High altitude aerosol on Mars: implications for the water cycle and thermal regime of the atmosphere

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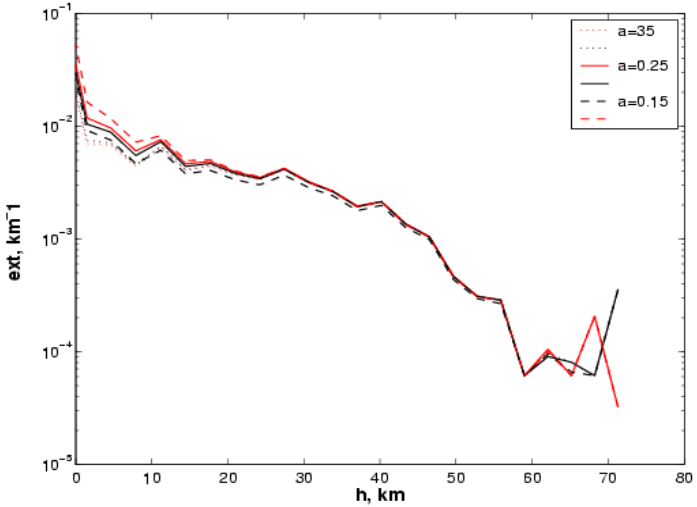
A variety of data received by SPICAM instrument shows scattering and extinction in spectral continuum from UV to NIR extending in altitude up to 60 km, interpreted as a manifestation of

faint, high-altitude haze in the Martian amosphere.

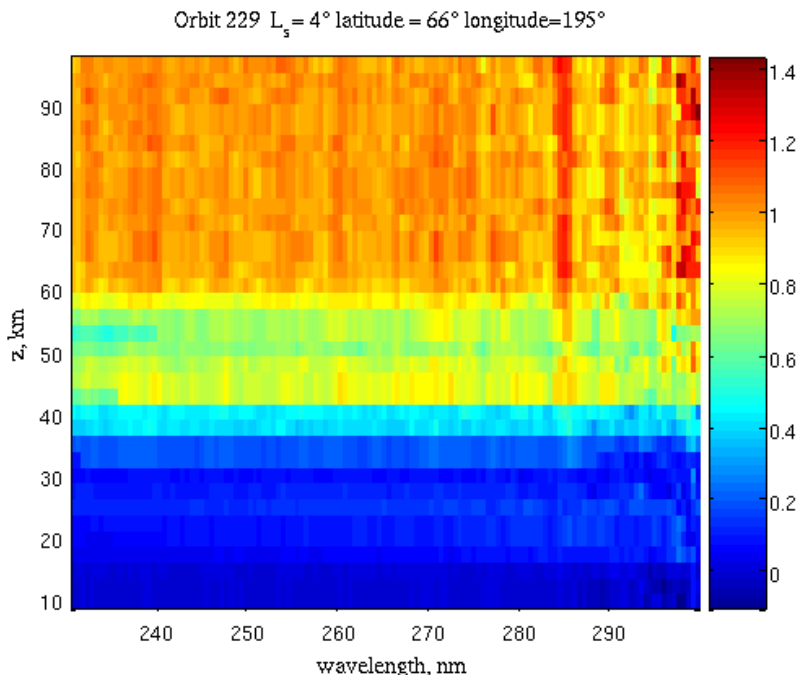


IR limb observations
(Fedorova et al., 2004)

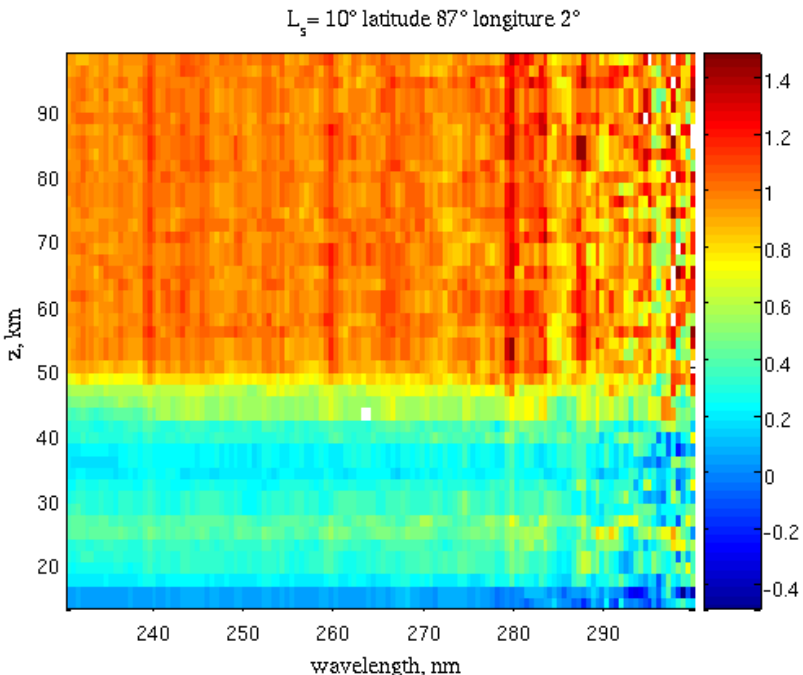
UV stellar occultations (Bertaux et al.)

