国家自然灾害防治研究院
NATIONAL INSTITUTE OF NATURAL HAZARDS

Progress on CSES/Swarm geomagnetic field modeling

Yanyan Yang[1] on behalf of CSES/Swarm Mag cal/val team

[1]National Institute of Natural Hazards, Ministry of Emergency Management of China

Contact: PI of CSES HPM, youngyany@163.com

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Outline

- Progress on CGGM model
- Progress on lithospheric field modeling
- Summary

Background

In 2019, we built CGGM 2020.0 model based on CSES 19 months magnetic field data.

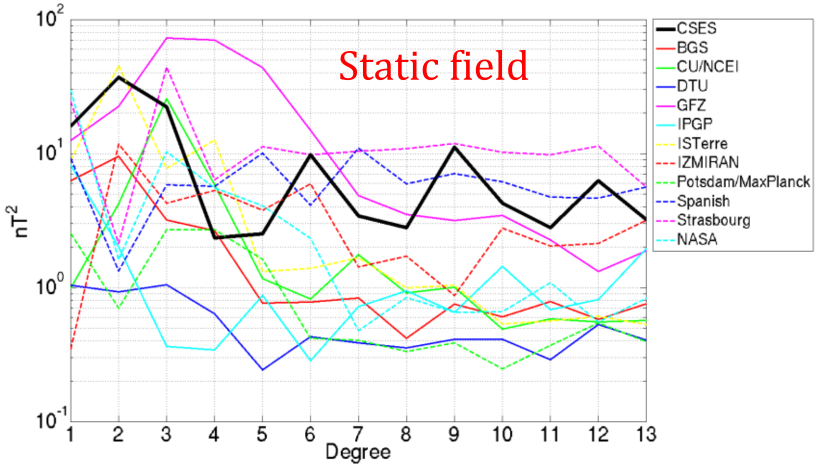
CGGM is an IGRF-type geomagnetic field model, which shows great potential of CSES data on core field modeling.

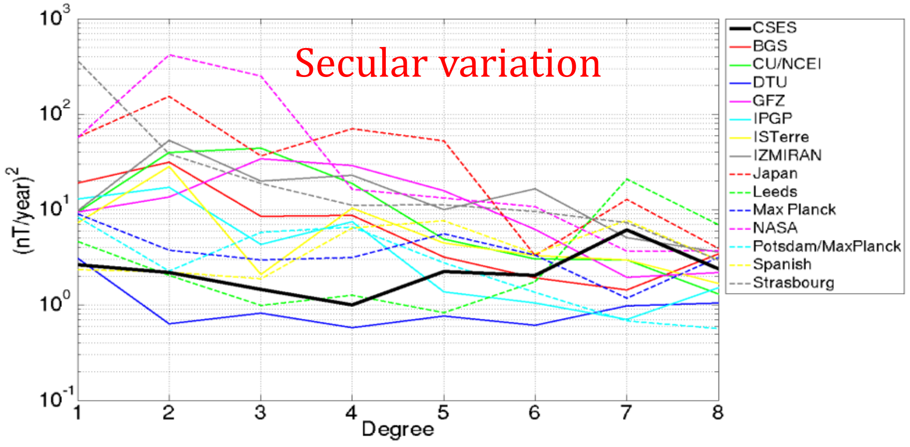
The good performance of the SV model may benefit from CSES revisiting orbit.

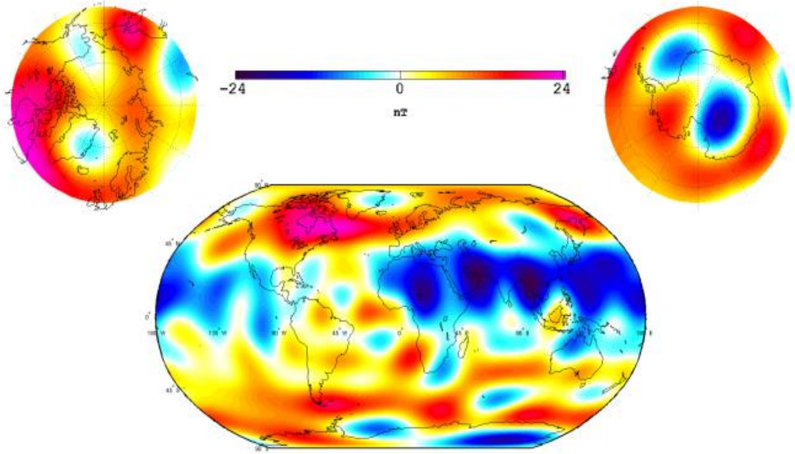
The model includes core and external field, is it possible to include lithospheric field model?

The necessary data improvement is needed!

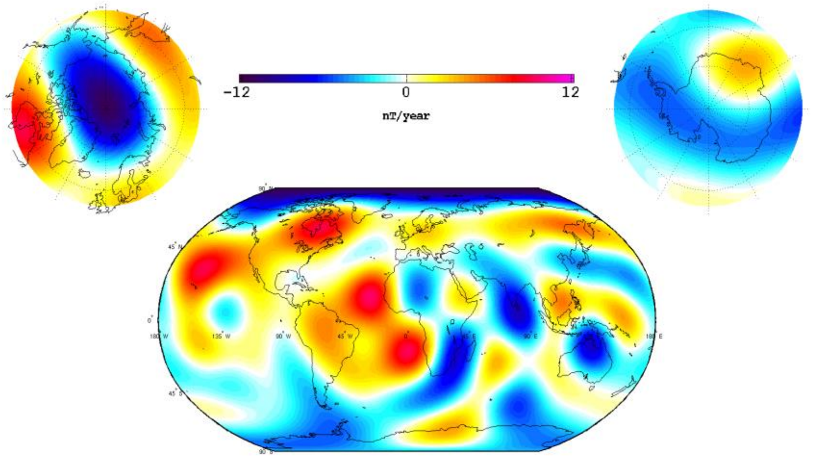
Comparison with other IGRF-13 candidate models



