Climatological Comparisons Between the Earth and Venus Upper Atmospheres

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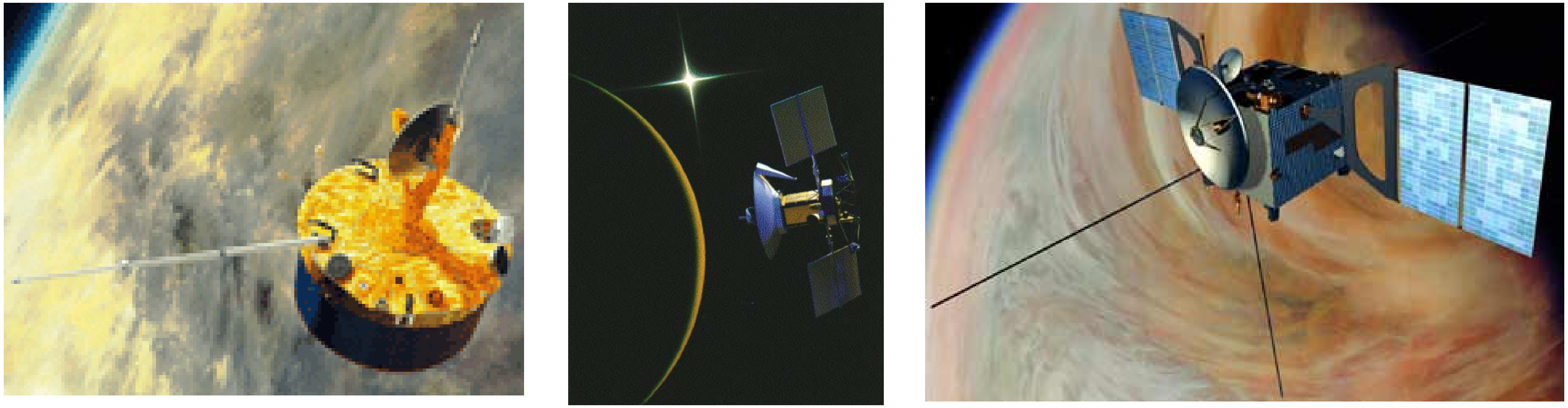

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Session 5: Climate and Atmospheric Dynamics, Wednesday, 13 May 2009, 14:40 (2:40pm)

Venus Orbital Decay (Aerobraking)

