Velocity of E region SuperDARN echoes and ExB plasma drift

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November 23, 2022

Abstract

Rankin Inlet (RKN) SuperDARN radar observations simultaneously with the Resolute Bay Incoherent scatter radar in nearly coinciding beams are considered to investigate the relationship between the velocity of HF echoes and ExB plasma drift component along the RKN beam. We focus on a case of observations roughly along the flow direction on 6 March 2016. We show that, depending on HF operating frequency, the RKN radar detects either E or F region echoes. For the E region echoes and fast flows of 700-1000 m/s, HF velocities are of two types: very slow with speeds below 100 m/s and fast with speeds up to 400 m/s. Velocities of slow echoes can be of opposite polarity at 10 and 12 MHz and not coincide with the ExB drift polarity. Velocities of fast echoes are somewhat larger at 12 MHz as compared to 10 MHz and both are less than the expected ion-acoustic speed of plasma at typical electrojet heights. No strong range (presumably, aspect angle) attenuation effect is noticed in the range profiles of such echoes. We relate the first type of echoes to the neutral wind turbulence while the second type – to the Farley-Buneman (FB) plasma instability processes. Periods have been noticed when E region echoes had speeds of ˜ 200 m/s which is well below the ion-acoustic speed and ExB drift component. We hypothesize that these echoes are owing to FB irregularities generated at low electrojet heights. The observations show existence of extended periods when the RKN radar detects F region echoes at 10 MHz and E region echoes at 12 MHz at the same ranges implying that the "transition region/ranges" for E and F region detection is very sensitive to the observational conditions.

SA11C-2755

Abstract ID: 414738

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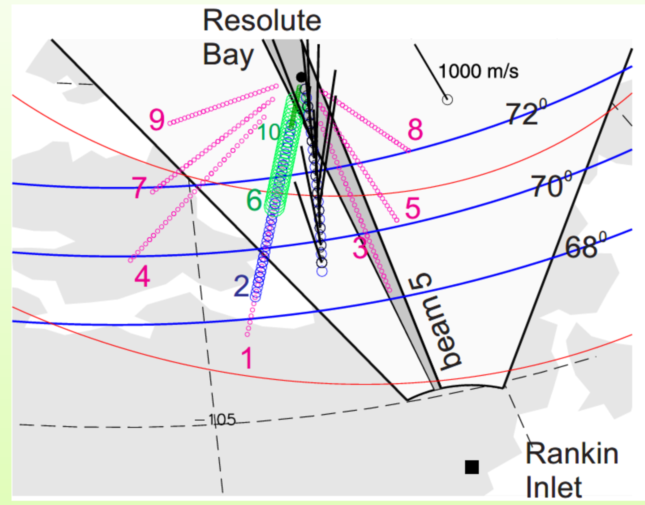
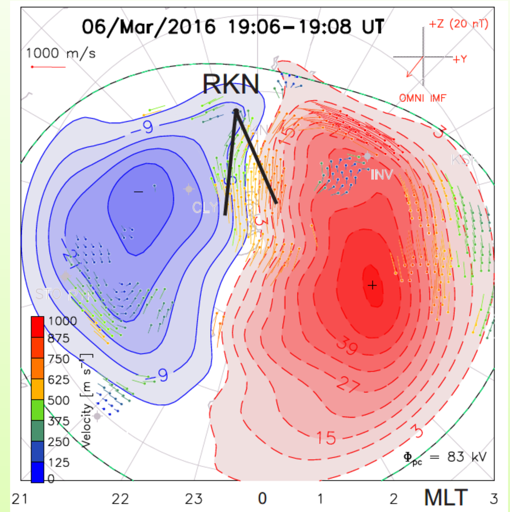
Rankin Inlet (RKN) SuperDARN radar observations simultaneously with the Resolute Bay Incoherent scatter radar in nearly coinciding beams are considered to investigate the relationship between the velocity of HF echoes and ExB plasma drift component along the RKN beam. We focus on a case of observations roughly along the flow direction on 6 March 2016. We show that, depending on HF operating frequency, the RKN radar detects either E or F region echoes. For the E region echoes and fast flows of 700-1000 m/s, HF velocities are of two types: very slow with speeds below 100 m/s and fast with speeds up to 400 m/s. Velocities of fast echoes are somewhat larger at 12 MHz as compared to 10 MHz and both are less than the expected ion-acoustic speed of plasma at typical electrojet heights. We relate the first type of echoes to the neutral wind turbulence while the second type – to the Farley-Buneman (FB) plasma instability processes. The observations show existence of extended periods when the RKN radar detects F region echoes at 10 MHz and E region echoes at 12 MHz at the same ranges implying that the "transition region/ranges" for E and F region detection is very sensitive to the observational conditions.

