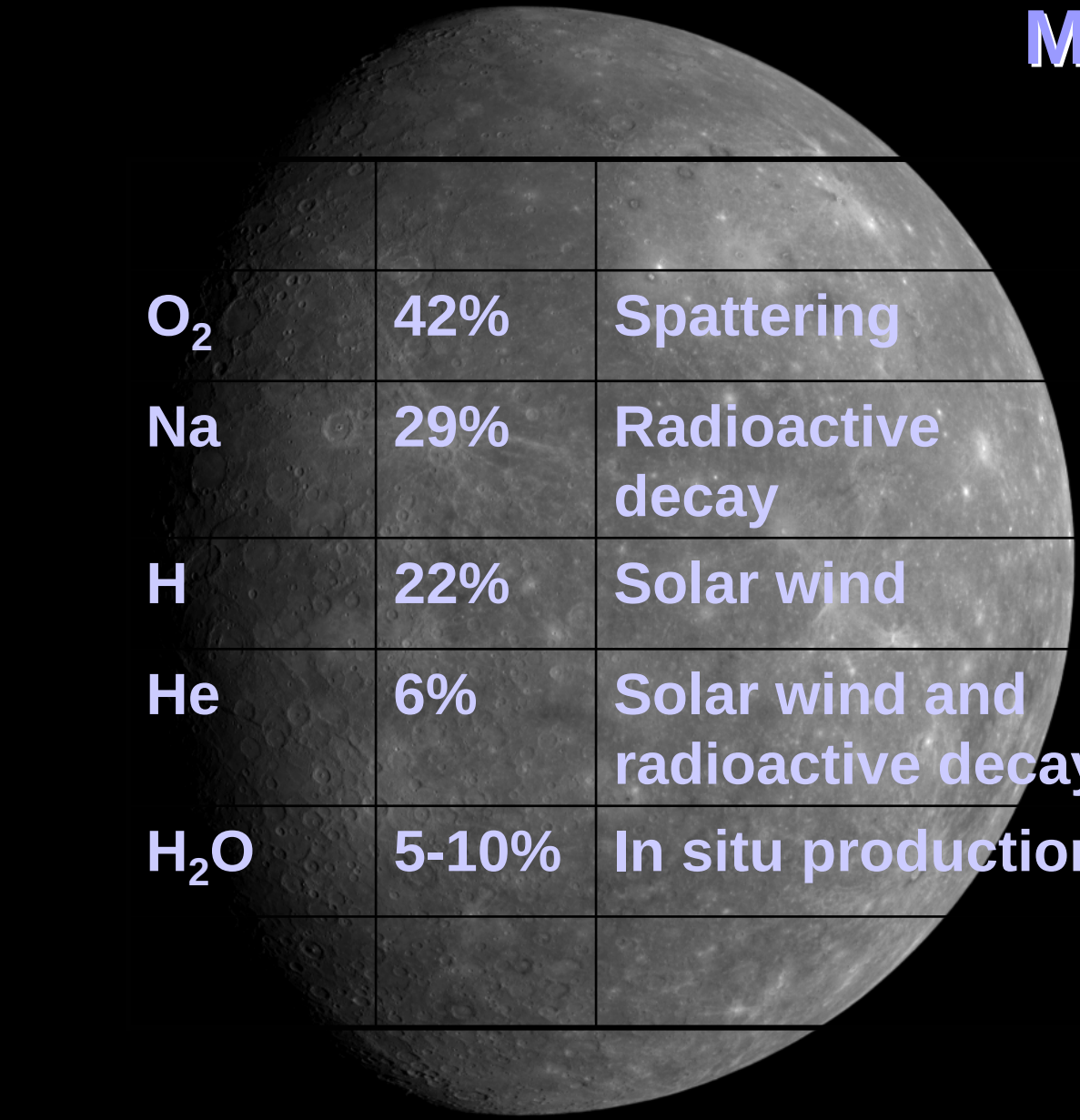
Planetary Atmospheres: a Grand Tour

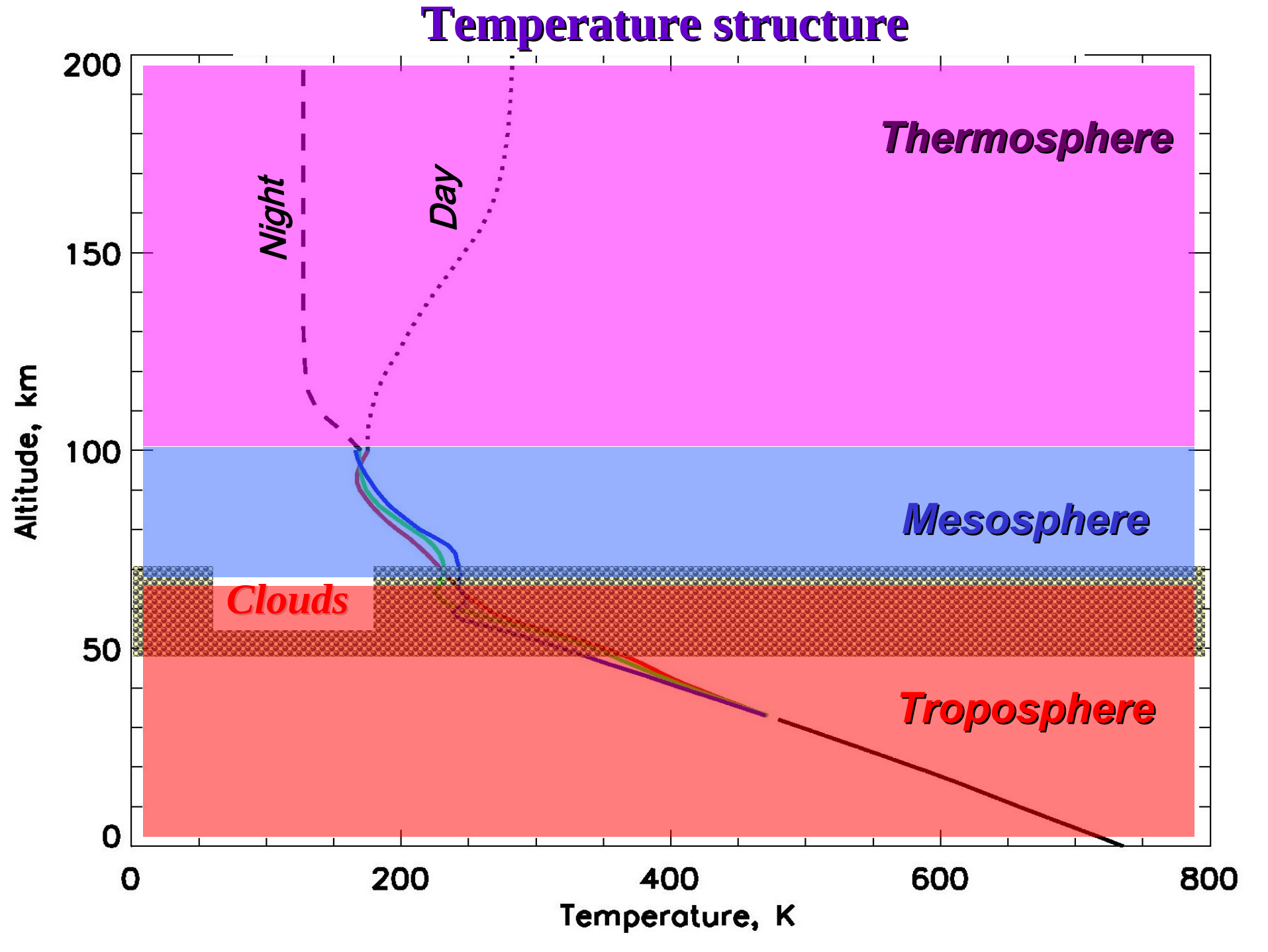
Mercury

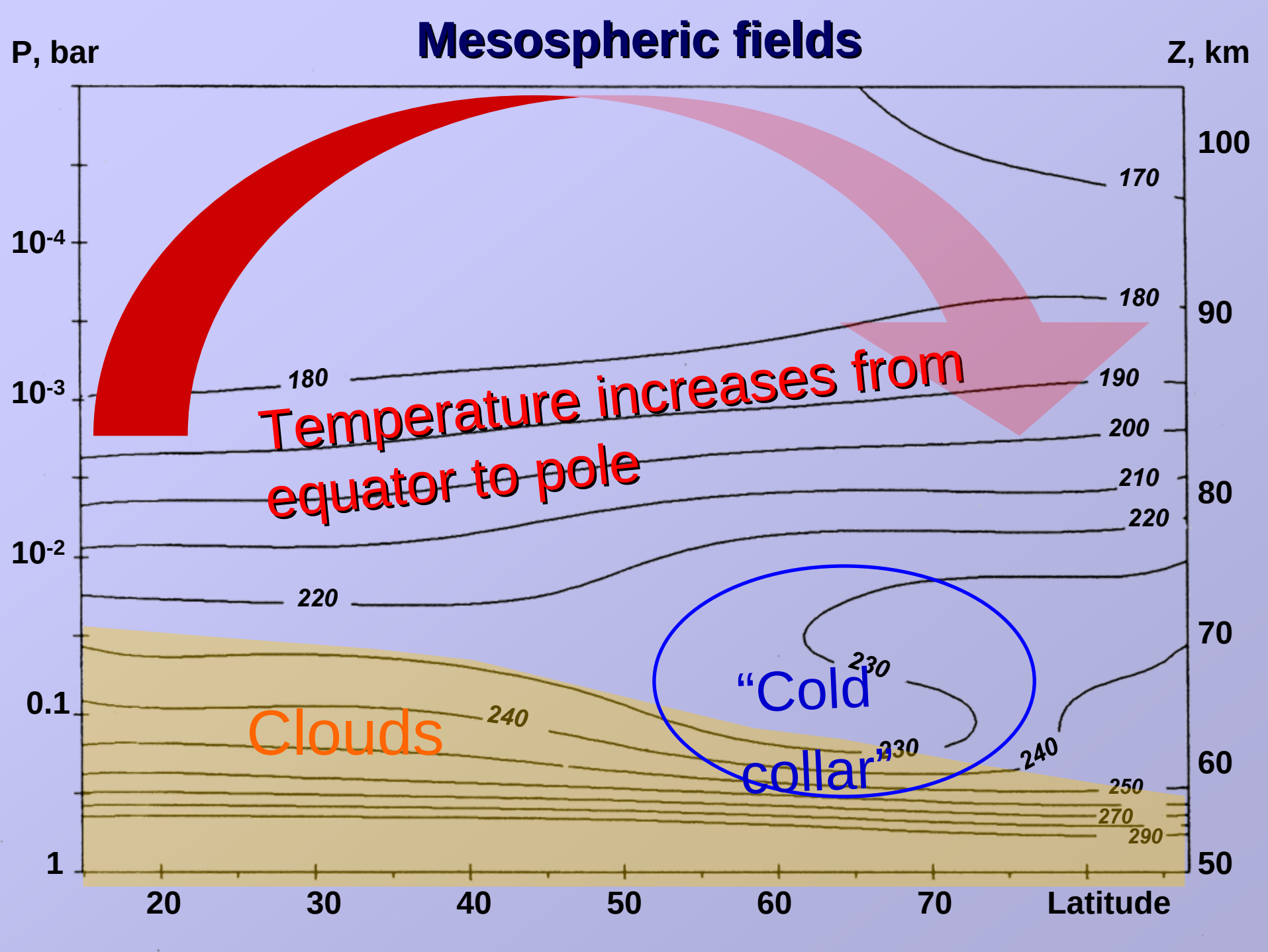


O_2	42%	Spattering
Na	29%	Radioactive decay
H	22%	Solar wind
He	6%	Solar wind and radioactive decay
H_2O	5-10%	In situ production

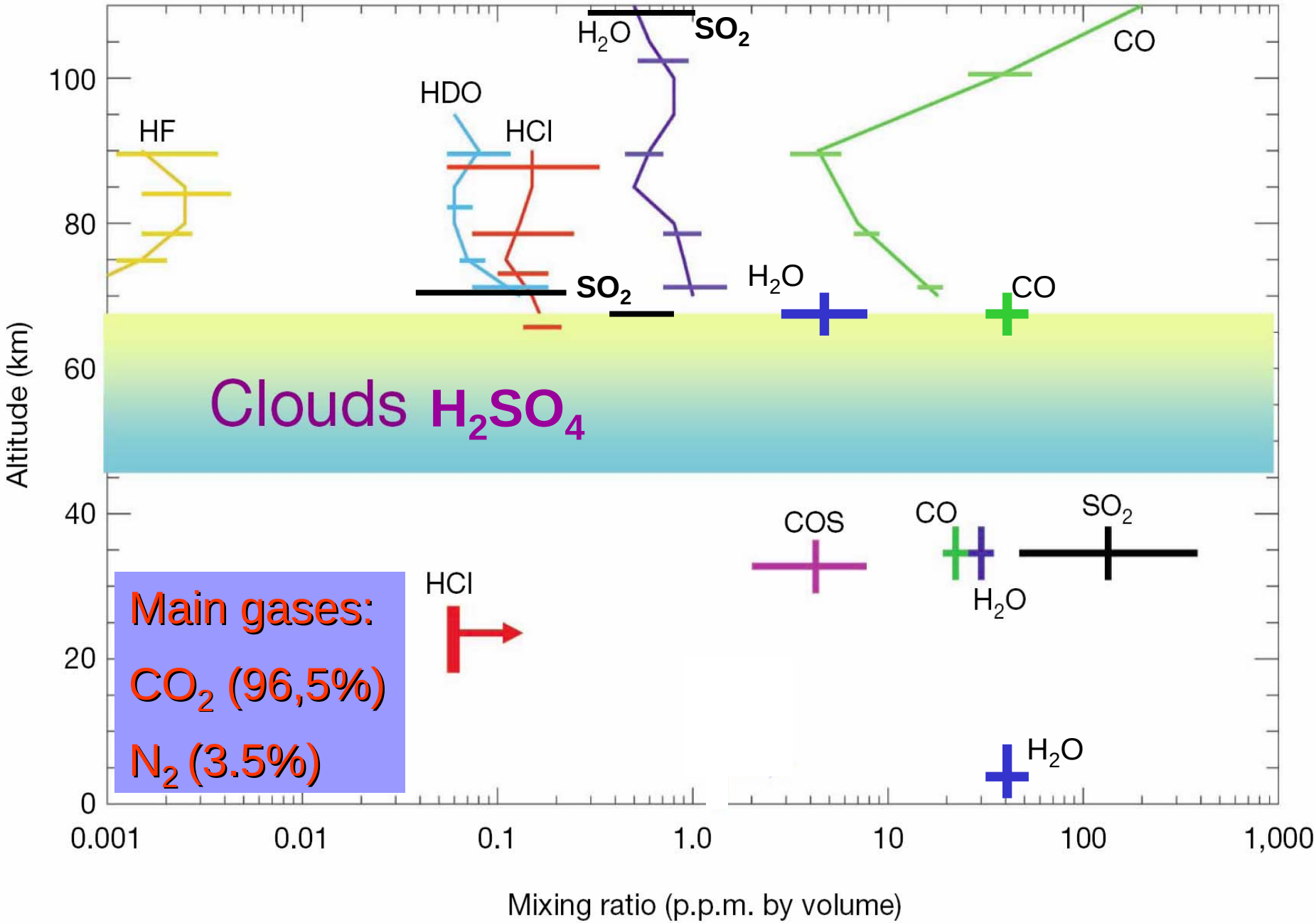
Venus

Temperature structure

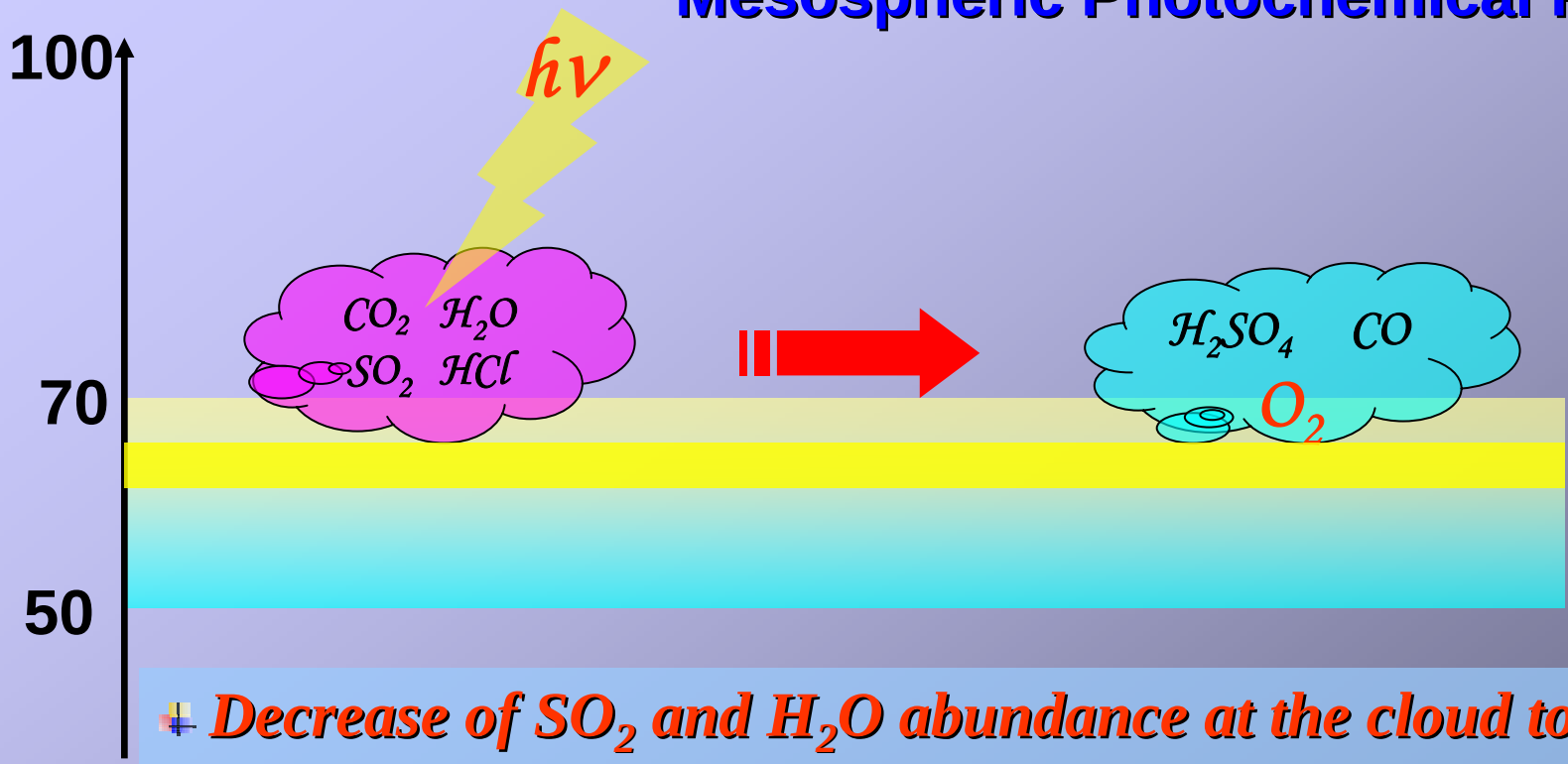



Mesospheric fields
P, bar
Z, km
10-4
10-3
10-2
0.1
1
100
90
80
70
60
50
170
180
180
190
200
210
220
220
Temperature increases from equator to pole
Clouds
240
"Cold" collar"
230
230
240
250
270
290
20
30
40
50
60
70
Latitude

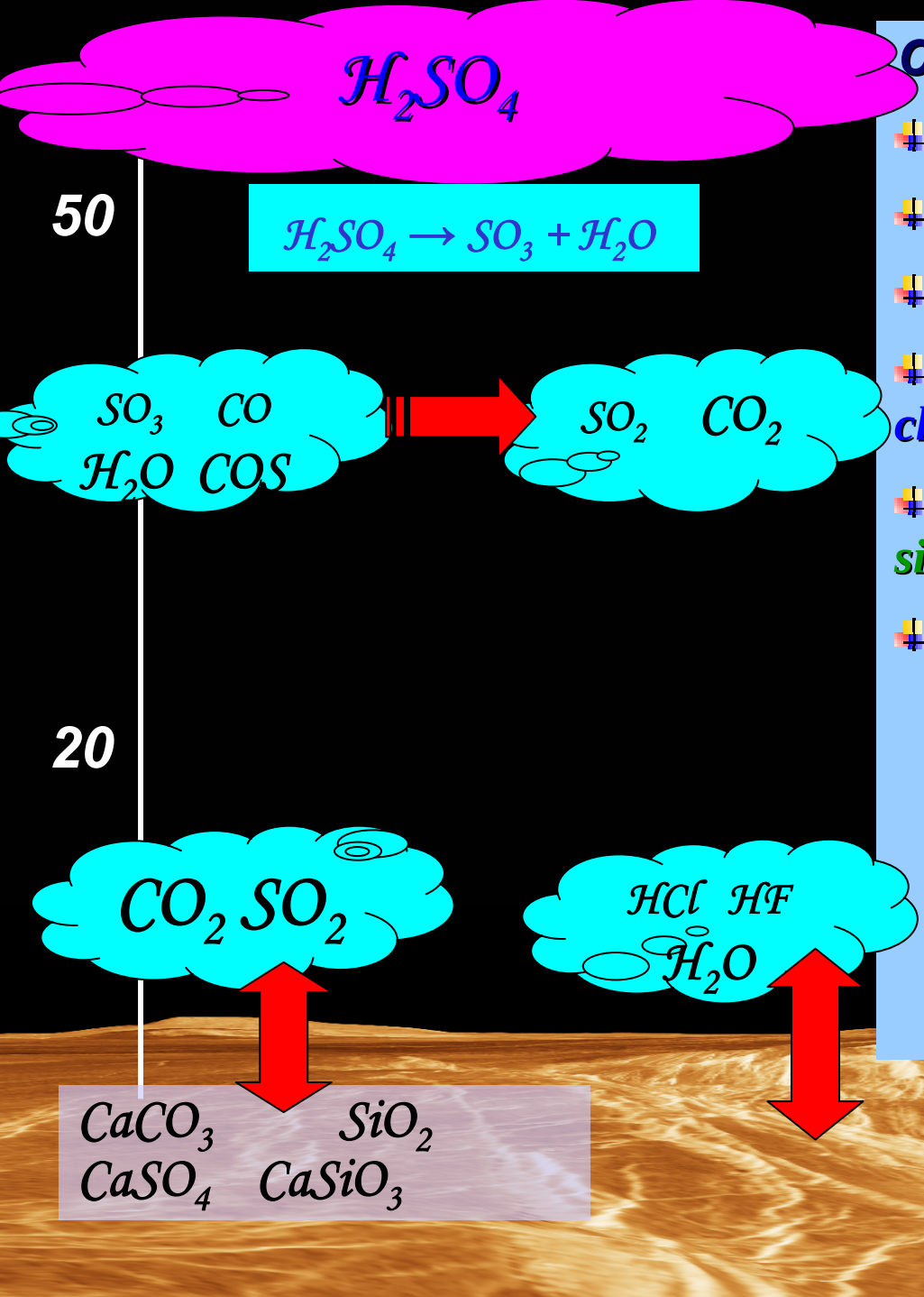
Composition of the Venus atmosphere



Mesospheric Photochemical Factory



- *Decrease of SO_2 and H_2O abundance at the cloud tops*
- *Formation of the H_2SO_4 aerosols*
- *Models do not explain observed amount of O_2*
- *Unknown UV absorber*
- *Chlorine and sulfur chemistry in the Earth atmosphere*