North spring equinox

Midlatitudes



North pole



(!)The depression of the haze level to the poles implies its connection to Hadley cell circulation

(!) Layered structures indicate contribution of condensational clouds

(?) What is the nature of faint haze

(?) How it affects atmospheric processes

namely:

1) thermal regime

2) cloud formation and water transport

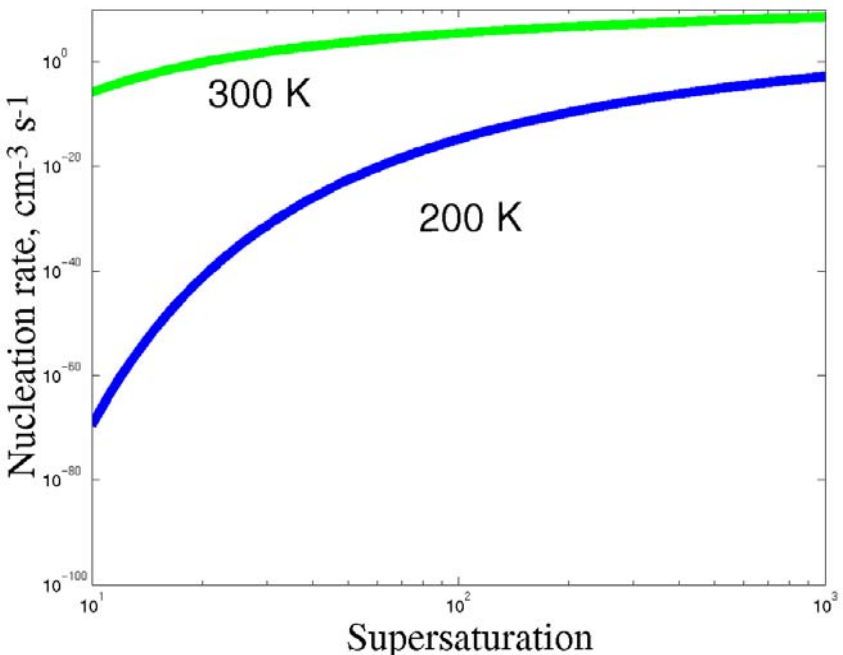
- questions to be explored with the GCM simulations

the GFDL Mars GCM

- SKYHI dynamical core
  - Basic resolution: 5°×6°, 40 / 20 nodes in altitude
  - High resolution: 2°×2°, 40 nodes in altitude
- resolved size spectrum of dust (2 / 4 bins)
  - 0.01 – 4 μm
- spectral microphysics of water ice clouds
  - 4 moments of size distribution (in linear radius)
  - heterogeneous nucleation
  - condensation & sublimation
  - Brownian coagulation
- Transport of dust and clouds by circulation
  - sedimentation based on microphysics
- surface boundary conditions
  - parameterized dust devil activity
  - dust release from the retreating polar caps
  - frost deposition & sublimation
  - diffusion regolith model; no subsurface ice
- radiation coupled with microphysics
  - Mie theory; double-layered spheres
  - Delta-Eddington in visible
  - Stream function technique in thermal IR

In the GCM, faint haze contribution is

- absorption of solar radiation
- supply of condensation nuclei



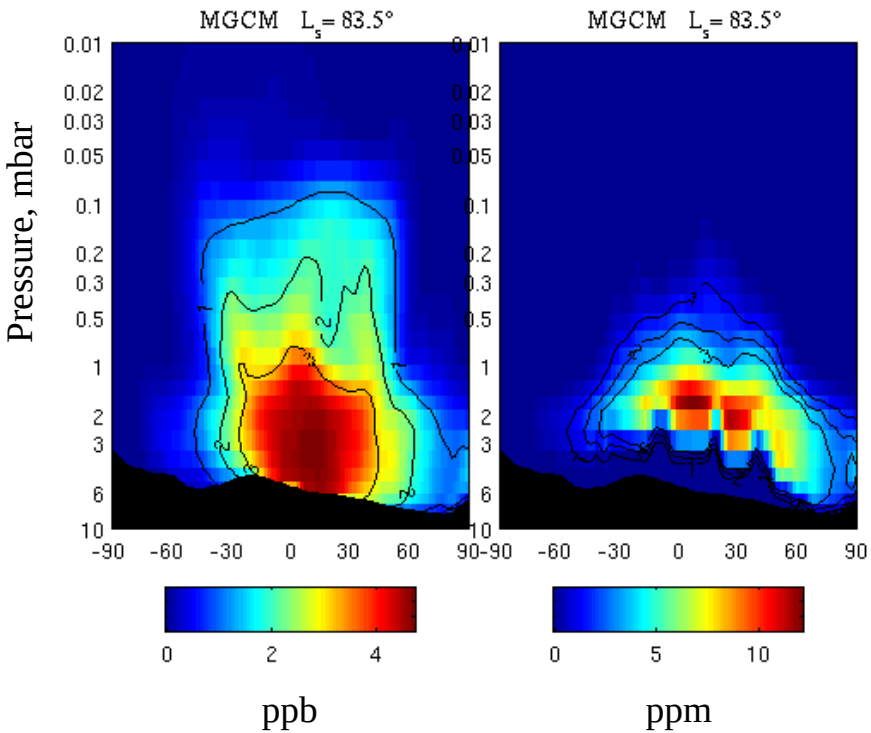
Homogeneous nucleation is strictly forbidden under cold Martian temperatures

