Properties and Generation of Large Scale Travelling Ionospheric Disturbances during 8 September 2017

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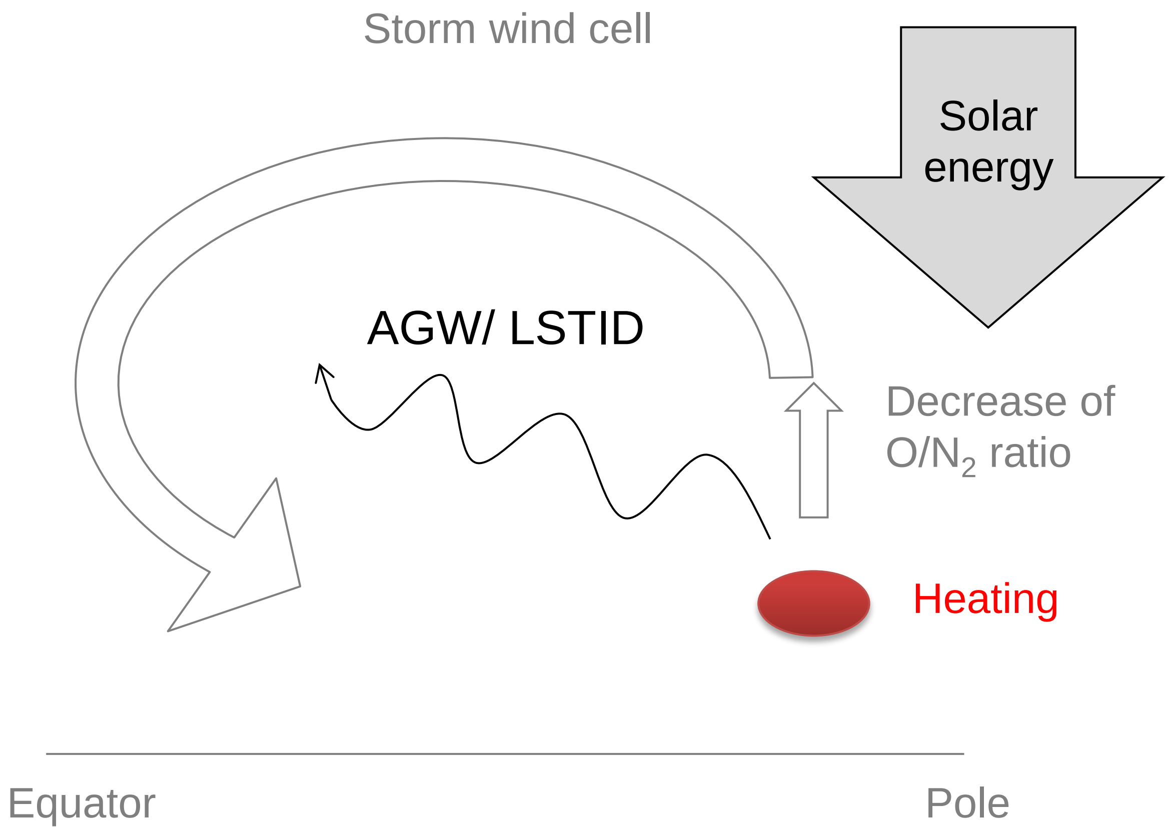
Introduction and Objectives

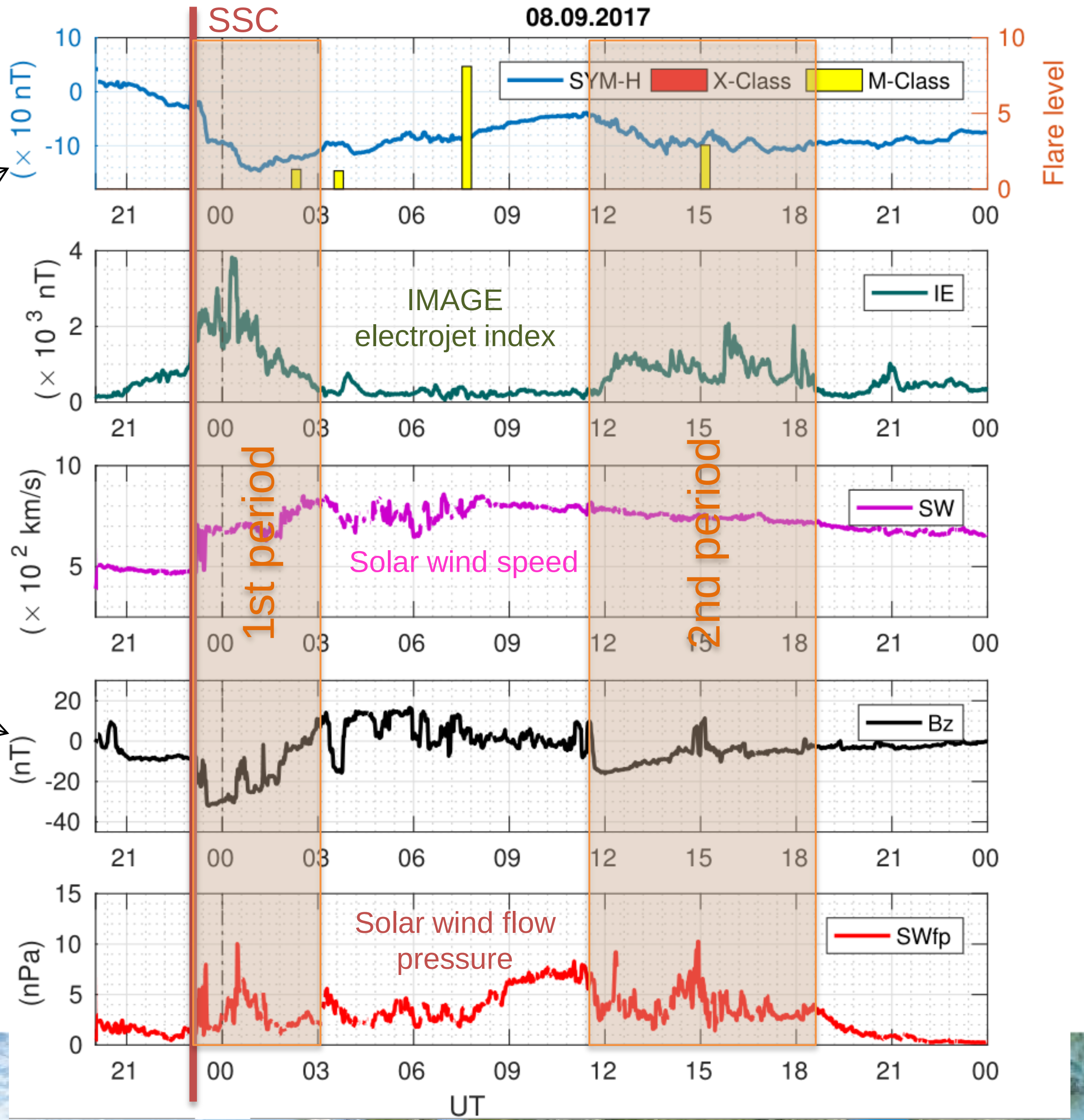
- Strong energy input in high latitudes during storm condition causes sudden intensive dynamics and changes in the thermosphere.
- This gives rise to a storm wind cell and large scale Atmospheric Gravity Waves (AGW)
- The winds and AGW transport energy to mid- and low latitudes
- The signature of the AGW can be detected in the ionosphere as Large Scale Travelling Ionospheric Disturbances (LSTID)



