Theoretical Simulations of the Martian Ionosphere and Comparisons to Observations

(How do thermospheric tides and variations in solar flux affect ionospheric variability?)

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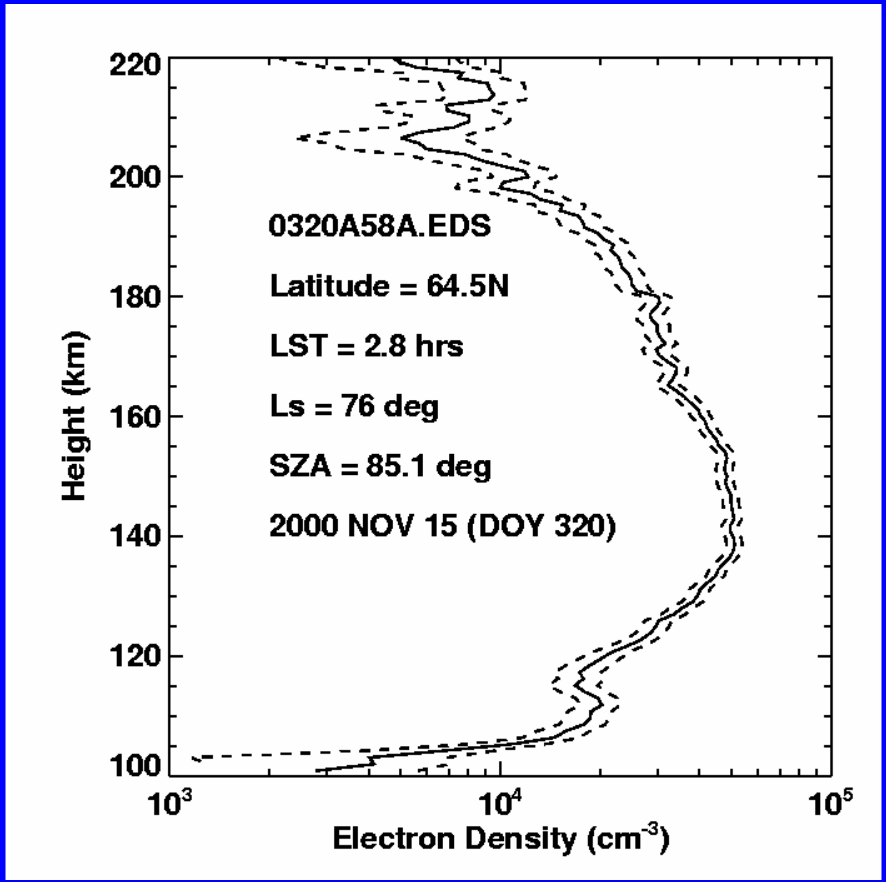
Introduction to Martian Ionosphere and MGS RS Data

MGS RS Data Coverage

60-85N, 60-70S
2-9, 12 hrs LST
70-180 deg Ls – over 2 yrs
70-87 deg SZA
Dec 98, Mar 99, May 99,
and Nov 00 – Jun 01



Simplified chemistry

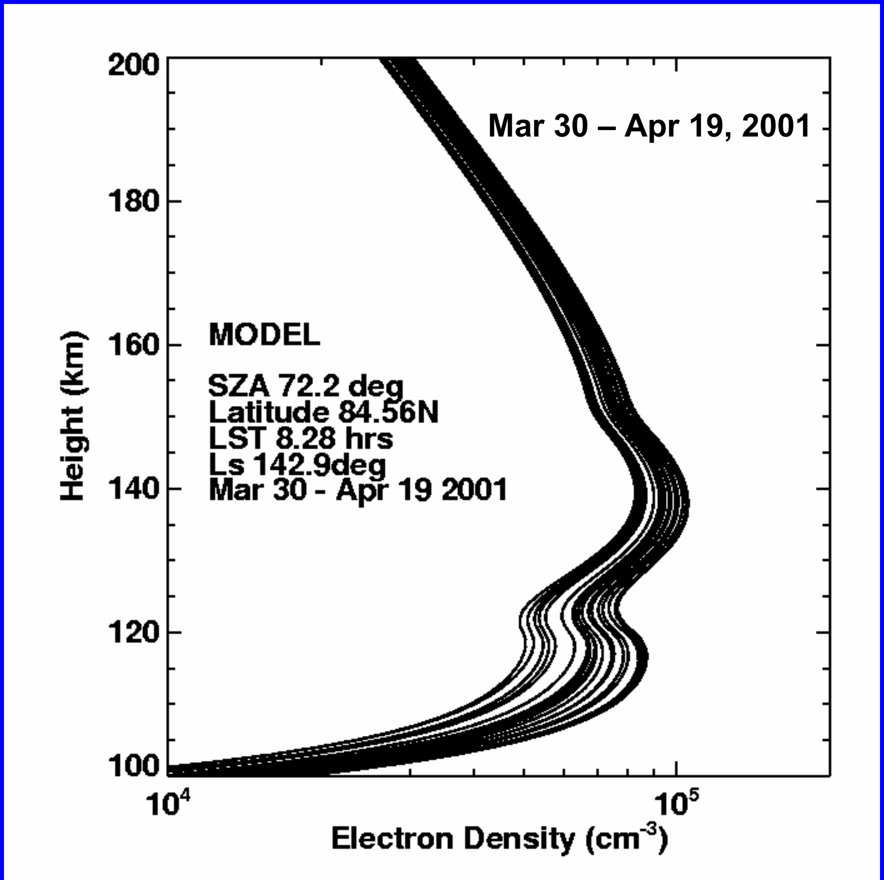
CO_2 + hv -> CO_2^+ + e (fast)
CO_2^+ + O -> O_2^+ + CO (fast)
O_2^+ + e -> O + O (slow)

