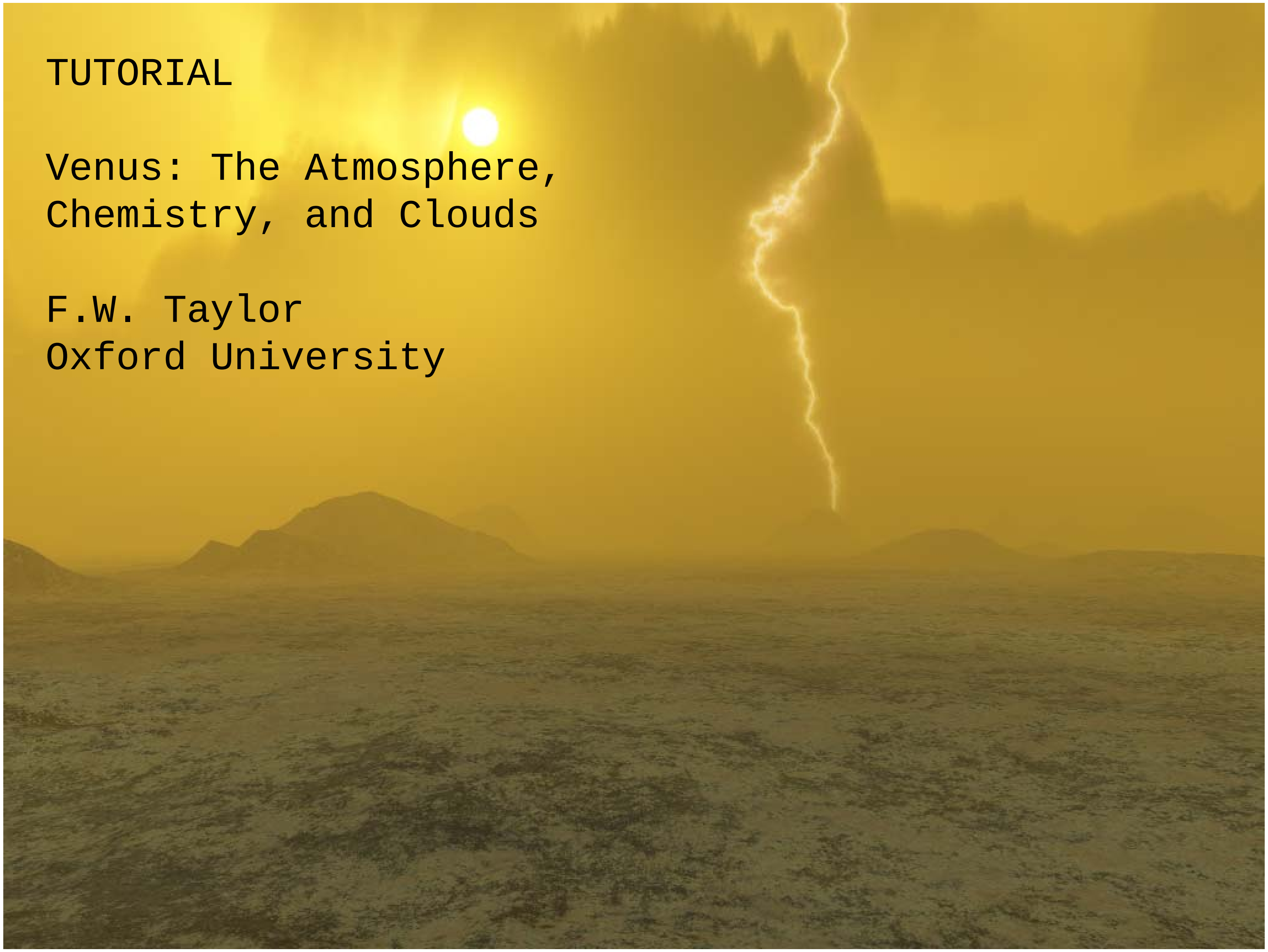

TUTORIAL
Venus: The Atmosphere, Chemistry, and Clouds
F.W. Taylor
Oxford University

Table X.3 Composition of the Lower Atmosphere of Venus

Species	Abundance (mole fraction)	Species	Abundance (mole fraction)
CO_2	0.965	He	12 ppm
N_2	0.035	Ne	7 ppm
SO_2	150 ppm	H_2S	3 ppm
Ar	70 ppm	HCl	400 ppb
CO	30 ppm	Kr	30 ppb
H_2O	20 ppm	HF	5 ppb

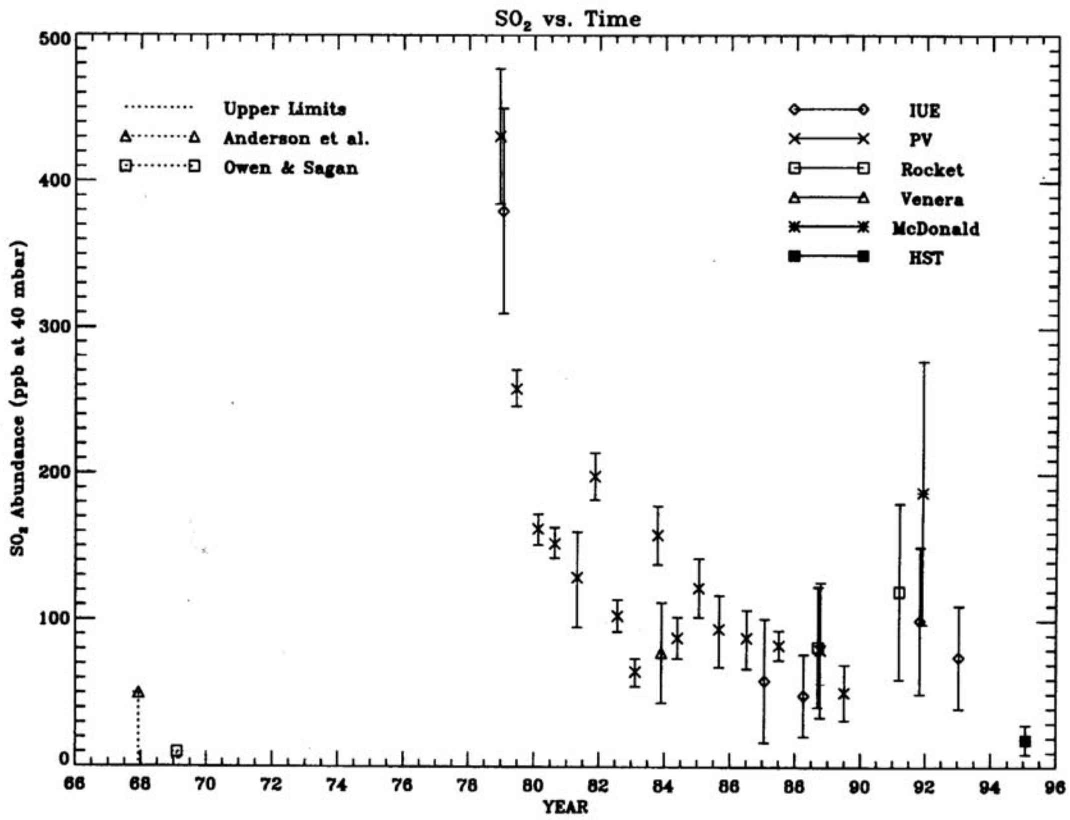
From 'Physics and Chemistry of the Solar System' by John S. Lewis

Table X.3 Composition of the Lower Atmosphere of Venus

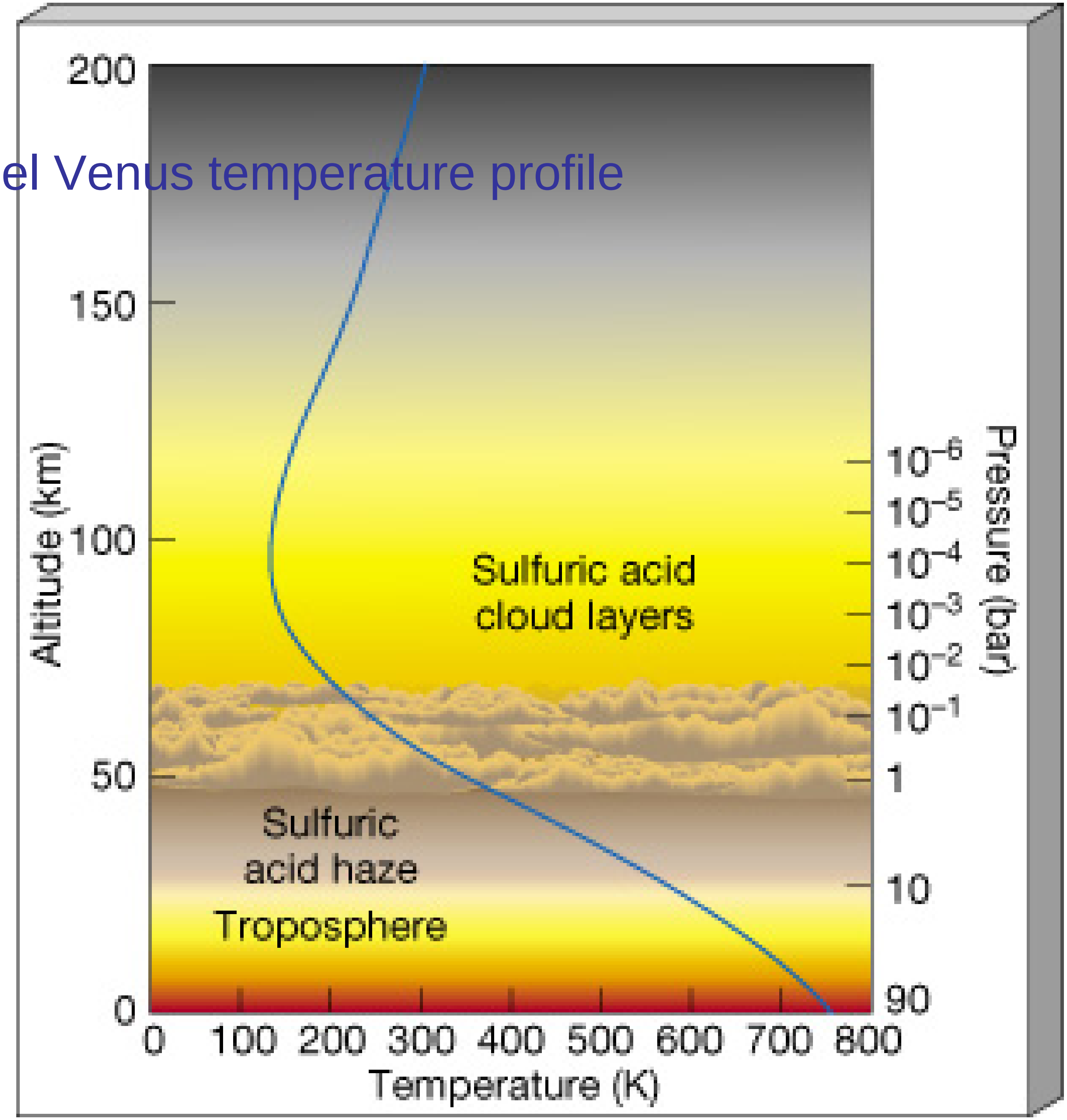
Species	Abundance (mole fraction)	Species	Abundance (mole fraction)
CO_2	0.965	He	12 ppm
N_2	0.035	Ne	7 ppm
SO_2	150 ppm	H_2S	3 ppm
Ar	70 ppm	HCl	400 ppb
CO	30 ppm	Kr	30 ppb
H_2O	20 ppm	HF	5 ppb

