eCSE04-08: Enabling a better global view of the magnetic field of Earth's rocks

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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. 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 the full compute capacity (512 cores) for up to six days.

The code is written in Fortran, loosely f90, and uses MPI for communication.

Aim

Models were limited by memory and compute capacity, not by the potential of the dataset. The problem size scales by n(n+2), so a desired 20km resolution model requires 4M parameters, compared to the existing 28km resolution model with 2M.

- Enable a degree 2000 (20km) model
- Improve parallel scaling

eCSE code development

Profiling was performed to highlight key areas for code development:

- Replacement of hardcoding with dynamic sizing of arrays
- Parallel IO from files converted to binary
- Workload partitioning to balance load across tasks
- Optimized MPI collective calls
- Pre-calculation steps
- Vectorisation of loops
- Eliminate large unnecessary arrays

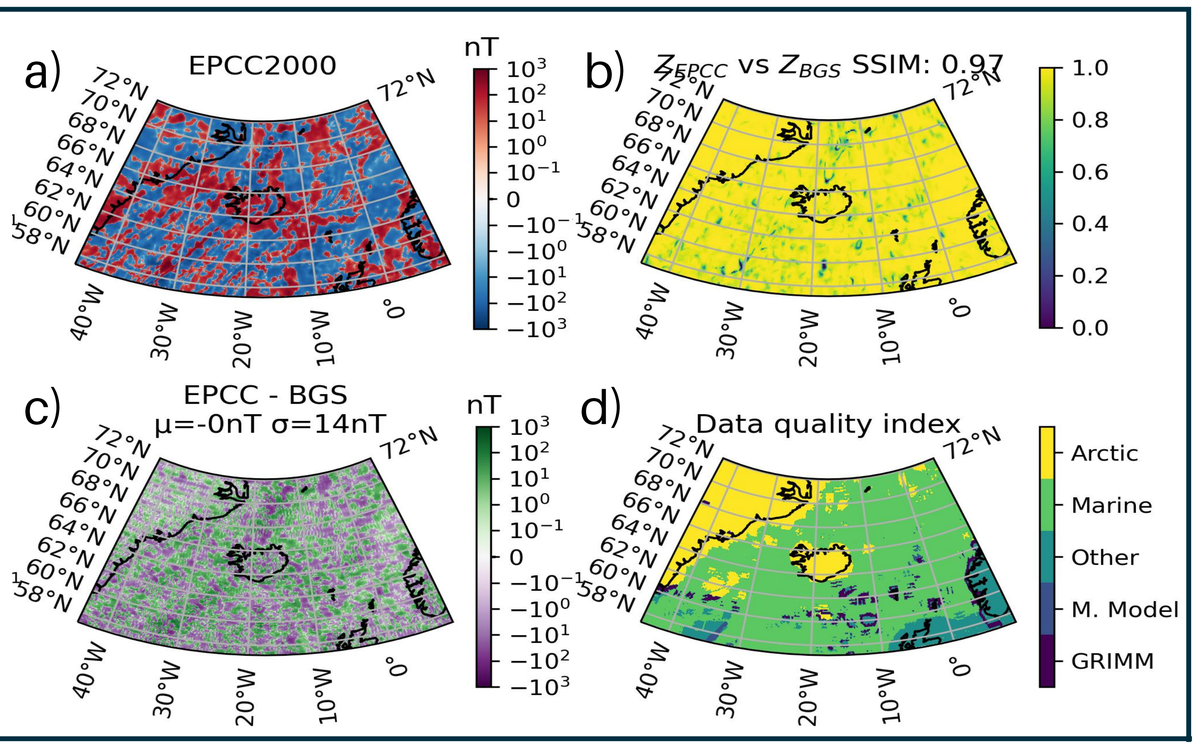
The revamped code on ARCHER2 was able to produce a 28km model in 49 minutes, down from 6 days, with parallel efficiency over 80% on 16k cores.

