Meridian Space Weather Monitoring Project (Meridian Project) and the International Collaboration

Guotao Yang

National Space Science Center, China

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Outline

- Overview of the Meridian Project (MP)
  - The Meridian Project Framework
  - Recent Development

- International Collaboration of MP
  - Overview of IMCP
  - Scientific goals
  - Progress
MP is a Chinese multi-station chain along 120°E to monitor space environment, starting from Mohe, the most northern station in China, through Beijing, Wuhan, Guangzhou and extended to Chinese Zhongshan station in the Antarctic.
Many basic physical processes occur along the meridian circle.

With the rotation of the Earth, we can make global measurements of the space environment.
Station Distribution
Observatories

15 Stations Selected，No new station will be built:
(develop/purchase new instruments, upgrade existing equipment, get all stations connected, build central data base, organize research and application activities)

- 120°E Meridian Chain (10 stations): Mohe, Manzhouli, Changchun, Beijing, Xinxian, Hefei, Wuhan, Guanzhou, Hainan, Zhongshan;

- 30°N Chain (5 stations): Shanghai (Hangzhou), Chongqing, Chengdu, Qujing, Laasa.

Among them, Beijing, Wuhan, Hainan, Zhongshan are multi-tasking stations.
<table>
<thead>
<tr>
<th>No</th>
<th>Station</th>
<th>Lat.</th>
<th>Lon.</th>
<th>Types of Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Mohe</td>
<td>53.5N</td>
<td>122.4E</td>
<td>Geomagnetic, Ionospheric</td>
</tr>
<tr>
<td>02</td>
<td>Manzhouli</td>
<td>49.6N</td>
<td>117.4E</td>
<td>Geomagnetic, Ionospheric</td>
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<tr>
<td>03</td>
<td>Changchun</td>
<td>44.0N</td>
<td>125.2E</td>
<td>Geomagnetic, Ionospheric</td>
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<tr>
<td>04</td>
<td>Beijing</td>
<td>40.3N</td>
<td>116.2E</td>
<td>Geomagnetic, Ionospheric, Lidar, MST Radar, IPS, Cosmic Rays, HF Doppler Array, All-sky Airglow Imager, F-P interferometer</td>
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<tr>
<td>05</td>
<td>Xinxiang</td>
<td>34.6N</td>
<td>113.6E</td>
<td>Geomagnetic, Ionospheric</td>
</tr>
<tr>
<td>06</td>
<td>Wuhan</td>
<td>30.5N</td>
<td>114.6E</td>
<td>Geomagnetic, Ionospheric, Lidar, MST Radar, HF Doppler Array, Meteor Radar</td>
</tr>
<tr>
<td>07</td>
<td>Hefei</td>
<td>33.4N</td>
<td>116.5E</td>
<td>Lidar</td>
</tr>
<tr>
<td>08</td>
<td>Guangzhou</td>
<td>23.1N</td>
<td>113.3E</td>
<td>Geomagnetic, Ionospheric, Cosmic Rays</td>
</tr>
<tr>
<td>09</td>
<td>Hainan</td>
<td>19.0N</td>
<td>109.8E</td>
<td>Geomagnetic, Ionospheric, Lidar, All-sky Airglow Imager, VHF Radar, Sounding Rocket</td>
</tr>
<tr>
<td>10</td>
<td>Zhangshan</td>
<td>69.4S</td>
<td>76.4E</td>
<td>Geomagnetic, Ionospheric, HF Radar, Aurora</td>
</tr>
<tr>
<td>11</td>
<td>Shanghai</td>
<td>31.1N</td>
<td>121.2E</td>
<td>Geomagnetic, Ionospheric</td>
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<tr>
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<td>Chongqing</td>
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<td>106.5E</td>
<td>Geomagnetic, Ionospheric</td>
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<tr>
<td>13</td>
<td>Qujing</td>
<td>25.6N</td>
<td>103.8E</td>
<td>Incoherent Scattering Radar</td>
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<tr>
<td>14</td>
<td>Chengdu</td>
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<td>103.7E</td>
<td>Geomagnetic, Ionospheric</td>
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<tr>
<td>15</td>
<td>Lhasa</td>
<td>29.6N</td>
<td>91.0E</td>
<td>Geomagnetic, Ionospheric</td>
</tr>
</tbody>
</table>
Parameters Observed

