Thermospheric wind variations at substorm onset: Multi-event study using a Fabry-Perot interferometer at Tromsoe, Norway

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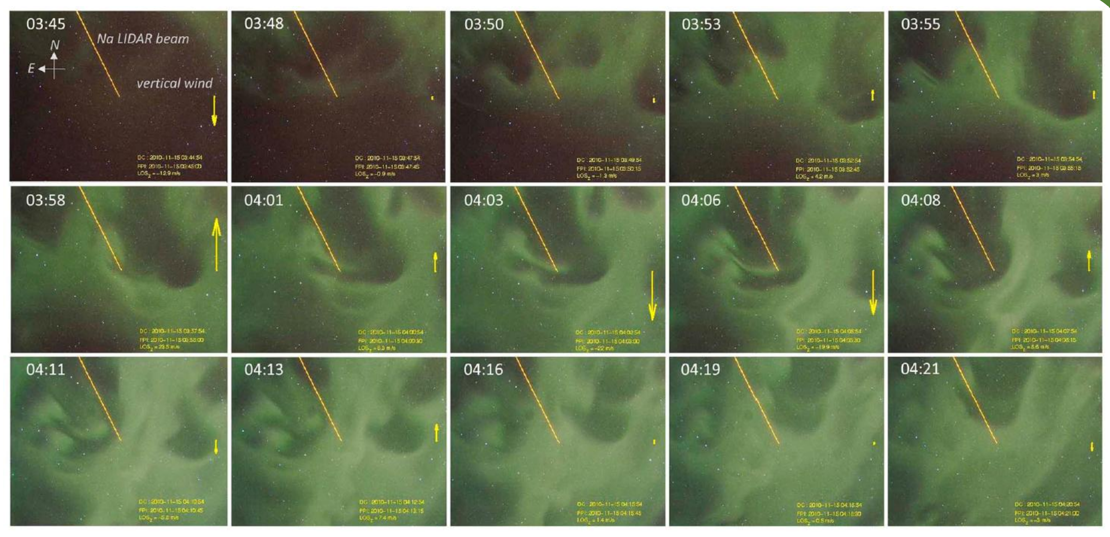
Introduction

In this study, we focused on the thermospheric wind variations at the **onset of isolated substorms**. Substorms input energy into the ionosphere from the magnetosphere, during which the high-latitude ionosphere and thermosphere are severely influenced. One purpose of this study is to find the **characteristics of thermospheric wind variations at the substorm onset**. At the same time, we expect to investigate the possibility that **wind variations as a potential driver of substorm-onset-related ionospheric current system** according to the magnetosphere-ionosphere coupling substorm model [Kan, 1993].

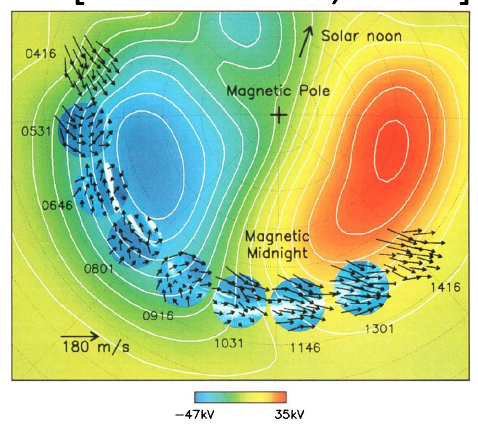
A Fabry-Perot interferometer (FPI) at Tromsoe of Norway provided us with wind observations from Doppler shift of both red-line (630.0 nm for the F region) and green-line (557.7 nm for the E region) emissions of aurora and airglow. We used seven-year data from 2009 to 2015 with a time resolution of ~13 min. We obtained **4** red-line events and **5** green-line events located at different local times. In order to discuss the possible causes of these wind variations, we checked the IMAGE magnetometer data, all-sky auroral images, directional winds as well as the real-time SuperDARN and EISCAT data.

At high latitudes, thermospheric wind is a mixture of **tidal wind** and wind driven by **plasma convection**.

