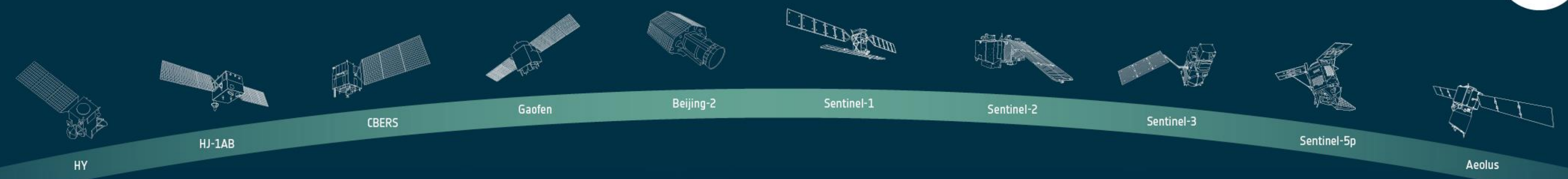

2022 DRAGON 5 SYMPOSIUM

MID-TERM RESULTS REPORTING

17-21 OCTOBER 2022

[PROJECT ID. 59236]

[THE CROSS-CALIBRATION AND VALIDATION OF CSES/SWARM MAGNETIC FIELD AND PLASMA DATA]

<DATE: **Thursday, 20/October/2022** >

ID. **59236**

PROJECT TITLE: **The cross-calibration and validation of CSES/Swarm magnetic field and plasma data**

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PRESENTED BY: [**Rui Yan on behalf of CSES-Swarm joint CAL/VAL team**]

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European Young scientist

Title	First name	Last name	Affiliation
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EO Data Delivery

ESA Third Party Missions	No. Scenes
1. Swarm A/B/C:magnetic field data	**1 file per day, about 10 years**
2. **Swarm A/B/C: plasma data**	**1 file per day, about 10 years**

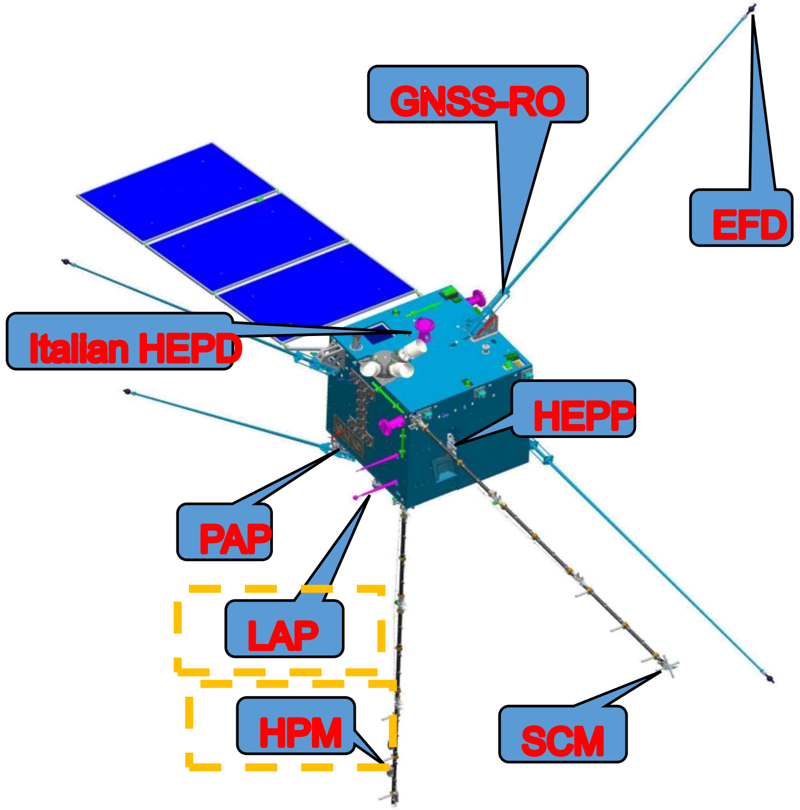
Chinese EO data	No. Scenes
1. ZH-1: magnetic data	**30 half-orbits per day, about 4 years**
2. **ZH-1: plasma data**	**30 half-orbits per day, about 4 years**

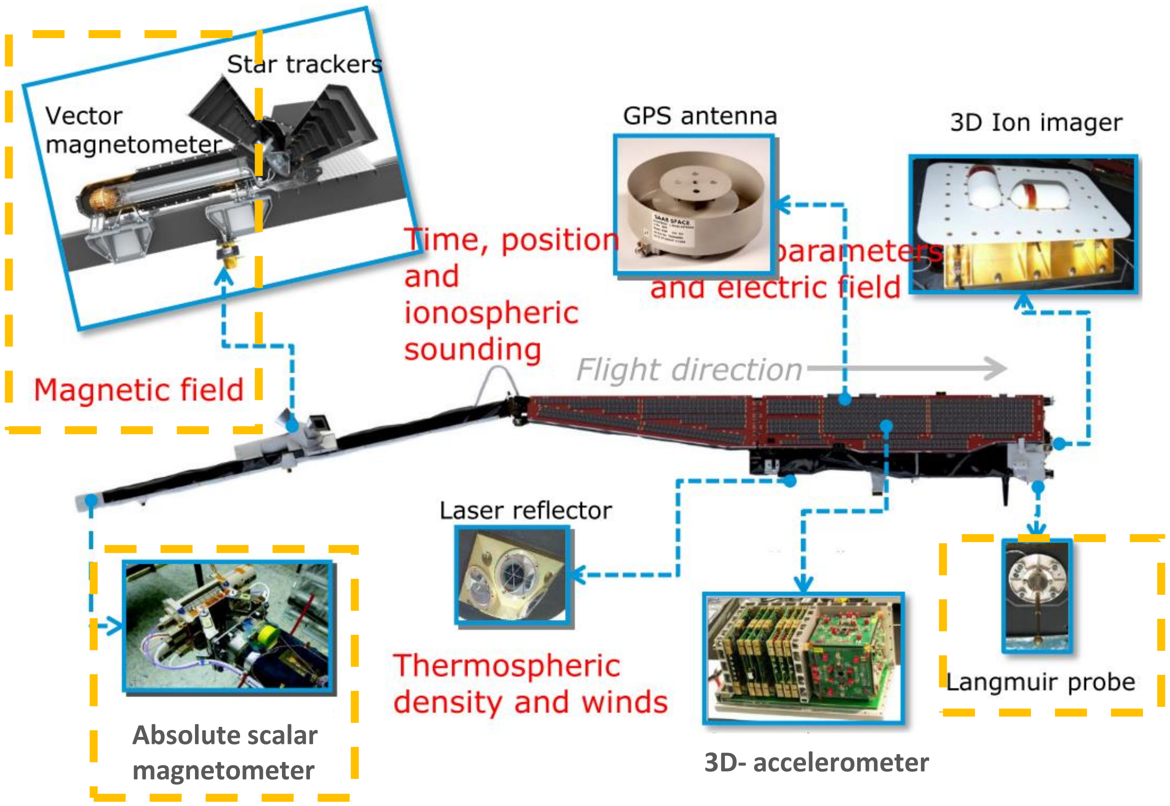
Content

The the project's objectives

CSES-01: launched into a sun-synchronous circular orbit on 2 Feb. 2018 with an initial altitude of ~507 km (*Shen et al*., 2018a, b).

The Swarm mission was launched on 22 Nov 2013, with three spacecraft at altitudes from 460 to 530 km (*Knudsen et al*., 2017).





(*Rune et al*., 2018)

The the project’s objectives

1) To cross-calibration/validation of ionospheric magnetic field and plasma parameters;

2) Jointly develop algorithms to eliminate the artificial influences from platforms;

3) Jointly develop and optimize the data processing tools for the magnetometers and Langmuir probe onboard CSES;

4) Jointly compare the simultaneous measurements of CSES and Swarm during active magnetic conditions;

5) Jointly study the details of some ionospheric structures;

6) To use the potential of working with CSES magnetic data for regional and global magnetic field modeling;

7) To explore the possibility for generating higher level scientific products from the magnetic measurements.

Content

Swarm/CSES cooperation activities

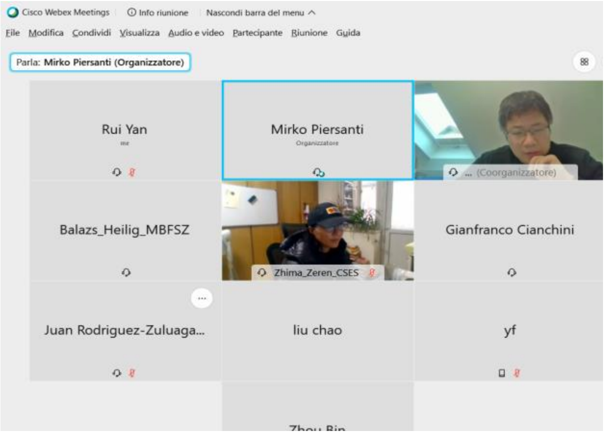
(1) Oct. 21 to 25, ISSI-BJ annual workshop

