Comparisons and simulations of same-day observations of the ionosphere of Mars by radio occultation experiments on Mars Global Surveyor and Mars Express

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Abstract 54.08

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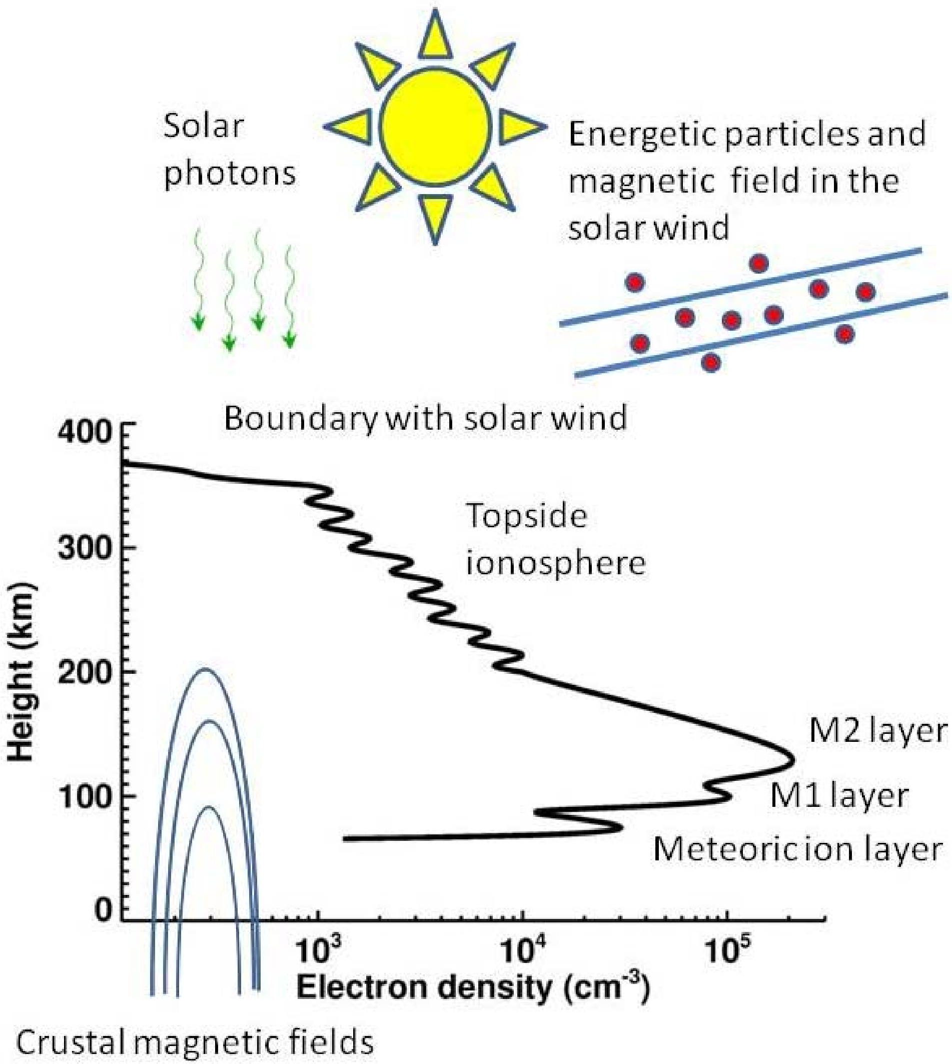
The ionosphere of Mars



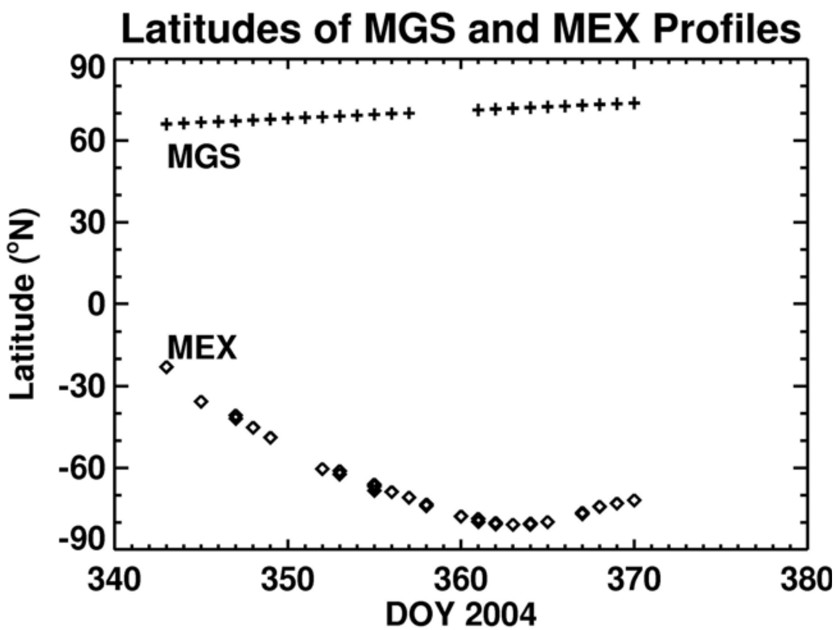
Neutral atmosphere is mainly CO_2, O becomes significant at high altitudes

