IONOSPHERE RESPONSE TO SOLAR EUV VARIATIONS

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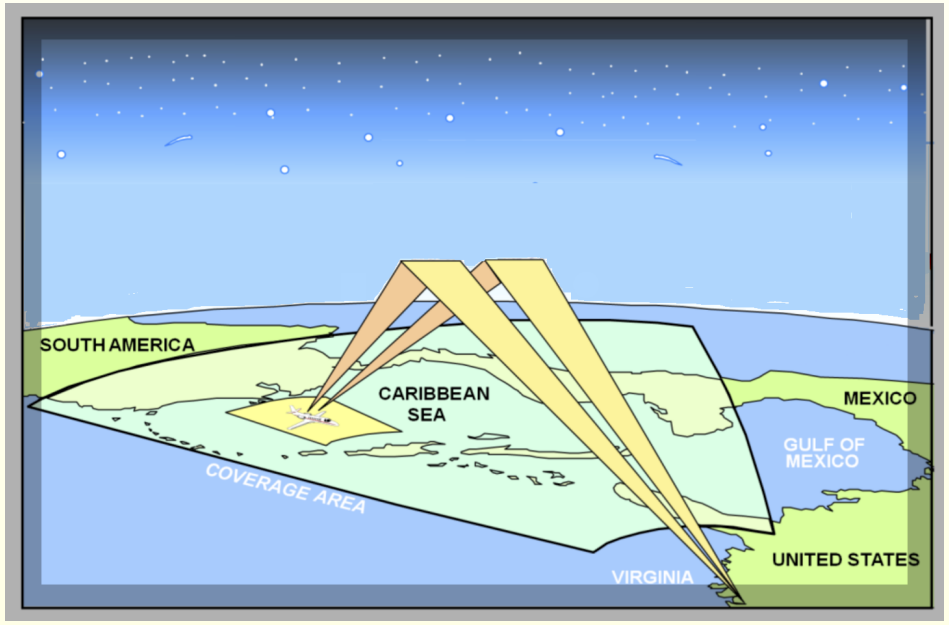
SPACE WEATHER EFFECTS

typically associated with large magnetic storms

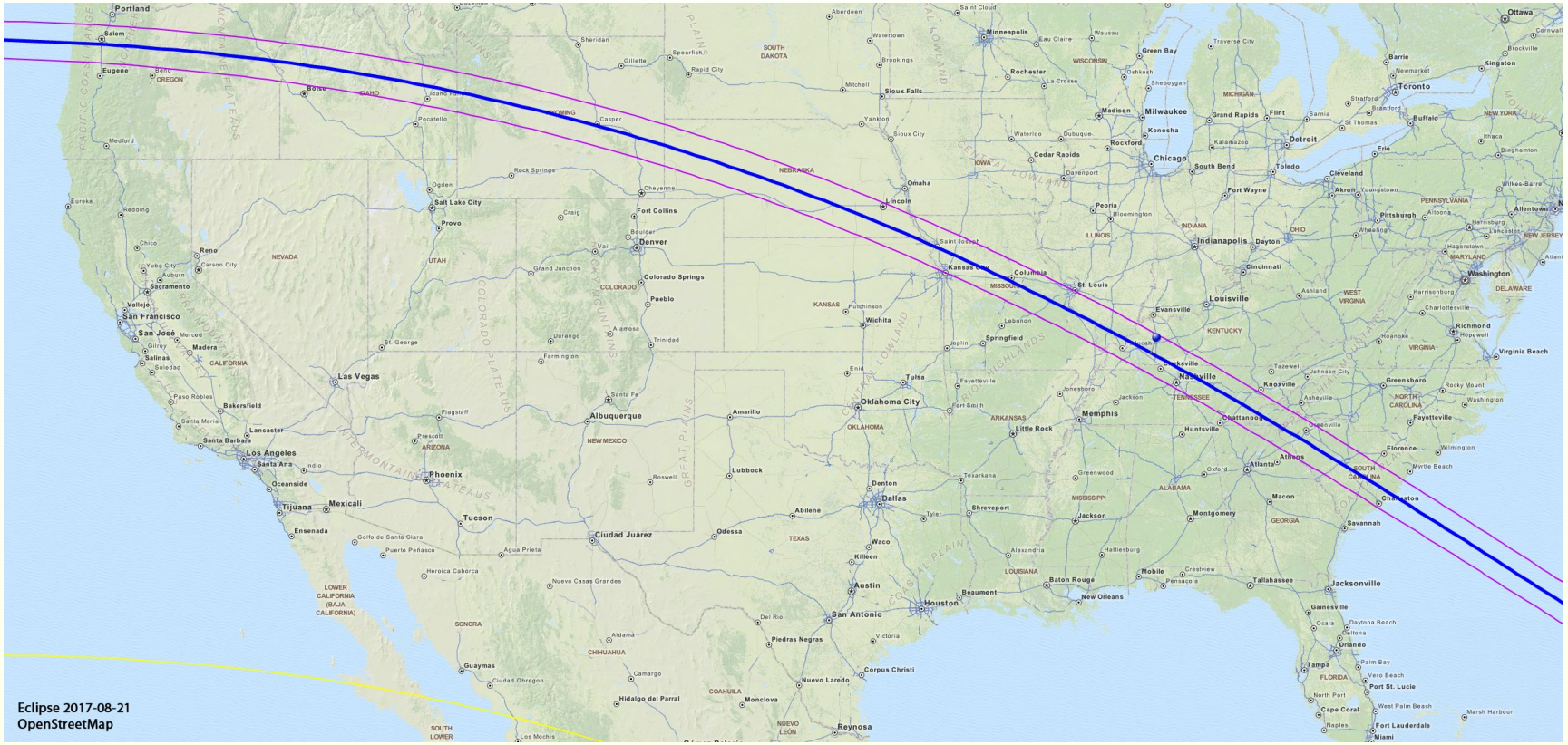
- ground induced currents (power plants)
- high energy particles (radiation belt/satellites)
- satellite drag (thermosphere)
- communication systems (HF)
- navigation systems (GPS)
- detection systems (over-the-horizon radar)