(2) ESA EO visiting ICD in Jan.15, 2020

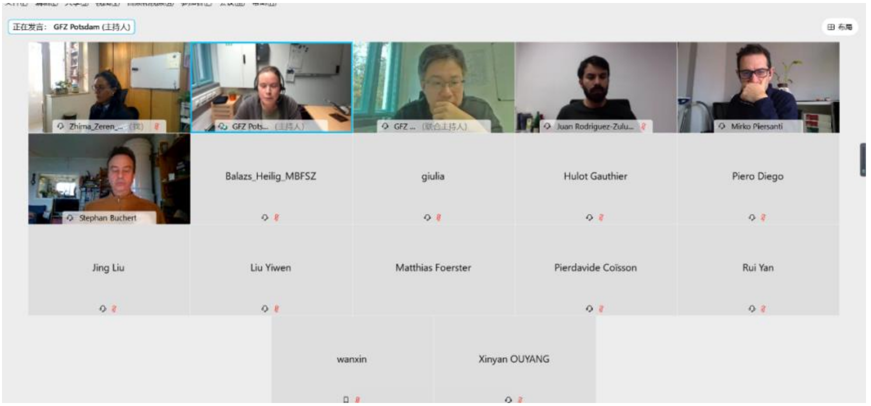
(3) CNSA-ESA virtual meeting on space cooperation on June. 2020

Swarm/CSES cooperation activities

(4) The 1st joint working seminar, October, 2020



(5) The 2nd joint working seminar, December, 2020



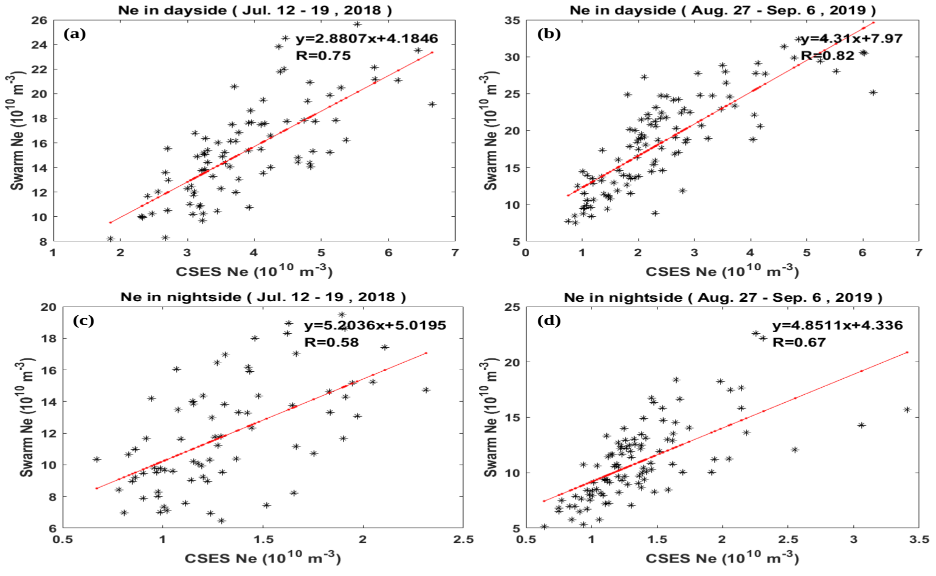
(6)The Dragon 2021 symposium, July, 2021

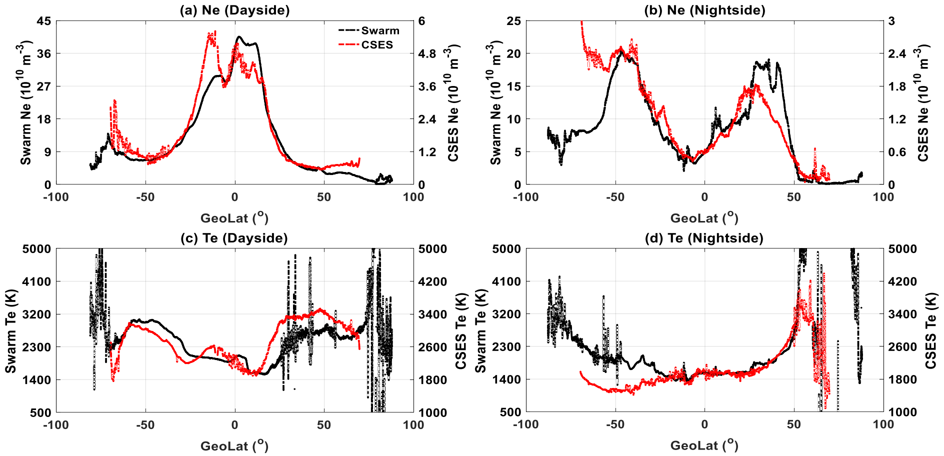
(7) Swarm 11th workshop, October, Athens, 2021

(8) CSES 5th workshop, October, Guiyang, 2021

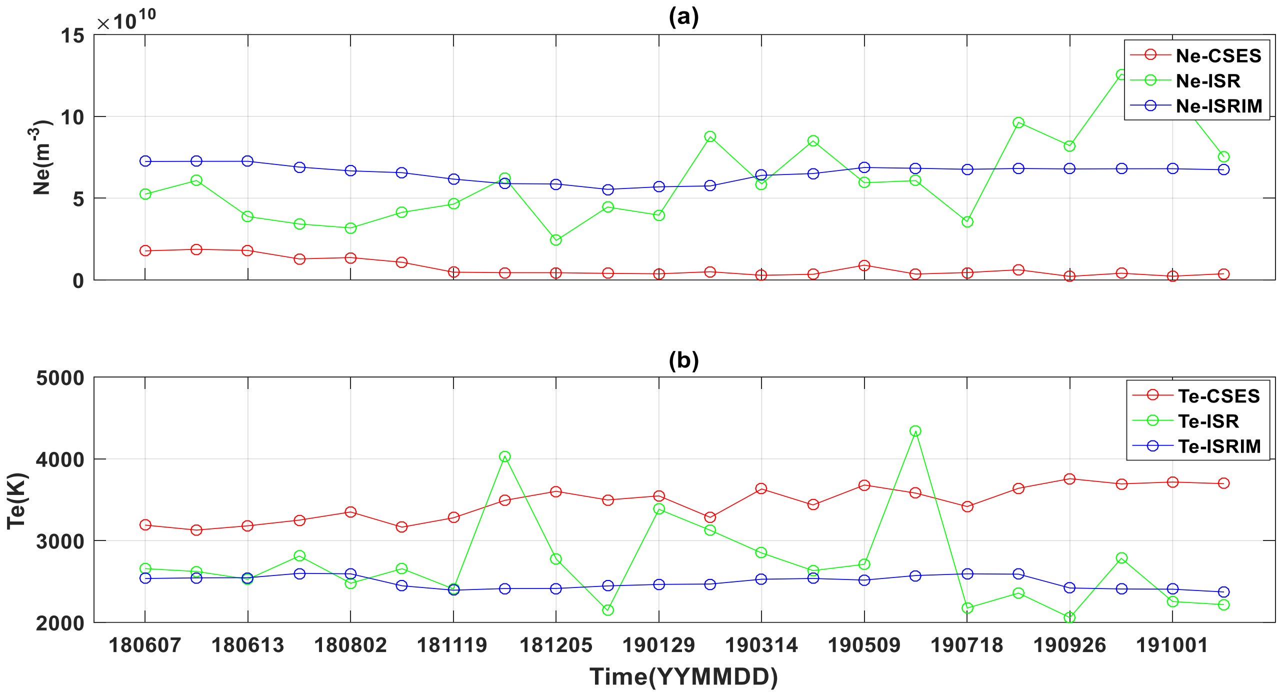
Content

Validation and data quality control of Plasma data





The comparison of *Ne*/*T*e measurements from CSES (red) and Swarm (black) within the closest orbits at closest local time in Nov. 25, 2018



The dayside Ne from CSES is nearly 60% lower (on average) than the values of ISR, but the Te values from CSES are about several hundred K higher than that measured by ISR.

1. Quite very similar latitudinal variations and good correlations

2. Lower CSES *Ne* than Swarm *Ne*, *Te* measurements the same range

[Yan et al., JGR, 2020]

