Multiscale Software Radar Networks and the Geospace Array

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Abstract

The Geospace Environment encompasses the Earth's Ionosphere, Plasmasphere, and Magnetosphere and their coupling to both the Heliosphere (above) and the lower atmosphere (below). Understanding the dynamics of Geospace phenomena requires global measurement capabilities which encompass the full range of important physical processes, provide wide coverage of critical regions, and allows for detailed investigations into the underlying physics. These measurements must be of fundamental physical parameters, available on an ongoing basis, and made in a sustained and sustainable manner. To accomplish such measurements a Global Geospace Array of instrumentation will be required which will resolve both large and small physical scales and give access to the meso-scale picture as well as the micro-scale dynamics on an continuous and ongoing basis.

Radio and radar instrumentation have historically played a key role in the observation of the Geospace environment. Ground based radio instrumentation has, in particular, provided a sustained record of observation and scientific discovery. However, the modern instrumentation network which has been constructed by the ground based radio science community has many issues. It is greatly limited by the ad-hoc and incremental nature of its creation, the differing technologies used for its implementation, and the cost and complexity associated with its maintenance and operations. For example, the existing incoherent scatter radar facilities provide coverage of significant portions of the globe but are not uniformly capable, operate intermittently, have high operational costs, and often must make operational choices which limit the applicability of the observations which are made. It is difficult to break free of these limitations due to the embedded costs, required resources, and the perceived risk of major changes. To address these issues requires a paradigm change.

Multi-scale software radar networks provide a means to address the limitations of current systems while building towards a more uniform capability for global observation. In concept, the Geospace Radar Array will use a large number of broadband software radio receivers and narrow band transmitters which will be distributed in a scalable arrays of tiles. Different transmit frequency bands will be implemented using tiles designed for specific frequency ranges to limit system complexity and to allow tradeoffs in total emitting power as a function of frequency. At a given site these tiles will be arranged using an aperiodic geometry with separations up to several tens of kilometers to obtain high performance for radar and radio imaging over a significant portion of the full sky. A lower density of tiles would also be distributed between sites at appropriate locations to provide additional multi-static observation capabilities. The majority of the tiles at a major site would be deployed in a dense central core to enable sufficient aperture for incoherent scatter radar measurements of the ionosphere. The elements would also be highly capable for passive observations and will be compatible with radio astronomical techniques for sensing the ionosphere, heliosphere, and larger radio environment. The EISCAT 3D Radar system, currently under development, promises to be a major step towards the development of such digital radio array capabilities.

A global Geospace Radar Array would apply radio and radar techniques of well demonstrated capability to enable measurements from the lower atmosphere, into the ionosphere, through the heliosphere, and to the surface of the Sun. The all digital and computing-focused technology used to implement such an array would create a consistent approach for addressing a diverse range of scientific topics. Measurement techniques would be implemented as software running on high performance computing systems which would control and interpret the flow of information from the sensor elements. With proper design it will be possible to use the instrumentation to perform multiple science experiments simultaneously and dynamically. The software radio technology used to implement such an instrument array would be very flexible in its application and could address science topics from the lower atmosphere to the surface of the Sun and beyond. Its creation would enable significant advances in our physical understanding of the atmosphere, the space environment, the Sun, and the coupling between them by allowing physical measurements of the critical regions which can then be studied in a system science context.

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