



# Introduction of International Meridian Circle Program and the Progress of Its Typical Demonstrations in Brazil

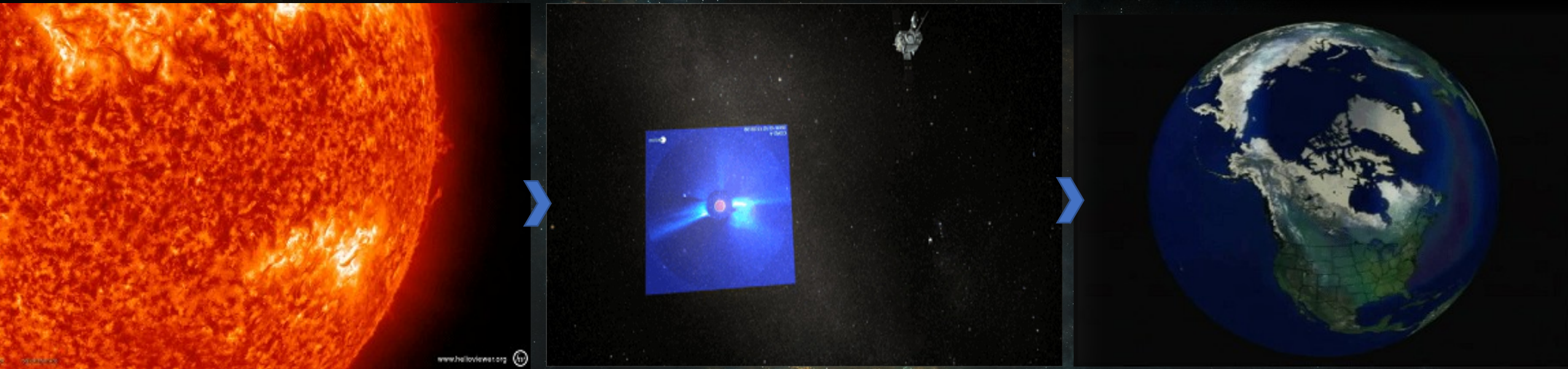
Hui Li

National Space Science Center, Chinese Academy Sciences

# Contents

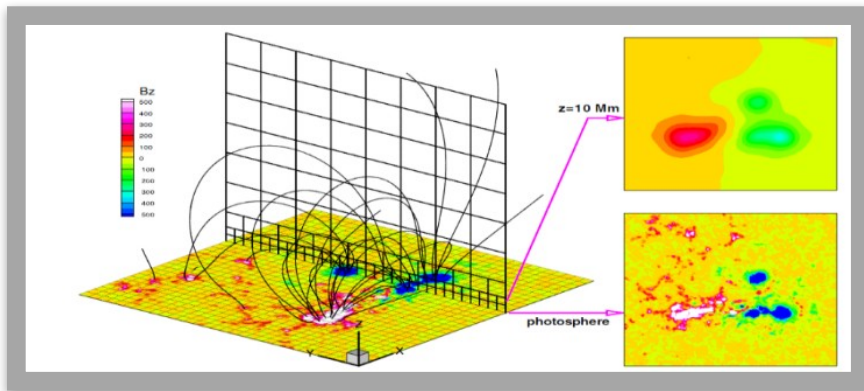
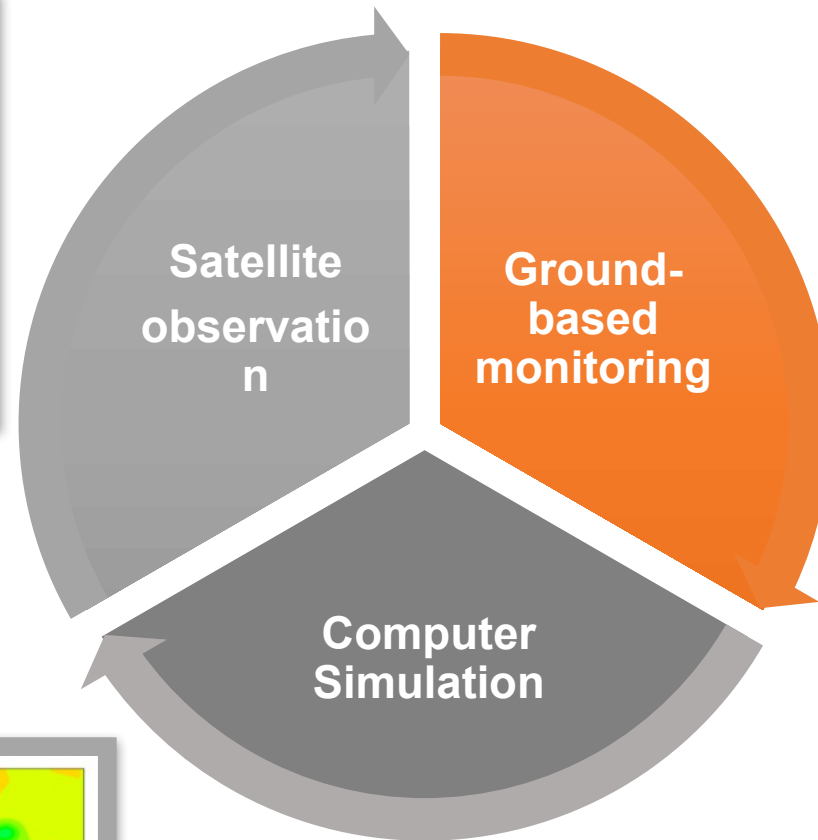
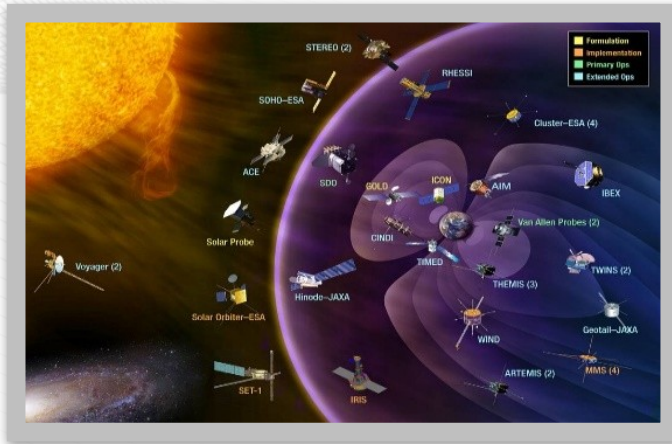
1. **International Meridian Circle Program**
2. **Typical Demonstrations in Brazil**

# Space Environment & Space Weather



**Space Weather : Dynamic changes in space environment, which threaten satellites, astronauts, and various high-tech systems on Earth**