- **Earth Surface**: Geomagnetic field, Geoelectronic field, Cosmic Rays;
- **Middle-Upper Atmosphere**: density, temperature, composition, electric current;
- **Ionosphere**: density of electron and proton, temperature, irregular structures, electric current;
- **Interplanetary Space**: solar wind plasma speed
Spatial Coverage

By

The Meridian Project
I. Geomagnetic Monitoring Subsystem

- To measure the variation of the geomagnetic (geoelectric) field
- To study the response of the geomagnetic (geoelectric) field to interplanetary disturbances
Geomagnetic Measurement

Absolute Measurement
- Proton Precession
  - Magnetometer: F
- Overhauser magnetometer
  - F
- DI-fluxgate magnetometer: D. I

Relative Measurement
- Fluxgate Magnetometer: H, D, Z
- Induction Magnetometer
# Geomagnetic Stations

<table>
<thead>
<tr>
<th>No.</th>
<th>Station</th>
<th>Geomagnetic</th>
<th>Geoelectric</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>DI</td>
<td>OVERHAUSE</td>
</tr>
<tr>
<td>1</td>
<td>Mohe</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Manzhouli</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Zhangchun</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Beijing</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Zhenzhou</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Wuhan</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Shaoyang</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Zhaojing</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Qionzhou</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Sanya</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>Zhongshan</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>Hangzhou</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>13</td>
<td>Chendu</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Lasha</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>6</td>
<td>13</td>
</tr>
</tbody>
</table>
II. Radio Monitoring Subsystem

- To measure the physical parameters of the middle-upper atmosphere, ionosphere and the interplanetary space by use of remote sensing technique.
Four Parts

1. Incoherent Scattering Radar (ISR)

- The most powerful equipment in MP
- ISR is located in Qujing, Yunnan Province (25.6°N, 103.8°E).
- To measure physical parameters of the middle-upper atmosphere and ionosphere from 70 up to 1000 km.
- ISR has a peak transmission power of ~3MW.
## 2. Radar Chain

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Detecting Content</th>
<th>Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MST Radar</strong></td>
<td><strong>Wind</strong> parameters of troposphere, stratosphere and mesosphere</td>
<td><strong>Beijing, Wuhan</strong></td>
</tr>
<tr>
<td><strong>HF Coherent Scattering Radar</strong></td>
<td>To detect the <strong>motion of the ionospheric structure</strong> within a azimuth angle of 52° and 3000 km height by use of the scatter features of the ionospheric irregular structures</td>
<td><strong>Zhongshan Station at South Pole</strong></td>
</tr>
<tr>
<td><strong>VHF Coherent Scatter Radar</strong></td>
<td>To detect the <strong>irregular structure</strong> and drift (electrical field) in the ionospheric E lay, and to detect intensity and drift of the spread F, by measuring the intensity and Doppler Shift of the echo from the field aligned irregular bulk.</td>
<td><strong>Hainan</strong></td>
</tr>
<tr>
<td><strong>Meteor Radar</strong></td>
<td>To detect the <strong>wind</strong> field and diffusive coefficient of the atmosphere, the flux, position and velocity of the meteors between 70~110 km by tracing the meteors</td>
<td><strong>Wuhan Mehe</strong></td>
</tr>
</tbody>
</table>
3. Ionosonde Chain

- **Digisonde (5)**
  - Mohe (new) – Beijing (new) – Wuhan (upgrade)-Hainan (upgrade) – Zhangshan (upgrade)

- **Traditional Ionosonde (4)**
  - Manzhouli – Changchun – Ghuanzhou – Chongqing - Lasha
### 4. Real time monitor chain of space environment

