Research Program

Climate Change and Carbon Management

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The Climate Change and Carbon Management program (CC&CM) is a growing interdisciplinary research effort within ESD. The program conducts research to increase the scientific foundation for climate change prediction, impact assessment, and mitigation. In addition, program research on biogeochemical cycles and climate also addresses other pressing issues under the purview of DOE and other public agencies, such as stewardship of water resources and the environmental effects of energy use and land use. To that end, we have active projects on climate and hydrology, climate change, terrestrial and marine biogeochemistry, and carbon management in geologic, oceanic, and terrestrial systems.

One of CC&CM's strengths is its active partnerships with universities, industry, and other research laboratories. The most important of these is our strong partnership with UC Berkeley, which includes collaboration with faculty, sharing research facilities, teaching, advising and mentoring UC students, and interaction with the Berkeley Atmospheric Sciences Center.

RECENT ACCOMPLISHMENTS

Below we illustrate some of the recent accomplishments of CC&CM in the areas of climate studies, terrestrial carbon cycling, oceanic carbon cycling, and carbon capture and storage in geologic reservoirs.

Coupled Climate Carbon Cycle Modeling

A major concern about future climate forcing is how the current terrestrial and marine carbon sinks will respond as fossil fuel emissions increase and climate changes. ESD scientist Inez Fung and coworkers recently added interactive land and ocean carbon cycles to the global Community Climate Simulation Model (CCSM) to study how diverse features of the environment, including plants, soil, precipitation, microbes, oceans, phytoplankton, clouds, and carbon dioxide emissions interact to affect the strength of carbon sinks. They found an inverse relationship between fossil fuel emission rates and land and ocean carbon sink capacity—the faster the emission, the less effective the carbon sinks. This result implies that carbon storage by the oceans and land will lag further and further behind, and climate warming will accelerate with growing carbon dioxide emissions. Climate warming will increase the amount of carbon dioxide in the atmosphere, which in turn makes the climate even warmer, and so on. This model and nine others in a coupled climate carbon cycle model intercomparison (C4MIP) predicted large decreases in ecosystem carbon uptake (especially in the tropics) with climate change, and consequently an acceleration of warming.

Regional Climate and Water Resources

Climate Change and Carbon Management scientists contributed to the Fourth Assessment Report of the Intergovernmental Panel for Climate Change through the above work and through regional climate analysis. The Fourth Assessment Report includes CC&CM's analyses of regional climate model projections, temperature extremes, and the impacts of snowpack on water resources. CC&CM researchers quantified the range of uncertainty in the hydrologic response, finding that, regardless of emissions scenario, there are likely to be significant decreases in snowpack and available water resources in California. This finding has led CC&CM researchers to develop a new water-energy model with surface water, groundwater, and dynamic vegetation, and to apply this to a multidecade drought study. They have determined new heat extreme likelihoods based on exceedence probability analysis, and determined the intensity and persistence of these heat extremes. Correlating these results with temperature-related energy demand suggests that current energy capacity projections will likely be exceeded. Additional recent activities include a regional climate model intercomparison that evaluated California land-use change between pre-industrial and present time, multidecadal high-resolution simulation of land-surface processes with the development of scaling relationships for soil moisture, an analysis of the impact of China's Three Gorges Dam on the local climate, an analysis of the relationship between atmospheric circulation and snowpack in the western U.S., heat island effects in the Central Valley, climate change water allocation sensitivities, and new ensemble simulations for the initialization of soil moisture and plant functional types.

Ocean Carbon Cycle

Oceans contain more carbon than any other dynamic reservoir on earth. They pose a great observational challenge because the

pulses of biological productivity are episodic and rapid, and the areas are vast. Climate Change and Carbon Management scientists have developed the Carbon Explorer, an autonomous float that uses satellite telemetry to report its observations from distant oceans. Twelve of these low cost robots have achieved the equivalent of 8 years of continuous observations of particulate organic carbon (variability in remote and biologically dynamic ocean regions since 2001, a data record that would not have been possible with conventional research ships. Seagoing work to prove and enhance new sensors for the Carbon Explorer is ongoing. CC&CM's new sensor for particulate inorganic carbon was operationally deployed to full ocean depth during a pole-to-pole survey transects of the Atlantic Ocean in July 2003 and January 2005. The data it reported allow the first comprehensive examination of the spatial variability of particulate organic and inorganic carbon. CC&CM's optical carbon sedimentation recorder was most recently deployed in Oyshio waters near Japan.

