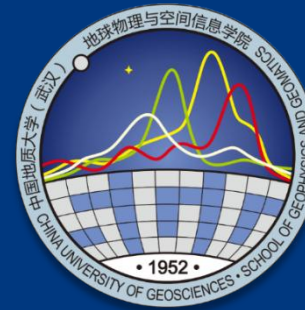


Estimating Curie Point Depth Beneath the Tibetan Plateau and Surrounding Regions Using Bayesian Inference and Wavelet Analysis

ESA-MOST Dragon Cooperation

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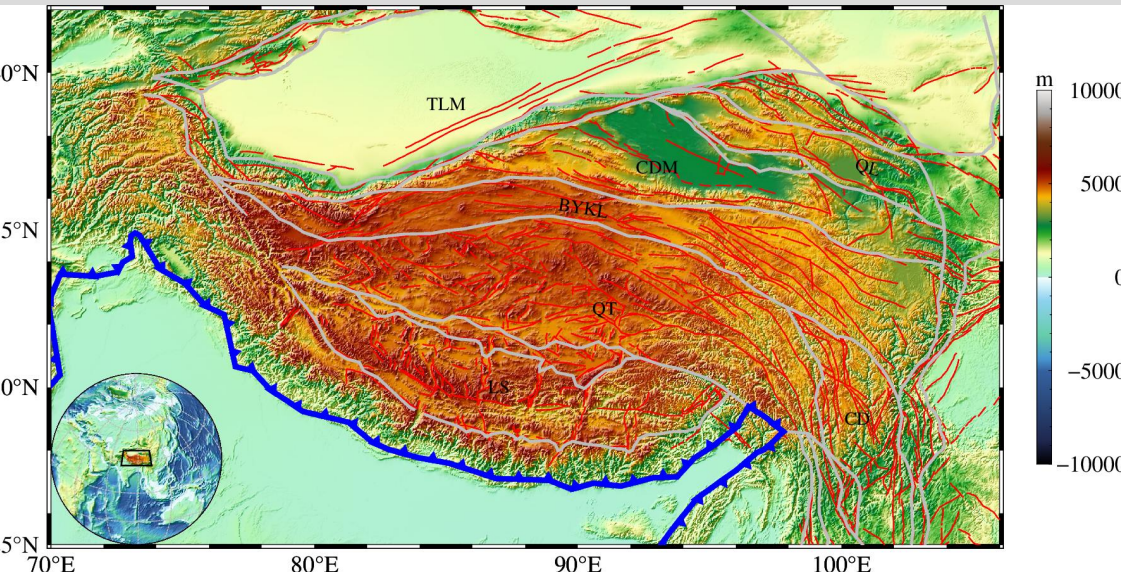
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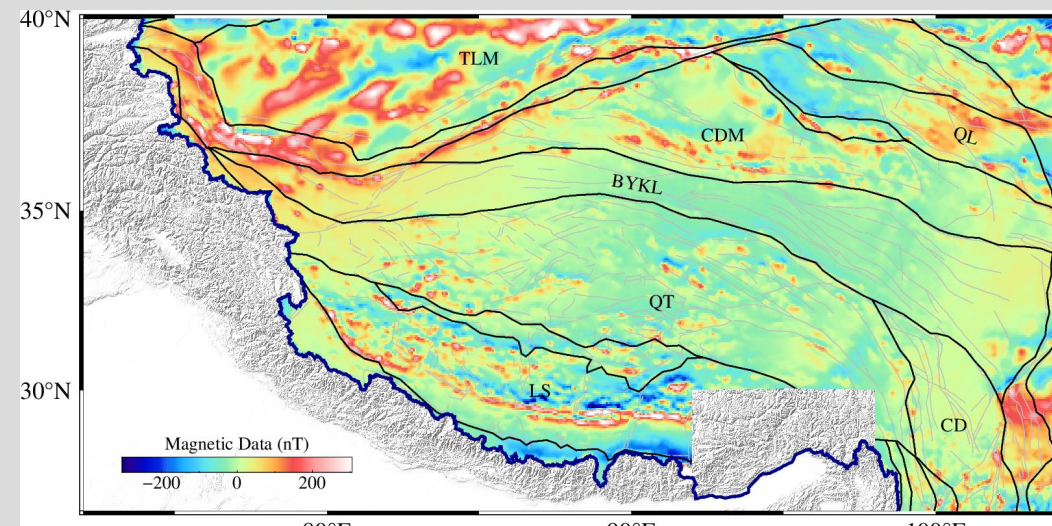
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Introduction