# Trinity of Space Weather Research



## 5C advantages

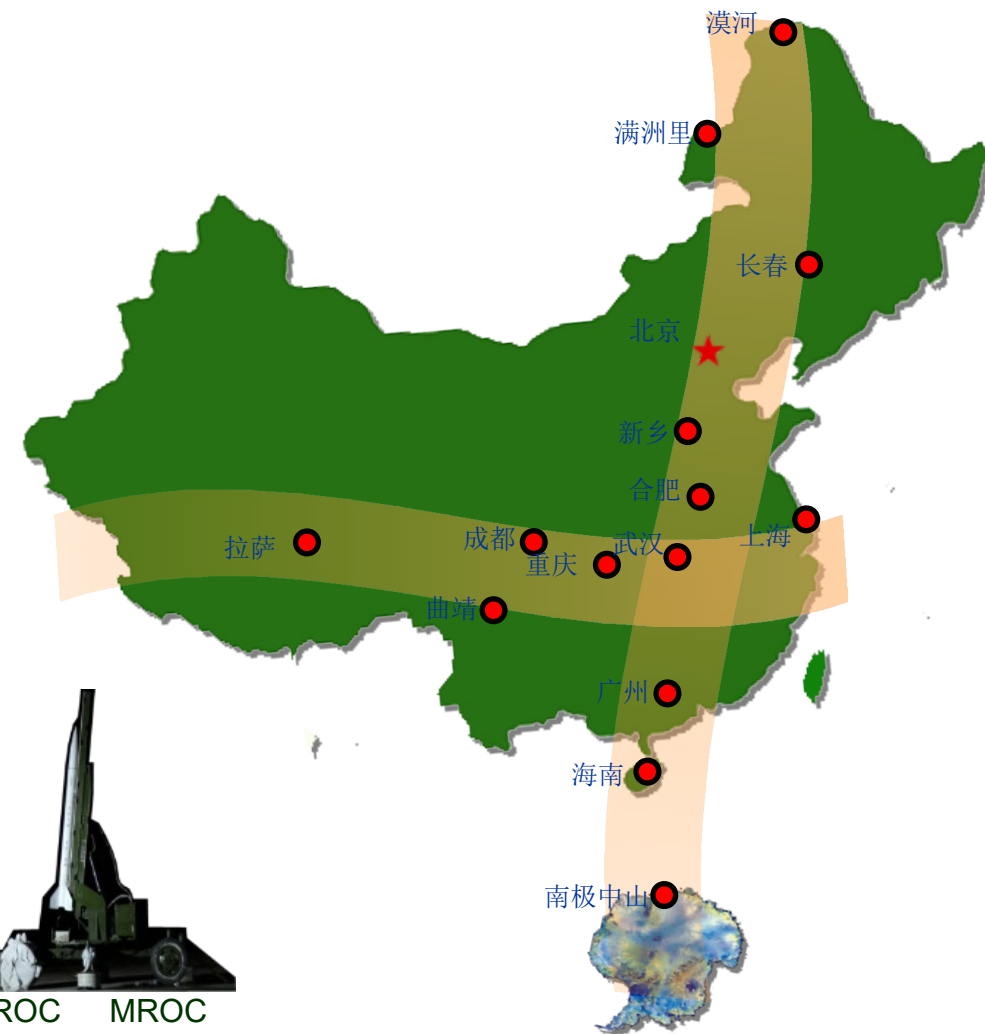


- Continuous**
- Convenient**
- Controllable**
- Credible**
- Cost-effective**

# Chinese Meridian Project – Phase I

87 facilities@15 stations

- Geomagnetic
- Optical-atoms
- Radio
- Rocket



Operation: 2012-now



子午工程数据中心  
Data Center for Meridian  
Space Weather Monitoring Project



<https://data2.meridianproject.ac.cn/>

Home Online Data Documentation Softwares

# Chinese Meridian Project – Phase II

1 Chain  
From Sun to Earth

3 Networks  
M, I, A

## 4 Focuses

High-latitude: Polar regions

Mid-latitude: North area of China

Low-latitude: South of China (Hainan)

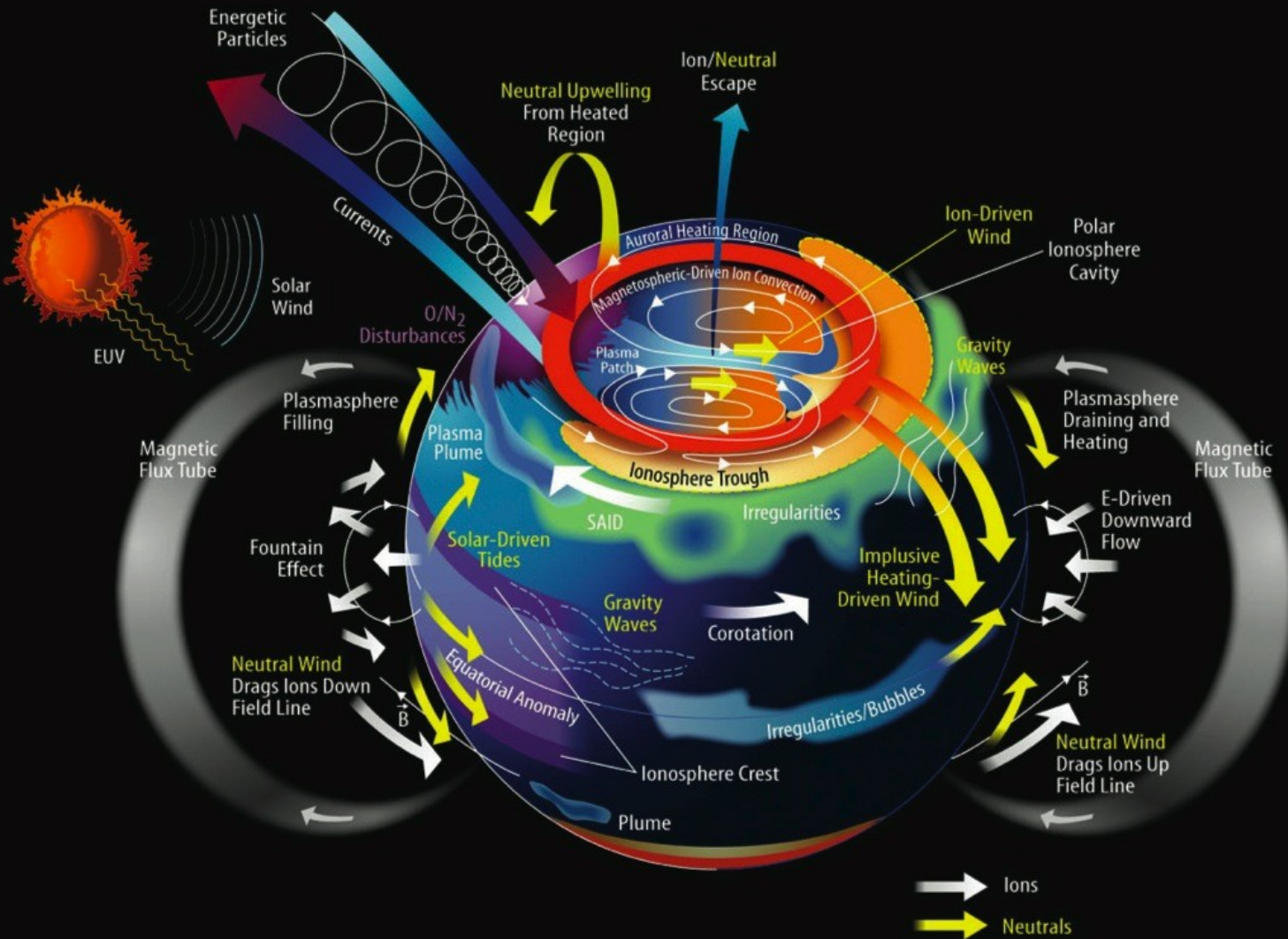
High-land: Tibetan Plateau

- A total of 282 instruments deployed at 31 stations across China and polar regions
- 1.31 billion CNY/183.9 million USD
- Completed in April 2024, in trial operation



