Dear Nicolas Coltice,

Thank you for providing useful suggestions for the manuscript. We agree that using the correct terms is important, so we revised the text to use the term inversion instead of data assimilation. We agree that the reported uncertainties resulting from the inversion procedure are not sufficient to represent the overall uncertainties of the model. In the revised ms., we show multiple models to assess the effect changes in input parameters to modelling results and discuss further the influence of assumptions and simplifications we made on the temperature estimates. Please find our detailed point-by-point responses to the comments below.

Kind regards,

Eszter Békési and co-authors

COMMENT #2 by Nicolas Coltice

The manuscript present a thermal reconstruction study of the Hungarian area of the Pannonian basin. It describes a new inverse methodology in order to obtain tectonic information on lithosphere thinning in the area. First of all, I state here that I am more a specialist of modelling than on the tectonics and geothermics of this area.

My point of view is the qualities of the manuscript lie in:

- the new methodology employed to get information of the deep lithospheric structure from temperature measurements.

- pushing the result towards interpretations on rheology and xenolith depth origin.

My opinion is that the shortcomings of this manuscript are:

- it is difficult to estimate if the method is able to improve the knowledge of the deep lithospheric structure, especially in a hot and thin crust area in which hydrothermalism and deformation/melting are present. Before inversion, the prior has already a very small misfit (1.33°C). I guess that the uncertainties on the depth of the different layers can introduce such misfit on its own (the thermal gradient is around 40°C/km). The misfit is improved through the process (0.43°C), but is it significant? Since we don't have here an analysis of how varying the properties of rocks and depth of interface within uncertainties impact the mist, it is hard to know if the authors can resolve the deep lithospheric thermal structure. Given the low value of the misfit prior to inversion, I would say no.

We revised the manuscript to comment further on the uncertainties of input parameters as well as a discussion on the limitations of the model. It is indeed an important point that the misfits prior to inversion were also low in the presented model (we show more scenarios in the sensitivity analysis of Appendix A). Although these reported uncertainties do not reflect the overall uncertainty of the model in the deep lithosphere, from which no direct constraints are available. Therefore, we emphasise in the revised ms. that the temperature estimates are valid

for a specific case of input parameters. Still, we think that the carefully selected model parameters allow for a realistic estimate of past-and present-day thermal field as well as the amount of lithosphere stretching through basin formation.

- the method is not a data assimilation method. Data assimilation, which is mostly used for chaotic models with butterfly effect, means that there are new data than can be assimilated (correction of the model) in time. Here, the observations are present-day only. So it is a classical inversion problem with a new methodology. This is a detail but it is worth to use the proper terms.

The used methodology is ES-MDA, which is a data assimilation method according to the Emerick, A. A. and Reynolds, A. C.: Investigation of the sampling performance of ensemble-based methods with a simple reservoir model, Computational Geosciences, 17, 325-350, https://doi.org/10.1007/s10596-012-9333-z, 2013b. We agree with the reviewer that it is used here for inversion for present-day data in agreement with synthetic studies in Emerick&Reynolds, and not progressively updated for incoming data. To clarify data assimilation has been changed to inversion workflow and use of data assimilation has been limited to section 3.4.

- most of the figures/captions require additional information.

Minor details along the text:

- Fig.1: explain more clearly why the country borders are used for the study (it is stated later in the text but it would be good to have it here)

We added the explanation of the study area extent to the caption of Fig. 1.

- Fig.2: orientation is missing (NW - SE)

Orientation added to Fig. 2.

- line 100: how is the LAB defined here? The study is thermal, so it would be good to explain.

We extended the text with the 1330 ºC prescription of LAB temperature.

- Table 1: the table is not very informative. Is it possible to either a graph or more details on how the variations are produced?

We could not find a better way to represent the values, but we extended the description of thermal properties in the text.

- Figure 3: Why gray, green and black circles for the same information? What does the color mean?

We revised and simplified the figure.

- line 146: that would be nice to have more details for the errors. Citing the papers of the first authors does not seem enough to evaluate where they come from.

We revised the errors associated with the measurements, please also see the previous comment of reviewer #2.

- line 159: remove statement on the inverse modeling. This is the forward model section and it is fundamental to distinguish the difference between the forward and inverse model.

We removed the statement and only mentioned inversion referring to the separate section.

- line 173: why 120km for the LAB?

Revised and explained in the revised ms.

- line 178: typo 'preduction'

Corrected.

- line 204: what is unrealistic? More details are needed here to evaluate how the authors rule out a model.

We added a more direct description. The subcrustal stretching factor of only slightly more than 1, predicted for the Transdanubian Range in Lenkey 1999, would results in a thermal field that is almost identical with the pre-extension thermal field, which is unrealistic considering the present-day LAB depth (Kalmár et al., 2023).

- equation 3: misplaced parenthesis

Corrected.

- section 3.4: more theoritical details on the inversion method would be good. Why this one and not another one? Where does equation (4) come from and why is it adapted to the problem?

We think the provided description is sufficient for an overview, and we refer for more details to the original papers describing the applied inversion procedure.

- line 248: explain what a variogram is? Provide a figure?

We added a short explanation to the revised ms.

- Figure 6: large errors in the hottest spots. Explain please.

For each well location, the maximum error is reported on the map. We added more description on the potential sources of the misfits in the ms., that can originate from measurement errors as well as local variations in thermal properties and compositions that are not included in the input model.

- Figure 7: the choice of colors make it difficult to read (black and blue lines especially)

Corrected.

- *line 294: ref missing*

Corrected.

- *Figure 8: same for colors*

Corrected.

- *Figure 10: what are the units?*

The title of the figure shows that the unit is MPa.