



A model of Earth's lithospheric magnetic field to 20 km resolution (spherical harmonic degree 2000)

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Speaker Bio

- Geomagnetic scientist at British Geological Survey, Edinburgh (2023 – present)
- Main focus is on global magnetic field modelling and related research
- Work with partners including industry, government, universities and space agencies
- PhD in Applied Mathematics / Theoretical Geophysics, University of Cambridge (2018 – 2022) – focus on mantle convection and magnetic field generation in the early history of the Moon.

What is lithospheric magnetism?

- Earth's crust and uppermost mantle have some magnetic rocks
- At the scales mentioned in this talk, it contributes about 0.2% of magnetic field strength on average at the surface, but can be 20% in places
- We're sitting right on top of it, so can see fine detail: from continents down to grains in rock
- Changes on geological timescales

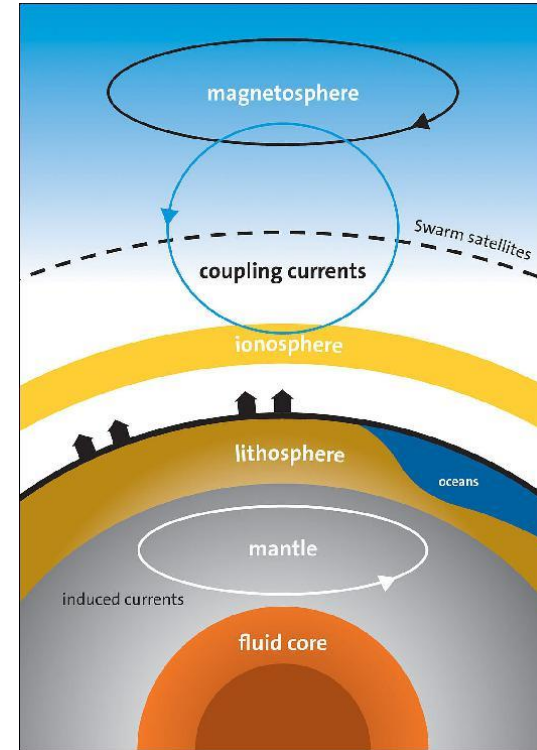
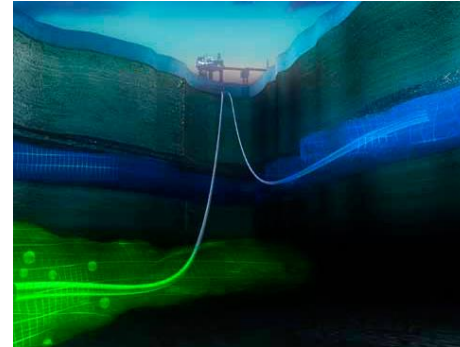


Figure adapted from Olsen, N. and Stolle, C. (2012)
Annu. Rev. Earth Planet Sci. 40:441-65

Why is lithospheric magnetism interesting?

- Can affect the local direction of magnetic north by several degrees
- Improves our understanding of geology
- Improves our understanding of the wider geomagnetic field



An artistic rendering of directional drilling

(© Alligator film / BUG / Statoil)

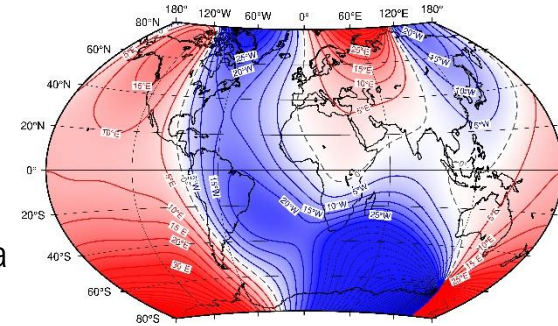


Gneiss containing magnetite (an iron ore)

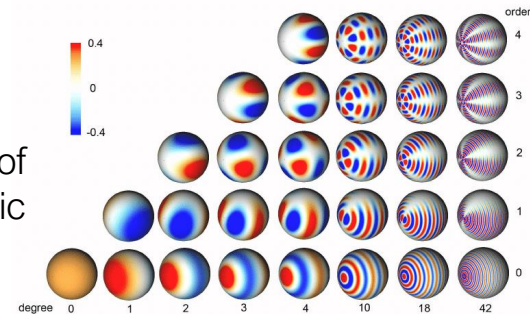
Background in magnetic field modelling

- Magnetic field models are made up of spherical harmonic basis functions
- The maximum degree N of a model is approximately the number of wavelengths in the circumference of the Earth
- Problem is big: a degree-N model requires over N^2 coefficients

