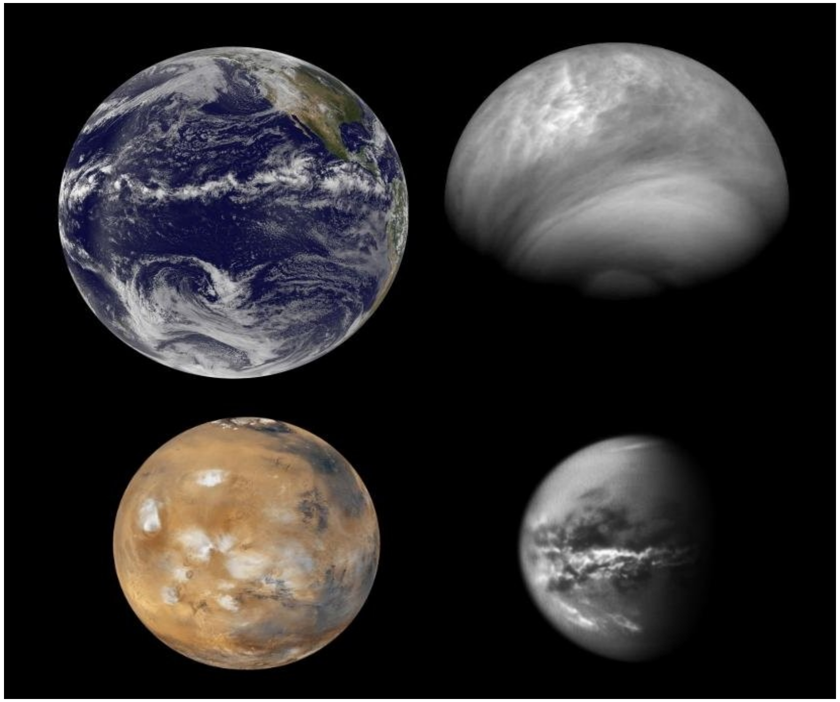
PLANETARY ATMOSPHERES



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PLANETARY ATMOSPHERES

Radiative transfer, composition and clouds

- How the atmospheric machinery works
- Radiative transfer
- A coupled system
- Temperature profiles : examples of couplings

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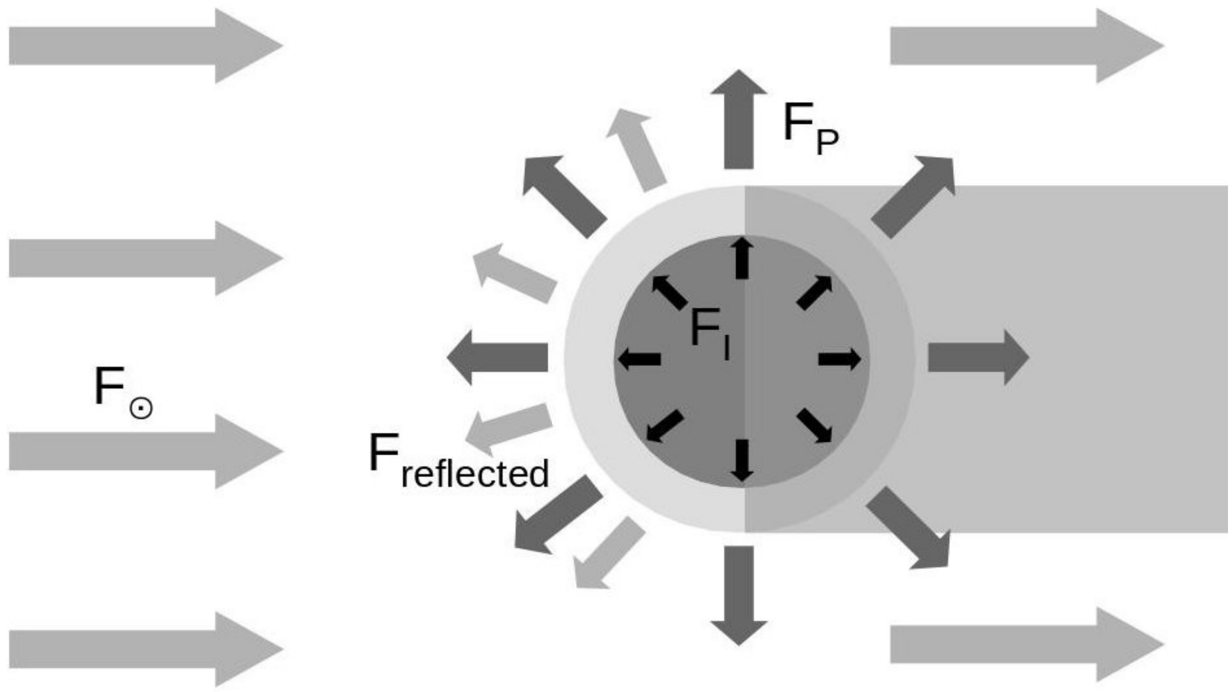
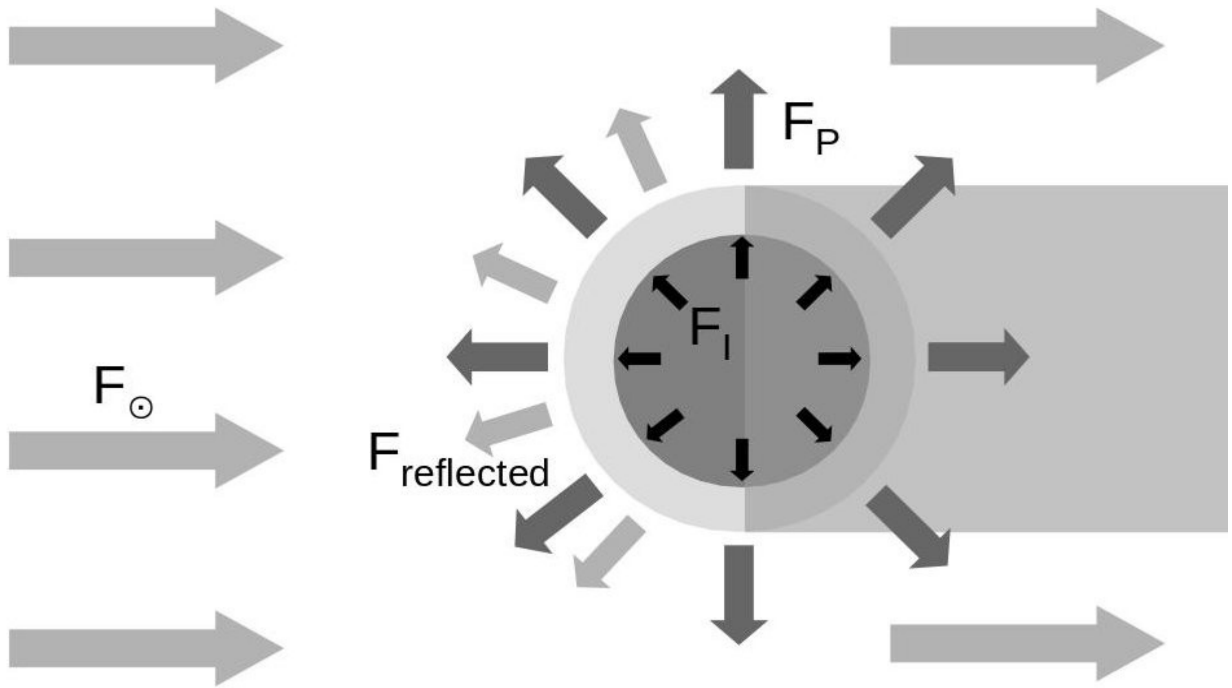
Energy balance of the atmospheric system



Energy balance of the atmospheric system



$$F_P \times (4\Pi R_P^2) = F_I \times (4\Pi R_P^2) + F_\odot \times (\Pi R_P^2) \times (1 - A)$$

$$F_P = \sigma_B T^4 \quad \rightarrow \quad \sigma_B T_{\text{eff}}^4 = F_I + F_\odot \times \frac{1-A}{4}$$

Greenhouse effect

Effective temperature

$$\sigma_B T_{\rm eff}^4 = \cancel{F_I} + F_\odot \times \frac{1-A}{4}$$

	Venus	Earth	Mars	Titan
$F_\odot$ (W/m^2)	2620.	1370.	590.	15.1
A	0.75	0.3	0.25	0.2
$T_{\rm eff}$ (K)	232	255	210	86
$< T_S >$ (K)	735	288	215	95

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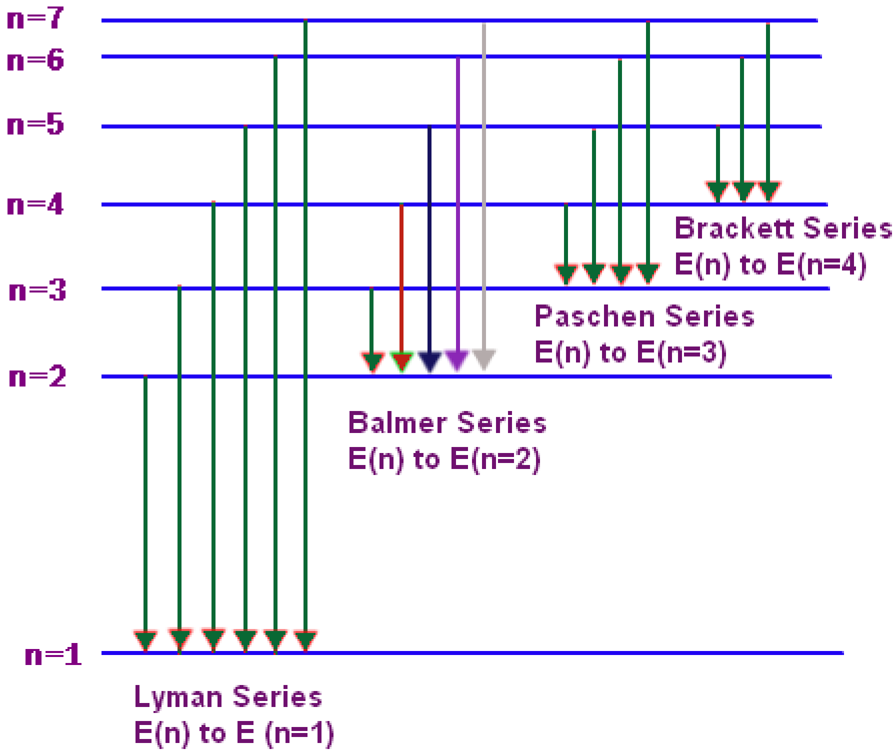
Elements of spectroscopy

Electronic transitions



Example for Hydrogen atom

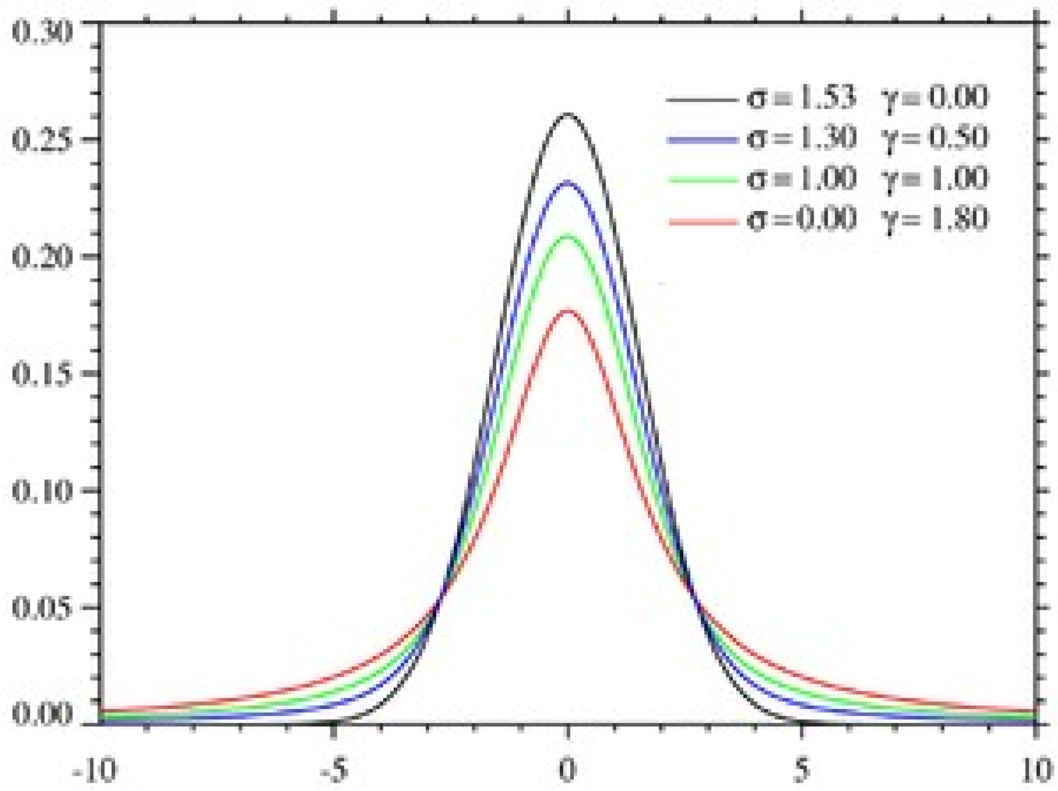
Elements of spectroscopy

Line shape

Doppler broadening : core of the line, **gaussian** profile
Pressure broadening : **Lorentzian** profile

