Altitudinal neutral wind responses in the high latitude E region during disturbed conditions

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CLEMSON

PHYSICS AND ASTRONOMY

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  - Weakly disturbed
  - Moderately disturbed
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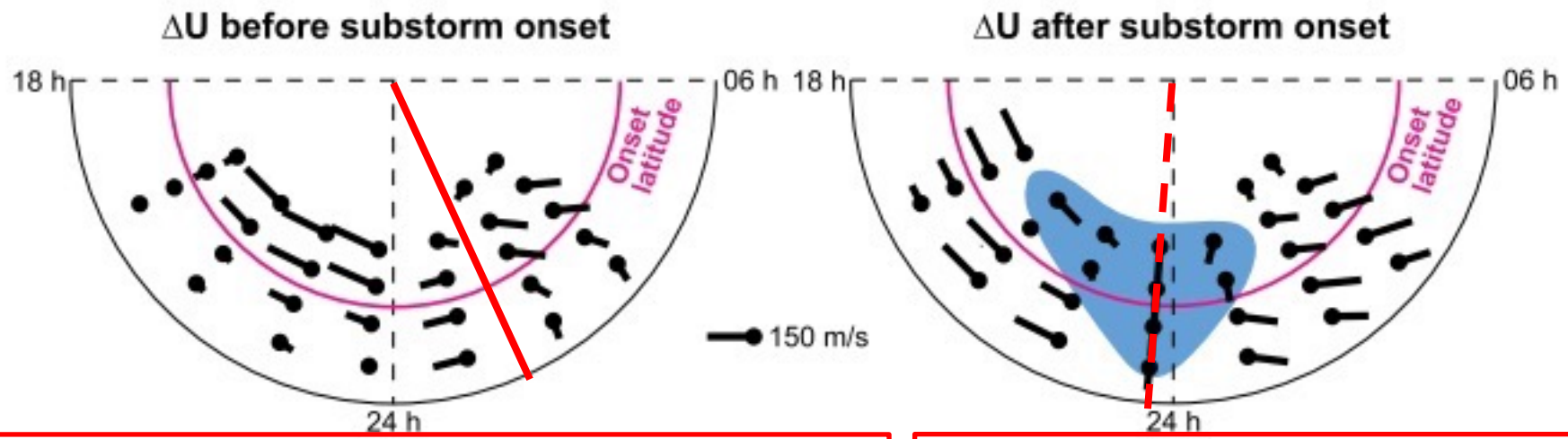
Introduction

- High latitude F region Neutral wind



Before onset:
1. Enhanced two cell circulation, reversal after midnight
2. Larger meridional wind in postmidnight sector than in the evening sector.

After onset:
1. Depressed zonal wind around reversal region (shifted to before midnight)
2. Enhanced zonal wind away from reversal region.
3. Larger meridional wind in postmidnight sector than in evening sector.

Zou, Y., Lyons, L., Conde, M., Varney, R., Angelopoulos, V., & Mende, S. (2021). Effects of Substorms on High-Latitude Upper Thermospheric Winds. *Journal of Geophysical Research: Space Physics*, *126*(1).

