Effect of Solar Variability on the Evolution of Equatorial Spread F

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Equatorial Spread F

Plasma density irregularities in the F region of the equatorial ionosphere

Scale sizes: 0.1 – 10^5 m

Observation Techniques

In situ: Rockets and satellites

Ground-based:

Radio waves => Coherent scatter radars

Ionospheric scintillations

Global Positioning System (GPS)

Optical => Airglow

Equatorial Plasma Bubbles (EPBs) and scintillations observed using GPS signals

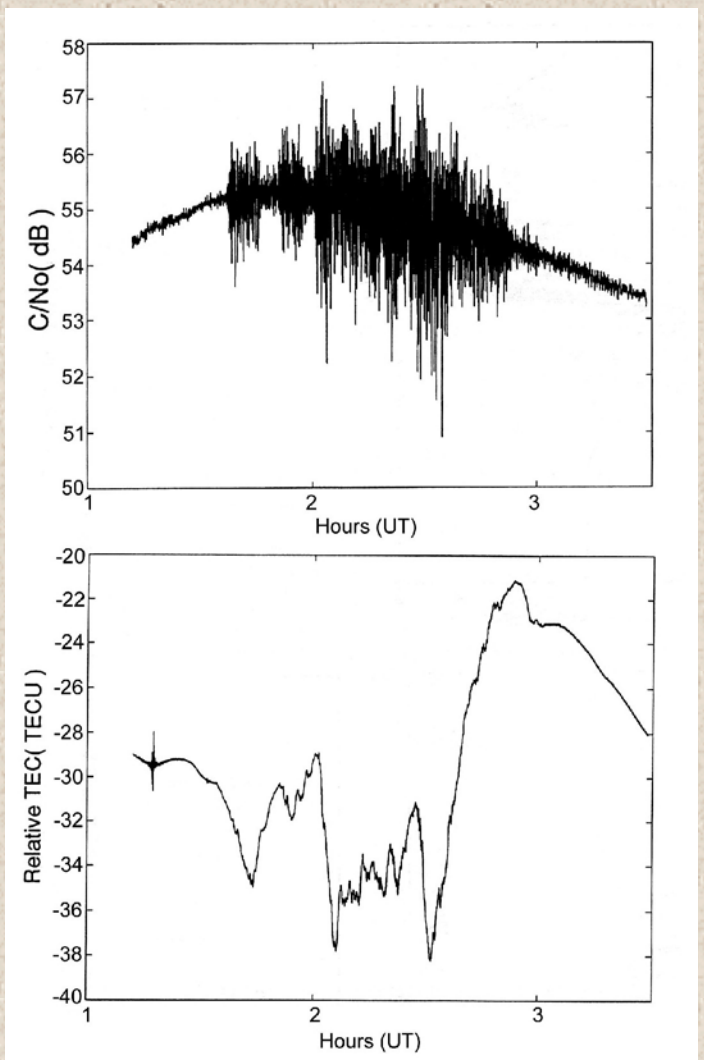
Intensity scintillations on GPS L1 signal

Contribution of ionosphere to the pseudorange:

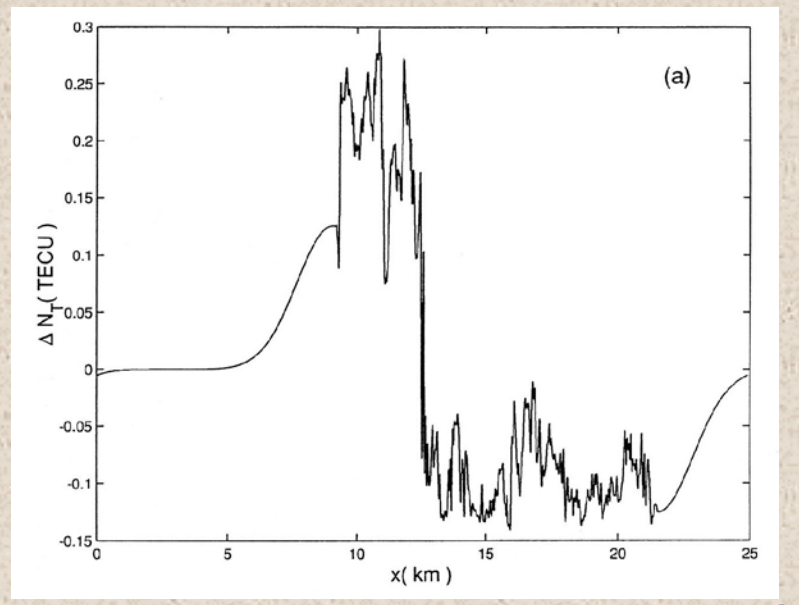
$$\Delta iono(f) = \frac{40.3}{f^2} \mathrm{N}_{\mathrm{T}}$$

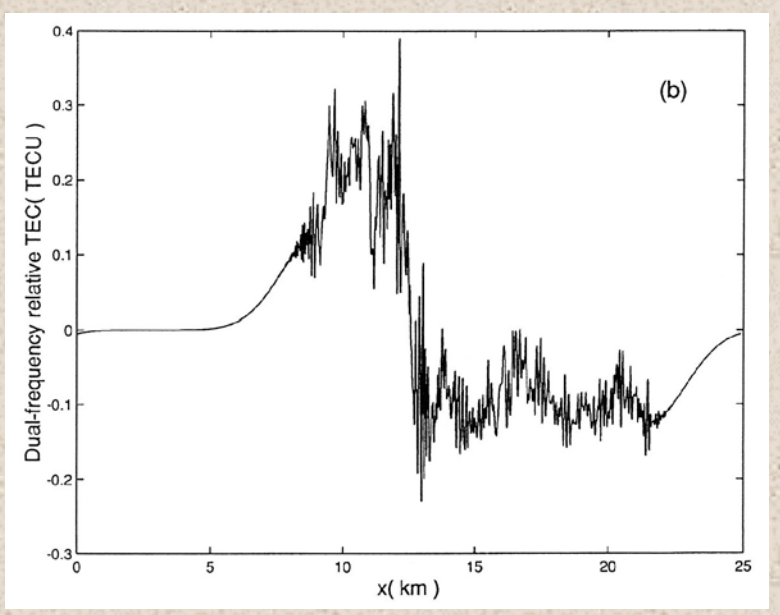
$$\mathrm{N}_{\mathrm{T}} = 9.52 (R_{L1} - R_{L2}) \ \mathrm{TECU} \ (= 10^{16} \ \mathrm{el/m^2})$$

Variations in total electron content (TEC) along the signal path due to the presence of EPBs