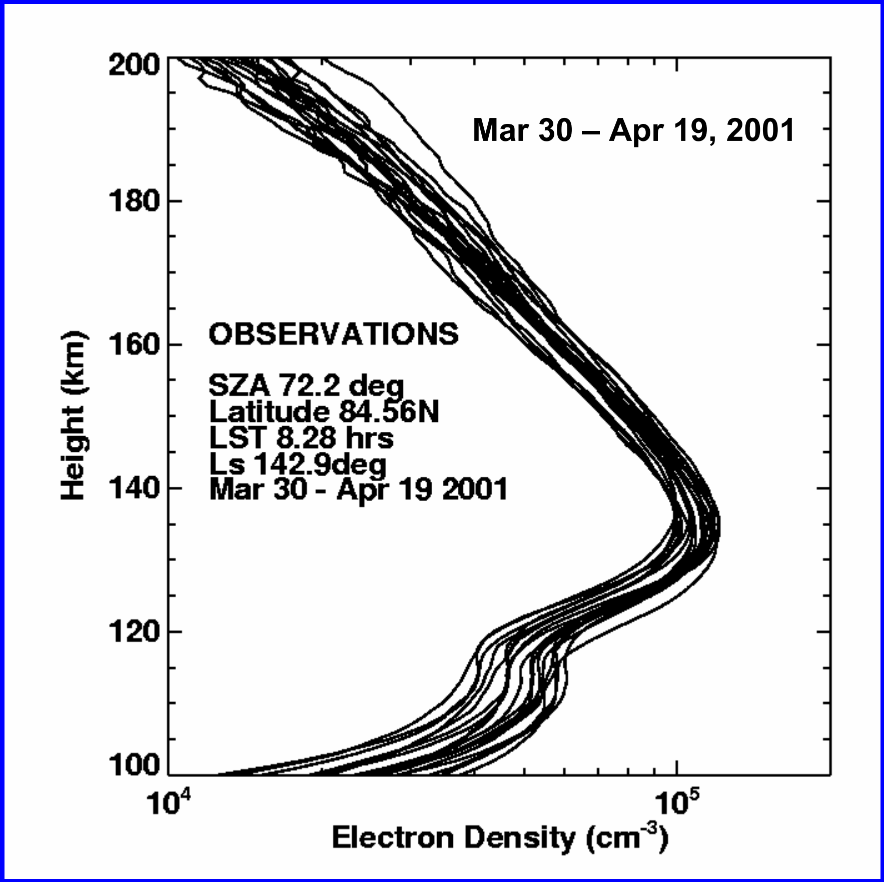
Typical Profile

Primary peak, well fit by alpha-Chapman function, 130-150 km, (4-14) x 1E4 cm^{-3}
Secondary feature (ledge, peak, etc) of variable significance, 110-120 km
Primary peak mainly from 30.38 nm (Helium) flux, secondary peak from few nm X-rays
Wavy topside with H decreasing as altitude increases

