Point-by-point reply reviewer 2

This study is an update of von Schuckmann et al. (2020) heat inventory. It provides 2 more years of the inventory from 2018 to 2020. There is one innovation compared to von Schuckmann et al. (2020): the new heat inventory includes now estimates of the permafrost thawing, inland freshwater and Antarctic sea ice heat uptake. In this paper, the authors call for a regular update of their heat inventory and for an implementation of the heat inventory in the Paris agreement's global stock take.

This manuscript is dealing with a very important aspect of climate change: the heat uptake of the climate system. The paper is well written and easy to follow. The methods used are sound.

Scientifically speaking, I am disappointed by this manuscript. I find the progress compared to von Schuckmann et al. (2020) is incremental and the results are not new. The uncertainties are not improved compared to von Schuckmann et al. 2020 (not better documented and not reduced in any manner either) and we don't get substantial new knowledge out of the analysis that are proposed.

However, in terms of climate policy and knowledge for action, I think this paper is relevant and support an important position in the community. I definitely agree with the authors that the heat inventory should be implemented in the Paris agreement's global stock take and should be more advertised to the general public. I find this manuscript supports nicely and efficiently this position.

In summary, I find that this paper is more a position paper than a scientific paper. I think the authors should acknowledge that and be clearer on this aspect. I also think the authors should target journals that are more suitable for position papers. By publishing in ESSD they may miss a substantial part of their targeted audience.

We have chosen ESSD because it allows for concurrent data publication, open review process, and recognition for similar regular reporting approaches such as the global carbon project. We hence believe that this journal is a choice taken to balance between science needs and transfer to a wider audience, and allow for the concurrent publication of the underlying data set.

We thank the reviewer for the comment, and the overall review, and we hope that the revised version of the paper will meet expectations. We would like to stress that this draft is intended to provide an update of the previous pilot study. A point-by-point reply is provided below.

Detailed comments:

L139-143: I find this picture of the heat accumulated in the Earth system, which would result from anthropogenic GHG emissions only, too simple and misleading. I think you should acknowledge there is a more complex situation here. At least you should mention the role of other important forcing such as the aerosol forcing and the role of internal variability as well.

We agree with the reviewer about needed revisions for this part of the introduction, and together in reply to comments of reviewer1 and this reviewer, we have now proposed a major revision for this part, and the second paragraph now directly goes into the complexity explanation as mentioned by the reviewer.

L151: you probably mean “confirmed” rather than “revealed”. The long-term heat gain has been revealed a long time ago (ex. Levitus et al. 2001)

We agree, but not relevant anymore as text had been now removed.

L160-161 : indeed the results are closely consistent with the IPCC AR6 and von Shuckmann et al. 2020. I don’t see here any significant improvement compared with previous estimates. The improvement only comes from the addition of two more years but the picture of the heat redistribution has not changed. I find this improvement is really incremental compared to von Shuckmann et al. 2020

We thank the reviewer for leveraging the major challenge of regular updates for a climate change indicator which will not reveal fundamental new advancements in science, but rather complements with each update the full picture of the current capacity of estimate, remaining challenges, and the current state and quantification of the EEI, and the Earth heat inventory. Moreover, this initiative allows for international collaboration, bringing together experts across all fields of climate research, and raises new discussions and research questions. As stated by the reviewer above, this update has succeeded to increase the collaboration for the cryosphere component, and to connect to communities for permafrost, and inland freshwater. New publications have been submitted in parallel to this work, and new research discussions are under the way. As for the global carbon project, we believe that this community momentum is of great value for the climate research community.

L185: To my knowledge ice shelf mass discharge has never been attributed to anthropogenic GHG emissions so far (although the attribution is highly probable). This is because attribution needs a thorough understanding and modelling of the processes at play which is not yet available for ice shelf. So I suggest to remove “ice shelf” from this sentence.

Thank for your comment. We have followed the information from IPCC AR6 for the concept of committed change, for which ice shelf counts to, see Foster et al., 2021.

L258 : I don’t understand why the heat inventory provides a tool for assessing the general status of the GCOS. Can you elaborate ?

Due to recommendations of reviewer 1, this part has been removed from the introduction.

L266 : Any other climate indicator or scientific study enables « concerted international and multidisciplinary collaboration ». I don’t see a special added value from the heat inventory over other initiatives.

Obsolete as text has been removed.

L269-273: I think these lines are the core of this paper. I understand you are calling for a regular monitoring of the heat inventory to support the IPCC solution pathways and to support regular stock taking of the implementation of the Paris Agreement. So this paper is more a position paper than a scientific paper reporting on recent progress. I think this aspect should be assumed from the beginning and the paper should be presented as a position paper rather than a scientific contribution.

We hope that with the proposed revisions we could follow the advice.

