Response to Referee 3

Overview:

I recommend major revisions, due to the reasons below and the 16 comment on the attached annotated manuscript.

Major Comments:

(1) Fundamentally, this paper ignores an important component of climate change, and that is advection of energy. Surface temperature does not just depend on vertical energy fluxes, but also on changes of atmospheric circulation. By ignoring impacts on atmospheric circulation and wind patterns, as well as on storms and cloudiness, it ignores fundamental processes of climate change.

Response: We agree with your opinion on the fundamental processes of climate change. We would like to explain that the main factor of surface air temperature change under SAI forcing we previously considered is the vertical energy fluxes rather than the advection of energy. Following your comment, in the revision, we have investigated the temperature change by diagnosing the surface energy balance equation (Lines 136–153). Results show that the changes in vertical energy fluxes (including downward surface longwave and shortwave radiations, latent and sensible heat fluxes) dominate the SAI-induced surface cooling over China in both summer and winter (Fig. 8a). In addition, the radiative effect of clouds, which is related to atmospheric circulation, also plays an important role in the temperature change. In summer, the moisture flux convergence increases cloud cover, resulting in a strong local cooling over northwestern and central China (Lines 287–290).

(2) Why does this paper just look at China? With all the data, why don't the authors look at the entire globe?

Response: We would like to mention that previous studies have investigated temperature changes from a global-scale perspective (e.g., Niemeier et al., 2013; Kashimura et al., 2017; Ji et al., 2018). In recent

years, increasing attention has been given to the climatic response to solar radiation modification (SRM) on a regional scale, such as over Africa (Pinto et al., 2019; Da-Allada et al., 2020) and America (Xu et al., 2020). As the largest developing country in the world, China plays an important role in combating climate change. China's attitude to geoengineering is crucial to the international geoengineering research community. Considering the combined effect of the Tibetan Plateau and the East Asian monsoon, the climate over China would be strongly influenced by SAI. But the climatic impact has not yet been investigated explicitly so far. It is therefore meaningful to focus on the temperature change over China under SAI forcing. The relevant explanation has been added in the revision (Lines 75–79).

(3) What is the new science? The results are what one would expect. and there is little diagnosis of the reasons for the changes.

Response: In the original manuscript, we intend to explain the surface air temperature change by establishing a relationship between changes in surface shortwave radiation and temperature under SAI forcing. In the revision, we have diagnosed the temperature change over China by using the surface energy balance equation (Lines 136–153). The results indicate that the SAI-induced surface cooling over China is dominated by the robust decreases in downward clear-sky radiation fluxes, and associated with the cloud effective forcing and surface albedo feedback changes. The shortwave radiative effect of clouds and the surface albedo feedback determine the spatial pattern of temperature change under SAI forcing. The physical processes which dominate the temperature change have been investigated in Lines 265–300.

(4) The authors only use three models, due to finding the data on ESGF, but the output from the rest of the models could have been obtained from the modeling groups.

Response: A total of 12 GCMs participated in the G4 experiment. We would like to explain that six models should not be considered in this study due to their known issues (Lines 106–111). According to your suggestion, we have contacted the modeling groups and obtained the model data. We have added the output from the other three models (BNU-ESM, CanESM2 and CNRM-ESM1) into the revised manuscript as you suggested (Table 1).

(5) I find the algebra and terms in section 2.3 confusing. What is the difference between R and alpha? They are both reflection.

Response: Both the R and α are reflections. In this study, the R (F in the revision) represents the fraction of solar radiation reflected by the atmosphere (Line 161). The α is surface albedo. It represents the fraction of solar radiation reflected by the surface (Lines 151–152). We have added the relevant explanations in the revision for clarity.

(6) There is a supplemental file, but it is not referenced at all in the manuscript.

