Overview about the Meridian Project
(Chinese Ground-based Space Weather Monitoring Project)

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Outline

- Milestone
- Framework
- Recent Advances
- International Collaboration
2005.08 Meridian Project was officially approved by the China National Development and Reform Commission as a mega-scientific project.

2006.06 The feasibility study of the Meridian Project was evaluated and approved. The total budget is about 24 million US$.

2008.01 Construction phase started

2012.10 Construction phase completed, official kick-off of operation
It 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.
Scientific Principles

☑ Many basic physical processes occur along the meridian circle.

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

15 Stations:

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

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

Among them, Beijing, Wuhan, Hainan, Zhangsan are multi-tasking stations.
Station Distribution

- DIM
- OFM
- FGM
- SCM
- SED
- DEM
- ASAI
- FPI
- LIDA
- AURO
- CRM
- TEL
- IPS
- DPS
- IONO
- DOPP
- TEC
- METR
- HFR
- MST
- VHF
- ISR
- SROC
- MROC
<table>
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<tr>
<th>Station</th>
<th>Lat.</th>
<th>Lon.</th>
<th>Instruments</th>
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</thead>
<tbody>
<tr>
<td>Mohe</td>
<td>53.5N</td>
<td>122.4E</td>
<td>magnetometer, digisonde, TEC monitor/ionospheric scintillation monitor</td>
</tr>
<tr>
<td>Manzhouli</td>
<td>49.6N</td>
<td>117.4E</td>
<td>magnetometer, ionosonde</td>
</tr>
<tr>
<td>Changchun</td>
<td>44.0N</td>
<td>125.2E</td>
<td>magnetometer, ionosonde</td>
</tr>
<tr>
<td>Beijing</td>
<td>40.3N</td>
<td>116.2E</td>
<td>magnetometer, digisonde, lidar, all-sky imager, Fabry-Perot interferometer, mesosphere-stratosphere-thermosphere radar, interplanetary scintillation monitor, cosmic ray monitor, TEC monitor/ionospheric scintillation monitor, high frequency Doppler frequency shift Monitor</td>
</tr>
<tr>
<td>Xinxiang</td>
<td>34.6N</td>
<td>113.6E</td>
<td>magnetometer, ionosonde, TEC monitor/ionospheric scintillation monitor</td>
</tr>
<tr>
<td>Wuhan</td>
<td>30.5N</td>
<td>114.6E</td>
<td>magnetometer, digisonde, lidar, mesosphere-stratosphere-thermosphere radar, meteor radar, TEC monitor/ionospheric scintillation monitor, high frequency Doppler frequency shift monitor</td>
</tr>
<tr>
<td>Hefei</td>
<td>33.4N</td>
<td>116.5E</td>
<td>Lidar</td>
</tr>
<tr>
<td>Station</td>
<td>Lat.</td>
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<td>Instruments</td>
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</tr>
<tr>
<td>Guangzhou</td>
<td>23.1N</td>
<td>113.3E</td>
<td>magnetometer, digisonde, lidar, mesosphere-stratosphere-thermosphere radar, meteor radar, TEC monitor/ ionospheric scintillation monitor, high frequency Doppler frequency shift monitor</td>
</tr>
<tr>
<td>Hainan</td>
<td>19.0N</td>
<td>109.8E</td>
<td>magnetometer, digisonde, TEC monitor/ionospheric scintillation monitor, Lidar, all-sky imager, very high frequency radar, sounding rockets, meteor radar</td>
</tr>
<tr>
<td>Zhangshan</td>
<td>69.4S</td>
<td>76.4E</td>
<td>magnetometer, digisonde, high-frequency coherent scatter radar, aurora spectrometer</td>
</tr>
<tr>
<td>Shanghai</td>
<td>31.1N</td>
<td>121.2E</td>
<td>magnetometer, TEC monitor</td>
</tr>
<tr>
<td>Chongqing</td>
<td>29.5N</td>
<td>106.5E</td>
<td>magnetometer, ionosonde</td>
</tr>
<tr>
<td>Qujing</td>
<td>25.6N</td>
<td>103.8E</td>
<td>Incoherent Scattering Radar</td>
</tr>
<tr>
<td>Chengdu</td>
<td>31.0N</td>
<td>103.7E</td>
<td>magnetometer, ionosonde</td>
</tr>
<tr>
<td>Lhasa</td>
<td>29.6N</td>
<td>91.0E</td>
<td>magnetometer, ionosonde</td>
</tr>
</tbody>
</table>
Spatial Coverage

By

The Meridian Project
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
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
Instrument

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 Instrument

Geo-electric

Overhauser

Fluxgate

Atmospheric electric

Induction

DI-fluxgate
Geomagnetic Observatories
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.
1. Incoherent Scattering Radar (ISR)

- 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 ~2MW.
ISR Radar

Aetna doom

transmitter

Control room

Cooling system
## 2. Radar Chain

<table>
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<tr>
<th>Instrument</th>
<th>Detecting Content</th>
<th>Sites</th>
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<tbody>
<tr>
<td><strong>MST Radar</strong></td>
<td>Wind parameters of troposphere, stratosphere and mesosphere, ~50MHz</td>
<td><strong>Beijing, Wuhan</strong></td>
</tr>
<tr>
<td><strong>HF Coherent Scattering Radar (HF Radar)</strong></td>
<td>To detect the motion of the ionospheric structure 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 (VHF Radar)</strong></td>
<td>To detect the irregular structure and drift (electrical field) in the ionospheric E layer, 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 wind 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</strong></td>
</tr>
</tbody>
</table>
MST Radar