Introduction

- High latitude E region Neutral wind

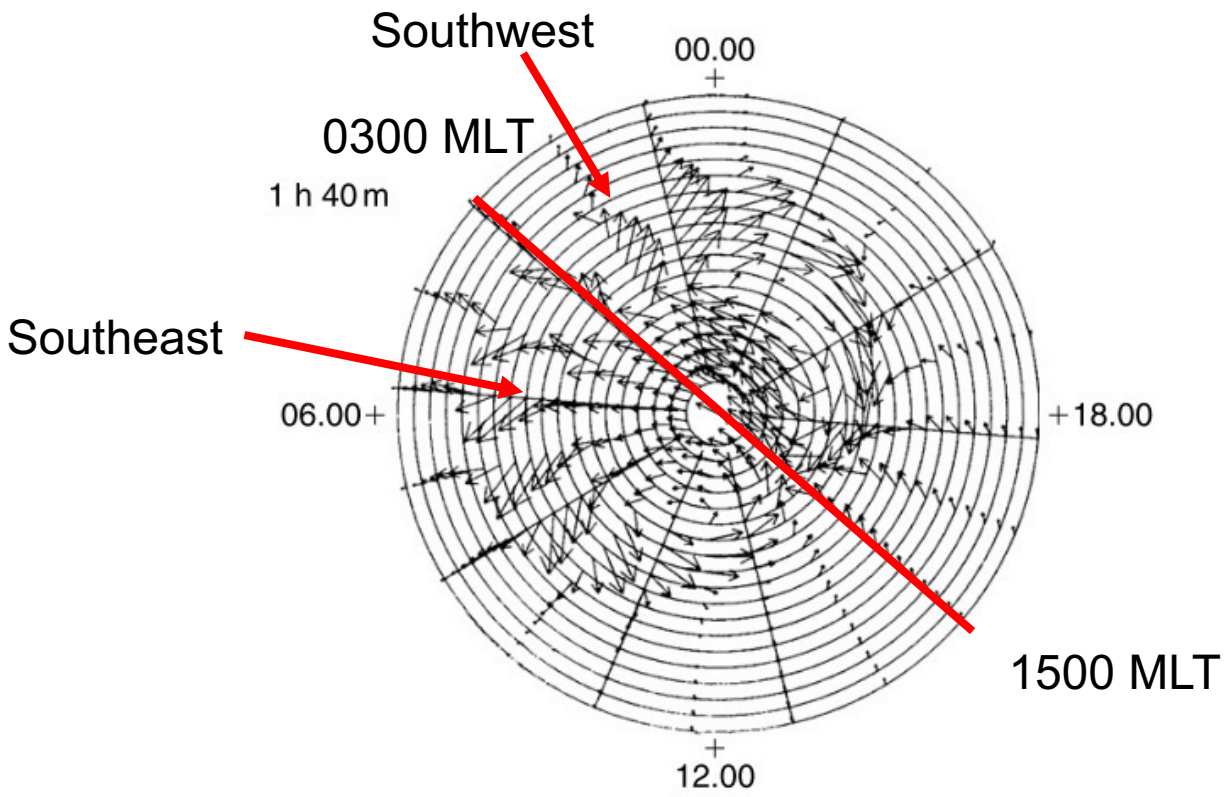


Figure 9.19 Plot of wind vectors from 50° latitude to the pole at 120-km altitude during a simulated substorm. The plot shown is at a time of 1 h 40 min after the substorm onset. Scale: an arrow the same length as 2° in latitude corresponds to 40 m/s. [After Fuller-Rowell and Rees (1981). Reproduced with permission of Pergamon Press.]

Kelley, M. C. (2009). *The Earth ' s Ionosphere. Second Edition*.

Introduction

- Altitudinal response of E region neutral wind during disturbed condition

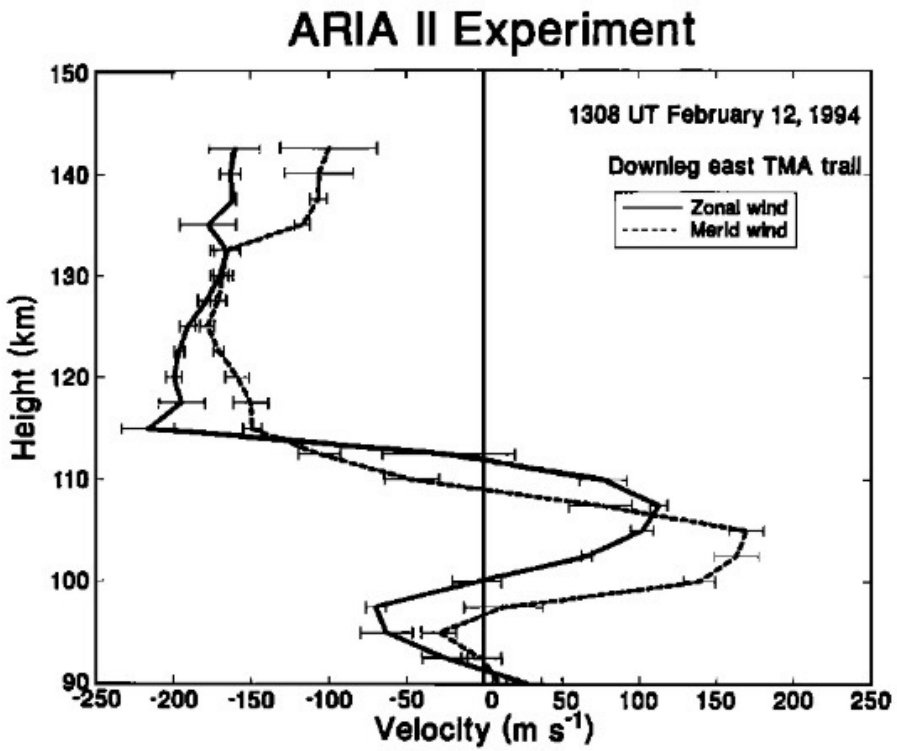


Figure 3. Wind profile observed during high magnetic activity on Feb 12, 1994.

Larsen, M. F., Christensen, A. B., & Odom, C. D. (1997). Observations of unstable atmospheric shear layers in the lower E region in the post-midnight auroral oval. *Geophysical Research Letters*, *24*(15), 1915–1918.

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Motivation and Science questions

- There are very limited studies on the E region neutral wind through ISR observations. Nozawa and Brekke (1995) did a statistical study using EISCAT measurements (11 days) under disturbed condition. Many E region wind measurements are made through chemical release experiments.

- Nearly continuously sampled PFISR measurements during 2010-2019 ensure enough events to do a statistical study.

  - ***What are the typical features of the E region neutral wind responses during different disturbed conditions?***

  - ***How are the features related to the auroral forcing from the magnetosphere and tidal forcing from below?***

Methodology

- Data selection
  - PFISR measurements in winter (Nov, Dec, and Jan) between 2010-2019
  - Local magnetometer measurements

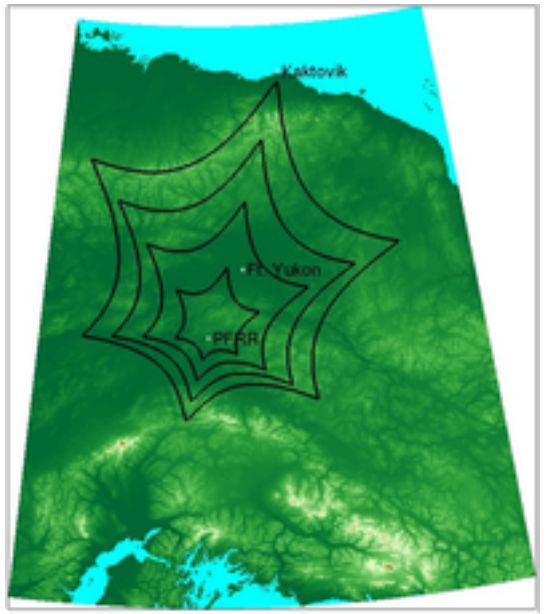
- Characterizing the impact of the auroral activity
  - Disturbance level indicated by H component ($\Delta H = H - H_{mean}$) from the local magnetometer

h1 h2

$$\Delta H \begin{cases} [-100, 0], & quiet \\ [-300, -100], & weakly\ disturbed \\ [-500, -300], & moderately\ disturbed \\ [-1000, -500], & strongly\ disturbed \end{cases}$$

