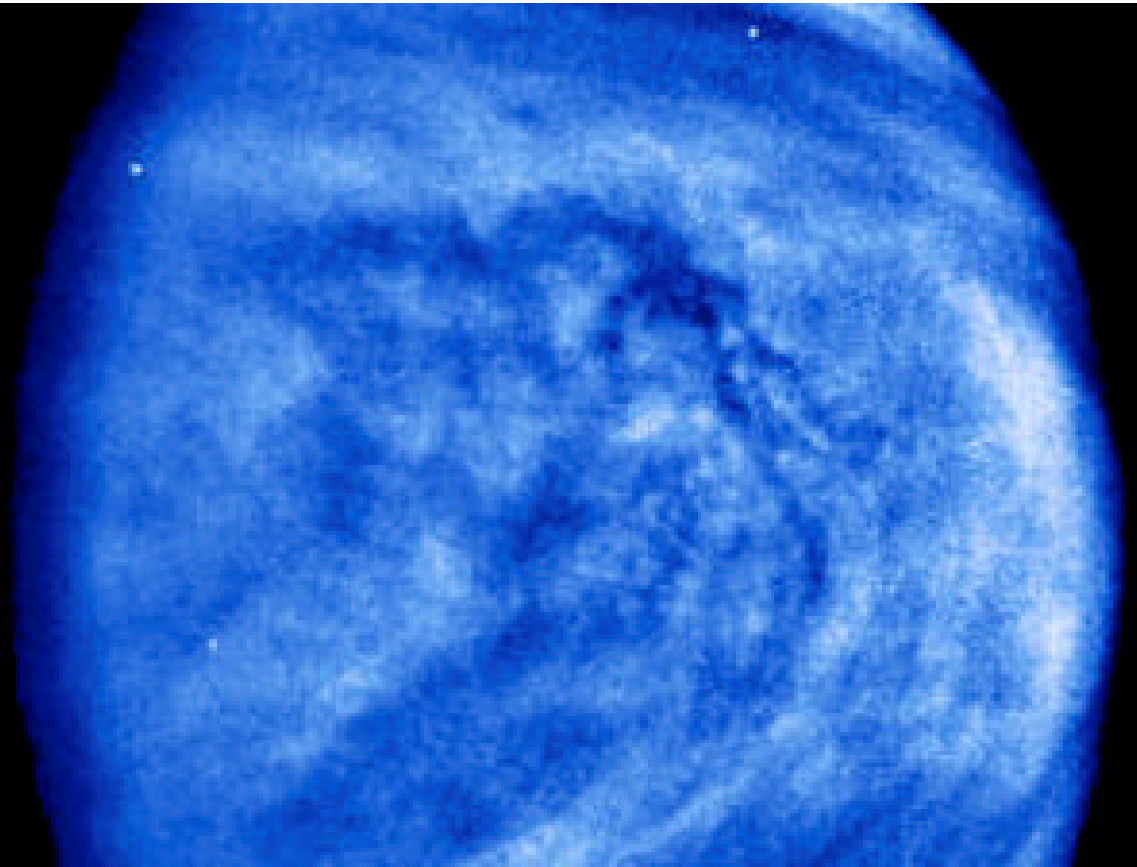
