Exploring Venus: Major scientific issues and directions. Summary of the AGU Chapman Conference Presented to VEXAG

Larry W. Esposito

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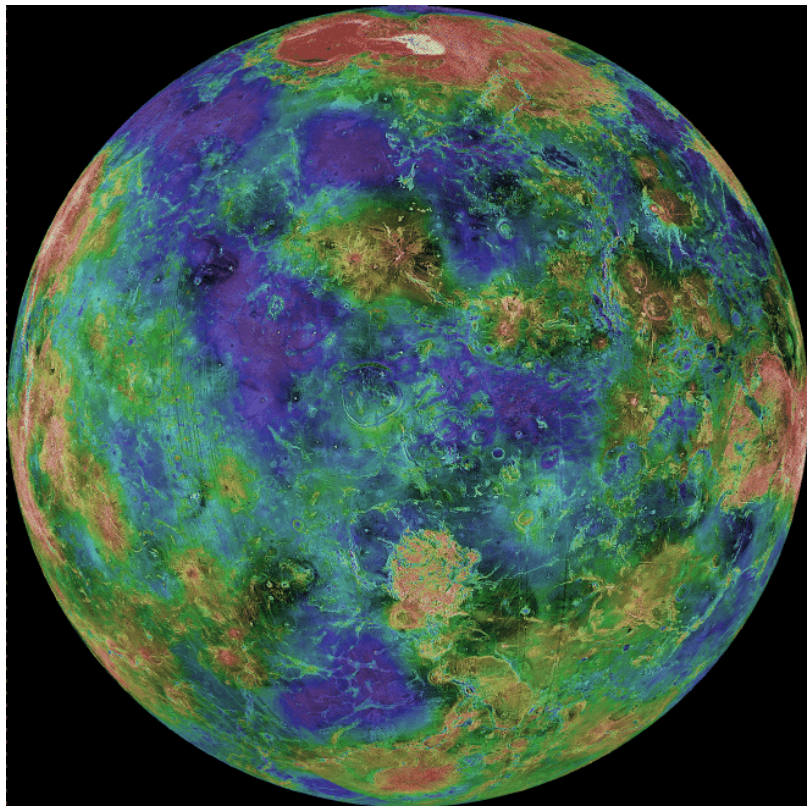
Chapman Conference Report

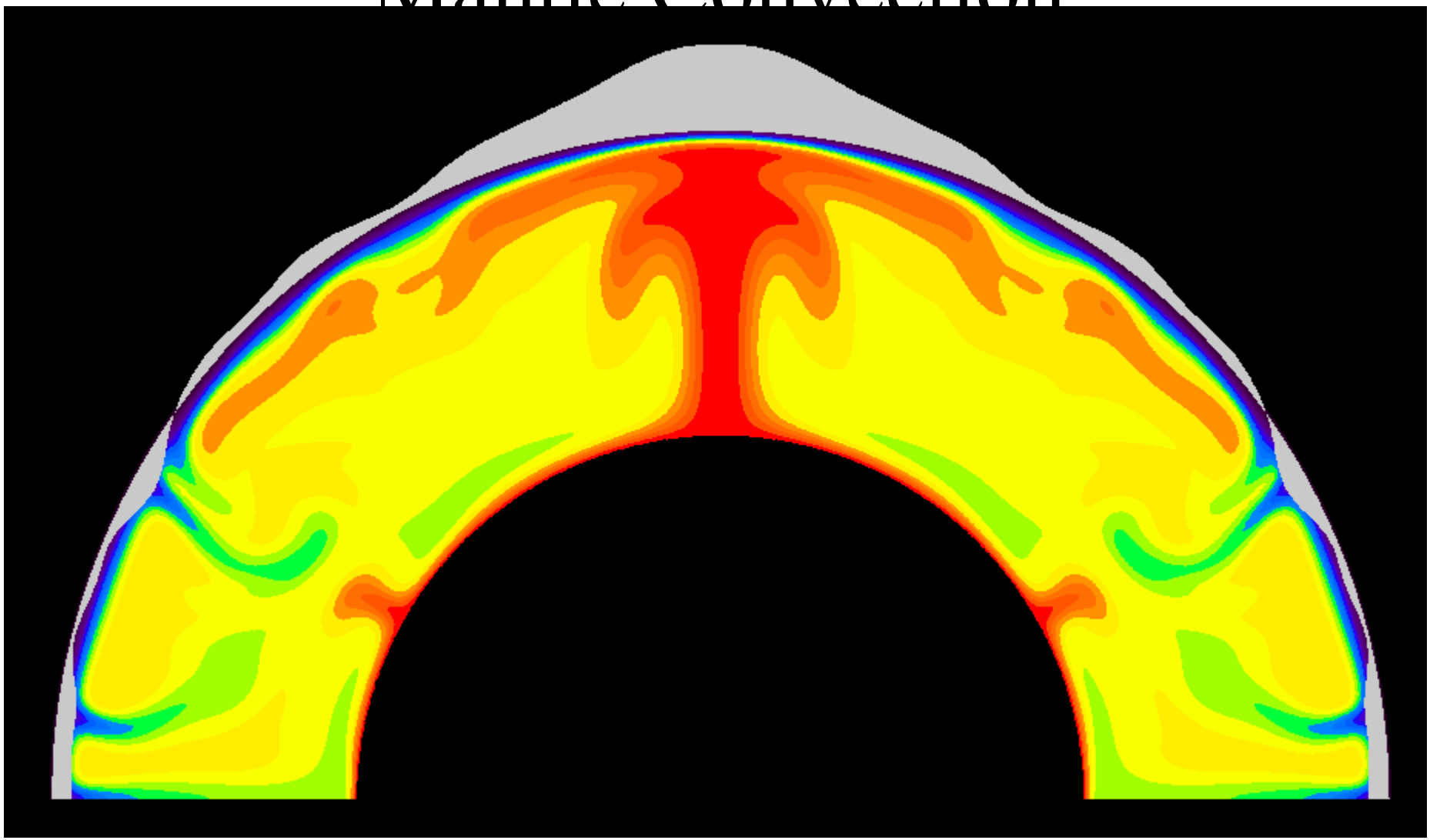
- Provided overview of current missions and research directions
- Highlighted key open questions
- Emphasized importance of Venus in understanding terrestrial planets
- Updates the NRC decadal survey: provides priorities for future exploration

Standard Views on Venus

1. Earthlike structure
2. No plate tectonics but mobile surface in the past?
3. Liquid outer core likely (inferred from solar tidal gravity) but no B field because..
   a. No inner core because of higher T; lower P than Earth. ***Or…***
   b. Planet currently heating up as it transitions from mobile to stagnant surface.



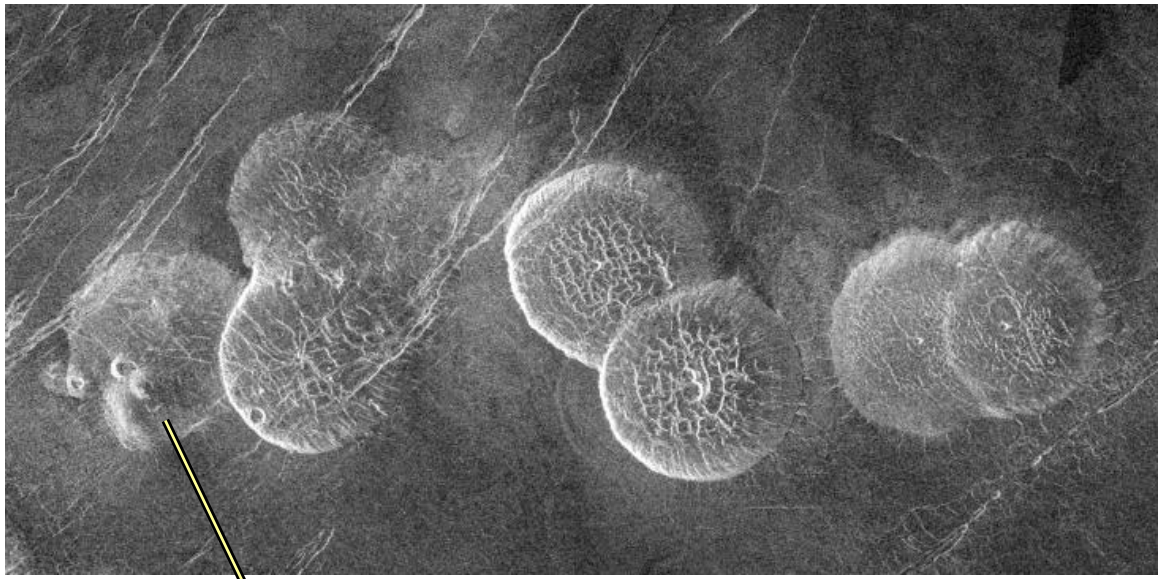
Mantle Convection



Kiefer and Kellogg (1998)