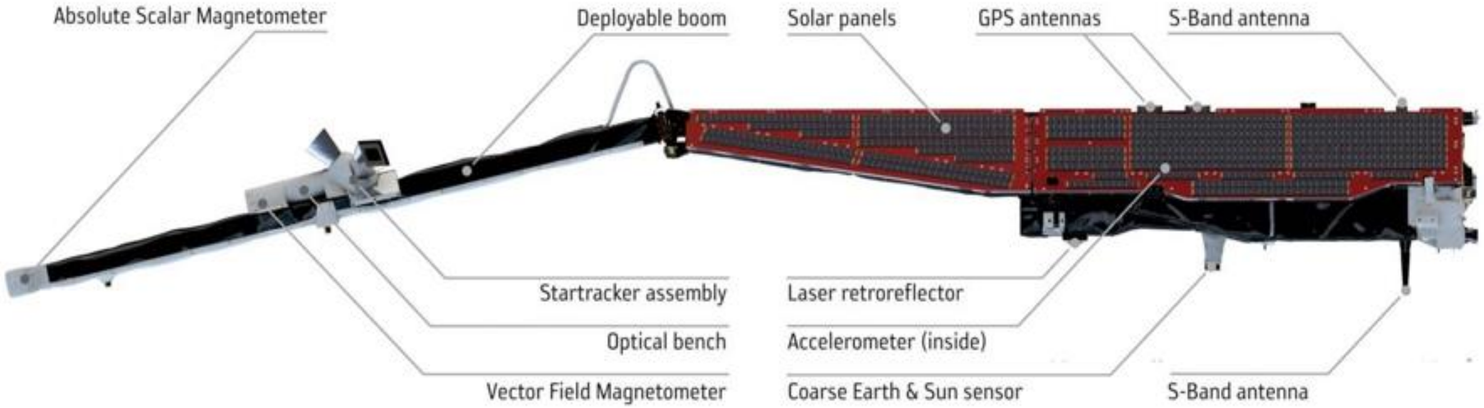




The difference between CSES-IGRF 2020 and official IGRF 2020 model

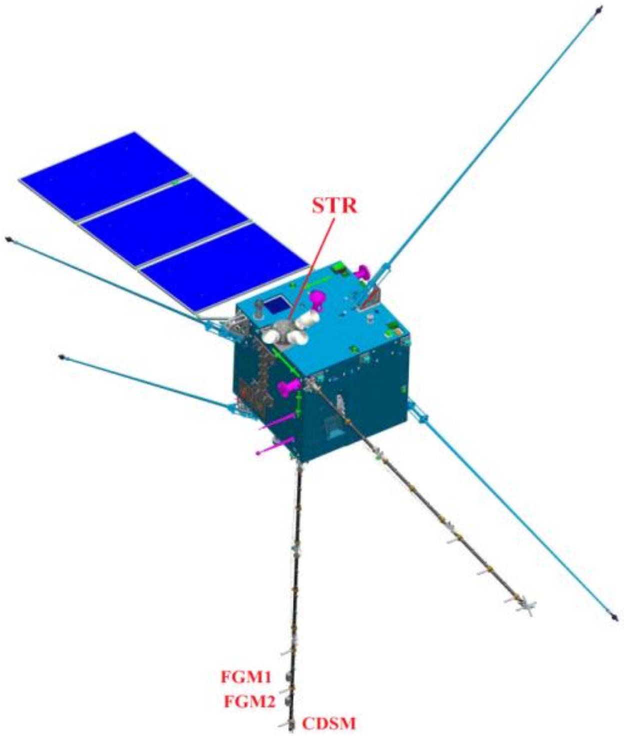


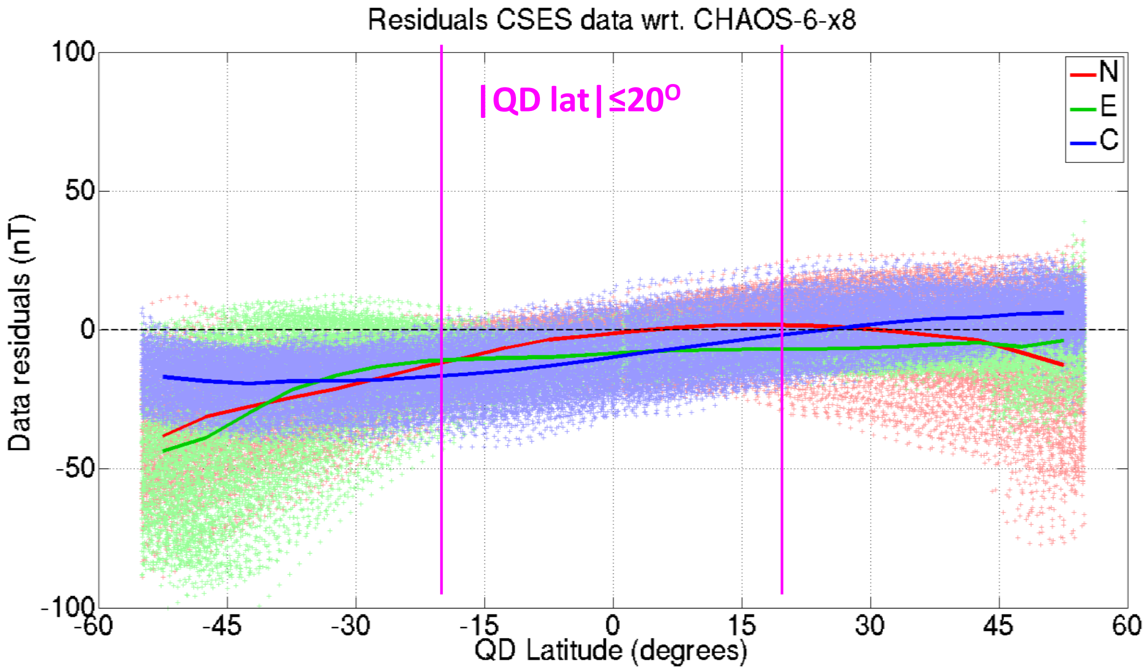
The difference between CSES SV 2020-2025 and official SV 2020-2025 model



The main issue: The Star camera is very far from FGM sensor, and the possible boom deformation are not included during the calibration.

A clear latitudinal trend can be seen in FGM vector data!



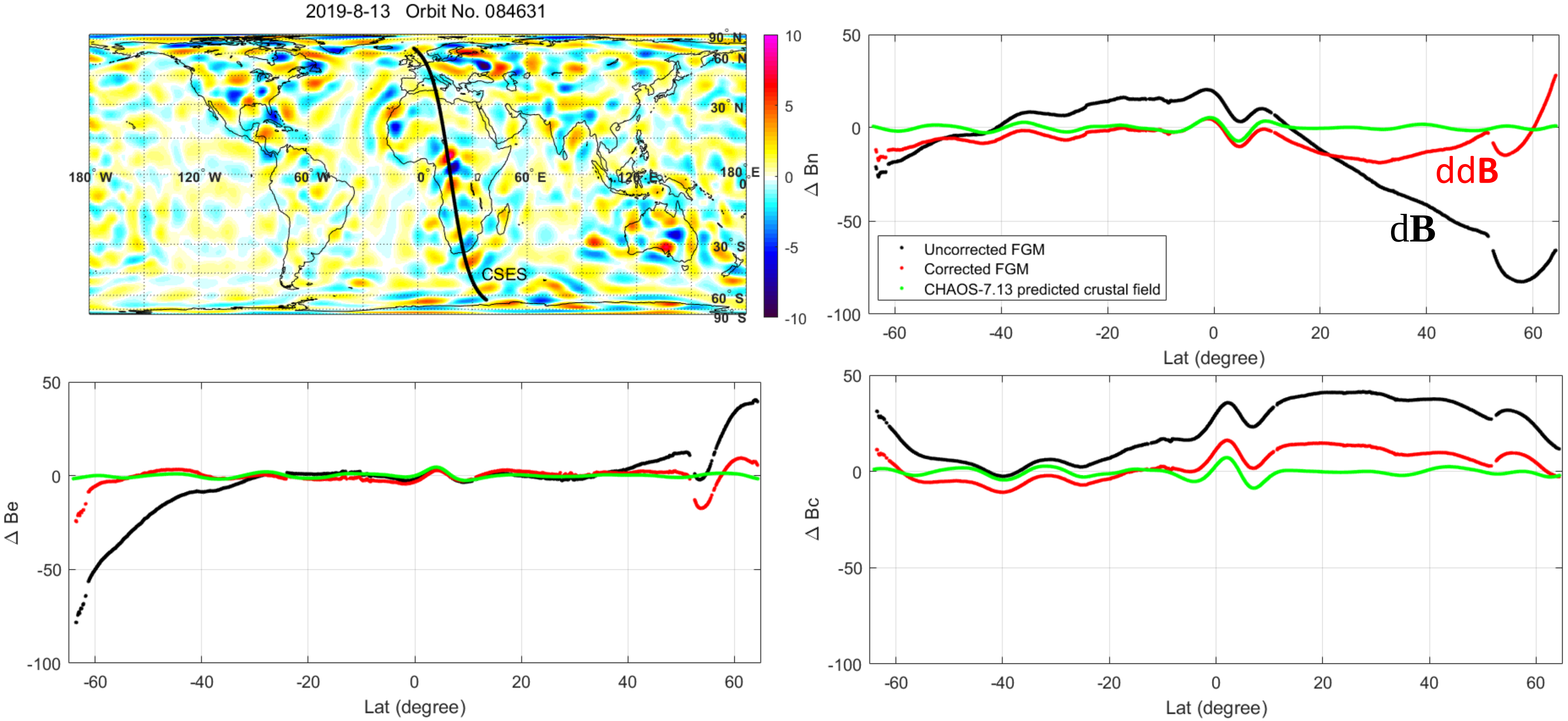


Data correction for boom deformation

Calculate the residual field $d\mathbf{B}=\mathbf{B}_{obs}-(\mathbf{B}_{core}+\mathbf{B}_{ext})_{CGGM}$ → Remove the latitudinal trend $dd\mathbf{B}= d\mathbf{B}\text{-polyfit}(d\mathbf{B})$ → Obtain the corrected new data $\mathbf{B}_{new}= \mathbf{B}_{obs}\text{-polyfit}(d\mathbf{B})$

