

Modeling the effects of drift shell splitting in two case studies of simultaneous observations of Pi1B and IPDP-type EMIC waves

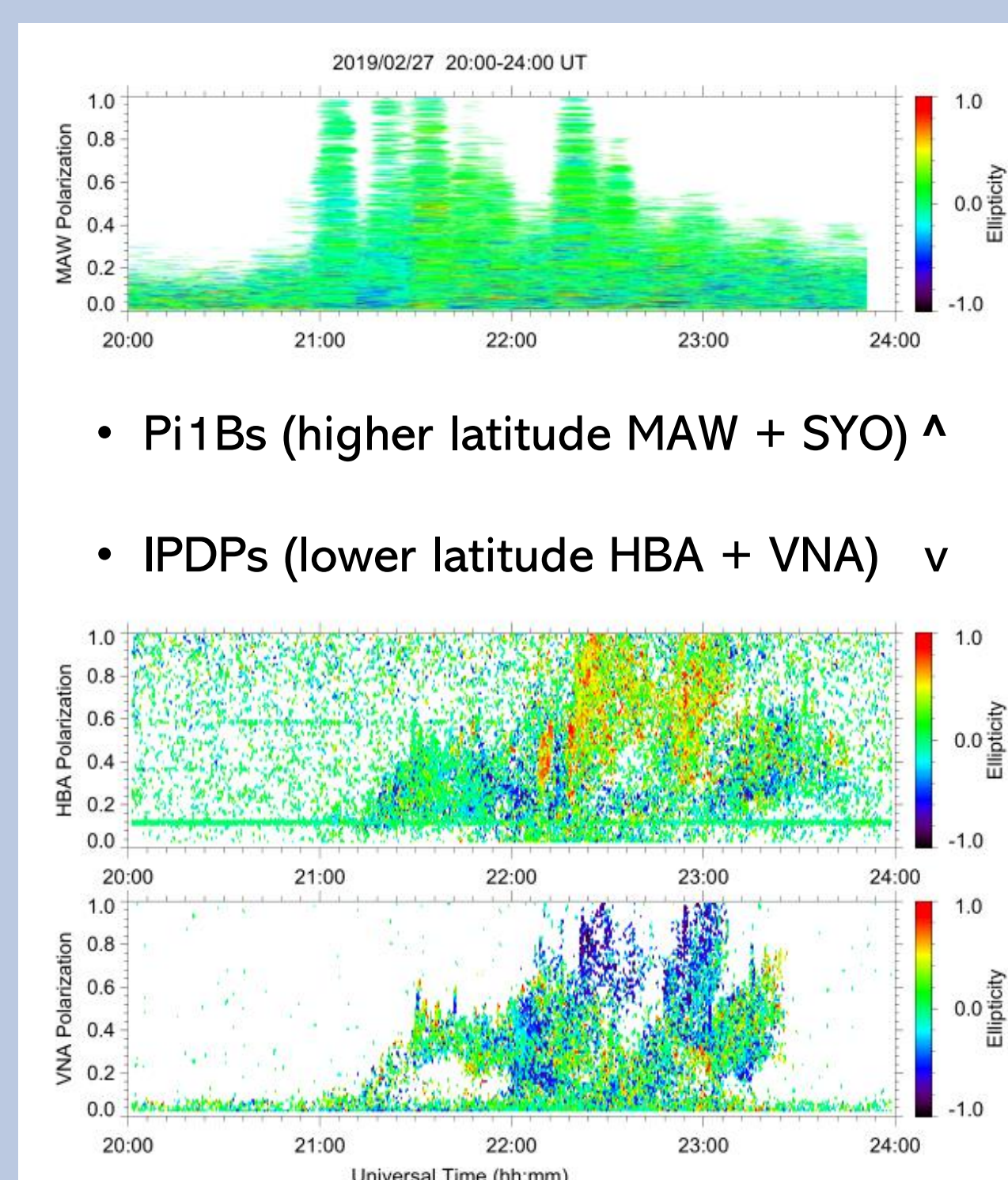
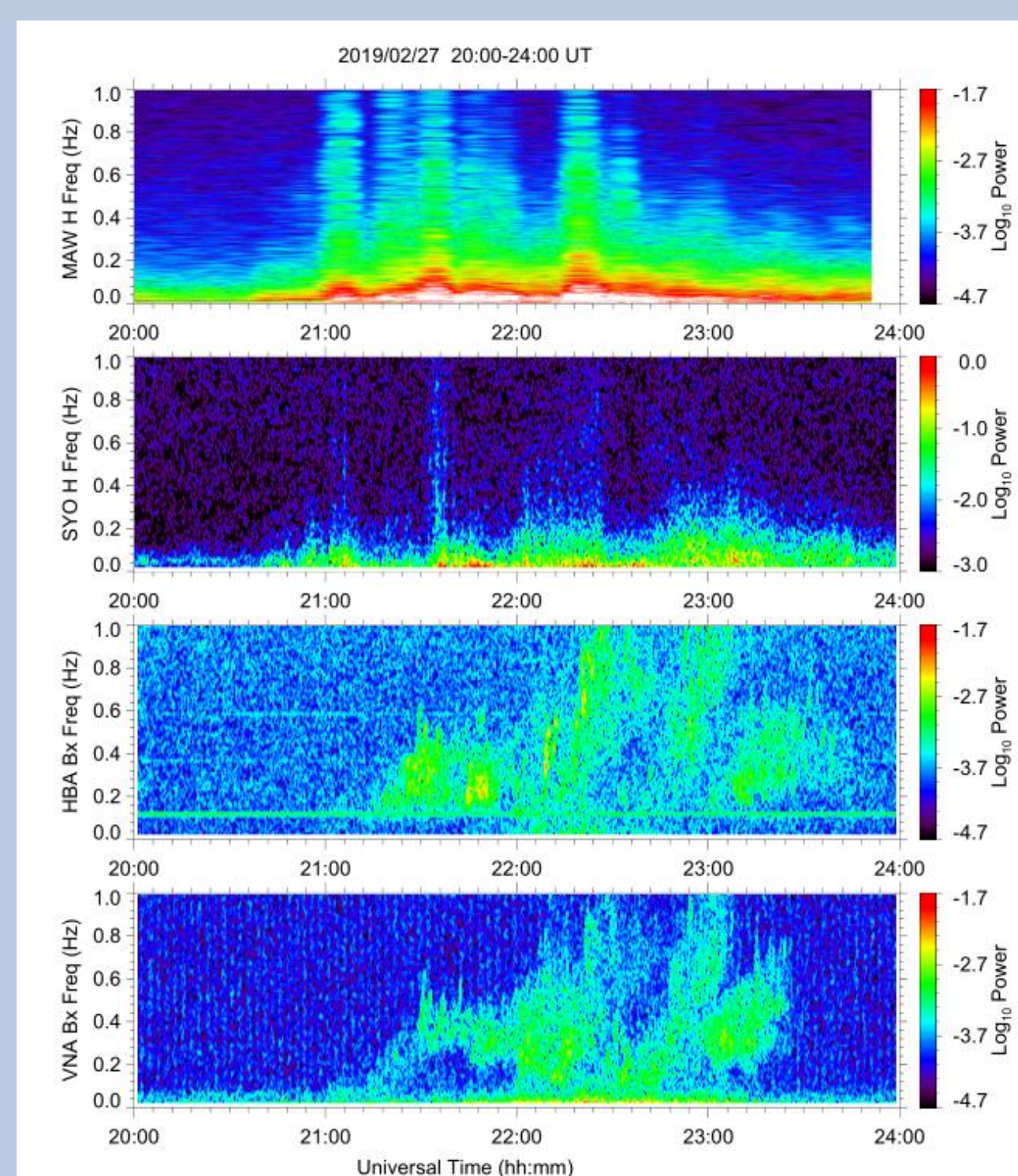
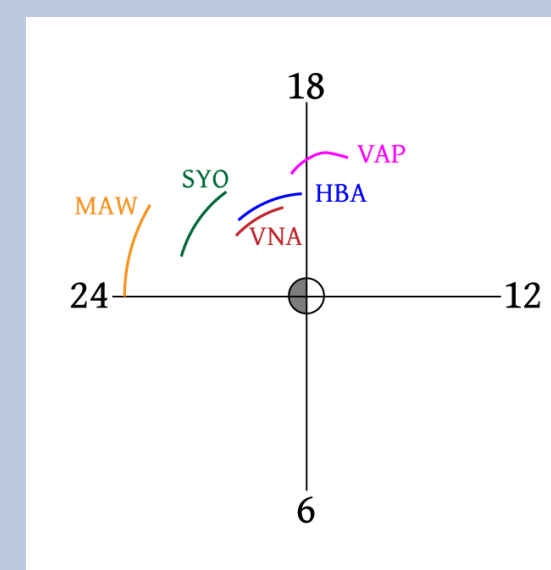
Abstract: Intervals of Pulsations of Diminishing Periods (IPDPs) are a subtype of Electromagnetic Ion Cyclotron (EMIC) waves that can be triggered by substorm onset. Pi1B waves are Ultra Low Frequency (ULF) broadband bursts that are well correlated with substorm onset. IPDPs are associated with increased fluxes of 40-60 keV substorm-injected protons which undergo gradient-curvature drifting and interact with the cold plasmasphere population. While particle trajectories and the generation of IPDPs have been modeled in the past, those models neglect the role that drift shell splitting plays in the process. This research investigates the different pathways that Pi1B and IPDPs take from their shared origin in substorm onset to their distinct observations on the ground, including the effects of drift shell splitting en route. This poster presents two case studies using data from an array of four ground-based Antarctic magnetometers that cover the evening sector, as well as in situ magnetometer data, proton fluxes, and proton pitch angles from the Van Allen Probes spacecraft. These observations identify a separation in geomagnetic latitude between Pi1Bs and IPDPs, and pinpoint a separation in Magnetic Local Time (MLT). From these observations we model the drift shell splitting which injected particles undergo post-onset. This study shows that simulations that incorporate drift shell splitting across a full injection front are dominated by injection boundary effects, and that the inclusion of drift shell splitting introduces a slight horizontal component to the time axis of the time-frequency dependence of the IPDPs.