Ionospheric Profiles, Observed and Modelled, Mar 30 – Apr 19, 2001

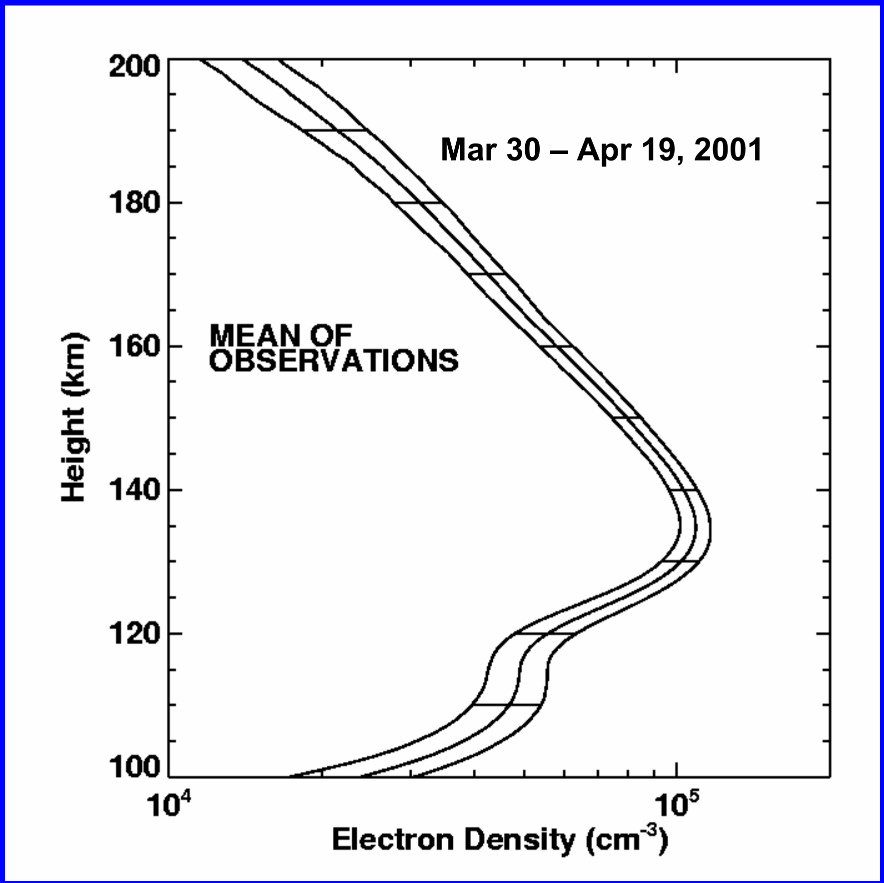
Aim: Relate ionospheric variability during this period to solar flux and dynamical effects

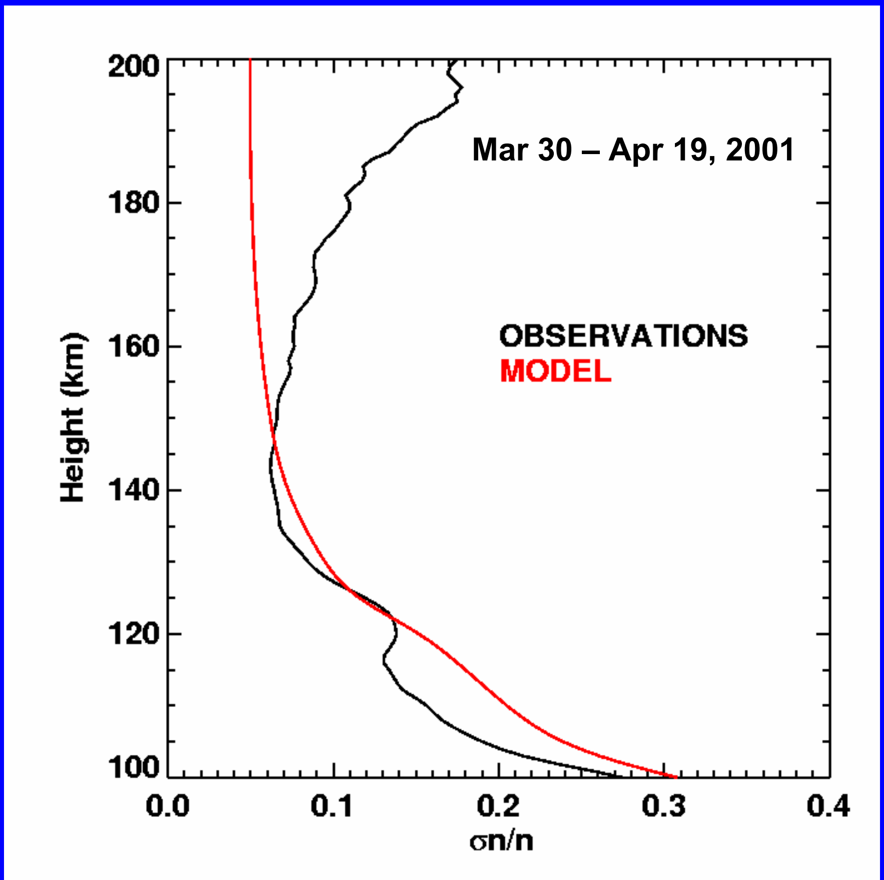




Photochemical model of Martinis et al., 2003
Fixed neutral atmosphere, solar fluxes from Tobiska's SOLAR 2000 for each day
Crude parameterization of secondary ionization by photoelectrons below 120 km
See also Withers et al., SA24A-05, Tuesday pm for more on solar effects