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Purpose</th>
<th>Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interplanetary Scintillation (IPS) Monitor</td>
<td>To monitor the interplanetary disturbance and obtain information about the solar wind velocity and plasma irregular structures</td>
<td>Beijing</td>
</tr>
<tr>
<td>Cosmic Ray Monitor</td>
<td>To detect the solar energetic particles and cosmic rays</td>
<td>Beijing, Guanzhou</td>
</tr>
<tr>
<td>GPS-TEC</td>
<td>To monitor the ionospheric TEC and scintillation in real time</td>
<td>Mohe, Beijing, Xinxiang, Wuhan, Hainan, Shanghai (Hangzhou)</td>
</tr>
<tr>
<td>HF Doppler Drift Monitor</td>
<td>To monitor multi-scale ionospheric disturbance propagation, by use of a long baseline system including a 3 HF Doppler antenna array in Beijing and a HF Doppler monitor in Wuhan</td>
<td>Beijing, Wuhan</td>
</tr>
</tbody>
</table>
### III. Optical-Atmospheric Monitoring Subsystem

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Content</th>
<th>Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lidar</strong></td>
<td>Temperature, density, and wind profiles of the middle atmosphere</td>
<td>Beijing, Wuhan, Hefei, Hainan</td>
</tr>
<tr>
<td></td>
<td>sodium density</td>
<td></td>
</tr>
<tr>
<td><strong>Fabry-Perot Interferometer</strong></td>
<td>Wind and temperature of atmosphere in the mesopause region and F2 layer</td>
<td>Beijing</td>
</tr>
<tr>
<td><strong>All-sky Airglow Imager</strong></td>
<td>The horizontal structure and transmitting feature of gravity waves in the mesopause region and the thermosphere</td>
<td>Beijing, Hainan</td>
</tr>
<tr>
<td><strong>Aurora Spectrometer</strong></td>
<td>Aurora spectrum, the atmospheric chemical species, the energetic spectrum of the energetic particles from the solar wind and the magnetosphere</td>
<td>Zhongshan Station in South Pole</td>
</tr>
</tbody>
</table>
IV. Rocket Sounding Subsystem

- To make in-situ measurements of temperature, density, pressure, wind etc. in the height of 20~200 km.
Hainan Station: Low-latitude Multipurpose Station (20°N)

- Rocket Sounding Base
- 8 types of ground based equipments
Ground-Based Instruments in Hainan Station

1. DPS-4 digisode
2. GPS- TEC Monitor
3. Ionospheric Scintillation Monitors
4. Lidar
5. All-sky Airglow Imager
6. CHIMAG Fluxgate Magnetometer
7. Geoelectric Monitor
8. Meteor radar
Data and Communication System

- Collect, transfer, process, store and distribute data
- International and domestic data exchange
Three-layer-Structure:

Station-Node-Center
Research and Forecast System

- Coordinate observations, research and management
- Carry out research and model
- Jointly make space weather forecast
- Promote international collaboration
Recent Development

Research and Forecast Center System has been constructed.

Operation Center

High Performance Computing Equipment
Recent Advances

Data Center
All the detection equipments have been developed.

ISR Radar has been developed.

- **Cover of antenna**
- **Control room**
- **Cooling system**
- **Emitting system**
ISR Radar observed results
MST radar are also been developed
Power spectra

Winds in the lower atmosphere
Power spectra

Winds in the middle-lower atmosphere
HF radar in Antarctic
雷达回波强度、电离层对流速度和雷达速度谱展宽
VHF Radar
Meteor Radar
Meteor radar observation

Observed wind

Observed meteors
Meteor radar observation: tidal winds

- Observation
- ♦️: GSWM02
Recent Advances

Cosmic Ray Detector has been constructed
IPS

50米天线

控制室
激光光束直指苍穹

发射激光绚丽耀眼

探测结果：Na回波光子数

分辨率（166秒，96米）

子午工程最新进展点滴
Simultaneously Observation of sodium layer and potassium layer
Recent Advances

Lidar

Initial Observations: Wind

Wind speed @ Hefei
All Sky imager
1. ASAI ---- Observation Data
2. FPI ---- at Beijing
Sound Rocket Launching
The first observation of the space environment respond to solar wind by Meridian Project (2010/08/03)
Strong Ionospheric disturb observed by MP, after Mar.11, 2011 Earthquake in Japan
International Collaboration
– The International Space Weather Meridian Circle Program (IMCP)

