NRL SAMI2/3 IONOSPHERE MODELS AT CCMC AND FUTURE UPGRADES

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SAMI2/3 AT CCMC

- magnetic field: IGRF-like
- 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
- chemistry: 21 reactions + recombination
- photoionization: Daytime (EUVAC) and nighttime

- ion continuity

$$\frac{\partial n_i}{\partial t} + \nabla \cdot (n_i \mathbf{V}_i) = P_i - L_i n_i$$

- ion velocity

$$\frac{\partial \mathbf{V}_i}{\partial t} + \mathbf{V}_i \cdot \nabla \mathbf{V}_i) = -\frac{1}{\rho_i} \nabla \mathbf{P}_i + \frac{e}{m_i} \mathbf{E} + \frac{e}{m_i c} \mathbf{V}_i \times \mathbf{B} + \mathbf{g}$$

$$-\nu_{in}(\mathbf{V}_i - \mathbf{V_n}) - \sum_j \nu_{ij} \left(\mathbf{V}_i - \mathbf{V}_j\right)$$

- ion temperature

$$\frac{\partial T_i}{\partial t} + \mathbf{V}_i \cdot \nabla T_i + \frac{2}{3} T_i \nabla \cdot \mathbf{V}_i + \frac{2}{3} \frac{1}{n_i k} \nabla \cdot \mathbf{Q}_i = Q_{in} + Q_{ij} + Q_{ie}$$

- electron momentum

$$0 = -\frac{1}{n_e m_e} b_s \frac{\partial P_e}{\partial s} - \frac{e}{m_e} E_s$$

- electron temperature

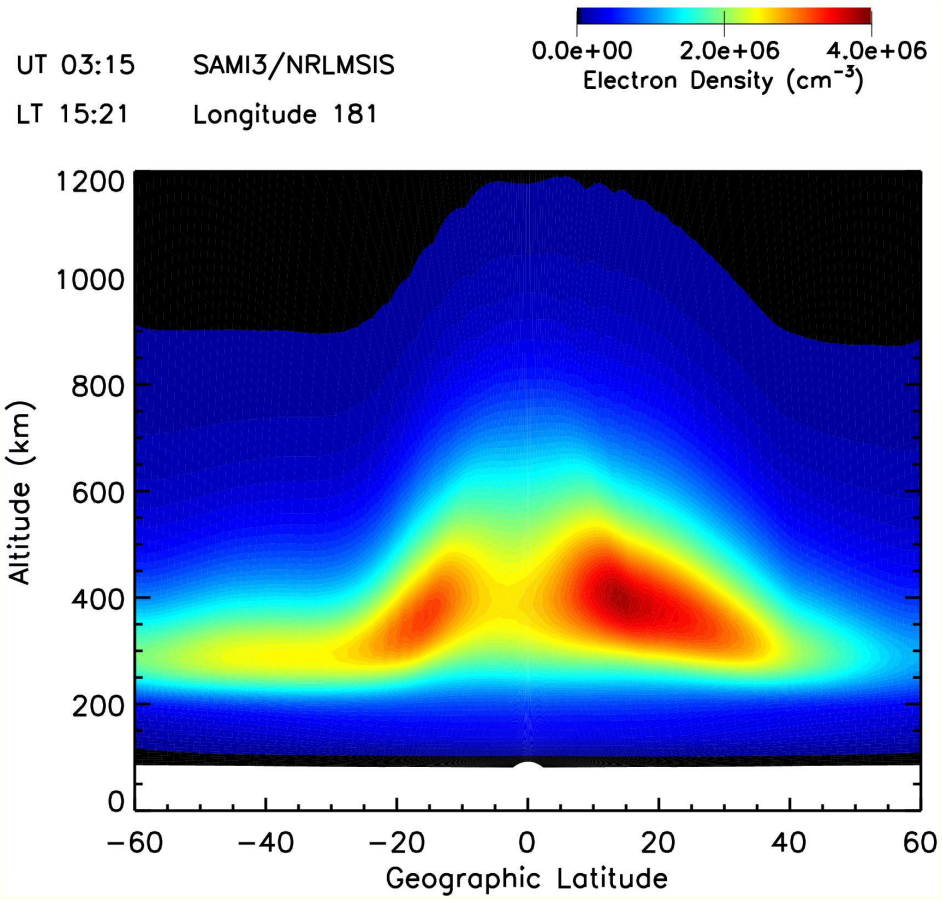
$$\frac{\partial T_e}{\partial t} - \frac{2}{3}\frac{1}{n_e k} b_s^2 \frac{\partial}{\partial s} \kappa_e \frac{\partial T_e}{\partial s} = Q_{en} + Q_{ei} + Q_{phe}$$

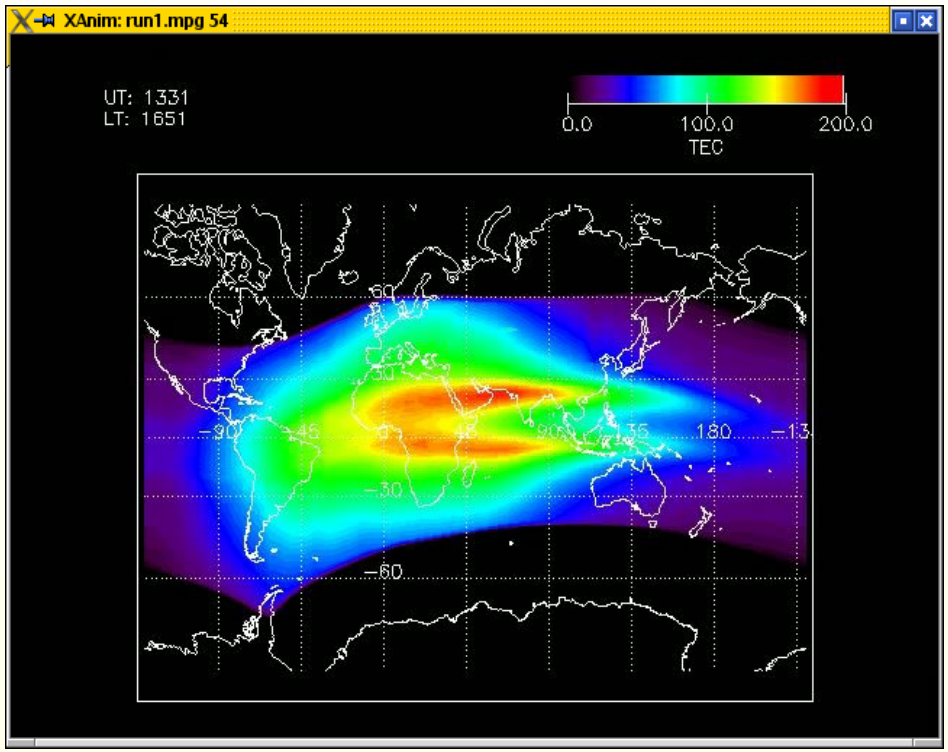
EMPIRICAL MODELS

- NRLMSISE-00 (Picone et al)
  - neutral composition H, He, O, N, N_2, O_2
  - neutral temperature T_n
- HWM93 (Hedin)
  - neutral wind V_n (meridional/zonal)
- electric field (Fejer/Scherliess)
  - $E \times B$ drift V_E (vertical at magnetic equator)