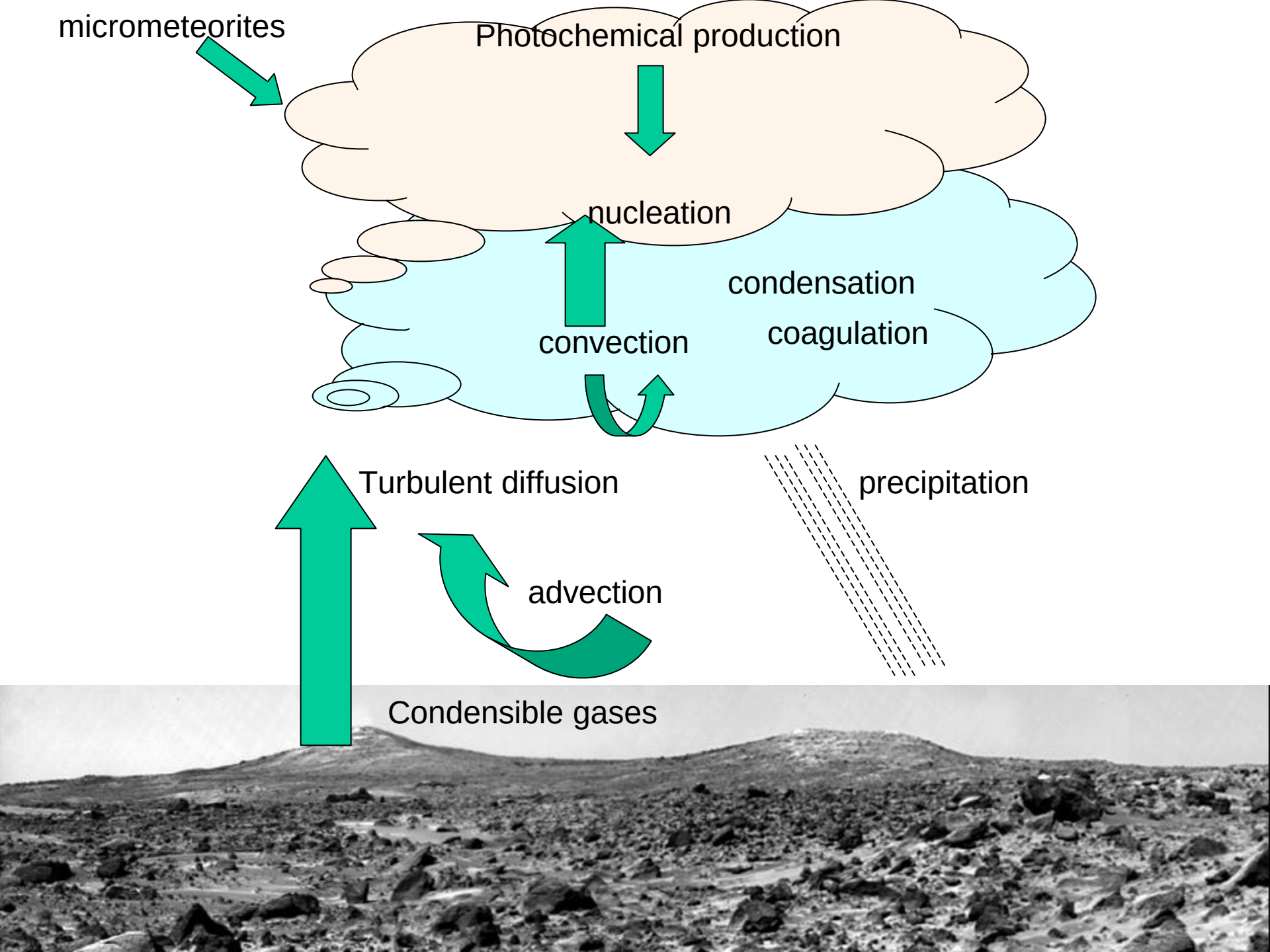
Aerosols in planetary atmospheres