- CO_2 and N_2 amounts ~'same' as the Earth
- Water very low ($\Rightarrow$ loss rate is high)
- D/H = 100 x Earth $\Rightarrow$ possible ancient ocean
- Abundant SO_2, H_2S, H_2SO_4 $\Rightarrow$ active volcanism?
- Some species are variable

SO_2 vs. Time (Na & Esposito, 1996)

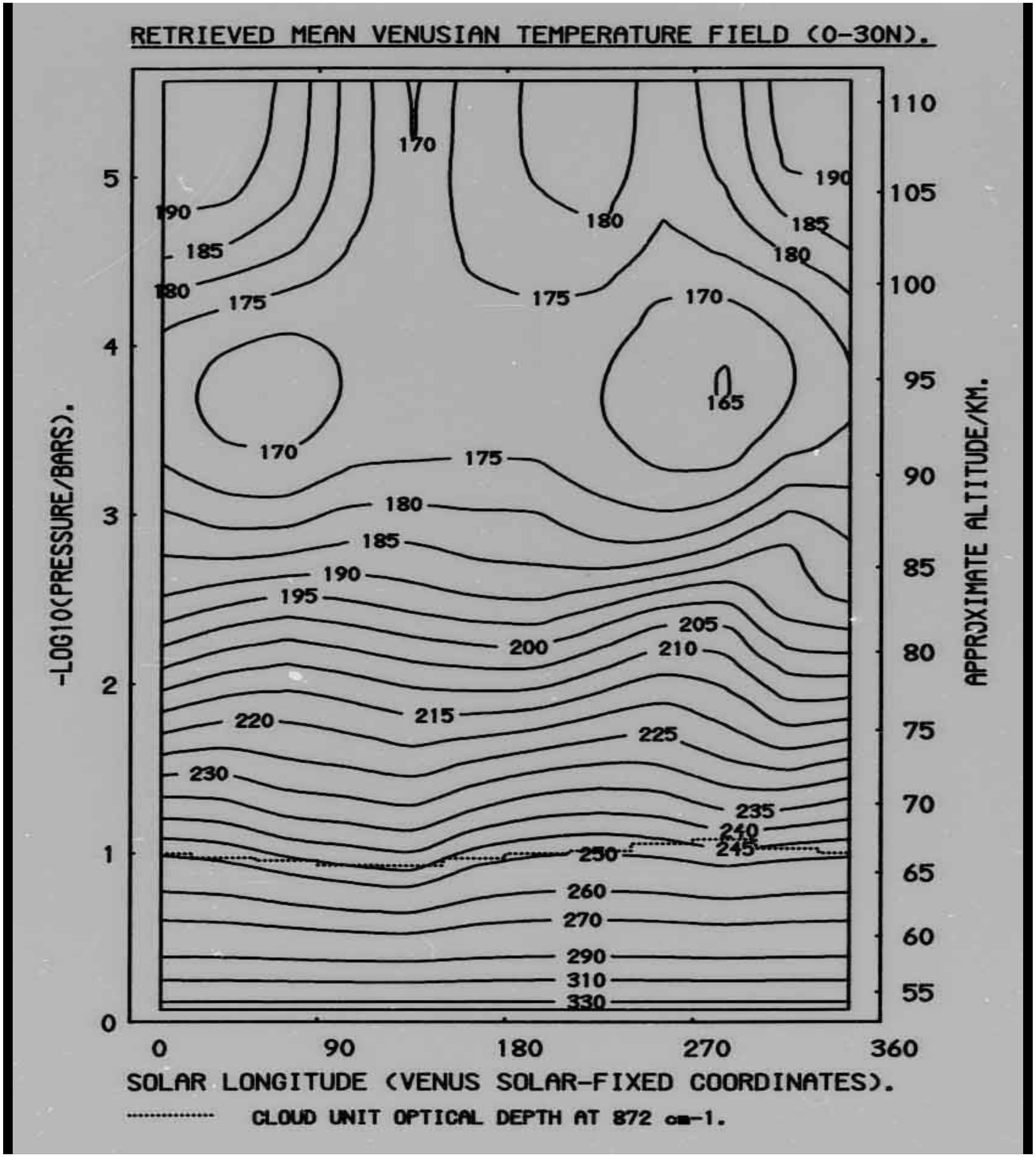


Model Venus temperature profile



Pioneer Venus OIR Measured Temperatures (3-month mean) vs. Height & Longitude at 0º latitude

(Schofield & Taylor, 1982)