Validation and data quality control of Plasma data

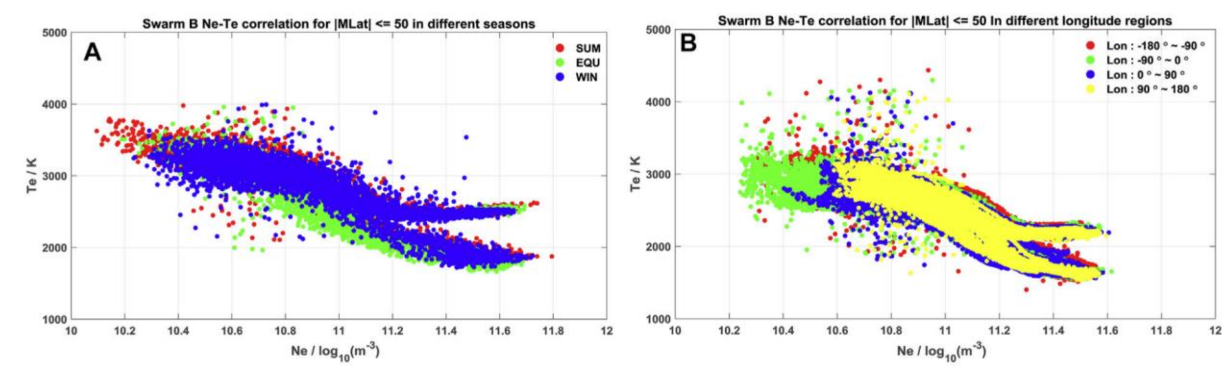
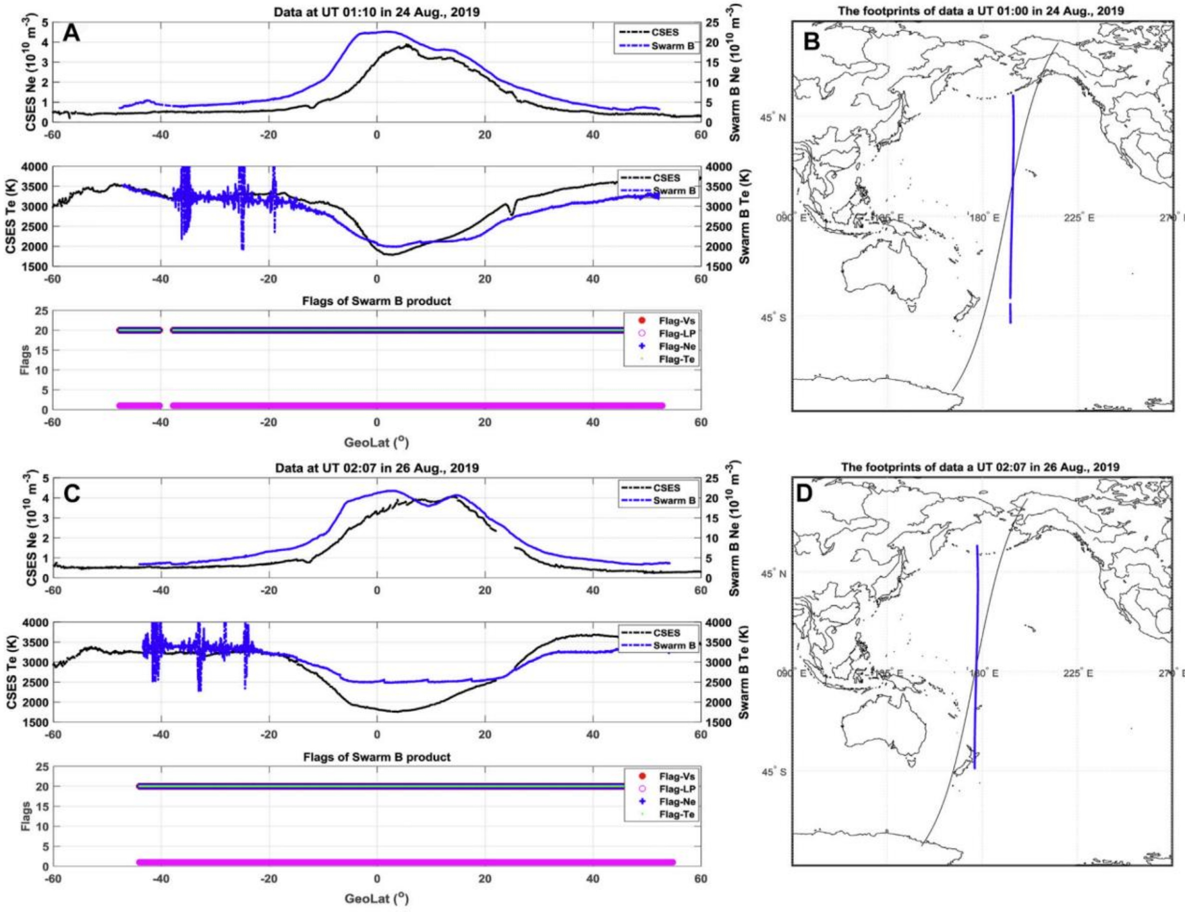


FIGURE 9 | Scatter plot of *Ne* and *Te* as measured by Swarm B. Each data point is confined into within the |MLAT|≤ 50° at around 14:00LT. **(A)** The observations during equinoxes, June solstice and December solstice are marked with green, red and blue. **(B)** The observations in different longitude regions including -180° ~ -90°, -90° ~ 0°, 0° ~ 90°, 90°~ 180° are marked with red, green, blue and yellow.

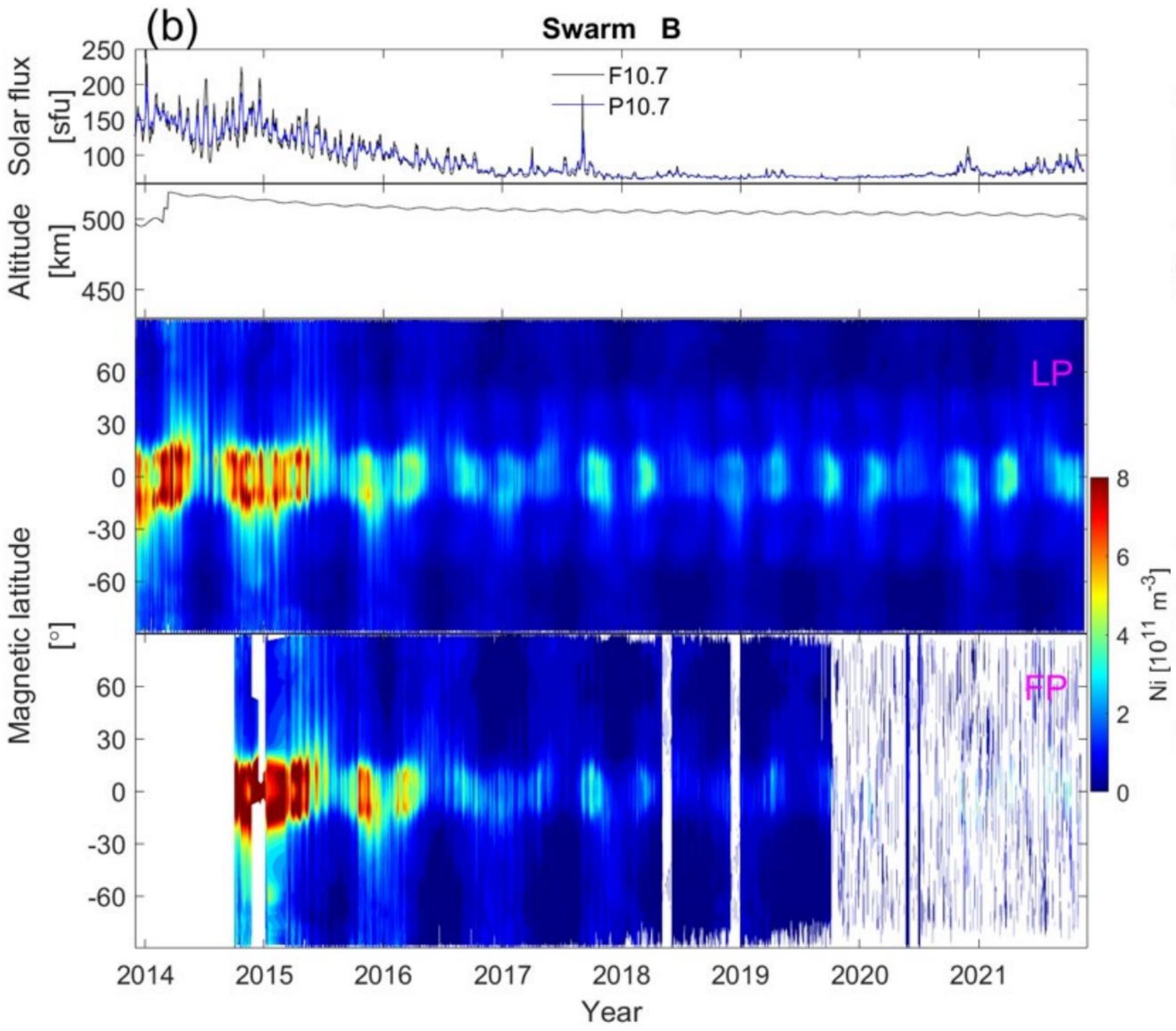


Two prominent features of the Ne/Te relation observed by Swarm satellites are: a) when Ne is larger than 1×10^{11} m^{-3} , Te are grouped into two branches at equatorial and low latitudes; b) when Ne is lower than 1×10^{11} m^{-3} , Te sometimes becomes very scatter at low and middle latitudes.

Detailed analysis reveals that the flags used in the Swarm Level-1B plasma density product cannot well distinguish the two abnormal features of Te, implying further efforts are needed for the Swarm Te data calibration.

[Yan et al., Front. Earth Sci , 2022]

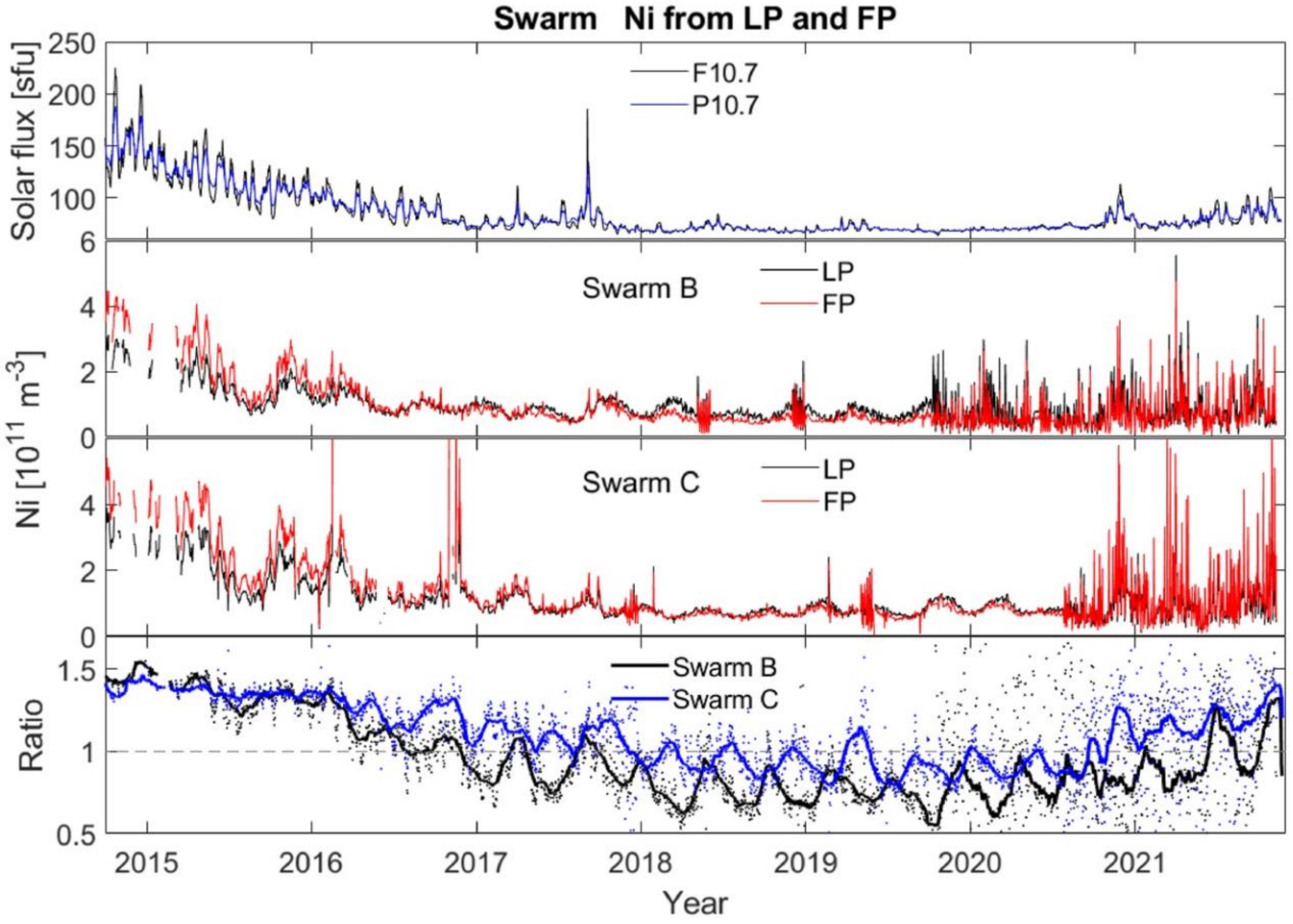
4. Influence on the plasma density measurements: Swarm

