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Potential temperature induced carbon-cycle feedbacks from solar radiation management geoengineering

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Ideas to reduce the amount of shortwave radiation coming into the Earth system, to address the radiative imbalance caused by increasing greenhouse gas concentrations, have gained increasing attention over recent years. Here, we investigated the potential temperature induced carbon-cycle feedbacks that may arise due to such solar radiation management (SRM) geoengineering interventions.

In this work, geoengineering is simulated by reducing the level of solar radiative forcing over the 21^{st} century in a reduced complexity, global climate-carbon cycle model, MAGICC 6 [1]. This simple model features a hemispherically averaged, upwelling diffusion ocean component and has been calibrated using 19 atmosphere-ocean global climate models. The harmonised emissions of the Representative Concentration Pathways (RCPs) are used to force the future climate and SRM geoengineering is applied to offset a portion, or all, of the positive radiative forcing generated by anthropogenic emissions. As noted previously by Matthews and Caldiera [2], the application of SRM can reduce simulated atmospheric carbon dioxide concentration considerably. Examination of the resulting carbon pools reveals that this atmospheric reduction occurs due to the temperature sensitivities of terrestrial respiratory fluxes. Since SRM artificially reduces surface temperatures, heterotrophic respiration decreases when compared to the non-SRM control run, and therefore less carbon leaves the soil pool. The simulated temperature response to SRM geoengineering therefore represents a combination of the response to a direct reduction in incoming shortwave radiation (i.e. the geoengineering intervention), and a response to increased outgoing longwave radiation from a reduction in atmospheric carbon dioxide (i.e. the carbon-cycle response to geoengineering). However, feedbacks within the carbon-cycle are not solely temperature dependent and may also be largely driven by precipitation, as well as changes to direct incoming shortwave radiation. Geoengineering that involves a reduction to the incoming solar flux would likely induce spatially inhomogeneous alterations to precipitation patterns [3, 4], so a full assessment of carbon-cycle feedback response to SRM would necessitate incorporation of precipitation driven feedbacks.

Here, the magnitude and duration of SRM geoengineering are varied, along with concurrent anthropogenic emissions. MAGICC 6 was calibrated to emulate the response of nine of the C^4MIP models, allowing a first order assessment of likely variation in the carbon cycle response. A range of other climate model parameters, including climate sensitivity, were also varied within their likely uncertainty ranges to explore the effect of the uncertainty in temperature response on the carbon cycle response.

References:

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