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

Appearance of fine dust layer and clouds formed on it in the GCM

Dust

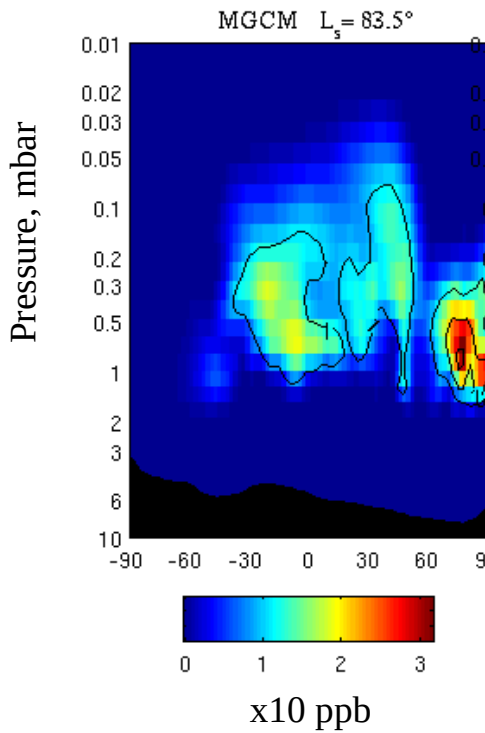
Fine component



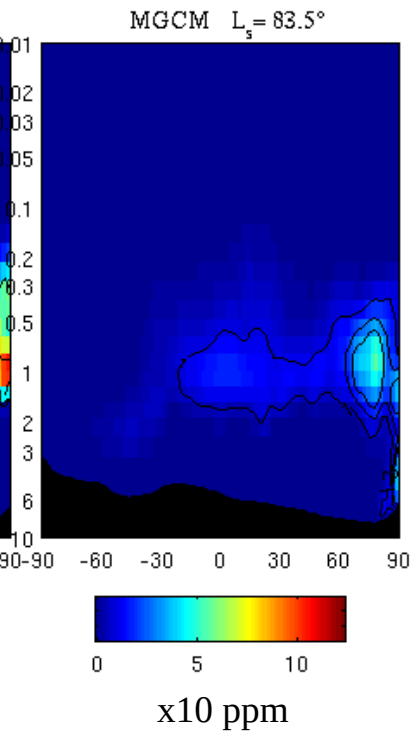
Normal component

Cloud

Fine component



Normal component

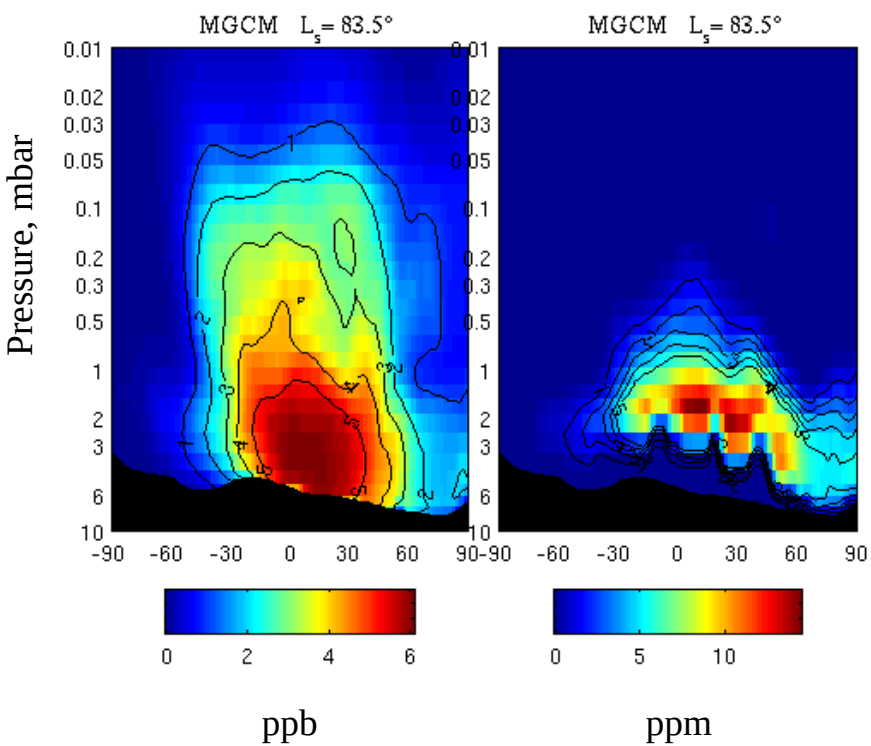


