Ionosphere/Plasmapause Variations During the 17 March 2013 Storm Identified by Ground-based and Space-based Observations

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Outline

- Project Introduction
- Data Sets
  - *GPS ground-based and space-base*
  - *van Allen Probes*
  - *Themis sensors*
- 17 March 2013
  - *Conditions*
  - *Plasmasphere Observations*
- Summary

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Introduction

NASA grant NNX16AG6G

- 3-year NASA grant to investigate the "Storm-time Dynamics of the Plasmapause and the Ionosphere/Magnetosphere"
- Objectives:
  1. *Determine the evolution of the global plasmasphere during geomagnetic active conditions including the location and erosion time scales of the plasmapause,*
  2. *Ascertain the relationship between plasmaspheric plumes and subauroral polarization streams (SAPS) as the two evolve during storms of different intensities,*
  3. *Characterize the variability of ionospheric plasma outflow during storm periods and as a function of location.*
- 5 Storm periods selected for initial study

Date	Max. Dst (nT)	Data Sets available
11 September 2005	-139	Ground GPS, IMAGE, DMSP F13-F15, MHO
17 March 2013	-132	Ground GPS, F15-F18, MHO, IMAGE, CORISS, GOX, van Allen Probes, THEMIS
28 June 2013	-98	Ground-GPS, F15-F18, MHO, IMAGE, GOX, van Allen Probes, THEMIS
19 February 2014	-116	Ground-GPS, F15-F18, MHO, IMAGE, CORISS, GOX, van Allen Probes, THEMIS
17 March 2015	-223	Ground-GPS, F15-F18, MHO, IMAGE, CORISS, GOX, van Allen Probes, THEMIS

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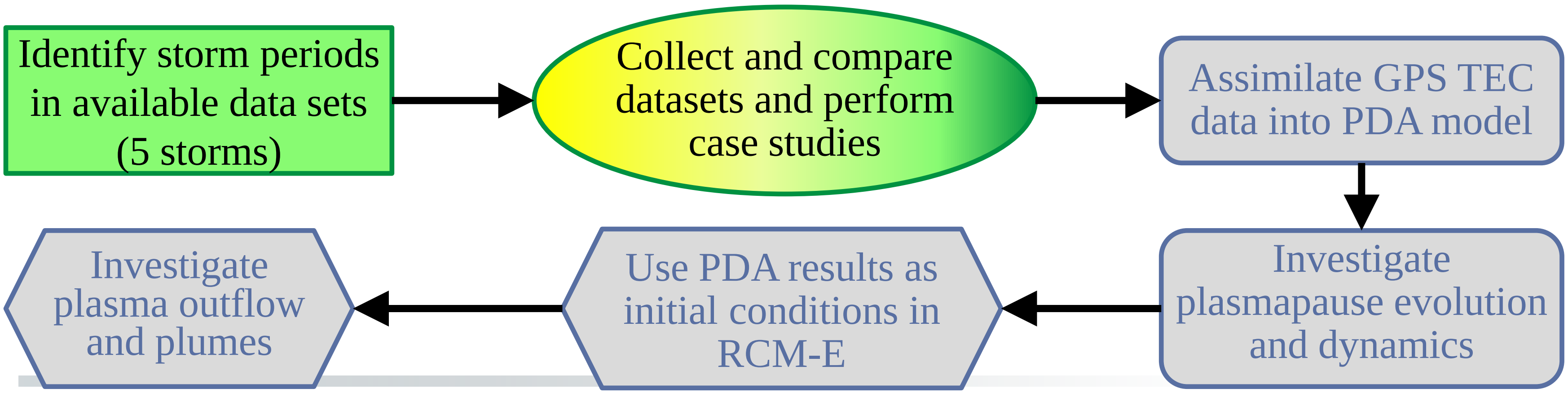
Introduction- Continued

- Combine ground & space data sets to provide a more comprehensive picture of plasmasphere
  - *Ground-based GPS (A. Coster)*
  - *Space-based GPS (R. Bishop)*
  - *Van Allen probes*
  - *Themis*
- Use RCM-E and PDA models combined with observations to simulate plasmasphere and MI dynamics.



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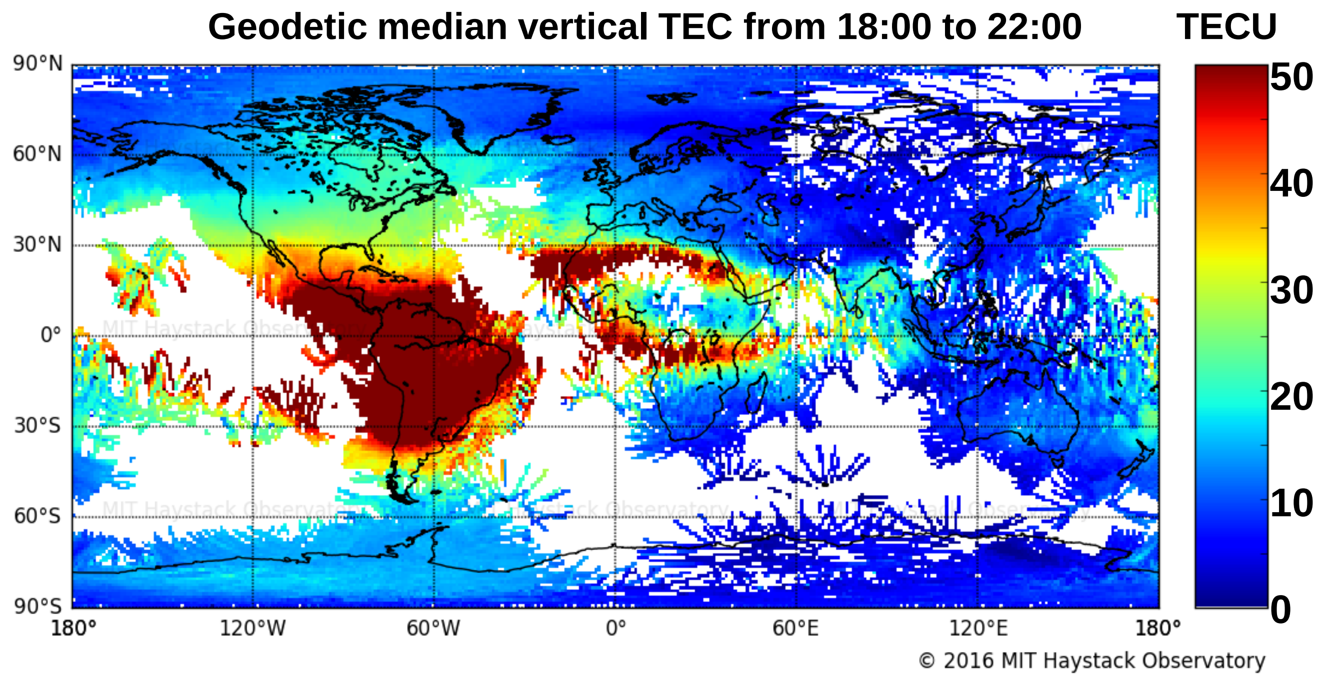
Ground-Based GPS Sensors

