Ground-Based Signatures of Poleward-Moving Auroral Forms

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Introductions:

- Poleward-Moving Auroral Forms (PMAFs) have been shown to be Alfvenic auroras generated by dayside magnetic reconnection at the magnetopause. Under Bz negative conditions this process can occur, sending particles, waves, and energy into the ionosphere.
- On the dayside, Shear Alfven waves are generated by magnetic reconnection and can be an energy source for auroras [Gurram et. al, 2021]. Alfven waves have a characteristic signature of field aligned current when measured by in-situ instruments and have been observed during PMAF events by instruments aboard several rockets.
- Shear Alfven waves cannot accelerate electrons, they are converted into kinetic Alfven waves which can [Lysak et. al, 2022]
- When the perpendicular wavelength of Alfven waves becomes comparable to the electron inertial length, parallel electric fields form. [Staciewitz et. al, 2000]

$$\omega_{pe} = \sqrt{\frac{ne^2}{\epsilon_0 m_e}} \qquad \lambda_e = \frac{c}{\omega_{pe}}$$

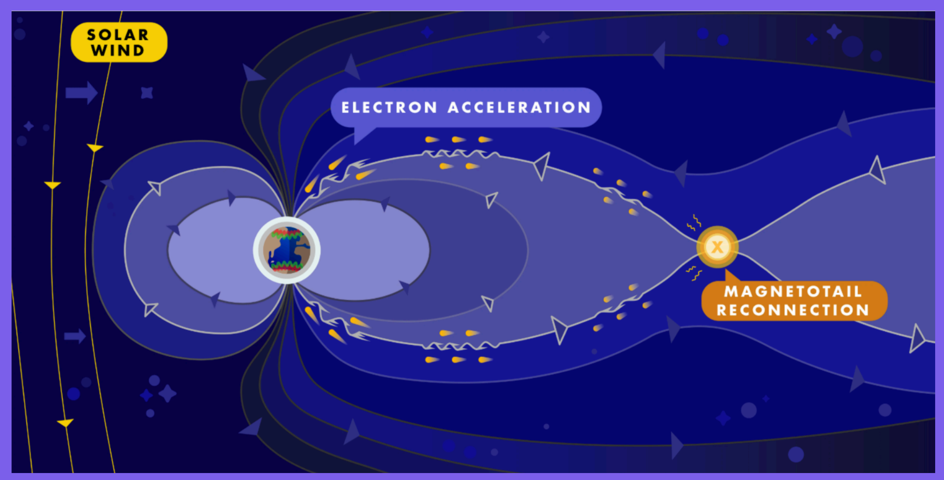

Figure 1: Representation of the motion of Alfven waves down magnetic field lines on the nightside image credit: Austin Montelius, College of Liberal Arts and Sciences, University of Iowa.

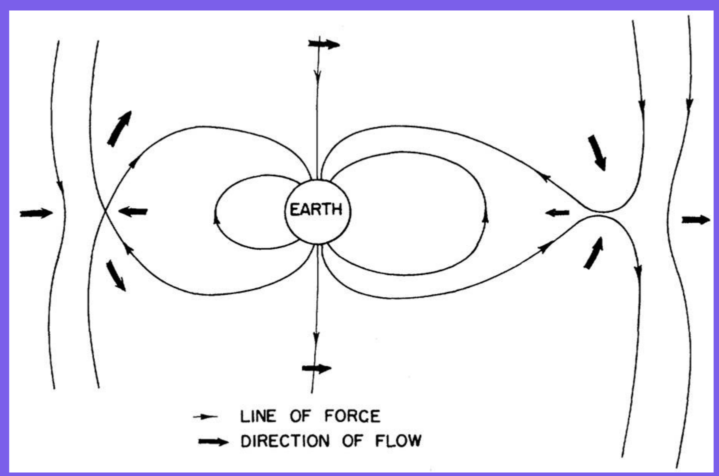

Figure 2: Interaction of the solar wind with the Earth's magnetic field [Dungee, 1961]