R = 0.1 μm

Finer dust doesn't form stable cloud layer penetrating through saturation level

Dust

Fine component

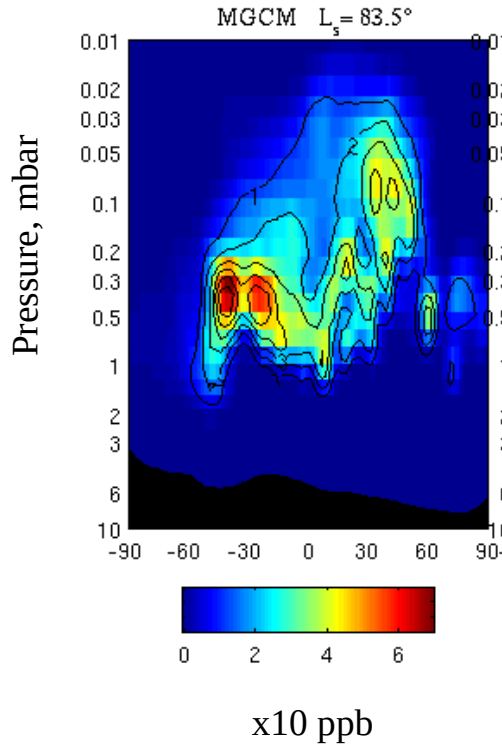


Normal component

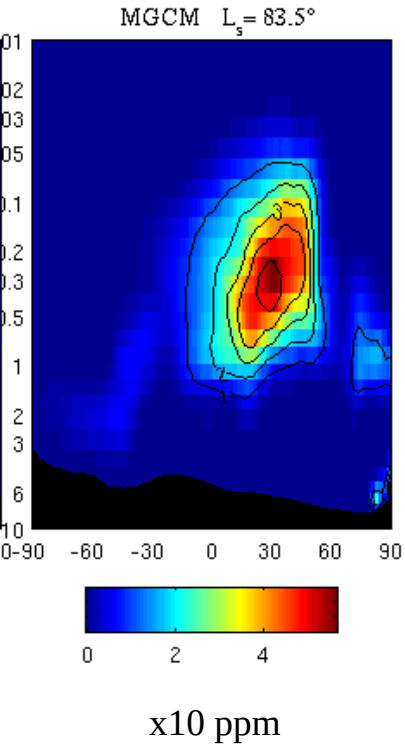
R = 0.01 μm

Cloud

Fine component



Normal component



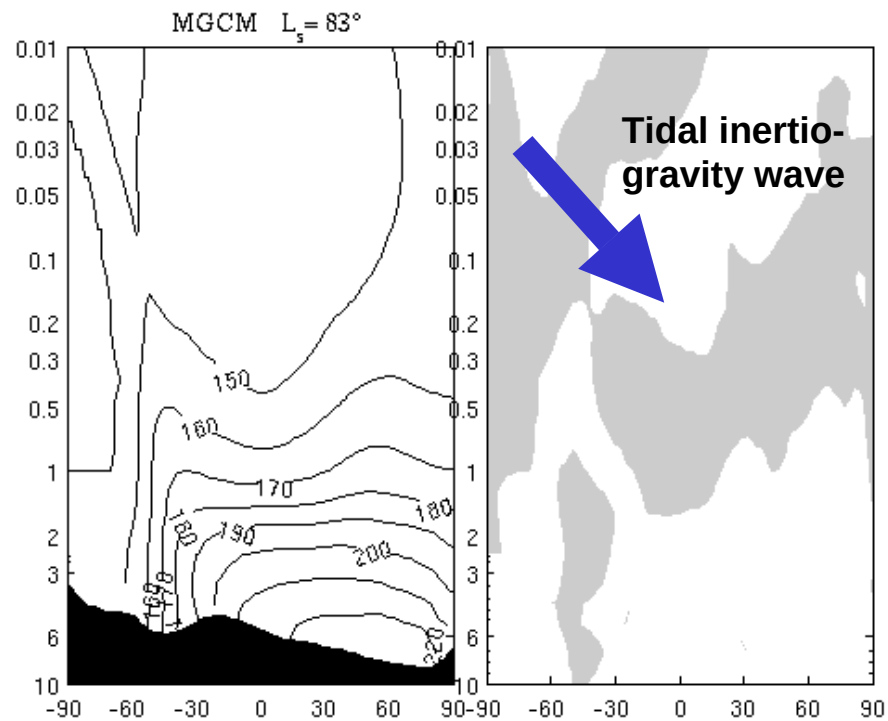