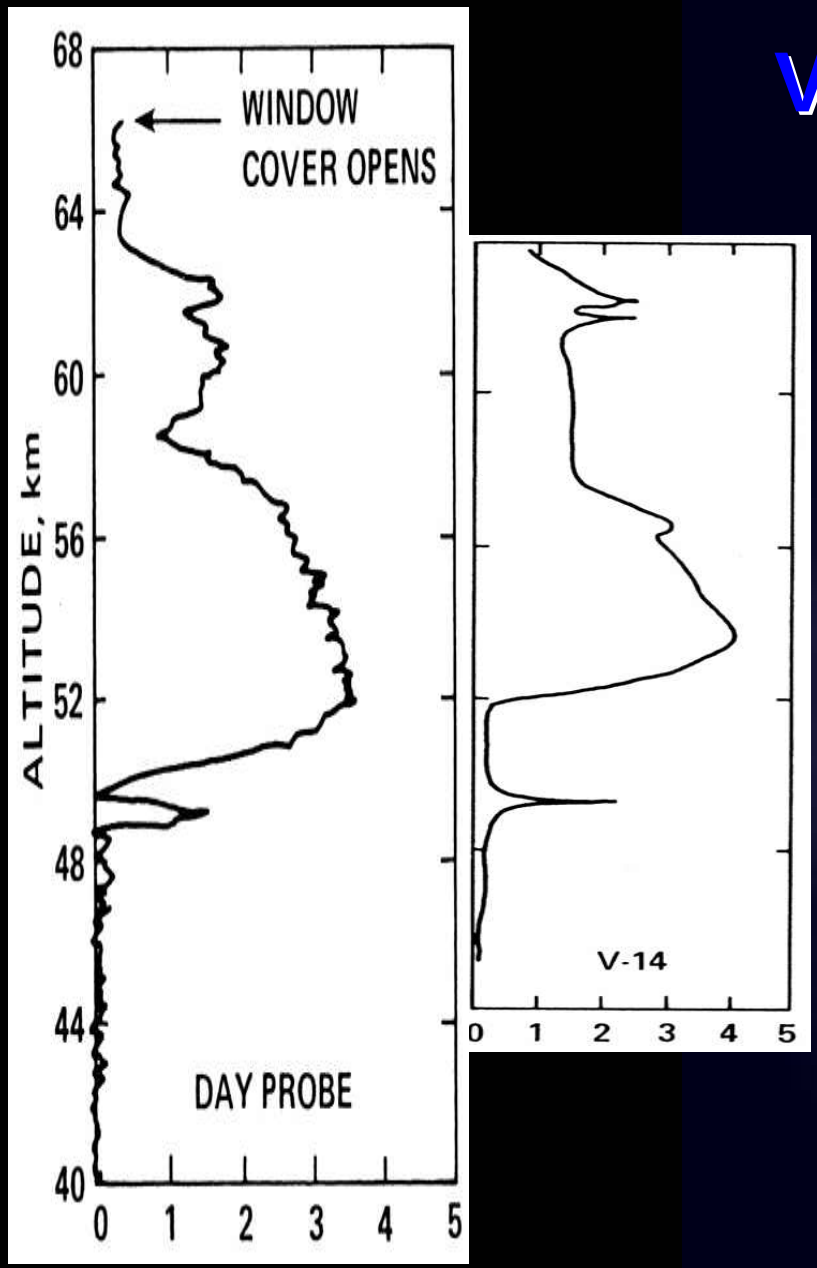
Chemistry of the lower Atmosphere

- Decomposition of H_2SO_4
- No photochemistry
- High temperatures and pressure
- Chemical disequilibrium except very close to the surface
- Buffering of the atmospheric composition by the surface
- Open questions
  - surface composition
  - CO and O_2 at the surface
  - too high SO_2 abundance
  - volcanism replenishes SO_2

Climate and composition

	Earth	Venus
Surface P, bar	1	**90**
Surface T, °C	+15	**+ 460 (!)**
Composition , %		
N_2	**0.78**	0.035
O_2	**0.21**	~ 0
Atmospheric H_2O	< 0.03	0.00005
Total H_2O, cm	~3	**$\sim 3 \cdot 10^5$**
CO_2	0.0003	**0.965**
SO_2	~0	0.0001
Clouds	**H_2O**	**H_2SO_4 +?**

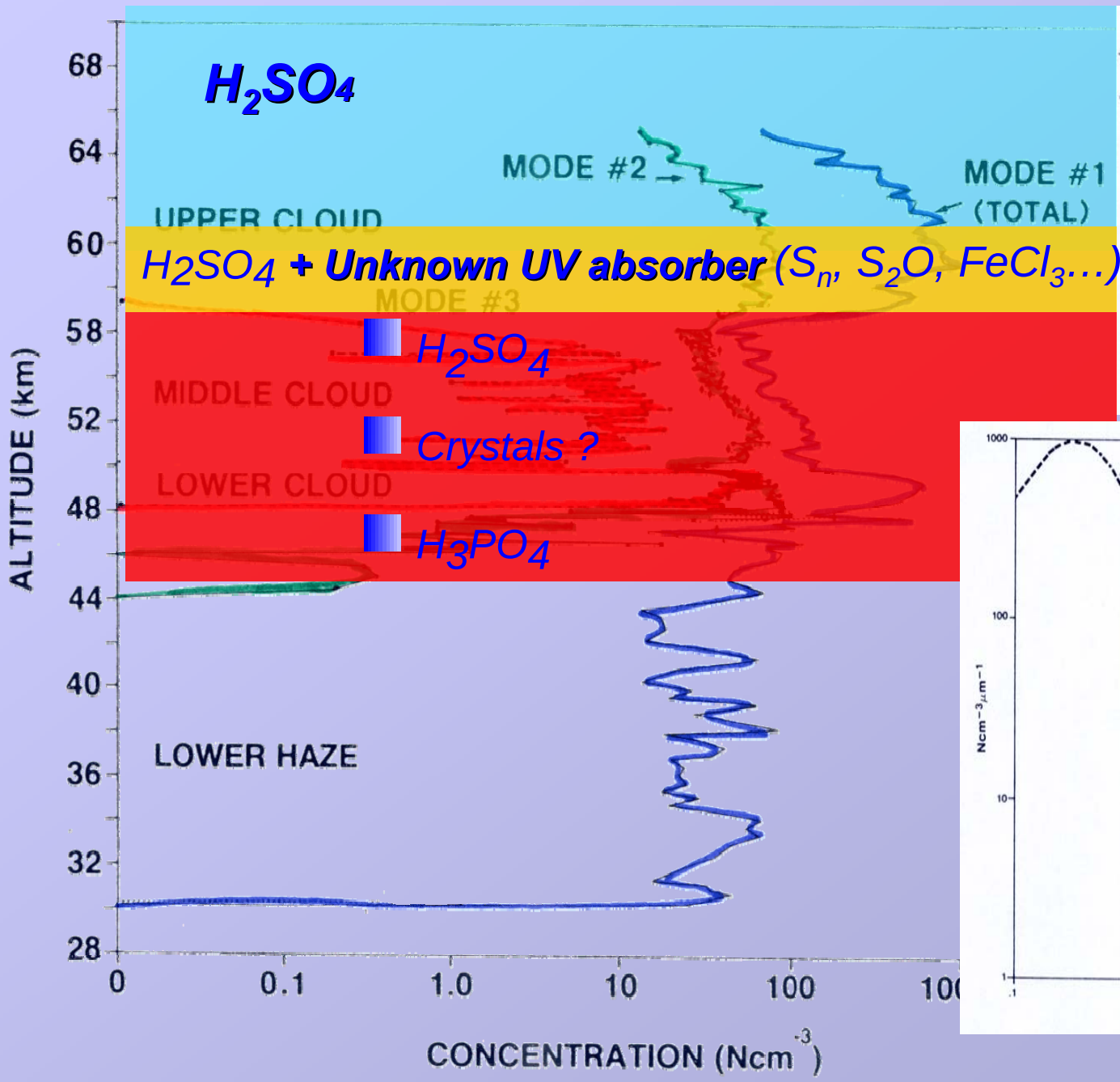
Venus Cloud Properties

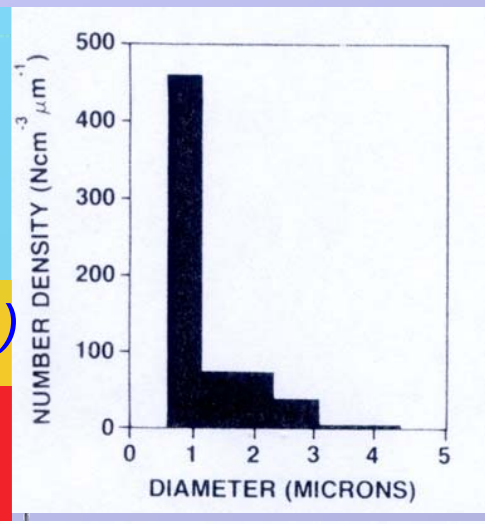


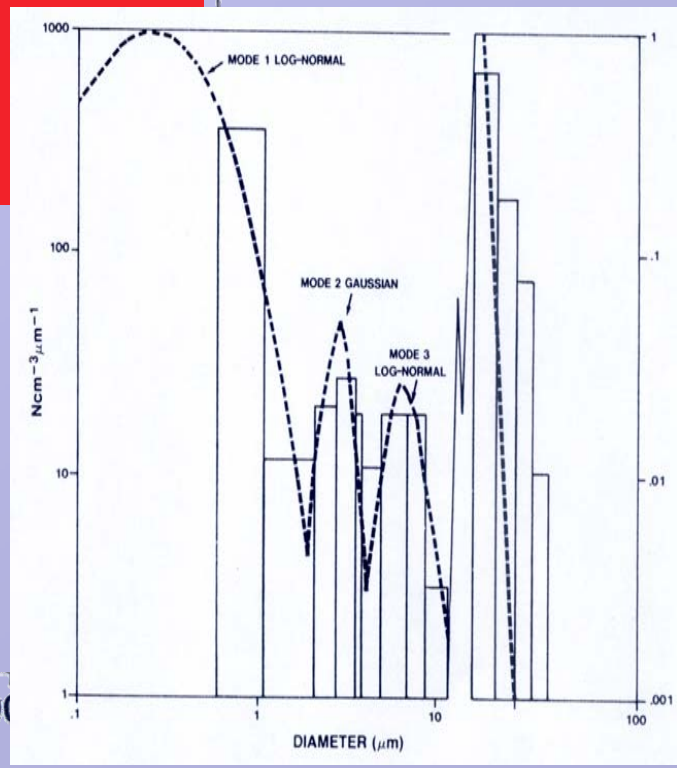
Aerosol extinction, km^{-1}

- *Altitude range 75 – 45 km*
- *Total opacity 20-40*
- *Visibility > 300 m*
- *Particles:*
  - *R = 1-10 μm*
  - *N = 100-1000 cm^{-3}*
- *Composition:*
  - *H_2SO_4 + ? (S_n, $AlCl_3$, H_3PO_4, …)*

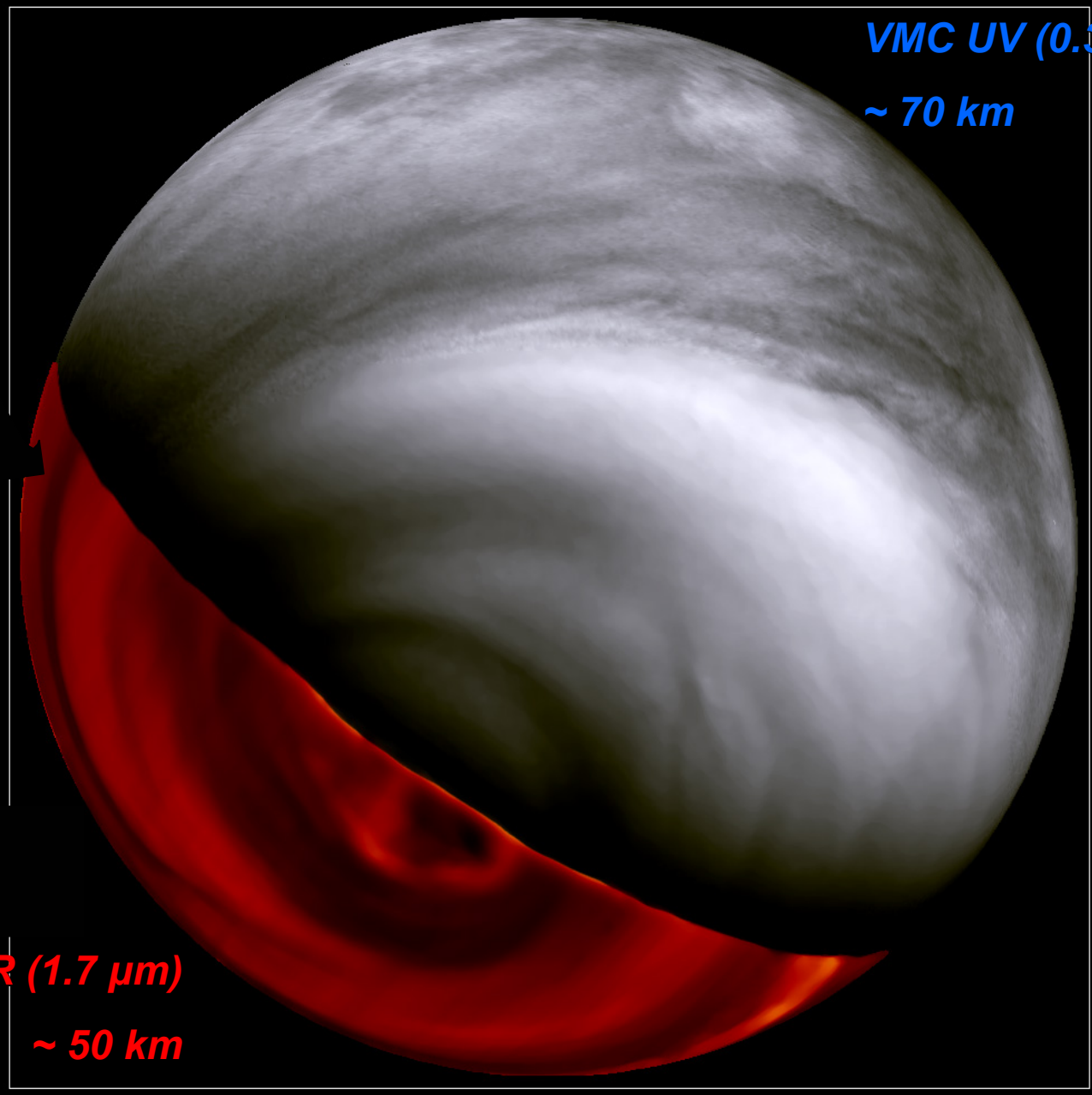
Aerosol population and composition



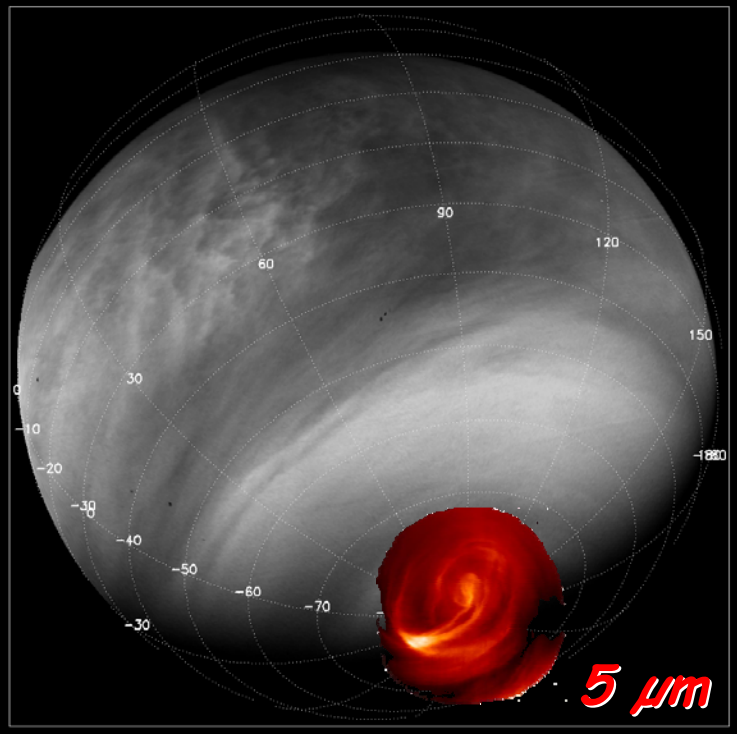


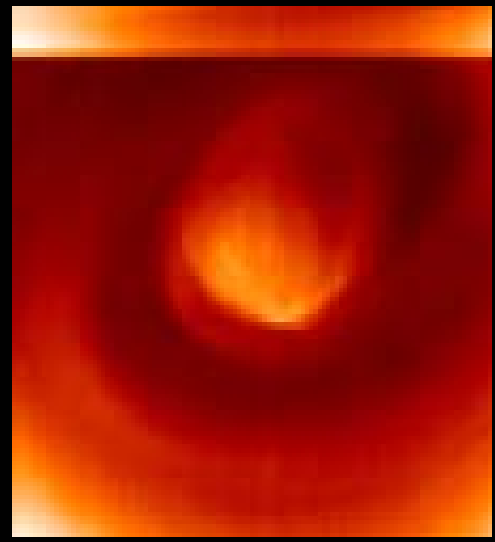


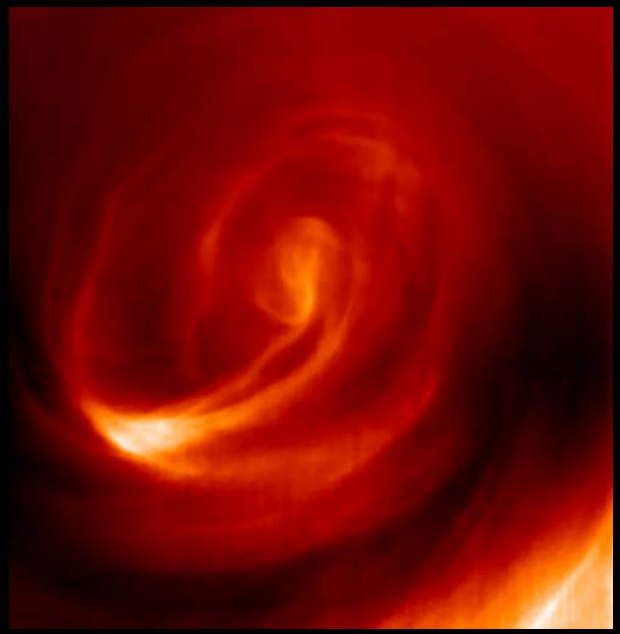
Venus planetary vortex

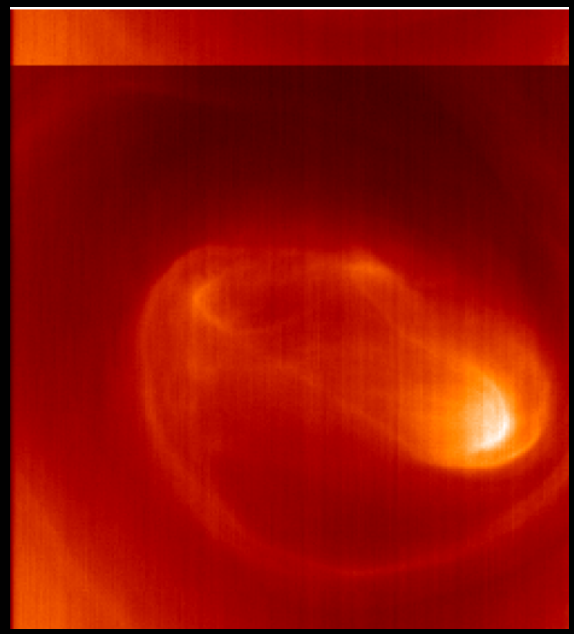


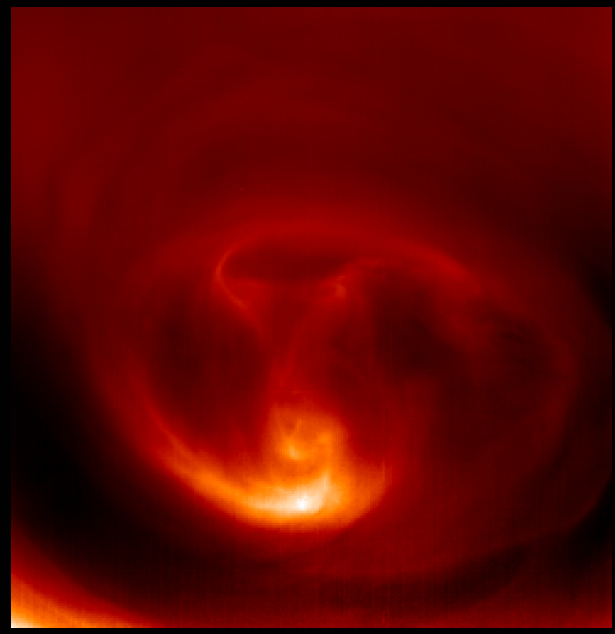
Polar “eye”



