Response to second-round review of CovidMIP

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We thank the editor for their commitment to rigorous scientific scrutiny and further opportunity to improve the paper. The first reviewer presented no issues for us to resolve, so we simply thank them for their time and will respond only to the points from reviewer 3 here. We remark that several criticisms from reviewer 3 are the opposite of points raised by reviewer 2 from the previous round of reviews, particularly concerning the level of importance of the task and consequently the computational effort that should be expended answering this question. We address their comments as follows:

- Reviewer comment: "While I do see some value in a rapid response tool to update emissions scenarios, I am rather sceptical as to what the authors are trying to achieve with Covid-MIP.":

  The motivation section of the introduction has been significantly expanded. We highlight the potential for findings concerning regional and precipitation differences, which are not convincingly investigable using simplified models. Beyond global and annual averages, many aspects such as regional changes or seasonal/sub-seasonal or even daily extremes can be examined. It is quite plausible that changes in aerosols may affect clear and cloudy sky environments and day and night-time temperatures differently - all aspects which cannot be gleaned from reduced complexity models. This is also briefly flagged in the abstract now.

  The fact that the MIP most likely will (and so far has, see Jones et al. 2021) produced null results on temperature metrics is reassuring to the climate modelling establishment, but is not a priori obvious and may well not hold across all metrics. For instance, there is a small but distinct risk that a perturbation like COVID-19 would result in a disruption to monsoon circulation. Many previous studies have found a sensitivity of monsoons to changes in emissions of aerosols (e.g. Meehl et al., 2008, doi:10.1175/2007JCLI1777.1; Li et al., 2016, doi:10.1002/2015RG000500; Lau et al., 2017, doi:10.1007/s00382-016-3430-y; Zhao et al., 2019, doi:10.1007/s00382-018-4514-7).

- "this would require nudged simulations and/or a clever comparison to observations so as to "control the weather. While nudged simulations are mentioned in the manuscript, they are optional. In the end, I am concerned that the climate modelling groups participating to Covid-MIP will use a lot of computing time to find out fairly small changes in atmospheric composition and climate. What the authors expect to learn on the climate system needs to be much better demonstrated in the manuscript.":

  We describe nudged experiments as "preferred where models have this capacity". We now highlight this feature in the introduction, as well as the importance of sufficient sample size, as especially valuable. As mentioned above, the possibility of seeing precipitation and regional patterns now receives more attention, which nudged models might underrepresent.

  These experiments are computationally much cheaper to run than a normal SSP scenario since they lasts only 30 years and use part of a previously computed run for the initial conditions. The people who had to pay for the computer time have been convinced of their value and the initial results have already been published!

- "This may require a prior quantification of the changes expected before embarking the community in a new MIP.":

  Studies doing this are cited in the paper, including Forster et al. 2020, although using older data (as well as Gettelman et al 2021, which uses a more complex nudged approach). They are, as might be expected, rather small but not obviously undetectable by full GCM models, and at a size where the difference between the simplicity of the simple climate models and the more complex models is likely to be relevant. We now explain that simple climate models are generally bad at capturing regional and precipitation changes, hence the need for a more complete analysis.

  Initial results from other studies, such as Fyfe et al. (doi:10.1126/sciadv.abf7133) also provided guidance during the formation of CovidMIP planning. Their results showed that while global temperature response was indeed

very small, changes in other aspects of the climate system merited further investigation with GCMs. The process of planning spanned many modelling groups, who all showed substantial interest in the activity and the experiments were designed accordingly to be as accessible as possible regards the cost and complication of implementation.

- "The manuscript relies heavily on Forster et al. (2020) and I had to go back to this article to understand the content of this manuscript.":

  We have now greatly extended the introduction to cover the key points of that paper, and expanded the scenario description to explain more about how scenarios were designed.

- "I tend to think IAMs are basically useless to predict the impact of the recovery packages on emissions. In this context the green stimulus scenarios put forward in the manuscript look like wishful thinking, and I do not see their usefulness beyond existing SSP scenarios. I would be happy to be contradicted but I have not seen a convincing argumentation in the manuscript":

  IAMs do not predict the impact of recovery packages (or anything else - they deal only in projections), but they aim to make projections circumscribing the likely probability space of the impacts. The first thing this set of scenarios offers above existing scenarios is that it diverges only in the future, rather than from 2015. We now highlight this more in the text. We expand on the descriptions of how these scenarios were devised to motivate their use. It is also correct that the scenarios examined in this exercise can mostly be considered linear combinations of the existing SSPs, but the advantage of them is that they have a clear narrative link to the events of COVID-19, whereas if we were to simply run the SSPs harmonised to past emissions values we would a) have to wait until the precise values were actually known; b) have no way to link the differences in future behaviour to choices at the moment, since the differences between SSP scenarios is nontrivial; and c) have to handle a discontinuity in the derivative at the end of harmonisation conflated with the impact of lockdown. This discontinuity point is discussed in the next point too.

- "In a sense SSP scenarios used for CMIP6 are already outdated, especially the low ones. The transition between past and future emissions is also poorly represented in these scenarios, with some continuity in emissions but not in the rate of change of the emissions. Maybe the work of the authors can go some way into that direction.":

  To clarify, this point is a criticism of the existing SSP database, not of our work. We agree with this point - it is unrealistic to assume that very strong mitigation action will begin in the earliest modelled timeperiod, and this makes some models in the SSP database age very rapidly. It is in part to avoid this sort of mistake that we always interpolate back to baseline after the end of the lockdown effects (usually in 2023) before starting a new trajectory. In general we do not expect short-term shocks to the economy to result in long-term deviations to emissions. We now refer to recent papers by Le Quere et al. and Gillingham et al. to demonstrate this point and motivate the distinction between long-term and short-term behaviour in our models.

- "Note that there are several initiatives to monitor emissions in near-real-time, it would be interesting to know how the work by the authors compare with others.":

  Work on this front is being investigated by other groups, e.g. the EGU meeting report by Pelletier et al. (https://doi.org/10.5194/egusphere-egu21-16450), indicating that our results based on the Forster method are comparable to the also-unpublished Doumbia results (https://doi.org/10.5194/essd-2020-348). In the cases where something approaching ground truth data have been analysed so far, our results appear to be slightly more accurate, although we will not state this in the paper.

- "In conclusion, the work presented by Lamboll et al is insufficiently motivated. It makes the whole manuscript a little unclear and it is hard to judge if the methodologies chosen to correct the emissions based on various proxies are sound or not for the objectives, given that the objectives themselves are poorly described / not convincing. I recommend rejection.":

  As described above we have more clearly motivated our work, and the take up by 12 models/300 simulations described in Jones et al., 2021 (doi:10.1029/2020GL091883) shows that the wide ESM community agree on the value of this exercise. This anticipated engagement from the community was known in advance and contributed to the development of the protocol described in our manuscript. As with all MIPs not all the final uses are known in advance – we had enough reason to perform the simulations to justify proceeding, but now there is a huge wealth of data available for wide and open analysis. It will stimulate interactions between scientists and scenario modellers. These groups can jointly look at forcings, feedbacks and impacts on atmospheric composition and air quality, resulting in further studies and enhanced experimental design as we learn more about the longer-term impacts of the pandemic on socio-economic behaviour.