Example correction from Bangui anomaly crossing

After the correction, we can remove the large trend caused by boom deformation and the lithospheric field is more remarkable

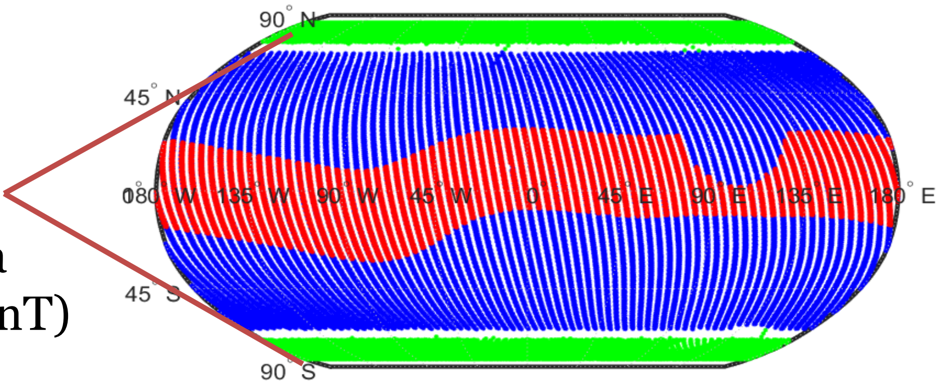


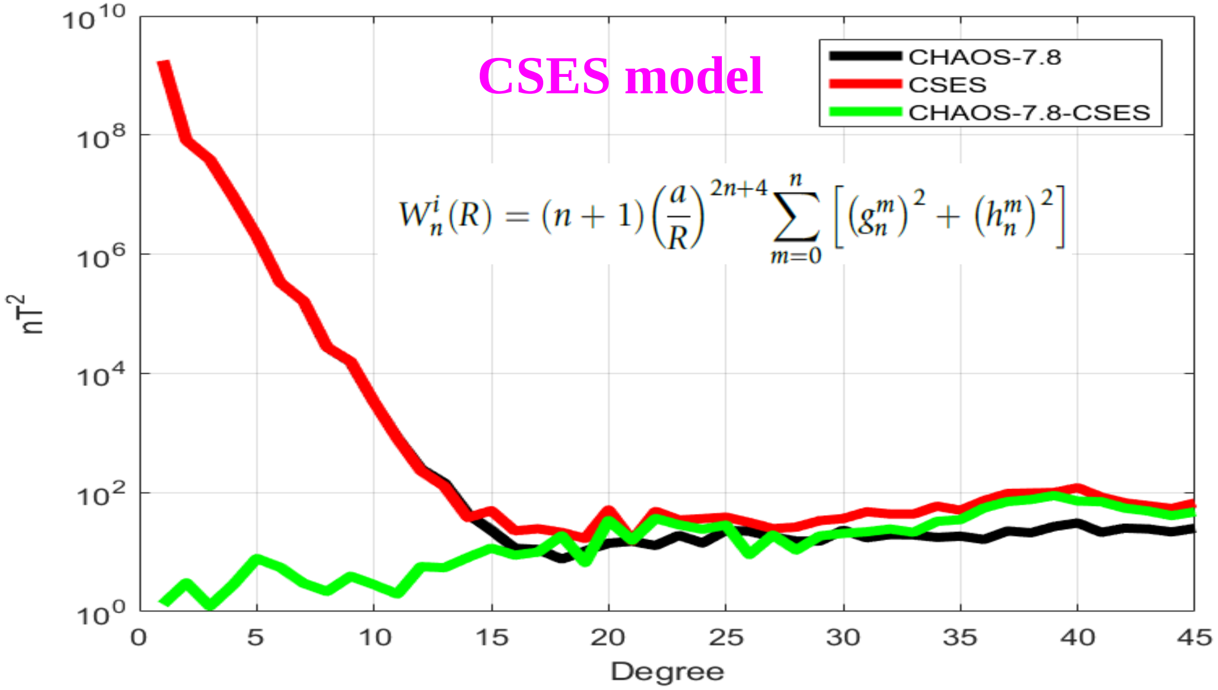
Updating scheme for new generation of CGGM model

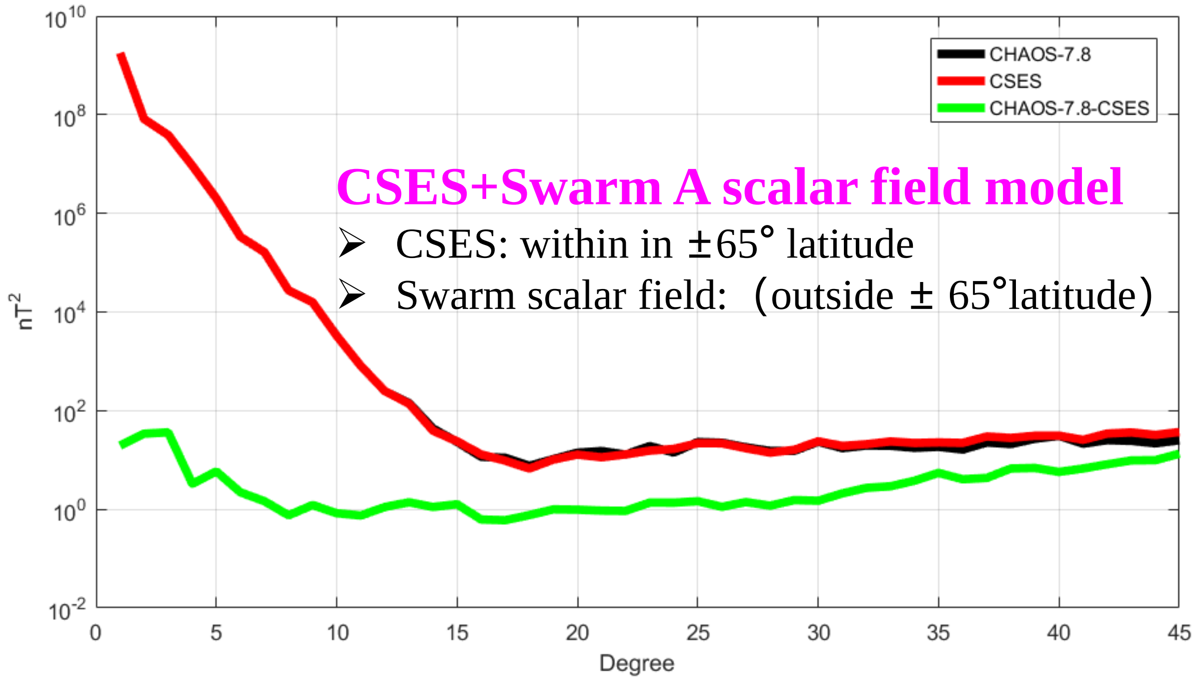
Time period: 2018.3- 2019.2 (preliminary result),
Both scalar and vector field are used for modeling

- **Main field and its secular variation**
  Linear variation, up to degree and order 8
- **Lithospheric field**
  Up to degree and order 45, ~900km
- **External field** (up to degree and order 2)

