

Ionospheric plasma irregularities at high latitudes as observed by CHAMP

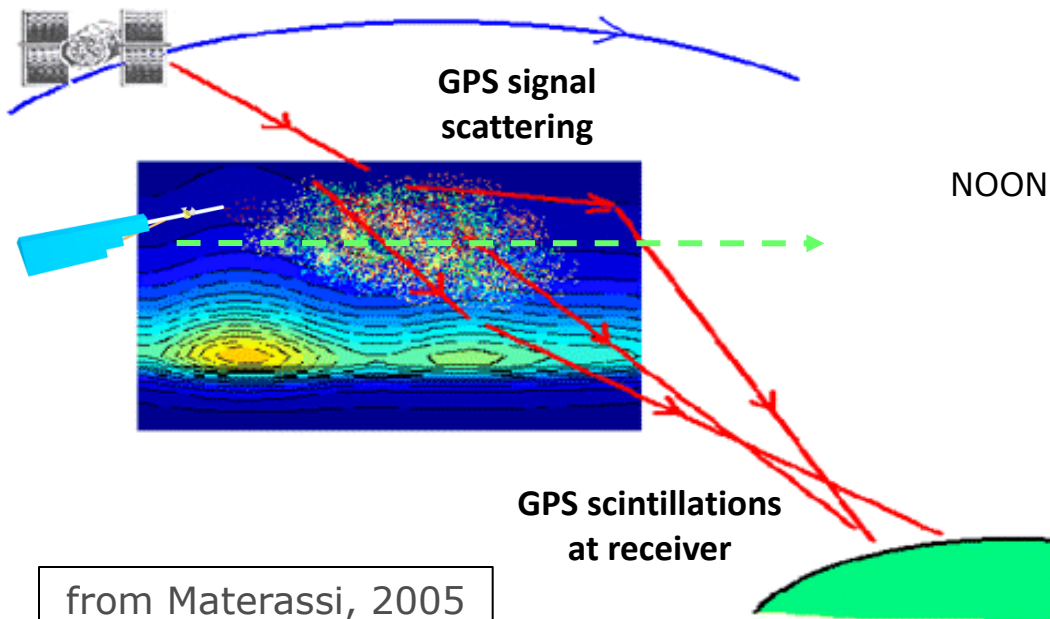
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Space Weather Workshop 2013
Boulder, CO, April 16-19, 2013

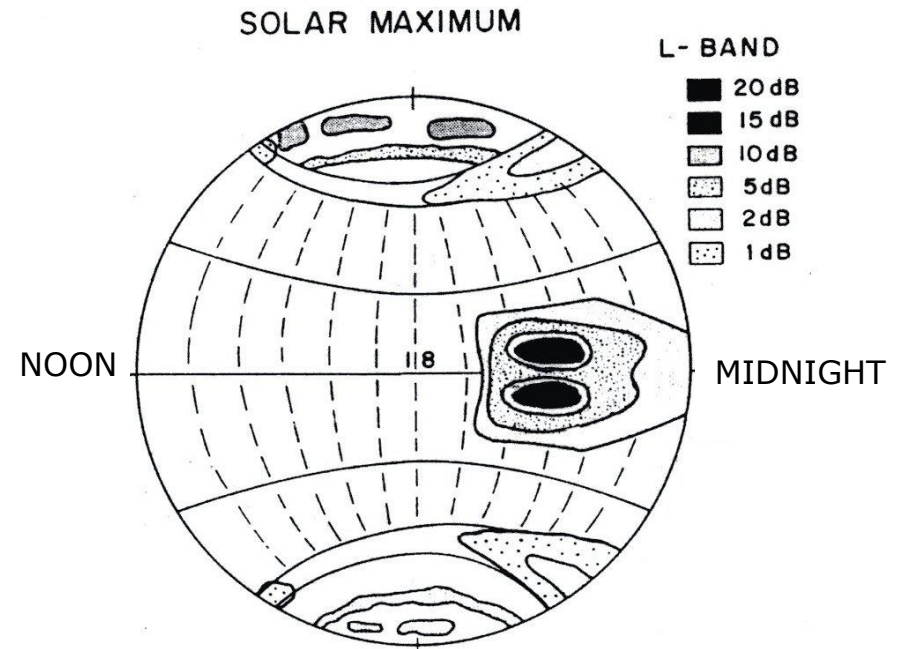
Disturbance of GPS signal by ionospheric irregularities

Steep electron density gradients scatter RF signals and affect systems like GPS.



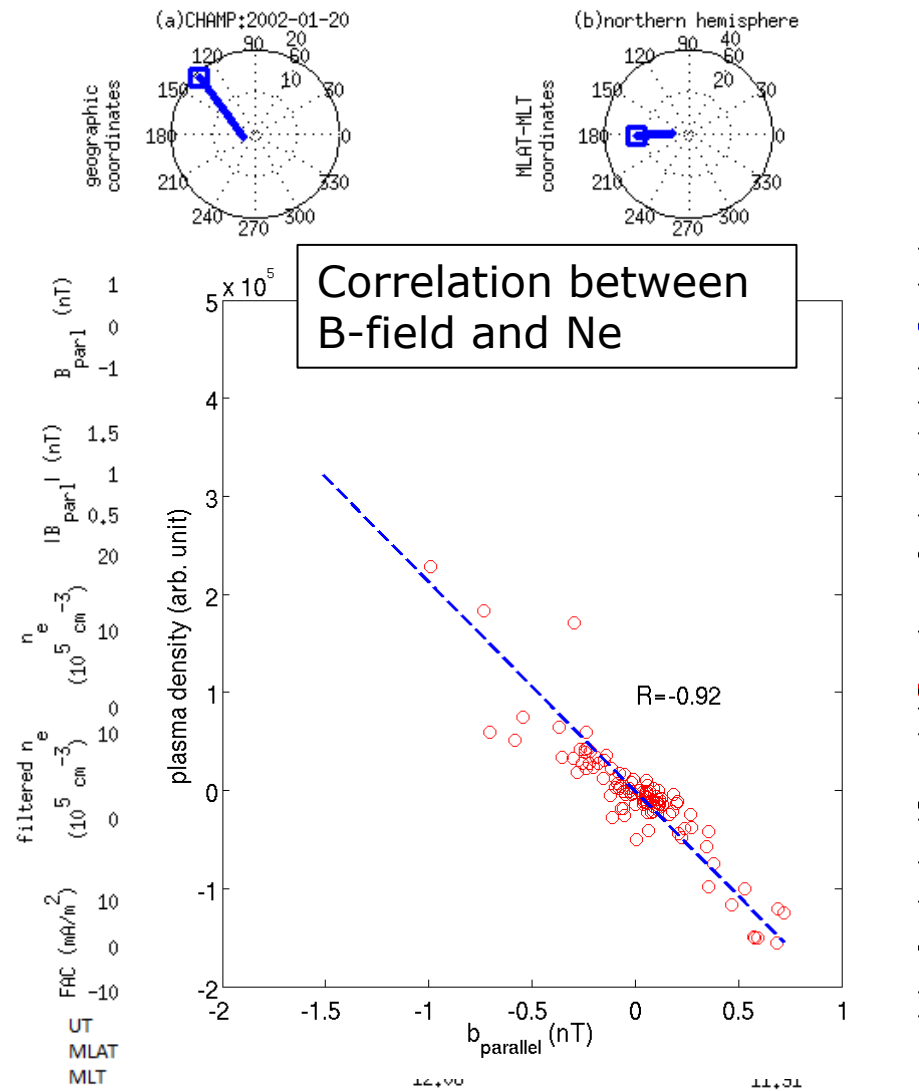
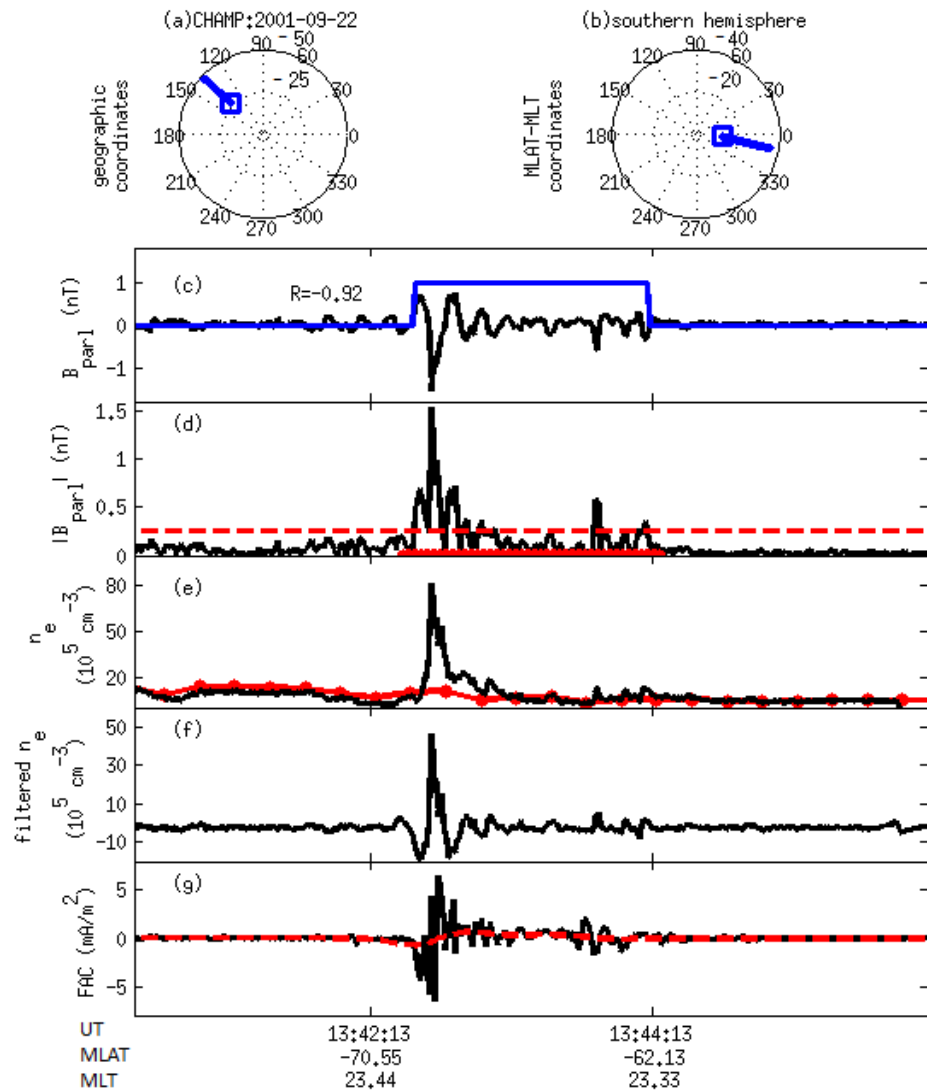
from Materassi, 2005

