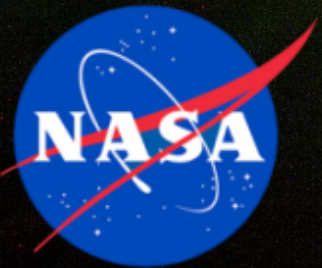


A photograph taken from space showing the Earth's horizon. The atmosphere is illuminated with vibrant green and purple aurora borealis. The ground below is dark, with some city lights visible. The background is a starry space.

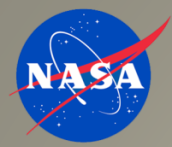
# NASA Technical Fellow for Space Environments View of CCMC

Joseph Minow  
NASA, Langley Research Center

8<sup>th</sup> Community Coordinated Modeling Center Workshop 2016  
Annapolis, Maryland 10 – 15 April 2016  
[joseph.minow@nasa.gov](mailto:joseph.minow@nasa.gov)







# Outline

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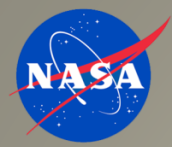
- Introductory comments
- Examples of CCMC benefit to NASA
  - CTIPe for ISS, ionospheric drivers of rapid charging
  - Geomagnetic storm impact on F2-region Ne, Te
  - ISS auroral charging
  - ISS EVA hazard assessments and CME speed
  - Real time effects tools
  - Equatorial plasma depletions
  - Auroral models and DMSP, ISS charging environments
  - DONKI



# Value of CCMC to NASA

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- The CCMC is an in-house NASA organization with flexibility to develop and implement experimental program specific space weather applications tailored to NASA needs
- NASA spacecraft operations and space environment engineering teams will continue to rely on NOAA SWPC real time space weather products (e.g., GOES, ACE/DSCOVR) and NOAA NGDC historical data records (e.g., GOES, POES, DMSP)
- NOAA SWPC and CCMC provide complementary services with different approaches
  - SWPC: official US space weather reporting authority, incorporation of new tools and modification of infrastructure is necessarily conservative and slow to change
  - CCMC: experimental and educational emphasis allows for rapid incorporation of new low TRL tools and models for testing, rapid support to NASA needs



# Value of CCMC to NESC

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- NASA's Engineering and Safety Center (NESC) is an independent technical authority in NASA reporting to the Office of the Chief Engineer
- CCMC personnel experienced in space physics research and space weather monitoring are a valuable resource for NESC technical assessment activities related to space environments and effects
  - Y. Zheng member of NESC team evaluating space weather launch constraint options for upcoming NASA mission
  - A. Pulkkinen leading development of NESC proposal for space weather architecture study
- CCMC runs-on-request and instant-run models are useful for space environment engineering community to obtain quick results from sophisticated space science models in support of technical analyses
- Future NESC technical assessments are likely to generate effects tools and other products that will be of interest to the space weather community, these will be provided to GSFC where appropriate to incorporate into the CCMC products



# Floating Potential Measurement Unit (FPMU)

MSFC/EV44 Natural Environments Branch

Ne, Te, ISS frame potential measurements used for:

- ISS EVA plasma hazard environments and vehicle charging
- Plasma interactions with ISS high voltage (160 V) solar arrays
- Anomaly investigations
- Collaborations with ISS science payloads
- Auroral charging, space weather studies
- Equatorial F2-region plasma instabilities
- CTIPe, GAIM, IFM, and IRI ionospheric model validation
- Incoherent Scatter Radar World Days
- High latitude ion troughs
- Conjugate photoelectron heating

FPP

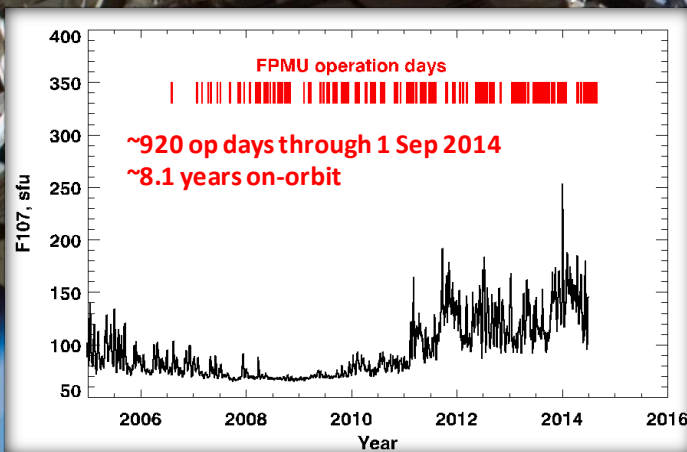
NLP

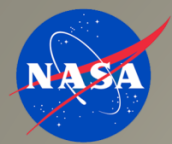
PIP

WLP

Electronics box

TV Camera  
Interface  
Controller



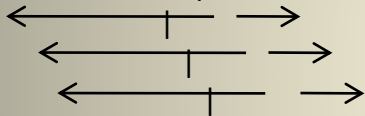


# CCMC Real-time Ionosphere Ne, Te for ISS

## 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

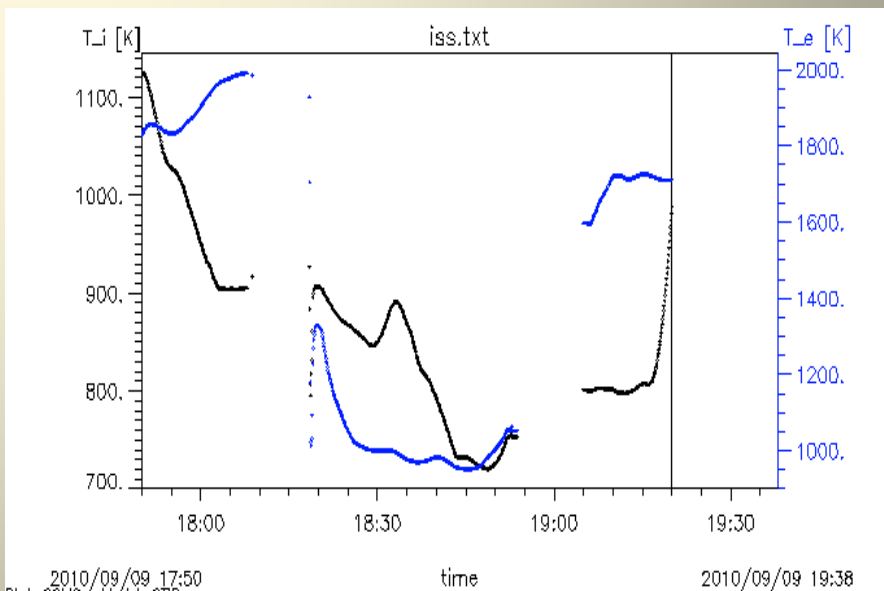
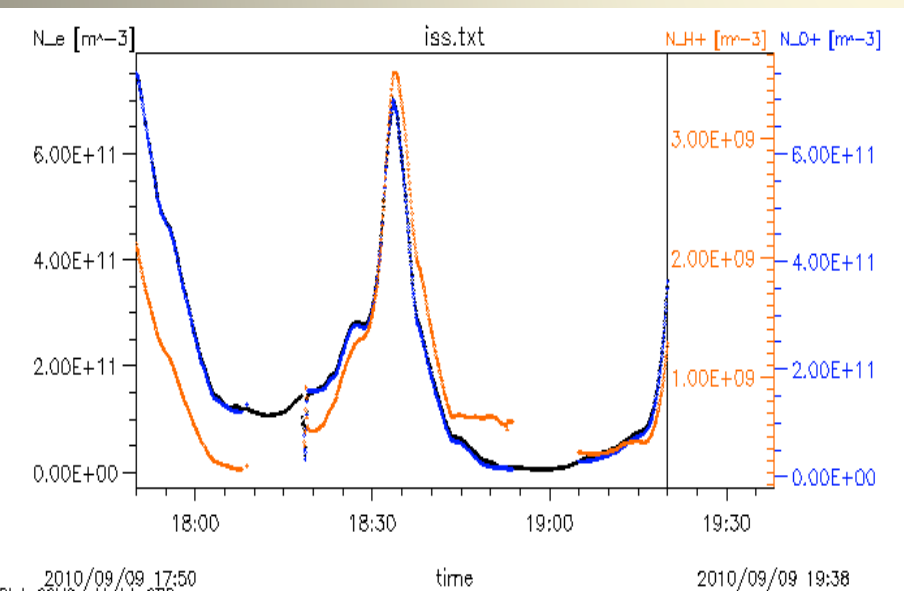
-70 min from file epoch to +20 min

