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International Project Readies Climate Models For Exascale Era

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However well-meaning, the efforts of individual nations to curb climate change will always fall short. Given that climate does not respect national borders, global cooperation will be the key to any solution. While international political cooperation to deal with the issue has been frustratingly slow, at least one aspect of the problem is now getting some global focus: climate modeling.

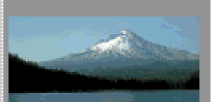
The first international effort to bring climate simulation software onto the next-generation exascale platforms got underway earlier this spring. The project, named Enabling Climate Simulation (ECS) at Extreme Scale, is being funded by the G8 Research Councils Initiative on Multilateral Research and brings together some of the heavy-weight organizations in climate research and computer science, not to mention some of the top supercomputers on the planet.

This project came out of the ongoing collaboration of University of Illinois at Urbana-Champaign (UIUC) and the French National Institute for Research in Computer Science and Control (INRIA) though their Joint Laboratory for Petascale Computing and takes advantage of the support of NCSA, which will provide access to the upcoming multi-petaflop Blue Waters system.

In a nutshell, the objective of the G8 ECS project is to investigate how to efficiently run climate simulations on future exascale systems and get correct results. It will focus on three main topics: (1) how to complete simulations with correct results despite frequent system failures; (2) how to exploit hierarchical computers with hardware accelerators close to their peak performance; and (3) how to run efficient simulations with 1 billion threads. This project also aims at educate new generations of climate and computer scientists about techniques for high performance computing at extreme scale.

The team is led by the UIUC's Marc Snir (project director), and INRIA's Franck Cappello (associate director). It gathers researchers from five of the G8 nations: the US (University of Illinois at Urbana Champaign, University of Tennessee and National Center for Atmospheric Research), France (INRIA), Germany (German Research School for Simulation Sciences), Japan (Tokyo Tech and University of Tsukuba), Canada (University of Victoria) and Spain (Barcelona Supercomputing Center).

HPCwire got the opportunity to ask project director Mark Snir and atmospheric scientist Don Wuebbles at UIUC and INRIA's Franck Cappello about the particulars of the G8 ECS effort and to provide some perspective on what it means to the climate research and computer science communities.



HPCwire: How do the current climate models that are being run on terascale and petascale systems fall short?

Don Wuebbles: There is a strong need to run global climate models with detailed treatments of atmospheric, land, ocean, and biospheric processes at very high resolution, with the newest generation of climate models that can be run on petascale computers being able to get to a horizontal resolution of as low as about 13 kilometers. Such a capability allows for many relevant processes to be treated without having to make the severe approximations and parameterizations found in the models used in previous climate assessments.

As an example, it is now known that ocean models need to be run at roughly a tenth of a degree or about 10 kilometers horizontal resolution in order to adequately represent ocean eddy processes. Even on a petascale machine, only a limited number of runs can be done with the new high resolution models. A exascale machine will allow for even high resolution as new dynamical cores are developed. Even more important though is that ensembles of the climate analyses extending over many hundreds of years can be run, thus allowing better representation of natural variability in the climate system.

In addition, exascale computing will allow for well-characterized studies of the uncertainties in modeling of the climate system that are impossible on current computer systems because of the extensive resources required.

HPCwire: Will ECS effort be able leverage any of the work done by the International Exacale Software Project (IESP)?

Marc Snir: Many partners of the project are active participants of IESP either as leader, members of the executive committee or experts of IESP. The research program has been defined taking into account the IESP results. IESP work was a instrumental in the clarification of the challenges and the definition of the research scope in the three main topic of our ECS project. Our project also carefully followed the discussions within the European Exascale Software Initiative (EESI) and Japan, where several G8 ECS partners are playing leading roles. IESP was instrumental in motivating the RFP that was issued jointly by seven of the G8 countries. However, one should remember that IESP established a roadmap. New collaborations are needed to implement it. The program that funds us and five other projects is a (very modest) first step in this direction.

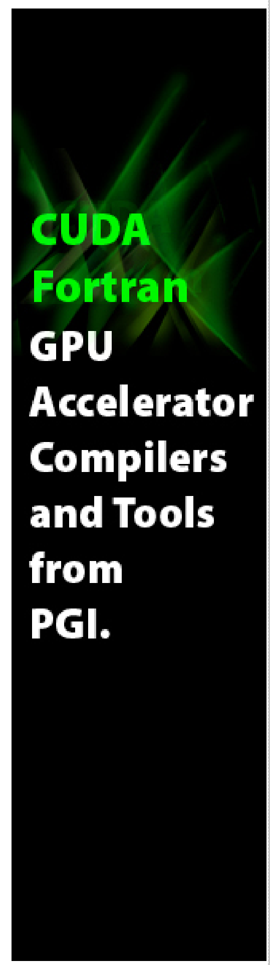
HPCwire: What kinds of assumptions will have to be made about the future exascale systems to redesign the software?

