Geosci. Model Dev. Discuss.,
https://doi.org/10.5194/gmd-2019-222-AC5, 2020
© Author(s) 2020. This work is distributed under
the Creative Commons Attribution 4.0 License.

Geoscientific Model Development Discussions

Interactive comment on "The SSP greenhouse gas concentrations and their extensions to 2500" *by* Malte Meinshausen et al.

Malte Meinshausen et al.

malte.meinshausen@unimelb.edu.au

Received and published: 15 April 2020

REPLY TO:

Interactive comment on "The SSP greenhouse gas concentrations and their extensions to 2500" by Malte Meinshausen et al. Anonymous Referee #1 Received and published: 2 December 2019

This paper describes the new Shared Socioeconomic Pathways (SSP) greenhouse gas scenarios for 2015 to 2500 based on the MAGICC7.0 climate-carbon cycle model. The future projections are combined with historical observationally-based concentration data to provide continuous time series from pre-industrial (1700) to 2500. Projections include monthly and latitudinal variations for 43 greenhouse gases: CO2,

CH4, N2O, the major chlorine and bromine-containing ozone depleting substances, and many fluorinated compounds. The paper documents the methodology and assumptions made for five high-priority scenarios and four additional scenarios that will be used to drive climate model simulations for the upcoming CMIP6 activity. The paper also provides some analysis of the expected impacts of the scenarios on global and regional surface temperature and sea level rise, and includes some comparisons with the previous RCP greenhouse gas scenarios. This is an important paper which is generally well-written. However, some aspects of the text should be clarified and/or improved prior to publication. These are listed below, along with some other minor corrections.

REPLY: We thank Referee #1 for the time to go through this extensive manuscript. END REPLY

The figures, overall, are too complicated and filled with unnecessary details at this point. Most of the figures have too many panels and many panels are too small to be discernible. I would recommend the authors to put some serious thoughts into what are the most important figures that are essential in terms of conveying the key messages of this paper for the modeling and the general scientific communities. Keep those figures/panels, and move the rest to supplementary material.

REPLY: Thank you. We moved Figures 6 (the 2005 to 2030 excerpt of historical observations and future concentrations) and 13 (the effect of the latitudinally resolved concentrations in CESM2) to the Supplementary Material and deleted Figure 12 (the temperature and SLR projections under SSPs and RCPs). END REPLY

Abstract: line 38, change to ". . . has quantified" REPLY: Done.END REPLY

line 41, change to "concentrations" REPLY: Thx. Done. END REPLY

line 51, ". . .from today 66%...." sentence structure is not right. Do you mean, eg, ". . . from 66% for present day to roughly 68% " ?

REPLY: Thx. Suggestion implemented. END REPLY

line 55, ". . . expected global mean temperatures extend to lower 2100 temperatures" Please reword this. It's not clear what is being said here.

REPLY: Thank you. We shortened and hopefully clarified the sentence by saying that: "In comparison to the RCPs, the five main SSPs (SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5) are more evenly spaced and extend to lower 2100 radiative forcing and temperatures." END REPLY

Line 58, spell out MAM. REPLY: Done. END REPLY.

line 63, I was confused by the term "collective" here. I suggest "societal" instead.

REPLY: Thx for the suggestion. Implemented. END REPLY

line 64, change "manage" to "limit" REPLY: Thx for the suggestion. Implemented. END REPLY

lines 60-64. This is a very long sentence. I suggest separating into two sentences. Eg, start new sentence on line 63 to read: ". . ... upwards shape. It is a"

REPLY: Thx for the suggestion. Implemented. END REPLY

Main text: p. 3, CMIP6 was defined three times on this page. Suggest introduction of CMIP-6 at lines 72-73. Please consistently use either CMIP6 or CMIP-6 throughout the text. REPLY: Implemented. END REPLY

p. 3, line 77, define GHG here as greenhouse gases (GHG). You may consider using GHG, instead of greenhouse gases throughout the text hereafter. REPLY: We opted to introduce the abbreviation GHG in the next paragraph. At this location (line 77) it could have led to misunderstandings – given it refers to non-CO2 GHGs..END REPLY

p. 3, line 79, insert "minor" after "other". REPLY: Done. END REPLY.

p. 6, line 170, consider use "concentrations", instead of "mixing ratios" REPLY: Done.

END REPLY

p.7, line 193, change "CO" to "OC" REPLY: Oups. Thanks for spotting that. END REPLY

p. 12, line 323, delete "to"

REPLY: Thank you. Done. END REPLY

p. 13, Section 2.4.3, lines 363-365, the change in stratospheric lifetime per BDC change, and the BDC change per warming beyond 1980 levels. These are important points, but how were these numbers obtained? This should be explained and/or references cited.

REPLY: Thank you and apologies that we insufficiently explained this step in our calibration. The text now reads: "The Brewer-Dobson circulation is assumed to increase 15% per degree of warming beyond 1980, derived from Butchart and Scaife's finding of an approximately 3% increase per decade (2001) and assuming a 0.2C warming per decade (Meinshausen et al., 2011). Calibrating our gas-cycle models to the results by Holmes et al. (2013), it seemed however that our Brewer-Dobson circulation speed-up shortened the longer-term lifetimes in higher-warming scenarios substantially more than predicted by the results of Holmes et al. (2013). Assuming no change in the height-age distribution of the air parcels that travel through the stratosphere, the speed-up of this meridional circulation could 1:1 lower stratospheric lifetimes. However, assuming shorter residence times could offset some of the effect. We proceeded with a pragmatic approach and calibrated an effectiveness/scaling factor of 0.3 to match methane concentration projections by Holmes et al. (2013). That means that every 1% increase in the Brewer-Dobson circulation, the partial stratospheric lifetimes are reduced by 0.3%. However, we acknowledge that this effectiveness factor possibly summarizes multiple underlying differences between un-scaled MAGICC results and the Holmes et al. 2013 projections that are unrelated to the Brewer-Dobson circulation." END REPLY.

