

Modeling the effects of solar flares on the ionosphere of Mars

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A Typical Mars Ionospheric Profile

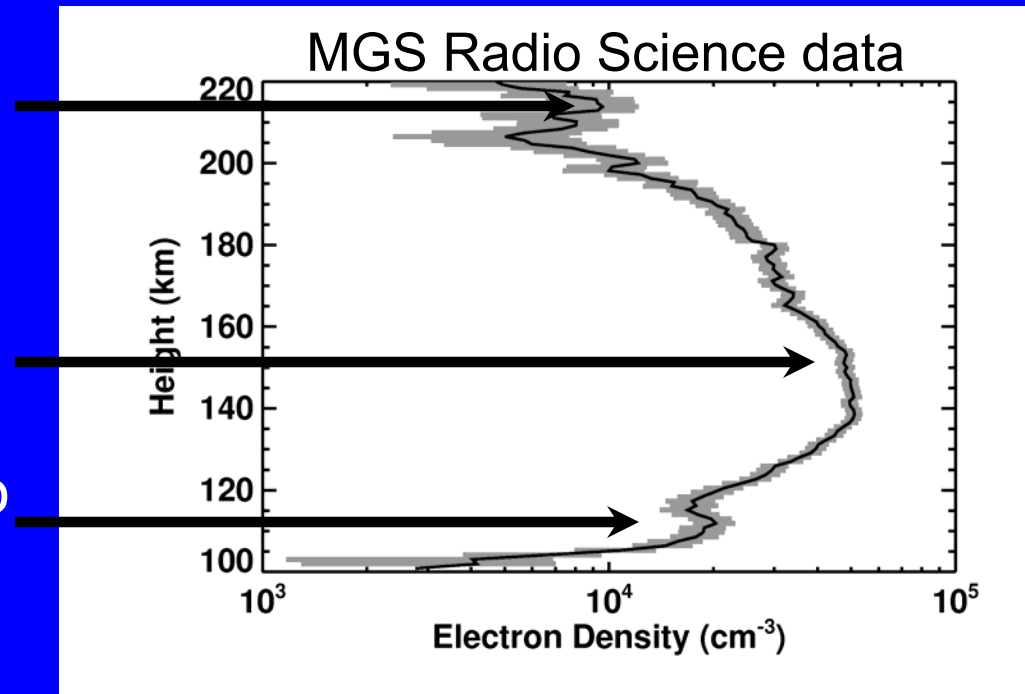
Transport important above
~180 km

Main peak at 140 km due to
EUV photons

Lower peak at 110 km due to
X-rays. Each X-ray that is
absorbed produces multiple
ion-electron pairs

“secondary ionization”

- $\text{CO}_2 + h\nu \rightarrow \text{CO}_2^+ + e$
 - (production)
- $\text{CO}_2^+ + \text{O} \rightarrow \text{O}_2^+ + \text{CO}$
 - (chemistry)
- $\text{O}_2^+ + e \rightarrow \text{O} + \text{O}$
 - (loss)