microphysics

dynamics

radiation




micrometeorites
Photochemical production
nucleation
condensation
coagulation
convection
Turbulent diffusion
precipitation
advection
Condensible gases

Aitken cores	10^{-3} -10^{-1} μm
soil weathering products	0.1 -10 μm
crystal clouds (cirruses)	1-50 μm
cloud drops	10-500 μm
raindrops	0.1-10 mm

Homogeneous nucleation

$$J_{\text{hom}} = \frac{1}{r}\left(\frac{2N_A^3 M s}{p}\right)^{1/2}\left(\frac{e_{sat}}{RT}\right)^2 s e^{-\frac{F_{\text{hom}}}{kT}},$$

surviving germs have to be created by fluctuations

$$F_{\text{hom}} = \frac{4\pi a_g^2 s}{3}, \qquad a_g^2 = \frac{2Ms}{RT\rho r \ln(S+1)},$$

Heterogeneous nucleation

$$J_{het} = \frac{4p^2 r^2 Z e_{sat}}{(2p\dot{m}kT)^{1/2}} a_g^2 c_{1,l} e^{-\frac{F_{het}}{kT}},$$

$$F_{het} = \frac{p a_g^2 s}{3} (2+m)(1-m)^2.$$

m is the ratio of surface tension of nucleation core and condensate particle

Condensational growth

$$\frac{dr}{dt} = \frac{S + 1 + A_k}{r} \cdot \frac{e_s DM}{r\,RT}$$

Kelvin correction

$$A_K = \frac{2s\ M}{RT\ r\ r}$$

Coagulation

*Loss of particle **a** by collision with any other*

*Birth of particle **a** by coalescence of any pair **x** and **a-x***

$$\frac{\partial f(a)}{\partial t} = -\int_0^{\infty} K_b(a,x)\, f(a)\, f(x) dx + \frac{1}{2}\int_0^{a} K_c(x, a-x)\, f(x)\, f(a-x)\, dx.$$

For Brownian coagulation $K(r_1, r_2) = \dfrac{2kTa(r_1 + r_2)(r_1^{\,2} + r_2^{\,2})}{r_1^{\,2} r_2^{\,2}}$

Smoluchowsky iterative solution: *K~r*

$$f_k = \frac{t^{k-1}}{(t+1)^{k+1}}, t = 8pDrn_0 t.$$

Analytical solutions are also known for

$$K(r_1, r_2) = A + B(r_1 + r_2) + Cr_1 r_2$$

The case $K(r_1, r_2) \sim r_1^{\,l} r_2^{\,l}, \quad l > 1$

results in runaway coagulation

Final continuity equation

$$\frac{\partial n}{\partial t} = -\nabla\left(n(\mathbf{v}+\mathbf{u})\right) - \frac{\partial}{\partial r}\left(n\dot{r}\right) + \nabla\left(Kr\,\nabla\frac{n}{r} \right) + Q^{+}{}_{n} + Q_c - Q_b - Q^{-}{}_{n},$$

