

# Improving Performance of the BGS Geomagnetic Field Modelling Code

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ESA Swarm satellites

## WHAT IS THE BGS GEOMAGNETIC FIELD MODELLING CODE?

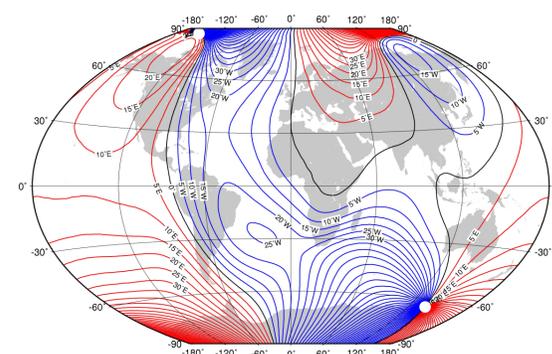
The BGS Geomagnetic Field Modelling code is used to develop mathematical models of the Earth's magnetic field for scientific, government, and industry stakeholders. The models are constructed from data collected from geomagnetic observatories around the globe and satellites in orbit (such as the ESA Swarm project shown on the left). Example models are the International Geomagnetic Reference Field (IGRF), the World Magnetic Model (WMM), and the BGS Global Geomagnetic Model (BGM). These models are derived from parent models output by the BGS code which generally have millions of input data to estimate thousands of coefficients that describe the Earth's magnetic field. The scale of the task requires efficient parallelised algorithms in order to calculate these values in a reasonable amount of time and with consistent results.

## EXAMPLES OF MODELS PRODUCED BY THE CODE

**IGRF** a standard mathematical description of the Earth's main magnetic field that is used widely in studies of the Earth's deep interior, its crust and its ionosphere and magnetosphere.

**WMM** aims to provide a reliable estimate of the magnetic field's strength and direction on or near the Earth's surface. It is used by many corporate and governmental organisations as their standard model for navigation and in attitude and heading referencing systems. Many electronic devices, such as smartphones, incorporate the model to improve compass-based navigation.

**BGM** widely used in the oil industry for directional drilling with Measurement-While-Drilling (MWD) magnetic survey tools. These tools measure the direction of the well-bore relative to the direction of the local geomagnetic field and are used to navigate wells towards precisely known underground targets. An example of the model is shown on the right, which shows the angle between *True North* (towards the geographic North Pole) and horizontal direction of the Earth's magnetic field.



Declination map of the globe

## THE CHALLENGE

The BGS modelling code is run on part of a  $28 \times 16$ -core node, InfiniBand<sup>®</sup>-connected cluster. It is an MPI-based hand-parallelised code. While most of the application code scales well, the code contains a bottleneck which is executed on a single node. This bottleneck inverts a matrix of roughly  $7000 \times 7000$  elements by iteratively computing its eigenvectors.

*The goal is to leverage compiler technology from Heriot-Watt University to enable scaling of this bottleneck code.*



www.sac-home.org

SAC is freely available from  
<http://www.sac-home.org/>.

## OUR SOLUTION

We use the SAC programming language and compiler ecosystem to rewrite the bottleneck code, and subsequently auto-parallelise it. We re-implement 200 lines of Fortran code in SAC. While most of that code can be rewritten in a straight-forward manner, 30 lines of the code were actually re-factored. This re-factoring addressed two aspects: Firstly, the SAC code, in contrast to the original Fortran code, reflects the two-dimensional nature of the algorithm more directly. Secondly, this two-dimensional formulation reveals the data-parallelism present in the algorithm (the data can be segmented into separate computable chunks). This enables our compiler to utilise all the cores on the executing node.

## RESULTS

We run the modified code on the original data using a single 16-core node of the cluster containing two Intel<sup>®</sup> Xeon<sup>®</sup> CPUs E52650 2.6GHz with 128 GB RAM. For the Fortran runtimes of the original code we use the PGI compiler `pgfortran 14.7-0`. For the SAC runtimes we use the SAC compiler `sac2c v.1.0 rev 18494` as frontend and `gcc 4.8.2` as backend compiler.

