

A BAYESIAN FRAMEWORK FOR SIMULTANEOUS DETERMINATION OF SUSCEPTIBILITY AND MAGNETIC THICKNESS FROM MAGNETIC DATA



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1. INTRODUCTION

Estimating the Depth to the Bottom (DTB) of magnetic sources is a popular interpretation step applied to magnetic anomaly data. Since the DTB might be related to the Curie isotherm, this is a possible link between the crustal magnetic field and the thermal state of the lithosphere.

The most common way of estimating DTB are spectral techniques. The power spectrum inside separate windows is fit with a theoretical spectrum that depends on the mean DTB in the window. Interpolating between the windows then creates a map of DTB in the study region.

Numerous criticisms have been raised against spectral DTB determination. E.g. the spectral estimates might be unreliable, the results depend heavily on window size and important parameters are chosen ad-hoc.

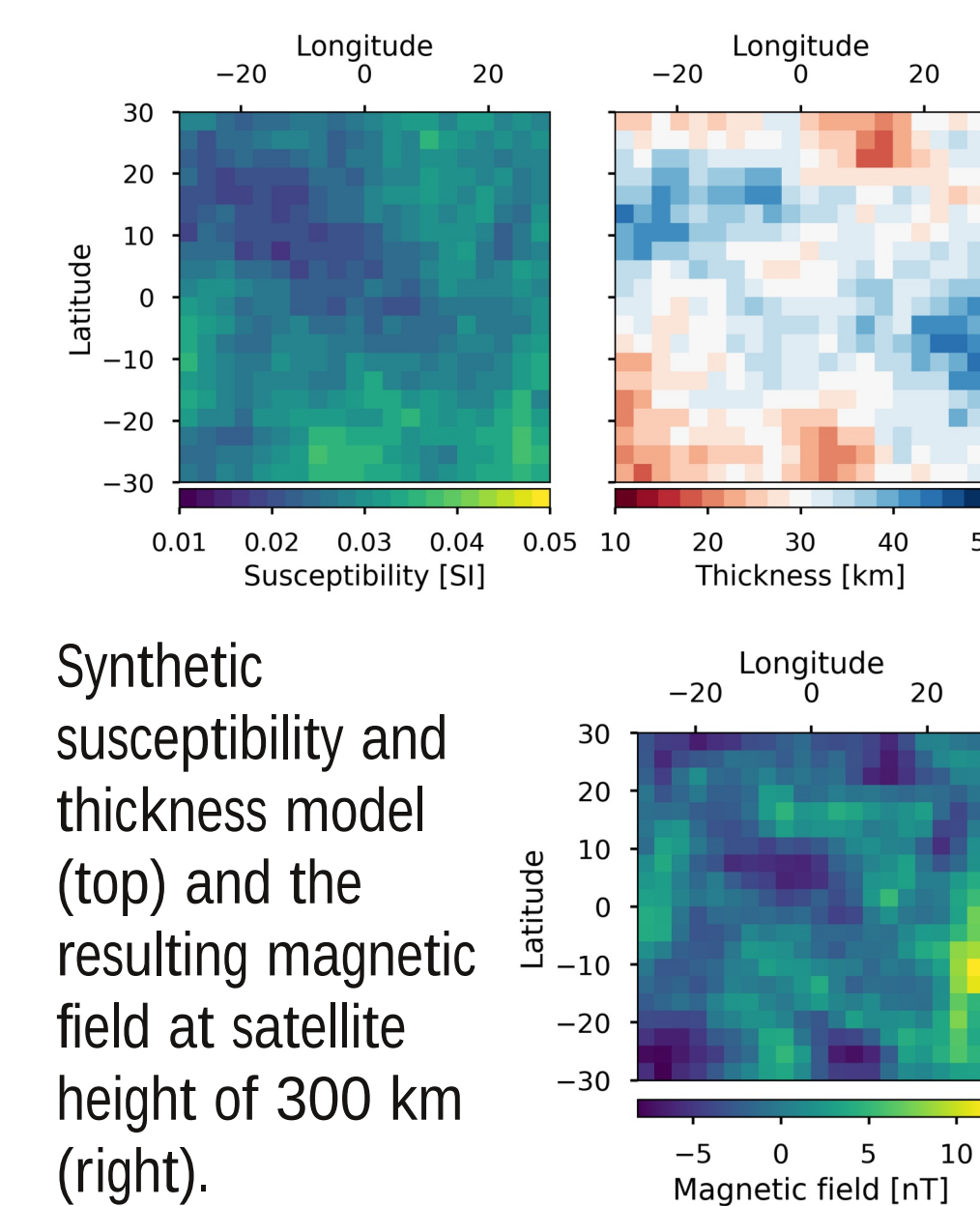
In light of these criticisms, we have developed a Bayesian treatment of the estimation problem in space domain. We simultaneously determine the susceptibility and DTB distribution, because there is substantial trade-off between the two. Using a Monte Carlo Markov Chain (MCMC) approach, uncertainties from model parameter choice are considered in the final uncertainties, giving a more realistic picture of the method's reliability. Here we present the new method and first results after application to synthetic data.

