Aerosols and Clouds on Earth and Venus

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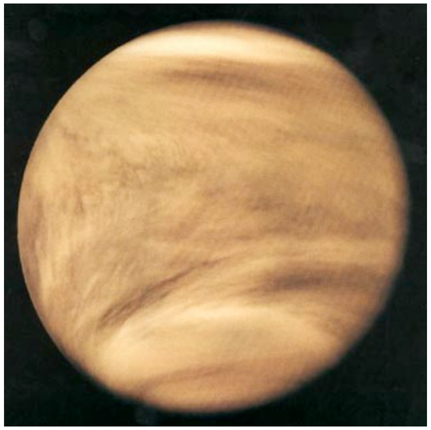
There are many unexploited science problems on Venus

Basic understanding of clouds



Learning about dynamics by using clouds as tracers

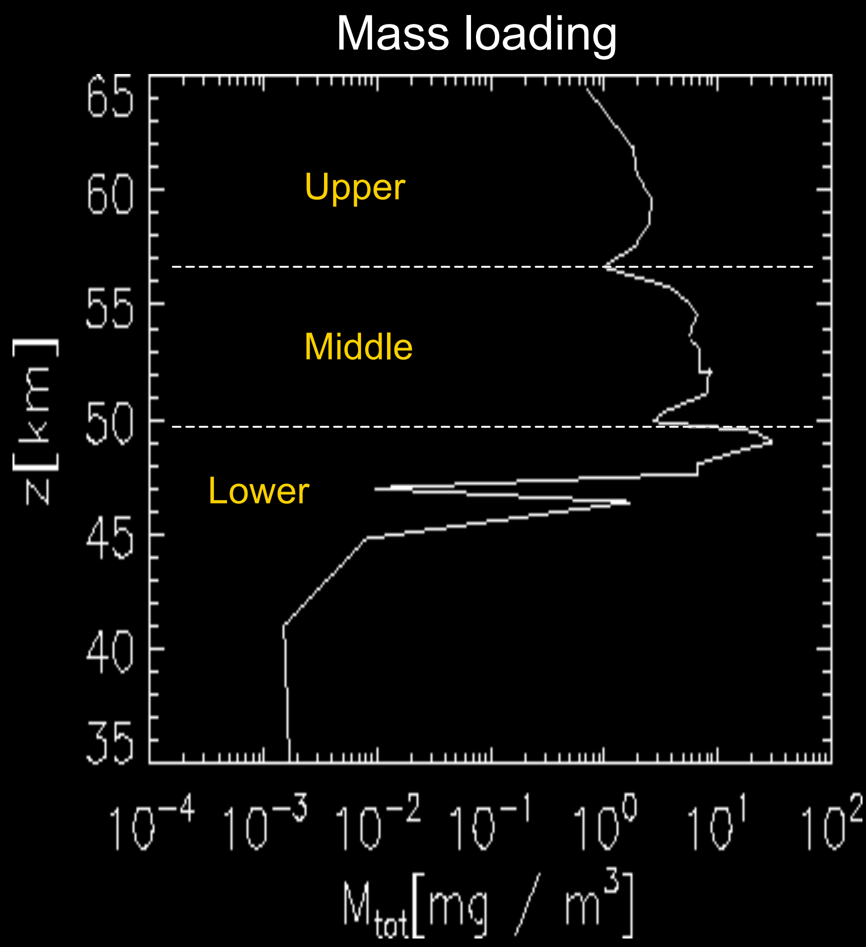
Parallels between Earth and Venus

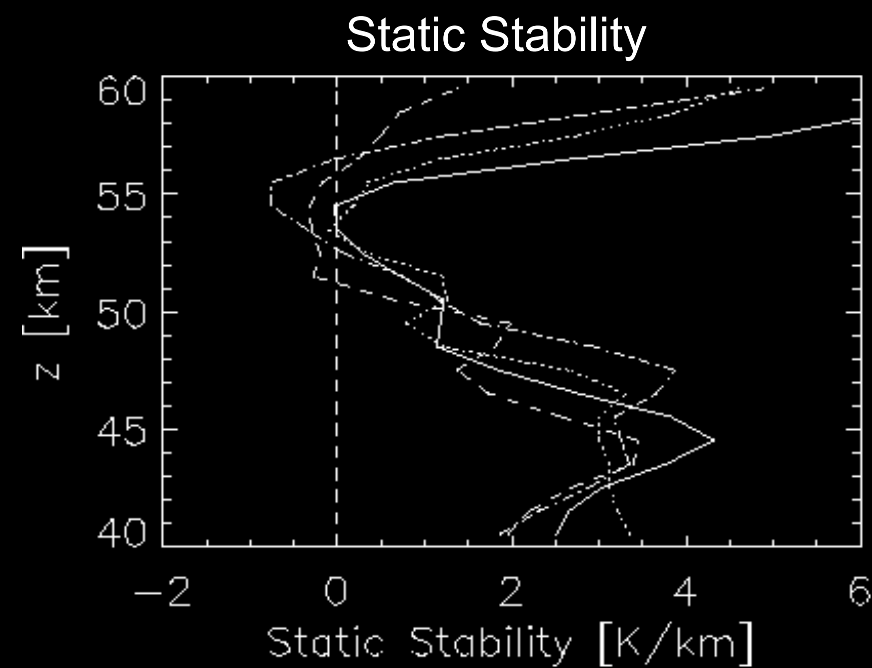
Clouds play a role in Venus climate and climate change

Clouds of Venus are Sulfuric Acid:

Upper cloud is photochemically produced

H_2SO_4 clouds are a significant contributor to the greenhouse effect; and condensational clouds may produce a radiative-dynamical feedback.





Upper cloud (z>57km) is produced photochemically from SO_2 and H_2O

Middle and lower clouds (z<57km) are produced condensationally

Atmosphere is neutrally stable between about 50 and 57 km: in the middle cloud deck.

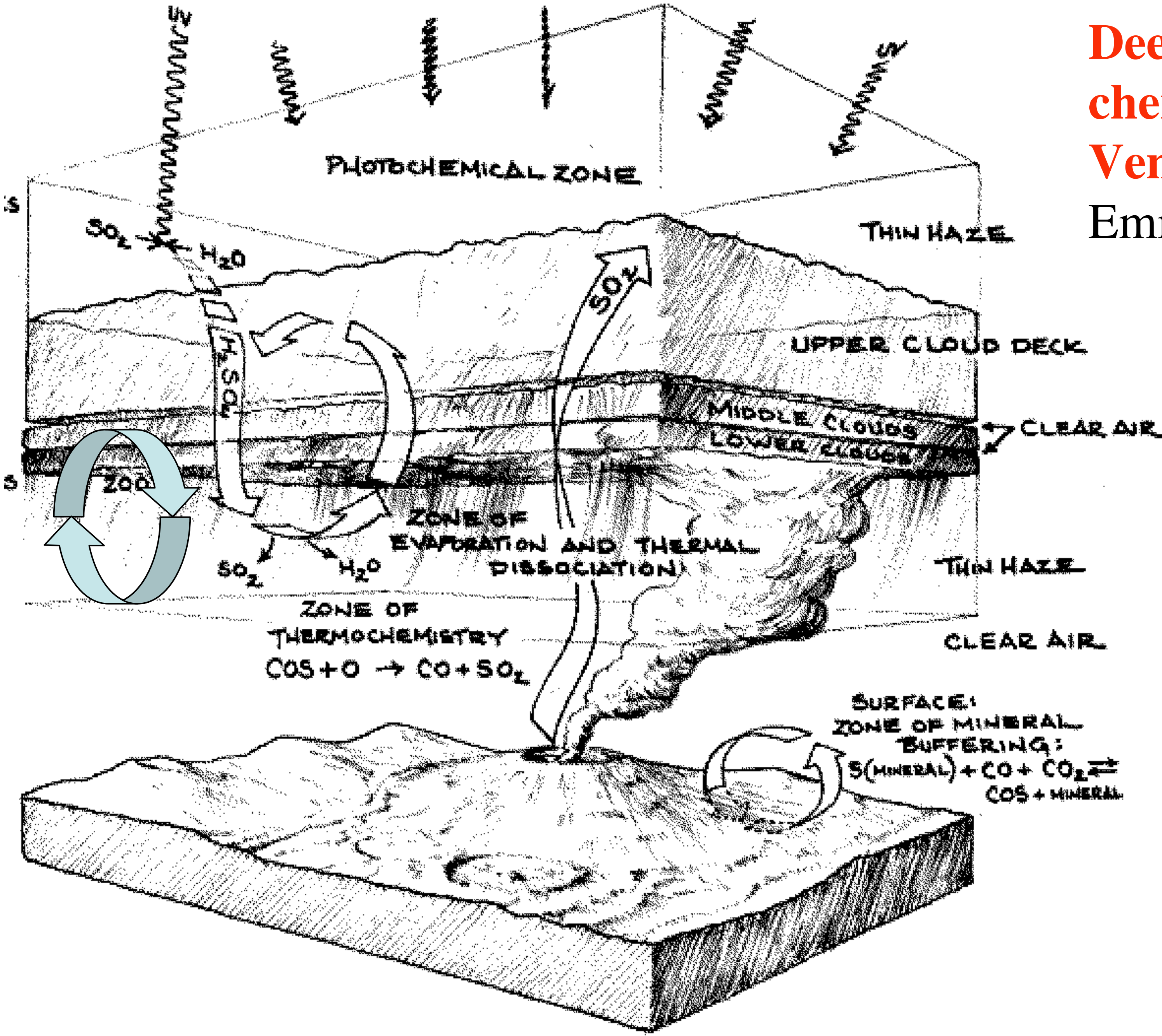
The sulfur cycle in the Venus atmosphere

The turn over rate of the sulfur is very large

Mass density of cloud*fall velocity at base*area=
10^{-7} g/cm^3*0.05 cm/s*5X10^{18}cm^2*3X10^7s/yr
=7.5x10^{17}g/yr.