  - Ensuring significant response of the neutral wind

    Duration (ΔH < h2) >= 1 hour and Duration (ΔH > h1) < 1 hour between 1700 – 05 MLT



https://amisr.com/amisr/about/about_pfisr/

Results

$H_{min} \in [-100, 0] nT$

Quiet

ΔH

Ne

E

F region drift

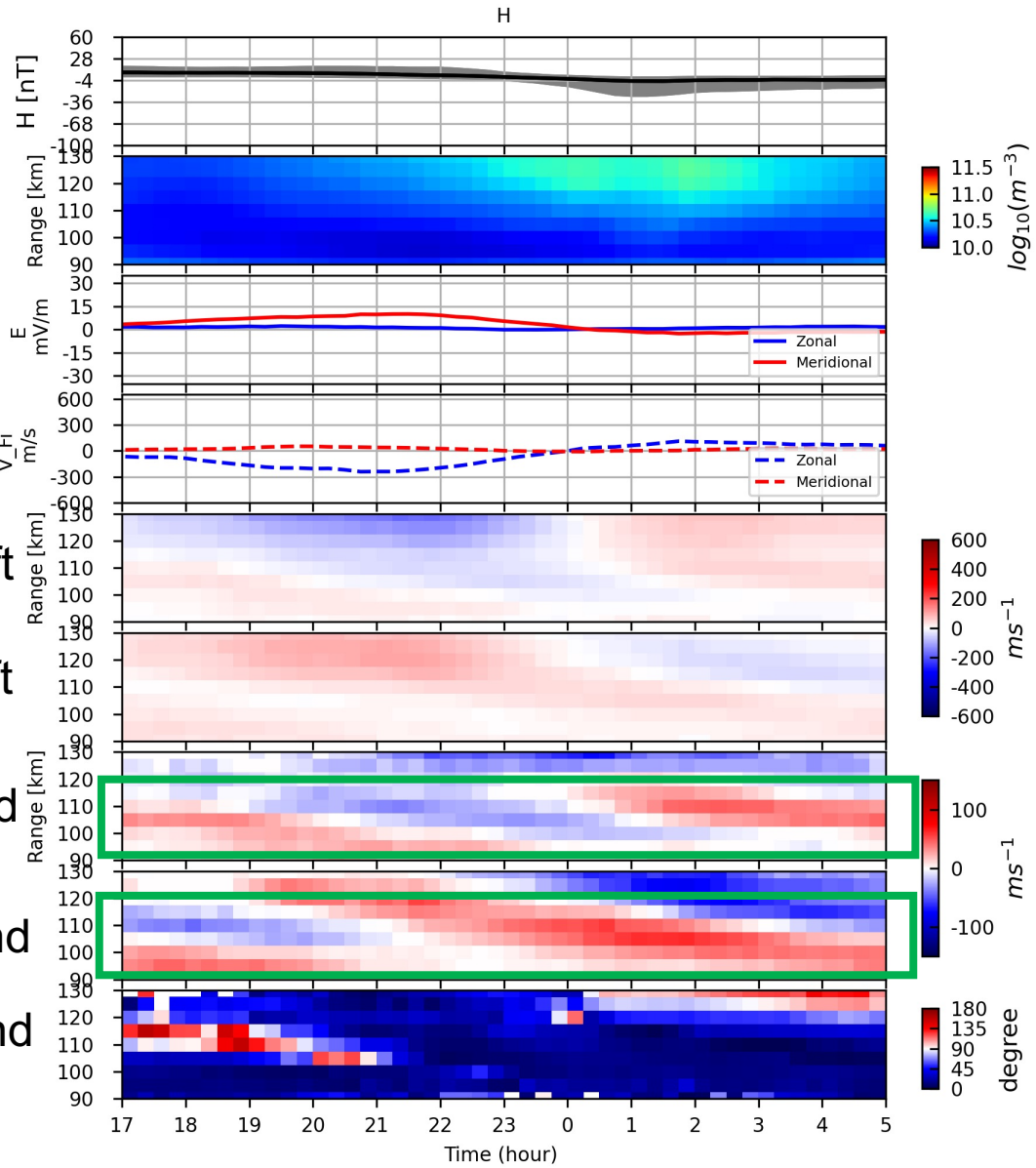
E region zonal drift

E region meridional drift

E region zonal wind

E region meridional wind

Angle between wind vector and E region ion velocity



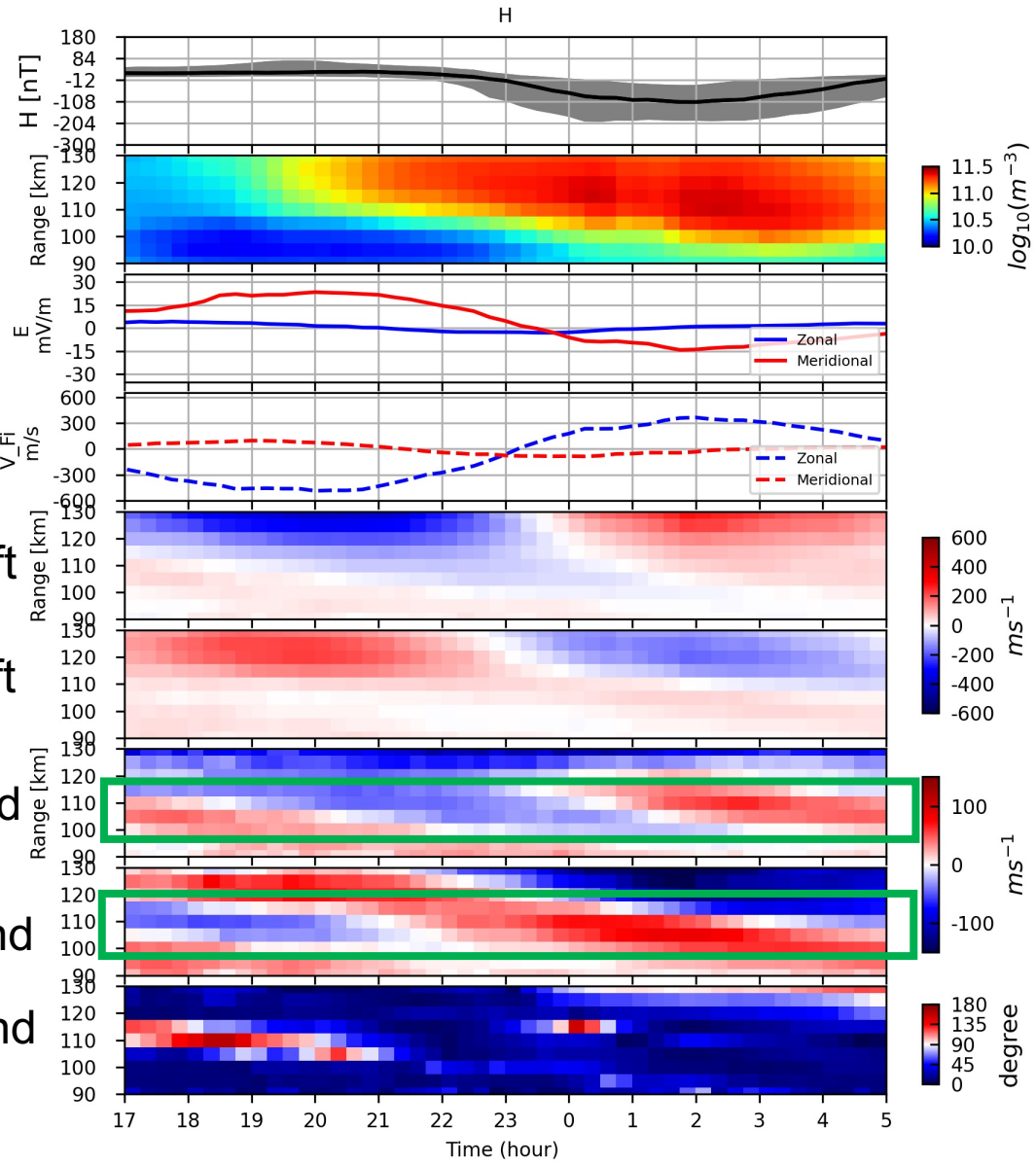
352 events

1. Tidal features are seen below 120 km.

Results

$H_{min} \in [-300, -100] nT$

Weakly disturbed



ΔH

Ne

E

F region drift

E region zonal drift

E region meridional drift

E region zonal wind

E region meridional wind

Angle between wind vector and E region ion velocity

111 events

2. Between 100-120 km, zonal and meridional winds are enhanced compared to previous figure.

Above 120 km, zonal and meridional winds show strong impact from the convection plasma flow.