"WORST CASE" FADING DEPTHS AT L-BAND



(Basu et al., 2002)

Two examples of ionospheric irregularities at high latitudes



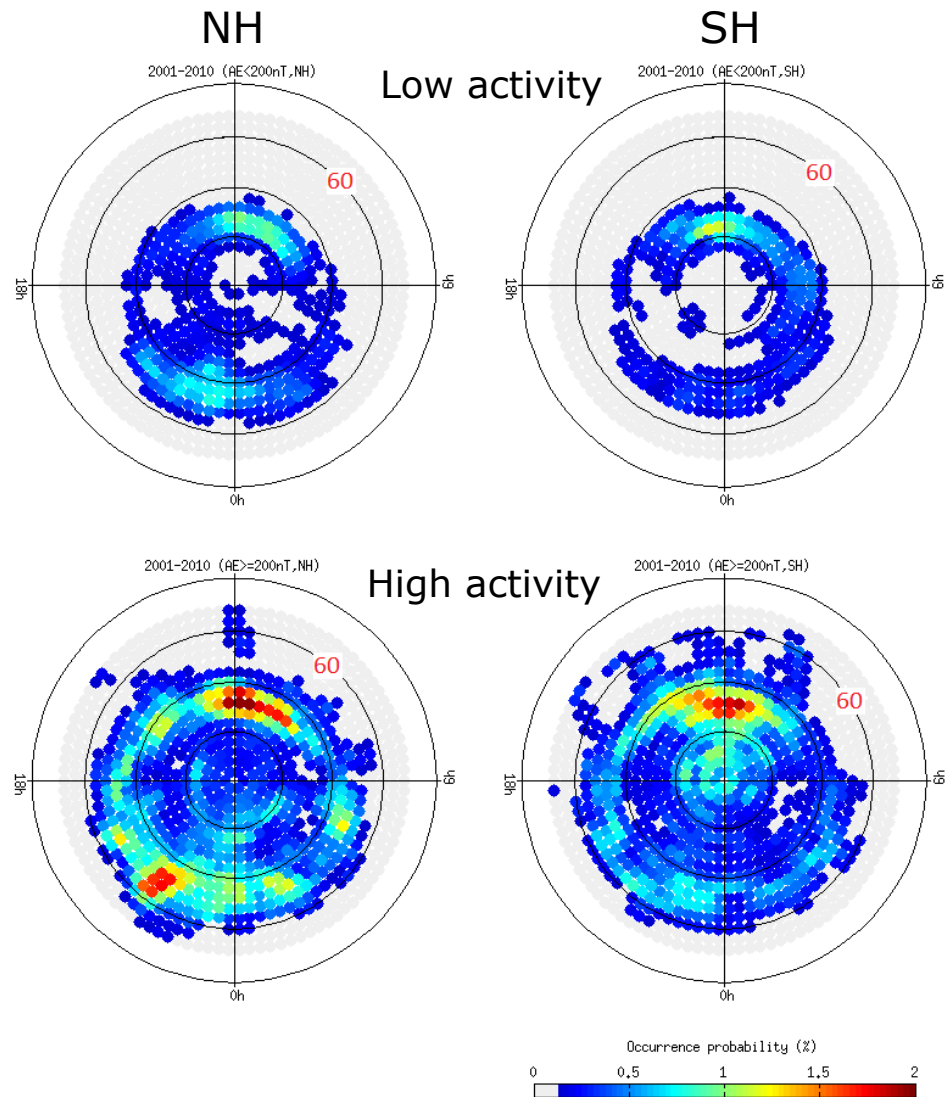
Characteristics of high-latitude irregularities

- ❖ The electron density is locally enhanced over scales of $\sim 100\text{km}$ (steep gradients).
- ❖ As a response, the magnetic field strength is decreased (diamagnetic effect of dense plasmas).
- ❖ Irregularities are always accompanied by bursts of small-scale field-aligned currents.

Dependence of irregularities on auroral activity

The occurrence frequency of irregularities depends significantly on the auroral activity.

Preferred region of occurrence is the auroral oval. In particular, the cusp around noon and the substorm sector before midnight.



Seasonal dependence of irregularities

The occurrence rate is generally high during equinox months.