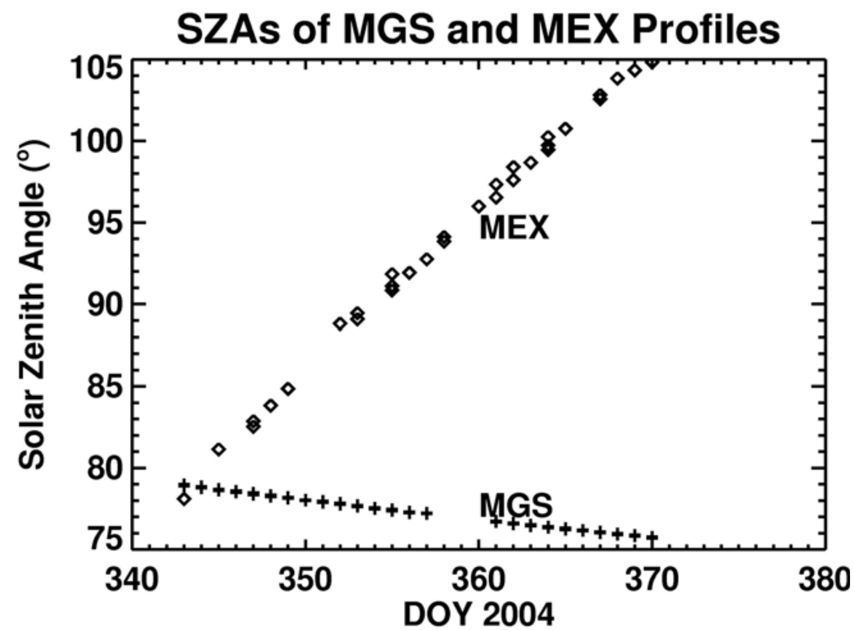
O_2^+ is main ion at all altitudes (?)

EUV photons responsible for main M2 layer
Soft X-ray photons responsible for lower M1 layer, aided by strong secondary ionization

<u>Secondary ionization or electron-impact ionization</u>
Photoelectrons produced during photoionization events may be very energetic, they can produce additional ion-electron pairs as they thermalize by collisions