EXAMPLE OUTPUT

SAMI2 (electron density contour); SAMI3 (TEC)





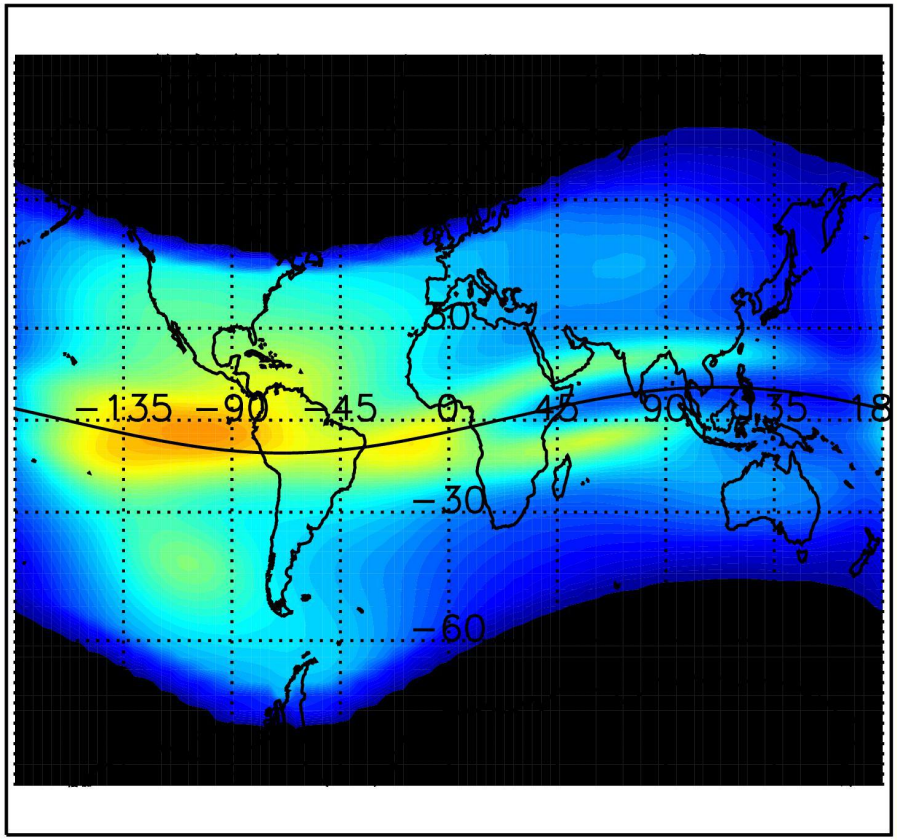
UPGRADES

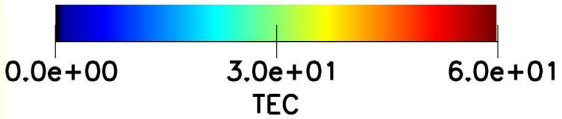
- neutral wind dynamo electric field
- IGRF (with Gang Lu)
- SAMI3/Volland-Stern/Weimer
- SAMI3/RCM
- flux corrected transport (4th order, partial donor cell method)