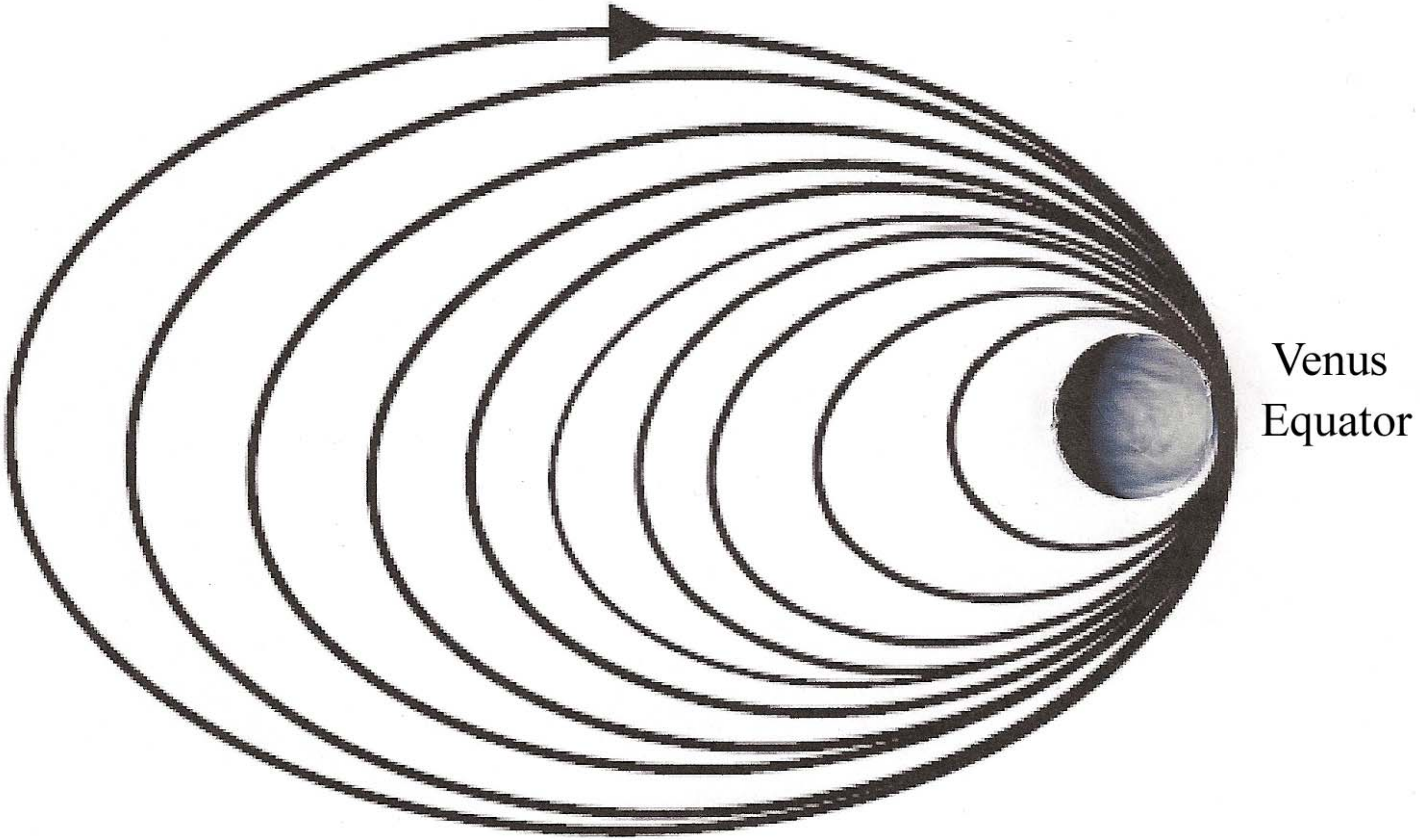


Figure 1

Temperature as a Function of Mean Molecular Weight and Scale Height

$$T = \frac{(m)(g)(h)}{R}$$

T=Temperature

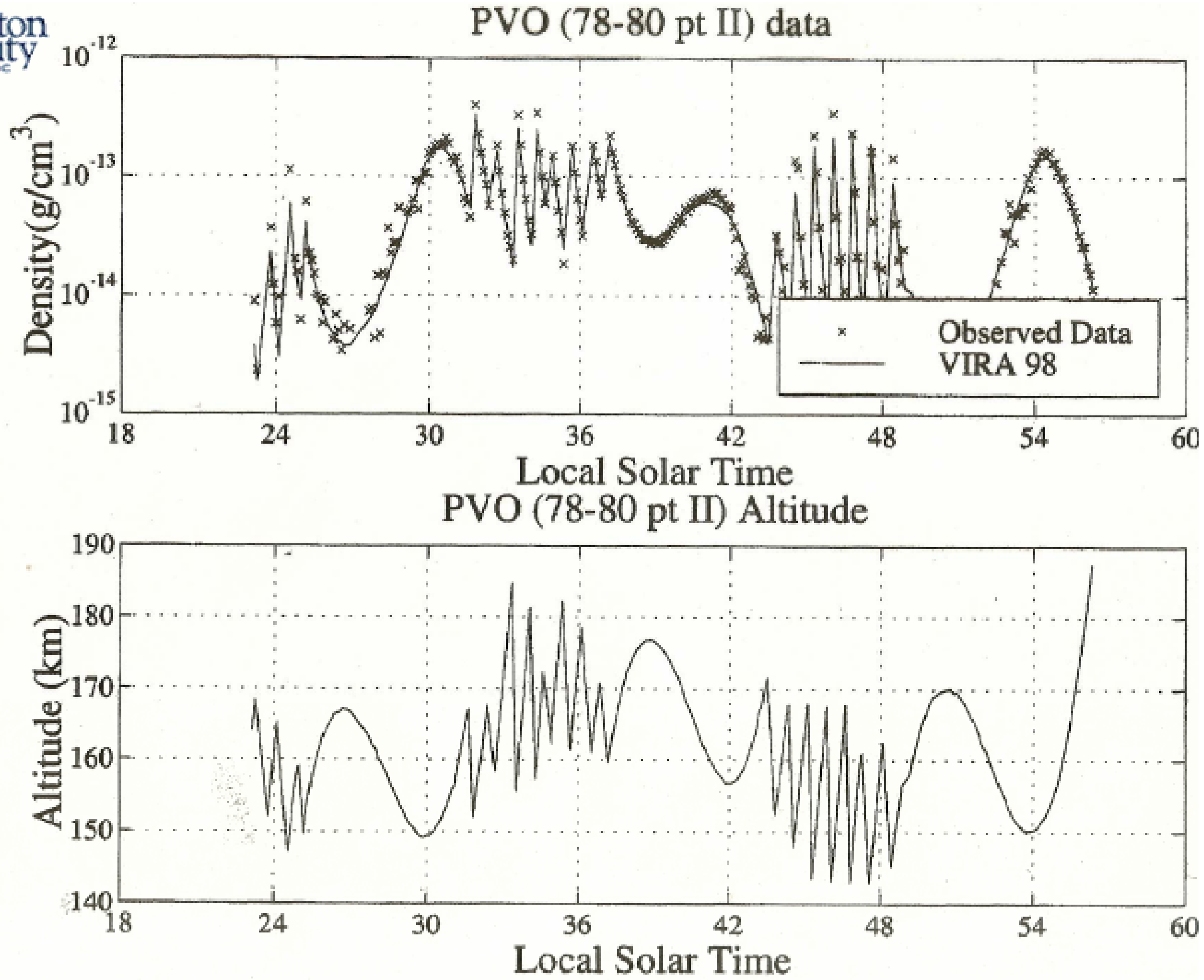
m= mean molecular weight

g= gravity

h= scale height

R= gas constant

Figure 2



Model Coefficients loaded from file: coefs 11 20 1998 13 23 2c1

Figure 3

ATMOSPHERIC TEMPERATURES ON EARTH AND VENUS

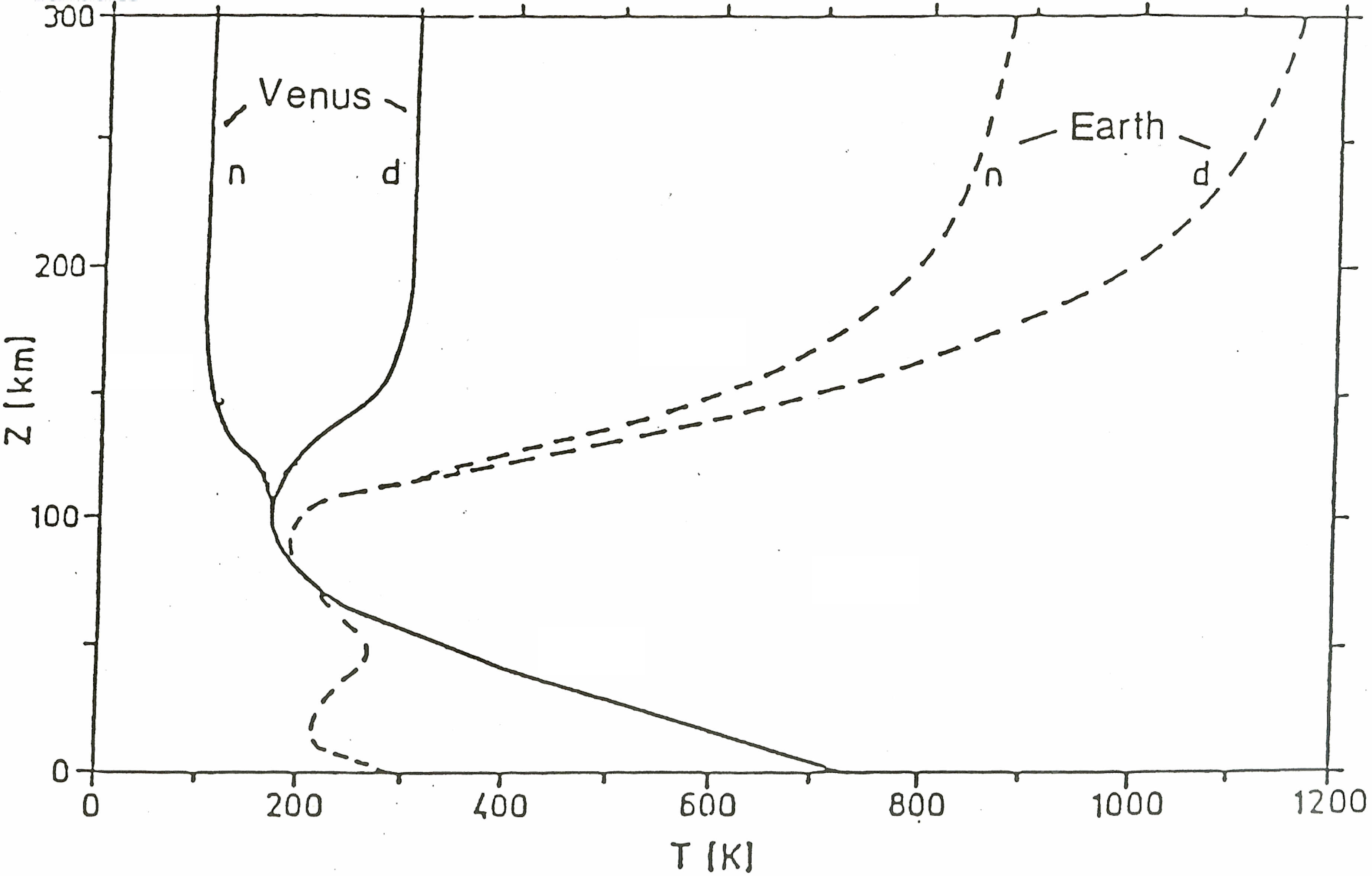
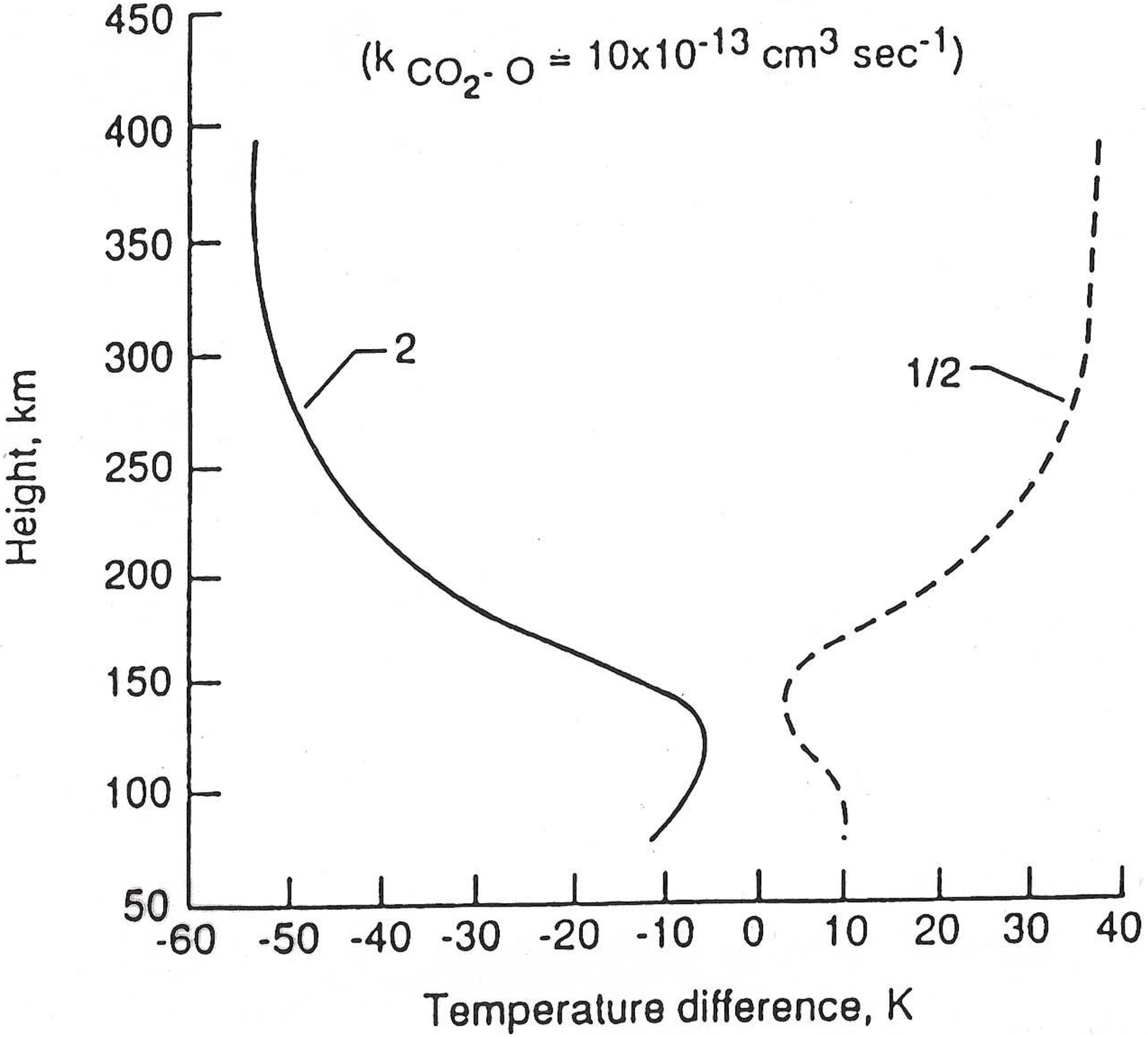


Figure 4

Earth temperature change due to doubling & halving CO_2 and CH_4



(after Roble and Dickinson, 1989)

