We thank for the constructive and helpful comments from the Reviewers. Our answers are given in red. When we have accepted the suggestion, this is given by an "OK".

Reviewer 1:

General Comments

This is a well written and interesting study that explores how optimal mitigation of short-lived climate forcers could contribute to cooling (or reduced warming) over the next few decades. It provides useful information for policymakers considering how to limit warming through non-CO2 measures. There are, of course, many uncertainties, but this study demonstrates very nicely what could be done. My main concern is that the uncertainties in the ARTP values should be discussed more deeply than they are currently; this also extends to better explanations of the error bars on some of the figures (see below). If this point and the other, relatively minor points below are addressed, then I am happy to recommend publication in ACP.

We have added more details on the ARTP values, such as what processes are included, how they were estimated in the studies we refer to, as well as on uncertainties. We have also edited the explanations of the error bars. See specific replies below.

Specific Comments

In the Abstract, clarify that mitigation of some SLCFs (e.g. SO2) leads to warming. We have added this sentence to the abstract: "On the other hand, mitigation of other SLCFS (e.g., SO2) leads to warming."

P1 l7 Change text to: '…policies is, however, still uncertain.' OK

P1 l21 'outsized impact' -> large impacts? OK

P2 l7 SLCFs -> SLCF OK

P2 l19 I think you need to say something like "…may lower the global temperature by 0.22C in 2041-2050 compared to a reference scenario." OK

P2 l19 "complete removal of anthropogenic aerosol emissions (BC, OC, SO2)…" SO2 is, of course, an aerosol precursor, not an aerosol. "Complete" seems excessive, as I don't think you mean removal of species like NOx and NH3 (which are also aerosol precursors), so I would use slightly less all-encompassing language here. We have revised the sentence to:
"In comparison, a complete removal of anthropogenic emissions of black carbon (BC), organic carbon (OC) and SO2 (sulphate aerosol precursor) would induce a global mean surface heating of 0.5–1.1°C, according to four recent climate models (Samset et al., 2018)."

P2 l22 "…a range of the UN SDGs." This is a bit vague – presumably you mean air quality, food security, etc. Can you be a little more specific? We have reworded and extended this part to:
"Going beyond temperature and precipitation impacts, SLCF emission mitigation is also known to have multiple co-benefits and trade-offs with the UN Sustainable Development Goals (Haines et al., 2017). The co-benefits are generally larger than the trade-offs. Among the most well-known co-benefits, we find that SLCF mitigation will reduce air pollution and, hence, reduce premature deaths (SDG3), as well as reduce crop losses (SDG2)."

P2 l24 potential of SLCFs. OK

P2 l29 delete ‘that’ OK

P2 l32 State year for ‘current legislation’ – 2019? The year for current is 2015 in the emission dataset, so we added “(2015)” in the sentence.

P3 l1 technically OK

P3 l20, l22 capitalise Absolute OK

P3 l25 How well constrained/model dependent are the (crucial) ARTP values? This is rather important and deserves some discussion. For example, is nitrate aerosol included in the model(s)? How are the indirect effects of aerosols handled in the model(s)? Do the models include interactive vegetation, e.g., that responds to air pollution induced damage? How do the models represent the mixing state of aerosols? Do we have any idea about how these missing processes (I am assuming they are missing) will affect the model results? I appreciate that you can only use state-of-the-art models to make your best estimate of temperature responses, but some discussion of how uncertain the results (ie ARTP values) are should be included, to give some perspective. I note you do quote errors on your values – but I think these cover just the known unknowns. We have added a couple of paragraphs in the method section (Section 2.3) on the ARTP values and what processes they include.

“The ARTP dataset utilized here are presented in detail by Aamaas et al. (2017), including how they were estimated, the processes included, and the robustness. That paper built on RF values calculated by Bellouin et al. (2016). The paper applied four different coupled chemistry-climate models or CTMs. They compared control simulations with perturbed simulations where emissions were reduced by 20% for one species and one emission region. We apply the average values across models. For the aerosols and aerosol precursors, three out of four models included the aerosol direct and first indirect (cloud-albedo) effect. RF for BC deposition on snow and ice surfaces and the semi-direct effect was estimated in one of the models. For the ozone precursors (NOx, CO, and VOC) and CH4, RF is modelled for the aerosol direct effect and first indirect effects, short-lived ozone effect, methane effect, and methane-induced ozone effect. Nitrate aerosols are also considered based on results from one model.

