Recent results from Boston University

Paul Withers and Majd Matta

(withers@bu.edu)

With contributions from Michael Mendillo, Anthony Lollo, Joei Wroten, Robert Pratt, Jeffrey Russo

MEX Workshop

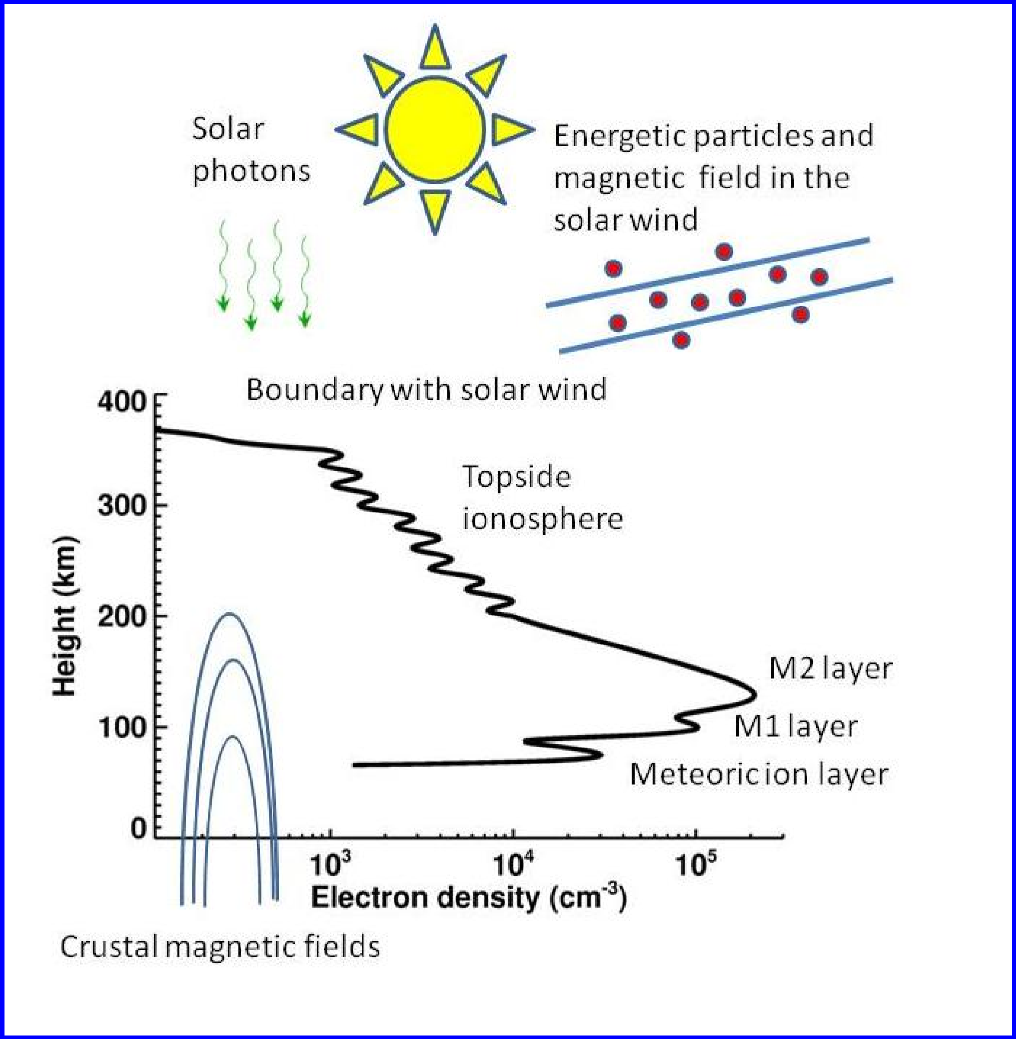
2010.01.25-26

Max Planck ISSR, Katlenburg-Lindau, Germany

Overview

- White paper on Mars ionosphere
- Review article on Mars ionosphere
- Ionospheric effects on radio signals
- Simulations of simultaneous MGS and MEX radio occultations
- Simulations of solar flares
- NASA wants to give you money (MAVEN)

White paper on Mars ionosphere



Community contribution to NASA Decadal Survey, thank you to co-authors

1) Please don't cancel MAVEN
2) Please extend MAVEN
3) Ionospheric science should not end with MAVEN

ELSEVIER

Available online at www.sciencedirect.com

ScienceDirect

Advances in Space Research 44 (2009) 277–307

ADVANCES IN SPACE RESEARCH (a COSPAR publication)

www.elsevier.com/locate/asr

Review

A review of observed variability in the dayside ionosphere of Mars

Paul Withers

Center for Space Physics, Boston University, 725 Commonwealth Avenue, Boston, MA 02215, USA

Received 3 September 2008; received in revised form 3 April 2009; accepted 29 April 2009