Figure 5

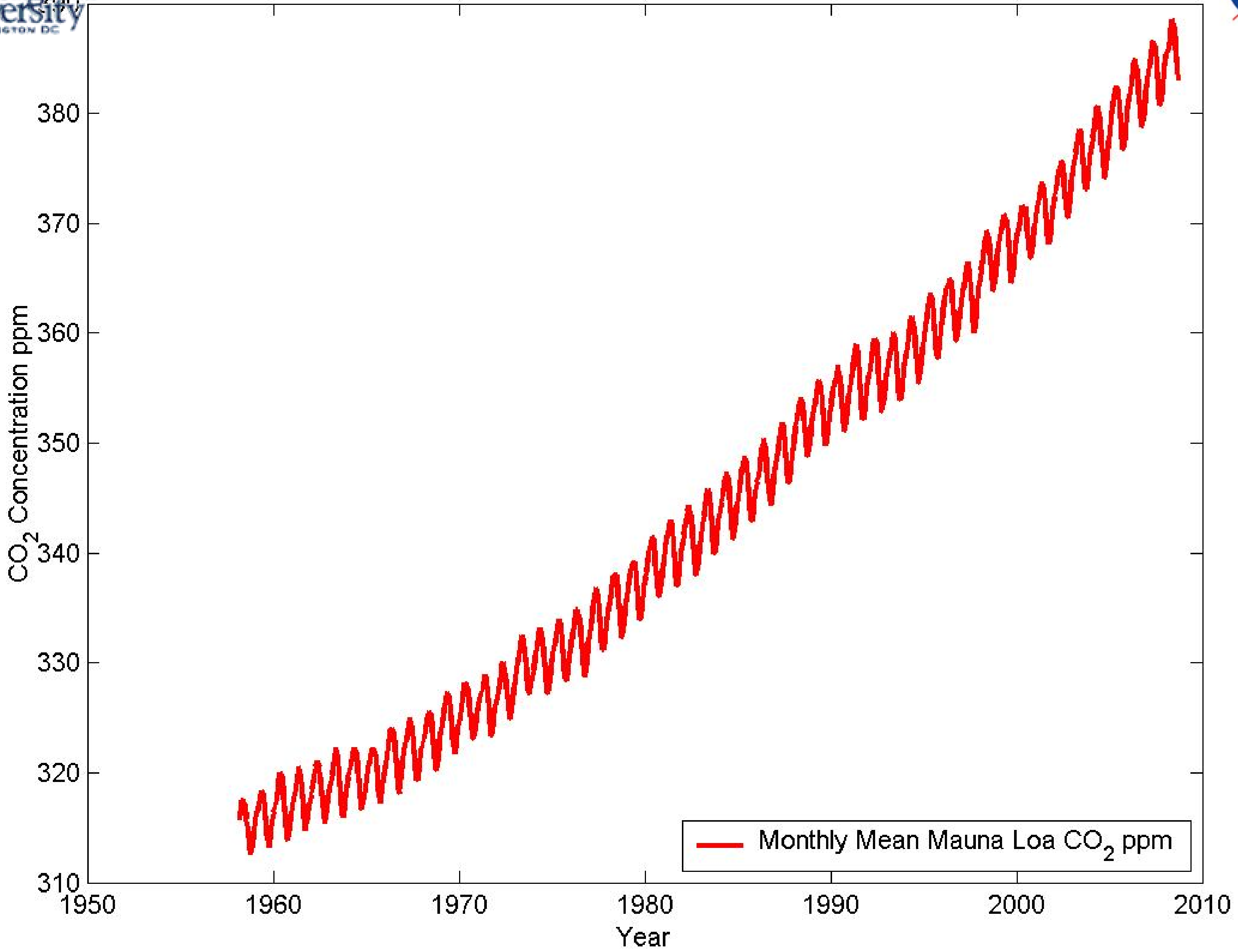

CO$_2$ Concentration from 1958-2008 Measured at Mauna Loa Observatory

Figure 6

F10.7cm 81-Day Mean Flux

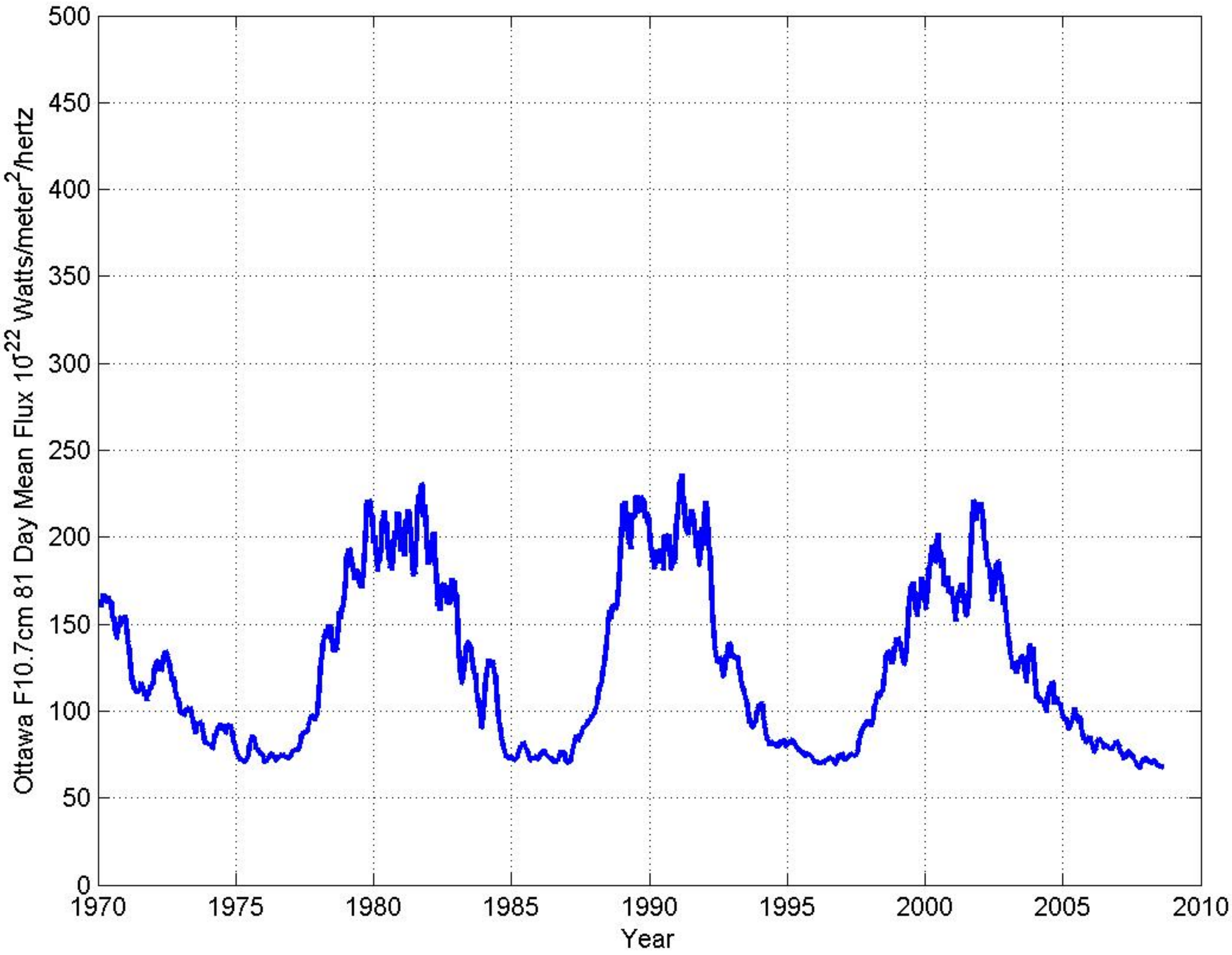


Figure 7

Percent Decline in Thermospheric Density From 1976 to 1996 (Dayside and Nightside, All Latitudes, All ap)

Satellite Number (NORAD Designation)	Decline (%)	Average Periapsis Altitude (km)
60	-8.74%	411
614	-7.40%	342
829	-10.32%	411
963	-11.97%	240
2389	-14.78%	363
2643	-22.39%	328
2800	-4.26%	427
4330	-8.62%	320
4382	-13.66%	447
4392	-6.79%	430
5281	-4.52%	380
7003	-11.98%	404
7004	-8.80%	395
7337	-9.66%	400
Average	-10.28%	378.4286
Standard Error	1.24%	