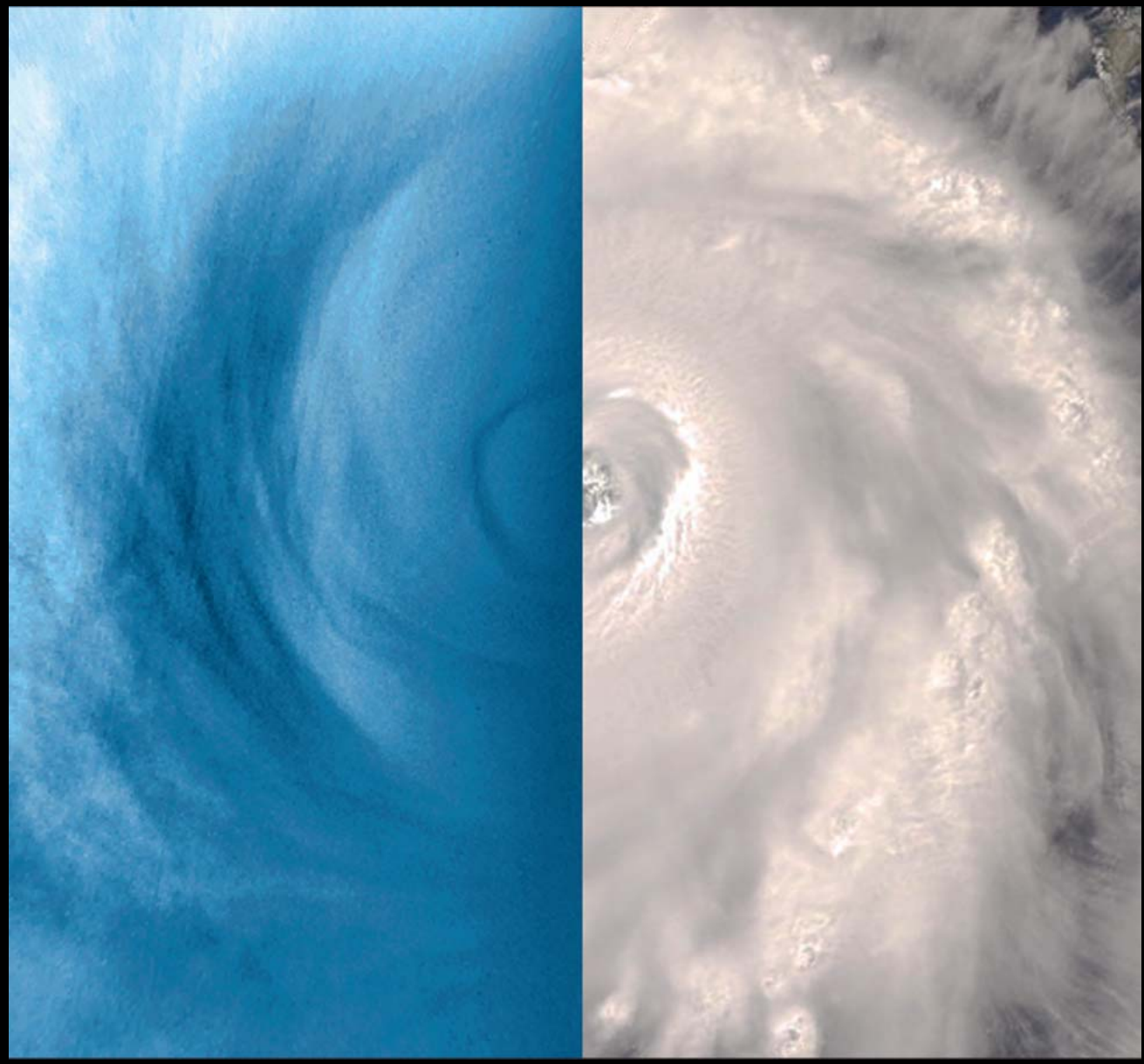






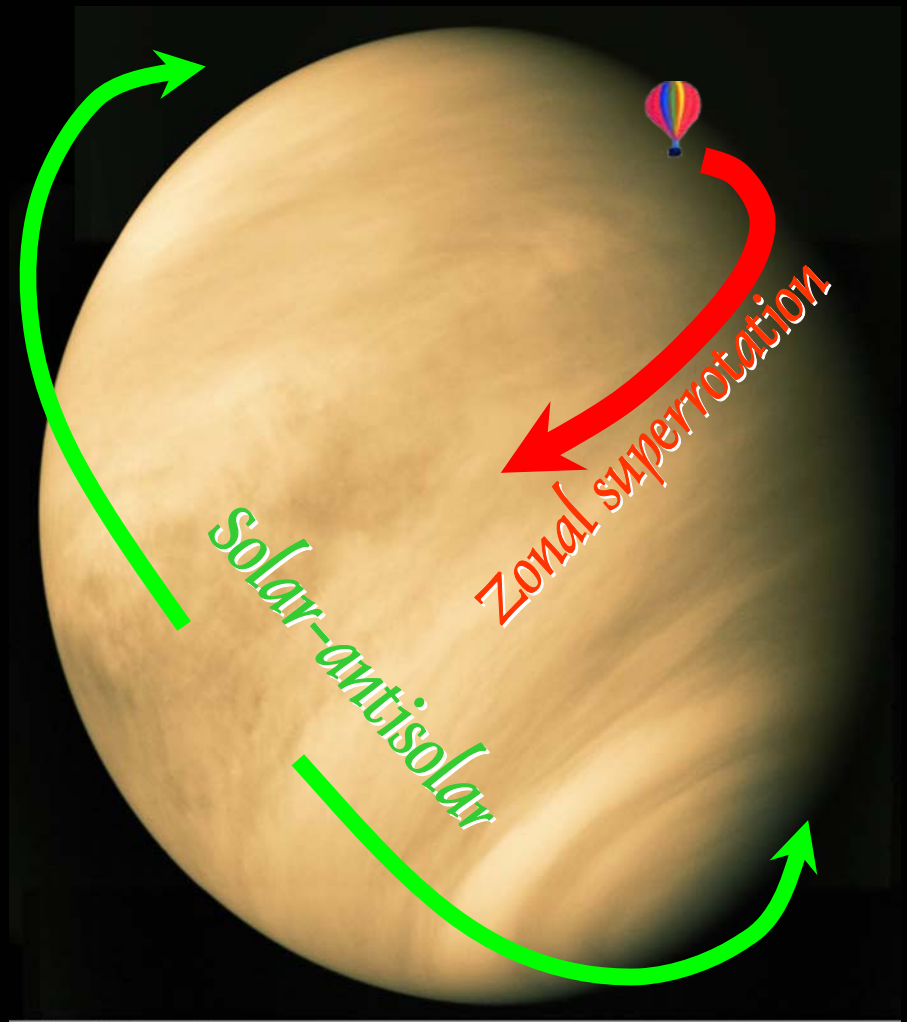


Venus polar vortex and hurricane Frances



S. Limaye et al.

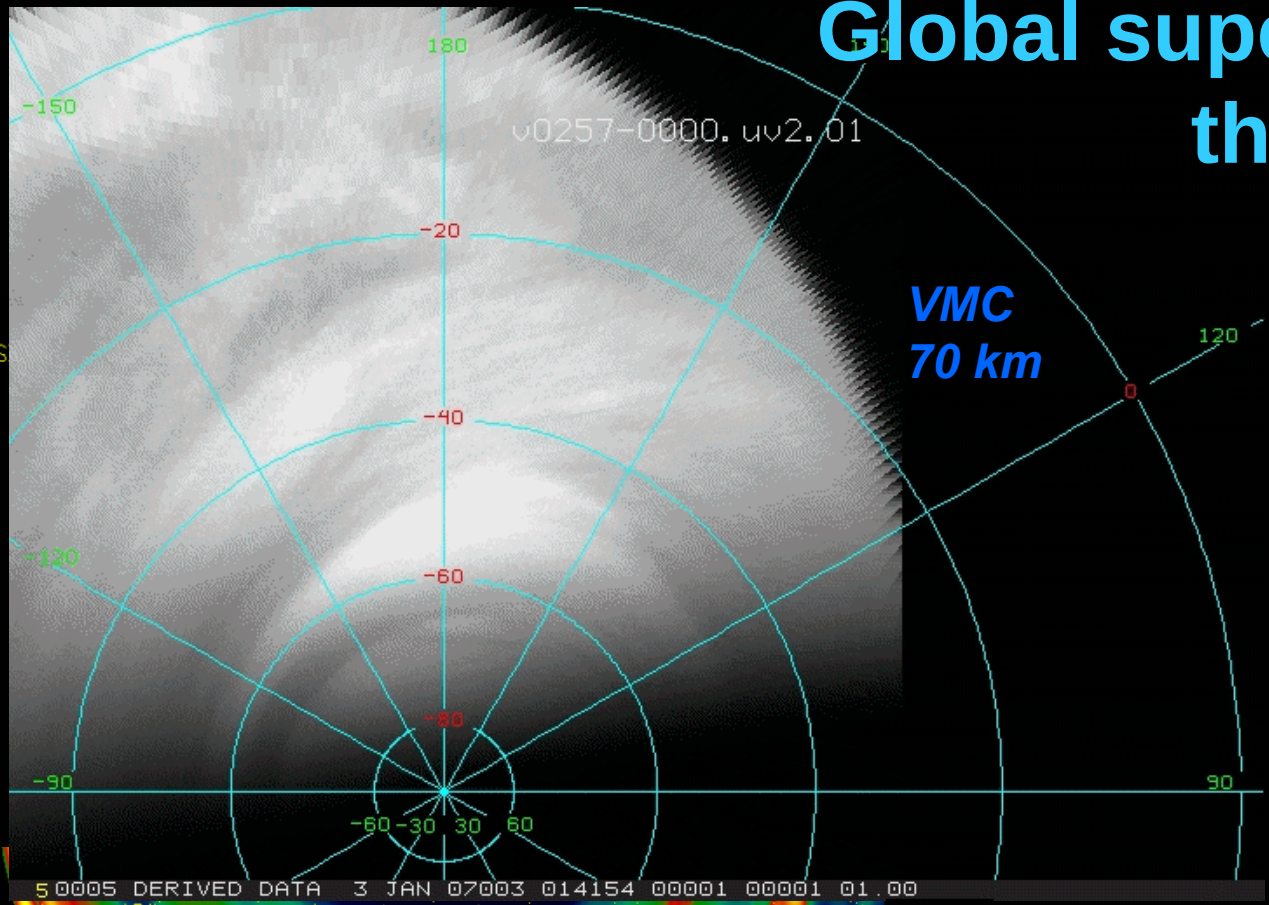
Global Circulation Regimes



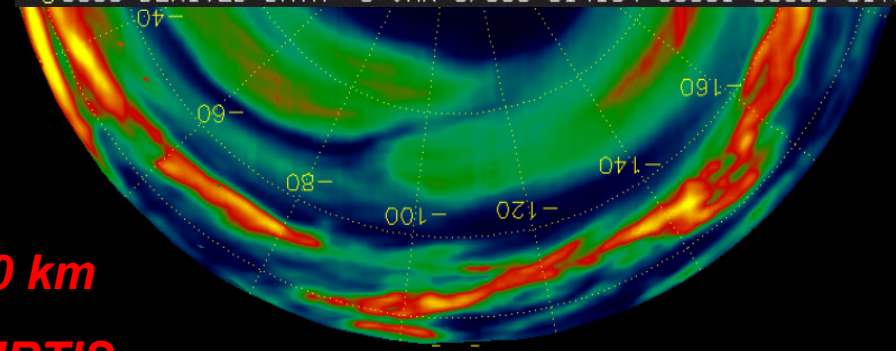
Mariner 10 Image of Venus

- *Troposphere and mesosphere*
  - *Zonal superrotation (>100 m/s)*
  - *Poleward winds v ~ 10 m/s*
- *Thermosphere (> 120 km)*
  - *Zonal superrotation (~100 m/s)*
  - *Solar-antisolar circulation (~200 m/s)*

Global super-rotation at the cloud level



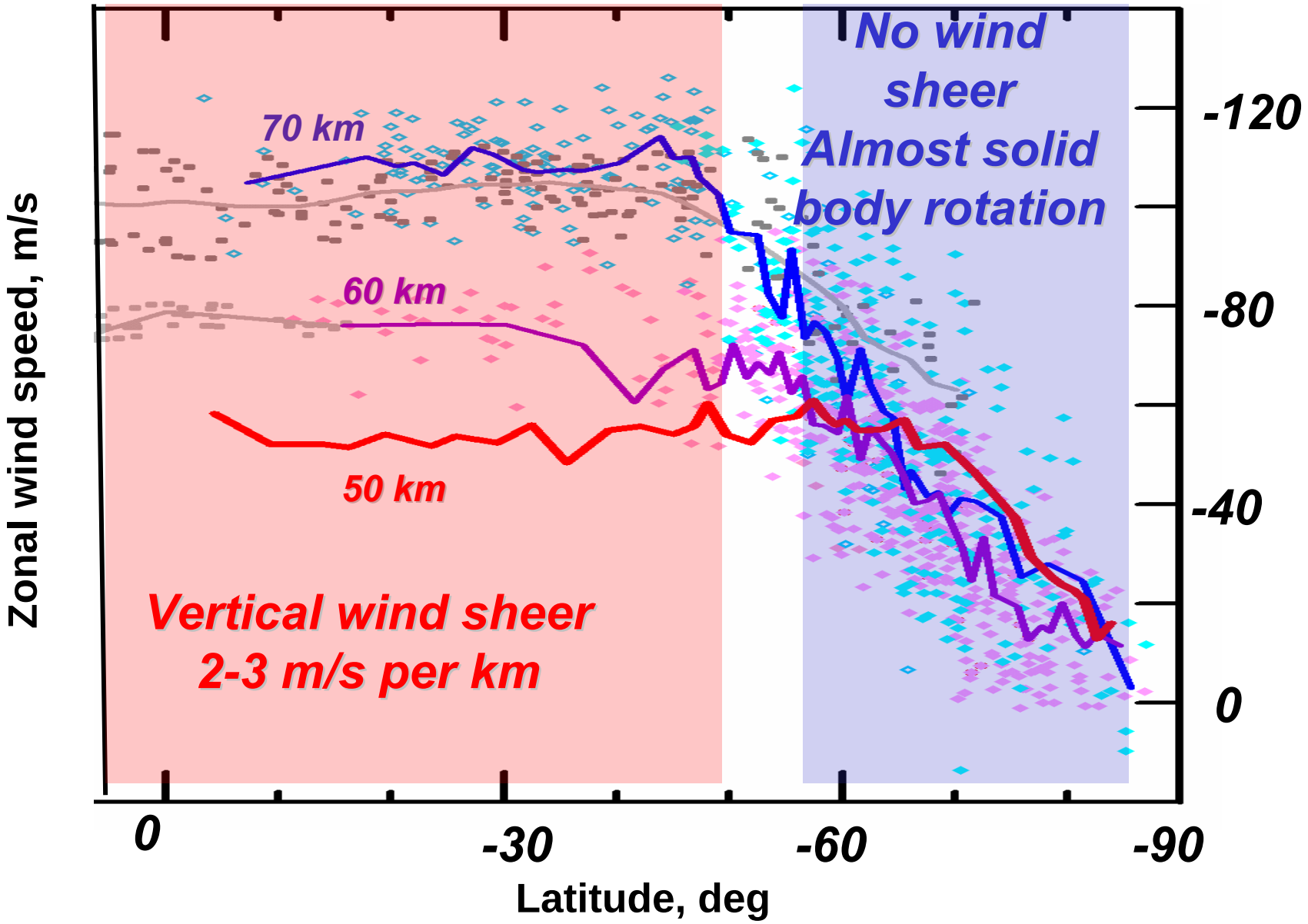
VMC
70 km



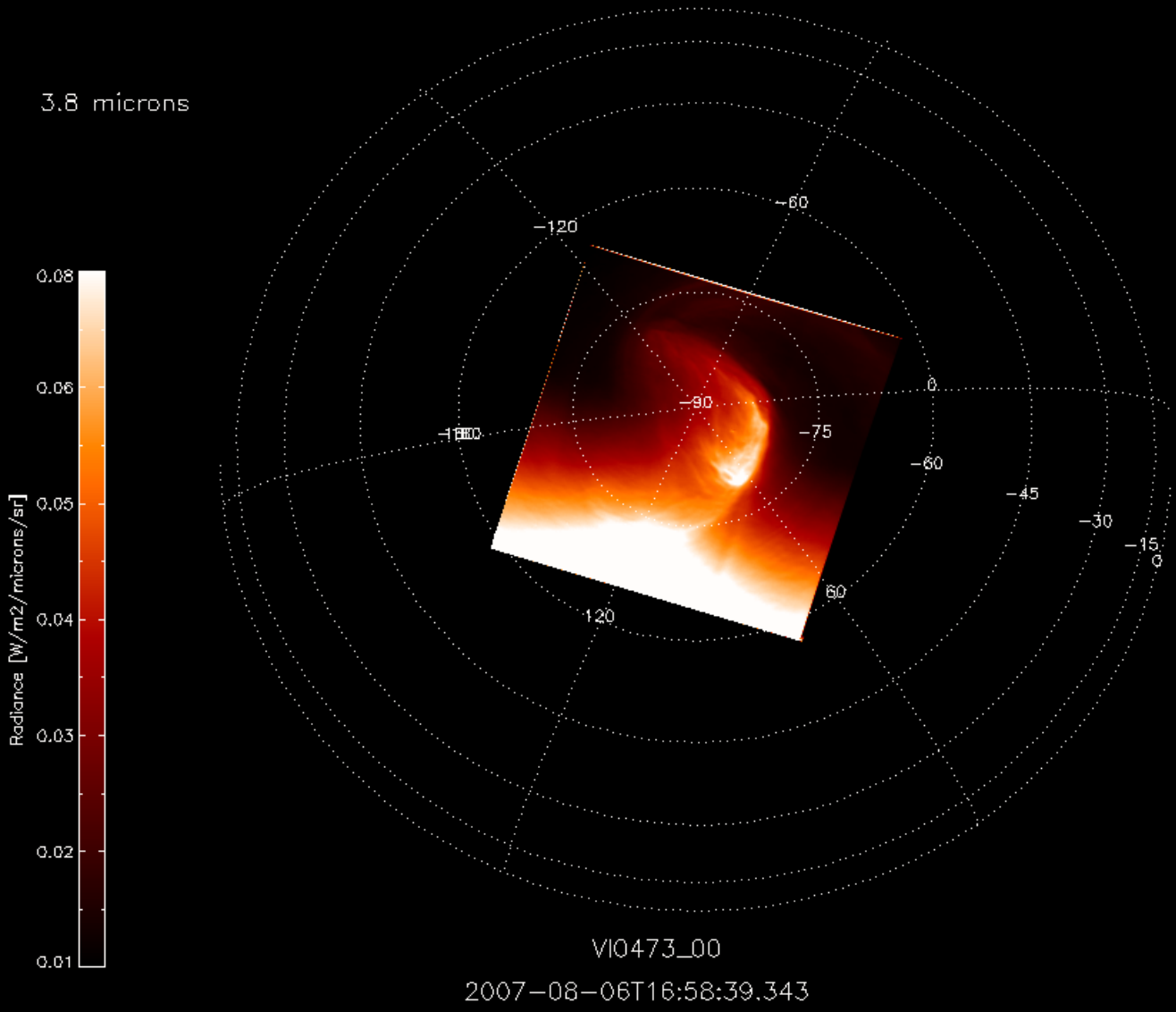
50 km

VIRTIS

Zonal wind field

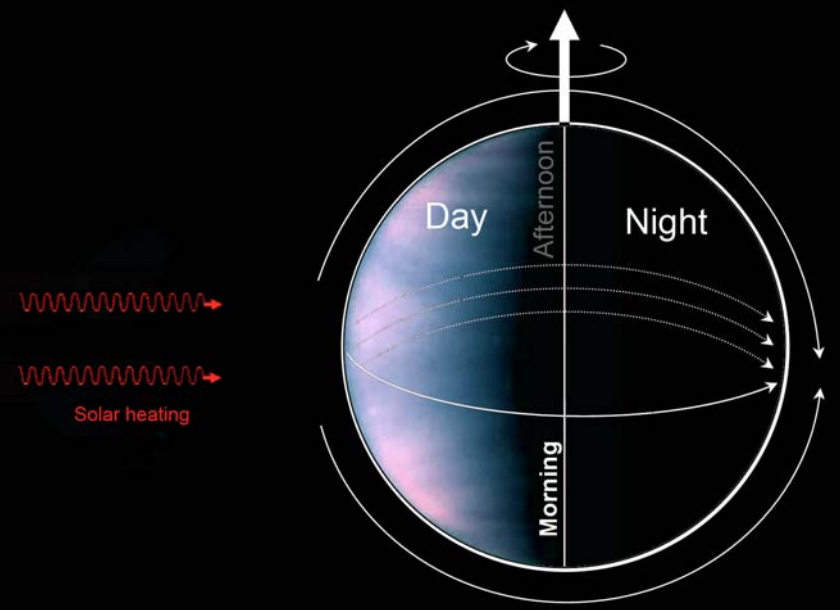


Eye of the polar vortex



Piccioni, Drossart

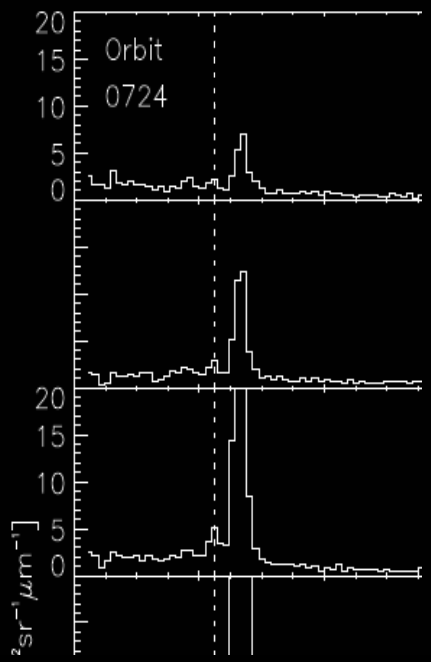
Venus night airglow

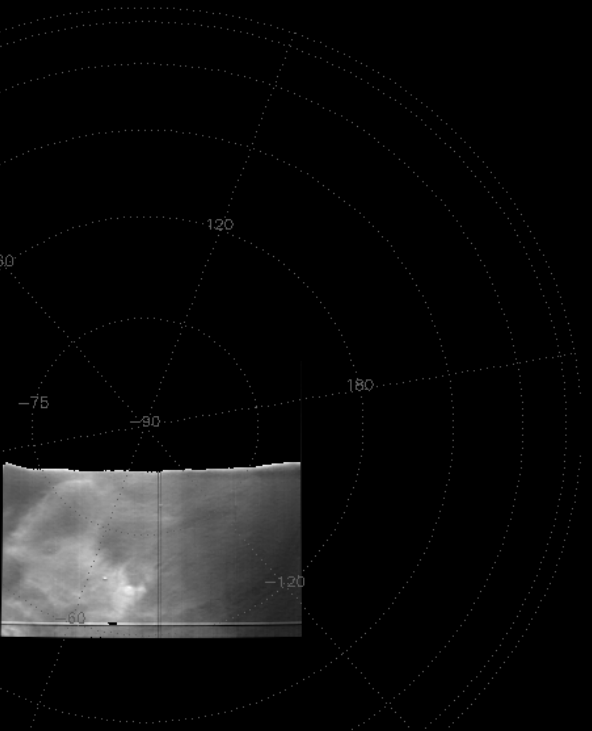


Recombination	$O + N \rightarrow NO^*$
3-body recombination	$O + N + CO_2 \rightarrow NO + CO_2$
Emission	$NO^* \rightarrow NO + h\nu$
Loss	$N + NO \rightarrow N_2 + O$

Recombination	$O + O + CO_2 \rightarrow O_2^* + CO_2 + 5.17\ eV$
De-excitation	$O_2^* \rightarrow O_2 + h\nu$
Quenching	$O_2^* + M \rightarrow O_2 + M$

O_2 airglow at 1.27 µm (VIRTIS)



