The Role of Ion Demagnetization Altitude in MIT Energy Transfer

A. M. Pepper and S. R. Kaeppler

CLEMSON UNIVERSITY

Abstract

Ion-neutral coupling is critical to understand energy transfer between the magnetosphere and the ionosphere. The altitude at which the ions demagnetize represents a transition from dominantly electromagnetic forcing toward dominantly forcing from the neutral atmosphere. Investigations of the altitude profile of ion demagnetization are important for understanding energy transfer in the E-region. One relatively unexplored regime is understanding the demagnetization process during different magnetic local time (MLT) sectors. We present results of the ion demagnetization altitude using observations from two previous sounding rocket campaigns launched during different MLT sectors from the Poker Flat Research Range with suitable instrumentation to investigate ion-neutral coupling in the ionosphere. These two investigations occurred in different MLT sectors, and we compare past observations during the Joule II sounding rocket mission (2007) with more recent observations from the Jets sounding rocket mission, launched in 2017. We additionally use the Poker Flat Incoherent Scatter Radar (PFISR) and ground-based magnetometers to provide contextual information associated with these events. Altitude resolved neutral wind profiles are determined from vapor trail observations that are triangulated utilizing the line-of-sight projection method to produce neutral velocity profiles between 100-140 km. We calculate the ion demagnetization altitude in the same manner as what is described in Burchill et al., JGR, 2012 and Sangalli et al., JGR, 2009.

Motivation & Methods

$$\kappa = \frac{\Omega_i}{\nu_{in}} = \frac{\left|\vec{v}_i - \vec{U}_n\right|}{\left|\frac{\vec{E}}{B_0} + \frac{\vec{v}_i \times \vec{B}}{B_0}\right|} \quad (1)$$

Component	Origin	Method
Ω_i	IGRF	1
ν_{in}	NRLMSIS00 & IRI	1
$\vec{v}_i$	PFISR (AC)	2 & 3
$\vec{U}_n$	In-Situ	2 & 3
$\vec{E}$	PFISR (LP)	2 & 3
$\vec{B}$	IGRF	2 & 3

- **What is the response of the ion demagnetization altitude during different MLT sectors?**

- The ion demagnetization altitude is the case when equation (1) is equal to one which represents the balance of the Lorentz force and the ion neutral drag force. The collisional dominated regime is when equation (1) is less than one, and the collisionless dominated regime is when equation (1) is greater than one. To determine the demagnetization altitude profile, we use a combination of in-situ data and incoherent scatter radar (ISR) data.
- To estimate the perpendicular ion drifts in the E-region we use the methodology described in Heinselman and Nicolls, RS, 2008. The electric field is estimated in the F-region using long pulse ISR and the electric field is assumed to map vertically into the E-region. Both the long pulse and alternating coded data are integrated to achieve a 5-minute time resolution for both campaigns.
- The vapor trail technique was used to provide measurements of the altitude resolved E-region neutral winds. The vapor trails of trimethylaluminum (TMA) were photographed and triangulated to obtain neutral velocity profiles utilizing the line-of-sight projection method providing neutral velocity profiles between 100-140 km.
- The ion demagnetization altitude is calculated using equation (1) in three ways for each event:
    1. The middle section of equation (1) using derived values for the ion-neutral collision frequency (NO+ and O2+) taken from models (NRLMSIS00 and IRI), and the formulas from Schunk & Nagy, 2009.
    2. Right side of equation (1) using PFISR data with the neutral profile.
    3. Right side of equation (1) using PFISR data without the neutral profile.