2. PARAMETRIZATION

- Satellite magnetic data (300 km height)
- Model size: 21 x 21 cells with ~ 300 km edge length
- Each cell has a constant susceptibility and thickness value
- Forward magnetic calculation with in spherical domain with tesseroids
- Susceptibility and thickness have Matérn covariance function, these describe either field's smoothness
- The parameters of the covariance functions are not fixed, but estimated based on magnetic data
- Point-wise constraints on DTB from heat flow measurements can also be included

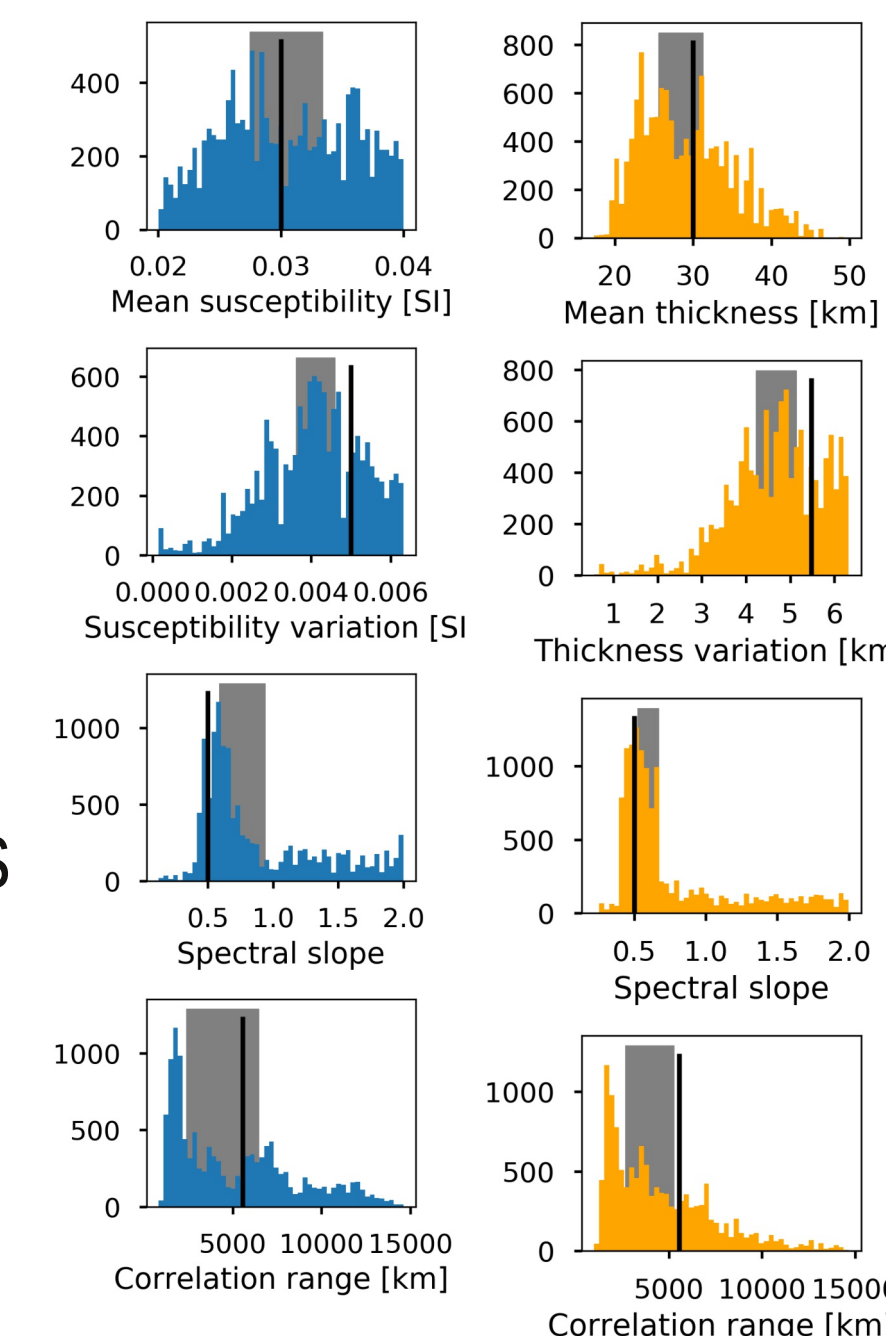
3. SYNTHETIC MODEL GENERATION

- We generate synthetic susceptibility and thickness from a Matérn covariance function using spherical harmonics
- Each random field then depends on 4 hyper-parameters:
 - Mean value,