Results

$H_{min} \in [-500, -300] nT$

Moderately disturbed

ΔH

Ne

E

F region drift

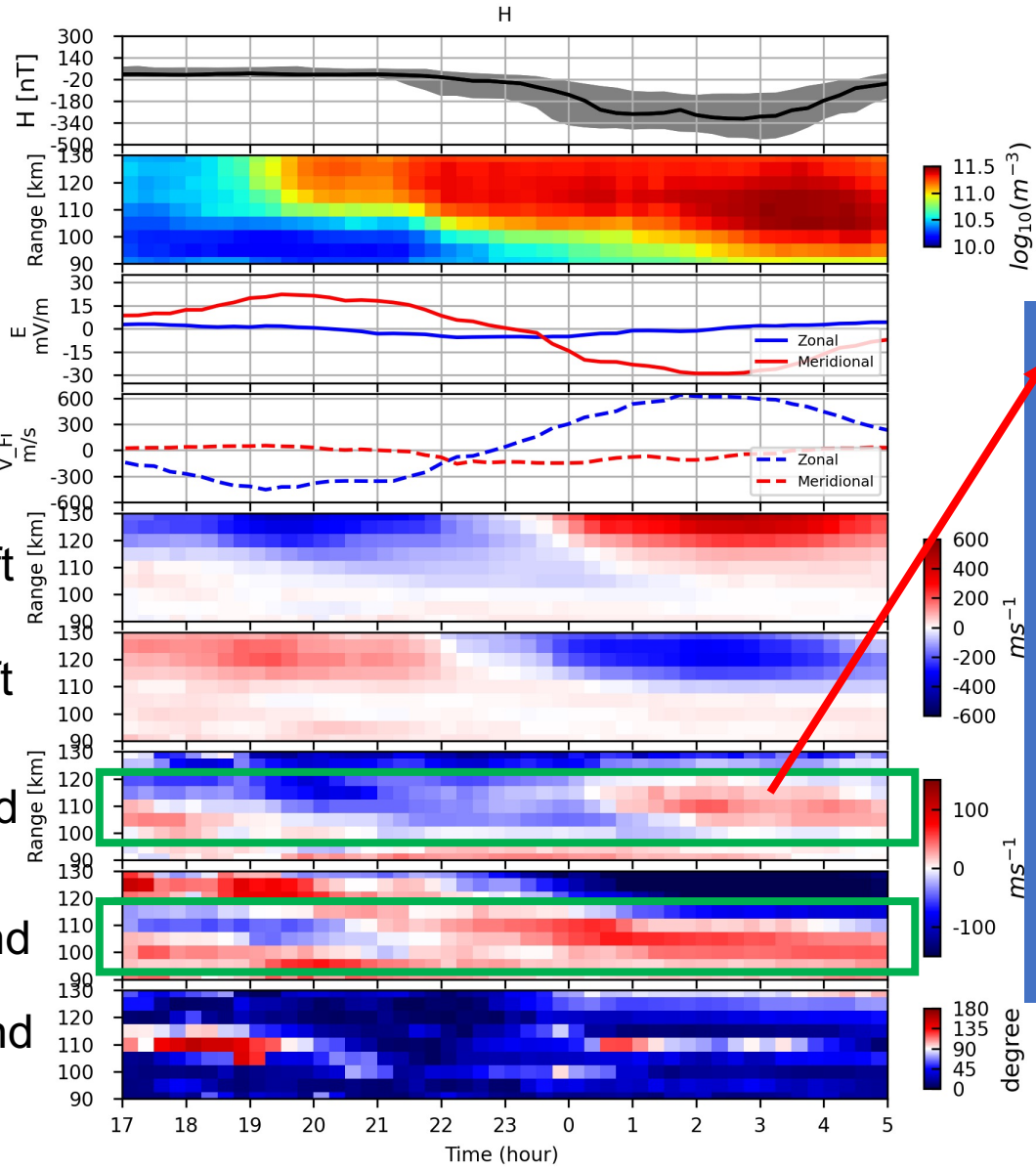
E region zonal drift

E region meridional drift

E region zonal wind

E region meridional wind

Angle between wind vector and E region ion velocity



32 events

3. Between ~100-115 km, tidal feature is depressed compared to previous figure. Why?

Between 115-120 km, zonal wind is enhanced in the premidnight sector, and depressed in the postmidnight sector. Meridional wind is enhanced in the post-midnight sector.
Hall drag effect?