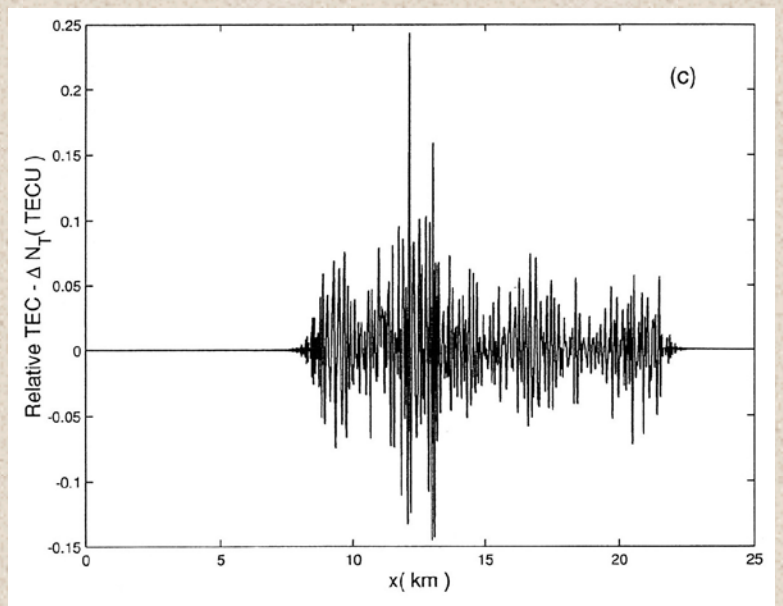
Phase scintillations on GPS signals





scattering

Model irregularity layer



Contribution of phase scintillations

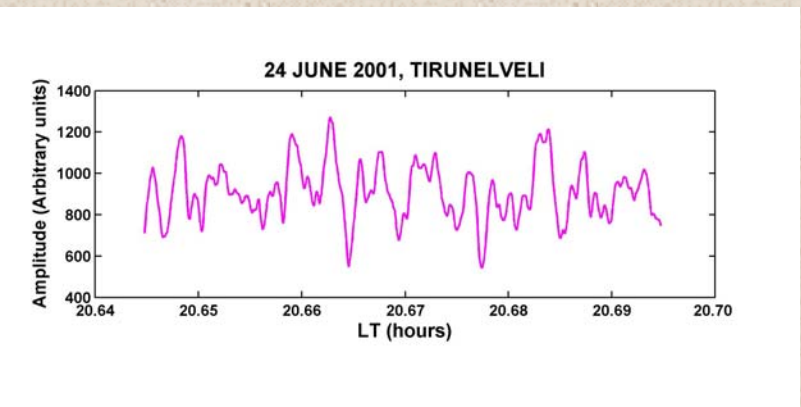
Signal degradation due to scintillations

- **Depth of fading:**

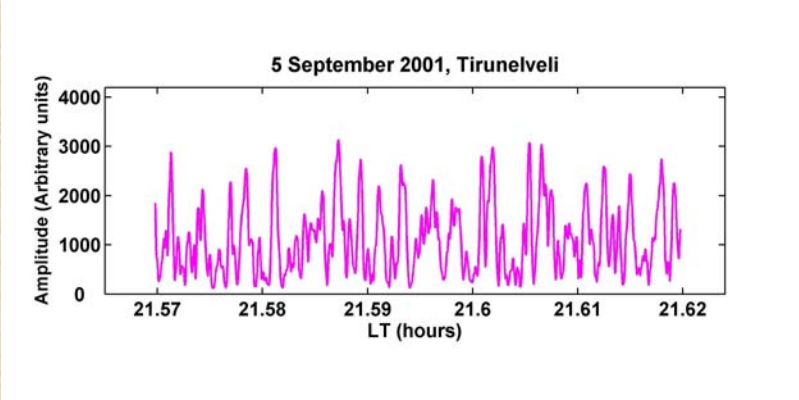
Depends on strength and spatial structure of irregularities

- **Fading rate:**

Depends on (a) strength and spatial structure of irregularities; (b) movement of irregularities across signal path.