EUV variations affect E/F region electron density profiles which can impact communication/radar propagation paths



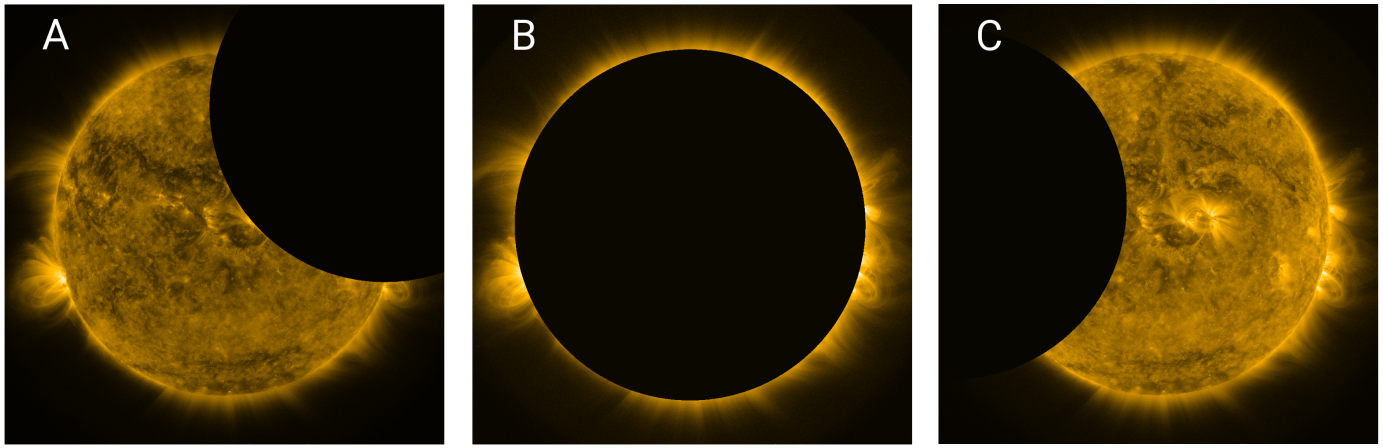
PATH OF SOLAR ECLIPSE

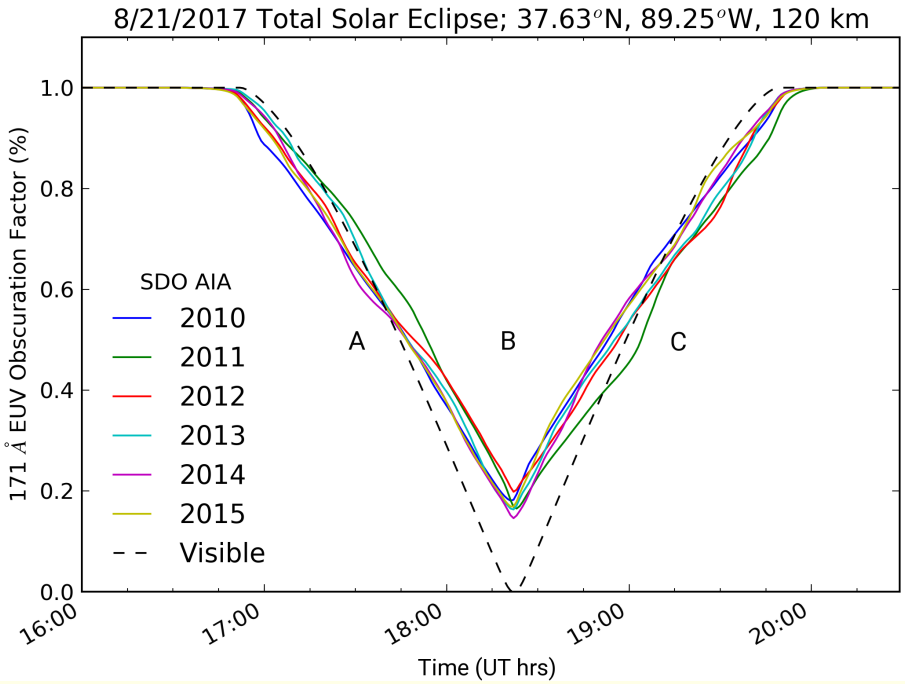
over continental USA (21 August 2017)



EUV OBSCURATION

uses Solar Dynamics Observatory (SDO) data and NOVAS





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

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

