Last comment on: “The Earth's climate lagged, recurrent and non-linear solar and lunar multi-millennial scale responses: An oceanic hypothesis, evidence, verifications and forecasts” (document ESD-2021-84)

by Jorge Sánchez-Sesma

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A. Answers to referee #1

In the following the referee #1 comment (RC1), in brown color, is followed with my answers(in red color)

Review of the manuscript '**The Earth's climate lagged, recurrent and non-linear solar and lunar multi-millennial scale responses: An oceanic hypothesis, evidence, verifications and forecasts'** by Jorge Sánchez-Sesma (Independent researcher).

The author presents the 'Lagged & Recurrent Climate Hypothesis' (LRCH), claiming that much of the climate millennial scale variability (with periods between some hundreds of years and a few millennia) is driven by intrinsic solar variability and extreme tides associated with Sun-Earth-Moon orbital coincidences, reoccurring at certain repeated periods. Those extreme tides generate cooling of the sea surface by increased vertical mixing. The lagged response of that forcing in the surface temperature is driven by the Ocean conveyor belt (OCB) with the lag being the 'age of the water' roughly measured by the 'oceanic accumulated distance from the tropical East Pacific'.

The **above mechanistic theory** is quite **simplistic** and even not **falsifiable** according to a fundamental Popper's criterium (https://en.wikipedia.org/wiki/Falsifiability) for the validity of scientific theories, The justification of the theory is based on: 1) ad-hoc, physically not well-grounded arguments, generally taken from **ancient literature** and 2) a set of (nonstatistically validated) fitting regressions using over-simplistic linear modulated/lagged models using as predictors extrapolated data by Fourier analysis of the total solar irradiance (TSI) at every 9.5kyr and of the tidal forcing at every 5kyr. **The 9.5kyr solar recurrence** is misleadingly supported by the same author in Sesma 2016 (SS16 in the manuscript) by a spectral analysis without any statistical significance study analysis of the spectral peaks. That replication (both in the past and future) for a multiple number of Fourier analysis timeseries length (9.5 Kyr) is extremely dangerous due to the high dependence of phases of Fourier components from the analysis period. Moreover, **the concept of 'age of water' is quite ambiguous because the OCB** is a graph with multiple bifurcations, dispersion, stochasticity etc., hence not allowing to estimate the age of water by simple backward cinematics.

1. **Simplistic** is a desirable characteristic of any climate variability explanation.
2. The **Falsiability** of a theory and/or hypothesis will not be required, because my paper will present only "empirical evidences" of climate lagged variations.
3. However the background section of my work is valid, because the supposed "**ancient literature**" could be justified: Although those literature is coming from around 50 or more years ago, at that time the isotopic information began to be available, and the human mind development (based on anthropological knowledge), has been in similar and possible better condition than present times, because they spent more time to analyze the climatic processes. For instance, the Albert Einstein studies developed at the earlier 20th century, would be discarded by the Referee #1 as "ancient literature".
4. The recurrences of solar activity at every 9.5kyr and of the tidal forcing at every 5kyr, **will not be considered in final version of the ESD-21-84 document.** However, shorter recurrences, around 900 and 177 years, previously detected in climate and astronomical studies are going to be employed.
5. Although the concept of '**age of water**' was not employed, in the original paper it was proposed an accumulated distance travelled by surface flows of the OCB, from eastern equatorial Pacific, and a lag respect the TSI record. However the new approach in my new paper will not depends objectivally from these variables. A new variable will be

analyzed: it is a relative lag/lead of the GT climate records.

The author commits too many methodological and technical flaws in his presentation and discussion of results.

Moreover, the author does not cite or contextualize in his research, related (well supported and methodologically much more advanced) works studying the possible origins of the millennial variability at scales slower than that of Milankovitch forcings. In fact, it is an open discussion, far from being at the end, if the above referred variability comes mostly from the solar/tidal forcing or from the internal slow (not externally forced) variability of the climate system (Soon et al. 2016) or even from magnetic forcing.

The author explained millennia scale climate variations mainly as a response to astronomical forcing. Through the ocean flows the astro-forcing is moved and delayed in its influences. Although it is a Simplistic explanation, but also is a desirable explanation of climate varibility that will complement the actual models and, surely, will promote better understanding.

The author's belief both in the LRCH and his simplistic model, led him to produce forecasts of the global surface temperature for the next decades, in a clear confrontation and contradiction with the decadal forecasts of the much more sophisticated and physically well-grounded models presented worldwide in the IPCC reports.

For science development, confrontation and contradiction of ideas is a desirable situation, speciallly when the future of global climate is analyzed. Simplistic models can contribute with more fresh ideas in the present "conundrum" of climate models that was explained in the first version of my paper.

Despite the author's recognition in the conclusion of the paper, that **his model deserves much more work and physical evaluation, the present work cannot be considered appropriate to be published in the scientific journal ESD.**

My paper, in its final version, will show a new empirical approach that needs to be taken into account to better appreciate the complexity of natural climate variations. It is not an ended work but, surely, it will open many efforts and contributions to develop, together, a complete and robust climate science theory that provide reliable climate scenarios.

Next, there are presented some of the major technical and methodological pitfalls of the manuscript:

1) **Figure 1a is totally inappropriate**

2) **Figs 3a and 3b are not legible.** The adapted Fig. 3c is too much stretched and without legibility.

3) **The model in Eq. (1)** of the climate proxy variable, uses the solar proxy variable S(t) which is supposed itself to be self-similar (with a 9.5kyr period). **Therefore, any slower variability with periods larger than 9.5kyr is ignored.** The regression score (e.g. MSE) of the fitting is never shown systematically for the tested climatic proxies neither compared against any 95%-expected score of a null-hypothesis model (e.g. an red noise AR1 model). Therefore, the absence of statistical validation is not allowing any attribution arguments of the variability to the tested external forcing.

4) **Eq. (5)** is completely out of the context and add nothing about the tidal forcing particularities.

5) The details of models (Section 4) should preferentially **be presented in a Table.**

6) Fig.4 is not clear at all. All panels (except panel b) present two curves which are not explained anywhere, even in the caption. Observed proxy data of some of the timeseries does not match perfectly with graphs of the papers from which they where obtained. For instance: a) the Record crbT (green curve of fig 4a) seems to be a degraded representation of data presented in Fig. 2c of Weijers, et al.(2007). b) Record jriT (fig. 4b) representing the Northeast Antarctic Peninsula temperature, jriT (Mulvaney et al., 2012) should represent in effect an anomaly (with respect to the period 1961-1990) in the Antarctic James Ross Island, presented in Fig. 3 (black curve) of Mulvaney et al., 2012. The curves don't match.
7) The **Figs 4d and 5d**, supposedly to present the global temperature anomaly do not match. Difference between curves are not explained anywhere.
8) **Fig. 8a** is an appropriate stretched copy-paste figure without any information of the time scale.
9) **Figs. 8b and 8c** presumably showing the contributions of the solar and tidal influences to the global temperature, are not all well explained. The explained variances are not computed and tested against null hypothesis.
10) The manuscript is full of confusing acronyms, which are not well defined in the text, like NonRad&NonLinear , TidalNonLin , climate(laggedTSI).
11) The description of the **tidal contributions** in the Discussion section 5, pg. 13 lines 23-34 is quite confusing.
12) **Figs 10a,b** present forecasts of the global temperature up to 4000 cal A.D. The author claims that the use of the NASA's solar system astronomical model represents an independent verification of the model. For instance, the time-series issued from models Trend + mTSI + TidalNonLin (blue line) and Trend + mTSI + TidalNASA (cyan line) appear to be quite different and hence not corroborating the empirical proposed model Trend + mTSI + TidalNonLin.

1. **Figures 1a, will be eliminated.**
2. **Figure 3, will be re-made, considering the comment about, but focused on the Atlantic ocean and their "Gulf stream" and other surface currents.**
3. **Equation 1 indicates a model for the lagged and linear reconstructed solar influences on climate (not solar model). Statistical and spectral validations are conditions and test that will be required with more precise models and information.**
4. **Equation 5 indicates a model for astronomical aceleration of Earth masses due to solar and lunar influences. It provides an objective approximation for the original tidal influences.**
5. **Main results will presented in a Table.**
6. **Figures 4 and 5 will be re-made considering only four records (crbT, Antarctic tempertaures, GrT and GT) withouth the jriT record,**
7. **Figures 4 and 5, related with the GT record will be improved and reformatted.**
8. **Figure 8 will be reformatted, eliminating the tidal recurrences, and keeping only the part of the Fig 8c, related with the objective evaluation of "tidal forcing" based on Eq. 5.**
9. **No one statistical test is applied in this work, but confirmations with multiple and independent lines of evidence are developed.**
10. **All the acronyms employed will be reviewed.**
11. **The description of tidal influences (only those from Eq.5) will be reviewed.**
12. **Figure 10, will be re-made, and the corroboration of results, associated with GT forecast will be focused on the 21st century. It will be presented in additional figures and will consider more than 10 independent climate records.**

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B. Answers to referee #2

In the following the referee #2 comment (RC2), in brown color, followed with my answers(in red color)

Referee comment on "The Earth's climate lagged, recurrent and non-linear solar and lunar multi-millennial scale responses: An oceanic hypothesis, evidence, verifications and forecasts" by Jorge Sánchez-Sesma, Earth Syst. Dynam. Discuss., https://doi.org/10.5194/esd-2021-84-RC2, 2022

This manuscript seeks to address an extremely relevant scientific problem to the Earth System Dynamics community. Hence, in terms of placement within the scope of the journal, it would be perfect - provided the research would have been conducted in a thorough comprehensive and fail-proof or at least falsifiable manner.

However, notwithstanding the intellectually fertile ideas and insights as expressed in the conjectures and hypothesis laid out for investigation, formally speaking **the study undertaking lacks fundamental scientific grounds to take off as a full-fledged research study. As also already pointed by another reviewer, whose words I fully endorse and hence will not repeat for obvious reasons, there are profound shortcomings and severe hindrances at both technical and scientific levels that make it unfeasible to simply amend in view of a possible publication.**

I have taking into account, in a detailed manner, the comments and suggestions of Reviewer #1,

I am aware of the author's keen efforts to further clarify and improve the manuscript. However, while I sympathise with such efforts and persistence, unfortunately I am so sorry to say that the fatal concerns are not yet sufficiently addressed. **This study needs to go back to the drawing board and reframed from its very foundations, rather than undergoing amendments over what are unstable principles, assumptions and procedures.** Therefore, to that regard, **my recommendation is for the author to take the fertile insights towards producing a clean, sharp, effective study.**

Following these excellent ideas, I have been working in a new version of my paper, taking into account fully the comments and suggestions of Reviewer #2,

The present preprint is citeable and holds the proof of the precedence of the raised ideas and insights. But these need to be thoroughly investigated with technically sound methodologies to provide results that can provide a scientifically sound set of results that can give confidence about the proposed contribution. Until that happens, this study conveys a fertile albeit speculative exercise that is not yet sufficiently close to physical consistence to be deemed appropriate for final publication at Earth System Dynamics.

All in all, the problem is not on the hypothesis raised by the author, and which should indeed merit further investigation. It is about how such hypothesis are scientifically worked towards providing a robust contribution to the advancement of knowledge beyond a speculative theoretical exercise grounded on debatable foundations that themselves need to be properly investigated and potentially validated in perhaps a seminal study on its own.

It is important to emphasize that in the new version of my paper, no one hypothesis is made, it is focused in evidences and their verifications, that will help as initial ideas of new approaches in climate research.

C. General answers to both referees

The final answers to both reviewers are as follows:

1. I am going to fully modify the original article considering each one of the observations made by both Referees. To do this, I will proceed to the following:
a) I will not mention (neither use) solar and lunar millennia-scale recurrences,
b) I will reestimate the future evolution of the global temperature considering reconstructed and published records of the TSI and the Sun-Moon gravitational accelerations on the terrestrial mass, an amplification is applied during the last centuries supposing volcanic and solar influences (in this document new elements and evidences about volcanic forcing are presented, that empirically justify this amplification) and the remaining residual oscillations will be analyzed through multidecadal-scale analogs. The results will provide empirical scenarios of GT for the 21st century (ES-GT-21stC).

2. I will give a new approach to the article:
a) I will present as evidence of the climate delays based on:

- the records in Wiejers et al., 2007, that show increasing relative lags from the crbT record, going from the South to the North Pole, following the Surface flows over the Atlantic ocean.
- the results published by Shakun 2012, which show the relative thermal delay of the Northern Hemisphere with respect to the Southern Hemisphere;
- the new results published by Kaufman et al., 2021, which provide zonal estimations that show the lagged responses of GT respect to South pole records.

3. I will include more climatic records directly related to the Atlantic Ocean and especially in the North Atlantic, to verify the ES-GT-21stC for the coming decades. Special contributions will be including: a) rcp0.0 extrapolated IPCC scenarios complemented with constrained scenarios (Risbes et al. (2021); hereafter R21), b) Potential volcanic contributions (Bethke et al. (2017); hereafter B17), c) Antarctic and tropical contributions, and d) tropical, western and northern, North Atlantic records.

4.. Finally I want to:
a) Mention the need, and oportunity, to discuss new options for climate analysis.
b) Thank to referee #2 for his wise comments about making an article clearer, simpler and more direct. Those ideas will be fully considered in the last version

D. Description of the final document

D.1 New tittle: *Empirical evidence of astronomical lagged influences on climate: A consequent and multi-verified, global 21st century forecast*.

D.2 New approach: It is focusing around global temperature. In addition to lagged responses to solar and tidal forcing that result in the GT scenario for the 21^{st} century (GT-21^{st} Cent), in this updated document, multi-evidences to support GT-21^{st} Cent, were included.

D.3 New and important evidences. In the following a description of these evidences are provided:

D.3.1: Evidence of different lagged responses in climate.
Respect the crbT record, a continental tropical from Congo River Basin (CRB)[W07], the climate variations of Antarctic climate(Dome C), Eastern Equatorial Atlantic SST (S05), Greenland (GISP2) and Global (S12, M13) temperatures show increasing relative lags. It is shown in Figure 1.

It is important to mention here that the W07 and S05 records are coming from the same core of deep sea sediments, lipids indicate the tempearture of SAT in the CRB but the isotopic values from foraminifera skeletons indicate the SST just in front the Congo River discharge. These variables indicate different processes with relative lags of more than 2000 years The crbT indicate the continental quick response to solar forcing, while the crdSST indicate the movement of sea water from Pacific, Indian and Antarctic oceans before to enter the Atlantic ocean.

Respect the SHT(Shakun et al., 2012) and South pole (Kaufman et al., 2020) records, the NHT (Shakun et al., 2012) lags more than 1000 years. It is shown in Figure 2.

D.3.2: Empirical forecast for the next centuries of GT (lagging South Pole and Caribbean climates).
Taking into account three south Pole climate records an empirical GT forecast is developed. We use the EDML record, the SST west of Antarctic Peninsula (Shevenellet al., 2012), and the zonal integration (60-90 °S) of proxy information (Kaufman et al., 2021). A Cariaco SST record is also analyzed (Black et al., 2004). These empirical modellings are shown in Figure 3, and their details are shown in Figure 4.