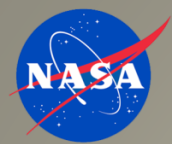


```

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.

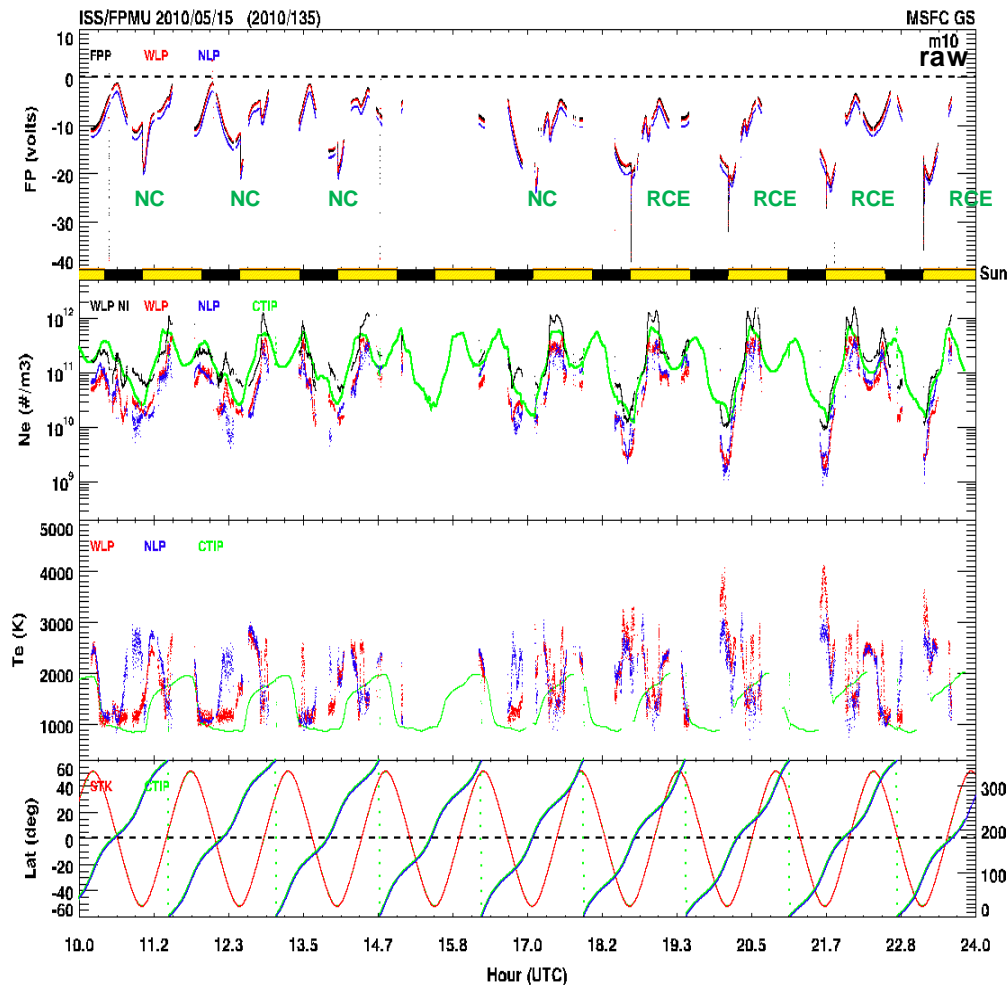
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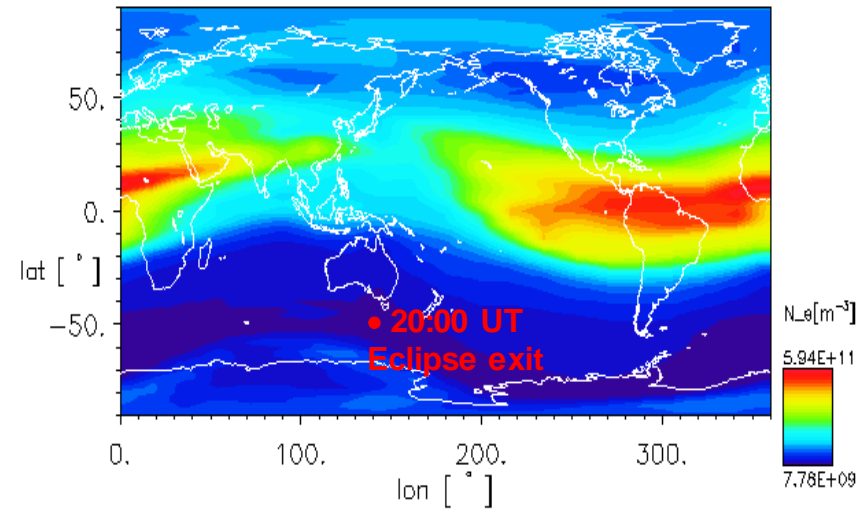


# Characterizing High Latitude Charging Environment

- ISS environments teams are investigating variations in physics of eclipse exit charging
- 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



06/15/2010 Time = 20:00:00 UT H= 360.km



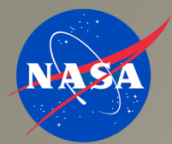
## 10-17 UT Eclipse Exit

Normal charging (NC) events observed at eclipse exit

## 17 - 24 UT Eclipse Exit

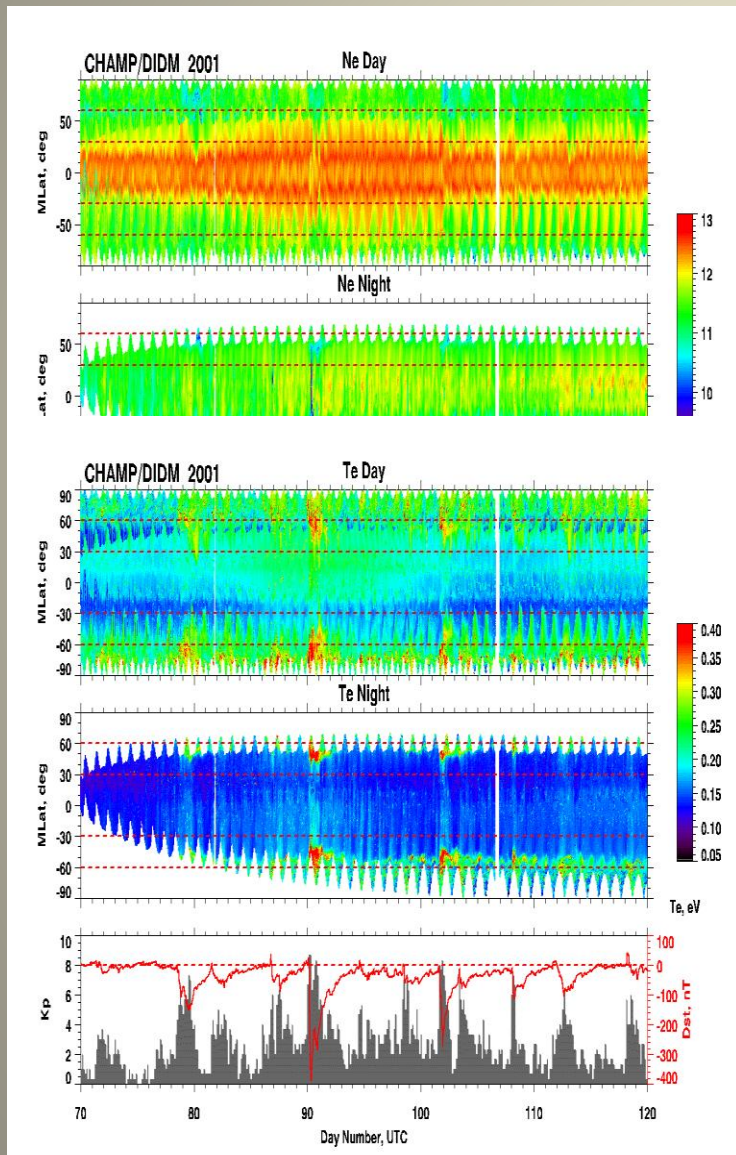
Rapid charging (RC) events observed when eclipse exit occurs in low density plasma troughs



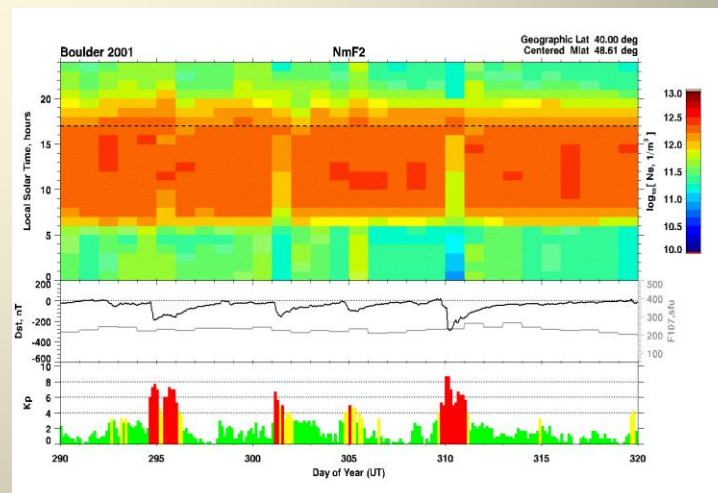
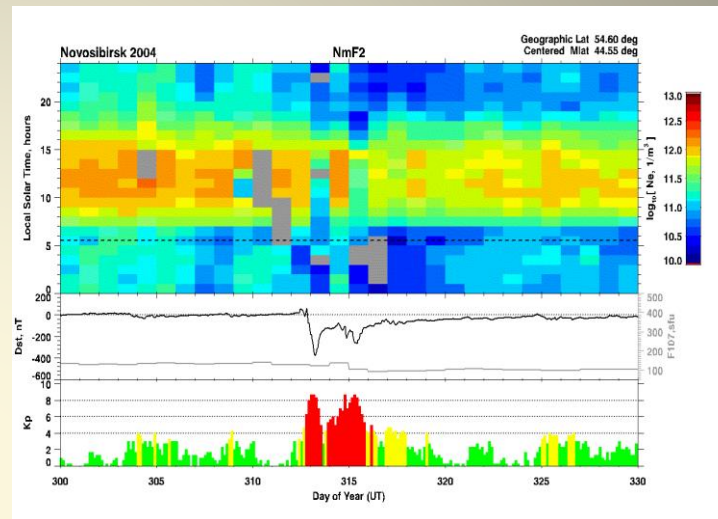


# Storm Effects on F2 Plasma Ne, Te

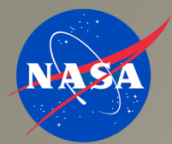
CHAMP DIDM ~400 km, 70 deg



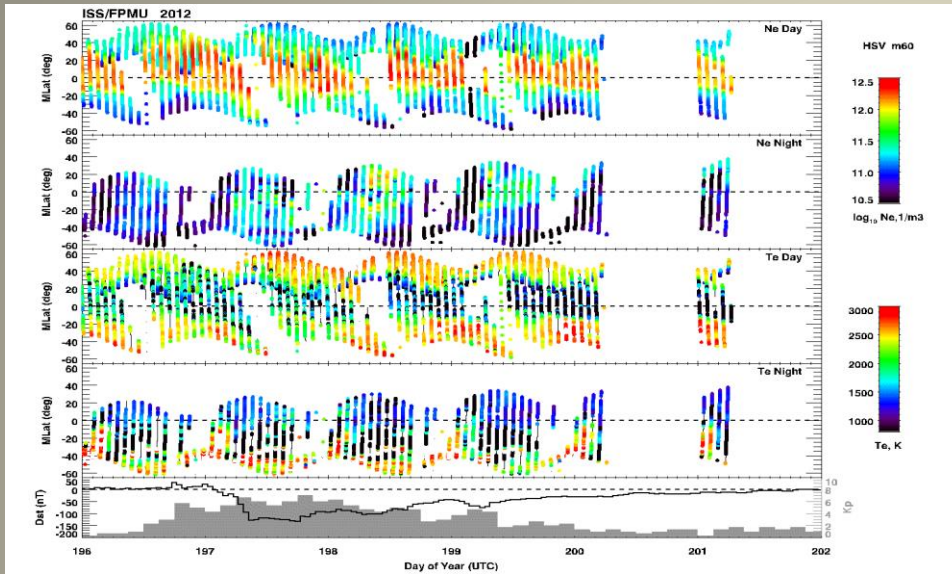
Ionosonde NmF2





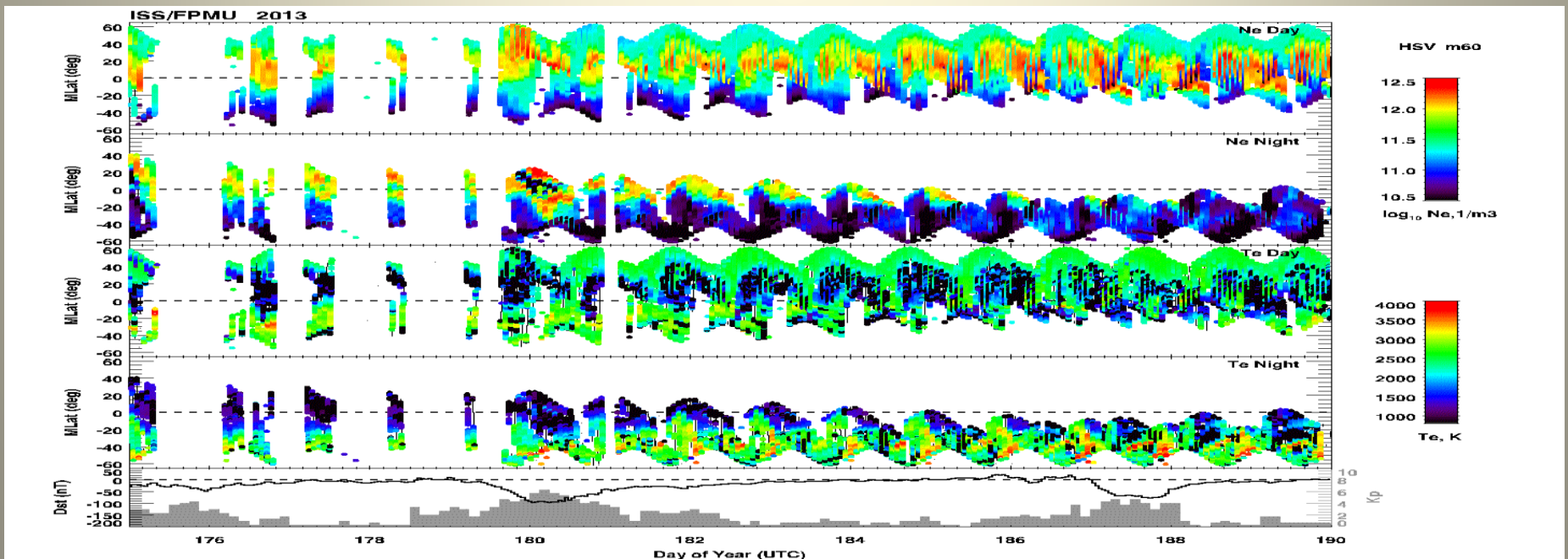


# Storm Impact on FPMU Ne, Te



- Storm effects not so clear in FPMU records.....

- Plan to use CCMC CTIPe results along ISS trajectory to help understand the FPMU results





# ISS Auroral Charging Periods

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## ISS Auroral Charging Periods

## FPMU Operations

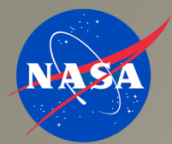
---

26 March 2008 (GMT 086)	STS-123/ESA ATV-001 docking
5-6 April 2010 (GMT 095-096)	STS-131/19A
22,23,25 January 2012 (GMT 025)	SWx: M8.7 flare, CME ~2211 km/s
9-11 March 2012 (GMT 069-071)	SWx: X5.4 flare, CME ~2200 km/s X1.3 flare, CME ~1800 km/s
23 May 2012 (GMT 144)	SpaceX Dragon berth/unberth
15-16 July 2012 (GMT 197-198)	SWx: X1.4 flare, CME ~1400 km/s
3 September 2012 (GMT 247)	US EVA 19
20 January 2013 (GMT 020)	Solar Cycle 24 Solar Maximum Conditions
