Anonymous Referee #3

We thank the referee for their insight into the Geoengineering aspect of the paper

The submitted paper discusses the response of Arctic Sea ice September coverage at global mean temperatures of 1.5 or 2 degrees Celsius above pre-industrial, the targets referred to in the Paris climate agreement.

In contrast to previous studies, which have focussed on scenarios which achieve these targets through greenhouse gas mitigation alone, the present study considers joint mitigation and solar radiation management (SRM) to achieve global mean temperature goals.

The study is potentially interesting, but does not address the most interesting issue which could potentially be discerned from this dataset: is there a difference in the projected avoided sea-ice loss which can be obtained through solar radiation management, compared to greenhouse gas mitigation alone?

Firstly - the authors have considered only one target in their geo-engineering experiment: the global mean temperature, and the authors have used globally uniform sulphate distributions to represent their SRM. It has long been noted that such compensation of uniform sulphate increase, whose effect peaks in the tropics combined with increased CO2, whose effect peaks at the pole - results in significant warming at the poles relative to the CO2 mitigation case (Ricke 2010). This would imply that the author's estimates of ice distribution at 1.5 or 2 degrees are likely to show more loss than a pure mitigation case. This is undiscussed in the paper - and is a central point.

Moreover, recent studies have highlighted that targeted injection patterns can mitigate the polar warming effect (Kravitz 2017, Modak 2013) by increasing choosing injection sites which increase the relative sulphate loading over the poles or summer hemisphere. Even if the authors' model is not capable of resolving interactive aerosols, a non-uniform sulphate loading distribution could quantify the efficacy of such approaches for sea ice conservation.

A clear possibility here is to quantify minimum sea ice cover not just as a function of global mean temperature - but as a function of forcing type and transient forcing history (is there any detectable lag in the response of sea ice to falling temperatures as the sulphate loading is increased?).

This is an interesting dataset, but it has been interpreted as a straightforward assessment of climate at 1.5 and 2 degrees, although there are strong reasons to believe that the geoengineered climates considered here would be unlike those observed at global mean temperatures of 1.5 or 2 degrees during a conventional RCP. The paper should acknowledge this, and consider more deeply how climate targets achieved using SRM differ from those achieved using mitigation.

We would agree that there is more that could be looked at in these experiments related to geoengineering, much of which could be made relevant to the impacts on the cryosphere. Another paper, Wiltshire et al. (in preparation), looks at the impacts of different pathways to a target global temperature through geoengineering and mitigation. In the longer term the impacts of different injection patterns may also be investigated, probably using our CMIP6 model which has a well resolved stratosphere and complex chemistry scheme. However, our choice in the format of a Brief Communication, is to focus on a single topic; the response of the Arctic sea ice to 1.5C and 2C global temperatures. The SRM approach is different than other published methodologies and in that context the SRM is the means to an end in our case using existing methodologies and simulations.

Figure 3 now shows the RCP4.5 (mitigated to 2.8 degrees C) and RCP2.6 (mitigated to 2 degrees C) scenarios as well as the SRM simulations. Reference is made to Kravitz et al (2017) and Jones et al. (2018), which remarks on the reduction of polar amplification using SRM. We note that at 1.5 C there is a difference in ice cover in the transient simulations over those of the SRM ensembles, but it is not statistically significant (also mentioned in Results section). In essence the Arctic sea ice appears to simply be responding to global temperature in a time averaged sense.

Minor Issues:

The injection quantities use information derived from the multi-model mean - which is a piece of information which would not be known in the real world. This should be acknowledged.

Now mentioned in the Methods section.

There are multiple typos. Please proof read before resubmission.

Many typos corrected.

Ricke, K. L., Morgan, M. G., & Allen, M. R. (2010). Regional climate response to solar-radiation management. Nature Geoscience, 3(8), 537.

Kravitz, Ben, Douglas G. MacMartin, Michael J. Mills, Jadwiga H. Richter, Simone Tilmes, Jeanâ A R Francois Lamarque, Joseph J. Tribbia, and Francis Vitt. "First simulations of designing stratospheric sulfate aerosol geoengineering to meet multiple simultaneous climate objectives." Journal of Geophysical Research: Atmospheres 122, no. 23 (2017).

Modak, A., and G. Bala. "Sensitivity of simulated climate to latitudinal distribution of solar insolation reduction in SRM geoengineering methods." Atmos Chem Phys Discuss, 13 (2013): 25387-25415.

Interactive comment on The Cryosphere Discuss., https://doi.org/10.5194