p. 14, lines 365-366, in addition to scaling of lifetime with the OH abundance, shouldn't you consider scaling of the OH reaction rates due to temperature changes as well, as these rates are temperature-dependent (same as the CH4-OH rate)? REPLY: Yes, that is a good point. Somewhat implicitly, MAGICC does indeed account for this temperature dependence of the OH-related sinks for other gases. That is because, the OH-related lifetime for those gases is scaled by the relative change over time of the OH-related and temperature-dependent CH4 partial lifetime. Hence, we clarify that sentence to say: "We assume that partial lifetimes related to the (changing) tropospheric OH sink scale with the OH- and temperature-dependent methane lifetime". END REPLY.

p. 14, line 371, delete "now"

REPLY: "Done". END REPLY.

p. 15, lines 414-418, this sentence is long, awkward, and doesn't flow logically. Consider rewrite. REPLY: Thank you. And apologies for this sentence that was indeed awkward. We now rewrote it to read "There are large natural CH4 emission sources, predominantly in the northern hemisphere. In addition, anthropogenic emissions are higher in the northern hemisphere. This largely explains the observed atmospheric concentration gradient: At the end of the historical period (2010 to 2014), CH4 concentrations are 80 ppb above the global average in the Northern mid-latitudes while Southern hemispheric concentrations gently slope towards a minimum of 60 ppb below the global average at the pole (Figure 11b in Meinshausen et al., 2017)." END REPLY.

p. 15, lines 414-418 and hereafter throughout the text, be consistent when you capitalize "Northern hemisphere" and "Southern hemisphere" or not. REPLY: Thank you. Done. END REPLY.

p. 16, line 429, change to "increase strongly" REPLY: Thank you. Done. END REPLY.

p. 20, line 550, change "this" to "these" REPLY: Corrected. END REPLY.

p. 22, lines 600 and 603, remove "as" REPLY: Thank you. Corrected. END REPLY.

p. 24, line 638, "Even stronger. . .." is awkward. I suggest "More notable. . ." REPLY: Suggestion adopted. END REPLY.

p. 24, line 645, change to: ". . . in China. The similarly short-lived methylene chloride (CH2Cl2) also had " REPLY: Suggestion adopted. END REPLY.

p. 25, line 670, change to: ". . .for CO2, are miniscule... " REPLY: Thank you. Corrected. END REPLY.

p. 25, line 672, remove "to" REPLY: Thank you. Corrected. END REPLY.

p. 25, line 673, remove "These" REPLY: Thank you. Corrected. END REPLY.

p. 25, lines 675-676, change to: "... concentrations of methane decrease pronouncedly over the 21st century. CO2, for which lower "

REPLY: Thank you. We largely followed this suggestion, but changed the second sentence, so that it reads: "Reflecting the shorter lifetime, concentrations of methane decrease noticeably over the 21st century. The stronger mitigation scenarios include net negative emissions for CO2, so that CO2 concentrations recede over the long term to around 350ppm in case of the SSP1-1.9 scenario." END REPLY.

p. 27, line 739, what do you mean by "cooler"? Colder temperatures? REPLY: Due to the strong interest of the user community in temperature comparisons, we decided to actually pull this section and turn it into a separate manuscript with the background methodology description it deserves. END REPLY.

p. 27, line 741, either "relatively comparable" or "closely comparable", "relatively closely comparable" doesn't make sense. REPLY: ibid. Due to the strong interest of the user community in temperature comparisons, we decided to actually pull this section and turn it into a separate manuscript with the background methodology description it de-

serves. END REPLY.

p. 27, line 745, should be “easily communicated”? REPLY: ibid. Due to the strong interest of the user community in temperature comparisons, we decided to actually pull this section and turn it into a separate manuscript with the background methodology description it deserves. END REPLY

p. 28, lines 759-769, references to Figure 12b are missing. REPLY: ibid. Due to the strong interest of the user community in temperature comparisons, we decided to actually pull this section and turn it into a separate manuscript with the background methodology description it deserves. END REPLY.

p. 29, line 786, MAM is a spring season, not winter. REPLY: Now corrected so that it says: “In the DJF and MAM northern hemispheric winter and spring season, ...” END REPLY.

p. 29, lines 793-4, wording is redundant, change to: “. . .. poleward of 65 degrees North”, or something to that effect. REPLY: Thank you. Suggestion taken up. END REPLY.

p. 29, line 796, change to “4500-year long” REPLY: Thank you. Corrected. END REPLY.

p. 29, lines 801 and 803, what do you mean by “the MAM region” and “the DJF region”? REPLY: Apologies. Corrected to now read “MAM period” and “DJF period”. END REPLY.

p. 28-29 and Figure 13, what about the responses/impacts in the other two seasons, JJA and SON? Whether significant impacts were expected or not, at least there needs to be a note on this? REPLY: See below the figure for JJA and SON. As to be expected, the difference in the signal is not as pronounced, if any. That is because the lower summer/autumn northern hemispheric CO2 concentrations due to the seasonality are offset by the North-to-South latitudinal gradient of forcing due to all GHGs. See the JJA

and SON figure below.