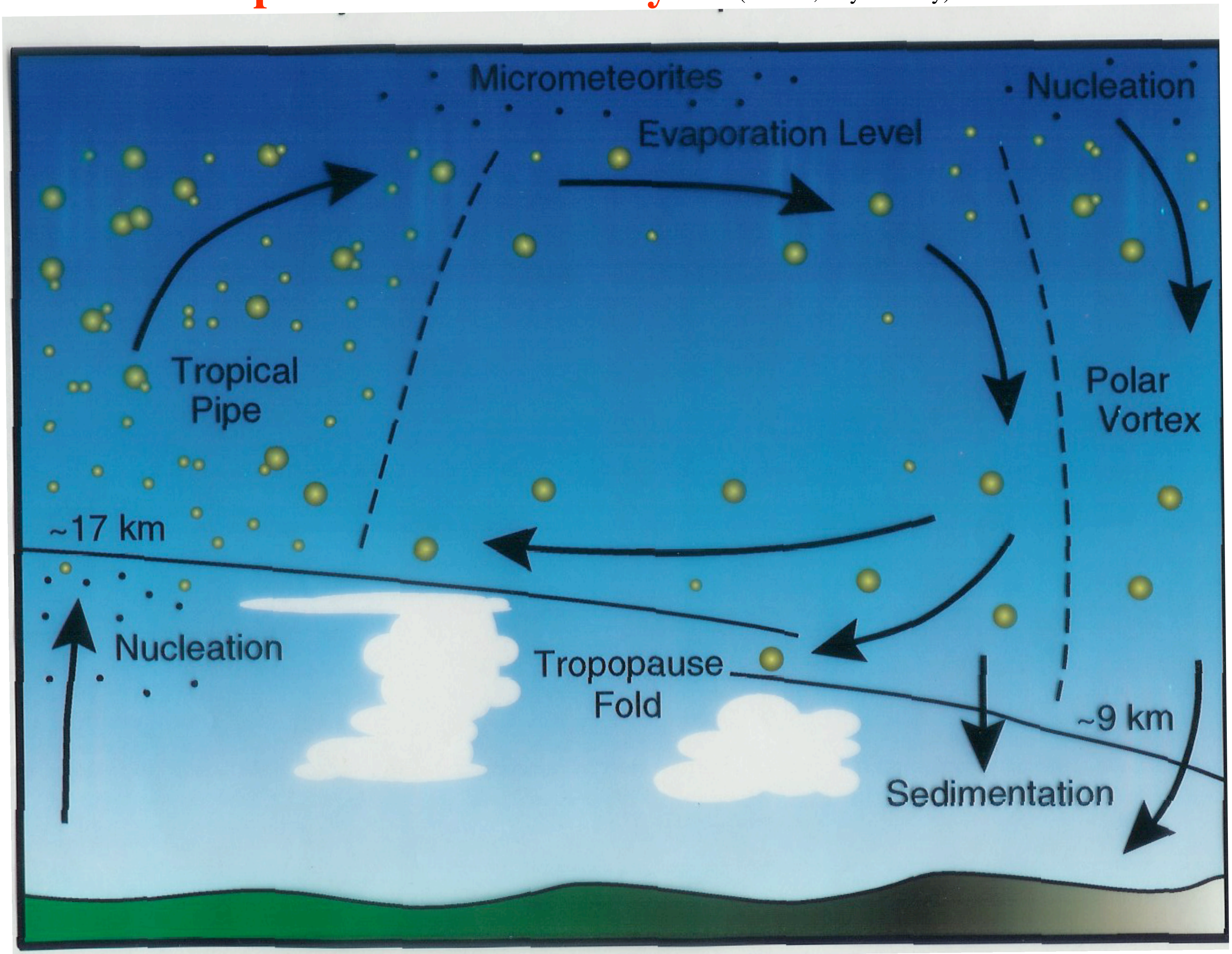
From photochemical models about 6x10^{16} g H_2SO_4 is produced every year.

Earth's sulfur budget is about 2x10^{14} g/yr, 0.02% of Venus
Earth's water budget turns over 5X10^{20} g water per year, 600 times the Venus sulfur cycle.

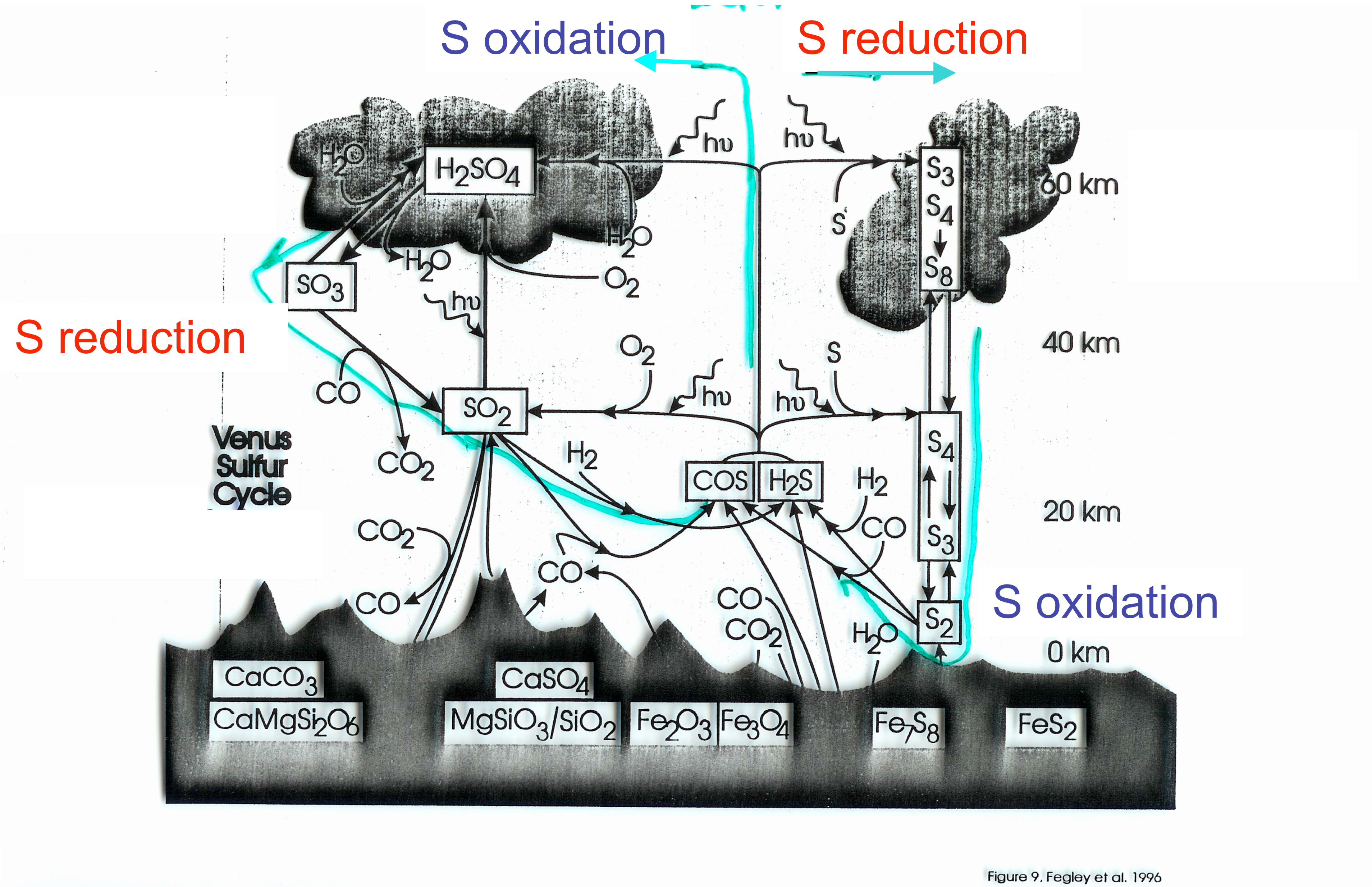


Deep chemistry on Venus, Carter Emmart

Stratospheric aerosol life cycle (Hamill, Phys. Today)

