Toward Scatter Classification at Middle Latitudes

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SuperDARN Network

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013000 UT 01 May 2011

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Miller, et al

SuperDARN 2011 — Mid-Latitude Scatter
Mid-Latitude SuperDARN

- Installed to observe expansion of convection pattern equatorward of traditional SuperDARN boundaries.
  - This happens with some regularity, but quiet conditions prevail.
- What is observed during quiet time?
- Signal to one is noise to another.
  - $\text{scatter} \in \{\text{ionospheric, ground}\}$ does not describe mid-latitude variability accurately.
  - $\text{scatter} \in \{\text{ionospheric, ground}\}$ algorithm does not describe mid-latitude $\text{physics}$ accurately.
- Consider first climatological behavior.
2009 Wallops Island SuperDARN beam #7 backscatter power > 10 dB Climatology
Sub-Auroral Trough
Irregularities in the sub-auroral trough produce significant backscatter on many nights. (See Talaat, et al, poster.)

Meteor Echoes
Ablating meteors deposit trails of metallic ions in the E region. Sporadic-E layers also contribute to this prevalence.

Ground Scatter
Echoes returned off of the land or sea.
Propagation Mechanisms

Refraction
Propagation Mechanisms

Refraction

Field-Aligned Irregularities (FAI)
Propagation Mechanisms

- Refraction
- Field-Aligned Irregularities (FAI)
- Specular Reflection
- Density Structure
Meteor Scatter

- Essentially all SuperDARN meteor scatter is *specular*.
  - FAI typically observed by powerful IS-class radars.
- Meteor trails have short lifetimes (∼100 ms).
- Individual trails usually only appear in one range gate in space and time.
- Ensemble of many trails yields “cloud” of scatter at close ranges.
Sporadic-\(E\)

- Thin, dense, turbulent layer of metallic ions at \(E\)-region altitudes.
- Specular echoes, FAI, ground scatter, all possibilities.
- Separating specular echoes from FAI?

Raytracing

- Need not be complicated to be informative.
  - Parabolic or Chapman profiles driven by standard URSI coefficients. Or interpolate other datasets, use IRI (called directly from MATLAB).
  - Geomagnetic field (IGRF is easy in MATLAB).
  - Basic Appleton-Hartree magneto-ionic effects.
  - Loosely based on Jones-Stephenson code, but only for 2.5D.

- Find ground scatter location.
- Find $k \perp B \rightarrow$ possible FAI location.
- Drive with Millstone Hill Digisonde.
- Wallops beam #7 passes directly over Millstone.
Wallops Predictions
• Convert pretty (but useless) 3D plot to Virtual Range vs altitude.
Scatter Geolocation Tool

- Triple-hop sporadic-$E$ (G-$E_s$) ground scatter 0000–0045 UT.
- Field-aligned irregularity (FAI) scatter from locations where $\mathbf{k} \perp \mathbf{B}$.
- Differentiate between FAI-$F$ and G-$E_s$ using Doppler velocity.

![Scatter Geolocation Tool Diagram]

15 May 2010 - Wallops Island SuperDARN beam #7 - 10.5 MHz

F ground scatter
Es ground scatter
F FAI scatter
E FAI scatter

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Discussion

• Mid-latitudes exhibit new and subtle sources of SuperDARN scatter.
  • Non-auroral FAI.
  • Sporadic-\textit{E}.

• Raytracing and phenomenology provide some guidance.
  • Not operational, but good for case studies.
  • Interferometer elevation can also help (not active at Wallops presently).
  • Raytracing in inhomogeneous ionosphere for irregularity studies.