Sedimentation & advection

Condensation & sublimation

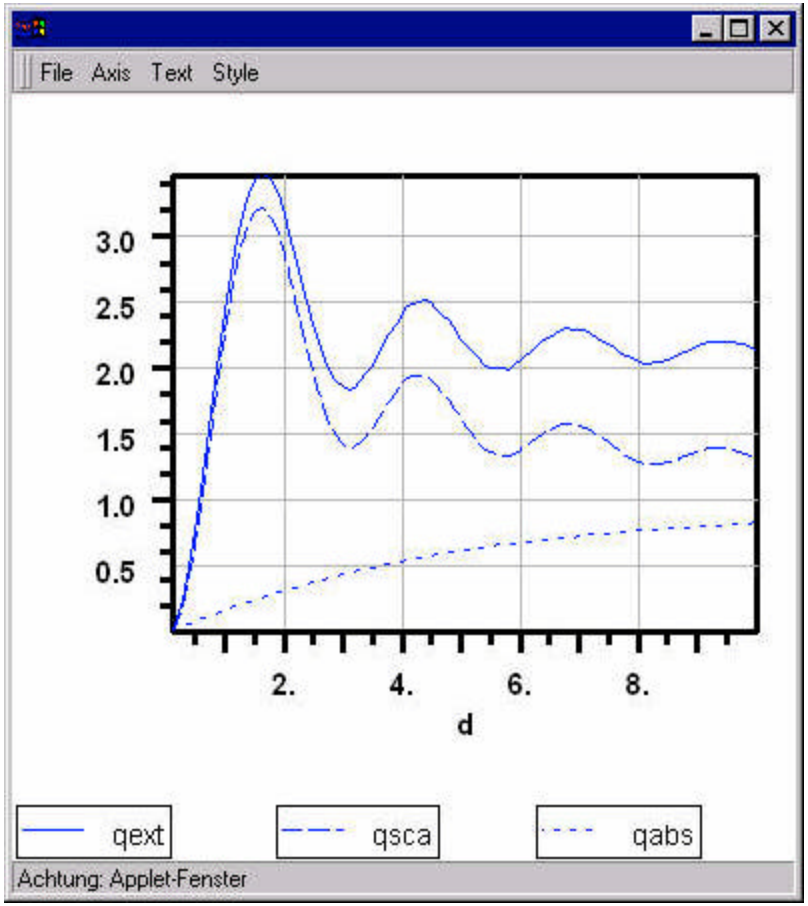
Eddy diffusion

$t_{cond} \sim 1\text{-}10^5\ s$

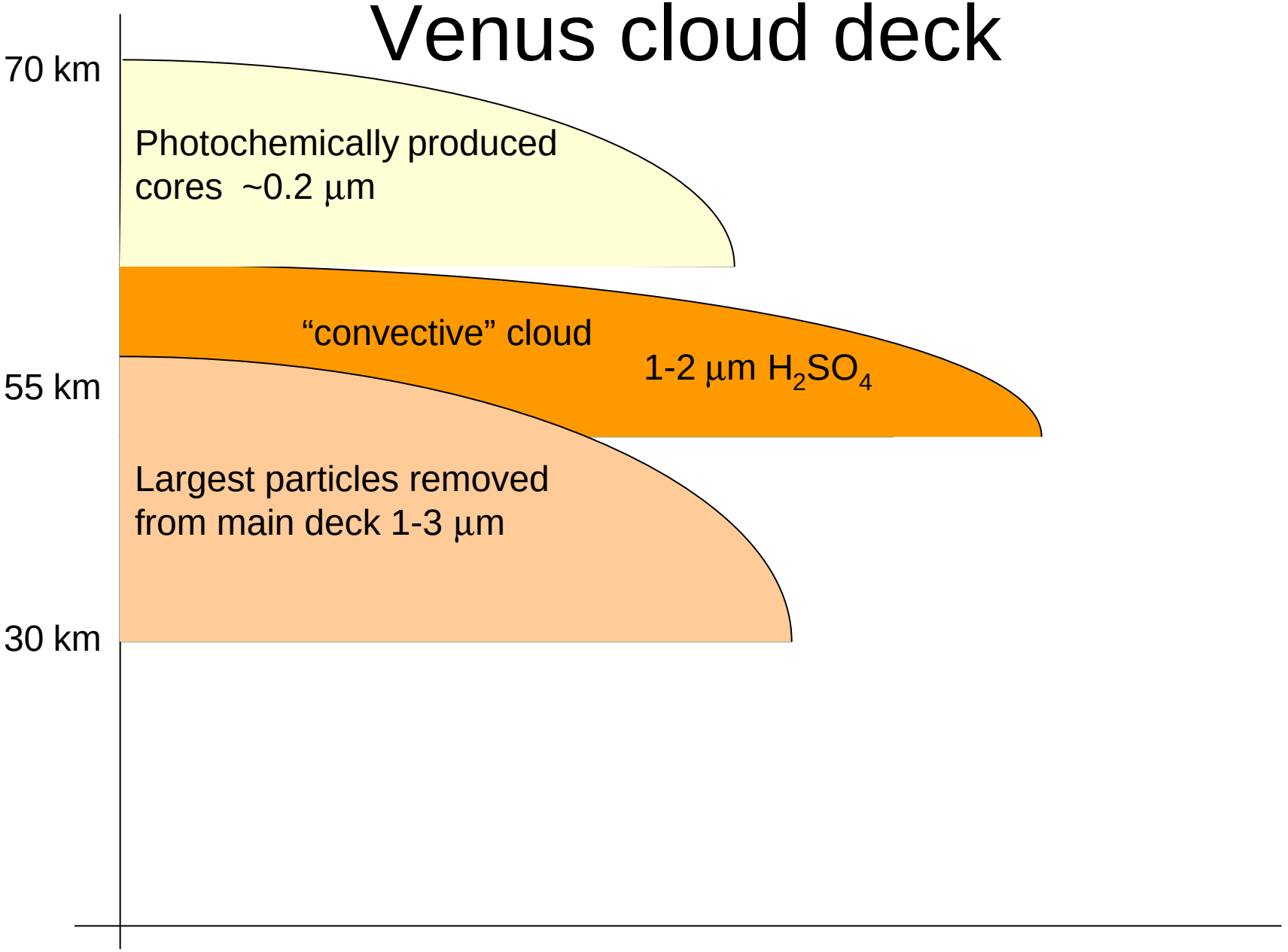