R = 0.05 μm, ω_0 fixed

Thermal effect

No fine dust

Zonal-mean temperature
16:00 LT

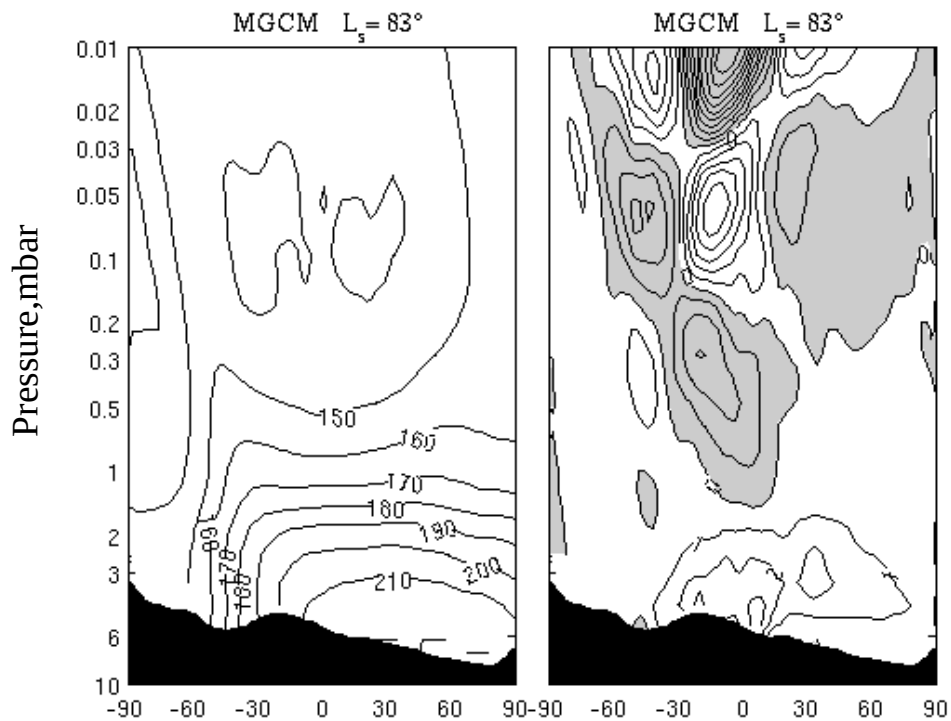
Diurnal tide



Fine dust included, no cloud radiation

Zonal-mean temperature
16:00 LT

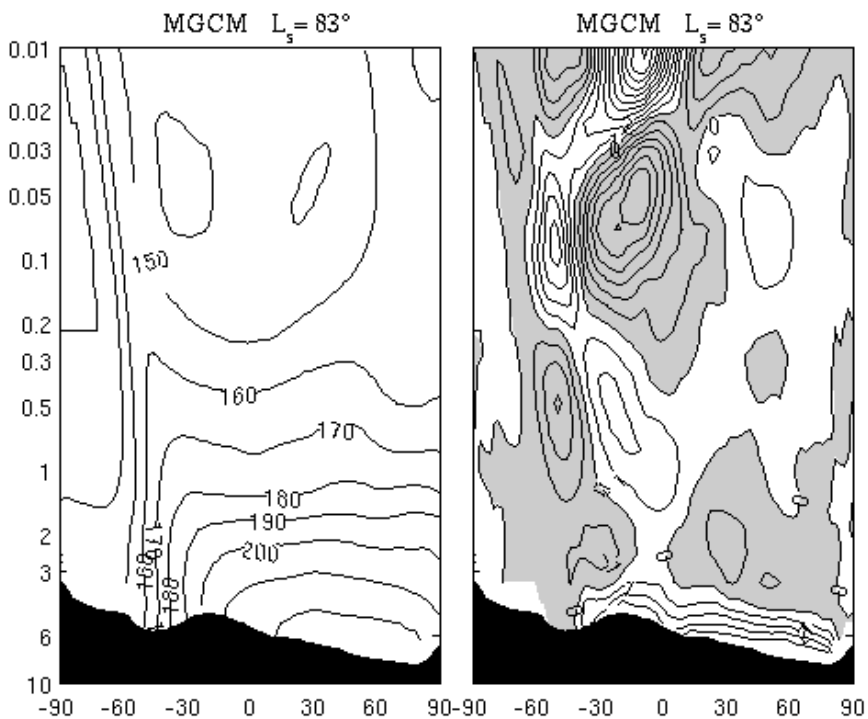
Diurnal tide



Thermal effect

R = 0.1 μm

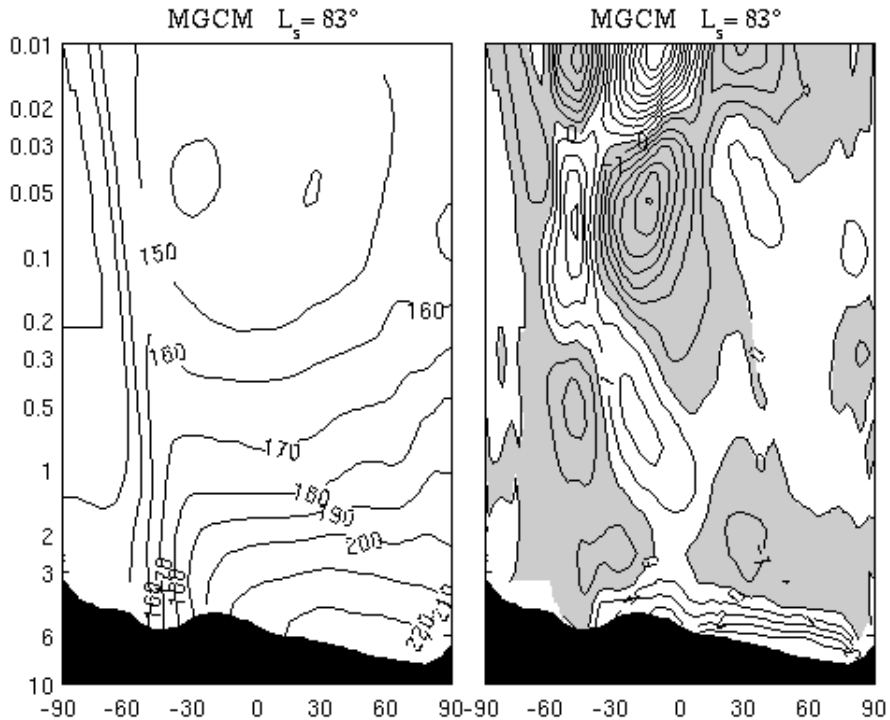