Right:
International
Geomagnetic
Reference Field: a
degree-13 model

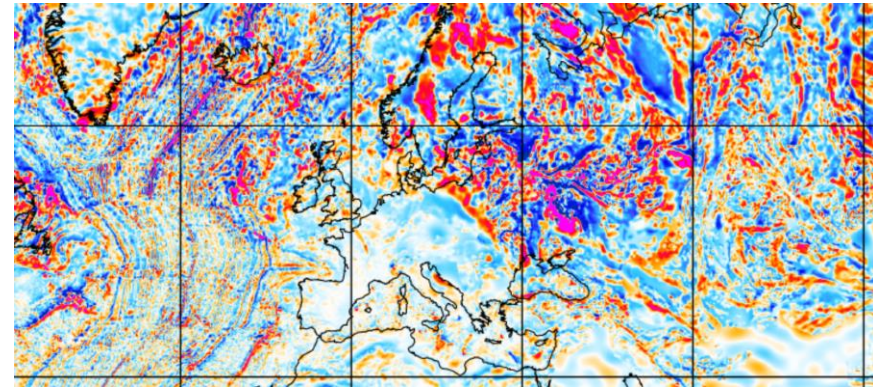


Right: Illustration of
spherical harmonic
basis functions



Our starting point: WDMAM (World Digital Magnetic Anomaly Map)

- An international task force put in a large diplomatic and scientific effort to stitch together survey data into a global map
- 0.05-degree (about 5.6 km) grid – nearly 26 million data points
- Reduced to 5 km altitude over land, and sea level at sea
- Updated version released in March 2025

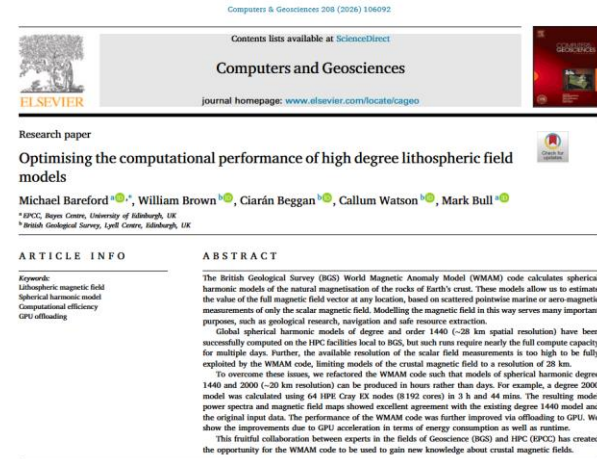


Map of WDMAM v2.2 from wdmam.org

Choi, Y., Dyment, J., Lesur, V., Garcia Reyes, Catalan, M., Ishihara, T., Litvinova, T., Hamoudi, M., the WDMAM Task Force, and the WDMAM Data Providers (2025)

Modelling inversion improvements

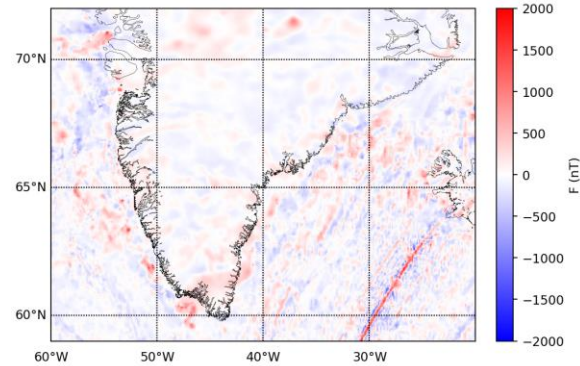
- Greatly improved performance in our modelling code was the subject of a recent paper
- Together with hardware updates, this means we can now calculate around *100 times* faster than before
- More detailed models, previously impractical to work with, can now be calculated



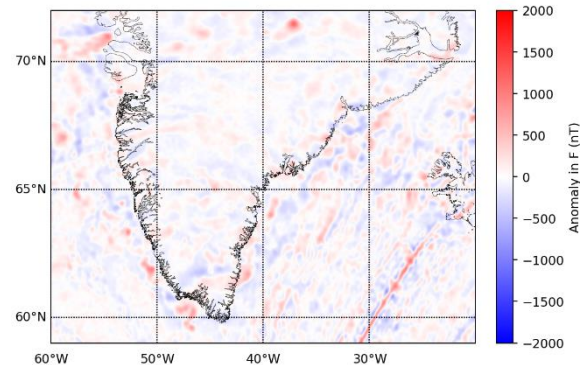
Bareford, M. *et al*, Optimising the computational performance of high degree lithospheric field models, *Computers & Geosciences* 208 (2026) 106092. doi:10.1016/j.cageo.2025.106092