Characteristics of Ionospheric Variability





#1 - Model variability asymptotes to minimum at high altitude

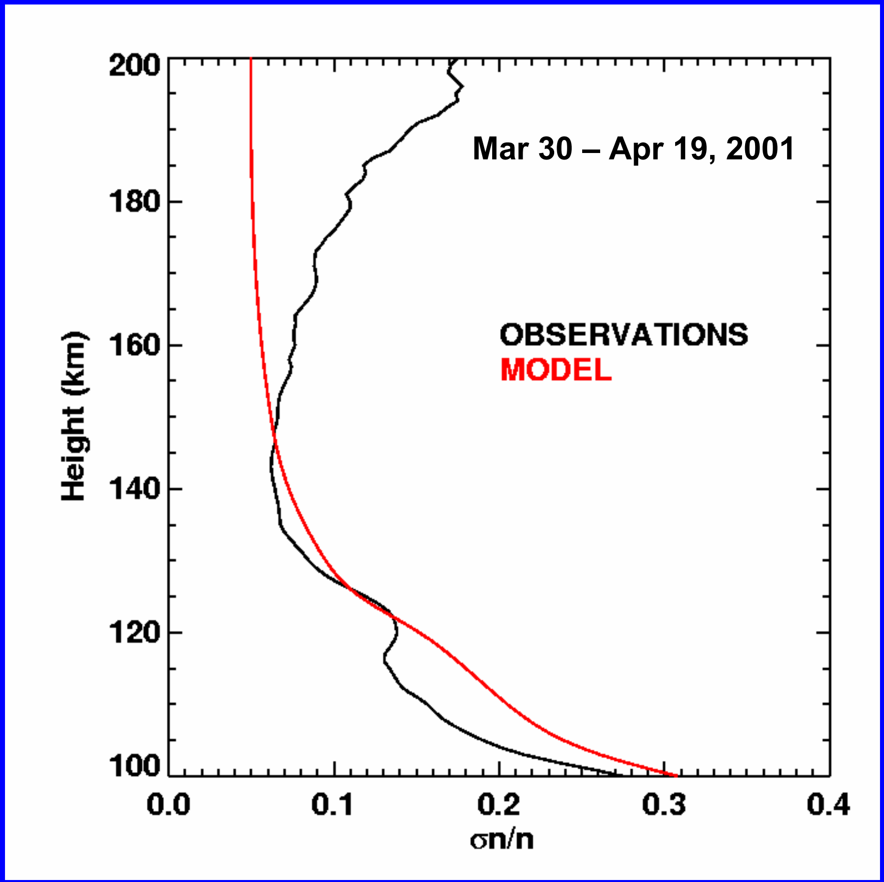
#2 - Model variability increases monotonically as altitude decreases

#3 - Observed variability has minimum just above peak, then increases as z increases

#4 - Observed variability has bulge between primary peak and secondary feature

Explanation of Characteristics #1 and #2

$$\alpha n_e^2 = n_{CO2} \sum_{\lambda} \sigma_{xs}(\lambda) F_0(\lambda) \exp\left(-Chfn \times n_{CO2} \sigma_{xs}(\lambda) H\right)$$