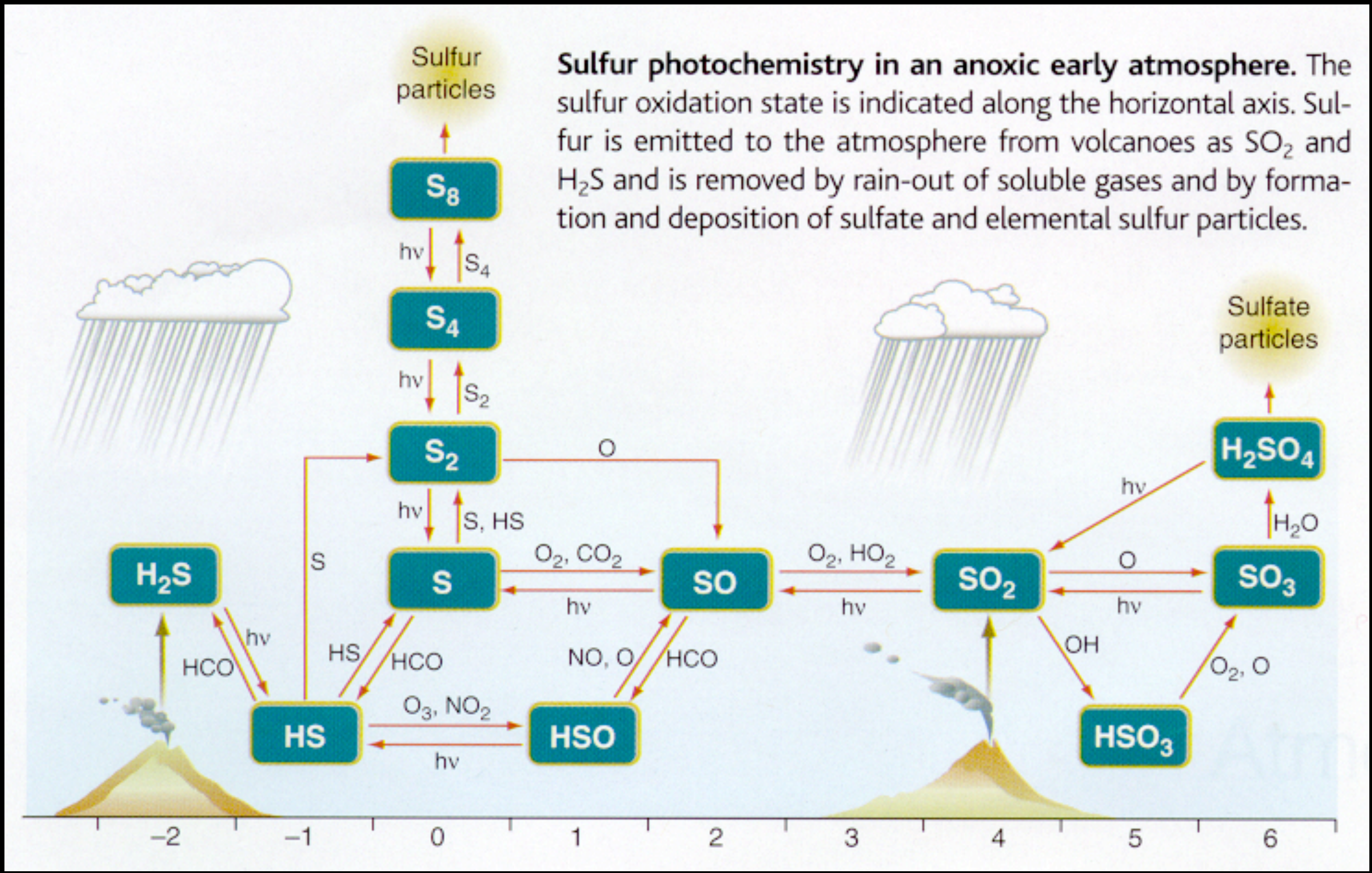


Eq. Pole



The overall Venus sulfur cycle, Fegley

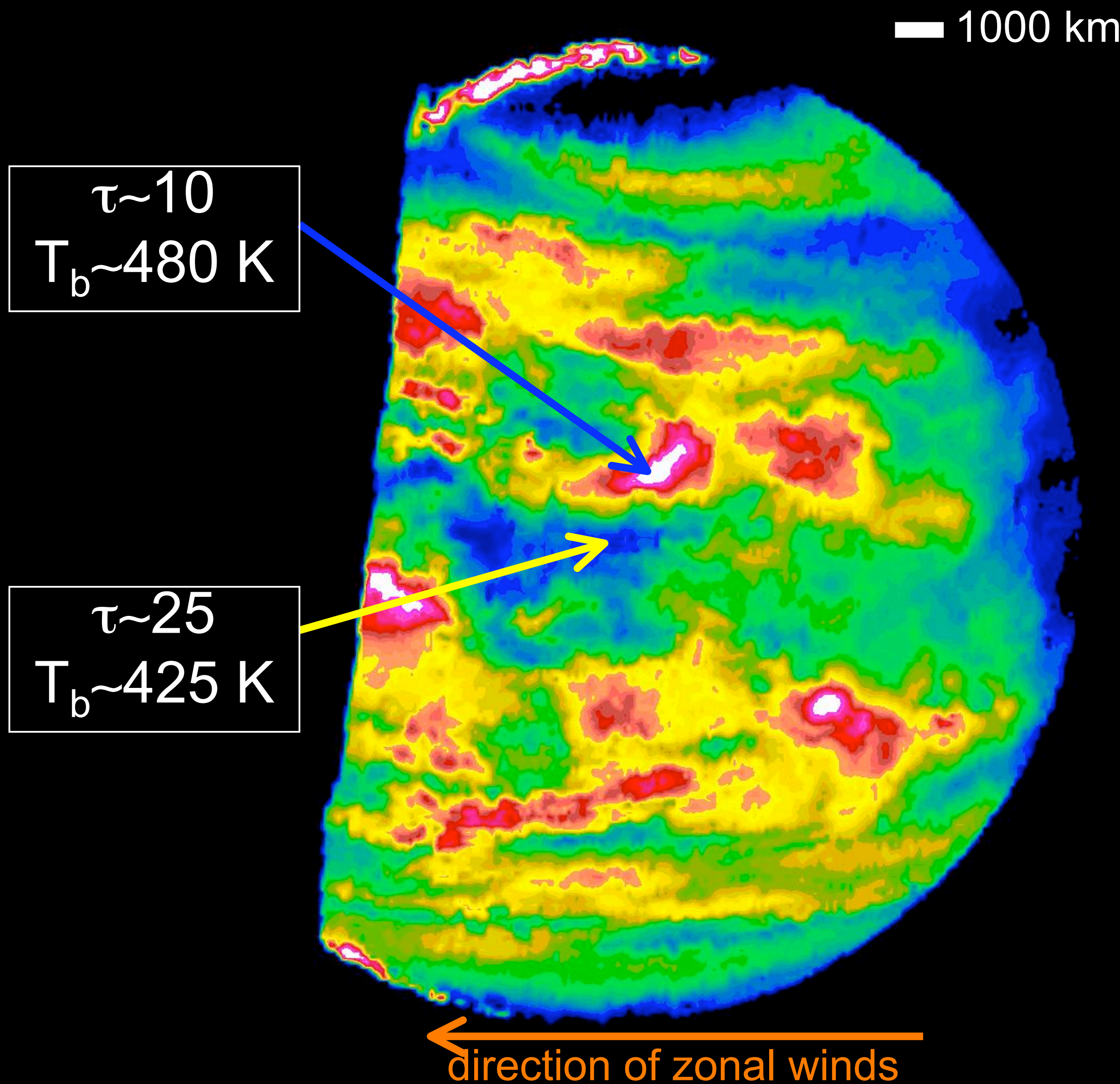
Archean Sulfur Cycle



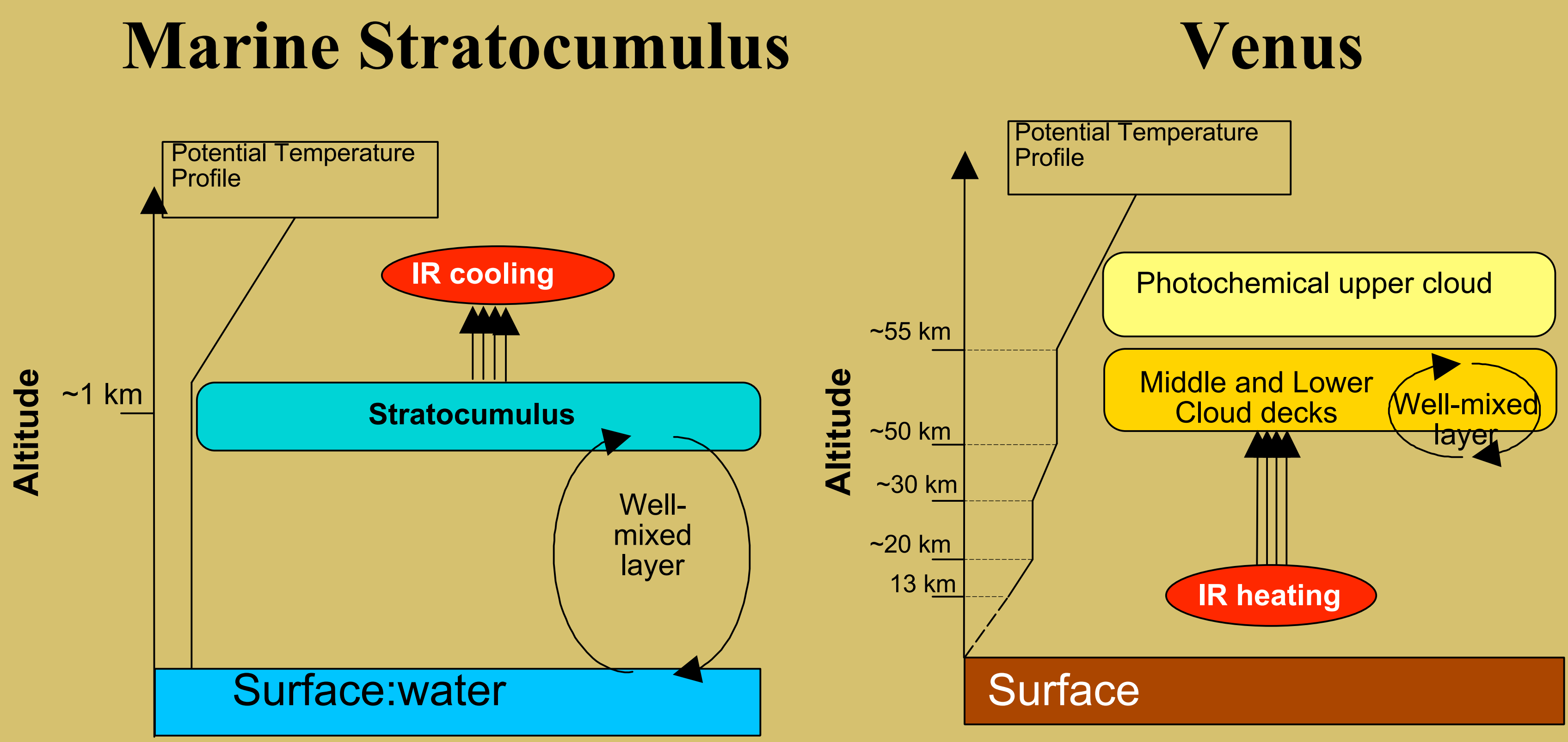
Pavlov and Kasting 2002

Some dynamical and radiative properties of a typical near-ir hole in the clouds of Venus

- 2000 km hole at 16° latitude
- Intensity contrast between hole and cloud at 1.74 μm is about 5:1
- A contrast of 2:1 certainly observable
- Observed to persist for 11-16 days
- Roughly five day period of the clouds → zonal wind speed ~83 m/s

