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Earth System Dynamics Discussions

Interactive comment on "Incremental improvements of 2030 targets insufficient to achieve the Paris Agreement goals" *by* Andreas Geiges et al.

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Geiges et al.: "Incremental improvements of 2030 targets insufficient to achieve the Paris Agreement goals" https://doi.org/10.5194/esd-2019-54 Compiled author responses to reviewer 1 comments

REVIEWER #1

General Comment

Reviewer Comment (RC1.00): This paper examines GHG emissions out to 2030 as pledged in the NDCs of the ParisClimate Agreement and creates scenarios for further

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reductions, then extends these emissions scenarios to 2100 with statistically analogous scenarios from an existing database. The paper translates these emissions scenarios to end-of-century global mean temperature anomalies (relative to preindustrial) using a simple climate model, MAGICC6, and examines the consequences of such temperature increases for sea level rise, maximum temperature days, and economic damages. Based on this analysis, the paper states that the global community needs to reduce emissions noticeably more than they have already committed to do with the existing NDCs if they wish to avoid climate catastrophe, as none of the scenarios presented herein provide end-of-century temperature below the Paris Climate Agreement goal of 1.5 degrees of warming. Overall, this paper is very well-written in terms of language and accessibility, with very few typographical or grammatical errors as well as a relatively straightforward and clear writing style. The paper is informative without being overly technical, and does a great job of succinctly placing the more technical modeling results in the context of a range of real-world consequences. However, there is one significant problem with the submitted manuscript that should be addressed prior to acceptance for publication. As detailed below, the MAGICC6 model tends to warm more quickly than the aggregate of CMIP5 atmosphere-ocean global climate models. Furthermore, the CMIP5 AOGCMs warm more quickly than observations. As a result, the paper as submitted provides an overly pessimistic view of theGHG emission reductions that will be needed to meet the Paris Climate Agreement. Upon revision, this tendency for MAGICC6 to overestimate warming needs to be addressed.

Author Response (AR1.00): We would like to thank the reviewer very much for this thorough and constructive review and are pleased that our work is considered to be informative and valuable. We hope that our below responses will address the main reviewer concern that MAGICC6 would be warming too quickly, potentially leading to an overestimation of required emission reduction needs. All responses to the reviewer comments are listed below.

Major Comments

RC1.01: The relationship between 2030 emissions and 2100 temperatures constitutes the core of this paper. The methods state that MAGICC6 is run with the climate sensitivity range of AR5, largely driven by CMIP5, and the carbon cycle range of C4MIP. However, MAGICC6 tends to exhibit a faster increase in global mean surface temperature (GMST) than AOGCMs when run with comparable values for climate sensitivity (Schwarber et al. 2019, ESD, doi: 10.5194/esd-10-729-2019 – particularly figure 4). Also, the CMIP5 AOGCMs tend to warm more rapidly than observed GMST (AR5 figure11.25; Fyfe, Gillett, and Zwiers 2013, Nature Clim Change, doi:10.1038/nclimate1972; Millar et al. 2017, Nature Geoscience, doi:10.1038/ngeo3031). Projections of future GMST provided by observationally constrained models are similarly noticeably lower than those from free-running AOGCMs (Chylek et al. 2016, Climate Dynamics,doi:10.1007/s00382-016-3025-7; Salawitch et al. 2017, Springer International Publish-ing, doi:10.1007/978-3-319-46939-3).

AR1.01: We would like to thank the reviewer for raising these two crucial issues: MAGICC6 vs AOGCM/ESM warming rates and AOGCM/ESM warming vs observations. We very much appreciate the opportunity to clarify these issues by providing further information and evidence.

