Magnetic inversion and why it's useful

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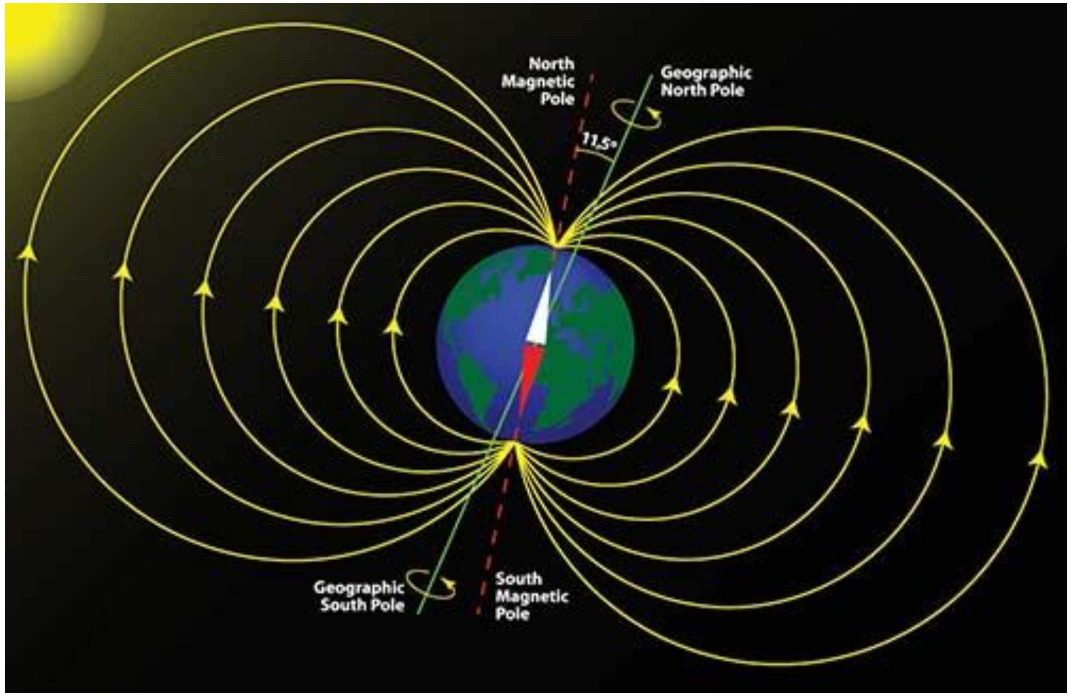
14. December 2021

Potential field - geomagnetics



- Measure the static magnetic field
- Analyse the local deviation from the background field => geology
- The magnetic flux is a $1/r^3$ field

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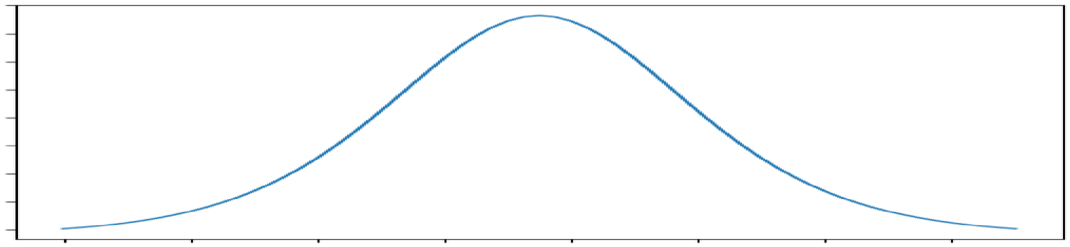
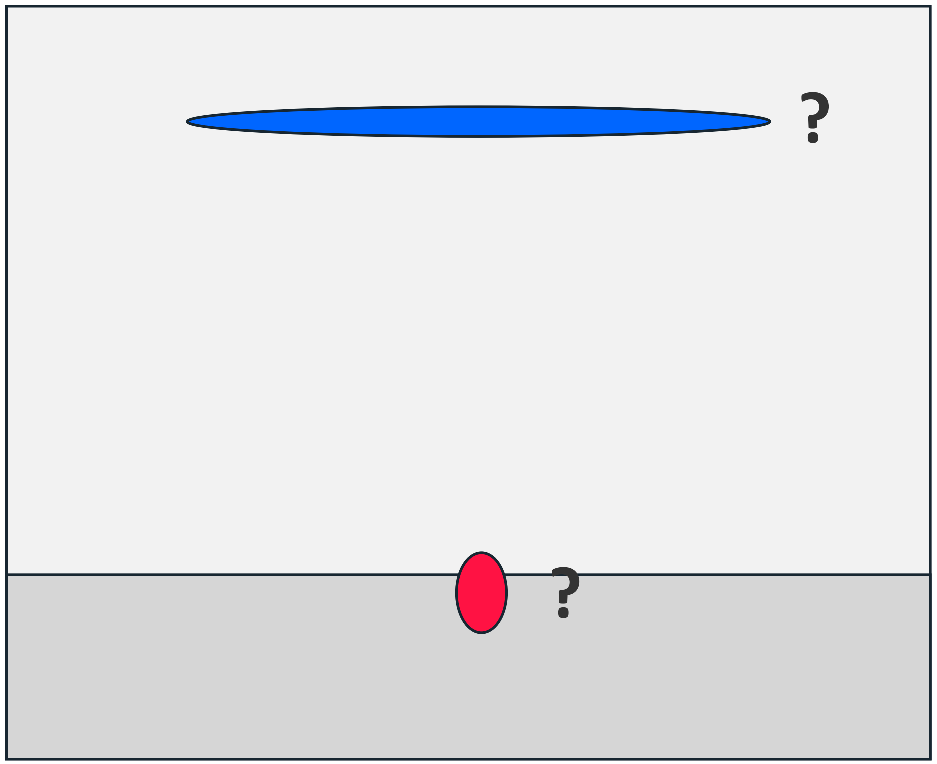
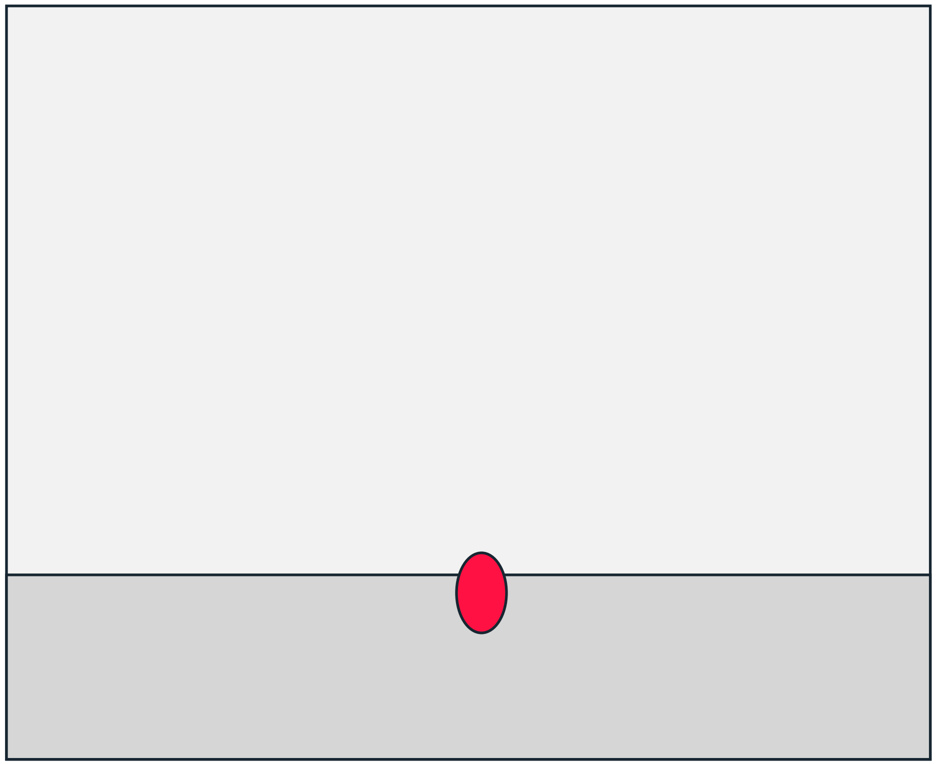
The deep vs shallow ambiguity of gravmag



