.1-106.5 mcbf) and PAS Va2 (208-203 ka, 101.3-99.9 mcbf), are broadly equivalent to MIS 7d and MIS 7a.’ (now line 367-369).

**9 290** Please give references (after “: : : Lebanon and southern Europe.”)

Done.

**9 293-4** This description of the vegetation during the interval equivalent to MIS 7b is not consistent with the description of this interval above (where 7d and 7b, to use the informal shorthand, are described together as having “extensive steppe vegetation: : : [and] inhibited tree growth: : :”

Thank you very much for this comment. We improved the description of the vegetation during cold periods and paid attention on exact wording. Now it reads: ‘At Lake Van, cold periods are generally characterized by: (I) extensive steppe vegetation when tree growth was inhibited either by dry/cold or low atmospheric CO<sub>2</sub> conditions (Litt et al., 2014; Pickarski et al., 2015b), ....’ and ‘In contrast to conventional cold periods at Lake Van, the second phase (PAS Va2) recognizes only a slight and short-term steppe-forest contraction.’.

**9 297** Why is higher in ‘: : :’? (another occurrence in line 304: ‘high’)

We deleted both ‘....’.

**10 299** Delete “arboreal”

Done.

**10 300** “i.e.” should be “e.g.” here

Done.

**10 305** Check – if CO<sub>2</sub> was higher in 7b, it is more likely to have been warmer than 7d.

You are right. The CO<sub>2</sub> content during MIS 7b was a bit higher (c. 230-240 ppm) than during MIS 7d (c. 207-215 ppm).

**10 308** and onwards Consider using past tense in this section as it discusses events in the past rather than the record of those events.

We have paid more attention to the use of correct tenses.

**10 315** Delay relative to what: : :?

...relative to the glacial/interglacial boundary as defined in NGRIP and GL<sub>T-syn</sub>. We revised this sentence. Now it reads:

‘...the MIS 8/7e, MIS 7d/7c as well as the MIS 6/5e boundary in the continental, semi-arid Lake Van region recognized a delayed expansion of deciduous oak steppe-forest of c. 5,000 to 2,000 years, comparable to the pollen investigations of the marine sediment cores west of Portugal by Sánchez Goñi et al. (2002, 1999). As already shown in high-resolution Lake Van pollen studies by Wick et al. (2003), Litt et al. (2009), and Pickarski et al. (2015a), a delay in temperate oak steppe-forest refer to the Pleistocene/Holocene boundary as defined in the Greenland ice core from NorthGRIP stratotype (for the Pleistocene/Holocene boundary; Walker et al., 2009) as well as from the speleothem-based synthetic Greenland record (GL<sub>T-syn</sub>; Barker et al., 2011; Stockhecke et al., 2014) can be recognized. (now line 409-417) (see also reply to comment **7 207**).

**10 318** Replace “due” with “indicated by”

Done.

**10 324** “However: : :” doesn’t make sense here.

We rephrase this sentence as follows: ‘Compared to *Carpinus betulus*, deciduous oaks are....’.

**10 327** Reference required (to support observation about range of ecological requirements within the *Quercus* genus).

In general, we have added some additional information about the ecological requirements of dec. *Quercus* and added relevant references (see also reply below)

**10 328** There seem to be some logical steps missing: : : can this be explained more clearly? Make clear that both abundance and composition of tree populations differs. Also, it is necessary to reconcile this argument for wetter/cooler conditions with the presence of *Pistacia* close to the start of the “forest” interval corresponding to MIS 7e.

See also reply above. We added further information to close the missing steps.