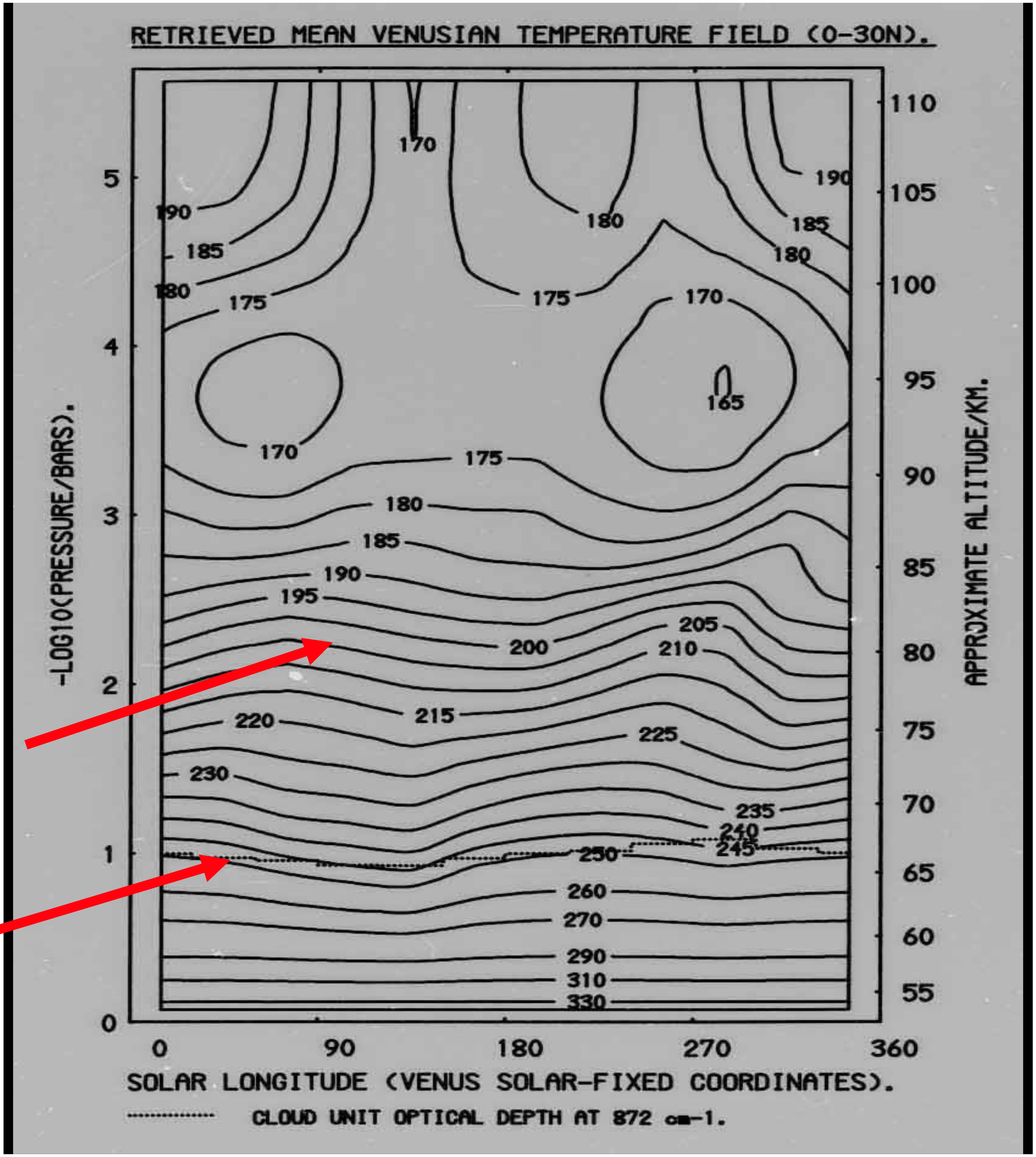


[Pioneer Venus OIR]() Temperatures vs. Height & Longitude

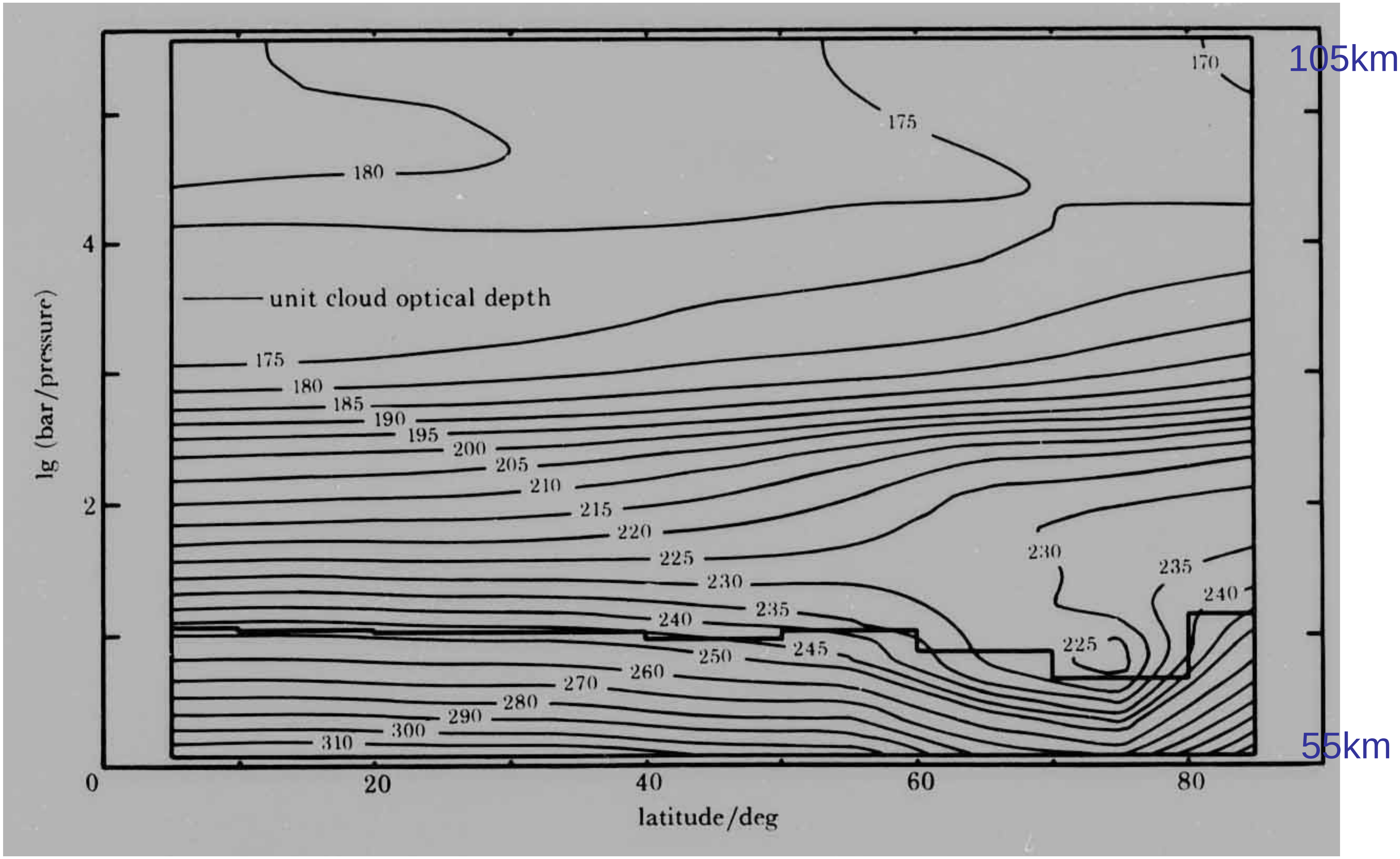
Solar Tide

- wavenumber 2 in stratosphere

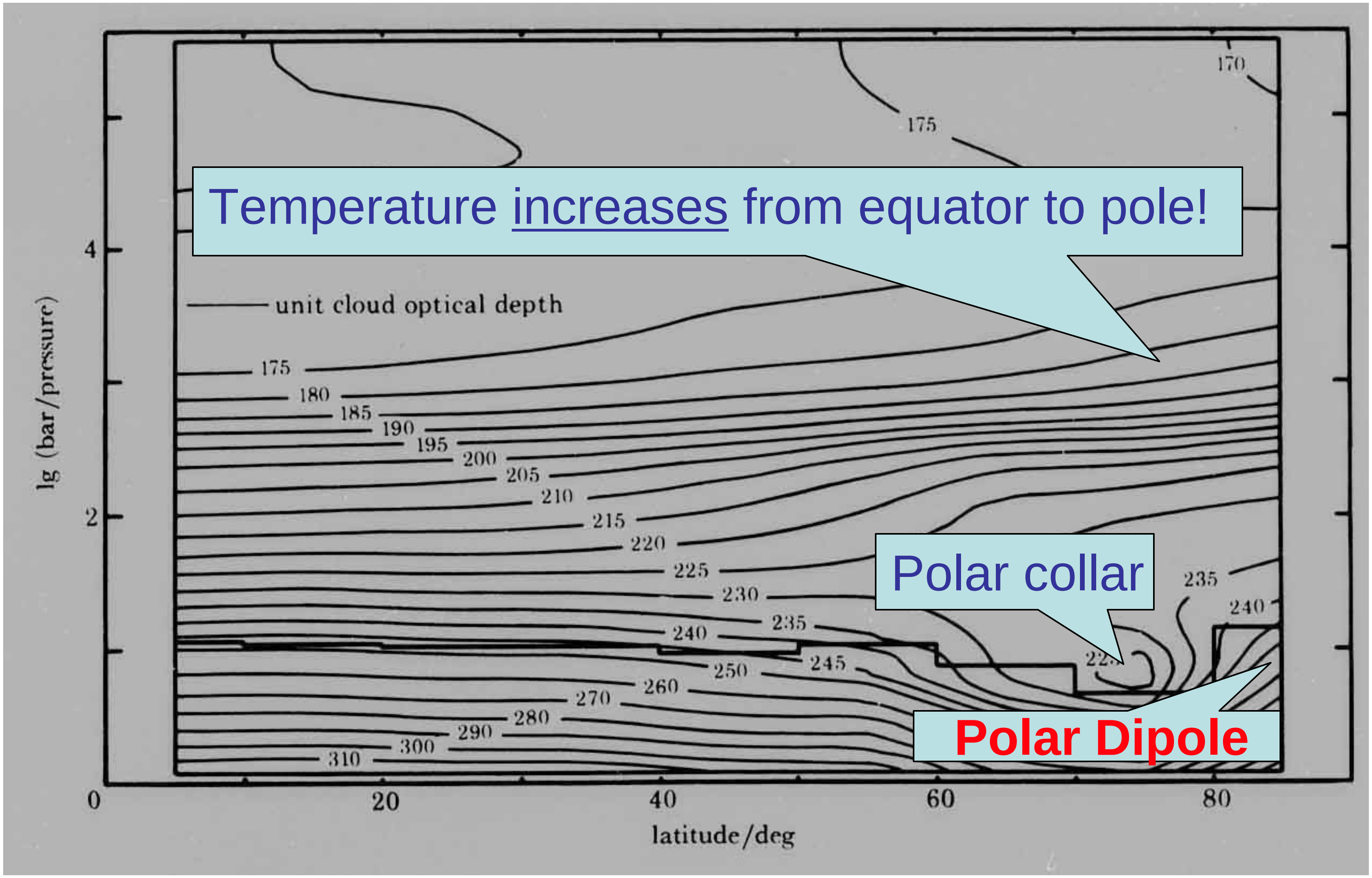
- wavenumber 1 at cloudtops

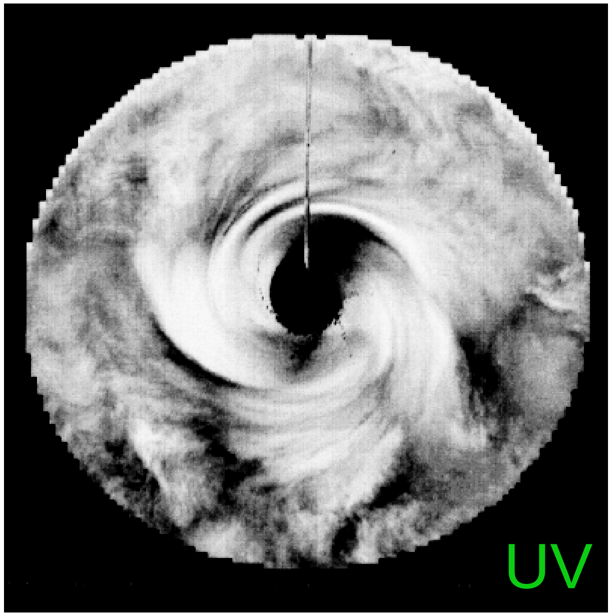


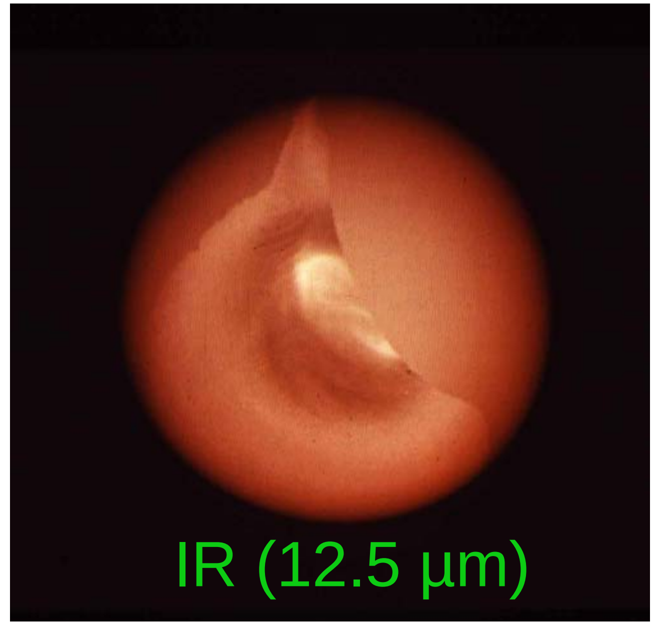
Pioneer Venus OIR Temperatures vs. Height and Latitude



