Stormtime ring current heating of the plasmasphere and ionosphere

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November 22, 2022

Abstract

The energy deposition from ring current ions into the high density "cold" plasma of the ionosphere and plasmasphere is analyzed, based on a Comprehensive Inner Magnetosphere-Ionosphere (CIMI) simulation of the 2015 October 7 storm. In this re-examination of ring current heating generating the observed O$ˆ+$ shell in the outer plasmasphere [1], the Naval Research Laboratory (NRL) Sami3 is Also a Model of the Ionosphere (SAMI3) ionosphere/plasmasphere code [2] is used to simulate the effect of ring current heating on the ionosphere. We find that energy is deposited at altitudes as low as 100 km. We show that heating along the entirety of any given field line, both in the ionosphere and plasmasphere, contributes to the heating effect and subsequent cold O$ˆ+$ outflows. We further show that, relative to the heating of the plasmasphere, the direct heating of the ionosphere by ring current ions produces only a small contribution to the thermal O$ˆ+$ outflow that forms the O$ˆ+$ shell. [1] Krall, J., J. D. Huba, and M.-C. Fok (2020), Does ring current heating generate the observed O$ˆ+$ shell?, Geophys. Res. Lett., 47, e2020GL088419, doi:10.1029/2020GL088419 [2] Huba, J., and J. Krall (2013), Modeling the plasmasphere with SAMI3, Geophys. Res. Lett., 40, 6–10, doi:10.1029/2012GL054300 Research supported by NRL base funds and NASA.

U.S. NAVAL RESEARCH LABORATORY

Stormtime Ring Current Heating of the Plasmasphere and Ionosphere

2021 AGU Fall Meeting, December 14, 2021

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Supported by the NRL base program and NASA

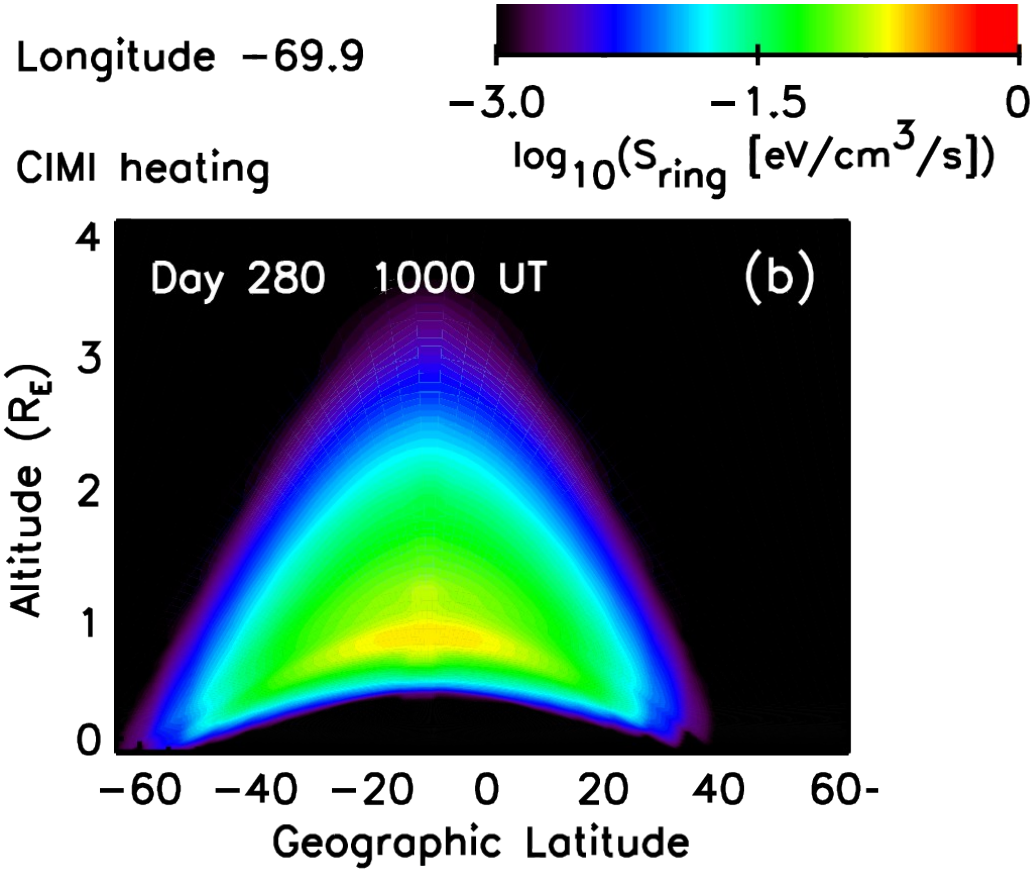
SAMI3 and CIMI modeling

NRL PPD

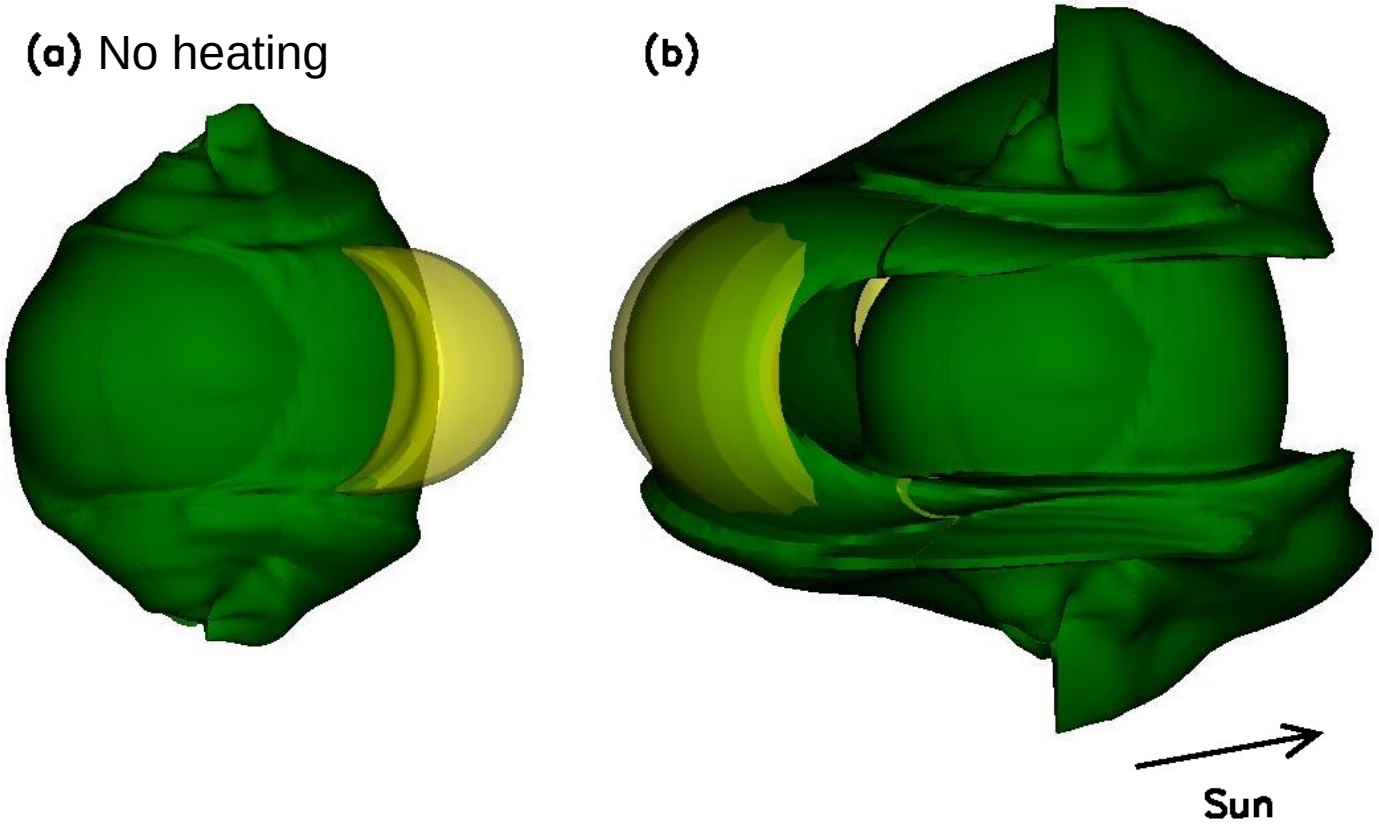
We have been running SAMI3 simulations with ring current heating included, based on CIMI ring current simulations.

