U.S. NAVAL RESEARCH LABORATORY

The Effect of Atmospheric O and H on the Plasmasphere

Jonathan Krall (NRL), GEM/CEDAR, June 20, 2016

Credits: Joe Huba (NRL), SAMI3 ionosphere/plasmasphere code

Sarah McDonald, P.I., "Counting Electrons" (NASA/HSR)

Session conveners: Alan Burns (UCAR)
Sarah McDonald (NRL)
John Emmert (NRL)
Fabrizio Sassi (NRL)

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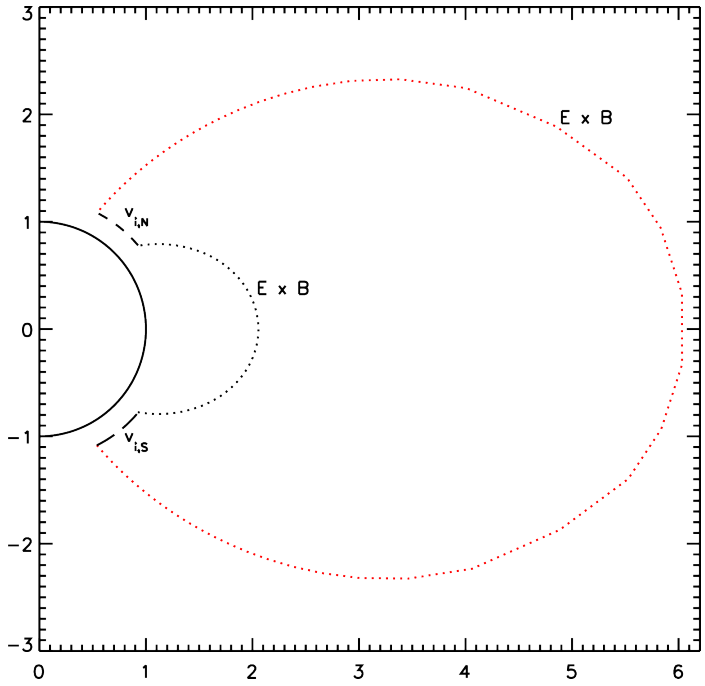
A challenge

The plasmasphere is "eroded" during a geomagnetic storm. Afterwards, it "refills."