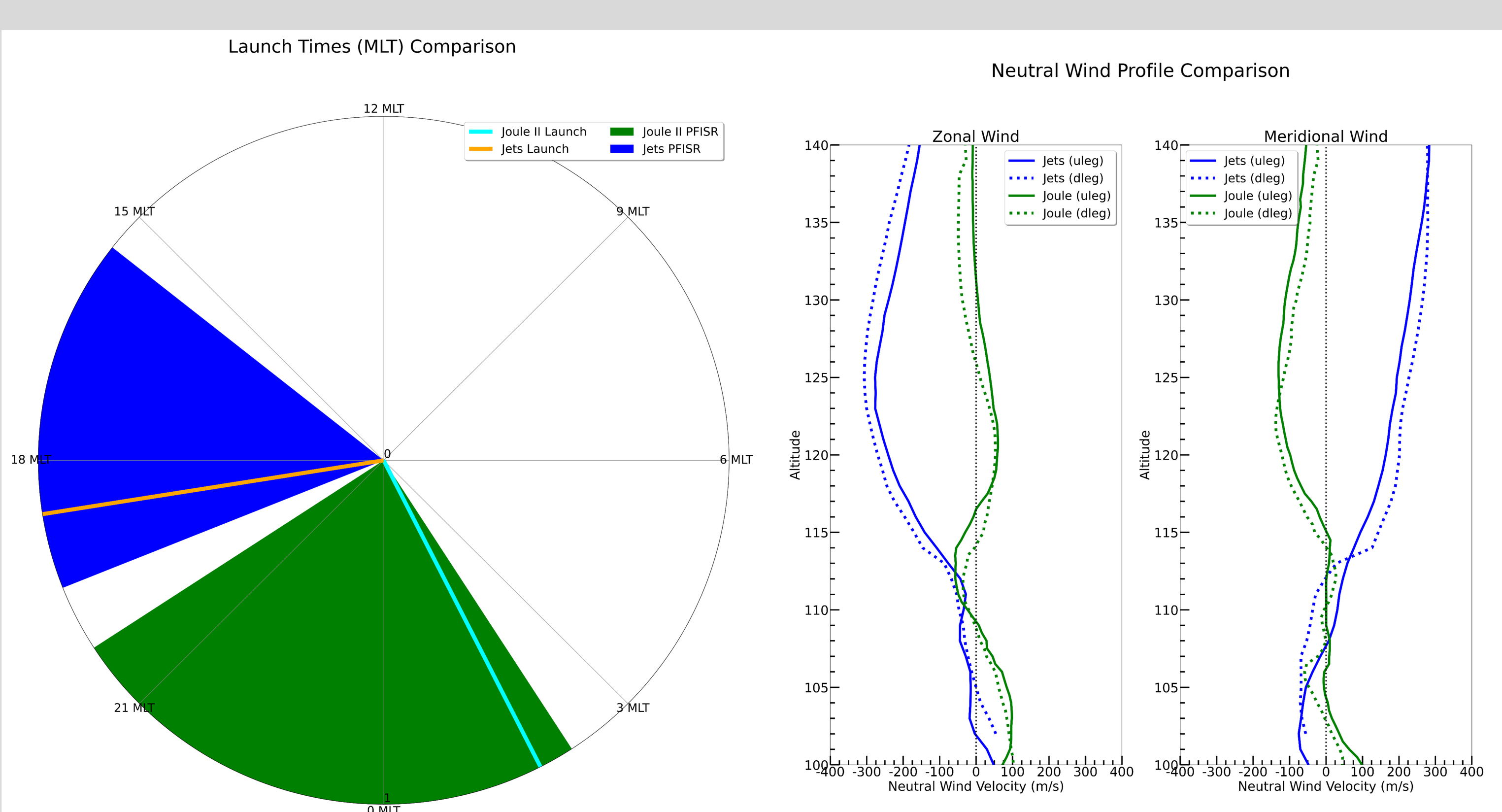

Figure 1: The left polar plot details the differences between the launch times in magnetic local time (MLT) of both the Joule II and Jets campaigns launched from Poker Flat Research Range. The shaded regions of each campaign illustrate the temporal range of PFISR data that was used in this study. The right-hand side of this figure compares the zonal and meridional components of the neutral wind profiles for the dusk and post-midnight sectors corresponding to Jets and Joule II, respectively.

