Review of Robles et al.: Climate changes during the Lateglacial in South Europe: new insights based on pollen and brGDGTs of Lake Matese in Italy

General comments:

The manuscript by Robles et al. is generally well written and its subject well-suited for publication in 'Climate of the Past'. The authors present reconstructions of temperature and precipitation changes in southern Italy based on biomarker proxy data and the application of statistical methods on palynological data. The data helps to increase the resolution on the spatial extend of prominent climate fluctuations in Europe and the Mediterranean during the deglacial and will therefore be of interest to the paleoclimate research community.

As the title suggests, both pollen and terrestrial biomarker data are equally important for the reconstruction of deglacial climate change at Lake Matese. However, it appears as if the authors are not quite sure what to make of the biomarker-based mean annual air temperature curve (brGDGT MAAT) as it diverges from other data records. They therefore highlight the need for proxy calibration that is more specific to certain sites or environments, and quite rightly so as this is a general issue. However, MAAT strictly speaking reflects soil temperature. Temperature and export of soil material towards the lake can be influenced by a range of local, catchment-specific factors (soil exposure, preferential erosion) that the authors should discus alongside fluctuation in pollen record and Ti and based on their detailed knowledge of the lake's catchment and local conditions. See below for more detailed comments.

The presentation and discussion of the radiocarbon data used for dating the core could be streamlined. I suggest shifting chapter "4.2 Age-depth model" and chapter "5.1 Validation of age-depth model" into chapter "3.2 Chronology and age-depth model". Establishing the age of the core should be part of the methodology unless, e.g., findings from the radiocarbon data support paleoenvironmental interpretations.

Overall, and I recommend publication of the manuscript following minor revisions.

Specific comments:

line 176: "with a maximum at Campitello Matese (1400 m a.s.l.)" – What is the maximum precipitation, then? This needs a rainfall value.

lines 180/181: "The precipitation is less important in the southeastern part of the massif" – What does "less important" mean here?

lines 256/257: "A simplified pollen diagram was constructed with the R package" – I assume, this diagram is incorporated in Figure 2? Please, refer to the figure. For readers used to looking at extensive plots of palynological data it could be emphasised here that variations of individual species are not the focus of this study. However, the complete data should be provided, e.g., as supplementary material.

lines 321/322: "The analytic**al** reproducibility was assessed based on a sediment internal standard." – Which compound was used as standard? How was 'reproducibility' assessed without duplicate analyses or duplicate extractions? Or do the authors mean analytical precision?

lines 387/388: "most of the 14C dates (Table 3) are not included in the age-depth model" – It would be good to know why exactly most of the radiocarbon dates were omitted rather than being referred to the good match of the pollen curves and tephra dates. In chapter 5.1, the authors speculate that root penetration may be the cause for biased 14C ages. It would be good to bring this point forward.

lines 409/410: "At the transition with phase 4, a significant decrease in the precipitation parameters is recorded." – It would be worth pointing out that this coincides with the maximum amount of *Artemisia* pollen and a peak in Ti. Is there a causal relationship or could catchment processes be responsible for this? Notably, the brGDGT-derived parameters show some fluctuations there, as well.

lines 540-546: "Lake Matese is located at an altitude of 1012 m a.s.l. and the strong seasonal variability may have influenced the brGDGT distribution. Moreover, the Lake Matese climate reconstructions are based on several global lacustrine calibration datasets, which may not be well adapted to reconstruct paleotemperatures in the Mediterranean region. According to Dugerdil et al. (2021a), local calibrations perform better to reconstruct more reliable absolute values. Unfortunately, at date, only a few global lacustrine calibrations are available, and a local calibration dataset for the Mediterranean region is still missing" – It is highly likely that site-specific factors hamper the application of more general calibrations. However, these factors are currently not discussed. For example, brGDGT-derived temperature values strictly speaking, reflect soil temperatures and are not necessarily linearly related to air temperature. This is particularly true for high-altitude settings where thin soils exposed to sunshine may warm up significantly beyond the actual air temperature while soil temperatures in shaded areas, e.g., under forest vegetation are closer to the temperature of the air. In an attempt to develop a local brGDGT calibration for the Lake Ohrid Basin (Albania, North Macedonia), I determined brGDGT-based MAAT values along a west-facing 1000m altitude transect where all values from forested areas show an excellent correlation with altitude. However, the by far highest value came from a thin, rocky soil exposed on a plateau above the current tree line (unpublished data). Thus, one might speculate that, at Lake Matese, the effect of shading from enhanced tree cover may be responsible for the missing difference in brGDGT-derived MAAT values between Phases 2 and Phase 3. Changing supply of brGDGTs from different parts of the lake catchment may also be responsible for this, e.g., enhanced supply from areas where the soils were not consolidated by tree cover and more susceptible to erosion in Phase 3 or from areas facing different directions (North vs. South). For example, the sediments of Lake Ohrid recorded much higher brGDGT-based MAAT values prior to the major expansion phase of the lake. This may be explained by the associated drowning of wetlands, some of which were likely to include peatbogs without tree cover and dark soils supplying brGDGT that would bias calculated MAATs towards higher values (Panagiotopoulos et al., 2020). Some anecdotal observation of my own: on a sunny day in the field, the water in a dark pool in a peatbog at ~1800m altitude in Albania exceeded 30 degrees C.

