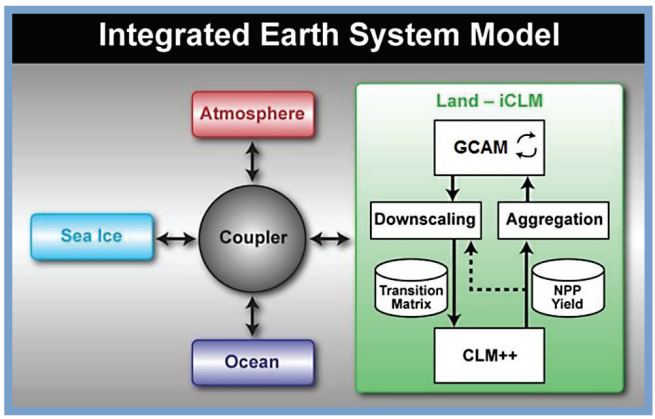
IMPROVING THE REPRESENTATIONS OF HUMAN-EARTH SYSTEM INTERACTIONS: iESM PROJECT

Sponsored by the U.S. Department of Energy Office of Science, the Integrated Earth System Model (iESM) Project has produced a first generation, complex earth system model that integrates detailed representations of human systems. By merging major components from two of DOE's core modeling programs, Earth System Modeling and Integrated Assessment Science and Modeling, a new breed of sophisticated, detail-rich simulation capabilities has emerged to advance the science of human and Earth system interactions, including studies of land use, future bioenergy systems, hydrology, climate adaptation and mitigation. IESM is built around four underlying models: human systems components from the Global Change Assessment Model (GCAM); the Community Earth System Model (CESM) and a major CESM component model, the Community Land Model (CLM), as well as a land coupling model, the Global Land Model (GLM).

Initiated in 2009 and running through 2013, this 5-year project is a collaboration between five institutions. Pacific Northwest National Laboratory's Joint Global Change Research Institute develops and maintains GCAM while providing regional testbed development capabilities for hydrology modeling. Oak Ridge National Laboratory is working with the Community Land Model, a component of the CESM. Lawrence Berkeley National Laboratory is developing the code structure for full integration within the CESM framework. University of Maryland applies and develops the GLM model to integrate land representations between GCAM and CLM. All five institutions work together on experimental applications for overall model development and analysis.



OPPORTUNITY

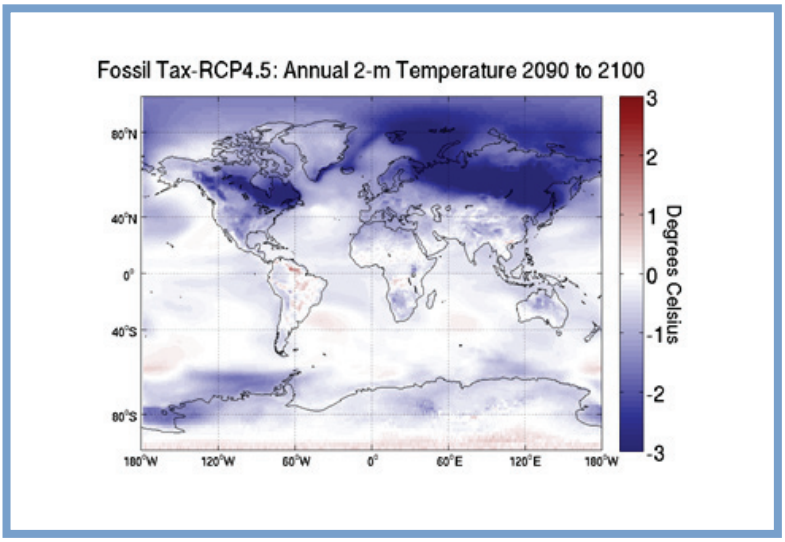
Create a first-generation iESM with both the human components of an integrated assessment model and the physical characteristics of an earth system model.

Further develop components and applications within the iESM and test the model against policy scenarios to improve the understanding of the coupled physical, ecological, and human systems.

Add realistic hydrology, including freshwater availability from surface water, ground water, and desalinization.

CHALLENGE

Development of an iESM makes it possible to integrate human dimensions of energy and land use scenarios directly into full global climate models to improve prediction of potential future climate change, the implications of emissions mitigation options, and climate change impacts and adaptation options. Changes in behavior of the coupled climate-energy-land modeling system based on full ESMs, such as CESM, are yielding different results than coupled models based on Earth System Models of Intermediate Complexity (EMICs) and significantly different results than uncoupled models. One trade-off, however, is computational intensity for the near limitless options in human systems and decision-making. Accordingly, iESM is expected to advance a new class of human-earth systems understanding and analytic capabilities while working in tandem with other established modeling capabilities. The convergence of these leadership class models will greatly advance our understanding of the physical climate system.



A first experiment explored the role of land use policy on climate change and found that a carbon tax scenario that accounts for terrestrial carbon results in greater land area in bioenergy crops and less forest land would result in substantial decrease in warming, even though total radiative forcing from greenhouse gases is held constant with these two scenarios.

Jones et al. 2012 "Greenhouse gas policy influences climate via direct effects of land use change." Journal of Climate, In preparation

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APPROACH

For the GCAM model, the team developed a flexible time step capability, as well as new agricultural and land use model capabilities. A module for water supply demand and allocation assessment is currently under development. The CLM was enhanced with a land-use land-cover change capability. Bioenergy feedstock for plant functional types will be added soon. The GLM has been integrated with CLM, allowing dynamic land use change from human activities to be considered in CESM.

ACCOMPLISHMENTS & FINDINGS

During the first experiment, the team demonstrated that scenarios with the same atmospheric radiative forcing from greenhouse gases can have very different climate outcomes due to differences in land use patterns resulting from changes in human behaviors. When two different policy scenarios are applied to GCAM—one including terrestrial carbon in the economic framework as a universal carbon tax (UCT) and one excluding the fossil fuel and industrial emissions carbon tax (FFICT)—very different patterns of land use change occur. When terrestrial carbon is included in the economic decisions for mitigation, forest lands expand (UCT) and when it is not included, cropland expands for bioenergy production (FFICT).

Both reach the same level of atmospheric radiative forcing. However, when coupled with CESM, the team found that the climate system is dramatically different as a result of the land use patterns. The land use changes are responsible for a difference of 1.5 W/m2 of radiative forcing, which moves the alternative land use policy scenario outside the ensemble range of the RCP4.5 land use policy. The experiment successfully demonstrated that radiative forcing of greenhouse gas constituents by itself is not an adequate measure for evaluating the evolution of the climate system. Through iESM, these outcomes can be attributed to differences due to the geophysical consequences of humans changing their land use.

Currently, validation of the first experiment is underway, and it is planned to release iESM to the CESM community in 2013.

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Project Website:
http://climatemodeling.science.energy.gov/projects/improving-representations-human-earth-system-interactions