① - Overview of IMCP
② - Scientific goals
③ - Progress
International Collaboration

The International Space Weather Meridian Circle Program (IMCP), proposal to connect 120°E and 60°W meridian chains of ground based monitors and enhance the ability of monitoring space environment worldwide.
- USA
- Canada
- Russian
- Brazil
- Australia
- Japan
- etc
International ground-base observation system

Russia-Yakutsk

Arctic-SuperDARN

America-SAMBA

Canada - CGSM

INPE Space Weather Project

Antarctic-SuperDARN

Japan - MAGADAS
Proposed Frame of IMCP

- **Geomagnetic circle**
  - Russia: 25 stations
  - Canada: 7 stations
  - Australia: 10 stations
  - USA: 17 stations
  - China: 15 stations

- **Aura observation net**
  - Russia: 5 stations
  - Canada: 7 stations
  - Australia: 10 stations
  - USA: 17 stations
  - China: 15 stations

- **Cosmic ray circle**
  - Russia: 5 stations
  - Canada: 7 stations
  - Australia: 3 stations
  - USA: 17 stations
  - Argentina: Pierre Auger
  - China: Beijing

- **Ionosphere Circle**
  - Russia: 5 stations
  - Canada: 7 stations
  - Australia: 3 stations
  - USA: 17 stations
  - Argentina: Pierre Auger
  - China: Beijing

- **IPS Observation net**
  - Australia: Canberra, Culgoora
  - Mexico: Michoacan
  - Japan: 4 stations
  - China: Beijing

- **Middle – upper atmosphere circle**
  - Australia: South Pole
  - USA: Wallops Island

- **IMCP**

- **MST radar**
  - Australia: Canberra, Culgoora
  - Mexico: Michoacan
  - Japan: 4 stations
  - China: Beijing

- **Non-coherent scattering radar**
  - Australia: South Pole
  - USA: Wallops Island

- **GPS-TEC**
  - Australia: South Pole
  - USA: Wallops Island

- **HF-Radar**
  - Australia: South Pole
  - USA: Wallops Island

- **Laser radar LIDAR**
  - Australia: South Pole
  - USA: Wallops Island

- **Optical interferometer FPI**
  - Australia: South Pole
  - USA: Wallops Island

- **All-sky airglow imager ASAI**
  - Australia: South Pole
  - USA: Wallops Island

- **Meteors radar MST radar**
  - Australia: Canberra, Culgoora
  - Mexico: Michoacan
  - Japan: 4 stations
  - China: Beijing
1. Use diverse instrumentation to observe physical parameters that pertain to the global space weather system, as well as its coupling to the Earth’s atmosphere, with a special emphasis on the collection of data and information from all latitudes along a meridian circle.

2. Cooperate with appropriate space missions with a view toward characterizing the near-Earth space weather system as a coupled three-dimensional entity.

3. Understand the behavior of the geospace-atmosphere system under conditions of major magnetic storms and particle radiation.
Scientific Goals

4. Understand the coupling and feedbacks between geospace and the atmosphere in a global context.
5. Develop models and numerical capabilities to simulate and predict space weather in the geospace-atmosphere system covered by IMCP.
6. Produce space weather information and data products to improve related research in the participating countries and global community.
7. Use the collective resources of IMCP to promote awareness, public outreach, and education about space weather.
An IMCP Scientific Committee are established to promote and coordinate cooperative activities, by engage in the following activities:

- Promote space weather monitoring and research through coordinated ground-based observations
- Support the International Space Weather Initiative (ISWI) and similar international programs
- Organize biennial IMCP scientific workshops
- Coordinate collaborative research activities within IMCP, as well as externally.
Cooperation agreements have been signed between Meridian Project and the above countries:

- Russian
- Canada
- Brazil
- Australia
- American (intend)
- Japan (intend)
- ...
Summary

- Meridian Project is a ground-based network program to monitor space environment, which consists of a chain of ground-based observatories with multiple instruments.

- International collaboration will make it possible to constitute the first complete environment monitoring chain around the globe.
Thank You!