Atmospheric aerosols properties via solar infrared occultation observations by SPICAM IR

mars express

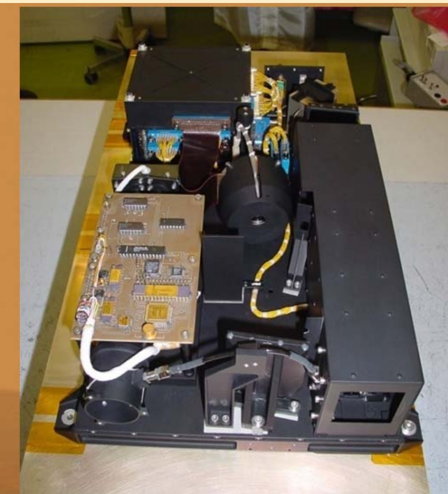
ИКИ
ИНСТИТУТ
КОСМИЧЕСКИХ
ИССЛЕДОВАНИЙ
РАН

Scientific Workshop:
“From Mars Express to ExoMars”
27–28 February 2018,
ESAC Madrid, Spain

ACS Atmospheric Chemistry Suite

D.S. Betsis, A.A. Fedorova, O.I. Korablev,
J.L. Bertaux, F. Montmessin, F. Lefevre
Space Research Institute (IKI), Moscow, Russia, CNRS
LATMOS, Guyancourt, France

SPICAM IR



Infrared spectrometer

- Spectral range : 1-1.7 µm
- Spectral resolution : ≈ 3.5–4 cm^{-1}
- Employing an Acousto-Optic Tunable Filter (AOTF)
- Resolving power :

  from 1800 at 1.6 µm to 2400 at 1.1 µm
- Objects of interest :

  gaseous CO_2 (absorption bands in the range of 1.4–1.65 µm), O_2

  gaseous H_2O (in the 1.37 µm band),

  aerosols (mineral dust and H_2O ice).

- Launch - July 2003,
- Start of scientific operations – 2004

Spacecraft to limb distance

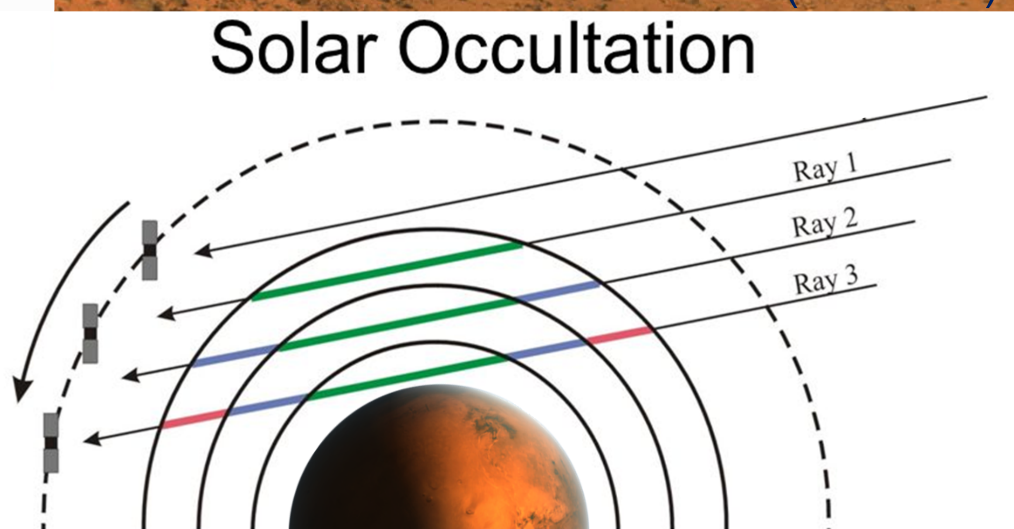
from 1000 to 13000 km

Vertical resolution

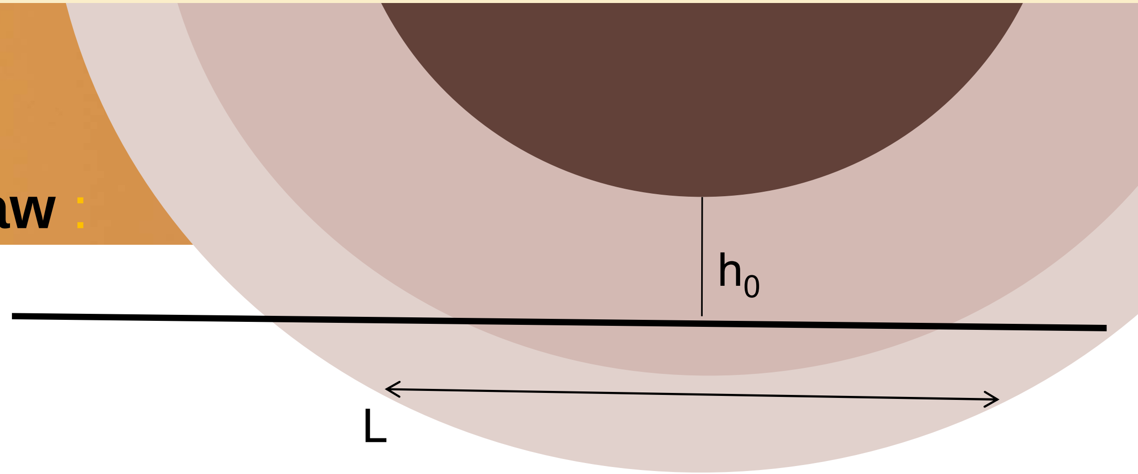
4–5 km (varies from 1 to 12 km)

Field of view

4.2 arc min (1.2 mrad)



Data retrieval



Beer–Lambert–Bouguer law :

$$I(l) = I_0 e^{-k_\lambda l}$$

$$\tau_\lambda(L) = 2\int_{h_0}^{\infty} k_\lambda(l)\,dl$$

$$\tau_\lambda(L) = -\ln\left(I_\lambda(L)/I_0\right)$$

$$r_{\text{eff}} = r_g \exp\left(\frac{5}{2}\ln^2\sigma_g\right)$$

$$\nu_{\text{eff}} = \exp\left(\ln^2\sigma_g\right) - 1$$

At each altitude layer:

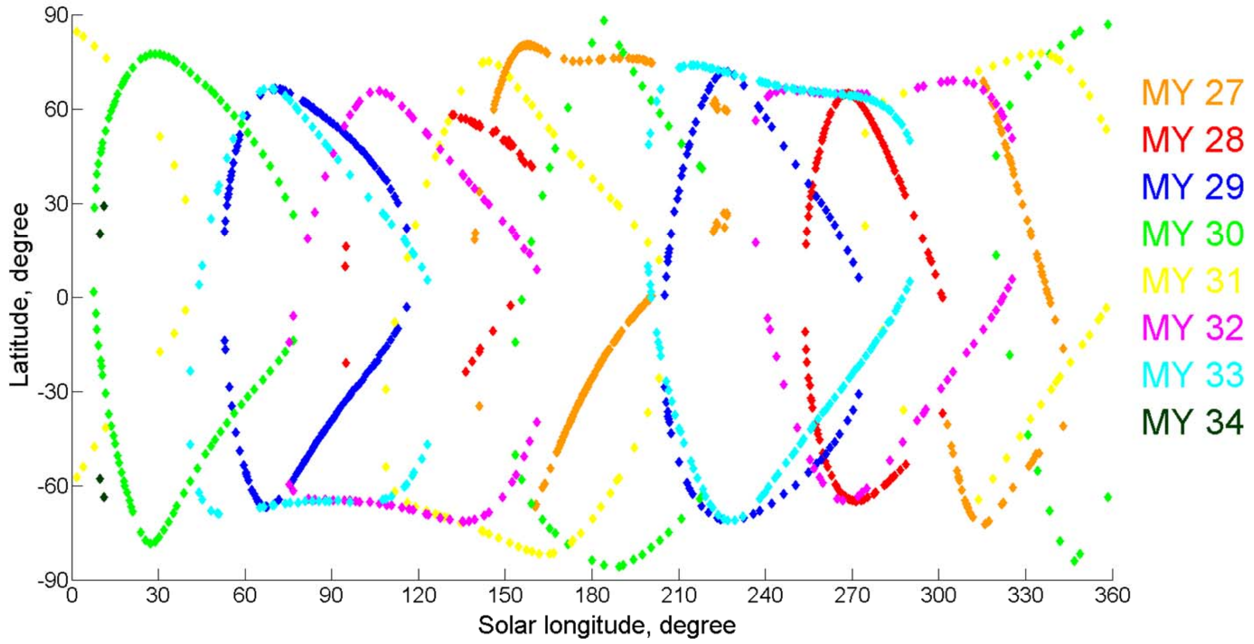
$$k_{\text{ext}}(\lambda, z) = \int_0^{\infty} \sigma_{\text{ext}}(r, z)\,n(r, z)\,dr$$

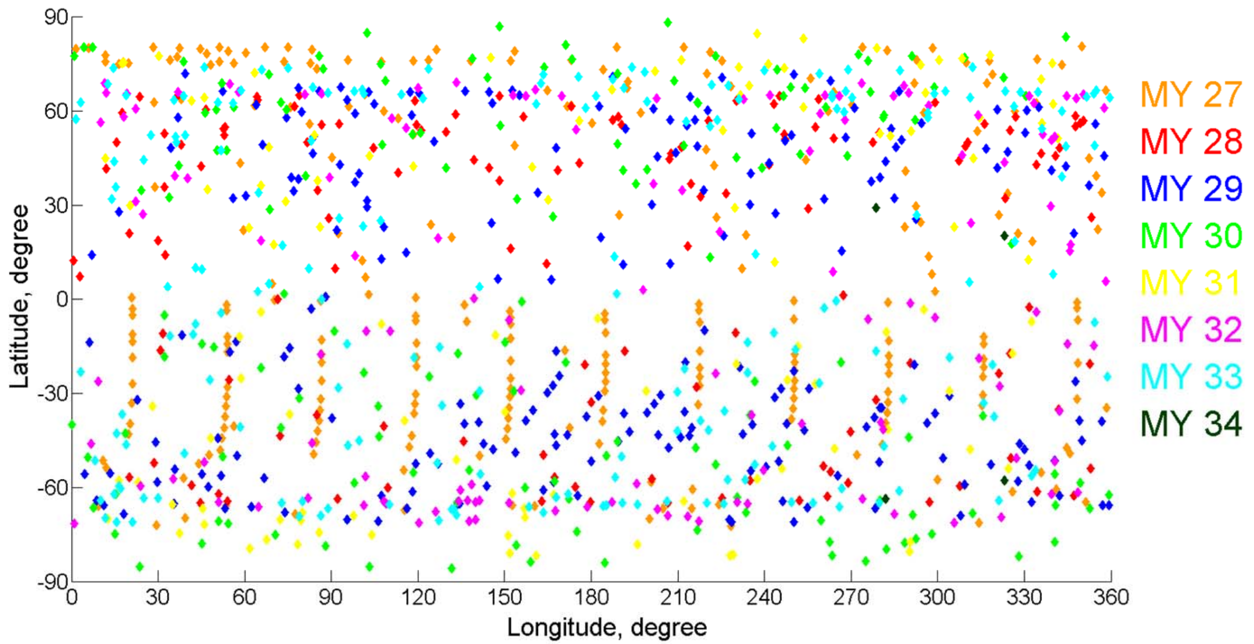
Number density:

$$N(z) = \frac{k_{\text{ext}}(z)}{\int_0^{\infty} \pi r^2 Q_{\text{ext}}(\lambda, z)\,n(r, z)\,dr}$$