1

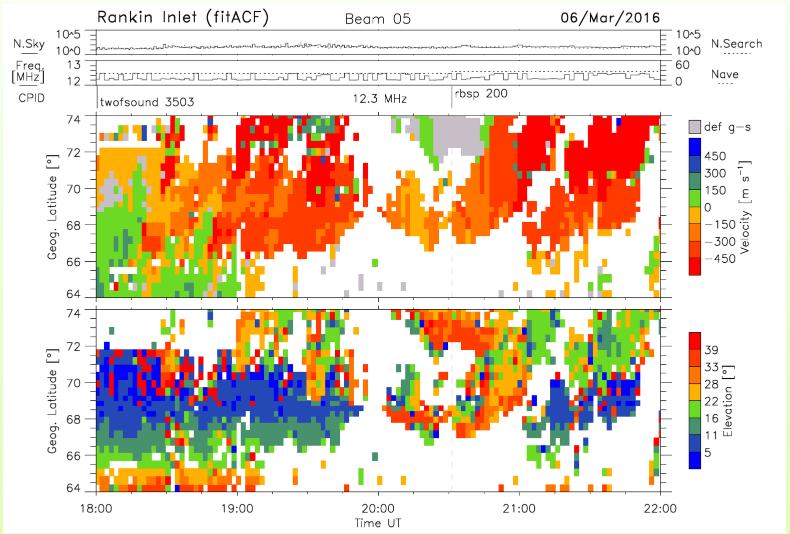
FoVs of the Rankin Inlet HF radar and Resolute Bay ISR



Typical flow pattern



Rankin Inlet HF data

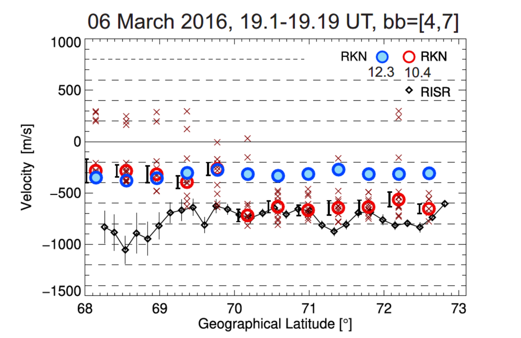


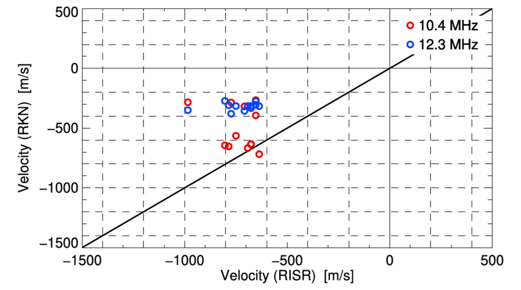
We consider the event of 06 March 2016, for which RISR-C velocities were very consistent across the latitudes, the flow (according to SuperDARN) was uniform and predominantly poleward (IMF Bz <0 conditions).

The RKN radar was observing postnoon echoes roughly along the ExB flow. Elevation angles indicate that the echoes were mostly coming from the E region. Their velocities were often fairly large, above 300 m/s.

2

Example of RKN and RISR velocity measuremrnts along the same direction



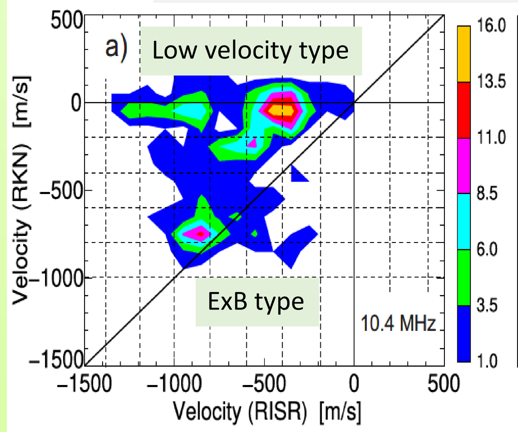


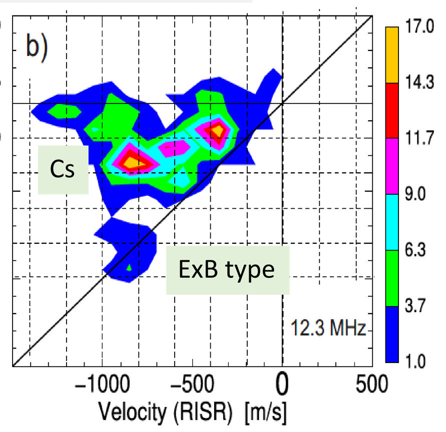
At low geographic latitudes (GLATs), 10 and 12 MHz velocities are close to each other, at ~ 300 m/s, and well below the ExB component.