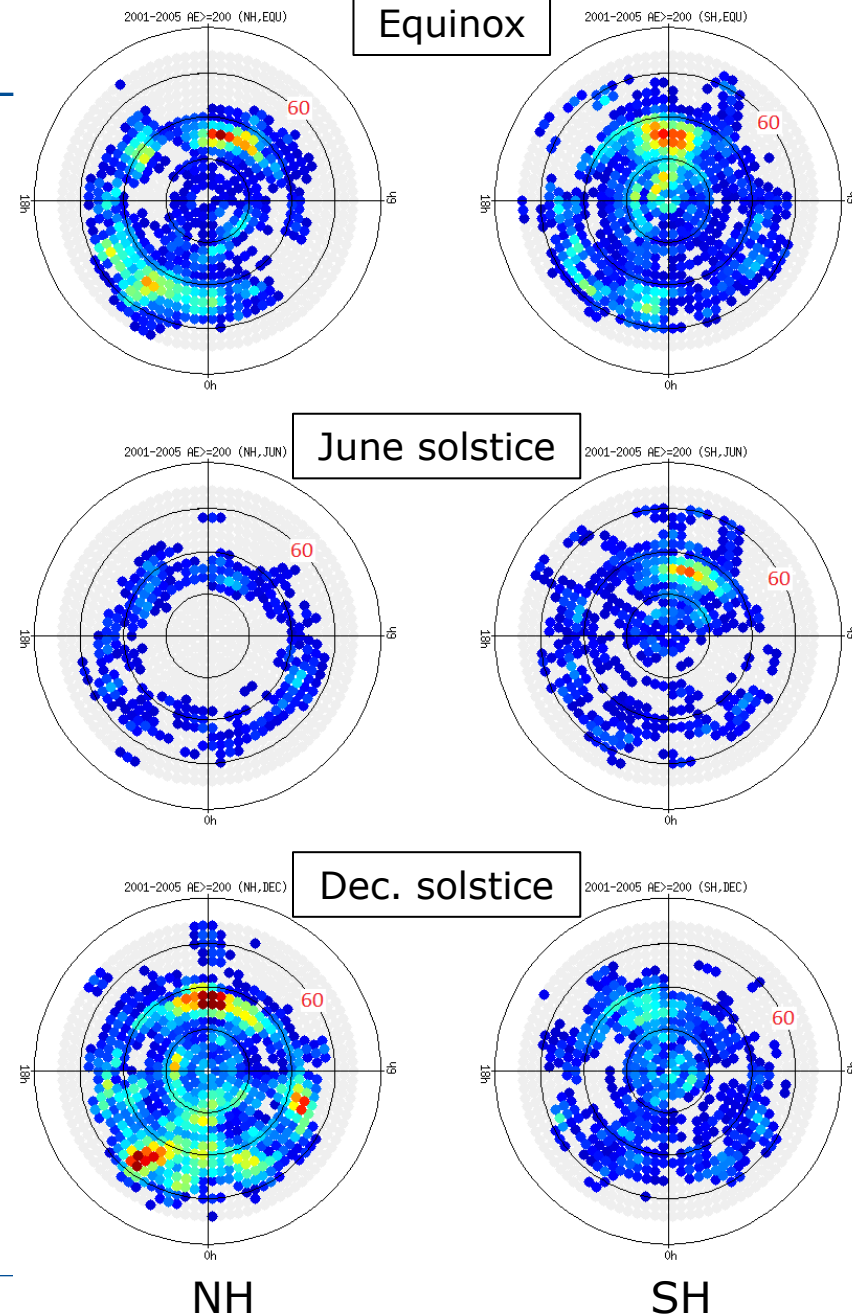
In the northern hemisphere many more events are observed around December solstice than around June.

This seasonal difference is not so pronounced in the southern hemisphere.

Two effects are playing a role:

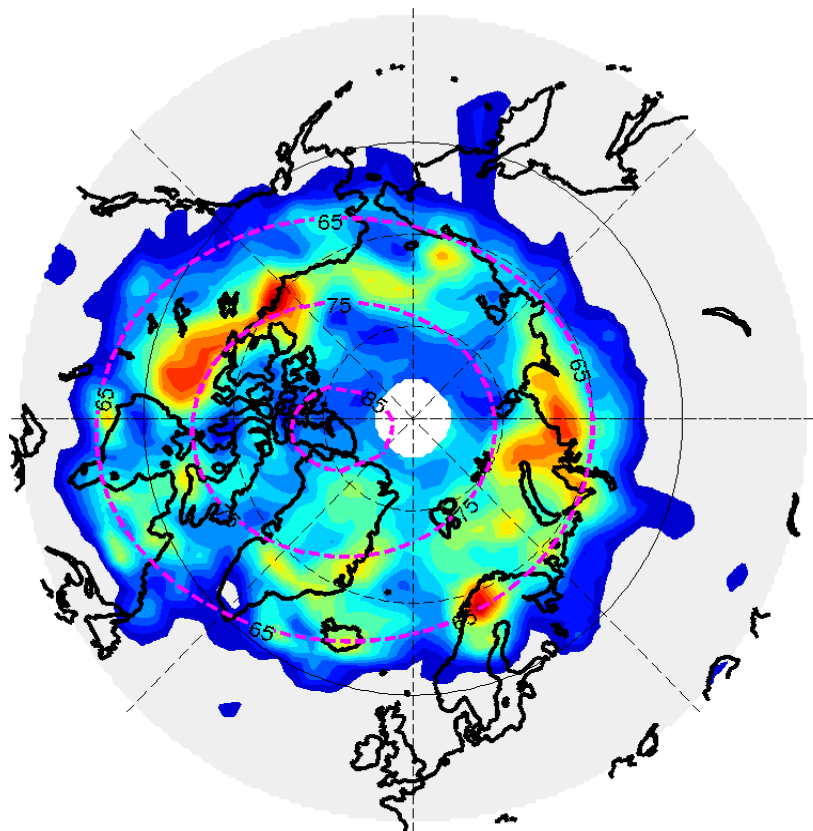
- The annual variation with a minimum around June/July,
- The seasonal dependence, preference of dark ionosphere.

In the NH both effects are in phase, in the SH they are in anti-phase.

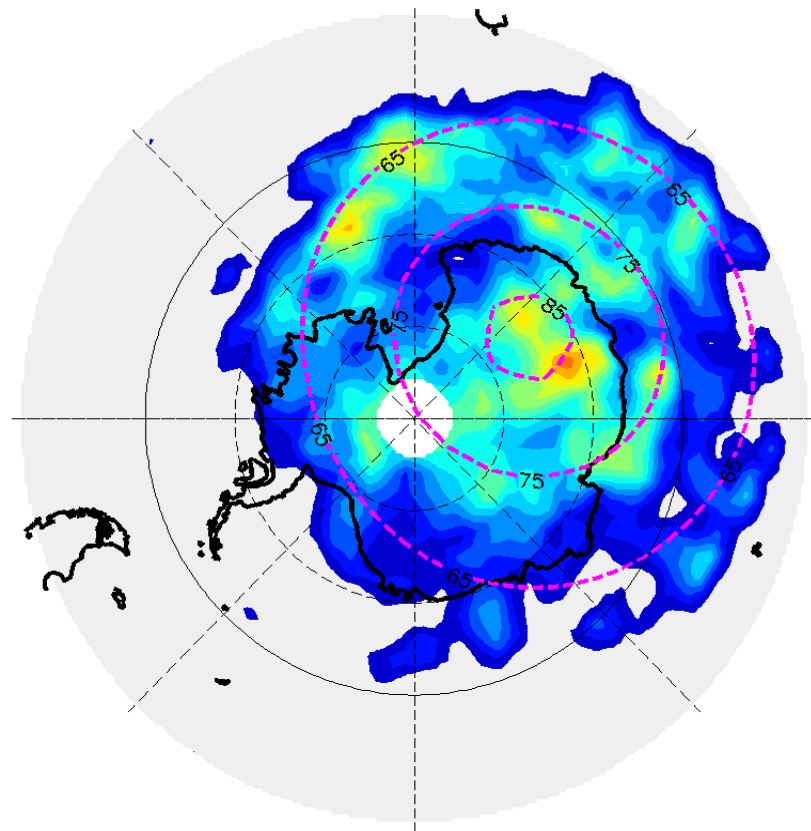


Irregularities appear preferably in certain geographic regions

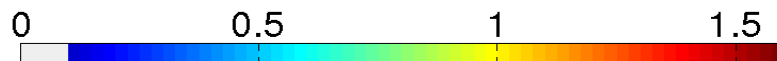
2001-2005 AE \geq 200 (NH)