- Some Alfven waves are trapped within a resonance cavity, the Ionospheric Aflven Resonator (IAR) [Knudsen et. al, 1992] due to a cavity where Alfven speed is abruptly decreased

$$V_A = \frac{B}{\sqrt{\mu_0 n m_i}}$$

- Phase mixing within the IAR can explain broadband electron acceleration [Lysak et. al, 2022]
- The interference of Alfven waves in the cusp region leads to complex patterns in the resulting PMAF events.
- PMAF events prompt ion outflow, which has been shown to be correlated to neutral upwelling (see Jenna Burgett's poster)
- In this study, we link ground-based induction coil magnetometer signatures to PMAF's, based on the in-situ observations from three rockets.

Data:

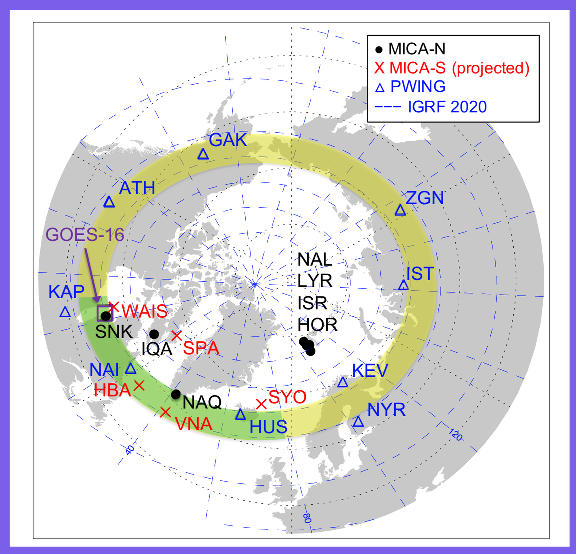

Figure 3: Map of the induction-coil magnetometers in the cusp region, stations in the southern hemisphere are in red font and marked with an X. All other stations are in the northern hemisphere.

- Data was gathered from the CREX 2, RENU 2, and SCIFER 2 missions. On three dates: January 18, 2008, December 13, 2015, and December 21, 2021, rockets were launched into ongoing PMAF events.
- Instruments aboard the RENU 2 and CREX 2 missions gathered electron data in situ throughout the flight.
- Data from Induction-coil magnetometers in Longyearbyen, Ny-Alesund, and Hornsund are used to relate wave activity measured on ground to in-situ data.
- We also demonstrate that the ground-based data from the cusp region (Hornsund, Sondestrom, and Iqaluit) and one in the southern hemisphere (South Pole Station) can be used to estimate the duration of PMAF events on global scales

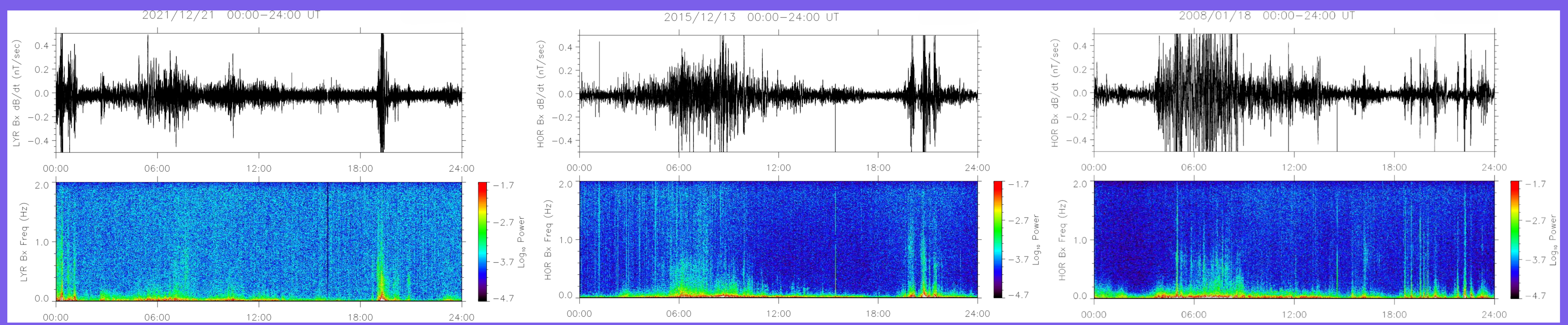

Figure 4: Data collected from an induction-coil magnetometer located in Svalbard on the three rocket launch dates: Jan. 18, 2008; Dec. 13, 2015; and Dec. 21, 2021.