- 5000 ground receivers provide data (MIT Haystack Group)
- Data collected on a 1-10 min cadence
- For study data averaged into 4-hour periods



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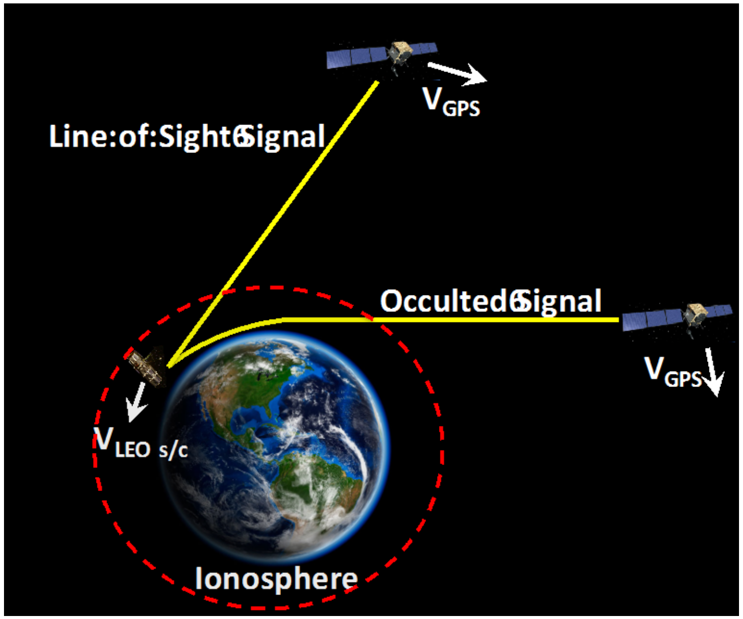
GPS Observations from LEO

Occultation vs. Upward Line-Of-Sight (LOS)

- Multiple GPS satellite signals observed simultaneously
  - *Number of GPS satellite signals observed is dependent on number of receiver channels*
- Observed signals are Line-of-Sight (LOS) or occulted (RO = radio occultation)
- Every occulted signal has a unique tangent point altitude
- LOS signals have no reference altitude (similar to ground GPS)
- For RO, maximum tangent altitude is less than s/c altitude



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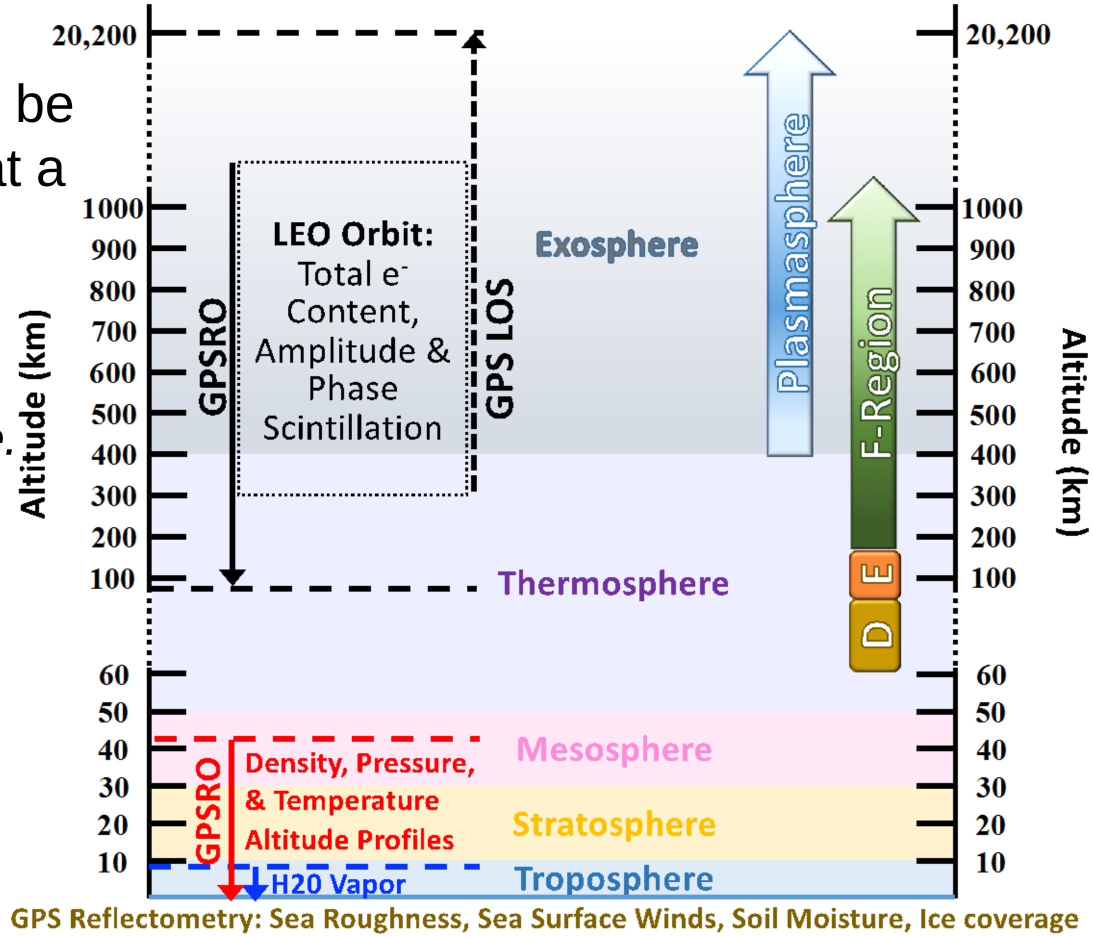
On-orbit GNSS Products

