Altitudinal responses of the auroral E-region neutral wind to substorm events

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Abstract

In this presentation, we seek to understand the altitudinal response of the auroral E-region neutral wind to substorms using observations from the Poker Flat Incoherent Scatter Radar (PFISR). Zou et al. (2009) presented different nighttime ion drift pattern associated with three different types of substorm events whose onset locations were at, to the east and to the west of PFISR. In addition, Zou et al. (2021) presented different types of latitudinal responses of the F-region neutral wind to substorm events and suggested that the response is highly local time dependent. While these two studies give much insight on the F region ion and neutral responses during substorm events, the E region neutral wind response is not well-understood. Previous studies showed that during disturbed conditions E-region winds, in particular below 110 km, are larger than what tidal theory predicts, while the winds in the upper E-region shows strong impacts from the convection flow. We select events whose onset locations are over the PFISR radar site, but in different MLT sectors using the SuperMag data product during 2010-2019. We present a superimposed epoch analysis of three different types of events after subtracting the quiet background neutral winds. This study will further our understanding of the contribution in a statistical view from forces that are associated with the E-region wind variation during substorm events during different MLT sectors and spanning the altitude range from 90-130 km.

Altitudinal responses of the auroral *E*-region neutral wind to substorm events

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Abstract: In this poster, we seek to understand the local altitudinal response of the auroral *E*-region to substorms using PFISR measurements. The focus is given to the events whose onset magnetic local time are in the premidnight, midnight, and postmidnight sectors at the PFISR radar site. Zou et al. (2009) presented different nighttime ion drift patterns associated with three different types of substorm events whose onset locations were at, to the east and to the west of PFISR. Zou et al. (2021) presented different types of latitudinal neutral wind responses in the F region to substorm events and suggested that the response is up to the MLT sector. While these two studies give much insight on the F region ion and neutral responses during substorm events, the E region neutral wind response is less known. Previous studies showed that E region wind during disturbed conditions is larger than what tidal theory predicts. So, this study will help to understand the forces contributing to the E region wind enhancement during substorm conditions.

The main findings are:
1. After substorm onset, only when the onset time corresponds to MLT premidnight and to the east of PFISR westward winds are observed;
2. After substorm onset, only when the onset time corresponds to MLT midnight and over PFISR, weak eastward winds are observed;
3. After substorm onset, strong southward winds are observed in all conditions.

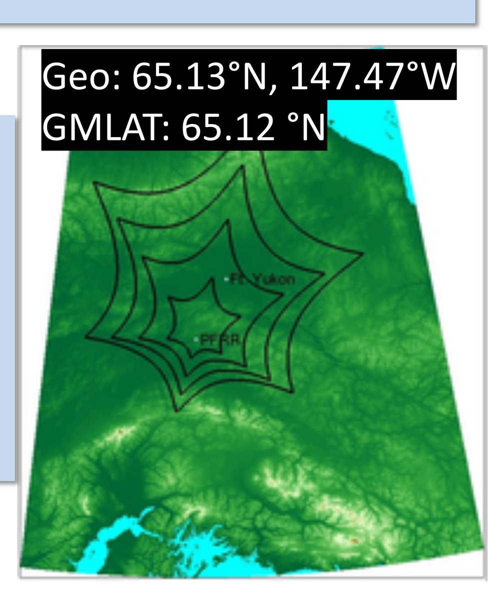
1. INTRODUCTION

- ❑ In the high latitude E region, Ion motion evolves from moving with the neutrals in lower altitudes to dragging the neutrals at higher altitudes due to the change of ion-neutral collision frequency. In this way, the neutral wind can either lose or obtain mechanical energy through momentum transfer in this region.
- ❑ Previous studies show that neutral flow in the auroral region mimics the typical two cell convection with the reversal shifted to later times due to the slow response time. However, this two-cell convection of neutral wind could be shifted in local time by the tides. Therefore, during disturbed conditions, the neutral wind flow will be mainly determined by the competition of the tidal force from below and and the auroral forcing from above. Also, other forces such as heating-related pressure gradient force, centrifugal force and Coriolis force could also impact the neutral wind flow. Thus, the neutral wind in high latitude E region is expected to present different behaviors at different altitudes due to the differences at different altitudes among different forces.
- ❑ During auroral substorm, the ion drift has been fully investigated, but the neutral wind, especially in the E region, is less known.