Reflecting these results, we added a sentence: “As one would expect, our analysis does not suggest significant latitudinal temperature perturbations at the 5% level for the JJA and SON periods (not shown), when seasonally lower CO2 concentrations are partially offset by the latitudinal gradient of concentrations in the Northern hemisphere.”. END REPLY.

[HERE FIGURE RC1.1 – JJA and SON periods from CESM2 runs: Difference between CESM2 runs with seasonally and latitudinally varying GHG surface concentrations and CESM2 runs with globally and annually homogenous surface concentrations.]

Figure 2: I am not sure the color and line-style grouping for this figure are the best choices or reader-friendly. First I would suggest to use thicker lines for the RCPs so that we can distinguish the SSP lines easily from the RCP lines. Second, why break thick solid lines from thin solid lines just because these are the four scenarios for which long-term CMIP6 model experiments are planned? Isn’t it more meaningful to use the thick vs. thin lines to break the high-priority (“Tier 1” + SSP1-1.9) and “Tier 2”, to support the discussion in the text? REPLY: Done. Thank you for the suggestion. We now adapted the color code of the SSP scenarios to the official IPCC AR6 color guide. We highlighted (by virtue of the boxed labels) all the high-priority SSPs. We also increased the stroke width for the RCP scenarios and distinguished them from the SSP scenarios by line style rather than color (RCPs are now all dark grey). END REPLY

A few minor comments: 1) what is the first vertical blue line, 2010? 2015? Please state. REPLY: Done. END REPLY

2) Also the small SSP labels, and the x-axis and y-axis labels all need to be bigger and darker. They are hard to read as is.

REPLY: Done. END REPLY

3) Overall, the thin lines are too thin, which make them almost not readable on printout

versions. REPLY: Corrected. The thinnest line width is now increased from 0.5 to 1.5pt. . END REPLY

4) “Total N2O emissions” in panel g should be “Total anthropogenic N2O emissions”, to be accurate?

REPLY: We think it will lead to less confusion, if we adapt the figure caption by stating that these are all anthropogenic emissions. If we inserted that flag only for a single gas, people will wonder whether the Total CH4 emissions are for example both natural and anthropogenic. We hence adapted the caption. END REPLY

Here is the adjusted Figure 2:

[HERE FIGURE RC1.2 – Revised manuscript Figure 2 - SSP emissions and their extensions.]

Figure 3, panels eg, are the y-axis showing latitudes? If so, please mark clearly.

REPLY: The fifty permafrost zonal bands are simplified presentations of the latitudinal (and topographic) distribution of the permafrost in the northern hemisphere. These bin numbers hence do not refer to latitudes. The full description from Schneider von Deimling permafrost module (2012 www.biogeosciences.net/9/649/2012) is provided in their schematic Figure 1 or A1, with the Appendix A describing the assumption about thawing threshold and carbon content distributions across these zonal bands. See e.g. Figure 1 in Schneider von Deimling

And the technical Appendix specifies the carbon content assumption.

We hence insert a reference in the caption that now reads:

“The permafrost zonal bands are a simplified approach to represent the range of thawing thresholds and permafrost carbon contents and are described in Schneider von Deimling et al. (2012).” We also added the additional description “(Southernmost =1) into the y-label caption. END REPLY

I assume panels eg are for CO2-related emissions and panels fh are for CH4-related emissions? If so, please indicate clearly in the legends, or at least, explain in the figure caption.

REPLY: Close, but not quite. The anaerobic decomposition shown in panels f and h will initially produce CH4, but some of the methane is oxidized on its path to the atmosphere and emerges as CO2. Thus, those panels are simply what their titles are, the Anerobic or Aerobic decomposition of the mineral or peatland soil carbon. We added an extra sentence in the caption:

“The mineral and peatland soil decomposition under aerobic conditions (panels e and g, respectively), and also the oxidised part of the methane that originates from the anaerobic decomposition (panels f and h) contribute to the net CO2 emissions from permafrost thawing.”

The slightly adapted figure is now:

[HERE FIGURE RC1.3 – Revised manuscript Figure 3 - Revised Permafrost figure]. END REPLY

Figure 4, top left panel, what is the black lettering in the upper right? Remove or clarify. I am not sure I understand Figure 4d at all, particularly the top ranges for N2O, CH4.

REPLY: Thank you. We now expanded the title of Figure 4d and added some additional text. The black lettering is an odd display issue that arises when the journal’s submission website converts the submitted PDF. It unfortunately does not arise on our side, so we are unsure how to fix that. Here is the adapted graph.

[HERE FIGURE RC1.4 – Revised manuscript Figure 4 – Revised figure regarding Etminan forcing]. END REPLY

âĹij Figure 5, I don’t see the need of including this figure (or at least many of the subpan- els) in the main text of this paper. There are 10 subpanels in this figure, which include lots of repetitive information illustrating the long term global trend, NH-SH

differences, seasonality and their changes w.r.t. time, etc, for just CO2 under the SSP1-1.9 sce- nario. Are these all essential information for the purpose of SSP scenarios? If so, there should be some discussion on why these information are important in the text. At this point, there are almost no references to this figure (except line 507 that briefly reference to figure 5b) throughout the text. Second, many of the labels and the legend are much too small. For example, panel f shows 25 different lines, which I can't tell apart from each other at all. This is the consequence of jamming too many complicated panels into a single figure. There got to be a way that the information can be conveyed through 3-4 subpanels, if the authors have a compelling reason to show figure 5. In the next revision, please indicate at the top of the figure (not just in the caption) that it is CO2 surface mole fraction under the SSP1-1.9 scenario. Also, Make all fonts bigger and lines thicker and darker.