L310-313 : OHC estimates from remote sensing through the global sea-level budget are not merely “possible”. They are now mature (See Hakuba et al. 2021, Marti et al. 2022). You should consider these estimates here.

Thank for this comment, and we agree that the current formulation is mis-leading, and further information are missing. We have interacted with this group of experts, and now experts are onboard as co-authors. Accordingly, and after advice from the additional experts, we have now added more text, and discussion. In addition, we have now included the satellite full-depth estimate for the most recent period (2006-2020 and 2006-2019), and compare it to the in situ full-depth estimate (see table 1, and text).

L352: the problem in using the spread as a proxy for uncertainty is that you don’t know the sources of uncertainty. Can you tell us more about the uncertainty here? What are the main sources of uncertainty? Which one dominates? What is the temporal structure of the uncertainty? Is it correlated in time? Do you consider this information to compute the tendency?

Thank you for the comment. We have discussed these different aspects at different places in this section. We have now better grouped the information, including the knowledge obtained on the different sources of uncertainty according to previous studies, and better clarified the fact that the different mapping approaches and the choice of the climatology are a major player, together with the bias correction approaches for the historical time series. Relevant references are provided. For the trend estimate, a large number of sensitivity tests have been performed on advance as part of a Ph.D. thesis which are about to be published elsewhere (still draft development stage). Results from this study indicate in agreement to the study of Cheng et al., 2022 that for this approach, the use of LOWESS as discussed in Cheng et al., 2022 has been used, together with a monte-carlo approach for the uncertainty range. This is well discussed in the text. We have additionally also highlighted now better the important use of the so called ‘synthetic profiles approach (Allison et al., 2019), and future evaluations are needed for a more in-depth evaluation of the uncertainties which is however out of the scope for this study.

L402: what does “largely homogeneous criteria” mean? Please be specific

Thanks, yes, we agree that this sounds awkward, and we have removed ‘largely’, and added a double point at the end of the sentence to indicate that the criteria follow.

L416 : do you mean « of the corresponding ensemble”?

Yes, and changed accordingly.

L430: time correlation in the uncertainty could bias significantly your trend estimate. Have you considered this?

Thank you for this question, and no, with the ensemble approach we are not able to consider this aspect, and this would need to undergo a systematic study (e.g., based in the systematic profile approach, e.g., Allison et al., 2019) such as discussed in the paragraph above, and according to the reply to the reviewer’s question above.

L448: by “below 700m” you mean between 700m and 2000m depth, right? Please be specific

Thanks, and yes, we agree, and it has been changed accordingly, now clearly referring to the 700-2000m depth layer.

L529: there are typos in the equation. Please correct it

Thank you, corrected, and also one variable naming improved plus related small text edits implemented around (the import of this equation into the joint manuscript inadvertently had led to partial loss of characters).

L618 Figure 4: same remark as before. You are using the spread as a proxy for uncertainty. The problem is that you do not know the sources of uncertainty. Can you tell us more about the uncertainty here? What are the main sources of uncertainty? Which one dominates? What is the temporal structure of the uncertainty? Is it correlated in time? Do you consider this information to compute the tendency? What about systematic sources of uncertainty?

Yes, we use the spread as reasonable proxy for the overall uncertainty captured by these multiple atmospheric datasets and discuss key aspects of uncertainty sources, respectively the long-term quality, in Subsection 3.2 related to the input datasets. Here we particularly refer to key references both for the reanalysis and observational datasets, where the dataset providers have characterized individual dataset quality in more depth as well as discuss why we left out some older “outdated” datasets, which would unduly increase spread given they are known from cited sources to be of inferior quality. In the last paragraph of Subsection 3.2 we also discuss that the differences of sampling between observational and reanalysis datasets are a minor source of uncertainty in the resulting AHC estimates (i.e., much smaller than the ensemble spread). The discussion of key aspects how the uncertainties that make up the spread in AHC gains (i.e., of the trend fits to the AHC anomaly data) is part of Subsection 3.3, where especially the fairly large spread induced in latent AHC gain and its uncertainty sources is discussed, mainly rooting in observational (RS, RO) differences as discussed and, in general, also in natural variability.
To further improve the discussion, we have now included an additional last paragraph in Subsection 3.2 to summarize for these atmospheric datasets the role of the ensemble spread as uncertainty measure, which is in fact of minor relevance for the AHC trend (i.e., AHC gain) uncertainties which are dominated by interannual natural variability, plus special characteristics of time-dependent systematic effects in individual datasets as discussed in Subsection 3.3 (e.g., discussed for the RS data; time-constant systematic errors, or biases, would anyway play no role in these anomaly time series analyses that focus on time changes and temporal trends).

L667-670 I agree with the authors, the study here essentially confirms von Schuckmann et al. 2020

OK.

