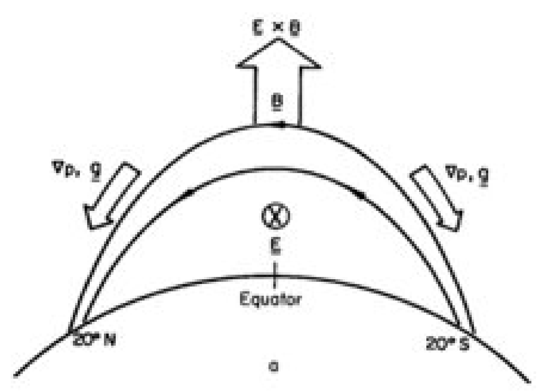
Ionospheric Disturbances During the September 2017 Geomagnetic Storm

A. Newheart[1], S. Sazykin[1], A. J. Coster[2], V. Coffey[3], M. Chandler[3], B. Fejer[4], P. J. Erickson[2],L. Navarro[4]
[1] Rice University [2] MIT Haystack Observatory, Westford MA [3] NASA Marshall Space Flight Center [4] Utah State University

How did the electron density in the F-region equatorial ionosphere respond to the September 2017 geomagnetic storm?

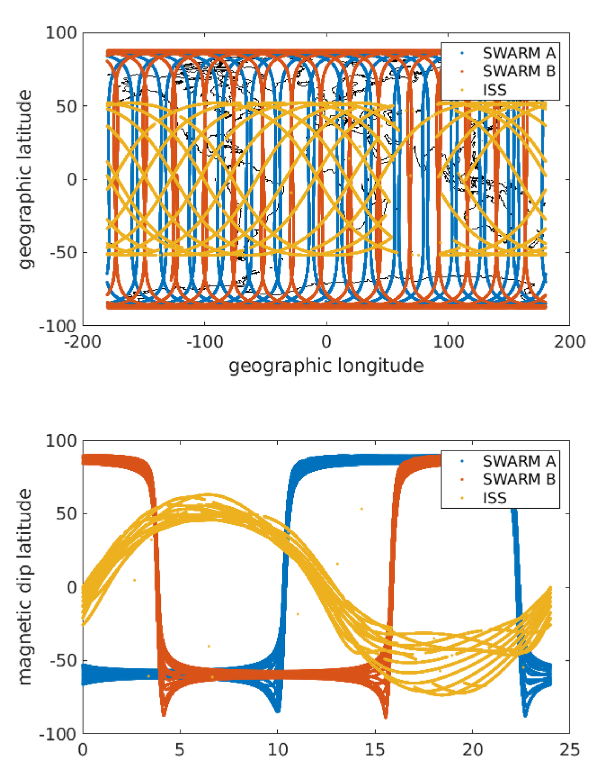
The Equatorial Ionization Anomaly

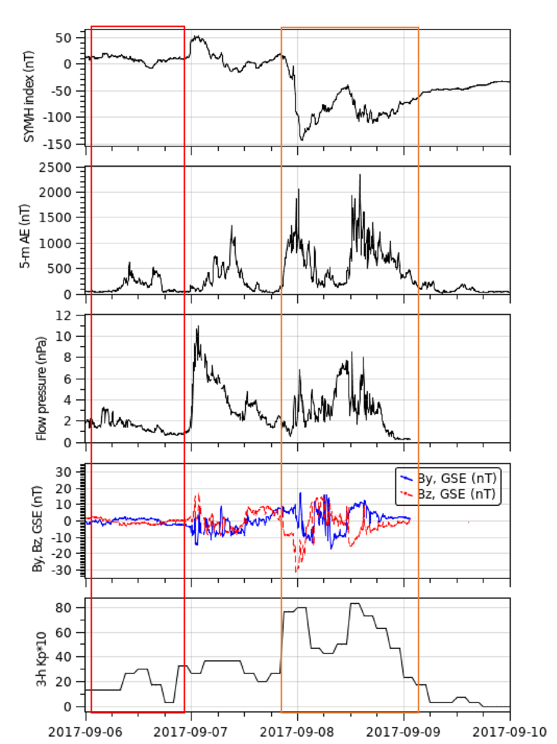
- The EIA is a well-known low latitude phenomenon in the **afternoon** to **post-sunset local-time sector**.
- On the dayside, the electric field at the equator points west causing an upward E x B drift. After the plasma drifts upwards, gravity pulls it downwards along the magnetic field lines as seen below.
- These two effects cause a peak slightly northward and southward of the magnetic equator, at approximately +/- 20° magnetic latitude.