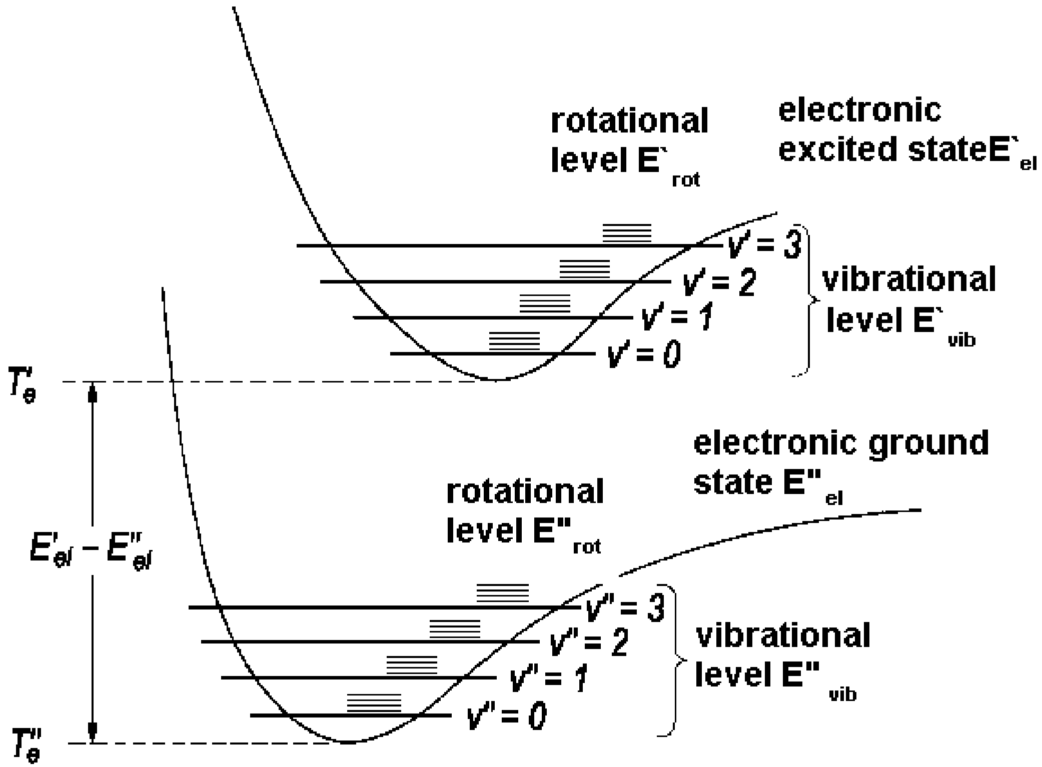
=> **Voigt** profile

Far away from center :
Sub-Lorentzian correction

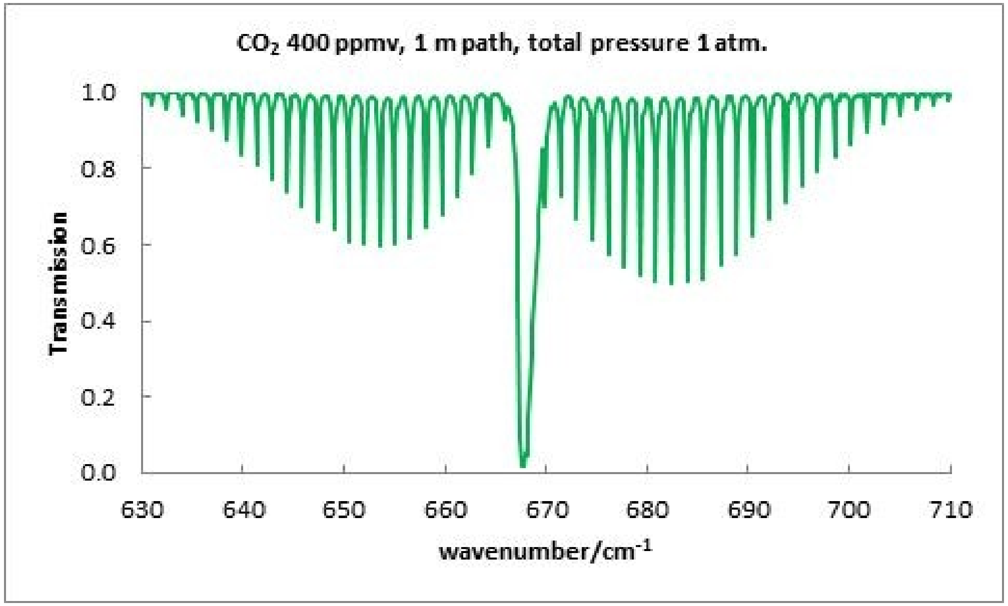


Elements of spectroscopy

Molecules : vibrations, rotations

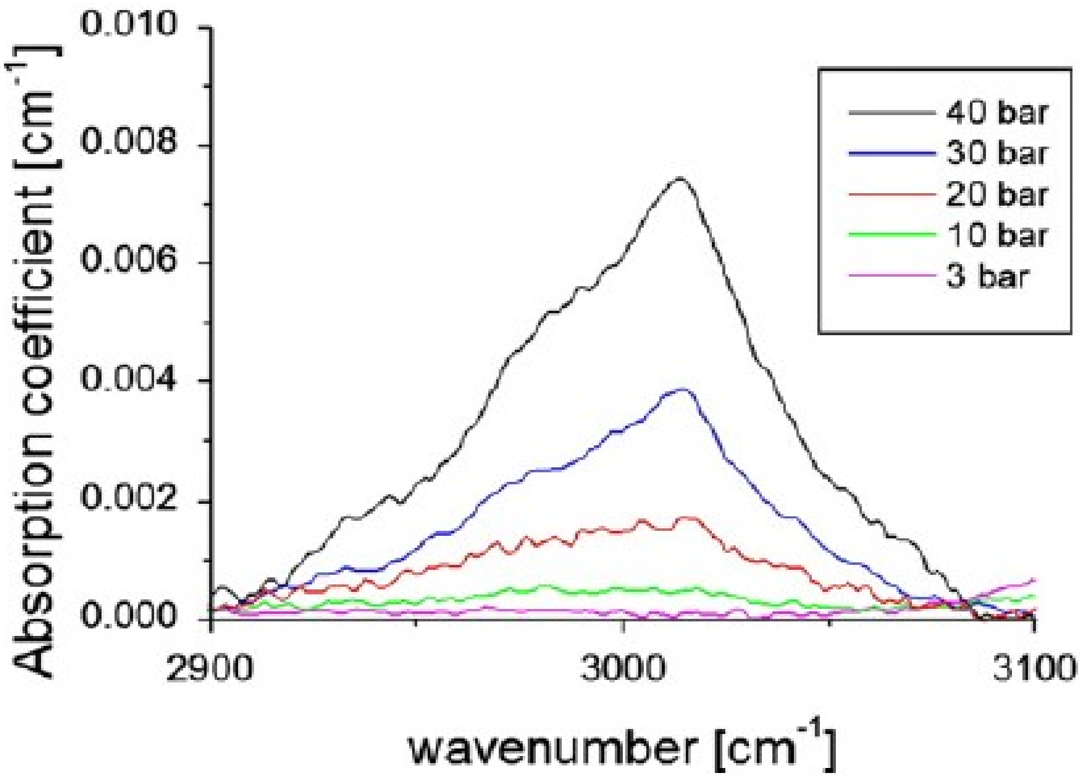


Example of CO2 15 micron band



Elements of spectroscopy

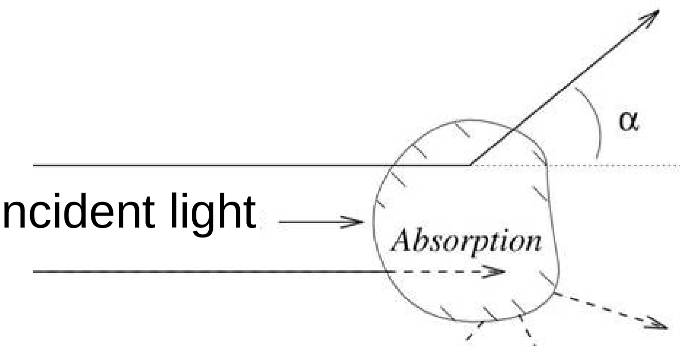
Collision-induced absorption



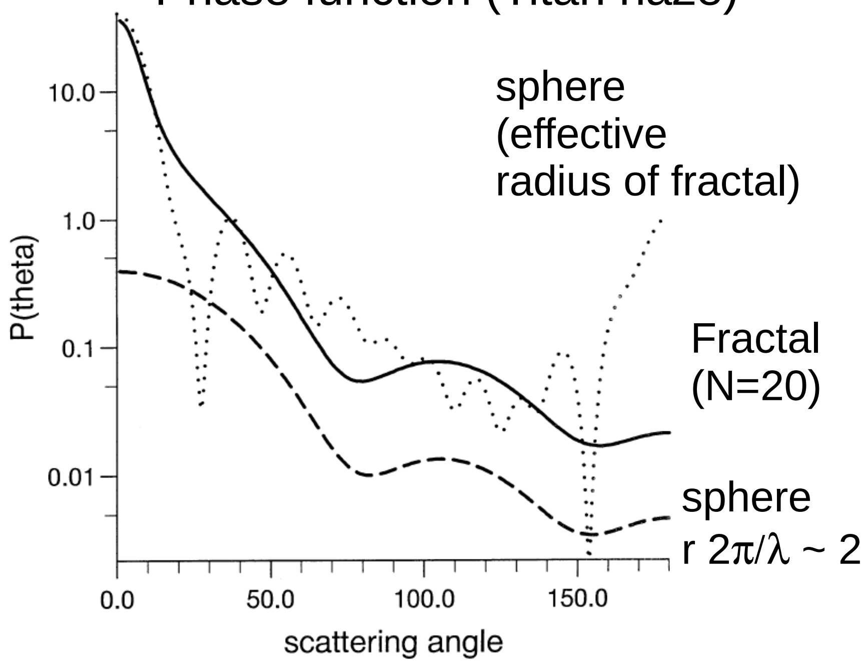
Example of CO2 dimer CIA
relevant for Venus deep atmosphere