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

- ion temperature

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

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

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

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

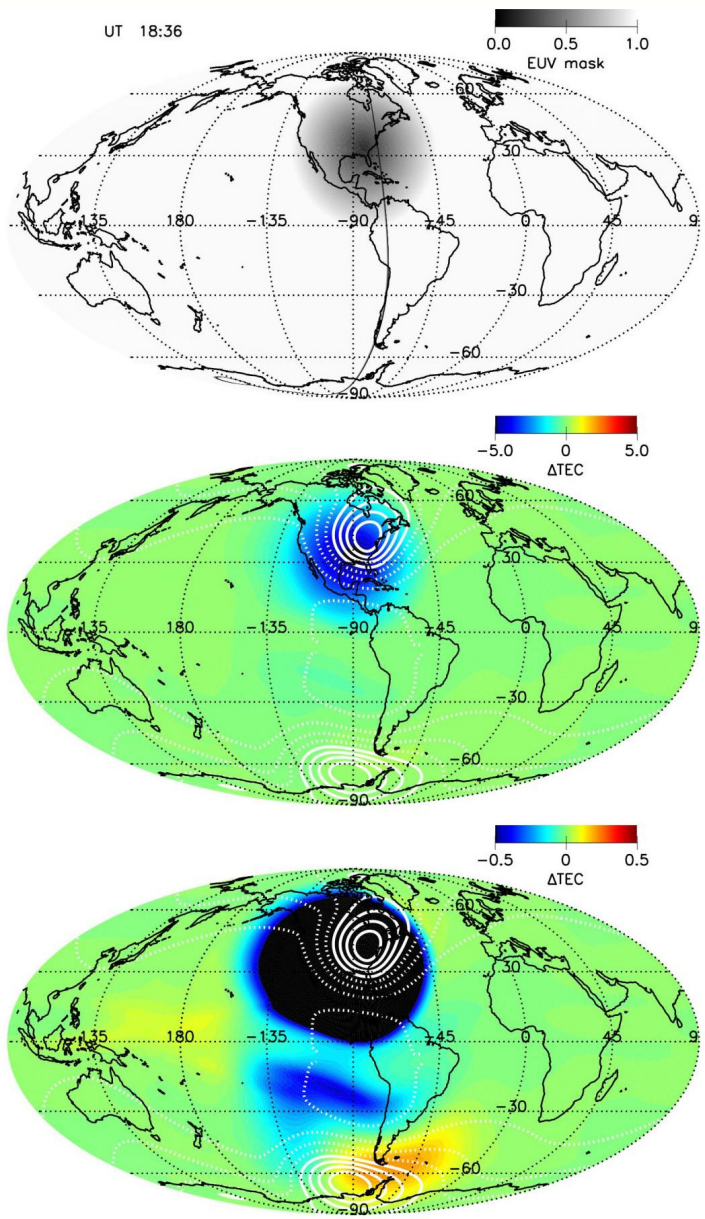
$$\sigma_H = -\sum_i \frac{n_i e c}{B} \frac{1}{1 + \nu_{in}^2/\Omega_i^2} + \frac{n_e e c}{B} \frac{1}{1 + \nu_{en}^2/\Omega_e^2}$$