I therefore suggest that, with the benefit of detailed knowledge of Lake Matese's catchment, the authors discuss possible mechanisms that may modify brGDGT-derived MAAT values one way or other rather than pointing out shortfalls of specific proxies and calibrations. As with many other proxies (e.g., C/N, bulk d13Corg), brGDGTs probably produce correct values of the soil temperature at their specific source, it's just a matter of knowing the dynamics of different sources and local factors in order to interpret their variability correctly. Some of this discussion is already presented, e.g. in Chapter 5.3.2, lines 658-660.

line 559: "Molecular biomarkers are considered as indicators of annual temperatures like brGDGTs (this study) or alkenones […]" – brGDGTs can only be produced by soil bacteria when the soil is not frozen, i.e. there may be some bias towards the warmer seasons, particularly in high-altitude settings. Alkenone-based SSTs are not annual average values, either as marine haptophytes do not thrive year-round. Alkenones are mainly produced during the chlorophyll maxima in spring and early summer before the nutrients of the seawater are depleted. In the Mediterranean, nutrient loads will also vary with climate and, thus, change the growing season for alkenone-producing haptophytes. Alkenone-based SSTs are generally highly accurate, with very low analytical error and much stronger calibrations than GDGTs. Changes in the main growing season and in ocean circulation will have to be considered for a correct interpretation of alkenone-based SST values.

lines 649-651: "At Matese, a decrease of temperatures is evidenced by the pollen-based reconstructions, but it is less clear from the brGDGT-based reconstructions." – This is where factors such as the effect of shading, exposure or changes in source area could be discussed.

line 653/654: "The basin size of the Lake Matese is larger than 5 hectares, which suggest a signal of regional vegetation rather than local […]" – I would have thought that the size of the pollen catchment strongly depends on local topography, i.e. altitude and the surrounding morphology. The majority of pollen grains settles close to the source. Thus, if a lake basin is situated at elevated altitude and surrounded by mountains, I would expect a local pollen signal rather than regional. The relatively narrow range of species present in the Matese record would support this. Perhaps, the authors could elaborate on this?

lines 658-660: "high erosion rates in the catchment […] could favour greater soil-derived brGDGTs and induce a warm bias in temperatures […]" – This is almost certainly the case. Similarly, the minimum in brGTGD-derived MAAT during the BA may be caused by the erosion of soil strata carrying a cooler climate signal following hydrological changes in the catchment. Does it coincide with a peak in Ti, for example?

lines 672/673: "In terms of precipitation, the marine cores located south of latitude 42°N record a slight temperature increase based on pollen" – How is the temperature change linked to precipitation here?

lines 688/689: "in northern sites an abrupt increase of precipitation is recorded" – This is certainly true for the data by Li et al. (2021). However, the record from Corchia cave appears very low resolution, so "abrupt" probably does not apply here.

lines 699/700: "their reconstructions are also influenced by a record from Bulgaria which ~~can~~could potentially have biased the signal of Southern Europe" – I fail to see the causal relationship here. How would a data record from Bulgaria "bias" proxy data from Southern Europe?

Technical comments/corrections:

line 49: Replace "wet" with "wetter".

lines 54, 720, 749, 757: Replace "On the contrary" with "By contrast".

line 72: Replace "bec**o**me" with "bec**a**me".

lines 98/90: Replace "in **the** Southwestern Europe and Mediterranean area" with "in Southwestern Europe and the Mediterranean area."

line 91: Replace "North**-W**est" with "Northwest".

line 126: Replace "reconstruction" with "reconstruct**ing**".

line 127: Replace "somewhat unknown" with "elusive".

line 142: Replace "study" with "studies".

line 171: Surely, the lake does not have a volume of merely 15 mm^3? That would be drop.

line 182: Insert “the” before “mountains”.

line 195: Replace “Coring” with “Core”.

line 142: Replace “master” with “composite”.

line 225: Replace “based on radiocarbon dates and correlated tephra ages” with “based on **one** radiocarbon **date** and correlated tephra ages”. Clarifying this here means that the readers won’t have false expectations with regard to the radiocarbon dating.

line 252: Replace “counts” with “concentrates”.

line 261: Replace “more” with “greater”.

line 272: Delete “The” before “WAPLS”.

line 281: Insert ‘p’ in “bootstrap**p**ing”.

line 282: Replace “applied on” with “applied to”.

line 327: Introduce the abbreviation “CBT” (cyclisation of branched tetraethers).

line 337: Insert ‘±’ before “0.040 for CBT” and other values.

line 346: Replace “geochemistry” with “XRF” for specification.

line 347: Insert ‘the’ before “Matese core”.

line 349: Replace “macroscopic” with “macroscopic**ally**”.

line 419: Replace “dotted” with “dashed”.

line 670: Delete ‘s’ in “appear**s**”.

line 710/711: Replace “in” with “for” in “not reconstructed in this region”.

line 714: Replace “into” with “in” before “the Mediterranean”.

line 715: Insert comma after “latitude 42°N”.

line 735: Replace “South Central” with “Central Southern”.

Figures:

If possible, add small symbols to the data points in all proxy records so that the reader can get a better idea of the resolution of these records.

Figure 3: Replace “Gray bands are 95% confidence intervals” with “The gr**e**y band is the 95% confidence interval” (I can see one grey band, only).

Figure 5: For better comparability with Figures 9 and 10, please insert the climate stages OD, B/A, YD and EH into the plots, at least the ones at the bottom.

Reference used in this review:

Panagiotopoulos et al. (2020): Insights into the evolution of the young Lake Ohrid ecosystem and vegetation succession from a southern European refugium during the Early Pleistocene, *Quaternary Science Reviews*, 227, 106044, doi.org/10.1016/j.quascirev.2019.106044.