IMF Influence on Nightside Quiet Time Subauroral Ionospheric Convection Observed by the North American Midlatitude SuperDARN Radars

M. Maimaiti [1], J. M. Ruohoniemi [1], J. B. H. Baker [1]

1: Department of Electrical and Computer Engineering, Virginia Tech, Blacksburg, VA, USA

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Abstract

Recent studies suggest that, in addition to the neutral wind, penetration of high latitude convection electric field can also significantly influence the subauroral convection under even quiet conditions. In this study we have used six years of quiet-time nightside data from six midlatitude SuperDARN radars in the U.S. continent to characterize the subauroral convection in terms of magnetic latitude (MLAT), local time (MLT), and IMF clock angle. Our results show that, compared to northward IMF Bz conditions, westward subauroral convection under southward IMF is significantly enhanced in the premidnight sector and is weakened in the postmidnight sector (even turned eastward near dawn at higher subauroral latitudes), consistent with the expected signature of electric fields penetrating from high latitudes. The effects of IMF By are not as strong as IMF Bz, and duration of stable IMF are found to be rather insignificant. In this study, we characterize the morphology of the subauroral convection pattern under various IMF conditions and discuss the results in terms of Ionosphere-Magnetosphere coupling and the penetration of electric fields to the nightside subauroral ionosphere.

Introduction

- Mid-latitude SuperDARN radars frequently observe subauroral ionospheric backscatters (SAIS) with low Doppler velocities on most geomagnetically quiet nights *[Greenwald et al. 2006; Ribeiro et al., 2012]*. Figure 1 shows one of such low velocity plasma motions in a typical geomagnetically quiet night.
- The Fields of view of the six mid-latitude SuperDARN radars are shown in Figure 2 in AACGM coordinates.

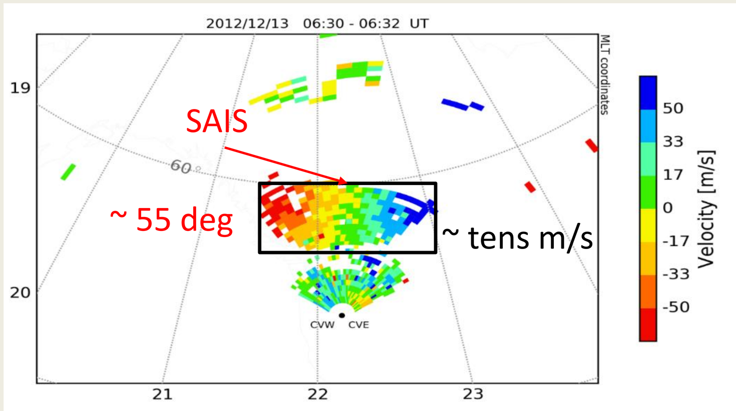

Figure 1: Two-minute scan plot of line-of-sight velocities observed by Christmas Valley West and Christmas Valley East (Oregon) radars at 6:30-6:32 on December 13, 2012. (the positive velocities indicate motion towards the radar.)

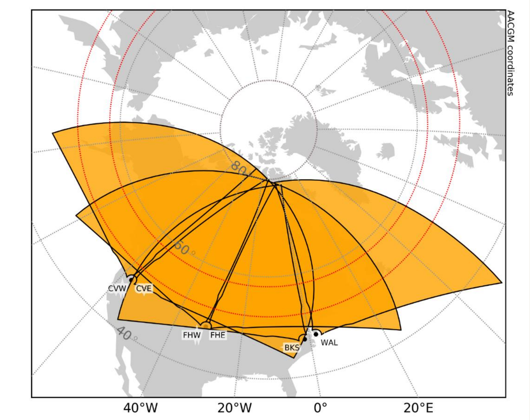

Figure 2: Fields of view of the six North American mid-latitude SuperDARN radars in AACGM coordinates. From west to east the radars are: Christmas Valley West, Christmas Valley East (Oregon), Fort Hays West, Fort Hays East (Kansas), Blackstone, and Wallops Island (Virginia). The regions of interest lie between 52° - 58° magnetic latitudes indicated by the two red circles.

Model Derivation

- Figure 3 shows an overview of data processing procedures. Six years (2011-2016) of Line-of-sight (LOS) velocities from the six radars are binned into LOS azimuthal bins. A 2D flow vector is calculated by fitting a cosine curve to LOS velocities vs azimuth.