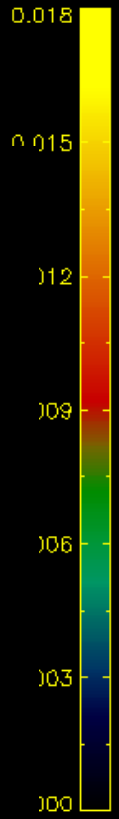


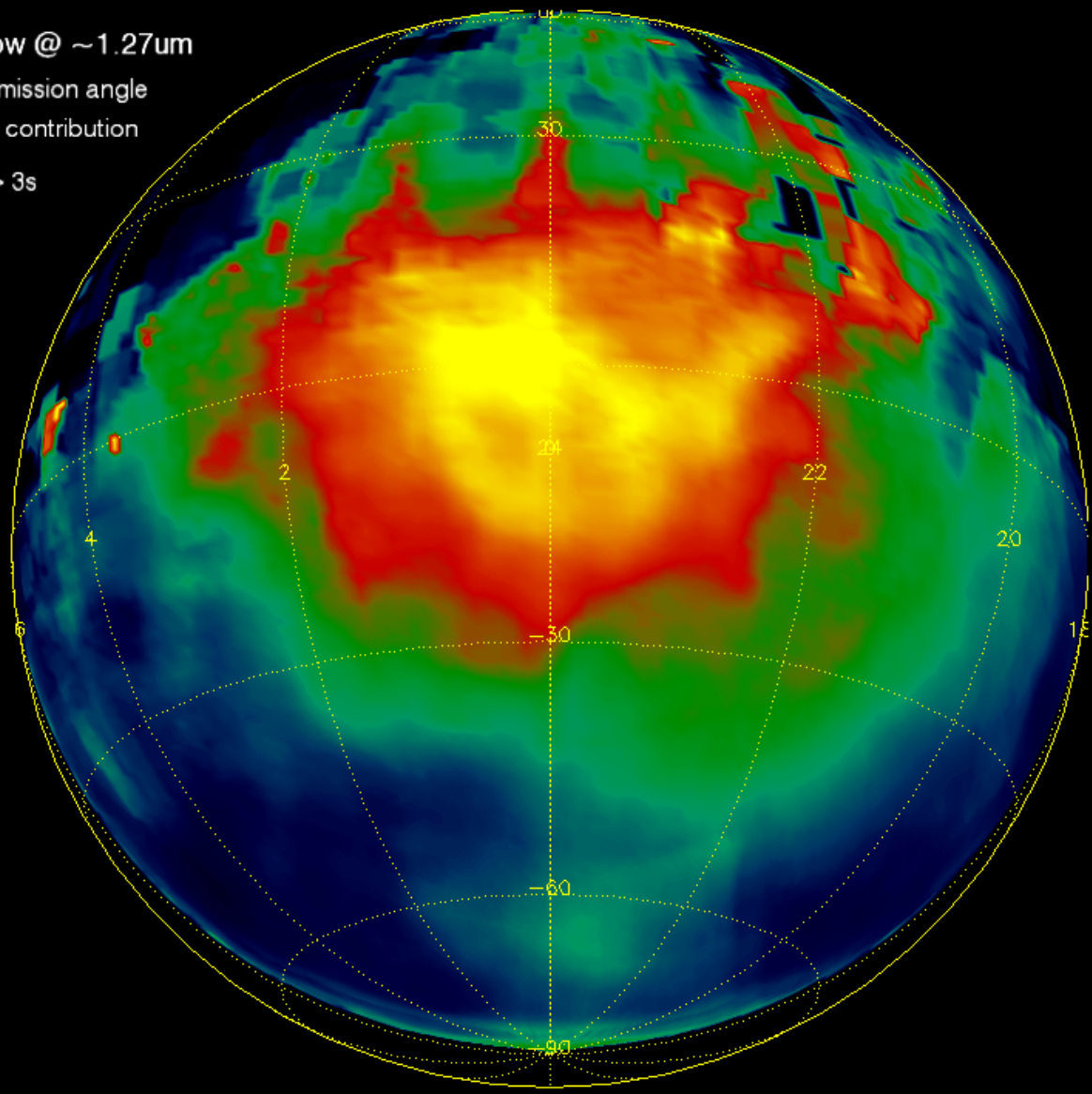
Oxygen Airlgow @ ~1.27um

Corrected for emission angle
and for thermal contribution

Exposure time > 3s

Orbits 100-599

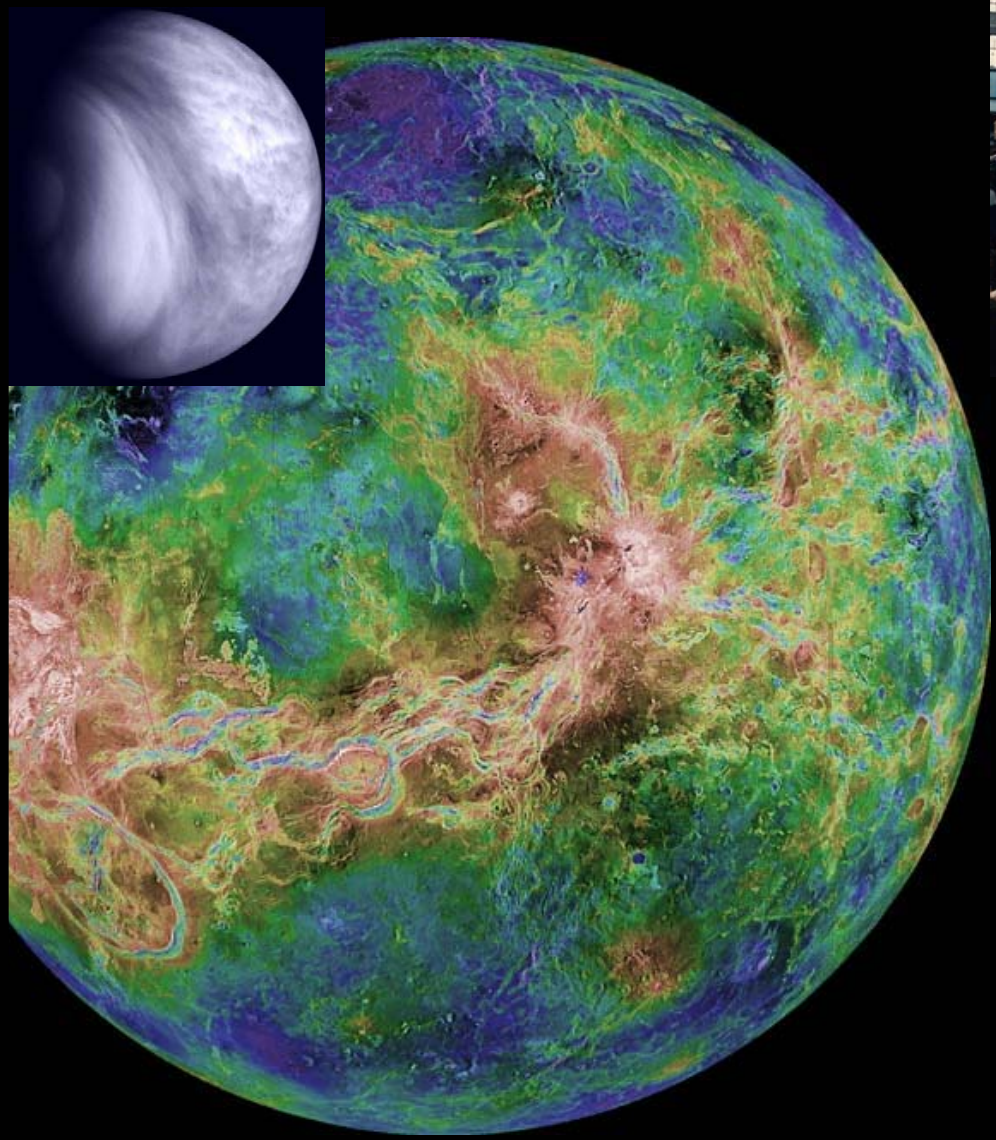


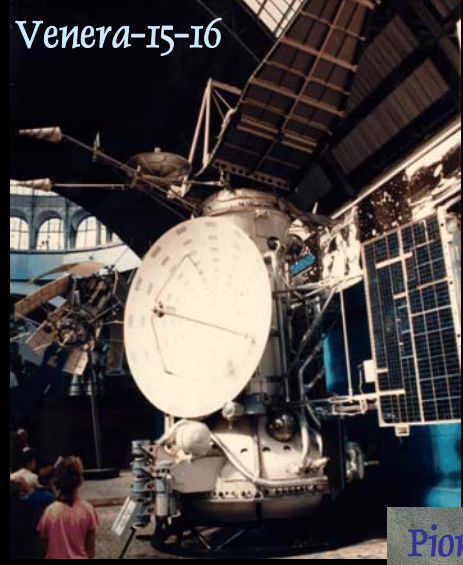


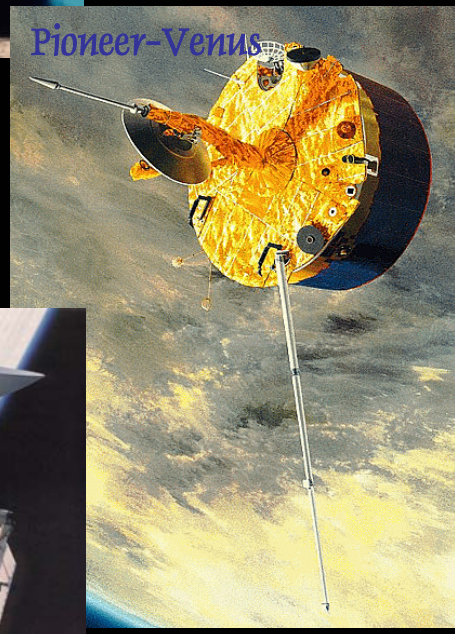
Venus South Pole - Latitude vs Local Time

Gerard, Drossart, Piccioni

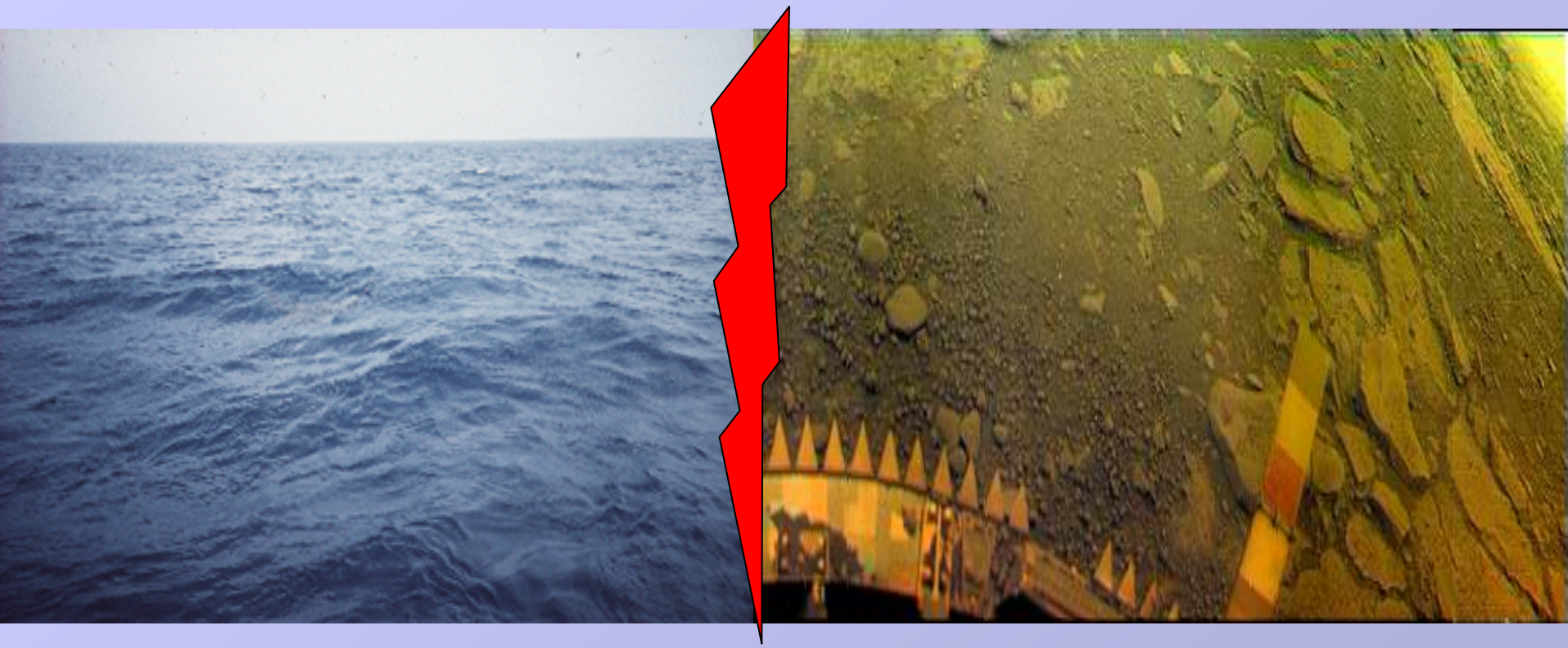
Venus unveiled…





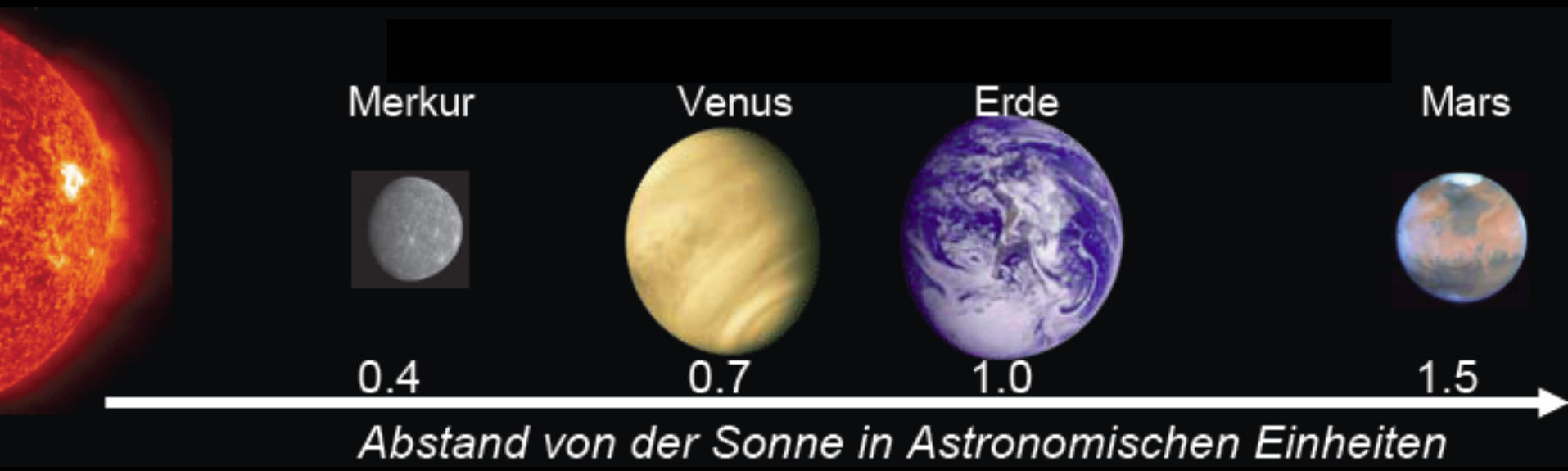


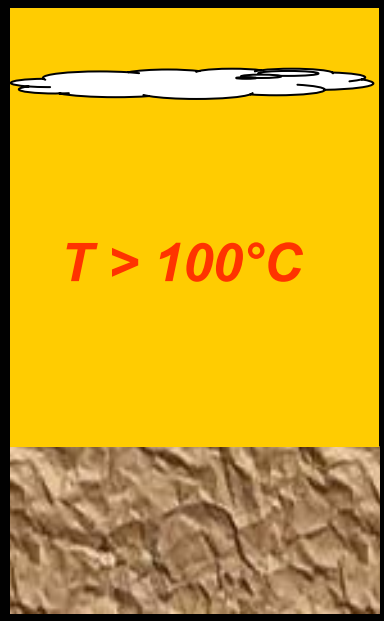
Greenhouse effect and water loss (1)

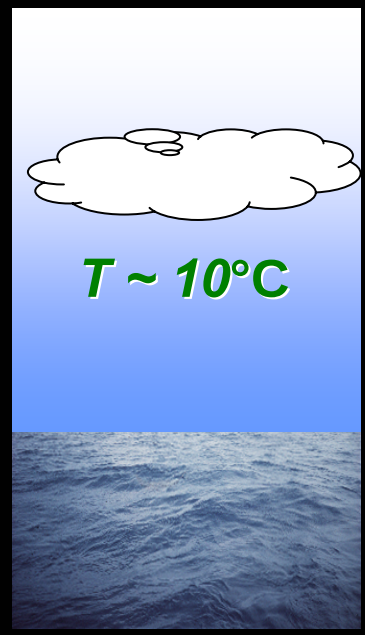


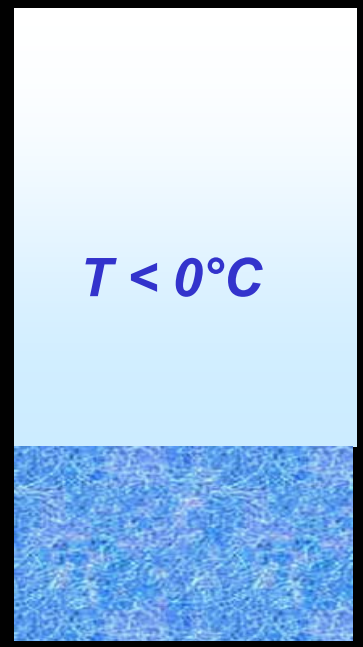
- Similar volatile inventories at origin
- Present water amount: $H_2O_{VENUS} \sim 10^{-5}\ H_2O_{EARTH}$
- Deuterium enrichment: $(D/H)_{VENUS} \sim 150\ (D/H)_{EARTH}$

