How well do integrated assessment models represent non-CO2 radiative forcing?

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Introduction

This study aims to understand how different Integrated Assessment Models (IAMs) perform in describing the climate forcing by non-CO2 gases and aerosols. Variations herein play a potentially large role in the choice of a cost-optimal mitigation strategy, given that roughly one third of global warming can be attributed to non-CO2 forcing.

Approach

We have included several non-CO2 forcing representations from IAMs in this analysis: MERGE_ETL, MERGES, and PAGE09 and DICE2013R as well as two versions of MAGICC (5.3 and 6.3), used by most, more detailed IAMs. We refer to all these representations as Simple Climate Models (S8Ms). The S8Ms have been run with the same pre-described anthropogenic emission pathways (the so-called Representative Concentration Pathways, RCPs) and have been compared to the results of analysis by complex atmospheric chemistry and climate models, or earth system models (ESMs), in terms of radiative forcing levels. The RCPs represent a scenario without climate policy (an 8.5 W/m² scenario) and a scenario with a stringent two degree climate target in 2100 (a 2.6 W/m² scenario). 16 ESMs have been run with precisely the same RCP emissions within the Atmospheric Chemistry and Climate Model Intercomparison Project (ACCIMP).

Conclusions

Overall, it can be concluded that the overall behaviour of non-CO2 gases and aerosols seems to be reasonably captured by most models, given that most overall non-CO2 radiative forcing projections are found within the expert model range.

There is a very large spread between the S8Ms for the same emitted-driven mitigation scenario (0.74 W/m² for RCP2.6). This implies that the choice of a climate model has large implications for determining the mitigation strategies in terms of CO2 reduction and associated policy costs. Models may want to move closer to the median of the expert model range. Differences in aerosol assumptions (notably indirect, cloud forming effects) account for the largest spread in forcing projections. Variations in N2O, halogenated gas and exogenous forcing assumptions also play a large role in the spread in forcing outcomes. For N2O as well as for CH4, model differences mainly occur in calculation of concentrations while models show consistency in deriving forcing levels from concentrations.

Compared to expert models, many IAMs seem to show a less rapid decline of negative aerosol forcing and could in that sense be improved. MAGICC8.3, which has a particularly negative forcing projection in 2100, could benefit from compensating for differences in indirect forcing effects of specific aerosols. For well-mixed greenhouse gases, forcing estimates are possibly too high across several models, yet further comparison with expert models is needed.

Because most S8Ms generally do not include important forcers such as O3, BC and stratospheric vapour from CH4, they run the risk of underestimating forcing differences between baseline and mitigation scenarios.

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