IGRF

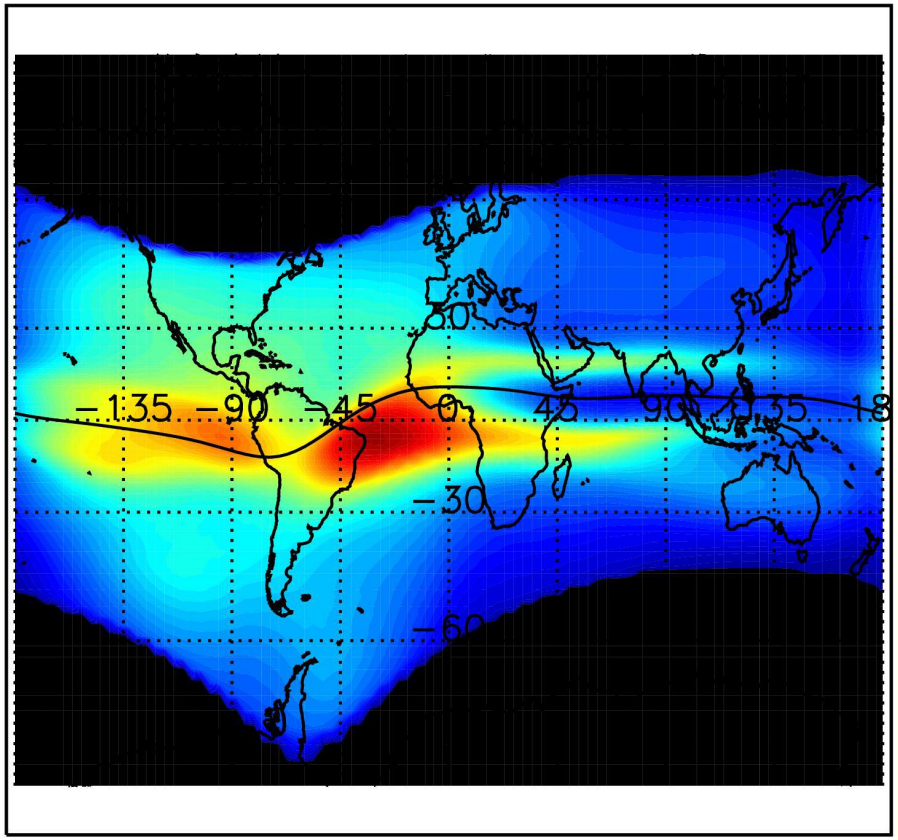
preliminary results

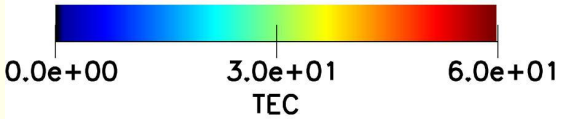
TILTED: HWM93





APEX: HWM93



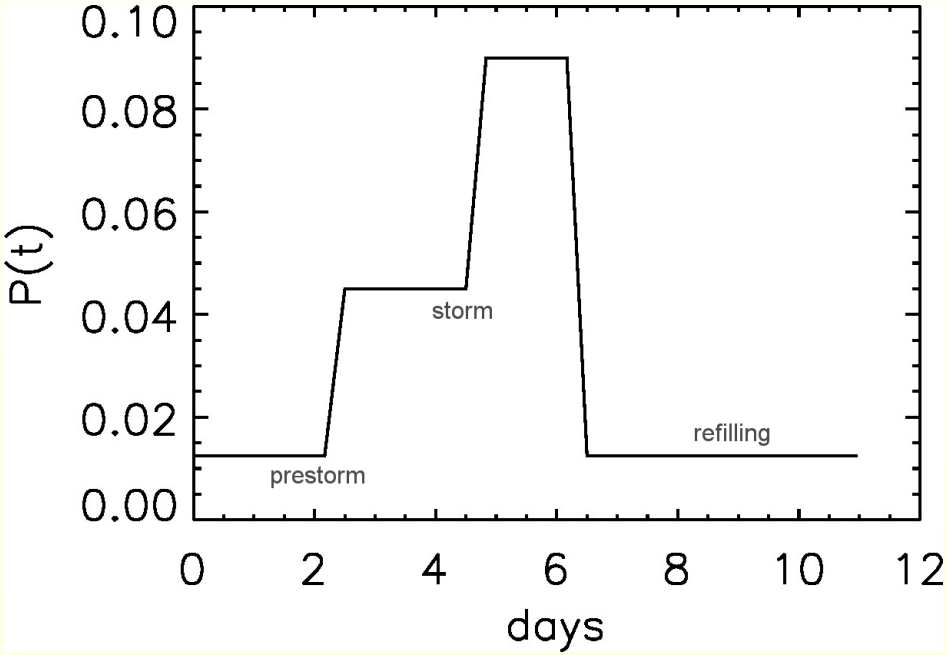


- corotation potential

$$\Phi_{\rm cor} = -92/r({\rm kV})$$

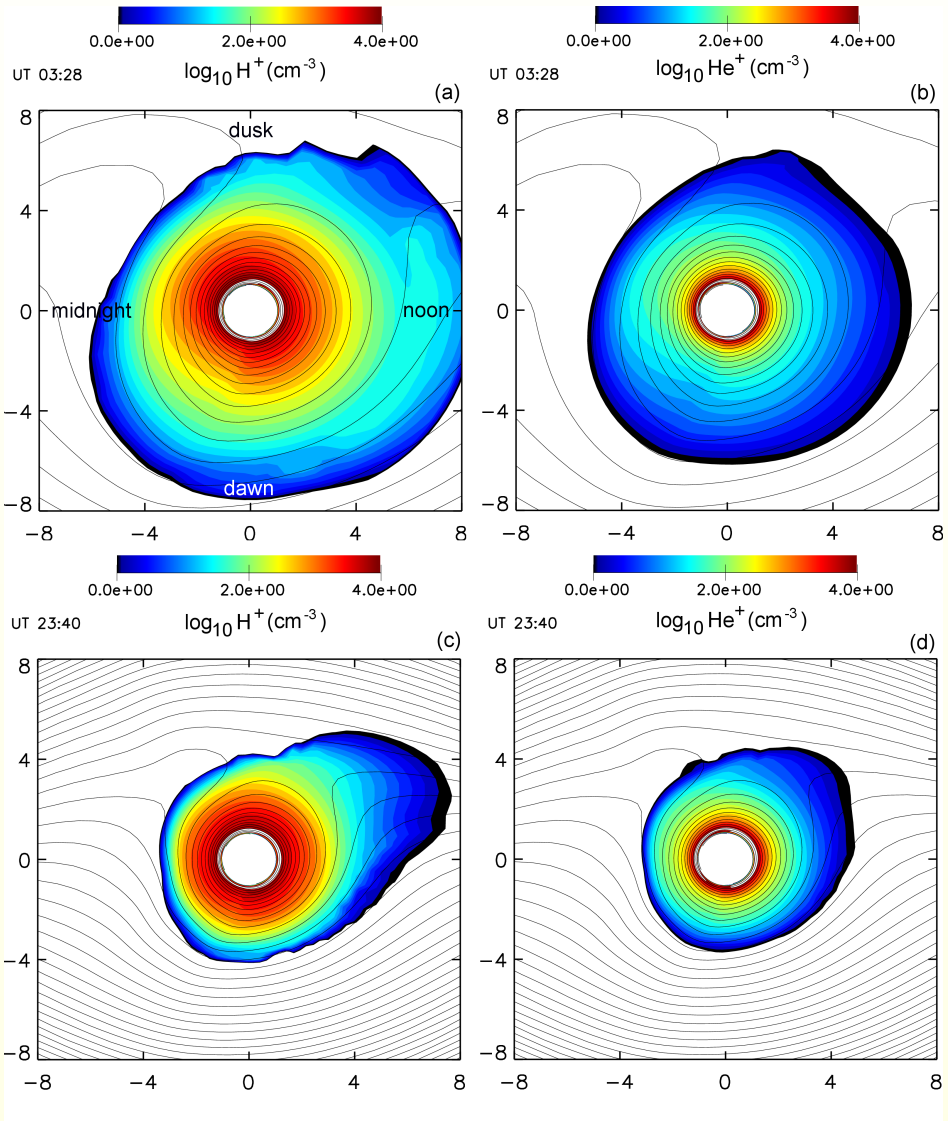
- volland/stern/maynard/chen potential $(K_p = 6)$

$$\Phi_{\rm vsmc} = Ar^2 \sin(\phi) \quad A = \frac{P(t)}{(1. - 0.159K_p + 0.0093K_p^2)^3}({\rm kV})$$



