SuperDARN in support of Magnetosphere-Ionosphere-Thermosphere coupling science, space weather research and operations

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Introduction: The Super Dual Auroral Radar Network (SuperDARN) has for decades provided observational coverage of geophysical phenomena at high and middle latitudes. The network is an international collaboration made up of 35+ radars operated by institutions in nine countries. SuperDARN data will be critical in providing the "big picture" context for upcoming NASA missions, including Geospace Dynamics Constellation (GDC) and Dynamic. The network provides a diverse range of science data products, covering high-latitude ionospheric electric fields, magnetospheric convection, mesospheric "meteor" winds and even ocean currents. A summary of these products is provided in Figure 1.

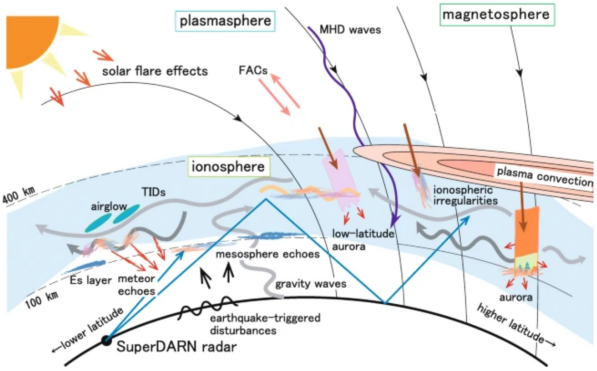

Figure 1 (from [1])**:** SuperDARN radars observe cross-scale and cross-domain phenomena related to Magnetosphere-Ionosphere-Thermosphere coupling science

Cross-scale and cross-domain coupling: SuperDARN combines broad spatial coverage (across the bulk of both Northern and Southern high latitudes) with high spatial and temporal resolution (15-km and <1-minute in some cases). The >100 TB data archive stretches back to 1993, and has recently been made public in its raw form [2]. SuperDARN data have been used to place regional phenomena such as the Sub-Auroral Polarization Stream (SAPS) within the global convection pattern. The radars have also been used for space weather awareness, in terms of identifying auroral clutter and absorption events. Recently, there have been a number of studies demonstrating the utility of SuperDARN as a meteor radar capable of resolving global-scale waves in the Mesosphere-Lower Thermosphere (MLT) region.

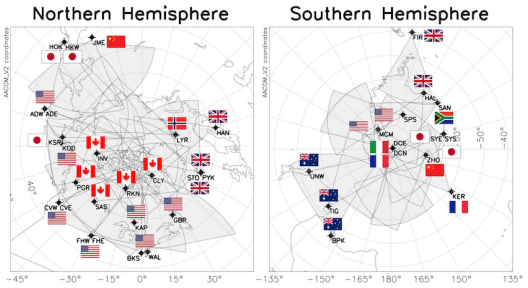

Figure 2: Fields-of-view of SuperDARN radars as of 21 January 2021

New developments: With planned enhancements SuperDARN is well-positioned to provide critical measurements to address themes identified in the Heliophysics 2050 discussions and white papers. These include M-I-T coupling, ionospheric electrodynamics from global through meso and small scales, and space weather science and operations in the ionosphere. The global infrastructure that makes up the SuperDARN network (encompassing radar sites, hardware, human skills and experience, data infrastructure) provides a great opportunity for development over coming decades. One aspect of this is the combination of SuperDARN data with other datasets. There is tremendous scope for improving SuperDARN data quality and quantity through the application of modern radio techniques. The network is undergoing upgrades to software-defined radio, with a long-term goal to operate as a distributed system rather than as separate ground stations. Novel imaging techniques can be implemented that enhance resolution by addressing field-of-view smearing and other artefacts caused by beam-forming [3]. The introduction of cross-polarized antennas at some sites promises to yield useful new ionospheric data products and to remove ambiguities in data analysis and interpretation. Multistatic capabilities and installation of down-range receivers have been proposed as a means of constraining HF propagation models, improving geolocation, and expanding the range of space weather products.

References: [1] Nishitani, N., Ruohoniemi, J. M., Lester, M., Baker, J. B. H., Koustov, A. V., Shepherd, S. G., ... & Kikuchi, T. (2019). *Prog. EPS*, *6*(1), 1-57. [2] https://www.frdr-dfdr.ca/repo/collection/superdarn [3] Bristow, W. A. (2019). *Radio Science*, *54*(7), 692-703.