Paper Analysis on

Petascale WRF simulation of hurricane sandy: Deployment of NCSA's cray XE6 blue waters

CS 575 Parallel Programming

PangFa Chou

Oregon State University

1. GENERAL THEME AND INTRODUCTION

Hurricane Sandy made landfall on the northeast coast of the United States in October 2012. Despite the weather forecast and many communities taking appropriate evacuation measures and sheltering at the time, Hurricane Sandy caused considerable damage. There is clearly still room for an improvement in accuracy in predicting the exact time and location of landfall and expected wind and flood damage. Therefore, the authors use high resolution numerical weather simulations with hundreds of thousands of processors on the largest supercomputers, the Cray XE6 “Blue Waters” at NCSA at the University of Illinois, as this can incorporate increasingly precise parameters into current storm models to provide more accurate forecasts.

2. AUTHORS’ BACKGROUND

There are five authors in this paper, and they are Peter Johnson, Mark Straka, Melvyn Shapiro, Alan Norton, and Thomas Galarneau.

Melvyn Shapiro

Melvyn Shapiro is a researcher in NCSA(National Center for Atmospheric Research). The fields of study he is best known for are Meteorology, Tropical cyclone, Climatology. Climatology, Meteorology, Extratropical cyclones, Mesoscale meteorology and Cyclogenesis are his primary areas of study. He has researched Climatology in several fields, including Storm and Atmospheric sciences. As part of one scientific family, he deals mainly with the area of Atmospheric sciences, narrowing it down to issues related to the Ozone, and often Clear-air turbulence and Cloud condensation nuclei. His most cited work include: Turbulent Mixing within Tropopause Folds as a Mechanism for the Exchange of Chemical Constituents between the Stratosphere and Troposphere (372 citations) A Review of the Structure and Dynamics of Upper-Level Frontal Zones (291 citations) Fronts, Jet Streams and the Tropopause (272 citations).[1]

Alan Norton

Alan Norton is a researcher in NCSA(National Center for Atmospheric Research). He received the PhD degree in mathematics from Princeton University in 1976. He is currently a software engineer at the National Center for Atmospheric Research, where he is a software developer and architect for the VAPOR visualization platform. Previously, he has held research and development positions at IBM Research, Silicon Graphics, Inc., Colorado School of Mines, and the University of Utah, and has written research papers on mathematics, parallel processing, fractals, computer graphics, computer animation, and scientific visualization. He has 3 publications with a total of 25 citations.[2]

Thomas Galarneau

Thomas Galarneau is a Research Physical Scientist in the Forecast Research and Development Division at the NOAA/OAR National Severe Storms Laboratory in Norman, Oklahoma. He received a B.S. in atmospheric science in 2001, M.S. in basic classroom teaching (earth science) in 2003, M.S. in atmospheric science in 2007, and Ph.D. in atmospheric science in 2010, all from the University at Albany. Thomas has broad research interests in multi-scale dynamic meteorology with expertise ranging from planetary to storm scales, and with particular emphasis on phenomenological and process studies of severe convective storms, extreme rainstorms, tropical cyclones, and midlatitude bomb cyclones. His work uses a combination of observations and numerical models to advance understanding and update conceptual models with the overarching goal to contribute to improvements in the forecasting of these phenomena.[3]

Peter Johnsen

Peter Johnson graduated from Iowa State University with a bachelor degree in meteorology from 1974 to 1979. He then worked in SGI and Cray Inc. for 6 years and 16 years respectively as a scientific applications software engineer. He provided meteorology insight and technique support as a computing meteorologist in this research. He participated in 5 research papers with 26 citations and 339 reads.[4]

Mark Straka

Mark Straka graduated from University of Illinois in computer science major, and provided support for the information technology needs of the research as a senior research programmer, including but not only service network backbone devices to maintain security and high availability. He participated in 3 research papers with 17 citations and 21 reads.

3. EXPERIMENT IN THIS PAPER

In preliminary experiments, with this hurricane simulation, the researchers observed little or no load imbalance due to heavy rain and extensive cloud cover, although weather simulations typically exhibit some load imbalance. Additionally, since the Cray analysis library provides an interface to PAPI hardware, this is useful for estimating loads, imbalances, and identifying topology optimization challenges. Then in the jitter analysis, the researchers found up to a 50% increase in large-scale experiments (over 10,000 cores). So the researchers tried to mitigate this apparent jitter through some of the most common methods. One way is to deliberately idle core modules or use the -r1 option of the aprun command while still using all cores on the node. Method two is to ensure that a dedicated torus partition is running. A third approach is to try to adjust the injected bandwidth of the compute nodes through the network to accommodate certain communication patterns. In the end, they concluded that this was most likely due to the Lustre ping effect, but at present researchers have no solution for the Lustre ping effect.