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)

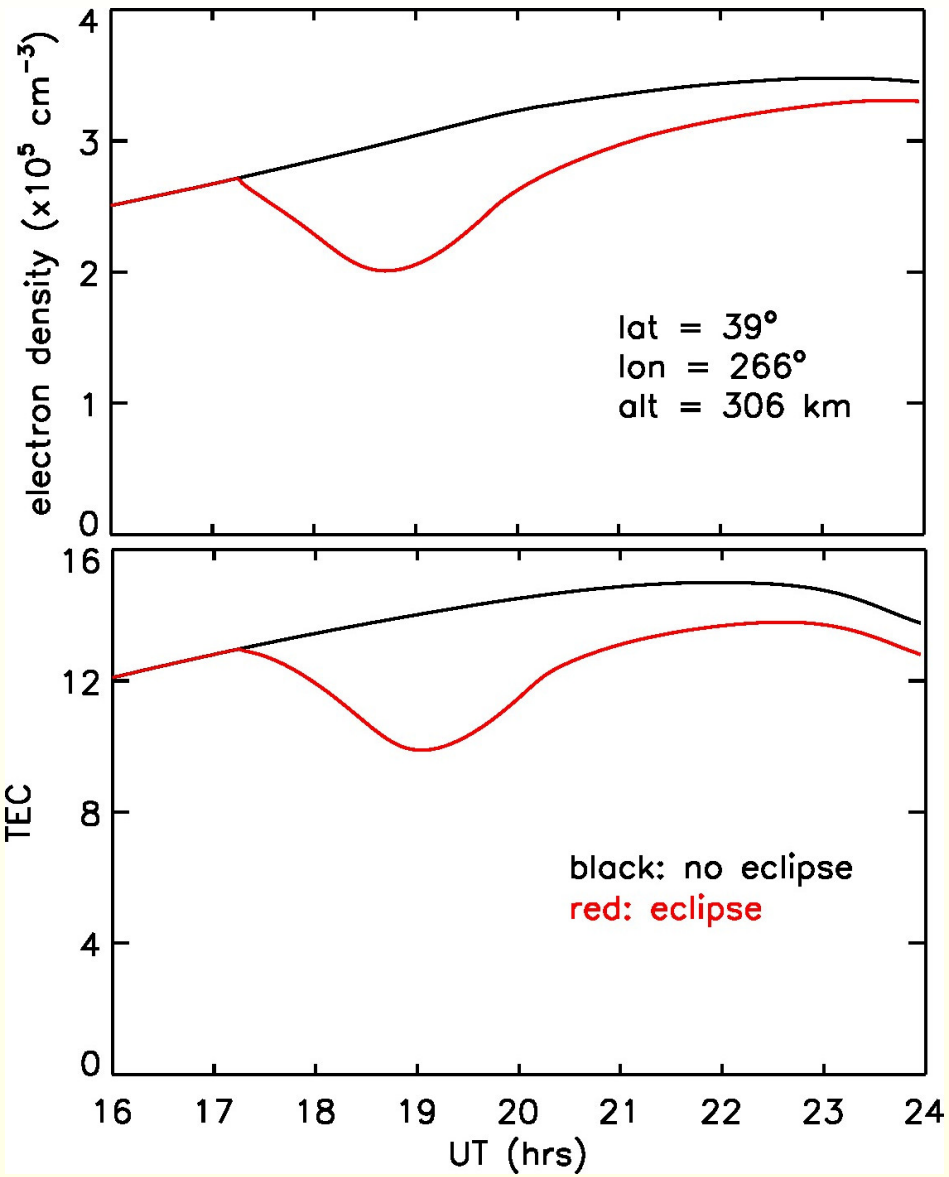
EUV mask and ΔTEC

18:36 UT



