Opportunities for the joint analysis of Swarm and SuperDARN measurements of ionospheric electric fields

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SuperDARN: Super Dual Auroral Radar Network
SuperDARN: New NERC funded radar in the Falklands
HF propagation modes and backscatter regions

- Coherent scatter (Bragg scatter) from field-aligned irregularities
- Radar wave vector must be orthogonal to the magnetic field
- HF rays refract in the ionosphere and thus achieve orthogonality at F-region heights even at high latitudes

Backscatter can be received:
- from both the E and F regions
- from the ground, via oblique reflection from the ionosphere (groundscatter)
- from far ranges, via multiple hop paths (ionosphere-ground-ionosphere)
SuperDARN measured parameters

The radar transmits a seven pulse multipulse sequence from which a 17 lag complex autocorrelation function (ACF) of the returned signal is obtained. The FFT of the ACF gives the Doppler spectrum.

Villain et al., 1996

Real and imaginary part of an ACF

Doppler spectrum from FFT of the ACF
SuperDARN measured parameters

Field-of-view
16 beams of 75 - 120 range gates, 15 - 45 km
gate length, max. range ~ 3500 km, area ~5×10^6 km^2
~3 - 7 s beam scan time giving 1 - 2 min full scan time

Advantages
Large area covered; high time resolution

Disadvantages
Line-of-sight velocity only; backscatter not ubiquitous
Range Spatial Resolution

In its standard mode a SuperDARN radar operates with 45 km range gates.

In myopic mode it operates with 15 km range gates giving a smaller overall field-of-view but higher spatial resolution.
**Time series analysis**

Range Time Velocity: The time variability of velocity measurements within a single beam can be inspected
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**Range gate velocity profile:** A time series of the velocity measured at a single location can also be extracted.
High Temporal Resolution

For a standard 1 min scan each of the 16 beams have a dwell time of 3 s.
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If the radar is ‘stereo’ then one channel can camp on a single beam whilst the other performs a full scan, resulting in data such as this.
The SuperDARN "map-potential" technique
(Ruohoniemi and Baker, 1998)

Developed by APL

Combine sparse I-o-s velocities to give estimate
of instantaneous, global
potential pattern
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Combine sparse l-o-s velocities to give estimate of instantaneous, global potential pattern

15:05:00 - 15:06:00 UT
21 Jan 2001
12 MLT
00 MLT

University of Leicester
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APL MODE
6<BT<12
Bz-/By-
Based on a technique used to determine ionospheric equivalent currents from ground magnetometer data (Amm and Viljanen, 1999)

Involves fitting to a series of local 'poles', the locations of which can be placed freely such that they are most suitable with respect to the density of the measurements

Results in more local detail as well as better preserving the l-o-s velocity magnitudes than the global fitting technique
Joint space- and ground-based studies

SuperDARN velocity data can be used to relate in-situ magnetospheric observations to the macro-scale and global-scale convection

By mapping down the magnetic field magnetospheric observations can be directly compared with ionospheric observations
SuperDARN comparison with DMSP drift vector measurements

SuperDARN Map Potential convection patterns with DMSP overpasses showing the cross track ion drift overlaid

DMSP reveals flow structure on smaller spatial scales than SuperDARN, but the radars provides the global context not evident in the spacecraft data

SuperDARN map is 2 min snapshot, DMSP track covers ~20 mins

DMSP altitude is ~900 km vs. ~250 km for SuperDARN scatter
SuperDARN comparison with DMSP drift vector measurements

SuperDARN l-o-s velocity versus DMSP cross-track ion drift

Best fit suggests that DMSP measures slightly higher velocities

Overall correlation is very good (R=0.92)

Discrepancies may be caused by differences in the spatial / temporal ambiguity in measurements made by moving spacecraft - Swarm may overcome this

Gillies et al., 2009
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Gillies et al., 2009
SuperDARN gives us:

- The ability to image the global convection pattern allowing remote sensing of the state and dynamics of the magnetosphere and magnetotail, in real time
- A means to validate electric field variations over the lower part of the spatial and temporal frequency spectrum, including on the spacecraft separation scale of 150 km
- The ability to distinguish between spatial variations in the field at a given time, and temporal variations at a given location

For a more comprehensive review of SuperDARN results and capabilities see the recent review paper by Chisham et al. in Surveys in Geophysics (2007).
The Future of SuperDARN

**StormDARN**
For studying radiation belt physics and active times when the polar cap has expanded to lower latitudes.

**PolarDARN**
Overlooking the geomagnetic pole, filling in a pre-existing gap and enabling the dynamics of the polar cap to be better understood.

**SiberDARN**
Four new radars in Siberia to complete northern hemisphere coverage and provide fully global monitoring.