The 12 MHz velocity is about the same at all latitudes. The 10 MHz velocity magnitude jumps up at GLAT~70⁰. At these latitudes, the radar detects echoes from the F region and measures the ExB drift component.

Scatter plot shows two clusters of points, Cs type and ExB type (the red-coloured cloud of points)

Statistics for all data

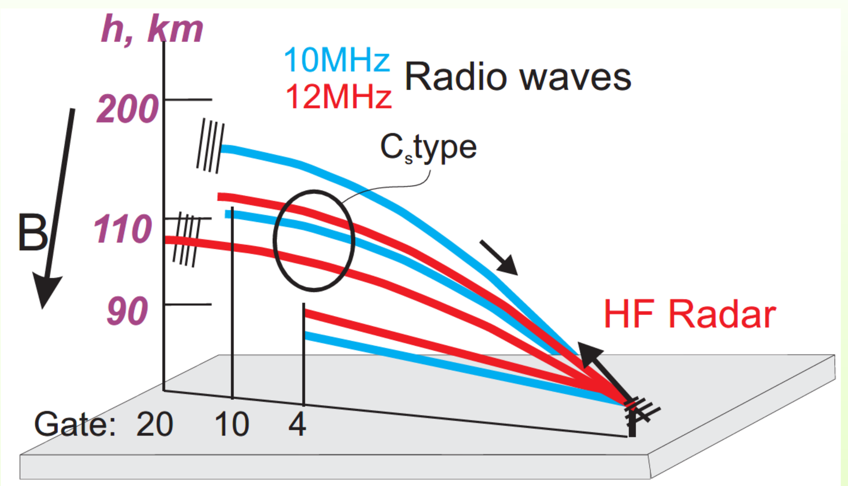




3 clusters of points: low velocities at any ExB (echoes from the bottom of the E layer), high velocities close to ExB (echoes from above the E layer) and intermediate velocities in between -400 and – 200 m/s (Cs type, from electrojet heights).

3

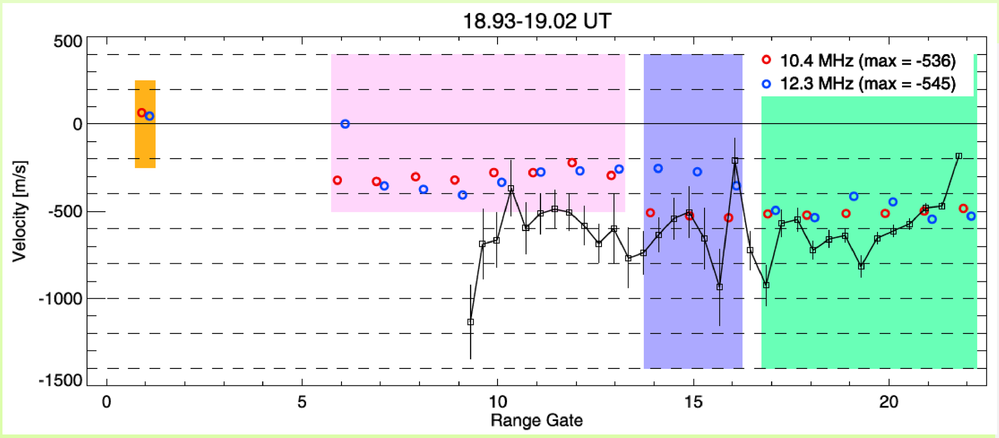
Possible propagation modes of SuperDARN radio waves at 10 and 12 MHz



Depending on the density distribution in the ionosphere and radar operating frequency, HF echoes can be received from the bottom of the E layer, its central part, its top part or even F region.

It is expected that, generally, 10 MHz echoes would come from lower heights as compared to 12 MHz echoes owing to stronger refraction. However, 10 MHz radio waves can occasionally penetrate deeper into the ionosphere causing F region echoes.

