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Forward modeling of the Earth's lithospheric field using spherical prisms

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The ESA satellite mission Swarm consists of three satellites that measure the magnetic field of the Earth at average flight heights of about 450 km and 530 km above surface. Realistic forward modeling of the expected data is an indispensible first step for both, evaluation and inversion of the real data set. This forward modeling requires a precise definition of the spherical geometry of the magnetic sources. At satellite height only long wavelengths of the magnetic anomalies are reliably measured. Because these are very sensitive to the modeling error in case of a local flat Earth approximation, conventional magnetic modeling tools cannot be reliably used.

For an improved modeling approach, we start from the existing gravity modeling code "tesseroids" (http://leouieda.github.io/tesseroids/), which calculates gravity gradient tensor components for any collection of spherical prisms (tesseroids). By Poisson's relation the magnetic field is mathematically equivalent to the gradient of a gravity field. It is therefore directly possible to apply "tesseroids" for magnetic field modeling. To this end, the Earth crust is covered by spherical prisms, each with its own prescribed magnetic susceptibility and remanent magnetization. Induced magnetizations are then derived from the products of the local geomagnetic fields for the chosen main field model (such as the International Geomagnetic Reference Field), and the corresponding tesseroid susceptibilities. Remanent magnetization vectors are directly set. This method inherits the functionality of the original "tesseroids" code and performs parallel computation of the magnetic field vector components on any given grid.

Initial global calculations for a simplified geometry and piecewise constant magnetization for each tesseroid show that the method is self-consistent and reproduces theoretically expected results. Synthetic induced crustal magnetic fields and total field anomalies of the CRUST1.0 model converted to magnetic tesseroids reproduce the results of previous forward modelling methods (e.g. using point dipoles as magnetic sources), while reducing error terms. Moreover the spherical-prism method can easily be linked to other geophysical forward or inverse modelling tools.

Sensitivity analysis over Fennoscandia will be used to estimate if and how induced and remanent magnetization can be distinguished in data from the Swarm satellite mission.