Geophysical Research Abstracts,
Vol. 11, EGU2009-14133, 2009
EGU General Assembly 2009

Geoengineering to Avoid Overshoot: An Uncertainty Analysis

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Geoengineering (or climate engineering) using stratospheric sulfur injections (Crutzen, 2006) has been called for research in case of an urgent need for stopping global warming when other mitigation efforts were exhausted. Although there are a number of concerns over this idea (e.g. Robock, 2008), it is still useful to consider geoengineering as a possible method to limit warming caused by overshoot. Overshoot is a feature accompanied by low stabilizations scenarios aiming for a stringent target (Rao et al., 2008) in which total radiative forcing temporarily exceeds the target before reaching there. Scenarios achieving a 50% emission reduction by 2050 produces overshoot. Overshoot could cause sustained warming for decades due to the inertia of the climate system. If stratospheric sulfur injections were to be used as a “last resort” to avoid overshoot, what would be the suitable start-year and injection profile of such an intervention? Wigley (2006) examined climate response to combined mitigation/geoengineering scenarios with the intent to avert overshoot. Wigley’s analysis demonstrated a basic potential of such a combined mitigation/geoengineering approach to avoid temperature overshoot – however it considered only simplistic sulfur injection profiles (all started in 2010), just one mitigation scenario, and did not examine the sensitivity of the climate response to any underlying uncertainties.

This study builds upon Wigley’s premise of the combined mitigation/geoengineering approach and brings associated uncertainty into the analysis. First, this study addresses the question as to how much geoengineering intervention would be needed to avoid overshoot by considering associated uncertainty? Then, would a geoengineering intervention of such a magnitude including uncertainty be permissible in considering all the other side effects?

This study begins from the supposition that geoengineering could be employed to cap warming at 2.0ºC since preindustrial. A few mitigation scenarios having overshoot are formulated. Optimal injection profiles (start-year and magnitude) for capping temperature rise at 2.0ºC are calculated for each mitigation scenario. The sensitivity of such results to the uncertain parameters (climate sensitivity, tropospheric aerosol forcing, and ocean diffusivity) is then examined – in particular, I account for the inter-dependency of the estimates of these parameters such that they are consistent with historical observations (e.g. temperature records) by using an inverse estimation approach. I use the simple climate model ACC2 (Tanaka and Kriegler et al., 2007; Tanaka, 2008) – which (unlike Wigley’s MAGICC model (Wigley and Raper, 2001)) includes an inversion setup that allows for the exploration of parameter inter-dependency based on historical observational constraints.

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