❑ In this study, we seek to address the following questions:
1. ***What are the characteristics of altitudinal variation of the E region neutral wind during substorms?***
2. ***To what extend are the behaviors of the neutral wind associated with the auroral forcing?***

2. RESEARCH APPROACH

2.1 PFISR



Pulse-to-pulse based, electronic beam-steering phased array radar system, capable of simultaneous measurements of the electron density and line-of-sight ion velocity.
Long pulse code for F region, alternating code for E region.
Four-beam IPY mode and high duty cycle mode.

2.2 Measurements and Data Selection

PFISR measurements between 2010-2019 are collected.
F and E region line-of-sight ion velocities are used to estimate electric field and neutral wind, respectively, through a Bayesian inversion method described in Heinselman et al. (2008).
Substorm list is obtained at Supermag (https://supermag.jhuapl.edu/info/)

$$\mathbf{v}_{los} = (A \cdot D)\mathbf{x} + \mathbf{e}_{los}$$

$$x = [E_{pe}\ E_{pn}\ E_{||}\ U_{pe1} U_{pn1}\ U_{||\ 1}\ U_{pe2}\ U_{pn2} U_{||\ 2} \ldots\ U_{pen}\ U_{pnn}\ U_{||\ n}]^T$$

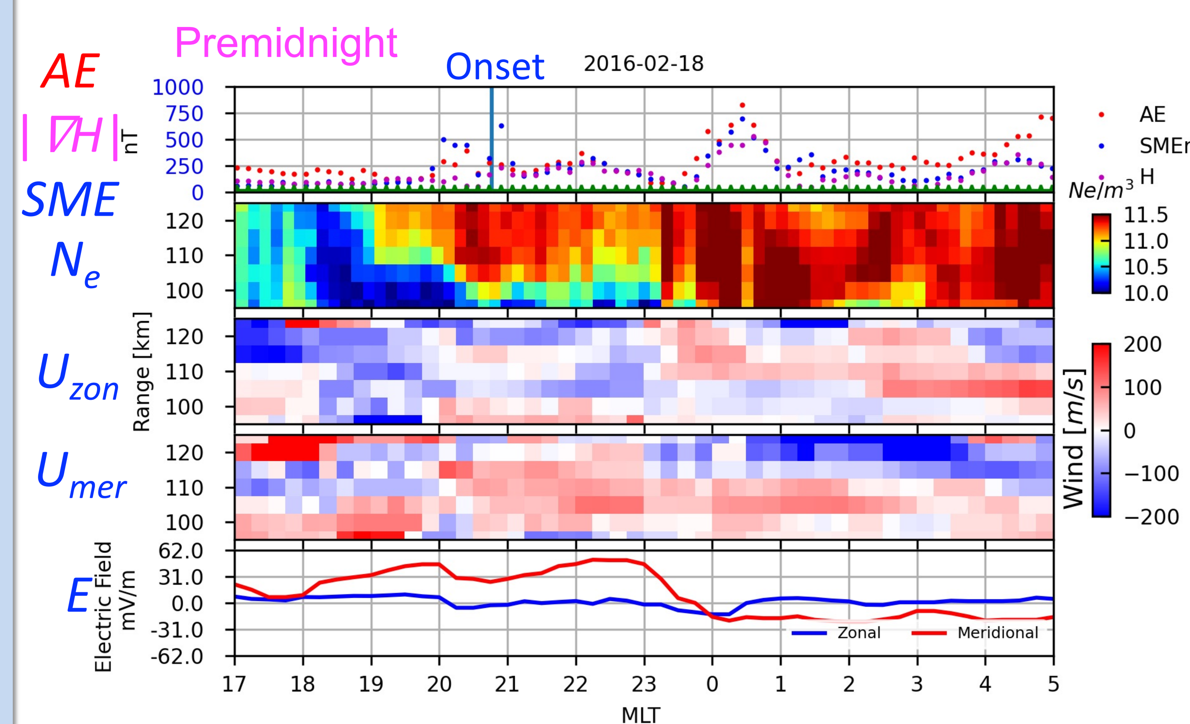
Isolated substorm events: **Dst_min > -50 nT** (past 3 days), **AE < 300 nT** (before onset)
Substorm strength: **AL_min < -200 nT after onset**
Substorm onset MLT sector: **premidnight 1700-2100 MLT; midnight 2100-0100 MLT; postmidnight 0100 – 0500 MLT**