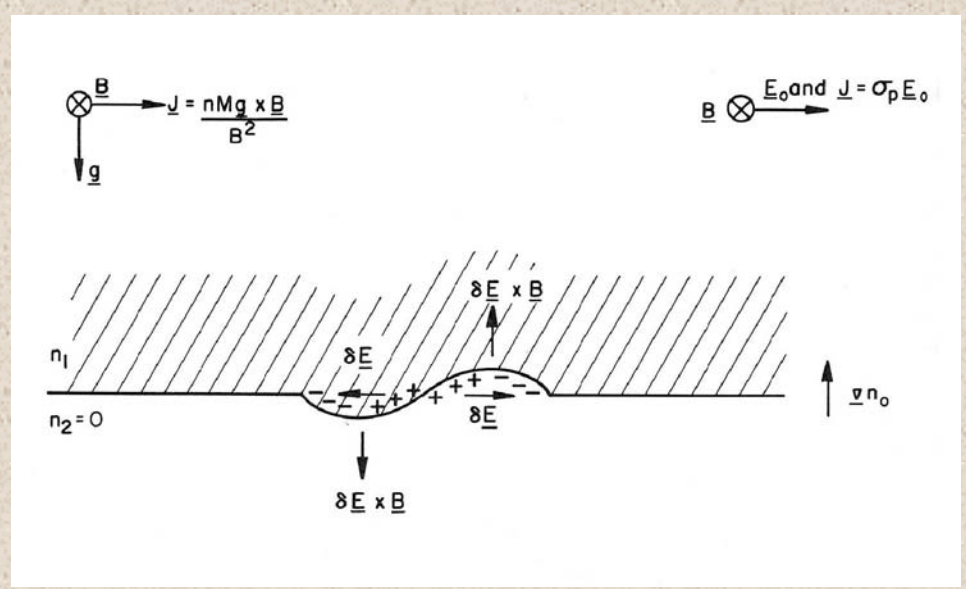


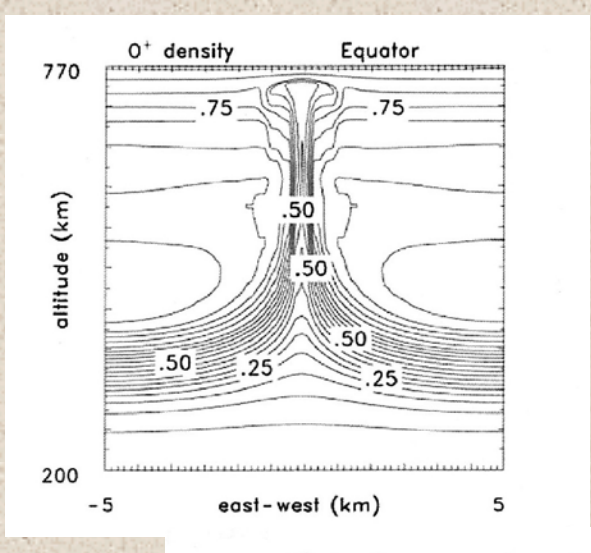
Weak scintillations with slow fading

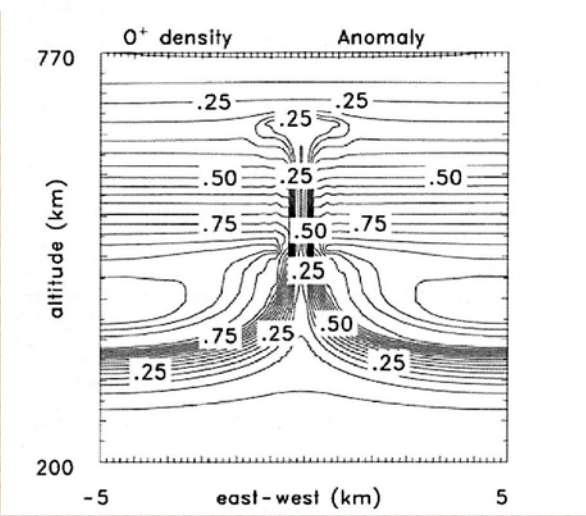


Strong scintillations with fast fading

Evolution of equatorial plasma bubbles







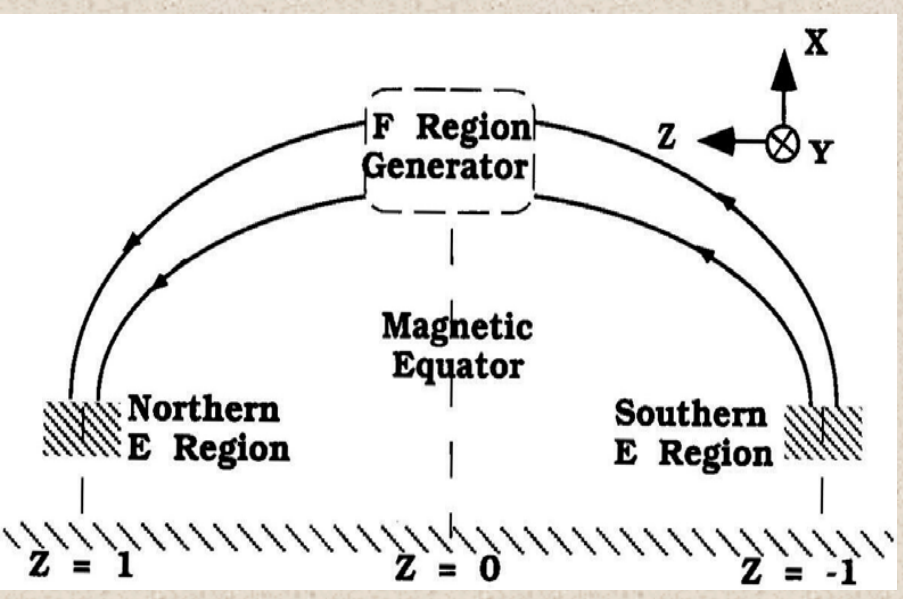
Development of an EPB on the bottomside of the post-sunset equatorial ionospheric *F* region due to growth of the Rayleigh-Taylor (R-T) instability

Non-linear evolution of EPB

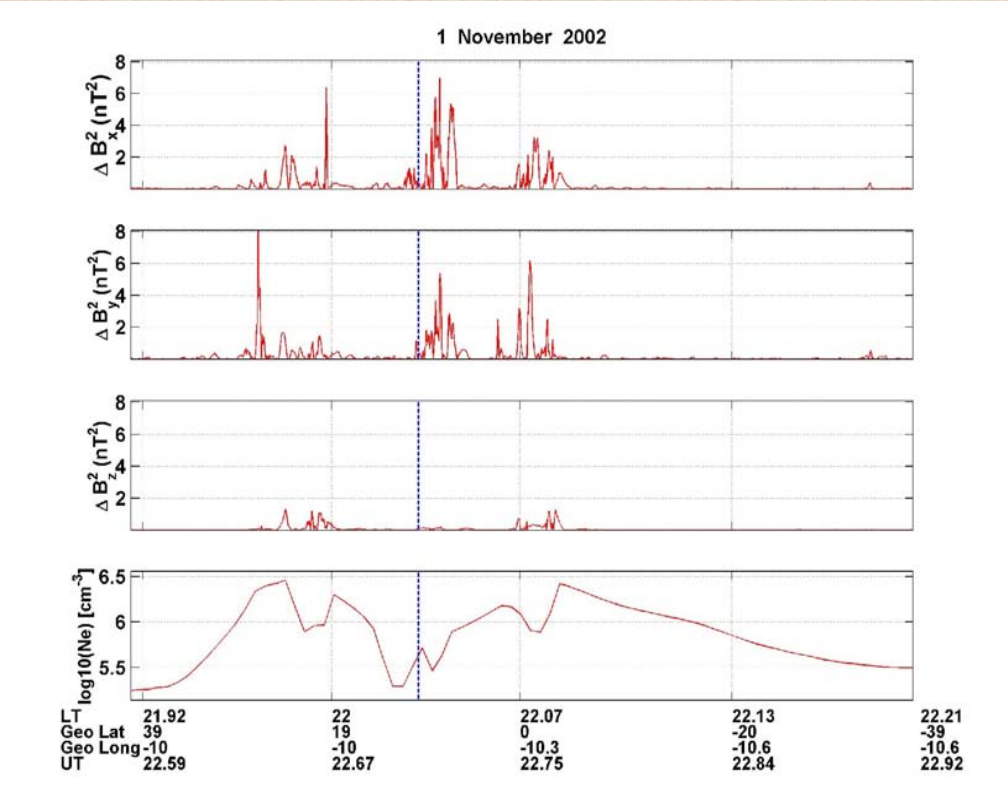
(Keskinen et al., 2003)

Coupling with conjugate E regions through field-aligned currents

Transmission line analogy



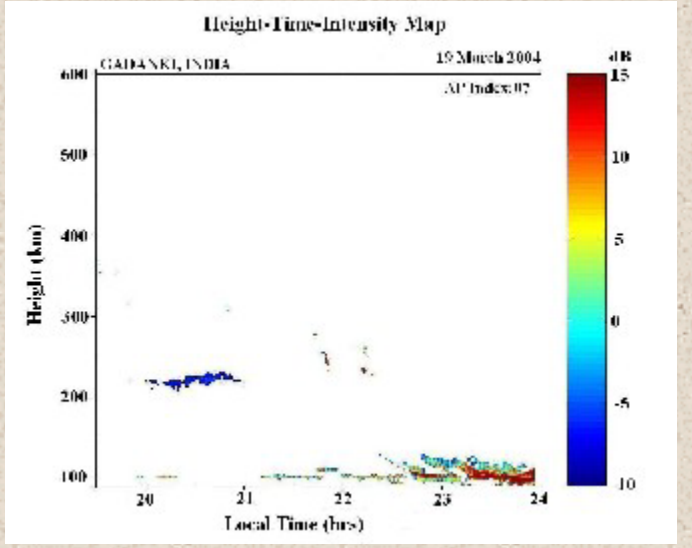
Magnetic field fluctuations associated with plasma bubbles observed by CHAMP satellite at 420 km altitude

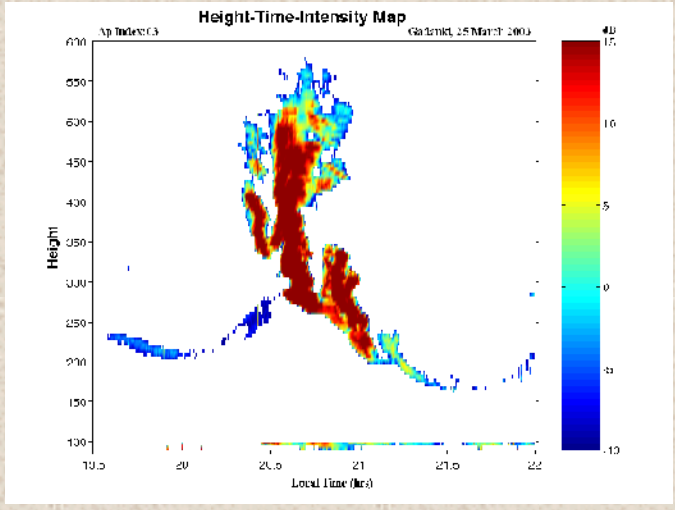


A condition for evolution of EPB due to growth of the R-T instability:

$$\nu_i + \frac{\mu_0 V_A^2 \Sigma_P^E}{l} < \sqrt{\frac{g}{2L}}$$

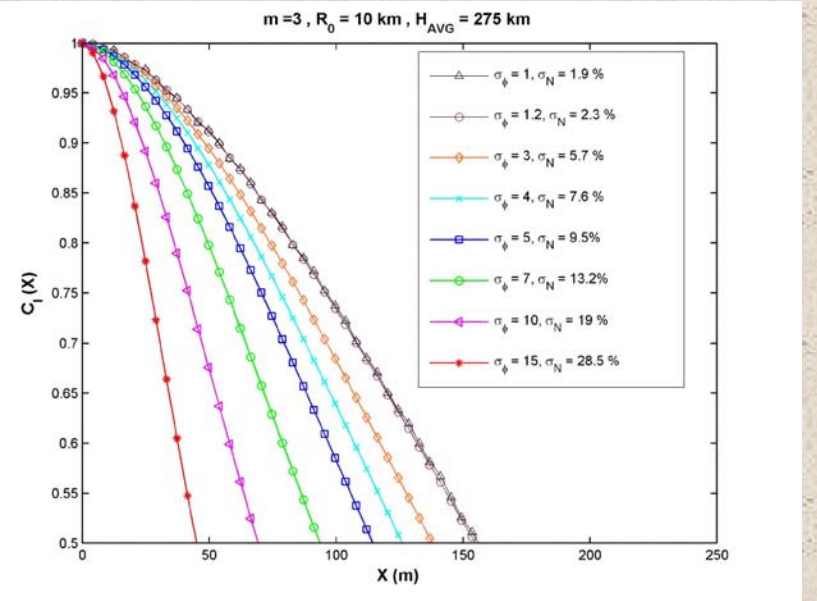
Rate of discharge of the bubble by currents flowing through the conjugate E regions

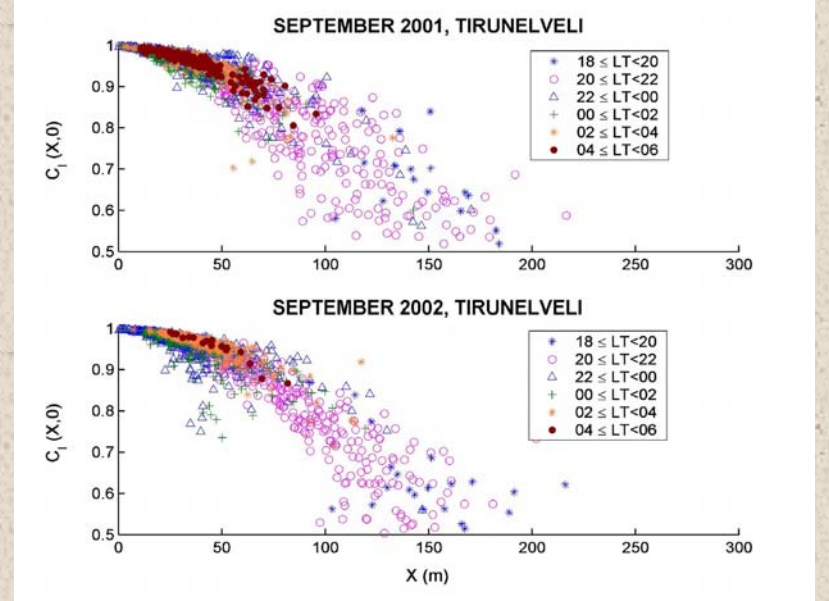




MST radar observations at Gadanki (dip lat. 6.3° N)

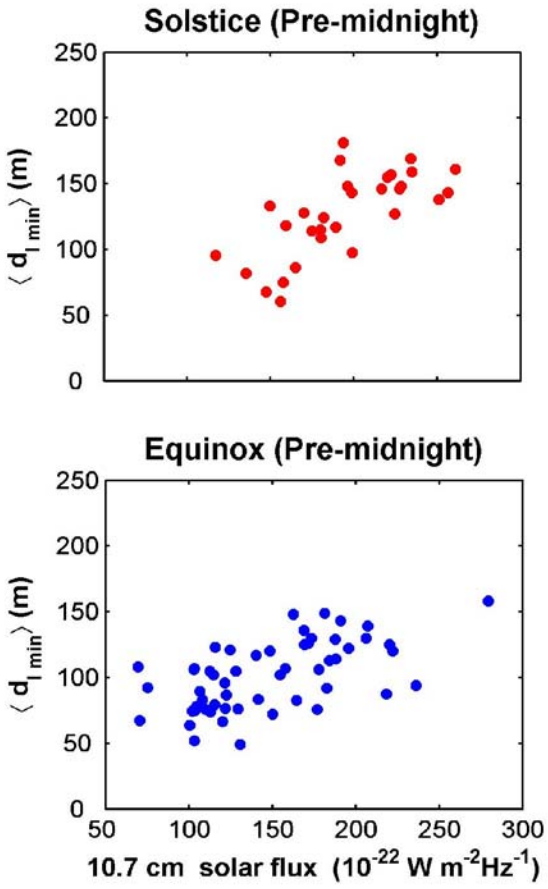
Spatial scales in the ground scintillation pattern

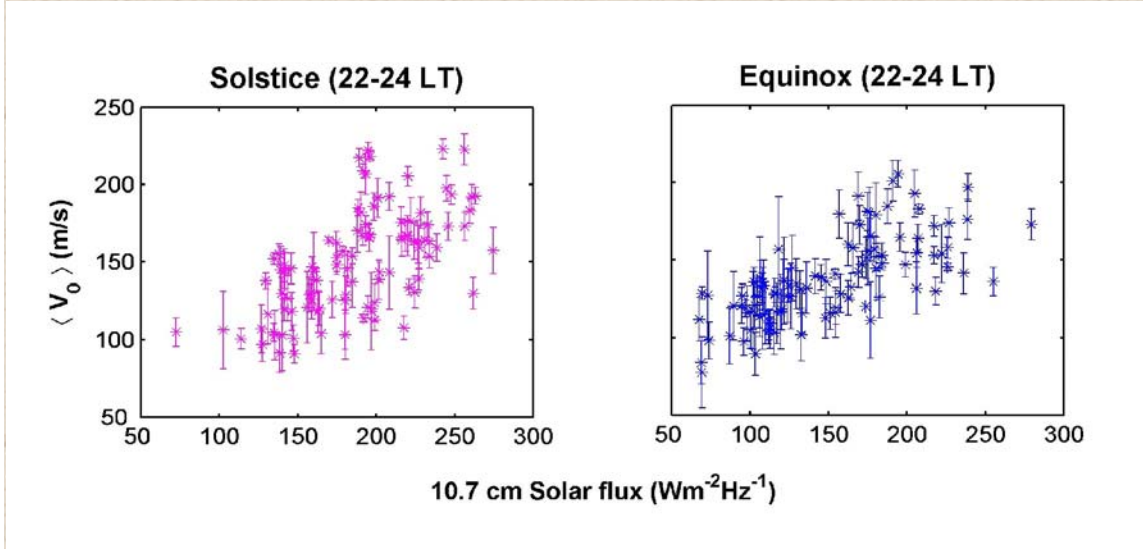




Coherence scale lengths (for 50% decorrelation) of intensity fluctuations in the ground scintillation pattern varying with irregularity model parameters (left) and derived from scintillation observations (right).