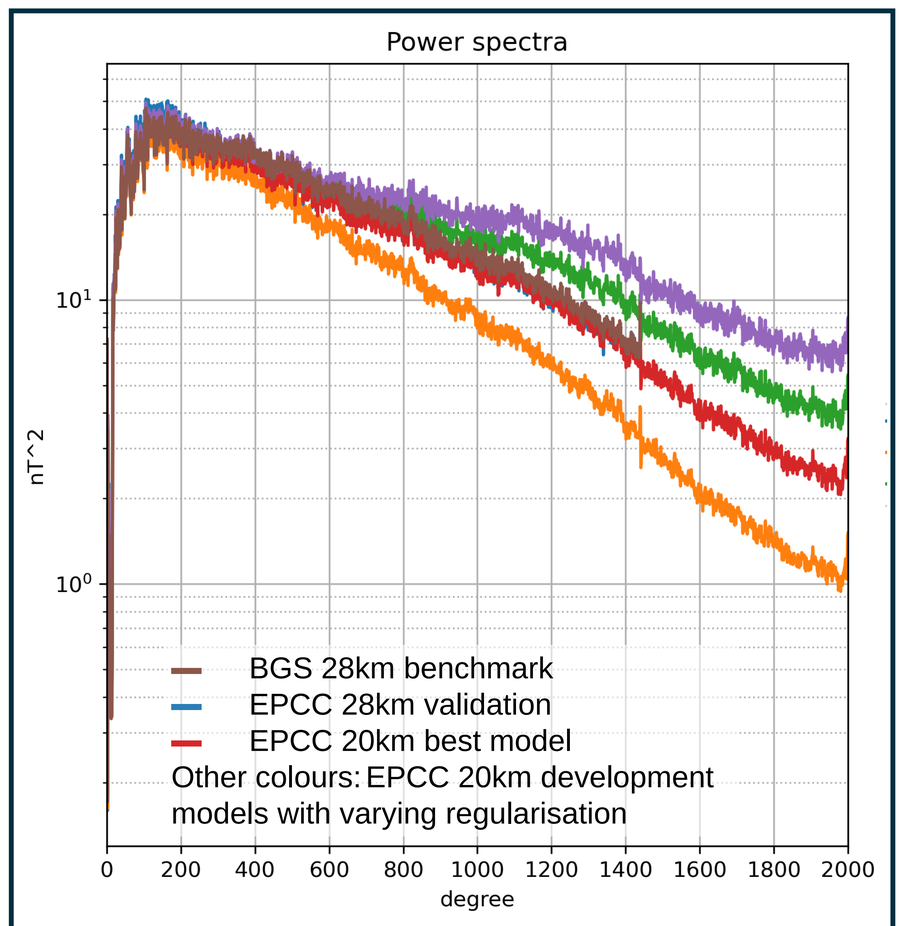
Degree	Tasks	Runtime [s]	Speedup BGS	Speedup ARCHER2
200	64	70	8.37	2.63
300	64	426	10.12	3.53
720	256	3,989	8.27	5.71
1440	1024	19,332	6.6	5.58

Speedup of revised code vs original, when run on BGS and ARCHER2 HPCs.

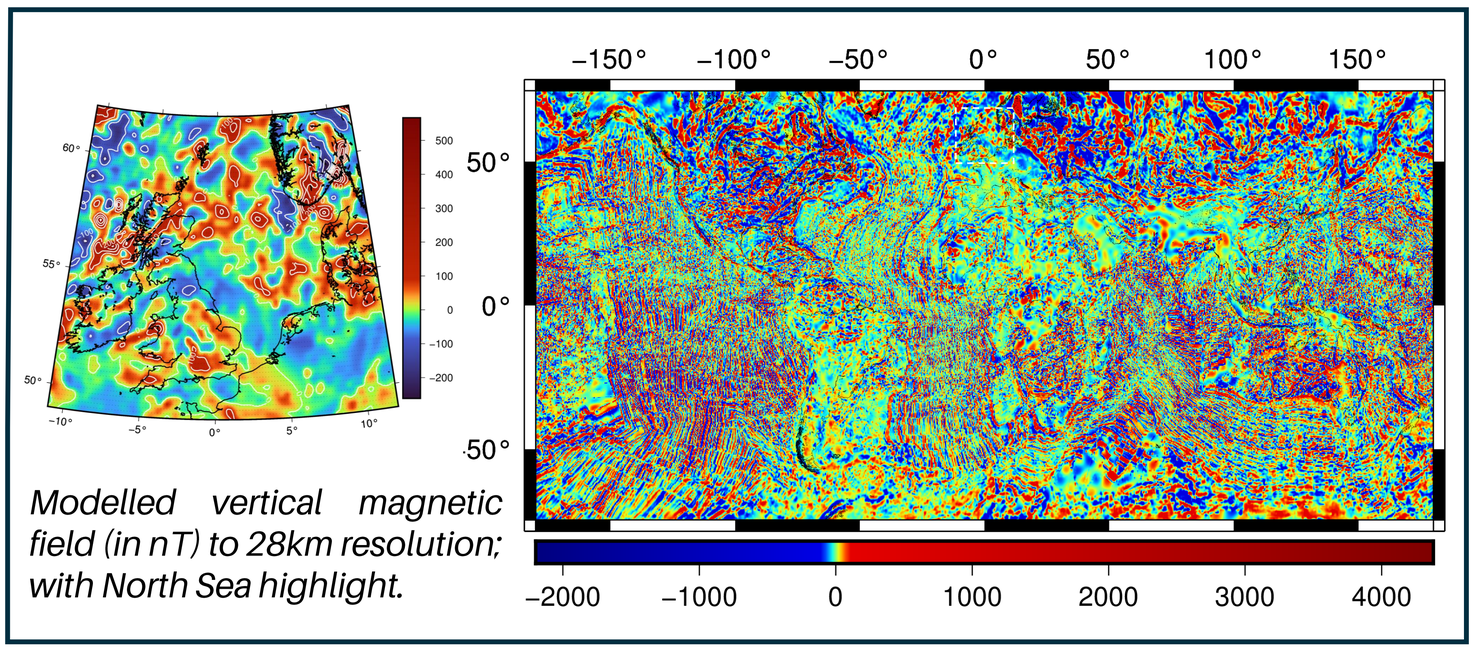
Results

Validating the new 20km model around Iceland: a) modelled vertical magnetic field at 20km resolution; b) spatial correlation between 20km and 28km models; c) difference between 20km and 28km models; d) distribution of data types in region (yellow/green: high-res., blue: low-res.).





Power spectra validate that the EPCC revised code can reproduce the BGS 28km benchmark model, and makes possible the practical calculation and evaluation of a 20km model for the first time.



Modelled vertical magnetic field (in nT) to 28km resolution; with North Sea highlight.

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