MAGICC6 vs AOGCM/ESM warming: MAGICC is an emulator which is calibrated against AOGCM data including climate sensitivity and carbon cycle information. By definition, MAGICC is designed to capture the magnitude and rate of change from complex models and it has been shown in numerous publications that model version 6 is able to do so for both CMIP3 models (Meinshausen et al 2011, Figure 2) and CMIP5 models (IPCC AR5 WGI, Figure 12.36, Nauels et al 2017, Figure 5), also, for example, allowing for efforts comparing SRES and RCP scenarios, informed by both CMIP3 and CMIP5 models (Rogelj et al 2012, IPCC AR5 WGI, Fig 12.40). The reviewer refers to Figure 4 of Schwaber et al 2019 to illustrate the assumed faster temperature response under an instantaneous quadrupling of CO_2 for MAGICC6. The figure, however, nicely shows that MAGICC6 is right within the range of CMIP5 models in terms of rate and absolute level of warming, underlining the conclusion of the Schwarber et al 2019 that "the comprehensive SCMs [simple climate models] can generally replicate the long-term results of general circulation models" (Schwarber et al 2019).

AOGCM/ESM warming vs observations: The reviewer raises the concern that CMIP5 models (replicated well by MAGICC6) would overestimate observed warming and near-term temperature change, by citing IPCC WGI AR5 Figure 11.25 and Fyfe et al 2013, both published during the time of what became known as the "warming hiatus". Figure 1 shows an update of IPCC WGI AR5 Figure 11.25 (https://www.climate-lab-book.ac.uk/comparing-cmip5-observations/) created by Ed Hawkins.

Figure 1 (Ed Hawkins): Updated version of IPCC AR5 Figure 11.25b with the HadCRUT4.6 global temperature time-series and uncertainty (black). The CMIP5 model projections are shown relative to 1986-2005 (light grey) and 2006-2012 (dark grey). The red hatching is the IPCC AR5 indicative likely range for global temperatures in the 2016-2035 period, with the black bar being the assessed 2016-2035 average. The blue lines represent other observational datasets (Cowtan & Way, NASA GISTEMP, NOAA GlobalTemp, BEST). The green axis shows temperatures relative to 1850-1900 (early-industrial period).

Numerous more recent studies have been able to show that the causes for this temporal flattening of the warming curve are well understood (Medhaug et al. 2017) and that CMIP models can be reconciled well with observations if the right methodologies are applied (Cowtan et al 2015, Tokarska et al 2019, Hausfather et al 2020). Figure 2 shows the contributions to the differences in recently observed and modelled warming results, as presented in Tokarska et al (2019).

Figure 2 (Tokarska et al 2019): Contributions to differences in recent observed and modelled warming. a,b, Time series of modelled and observed warming (a) and different effects leading to adjustments in observed and modelled GBST (b). The length of the bars (horizontal black lines in b) shows upper (lower) estimates of the influence of

Pacific variability on warming. The spread arises from uncertainty in both observations and the forced signal (effects 5 and 6), from missing years (effects 8 to 10), and reflects the range across four studies (effect 7). Vertical black lines in b indicate 5–95% uncertainty ranges. Effects indicated by an asterisk are used for the net effect (bar 4). The global mean temperature base period is 1961–1990 in a, and 2006–2015 relative to 1986–2005 in b (see Methods for details). AA, anthropogenic aerosols; S, solar; V, volcanic.

In order to increase the transparency with regard to the MAGICC6 performance compared to observations, we have revised and re-organized Figure 1 and included the most recent HadCRUT4 (HadCRUT4 - global temperature dataset) and BEST(Berkeley Earth Surface Temperature Study (BEST)) observational datasets, as well as the likely GMT response range (66% model range) for the assessed pathways:

Figure 3 (manuscript Figure 1): Historical and annual global Greenhouse Gas (GHG) emission and Global Mean Temperature (GMT) trajectories for the NDC reference scenario and two NDC improvement scenarios with a 10% and 33% reduction of 2030 emission levels relative to the NDC reference. Scenarios for Big Emitters are labeled "BE" and scenarios for all countries using "ALL". Also shown is the observed global temperature change based on HadCRUT4 (solid grey ,HadCRUT2020) and BEST (dashed grey, BEST_2020) datasets. All GMT estimates are provided relative to the 1850-1900 average. Annual global GHG emissions are provided in gigatonnes CO_2 equivalent (Gt CO2eq).

