Global Scale Ionospheric Monitoring - Future Development

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Abstract

Incoherent scatter radars have developed considerably in recent years with the deployment of multiple new systems (Poker Flat, Alaska, Resolute Bay, Canada, and in development in China, Argentina, Antarctica, and Scandinavia, as well as a second system at Resolute Bay) and operational changes to support continuous and remote measurements.

We will discuss plans to add further observational sites, built around phased array incoherent scatter radars, to cover a complete geomagnetic meridian; plans to further integrate the routine operation of many radars around the globe; and the potential for hardware collaboration for future incoherent scatter radar systems.

1. Introduction

Aeronomers have made huge strides in understanding the detailed physics and chemistry of the upper atmosphere and in designing, constructing and operating advanced facilities to monitor, measure, and in some cases, perturb that medium. The big picture, with its accompanying ability to predict the behavior of the geospace system both in response to natural, solar, and anthropogenic factors, remains elusive.

Neither existing ground-based facilities, nor current or planned space missions, can provide the detailed, reliable, global coverage of geospace required to support both new and insightful scientific understanding and future operational capabilities to trace Atmosphere-Ionosphere-Magnetosphere (AIM) weather, climate, and global change.

Current incoherent scatter radars (ISRs) have the ability to operate reliably, remotely, and largely autonomously for extended periods and the procedures to build, deploy, operate, and maintain them are well developed. For the first time, it is now practical to propose a global ISR deployment capable of providing the precision measurements required.

A Magnetic Meridian Ring of ISRs (Figure 1) and related instrumentation, including existing installations, planned installations, and potential international collaborations, would provide continuous detailed data along a full geomagnetic meridian encircling the globe and affording scientists, modelers, and data consumers uninterrupted coverage including inter-hemispheric, day-night, and seasonal measurements under all conditions and at all times.

Seven to ten new sites, each employing two phased array radars, together with potential international partnerships, will drive major scientific progress in (for example): geospace science, system science, solar terrestrial interactions, and planetary energy budget, geospace system modeling, now, and fore-casting as well as providing the reliable and detailed inputs needed to support effective geospace management, threat evaluation, and mitigation procedures, as recommended and elucidated in the National Science Foundation's (NSF) GeoVision Report [1].

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2: Science Concept

Extending observational capabilities over larger areas of geospace provides both an essential foundation for continuing cutting-edge scientific research and an essential input to forecasting activities, including space weather and climate change/disruption. The most effective way to maximize observational coverage is to locate the most capable instruments at the accessible edges of geospace.

The last National Research Council (NRC) Decadal Survey [2] recognized the importance of global networks of ground-based ionospheric and geomagnetic measurement stations as integral components of the arrays needed to solve the complex, nonlinear, coupled AIM systems.

ISRs are ideal for studying energy and mass transport within the AIM and the effects of Solar Wind – Magnetosphere interactions. ISRs measure both the predominantly horizontal redistribution of energy about the planet and vertically between atmospheric regions, and between the lower atmosphere and the ionosphere and magnetosphere.

Facilities can be arranged in many different configurations to sample various regions of the AIM system. However, there is one arrangement that will perform all the measurements that are needed to answer many of the fundamental questions. This consists of a ring of facilities located along a complete magnetic meridian encircling the globe. The configuration provides simultaneous day and night measurements (when the ring is at or near the noon-midnight meridian), measurements along the day-night terminator (when the ring is in the dawn-dusk meridian), and inter-hemispherical asymmetries and summer-winter asymmetries at all latitudes. It can follow the latitudinal propagation of ionosphere-thermosphere disturbances such as neutral winds and gravity waves with time resolution of a few minutes to hours, as well as long term circulation effects including the redistribution of ice and aerosol particles in the mesosphere.

Figure 1 shows the conceptual Magnetic Meridian Ring constructed around the magnetic meridian passing through existing and planned ISRs in the American sector, passing close to the South Atlantic Anomaly and including radars and instrumentation in Southeast Asia, China, and Russia. Some facilities that would be part of the Magnetic Meridian Ring are already in operation, or in detailed planning, such as the Antarctic Radars proposal, and the AIRES radar in Argentina. Other Magnetic Meridian choices are possible, but the Figure 1 concept maximizes the use of existing installed infrastructure, capitalizes on the availability of land masses to maximize coverage and simplify support, and provides excellent opportunities for meaningful and effective international collaboration.

The step from local to global measurements mandated by system science objectives in the next ten years requires three types of measurements.
(1) Tracking Space Weather effects from high- to low-latitudes and between high and low altitude.
(2) Tracking of the propagation of anthropogenic and natural atmospheric effects between high- and low-latitudes, between low- and high-altitudes and between hemispheres
(3) Measuring seasonal effects and separating them from other effects

All the processes mentioned above are influenced by or, in some cases even determined by, asymmetries between summer and winter hemispheres, transition between dayside and night side conditions, or solar cycle. For instance, the effect of differences in ion composition, temperatures, humidity, topology – and hence wind and wave patterns – in the two hemispheres over extended timescales is little understood. We must understand how asymmetries modify the fundamental properties of the AIM system and we must be able to separate a given effect from all others. Simultaneous measurements in both hemispheres are needed. The long, continuous data sets that will be available eventually from the multiple ISR locations under all geomagnetic conditions for decades to come will be fundamental in documenting and explaining these processes from a systems perspective.