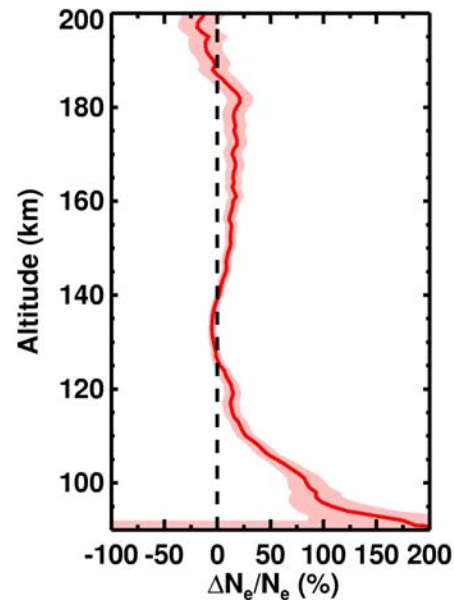
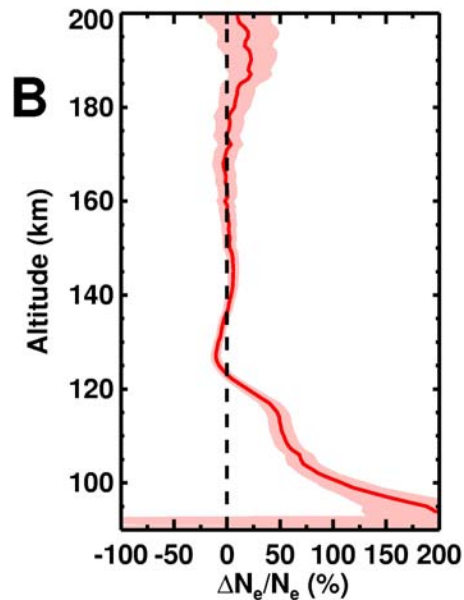
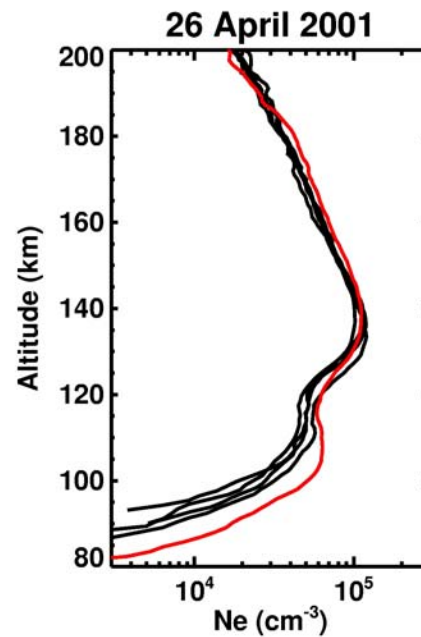
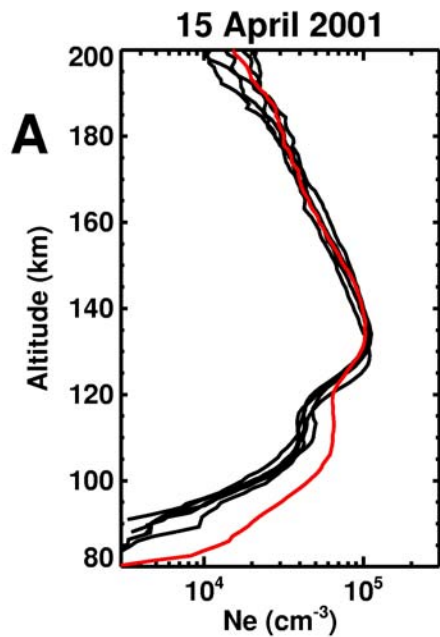
Outline of talk:

Observations of Mars ionosphere
during a solar flare

Model description

Models of Mars ionosphere during a
solar flare

Conclusions



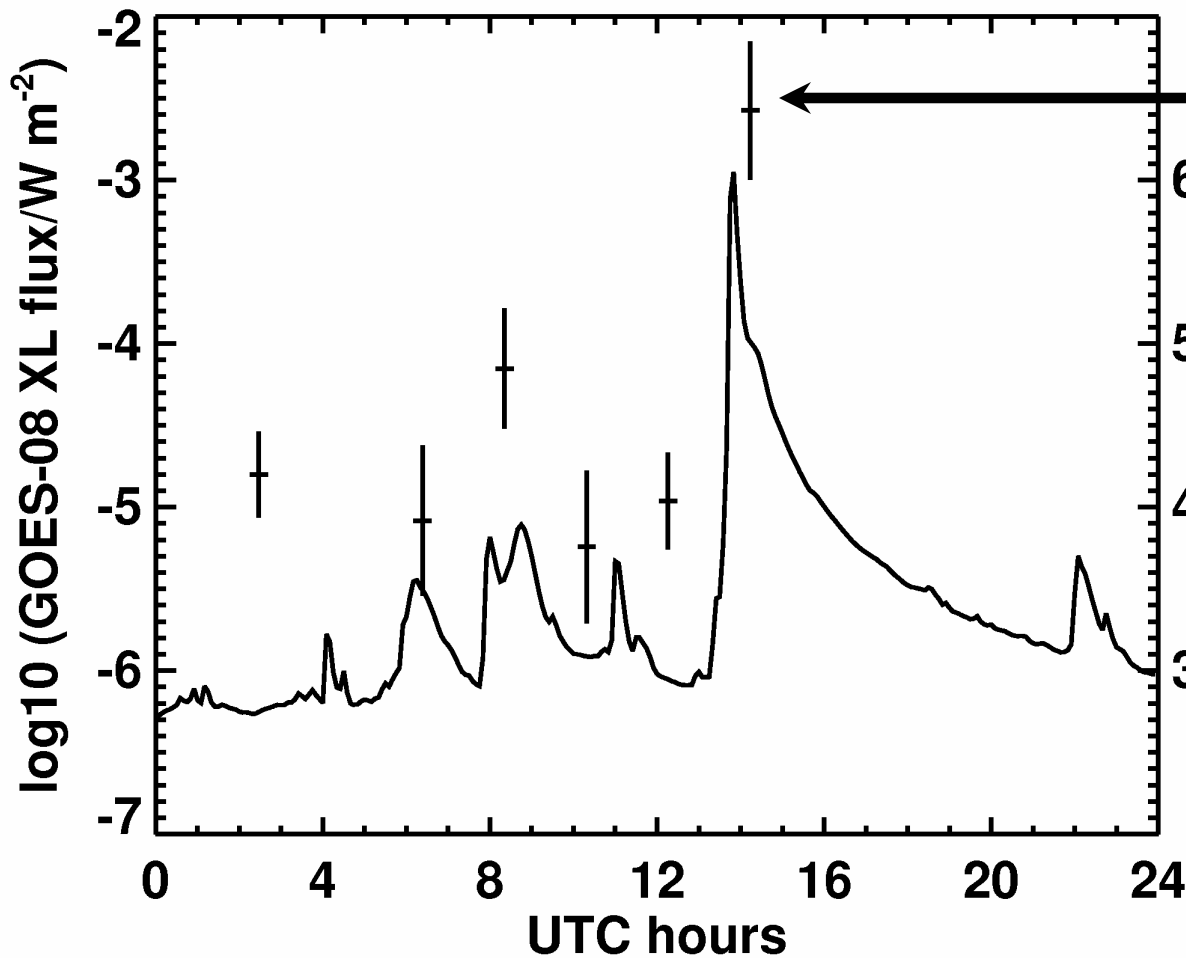
Enhanced electron densities seen below 120 km in one of six profiles on each day