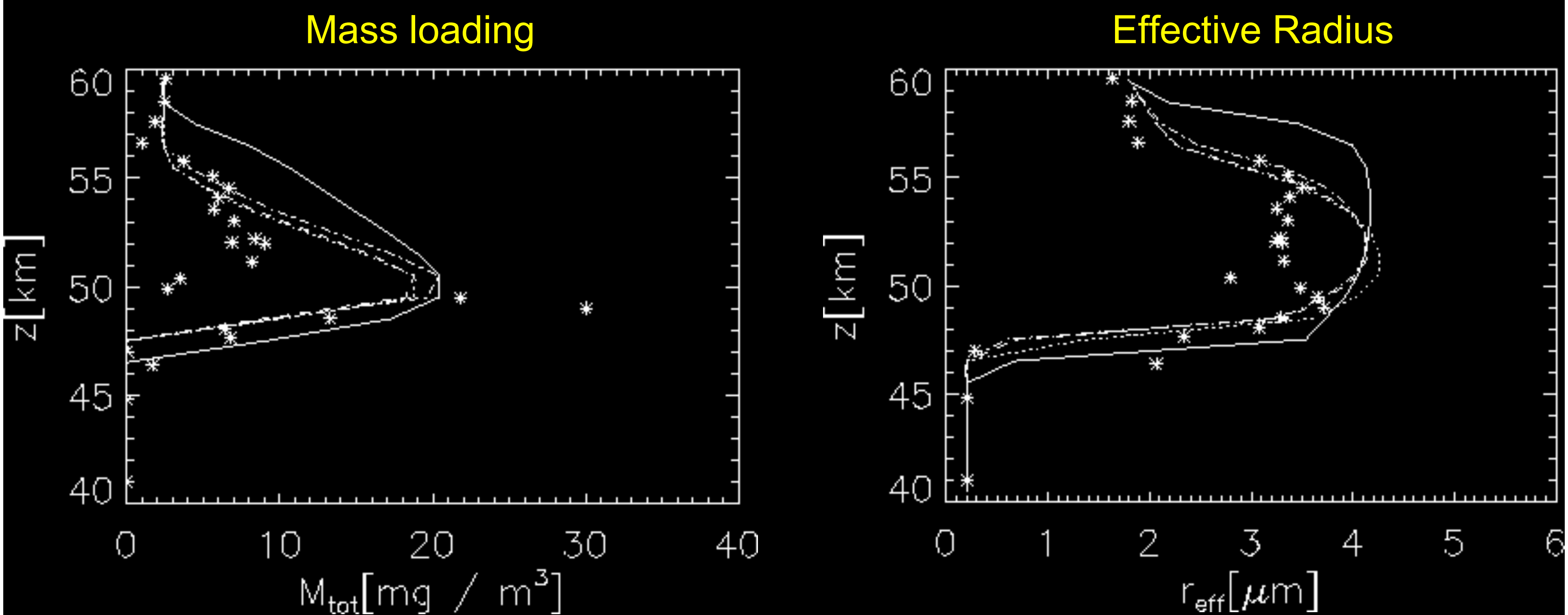


Middle and Lower cloud decks are Condensational clouds, similar to Terrestrial marine stratocumulus



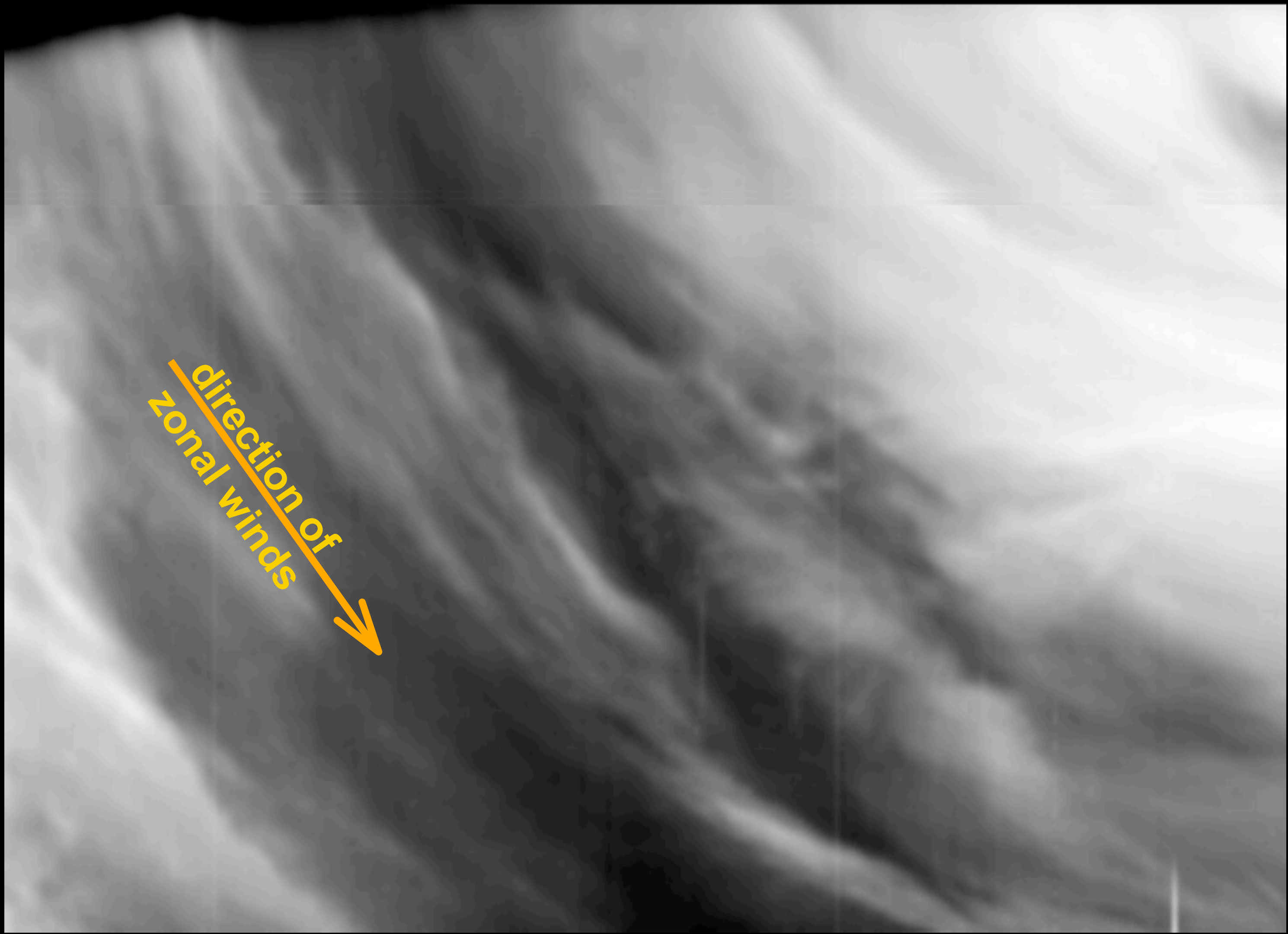
We simulate vertical motions driven by the radiative-dynamical feedback with a eddy diffusion parameterisation based on the value of the Richardson Number

Cloud simulated with a radiative-dynamical feedback matches observations of the Venus clouds.

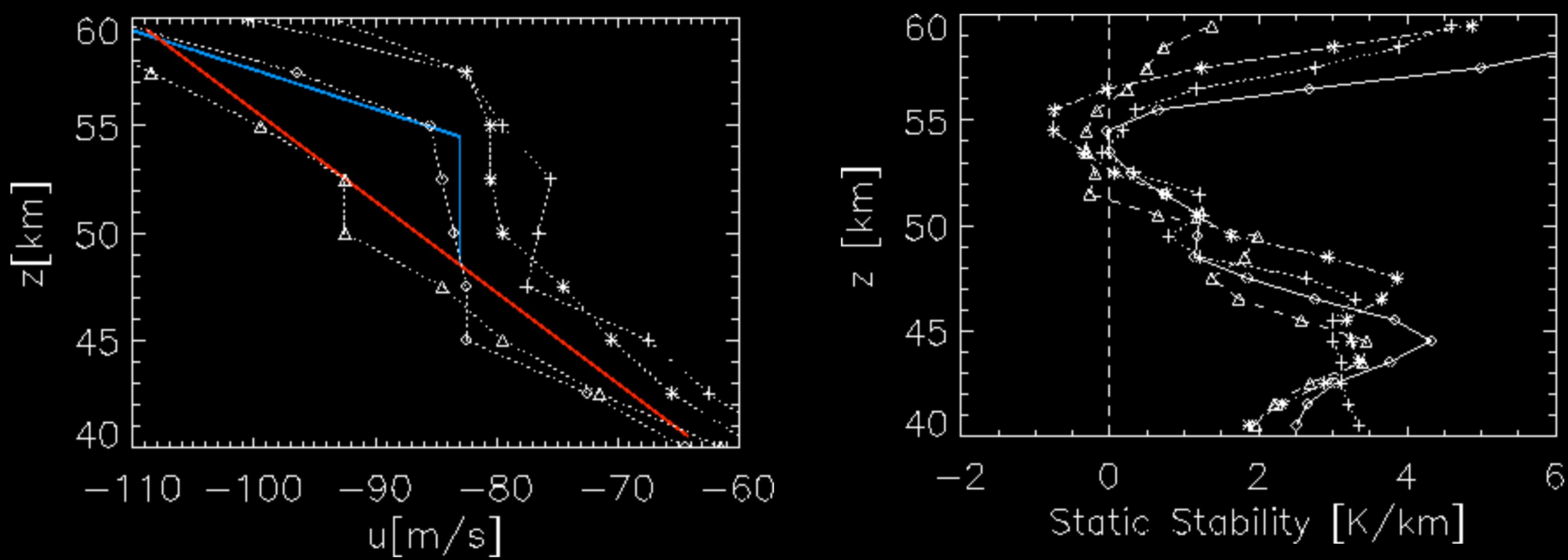


Optical depth of simulated cloud is 22.3, also consistent with observations

A large cloud, about 2000 km long and 500 km wide, observed by VIRTIS at 2.3μm (negative: clouds are bright here). Clouds are greatly elongated due to high zonal winds and vertical shear