Disturbed
Scalar data
(within 20nT)

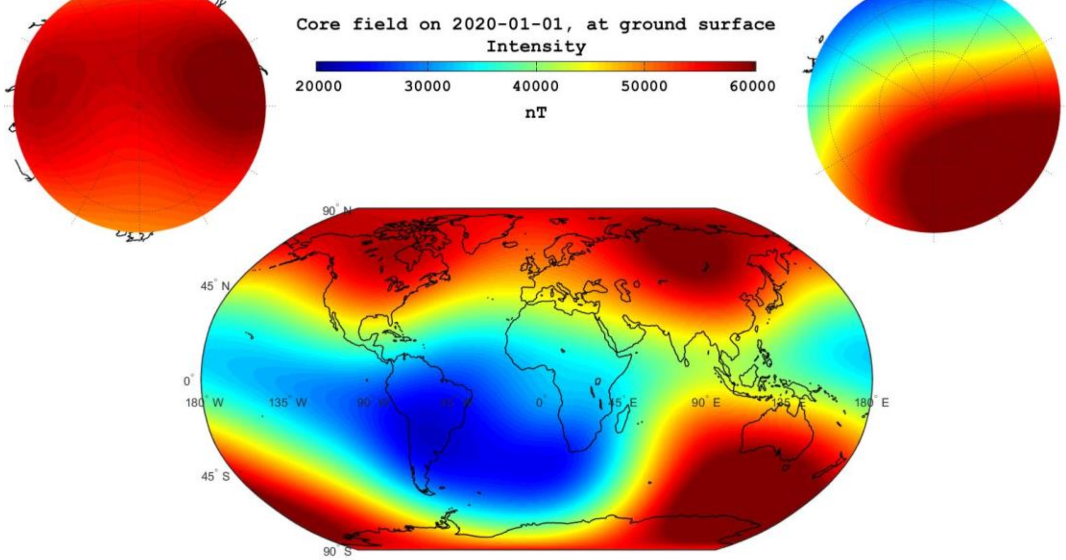




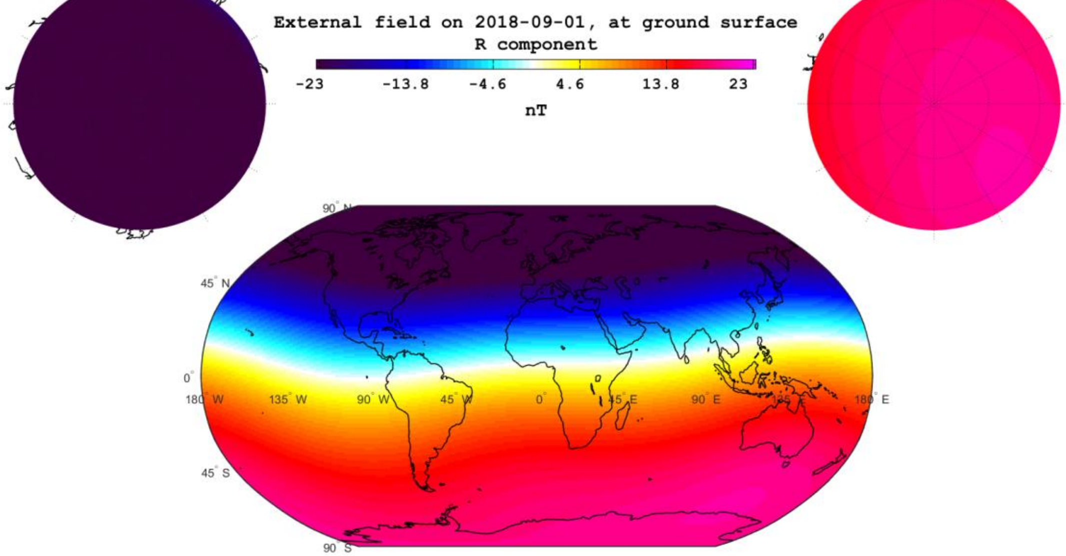


Poor lithospheric field is caused by continuously disturbed high latitude scalar data (the disturbance is from magnetic torque)