Venus crust

Volcanic constructs: steep-sided domes



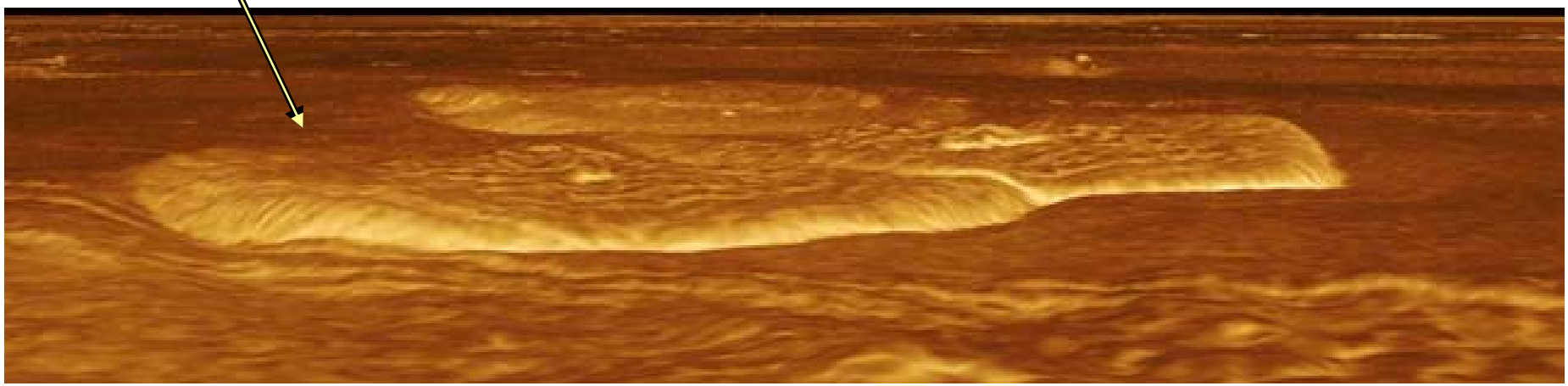
Tens km in diameter,
Hundreds meters high,
Steep-sided:

=> Viscous lavas

=> **Evolved composition e.g. dacites?**

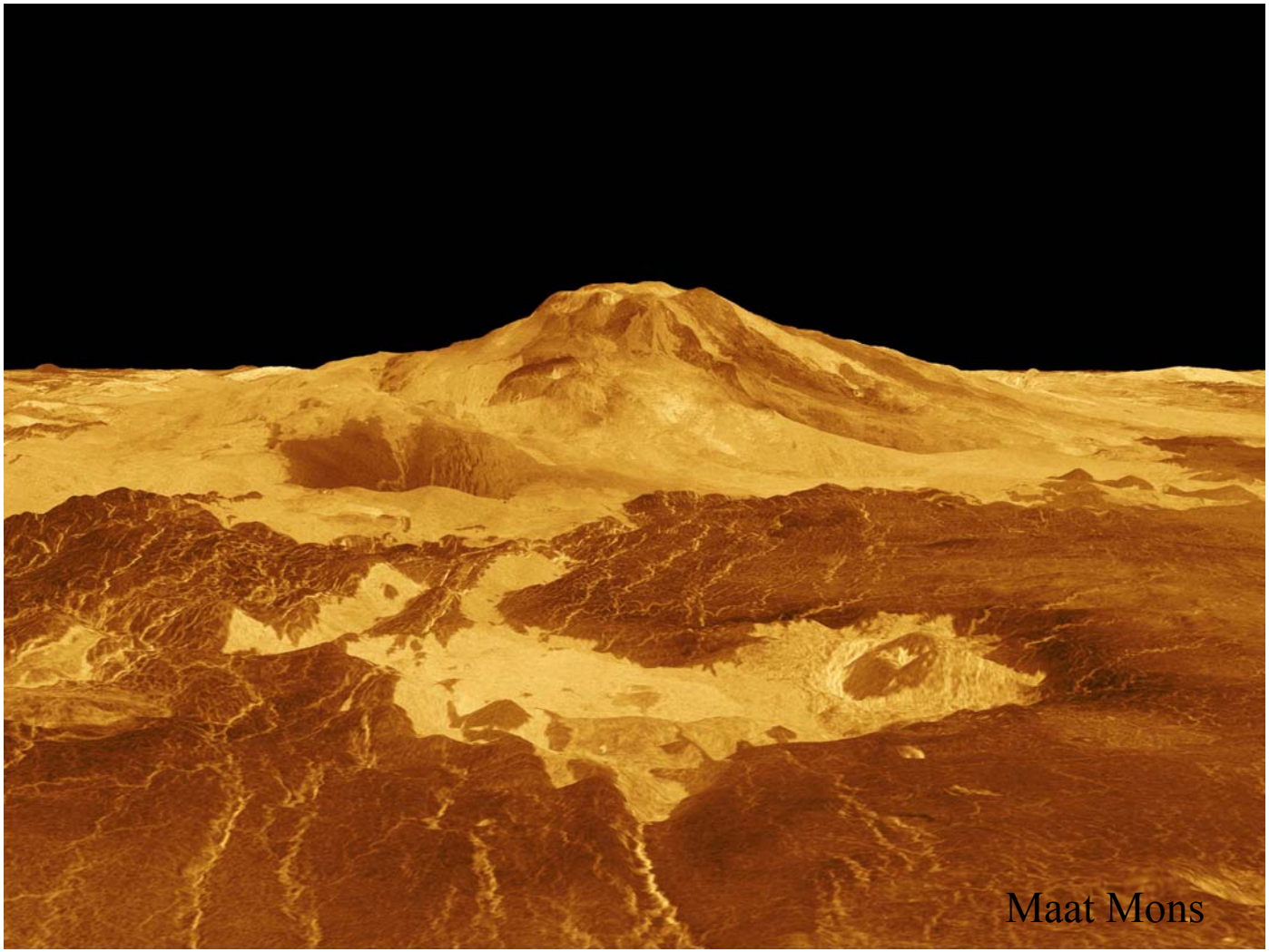
or

=> **Basalt with gas bubbles?**

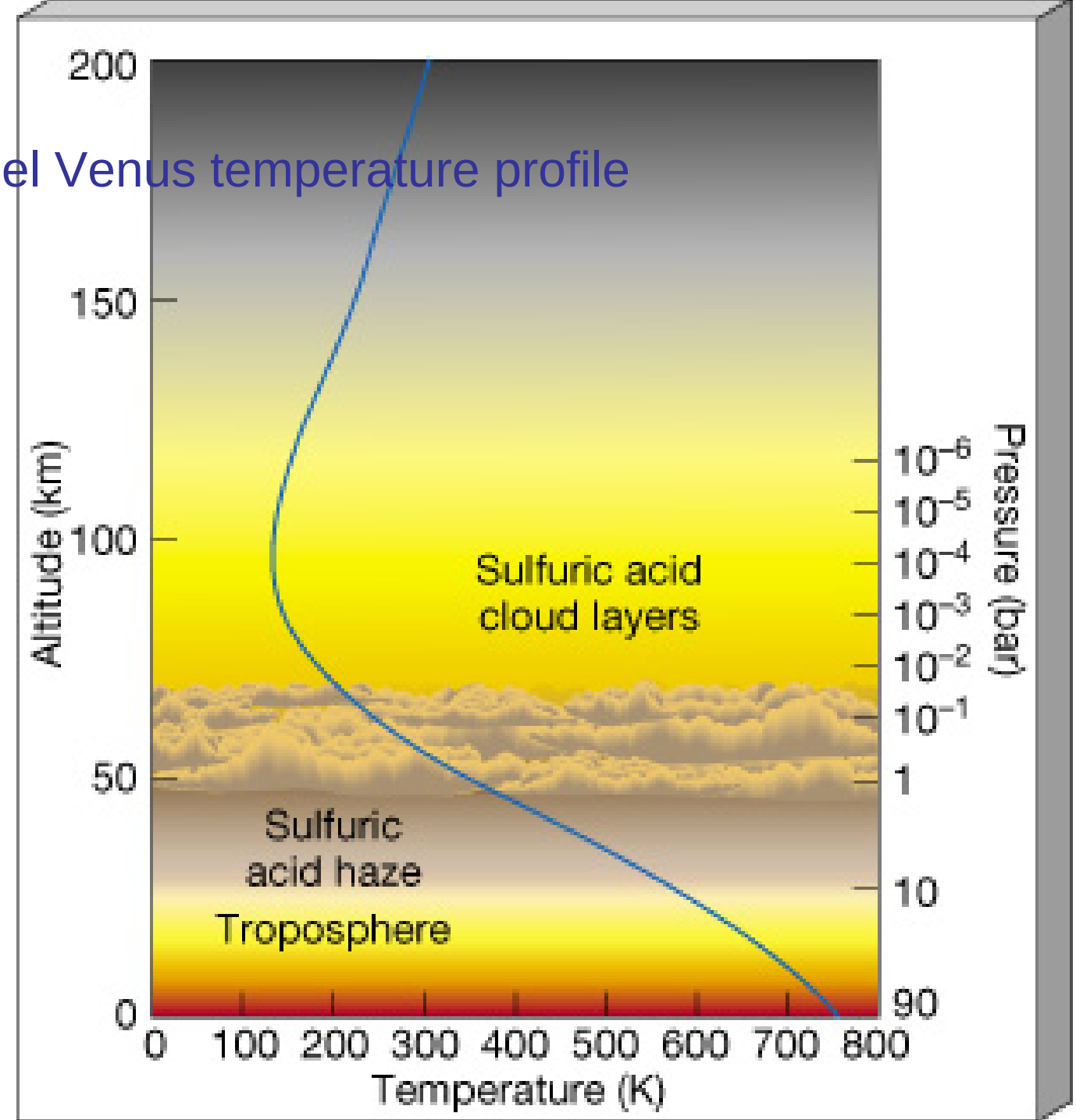


Theoretical Argument

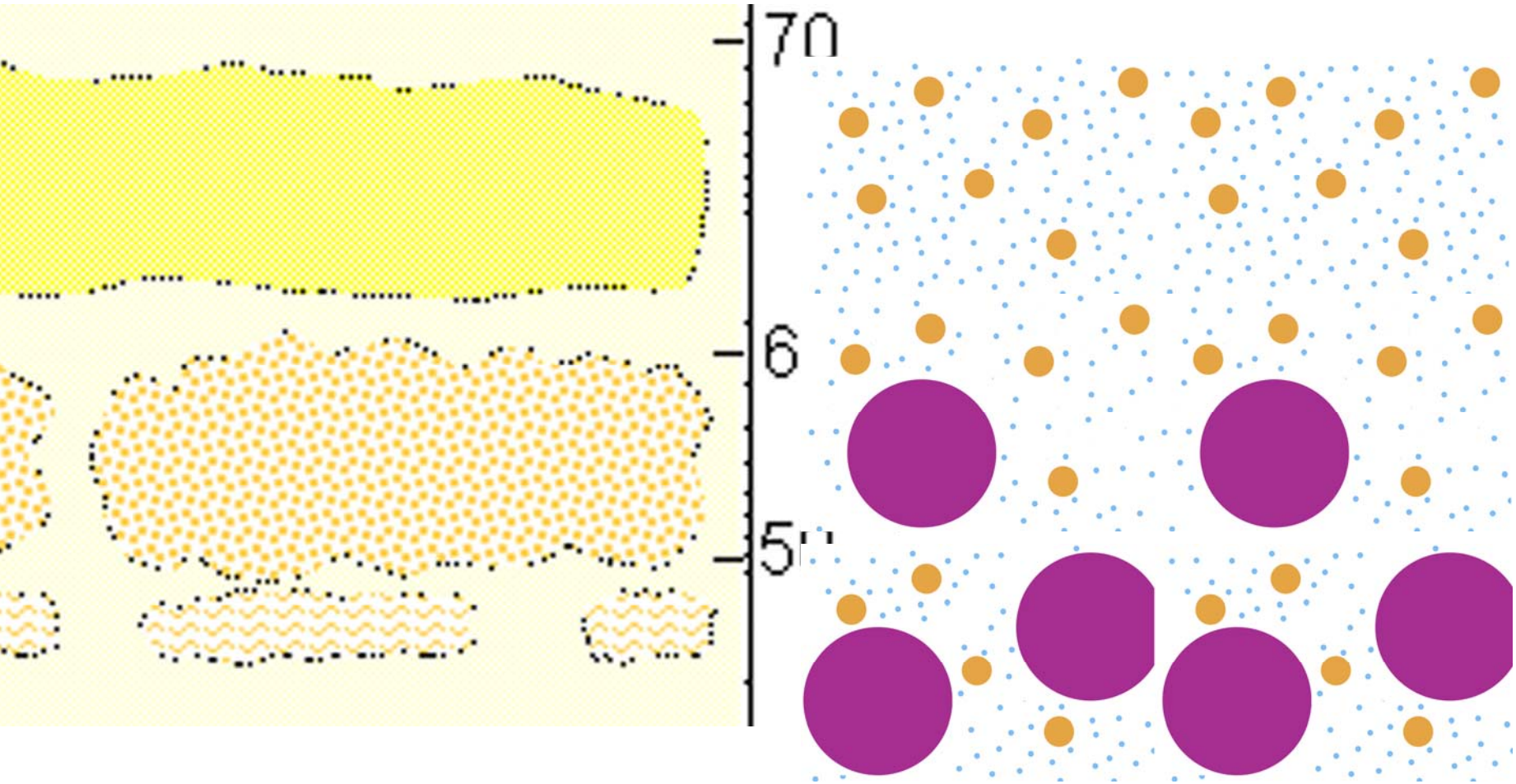
If Venus underwent a global resurfacing event about 500 Myr ago, then it could have produced a lithosphere as thick as 300 km in the intervening time.

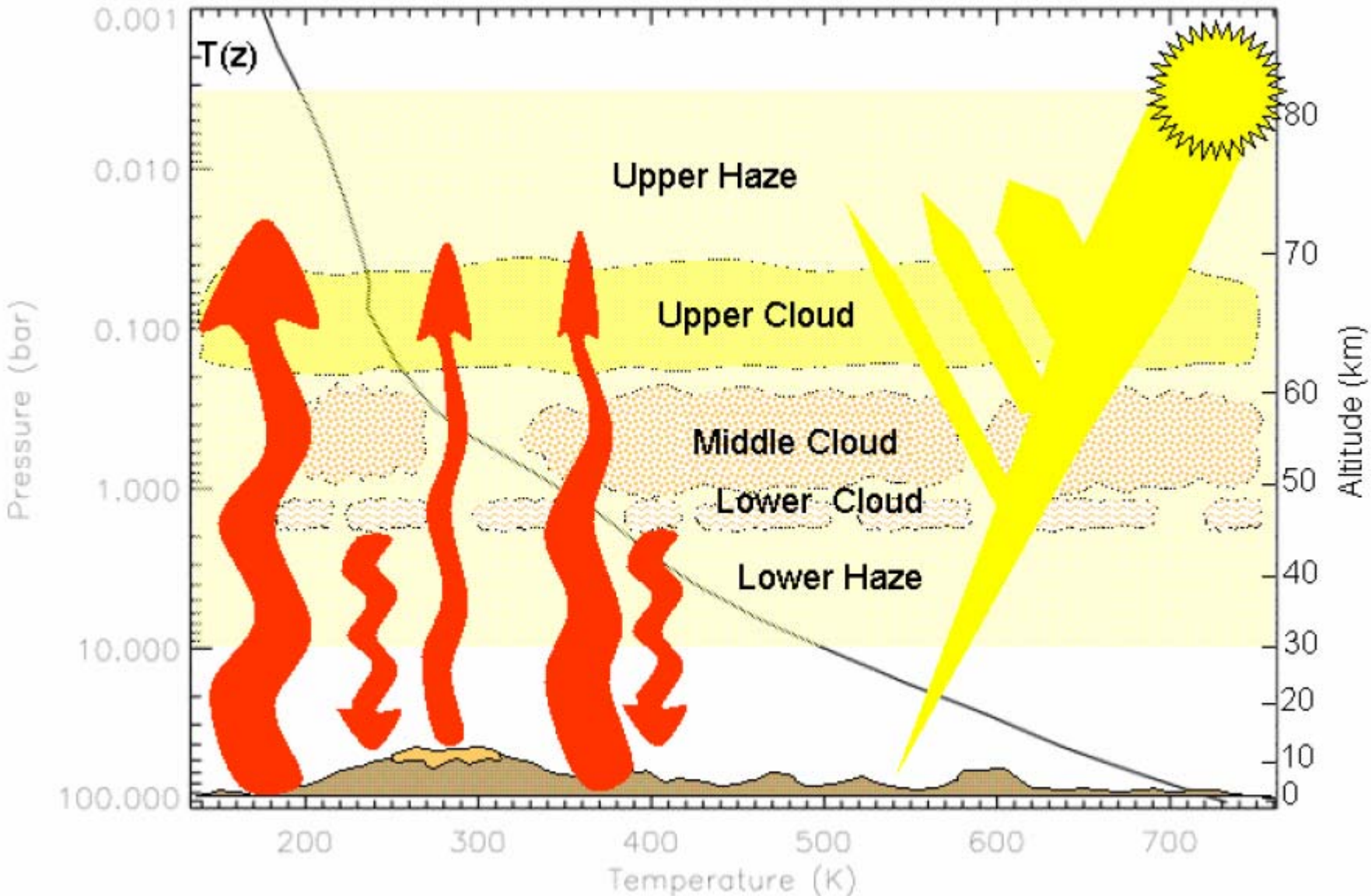


Model Venus temperature profile



Cloud Particles: Physical Properties




T(z)
Upper Haze
Upper Cloud
Middle Cloud
Lower Cloud
Lower Haze
0.001
0.010
0.100
1.000
10.000
100.000
Pressure (bar)
200
300
400
500
600
700
Temperature (K)
80
70
60
50
40
30
20
10
0
Altitude (km)

