ISS Plasma Environment:
Status of CCMC Products for ISS Mission Ops

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ISS Space Weather Needs*

- Solar activity/thermosphere density prediction and satellite torque/drag predictions for:
  - Mission planning and controllability/real-time operations
  - MM/OD environment evolution
- MSFC meteor storm severity predictions driven by the Perseids on Mir events of 12 August 1993
- Role of solar/geomagnetic activity/thermosphere in managing ISS crew ionizing radiation dose exposure
- ISS interaction with auroral particle precipitation – why this isn't a problem or do we need forecasting?
- Monitor for changes in the SAA altitude structure and geographic extent for crew IR dose management
- Ionospheric Ne, Te values along ISS orbit for characterizing ISS charging hazards:
  - Near real time Ne, Te data
  - Well validated real time model Ne, Te output

*from S. Koontz/ISS Environments Manager

Introduction

Overview

- Background
  - ISS interaction with plasma environment
  - Charging hazards to vehicle and crew
  - ISS Program hazard mitigation strategies
- ISS plasma environment monitoring
  - Floating Potential Measurement Unit (FPMU)
- CCMC CTIPe real time plasma model
  - Examples of success
  - Issues in work
- Summary and future needs

ISS/FPMU:	JSC	Steve Koontz (ISS Environments Lead), John Alred, Jack Bacon
	MSFC	Mike Chandler, Victoria Coffey, Joseph Minow, Paul Craven, Todd Schneider, Ken Wright (UAH)
	Boeing	Drew Hartman, Leonard Kramer, Ron Mikatarian, Danny Schmidl
CTIPe model:	NOAA	Tim Fuller-Rowell
CCMC team:	GSFC	Ja Soon Shim (UMBC/NASA), Lutz Rastaetter (NASA), Masha Kuznetsova (NASA)

ISS Structure Potential Variations and Hazards

- ISS potential varies in low Earth orbit environment due to:

Current collection	Observed Voltage Ranges to Date
– Current collection from ambient plasma	- 0.1 to -0.5 volts
– 160 V US solar array	-20 to -90 volts
– Visiting vehicle (high voltage) solar arrays	-10 volts
– Operation of payloads that emit current sources	+10 to +25 volts
Inductive potentials	
– (vxB).•L due to motion across geomagnetic field	+/-40 volts
– E.• L due to ionospheric electric fields	few volts
– Auroral electrons	-20 volts

- Hazards to vehicle and crew
  - ISS-EVA-305: long term degradation of thin dielectric surface thermal control coatings due to arcing …EVA touch temp violations (eventually)
    - Hazard marginalized by test and analysis - no controls needed
  - ISS-EVA-312: EVA electric shock
    - Hazard 1 - Catastrophic at floating potentials more negative than -40V
    - Hazard 2 - Critical to catastrophic at positive floating potentials (> 0V)
    - Hazard 3 – critical to catastrophic ISS electrical power short through EVA crew to ground
      - Plasma is a secondary cause – one circuit closure pathway

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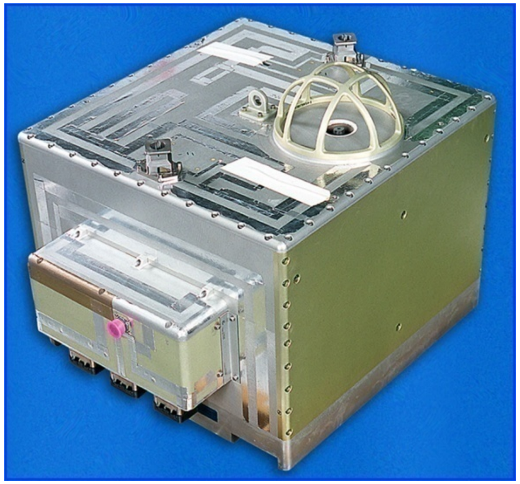
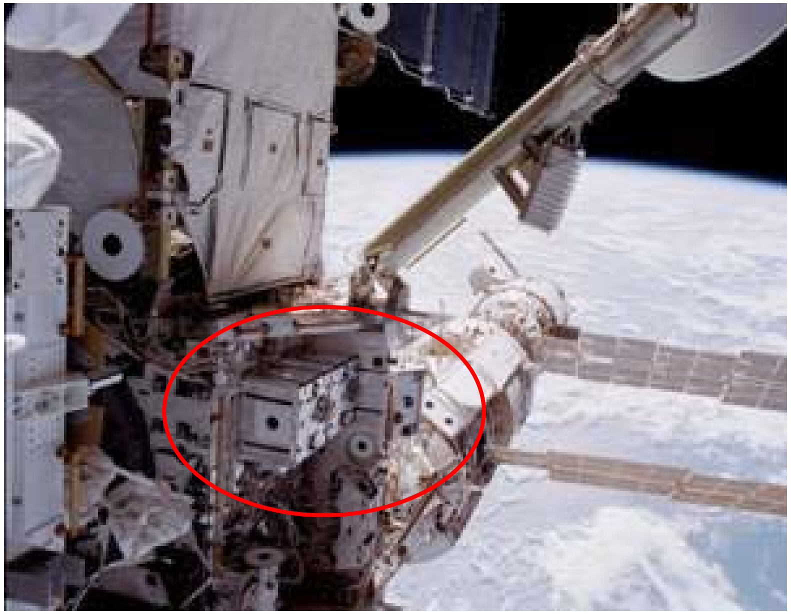
ISS Plasma Hazard Management

ISS Program controls plasma hazards through a process of active potential control, operational mitigation strategies, environment monitoring and characterization, and probabilistic risk assessment



- **Plasma Contactor Units (PCUs)**
  - Provides active ISS "ground" by dissipating surface charges to space
  - Two redundant PCU units provides single fault failure tolerance, two required for EVA



- **Operational control using ISS flight attitude, solar array wing angle, and solar array shunt state**
  - Manages solar array and magnetic induction charging
  - Provides two fault tolerance
- **Floating Potential Measurement Unit (FPMU)**
  - Provides validated measurements of ISS floating potential and ionospheric Ne, Te along ISS orbit
- **Plasma Interaction Model (PIM)**
  - ISS charging model validated with FPMU data
  - Predicts charging hazard severity and frequency of occurrence

Floating Potential Measurement Unit (FPMU)

FPP: Floating Potential Probe

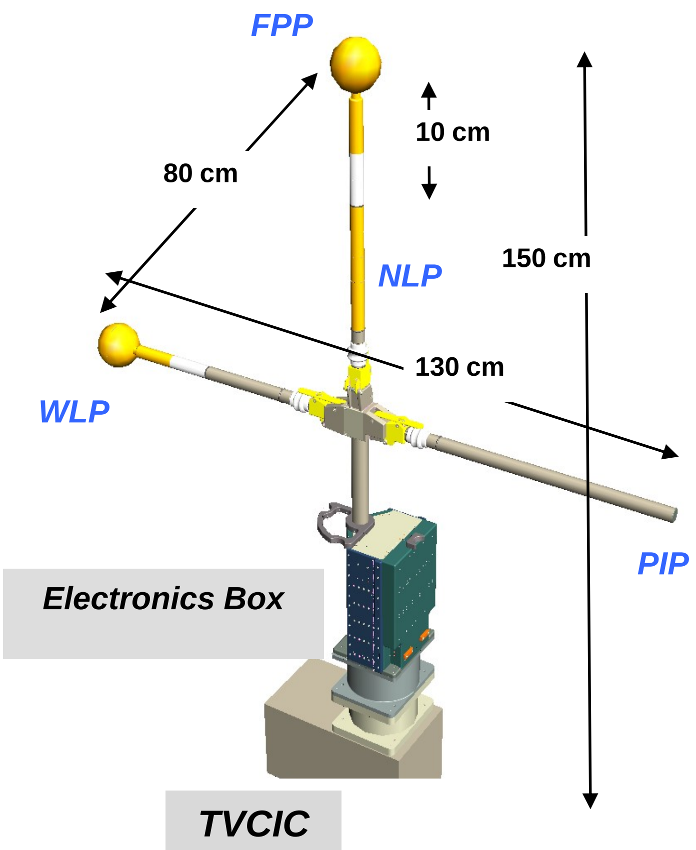
WLP: Wide-sweep Langmuir Probe

NLP: Narrow-sweep Langmuir Probe

PIP: Plasma Impedance Probe

Role:

- *Validation of PIM*
- *Assess PV array variability*
- *Interpreting IRI predictions*
- *Characterize ISS charging*

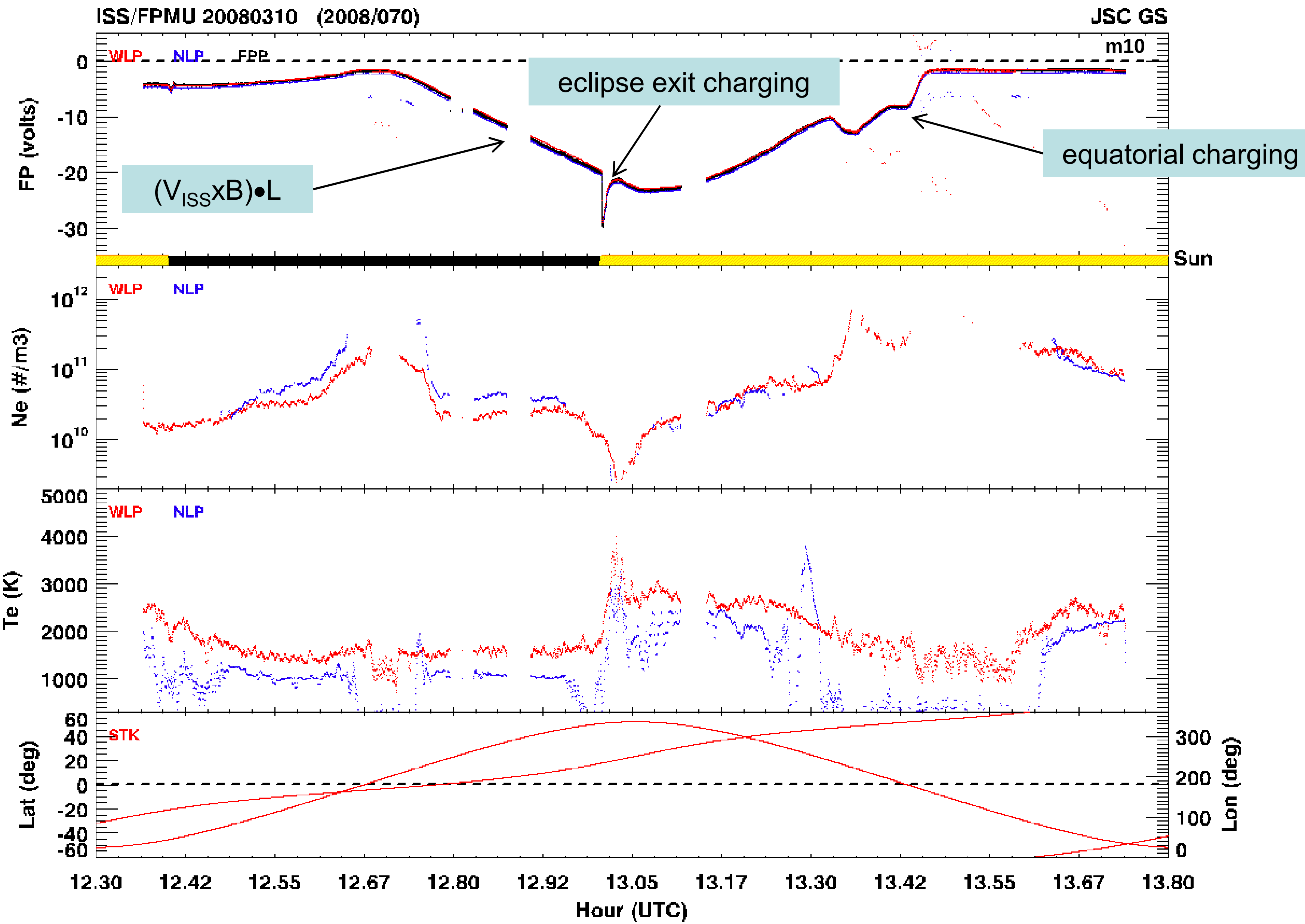


Sensor	Measured Parameter	Rate (Hz)	Effective Range
FPP	V_F	128	-180 V to +180 V
WLP	N T_e V_F	1	10^9 m^{-3} to $5 \cdot 10^{12}$ m^{-3} 500 K to ~10000 K -20 V to 80 V
NLP	N T_e V_F	1	10^9 m^{-3} to $5 \cdot 10^{12}$ m^{-3} 500 K to ~10000 K -180V to +180 V
PIP	N	512	$1.1 \cdot 10^{10}$ m^{-3} to $4 \cdot 10^{12}$ m^{-3}

[*Wright et al.*, 2008; *Barjatya et al.*, 2009]

2007

Characterizing ISS Environments, Charging



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Alternative Ne, Te Data and/or Model Sources

We have in-situ FPMU Ne, Te measurements along ISS orbit…
…but we are interested in identifying independent Ne, Te data sources from both measurements and models appropriate for ISS altitudes

- FPMU validation against independent measurements, models
  - Incoherent scatter radar Ne, Te, ionosonde Ne, TIMED/GUVI Ne
  - IRI, GAIM model Ne, Te

- FPMU data unavailable during EVA, docking, and other operations with higher Ku band video downlink priority
  - Real time data, models may be useful to provide coverage during these periods

- FPMU operated on campaign basis (~25 to 30% of year)
  - Well validated models or alternate data sources can provide environment characterization data between FPMU runs

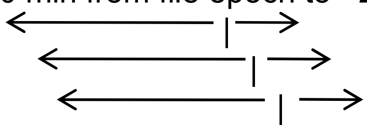
- Contingency planning in case of FPMU failure
  - Default to current “worst case” analysis for EVA planning…but that impacts ISS power availability
  - Alternative data, validated models could provide operations relief to power constraint

CCMC Real-time Ionosphere Ne, Te for ISS

Coupled Thermosphere Ionosphere Plasmasphere Electrodynamics (CTIPe) Model

– CCMC implemented real time CTIPe model in spring 2010 (CTIPe_RT) with output specific for ISS orbit
– ISS ephemeris from GSFC/SSCWeb
– New record every 10 minutes gives 90 minutes of data at 5 sec time steps