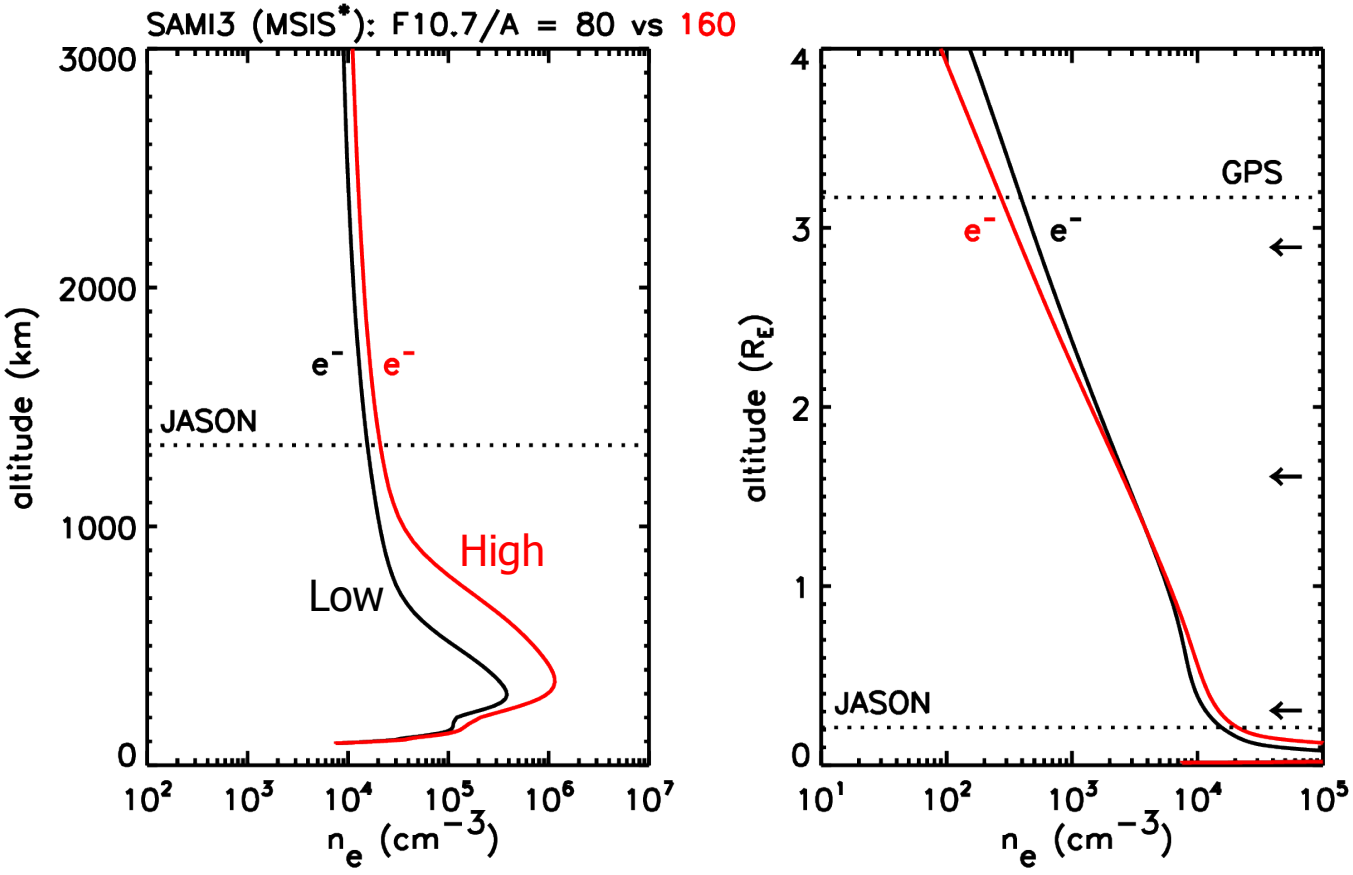
The refilling rate is observed to decrease with increasing solar activity.

The challenge: Can SAMI3 simulations reproduce this result in agreement with observations?



Observed/simulated refilling: Krall et al., 2016, JGR
SAMI3: Huba and Krall, 2013, GRL

Profile at low and high solar activity (MSIS*)



Source of H^+: $O^+ + H \leftrightarrow O + H^+$

Modifications to MSIS oxygen density

In order to obtain agreement with refilling rates (and pTEC) we modified the NRLMSISE-00 atmosphere by reducing atomic oxygen density