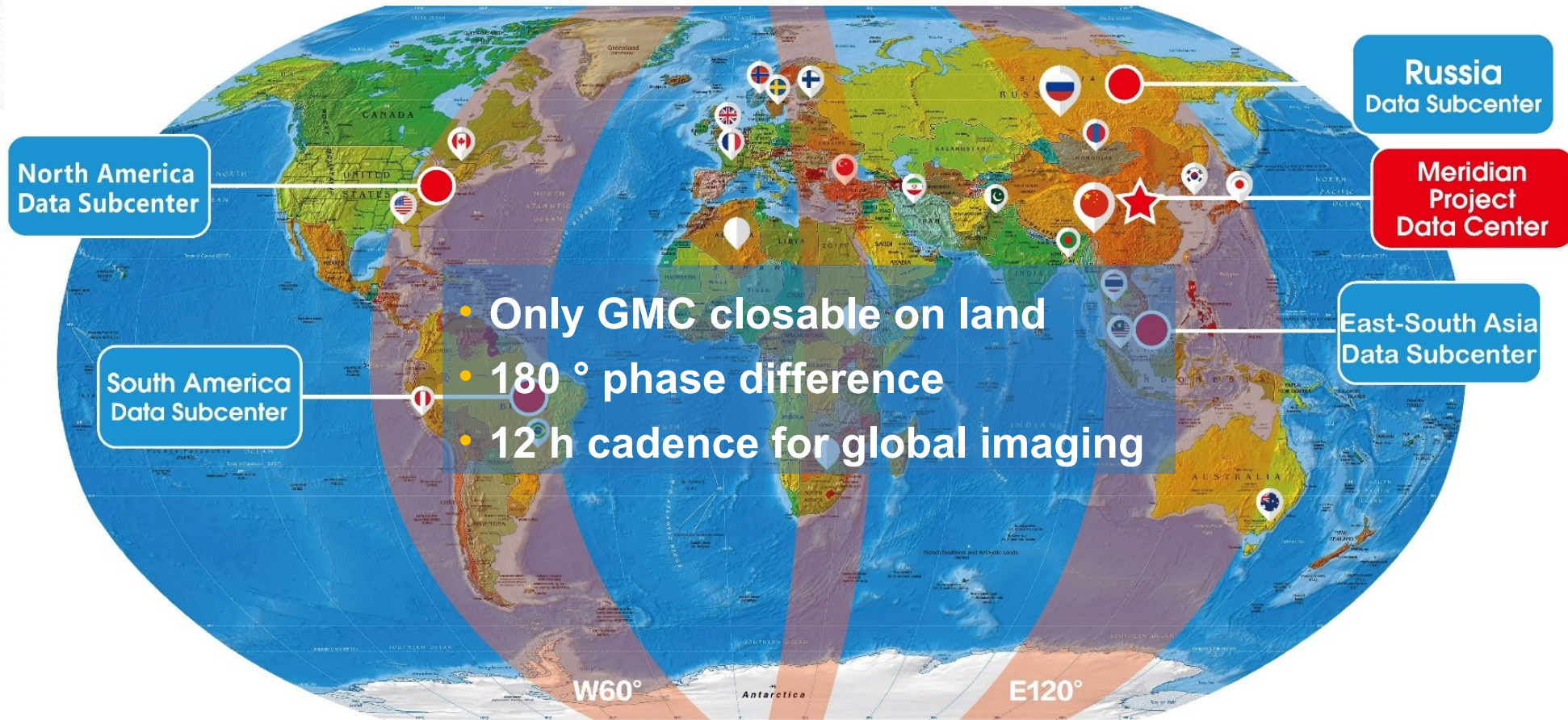
# Space Weather

—global phenomenon, require global solution



- Affecting every corner of the Earth's space
- A common challenge faced by all of humanity

# International Meridian Circle Program (IMCP)

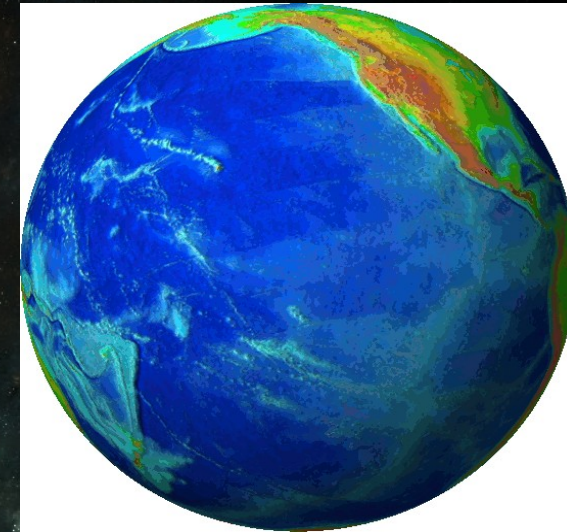
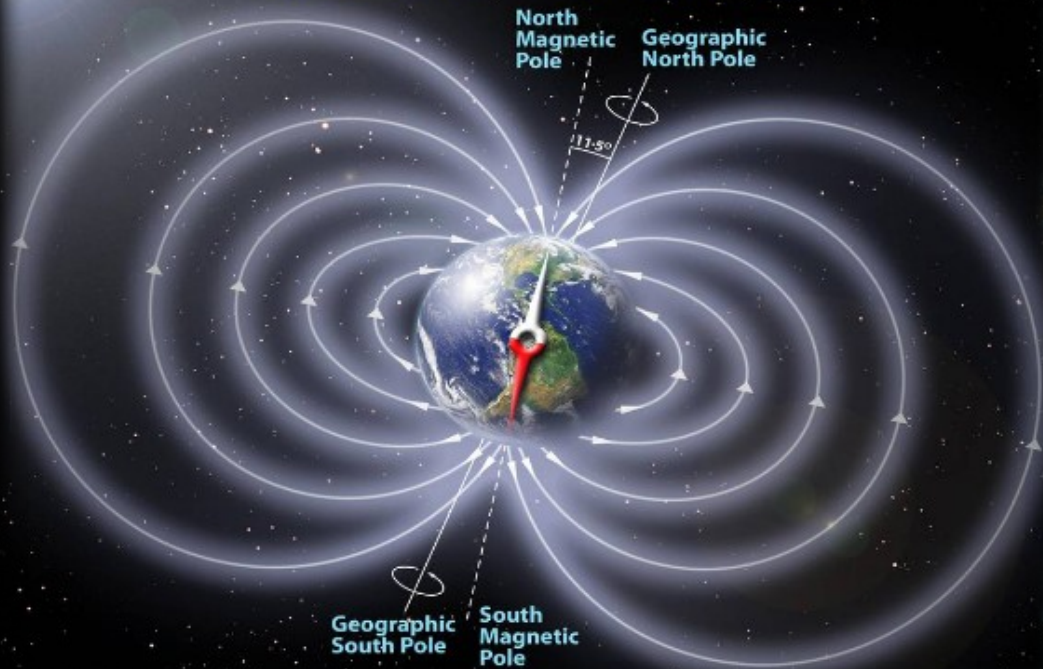


- Outgrowth of the **Chinese Meridian Project**
- Integrate ground-based observatories along the Great Meridian Circle



# Principle of Observation

The Earth's Magnetic Field



- Space weather events propagate along the meridian
- Ground-based instruments can detect physical processes within 0-3000 km
- As the Earth rotates, IMCP can obtain a **3D global image of geospace** every 12 hours

# Overall Architecture

## ■ IMCP Headquarters

@Huairou Science City,  
Beijing

Welcome our Russian  
friends !