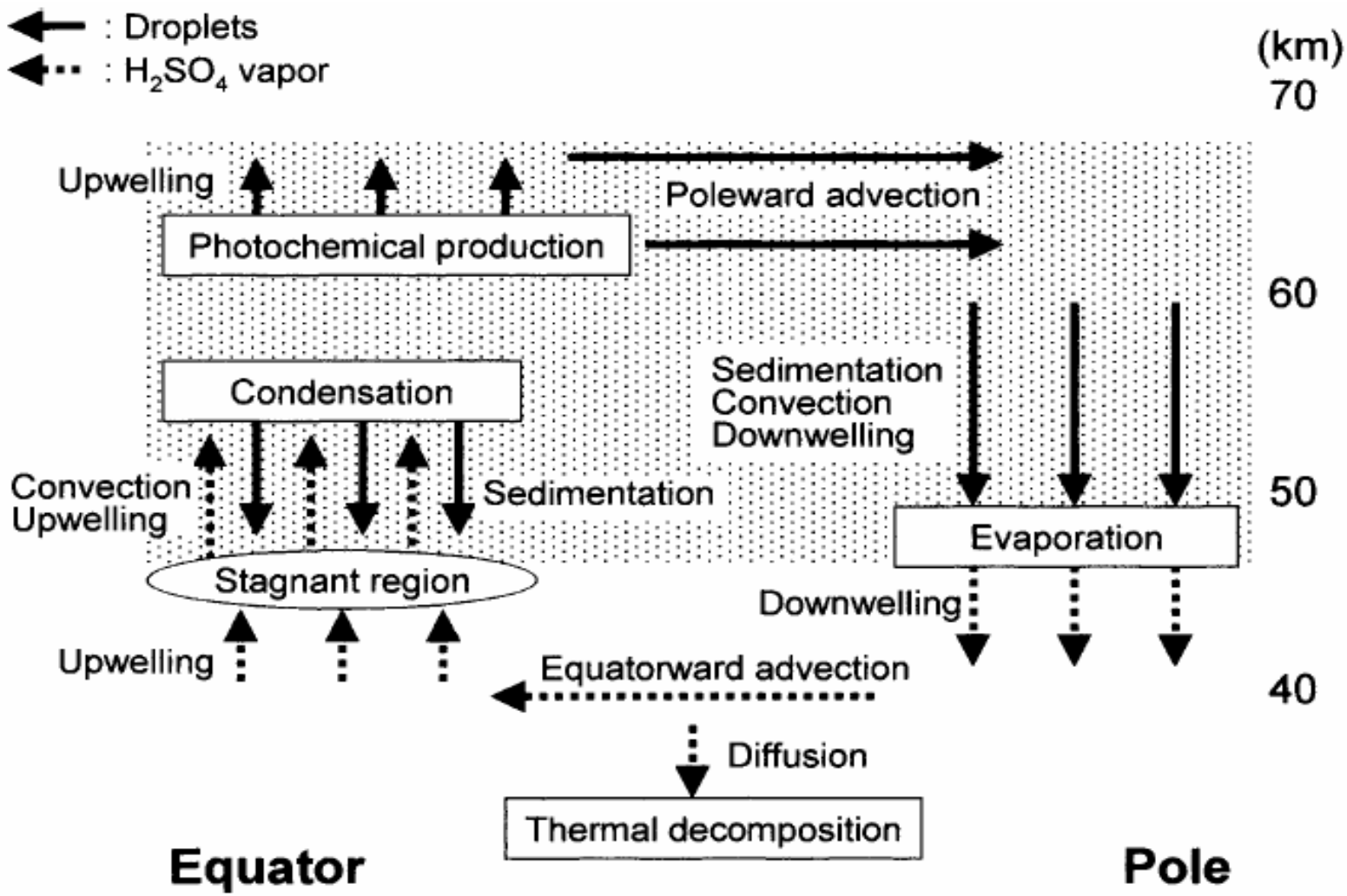
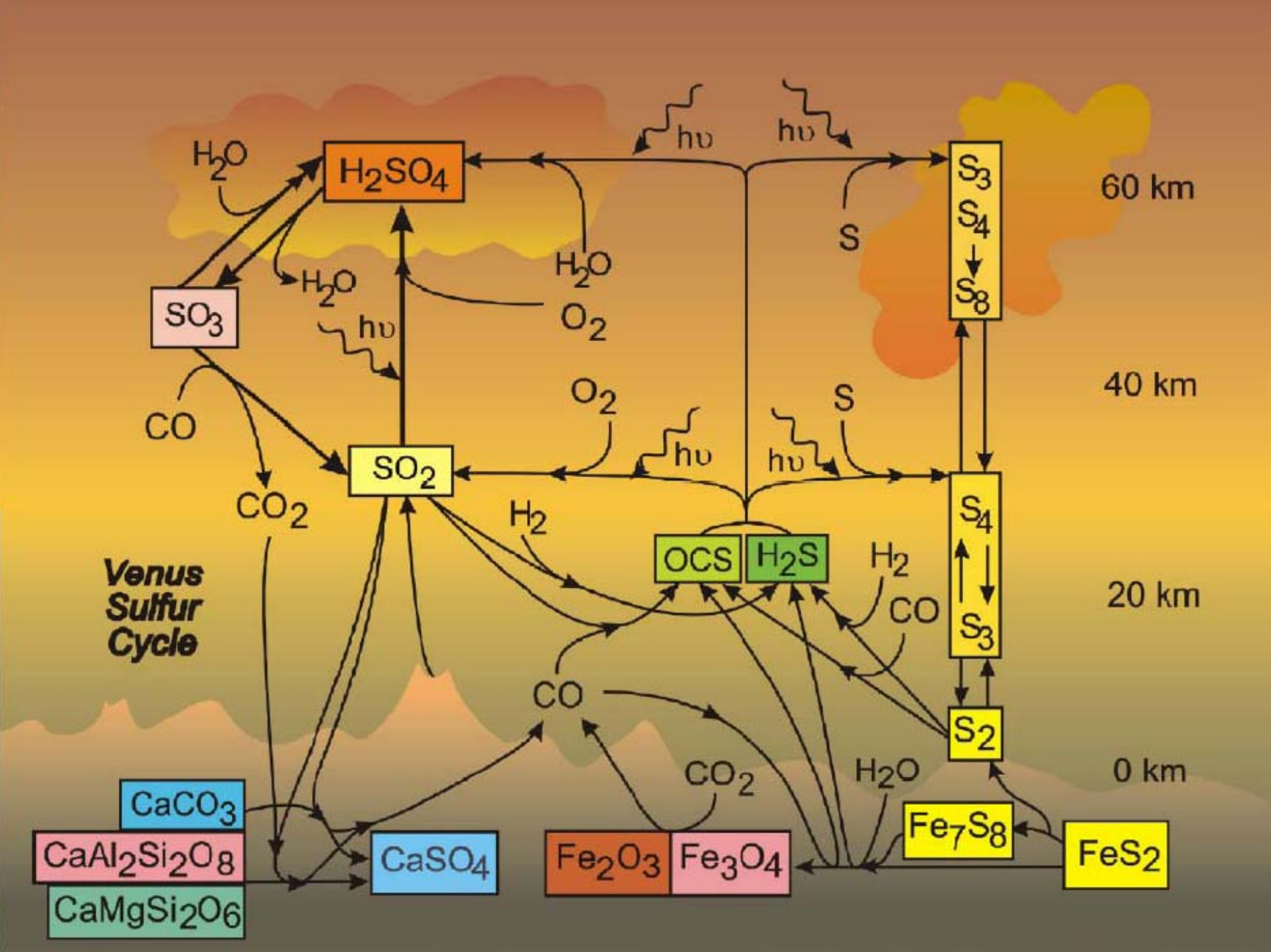


FIG. 1. Schematic view of the H_2SO_4 cycle in the Venusian atmosphere (Imamura and Hashimoto 1998). Cloud particles created photochemically near the cloud top are transported poleward by Hadley circulation, being subsequently transported downward at high latitudes and evaporating in the hot lower atmosphere. The resulting H_2SO_4 vapor is transported equatorward beneath the cloud by return flow and eventually ascends in the rising branch of Hadley circulation near the equator. Droplets that are formed in the rising air subsequently fall due to their large size and H_2SO_4 vapor accumulates near the cloud base in the equatorial region.

[Imamura and Hashimoto, JAS, 2001]


Venus Sulfur Cycle
60 km
40 km
20 km
0 km
H2SO4
SO3
SO2
S3
S4
S8
S4
S3
S2
OCS
H2S
CaCO3
CaAl2Si2O8
CaMgSi2O6
CaSO4
Fe2O3
Fe3O4
Fe7S8
FeS2
H2O
CO
CO2
O2
H2
S
hυ

Some Conference Highlights

- Deepest part of atmosphere still unexplored
- Super-rotation of atmosphere unexplained
- Surface mineralogy unknown
- Beta-Atla-Themis region is younger
- Early magnetic field could leave signatures
- Climate history has more sensitivities: Venus ocean could have persisted 2 b.y.
- Venus may have been habitable for much of its history