September 2017 Geomagnetic Storm

- The storm began at 23 UT on 9/6/2017.
- The main phase of the storm began at ~22 UT on 9/7/2017 when a large CME arrived as shown below.

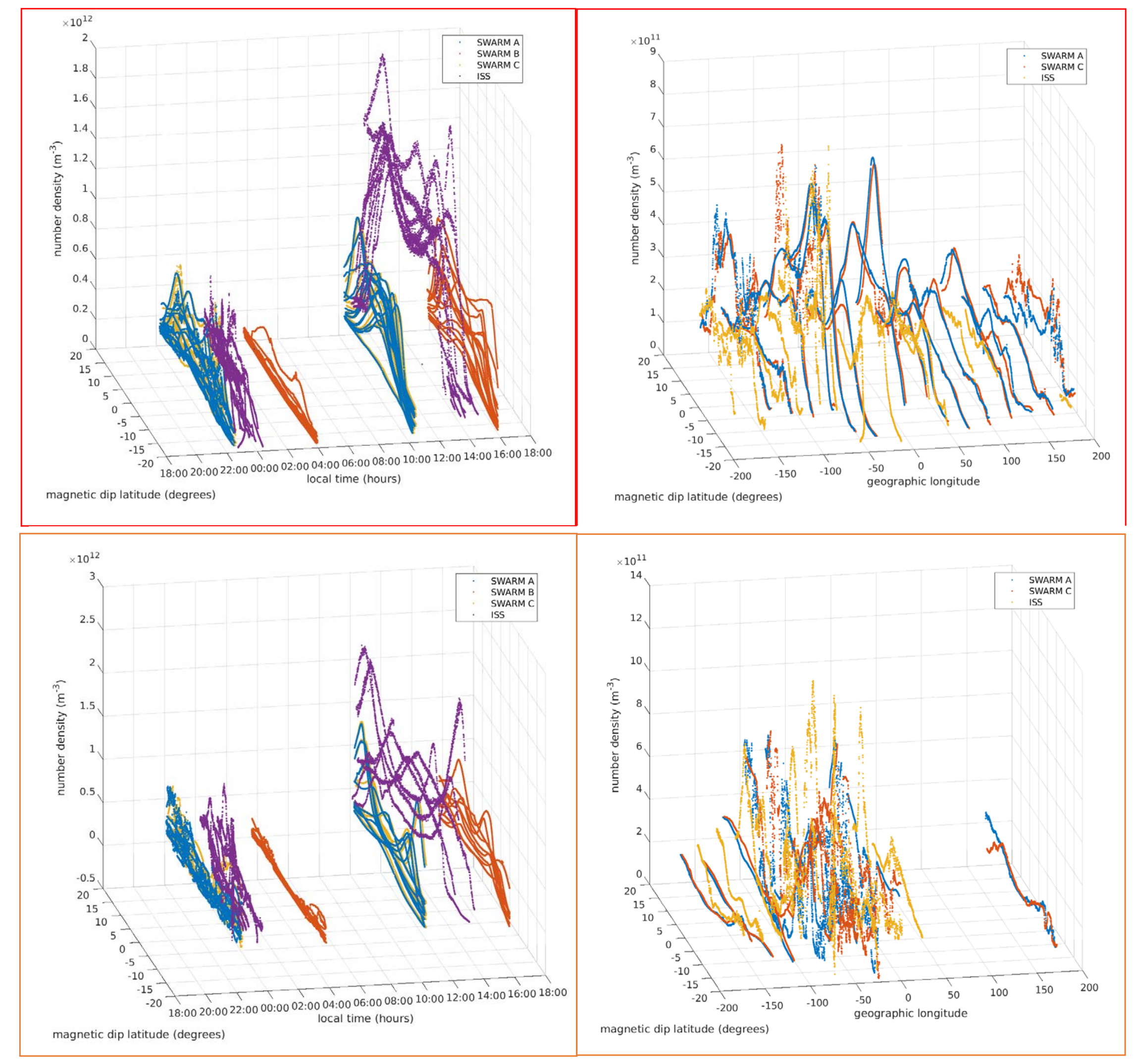




Datasets

- **World-wide GNSS Receiver Network**: These receivers can be used to measure the line-integrated electron between the satellite and the receiver (**TEC**). The GNSS network >2,000 receivers. We use the Madrigal database of TEC values binned into 5-minute bins on a 1° by 1° grid.
- **Floating Potential Meter Unit aboard the International Space Station**: The FPMU measures ion density and electron temperature at 400km altitude, with 1-second resolution when the instrument is activated. ISS is in an unusual mid-inclination orbit shown above (~ 51° 92-minute orbital period). Over the course of a day, ISS covers all longitudes, but only crosses the equator in two narrow bands in local-time which shift each day.