$$n_O = 0.7\, n_{O,\,MSIS}$$

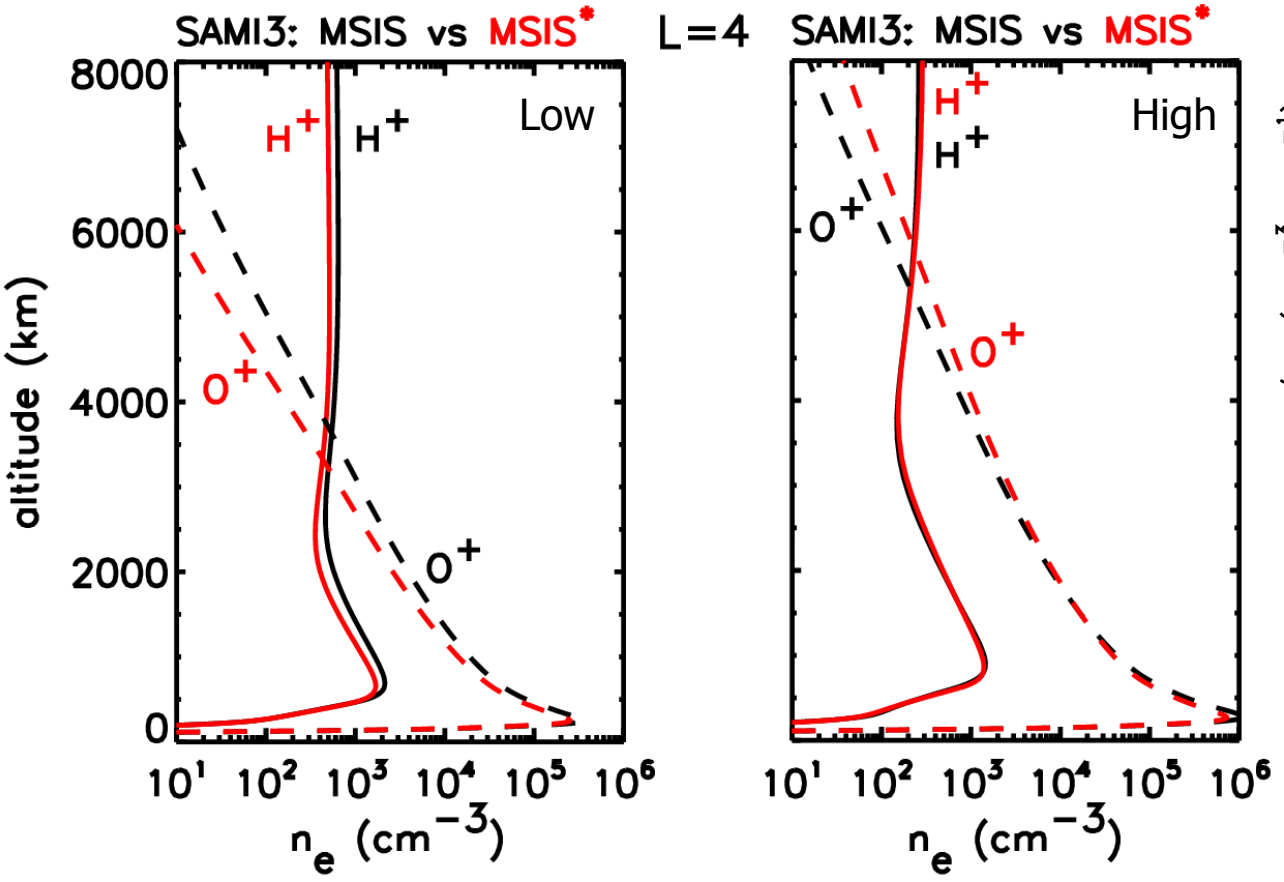
and by forcing the density to fall off faster with height above 600 km (in the exosphere)

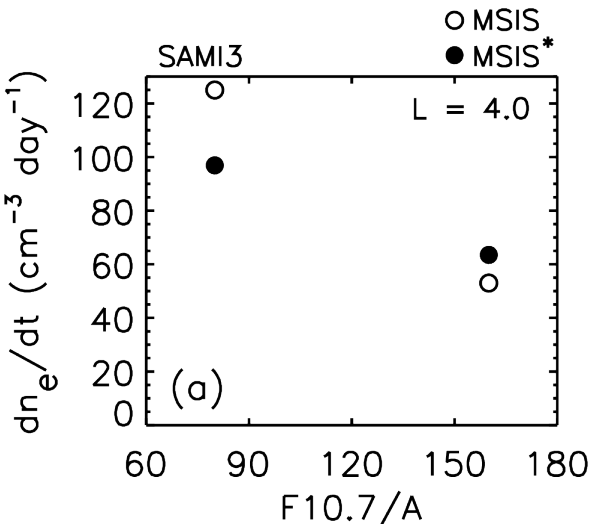
$$T_{O,exo} = 0.8\, T_{O,\,MSIS}$$

$$n_{O,\,exo} = n_{600}\left[n_{O,\,MSIS}/n_{600}\right]^{1.25}$$

(In Krall et al., 2016, JGR, $n_O = 0.8\, n_{O,\,MSIS}$ instead of 0.7)

Affect of the modified atmosphere





Refilling rate increases with topside H^+ density

Low solar activity: more O leads to more O^+

High activity: O acts as a barrier to O^+ (less O, more O^+)

Is our modified atmosphere realistic?

NRL PPD

An overall density reduction by 0.7 or 0.8 is realistic.

The overall temperature reduction isn't in the data.