- On-orbit GNSS receivers can be used to measure conditions at a large range of altitudes
- For occultation observations:
  - *Signals are refracted passing through the upper atmosphere.*
- Receiver measures:
  - *SNR, pseudorange, phase*
- Space Weather Products:
  - *TEC*
  - *Amplitude scintillation (S4)*
  - *Phase scintillation (σ_ϕ)*



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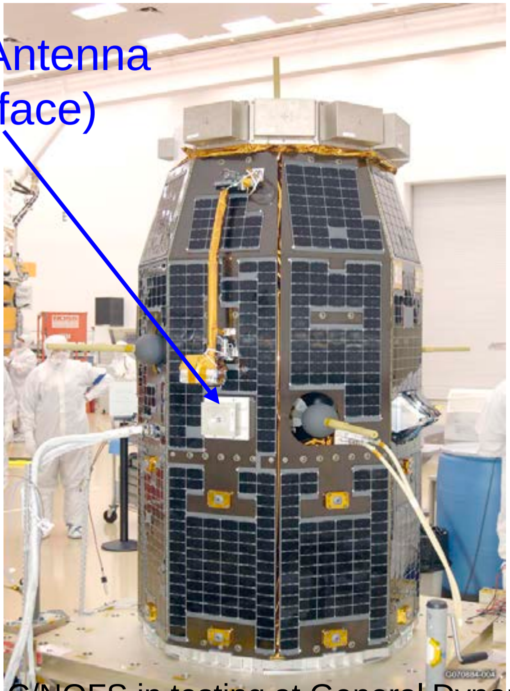
CORISS Overview

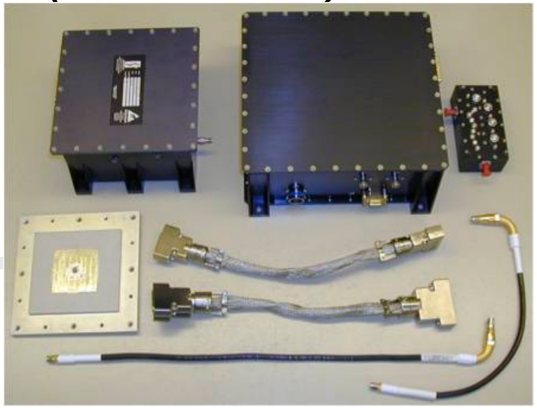
C/NOFS Occultation Receiver for Ionospheric Sensing and Specification

- CORISS is a Modified Version of the Jason/ICESat Receiver
  - *RF front end adapted to C/NOFS RFI requirements*
  - *Single patch antenna on s/c anti-velocity face*
  - *Receiver s/w updated by The Aerospace Corporation to perform occultations & other special functions (Tom Meehan consulting)*
    - On-board processing of scintillation parameters: S4, σ_ϕ, spectra
- Payload on the C/NOFS satellite
  - *C/NOFS is in a 13º inclination elliptical (400×850 km) orbit*
  - *Launched 16 April 2008*
  - *Re-entered 28 November 2015*

CORISS Antenna
(Anti-ram face)



C/NOFS in testing at General Dynamics
[*Courtesy of AFRL]*



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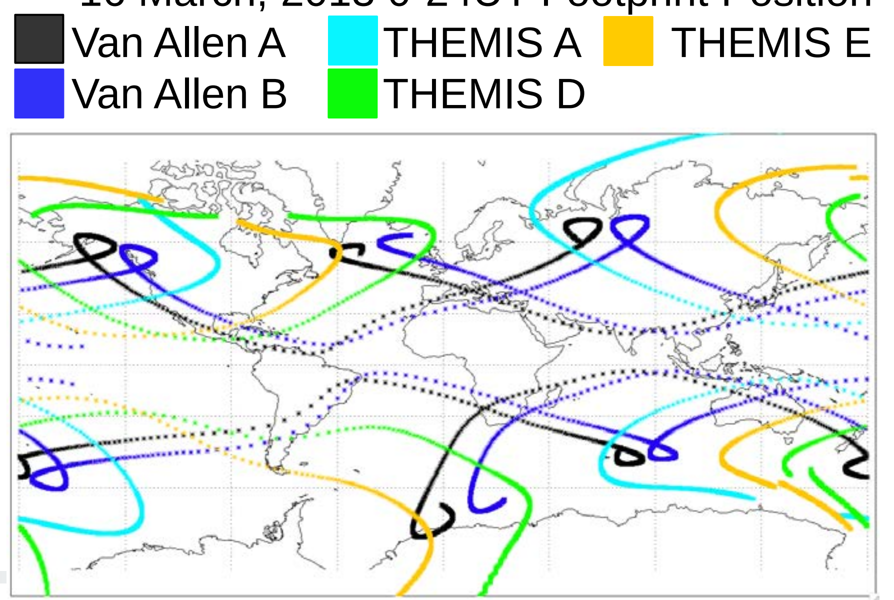
van Allen and THEMIS

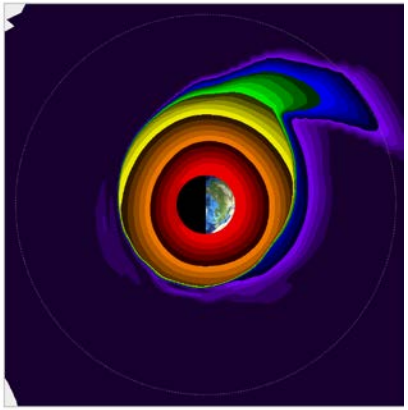
- van Allen Probes consists of 2 identically instrumented s/c
  - *Near equatorial, near identical, GEO-transfer-like orbits (apogee: ~6 RE, perigee: <1000 km)*
  - *Observes plasma density, energetic particles, fields, and waves*
- THEMIS consists of 3 identically instrumented s/c
  - *Highly elliptical, near equatorial orbits (apogee: ~12 RE, perigee: ~1000 km)*
  - *Observes plasma density, electric fields*
- Both missions cross plasmapause several times per orbit
- 350 km footprints used to compare with GPS data
- Long orbit periods limits global coverage during storms
- Data used to:
  - *Validate PDA plasmasphere maps*
  - *Constrain RCM-E model runs*