17 March 2013 (GMT 076)	SWx: M1.1 flare, CME ~1400 km/s
28,29 June 2013 (GMT 179,180)	US EVA 22,23
7 November 2013 (GMT 311)	RS EVA 36
19 August 2014 (GMT 231)	SSU POR monitoring
27-29 August 2014 (GMT 239-341)	SSU POR monitoring
17-18 March 2015 (GMT 76,77)	SWx, C9.1 flare, CME ~750 km/s
10 April 2015 (GMT 100)	SWx: XX flare, CME ~917 km/s
23-23 April 2015 (GMT 173-174)	SWx: M2.0, M2.6, flare and CME ~1250 km/s

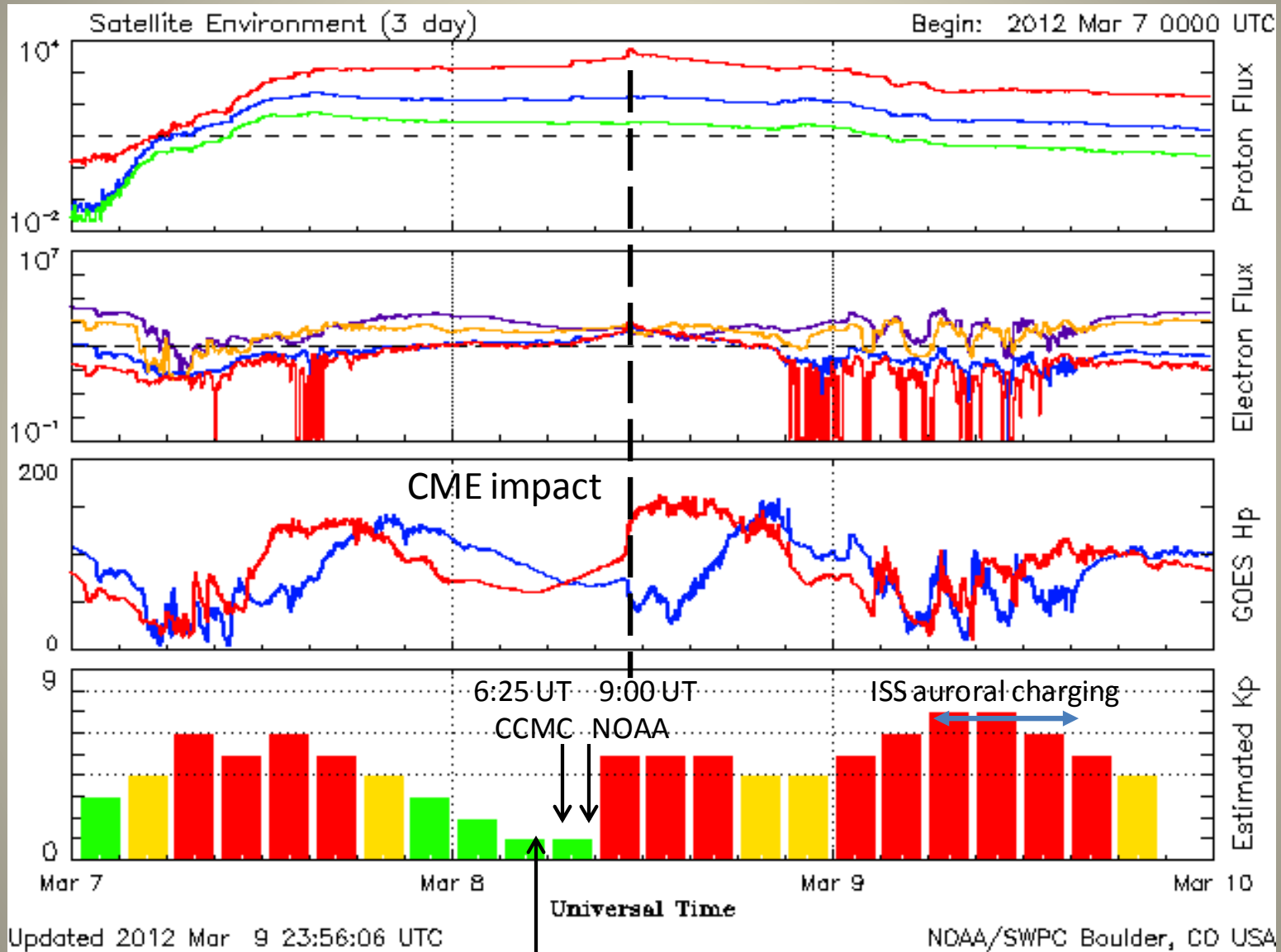
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ISS engineering activity support  
Space weather operations

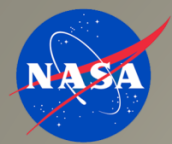




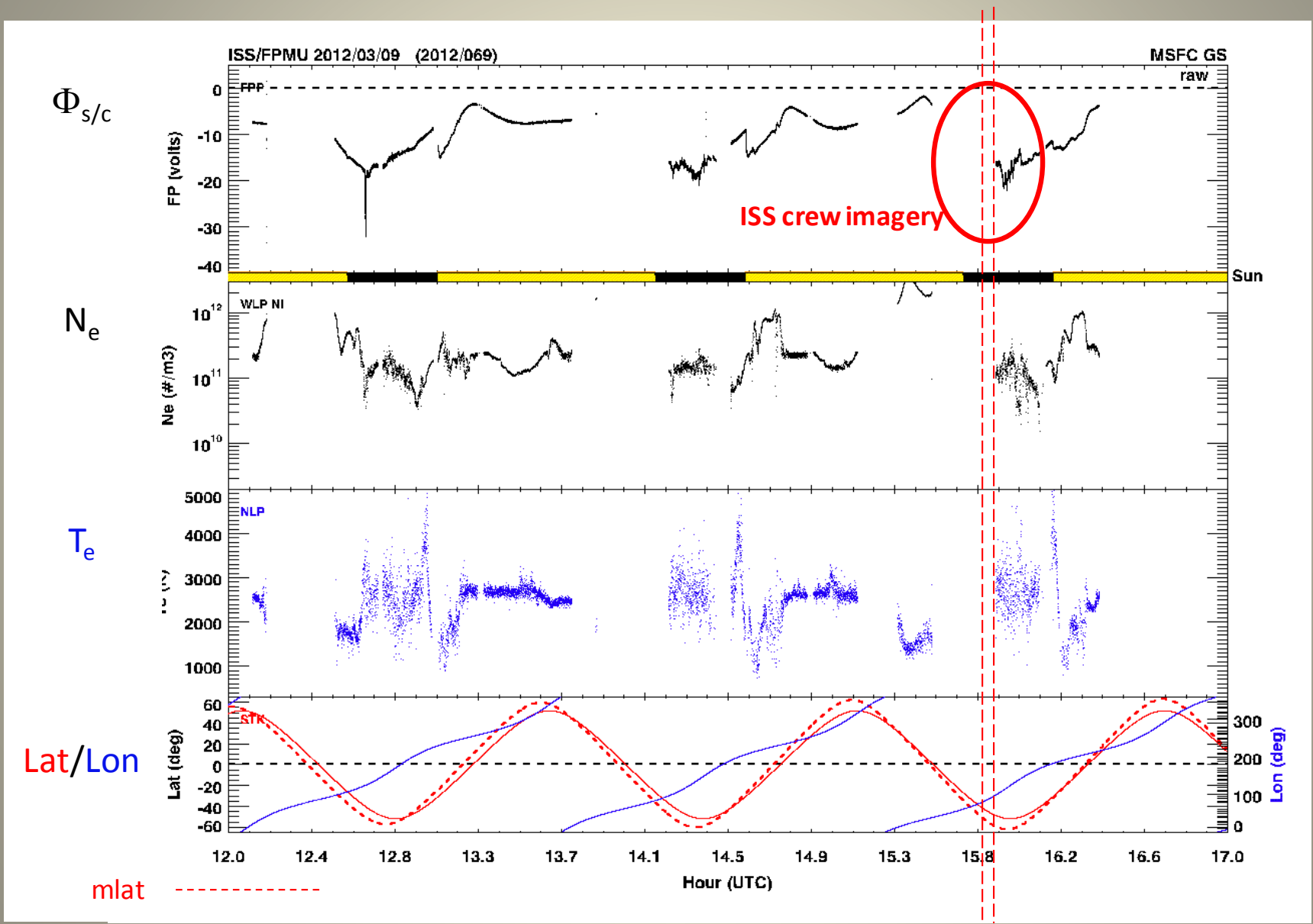
# March 2012 Geomagnetic Storm



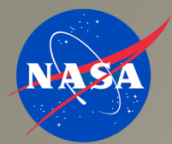
FPMU activated based on CME alerts



# 9 March 2012



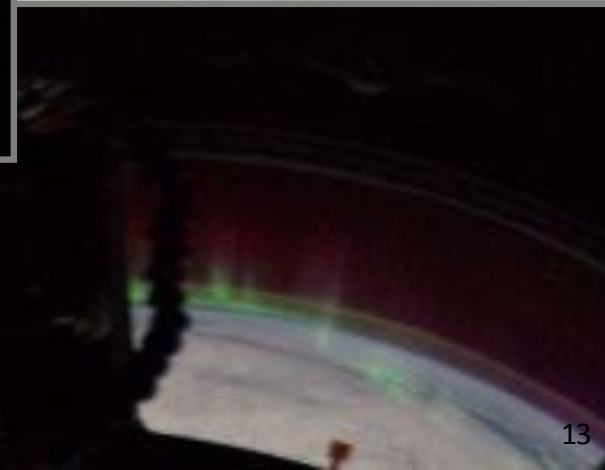


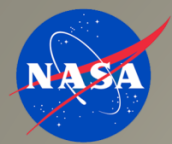


# Auroral Images

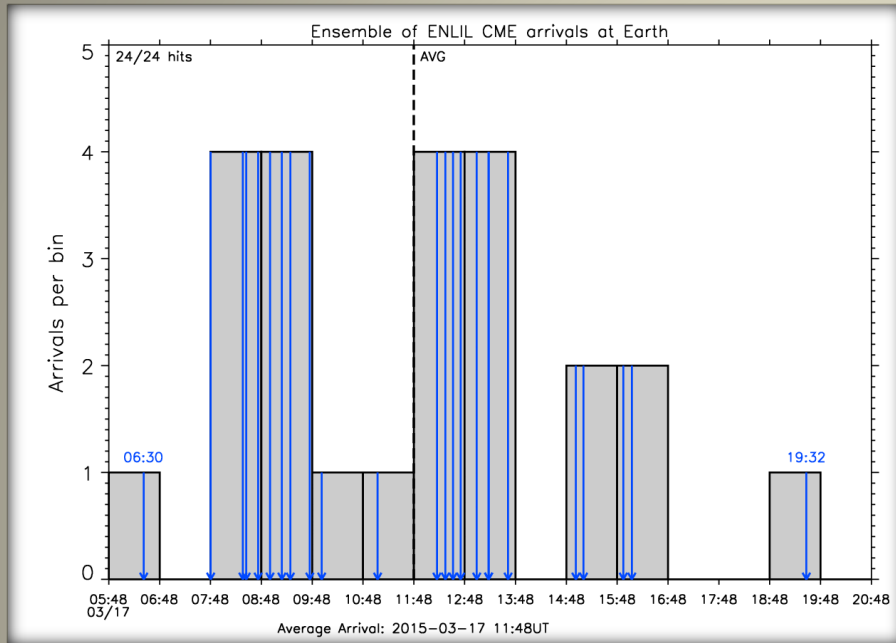
Aurora images using wide angle lens on digital camera through ISS Cupola (Don Pettit, Exp 30/31) show aurora in nadir and ahead of ISS immediately before FPMU records of auroral charging

Documents ISS passing through auroral arc!



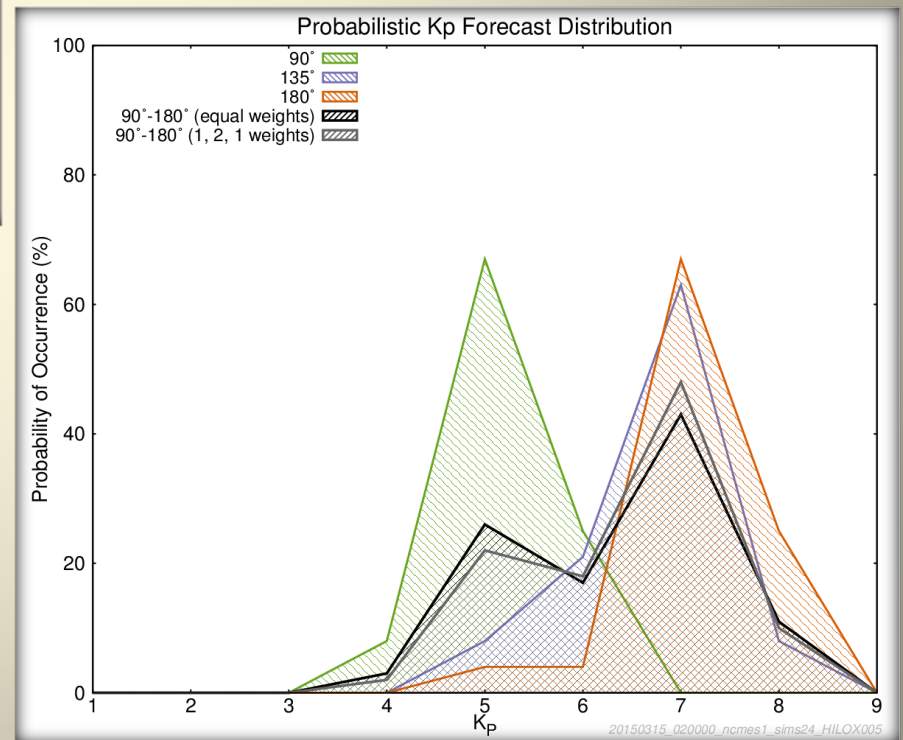


# CCMC Ensemble Products

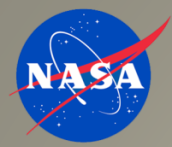


CME arrival at Earth

## Predicted Kp







# ISS Space Weather

- FPMU Ne, Te measurements obtained days to weeks in advance of an EVA are used in analysis of ESD threat to crew during EVA assuming persistent of conditions
- Space weather is monitored for Earth directed fast CME's that invalidate the environment assumptions if they exceed a speed threshold
- CCMC Earth directed CME alerts are now the primary source of CME initial speed data since SWRC is the only space weather monitoring organization regularly providing this information