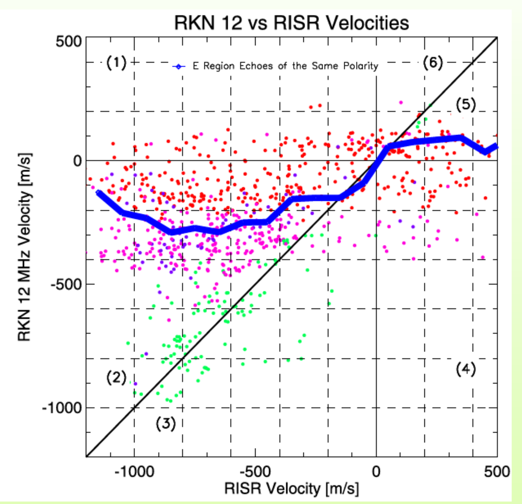
Echo classification scheme along HF range profile

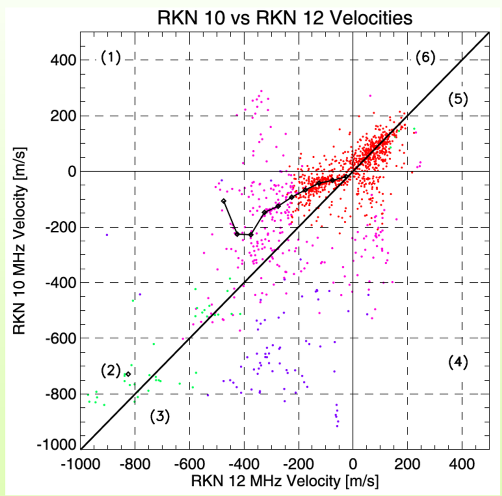


1. Low velocities at both frequencies < 200 m/s, any gate
2. Comparable velocities in the range of 200-500 m/s, gates 8-15 – Cs type
3. Large velocity at one frequency and low velocity at the other frequency, gates 8-15, Cs type
4. Both velocities are large and comparable to ExB, gates >10, ExB type

4

RKN-RISR velocity comparison (with echo types)

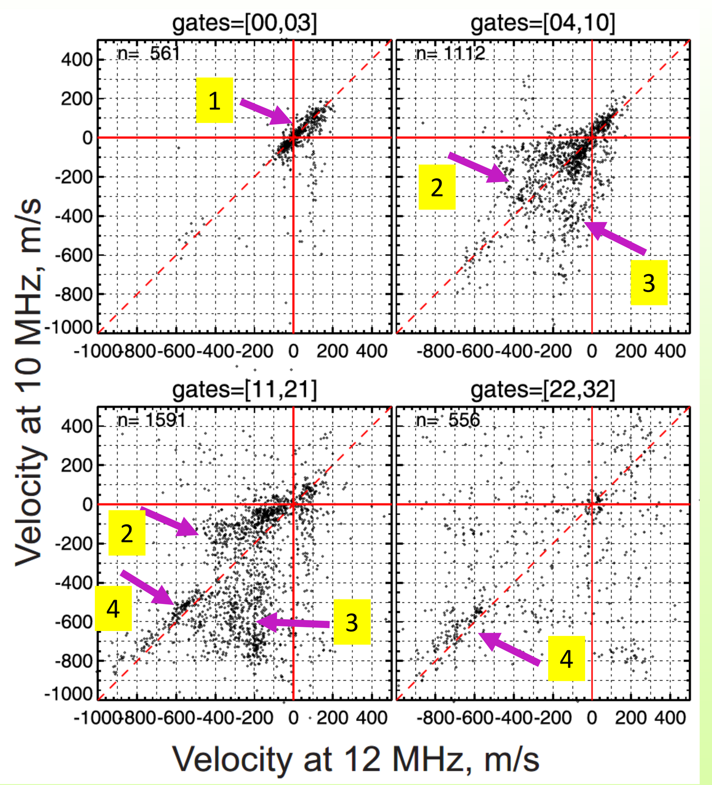




Identified features: 1) HF Velocity can be low (<200m/s) even for ExB = 800-1000 m/s **2)** Cs type HF velocities tend to cluster around 200 and 300 m/s **3)** For Cs type HF echoes, velocity at 10 MHz < velocity at 12 MHz **4)** Cases of 12 MHz at ExB and 10 MHz at Cs or below are rare **5)** Occasionally, Cs type echoes present up to gate 20