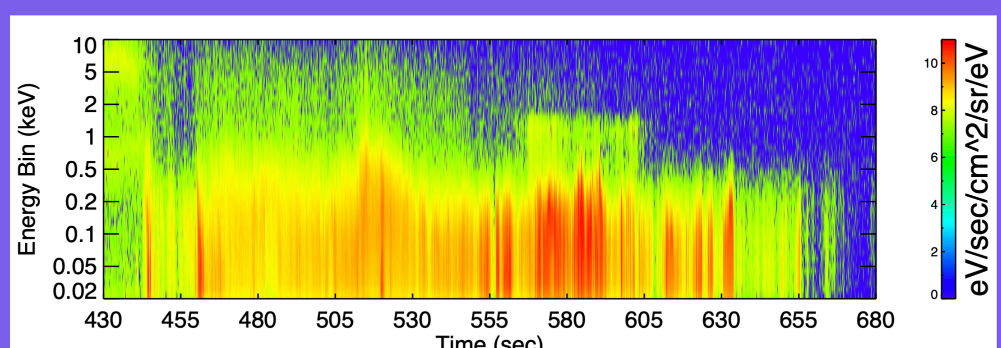

Figure 5: Electron Data from CREX 2 flight measuring energy on y-axis and time in seconds on x-axis in the time interval from 600 sec to 800 sec, color indicates intensity

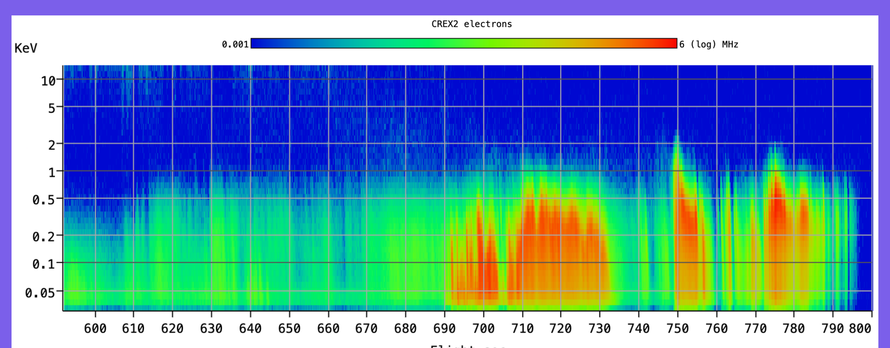

Figure 6: Electron Data from RENU 3 flight measuring energy on y-axis and time in seconds on x-axis in the time interval from 430 sec to 680 sec, color indicates intensity

Data Cont.:

- Data below was sourced from Hornsund, SDY, Iqaluit, and SPA stations on Dec. 13, 2015. Between 6 am UT and about 16 UT, Bz conditions of the IMF were consistently negative, measured by the ACE satellite.
- As time progresses, the Earth turns, and three different stations at the same latitude passed through the cusp, as well as a south pole station
- The measurements from South Pole Station, SPA, along the conjugate field line connected to Sondrestrom (SDY) are presented below.