REPLY: Thank you. We share the observation that a lot of information is cramped into this "factsheet" figure. For the research community, we offer these kinds of factsheets for every gas and every scenario (see greenhousegases.science.unimelb.edu.au) and would hence like to keep the general format. Thanks to the reviewer's comment that we failed to appropriately explain the various panels in the text, we now added more explanatory text and made presentation changes to this factsheet (bigger fonts, clearer labelling, clarification of "zoom" panels f, g and h). The revised figure with the updated font size and labelling is here:

[Here Figure RC1-5 – Revised manuscript Figure 5 – GHG Factsheet for SSP1-1.9 CO2 concentrations.]

We amended section 3.1 on the Carbon Dioxide, referring to all subpanels of Figure 5, so that the reader has a textual guidance. The text previously read:

"The projected CO2 concentrations range from 393 to 1135 ppm in 2100, with the low scenario SSP1-1.9 decreasing to 350 ppm by 2150. Given the assumption of zero CO2 emissions in the lower scenarios beyond that, the lower end of the projected CO2

concentrations is not projected to decrease much further. On the upper end, under the SSP5-8.5 scenario global-average concentrations are projected to increase up to 2200 ppm by 2250 (Table 4 and Table 5). The latitudinal gradient implies a difference of annual-average northern midlatitudes to South pole concentrations of about 7 ppm. For the future, the applied projection methods result in a zero latitudinal gradient by $\sim$2060 in the lowest SSP1-1.9 scenario (Figure 5b) because CO2 emissions revert from positive to net negative. Under the highest SSP5-8.5 scenario, the northern midlatitude to South Pole difference expands to more than 23 ppm by 2100 (not shown in plot, but viewable in online data repository at greenhousegases.science.unimelb.edu.au)."

And is now expanded to read:

"The projected CO2 concentrations range from 393 to 1135 ppm in 2100, with the low scenario SSP1-1.9 decreasing to 350 ppm by 2150 (Figure 5g). Given the assumption of zero CO2 emissions in the lower scenarios beyond that, the lower end of the projected CO2 concentrations is not projected to decrease much further. On the upper end, under the SSP5-8.5 scenario global-average concentrations are projected to increase up to 2200 ppm by 2250 (Table 4 and Table 5, and see also online "GHG factsheets" at greenhousegases.science.unimelb.edu.au). The latitudinal gradient implies a difference of annual-average northern midlatitudes to South pole concentrations of about 6 ppm in current times (Figure 5b). As future seasonality is correlated with projected NPP, the CO2 seasonality change pattern (Figure 5a.1) is scaled with the a normalized projected NPP (Figure 5a.2). Future latitudinal gradients are derived by projecting the first two principal components or EOFs, where the first (dark blue line in Figure 5c) is regressed against global emissions – with the implied future scaling factor show in Figure 5d (dark blue line). The second EOF (turquoise line in Figure 5c) is assumed constant in the future (turquoise line in Figure 5d). The applied projection methods result in a continuous projection of CO2 concentration from the observationally derived historical values, including their latitudinal gradients and seasonality (Figure 5h). By approximately 2060, a zero latitudinal gradient is projected in the low-

est SSP1-1.9 scenario (Figure 5b) because CO2 emissions revert from positive to net negative. Under the highest SSP5-8.5 scenario, the northern midlatitude to South Pole difference expands to more than 23 ppm by 2100 (not shown in plot, but viewable in online data repository at greenhousegases.science.unimelb.edu.au)." END REPLY

Figure 6, this is a key figure, but I would suggest to just keep the mean global, NH, SH lines with the envelopes showing the range of the various scenarios. The rest of the information are too trivial for the sake of this figure and literally unreadable, when included.

REPLY: Thank you. We took out all the binned averages, i.e. included 12 of the shown timeseries. We consider the main importance of this figure in the three aspects (1) the zoomed-in focus on the transition between historical and future values, (2) the emerging spread between the various scenarios in the future (see SSP 2030 range on the right) and (3) zoomed-in comparison with a few key alternative datasets. Hence, we hope that this version strikes a balance and brings out the key points. We also increased the font sizes. See here the revised figure.

[Here Figure RC1.6 – Revised manuscript Figure 6 – Transition from historical to future GHG concentration datasets]. END REPLY

Figure 7, As in Fig. 6, many of the labels and lettering are too small, including the species labels. Also, why is there a white square area in the bottom right panel?

REPLY: Our apologies. We are not sure. Again, this is a graphical element that only pops up after the conversion of the manuscript on the submission website. We hope that the new version corrected the problem.

[HERE Figure RC1.7 – Revised manuscript Figure 7 – Radiative forcing contributions from different gases under the "high priority" scenarios]. END REPLY

Most important of all, do we really need all these details on time variations of individual gas contribution to radiative forcing? In my view, a condensed bar graph showing the

total radiative forcing, with stacked bar graph attribution of individual RF for all nine scenarios will be adequate and useful. You may also consider lumping all CFCs, other ODSs, HFCs, PFCs, respectively, instead of showing individual gases that no one can tell apart.