“Earth” at different distances from the Sun

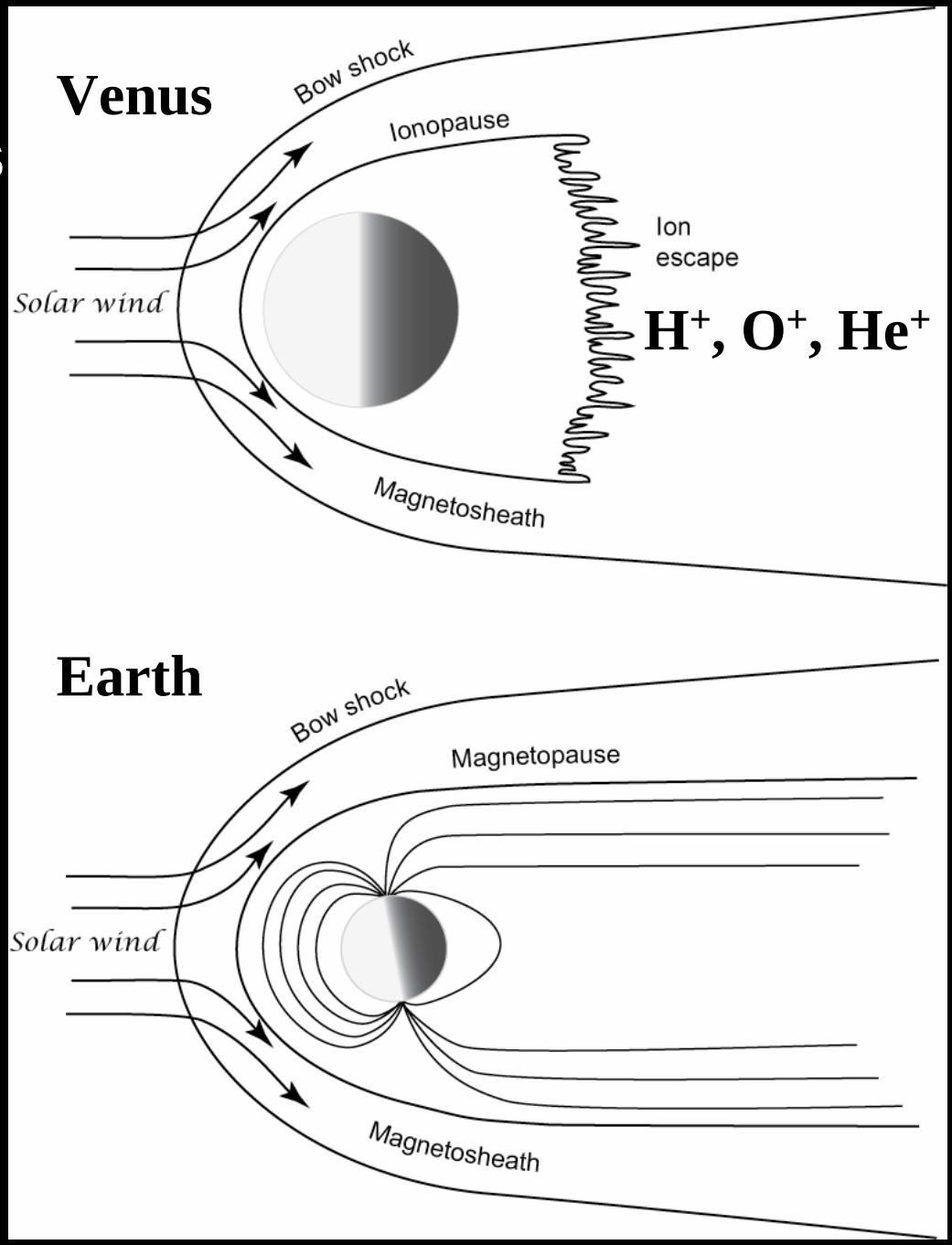






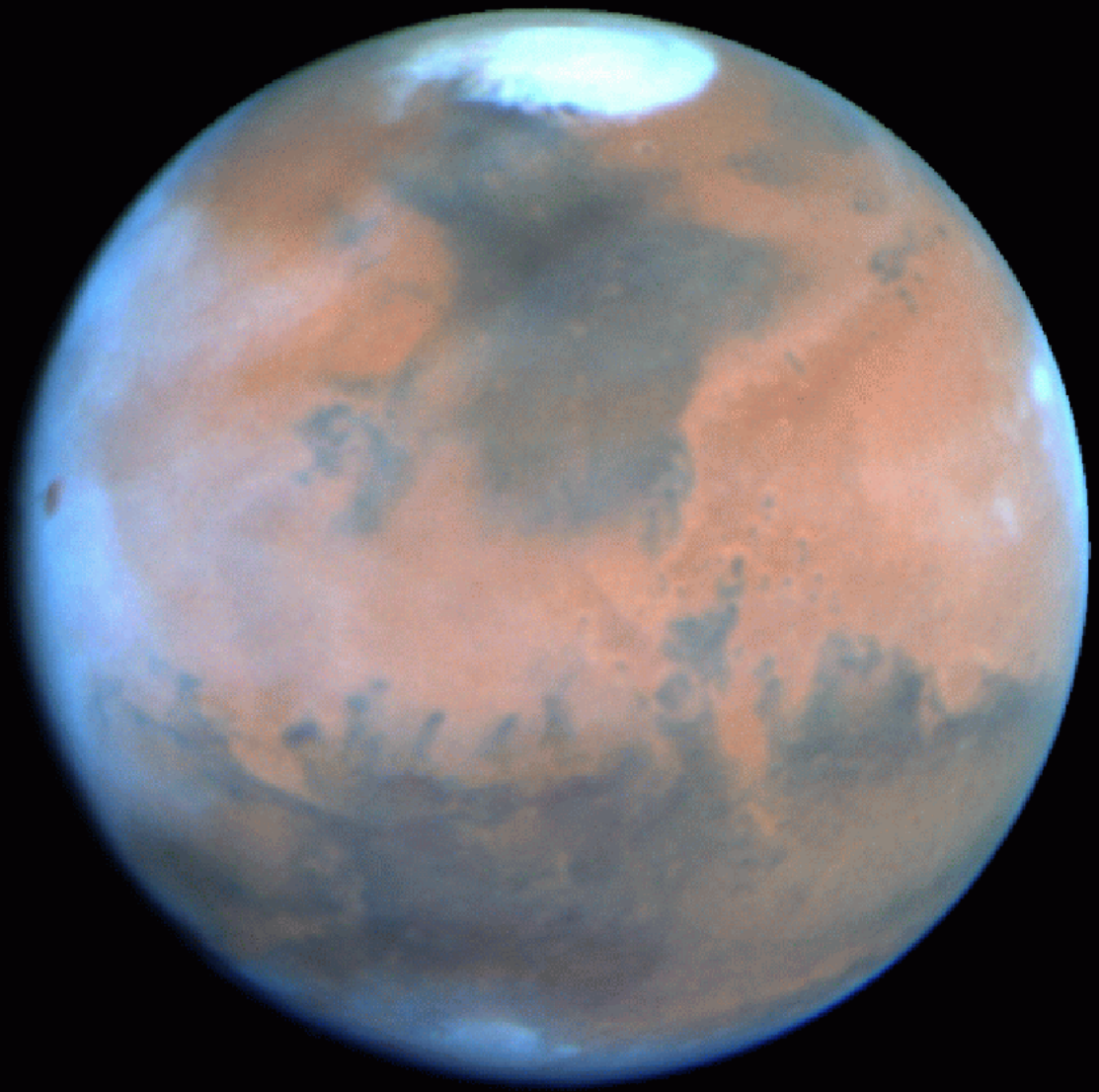


Plasma environment and escape processes



Mars

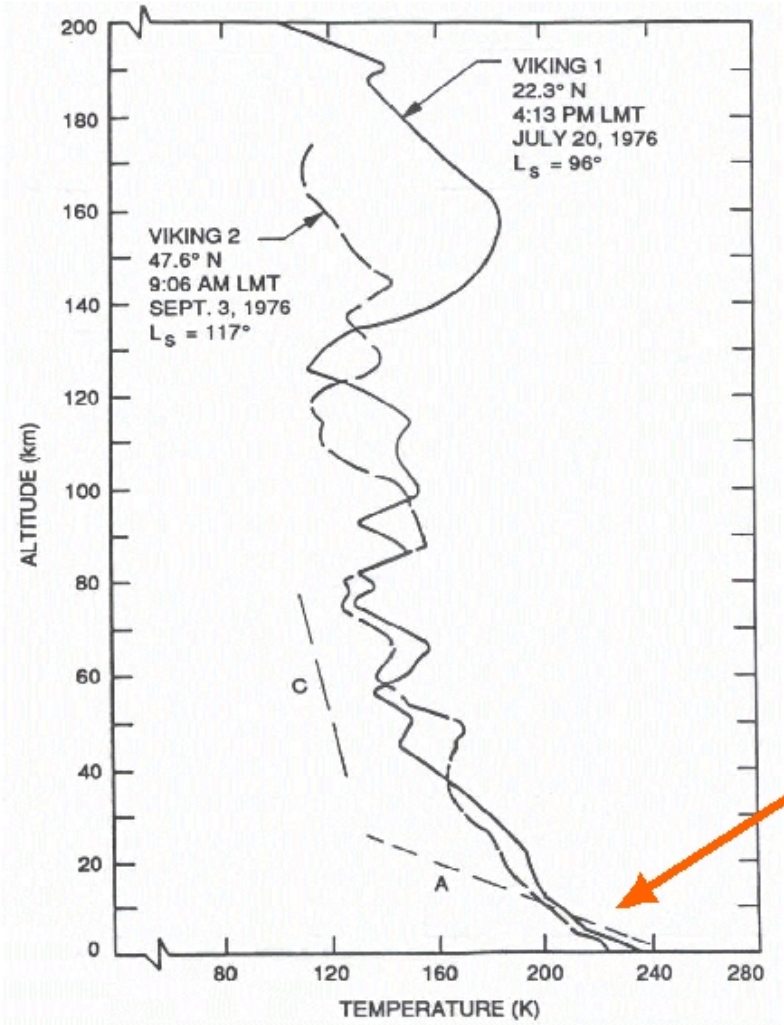
Basic facts about Mars



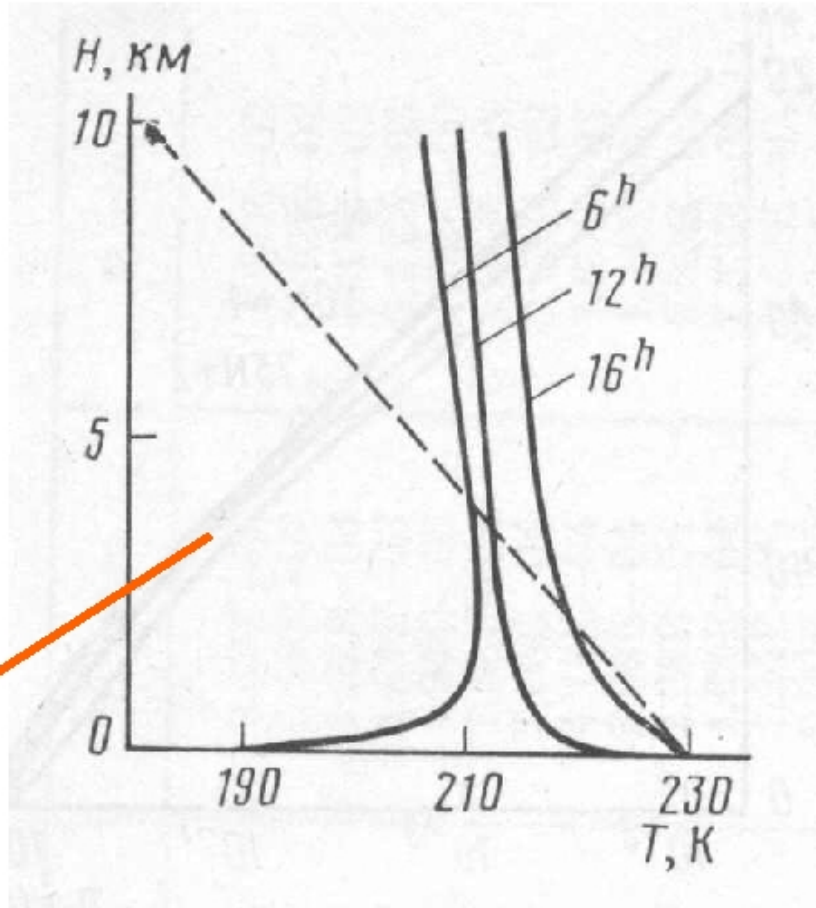
- Orbital radius - 1.52 a.u.
- Eccentricity ~0.09
- Obliquity 25 deg
- Sidereal day 24h 37 min
- Orbital period 687 days
- R ~ 3400 km
- Surface P ~ 6 mbar
- Surface T=120-280K
- Atmospheric composition
  - 95.3% CO_2
  - 2.7% N_2
  - 0.13% O_2
  - 100-1000 ppm H_2O

Atmospheric temperatures (1)

