

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.

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

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.
8. P5591 Line 4. Which “dominant terrestrial taxa” were excluded? This isn’t standard methodology so should be explained.
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.
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.
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?
12. P5592 Line 10-11. The authors should give the average temporal resolution for both the upper and lower parts of the core.
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?
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.
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?
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.]
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?
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?
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.
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.
21. P5598 Lines 19 onwards. The authors can be more explicit/concise and state that they are inferring repeated low-level agricultural clearance events.

22. P5599 Lines 5-17. This (interesting) palaeobotanical section might be excluded to shorten the overall manuscript.
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
24. P5600 Line 24. What do the authors mean by “scarcity of p-values?”
25. P5602 Line 6. Specify “taxonomic identification of macrocharcoal fragments suggest...”
26. P5603 Line 25-26. If this pattern has already been shown previously, maybe less space should be dedicated to the topic here.
27. P5609 Line 20-21. The shift from “wet, cooler summers” to “wetter summers” needs some clarification – what is the principal climatic driver here?
28. P5610 Line 28. Specify the timescale for the observation of “steady climate change”
29. Figure 2a caption. Core sites 1,2 and 3 don’t seem to be mentioned in the caption
30. Figure 6. I would recommend showing all graphs on a common x (time) axis, e.g. ranging from 8 – 18 ka.

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?
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”
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
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 Line 19. 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”