

# Stormtime Ring Current Heating of the Plasmasphere and Ionosphere

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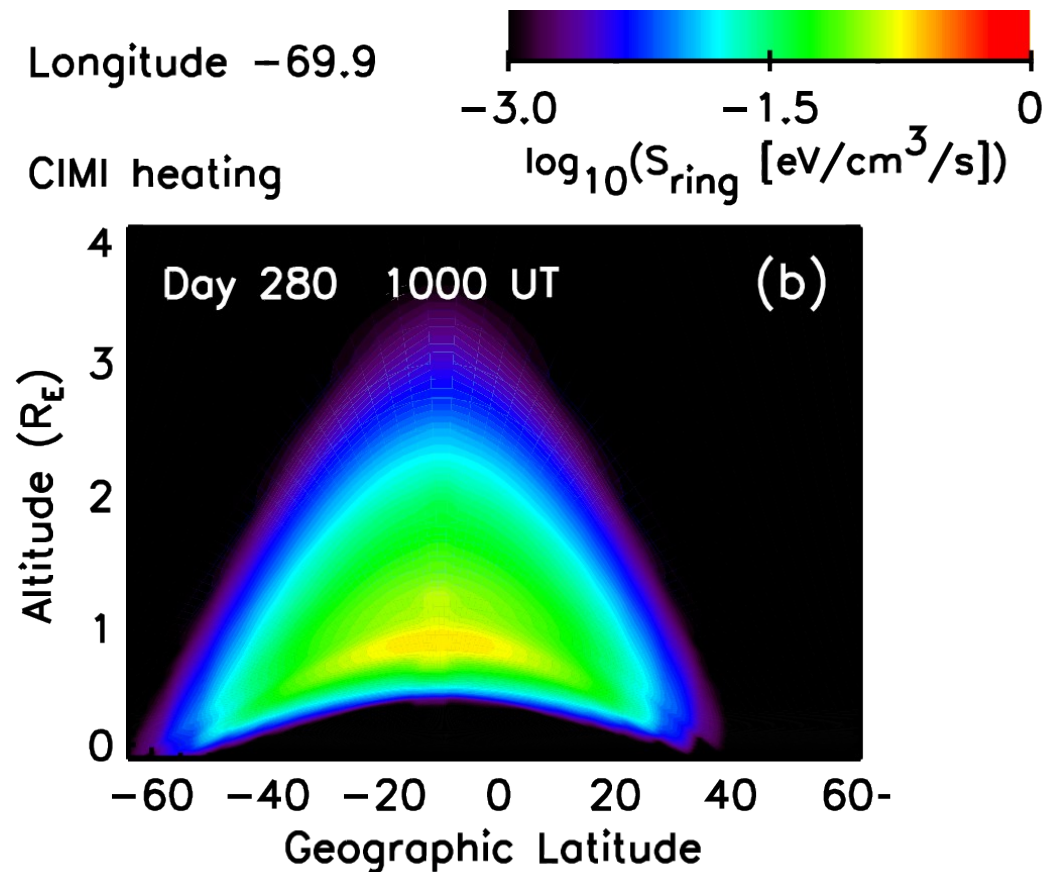
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# SAMI3 and CIMI modeling

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

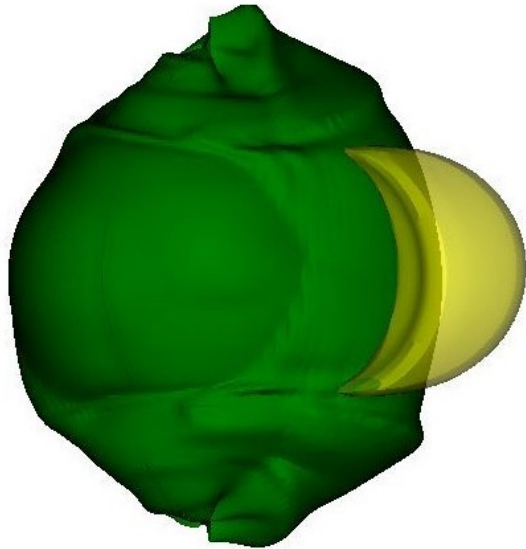
1. In Krall, Huba & Fok, GRL, (2020), we showed that ring current heating can generate the observed cold  $O^+$  shell.