The mechanisms of LSTID generation are not yet completely understood and need in detail analyses.
This study contributes with a case analysis for 8 September 2017 storm

Introduction to 7-8 September 2017 space weather conditions

- Multiple CMEs associated with a X9.3-class solar flare on 6 September 2017 reached Earth starting 7 September 2017, 23:04 UT (SSC, red bar)
- Triggered a geomagnetic storm with a double main phase resulting in two periods of intense auroral activity (orange boxes)
- Solar wind speed increased with the arrival of the first CME
- The two periods of enhanced auroral activity were related to the periods of southward directed Interplanetary Magnetic Field



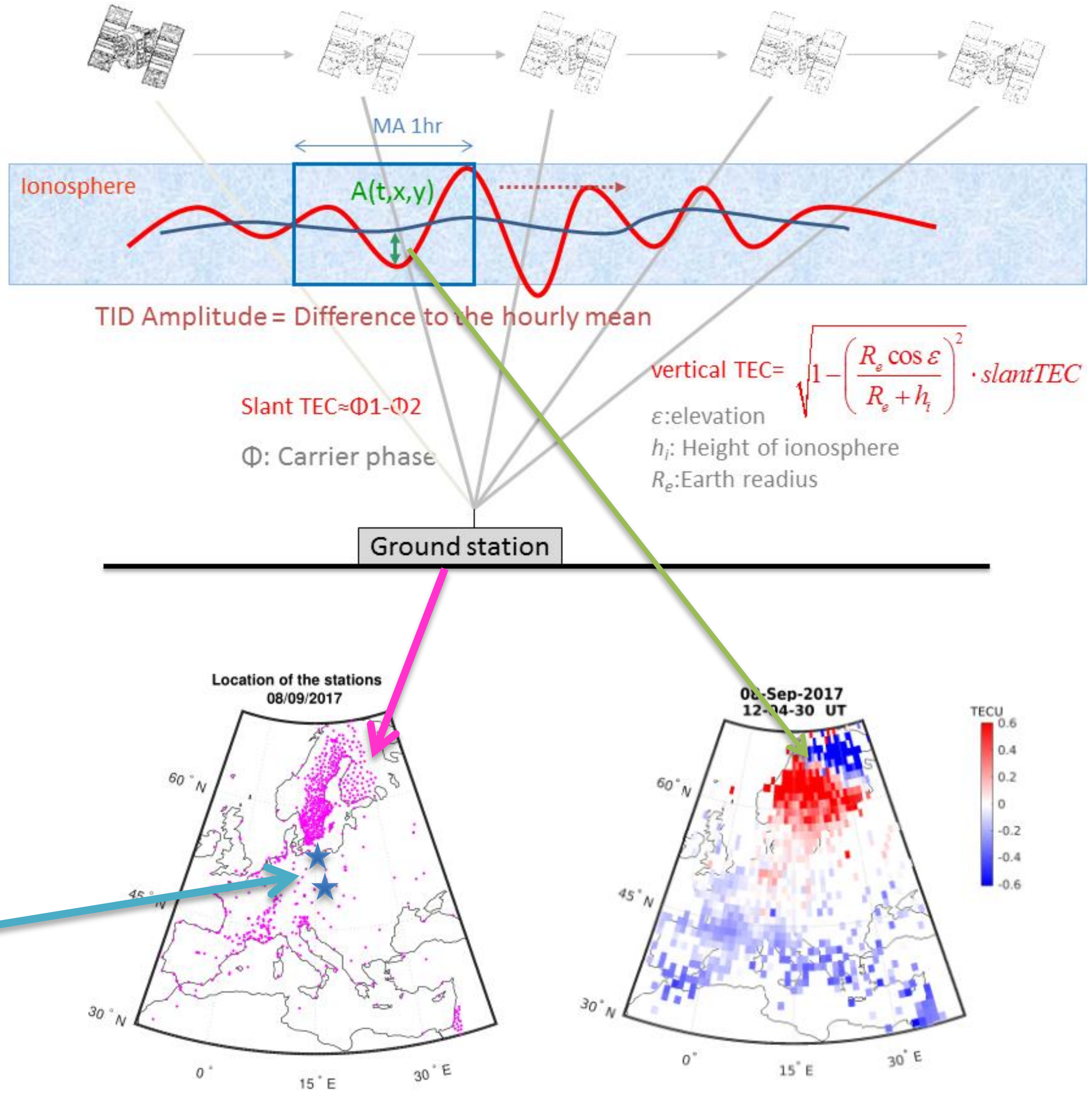
Data and Methods

GNSS TEC estimates

- More than 880 GNSS ground stations over the European region provided by CEDAR Madrigal database
- Calculate geometry free vertical Total Electron Content (TEC, red line)
- Calculate one hour running mean TEC for each satellite-receiver track separately (dark blue line)
- The difference between TEC and running mean is considered the TEC perturbation reflecting LSTID activity (lower right panel)