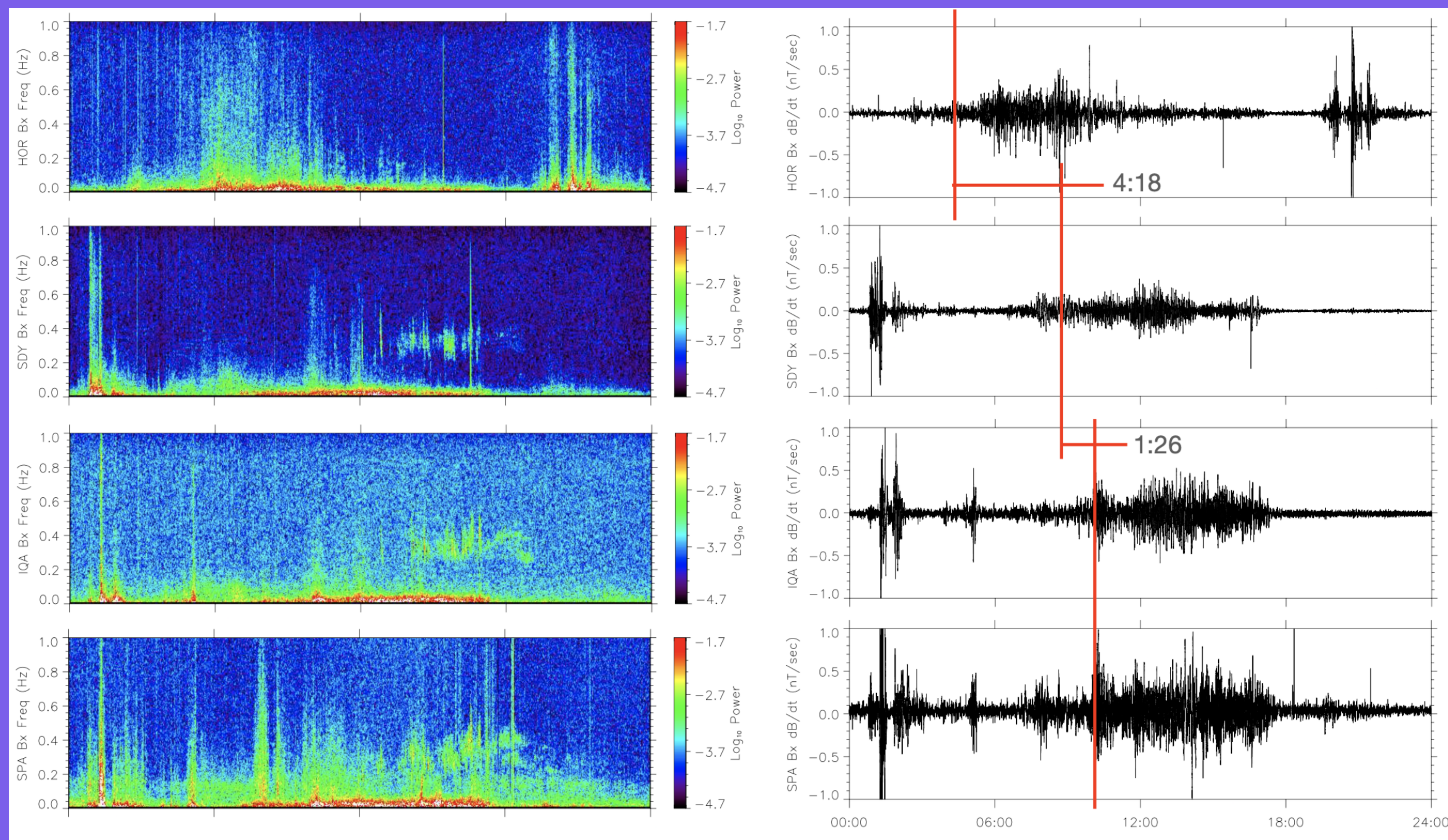

Table 1: MICA locations of the induction coil magnetometers, listed from north to south geographic latitudes. Geomagnetic coordinates in this table have been updated to epoch 2020-01-01 at 100 km altitude, using AACGM v2 at http://sdnet.thayer.dartmouth.edu/aacgm/aacgm_calc.php.