Size distribution:

$$n(r) = \text{const} \times r^{-1} \exp\left(-\frac{(\ln r - \ln r_g)^2}{2\ln^2\sigma_g}\right)$$





Coverage and distribution of observations

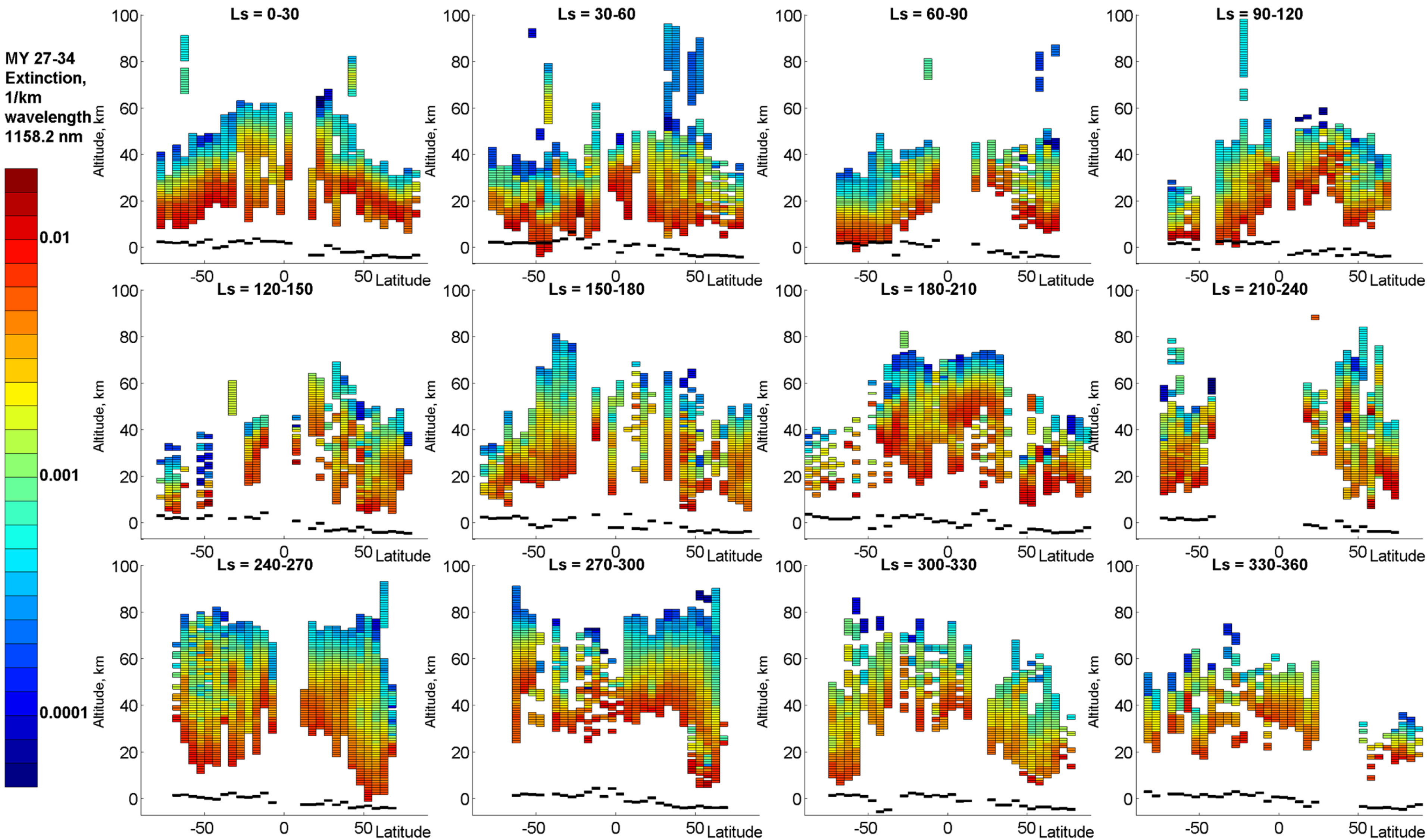
- **Seasonal**

- **Spatial**

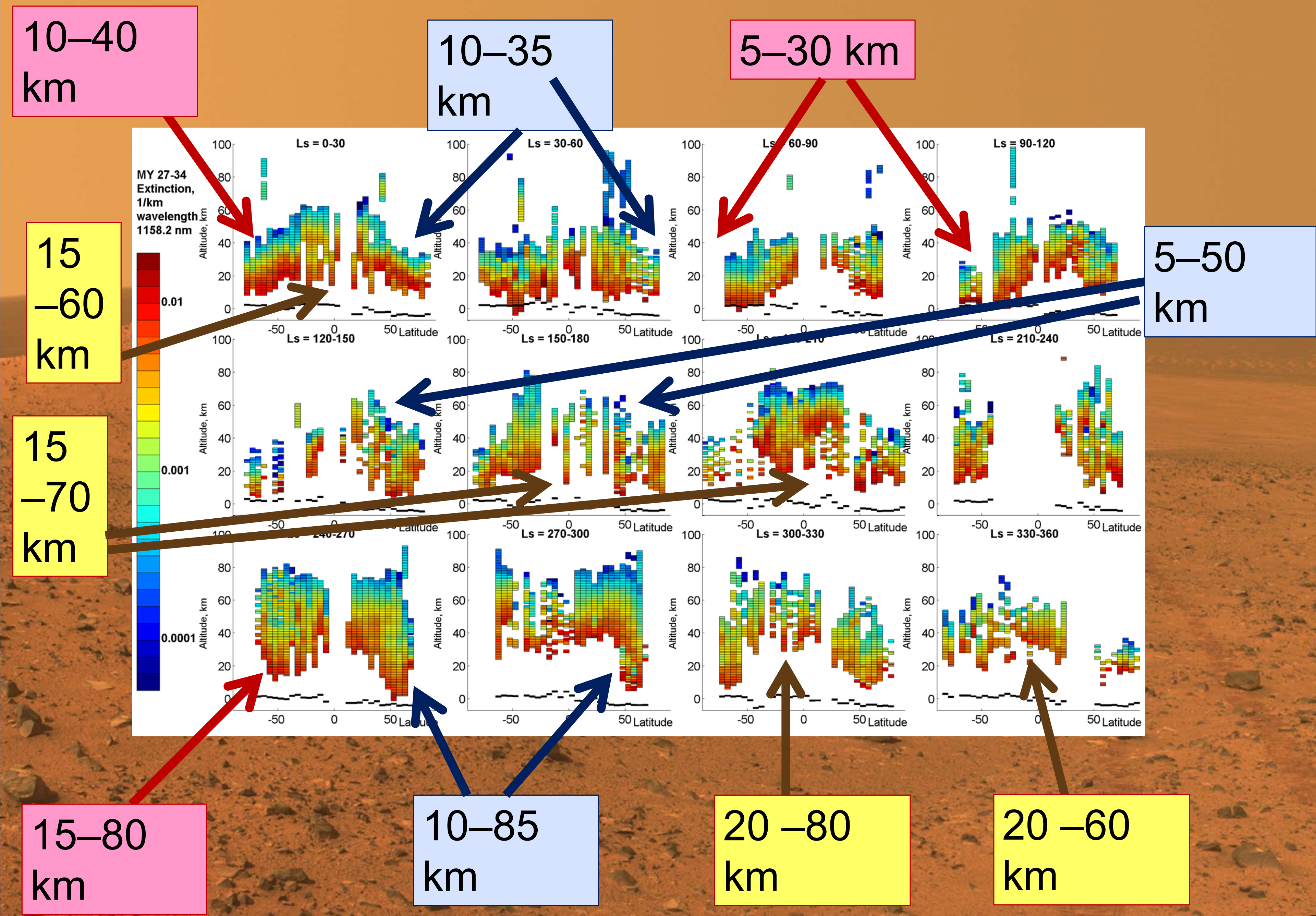
Since January 2005 – till now

Extinction coefficient

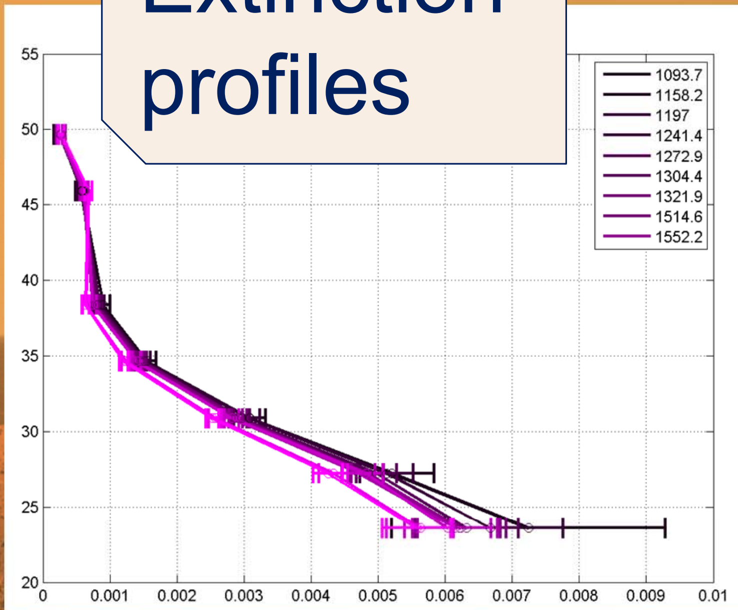
Seasonal and altitudinal dependence summarized and averaged over 7 Martian years

