



Introduction to China's Space Environment Ground-based Monitoring Network - Chinese Meridian Project (CMP)

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National Space Science Center, CAS

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■ Objectives and Development Strategy

Scientific objectives

Construction Process of CMP

■ General introduction of CMP system

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■ Some Key Instruments

Locations, specifications, and observation examples

■ Conclusions & Future

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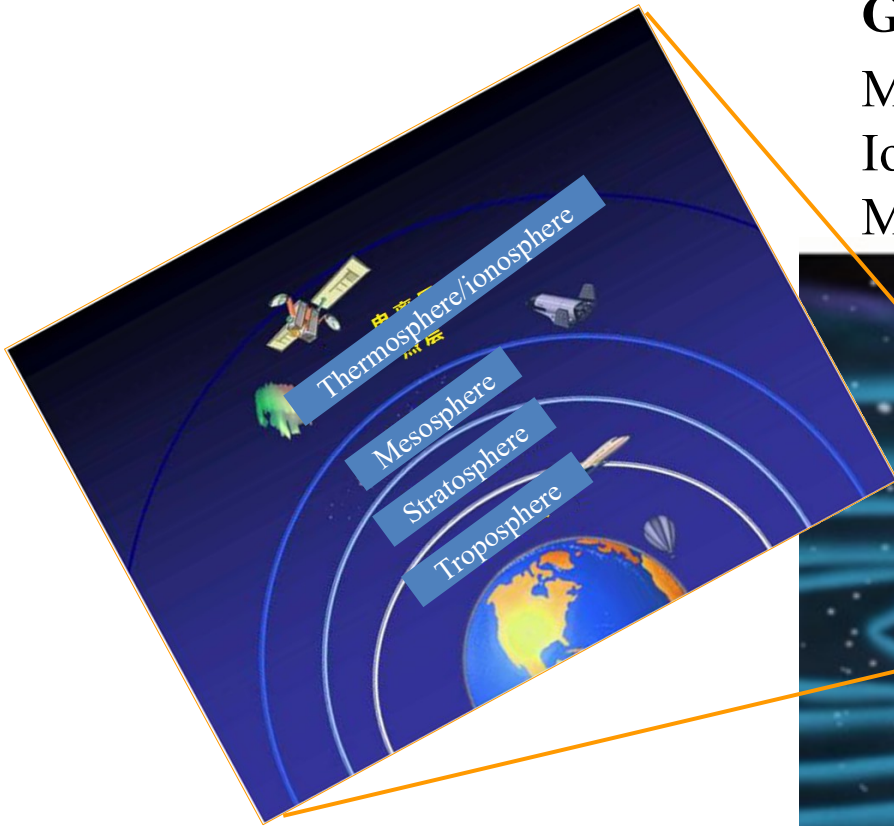
Overall Architecture

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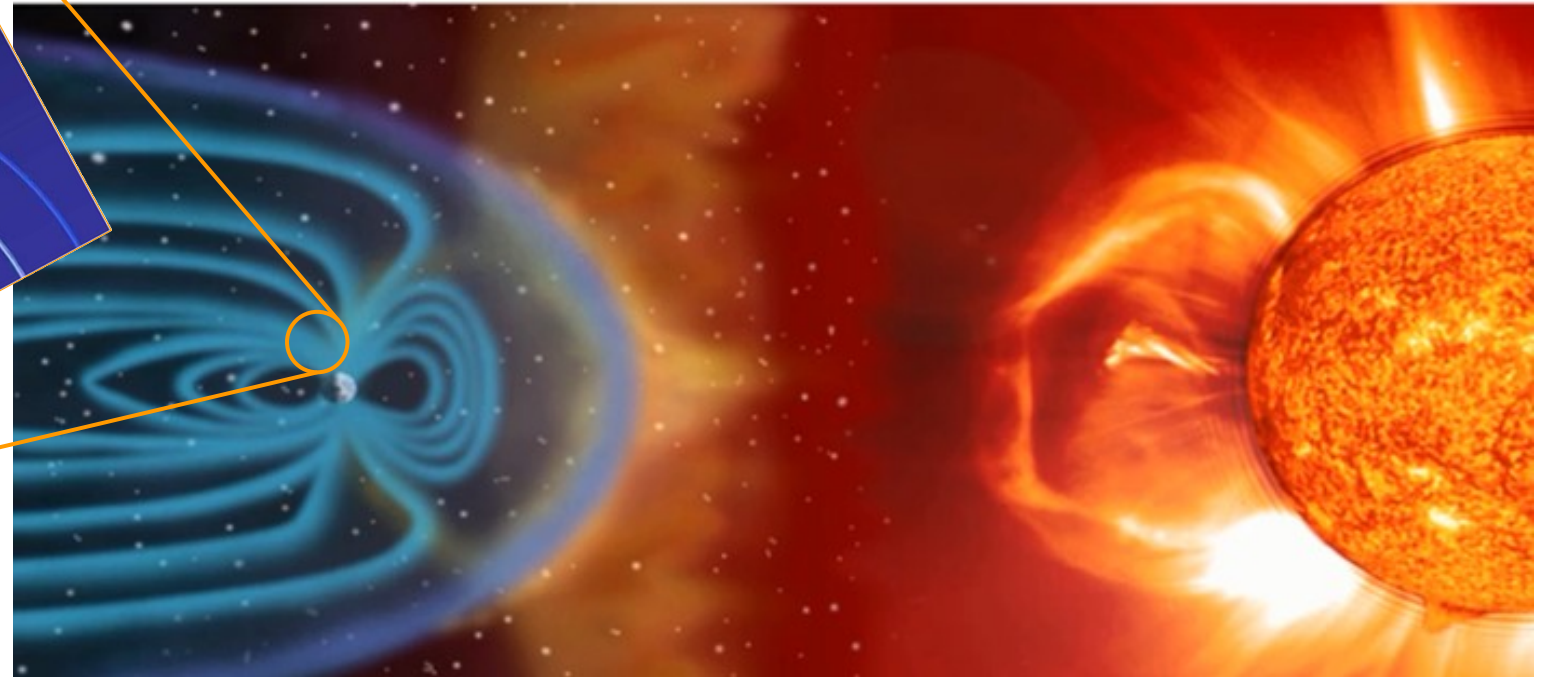
Detecting objects — the solar-terrestrial space



Geospace
Magnetosphere
Ionosphere
Mid-upper atmosphere

Interplanetary
Solar wind
Magnetic cloud

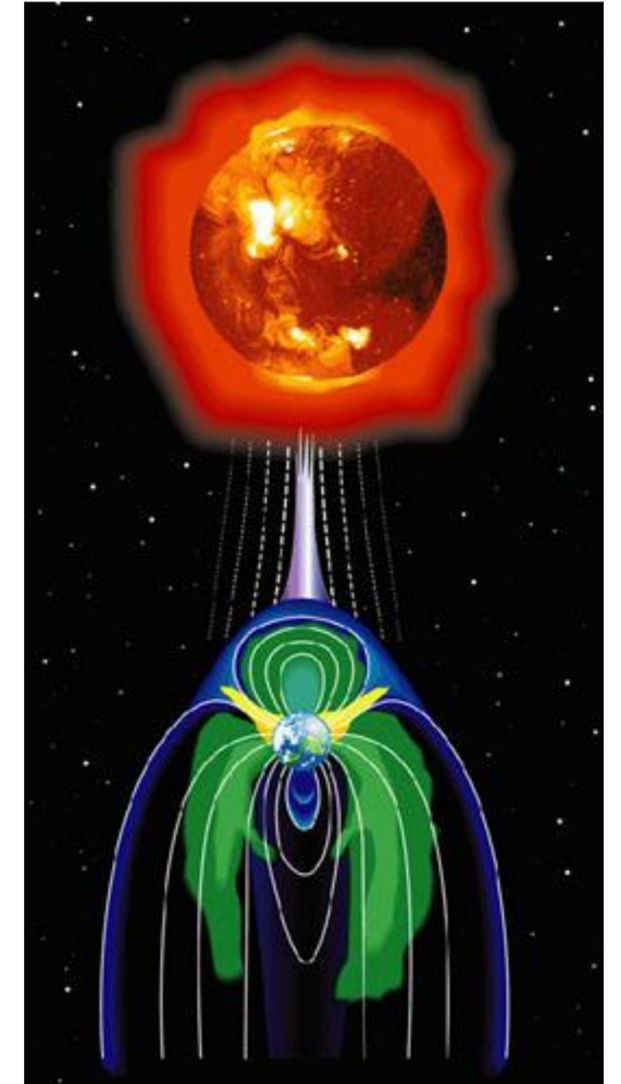
Solar
Photosphere,
chromosphere, corona



Parameters to detect: density, temperature, electromagnetic field, neutral wind, drift velocity, ionospheric irregularities.....

Study on Solar-Terrestrial Space, in high temporal-spatial resolution.

- (1) Regional Features:** To reveal the regional features of space environment above China, and their relationship to global space variations.
- (2) Coupling Mechanism:** To study coupling processes and mechanisms between different space spheres: solid Earth, lower atmosphere and near-Earth space environment
- (3) Propagation Characteristics:** To explore the propagation and evolution of space weather events from the solar atmosphere to near Earth space



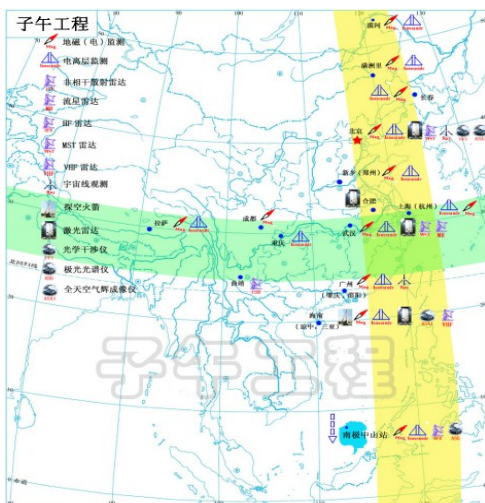
Construction Process of CMP



Tow steps of the Chinese Meridian Project construction:

CMP-phase I

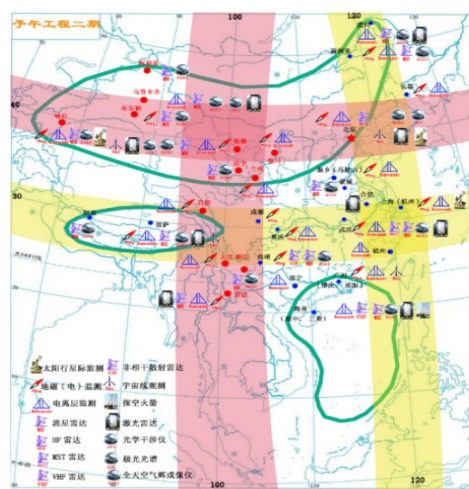
CMP-phase II



15 observatories
along 120°E and
30°N

87 conventional
automatic
instruments are
installed

0.167 billion



31 observatories
along 100°E &
120°E and 30°N
& 40°N (16 in
Phase II)

282
instruments (1
95 in Phase II)

1.3 billion

2008

2012

2019

2025

Operation period of CMP

Construction period
(CMP-I)

Operation period
(CMP-I)

Construction period
(CMP-II)

National Formal Acceptance

We are here now

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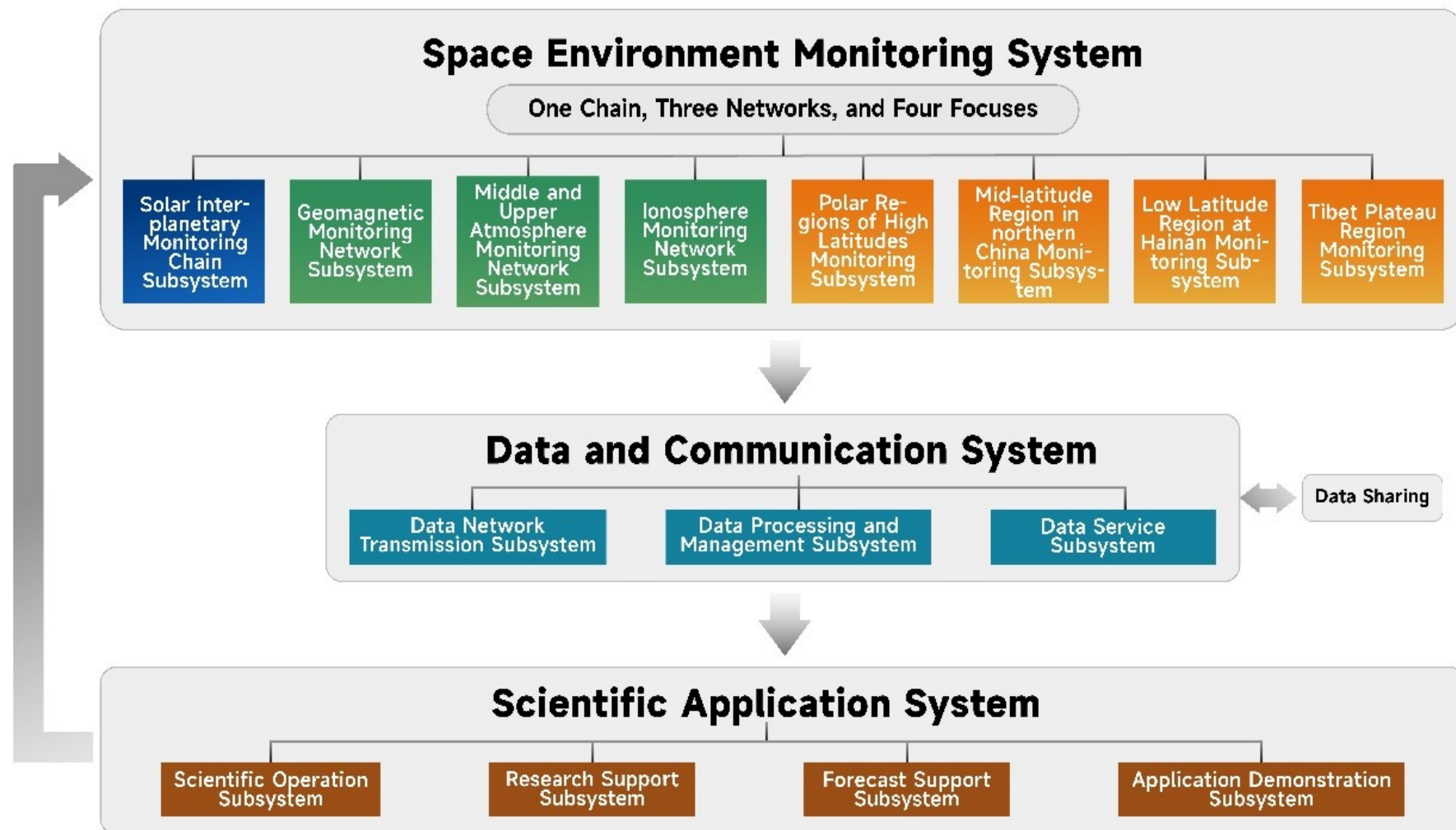
■ Some Key Instruments

Locations, specifications, and observation examples

■ Conclusions & Future

Three Systems

- Space Environment Monitoring System
- Data and Communication System
- Scientific Application System



System framework diagram of the Chinese Meridian Project.

