

Crustal magnetic field modelling to spherical harmonic degree 2000

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Background

The World Magnetic Anomaly Model (WMAM) code calculates a spherical harmonic model of the natural magnetisation of the Earth's crust, using data from the World Digital Magnetic Anomaly Map (WDMAM)¹. Such models allow us to estimate the value of the full magnetic field vector at any location, based on scattered measurements of only the scalar magnetic field strength. Modelled values of the magnetic field serve many important purposes, such as geological research, navigation, and safe resource extraction.

Models of degree 1440 (~28 km resolution) have been computed on the British Geological Survey HPC facility, but these require 256 cores for up to six days.

Aim

Models were limited by memory and compute capacity, not by the potential of the dataset. The problem size scales by $O(n^2)$, so a desired degree-2000 model requires 4M parameters, compared to the existing degree-1440 model with 2.3M.

- Enable a degree 2000 (20km) model
- Improve parallel scaling
- Easier to update when new input data are available

Code development

Profiling was performed to highlight key areas for code improvement. A collaboration between BGS and Edinburgh Parallel Computing Centre (EPCC) resulted in a substantial enhancement in parallel performance.

The revamped code on the ARCHER2 supercomputer was able to produce a degree-1440 model in 49 minutes, with parallel efficiency over 80% on 16k cores. On the BGS HPC a speedup factor of around three to five was achieved.

Degree	Tasks	Runtime [s]	Speedup
200	64	147	3.99
300	64	894	4.82
720	256	7989	4.13
1440	256	177347	2.88