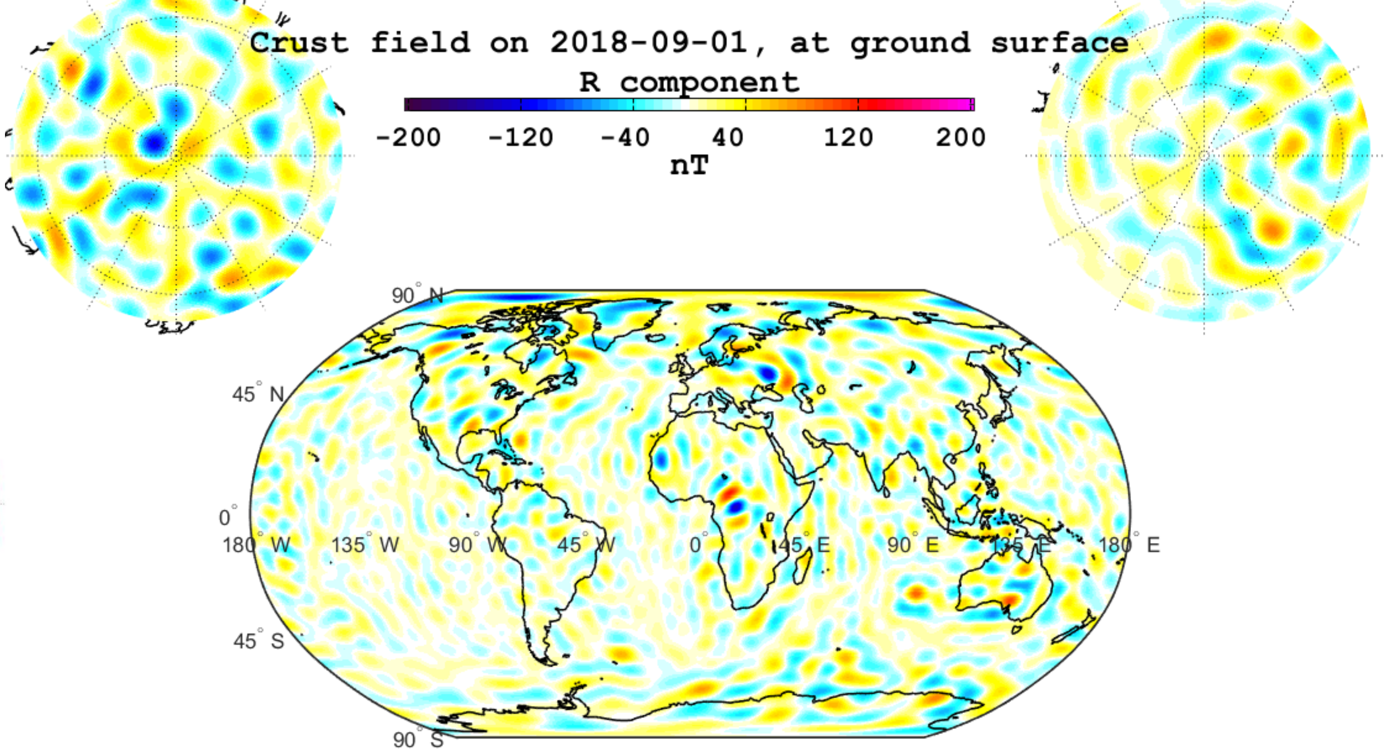
Main field



External field



Crustal field



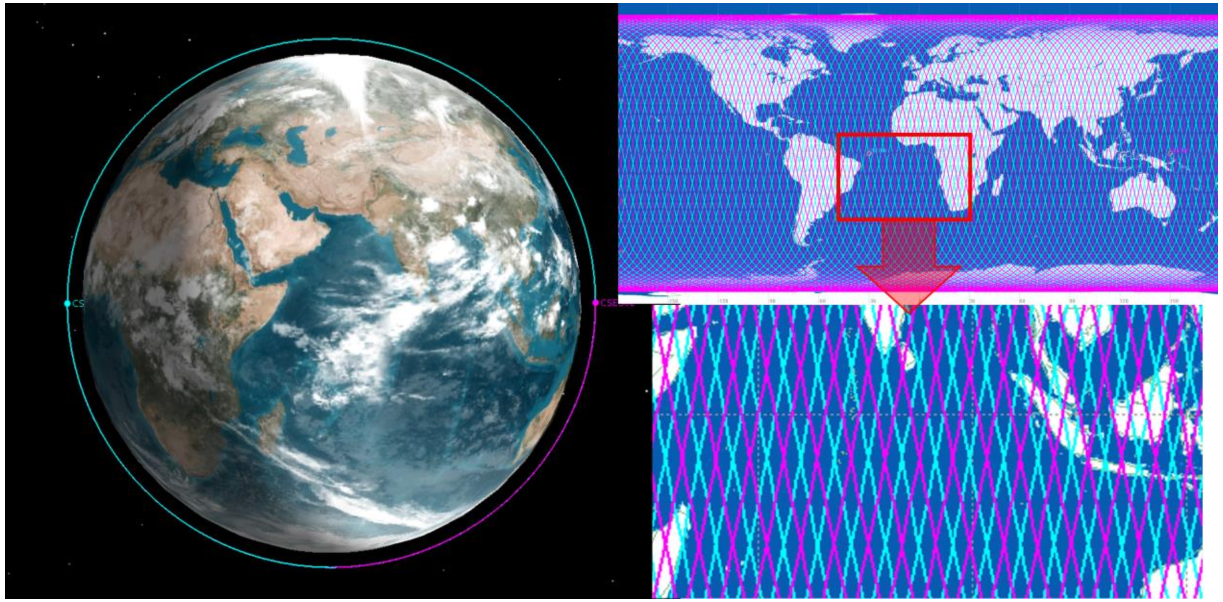
Upcoming CSES-02

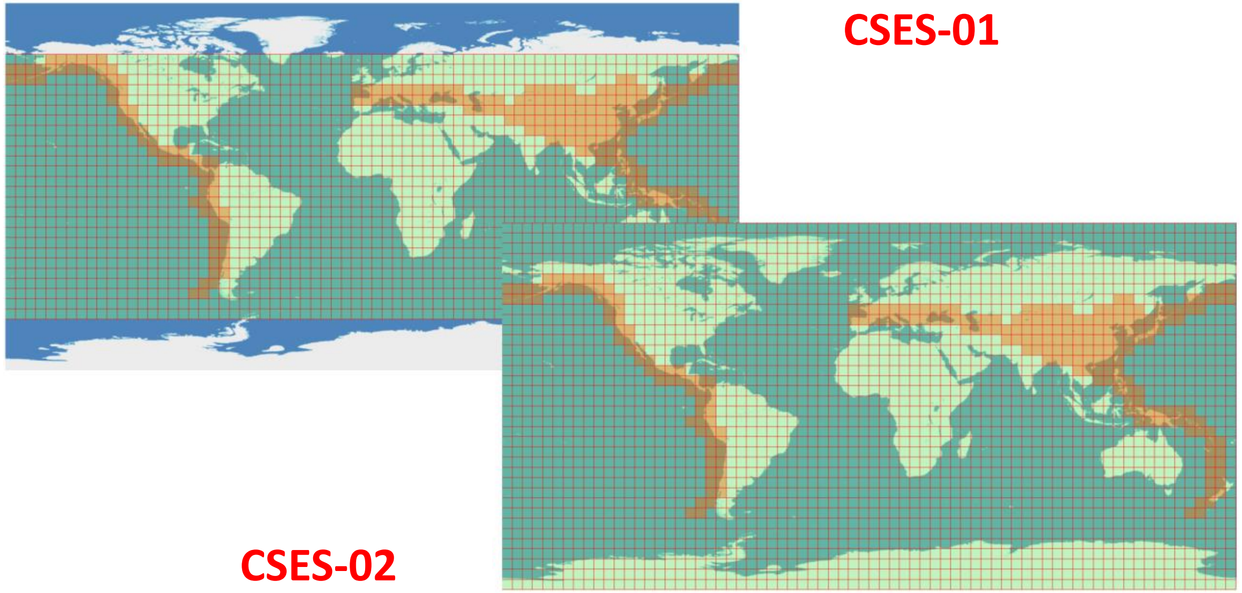
CSES-02 will be launched on 12 Dec 2024

CSES-02 has the same orbit with CSES-01, but with the phase difference of 180°

The observation area will extend from ±65° to global and there will be no continuous disturbance on HPM in high latitudes as the satellite working mode has been adjusted/improved.

The spatial resolution is improved from 500km to 250km and the revisiting period will be shorten from 5 to 2.5 days, which will be a huge advantage for core field modeling (especially for the secular variation model)





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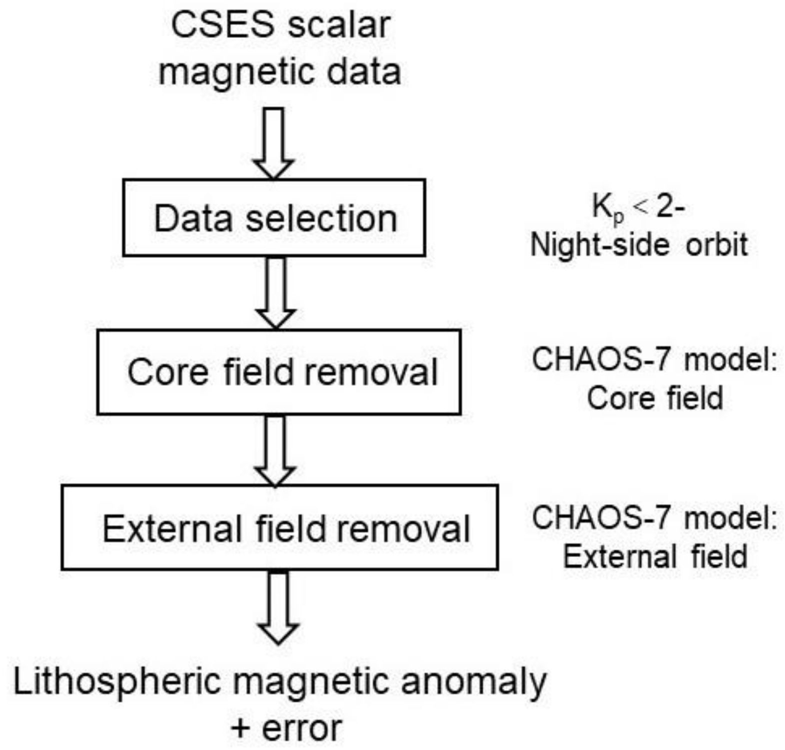
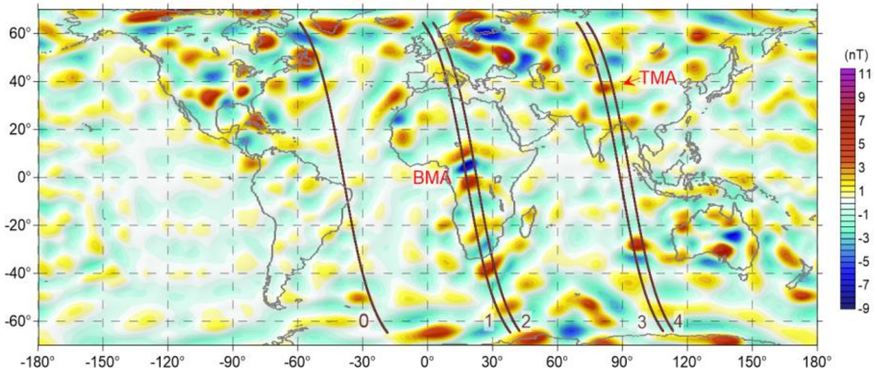
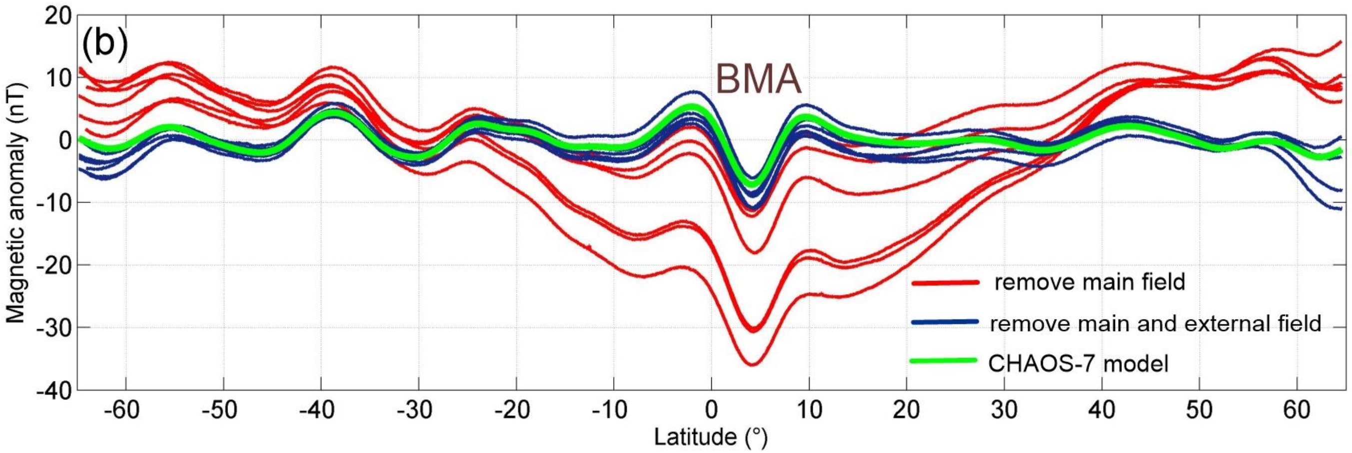
  -using CDSM scalar data
- Summary