Modelling results

- Can clearly see a good fit to total field in WDMAM
- Successfully extended WDMAM's fixed-altitude intensity-only grid to a continuous 3D model
- Compares favourably to previous lower-resolution models (see next slide)



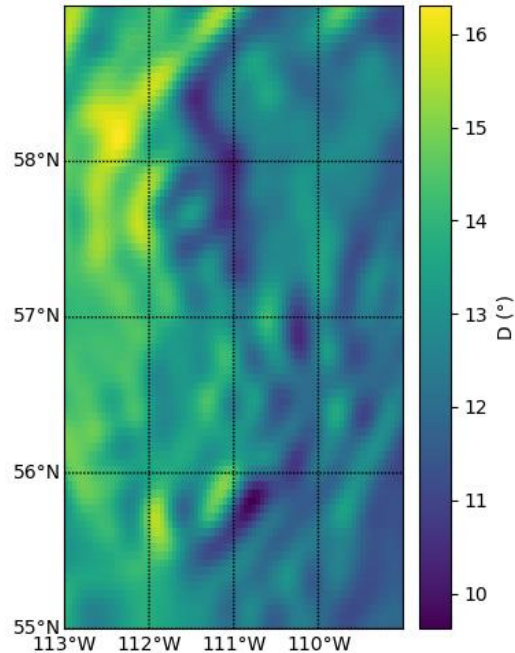
Top: Input data (5 km resolution)



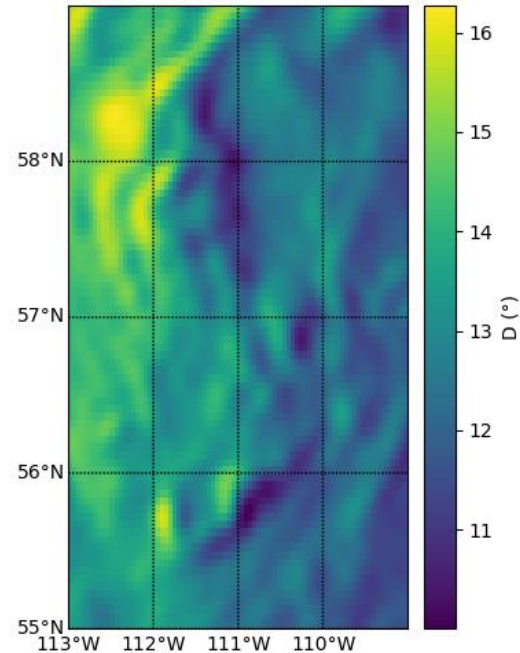
Bottom:
Corresponding modelled values
(20 km wavelength)

Comparison to a previous model in an area without new data

Existing degree-1440 model

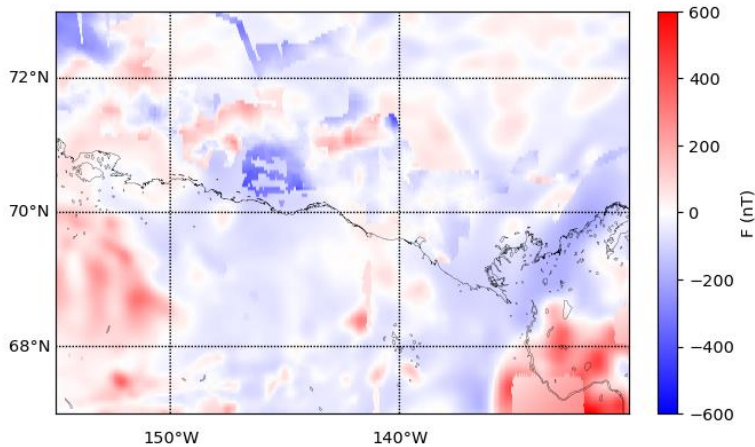


New degree-2000 model

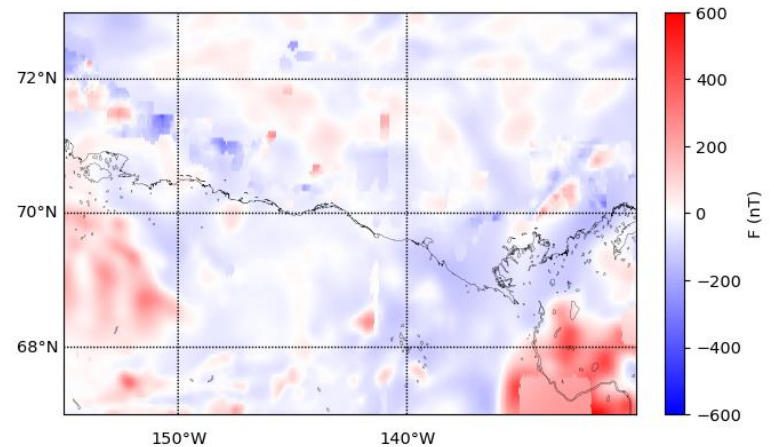


Areas with new data

Intensity data in WDMAM 2.0 (2015)