Response: We have listed the pertinent results for the MIROC-based models, together with the snow cover fraction change in the original supplement. Those results have been referenced in the original manuscript (Lines 210, 218, 226, 242, 249 and 272). In the revision, the spatial patterns of SAI-induced changes in key energy-related variables over China for the individual models have been illustrated in the supplemental file. Those results have been used to analyze the SAI-induced abnormal warming in the MIROC-based models and referenced in the revision (Lines 248, 259, 287 and 300).

(7) It is great that they evaluate the models first before using them, but although the Taylor diagrams look pretty good, there are still substantial biases.

Response: In the revision, the multi-model mean result is better than most models, but the bias still exists. The bias is inherent due to the limited understanding of the real climate system, the non-linear nature of some model equations, and the parameterization for processes. The results in the geographical distribution of simulation (Fig. 3) and the Taylor diagram (Fig. 2) both indicate the selected models can reproduce the climatology of temperature over China. The selected models are therefore reliable in this study.

(8) The manuscript is in quite a small font. In the future, make it larger to make it easier for the reviewers.

Response: The font size has been enlarged in the revision as you suggested.

Specific comments:

(1) Line 11: The is completely wrong. SAI does not exist, and there is no technology to do it. So "is" is wrong. It is a proposed scheme. Also, how do you know that it would be effective? The technology has never been proven. Is it really possible to produce a cloud of aerosols as modeled? Furthermore, why is it promising? It may produce more risks than it alleviates.

Response: We have replaced "a rapid, effective, and promising means" with "a proposed scheme" in the revision as you suggested (Line 12). By the way, the statements of "rapid" and "effective" are based on Table 3.4 in Shepherd et al. (2009), in which they consider that the cooling effect of SAI is feasible and potentially very effective. But it is impossible to simulate the real cloud of aerosols. The statement of "promising" is based on Visioni et al. (2018). They indicate SAI is a promising proposal because of its potential to cool the Earth and its assumed technological feasibility. However, we agree that it is not appropriate to describe SAI qualitatively before this technology is proven as you suggested.

(2) Line 16: "It has been shown" by others previously, or by you? If the latter, change to "We have found".

Response: Here we intend to express the result shown by us. We have changed "It has been shown" into "We have found" accordingly (Line 17).

(3) Line 57: No. The main mechanism is heterogeneous chemistry on the injected sulfate aerosols.

Response: This sentence has been rephrased in the revision accordingly (Lines 66–68).

(4) Line 70: Why just this region? Why not globally, since you have all the data.

Response: We have already answered this question above (please see our reply to Major 2).

(5) Lines 88-89: But the output from the rest can be obtained from the modelers.

Response: We have contacted the modeling groups and solved this problem in the revision (please see our reply to Major 4).

(6) Line 90: Delete "Note that".

Response: This sentence has been rephrased in the revision (Lines 107–108).

(7) Line 108: But advection is also important. What about changes in atmospheric circulation?

Response: We have answered this question above (please see our reply to Major 1).

(8) Lines 164 and 189: Where is the Xinjiang Province? Shown on map. Non-Chinese readers will not be familiar with these. Include on one of your maps the locations of all the Chinese regions you mention.

Response: The statements of location have been rephrased so that they can be understood by non-Chinese readers easily. For example, "the source region of the Yellow River and the Sichuan Basin" has been changed into "the upper reaches of the Yellow River and the middle and upper reaches of the Yangtze River" in the revision (Lines 220–221).

(9) Figure 1: Why are there two SW_C? You need to define all the terms in the caption. What is A^{cs}? What is R^{cs}? Why do you multiply SW_{net} by the other terms?

Response: The SW_C includes both the effects of changes in SW absorption and reflection rates of cloud. R^{cs} (F^{cs} in the revision) is the fraction of solar radiation reflected by the atmosphere under clear sky conditions, and A^{cs} the fraction of absorption during solar radiation passing through the atmosphere

under clear sky conditions. The relevant definitions have been illustrated in Lines 161–162.

For the net surface SW change (SW_{net}), we intend to express that the SW_{net} can be decomposed into four terms. This illustration should be rewritten as "$SW_{net} \approx SW_{SRM} + SW_{WV} + SW_{C} + SW_{SA}$". In the revision, Figure 1 has been removed due to the change in research method.