Event 1: February 27 2019 Ground Station and Van Allen Probes Observations

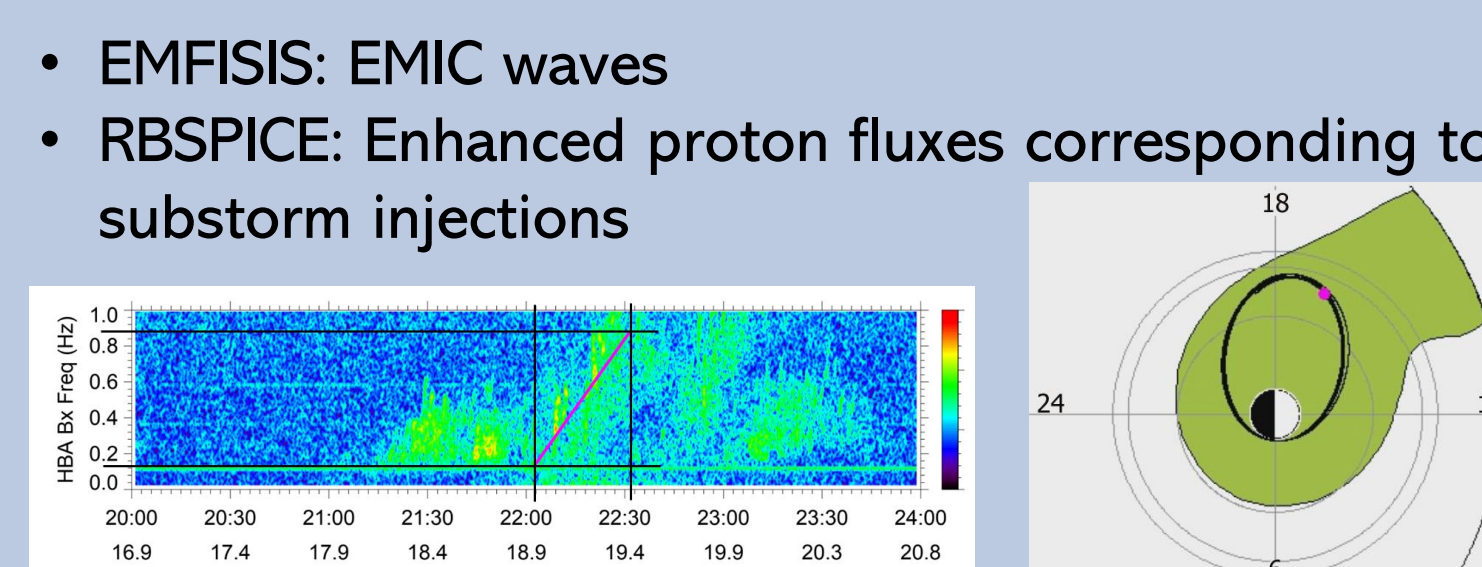
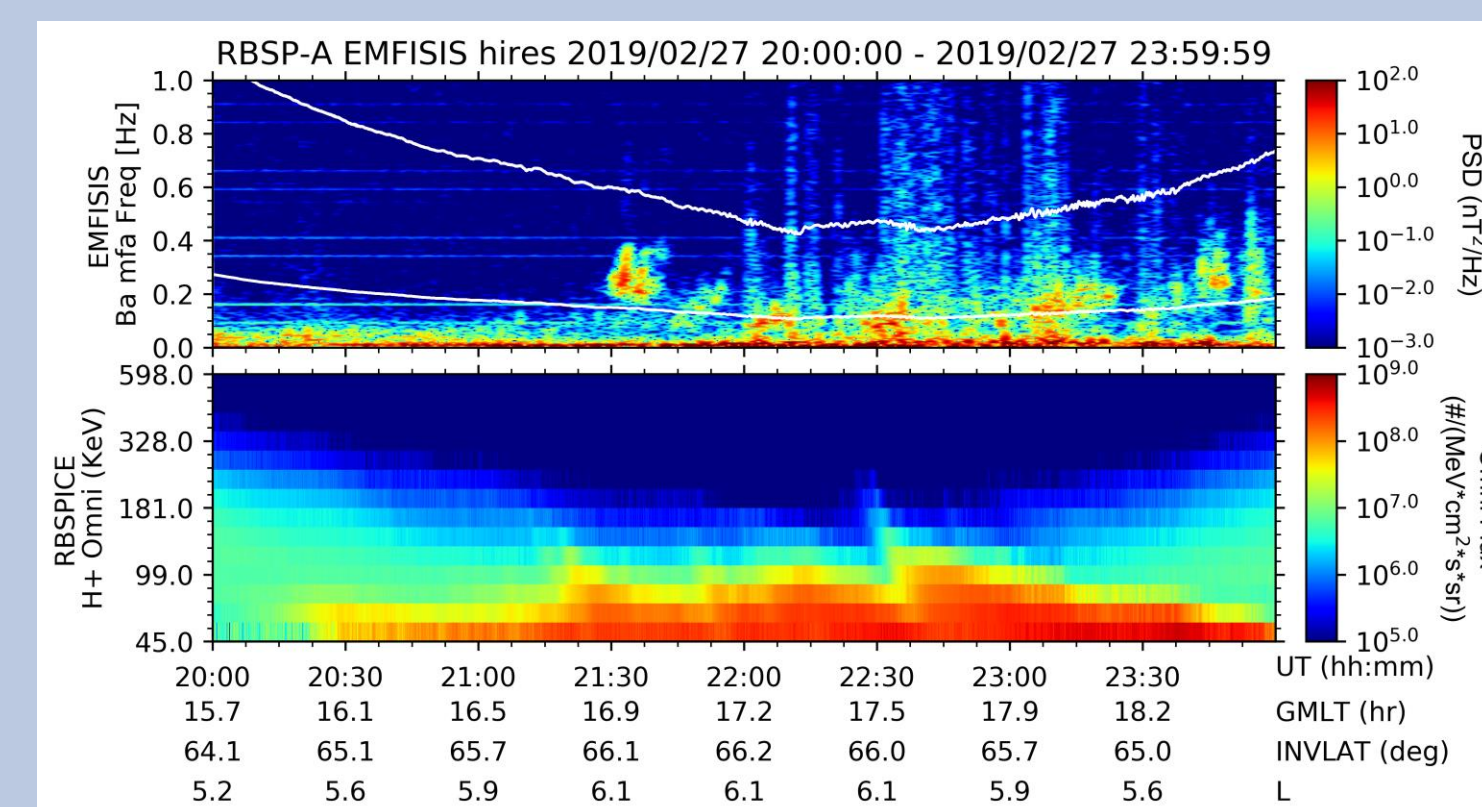
Station	Geo. Lat.	Geo. Long.	CGM Lat.	CGM Long.	MM	L
MAW	67.6 S	62.9 E	70.8 S	92.8 E	23:05	9.3
SYO	69.0 S	39.6 E	66.9 S	73.9 E	0:19	6.5
HBA	75.6 S	26.3 W	62.7 S	30.1 E	2:59	4.8
VNA	70.4 S	8.3 W	60.8 S	42.5 E	2:14	4.3



- Four Antarctic ground stations: Mawson, Syowa, Halley Research Station, and Neumayer III
- Plasmapause model used for boundary
- MLT clock represents spatial coverage of each station
- Event 2 available upon request