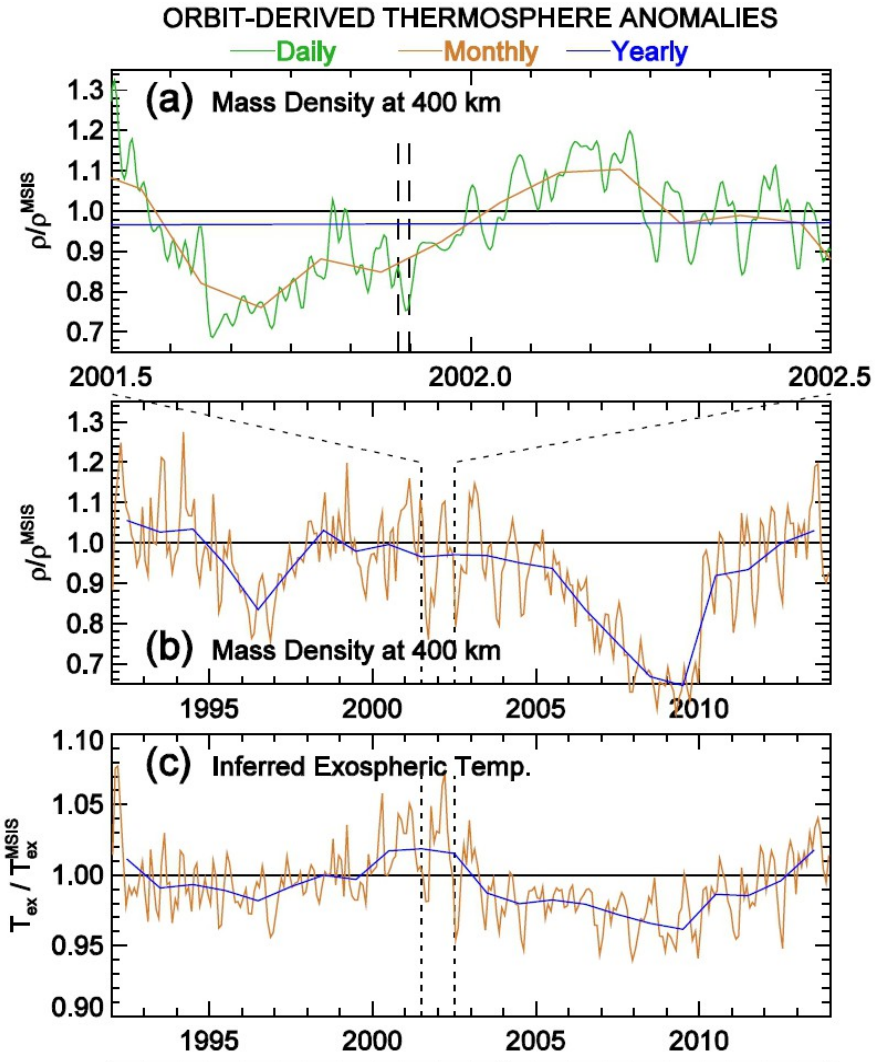
This "temperature" effect can come from the Burnside Factor

$$\nu_{\mathrm{O-O^+}} = F_B 2.4 \times 10^{-11} n_{\mathrm{O}} T_r^{1/2}$$

SAMI3: $F_B = 1.3$

Salah [1993]: $F_B = 1.7$

Here: $F_B = 0.7$



Emmert et al., 2014 JGR

Discussion

Refilling rates are sensitive to the O density.

O (and probably H) densities vary on a time scale of days.

Deviations from empirical models can be significant.

We need a better model exosphere, where atoms go ballistic.

We need an experiment to determine the Burnside factor.

What about H? Preliminary results show that doubling the MSIS H density nearly doubles the refilling rate.

References

Emmert, J. T., S. E. McDonald, D. P. Drob, R. R. Meier, J. L. Lean, and J. M. Picone (2014), Attribution of interminima changes in the global thermosphere and ionosphere, JGR, doi:407 10.1002/2013JA019484

Huba, J. D., and J. Krall (2013), Modeling the plasmasphere with SAMI3, GRL, doi:10.1029/2012GL054300

Krall, J., J. D. Huba, V. K. Jordanova, R. E. Denton, T. Carranza, and M. B. Moldwin (2016), Measurement and modeling of the refilling plasmasphere during 2001, JGR, doi:10.1002/2015JA022126

Krall, J., J.T. Emmert, F. Sassi, S.E. McDonald, and J.D. Huba, Day-to-day variability in the thermosphere and its impact on plasmasphere refilling, JGR, in press

Krall, J. and J. D. Huba, The plasmasphere electron content paradox, submitted to JGR

