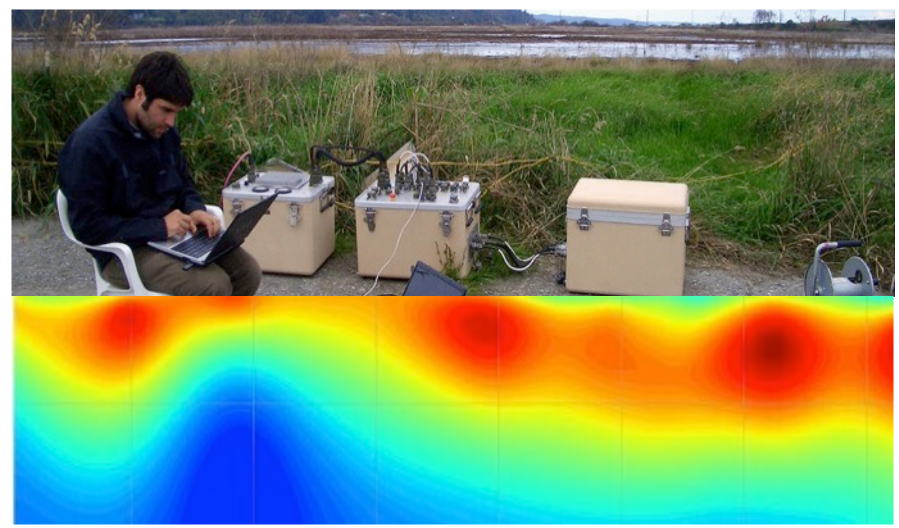
EOSC 350 : Environmental, Geotechnical and Exploration Geophysics I

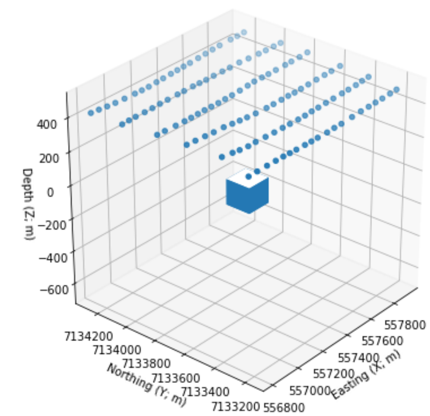
Magnetic Processing & Interpretation



September – December, 2017

Team activity: simulation-based survey design

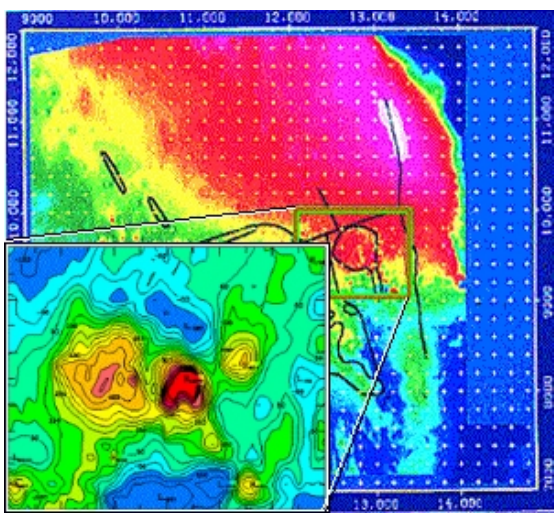
- Load “Mag_Induced2D.ipynb” and set
  - dx, dy, dz = 100 m (block size)
  - elev = 420 m (block elevation)
  - susc = 0.3 SI (block susceptibility)
  - Profile_azm = 0.0 (profile azimuth)