Beijing

Wuhan
HF Radar
VHF Radar
Meteor Radar
Meteor radar observation

Observed wind

Observed meteors
Meteor radar observation: tidal winds

- ♠: Observation
- ♦: GSWM02
3. Ionosonde Chain

• **Digisonde**

  Mohe (new) – Beijing (new) – Wuhan (upgrade) - Hainan (upgrade) – Zhangshan (upgrade)

• **Traditional Ionosonde**

  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><strong>Interplanetary Scintillation (IPS) Monitor</strong></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><strong>Neutron Monitor</strong></td>
<td>To detect the solar energetic particles and cosmic rays</td>
<td>Beijing, Guanzhou</td>
</tr>
<tr>
<td><strong>Ionospheric TEC and Scintillation Monitors</strong></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><strong>HF Doppler Drift Monitor</strong></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>
IPS

50-meter Atena

Control room
Neutron Monitor

Beijing

Guangzhou
III. Optical-Atmospheric Monitoring Subsystem

- To measure the density, temperature, wind field, airglow and aurora spectrum by use of active and passive optical tools.
Station Distribution

- **Lidar Chain:**
  - Beijing (new)-Wuhan (upgrade)-Hefei (new)-Hainan (new)

- **Beijing:** All-sky Airglow Imager, FP-interferometer (new)

- **Hainan:** All-sky Airglow Imager (new)

- **Zhangshan:** Aurora Spectrometer (new)
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<tr>
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<th>Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lidar</strong></td>
<td>Temperature and density profiles of the middle atmosphere</td>
<td>Beijing, Wuhan, Hefei, Hainan</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>
Lidar

Beijing

Hainan

Hefei
Origin data

Sodium density (double sodium layer)

Rayleigh temperature

Resolution: 166S and 0.96 km

Resolution: 20 min and 0.96 km
All-Sky Imager
A difference image between consecutive raw images of OH airglow at 05:14 LT and 05:15LT on Dec. 26, 2009. This image shows some gravity waves.
Aurora Spectrometer

Zhangshan
IV. Rocket Sounding Subsystem

- To make in-situ measurements of temperature, density, pressure, wind etc. in the height of 20~200 km.
The sounding rocket (~200km) was successfully launched on May 7, 2011.
Data and Communication System

- Collect, transfer, process, store and distribute data
- International and domestic data exchange
Three-layer-Structure:
Station-Node-Center
Data Center
Research and Forecast System

- Coordinate observations, research and management
- Carry out research and model
- Jointly make space weather forecast
- Promote international collaboration
Science Operation Center
Space Weather Warning and Forecast Center
First Observations of the geospace response of to the solar storm on Aug. 1 – 3, 2010
Observations of the geospace response of to the biggest solar storm since 2007 on Aug. 5–6, 2011

Geo Magnetic field

HF radar
Simultaneous Observation of plasmaspheric and ionospheric variations during magnetic storms

The plasmasphere dynamics seems to be controlled by the ionosphere during magnetic storms

(Wang et al. JGR, 2013)
Ionospheric disturbances caused by March 11, 2011 Japan big earthquake

Ionospheric Doppler-Shift Equipment

(Xiao et al. JGR, 2012)
Chinese Meridian Project provided high time resolution and continuous space environment data and space weather service for Chinese Manned-Program.
Editor’s Comments:

What an ambitious, broad-reaching, and hard-hitting endeavor!
Considering the global nature of geospace processes and their coupling to the thermosphere and mesosphere, a new initiative, called the International Space Weather Meridian Circle Project (IMCP) is proposed to connect ground-based instruments and observatories deployed along the great meridian circle inscribed by the 120° E and 60° W meridian lines.
What will IMCP do?

- **Data sharing and Exchange**
- **Coordinating observational campaigns**;
- **Encouraging collaboration on scientific research and observations**;
- **Promoting education and public outreach on space science and technology**.
Joint Space Weather Lab. 2014 - 2019

IMCP Workshop
Sanya, China, Feb 21-25, 2011

Hainan, China

Santa Maria, Brazil
- Chi Wang: Overview about the Meridian Project
- Shunrong Zhang: Meridian Circle International Observations
- John Foster: Coupled Observations of Space weather Storms in the Geospace
- Hongqiao Hu: An overview on PRIC’s UAP observation in the polar regions
- Anthony van Eyken: Space Weather: The current and future role of the Incoherent Scatter Radar network
- Qian Wu: Thermospheric wind observations and simulations
What Next?

- Scientific Committee for IMCP
- Executive Office for IMCP
- 2015 Workshop (every other year)
- Space Weather Observation Campaigns
- Research Plan for Space Weather
Meridian Project is a ground-based network program to monitor space environment, which consists of a chain of ground-based observatories with multiple instruments.

The Meridian Project started collecting data from Oct. 2012, and will last at least 10 years.

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