Figure 8

Table 1

Predicted and Observed Diurnal Variation in Density

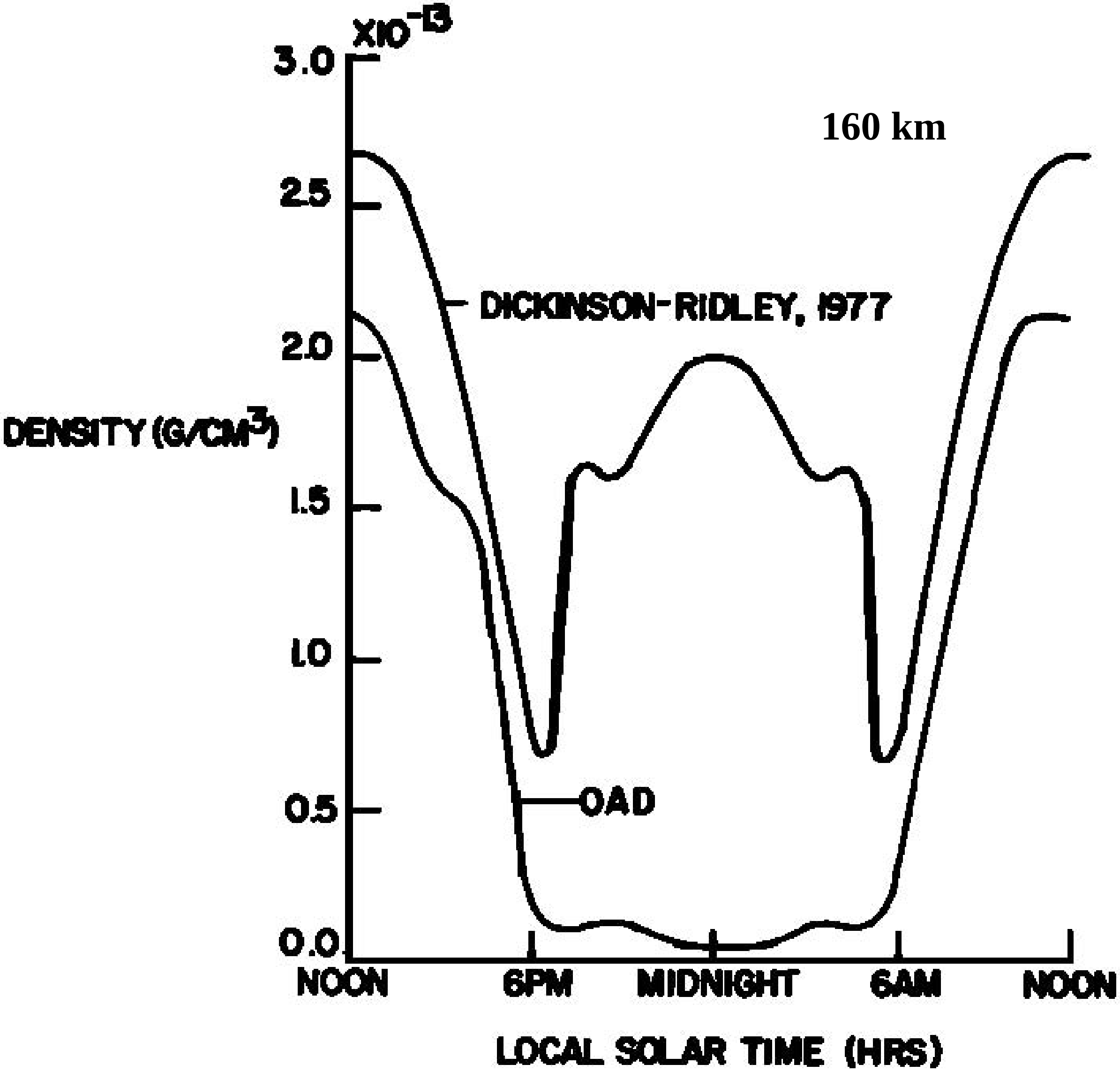


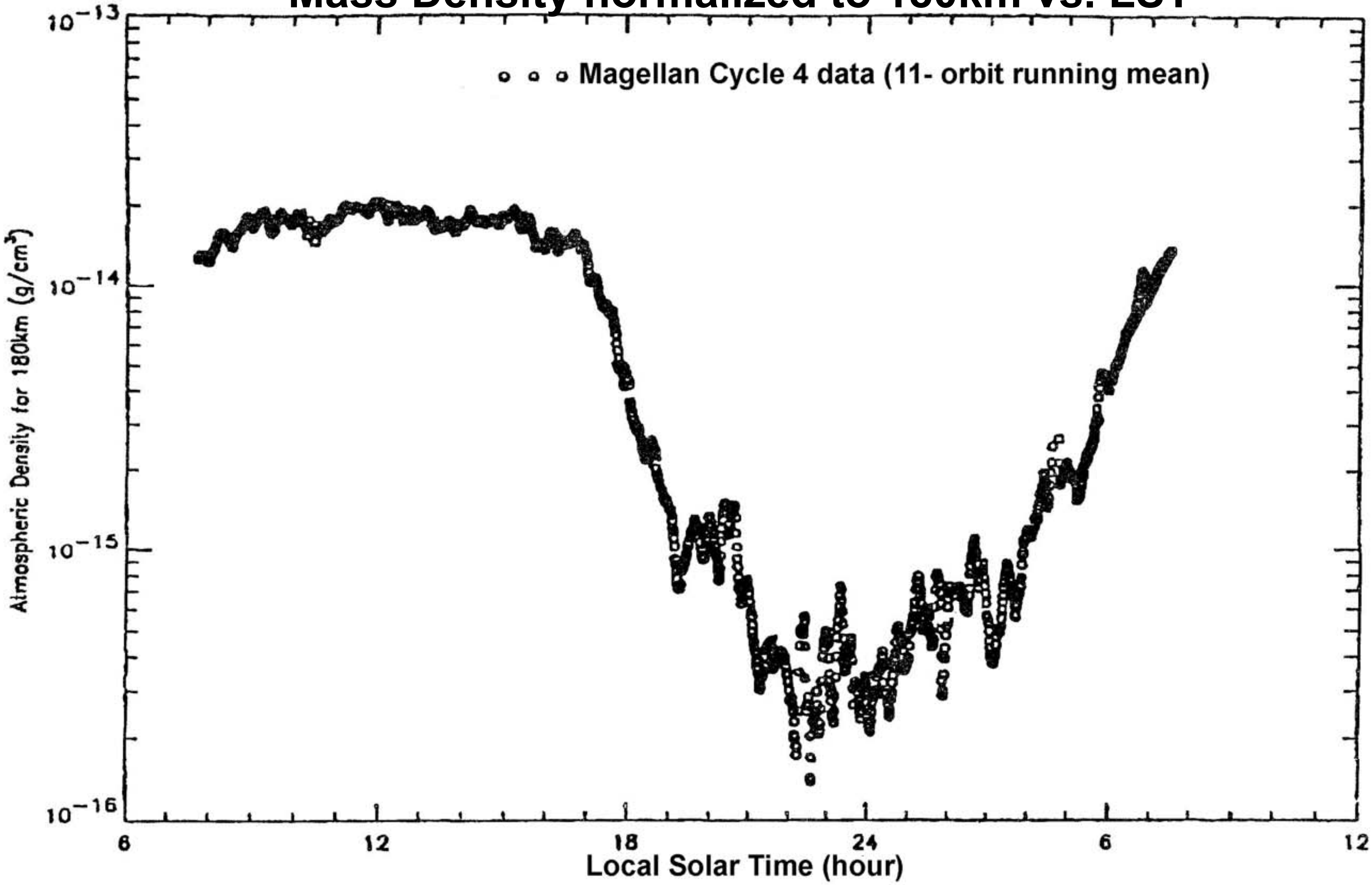
Figure 9

(Keating et al., *JGR*, **85**, 1980)

Diurnal Variation of Thermosphere/Cryosphere:

Magellan Cycle 4 data (11- orbit running mean)

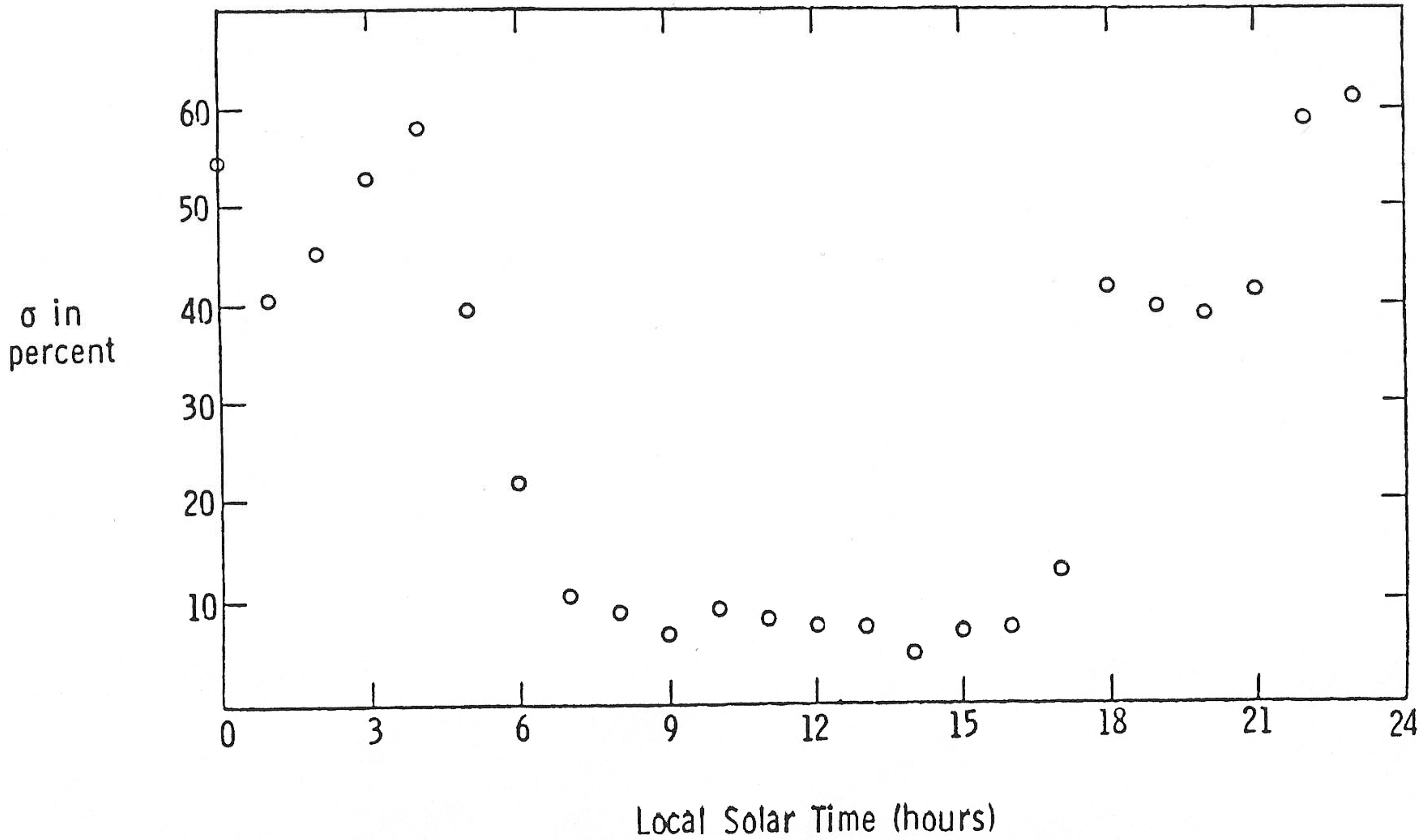
Mass Density normalized to 180km vs. LST