Pioneer Venus OIR Temperatures vs. Height and Latitude

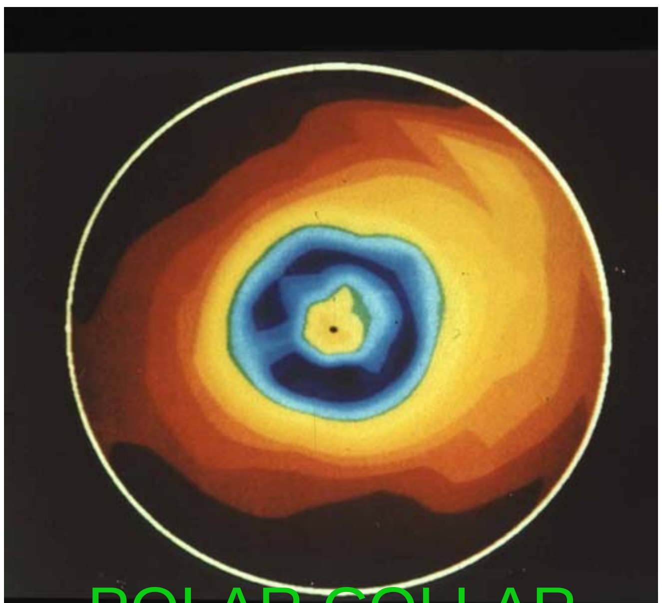


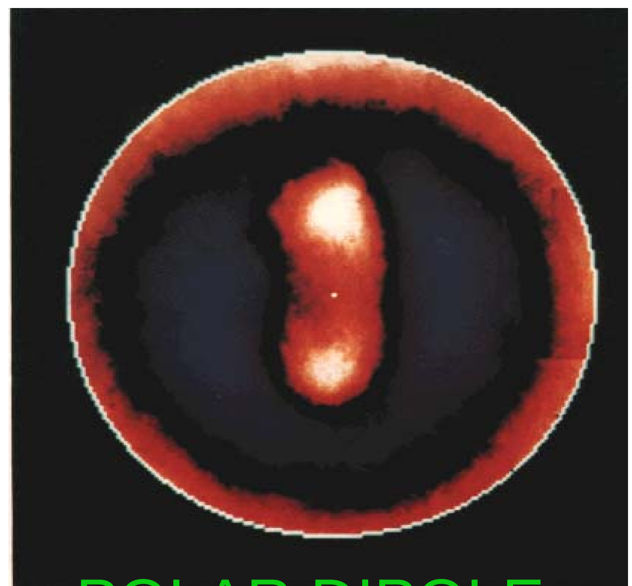




Four views of the North Polar region of Venus

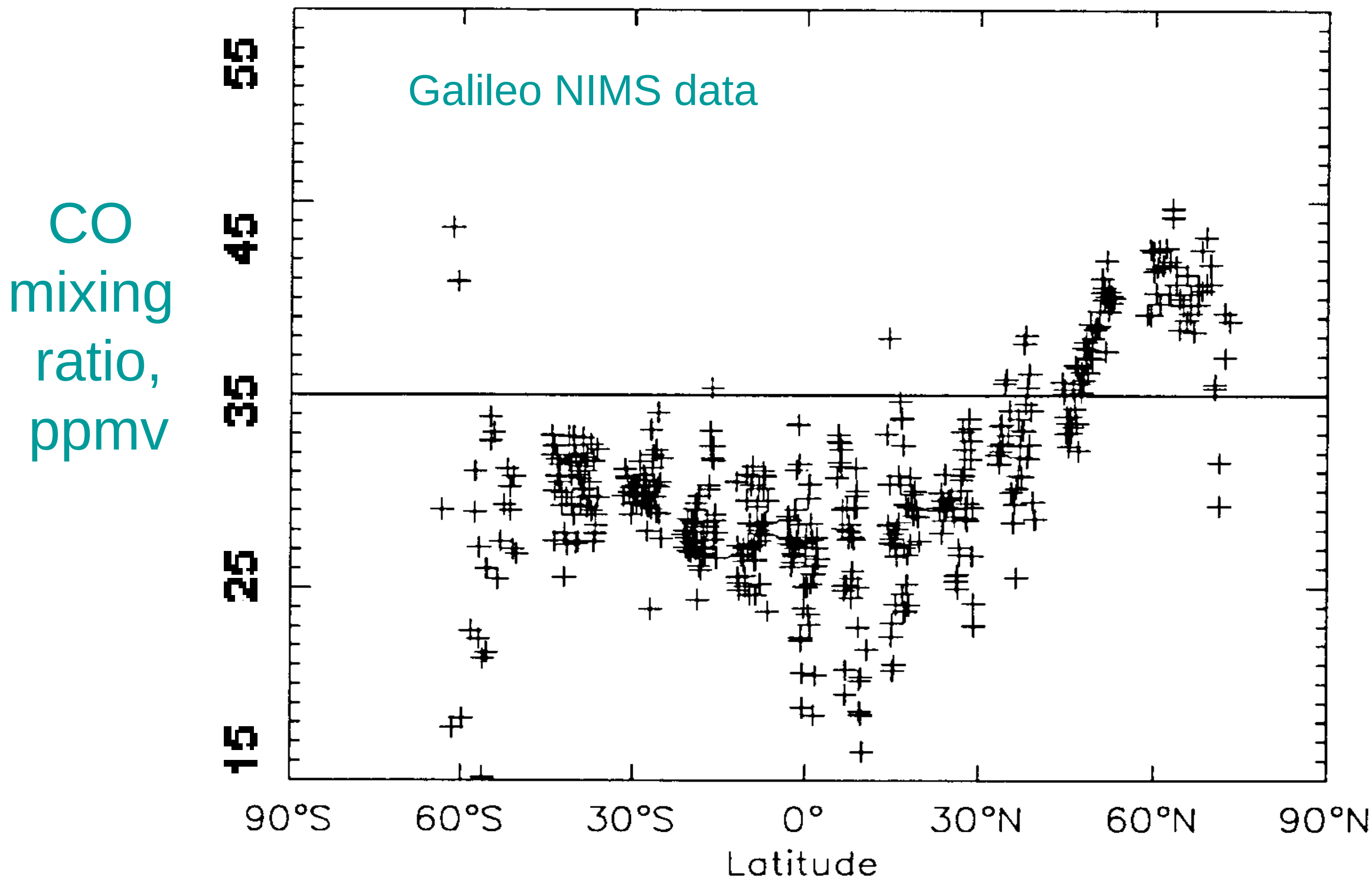
(M10 TV, PV OIR)



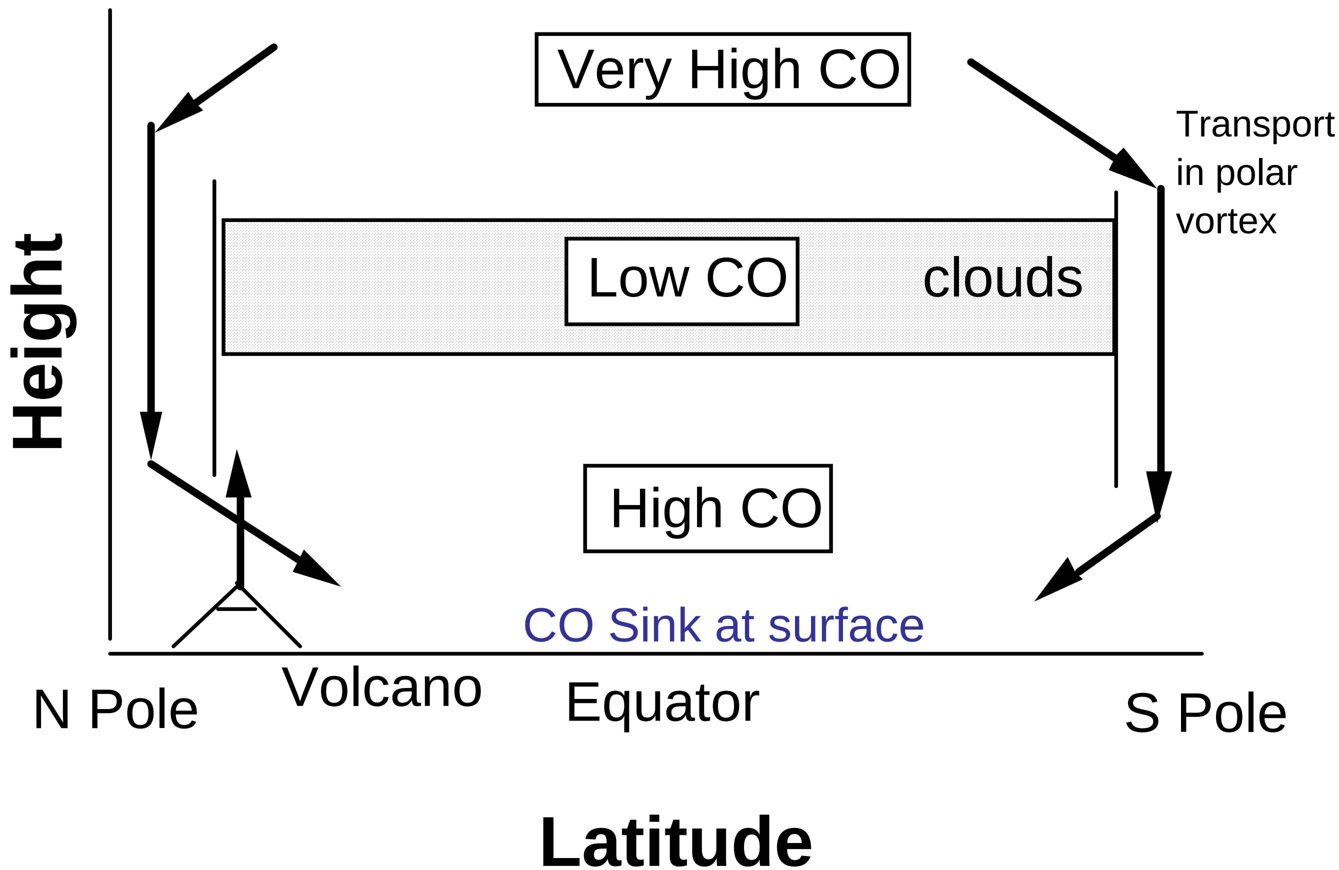


POLAR DIPOLE

The variation with latitude of carbon monoxide abundance near 30 km altitude (Collard et al., 1994).