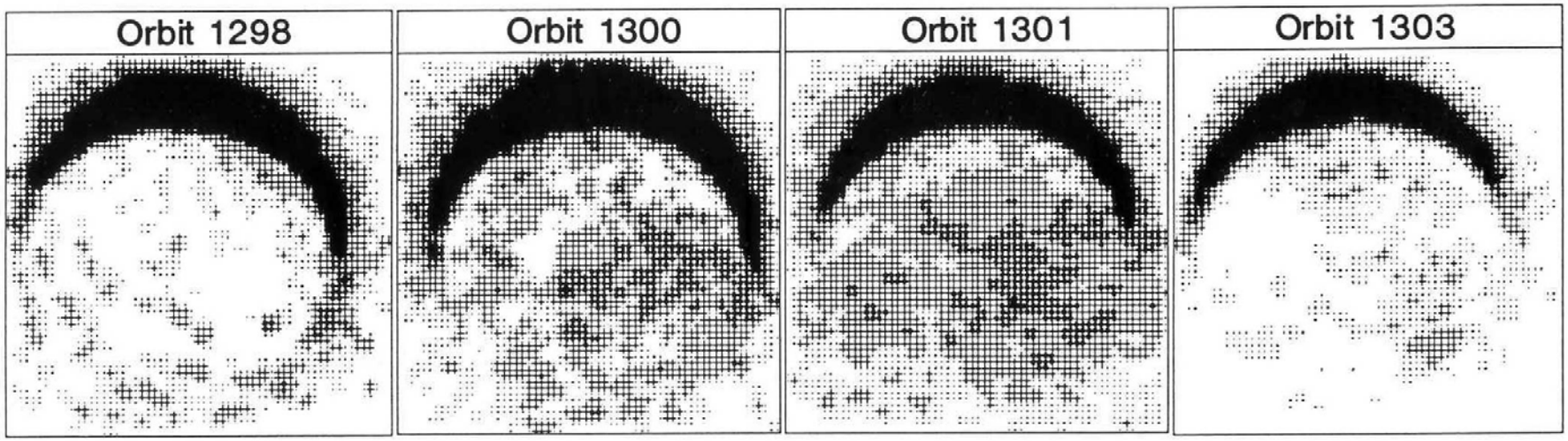
Comparative Planetology Laboratory

Handling the Topography of Venus with a Hybrid Sigma-Theta Coordinate GCM

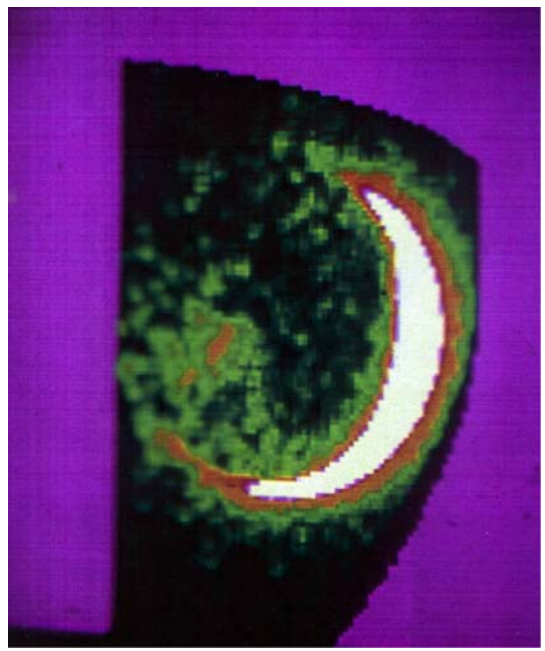
A. Herrnstein, T. Dowling

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Aurora at Venus

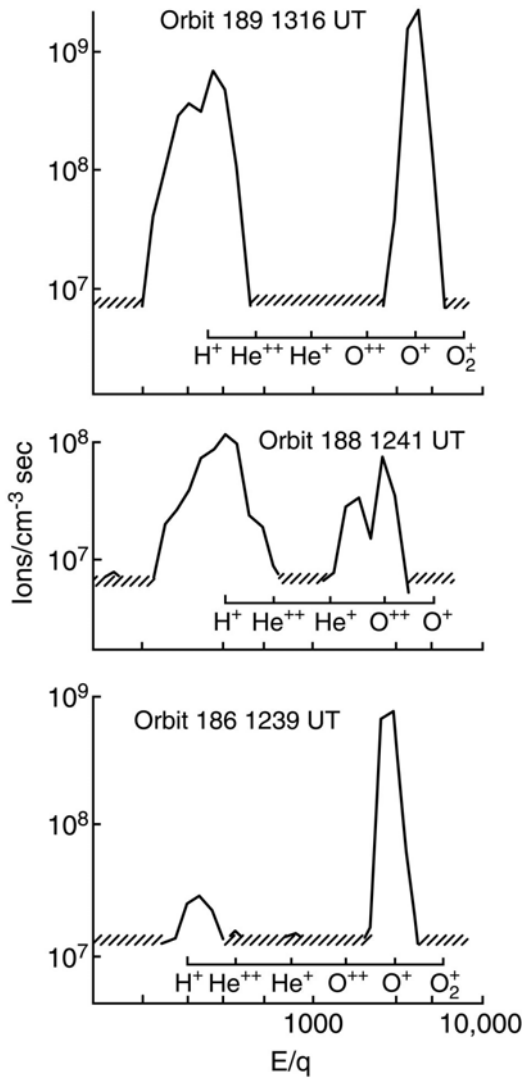


- Aurora can be distinguished from airglow by the ratio in intensity in different emission lines
- Auroras require energetic electron excitation
- Even though Venus has no interior or crustal magnetic field it does have aurora



Ion Pickup

- Pioneer Venus carried an electrostatic analyzer that took many spacecraft spins (over 10 minutes) to sample all energies and had a complex procedure to achieve data compression
- In order to detect picked up O^+ the plasma flow velocity had to be lower than normal and the magnetic field appropriately oriented
- In the examples shown here the plasma is flowing into the detector at about 200 km/s producing a 200 – 300eV peak of protons and a 3000 to 5000 eV O^+ peak
- Our interpretation of these peaks is that hot neutral oxygen is being ionized in slowly flowing magnetosheath plasma. If the solar wind moves much more rapidly the energy of the peak exceeds the instrument cut off



(Mihalov and Barnes, 1982)

Open questions: Geology

- How organized and directional is Venus surface history?
- Are tesserae ancient continents?
- When and how was Venus resurfaced?
- What is the surface mineralogy and how does it effect atmosphere and climate?
- Active volcanoes today?

Open questions: Atmosphere

- What processes are involved in zonal super-rotation? Polar vortices?
- How does the Hadley circulation work?
- What events led to the greenhouse?
- What is the blue absorber in the clouds?
- Lightning?

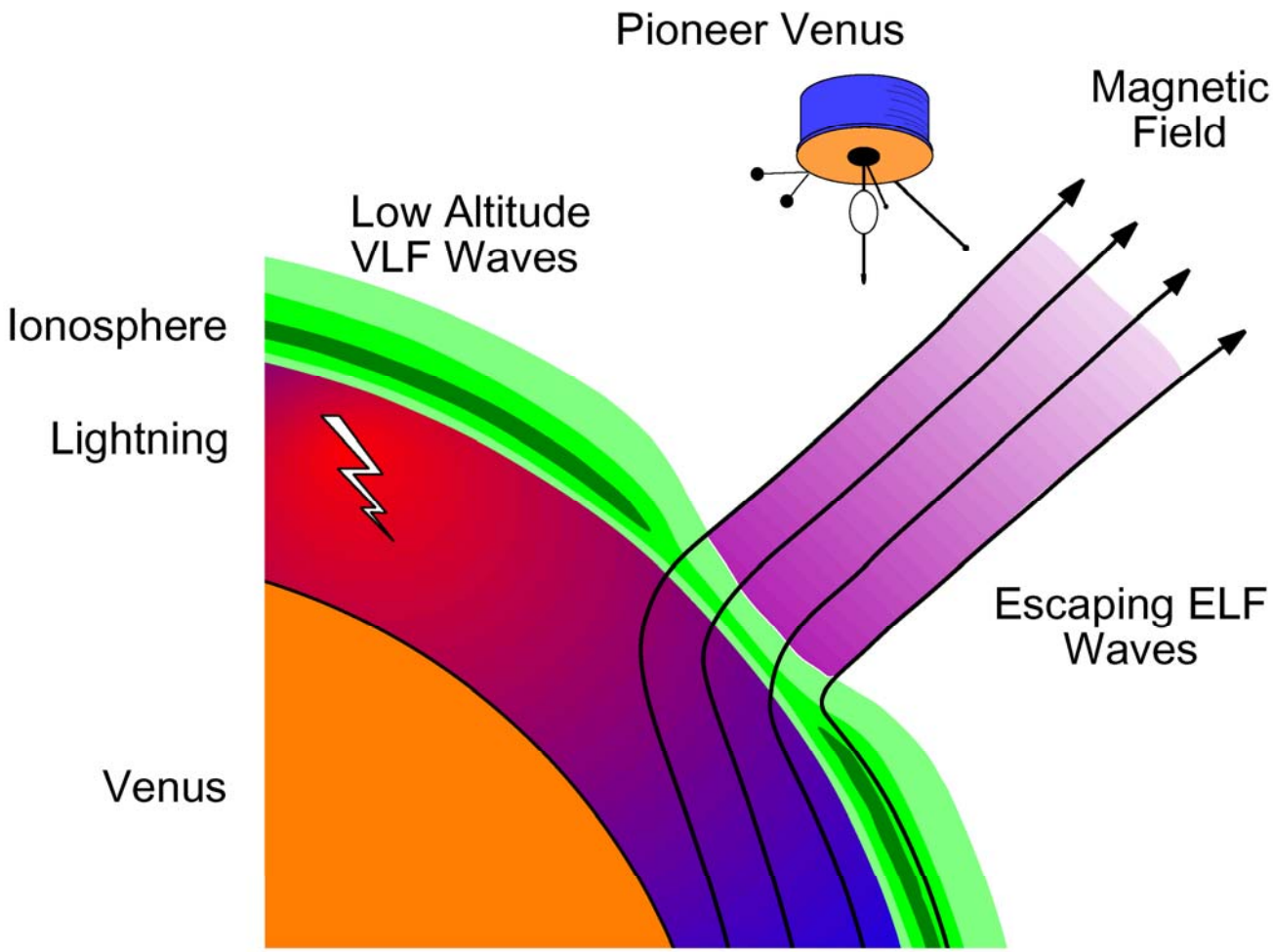
Open questions: Evolution

- What was the evolution of Venus atmosphere, surface, and interior?
- What is the stability and history of climate?
- What can noble gases and isotopes tell us?
- Did Venus have an ocean and when did it lose it?
- Was Venus ever conducive to life?
- Will future Earth resemble Venus?

