Quantifying and understanding uncertainties in regional impacts of solar geoengineering

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Anthropogenic climate change has emerged across many regions. Some of the observed changes we see are expected based on predictions from the current generation of physics-based global climate models, however many are opposite to our expectations. For example, the most concerning discrepancies between observed changes and our expectations are related to heat waves, drying, and rainfall changes over land. These discrepancies, which are connected to physical-science uncertainties, raise questions about the ability of the current generation of physics-based global climate models to accurately predict regional climate changes in some regions and for some variables.

The current generation of physics-based global climate models are the primary tool used to quantify the regional impacts of proposed solar geoengineering scenarios. The emerging regional climate discrepancies raise questions about our ability to predict regional impacts of solar geoengineering scenarios, particularly over land. What are the robust (agreed upon across climate models) regional impacts of solar geoengineering? Do regional climate discrepancies exacerbate or mitigate these impacts? How does physical-science uncertainty associated with known (small-scale parameterized physics, natural variability) and emerging (atmosphere-ocean coupling) factors cascade into uncertainty in regional impacts of solar geoengineering? How does physical-science uncertainty impact the detectability (time of emergence) of regional impacts of solar geoengineering scenarios? To date the impact of physical-science uncertainty on regional climate changes from solar geoengineering scenarios has not been fully quantified. Our mechanistic understanding of regional impacts of solar geoengineering is also not as advanced as for climate change due to greenhouse gases and tropospheric aerosols. The goal of our project is to answer the questions above and thereby fill knowledge gaps that have emerged as regional climate discrepancies have accumulated. The project will quantify the physical-science uncertainty of regional impacts of solar geoengineering scenarios.

The project makes use of the new MPI-M CMIP7 model (ICON-XPP, 80 km horizontal resolution for the atmosphere and 20 km for the ocean). The solar geoengineering scenarios will follow Stratospheric Aerosol Injection (SAI) scenarios from Geoengineering Model Intercomparison Project (GeoMIP) The proposed research will quantify how uncertainties in atmosphere-ocean coupling in the current generation of global climate models cascade into uncertainties in the regional impacts of solar geoengineering scenarios. We will conduct flux-adjusted solar geoengineering coupled climate model simulations with ICON-XPP. The parameterization of small scale physical processes, e.g. clouds, convection, aerosols and turbulence which couple the atmosphere, land and ocean, is another well-known source of uncertainty often referred to as structural uncertainty. Structural uncertainty is typically quantified using a perturbed parameter ensemble (PPE). Our planned PPE is based on a GeoMIP scenario and will use a prescribed artificial layer of sulfate aerosol in the stratosphere to reduce the global temperature.