SAMI3 PREDICTION OF THE IMPACT OF THE AUGUST 21, 2017 TOTAL SOLAR ECLIPSE ON THE IONOSPHERE - PLASMASPHERE SYSTEM

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with D. Drob and E. Astafyeva

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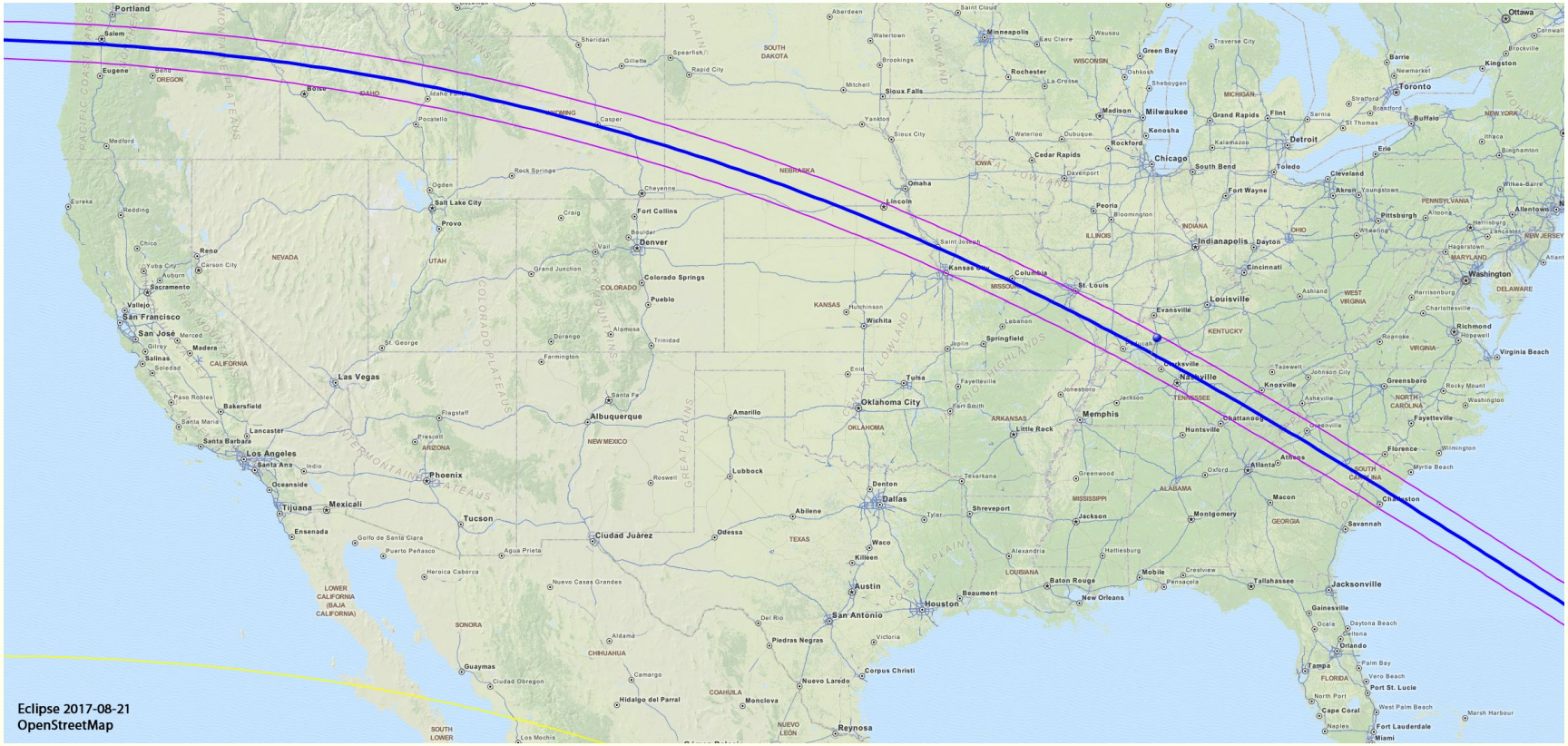
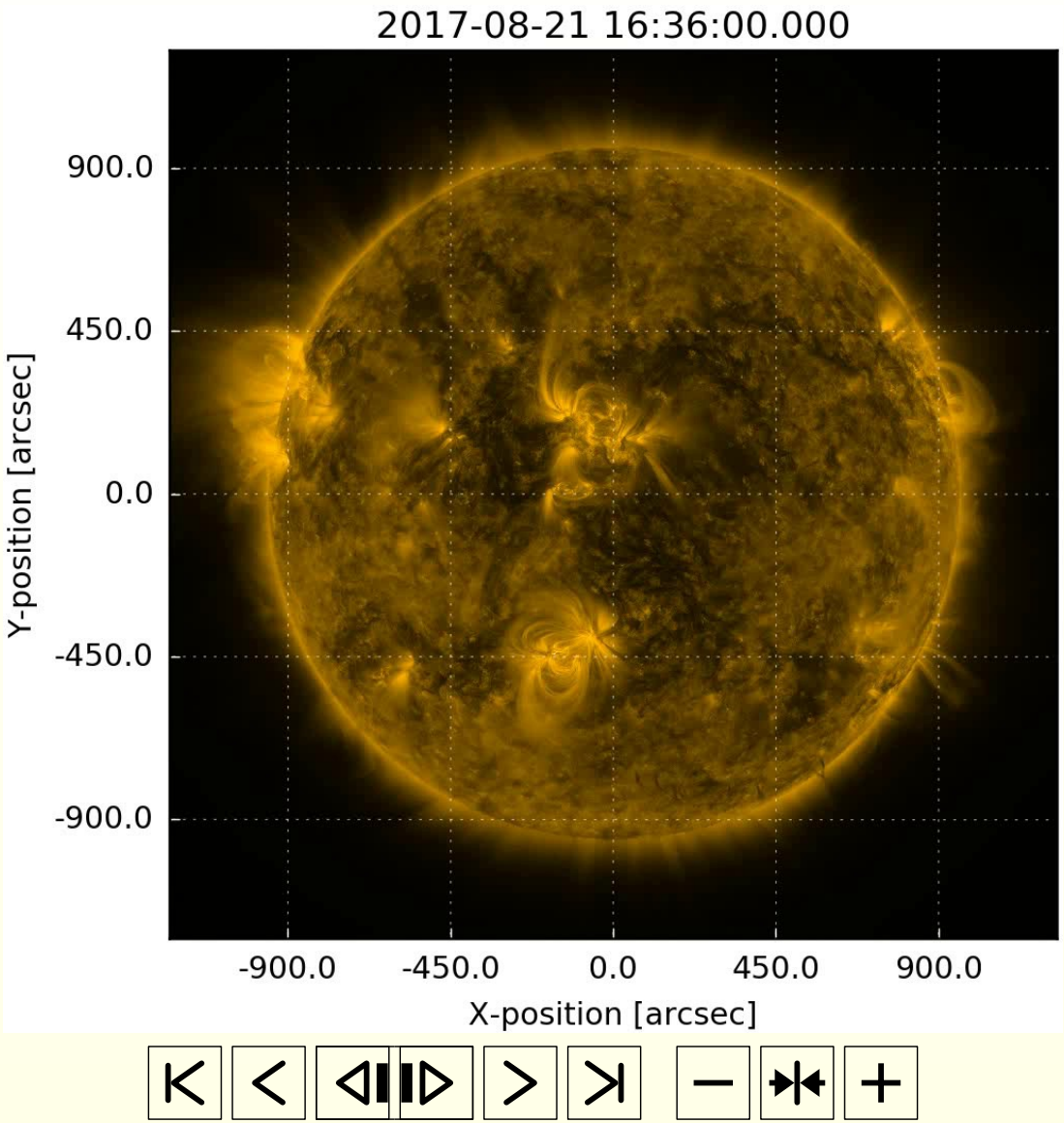
PATH OF SOLAR ECLIPSE