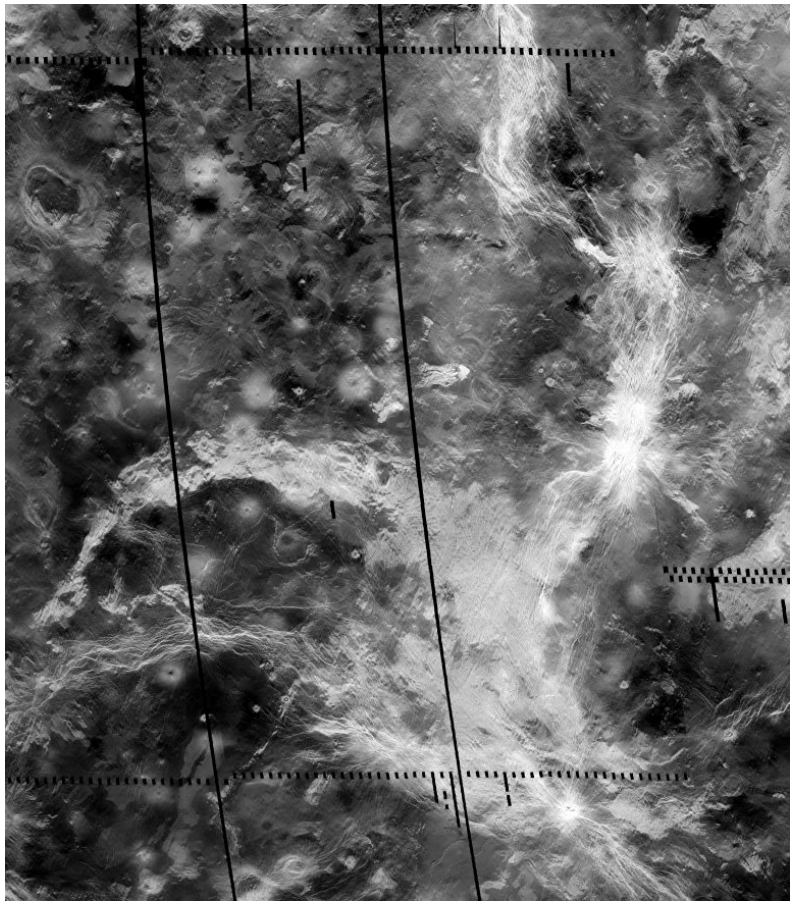
Open Questions: Solar wind

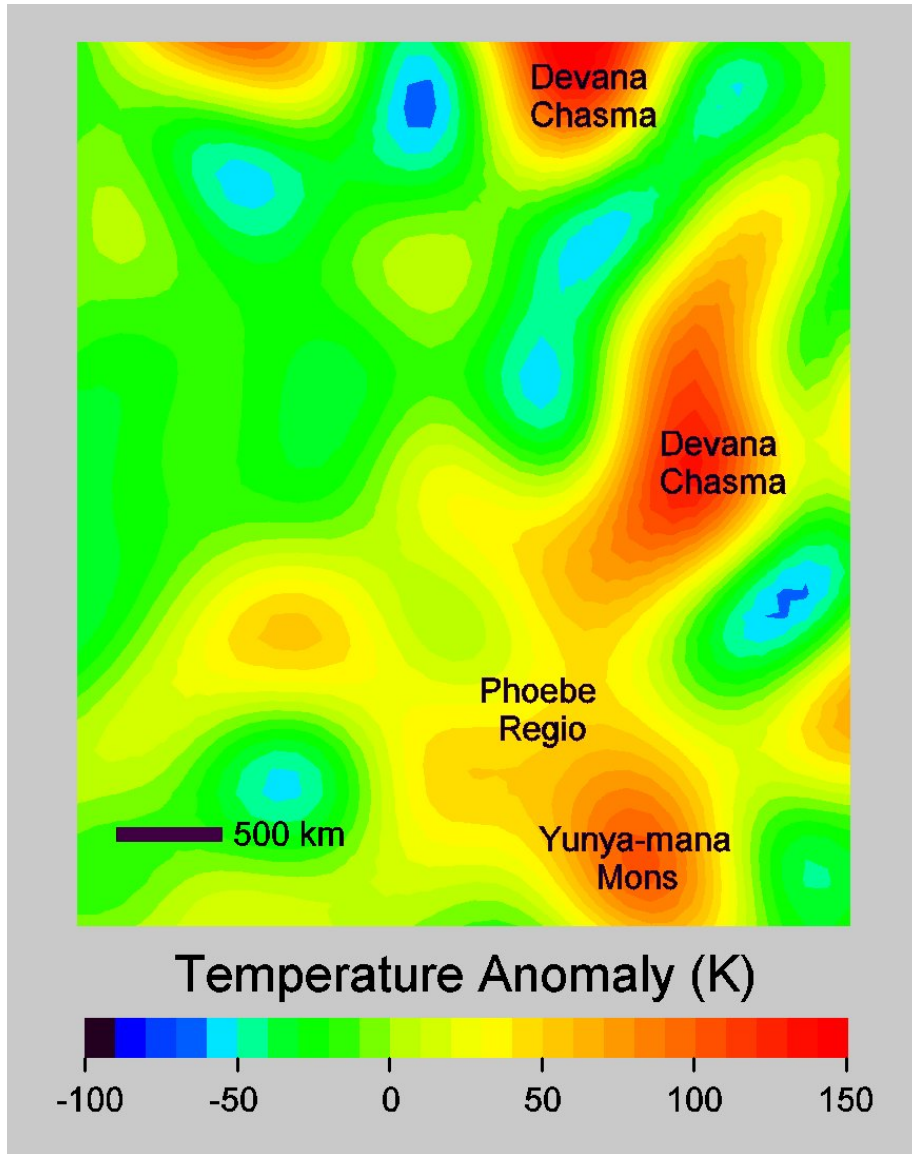
- Solar wind interaction and effect on atmosphere evolution?
- History of sources and escape?
- What can Venus tell us about other terrestrial planets?

Lightning Hypothesis



Is Venus Still Active Today?



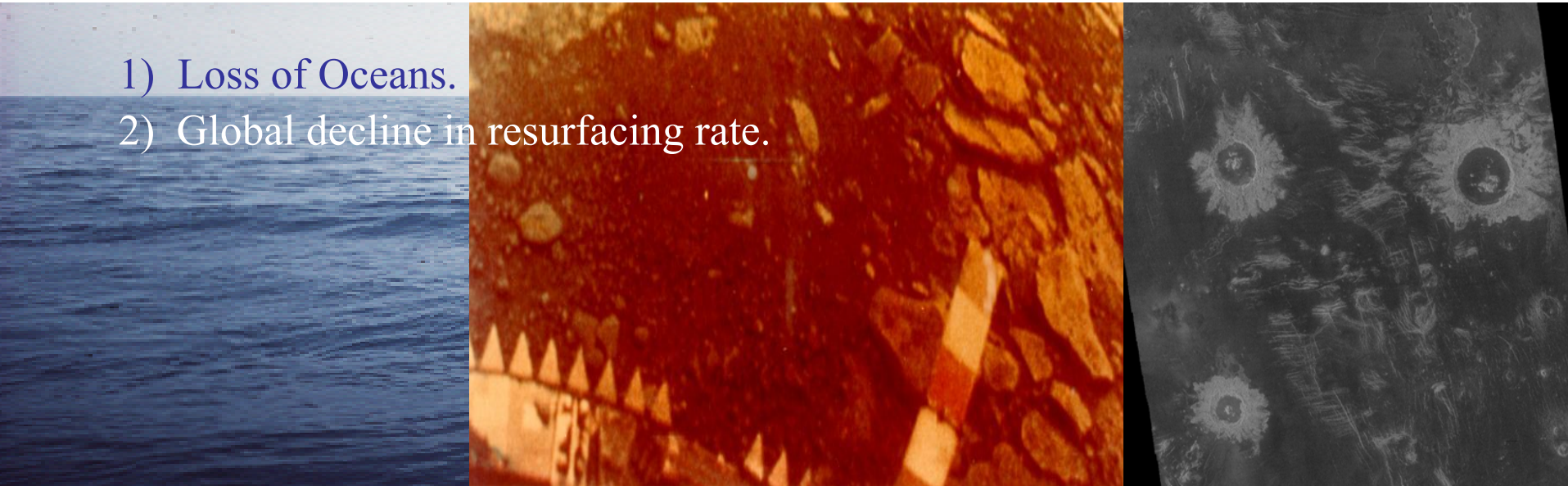


Kiefer and Peterson, 2003

Longevity of an Early Venus Ocean?

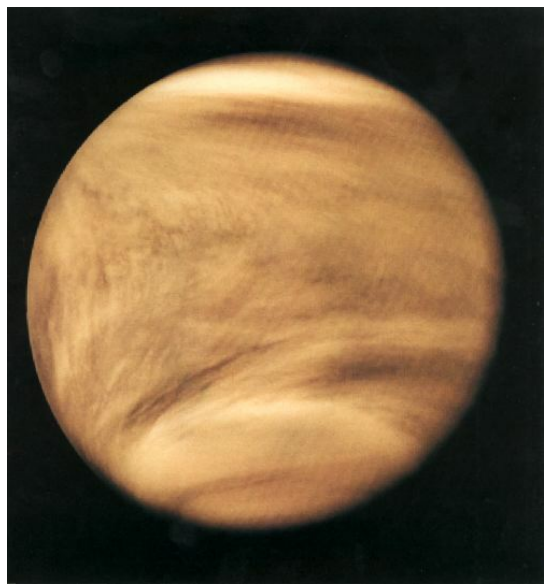
Kasting (1988) in many ways optimized to get rid of ocean quickly:

- Calculations produce **upper limit** on surface temperatures (and therefore upper limit on escape fluxes, and lower limit on lifetime of ocean).
- **Clouds excluded**. No cloud feedback which, qualitatively, is expected to stabilize surface temperatures with rising solar flux, and therefore extend the lifetime of the moist greenhouse.
- Preliminary new results (Grinspoon and Bullock, DPS 2004) suggest that the oceans of Venus may have persisted for ≈ 2 Gy. Venus may have been a habitable planet for much of Solar System history.
- Did Venus experience one great transition or two?



The Future of Life on Earth

- In about 1 Gy, the Earth may experience a runaway H_2O greenhouse (Kasting).
- Currently, there are regions of the tropical oceans that are in this runaway state (McKay et al).



Decadal Survey Update

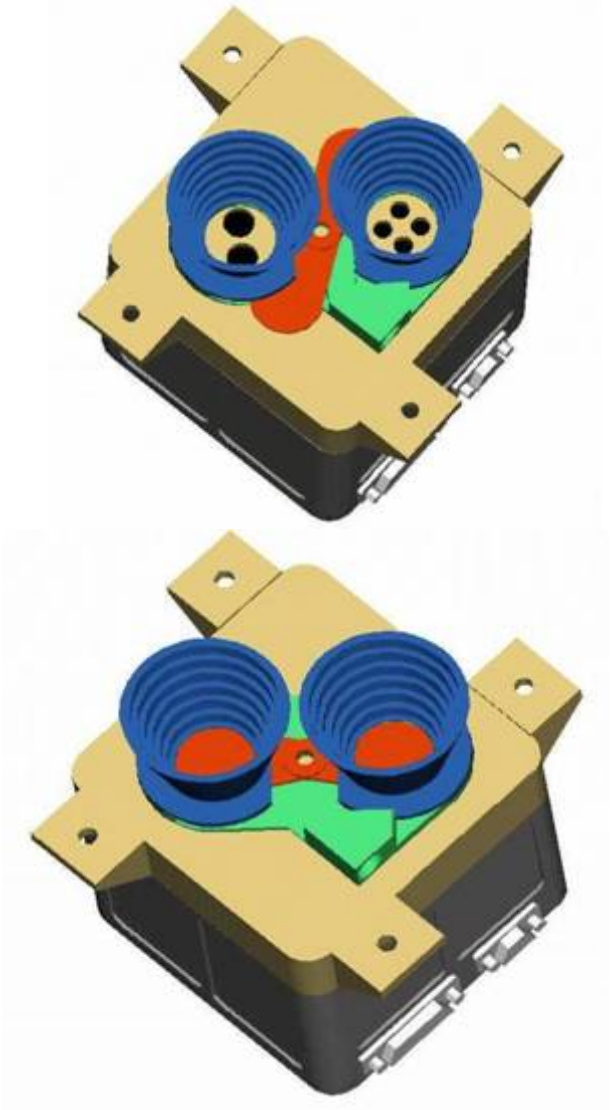
- No major changes. Current missions will answer and sharpen questions
- Even after Venus Express and Venus Climate Orbiter, many key questions will remain unanswered, particularly concerning history of the surface
- Future measurements include seismology, heat flow, surface magnetic field, altimetry