Space Environment Monitoring System

One Chain, Three Networks, and Four Focuses

Solar inter-planetary Monitoring Chain Subsystem

Geomagnetic Monitoring Network Subsystem

Middle and Upper Atmosphere Monitoring Network Subsystem

Ionosphere Monitoring Network Subsystem

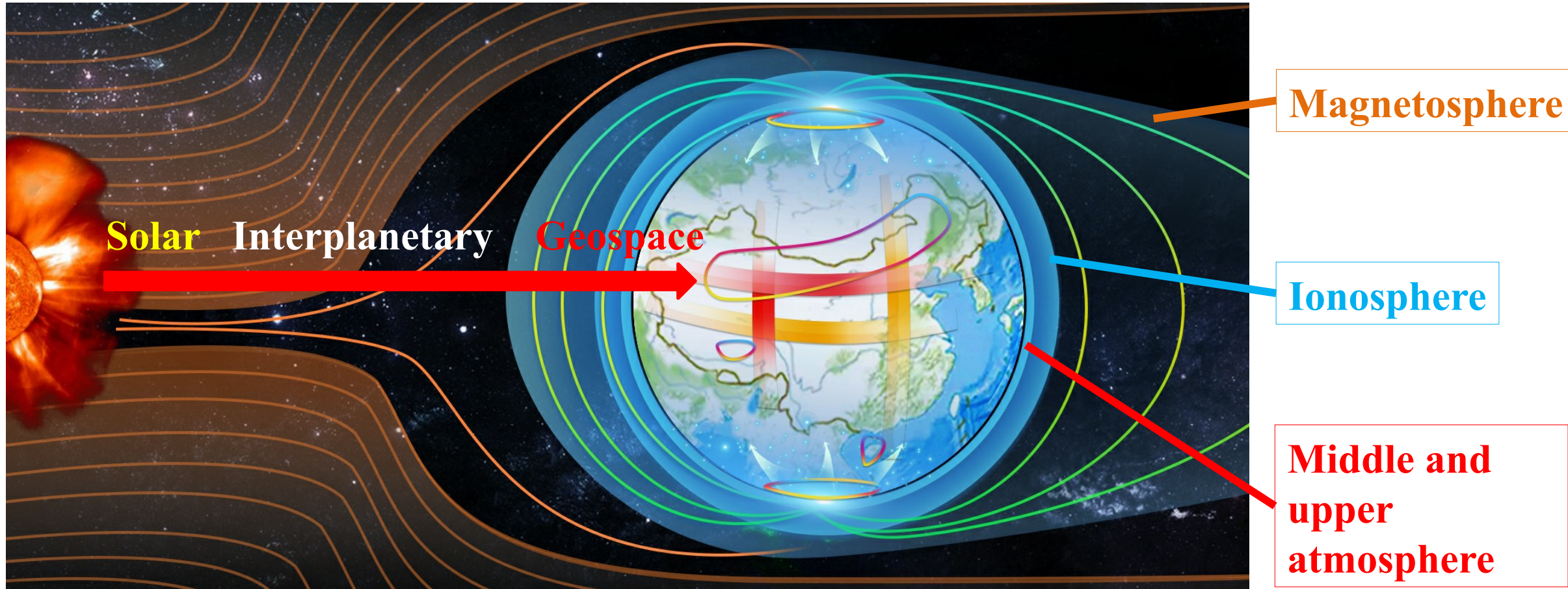
Polar Regions of High Latitudes Monitoring Subsystem

Mid-latitude Region in northern China Monitoring Subsystem

Low Latitude Region at Hainan Monitoring Subsystem

Tibet Plateau Region Monitoring Subsystem

Scientific Requirements



- A whole chain to trace disturbances from sun to interplanetary, and geospace.
- For geospace, a network observation is needed for detecting propagation of perturbations.
- For scientifically key regions, key comprehensive detections are needed.

Monitoring system architecture



- **One Chain:**

From sun, interplanetary to geospace.