In this context it may be useful to note that MAGICC6 has been providing crucial science input under the UNFCCC, for example in relation to the (I)NDC assessment of the recent past (UNFCCC, 2016). The presented assessment is therefore also consistent with the scientific basis informing the current international climate negotiations under the Paris Agreement.

In summary, we hope that we have been able to demonstrate that neither MAGICC6 significantly overestimates 21st century warming rates compared to AOGCMs/ESMs, nor the AOGCMs/ESMs used for the calibration of the MAGICC model would overestimate observed warming to a degree that would lead to the presented assessment being overly pessimistic.

RC1.02: While this paper is in line with IPCC's estimate of necessary reductions from the 1.5degree special report, the report largely relies on just MAGICC6 and FAIR (another simple climate model) to make these emissions statements. FAIR is only marginally better than MAGICC6 at meeting the median CMIP5 temperature response, as shown in Schwarber et al. 2019. MAGICC6 has enough tunable parameters to produce results in-line with CMIP5 models (Hartin et al. 2015, GMD, doi:10.5194/gmd-8-939-2015; Meinhausen et al. 2011b, ACP,* doi:10.5194/acp-11-1457-2011) and, presumably, observed GMST. However, these scenarios are not explored, and represent a shortcoming in the submitted paper. As a result, the warming scenarios used in this paper likely have a noticeable hot bias.

*(Meinshausen et al. 2011b, ACP, the companion paper to the one cited; it shows comparisons of MAGICC6 being both in line with and warmer than AOGCM results under different presentations)

AR1.02: While we appreciate the continued concern of the reviewer, we would like to point to our detailed response above and also highlight that warming results of theoretical pulse response experiments (which show that MAGICC6 is actually performing rather well) are different to climate projections based on actual emission pathways. Below, we show a figure from Nauels et al (2017), that directly compares MAGICC6 global mean temperature responses to available corresponding CMIP5 projections under all RCPs extended up to 2300, the timescale of concern for our analysis.

Figure 4 (Nauels et al 2017): Global mean temperature (GMT) projections until 2300 for all RCP extensions based on the historically constrained probabilistic MAGICC setup; 90% ensemble range in light colors, 66% ensemble range in darker colors, medians as solid lines. Available CMIP5 GMT reference time series are shown as thin black lines. All temperature projections are given relative to 1850.

Indeed, MAGICC6 has enough tunable parameters and it is able to capture the CMIP5 response accurately. Because this capability has been explored in previous work, there is no reason to believe that MAGICC6 has a significant hot bias (see Figure 3). Hence, this study focuses on pathways that allow to assess the longer-term implications of reducing 2030 emission levels.

In order to be more clear about the capability of MAGICC6 to capture the responses from more complex models, we have added the following sentence in line 115: "Previous studies have shown that MAGICC6 captures more complex model responses well (Meinshausen et al 2011, Nauels et al 2017), while overarching efforts to reconcile observations with complex model responses have been successful as well (Cowtan et al 2015, Tokarska et al 2019, Hausfather et al 2020)."

RC1.03: The consideration above would, of course, bring into question the core proclamation that none of the suggested NDC improvement scenarios meet the 1.5 degree goal. If the actual climate system does not warm as much under the ALL33 scenario (or any other scenario) as suggested by the MAGICC6 model runs, the likelihood of meeting the 1.5 degree goal would be much higher than suggested in the submitted paper. This criticism is not to suggest that the core message will change dramatically if the potential hot bias is accounted for – it could still very well be that the ALL33 scenario does not end below the 1.5 degree goal, or does end below 1.5 degrees but not strongly enough to say it would do so with sufficiently high confidence. However, for this paper to be considered for publication, more justification (and/or context) needs to be given for the amount of warming that results from each emissions scenario, with careful attention to how well MAGICC6 can simulate observed warming.