## ■ Four Pillars

SCIENCE

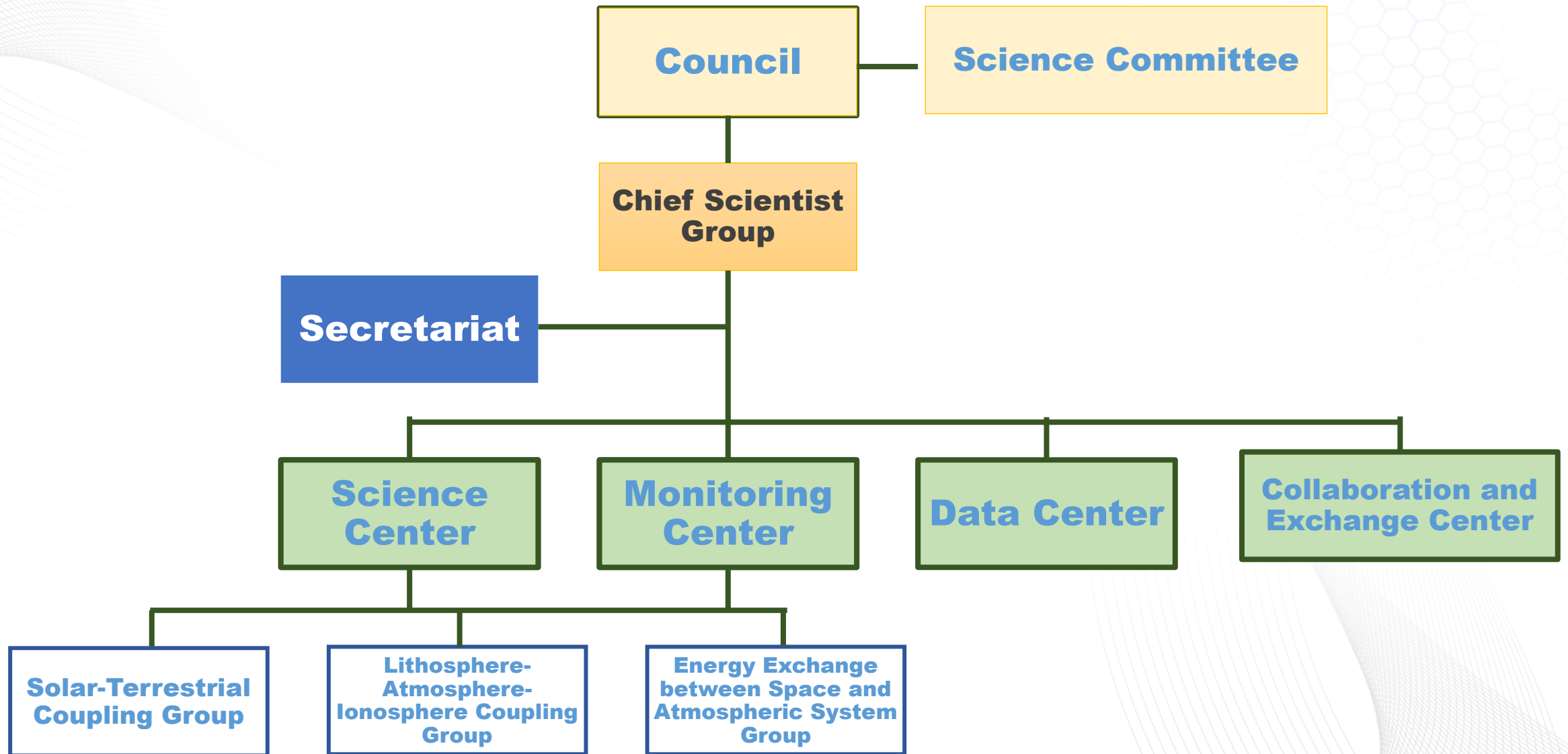
MONITORING  
NETWORKS

DATA

INTERNATIONAL  
COLLABORATION



# Organization



# Overarching Science Goal

## 1 System : Sun-Earth System

- Geospace/Atmosphere/Solid Earth
- Regional features ↔ Global features

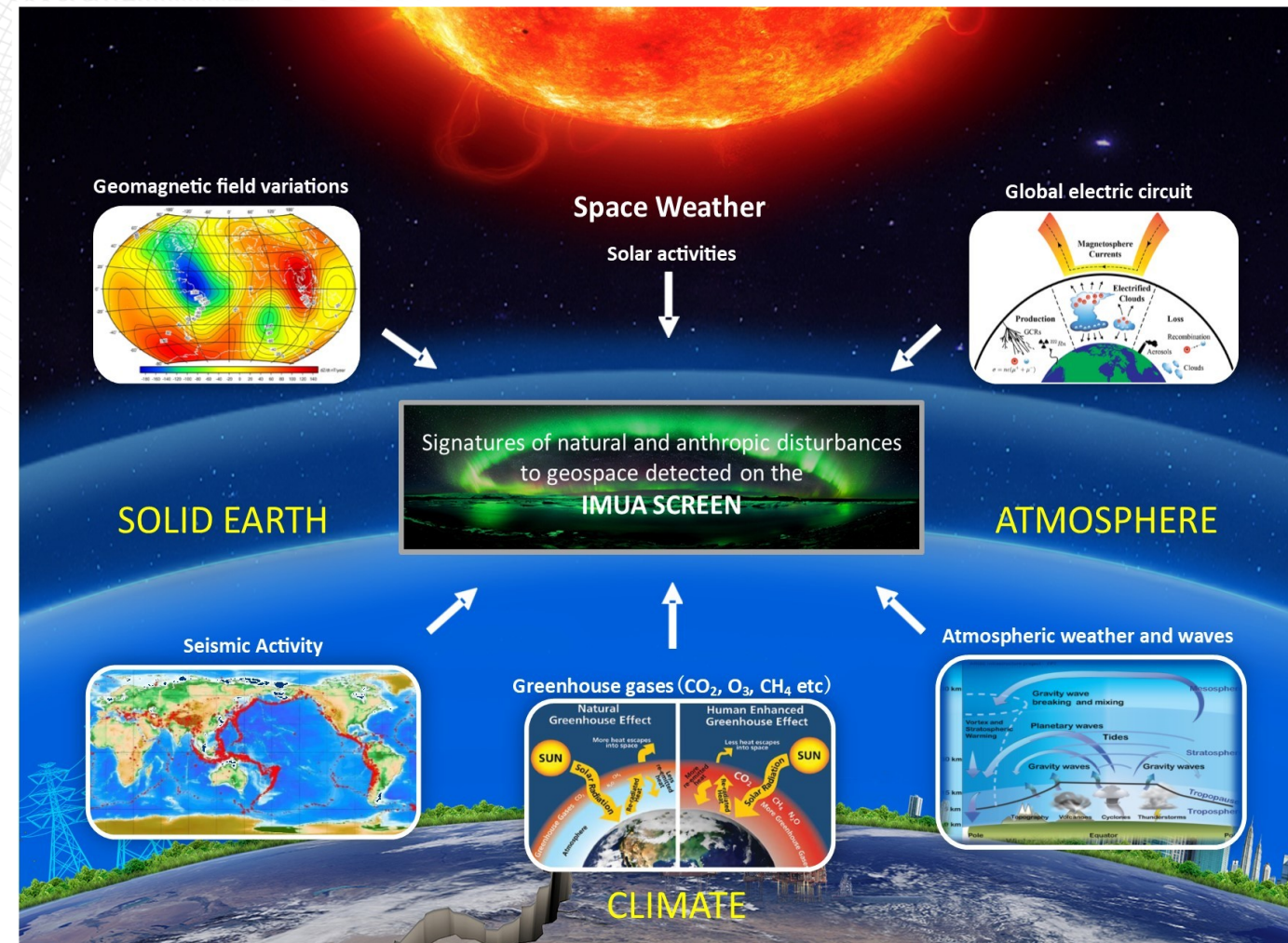
## 2 drivers

**Above**

**Solar activity → Space weather**

**Below**

**Solid Earth/Earth surface/Atmosphere  
→ Space weather**



**How the Sun-Earth System is driven and influenced by solar activities above and solid earth-atmosphere processes below**

# Scientific Consensus

- Scientists from over 30 major international research institutions have reached a consensus on the **scientific objectives**.
  - Consensus report 1 : Science Objectives and Observation System for the International Meridian Circle Program , *TAIKONG* , 2020
  - Consensus report 2 : Scientific challenges and instrumentation for the International Meridian Circle Program , *Science China Earth Sciences* , 2021 , **Cover story**
  - Consensus report 3 : Progress of International Meridian Circle Program, William LIU, Blanc MICHEL, Chi WANG et al. Chinese Journal of Space Science, 2022, 42(4): 584-587