REPLY: We fully appreciate the reviewer's focus on simplicity. We hence made some changes to the graph that hopefully guide the quick reader's eye to the main points, i.e. that the dark blue area is the CO2 forcing, that CH4 and N2O are on top and a bunch of OTHER greenhouse gases then also contributing a small forcing. However, while introducing shading that lumps all 40 other gases together in a very simple grey stripe, we opted for keeping the underlying lines of the individual lines. It might be a slightly different philosophy of how figures shall represent data in the time of less and less paper-printouts. For the younger generation of researchers, zooming into a graph and looking at the details is an important feature that we want to support. The data richness is hence kept for the few inquisitive readers, while the vast majority readers can enjoy the main features of the plot in a zoomed-out version. I hope the reviewer will permit us to cater for both reader groups in this graph. The revised graph, with the simplified grey shaded areas for the OTHER GHGs is shown above. END REPLY

Figure 9, this is certainly a very important figure. To make the message clearer and connects better with the discussion in the text, I would suggest to use different symbols or sizes for SSP1-1.9, the four Tier 1 SSPs, and the four Tier 2 SSPs, respectively. If helpful, the authors may consider add a brief discussion on the choice of CH4/CO2 scenarios between Tier 1 and Tier 2 SSPs, or connect back to the discussion in the Introduction section on p. 4.

REPLY: Thank you. As per the reviewer's suggestion we now created different labels for the high priority "Tier 1 + SSP1-1.9" and other illustrative marker SSPs. See the revised figure here:

[HERE FIGURE RC1.8 – Revised manuscript figure 9 – Mid-century concentrations

of CO2 and CH4 under the various SSP, RCP and SR1.5 database scenarios.] END REPLY

Figure 10: 1) Again, please make x-axis and y-axis labels bigger/darker. 2) The legends on panel a is not consistent with panel b or the rest of the figure. SH, NH, global averages are plotted as thick solid lines. 3) Are the firn measurements necessary here for the scope of this paper? I can see you need them for CO2 and CH4, but CFCs, especially that you have information from the surface networks. 4) What are the gray dots? NOAA monthly measurements from the stations? Do we need to show them here? I assume the SH, NH, global averages from this study are derived using these measurements, but you can just mention in the text how they are calculated using surface observations, without actually showing them in the figure. They make the figure extremely busy, without adding additional information. 5) The diamond symbol + dashed line for Velders et al., (2014) didn't show up in legend in panel. 6) The WMO (2014) and Velders et al (2014b) are both out of date now, which are quite visible by looking at these lines in Figure 10. Why aren't you using the WMO (2018) ODSs, which will have much better agreement with the NOAA measurements, and the results from this work.

REPLY: We revised the figure now to provide larger labels and deleted the extra literature timeseries that were not strongly visible. The main point arises from the comparison to the Velders et al. (2014) data, which assumes a strong phaseout / no-emission scenario, where concentrations are lifetime-driven. The comparison with the actual NOAA measurements is hence informative as it shows the discrepancy, which is now documented in a number of papers for CFC-11 and other species. Apologies also for the inconsistent legend. We had split the legend (which was valid for all panels) between panels a and b. For clarity, we moved the legend now below the panels. The revised figure is here:

[HERE FIGURE RC1.9 – Revised manuscript Figure 10 on the departure of recently observed atmospheric concentrations and previously projected ones] END REPLY

Figure 11, again, it would be useful to use different line styles for high priority SSPs vs. Tier 2 SSPs, which will tie better with the discussion in the text. Use bigger font size and thicker lines so that they are easy to read.

REPLY: Following the suggestion from the reviewer, we now doubled the line-width for the high priority SSPs and increased the font size for labels and legends. The revised figure is here:

[Here Figure RC1.10 – Revised manuscript Figure 11 on SSP concentrations for 21st century and over the longer timeframe from 1750 to 2300]. END REPLY

Figure 12, panel a, may be change y-axis title to " . . . temperature change with respect to 1750" to be consistent with panel b? panel b, y-axis, units should be meters (or cm?) not K.

REPLY: This Figure is now deleted.END REPLY

Figure 13 caption, line 1130, change to "January". Also, the final sentence in the caption is confusing: "In the high upper North during the MAM season, approximately 97 of the 100 control run segment differences are lower." Reword this sentence for clarity, and to better summarize the text from lines 801-803 on p. 29.

REPLY: Thank you. We reworded now as suggested. The new text now reads: "In the high upper North during the MAM season, the comparison with control run segment differences suggest that these ESM model results show a significant warming at the 5% level, given that only 3 to 5 of the 100 control run differences are higher."END REPLY

Interactive comment on Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2019-222, 2019.