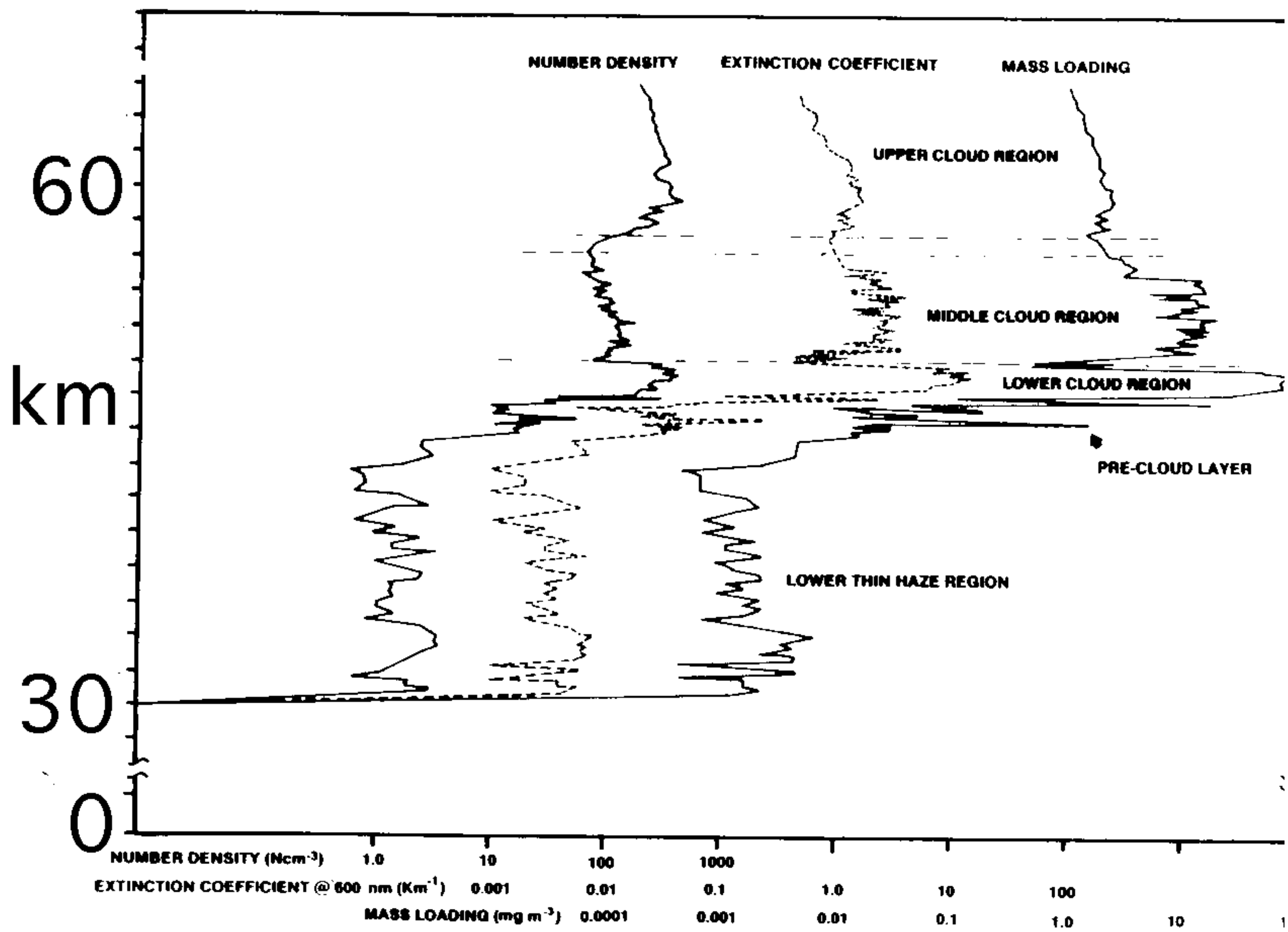


Conceptual model for CO sources on Venus:
transport from the upper atmosphere via the polar vortices.

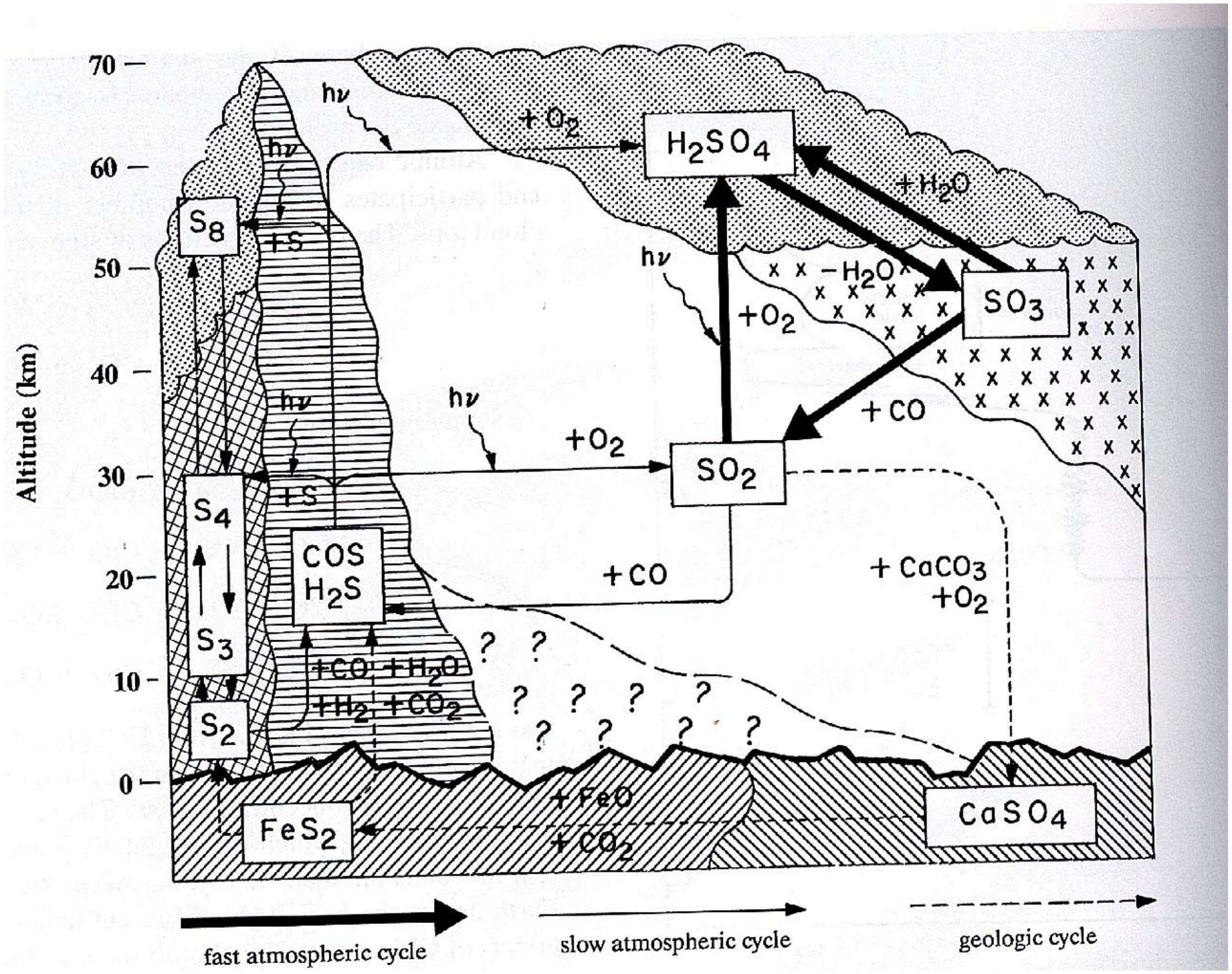


Profile of the clouds from the PV large probe

(RG Knollenberg and DM Hunten,1980)



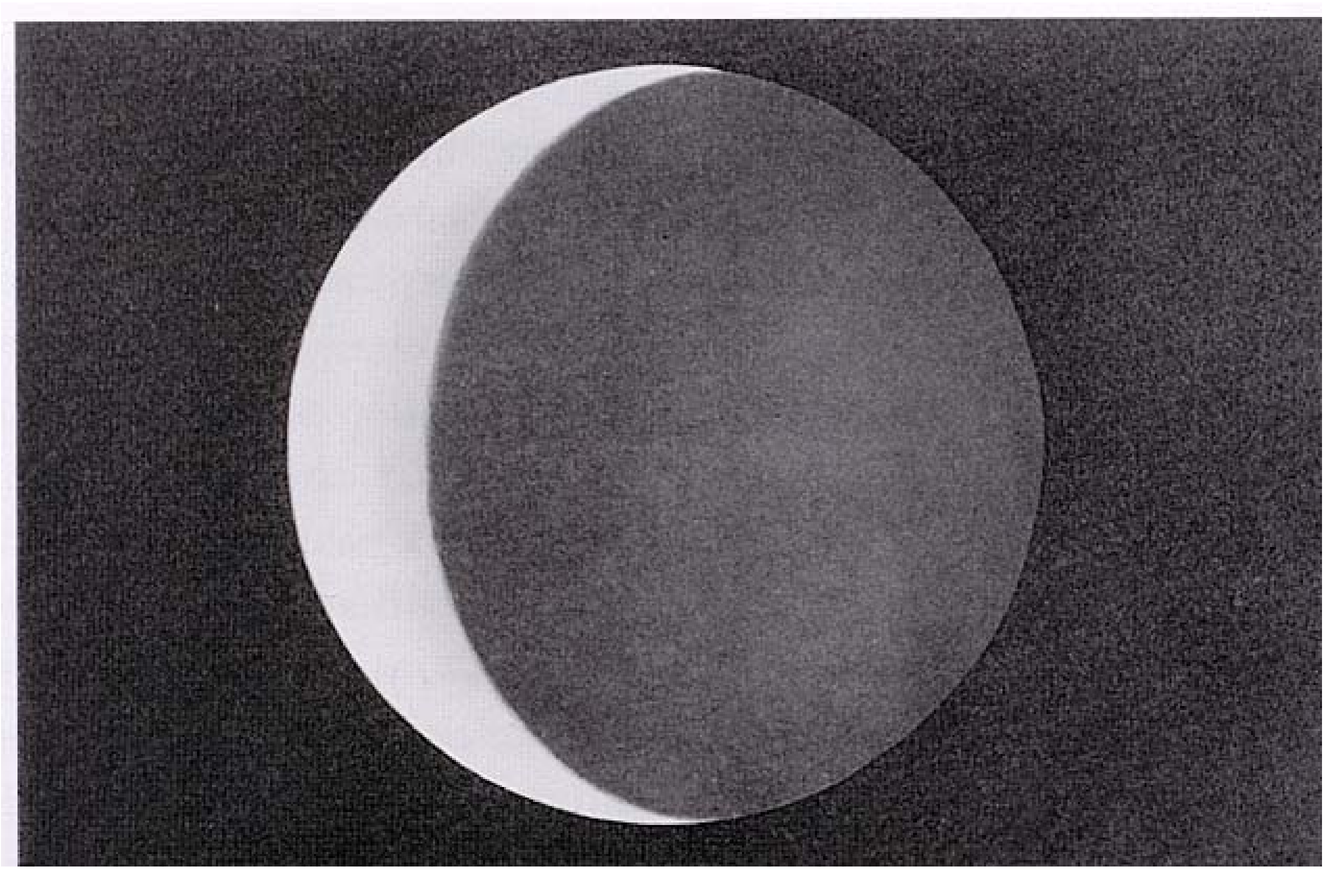
Atmospheric Chemistry dominated by Sulfur?