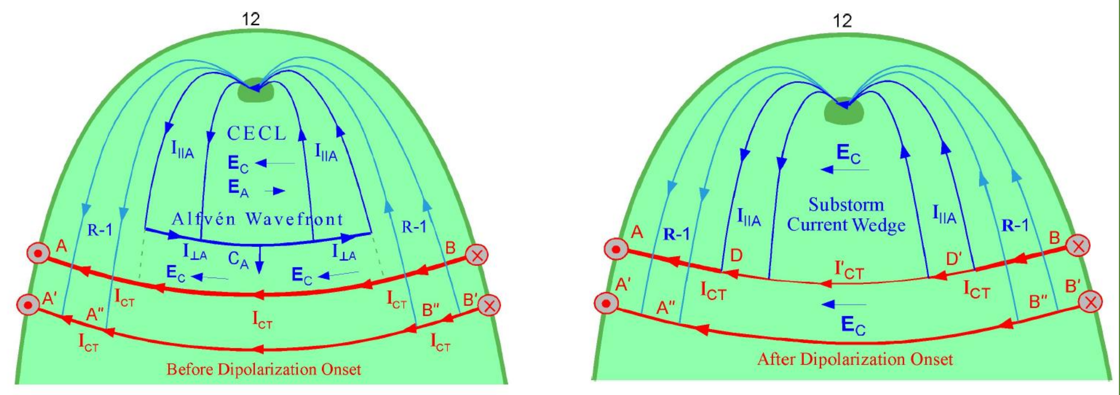
- Thermospheric wind variations **at the substorm onset** have not been studied yet.
- In the M-I coupling substorm model, The triggering for **initial ionospheric current system** at the substorm onset is still unknown. Wind variations may act as a possible driver.



[Oyama et al., 2016]

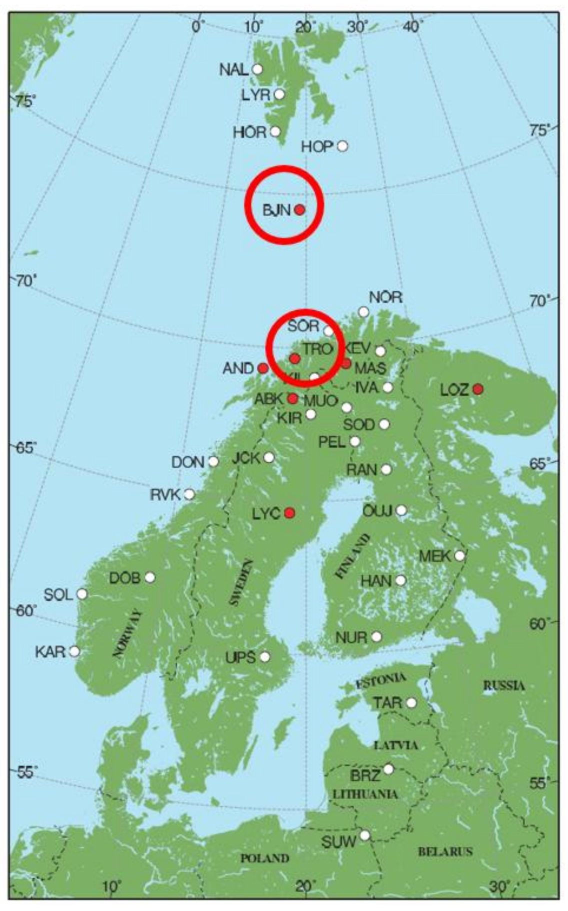


[Conde et al., 2001]

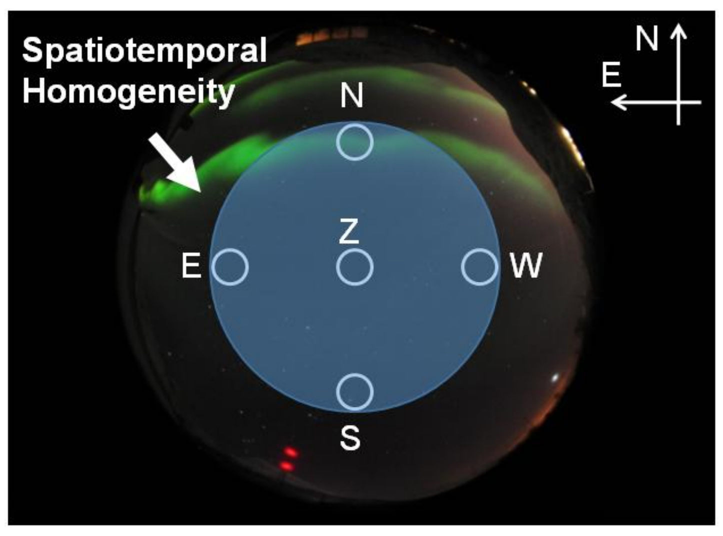


[Kan et al., 2011]