```
## NASA Goddard Space Flight Center, Space Weather Research Center ( SWRC )
## Message Type: Space Weather Notification - CME (Missions Near Earth) ## ## Message Issue
Date: 2015-03-15T19:20:25Z
## Message ID: 20150315-AL-001
## ## Disclaimer: NOAA's Space Weather Prediction Center (http://swpc.noaa.gov) is the United
States Government official source for space weather forecasts. This "Experimental Research
Information" consists of preliminary NASA research products and should be interpreted and
used accordingly.
```

```
## Summary:
C-type CME detected by SOHO.
Start time of the event: 2015-03-15T02:00Z.
Estimated speed: ~750 km/s.
Estimated opening half-angle: 45 deg.
Direction (lon./lat.): 32/-12 in Heliocentric Earth Equatorial coordinates (see [1] in Notes).
```

Activity ID: 2015-03-15T02:00:00-CME-001

Based on preliminary heliospheric modeling carried out at NASA GSFC Space Weather Research Center, it is estimated that this CME may impact NASA missions near Earth. Simulations indicate that the leading edge of the CME will reach NASA missions near Earth at about 2015-03-17T11:39Z (plus minus 7 hours). The roughly estimated expected range of the maximum Kp index is 5-7 (minor to strong).

Links to the movies of the modeled event (includes CME(s): 2015-03-15T02:00:00-CME-001):

[http://iswa.gsfc.nasa.gov/downloads/20150315\\_064500\\_2.0\\_anim.tim-den.gif](http://iswa.gsfc.nasa.gov/downloads/20150315_064500_2.0_anim.tim-den.gif)  
[http://iswa.gsfc.nasa.gov/downloads/20150315\\_064500\\_2.0\\_anim.tim-vel.gif](http://iswa.gsfc.nasa.gov/downloads/20150315_064500_2.0_anim.tim-vel.gif)  
[http://iswa.gsfc.nasa.gov/downloads/20150315\\_064500\\_2.0\\_anim.tim-den-Stereo\\_A.gif](http://iswa.gsfc.nasa.gov/downloads/20150315_064500_2.0_anim.tim-den-Stereo_A.gif)  
[http://iswa.gsfc.nasa.gov/downloads/20150315\\_064500\\_2.0\\_anim.tim-den-Stereo\\_B.gif](http://iswa.gsfc.nasa.gov/downloads/20150315_064500_2.0_anim.tim-den-Stereo_B.gif)  
[http://iswa.gsfc.nasa.gov/downloads/20150315\\_064500\\_2.0\\_anim.tim-vel-Stereo\\_A.gif](http://iswa.gsfc.nasa.gov/downloads/20150315_064500_2.0_anim.tim-vel-Stereo_A.gif)  
[http://iswa.gsfc.nasa.gov/downloads/20150315\\_064500\\_2.0\\_anim.tim-vel-Stereo\\_B.gif](http://iswa.gsfc.nasa.gov/downloads/20150315_064500_2.0_anim.tim-vel-Stereo_B.gif)

## Notes:

This CME event (2015-03-15T02:00:00-CME-001) is associated with C9.1 flare with ID 2015-03-15T01:15:00-FLR-001 which peaked at 2015-03-15T02:13Z.

[1]

[http://iswawiki.gsfc.nasa.gov/wiki/index.php/Glossary/Heliospheric\\_Earth\\_Equatorial\\_coordinates](http://iswawiki.gsfc.nasa.gov/wiki/index.php/Glossary/Heliospheric_Earth_Equatorial_coordinates)

SCORE CME typification system:

S-type: CMEs with speeds less than 500 km/s

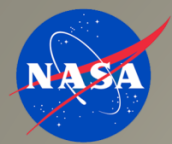
C-type: Common 500-999 km/s

O-type: Occasional 1000-1999 km/s

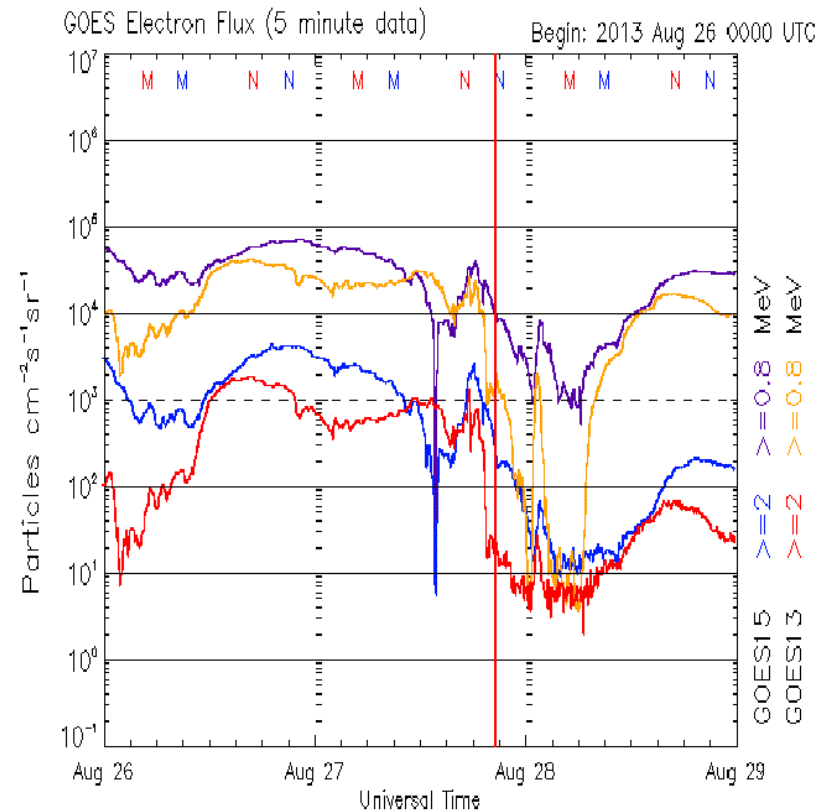
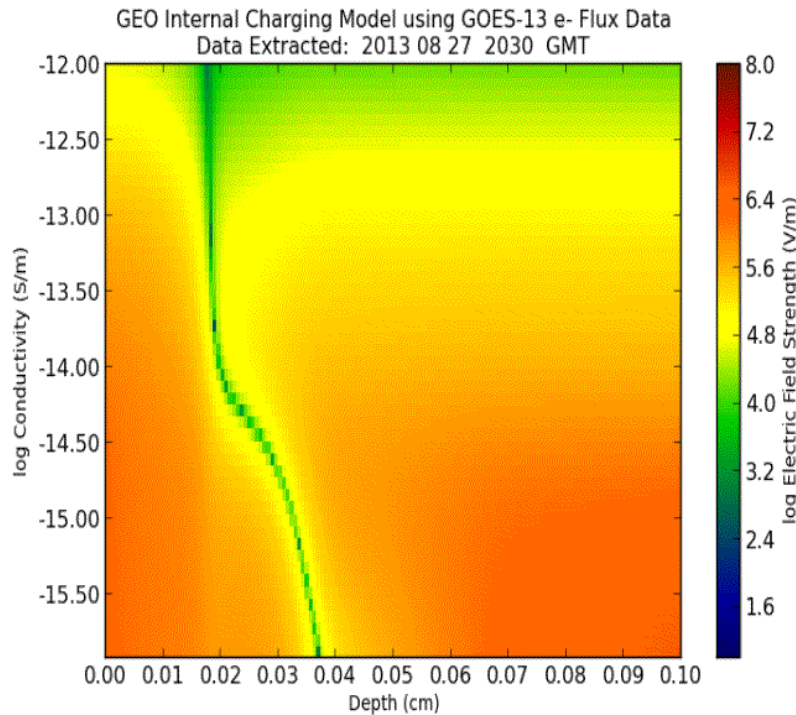
R-type: Rare 2000-2999 km/s

ER-type: Extremely Rare >3000 km/s

<http://swrc.gsfc.nasa.gov/main/score>



# Real-time GEO Internal Charging Tool

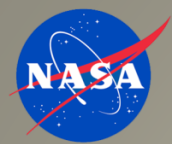


Updated 2013 Aug 28 23:56:03 UTC

NOAA/SWPC Boulder, CO USA

Current: GOES  $>0.8$  MeV,  $>2.0$  MeV electrons

Future: GOES  $>4.0$  MeV, 30-50 keV, 50-100 keV, 100-200 keV, 200-350 keV, 350 – 600 keV



# 10 April 2015 Equatorial Plasma Depletions

F18 Disk - 2015/100

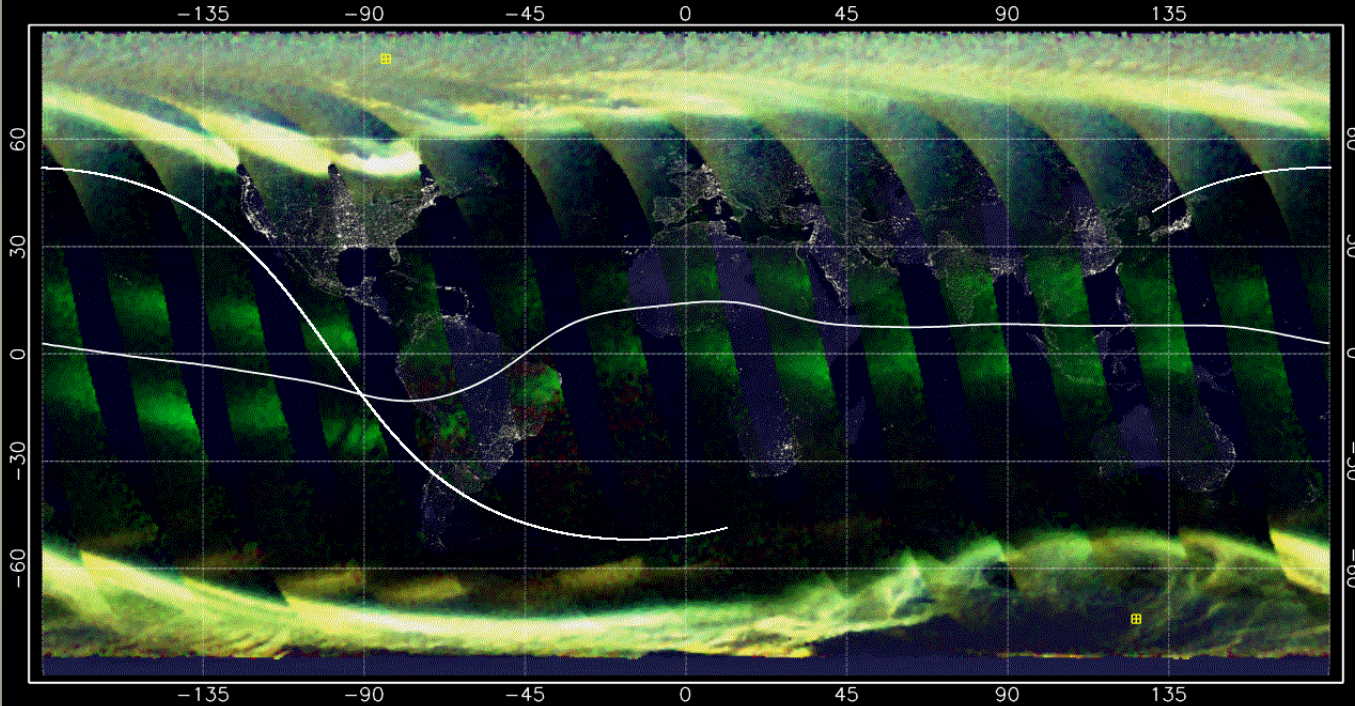
Orbits 28229-28243

SSUSI JHU/APL

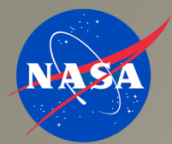
OI 1304 (blue, 4207 R max (data), 5000 R max (color scale))

OI 1356 (green, 2137 R max (data), 400 R max (color scale))

LBH short (red, 2420 R max (data), 1000 R max (color scale))







# 10 April 2015 Equatorial Plasma Depletions

F18 Disk - 2015/100

Orbits 28229-28243

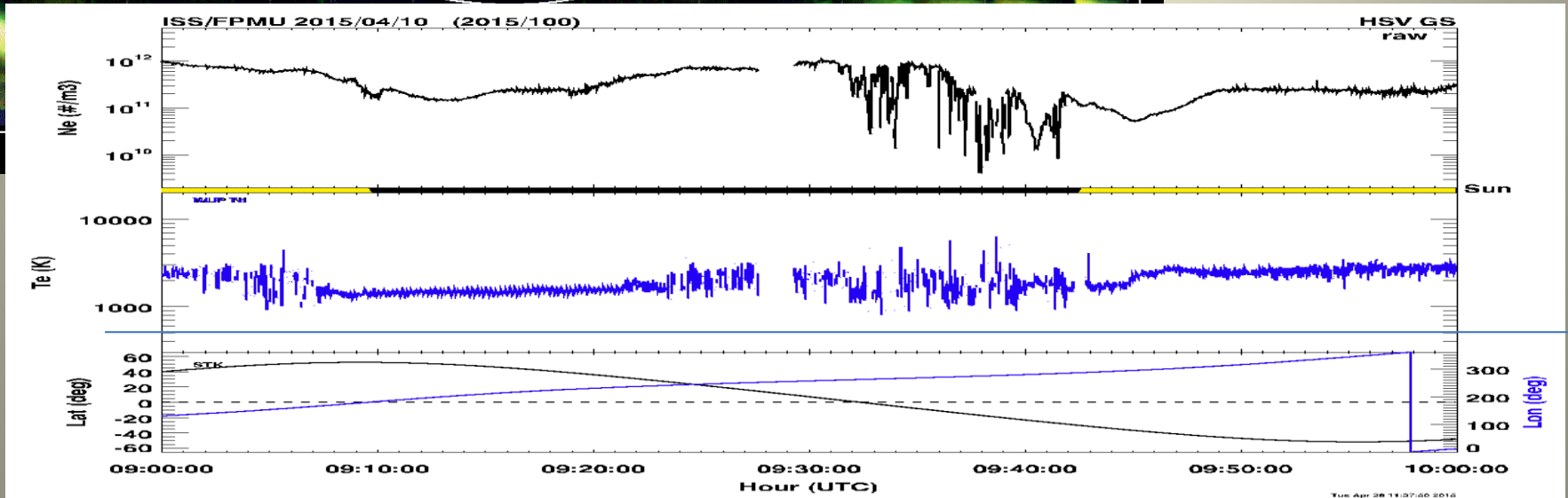
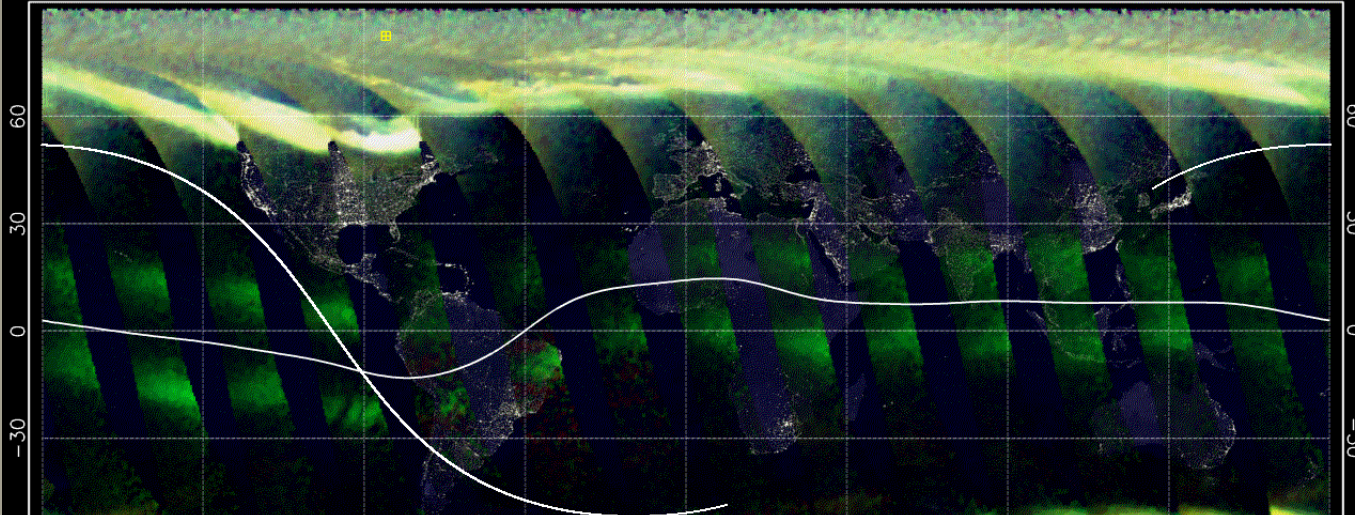
SSUSI JHU/APL

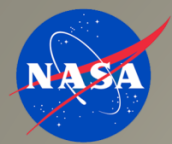
OI 1304 (blue, 4207 R max (data), 5000 R max (color scale))

OI 1356 (green, 2137 R max (data), 400 R max (color scale))

LBH short (red, 2420 R max (data), 1000 R max (color scale))

-135 -90 -45 0 45 90 135



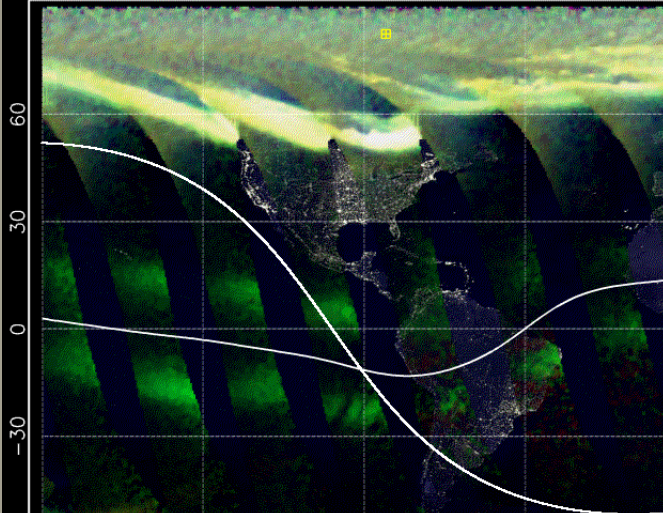


# 10 April 2015 Equatorial Plasma Depletions

F18 Disk - 2015/100  
Orbits 28229-28243

SSUSI JHU/APL

-135 -90 -45

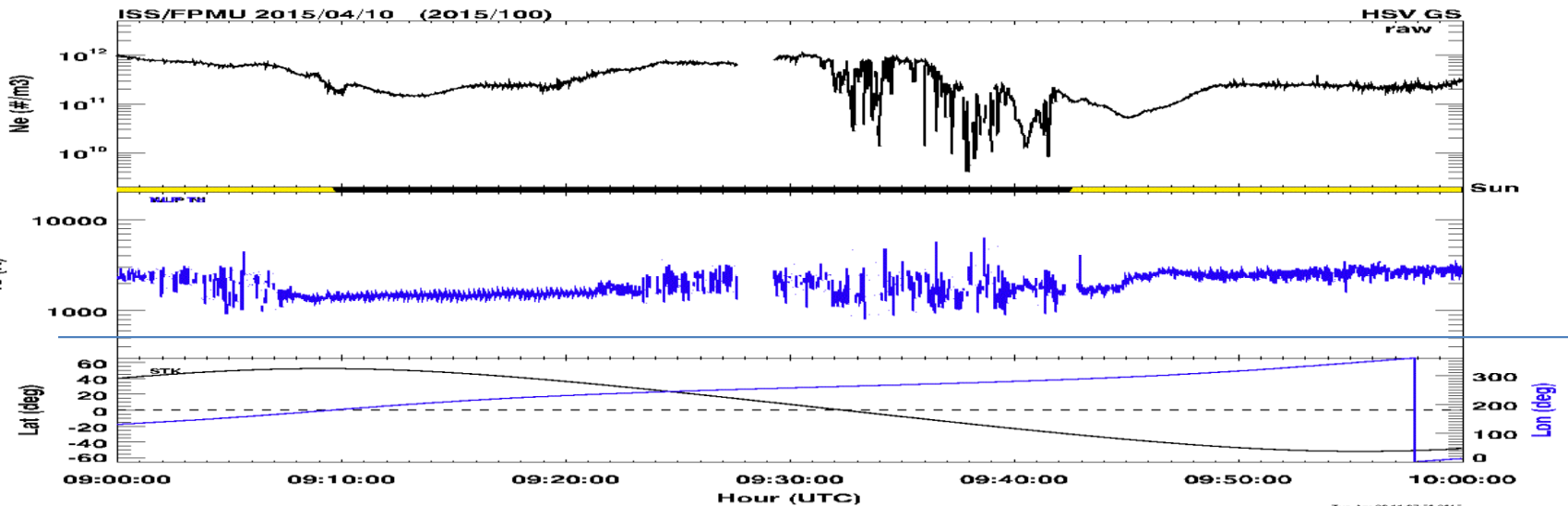
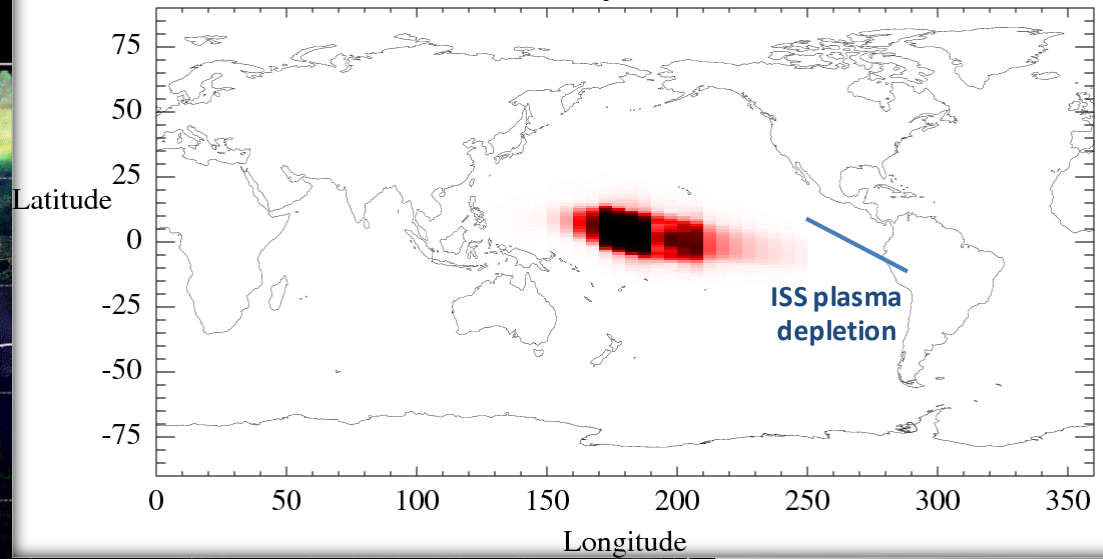


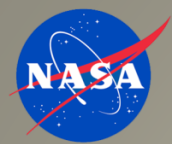
iSWA PBMOD

S4

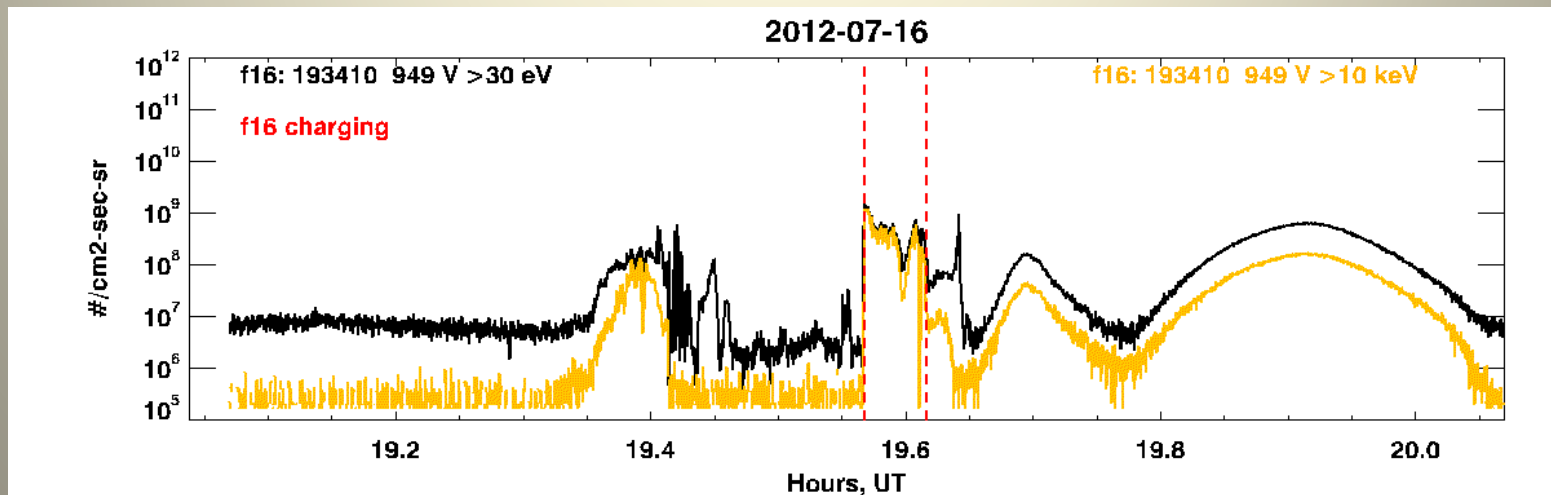
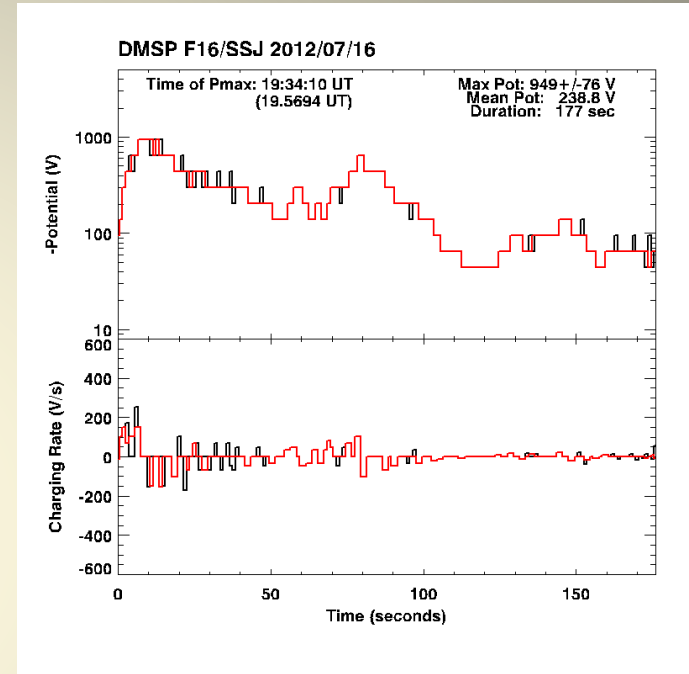
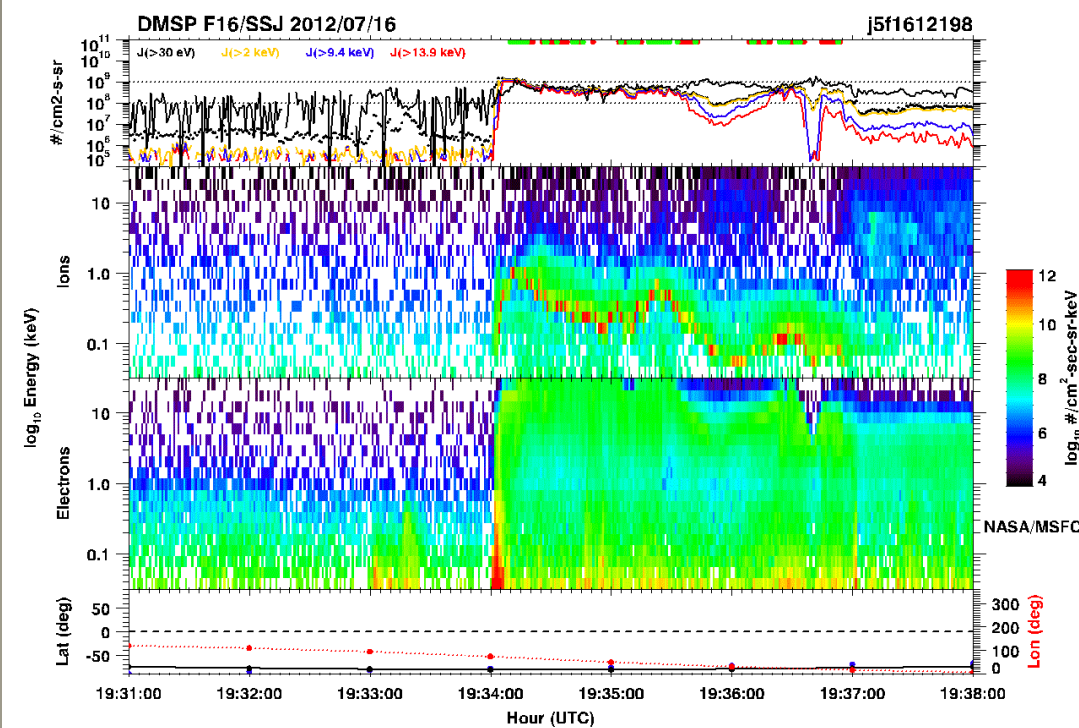
0 0.2 0.4 0.6 0.8

PBf20150410 mjd: 57122 UT: 9.75

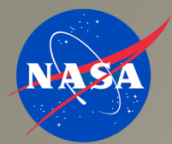




# Auroral Flux Models, Charging Environments







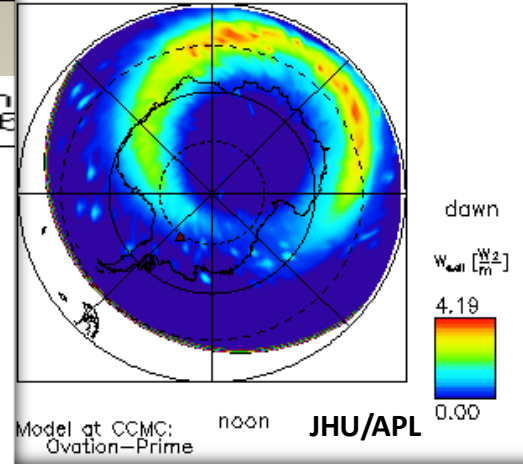
# CCMC Ovation Prime

CCMC: Lutz Rastaettner

07/16/2012 Time = 19:36:00

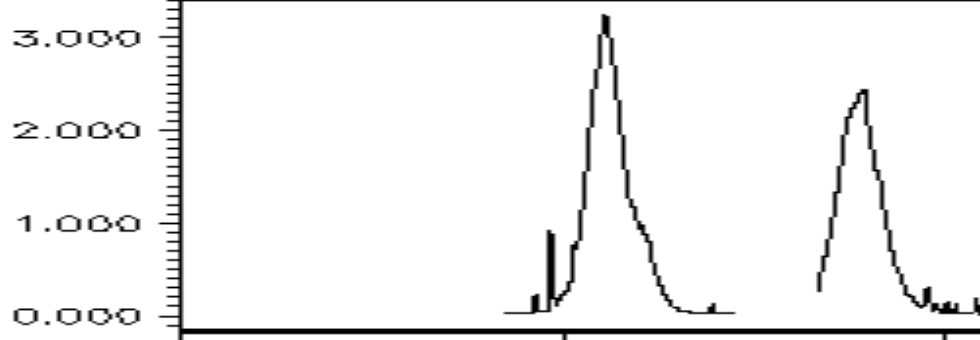
Southern Hemisphere

▲ DMSP-16



dmspf16 Start date, time  
07/16/2012 Time = 19:06

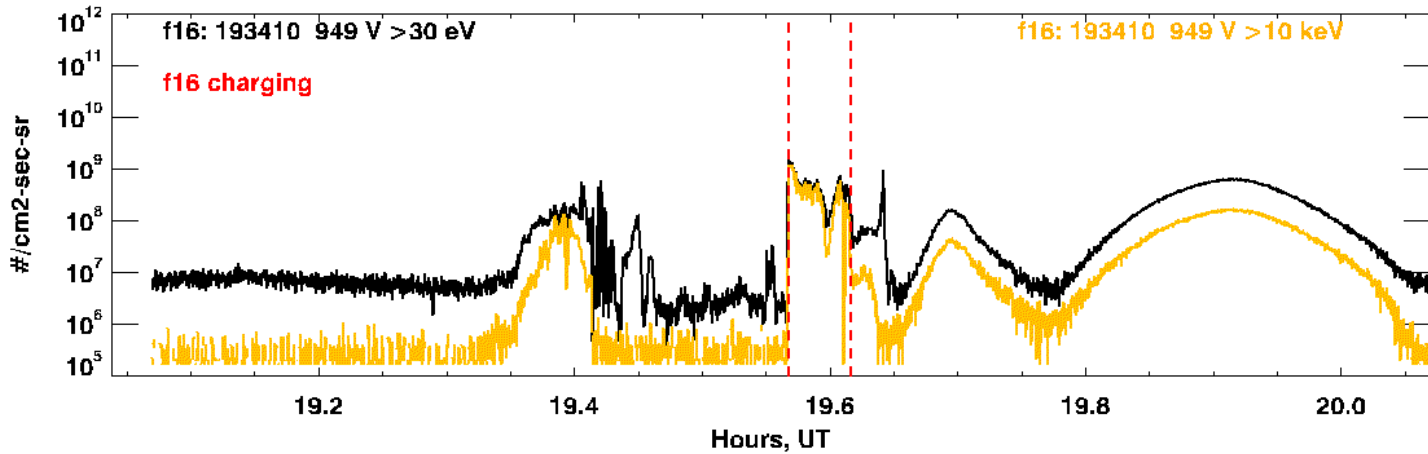
$W_{e,all} \left[ \frac{W}{m^2} \right]$

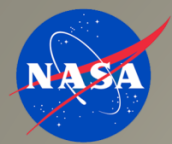


Time [d:h:m:s]	19:06:00	19:24:00	19:42:00	20:00:00
	85.6	149.8	146.2	82.3
	268.9	267.1	92.0	89.5
	1.017	1.017	1.017	1.017

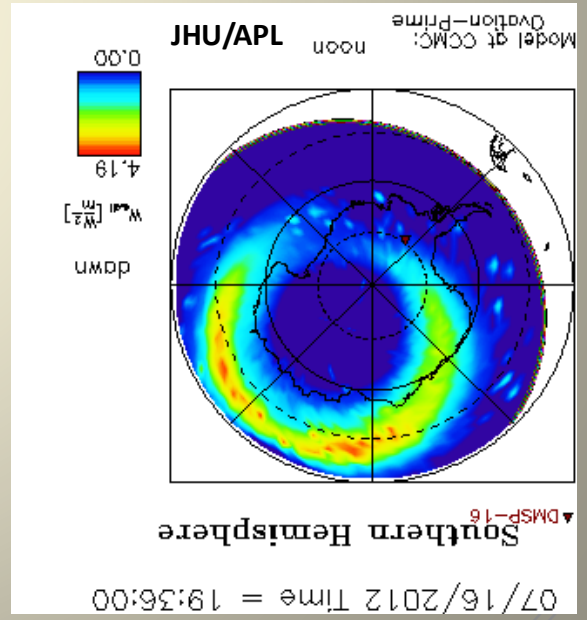
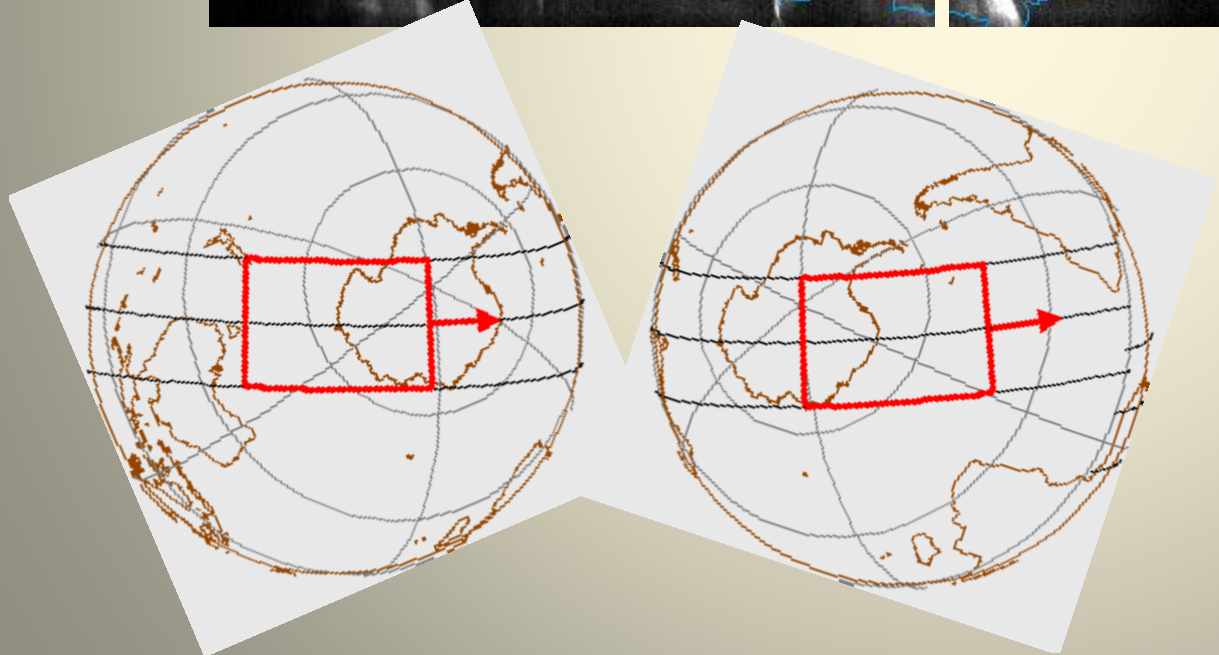
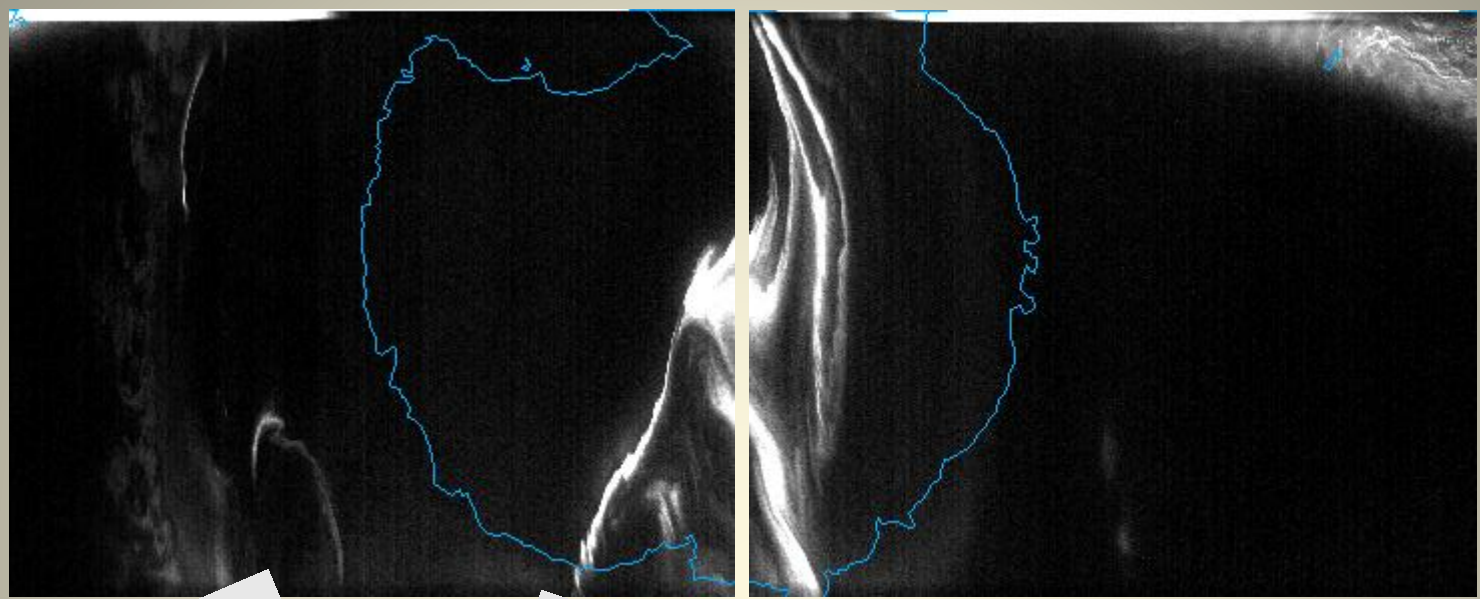
Model at CCMC: Ovation-Prime

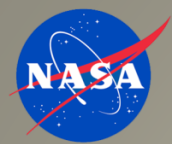
2012-07-16



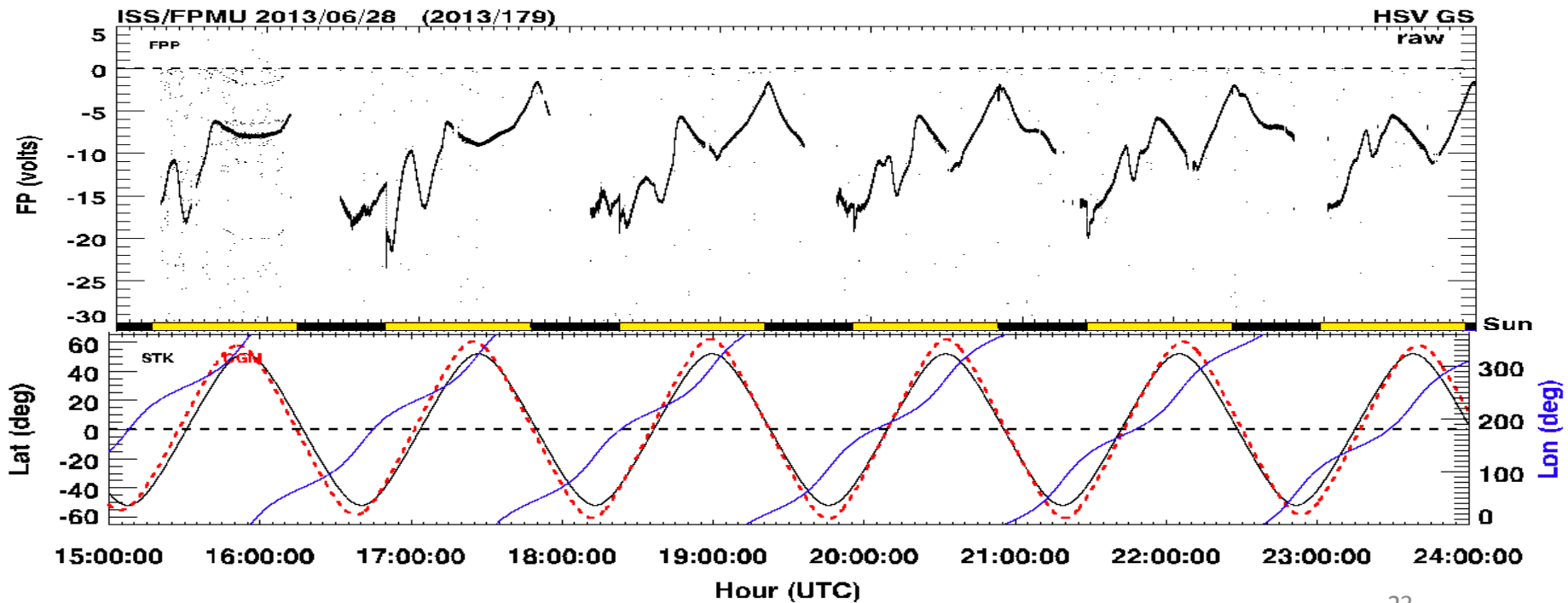
