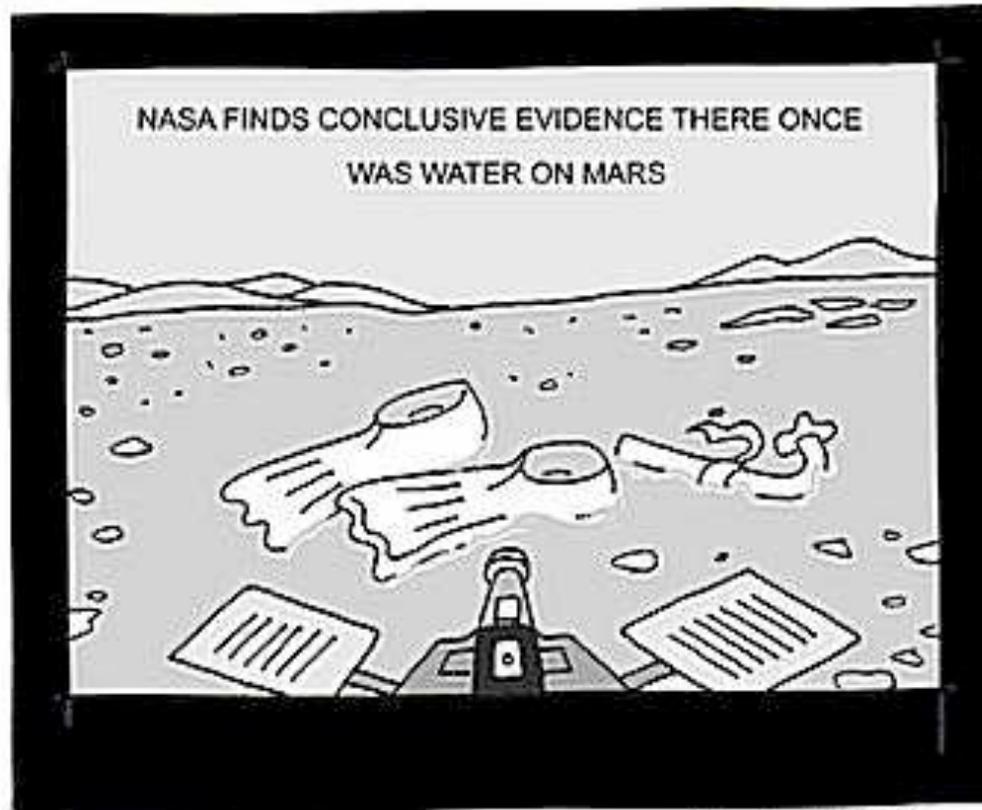


ASTR 380

Possibilities for Life in the Inner Solar System

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BROWN.

Possibilities for Life in the Inner Solar System

Now we will look at Venus (this lecture) and Mars (next)

Remember: We have only visited the Moon with people.
We only have rocks from the Moon to study on Earth!

We are examining the possibilities in these next few lectures.

- Seeing what existing evidence says
- What we can infer
- Few 100% conclusions



Evaluation Results

- Most people seem to be enjoying class
- Not many suggestions made by more than one person
- Two changes:
 - Will post powerpoint same day
 - If math, will go over in a little more detail
- Favorite request: more speculation on ET life
 - Yep, we're coming to it!

Possibility of Life in the Inner Solar System

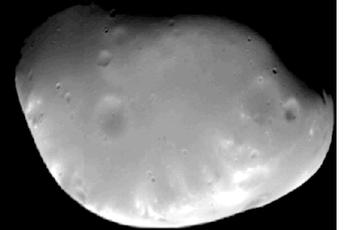
The Moon, Mercury, and the Moons of Mars



Moon



Mercury



Deimos

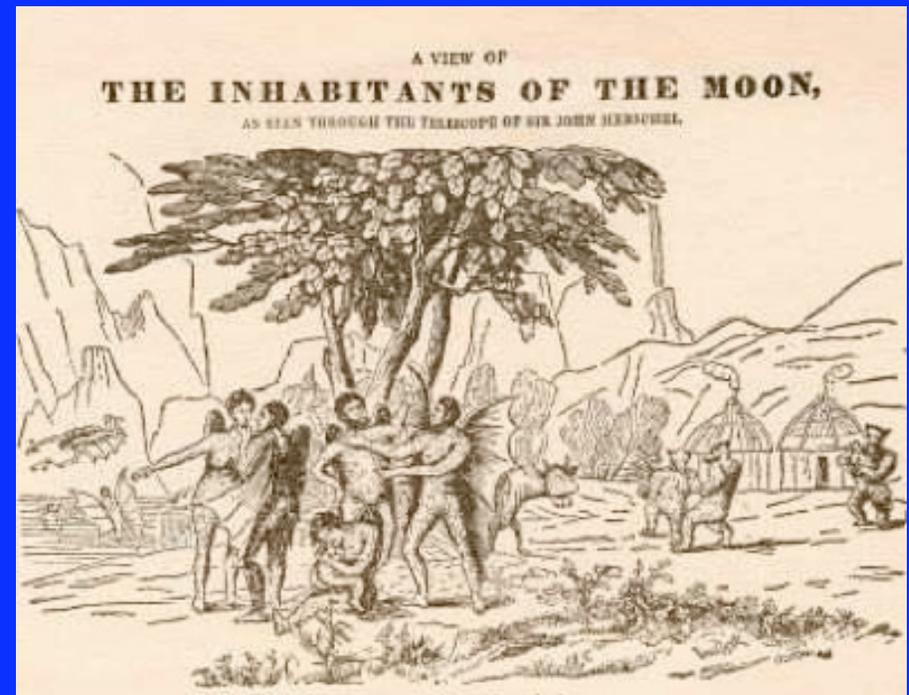


Phobos

NO LIFE NOW or EVER
This is a 98% conclusion!