  - Consensus report 4 : Progress and future of International Meridian Circle Program, Chi Wang. et al. Chinese Journal of Space Science, 2024



# International Collaboration

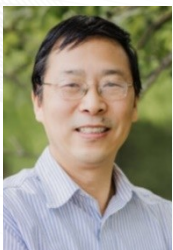
16 Agreements/MoU , 3 Letter of support



## 国际组织 International Organization



# IMCP Observational campaigns (2014~ )



Shunrong Zhang  
MIT



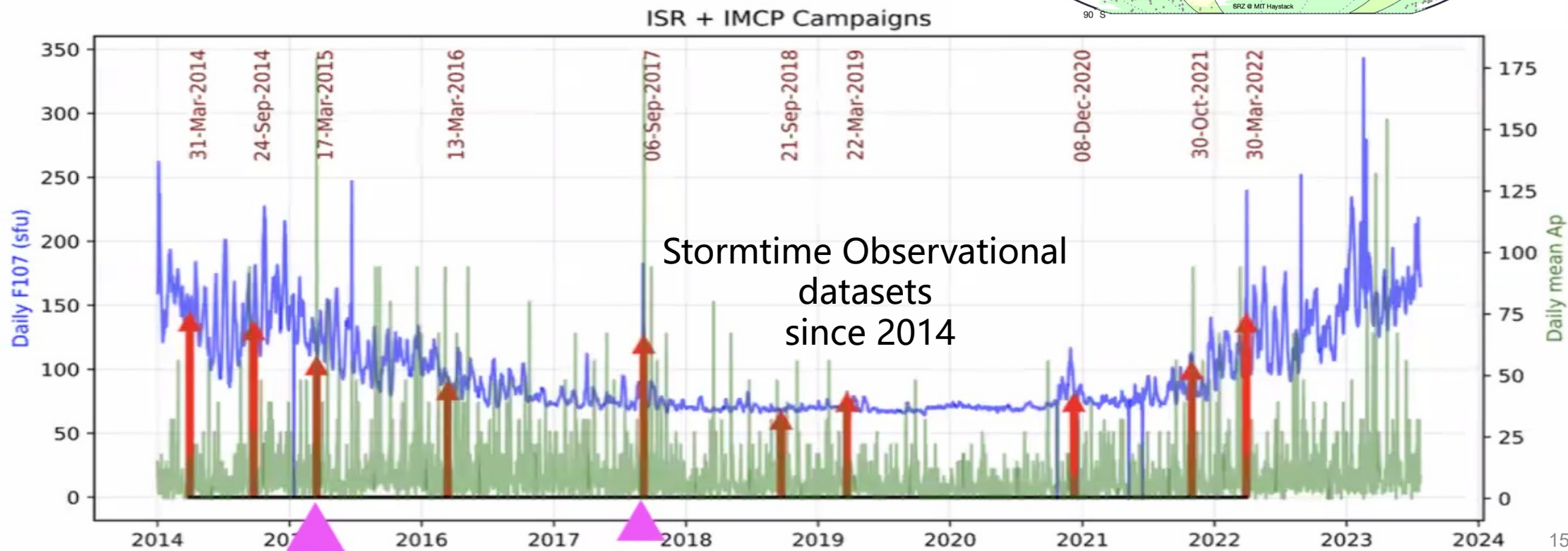
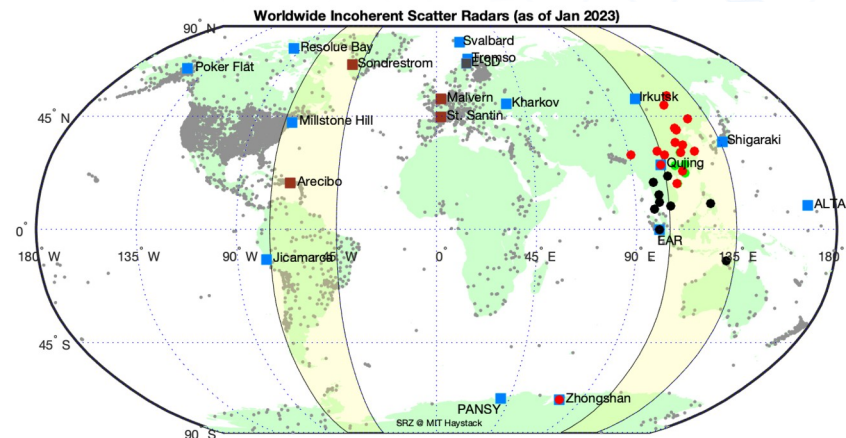
John Foster  
MIT



Lei Jiuhou  
USTC



Xu Jiyao  
NSSC



# IMCP workshop

## IMCP 2023: Sep 14-17

- Sponsored by SCOSTEP, NSFC, and CAS
- IMCP Headquarters Building inauguration
- **106 scientists from over 20 countries and international organizations participated**





# IMCP 2024 Workshop

- Co-organized with INPE, Sponsored by SCOSTEP, NSFC
- Participants registered over 70
  - ISWI Executive Director, Nat Gopalswamy
  - Director of the MIT Haystack Observatory, Phillip Erickson
  - Chief Scientist of the South African National Space Agency, Michael Kosch
  - Director of Department of Physics, University of Oslo, Wojciech J. Miloch