[IMAGE Website: http://space.fmi.fi/image/beta/?page=home]



[NIPR Website: http://polaris.nipr.Ac.jp/~acaurora/aurora/Tromso/]



Tromsoe
Geographic latitude: 69.59°
Geographic longitude: 19.227°
Geomagnetic latitude: 67.1°
Geomagnetic longitude: 116.4°

The FPI scans five directions to measure wind velocity. The northward (eastward) component is calculated by the subtraction of north and south (east and west) wind measurements.

Spatiotemporal homogeneity was discussed by the **auroral keograms**, **peak locations of ionospheric currents** and **directional winds**.

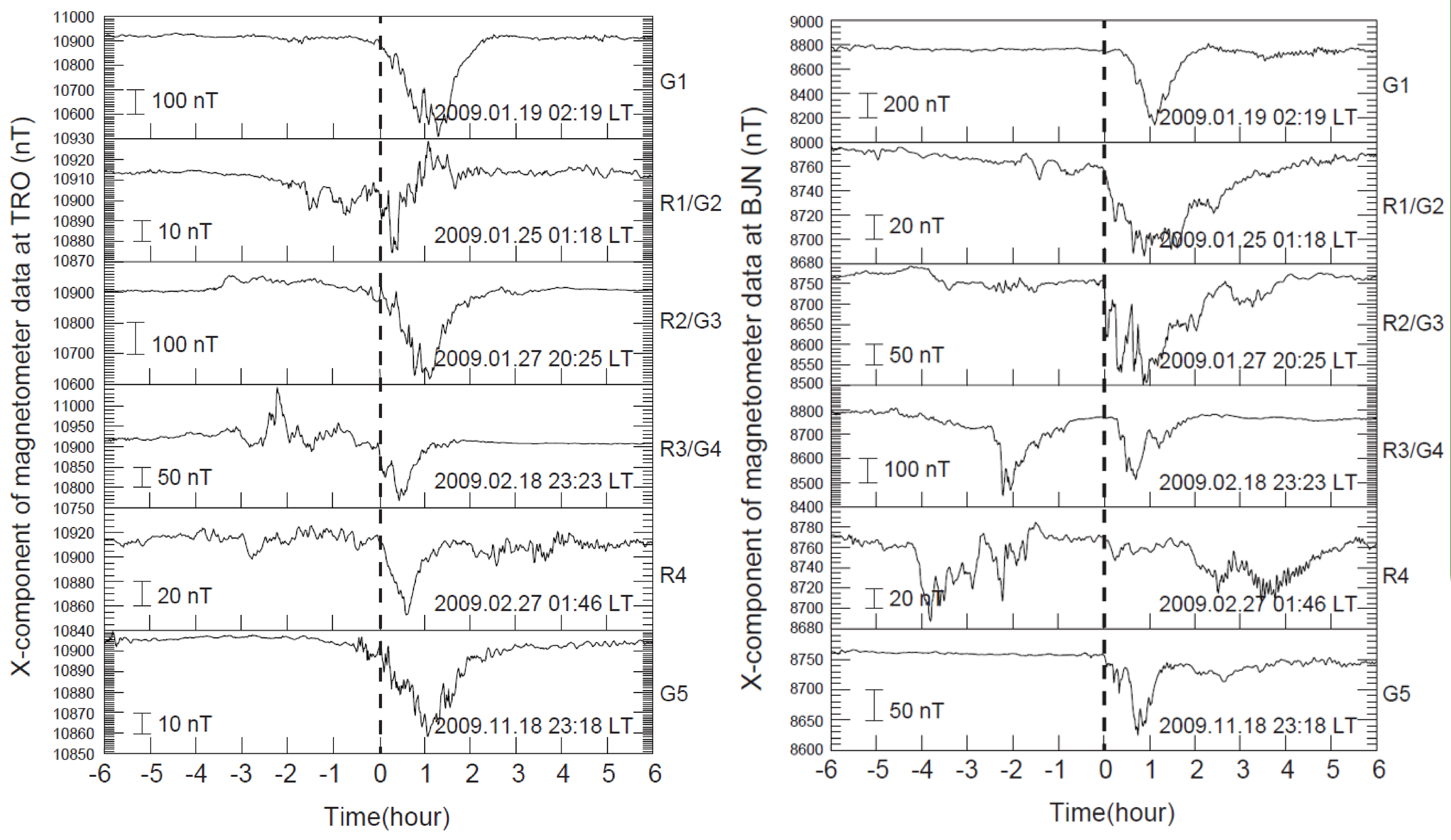


Fig 2. X-component of magnetometer data at TRO and BJN stations.