Relative increase in electron density increases as altitude decreases

Suggests that relative increase in flux is greatest at shorter, more penetrating wavelengths

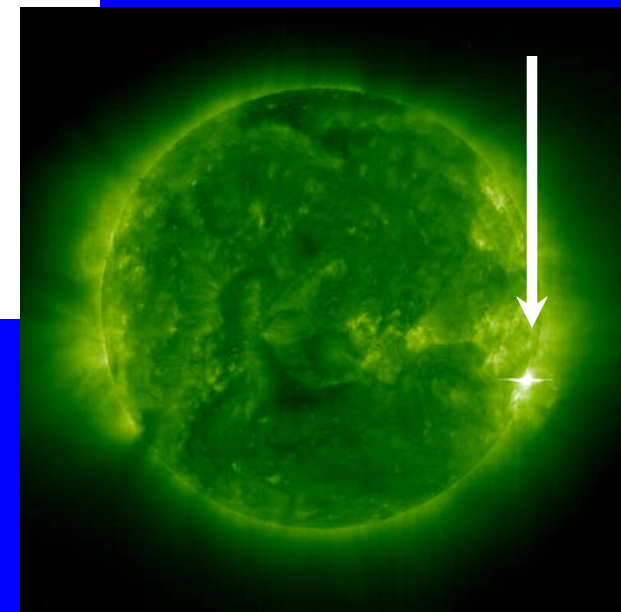
Factor of two increase in electron density at 100 km suggests factor of four increase in relevant ionizing flux. Optical depth ~ 1 at 100 km for 5 nm photons.

Tens of similar examples in the 5600 MGS profiles



Electron density at 110 km for enhanced profile

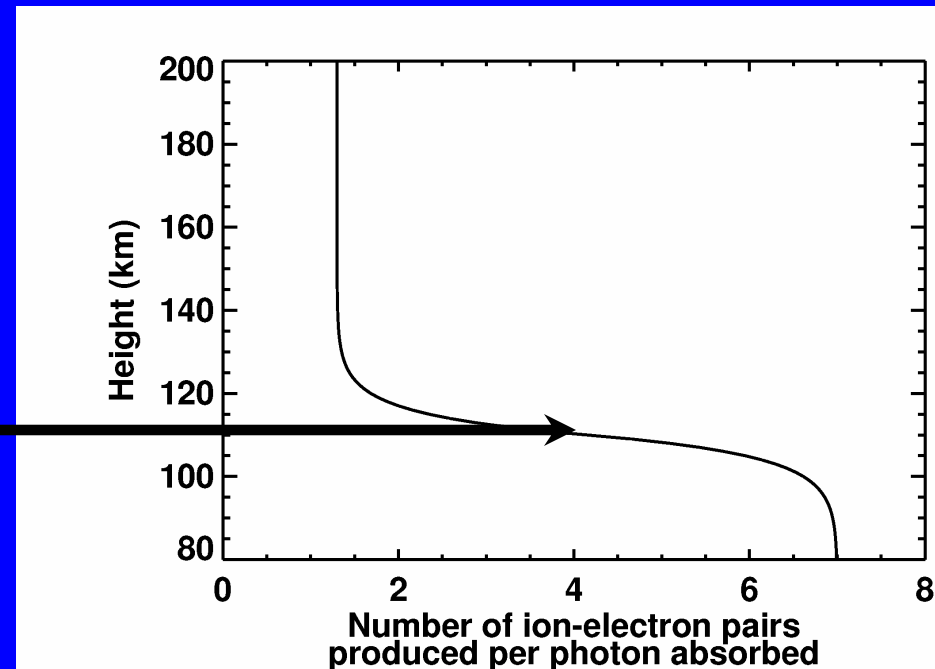
SOHO/EIT image at 19.5 nm at flare onset