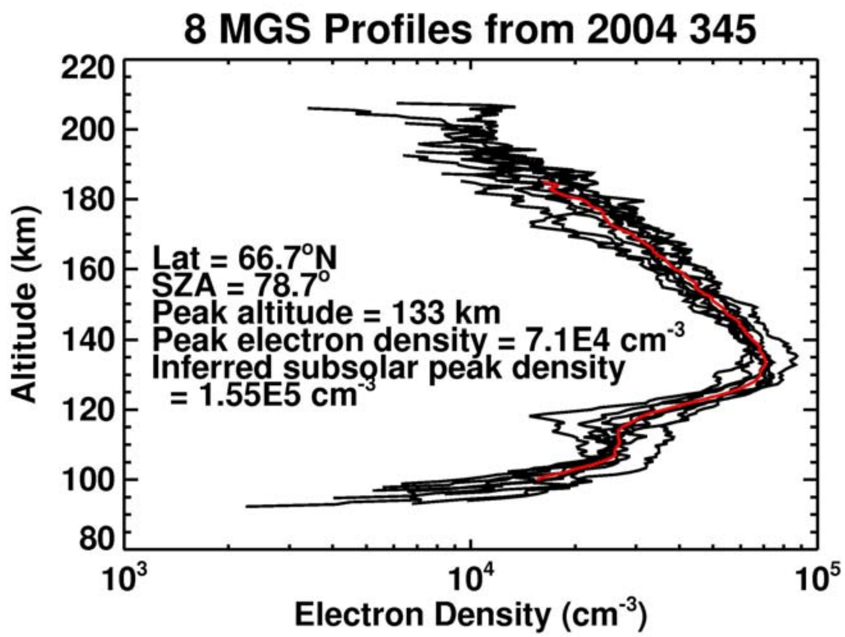
Data coverage

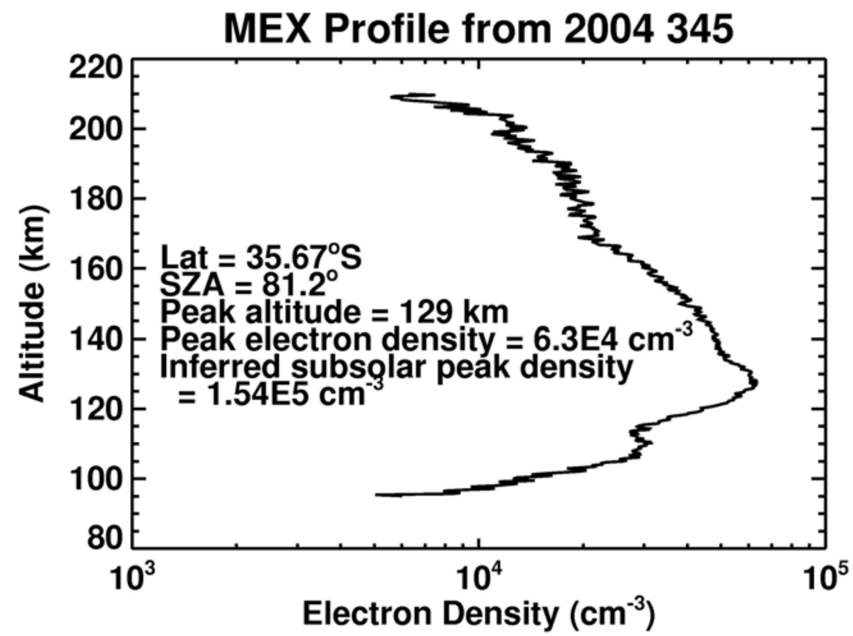




- 8 December 2004 to 4 January 2005
- Earth-Sun-Mars angle ~ 120^o
- Ls=126^o - 139^o
- F10.7 at 1 AU = 90 (close to solar minimum conditions)
- 229 MGS and 31 MEX electron density profiles

Same day profiles (10 December)