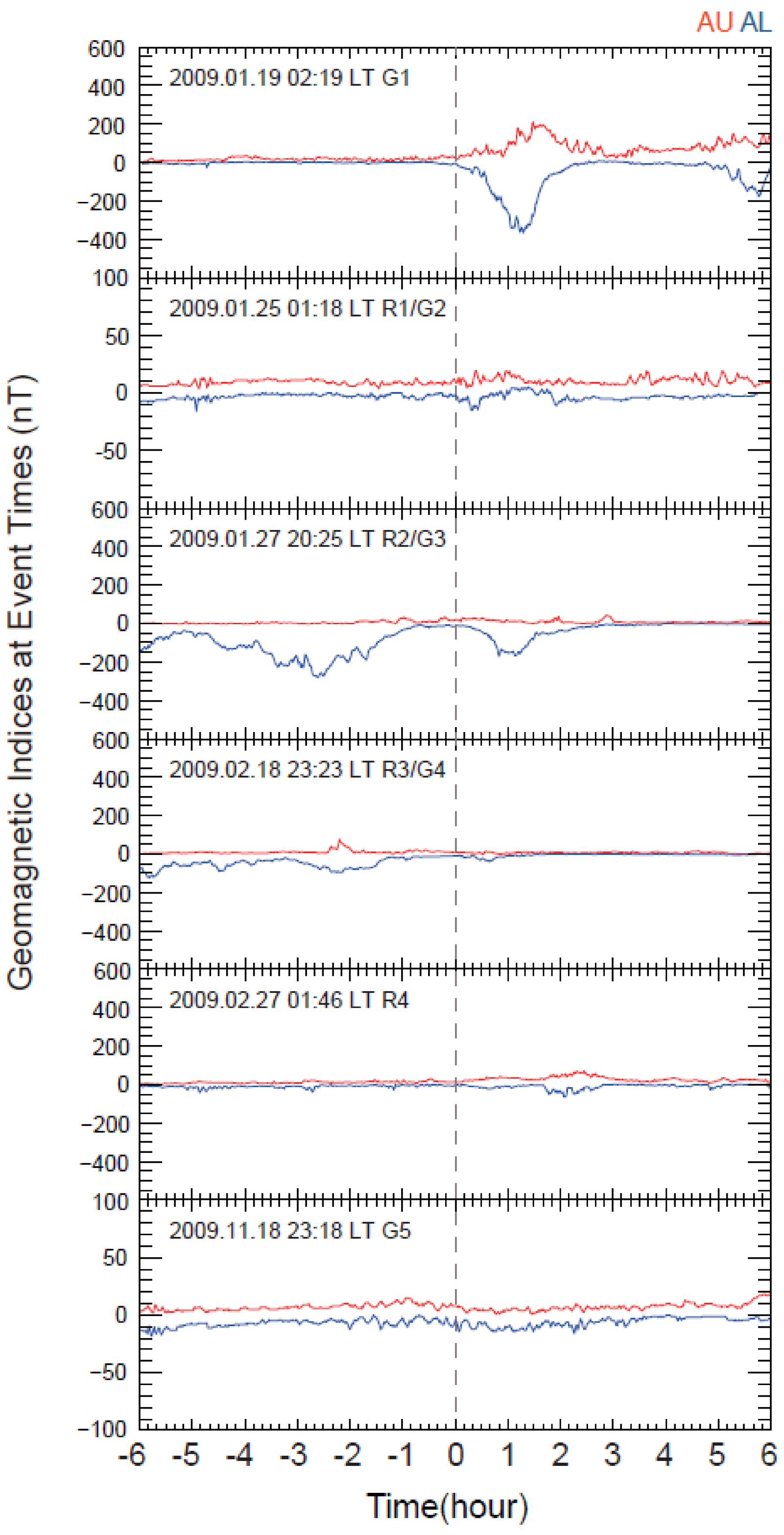