Abstract

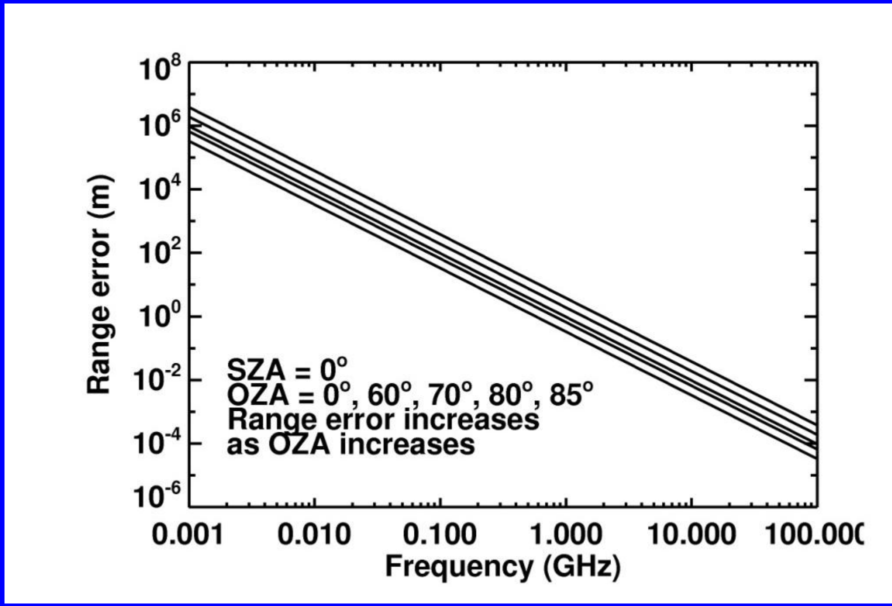
Recent measurements by Mars Global Surveyor and Mars Express have greatly increased the number of observations of the martian dayside ionosphere available for study. Together with earlier measurements from the Viking era, these datasets have been used to investigate variations in well-known properties of the martian dayside ionosphere and to discover new ionospheric features. The dayside ionosphere includes the main peak, called the M2 layer, and a lower layer, called the M1 layer. In the topside, above the M2 layer, electron densities exponentially decrease with increasing altitude.

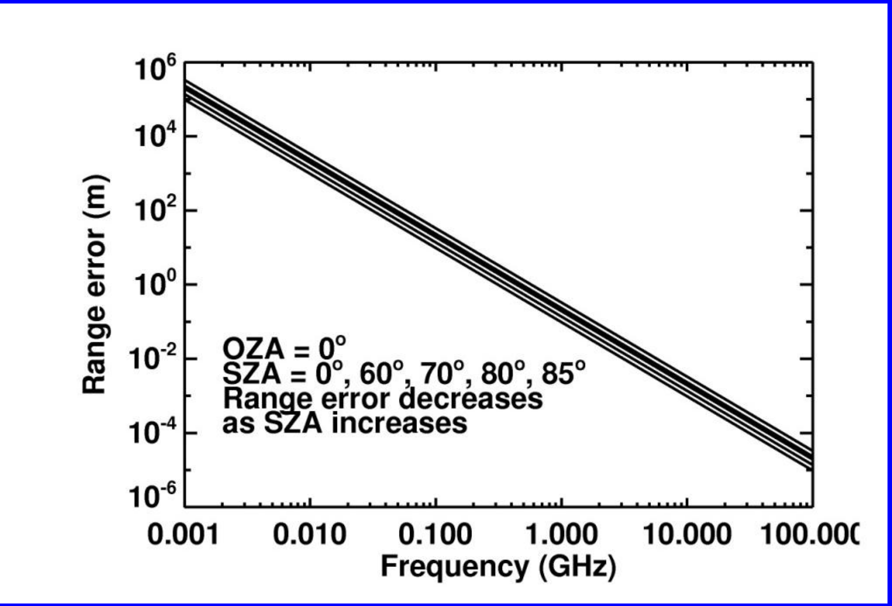
The following variations in ionospheric properties are addressed. Peak electron densities and altitudes depend on solar zenith angle as predicted by Chapman theory. Electron densities in the M1 layer have a similar dependence on solar zenith angle. Peak electron densities are sensitive to the Sun's rotation and solar flares, although the quantitative dependence of peak electron densities on solar irradiance is not as strong as theoretically predicted. Peak electron densities are increased in regions of strong and vertical magnetic field, possibly due to a two-stream plasma instability that increases electron temperatures. Peak altitudes follow fixed pressure levels in the neutral atmosphere, rising and sinking in response to thermal tides and dust storms. Electron densities below the M2 layer are highly variable because the relevant portion of the solar spectrum (<20 nm) varies significantly on a range of timescales. In addition, electron densities below the M2 layer increase in response to solar flares, solar energetic particle events, and increases in meteoroid flux. Electron densities above the M2 layer are affected by magnetic fields. Abrupt changes in topside electron density with altitude are sometimes observed above strong magnetic fields and topside electron densities are increased in regions of strong and vertical magnetic field. Layering has been observed at a range of altitudes throughout the topside. A bulge in electron densities is a persistent feature at 160–180 km, whereas layers above 200 km occur sporadically. The upper boundary of the ionosphere is affected by complex interactions with the dynamic solar wind.

In summary, external factors, including the solar irradiance, the solar wind, and meteoroid flux, and internal factors, including neutral atmospheric density and composition, solar zenith angle, and crustal magnetic fields, affect the variability of the martian dayside ionosphere.