2001-2005 AE \geq 200 (SH)

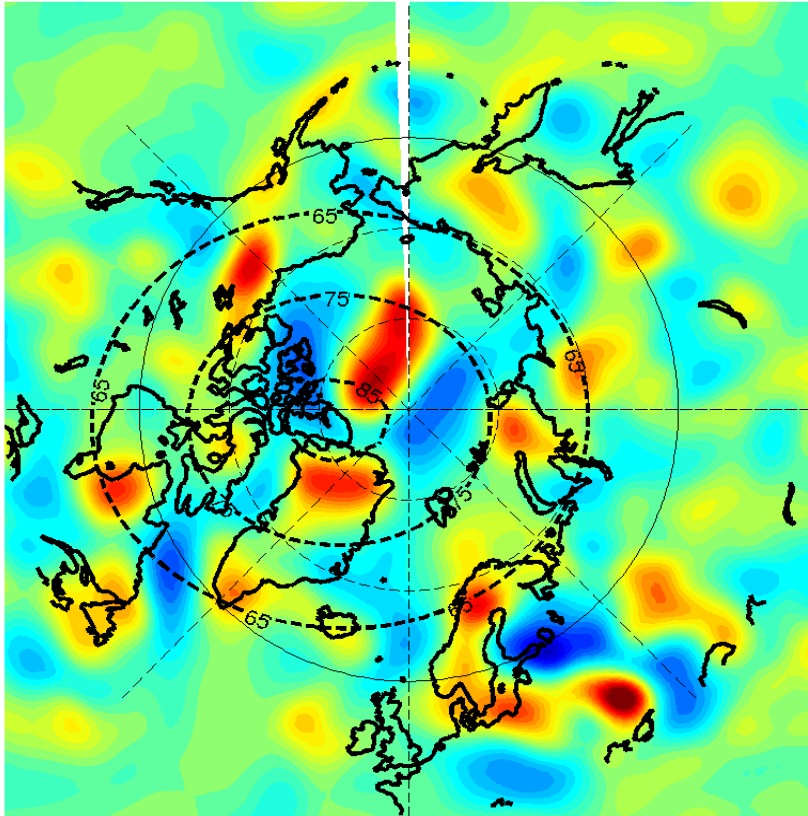


occurrence probability (%)

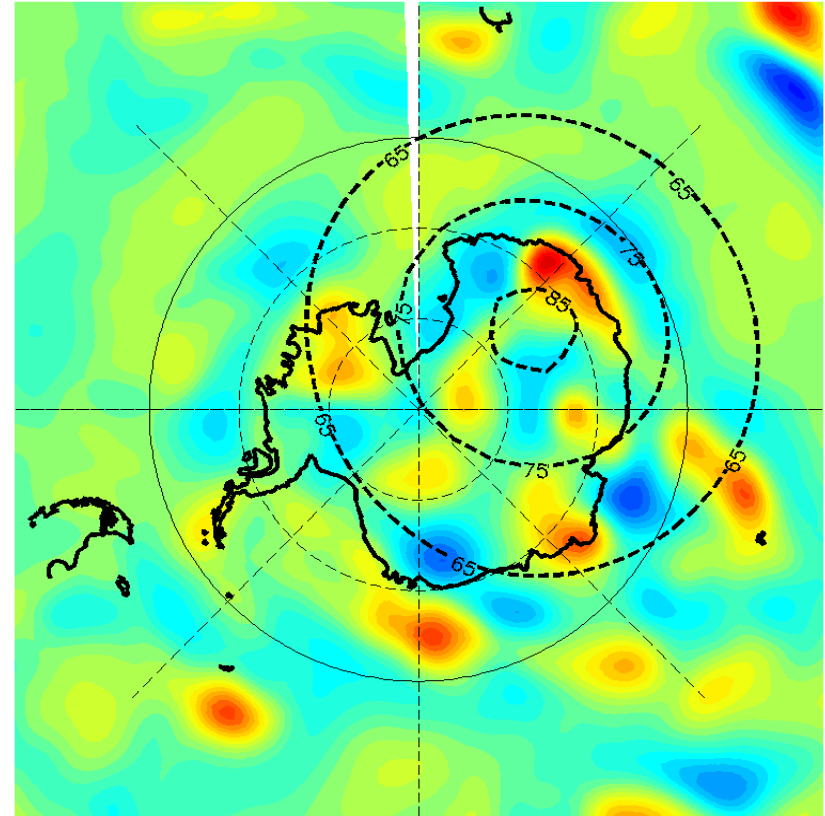


Crustal magnetic fields at CHAMP altitude ($\sim 400\text{km}$)

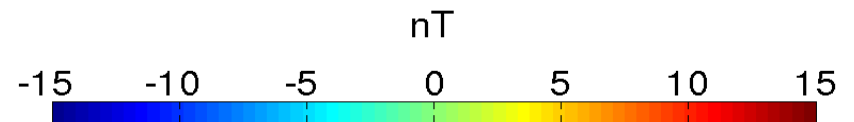
CRUSTAL FIELD ANOMALY (NH)



CRUSTAL FIELD ANOMALY (SH)