1. In Krall, Huba & Fok, GRL, (2020), we showed that ring current heating can generate the observed cold O^+ shell.

2. In our latest work, we consider the possibility that the ring current directly heats the ionosphere.



SAMI3: heating-driven O^+ outflow

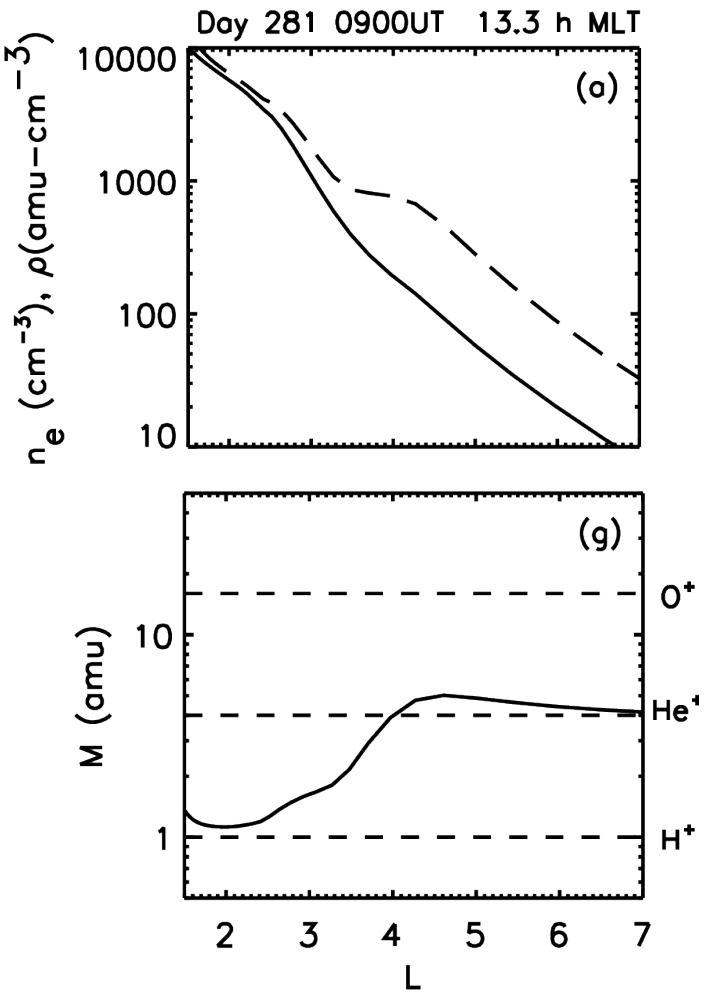


Green: O^+ density isosurface at 100 cm^{-3}

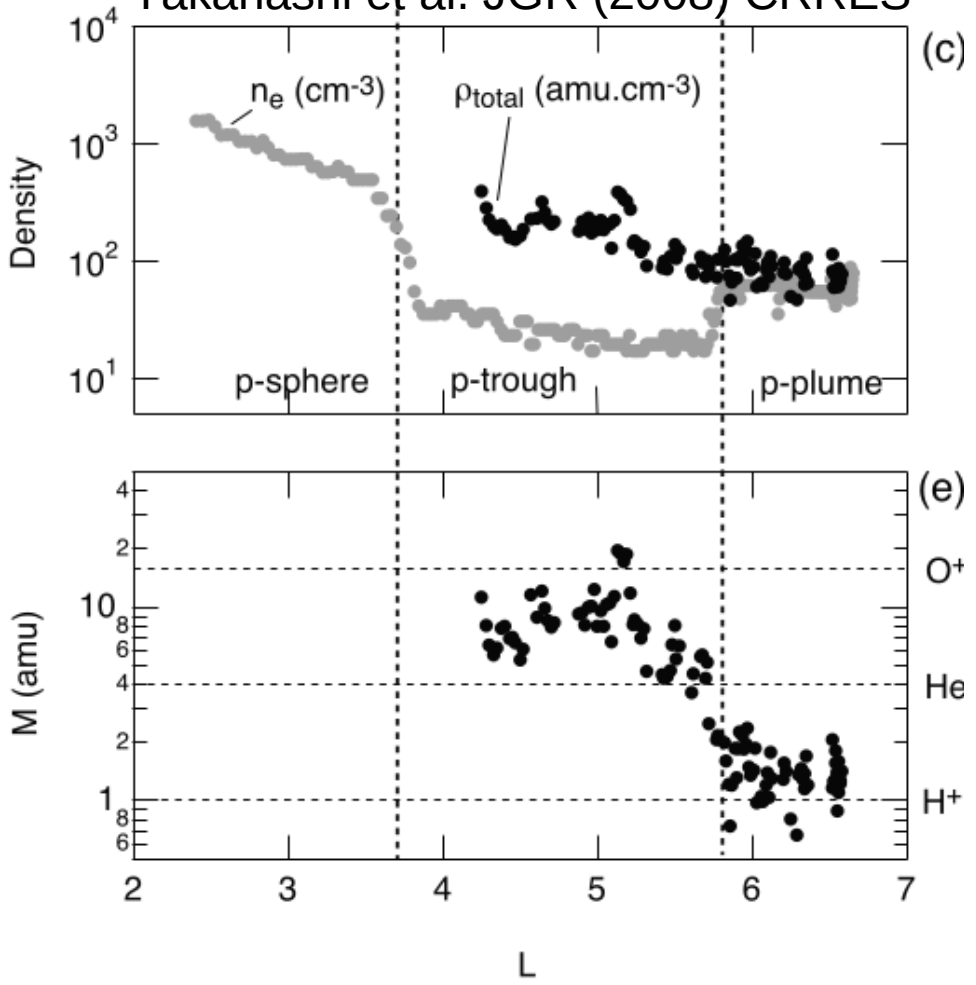
Yellow: e^- temperature surface at (a) 5.5 x 10^3 K, (b) 2 x 10^4 K