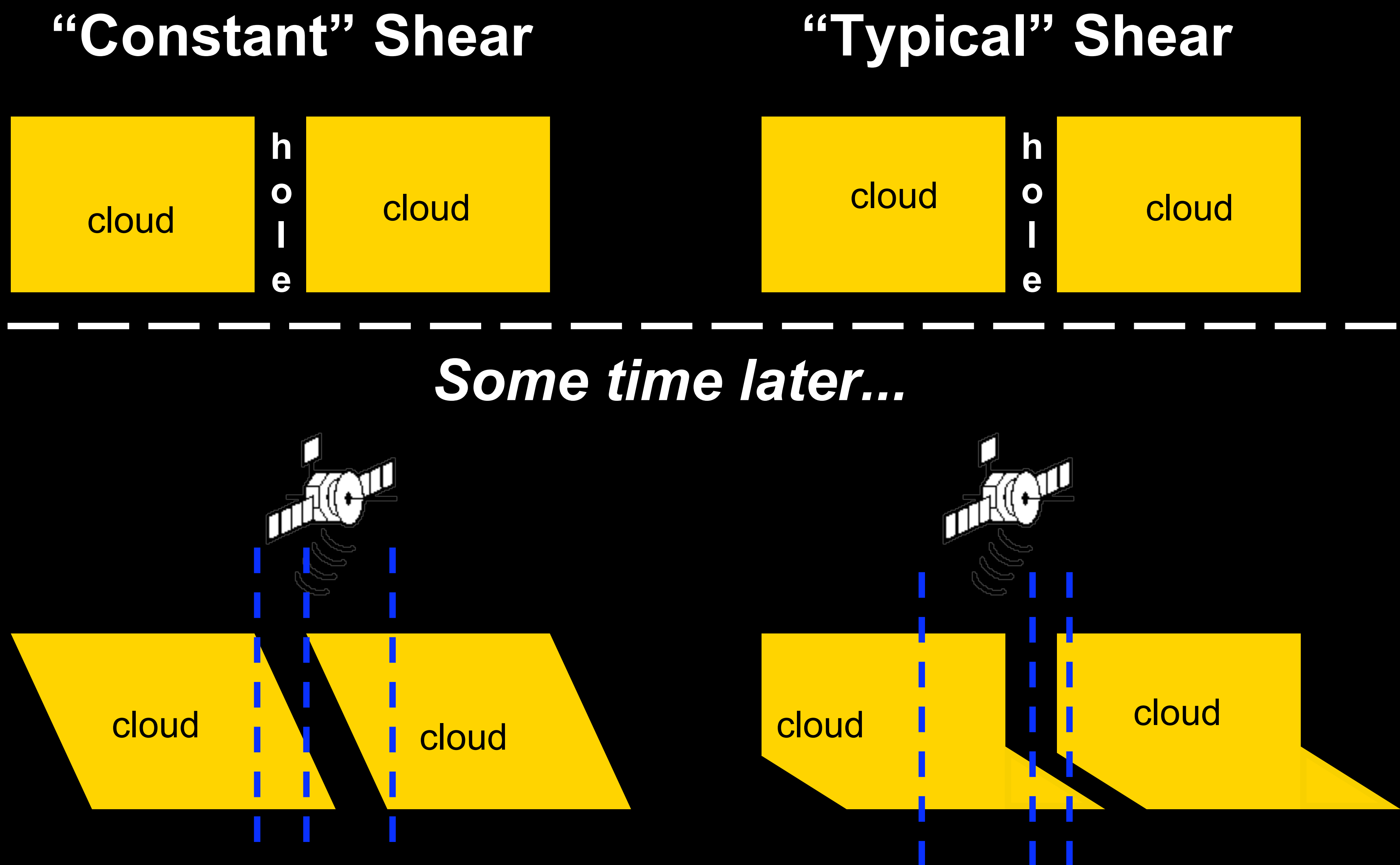


Observed zonal winds and stability



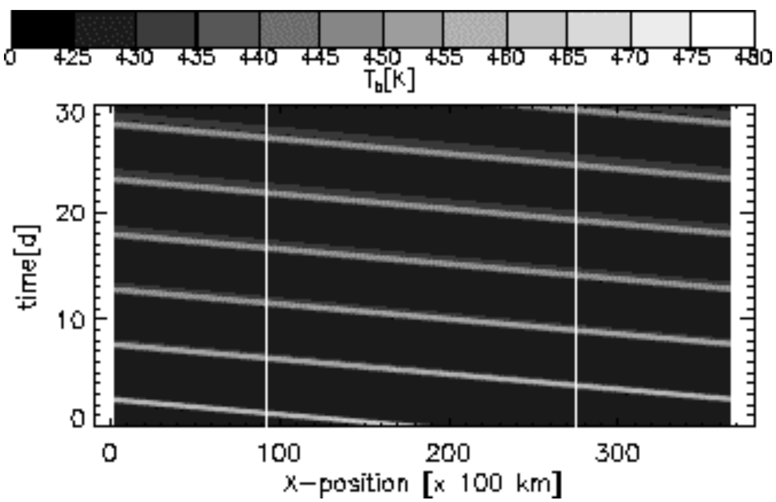
- There is significant vertical shear of the zonal wind in the Venus atmosphere
- There also is a correlation between shear and stability: most probes show minimal shear where atmosphere is neutrally stable
- North probe, however, measured nearly constant level of shear throughout descent