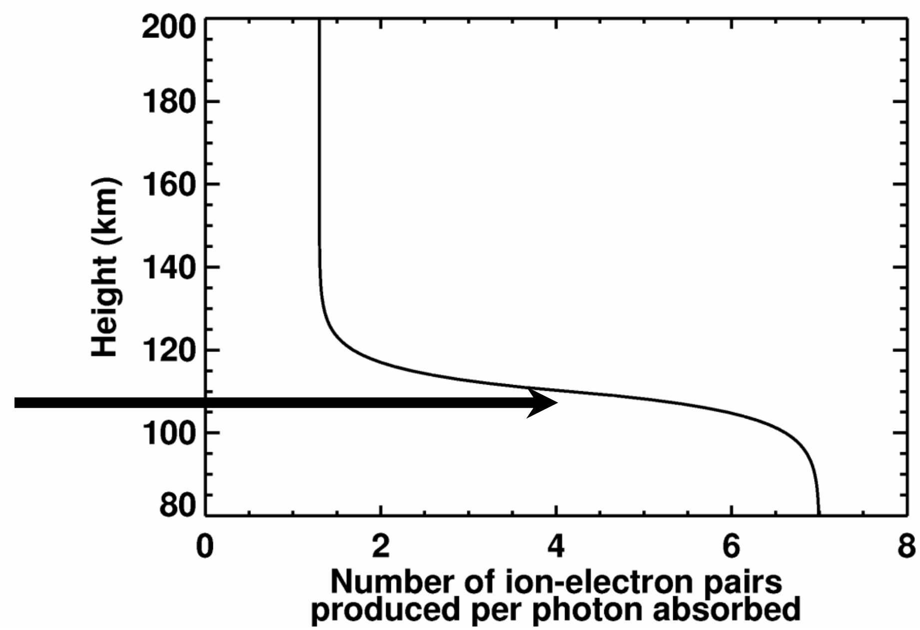




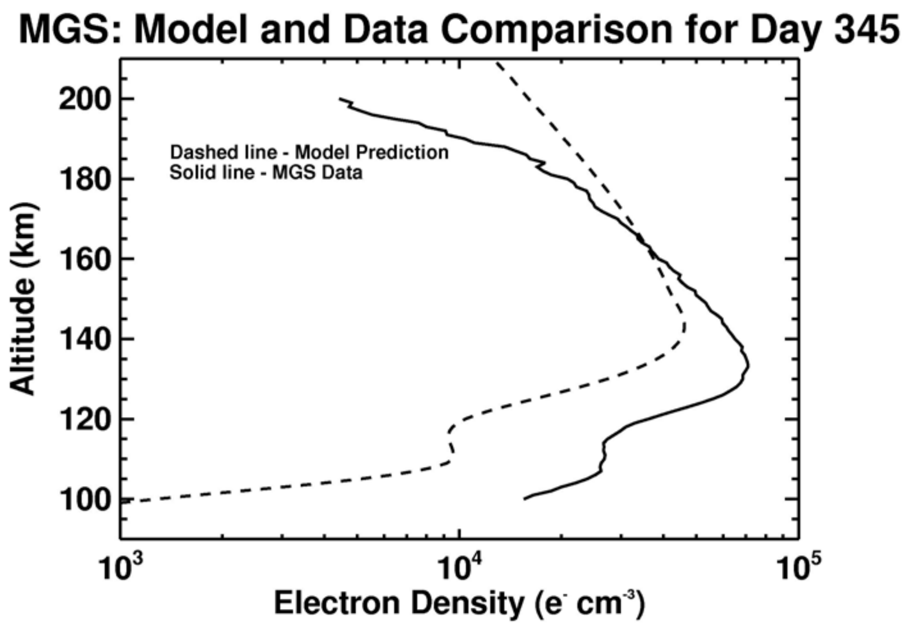
- 12% difference in peak densities, almost all of which can be attributed to SZA differences
- Inferred subsolar peak electron densities differ by <1%
- Expect MGS peak altitude to be ~2 km lower than MEX peak altitude, but it is actually 4 km higher

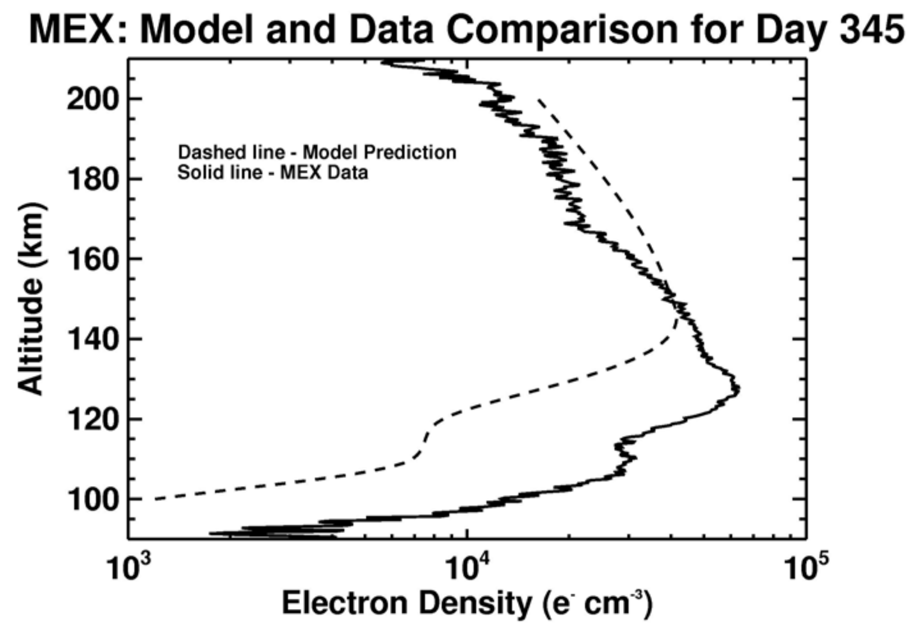
BU Mars Ionosphere Model

- 1-D photochemistry and vertical transport
- Single vertical profile for neutral atmosphere derived from Bougher MTGCM model at solar maximum
- Absorption and ionization cross-sections from Schunk and Nagy Ionospheres book (λ > 5 nm) and theoretical models of Verner (λ < 5 nm)
- Solar irradiances from Solar2000 model of Tobiska
- Reaction rates from Schunk and Nagy "Ionospheres" book
- Electron temperatures equal neutral temperatures
- Secondary ionization parameterized as function of altitude based on results of Fox



