Observations of deep ionospheric F-region density depletions with FPMU instrumentation and their relationship with the global dynamics of the June 22-23, 2015 geomagnetic storm

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Abstract -

- The magnetic storm that commenced on June 22-23, 2015 was one of the largest storms in our current solar cycle, resulting from an active region on the Sun that produced numerous coronal mass ejections (CMEs) and associated interplanetary shock waves.
- On June 22 at 18:36 UT the magnetosphere was impacted by the shock wave on the magnetosphere.
- Observations from several spacecraft observed the dynamic response of the magnetosphere and ionosphere.
- MMS observatories in the near earth tail These low altitude measurements are correlated in the magnetosphere with particle flux dropouts measured by MMS
- We follow the timing of this storm in the ionosphere with the density depletions throughout the ISS orbits, DMSP drift velocities, and enhanced AMPERE Birkland currents.
- Together these observations and simulation results will be assembled to provide each region's context to the global dynamics and time evolution of the storm.
- The models during these event support and flesh out the puzzle of the global dynamics.

Outline -

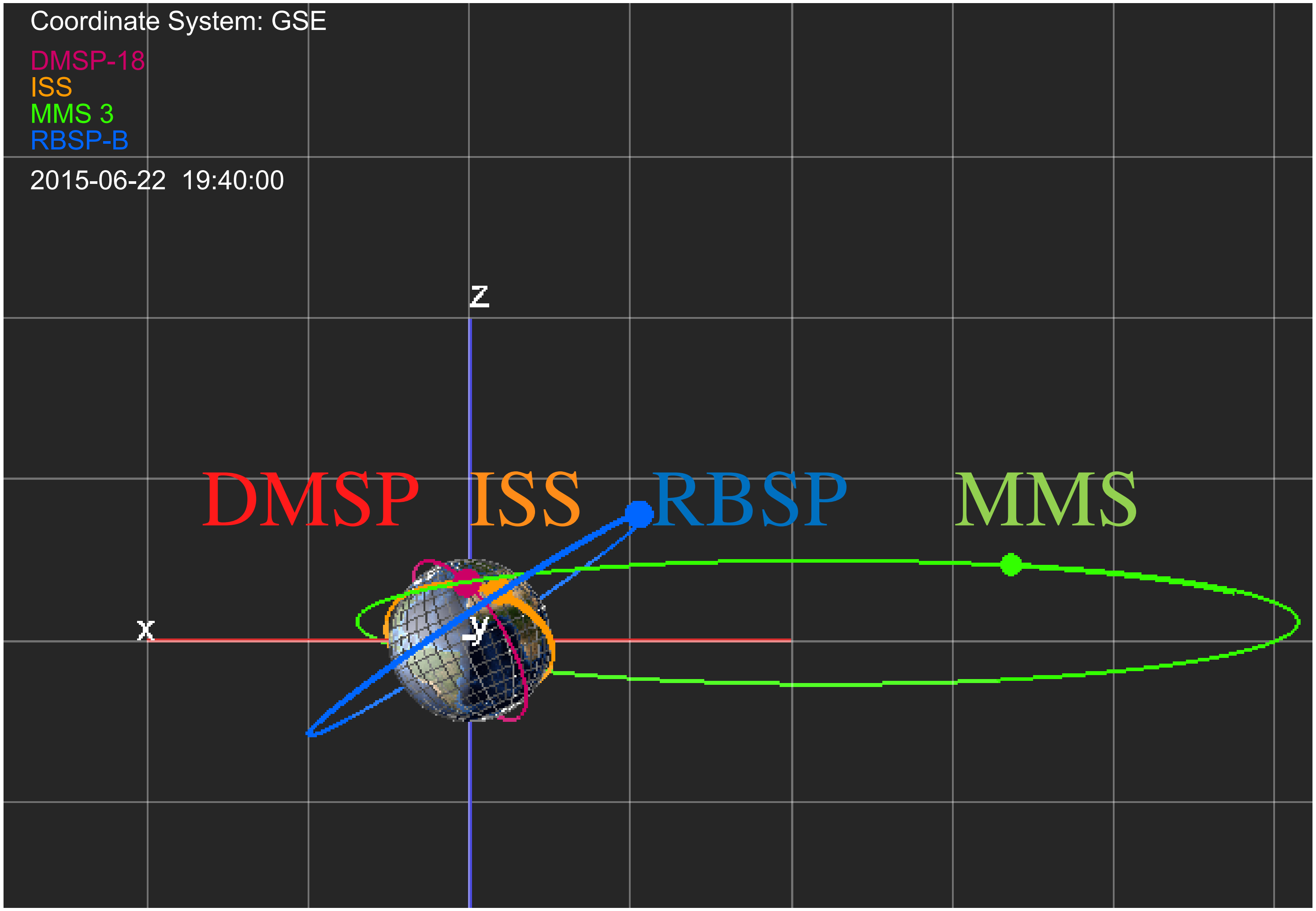
- Space Weather Indices
- Observations
  - Magnetosphere
  - Polar Ionosphere
  - Low-Latitude Ionosphere
- Modeling
  - Magnetosphere
  - Ionosphere
- Summary
  Magnetospheric – Ionosphere Coupling

Observation Orbits -

DMSP –sun synchronous polar orbits near 830 km

ISS – orbits with an inclination of 52° near 400 km.