-70 min from file epoch to +20 min



```
CTIPe_at_ISS_20100909_192000.txt                          09/09/2010    07:01PM
# Data printout from CCMC-simulation: version 1.1
# Data type:  CTIP  ionosphere/thermosphere
# Run name:   2010-09 Missing data:   -1.100E+12
# Coordinate System: GEO
# fixed dipole tilt angles used: SM-GSM:       0.00000 GSM-GSE:       0.00000
# Satellite Track: iss
# Output data: field with 1x1081=1081 elements
#YYYYMM DD HH MM    Sec    lon     lat     IP        N_e         N_O+        N_H+      T_i   T_e
# year month day  h m s  [deg]   [deg]   [km]     [m^-3]      [m^-3]      [m^-3]     [K]   [K]
2010 09 09 17 50  0.000  254.4 -9.250  351.5  7.522E+11  7.501E+11  2.108E+09  1125. 1828.
2010 09 09 17 50  5.000  254.6 -8.994  351.5  7.494E+11  7.473E+11  2.089E+09  1125. 1831.
2010 09 09 17 50 10.000  254.8 -8.738  351.4  7.465E+11  7.444E+11  2.069E+09  1125. 1834.
2010 09 09 17 50 15.000  254.9 -8.483  351.4  7.434E+11  7.414E+11  2.050E+09  1125. 1837.
2010 09 09 17 50 20.000  255.1 -8.227  351.3  7.402E+11  7.382E+11  2.030E+09  1124. 1840.
2010 09 09 17 50 25.000  255.3 -7.971  351.3  7.366E+11  7.346E+11  2.010E+09  1124. 1843.
2010 09 09 17 50 30.000  255.5 -7.715  351.2  7.312E+11  7.292E+11  1.989E+09  1123. 1844.
2010 09 09 17 50 35.000  255.7 -7.459  351.1  7.259E+11  7.239E+11  1.968E+09  1122. 1846.
2010 09 09 17 50 40.000  255.9 -7.203  351.1  7.205E+11  7.186E+11  1.947E+09  1120. 1848.
2010 09 09 17 50 45.000  256.1 -6.947  351.0  7.151E+11  7.132E+11  1.927E+09  1119. 1850.
                   ----------------  (records deleted)  ------------------------
2010 09 09 19 20  0.000  227.5 -14.02  352.8  3.634E+11  3.621E+11  1.289E+09  989.1 1710.
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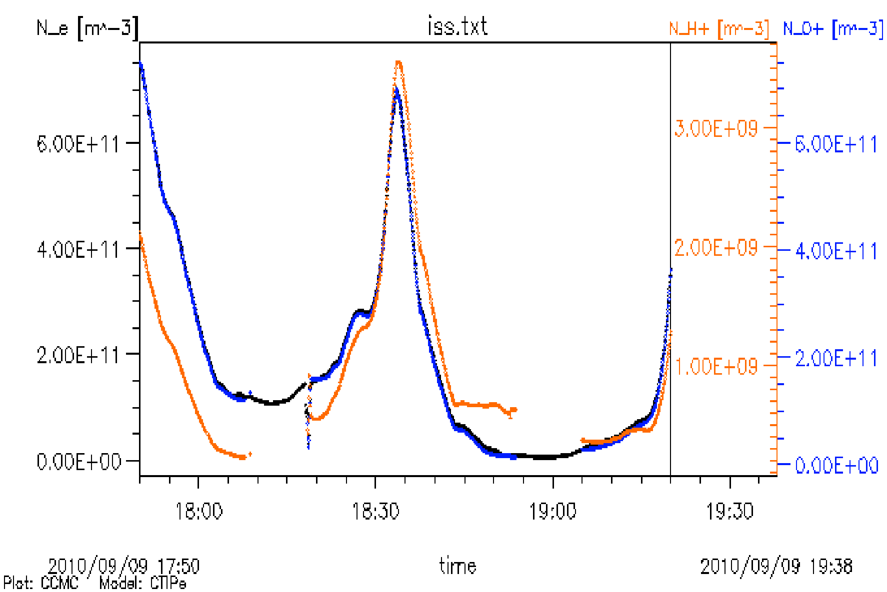

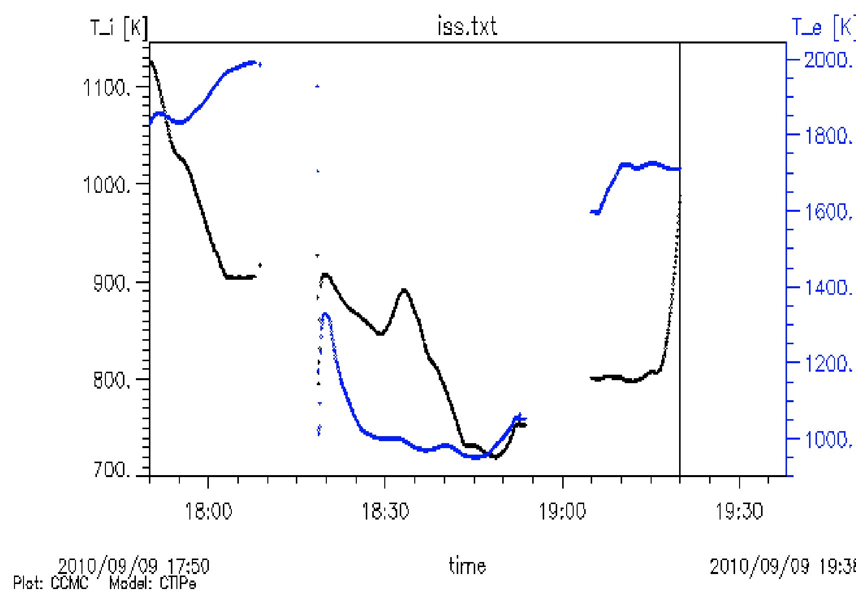