Elements of spectroscopy

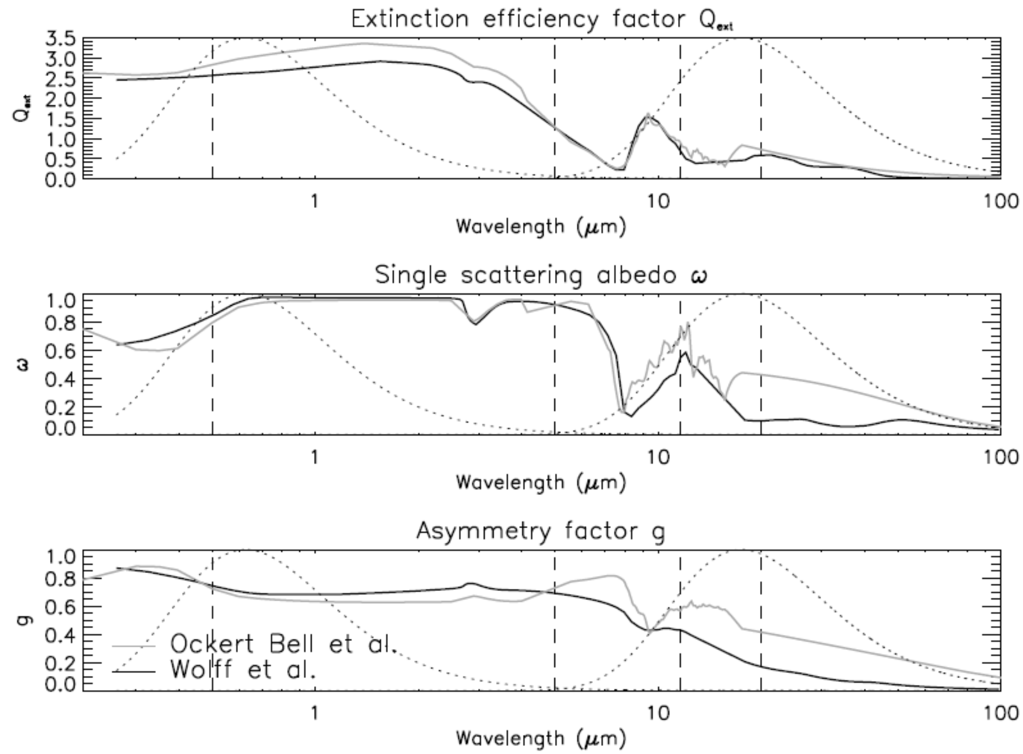
Properties of particles



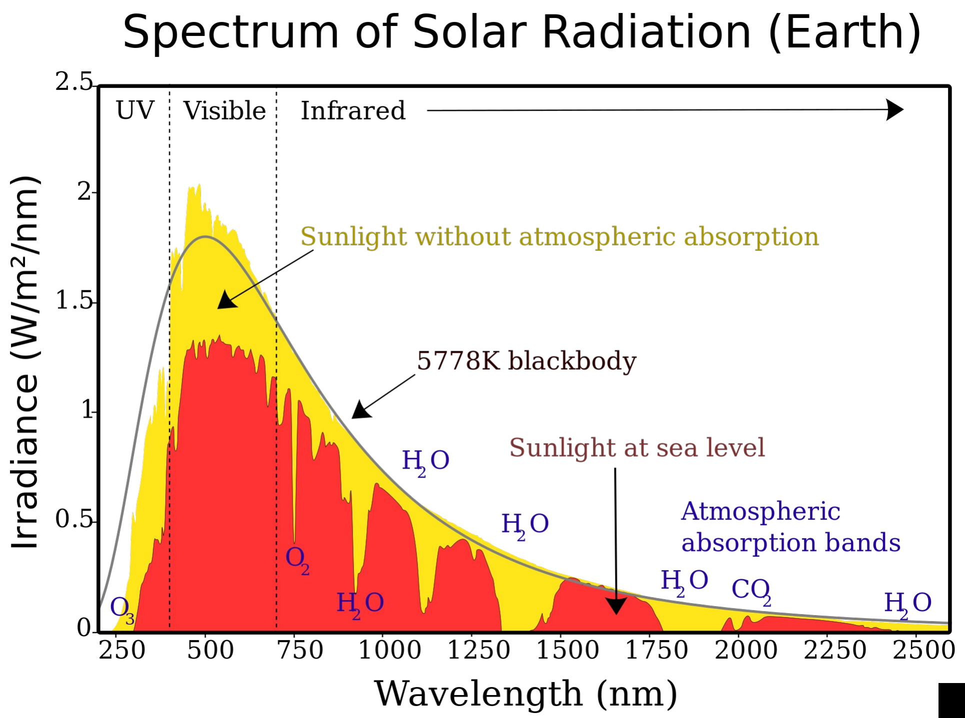
Phase function (Titan haze)



Absorption and scattering cross-sections (Martian dust)

