Center for Hybrid Multicore Productivity Research (CHMPR)

A CISE-funded Center

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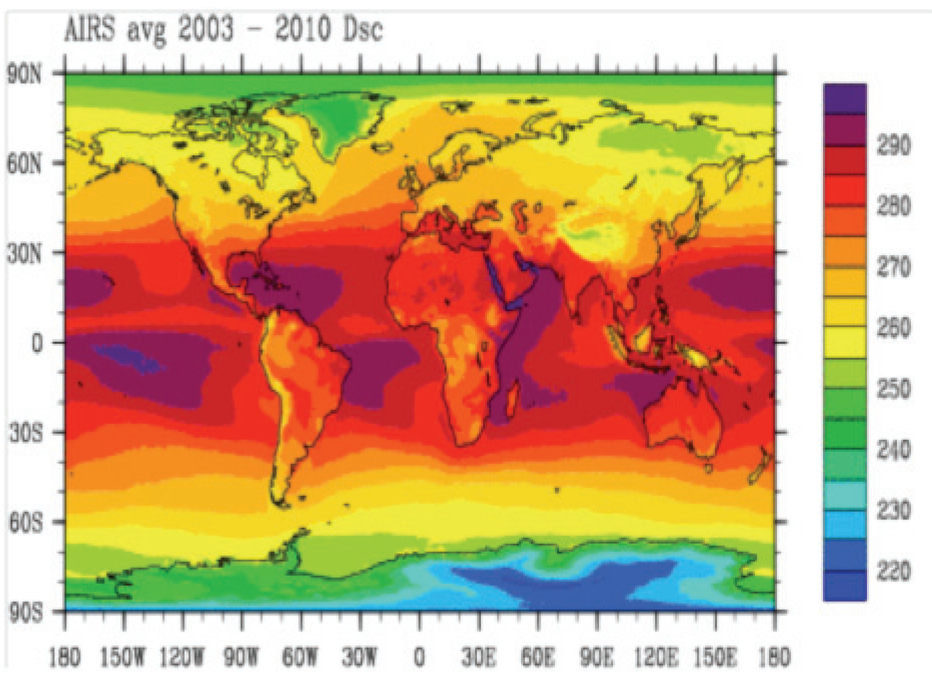
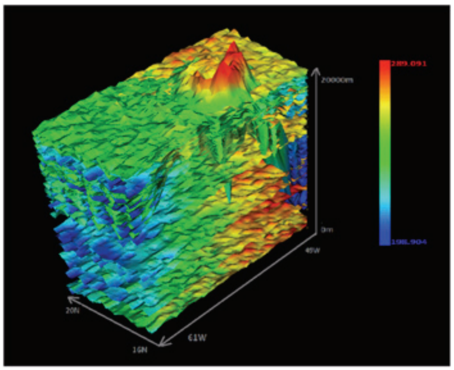
Distributed Cloud Computing: 3-D Visualization Services for Climate Data on Demand

This study is a collaboration between the Center for Hybrid Multicore Productivity Research (CHMPR) at UMBC and the "Center for Advanced Knowledge Enablement (CAKE)" on page 15 at FIU and FAU.



An example of the 8 year global average surface BT from 2003-2010.

Measuring the surface temperature of the entire Earth on a daily basis is a difficult challenge because 75% of the planet is covered with oceans and ice. Continuously determining, for several days to weeks, the vertical thermal field around a hurricane surrounded by dynamically rotating clouds is needed for more accurate landfall predictions. Thus, for applications ranging from climate change to hurricanes, satellites measure the Earth's emitted infrared radiation twice daily with sufficiently high spatial and spectral resolution to provide an estimate of vertical profiles of regional or global surface brightness temperature (BT). However, in order to assess global warming, these temperatures need to be measured to within an accuracy of 0.10 °C per year since models indicate CO_2 warming of ~20-30 over 100 years. Moreover, to resolve the structure around hurricanes, infrared data at resolutions of 1-5 km are needed. Not until 2002, when the Aqua satellite was launched, has there been a single satellite with instruments that can meet both the accuracy and the spatial resolution required.



Atmospheric temperature layers up to 20,000 meters (65,619 feet).

In this multi-center collaborative project, researchers from the Center for Hybrid Multicore Productivity Research (CHMPR) at UMBC and the Center for Advanced Knowledge Enablement (CAKE) at Florida International University (FIU) and Florida Atlantic University (FAU) have developed a capability to deliver a decade of 3-D gridded arrays of animated visualizations of spectral IR satellite radiance data from instruments on AQUA. These animations render in 3-D the vertical structure of a decade of global and regional temperature trends occurring at the surface and lower troposphere. In addition, the gridding algorithm developed by CHMPR has been applied to providing CAKE with 3-D temperature profiles that specify the thermal structure around hurricanes in order to improve their landfall prediction.