- For SMS we can exclude the shallow anomaly
- No magnetic sources in the waterlayer
- Use this to constraint the inversion



The general case



The SMS case

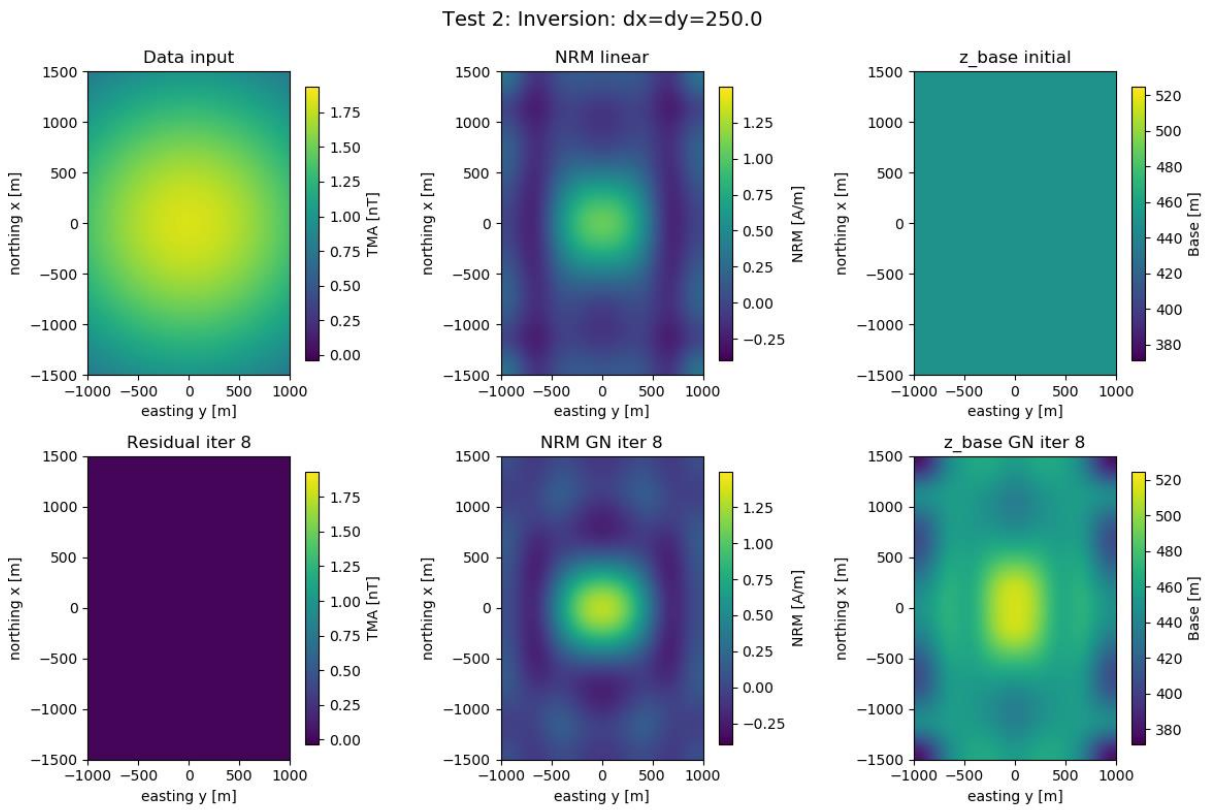
Magnetic inversion method

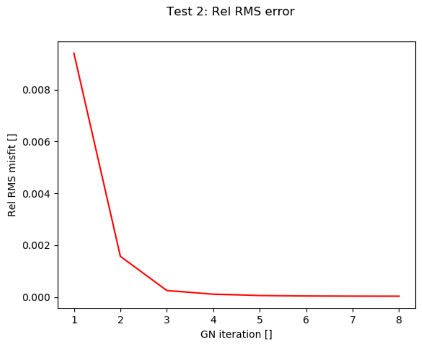
- Iteration 1: Linear.
  - Update magnetization only
- Iteration n>1: Non-linear.
  - Gauss-Newton
  - Update depth (and magnetization)