Ionosonde measurements

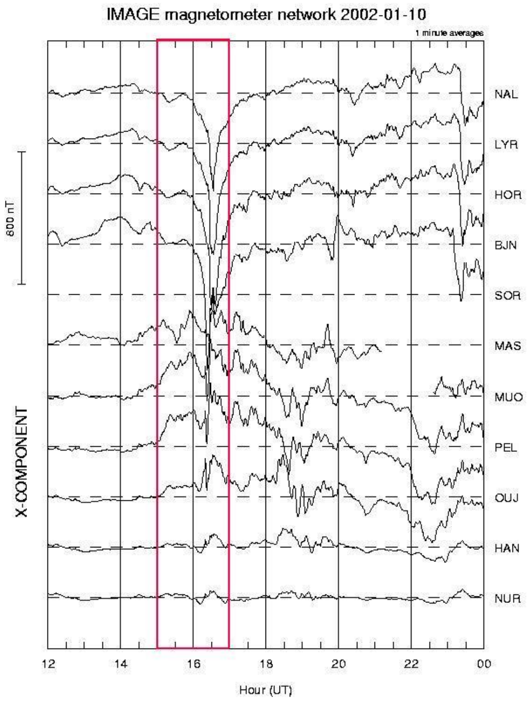
- Juliusruh (54.6°N 13.4°E)
- Pruhonice (50.0°N 14.6°E)

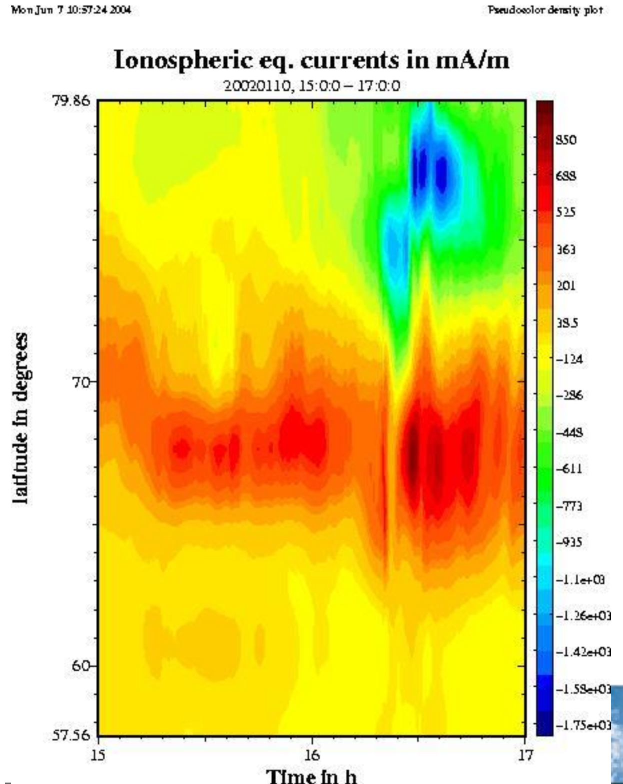


Data and Methods

IMAGE Equivalent Currents (IEC)

- IEC represent the ground magnetic disturbance caused by ionospheric horizontal currents
- Calculated from IMAGE magnetometer network in northern Europe



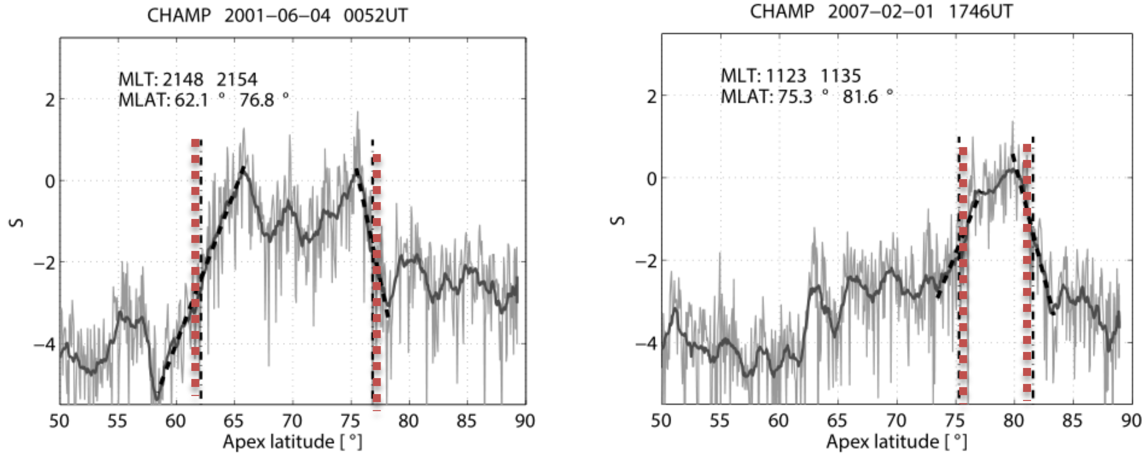


Field Aligned Currents (FAC) and auroral oval boundary estimation

- Swarm FACs data provided by ESA
- Auroral oval boundaries are based on the S variable, which is based on FAC density *j*