 - Variability (i.e. standard deviation),
 - Spectral slope (smoothness)
 - Correlation length (smoothness)



4. BAYESIAN INVERSION APPROACH

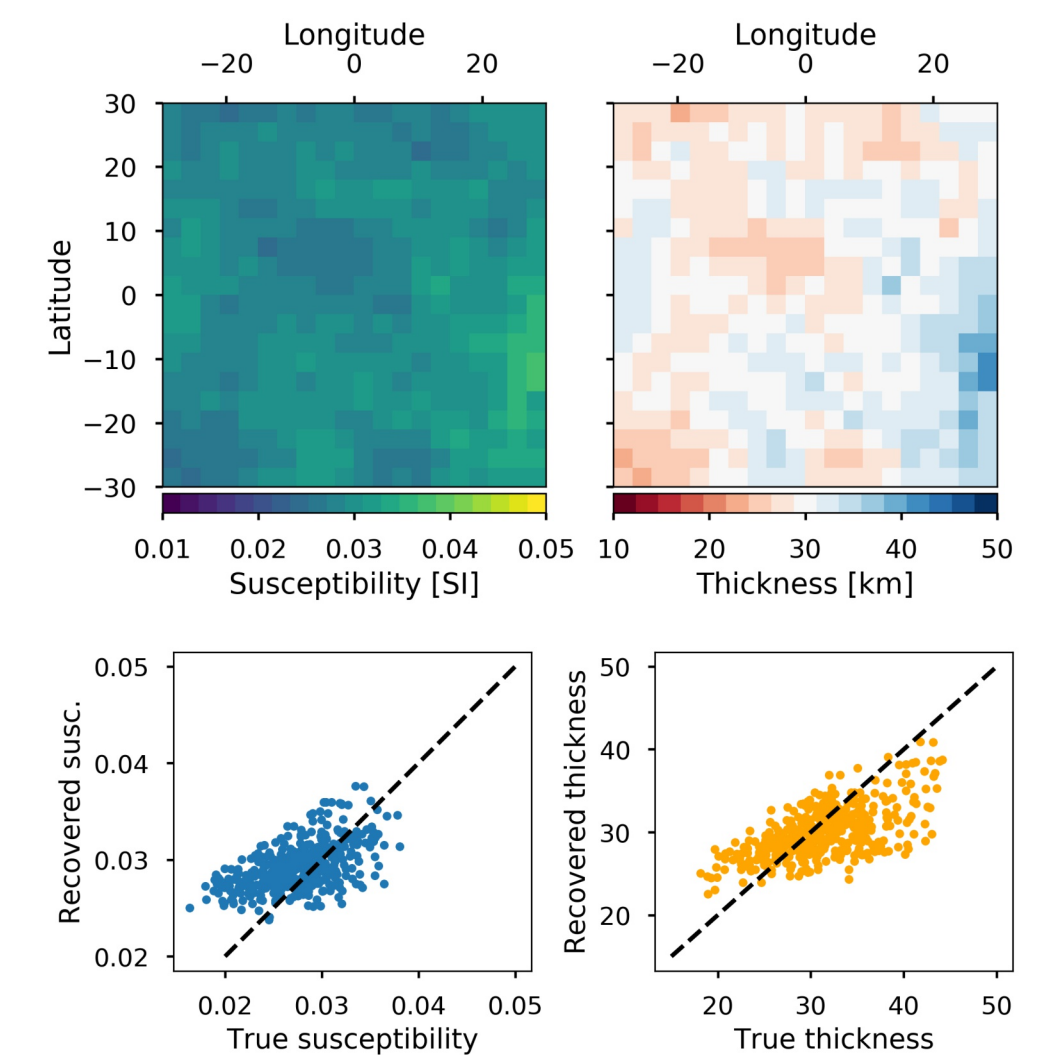
- The goal is to find susceptibility and thickness distributions that explain the magnetic data and are compatible with pointwise heat flow-derived depth estimations
- We break the inversion into two steps
- First, the hyper-parameters describing the spatial nature of susceptibility and thickness are estimated using Monte Carlo Markov Chain (MCMC). This generates an ensemble of parameter values (see histograms on right)
- Second, the ensemble of hyper-parameters is used to invert for susceptibility and thickness. The solution is then found as the mean of all susceptibility and thickness results