Turning to the topological effects of communication, the researchers noticed a performance improvement of more than 1% between batch and dedicated runs. This suggests that sharing the torus link with other running jobs has little performance impact. Again, we spend a lot of time researching the "best fit" node placement. This basically involves reserving the entire machine via batch processing and then allowing full connectivity of the torus and all available compute nodes from which job machines to run on some subsection can be optimally selected. Unfortunately, while this optimal node mapping technique has proven very successful in other applications on Blue Waters, it improves WRF only slightly. However, domain configuration and process placement using the MPI rank ordering capabilities of the XE6 Job Scheduler (ALPS) is the cornerstone of efficiently using the XE6 3D torus interconnect and allowing WRF to successfully scale it. The researchers used the Cray grid_order perl script to generate improved ranking placements for the main communication modes in the WRF solver. Reducing the number of neighbors communicating off-node is the main goal. They found that the most efficient way to run WRF on AMD Bulldozer core modules is to use a MPI/OpenMP hybrid mode with 2 OpenMP threads per MPI level. This places 16 MPI levels on each XE6 node. By default, the XE6 job scheduler places MPI queues on machines in serial order, packing processes according to the defined system topology.

4. CONCLUSION(What conclusions did the paper draw from them?)

This paper describes the validation of a weather forecast model using the WRF code applied to real data from Hurricane Sandy at a resolution and scale unprecedented in numerical weather forecasting. Performance characterization of WRF code on NCSA's Cray XE6, Blue Waters revealed several opportunities for optimization at the source, runtime, and operating system layers. Most of these findings stand out only on the scale of the new Blue Waters machines and therefore represent the next generation of true benchmarks against which future architectures will be judged and sourced. These practices are documented for dissemination to the entire WRF supercomputing community. Using NCAR's Vapor software suite, model accuracy for predicting key output fields such as rainfall, pressure, wind speed, and storm track is graphically verified with actual atmospheric measurements of the storm.

5. INSIGHTS FROM THIS PAPER

First of all, I greatly appreciate scientific research that starts from people's daily life and well-being. I understand that just because most scientific research isn't directly relevant to people's lives doesn't mean they're not contributing to humanity, but I am deeply moved seeing people recovering from this damage and everyone putting in their own efforts together to avoid the next disaster.

Back to the paper, I first noticed that the methodology part is the most meticulous part in the whole paper. I think it is reasonable because these researchers were trying to optimize the current weather forecasting model, so they need to specifically describe how to improve it step by step. Also, I found that most of the computer science related research papers, including other articles that are listed in the final paper list, have this kind of unique paragraph structure. Maybe this is a hidden difference between computer science majors and other science fields. Beyond that, it actually only brings me a little inspiration from this research paper. I think there are two main reasons. The first and most important reason is that I am not a meteorology major. Without the background of it, it is difficult to understand the decision researchers make in the experiment, like the parameter assigned in the topology model. The other reason is that I am inexperienced in parallel programming in so many aspects. The simulation was run in the Cray XE6 “Blue Waters”. It is a supercomputer at the University of Illinois. Its architecture is obscure to me and I cannot figure out the deployment of the simulation just by imagining it. However, there is still something that I can relate with. For example, when researchers find out the best way to run WRF on AMD Bulldozer core modules is to use MPI/OpenMP hybrid mode, I can understand the logical configurations of the hybrid paradigm.

6. FUTURE WORK ON RESEARCH

If I were one of the researchers, I would think that we need to deal with the Lustre ping effect, which is what we found in our jitter analysis. After that, future work will focus on practical testing in real incoming hurricanes. Also, we need to contact the NCSA for the next hurricane forecast. In addition, if the experiment is successful, it is necessary to contact the local government about the situation of the hurricane making landfall to help them evacuate as soon as possible in the future.

7. REFERENCE

[1] M. A. Shapiro: H-Index & Awards - Academic Profile. Research.com. (n.d.). Retrieved June 6, 2022, from https://research.com/u/melvyn-a-shapiro

[2] IEEE Xplore. (n.d.). Retrieved June 6, 2022, from https://ieeexplore.ieee.org/author/38035435700

[3] T. Galarneau - Research meteorologist - linkedin.com. (n.d.). Retrieved June 6, 2022, from https://www.linkedin.com/in/thomas-galarneau-02a42b40

[4] P. Johnsen. - linkedin.com. (n.d.). Retrieved June 6, 2022, from https://www.linkedin.com/