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

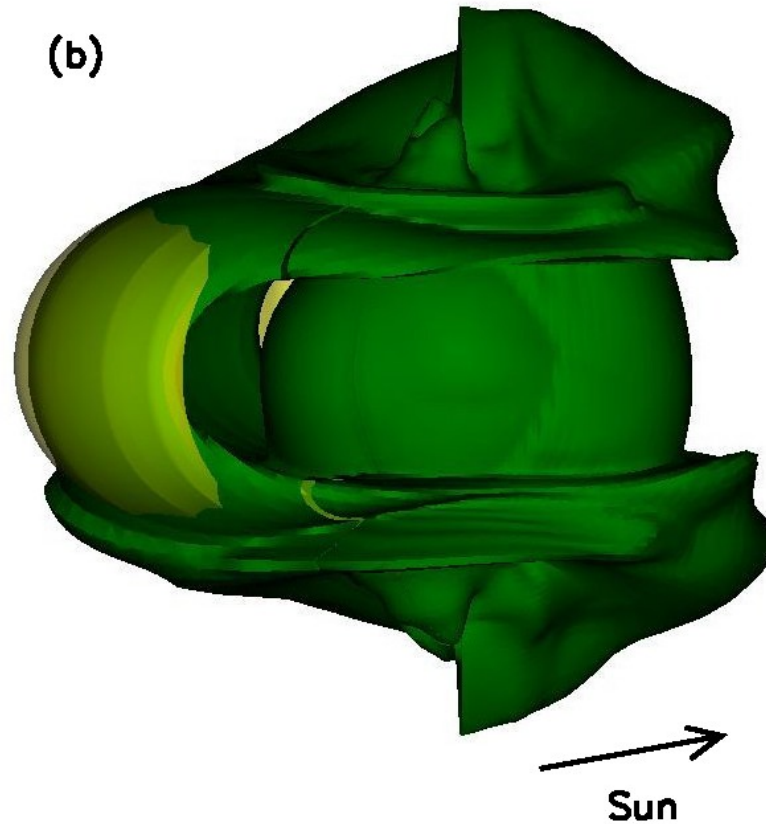


# SAMI3: heating-driven O<sup>+</sup> outflow

(a) No heating



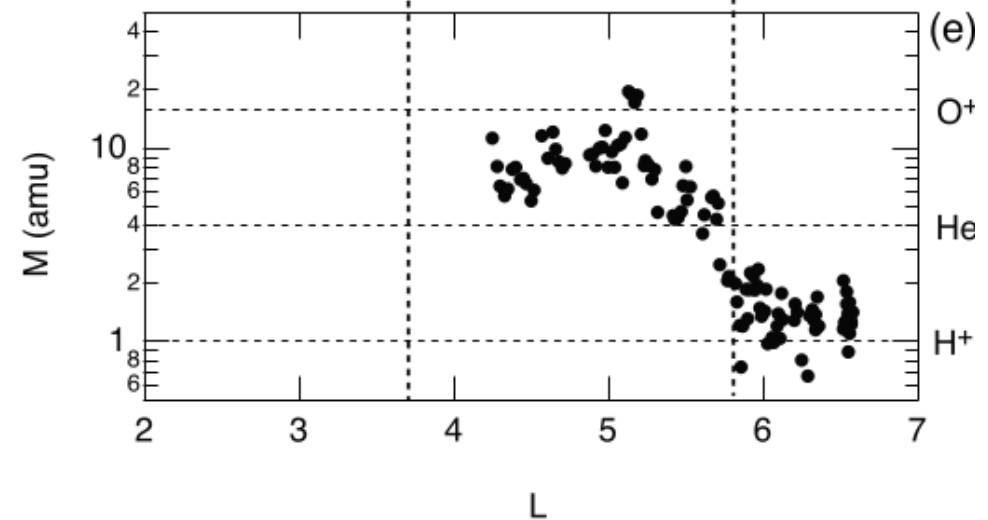
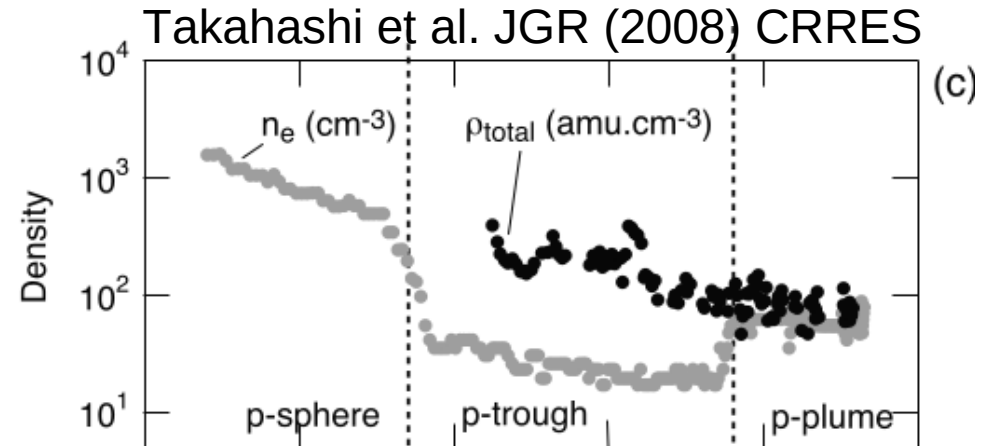
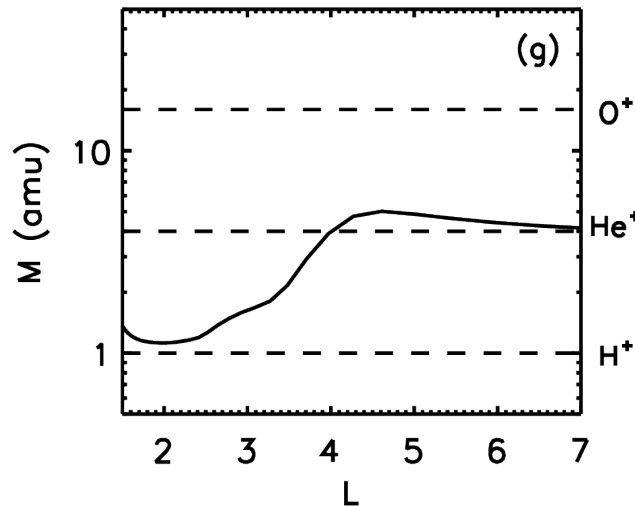
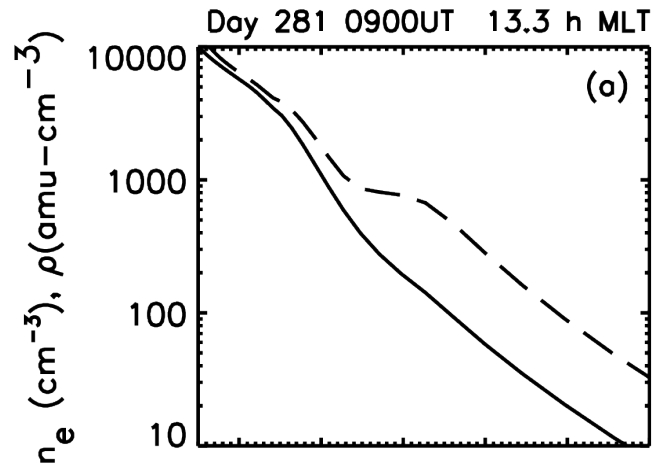
(b)



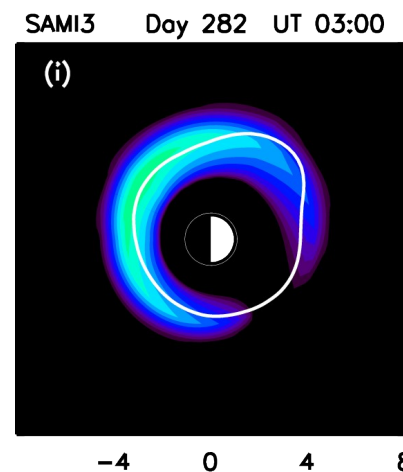
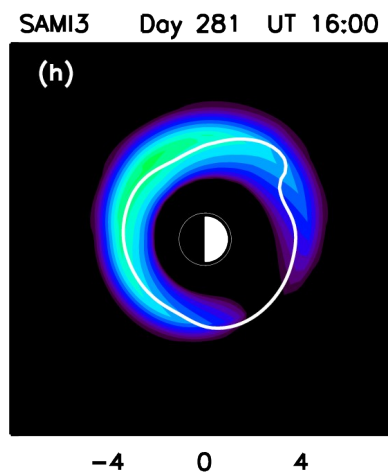
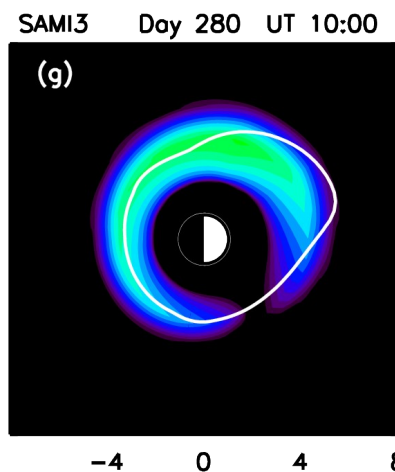
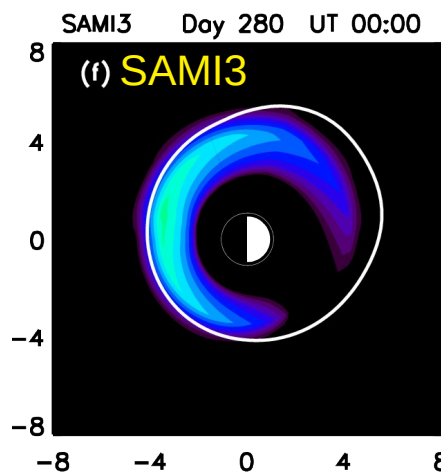
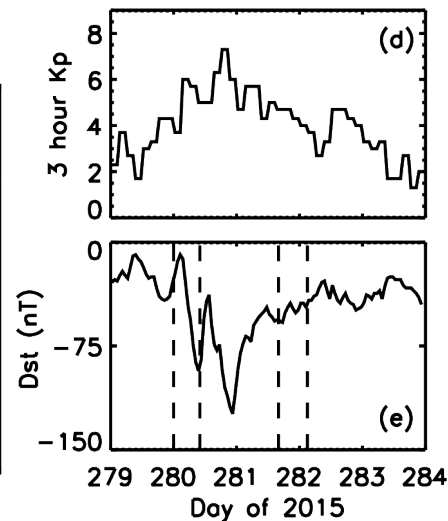
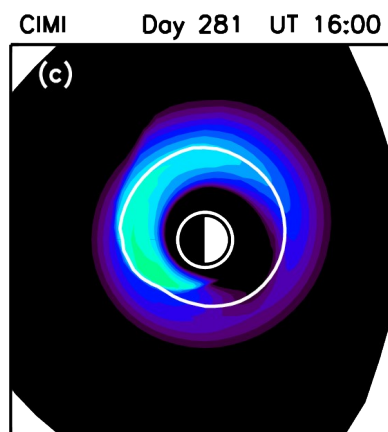
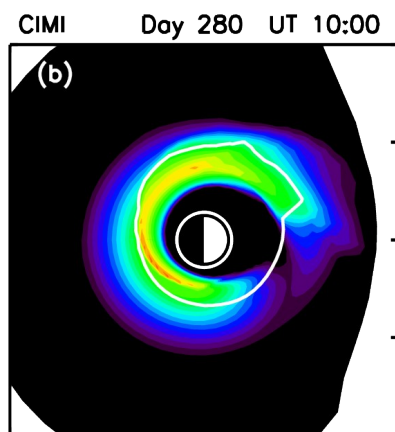
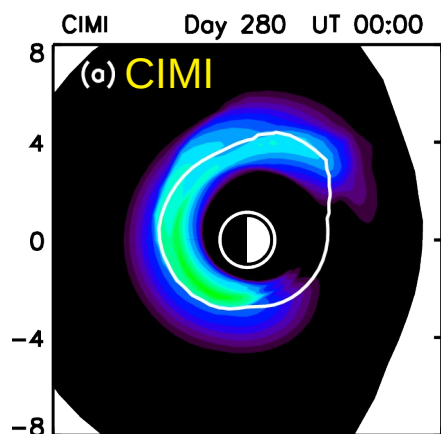
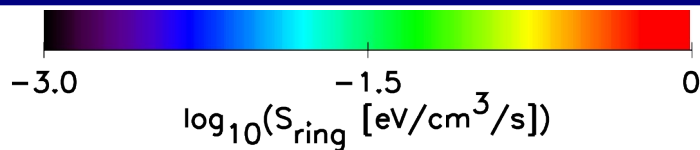
Green: O<sup>+</sup> density isosurface at 100 cm<sup>-3</sup>