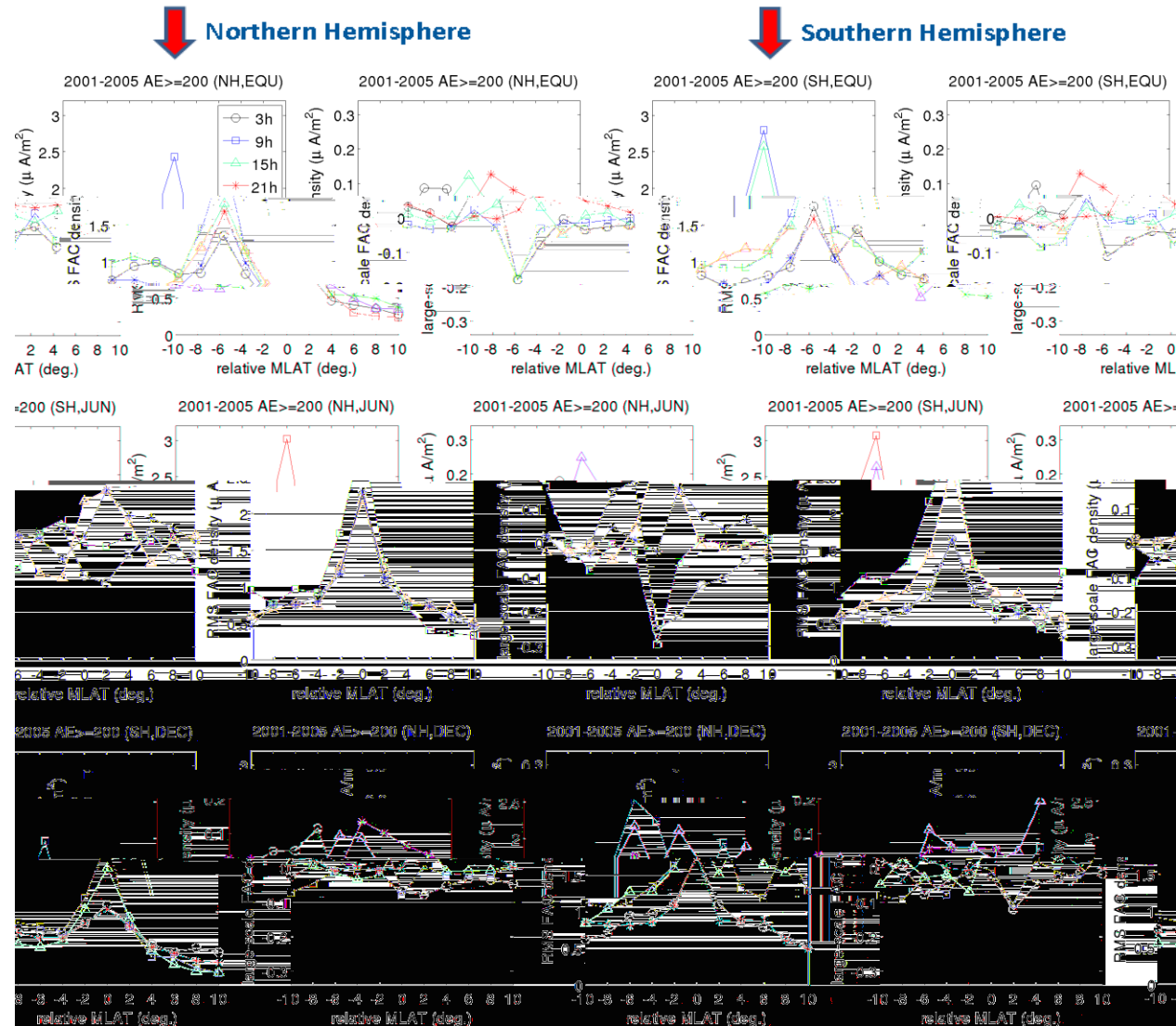
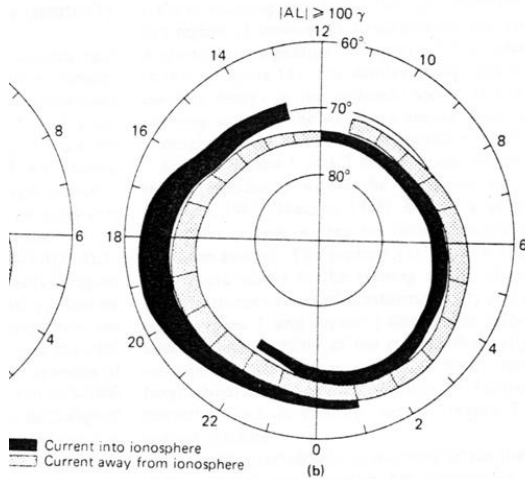


Regions of positive anomalies in the auroral zone correlate well with the event occurrence peaks.



Superposed epoch analysis of field-aligned currents co-located with events

Irregularities are always accompanied by bursts of small-scale FACs. In the morning and pre-noon sector events are co-located with downward FAC, during afternoon and evening they accompany upward FACs. This implies a co-location with the R1 FAC region.

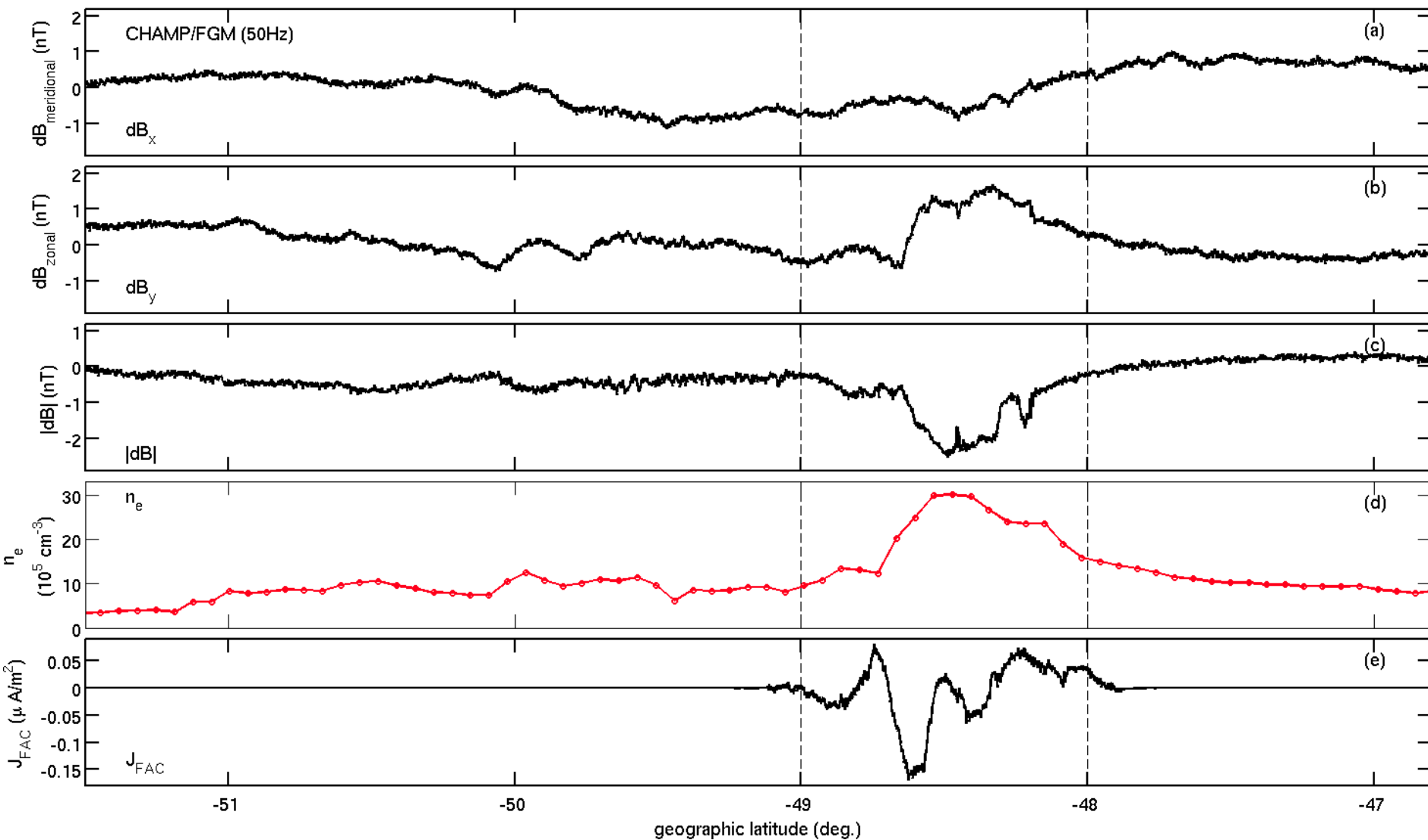


So far the statistical properties of high-lat. irregularities have been presented.

Next we study a long-lasting event occurring during the Halloween storm, Oct. 2003.