Results

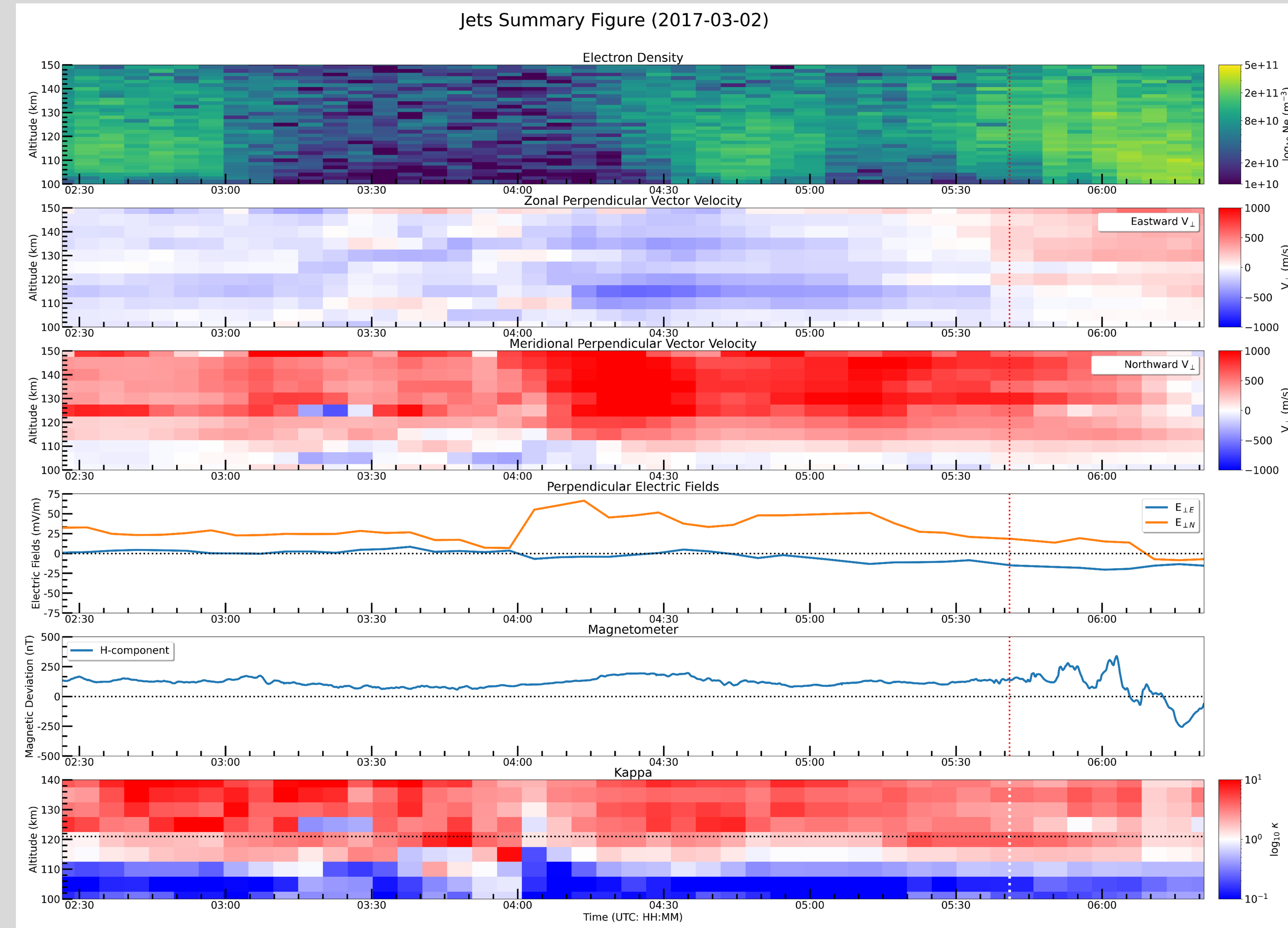

Figure 2: A summary figure depicting the geomagnetic conditions prior to the launch of Jets from Poker Flat Research Range on March 2nd, 2017, at 0541 UT as indicated by the dashed red line corresponding to the dusk MLT sector. Results from equation (1) are displayed on a log scale in the bottom row from 100 to 140 km, and the mean ion demagnetization altitude derived from MSIS00 and IRI is shown. The plasma drifts depicted in this figure correspond to the expected westward plasma drifts associated with the evening MLT sector.