D.3.3: Empirical modelling of GT (leading Hydroclimate)
In contrast Titanium and iron concentration data from the anoxic Cariaco Basin, off the Venezuelan coast, that can be used to infer variations in the hydrological cycle over northern South America during the past 14,000 years with subdecadal resolution (Huag et al., 2001), show different timing respect GT. These two independent records for Titanium and Iron content of deep sediments over the Holocene, indicate that GT leads them (for more than 200 years). Figures 5 and 6 ilustrate the connection between GT and those minerals contents.

The GT lags respect to South pole records indicate the ocean currents that takes heat and mass in a time journey of more than a millennium. In contrast, the GT leads respect to the Cariaco mineral records indicate the ocean-atmosphere currents from northern latitudes toward the tropics in a journey that includes hydrologic response that takes time of more than two centuries.

D.3.4: Empirical verification of previous GT forecast for the next decades.
Taking into account several independent climate records, their climate influences were estimated applying a linear transformation, a linear trend and a constant lag.

D.3.4.1 Estimations of GT based on South pole and Cariaco
The South pole records indicate GT lags (for more than 1000 years) with consequent forecast of GT with a cooling for the next centuries. The Caribean record indicate lower GT lags (for more than 600 years) with consequent forecast of GT with a cooling, at least for the next centuries. Figure 7 and 8 show these independent two GT forecasts.

D.3.4.2 Estimations of GT based on other Caribbean, North Atlantic and Arctic records
Figure 9 display 6 different forecast and its statistical range of values (mean, mean+StdDev, mean-StdDev) for the next decades. These variables have been discussed and analyzed in previous comments.

D.3.4.3 Updated IPCC 2013 TAS extrapolated scenarios to rcp0.0
Considering the GHG hypothesis is not able to apply in a climate system with the detected lagged climate responses, a simple linear extrapolations of the rcp0.0 was evaluated in a previous comment with IPCC 2013 unconstrained values. It should be noted that this extrapolation is valid at the end of the 21st century.

However, here we add another evaluation considering the constrained values (Risbes et al. (2021); hereafter R21). R21 have pointed out: “Many studies have sought to constrain climate projections based on recent observations. Until recently, these constraints had limited impact, and projected warming ranges were driven primarily by model outputs....we use the newest climate model ensemble, improved observations, and a new statistical method to narrow uncertainty on estimates of past and future human-induced warming..... Our results suggest that using an unconstrained multimodel ensemble is no longer the best choice for global mean temperature projections...”

We analyzed the rcp0.0 constrained scenarios for AR5 during the last two decades of the 21st century (2080-2100). The results confirm the rcp0.0 unconstrained scenarios for the AR5 evaluated previously. Both constrained (R21), with range and mean values, and unconstraind rcp0.0 (IPCC2013) scenarios with ensemble values, show compatible behaviour. The comparison is shown in Figure 10.

D.3.4.4 Extratropical Northern Hemisphere Temperature (ExTropNHT) extrapolated values for the next centuries.
Based on a detected recurrence of climate values with period of around 900 years (Schulz and Paul, 2001) and a possible orbital forcing independently estimated (Loutre et al.,) the extrapolation of the ExTropNHT reconstructed values (Buentgen et al, 20XX) was developed (See Appendix A). Its lagged influences of ExTropNHT on GT, around 20 years later, provides an additional verification for GT21st.

D.3.4.5 Influences of Volcanic Activity in the next decades.
Based on a detected recurrence of climate values with period of around 177 years the extrapolation of the N3v reconstructed values (Mann et al, 2005) was developed (See Appendix B). Its recurrent influences of N3v on GT, provides an additional verification for GT21st.

E. Last remarks

We have shown evidences of

1. Lagged climate processes in different scales: multimillenial, multicentennial and multidecadal.
2. Natural recurrences of climate processes with periods around 900 and 177 yrs.
3. Two regional studies of ocean deep water sediments, at Congo river discharge, and at Cariaco basin, provide information in different media (lipids, isotopic and mineral content) to different climate processes with different relative lags, of around millennia and millenium, respectively, that show parallel processes in climate with different timing.
4. Multiple climate processes that happen before the GT provide information not only to forecast a gentle cooling for the rest of the 21st century, but also, to forecast a similar gentle cooling and oscilations for the next 1 and a half millennium.
5. The importance of volcanic forcing and its recurrent responses, with periods of around 177 yrs, has been shown in the ENSO-N3v simulated records that clearly influence GT over the last century, not only provide elements for a special consideration (magnification) of the GT responses over the last centuries (made in the GT empirical modelling in the first document), but also provides values of volcanic influences for the rest of the 21st century.
6. The volcanic empirical modelling of climate responses, are similar in magnitude and timing to those analyzed by Bethke et al. (2017: hereafter B17) and published in Nature Climate Change, however the sign is different. While the B17 publication indicates negative contributions of volcanic activity, the empirical modelling generates in a simplistic form, but sustained with one of the best (simplified) models of ENSO, postive contributions of the volcanic activity. The key point of these differences is the “Ocean heat thermostat” (OHT) named by Clement et al. (1996) that discovered that the mean surface temperature change result of the ocean-atmosphere system at the tropics shows cooling (warming) when the radiation increase (decrease).

Taking into account the original paper ESD-2021-84 and all the comments developed, but specially this last one comment, I would like to emphasize that the natural processes of the Earth's climate system requieres this , and similar documents, to be better understood, and then better modelled.

Many empirical lines of evidences have shown that the rest of the 21st century will be characterized by a cooling processes. The IPCC warming for the same period present great modelling limitations, the mentioned “holocene conundrum” and the modelling of volcanic impacts on GT for the 21st century have shown important limitations. However, the most important limitation is that the ocean surface and at middle depths currents, have not being well considered as we have shown in all of our documents around ESD-2021-84.

F. References

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G. Figures

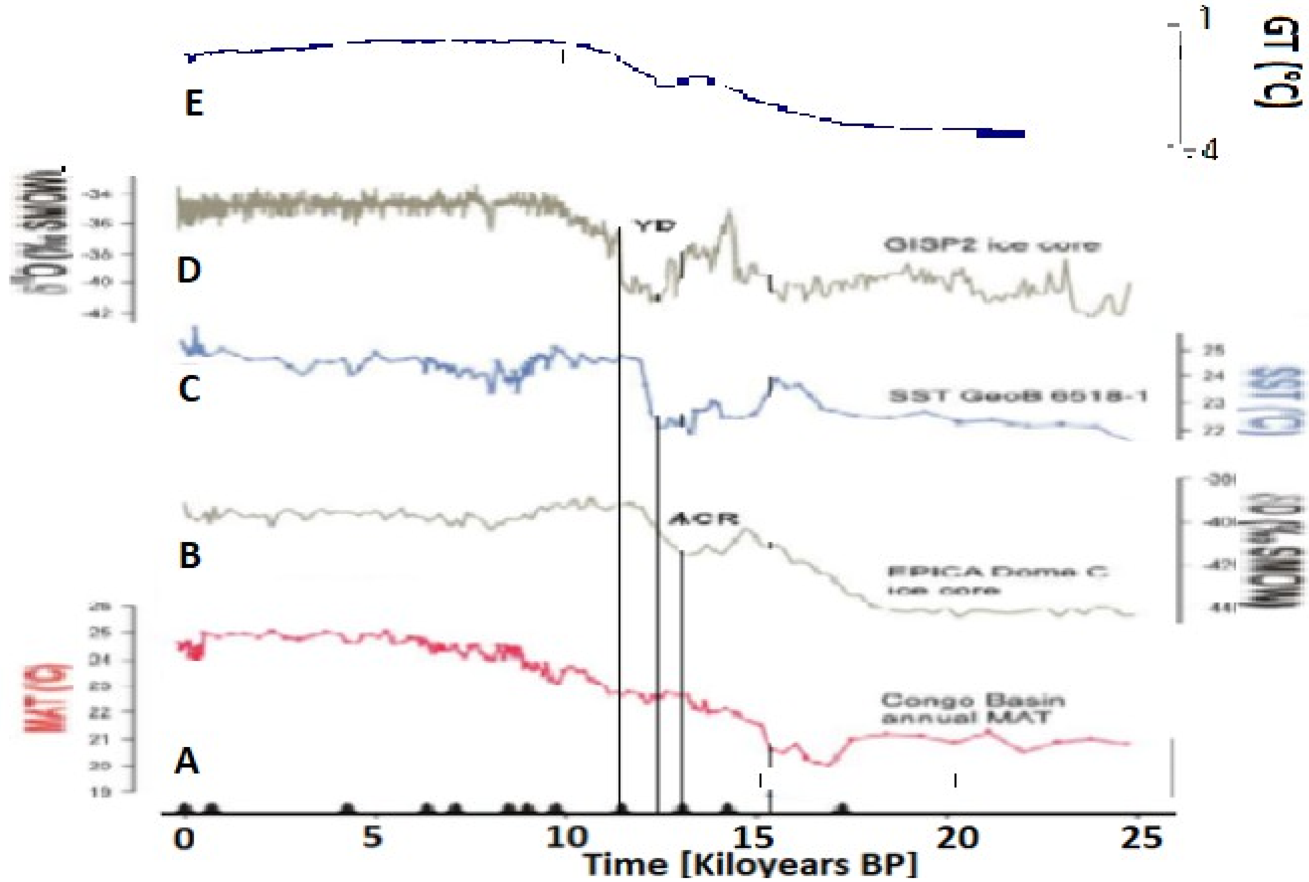


Figure 1. Five climate records, four (A, B, C and D) adapted from Wiejers et al., 2007 and one (E), the global temperature (GT) from Shakun et al, 2012 and Marcott et al, 2013. Two are coming from GISP2 and EPICA Dome C ice cores from polar regions (in gray color), and two are coming from the same sediment core from tropical regions (Congo river basin Temperatures [crbT] in red color, and Atlantic Eastern Tropical SST just in front the Congo river dischage [crdSST], in blue color). The GT record (E) appears to the last climate record, its variations are almost in sinchrony (some decades of difference) with GISP2. These records EPICA, SST, GISP2 and GT are showing relative lags respect the crbT of around 2400, 3000, 4000 and 4000 years, respectively.

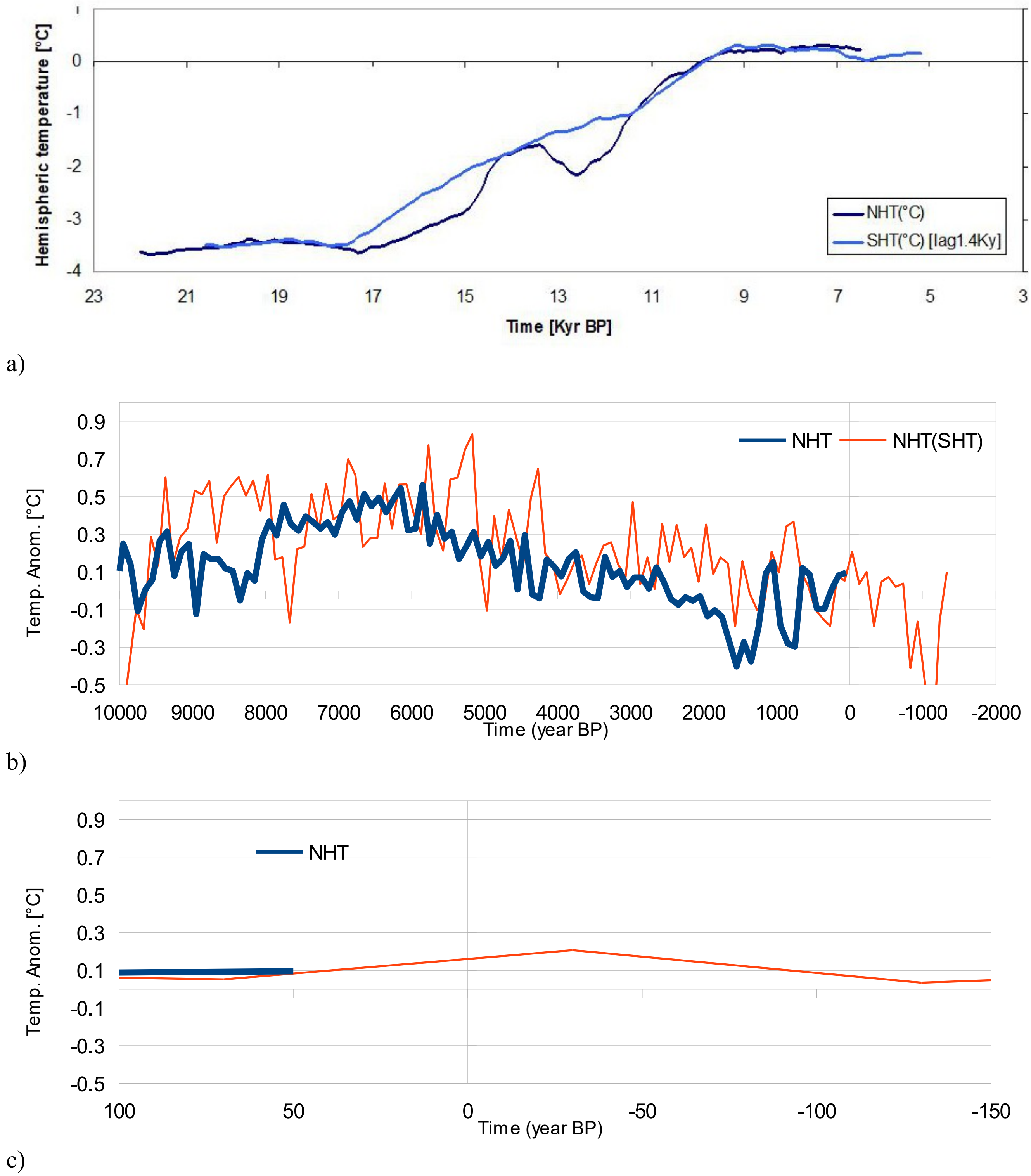
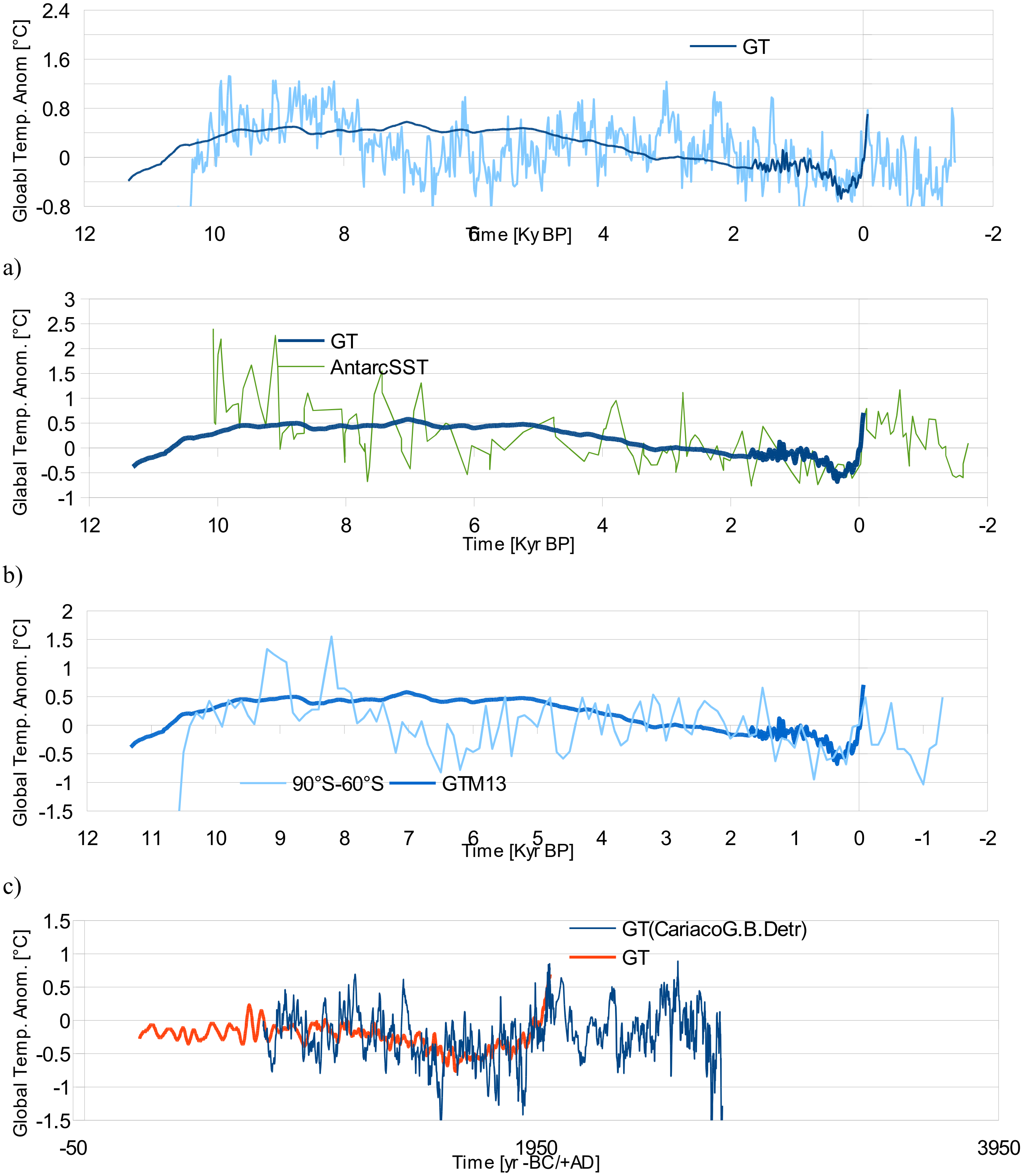


