Earth Syst. Dynam. Discuss.,
https://doi.org/10.5194/esd-2020-9-RC1, 2020

Earth System Dynamics
Discussions

Interactive comment on "A continued role of Short-Lived Climate Forcers under the Shared Socioeconomic Pathways" *by* Marianne T. Lund et al.

Anonymous Referee #1

Received and published: 13 April 2020

GENERAL COMMENTS

The manuscript makes an important contribution to the literature by providing a detailed assessment of SLCF emissions, implications of mitigation approaches, and understanding the implications for global temperature over different time horizons and under different SSPs.

I have two major, related methodological concerns that I believe the authors need to address (but also should be able to address) for the paper to deliver on its promise. Both concern the use of AGTP and convolution of an IRF to derive outcomes over different time horizons and for emission pathways, and the fact that the exact methodology is

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too opaque yet choices here are critical.

My first concern is that a comparison should be shown (can be done in Supplementary Material) of how the IRF and AGTP used in this paper compares to the IPCC AR5 and body of literature used in the draft IPCC AR6 (the authors obviously can't cite the IPCC AR6 draft, but it would be enormously helpful if their IRF and AGTP had a strong resemblance to what is coming out of the AR6 draft, because if it doesn't, it clear is missing some important science point).

One important aspect of this is the treatment of climate-carbon cycle feedbacks. There is enough literature and recommendations in various papers arguing that this should be included, and the consequences are non-trivial for SLCFs especially for longer time horizons of 100 years – based on the AR5, this more than doubles the AGTP100 of methane. Since the goal of the paper is to describe the impact of SLCF emissions and mitigation over both short and long time horizons, the choice here is critical – but I'm not at all clear based on the current manuscript what choice was made.

I'd argue strongly that the authors should include a climate-carbon cycle feedback in their IRF – as not doing so would make the results for 100-year horizons, and for emission pathways (i.e. the effect of sustained SLCF emissions) misleading. Given the different lifetimes within SLCFs, this could also affect the ranking of different regions and sectors – it would not be a uniform scaling such as from the choice of ECS. So this really matters in my view for the validity of findings.

I would therefore ask the authors to (a) make fully transparent how their IRF and AGTP compares to IRF and AGTP that include climate-carbon cycle feedbacks from the IPCC AR5, and glancing at the studies and assumptions used in the AR6 draft, and (b) if their current IRF and AGTP does not include climate carbon cycle feedbacks or is missing some other critical aspects, to update their IRF and re-run their analysis. I'm hoping that this would be possible without requiring too much additional work since the framework for analysis should not change (and some results may not change either –

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which in itself would be a useful finding from this study!)

My second concern is that their IRF and AGTP apparently does not include saturation effects arising from concentration changes (although it took me until the discussion on page 12 to realise this, which underscores my sense that the methodology is not transparent enough). The use of a linear AGTP is not acceptable in my view for the part of the paper that compares outcomes under different SSPs and mitigation targets. For some gases (methane as the biggest forcer included), their concentration differs markedly between the stringent and non-mitigation scenarios, which has a substantial effect on their radiative efficacy and hence contribution to warming over time. It is simply not defensible in my view to exclude this dependency but in a paper that seeks to evaluate the contribution to temperature from different gases under those different scenarios. Using a dynamically updated AGTP (i.e. adjusted based on concentration of each gas) could well change some of the results substantially (at least sufficiently to make the quantitative results questionable).

Again, I think this is doable – it would not be hard to scale the AGTP based on the concentration of each gas and changing radiative efficacy, and re-run the analysis with such a dynamically updated AGTP. As for my other main comment, the framework for analysis would remain unchanged, and some or many key results may or may not change – which, again, would be a useful result in itself.

All other comments are comparatively minor (though some include requests to broaden discussion or restructure some sections), as detailed below.

SPECIFIC COMMENTS

L83: “increase” should come after “temperature”

L91: “complimentary” should be “complementary” (different meaning!)

