

William Fletcher

Thanks to his review, we added and clarified specific changes.

General comments

This manuscript by S. Joannin and co-authors presents new findings of multiproxy (palynological and sedimentological) research at the site of Lake Ledro in the southern Alps. The manuscript contains a wealth of new data and presents important insights into regional patterns of vegetation development and inferences about climatic changes during the Lateglacial and early/mid Holocene. The study is based on a sound methodological approach (although some specific clarifications are requested below), and the interpretation is supported by extensive linkage to the relevant regional literature. The manuscript is supported by clear and useful tables and figures. The manuscript aims to integrate the understanding of glacial-interglacial vegetation dynamics (geographical and altitudinal patterns over time) and centennial-to-millennial-scale climatic variability; this approach is exciting and relevant, if nevertheless challenging to fit into one manuscript.

My overall impression is that the manuscript is currently too long, and should be revised to highlight more clearly the key new findings of this study to a multidisciplinary readership. There is some redundancy for example between sections 4.2.1 (Pollen sequence and terrestrial vegetation dynamics) and 5.1 (Pollen-based vegetation dynamics at Ledro and in northern Italy), and other sections could be shortened/deleted (mentioned below). One can imagine that the authors might have considered two separate manuscripts – one examining the implications of the pollen record for regional vegetation dynamics, and one detailing the history of climatic fluctuations as recorded in the combined biotic and abiotic proxies. The authors' decision to combine these topics into one manuscript allows for some exciting insights into the impact of short-lived climate events on longer term vegetation development. However, the authors should be sure to keep a tight focus on this objective, make the links between the two topics very explicit, and make very clear to the reader the benefits of this approach.

During the writing phase of this manuscript and in order to respect the editorial directives we choose in the Lama's project team, we decided to dedicated this manuscript to 1- a description of vegetation changes inferred from the deep core of lake Ledro, 2- a comparison of taxa immigration and development in the southern Alps, 3- a climatic vs human interpretation of this changes. We wanted to deal with these topics in a single manuscript because, if it is easier to read a shorter paper, it is sometimes worth to slalom between two papers in order to get the whole story.

The whole section is almost 200 samples, and of course covers the entire Holocene. So in order to shorten the number of focuses, we finally took apart the four last thousands years which are really dedicated to human impact, and to not extend the vegetation and climate changes to a larger-spatial size (central Mediterranean scale). However, the manuscript remains long, and the redundancy between results and discussion sections is due to the comparison in the last part of the Ledro's pollen record with other records from the southern Alps. Another solution (not recommended by the reviewers) should have been to separate the discussion concerning delay in immigration or development of the four taxa discussed in figure 6, however, this discussion also helps to the comprehension of the climate changes.

Specific scientific and linguistic comments detailed below:

Scientific comments

1. *Abstract Line 1. The authors open with reference to an “ongoing debate regarding vegetation recolonisation in Europe” – can they specify as to which aspect of recolonisation is debated, e.g. the nature? the timing? the rate?*

We added : (more particularly the timing)

2. *Abstract Line 11. After introducing the Latin (and common or English) name for taxa, use only the Latin name in the remainder of the text.*

We used this two nomenclatures as common names applied for plants and vegetation types while Latin names applied for taxa.

3. *P5586 Line 15. Why is comparison with the nearby potential Euganean hills refuge important? The relevance of this geographic factor needs to be introduced more fully.*

We added for this point: [1] they have to be located in the key zone of southeastern Alps which was a potential route for tree immigration from southern Italy and Balkans and for comparison with the nearby potential Euganean Hills refuge (Kaltenrieder et al., 2009),...

4. *P5586 Line 25. Add reference to Fletcher, W.J., M.F. Sanchez Goñi, O. Peyron, I. Dormoy. "Abrupt climate changes of the last deglaciation detected in a western Mediterranean forest record." *Climate of the Past* 6, (2010) 245-264. (This paper is relevant here as it deals with the detection and spatial characteristics of Preboreal and boreal oscillations in the Mediterranean region)*

We added this reference.

5. *P5587 Line 17. The authors state that high resolution for the Lateglacial is one of the key criteria (no. 2) then go on to indicate that this study doesn't meet that requirement. Can some rewording be undertaken to avoid this contradiction?*

We precise: This study provides a low temporal resolution for the early Lateglacial (higher in the upper part), ...

6. *P5588 Line 8. The dominant/characteristic vegetation of the subalpine belt (1600-2000m) seems to be missing.*

We added: The subalpine belt (1600-2000 m) is dominated by larch (*Larix*) and *Picea* and is replaced by grasslands above 2000 m.