Results

$H_{min} \in [-1000, -500] nT$

Strongly disturbed

ΔH

Ne

E

F region drift

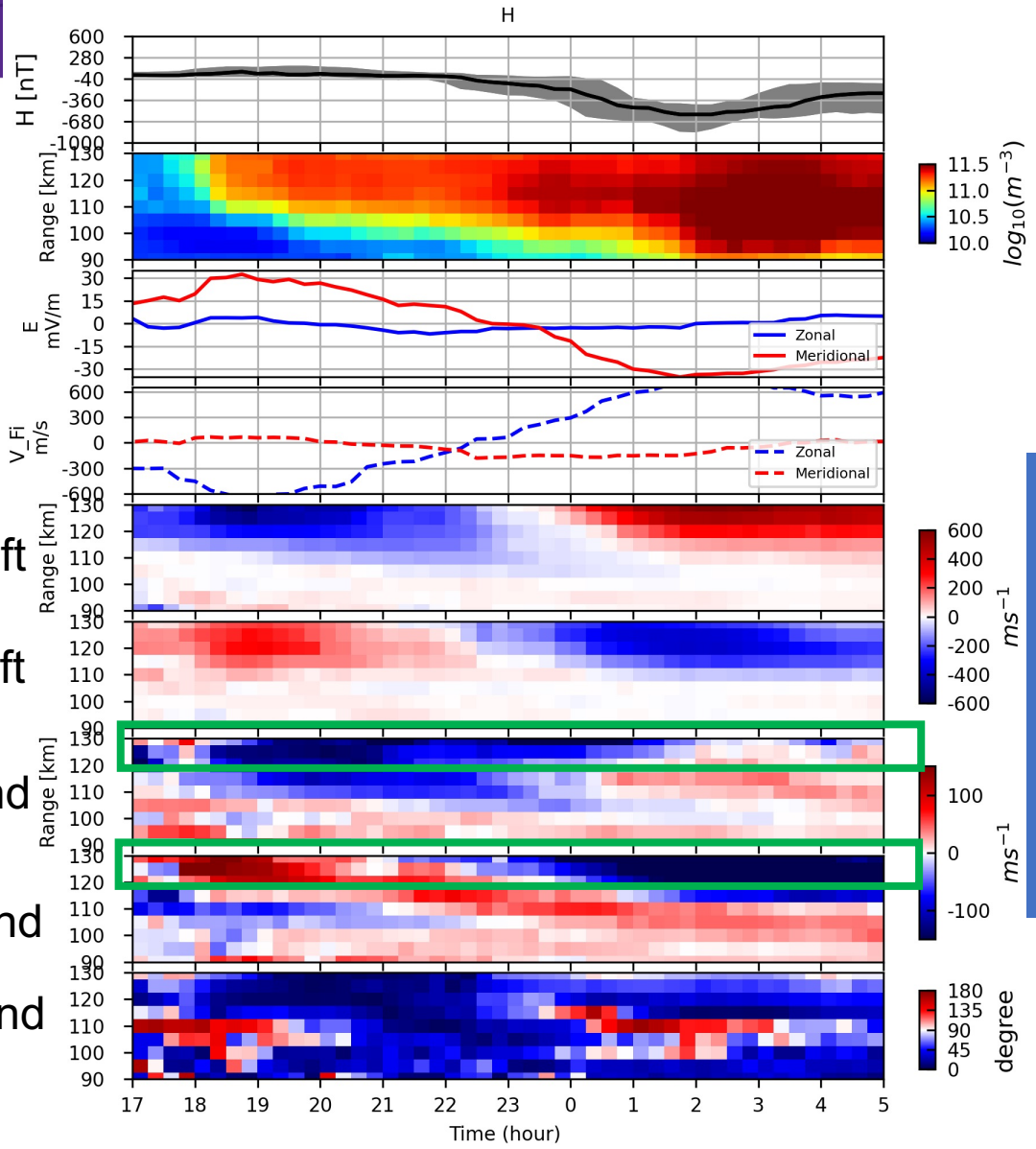
E region zonal drift

E region meridional drift

E region zonal wind

E region meridional wind

Angle between wind vector and E region ion velocity

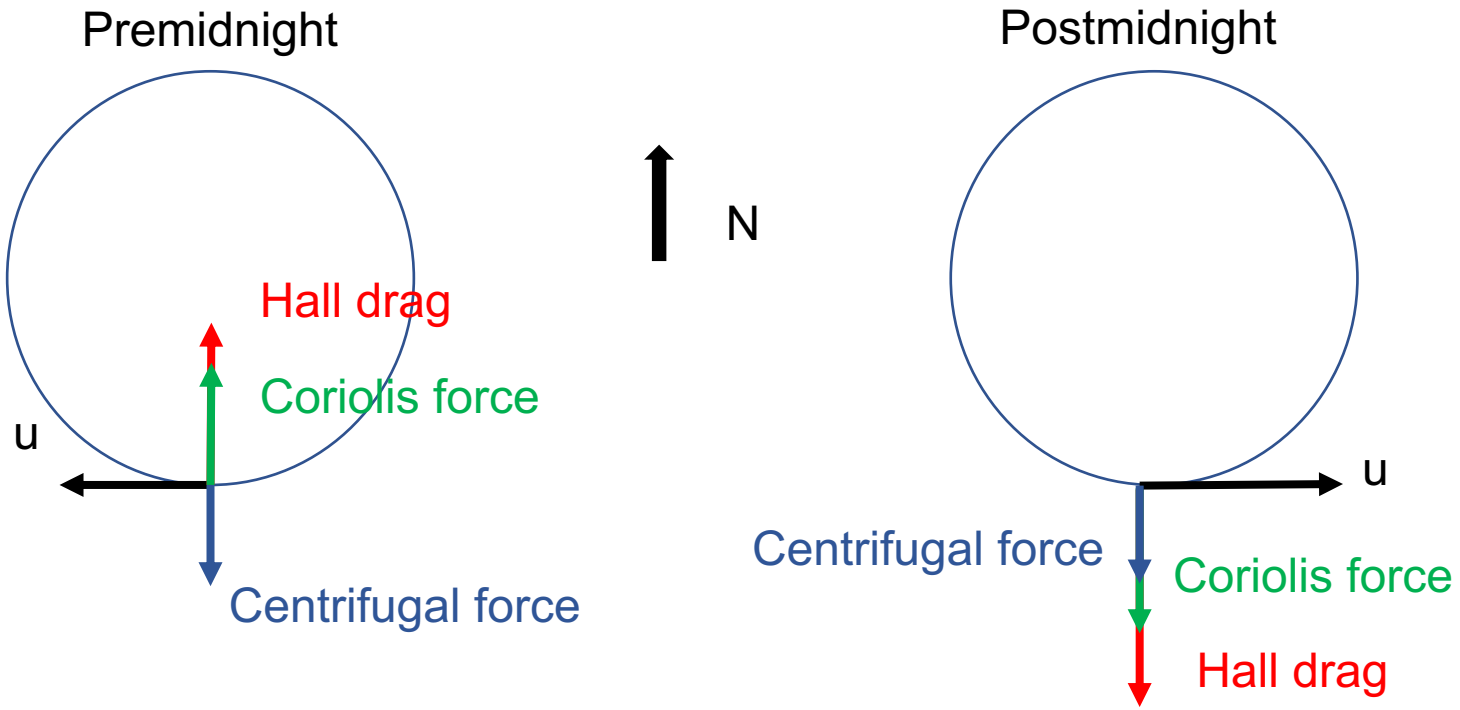


14 events