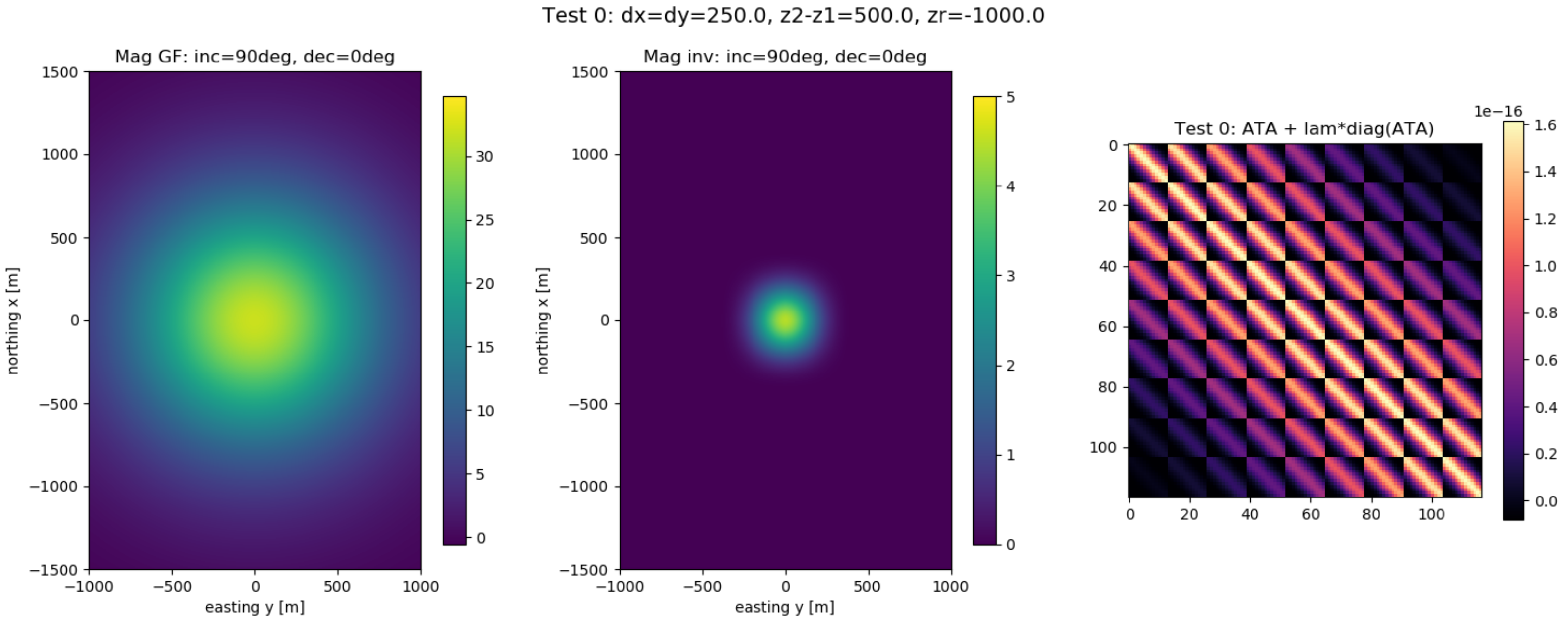
Magnetization = magnetic dipole moment per unit volume

Initial depth of source layer

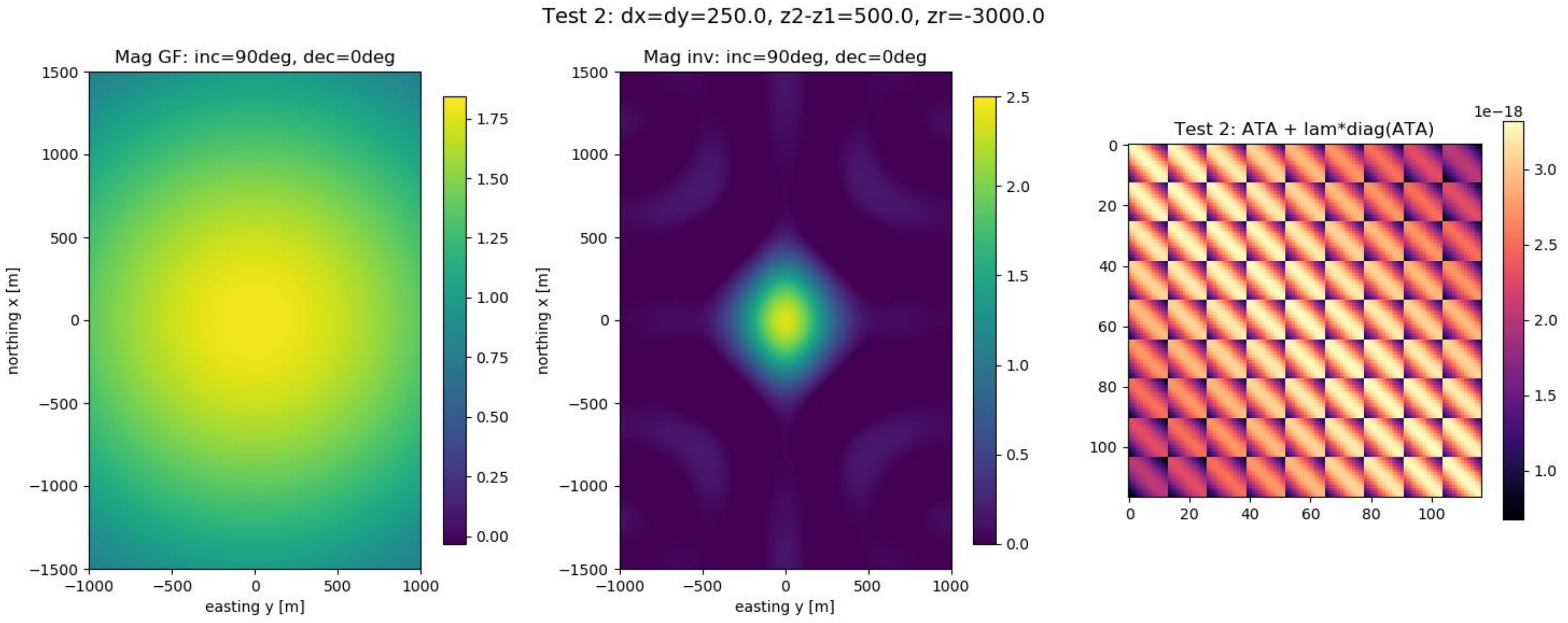
- Guessing
- Power-spectral method (Fourier analysis)
- Interpretation (seismic)







How close do we need to measure to resolve a small target?