2.3 Methods

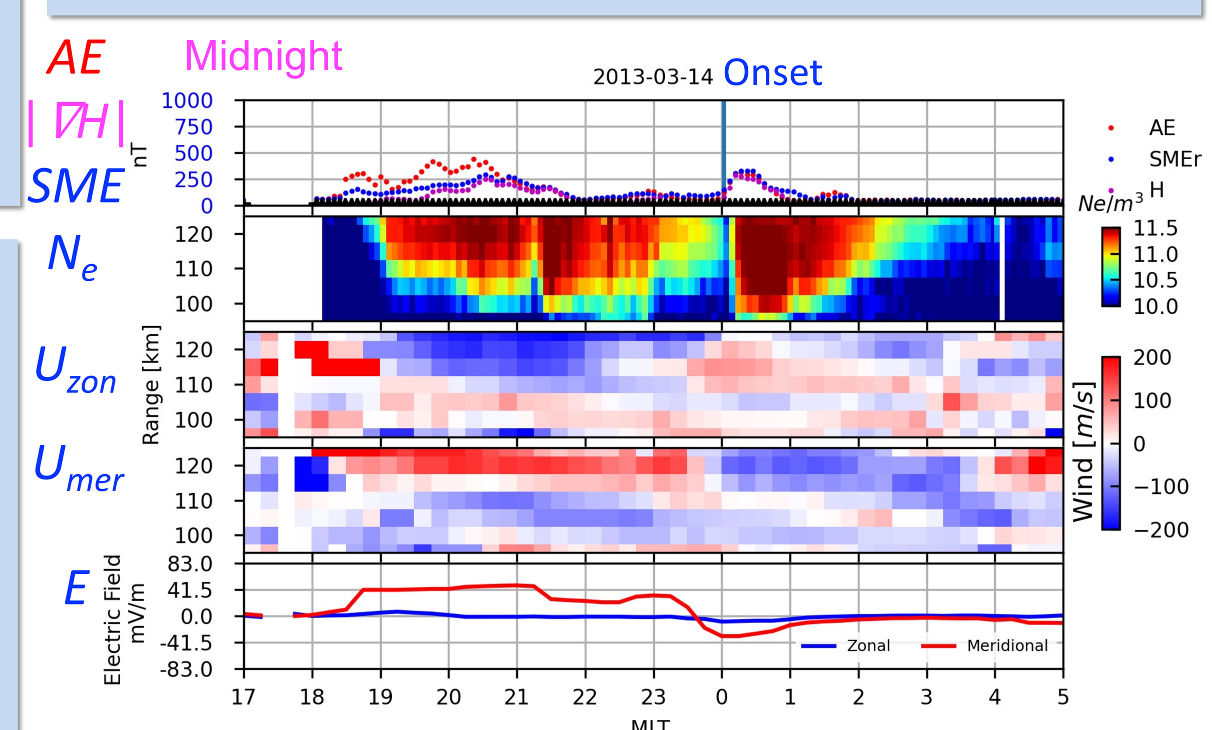
Measurements are filtered with a 1-hour median filter every 15 minutes. Measurements of the E region electrodynamic parameters during the one hour before the substorm and 4 after onset are selected to do superposed epoch analysis by aligning with the substorm onset MLT.
To aid the analysis, the electric field, electron density, neutral wind in the E region are all presented.