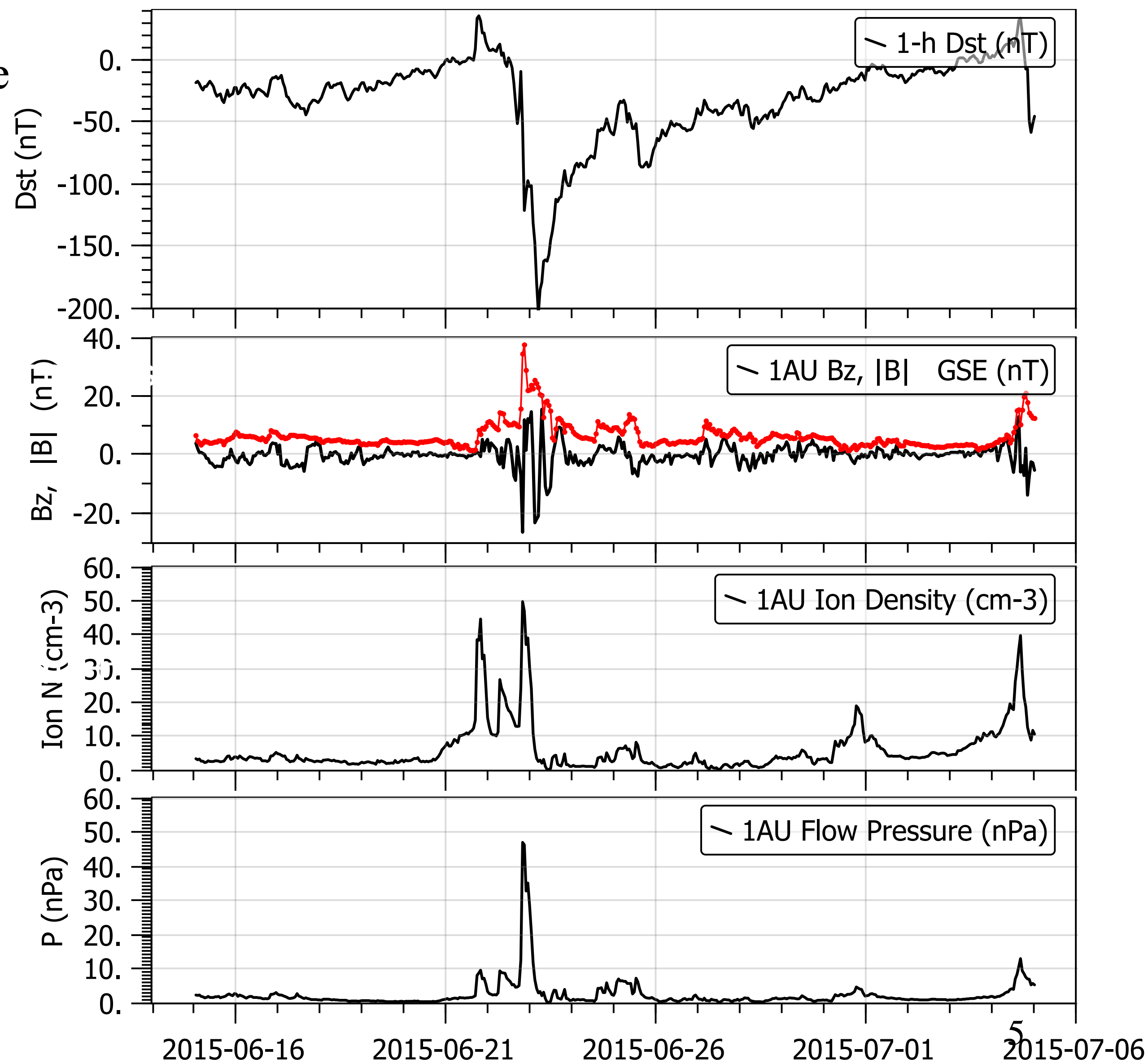
MMS - orbit in pre-midnight sector in the equatorial plane



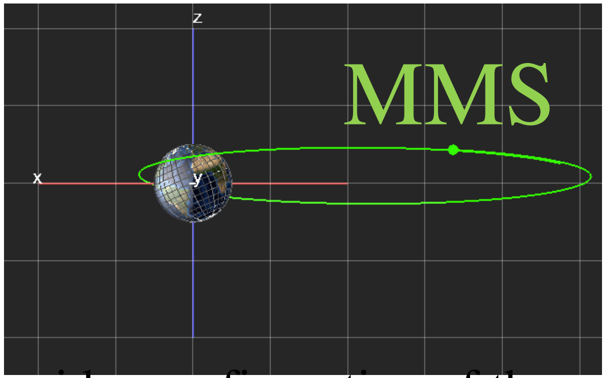
Space Weather Indices

- DST dips south on late June 22 , reaching -200 nT in early June 23
- Interplanetary Bz dips below -20 nT and the magnitude of B reaches 40 nT
- Interplanetary density at reaches 50 cm^{-3} and
- 1 AU Pressure reaches almost 50 nPa.