Zonal-mean temperature
16:00 LT



Diurnal tide

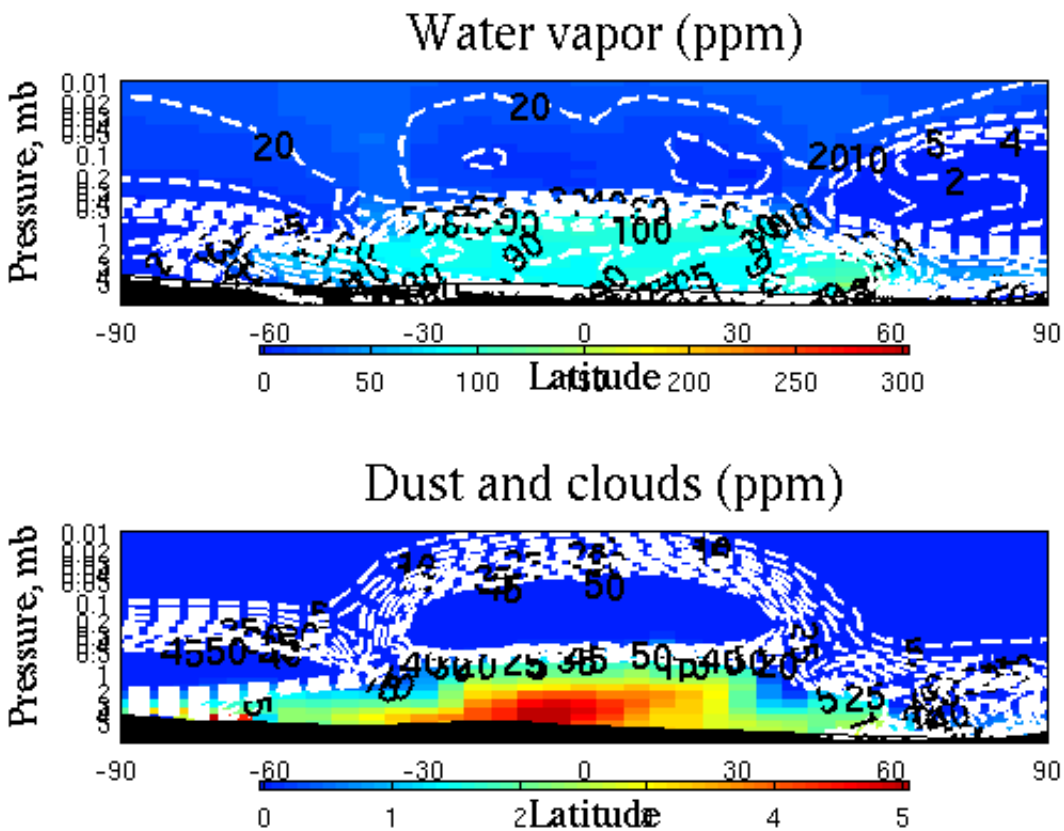
R = 0.01 μm

Zonal-mean temperature
16:00 LT



Diurnal tide

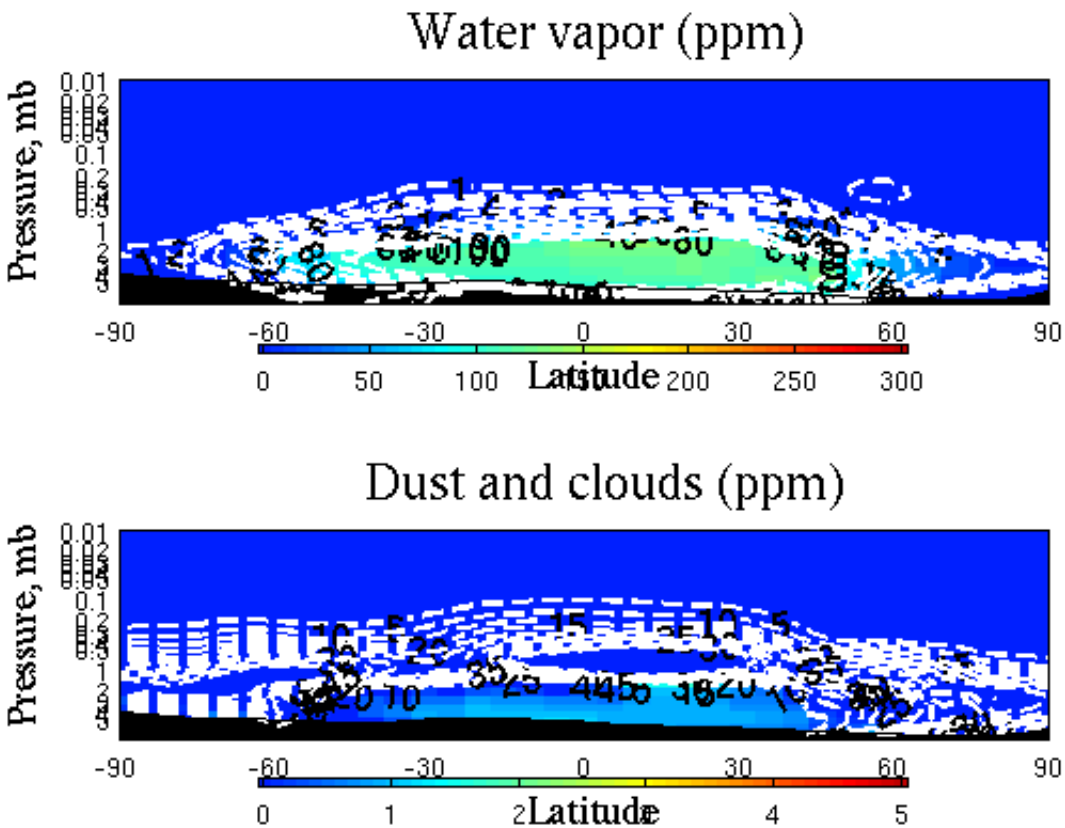
Without fine dust component,
supersaturated water vapour leaks through cloud layer,
as all condensation nuclei are scavenged out