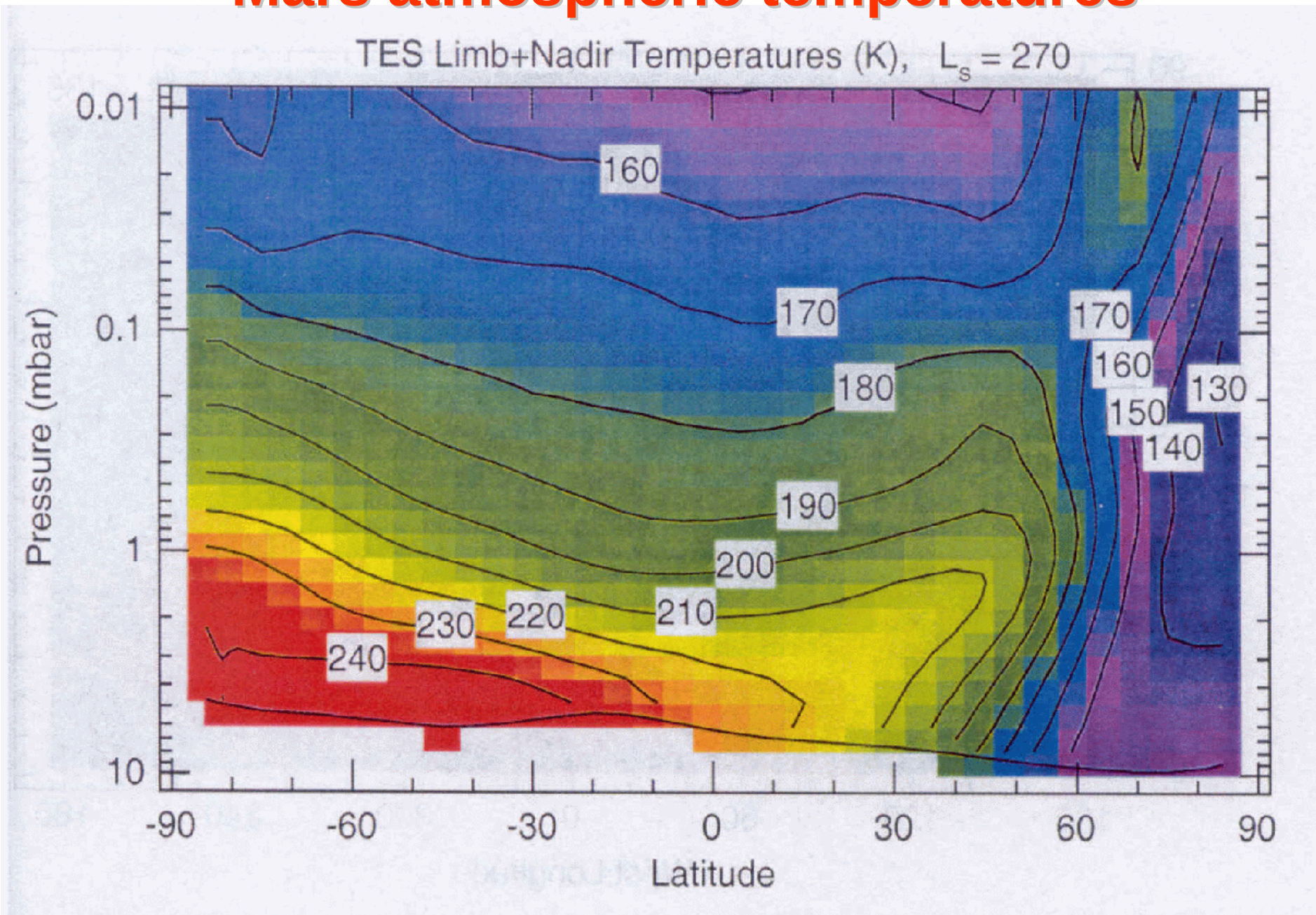
Viking landers



Boundary layer



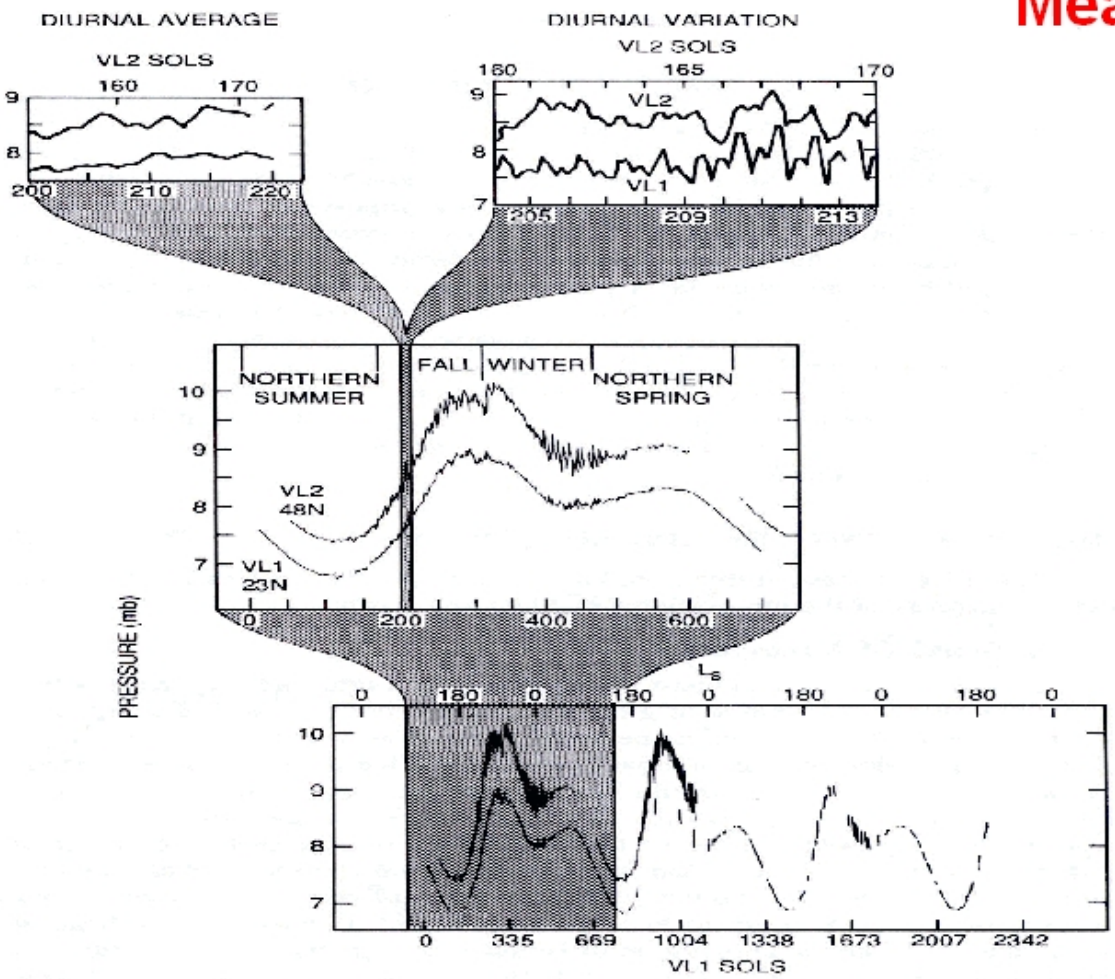
Mars atmospheric temperatures



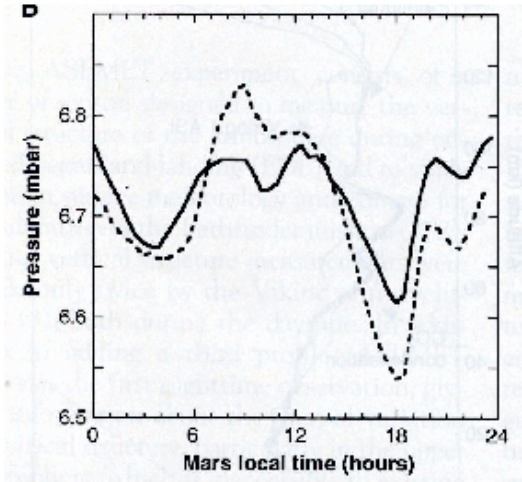
Surface pressure variations

Viking landers

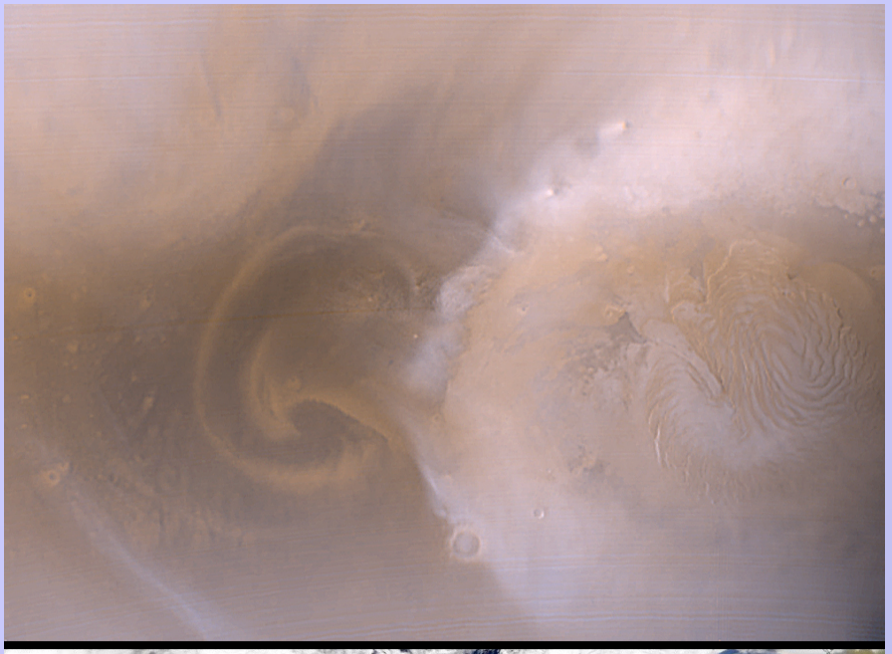
Mean pressure ~6.1 mbar

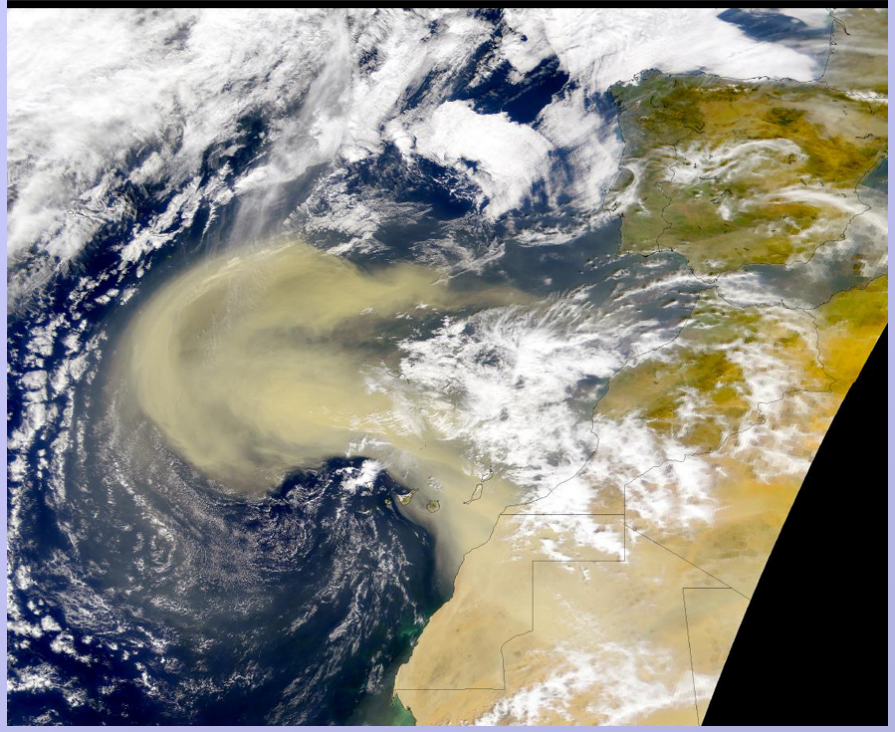


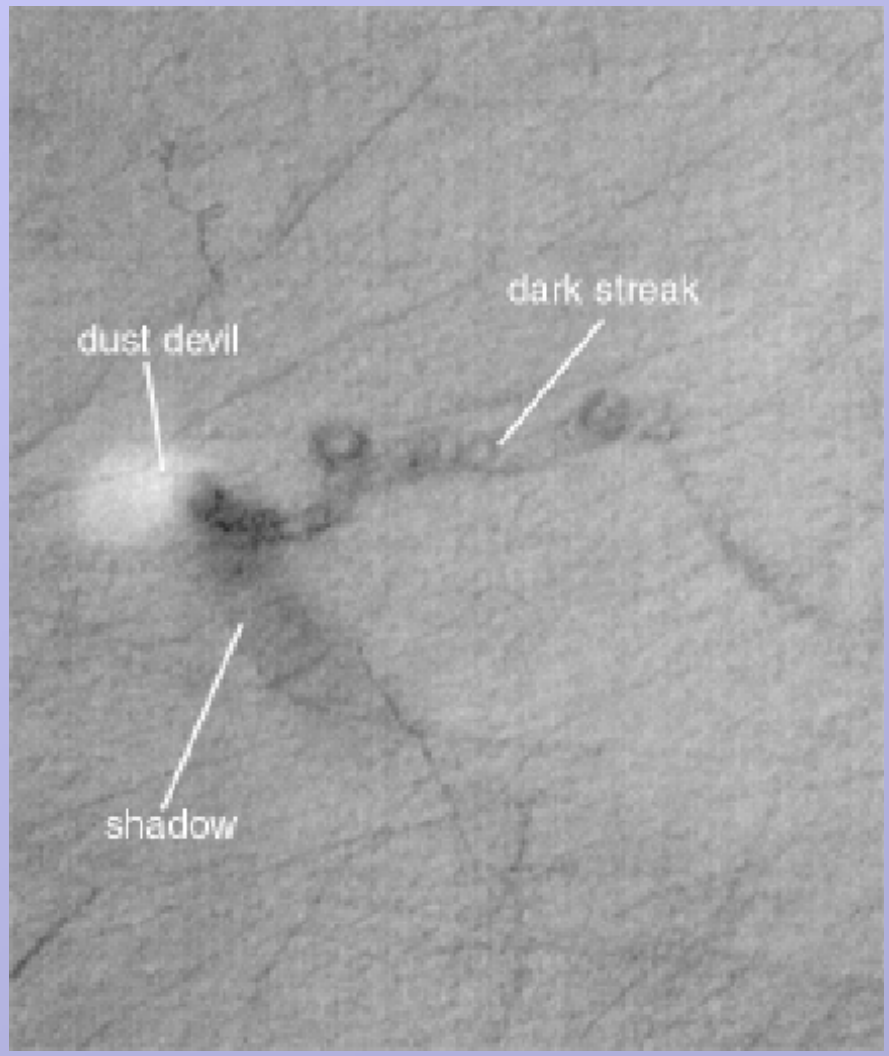
Pathfinder



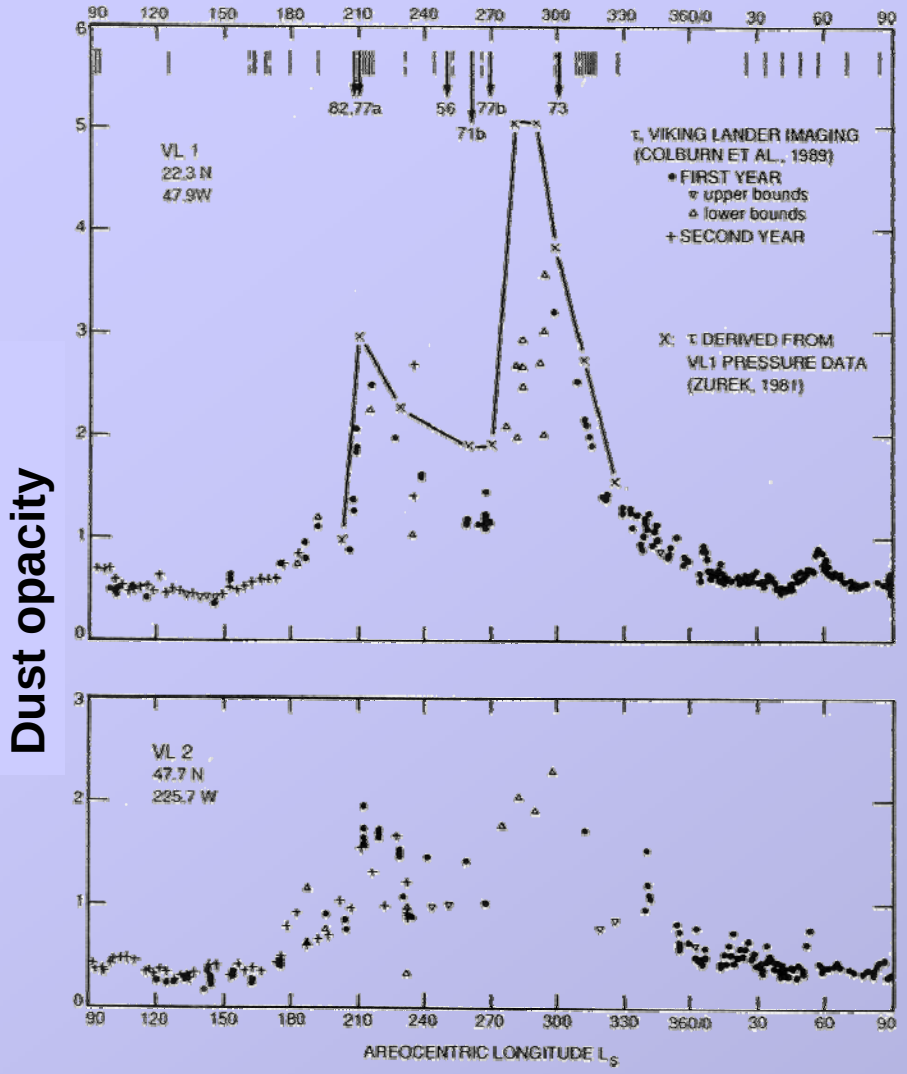
Dust storms and dust devils



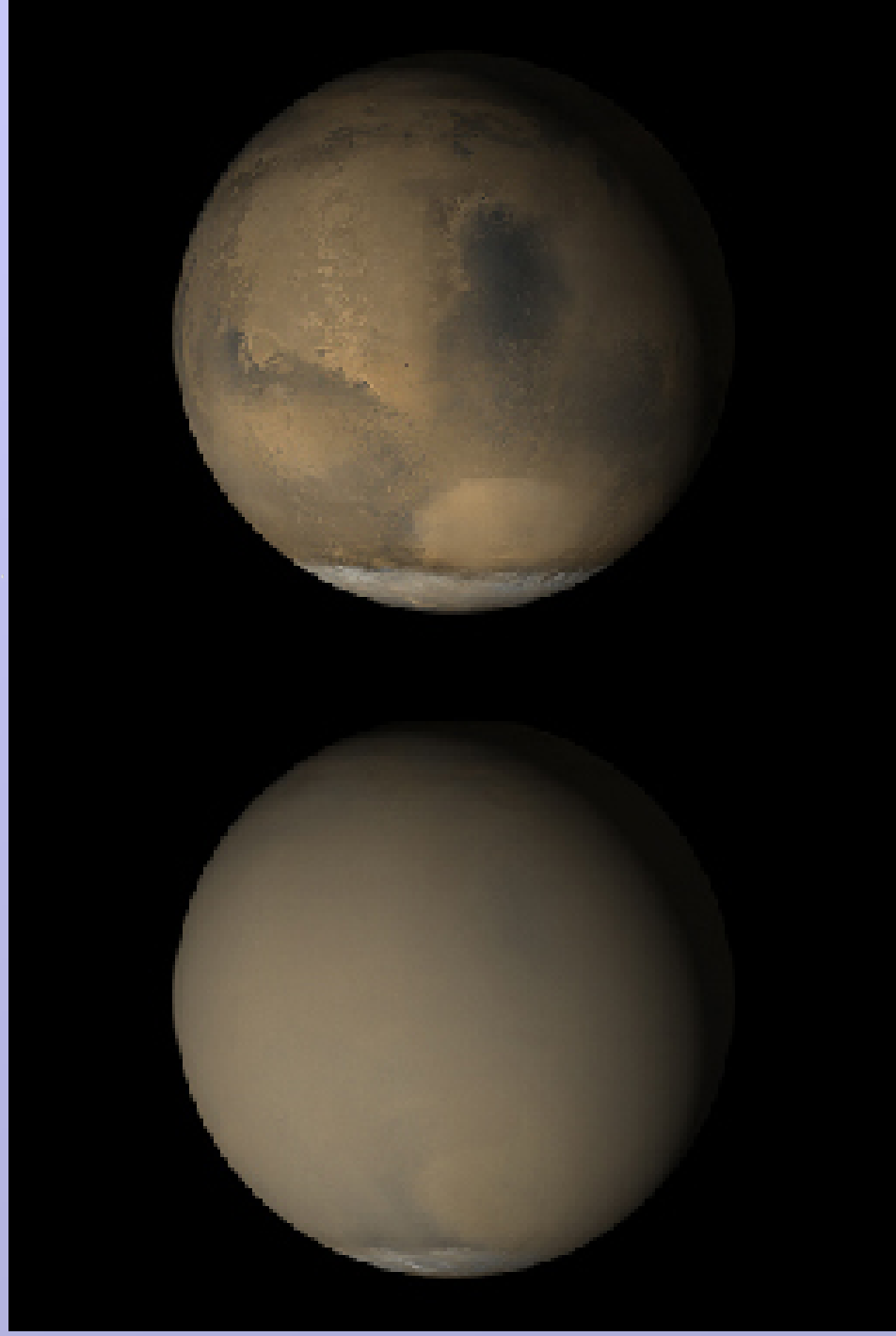




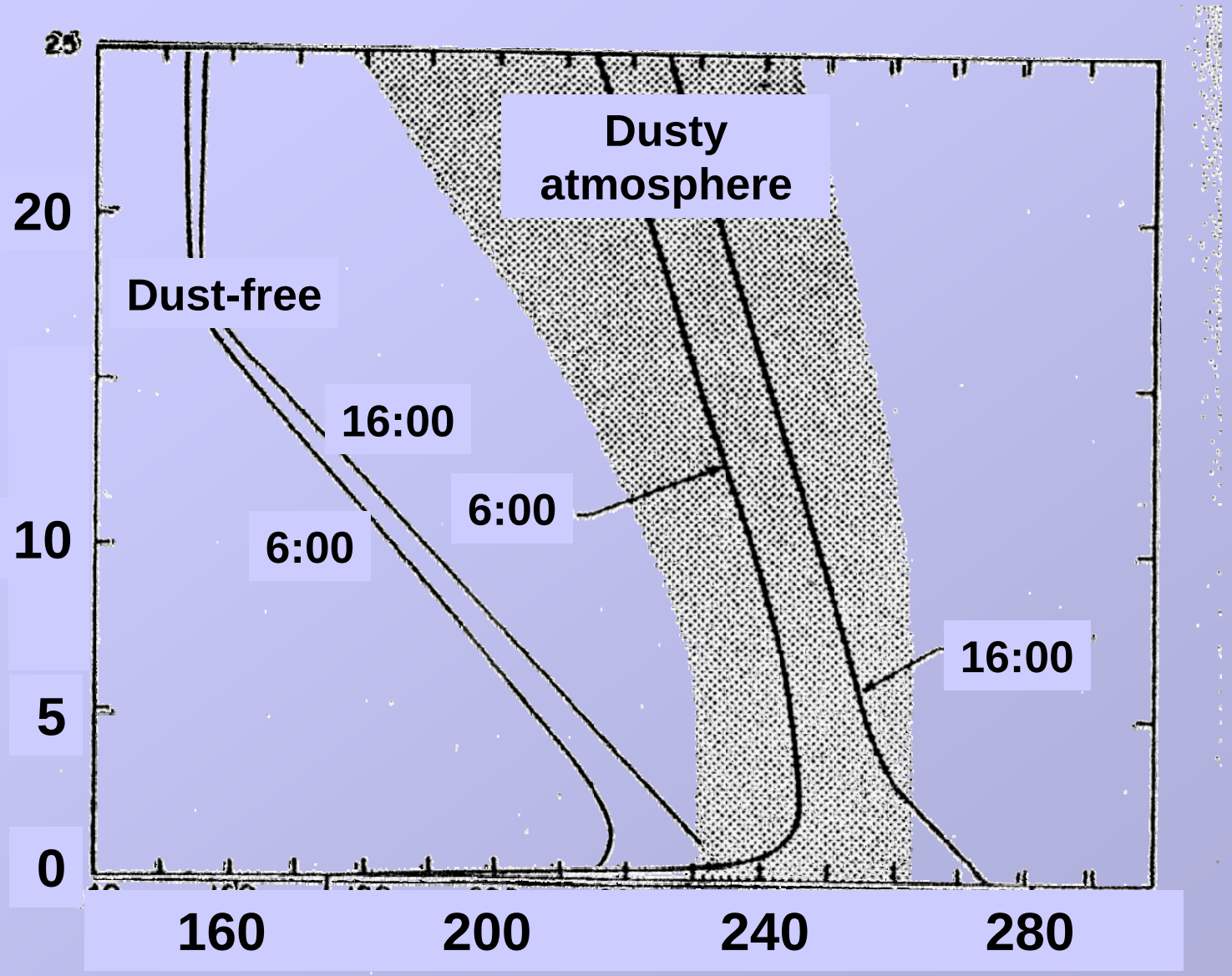
Global dust storms



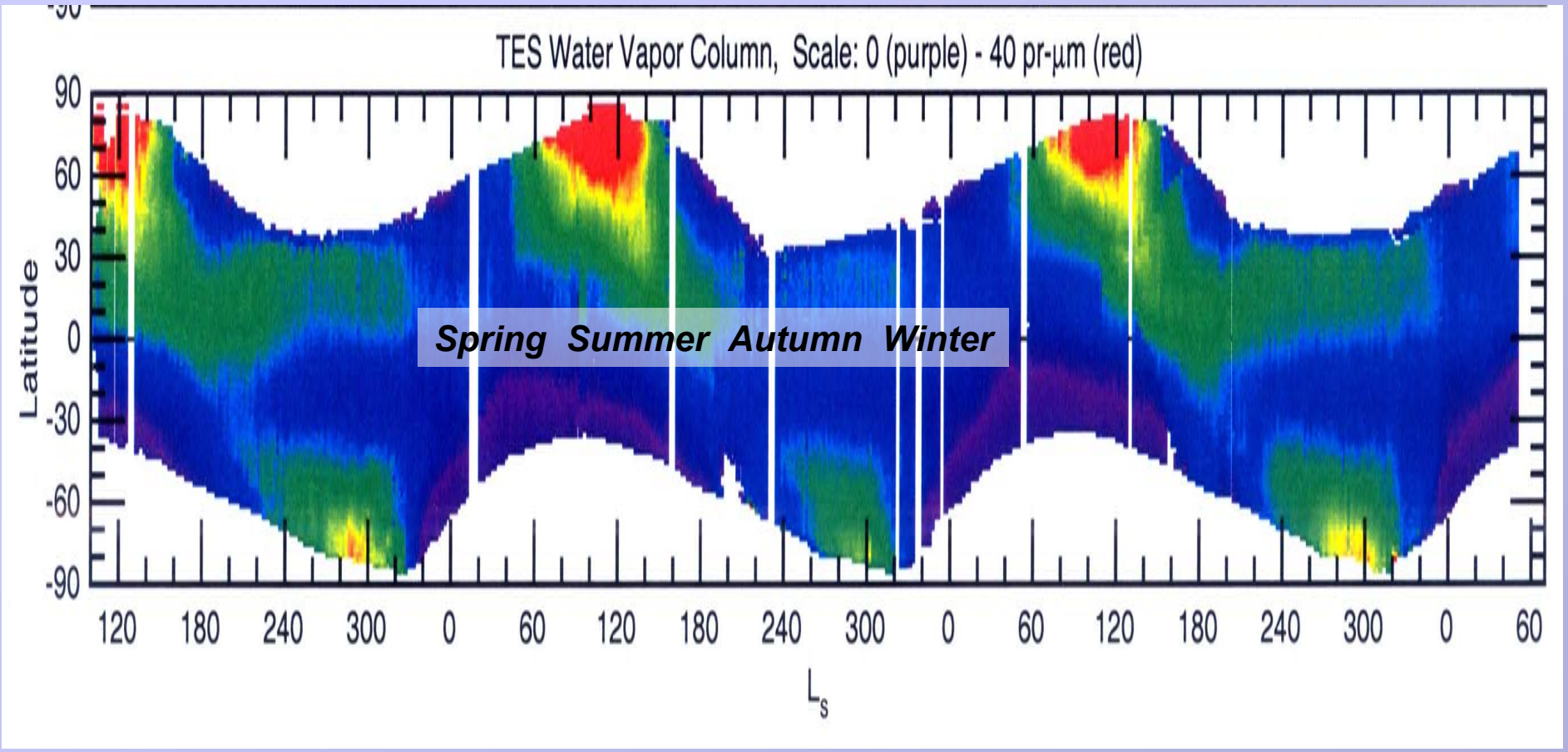
N summer **N winter**



Dust and atmospheric temperature

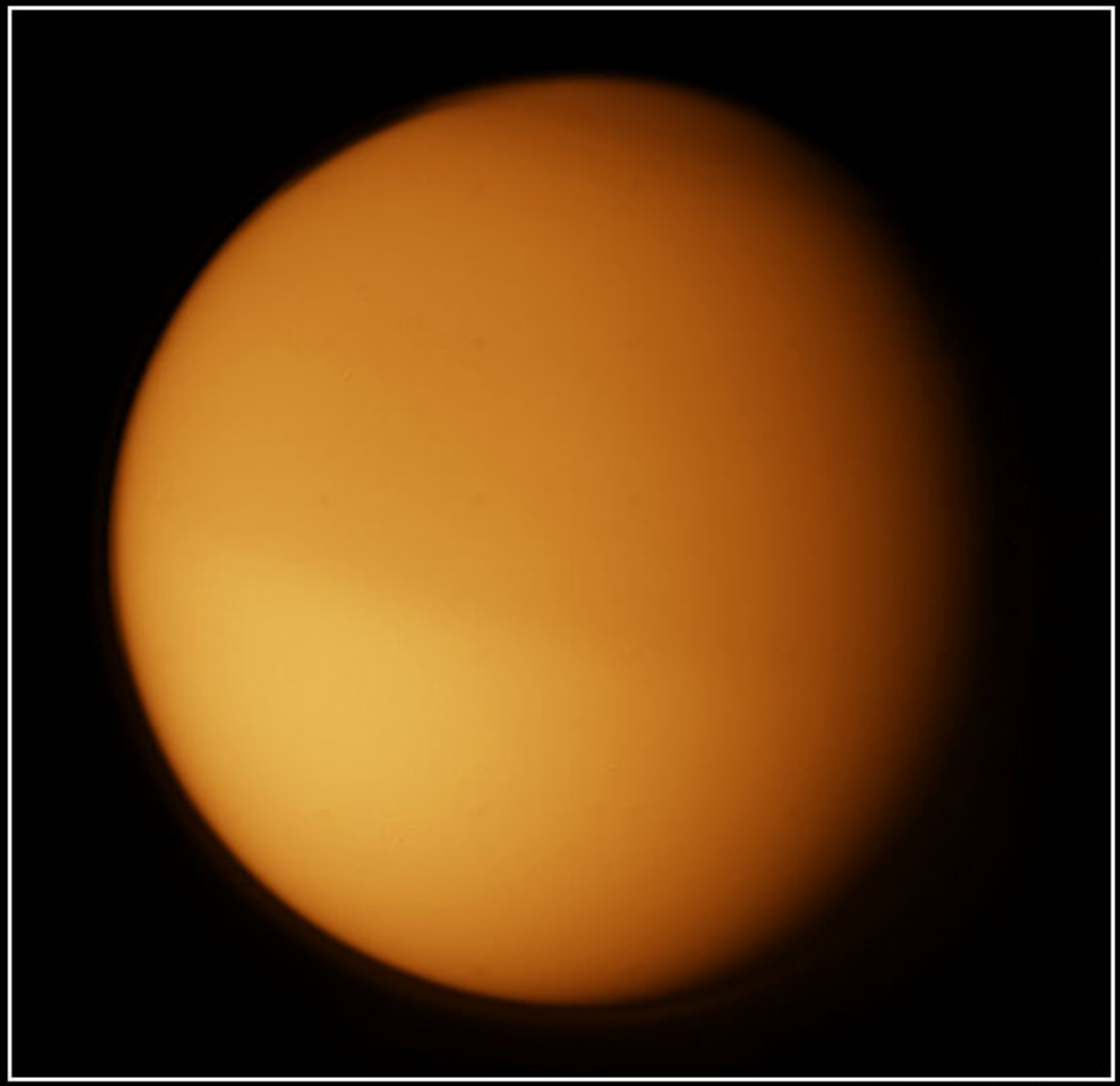


Seasonal water cycle on Mars



- Seasonal variability 100 – 1000 ppm
- Advective transport
- Non-atmospheric reservoirs (polar caps, regolith)

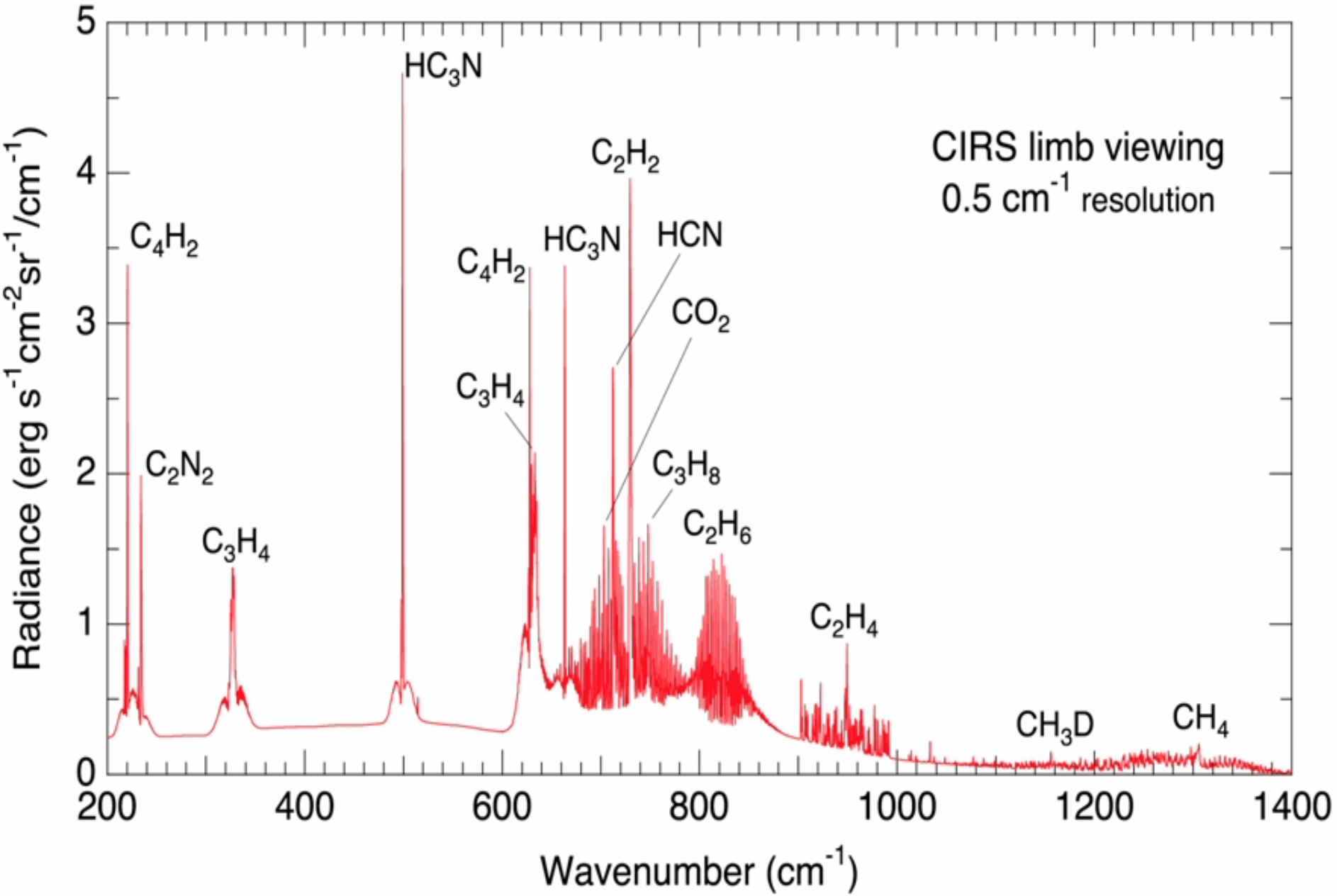
Titan



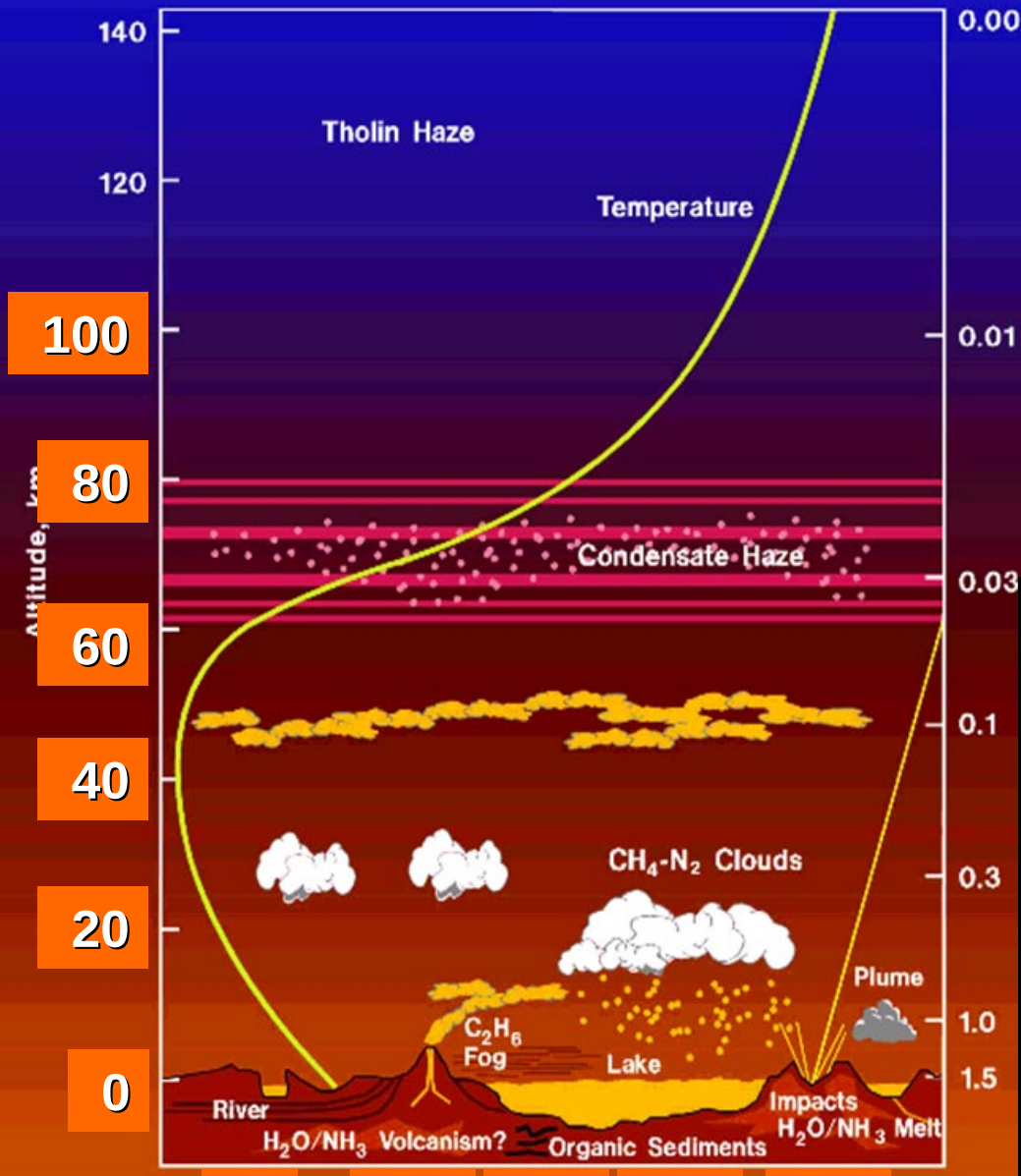
Titan

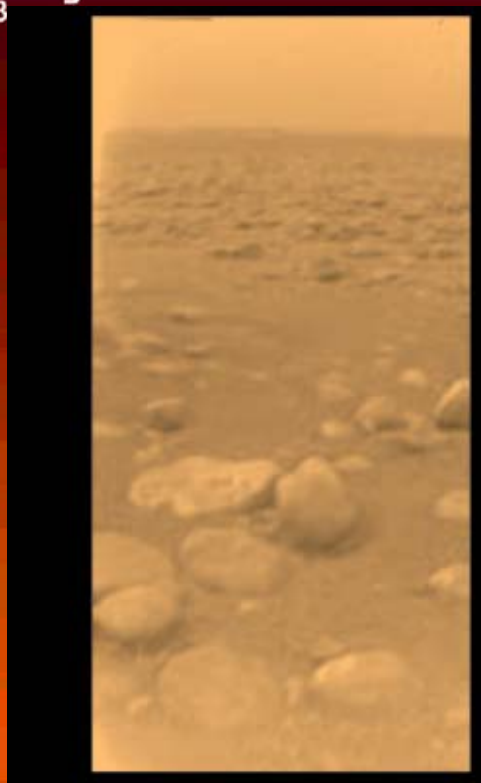
N_2	90-97%
CH_4	4%
C_2H_2	2 ppm
C_2H_6	10 ppm
CO_2	10 ppb
CO	10 ppm
H_2O	0.4 ppb

