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International Meridian Circle Program*

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Abstract The Earth is buffered from the ferocious onslaught of the solar wind by a thin layer of matter known as the atmosphere and geospace. This layer absorbs energy from irradiance and outburst from the Sun, as well as from disasters, transient phenomena and anthropogenic emissions originated from Earth. Through complicated physics, the absorbed energy changes the atmospheric and geospace state and sometimes gets re-released to power extreme events such as space weather. Taking place globally, these complicated processes cannot be understood unless they are studied globally. The Chinese scientists have proposed the International Meridian Circle Program (IMCP) to meet this demand. By operating nearly 1000 instruments encompassing all latitudes along with the 120°E–60°W longitudes, IMCP aims, for the first time, to construct comprehensive 3D data representation of the atmosphere and geospace on a global scale and empower interdisciplinary research to tackle key questions related to Earth's environment and climate change.

Key words International Meridian Circle Program, Chinese Meridian Project, Ground-based observation, Space weather, Solar-terrestrial physics

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The changing environment is one of the greatest challenges humanity faces in the 21st century. In spite of enormous progress, our science is still not in a position to offer clear solutions to many environmental problems confronting us today. Since the environment is a global whole, its understanding demands a global effort from all countries. The International Meridian Circle Program is a call for global action to tackle one of the most critical scientific questions of the century, namely, how does

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energy from the Sun and Earth change the atmosphere, how can the resulting change pose a threat to the human society, and how can we mitigate and manage the negative consequences of this change.

The atmosphere and its extension into space (known together as Geospace) are fundamental to the survival of humanity; a 1% deviation of some Geospace parameters from their present values could have catastrophic consequences. The Geospace system is driven by an ever-present flow of energy from the Sun and Earth. The light energy from the Sun maintains the delicate balance in the ecosphere and regulates the tropospheric weather. The magnetic energy from the Sun stirs the often-stormy solar wind through which the Earth sails uneasily. The heat energy within Earth drives tectonic movement and oceanic circulation. The land features of Earth perturb the air circulation and feedback on local and global weather. All these inputs and interactions account for the high variability of Earth's climate and weather and are often associated with natural disasters or undesirable long-term trends.

The Ionosphere and Mid-Upper Atmosphere (IMUA), located in the altitude range 20~1000 km, is crucial to Geospace Change. Energy extracted from the solar-terrestrial interaction and energy propagating upward from the troposphere give rise to a complex pattern of motion and turbulence, which can change significantly the distribution of species participating in the chemistry of Global Change. IMUA is also the seat of extreme Space Weather, an electromagnetic meltdown in space posing a major threat to economy and potentially human life. According to a 2008 report by the US National Research Council[1], if the largest recorded space weather incident, the Carrington event in 1859 (when the use of electric power was still a novelty), were to recur today, the potential economic loss could exceed $2 trillion in the US alone, with a potential loss in life measured in millions. Moreover, the pattern of IMUA motion and turbulence is a mirror image of their respective solar and terrestrial energy sources, raising the possibility of using IMUA perturbation patterns to predict space weather and Earth-originated disruptions.

Till now we have not understood fully Space Weather or how Global Change responds to energy flows from the Sun and Earth, much less making robust predictions based on the understanding. However, there is a strong foundation to achieve this understanding. Over the years, the scientists have built powerful regional and continent-scale arrays of sophisticated ground-based instruments capable of taking the snapshots of IMUA over a large area. Combined these snapshots gives a fuzzy collage of Geospace, but not a smooth movie. The goal of the International Meridian Circle Program is to obtain, on a continuous basis, global movie of Geospace in motion, by (i) synchronizing the observations from the existing networks around the globe, (ii) harmonizing data formats and analytics standards, (iii) building strategically important new research capacities, and (iv) establishing an International Meridian Organization to oversee the research and operational activities of the combined global network.

The majority of the existing Geospace-observing networks are distributed along the Great Meridian Circle along with the 120°E and 60°W longitudes, cutting across China, Russia, Canada, the United States, Latin America, Antarctica, Australia, and Southeast Asia, with about 1000 instruments in operation or under construction. In particular, in China, the Chinese Meridian Project (Phase 1 and 2) will deliver, by 2023, the world's most extensive ground-based Geospace-observing network with more than 300 instruments measuring 38 different parameters.