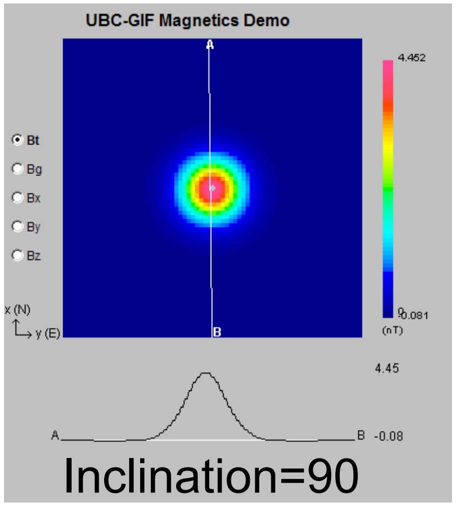


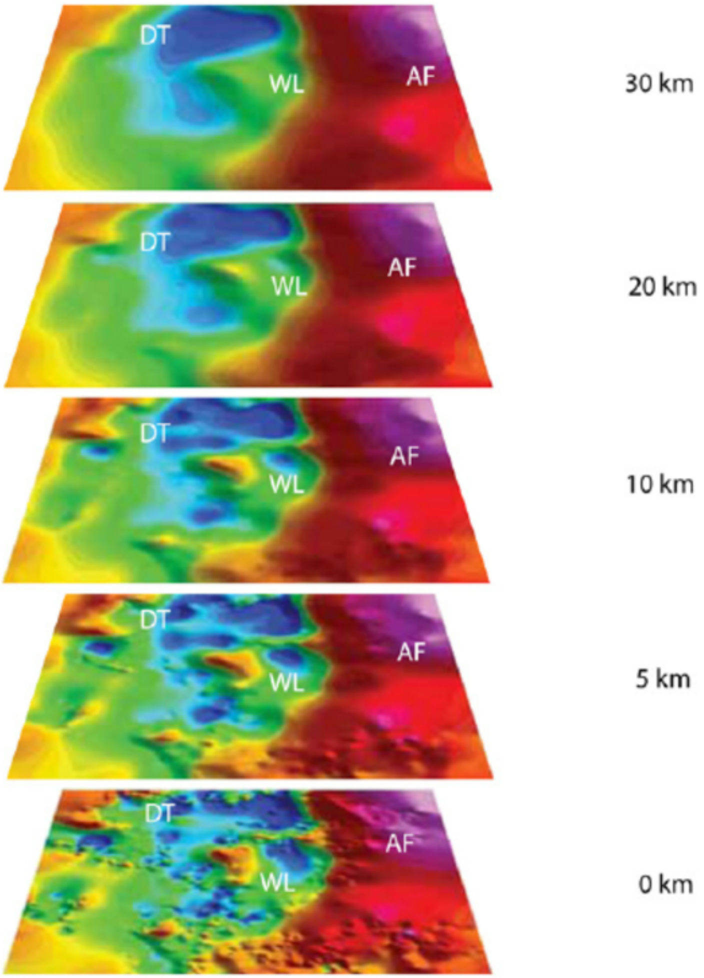
- Lightning presentation – determine:
  - Peak value and “width” of the anomaly?
  - Station spacing?
  - Profile length?

Inference from data images/curves

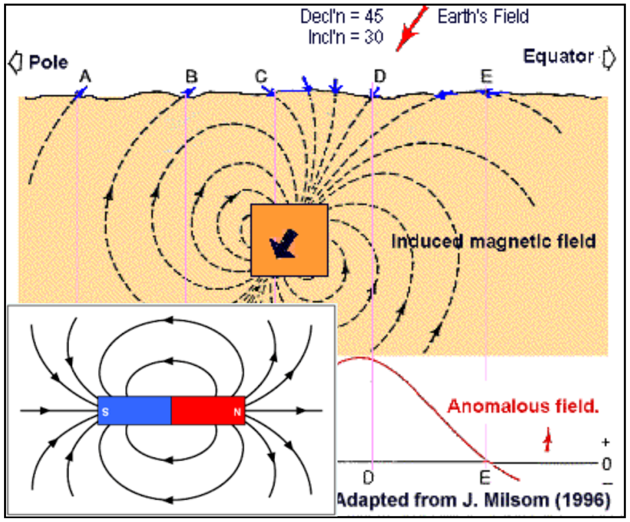
- Regional removal
- Upward continuation
- Reduction to pole

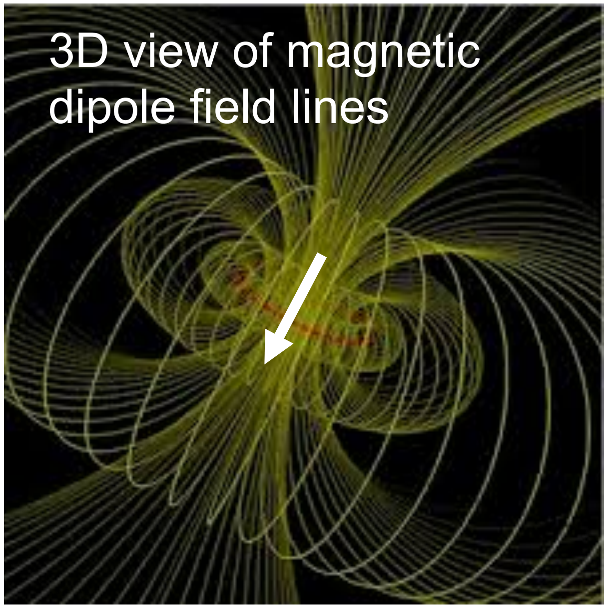


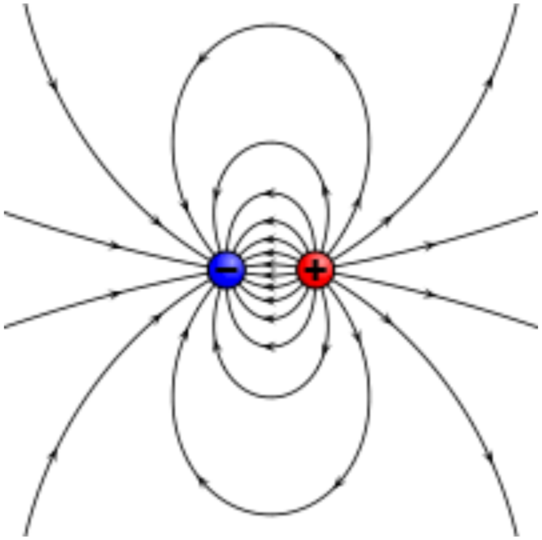




Magnetic dipole model



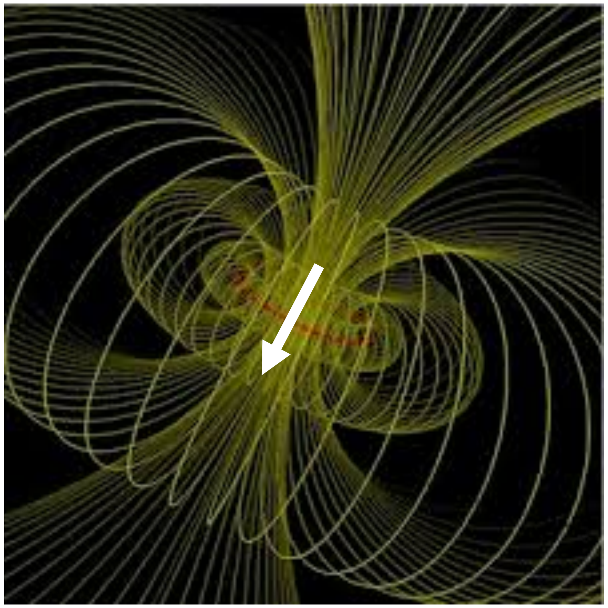




- Small Bar magnet (N and S)
- Two charges of opposite signs
    - positive: emit field lines
    - negative: attract field lines

Question: how small is “small”?