ELECTRON DENSITY AND TEC VS UT

over dick hubbard's farm



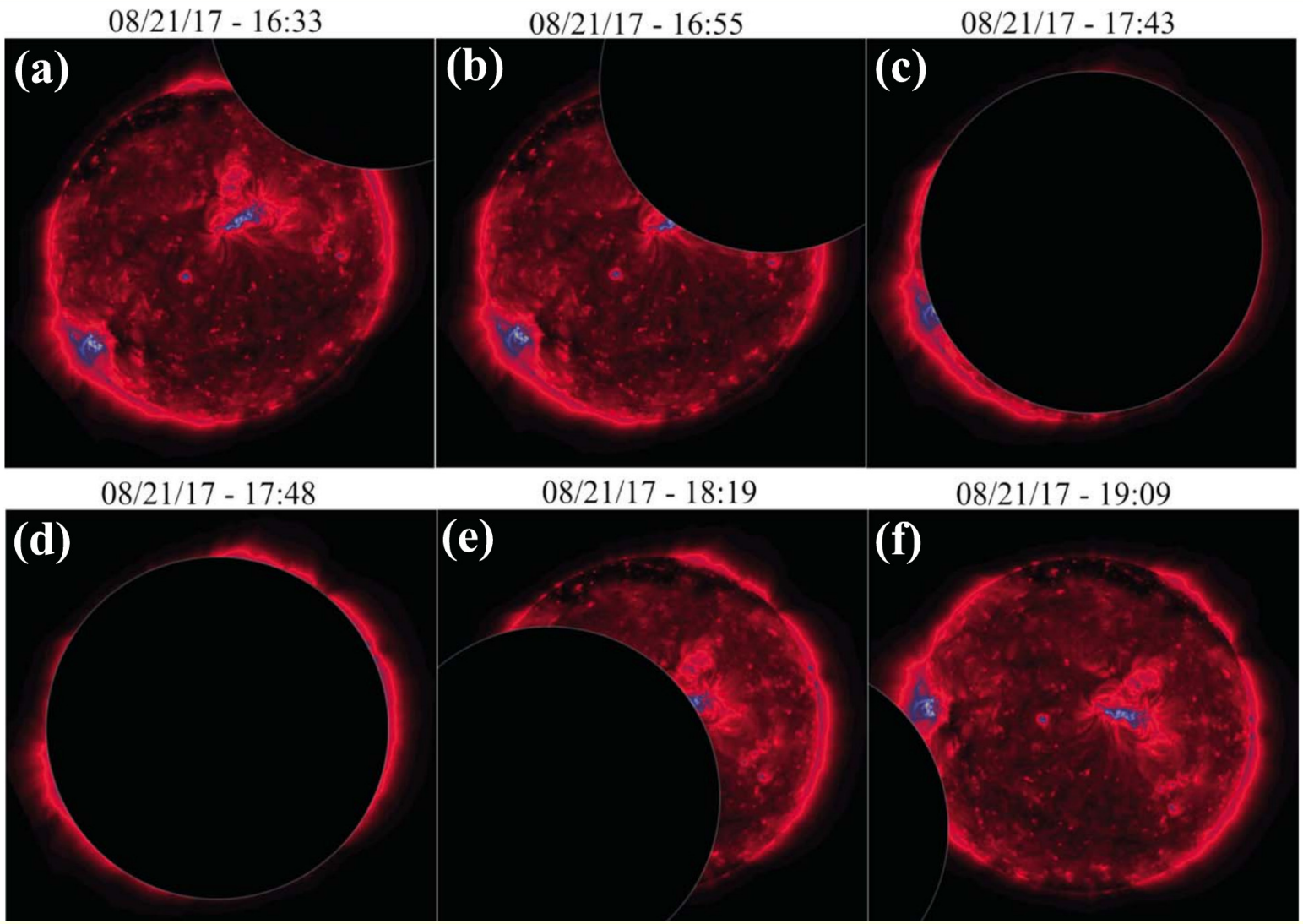
INTERESTING OBSERVATIONS

Mrak et al., *GRL* (2018)