From ‘Physics and Chemistry of the Solar System’ by John S. Lewis

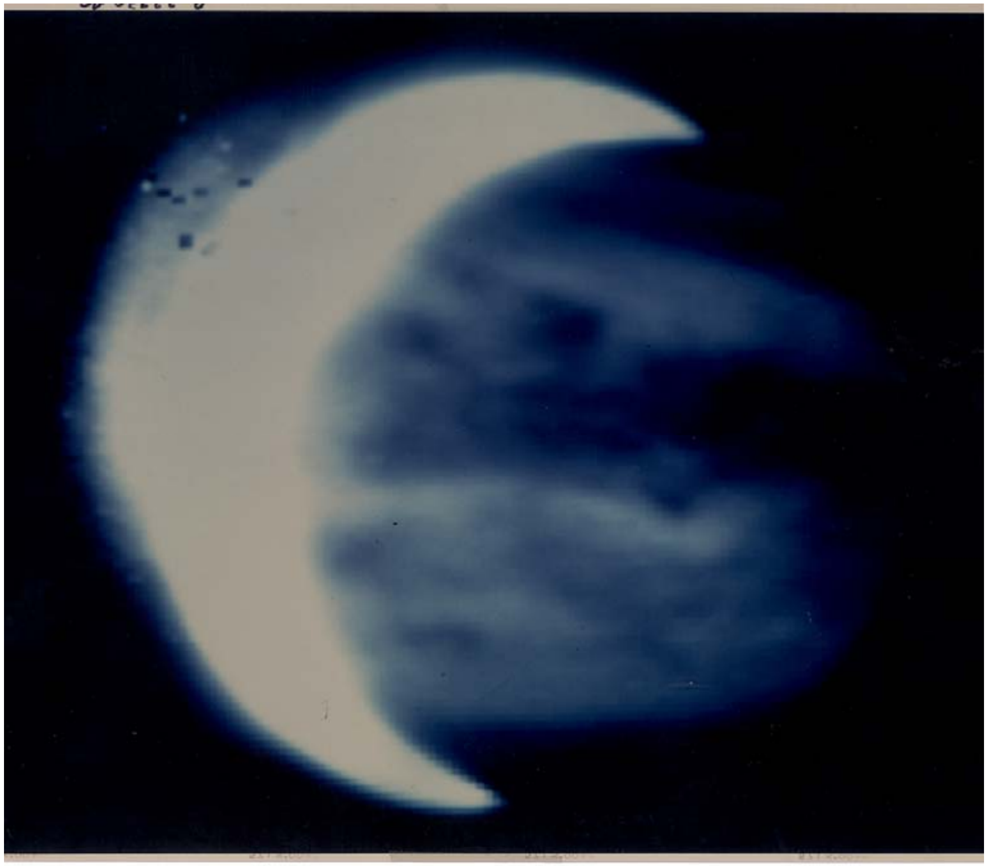
The 'Ashen Light' of Venus

first observed by Giovanni Riccioli on January 9, 1643



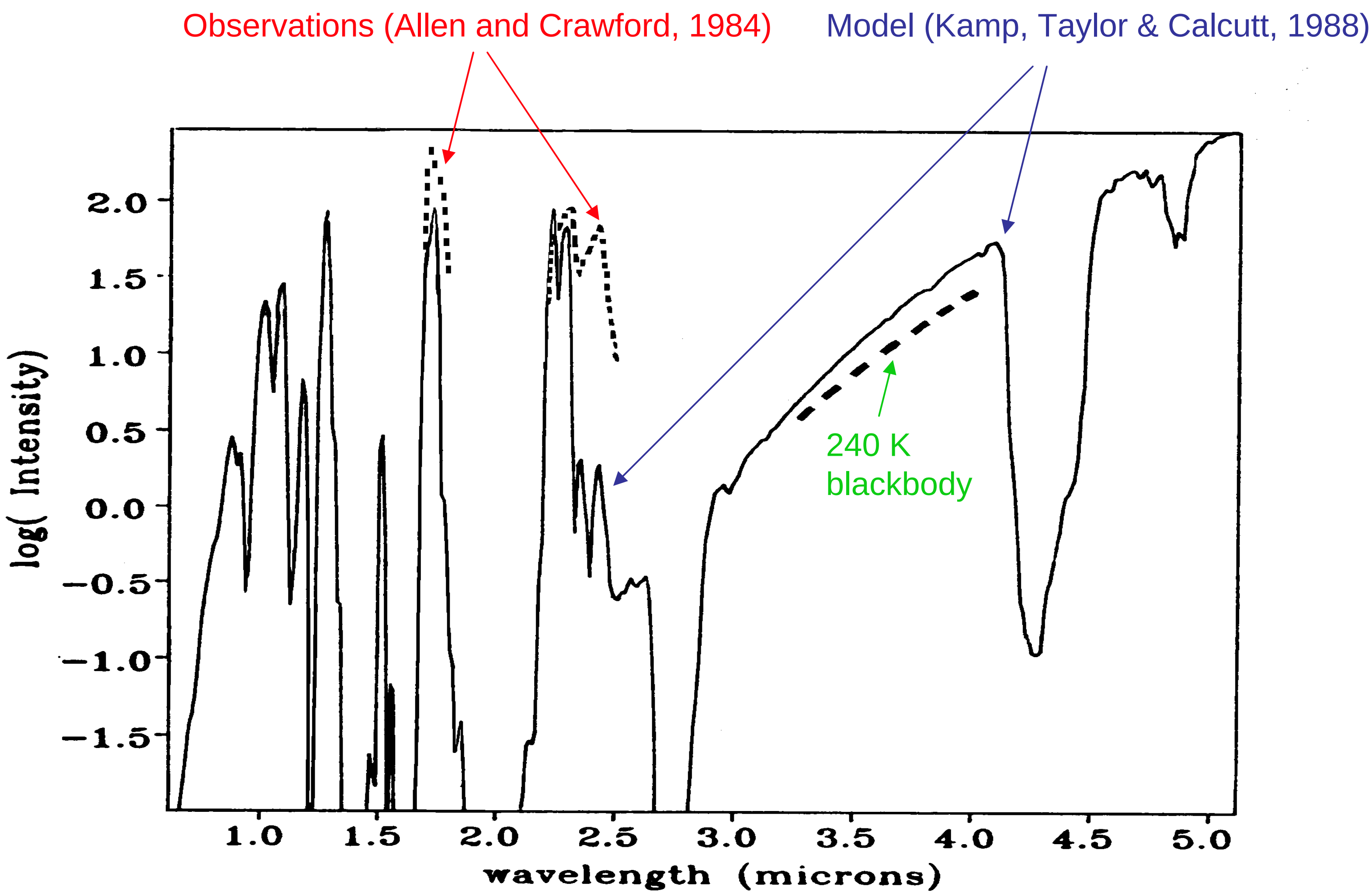
[P. Moore]

… at 2.3 microns

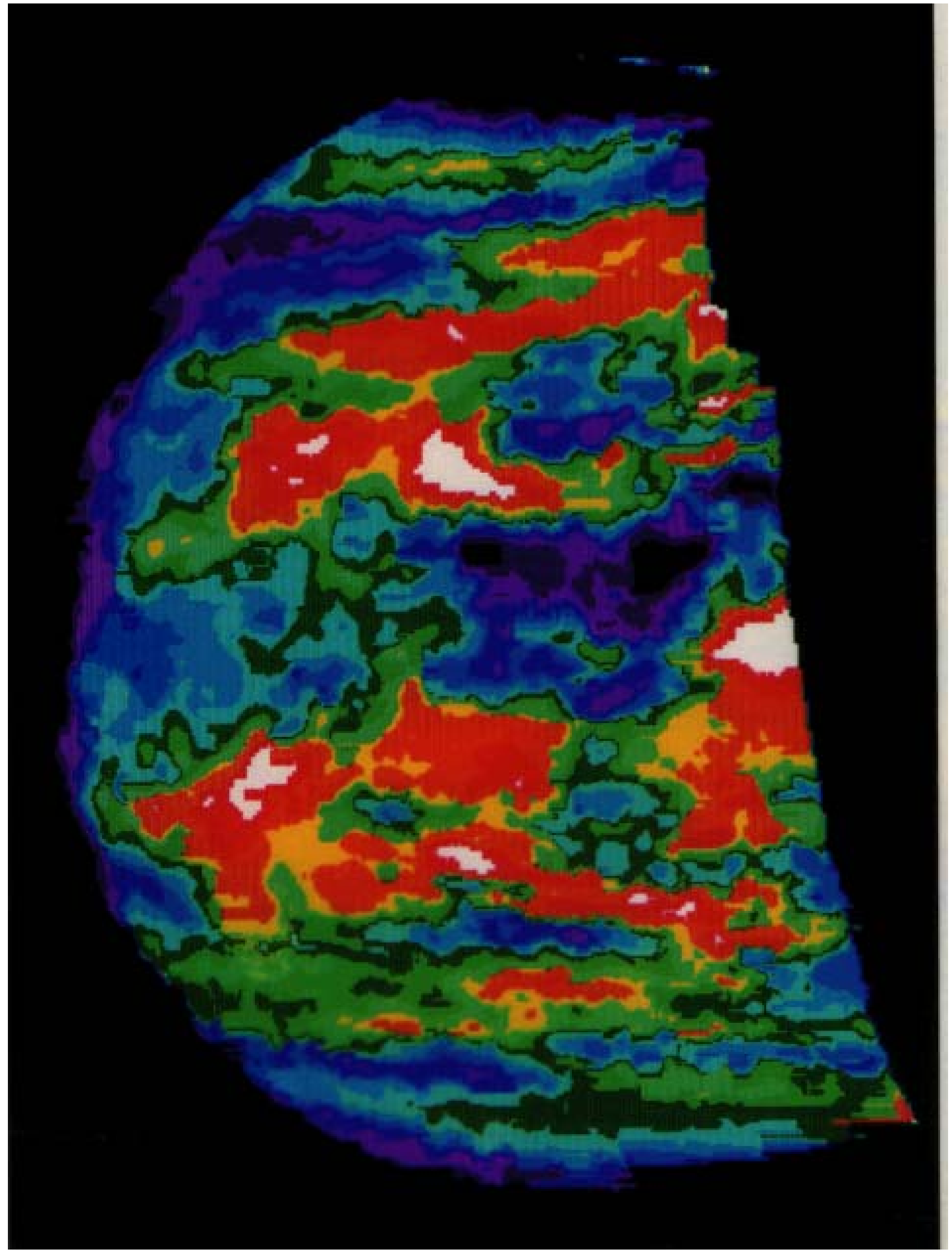


D. Crisp, NASA/JPL

Venus Near-IR Spectrum



Galileo NIMS view of mysterious 'weather' in the deep atmosphere of Venus (Carlson et al.)



Energy Balance of the Earth

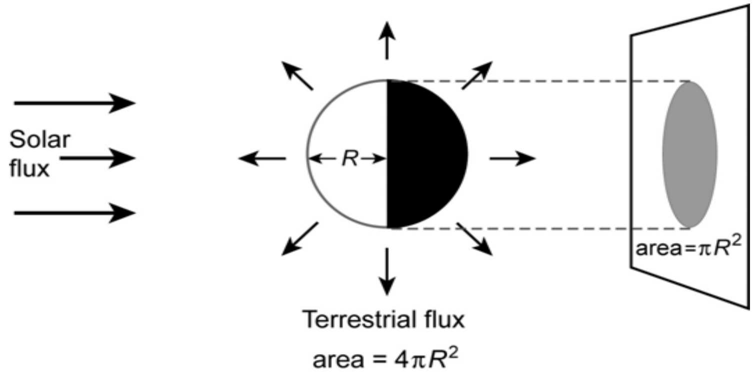
Applying the Stefan-Boltzmann law we obtain for the total radiant power of the Sun, with temperature T_S & radius R_S:

$$E_{Sun} = 4\pi R_S^2 \sigma (T_S)^4 = 4\pi S R_{ES}^2$$

where S is the solar constant and R_{ES} the distance Earth –Sun. Now:

$$E_E = 4\pi \sigma R_E^2 (T_E)^4 = (1\text{-}A) S \pi R_E^2$$

$\rightarrow$ *radiometric temperature* of the Earth $T_E = 255$ K.