**Chi Wang**

National Space Science Center (NSSC)  
Chinese Academy of Sciences  
China



**Clezio De Nardin**

National Institute for  
Space Research (INPE)  
Brazil



**Shun-Rong Zhang**

Massachusetts Institute of  
Technology (MIT)  
USA



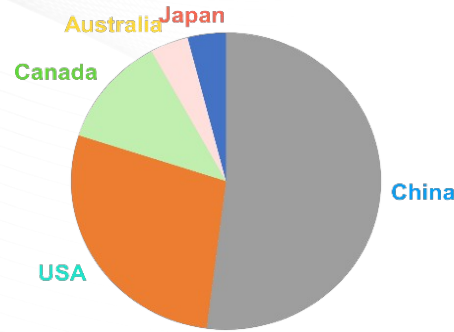
**Michel Blanc**

Institut de Recherche en  
Astrophysique et  
Planétologie (IRAP)  
Observatoire Midi-Pyrenees  
France

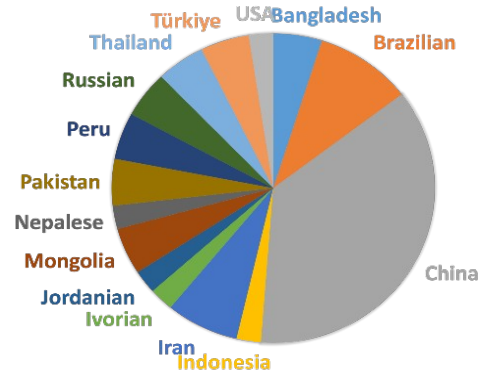
# IMCP Space Weather School

- **2023 IMCP School** , 41 students from 14 countries

Lecturers (25)

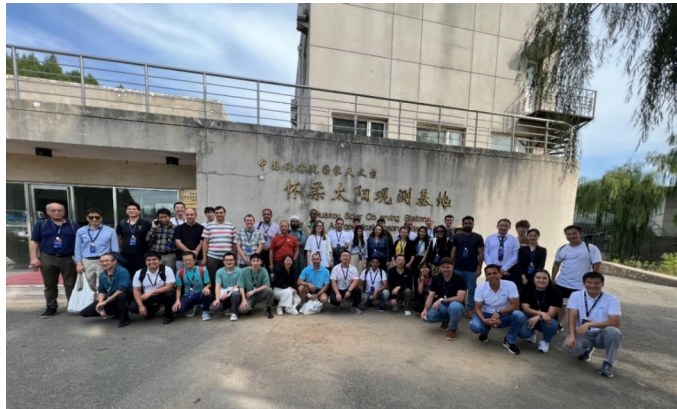


Students (41)



- APSCO gave high ratings in their evaluations
- co-organized with APSCO

- **2024 IMCP/SuperDARN School**



- **2025 IMCP School** , to be held in Nov, Hainan, China, Stay tuned!

- Co-organized by APSCO and IGGCAS

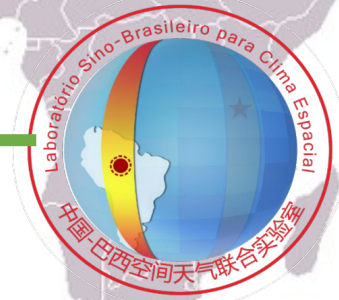
# Contents

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# China-Brazil Cooperation

Two countries have  
**unique geophysical features of global importance**  
(e.g., Himalayas and Amazons )

**Geomagnetic conjugacy**  
makes the two countries the ideal pivotal  
points for IMCP



**Joint laboratory for space weather**  
set a strong foundation for cooperation

**Low-latitude regions are unique** for ionospheric and middle and upper atmospheric studies

# Pilot Project: China-Brazil Joint Laboratory for Space Weather(CBJLSW)

## Phase 1

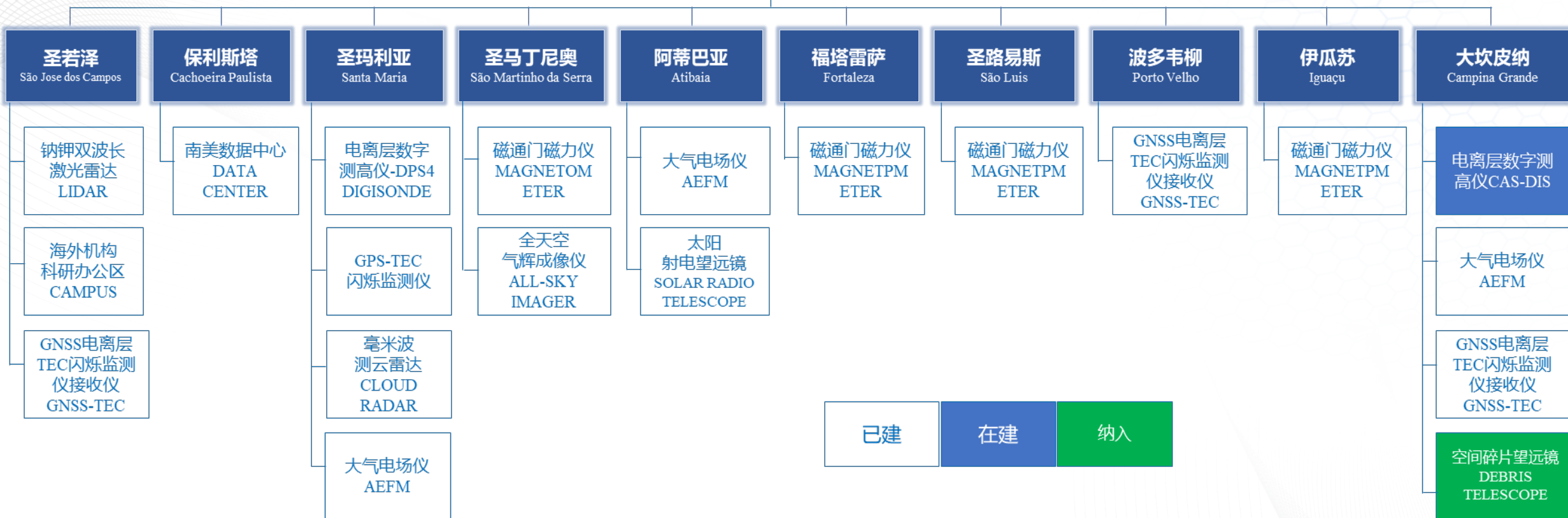
- Aug 2014-Late 2018

## Phase 2

- Early 2019-Nov 2024



## 中国-巴西空间天气联合实验室 (CBJLSW)



- **Data Center** : Capacity , 200TB , data collected , **3.5+TB**
- **Monitoring stations** : **10**
  - 1 Headquarters Campus; 1 Science outreach center; 3 Comprehensive Stations
- **Monitoring instruments** : **16+1**

- 70+ papers in top-tier journals
- High-citation paper award from the JGR



WILEY

## Top Cited Article 2021-2022



Congratulations to:

Laysa Resende

whose paper has been recognized as a top cited paper\* in:

### JOURNAL OF GEOPHYSICAL RESEARCH: SPACE PHYSICS

The Impact of the Disturbed Electric Field in the Sporadic E (Es) Layer Development Over Brazilian Region

\*Among work published in an issue between 1 January 2021 - 15 December 2022.

## Congratulations

On behalf of the **China-Brazil Joint Laboratory for Space Weather**, I would like to congratulate the three postdoctoral researchers for their articles published in the *Journal of Geophysical Research: Space Physics*, which were cited among the top 10% most downloaded papers for the period of 2018-2019! We strongly acknowledge their very productive research effort and expect to continue working together in our Lab in order to produce in the future even more important contributions to Space Science.

