Computing Climate Change: Just the Tip of the Iceberg

Scientific grid portal will host climate-change models, offer special public Web interface

Phillip M. Dickens, Ph.D.


Phillip Dickens leads a University of Maine Computer Science Department team that is developing Maine's first scientific grid portal.

Calculating the impact of environmental changes on the world is a complex assignment that must consider myriad variables spanning ocean, air and earth, and nearly everything that comes into contact with them. My team at the University of Maine's Computer Science Department is focusing on one small piece of the puzzle — climate change. While most scientists conceal research findings until their work is published, we see enormous potential in sharing findings, especially when it comes to climate change. Our team is developing Maine's first scientific grid portal that will execute climate-change models and provide high-resolution visualizations of output data in real time for use by researchers as well as students and educators in the state's public school system.

Research in a small power envelope

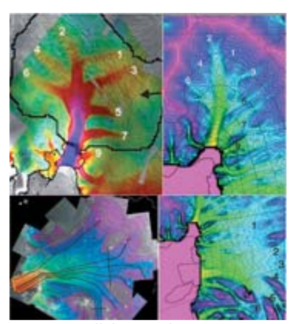
Distilling complex global warming research down for students' desktop computers requires a large, high-productivity computing (HPC) system that is powerful enough to create simulations of ice sheets, animations and other visual information in real time — all while making the research results easy to interpret, whether the 'student' is a Ph.D. or a fifth grader. More importantly, the scientific knowledge gleaned from large-scale climate models is directly related to the resolution of the models, and higher resolution models require more computing power. Thus, in designing the portal, we required an HPC system that could deliver enough compute power to satisfy complex problems, but that also would require little space and electricity from the university's limited resources.

Often, high-powered HPC systems require special housing equipped with advanced cooling systems because they tend to run hot. Unfortunately, even small computing clusters require more power than was available within the department's power envelope. In fact, installing additional air conditioners in the laboratory was banned due to the strain they would put on the existing electrical system. Moreover, constructing a separate data center to house the HPC system would have proven too costly.

HPC for climate change simulations

Complex climate change modeling requires an HPC system with many nodes, but with minimal switches to interconnect each node to minimize message-passing costs. This means that, if our team opted for a conventional HPC system, we faced a potential trade-off between computing power and a fast interconnection network due to capital and energy constraints.

Based on research during the acquisition process, as well as evaluation of the success of machines installed at Argonne National Laboratory, our team ultimately selected two HPC systems. The first is a 72-core desktop system that is used for code development. The other is equipped with four boards and features 27 nodes per board. Each node shares four gigabytes of memory between six cores, each of which operates at a speed of 733 MHz. The interconnection fabric is extremely fast with an approximate two microsecond message-passing delay between nodes. These systems were selected based on their performance in: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• HPC power and productivity: The two machines deliver ample HPC power and productivity using minimal space and electricity to run the complex simulations within the existing space of the lab. Between the two systems, we are able to achieve 720 core processors running at 733 MHz for a theoretical maximum of 979 gigaflops per second. Moreover, housing the computers in close proximity within the Computer Science Laboratory — as opposed to

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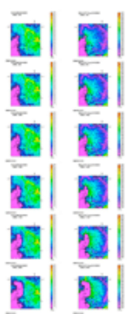
being located in a separate data center — helps to boost productivity, while delivering the needed computing power at the lowest purchase and operating costs.

• Ease of installation: The machines' compact design — with a self-contained, single cabinet and single plug system — was an important factor in fitting the high-productivity system within our existing, small physical footprint. In fact, recently, when I was asked how much preparation was required before installing the systems directly into the lab, my response was "I think we had to sweep the floor first." Energy efficiency: Energy consumption also was considered. Like many computer scientists, we are continually searching for new ways to reduce the amount of energy it takes to operate the systems. Traditional HPC systems require vast amounts of electricity to run, and often require an equal amount to keep cool, resulting in electricity bills that quickly outpace the initial cost of the computer itself. The selected machines achieve the highest level of energy efficiency available in an HPC system, and their power requirements are low enough that no updates were needed to the existing electrical system in our department's antiquated lab space.