Results similar to observed O^+

NRL PPD

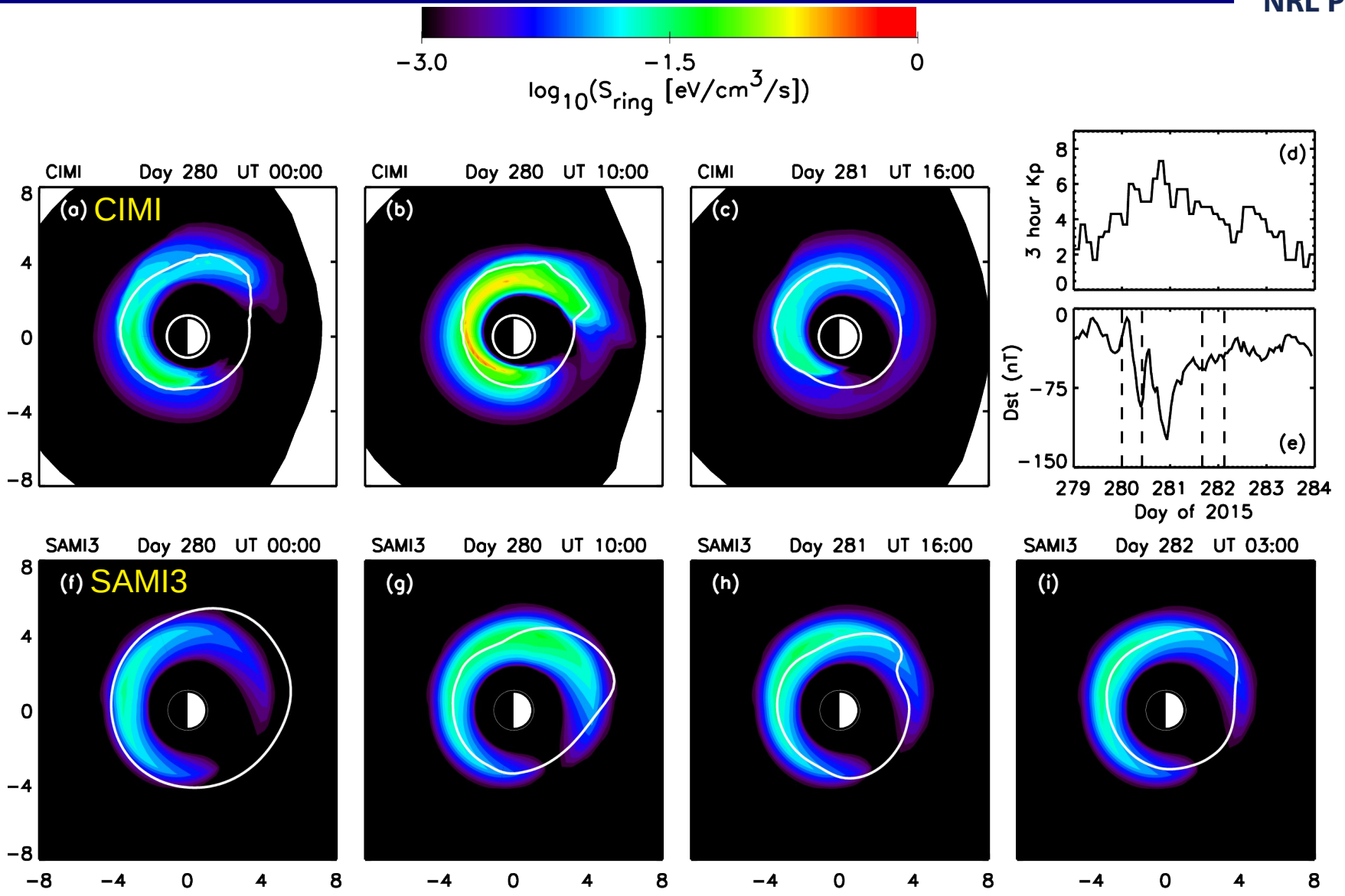


Takahashi et al. JGR (2008) CRRES



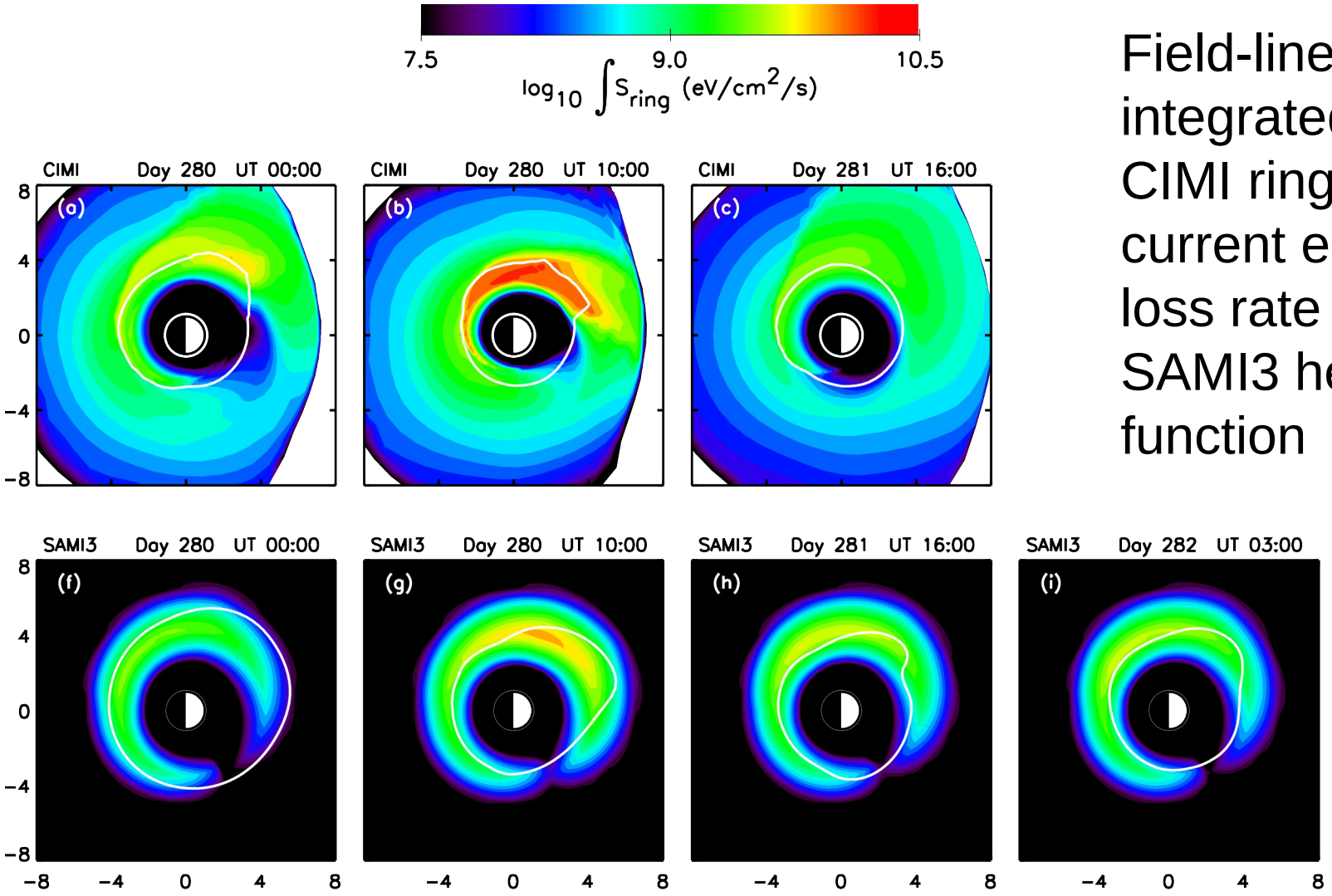
SAMI3 with ring current heating

NRL PPD



SAMI3 and CIMI modeling

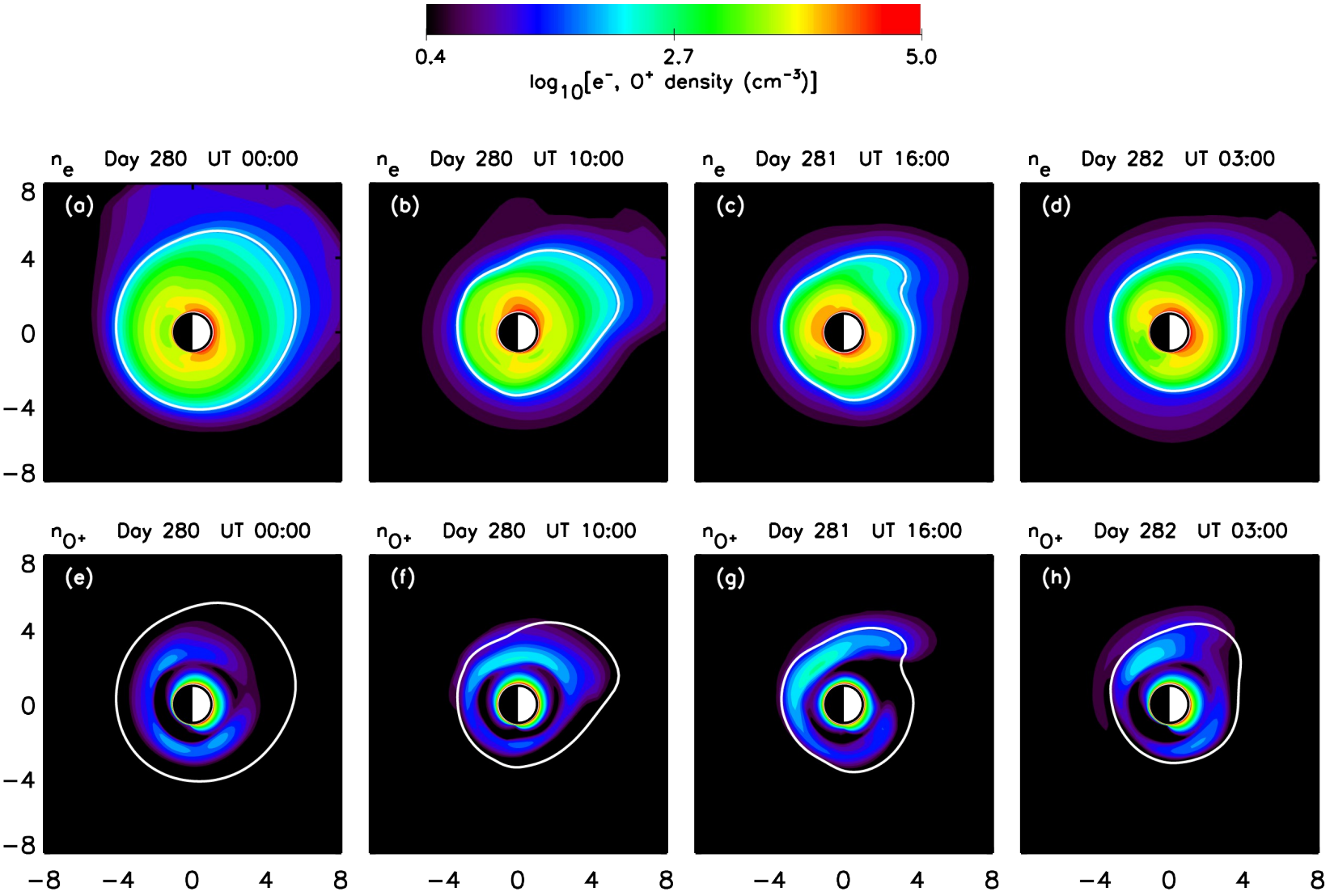
NRL PPD