- **SWARM Electric Field Instrument**: The Swarm mission is mini-constellation of three satellites in a polar orbit (shown above) with a 90-minute orbital period launched by ESA. Swarm A and C fly next to each other with a 1° separation at an altitude of approximately 450 km while Swarm B flies at an altitude of 530 km. The EFI aboard each satellite measures electron density and electron temperature with 1-second resolution. Each satellite covers all longitudes over the course of a day, but only crosses the equator in two narrow bands of local-time.
- **Jicamarca Incoherent Scatter Radar**: The main radar at Jicamarca Radio Observatory is a VHF radar operating on 50 MHz. When running in ISR mode, Jicamarca measures electron density, electron and ion temperature, and drift velocities.

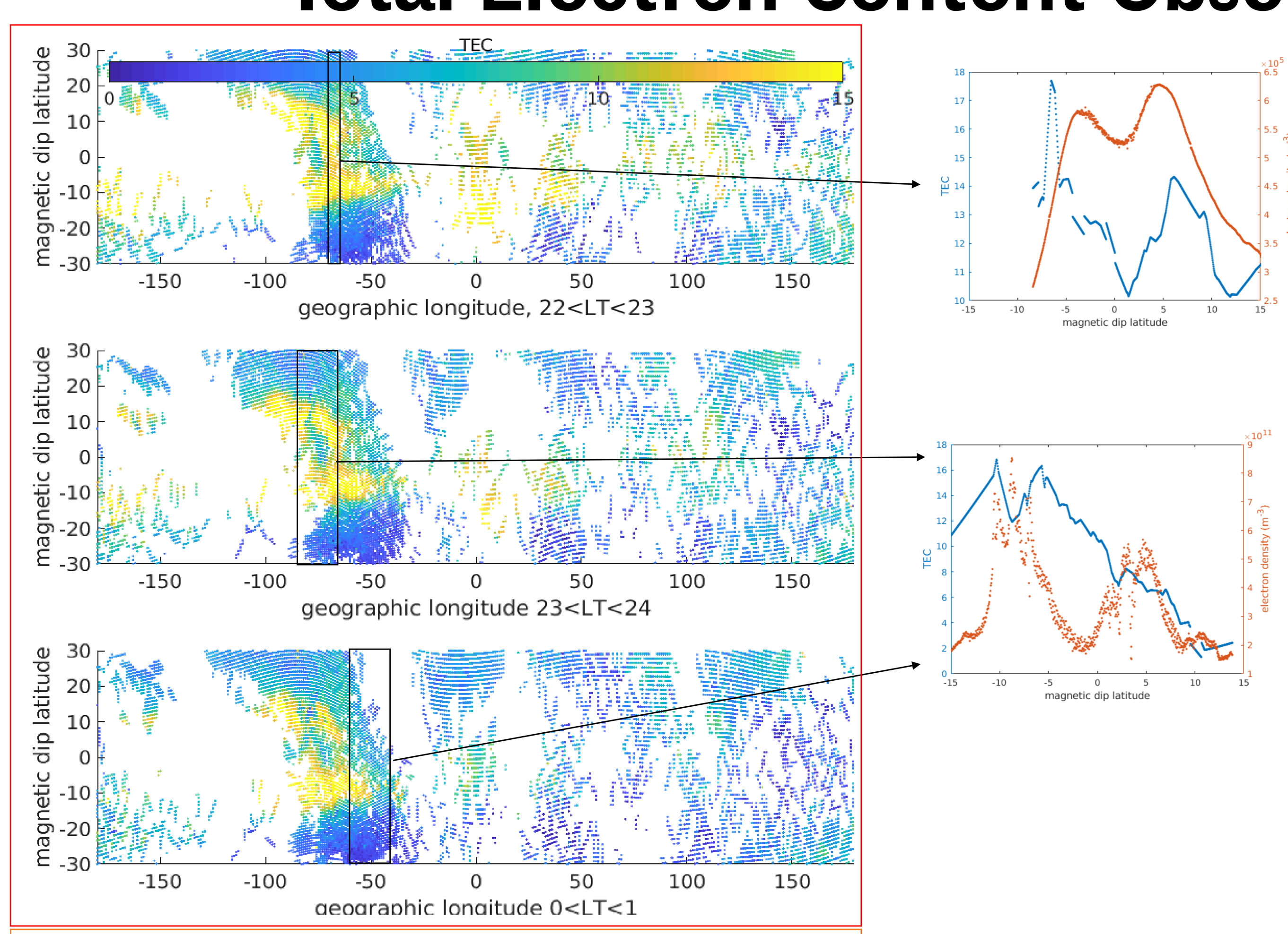
ISS and SWARM F-Region In Situ Observations