Topside (#3) and bulge (#4) not adequately explained by solar flux

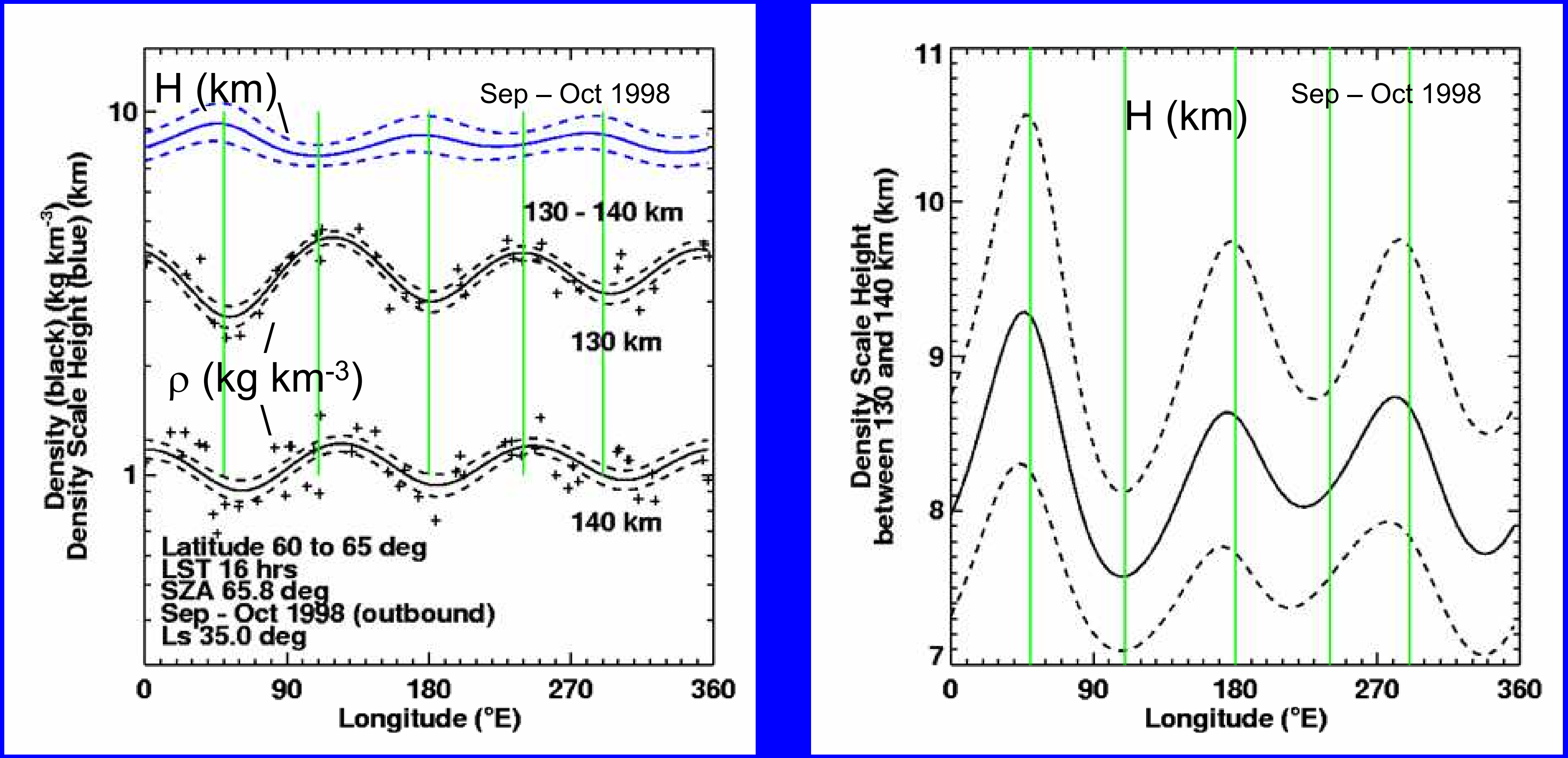
(#1) When optically thin, at high altitude

$$2\frac{\delta n_e}{n_e} = \frac{\delta\left(\sum \sigma_{xs}(\lambda) F_0(\lambda)\right)}{\left(\sum \sigma_{xs}(\lambda) F_0(\lambda)\right)}$$

(#2) Since the least variable wavelengths of solar flux are absorbed at highest altitudes, and most variable few nm X-rays are absorbed at lowest altitudes, model variability increases as altitude decreases.

Magnitude of observed minimum is comparable to model prediction, as is variability at 100 km.

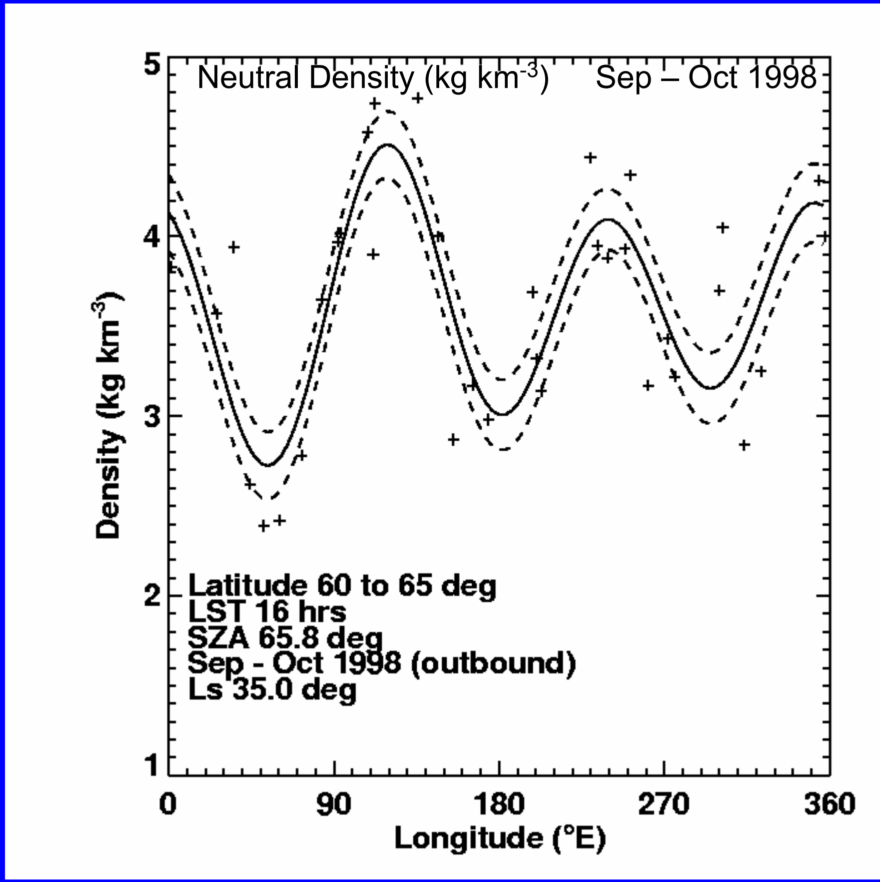
Tides in the Neutral Atmosphere at Different SZA, Ls, and Lat