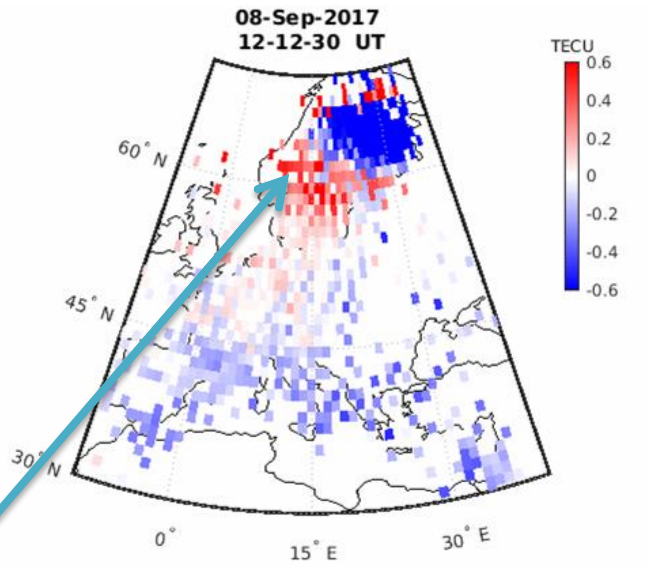
$$S = \langle log_{10} j_{||}^2 \rangle_{20s}$$

- The auroral boundary is estimated via an iterative process of finding the linear parts of the curve S with steepest gradients (Xiong et al., 2014)

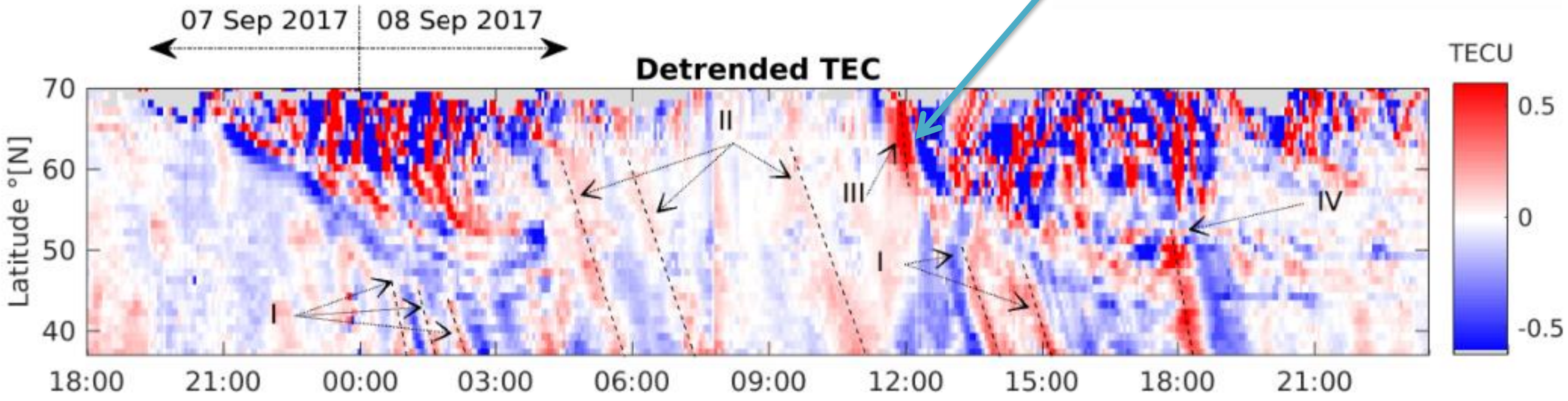


Results
LSTID observation with GNSS based TEC

I. Fast LSTIDs are observed in midlatitudes between 0-3 UT and 13-16 UT.
II. Slow LSTIDs are observed between 3-12 UT.
III. A significant strong wave-like TEC perturbation occurred in high latitudes at noon, which vanished at around 55°N.
IV. A strong single LSTID in mid-latitudes generated in high latitudes around 18 UT