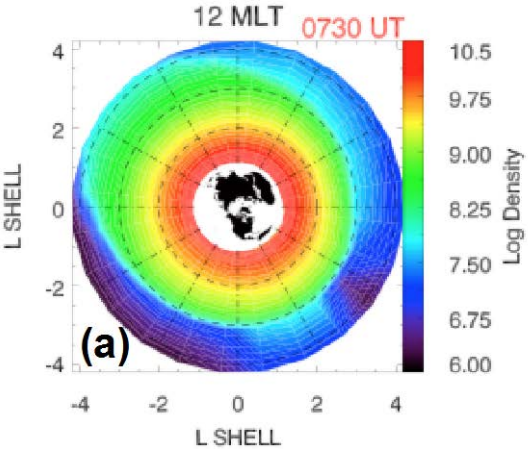
16 March, 2013 0-24UT Footprint Position

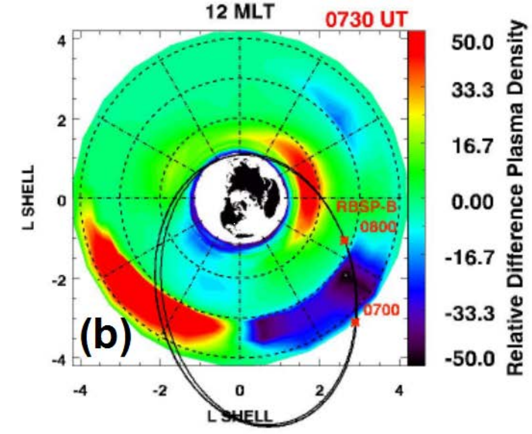


RCM-E & PDA

- Rice Convection Model-Equilibrium
  - *Model of inner magnetospheric dynamics with ionosphere coupling.*
  - *Computes plasma drift with self-consistent **E**-field and **B**-field*
  - *Modified to facilitate massive parametric simulations*
- Plasmasphere Data Assimilation Model (PDA)
  - *Time-evolving maps of 3-D global plasmaspheric Ne structures*
  - *Ingests data such as GPS TEC.*
  - *Extension of IDA4D data assimilation method*
  - *Figures shows TEC (top) and difference between PDA and Global Core Plasma (GCP) model (botom)*







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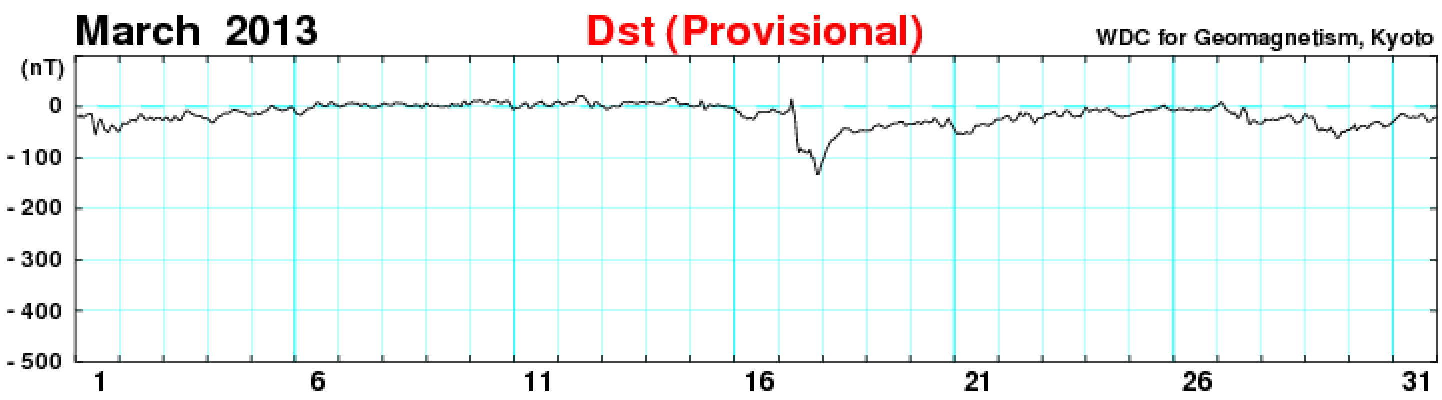
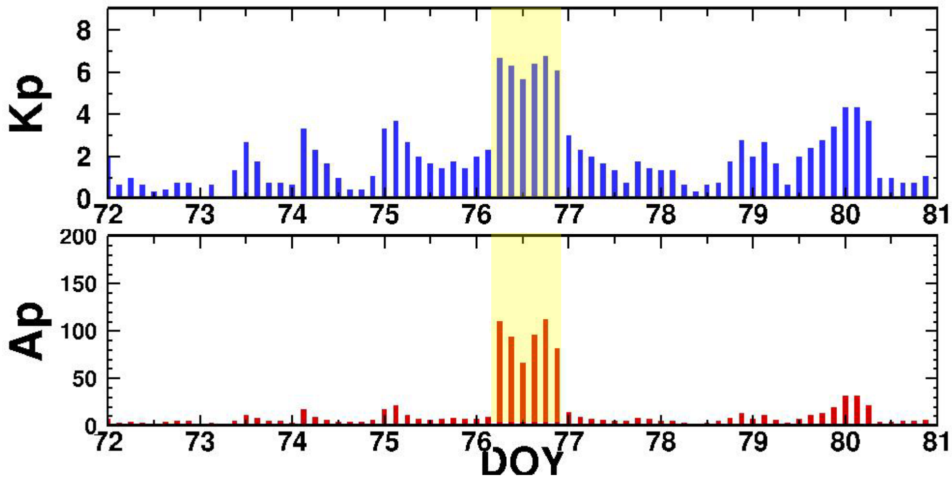
17 March 2013 Storm