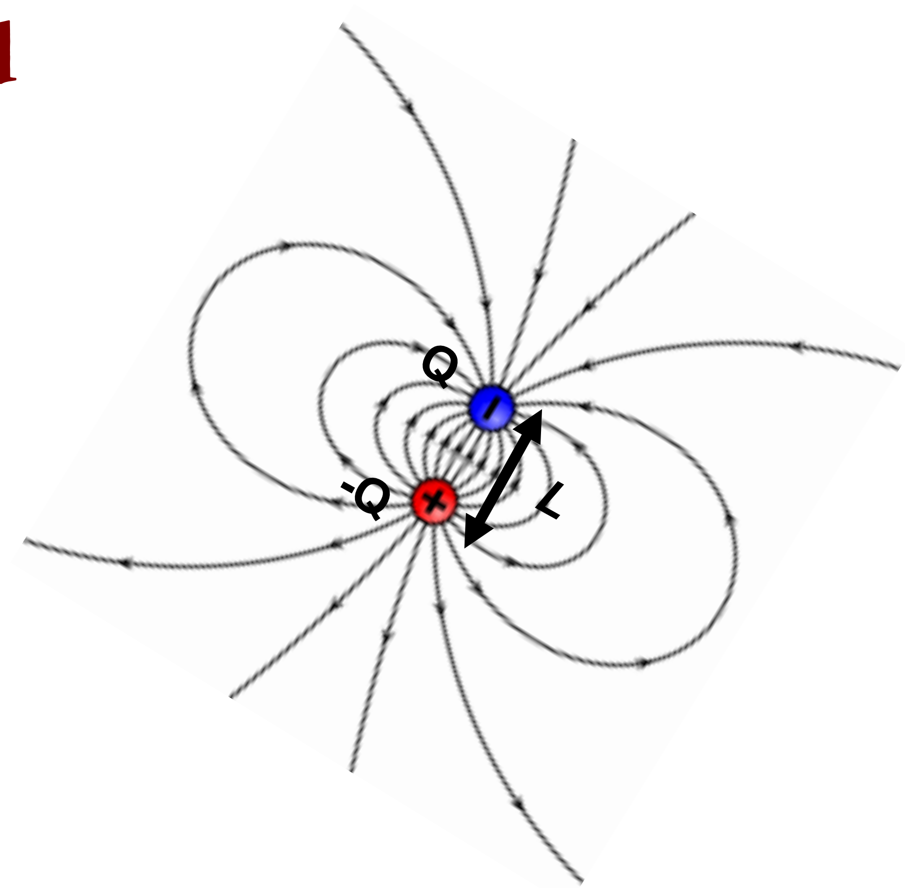
Magnetic dipole field



Vector field from a magnetic dipole

$$\mathbf{B}(\mathbf{r}) = \frac{\mu_0}{4\pi}\left(\frac{3\mathbf{r}(\mathbf{m}\cdot\mathbf{r})}{r^5} - \frac{\mathbf{m}}{r^3}\right)$$