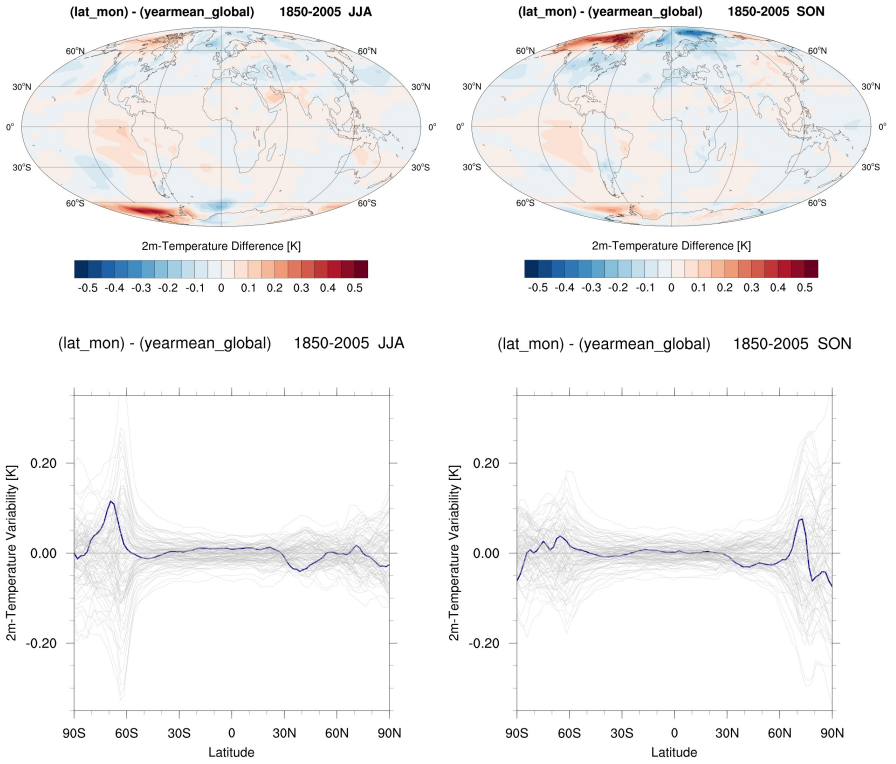

Fig. 1. FIGURE RC1.1 – JJA and SON periods from CESM2 runs: Difference between CESM2 runs with seasonally and latitudinally varying GHG surface concentrations and CESM2 runs with globally and annually ...

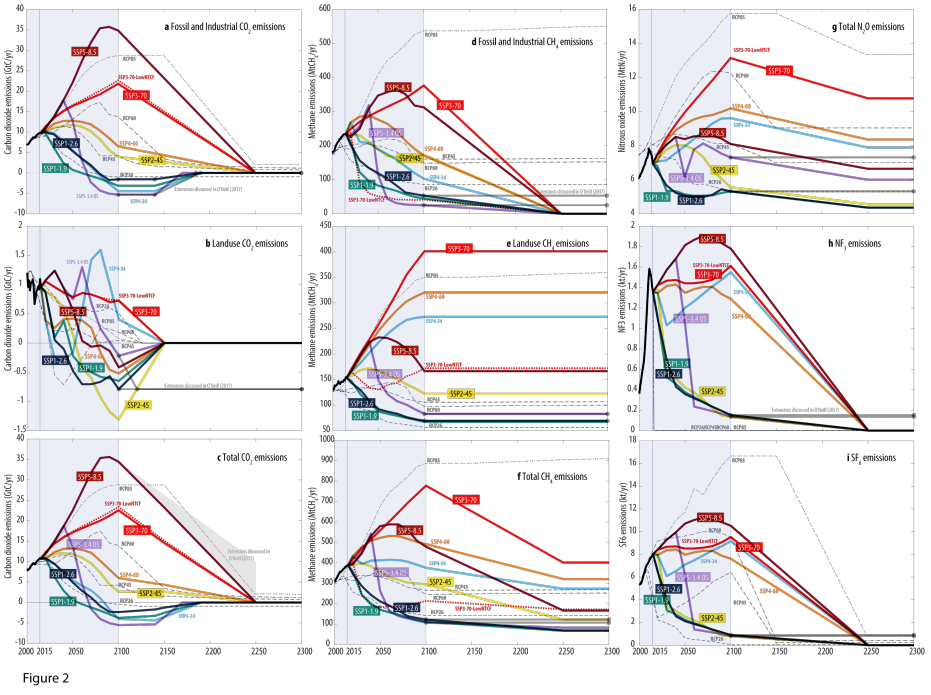

Fig. 2. FIGURE RC1.2 – Revised manuscript Figure 2 - SSP emissions and their extensions