AR1.03: We thank the reviewer for elaborating on this further. By showing that MAGICC6 provides robust and consistent projections when comparing its output to CMIP results, we hope that the reviewer's concern that this study may provide overly warm projections could be addressed.

In addition, we have adjusted Figure 1 (please see AR1.01) to address the referee's concern and increase transparency in terms of the uncertainties related to MAGICC. We have now included likely ranges in Figure 1, with the intention to highlight the probabilistic nature of the MAGICC projections as well as the wide range of uncertainties underlying these estimates. Like this, we hope to also visualise more clearly that projected warming could still be significantly lower, or significantly higher than the median "best estimate".

As already mentioned in RC1.01, we have now also included the HadCRUT4 observational dataset in Figure 1 to allow for a direct comparison of MAGICC6 output and observations, noting the issues with the blended-masking temperature metric applied in HadCRUT4 that is discussed in great detail e.g. in Tokarska et al (2019).

RC1.04: On one hand, if this particular configuration of MAGICC6 does definitively have a hot bias (as indicated by papers cited above), its use could be justified by stating that application of a hot model means any emissions scenario that meets the 1.5 degree goal under this analysis should meet that temperature goal no matter what model (or ensemble of models) is considered. That is, intentional underestimation in an emission scenario's potential success has the policy benefit of higher confidence in that scenario overall. On the other hand, statements such as the penultimate sentence of the abstract (lines 15-17), the opening paragraph of section three (lines 156-159), or the "clear evidence" conclusion (line 257) should probably be made based on likely warming scenarios, not on warmer-than-average scenarios.

AR1.04: We thank the reviewer for providing a rationale that incorporates the rationale of probabilities for achieving certain climate targets. As stated above, the existence of a large array of different uncertainty sources means that there is a chance of overestimating (or underestimating) future warming with the presented approach, as well as all existing other modelling approaches. However, we are confident that we are providing an up-to-date and robust set of temperature projections. We would not consider publishing results knowing that the underlying modelling would be biased and likely overestimate warming, just in order to be on the “safe side” when it comes to the policy context. We have revisited the statements highlighted by the reviewer in order to not provide the impression that we are overly confident in our results. Lines 15-17 now read: “An increase in aggregated NDC ambition of big emitters by 33% in 2030 does not reduce presented climate impacts by more than about half compared to limiting warming to 1.5°C.” Lines 156-159 now read: “Applying a consistent model setup, our slightly more optimistic "current NDC" reference scenarios used here would lead to a warming reduction by about 0.2°C, implied by a reduction in 2030 GHG emission levels of about 1.5 Gt CO2eq compared to the 2018 CAT pathway.” Line 257 now reads: “Our results show the need for a transformational increase in 2030 ambition by countries to achieve the 1.5°C limit and to avoid the impacts of exceeding this level of warming.”

Minor Comments

RC1.05: Line 112 – spacing

AR1.05: The spacing in line 112 has been fixed.

RC1.06: Lines 136 to 140 – sentences are a little hard to follow

AR1.06: Lines 136 to 140 have been restructured to allow for better readability. “We present changes in hot extremes as land fraction distributions of changes in the intensity of the hottest day in a year (TXx), following the method introduced by Fischer et al (2013). This analysis is based on a time-slicing approach: for each model, a 21-year time period is selected for which the averaged global warming corresponds to the end-of-century GMT increase given by the respective scenarios (see Table 1). At each grid-cell, the hottest days of a year (TXx) are averaged over the selected 21-year period and these averages of all selected CMIP5 runs are merged into one TXx change distribution per scenario and region.”

RC1.07: Line 165 – verb confusion

AR1.07: The sentence was simplified. It now reads: “Scenarios in which emission reductions are limited to big emitters only lead to higher warming levels.”