Yellow: e<sup>-</sup> temperature surface at (a)  $5.5 \times 10^3$  K, (b)  $2 \times 10^4$  K

# Results similar to observed O<sup>+</sup>

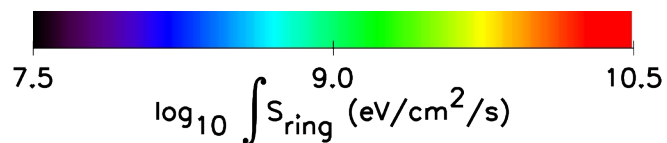


# SAMI3 with ring current heating

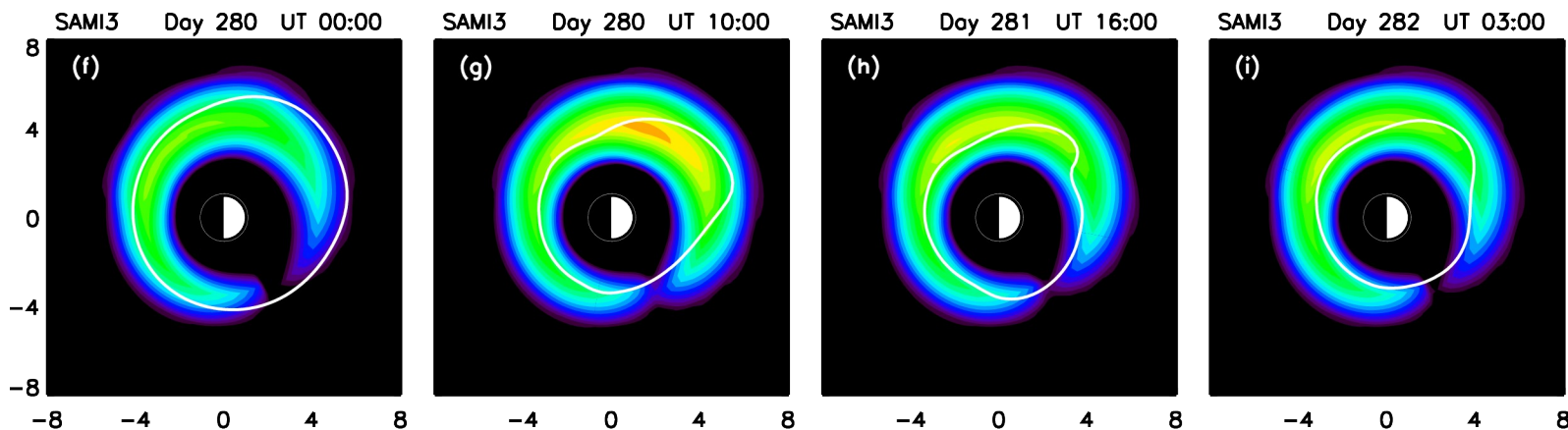
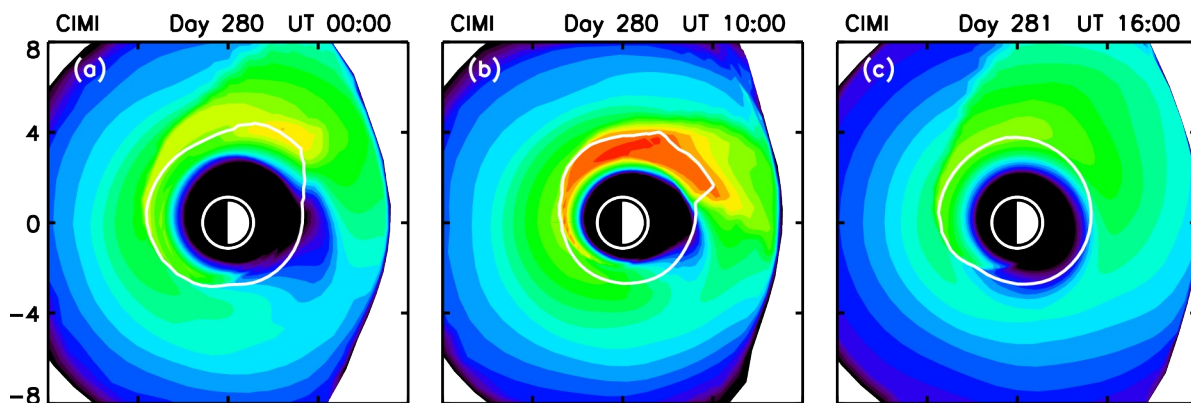




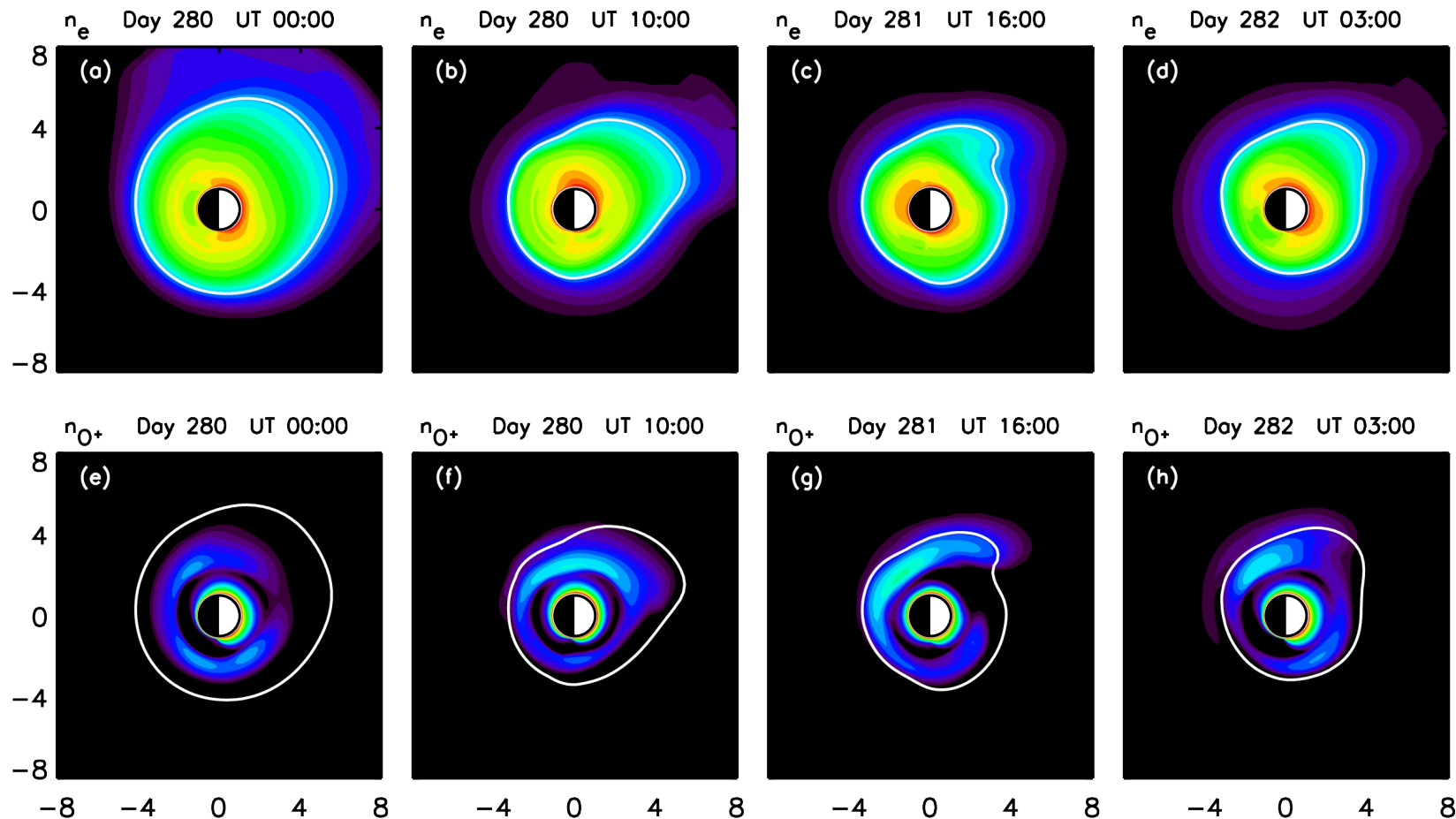
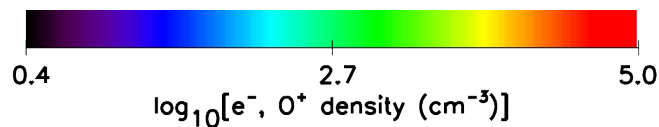
# SAMI3 and CIMI modeling



