

COUPLING APPROACHES FOR NEXT GENERATION ARCHITECTURES (CANGA)

Computer models for simulating the Earth system combine component models of the atmosphere, ocean, land and ice to investigate how the system functions, how it has changed over time, and to project how it is likely to change in the future.

Coupling Approaches for Next-Generation Architectures (CANGA), a U.S. Department of Energy (DOE) project under the Scientific Discovery through Advanced Computing (SciDAC) program, is exploring a new technique for assembling these components within earth system models (also known as ESMs) to better utilize new high-performance computing architectures. CANGA is also developing new methods for transferring data between the atmosphere, ocean, land and ice models to improve the accuracy and reliability of the fully coupled system.

MANAGING COMPLEXITY AND PERFORMANCE

High-performance computing architectures are becoming more complex due to physical constraints on microprocessor performance. New computer systems now include a very large number of processing elements that combine different types of processors (e.g., graphical processing units, many-core chips, etc.). To utilize these systems effectively, the computational work for codes, such as earth system models, must be broken down into parallel units of work that can be spread across more and more processing elements.

Current earth system models break up the Earth into spatial subdomains and distribute these across computer processors so that the equations in each spatial region can be computed at the same time, or in parallel. However, as computers get larger, this technique is not providing enough parallelism and flexibility to utilize new architectures effectively.

At the same time, scientists are adding more processes, such as river biogeochemistry and cloud updrafts, and more components, such as dynamic ice sheets, to the coupled Earth system to better represent the many interacting elements. To manage this complexity and provide more parallelism to utilize advanced



The CANGA project is exploring a new technique to incorporate atmosphere, ocean, land and ice model components with earth system models to better use high-performance computing architectures.

architectures, CANGA is exploiting a technique known as task parallelism, in which a complex model, like an earth system models, is formulated as a collection of computational tasks that must exchange information.

New software developments will analyze how the tasks interact and optimally schedule the tasks for execution. Such an approach, or “task model,” will allow scientists to exploit additional parallelism, map tasks to appropriate hardware elements, and provide some resilience to hardware failure. In addition to these computational advantages, task models help manage scientific complexity. For example, adding a new capability like a nutrient cycle or a new cloud interaction—only when the science requires it—is a simple matter of adding or removing tasks from the task list. Each task or process may also be permitted to connect (or couple) at a much finer granularity when the science requires it. A taskbased model can better manage work that varies strongly in space and time, balancing work across the machine for cases like the expensive radiation calculations that occur only where the sun is shining, or including more frequent atmosphere-ice coupling if icemelting processes are active.

MODEL COMPONENT COMMUNICATION

Another critical feature of a complex coupled model is the transfer of data, such as wind stress or moisture, between components (or tasks) on different earth system meshes.

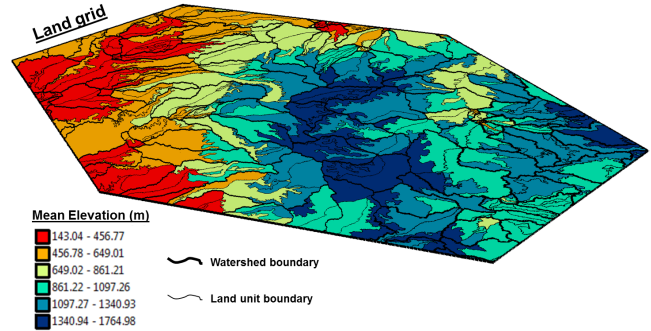
CANGA scientists are also developing new remapping and interpolation—the process of constructing new data points within the range of a discrete set of known data points—schemes that can preserve important properties of fields. For example, wind or ocean currents fields will be mapped to more general time-dependent meshes. Meshes based on watershed domains and changing coastlines as sea level changes will be developed and coupled.

SYSTEM EVOLUTION

A third consideration in a coupled system is how often to communicate data and how to combine those timescales to step the model forward in time to project future change. Typically, earth system models pick a time to transfer information between earth system components based on simple estimates or practical needs, without considering how often this is needed for optimal accuracy.



CANGA will improve the accuracy and efficiency of communication between components of an earth system model, by reformulating calculations as flexible tasks.



Next-generation earth system models will use advanced grids that match system processes rather than simple rectangular grids, such as the irregular watershed mesh for land model computations. However, these advanced grids will need better methods to couple or communicate with other parts of the system.

CANGA will provide a robust mathematical analysis of the stability and accuracy of the coupling timescale choice. CANGA will also be creating a mathematical framework for analyzing the full coupled system and generating new techniques for integrating the model forward in a manner that ensures a good and stable mathematical solution.

SPONSOR

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