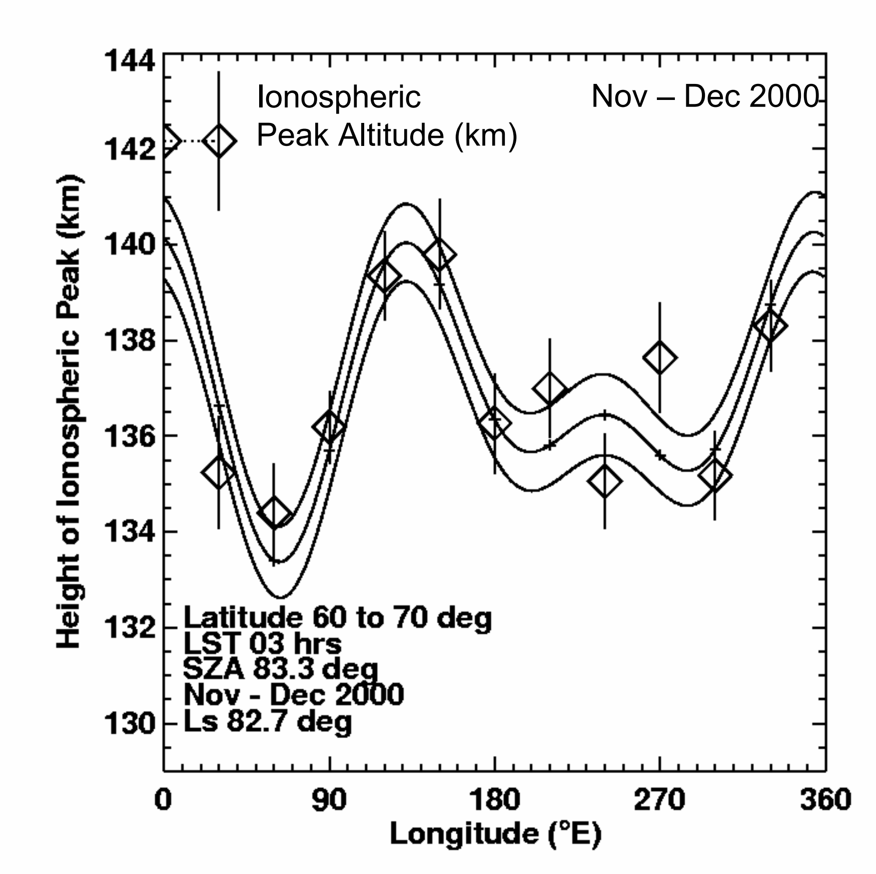


Peaks and troughs in density and scale height are anti-correlated
This is because zonal structure decays to a zonal mean by ~ 160 km

Dashed lines show 1-sigma error in best fit as function of longitude
They do not show the 1-sigma standard deviation that 67% of future observations should lie within.