RC1.08: Lines 173 to 176 – I don’t follow this sentence at all

AR1.08: The corresponding paragraph was revised. Line 173 to 177 now reads: “In addition to the GMT trajectories over the 21st century, assessments of related climate impacts are provided. These additional impacts are provided for three scenarios: the "current NDC" ambition reference pathway, the 33% reduction of 2030 emissions from the "current NDC" ambition pathway for big emitters (BE33) and a representative 1.5°C pathway (based on SSP1-RCP1.9). This allows for the comparison of impacts implied by the three scenarios ranging from the current ambition level to a Paris compatible level of ambition (1.5°C).”

RC1.09: Line 180 – the unit “cm” is separate from its numbers on the previous line

AR1.09: Thanks, this has been fixed.

RC1.10: Line 181 to 182 – the two parts of the sentence are ordered backwards from what a reader might normally expect

AR1.10: The two parts of the sentence have been swapped, the sentence was reformulated.

RC1.11: Table 2, NDC column, 2300 row – spacing

AR1.11: Thanks, Table 2 has been reformatted!

RC1.12: Lines 219 to 220 – the last phrase here feels awkwardly worded

AR1.12: The whole paragraph has been restructured. Lines 218 to 222 now read: “As expected, lower emission targets for big emitters have the biggest effect on GMT and related impacts. Therefore, scenarios for big emitters only show relatively similar temperature responses for high GMT trajectories compared to scenarios for all countries. However, the increasing differences in temperature outcomes between these two scenario groups show that, with increasing ambition, the relative importance of the contributions from small emitters grows (compare Table 1)."

RC1.13: Line 245 – unnecessary comma after first word; also "...each country's specific..."(possessive)

AR1.13: Both errors have been corrected.

RC1.14: Line 249 – unnecessary capitalization ("Land use")

AR1.14: Thanks, has been corrected.

RC1.15: Overall – aside from the major reservation about warming bias in the chosen model this is a very well-written and well-reasoned paper.

AR1.15: Thank you very much for this positive feedback. We have tried to address the warming bias concerns comprehensively and hope that, in combination with the presented extensive revisions, the manuscript has been improved to the reviewer's satisfaction.

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Interactive comment on Earth Syst. Dynam. Discuss., https://doi.org/10.5194/esd-2019-54, 2019.

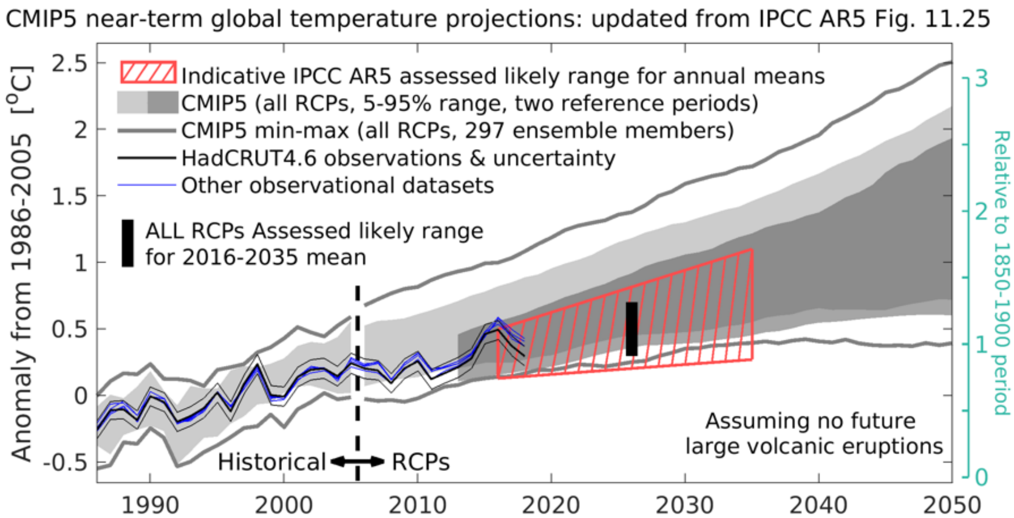

Fig. 1. Figure 1 (Ed Hawkins): Updated version of IPCC AR5 Figure 11.25b with the HadCRUT4.6 global temperature time-series and uncertainty (black). The CMIP5 model projections are shown relative to 1986-2005