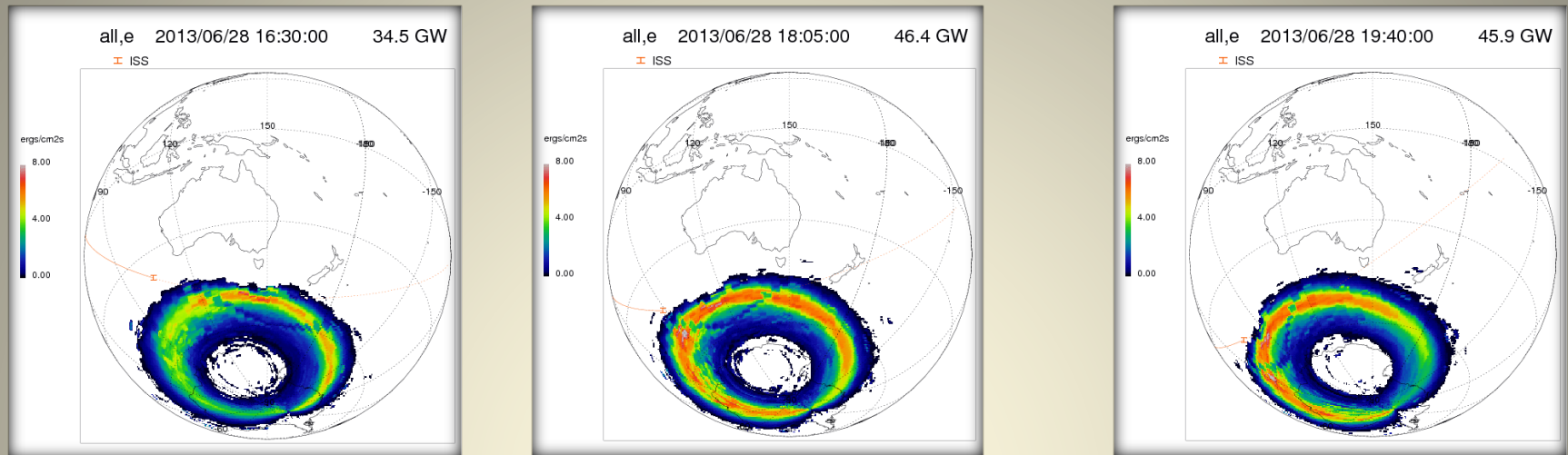


# DMSP Operational Linescan System (OLS)





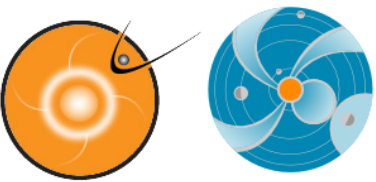
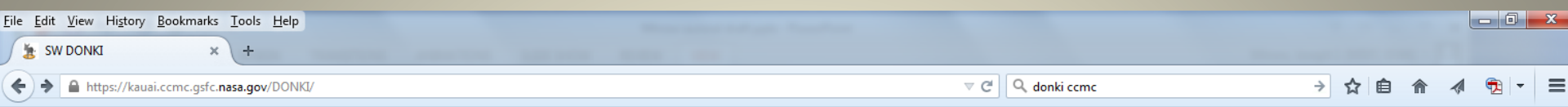
# iSWA Ovation Prime, ISS Charging







# CCMC DONKI



## Space Weather Database Of Notifications, Knowledge, Information (DONKI)

- Go to:
- [DONKI Home](#)
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  - [Search Space Weather Activity](#)
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Space Weather Database Of Notification, Knowledge, Information (DONKI) (developed at the Community Coordinated Modeling Center, [CCMC](#)) is a comprehensive on-line tool for space weather forecasters, scientists, and the general space weather community.

DONKI provides:

- Chronicles the daily interpretations of space weather observations, analysis, models, forecasts, and notifications provided by the Space Weather Research Center ([SWRC](#)).
- Comprehensive knowledge-base search functionality to support anomaly resolution and space science research.
- Intelligent linkages, relationships, cause-and-effects between space weather activities.

DONKI Goals:

- One-stop on-line tool for space weather forecasters.
- Gathers and organizes space weather scientists interpretations and daily activities with correlations and direct links between relevant space weather observations.
- Enables remote participation by students, world-wide partners, model and forecasting technique developers.

Using DONKI (see menu on the left):

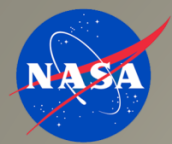
- Anyone can [search/view](#) data already stored on DONKI.
- Registered Users can make comments on any SW Activity.
- Power Users can [enter data](#) into DONKI (Click [here](#) to request power user privileges).

### [Important Disclaimer Notice](#)

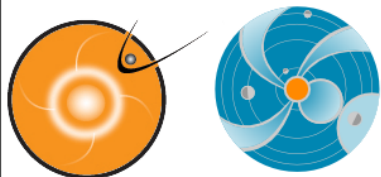
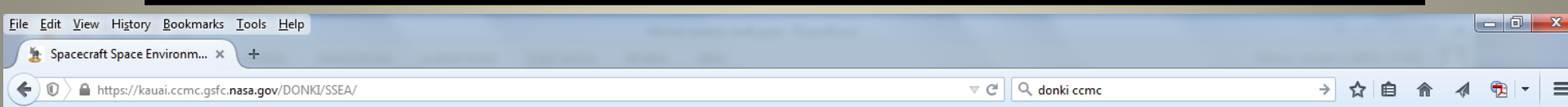
If you are looking for the official U.S. Government forecast for space weather, please go to NOAA's Space Weather Prediction Center (<http://swpc.noaa.gov>). This "Experimental Research Information" consists of preliminary NASA research products and should be interpreted and used accordingly.

NASA Official: Maria Kuznetsova

<http://kauai.ccmc.gsfc.nasa.gov/DONKI/>



# Space Environment Effect and Anomalies Archive



## Space Weather Database Of Notifications, Knowledge, Information (DONKI)

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### Space Environment Effect and Anomalies Archive

click on the link below to generate/search reports in the archive

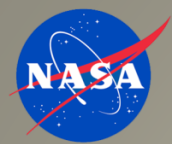
- [Report Space Environment Effect](#)
- [Report Spacecraft Anomaly](#)
- [Search Archive](#)