Now it reads: ‘...*Carpinus betulus* usually requires high amounts of annual rainfall (high atmospheric humidity), relatively high annual summer temperature, and is intolerance of late frost (Desprat et al., 2006; Huntley and Birks, 1983). In oak-hornbeam communities, *Carpinus betulus* is replaced as the soils are relatively dry and warm or too wet (Eaton et al., 2016). Compared to the common hornbeam, deciduous *Quercus* species are ‘less’ sensitive to summer droughts (even below 600 mm/a; Tzedakis, 2007), and therefore, a decrease in soil moisture availability would favor the development of deciduous oaks (Huntley and Birks, 1983). Especially, the deep penetrating roots of *Quercus petraea* allow them to withstand moderate droughts by accessing deeper water (Eaton et al., 2016). However, a variation in temperature is difficult to assess because deciduous oaks at Lake Van include many species (e.g., *Quercus brantii*, *Q. ithaburensis*, *Q. libani*, *Q. robur*, *Q. petraea*) with different ecological requirements (e.g., San-Miguel-Ayanz et al., 2016). Finally, the absence of *Carpinus betulus*, the overall smaller abundances of temperate trees (e.g., *Ulmus*), and the general low diversity within the temperate tree populations during the climate optimum of the first penultimate interglacial compared to the last interglacial indicates warm but drier climate conditions (similar to the Holocene).’ (now line 429-444).

**11 335-6** This assumes that the “climate optimum” is equivalent to the “terrestrial temperate interval” – either justify this equivalents or use “terrestrial temperate interval” both times.

In this case, we use the term ‘terrestrial temperate interval’ for both times.

**11 341** Replace “evident” with “suggested” or “indicated”

Done.

**11 343** The “rapid decline in temperate trees” does not make sense: : : which decline does this refer to?

Revised to: ‘Such observed climate deterioration is suggested by the dominance of semi-desert plants (e.g., *Artemisia*, *Chenopodiaceae*) and by the decline in temperate trees (mainly deciduous *Quercus* <5%) similar to that of the last glacial at the same site.’ (now line 459-461).

**11 350-351** “: : : resembles the pattern of interstadial to stadial stages.” - as defined by what?

The interstadial/stadial pattern (e.g., Dansgaard-Oeschger events) was defined in the Greenland ice core record, esp. by, e.g., NGRIP, 2004; Rasmussen et al., 2014 for the last glacial period. We added some references and revised the sentence.

**11 359** A landscape cannot be “less extensive”

We removed this phrase.

**11 360** “greater” would make more sense than “great” here.

Done.



**11 362** Replace “values” with “populations” as this is about inferred vegetation now, rather than the pollen record.  
Done.

**12 370** Should also cite Margari et al. 2010 for the Iberian margin marine pollen record of MIS 6.  
Done.

**12 379** : : : and this pattern is also recorded at Lake Van?

What we see is that the Ca/K ratio (and also the TOC record at Lake Van, which is not mentioned in the manuscript) documents slight change to lower erosion processes around 150 ka (We have added this observation to the manuscript). I think the vegetation signal is too weak/subdued in an overall cold/dry climate to see any small changes in the record.

**12 385** Which transition does this refer to? Or should it read “transitions”?  
Changed.

**12 394** At face value, this should not be the only reference given for the DO events 17 to 12.  
We added further reference for Dansgaard-Oeschger events.

**12 396** Not clear what is meant by “compared to”: : : do you mean “comparable with” or “similar to”? Or something else?  
We replaced ‘compared to’ with ‘comparable with’.

**12 397** “Intensities” is ambiguous: : : should it be amplitude?  
Changed.

**13 403** “is supported by” should be “suggests” if the pollen forms the basis of this climatic inference.  
Changed.

**13 409** “: : : points to a general picture of cold but ‘wet’ conditions during MIS 6e than experienced during MIS 3.” This is not grammatically correct.  
We revised this sentence as follows: ‘Nevertheless, the occurrence of *Pinus*, *Ephedra distachya*-type as well as the cold-tolerant algae *Pseudopediatrum kawraiskyi* indicates colder/wetter climate conditions during MIS 6e compared to MIS 3.’ (now line 527-529).

**13 426-7** It is not clear to me what this vegetation formation would look like. Which aspect was “dense”? I think the term “steppe” is incompatible with the term “dense forest” unless the two kinds of vegetation occurred simultaneously in different areas (e.g. open steppes with discrete areas of dense forest: : : but that wouldn’t be called a “steppe forest”)  
We replaced ‘dense’ by ‘well-developed’. See also reply Referee #2.

