Additional Specifications on G6solar/G6sulfur

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G6sulfur and G6solar are based on the high forcing and medium forcing Tier 1 experiments in ScenarioMIP. These are SSP5-8.5 and SSP2-4.5, respectively (<https://cmip.ucar.edu/scenario-mip/experimental-protocols>). All of the input files for these baseline scenarios are available through ESGF at the input4mips interface (<https://esgf-node.llnl.gov/search/input4mips/>).

Computing the exact amount of forcing to offset in each model could require quite a lot of work, and not all models are set up to do that. Furthermore, it would make sense for forcing to be defined as ERF, which can only be diagnosed and is not provided by any community. As such, calibrating the amount of sulfate aerosol or solar reduction to be implemented in each year is likely to be difficult if the target is radiative forcing. A few of us have been discussing the best way to proceed, and we came to the conclusion that it might be best to instead specify the tolerances in terms of global mean temperature rather than radiative forcing. Obviously the two are related, so this isn't really a major change to the protocol - it's more along the lines of making it easier to follow the protocol. In particular, we recommend the following procedure:

 1) For each method of geoengineering, complete a decade of simulation in which the solar constant is reduced or sulfate aerosol is injected against a background of SSP5-8.5. These decades should be 1 Jan 2021-31 Dec 2030, 1 Jan 2031-31 Dec 2040, etc. The year 2020 should be re-run as is.

 2) Average the global mean temperature over that decade and compare it to the global mean temperature over that decade for SSP2-4.5.

 3) If the value of the geoengineering simulation is within +/- 0.2 K of the value for SSP2-4.5, then proceed to the next decade. If not, repeat steps 1 and 2 for a different amount of geoengineering.

This process may seem a bit cumbersome, but I have a strong suspicion that it will not be so bad. The global mean temperature response (in the range of values explored here) is likely to be linear with injection rate for many models (although I've already seen one case where that isn't true). Therefore, I anticipate that most of you could do a few calibration runs ahead of time and predict the appropriate amount of geoengineering for each decade with reasonable accuracy.

Over the course of these simulations, geoengineering forcing will be ramped up from 0 in 2020 to -4 W/m2 in 2100. If the averages are computed every decade, each step (the changes will be discontinuous) will be on average 0.5 W/m2. These step changes will be mediated by the climate response and therefore smoothed out to some degree. We view these discontinuities as a compromise to improve the ease of simulation and thereby intercomparability of model responses.

For some models, sensitive dependence on the initial conditions or nonlinear behaviors may be important enough to cause substantial differences between different ensemble members. As such, we recommend that this procedure be done for each ensemble member independently. So every G6 ensemble member will correspond to an appropriate SSP2-4.5/SSP5-8.5 set of simulations.

There are studies in which temperature change is controlled on a year-by-year basis through control theory. While this has been implemented in some models, the required infrastructure to implement it is nontrivial, so we opted not to require this from the modeling groups.

For sulfur injection, the amount of sulfate aerosol precursor should be evenly distributed across the model layers that span approximately 18-20 km. Emission rates should be constant over the relevant time periods.

**Background aerosols**

The CMIP6 specifications for SSP2-4.5 and SSP5-8.5 prescribe linear trends in the background stratospheric AOD over the baseline period 2015-2024, with AOD values in 2024 set to preindustrial levels. We aim to diagnose the anthropogenic sulfur flux in the stratosphere (beyond any natural flux) that is suitable to reduce the forcing from SSP5-8.5 to SSP2-4.5. Thus te natural sulfur flux to the stratosphere in G6sulfur is expected to be radiatively equivalent to the background stratospheric aerosols used in SSP2-4.5 over the 2025-2100 period, indicating that no changes in background aerosol need to be made for that period. The only potential issue is over the period 2020-2024, when there is a linear trend in background aerosols. If possible, it would be helpful to set the background aerosols to those used in SSP2-4.5 for the whole 2020-2100 period, although that would entail a varying background over 2020-2024 to track the linear transition specified by CMIP6. However, ignoring the 2020-2024 variation in background aerosols when geoengineering is just ramping up is acceptable given the small associated forcing.