Keywords: Mars; Ionosphere; Plasma

GPS range error





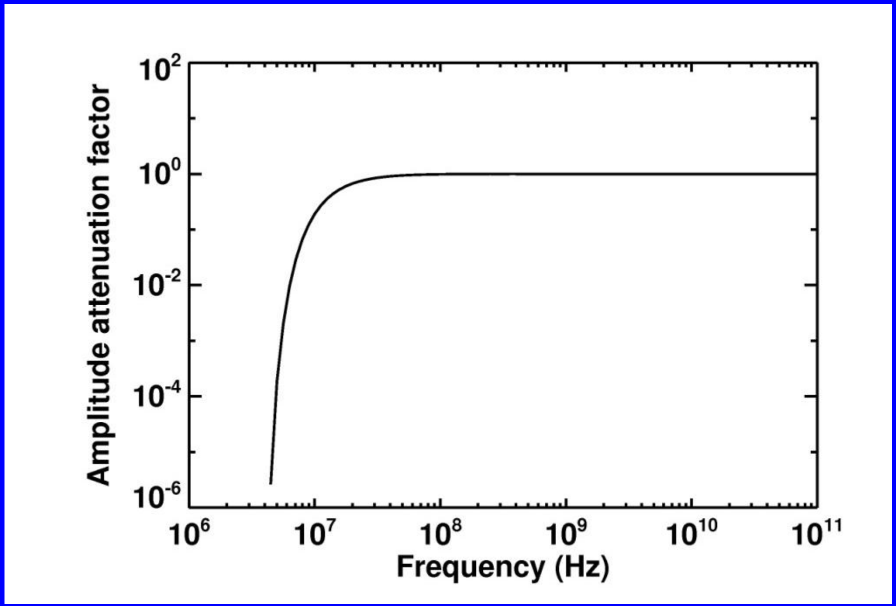
General case

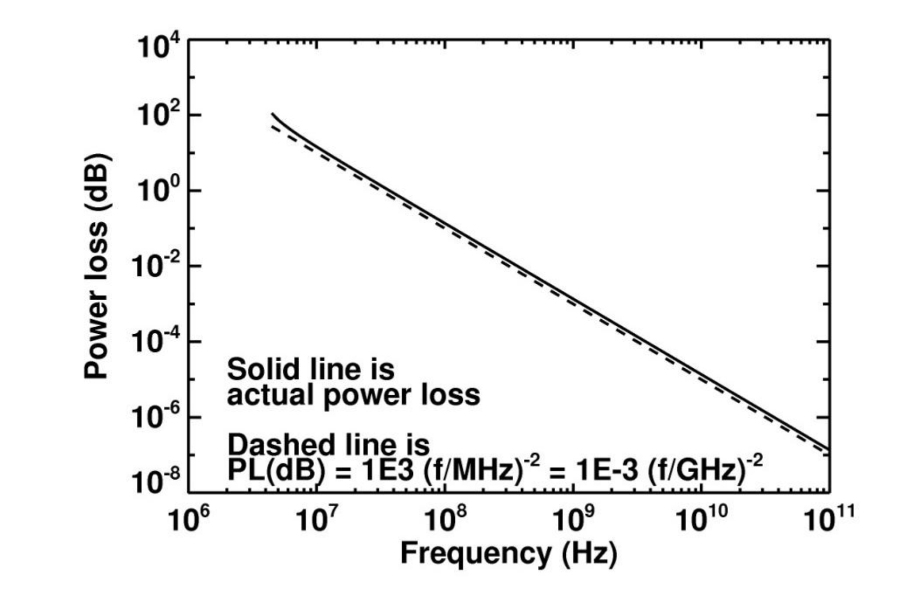
$$\Delta D = \frac{0.403\ \mathrm{m}}{\cos\left(\mathrm{OZA}\right)} \left(\frac{\mathrm{GHz}}{f}\right)^2 \frac{\int N_e\, dz}{1\mathrm{E}16\ \mathrm{m}^{-2}}$$

Chapman layer

$$\Delta D = 0.33\mathrm{m}\ \frac{\sqrt{\cos\left(\mathrm{SZA}\right)}}{\cos\left(\mathrm{OZA}\right)} \left(\frac{\mathrm{GHz}}{f}\right)^2 \frac{N_0}{2\mathrm{E}11\mathrm{m}^{-3}} \frac{H}{10\mathrm{km}}$$