Franck Cappello: We tried to take reasonable assumptions according to the current state of the art, the projections made in the exascale preparation reports and discussions with hardware developers. These assumptions are essentially following the ones considered in IESP. Exascale systems are likely to have hybrid (SIMD plus sequential) cores, hundreds of cores per chip, many chips per nodes and deep memory hierarchies. Another important element is the uncertainty about the system MTBF predictions. This essentially will depends on the level of masking provided by the hardware.

A key choice in our project was to test our research idea on a significant variety of available HPC systems: Blue Waters, Blue Gene P and Q, Tsubame2, the K machine in Kobe and Marenostrum2. We believe that what we will learn by testing our improvements on these machines will help us to better prepare climate code for exascale.

HPCwire: What kinds of changes to today's climate simulations do you anticipate to bring this software into the exascale realm?

Cappello: Our project focuses on three key issues: system level scalability, node level performance and resilience. No existing climate model scales to the order of a million cores. Thus, studying system level scalability is a critical. The main research driver is to preserve locality, since strong locality will be crucial for performance. We shall explore three key areas: topology and computation-intensity-aware mappings of simulation processes to system, communication-computation overlap, and the use of asynchronous collective communications.



Concerning node level performance, we shall explore modeling and auto-tuning/scheduling of intra-node heterogeneity with massive numbers of cores, for example, GPUs; exploiting locality and latency hiding extensively to mitigate the performance impact of intra-node traffic; and studying task parallelism for the physics modules in the atmosphere model.

ECS will address resilience from multiple complementary approaches, including resilient climate simulation algorithms, new programming extensions for resilience, and new fault tolerant protocols for uncoordinated checkpointing and partial restart. These three approaches could be considered as three levels of failure management, each level being triggered when the previous one is not enough to recover the execution.

Our work is by no means a full solution to the problem of exascale climate simulations. New algorithms will be needed. There is another G8 project that looks at algorithm changes to enhance scalability.

New programming models may be needed to better support fine-grain communication and load balancing. Some of us are involved in other projects that focus on this problem. However, our work is, to a large extent, agnostic on these issues.

HPCwire: By the time the first exascale systems appear in 2018 to 2020, climate change will almost certainly be much further along than it is now. Assuming we're able move the software onto these exascale platforms and obtain a much more accurate representation of the climate system, what will policy makers be able to do with these results?

Snir: I suspect that all participants in our project believe that the time to act on global warming is now, not ten years from now. The unfortunate situation is that we seem incapable of radical action, for a variety of reasons. It is hard to have international action when any individual country will be better served by shirking its duties -- the prisoner's paradox -- and it is hard to act when the cost of action is immediate and the reward is far in the future.

As unfortunate as this is, we might have to think of mitigation, rather than remediation. More accurate simulations will decrease the existing uncertainty about the rate of global warming and its effects; and will be needed to assess the effect of unmitigated climate change, and the effect of various mitigation actions. Current simulations use 100 km grids. At that scale, California is represented by a few points, with no discrimination between Coast Range and Central Valley, or Coastal Range and Sacrament-San Joaquin Delta. Clearly, global warming will have very different effects on these different geographies. With better simulations, each House member will know how his or her district will be impacted.

HPCwire: How much funding is available for this work and over what time period? Is each country contributing?

Cappello: This three-year project receives G8 coordinated funding from the Natural Sciences and Engineering Research Council of Canada (NSERC), French National Research Agency (ANR), German Research Foundation (DFG), Japan Society for the Promotion of Science (JSPS) and the National Science Foundation (NSF). This project, together with five other projects, was funded as part of the G8 Research Councils Initiative on Multilateral Research, Interdisciplinary Program on Application Software towards Exascale Computing for Global Scale Issues.

This is the first initiative of its kind to foster broad international collaboration on the research needed to enable effective use of future exascale platforms. The total funding for this initiative is modest, about 10 million euros over 3 years, spread over 6 projects.

HPCwire: Is that enough money to meet the goals of the project? Do you anticipate follow-on funding?

Snir: The project has received enough money to fund the research phase and develop separated prototypes on the three main topics. Our focus is on understanding the limitations of current codes and developing a methodology for making future codes more performing and more resilient. The development of these future codes will require significantly higher funding. We expect to collaborate with other teams that are continuing to improve climate codes and seek future funding to continue our work as new codes are developed.

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