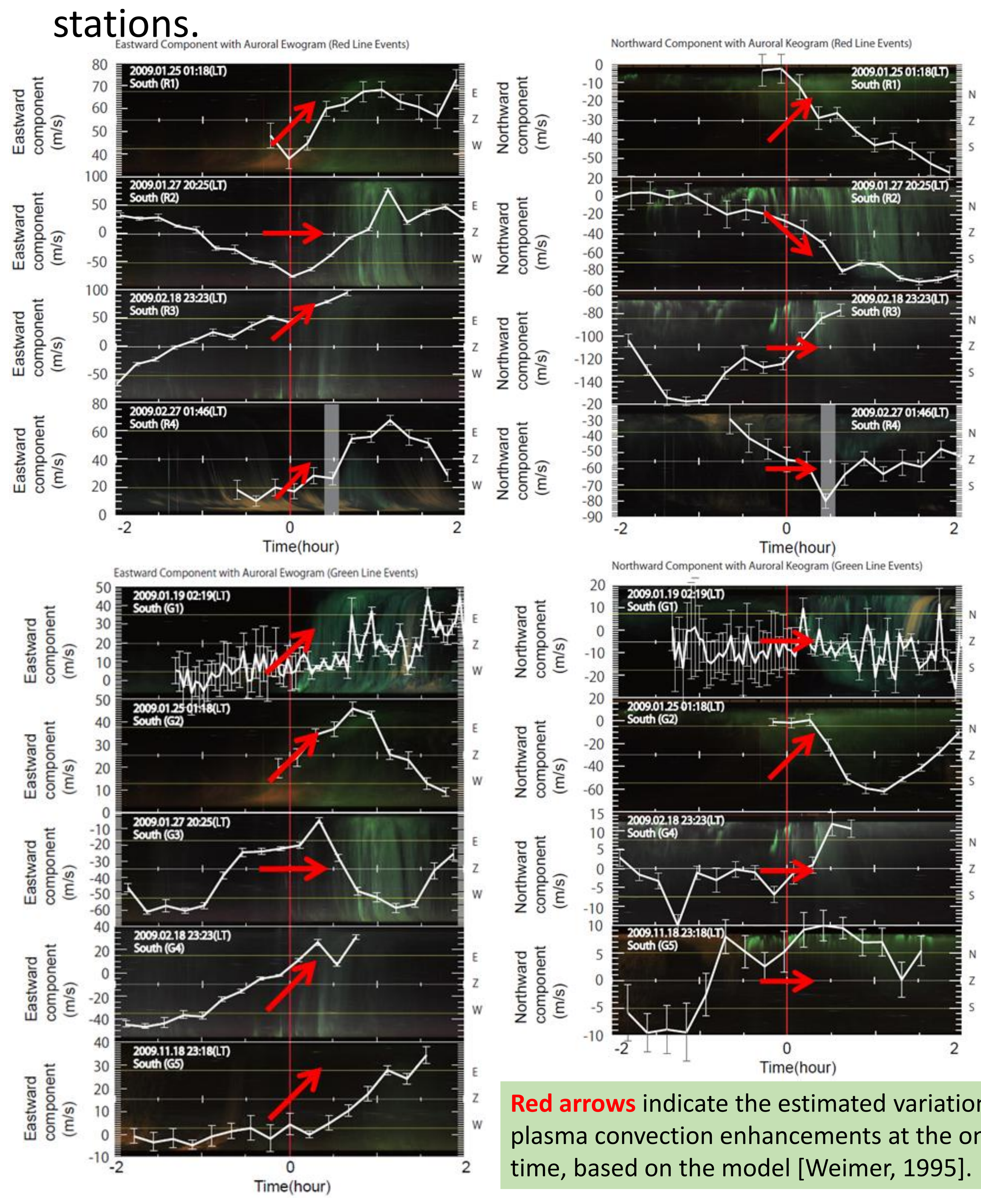