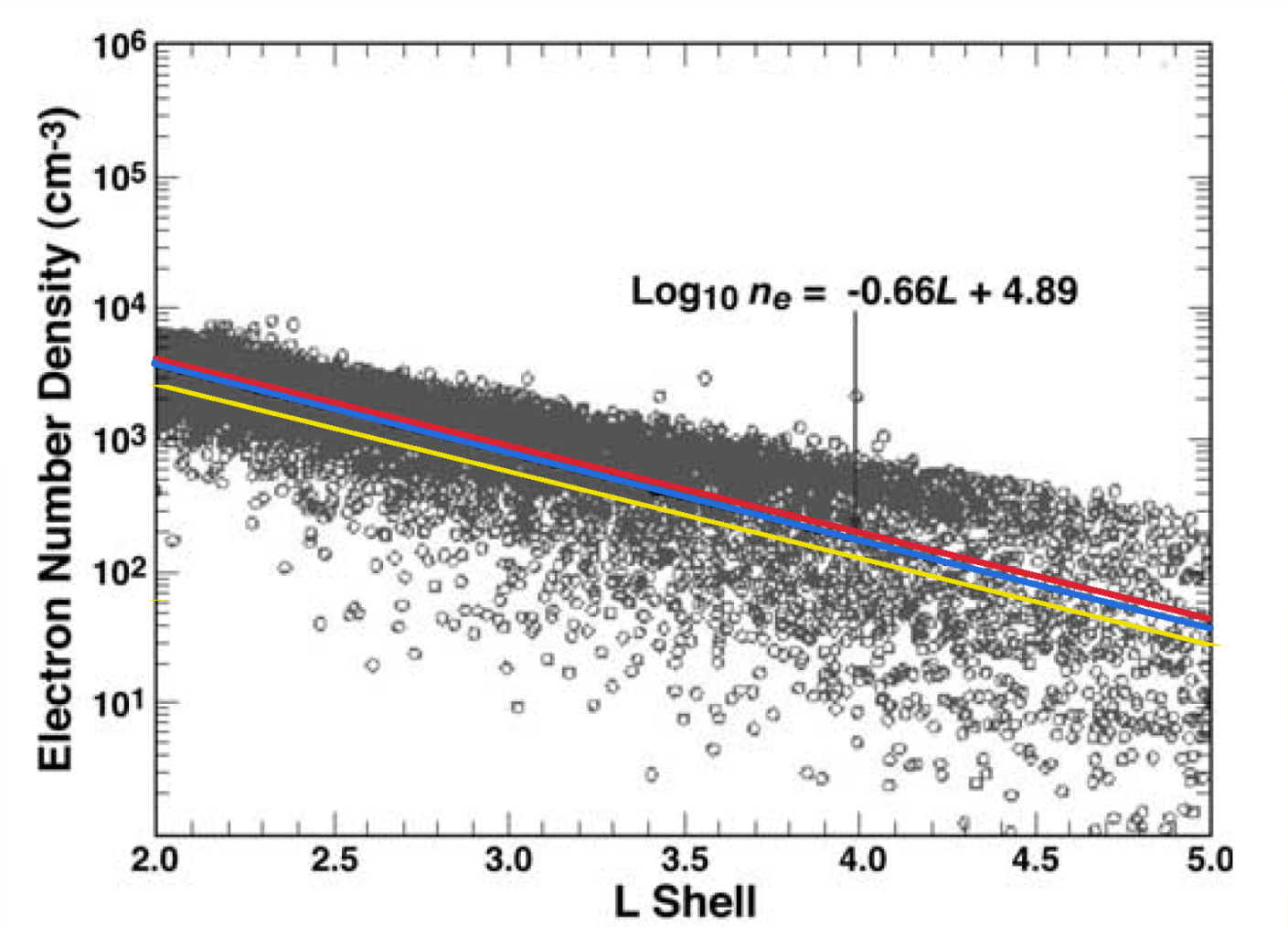
H^+/He^+ CONTOURS

hydrogen / helium ion density contours at t = 52 hrs and 96 hrs in equatorial plane



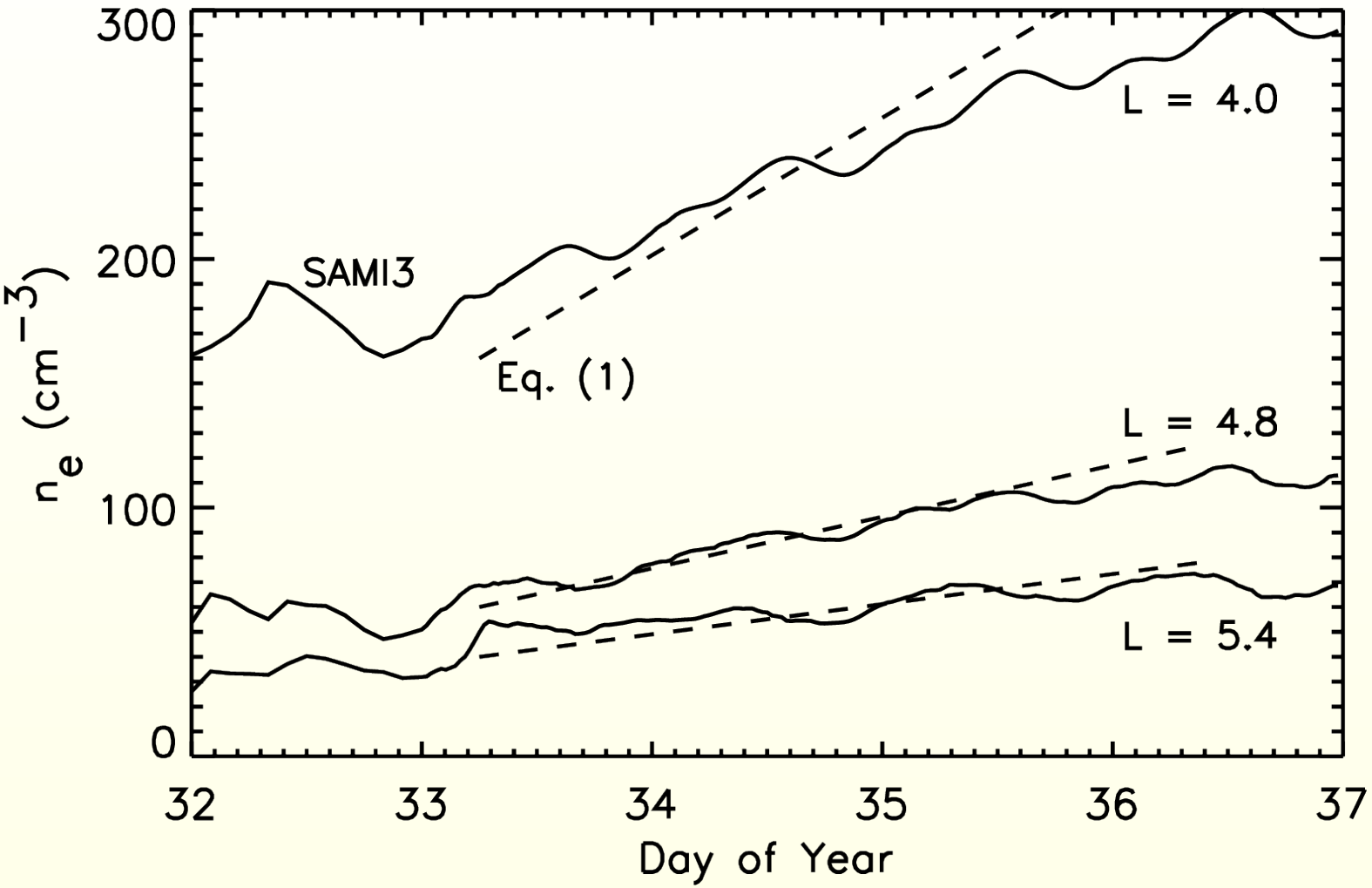
ELECTRON DENSITY AND SAMI3 DATA

line plots of electron density vs L shell; empirical relationship (Berube et al., JGR, 2005)