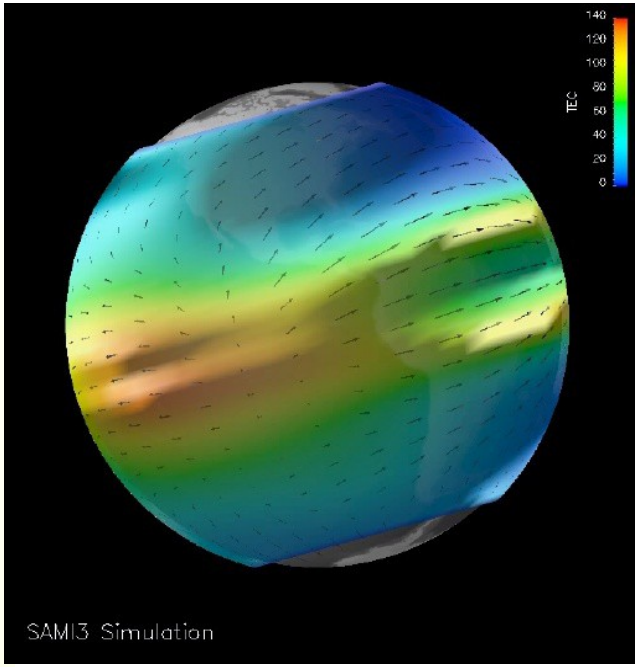
Extra slides

NRL PPD

NRL SAMI3 Ionosphere/Plasmasphere Model

NRL PPD

- Magnetic field: ~~IGRF-like~~ Non-tilted dipole
- Interhemispheric
- Nonorthogonal, nonuniform fixed grid
- Seven (7) ion species (all ions are equal): H^+, He^+, N^+, O^+, N_2^+, NO^+, and O_2^+
  - Solve continuity and momentum for all 7 species
  - Solve temperature for H^+, He^+, O^+, and e^-
- Plasma motion
  - $\mathbf{E} \times \mathbf{B}$ drift perpendicular to $\mathbf{B}$
  - Ion inertia included parallel to $\mathbf{B}$
- Neutral species: NRLMSISE00 and ~~HWM93~~ HWM14
- Chemistry: 21 reactions + recombination
- Photoionization: Daytime (EUVAC) and nighttime



SAMI3 is coupled to a magnetosphere potential model and a thermosphere model.

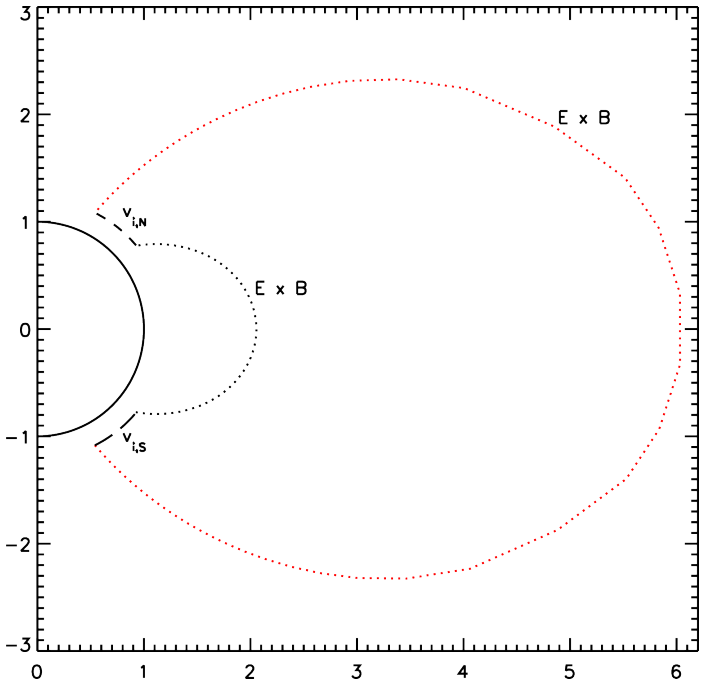
[Huba et al., JGR, 2000; Huba and Joyce, GRL, 2010; Huba and Krall, GRL, 2013]

A challenge

The challenge: Can SAMI3 simulations reproduce...

1. … the observed decrease in the rate of post-storm plasmasphere refilling with increasing solar activity?