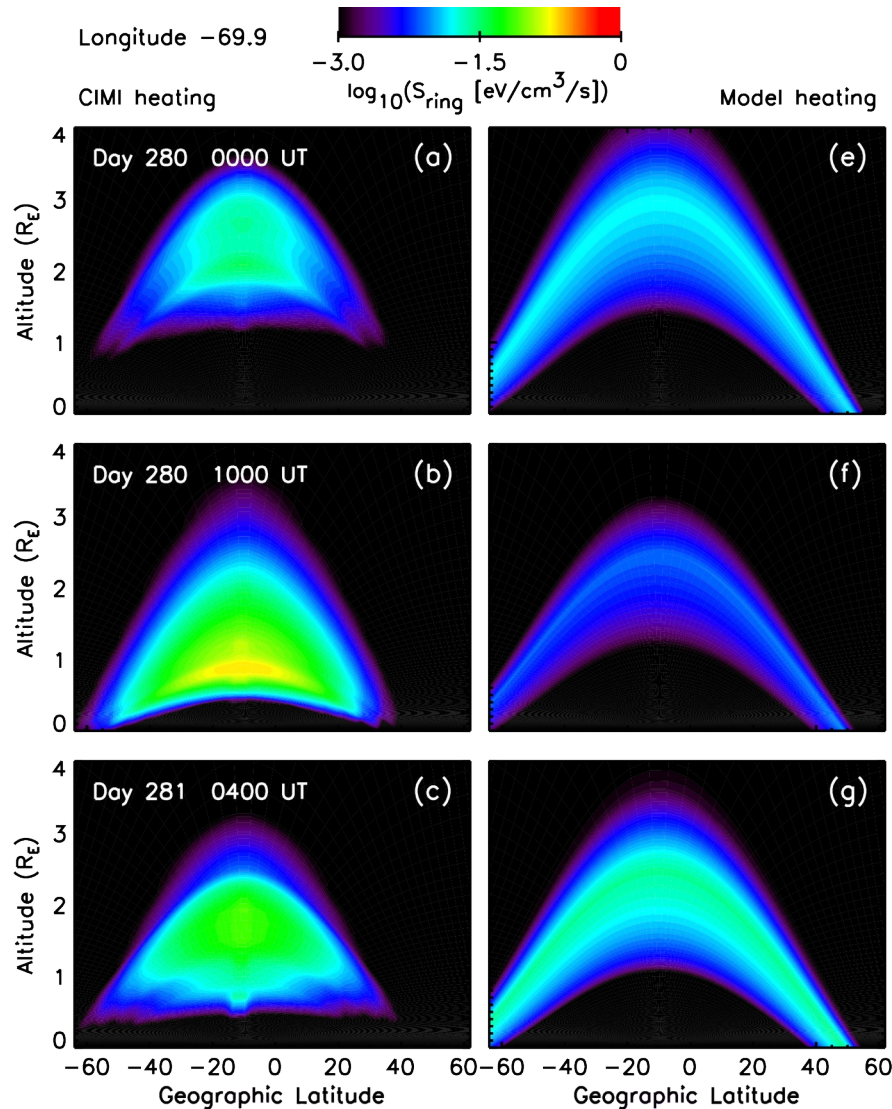
Field-line  
integrated  
CIMI ring  
current energy  
loss rate and  
SAMI3 heating  
function



# SAMI3: heating generates O<sup>+</sup> shell



# Direct heating of the ionosphere?



Left: CIMI heating interpolated into SAMI3 in magnetic coordinates.