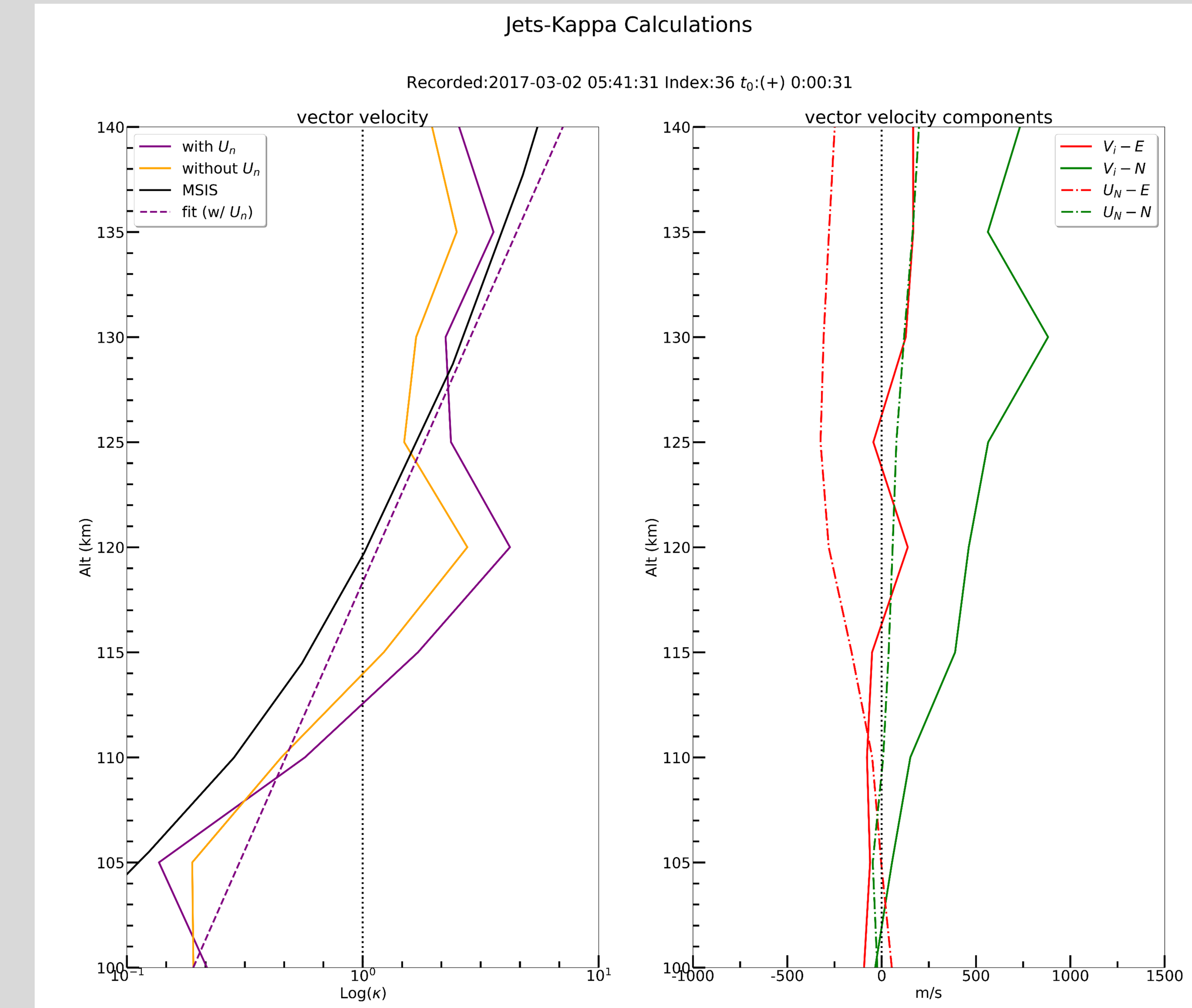

Figure 3: Snapshot of the ion demagnetization altitude during the launch of the Jets campaign. The ion demagnetization altitude is depicted with (gold) and without (purple) neutral winds on the left, and the perpendicular velocity and neutral wind components are shown on the right in geomagnetic coordinates. The fit shown has an agreement with the MSIS00 and IRI value, and the enhanced northward ion drift and westward winds depict an active event.