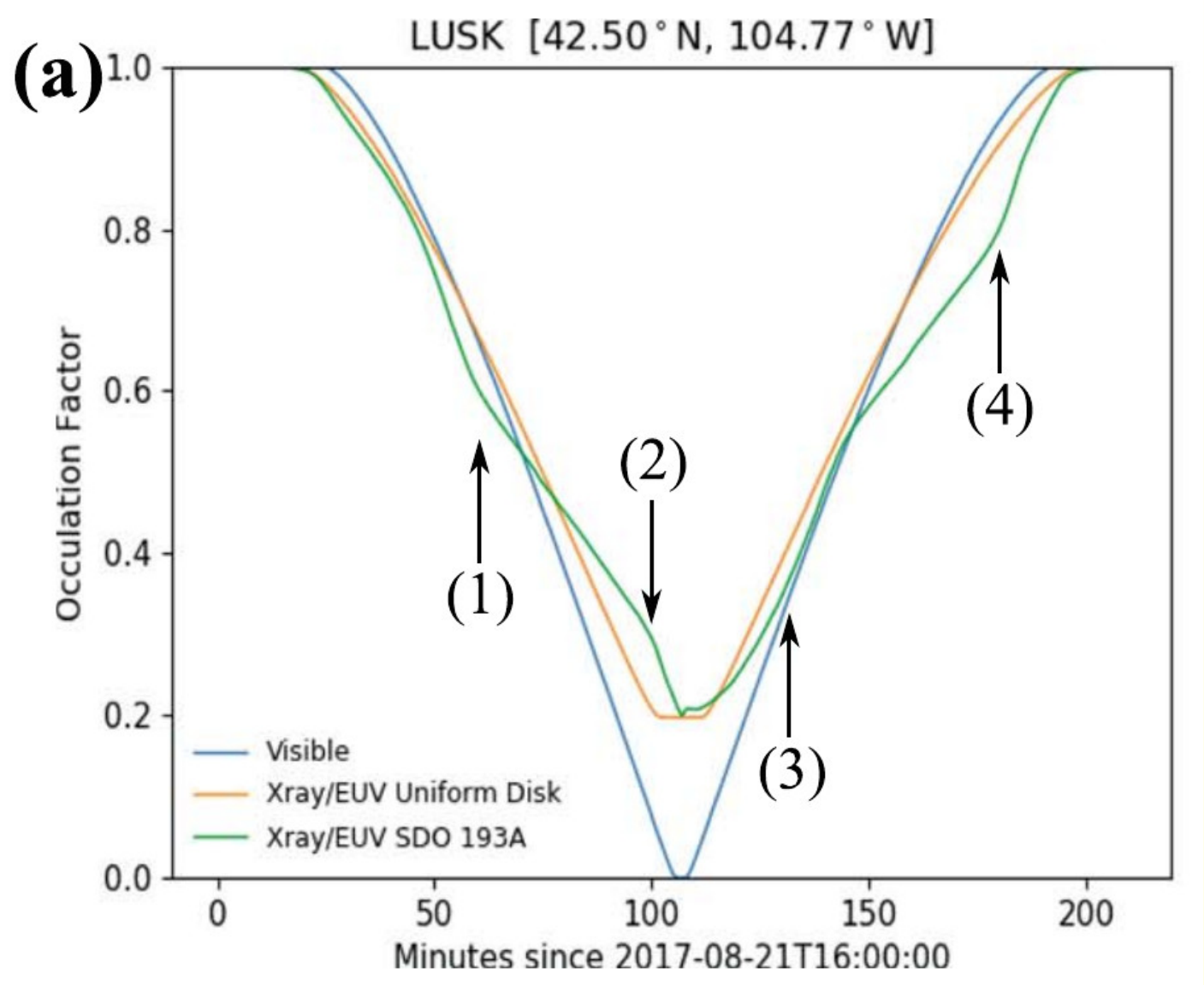
- 'Direct EUV/X-Ray Modulation of the Ionosphere During the August 2017 Total Solar Eclipse'
- EUV modulations associated with two active regions
- causes large-scale TEC perturbations (but quite small $\sim \pm 0.1$ TECU)