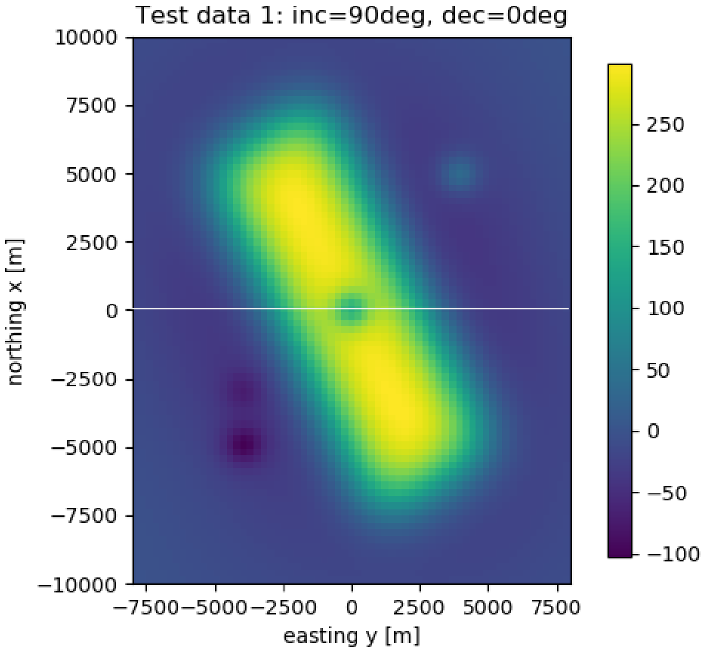
Inversion tests

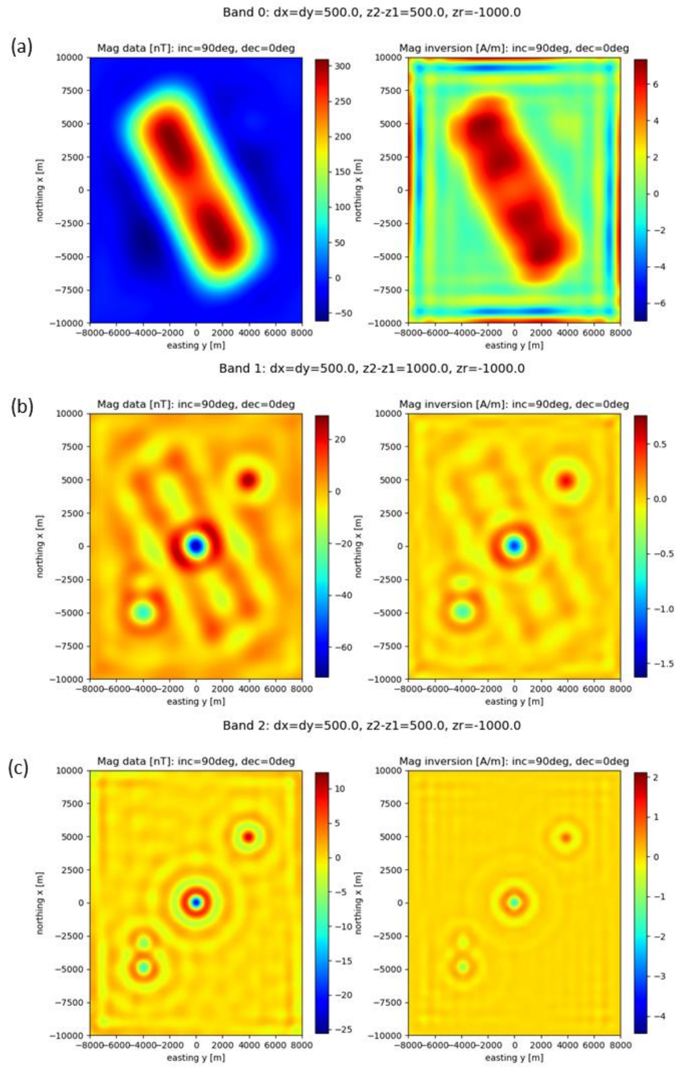
- 1000m above (top)
- 300m above (bottom)

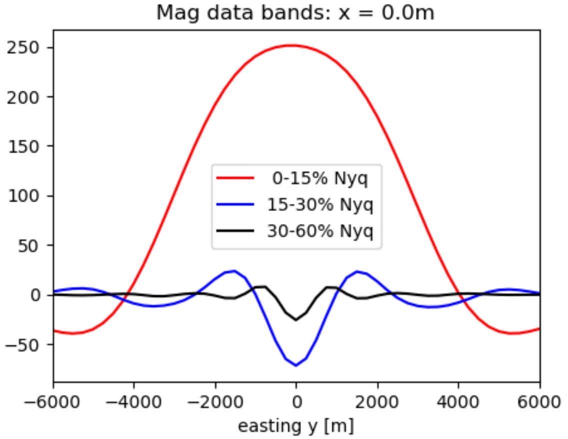
Indicator of resolution:

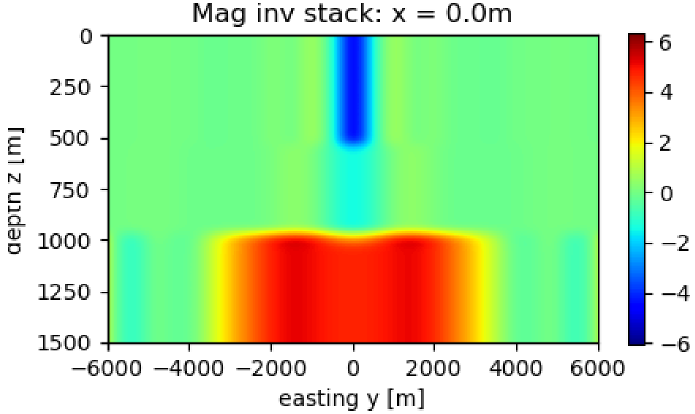
- Rank of the matrix
- Linear algebra

Inversion of wavenumber bands







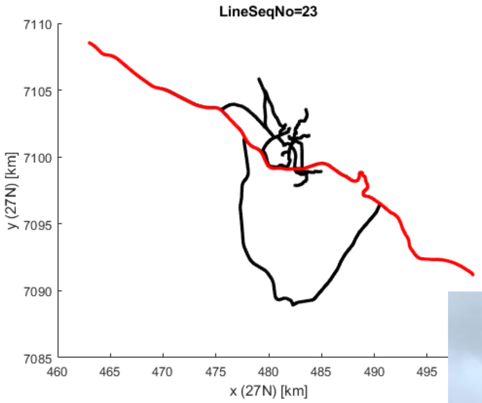


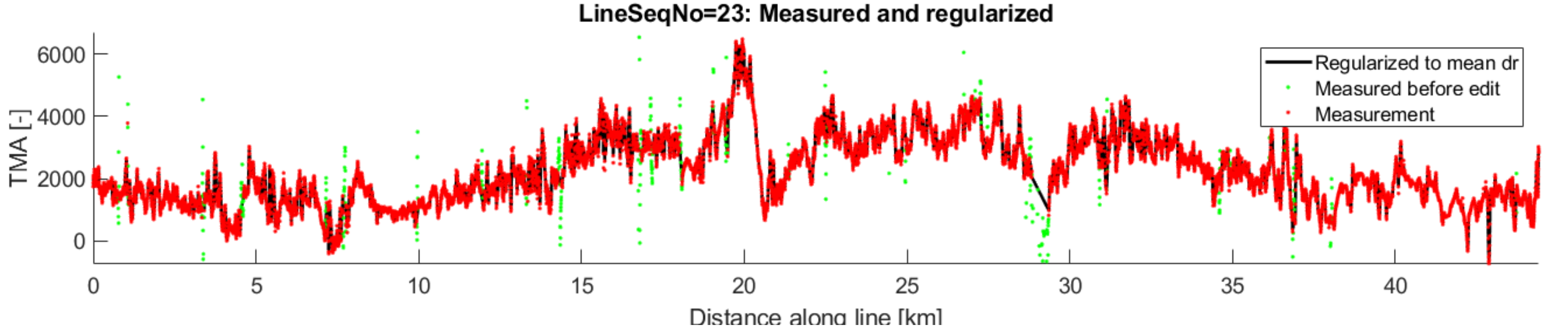
Inversion procedure

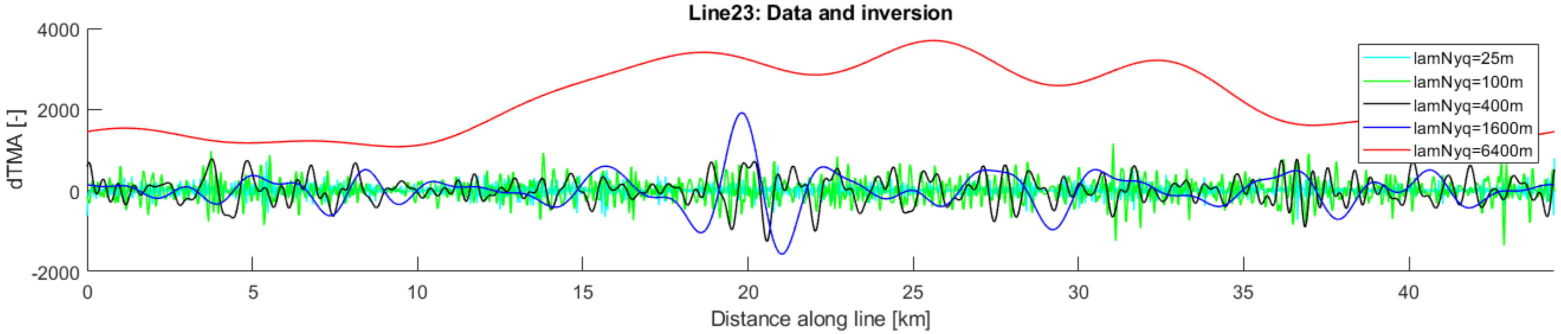
1. Decomposition into (radial) wavenumber bands
2. Inversion of each band separately
3. Stack the partial images