Initial data-model comparison





- MGS data have peak at 133 km, model has peak at 143 km
- MEX data have peak at 129 km, model has peak at 145 km

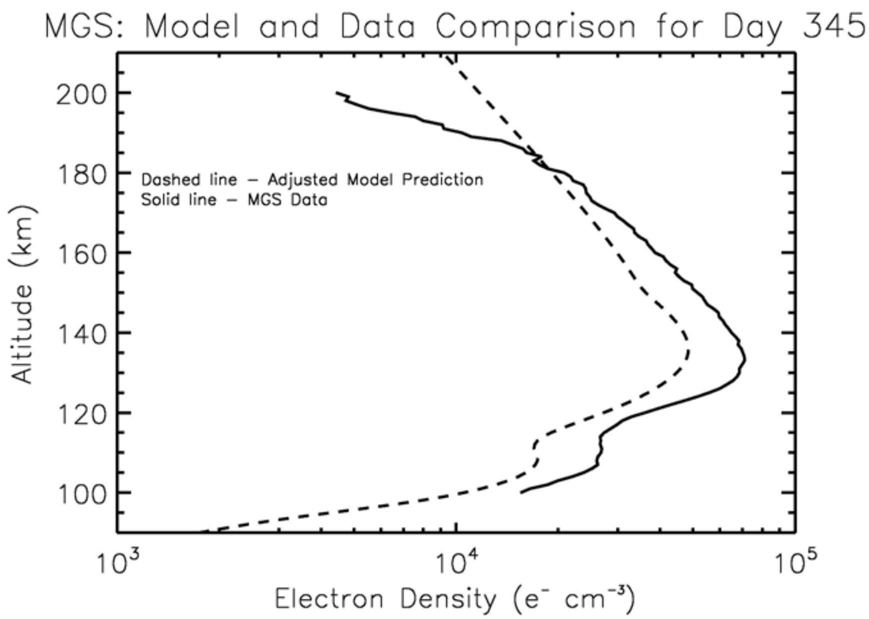
- Both predicted peak densities are 35% smaller than observed

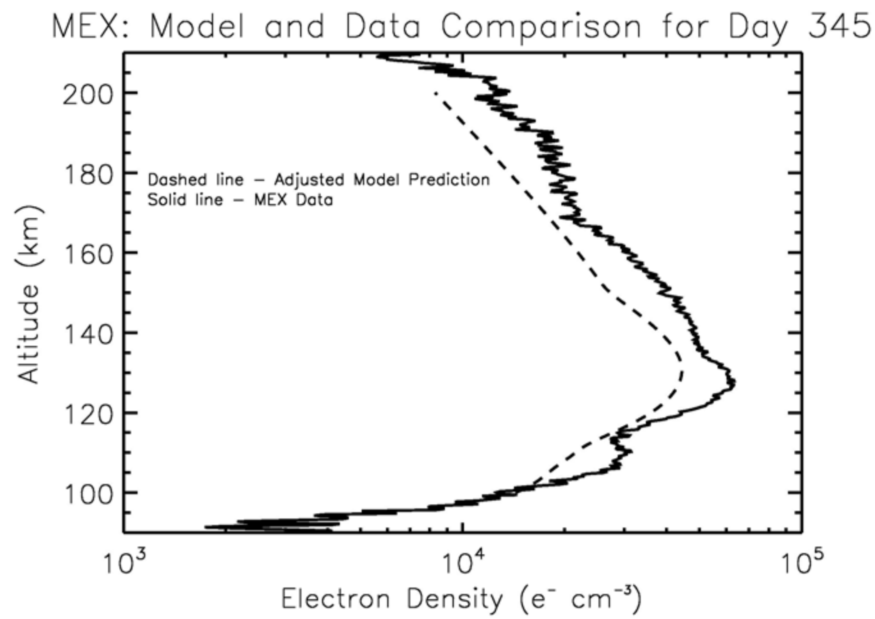
- Height of M1 layer is OK, but predicted densities are at least 60% smaller than observed