- **Three Networks:**

Geomagnetic field, Ionosphere, Mid-upper atmosphere

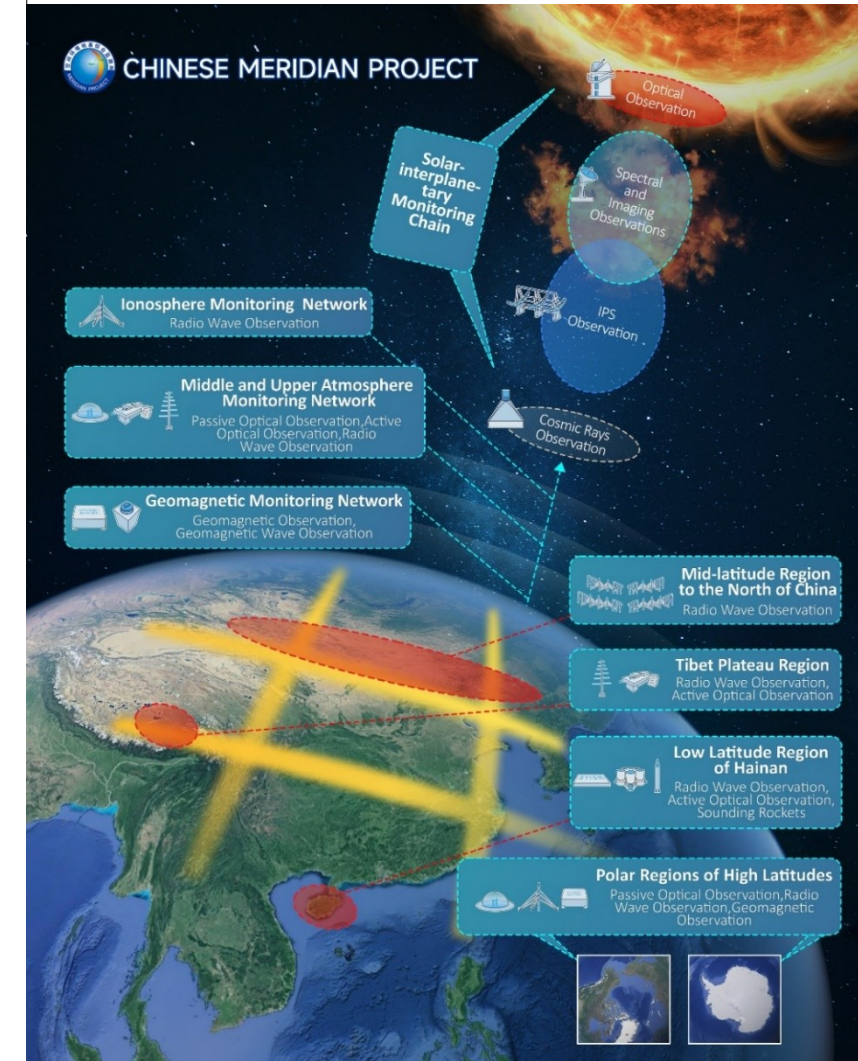
- **Four Focuses:**

High latitude polar regions

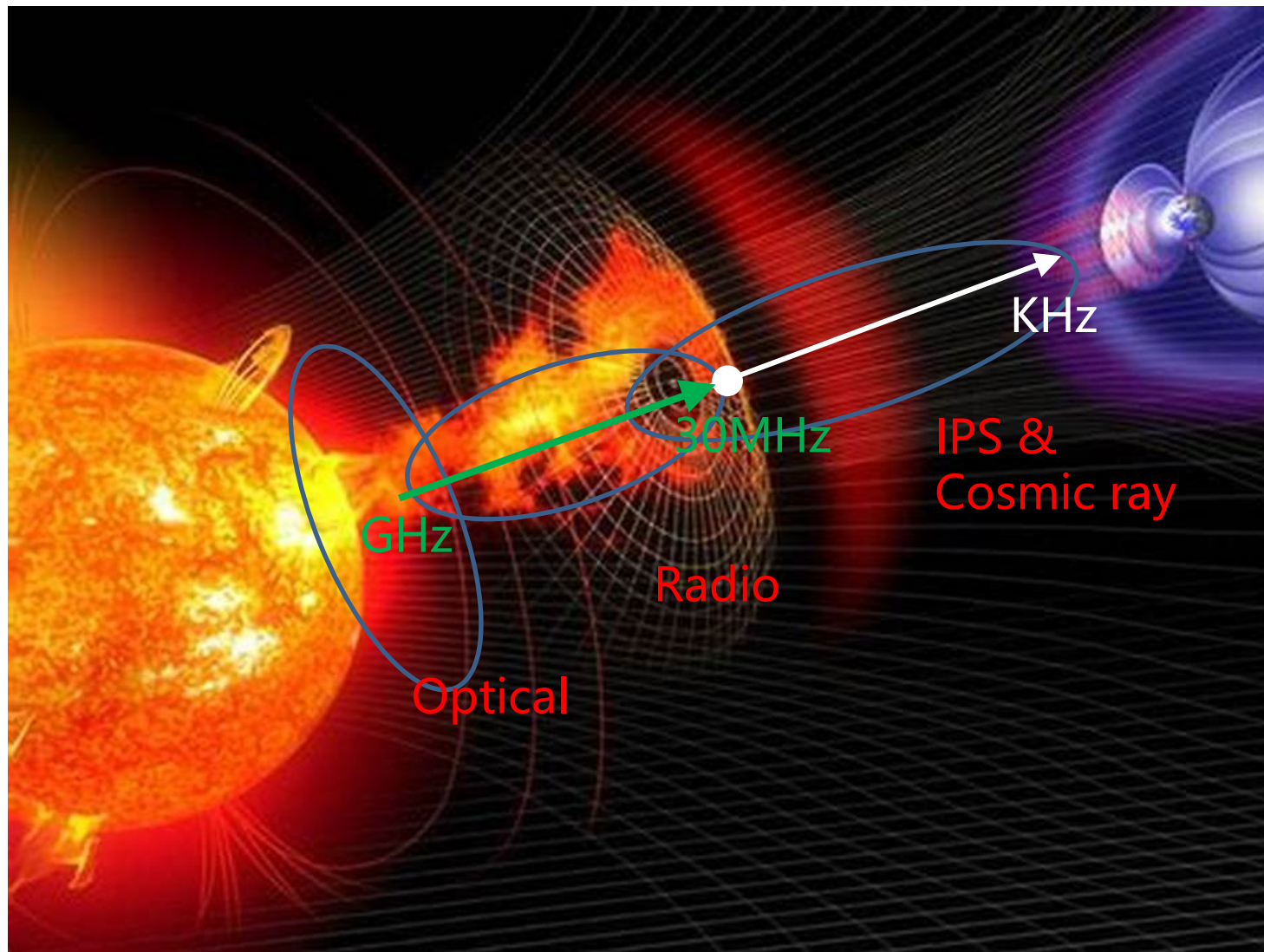
(Mid-latitude) North area of China

Low latitude region near Hainan

Tibetan Plateau



One Chain – Solar Interplanetary

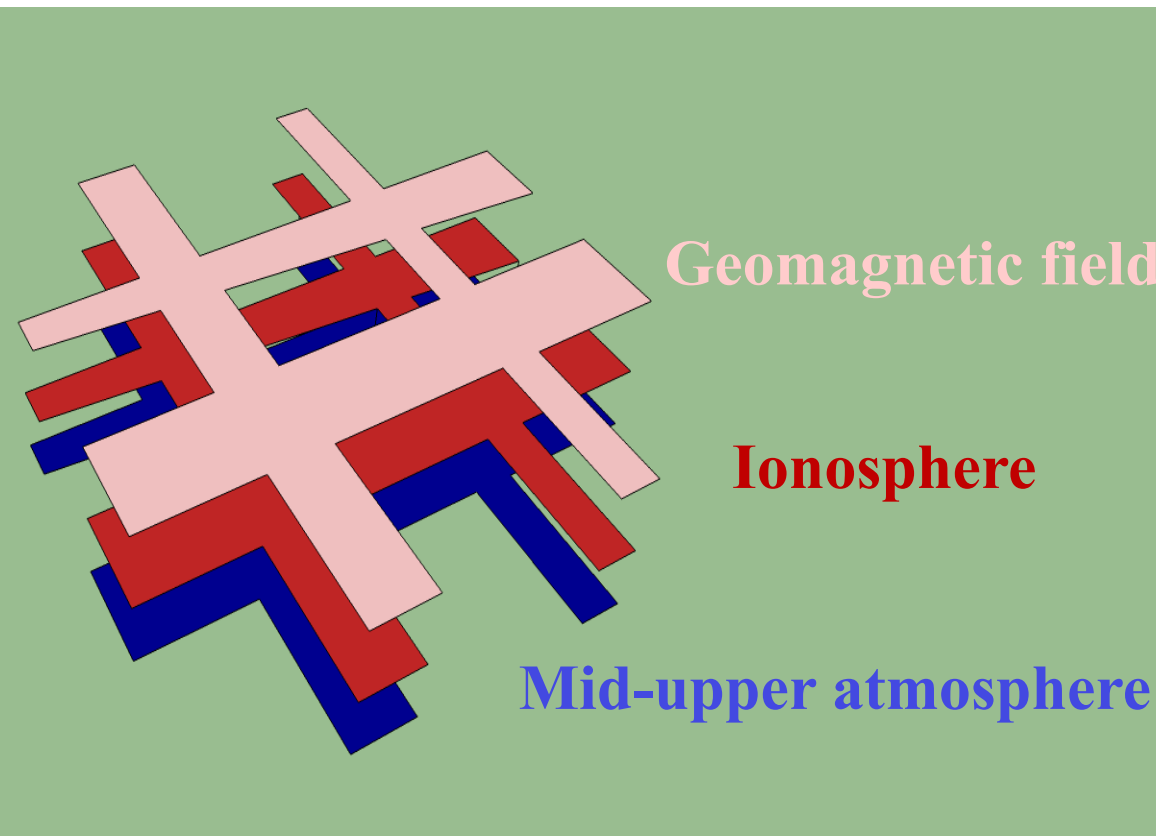
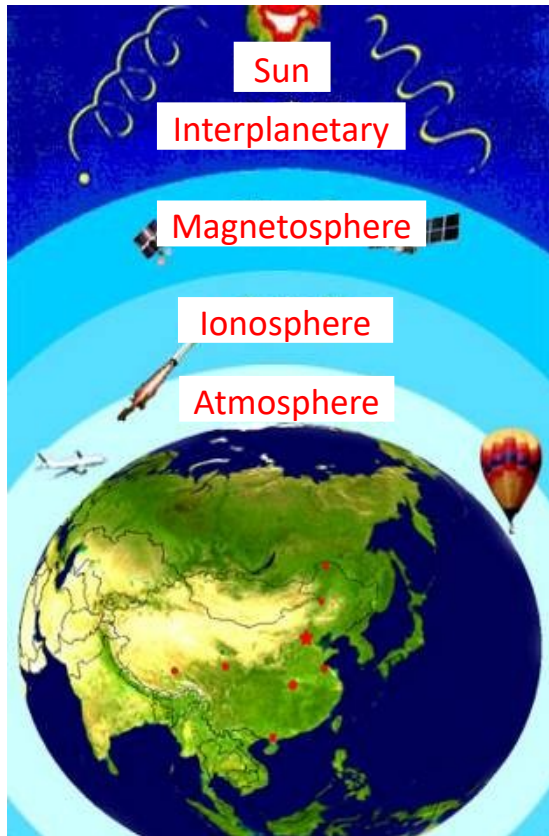


| Distance | Method |
|---------------------|------------|
| 0Rs (Solar surface) | Optical |
| 0.05 ~ 1.0Rs | |
| 0.3 ~ 1.5Rs | Radio |
| 1 ~ 5Rs | |
| 20 ~ 200Rs | IPS |
| to ~ 215Rs | Cosmic ray |

Instruments: Magnetic Imagers, Coronagraphs, Radioheliographs, IPS telescopes, and Cosmic ray detectors.

Multiple methods & frequencies, form a full observation chain.

Three Networks



Networks for three geospace layers

Cover the whole territory of China

Monitor mid to small scale phenomena

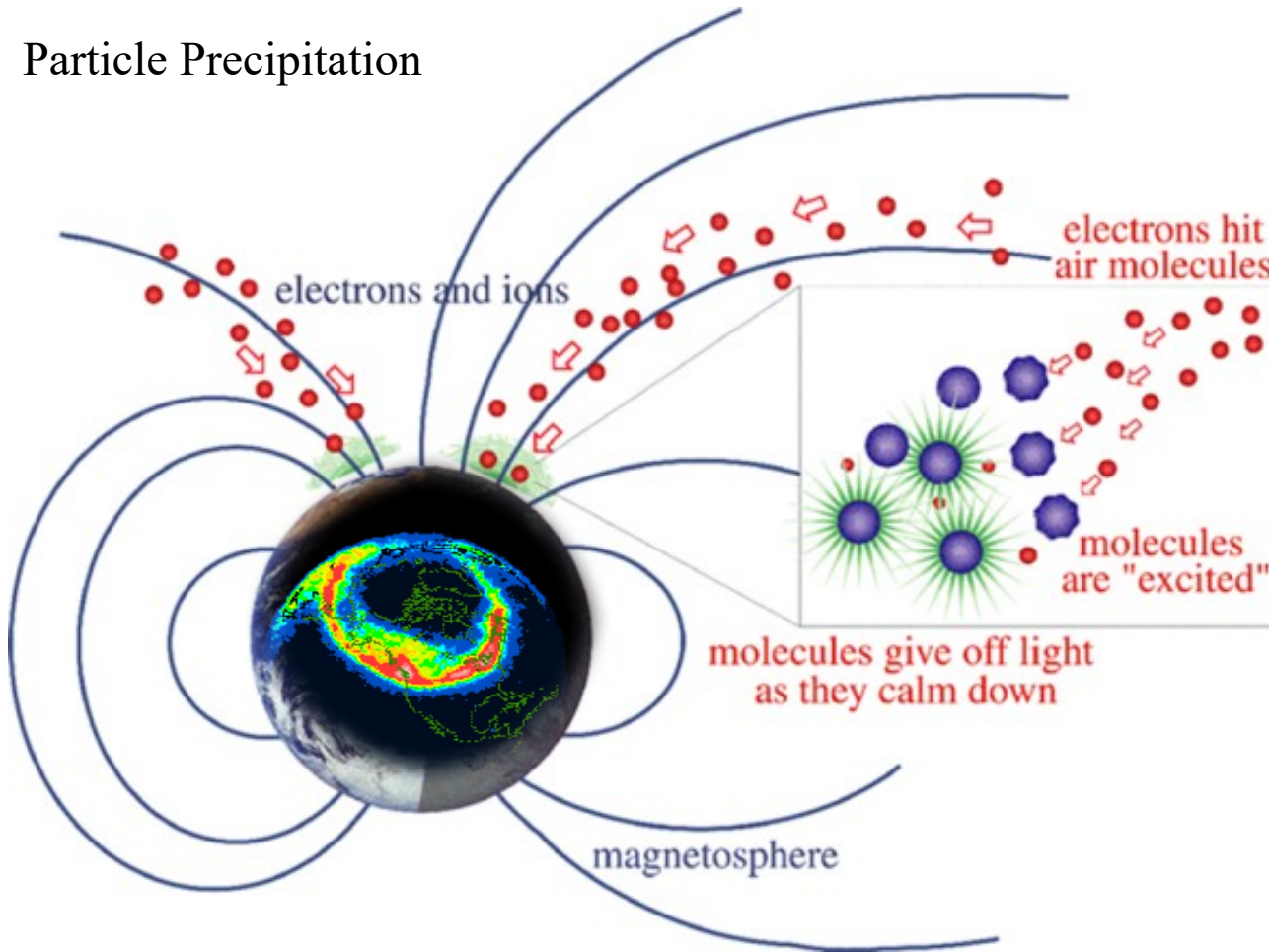
Mainly consist of conventional instruments:

- **Magnetosphere:** Magnetometers, Wave monitors, Atmosphere electric field monitors
- **Ionosphere:** Ionosondes, TEC and scintillation monitors, Doppler shift monitors.
- **Mid-Upper Atmosphere:** Lidars, Meteor radars, MST radars, Airglow imagers

Focus 1: Polar Regions

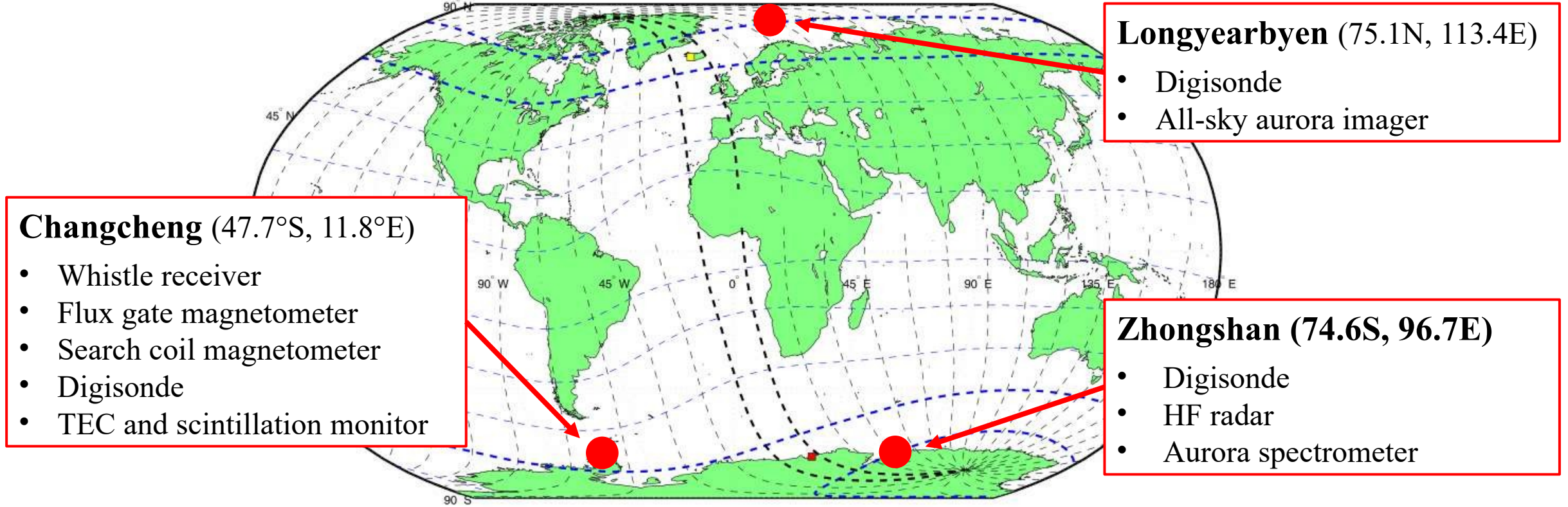


Particle Precipitation



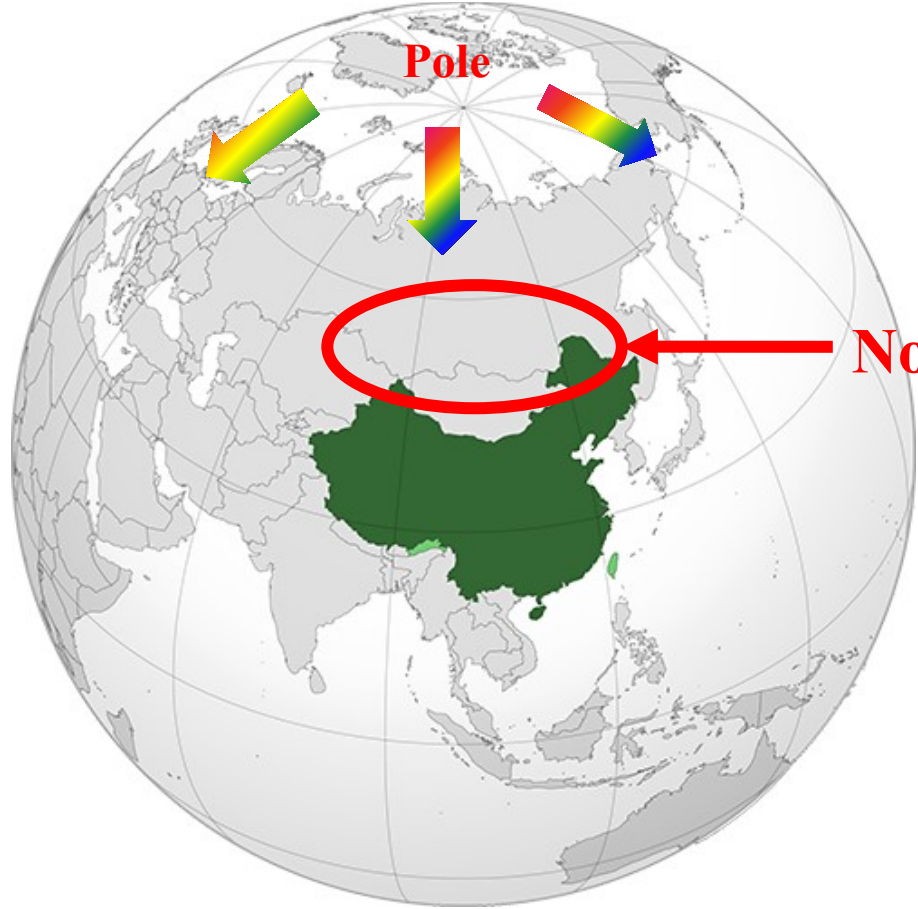
- **Open Window:** A window for solar wind to enter into geospace.
- **Intense Coupling:** Coupling between solar wind-magnetosphere-atmosphere takes place in a very dramatic way.
- **Source Region:** An important source region for disturbances that occur at lower latitude regions.