- Main period of storm lasts ~18 hours
- Observations broken into Pre-, Storm-, Recovery-, Post- periods.
- Minimum Dst = -132 nT



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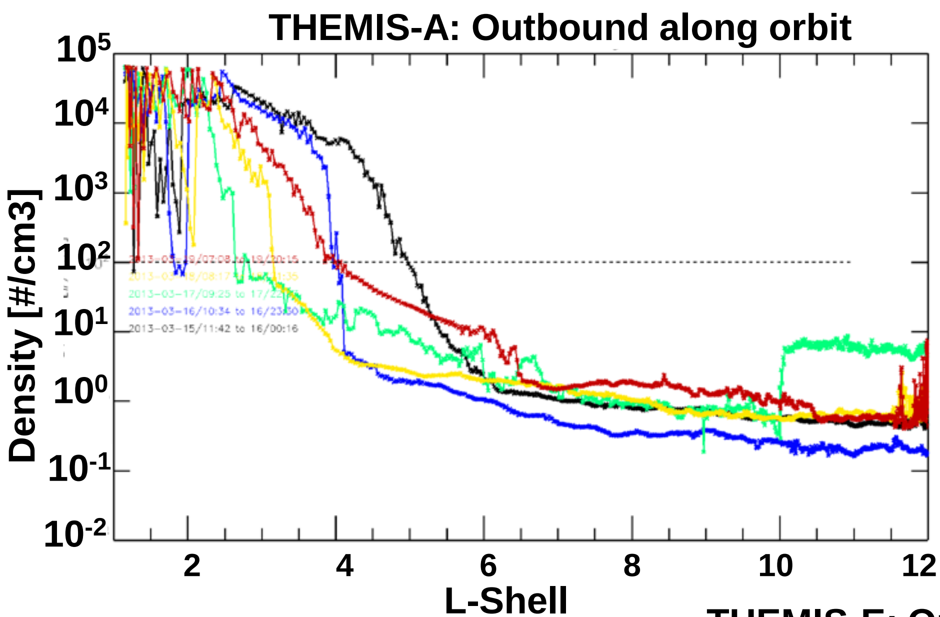
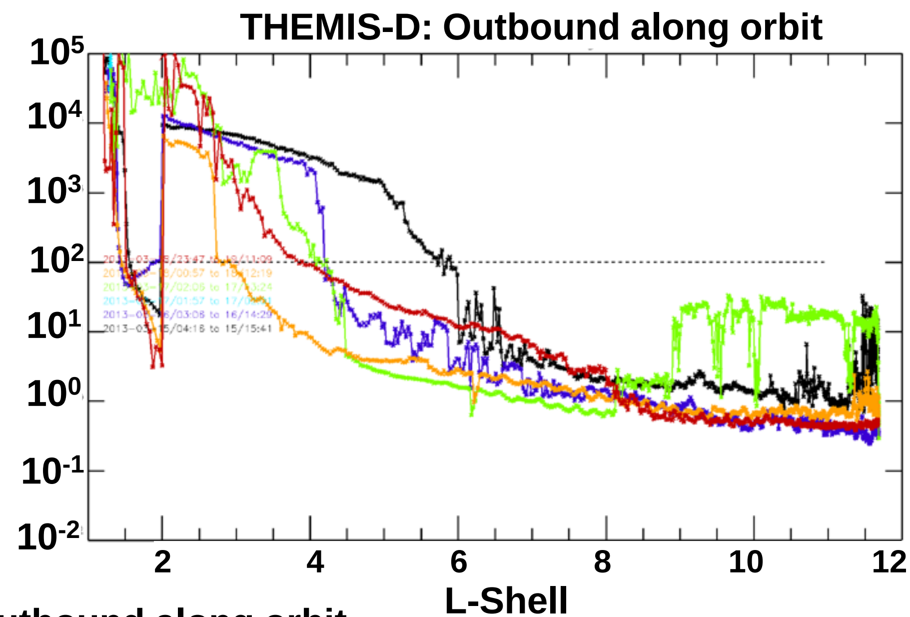
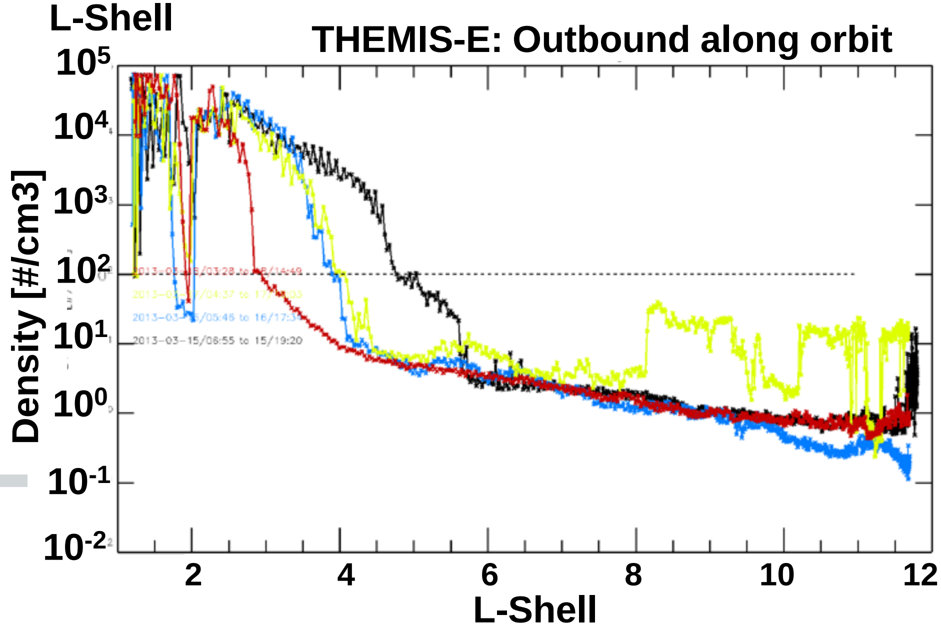
THEMIS