over continental USA (21 August 2017)



SOLAR ECLIPSE



PLASMA DYNAMICS: IONS

H^+,O^+,He^+,N^+,N_2^+,NO^+,O_2^+

- ion continuity

$$\frac{\partial n_i}{\partial t} + \nabla \cdot (n_i \mathbf{V}_i) = \mathcal{P}_i - \mathcal{L}_i n_i$$

- ion velocity

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

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

- ion temperature

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

PLASMA DYNAMICS: ELECTRONS

- 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

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

POTENTIAL EQUATION

based on current conservation: $\nabla \cdot \mathbf{J} = 0$ and equipotential field lines

$$\nabla \cdot \underline{\underline{\Sigma}} \cdot \nabla \Phi = S(V_n)$$

$$\mathbf{E} = -\nabla \Phi$$

where

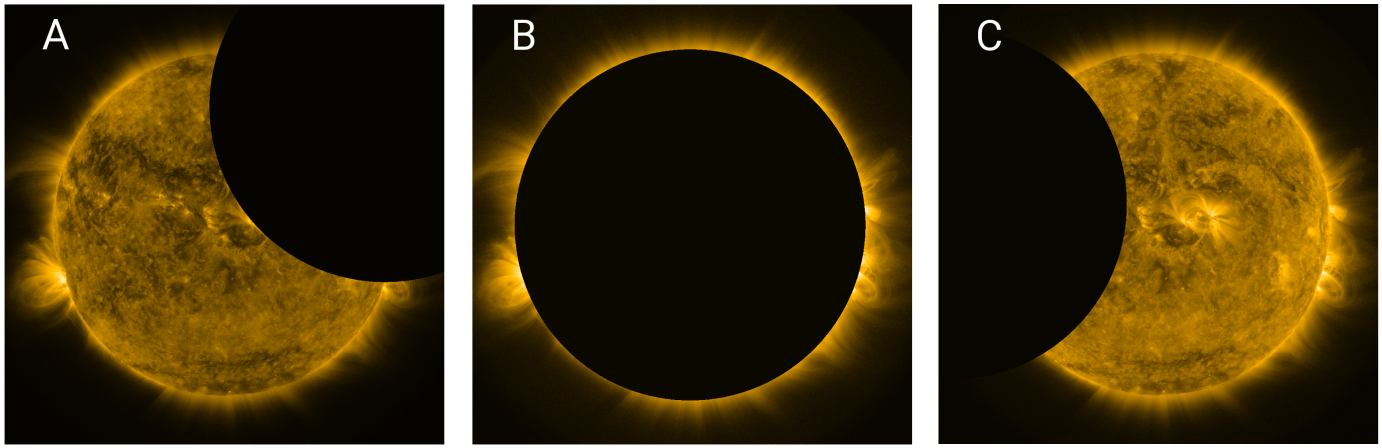
$$\underline{\underline{\Sigma}} \propto \sigma_P, \sigma_H$$

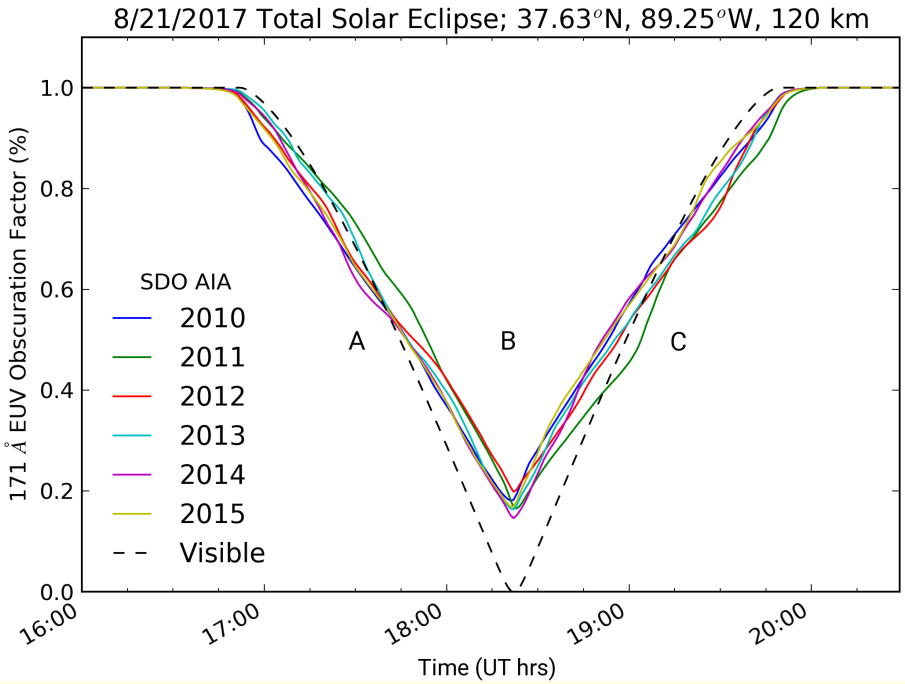
$$\sigma_P = \sum_i \frac{n_i e c}{B} \frac{\nu_{in}/\Omega_i}{1 + \nu_{in}^2/\Omega_i^2} + \frac{n_e e c}{B} \frac{\nu_{en}/\Omega_e}{1 + \nu_{en}^2/\Omega_e^2}$$

$$\sigma_H = -\sum_i \frac{n_i e c}{B} \frac{1}{1 + \nu_{in}^2/\Omega_i^2} + \frac{n_e e c}{B} \frac{1}{1 + \nu_{en}^2/\Omega_e^2}$$