Figure 2. Comparison of NHT and adjusted SHT with linear transformations and lags of around 1400 and 1380 years for the a) Shakun et al. 2012, and b) Kaufman et al., 2021, reconstructions, respectively; c) a zoom of b) indicated decreasing temperatures for the early and middle of the 21st century (-50 to -150 years BP).



d)

Figure 3. Comparison of GT updated record (see Appendix A of the first version of thiswork) with four adjusted and lagged climate records of temperature coming from South pole and Caribbean. a) EDML record, b) SST west ofAntarcticPeninsula (Shevenellet al., 2012), and c) zonal integration (60-90 °S) of proxy information (Kaufman et al., 2021), and d) Cariaco SST (Black et al., 2004). Note that: 0 KyBP=1950AD

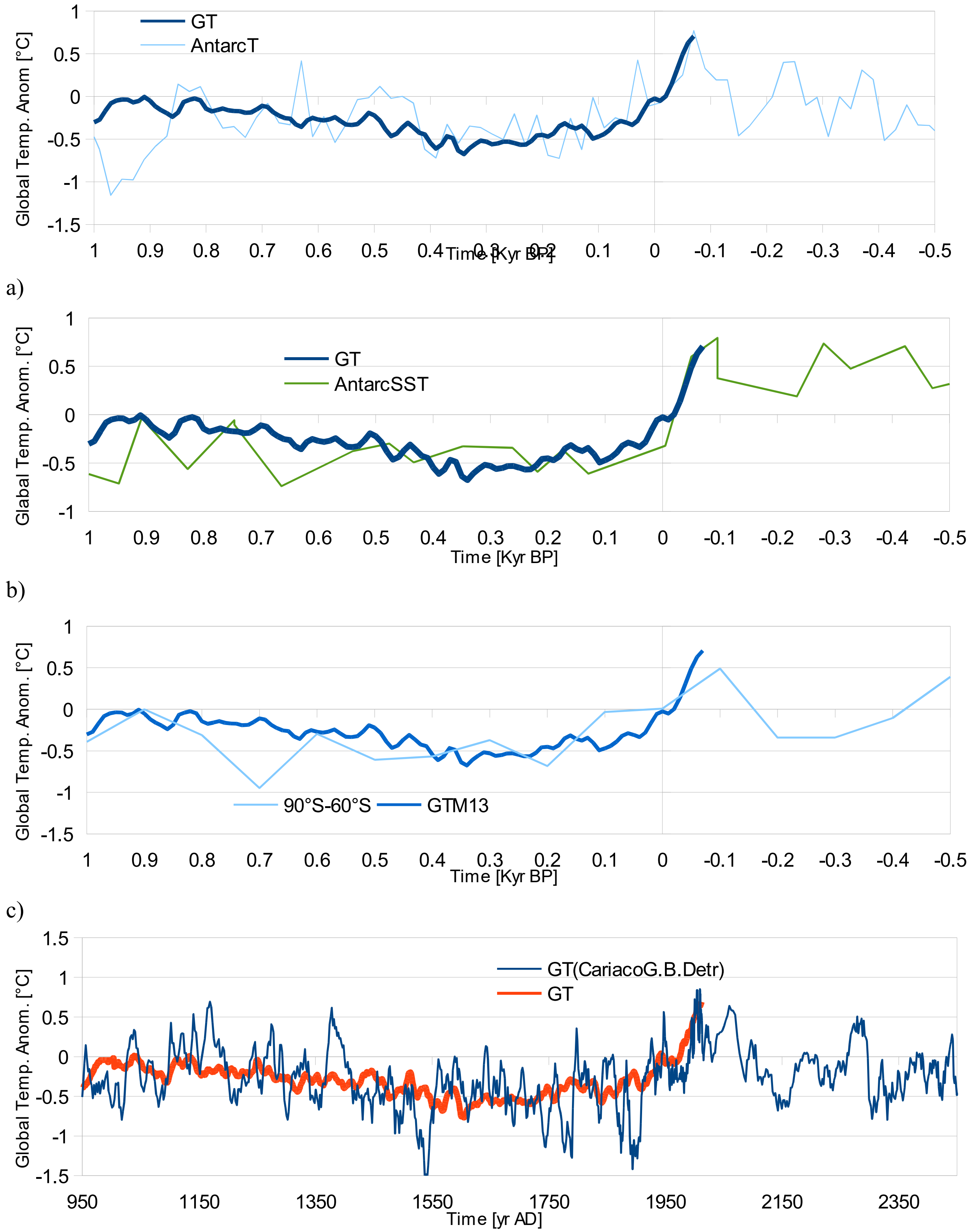
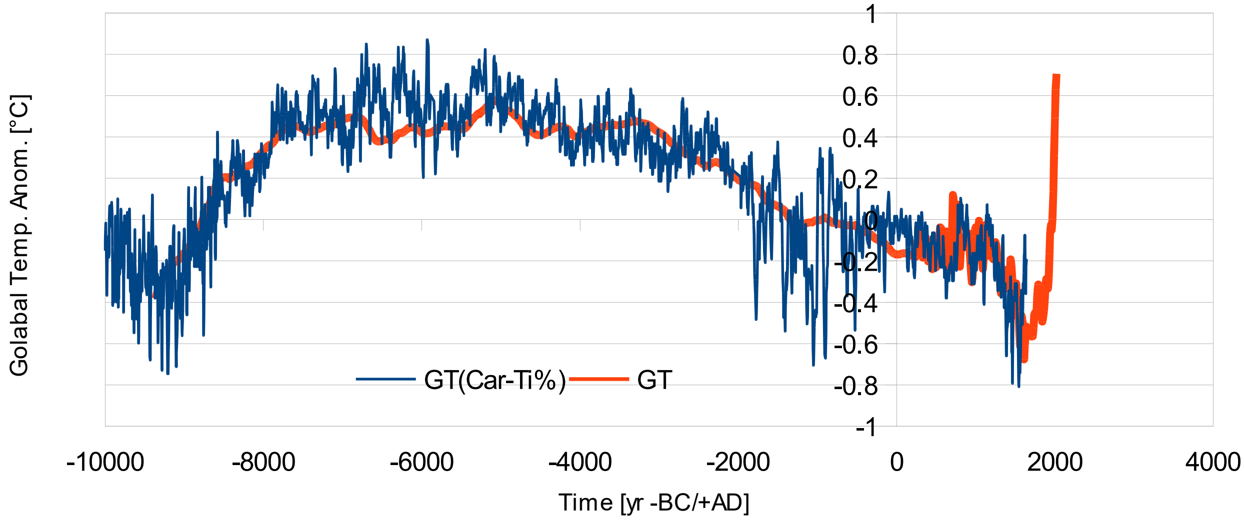
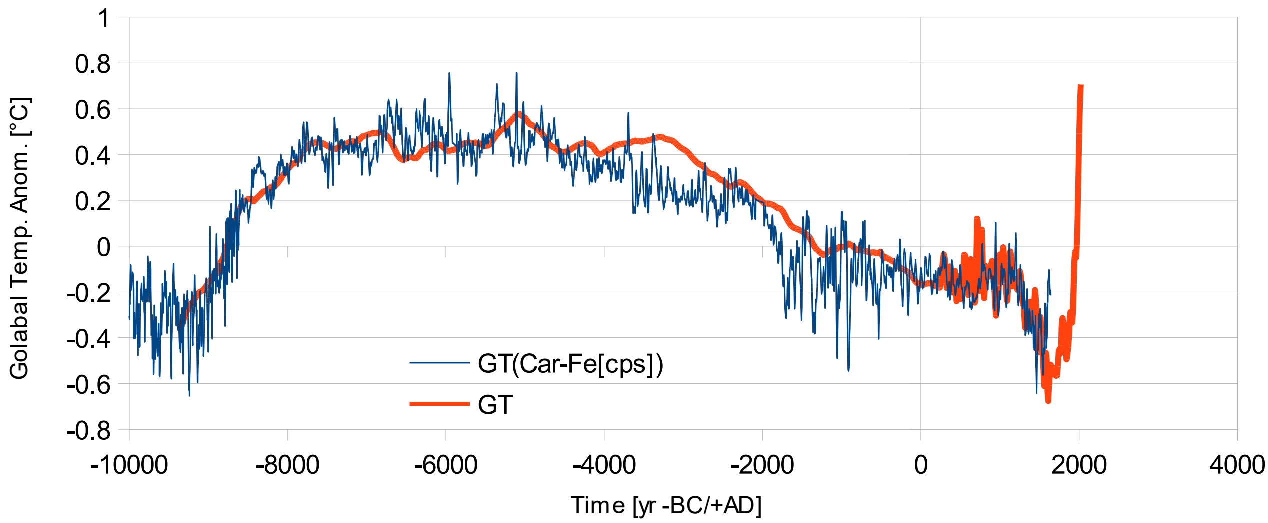


Figure 4. A zoom of forecast based on South Pole climate (Figures 3) covering the period 1-(-0.5) Kyr BP [950-2450 AD].

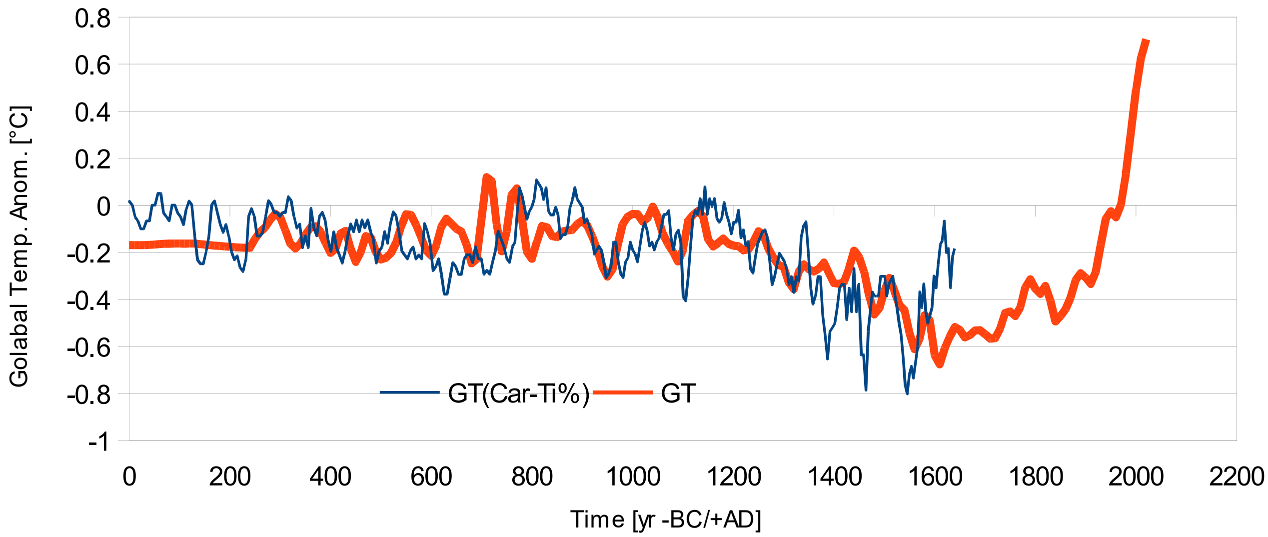


a)



b)

Figure 5. Global Temperature reconstructed compared the Cariaco a) Ti% and b)Fe content reconstructed from deep sea-sediments (Huag et al., 2001). The GT record leads both Cariaco mineral content by more then 200 years.