SAMI3 REFILLING

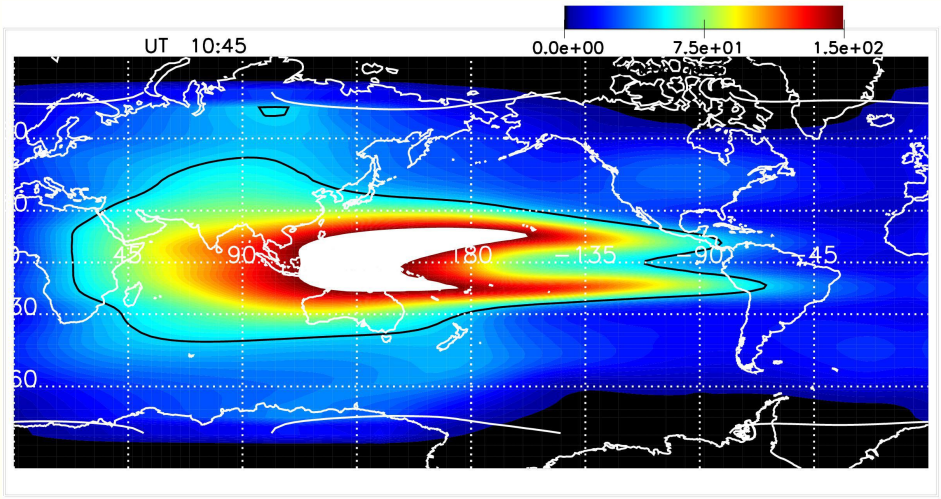
use Weimer model

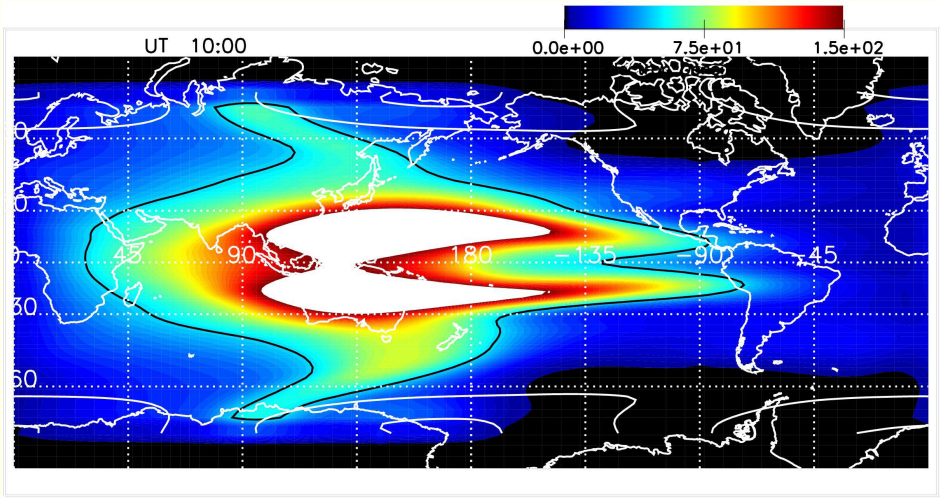


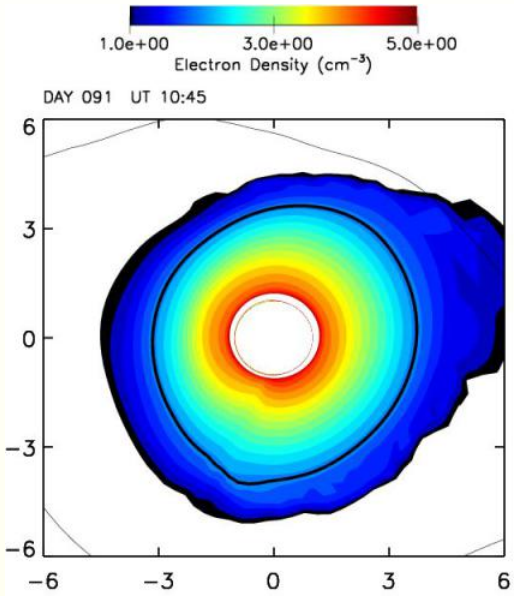
$$dn_e/dt = 3.81(6.8/L)^{4.94}\mathrm{cm}^{-3}\mathrm{day}^{-1} \qquad (1)$$

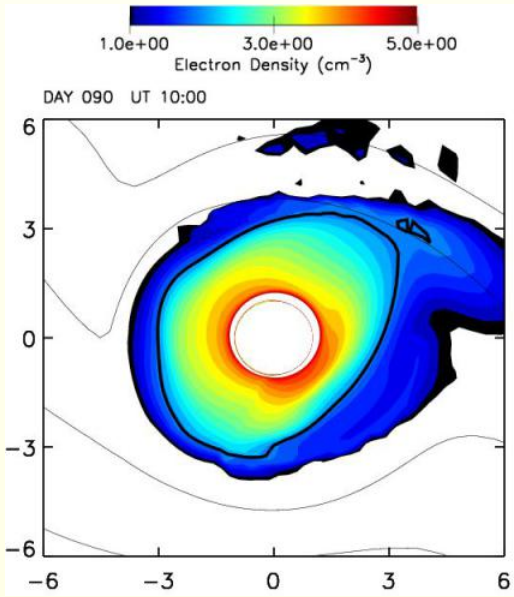
SAMI3/RCM

march 29, 2001 storm (preliminary results)