Fig 1. AE indices for all the event times.



Red arrows indicate the estimated variations by plasma convection enhancements at the onset time, based on the model [Weimer, 1995].

Fig 3. 4-h wind variations of green-line events over-plotted on the auroral keograms.

We calculated the **weighted means** in two time intervals (during and after the substorm onset). The differences of them were used to indicate the **degree of variation** (**wind velocity variation vector**).

$$\bar{v} = \frac{\sum_1^n v_i/\sigma_i^2}{\sum_1^n 1/\sigma_i^2}$$

Conclusions

- The observed wind changes at these substorm onsets were less than **49 m/s** for red-line events, and **26 m/s** for green-line events. These wind changes are much **smaller** than the typical plasma convection speed, indicating that **the plasma motion caused by thermospheric wind through ion-neutral collision is a minor effect as the driver of high-latitude plasma convection**, as well as the triggering of substorm onset.
- The red-line events show increased eastward component from pre-midnight sector to post midnight sector, decreased northward component except for midnight sector. The green line events show increase eastward component from pre-midnight sector to post midnight sector, increased northward component before midnight and decreased northward component after midnight.
- The **competition** between tidal wind and effect of plasma convection was suggested to affect the wind variations. At the onset time, wind variations **were consistent with the plasma convection enhancements** for **half** of the wind components. Most of them showed **increased eastward components**.

We checked SuperDARN data, but there were no reliable echoes. We have EISCAT data for one event, we averaged the ion drift velocities over 180-280 km.

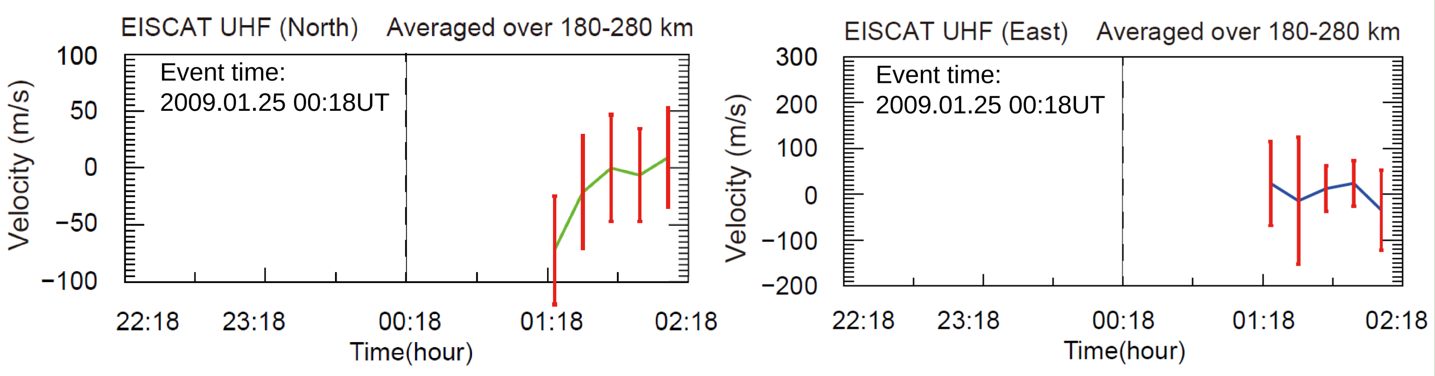
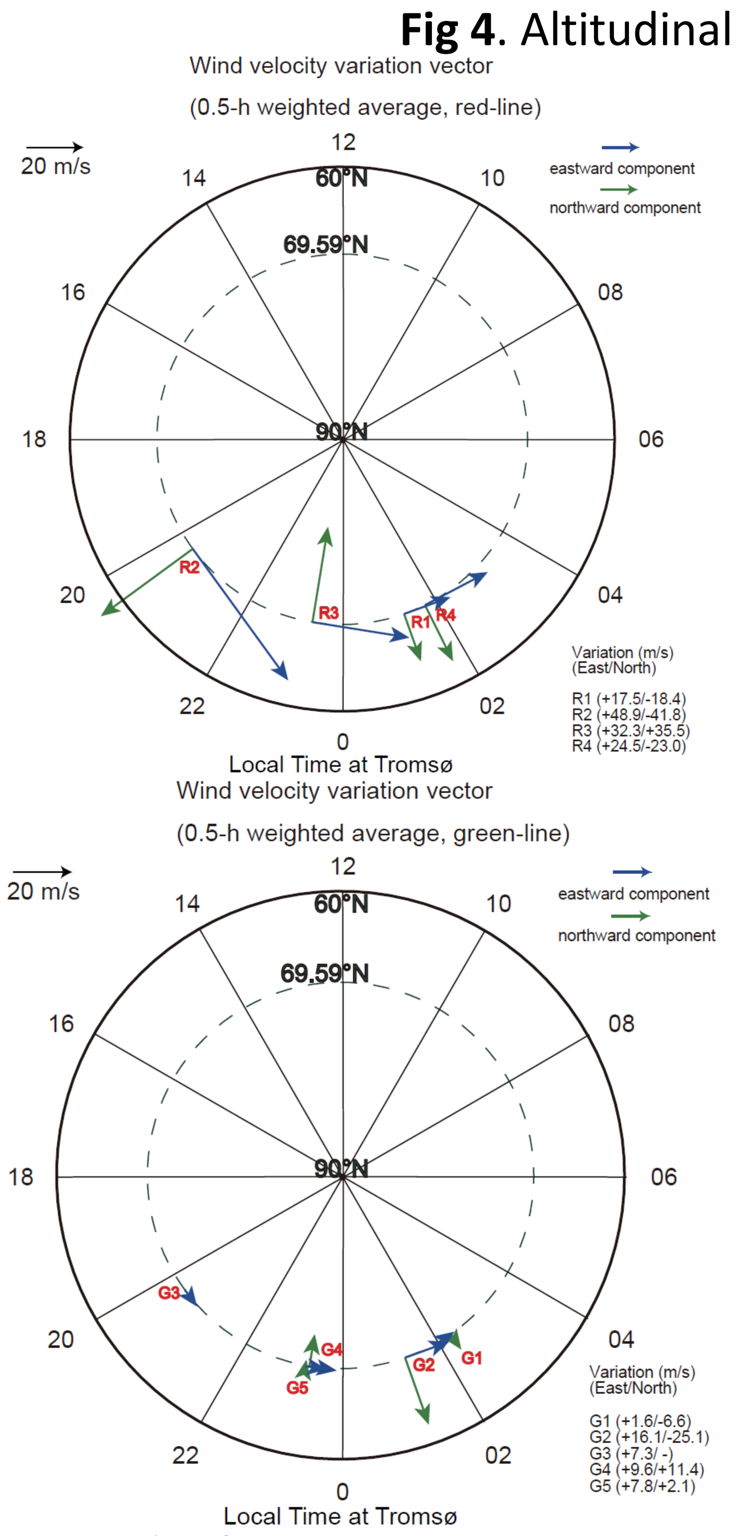