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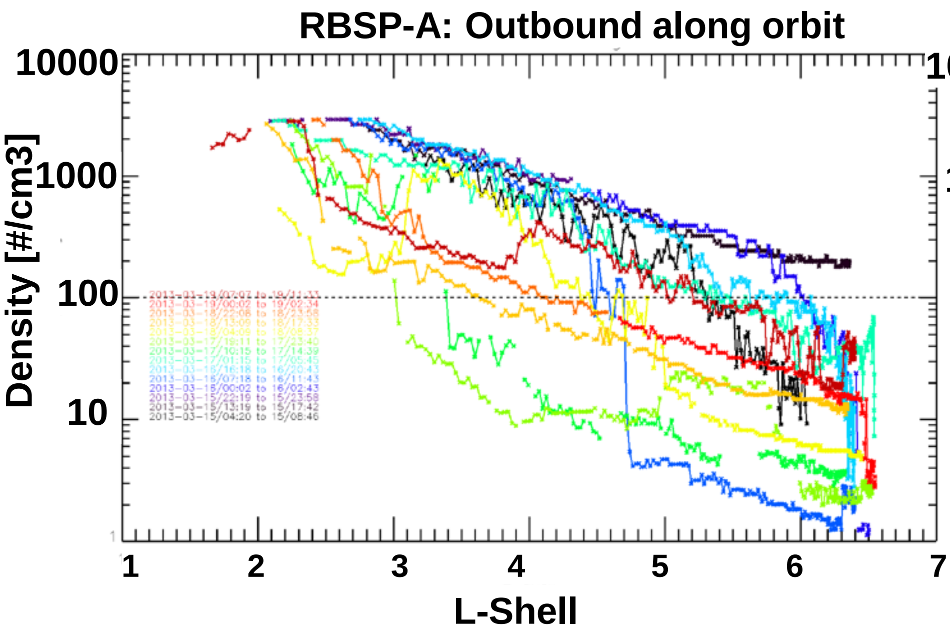
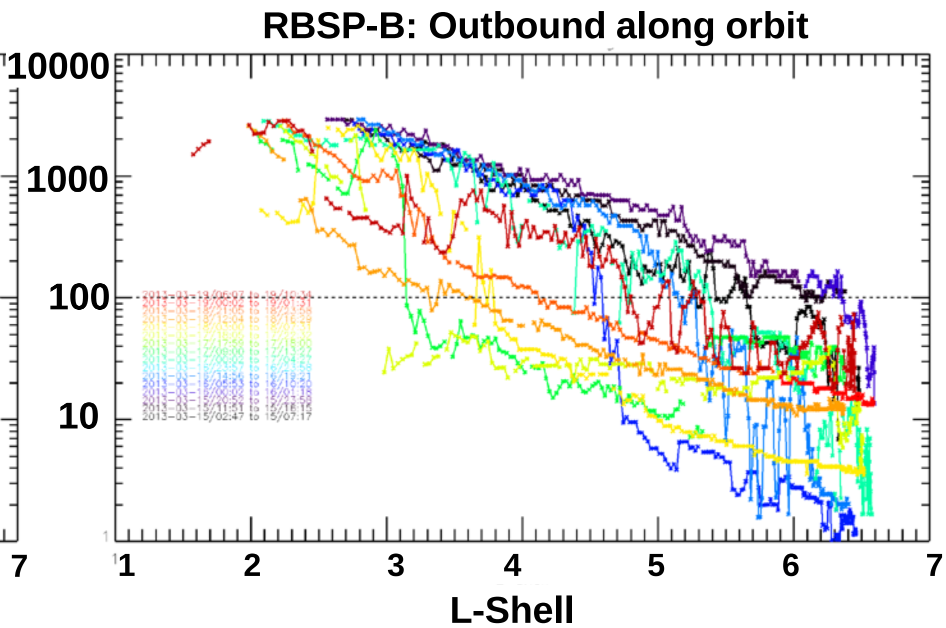
van Allen Probes





- Black to Red → Early to Later time
- Plasmapause is sudden drop of density (but not always!)

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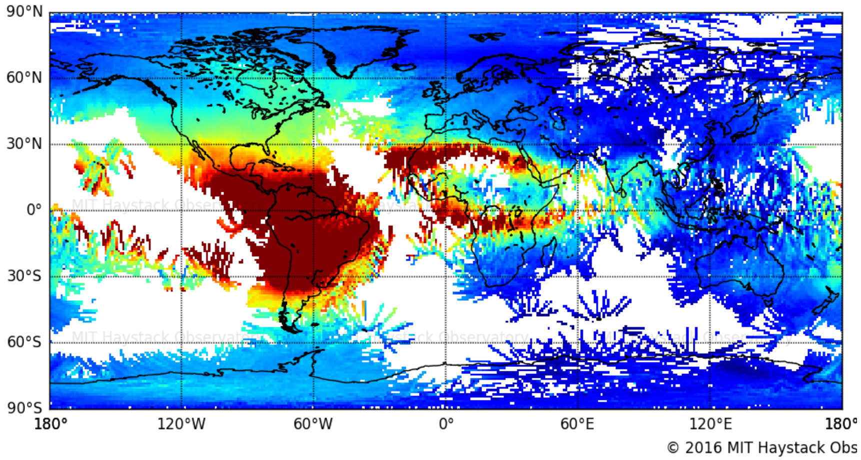
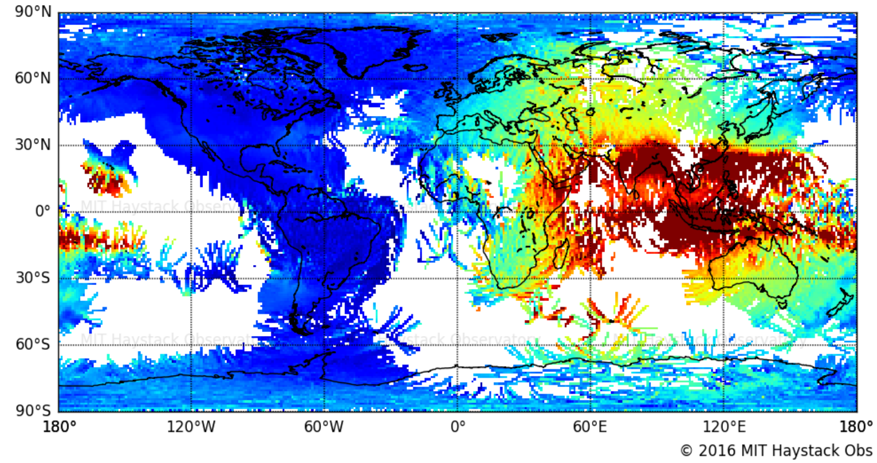
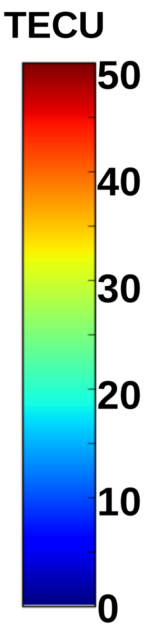
Ground-based GPS