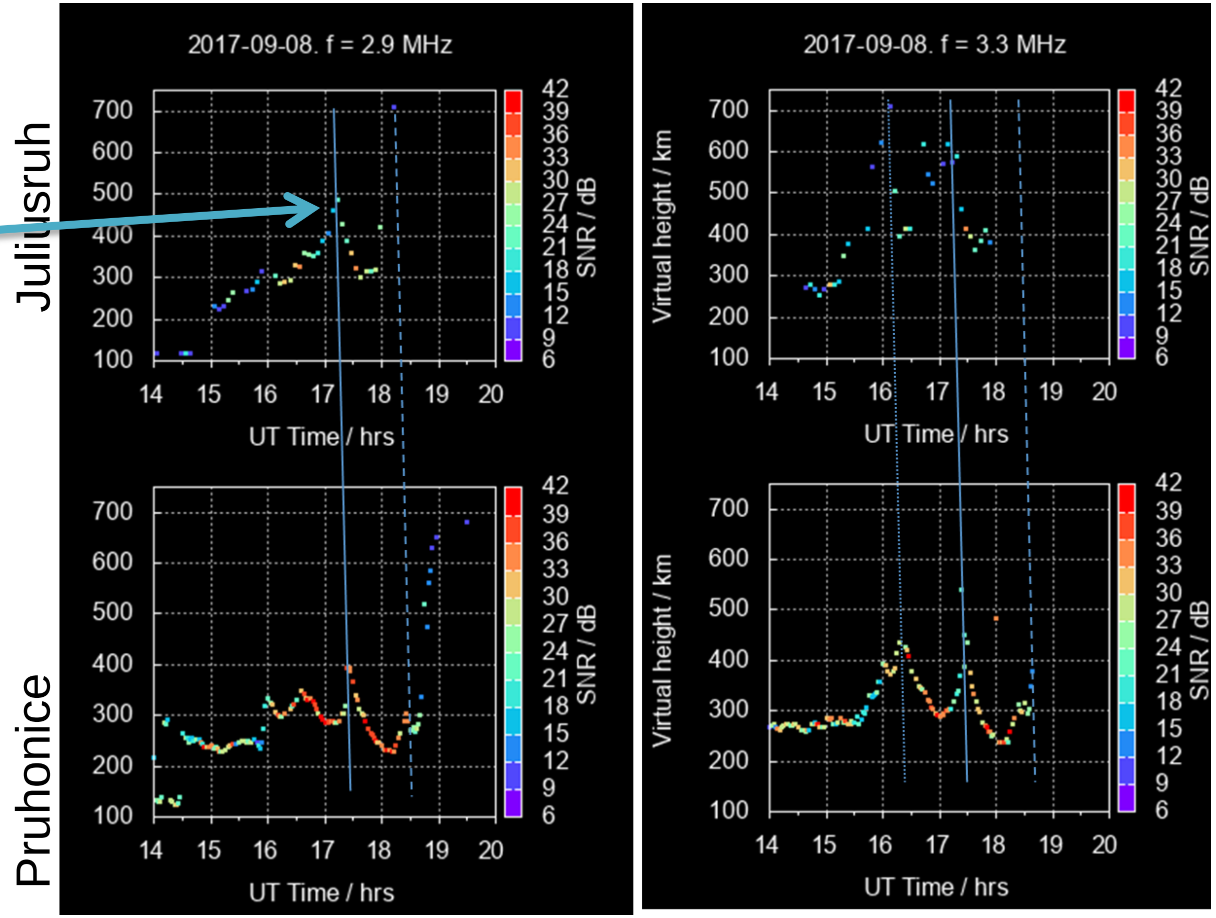


Type I-IV LSTIDs



Results
LSTID observation with ionosondes

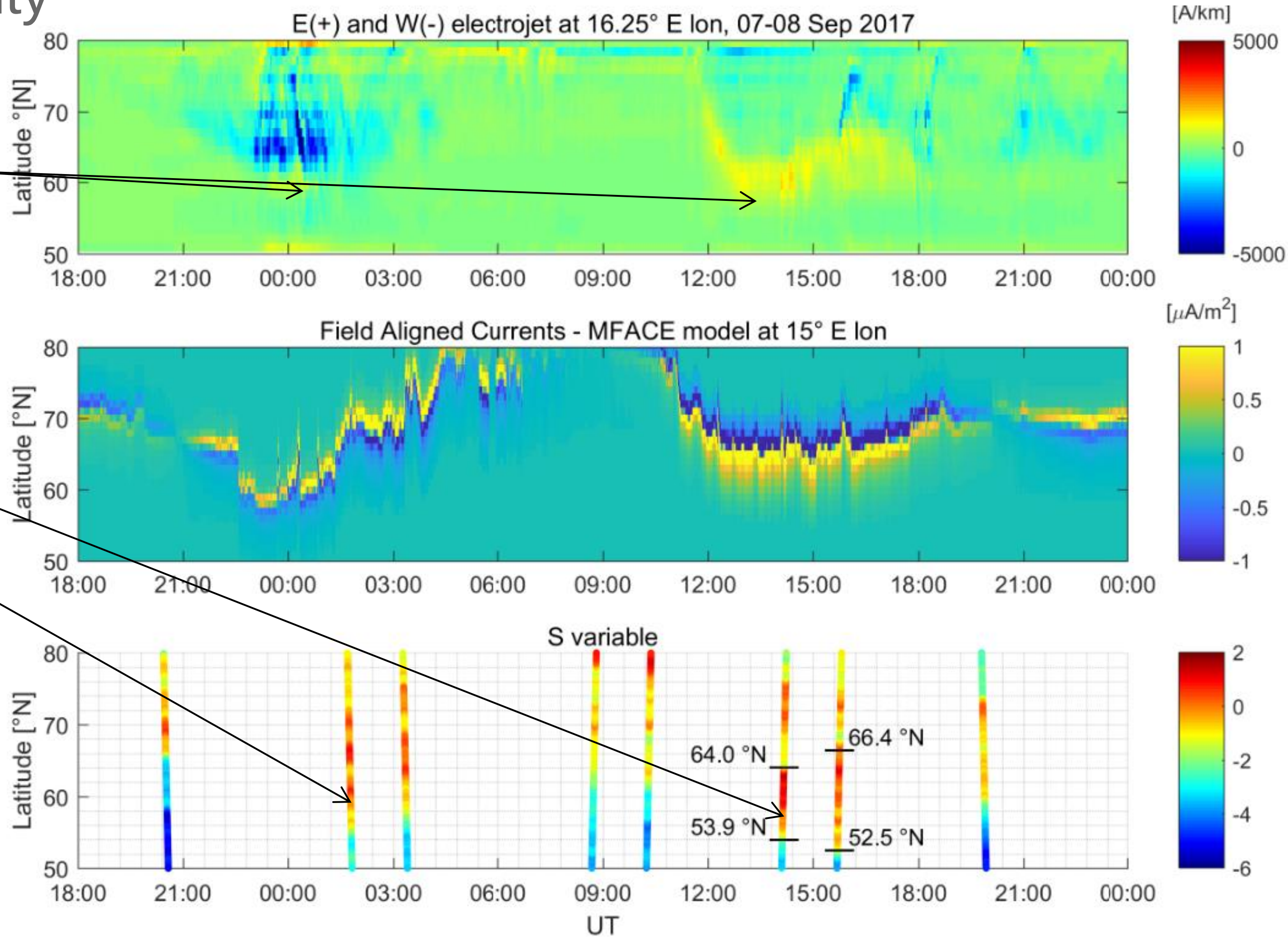
- TIDs cause height variations in the ionospheric plasma observed by the ionosondes
- TIDs are visable as virtual height variations at the same plasma frequencies in a time series of consecutive ionograms
- After 16 UT we observe wave-like structures in the virtual height time series with wave periods of ~1 hour at both ionosonde stations
- Maxima for Pruhonice are delayed by about 12-14 minutes to Juliusruh (distance of 517km) resulting in estimates of velocity ~ 615 m/s and the wave length ~2450 km
- These waves belong to Type I LSTIDs



Results

Horizontal and vertical currents activity

- During times of Type I LSTIDs,
  - IEC are enhanced and located about 10° north to the LSTID start region
  - FAC are strong and close to the LSTID start region
- During times of Type II LSTIDs
  - No significant current activity is observed
- Type III LSTIDs occurs simultaneously with an intensification and equatorward extension of IEC and FAC which is related to a sudden equatorward shift of the cusp (Yamauchi et al., 2018)
- Type IV LSTID starts, when eastward IEC suddenly change to westward