(10) Line 465: What does "the oblique dotted line" mean? Which line?

Response: We refer to the dotted straight line here. This sentence has been rephrased in the revision (Line 539).

(11) Line 474: What is the Theil-Sen trend?

Response: The Theil-Sen trend estimation method is a nonparametric technique for estimating the linear trend. In the revision, we have changed the Theil-Sen method into the widely used linear regression method (Figs. 4–5).

(12) Figure 9: Add January on right side of figures, too. So as to plot the entire 12-month seasonal cycle.

Response: Figure revised (Fig. 10).

(13) Line 500: "The stratospheric AOD". At what wavelength?

Response: The SAOD is determined at 550 nm in this study. This information has been added accordingly (Line 583).

(14) Figure 11: But clouds affect longwave, too.

Response: In the original manuscript, we have illustrated how the related physical processes impact

the surface shortwave radiation change in Fig. 11. The schematic diagram has been redrawn to summarize the downward surface radiation changes over China under SAI forcing in the revision. This diagram includes the cloud longwave radiative forcing as you suggested (Fig. 12).

Reference:

Da-Allada, C. Y., Baloïtcha, E., Alamou, E. A., Awo, F. M., Bonou, F., Pomalegni, Y., Biao, E. I., Obada, E., Zandagba, S., Tilmes, S., and Irvine, P. J.: Changes in west African summer monsoon precipitation under stratospheric aerosol geoengineering, Earths Future, 8, e2020EF001595, https://doi.org/10.1029/2020EF001595, 2020.

Ji, D., Fang, S., Curry, C., Kashimura, H., Watanabe, S., Cole, J. N., Lenton, A., Muri, H., Kravitz, B., and Moore, J.: Extreme temperature and precipitation response to solar dimming and stratospheric aerosol geoengineering, Atmos. Chem. Phys., 18, 10133–10156, https://doi.org/10.5194/acp-18-10133-2018, 2018.

Kashimura, H., Abe, M., Watanabe, S., Sekiya, T., Ji, D., Moore, J. C., Cole, J. N., and Kravitz, B.: Shortwave radiative forcing, rapid adjustment, and feedback to the surface by sulfate geoengineering: Analysis of the Geoengineering Model Intercomparison Project G4 scenario, Atmos. Chem. Phys., 17, 3339–3356, https://doi.org/10.5194/acp-17-3339-2017, 2017.

Niemeier, U., Schmidt, H., Alterskjaer, K., and Kristjánsson, J. E.: Solar irradiance reduction via climate engineering: Impact of different techniques on the energy balance and the hydrological cycle, J. Geophys. Res.-Atmos., 118, 11905–11917, https://doi.org/10.1002/2013JD020445, 2013.

Pinto, I., Jack, C., Lennard, C., Tilmes, S., and Odoulami, R. C.: Africa's climate response to solar radiation management with stratospheric aerosol, Geophys. Res. Lett., 47, e2019GL086047. https://doi.org/10.1029/2019GL086047, 2020.

Shepherd, J. G.: Geoengineering the Climate: Science, Governance and Uncertainty (Policy Document No. 10/09), London: Royal Society, 82 pp, 2009.

Visioni, D., Pitari, G., di Genova, G., Tilmes, S., and Cionni, I.: Upper tropospheric ice sensitivity to sulfate geoengineering, Atmos. Chem. Phys., 18, 14867–14887, https://doi.org/10.5194/acp-18-14867-2018, 2018.

Xu, Y., Lin, L., Tilmes, S., Dagon, K., Xia, L., Diao, C., Cheng, W., Wang, Z., Simpson, I., and Burnell, L.: Climate engineering to mitigate the projected 21st-century terrestrial drying of the Americas: a direct comparison of carbon capture and sulfur injection, Earth Syst. Dynam., 11, 673–695, https://doi.org/10.5194/esd-11-673-2020, 2020.