Signal attenuation results

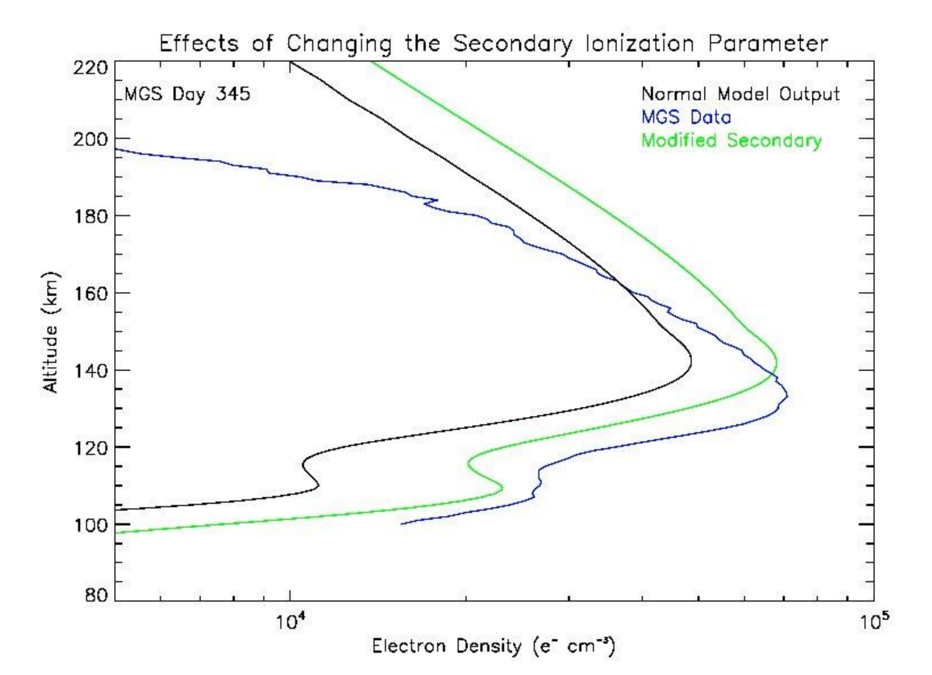


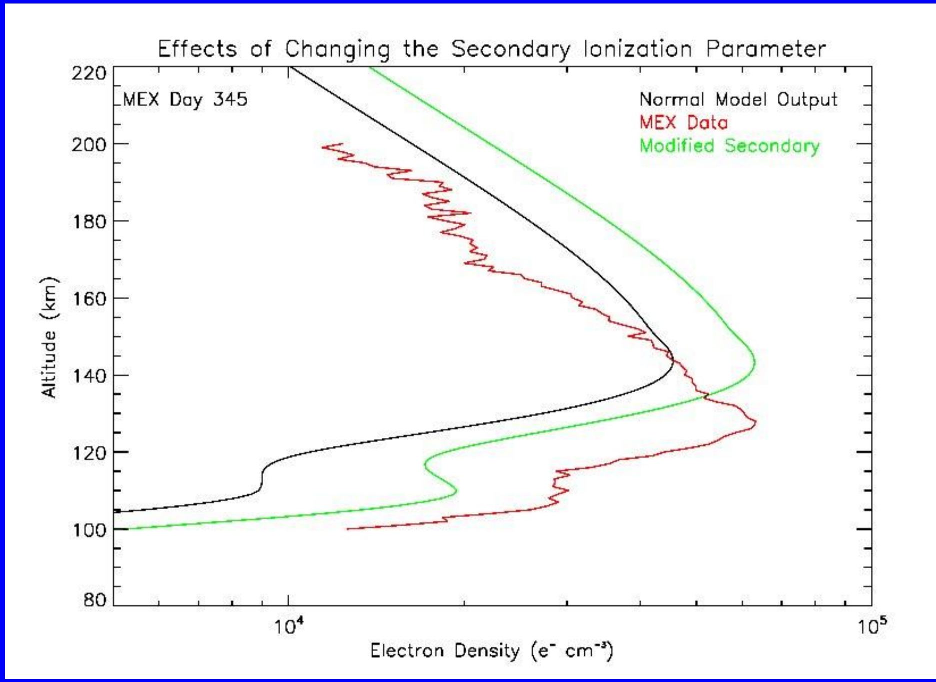


SZA = 0 degrees, OZA = 0 degrees

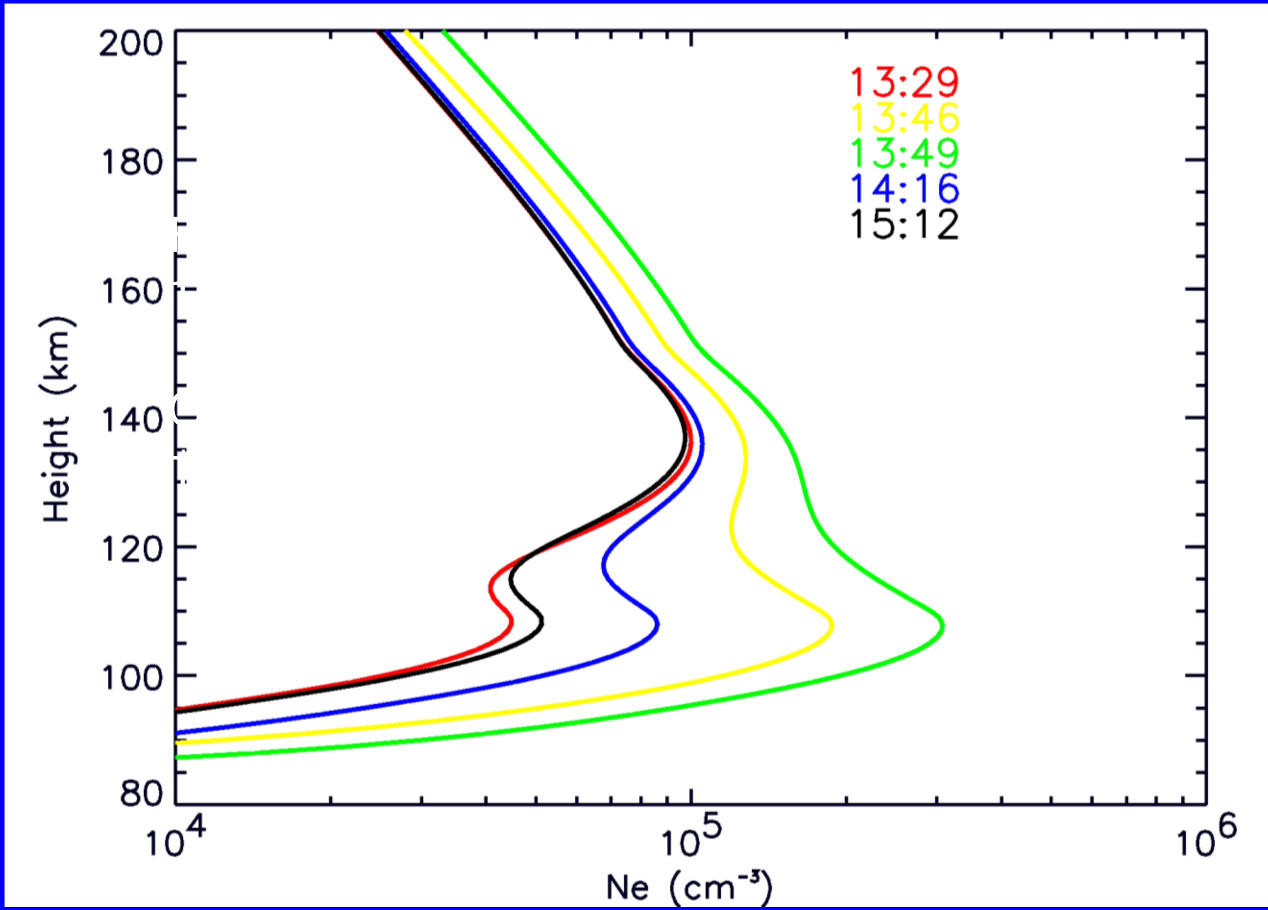
Extend from normal ionosphere to disturbed ionosphere, including MARSIS surface blackouts

10 Dec 2005 – MGS at 67N, MEX at 36S What model parameters reproduce both observations well?





Simulated ionosphere for solar flare



<u>Next steps:</u>

Compare model with data
Optimize model inputs
Are optimized inputs like the atmosphere, electron temperatures, secondary ionization realistic?

MAVEN Critical Data Products
mepag.jpl.nasa.gov/cdp/
3 page proposals due 1 March