The matrix of regional response coefficients (RCS), which enables us to go from regional RFs to regional temperature responses and ARTPs, are also presented in detail by Aamaas et al. (2017). The RCS values are mostly based on coefficients modelled by Shindell and Faluvegi (2009). A weakness with our chosen method is that Shindell and Faluvegi (2009) is to our knowledge the only study that provide the necessary relationships between regional RFs and regional temperatures to create RCS values.”

We have also some more text in the paragraph about uncertainties in Section 2.3:

“Previous work by Aamaas et al. (2016) shows that the assumption of independent radiative forcing uncertainties gives a total uncertainty range for emission reductions for a mix of species that is similar to the range seen between different models. Further, they also found robustness for the method we use here to estimate temperature changes, such as models agreeing on whether different mitigation scenarios lead to warming or cooling.”

P5 l18-l26 Please quote values +/- errors correctly. It is incorrect to quote -0.33 +/- 0.083 C. The error should probably only be quoted to one significant figure, although you may feel justified to quote to two, as you have done. But the value then needs to be quoted to the same number of decimal places as the error, i.e. it should be, e.g., -0.335 +/- 0.083 C, or -0.33 +/- 0.08 C. The same inconsistency

appears on several of the subsequent lines. We have edited how we quote the errors, mostly to one significant figure.

P6 l2 on -> in OK

P6 l5 on -> to OK

P7 l2 estimates OK

P7 l11 usage -> use OK

P7 l20 it contributes -> they contribute OK

P8 l14 values -> value OK

P8 l15 is -> are OK

P8 l24 SLCFs reduction -> SLCF reductions OK

P8 l30 implicitly OK

P9 l3 how -> what OK

P9 l18 …may be smaller than those estimated here… OK

Figure 2 caption should explain the origin of the error bars. We have added:
"Error bars representing 1 standard deviation are given for the net response in 2030, 2050, and 2100. They are calculated based on literature values for gaussian uncertainties in per-component RF, assuming no inter-species correlation, and estimated using a Monte Carlo analysis (100 000 pulls) where component forcing values are drawn from within the uncertainty distributions."

Figure 4 caption should explain the origin of the error bars (on the global values). We have added:
"Error bars representing 1 standard deviation are given for the sectors for the global temperature response. They are calculated based on literature values for gaussian uncertainties in per-component RF, assuming no inter-species correlation, and estimated using a Monte Carlo analysis (100 000 pulls) where component forcing values are drawn from within the uncertainty distributions."

Figure 5 caption – the explanation of the error bars could be clearer. We have edited to:
"Error bars representing 1 standard deviation are included. The blue and black error bars are calculated based on literature values for gaussian uncertainties in per-component RF, assuming no inter-species correlation, and estimated using a Monte Carlo analysis (100 000 pulls) where component forcing values are drawn from within the uncertainty distributions. The blue error bars indicate the uncertainty for the emission regions, the black error bars for the emission sectors. The grey error bars are estimated from uncertainty in the climate sensitivity based on Monte Carlo analysis (100 000 pulls) with values drawn from within the lognormal uncertainty distribution."

Reviewer 2:

In this study, the authors investigate the potential temperature implications of stringent air quality policies, by applying matrices of regional temperature responses to new pathways for future anthropogenic emissions of aerosols, methane (CH4) and other short-lived gases. This is an

interesting and relevant topic since there are still a lot of uncertainties on how regional temperatures are affected by ambitious SLCF emission mitigation policies.