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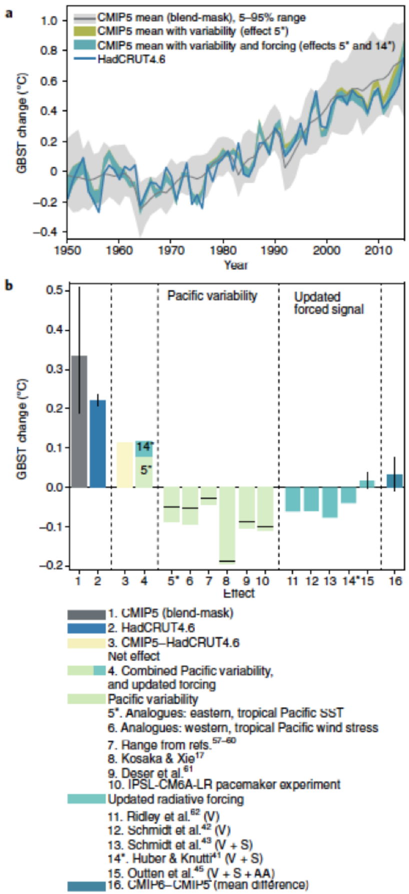

Fig. 2. Figure 2 (Tokarska et al 2019): Contributions to differences in recent observed and modelled warming. a,b, Time series of modelled and observed warming (a) and different effects leading to adjustments