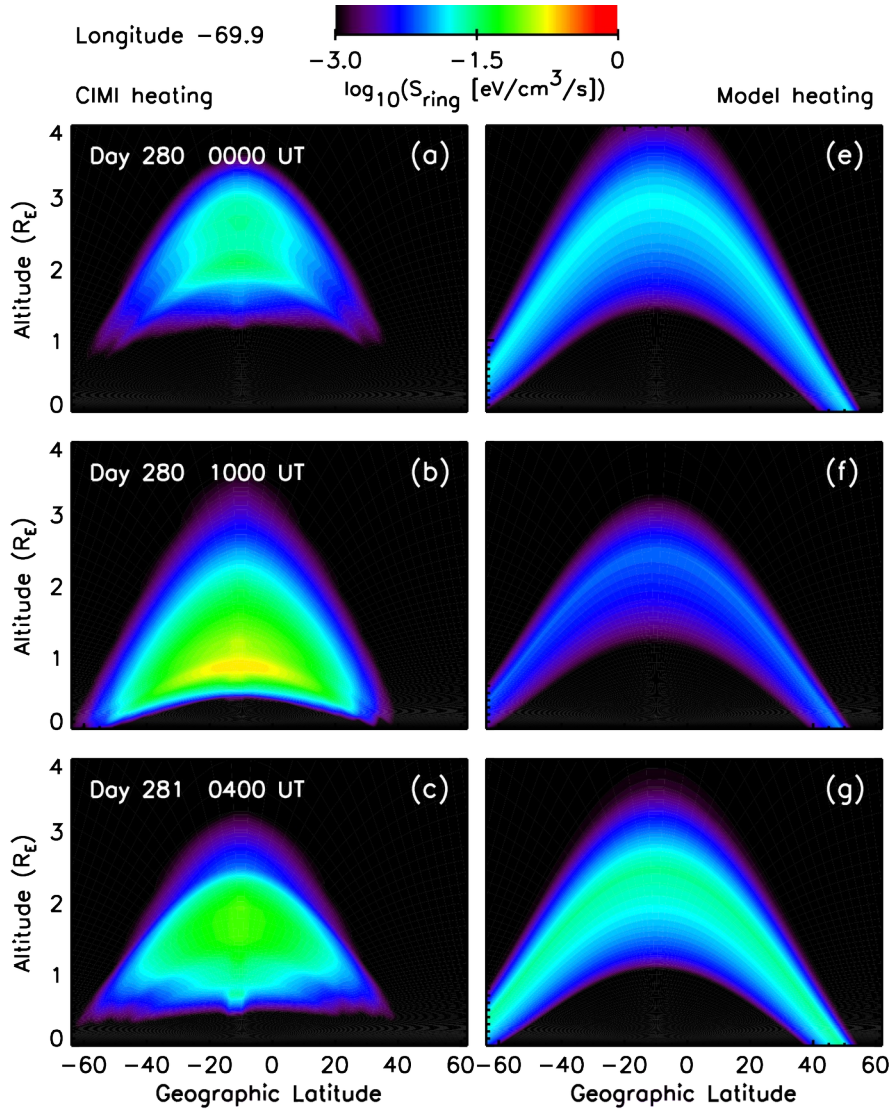
Field-line integrated CIMI ring current energy loss rate and SAMI3 heating function

SAMI3: heating generates O^+ shell

NRL PPD



Direct heating of the ionosphere?



Left: CIMI heating interpolated into SAMI3 in magnetic coordinates.