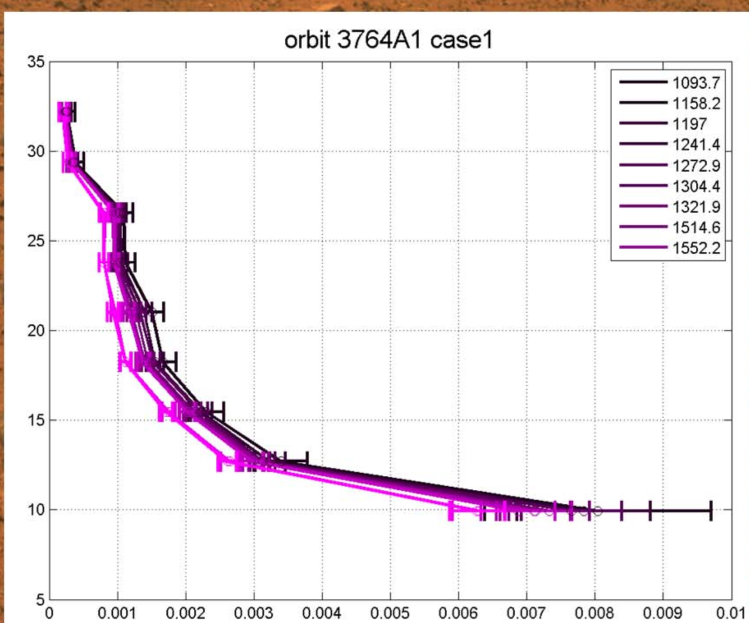


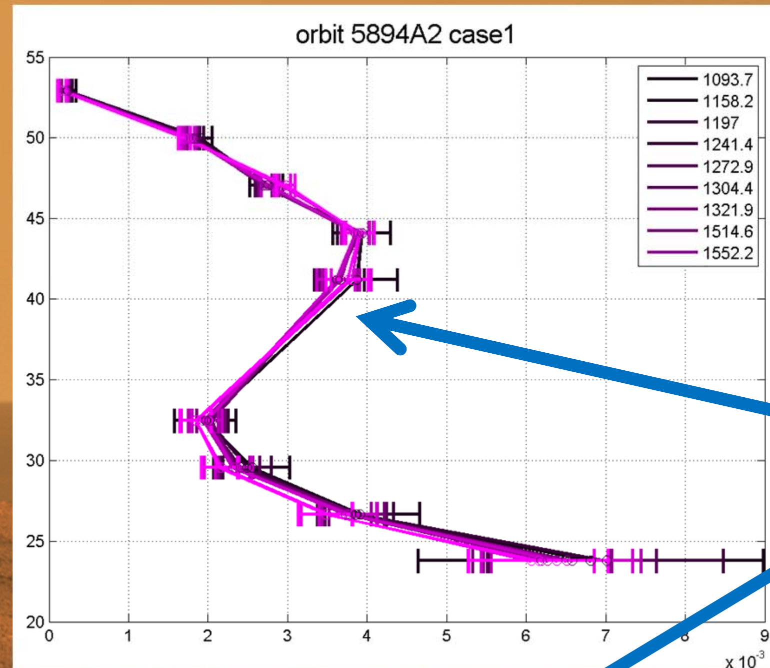
Where can we observe

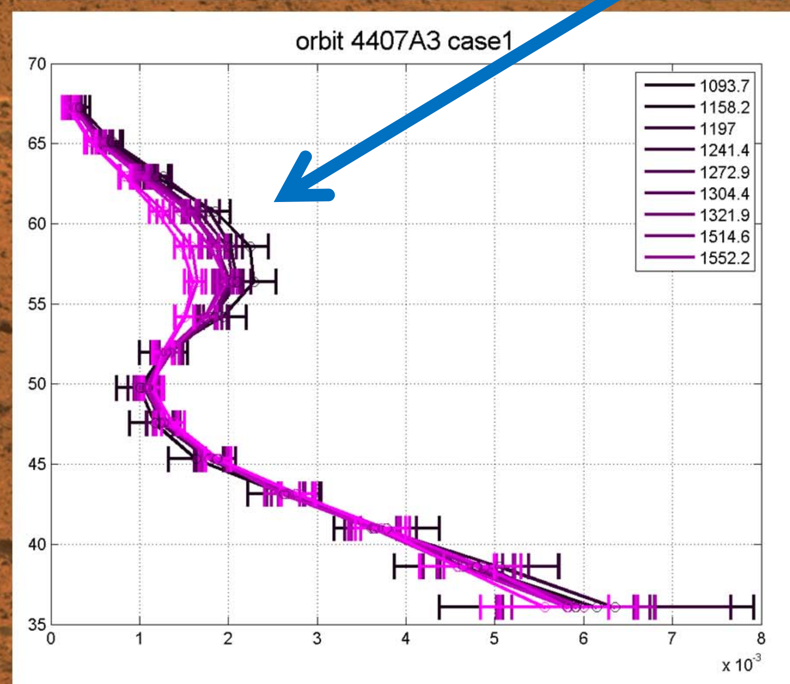


Extinction profiles



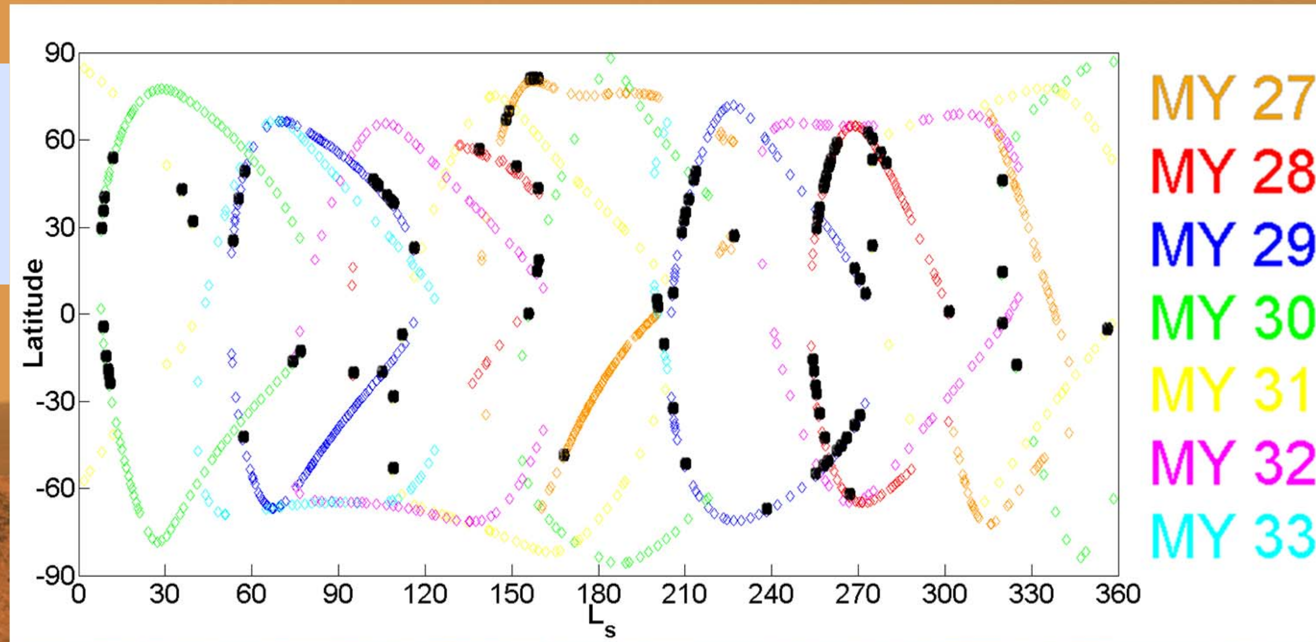


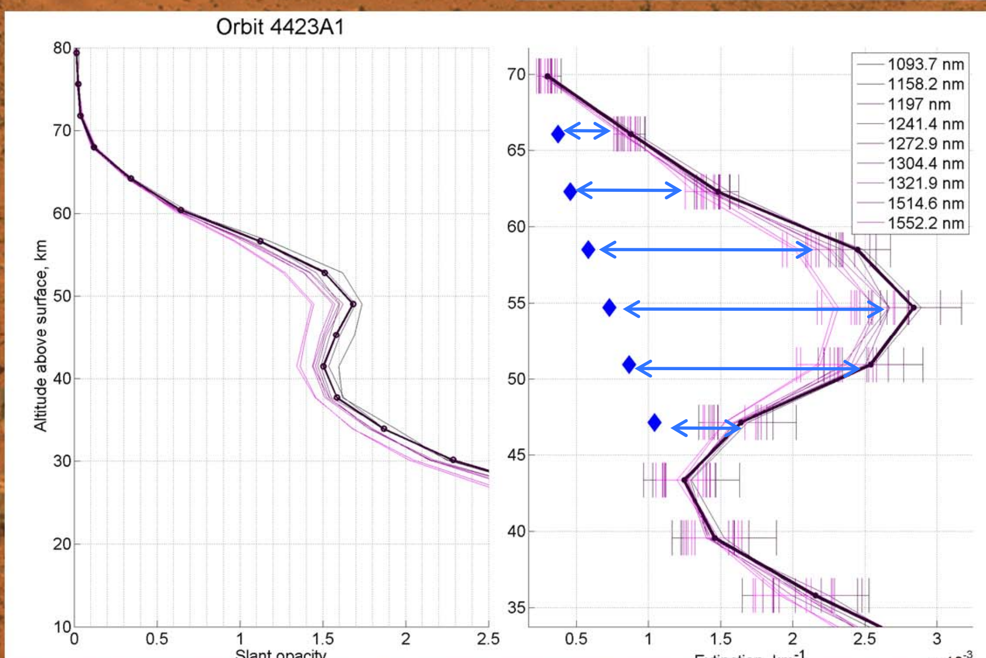




Water ice clouds

Water ice clouds





Particle sizes	0.8 – 1.4 µm
Opacity	0.002– 0.08
Altitudes	30 – 60 km

Mostly the **size distribution** is narrow

ν_{eff} = 0.1 – 0.3

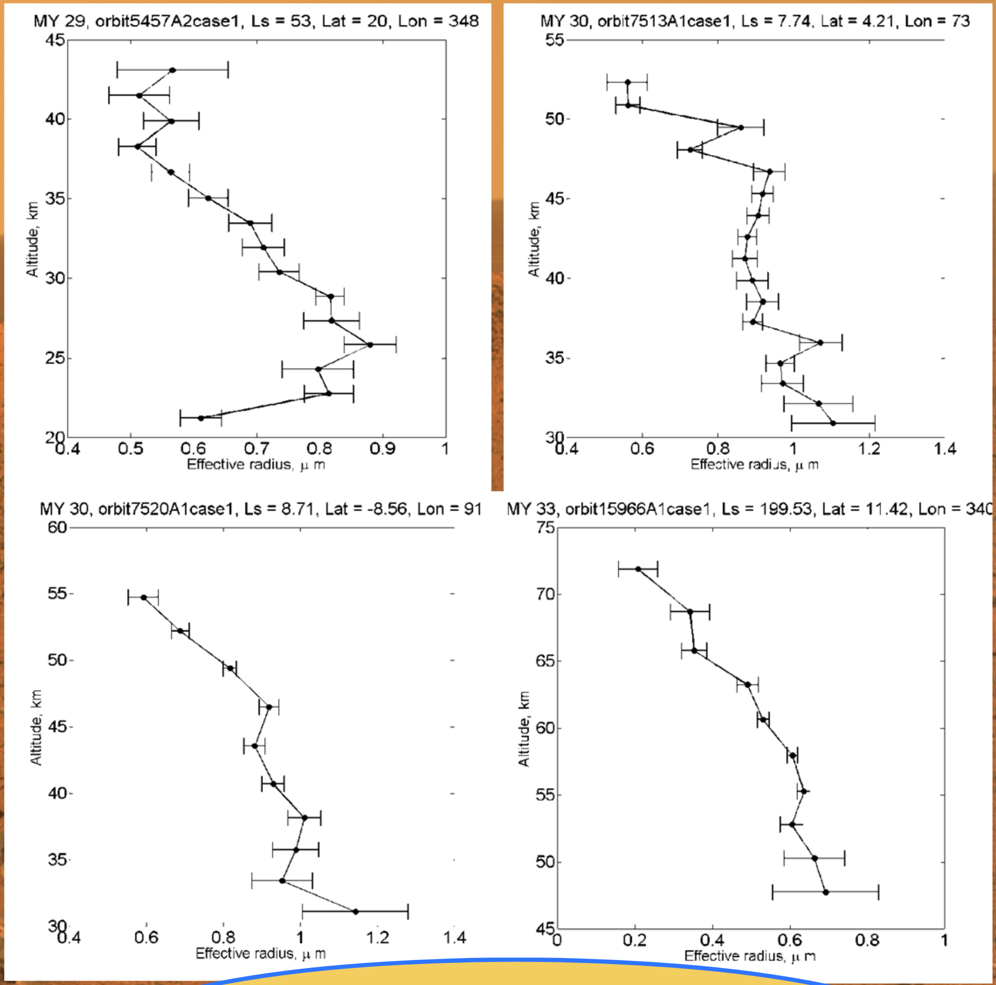
Refractive indices for water ice are taken from:

Warren, S.G., Brandt, R.E., 2008. **Optical constants of ice from the ultraviolet to the microwave: A revised compilation**. J. Geophys. Res. 113, D14220. http://dx.doi.org/10.1029/2007JD009744