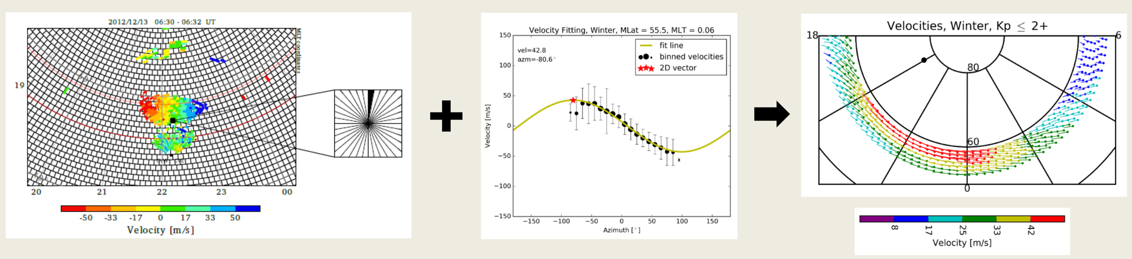

Figure 3: An overview of data processing procedures. (a) Line-of-sight velocities overplayed on MLAT-MLT grid cells. The inset is an expanded view of the 10 degrees azimuth bins within each grid cell. (b) An example cosine fit to the line-of-sight velocities collected in azimuth bins within a single MLAT/MLT grid cell. (c) 2-D convection vectors derived for winter. *[Figure from Maimaiti et al. 2018]*.

IMF Influence on SAIS

- Seasonal variation of SAIS is reported by *Maimaiti et al., 2018*. Here we characterize the IMF influence on SAIS during winter season (Nov., Dec., Jan,., and Feb.).
- Figure 4 shows the histograms of IMF clock angles in four different bins (left) and the corresponding 2-D flow vectors (right) calculated for winter. Figure 5 shows similar results for periods for which IMF clock angel was stable for at least 60 minutes (vs 30 minutes in Figure 4).
- Under all IMF clock angle conditions, the subauroral flow is predominantly westward throughout the night and becomes meridional during the dawn and dusk hours.
- The convection for IMF Bz- is significantly stronger than that for IMF Bz+, especially in the premidnight sector.

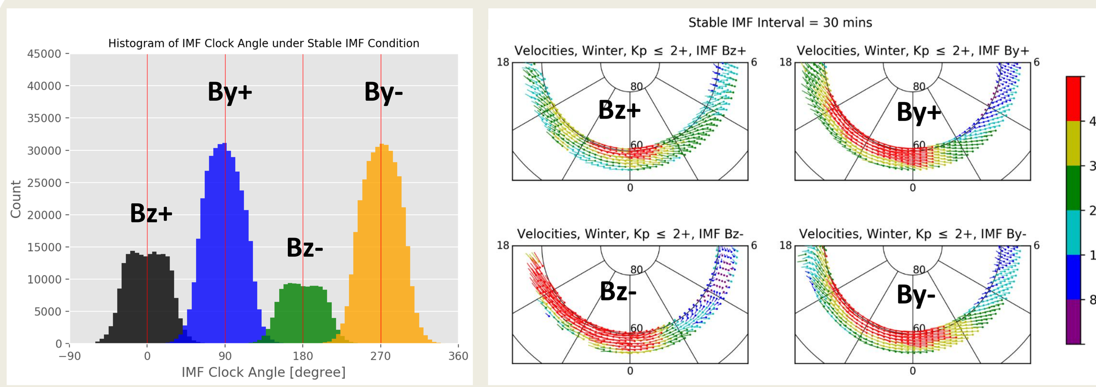

Figure 4: Histograms of IMF clock angles (left). Corresponding 2-D convection patterns (right) for winter (November-February) for the region between 52° - 58° magnetic latitudes centered at zero MLT.