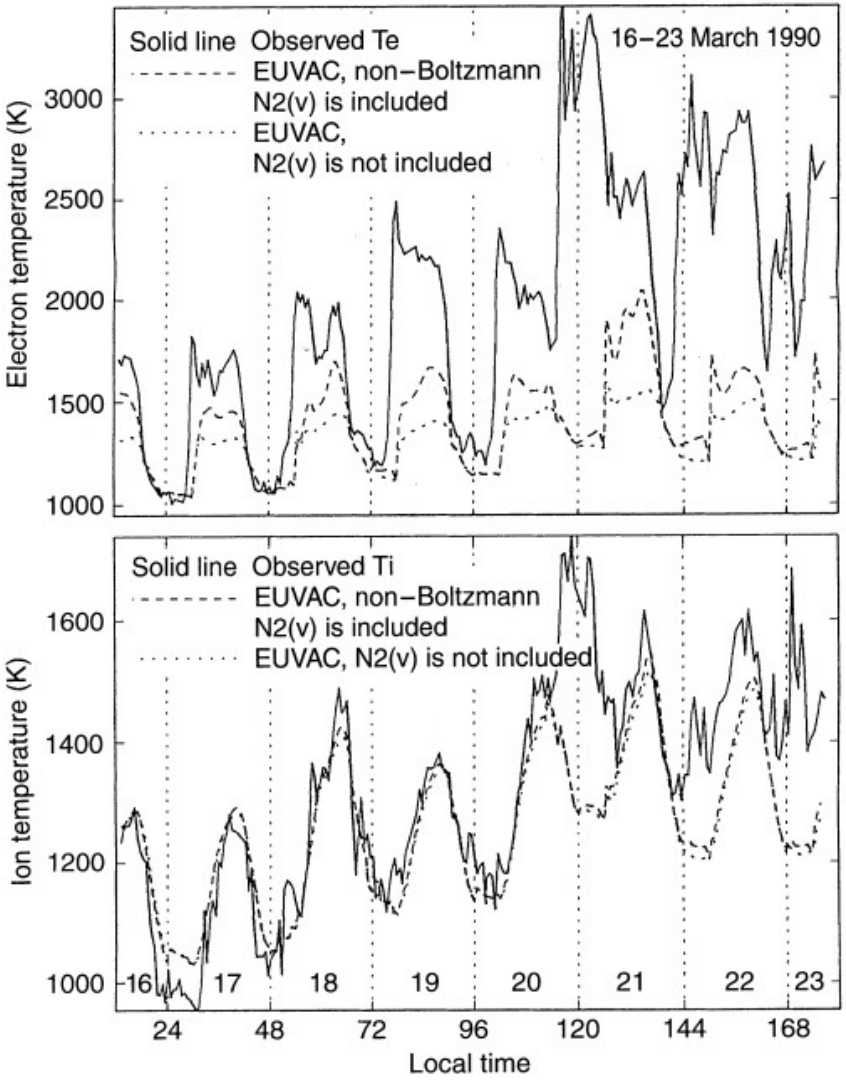
Right: Dst-driven heating function

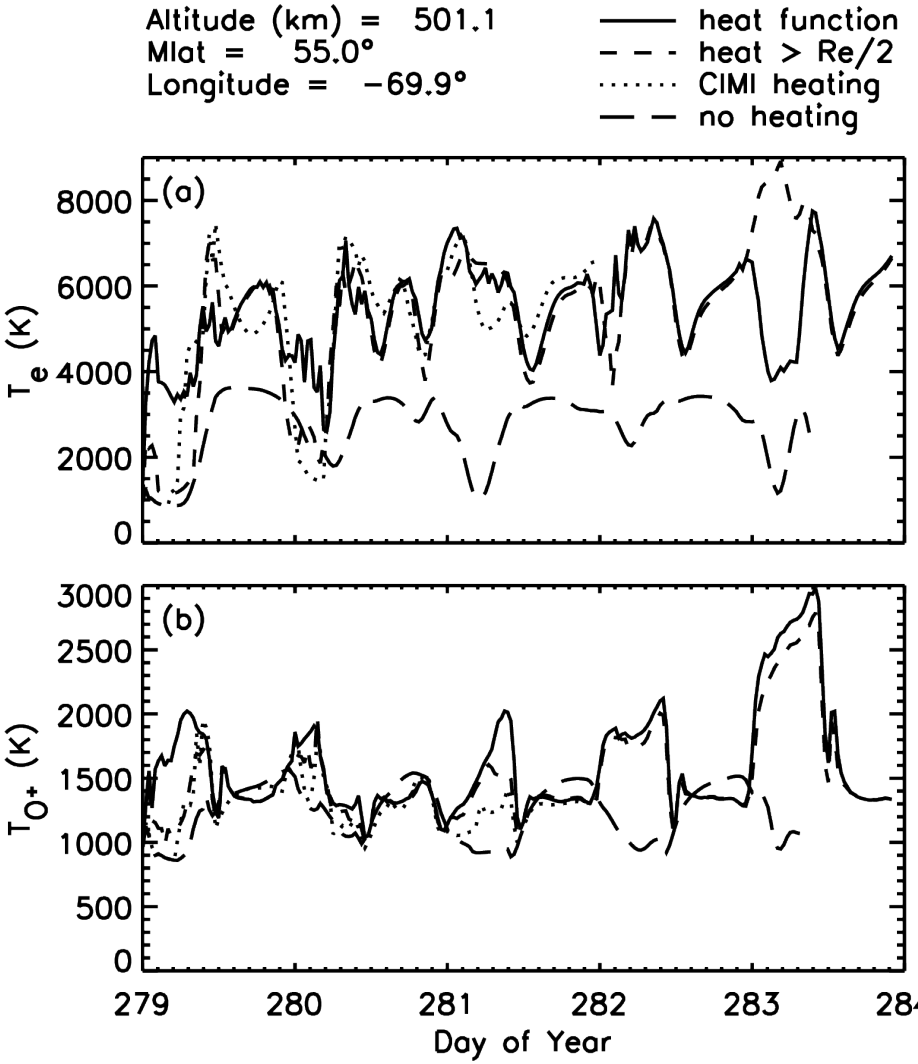
1. Direct heat
2. Indirect heat (altitude > $R_E/2$)
3. CIMI heat
4. No heat

Direct heating of the ionosphere?