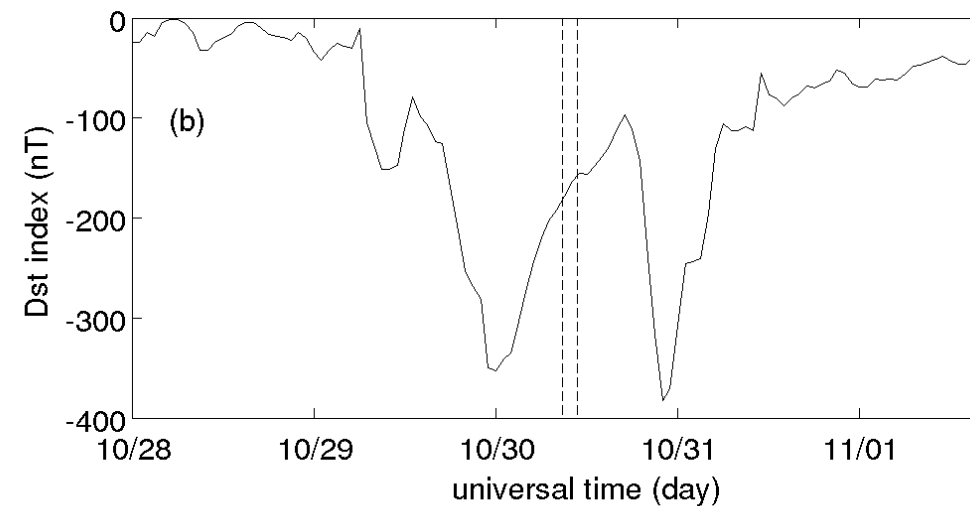
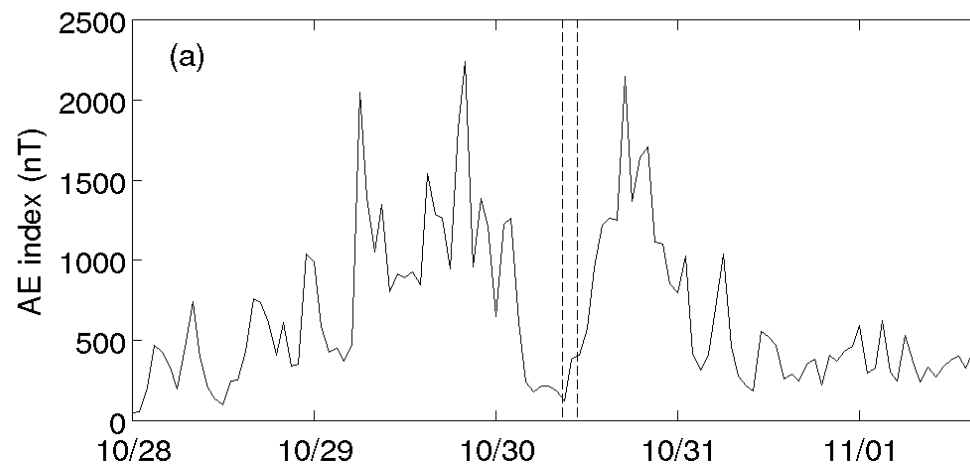
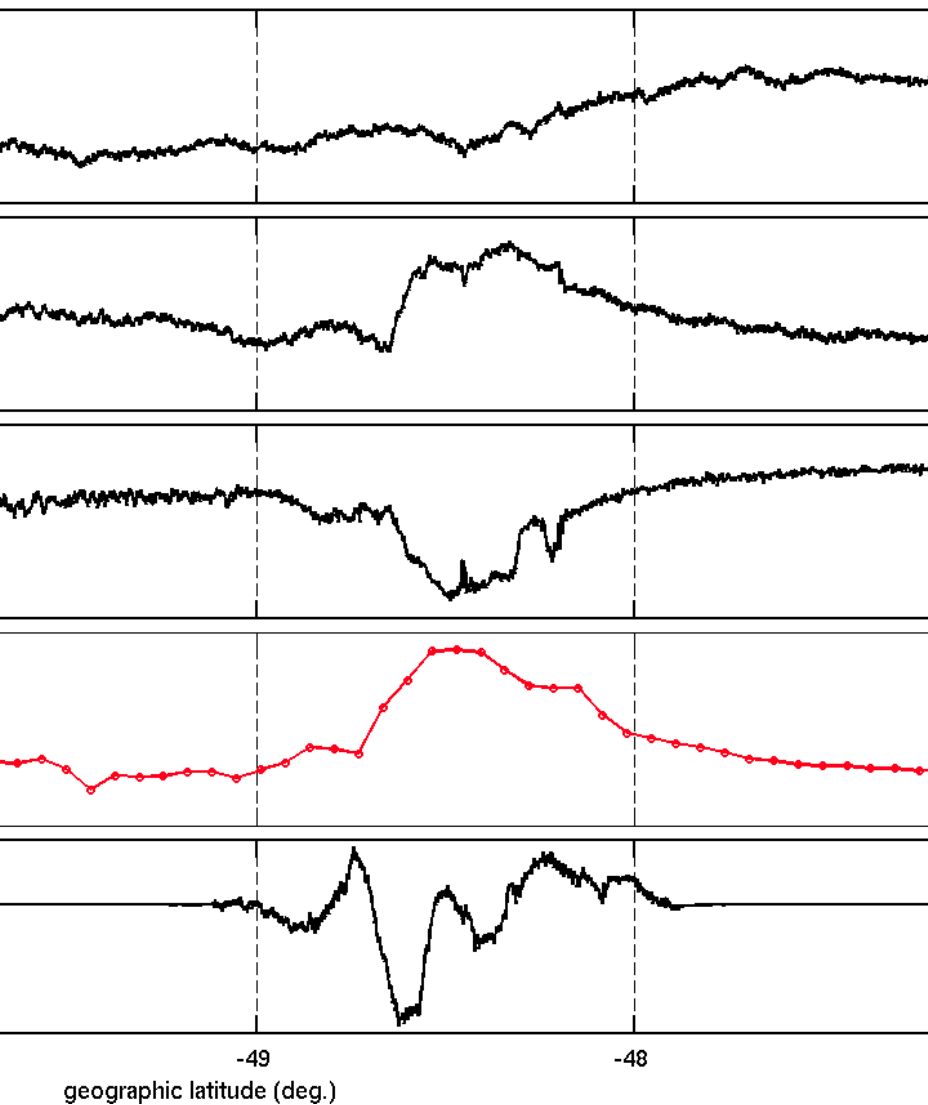
Long-lasting event during "Halloween storm"

CHAMP/FGM 2003-10-30 UT:08 geographic longitude: 241°



Long-lasting event during "Halloween storm"

