CASE STUDY

COSMO Dynamics and Physics Modules Are Accelerated as a Part of HP2C Initiative Using OpenACC

Overview

COSMO is an atmospheric model used for daily weather forecasting by the German national weather service (Deutscher Wetterdienst), MeteoSwiss, and other institutions. The COSMO model is developed and maintained by the Consortium for Small-scale Modeling (a.k.a. COSMO), a group of seven national weather services. Scientists at more than seventy universities and research institutes use COSMO for climate research.

Challenge(s)

Over the past three years, developers from the Center for Climate Systems Modeling at ETH Zurich and MeteoSwiss have been analyzing and revising the COSMO model, as part of the Swiss High Performance and High Productivity computing (HP2C) initiative. The goals of the project were to increase the accuracy of regional weather and climate simulations and to adapt the COSMO model to run on energy-efficient accelerators.

Solution

The port to accelerators used two fundamentally different approaches. Performance analysis of the CPU-only version of COSMO showed that the dynamical core accounted for ~60% of the runtime, while physical parameterizations took another ~25% of the runtime. To maximize the performance of the dynamical core, the HP2C researchers completely rewrote its complex finite difference operators, using a newly created library written in C^{++}, with x86 CPU and CUDA GPU back-ends.

Rewriting the physical parameterizations was not an option: COSMO shares these modules with other weather and climate models. To maintain a single Fortran source tree, enable an incremental approach to development, and maintain portability across several target architectures, the team used OpenACC compiler directives.

Using OpenACC, developers insert directives into their source code that help an OpenACC-enabled compiler know which parts of the code can be run in parallel. OpenACC directives look like comments to ordinary compilers. Using OpenACC, the HP2C developers were able to leave most loop structures unchanged, while adding directives to accelerate computationally intense kernels for the microphysics, radiation, turbulence, convection, soil vegetation atmosphere transfer, and sub-grid scale orographic drag schemes. They used profiling information to optimize code, reducing data transfers and replacing intermediate arrays with scalars. They restructured some loops to reduce kernel call overhead and increase cache reuse.

Results

Using OpenACC, the HP2C team was able to accelerate the microphysics kernel by 7.0x, radiation by 3.8x, and turbulence by 4.0x. The three kernels make up more than 90% of the total runtime of the physical parametrizations. Less than 5% of the 60,000 lines of code were modified.

Xavier Lapillonne, a member of the HP2C team, said "OpenACC makes GPU porting accessible to domain scientists. Using OpenACC directives, we were able to successfully port a large part of COSMO."

Lessons Learned and Next Steps

Encouraged, the COSMO consortium decided to integrate the accelerated dynamics and physics modules into the official version of COSMO. This means that after integration and testing, an accelerated version of COSMO will be distributed to all users of the model.

Oliver Fuhrer, a senior scientist with MeteoSwiss, said "this decision is a huge success for the HP2C project," and noted that the project illustrated three important points:

> *Firstly, it is feasible to target GPU-based hardware while retaining a single source code for almost all the COSMO code. Secondly, using GPU hardware is very attractive for accelerating simulation time and reducing the electric power required to run the computer executing the simulation. Thirdly, it is possible for domain scientists to develop and work with this new version of the COSMO model.*

To learn more about COSMO, go to:

- Towards operational implementation of COSMO on accelerators at MeteoSwiss, https://www2.cisl.ucar.edu/sites/default/files/20130911_fuo_cas2k13.pdf
- Porting COSMO to Hybrid Architectures, http://data1.gfdl.noaa.gov/multi-core/2012/presentations/Session_2_Messmer.pdf
- Physical parametrizations and OpenACC directives in COSMO, http://www.c2sm.ethz.ch/research/High_Performance_Computing/FinalHP2CMeeting/FinalHP2CMeeting/6Lapillonne
- Scientists Prepare Weather Model for GPU-based Systems, http://www.hpcwire.com/hpcwire/2013-10-25/scientists_prepare_weather_model_for_gpu-based_systems.html
- COSMO goes hybrid: Interview with Oliver Fuhrer of MeteoSwiss, http://www.hpc-ch.org/cosmo-goes-hybrid-interview-with-oliver-fuhrer-of-meteoswiss/

To learn more about OpenACC, go to www.openacc.org.