UMISM calculates ice velocities, including predictions of where fast flow into ice streams should occur. The figure shows measured velocities (Lang et al., 20041 and Rignot et al., 20042) for the Pine Island Glacier (top left) and the Thwaites Glacier (bottom left), both of which are major ice streams flowing into the Amundsen Sea from West Antarctica. To the right are shown the model-derived velocities with various matching tributaries of the dendritic flow indicated by the numbered labels. The agreement between model predictions and measurements is high.

Accessing the grid

Climate change research requires a multidisciplinary approach, including physicists, computer scientists, network specialists and computational scientists. In using the new system, our computer science researchers are embracing the general trend of a grid model in HPC, where virtual organizations can cooperate even when they are geographically distributed. Research initiatives, such as this University of Maine project, enable collaboration throughout disciplines and locations. The grid portal will give users the opportunity to experiment with environmental parameters and to receive immediate feedback through real-time animations on the impact of these changes.



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ONE POSSIBLE retreat pattern of the West Antarctic Ice Sheet over the next 2000 years. Snapshots of ice thickness as colors with superimposed surface elevations as contour lines are shown at 100, 500, 1000, 1750 and 2000 years, with retreat starting at 100 years, driven by increased thinning at the grounding line, a result of warmer ocean temperatures in the Amundsen Sea.

Our team's vision is that students and powerful research groups alike will ultimately use the research and tools available through the grid portal, which can be accessed over the state's high performance optical network. We are trying to make some of our research available to the public, and are designing a special interface so it can be accessed by the public and students in K-12. Of course, the project not only addresses the needs of researchers and grade school students; it also presents enormous learning opportunities for the department's undergraduate students. Funded through a research grant provided by the National Science Foundation (NSF), the grid will give University of Maine students dual learning experience in research and supercomputing, as well as experience with team collaboration — classroom and real-world experiences that will prepare them for a wide spectrum of future careers.

Research collaboration

When it launches this fall, the grid will enable collaborating scientists to both use and access data, as evidenced by a planned partnership between our University of Maine research team and the Jackson Laboratory, a leading genetics research center that is immersed in highly intensive applications. Researchers at Jackson Laboratory will be able to upload data to University of Maine systems for processing, and the supercomputers will then compute the models and send back the visual renderings of the lab's data — a true collaboration in solving large problems and a first for the state of Maine. This technology makes it possible to solve problems that are too large to execute at either facility alone by distributing the task across both the University of Maine system and the Jackson Lab cluster so that they can execute the task concurrently.

Similarly, a future interface will enable climate change researchers to remotely input their own data in existing climate change models, such as the University of Maine Ice Sheet Model (UMISM), which was developed by physicist James Fastook to very quickly execute high-resolution models of a piece of the Antarctic ice sheet. The original version of the model, which looks at all variables that affect behavior and cause change in the ice sheet, was running on a Mac Pro. In order to obtain higher resolution, the model will be spread out over many processors on the new system. This parallelization will produce much finer resolution and allow real-time animation of the output of the model. With these interactive simulation capabilities, researchers will be able to create and make adjustments to steer the simulation as the model is running, providing immediate feedback on the effect of the changes.

Future expansion will allow more scientists to run their work on the portal, including the University of Maine's Climate Change Institute, an interdisciplinary research unit organized to conduct world-class research, graduate education and environmental outreach focused on the variability of Earth's climate system, as well as on the interaction between humans and the natural world. Ultimately, as more of the state's research facilities join the grid portal, it will have the computing power and expertise to solve problems of national and global significance.

Conclusion

Going forward, the team plans to work closely with other scientists to parallelize their code so they can take advantage of the opportunities the grid provides, as well as significantly increase the models made available through the portal. The project also will provide functions to other scientific modelers so they can utilize University of Maine code to work on the system through remote visualization and still interact and receive images as their model is executing. Other challenges, such as those presented by multiple simultaneous users running independent versions of the model at the same time, will be tackled as well.

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Phillip Dickens is an assistant professor of computer science at the University of Maine. He may be reached at editor@ScientificComputing.com.

Email for more Information.

Scientific Computing
Rockaway NJ 07866

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