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Example CTIPe_RT Daily Output

CTIPe_RT output at CCMC:

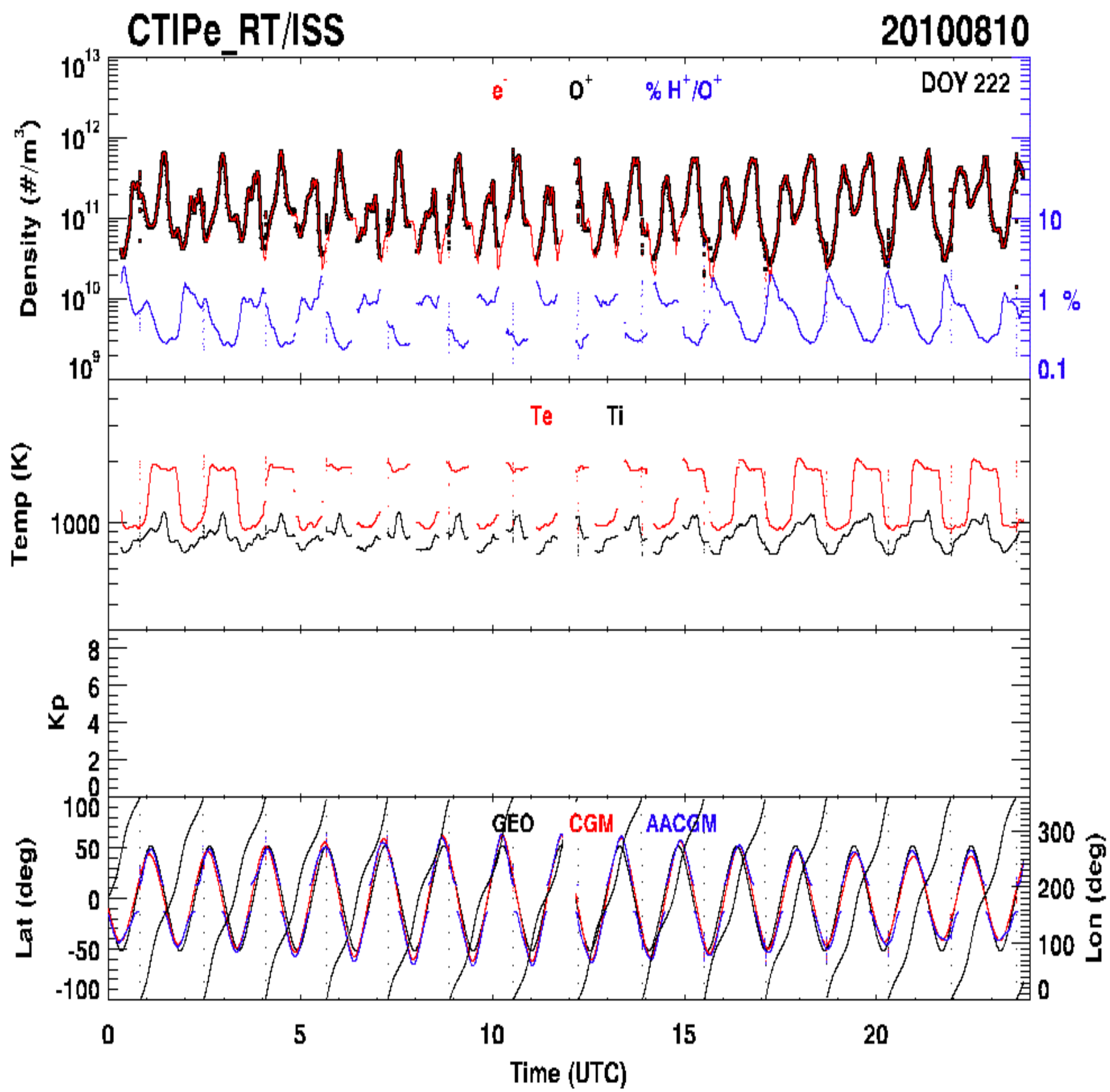
Integrated Space Weather Analysis System (iSWA)
http://iswa.gsfc.nasa.gov/iswa/iSWA.html

Anonymous ftp
ftp://hanna.ccmc.gsfc.nasa.gov/

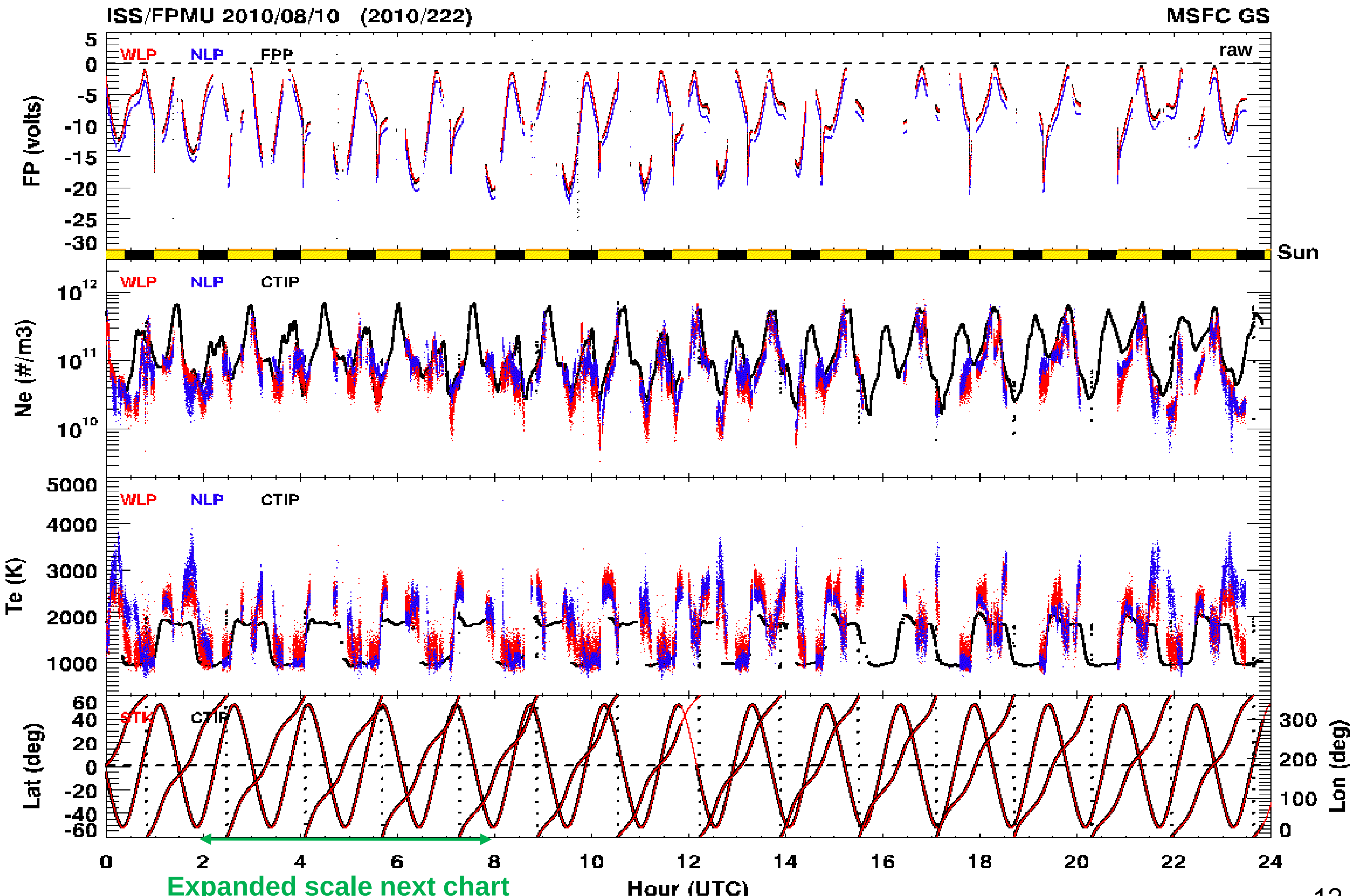
CTIPe Model Description:
http://ccmc.gsfc.nasa.gov/models/modelinfo.php?model=CTIPe

MSFC is evaluating CTIPe_RT for possible ISS ops use:

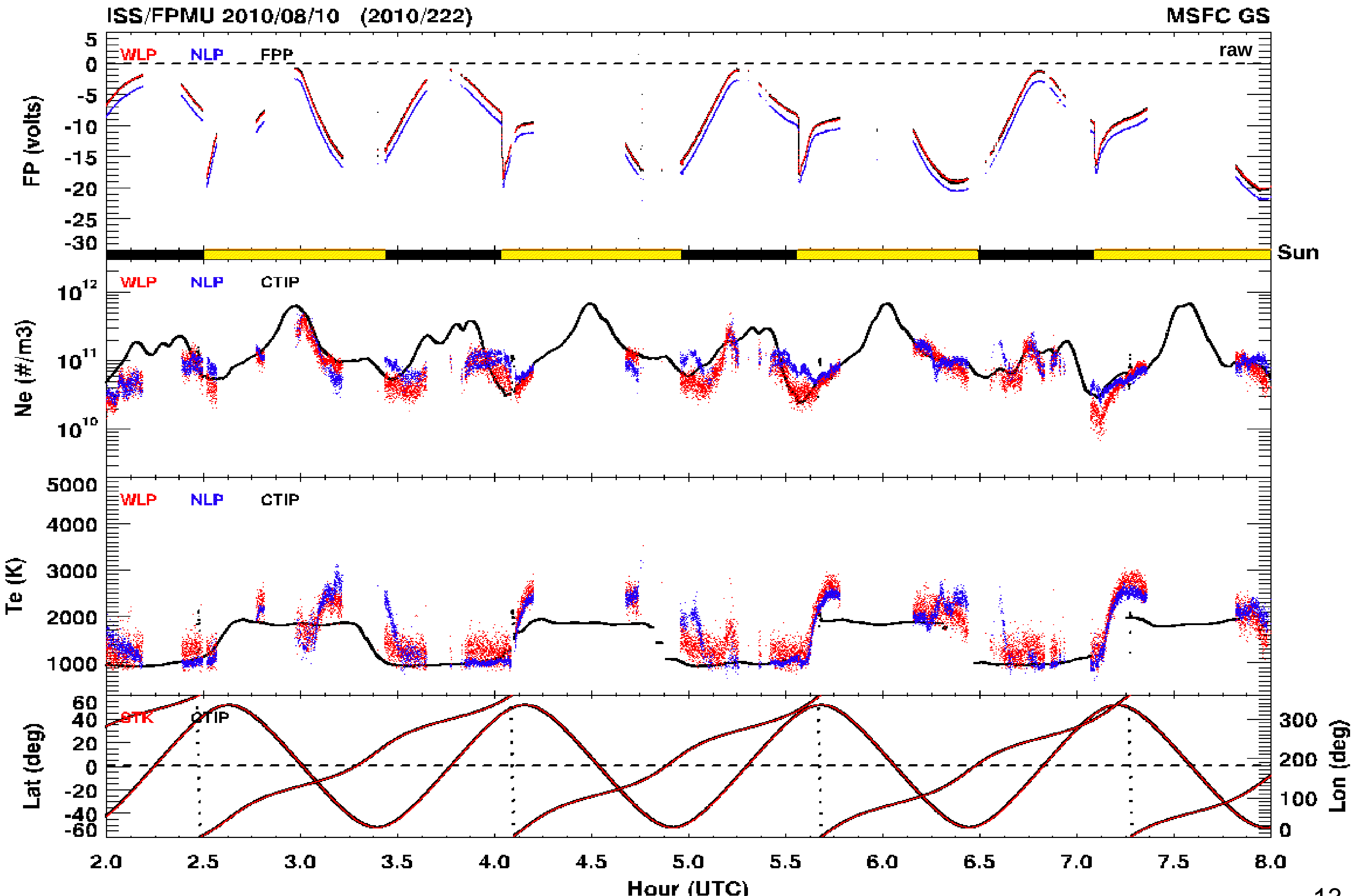
- Periodically download text output files and process into daily data sets retaining the unique records
- Compare CTIPe_RT Ne, Te with measurements from FPMU
- This is a work in progress, both for ISS and CCMC! Only preliminary results shown here…



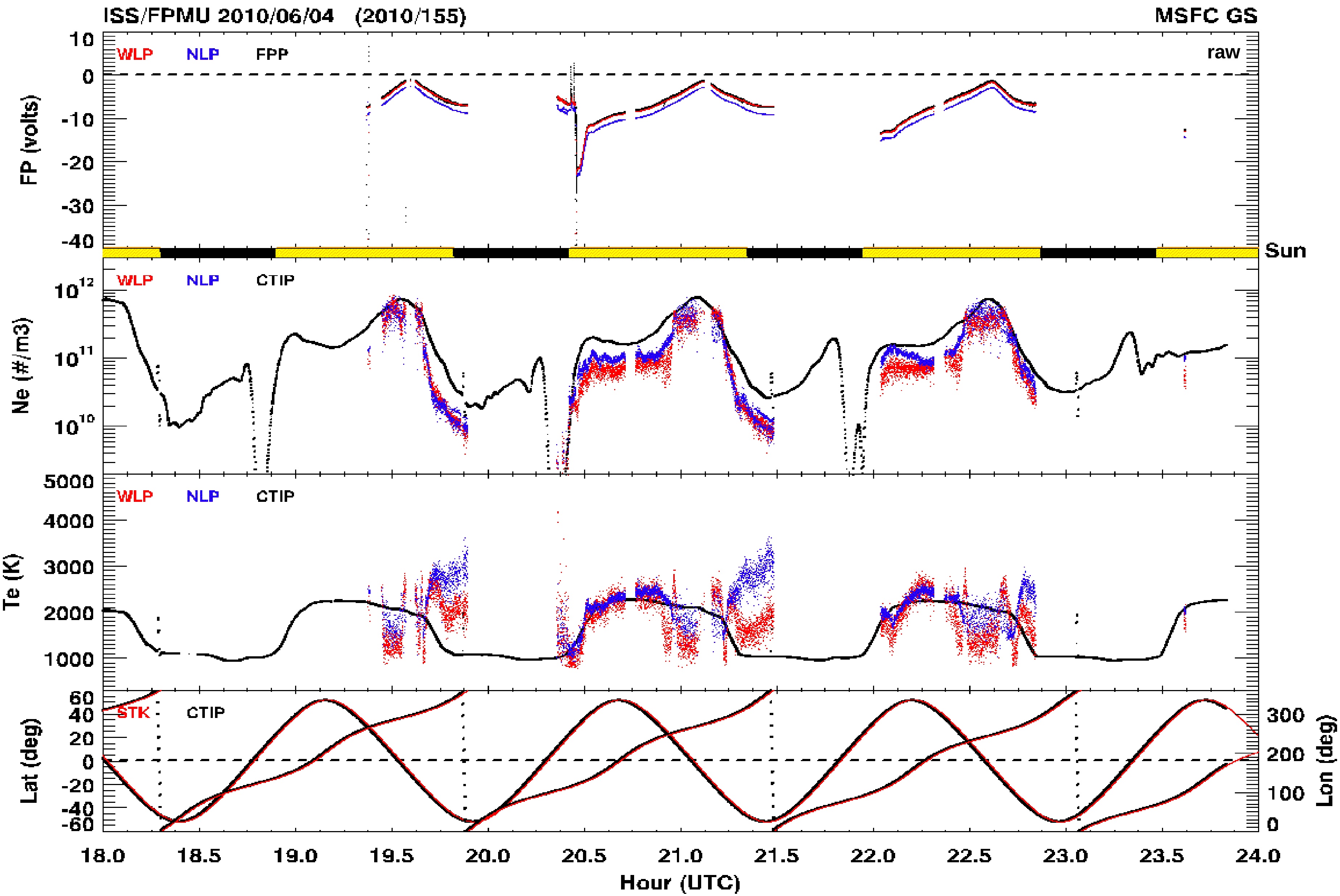
CTIPe_RT Output and FPMU Survey Plot



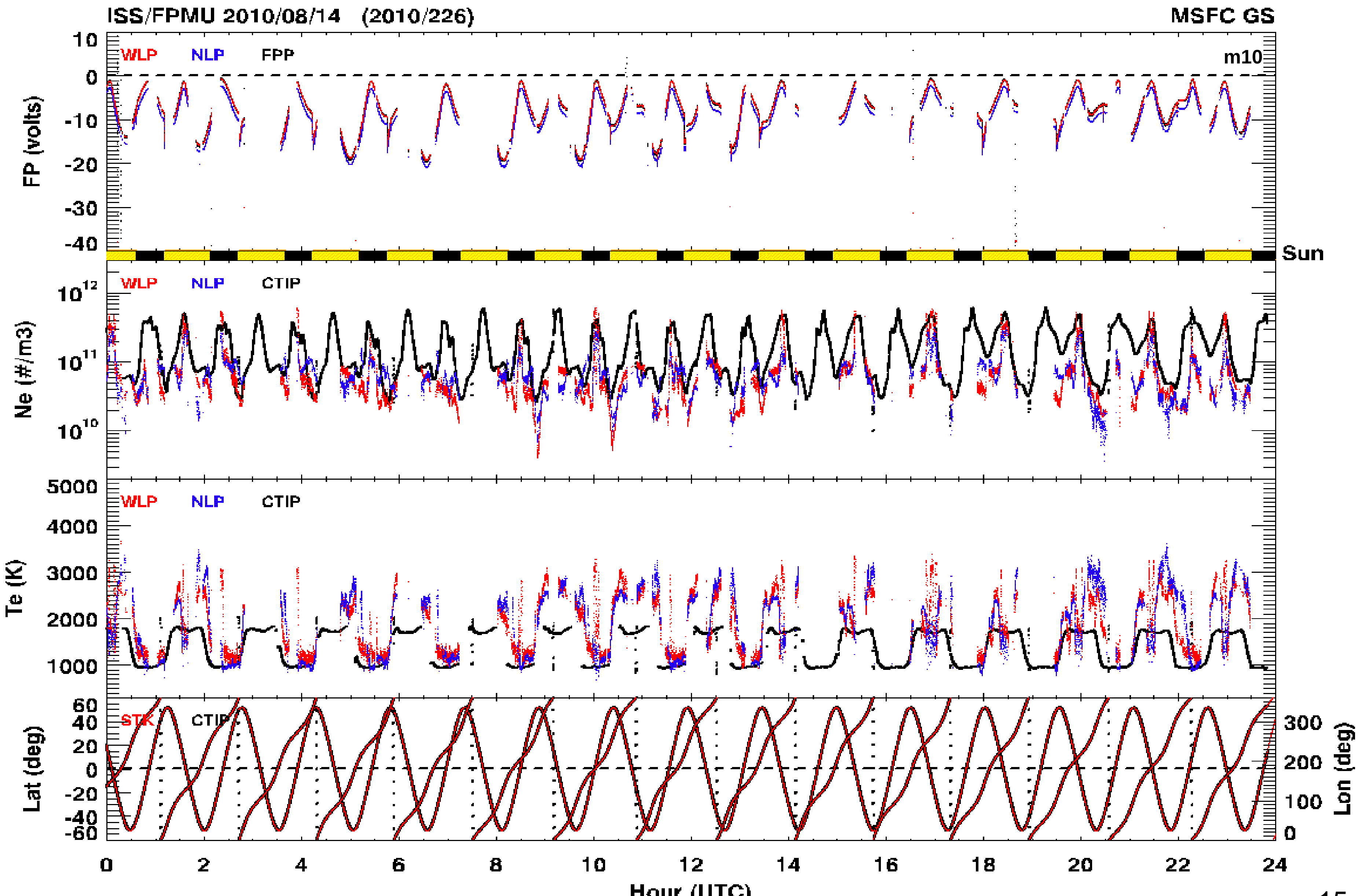
Good CTIPe_RT/FPMU Comparison



Good CTIPe_RT/FPMU Comparison