L96: insert “sources and” before “mitigation strategies”

L98: “inexorably” is too strong: not all SLCFs are (especially HFCs, and methane not

in all regions)

L112: insert “co-emitted” after encompass; also, I feel it is not correct to claim that sulfate aerosols have received considerably less attention so far – certainly in the 1990s that was the dominant aerosol included in climate studies. This should be clarified a bit and some of the older literature may well be highly relevant here (e.g. focus in the US on sulfate reduction from energy systems).

L117-121: I can’t agree with that generic claim: the SRES scenarios had a wide range of evolution of methane emissions, with significant continued increases in emissions especially in the A2 scenario but also A1FI. SSPs are more nuanced but there hasn’t been a material shift (unless you focus only on aerosols here – in which case, say so).

L160-191: As per my main comment, please expand this methodological section (possibly using SM) to demonstrate how the IRF and AGTP used in this paper ompares to other IRFs. In particular, clarify whether longer-term warming contributions related to climate-carbon cycle feedbacks have been included (I argue strongly you should – tell us what the AGTP100 is for methane and HFC23). Also, add a comment here about how the AGTP adjusts over time in response to changing global GHG concentrations (again as per my main comments, I think it has to be changed dynamically to allow authors to derive conclusions about differences between SSPs/RCPs).

L216: this section is not well structured in my view. It makes it hard to derive clear conclusions. I would suggest to improve on the structure by having one discussion about sectors, and another one about regions; also ensure you add a long-term (100 year) dimension, at present most of the discussion is for the near-term horizon.

L218-223: I can see the benefits of using 10 years, but I also struggle with the claim that this is “commonly used”. Especially if the authors accept my main comment, that they need to re-do their analysis with a revised IRF/AGTP, I would urge you to consider a 20-year time horizon. The reason is that (a) this is in fact commonly used (GWP20), but also (b) that 20 years puts us very close to the time when temperatures should

(begin to) peak in 1.5°C scenarios – so 20 years is much more policy relevant in my view than 10 years, which is really just the near-term rate of change.

L226/227: add a bit of nuance here: the lifetime of SLCFs varies widely, with some causing warming for many decades (methane) whereas for others the bulk of warming is in the space of a few years.

L261-277: there's a bit of confusion about whether "mitigation potential" refers to the potential to reduce the emissions of a given SLCF, or to the potential for an intervention that might affect a range of SLCFs to reduce or increase temperature in the near or long term. These are very different aspects. I would reserve the word "mitigation" for anything that focuses on the reduction of emissions of a given species, and from there discuss the implications of such actions for temperature once changes in emissions of co-emitted species are taken into account over different time frames.

L279: It would be really helpful if this section could clarify the scale of mitigation outcomes from SLCF mitigation compared to CO2 (and other long-lived GHG) mitigation. This would help keep the importance of SLCF mitigation in perspective, and allow the authors to use words such as "significant" with a lot more precise and justified meaning. If you only compare outcomes between SLCF mitigation approaches, but don't provide an overall scale (how much of the total mitigation in a given scenario comes from SLCFs, how much comes from CO2 and other LLGHGs), the paper could potentially be dancing on the head of a pin. You need to demonstrate how relevant this SLCF mitigation is in the bigger context (essentially a brief update from Shindell et al 2012).

Also, I feel this section needs to spell out in quite a bit more detail the assumptions behind each policy entry point and how this translates into quantified emission reductions. E.g. L285/286 says that P2 is about methane reductions, but then L305/306 seems to suggest that it can also be about CO2 reduction in the energy sector? Also more details are needed to understand the detailed emission reductions, and chemistry assumptions, for the agricultural mitigation scenarios (a lot of policies that target

agricultural methane will affect agricultural N2O within farm systems).