<p>TOP DOWNLOADED PAPER 2018-2019 CONGRATULATIONS TO <b>Juliano Moro</b> whose paper has been recognized as one of the most read in <i>Journal of Geophysical Research: Space Physics</i> WILEY</p> <p>Moro, J., Xu, J., Denardini, C. M., Resende, L. C. A., Silva, R. P., Liu, Z., et al. (2019). On the sources of the ionospheric variability in the South American Magnetic Anomaly during solar minimum. <i>Journal of Geophysical Research: Space Physics</i>, 124. <a href="https://doi.org/10.1029/2019JA026730">https://doi.org/10.1029/2019JA026730</a> E-mail: juliano.moro@inpe.br</p>	<p>TOP DOWNLOADED PAPER 2018-2019 CONGRATULATIONS TO <b>LIGIA ALVES DA SILVA</b> whose paper has been recognized as one of the most read in <i>Journal of Geophysical Research: Space Physics</i> WILEY</p> <p>Da Silva, L. A., Sibeck, D., Alves, L. R., Souza, V. M., Jauer, P. R., Claudepierre, S. G., et al. (2019). Contribution of ULF wave activity to the global recovery of the outer radiation belt during the passage of a high-speed solar wind stream observed in September 2014. <i>Journal of Geophysical Research: Space Physics</i>, 124. <a href="https://doi.org/10.1029/2018JA025164">https://doi.org/10.1029/2018JA025164</a> E-mail: ligia.silva@inpe.br</p>	<p>TOP DOWNLOADED PAPER 2018-2019 CONGRATULATIONS TO <b>Daiki Koga</b> whose paper has been recognized as one of the most read in <i>Journal of Geophysical Research: Space Physics</i> WILEY</p> <p>Koga, D., Gonzalez, W. D., Souza, V. M., Cardoso, F. R., Wang, C., &amp; Liu, Z. K. (2019). Dayside magnetopause reconnection: its dependence on solar wind and magnetosheath conditions. <i>Journal of Geophysical Research: Space Physics</i>, 124. <a href="https://doi.org/10.1029/2019JA026589">https://doi.org/10.1029/2019JA026589</a> E-mail: dkaqua@kyudai.jp</p>
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## China's Contributions

scientific equipment (17)

Research Funding (50.99 million CNY)

Research personnel (68)

Co-constructed facility

Data sharing

Joint research

Talent cultivation

## Brazil's Contributions

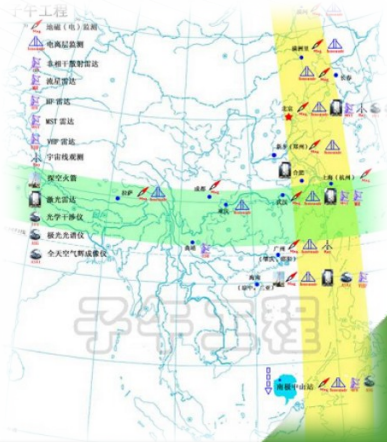
Research facilities ( 170 00 m<sup>2</sup> )

Basic infrastructure (water, electricity, network)

Research personnel (29)



# Vision: 1- 4 dimension of global research



## CMP Phase I

Multi-instrument network to study how energy spreads from high to mid-low latitudes and how the latter backreacts on the former

**1<sup>st</sup> dimension of global research**



## CMP Phase II

Ground-based coordinated observation from the Sun to Earth  
**2<sup>nd</sup> dimension of global research**



## IMCP

Complete latitudinal coverage of geospace. Taking advantage of Earth's rotation, render a scanned image of geospace every 12 hours.

**3<sup>rd</sup> dimension of global research**



## Future

Space-based and ground-based collaborative research  
**4<sup>th</sup> dimension of global research**

# China-Russia Joint Research Center on Space Weather

- Established in 2000 by ISTP SB RAS and NSSC, CAS
- Scientific workshops are held every two years, 14 workshops have been held successfully



**G.A.Zherebtsov**

Academician of RAS

Award for International Scientific  
Cooperation of CAS , 2012  
Foreign Member of CAS, 2021



**Ji WU**

Fellow of the IEEE  
Foreign Member of RAS, 2022



# China-Russia Joint Research Center on Space Weather

Jointly plan and develop northern East Asia ionosphere and atmosphere monitoring system with **Russia** , deploying all-sky airglow imagers, GNSS-TEC and scintillation monitors, atmospheric electric field instruments

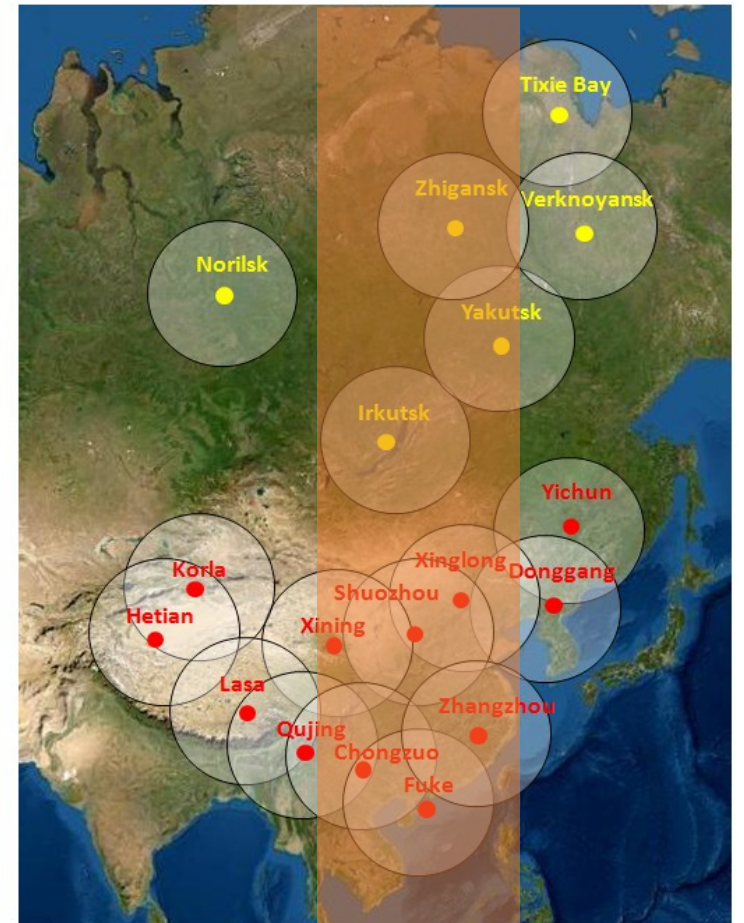
## Cooperation Agreements

- 2021, Moscow State University
- 2022, the Polar Geophysical Institute of the Kola Science Centre, RAS
- 2022, Institute of Cosmophysical Research and Radio Wave Propagation, Far Eastern Branch of the RAS