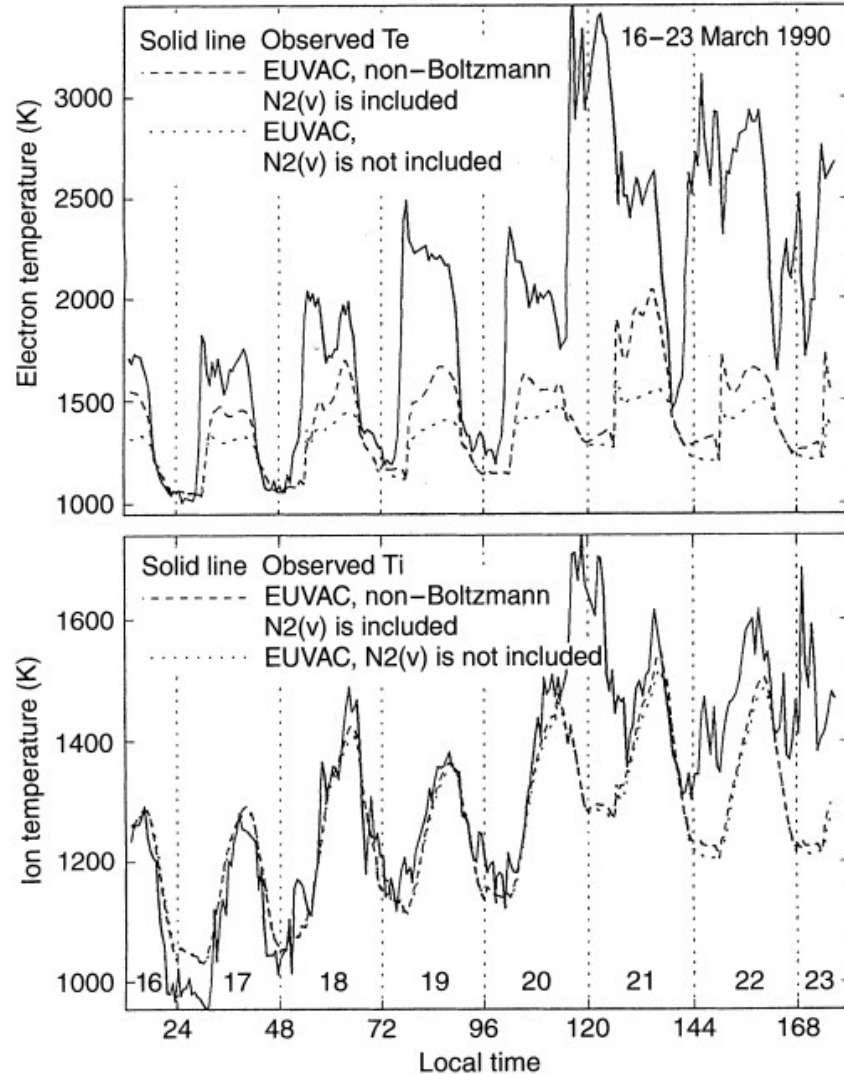
Right: Dst-driven heating function

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



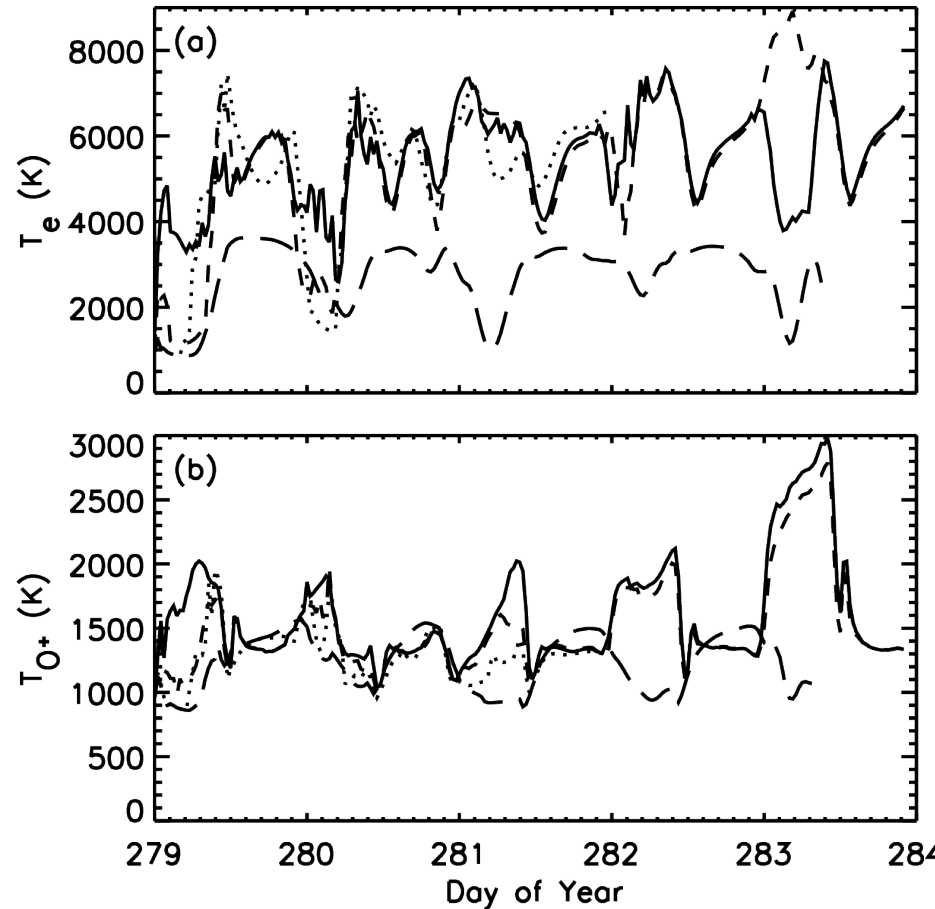
# Direct heating of the ionosphere?