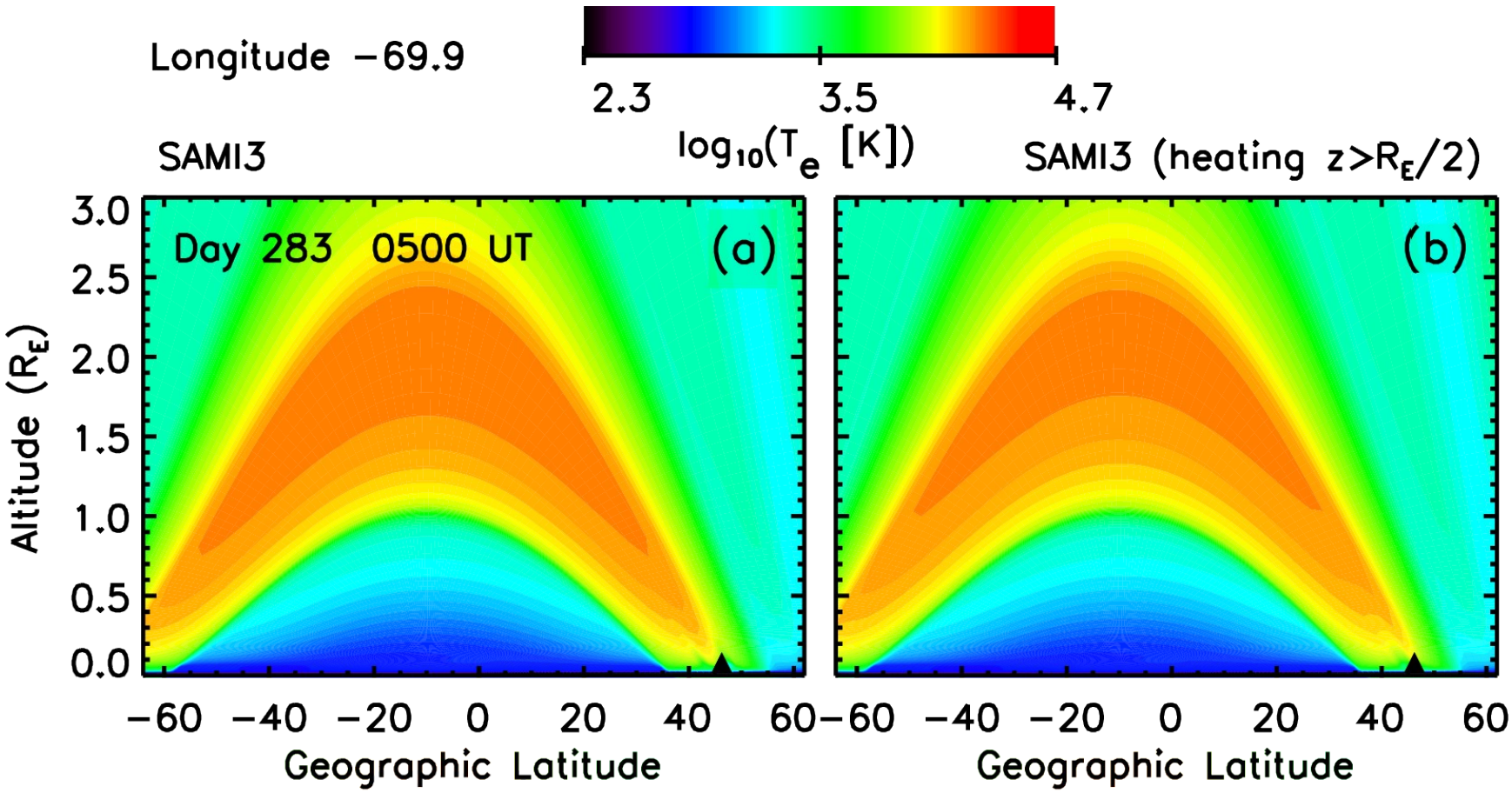
NRL PPD

Pavlov et al. Angeo(1997) Millstone Hill



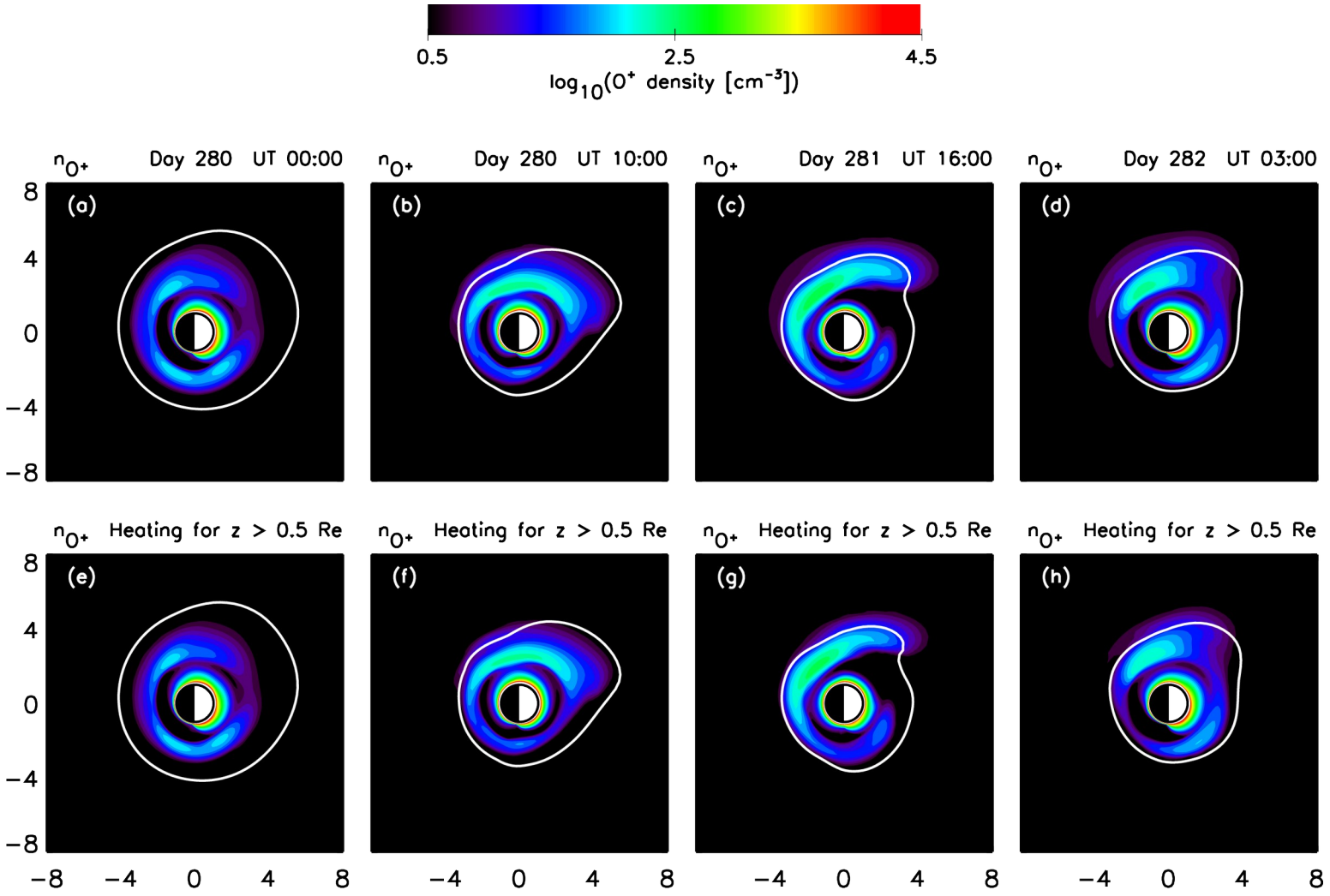


Direct heating of the ionosphere?

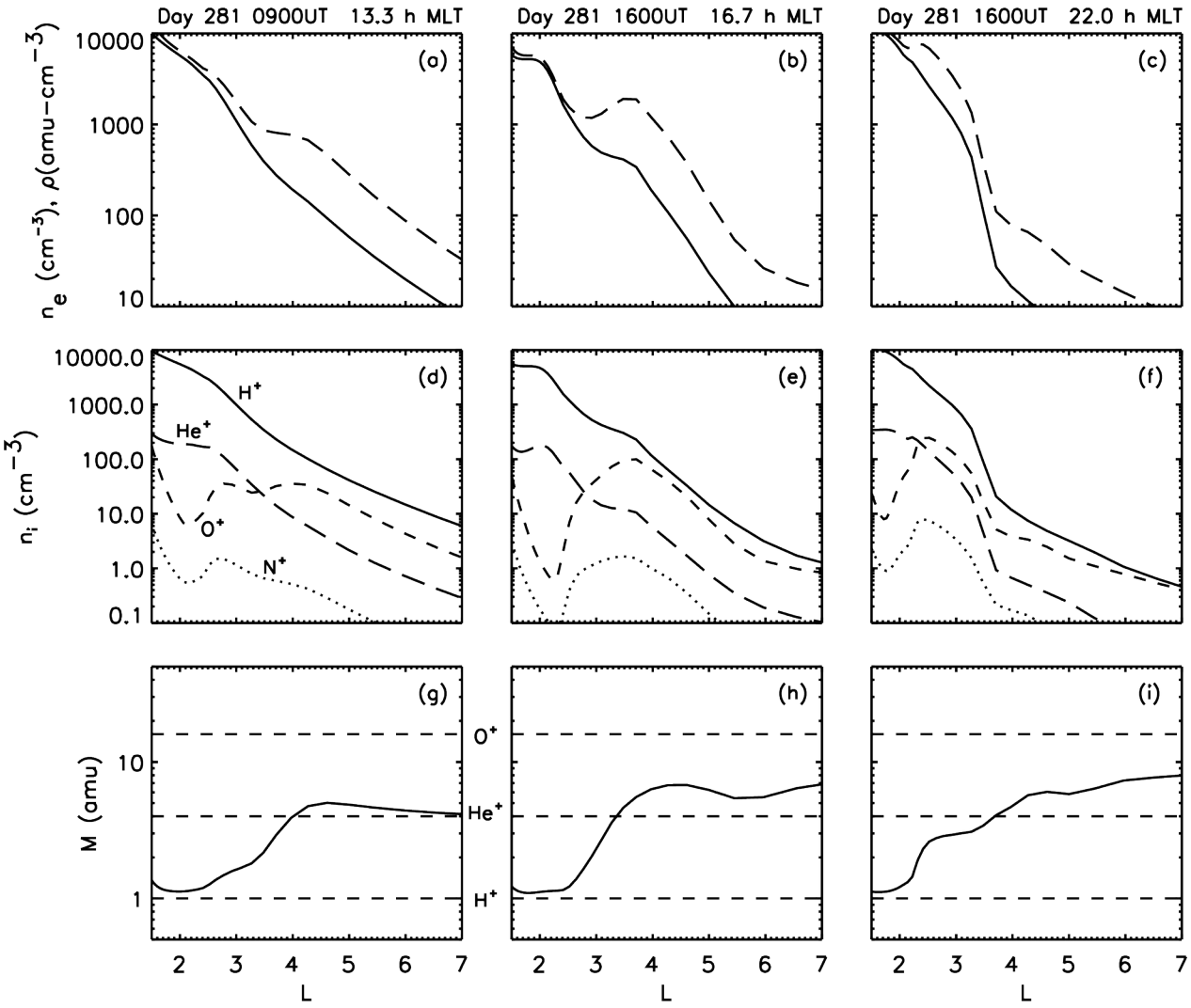


Direct heating of the ionosphere?