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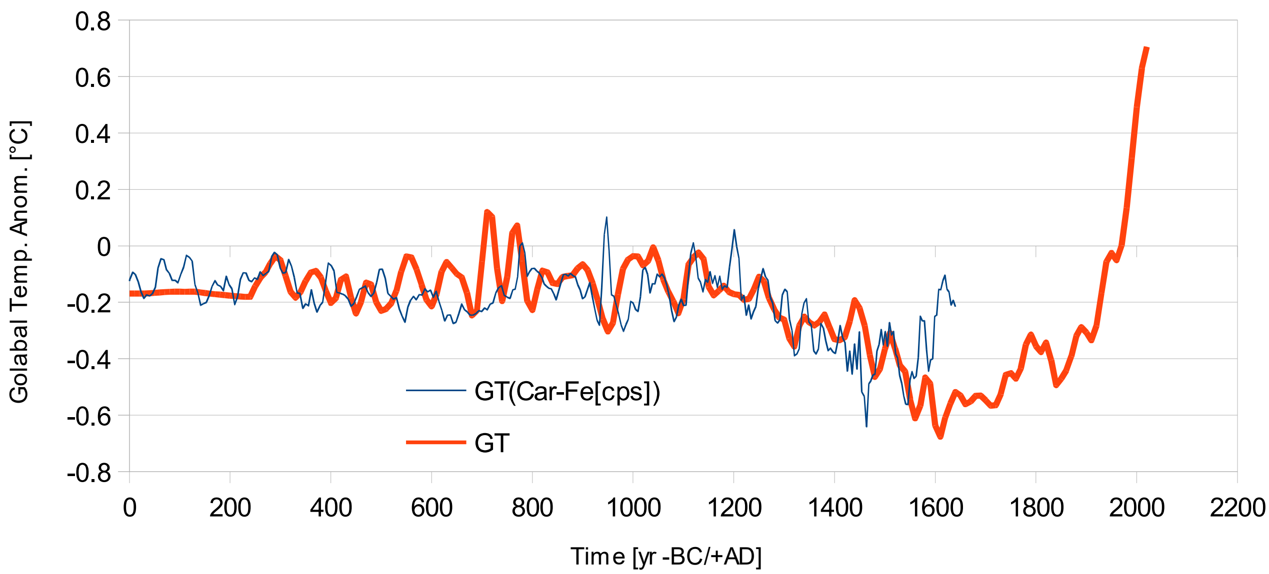
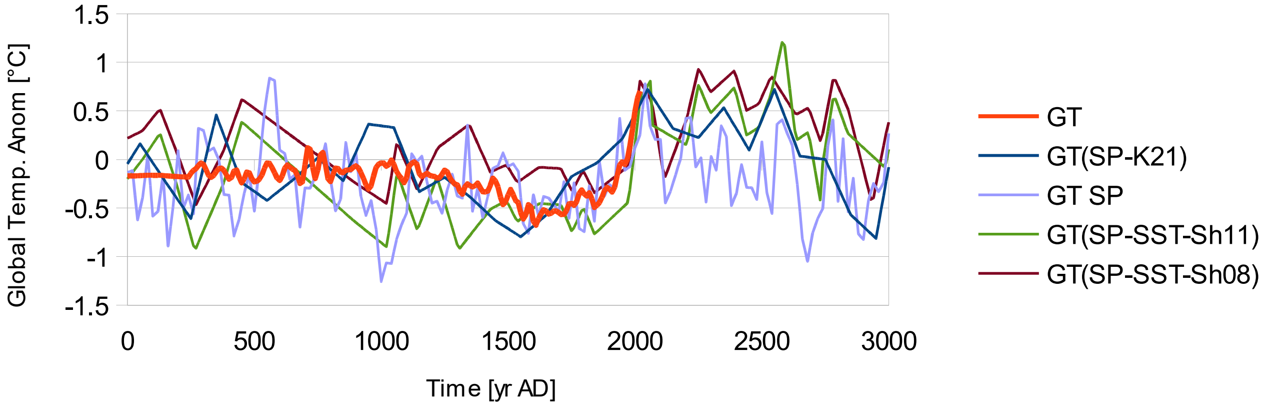


b)

Figure 6. A zoom of Figures 5 covering the last 2000 yr. a) Ti , b) Fe.



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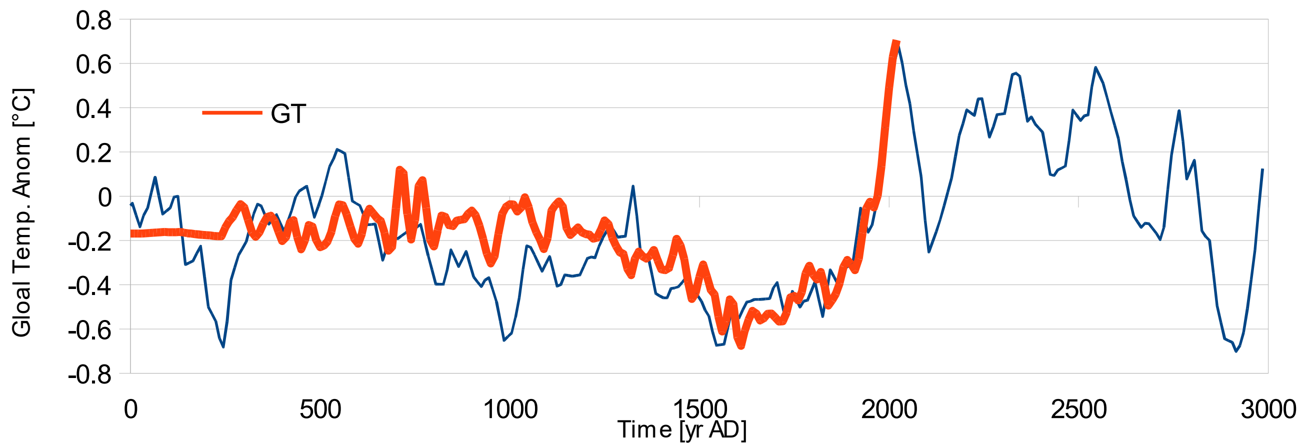

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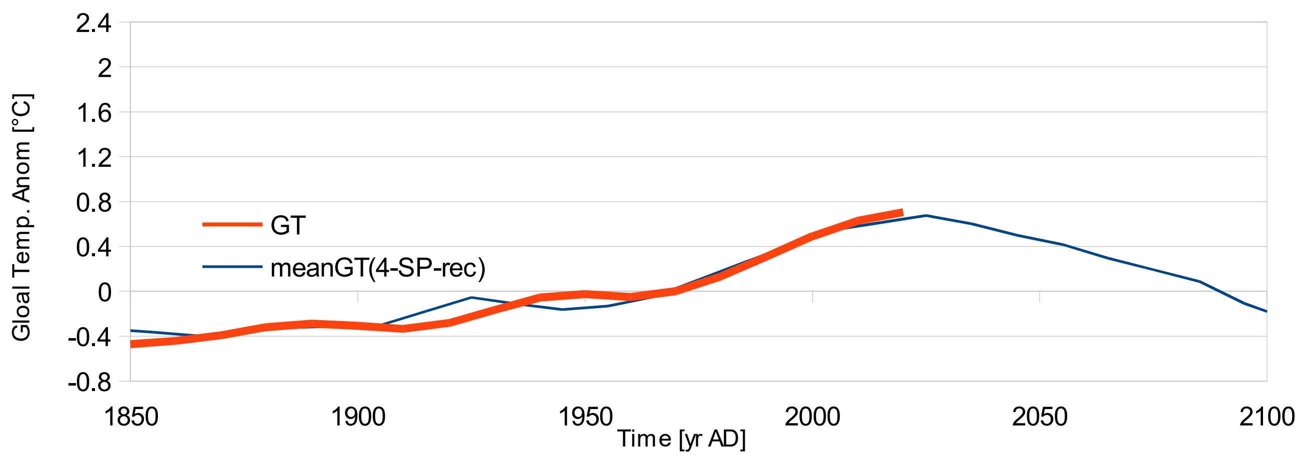
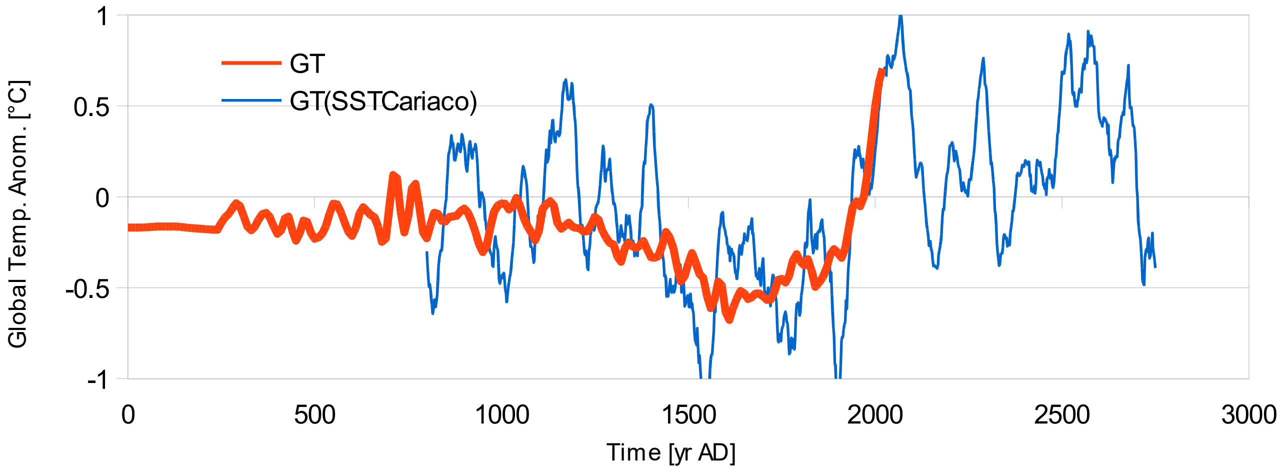


c)

Figure 7. Integration of global temperature Forecasts based on South Pole records. a) Integration of SP records (Figures 3 a, b and c and 4 a, b and c), b) Mean values for the records shown in a), and c) a zoom 1850-2100 of b)



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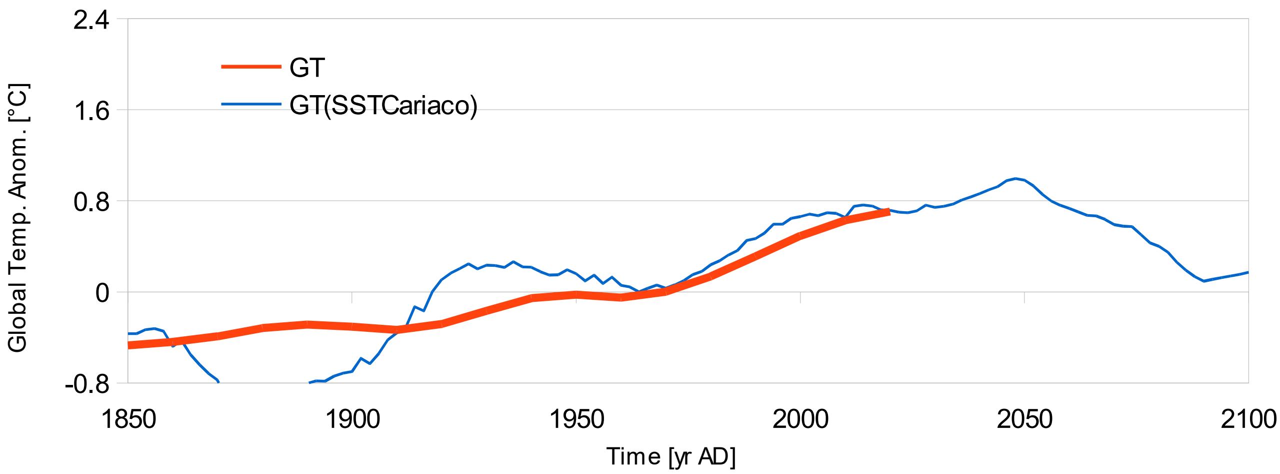
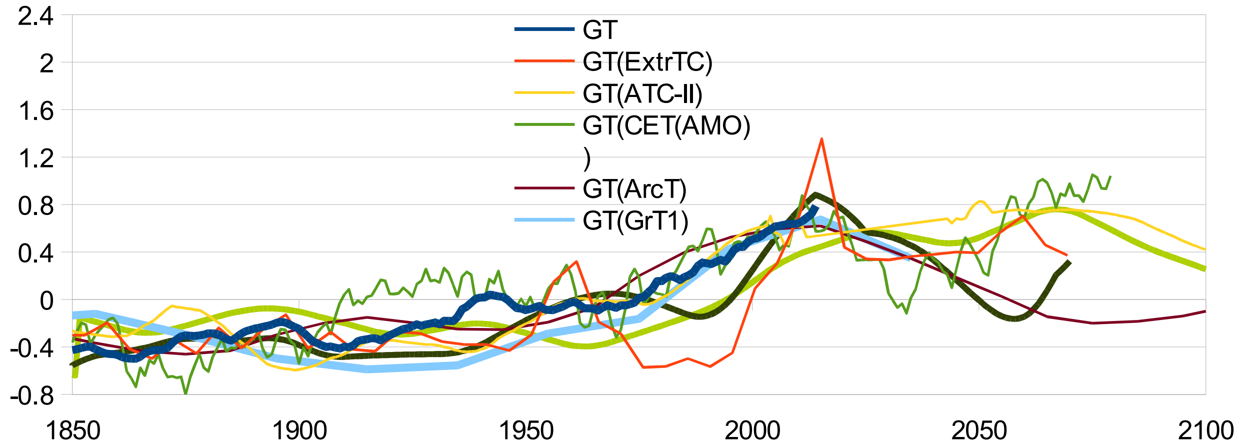


b)

Figure 8. Global temperature Forecasts based on Cariaco SST record. a) GT forecast baed on Cariaco SST (Black, et al., 2004), and c) a zoom 1850-2100 of b)



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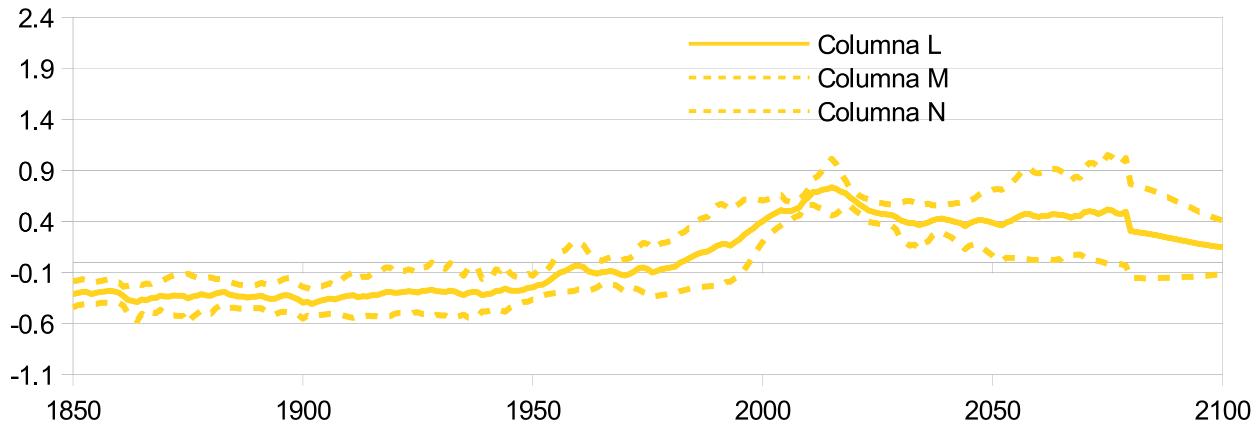

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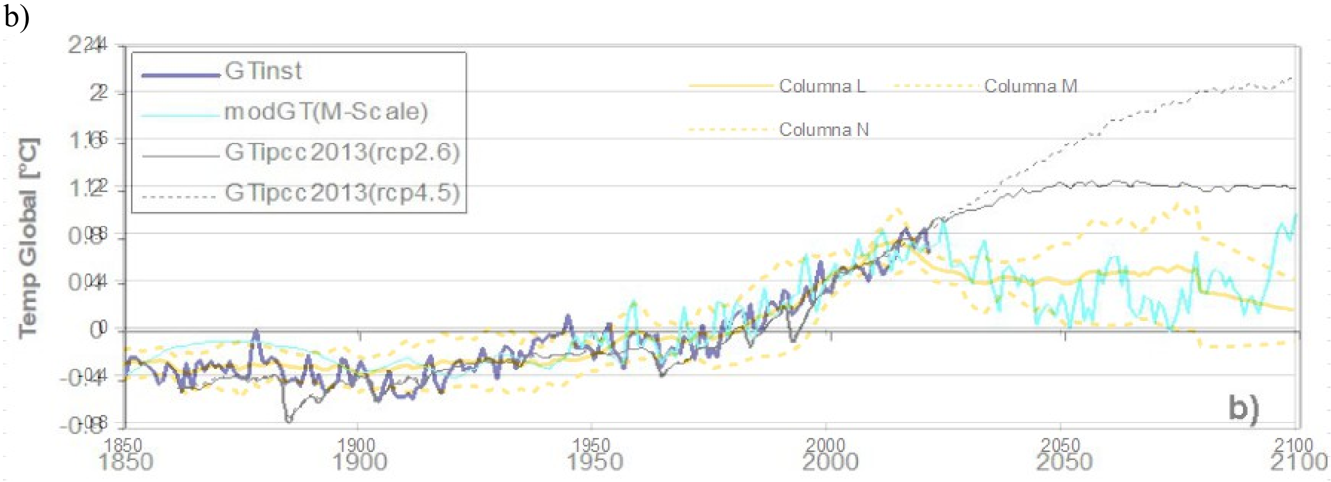


c)