Major faults in red, Eurasian plate boundary in blue, surrounding active landmasses in gray;
TLM-Tarim landmass, CDM-Chaidam landmass, QL-Qilian landmass, BYKL-Bayanqara landmass, QT-Qiangtang landmass, LS-Lhasa landmass, CD-Chuan-Yunnan landmass



Aeromagnetic anomalies in the study area

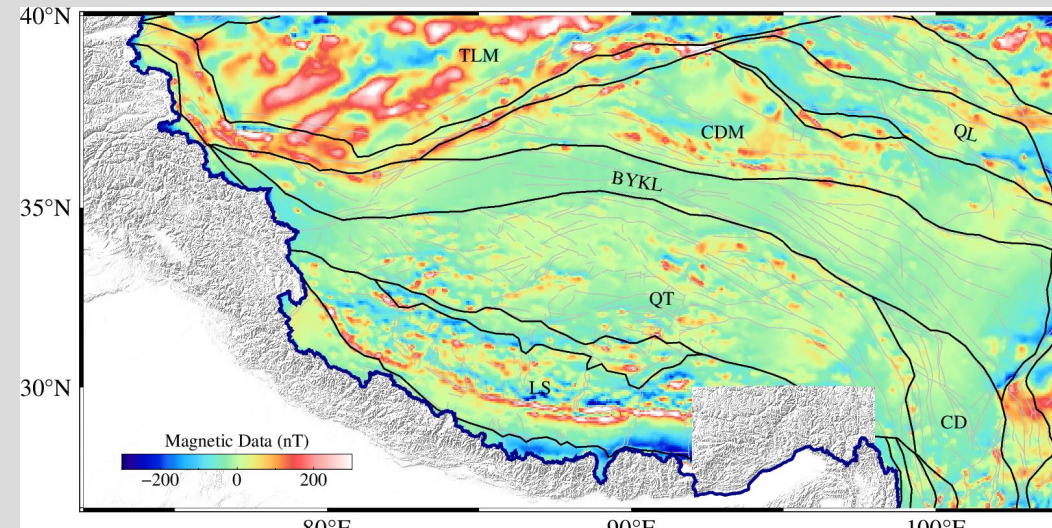
Background

1. The Tibetan Plateau - a product of the collision between the Indian Plate and the Eurasian Plate, inhabited by the study helps to reveal the deep thermal structure of the plateau and the mechanism of tectonic evolution.
2. Tibetan Plateau exhibits low magnetic anomaly.
3. The Long-wavelength component of aeromagnetic anomaly data are unreliable.
4. The long-wavelength component of the aeromagnetic anomaly, which is unreliable, was replaced using LCS-1 data, following the method described in Zhang et al. (2022).

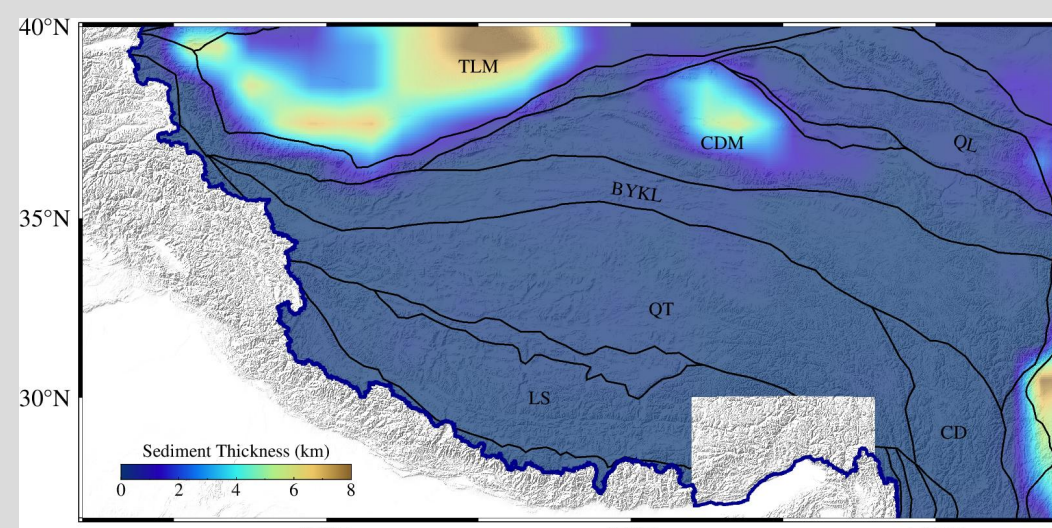
Key research priorities:

Curie point depth, Qinghai-Tibet Plateau, Bayesian inversion

Data



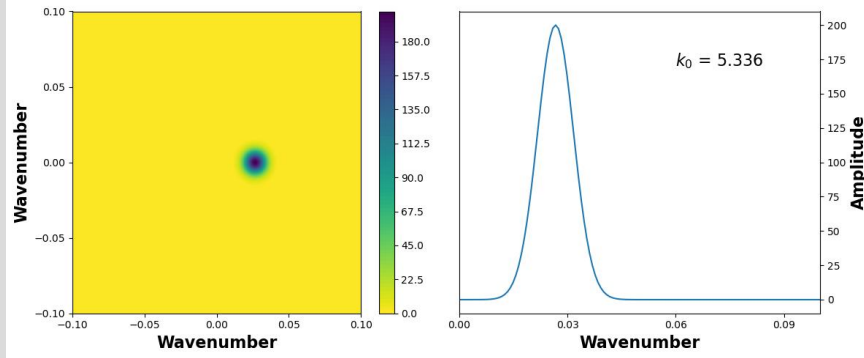
Data after replac the Long-wavelength component



Sedimentary thickness data

- Replace the 16–90 degree components of the aeromagnetic data with the 16–90 degree components of the LCS-1 model using the 2D revised spherical cap harmonic analysis (R-SCHA2D) method (Zhang et al., 2022).
- To enhance inversion accuracy, constrain the fixed parameter Z_i with sedimentary thickness data from ECM1 (Mooney et al., 2023). Interpolate the original $1^\circ \times 1^\circ$ sediment layer resolution to match the magnetic anomaly data resolution for compatibility.

Methods



$$\hat{\psi}^*(k) = \frac{1}{N_\theta} \sum_{i=0}^{N_\theta-1} e^{-\frac{[a - \log(\sin \theta) \hat{r}^2 + (-\log \sin \theta) \hat{r}]^2}{2}}$$

$$P(m|d) = \frac{P(d|m)P(m)}{P(d)} \begin{cases} m = (A, \beta, Z_i, \Delta Z) = (A, \Delta Z) \\ P(m|d) = Ce^{-\sum_{i=1}^n \frac{(\mu_i - d_i)^2}{2\sigma^2}} \\ P(m): \text{prior information, using a reasonable range of Gaussian or uniform distributions;} \\ P(d): \text{likelihood} \end{cases}$$

$$|\Phi_r(k)|^2 = Ck^{-\beta} e^{-2|k|Z_i} (1 - e^{-|k|\Delta Z})^2$$

$$\ln(|\Phi_r(k)|^2) = \ln(C) - \beta \ln(k) - 2kZ_i + 2 \ln(1 - e^{-k\Delta Z})$$

Fan wavelets are defined as complex wavelets averaged over Morlet wavelet superposition.

The PSD for the definition of wavelet transform in the Fourier domain is:

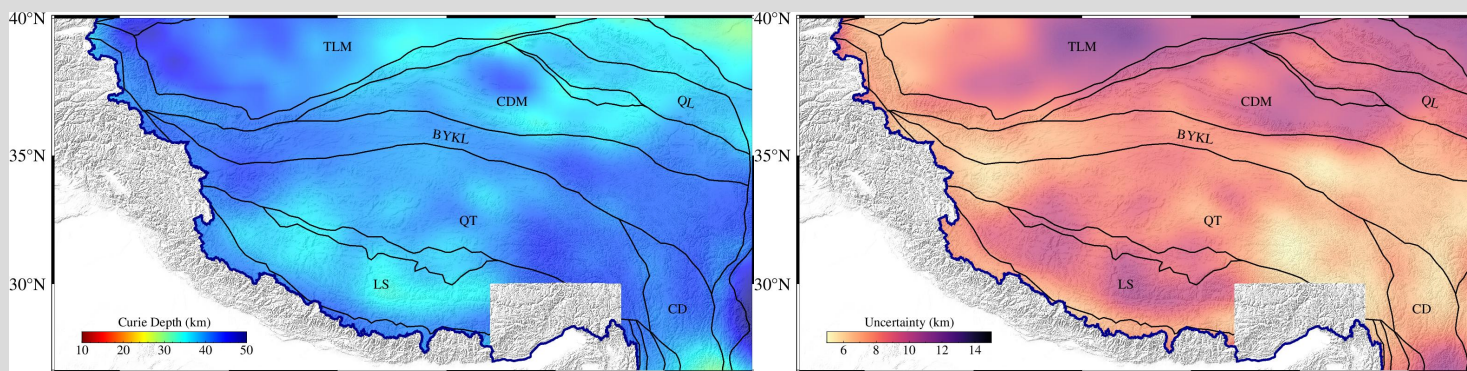
$$S(a, b) = \frac{1}{N_\theta} \sum_{i=0}^{N_\theta-1} |W[f]_{a,b,\theta_i}|^2$$

Bayesian methods are used instead of traditional linear or nonlinear fitting inversion, The inversion was constrained using ECM1 data for Z_i , with fixed β values of 2.5, 3.0, and 3.5.

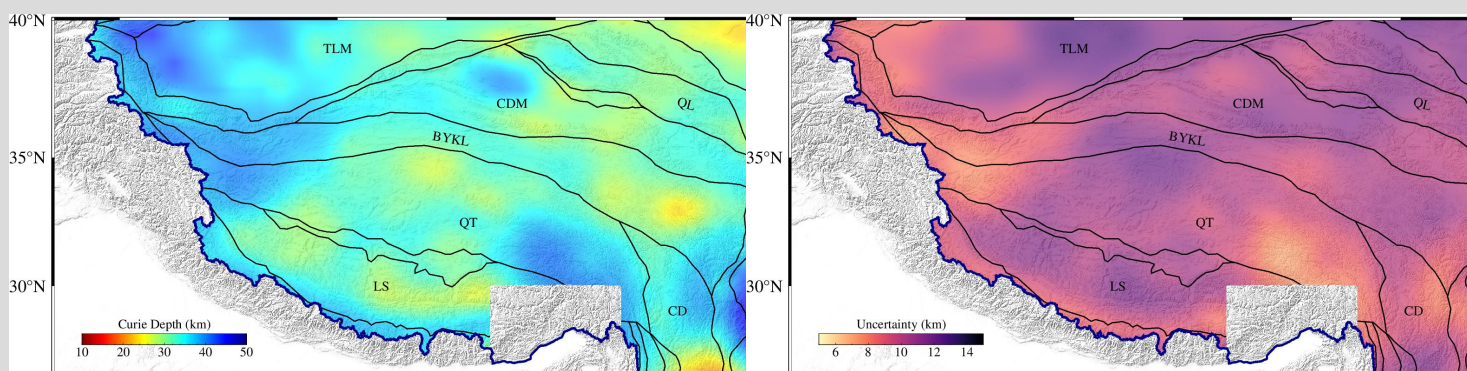
The theoretical PSD is defined as the equation on the left, corresponding to the wavelet transform $S(a, b)$