$t_{adv} \sim 10^5\text{-}10^6 s$

$t_{diff} \sim 10^6\text{-}10^8 s$

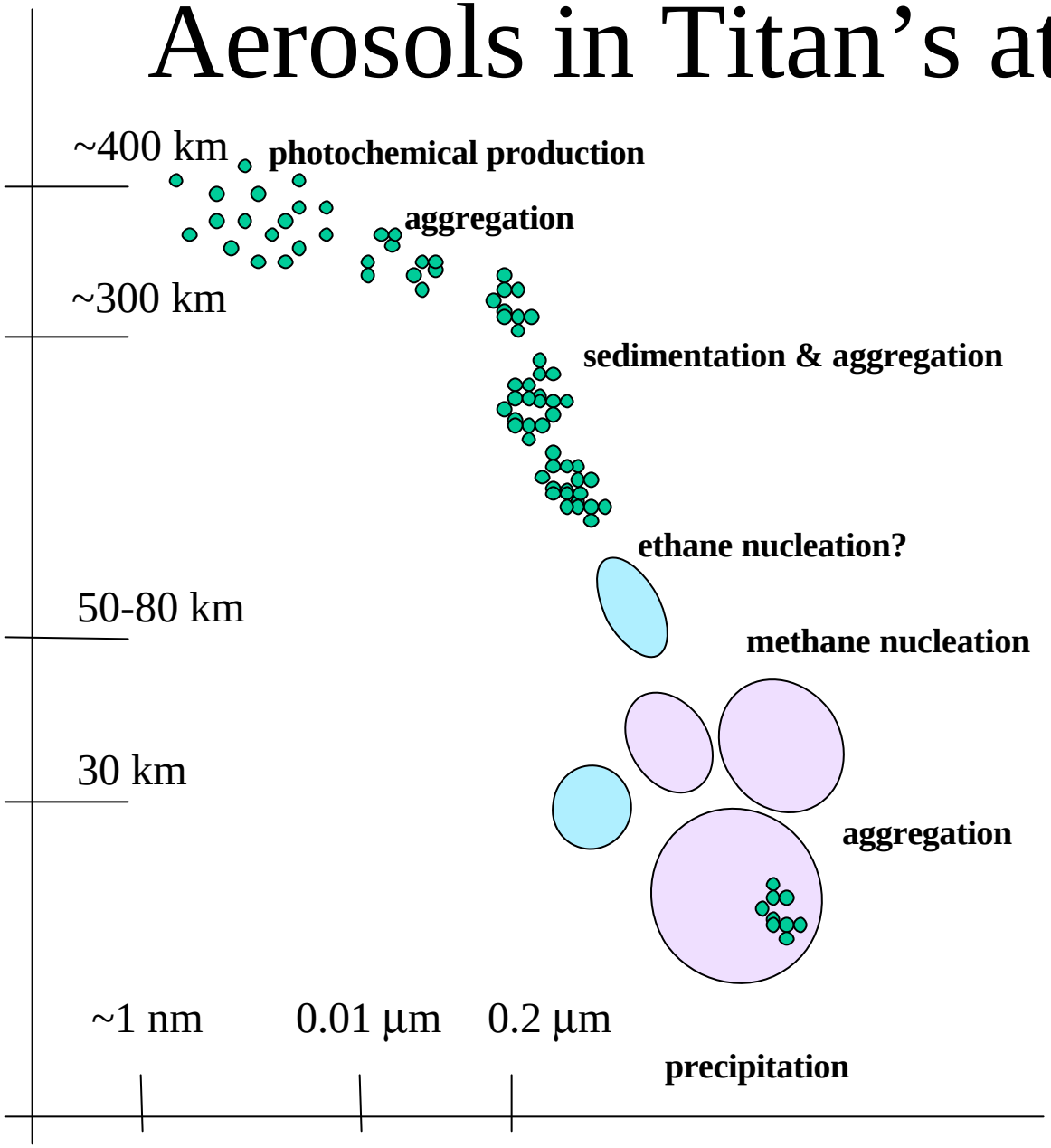
Light scattering by spherical particles: Mie theory