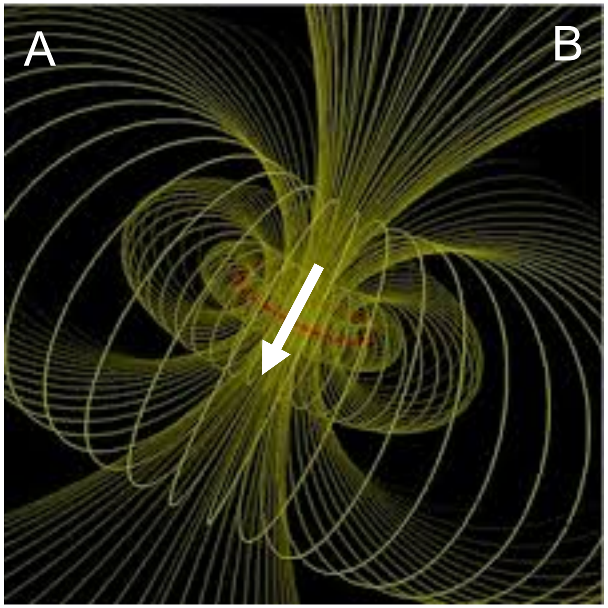
m: dipole moment
r: distance

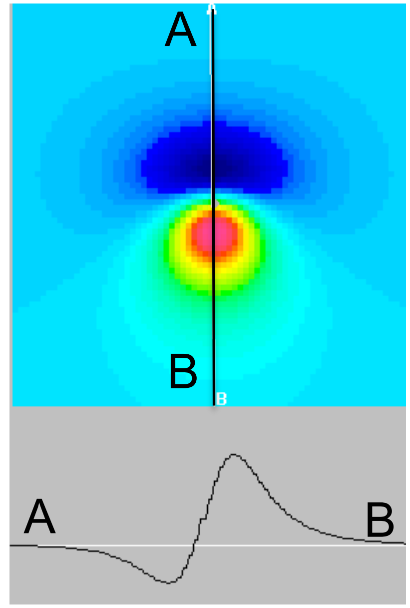


Magnitude of magnetic dipole moment

$$\mathrm{m} = \frac{\mathrm{Q}\,L}{\mu_0}$$

Magnetic dipole field on surface





Plan view

Profile view

Vector field from a magnetic dipole

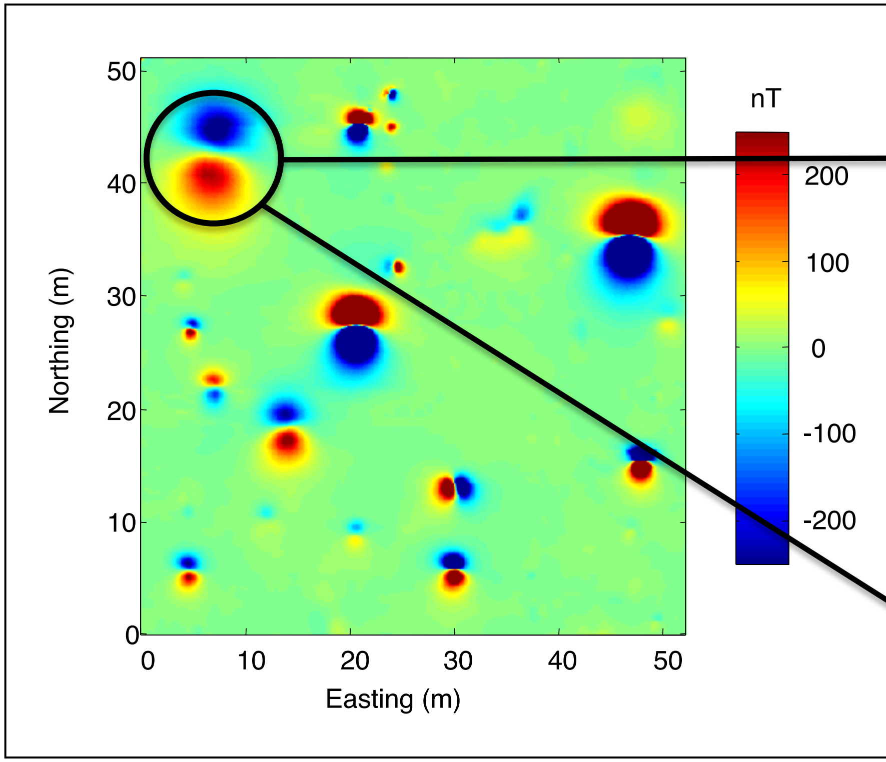
$$\mathbf{B}(\mathbf{r}) = \frac{\mu_0}{4\pi}\left(\frac{3\mathbf{r}(\mathbf{m}\cdot\mathbf{r})}{r^5} - \frac{\mathbf{m}}{r^3}\right)$$