How shear can dissipate a hole in the clouds

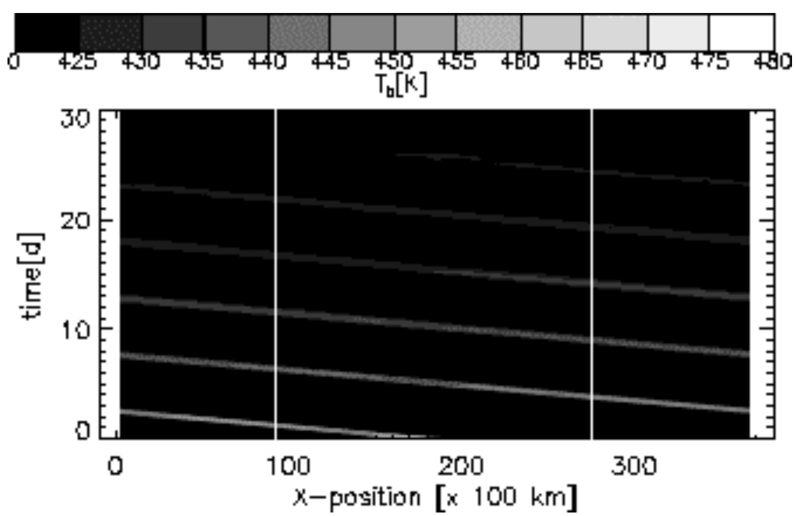


Shear Simulations: both profiles, with and without feedback

2dnvt

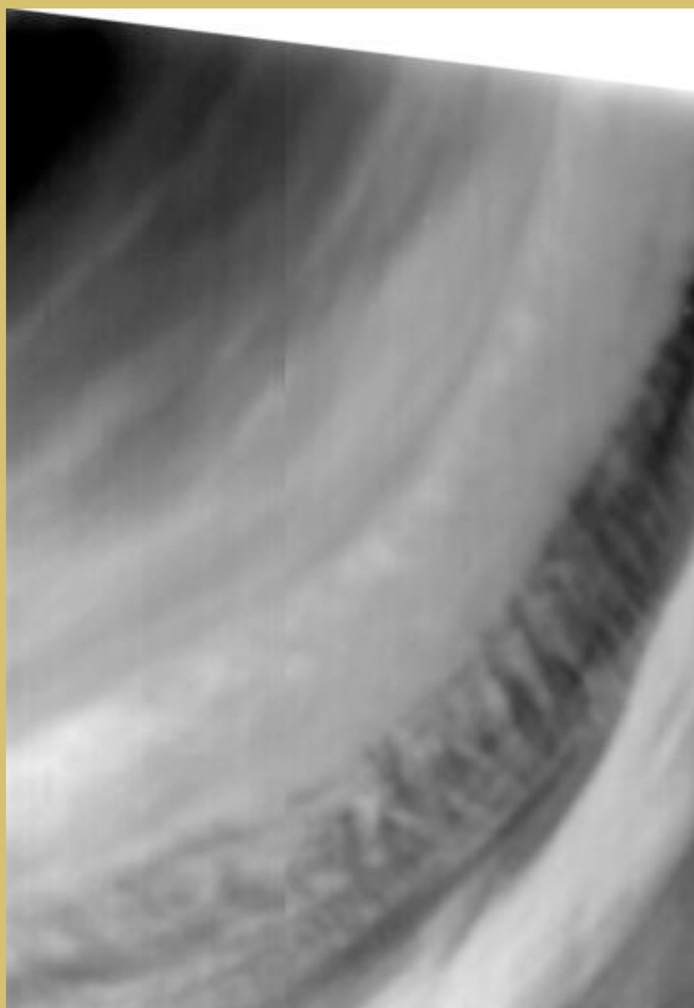


2dall

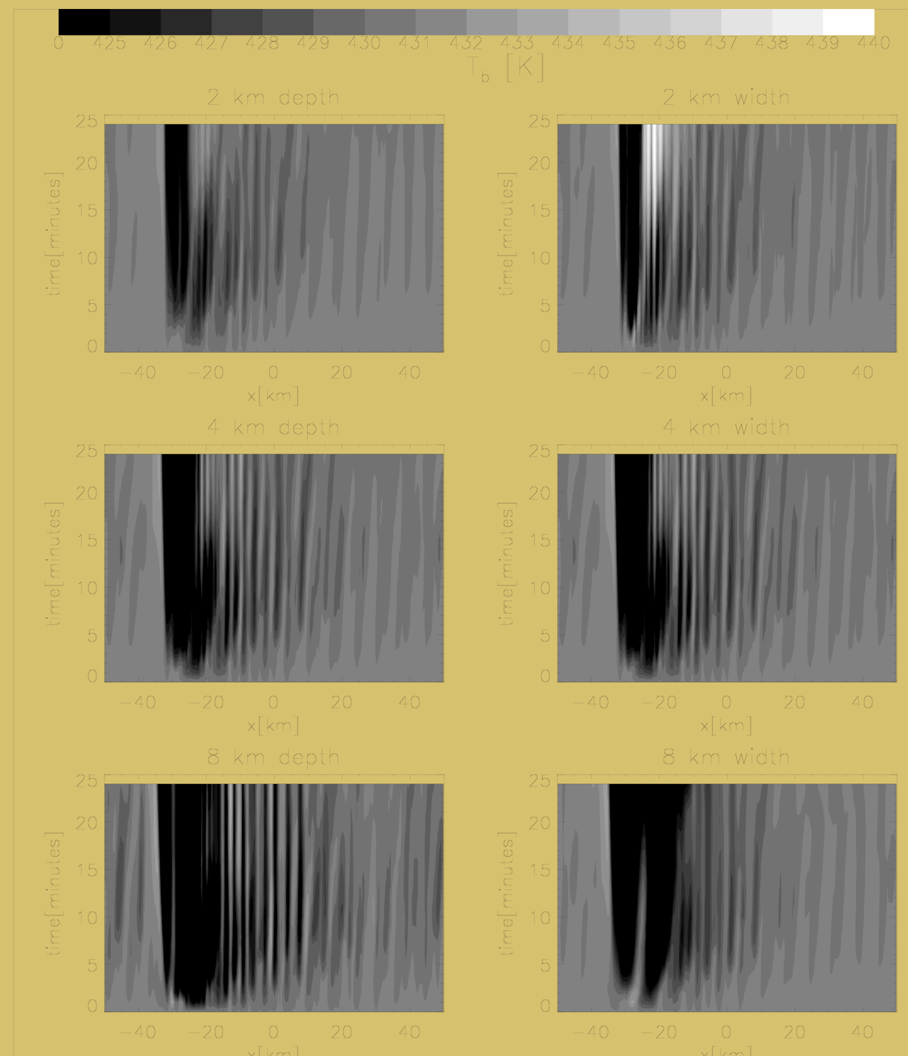


Can simulate waves with our model, and compare results with VIRTIS imagery of the clouds

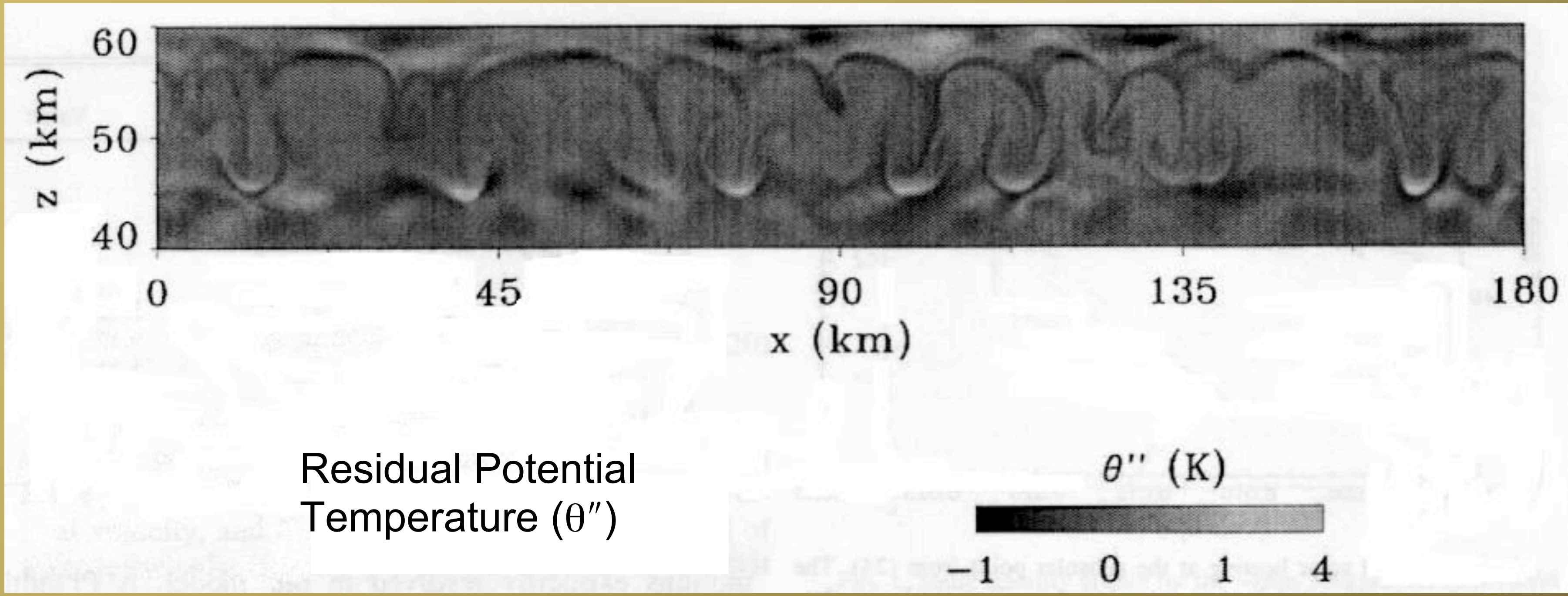
VIRTIS: 1.74 μm image
(from Venus Express website)



- 1.74 μm brightness temperature
- gravity wave launched from -30km
- time on vertical axis
- wave train develops; more obvious when launched by deeper plume (lower left)



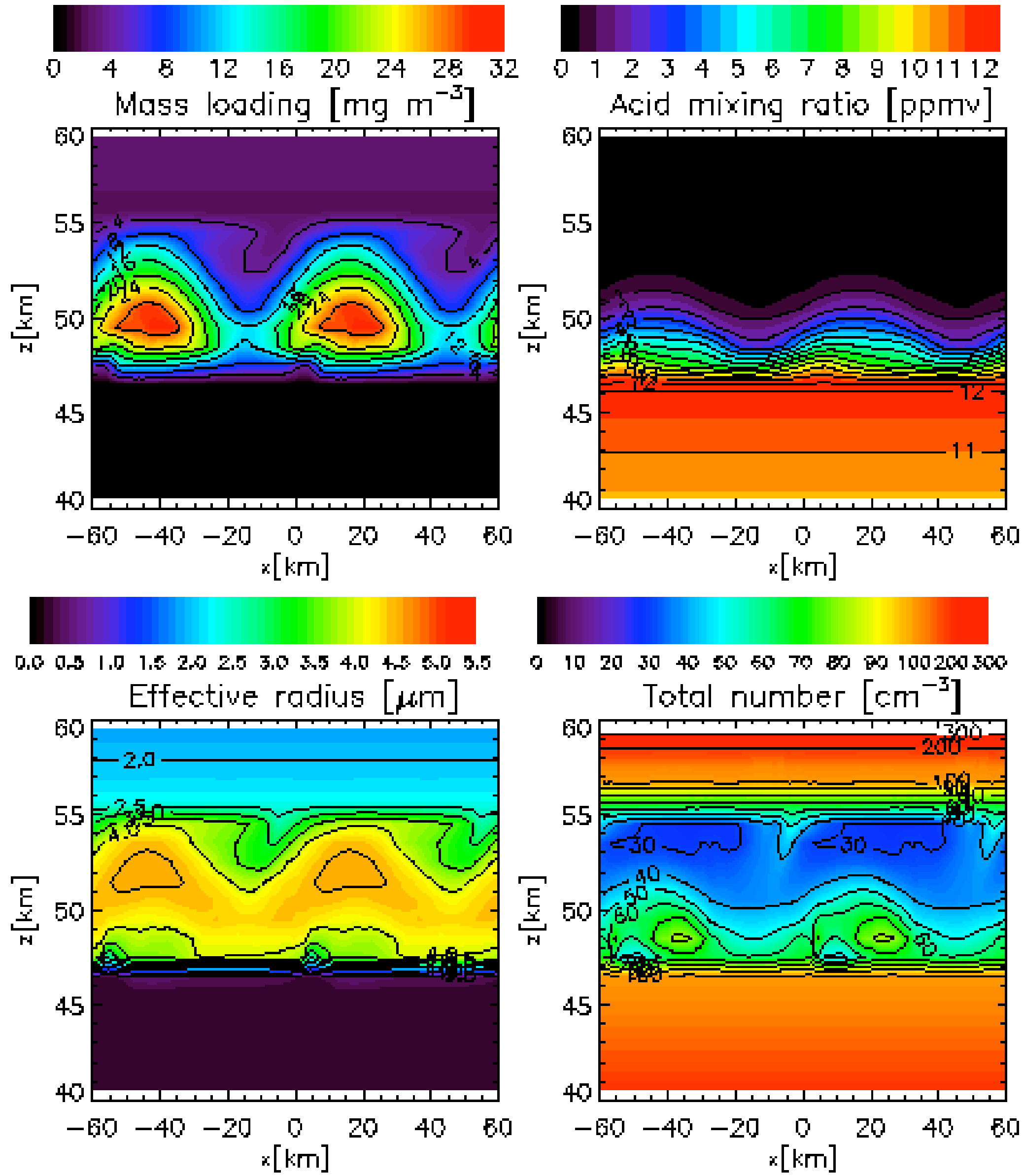
Dynamics simulations predict penetrative convection in the clouds



In this simulation by Baker et al. (1998), cold, narrow, downplumes penetrate the stable layer beneath the cloud. Warm, broad upflows ascend to the top of the middle cloud deck.

The mass loading, acid vapor mixing ratio, particle number and effective radius respond to the imposed pseudo-convective winds.