Once integrated, the 1000 instruments deployed along the 120°E–60°W meridian circle can give a complete cross-sectional scan of Geospace from ground level to up to 3000 km altitude, including density, temperature, electric and magnetic fields, wind fields, planetary waves, and distribution of minor species involved in Global Change. By virtue of Earth's rotation, this network can give a complete three-dimensional representation of these key Geospace parameters every 12 h. Accumulated over years and decades, this dataset will provide valuable insight on how Climate and long-term atmospheric change are influenced by the solar and terrestrial energy input. By detecting and tracking short-term anomalies in Geospace parameters, the network can

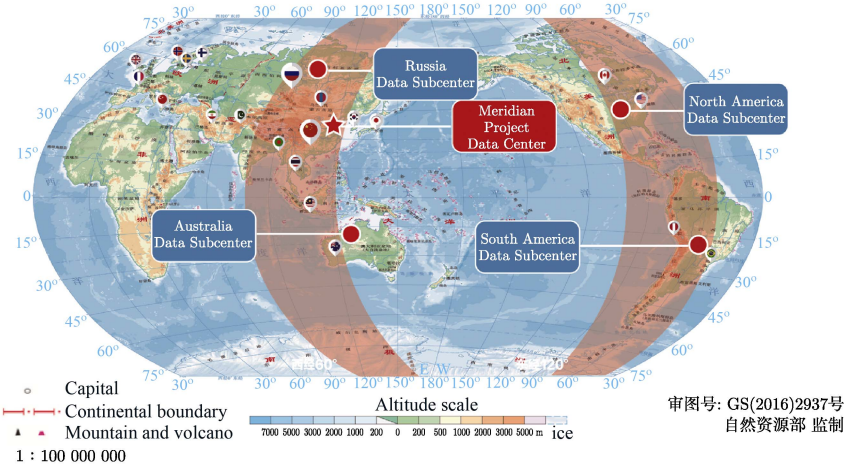

Fig. 1 Illustrative map of IMCP

provide advanced warnings on space weather and terrestrial disasters such as earthquakes.

The idea of a circumpolar chain of ground-based instruments for space weather study was first conceived by Prof. Wei Fengsi in 1994, just about the time when space weather became an international concern. In 2004, this idea was crystallized in the proposal of the Chinese Meridian Project (CMP) and received formal support from the National Development and Reform Commission in 2008.

The International Meridian Circle Program emphasizes the development of new research capacities to tackle scientific questions arising from the expanded view of Geospace, first as a system driven by energy flows from both solar and terrestrial sources, and second by taking into account longer time-scale variability associated with Global Change. These new capacities could include innovative use of nanosatellite technology to complement and complete the ground-based observations.

For program direction and management, we envision a new type of international research organization, with a permanent and fully staffed headquarters in Beijing, and four program platforms, namely, research, coordinated network operations, data sharing, and HQP training distributed around the globe. An International Meridian Organization will be created through an international charter approved by participating countries and given independent power and authority to manage the International Meridian Circle Program in the best interest of science.

Now, IMCP is selected as a candidate mission for the International Big Science Initiative supported by Chinese Academy of Sciences, and has been funded as a concept study by Beijing Municipal Science and Technology Commission. Besides, Government of Beijing already allocated funds for an 8000 m^2 IMCP HQ building.

IMCP is building international support at an impressive rate. To date, close to 20 countries have expressed an interest to cooperate. These include major advanced economies such as Great Britain and France, BRICS countries such as Russia and Brazil, countries with major existing capabilities and crucial territories such as Canada and Australia, leading developing countries such as Indonesia and possibly India. Despite temporary strains in relationship, scientists from the United States have been very active in supporting the IMCP. Many international organizations have endorsed IMCP as a valuable contribution to global science, including IUGG, COSPAR, SCOSTEP, URSI, SCAR, and ISWI.

IMCP will be a major step forward from the outstanding foundation of CMP Phases 1 and 2. Set in an international context demanding greater global cooperation to tackle grand challenges humanity faces as a whole, IMCP will be a compelling entry point for Chinese research to reach an elevated altitude in international science.

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