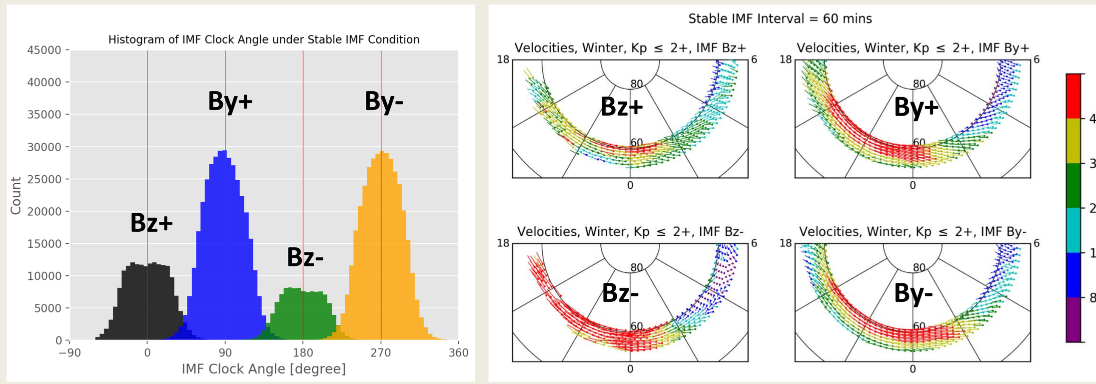

Figure 5: The same as Figure 4 but for intervals for which IMF clock angle values stay in a particular bin for at least 60 minutes.

IMF Influence on SAIS (Cont.)

- The 2-D convection patterns in Figures 4 and 5 are very similar, which implies that the duration of stable IMF intervals does not significantly affect the convection pattern.
- Figure 6 shows the fitted zonal velocities by MLAT vs MLT. The most prominent features are:
  - Pre-midnight flow is strongest under IMF Bz- and weakest under IMF Bz+.
  - A latitudinal gradient in speed exists between 18 and 1 MLT under all IMF conditions but most pronounced under IMF Bz-.
  - Under IMF By conditions, the latitudinal gradient converges at earlier MLT for IMF By+ compared to IMF By-.

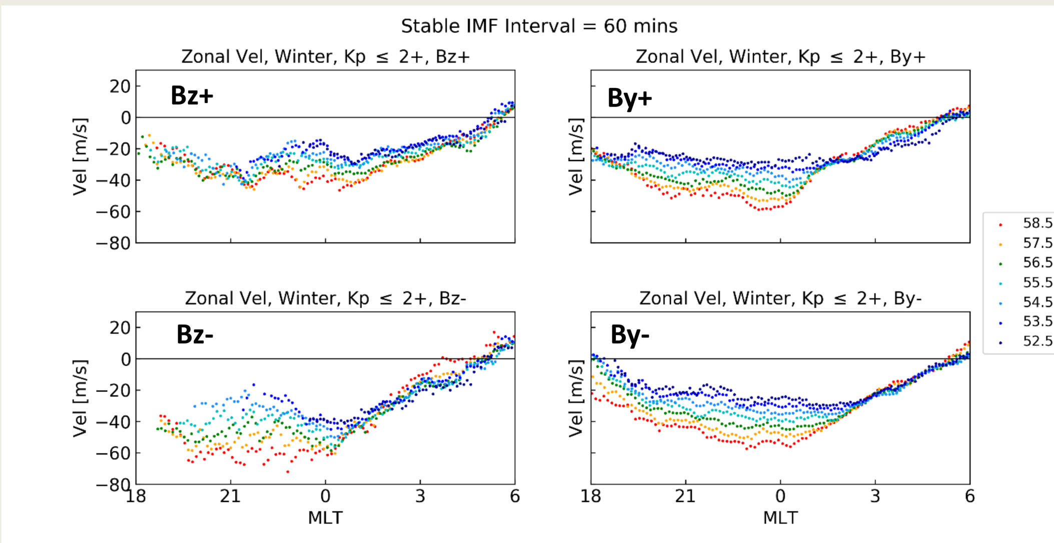

Figure 6:Fitted zonal velocities (positive eastward) by magnetic latitude versus MLT for four different IMF clock angle bins.

IMF By Influence

- As shown in Figures 4-6, the latitudinal gradient in the pre-midnight westward flow converges at around 1 MLT for both IMF Bz- and IMF By+, but is delayed for IMF Bz+ and IMF By-. Here we further divide the IMF By intervals into four different subgroups to decouple the effect of IMF Bz from IMF By. The results are shown in Figure 7.
- Under dominant IMF By conditions, the IMF Bz influence is still noticeable: the pre-midnight westward flow is stronger under IMF Bz- compared to Bz+.
- Strong westward flows (red-colored vectors) seem to extend to morning sector under IMF By- conditions.