Site	Abbrev.	Geographic Lat.	Geographic Lon.	Geomagnetic Lat.	Geomagnetic Lon.	MLT MN	L Shell	Year deployed
Hornsund[1,9]	HOR	77.0 N	15.3 E	74.7 N	105.6 E	22:11	Cusp/Polar cap	
Sondrestrom[1,3]	SDY	66.6 N	50.6 W	71.2 N	38.5 E	2:29	9.9	
Iqaluit[1,7]	IQA	63.5 N	68.3 W	70.8 N	14.9 E	3:55	9.5	
South Pole[1]	SPA	90.0 S	—	74.6 S	18.6 E	3:41	Cusp	

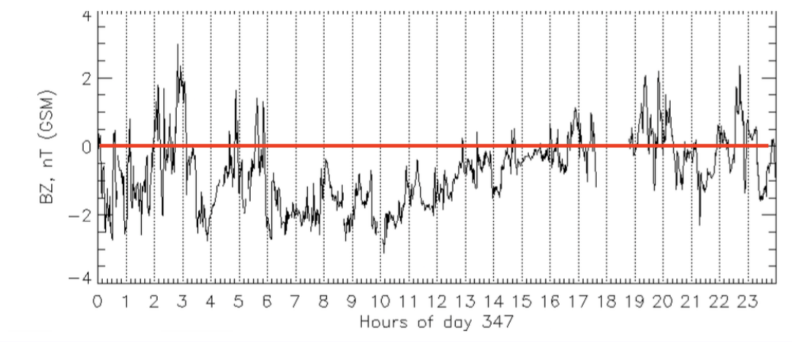

Figure 7: The data above shows the wave activity measured at four different stations during Bz negative conditions. The top four graphs n the left and right columns indicate measurements of wave activity by induction-coil magnetometers at the Hornsund, SDY, Iqalui, and SPA stations on Dec. 13, 2015. The vertical red lines in first four graphs in the right column indicate position in the cusp in magnetic local time (MLT) as noted by the table in the bottom left. The graph in the bottom right indicates the Bz component of solar wind over time on the date. The red line is placed at 0 to divide positive and negative.

Results:

From left side of poster:

- On each flight date, wave disturbances were observed which lasted through the duration of the PMAF event.
- Rocket data confirmed that the waves were Alfvenic on the three flight dates, since the electrons were observed to be traveling in the field-aligned direction.
- Wave signatures were Pi1-b waves.

From Right side of poster:

- On Dec. 13, 2015, negative B_z conditions continued for 10 hours, with PMAFs being visible in Longyearbyen starting before 07:00 UT. Magnetometers located near the same magnetic latitude (i.e, the cusp region) scanned the event. As each station came to face the sun due to the rotation of the Earth, the magnetometers registered PMAF wave activity near the same approximate MLT, with each magnetometer providing similar readings when facing the sun.
- The observations show that nearly identical PMAF signatures also occurred in the southern hemisphere, at South Pole Station (nearly conjugate to Iqaluit). The levels of activity at all sites is comparrable.
- This event provides evidence for our understanding of the magnetometer response to PMAF events. It also demonstrates the capability for placing the observations in a global context. For example, the set of observations show that this particular PMAF event persisted for at least 10 hours — presumably driving ion outflow and neutral upwelling the entire time.

Conclusions:

This poster shows ground- and space-based observations of PMAFs, identifying a classic Pi1B signature for these events. That same signature is then used to estimate the global extent of PMAF effects, presumably including ion outflow and neutral upwelling. We summarize as follows:

- Sounding rocket observations of 3 PMAF events were compared to ground-based magnetometer data in order to identify their ground-based signature. We determine that the Alfven waves that drive the aurora produce the ground-based signatures of PMAFs. The implication is that a network of ground-based magnetometers support indirect observations of PMAFs.
- Extending the ground-based observations to include data from other sites near "cusp latitudes", we find that the PMAF persisted for at least 10 hours. Noting that PMAFs have been strongly linked to ion upflow and neutral upwelling, a reasonable conclusion is that this event provided 10 hours of both processes.
- Taking this work one step further, we also show (though only at a single station) comparable and simultaneous obsersations in the southern hemisphere

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