

Approaches to linking human and earth system models for interdisciplinary research

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Both societal and physical processes play a role in addressing many key questions related to the consequences of climate change and to mitigation and adaptation options for responding to it. For example, human processes such as changes in population, economic conditions, and policies govern the demand for land, water and energy, while the interactions of these resources with physical systems determine their availability and environmental consequences. As a result, researchers addressing such questions face a choice in how to represent societal and physical processes in models, and in particular how to model interactions between them. These processes act at a variety of spatial scales and across multiple sectors, providing additional challenges to integration.

A variety of approaches are available to make this linkage, each with benefits and drawbacks. I summarize principal types of approaches, distinguishing them based on the type of coupling between human and earth system models they involve, from one-way to full two-way coupling, and from tightly connected, hard-coded models to soft linkages. Each approach has advantages and disadvantages, and is most suitable to specific types of questions. There is a need for a standardized, widely accepted set of terminology and definitions for different types of coupling in order to improve communication and transparency about how research has been carried out and to facilitate progress on this topic. I propose such terminology and use it to clarify differences in approaches in the literature to investigating interactions between land use and climate change.

In addition, I illustrate how research involving one-way linkages between human and earth system models can be carried out efficiently, based on experience linking the NCAR-DOE Community Earth System Model (CESM) to different types of human system models for investigating climate change impacts on society. In many cases these links have been made using a new toolkit designed for this purpose, called the Toolbox for Human-Earth System Integration and Scaling (THESIS, https://www2.cgd.ucar.edu/sections/tss/iam/THESIS_tools). THESIS consists of models and software tools to translate, scale, and synthesize information from and between human system models and earth system models (ESMs). I illustrate their application to both the projected exposure of population to climate extremes and to the evaluation of climate impacts on the agriculture sector, carried out by linking the NCAR integrated assessment model, iPETS, with CESM.

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