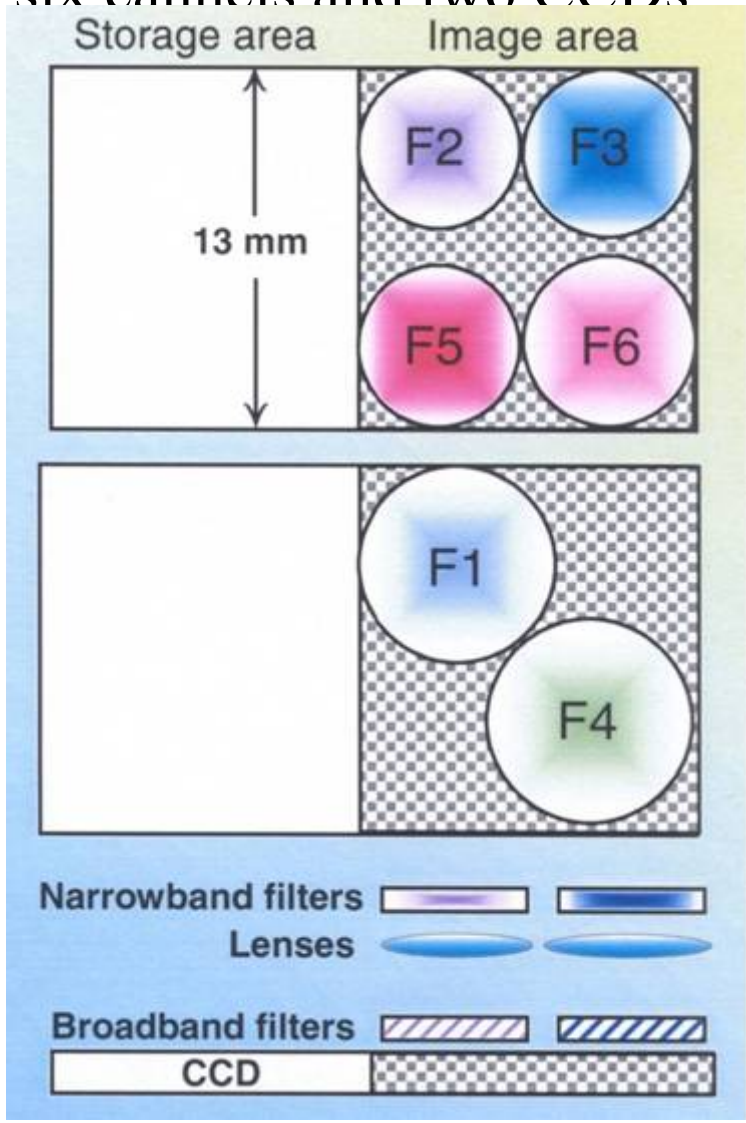
Future Missions

- Venus In Situ Explorer (VISE) and Venus Surface Explorer (VSE) will address coupling of surface/atmosphere, origin/evolution; allow further direct comparisons to Mars, Earth; expectations and interpretations for extra-solar planets
- Future investigations will require technology development