5. INVERSION RESULTS

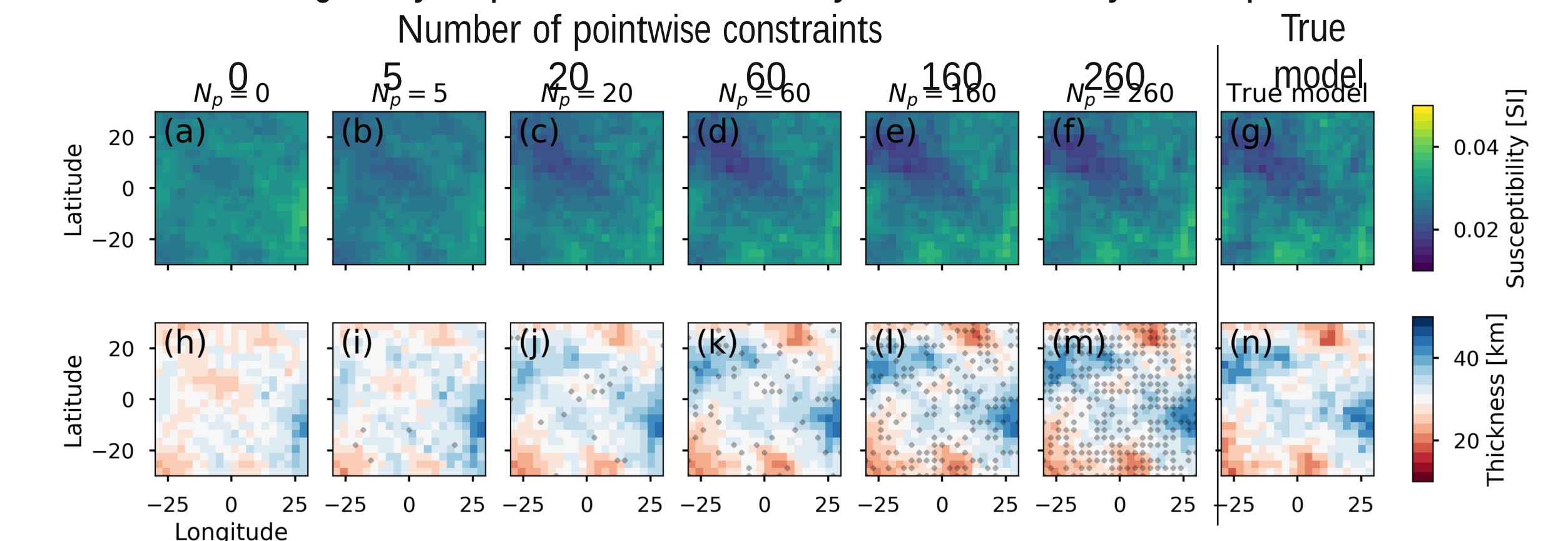
For the first inversion, no heat flow constraints were included

- The recovered susceptibility and thickness are highly correlated. Effectively, only their product is resolved.
- The variability is subdued compared to the actual synthetic model.



6. HEAT FLOW CONSTRAINTS

We now include pointwise constraints that simulate Curie depth estimations from heat flow. This greatly improves the recovery, even with only a few points.



7. CONCLUSIONS

- We present a new Bayesian approach to analyze the estimation of susceptibility and magnetic thickness from magnetic data
- First results highlight the importance of additional constraints

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