## Chinese-Russian joint project

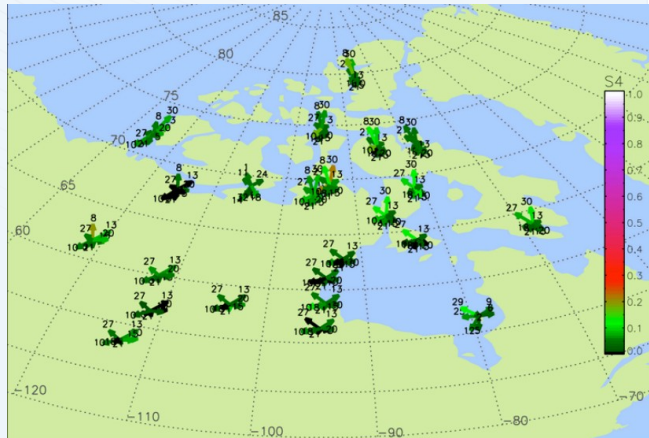
**Key International Cooperation Funding of the NSFC , 2022:** Research on Solar Flares and Active Regions Based on the Next-Generation Chinese-Russian Radio Telescopes;

**Partner:** Institute of Solar-Terrestrial Physics, RAS



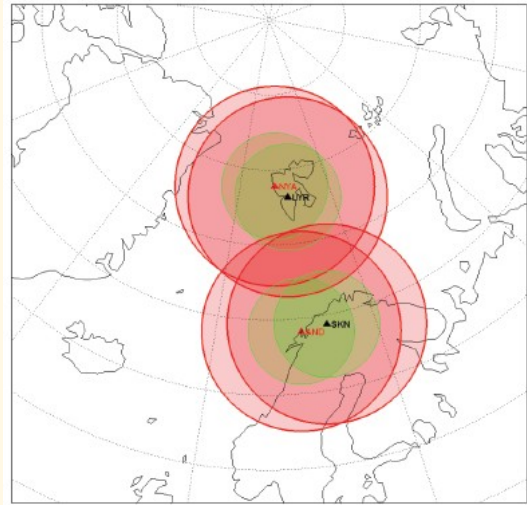
# North Polar Region (Canada, Europe, Chinese Polar Stations)

## Canada High Arctic Ionosphere Network (CHAIN)

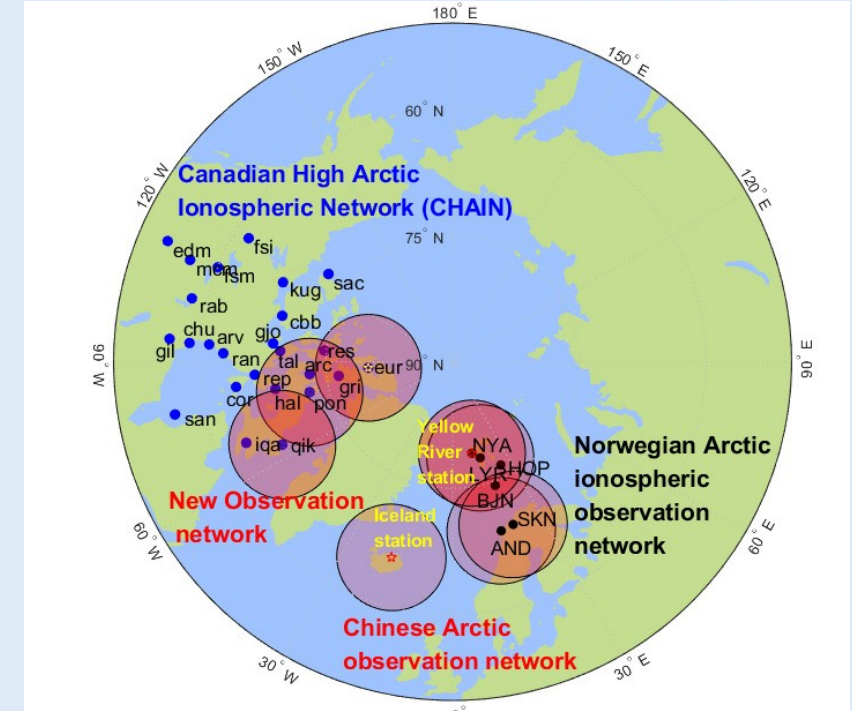


- 25 GNSS receivers
- 6 Digisondes
- ...

## University of Oslo Network



- 4 GNSS receiver
- 4 All sky imagers
- ...

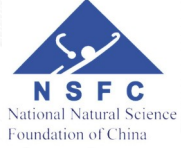
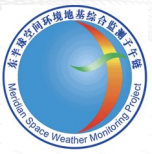


- Add > 3 All sky imagers, >3 photometers
- Partially filling the coverage gap, but not enough

Chinese PI : Qinghe Zhang, zhangqinghe@nssc.ac.cn

# Southeast Asian Ionospheric and Atmospheric Network

## International cooperation



Pakistan

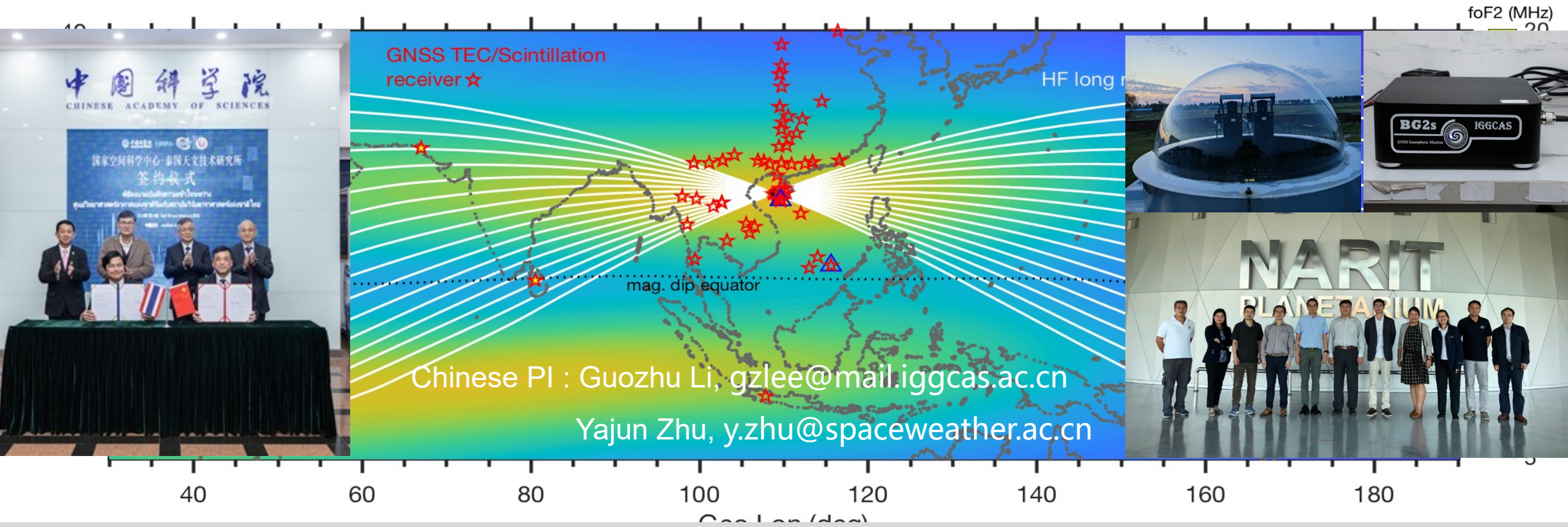
Thailand

Laos

Cambodia

Indonesia

- GNSS TEC/scintillation receivers
- Airglow Imagers
- .....



Observing background ionosphere and plasma bubbles over a wide longitude from Indian ocean to west Pacific



**Thank you!**

2024.09