X-ray flux (0.1 to 0.8 nm) measured in Earth orbit. Flux increases by 2-3 orders of magnitude

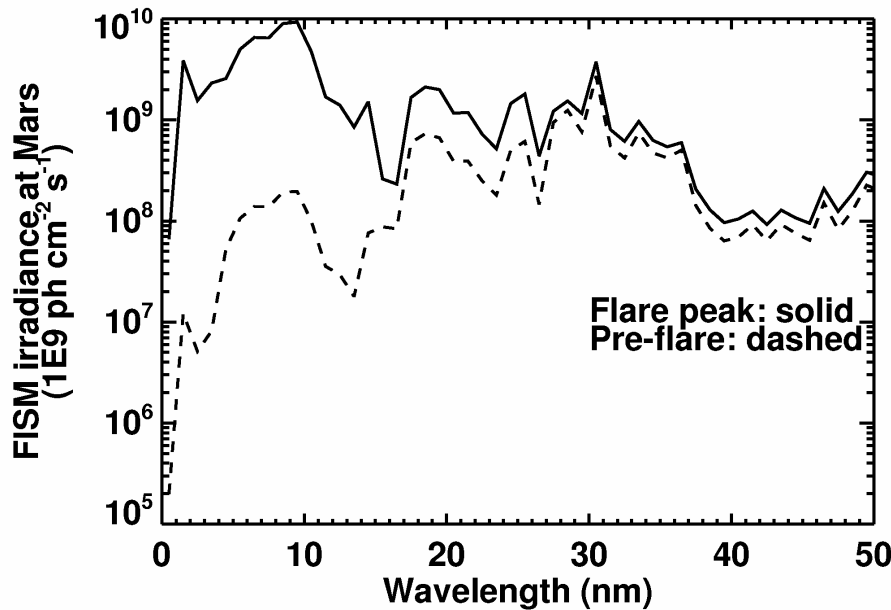
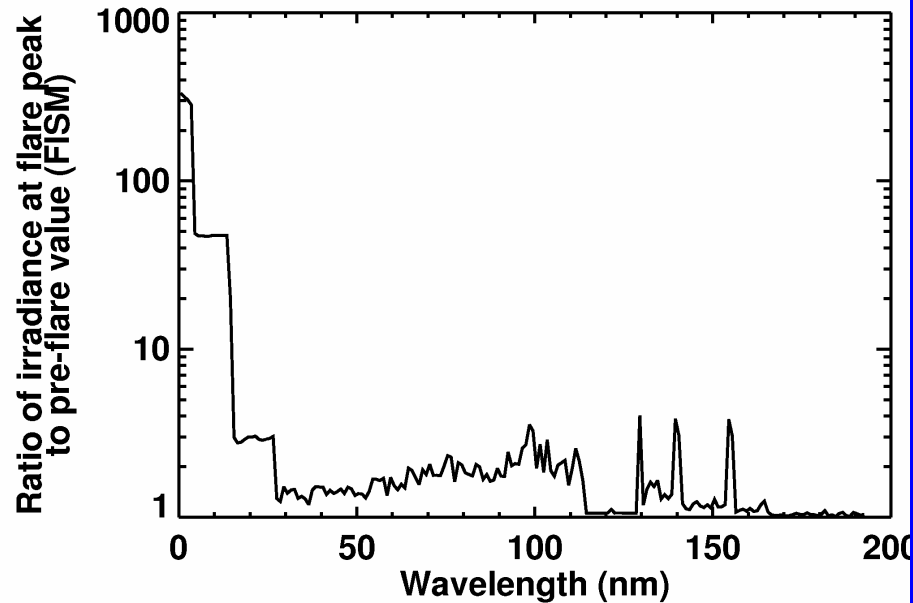
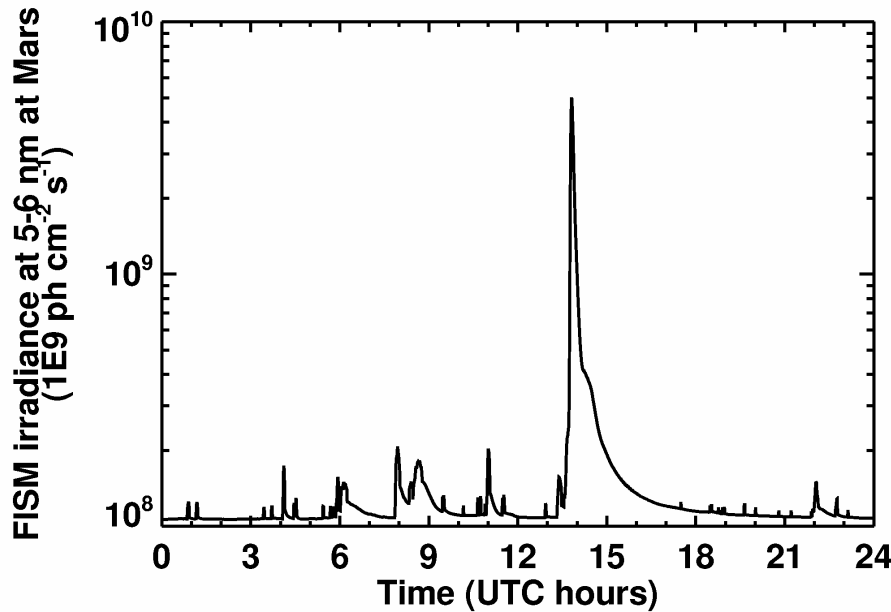
BU Photochemical Mars Ionosphere Model