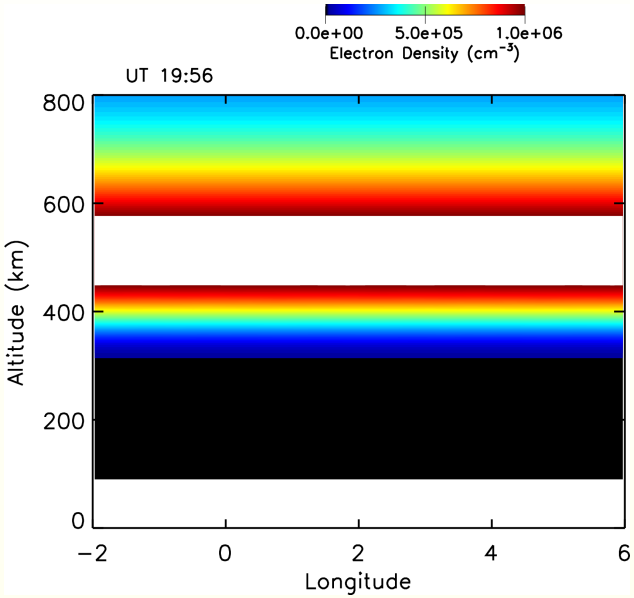


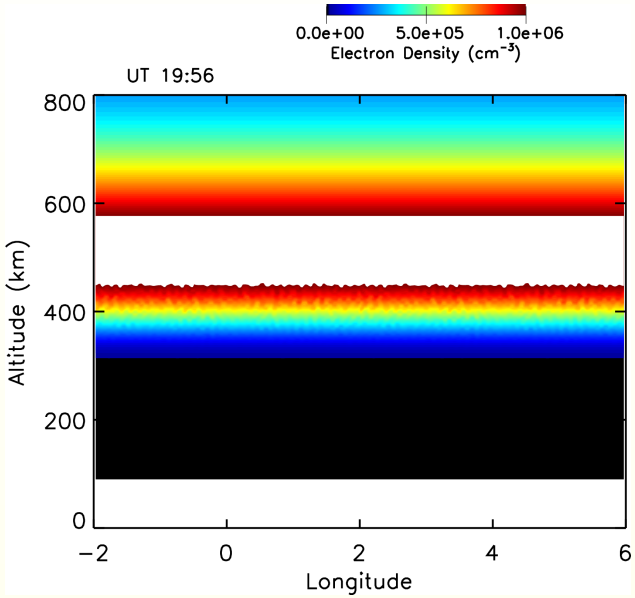


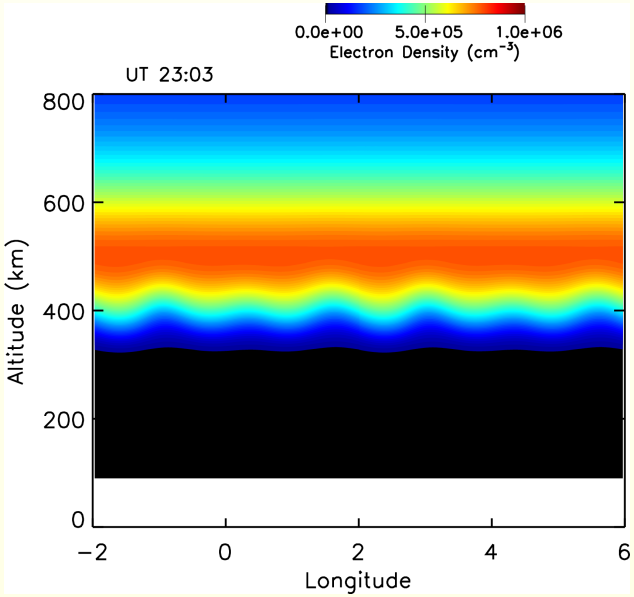


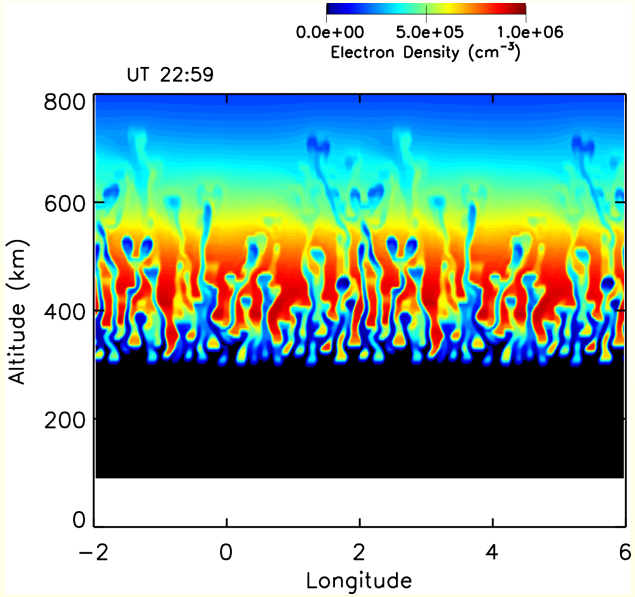
LOW/HIGH ORDER SAMI3

sami3/esf (uniform 100 m/s zonal wind)