So I think the authors need to provide much more detail and quantification of how the broad policy principles in P1-P3 translate into mitigation of individual species for the different sectors. It's fine if there are subjective choices made – but we need to know what exactly those choices were to better understand to what extent the results are a function of those choices, or of the properties of the individual species that this paper helpfully aims to disentangle.

L317: add "and mitigation targets" or something like this to the section heading, as the scenarios explored are not just the SSPs but the imposition of different mitigation targets on the SSPs (i.e. they are SSPs plus climate policy). Also clarify whether the way that the mitigation of SLCFs is then implemented follows the SPA protocol developed for mitigation modelling using SSPs (Kriegler E, Edmonds J, Hallegatte S et al (2014) A new scenario framework for climate change research: the concept of shared climate policy assumptions. Climatic Change 122(3): 401-414), since this could well affect how individual SLCF emissions change for different regions.

L324: I question the utility of using SSP5-8.5 for this paper. This scenario has value but by now is clearly counterfactual as far as emissions are concerned. This would not be a critical issue, but at the same time the paper is missing a much more relevant scenario such as SSP2-2.6, or SSP5-2.6. As it stands, the only stringent mitigation scenario is for an SSP1 world, which is only one of many worlds, understanding how SLCF emissions might evolve in a different socio-economic context but also stringent mitigation would be much more valuable than to take up space for the largely academic SSP5-8.5 scenario. So my main concern is: add a stringent mitigation scenario (RCP2.6) using a different SSP (other than SSP1), otherwise this paper is missing a really important dimension. If you then keep the 8.5 scenario or drop it is in a way secondary.

L336/337: "we note that negative CO2 emissions are not included in these calculations": I'm puzzled by this. How can you evaluate SSP1-1.9 without negative emis-

sions? Why not? This problem would only grow if he authors follow my advice to include SSP2 or SSP5-2.6.

L341/342: There seems to be a rather important finding buried here: are the authors saying that globally, energy contributed less to actual temperature change than agriculture and RES? If correct this might be worth highlighting more prominently to show how including SLCFs can change relevance over different time frames. Not that this should take away from the critical importance of mitigating CO2 from ENE, but it does seem a significant element. Another study that looked at warming attributable to livestock seems to go in a similar direction (Reisinger A, Clark H (2017) How much do direct livestock emissions actually contribute to global warming? Global Change Biology DOI: 10.1111/gcb.13975).

L376/377: I had to read this a few times to understand the "put another way" – might be worth rephrasing or disentangling a bit

L378-390: again here, as for section 3.2, I would like to see a comparison with mitigation achieved by CO2 reductions, simply to avoid readers to take away misleading conclusions that somehow SLCFs are the dominant issue for climate change – I would say they are an important but second-order issue. Useful if the paper could state and substantiate this in some way. Also for L393-395: there is "much" to be gained – how much? Compared to how much from CO2?

L395-422: I find this section weak on actual policy, and inconsistent: for some sectors, authors mention specific interventions, whereas for agriculture, it just says "addressing agriculture emissions" – that's not a policy or intervention. Expand this to illustrate consistently what feasible interventions are for all sectors (including a brief flag for supply vs demand side interventions).

L424-43: this is a useful thought experiment: how much warming would be avoided simply by improving technology for SLCFs (i.e. reducing emission factors consistent with SSP1), even in the absence of any dedicated climate policy (i.e. SSP3-7.0 vs

SSP3-lowNTCF).

L449-480: please break this discussion into chunks – lots of different issues being discussed in a single mammoth paragraph. As flagged in main comments, using non-dynamic AGTP to explore SSP/RCP pathways is a real problem that the authors have to address.

L464-466: agricultural non-CO2 emissions should be included in this list as they are also highly uncertain especially in developing regions (AFR, SEA, SAS).

L486: add that emission reductions of SLCFs have to be sustained to achieve long-term temperature change

L494-498: You could emphasise more strongly that this technological advancement brings benefits even if there is no dedicated climate policy addressing SLCFs, simply by reducing emission factors.

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