Simulation system provides integrated approach to crop and climate change models

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A UChicago-led project allows researchers to run more realistic environmental and agricultural simulations. Credit: Jeff Vanuga, USDA Natural Resources Conservation Service

Earth's fields and forests, oceans and aquifers, and animals of the land, sea and sky don't exist in a vacuum. But too often, environmental and agricultural models treat them as if they do. Truly understanding the role that climate and climate change plays on them calls for an integrated approach.

That's where the work of Joshua Elliott, research scientist and fellow at the University of Chicago Computation Institute, comes in. Whereas an individual crop model can only be run for one spatial point at a time, and for a limited number of scenarios, Elliott is leading an effort to make it possible to run each model "on hundreds of thousands of points for hundreds of simulated years and thousands of scenarios using coordinated inputs and processing methodologies."

The project that Elliott leads is an outgrowth of the Center for Robust Decision Making on Climate and Energy Policy, established by UChicago to bring together experts in all relevant fields to improve models, with the hope of giving policymakers the best computational models to understand climate change and the steps needed to mitigate it.

Elliott's project, the parallel System for Integrating Impact Models and Sectors, isn't so much one big model as "a framework for leveraging multiple existing models, big and highly variable data resources, and high-performance computing to solve problems at scales previously unthinkable," he said.

This was not a simple task. First, every model within pSIMS was developed separately, and none were developed in-house; some contained multiple models within themselves.

"Each of our crop models supports anywhere from five to 10 different crops as well as pasture grasses, biofuel crops and other things we've added into the framework," he explained. "Each is its own unique model which fits into a model crop framework. It's really a model of model of models."

Furthermore, the models sometimes used input and output formats that were slightly different from each other; getting them to work together meant that pSIMS needed to provide tools to automatically transform data, such as geospatial coordinates, for the next model to use. Finally, pSIMS had to be flexible enough to accommodate for working on multiple kinds of platforms, including supercomputers, clusters, grid computing and clouds.

The pSIMS project has made good use of the Research Computing Center's supercomputing cluster, Midway. "Before Midway came along, we were doing our simulations pieced together from different, much smaller clusters around the university, and inevitably…it would take a day just to get the data ported" from one machine to the next, Elliott said. "Just centralizing things on Midway has been plain useful for us."

RCC's ability to accommodate large, sprawling research groups came in handy, too.

"We have a massive number of people under our project account," he said. "RCC has been supportive of our unique big data and systems, and has been very patient with us as we try to wrangle our data usage down to something manageable. At one point, I think we had something like 20 million files on Midway."

Global applications

The open-source pSIMS code was released to the world last year. As of today, it supports a plantation forestry model, two families of crop models and models of various different kinds of pasture and hay grasses—and the researchers hope to add more in the near future.

But pSIMS has already been influential with policymakers, providing analysis for a United States/United Kingdom joint task force on the resilience of the global food system, a program that was sponsored by the UK Foreign Office. Elliott has used pSIMS and Midway to contribute to the Global Gridded Crop Model Intercomparison project, run by UChicago, Argonne National Laboratory, NASA and the Potsdam Institute for Climate Impacts Research. That project's report influenced the most recent assessment of the International Panel on Climate Change. Elliott is a principal investigator on GGCMI, and RCC hosts the data storage and computing needs for the project.

Meanwhile, the pSIMS team is trying to make the framework available through the Framework to Advance Climate, Economic and Impact Investigations with Information Technology, a cloud-based computing infrastructure that allows users from anywhere, particularly the developing world, to use the same computing resources that their peers in wealthy countries use.

"A researcher from Ghana could go online and run their own simulations for West Africa…without ever having to download the data or have their own computing resources," said Elliott. They also aim to increase the complexity of the simulations by a few orders of magnitude next year, port the programs to Argonne's Mira supercomputer, and scale pSIMS up to the exascale by 2023.

Given his involvement in climate and crop modeling, it's a bit surprising to learn that Elliott is not an agronomist or ecologist by profession, but rather a high-energy physicist. His training in fluid dynamics came in handy, he said, as did his experience with intensive computing. Still, whether it's cereal crops or theoretical physics, in the final analysis it's just another complex simulation bettering our understanding of the world we all share.

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