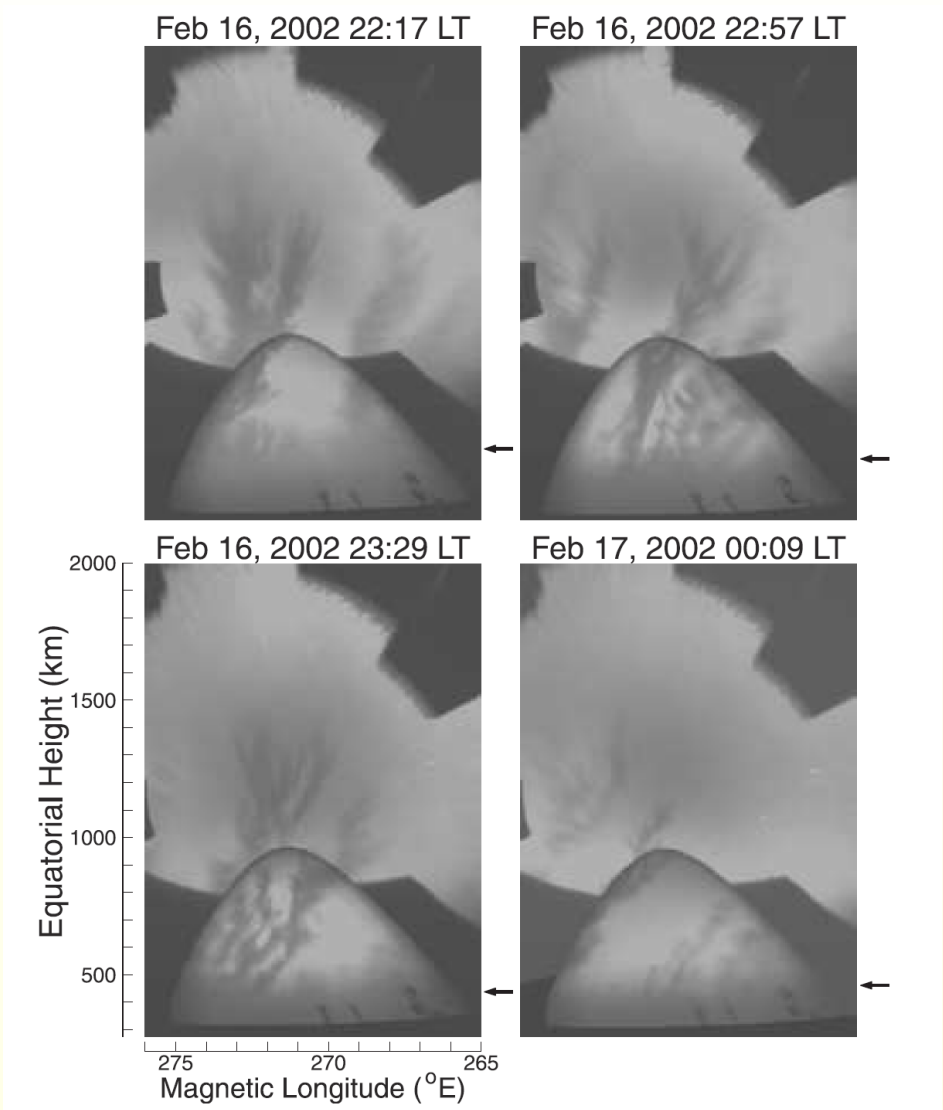


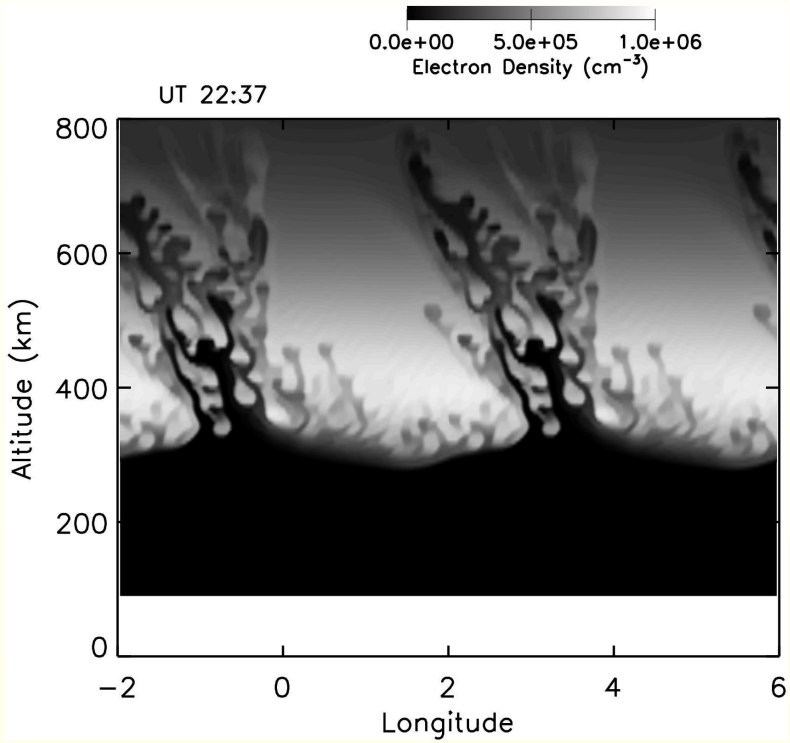




SAMI3/ESF

data (kelley et al., 2003) and simulation (HWM93 zonal wind)

