Self-demagnetization Modelling

Objectives

All magnetic bodies are affected by self-demagnetisation (SDM) to a degree. These effects can reasonably be ignored for bodies with a magnetic susceptibility of less than 0.1 (SI). However, the magnitude of the anomalous fields generated by moderately to highly susceptible bodies (above ~0.1) do not scale linearly with the susceptibility. The internal fields of arbitrary bodies can differ from the applied fields and are complex to model. Figure 1 shows a schematic of the relevant fields. In general, the amplitude of the internal magnetisation is reduced and its direction may rotate into the plane of the body. These effects need to be compensated for to allow accurate subsurface modelling and data interpretation. The objectives of this work is to investigate correction schemes for modelling highly susceptible magnetic bodies and develop software for accurate modelling and inversion on real data.

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Theory

Analytic modelling may only be carried out for homogeneous bodies bounded by a second degree surface (i.e. an ellipsoid). Numerical techniques are needed for accurate modelling of SDM effects in complex geometries and the approximations in ModelVision, for example, are not reliable for all geometries. The field corrected for self-demagnetising can be written in terms of a demagnetisation factor and the effective magnetisation for a homogeneous ellipsoid, where the subscript i refers to the directions along its principal axes. In the case that we align the axes with the 3 Cartesian directions, the field can be written as

\[ H_i = H_0 - N_i J_i, \]  

where the effective magnetisation is produced by a uniform inducing field \( H_0 \). The effective magnetisation including self-demagnetising effects is then,

\[ J_i = H_i / (1 + N_i), \]  

(Osborn, 1945). The right hand side of (2) may be written in terms of the effective susceptibility, i.e.

\[ \chi = (1 + N_i). \]  

The components of the demagnetisation factor for the triaxial (semi-axes \( a=b=c \)) ellipsoid are functions of the semi-axis ratios and are written in terms of elliptic integrals which may be calculated exactly (Emerson et al. 1985; Clark et al. 1986). A useful result for this ellipsoid is that the components \( N_i \) sum to one, with the special case of a sphere where \( N_i = 1/3 \). Generally \( N_i \) is an approximate demagnetisation factor which may have unequal components for each axis or may be a function of susceptibility. For example, a cubic body of low susceptibility (<0.1) has \( N_i = 1/3 \) which decreases towards \( N_i = 0.26 \) as (Sharma 1966; Eskola et al. 1977).

Numerical Methods

![Figure 1. Schematic diagram showing the relevant fields for a magnetic body. Here the inducing field is labelled \( F_0 \), the demagnetising field \( F_d \), and the effective magnetisation \( J_e \). (Figure from Purss and Cull, 2005)](image-url)
Calculation of the demagnetisation factor for non-ellipsoidal bodies becomes difficult for $>1$ since edge effects begin to dominate the mean induced secondary field. Lee (1980) showed that SDM effects may be approximated by performing a surface integral over a faceted body of constant magnetisation and susceptibility. This approximation begins to break down at high susceptibilities due to the number of facets required. We are currently investigating correction schemes based on dividing a magnetic body up into many subvolumes and calculating the multi-body interactions that lead to self-demagnetisation effects. We have developed an iterative cubic voxel scheme similar to that proposed by Sharma (1966) and a recent scheme based on spherical subvolumes by Purss and Cull (2005). Figure 2 plots the TMI calculated for a cubic and spherical source both with and without a self-demagnetisation correction. This method has proved to be both accurate and fast to calculate, and so we are turning our attention to inversion modelling including self-demagnetisation effects and possibly remanence.

**CESRE Publications**


**Key References**


**Figure 2.** Self-demagnetisation effects calculated via the cubic voxel scheme for two magnetic bodies, a cube (left column) and a sphere (right column). (Top row) The body approximated by many cubic voxels. (Middle row) The TMI calculated with no self-demagnetisation correction. (Bottom row) The TMI calculated using the self-demagnetisation correction.