Focus 1: Polar Regions

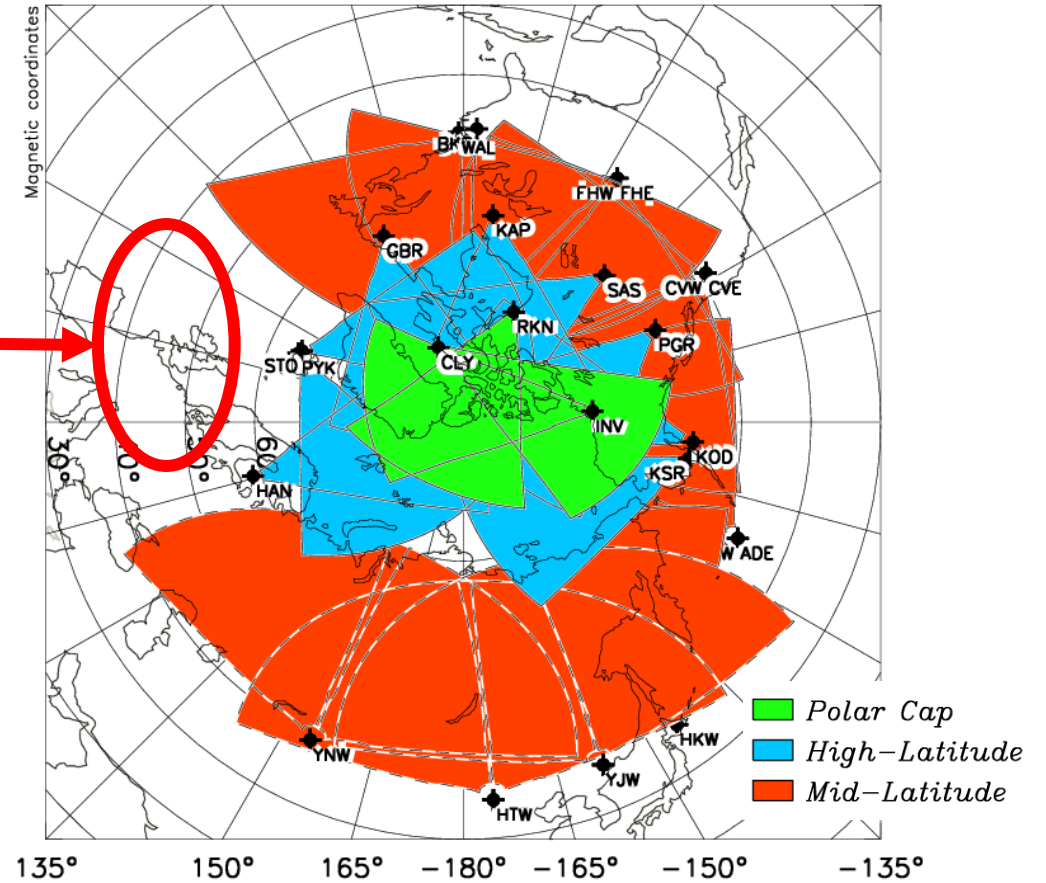


- Conjunction Positions: Longyearbyen and Zhongshan.
- West Hemisphere: Changcheng station.
- East Hemisphere: Zhongshan and Longyearbyen stations.

Focus 2: North of China (Mid-latitude)

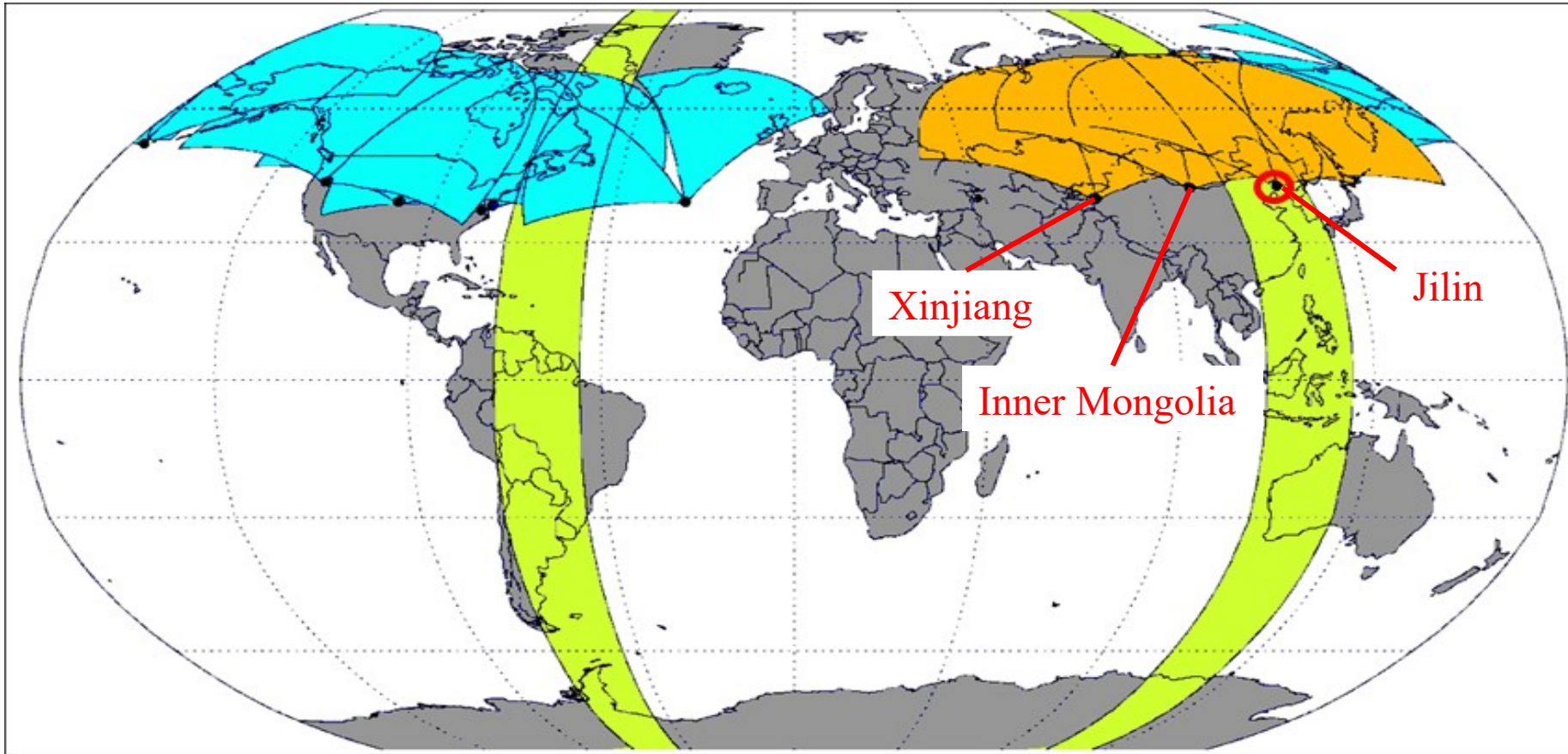


North of China



- How does polar disturbance propagate to mid to low latitude regions of China?
- Gap of detection of the international SuperDARN program.

Focus 2: North of China (Mid-latitude)

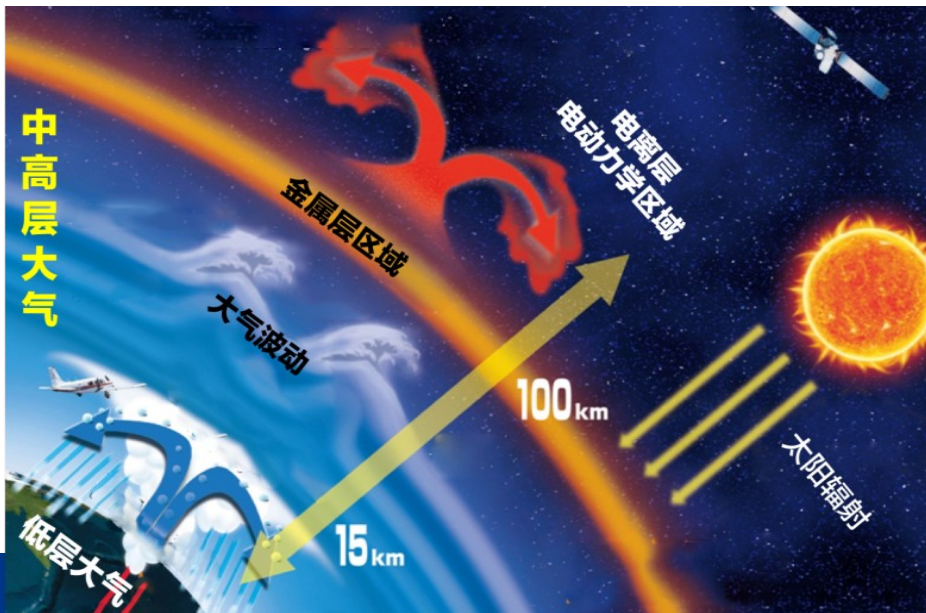


- 3 stations, each equipped with 2 HF radars, monitor irregularities for a large area at the upstream of China's territory.
- Combined with SuperDARN, mid-latitude regions is well covered.

Focus 3: Low Latitude Region Near Hainan

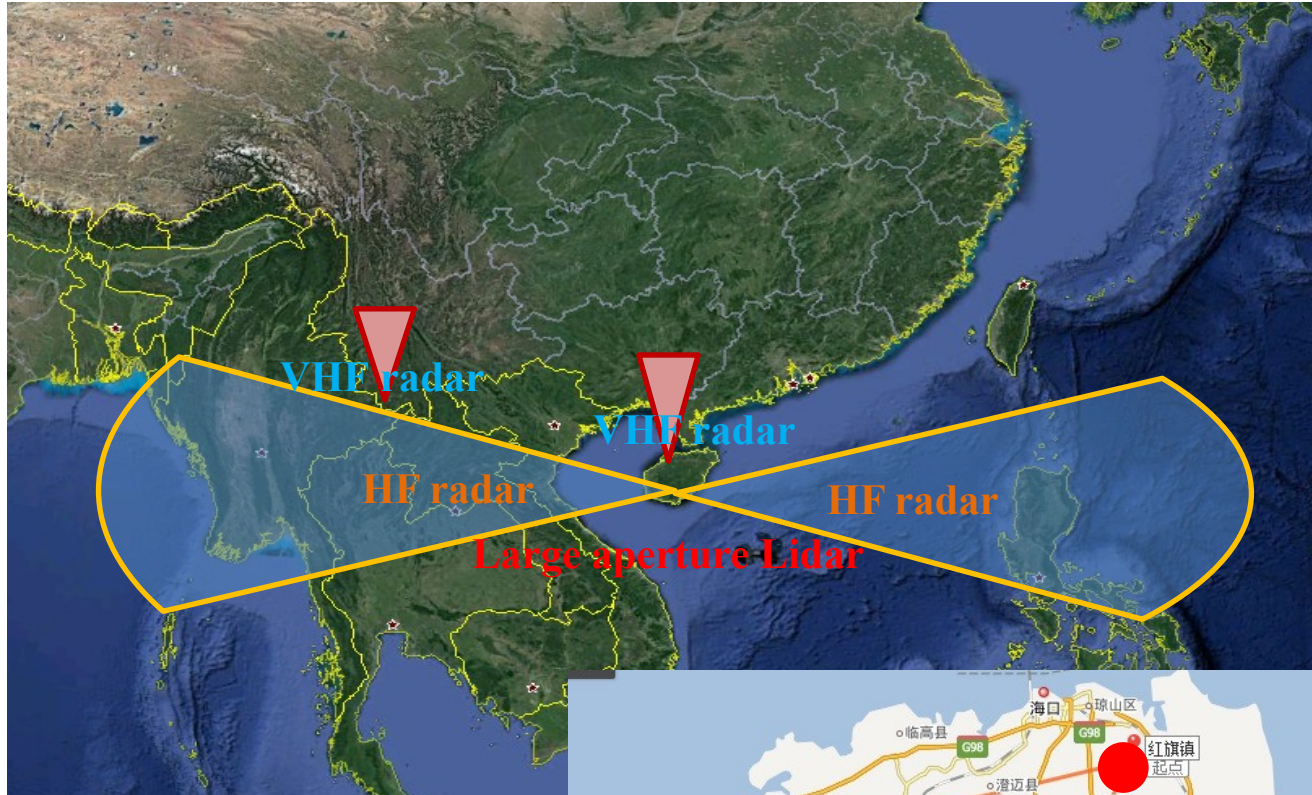


- **Intense Perturbation:** The intense disturbance zone of the ionosphere and thermosphere, in the EIA.
- **Tight Coupling:** The intense coupling zone between the thermosphere and ionosphere, the vertical coupling between the upper and lower



Ionospheric supper fountains can even reach the magnetosphere!

Focus 3: Low Latitude Region Near Hainan

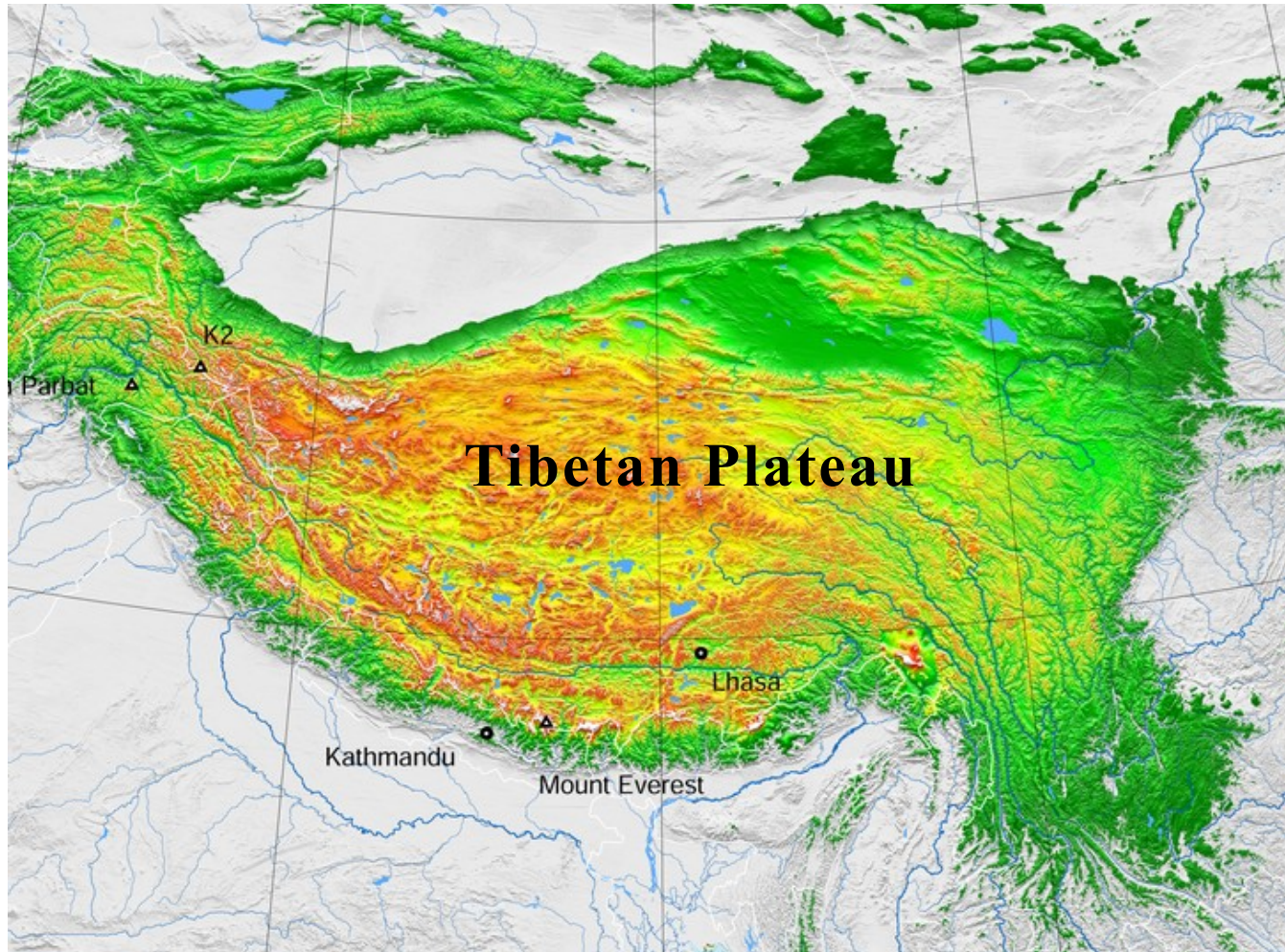


- Two VHF radars observing ionospheric irregularities.
- One low-latitude HF radar monitoring ionospheric convection
- A three-station incoherent scattering radar, detects 3D plasma speed vectors and other important parameters.
- A large aperture Lidar detects the atmosphere up to 1000km.