#### [Important Disclaimer Notice](#)

If you are looking for the official U.S. Government forecast for space weather, please go to NOAA's Space Weather Prediction Center (<http://swpc.noaa.gov>). This "Experimental Research Information" consists of preliminary NASA research products and should be interpreted and used accordingly.

NASA Official: Maria Kuznetsova

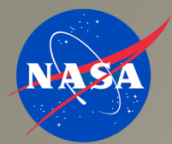


# CCMC SEEA

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- [Logout](#)
  - [Edit Personal Profile](#)
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<a href="#">Activity ID</a>	<a href="#">Project Name</a>	<a href="#">System</a>	<a href="#">Effect Time in UT</a>	<a href="#">Orbit Type</a>	<a href="#">Effect Type</a>	<a href="#">Effect Description</a>
<a href="#">2012-02-27T03:24:00-CHANDRA-RAD-001</a>	CHANDRA	instrument	2012-02-27T03:24:00Z	Elliptical	radiation event	2012/058: Chandra X-Ray Observatory (CXO) Advanced CCD Imaging Spectrometer (ACIS) instrument radiation intervention. Science observations interrupted 27 Feb at 03:24 UTC to 27 Feb 20:23 UTC (16.9 hours) by a manual event due to ACE P3' (soft) particle signature.
<a href="#">2012-03-07T05:30:00-CHANDRA-RAD-001</a>	CHANDRA	instrument	2012-03-07T05:30:00Z	Elliptical	radiation event	2012/067: Chandra X-Ray Observatory (CXO) Advanced CCD Imaging Spectrometer (ACIS) instrument radiation intervention. Science observations interrupted 7 Mar at 05:30 UTC to 13 Mar 05:14 UTC (122.2 hours) by an auto event due to HRC (hard) particle signature.
<a href="#">2012-03-09T12:00:00-ISS-CHRG-001</a>	ISS	vehicle	2012-03-09T12:00:00Z	Inclined	spacecraft charging	2012/069: ISS auroral frame charging observed at high southern latitudes in period 12:00 UTC to 16:30 UTC. Maximum frame potentials ~-6 to 14 V. Kp=5.7 to 6.7 at times of significant charging. Charging levels from ISS Floating Potential Measurement Unit.
<a href="#">2012-03-10T10:00:00-ISS-CHRG-001</a>	ISS	vehicle	2012-03-10T10:00:00Z	Inclined	spacecraft charging	2012/070: Possible ISS auroral frame charging at high southern latitudes in period 10:00 UTC to 14:00 UTC. Maximum frame potentials ~1 to 2 V. Kp=2.0 to 2.7 at times of significant charging. Charging levels from ISS Floating Potential Measurement Unit. (Note: Additional verification required due to low Kp.)
<a href="#">2012-03-13T22:41:00-CHANDRA-RAD-001</a>	CHANDRA	instrument	2012-03-13T22:41:00Z	Elliptical	radiation event	2012/073: Chandra X-Ray Observatory (CXO) Advanced CCD Imaging Spectrometer (ACIS) instrument radiation intervention. Science observations interrupted 13 Mar at 22:41 UTC to 14 Mar 13:57 UTC (14.8 hours) by an auto event due to HRC (hard) particle signature.
