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Simulating the impact of Carbon cycle and climate uncertainties in century-scale mitigation scenario simulations with the AIM/Impact[Policy] Integrated Assessment model

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Integrated Assessment Models (IAM) for intertemporally optimized emission trajectories are often limited by oversimplified climate system representations. Omission of carbon cycle uncertainties results in overconfident allowable emissions and potentially misleading results on the cost and feasibility of mitigation targets.

The uncertainty of future warming, dominated on the physical side by Climate Sensitivity (CS), is conventionally dealt with by setting policy targets in terms of Radiative Forcing (RF). Forcings are, however, uncertain, particularly the contribution of aerosols, which is important in the transient temperature change of mitigation simulations. Further, real policy targets are stated in terms of global surface air temperature (SAT), a measure closer to impacts and more relevant than RF. To shift focus of IAM policy simulations to temperature seems logical, but requires the use of a simple, yet realistic climate model component.

Here, the AIM/Impact[Policy] IAM is used with a coupled BernCC-type C cycle-climate component for century-scale emission scenarios under RF and SAT policy targets. A mixed-layer pulse-response function simulates ocean uptake of both C and heat, resulting in physically consistent and accurate emulation of parent ocean models, in the present case HILDA and, alternatively, Bern2.5D. Land C is simulated with the simple Bern 4box and, alternatively, a multibox substitute of the High Resolution Biosphere Model (HRBM). This setup allows for factorial simulations with/without the main uncertain feedbacks C fluxes, including CO_2 fertilization, the enhancement of heterotrophic respiration by warming, and the temperature feedback on ocean C uptake through surface CO_2 pressure dependence on temperature (as compared to earlier AIP applications which used only an optimistic standard setup).

Historical constraints on atmospheric CO_2 and global SAT are used to obtain consistent and robust future projections. For C, any residual fluxes arising from prescribed atmospheric CO_2 are simply assigned to land C exchange and are carried forward into the future. Historical global SAT is matched by estimating scaling factors for radiative forcings within the respective uncertainties. The resulting parameter distribution is sampled for representative projections. A fully probabilistic treatment is not attempted at this stage, as not all important parameters are accessible in the model, spatial patterns are not considered, and results are contingent on uncertain parameters from CS to economic assumptions, which are varied independently. Instead, a set of sensitivity simulations is obtained which cover the major uncertainties realistically without attaching an explicit probability to them.

AIP is an intertemporal utility optimizing IAM with a simple economy whose main purpose is climate change impact assessment. The inclusion of C cycle-climate uncertainties for impacts allows for comprehensive treatment of uncertainties over the whole cause-effect chain in future impact assessments with AIP.