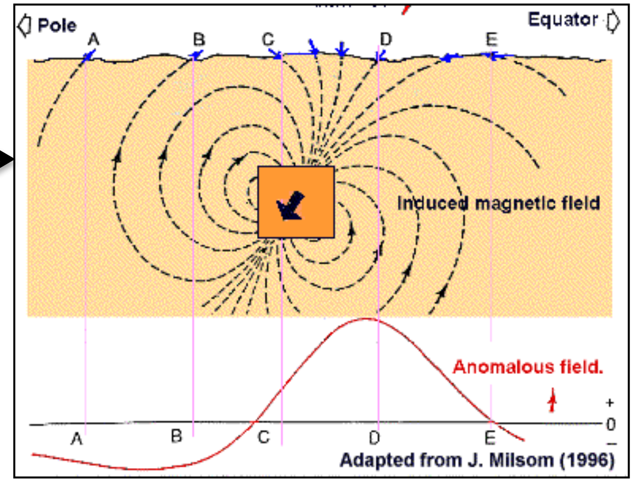
m: dipole moment
r: distance

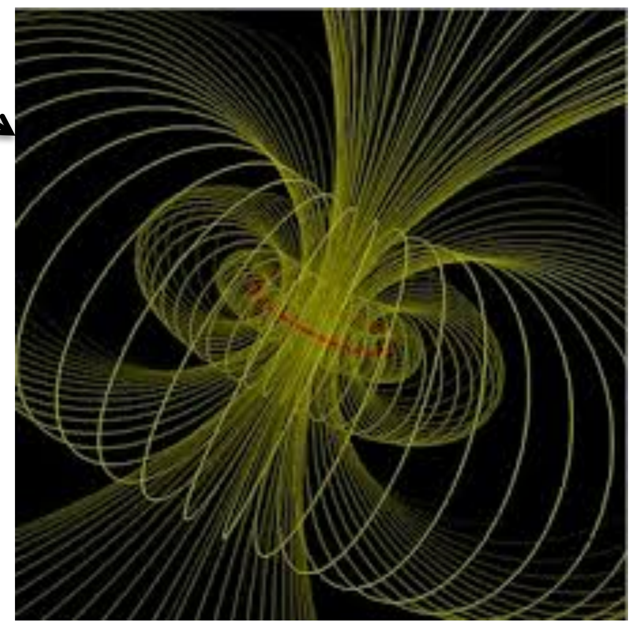
Single dipole anomaly

- Positive and negative
- Horizontal dipole direction

Inference using the dipole model





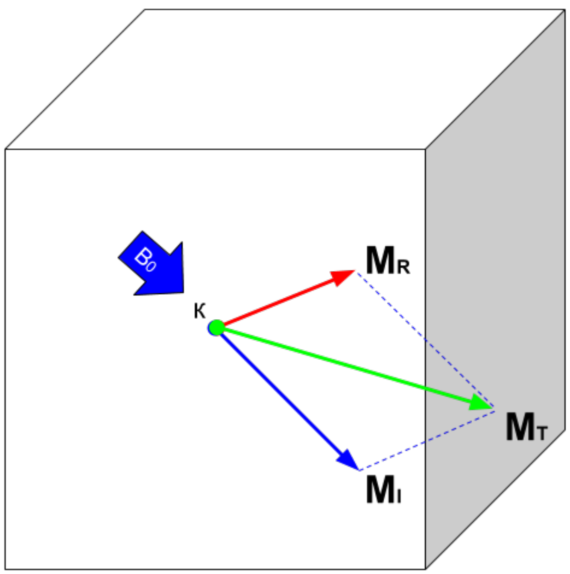


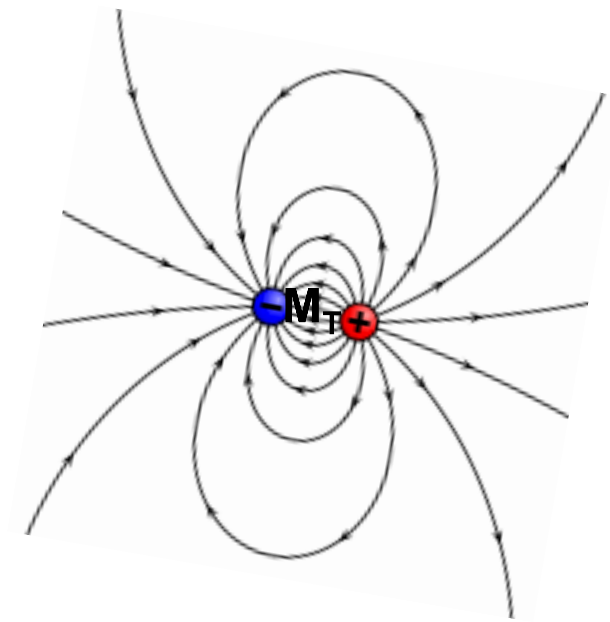
A UXO anomaly map:

- Dipole field on the surface
- Induced or remanent?
- How can we tell it's a UXO?

Small UXO as a dipole

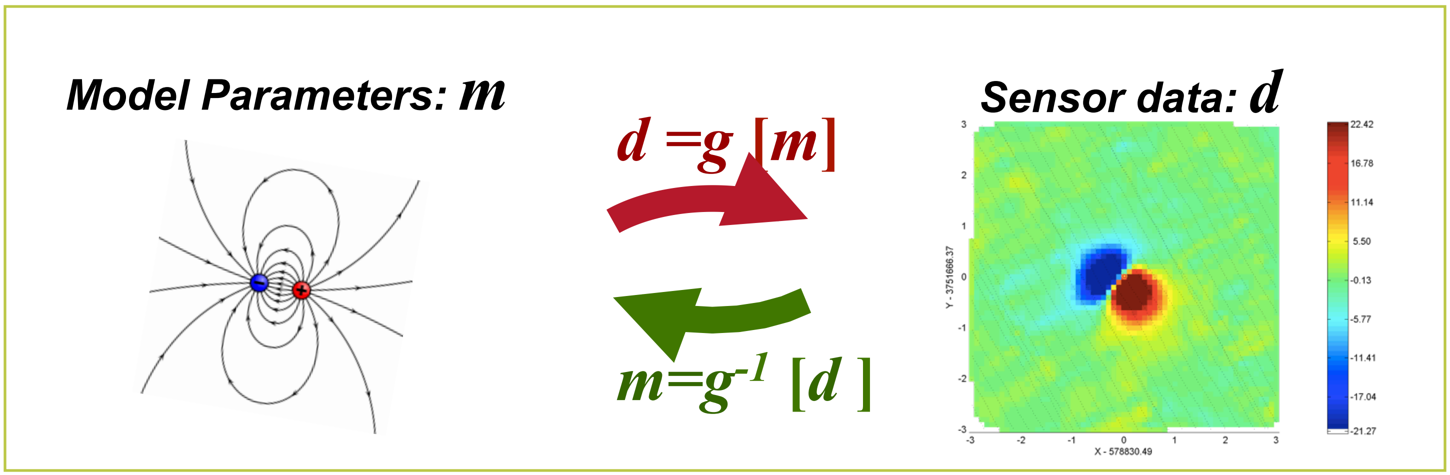
- Following parameters uniquely define a dipole:
  - Position (X, Y, Z)
  - Total dipole moment vector (M_T) from induced and remanent (Mx, My, Mz)