Size distribution: effective radius

$$n(r) = \frac{Const}{r} \cdot \exp\left(-\frac{(\ln r - \ln r_g)^2}{2\ln^2 \sigma_g} \right)$$

$$r_{eff} = r_g \exp\left(\frac{5}{2} \ln^2 \sigma_g \right)$$



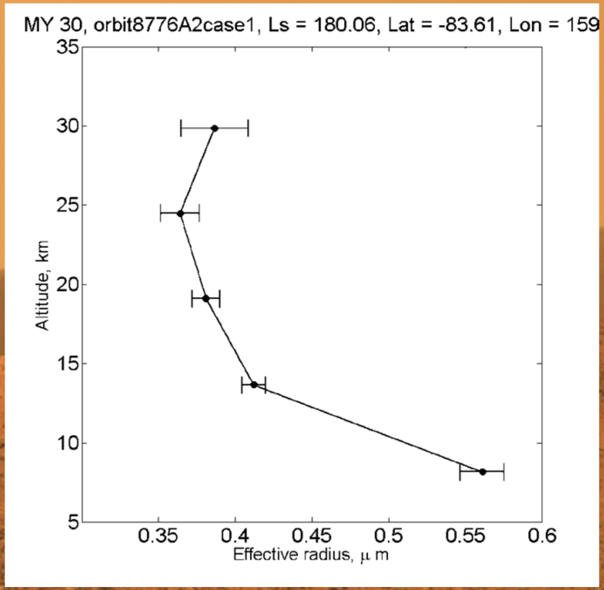
Samples of profiles at low latitudes: particles ~ 1 μm

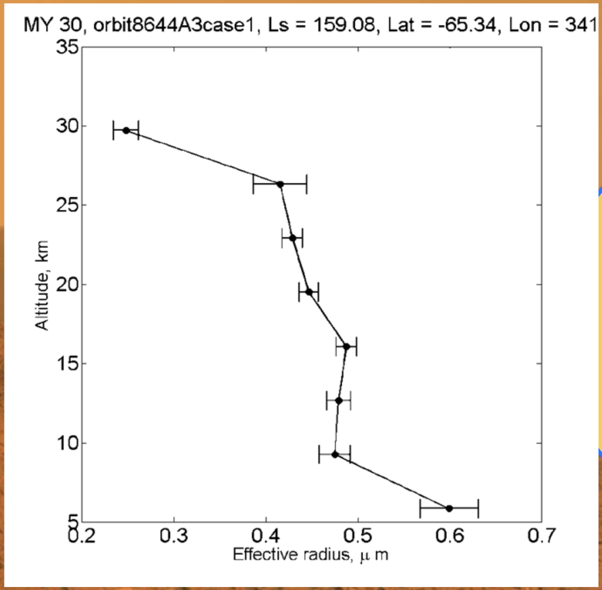
The method is described in detail in:
Fedorova, A.A., Korablev, O.I., Bertaux, J.-L., Rodin, A.V., Montmessin, F., Belyaev, D.A., Reberac, A., 2009. ***Solar infrared occultations by the SPICAM experiment on Mars Express: Simultaneous observations of H_2O, CO_2 and aerosol vertical distribution****. Icarus, 200 (1), 96–117. DOI: http://dx.doi.org/10.1016/j.icarus.2008.11.006*

Calculation algorithm:
Mishchenko, M.I., Dlugach, J.M., Yanovitskij, E.G., Zakharova, N.T., 1999. ***Bidirectional reflectance of flat, optically thick particulate laters: And efficient radiative transfer solution and applications to snow and soil surfaces****. Journal of Quantitative Spectroscopy and Radiative Transfer, 63, 409–432. DOI: http://dx.doi.org/10.1016/S0022-4073(99)00028-X*

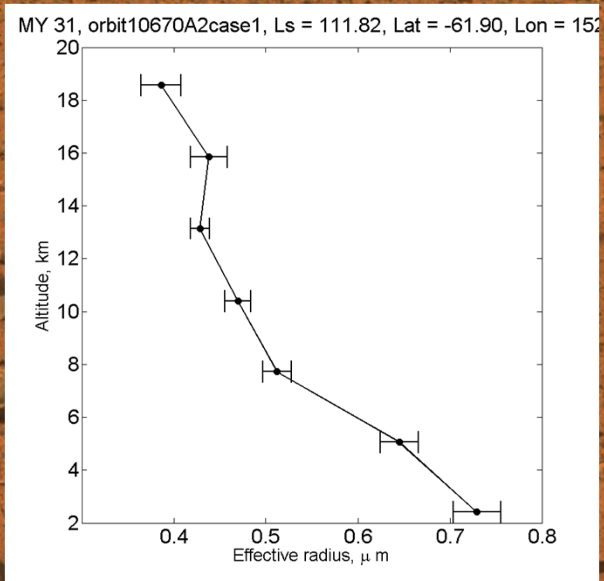
Refractive indices for mineral dust are taken from:
Wolff, M.J. et al., 2009. ***Wavelength dependence of dust aerosol single scattering albedo as observed by the Compact Reconnaissance Imaging Spectrometer****. J. Geophys. Res. 114, E00D04. DOI: http://dx.doi.org/10.1029/2009JE003350*

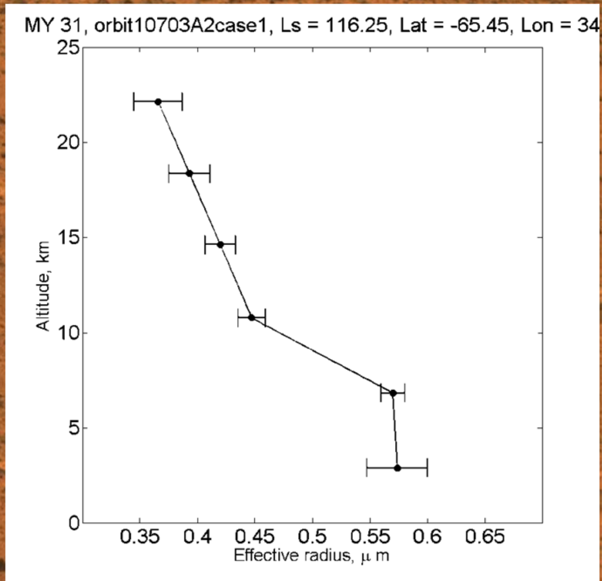
Size distribution: effective radius

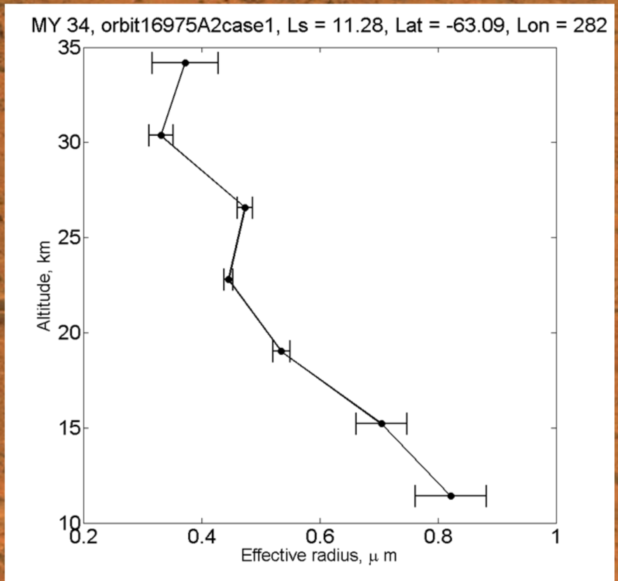




Samples of profiles at high latitudes in the Southern hemisphere during the Southern winter (**calm season**): particles ~0.3–0.7 µm



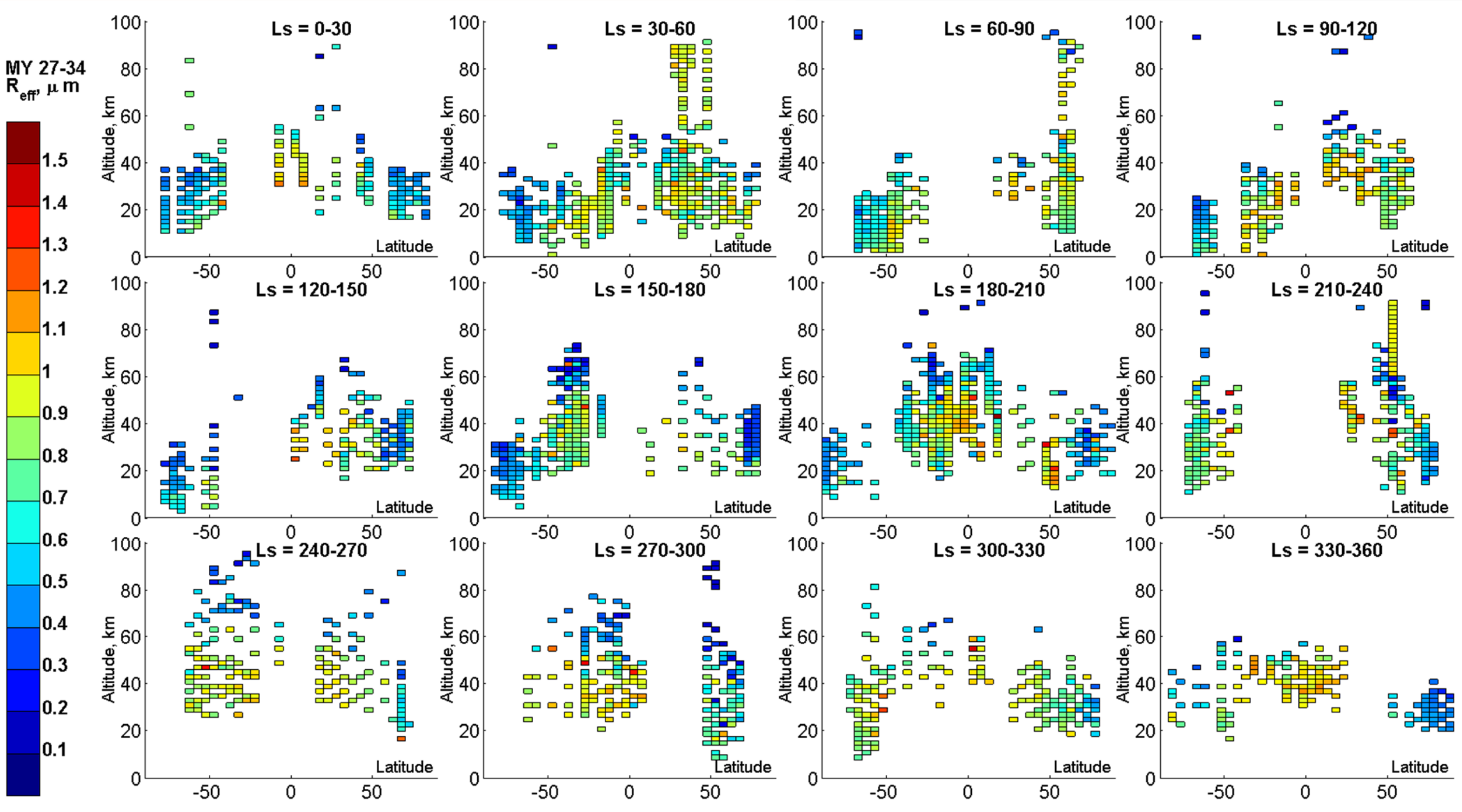




Size distribution: effective radius

$$n(r) = \frac{Const}{r} \cdot \exp\left(-\frac{(\ln r - \ln r_g)^2}{2\ln^2 \sigma_g} \right)$$