7. *P5590 Lines 13-19. The authors might also consider testing the timing of the Holocene onset in the pollen record on the basis of the available radiocarbon dates independently.*

We thought this to be ok, as it comes from the same lake record (i.e. the littoral site) and it is dated.

8. *P5591 Line 4. Which “dominant terrestrial taxa” were excluded? This isn't standard methodology so should be explained.*

In our view, it is logic to exclude the dominant taxa as it avoids to overexpress this taxa when calculating the percentage. It is very important, because if I wish then to exclude the dominant taxa from my calcul it is only possible if it has not been counted appart in the countage. As the taxa dominance change from sample to sample, it will not be helpful to give the list. I have always used this method

9. P5591 Lines 5-6. Clarification needed on the percentage basis. The text states “percentages were calculated based on total pollen” - again this contrasts with the standard practice of using a Main Pollen Sum which typically excludes some aquatic and local taxa so should be explained or reworded if the meaning is not clear.

Sorry for this confusing sentence. We added: Terrestrial pollen percentages were calculated based on total pollen.

10. P5591 Line 24-25 (i). Why do the authors only present the precipitation reconstruction? I would expect that compositional changes in tree species dominance reflected in the pollen record could be influenced by temperature changes.

It is an editorial line decided together with O. Peyron in order to save part of the discussion in her own article.

11. P5591 Line 24-25 (ii). The authors need to explain why *Pinus* was excluded from the reconstruction – it’s a very important taxon in the record with abundances that suggest local presence. Why exclude it then in the search for good vegetation analogues?

We gave a wrong information, so we suppressed “with *Pinus* excluded” and added to the text: To reduce uncertainties, we have applied to the analogues selection a constraint by biomes (Peyron et al., 1998). The biomes assigned to the selected modern analogues are compared to the biome assigned to the fossil assemblage, and only the analogues with consistent biomes are retained for the analogue matching step.

12. P5592 Line 10-11. The authors should give the average temporal resolution for both the upper and lower parts of the core.

We added: “The average temporal resolution for the upper part is estimated to 77 yrs/sample”. We did not give an average for the lower part, as the sampling clearly decreased toward the bottom of the core as shown in figure 4a-b.

13. P5593 Line 14. The authors interpret the record as indicating “open vegetation” – but AP is around 60-70% - this seems too high to be considered open vegetation – perhaps open woodland or forest steppe might be more appropriate terms. Can the authors justify their description with reference to previous studies or modern surface samples?

This description was based on the AP_{wp} which is below 20% (see table 2). Considering the high potential of pollen productivity and transport of pines, it is preferable to observe the curve of AP_{wp}. We replace “open vegetation” by “a mixed-open forest” and it is mentioned steppe-tundra in table 3.

14. P5593 Line 23. Given the previous comment and the rather minor changes in AP values, I’m not convinced that the record for zone LL-3 shows “afforestation” as the authors suggest, but instead subtle but significant changes in the woody taxa composition.

We change this sentence by: From ca. 14100 cal. BP (zone LL-3, Table 2), pollen-inferred vegetation around Lake Ledro indicates a change in the woody taxa composition, illustrated by AP_{wp} increase (up to 60%).

15. P5594 Line 9. “less deep lake” – can the authors be more specific, i.e. less deep than what? Are there any suggested optimum depths for *Volvocaceae*?

It is very difficult to be more specific as the change in lake water depth is unknown for this period and because very few are known about Volvocaceae. Today the lake depth is 48m, so if the lake depth was lower during the lateglacial, we cannot assume a “shallow” lake. This is why we used these words: less deep lake. However we added: less deep lake than today.

16. P5595 Line 3-5. The authors suggest that “a remarkably stable plateau in AP values” leads to the clustering of four subzones. This doesn’t seem to make sense, unless AP percentages were specifically included in the CONISS analysis. The authors need to clarify here or else delete this part. [I also note that the authors don’t indicate in the methods whether all taxa were included in the zonation, or only those above a set abundance threshold.]

We precised: As a result, a remarkably stable plateau in AP values (between 81 and 96%; LL-6) is observed. The CONISS function groups the four subzones (LL-6a-b-c-d).

We didn’t mention that all taxa were included in the zonation, because we wanted it to be the more neutral.

17. P5595 Line 18. Do the authors also consider that Alnus may have developed locally around the lake margins, rather than as a component of the wider forest?

We considered this point of view but as the Alnus development is very fast (immigration and development phases form almost one phase) in the pollen diagram (fig 5) and because it is considered as large synchronic development trough Europe around 9500-9000 cal. BP (Giesecke et al., 2011), it sounded more logical to assume it entered the forest composition.