Result

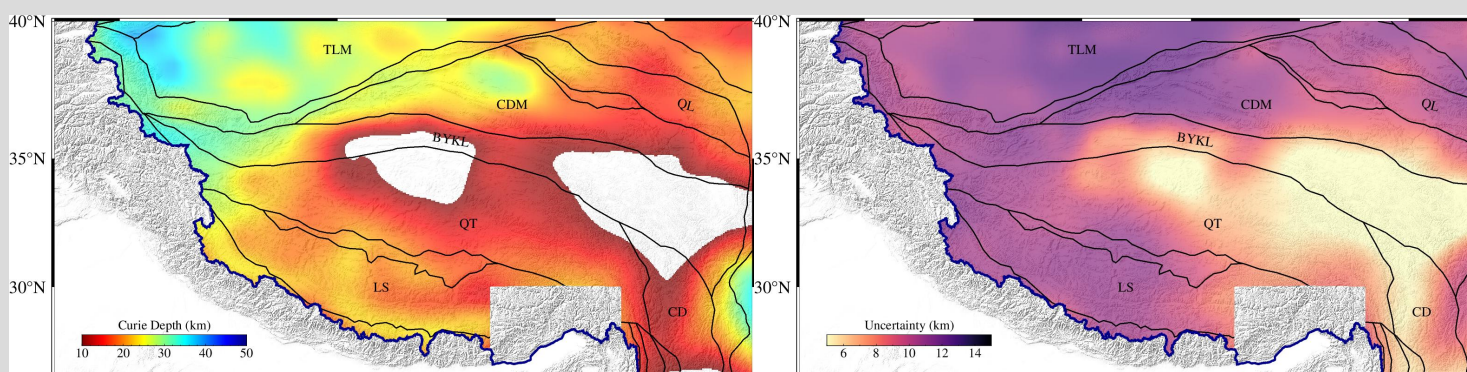
- The central wavenumber k_0 used in the study was 5.336
- As β increases from 2.5 to 3.5, the overall Curie point depth across the Tibetan Plateau decreases from ~40 km to ~20 km.
- The Bayan Har and Qiangtang terranes exhibit more dramatic reductions, reaching only ~10 km at $\beta=3.5$.
- The amplitude of depth variation in the Tibetan Plateau significantly exceeds that of the Tarim Basin.
- Despite β variations, the hierarchical depth relationships among regions remain unchanged, confirming the reliability of their differential patterns.
- Uncertainty has little to do with β selection and is tied to the Curie point depth results of the inversion.



$\beta=2.5$



$\beta=3.0$



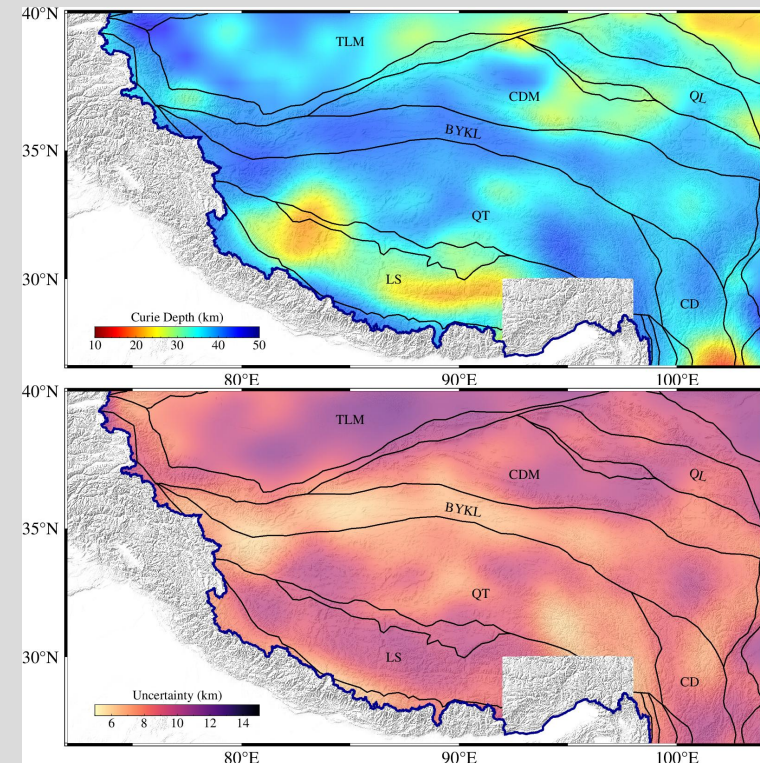
$\beta=3.5$

Inversion of the Curie point depth of the study area ($k_0=5.336$) and its uncertainty distribution (white part is the area with depth <10km)