Figure 9. Different GT forecasts for the 21st century. a) GT climate scenarios based on tropical and Northern Atlantic climate records, b) their mean and standard deviations range and c) their comparison with previous GT scenario (ESD-2021-84)

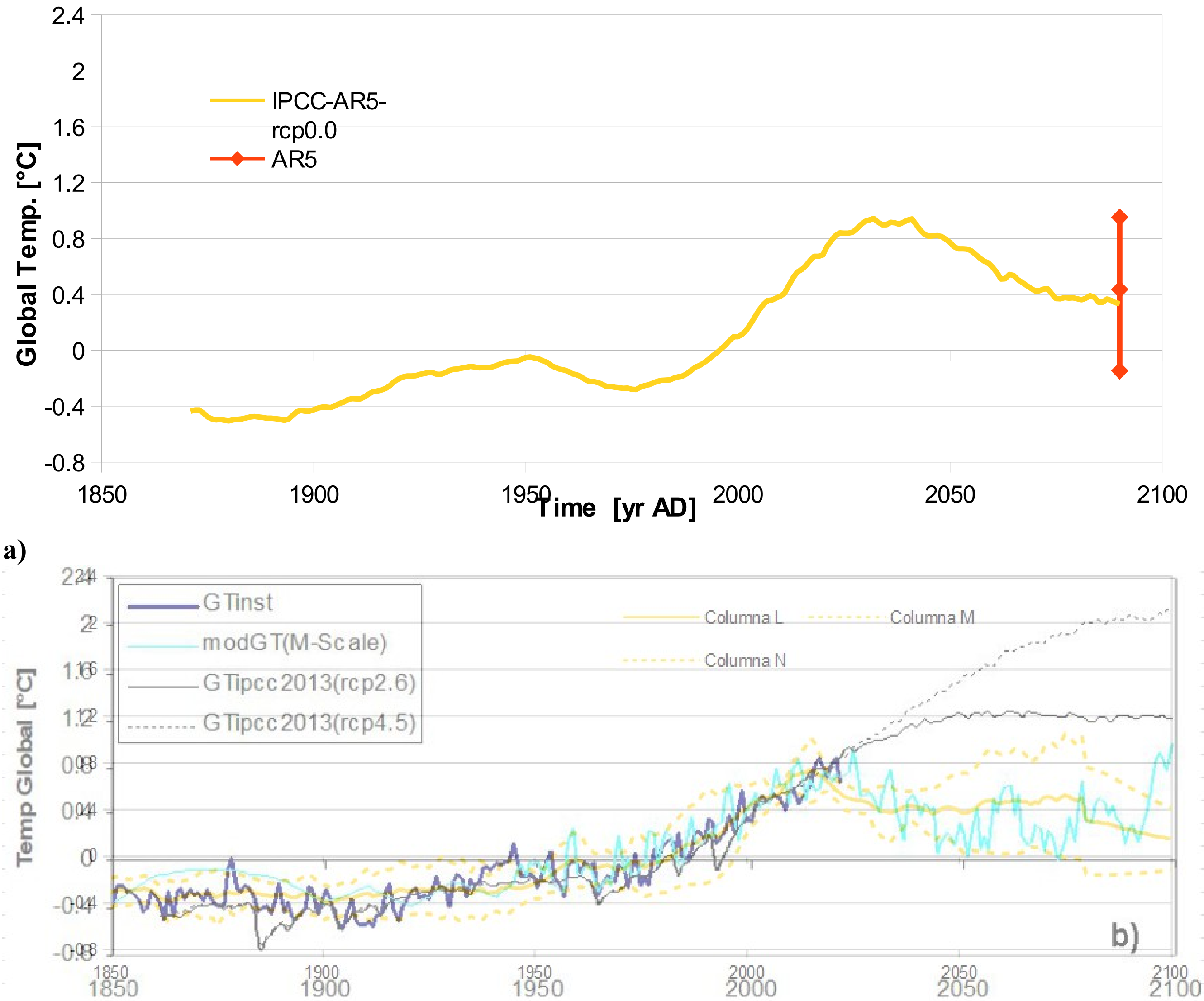
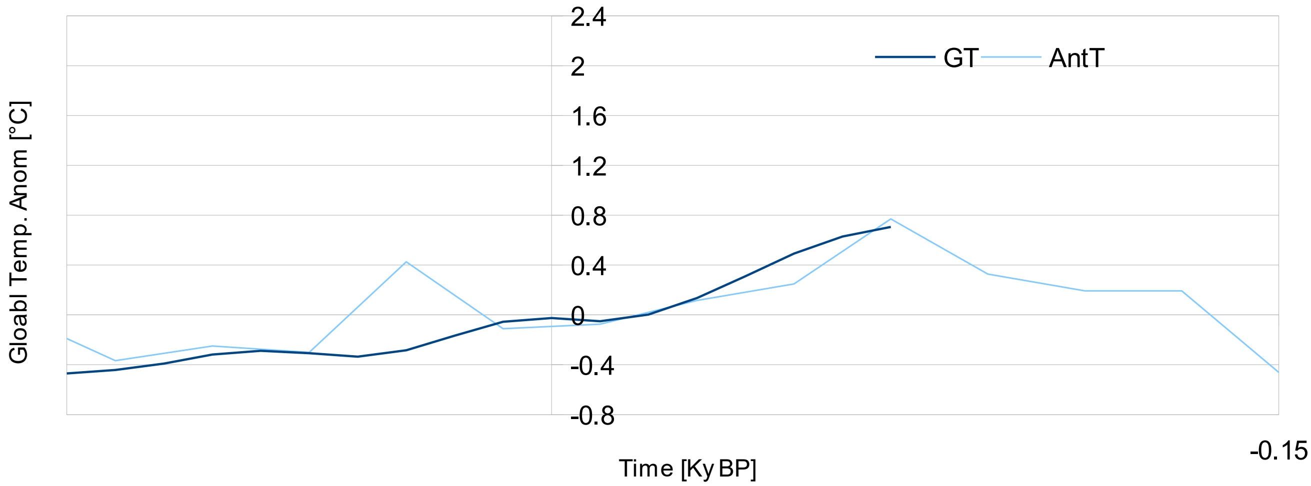


Figure 10. Different GT forecasts for the 21st century. a) GT climate scenarios extrapolated to rcp0.0 and complemented with constrained scenarios, b) previous GT scenario (ESD-2021-84) and complemented with multiple records (see Fig. 9)



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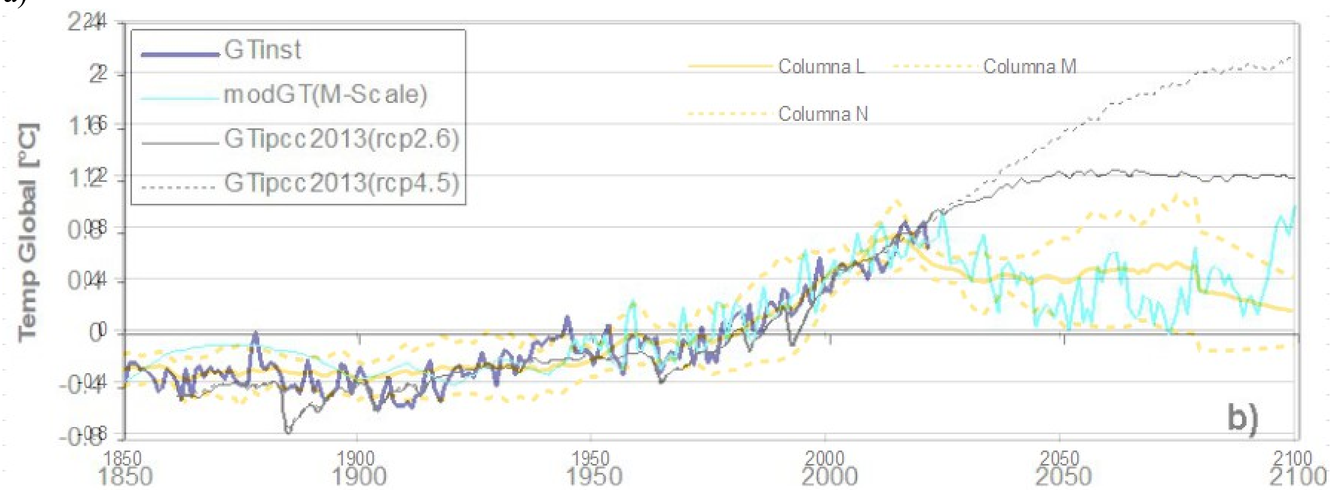
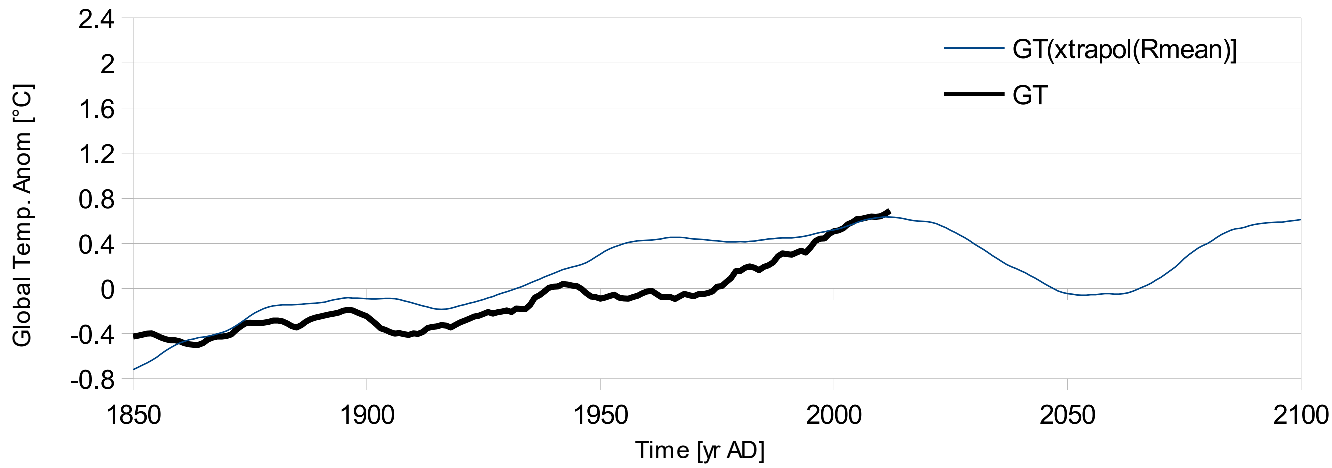


Figure 11. Different GT forecasts for the 21st century. a) GT climate scenarios based on an Antarctic record, b) previous GT scenario (ESD-2021-84) and complemented with multiple records (see Fig. 9)



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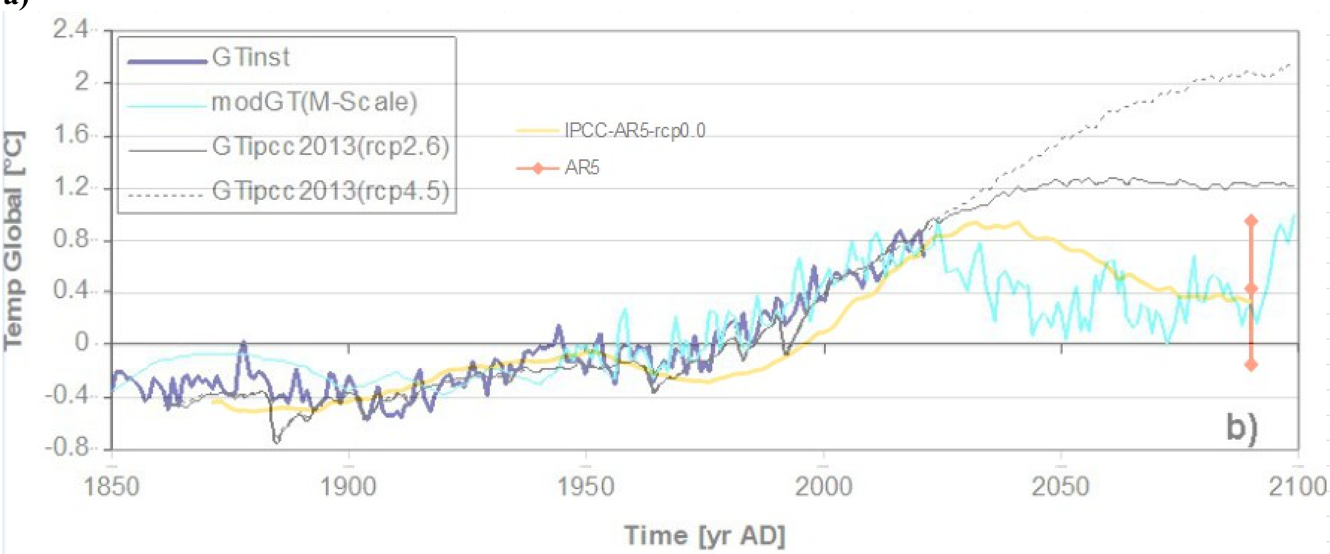
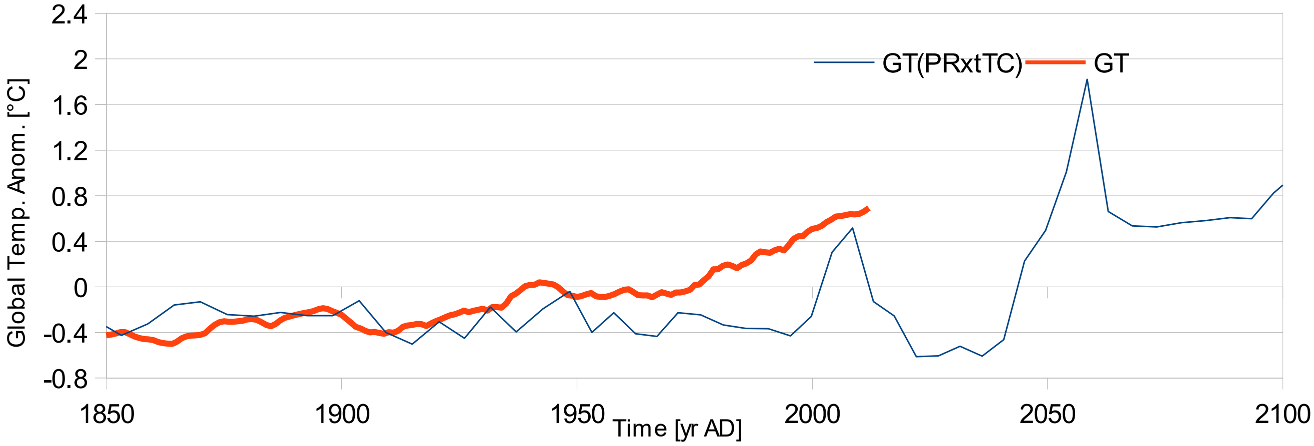


Figure 12. Different GT forecasts for the 21st century. a) GT climate scenarios based on extratropical Northern Hemisphere reconstructed record, b) their comparison with previous GT scenario (ESD-2021-84), rcp0.0 previously presented and complemented in this work with constrained scenarios.



