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

Anonymous Referee #1

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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

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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.

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.

Abstract:

line 38, change to "... has quantified"

line 41, change to "concentrations"

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

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

Line 58, spell out MAM.

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

line 64, change "manage" to "limit"

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 ...."

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.

p. 3, line 77, define GHG here as greenhouse gases (GHG). You may consider using GHG, instead of greenhouse gases throughout the text hereafter.

p. 3, line 79, insert “minor” after “other”.

p. 6, line 170, consider use “concentrations”, instead of “mixing ratios”

p.7, line 193, change “CO” to “OC”

p. 12, line 323, delete “to”

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.

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)?

p. 14, line 371, delete “now”

p. 15, lines 414-418, this sentence is long, awkward, and doesn’t flow logically. Consider rewrite. p. 15, lines 414-418 and hereafter throughout the text, be consistent when you capitalize “Northern hemisphere” and “Southern hemisphere” or not.

p. 16, line 429, change to “increase strongly”

p. 20, line 550, change “this” to “these”

p. 22, lines 600 and 603, remove “as”

p. 24, line 638, “Even stronger. . ..” is awkward. I suggest “More notable. . .”

p. 24, line 645, change to: “. . . in China. The similarly short-lived methylene chloride

(CH2Cl2) also had. . .”

p. 25, line 670, change to: “. . .for CO2, are miniscule. . .”

p. 25, line 672, remove “to”

p. 25, line 673, remove “These”

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

p. 27, line 739, what do you mean by “cooler”? Colder temperatures?

p. 27, line 741, either “relatively comparable” or “closely comparable”, “relatively closely comparable” doesn’t make sense.

p. 27, line 745, should be “easily communicated”?

p. 28, lines 759-769, references to Figure 12b are missing.

p. 29, line 786, MAM is a spring season, not winter.

p. 29, lines 793-4, wording is redundant, change to: “. . . . poleward of 65 degrees North”, or something to that effect.

p. 29, line 796, change to “4500-year long”

p. 29, lines 801 and 803, what do you mean by “the MAM region” and “the DJF region”?

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?

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? A few minor comments: 1) what is the first vertical blue line, 2010? 2015? Please state. 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. 3) Overall, the thin lines are too thin, which make them almost not readable on printout versions. 4) "Total N2O emissions" in panel g should be "Total anthropogenic N2O emissions", to be accurate?

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

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.

Figure 5, I don't see the need of including this figure (or at least many of the subpanels) 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 scenario. 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

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and lines thicker and darker.

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.

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? 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.

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.

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.

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.

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.

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.

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