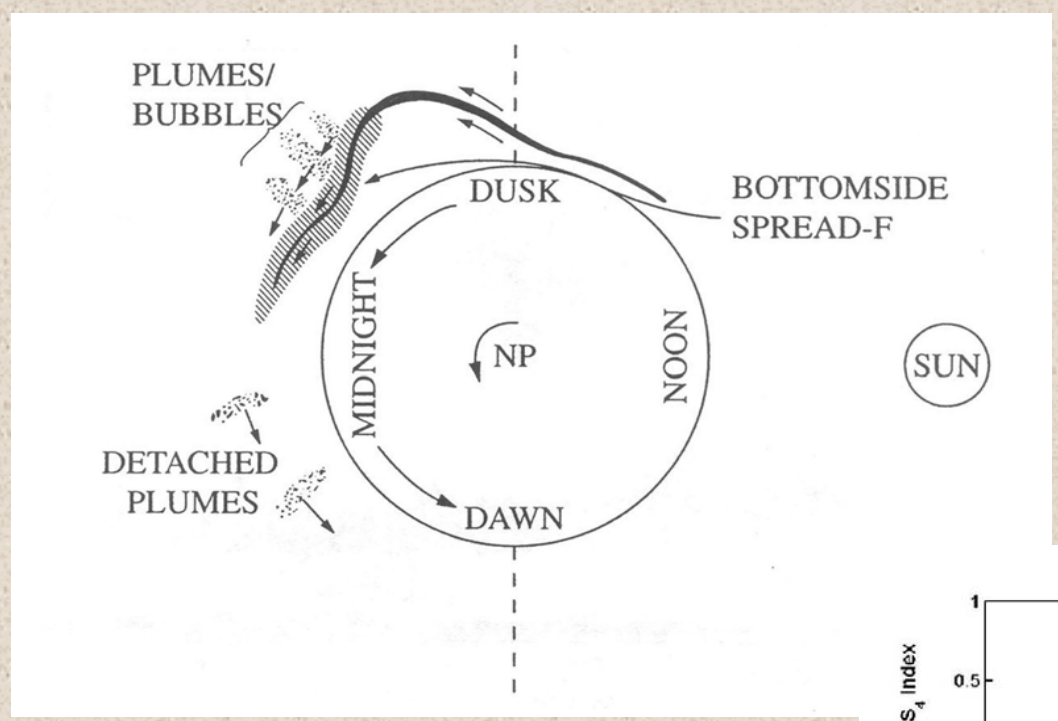
Variation of shortest coherence scale in ground scintillation pattern and average zonal drift of the pattern with solar flux



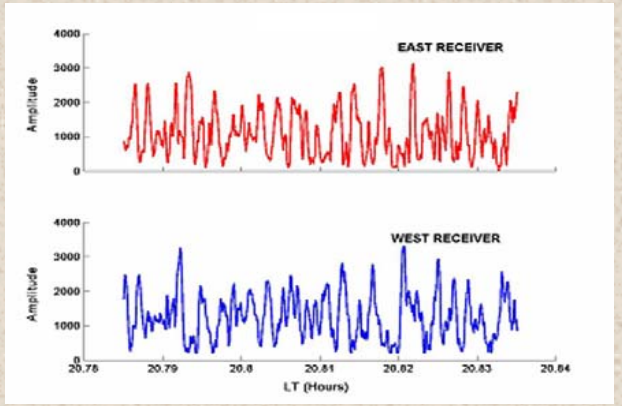


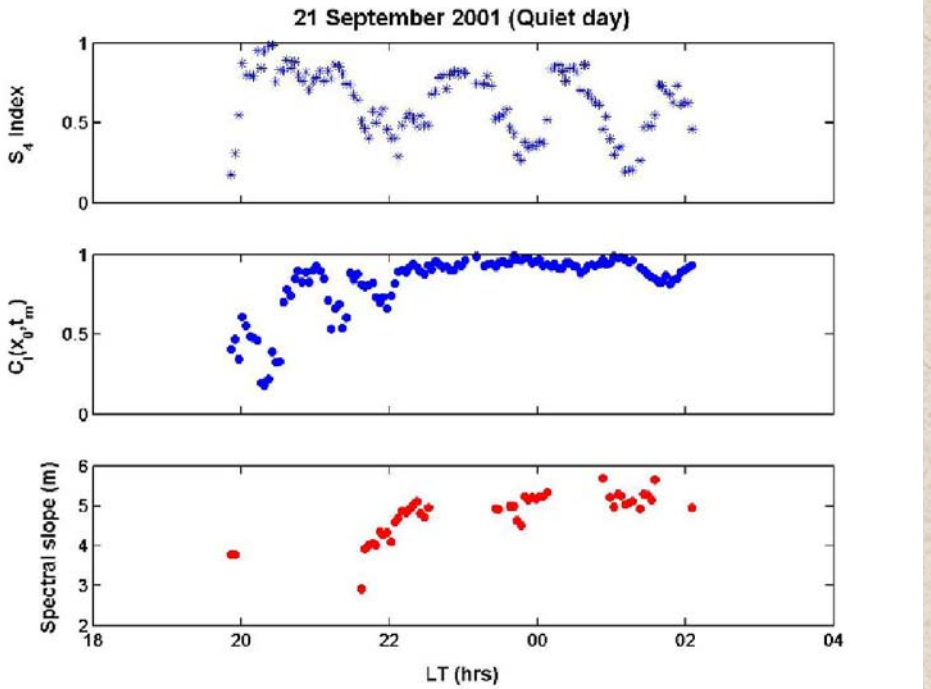
More rapid decay of short scale length irregularities for higher solar activity causes the fading rate to level off after an initial rapid decrease with increasing $F_{10.7}$ upto ~ 150 during equinoxes.

Signature of nascent plasma bubble

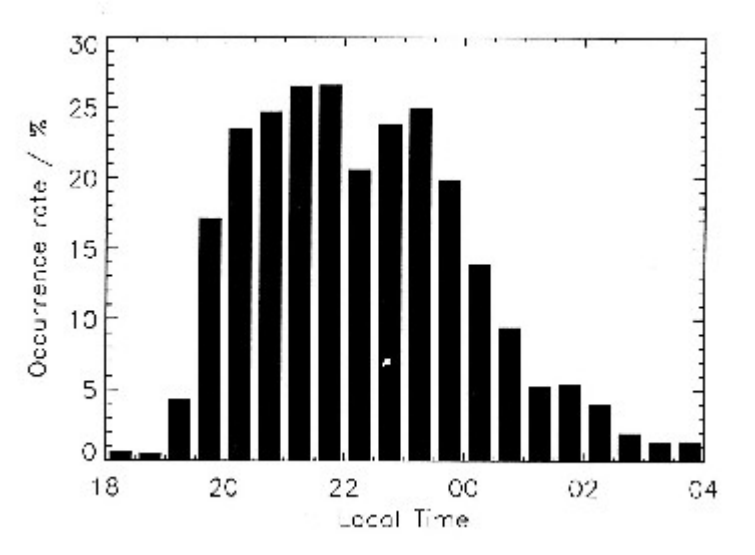


Parameters derived from ionospheric scintillations recorded by spaced recievers at an equatorial station.

