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Aggregate models of climate change: development & applications
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Abstract

Impulse-response-function (IRF) models are designed for applications requiring a large number of climate simulations, such as multi-scenario climate change impact studies or cost-benefit integrated-assessment studies. The models apply linear response theory to reproduce the characteristics of the climate response to external forcing computed with sophisticated state-of-the-art climate models like general circulation models of the physical ocean-atmosphere system and three-dimensional oceanic-plus-terrestrial carbon cycle models. Although highly computer efficient, IRF models are nonetheless capable of reproducing the full set of climate-change information generated by the complex models against which they are calibrated.

While limited in principle to the linear response regime (less than about 3^{o}C temperature change), the applicability of the IRF model presented in this paper has been extended into the nonlinear domain through explicit treatment of the climate system's dominant nonlinearities: CO_2 chemistry in ocean water, CO_2 fertilization of land biota, and sublinear radiative forcing. The resultant Nonlinear Impulse-response model of the coupled Carbon cycle-Climate System (NICCS) computes the temporal evolution of spatial patterns of climate change in four climate variables of particular relevance for climate impact studies: near-surface temperature, cloud cover, precipitation, and sea level. The space-time response characteristics of the model are derived from an EOF analysis of a transient 850-year greenhouse warming simulation with the Hamburg atmosphere-ocean general circulation model ECHAM3-LSG and a similar response experiment with the Hamburg ocean carbon cycle model HAMOCC.

Emission scenarios studied with the model cover time horizons ranging from 30 years (the Kiel-Volkswagen model) over projections for the 21st century (IIASA) to two idealized 1000-year scenarios which demonstrate that the use of all currently estimated fossil fuel resources would carry the Earth's climate far beyond the range of climate change for which reliable quantitative predictions are possible today, and that even a freezing of emissions to present-day levels would not be sufficient to prevent a major global warming in the long term.

Further applications of the model include its combination with, and incorporation into, other models: integrated assessment studies, investigations of climate change feedbacks onto the terrestrial carbon cycle, and an educational tool developed for the EXPO2000 World Exhibition.