3. RESULTS AND DISCUSSION

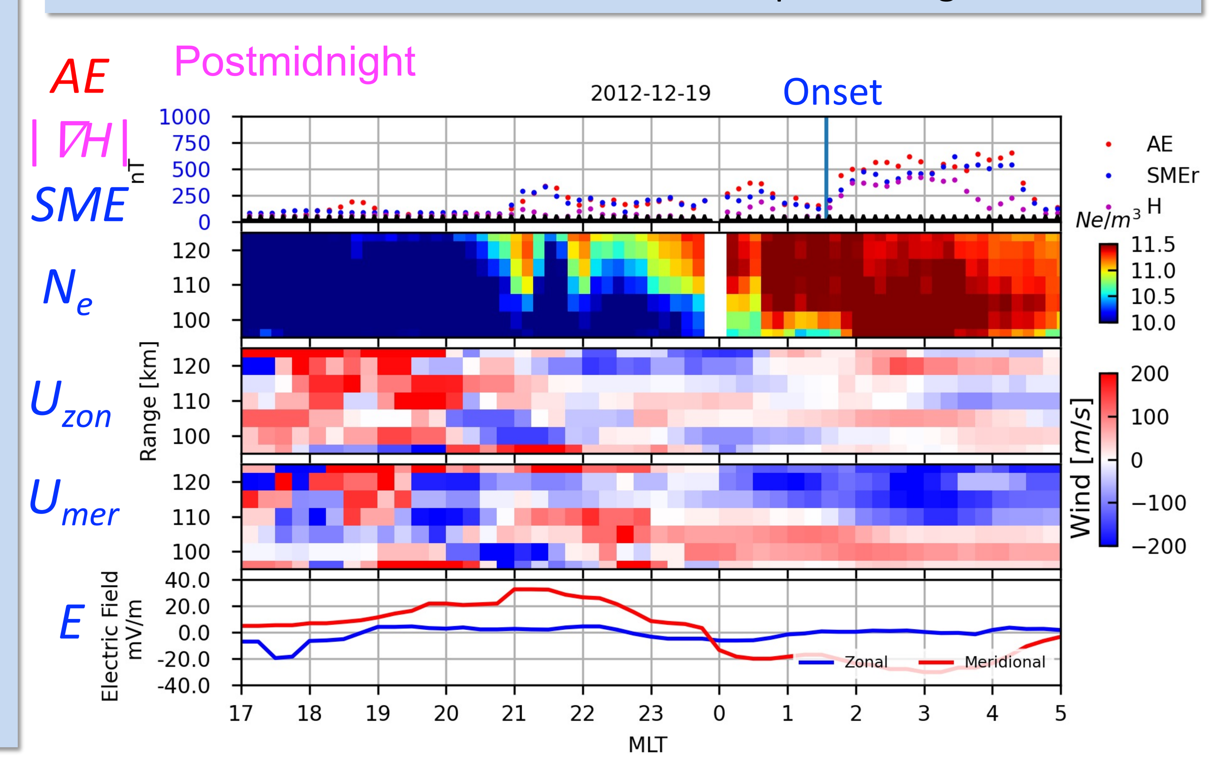
3.1 Examples



After the weal substorm onset, zonal wind keeps westward at the upper E region and the meridional wind keeps blowing northward.



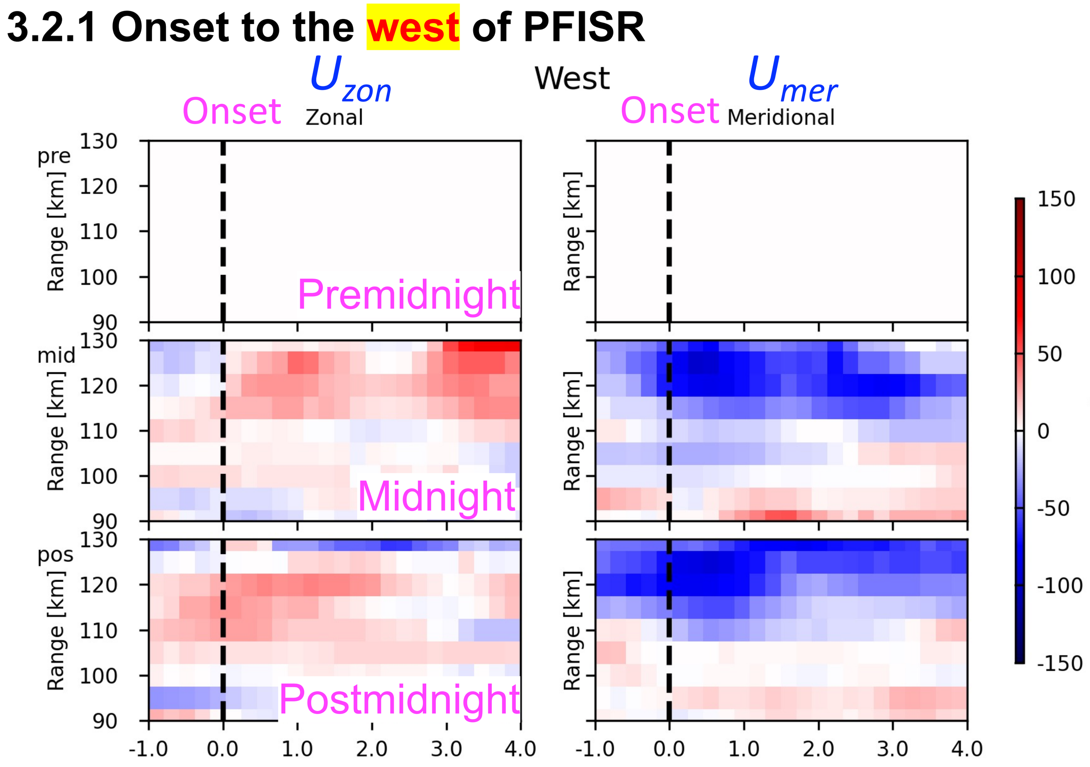
During the growth phase before the onset, winds turn eastward and southward in the upper E-region. Eastward wind blows for 2 hours after onset and southward wind keeps blowing for 3.5 hour.