NRL PPD

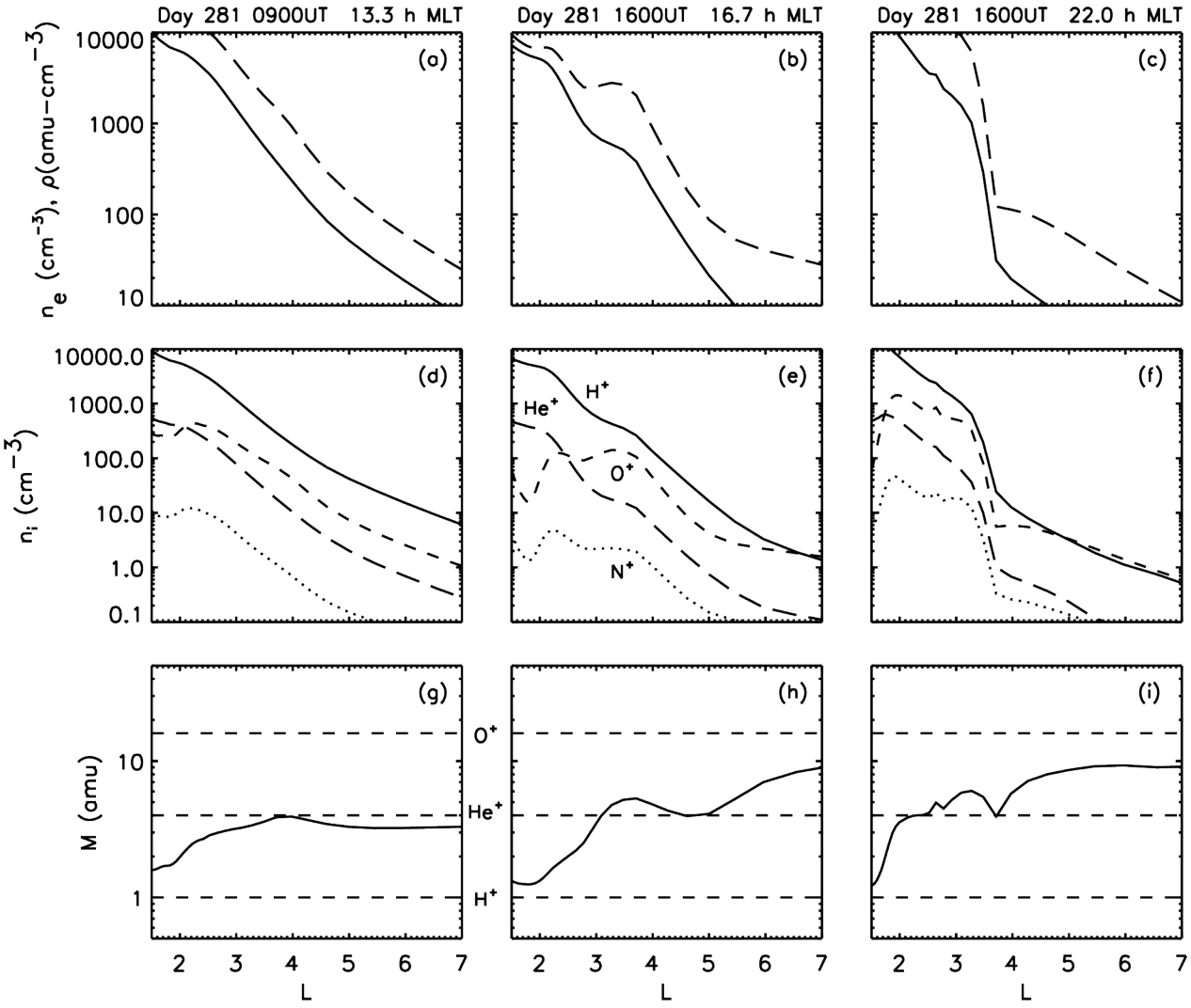


Results similar to observed O^+



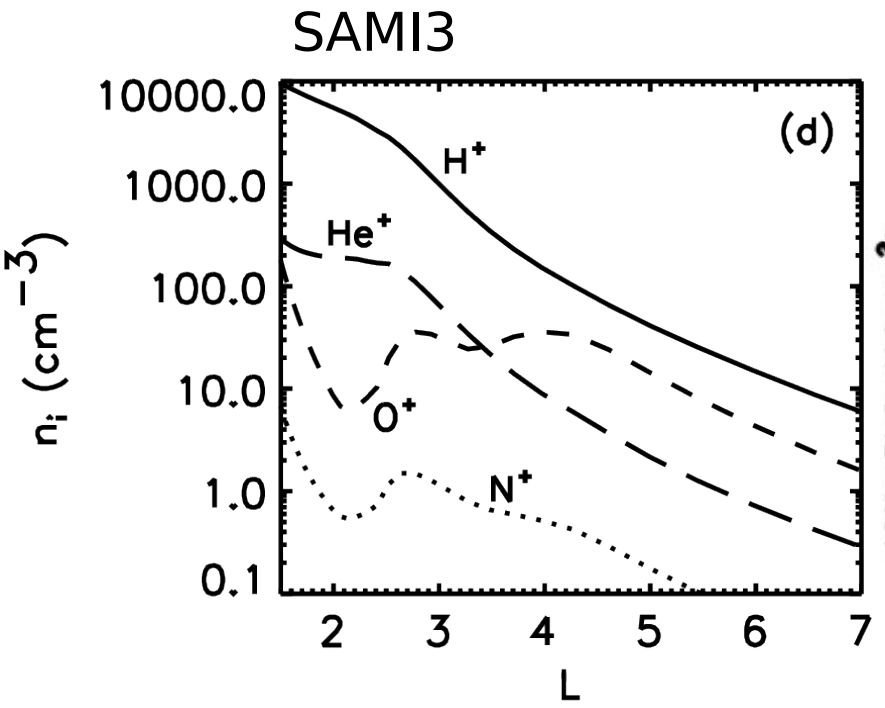
New results similar to observed O^+

NRL PPD

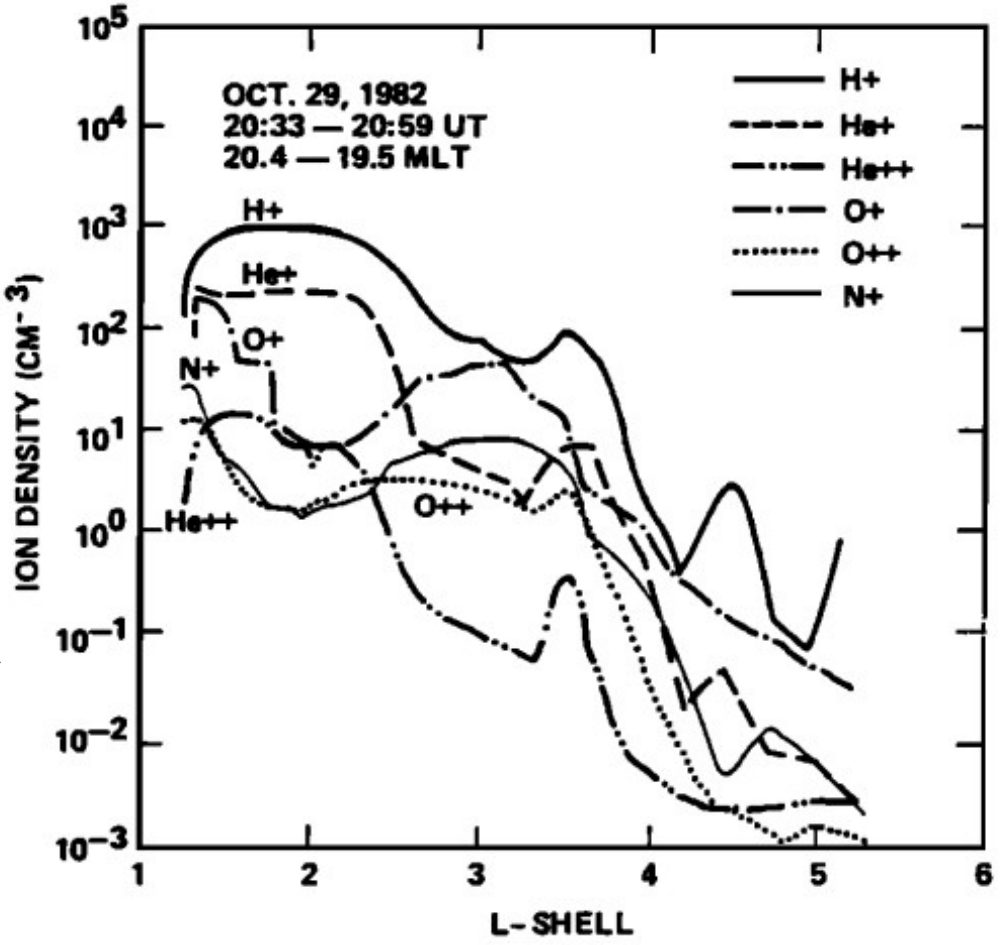


‘Heavy ion’ shell: N^+ content

NRL PPD



Roberts et al. JGR(1987) DE:RIMS

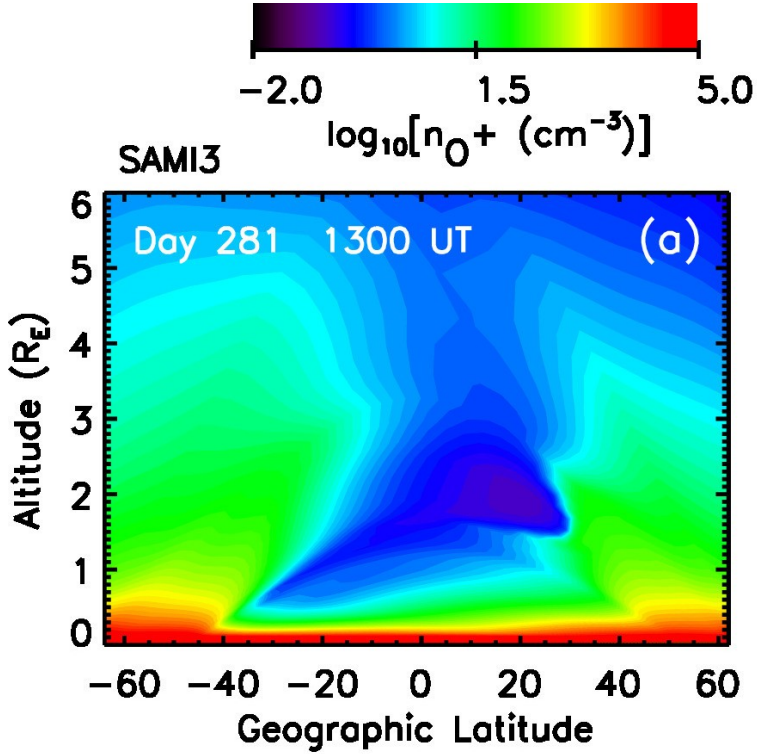


Discussion

Results suggest that the ring current heats the ionosphere, but direct heating of the ionosphere does not produce significant additional O^+ outflow.