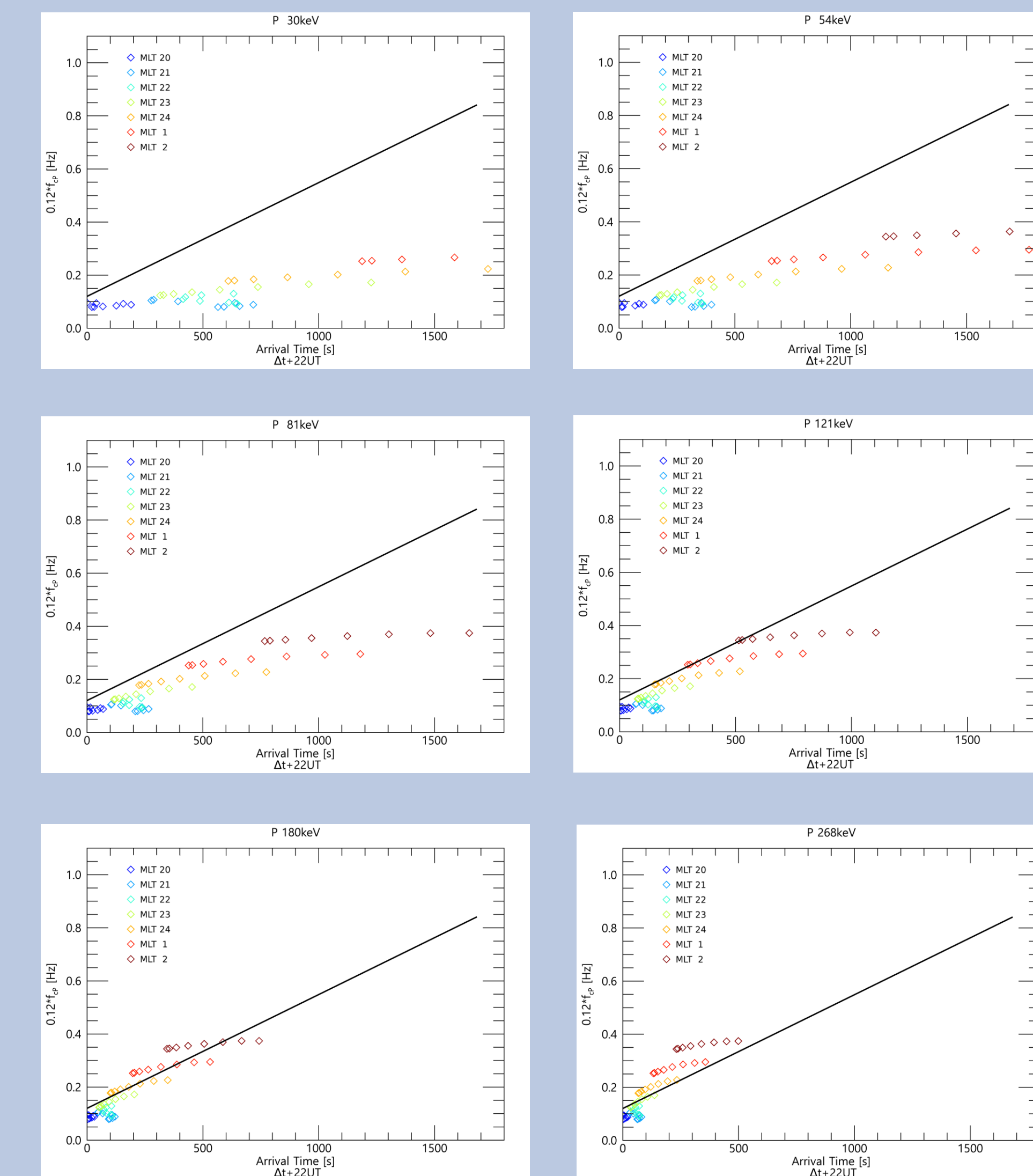


- Pi1Bs (higher latitude MAW + SYO) ^
- IPDPs (lower latitude HBA + VNA) v



- EMFISIS: EMIC waves
- RBSPICE: Enhanced proton fluxes corresponding to substorm injections
- Slope chosen for comparison to simulation results

Simulations and Parameters



- Uses full injection front
- Model traces charged particle paths by solving guiding center averaged equation using Runge-Kutta 6th order algorithm
- Background magnetic field provided by TS05 model
- Injection boundary uses geomagnetic activity-dependent model suggested by Mauk and McIlwain
- Starting locations of particles evenly spaced with 1 hour MLT along injection boundary model between 20/21 MLT and 2 MLT for February/March events
- Arrival MLTs of 18.86 at HBA/18.5 at VNA were used for February/March events
- Simulations normalized by factor of 0.12 (comes from normalizing observed frequency of 0.3 Hz at Van Allen probes by local proton gyrofrequency)
- Simulations run for pitch angles between 20 and 90 degrees in 10 degree intervals
- X axis: traveling time of particle from injection boundary to these MLTs

Conclusions

- Observations were used as boundary conditions and created simulations of protons injected over an extended region during substorm onset and subject to drift shell splitting following their injection; these simulations produce results that are consistent with the time-frequency dispersion of IPDP waves as observed from the ground.
- Particle trajectories and the overall frequency increase of the IPDPs are dominated by injection boundary effects
- Drift shell splitting adds a slight horizontal component to the time-frequency dependence of the IPDPs, influencing the shape