5

10-12 MHz velocity comparison for three separate events



1. At short ranges, velocities are low and Vel_10~Vel_12.

2. At nominal E region ranges, 150-650 km, Vel_10 < Vel_12.

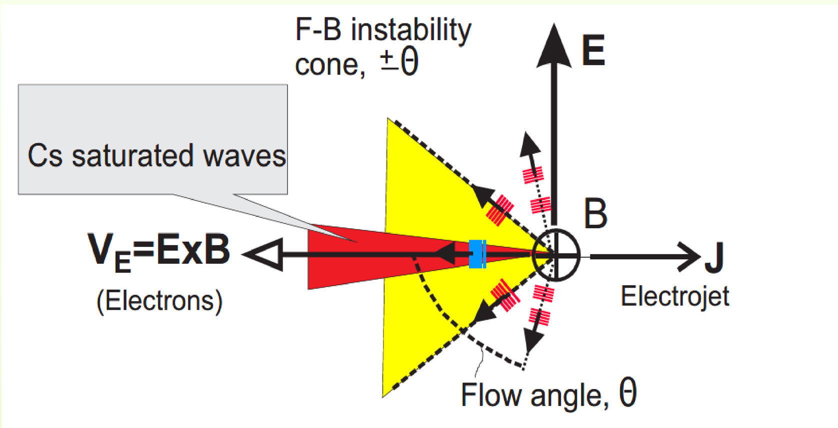
3. In the transition region, ranges 650-100 km, Vel_10 is often well above Vel-12 implying that 10 MHz echoes are from the F region. Vel_12 is below nominal Cs. Occasionally, vel_10 is below vel_12 while 12 MHz velocity magnitudes are below 200 m/s.

4. At ranges > 1200 km, Vel_10=vel_12 and both are presumably the ExB component

6

Interpretation: Reasons for HF velocity to be below Cs

1) Bahcivan et al. (2005) model

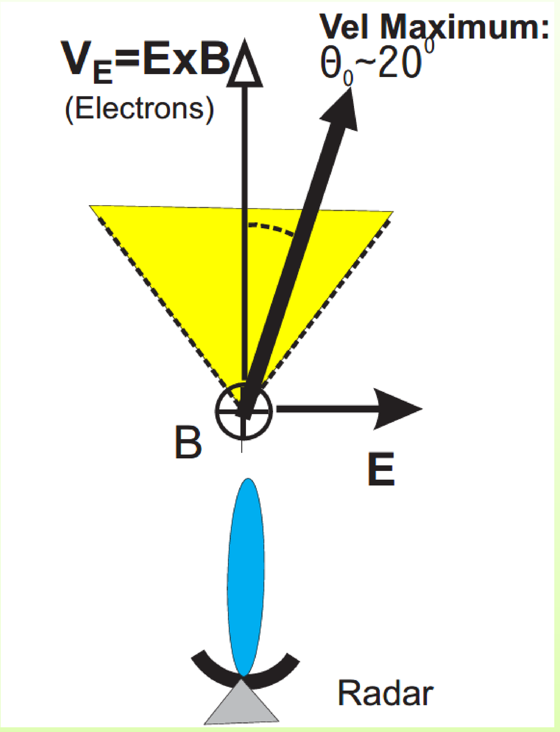


Cs saturated FB waves along ExB $V_{ph} = C_S$

All other directions: $V_{ph} = C_S\cos\theta$

3) Since heights of 10 MHz echoes are below those at 12 MHz, the 10 MHz velocity is expected to be smaller

2) Gorin et al. (2012) results



In our event, look angle deviations from the ExB direction and the expected maximum of FB velocity were up to 45 deg. This explains Vel<Cs

7

Conclusions

1.We observed short-range high- and low-velocity HF echoes at large ExB drifts of > 500-1000 m/s

2. Low velocity echoes had no visible relationship to ExB, observed at short and far ranges. The velocity magnitudes were often somewhat smaller at 10 MHz. These echoes are very likely owing to irregularities produced by wind-driven plasma instabilities

3. High velocity echoes had magnitudes of ~ 300 m/s which is BELOW the nominal Cs of 400 m/s. Such echoes existed at many ranges simultaneously, their velocities can be explained by $\mathbf{Vel = C_S \cos(\theta)}$ although observations were sometimes "almost" along the ExB

4. HF echoes were occasionally from the E region at far ranges of ~ 800-1000 km, in agreement with Davies et al. (1999). HF echoes were occasionally from the F region at short ranges of ~600 km. The range boundary separating E and F region SuperDARN echoes is VERY unsettled. Occurrence of far-range E region echoes implies effectively "underestimation" of the ExB drift which affects quality of SuperDARN convection mapping

References

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Acknowledgement

We acknowledge NSERC, CFI and CSA (all Canada) and NSF (USA) funding of the instruments involved in this project.