CHMPR and CAKE have implemented a distributed cloud computing web-based service, called SOAR, that incorporates this visualization capability as a public service available on an advanced IBM-based server cluster. This system provides researchers and students with the ability to select regional and temporal periods and automatically transform IR orbital satellite data into spherical grid arrays of 3-D temperature profiles for viewing the continuous changing thermal structure of the atmosphere. The FIU site at CAKE augmented the satellite data visualization by providing spatiotemporal visualization and animation of the data (http://cake.fiu.edu/SOAR). The FAU site at CAKE has developed tools for 3-D visualization of the vertical temperature profiles. When coupled with gridding CHMPR software, render for the past decade the first integrated scientifically validated multi-year infrared brightness temperature record.

Economic Impact: Fundamental Decadal Data Records are highly desired products recommended by the National Academy of Science/National Research Council. The SOAR distributed cloud computing web-based service enhances NASA's ACCESS program by providing fundamental brightness temperature records. This can go a long way towards improving scientific and public understanding of the nature of global and regional climate change. As a result, everyone can be better positioned to design any necessary policies and actions for mitigating negative impacts on the economy.

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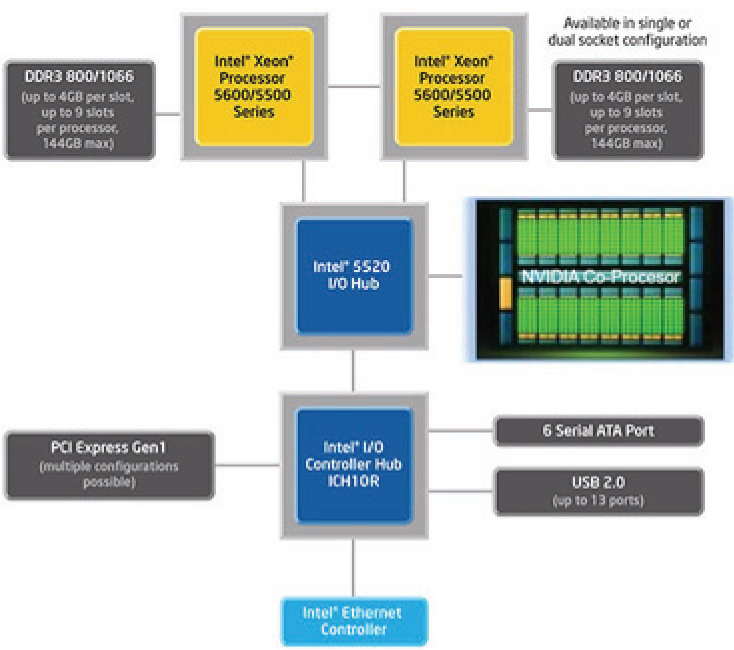
Specialized Graphic Processors

Until this year, supercomputers were based on tens of thousands of commodity processors like Intel and AMD multicore chips with 2 to 8 processors found in ordinary personal computers (PCs). These PCs contain specialized graphics cards that use hundreds of processors on their chips to render animations for games, simulations, and videos that are very fast and cheap. The graphics chips (GPUs) have evolved software and hardware that can not only do more than graphic renderings but can also perform complex floating point arithmetic.

Lockheed Martin, a CHMPR member, supported a project at UMBC to study and test the performance of these GPUs when added to commodity based clusters. The company wanted to know whether such GPUs can accelerate the performance of the solution of a system of equations with more than a million unknowns. Such problems lead to enormous matrices of 1 million by 1 million terms or more than 30 Terra-bytes (32X1012 or 32 million million) well beyond the capability of any computer to hold all these data internally in memory. Thus, this data intensive problem requires continuous moving of data from disks in and out of memory so that the processors can compute on them and then store them back on disks for future operations. It requires that all of the operations need to work in parallel. The method chosen for solving such equations is known as Gauss elimination and for implementation uses a transformation of the matrix into lower and upper triangular forms for direct and very fast solutions. These problems are commonly used in economics, chemistry, computer science, physics, and engineering.



As pointed out, the unique application here performs LU decomposition on a disk based out-of-core 64-bit precision, full complex valued, non-symmetric matrix. Even with high speed interconnects, disks and CPUs the solution time for 1 million unknowns exceeds 25 days on a single multicore commodity chip. As a test case for Lockheed Martin, this project used two systems to perform timing tests. One system was based on their Cray computing node with an AMD chip and an Nvidia GPU. The other system used the CHMPR computing node with an Intel chip and also an Nvida GPU processor. A key result obtained with the additional graphic co-processor (the Nvidia GPU) added to the system was a reduction in wall clock time for solving a problem of 40,000 unknowns from 5 hours of solid computing to 40 minutes. Further studies show that a potential exists for reducing this time to less than 2 minutes when more recent available GPUs are used combined with solid state disks.

Other of our government sponsors such as the NOAA/National Center for Environmental Prediction responsible for operational weather and climate forecasting and The NSA/Laboratory for Physical Sciences is supporting research into the resiliency of such hardware configurations when scaling to hundreds of millions of such processors.

> **Economic Impact:** Enormous cost benefits savings and new performance studies are possible for such critical problems when using the capabilities developed at CHMPR for capitalizing on the parallel nature of the architecture. This work made more feasible general accelerator technologies for solving large 64-bit complex valued matrices exceeding 1M unknowns. It is general enough that any type of accelerator with C or Fortran subroutine interfaces can be used to great effect by reducing design turn around times.

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