OFFICE OF BIOLOGICAL AND ENVIRONMENTAL RESEARCH

Climate and Earth System Modeling

U.S. DEPARTMENT OF ENERGY | Office of Science

INTEGRATING WATER SUPPLY AND DEMAND INTO THE GLOBAL CHANGE ASSESSMENT MODEL (GCAM)

The Global Change Assessment Model (GCAM) is a state-of-the-art, global integrated assessment model that brings together representations of the economy, energy system. Over the last three decades, GCAM and its predecessors have been used for a wide range of analyses to support both public- and private-sector decision making, including research on the implications of new and improved technologies, scenarios of socioeconomic development and resource availability, national and international climate policy frameworks, national energy policy approaches, and land use policies.

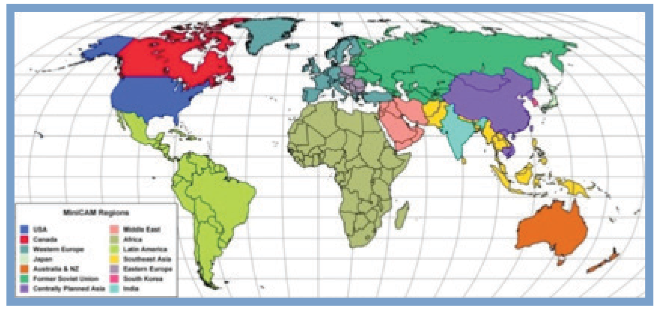
New improvements in GCAM are focused on representing the impacts of climate change and adaptation strategies and their linkages to mitigation strategies. Water lies at the heart of these interactions. It is critical to energy supplies, including hydroelectric power, thermoelectric power (as cooling water), and bioenergy production. Water supply technologies, such as emerging technologies like desalinization, could require substantial energy. In addition, a changing climate will alter precipitation patterns both locally and globally, in ways that are highly uncertain.

CHALLENGES

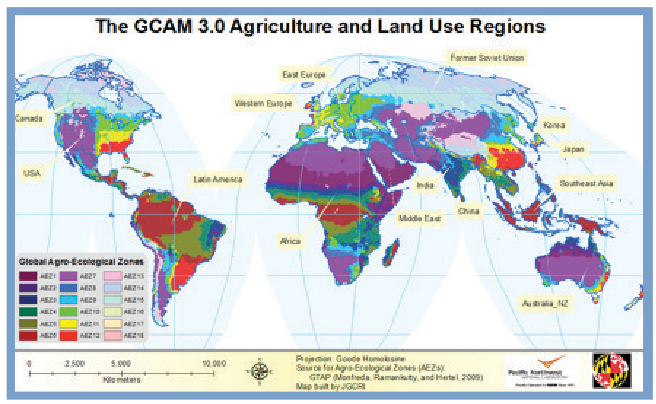
Incorporating water into a global integrated modeling framework raises many challenges. Water supply and demand issues can be highly local, calling for modeling at higher spatial resolution than is typical in integrated global assessment models. Water data, particularly global, is of limited scope and quality. The use and allocation of water is confounded by complicated regulatory architectures that vary regionally. Finally, the modeling of water in an integrated framework calls for explicit representation of the many interactions between water supply and demand.

MAJOR COMPONENTS AND/OR THEMES

Representing water in GCAM involves three steps. The first is to develop representations of key demands in terms of both consumption and withdrawals. Key sectors include the energy sector, households, and agriculture. In all of these sectors, a meaningful representation of demand requires representations of multiple technology options that can capture economic choices regarding water use such as different cooling systems for electricity generation. The second is to construct a water supply model that can operate at a global scale appropriate for an integrated assessment



GCAM's 14 geopolitical regions are shown here.