Terrestrial and Atmospheric Carbon Cycle

One of the focal points of carbon cycle research is the vast range of scales—from a single leaf to an entire continent—that must be bridged with measurements and models. The Climate Change and Carbon Management program has implemented a coordinated suite of carbon concentration, isotope, and flux measurements in the Southern Great Plains, as part of the DOE Atmospheric Radiation Measurement (ARM) Program. Simultaneously monitoring from crop fields, tall towers, and aircraft, this facility is one of the best-instrumented site for regional carbon studies in the world. To support the North American Carbon Program, various approaches to estimating regional scale ecosystem CO_2 fluxes are underway.

The second major thrust in this area is determining terrestrial carbon residence times and storage strategies. Soils contain twice as much carbon as the atmosphere and efflux carbon at ten times the rate of fossil fuel emissions. CC&CM scientists are using ecosystem experiments and isotopic analysis to study the rates of C cycling and storage belowground. Results from this work are leading to changes in forest ecosystem models and estimates of the amount of carbon pumped belowground by root growth.

CC&CM has recently begun a new project exploring the impact of climate change on ecosystems: "An Annual Grassland Exploration of Scaling from Genomes to Ecosystem Function." This effort tests whether we can enhance our ability to predict ecosystem response to future environmental conditions by incorporating genomic, transcriptomic, and bioinformatics analysis with traditional biogeochemical and physiology approaches.

Carbon Capture and Storage

Carbon dioxide capture with storage in deep geological formations is one of the most promising options for mitigating CO_2 emissions over the next century. DOE began funding ESD research and development in 2000, to develop greater understanding of storage processes and security through the application of high-resolution monitoring tools to field-scale pilot and industrial scale projects.

CC&CM scientists are playing a leading role in WESTCARB (the West Coast Regional Sequestration Partnership). This is one of seven partnerships recently established by the DOE-Fossil Energy to evaluate CO_2 capture, transport, and sequestration technologies best suited for different regions of the country. A number of major tasks have already been completed within this partnership, including the identification of major CO_2 point sources and transportation options, an assessment of the ability for geologic sinks in the West Coast region to store CO_2, development of monitoring approaches and screening criteria for comparing storage sites, and identification of sites and industry partners for three pilot tests in California and Oregon to be conducted over the next four years.

Also, over the past year, CC&CM scientists have played a leading role in designing and monitoring the first U.S. pilot test of CO_2 storage in a deep saline formation on the Texas Gulf Coast. The test involved injecting 1,600 tons of CO_2 into highly permeable sandstone 1,540 m below the ground surface. A combination of seismic imaging, pressure monitoring and fluid sampling successfully tracked migration of the injected CO_2 and demonstrated that its movement was consistent with model predictions. As part of this work, CC&CM researchers developed a novel U-tube sampler for rapid sampling of formation fluids under in situ pressure conditions, to monitor CO_2 arrival at the observation well. They also demonstrated the use of crosswell seismic methods to image CO_2 in the subsurface.

In addition, CC&CM began participation in a new research program on geologic CO_2 storage, the Zero-Emission Research and Technology Program (ZERT) which aims to generate the fundamental understanding necessary for predicting long-term performance of geological storage and selecting secure storage sites. For ZERT, CC&CM is developing reliable techniques to predict CO_2 migration and trapping mechanisms, and demonstrating storage effectiveness, and quantifying migration out of the storage formation and release rates at the surface. A combination of laboratory, field, theoretical and simulation studies are being used to accomplish these goals.

Funding and Partnerships `

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