

## General response

We thank the two anonymous reviewers for reading our article carefully and providing constructive criticism. We have done further work to account for their suggestions and to address their concerns. In summary, we reduced the length of the paper removing some, not strictly necessary, parts; we highlighted the advance of our paper compared to recent literature on the same case study; and we incorporated the reviewers' suggestions to improve clarity in certain points. We believe that the Reviewer's comments substantially improved the manuscript. The detailed responses are provided in the two attached pdf files. The reviewers' comments appear in black font and our responses in red. All line numbers in the response documents refer to the lines in the revised manuscript without Track Changes (the manuscript is also provided with Track Changes).

### Point-to-point response to Reviewer #2

#### General comments:

Firstly, I congratulate the authors for a very well organized and presented manuscript. It must be noted that it is not always easy to summarize and present such a multidisciplinary work, spanning different approaches, and the authors were able to provide this in a very clear and organized way, and furthermore, in a relatively concise way, which is also not easy. The quality of the writing is very good, thus very clear for the reader, and the text avoids being too "heavy", so being easy to follow.

The manuscript is well structured, with the Abstract and Introduction stating in a clear way the motivation and objectives of the work. The same is valid for the Methods, which are presented in a sound way, providing, as said before, a clear structure of the work flow, despite the complexity of the multidisciplinary approach.

As a consequence, I believe the manuscript is very close to a format suitable to be published. Accordingly, I have just some small comments, which could enhance some small parts/sections. Besides that, I have only a few minor comments regarding one or two less clear sentences and/or typos.

We sincerely thank the reviewer for their positive feedback on our work and for their suggestions that helped improve the accuracy of the manuscript.

#### Specific comments:

- L58-60: While I understand the idea in this sentence, I find it presented not in the best way. I would probably suggest the authors to be more specific regarding this specific event.

Thank you for the suggestion, we rephrased to make it more specific (lines 58-60):

"A probabilistic attribution assessment of the heatwave in Germany showed that such events of prolonged heat have become more likely due to anthropogenic global warming."

- L286: How did the authors estimate the impact and potential loss of confidence from regridding the ERA5 data?

Thank you for this comment. Due to the difference in resolution between models and observational/reanalysis data, regridding is a very common procedure to facilitate comparison. Here, we used the 'remapbil' function in CDO, which is commonly used for such applications. To make sure there is no significant difference between the "raw" and the regridded ERA5 data, we calculated the cumulative

heat for the 2018 summer in both cases (the point shown with a white “X” in Fig. 9) and when scaled for the different amount of grid cells, the two values are almost identical (i.e. 1.90 °C without regridding, and 1.92 °C with regridding). The values are also identical for 2010, which was the year with maximum cumulative heat in Europe (in both grids ~4.014 °C). Therefore, we are confident that the regridding does not affect the reliability of the data in representing cumulative heat over Europe.

-L309-311: Why this specific timeframe?

We decided to use a 30-year timeframe within our attribution system in agreement with a climatological timeframe (according to the World Meteorological Organization - WMO recommendation, see for example: <https://www.ncei.noaa.gov/products/wmo-climate-normals>) to have a sufficient number of years available per model ensemble while keeping the length of the time series short enough to minimise the effect of a non-stationary climate system. The selection of the particular 30-year timeframe (1985-2014) was based on the CMIP data availability, with 2014 being the last year for which CMIP6 historical simulations are produced. We acknowledge that the time frame could be extended using scenario simulations from CMIP6 to the end of 2020, which is the last year for which Detection and Attribution Model Intercomparison Project (DAMIP) data are available, however, we decided to focus our analysis on the historical simulation period of CMIP6.

- Regarding feedbacks between soil moisture deficit and heatwave amplification, while the presented material and evidence is in my point of view more than sufficient for this multidisciplinary approach, I would probably appreciate some more discussion on the soil desiccation mechanisms, and the approaches/methodologies to address this relatively complex subject, which have for example been very well discussed (e.g. 2010 European HWs) in works such as the ones from Miralles et al. (2014), or Schumacher et al. (2019).

Thank you for the suggestion. We added a couple of sentences and references on the feedbacks between soil moisture deficit and heatwave amplification in the Introduction (lines 126-129) and Results (lines 493-496, 517-519).

- L430-434: I understand the local/regional description, however this may be somehow slightly misleading. I am not sure if extreme heat and temperature records in NW Iberia related with the advection of a Saharan air mass could or not be completely defined as “regional”. In particular, the role of the advection of desertic air masses (associated with ridge activity) for Iberian heatwaves has been discussed in Sousa et al (2019).

With the use of “local” origin of the air masses here, we refer to the closer origin (Northern Africa) of the air masses over the Iberian peninsula, compared to the “remote” origin of the air masses over Scandinavia and central Europe, which are found over the central North Atlantic. However, we understand the reviewer’s concern and we rephrased this paragraph to convey the correct message, also referring to Sousa et al. (lines 421-423).

#### **Minor comments:**

- L467 (and other instances): “warm conveyor belt”

Thank you for spotting this, it has now been corrected throughout the manuscript.

- Fig.6 seems a bit too stretched vertically

We corrected this.

- L547/551: I suggest adding here in brackets the period considered for ERA5 and “recent climate”

Thank you for the suggestion. We added the period for ERA5 and “recent climate”, which is the same one, 1979-2021. Note that in the original version of the article, the ERA5 period was mentioned wrongly as 1950-2021 in this paragraph and this has now been corrected (lines 536, 539-540).

- L618: has warmed ~2°C since when / compared to?

This is compared to pre-industrial levels. We added this to the text (lines 610-612) .

- L662: please put the mentioned UK record into context (very briefly of course, dates, etc.)

Thank you for this suggestion. We assume this refers to L622, where indeed the 2022 UK record was brought up without context. We were referring to the exceptional heatwave that affected large parts of the UK on 18-19 of July 2022, and we added this to the text (lines 614-615).