SOLAR DISK ACTIVE REGIONS

19.3-nm wavelength / SDO

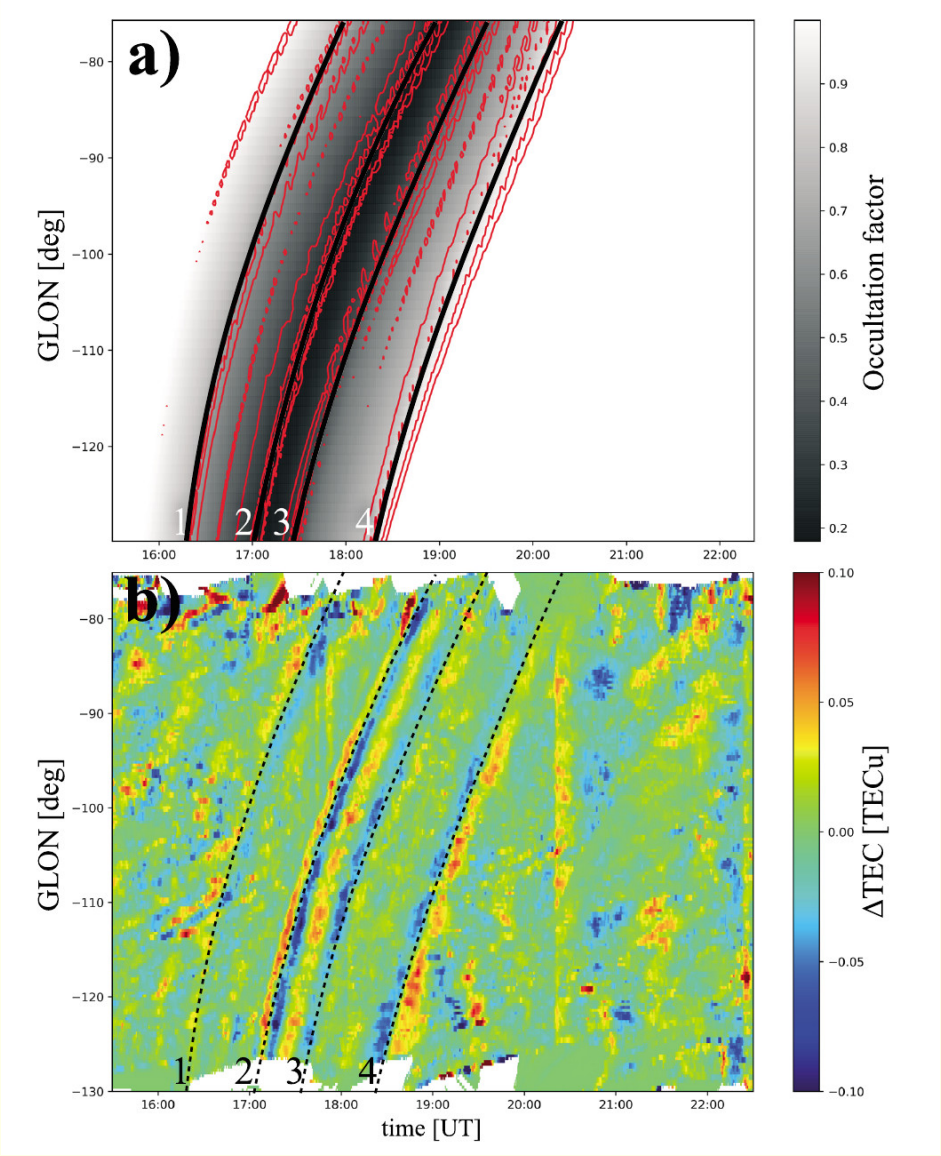


OCCULTATION FACTORS



KEOGRAMS

obscuration and ΔTEC



COMMENTS

- solar EUV variations (say, associated with active regions) will impact the ionosphere electron density
- unlikely to have significant space weather effects
- for example, gravity waves and traveling ionospheric disturbances (TIDs) likely to be more important in affecting HF/OTH wave propagation
- from modeling point of view - using different EUV models will probably introduce more uncertainty than relatively small-scale variations