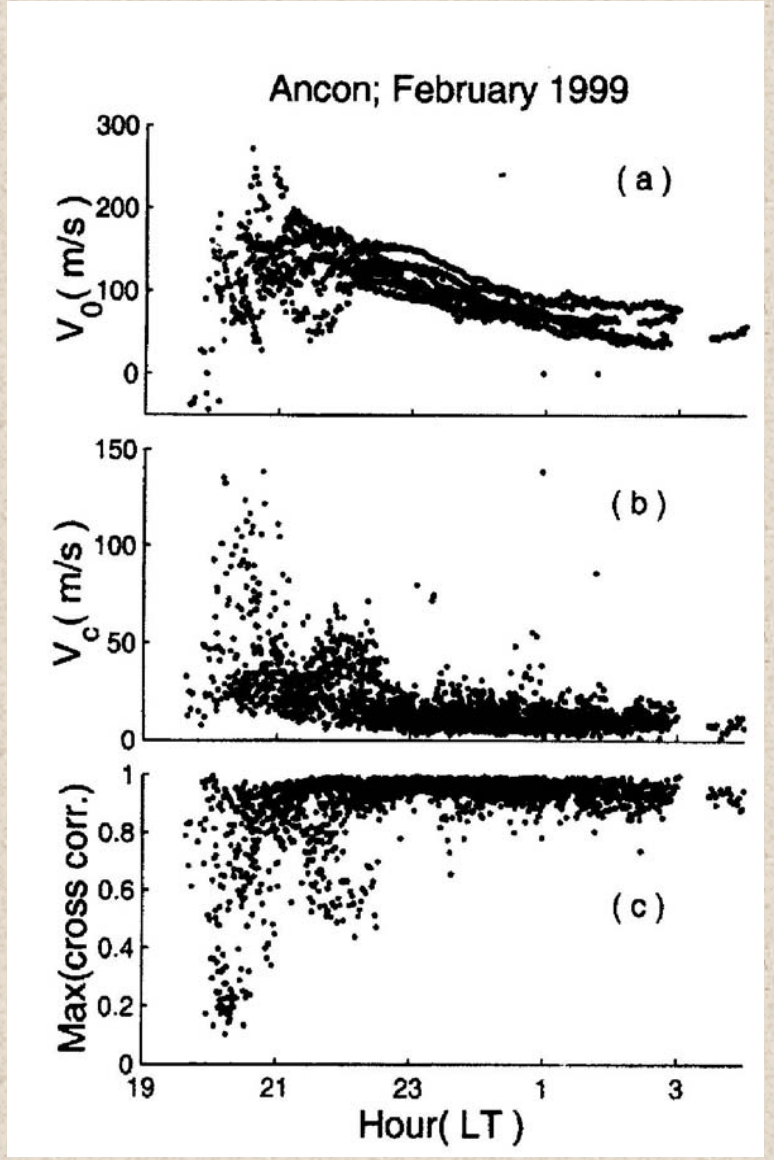




Electric and magnetic field fluctuations associated with EPBs



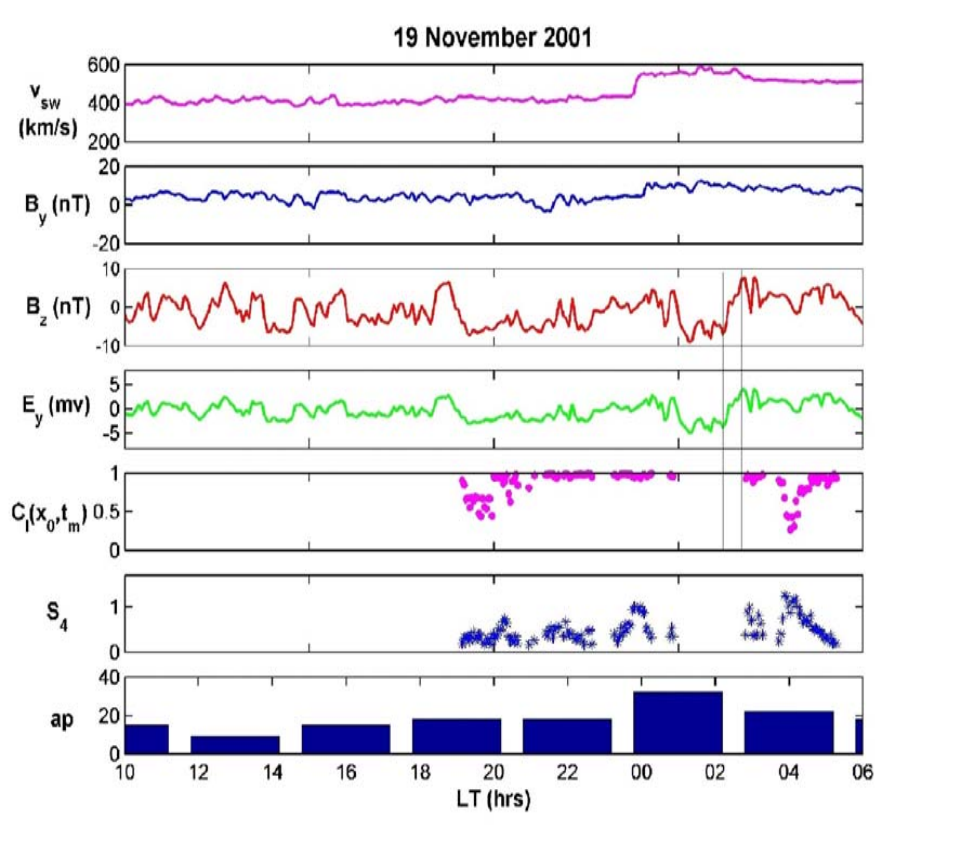
Occurrence rate of magnetic field fluctuations associated with EPBs observed by CHAMP (Stolle et al., 2006).

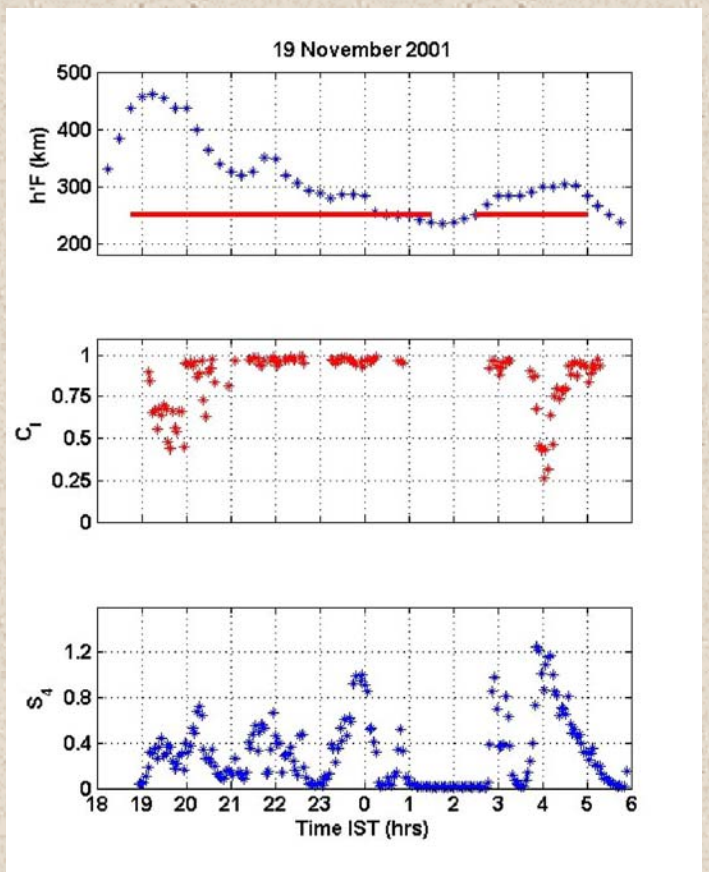


Decorrelation of spaced receiver scintillation signals due to electric field fluctuations associated with EPBs

Either electric or magnetic field fluctuations associated EPBs may be used to identify nascent EPBs.