**13-14 431-2** “: : : strong thermal and hydrological seasonal contrasts during the last interglacial, and a higher humidity during the Holocene climate optimum: : :” are not discussed in the rest of the manuscript. If they are to appear in the conclusions, they need to appear earlier in the text as well.  
You are right. This topic was not discussed in the manuscript. Therefore, we removed this sentence.

**15 453** Check spelling of Miriam: : :  
Thank you very much for marking the typing error.

**20 Fig 2** Please add an indication of the basis on which the taxa shown were selected (ecological importance, abundant: : : ?). It would be helpful to know how many AP taxa are not included (and what proportion of the sum this represents). A curve for “other AP” would demonstrate this (if they are too rare to show, then this needs to be said). The same point applies to the NAP. Also, the curves are black (the fill is white).

We summed all other arboreal taxa in an 'Other AP' curve. We did the same for all other non-arboreal taxa 'Other NAP'. For a better distinction, all arboreal pollen curves are marked in black, whereas all non-arboreal curves are presented in grey. All exaggerations are marked in white (fill).

**21 Fig 3** Please indicate on what basis the MIS equivalents are assigned. Even if this is addressed in another paper, for this paper to make a convincing case, it needs to be said here too.

We revised this figure. We added the LR04 isotopic record after Lisiecke and Raymo (2004) and rewrote the caption as follows: 'Comparative study of Lake Van paleoenvironmental proxies during the penultimate interglacial-glacial cycle. (a) LR04 isotopic record (in ‰ VPDB) with Marine Isotope Stage (MIS) boundaries (grey bars) following Lisiecki and Raymo (2004); (b) Insolation values (40°N, Wm<sup>-2</sup>) after Berger (1978) and Berger et al. (2007); (c) Lake Van oxygen isotope records  $\delta^{18}\text{O}_{\text{bulk}}$  (‰ VPDB; new analyzed isotope data including the already published isotope record by Kwiecien et al., 2014); (d) Calcium/potassium ratio (Ca/K) after Kwiecien et al. (2014); (e) Fire intensity at Lake Van (>20  $\mu\text{m}$ , charcoal concentration in particles cm<sup>-3</sup>); (f) Selected tree percentages (total arboreal pollen (AP), deciduous *Quercus*, and *Pinus*) including the pollen data from Litt et al. (2014); PAZ – Pollen assemblage zone. Termination III at 250 ka, TIIIA at 223 ka and TII at 136 ka are indicated after Barker et al. (2011) and Stockhecke et al. (2014a).'

**22 Fig 4** Add a statement to explain on what basis the interglacials illustrated here (MIS 5e, 7e) are defined (because under some definitions, 7c could also be an interglacial).

Due to general improvements of the chapter '4.2 The penultimate interglacial complex', we added the definitions of interglacial/interstadials as well as the correlation with terrestrial temperate intervals with Marine Isotope Stages in the discussion (see replies above).

**23 Fig 5** Inclusion of AP-PJB% from Ioannina (as well as AP%) would have been more informative as this signal is more sensitive to climatic fluctuation and picks out a very similar pattern to that in lake Van: : e.g. the minor decline of temperate tree populations associated with MIS 7b and a post-MIS 7a millennial scale oscillation.

Caption: Is it a "correlation scheme" if each curve is presented on its own timescale? There are some pronounced offsets in the timing of major vegetation changes which seem too large to be real and are likely to be exaggerated by age uncertainties.

Could you clarify how this diagram was constructed (in the caption if not in the text), where timescales align NECESSARILY (because of the way the age models have been developed, for example) and where timescales are the original published ones (and the sources for those age models: : for example, have you placed the I-284 curve on the GL synth timescale, or on the timescale published in 2008?). Without this kind of information, it is difficult for the reader to understand the significance of apparent alignments and offsets.

We have added the AP-PJB% pollen curve from Ioannina, because this curve shows some new information to climate changes/fluctuation during the penultimate glacial. We also added the AP-PJ% pollen curve from Tenaghi Philippon to the figure to get additional information about regional climate fluctuations.

Concerning the different timescales of each climate archive, we revised the caption as follows: 'Comparison of Lake Van pollen archive with terrestrial, marine and ice core paleoclimatic sequences on their own timescales.'