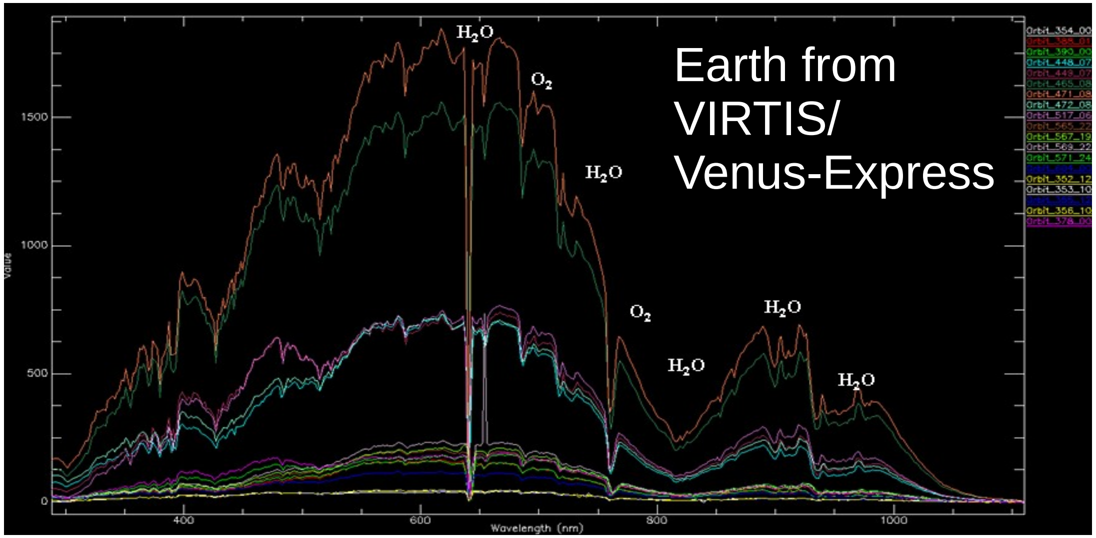


Planetary spectrum



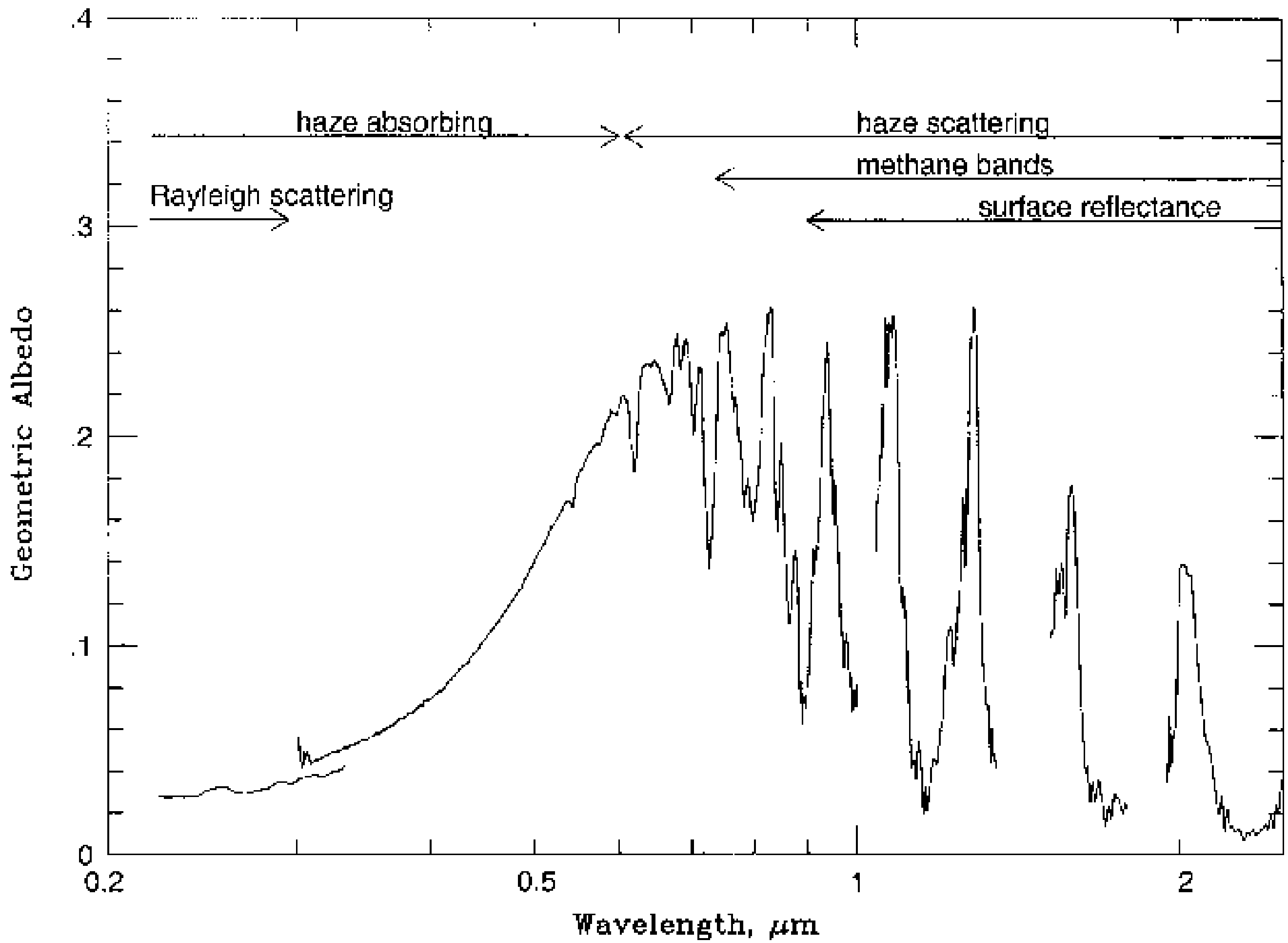
Absorbed and reflected solar spectrum

Earth



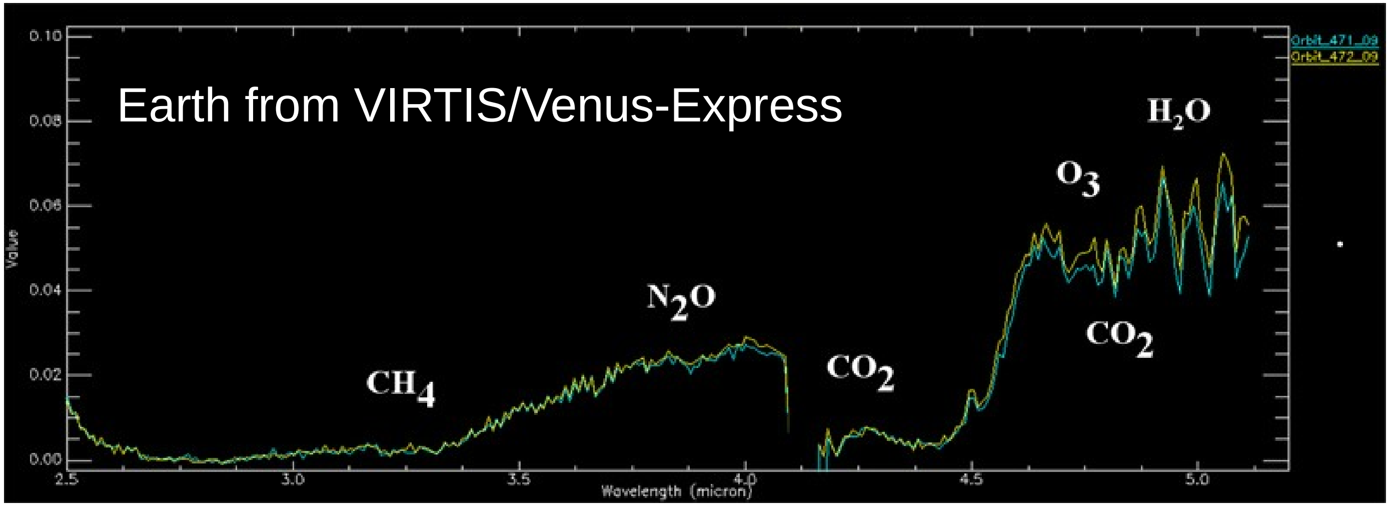
Planetary spectrum

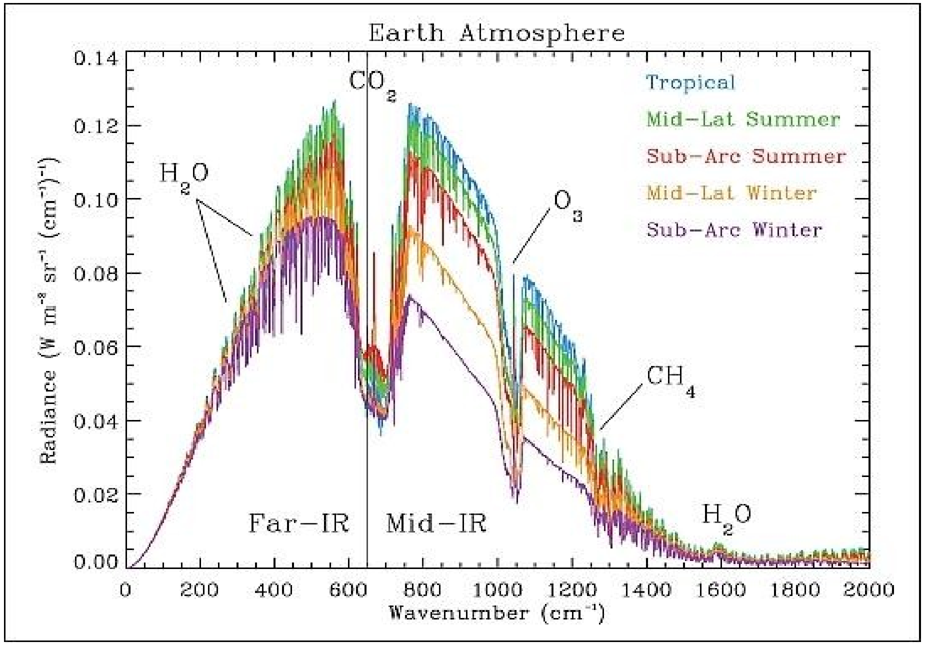
Absorbed and reflected solar spectrum :Titan