Magellan Cycle 4 mass density from drag measurements (Keating and Hsu 1993), taken at SMED conditions, normalized to 180km and plotted vs. local solar time. The data have been smoothed by an 11- Orbit running mean.

Figure 10

STANDARD DEVIATIONS OF VENUS UPPER ATMOSPHERIC DENSITIES ON DAY- AND NIGHT-SIDES (OAD)



(Keating et al., 1986)

Figure 11

Response to Solar Rotation Variations:

Variations of thermospheric temperature residuals (ΔT) with solar activity ($\overline{F_{10}}$)

Second diurnal survey (12/5/79 – 3/6/80)

Pioneer Venus Orbiter atmospheric drag measurements (OAD)

11 day running means

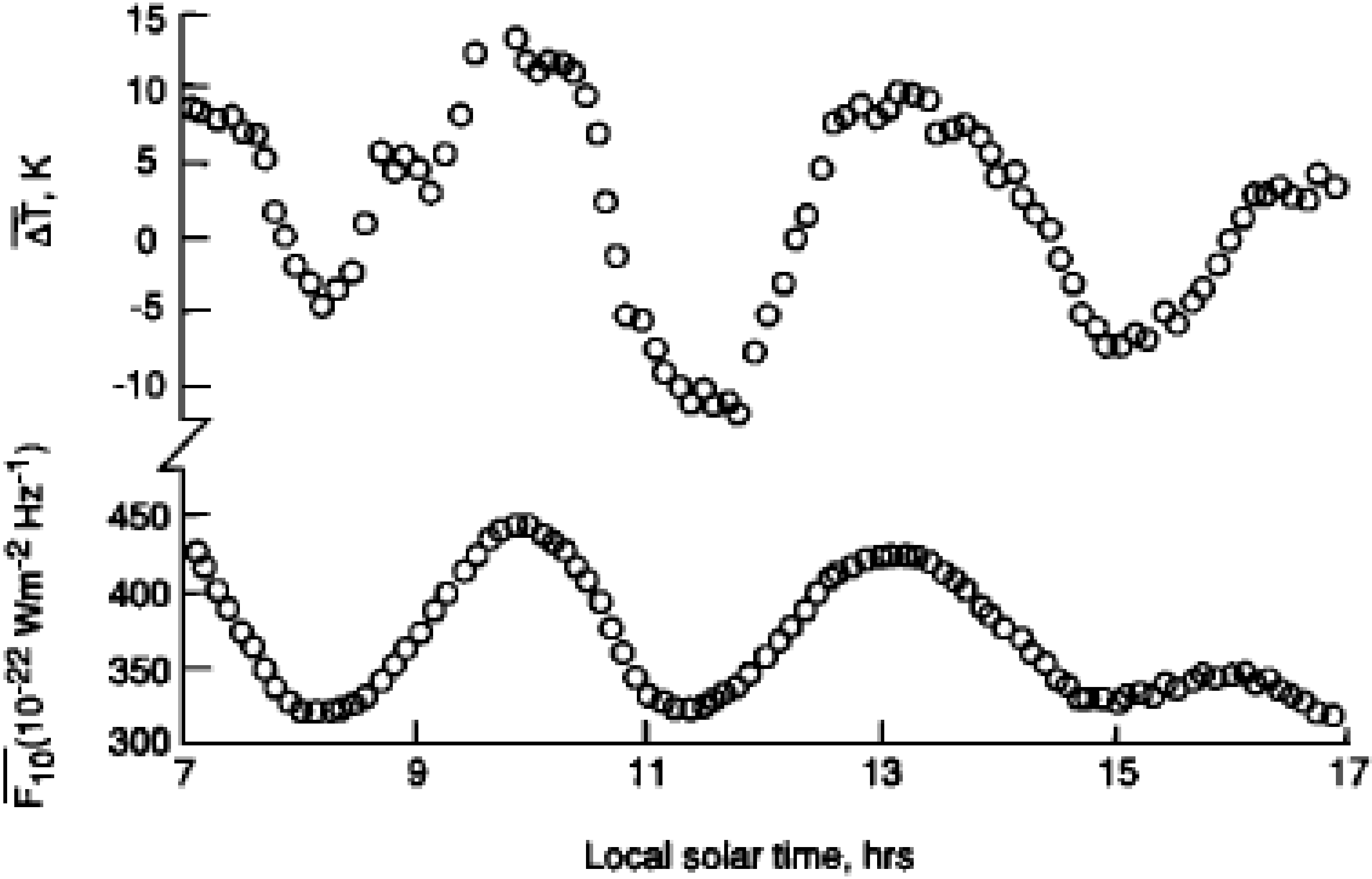
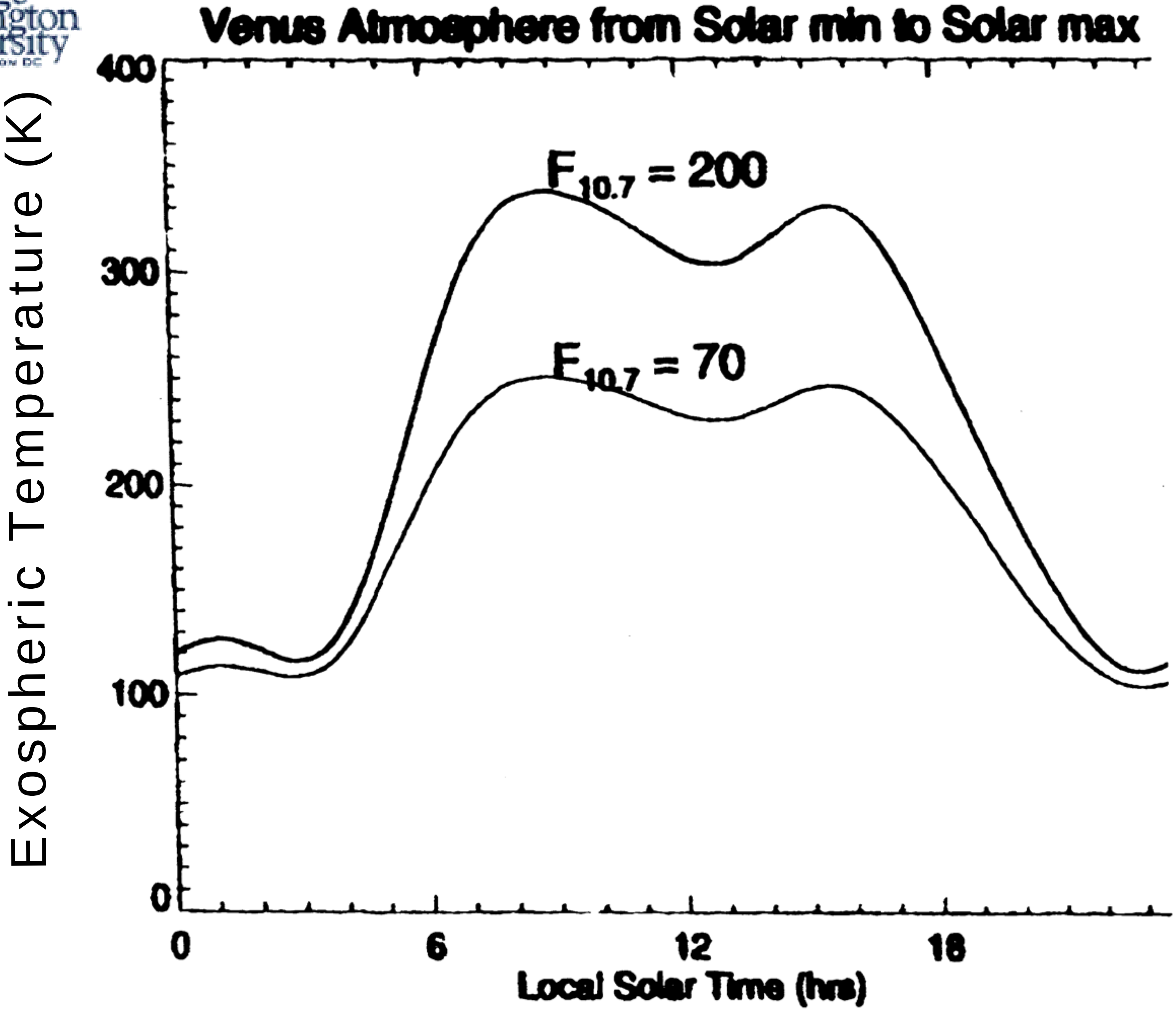


