Near Real-Time Monitoring of HF Propagation with SuperDARN Radars

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Abstract

The Super Dual Auroral Radar Network (SuperDARN) operates on High Frequency (HF) to benefit from refraction in the ionosphere to illuminate plasma irregularities in the F-layer. The motion of these irregularities are observed to create convection maps of the ionosphere that indicate space weather conditions. A by-product of regular operations is information on HF propagation conditions which are useful for establishing communications links. As part of a previous project, we analyzed the impact of solar flares on the dayside ionosphere as seen by SuperDARN radars in ShortWave Fadeout (SWF) events. We have developed a prototype of a system to alert HF users to the occurrence of SWF in the North American sector in near real-time. There are technical challenges with maintaining links to radars in remote locations, but reliability could be improved if needed. In addition to regular operations, some radars have been upgraded with more modern software-defined radios which enable more complex waveforms and digital signal processing (DSP) to be performed with the radars. One recent study is using phase-code modulation on the transmit waveform to reduce the range resolution from 45 km to 6km over the 3500 to 4500 km range of our radars. In this presentation we review the capabilities of the near real-time monitoring of HF propagation in a beneficial way to space weather operations and how it relates to the security domain.

SuperDARN Observations

- ❑ Mid-latitude radars observe steady ground scatter band through daylight hours.
- ❑ Intense solar flares interrupt daytime groundscatter in two characteristic ways:
- ❑ 1) Absorption effect leading to ShortWave Fadeout (SWF)
- ❑ 2) Sudden Frequency Deviation – quick appearance of Doppler shift in place of groundscatter

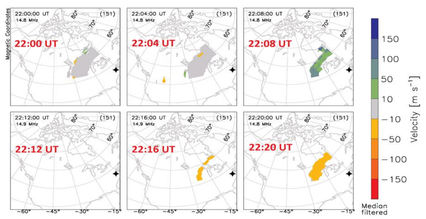


Figure 1 Solar flare impacts seen from Blackstone, VA radar on-set at 22:08 UT, then SWF at 22:12 UT, and slow recovery of groundscatter band between 22:16 and 22:20 UT.

SuperDARN Coverage

- ❑ SuperDARN radars operate on HF frequencies between 8 and 18 MHz from mid-latitudes to the polar cap on a 24/7 basis with a large coverage over the Northern hemisphere.

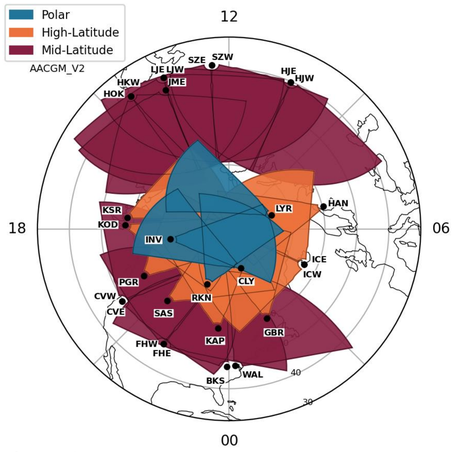


Figure 2 Northern hemisphere field-of-view coverage of SuperDARN radars with the polar cap radars in blue, high-latitude radar in orange, and mid-latitude radars in maroon.

- ❑ Virginia Tech operates five radars across four sites: Blackstone (BKS), Fort Hays East (FHE), Fort Hays West (FHW), Goose Bay (GBR) and Kapuskasing (KAP)
- ❑ Blackstone electronics upgraded with software defined radios (SDRs) prior to the 2024 Great American Eclipse.
- ❑ Recent updates to software have enabled 15km to 6km range resolution operating modes (Figure 3).
- ❑ Near real-time streaming of data from radar sites enables monitoring ionospheric conditions and HF propagation and impacts from shortwave fadeouts.

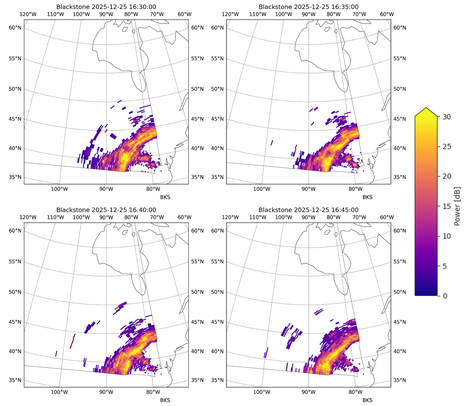


Figure 3 Blackstone field-of-view plots in 5-minute increments with 15 km range resolution over 3500 km of range. Changes in power(SNR) intensity represent changes in propagation paths during dayside ionospheric conditions

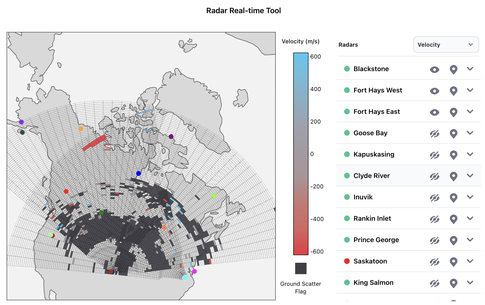


Figure 4 Near real-time monitoring on VT SuperDARN website with green circles indicating connected radars. Fields-of-view for three radars (Blackstone, Fort Hays East, and Fort Hays West) are shown.