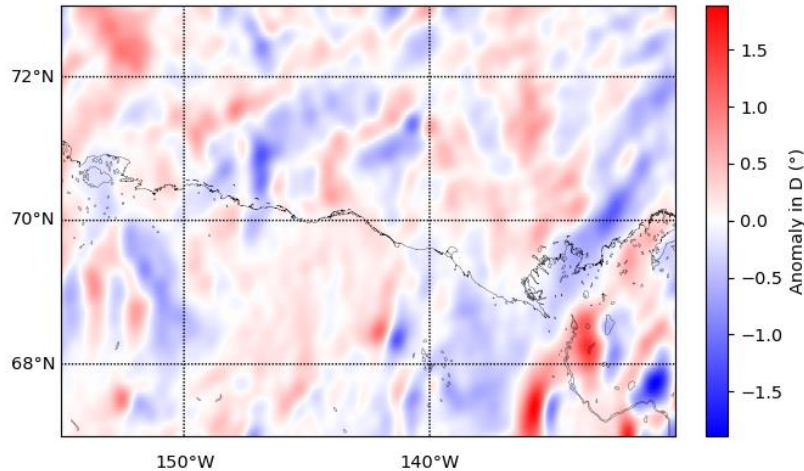


Intensity data in WDMAM 2.2 (2025)