EUV OBSCURATION

uses Solar Dynamics Observatory (SDO) data and NOVAS





EUV MASK

used in SAMI3

- start of eclipse (oregon)

  t_i = 17:15 UT at $\theta_i = 44°$ and $\phi_i = 236°$
- end of eclipse (south carolina)

  t_f = 18:49 UT at $\theta_f = 33°$ and $\phi_f = 281°$
- radius of obsuration $R_o = V_e \tau_o \sim 4000$ km
  (where $V_e \simeq 0.7$ km/s and $\tau_o \simeq 95$ min)

$$M(r,t) = \begin{cases} 1 & r \geq R_o \\ 0.15 + 0.85|r - R_e(t)|/R_o & r < R_o \end{cases}$$

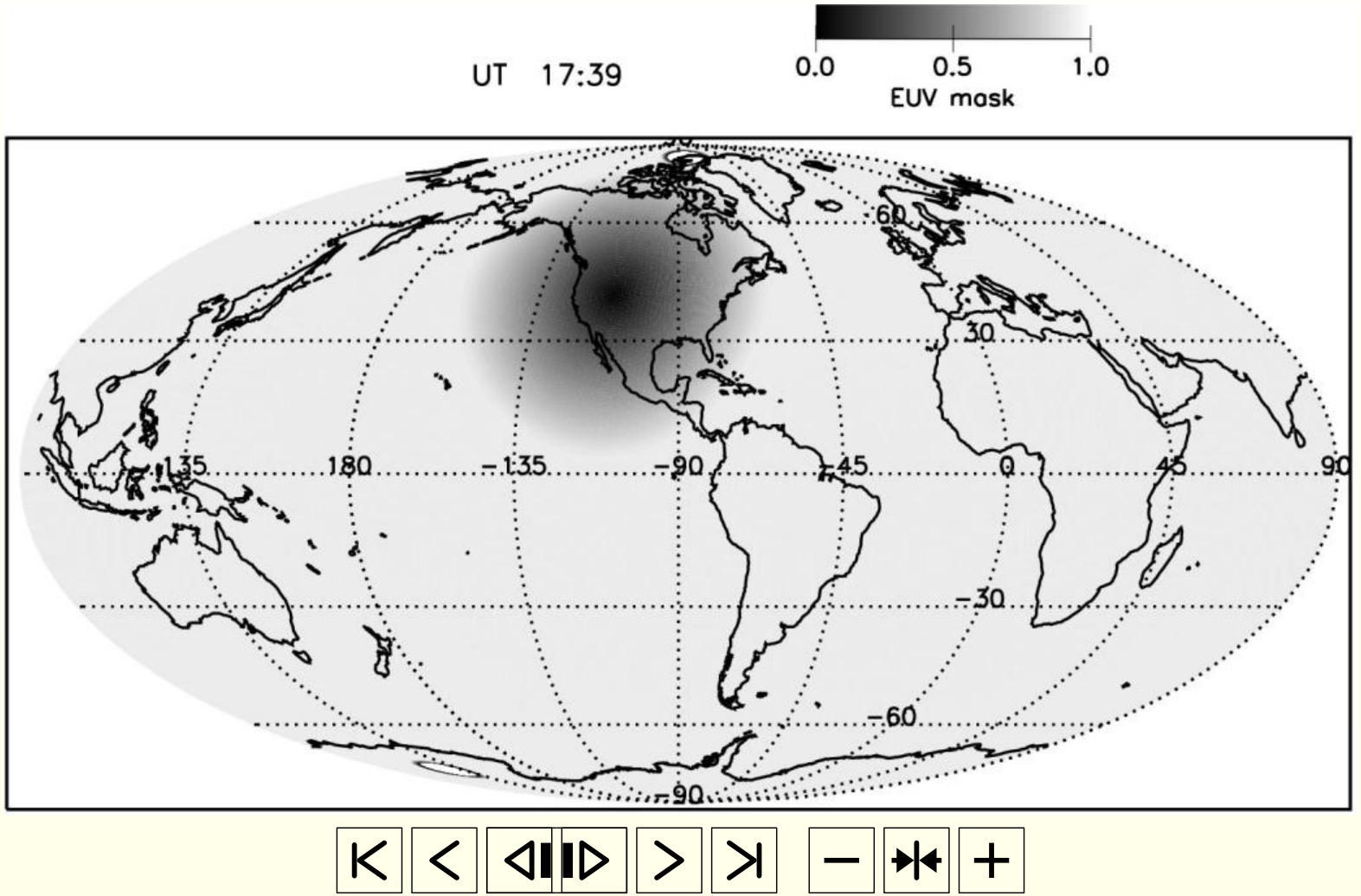
where r is the position of a SAMI3 grid point projected onto the surface of the earth and R_e is the position of the total solar eclipse on the earth

SAMI3 SIMULATIONS

- two sets of simulations: eclipse and no eclipse
  to quantify effect of eclipse on the system
- geophysical parameters (quiet)
  - day-of-year: 233 (21 aug 2017)
  - F10.7 $= 90$
  - F10.7A $= 90$
  - Ap $= 4$
- grid
  - nz $= 204$ (number of cells along B)
  - nf $= 124$ (number of 'field lines' - latitude $\Delta\theta \lesssim 1^\circ$)
  - nl $= 360$ (number of longitudes - longitude $\Delta\phi = 1^\circ$)
- magnetic field: Richmond apex model (IGRF)