A statistical study relating IPDPs to substorm onset via the SuperMAG SML index

Abstract: Intervals of Pulsations of Diminishing Periods (IPDPs) are a subtype of ElectroMagnetic Ion Cyclotron (EMIC) waves that are characterized by an increase in frequency over time when observed from the ground. They are well known to have their generation mechanism in substorm onset, during which particles with sufficient temperature anisotropies will be injected into the plasmasphere. However, while substorm onset is a daily occurrence, IPDPs occur far less frequently. The research presented in this study seeks to compare IPDP observations from southern hemisphere stations Neumayer and Halley Research station with substorm onset via the SuperMAG SML index and its derived substorm products, mainly the Newell and Gjerloev substorm list. This research compares trends in SML surrounding list-identified onsets between all substorm onsets and just substorm onsets with associated IPDP observations. To account for the mismatch between southern hemisphere IPDP observations being compared to a north-ern hemisphere index and to ensure the validity of this study, the data sets are filtered by Pi1B observations— which are well known to be associated with substorm onset— from the southern hemisphere Mawson. This study finds that trends in the SML index are virtually identical across all data sets, but more interestingly finds an indication that not all IPDPs have their generation mechanism in substorm onset.

Data Sets

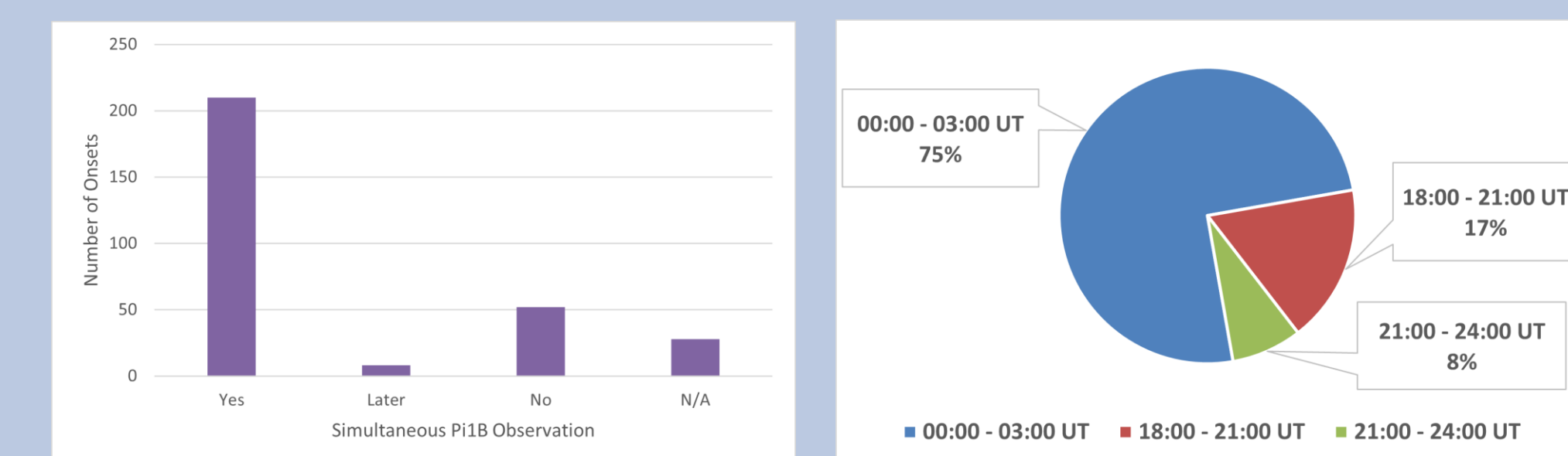
- Ground magnetometer observations from HBA, VNA (IPDPs) and MAW (Pi1Bs)
- SuperMAG SML index: similar to AE (Auroral Electrojet) indices but uses 200-300 SuperMAG stations (not IAGA authorized)
- Newell + Gjerloev substorm list (derived from SML index)
- Data taken between March 2019 and March 2020
- Limited data sets between 1800-0300 UT, which covers the evening sector for these ground stations
- Note: MAW searchcoil decommissioned in December 2019