Figure 12

(Keating & Bougher, *JGR*, **97**, 1992)



Venus Atmosphere from Solar min to Solar max

(Keating & Hsu, *GRL*, **20**, 1993)

Figure 13

Response of Venus and Earth Thermospheres to Solar Variability

- 11-year Variations at Venus 25% of Earth Response
- 27-day Variations at Venus 10% of Earth Response

Figure 14

Effects of Super-rotation in Thermosphere
4-Day Variations of Magellan Atmospheric Densities

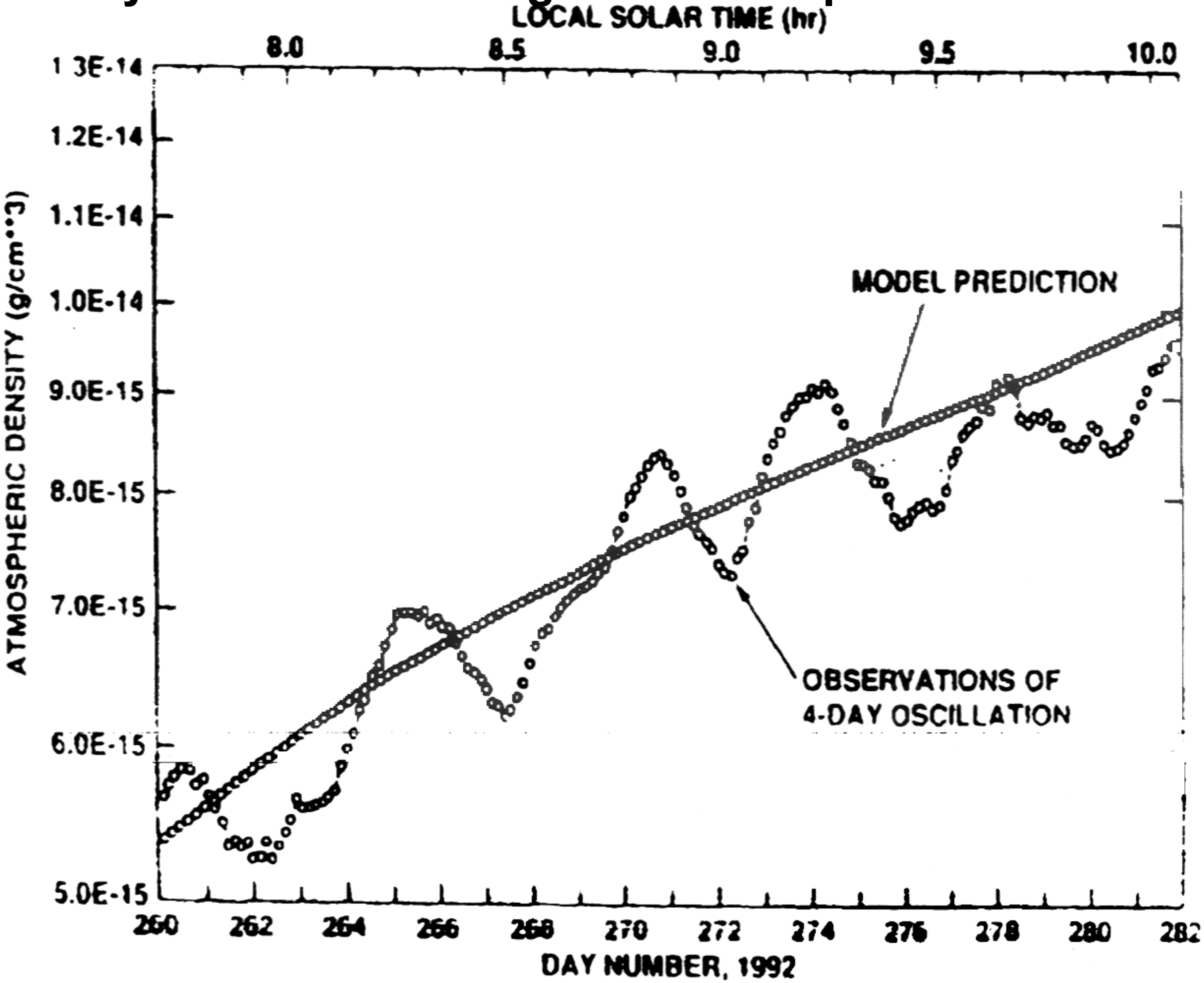


Figure 15

(Keating et al., 1993)

