Response to the editor:

We highly appreciate and are very thankful for the time and effort that was invested in reviewing our manuscript. The detailed and constructive feedback will help us to improve the manuscript. In the following, we provide an answer to each comment brought up by the editor and reviewers. The original comments are in italic red while our responses are in black.

Title: Recommend replacing with the word "driver" with "preceded," driver implies causality which is not explicitly shown in this paper.

We agree with the editors suggestion and plan to change "Extremely Warm European Summers driven by Sub-Decadal North Atlantic Heat Inertia" to "Extremely Warm European Summers preceded by Sub-Decadal North Atlantic Heat Accumulation".

L 27 please specify "different ocean-related quantities"

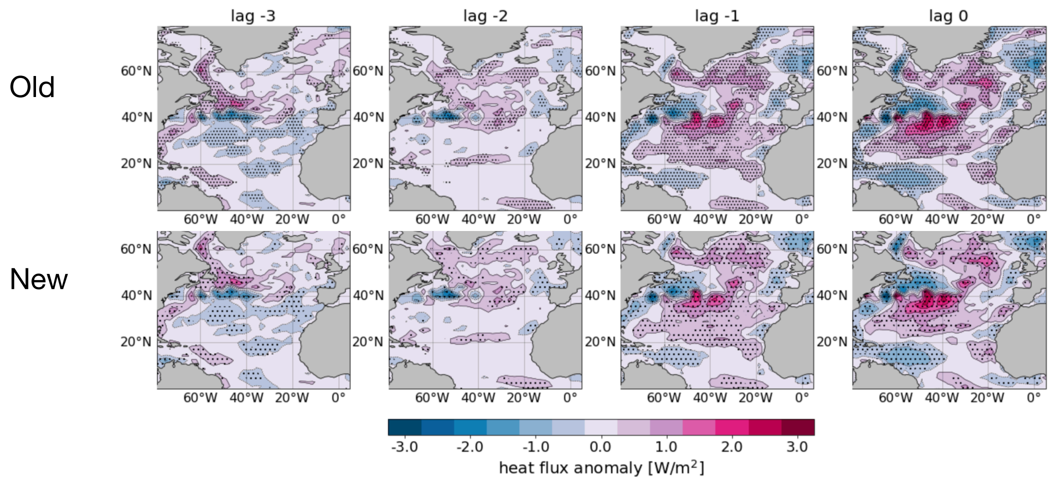
The different ocean related quantities refer to the overturning stream function, ocean heat content, barotropic stream function, and sea surface temperature. In order to specify this term, we will change this sentence to "The variability in the North Atlantic region for different ocean-related quantities, such as the overturning stream function, ocean heat content, barotropic stream function, and sea surface temperature, indicates a fully coupled atmosphere-ocean cycle with a period of about 7-10 years".

L59 please explain the taper method

The multi-taper method after Arthun et al. (2018) is a spectral analysis technique used to estimate the dominant frequency of time series data by decomposing the data into a set of orthogonal tapers and computing a set of spectral estimates. The dominant frequency is then identified as the highest spectral peak in the resulting spectrum, which helps to characterize and understand the dominant oscillatory patterns and variability of the data over time.
For clarification, we will add this explanation to the corresponding paragraph.

L68 Please also control for the false discovery rate -> see Wilks https://doi.org/10.1175/BAMS-D-15-00267.1

We want to thank the editor for this suggestion. We will calculate the p-value from our 1000 bootstraps and control for the false discovery rate (equation 3 in Wilks et al. 2016) with a chosen control level of α_{FDR}= 0.1. Preliminary tests show no substantial effect on our results, e.g. for the heat flux anomalies:



L72ff Please add equations to the explanations for clarification

We agree with the editor and will add physical equations for completion of the equation that already exists in written out form.

L82 Please mention how the anomalies are defined?

The anomalies are calculated by removing the long-term climatological average defined in the period 1850 to 2022.

L105 mechanism --> pattern

We will change “mechanism“ to “pattern“.

L112 Please explicitly formulate the suggested causal relationship

In this case, the causal relationship refers to the relationship between North Atlantic heat inertia (cause) and extremely warm European summers (effect). In particular, we analyze if the oceanic variability in the North Atlantic can influence atmospheric circulation patterns via heat accumulation and release, which in turn could lead to extremely warm European summers. We will rewrite this sentence to be more precise, such as “To test the relationship between ocean inertia and extremely warm European summers, we analyze if the oceanic variability in the North Atlantic can influence atmospheric circulation patterns via heat accumulation and release which in turn could lead to extremely warm European summers. First, we analyze the ocean heat content, which influences the temperature gradient between the ocean and atmosphere and thus alters the rate of heat exchange and is therefore a driver for the ocean-atmosphere heat flux.“

L113 gradient --> difference

We will change “gradient“ to “difference“.

L132 Please explain for a non-oceanographer how the barotropic stream function can alter the path of the currents? The stream function is per se only a diagnostic measure.

We agree with the editor that the barotropic stream function is per se only a diagnostic measure and therefore, it can not alter the path of the currents or accelerate/slowdown them. We will revise the manuscript accordingly.

L149 Why do we know that the heat is coming from the ocean?