Fig 4. Altitudinal averaged EISCAT ion drift velocity.



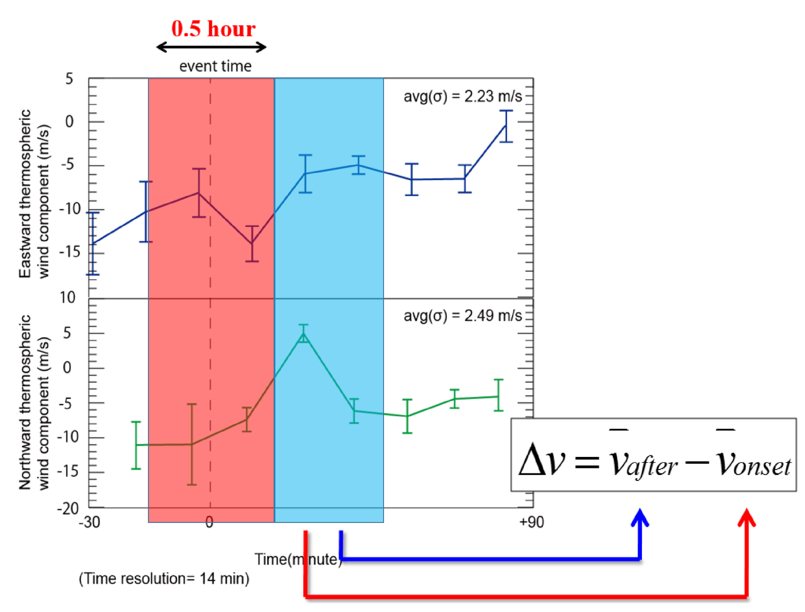


Fig 5. Wind velocity variation vector on the polar plot.

Acknowledgement

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