Diurnal Variation of Composition at 200 km near Solar min

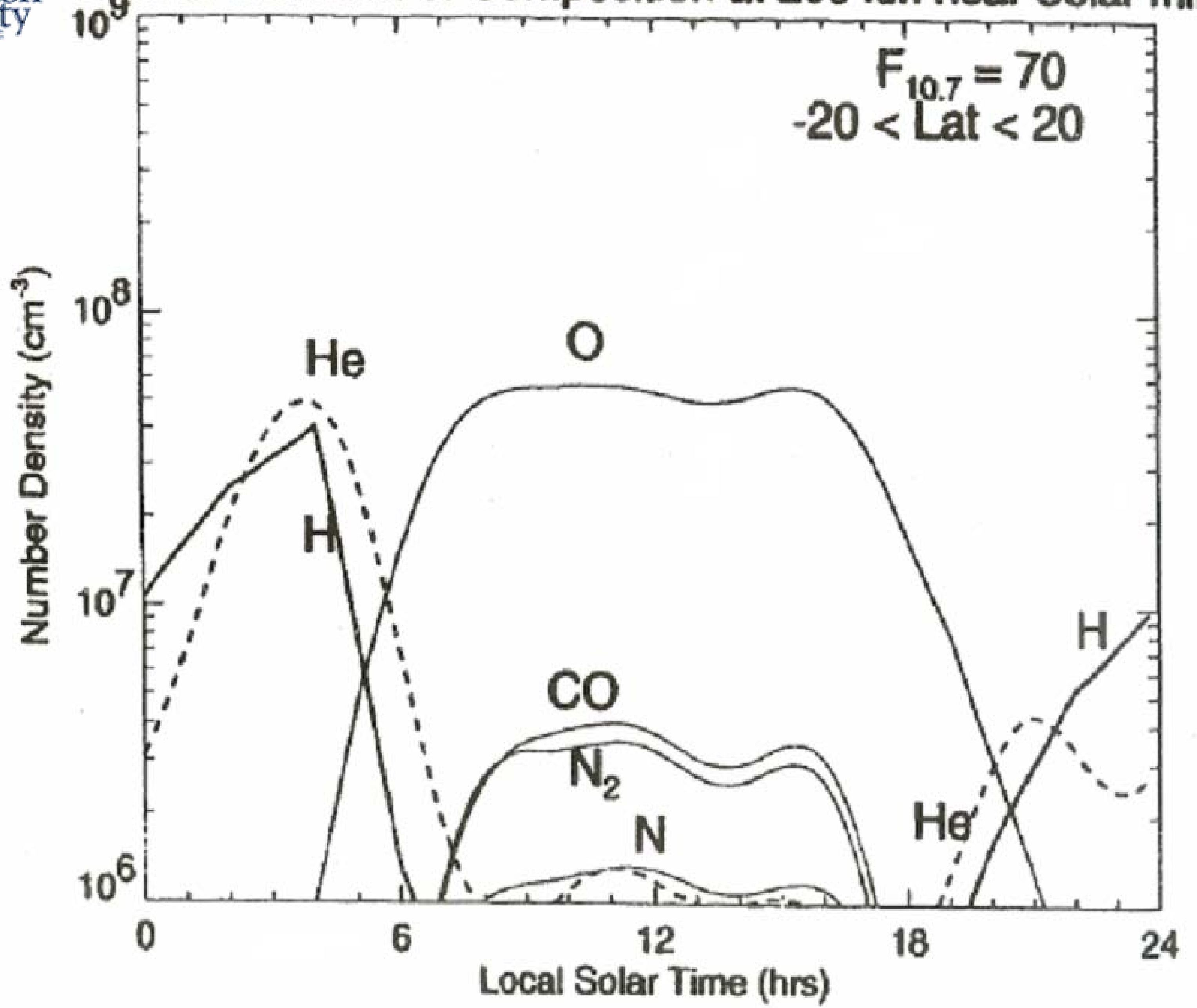
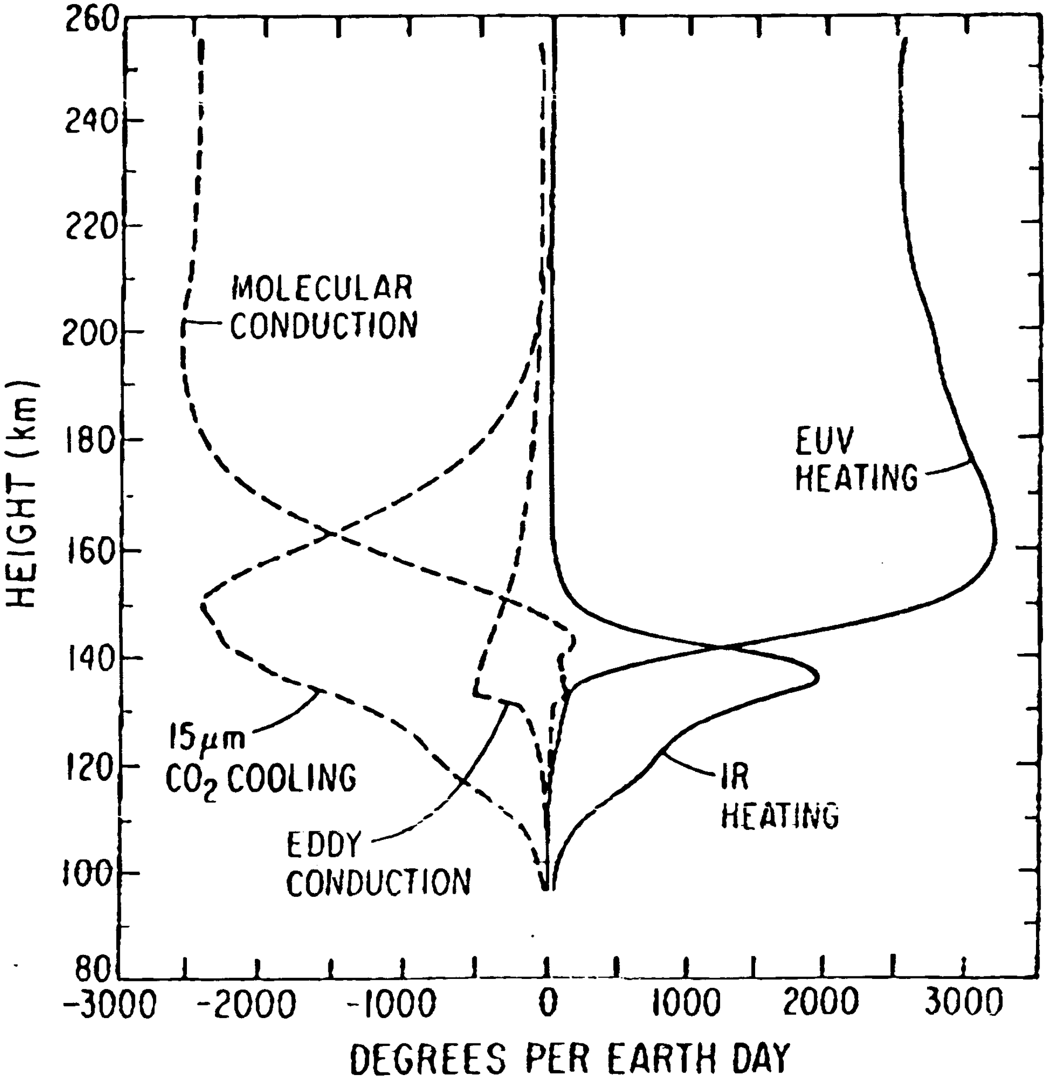


Figure 16

VENUS DAYSIDE MEAN HEATING RATE



(Keating & Bougher, *JGR*, **97**, 1992)

Figure 17

Comparison of Venus and Earth Thermospheres from Orbiter Atmospheric Drag Measurements

- Earth thermosphere much hotter than Venus thermosphere even though Venus is closer to the sun
- Cold Venus Thermosphere on dayside (Venus 300K, Earth 1100K)
- Discovery of Venus Cryosphere on nightside, Temperature decreasing with increasing altitude unlike a thermosphere
- Requirement for very strong O/CO_2 15 micron cooling to explain cold Venus thermosphere
- Discovery of 27-day Venus thermosphere oscillations resulting from 27-day solar rotation, weak response compared to Earth thermosphere
- Discovery of 11-year Venus thermospheric variation related to 11-year solar cycle, weak response compared to Earth thermosphere
- Weak response of Venus to solar variations compared to Earth probably results in increases in atomic oxygen with increased solar activity, but also increased cooling from 15 micron emission with net weak response to solar activity increases (a thermostatic effect)
- Requirement for increased wave breaking on nightside to explain the reduced flow to the cryosphere
- Indications from first VEX atmospheric drag measurements that the polar thermosphere is unexpectedly cold. This latitudinal coverage should allow for a global picture of the thermosphere.
- The discovery of cooling of the Earth's thermosphere due to increases in greenhouse gases should result in factor of 2 decreases in density at 400km by the end of this century (moving us closer to Venus conditions).