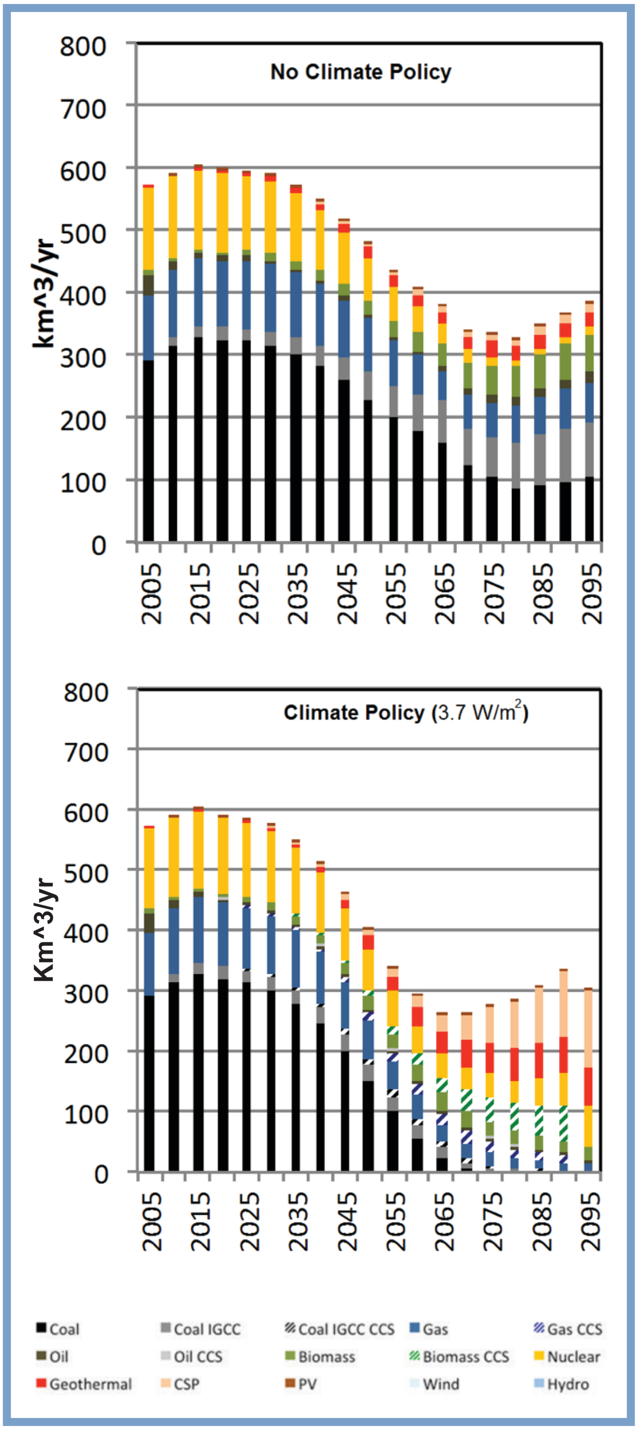


This map illustrates GCAM's 151 agro-ecological zones.

model. The GCAM approach is to build a gridded water-balance global hydrologic model with a resolution of 0.5x0.5 degrees. To supplement fresh water sources, this is accompanied by integrating representations of non-renewable ground water supplies and desalination technologies into GCAM. The third is to link water supply and water demand in a way that can represent different allocation and water market schemes.

FUTURE WORK

Staff at Pacific Northwest National Laboratory (PNNL) have developed separate modules for water supply and water demand. The demand modules compute water withdrawals and water consumption on an annual basis for irrigation, livestock, domestic purposes, electricity generation, primary energy production, and manufacturing. In one set of experiments, the power sector's water demands are assessed for three climate change mitigation policies: no action to limit



Global water withdrawal for electricity generation by technology for scenarios with no policy (top), as compared with scenarios meeting 3.7 W m^{-2} stabilization targets (bottom), with a renewables-focused strategy (Kyle et al. 2013).

climate warming due to greenhouse gas emissions; stabilization of radiative forcing at 4.5 Watts per meter squared (4.5 W/m^2); and stabilization of radiative forcing at 3.7 W/m^2. The findings suggest that generating electricity using new low-emissions technologies is not likely to increase water demand through the end of the century.

Efforts to fully link water supplies and demands are ongoing. However, research efforts are already comparing supplies and demands at a global level to identify areas of scarcity. By combining results from the water balance model with spatially downscaled representations of water demand, PNNL has produced a dynamic, high-resolution view of global, annual water scarcity under a range of future conditions, including different strategies for the use of bioenergy in climate mitigation. The findings highlight, among other things, potentially substantial implications of water scarcity for bioenergy production as a mitigation option. Current research is directed at full integration between water supplies and demands, more sophisticated representations of technology choices for water demand, and extending the modeling capability to capture sub-regional interactions among the U.S. economy, energy, land use, and water systems.

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Project Website

http://www.globalchange.umd.edu/models/gcam/