GPGN 411/511: Advanced Gravity and Magnetic Exploration

Lab Exercise #02: Modeling Magnetic Data using the Gravity Gradient Code from Lab01

Objectives:

Continue the development of the code from last week to produce a modeling code for magnetic anomalies due to a susceptible prism.

Background:

The magnetic anomaly vector produced by a rectangular prism with magnetization $\vec{M}$ is given by

$$\vec{B}_a = \frac{\mu_0}{4\pi}\mathbf{\Gamma}\vec{M} \tag{1}$$

where Γ is the dyadic Green function used in the gravity gradient modeling (Lab01),

$$\mathbf{\Gamma}(x,y,z,;x',y',z') = \int_{a_1}^{a_2}\int_{b_1}^{b_2}\int_{c1}^{c2}\nabla\nabla^T \frac{1}{\sqrt{(x-x')^2+(y-y')^2+(z-z')^2}}\,dx'dy'dz', \tag{2}$$

When the anomalous field is much smaller than the background (IGRF) field, the total-field anomaly is given by the projection of the anomalous field vector onto the background field direction,

$$\begin{aligned}\Delta T &= \left|\vec{B}_0 + \vec{B}_a\right| - B_0 \\ &\cong \frac{\mu_0}{4\pi}\hat{B}_0^T\mathbf{\Gamma}\vec{M}\end{aligned} \tag{3}$$

where the unit vector $\hat{B}_0$ is the direction of the Earth's main magnetic field (inducing field) and is defined in the Cartesian coordinate by the inclination I and declination D such that,

$$\begin{aligned}\hat{B}_{0x} &= \cos(I)\cos(D) \\ \hat{B}_{0y} &= \cos(I)\sin(D) \\ \hat{B}_{0x} &= \sin(I)\end{aligned} \tag{4}$$

Assuming a weakly magnetic materials with susceptibility $\kappa << 1$, the induced magnetization is given by the product of the magnetic susceptibility and the inducing field

$$\vec{M} = \kappa\vec{B}_0 / \mu_0 \tag{5}$$

Equations 1-5 provide a complete description of total-field magnetic anomaly due to a right rectangular prims. We explore this aspect in the current lab.

Tasks-I

Generate a code to perform the following

(1) Calculate the $\hat{B}_0$ and $\vec{M}$,

(2) Calculate the dyadic Green's tensor $\boldsymbol{\Gamma}$ using the code from Lab01,

(3) Taking the products of the dyadic Green's tensor with the magnetization $\boldsymbol{\Gamma}\vec{M}$ to model the three components of magnetic anomaly and the corresponding total-field anomaly (make sure you have the correct unit in nT for the magnetic anomaly!)

(4) Output each anomaly map to a file with the following format (as in lab01):

n_E n_N
E(1) N(1) d(1,1)
E(1) N(2) d(1,2)
…
E(1) N(n_N) d(1,n_N)
E(2) N(1) d(2,1)
…
E(2) N(n_N) d(1,n_N)
…
E(n_E) N(n_N) d(n_E,n_N)

Note:

(1) The program should be capable of inputting user-defined source parameters and data grid. The input parameters include the inducing field (inclination, declination, and strength), in addition to the source parameters.

(2) Name the output files using a unique file name so you can input them to a program in future labs.

Tasks-II

Assume a magnetic susceptible cube that is buried at a depth to the top of 50 m, has a dimension of 300 m on all sides and a susceptibility of 0.05. Furthermore, assume the earth field is 50,000 nT and has an inclination of 45° and declination of 25°. Calculate and display the three components of the anomalous field and the total-field anomaly over a grid centered directly above the prism:

(1) Northing: (xmin, xmax)=(-775, 800), dx=25 m
(2) Easting: (ymin, ymax)=(-775, 800), dy=25 m
(3) the prism center would be located at (x',y',z')=(0,0,200)

Tasks-III

For the prism and grid in Task-II, calculate the total-field anomaly for the following scenarios:

(1) I=90°, D=0°
(2) I=0°, D=0°

Display the two data sets and compare them with the Tzz and Txx, respectively, from Lab01 and explain the similarity in the patterns.

Report:

(1) Submit your codes
(2) Submit a report in the same format as lab01.

Note, please have a title page containing the class, lab title, your name, an date.