Possible adjustments

- Neutral composition, primarily O/CO_2 ratio
  - Effects minimal for plausible compositional changes
- Solar irradiance
  - Need to more than double ionizing flux to obtain accurate peak densities
  - Unrealistically large for validated Solar2000 model
- Neutral densities
  - Will affect peak altitude, but not peak electron density
- Electron temperatures
  - Will affect electron densities
- Parameterization of secondary ionization
  - Can be used to cure problems in M1 layer, but unlikely solution to poor predictions of peak altitude and peak electron density

Rescale neutral atmosphere…

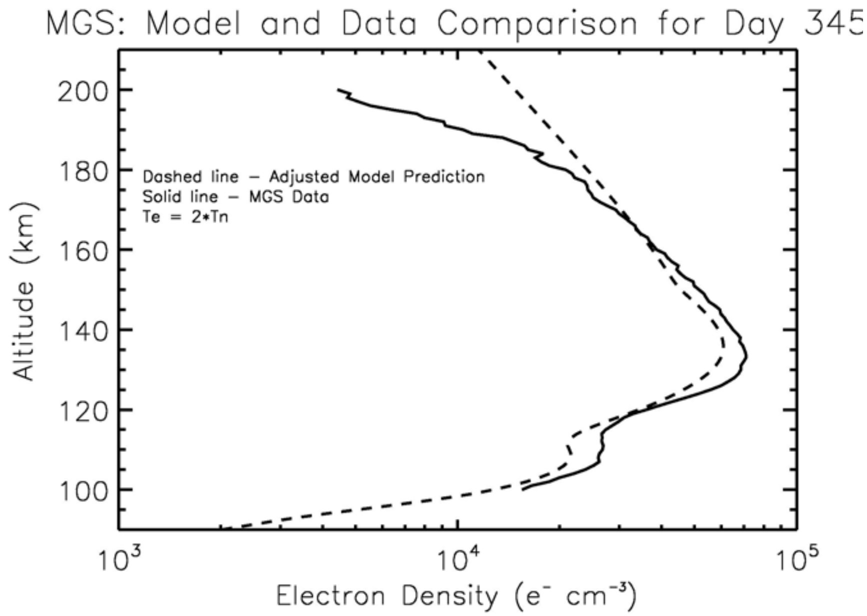


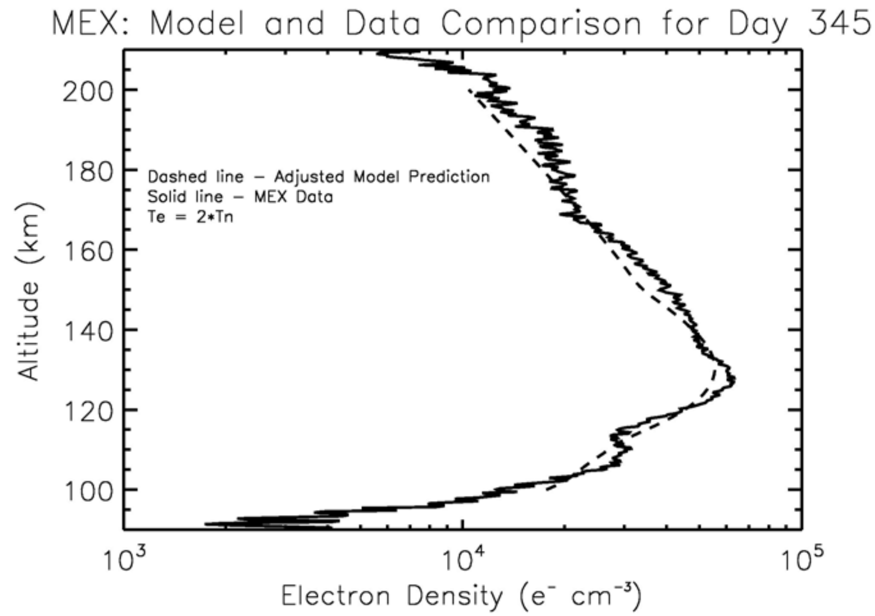


- MGS neutral densities multiplied by 0.5 (summer hemisphere)
- MEX neutral densities multiplied by 0.25 (winter hemisphere)
- These modifications to solar maximum atmosphere are reasonable

- Both predicted peak electron densities are still 35% smaller than observed
- Discrepancies in electron densities in the M1 layer are thankfully reduced to similar magnitudes
- Predicted M1 layer altitudes remain consistent with observations