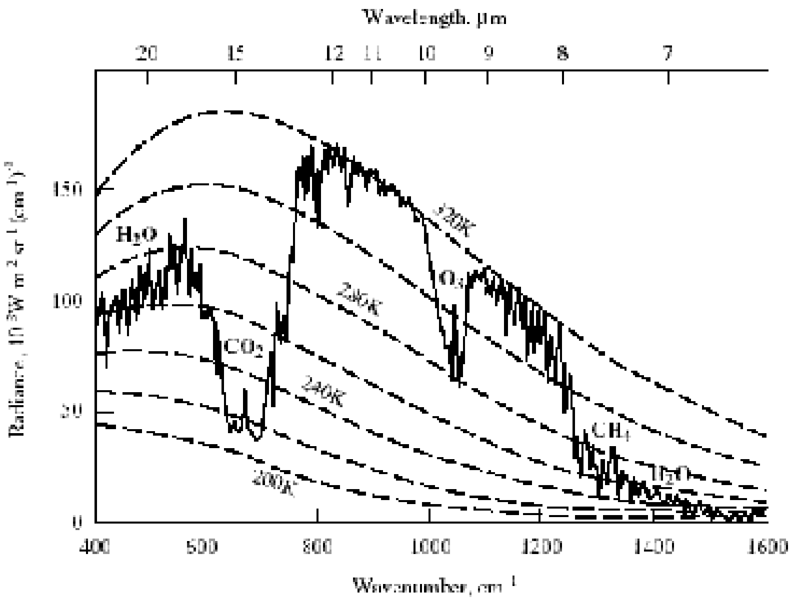


Planetary spectrum

Infrared spectrum : thermal emission — Earth

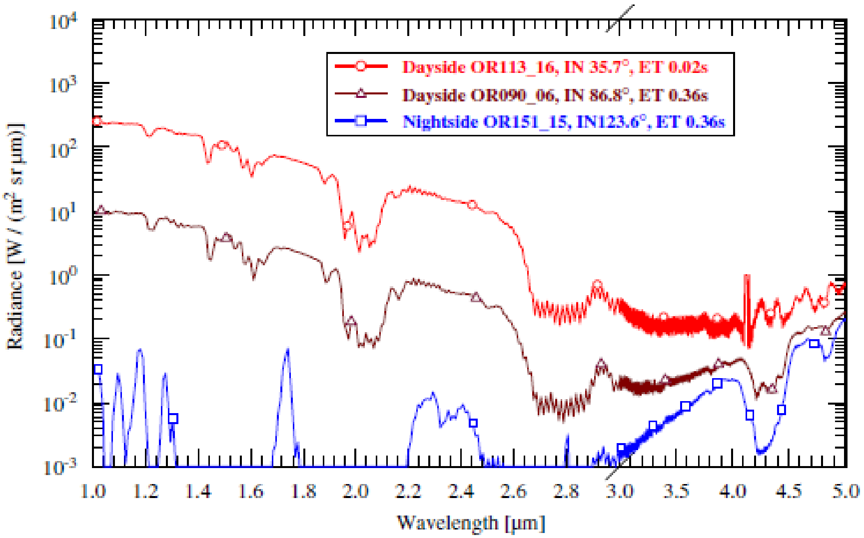


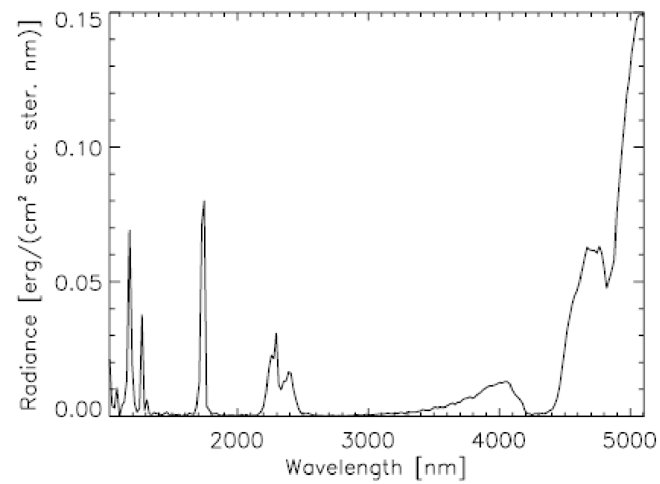




Planetary spectrum

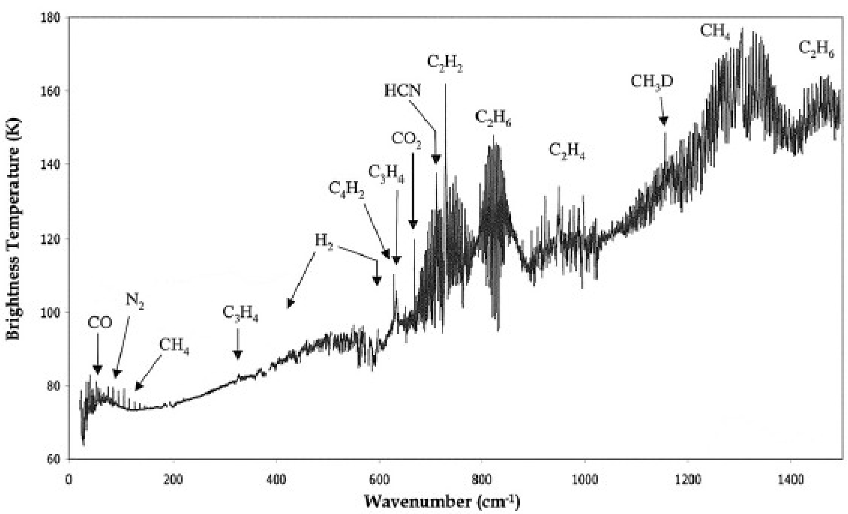
VIRTIS-M/ VenusExpress

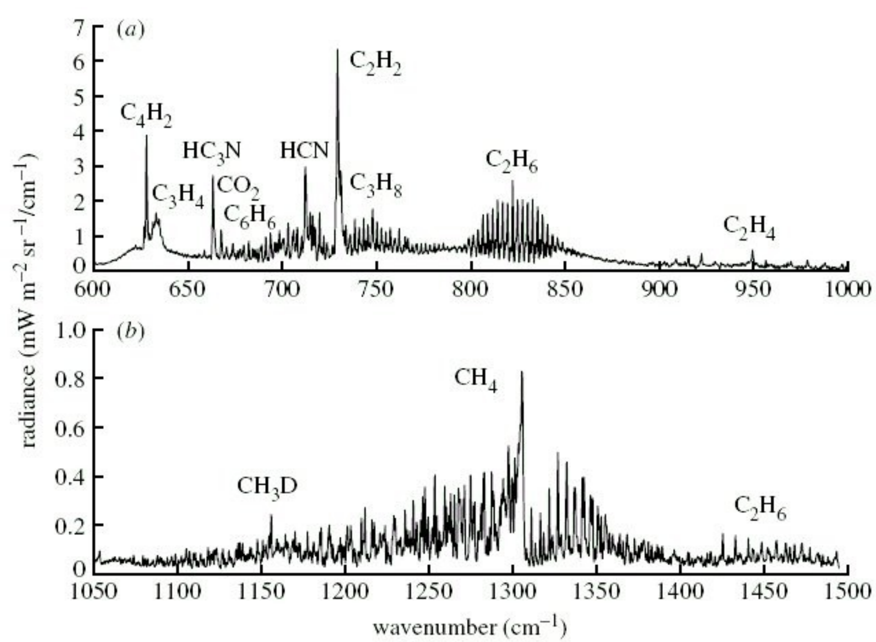




CIRS/Cassini Titan spectra

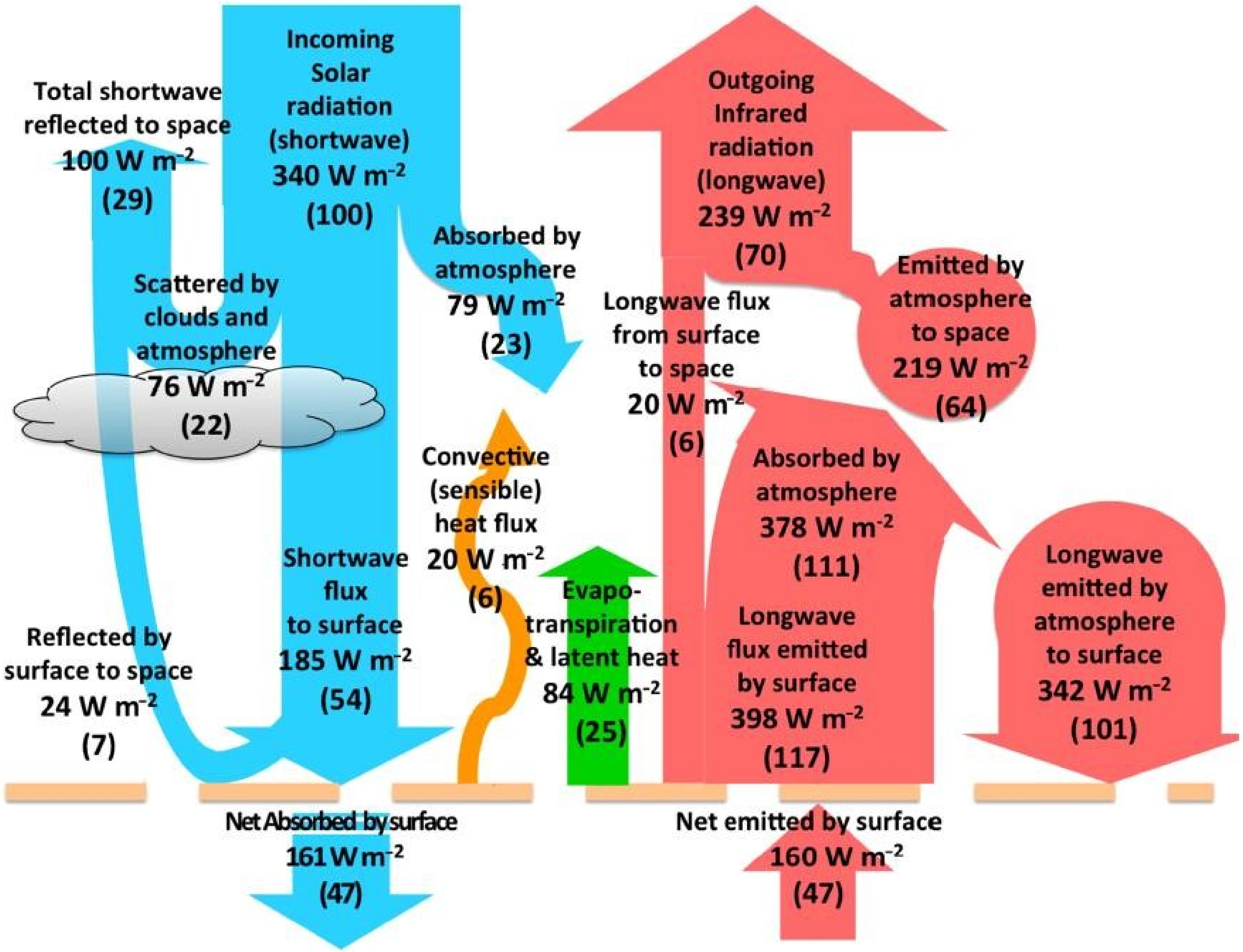
Nadir - Limb





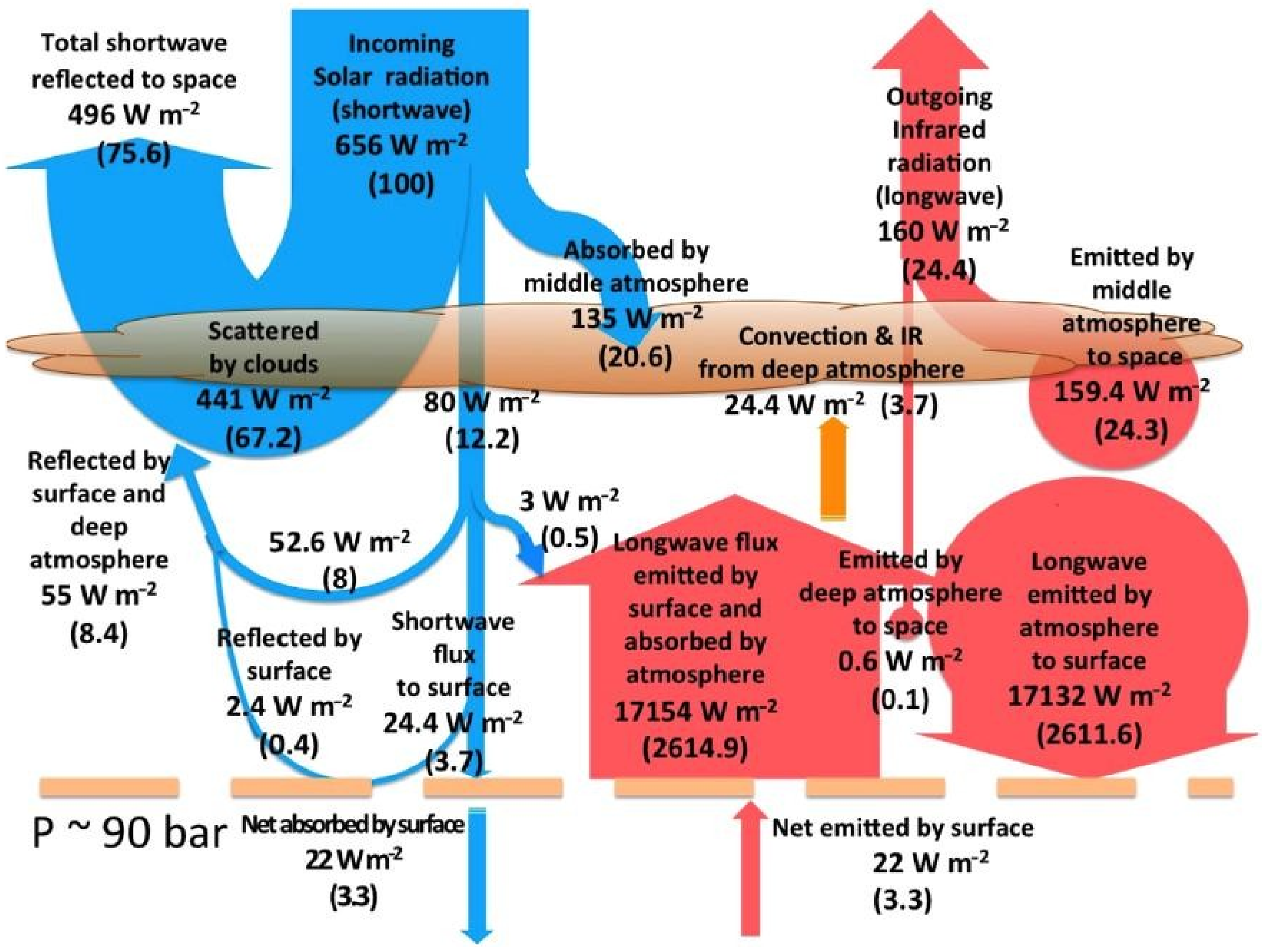
Energy transfers

Trenberth diagram : Earth



Energy transfers

Trenberth diagram : Venus



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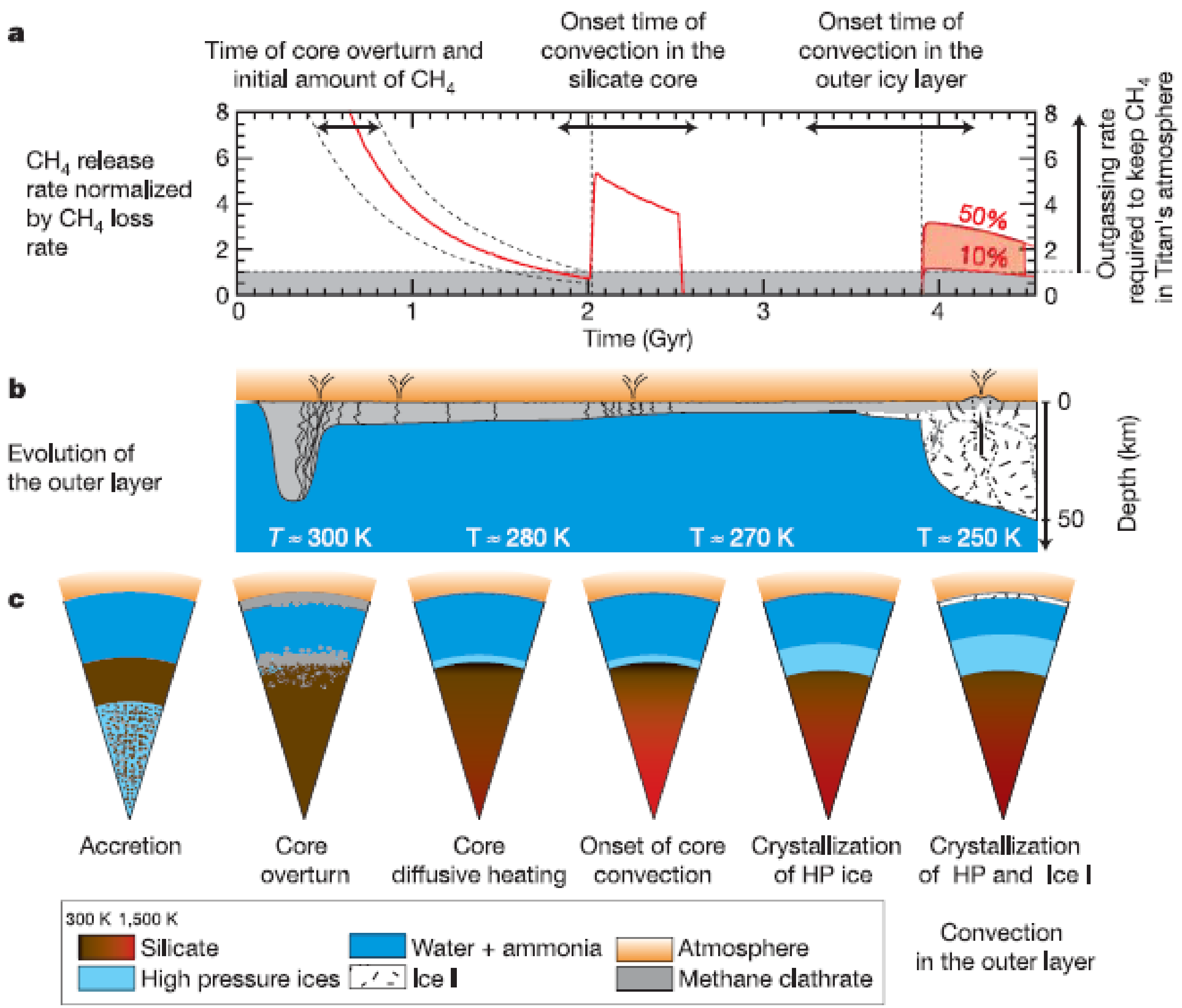
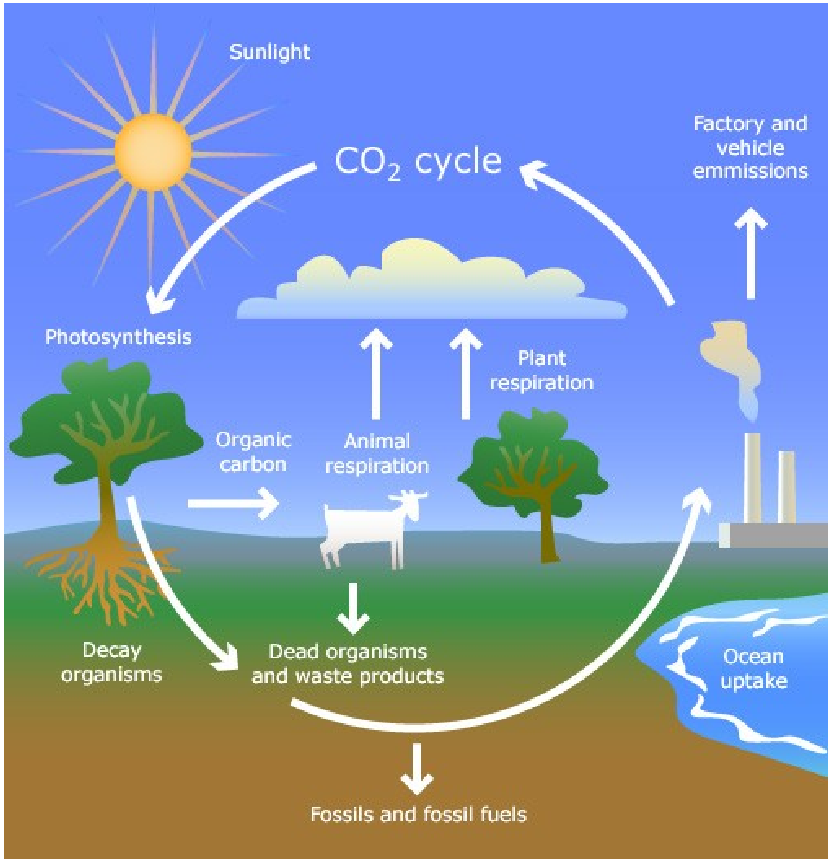
Atmospheric composition

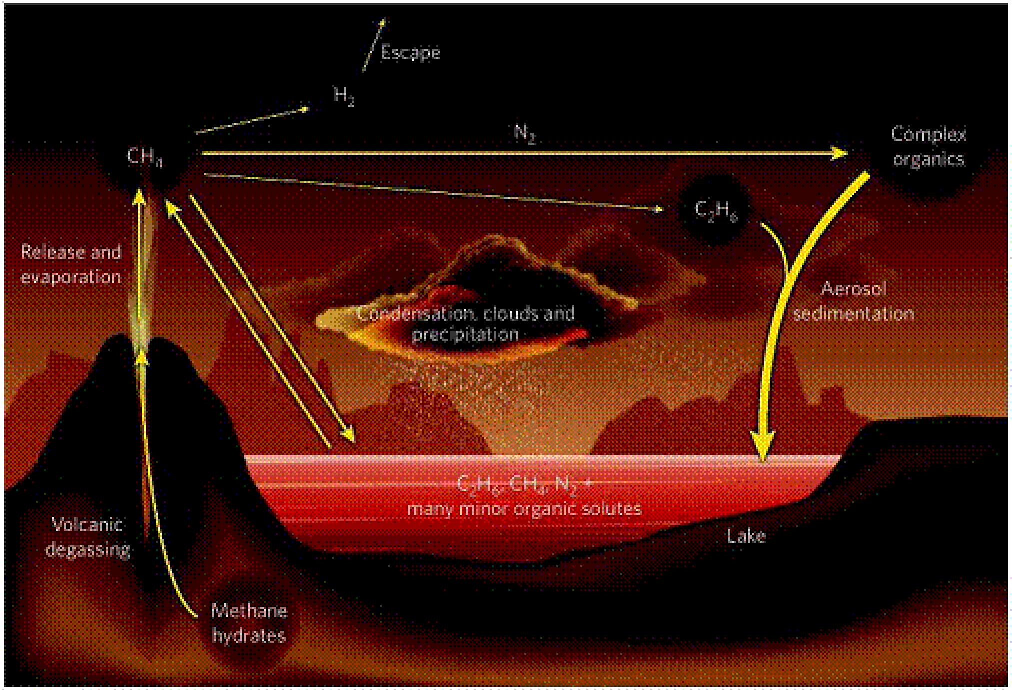
A scenario for the history of Titan's atmosphere