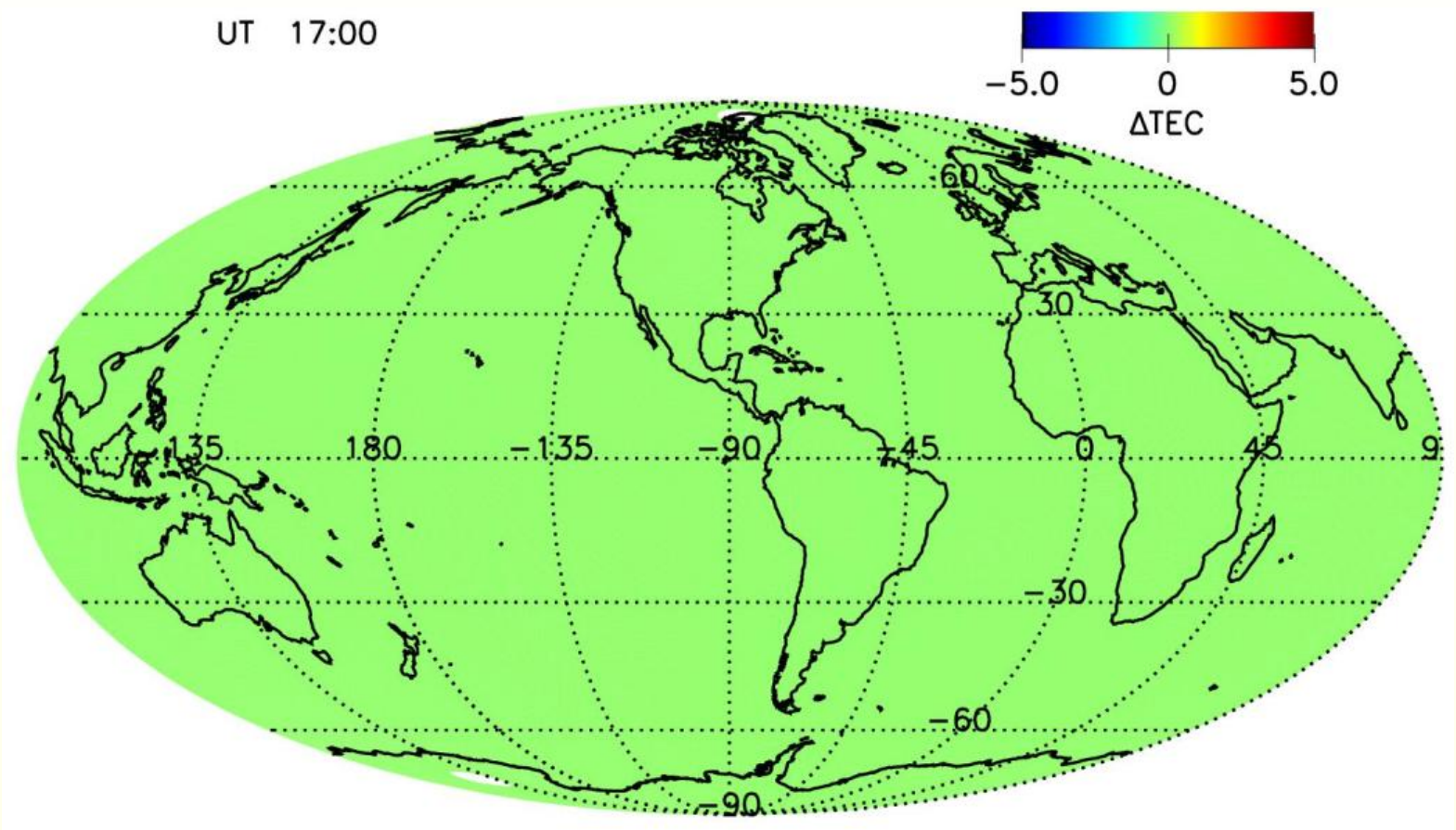
EUV MASK

used in SAMI3



ΔTEC AND $\Delta\phi$

eclipse - no eclipse