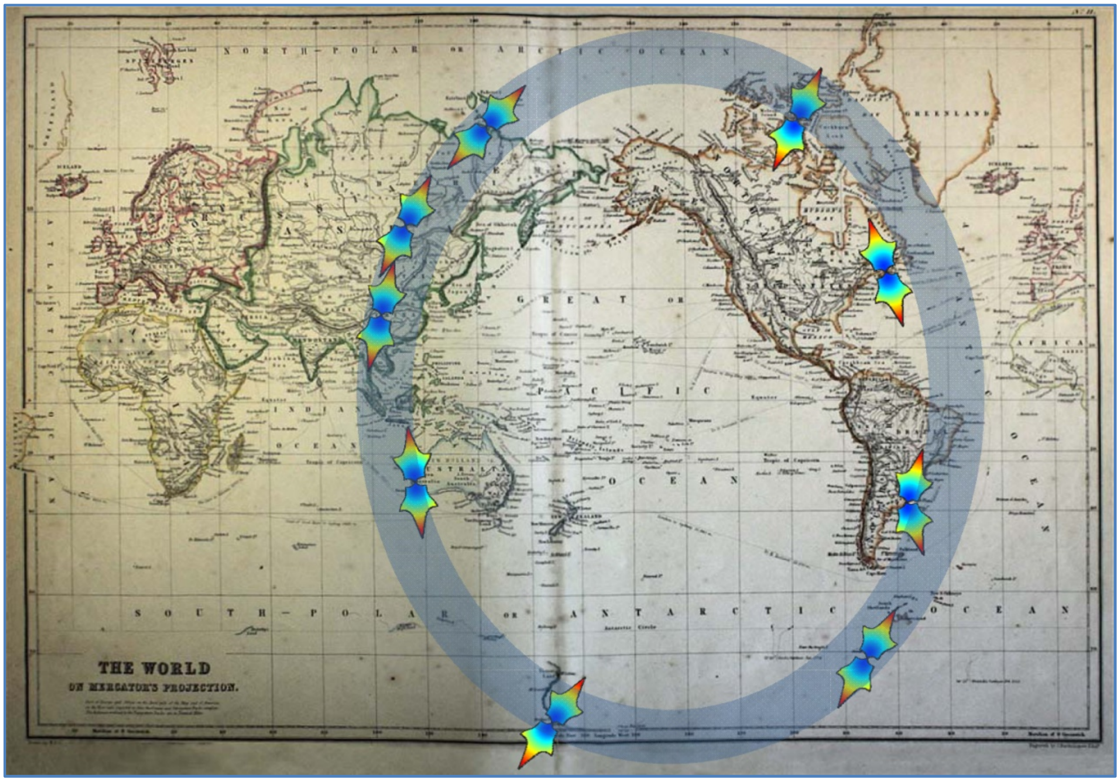

Figure 1: Conceptual Magnetic Meridian Ring: Like early map makers, we know much about geospace, but lack the big picture. The Magnetic Meridian Ring concept exploits existing and planned facilities and partnerships to provide comprehensive measurements along a complete magnetic meridian for the first time.

3: Operational Capabilities

Global understanding of climate, climate change and disruption, and the impact of space weather events on technological and societally important systems requires effective and reliable modeling to enable now- and fore-casting and to allow meaningful assessment of risk, evaluate options, and plan economic, social, and mitigation strategies. Understanding and quantifying these processes is essential if global atmospheric and climate models are to have practical application in effective now- and fore-casting, in informed evaluation of climate change and climate disruption mitigation measures, and in illuminating the global debate over how, where, and when to develop and deploy such measures. The Magnetic Meridian Ring provides the essential global scale, real-time, data input essential to ensure that models and forecasts are accurate, realistic, and above all reliable.

4: Integrated Radar Operations

The Magnetic Meridian Ring will take some time to be constructed. In the meantime, the operations, data handling, and data distribution of the existing ISRs can be more fully integrated and coordinated to ensure that the best possible data sets and data products are provided to current and future user communities. Existing facilities can exploit high bandwidth communications for monitor and control and to distribute observational data routinely to scientific and service users. The software infrastructure required to disseminate data reliably and transparently can be developed jointly from existing systems and available capacity can well address the parallel needs of initiatives such as the Small instrument Distributed Ground-based Network (DASI) recommended in the Decadal Survey [2].

5: Hardware collaboration for future incoherent scatter radar systems.

Most new ISRs use distributed transmitters and receivers in phased array designs. While each system is different, there are many similarities in the required hardware and software. Community resources can be leveraged by cooperating on such developments and more closely integrating the hardware and software solutions and technologies.

References

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