Atmospheric composition

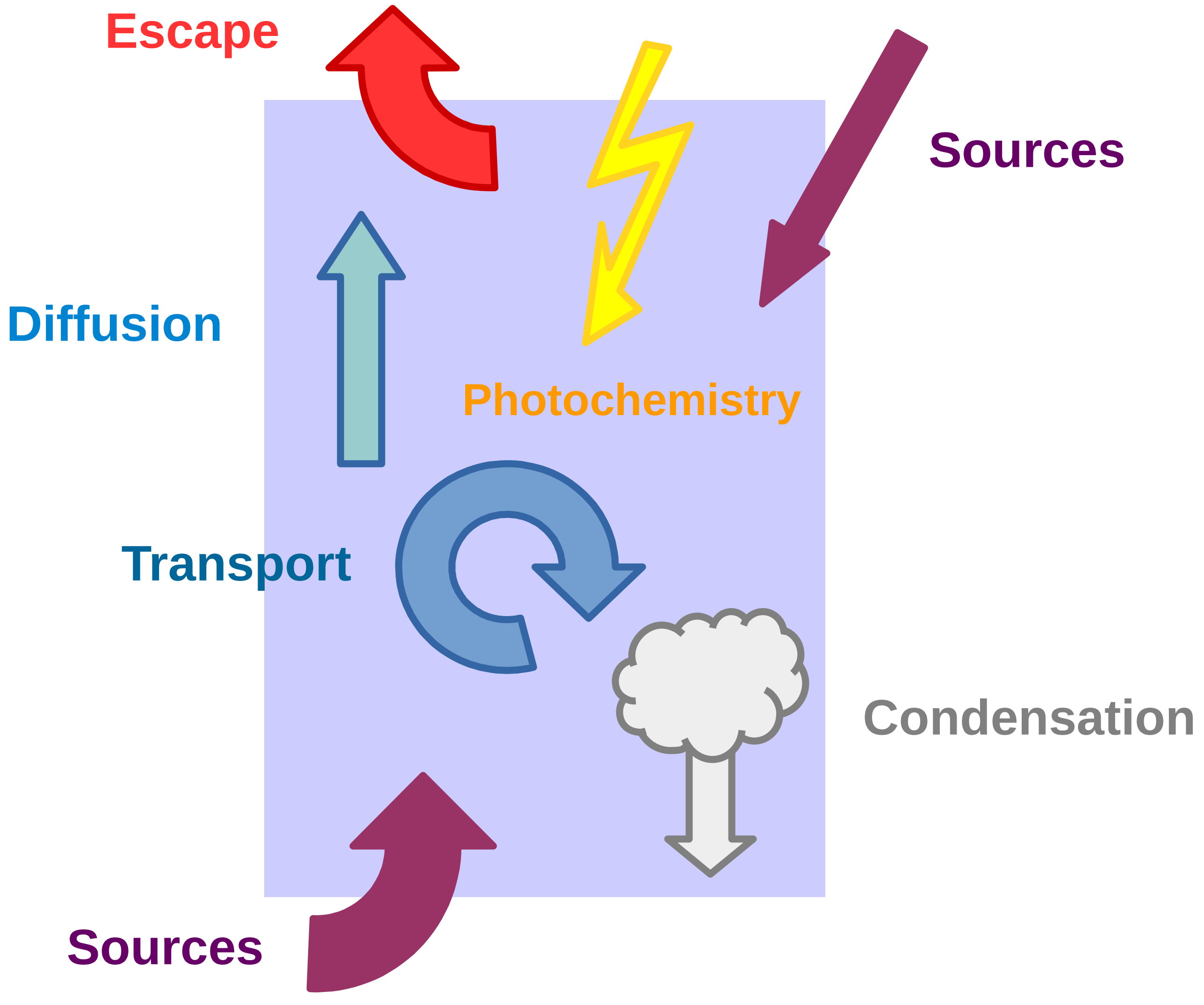
Interactions with the surface





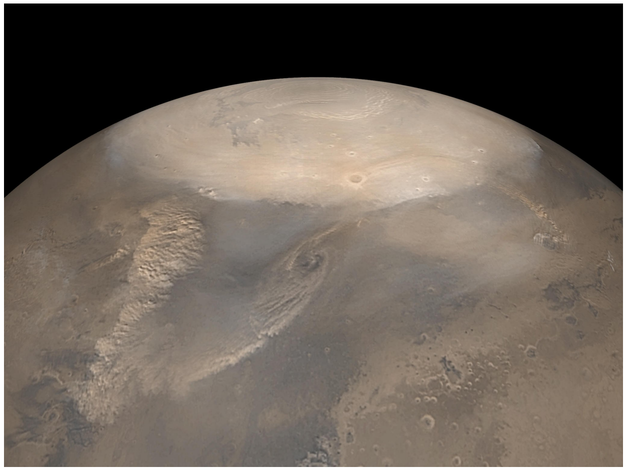
Atmospheric composition

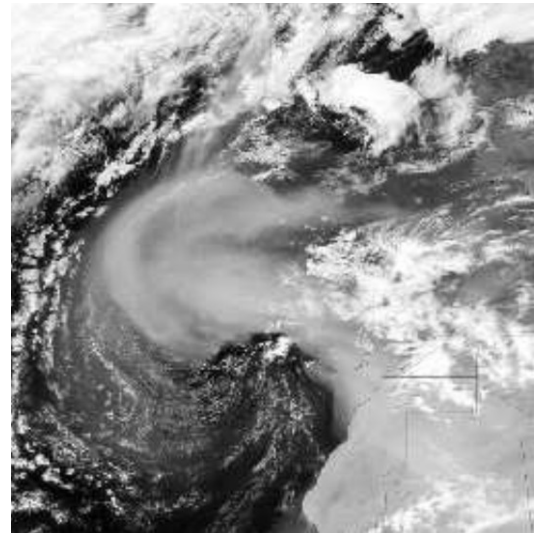
Vertical distribution : balance of many processes