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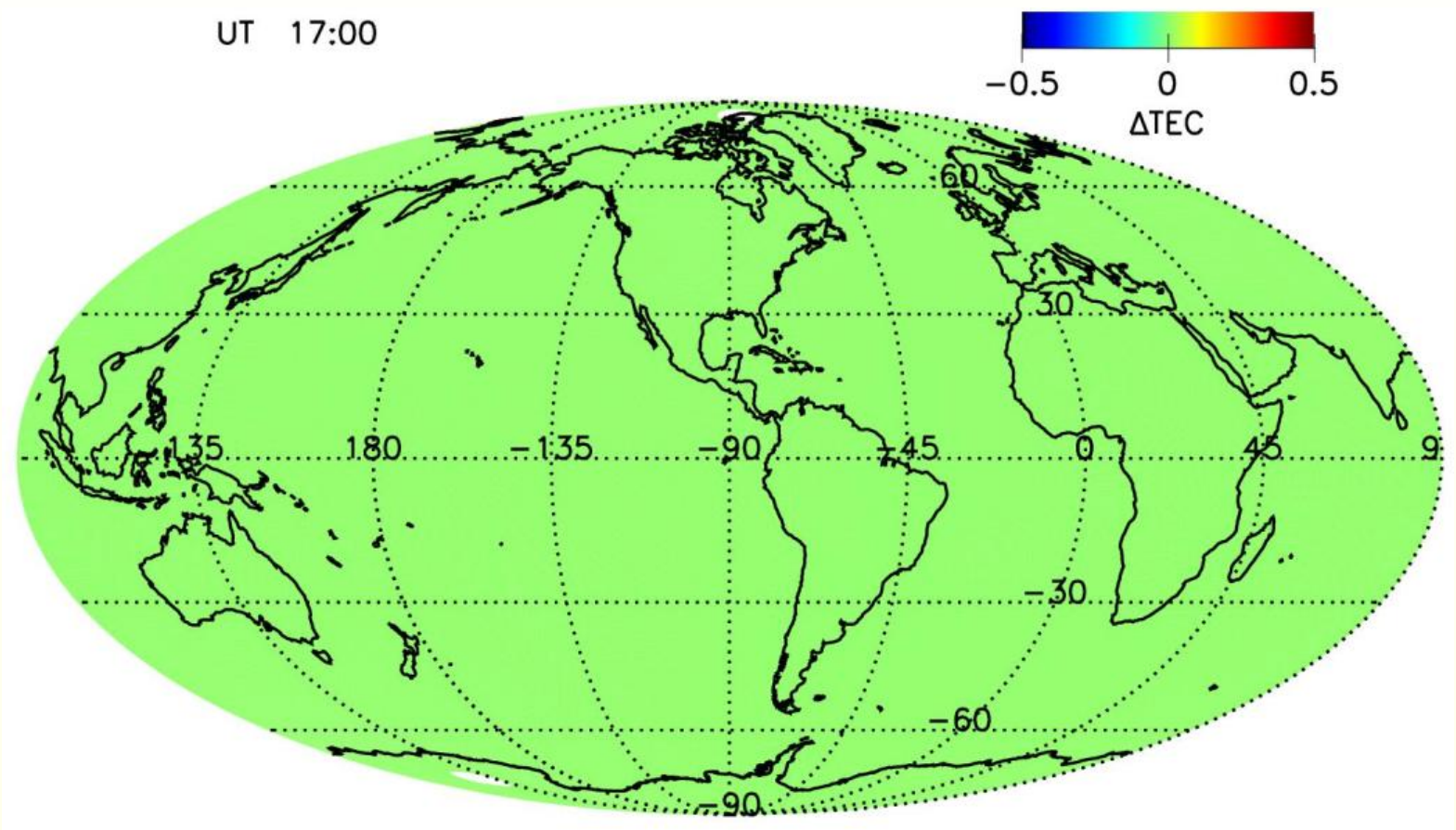
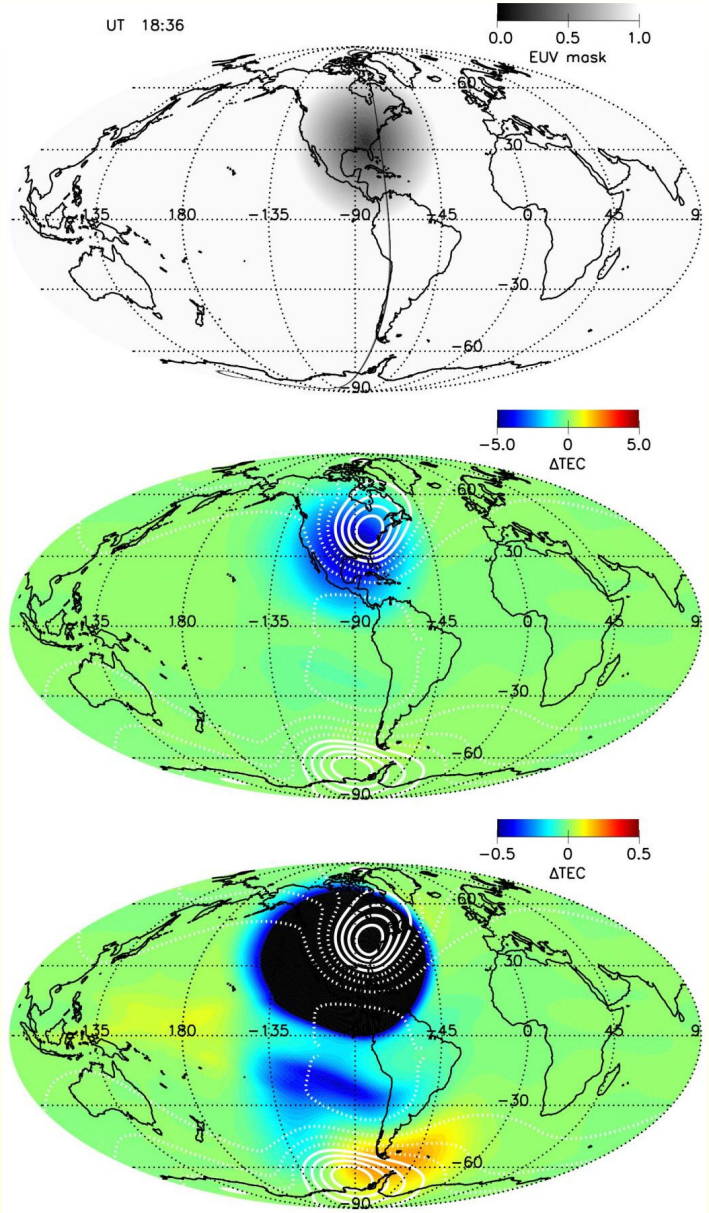