Methodology

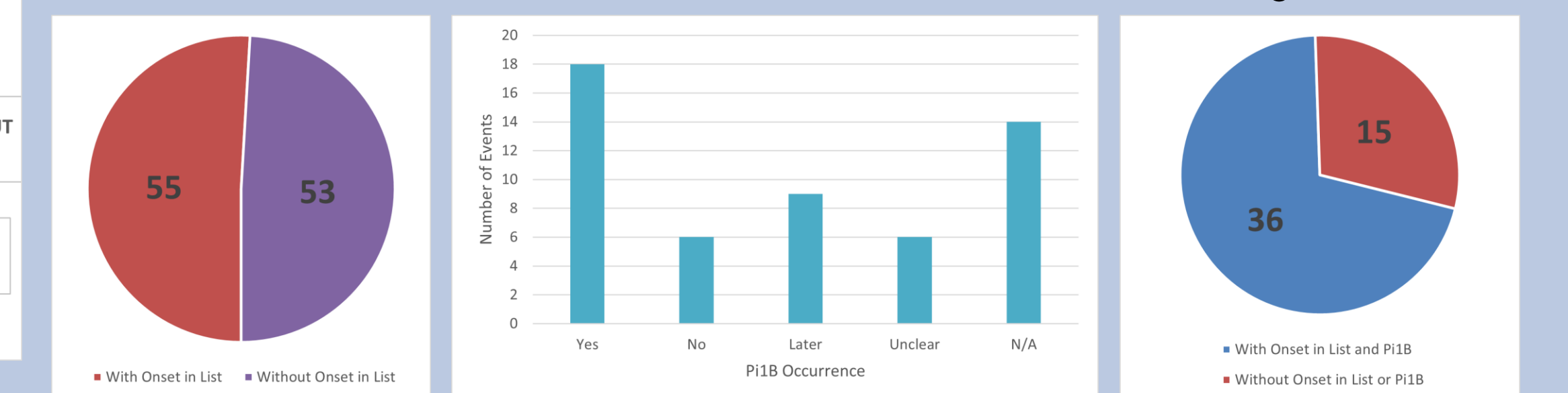
- Substorm list criteria: sharp drop in SML (45 nT in 3 mins), sustained (avg 100 nT below initial value for 30 mins)
- IPDP criteria: identified visually in spectrograms, rising tone EMIC wave, multiple IPDPs in short succession were considered one 'event'
- Pi1B criteria: identified visually using both spectrograms and time series data, start time confidence within 5 minutes
- Correlation criteria: Substorm must precede IPDP; Pi1B must be within 5 minutes of substorm
- IPDPs: Pulled start time, end time, slope (measuring from middle), polarization
- Substorm: SML strength at onset, SML strength of initial negative bay (first peak), sharpness of first peak, change in SML over first peak, maximum peak in SML over next 30 minutes, change in SML from initial to max change
- If next substorm onset happened less than 30 minutes after previous one, lowest value of max dSML before next onset chosen
- Using a northern hemisphere index and southern hemisphere observations is generally not advisable
- To account for this mismatch, used southern hemisphere Pi1B observations to effectively filter the datasets
- Pi1B waves are well correlated with substorm onset
- Filtered datasets by removing any substorms without simultaneous Pi1B observations, looking for IPDPs that had neither substorm onset nor Pi1B observations
- Pi1Bs: Only identified for events with substorm onset or IPDP

Results

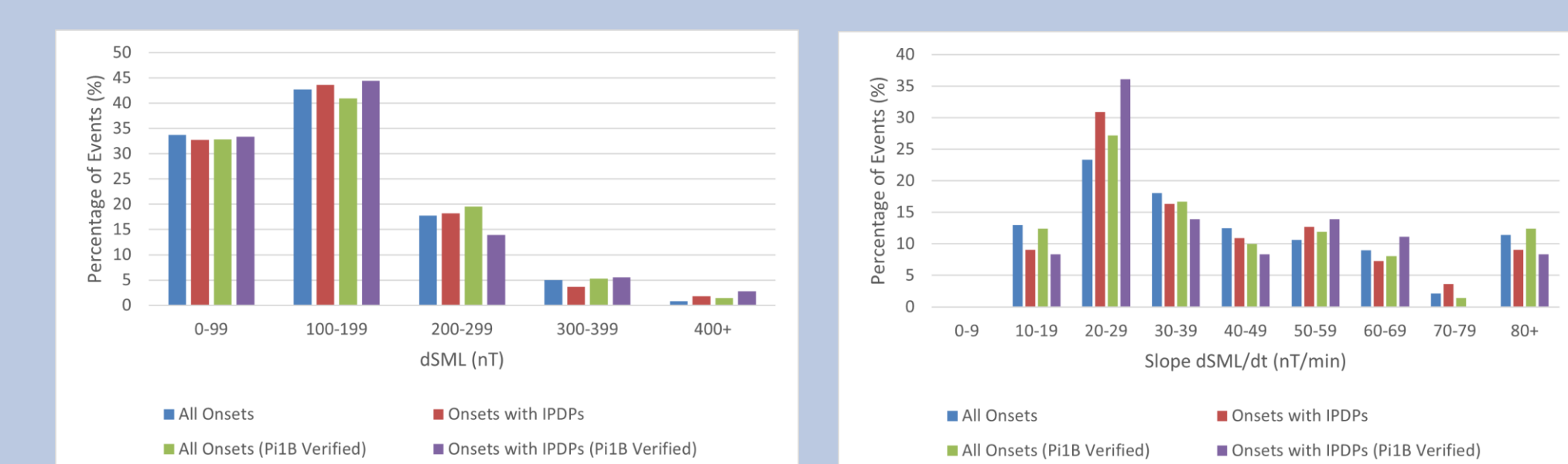
Substorm onsets with simultaneous Pi1B onset and time breakdown for substorms without simultaneous Pi1B onset