Less Good CTIPe_RT/FPMU Comparison



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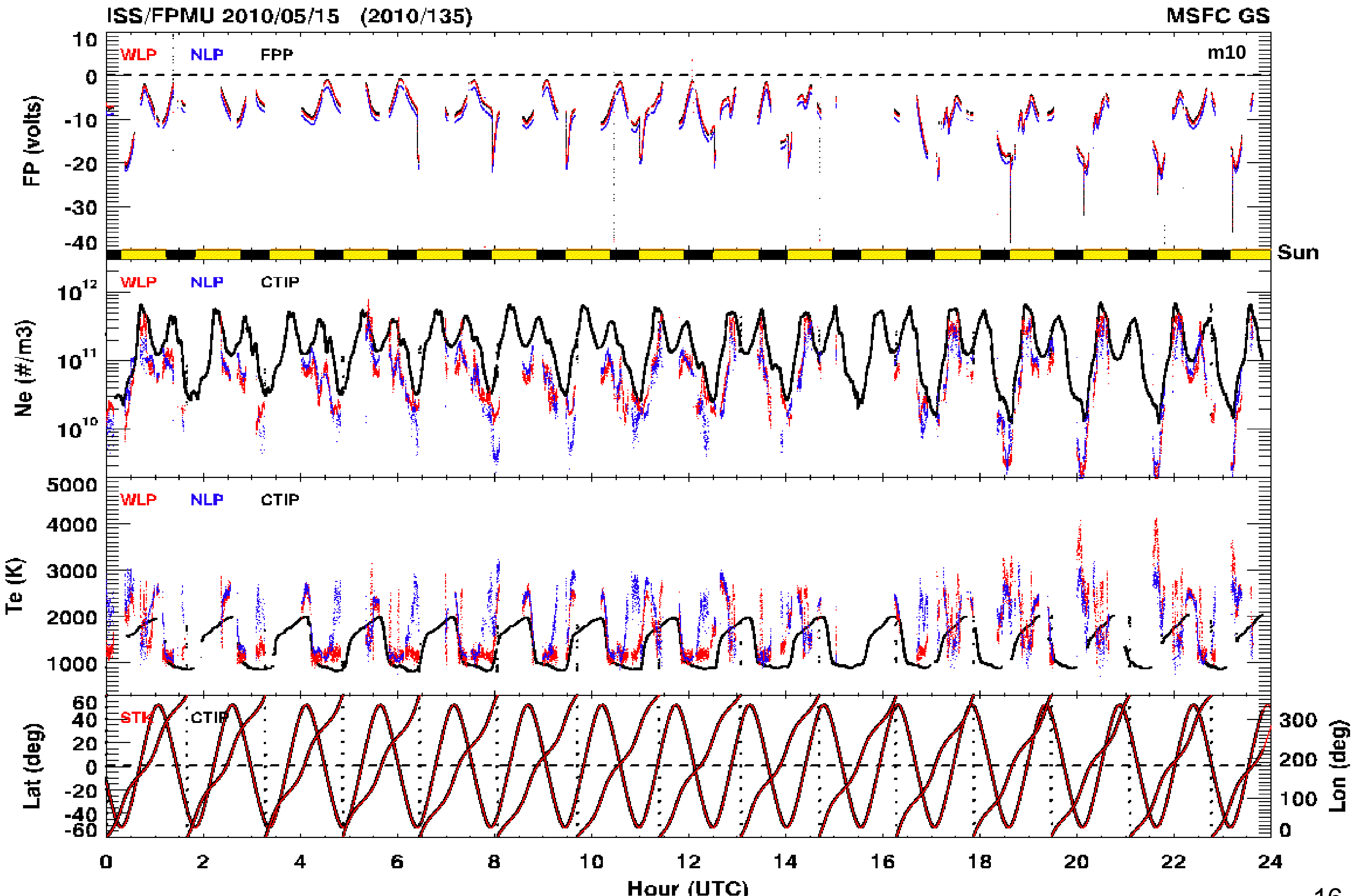
Poor CTIPe_RT/FPMU Comparison



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Incorrect CTIPe_RT ISS Ephemeris Issue

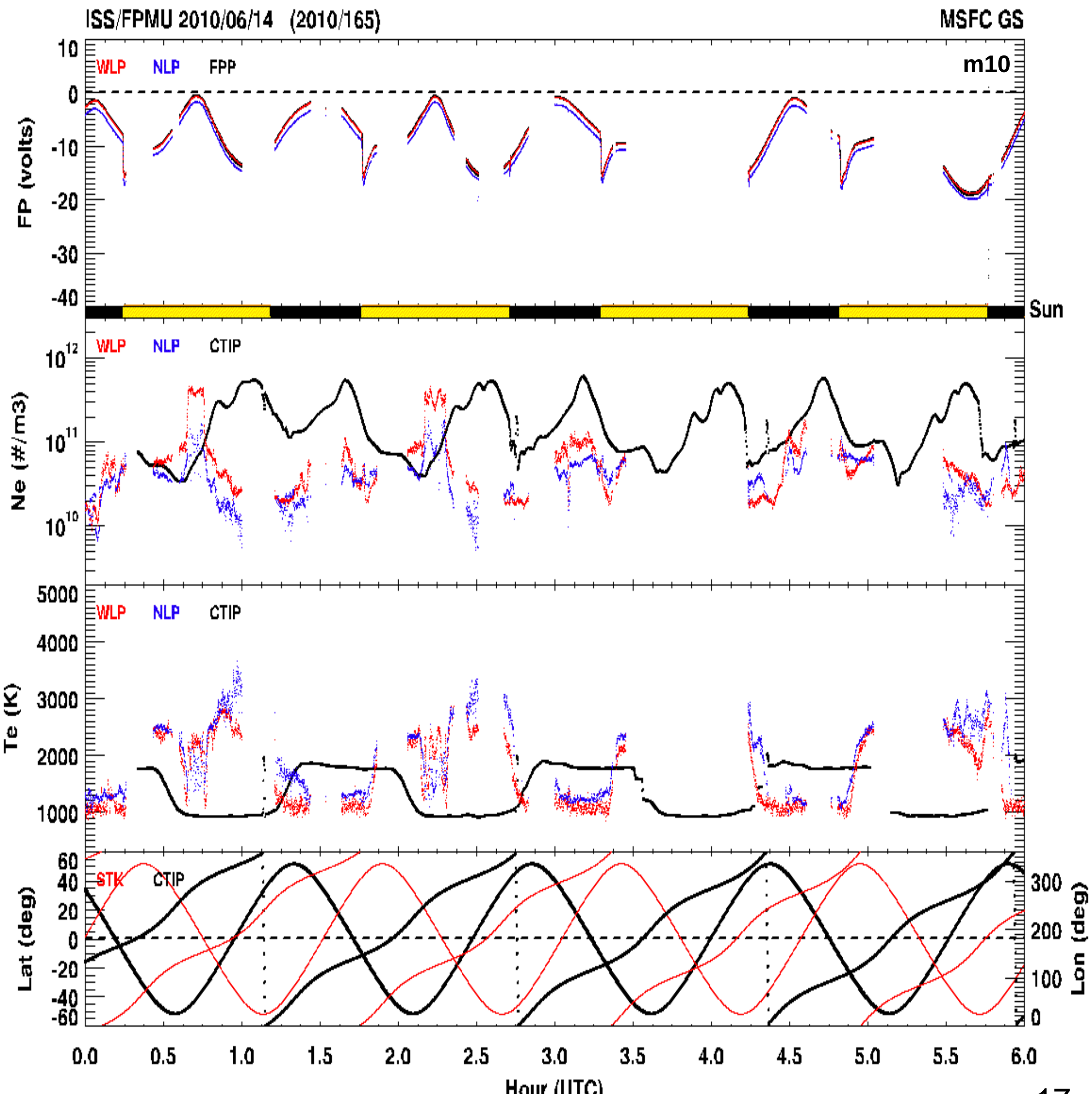
MSFC FPMU analysis software

- ISS ephemeris generated from NORAD TLE's using Satellite Tool Kit (STK) software is consistent with ISS/FPMU data

CCMC real time model

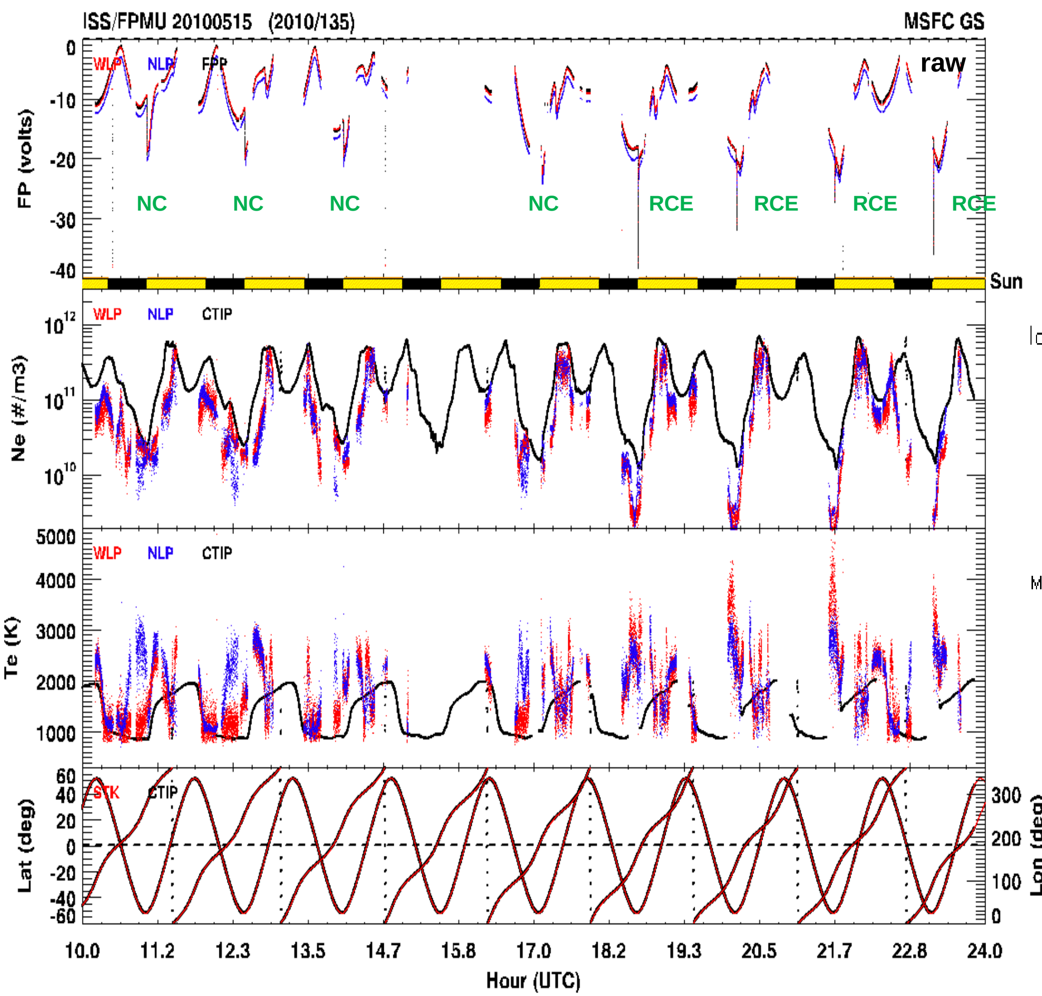
- CTIP output based on incorrect ISS ephemeris obtained from SSCWeb for complete 2010/165 – 168 ISR World Day campaign

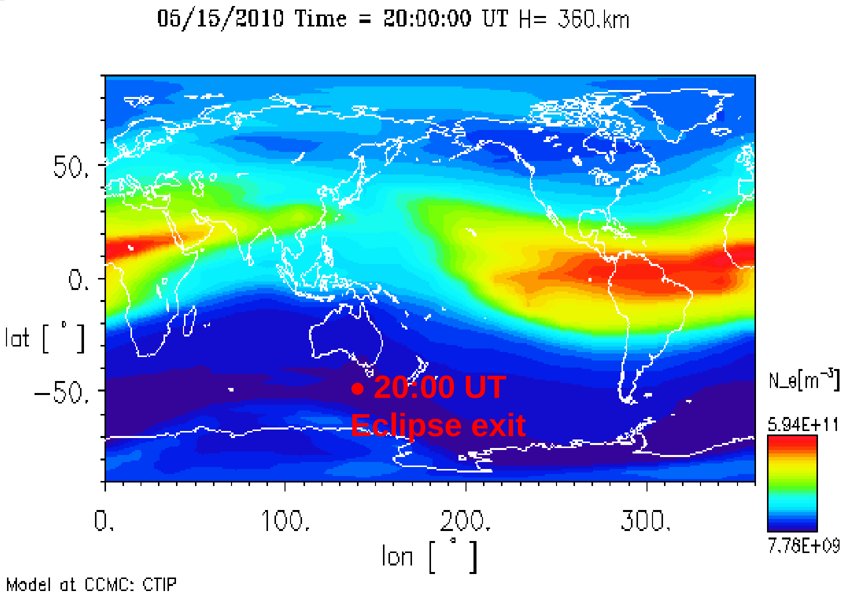
- CCMC considering options for robust orbit generation tools for real time model support



Characterizing High Latitude Charging Environment

- ISS environments teams are investigating vehicle charging observed at eclipse exit