Pavlov et al. Angeo(1997) Millstone Hill

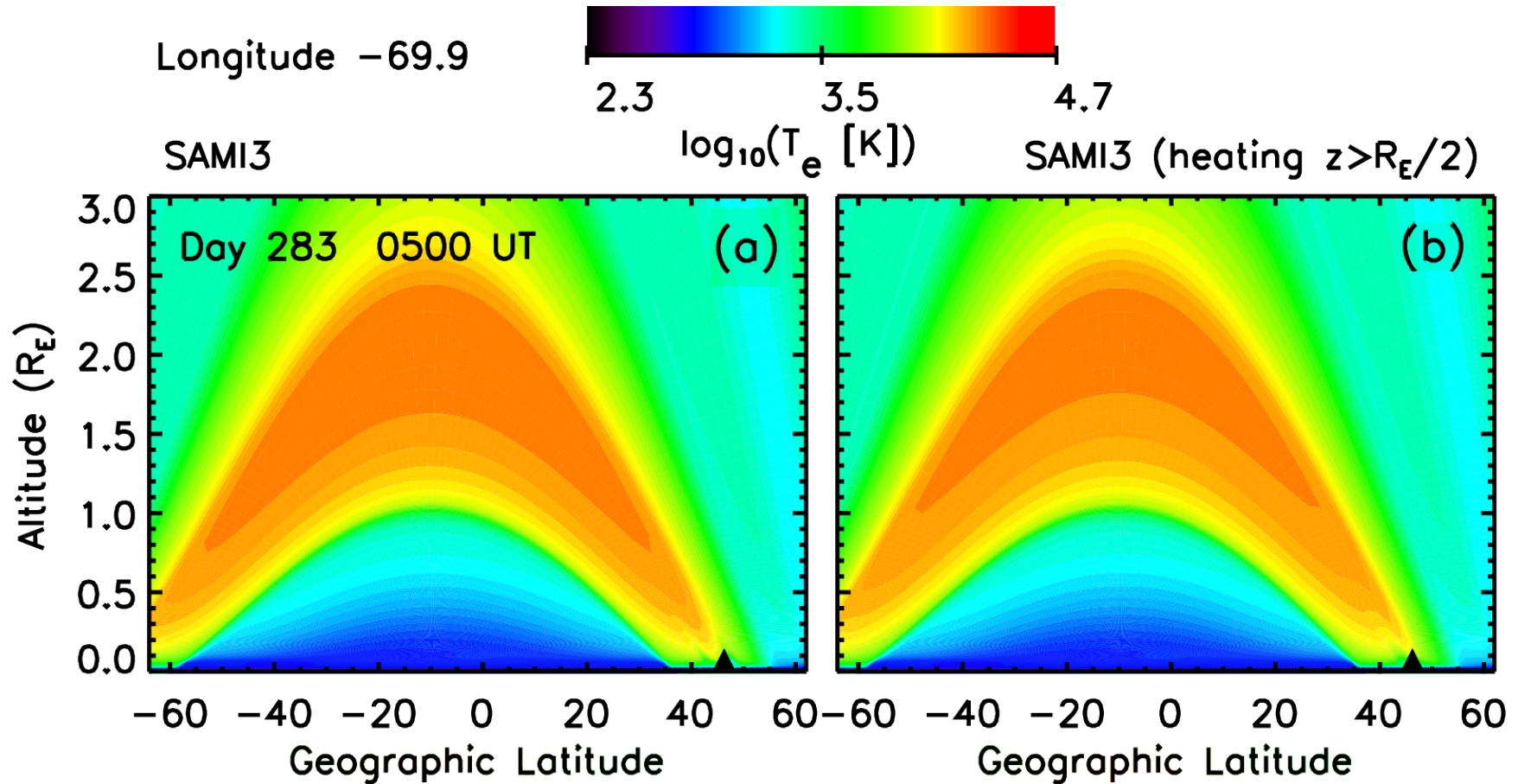


Altitude (km) = 501.1  
 Mlat = 55.0°  
 Longitude = -69.9°

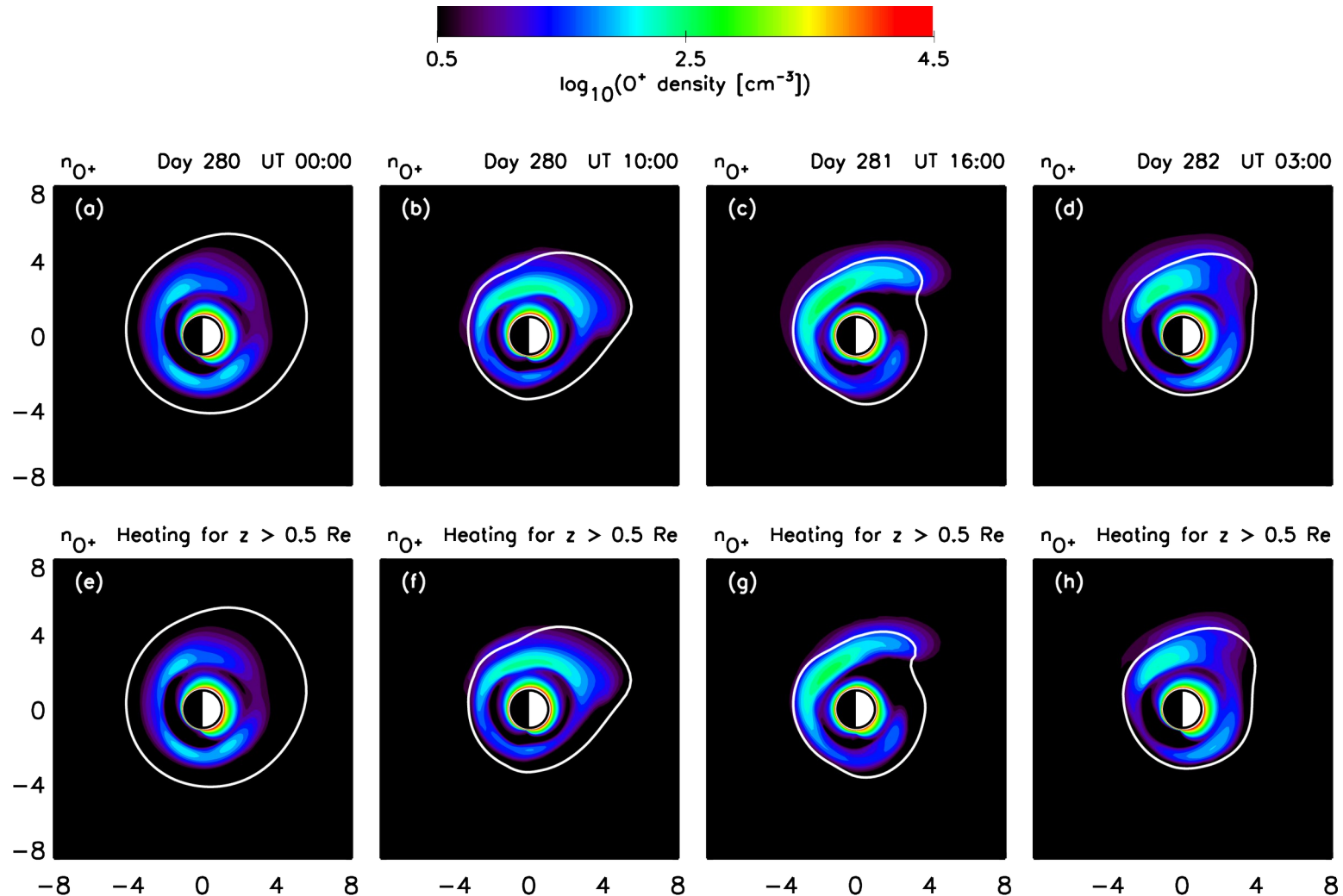
— heat function  
 - - - heat >  $Re/2$   
 ..... CIMI heating  
 — no heating



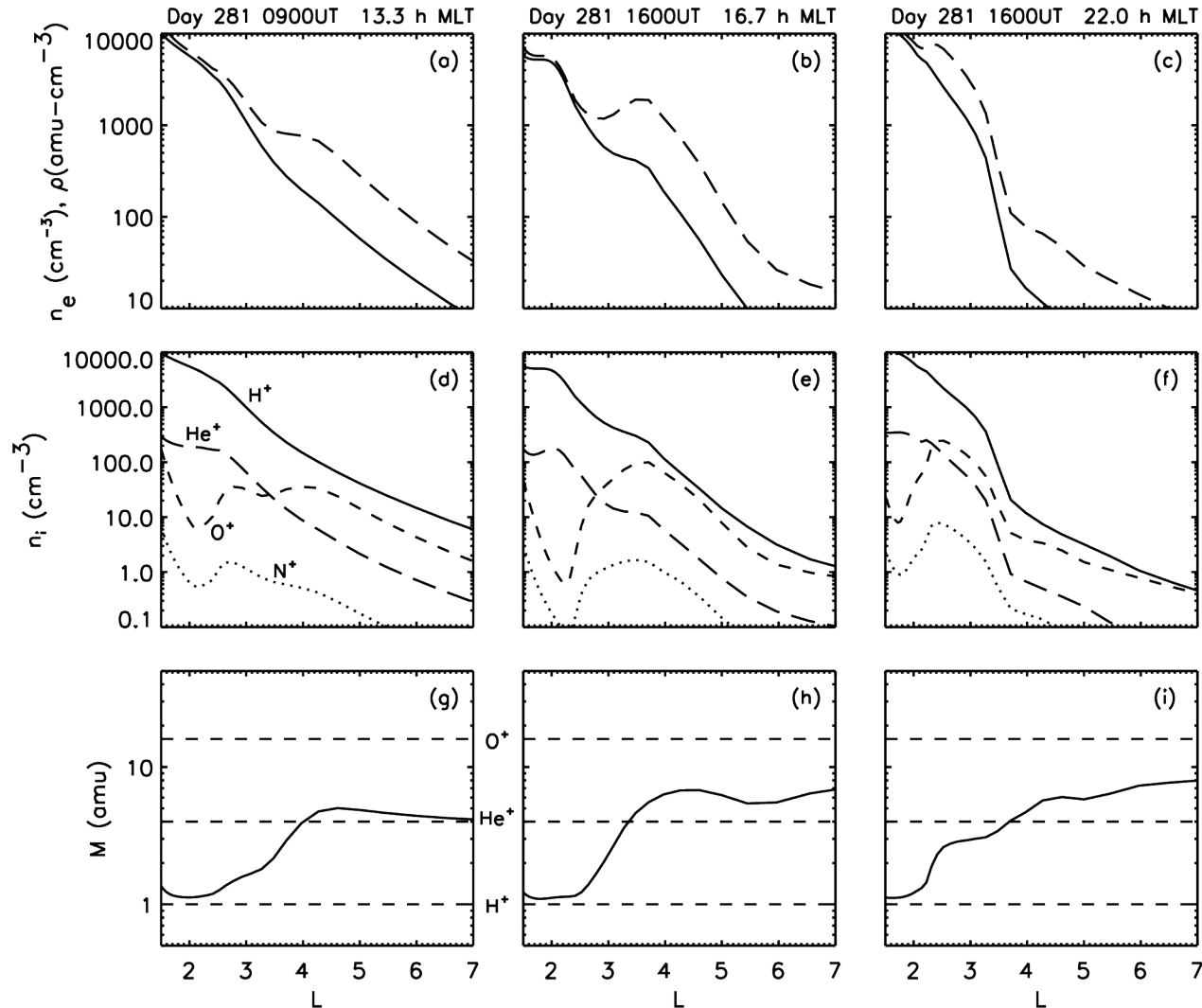
# Direct heating of the ionosphere?