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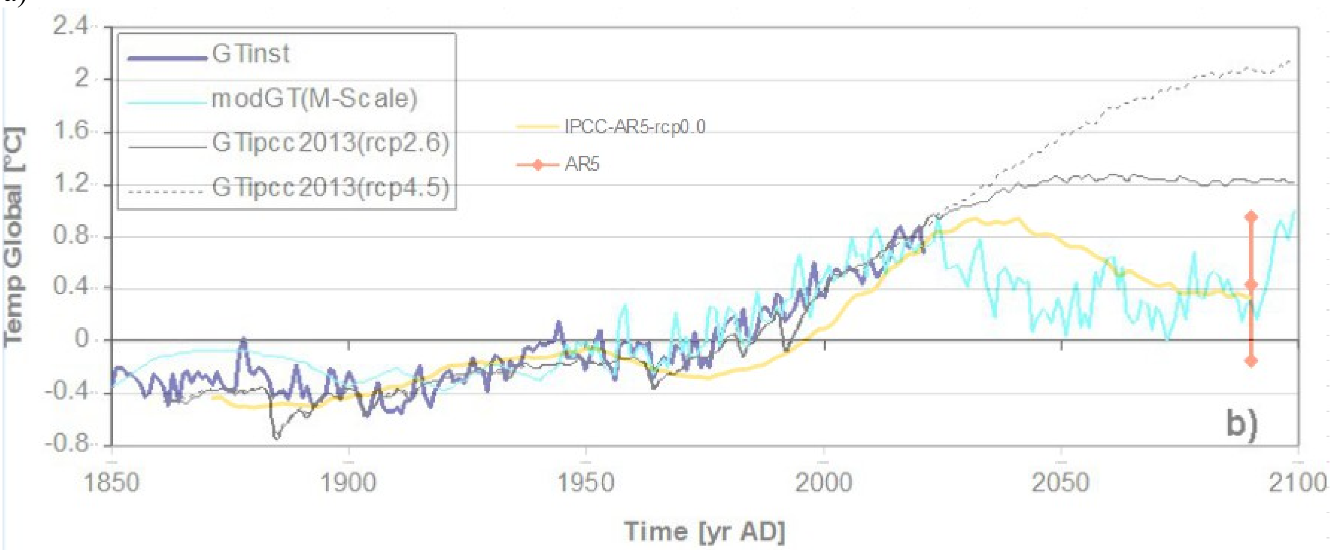
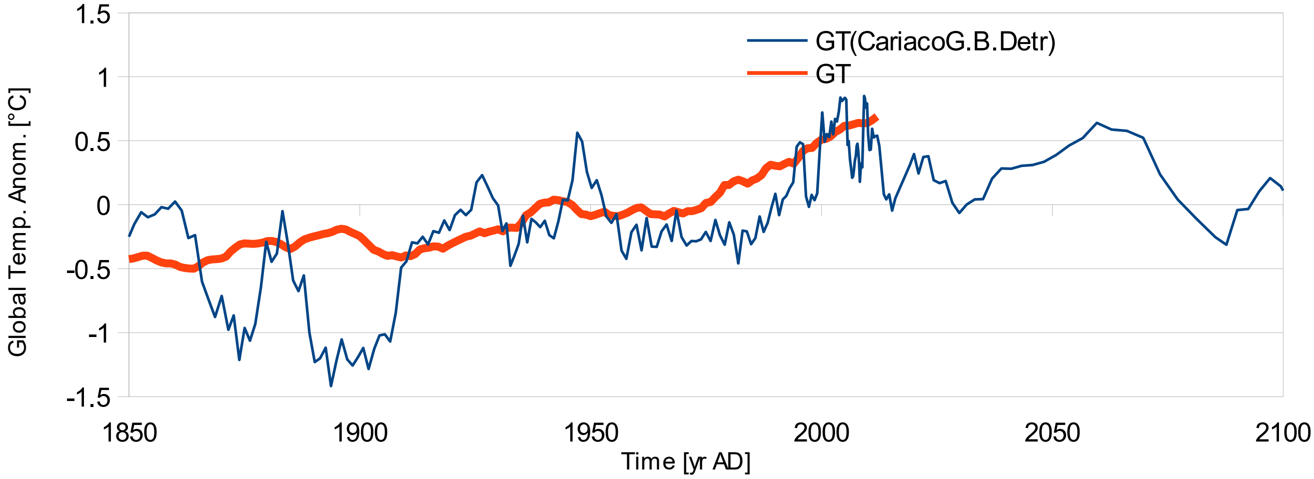


Figure 13. Different GT forecasts for the 21st century. a) GT climate scenarios based on PuertoRico extreme tropical cyclones (PR-xtrTC) reconstructed record (Donnelly et al., 2007), b) their comparison with previous GT scenario (ESD-2021-84), rcp0.0 previously presented and complemented in this work with constrained scenarios.



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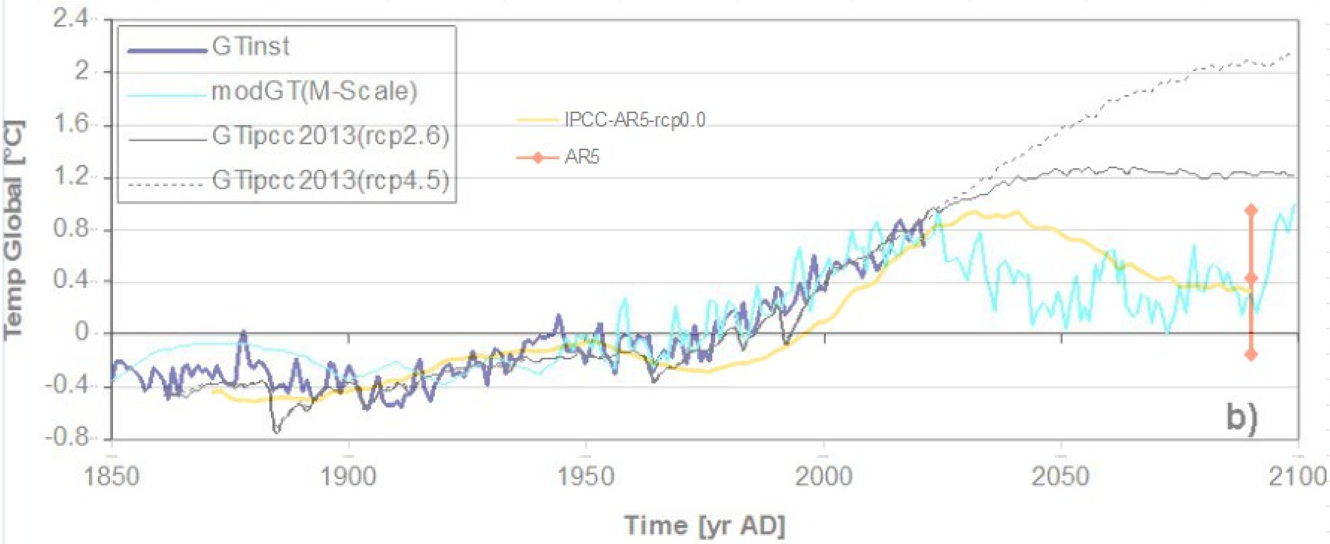
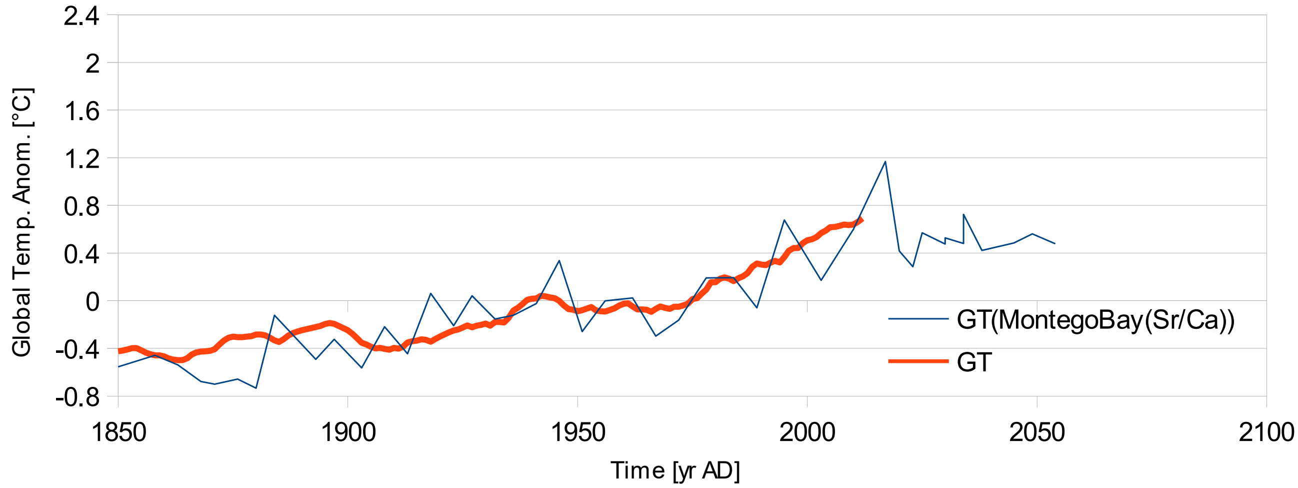


Figure 14. Different GT forecasts for the 21st century. a) GT climate scenarios based on Cariaco SST reconstructed record (Black et al., 2004), b) their comparison with previous GT scenario (ESD-2021-84), rcp0.0 previously presented and complemented in this work with constrained scenarios.



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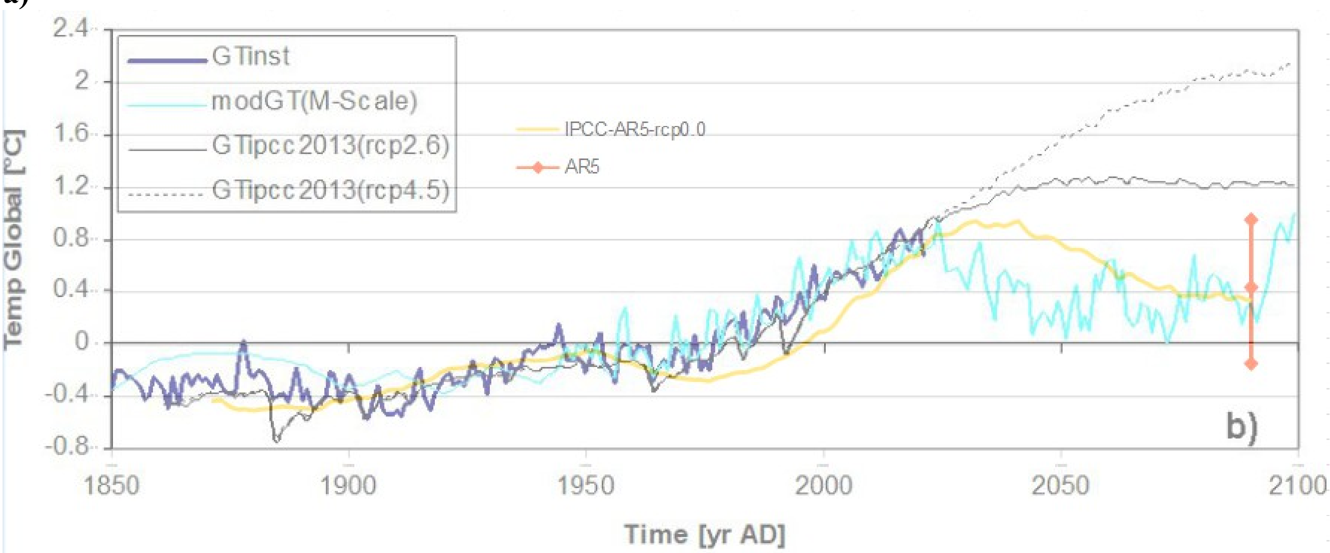
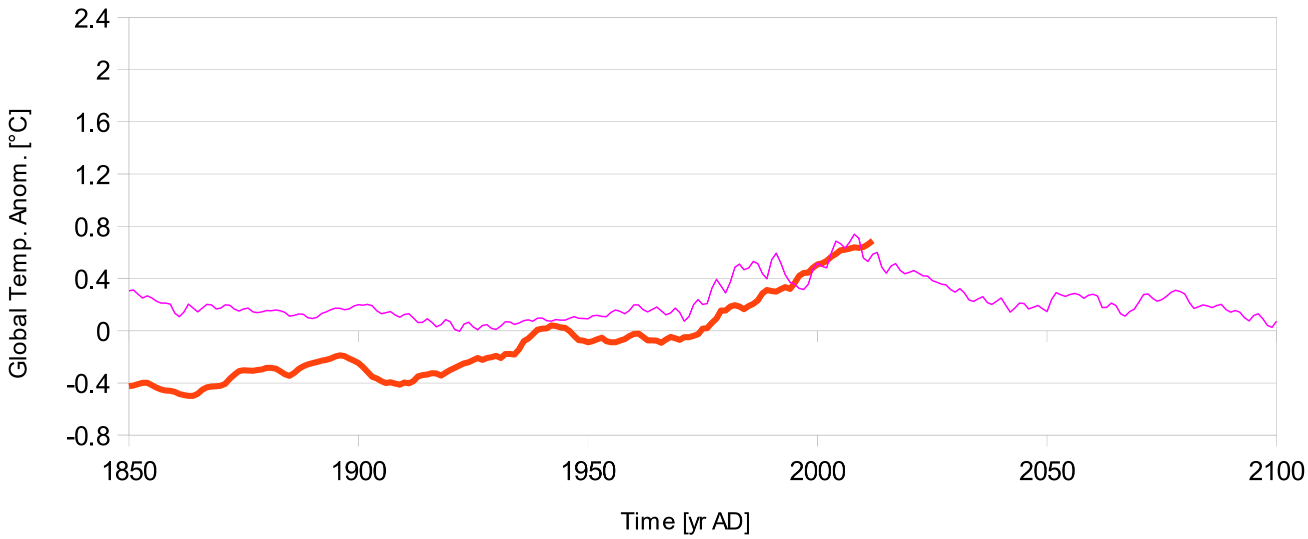


Figure 15. Different GT forecasts for the 21st century. a) GT climate scenarios based on Montego-Bay Jamaica SST reconstructed record (Haase-Schramm et al., 2005), b) their comparison with previous GT scenario (ESD-2021-84), rcp0.0 previously presented and complemented in this work with constrained scenarios.