… then double electron temperatures





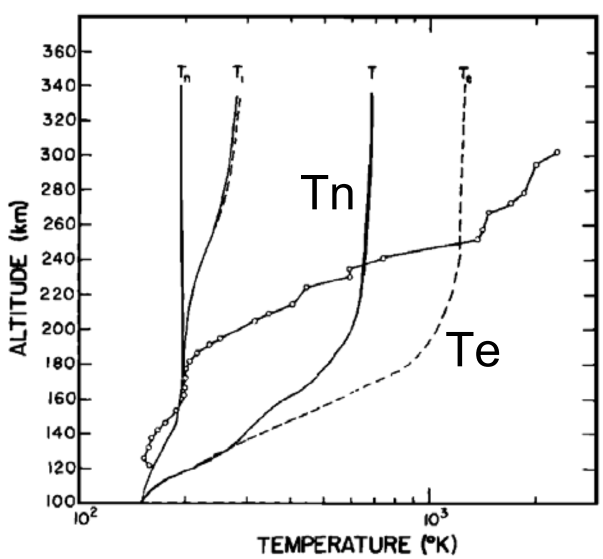
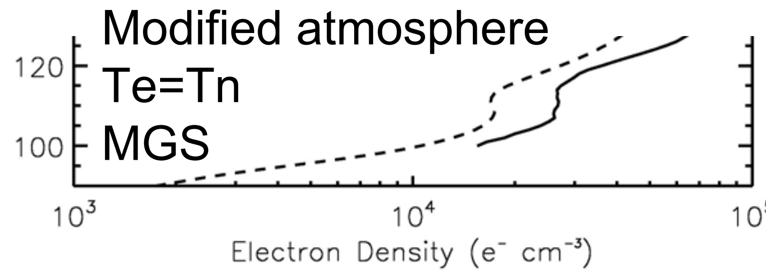
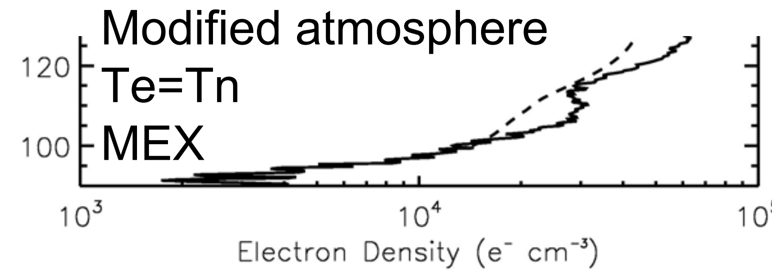


Fig 3 of Chen et al. (1978)

- Predicted peak altitude and peak density are accurate for both MGS and MEX
- Viking data show Te=Tn at M1 layer, but Te>Tn at M2 layer and above
- High electron temperatures make it harder for ions to dissociatively recombine, thereby increasing electron densities

What about M1 layer at 110 km?





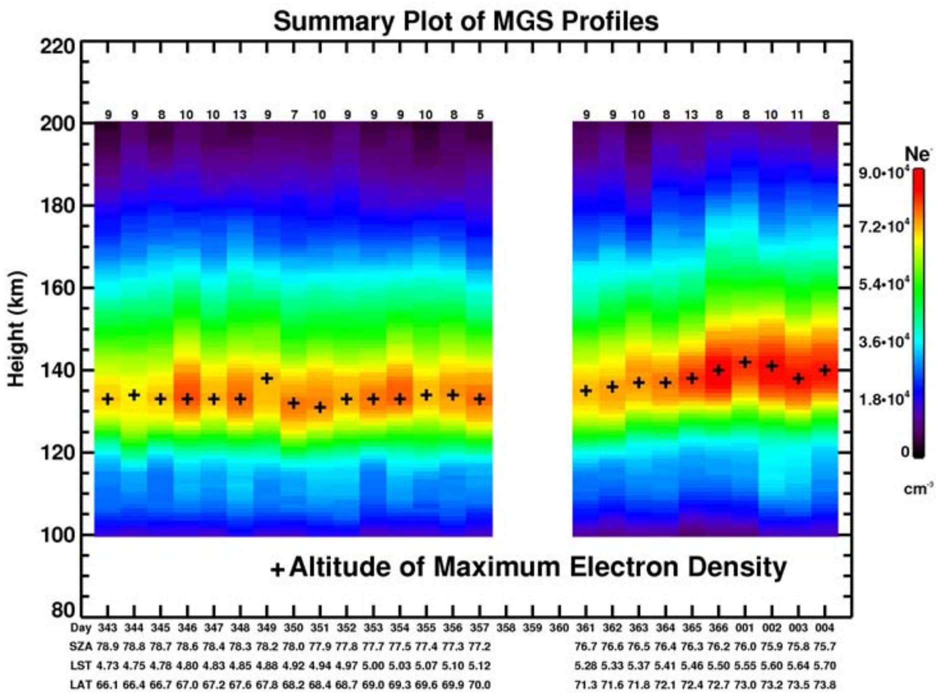
- Unrealistic to modify Te as low as 110 km
- Require some other adjustment(s) to increase simulated M1 layer electron densities
- Errors in predicted M1 layer densities are almost identical for MGS and MEX cases, so perhaps one adjustment to the model will be sufficient
- Increased secondary ionization?
  - Currently have 4 ions produced per photon at 110 km, asymptotically approaching 7 ions at lower altitudes
  - Require ~8 ions produced per photon absorbed at 110 km
- Enhanced irradiance at soft X-ray wavelengths?
  - Earth-Sun-Mars angle is 133°, so this is possible