- Neutral atmosphere derived from Bougher MTGCM model
- Absorption and ionization cross-sections from Schunk and Nagy Ionospheres book ($\lambda > 5$ nm) and theoretical models of Verner ($\lambda < 5$ nm)
- Reaction rates from Schunk and Nagy Ionospheres book
- Secondary ionization parameterized as function of altitude based on results of Fox



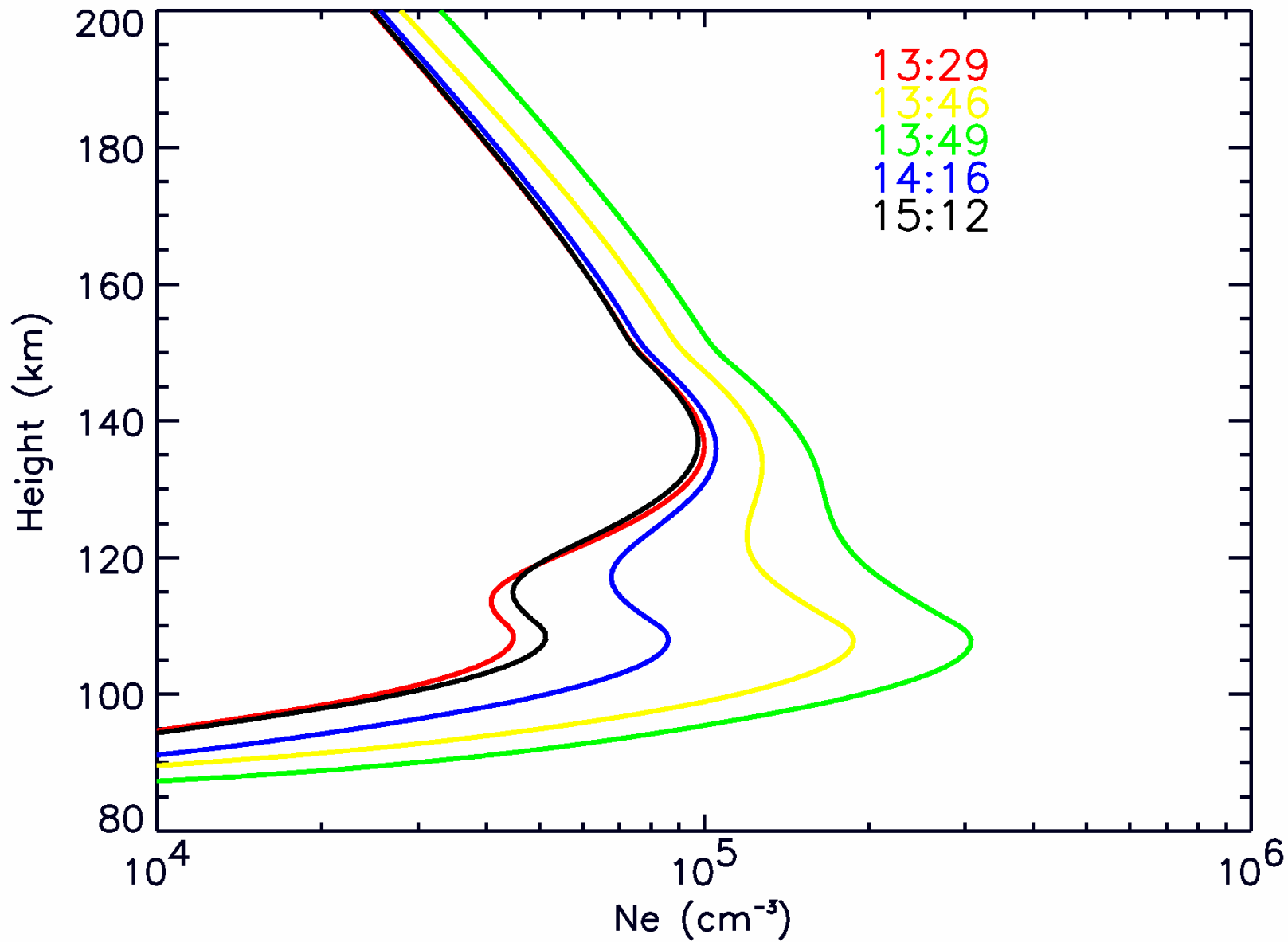
Solar Irradiances at Earth

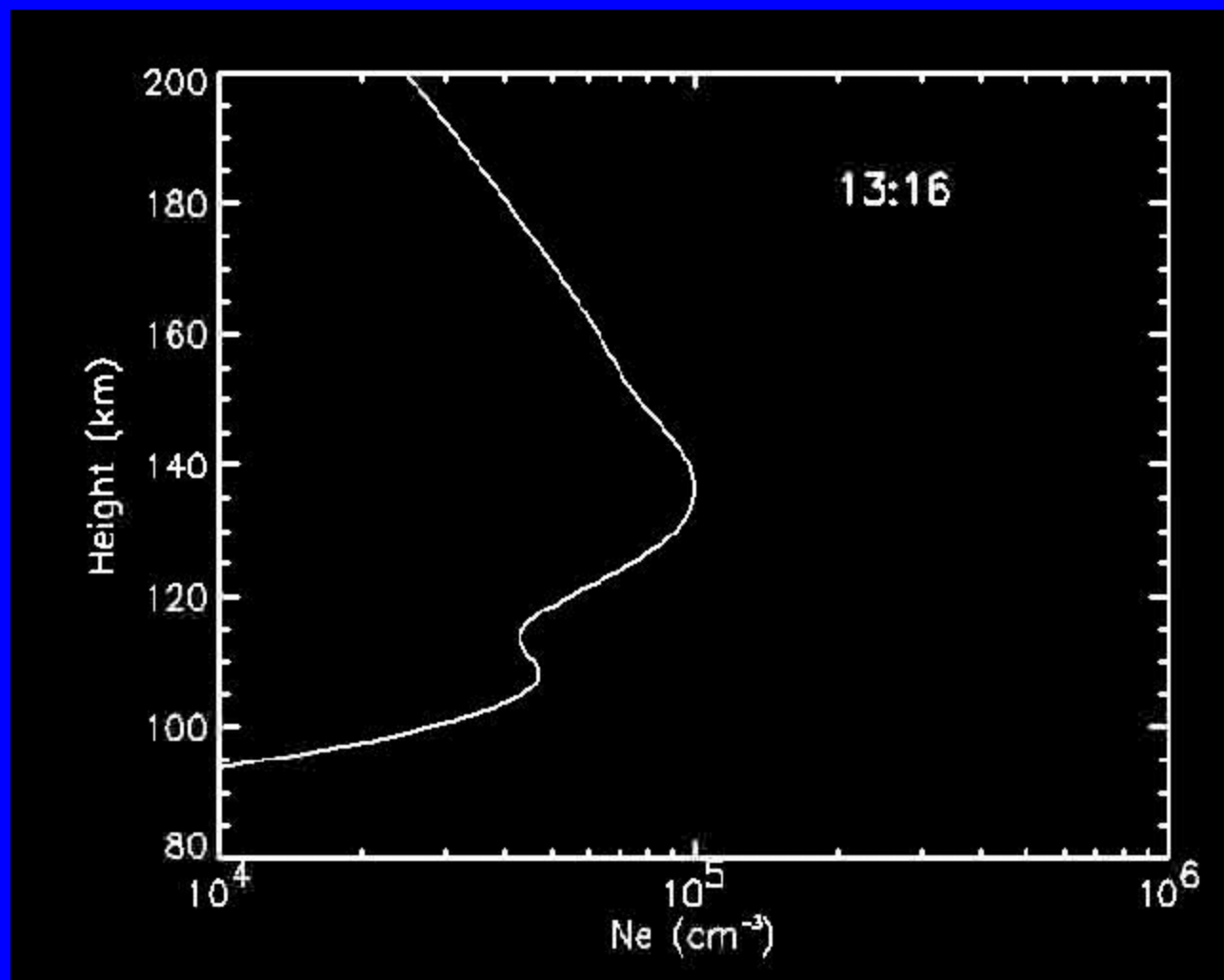
- Solar2000 (Tobiska)
 - 39 or 867 bins from 1.8 – 105.0 nm
 - One spectrum every day
 - Empirical model
- Flare Irradiance Spectral Model (Chamberlin)
 - 195 bins of 1 nm width from 0.5 – 195.5 nm
 - One spectrum every minute
 - Empirical model based on TIMED SEE, UARS SOLSTICE, GOES
- Irradiances resampled so that we have 20 bins shortward of 5 nm, 37 bins longward of 5 nm
- Spin up with Solar2000, then transition to FISM
- No previous Mars ionosphere model has used time-varying solar irradiance (?)