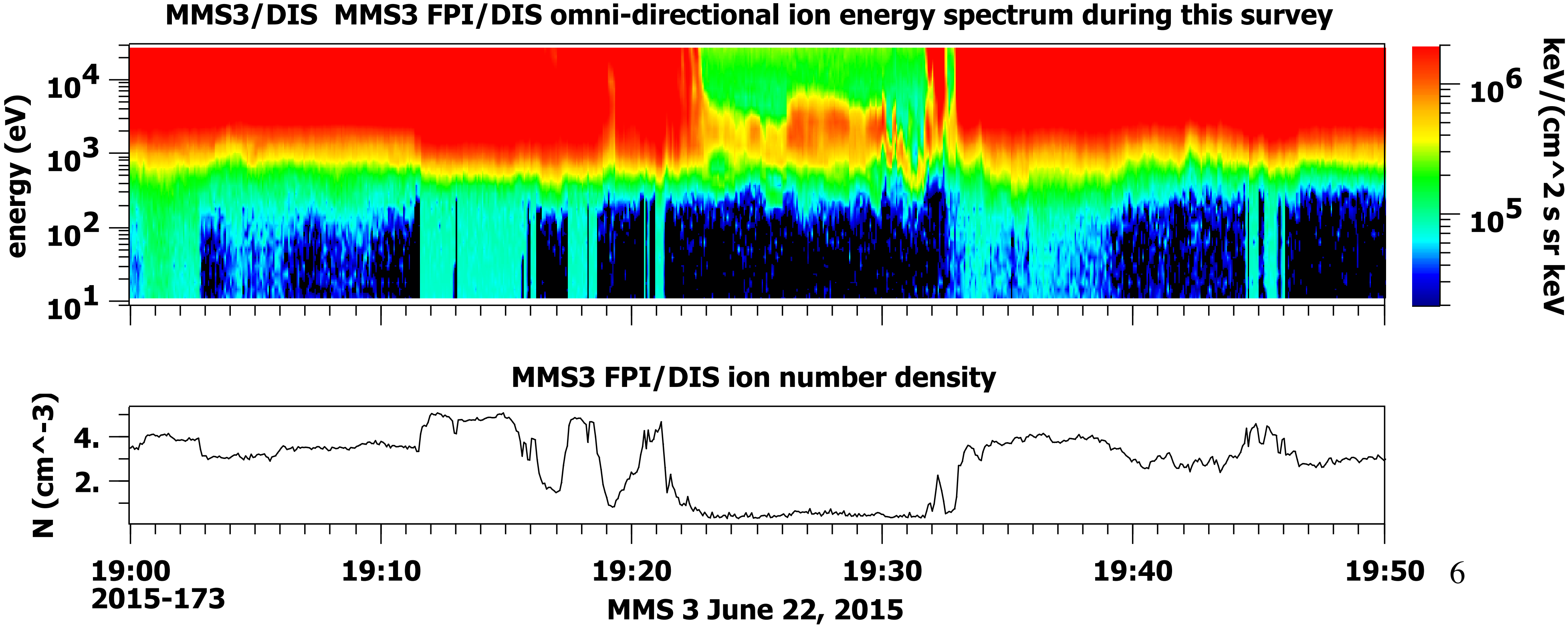
Omni data provided by King, Papatashvilli at ADNET, NASA GSFC, and CDAWeb



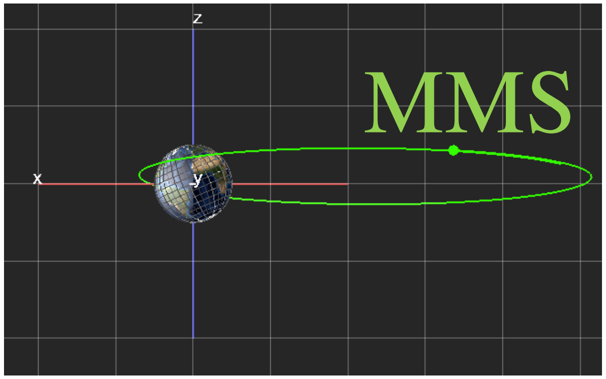
Near-Earth, Equatorial Plane
MMS Observations



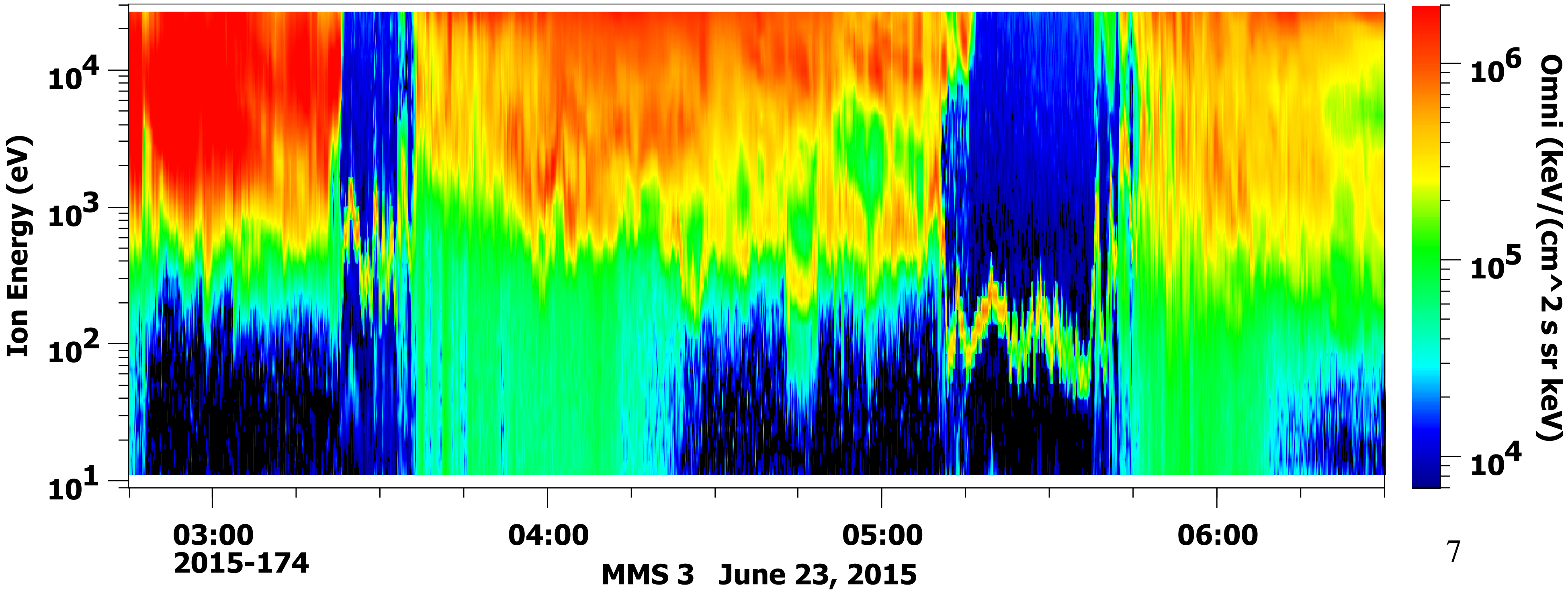
- The MMS spacecraft in the near-earth equatorial plane observed a rapid reconfiguration of the magnetic field near 1923 UT.
- Initially in the warm plasmasheet, particle flux dropouts were observed as they tracked the plasma-sheet to lobe transitions with the stretching and thinning of the plasmasheet.
- While in the lobe, anti-sunward flowing O^+ ions from the ionosphere were measured.