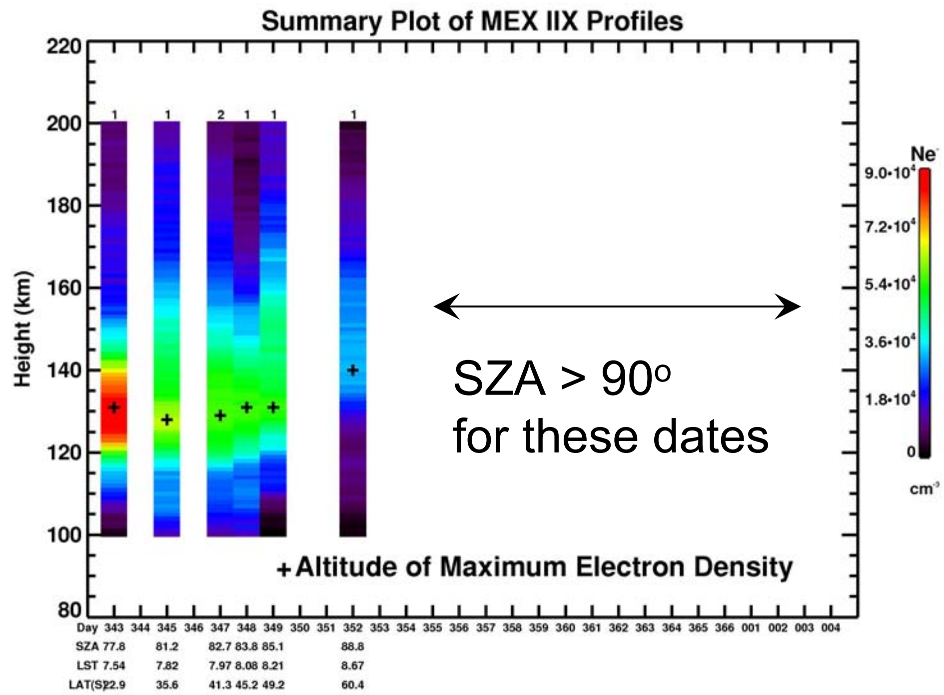
Conclusions

- Electron density profiles were measured by both MGS (NH) and MEX (SH) during December 2004
- MGS/MEX differences in peak altitude imply hemispheric differences in neutral atmospheric densities
- MGS/MEX similarities in inferred subsolar peak electron density imply similar photochemical processes and rates in both hemispheres (ie Te is similar in both hemispheres)
- Accurate simulation of peak altitude requires reasonable adjustment to initial neutral atmosphere
- Accurate simulation of peak electron density requires reasonable adjustment to initial electron temperatures
- Simulated M1 layer
  - Simulated altitude is OK
  - Cannot solve underpredicted electron densities with increased Te
  - Perhaps secondary ionization in model must be increased
  - Perhaps assumed solar soft X-ray fluxes are too small
  - Examining the <u>shape</u> of the M1 layer may be productive

Backup

Summary of MGS and MEX profiles





- Daily averaged profiles plotted for MGS
- One profile per day for MEX (except DOY 347 which has two)

- Peak electron densities typically greater for MGS than for MEX
- MGS peak altitude increases as SZA increases