Sources and Characteristics of Medium Scale Traveling Ionospheric Disturbances Observed by SuperDARN Radars Across North America

N.A. Frissell1, J.B.H. Baker2, J.M. Ruohoniemi3, R.A. Greenwald4, A.J. Gerrard5, E.S. Miller5, and M.L. West4

1Virginia Tech 2New Jersey Institute of Technology 3Johns Hopkins Applied Physics Laboratory 4Montclair State University

Contact: nafrissell@vt.edu

Introduction

- Medium Scale Traveling Ionospheric Disturbances (MSTIDs) are wave-like perturbations of the F-region ionosphere with horizontal wavelengths on the order of 100-250 km and periods between ~15–60 min (e.g., Ogawa et al., 1987).
- Daytime MSTIDs associated with Atmospheric Gravity Waves (AGWs) can provide important dynamical coupling as they can transfer energy and momentum from one region of the atmosphere to another [Rines, 1960; Fritts and Alexander, 2003; Alexander et al., 2010].
- The Super Dual Auroral Radar Network (SuperDARN) is an international network of high frequency (HF) radars which can detect MSTIDs. Many previous SuperDARN studies point primarily to auroral/space weather generated sources for both mid and high latitude MSTIDs, in spite of weak correlations with space weather phenomena. This assertion is primarily based on the predominant observed southward direction of travel as well as theories of AGW production and propagation [Francis, 1974; Samson et al., 1989, 1990; Bristow et al., 1994; Ishida et al., 2008; Gracott et al., 2013; Frissell et al., 2014].

Study Parameters

- 10 North American Radars
- 1 Nov – 30 Apr 2011-2015
- 06 – 18 SLT (Daytime MSTIDs)
- 2-hour Sampling Windows
- Boxcar Median Filter
- 15 – 60 min Filter
- Lρo = 750 km

MSTID Occurrence

- All North American radars, both at mid and high latitudes, observe the same large-scale MSTID activity.
- Activity is elevated starting in November and decreases beginning in February.
- Distinct periods of enhanced or decreased MSTID activity may last multiple weeks at a time.
- These time and spatial scales are suggestive of polar tropospheric sources rather than space weather drivers.

MSTID Connection?

- It has long been thought that space weather activity launches the AGWs that generate daytime MSTIDs. However, SuperDARN MSTID observations correlate poorly with typical space environment parameters. These two case examples highlight the poor correlation with OMNI data.

Geomagnetic Connection?

- Four seasons (November – April) of North American daytime SuperDARN MSTID observations were analyzed using a fully automated technique.
- MSTID propagation is dominantly southward.
- MSTID activity is enhanced in November–February and reduced from February – April.
- Collective MSTID behavior is seen across all radars at both high and midlatitudes.
- Periods of MSTID enhancements or reductions can last weeks at a time.
- MSTIDs across radars may be collectively perturbed eastward or westward.
- Observed MSTIDs are poorly correlated with space weather/auroral activity.

Conclusions

- Good correlations with polar geopotential data and dominant southward propagation suggest winds associated with the polar vortex generate and/or control the atmospheric gravity waves that generate the majority of SuperDARN observed daytime MSTIDs.

References and Acknowledgments


Instrumentation and Method

SuperDARN radars sense daytime MSTIDs by observing ground backscatter power variations caused by a focusing and defocusing of radar rays resulting from MSTID-generated ionospheric electron density perturbations [Samson et al., 1989, 1990]. This figure shows a ray trace of the Blackstone SuperDARN radar through an International Reference Ionosphere (IRI) run perturbed by a simple sinusoidal function [de Larquier et al., 2013; Bilitza et al., 2014].

- A fully automated algorithm bins sampling windows as MSTID, Quiet, or Discard based on amount of ground scatter and spectral power in the 15-60 min band.
- The MUSIC (Multiple Signal Classification) algorithm provides estimates of MSTID direction and horizontal wavelength using cross-spectral analysis from signals observed by an array of sensors [Schmidt, 1986; Samson, 1990].

MSTID Characteristics

- All North American radars show similar MSTID characteristics consistent with previous MSTID studies.
- The dominant southward propagation direction observed in both high and mid latitude radars suggests a polar source.

Polar Vortex

- SuperDARN data is compared to geopotential data from the European Center for Medium-range Weather Forecasting (ECMWF) Global Surface and Upper Air Analyses.
- Enhanced MSTID activity occurs when the polar vortex is in its nominal position and well defined at the 1 and 10 mbar levels.
- Decreased activity occurs when the polar vortex loses coherence at 1 and 10 mbar levels.
- Radars collectively see periods of East-West perturbation in MSTID direction. These observations suggest the polar vortex winds are responsible for the generation or control of the majority of SuperDARN observed MSTIDs at both high and mid latitudes.