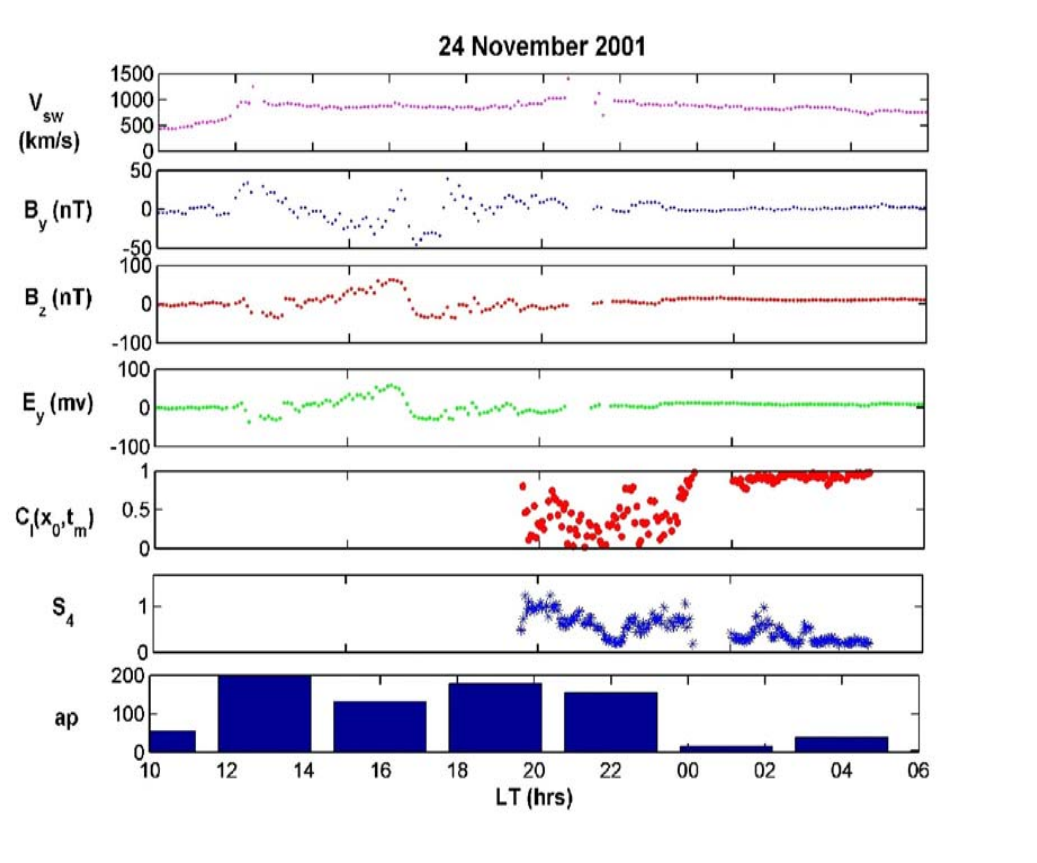
A case of plasma bubble generation due to prompt penetration of a high latitude eastward electric field into the nighttime equatorial ionosphere?

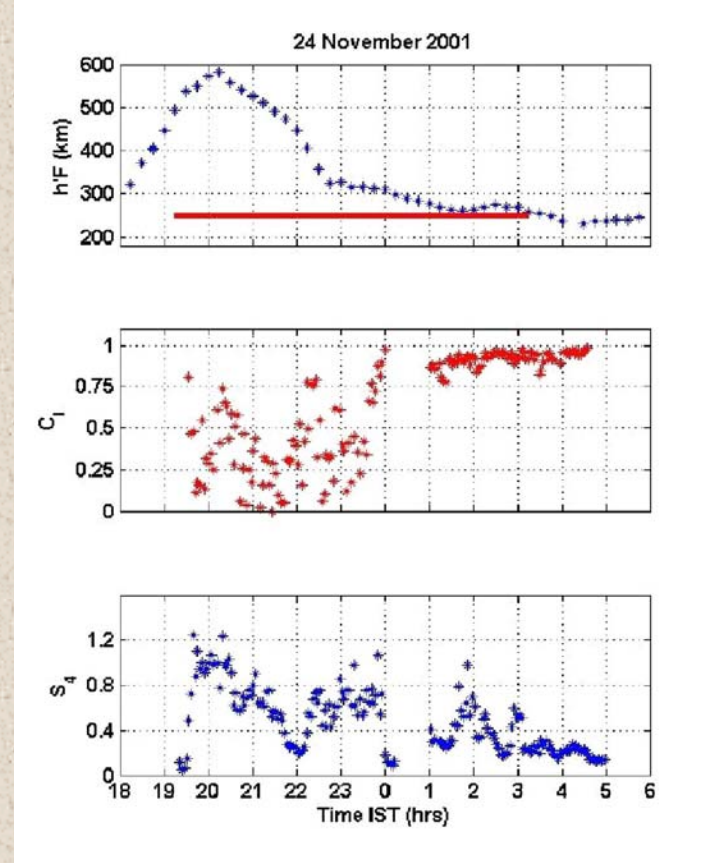




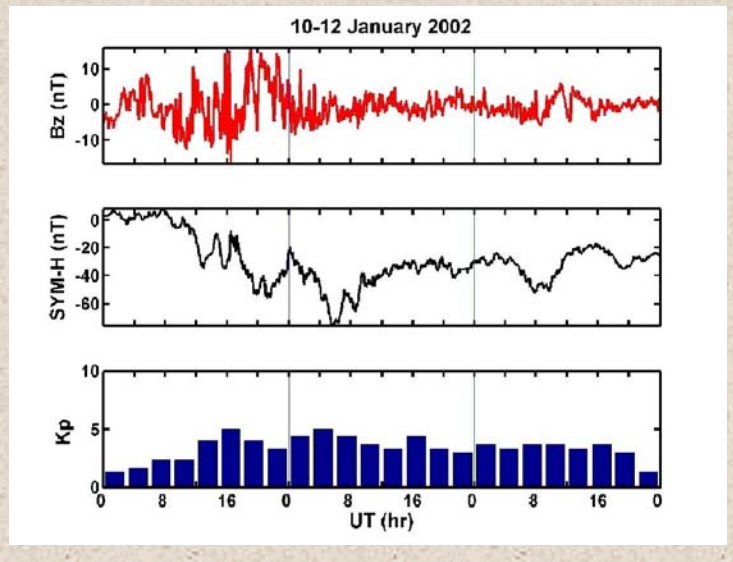
Scintillation observations at Tirunelveli (77.8^o E, 8.7^{o}N, dip lat. 0.7^{o}N) and ionosonde observations at Trivandrum (77^o E, 8.5^o N, dip lat. 0.5^{o}N)