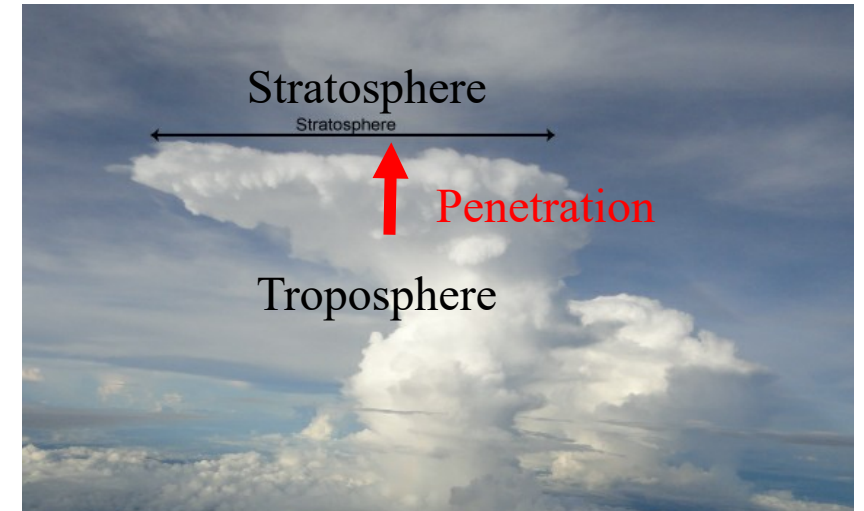


....., and other instruments, including sounding rockets taking in-situ measurements.

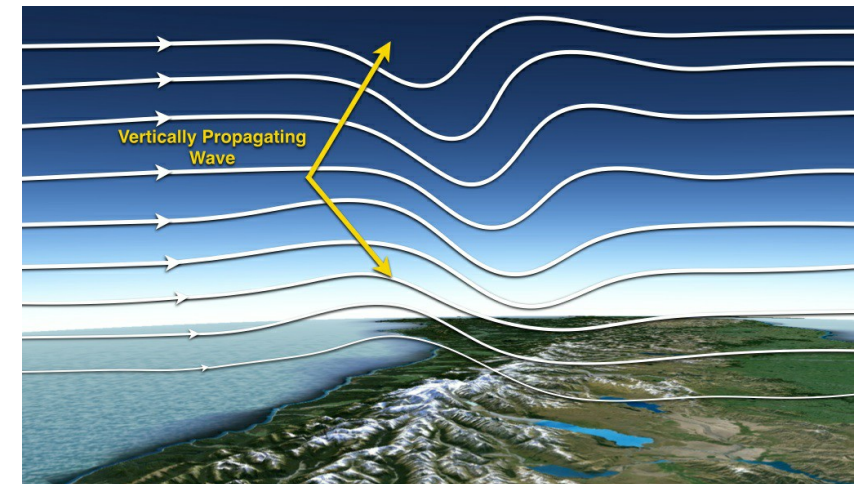
Focus 4: Tibetan Plateau



Plateau: a special and important area for studying vertical coupling



Strong circulation

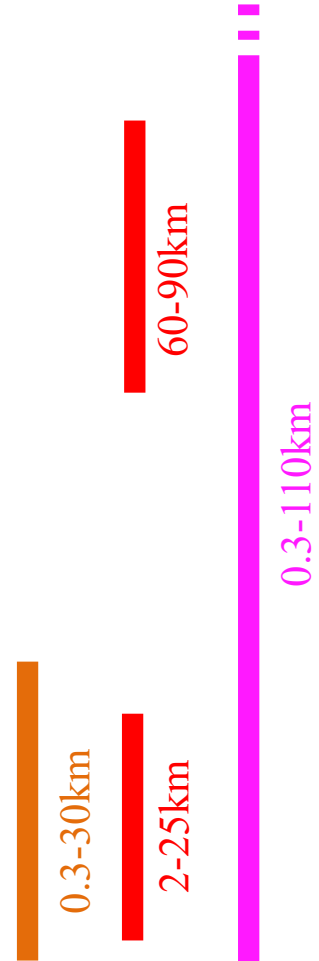
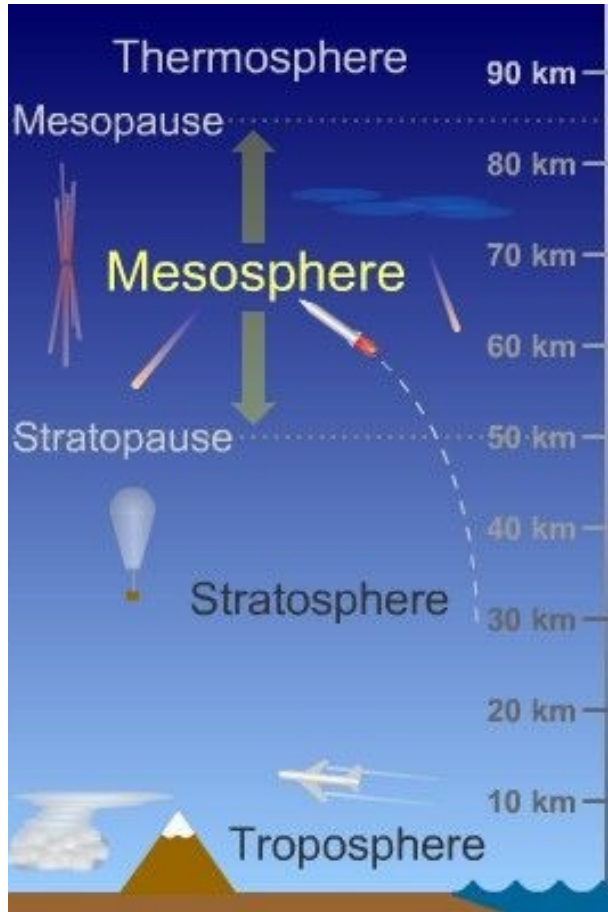


Gravity waves

Focus 4: Tibetan Plateau



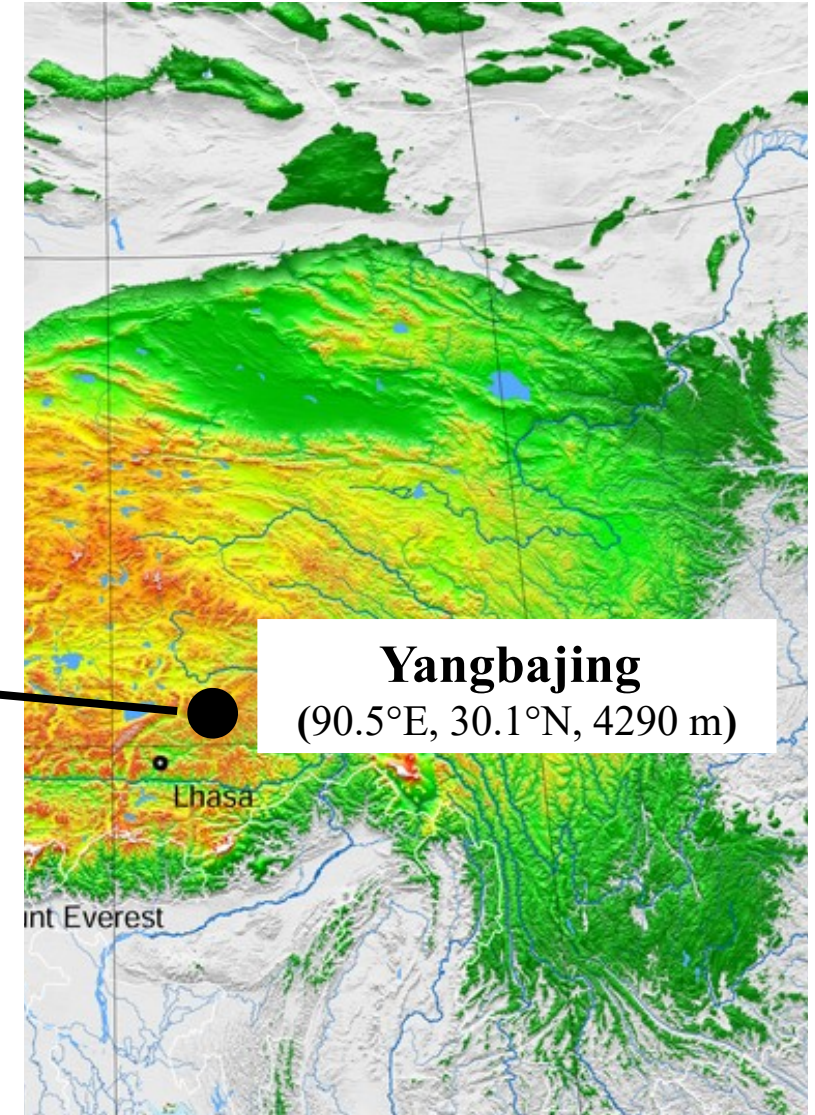
Whole height observation from low atmosphere to thermosphere.



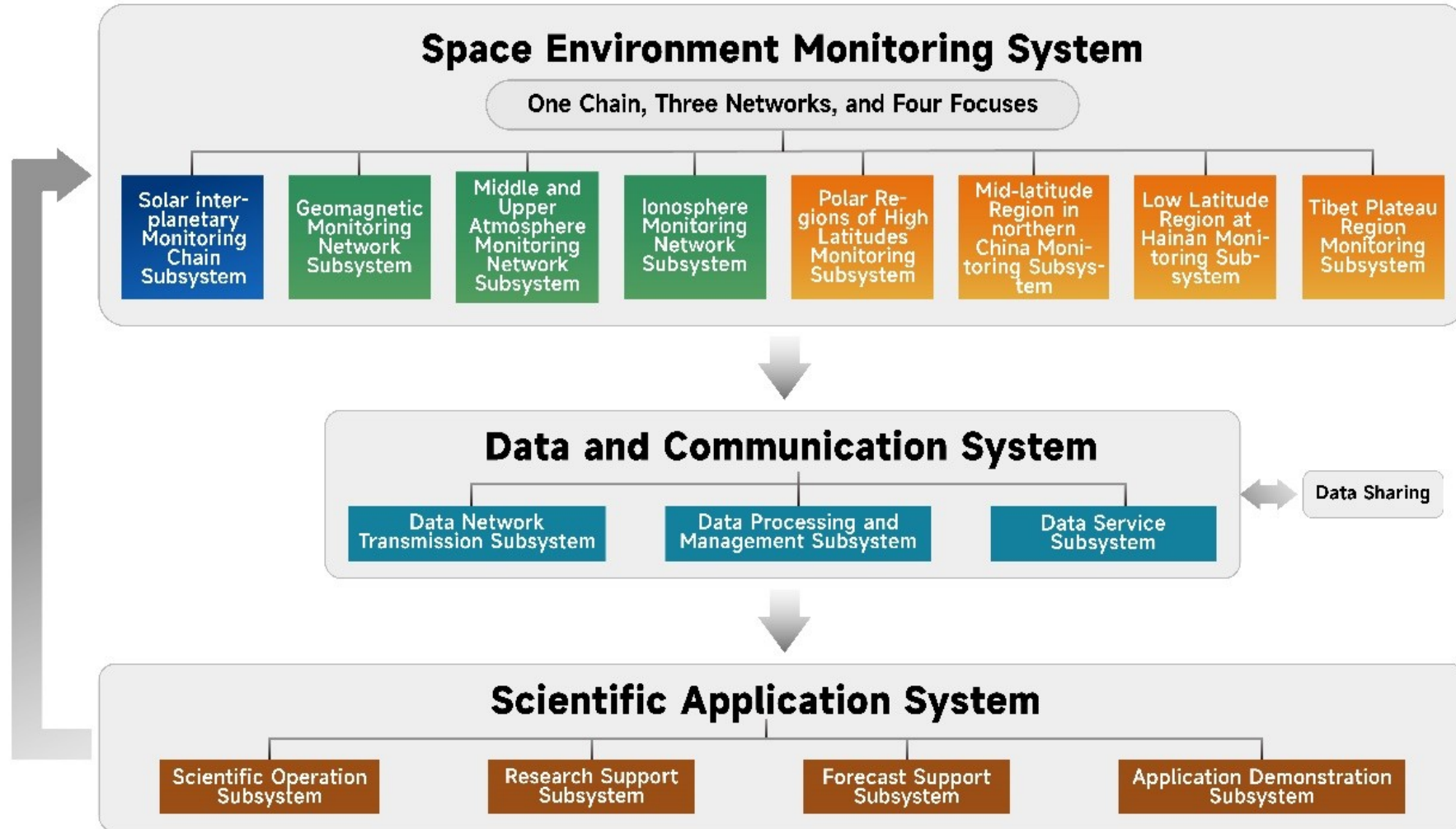
Wind & temperature
Lidar

MST radar

Millimeter wave &
infrared imager



Overall Architecture

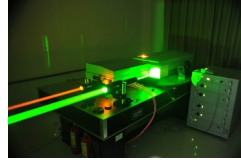


System framework diagram of the Chinese Meridian Project.