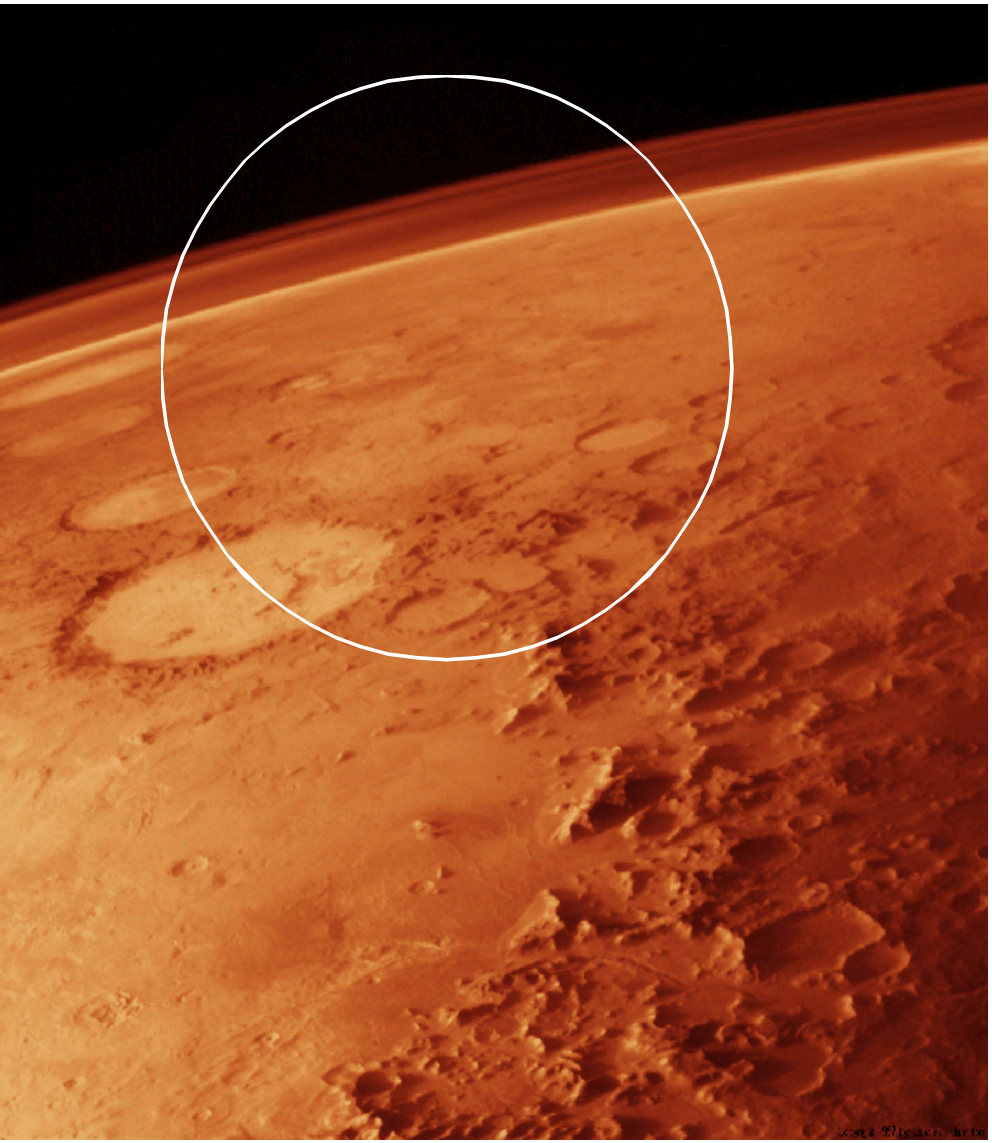
VENUS

VMC original design with six cannels and two CCDs



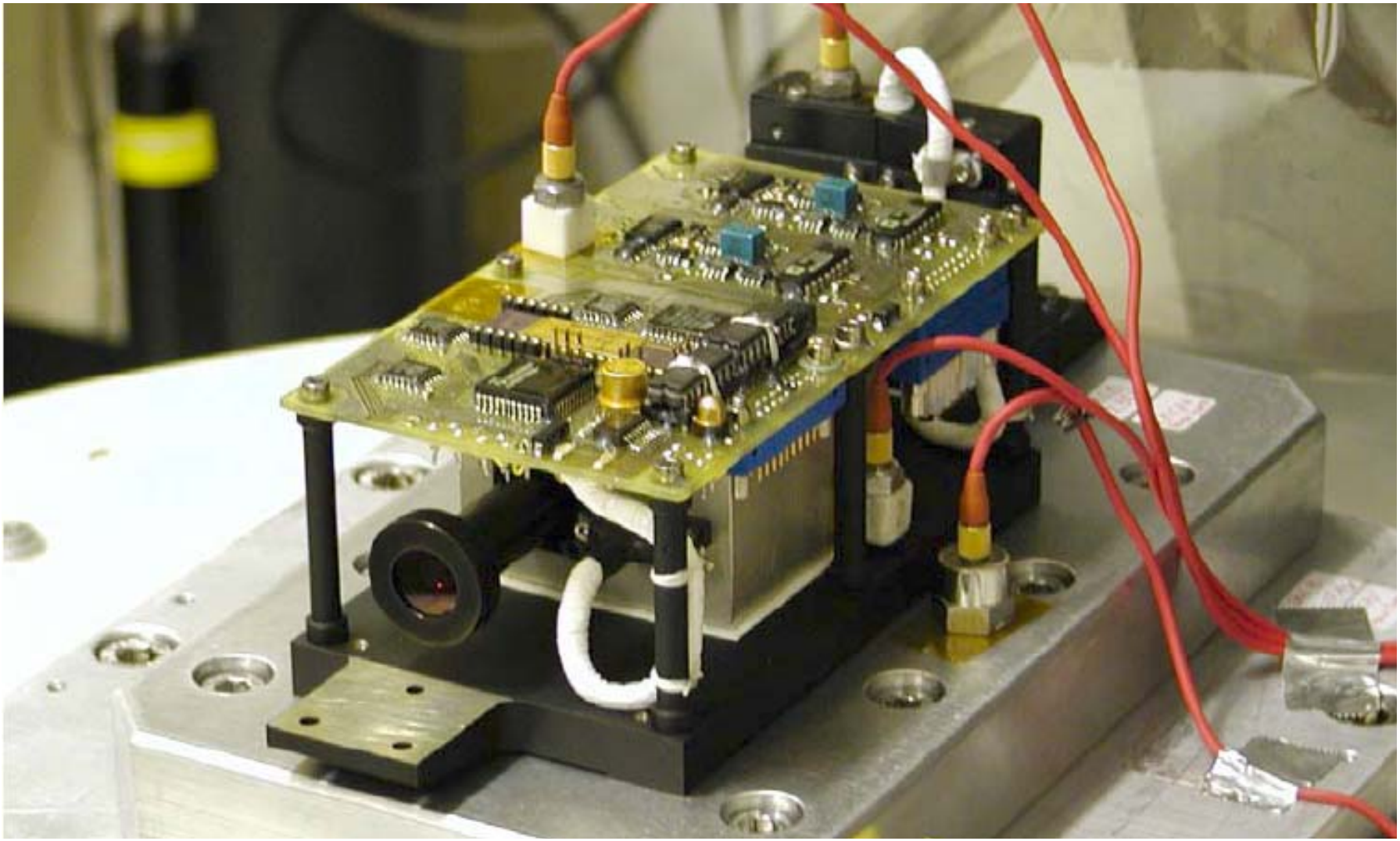


VMC QM all channels

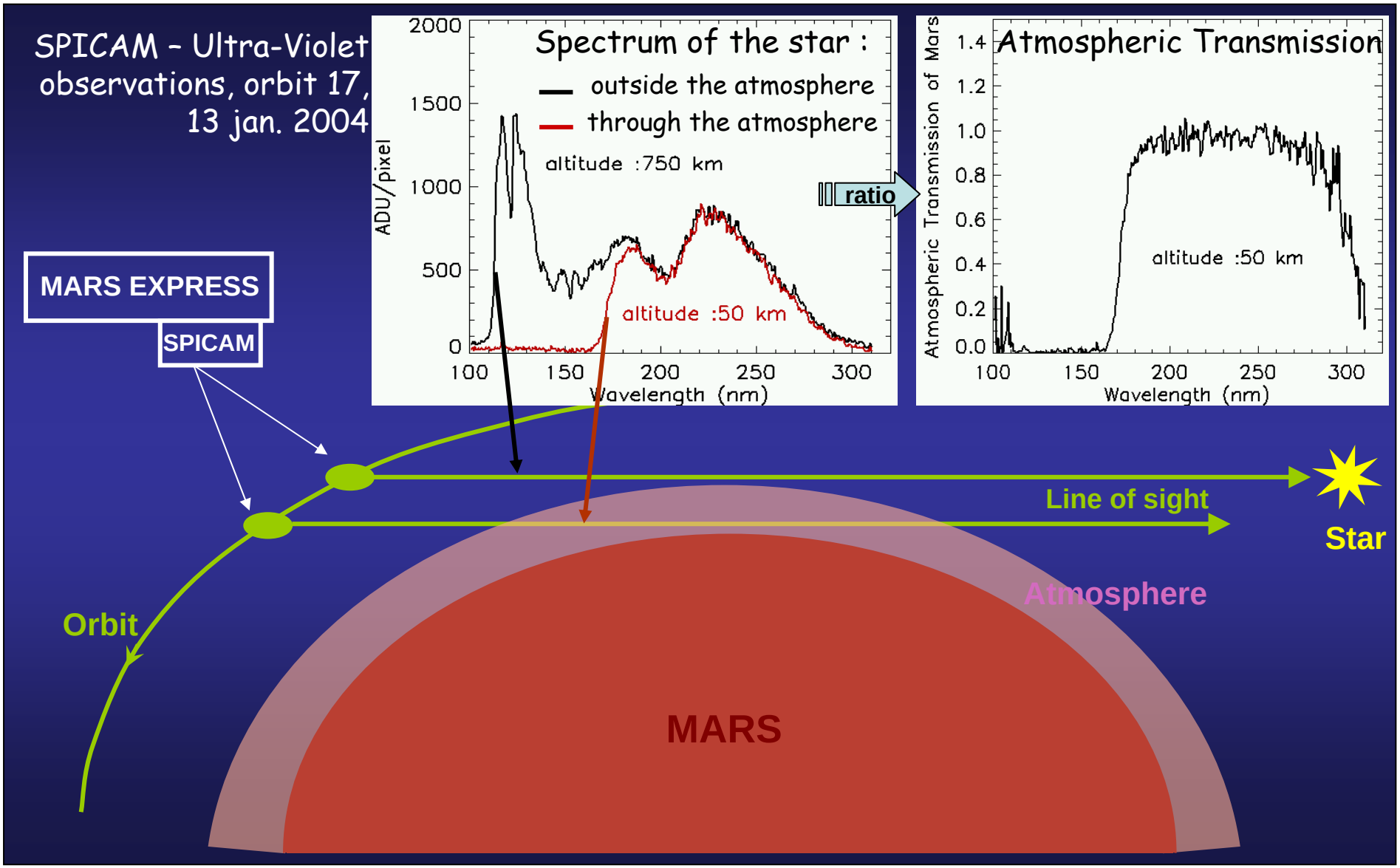


Limb mode

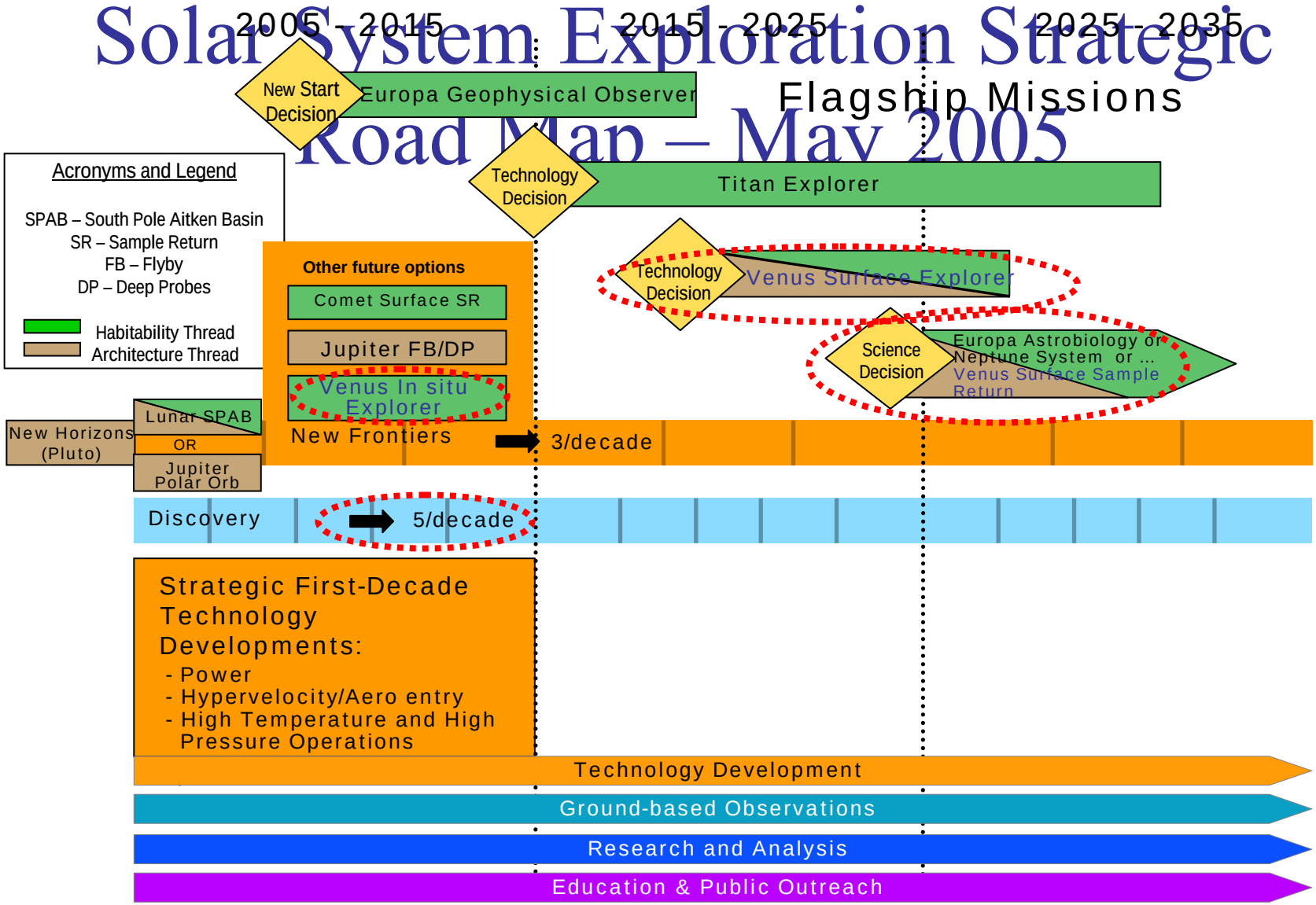
- Distance: ~ 2,000 km
- Total FOV: ~ 500 km
- Spatial resolution: ~ 1.5 km



Star Occultation: Demonstrated on Mars



Solar System Exploration Strategic Road Map – May 2005



All mission categories in the SSE Roadmap (2005) includes missions for Venus Exploration
These categories are: Flagship, New Frontiers and Discovery

Meeting Summary

- 117 attendees represented many nations, missions and investigations
- Comprehensive coverage included tutorials
- Contributed posters had short introductions in plenary sessions
- State-of-the-art Venus science summary proposed as an AGU monograph
- Provides an incremental update to NRC Decadal Survey
- Findings will be transmitted to VEXAG, which has a key role to carry forward latest information