Equatorial plasma bubble generation due to a disturbance dynamo electric field



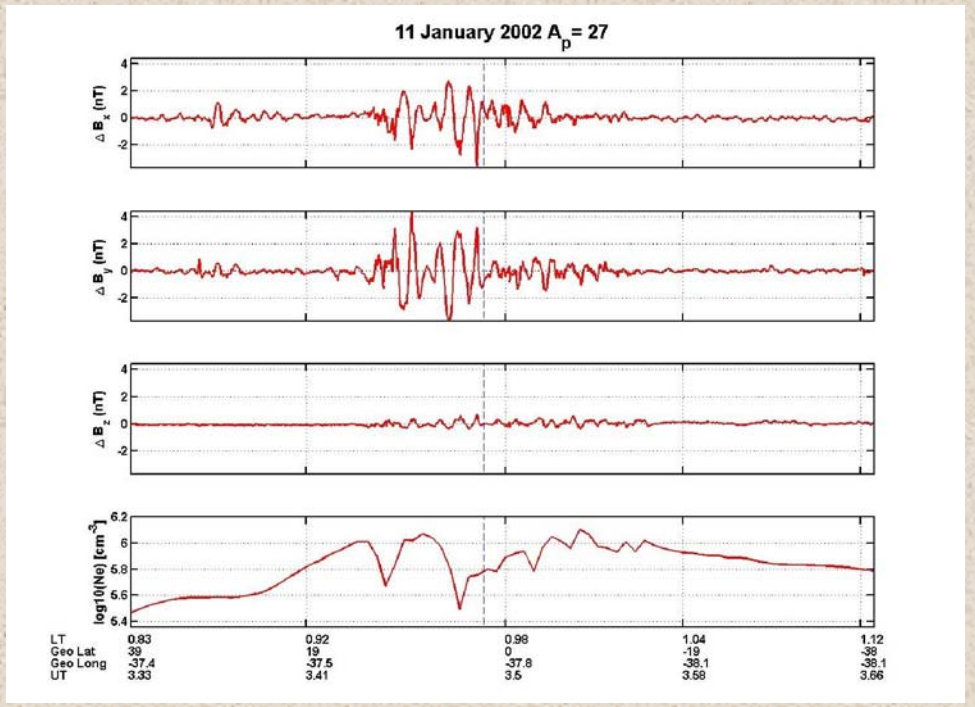


CHAMP satellite observation of EPBs generated due to magnetic activity

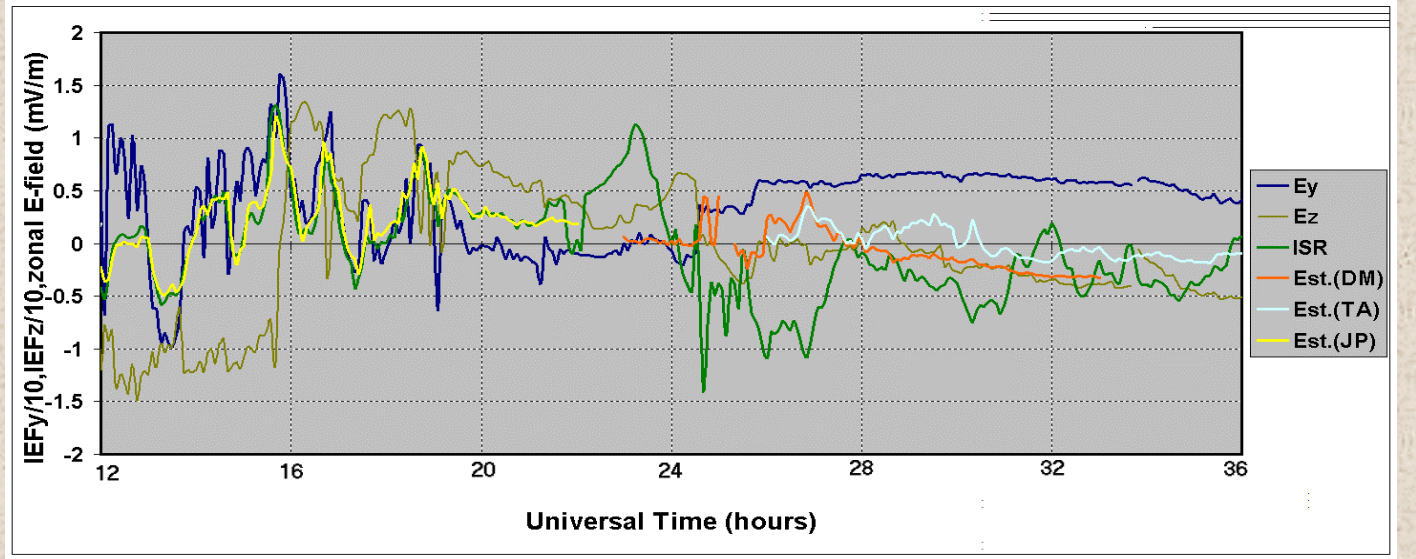


IMF B_Z and magnetic indices for 10-12 January, 2002

Fluctuations of ~ 4 nT in the magnetic field components transverse to the mean magnetic field aligned with the z-axis, are associated with EPBs generated on January 11, 2002.



Response of equatorial ionosphere on day and nightside to geomagnetic storm

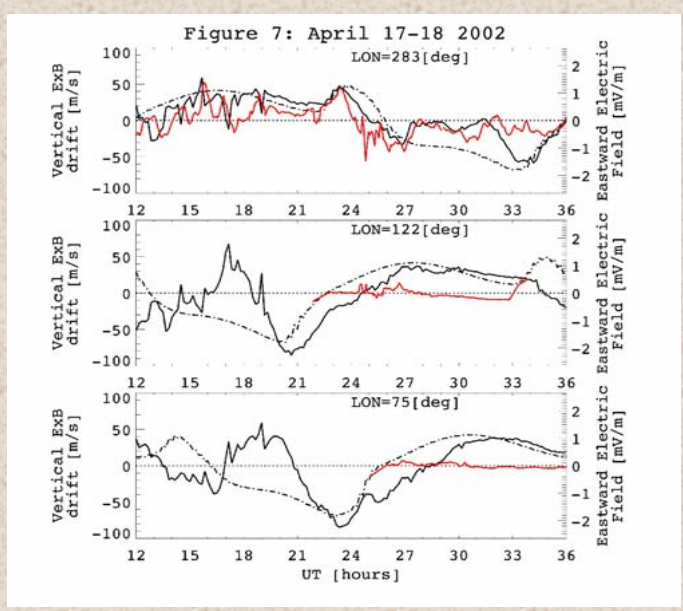


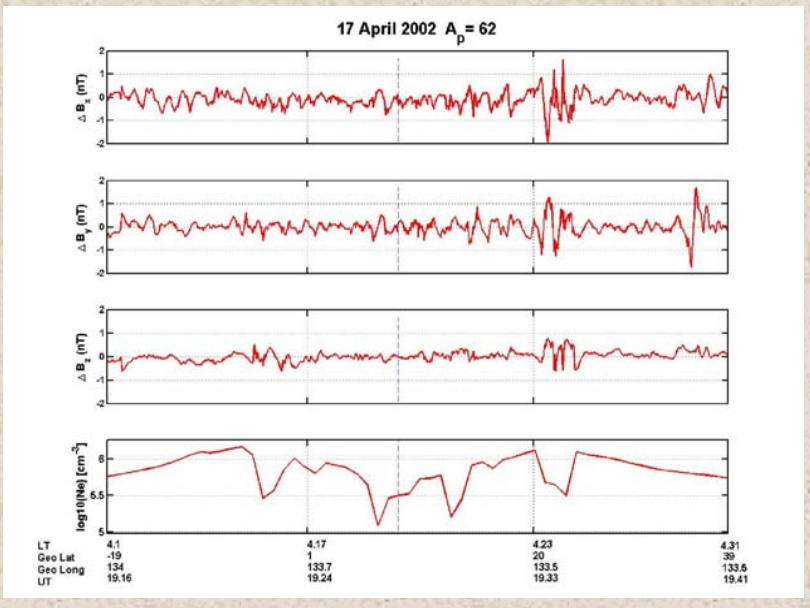
Prompt penetration of high-latitude electric field

(Anderson et al., 2006)

CHAMP data

Model calculations of eastward electric field at different longitudes (Maruyama et al., 2006)





Summary

- Evolution of ESF irregularities is influenced by long term solar variations; more rapid decay of short scale length irregularities with increasing $F_{10.7}$ implies that coherence interval does not decrease any further with $F_{10.7}$ increasing beyond 150.

- Equatorial plasma bubbles are not generated when the height of the equatorial F layer is below a threshold. However, bottomside sinusoidal irregularities may be generated.

- In order to establish a cause-effect relationship between transient solar events leading to geomagnetic activity, and the generation of EPBs, it is necessary to first identify nascent EPBs. Either electric field or magnetic field fluctuations associated with the instability may be used for the purpose.