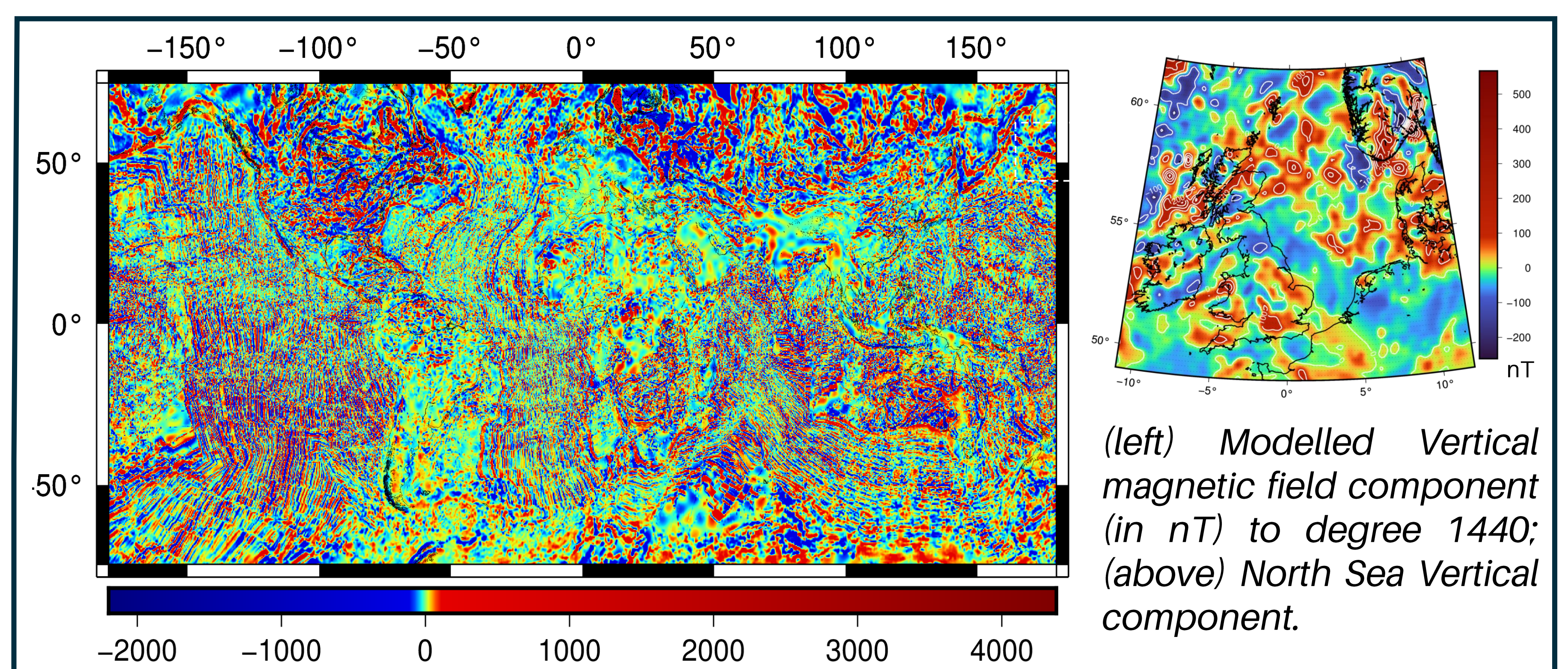
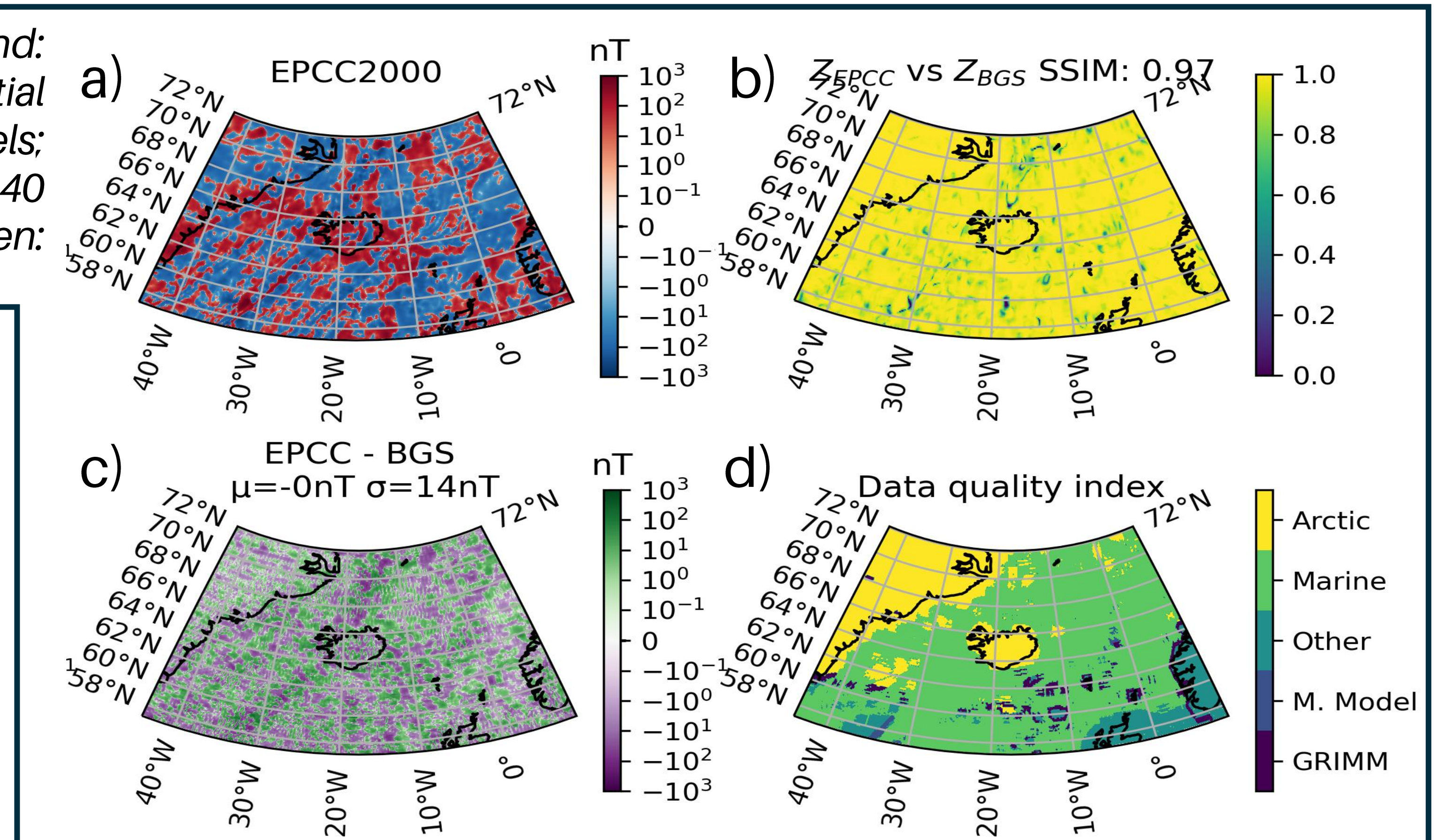
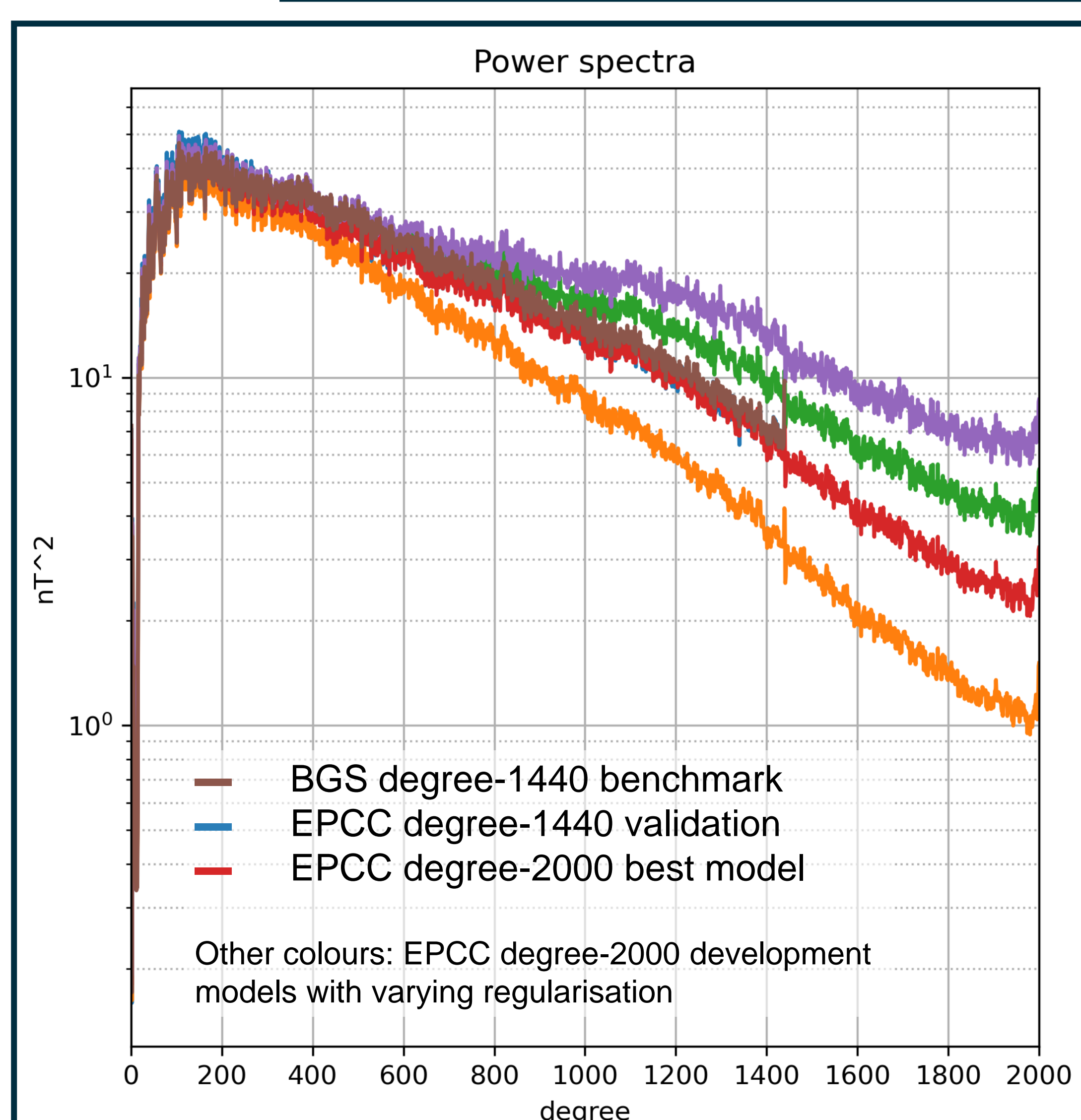
Speedup of revised code vs original, when run on BGS HPC.

New data

The first update to the WDMAM dataset in eight years (Version 2.1)¹ was released in 2023 with improved detail in many parts of the world. This has also resulted in improvements to WMAM, and a further correction to the dataset is expected soon, which is likely to improve our model in Antarctica.

Results

Validating the new degree-2000 model around Iceland: a) modelled vertical magnetic field to degree 2000; b) spatial correlation between degree-2000 and degree-1440 models; c) difference between degree-2000 and degree-1440 models; d) distribution of data types in region (yellow/green: high-res., blue: low-res.).



¹Choi, Y., Dymant, J., Lesur, V., Garcia Reyes, Catalan, M., Ishihara, T., Litvinova, T., Hamoudi, M., the WDMAM Task Force, and the WDMAM Data Providers, World Digital Magnetic Anomaly Map version 2.1, available at <http://www.wdmam.org>