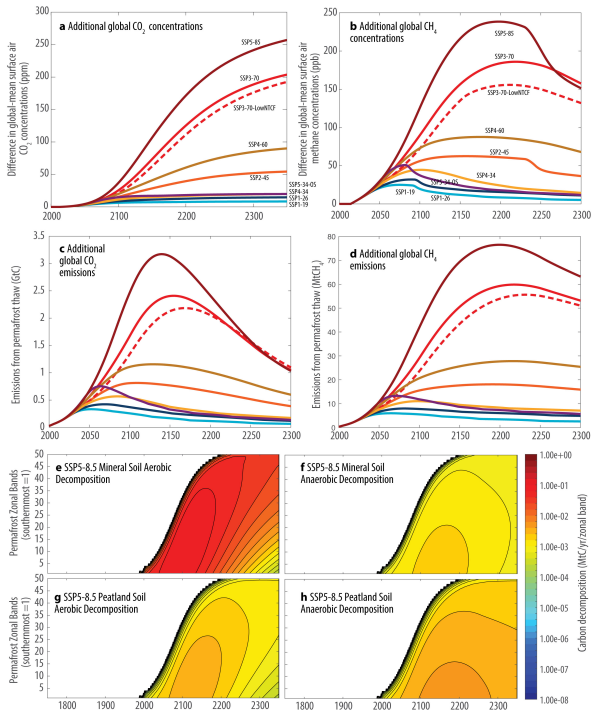

Figure 3

Fig. 3. FIGURE RC1.3 – Revised manuscript Figure 3 - Revised Permafrost figure

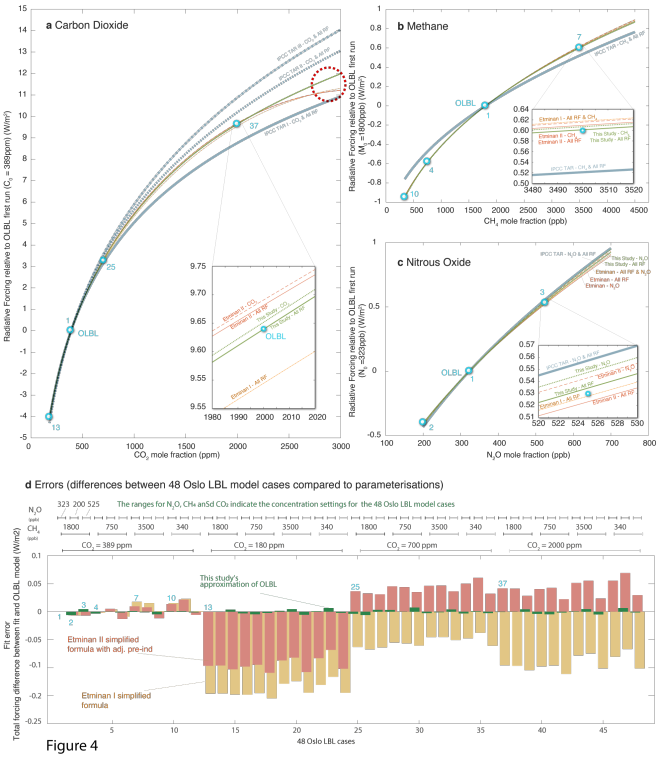

Figure 4

Fig. 4. FIGURE RC1.4 – Revised manuscript Figure 4 – Revised figure regarding Etminan forcing

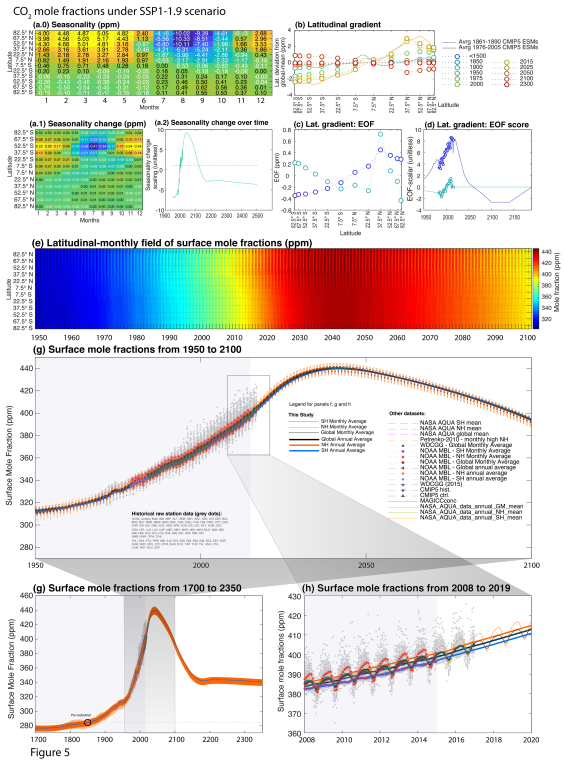

Fig. 5. Figure RC1-5 – Revised manuscript Figure 5 – GHG Factsheet for SSP1-1.9 CO2 concentrations

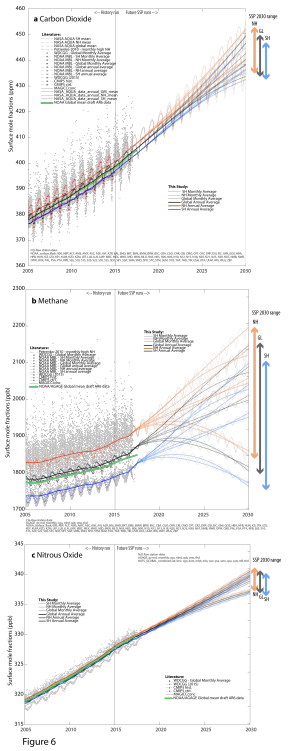

Fig. 6. Figure RC1.6 – Revised manuscript Figure 6 – Transition from historical to future GHG concentration datasets

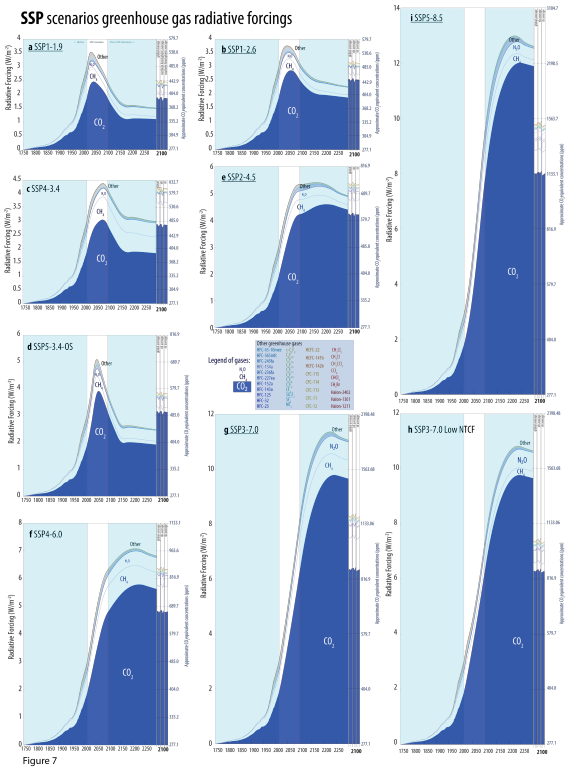

Fig. 7. Figure RC1.7 – Revised manuscript Figure 7 – Radiative forcing contributions from different gases under the "high priority" scenarios