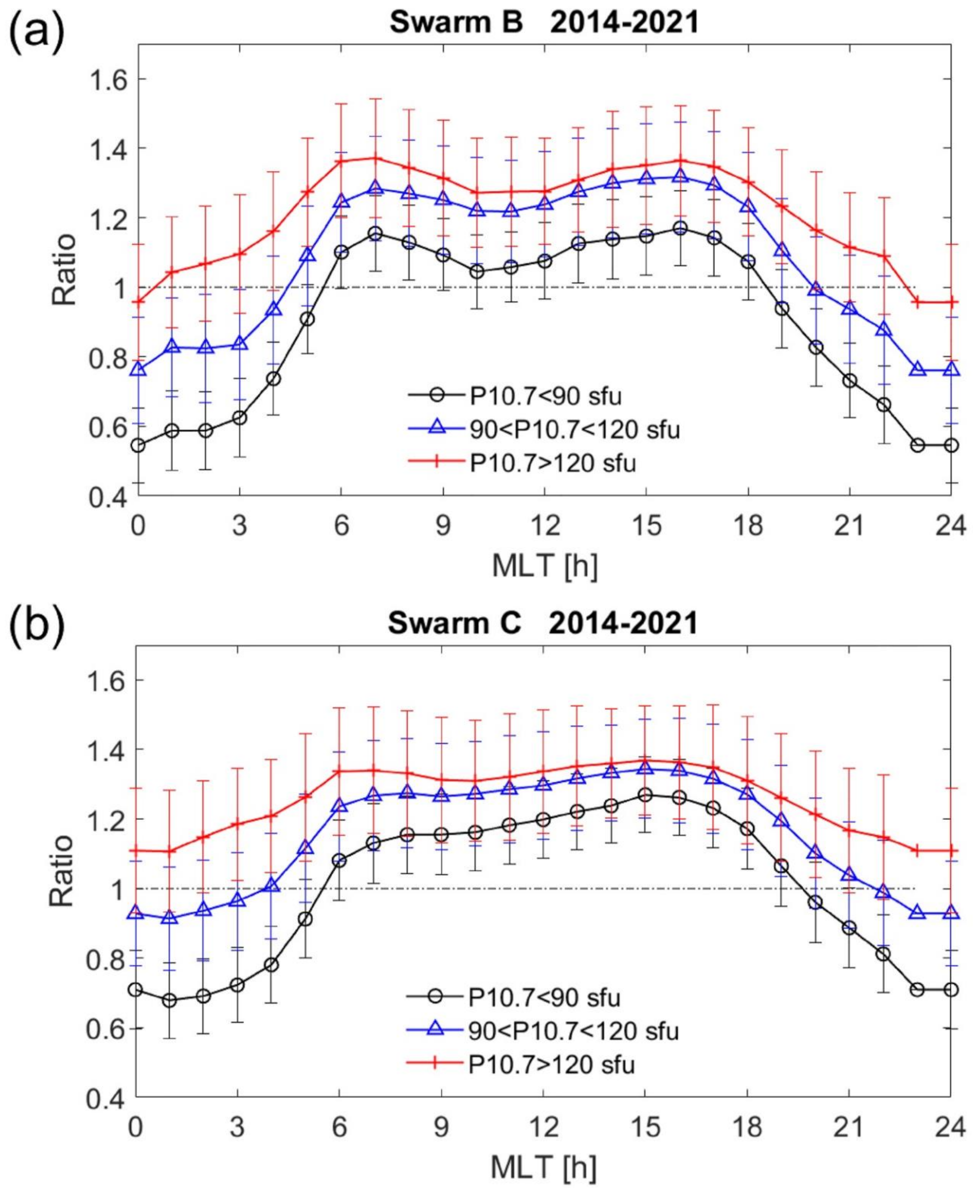


[Xiong et al., 2022, JGR]

- Xiong et al. (2022) showed that the FP densities had very low bias compared to the ISR electron densities
- Therefore, we can use the FP data as reference to calibrate the LP densities
- This calibration would depend on many parameters, and therefore machine learning would be a very good tool to learn these dependencies
- The FP densities are only available for several orbits per day, mainly before 2020, and therefore the data are more sparse
- **However, there is enough data to train a neural network, which would give a ratio between FP and LP densities**

4. Influence on the in situ plasma density measurements: Swarm





4Influence on the in situ plasma density measurements: Swarm

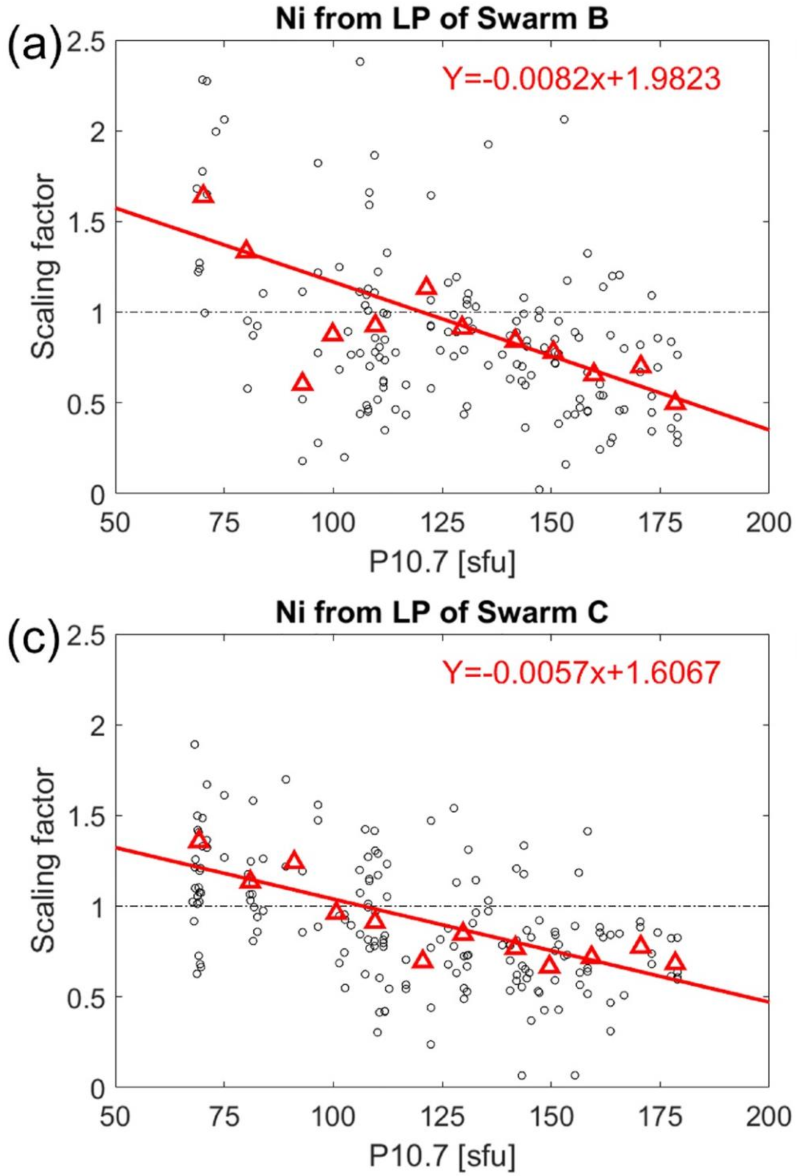
$$\mathrm{Ni}_{\mathrm{LP}} = \frac{m_i u_i}{2\pi (e r_p)^2} d_{\mathrm{ion}}$$

$$\mathrm{Ni}_{\mathrm{FP}} = \frac{I_{\mathrm{FP}}}{\mathrm{eAu}_i}$$

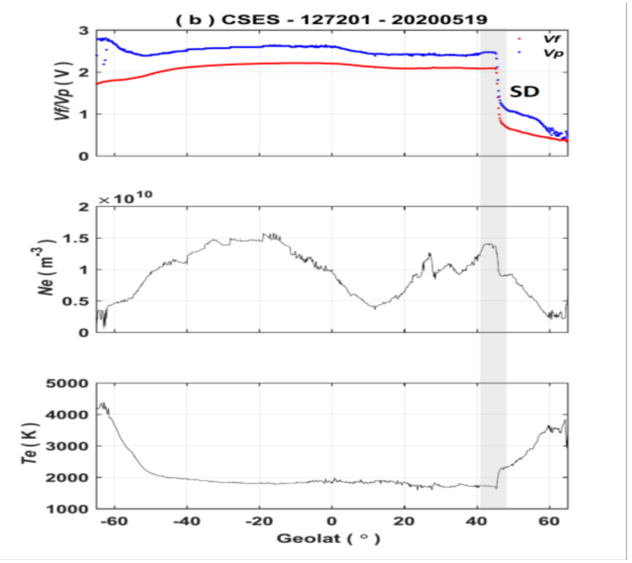
We suggest that the solar flux dependence of LP-derived Ni is related to the ion compositions change at Swarm altitude, which has not been properly accounted for in the LP processing algorithm. More light ions (e.g., H+), diffusing down from the plasmasphere to the Swarm altitude, seem to cause the overestimation of Ni from LP during low solar activity.