Parameter extraction

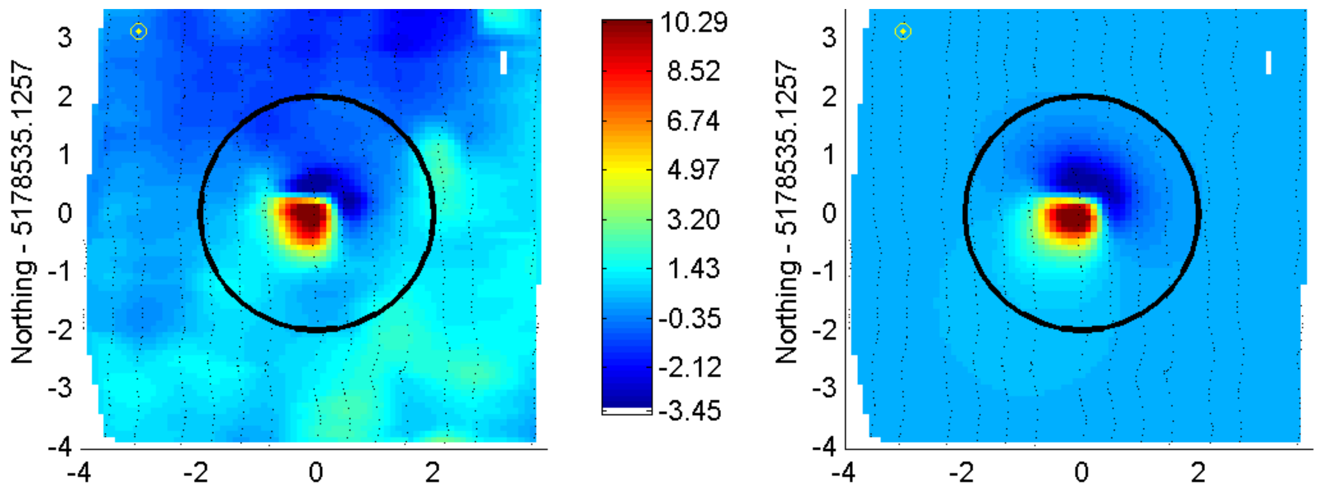
- Six parameters m = [X, Y, Z, Mx, My, Mz]
- Data inversion: search the parameter space to find a particular combination of [X, Y, Z, Mx, My, Mz] that reproduces the dipole pattern on the map
- Automatic search or manual data fitting (gpgLabs)



$$\mathbf{B}(\mathbf{r}) = \frac{\mu_0}{4\pi}\left(\frac{3\mathbf{r}(\mathbf{m}\cdot\mathbf{r})}{r^5} - \frac{\mathbf{m}}{r^3}\right)$$