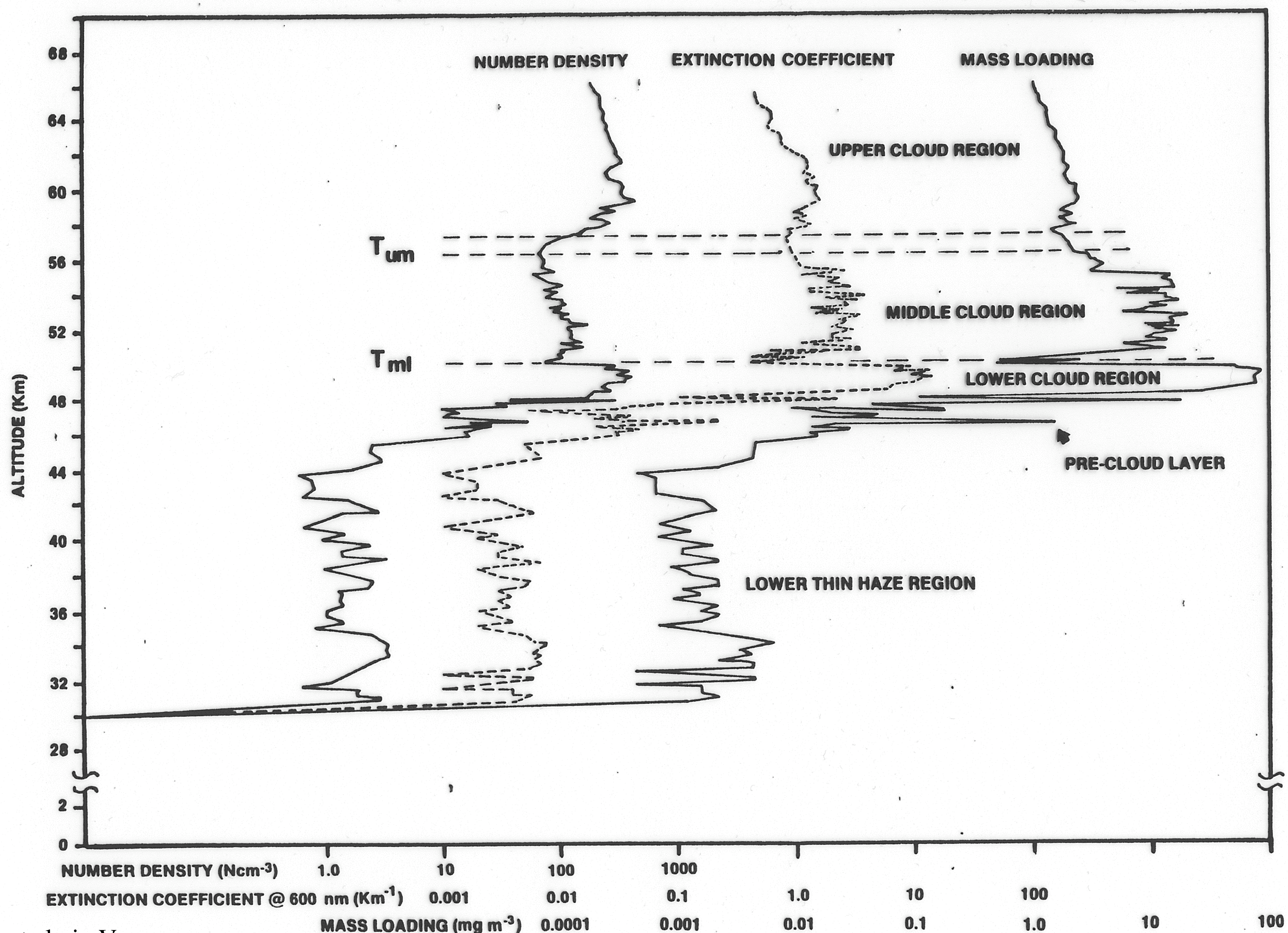
- Increases in mass loading and sulfuric acid vapor mixing ratio in regions of updraft
- Similarly, decreases in regions of downdraft.
- Effective radius behavior not as simple
  - Increases at higher altitudes; but decreases at lower altitudes in updraft.
  - This is due to growth versus activation processes.



What might we learn from studies of the Venus clouds

- Information about convection, waves, and large scale motions in the 45-60 km region from interpretations of near infrared markings. These motions may be drivers of the circulation.
- A better understanding of the sulfur cycle, and possibly climate change.
- The identity of the UV absorber with possible parallels to the anoxic early Earth.
- Insights into SO2 reaction rates from the SO2 vertical profile, and its changes

VERTICAL STRUCTURE OF VENUS CLOUD SYSTEM



Espostio et al., in Venus

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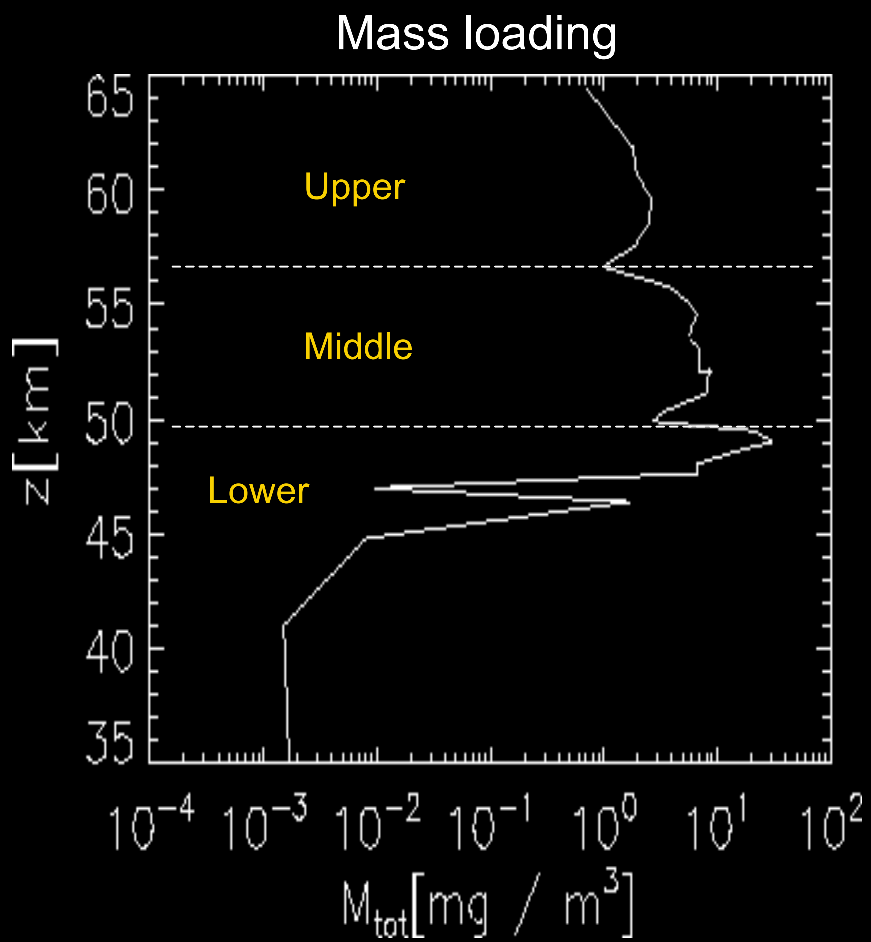

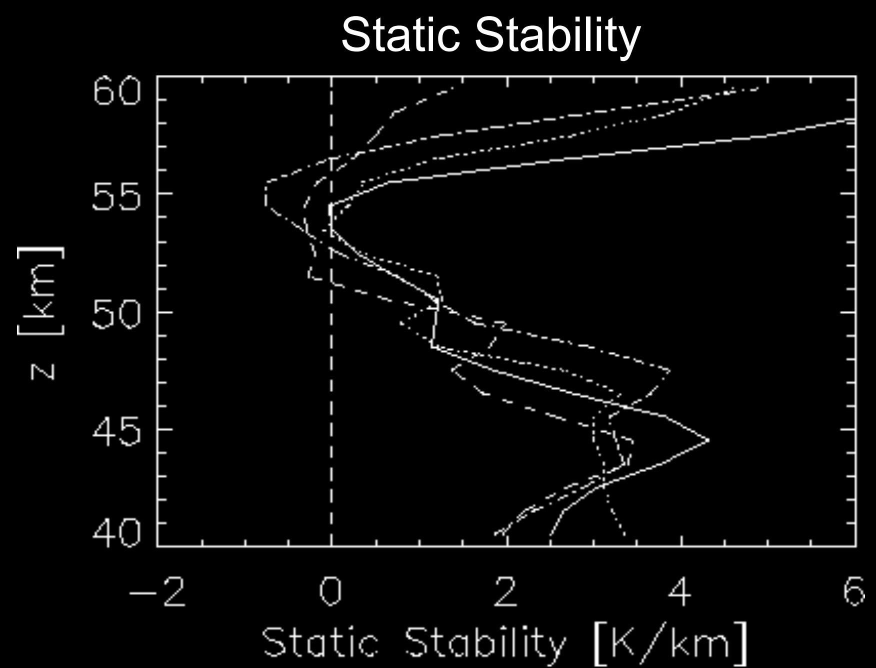

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McGouldrick, K. and Toon, O.B., 2007. An Investigation of possible causes of the holes in the condensational Venus cloud using a microphysical cloud model with a radiative-dynamical feedback. *Icarus* (In Press).