Overall Architecture



Space Environment
Monitoring System



- Instruments for observation



Data Communication
System

- Collecting
- Processing
- Distribution

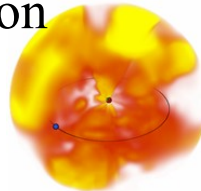


Data & research center
(Hairou, Beijing)



Science Application
System

- Coordination
- Modeling
- Research



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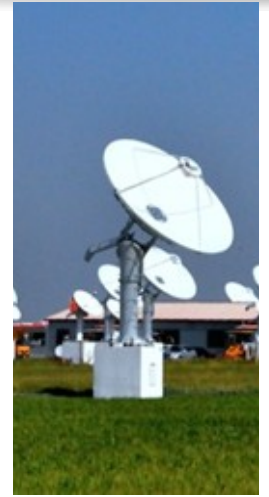
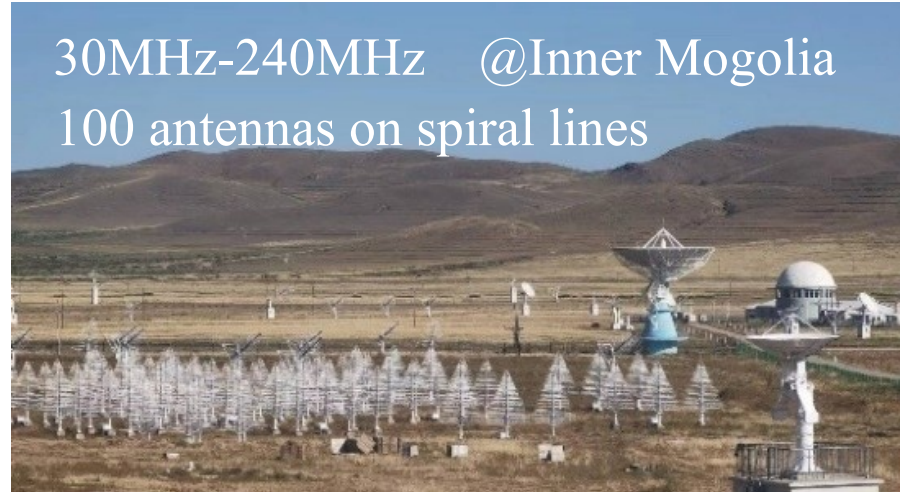
1. Solar radio imaging arrays (Radioheliographs)



150MHz-450MHz @Sichuan Daocheng
313 antennas. Circle with diameter 1000m



30MHz-240MHz @Inner Mogolia
100 antennas on spiral lines



SDU

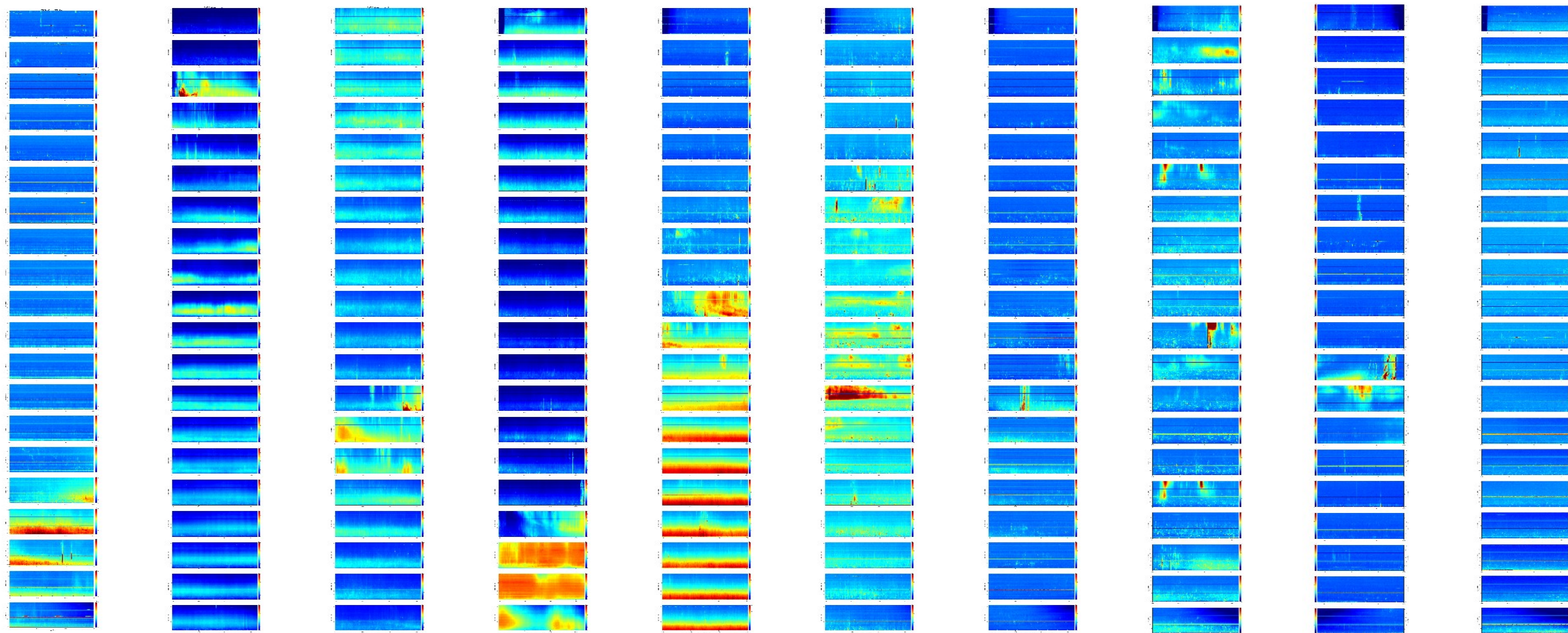
2-15GHz @Inner Mogolia



- **Super wide frequency band: 30M- 15GHz**
- **Solar radio imaging and spectroscopy.**

Performances, such as time resolution (~ 0.1 s) and frequency resolution (~ 2 MHz), reach the highest level in the world.