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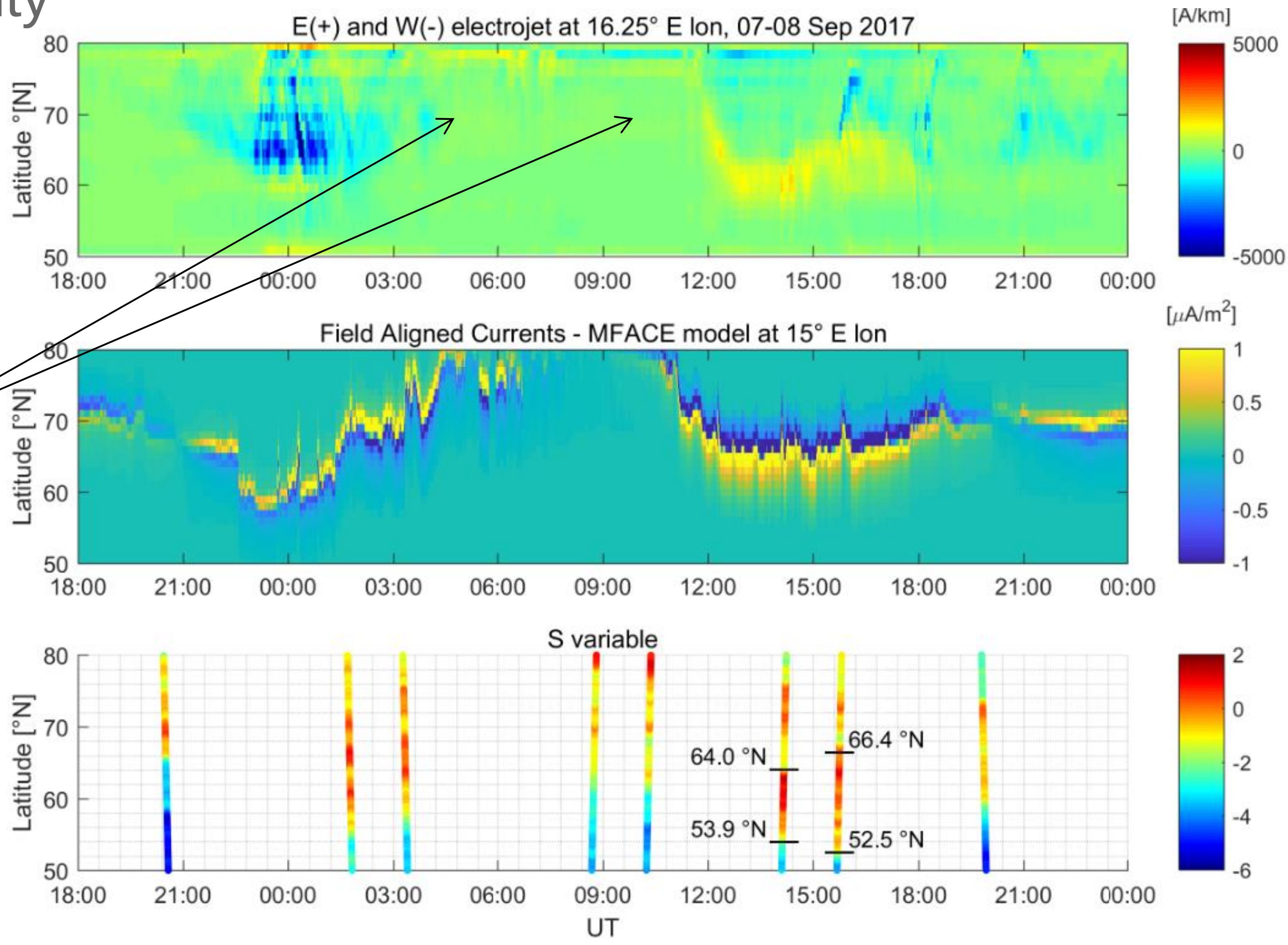

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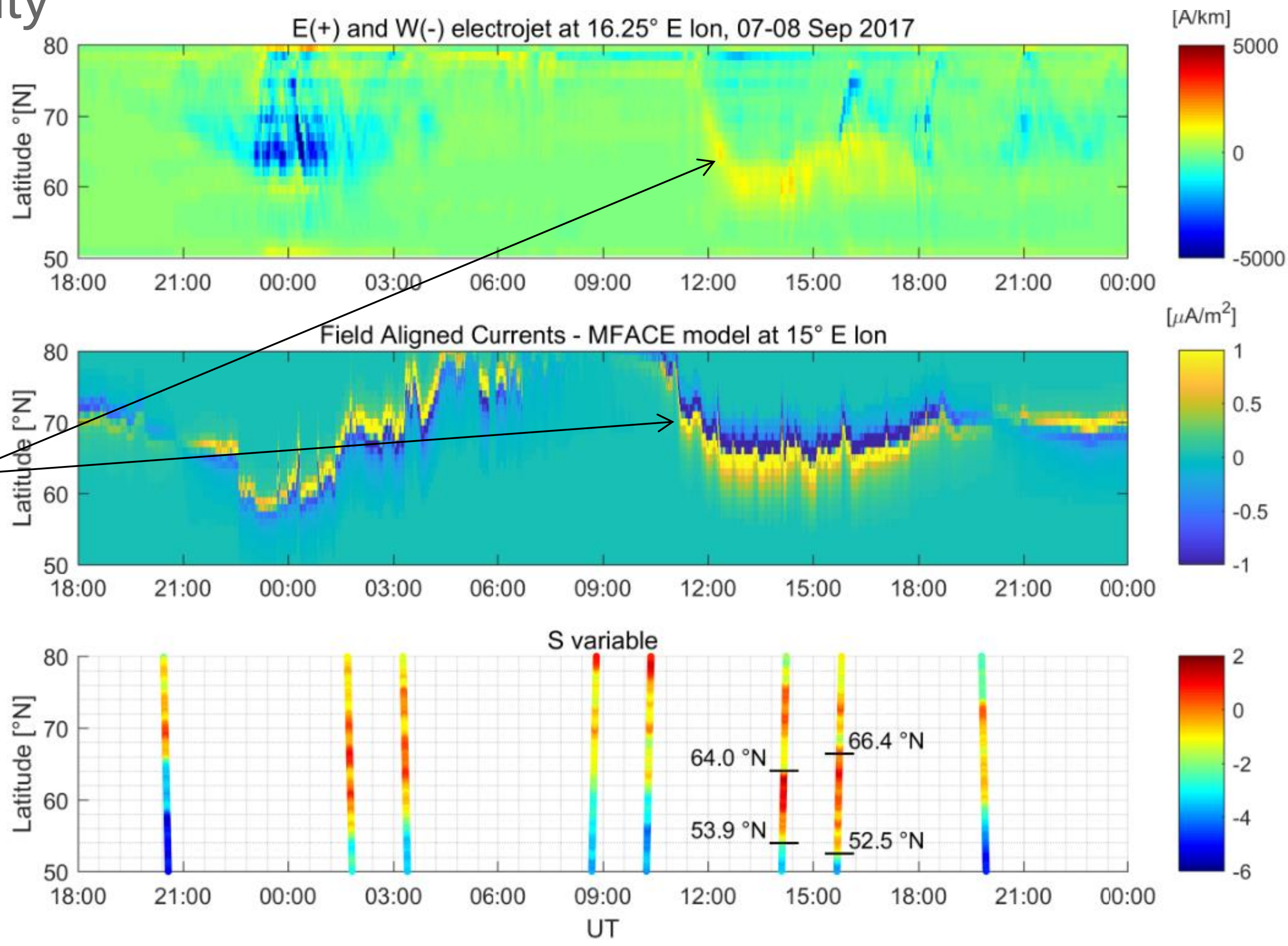