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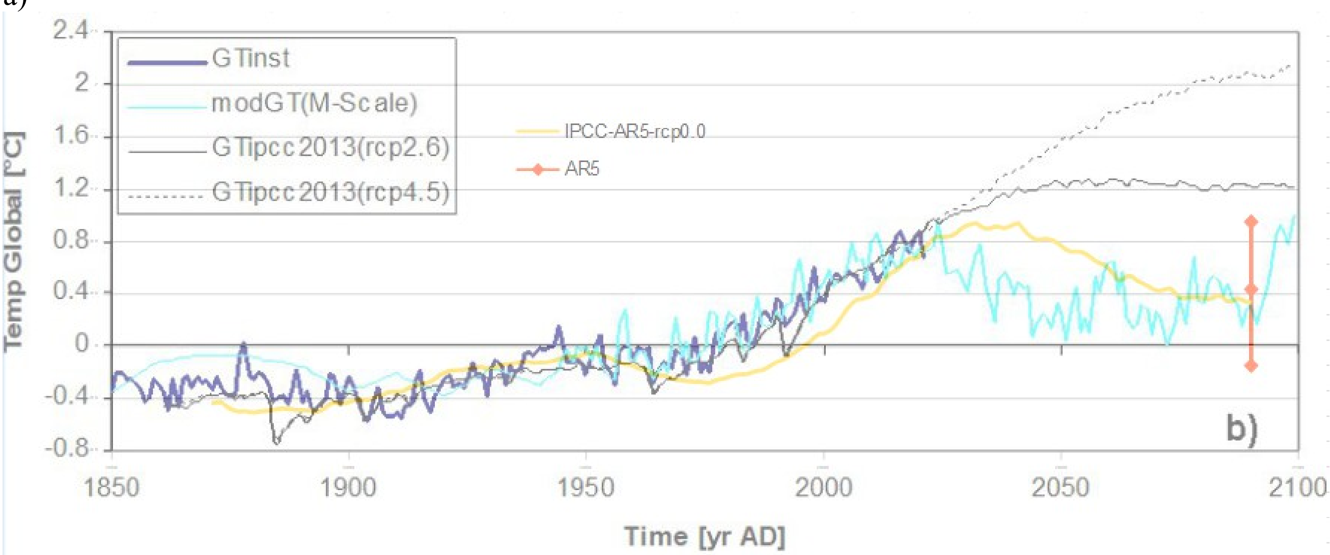


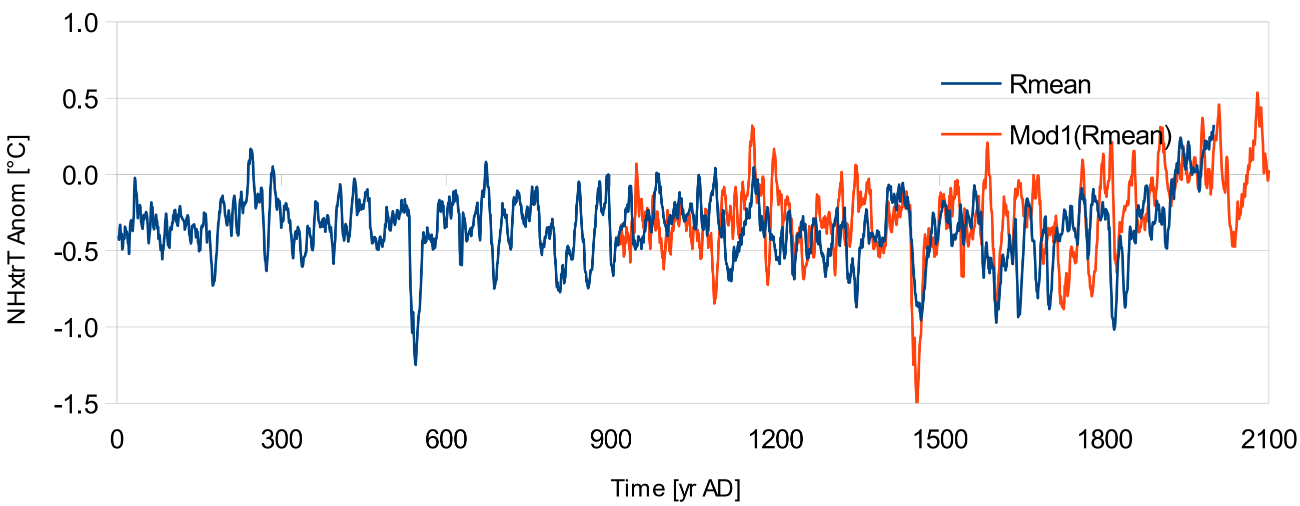
Figure 16. Comparison of a) GT forecast 2020-2100 made in ESD-2021-84 and this last comment, with b) a model of GT based on ENSO volcanic response (SST N3v) simulated with the ZC model by Mann et al. (2005). For additional comparison volcanic influences on climate (considering model shown in b) and those from Bethke et al., (2017) see Appendix B.

H. Appendices

APPENDIX A: Global Temperature forecast based on the extrapolation of Northern Hemisphere Extratropics Temperature (NHExtrT) [Büntgen et al, 2020]

The recent NHExtrT climate reconstruction for the last 2000 years (Büntgen, et al., 2021) is analyzed and extrapolated here. These authors, have reconstructed the full range of past Northern extra-tropical summer temperature variation from 1 to 2010 CE. They apply a novel ensemble climate reconstruction approach on updated tree-ring width (TRW) chronologies from high-elevation/-latitude sites across the Northern Hemisphere. In order to better visualize recurrent pattern the record and its moving standar deviation, each 20 years, are shown in Figure A1.

In the same Figure A1, the NHxtrT and its StdDev records are modelled with analogs lagged around 900 years. The Figure A1a shows the NHxtrT and its analog model (the same record lagged 917 years). The Figure A1b shows the StdDev(NHxtrT) and its analog model (the same record lagged 900 years).



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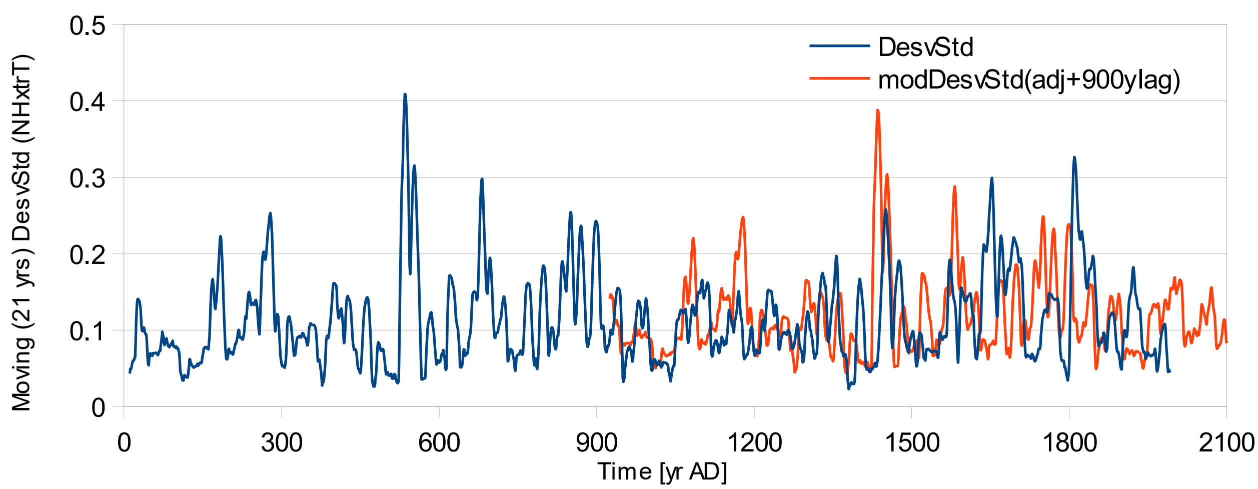


b)

Figure A1. NHxtrT a) values and b) stddev records and their analog models.

The lags of around 900 years in both shown models of NHxtrT, could be justified by detected recurences both in climate records (Shulz and Paul, 2002) and in orbital high-frequency variability analysis (Loutre et al. 1992).

Based in the extrapolated NHxtrT a GT forecast is made. It is developed linerly adjusting and lagging the NHxtrT record to the GT record.

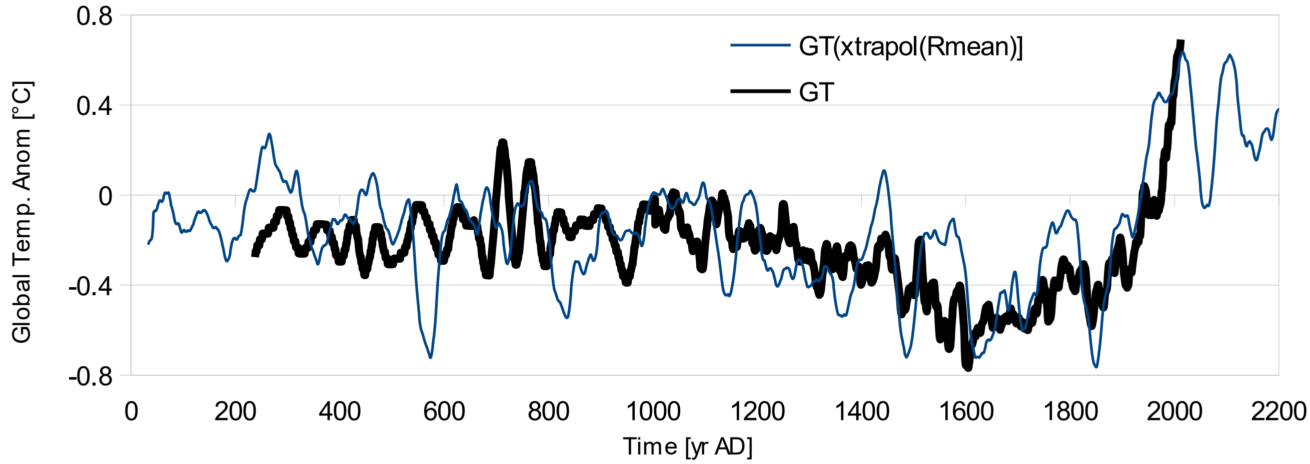


Figure A2. Global temperature forecast based the linearly adjusted and lagged extrapolated NHxtrT.

APPENDIX B: Global Temperature forecast based on the SST-Niño3 reconstructed with volcanic forcing (Mann et al., 2005)

We analyze an ENSO simulation with solar and volcanic forcing (Mann et al., 2005). The limited area Cane-Zebiak model provides SST evolution over the tropical Ocean-atmosphere model forced by solar and volcanic activity. This only-volcanic-forcing modelling emphasize the intermittent and aparently errative volcanic activity and results in ENSO variation over the last millennium with oscillations of around 177 years. In order to verify the existence of this oscillations an analog model (a linear transformation of the original record) lagged 177 years, it is overlappped with a very good match (See Figure B1). This model is extrapolated to the next 177 years. The 177 year oscillation, and the corresponding lag, can be justified considering the existence a similar recurrence between several of the major planets of the solar system. An averaging of astronomical information (Fairbridge and Sanders, 1987) for multiple Saturno Jupiter Lap (SJL=19.857 yr), 9*SJL=178.713 yr, Neptune Uranus Lap (NUL=171.39 yr), and multiple Uranus Saturn Lap(USL=45.387yr), 4*USL =181.548yr, results in 177.21 yrs.

Figure B2 show the adjusted extrapolated analog model of N3v to GT. The increasing amplitude of the N3v present a very good match with the GT warming of the 20th century.

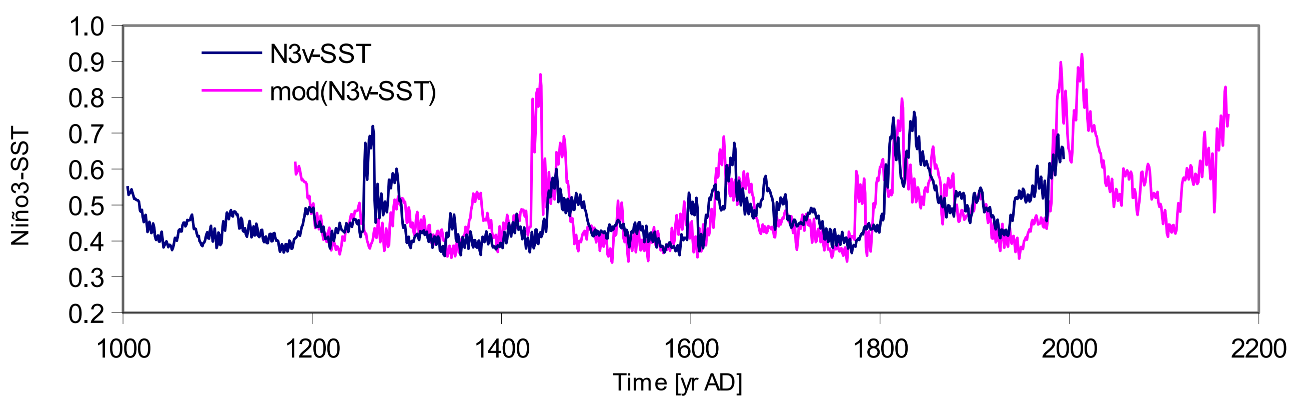


Figure A2. ENSO Niño3-SST reconstructed response to volcanic forcing (Mann et al., 2005) and its analog model (with an adusted linear transformation and a lag of 177yr).

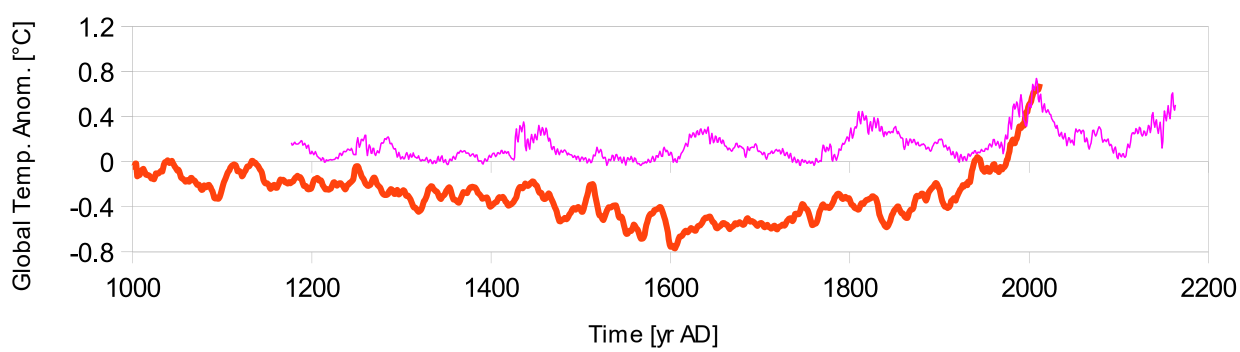
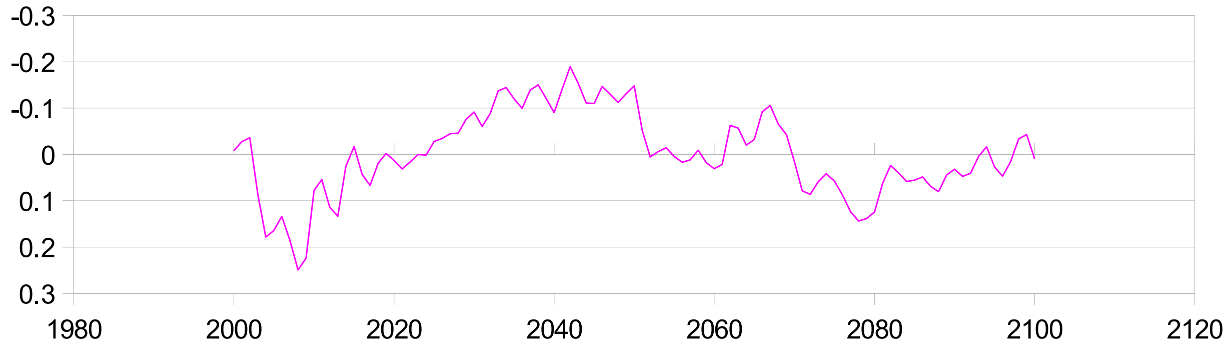
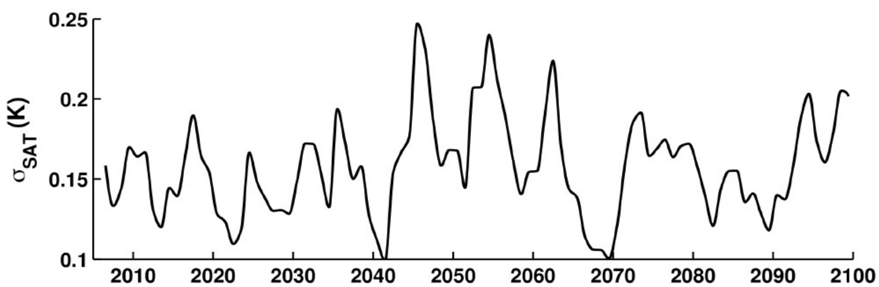


Figure B2. Global temperature forecast based the linearly adjusted N3v analog model.