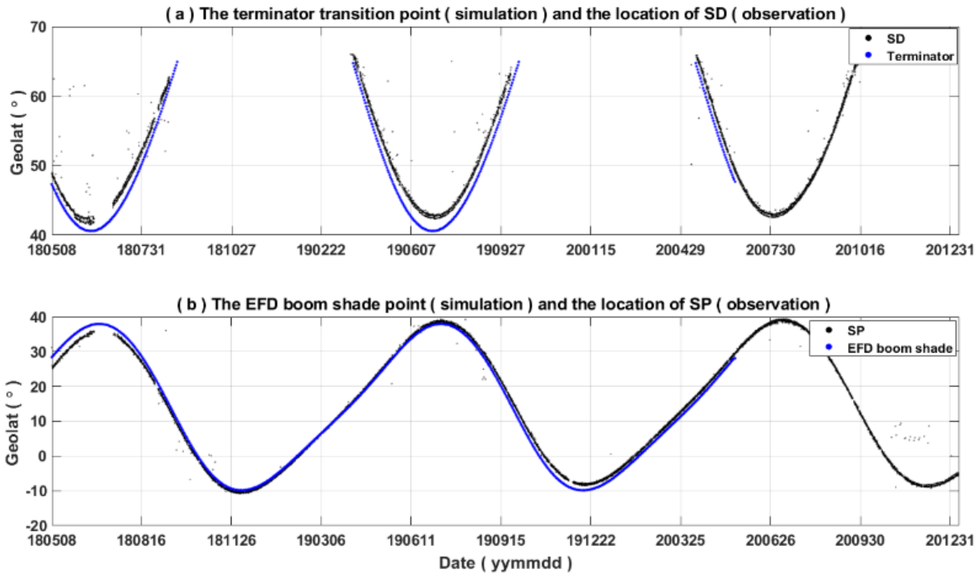
$$\text{Swarm B}: \mathrm{Ni}_{\mathrm{LPcorr}} = -0.0082 \times V_{P10.7} + 1.9823$$

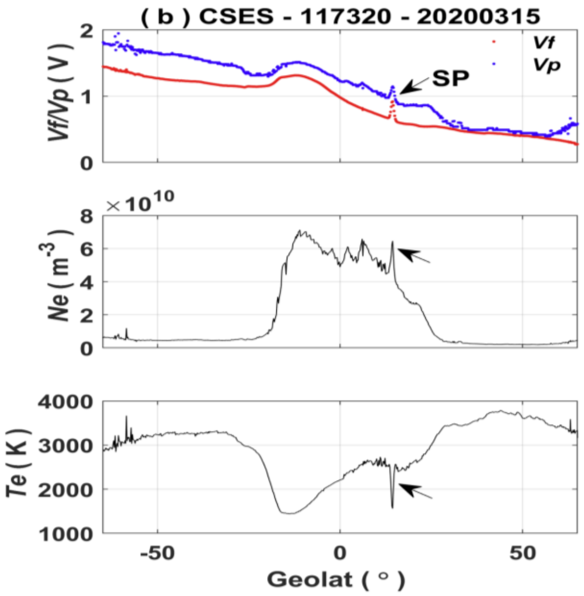
$$\text{Swarm A and C}: \mathrm{Ni}_{\mathrm{LPcorr}} = -0.0057 \times V_{p10.7} + 1.6067$$

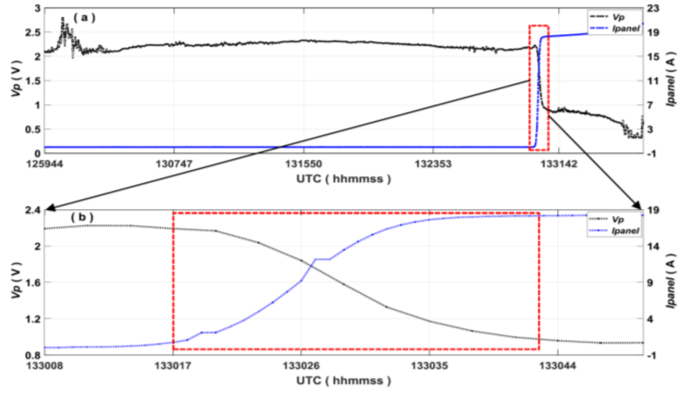


The regular features recorded by LAP onboard CSES



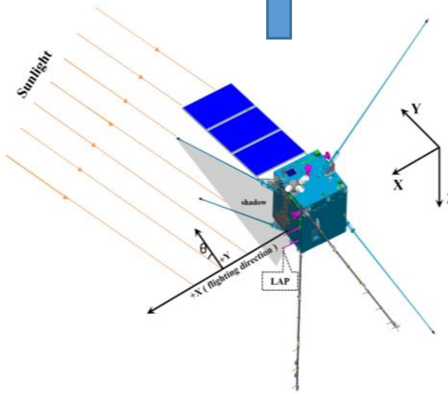






The SD is caused by satellite-current system adjustment due to the solar illumination change at the terminator transition point.

The SP is caused by instantaneous illumination changes of probe surface when the boom of the electric field detector installed in the windward panel shades the Langmuir probe.



[Yan et al., JGR, 2022]

Content

1. The the project's objectives

2. Overview of CSES/Swarm cooperation activities

3. Outcomes of CSES/Swarm cooperation

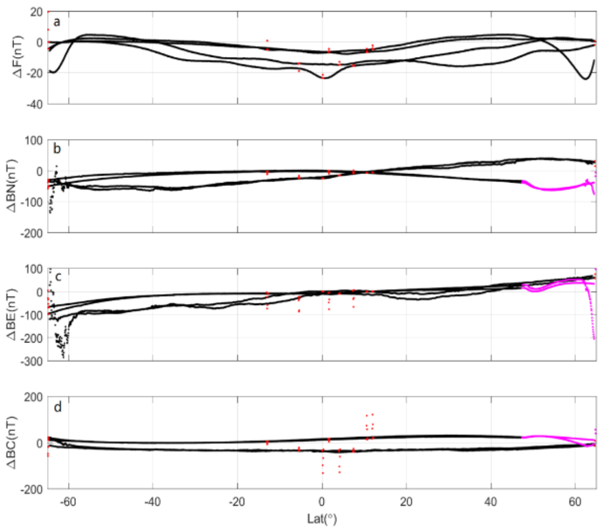
   - Plasma data
   - Magnetic field data

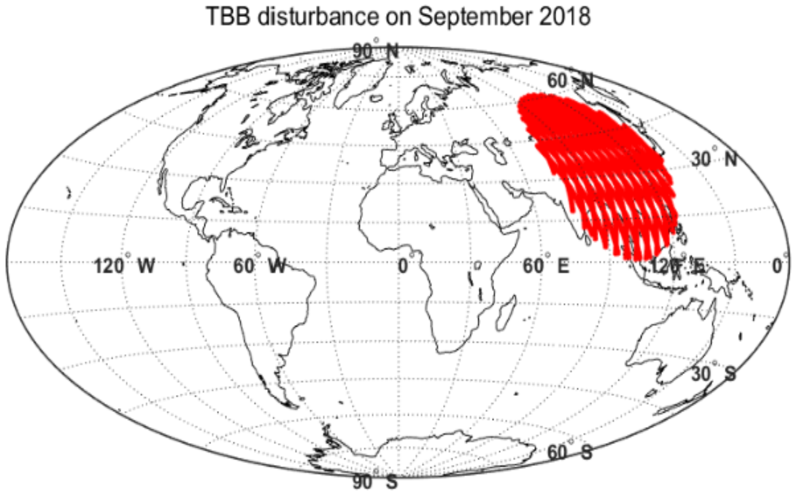
4. Proposals for next-step bilateral cooperation

Validation and data quality control of magnetic field data

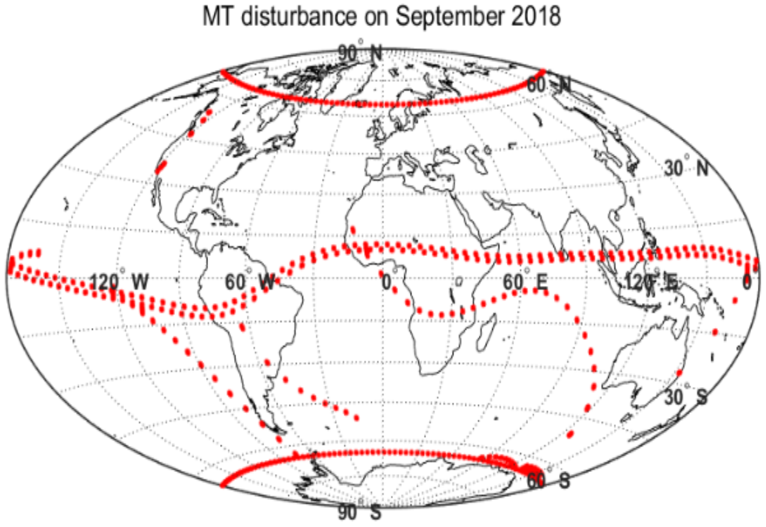
Three disturbance sources:

- ➢ Magnetic Torque
- ➢ Tri-Band Beacon
- ➢ Ground shadow



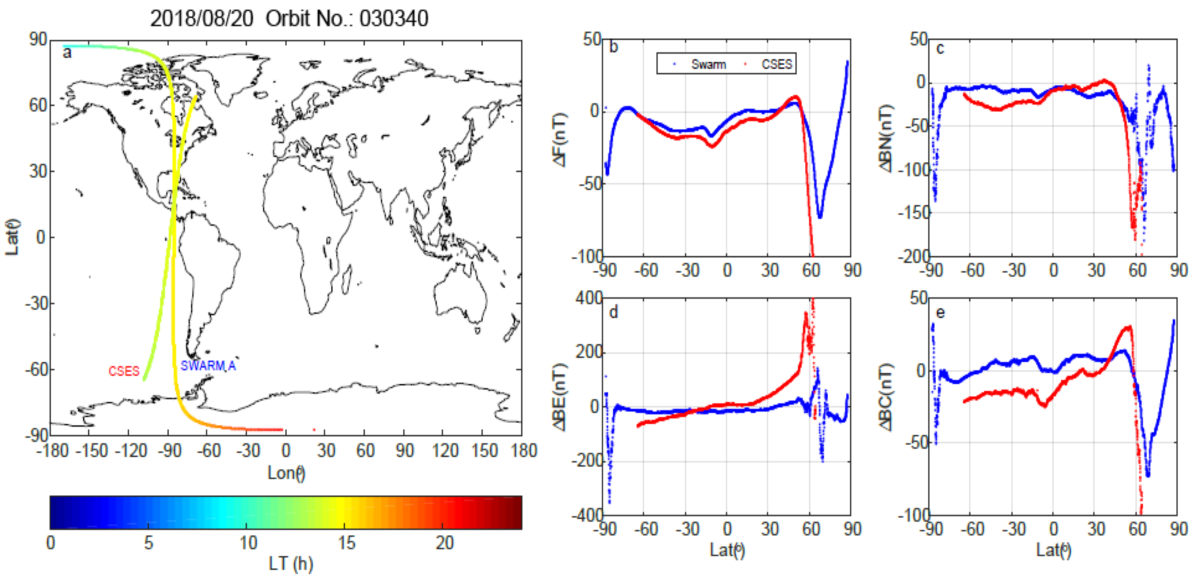


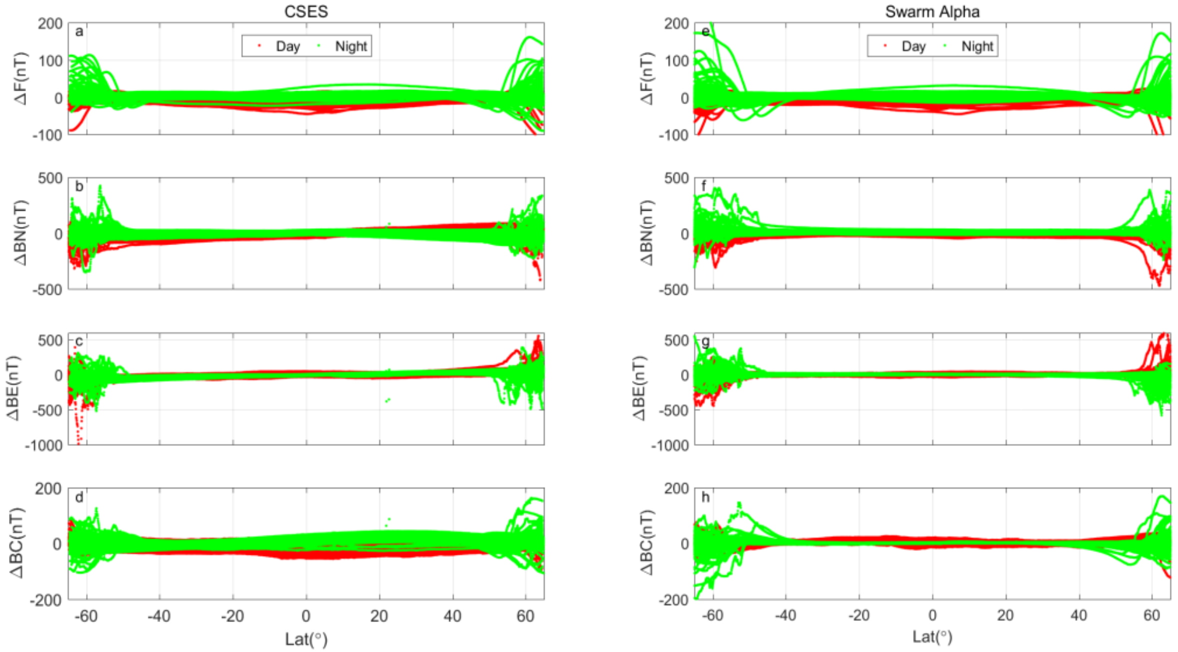
- ➢ Disturbances from the MT basically concentrate near the magnetic equator and latitudes around 65º
- ➢ Disturbances from the TBB only occur above the Chinese territory
- ➢ Users are suggested to properly check Flags when using HPM data.



CSES and Swarm magnetic field cross validation

The residual field (observations minus CHAOS-6-x7 model) for the magnetic field intensity and the three vector components (in NEC frame)





- ➢ The main trend of the residual field is consistent for CSES and Swarm
- ➢ The CDSM scalar data is very good

Upper: CSES and Swarm residual field for the intensity and three vector components (for latitude<65°)

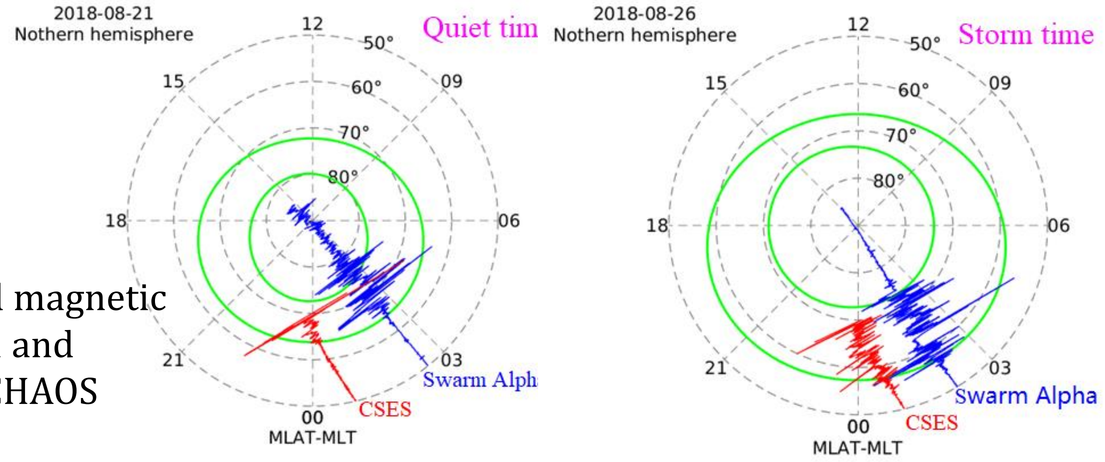
Scientific study : ionosphere current systems

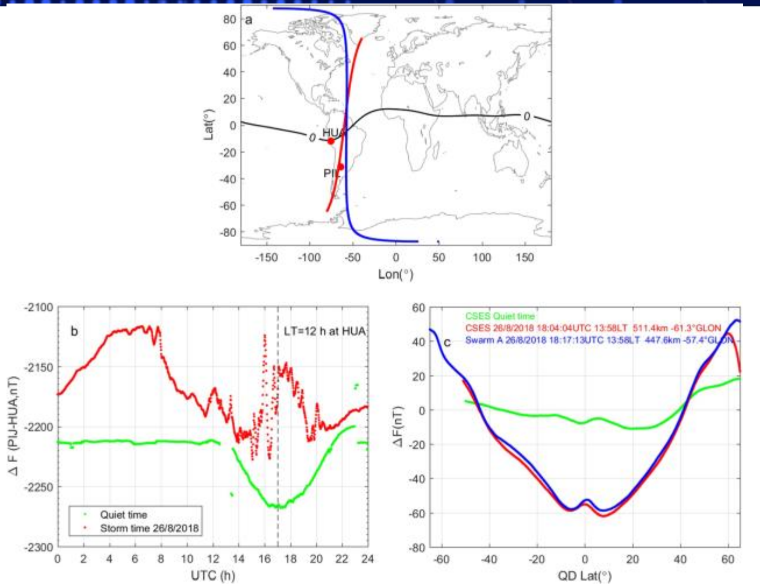
- Estimate FACs

$$j_r = \frac{1}{\mu_0 v_x}\frac{dB_\phi}{dt},$$

$$j_{FAC} = j_r \,/\, \sin(I)$$

is the residual of the eastward magnetic field after removal of core, crustal and magnetospheric fields using the CHAOS model