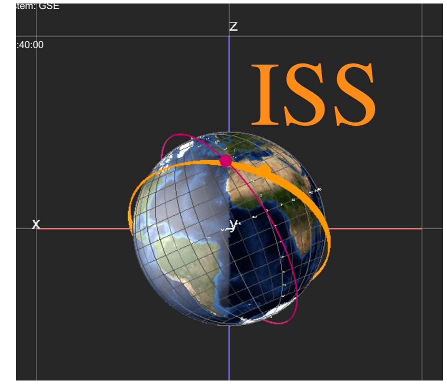
Near-Earth, Equatorial Plane
MMS Observations



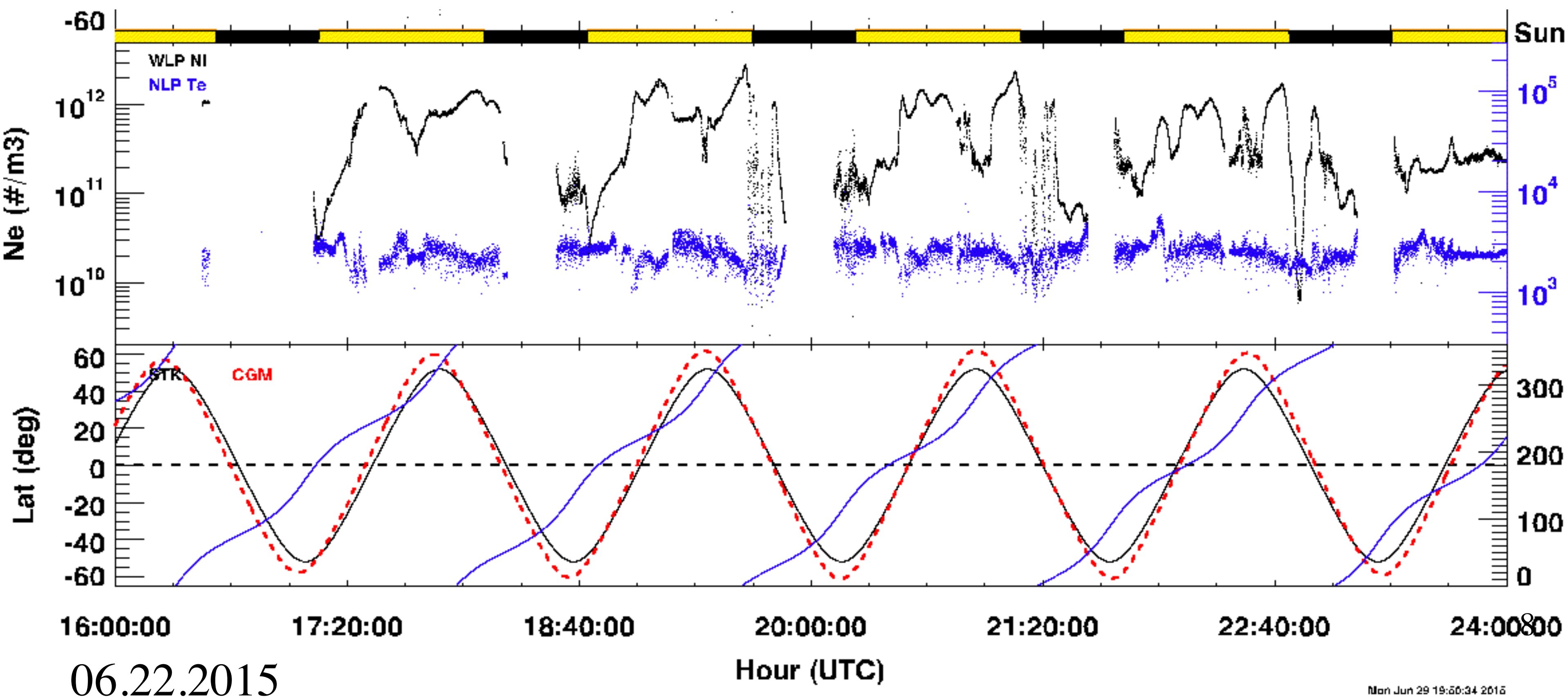
- Flux dropouts were also observed on June 23 starting near 3:20 and 5:11 UT.
- While in the lobe, O^+ was observed outflowing from the ionosphere. Observed.
- These dropouts again are represented with MMS excursions into the lobe due to thinning and expansion of the plasmasheet and up and down motion of the current sheet.



Low Latitude Ionosphere
ISS Observations



- FPMU observed density depletions at post-sunset, equatorial latitudes starting near ~19:30 UT evolving into more coherent wide density holes with subsequent obits,