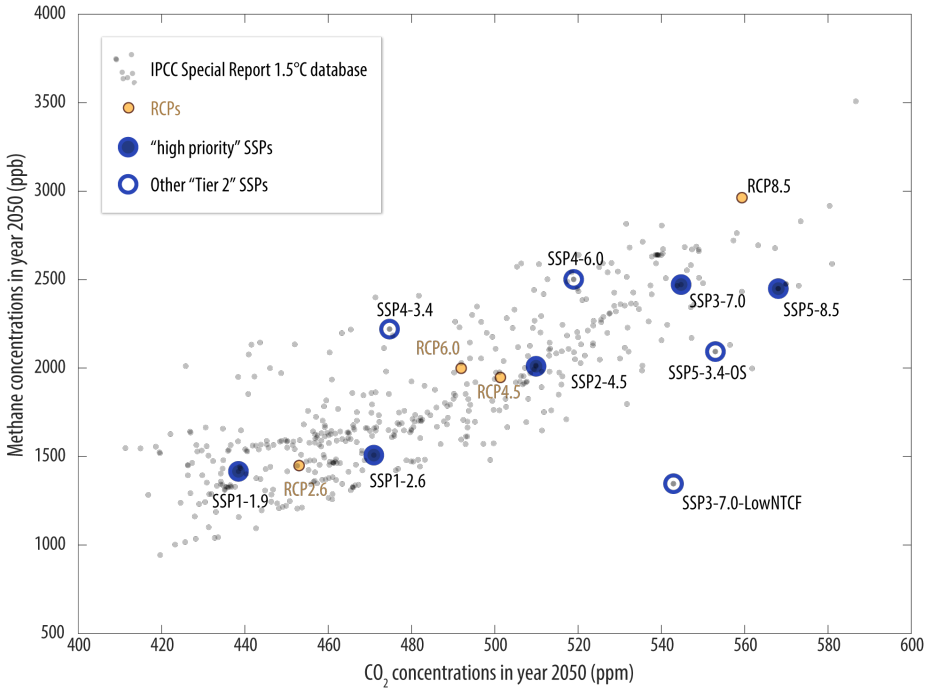

Fig. 8. FIGURE RC1.8 – Revised manuscript figure 9 – Mid-century concentrations of CO2 and CH4 under the various SSP, RCP and SR1.5 database scenarios

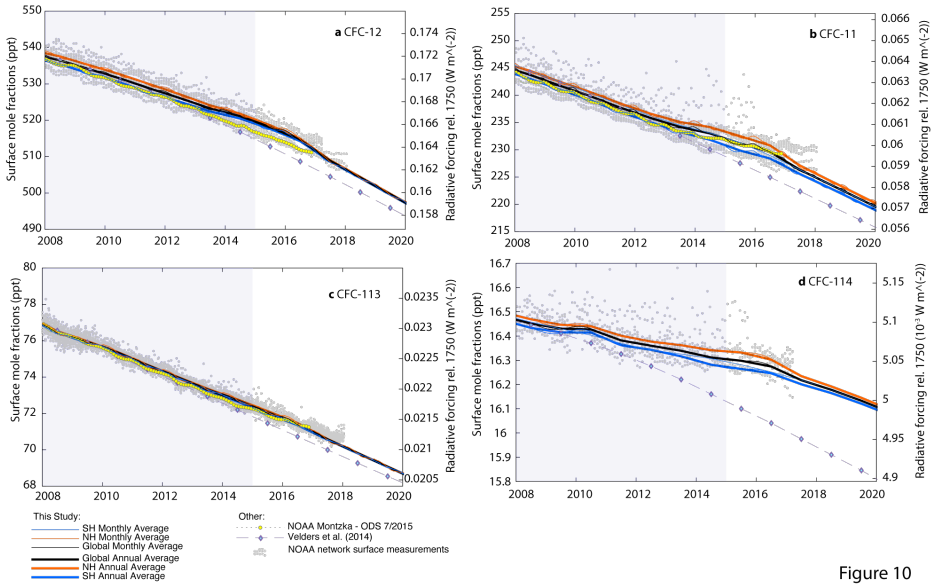

Fig. 9. FIGURE RC1.9 – Revised manuscript Figure 10 on the departure of recently observed atmospheric concentrations and previously projected ones

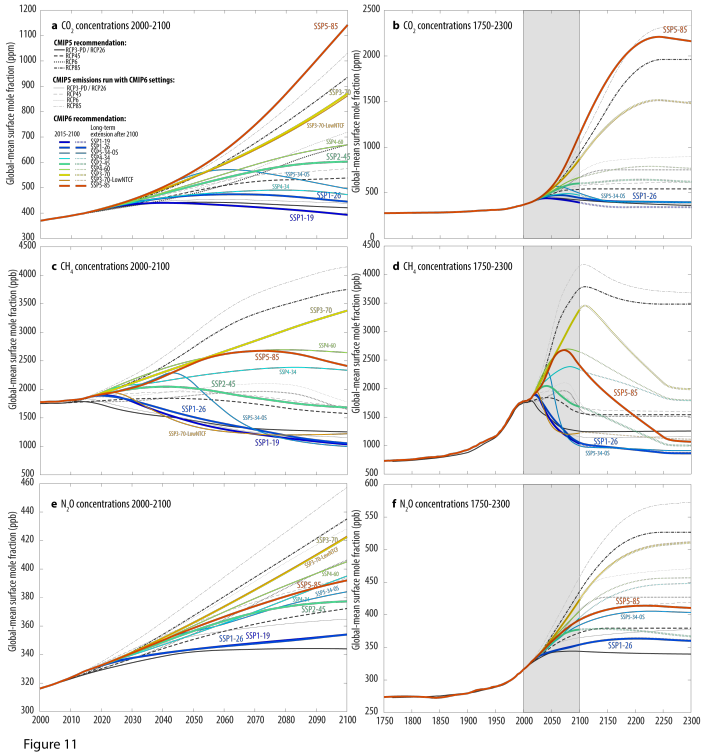

Fig. 10. Figure RC1.10 – Revised manuscript Figure 11 on SSP concentrations for 21st century and over the longer timeframe from 1750 to 2300