- CTIPe_RT model confirmed physical origin of the plasma depletions for charging events observed at high latitudes, allows us to predict periods for studying charging phenomenon

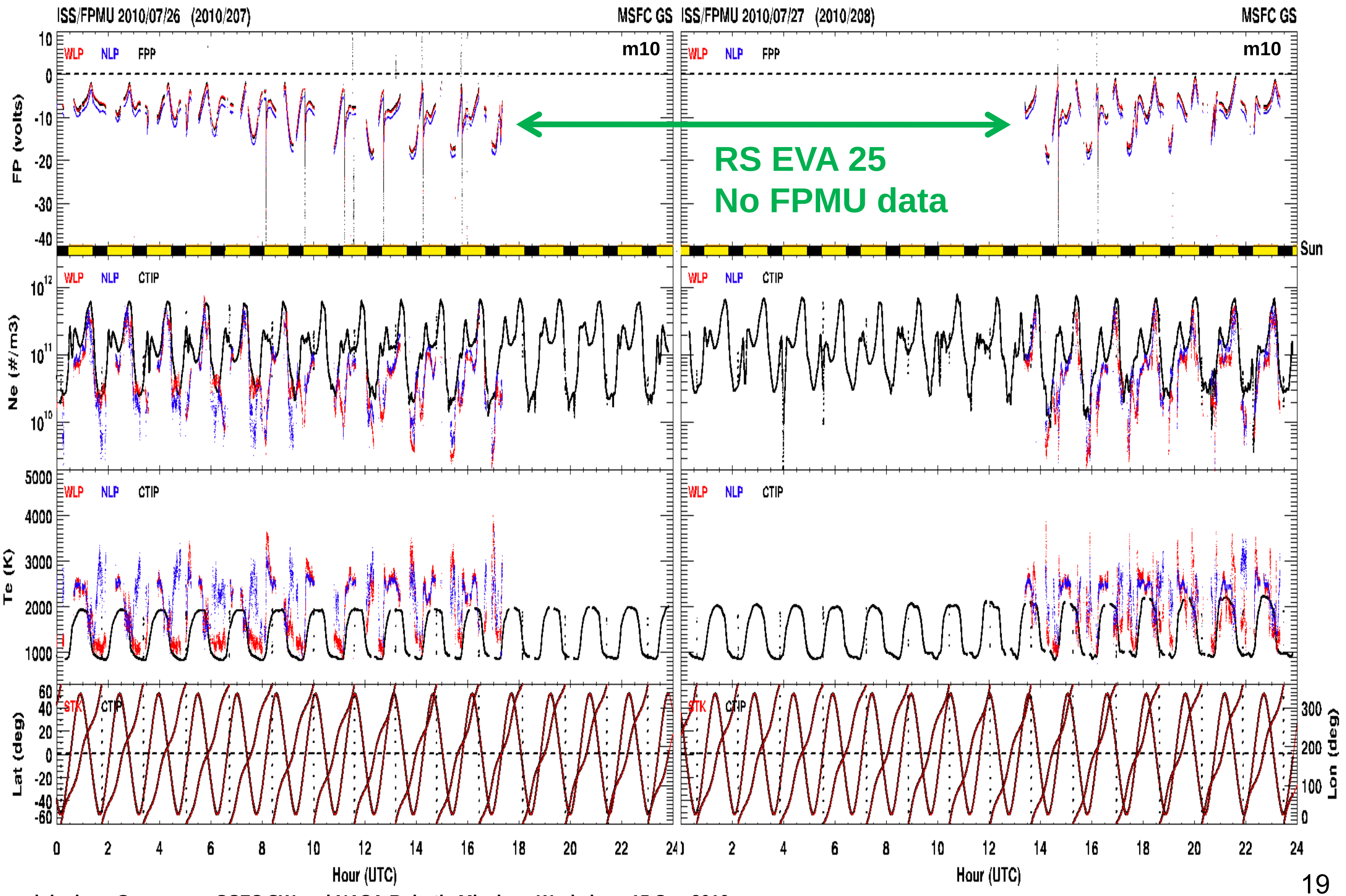




10-17 UT Eclipse Exit
Normal charging (NC) events observed at eclipse exit

17 – 24 UT Eclipse Exit
Rapid charging (RC) events observed when eclipse exit occurs in low density plasma troughs

FPMU Data Unavailable During EVA



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Summary and Future Needs

- **ISS Program currently using FPMU Ne, Te in-situ measurements to support operations and anomaly investigations**
  - Working to acquire alternative data sources if FPMU is not available

- **Work is progressing on CCMC tools for low Earth orbit ionosphere characterization**
  - Validation against FPMU data required before model output can be used for ISS operational support
  - MSFC plans to continue comparing CTIP output during FPMU campaigns
  - Results to date have been useful in identifying ionospheric origins of high latitude charging environments

- **CTIPe-RT model issues to be addressed before using output for ISS ops:**
  - Accuracy — initial evaluation showing discrepancies with FPMU data
  - Operational reliability — 24/7 availability to support ops; orbit propagator issues (accuracy, availability)

- **Preliminary results to date focused on model implementation**
  - Forward work will emphasize quantitative CTIP, FPMU Ne, Te comparisons
  - CCMC personnel are very responsive in discussing options and addressing needs!

- **Future needs:**
  - Implement CTIPe_RT output for ISR, ionosonde sites
    - Provide additional data for validating CTIP output
    - Support validation of real time data to supplement FPMU output
  - Implement assimilative ionosphere models (e.g., GAIM)
    - Models constrained by Ne, Te data better for operations support, anomaly investigations