Before the substorm onset, winds blow eastward and southward in the upper E-region.
After the onset, southward wind becomes much larger.

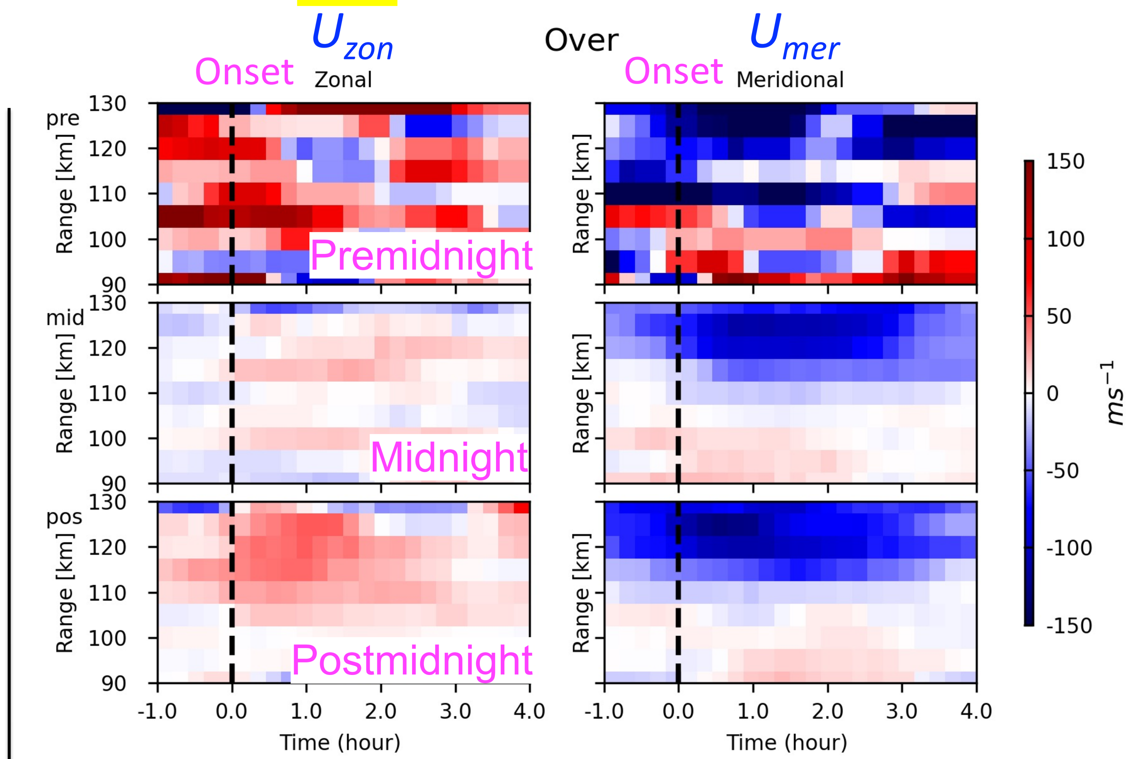
3.2 Superposed Epoch Analyses

3.2.1 Onset to the west of PFISR



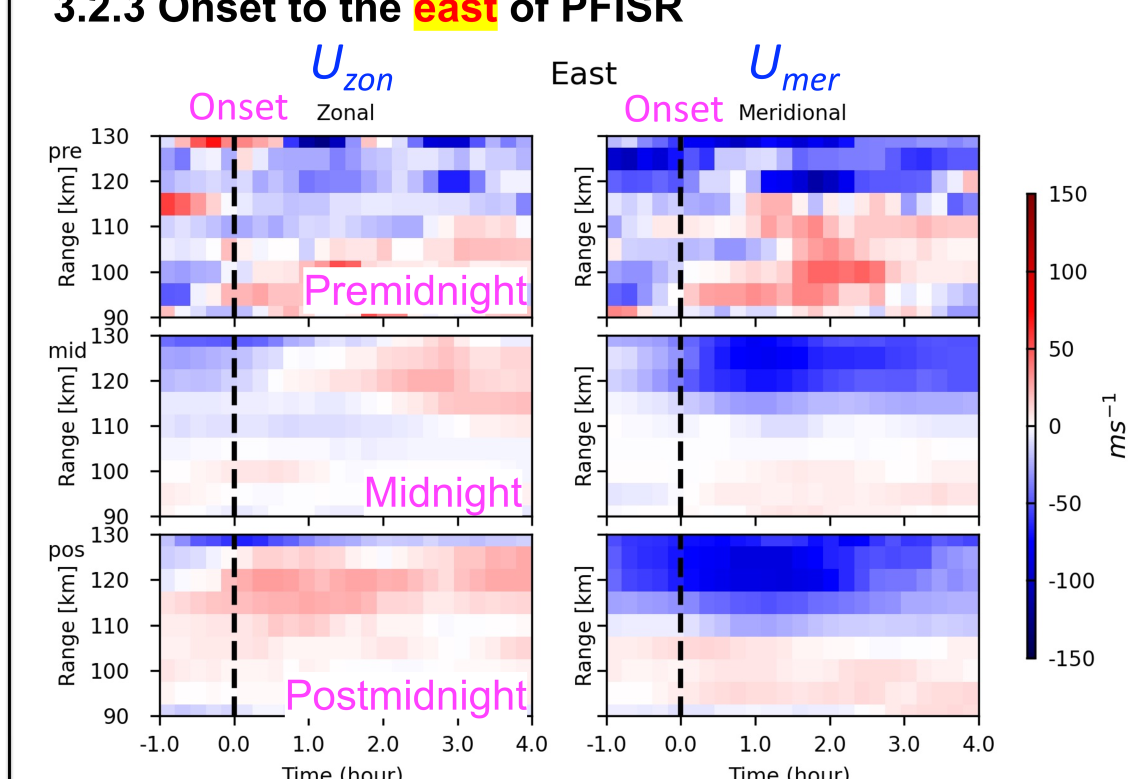
☞For the zonal wind, it blows westward before the onset and turns eastward after onset in the upper E-region in the midnight onset condition. It is eastward before the onset and keeps eastward for 2 hours after the onset in the postmidnight onset condition.
☞ For the meridional wind, it blows southward and is weak before the onset and becomes enhanced southward after the onset for 3 hours for the midnight onset condition.

3.2.1 Onset over PFISR



☞ For the zonal wind, it blows westward and is weak before the onset and turn eastward after the onset in the upper E-region for the midnight onset condition. It is weakly eastward before the onset and becomes enhanced eastward after the onset in the postmidnight onset condition. The enhancement is greater than that in the midnight onset condition.
☞ For the meridional wind, it blows southward before the onset and gets enhanced after the onset in the upper E region in the midnight onset condition. It gets more enhanced after the onset in the postmidnight onset condition.

3.2.3 Onset to the east of PFISR



☞For zonal wind, it blows westward before and after the onset for the premidnight onset condition. It blows westward before the onset and turns eastward around 0.5 h after the onset during the midnight onset condition. It is weak and blows westward before the onset and turns eastward around the onset during postmidnight onset condition.
☞For the meridional wind, it blows southward in three conditions and becomes much stronger after onset during the midnight and postmidnight onset condition.

4. Summary

I. **Before the onset**, for the zonal wind, westward wind is observed when the onset is in premidnight sector and to the east of PFISR. Westward winds are observed for the onset located to the west of, over and to the east of PFISR and in the midnight sector. Weak westward wind is observed when the onset is in the postmidnight and to the east of PFISR. It is eastward when the onset is in the postmidnight and to the west of and over PFISR. For the meridional wind, it is generally southward in all conditions with stronger southward wind in the postmidnight onset conditions.
II. **After the onset**, for the zonal wind, it blows eastward almost in all conditions with exception when the onset is in the premidnight sector and to the east of PFISR and the wind the wind blows westward. Stronger eastward winds are observed in the postmidnight onset conditions, especially when the onset is over PFISR. For the meridional wind, southward winds become enhanced and get much more enhanced during postmidnight onset condition.
III. Further studies by subtracting the background winds should be done to better characterize the impacts from the substorm.

References:
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3. Heinselman, C. J., and M. J. Nicolls (2008), Radio Sci., 43, RS5013, doi:10.1029/ 2007RS003805.