A rare case where NASA $ can flow to Europe

3.0 MAVEN CRITICAL DATA PRODUCTS NEEDS

Characterize the 3-D Mars thermospheric structure in the lower atmosphere (<200 km) extending from the exobase downward to the vicinity of its homopause (~115-150 km) to flag regions of potentially extreme atmospheric perturbations and for support of five specific "deep dip" campaigns down to ~125 km during the 1-year MAVEN mission:

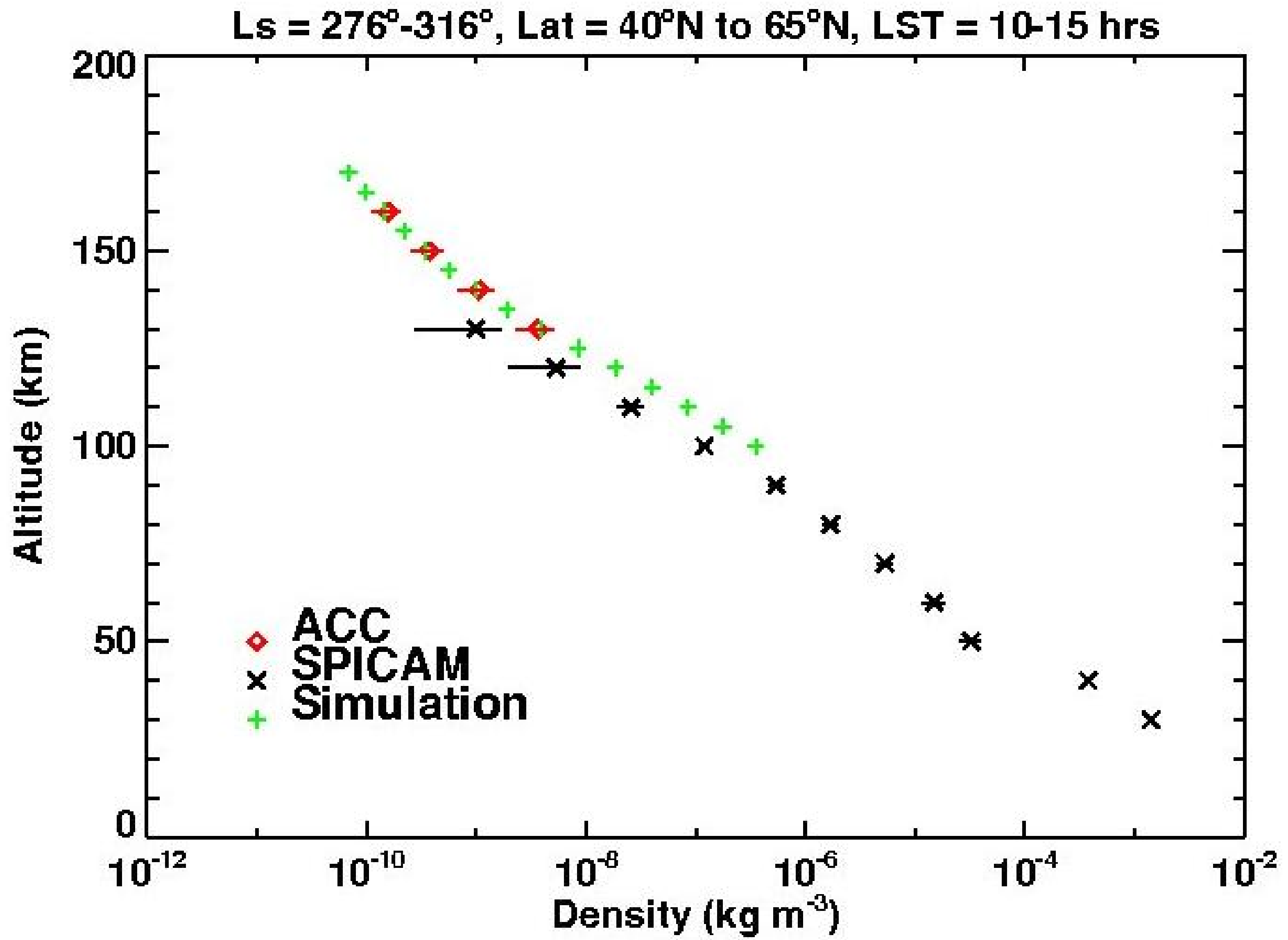
A. Simulate the 3-D neutral temperature, composition (including mass densities), and horizontal (zonal and meridional) wind structure, along with potentially extreme orbit-to-orbit variations.