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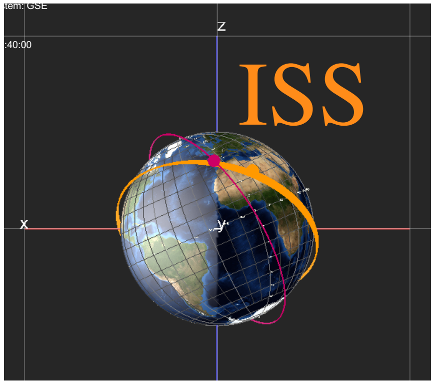
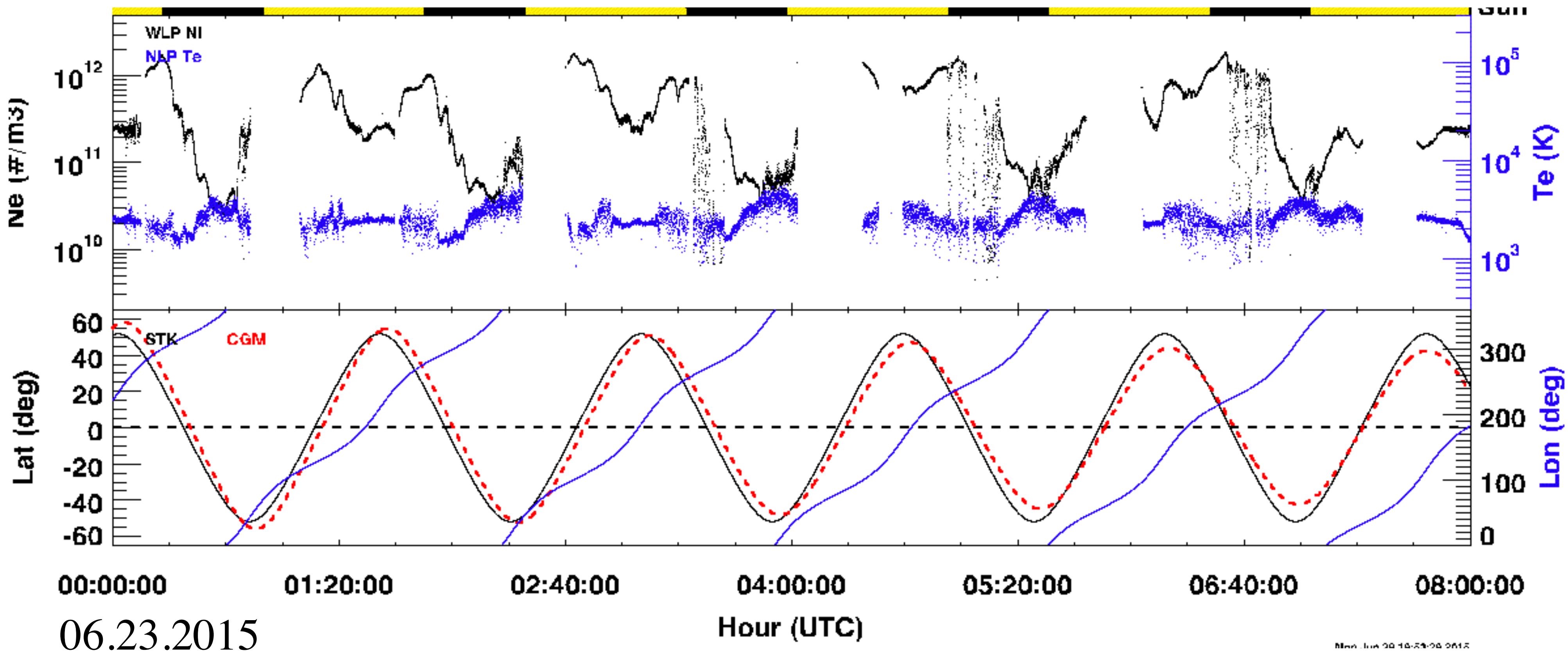
Low Latitude Ionosphere
ISS Observations



- ISS FPMU deep density depletions observed again at post-sunset equatorial latitudes on following day, June 23rd.
- These coincided with the flux dropouts observed by MMS near ~ 3:30 and 5:30 UT.



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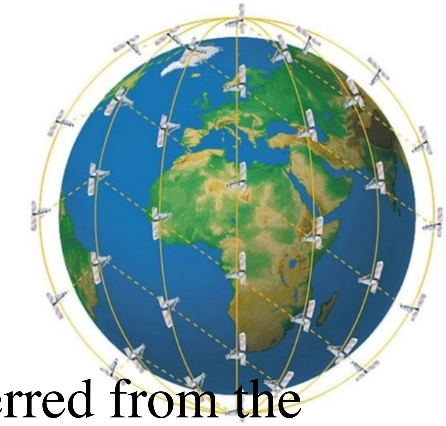
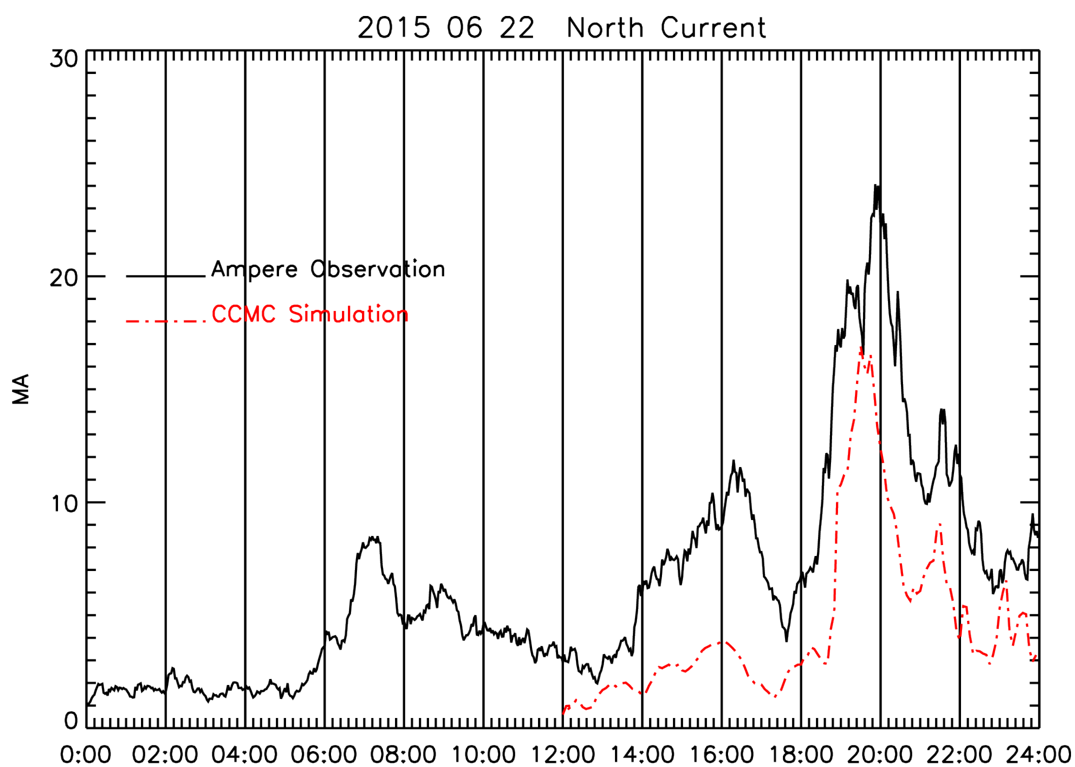
Polar Ionosphere:
AMPERE observations