Parametric inversion

Field data **Simulated data**



Easting = -0.13 m

Northing = 0.16 m

Depth = 0.26 m

Moment = 0.0226 Am^2

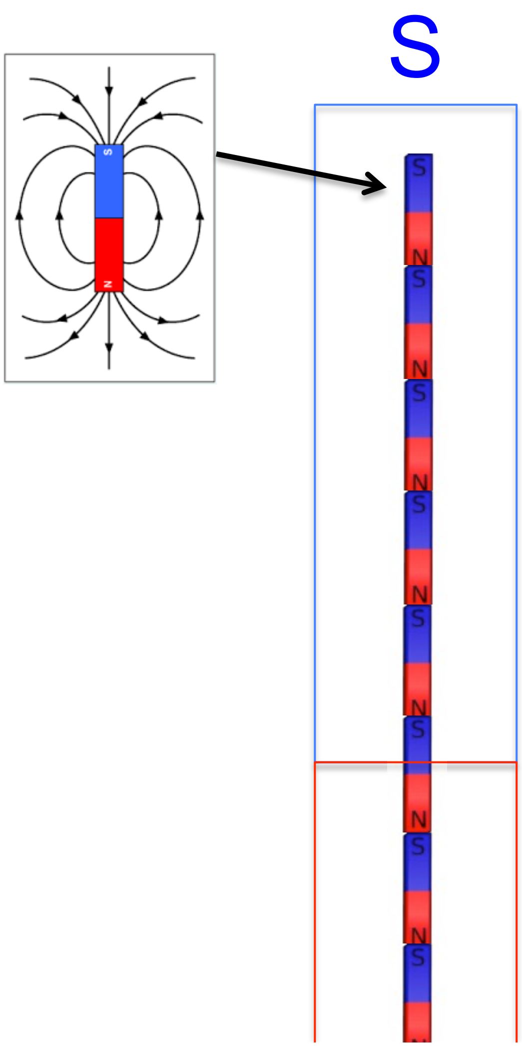
Azimuth = 37^o

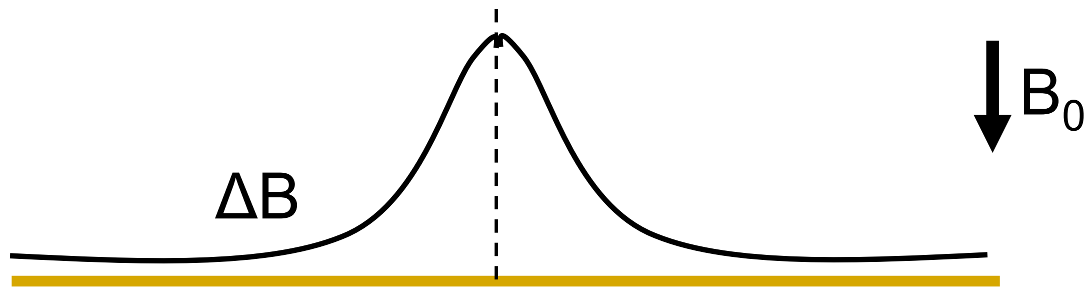
Dip = 28.8^o

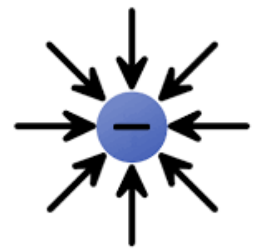
Fit quality = 0.95

Use the recovered dipole parameters to identify UXO

Build a long pipe using dipoles



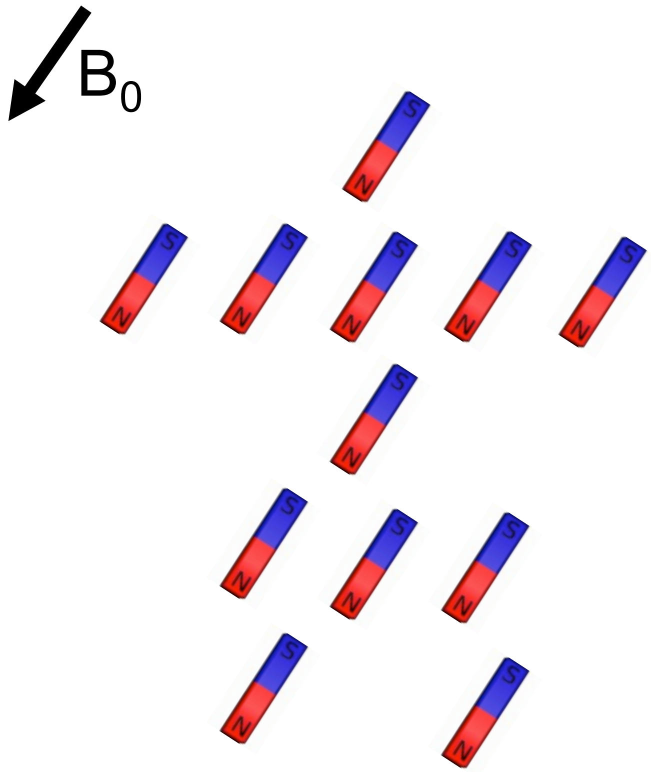




$$\mathbf{B} = \frac{\mu_0 Q}{4\pi r^2}\hat{\mathbf{r}}$$

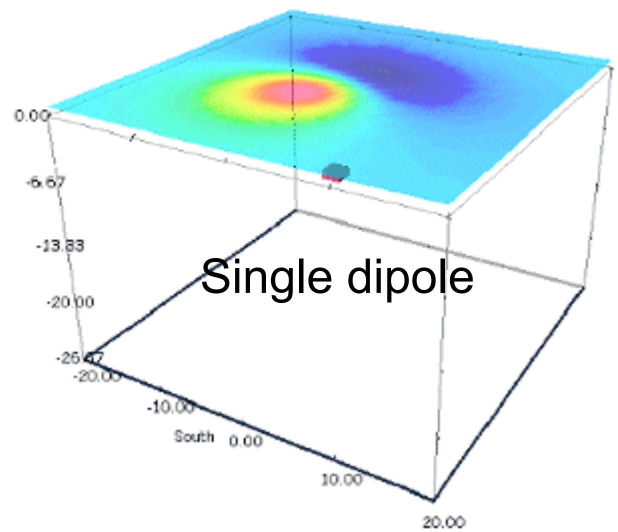
- N and S inside the pipe cancel out
- Net negative and positive charge at two ends
- Only “see” one change if the pipe is vertical
- A **monopole** anomaly (field lines determined by a single magnetic charge)
- What if the remanence makes the magnetization not uniform inside the pipe?

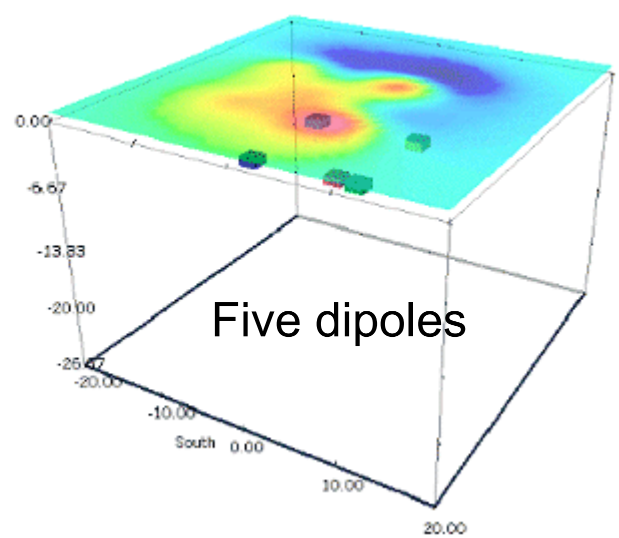
Build a complex body using dipoles



Sum up contribution from each dipole

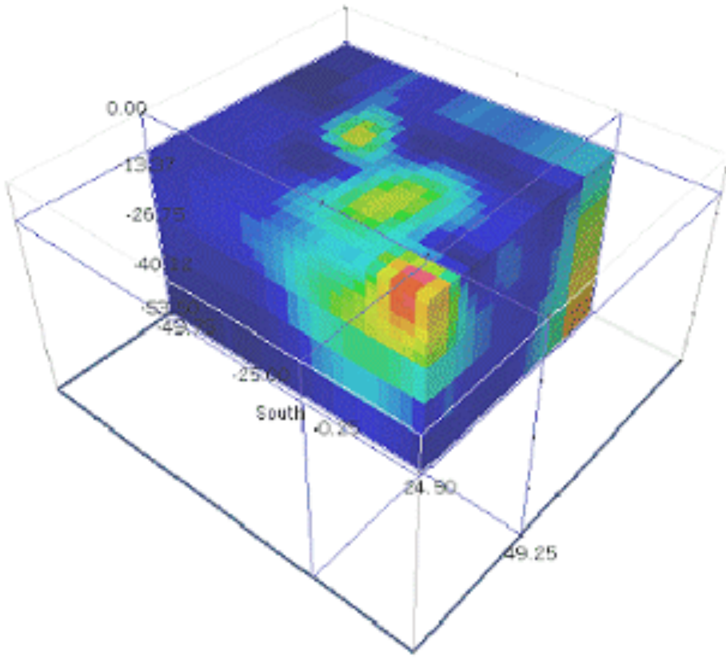
$$\mathbf{B}(\mathbf{r}) = \frac{\mu_0}{4\pi}\left(\frac{3\mathbf{r}(\mathbf{m}\cdot\mathbf{r})}{r^5} - \frac{\mathbf{m}}{r^3}\right)$$