Lithospheric field anomaly

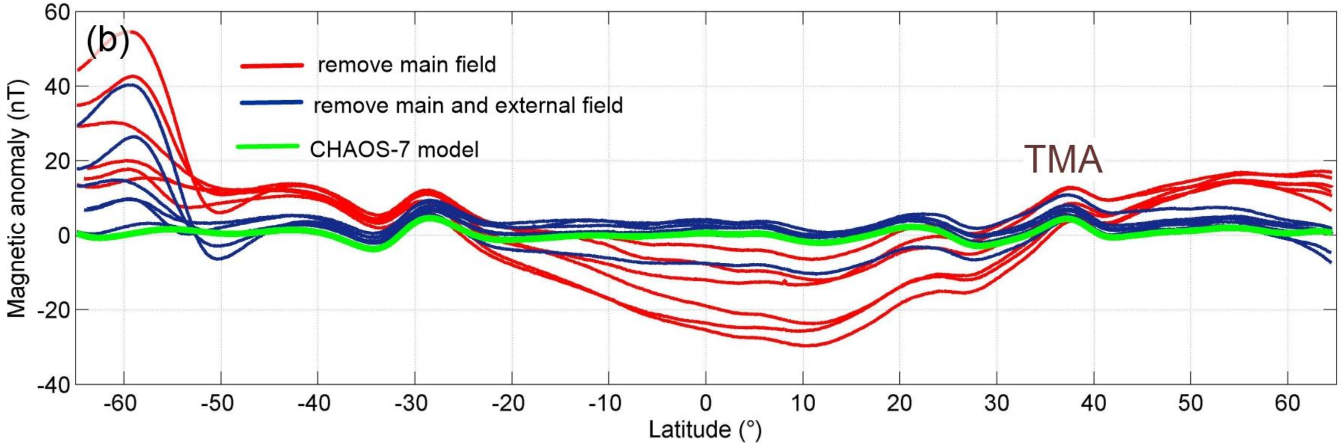




Bangui anomaly



Tarim basin anomaly



Lithospheric field model around Chinese region

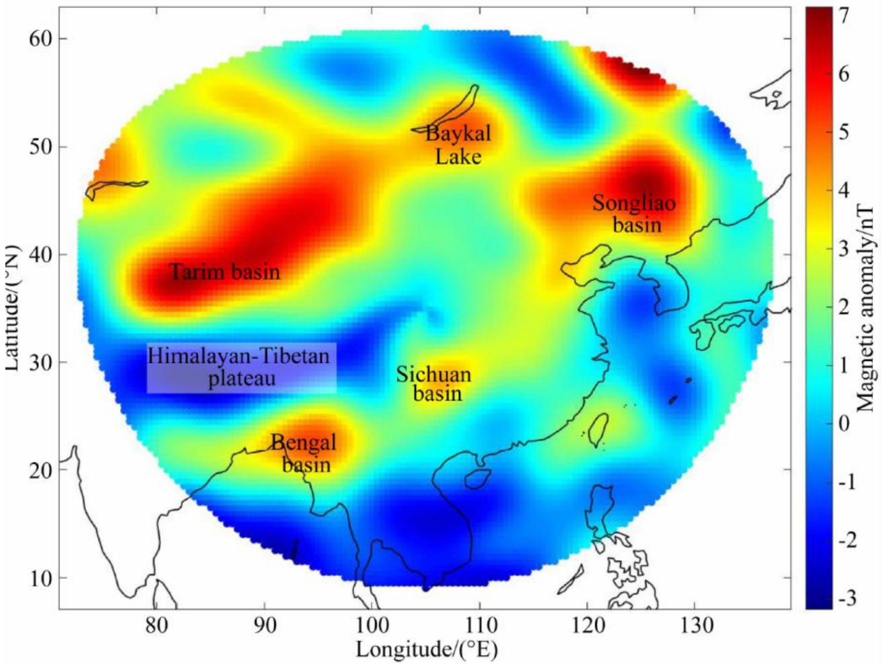
Datasets: CSES and Swarm Alpha 2018.3-2022.5
Spherical cap harmonic analysis

$$B_x = -\sum_{m=0}^{\infty}\sum_{k=m}^{\infty}\left(\frac{a}{r}\right)^{n_k(m)+2}\frac{dP_{n_k(m)}^{m}(\cos\theta)}{d\theta}\left\{g_k^m\cos(m\lambda)+h_k^m\sin(m\lambda)\right\}$$

$$B_y = \sum_{m=0}^{\infty}\sum_{k=m}^{\infty}m\left(\frac{a}{r}\right)^{n_k(m)+2}\frac{P_{n_k(m)}^{m}(\cos\theta)}{\sin\theta}\left\{g_k^m\sin(m\lambda)-h_k^m\cos(m\lambda)\right\}$$

$$B_z = \sum_{m=0}^{\infty}\sum_{k=m}^{\infty}(n_k(m)+1)\left(\frac{a}{r}\right)^{n_k(m)+2}P_{n_k(m)}^{m}(\cos\theta)\left\{g_k^m\cos(m\lambda)+h_k^m\sin(m\lambda)\right\}$$

