

Interactive comment on “The case of a southern European glacier disappearing under recent warming that survived Roman and Medieval warm periods” by Ana Moreno et al.

Anonymous Referee #1

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General comments The paper is interesting and reports worthwhile chronological and elemental data, interpreted in terms of recent intense ablation removing ~600 years of ice from MPG (despite the glacier surviving warm times before then). Unfortunately, as presented, I am not convinced the data analysis supports the main conclusions and I cannot recommend the manuscript be published in its current form.

First and most importantly, I believe the chronology needs to be addressed with greater structure and formal rigour. For example:

• Since this is so central to the paper’s message, I find the translation from lateral surface samples to depth too difficult to follow in detail.

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• It appears seven of 17 age samples were dismissed from the analysis; these need detailed comment on each.

• The interpretation of debris-rich englacial layers as periods of ablation (concentrating the debris) needs a far more rigorous argument based on physical analysis and exclusion of alternative possibilities. At present, the reader does not know whether these are isochronous, or whether they deform passively or cut-across primary layering/stratification. Could they be basally-derived? How are supply-rate variations excluded?

• How were the three core samples (and two deep samples) combined with the ~100 surface samples?

• Since the annual 0 deg. C contour is at ~3,000 m why wasn’t snow/firn/ice sampled from the upper glacier. This glacier seems all to lie above this elevation and may therefore be accumulating, providing an undisturbed record of accumulation change?

• For me, too much key material seems to be given in the supplementary information rather than forming a central part of the argument of the main paper.

• For comparison, what elemental values have been measured in recent ice (not snow/firn)?

Second, substantial relevant material relating to the chronology of MPG appears later in the manuscript when I believe it should be summarised in full in the Introduction, directing the specific aim and objectives of this study. In my view, it’s fine to introduce related information in the Discussion (such as the chronology of lakes in the area or of broader Alpine glaciers), but material directly relating to MPG - and particularly the focus of this submission (i.e., its chronology) - should form relevant background material in the Introduction.

Third, I found several of the sections and their contents to be confusing. For example, what I consider to be results are presented in the Field Site and Methods section, and

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I would separate Results from Discussion.

Specific comments

Note, the manuscript includes many slight grammatical and typographical errors, as well as a few stylistic imperfections, which I have mostly not corrected. For me, the meaning was almost always clear, if not grammatically perfect.

Line/Location Comment/Suggestion

1 Title is awkward because 'that' is unspecified.

47 I'd avoid 'proves' unless the sentence states 'if we assume the chronological model is correct...'

54-55 This claim needs to be supported by a rigorous analysis.

94-105 I'd invert this: state the aim of the paper and then state how it was achieved.

141 Data need to be presented and analysed to substantiate the claim that '(GPR and modelling)... suggested that the oldest ice could be located in these areas.' This claim is central to the chronology presented in the manuscript.

161 1 m of what? A Jacob's staff should be described, or just use 'staff'.

175 Which 'uppermost five samples'?

175-6 These are Results

176-8 This is Interpretation

186-96 These are a mixture of Results and Interpretation. What values would be expected or have been measured on accumulating glaciers in similar settings?

209 How and where did these samples come from? How were they treated?

231-2 Why a second-order polynomial/quadratic? If there is a theoretical basis for such a relationship, then that should be presented. If there is not, then what justification is

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there for this form?

234-8 This argument relating to debris concentration by ablation/low accumulation needs substantial background and argument, including arguments for this interpretation and against alternative interpretations of englacial debris bands. For example, how are supply-rate variations or a source at the glacier bed excluded?

288-91 These arguments need formalising, expanding and presenting as a logical progression of argument; currently, it is difficult to evaluate the accuracy of the chronology because this logical progression in argument (supported by illustrated data) is missing or split up through the paper and supplementary information.

281- I find this section difficult to follow since in some places Results have already been presented and they are only referred to here (e.g., 306-8) or Results are mixed with Interpretation, and in some case Methods are included here (318-27). In relating to the last point, I'd discuss sample removal from analysis in Methods and not Results.

328-30 These criteria should be discussed in full and presented in Methods rather than Results.

333 I'd bullet or number these three main periods and interpret consistent/repeated data across all three.

361- I'd move much of this into a dedicated Discussion section

412-26, 434-7 & 467-70 I'd move this published material relating specifically to the chronology of MPG to the Introduction. That way it would contribute to, and form the framework/rationale for, the aims and objectives of the present study.

Fig 1 Needs panel letters and I would find it easier to interpret if both had a similar orientation. Precise sample locations are needed. Are the locations of the three cores and the two deep samples noted here?

Fig. 2 Y axis states 'h' but caption states 'depth'. 'h' is undefined, but appears to be

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height above bed. I know this depth scale is determined by translating the surface transect but it needs formal presentation and geometrical-dynamic argument and an error analysis. What flow model was used? If a flow model was not used, then at the very least the 3D surface geometry of the sample profile needs to be presented and the geometrical translation illustrated – in the main text. Is the glacier 100 m deep at present? Where in the glacier does this model relate to?

Fig. 3 Show uncertainty in elemental ratios. Panels need labelling.

Recommendations

I would combine all that is currently published relating to the chronology of MPG into the Introduction and then recast the aims to address a clear knowledge gap. For example, it is already known that the glacier has lost ~40 m of ice since 1980. If so, roughly how many years of accumulation does this cover and, if we are not sure, then can that – along with the existing chronology - form the basis of rationale for a chronological study based on flow-line surface sampling. Why here and not in the upper glacier?

An age-depth model derived on the basis of the analysis of samples from the ablation area of an ablating glacier is not a trivial glaciological advance. I think this should form the main aim of the paper and be presented and argued in a logical and formal way, with relevant data presented in the main text and not supplementary information. Having done this, I would like to see a rigorous assessment and inclusion of all uncertainties involved in the age and depth scales, included in Figures such as current Fig. 2. I realise this cannot be achieved with great confidence, but I imagine it can be approximated.

(i) Methods, (ii) Results, and (iii) Interpretation/Discussion/Conclusions need to be separated clearly. As a minimum, Results need to be separated from Interpretation and Discussion.

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