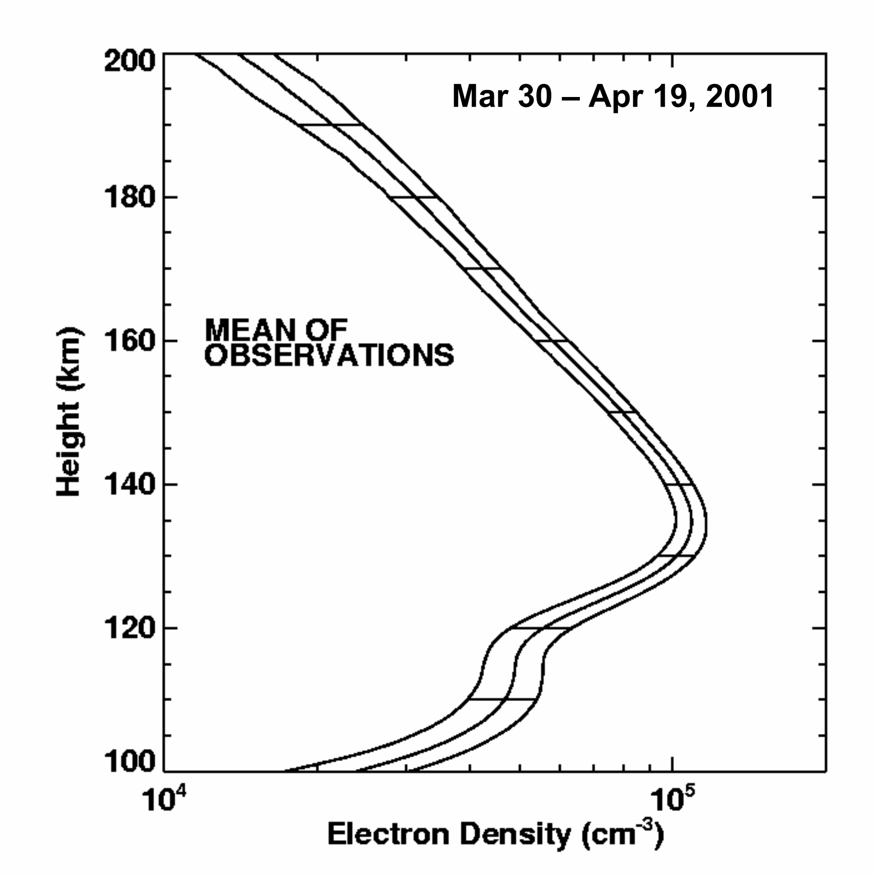
Comparison of Thermosphere and Ionosphere at Most Similar SZA, Ls, Lat

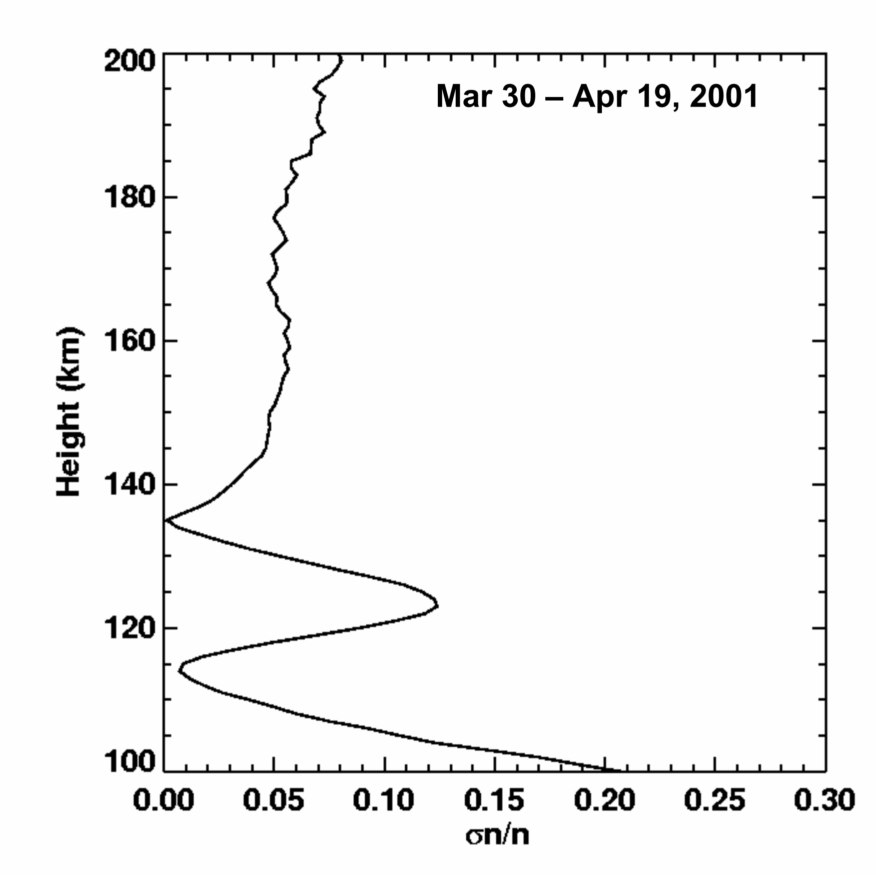




As previously found by Bougher et al., wave-3 harmonics dominate in both cases and their phases are similar -> semidiurnal disturbance