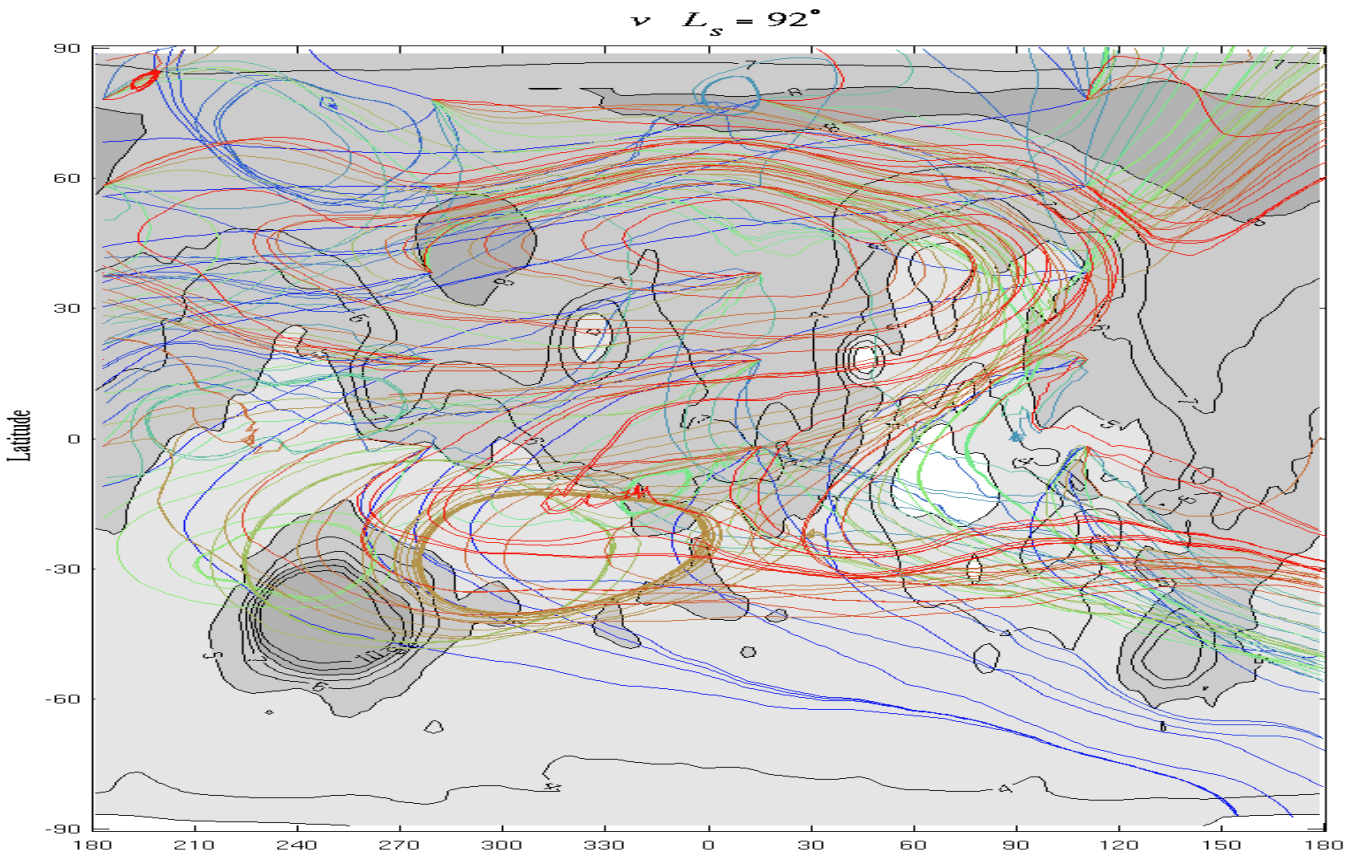
***Fine dust included**:*

due to low nucleation probability

free condensation nuclei are available at high altitudes

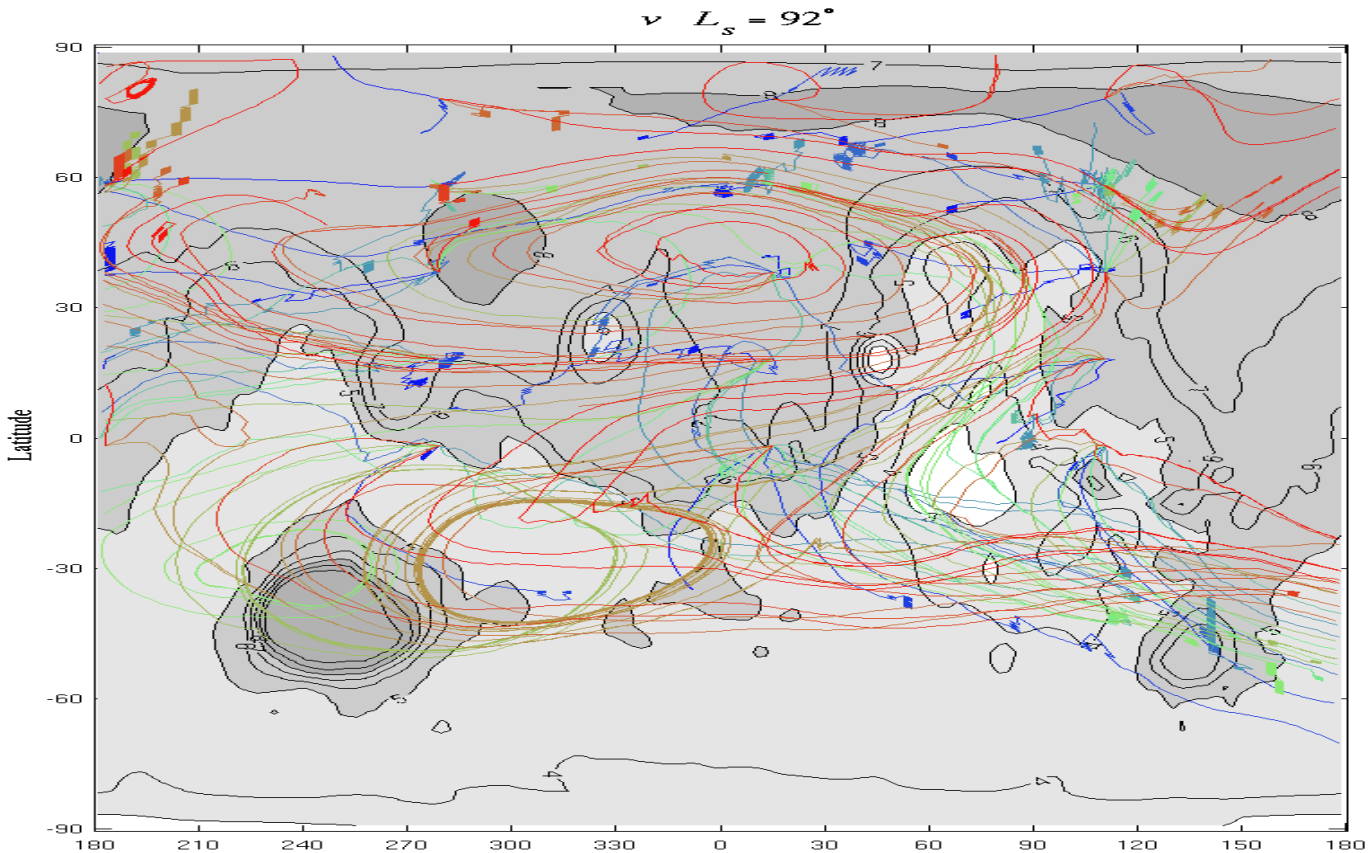


total water transport



Blue – 2 km, green – 12 km, red – 25 km

water transport: clouds only



Blue – 2 km, green – 12 km, red – 25 km

Conclusions

- Fine particulate mode as seen by SPICAM instrument is favored by GCM simulations; it presumably consists of small dust particles with 0.01μm<***r***<0.1 μm and submicron water ice particles
- it results in decreasing vertical thermal gradient, with total effect reaching 10 K above 30 km
- extra heating alters tidal wave modes above 30 km
- fine dust mode, capable to survive scavenging due to condensation, provides nuclei for water condensation above main cloud deck.
- availability of fresh condensation nuclei increases the efficiency of sealing atmospheric water off poleward transport by the Hadley cell circulation