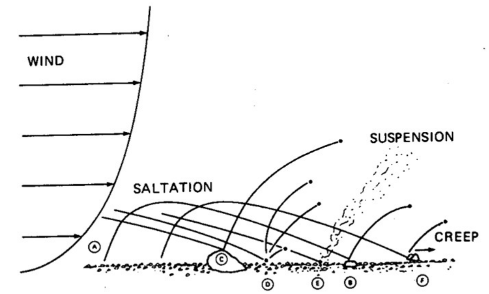


Particles in the atmosphere

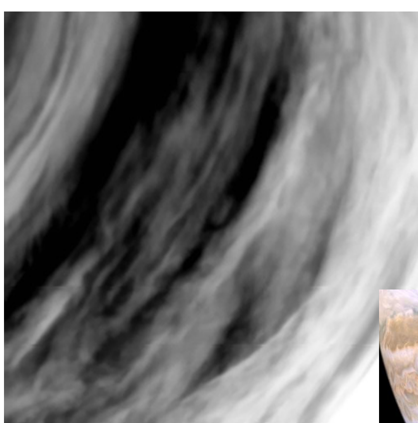
Dust

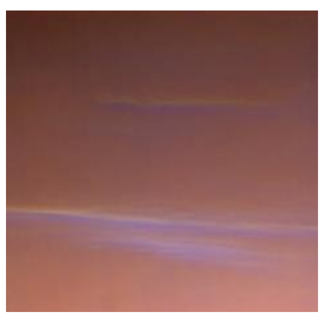


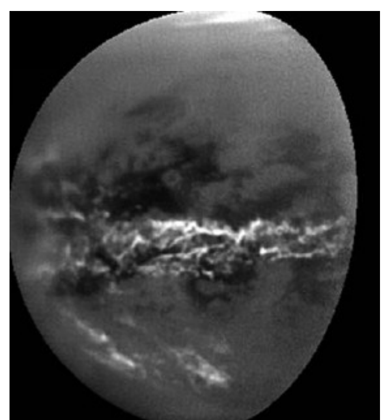




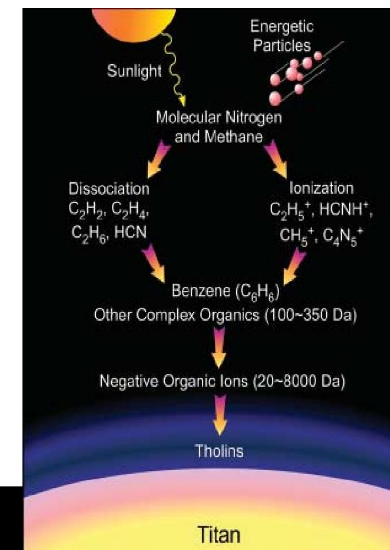
Clouds

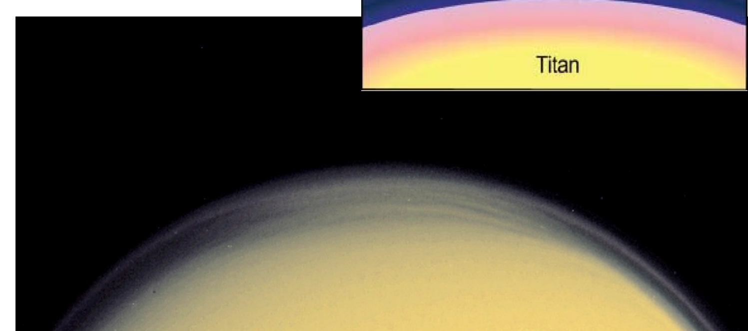




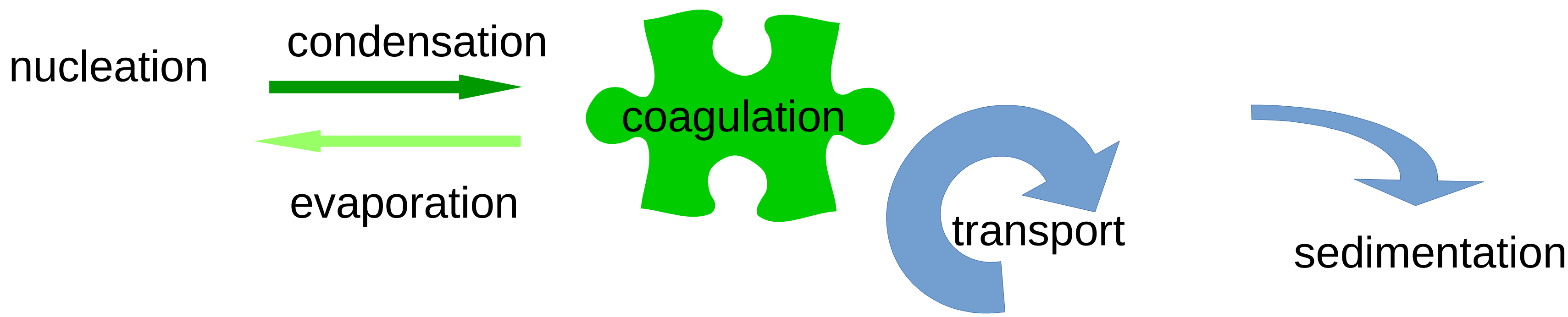


Haze

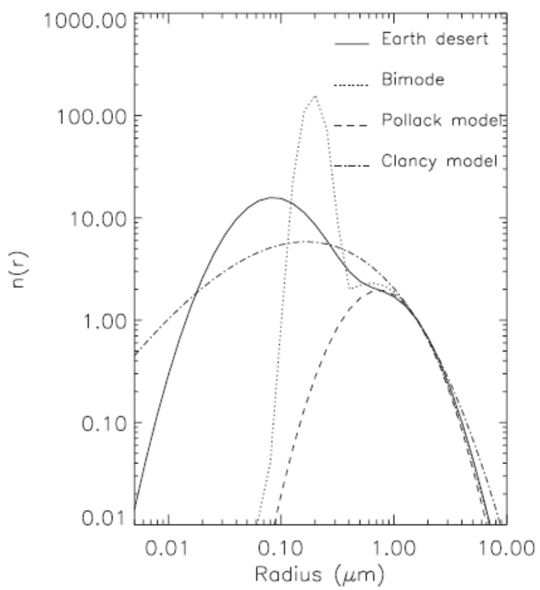




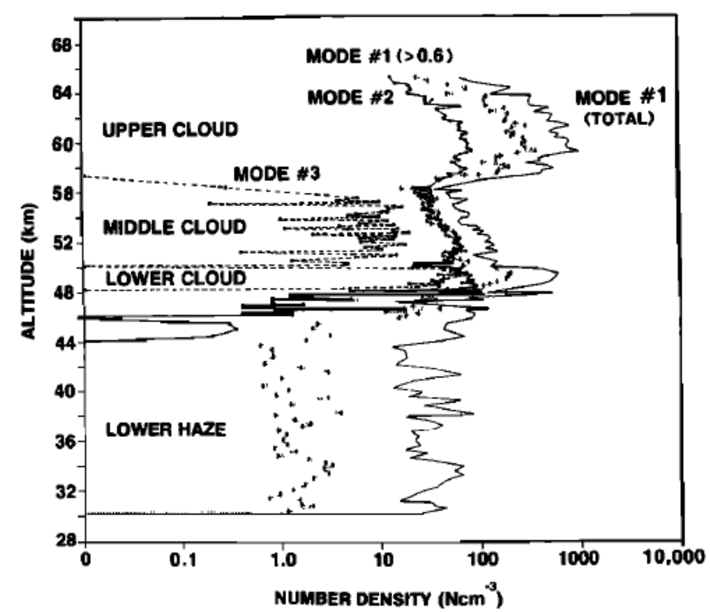
Microphysics



Particle distributions

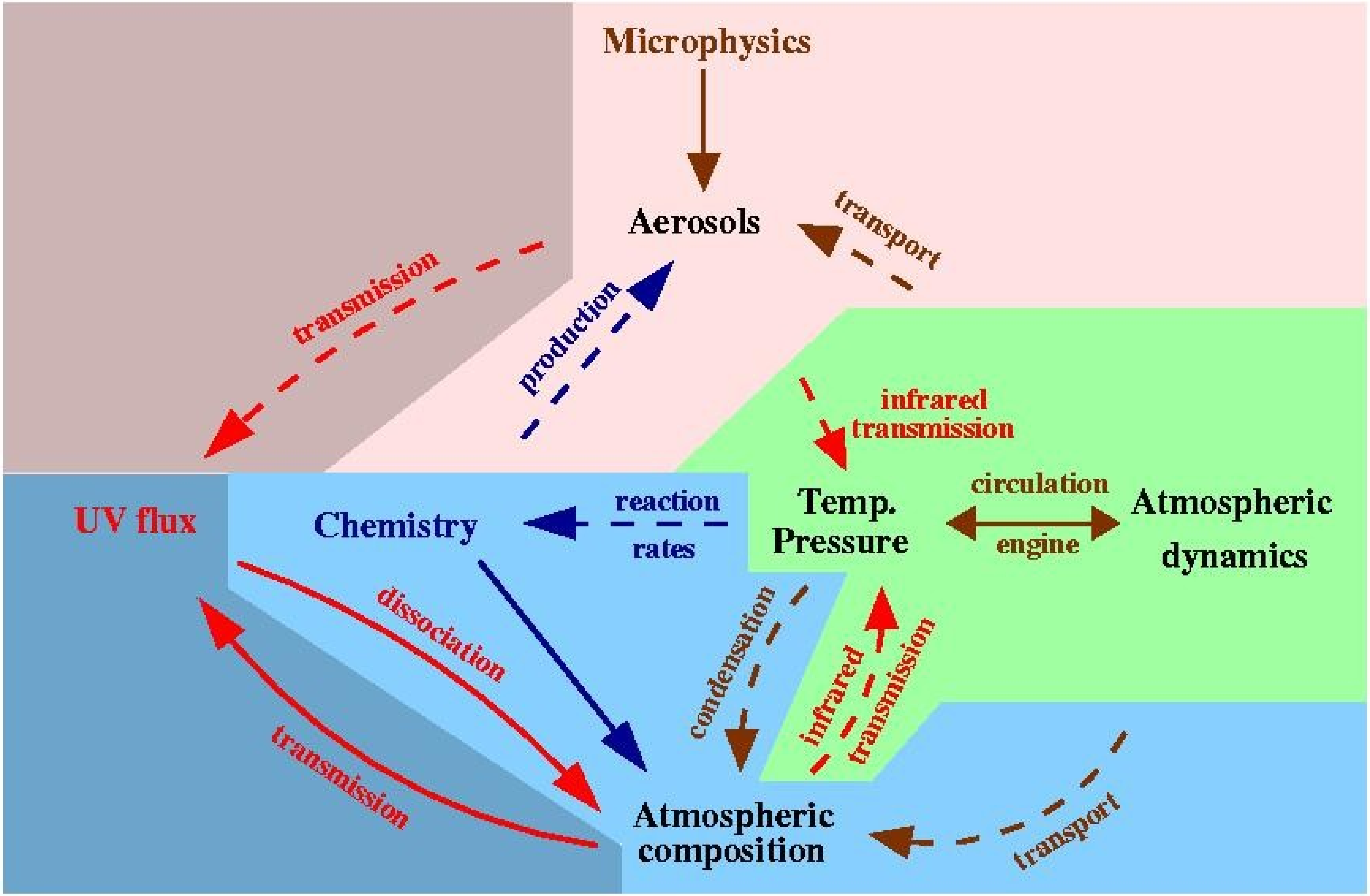


Model of Martian dust



Cloud particle distributions deduced from in-situ PioneerVenus observations

A coupled system



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Computing the radiative transfer and temperature structure

Fluxes and heating rates

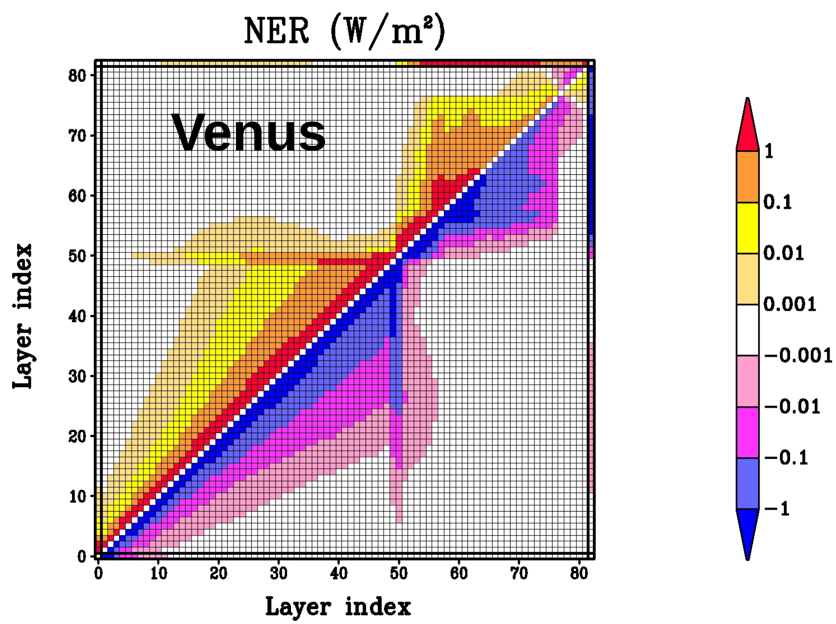
heating rates : $$\frac{dT}{dt} = \frac{g}{c_p} \frac{dF^{net}}{dp}$$

Net Exchange Rates formulation

$$\Psi(i,j) = E(j \rightarrow i) - E(i \rightarrow j)$$

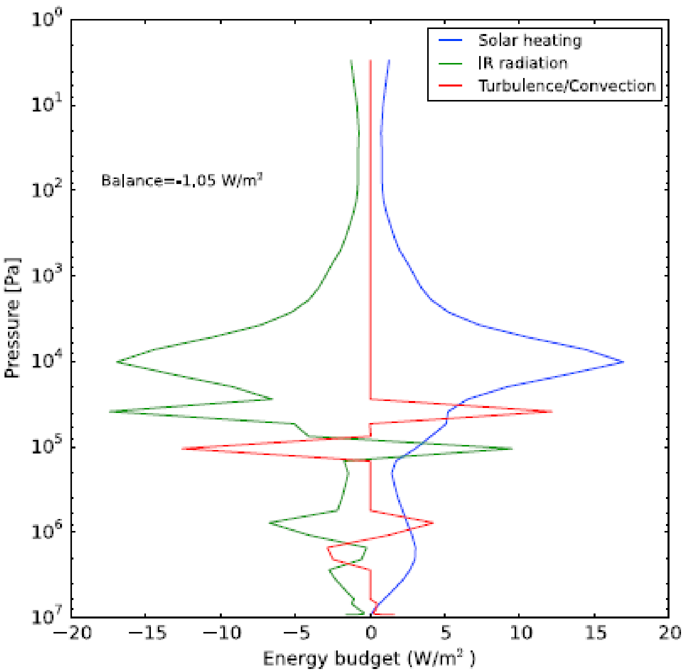
$$\Psi(i,j) = \int_{IR} d\nu \int_{\Gamma_{i,j}} d\gamma \xi_\nu(\gamma)[B_\nu(\gamma,j) - B_\nu(\gamma,i)]$$

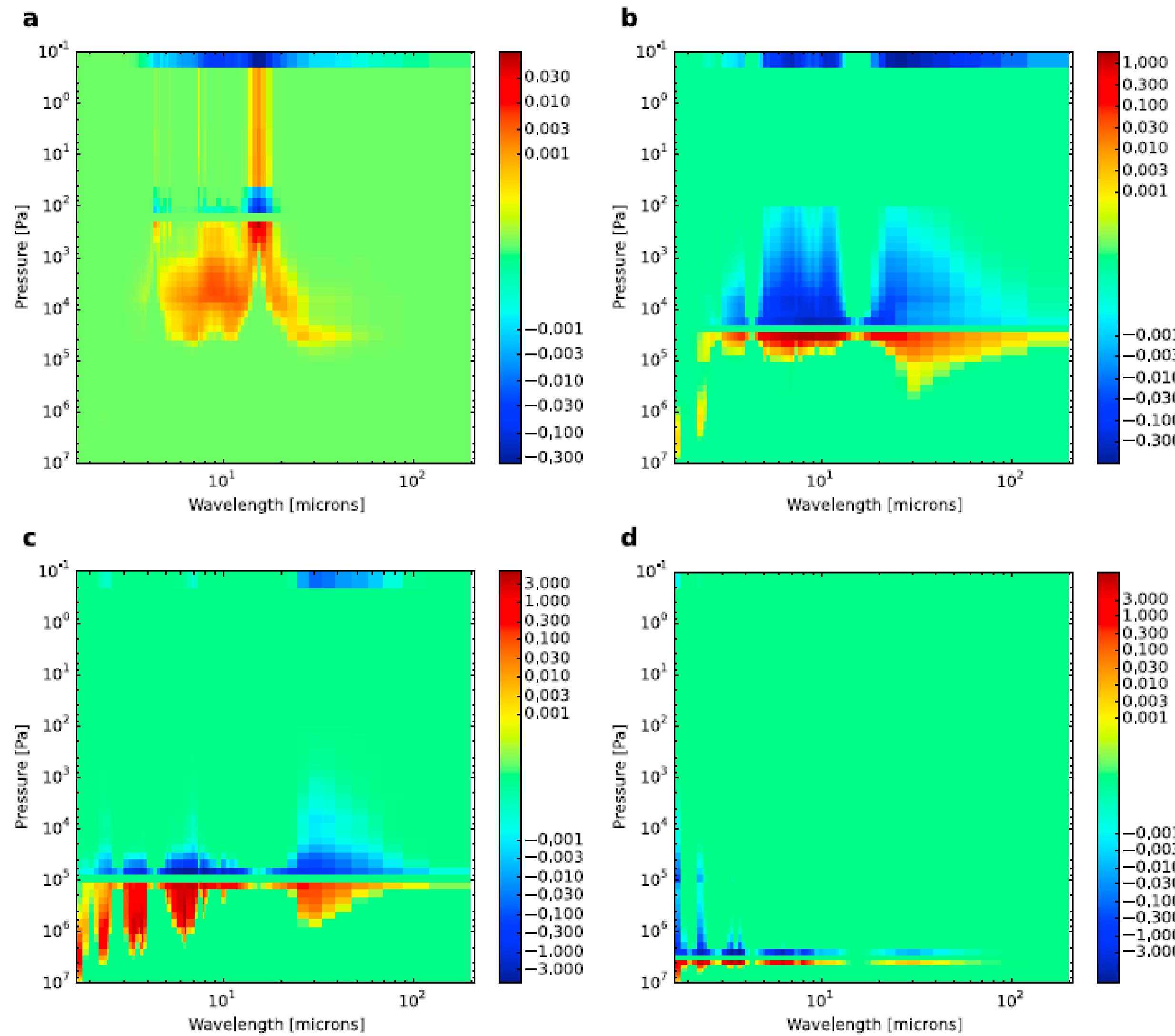
heating rates : $$\zeta(i) = \sum_{j=0}^{m+1} \Psi(i,j)$$