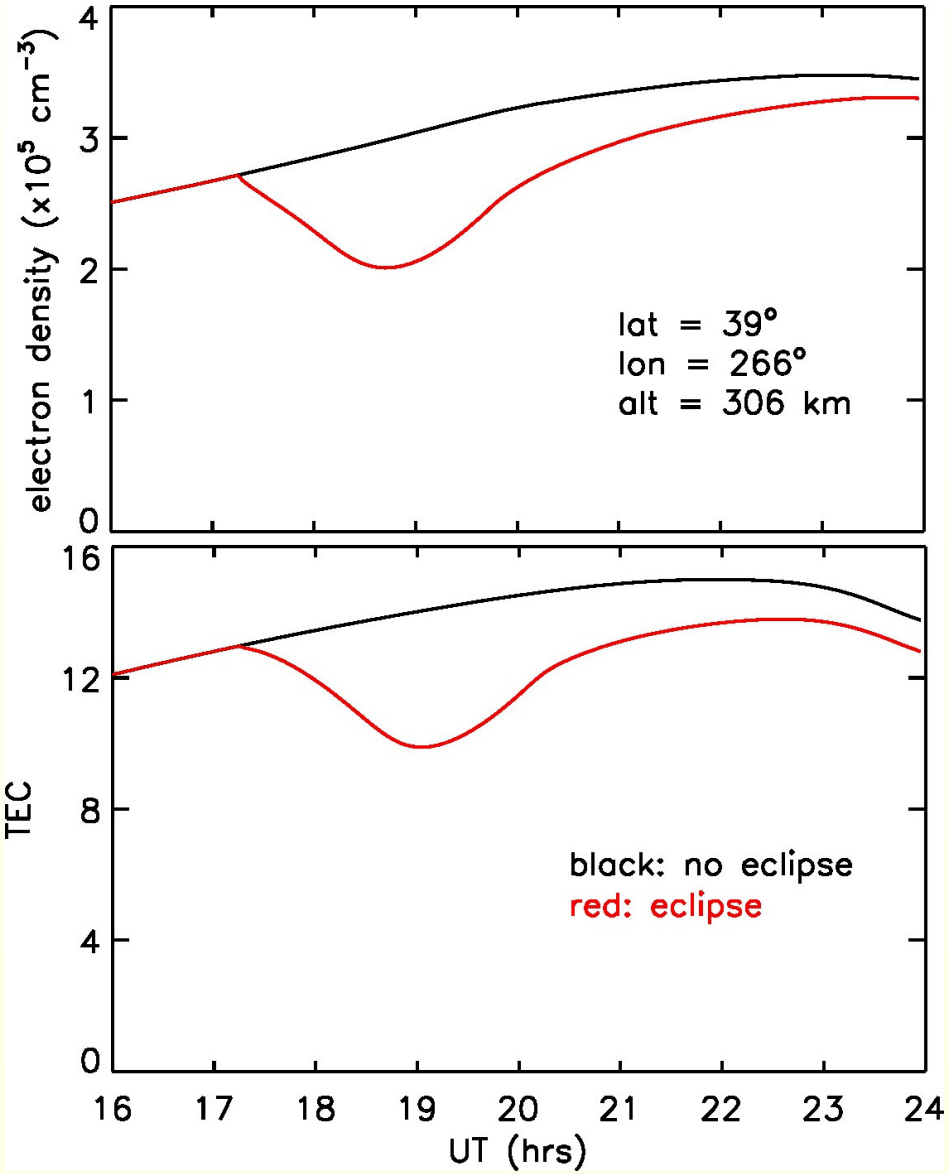
EUV mask and ΔTEC

18:36 UT



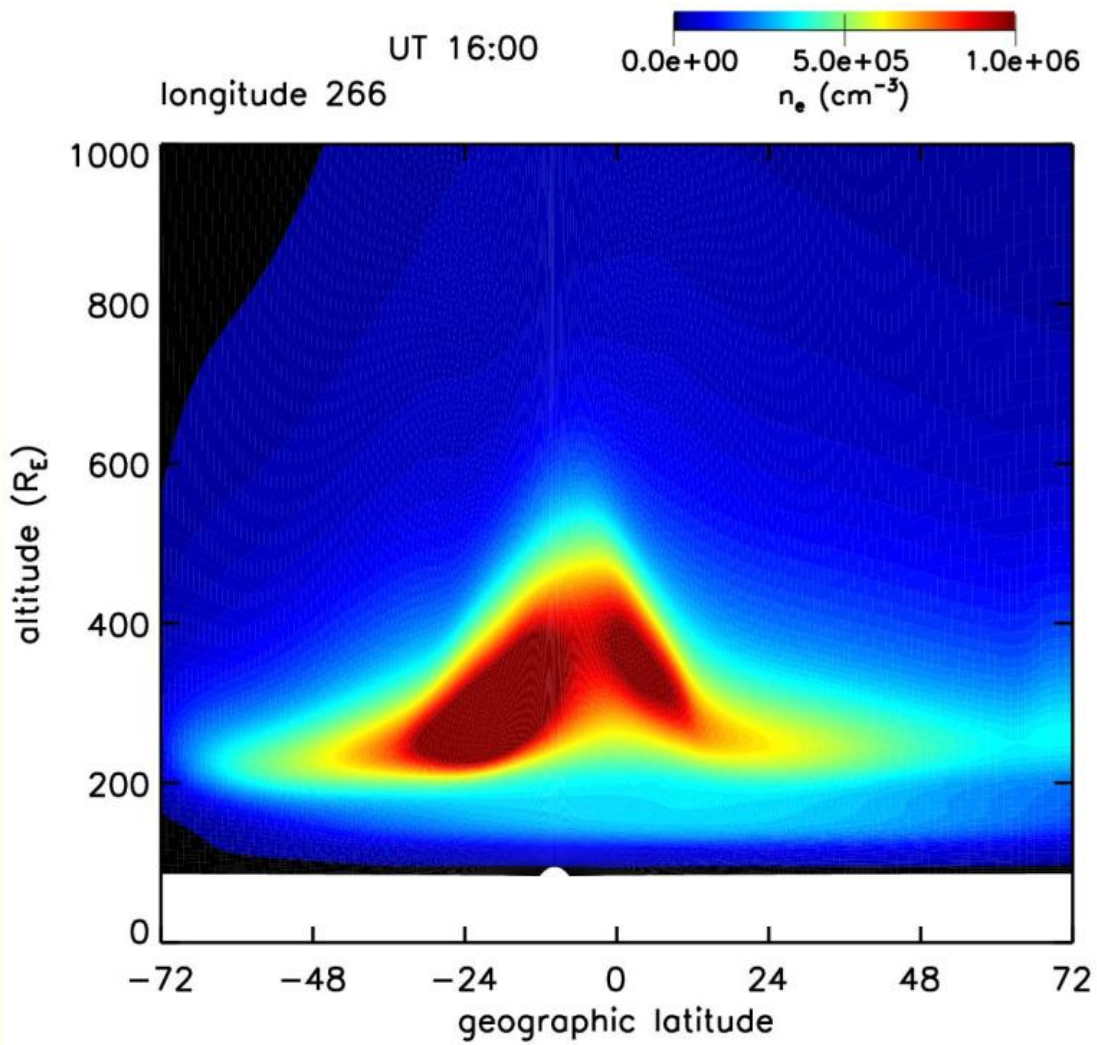
ELECTRON DENSITY AND TEC VS UT

over dick hubbard's farm



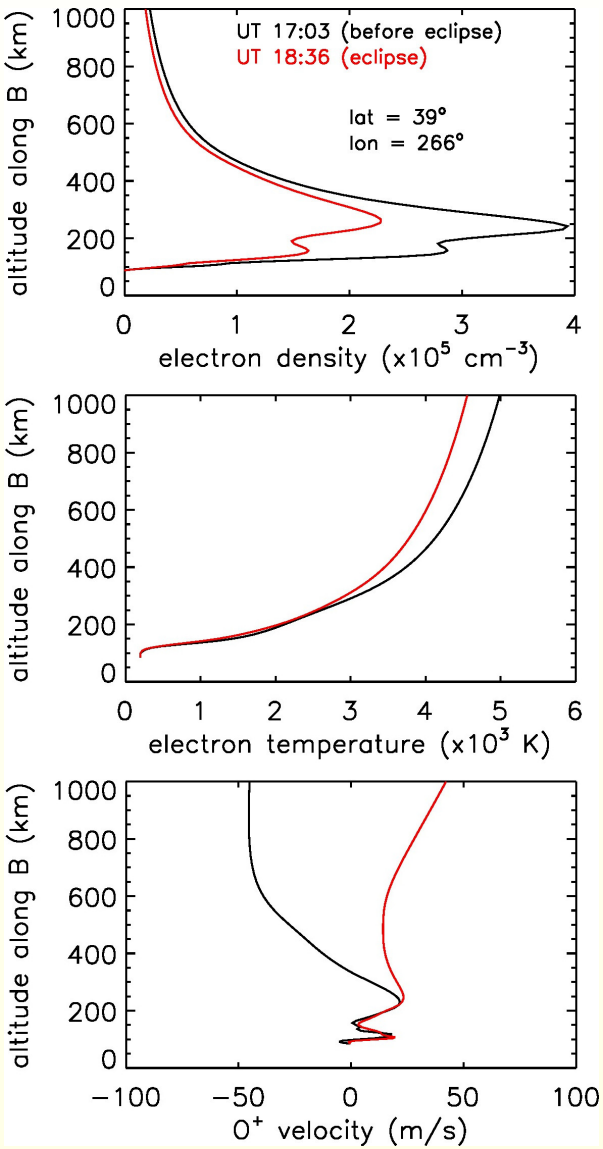
ELECTRON DENSITY

latitude vs altitude at $\phi = 266^\circ$



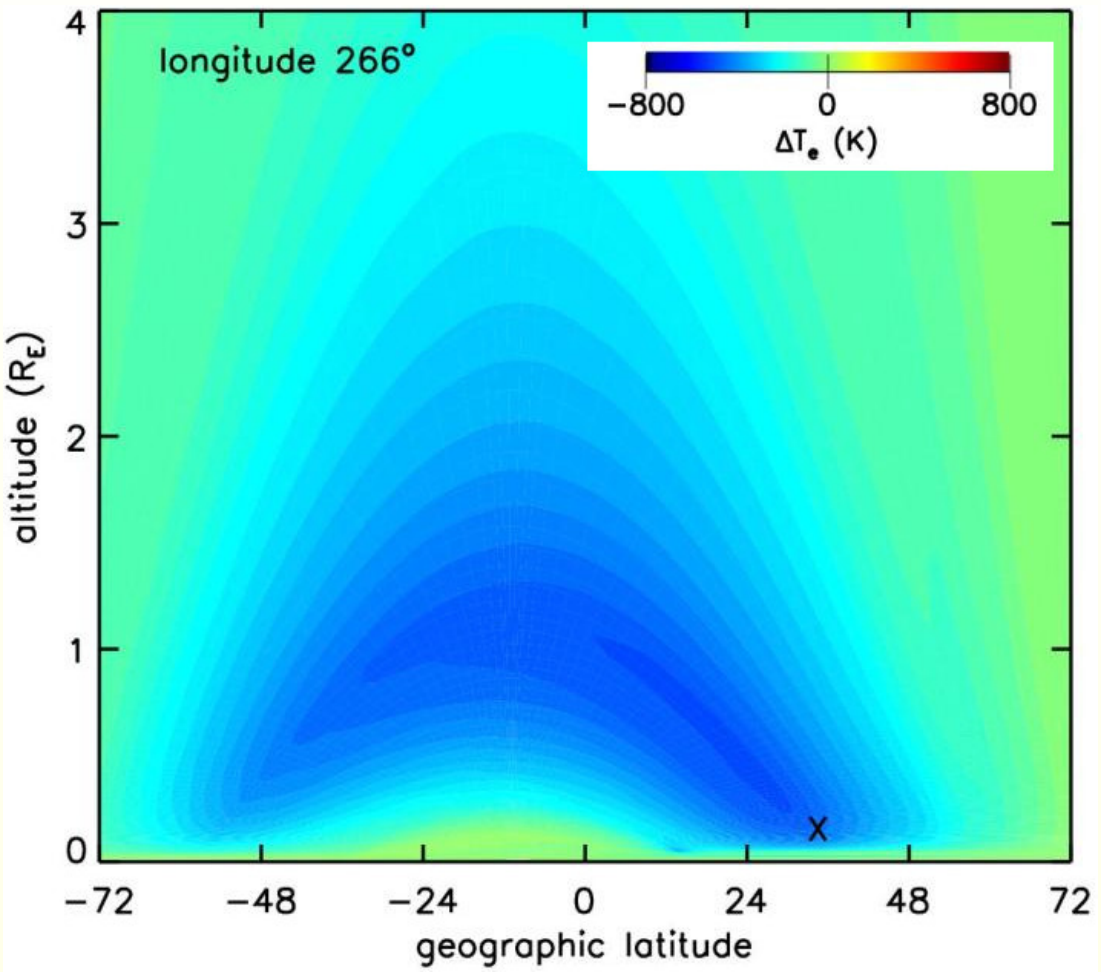
PLASMA PROPERTIES ALONG B

eclipse vs no eclipse



ELECTRON TEMPERATURE

T_e (eclipse) - T_e (no eclipse)



SUMMARY

- SAMI3 predictions
  - the total electron content (TEC) decreases by up to ~ 5 TECU (35%)
  - the electron density decreases by a factor of 2 between 150 km and 300 km (50%)
  - the electron temperature decreases by up to ~ 800 K in the plasmasphere (15%)
  - the O^+ velocity changes from ~ 40 m/s upward to ~ 20 m/s downward in the F region
  - modification of the ionospheric conductance modifies the global electric field (~ 0.5 kV - 5%) which leads to changes in the TEC $\lesssim 1$ TECU in the southern conjugate hemisphere and evening terminator

- Salah et al., JGR, 1986
  - the electron density decreases by 60% between 130 km and 250 km
  - the electron density decreases by 15% - 30% at higher altitudes
  - the electron temperature decreases by 500 - 700 K in the F region
  - difficult to conclude eclipse had an effect on the electric field