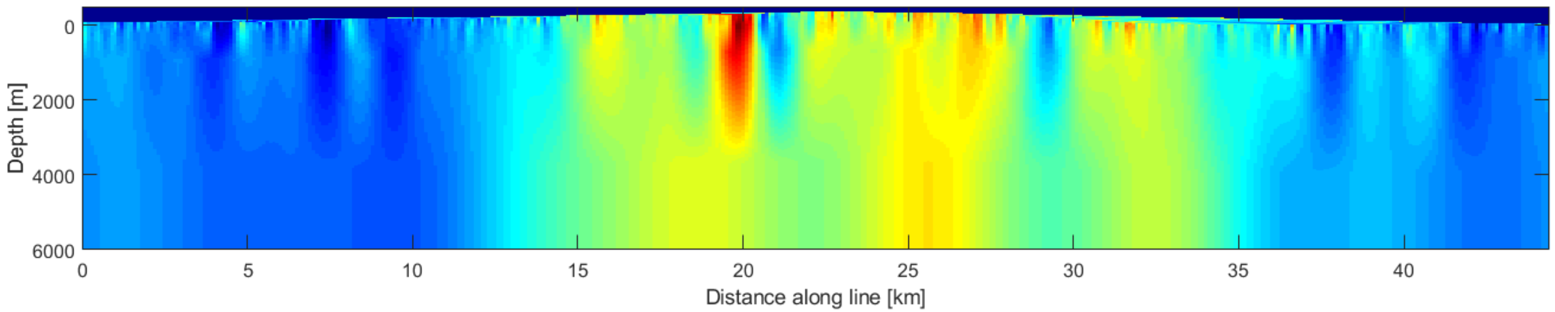
Open

Hellisheiði
Hi-Res magnetics

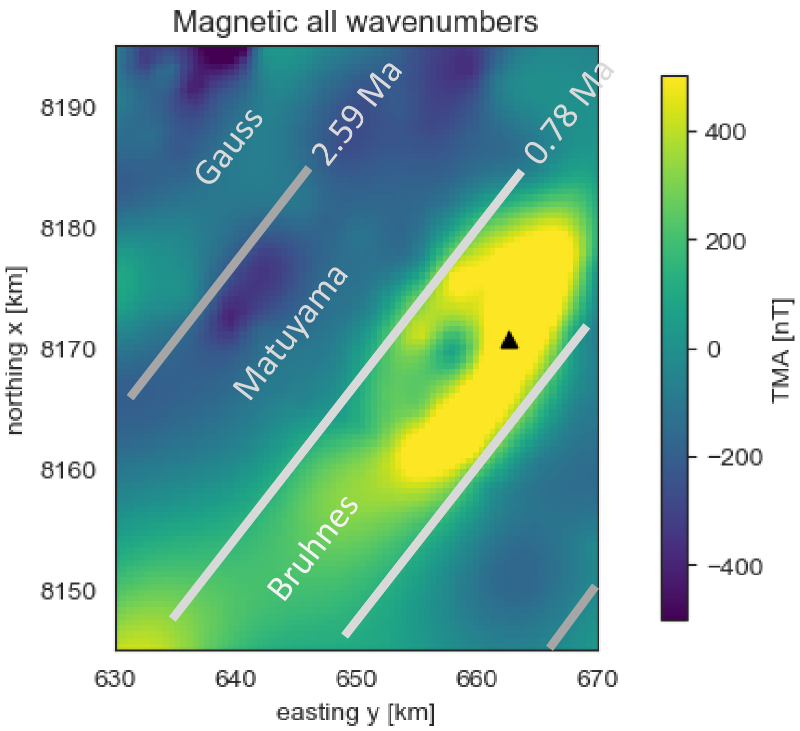




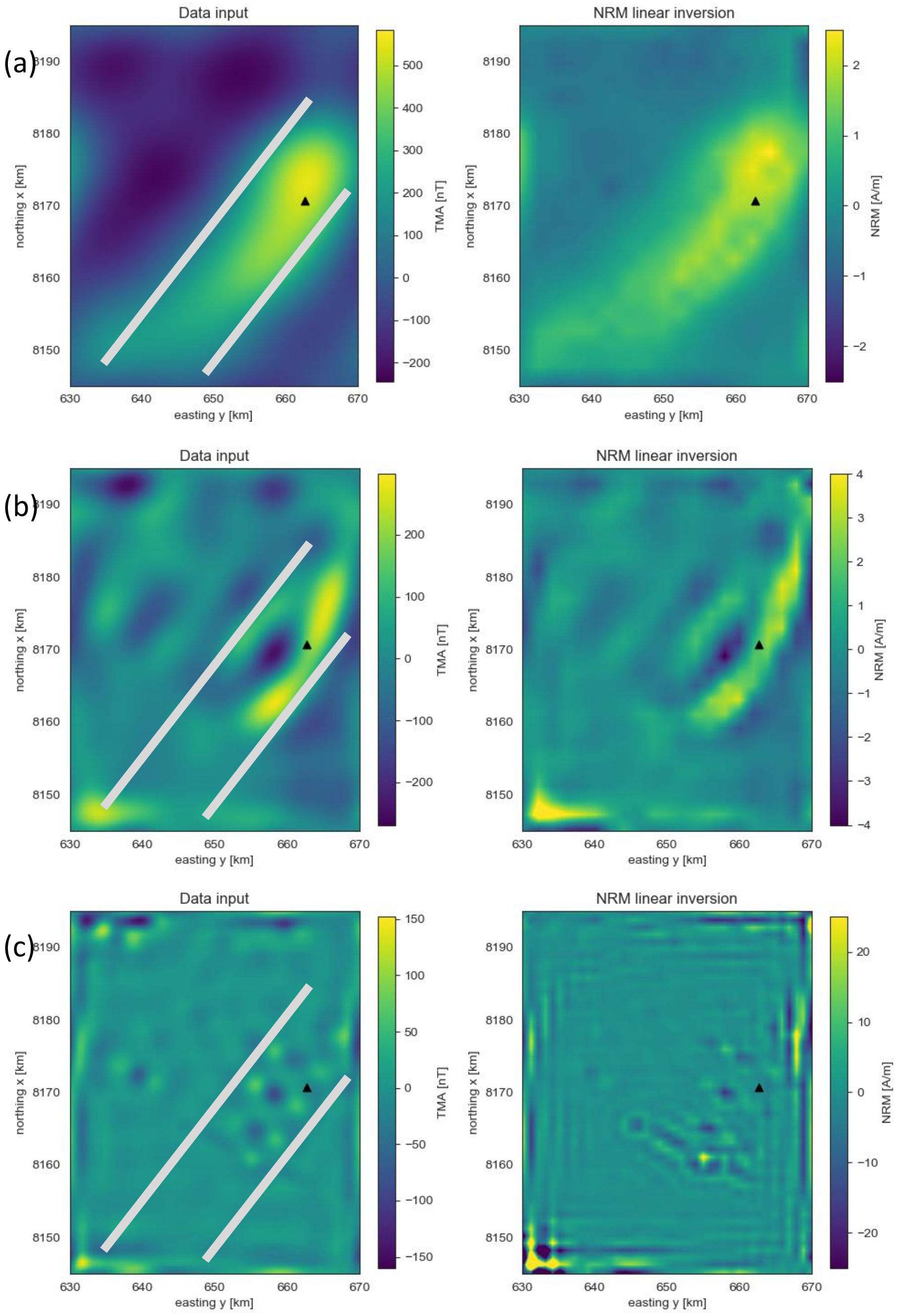


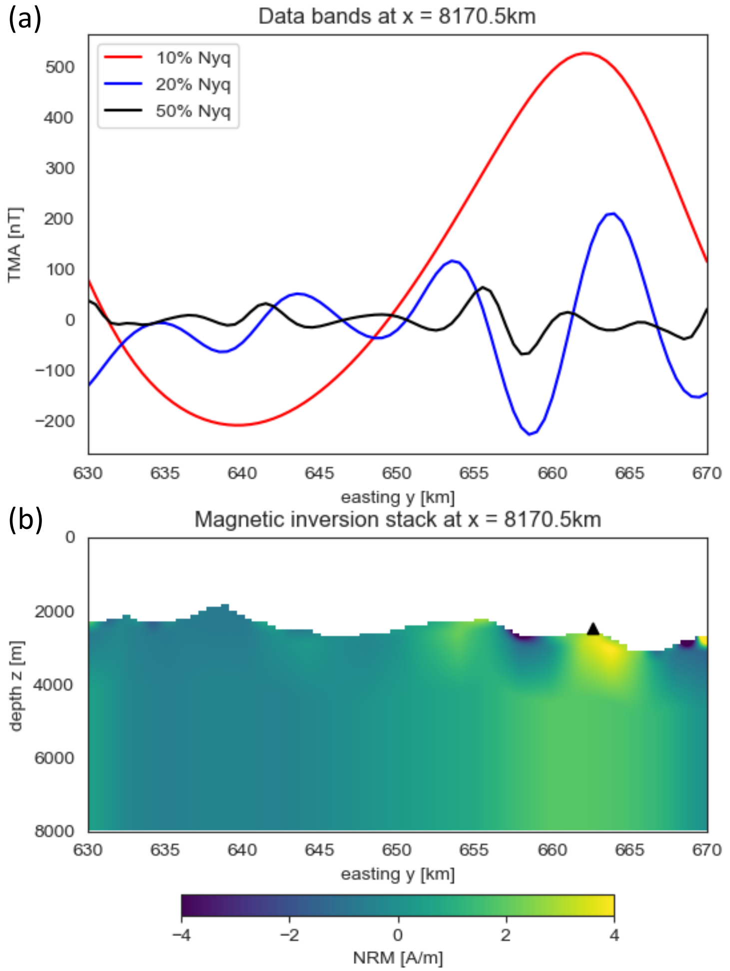


Mohn’s Ridge aeromagnetic



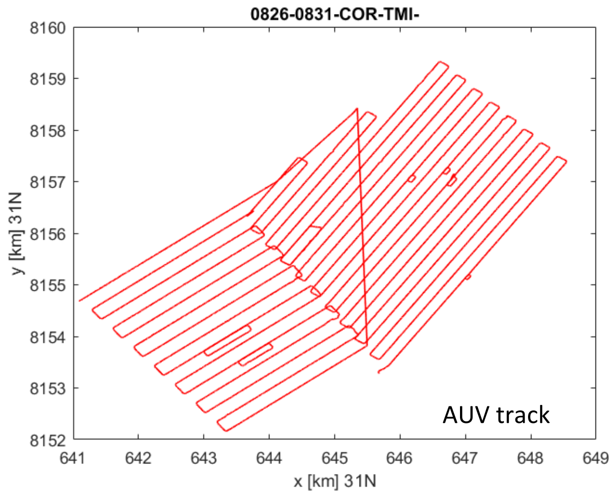
Assuming spreading rate of 15 mm/a

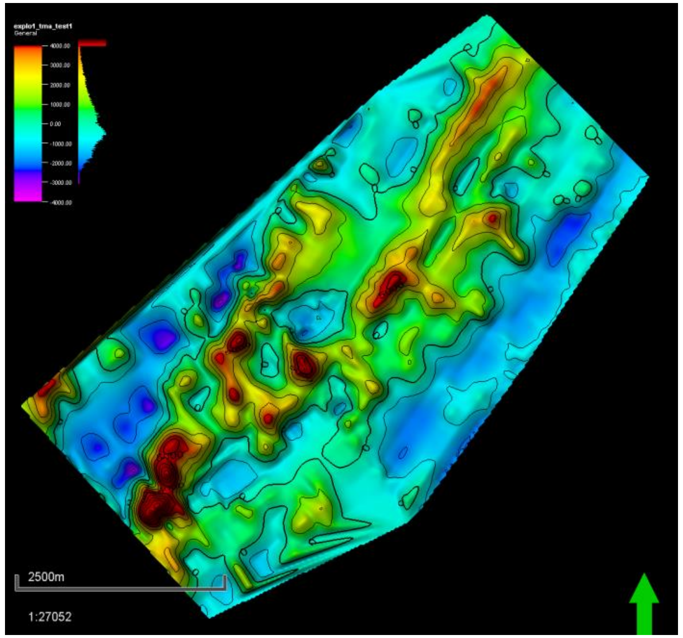




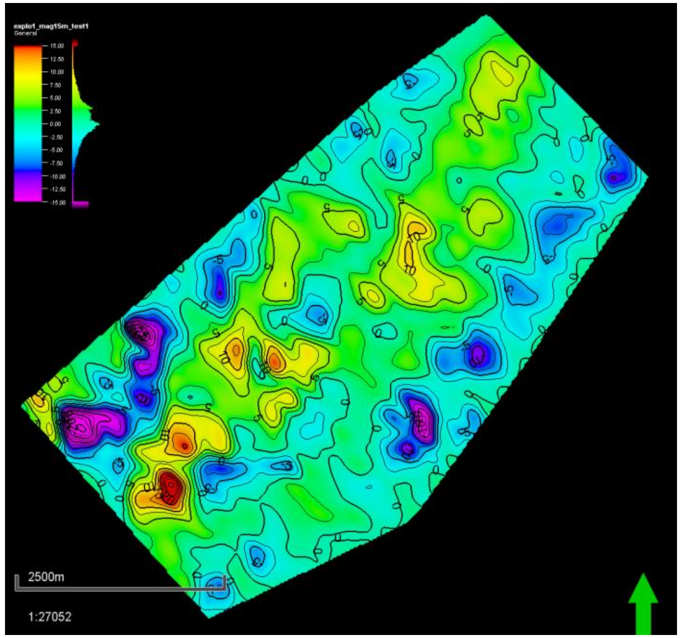
Magnetic inversion

- Data from NTNU MarMine 2016 cruise to Mohn's Ridge (Lim et al., 2019)
- Inhouse magnetic inversion code
- Remanent and induced magnetization

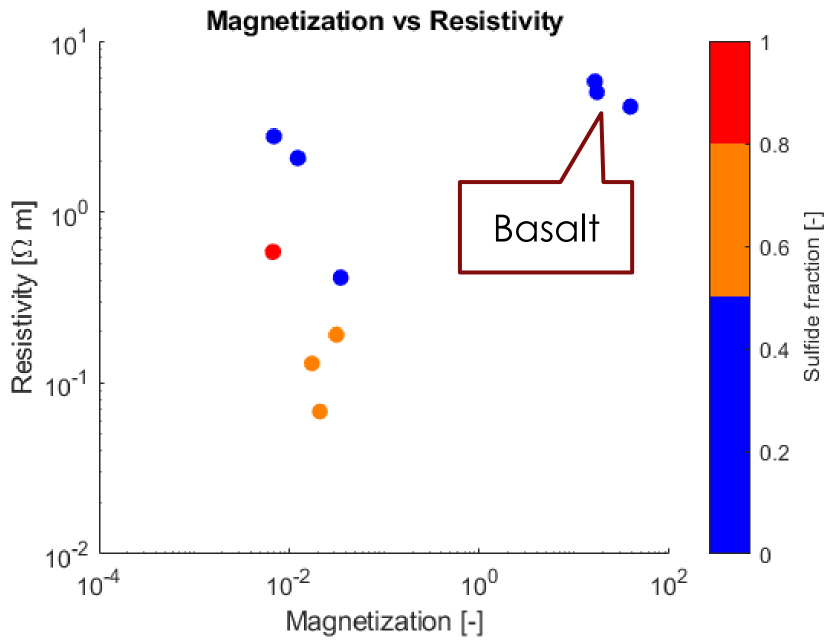




Total magnetic anomaly (TMA)