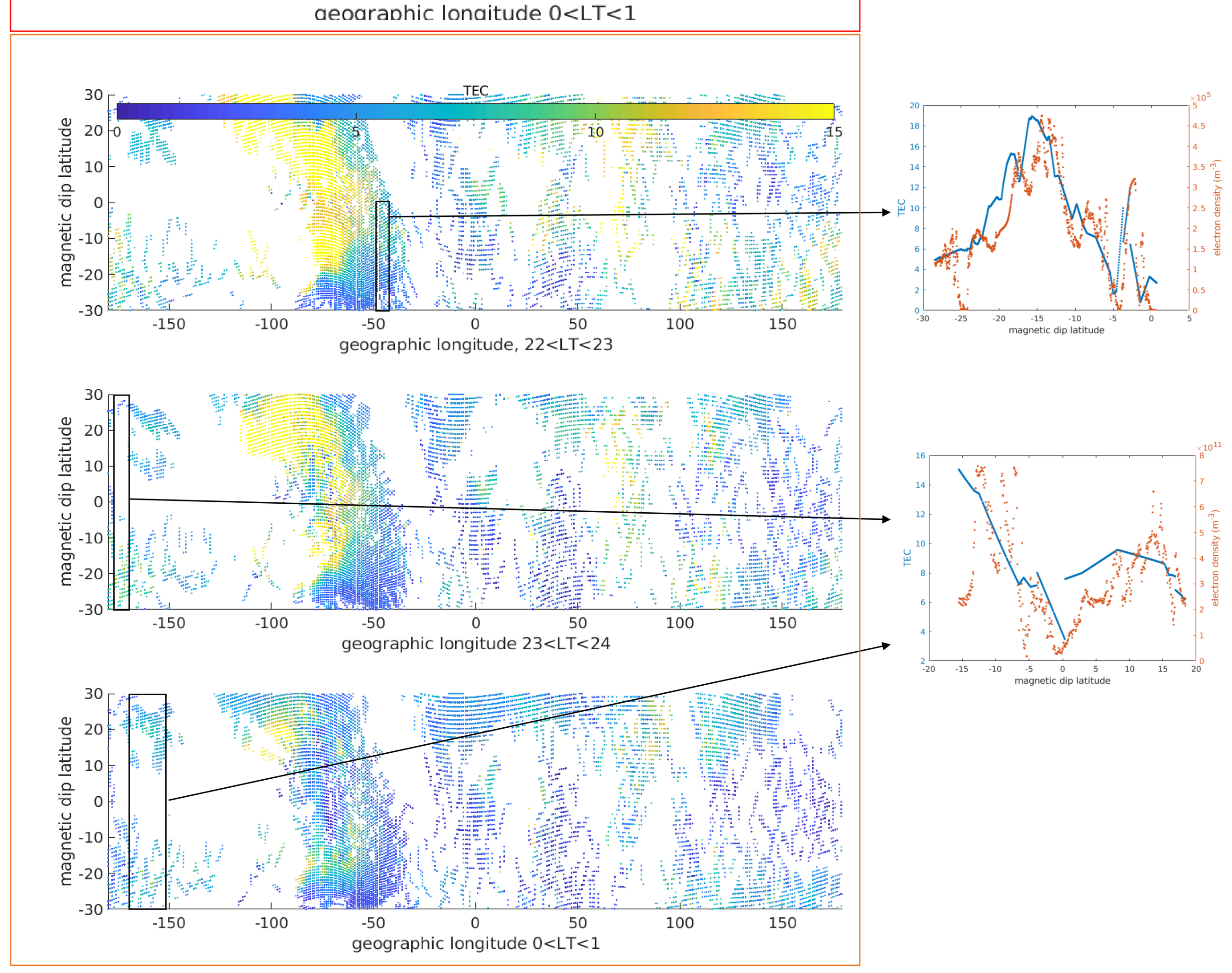
- Before the storm began (9/6/2017 0-23 UT), ISS observed **the EIA near midnight** in two orbits (left panel). SWARM A/C observed the EIA at 22:15 LT in four orbits.
- The nighttime EIA appeared to have a **longitudinal dependence**. The instances of the EIA at nighttime were most prominent in the American sector, but occurred at other longitudes as well (right panel shows nighttime equatorial crossings).