March 16, 2013 18:00 to 22:00 UT (Pre)

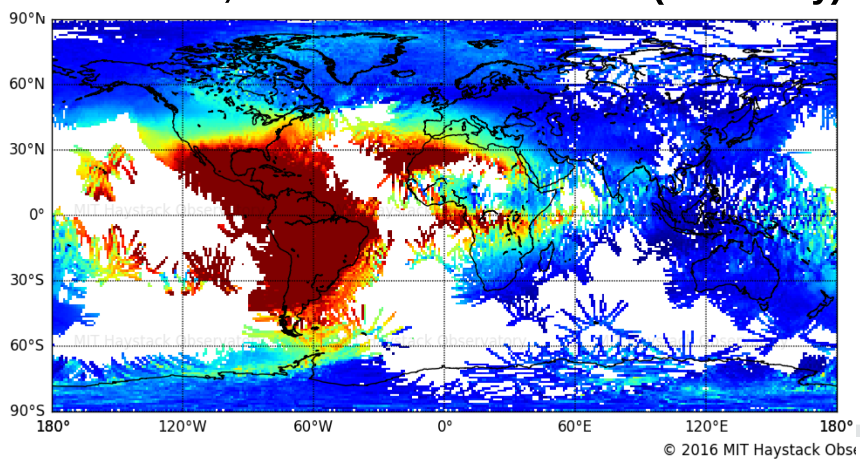


March 17, 2013 06:00 to 10:00 UT (Storm)

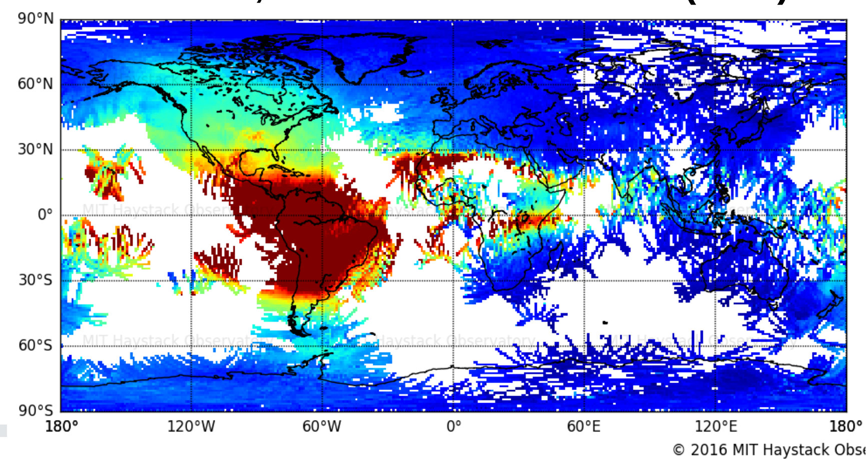




March 17, 2013 18:00 to 22:00 UT (Recovery)



March 18, 2013 18:00 to 22:00 UT (Post)



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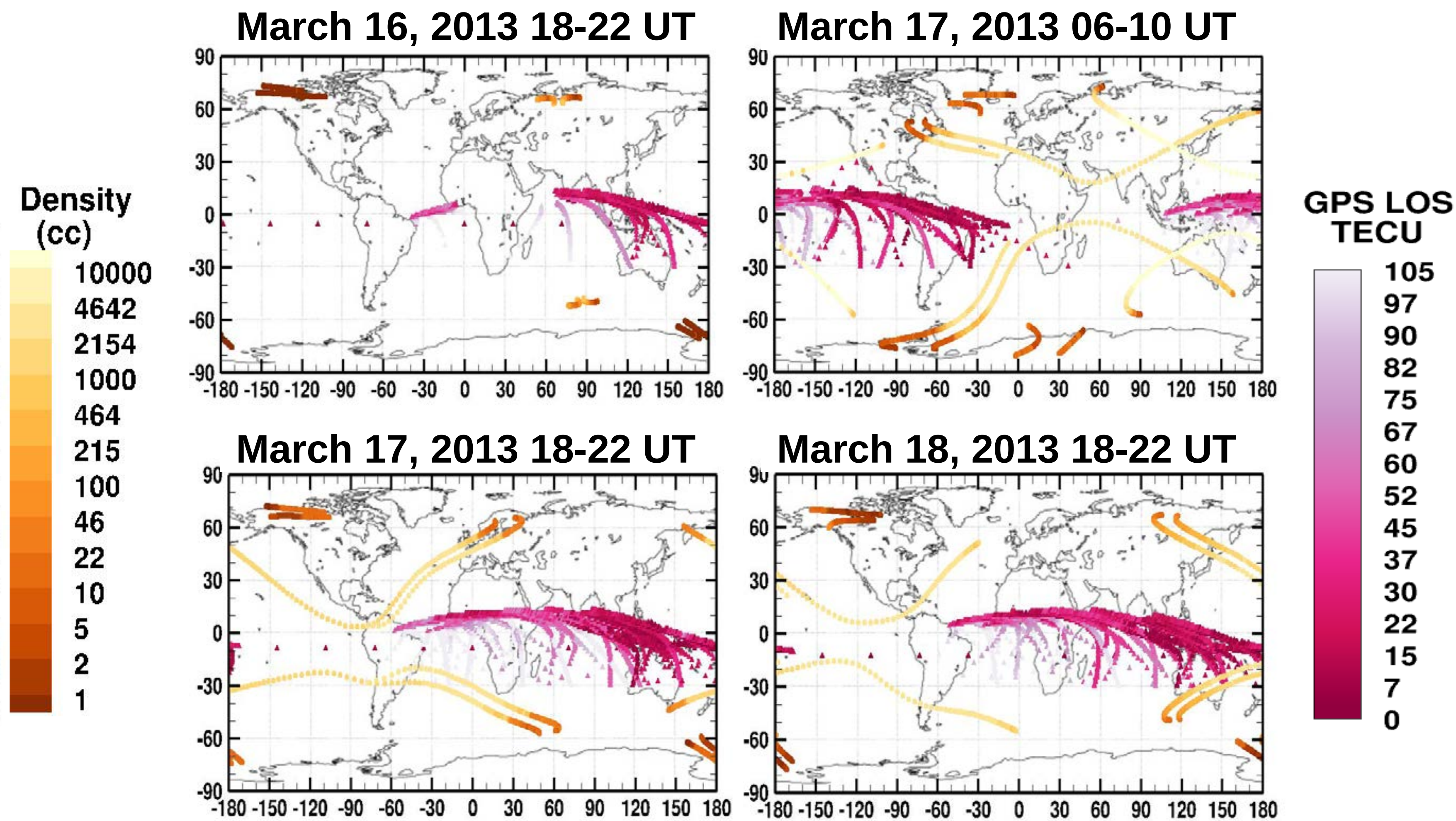
THEMIS, van Allen Probe, CORISS LOS Observations