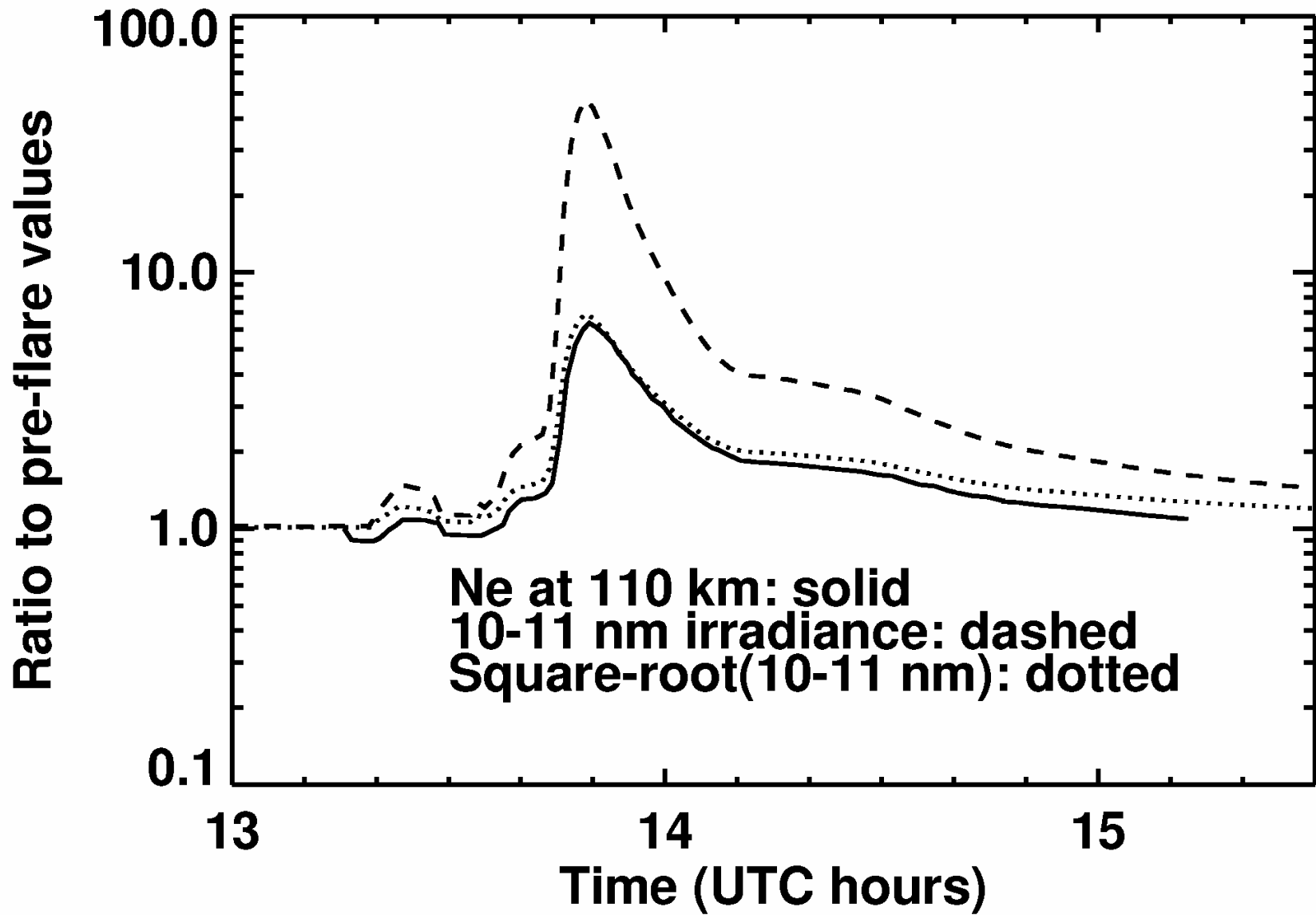


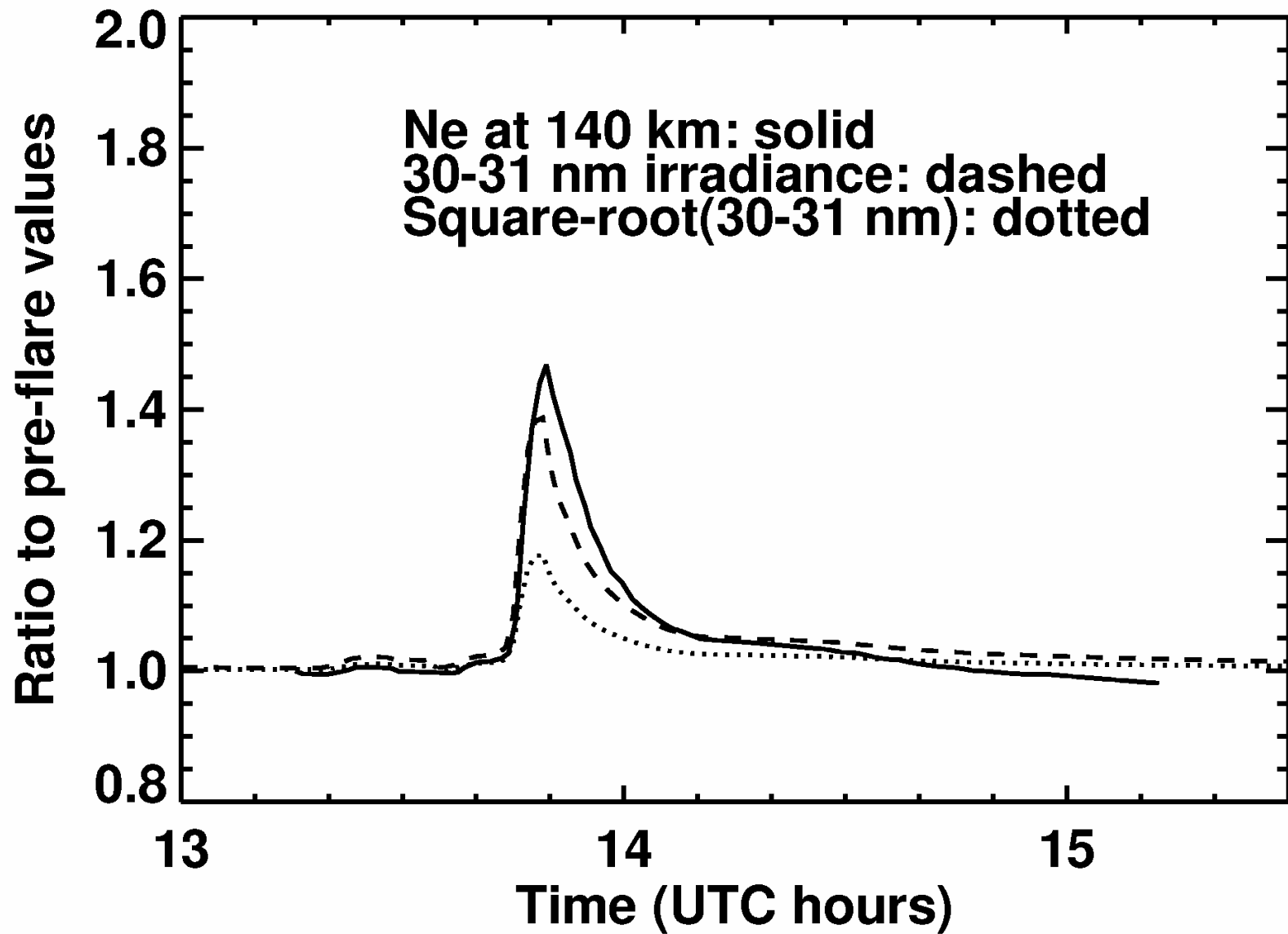
Time of flare-enhanced profile
= 14:14 UTC, 8.7 hrs LST,
72 ° SZA (84 °N)

SZA = 71° 1 hr earlier and
73° 1 hr later – very small
changes in Ne(z) due to
this









Conclusions

- Observations show ionosphere responding to solar flares
- Photochemical model with time-varying solar flux can reproduce the basic characteristics of flare-affected profiles
- Secondary ionization parameterization is important
- Detailed comparisons between data and models are planned