L759-760: I understand the much lower uncertainty in ground heat uptake in this study is coming from the new inversion method for the vertical temperature profiles. Why should we trust this new uncertainty estimate rather than von Schuckmann et al. 2020? What makes it superior?

There is a publication now, Cuesta-Valero et al. (2022a), explaining all details of the new inversion method, including a thorough comparison with the inversion method used in von Schuckmann et al. (2020), and demonstrating that the previous inversion method leads to the new uncertainty results when standard error propagation is applied. Cuesta-Valero et al. (2022a) shows that the previous technique used to aggregate inversions from individual profiles was markedly conservative, overestimating the 95 % confidence interval for the global mean inversion. Therefore, we consider the uncertainty reported here to be more robust than the uncertainty estimated in von Schuckmann et al. (2020).

L929: Why attributing the same uncertainty to GIOMAS as to PIOMAS? Is it reasonable? Why so?

Thank you for the comment, and according to the reviewer's comment we have now revised the draft to *'In the absence of a detailed characterization of uncertainties for these estimates, we use the uncertainty in GIOMAS sea-ice thickness of 0.34 m (Liao et al., 2022) to estimate the uncertainty in GIOMAS sea-ice volume to be ±4.0x10^3 km^3, fo which have used an annual mean sea-ice extent of 11.9x10^6 km^2 (Lavergne et al., 2019). One caveat to this is that the observational estimates have their own significant uncertainties (Kern et al., 2019; Liao et al., 2022)."*

L 1032: how do you estimate the rate in EEI and the associated uncertainty . I don't understand how you can get such a small uncertainty in the rate of change of EEI when you have such large uncertainties in the estimate of heat uptake of different components of the Earth system. Please, detail your uncertainty estimate here?

This part, together with Fig. 9 have been now removed according to the review process.

L1044: I disagree. Fig 9 shows that the primary need is to reduce uncertainties rather than to extend the time series. Can you comment on this? Why do you put forward the extension while uncertainties are still so large?

This part, together with Fig. 9 have been now removed according to the review process.

L1088: not "reveal" rather "confirm"

Thank you for this comment, but we do not agree. This is a new result according to this analysis approach, and for a different period, with hence continued heat accumulation. TO our knowledge, no heat inventory is today published up to 2020.

L1100-1127: I agree with this paragraph and I agree this is important to call for implementation of the Earth heat inventory into the global stock take. But I don't think it should be done in a scientific technical paper. It should rather be done in a scientific position paper. In addition, ESSD is probably not the best place to do that.

We would like to thank you. The journal webpage states: 'Earth System Science Data (ESSD) is an international, interdisciplinary journal for the publication of articles on original research data (sets), furthering the reuse of high-quality data of benefit to Earth system sciences. The editors encourage submissions on original data or data collections which are of sufficient quality and have potential to contribute to these aims. '

We believe that this paper provides a rationale for the datasets we publish with this article, driven and described by the international community on the Earth heat inventory and their different components. And we are convinced that these research data sets are of benefit to Earth system sciences.

L1147-1267: How come there are no recommendations on improving/reducing uncertainties? Figure 9 is probably the most advanced scientific result of this paper and it definitely calls for a reduction of uncertainties. I suggest to put some recommendation along these lines at a high level of priority. If not, we would like to understand why uncertainties are ignored

Thank you for the comment, and we fully agree with the reviewer, and have now added several sentences in the conclusion accordingly.

L1269: Here again, I find the position of the paper is not clear. If this is a scientific paper dedicated to scientists (as ESSD is for) then updating the record is not so important. Reducing uncertainties is probably much more of a priority. But, if this paper is a position paper more oriented toward climate services which calls for the implementation of the heat inventory in the global stock take then yes the priority is probably to update regularly the record. In the latter case the manuscript is probably proposed to the wrong journal and I am afraid you may miss your targeted audience.

As replied in the comment further above, we think that the inclusion of this update is justified for ESSD, and such type of regular updates are provided also for other indicators (e.g., the global carbon budget). This paper is not only a perspective piece, but it brings together international and multidisciplinary expertise on the different Earth system components. Also, new estimates from the science community have been added for this second update, and there is today no information in science literature available on the different Earth system components up to 2020. This evaluation cannot be picked up currently from a climate service for example for regular operational update as scientific expertise and analysis is needed to provide the quantifications based on joint data and model studies, with for example 2 scientific papers currently under review have been needed to provide a contribution for some estimates. Moreover, these time series for all Earth system components have been made available for the science community (and all), and we are convinced that they will become of important value for new scientific studies, and climate model evaluation purposes. Finally, our discussions and results also provide a fundamental foundation for observing system recommendations. These results lead into a science-driven provision of climate data relevant for climate research, and for the use of climate change reporting.