ACRC Case Study:
Modelling Volcanic Ash Hazard on Blue Crystal

Michael Boulton, Susanna Jenkins & Simon McIntosh-Smith

Overview

The eruption of the Eyjafjallajökull volcano in Iceland in May 2010 disrupted European airspace for over a month. Ash from an erupting volcano can have far reaching affects. Close to the source, people will be at risk to respiratory health hazards and critical infrastructure can be damaged. Further afield the ash cloud is very hazardous to aircraft—around 20 countries closed their airspace to commercial jet traffic. Areas thousands of kilometres from the source were affected.

Volcanic ash being erupted from Eyjafjallajökull volcano in Iceland in 2010. Image: Susanna Jenkins

Forecasting where and how much ash will fall from a volcanic eruption is complicated because the amount of ash that will be erupted, and the wind conditions that the ash will be erupted into, are unknown before the eruption starts. Probabilistic (Monte Carlo) simulation techniques must be used. These simulations are computationally intensive however, and this computational expense has limited our global understanding of the volcanic ash hazard.

Aims

Susanna Jenkins in Earth Sciences at the University of Bristol had previously developed a C++ model that ran in parallel on a 24 CPU cluster to consider the dispersion of ash from 190 volcanoes in the Asia-Pacific region. The model simulated 1,000 eruptions per volcano into varying wind conditions and accumulated the outputs of volcanic ash thickness at ground level. Additional analysis modules were then run which interrogated the data to calculate return periods for over 1 billion km^2 of land. Each simulation took approximately 2-3 minutes to run, with the analysis modules taking around an extra minute per simulation. Thus with the original 24 CPU cluster, this model took around 2 to 3 weeks to produce usable outputs.

Since development of this model, the United Nations Development Program has asked the University of Bristol volcanology research group, through the Global Volcano Model initiative (globalvolcanomodel.org), to contribute information about volcanic hazard and risk to their Global Assessment Report for 2015 (UNDP GAR-15). This is the first time that volcanoes will be considered within this important and influential report.

The project with Simon McIntosh-Smith and Michael Boulton from the HPC group within the Department of Computer Science included porting and fully optimising the code to run on Blue

Crystal Phase 3, the university's latest supercomputer. The port included writing an OpenCL version that can run on the latest high-speed processors from Intel and NVIDIA.

Technical Highlights

- OpenCL code can run (simultaneously) on a wide variety of host x86 CPUs and GPGPU processors, making the software highly portable.
- Commodity GPGPUs are composed of many, simple processors operating in parallel. As a consequence, they are computationally powerful while also being both energy and cost efficient.

Challenges

A critical component of the Bristol submission to UNDP GAR-15 will be to map ash hazard across the globe from 750 volcanoes, following the model and methods developed previously for the Asia-Pacific region. To do this using the original cluster would have taken 2 to 3 months, assuming sole use and full reliability of the cluster.

Outcomes

Following the optimisation, ash cloud modelling that would have previously taken 3 weeks on the original 24 CPU cluster can now be achieved in under 1 day on just one GPU: **a 600-fold improvement in runtime**. "This phenomenal optimisation allows us to not only expand the modelling globally for the UNDP report, but to also produce more than 1000 simulations at each volcano and therefore better quantify the uncertainty associated with modelling volcanic and meteorological processes."

Another key benefit of the work undertaken by the HPC group is the conversion of the code from outputting on a uniform UTM (Universal Transverse Mercator) grid, where additional analysis was required to make results across neighbouring grids compatible, to a uniform latitude longitude grid. This allows the results to be easily mapped by end-users and allows direct comparison with grids such as population density to estimate potential risk and impact of volcanic ash.

Future Work

"This project has been so beneficial to our work that we are now looking to work with the HPC group to develop a more sophisticated probabilistic model that may be able to assess the potential threat of volcanic ash to aviation at a global scale, accounting for varying wind conditions over time, space and altitude."

Contact: Dr Gethin Williams
School of Geographical Sciences,
University Road, Bristol. BS8 1SS.
(0117) 928 8301
Gethin.Williams@bristol.ac.uk

Susanna Jenkins: "This level of scientific discovery has only been possible because of the access we have in Bristol to skilled HPC experts and world-leading HPC computer resources."

Simon McIntosh-Smith: "This project is an excellent example of the benefits of domain scientists and computer scientists working together in high performance computing."