2. … the observed increase in the plasmasphere contribution to "total electron content" (pTEC) in increasing solar activity?



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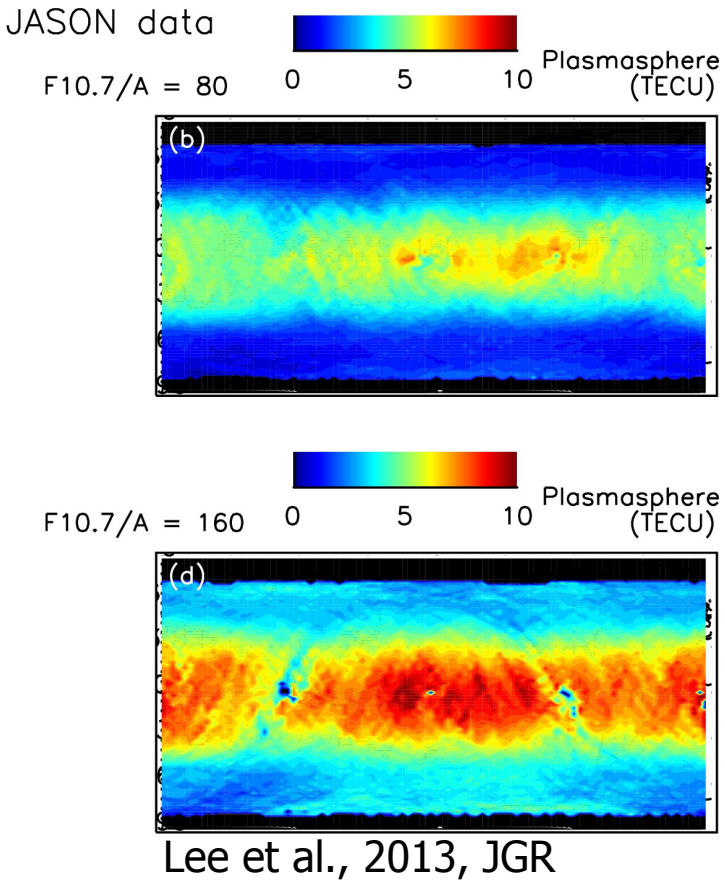
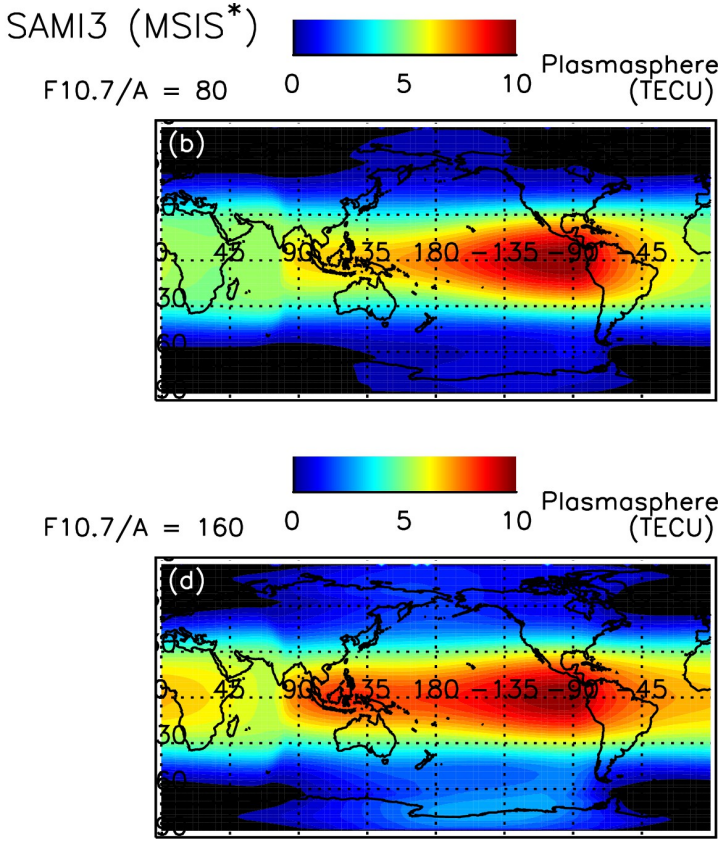
SAMI3: Huba and Krall, 2013, GRL

pTEC increases with solar activity.