General comments

The Introduction is too short, I suggest the authors to add more information about SLCF description. For example, here you show results for BC, OC, SO2, NOx, CO, VOC, and CH4. Some description about their cooling/warming impact of them will help to a better understand of the results. Also, maybe a bit more description of the ECLIPSE project would be good, since this works is strongly connected to it.
We have added several sentences on the ECLIPSE projects, its findings, and connections with our manuscript in the fourth paragraph of the introduction:

"That paper synthesized the work in the project ECLIPSE (Evaluating the Climate and Air Quality Impacts of Short-Lived Pollutants). The project designed realistic and effective mitigation scenarios for SLCFs and quantifying its climate and air quality impacts. The work started with producing new emission inventories for the recent past and until 2050. Those emissions were applied in several advanced Earth system models (ESMs) and chemistry transport models (CTMs). The climate impacts were estimated with two different paths of research, where the first was to calculate radiative forcing (RF) and then produce emission metrics such as ARTP. The second path was on modelling transient climate responses with ESMs. Results from the first path were applied in an integrated assessment model to identify emission mitigation measures that are both beneficial for air quality and short-term climate impact. That study found that estimates on global temperature change are similar for the decade 2041-2050 by applying these two different paths. Further, the two different research paths partly agree on how much emission changes in CH4 is responsible for the temperature change versus emission changes of the other SLCFs. Our study utilizes several aspects of the ECLIPSE research, including emission inventories, mitigation pathways, and ARTP values."

We have also added these sentences to the first paragraph of the introduction, to describe the different SLCFs in more detail:

"The SLCFs considered here are black carbon (BC), organic carbon (OC), sulphur dioxide (SO2), nitrogen oxides (NOx), carbon monoxide (CO), volatile organic compounds (VOC), and methane (CH4). CH4, which is a greenhouse gas and a precursor of O3 and stratospheric water vapor, is the SLCF that gives the largest warming at current emission levels. BC (also known as soot) is a result of incomplete combustion, that causes warming through absorption of sunlight and reduced albedo of contaminated snow and ice surfaces, but also cooling, mainly from affecting clouds. Removing all anthropogenic BC emissions would cause a cooling of -0.05 °C according to Stohl et al. (2015). Several aerosols are cooling the climate through scattering solar radiation and altering the radiative properties of clouds, with sulphate aerosol formed from SO2 and ammonia (NH3) giving the largest cooling. Stohl et al. (2015) estimate that removing all anthropogenic emissions of SO2 would increase the global temperature by 0.69 °C. OC is another cooling aerosol, of which a complete removal of anthropogenic OC emissions would lead to a warming of 0.13 °C (Stohl et al., 2015). The ozone-precursors NOx, CO, and VOC produce tropospheric O3, which is a greenhouse gas. Emissions of these species will also impact the hydroxyl radical (OH) concentration, which impacts CH4. The impact of current emissions of these ozone precursors is small compared to the impact of current emissions of CH4 and SO2."

Some figures are not well described in the text, for example, the authors directly mention Fig. 2 or 3 after describing a result obtained. The figures should be defined saying what it is representing there, and if needed, some explanation about how to interpret the graphic (if I got it right, the different symbols in fig 3 shows the influence of the different sectors of that region in a latitude band). This

way it will be easier to follow the text. Please, do it whenever the figure has not been described in advanced. There is also a lack of mention some figures that I will point out in the technical comments.
We have clearer presented the figures in the text. Further, we have added several callouts to the figures in the text. We have added a sentence for captions for Figure 3 and 4 that explains the symbols.

A better organization of the results must be done. It would be better to organize them in subsections, like "Global/Regional temperature change" or/and "Results by regions", as an example. Furthermore, more quantitative results could be added. Complementing with a table would be helpful for a better overview of the results found in this study (and comparing the results found in Stohl et al., 2015). We have added subtitles. These are Global temperature change, Regional temperature change, Temperature change by emission region, Temperature change by emission sector, Uncertainties. We have also added a table (Table 2), which is an overview of the results given in Figures 2, 3, and 4. Further, we have extended the result section to clearer organize the results and present the results in more details.