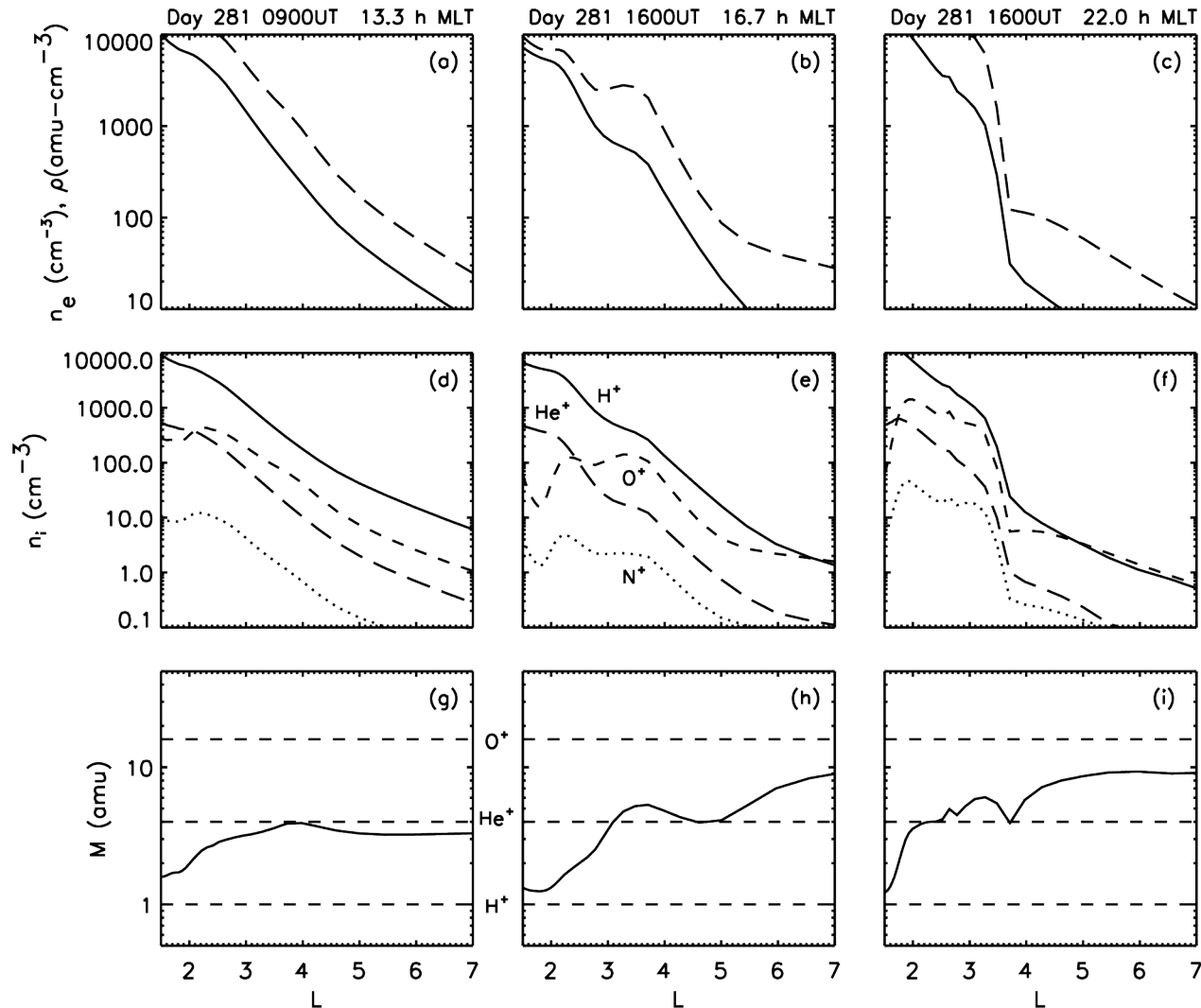
# Direct heating of the ionosphere?



# Results similar to observed O<sup>+</sup>



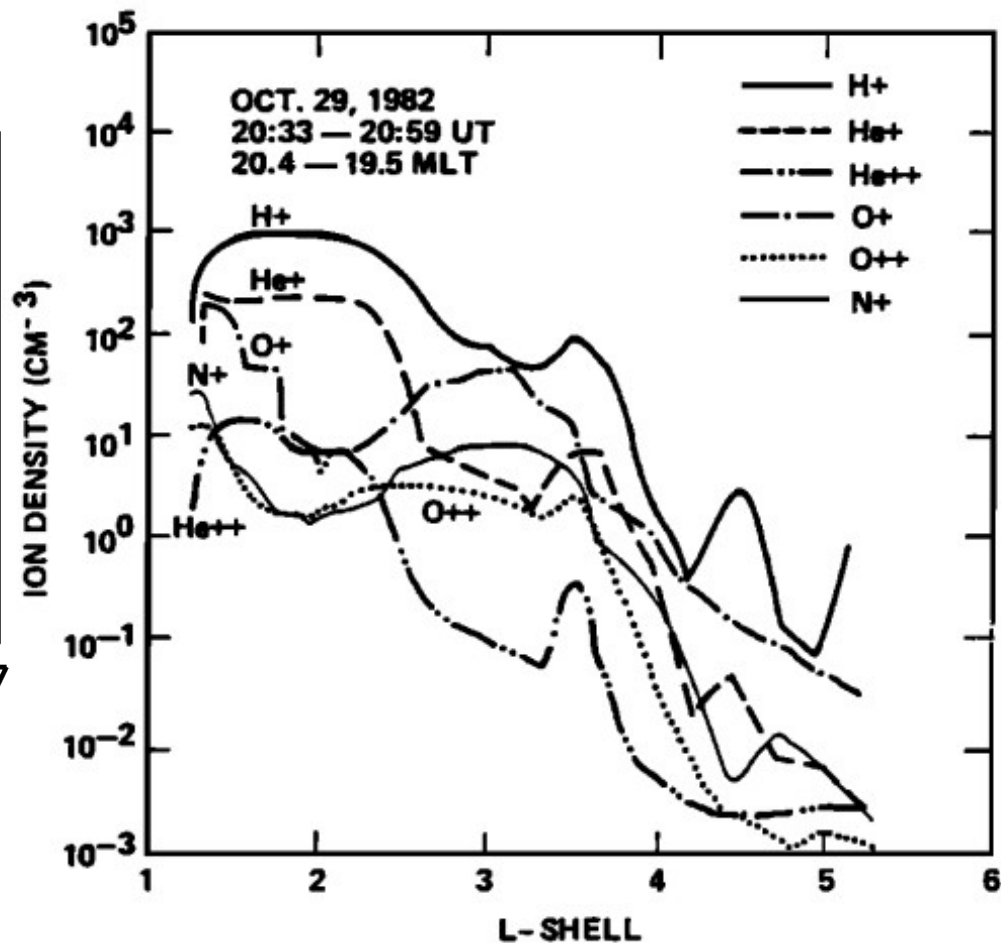
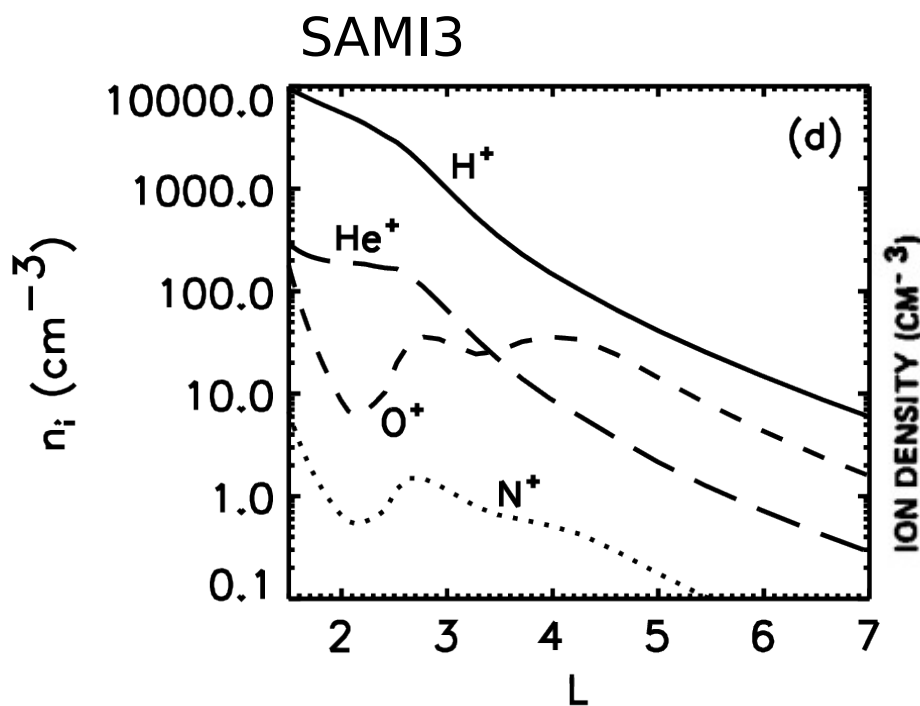
# New results similar to observed O<sup>+</sup>





# 'Heavy ion' shell: $N^+$ content

Roberts et al. JGR(1987) DE:RIMS

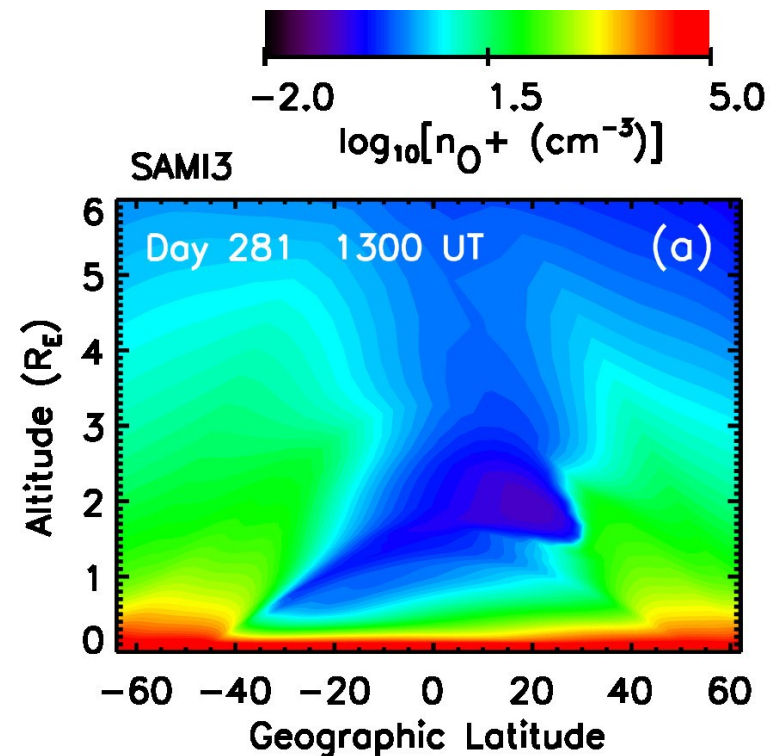


# Discussion

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.