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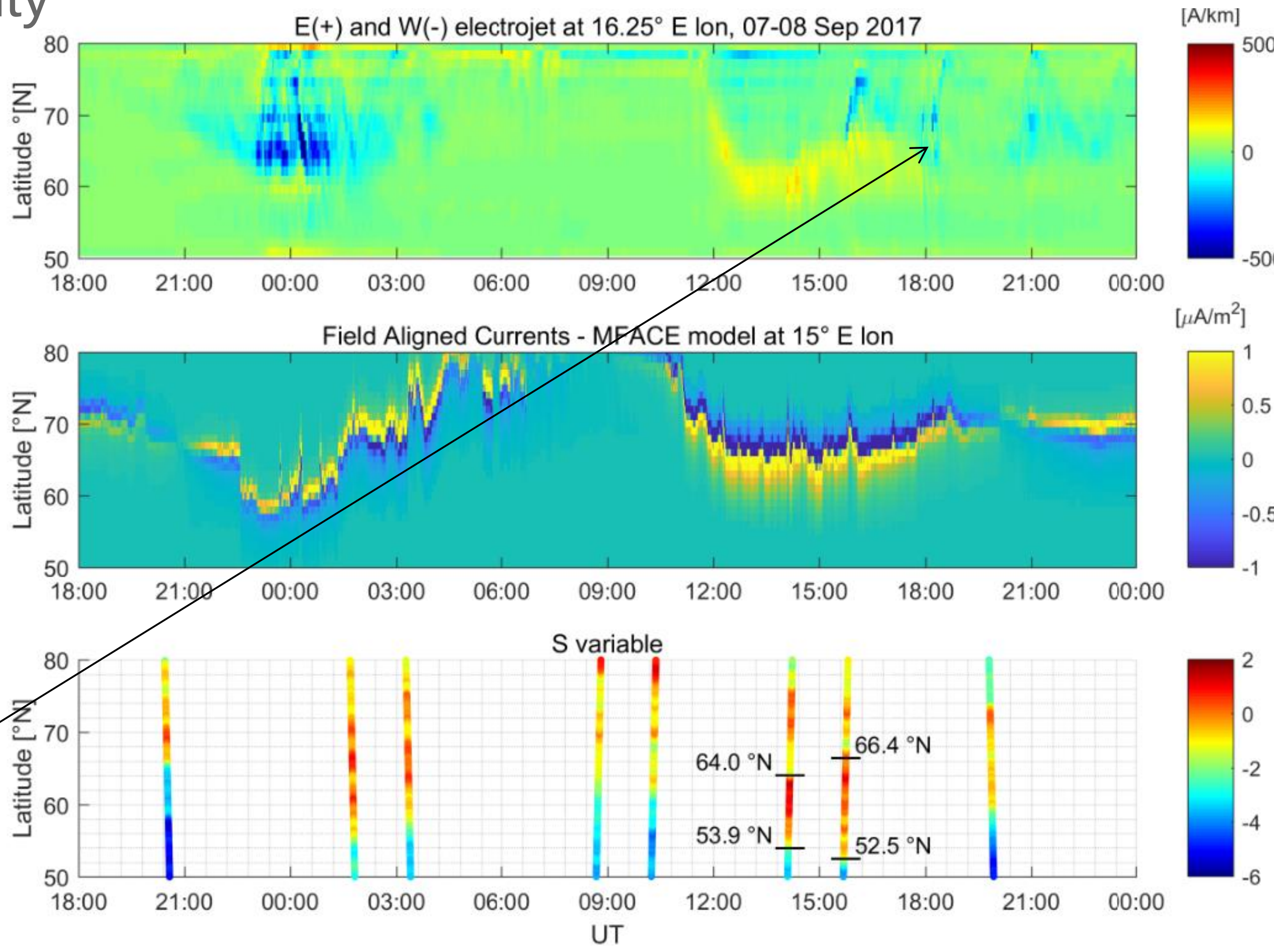
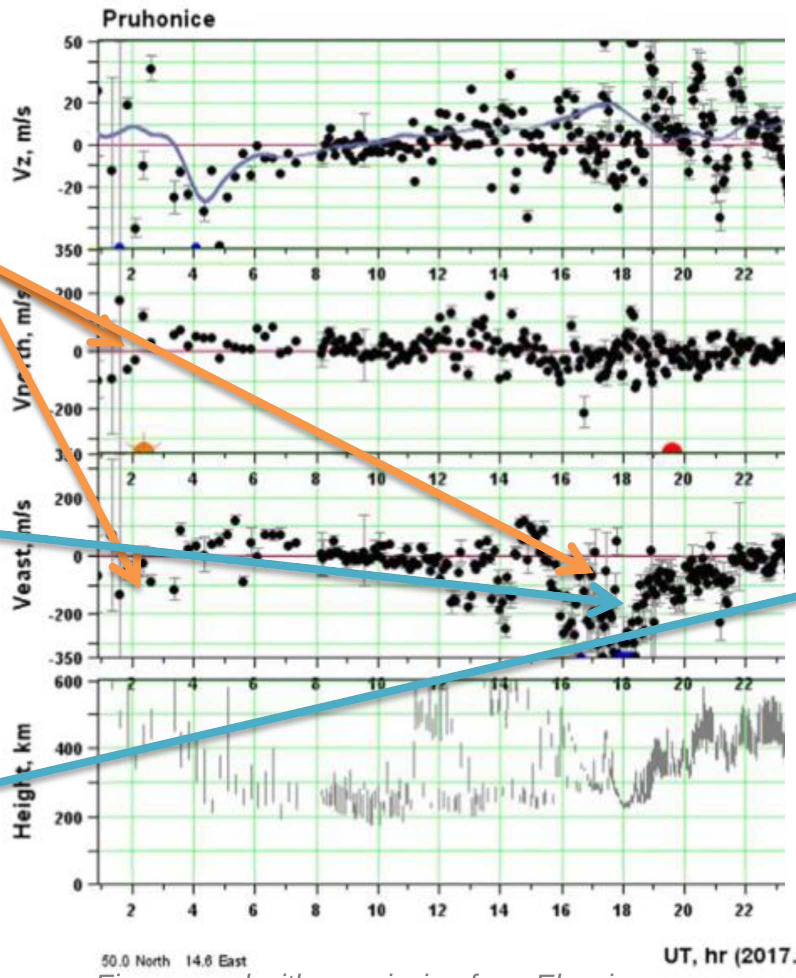