The degree to which the observed heating of the ionosphere during a storm is caused by this direct effect is not entirely clear.

Topside ionosphere stormtime temperatures are elevated in all cases where ring current heating is included.



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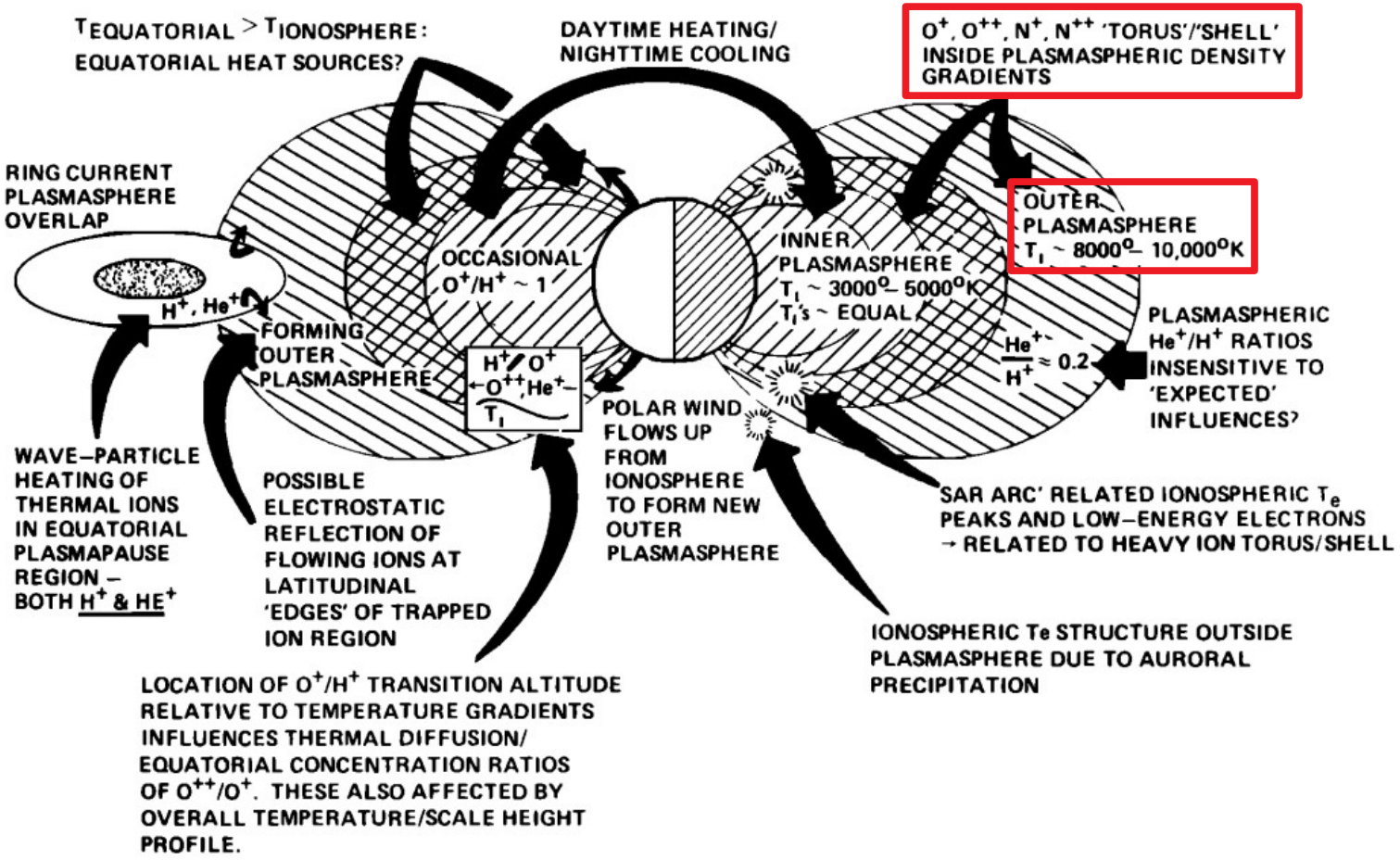
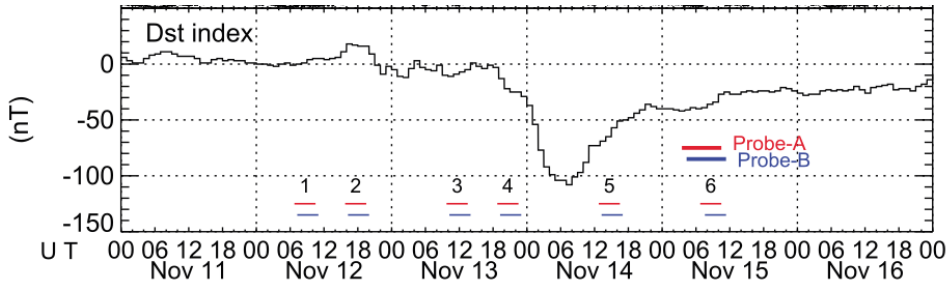
Where is the O^+ Shell?

NRL PPD

Horwitz et al. (1986):



More examples of the O^+ shell



[Nosé et al.,JGR, 2015]