- At ionospheric altitudes, the integrated field-aligned currents inferred from the AMPERE data showed highly variable currents exceeding 20 mA after 19:32 UT.
- The BATS-R-US also showed large field-aligned currents and although accurate in timing, the magnitudes were 20-50% smaller in magnitude from AMPEREs



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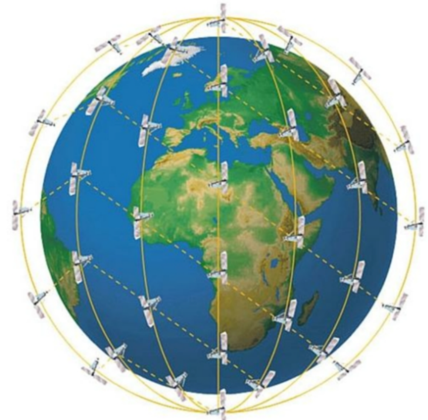
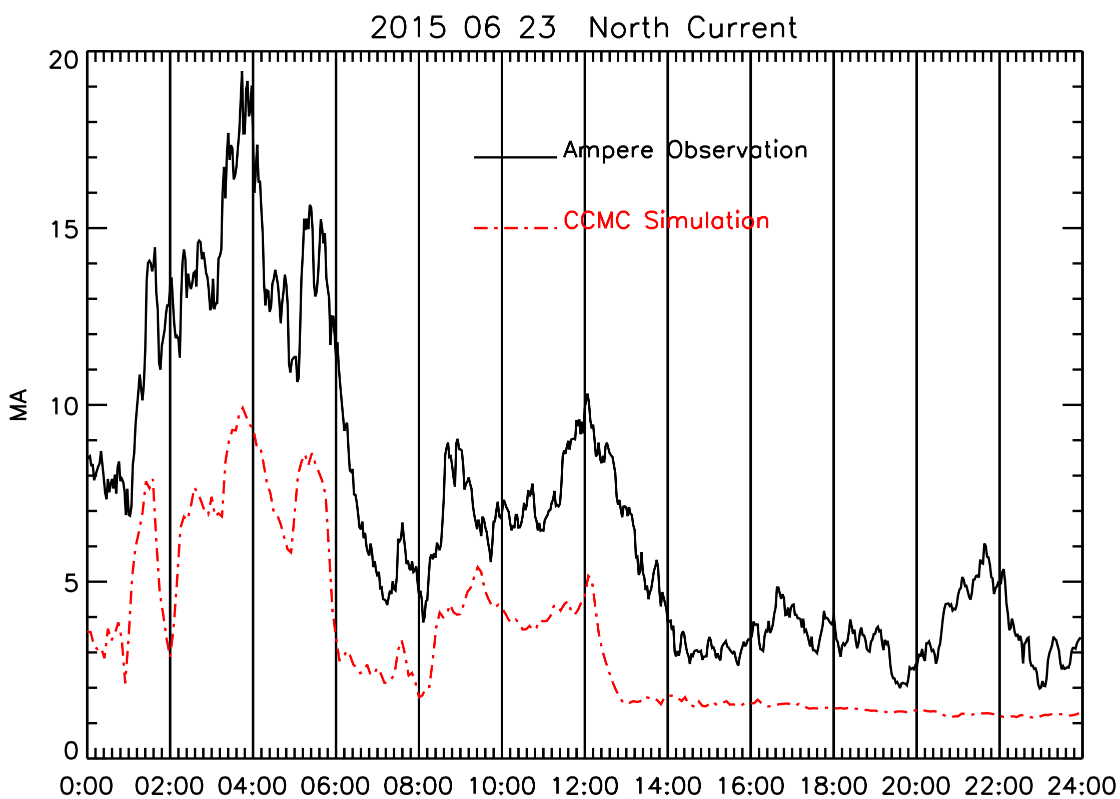
Polar Ionosphere:
AMPERE observations



- The highest field-aligned currents were also inferred by AMPERE after 3:20 UT and 5:00UT on the following day, coinciding with MMS and ISS