18. P5596 Line 5. What do the authors mean by a “questionable apparition of Juglans”? Is it the identification or the botanical implications that are uncertain?

No problem with the identification of this pollen grain. But we have to remain careful as it is only one grain in sample at 484.8 cm depth.

19. P5597 Line 13. Again, in light of AP values > 80%, perhaps the interpretation of vegetation change would be better phrased as a reduction/thinning of woody vegetation cover as opposed to a “mixed-open” vegetation development.

We replace by: mixed-open forest. But again, considering the high potential of pollen productivity and transport of pines, it is preferable to observe the curve of AP_{wp}.

20. P5597 Line 16. The authors refer to “three climate deteriorations” inferred from the GRIP ice core. I would recommend presenting a more general statement to the effect that the record suggests rapid climatic variability within the YD. To my knowledge, there is no clearly defined basis for three specific climate deteriorations within the YD, certainly not reported or easily visible in Dansgaard et al., 1993. If this point is very important, then perhaps the Greenland record needs to be shown and records compared on their respective timescales.
We erased this sentence.

21. P5598 Lines 19 onwards. The authors can be more explicit/concise and state that they are inferring repeated low-level agricultural clearance events.

In fact it is not clear that these pollen events are triggered by human impact. We tried to discuss it but in absence of fire history, we cannot go further. We simplify by erasing this sentence: Agricultural activities documented by cereal-type grains and anthropogenic

indicators appeared at ca. 6000 cal. BP, providing a more complete description of human occupation around the lake, which eventually caused vegetation replacement.

22. P5599 Lines 5-17. *This (interesting) palaeobotanical section might be excluded to shorten the overall manuscript.*

To our point of view, this paragraph is useful for the discussion of *Fagus* triggers and therefore strongly needed for the last chapter of this article.

23. P5599 Line 27. *The authors report previous work showing that the assumed pollen % threshold (from 0.5% to 8%) "is not important" – do they mean that these values are too high? – specify for clarity*

We used the sentence from van der Knaap in order to distorted as less as possible their original meaning. However, we try to clarify this sentence and replace it by : This characteristic is confirmed by Van der Knaap et al. (2005) who indicated that the assumed pollen-percentage thresholds (between 0.5% and 8%) are similarly robust when studying spatial patterns (latitude, longitude, and elevation) in migration and/or population expansion.

Moreover, we place below citations of the original article from Van der Knaap et al. (2005).

5.1. Tree migration and population expansion in relation to space (Tables 2 and 3, Figs. 9–16)

In the spatial relationships (latitude, longitude, and elevation) of tree migration (Table 2) and population expansion (Table 3), the results in terms of positive or negative statistical relationship and statistical significance or not are mostly similar for the steps of pollen-percentage thresholds from 0.5% to 8%. In other words, the statistical results are relatively independent of the level of pollen-percentage threshold chosen. The choice of the pollen-percentage threshold used is therefore not that important for the study of *spatial patterns* (or direction) in migration and/or population expansion.

...

The method of using pollen-percentage thresholds for the reconstruction of *directions* of migration and population expansion appears to have some robustness, as results are mostly similar for different thresholds between 0.5% and 8%. For the reconstruction of *ages* of arrival or migration, however, a pollen-percentage threshold appropriate for the taxon should be chosen.

24. P5600 Line 24. *What do the authors mean by "scarcity of p-values?"*

Again it is the word from van der Knaap et al., (2005).

1983). Provided that the present-day altitudinal abundance reflects the ecological optimum of each tree (past and present), it is possible that tree migration was faster and/or population expansion stronger at optimum elevation and slower both at lower and at higher elevation, rather than linear relationships with elevation. Inadequacy of linear regression with elevation is indicated in Table 2 by the scarcity of *P*-values <0.05 for *Abies*, *Picea*, and *Fagus*. The situation may be

25. P5602 Line6. Specify “taxonomic identification of macrocharcoal fragments suggest...”
We change accordingly.

26. P5603 Line 25-26. If this pattern has already been shown previously, maybe less space should be dedicated to the topic here.

It is always interesting to confirm previous observation and hypothesis with new data (including this study and others published since 2005).

27. P5609Line 20-21. The shift from “wet, cooler summers” to “wetter summers” needs some clarification – what is the principal climatic driver here?

We added: [1] stopped between ca. 6000 and ca. 5300 cal. BP during wet, cooler summers (based on the pollen-based temperature of the warmest month; Peyron et al., this volume), and [2] was strong thereafter due to wetter and warmer summers

28. P5610 Line 28. Specify the timescale for the observation of “steady climate change”

The time-scale is in the precedent sentence.