Thermal IR spectrum



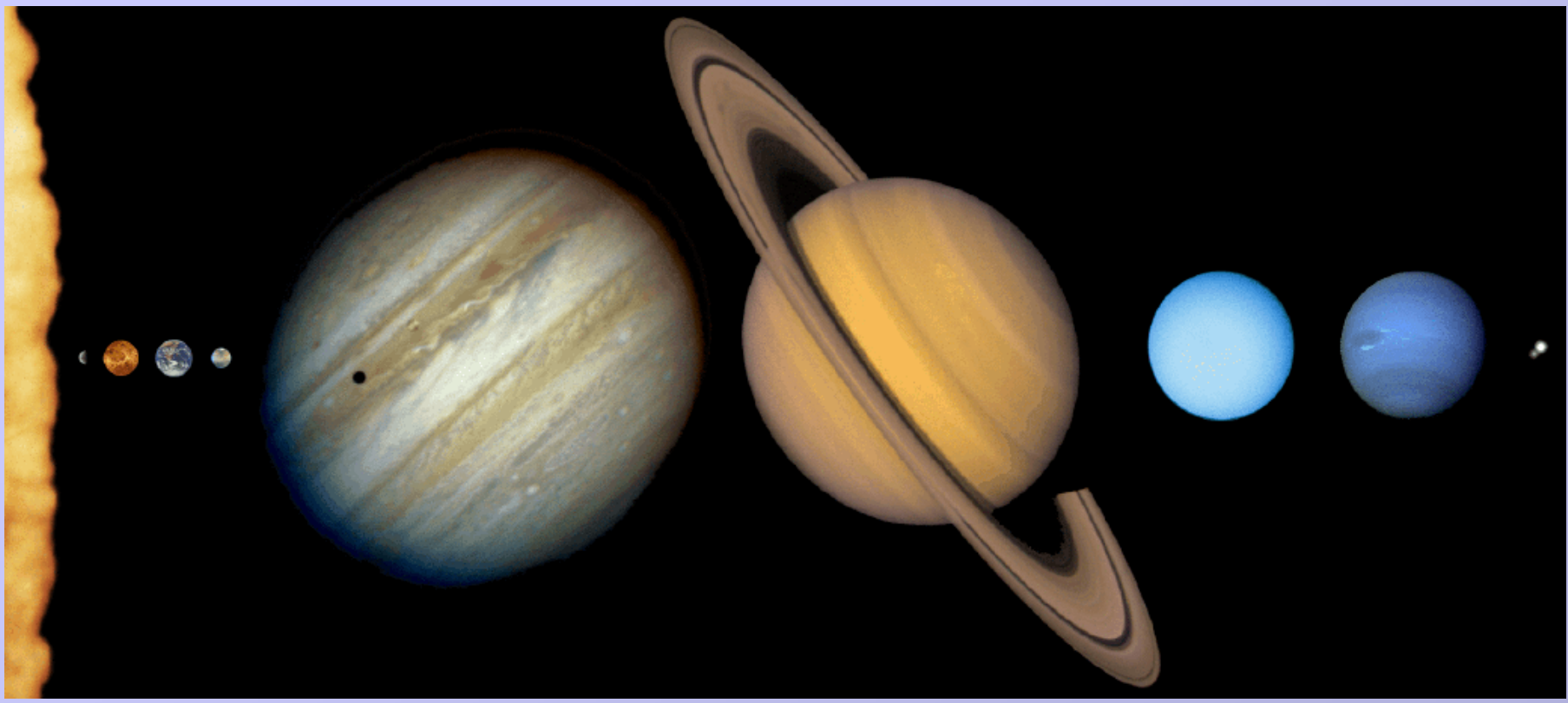
Titan


140
120
100
80
60
40
20
0
Altitude, km
0.003
0.01
0.03
0.1
0.3
1.0
1.5
ure, bar
Tholin Haze
Temperature
Condensate Haze
CH_4-N_2 Clouds
Plume
C_2H_6
Fog
Lake
River
H_2O/NH_3 Volcanism?
Organic Sediments
Impacts
H_2O/NH_3 Melt
80
100
120
140
160
180



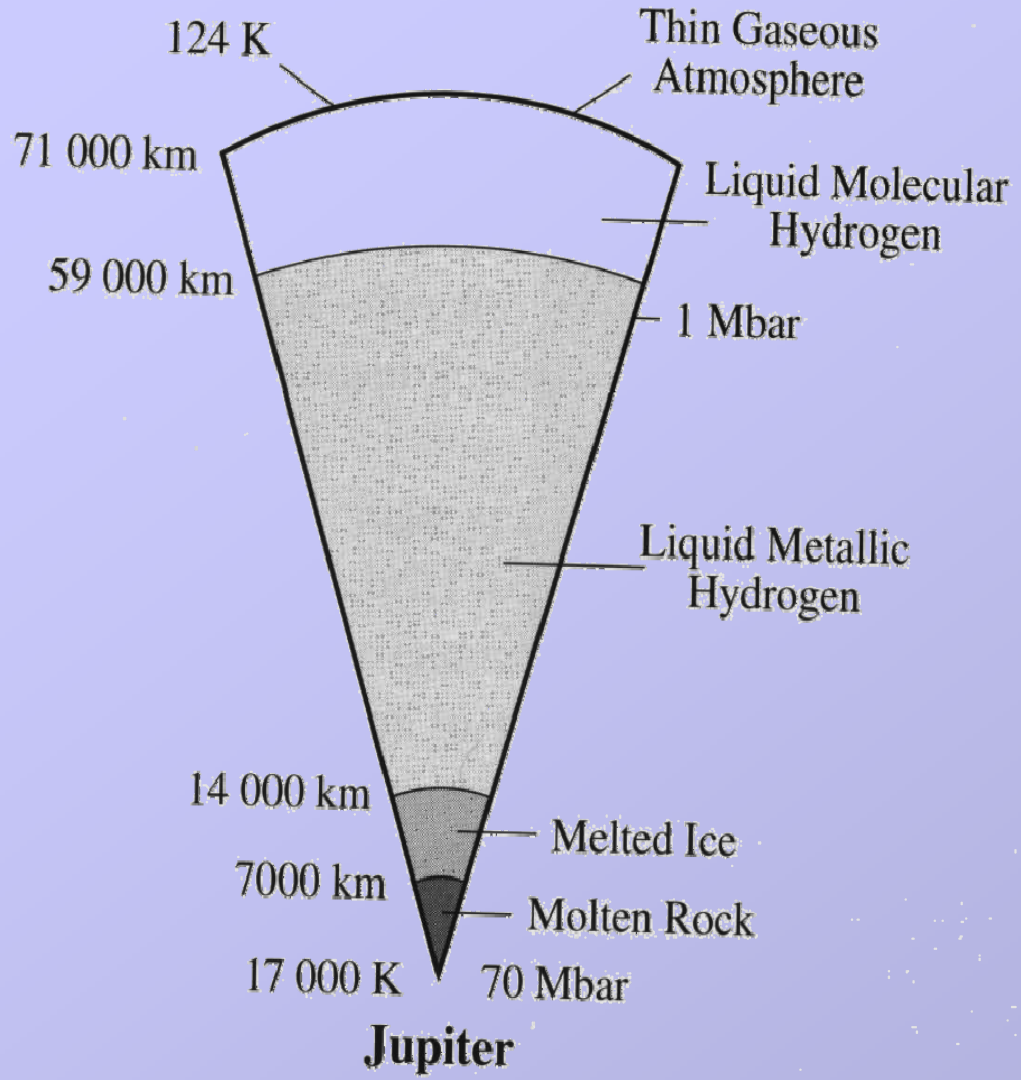
Giant planets

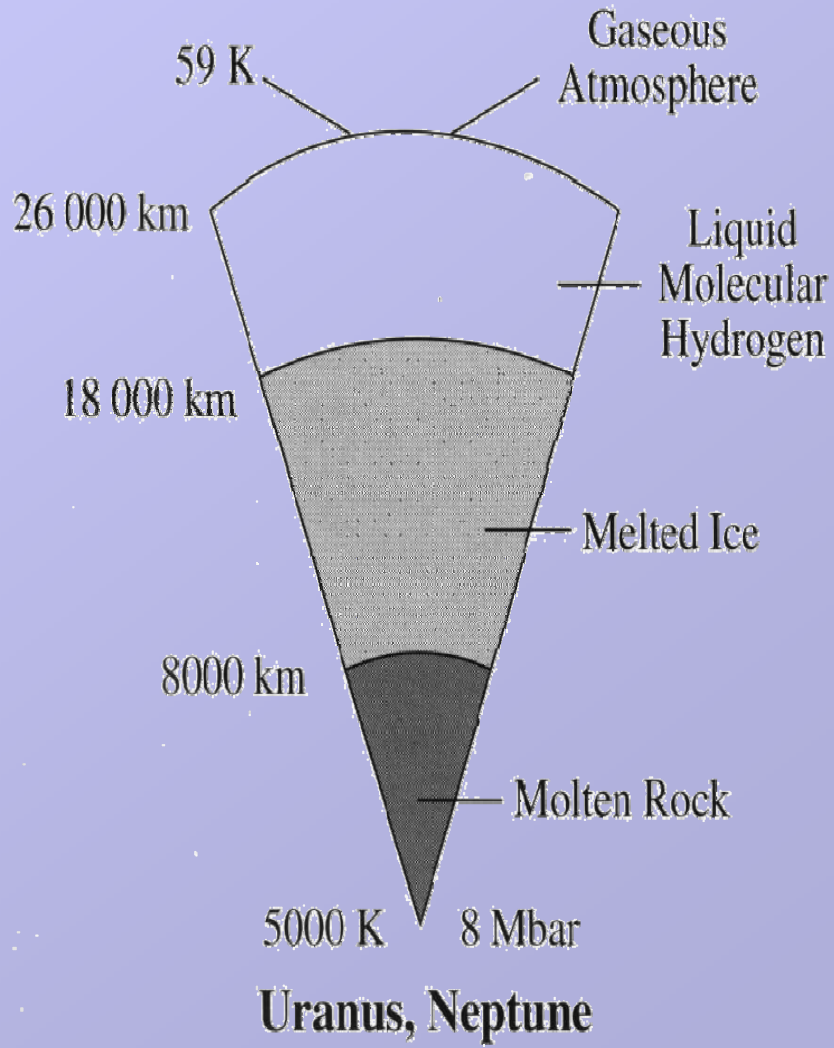
Basic Features



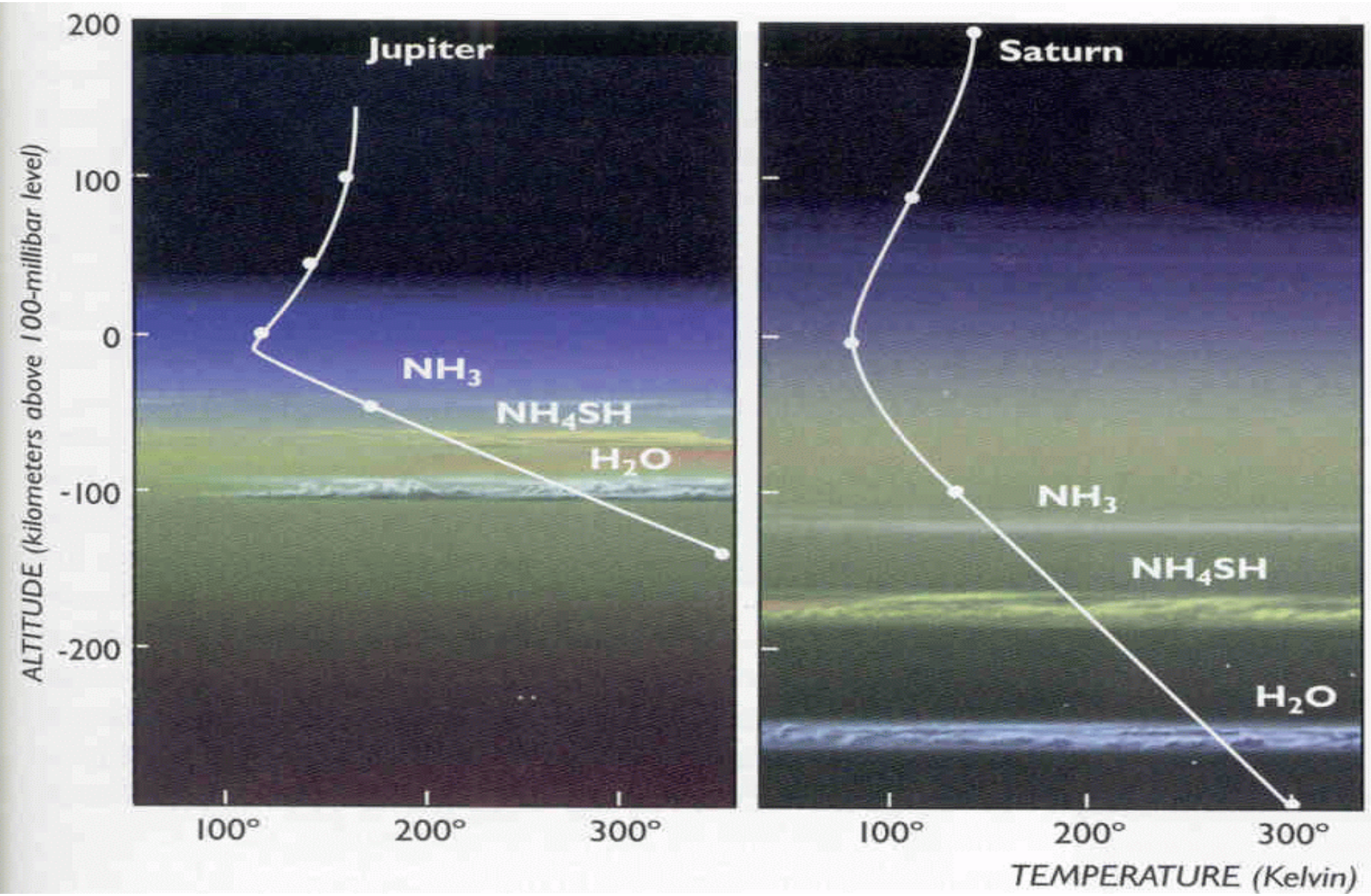
- Distance to the Sun > 5 a.u.
- R = 10-4 R_{Earth}
- Composition: H_2, He, ices H_2O, NH_3, CO_2, H_2S, Ne, Ar, Kr, Xe
- Mean density ~1.3-1.6 g/cm^3
- Rotation periods ~10 -17 hours, non spherical shape
- Effective temperature 170 – 60 K

