Editorial

Special Issue: "SuperDARN / Studies of Geospace Dynamics - Today and Future"

ABSTRACT

This Polar Science special issue, "SuperDARN / Studies of Geospace Dynamics - Today and Future," originated from an international SuperDARN (Super Dual Auroral Radar Network) annual workshop held in Japan in June 2019, and is focused on studies of geospace dynamics particularly related to SuperDARN. Its purpose is to overview recent wide and active research, new scientific results and future perspectives mainly through, but not limited to, the scientific papers presented at the workshop. This special issue is an opportunity to commemorate a quarter century since the establishment of SuperDARN in 1995 and to contribute to the further development of geospace sciences and relevant technology. Thirteen valuable papers have been published covering a wide variety of scientific and technical topics.

Keywords: SuperDARN, geospace dynamics, polar science

SuperDARN (Super Dual Auroral Radar Network) is an international high-frequency (HF) coherent radar network established in 1995 (Greenwald et al., 1995, Chisham et al., 2007, Nishitani et al., 2019, and references therein). More than 35 radars are currently operated by more than 15 research institutes in about 10 countries, distributed from middle to polar latitudes with a wide longitudinal coverage so that their overall fields-of-view cover considerable portions of the global ionosphere in both hemispheres. The primary scientific objective of the network was to obtain global plasma convection and electric field maps, which had never been done before, to contribute to space weather research. Since fundamental and essential physical parameters in the ionosphere are obtained, SuperDARN can also address a number of scientific questions on the upper atmosphere and geospace relating to a variety of ionospheric and magnetospheric phenomena. These include magnetosphere-ionosphere coupling, the neutral atmosphere and its coupling with the ionised atmosphere, influence of geospace on the lower atmosphere and possible global climate change, pure plasma physics and astronomy, and practical applied physics including space weather nowcast and forecast.

The annual international SuperDARN workshops have been held in a variety of locations to share and discuss important scientific research and new findings as well as current issues to be resolved and future scientific directions. The 2019 SuperDARN Workshop was held in Fujiyoshida, Yamanashi, at the foot of Mt. Fuji in Japan between the 2nd and 7th June 2019, hosted by NICT (National Institute of Information and Communication Technology), NIPR (National Institute of Polar Research), ISEE (Institute for Space-Earth Environmental Research) in Nagoya University, ICSWSE (International Center for Space Weather Science and Education) in Kyushu University and the University of Electro-Communications.

A quarter century has passed since the establishment of SuperDARN in 1995, and not only has the number of SuperDARN research groups, radars and its total fields-of-view grown, but they, and their scientific research areas and abundant scientific achievements continue to grow. Therefore, we proposed this special issue of the Polar Science journal, which is focused on studies of geospace dynamics particularly related to SuperDARN. Our aim is to overview recent wide and active research, new scientific results and future perspectives mainly through, but not limited to, the scientific papers presented at the workshop, whilst contributing to the further development of geospace sciences and relevant technology. A total of thirteen valuable papers have been published covering a wide variety of scientific and technical topics, which are outlined below.

Geomagnetic storms and substorms are two of the most important themes for developing a true understanding of the physical mechanisms of space weather phenomena and impacts that occur mainly in the polar region. Temporal and spatial changes of GNSS total electron content (TEC) and phase scintillation during major geomagnetic storms and auroral substorms in the polar region are investigated using GNSS, SuperDARN and other instruments and models (Priyadarshi et al., 2021 and Prikryl et al., 2021).

Polar cap phenomena and the polar cap boundary or open-closed field line boundary (OCB) are also of great importance to fully understand energy transportation and interaction between the solar wind and magnetosphere. Factors controlling the occurrence rate and luminosity of polar cap airglow patches observed by an optical instrument near the geomagnetic pole are investigated in terms of UT and IMF By dependence in conjunction with SuperDARN data (Hosokawa et al., 2021). An improved method to estimate OCB locations using SuperDARN convection flow data is proposed (Hoque et al., 2021).

The Dome C East and North (DCE and DCN) radars have recently begun operating near the southern geomagnetic pole with fields-of-view covering the pole down to auroral latitudes as part of PolarDARN (high latitude SuperDARN). Echo occurrence rates for the radars are studied with an ionospheric electron density model and ray tracing simulation to understand the high variability observed with season and to show their large potential for understanding magnetospheric dynamics (Marcucci et al., 2021).

SuperDARN enables us to monitor geomagnetic pulsation activities which are key to understanding the characteristics and dynamics of the plasma medium and various plasma instabilities which provide essential information on energy transportation and conversion in geospace. Research on storm-time compressional Pc5 waves showing the drift compressional mode observed with the mid-latitude SuperDARN-type Ekaterinburg (EKB) radar is reviewed in detail (Chelpanov and Mager, 2021).

Studies on the interaction between the ionised and neutral atmosphere have revealed the importance of understanding vertical coupling in the upper atmosphere, the impact of interplanetary and geospace phenomena on the lower atmosphere, and their possible influence on global climate changes. Medium-scale travelling ionospheric disturbances (MSTIDs) are one phenomenon that facilitates such an interaction, as they are thought to play an important role in energy coupling between high and low altitudes as well as between polar and lower latitudes. MSTIDs observed by the Antarctic SANAE (SAN) and Halley (HAL) SuperDARN radars under quiet geomagnetic conditions are studied to investigate their generation mechanism and energy dissipation (Atilaw et al., 2021). The direct collisions between thermospheric neutral particles and convecting ionospheric ions, that result as ion-drag and Joule heating due to friction, cause energy from the solar wind to be deposited into the Earth's atmosphere. Auroral arcs and sub-auroral polarization streams (SAPS) also modify neutral winds. Recent relevant studies using SuperDARN, and future research directions, are also reviewed and discussed (Billet and McWilliams, 2021).

Apart from these scientific achievements introduced above, related technical progress has also been made. Yan et al. (2021) demonstrate a digital beam forming technique using the Jiamusi East AgileDARN radar in China to obtain a higher spatial resolution of SuperDARN data. Nishitani et al. (2021) describe the development and initial results of a remote HF wave receiver located in the backlobe of the Hokkaido East (HOK) radar and used to monitor the ionospheric environment and its variation to supplement SuperDARN observations.

SuperDARN radars were originally designed to obtain global physical parameters or spectral properties across their large fields-of-view, particularly in the F-region ionosphere. However, near range echoes backscattered at much lower altitudes have recently been recognized as having abundant information on a wide range of scientific themes as well, since they include E and D region ionospheric echoes, meteor echoes providing neutral wind velocities, and even possibly new types of echoes which are unknown. To estimate height and geolocation information from such echoes properly, interferometer measurements need to be calibrated more adequately. Therefore, the SuperDARN community launched a new task force and made considerable efforts to improve this capability of SuperDARN. Chisham et al. (2021) summarise their efforts, comparisons of different calibration methods and recommendations for data users and radar operators. This paper is a particularly crucial step for future SuperDARN research and should be seen as one of the major technical achievements for the whole SuperDARN community. Berngardt et al. (2021) also describe a new method and its results to calibrate their EKB radar using meteor echoes in a different manner.

Finally, to commemorate a quarter century since the establishment of SuperDARN in 1995, as well as the third SuperDARN workshop held in Japan, the history of the Japanese SuperDARN project, specifically focusing on the initiation stage of SENSU Syowa radars, and progress of the Japanese contribution to the SuperDARN project since the beginning of SuperDARN in 1995, are reviewed (Sato et al., 2021).

We believe that these valuable papers published in this special issue will contribute to the further development of SuperDARN research, geospace sciences and relevant technology.

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