Discussion

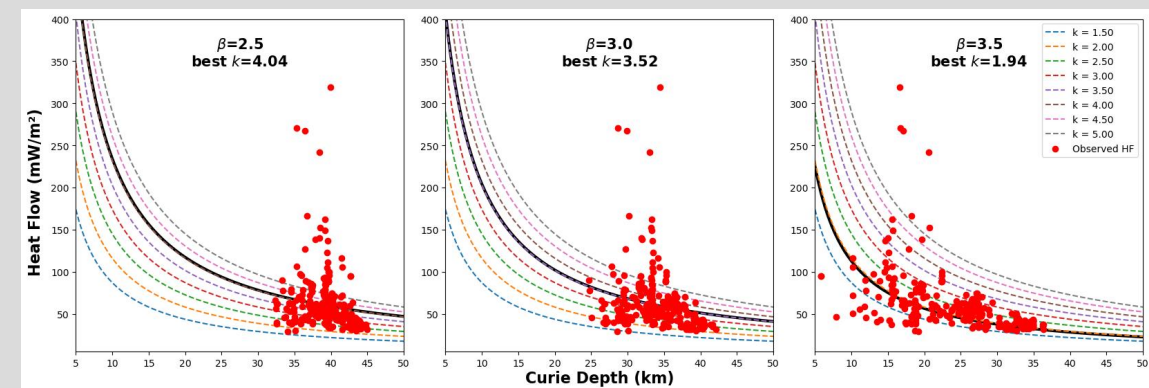
Different k_0 ($=7.547$) discussion

1. Regions that are deeper/shallow at low k_0 remain relatively deeper/shallow at high k_0 .
2. Uncertainty distribution generally correlates with Curie point depth results and decreases as k_0 increases.
3. The reduction in uncertainty at higher k_0 may result from insufficient resolution of Long-wavelength components, which typically exhibit higher uncertainty.
4. Increasing k_0 leads to smoother inversion results with reduced topographic variations.



Heat Flow

The optimum thermal conductivities k for different values of β are 4.04 W/mK, 3.52 W/mK, and 1.94 W/mK, respectively.



The upper panel shows the inversion of the Curie point depth and its uncertainty distribution ($k_0 = 7.547$, $\beta = 3.0$) for the study area.
The lower panel shows the thermal conductivity fitting

$$q_0 = k \frac{T_c - T_0}{Z_c - Z_0} + H_0 h_c \frac{e^{-\frac{Z_c}{h_c}} - e^{-\frac{Z_0}{h_c}}}{Z_c - Z_0} + H_0 h_c e^{-\frac{Z_c}{h_c}}$$

Conclusions

- Successfully improved the resolution of Curie point depth in Tibet Plateau, thanks to newly aeromagnetic anomaly data.
- Bayesian inversion can be more accurately applied to spectral analysis, and it can give uncertainty.
- The Curie point depth is in general agreement with the tectonic blocks.
- In contrast to the window size of the Fourier method, the wavelet method has less influence on the change of k_0 .

References

- 熊盛青, 周伏洪, 姚正煦, 等. 青藏高原中西部航磁调查[J]. 物探与化探, 2007, 31(5): 404–407.
- 张攀, 杜劲松, 王震, 等. 区域航磁异常汇编数据的长波成分提取、评价与替换技术[J]. 地球物理学报, 2022, 65(7): 2595–2612.
- Audet P, Gosselin J M. Curie depth estimation from magnetic anomaly data: a re-assessment using multitaper spectral analysis and Bayesian inference[J]. Geophysical Journal International, 2019, 218(1): 494–507.
- Audet P, Mareschal J C. Wavelet analysis of the coherence between Bouguer gravity and topography: application to the elastic thickness anisotropy in the Canadian Shield[J]. Geophysical Journal International, 2007, 168(1): 287–298.
- Gaudreau E, Audet P, Schneider D A. Mapping Curie depth across western Canada from a wavelet analysis of magnetic anomaly data[J]. Journal of Geophysical Research: Solid Earth, 2019, 124(5): 4365–4385.
- Audet P, Gosselin J M. Curie depth estimation from magnetic anomaly data: a re-assessment using multitaper spectral analysis and Bayesian inference[J]. Geophysical Journal International, 2019, 218(1): 494–507.