4. Above 120 km, in the premidnight sector, westward and northward winds become much stronger; in the postmidnight sector, zonal wind turns to eastward; southward meridional wind becomes much stronger.

Results

- Forces on the zonal wind (Hall drag effect)



Results

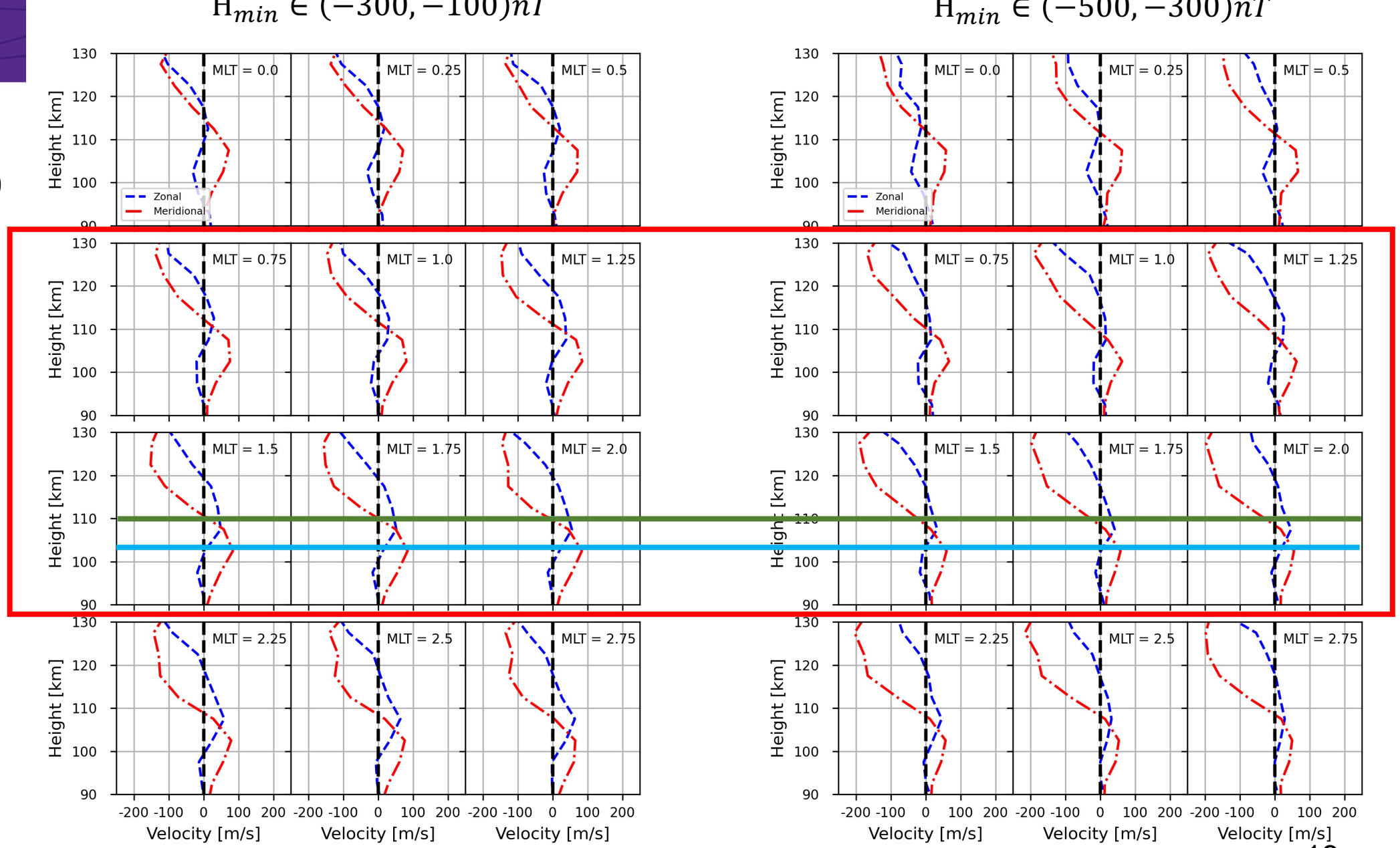
- With the increase of the geomagnetic activity, why is the tidal feature enhanced at first and then depressed?
  - A guess:

    Because of the change (dispersion relation) in the E region neutral environment by Hall drag during different disturbed conditions,
    - Tides of different periods (diurnal and semidiurnal) could be trapped in the E region and cause enhancements?
    - Some components of tides (diurnal) could not propagate up to the E region and cause depression?
    - A discussion could be found in Larsen et al. (1995).

Larsen, M. F., Marshall, T. R., Mikkelsen, I. S., Emery, B. A., Christensen, A., Kayser, D., Hecht, J., Lyons, L., & Walterscheid, R. (1995). Atmospheric Response in Aurora experiment: Observations of E and F region neutral winds in a region of postmidnight diffuse aurora. *Journal of Geophysical Research*, *100*(A9), 17299.

Results

Shear
(90-120 km)



Results

$H_{min} \in (-300, -100) nT$

$H_{min} \in (-500, -300) nT$

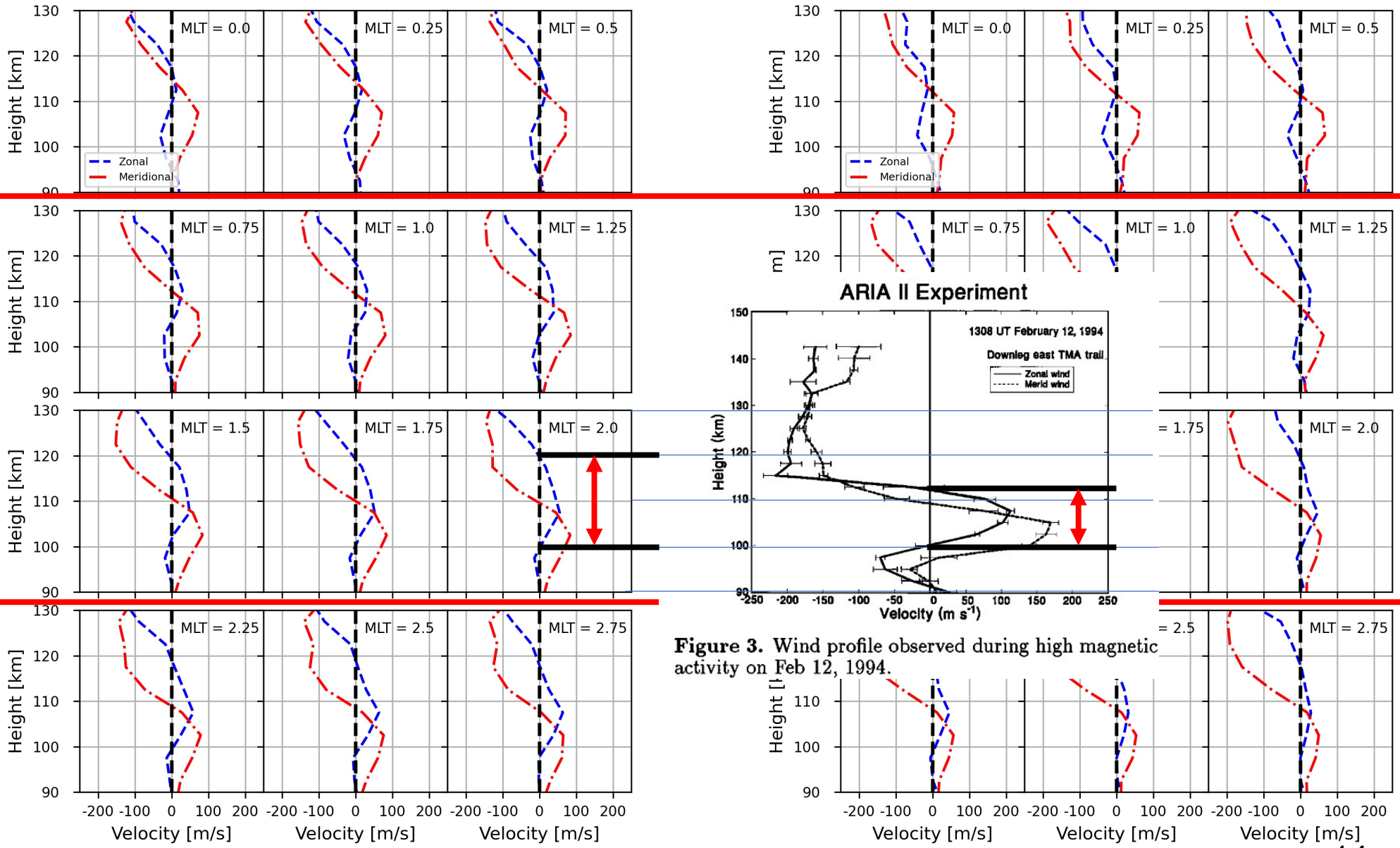


Figure 3. Wind profile observed during high magnetic activity on Feb 12, 1994.