<a href="#">2012-05-17T02:18:00-CHANDRA-RAD-001</a>	CHANDRA	instrument	2012-05-17T02:18:00Z	Elliptical	radiation event	2012/138: Chandra X-Ray Observatory (CXO) Advanced CCD Imaging Spectrometer (ACIS) instrument radiation intervention. Science observations interrupted 17 May at 02:18 UTC to 18 May 04:52 UTC (26.1 hours) by an auto event due to E1300 (hard) particle signature.
<a href="#">2012-07-12T19:59:00-CHANDRA-RAD-001</a>	CHANDRA	instrument	2012-07-12T19:59:00Z	Elliptical	radiation event	2012/194: Chandra X-Ray Observatory (CXO) Advanced CCD Imaging Spectrometer (ACIS) instrument radiation intervention. Science observations interrupted 12 Jul at 19:59 UTC to 14 Jul 00:09 UTC (17.1 hours) by an auto event due to E1300 (hard) particle signature.
<a href="#">2012-07-14T21:08:00-CHANDRA-RAD-001</a>	CHANDRA	instrument	2012-07-14T21:08:00Z	Elliptical	radiation event	2012/196: Chandra X-Ray Observatory (CXO) Advanced CCD Imaging Spectrometer (ACIS) instrument radiation intervention. Science observations interrupted 14 Jul at 21:08 UTC to 16 Jul 05:16 UTC (22.3 hours) by an auto event due to E1300 (hard) particle signature.





# Space Environment Effect Report

File Edit View History Bookmarks Tools Help

View Space Weather Activity x +

https://kauai.ccmc.gsfc.nasa.gov/DONKI/view/SEffectReport/6829/1 donki ccmc

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**Space Environment Effect Report**

Activity ID: 2012-03-09T12:00:00-ISS-CHRG-001  
 Project/Spacecraft Name: International Space Station  
 System: vehicle  
 Orbit Type: Inclined  
 Effect Time (UTC): 2012-03-09T12:00:00Z  
 Effect Time (MLT):  
 Effect Type: spacecraft charging  
 Location Info: LON=None Entered LAT=None Entered ALT=None Entered (undefined)  
 Effect Duration: None Entered  
 Effect Magnitude: undefined  
 Allow Public Access: false  
 Description:

2012/069: ISS auroral frame charging observed at high southern latitudes in period 12:00 UTC to 16:30 UTC. Maximum frame potentials ~6 to 14 V. Kp=5.7 to 6.7 at times of significant charging. Charging levels from ISS Floating Potential Measurement Unit.

Image file: [FPMU summary data](#)

*Submitted on 2014-09-30T19:42Z by Joseph Minow*

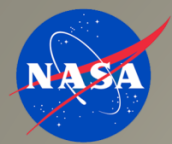
[Edit This SE Effect Report](#)

[Add Related Space Weather Activity](#)

**All directly linked activities:**

<a href="#">2012-03-09T03:00:00-GST-001</a>	
NOAA Kp: 7 (2012-03-09T06:00Z)	<a href="#">DELETE</a>
NOAA Kp: 6 (2012-03-09T12:00Z)	

Post a Comment:



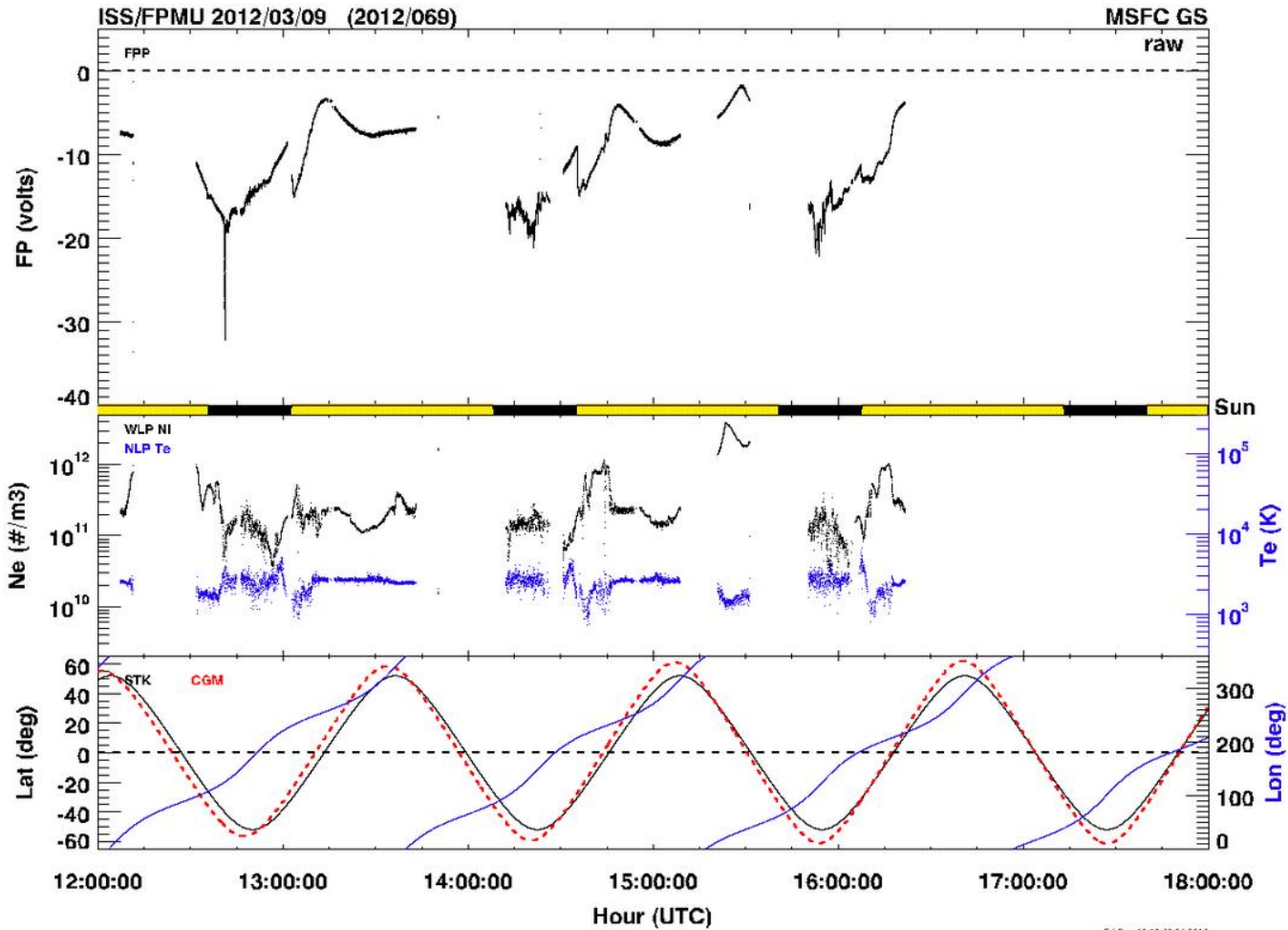
# Space Environment Effect Report

File Edit View History Bookmarks Tools Help

AS\_2012\_069\_1200\_1800.png (P... x +

https://kauai.ccmc.gsfc.nasa.gov/DONKI/resources/images/protected/AS\_2012\_069\_1200\_1800.png

donki ccmc





# Questions?

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