$$r_{eff} = r_g \exp\left(\frac{5}{2} \ln^2 \sigma_g \right)$$

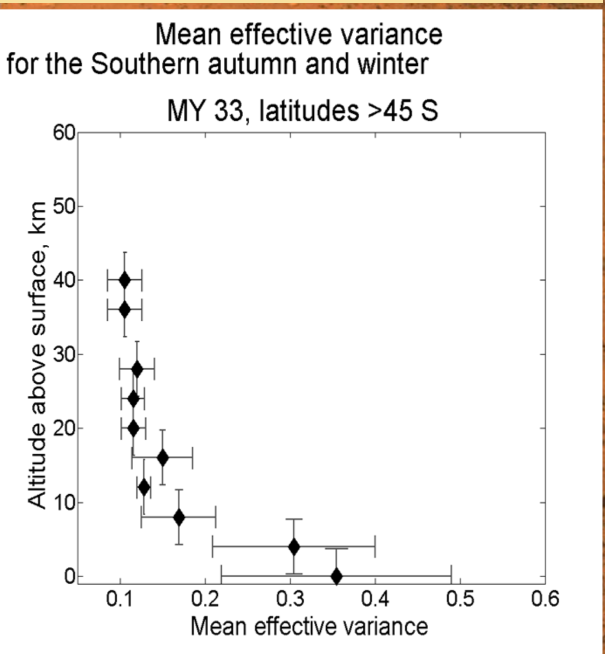


Size distribution: effective variance

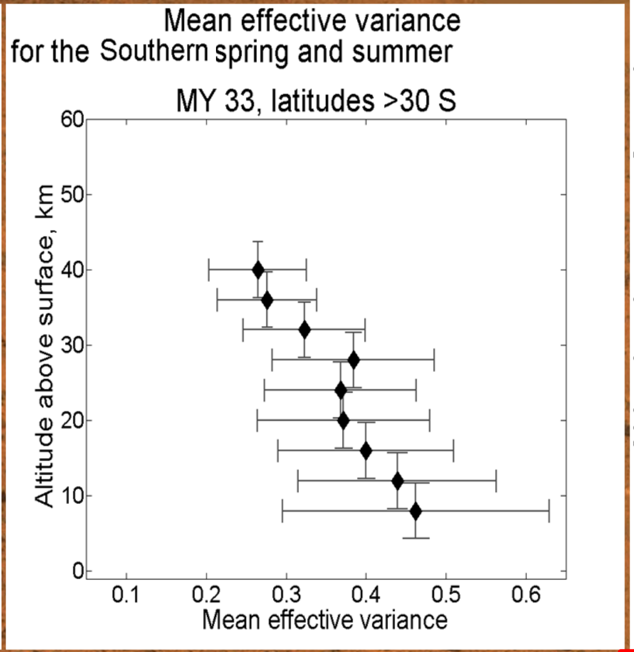
$$n(r) = \frac{Const}{r} \cdot \exp\left(-\frac{(\ln r - \ln r_g)^2}{2\ln^2 \sigma_g} \right)$$

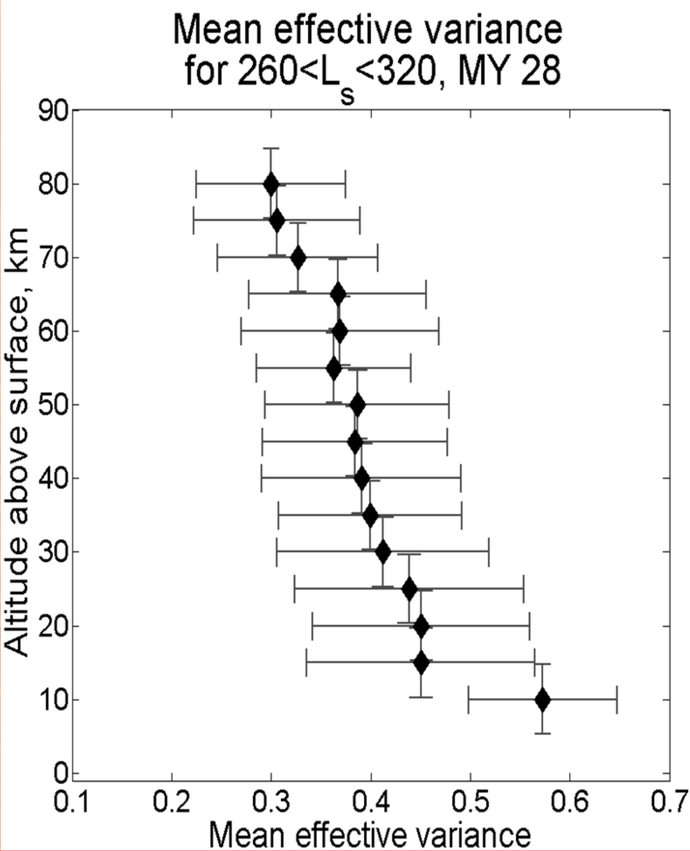
$$\nu_{eff} = \exp\left(\ln^2 \sigma_g\right) - 1$$

High latitudes in the Southern hemisphere,
Southern autumn and winter
(**calm season**)



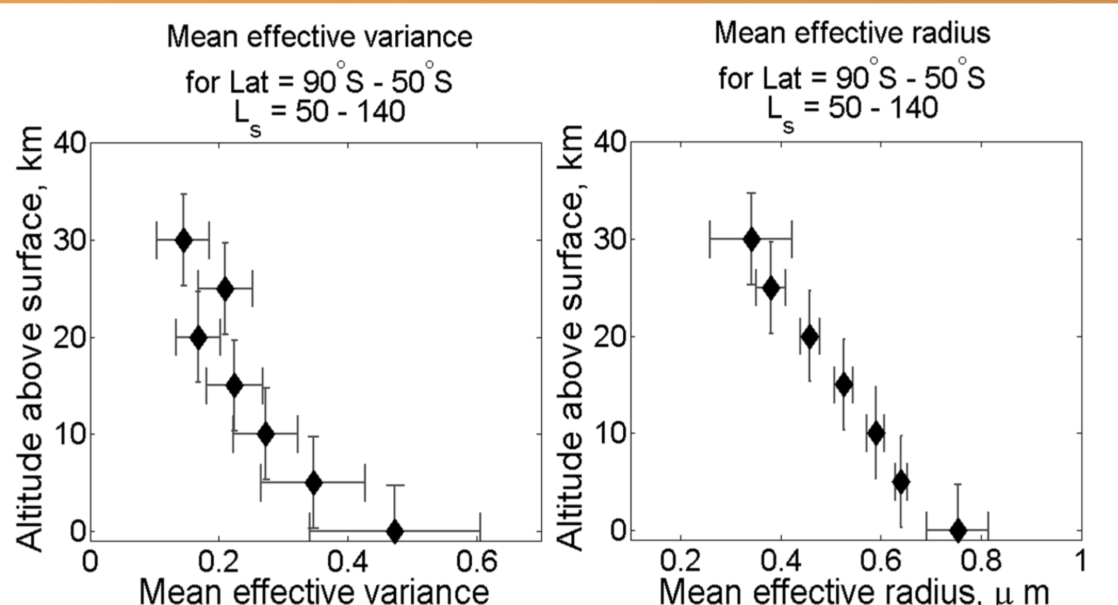
High and middle latitudes in the Southern hemisphere,
Southern spring and summer
(**dust season**)





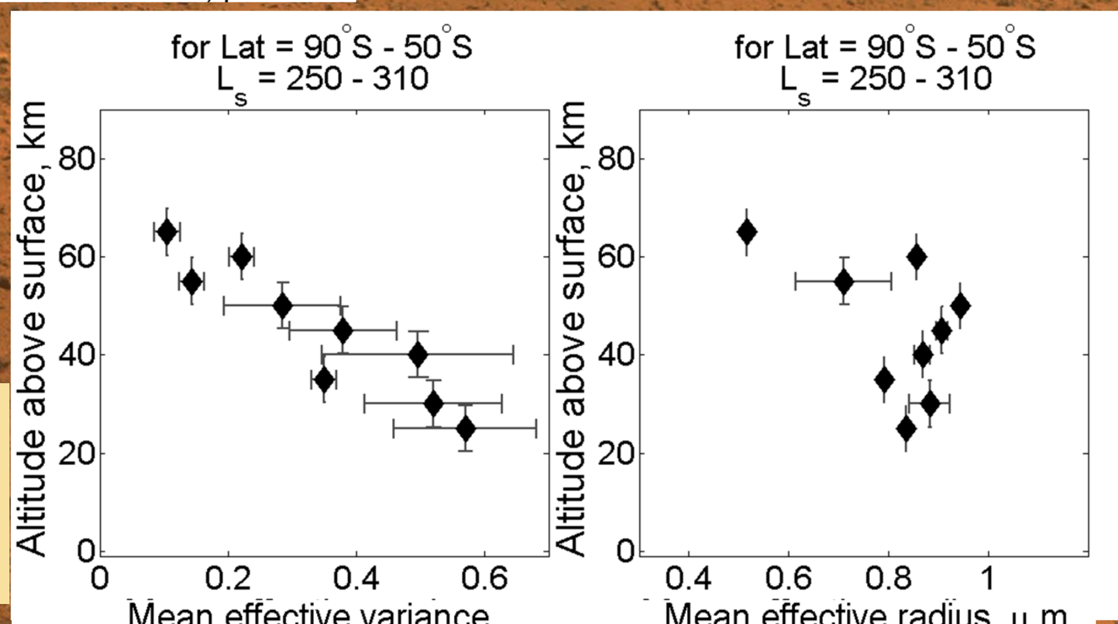
Global dust storm 28 Martian Year

Size distribution

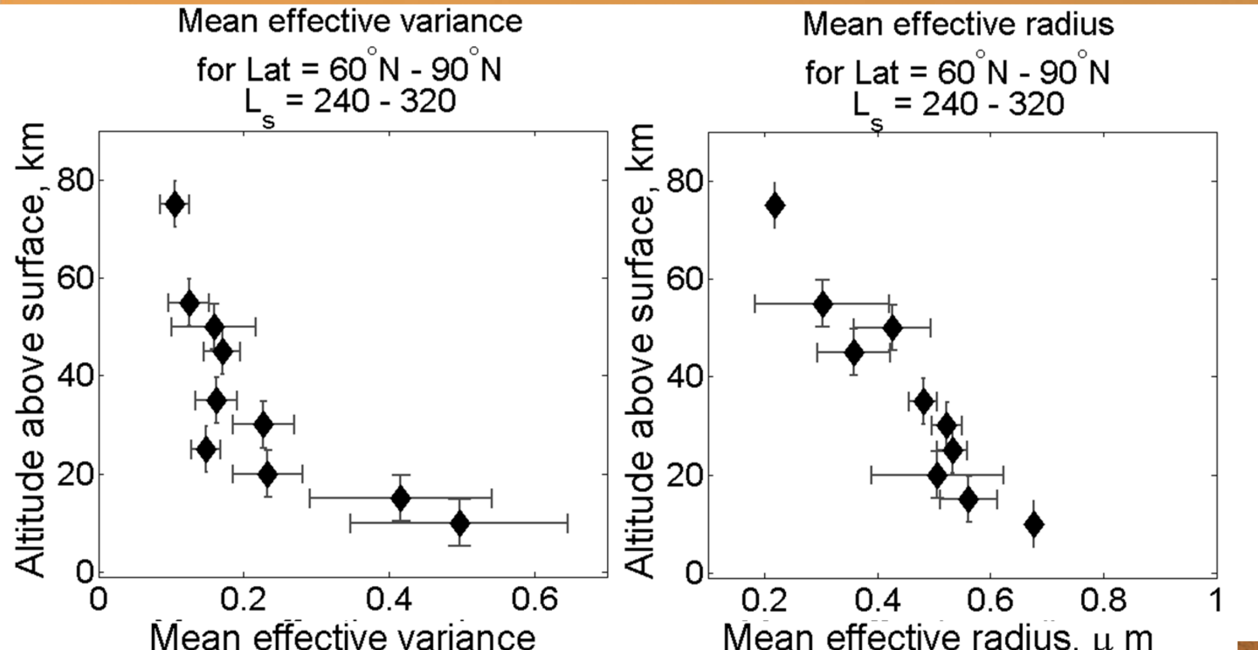


We can retrieve the averaged profiles for the different seasons: for effective radius and variation of distribution