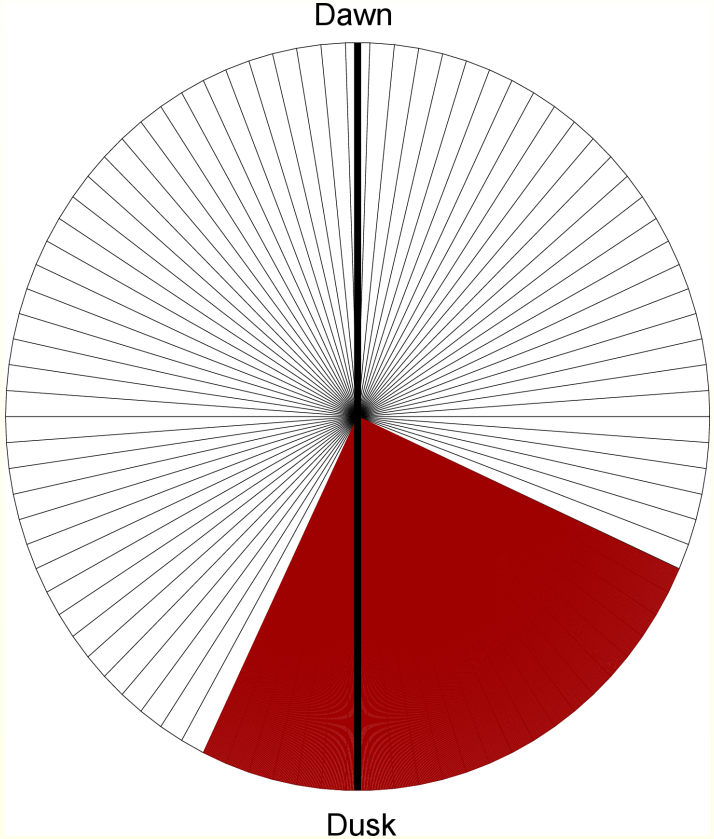




GLOBAL SOLUTION

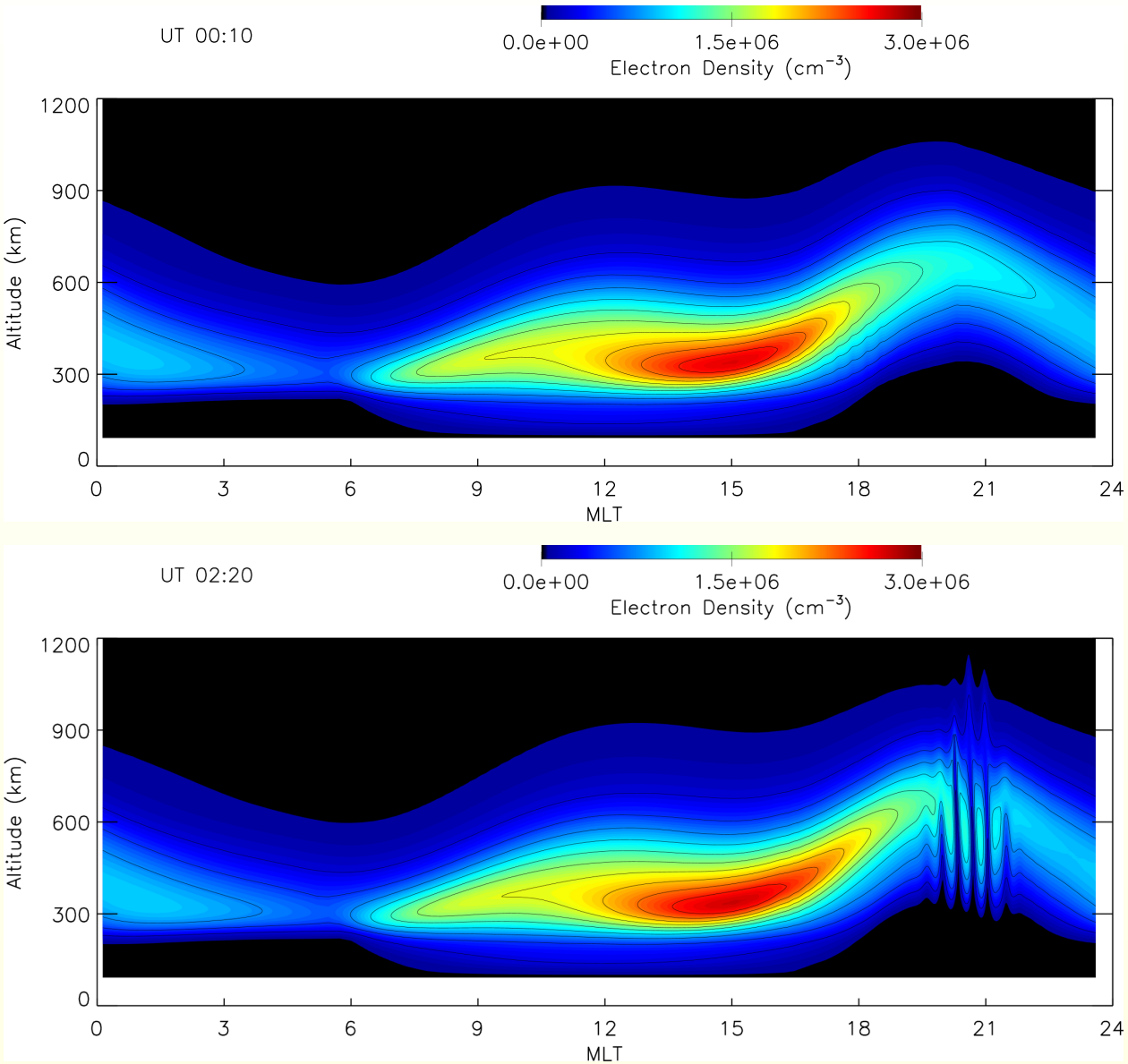
incorporate a high-resolution grid in a global model, i.e., SAMI3

- reference frame: copernican (sun-fixed: rotating earth)
- coarse mesh: 90 grid points
- zonal resolution $\sim$ 500 km
- high resolution mesh: 956 grid points between $\sim$ 16:30 MLT - 22:30 MLT
- zonal resolution $\sim .0625^{\circ}$ or $\sim$ 7 km



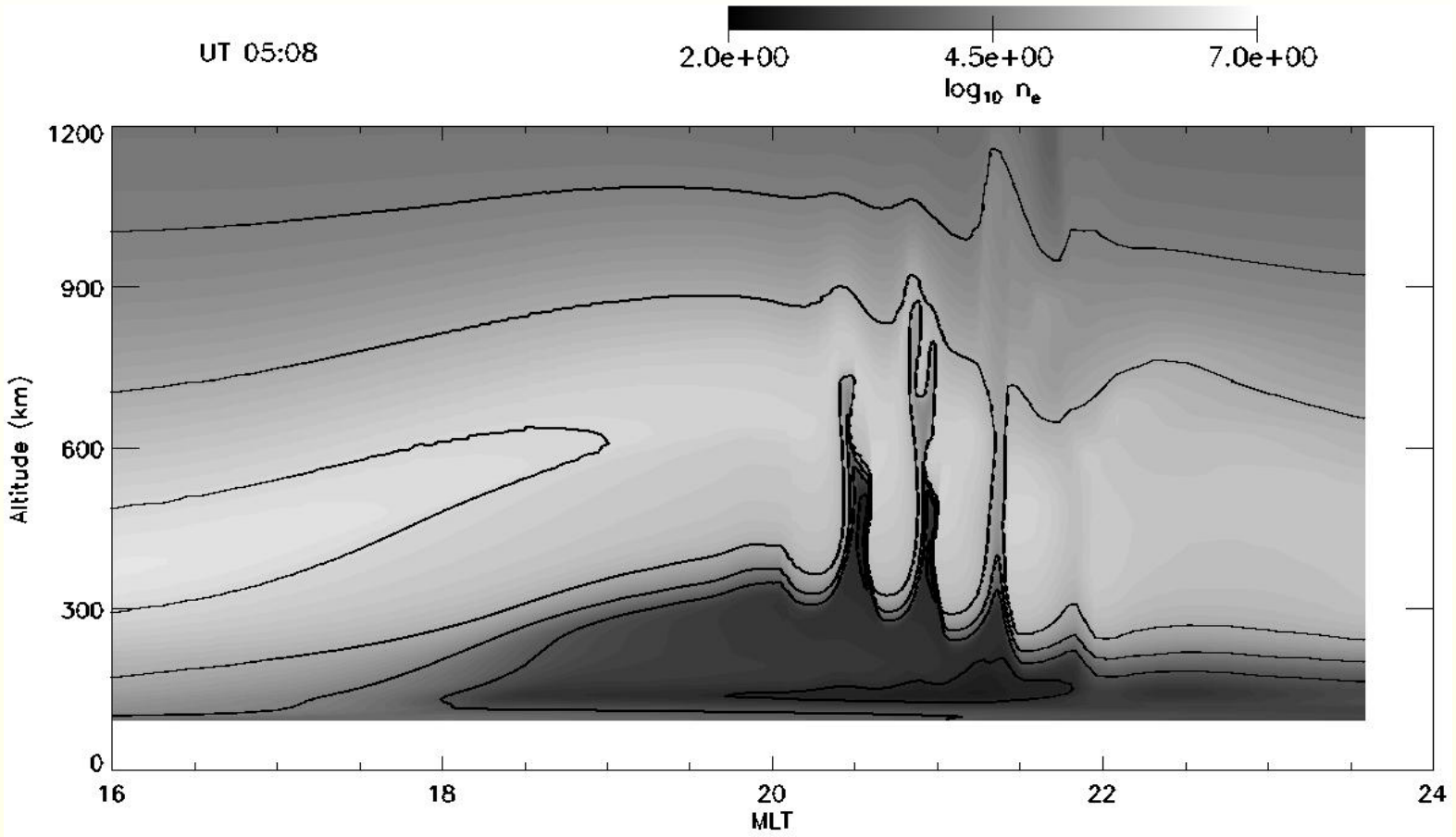
FIRST GLOBAL MODEL OF ESF

Huba and Joyce, *GRL*, 2010



APPLICATION TO SAMI3

hi-res global code (under development)



FUTURE UPGRADES AT CCMC: SAMI3

- global low- to mid-latitude ionosphere model with IGRF magnetic field
- global low- to high-latitude ionosphere model with Volland/Stern/Maynard/Chen and Weimer potentials
- global low- to high-latitude ionosphere model with RCM potential