- Determine variations of these parameters over a range of solar activity (at least F10.7 from 130 to 200) and all Mars seasons.
- Determine variations of these parameters over regions of the lower atmosphere containing different horizontal dust distributions (e.g., including variations measured by TES or THEMIS, or modeled variations based on TES or THEMIS inputs).

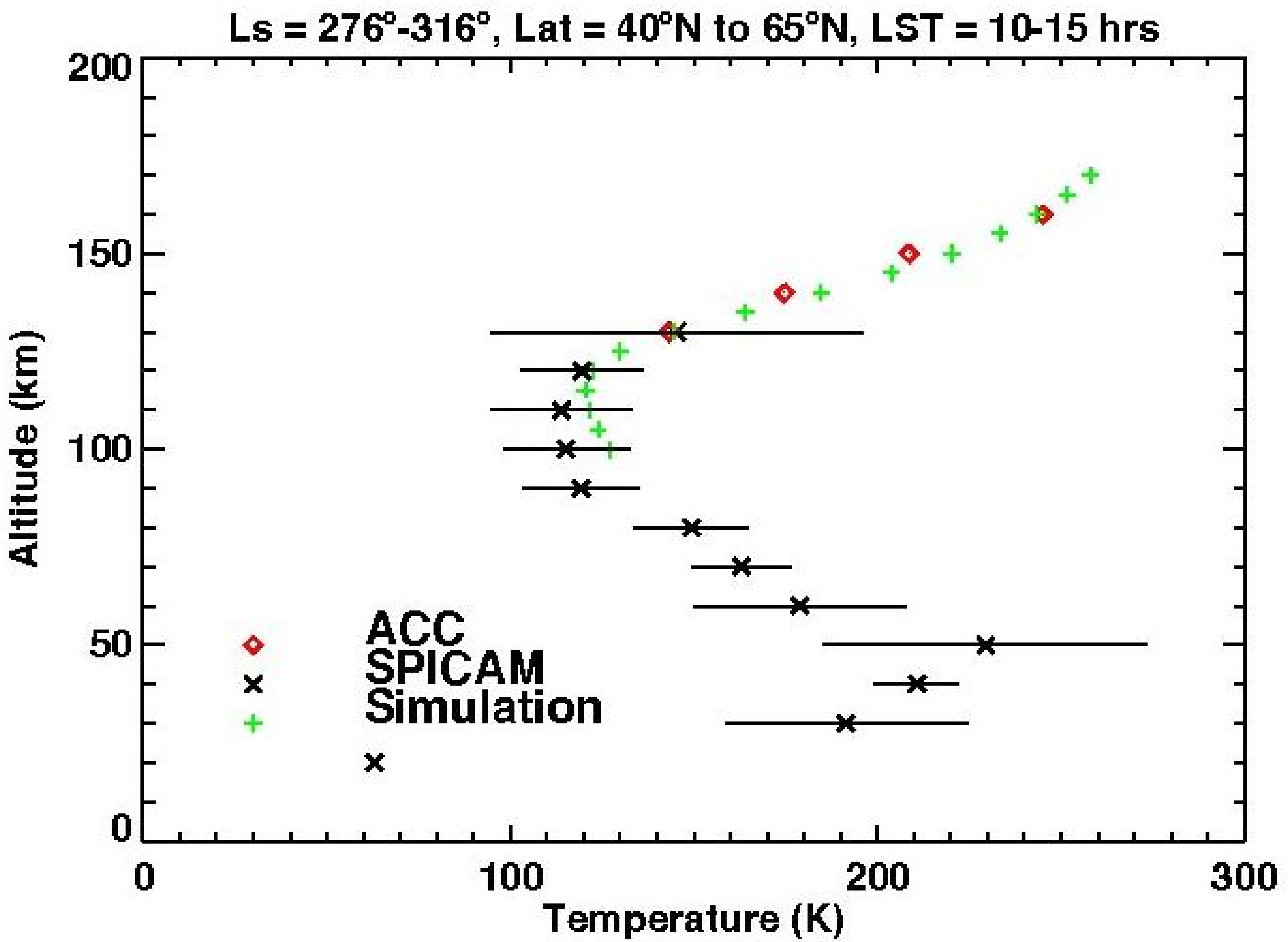
B. Provide tabular and plotted outputs of these parameters (and their variations) for the locations (latitude, season, local solar time, and possible dependence on longitude) of the five specific MAVEN "deep dip" campaigns.