Figure 18

Magellan Cycles 4,5,6 Local Solar Time vs. Latitude

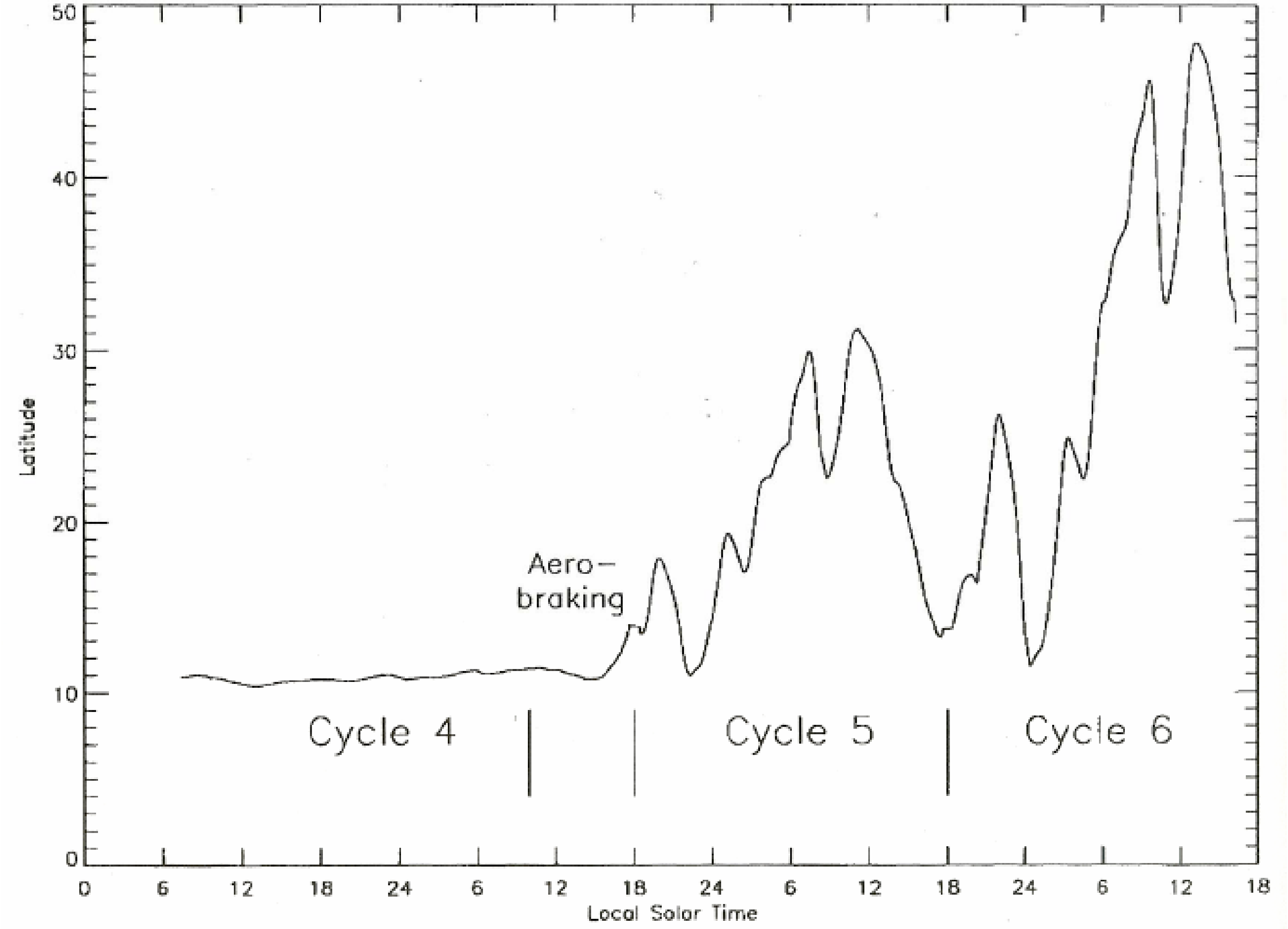


Figure 19

VEX Pericenter Altitude Jul-08 to Apr-09

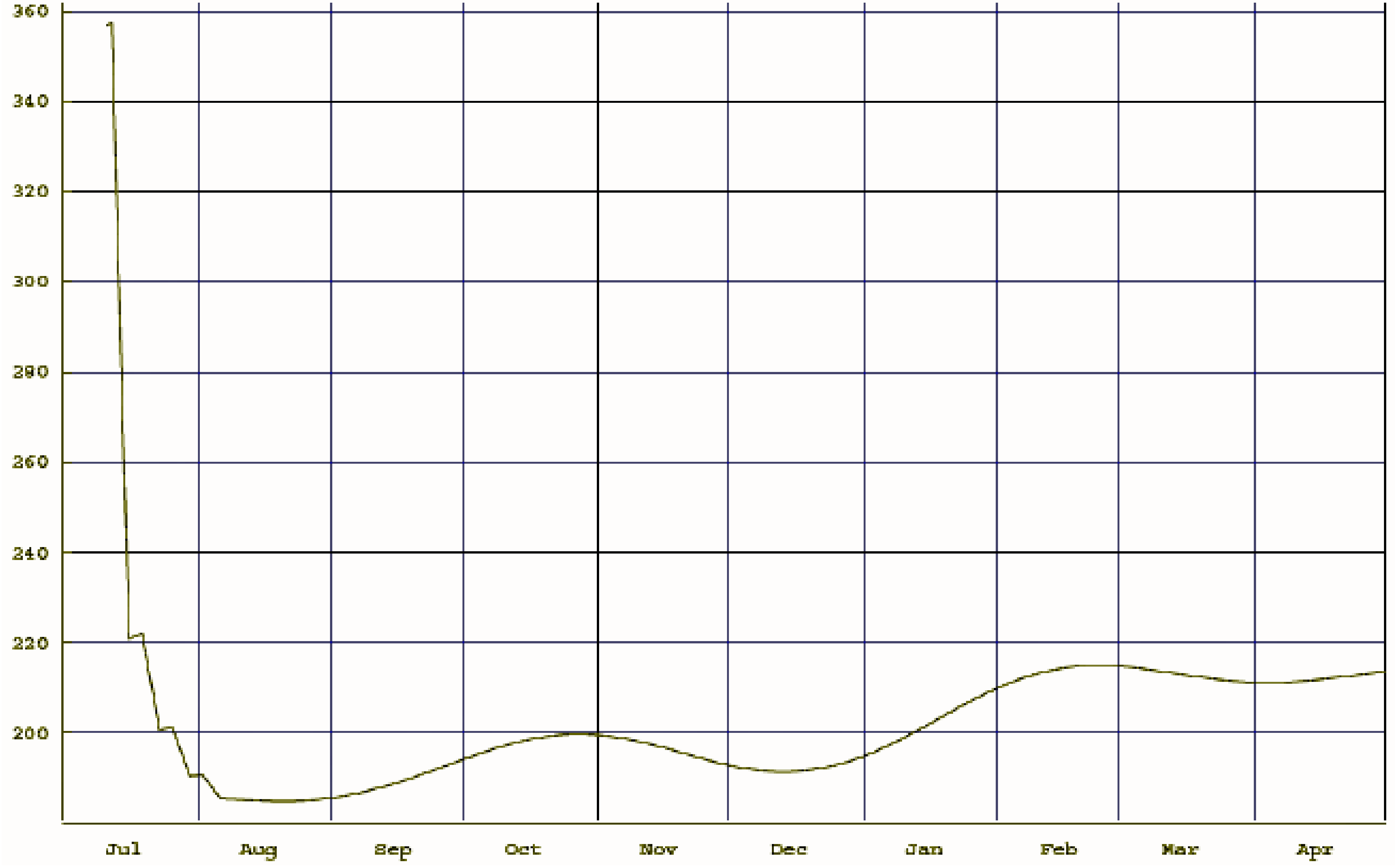
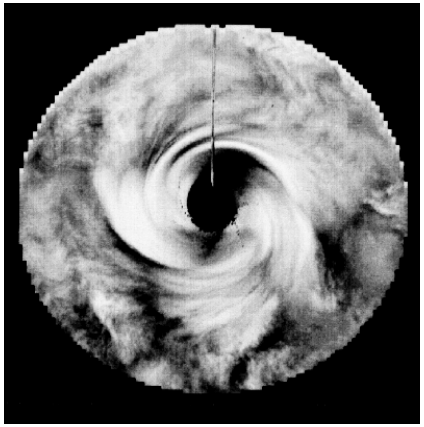


Figure 20

Vortex Measurements from Pioneer Venus Orbiter

Figure A (top left): ultraviolet image by Mariner 10, showing vortex behaviour centred on the pole.



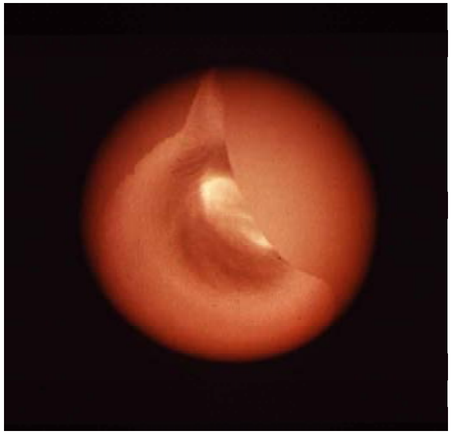
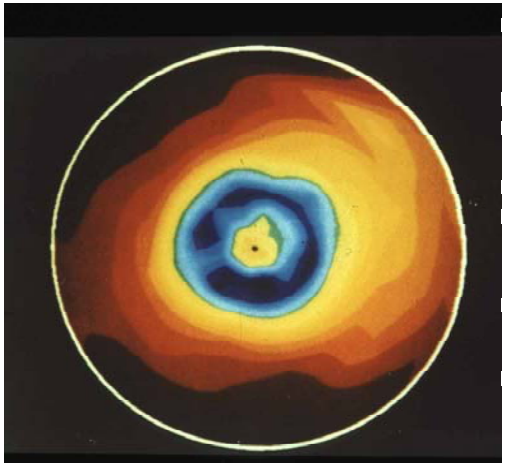


Figure B (top right): a thermal image of the vortex (11.5 microns wavelength) by Pioneer Venus, showing the complex structure of the 'eye' and its double nature or 'dipole'.

Figure C(Bottom left): An average of images similar to B over a 72-day period. The averaging smears out the rotating dipole and emphasises the average appearance of the cold collar (and the thermal tides at lower latitudes).



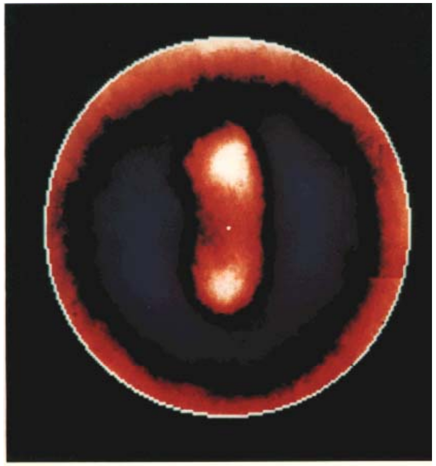


Figure D(bottom right): the same data as C, but this time averaged in a rotating co-ordinate frame with a period of 2.7 days, the same as the dipole. This emphasises the dipole and smears out the collar. The thermal contrast between the brightest part of the dipole and the coldest part of the collar is about 50K. The distance across the 'eyes' is about 2000 km.

Polar projections of various views of the northern hemisphere of Venus, looking down from above the N pole.

(F. W. Taylor, 2004)

Figure 21

VEX Accelerometer and Orbital Decay Investigations of Venus Polar Thermosphere Region

1) First vertical, diurnal, latitudinal and longitudinal measurements of the structure of the polar thermospheric region. What is the character of waves in this region?
2) Measure the nature of the transition from the polar thermosphere to the polar cryosphere.
3) How is the cryosphere maintained and insulated from thermosphere? Does wave breaking near the terminator inhibit mass and energy transport to the nightside?
4) Is there coupling between the middle atmosphere polar dipole and polar collar with the thermosphere? Can the 2.7 day super-rotation of the polar dipole be detected in the thermosphere?
5) Is the polar thermosphere super-rotation similar to the equatorial thermosphere super-rotation? What processes spin up the polar thermospheric vortex?

Figure 22

VEX Accelerometer and Orbital Decay Investigations of Venus Polar Thermosphere Region (continued)

6) What is the impact of a super rotating thermosphere on escape rates and the evolution of the Venus atmosphere?

7) How do the characteristics of the morning and evening near equatorial terminators compare with the polar terminator region?

8) How does the polar thermosphere respond to solar EUV variations related to the rotating sun and to the Solar Wind?

9) What can be learned about forcing from below and above by comparisons with other VEX instruments?

10) How do thermospheric variations correlate with ionospheric variations?

11) How do the polar thermospheres of Venus, Earth, Mars, & Titan compare?

Figure 23

Venus Express

Figure 24

Backup

Figure 25