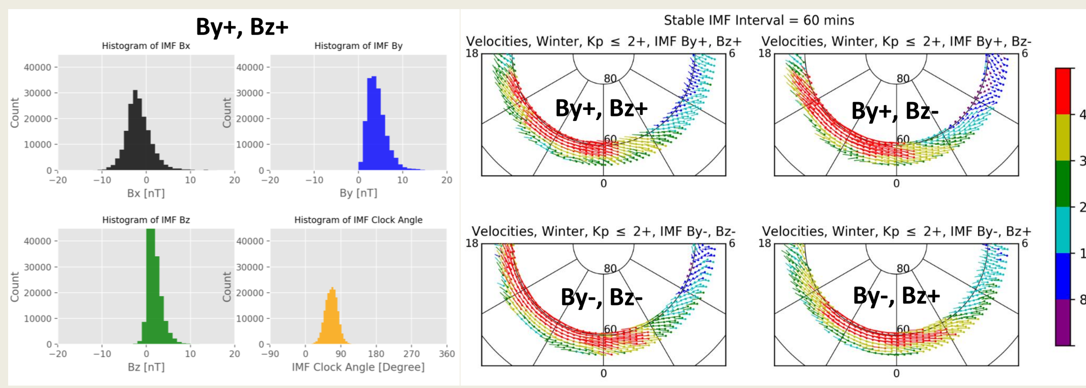

Figure 7: Histograms of IMF Bx, By, Bz, and clock angle for IMF By+ and Bz+ intervals (left). 2-D convection patterns under four different IMF By conditions (right) for winter (November-February) for the region between 52° - 58° magnetic latitudes centered at zero MLT.

IMF By Influence (Cont.)

- Figure 8 shows the zonal components of fitted 2-D vectors presented in Figure 7.
- Under IMF By dominant conditions, the pre-midnight flow is still stronger for IMF Bz- compared to IMF Bz+. The latitudinal gradient converges at earlier MLT for By+ compared to By-.

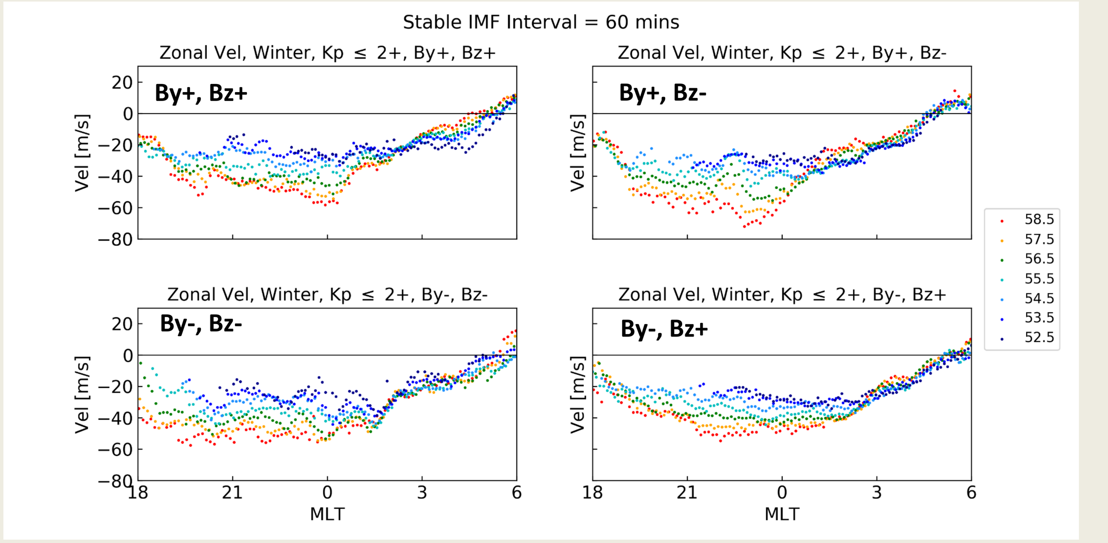

Figure 8: The same as Figure 6 but for four different IMF By conditions.

Summary & Conclusions

- We characterized the morphology of the subauroral (52° – 58°) convection pattern under various IMF conditions using data from mid-latitude SuperDARN radars. Main conclusions are:
  - Under all IMF conditions, the subauroral flows are predominantly westward throughout the night and become meridional during the dawn and dusk hours.
  - Pre-midnight flows are strongest in magnitudes under IMF Bz- and weakest under Bz+. Post-midnight westward flows are depressed under IMF Bz-.
  - A latitudinal gradient in speed exists between 18 and 1 MLT under all IMF conditions but is most pronounced under Bz-
  - Under dominant IMF By conditions, the latitudinal gradient converges at earlier MLT for IMF By+ compared to IMF By-.
- The emergence of an IMF dependence in subauroral convection provides further evidence that the penetration of high-latitude convection E-fields is a significant factor.

References

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Contact: *rafiq@vt.edu*

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