Solar radio spectra in May of 2024



14

13

12

11

10

9 日

8 日

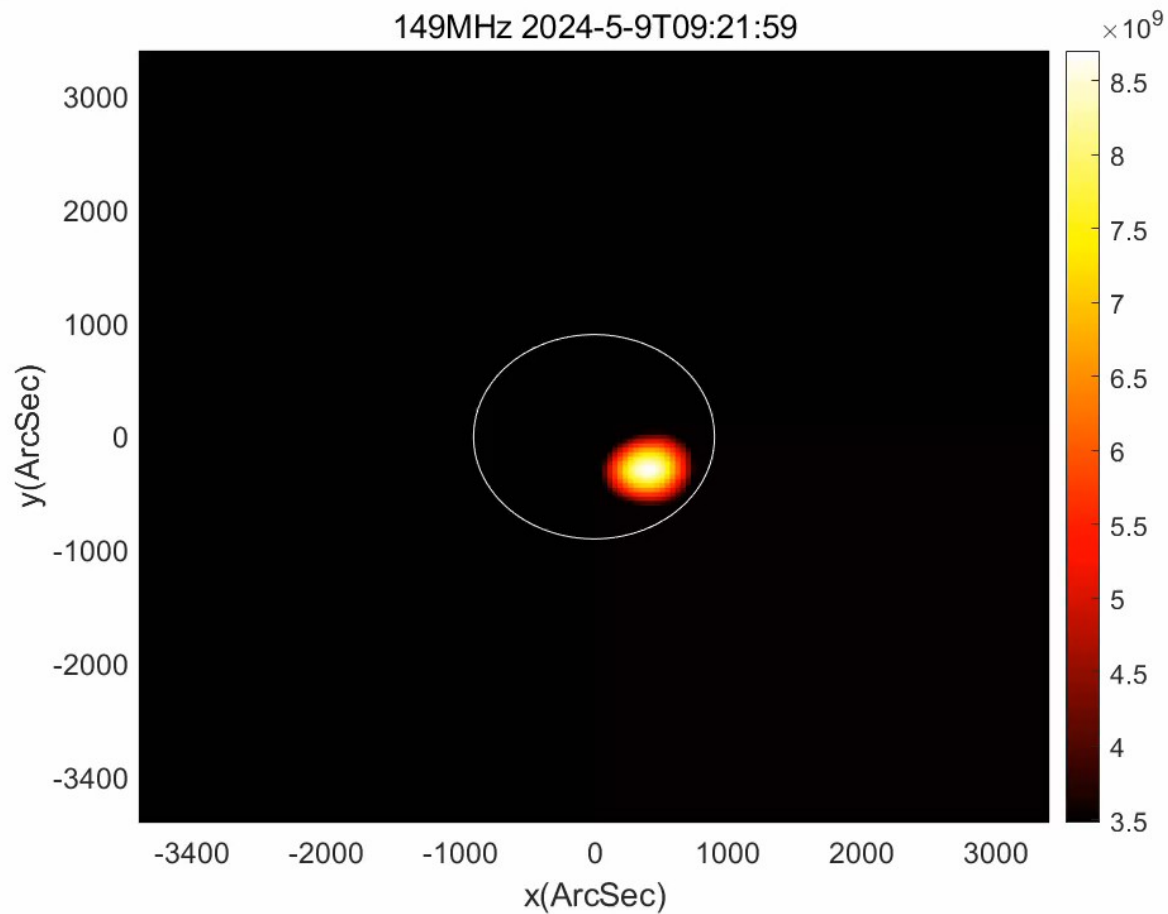
7 日

6 日

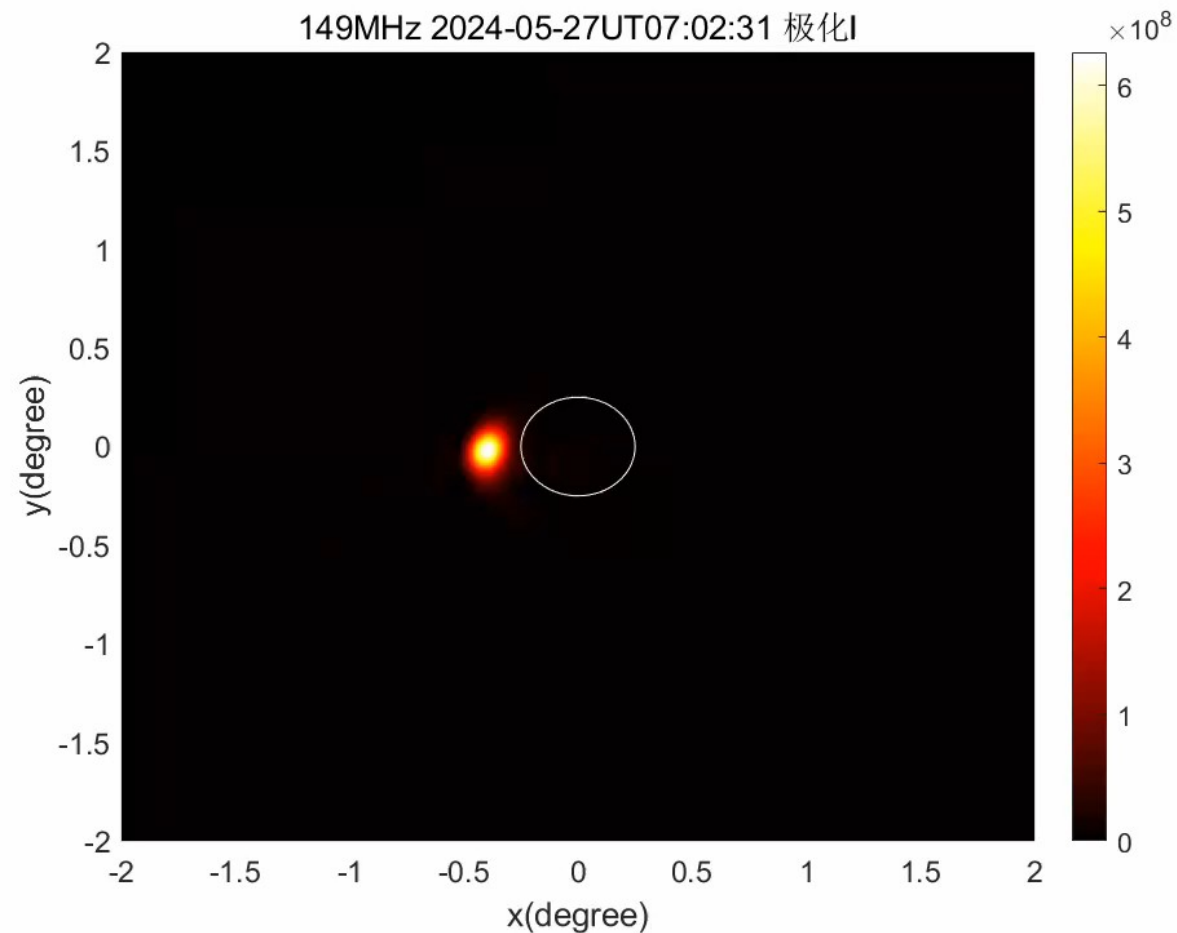
5 日

Solar radio image

2024-05-09



2024-05-27

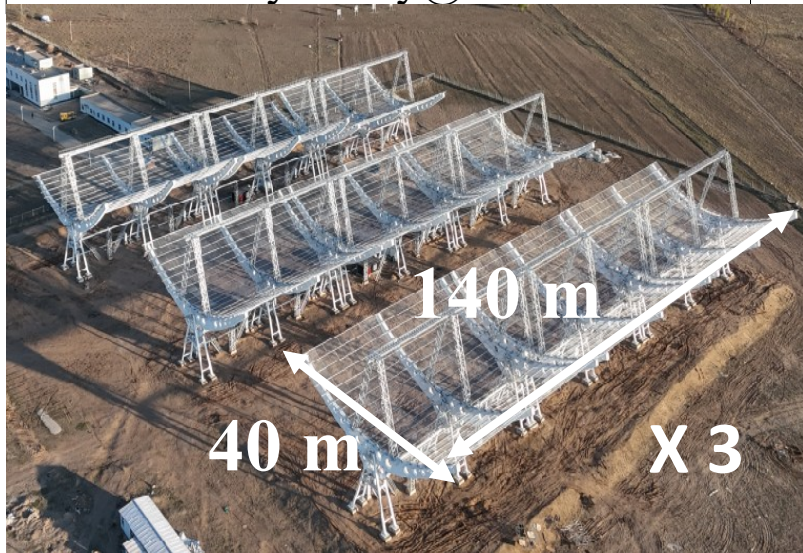


2: Interplanetary Scintillation (IPS) telescope array



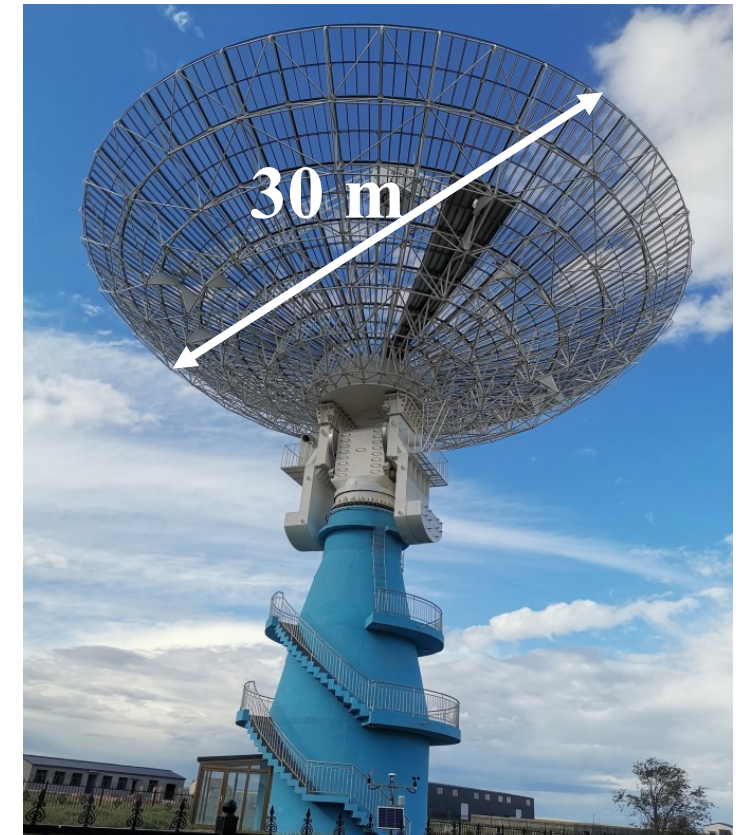
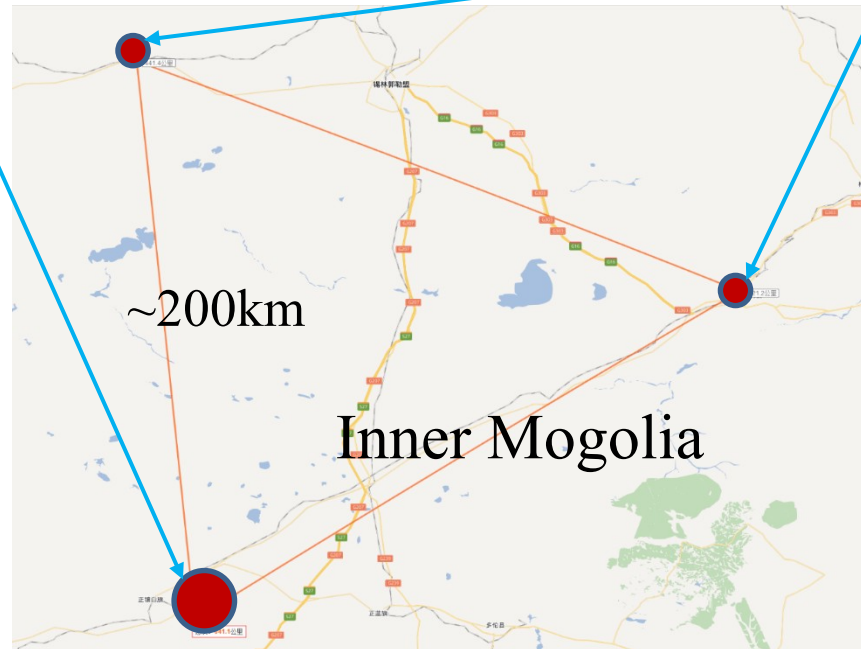
Major Station

- Large antenna (140m X 40m X 3)
- Frequency: 327、654MHz
- Sensitivity: 8mJy@1s



Minor Station

- 30 meter antenna
- Freq: 327, 654MHz, 1.4GHz
- Sensitivity: 600mJy@1s



- Large aperture, high sensitivity, multiple freq., flexible operation.
- Very large detecting range from solar surface (~20Rs-200Rs).

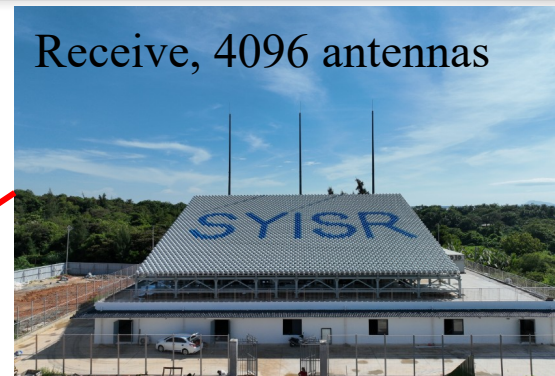
3. Multi-static Incoherent Scatter Radar



Receive, 4096 antennas



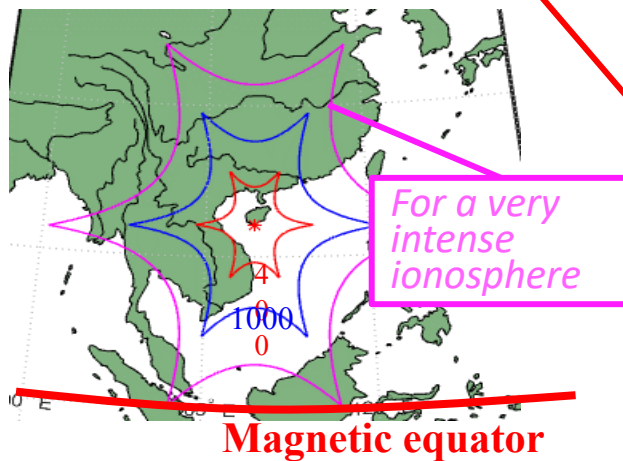
Receive, 4096 antennas



Transmit & receive, 8320 antennas



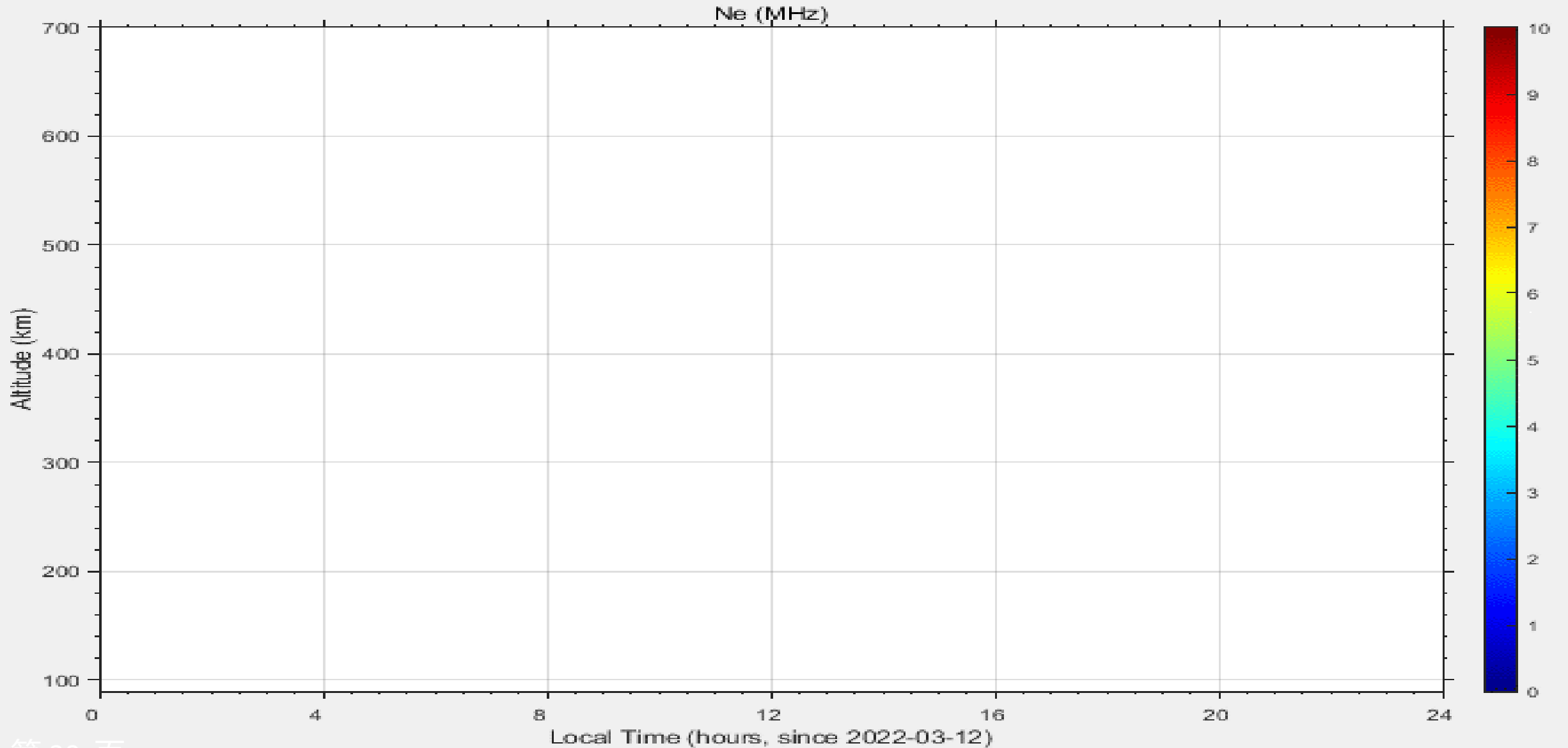
Ionosphere



- Frequency: 440MHz
- Peak power: 4.7MW
- Range: 80-1000km
- Beam width: 0.67°
- Antenna gain: 46dB
- Noise temperature: 107K

The first 3-station type phased incoherent scattering radar in the world.

Electron Density distribution observed by the SYISR



4. Array-type large aperture Lidar



6 telescopes

Combined aperture: 4.8m²

Helium fluorescence: He atom density, 200 - 1000km

First time to measure up to 1000km, using ground-based method

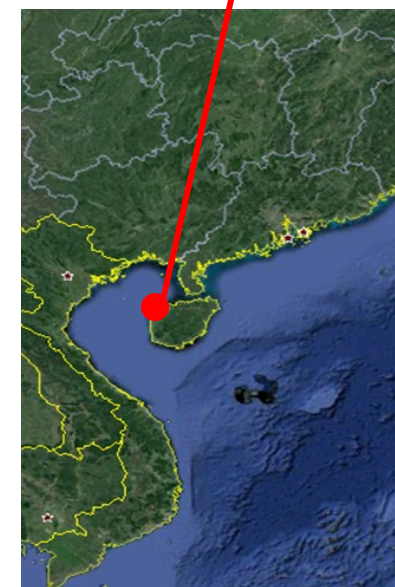
Sodium(Na) fluorescence: Na density, temperature, wind
80 - 105km

Rayleigh scattering: Density, temperature, 30 - 85km



1083nm laser transmitter

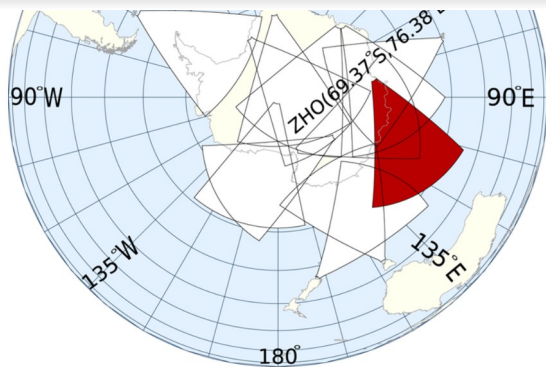
On Hainan island



5. High-frequency radars

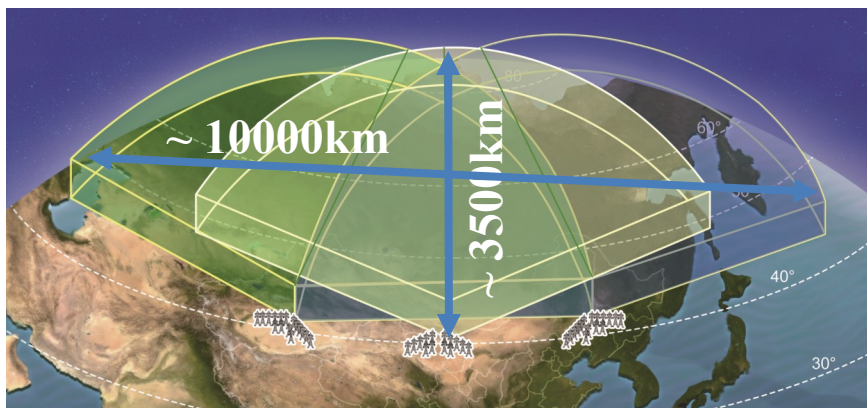


High latitude



Irregularity distribution, drift velocity, convection electric field.