- During the first main phase of the storm (9/7/2017 21 UT to 9/8/2017 11 UT), the nighttime EIA occurrences have larger densities (left panel). Many **spread-F type irregularities** occur during this period, often with the nighttime EIA.
- During this period, the nighttime EIA expands to more longitudes (right panel shows nighttime equatorial crossings). The nighttime EIA remains most pronounced in the American sector.

Total Electron Content Observations

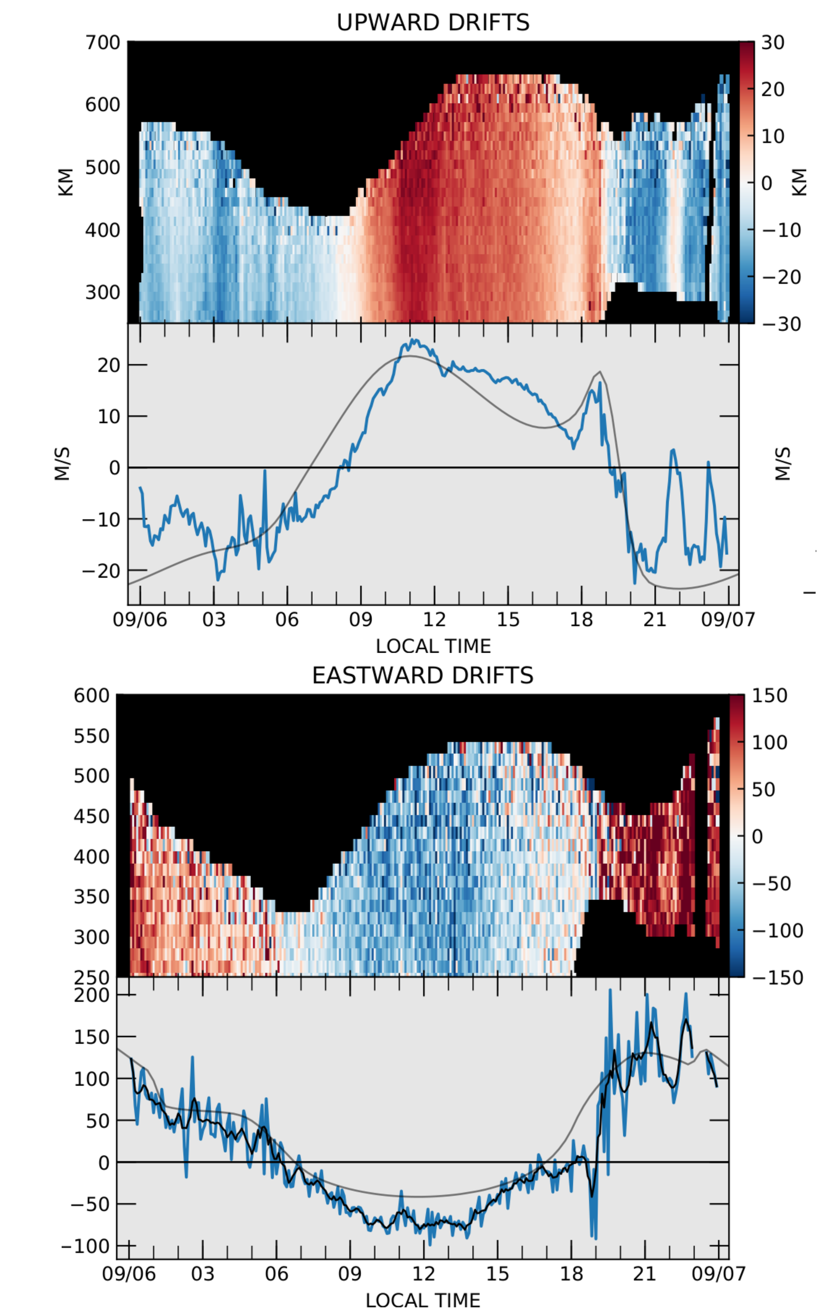


- TEC observations before the storm (9/6/2017 0-23 UT, left panel) also show **the EIA extending to post-midnight** in agreement with SWARM and ISS observations.
- TEC also shows a longitudinal dependence of the EIA at night.
- SWARM A observed the EIA at night at 02:40-02:50 UT at local time 22 in agreement with TEC (upper right panel).
- ISS observed the EIA at night at 4:15-4:30 UT at local times 23-01 also in agreement with TEC (lower right panel).



- During the main phases of the storm (9/7/2017 21 UT to 9/9/2017 4 UT, left panel), TEC continues to show the EIA at night **while numerous irregularities emerge**.
- SWARM A observed a spread-F type irregularity on 9/8/2017 01:28-01:38 UT at 22 local time.
- ISS observed a spread-F type irregularity on 9/7/2017 11:13-11:23 UT at 23-01 local time.
- In total, ISS observed **13 spread-F type irregularities** during the storm and SWARM A/C observed **11**.

Jicamarca ISR Observations