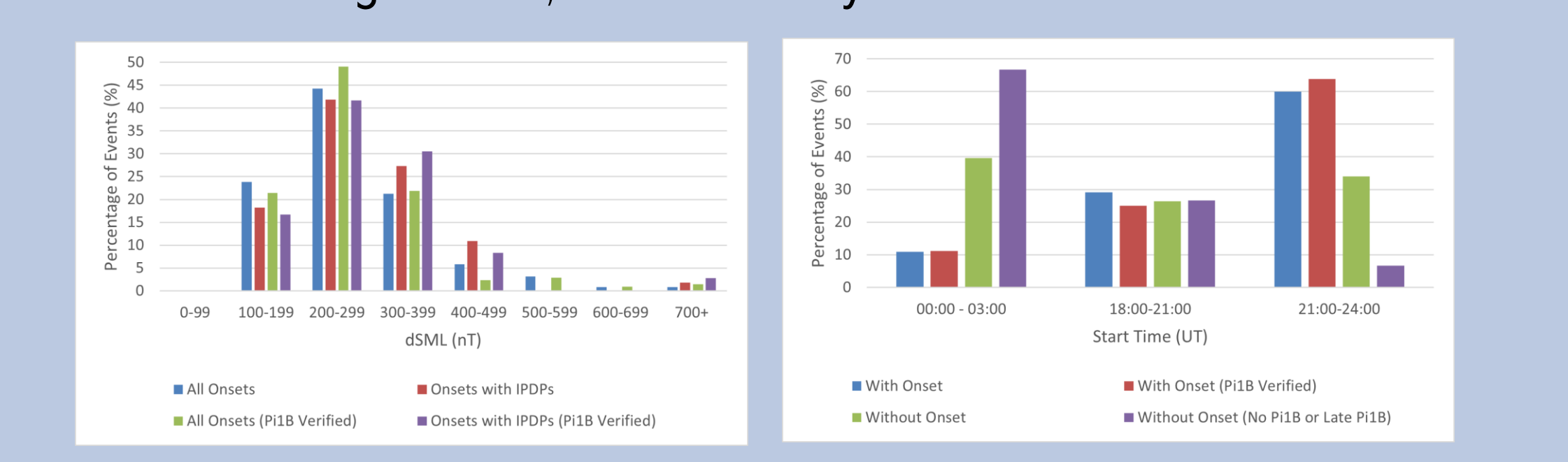
Breakdown of IPDPs observed with and without substorm onset pre-filtering; Pi1B observations compared to IPDP observations without substorm onset; breakdown of IPDPs observed with and without onset after filtering



Trends in initial negative bay at substorm onset and its slope for both filtered and unfiltered datasets



Maximum change in SML, start time analysis for IPDPs



Conclusions

- Trends in SML largely the same for both filtered and unfiltered datasets
- Before filtering, 55/108 IPDPs found to be associated with substorm onset; 53/108 IPDPs not associated with substorm onset
- After filtering, 36/46 IPDPs found to be associated with substorm onset; 11/46 IPDPs not associated with either substorm onset or preemptive Pi1B observation
- IPDPs associated with substorm onset tended to be observed between 2100-2400 UT in the middle of the evening sector

- IPDPs not associated with substorm onset tended to be observed between 0000-0300 UT in the late evening crossing into post-midnight sectors
- In the literature, IPDPs are widely accepted to always be triggered by substorm onset (only found one case study where this is not the case)
- Initial motivation wanted to understand why not all substorms trigger IPDPs
- However, results indicate that IPDPs may not always be triggered by substorm onset
- As data sets used here are not definitive and may have missed onsets, future work will involve deeper case studies