Mid latitude



Freq.: 8 ~ 22MHz

Range res.: 15 ~ 45km

Time res.: 2min

Low latitude



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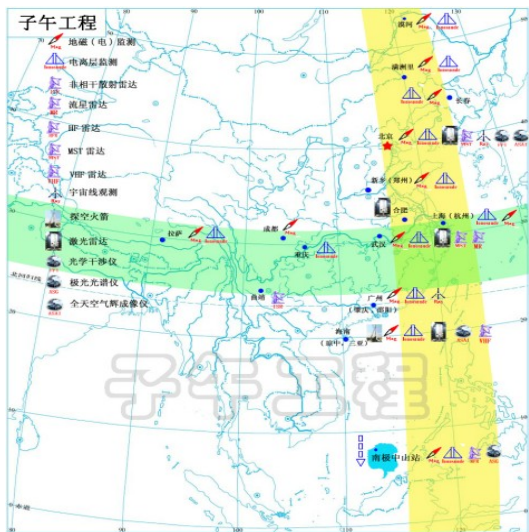
■ Conclusions & Future

Conclusion

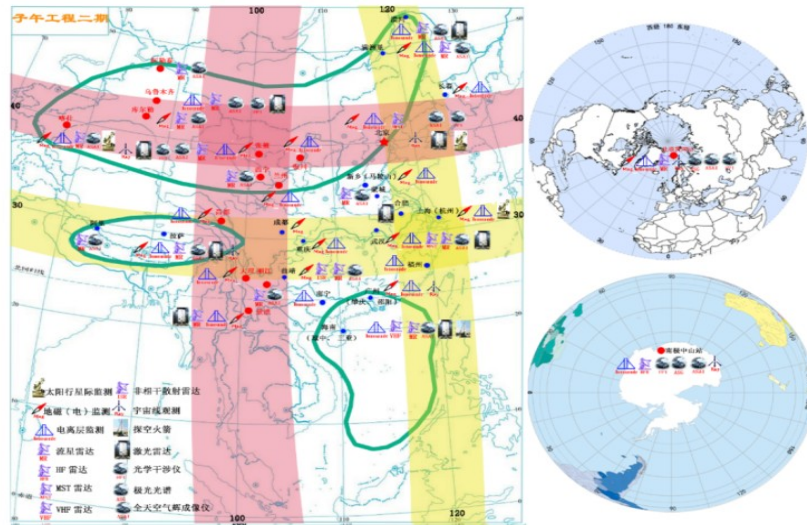
- **The CMP has an monitoring architecture of “One Chain, Three Networks and Four Focuses”, and deployed a bunch of advanced instruments. It has three main features:**
 1. Achieve end-to-end tracking and monitoring capabilities for solar storms from the Solar Atmosphere to near Earth Space.
 2. Have stereoscopic comprehensive network monitoring capabilities covering all space layers from the solar atmosphere to the Earth’s middle and upper atmosphere.
 3. Realize the ability to focus on monitoring the fine structures for key regions.
- **CMP is about to carry out national formal acceptance soon. Then it will be put into formal operation soon.**

Future plans: Meridian Project Trilogy

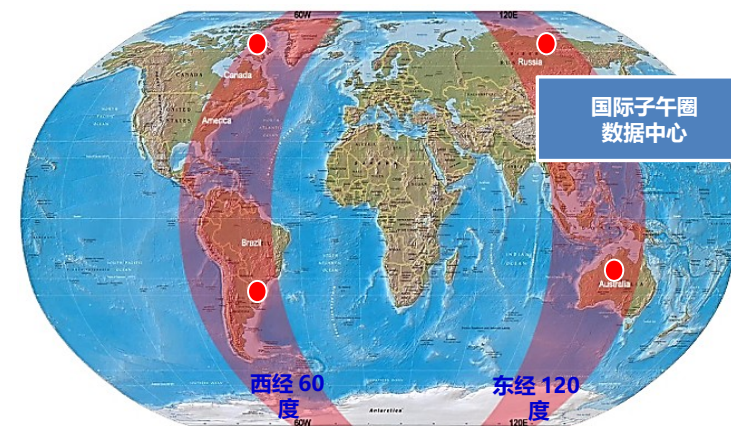
CMP-phase I



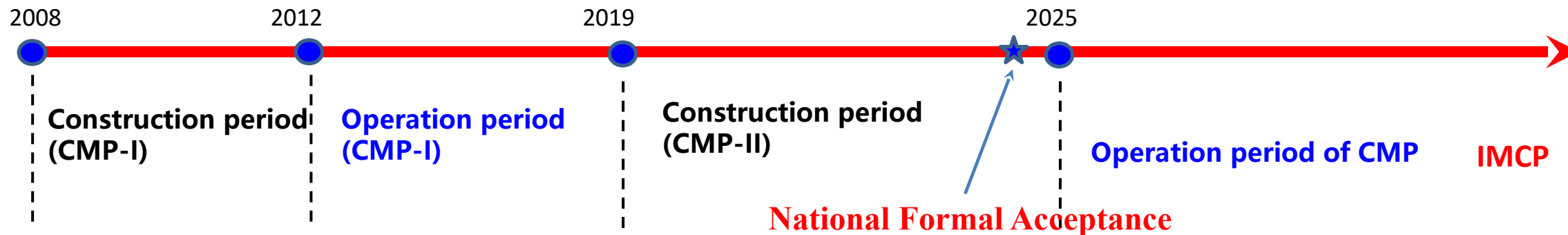
CMP-phase II

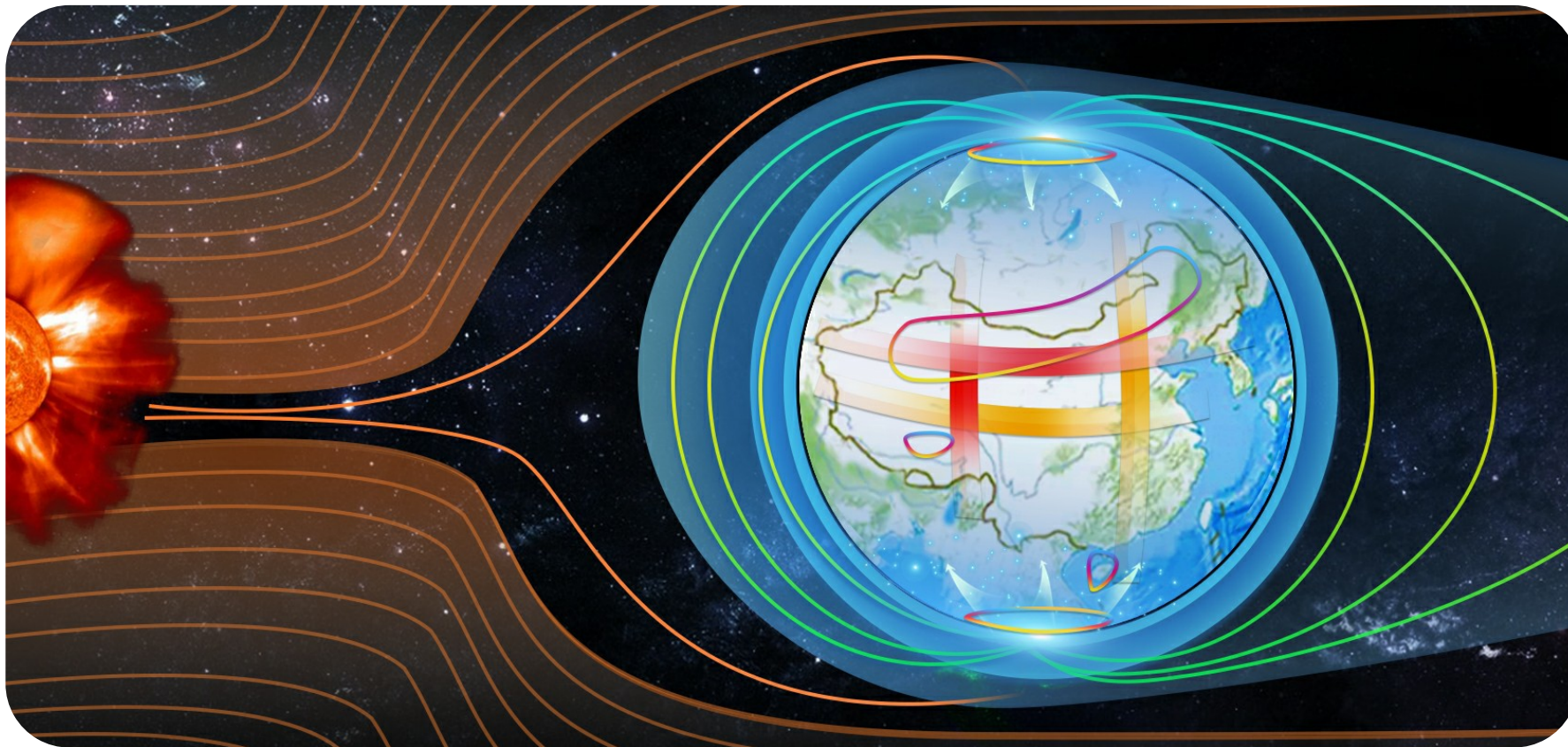


IMCP



International Meridian Circle Project





Website: <http://data.meridianproject.ac.cn>

International cooperation are welcomed!

Thanks !

Overall instrument layout



Two-cross networks

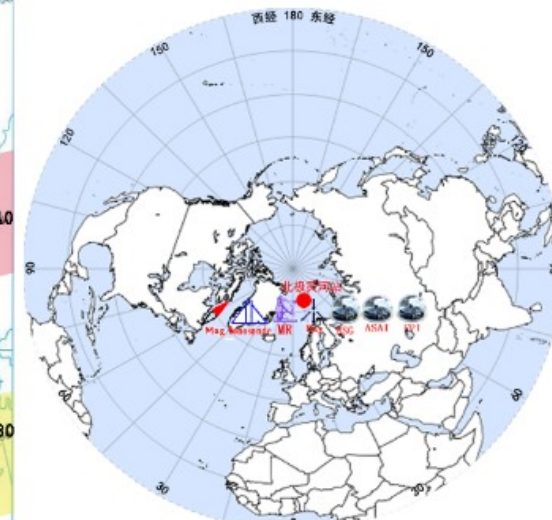
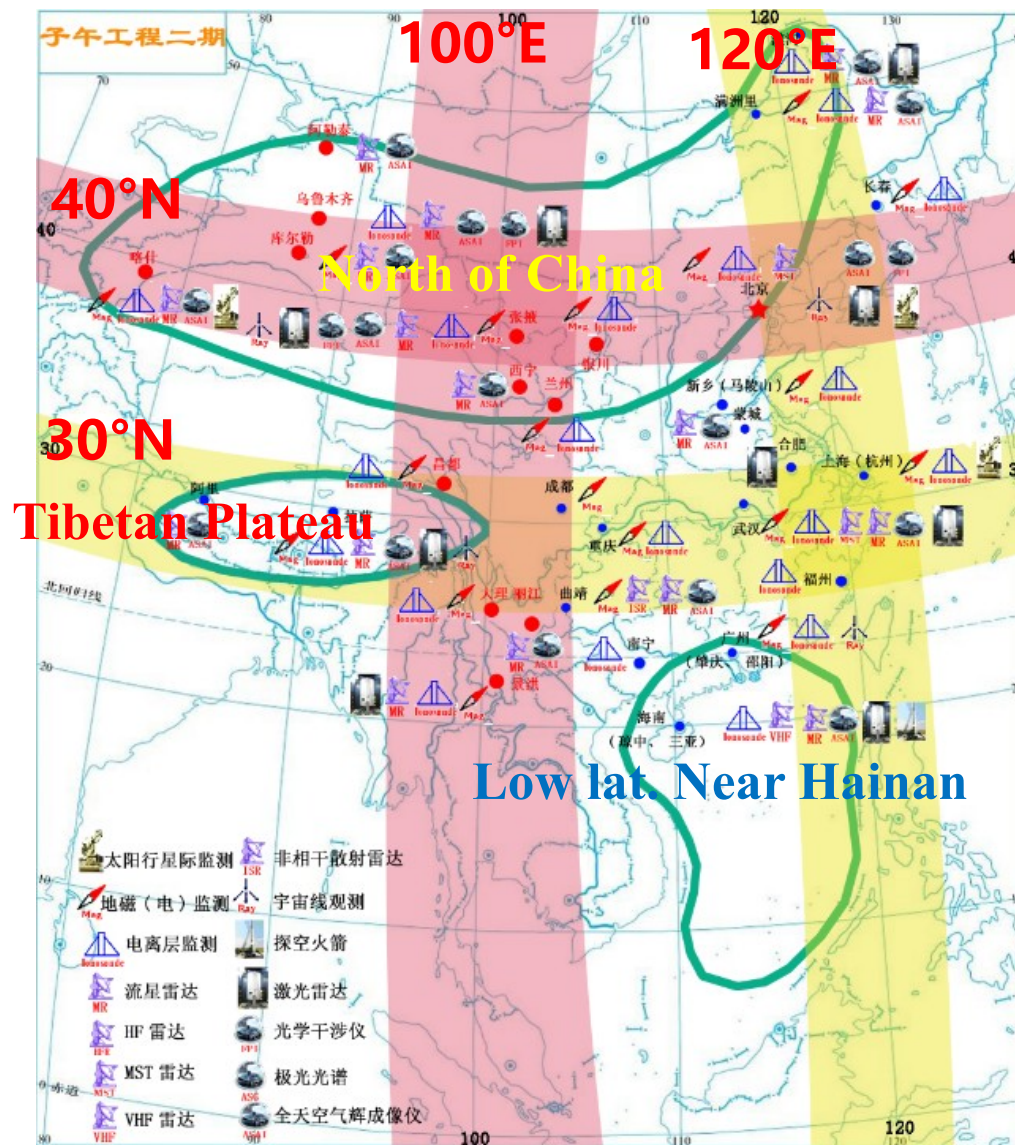
Focus on key regions

- Polar regions
- North of China
- Low lat. Hainan region
- Tibetan Plateau

■ Instruments: 282

■ Stations: 31

■ Coverage: China & the polar regions



Polar region