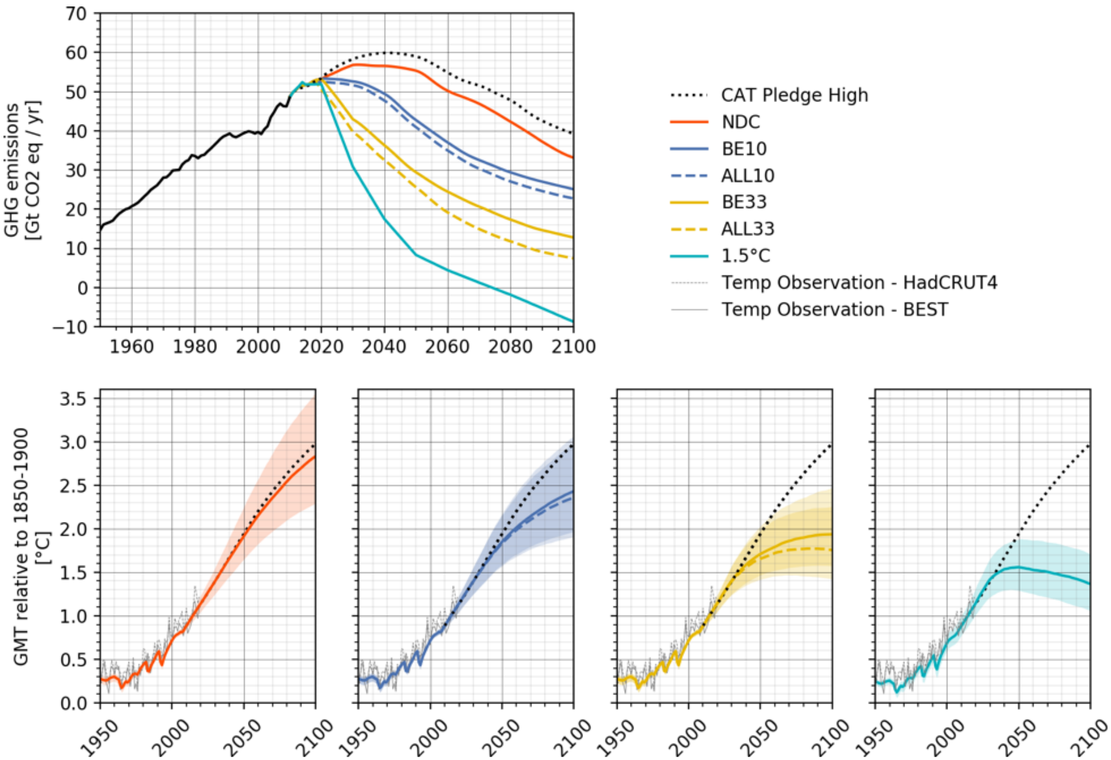

Fig. 3. Figure 3 (manuscript Figure 1): Historical and annual global Greenhouse Gas (GHG) emission and Global Mean Temperature (GMT) trajectories for the NDC reference scenario and two NDC improvement scenari

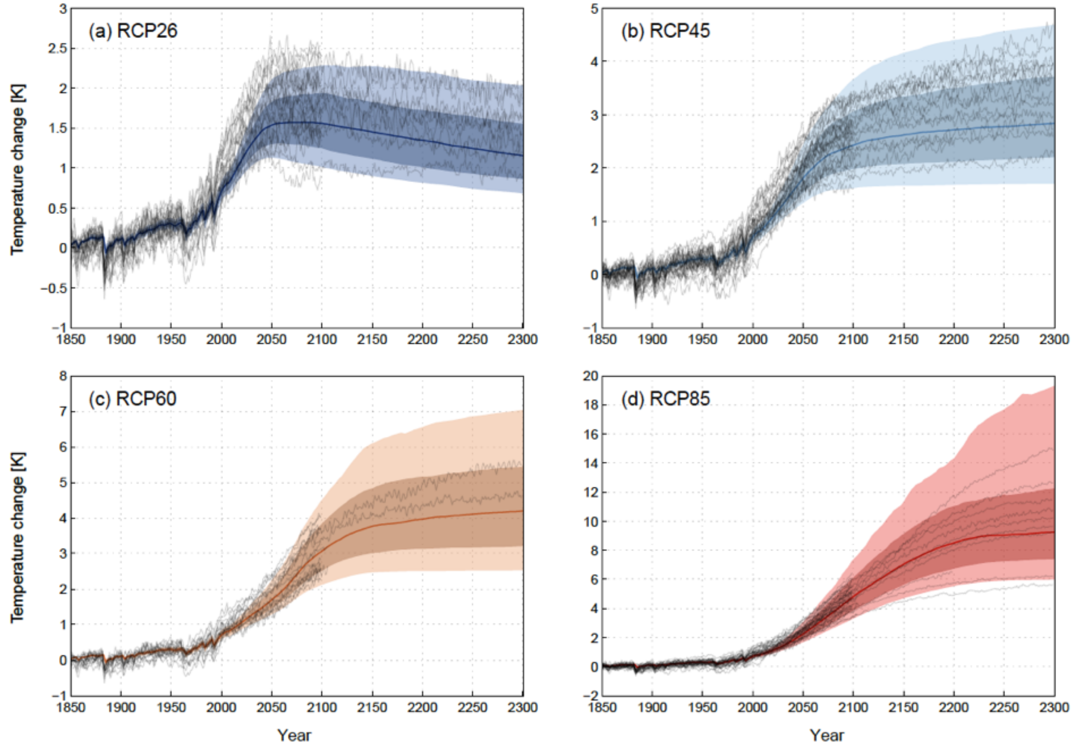

Fig. 4. Figure 4 (Nauels et al 2017): Global mean temperature (GMT) projections until 2300 for all RCP extensions based on the historically constrained probabilistic MAGICC setup; 90% ensemble range in light

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