Specific comments

Page 1, line 16, authors state that "cutting CH4 and BC emissions contribute the most. This could offset warming equal to approximately 15 years of current global CO2 emissions." How do you get to this conclusion? I haven't seen it in the manuscript.
This point is discussed in the third paragraph of the discussion section. We have revised the sentence to make the point clearer:

"The net global cooling could offset warming equal to approximately 15 years of current global CO2 emissions."

Page 2, line 24, when mentioning the work of Stohl et al., 2015, although the authors mention it throughout the text, it will be good to have more description of the what they found. See reply to the first general comment by the Reviewer. We have expanded this paragraph to better present ECLIPSE, including some of their findings.

Page 2, line 29, here the description of the scenarios is done. I have several comments:

• The description of the SLCP_scen is not clear for me, so the difference is that the SLCP_scen only has 50 different mitigation measures on SLCFs compared to the 2 MTFR; a) how many has the MTRF scenario? And b) in what is it based to be called optimal? We have added one sentence regarding a): "The model behind includes more than 2000 technologies to control air pollutant emissions and 500 options to control greenhouse gas emissions." b) SLCP_scen is optimal in the sense of reducing the global temperature, hence, climate-optimal. This should be clearer with the new table (see point below) and modified description.

• It would be helpful to have the scenarios description as a list or as a table with a short description. We have produced a table (Table 1) as an overview of the three different scenarios. Some sentences from the text have been moved into the table.

• Check that you call the baseline scenario as "baseline" in the text. There are couple of times where you call it CLP, and sometimes is confusing to follow all the acronyms. We think the Reviewer is pointing out to CLE. We have either replaced CLE with baseline or added the word baseline in the text.

Page 3, line 7, IIASA has not been described. We have written out “The International Institute for Applied Systems Analysis”.

Page 5, line 5, do you refer to the results shown in figure 5? If so, you could refer to it here. We refer to Figure 5 in the last section of the results section. We prefer not to link a figure from the results section to the method section.

Page 5, line 20, “The global temperature change is calculated as the area-weighted sum of the net regional changes given by equation 1.” Can be added to the subsection 2.2, after describing the ARTP. We have moved this sentence to Section 2.3, as this section is most suitable for this information.

Page 5, line 28, “a warming of more tan 0.2ºC” how do you get this value? This finding is from Figure 2a, which we now have added a call-out to in the previous sentence. We have also revised the sentence to better reflect that this warming is solely from the reduction of the cooling components, by adding “from those”.

Page 6, what about the warming temperature response found in fig. 3b and 4b? Authors only focus on cooling temperature response results. This comment could point to two different issues. First, that we don’t discuss the warming responses. But we describe the net effects, which is a combination of the warming and cooling temperature responses. Second, and most likely point raised, that we don’t present the findings in Figures 3b and 4b. We do write about these results and have added callouts to the b-figures to show this clearer.

Page 7, line 14, to what scenario does the value -0.33 ºC correspond? We have added “in SLCP_scen” in the sentence.

Technical comments

Page 1, line 13, “using existing regional temperature change potential (ARTP)” did you mean, using absolute existing regional temperature change potential? OK

Page 1, line 25, add a comma after “pollution”. OK

Page 3, line 16, move “in Table 3 in Stohl et al. (2015) ” to the beginning of the sentence in line 15 to avoid “Stohl et al. (2015). Stohl et al. (2015) ” OK

Page 4, line 14, “CLE” to “baseline”. OK

Page 5, line 25, add Fig. 2A somewhere in this line. OK

Page 5, line 30, add Fig. 2B somewhere in this line. OK

Page 6, line 9, “CLE” to “baseline”. We have changed to “baseline CLE”.

Page 6, line 14, in “mitigation scenarios” do the authors refer to MTRF?. If so:
Page 6, line 14, add Fig. 3b after “rest of the World”. This sentence refers to both Figure 3A and 3B. We have added references to both Figure 3a and 3b in the paragraph.

Page 6, line 21, it should be Fig. 4a. OK

Page 6, line 25, add Fig. 3b after “to cooling.”. OK

Page 10, line 11, doi is missing. But the DOI is there already: 10.1146/annurev-environ-052912-173303