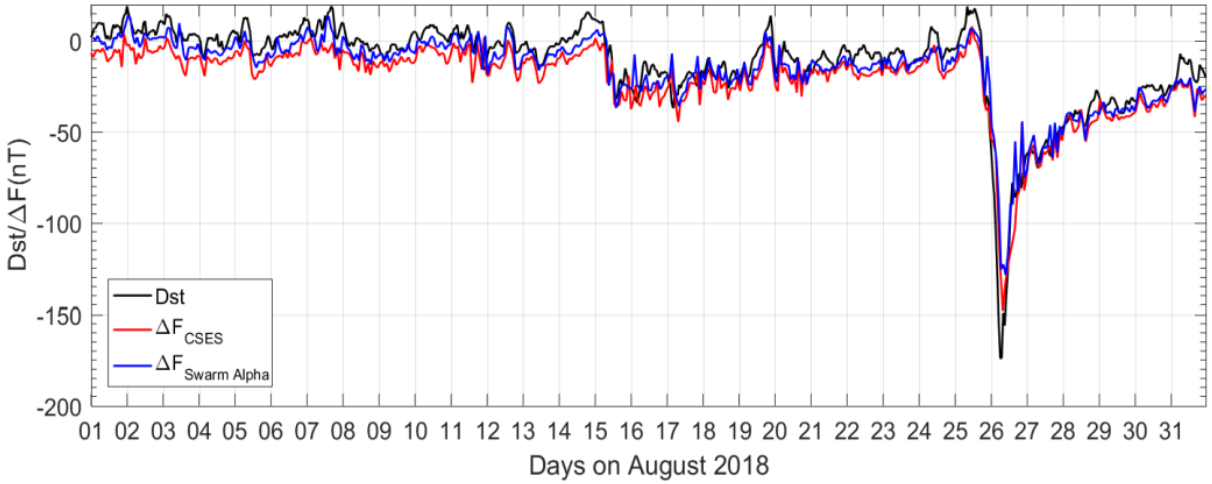




- FACs observed on CSES and Swarm is consistent with model results;
- During Storm time (strong activities), clear equatorward movement of FACs can be observed.

- Study EEJ (CEJ)+Sq

- Using magnetic field intensity data, we can also produce estimates of the Dst index on an orbit-by-orbit basis
- Night time orbits
- For each orbit, the magnetic field data at dipole latitude 0° is chosen as the dataset
- Use CHAOS-6-x7 model to remove core and crust field



[Yang et al., JGR, 2021]

Scientific study : magnetic field disturbance before Earthquake

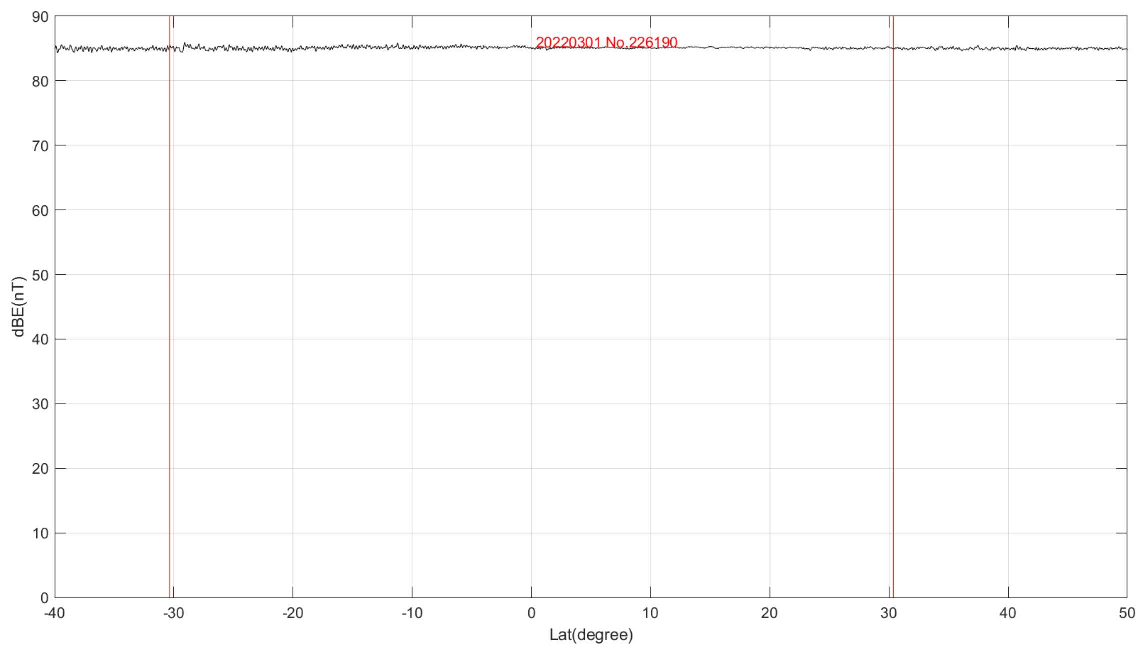
Ms 6.1 Lushan EQ on 1 June 2022 17： 00UT

Location: 30.37°N， 102.94W°

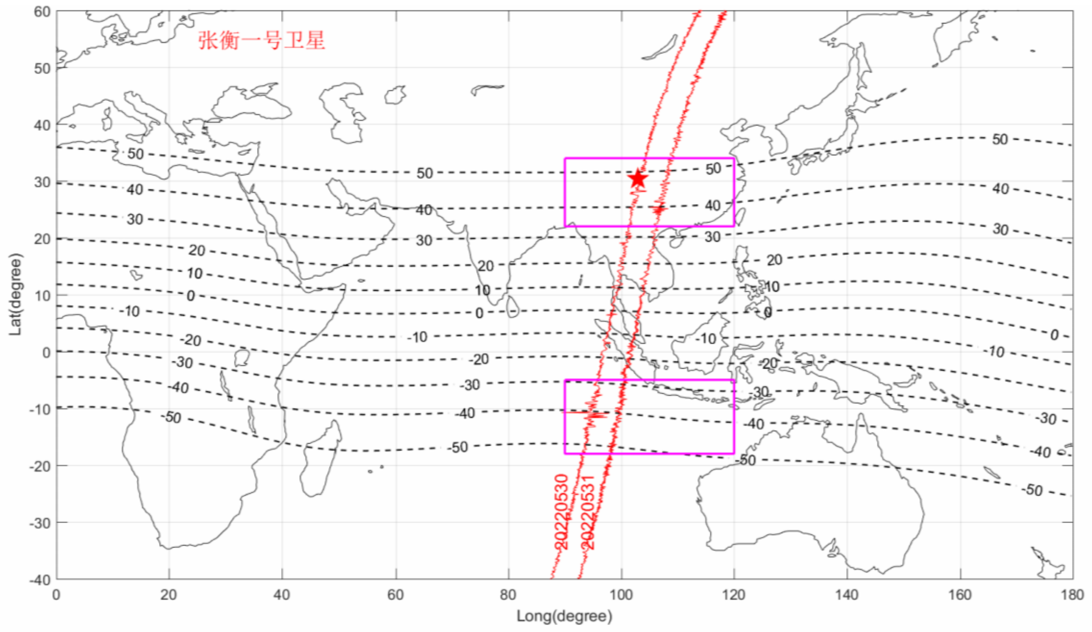
Depth: 17km

Both CSES and Swarm observed clear disturbance

Before 30 May 2022, magnetic field is very quiet



Spatial distribution of the magnetic field disturbance: CSES and Swarm



Clear magnetic field disturbance is observed 2 days before the EQ

Scientific publications

Paper with Published/ In Press (15)+ under review (5).