Results

$H_{min} \in (-300, -100) nT$

$H_{min} \in (-500, -300) nT$

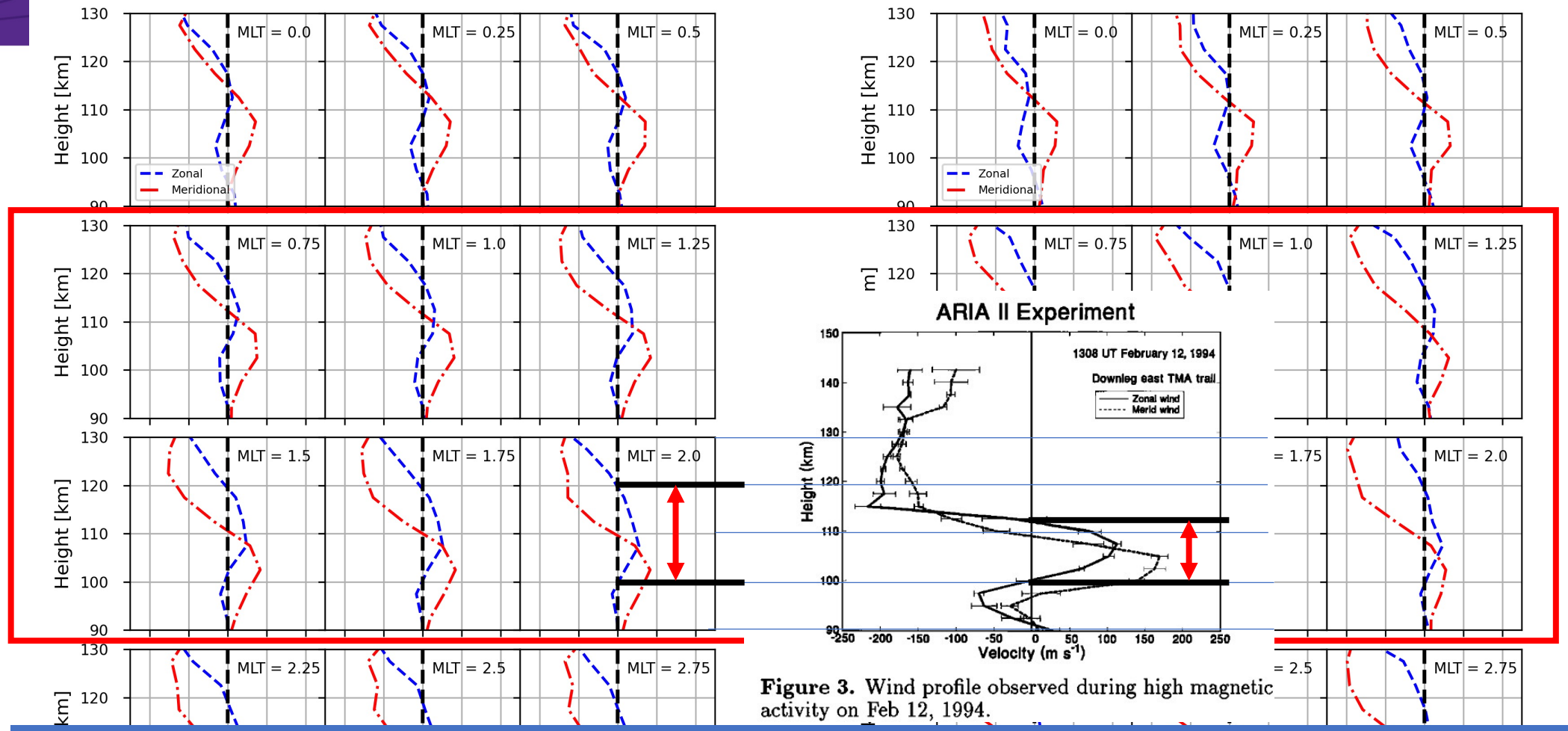


Figure 3. Wind profile observed during high magnetic activity on Feb 12, 1994.

5. The maximum magnitudes around 110 km for zonal wind and around 102 km for meridional wind are smaller compared to that of TMA measurements. The maximum of meridional wind is greater than zonal wind in both. Shears below and above the maximum are seen in the zonal wind but only above for the meridional wind. The vertical scale is larger than the TMA measurements.

Summary

- **Tidal features** are seen in the zonal and meridional winds below 120 km and could be **enhanced** during **weakly disturbed condition**. While the geomagnetic activity becomes more **stronger**, they will be **depressed**. This could be associated with the change of the E region neutral environment.

- With the increase of the geomagnetic activity, above 120 km, zonal and meridional winds show direct impacts from **convection flow**.

- Between 115-120 km the zonal wind could be enhanced in the premidnight sector and reduced in the post-midnight sector; meridional wind could be reduced in the premidnight sector and enhanced in the postmidnight sector. These could be related to the **Hall drag effects**.

- **Shear** between 90-110 km during postmidnight is seen in the zonal wind but not in the meridional wind.