Comparing SuperDARN Radar Measurements to Optical Characteristics of Polar Moving Auroral Forms in the Southern Hemisphere

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Background

Flux transfer events, or FTEs, open a window between the solar wind and the Earth's magnetosphere and in the process create rapidly moving plasma around the magnetopause[7].FTEs are observed through the production of this plasma, and the production of dayside, repetitive, auroral arcs near both magnetic poles is categorized as polar moving auroral forms, a specific and common hallmark of FTEs[3]. These polar moving auroral forms, or PMAFs, last on average only 5 minutes and contain plasma that can move as fast as a kilometer per second, meaning very high temporal and spatial resolution is required to discern internal convection features[2].

PMAFs have been studied extensively in the Northern Hemisphere by both visual and radar systems over the last six decades, but the magnetic pole in the southern hemisphere lies over water, so deploying ground-based instruments has been difficult. One of the few ground-based instruments providing continuous coverage for ionospheric convection in the Antarctic is the Super Dual Auroral Radar Network, SuperDARN, which uses an array of high frequency radars to measure line-of-sight plasma velocity[4]. The South Pole SuperDARN site has recently had its spatial resolution improved by installing Universal Software Radar Peripherals, USRPs, on every antenna, allowing for velocities to be estimated using radar imaging rather than traditional beam forming[1].

This improved spatial resolution allows for the analysis of small-scale features of PMAFs in the southern hemisphere and to thereby shed new light on the characteristics, especially their internal convective features and time evolution. We present here preliminary results and a few examples of PMAFs from January 2020 using the new imaging software that provides the improved spatial resolution possible from the installation of the USRPs at the South Pole site.

Preliminary Methods/Results

To identify potential PMAFs from the high resolution data, we started with 24 hour summary plots of at the South Pole station of the range of the observed plasma vs the time of day in universal time. We can use these graphs to observe the speed of the plasma from the color, as seen in the legend in Figure 1, generally varying from -1 km to 1 km per second. By reviewing the previous literature on PMAFs, we determined likely candidates for PMAFs would occur near local magnetic noon, clearly be heading towards or away from the pole, occur sequentially, and have a period of shorter than ten minutes. WIth these characteristics and data from 1/12 - 1/31, we found 5-6 potential PMAFs.

To confirm the presence of a PMAF (or several successive PMAFs in a period), we plotted sequential 1 minute field of view data of the South Pole site radar and marked the magnetic pole, as shown in Figure 2. This allows us to observe clear poleward or anti-poleward movement of the plasma over a few minutes and confirm the existence of a PMAF in our observation. For a more detailed view of the PMAF at a particular time, see Figure 2, an isolated field of view plot from the series shown in Figure 3.This detailed view is of interest to identify interior features of the PMAF and in automating recognition of these features moving forward, and it more clearly shows the magnetic pole annotation.

In summary- we have detected the presence of PMAFs in South Pole SuperDARN data both in high level summary data and in minute to minute field of view data using the high resolution improvements described by Bristow et al.

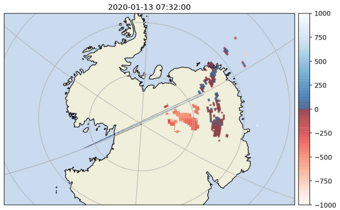

Figure 2- A FIeld of View plot of 01-13-20. See the red mass of plasma on the east side of the pole

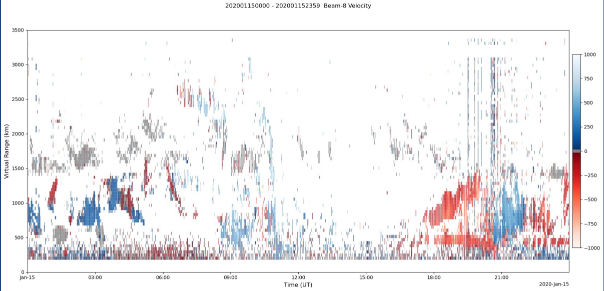

Figure 1- Range vs Time plot 1-15-20. Note the upward red streak, a mass of plasma moving away from the radar between 1800 and 1930 UT

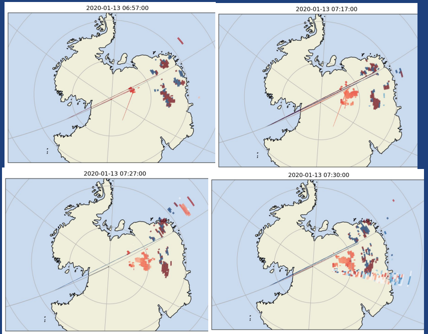

Figure 3- A series of Field of View plots, taken from 01-13 from 0717 to 0730 UT

Next Steps

We are leaving the solar minimum in 2022, meaning the chance for days with high incidence of aurora increases and with it, the chance to observe reconnection events. Given that we have now shown that we can identify PMAFs from radar signatures, SuperDARN's South Pole entire higher-resolution data set should now be analyzed and the PMAFs cataloged for statistical study. We hope to be able to measure internal features of PMAFs with the higher resolution available to us to study phenomena like convective channels and the gaps between PMAFs. Rather than just comparing features with optical characteristics, it will also be important to draw on magnetic field measurements and the solar context leading up to the formation of the PMAF, We are also interested in investigating Joule heating due to PMAFs and their impact on the density in the upper atmosphere and its resultant effects on low earth orbit satellites.

References

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