Computing the radiative transfer and temperature structure

Advantages of the NER matrix : detailed example for Venus





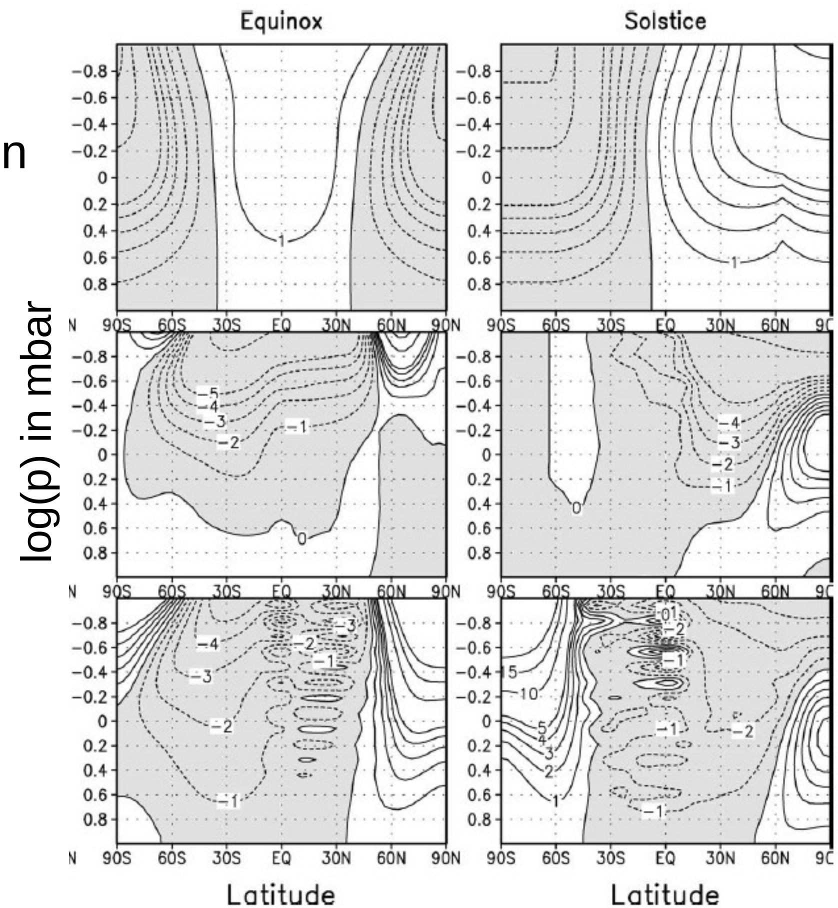
Computing the radiative transfer and temperature structure

Titan's haze and stratospheric temperatures

Solar radiation

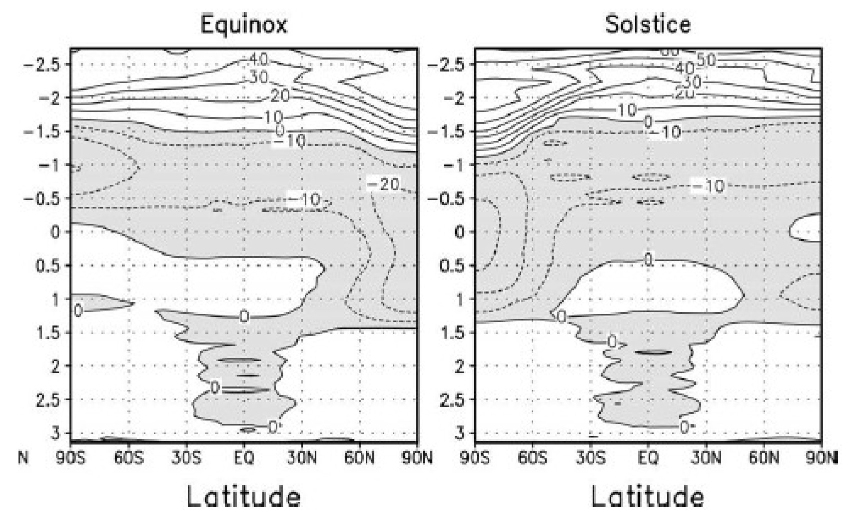
SW heating rate

LW cooling rate



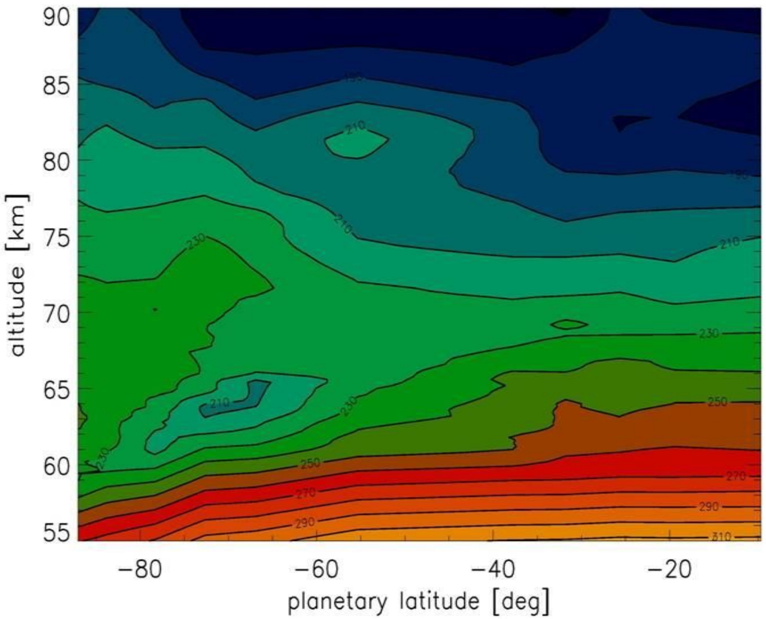
(coupled haze – uncoupled haze)

Impact of dynamics/haze/temperature coupling on T

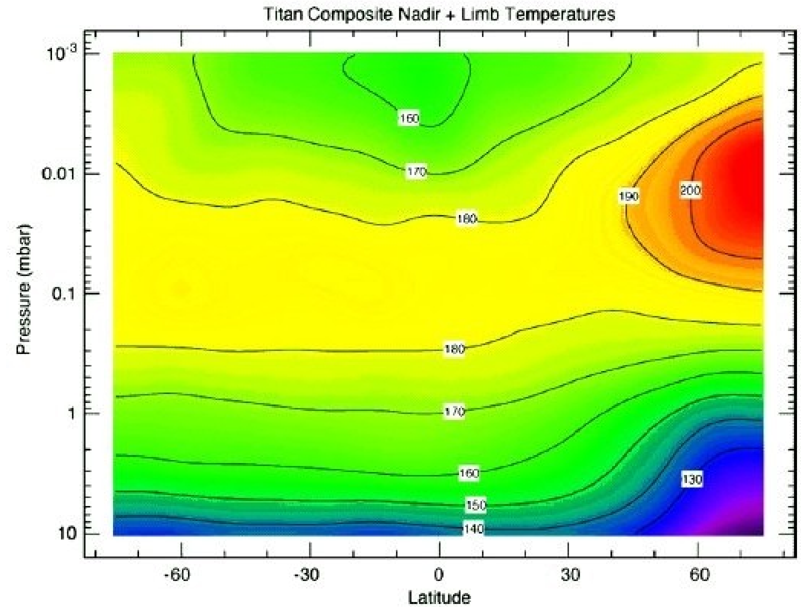


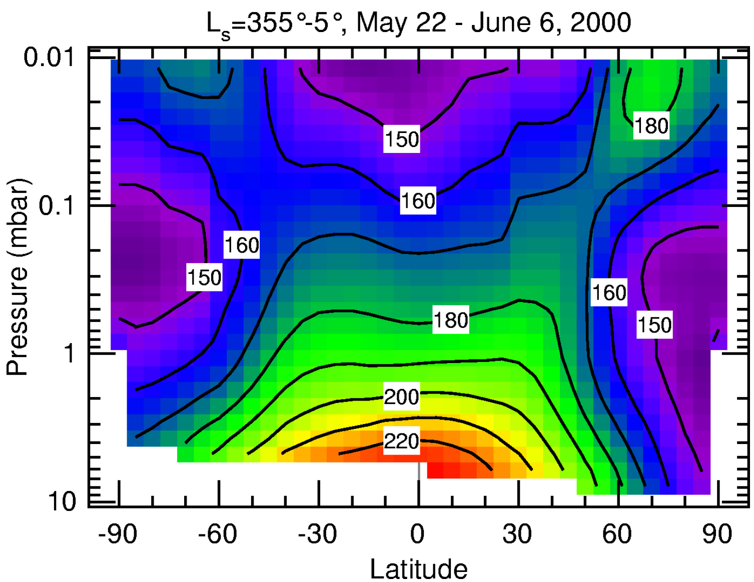
Observed temperature structures

Venus dayside, VeRa/VenusExpress

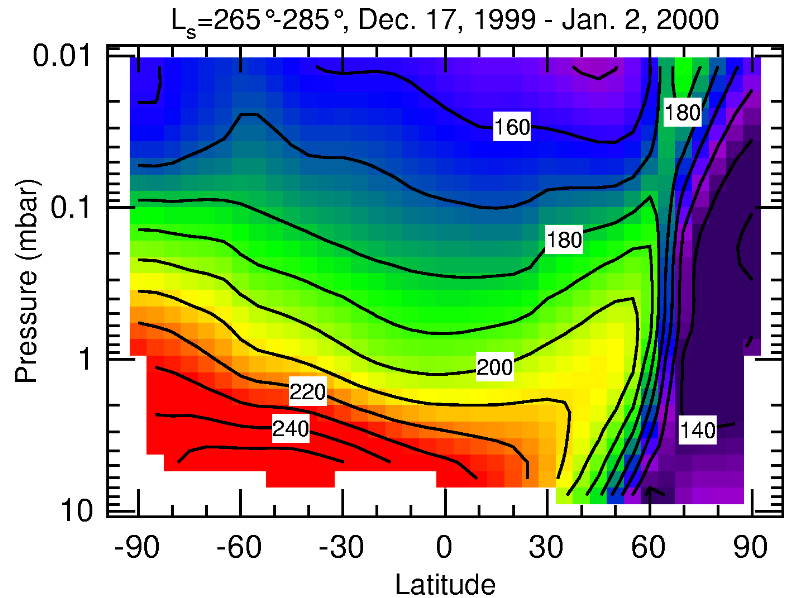


Titan, northern winter, CIRS/Cassini





Mars, N spring equinox, TES/MGS



Mars, N winter solstice, TES/MGS