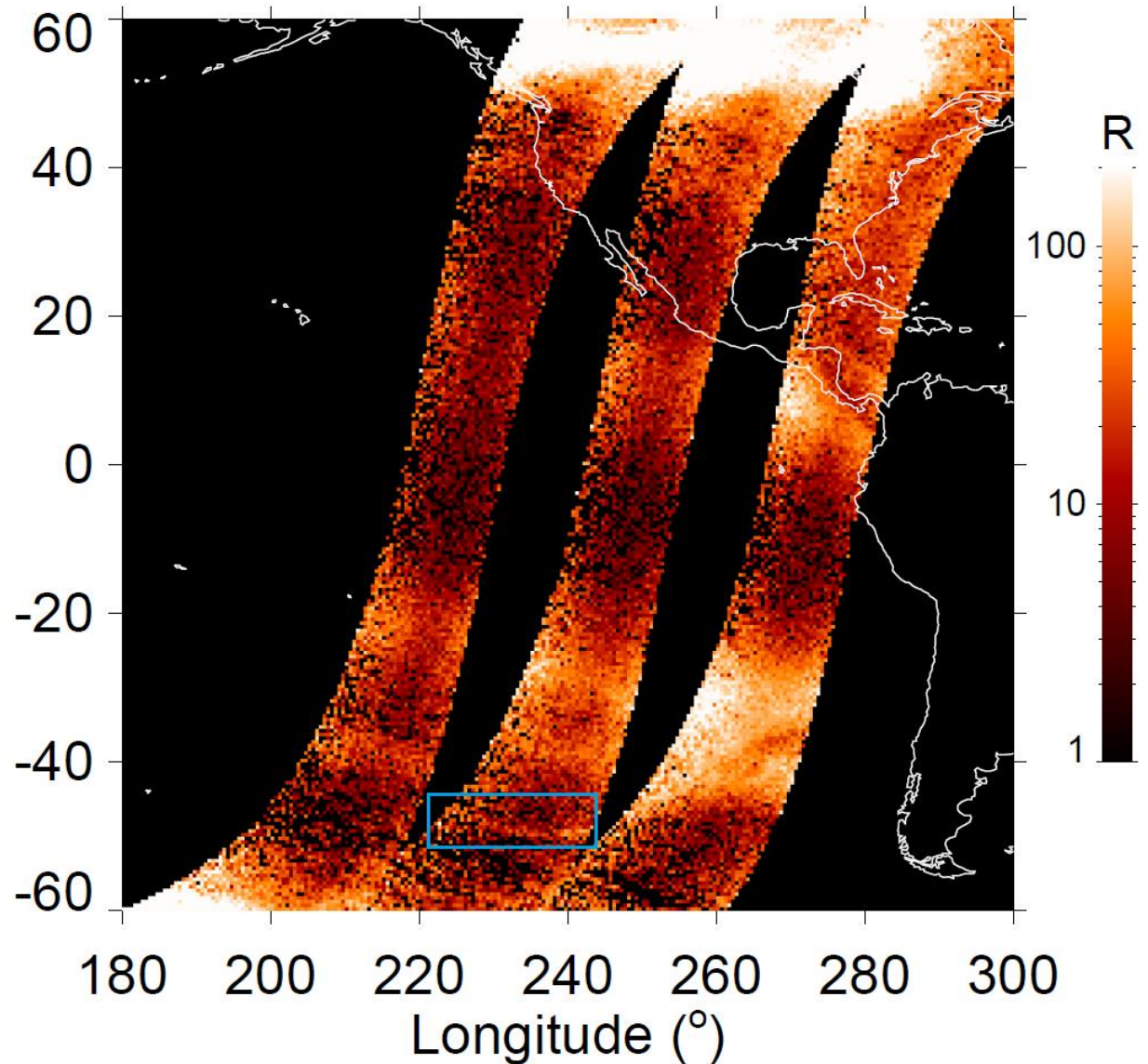
2003-10-30 UT:08 geographic longitude: 241°

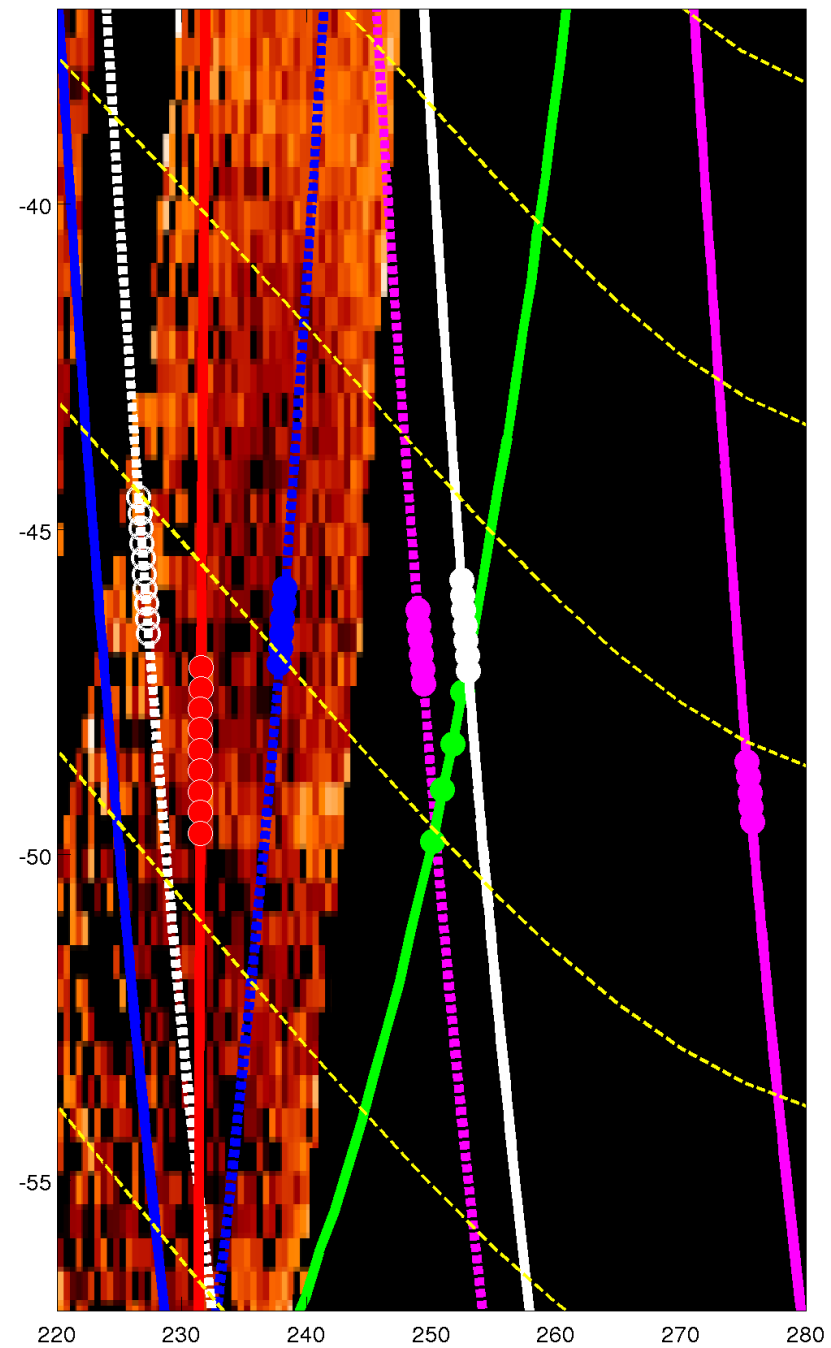
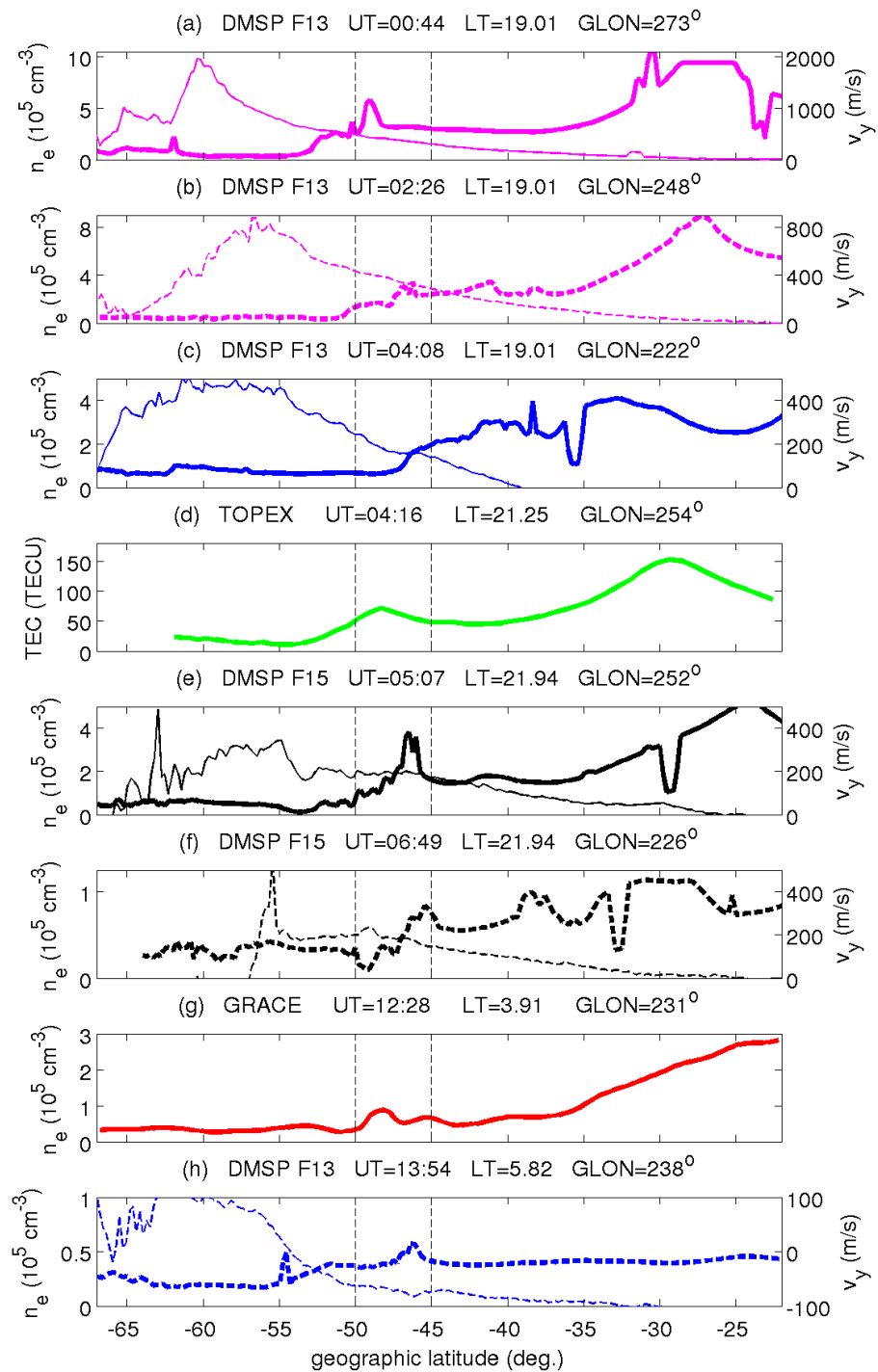