The decreasing amplitude of N3v for the next decades, represent not only another empirical forecast of the GT-21st-century, but the negative of the IPCC scenario for volcanic activity (Bethke et al, 2017) leaded around 10 yr. It is shown in Figure B3.



a)



b)

Figure B3. 21st Century comparison of Climate Volcanic scenarios. a) negative GT detrended model based on N3v (Seee Fig. B2) and b) the estimated Global volcanic scenario (Bethke et al., 2017) (leaded around 10 yr) that is added to each one of the different RCP scenarios.

APPENDIX C: Global Temperature forecast based on the Puerto Rican extreme tropical cyclone reconstructed record (PR-extr-TC) [Donnelly et al., 2015]

The ePR-extr-TC climate reconstruction for the last 5000 years (Donnelly et al., 2007) has been reanalyzed. Donnelly et al., 2015, have updated dates of extreme TC hits in Estearn PR. These sediment size values are depicted in Figure B1.

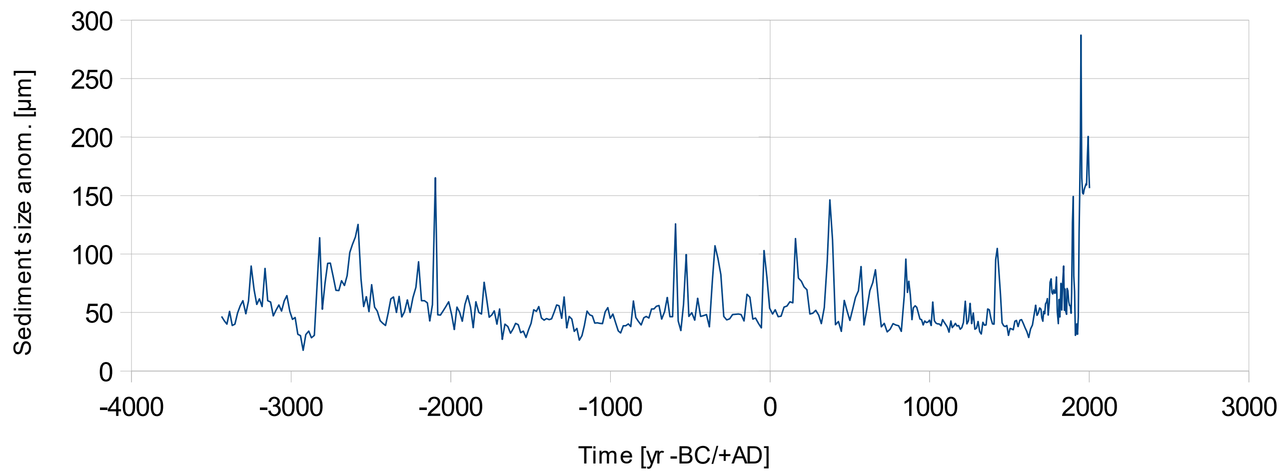


Figure C1. PR-xtr-TC values with updated dates (Donnelly etal., 2015).

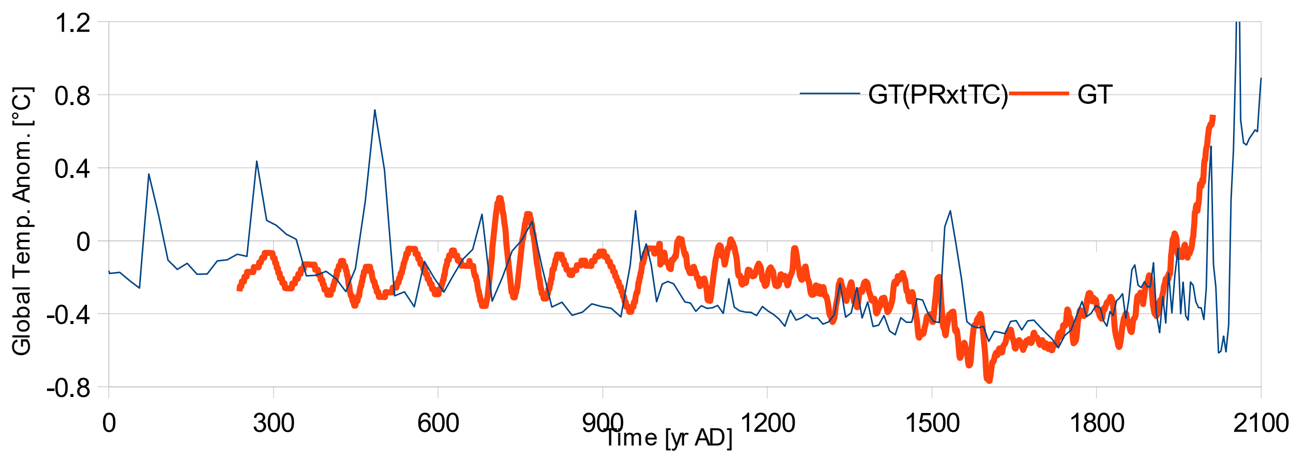


Figure C2. Global temperature forecast based on the linearly adjusted and lagged PR-xtr-TC. **The values for the model are coming from Donnelly et al. (2007 and 2016) and are lagged 110 years.**

APPENDIX D: Global Temperature forecast based on the SST of Cariaco Basin (SST-Car-d18O-G.Bull]) Black et al., (2004)

The recent SST-Car-d18OGBull climate reconstruction for the last 2000 years (Black et al., 2004) is analyzed here.

These authors, have reconstructed near-annually resolved oxygen isotope records from planktic foraminifera from the Cariaco Basin that reflect sea surface temperature (SST) and Intertropical Convergence Zone (ITCZ) precipitation-related salinity variations over the Caribbean and tropical North Atlantic spanning the last 2000 years. These recostructed values are shown in Figure C1.

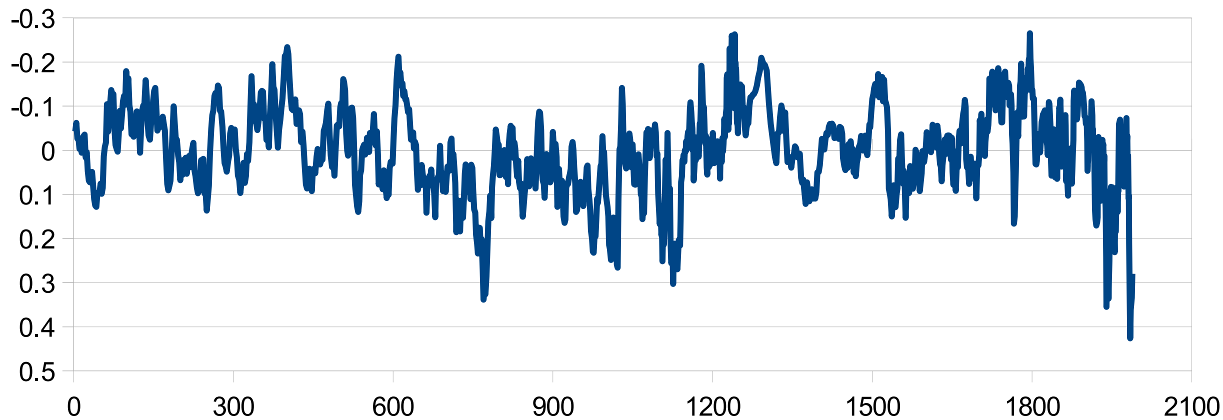


Figure D1. SST(d18OG.Bull) values from Black et al. (2004).

The Cariaco reconstructed record, lagged 670 years and linearly adjusted represent and forecast GT over the next seven centuries. It is depicted in Figure C2.

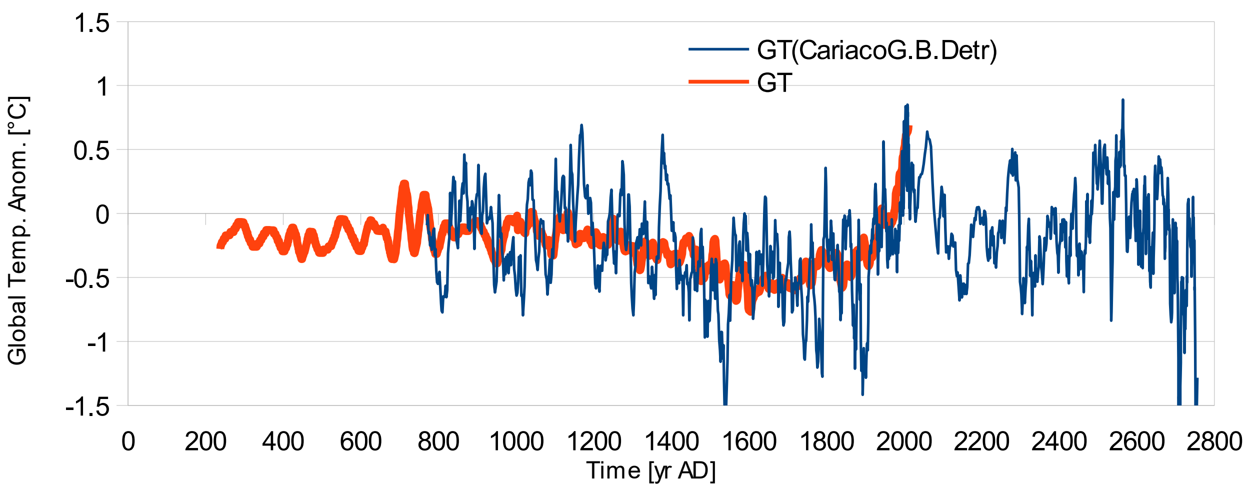


Figure D2. GT and its model based on Cariaco SST(SST-Car-d18OG.Bull). The values for the model are coming from Black et al. (2004) and are lagged 670 years.

APPENDIX E: Global Temperature forecast based on the SST of Jamaica (Montego Bay) (SST[Sr/Ca Sclerosponges]) Haase-Schramm et al., (2005)

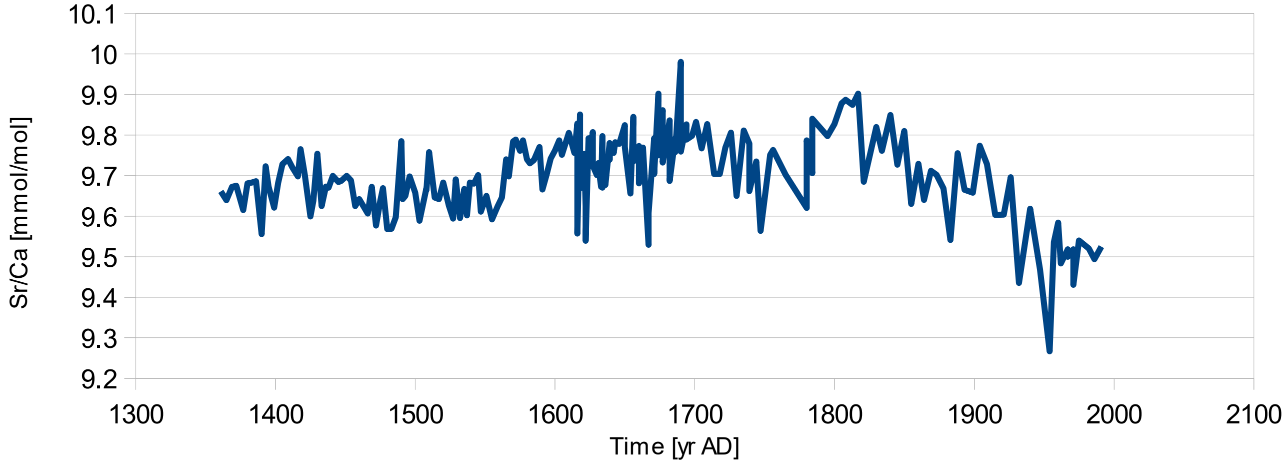


Figure E1. Jamaica SST(Sr/Ca) values from Haase-Schramm et al. (2005).

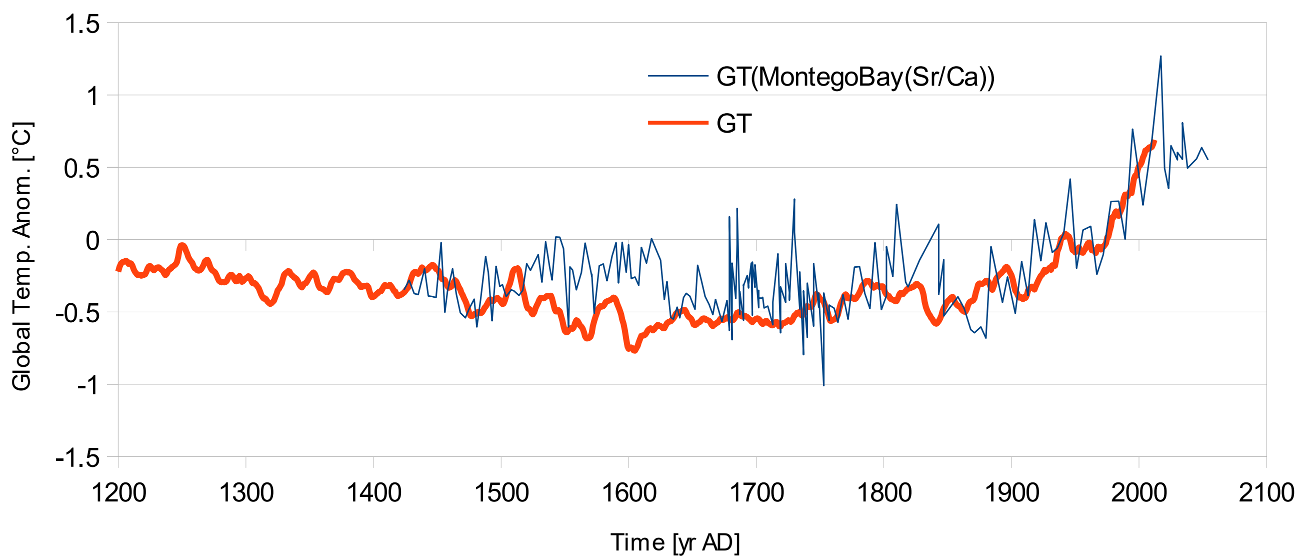


Figure E2. GT and its model based on Jamaica SST. The values for the model are coming from Haase-Schramm et al. (2005) and are lagged 65 years.