Explanation of Characteristics #3 and #4





$$n^*(z) = n(z) + \Delta z \frac{dn}{dz}$$

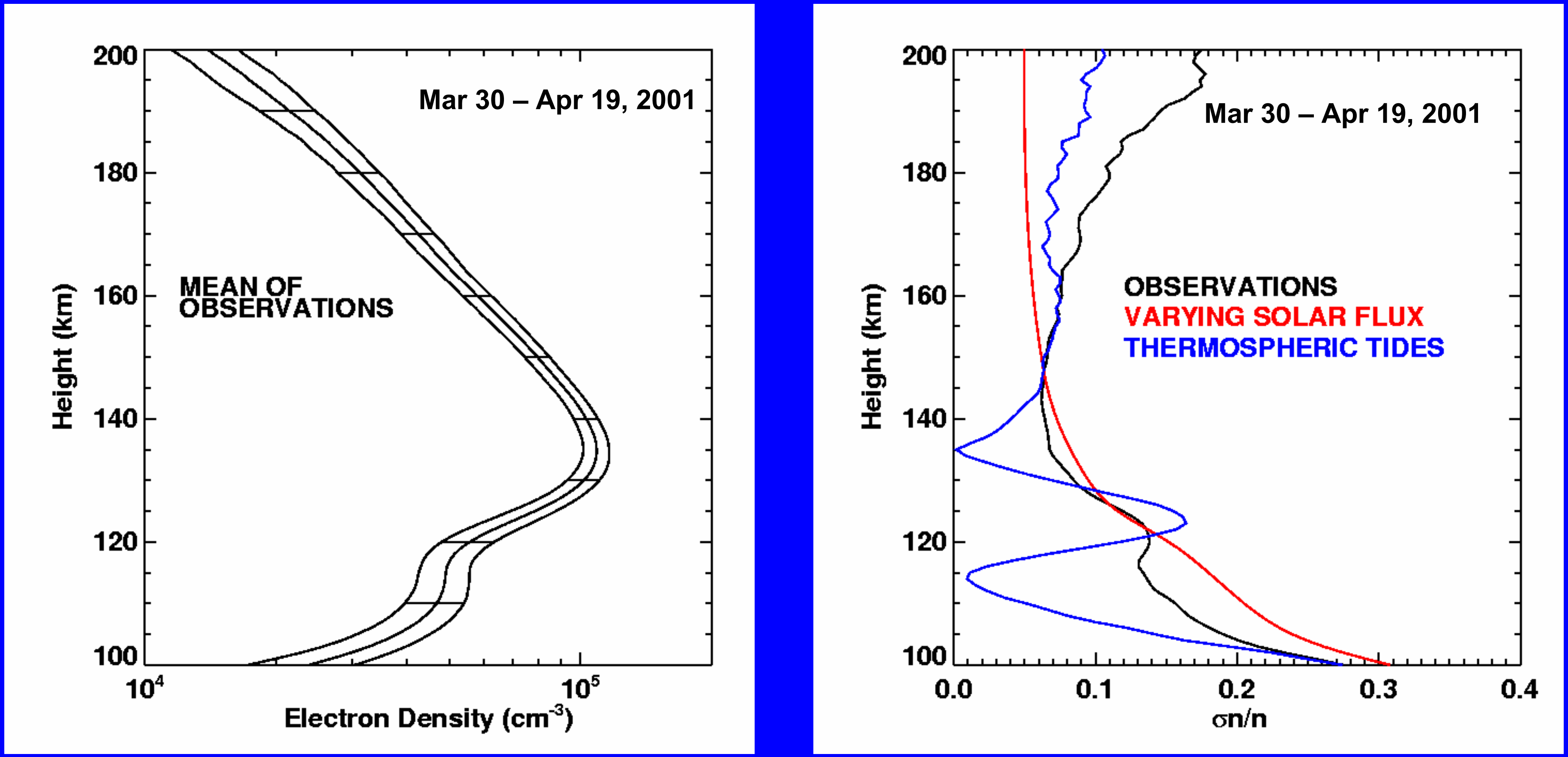
$$\frac{\Delta n}{n} = \frac{\Delta z}{n} \frac{dn}{dz}$$

(#3) Increased topside variability generated

(#4) Bulge between primary peak and secondary feature generated.

$\Delta z = 2$ km

Ionospheric Variability Due to Both Solar and Tidal Effects



Tides responsible for increased variability between peaks

Tides can contribute to increased topside variability

Combination of tidal and solar effects is not simple sum of models

Conclusions

- Variations in incident solar flux explain some, but not all, variations in observed ionospheric profiles
- Thermospheric tides can explain most of remaining variability
- Should not study these two effects in isolation, rather couple them in unified model
- Thermospheric tides affect H as well as ρ