Near Real Time Data

- ❑ Near real-time capabilities of SuperDARN radars rely largely on network connectivity and effort to process/display data.
- ❑ Links to the radars provide data for displaying HF propagation conditions in the D-, E-, and F-layers during daytime operations.
- ❑ The fields-of-view are updated every minute and new beam data updated every three seconds.
- ❑ Typically, the data is recorded with 45km range resolution.
- ❑ Higher resolution data can be available with Blackstone, other radars running SDRs

Data Available	
Power (SNR)	Doppler Velocity
Elevation Angle	Spectral Width
TX Frequency	Sky Noise (relative)
Range Separation	Timestamp of Record

- ❑ Classify radar returns by ionospheric or ground- scatter based on velocity

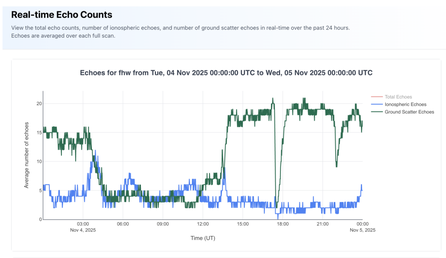
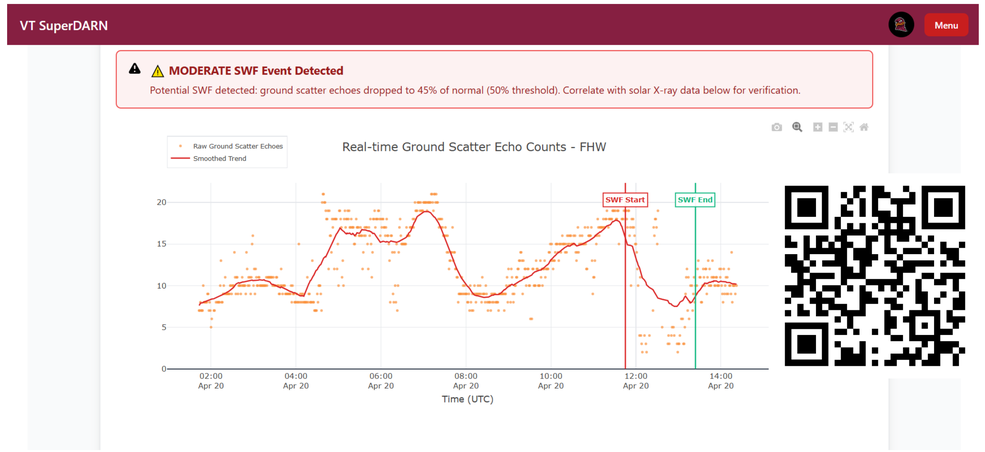


Figure 5 Blackstone field-of-view plots in 5-minute increments with 15 km range resolution over 3500 km of range. Changes in power(SNR) intensity represent changes in propagation paths during dayside ionospheric conditions



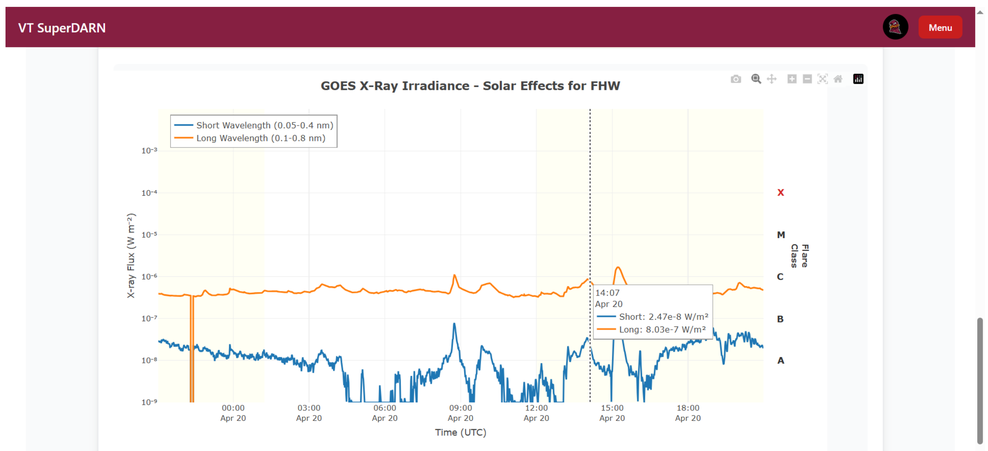


Figure 6 The real-time version of the Shortwave Fadeout Monitoring on the Virginia Tech SuperDARN website. The QR code provides a link to the monitoring page which features an archival section as well as a real-time display of data. The top part of the real-time display shows the average number of groundscatter echoes across the field-of-view for each minute with the solid line. The top figure also displays possible shortwave fadeout events. The bottom display shows the GOES X-Ray Irradiance data to monitor solar flares.

SWF Monitor

- ❑ The archival section of the Shortwave Monitor page on the Virginia Tech SuperDARN site displays color coded information as calendar view for past solar flare and SWF events.
- ❑ Days with solar flare activity show raw data collected from the real time streams from some radars. This plot tries to give an initial time marking for the SWF onset, blackout start and end, and recovery.
- ❑ Archival solar flare event also shows GOES X-ray measurements and X-Ray/RAP Absorption Map.
- ❑ Real-time SWF display shoes the raw data and average trend of groundscatter echoes for individual radars (so far just 4 out of the more than 35 in the network) as seen in Figure 6.

Future Development

- ❑ Updating real-time field-of-view display to properly display finer range resolution data that is being experimented with at Blackstone radar.
- ❑ Subsequently updates to shortwave fadeout monitor to account for increased number of echoes.
- ❑ Expand real-time data connections to more radars on the SuperDARN network.
- ❑ Expand shortwave fadeout monitor to ingest more radars
- ❑ Iterate design threshold on shortwave fadeout automated detection
- ❑ Develop typical groundscatter locations per radar per transmit frequency as a field-of-view plot to detect anomalous operations due to changes in HF propagation (and space weather conditions).

SuperDARN HF Radar Lab at Virginia Tech

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