29. Figure 2a caption. Core sites 1,2 and 3 don’t seem to be mentioned in the caption

We added:... sediment cores and of previously studied sites from Beug (1964) (1-3) and Magny et al. (2009) (I-II);...

30. Figure 6. I would recommend showing all graphs on a common x (time) axis, e.g. ranging from 8 – 18 ka.

We have tested this in a previous version of this figure, it is however not helpful to distinguish sites in the case of *Corylus*.

Technical corrections done:

Typographical/Linguistic comments (I recommend these to the authors in a collegial, not pedantic, spirit!)

1. Abstract Line 4/5. Change “Environmental changes that where” to “Environmental changes were”

2. Abstract Line 10. Change “history of distribution tree species” to “history of tree species distributions”

3. Abstract Line 15. I am not familiar with the abbreviation “n.e.” – please check/change

4. Abstract Line 16. Delete “short-lasting” – it’s redundant

5. Abstract Line 22. Change “low” signal to “a weak”

6. P5586 Line 3. Change “record” to “records”

7. P5586 Line 4. Change “refuges” to “refugia”

8. P5586 Line 8. Change “benefit” to “benefitted”; change “retreats” to “retreat”; change “conquer” to “colonise”

9. P5586 Line 12. Change “as it highlights” to “with”

10. P5586 Line 14. Change “cumulate three characteristics” to “meet three criteria”

11. P5587 Line 11. Regarding “relatively” – either specify the size or delete this word

12. P5589 Line 12. Change “primary” to “primarily”

13. P5589 Line 25. Consider changing “the amount of minerogenic material” to “proportions of different minerogenic components”?

14. P5590 Line 16. Typo “therefore”

15. P5590 Line 25 Change "Pollen" to "Pollen grains"
16. P5591 Line 11-12. The wording "This dashed line" is unclear as the previous sentence introduces eight dashed lines – to which are the authors referring?
We erased this sentence
17. P5591 Line 15-16. Delete "(calculated by excluding pine pollen grains)" – it's redundant
18. P5592 Line 4-5. Change "It helps us to perform a consistent age model" to something like "which permits the extension of the age model to..."
19. P5592 Line 14-15. Delete sentence beginning "The scheme appears robust" and simply state that there are strong contrasts in multi-millennial trends/episodes.
20. P5592 Line 20. "From Up"? – check
21. P5593 Line 4. Delete "eventually"
We prefer to let it as it is not always the case (that we observed a common impact of flood events on the pollen concentration)

22. P5593 Line 23 and throughout. Correct spelling of "thermophilous".
23. P5594 Line 15. Change "CONISS software" to "CONISS clustering method"
24. P5594 Line 28. Correct spelling of "sclerophyllous"
25. P5595 Line 24. Change "quasi" to "near"
26. P5595 Line 27. Change to read "as reductions in temperature and coniferous trees..."
27. P5596 Line 16. Change "signed" to "influenced"
28. P5597 Line 14. Spelling "heliophilous" – check throughout
29. P5599 Line 21. Change "shows" to "show"
30. P5599 Line 25. Delete "and discussed".
31. P5600 Line 17. Add Paragraph break .
32. P5601 Line 5. Change "refugee" to "refugial"
33. P5601 Line 8. Change "refugees" to "refugia"
34. P5601 Line 25. Change "is abundantly found" to "found in high abundance"
35. P5602 Line 19. Change "as it is" to "as is"
36. P5602 Line 22. Change "In more details" to "In more detail"
37. P5602 Line 28. Change "temporally" to "temporarily"
38. P5603 Line 14. Change "low pollen levels" to "low pollen level of X%" – i.e. give value again

We cannot specify as the authors didn't specify themselves, please see below (from Van der Knaap et al., 2005)

5.1.3. Picea (Figs. 4, 7, 13, 14)

In contrast to *Fagus*, we must assume (in absence of indications to the contrary) that population expansion of *Picea* followed directly upon immigration independent of a trigger such as climatic shift or anthropogenic disturbance. A low pollen-percentage threshold marks therefore both the approximate immigration age and the beginning of population expansion. The negative

39. P5604 Line 28. Change "difference questions" to "difference raises the question"
40. P5607 Line 29. Change "base on" to "based on"
41. P5609 Line 2. Change "declination" to "impacts" or "expression" and "affected" to "affected"
42. P5609 Line 17. Change "reports" to "report"

43. P5609 Line19. Change “observed” to “observe”
44. P5609 Line 25. Change “benefited” to “benefitted from”
45. P5610 Line 14. Cannot be considered a refugia – specify for which taxa or thermophilous taxa in general?
46. P5610 Line 20. Change “Expansion” to “The expansion”