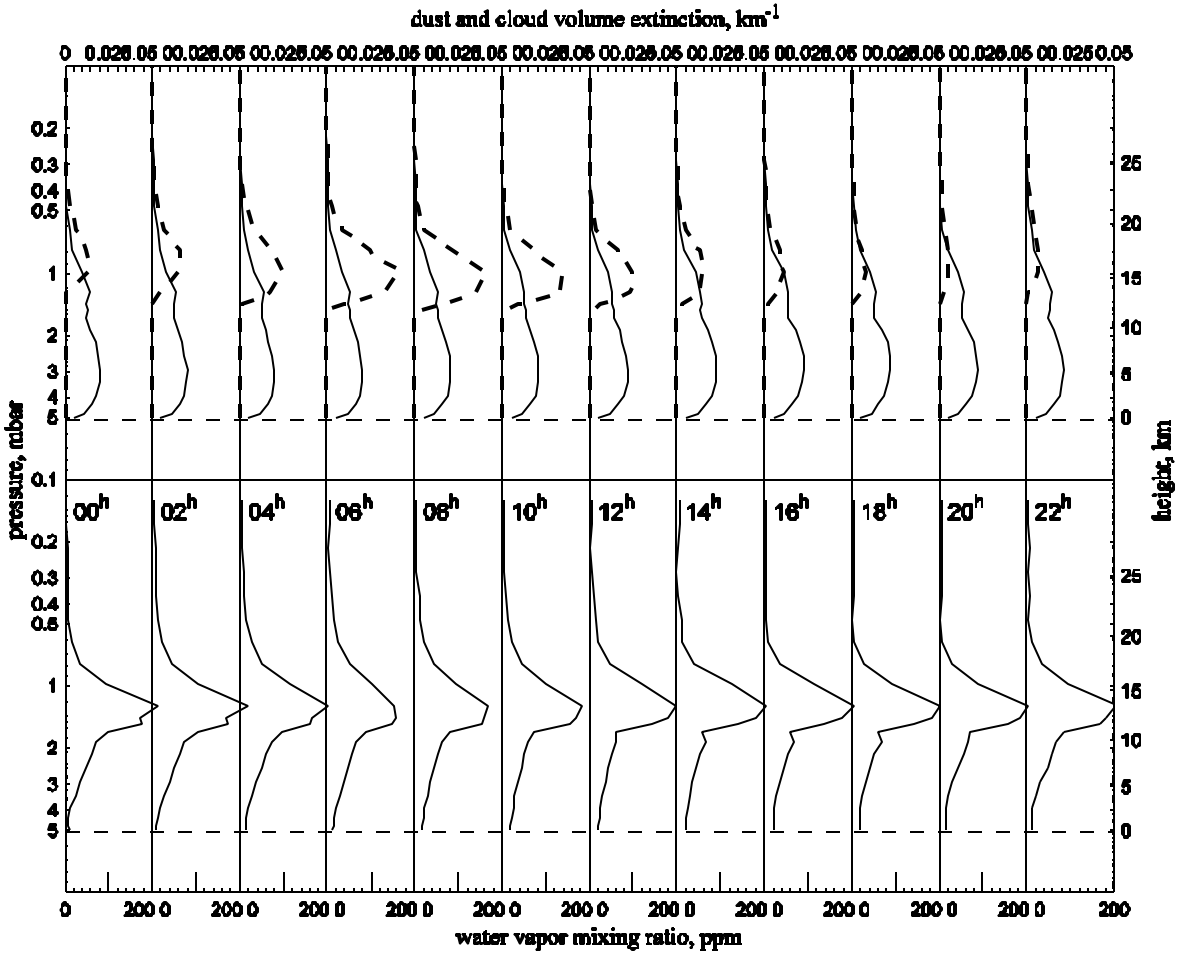
Venus cloud deck



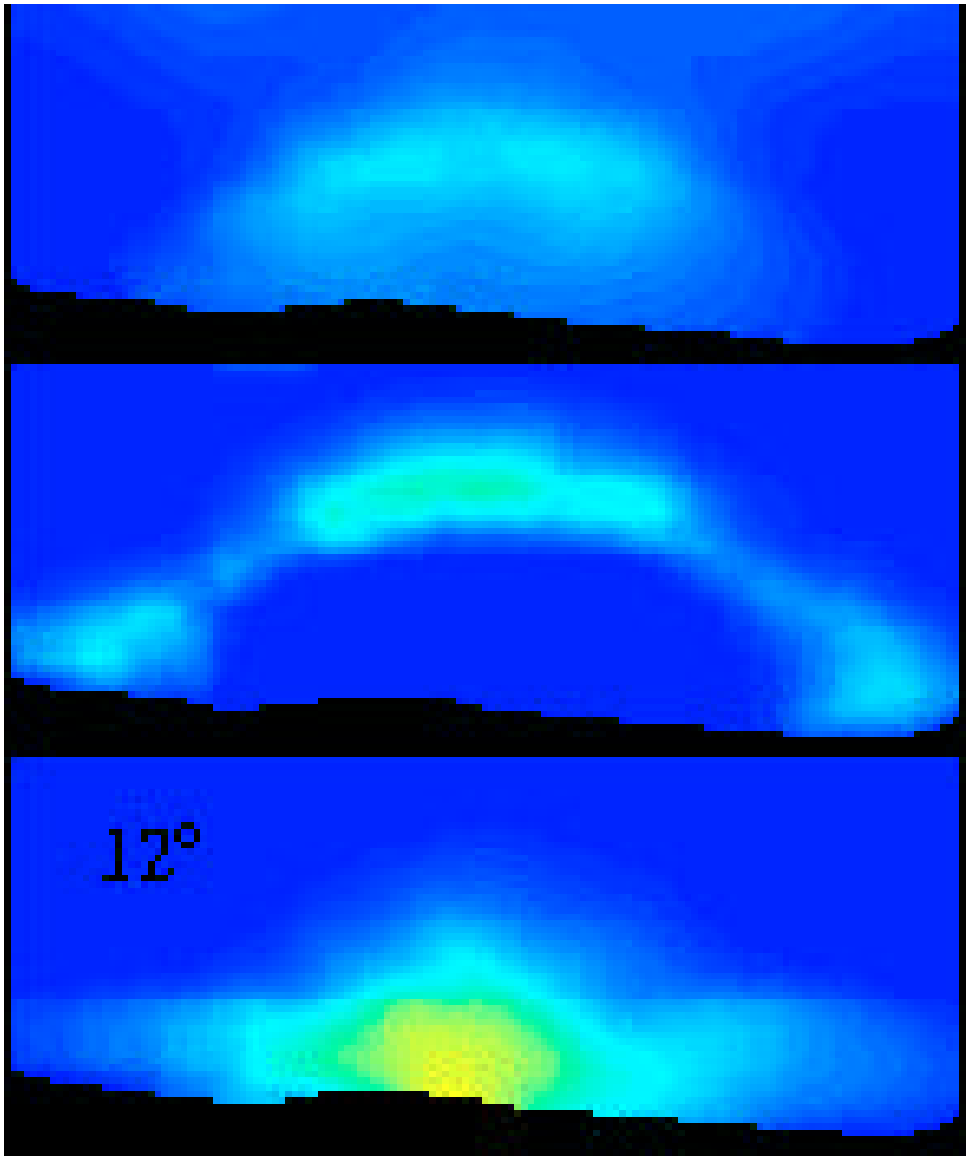
Aerosols in Titan's atmosphere



Diurnal cycle of Martian aerosols



Seasonal evolution of Martian global-scale clouds



water vapor

water ice clouds

dust