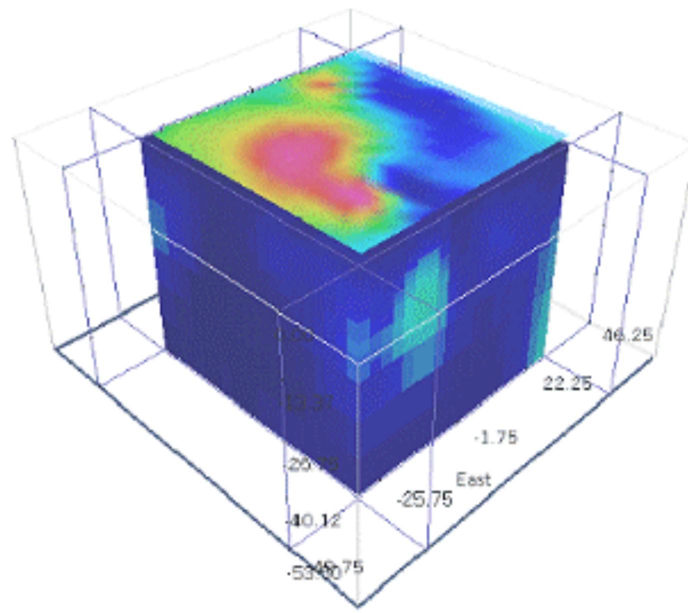


Earth can be complicated

A complicated earth model of κ
(Magnetization depends on κ)

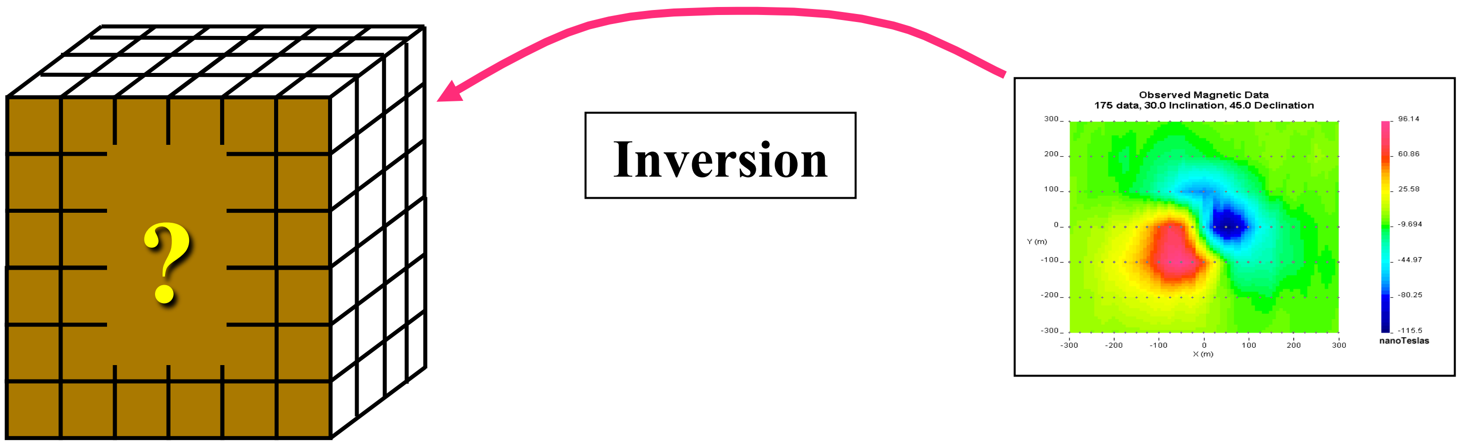


Magnetic data for a complicated earth model.



$$\mathbf{B}(\mathbf{r}) = \frac{\mu_0}{4\pi}\left(\frac{3\mathbf{r}(\mathbf{m}\cdot\mathbf{r})}{r^5} - \frac{\mathbf{m}}{r^3}\right)$$

3D inversion: Finding an earth model that generated the measured data



Divide the earth into many cells that contribute to the data on surface

- Each cell has a constant but unknown susceptibility (induced magnetization only)
- Each cell has an unknown magnetization vector (induced and/or remanent magnetization)

Summary

- Magnetic dipole
  - Moment, field, parameterization
- Interpreting magnetic data using dipoles
  - Single and small objects (UXO): dipole inversion
  - Elongated objects (pipe): monopole
  - Arbitrarily-shaped objects (ore body): 3D inversion

Upcoming activities

- Fri. Sept. 22
  - Lecture on applications of magnetic method
  - Quiz 2: Magnetics
- Mon. Sept. 25
  - TBL 2 Magnetics: Abandoned brine wells
- Wed. Sept. 27
  - Lecture on seismic
- Labs on Sept. 25, 26, 27
  - Magnetic Part 2: Interpretation of Wreck Beach data