Magnetization from inversion

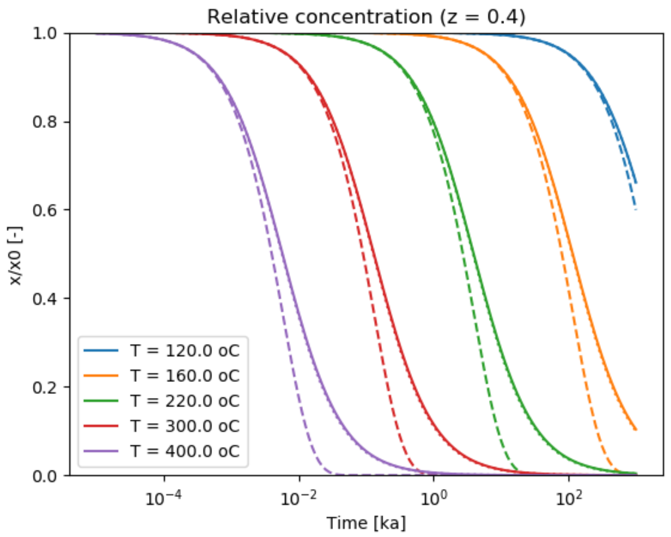


Data from TAG (ODP Leg 158)

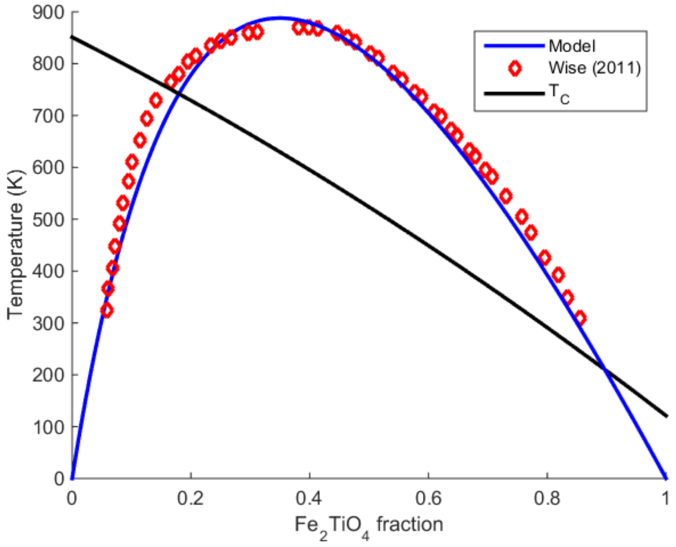
Controls on magnetization (the dipole moment per unit volume)

1. Oxydation (oxy-exsolution)
2. Solid exsolution(true exsolution)
3. Temperature dependence
4. TODO: Oxygen fugacity

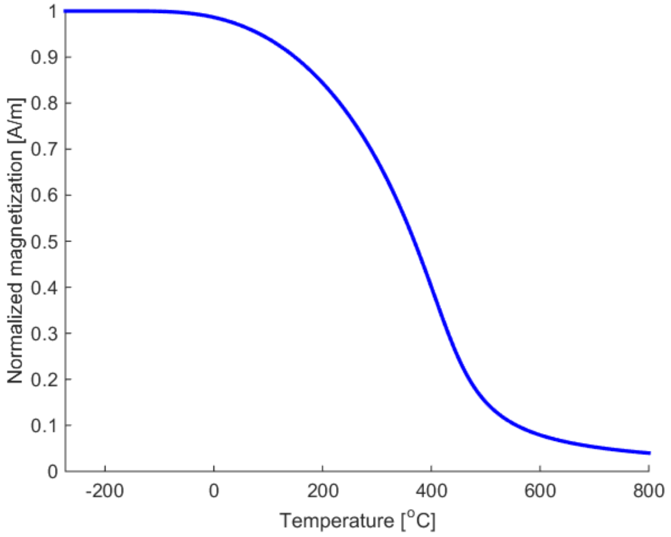
Low-temperature oxidation



Solid exsolution



Ising (1929) model



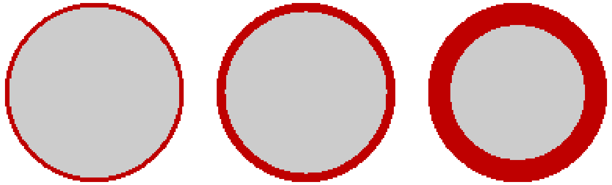
Oxidation of Ti-magnetite

- The main carrier of magnetism in oceanic crust is titanomagnetites (TM) and its oxidation products (Ti-maghemites)
- Fresh basalt (MORB): TM60 (60% Ulvöspinel)