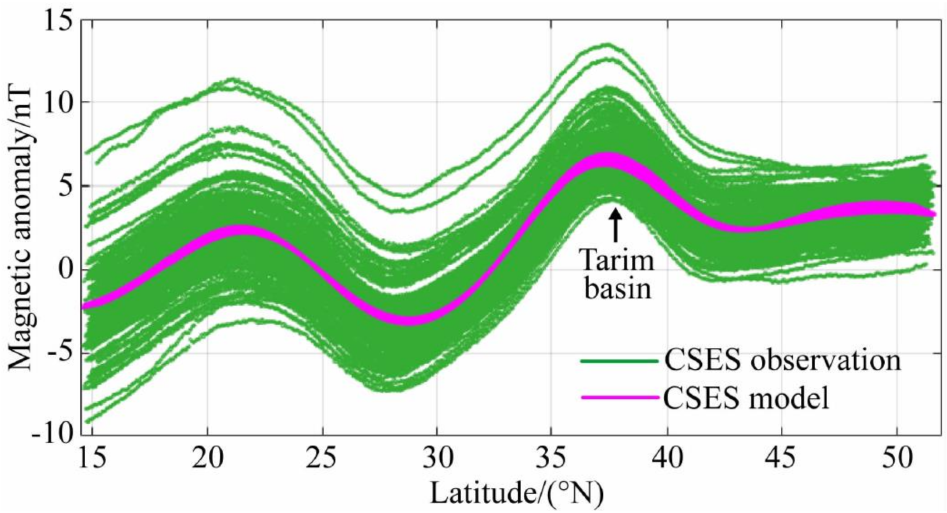
Center: 35^{o}N, 105^{o}E, k_{max}=15, Spherical cap of half angle=26^o, coefficients: (k+1)*2=256, $n_k(m)_{max}$=53.17, corresponding to the wavelength of $2\pi a/n_k(m)\approx$752km



Linear expression of the scalar magnetic anomaly

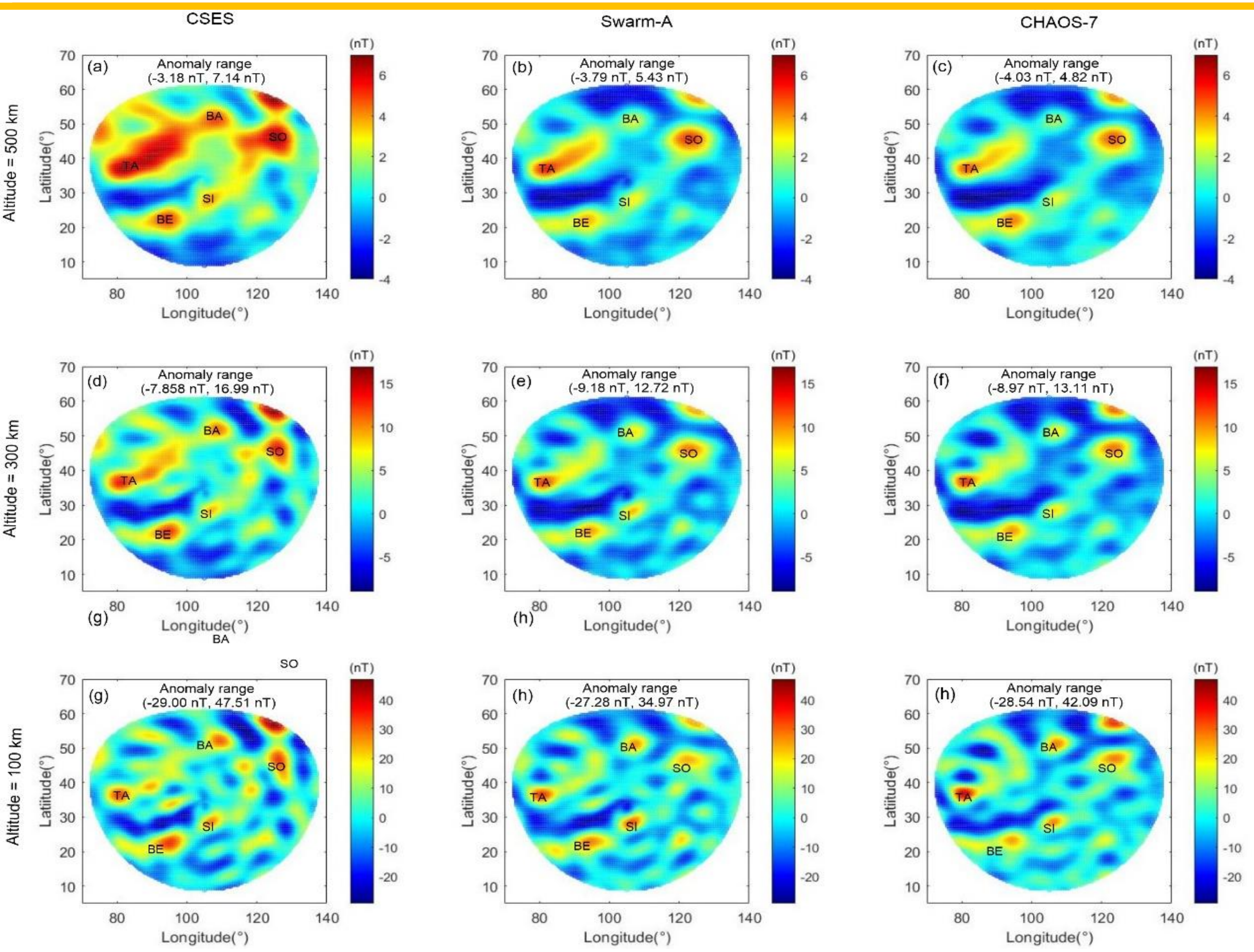
$$\Delta T = \frac{B_{core\_X}}{B_{core}}B_x + \frac{B_{core\_Y}}{B_{core}}B_y + \frac{B_{core\_Z}}{B_{core}}B_z$$

$$B_{core} = \sqrt{B_{core\_X}^{2} + B_{core\_Y}^{2} + B_{core\_Z}^{2}}$$



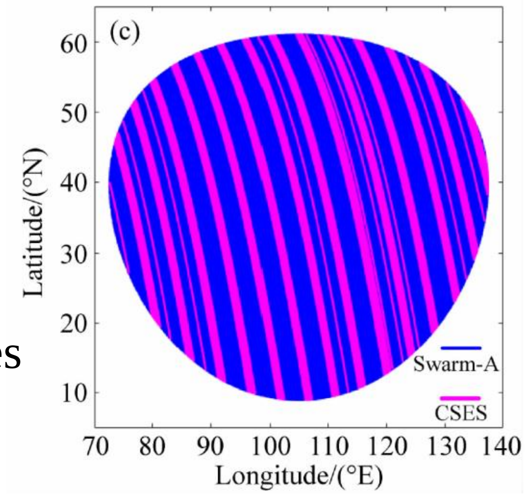
(Wang et al., 2023b, Chinese J. Geophys)