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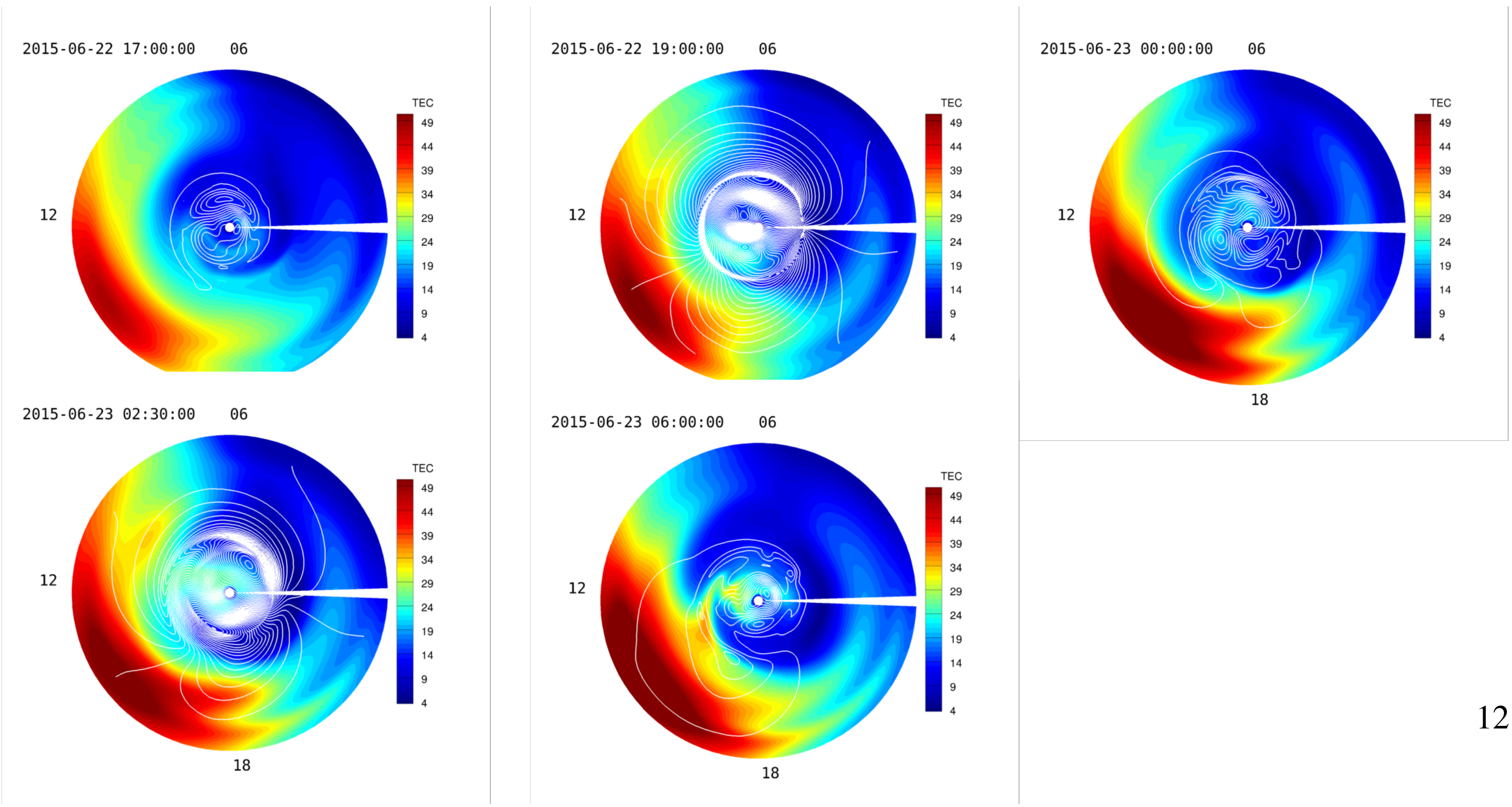
Polar Ionosphere
Modeling

- Development of a Tongue of Ionization (TOI) during the June 22, 2015 geomagnetic storm.
- Contour plots of TEC (color) and electric potential (white contour lines) before the storm (left), and at several times during the periods of interest. The sun is at the top.

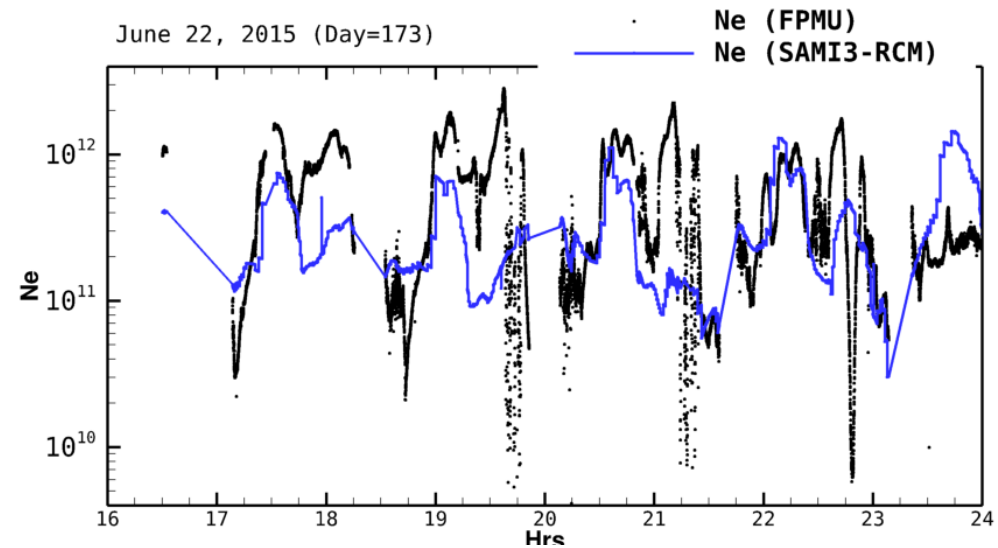


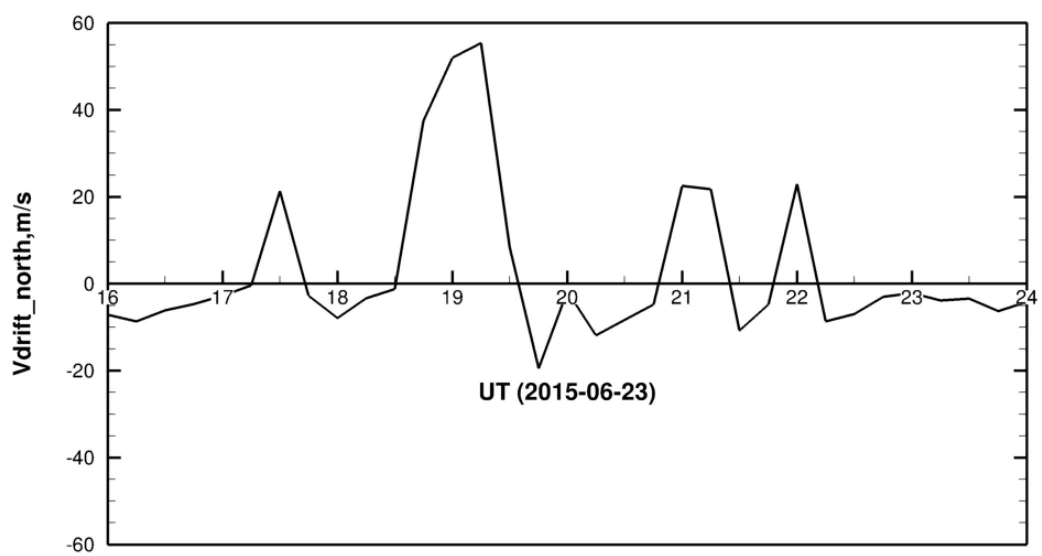
Low-Latitude Ionosphere Modeling

- A comparison of FPMU ion densities (black dotted line) with simulated densities (blue/continuous line). Also shown is the simulated vertical ExB drift velocity component in the meridional plane (positive up/north) at the equator near the dusk terminator (19 LT).