Jicamarca ISR observed a **large vertical uplift** from 18-24 UT on 9/7/2017. This period corresponds with beginning of the main phase of the geomagnetic storm. During this period spread-F type events were observed in the ISS electron density measurements. Local time for Jicamarca is 4.5 hours behind UT

Discussion

- ISS and SWARM F-region Ne data shows presence of **the EIA post-midnight** in the American sector.
- In the storm's early main phase, EIA crest densities at midnight reaches those similar to the typical daytime values. The enhancement during this time coincides with the large increase in upward ExB drift.
- ISR provides vertical drift in the same sector as ISS and SWARM observed enhanced nighttime EIA and spread-F type irregularities. During the same time period, Jicamarca ISR observed a **large vertical uplift**. This events clearly demonstrate the role of **penetration electric fields** on the onset of **spread-F type irregularities** and the EIA.
- TEC shows agreement with the general structure shown in electron density observed by ISS and by SWARM. This agreement demonstrates that **TEC generally tracks with F region density**. This result demonstrates the utility of TEC from GPS since it has spatial coverage that satellites do not.
- The longitudinal dependence of the EIA at nighttime may be associated with the 4-wave structure in the EIA described by Sagawa et al. in 2005.

On September 6th before the geomagnetic storm began and during the storm, the EIA extended to much later local times than previously observed. During the storm, ISS and SWARM observed numerous spread-F type irregularities during strong penetration electric field observations.