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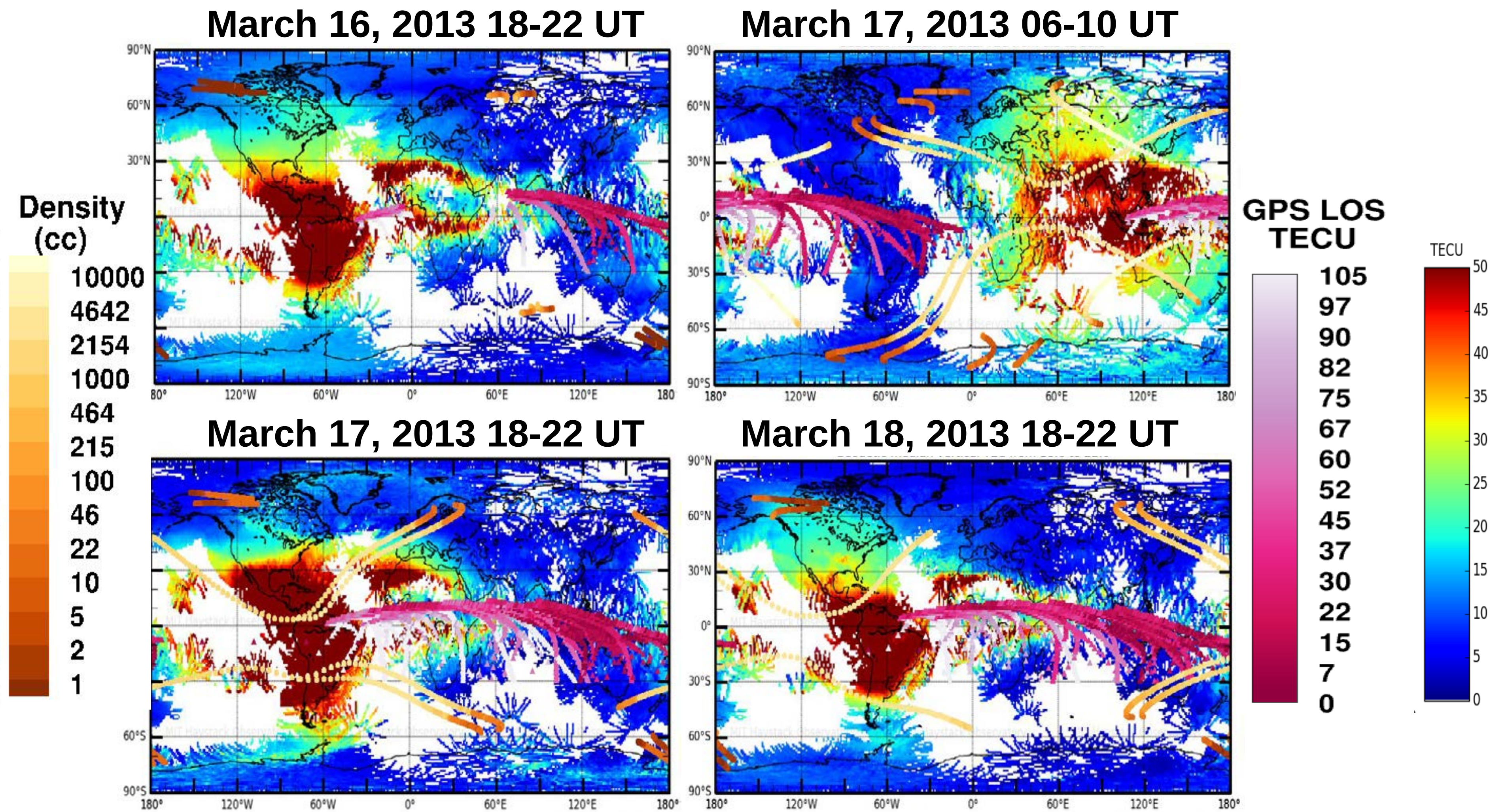

Summary & On-going Work

- Presented the first step in comparing disparate data sets.
- As reported by others, equatorial anomaly thickens in latitude and centers move equatorward
- Consistency seen between satellite and GPS data
- Primary challenge is visualizing datasets together
- Next Steps:
  – *Need to determine best metric for plasmapause location*
  – *Ingest ground and space-based data into PDA*
  – *Compare data to RCM-E and PDA output*

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