← High latitudes in the Southern hemisphere, Southern winter (**calm season**). Small particles, narrow distribution even above 15-20 km

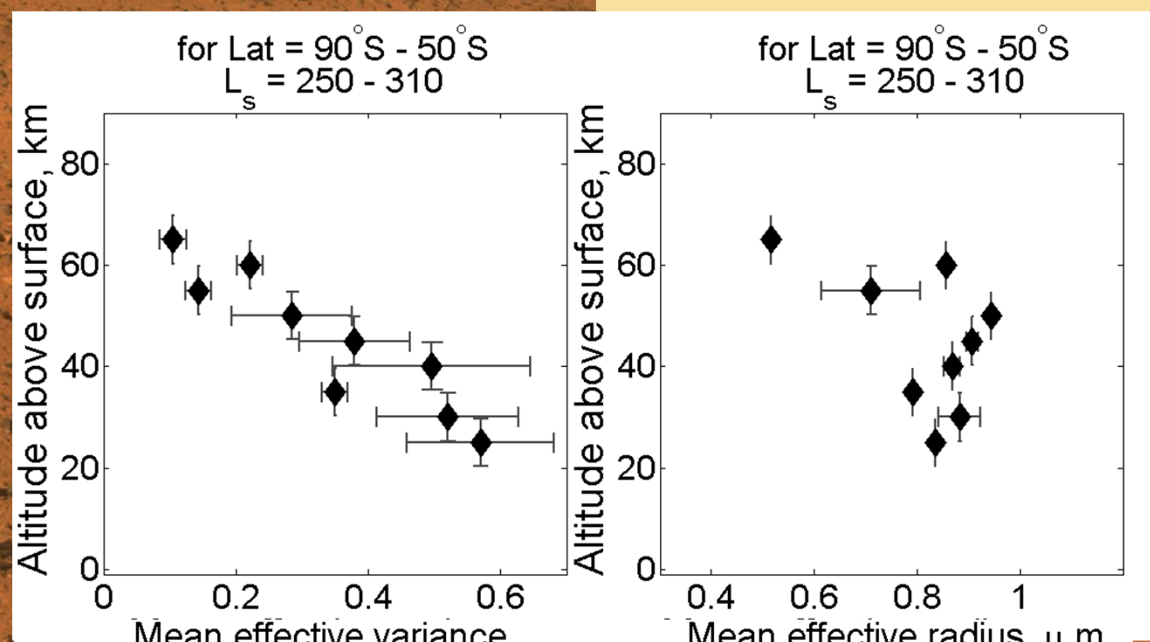


High and middle latitudes in the Southern hemisphere,
Southern summer (**dust season**):
Large particles, wide distribution



High latitudes in the Northern hemisphere,
Northern winter:
narrow distribution

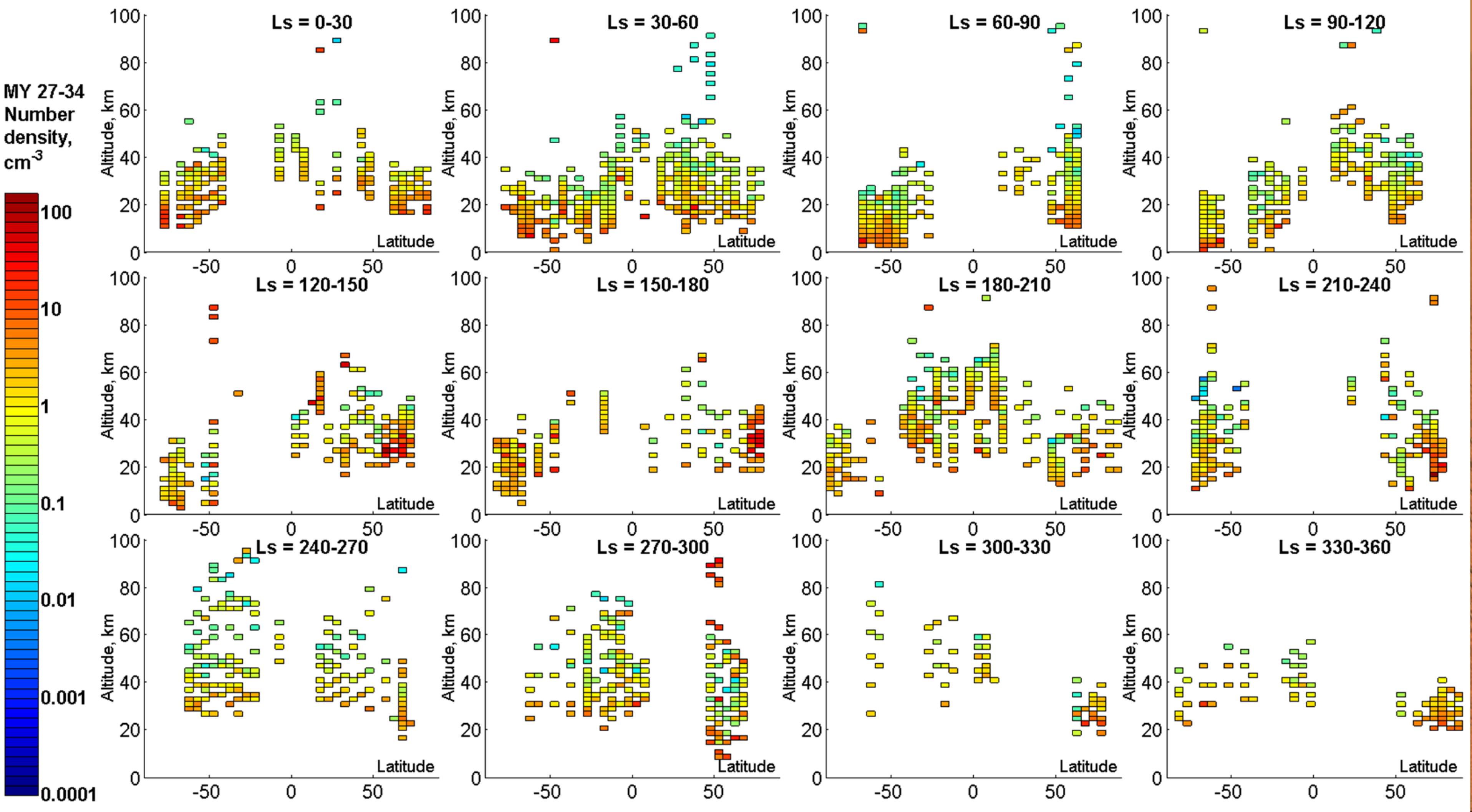
High and middle latitudes in the Southern hemisphere,
Southern summer (**dust season**):
large particles, wide distribution



Size distribution

Number density

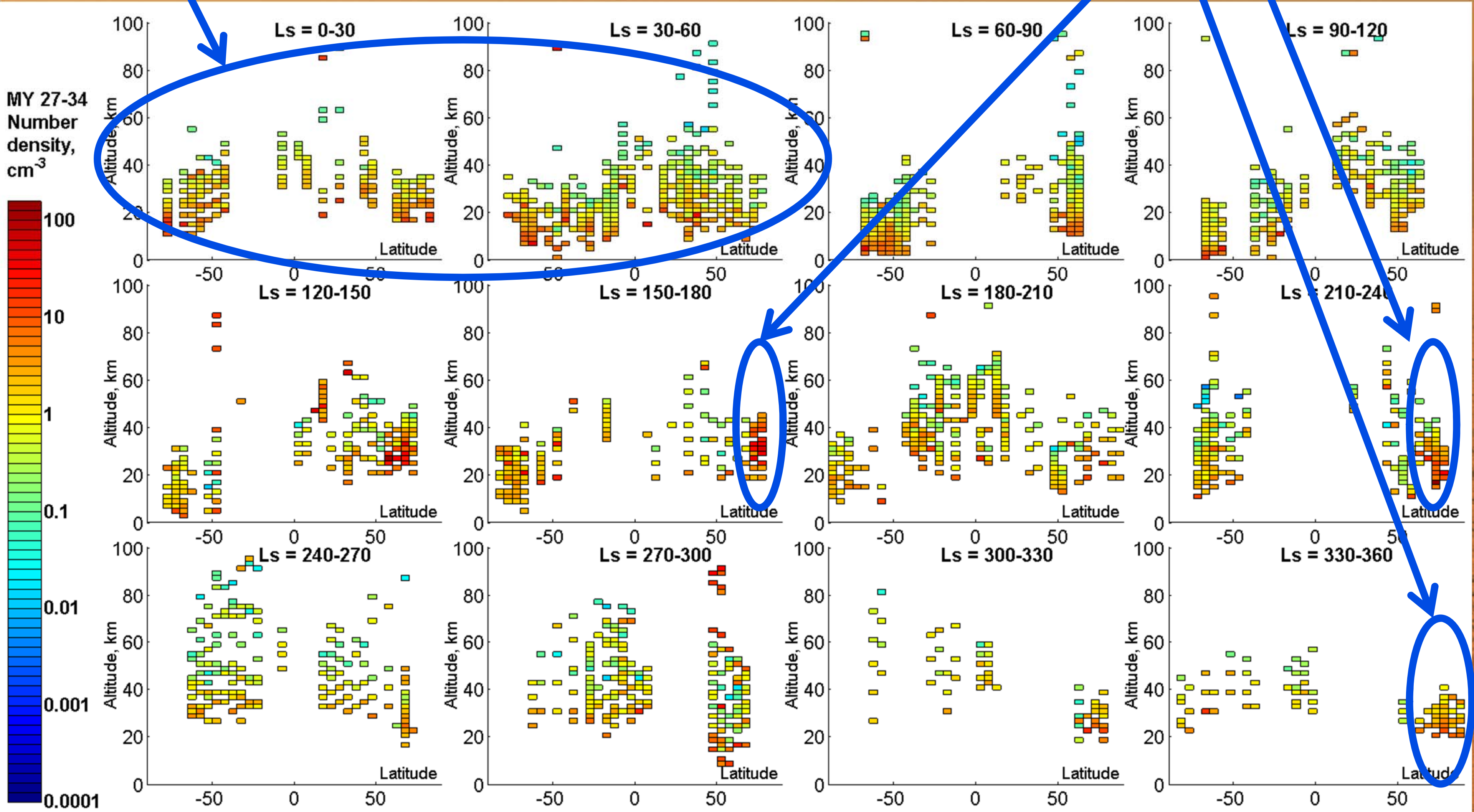
$$N(z) = \frac{k_{ext}(\lambda, z)}{\int_{r_1}^{r_2} \pi r^2 \tilde{Q}_{ext}(r, m, \lambda) n(r, z) dr}$$