$$Fe_{3-u}Ti_uO_4, \qquad u \simeq 0.6 \quad (TM60)$$

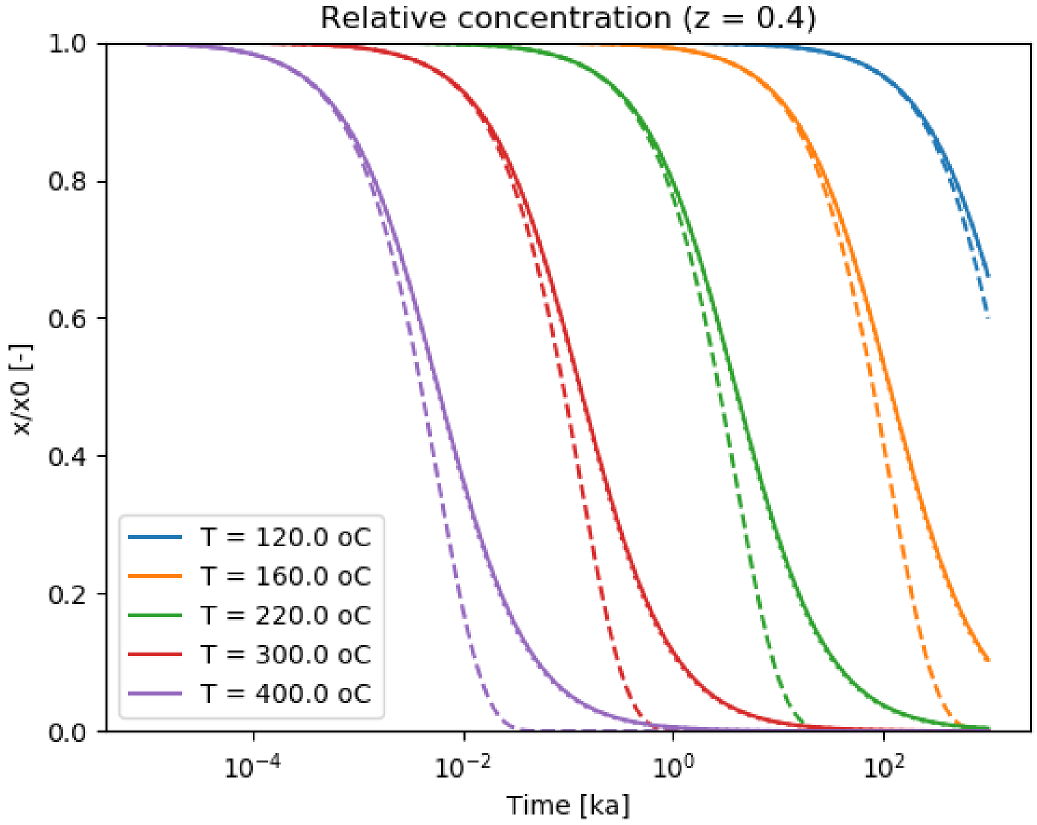
- Low-T oxidation (T<350 °C):

Ti-magnetite → Ti-maghemite



- Mixed-order kinetic model

$$\frac{dx}{dt} = -[k_1x^2 + k_2(1-x)x]$$
$$k_1 > k_2$$



Chemistry fun (Johnsen and Hall, 1978; Oliva-Urcia et al., 2010)

- Possible reactions taking place in TM oxidation and hydrothermal alteration

$$Fe^{2+} + \frac{1}{2}O_2 \rightarrow zFe^{3+} + (1-z)Fe^{2+} + zO^{-}$$

$$Fe_2TiO_4 + 2H^+ \rightarrow FeTiO_3 + Fe^{2+} + H_2O$$

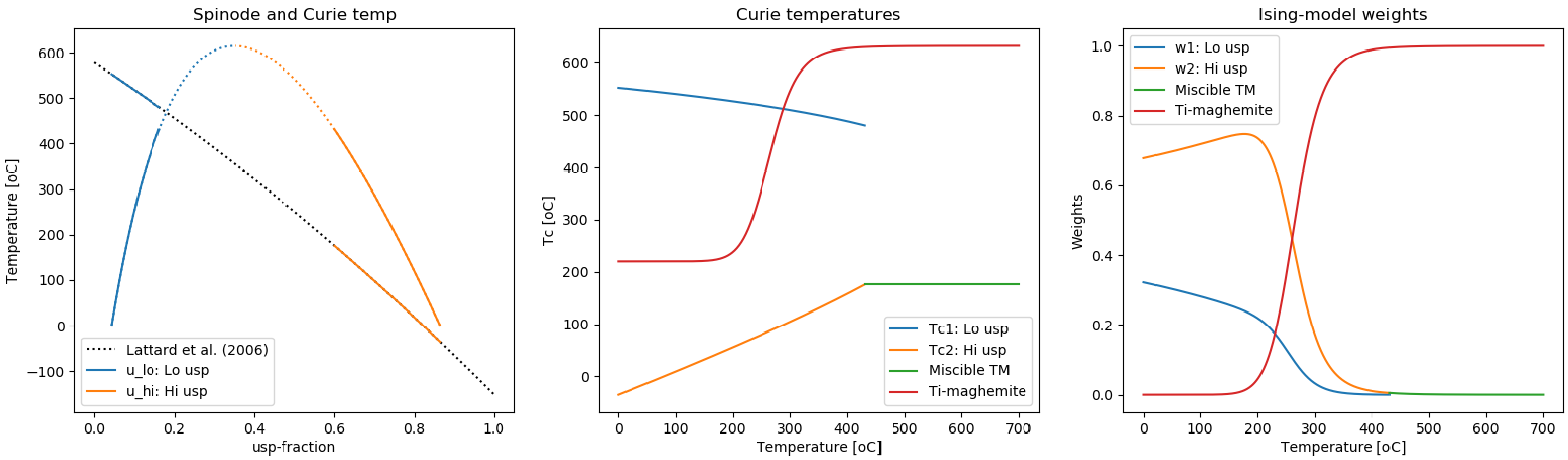
- TM oxidation is part of the SMS formation process

$$2H_2S + Fe^{2+} \rightarrow FeS_2 + 2H^+$$

$$2H_2S + Fe^{2+} + CuCl_2 \rightarrow CuFeS_2 + 2HCl + 2H^+$$

…

Magnetization forward model – putting things together



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Magnetization forward model
Part of multigeophysical inversion