We thank the reviewer for bringing this up. Since the mechanism we analyzed evolves over several years in the North Atlantic ocean, which includes the accumulation of heat, we conclude that the ocean is warming the atmosphere via the ocean-atmosphere heat flux rather than the atmosphere is cooling the ocean. Our conclusion is also supported by the positive sign of the heat flux anomaly (indicative of heat flux transfer from the ocean to the atmosphere).

L156 How do you know that this is a block and not just a high-pressure system?

The fact that we analyze summertime means, together with the weaker jet stream, leading to more stationary weather conditions, lead to the conclusion that this is at least a long-living high pressure system, favoring a blocking situation. A detailed analysis is in fact pending.

L158 How does it confirm the connection between the sub-decadal variability – please explain in more detail.

We agree with the editor, that this sentence needs to be expanded to explain the mentioned connection, which refers to the identification of the link from North Atlantic ocean heat inertia over specific atmospheric conditions (such as Scandinavian Blocking) to extremely warm European summers. We will extent and rewrite the sentence accordingly, such as "The Scandinavian Blocking can drive heat extremes over Central Europe (Spensberger et al., 2020)), and confirms the connection between sub-decadal North Atlantic ocean heat inertia leading to specific atmospheric conditions to extremely warm summers over Central Europe."

L160 The link between weaker jet streams and blocks is still contested, there are also arguments that a weaker temperature gradient results in a reduced blocking frequency see e.g., https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2014GL060764

We thank the editor for bringing this to our attention, to reflect this, we will soften our statement to "Additionally, some studies show that the weakening of wind speeds during extremely warm European summers can increase the probability of atmospheric blocking (Woollings et al., 2018), which would in turn increase the likelihood of heat extremes (Kautz et al., 2022)."

L161 I disagree with the statement that you show how the heat fluxes lead to blocking, this point needs to be further substantiated.

We have to apologize for this confusion. Our statement is perhaps a bit too overstated and we plan to tone down our wording. Here, we want to say that the heat flux anomalies can influence via the warming the atmosphere the atmospheric circulation and could thus affect the occurrence of long-lasting high-pressure systems such as blocking. Change to "Thus, we show how long-term North Atlantic heat inertia leads to accumulation of heat and an above average ocean-atmosphere heat flux, which can influence via the warming the atmosphere the atmospheric circulation and could thus affect the occurrence of long-lasting high-pressure systems such as blocking".

Figure 1 Please indicate how many events contribute to the composites

We have to apologize for the confusion. In figure 1 we actually do not show composites. Figure 1a and figure 1b show the dominant time scales of European surface air temperature variability in MPI-GE and ERA5 by using a cross-spectral analysis, figure 1c shows the amount of extremely warm European summers on sub-decadal time scales, and figure 1d the power spectrum of Central European surface air temperature. For our analysis we can investigate 730 extremely warm European summers in MPI-GE, we will add this number to the corresponding text.

Figure 1c: I do not understand the unit

We must apologize for this confusion. This refers to the number of extreme summers that occur during a simultaneous positive sub-decadal phase in European temperatures per grid cell. The number of extremely warm European summers (T>90th percentile) per ensemble member refers to the entire time period (73 years). This means that from the approximately 1 in 10th summers that are extreme, as exceeding the 90th temperature percentile, as many as shown in the figure occur during a positive phase of the different regions. We can see that on average over all 100 members more extreme summers linked to sub-decadal (5-10 year) variations occur over Central Europe than in other regions. We agree with the editor that the unit of this figure is not completely clear, therefore, we plan to revise the figure, for instance by indicating the percentage of extremely warm European summers occurring in positive sub-decadal phases per grid point, such as Figure A.

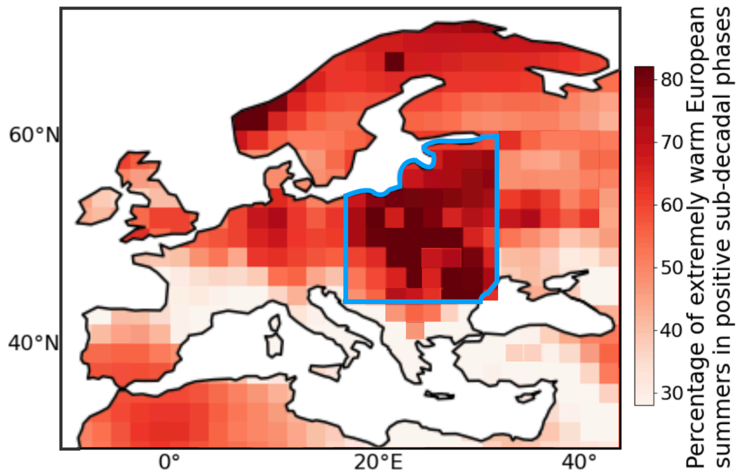


Figure A: Suggested new figure 1c, percentage of all heat extremes (T>90th percentile) occurring in a positive bandpass filtered phase (T_bandpass>0) per grid-point in MPI-GE. The blue box defines the region of interest for further analysis (Central Europe, ~15°-35°E; 45°-60°N).

Figure 2: dots are very hard to see

We agree that the dots are hard to see in a print-out. We will increase the dot size in order to increase their visibility.