Project: **550**, Allocation period: **1.1.2020 - 31.12.2020**

Titel: **“Implications and Risks of Engineering Solar Radiation to Limit Climate Change (IMPLICC)”**

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Project overview

The DFG SPP “Climate engineering (CE): Risks, challenges, and opportunities? “ (SPP 1689) ended in 2019. We continue our work in the DFG funded project VolARC, which is part of VolIMPCAT. We participate in the CMIP6 endorsed model intercomparison GeoMIP (Kravitz et al, 2015) and provide new simulations and data to the community. GeoMIP started in 2011. We are participating currently in the second round of model inter comparisons. One parts are the official Tier1 experiments, which are endorsed in CMIP6. Another part are Tier2 and so called test bed experiments. The outcome concentrates less on the climate impact but more on the evolution of sulfate aerosol. GeoMIP brings several modeling groups together and helps to gain knowledge on the stratospheric aerosols, not only from artificial injections but also after volcanic eruptions.

The aim of our project is to gain knowledge on the risks and impacts of climate engineering on climate and society. There are different climate engineering techniques proposed. We concentrate on solar radiation management, mostly stratospheric aerosol modification (SAM) by injection of sulfur into the stratosphere. The evolution of the particle is still uncertain as different models giver very different models. Thus, we still do not know which surface cooling would be result from a certain amount of sulfur injection.

We performed Tier1 experiments of GeoMIP6 and hope to finish most of them until the end of 2019. We will continue with GeoMIP test bed simulations and Tier2 experiments.

1. Range of planned work from the scientific view

The GeoMIP test bed experiment accumH2SO4 is designed to compare two different approaches of sulfur solar radiation management: The injection of gaseous SO2 and the injection of H2SO4. H2SO4 will be injected directly into the accumulation mode of the aerosols. We expect that the injection of H2SO4 would lead to an aerosol size distribution with overall smaller particles and, consequently, more efficient SW back scattering properties as well as less sedimentation. In the GeoMIP test bed experiment this hypothesis should be tested. Furthermore, potential differences in e.g. stratospheric heating or stratospheric circulation response should be investigated.

We plan a set of simulations with ECHAM5-HAM T63 L95 for the GeoMIP test bed. Injections of SO2 are not given in the GeoMIP test bed but they have to be performed for a better comparison to previous work (e.g. Niemeier and Schmidt, 2017).

- accumH2SO4-ctr: Control simulation without sulfur injections: 50 years due to high variability caused by quasi-biennial oscillation and polar vortex.
- accumH2SO4: Sulfur injections, each for 20 years, with four different injection rates of 5 Tg(S)/yr, 10 Tg(S)/yr, 25 Tg(S)/yr, 50 Tg(S)/yr, and for injections of SO_2 and H_2SO_4. This will be done with three different injection strategie, thus in total 24 experiments (4x2x3 = 24 experiments). 20 years are necessary due to the variability caused by the quasi-biennial oscillation and polar vortex. In detail:
  - Sulfur injections at one grid box at the equator
  - Sulfur injections into two grid boxes at 30^o N, 180^o E and 30^o S, 180^o W
  - Sulfur injections into the region between 30^o N and 30^o S over all longitudes
- Different models give different answers on the amount of sulfate that has to be injected into the stratosphere to get a certain amount of cooling. Similarly, the evolution of the sulfate aerosol after a volcanic eruption differs strongly between the models but depends also on the model setup, e.g. grid size, injection area. We plan to further participate in comparisons with other models, e.g. WACCM at NCAR (S. Tilmes and J. Richter) and perform simulations with different prescribed ozone concentrations, dif-

ferent sea surface temperatures and different injection rates. A still open topic is the role of the different sedimentation schemes in the two models.

2. Mathematical and/or computational aspects

Geoengineering, especially solar radiation management impacts the climate system globally. Therefore we use MPI-ESM to study the climate impact of SAM. Additionally, we use ECHAM5-HAM in a special version for the stratospheric aerosols to simulate the evolution of sulfate aerosols.

3. Algorithmic/mathematical/numerical methods and solution procedures

The planned simulations will be performed with ECHAM5-HAM in the high top version. The model version runs since several years in the DKRZ computers and was tested at MPI-M for good performance. Aerosol microphysics is computational expensive and needs to be done on a HLRE computer.

6. Required computing time and amount of storage space

Planed simulations	Number	Years	N-hours [hours]	Work [Gb]
accumH2SO4 Control (ECHAM-HAM)	1	1x50	2500	5750
accumH2SO4 (ECHAM-HAM)	24	24x20	24000	55200
Comparison ECHAM and WACCM	10	10x10	5000	11500
Analysis of previous simulations				10000
Summ			31500	82450

Computation time:
Computation time ECHAM-HAM (T63-L95): 2 Node, 24 task per Node: about 50 node hours per year

Disc space:
ECHAM-HAM: Monthly mean values and 6 hourly data of meteorological variables: 115 Gb/yr

7. Additional value compared to other projects

This is the only GeoMIP participation in Germany. We work in close collaboration with project bb1093. This project concentrates on climate engineering studies, while bb1093 has the focus on sulfur evolution after volcanic eruption. Additionally, bb1093 does first steps towards the use of ICON-ART, while bm0550 uses the old, but well known model ECHAM5-HAM.