The mean *surface* temperature of the Earth is about 288 K. The difference is due to the fact that only a small part of the thermal emission to space takes place from the surface; most is from the colder regions near the tropopause.

Energy Balance of Venus

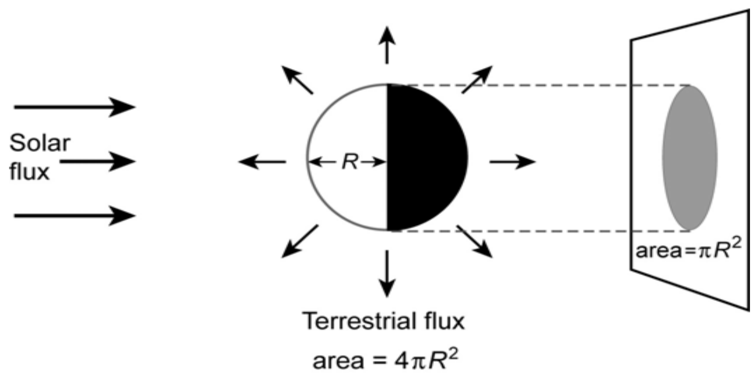
Applying the Stefan-Boltzmann law we obtain for the total radiant power of the Sun, with temperature T_S & radius R_S:

$$E_{Sun} = 4\pi R_S^2 \sigma (T_S)^4 = 4\pi S R_{VS}^2$$

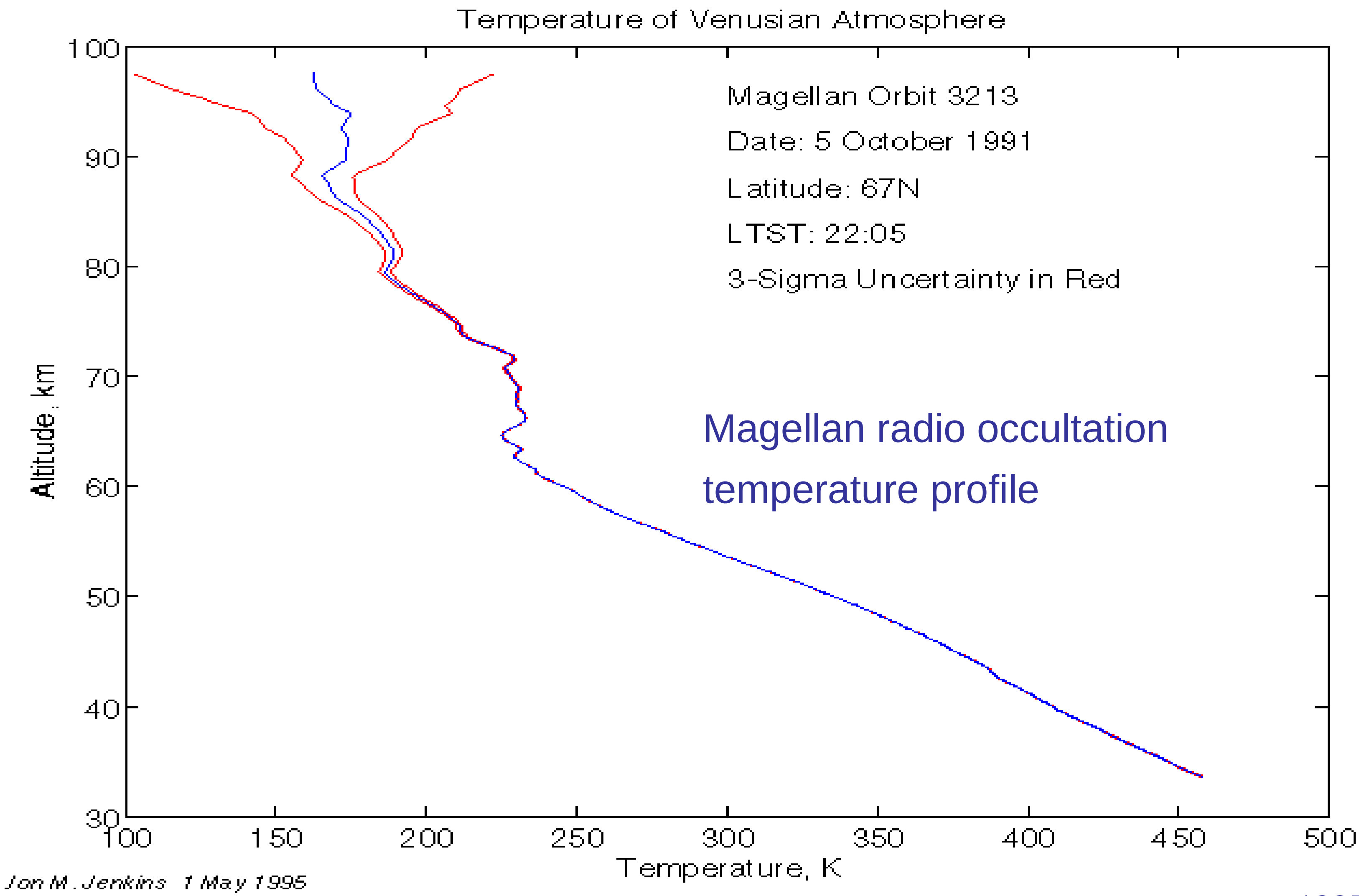
where S is the solar constant and R_{ES} the distance Earth –Sun. Now:

$$E_V = 4\pi \sigma R_V^2 (T_V)^4 = (1-A) S \pi R_V^2$$

$\rightarrow$ *radiometric temperature* of Venus $T_V = 240$ K.

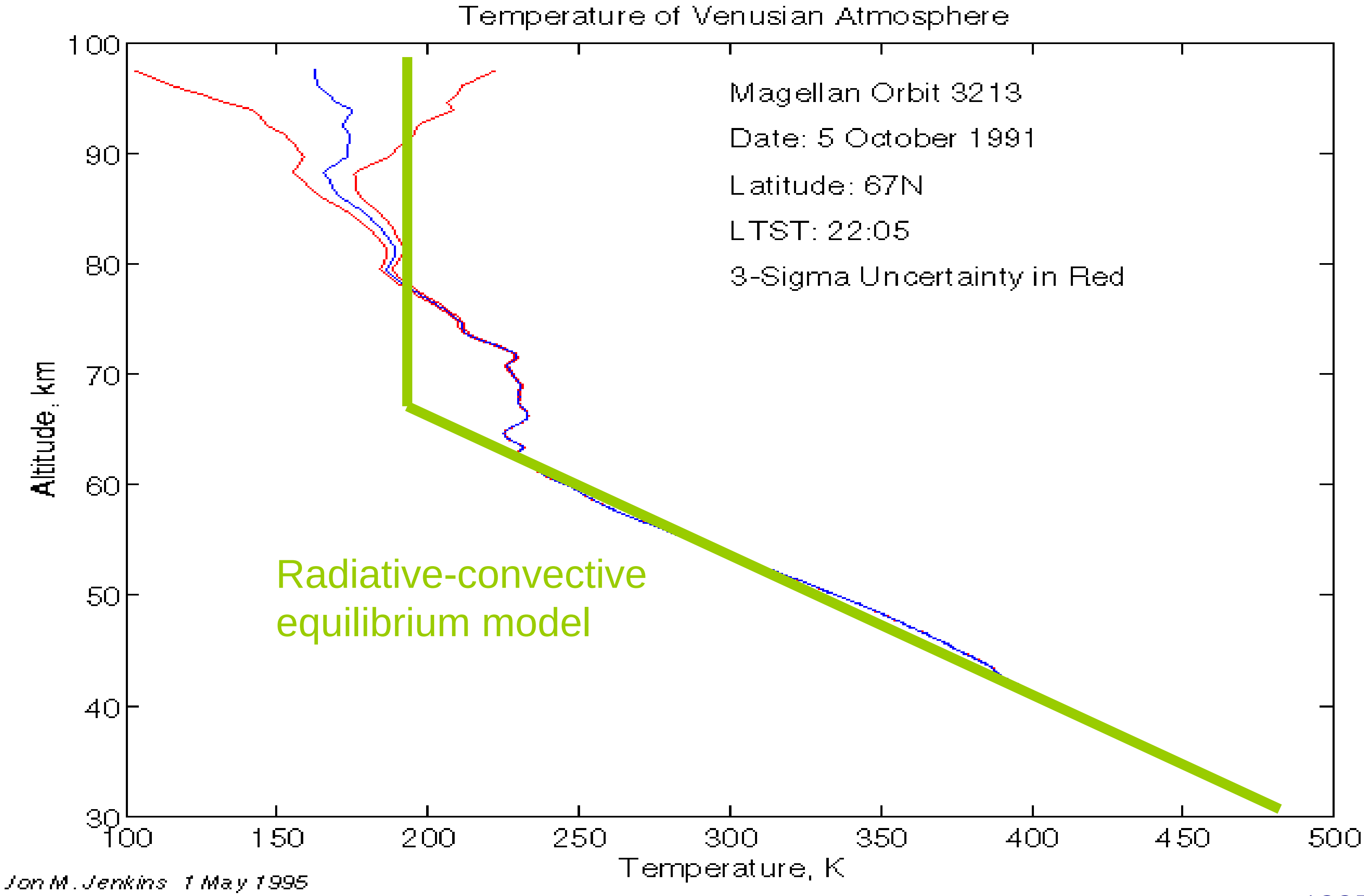


The mean *surface* temperature of Venus is about 760 K.
The difference is due to the fact that only a small part of the thermal emission to space takes place from the surface; most is from the colder regions near the tropopause.



Magellan radio occultation temperature profile

Jenkins, 1995



Jenkins, 1995

Why is Venus so hot?