Inner structure of the Giants

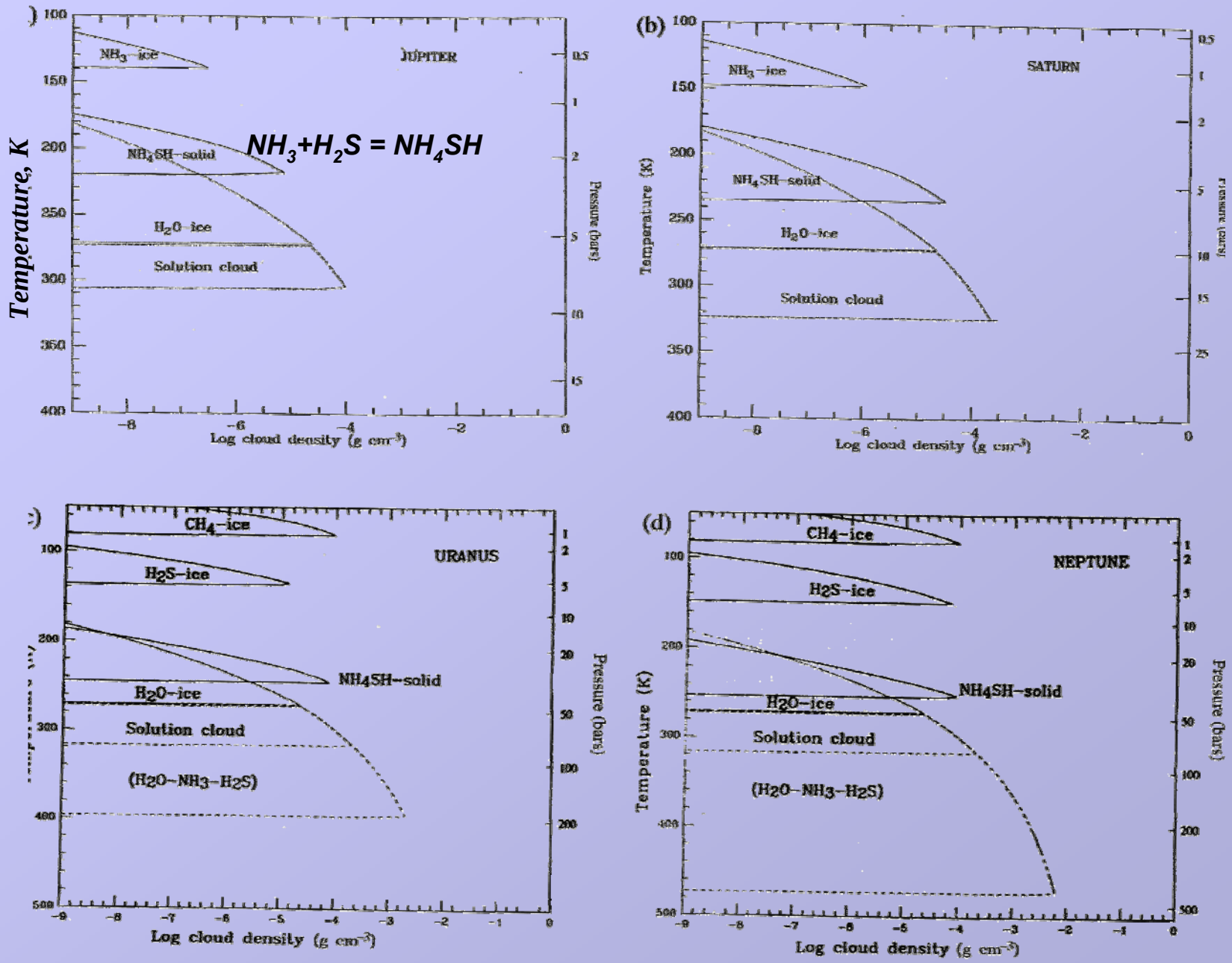




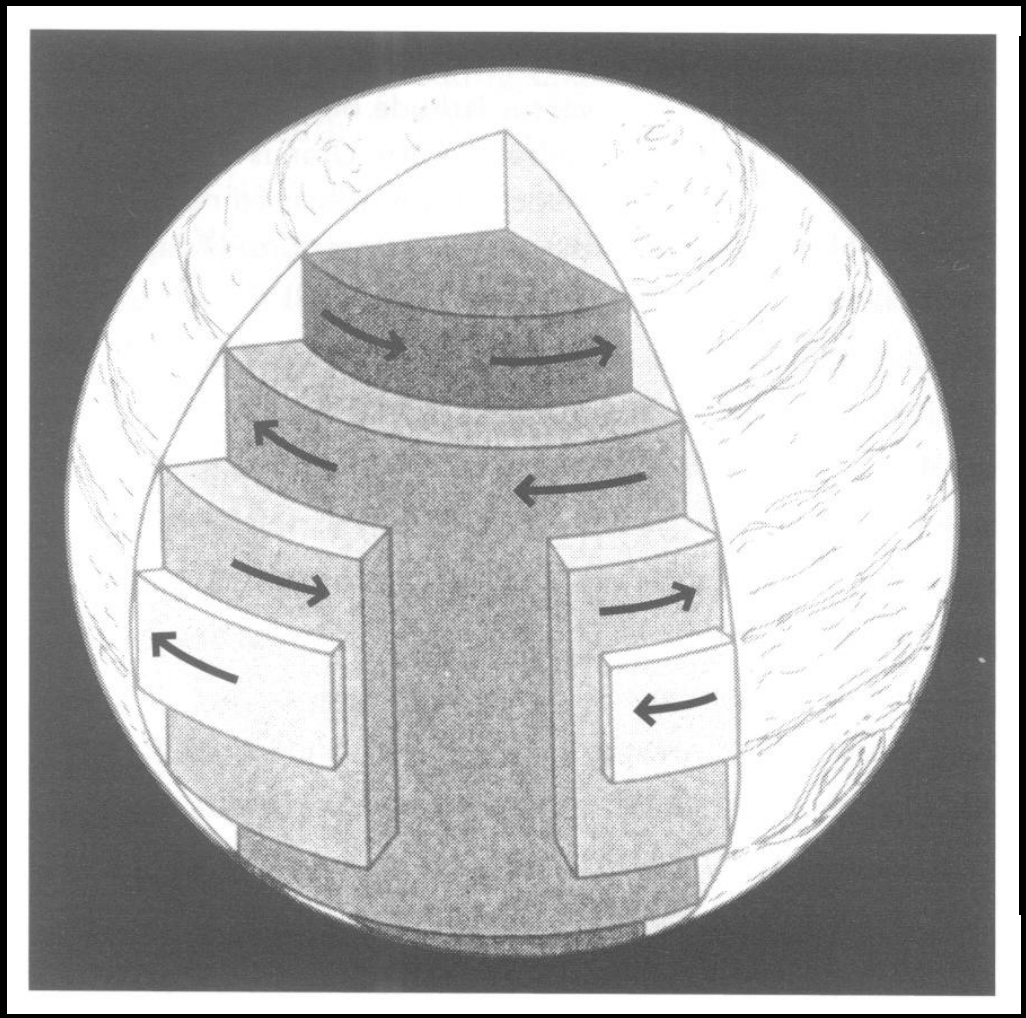
Atmospheric structure

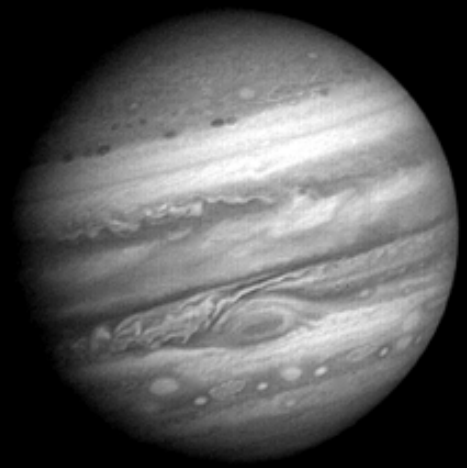


Clouds on the Giants

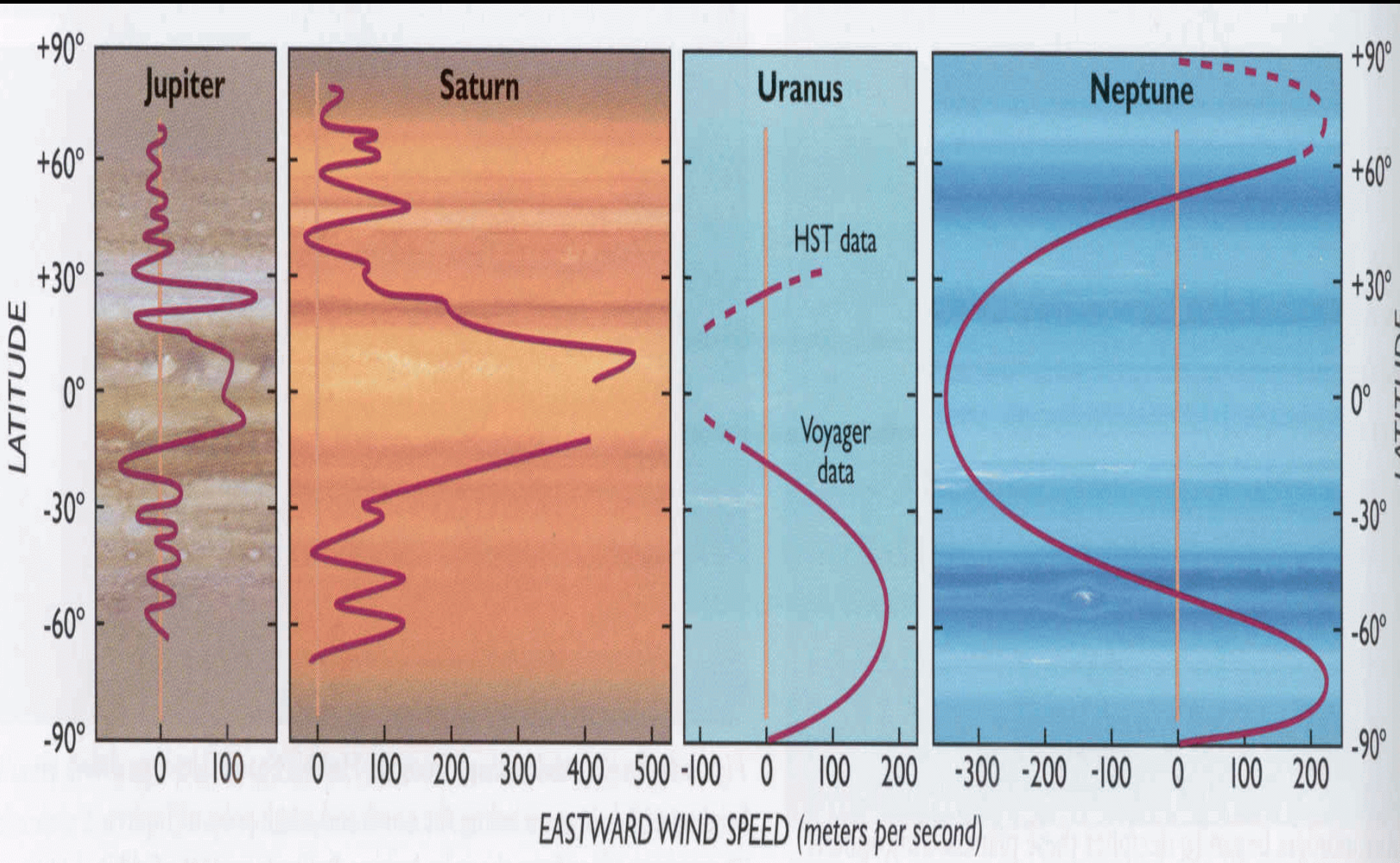


Jupiter band structure

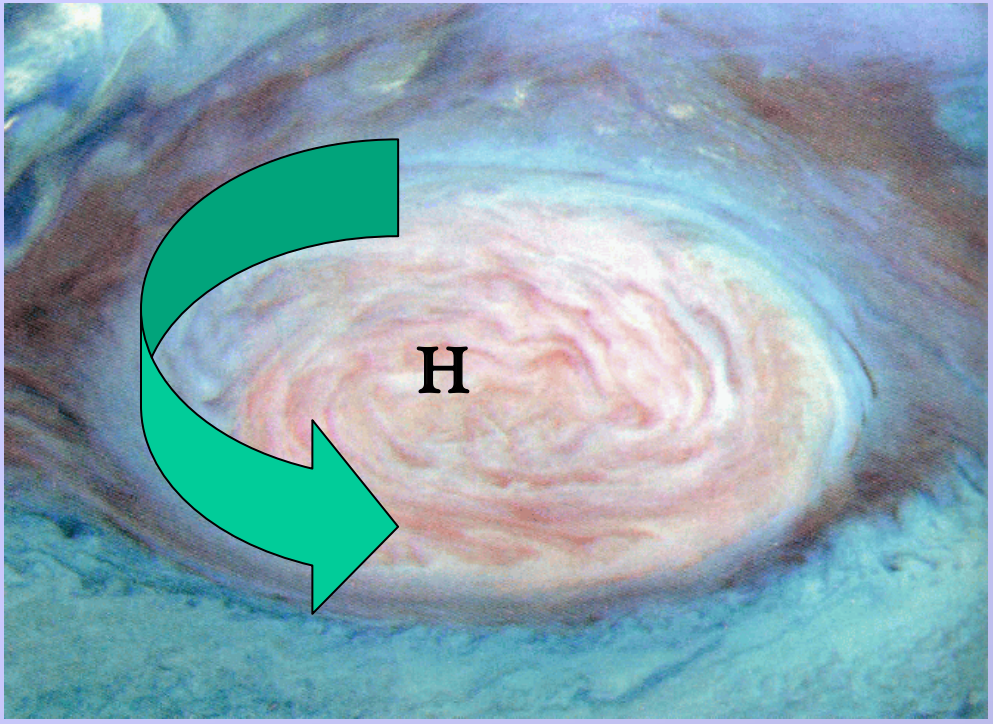


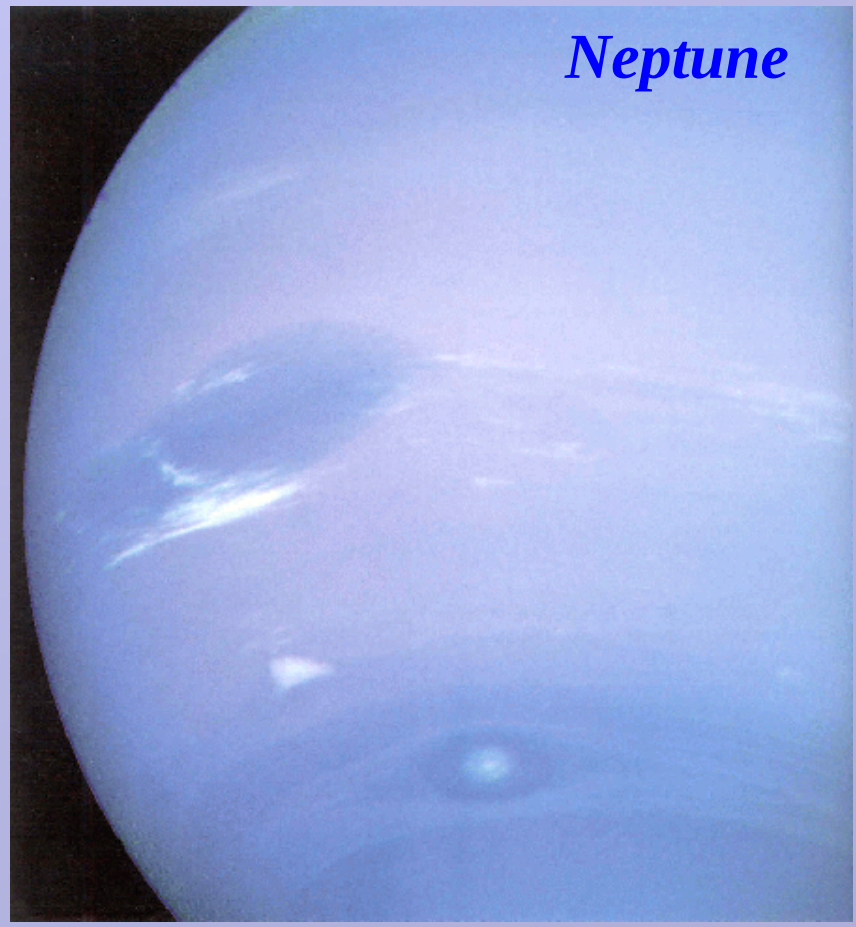


Winds at cloud top level



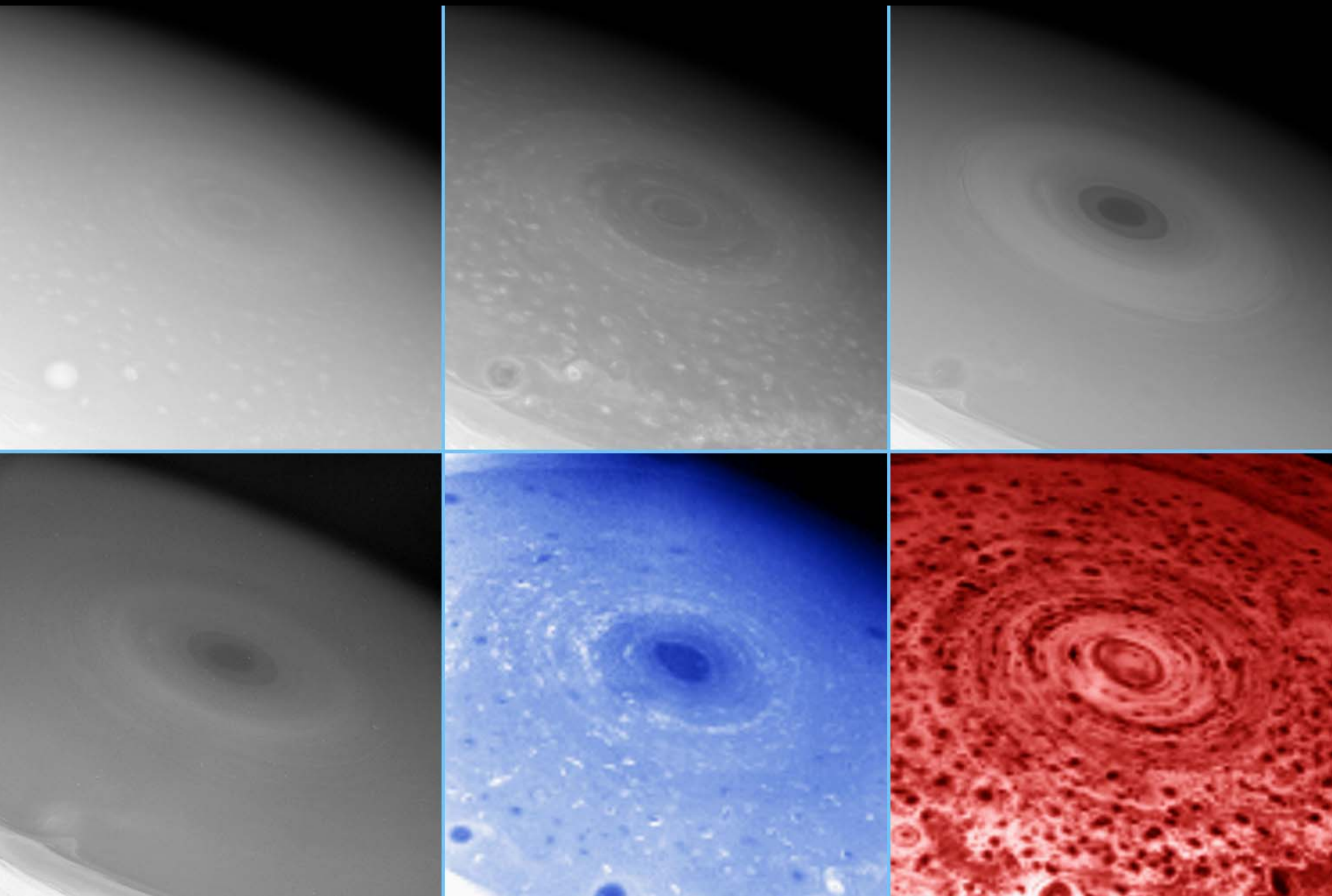
Great Red Spot



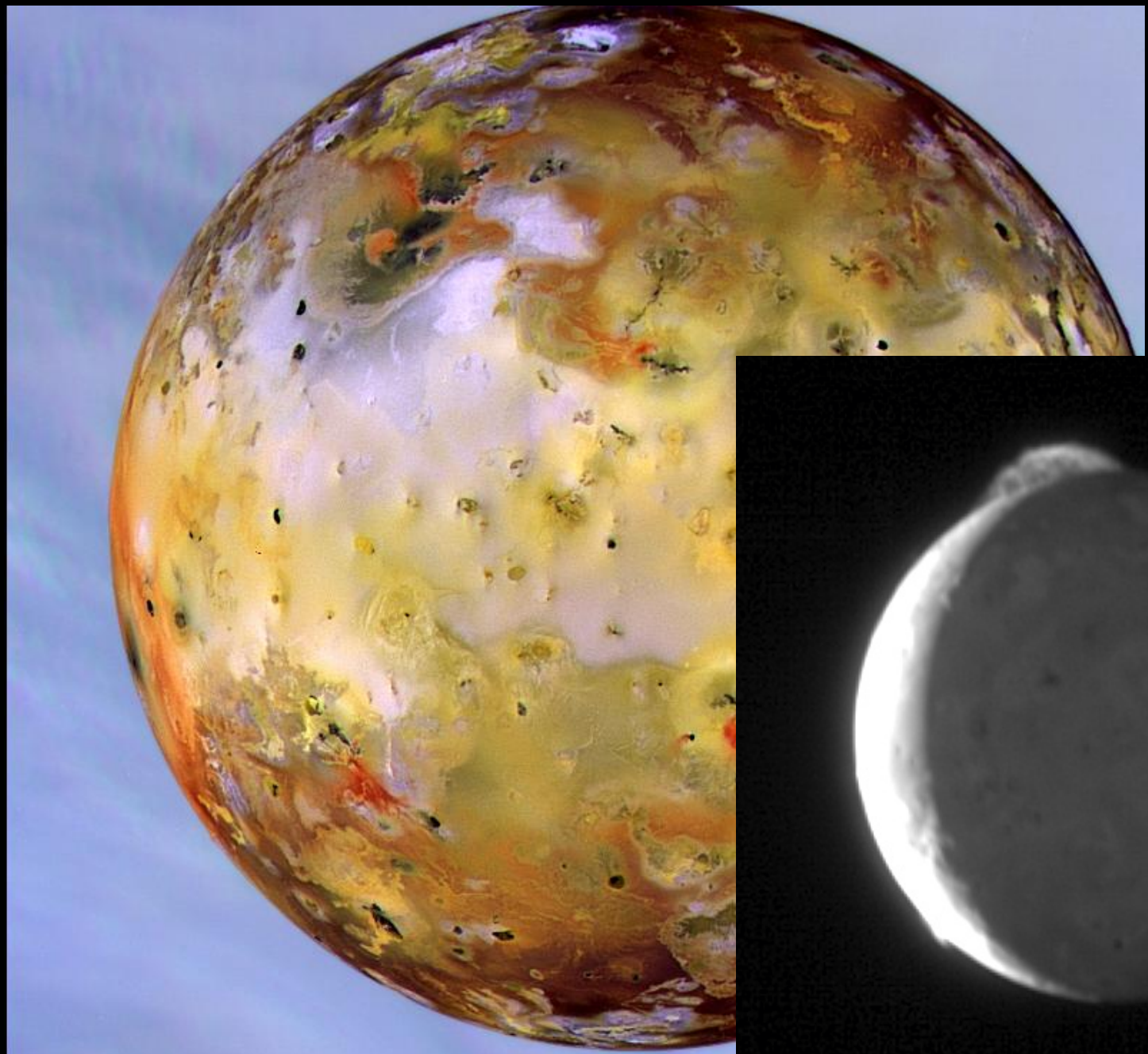


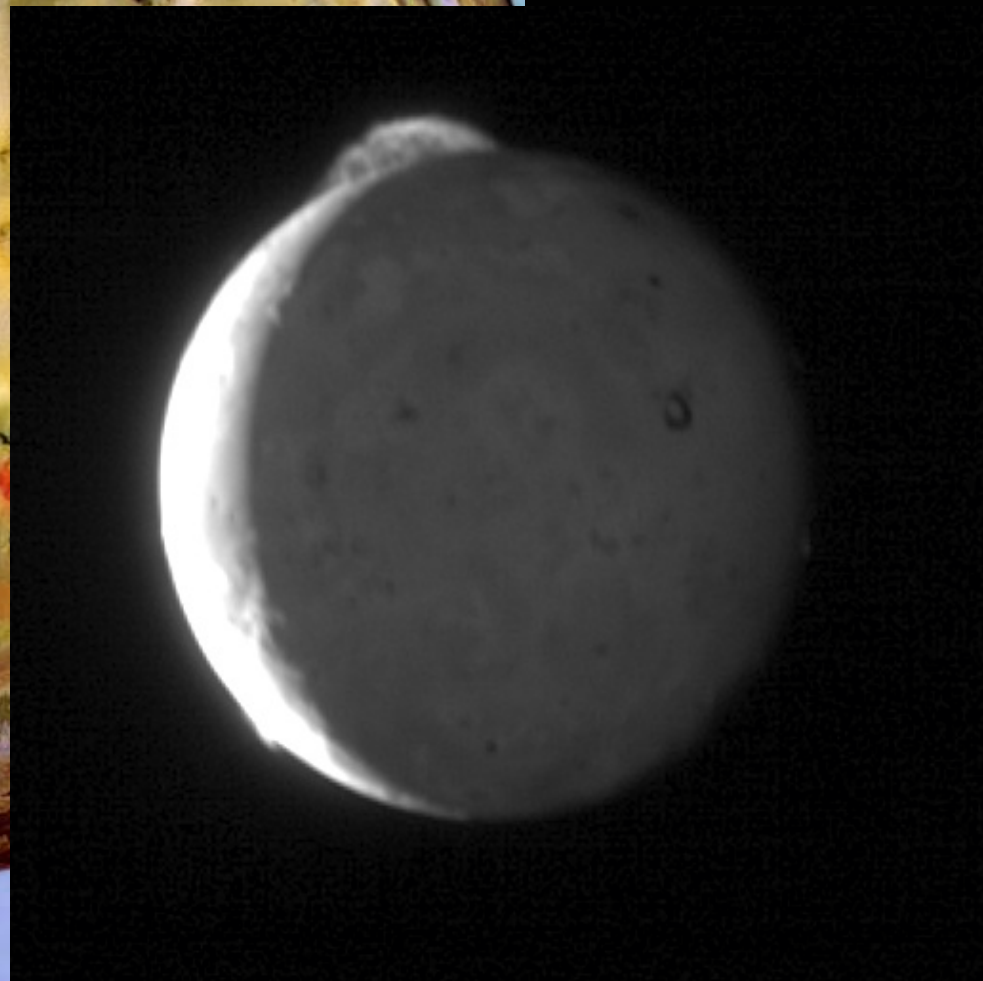
- GRS is variable
- GRS looks cold in the IR
- anti-clockwise rotation
- GRS – long-living anticyclon

Saturn polar vortex

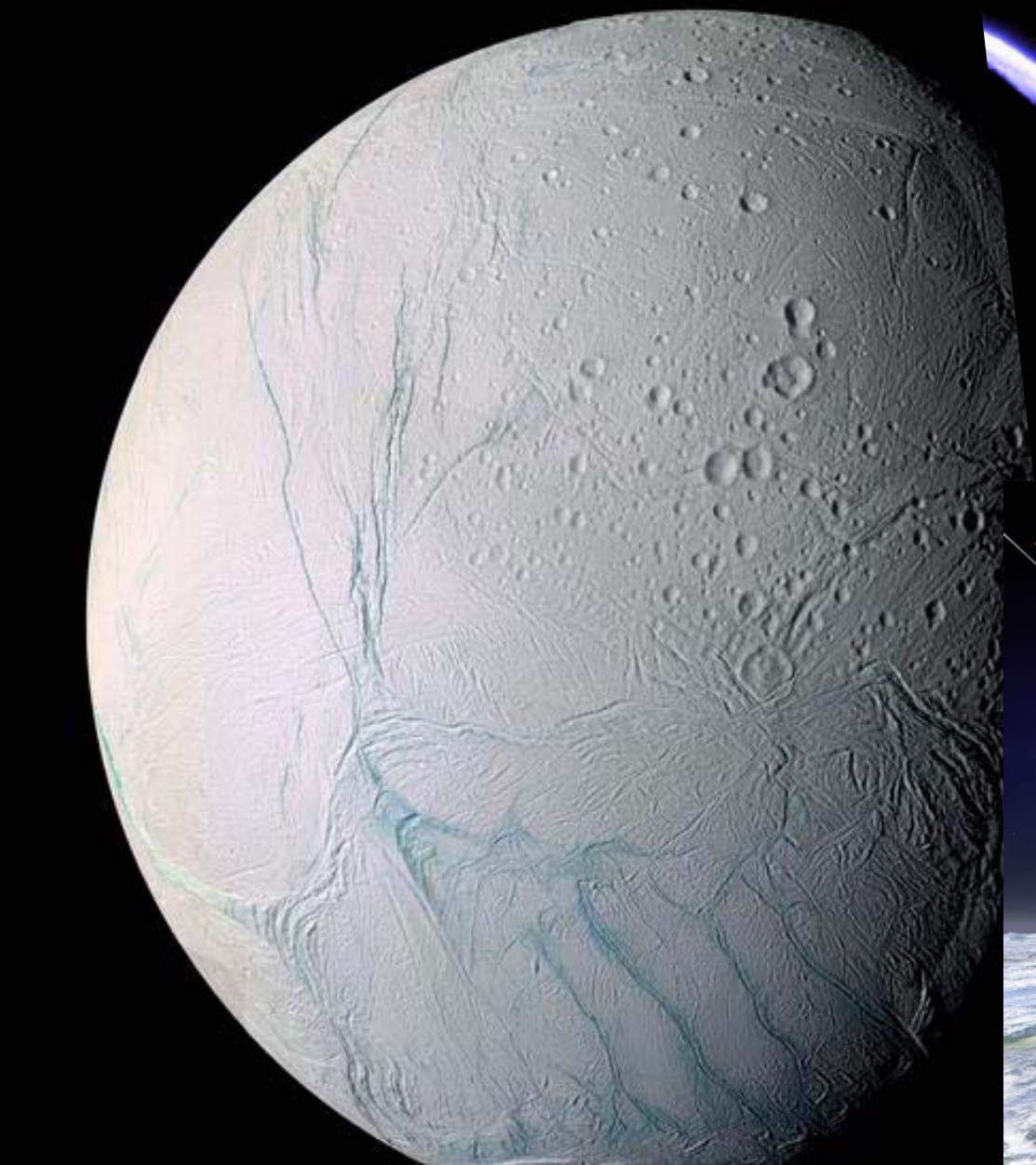


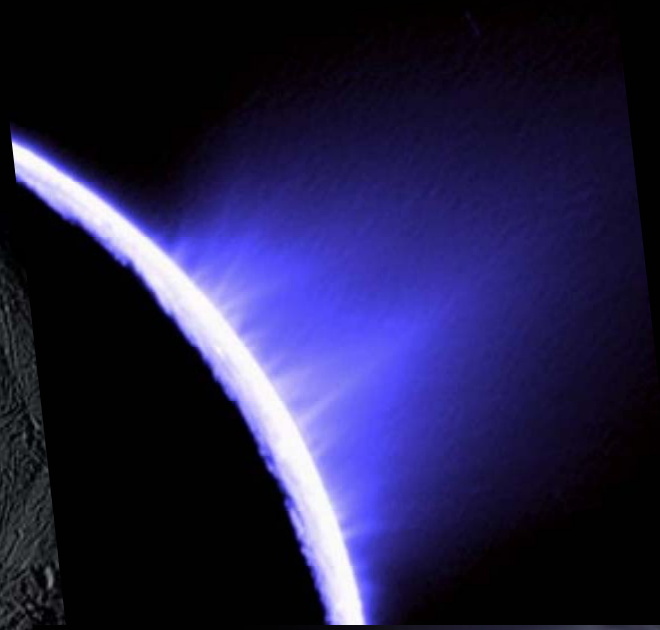
Io

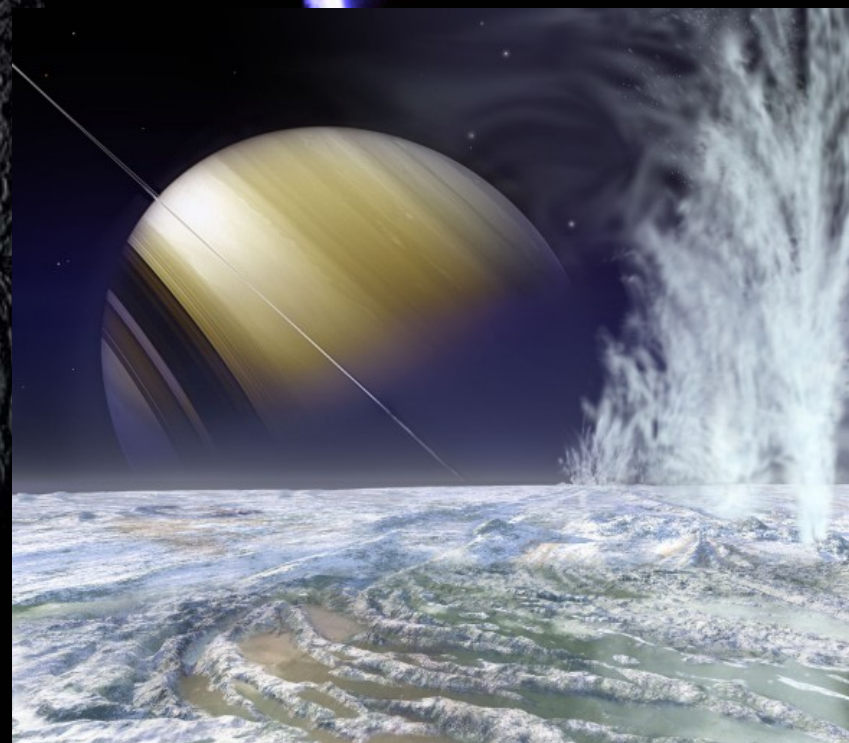




Enceladus







Home, home again…