# References



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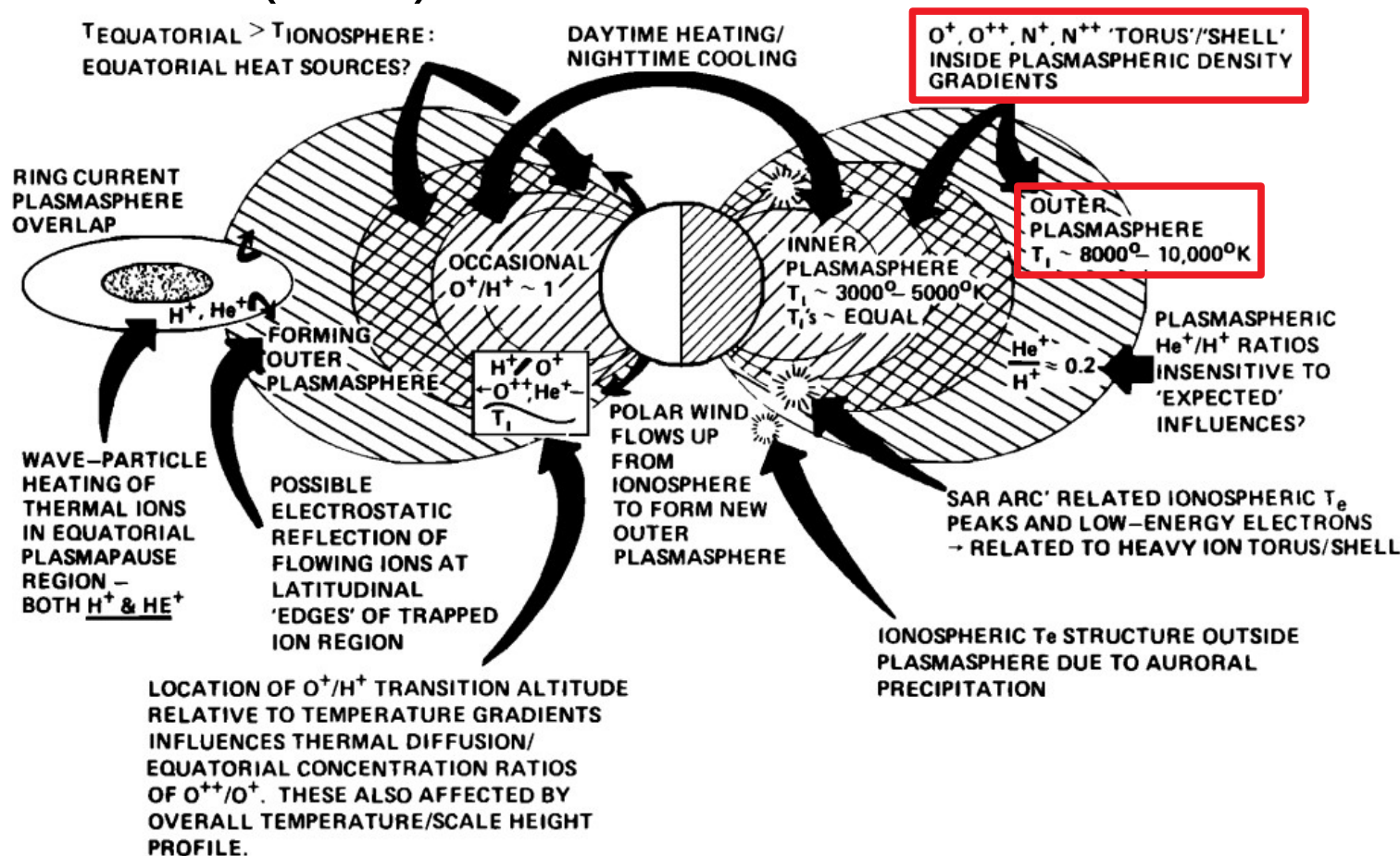
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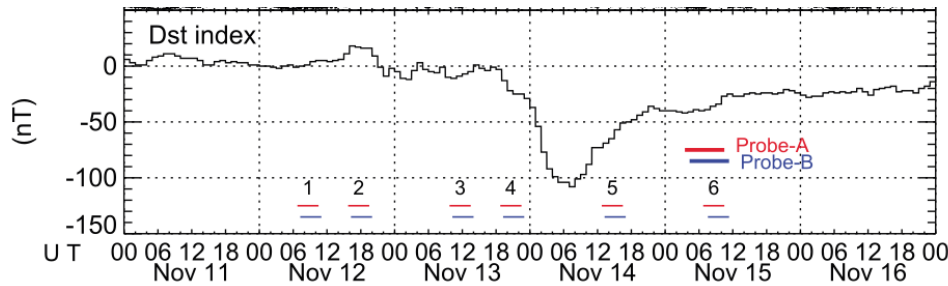
Takahashi, K., et al., (2008), Ion composition in the plasma trough and plasma plume derived from a Combined Release and Radiation Effects Satellite magnetoseismic study, JGR, 113 (A12), doi:10.1029/2008JA013248

# Where is the O<sup>+</sup> Shell?

Horwitz et al. (1986):

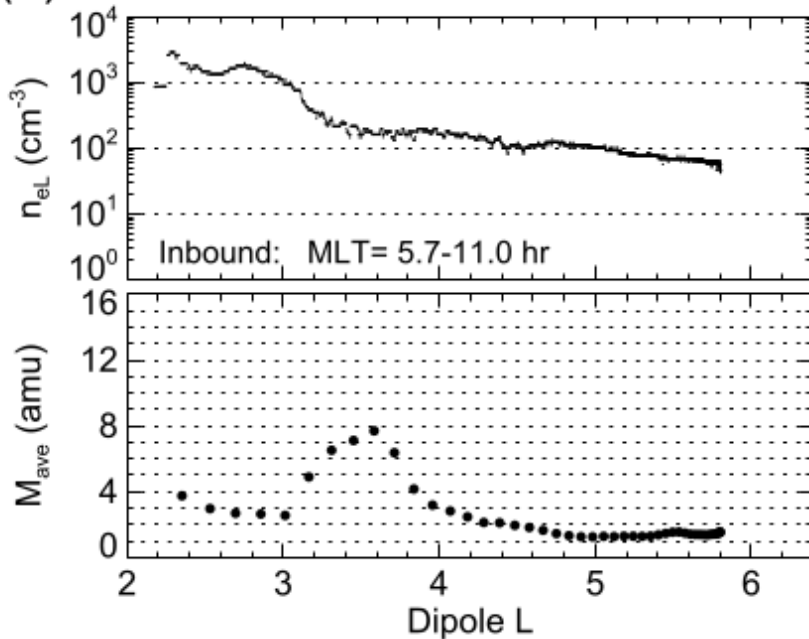


# More examples of the O<sup>+</sup> shell



[Nosé et al., JGR, 2015]

(a) Probe A 2012/11/15 06:38-10:30 UT



(b) Probe B 2012/11/15 07:26-11:20 UT