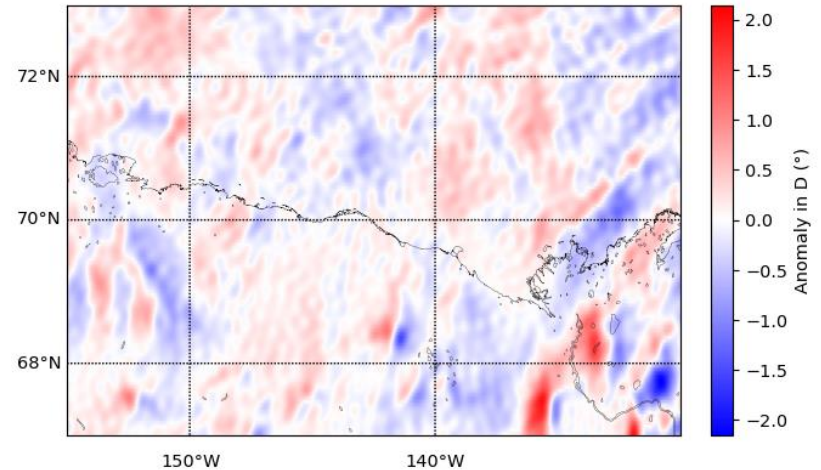


Comparison to a previous model in areas with new data

Existing degree-1440 model

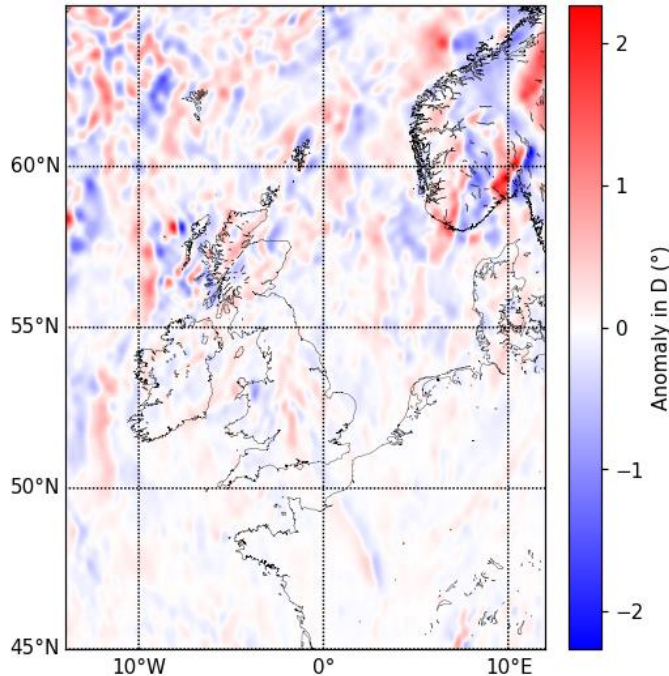


New degree-2000 model

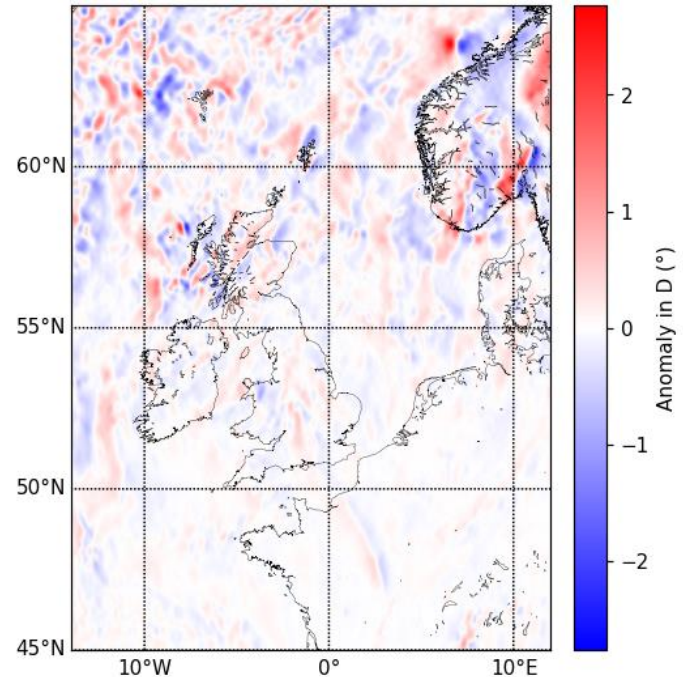


Comparison to a previous model in areas with new data

Existing degree-1440 model

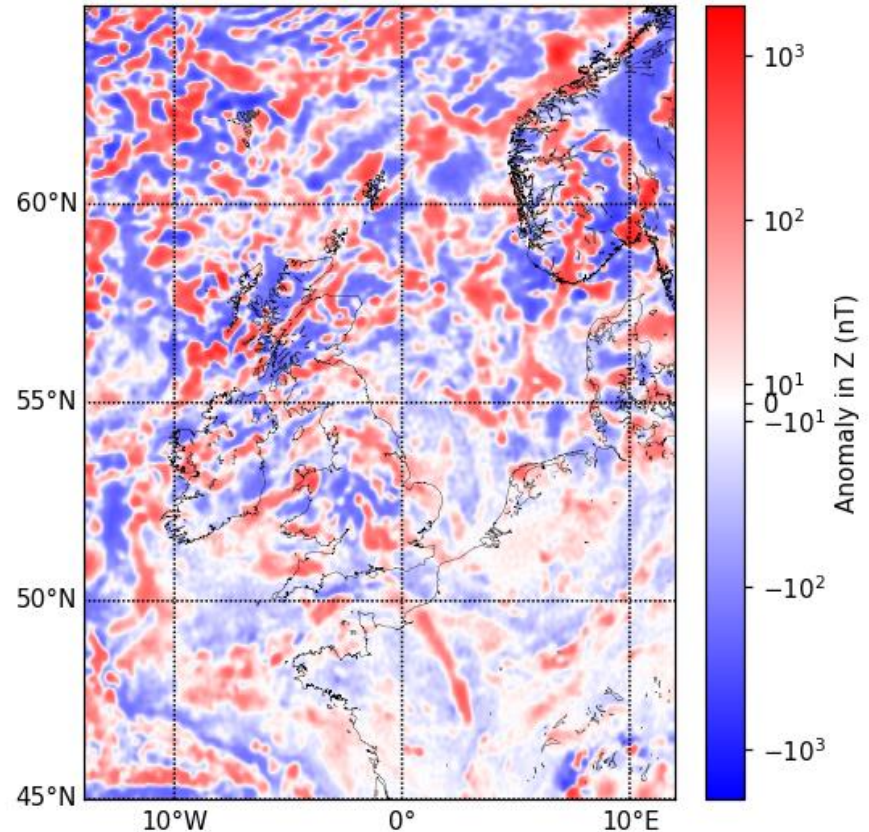


New degree-2000 model



Possible future improvements

- Weight different WDMAM data sources differently
- Consider different types of model regularisation (smoothing)
- Incorporate new lower-altitude satellite data, and any survey data that becomes available



Conclusions

- We have calculated a global magnetic field model to a 20 km wavelength, improving on the accuracy of our previous models.
- Grid of intensity-only data points extended to continuous 3D model of declination, dip and intensity
- New models can now be calculated much more quickly than before.