Results
Drifts and electric fields

- During Type I LSTIDs horizontal plasma drifts are significantly disturbed indicating the presence of strong electric fields and subauroral polarisation streams (SAPS)
- Type IV LSTID occurs when SAPS suddenly disappear. A strong change in electric fields is anticipated
- Type IV LSTID appeared after the geomagnetic field was impacted by a rapid strong change which is related to strong ionosphere currents and triggered a GIC (Dimmock et al., 2019)

F-region plasma drifts over Pruhonice estimated by Mosna et al. (2020)



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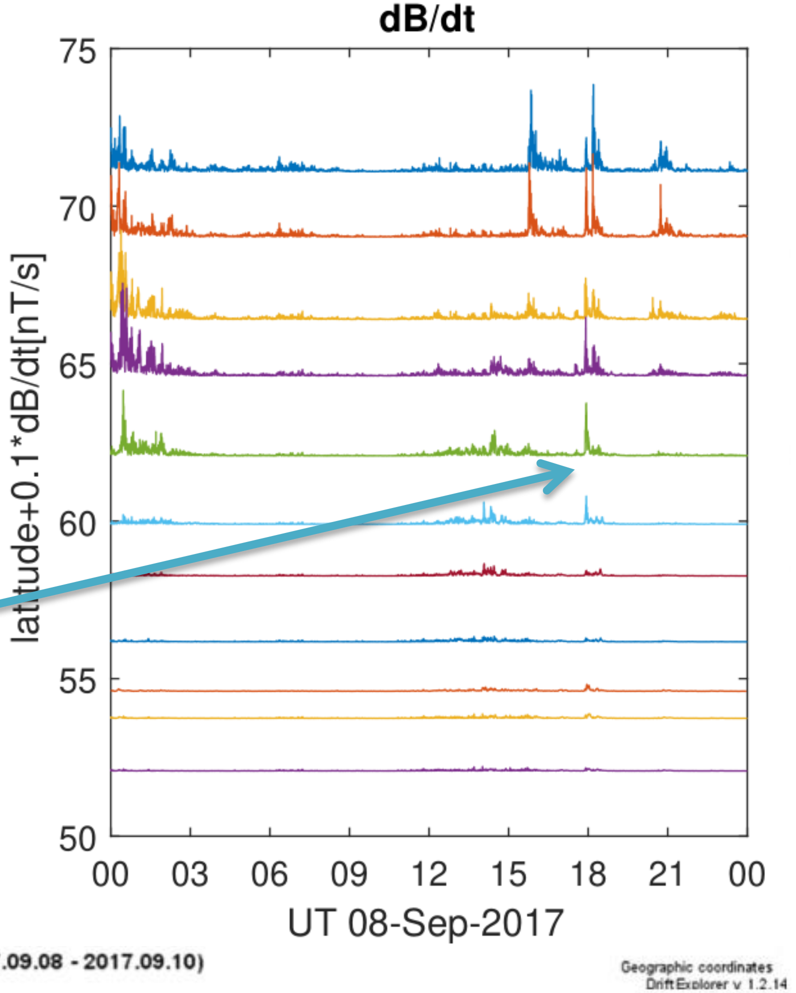
Change in magnetic field derived from IMAGE magnetometers



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Summary and Conclusions

Different types of LSTIDs were observed during 8 September 2017 ionospheric storm, each having different source mechanisms:

I. Fast LSTIDs are observed in midlatitudes between 0-3 UT and 13-16 UT.
   - *The generation of these LSTIDs is related to intense currents and SAPs*

II. Slow LSTIDs are observed between 3-12 UT.
   - *These LSTIDs are considered to be a regular phenomenon in the morning hours which occurs due to the passage of the solar terminator*

III. A significant strong wave-like TEC perturbation occurred in high latitudes at noon, which vanished at around 55°N.
   - *This perturbation is a forced wave which is related to an equatorward shift of the cusp*

IV. A strong single LSTID in mid-latitudes generated in high latitudes around 18 UT
   - *The generation of this LSTID is related to a reversal of electric fields and auroral currents.*

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