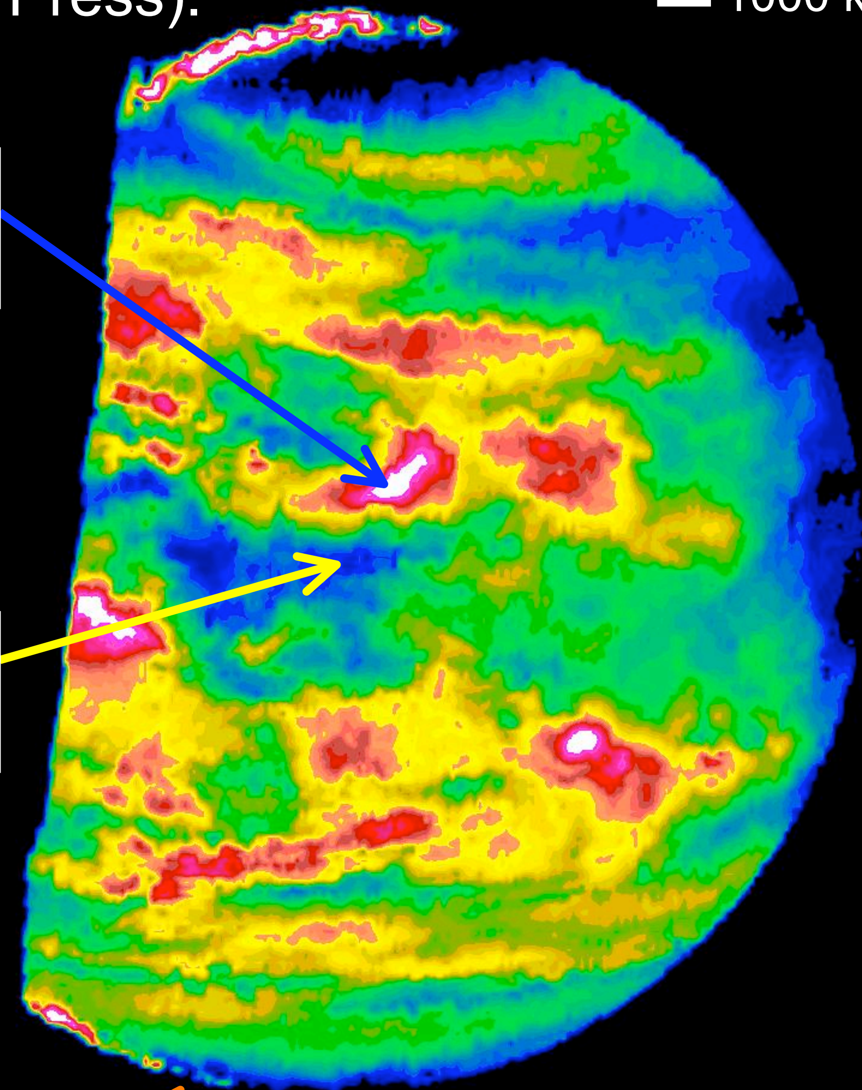
Can the clouds be simulated with a radiative-dynamical feedback?

Can we reproduce the holes in the clouds by varying model parameters?

τ~10
T_b~480 K

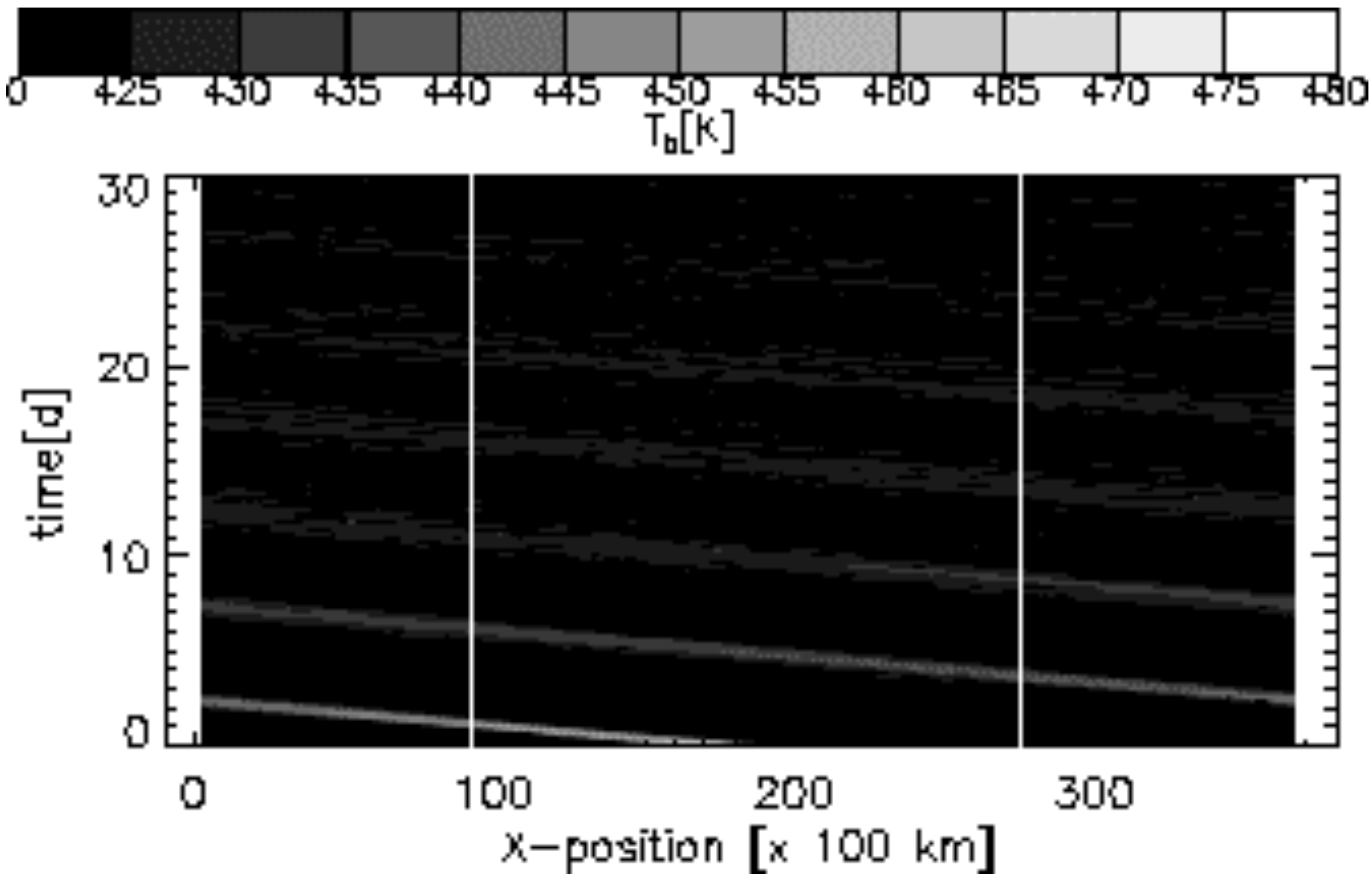
τ~25
T_b~425 K

1000 km

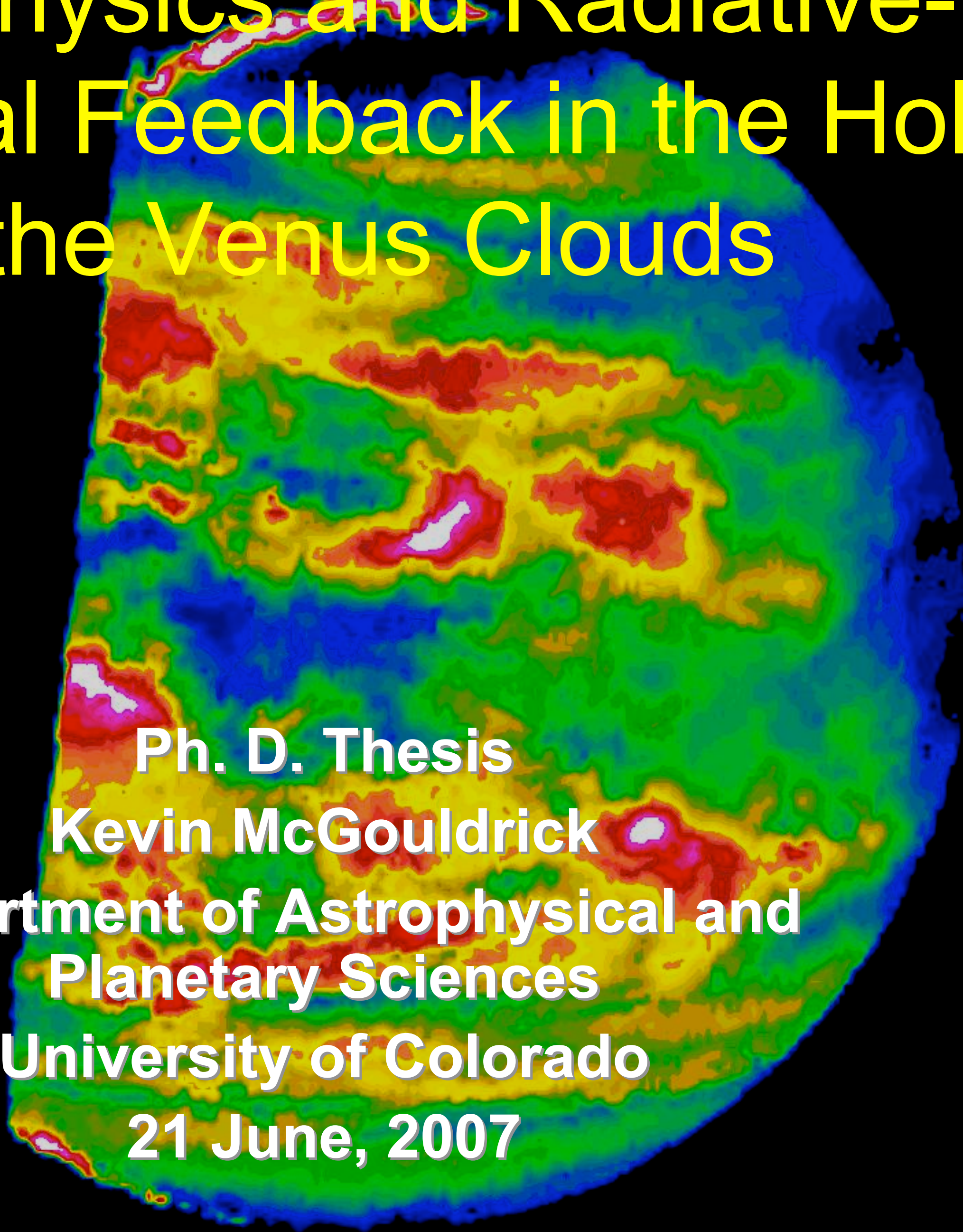


direction of zonal winds

“Variable” shear profile



Microphysics and Radiative-Dynamical Feedback in the Holes in the Venus Clouds



Ph. D. Thesis

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