INTEGRATED EARTH SYSTEM MODEL (iESM) OPEN SOURCE CODE

Today's energy-production and land-use practices are driving changes in the Earth system which, in turn, will impact future decisions regarding these human systems. For example, increasing human emissions of greenhouse gases from burning of fossil fuels, together with continuing human disruption of natural land cover, will produce additional warming of the Earth system; but as the Earth warms, the resulting environmental stresses will force reconsideration of current energy-production and land-use practices.

Until recently, this co-evolution of the human and Earth systems could only be crudely simulated. Human systems were represented by "integrated assessment models (IAMs)" that predicted the effects of alternative demographic, energy-production, and land-use trends on greenhouse emissions over the 21st century. Different potential emissions scenarios then were supplied to Earth Systems Models (ESMs) which predicted their physical consequences. However, the effects of a changing Earth on future human decision-making were not adequately represented.

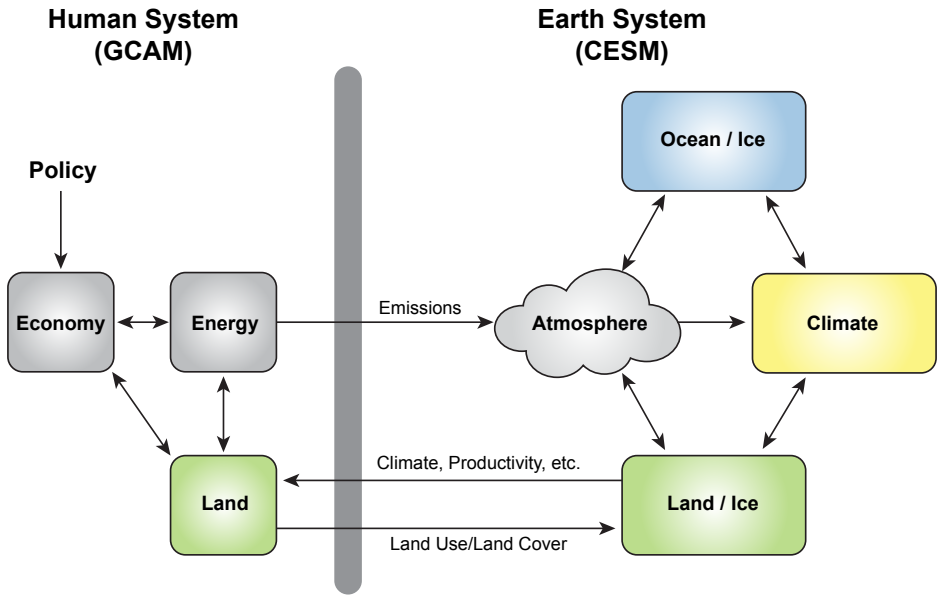

Figure 1. Human and earth system components are included in the same iESM modeling framework. Human-system interactions and resulting greenhouse emissions and land-use changes are predicted by the Global Change Assessment Model (GCAM), while subsequent changes in Earth components are simulated by the Community Earth System Model (CESM). The iESM's feedback loop involving human land-use and physical land change is indicated by the two-way arrows.

THE IESM INNOVATION

The DOE-sponsored development of the integrated Earth System Model (iESM) is a path-breaking effort to more realistically simulate such human-Earth systems interactions. In the iESM, a two-way coupling between the human and Earth systems is included within the same modeling framework, making it possible to reliably quantify these interactions[1]. The iESM open source software is now publicly available.

Get iESM 1.0

The integrated Earth System Model (iESM) v1.0 code and input sets are available for download at:

- ***http://github.com/ACME-Climate/iESM***
- ***http://dx.doi.org/10.5281/zenodo.820079***

INTEGRATING HUMAN AND PHYSICAL SYSTEMS

In the iESM, human systems are simulated by the Global Change Assessment Model (GCAM) which predicts how alternative economic, energy, and land-use practices will trigger changes in CO_2 emissions and land cover (Fig. 1). These human-initiated changes will impact the Earth system, with resulting alterations of the atmosphere, ocean, land, and ice being simulated by the Community Earth System Model (CESM) (Fig. 1). The GCAM and CESM previously operated as separate models, but iESM developers have successfully combined these diverse components into the same simulation framework[1].