Lee et al., 2013, JGR

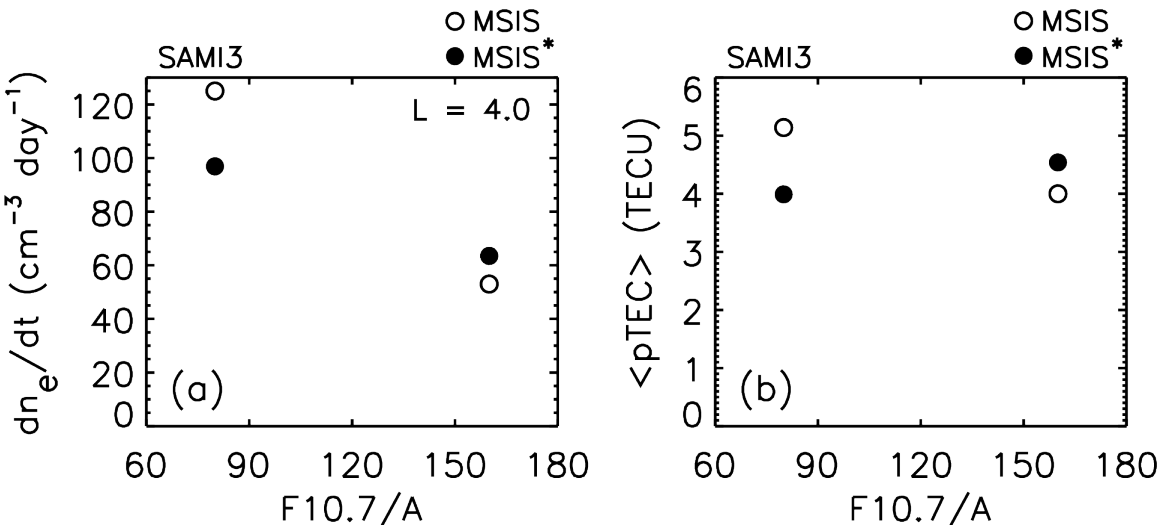


TEC is vertically-integrated density.

1 TECU = $10^{16}/m^2$

pTEC, is TEC contribution between JASON altitude (1340 km) and GPS altitude (20,200 km), increases with solar activity. Measured pTEC result based on data from 2002-2009.

Discussion



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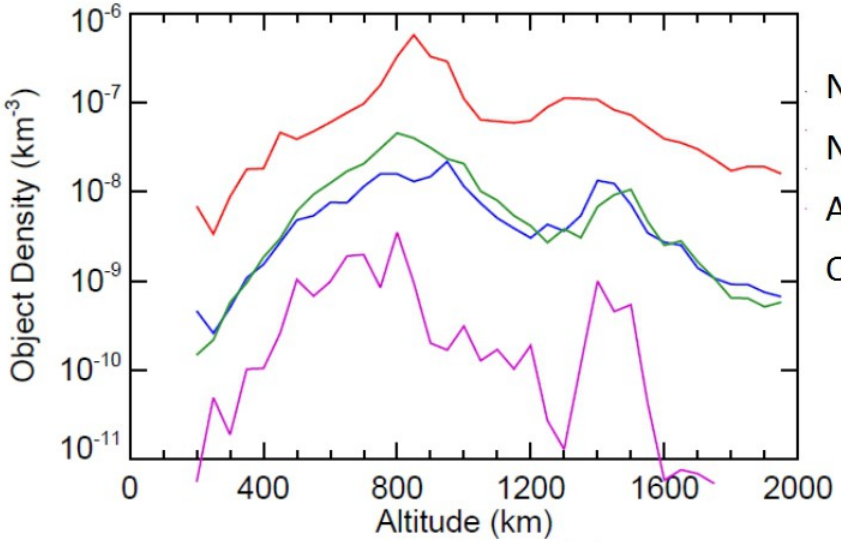
Satellite Drag in the Exosphere

Debris Density



NASA Debris Model, > 1 cm (~110,000)

NASA Debris Model, > 10 cm (~7,500)

Air Force Catalog (~11,500)

Operational Satellites (~500)

Atmosphere Mass Fraction