- CO_2 is in equilibrium with carbonates on surface (Urey, 1952)

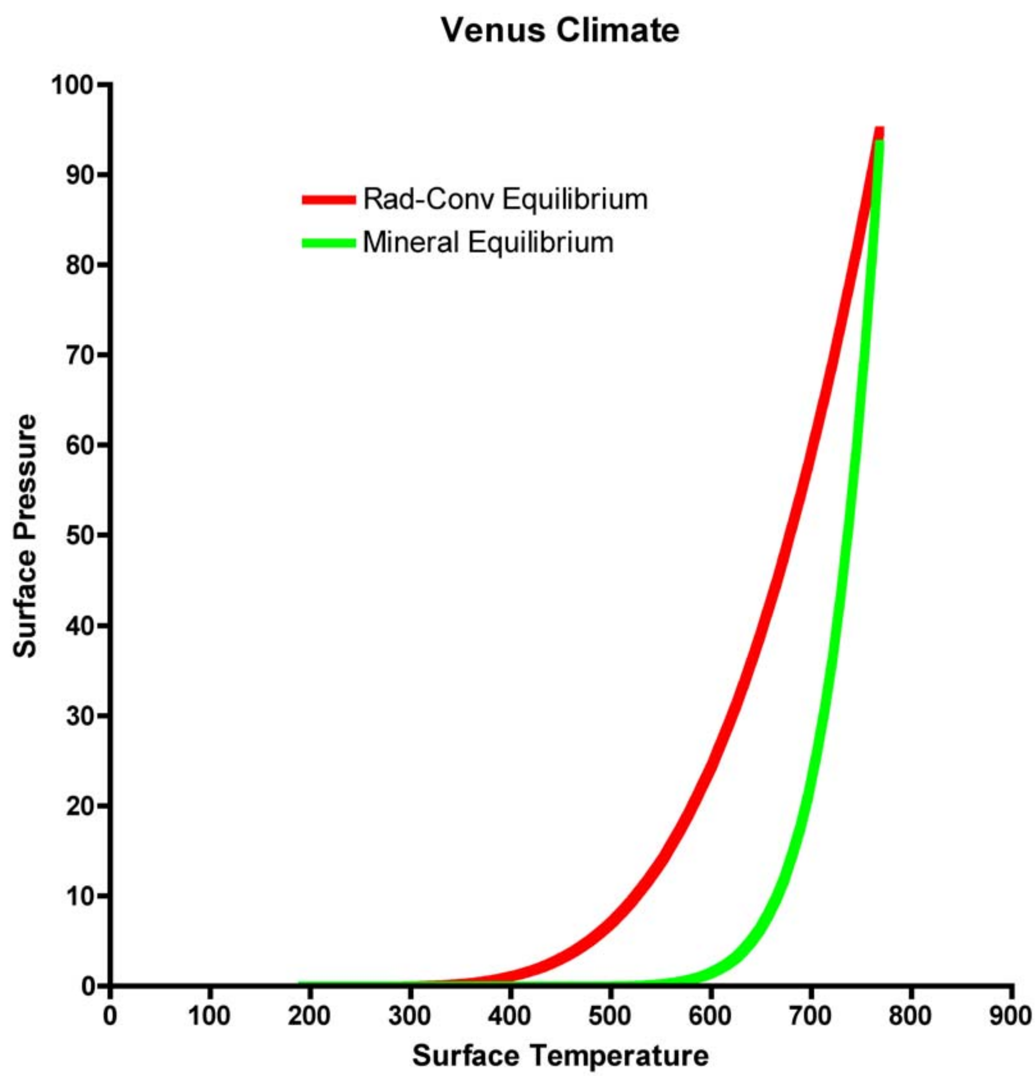
- the dominant reaction is expected (Bullock & Grinspoon 1996) to be

$$CaCO_3 + SiO_2 \Leftrightarrow CaSiO_3 + CO_2$$

- use thermodynamic data (e.g. Adamik and Draper, 1963) for the temperature dependence of the pressure of CO_2 in the form

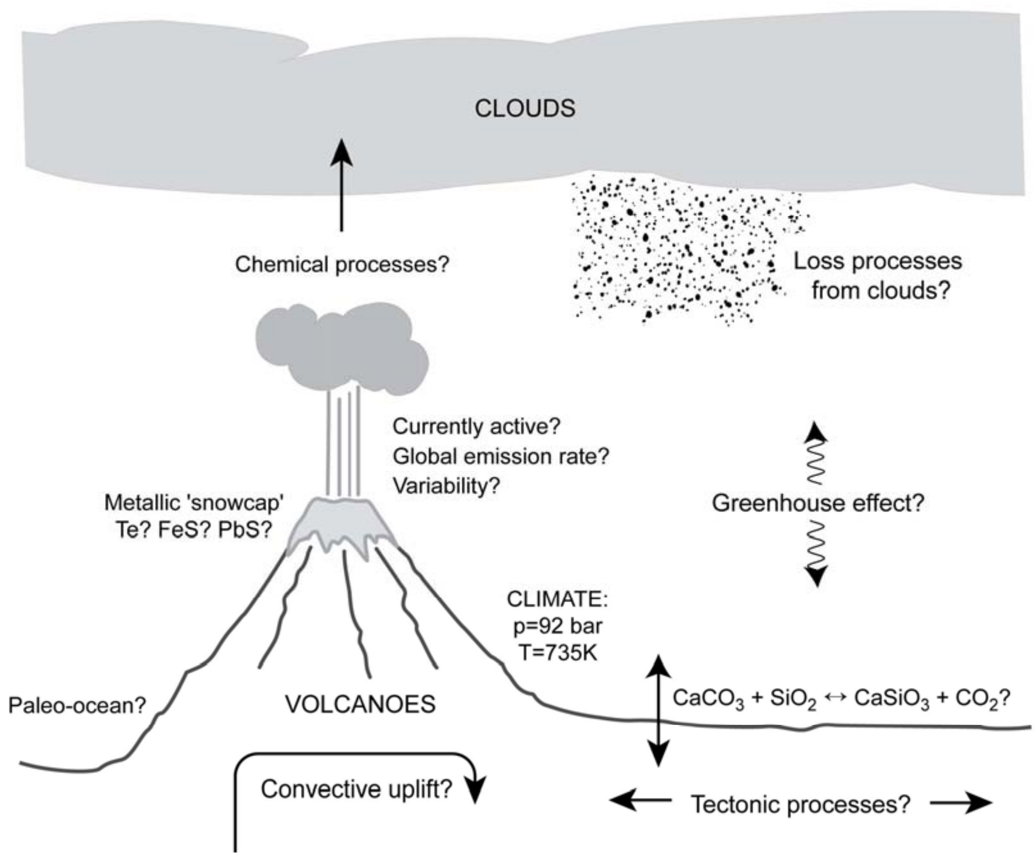
$$\log P = \Delta H/RT + \Delta S/R + A + BT + CT^{-2}$$

- use the radiative-convective equilibrium model for the surface pressure as a function of surface temperature

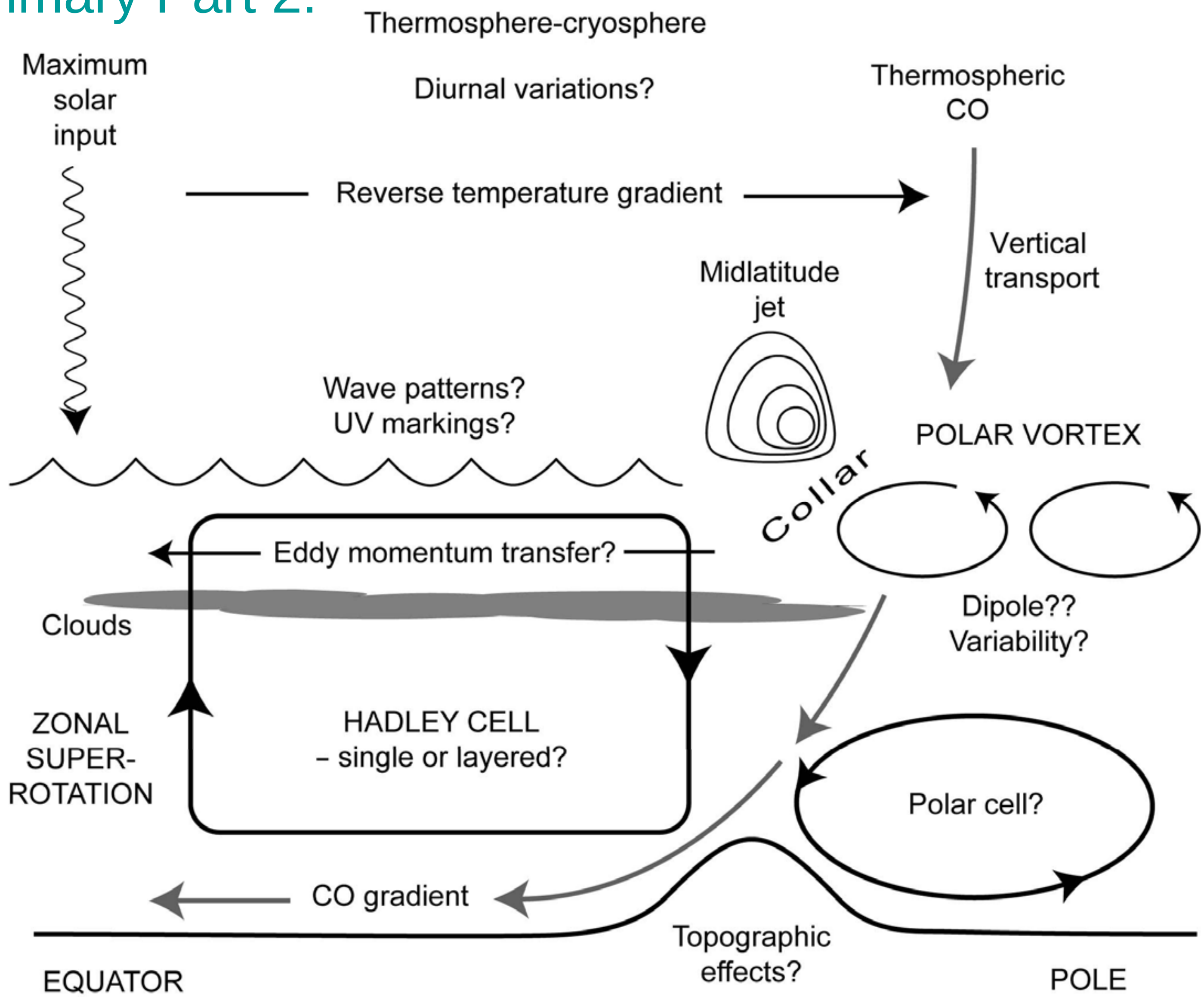


Venus Climate
Rad-Conv Equilibrium
Mineral Equilibrium
Surface Pressure
Surface Temperature
0
10
20
30
40
50
60
70
80
90
100
0
100
200
300
400
500
600
700
800
900

Summary Part 1:



Summary Part 2:



QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

More data! More data! From pole to equator!
Measure everything, everywhere, all of the time!