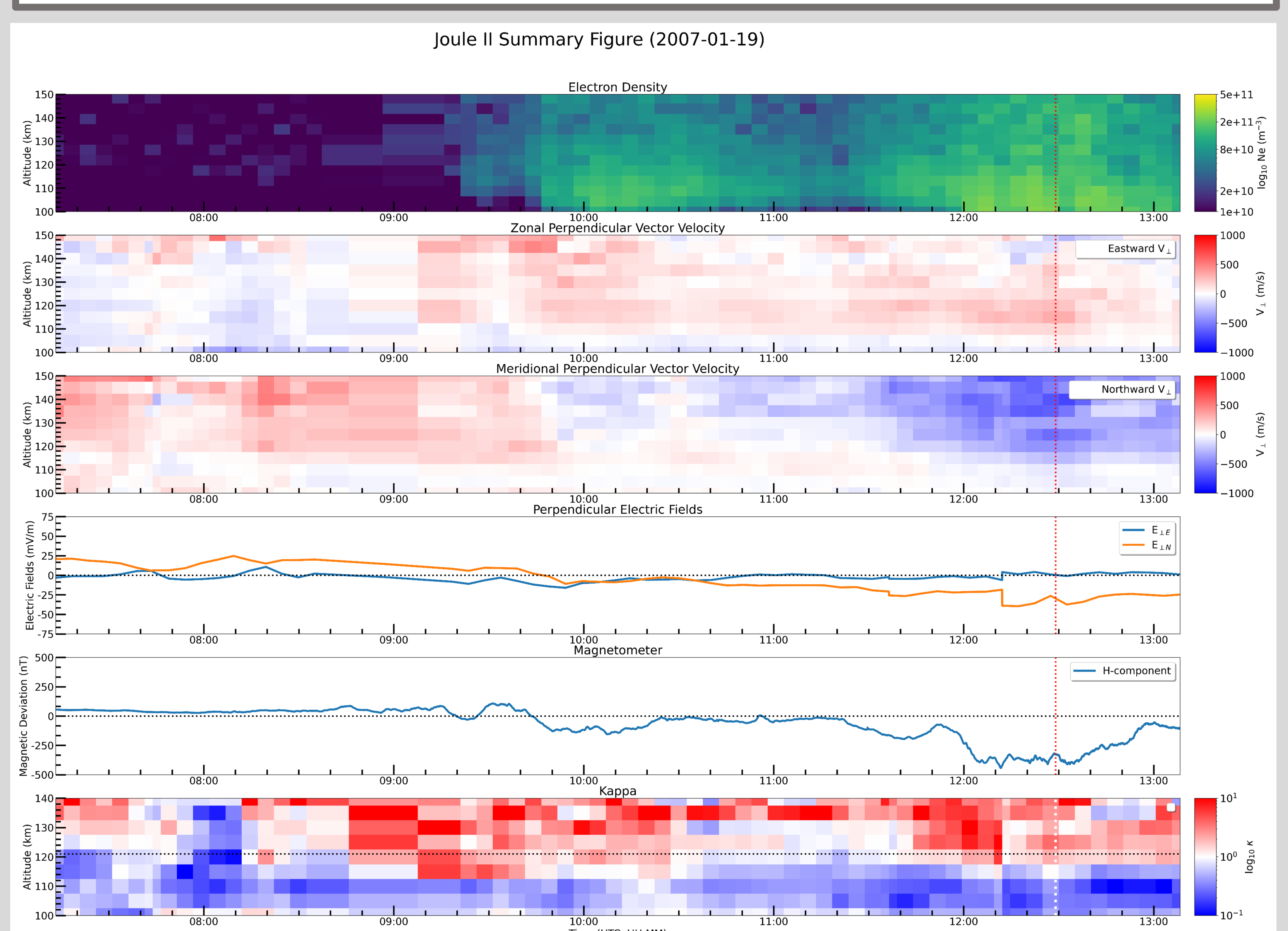

Figure 4: A summary figure depicting the geomagnetic conditions prior to the launch of Joule II from Poker Flat Research Range on January 19th, 2007, at 1229 UT as indicated by the dashed red line corresponding to the post-midnight sector. Calculations of equation (1) are displayed on a log scale in the 5th panel from 100 to 140 km, and the mean ion demagnetization altitude derived from MSIS00 and IRI is shown. The plasma drifts depicted are typical of the dawn side of the auroral oval, and the lack of enhanced perpendicular ion velocities before 11:30 UT results in poor resolving of Kappa which is especially prevalent at 8:00 UT.