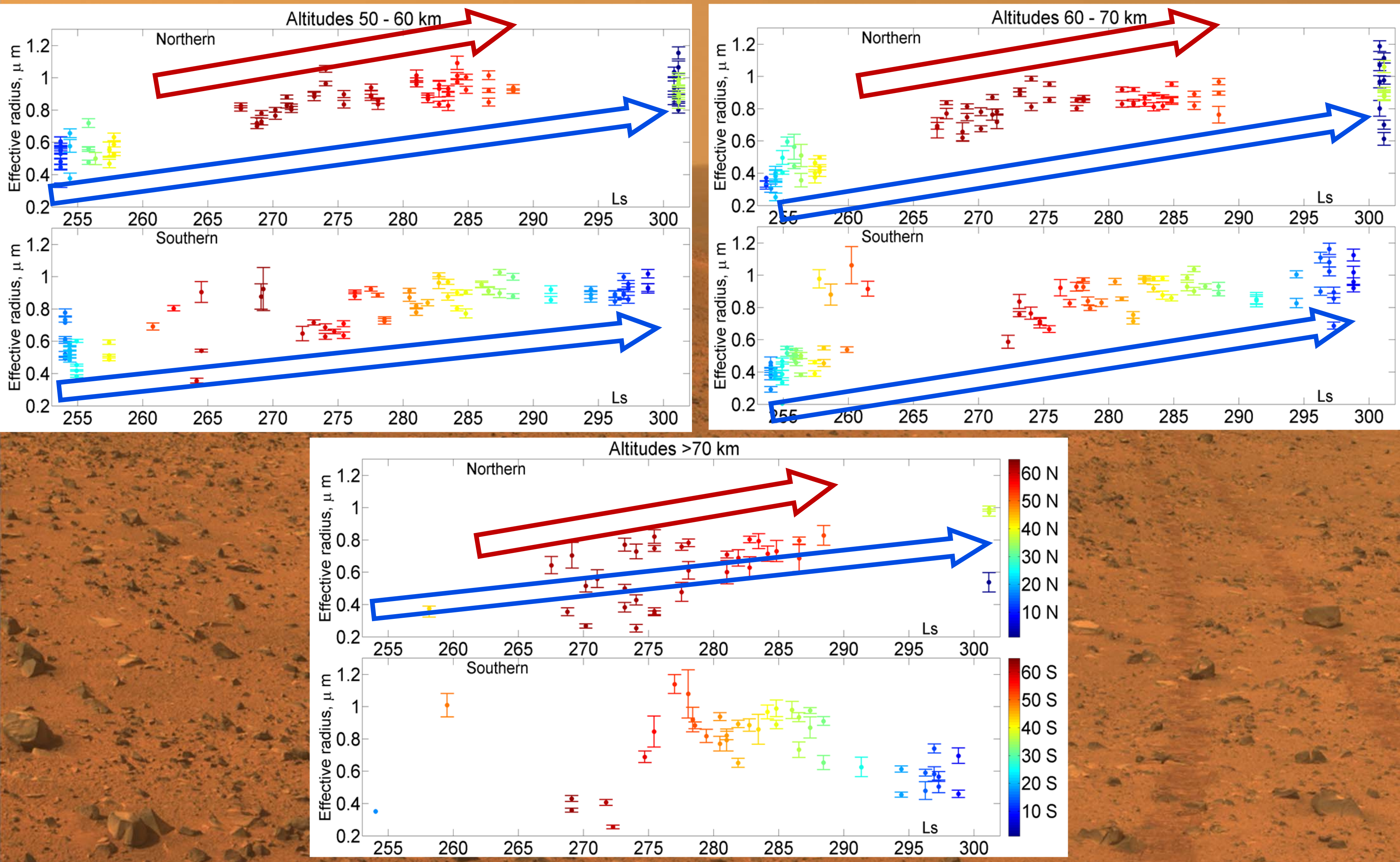
Number density

There is no clear dependence on latitude; Number density becomes higher close to surface

High concentration of small particles at high latitudes

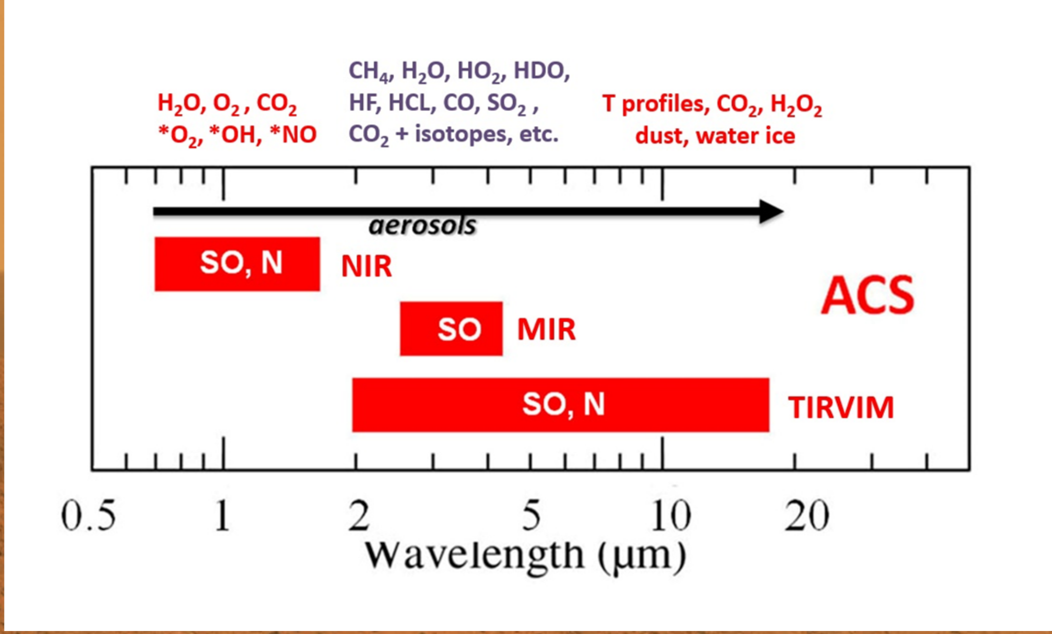


Global dust storm - 28 MY



From Mars Express to ExoMars

ACS - Atmospheric Chemistry Suite, three infrared instruments to investigate the chemistry and structure of the Martian atmosphere.



→ Using the retrieved size distribution,

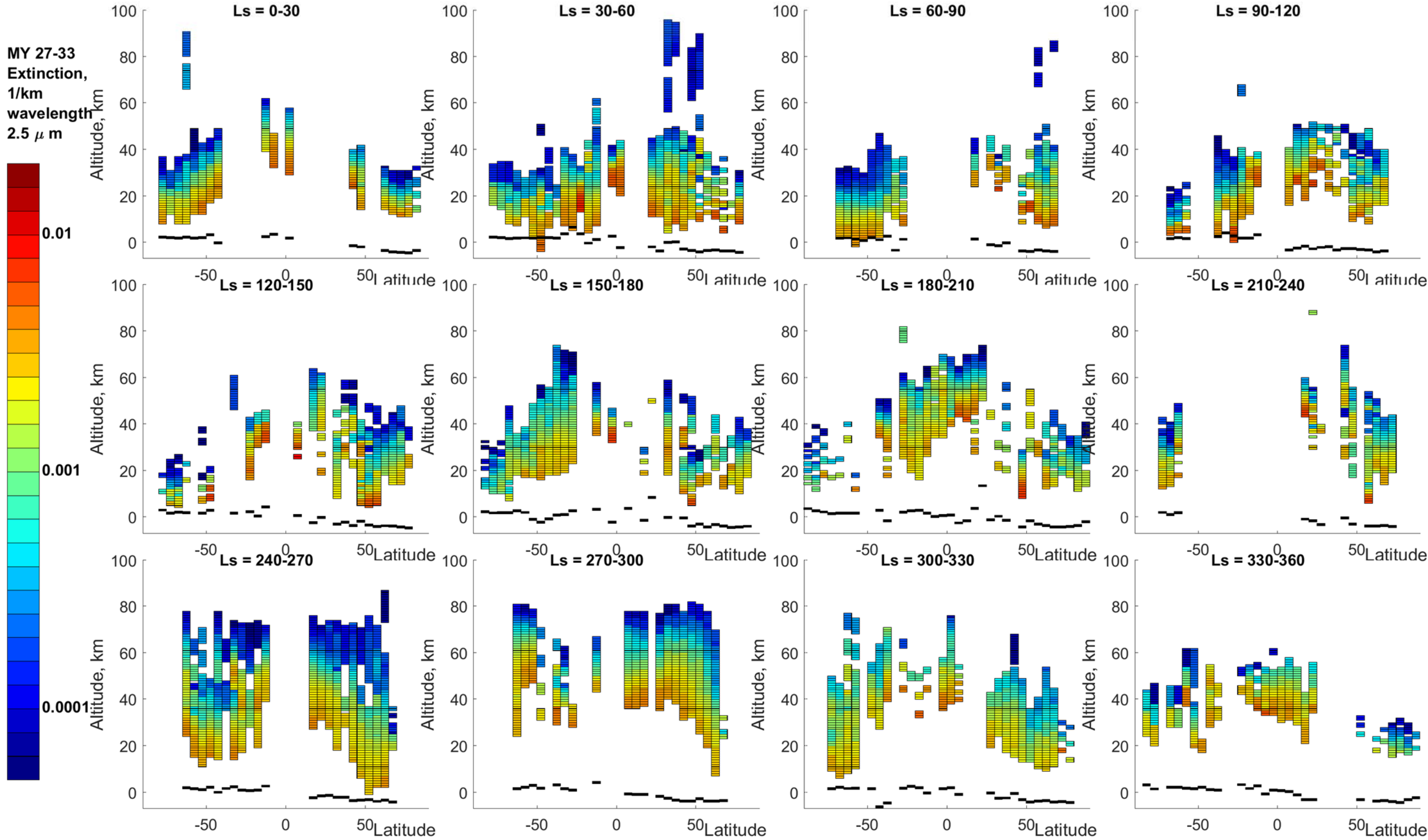
refractive indices and Mie theory

we can calculate the extinction coefficient as:

$$k_{\text{ext}}(\lambda, z) = \int_0^\infty \sigma_{\text{ext}}(r, z) n(r, z)\, dr$$

