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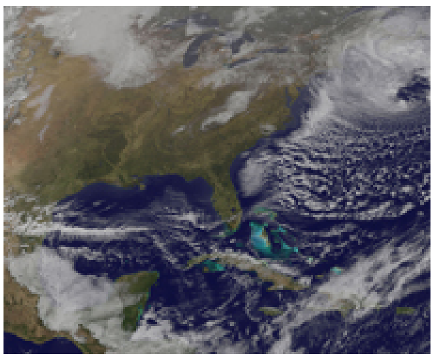
Supercomputing brings the climate picture into focus

September 1 2010, By Jared Sagoff



Current computer simulations of the Earth's climate capture only a fraction of the many intricate processes that shape our climate. (GOES satellite image, courtesy NASA/Goddard Space Flight Center/GOES.)

Recent advances in supercomputing have brightened the future of climate modeling, but they also bring to light complicated questions about the fundamental workings of our planet and our atmosphere.

Until very recently, atmospheric scientists could generate only a blurry picture of the interplay of the mechanisms that determine how the Earth's climate evolves. Even advanced computers capable of doing hundreds of trillions of calculations per second — like Intrepid, Argonne's IBM Blue Gene/P supercomputer — represented the complexity of nature in simplified ways.

“There are just so many different levels of interrelated physical, biological and chemical processes in nature that we’re only just now beginning to get a handle on exactly how they all interact at a level as broad as the planet’s climate,” said Rick Stevens, who leads Argonne’s work in computing, the environment and life sciences. “When you add in the anthropogenic mechanisms — the ways in which people are causing climate change — the challenge becomes even harder.”

The development of even more advanced “petascale” and “exascale” supercomputers, capable of doing quadrillions and eventually quintillions of calculations per second, has begun to change the game of climate science and modeling. The best verifiable climate models currently operate with data points that represent areas hundreds to thousands of square miles across.B In these models, an area the size of Lake Michigan would be represented by one or maybe two data points; that’s it.

Because new computers are capable of digesting and processing such vast quantities of data, scientists at Argonne and at other institutions around the world believe for the first time that they can generate models with resolutions down to possibly a single square kilometer, or about a third of a square mile.

“With most of the old models, you can’t see clouds, you can’t see the effects of cities and you can only handle a small range of terrain and vegetation types,” said Stevens. “The move to petascale and exascale computing presents us with both an opportunity and a challenge, which is finding a way to include the real nitty-gritty physics and biology that for a long time our technology had forced us to simplify.

“The potential of these computers to improve our understanding of climate and humanity’s role in shaping it is virtually unlimited,” Stevens added.

According to Stevens, the next generation of climate models will be able to more effectively integrate small-scale differences between soil types, vegetation profiles, cloud cover and even the environmental impacts of bacteria. The development of a new generation of models with greater accuracy and fewer assumptions depends on discovering the principles that regulate how these phenomena interact and feed into one another, he said.

“Argonne’s major strength comes from the fact that it employs researchers with expertise on every level from the gene to the entire atmosphere,” said Anthony Dvorak, director of Argonne’s Environmental Science Division. “If you really want to understand climate, you have to be able to connect all the dots.”

Stevens, Dvorak and other senior Argonne researchers have started a search for a world-renowned computational climate scientist to build and enhance Argonne’s climate program and reputation. Argonne has also teamed with the University of Chicago to explore the possibility of creating an institute that would house interdisciplinary teams that would work on important problems in climate and other areas of environmental research. The institute would host computer scientists, hydrophysicists, ecologists, environmental scientists, microbiologists, chemists and other experts who would collaboratively tackle these problems.

"We’re faced with a plethora of questions from a multitude of different disciplines,” Stevens said. “Are we getting the ecosystems right? Are we getting the soil chemistry right? Are we getting the reflectivity of the surface right? Each of these factors plays a role in determining the others, and we need to find ways to tie them all together.”

In addition to improving the spatial resolution of climate models, petascale and exascale supercomputers would also allow modelers to find ways to extend the runs of their simulations. Because studying changes in climatic patterns requires examining global trends over many years, model developers need to find ways of dealing with the accumulation of uncertainties, according to Stevens.

"The climate is in a perpetual state of disequilibrium for which both biological and physical processes are responsible," he said. "By uniting these processes through all the different levels in time and space, we can gain a much better understanding of how Earth's climate evolves."

Provided by Argonne National Laboratory

Citation: Supercomputing brings the climate picture into focus (2010, September 1) retrieved 28 April 2024 from https://phys.org/news/2010-09-supercomputing-climate-picture-focus.html