LAND-USE PROJECTIONS

Previously, the CESM simulation of changes in the types and amounts of land cover resulting from changes in the Earth system did not influence the GCAM prediction of future land-use practices. The key innovation of the iESM is to complete this feedback loop (indicated by two-way arrows in Fig. 1), so that the GCAM and CESM now exchange synchronous two-way information on land use/land cover, plant productivity, and CO_2 fluxes.

For instance, version 1.0 of the iESM predicts that medium-severity future increases in carbon dioxide (CO_2) emissions will enhance crop fertilization, resulting in 10-percent higher agricultural productivity by the end of the 21st century[2]. The ability to use less land area for agriculture then will make it feasible to adopt more beneficial land-use practices, such as growing additional forests to increase the uptake of CO_2 thus mitigating further warming of the Earth (Fig. 2).

FUTURE MODEL DEVELOPMENT

Other key human-Earth feedbacks—notably, the impact of greenhouse warming on future energy-production and water-management practices—is not yet represented in the iESM, but is current work-in-progress for the model development team. The public release of the open-source iESM software code also will make it possible for a broad community of users to experiment with different approaches to simulate additional human-Earth system interactions such as these.

SUPPORT

U.S. Department of Energy, Office of Science, Office of Biological and Environmental Research

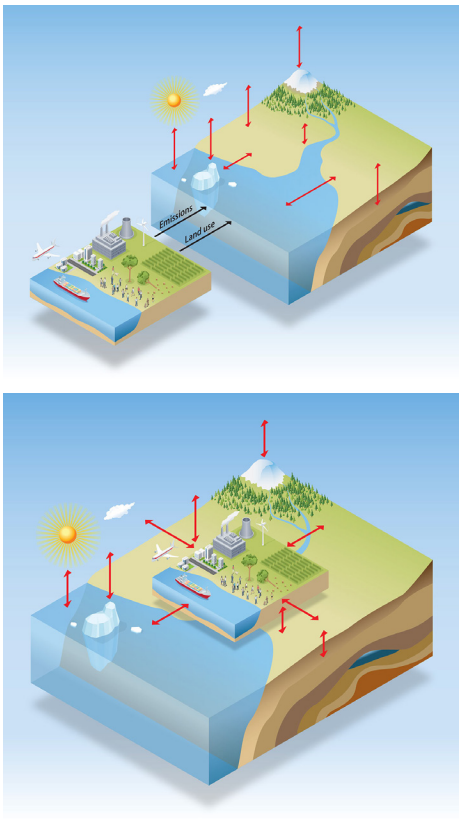

Figure 2. The iESM replaces one-way asynchronous interactions between human land use and the Earth system (indicated by black arrows, top image) with two-way synchronous interactions (bottom) that reveal the potential for increased future agricultural productivity. This will make it feasible to implement alternative land-use practices[2].

CONTACTS

Kate Calvin, Ph.D.
Principal Investigator
Pacific Northwest National Laboratory
katherine.calvin@pnnl.gov

Dorothy Koch, Ph.D.
DOE Program Manager
Earth System Modeling
dorothy.koch@science.doe.gov

[1] Collins, WD, et al. (2015). "The Integrated Earth System Model Version 1: Formulation and Functionality." *Geoscientific Model Development* 8(7): 2203-2219. DOI:10.5194/gmd-8-2203-2015

[2] Thornton PE, et al. (2017). "Biospheric Feedback Effects in a Synchronously Coupled Model of Human and Earth Systems." *Nature Climate Change* 7: 496-500. DOI:10.1038/nclimate3310