C. Model atmosphere response at MAVEN's periapsis altitudes in response to solar flares, Co-rotating Interaction Regions (CIRs), Coronal Mass Ejections (CMEs), and dust storm perturbations to the atmosphere that might be anticipated during the mission.

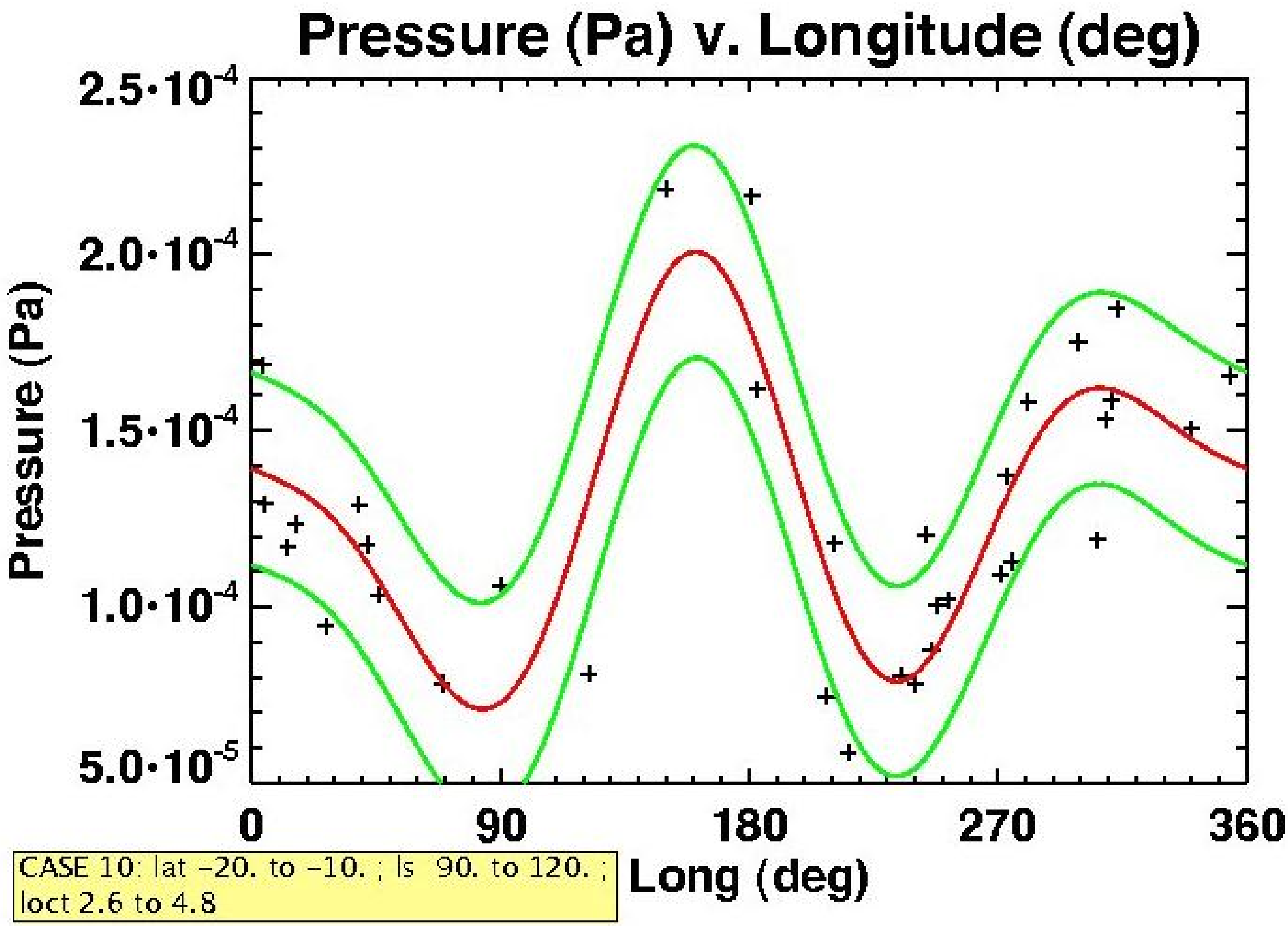
Backup

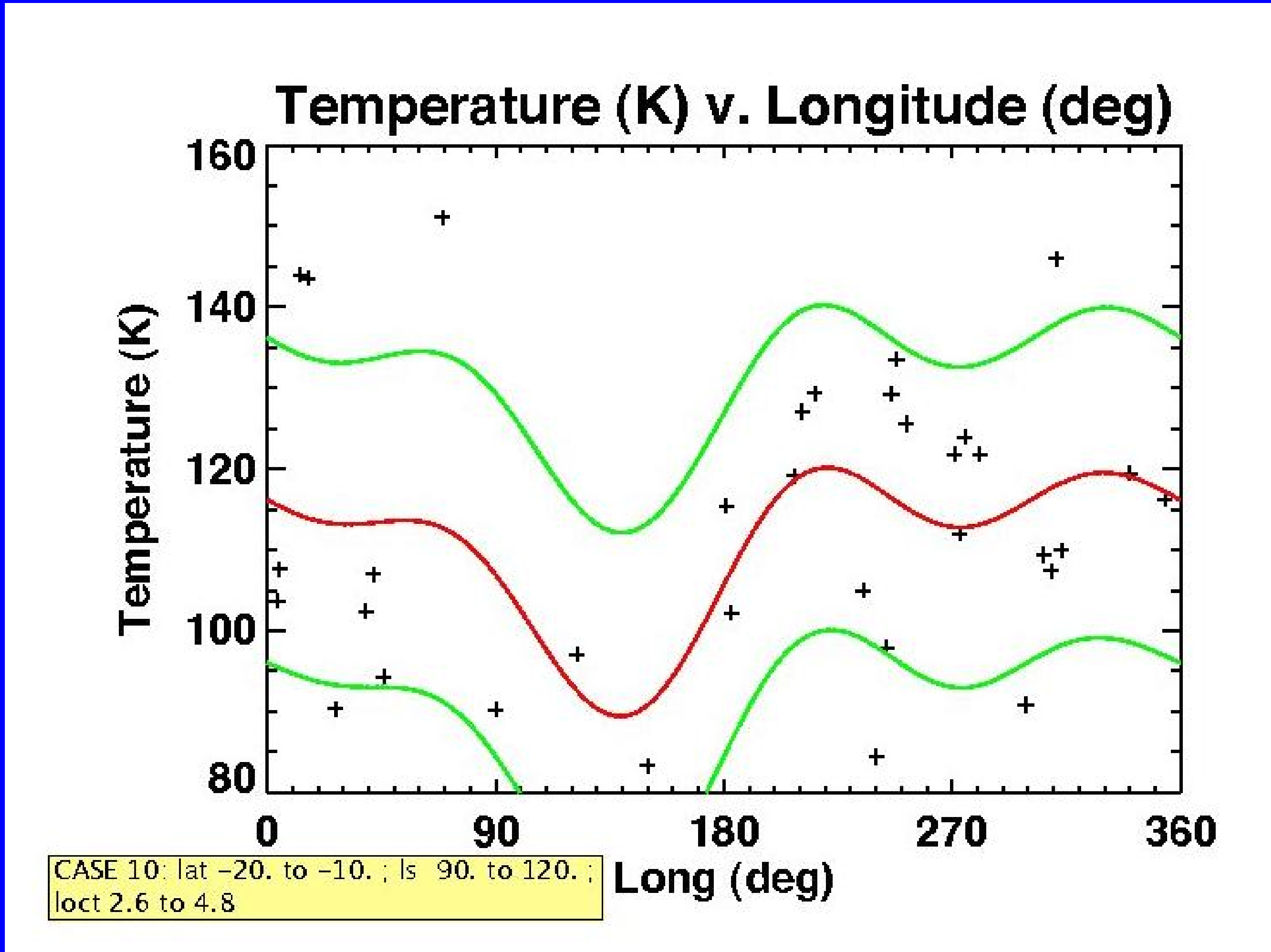


Ls = 276°-316°, Lat = 40°N to 65°N, LST = 10-15 hrs
200
150
100
50
0
Altitude (km)
10-12
10-10
10-8
10-6
10-4
10-2
Density (kg m-3)
ACC
SPICAM
Simulation



Ls = 276°-316°, Lat = 40°N to 65°N, LST = 10-15 hrs
Altitude (km)
Temperature (K)
0
50
100
150
200
0
100
200
300
ACC
SPICAM
Simulation


Pressure (Pa) v. Longitude (deg)
2.5·10-4
2.0·10-4
1.5·10-4
1.0·10-4
5.0·10-5
Pressure (Pa)
0
90
180
270
360
Long (deg)
CASE 10: lat -20. to -10. ; ls 90. to 120. ;
loct 2.6 to 4.8


Temperature (K) v. Longitude (deg)
Temperature (K)
160
140
120
100
80
0
90
180
270
360
Long (deg)
CASE 10: lat -20. to -10. ; ls 90. to 120. ;
loct 2.6 to 4.8

10 Dec 2005 – MGS at 67N, MEX at 36S What model parameters reproduce both observations well?