- Onset of enhanced depletions follows periods of large vertical drift excursions.

- This is the sheath period of the storm.



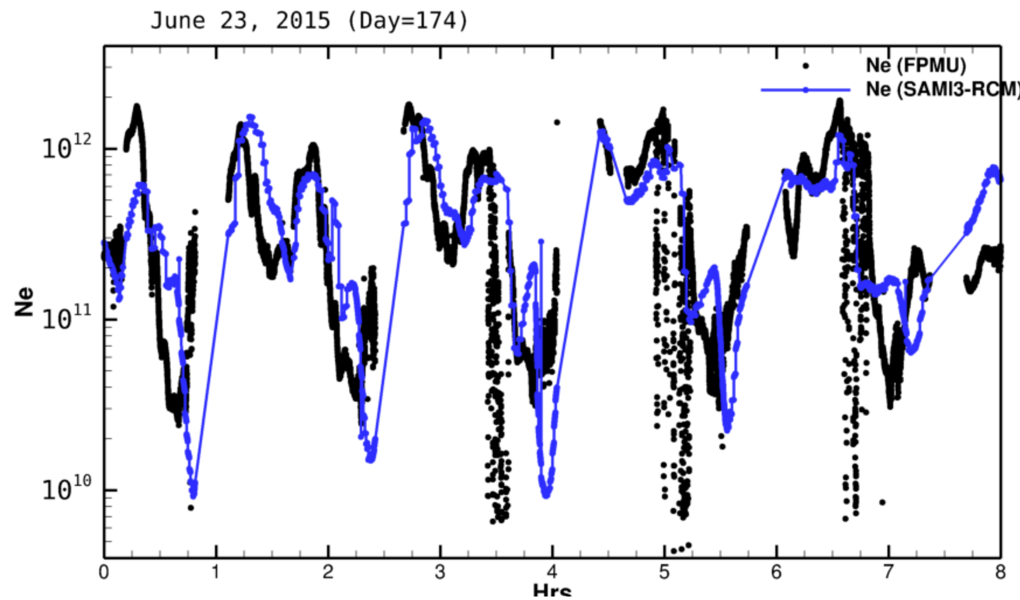


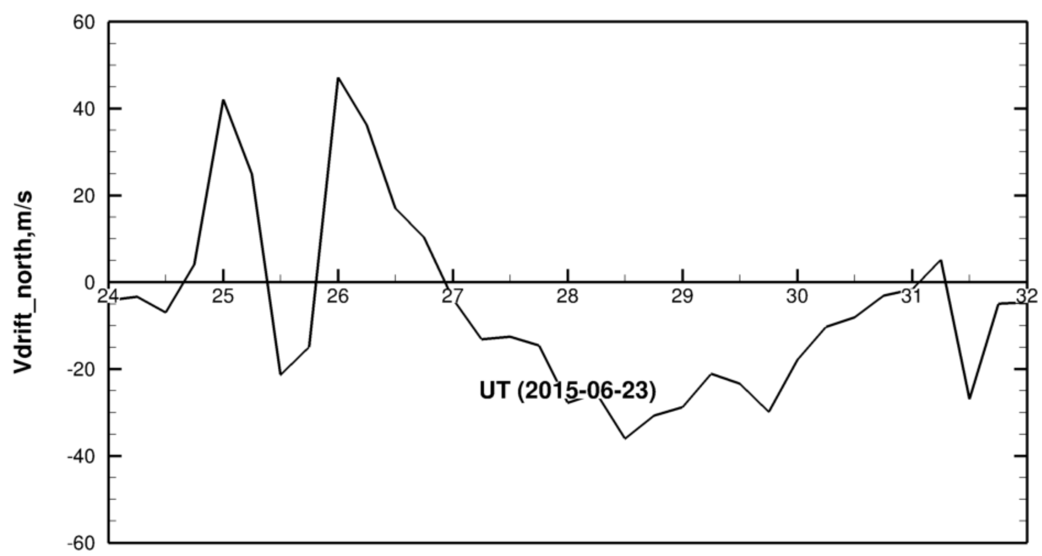
Low-Latitude Ionosphere Modeling

- A comparison of FPMU ion densities (black dotted line) with simulated densities (blue/continuous line). Also shown is the simulated vertical ExB drift velocity component in the meridional plane (positive up/north) at the equator near the dusk terminator (19 LT).

- Onset of enhanced depletions follows periods of large vertical drift excursions.

- This is the CME period of the storm.





Conclusions

- Large F-region depletions are observed near dusk by the FPMU instrument throught the storm period.

- Dropouts of energetic kilovolt particles are observed by MMS FPI plasma instrument.

- Both periods are seen to occur near same UT values

- Global and ionospheric first-principles simulations put observations from ISS FPMU, MMS, and AMPERE in the context of storm-time electrodynamics.

- We propose that it is storm-time convection electric field penetrating to low-latitude ionosphere during periods of large southward IMF Bz excursions are responsible for triggering onset of F-region dusk sector instabilities and depletions. Our model results at low latitudes support this suggestion, although the model itself does not have enough spatial resolution to model the small-scale physics.