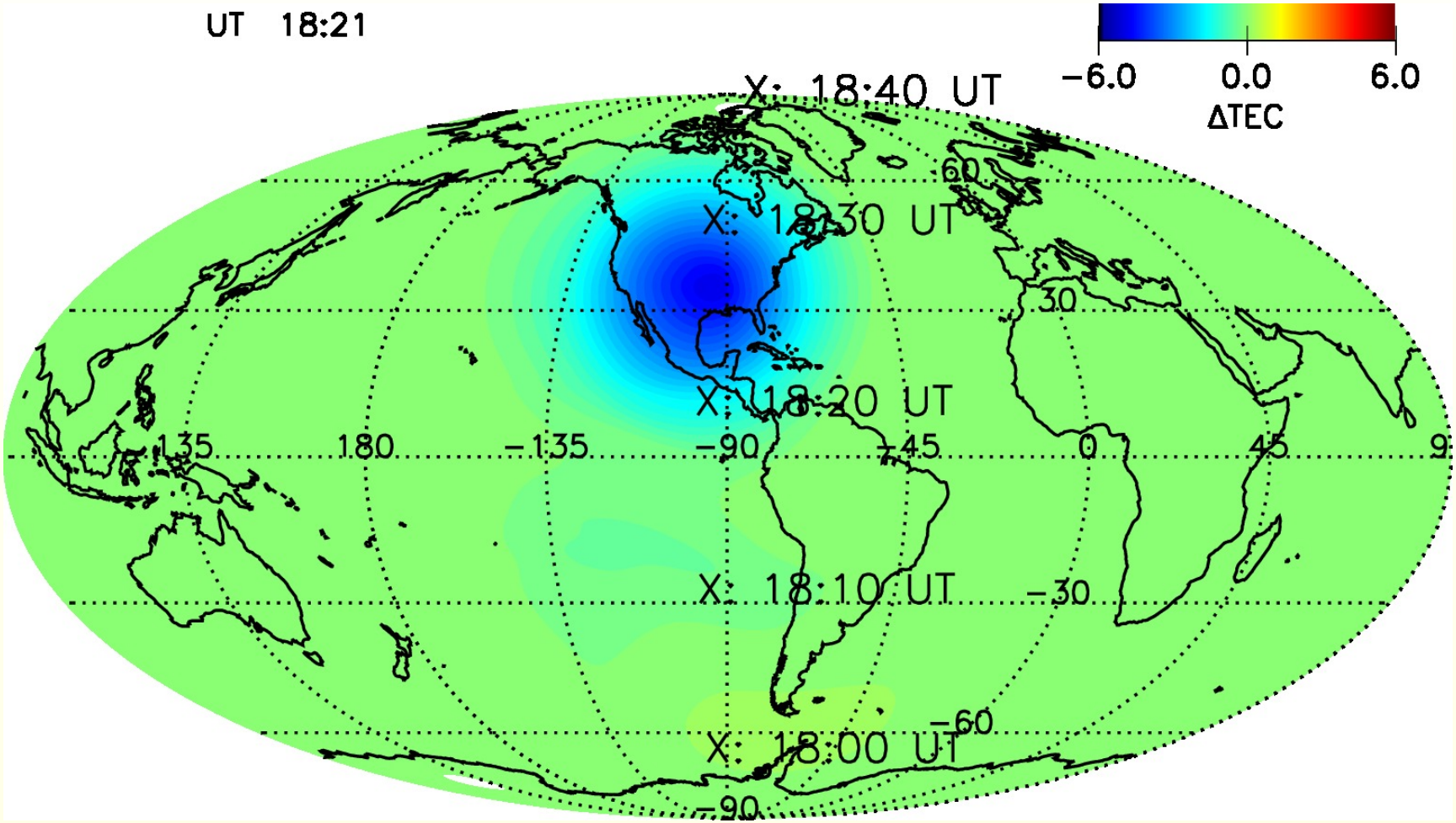
DISCUSSION

- ignored high-latitude convection electric field
  - ok for quiet times because only interested in low- to mid-latitude ionosphere dynamics
  - but if there is a magnetic storm during this period will need to consider high-latitude effects
- future work
  - design a more realistic EUV mask that takes into account differences in spectral bands and geometric factors (e.g., altitude, eclipse path)
  - examine dynamics at the evening terminator vis-à-vis equatorial spread F (i.e., generation of plasma irregularities)
  - collaborate with virginia tech researchers/students as part of NASA funded program

- GPS TEC data (north america and south america (LISN))
- ionosonde data (profiles of bottomside electron density)
- radar data (arecibo, jicamarca)
- satellite data (e.g., SWARM satellites)
- HF radiowave propagation

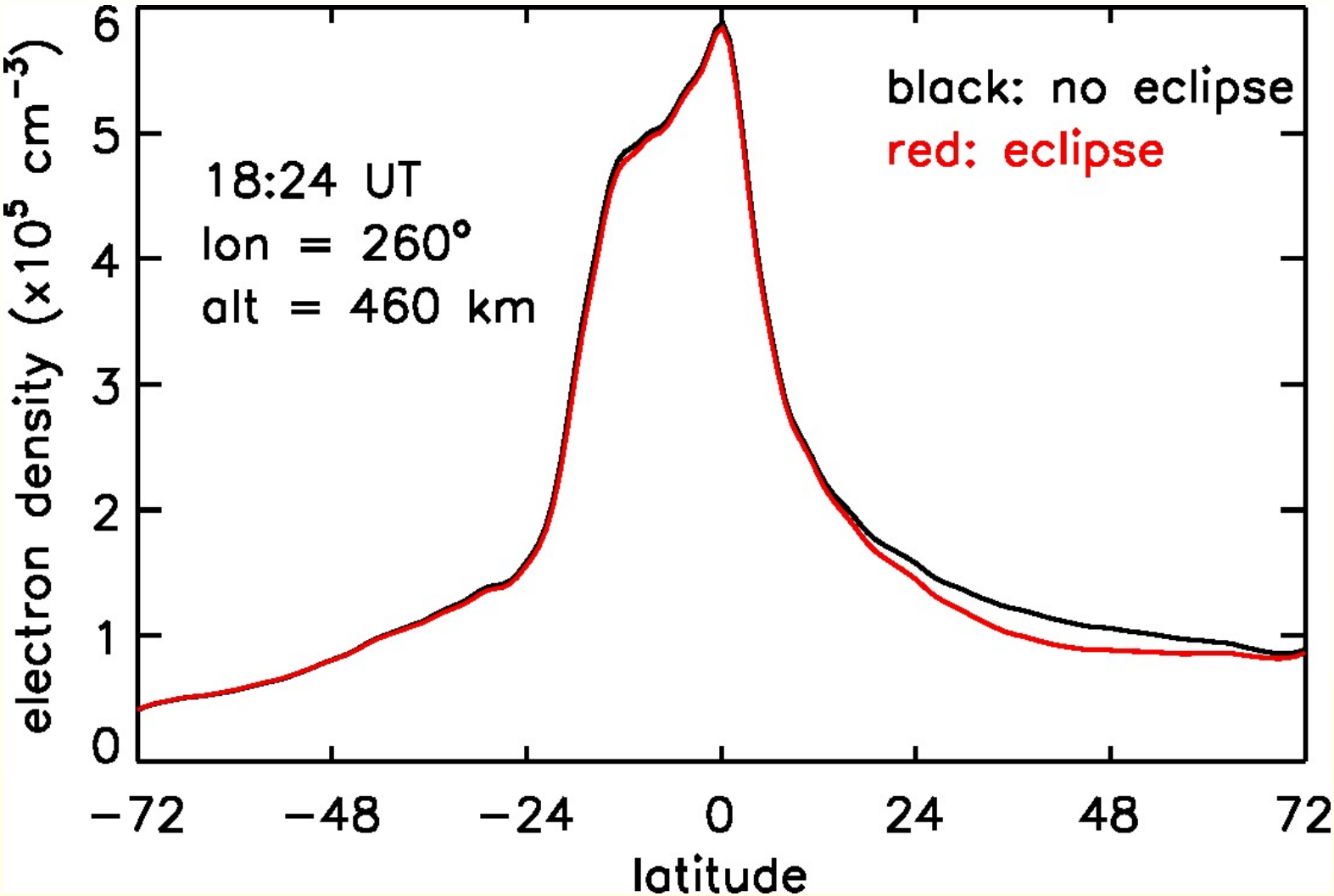
SWARM SATELLITES A/C

location and time



ELECTRON DENSITY

at Swarm A/C altitude 460 km



MY NEXT TALK

- if good results ...

  'comparison of 21 august 2017 solar eclipse observations with SAMI3 predictions'

- if not so good results ...

  'SAMI3 prediction of the impact of the april 8, 2024 total solar eclipse on the ionosphere - plasmasphere system'

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