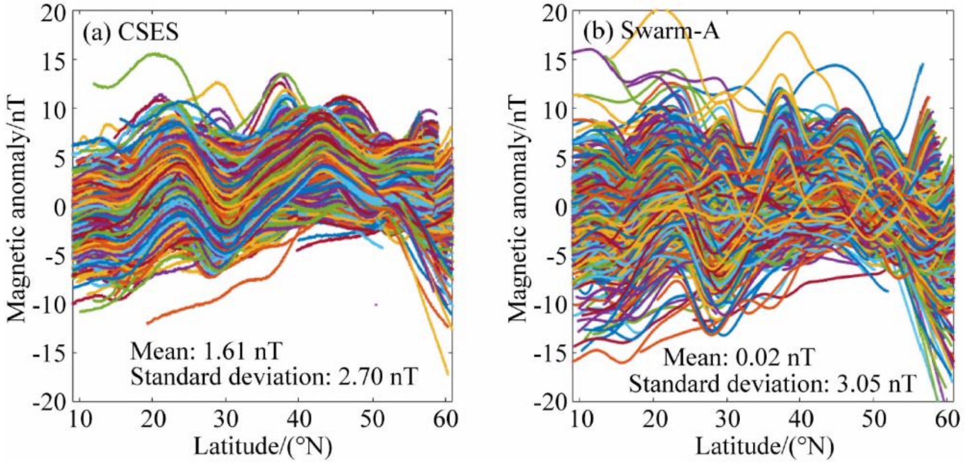
Comparison with Swarm model and CHAOS-7



Consistent distribution features between the three models

Orbit traces





Lithospheric anomaly datsets

Beside CSES, we also use Swarm Alpha for the same time period to build a model

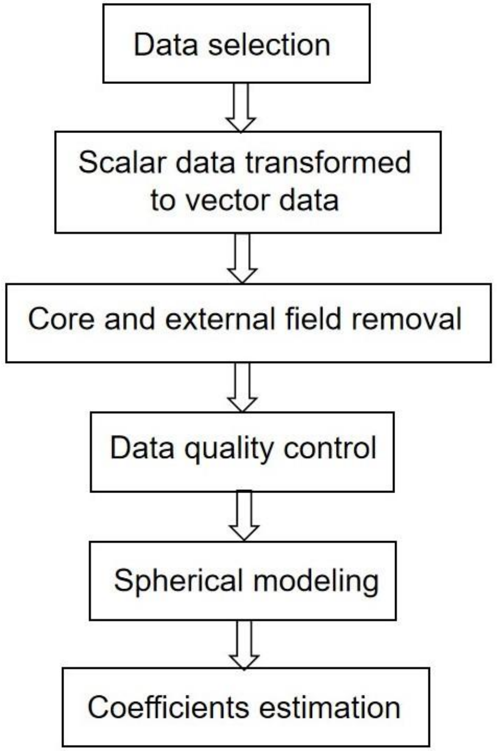
Global lithospheric field model based on CSES

Method: Spherical harmonic analysis

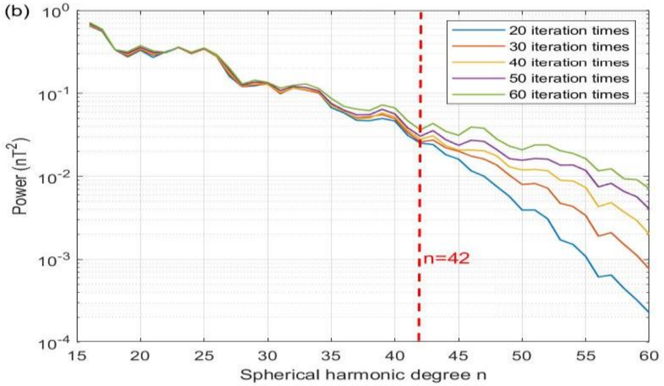
Datasets: CSES 2018.3-2022.5

Nmax=42, corresponding to wavelength of 953km

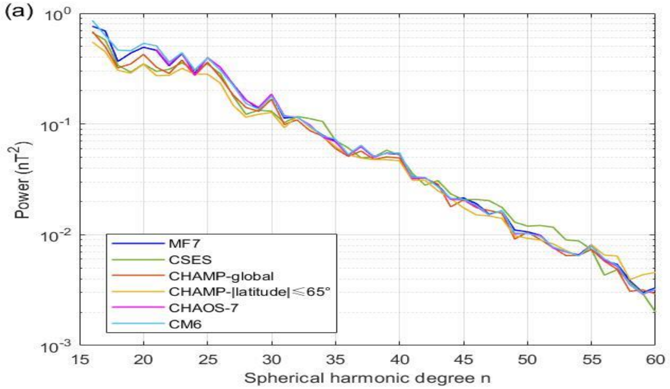
Data processing

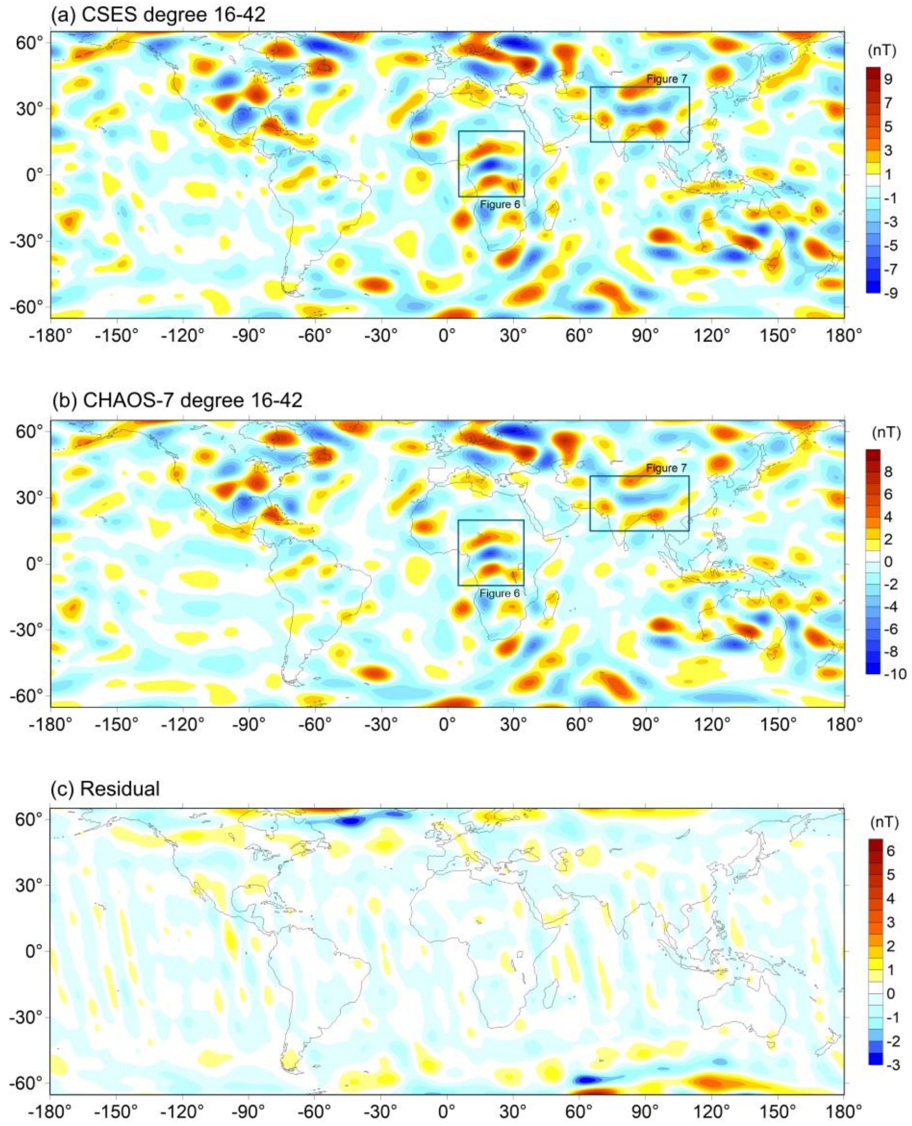


Power spectrum for different iteration



Power spectrum comparison with other models





(Wang et al., 2023b, PEPI)

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Summary

- After the correction of boom deformation for CSES FGM data, we can further optimize CGGM model to include the core field and its secular variation, lithospheric field and external field. This model is updating now by adding more datasets and hoping to provide a candidate model for new generation of IGRF-14.
- Only using CSES scalar data, we can build a regional (in China) and global lithospheric field model, the result is consistent with the model obtained from Swarm and CHAOS model.
- These results show great potential of CSES magnetic field data on the future updateing of geomagnetic field model, especially in conjunction with other missions such as Swarm, MSS. For example, the drifting orbits of Swarm has advantage to produce better lithospheric field and external field model while the revisiting orbits of CSES can help to improve the core field model.

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Thank you for your attention !