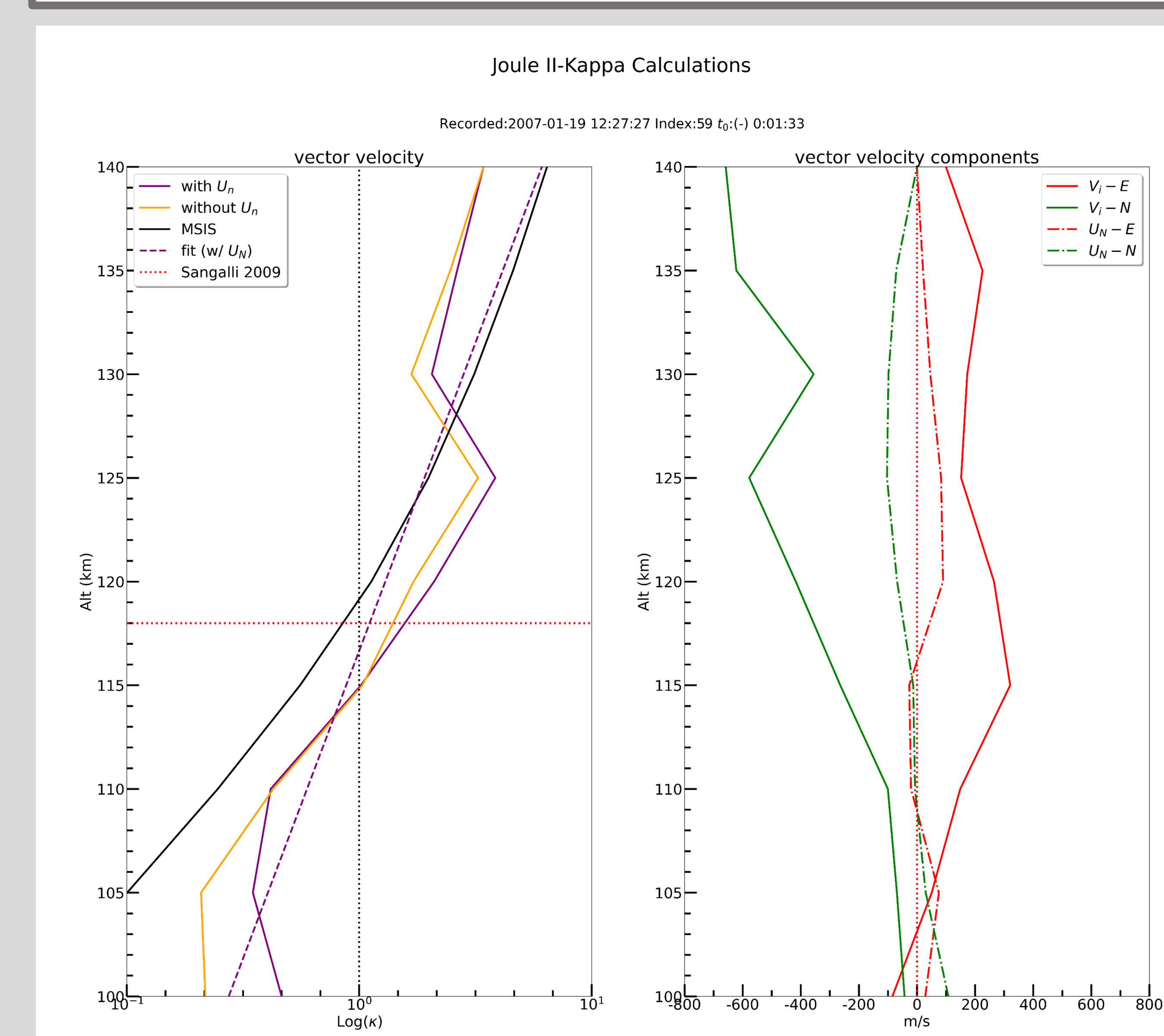

Figure 5: Snapshot of the ion demagnetization altitude closest to the launch of Joule II. The result of the calculation of equation (1) to determine the ion demagnetization altitude is depicted with (gold) and without (purple) neutral winds on the left, and the velocity and neutral wind components of this calculation are shown on the right in geomagnetic coordinates. The fit shows agreement with the modeled value, and the strong southward ion drift is clearly representative of the enhancement in the summary figure.

Summary

- For each campaign, we present summary figures detailing the evolution of geomagnetic activity level along with the calculation of the ion demagnetization altitude at the time of launch.
- Figure 5 shows the snapshot of the ion demagnetization altitude closest to the launch of Joule II. The fit for the ion demagnetization altitude agrees with the previously reported result of 118 ± 0.5 km from Sangalli et al., JGR, 2009.
- **Despite the differences in the ion and neutral forcing for these MLT sectors, the expression of the ion demagnetization altitude is remarkably similar.**
- This project is part of an on-going research investigation.

Acknowledgements: We thank M. Larsen (PI of Joule II) and R. Pfaff (PI of Jets) for providing neutral wind profiles and guidance essential in this study. We also acknowledge NASA grant #80NSSC19K0810 for funding.