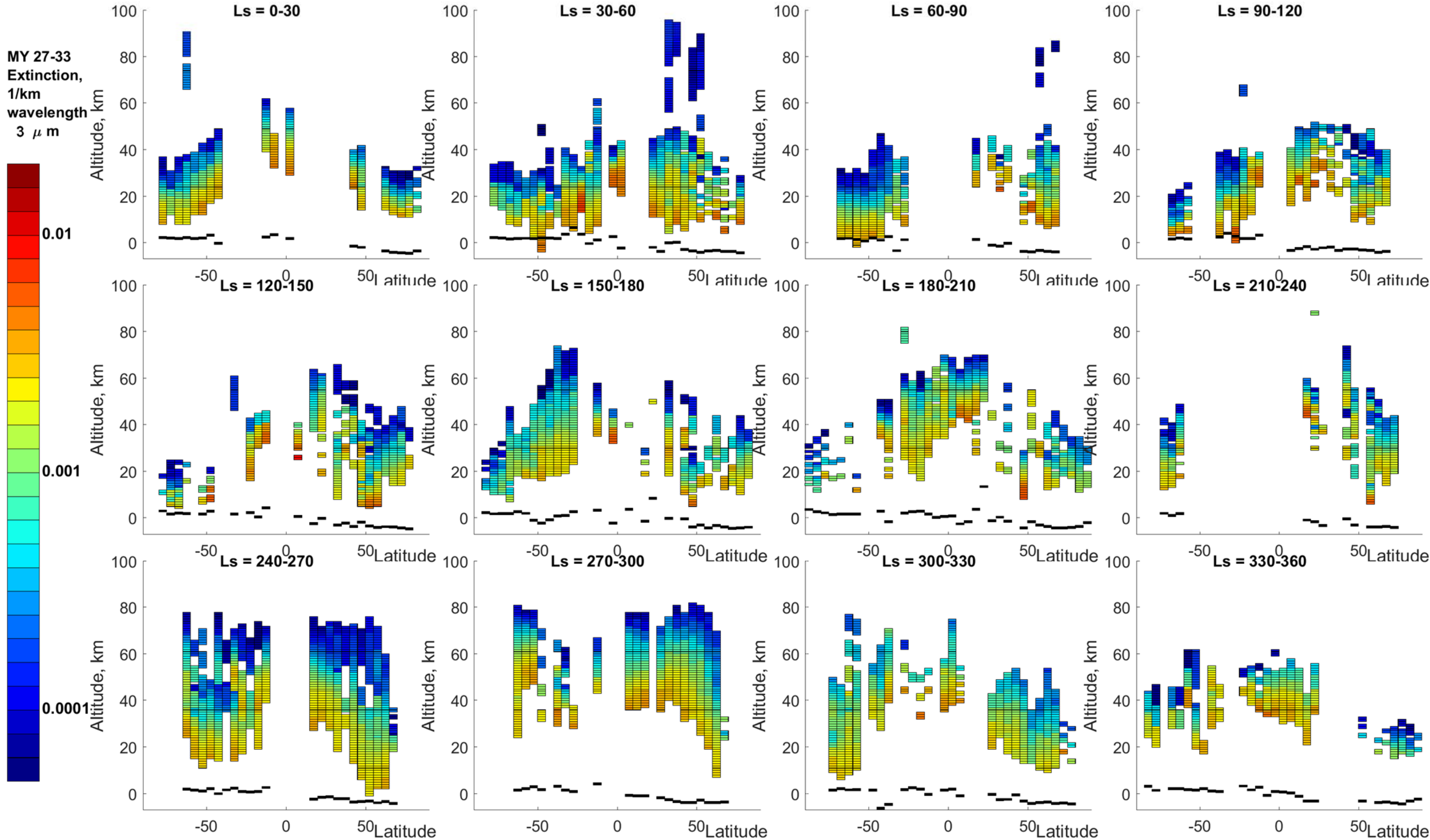
Extinction coefficient map on 2.5 μm

(calculated using retrieved particle size distribution)



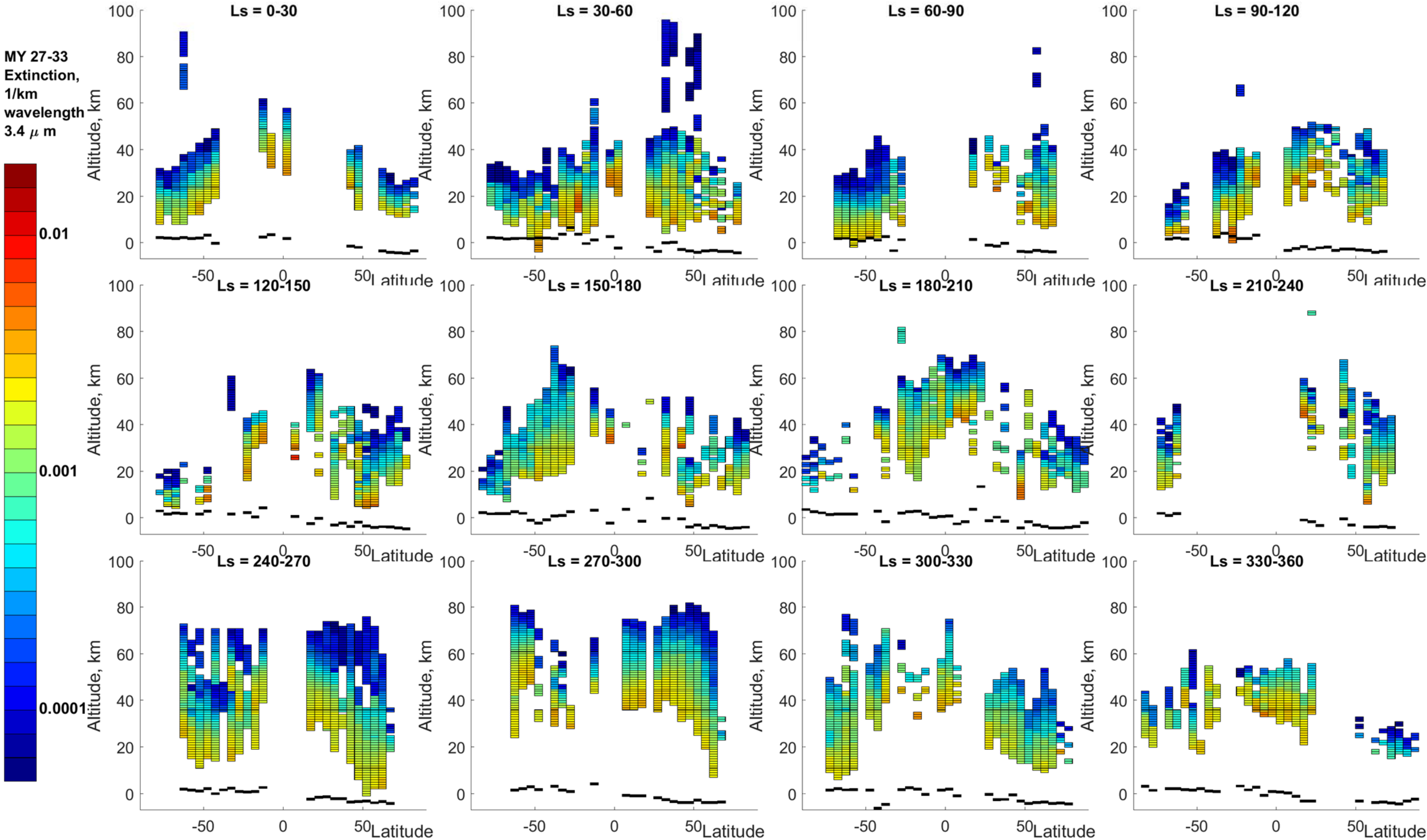
Extinction coefficient map on 3 µm

(calculated using retrieved particle size distribution)

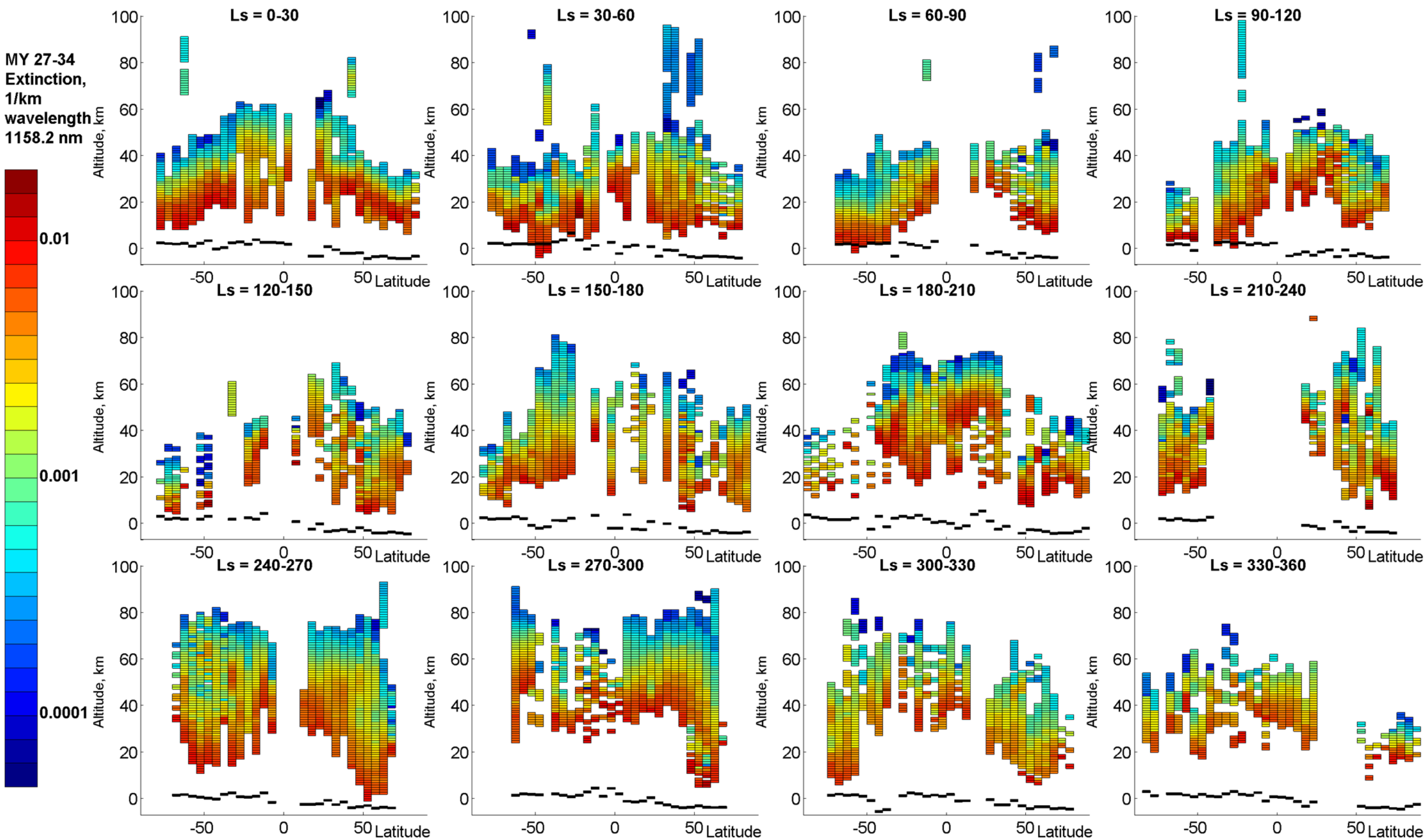


Extinction coefficient map on 3.4 µm

(calculated using retrieved particle size distribution)

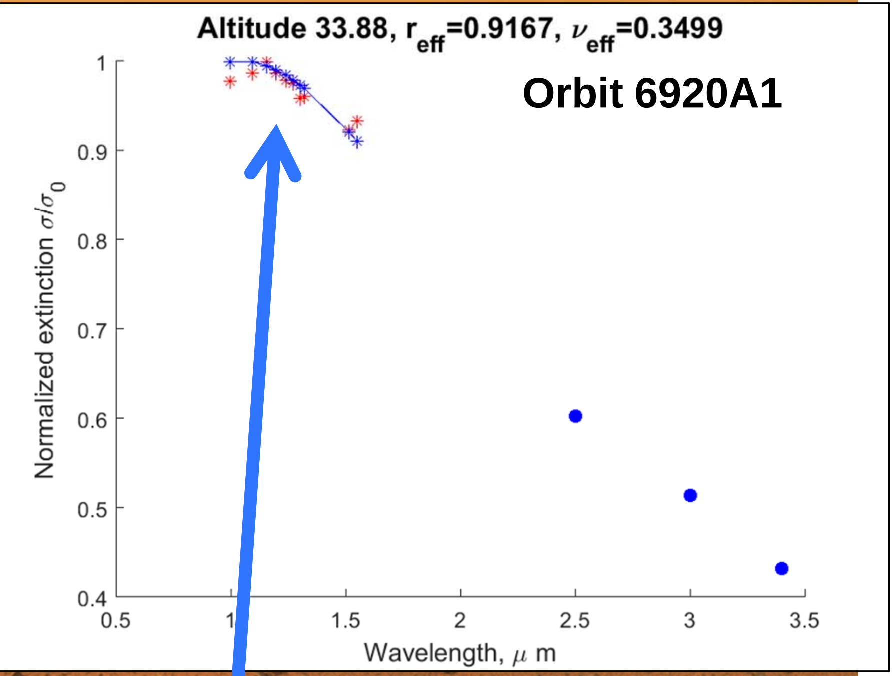


Extinction coefficient map on 1.158 µm




Thank you for your attention!

Calculation for extinction on 2.5 µm, 3 µm and 3.4 µm



Fitting SPICAM IR data