1. Cicone, A., Piersanti, M., D'Angelo, G., Consolini, G., Bertello, I., Diego, P., Materassi, M. and Ubertini, P. (2021). Auroral oval layers detection by using CSES plasma and electric field data, *Il Nuovo Cimento C*.
2. D'Angelo G., Piersanti, M., Diego, P., Pezzopane, M. and Ubertini. P. (2021). Analysis of the August 14, 2018 plasma bubble by CSES satellite, *Il Nuovo Cimento C*.
3. *Diego P., Huang, J., Piersanti, M., Badoni, D., Zhima Z., Yan, R., Rebustini, G., Ammendola, R., Candidi, M., Guan, Y., Lei, J., Masciantonio, G., Bertello, I. , De Santis, C., Ubertini, P., Shen X. and Picozza, P. (2021). The Electric Field Detector on board the China Seismo Electromagnetic Satellite: In-Orbit Results and validation,Instruments,5,1. https://dx.doi.org/10.3390/instruments 5010001.*
4. Liu, J., Guan, Y., Zhang, X., & Shen, X. (2021). The data comparison of electron density between CSES and DEMETER satellite, Swarm constellation and IRI model. *Earth and Space Science*, 8(2), e2020EA001475.
5. Piersanti M., Pezzopane, M., Zhima, Z., Diego, P., Xiong, C., Tozzi, R., D'Angelo, G., Battiston, R., Huang, J., Picozza, P., Yan, R., Shen, X., Sparvoli, R., Ubertini, P. , Yan, Y., Zoffoli, S.(2020). Can an impulsive variation of the solar wind plasma pressure trigger a plasma bubble? A case study based on CSES, SWARM and THEMIS data, Advances in Space Research, https://doi.org/10.1016/j.asr.2020.07.046
6. Spogli, L., Sabbagh, D., Regi, M., Cesaroni, C., Perrone, L., Alfonsi, L., ... & Ippolito, A. (2021). Ionospheric response over Brazil to the August 2018 geomagnetic storm as probed by CSES-01 and Swarm satellites and by local ground-based observations. *Journal of Geophysical Research: Space Physics,* 126(2), e2020JA028368.
7. Tong, Y., Cheng, B., Miao, Y., et al. (2021). Analysis and elimination of tri-band beacon interference with the fluxgate sensors onboard CSES. Sci China Tech Sci, 64, https://doi.org/10.1007/s11431-020-1799-y
8. Yan, R., Zhima, Z., Xiong, C., Shen, X., Huang, J., Guan, Y., ... & Liu, C. (2020). Comparison of electron density and temperature from the CSES satellite with other space-borne and ground-based observations. *Journal of Geophysical Research: Space Physics*, 125(10), e2019JA027747.
9. Yang, Y., Zhou, B., Hulot, G., Olsen, N., Wu, Y., Xiong, C., Stolle, C., Zhima, Z., Huang, J., Zhu, X., Pollinger, A., Zhao, X., Shen, X. (2021). CSES high precision magnetometer data products and example study of an intense geomagnetic storm. *Journal of Geophysical Research: Space Physics*, 126, e2020JA028026. https://doi.org/10.1029/2020JA028026
10. Zhima, Z., Hu, Y., Shen, X., Chu, W., Piersanti, M., Parmentier, A., Zhang, Z., Wang, Q., Huang, J., Zhao, S., Yang, Y., Yang, D., Sun, X., Tan, Q., Zhou, N., Guo, F., 2021. Storm-Time Features of the Ionospheric ELF/VLF Waves and Energetic Electron Fluxes Revealed by the China Seismo-Electromagnetic Satellite. Applied Sciences. 11, 2617.
11. De Santis, A., Marchetti, D., Perrone, L., Campuzano, S.A., Cianchini, G., Cesaroni, C., Di Mauro, D., Orlando, M., Piscini, A. , Sabbagh, D., Soldani, M., Spogli, L., Zhima, Z. and Shen, X. (2021). Statistical correlation analysis of strong earthquakes and ionospheric electron density anomalies as observed by CSES-01, *Nuovo Cimento C*, in press.
12. Zhu, K., Zheng, L., Yan, R., Shen, X., Zhima, Z., Xu, S, Chu, W., Liu, D., Zhou, N., Guo, F.(2021). Statistical study on the variations of electron density and temperature related to seismic activities observed by CSES. *Natural Hazards Research,* in press.
13. .Yan R, Xiong C, Zhima Z, Shen X, Liu D,Liu C, Guan Y, Zhu K, Zheng L and Lv F(2022) Correlation Between Ne and Te Around 14:00 LT in the TopsideIonosphere Observed by CSES,Swarm and CHAMP Satellites.Front. Earth Sci. 10:860234.doi: 10.3389/feart.2022.860234
14. Yan, R., Guan, Y., Miao, Y., Zhima, Z., Xiong, C., Zhu, X., et al. (2022). The regular features recorded by the Langmuir probe onboard the low earth polar orbit satellite CSES. Journal of Geophysical Research: Space Physics, 127, e2021JA029289. https://doi. org/10.1029/2021JA029289
15. Pignalberi, A.; Pezzopane,M.; Coco, I.; Piersanti, M.;Giannattasio, F.; De Michelis, P.;Tozzi, R.; Consolini, G.Inter-Calibration and Statistical Validation of Topside Ionosphere Electron Density Observations Made by CSES-01 Mission. Remote Sens. 2022, 14, 4679.https://doi.org/10.3390/rs14184679

Content

1. The the project's objectives

2. Overview of CSES/Swarm cooperation activities

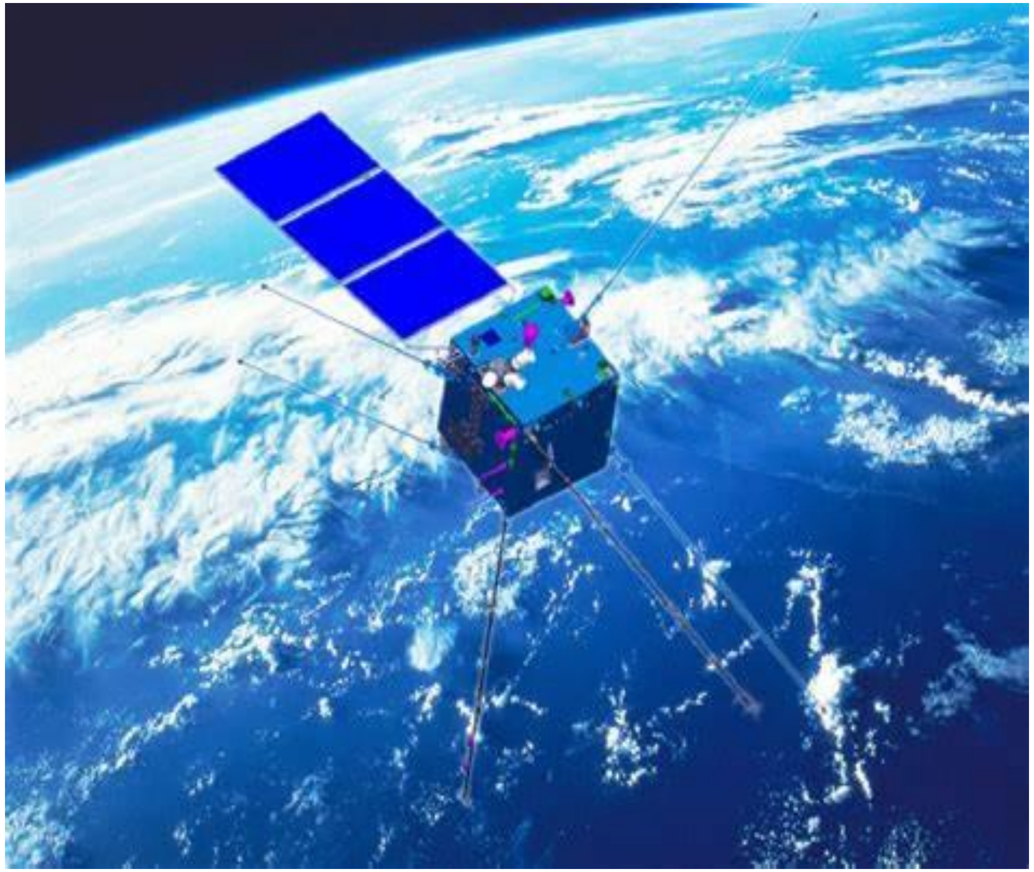
3. Outcomes of CSES/Swarm cooperation

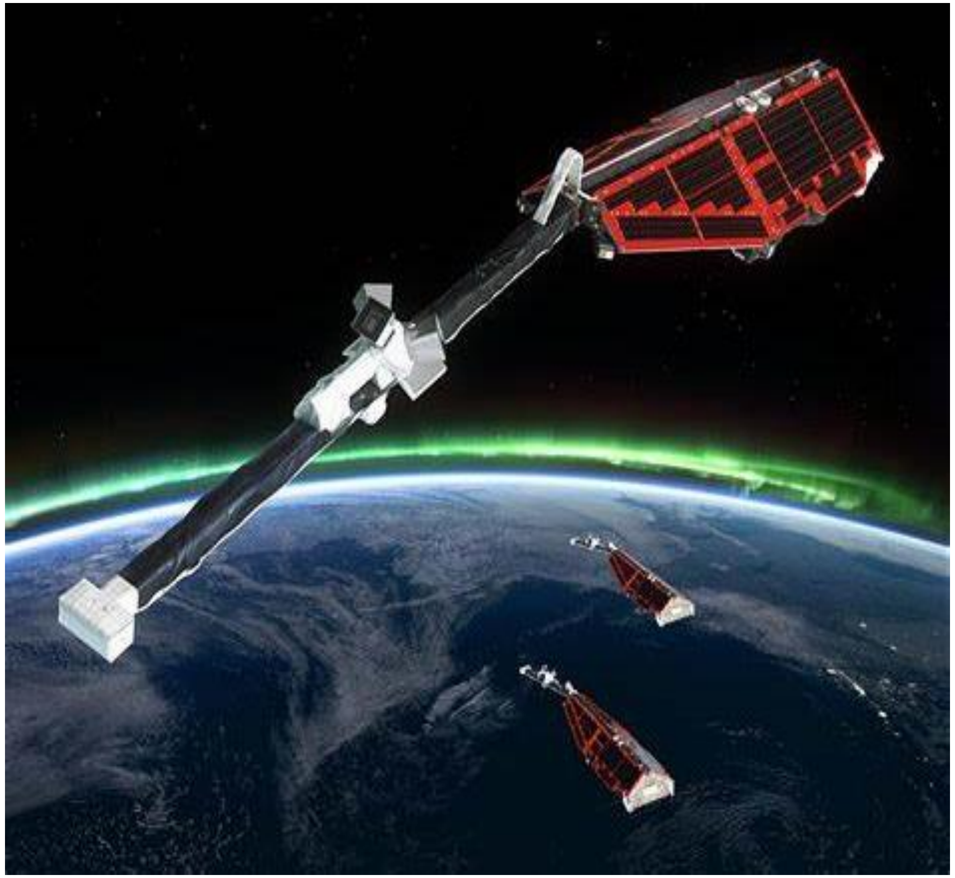
- Validation results
- Scientific results

4. Proposals for next-step bilateral cooperation

Goal: achieve high-level scientific outcomes

1. Jointly carry on the magnetic field, plasma data validation between Swarm and CSES;
2. Jointly modeling of geomagnetic field or ionosphere;
3. Jointly carry on the comprehensive studies on natural disaster events, e.g., earthquakes, volcano, geo-magnetic storms etc.;
4. **Jointly develop and optimize the data processing tools for the magnetometers and Langmuir probe onboard CSES;**
5. **Jointly study the details of some ionospheric structures;**
6. **To xplore the possibility for generating higher level scientific products from the magnetic measurements.**





Thank you for your attention!