Irregularity signature in airglow images

The irregularity is visible in airglow images of IMAGE.

It appears as a narrow ribbon extending in east/west direction over 2000 km.





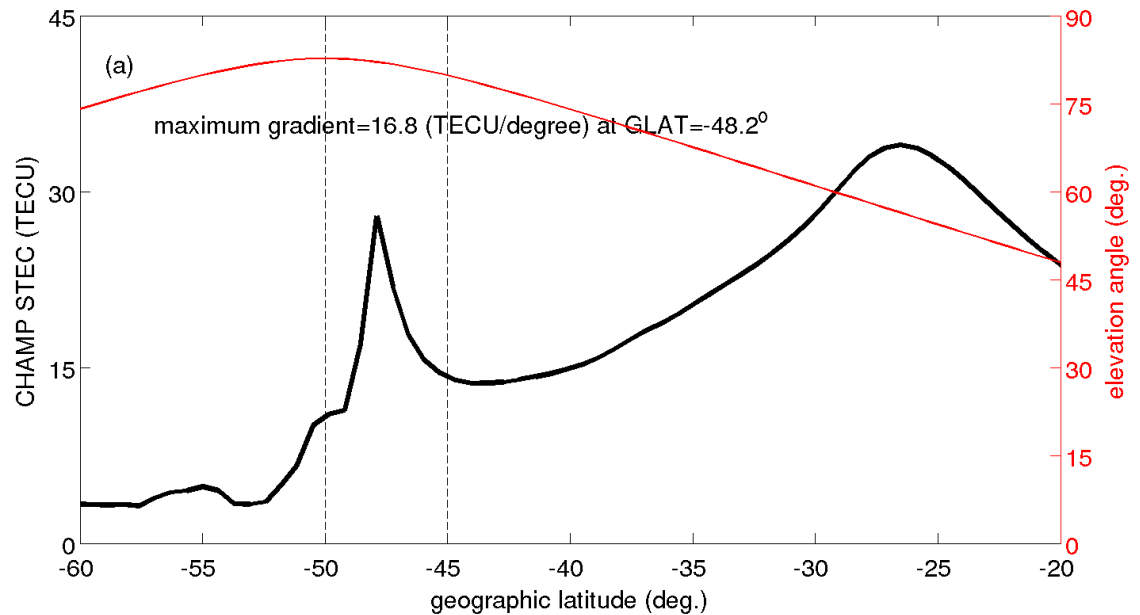
TEC signature of event

Steep TEC gradients are encountered above CHAMP.

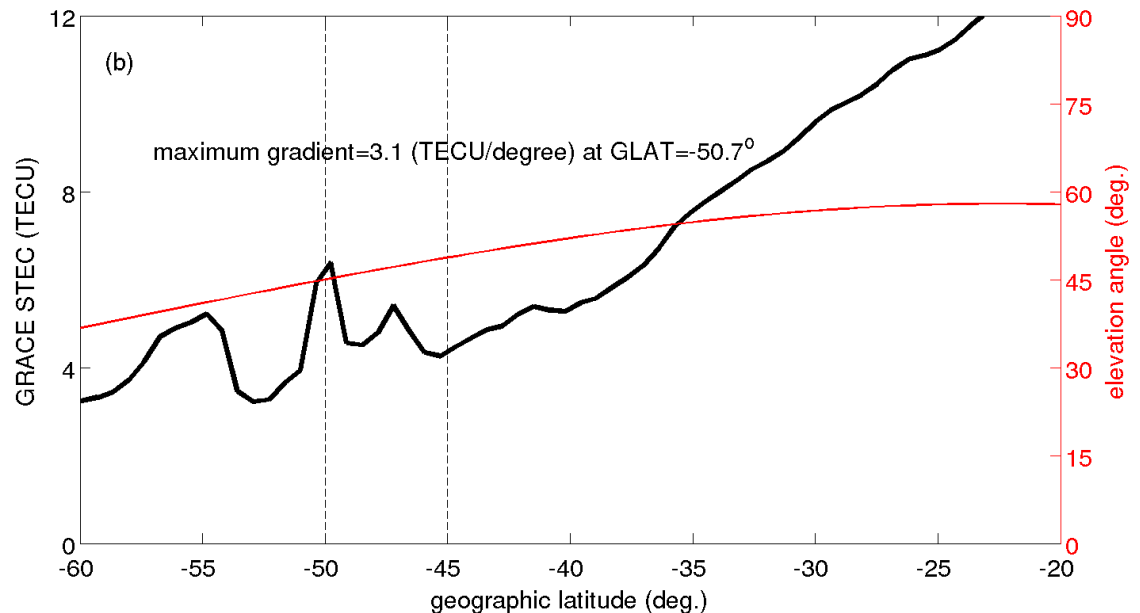
They suggest a high reaching field-aligned sheet of enhance electron density.

Even above GRACE (500km) it is still detectable 4 hours later.

STEC between CHAMP and PRN 30 2003-10-30 UT:08:34 GLON:242.3°E LT:0.7



STEC between GRACE and PRN 03 2003-10-30 UT:12:28 GLON:231.6°E LT:3.9



Summary

- High-latitude electron density irregularities occur as frequently as plasma bubbles at low latitude.
- Preferred region is the auroral region, in particular polar cusp and substorm region.
- There are geographic regions of high occurrence rates, Scandinavia, Siberia, northern Canada.
- After magnetic storms fossil irregularities can be encountered at middle latitudes that rotate with the Earth and persist for more than 12 hours.

References: Park et al. (2012, JGR); Park et al. (2012, JASTP)

Number of events during solar maximum and solar minimum years

	northern hemisphere		southern hemisphere	
	2001-2005	2006-2010	2001-2005	2006-2010
Equinox	1136	209	1177	196
June solstice	492	244	586	128
December solstice	1666	217	1069	335