The Great Moon Hoax

- Aug 25, 1835
- Claim: Sir John Herschel obs Moon with new telescope
- Saw bison, beavers, plants, huts with smoke, intelligent life
- When hoax revealed, circulation stayed high!



NY Sun, August 1835

Possibility of Life in the Inner Solar System

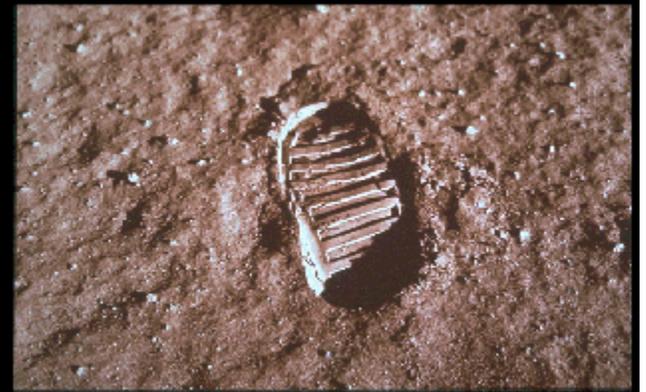
The Moon versus our checklist:

chemical building blocks: light on amounts of C, N, and O

energy: lots of sunlight

liquid: No. And no atmosphere

stability: Except near poles, 29 day day-night cycle
average day temperature = 107 C
average night temperature = -153 C



Possibility of Life in the Inner Solar System

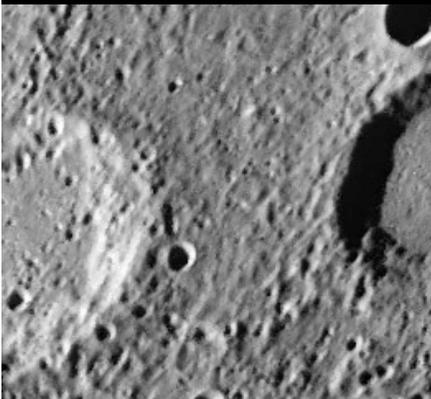
Mercury versus our checklist:

chemical building blocks: 70% metallic and 30% silicate
may have lost much C, N, O in a late large
collision.

energy: lots and lots of sunlight

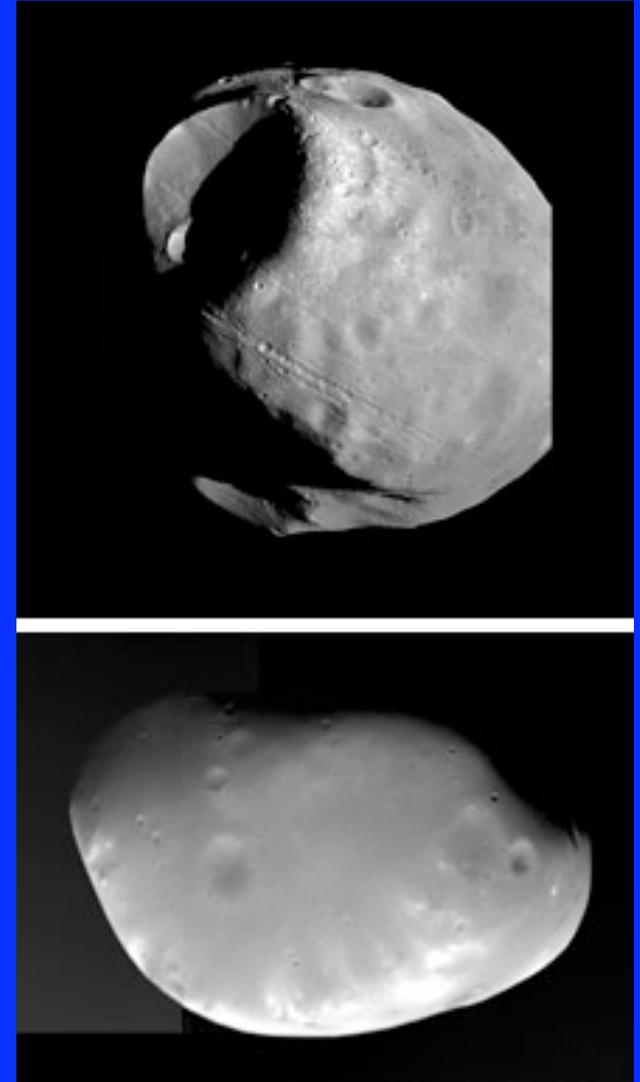
liquid: No. Nearly no atmosphere

stability: Due to 59 day long rotation (Mercury day)
and very slight atmosphere...
night time lows = -183 C
daytime highs = 427 C



Swift, Kepler, and Mars' Moons

- Gulliver's travels, 1726: voyage to Laputa
- Mars has two moons, orbital radii within factor of ~ 2
- But discovered in 1877!
- Explanation: Galileo anagram
smaismrmilmepoetaleumibunen
ugttauiras mistranslated by
Kepler to mean Mars has two
moons
- Dumb luck...



Possibility of Life in the Inner Solar System

The Moons of Mars versus our checklist:

chemical building blocks: Carbonaceous asteroids so good C,N,O

energy: reasonable sunlight

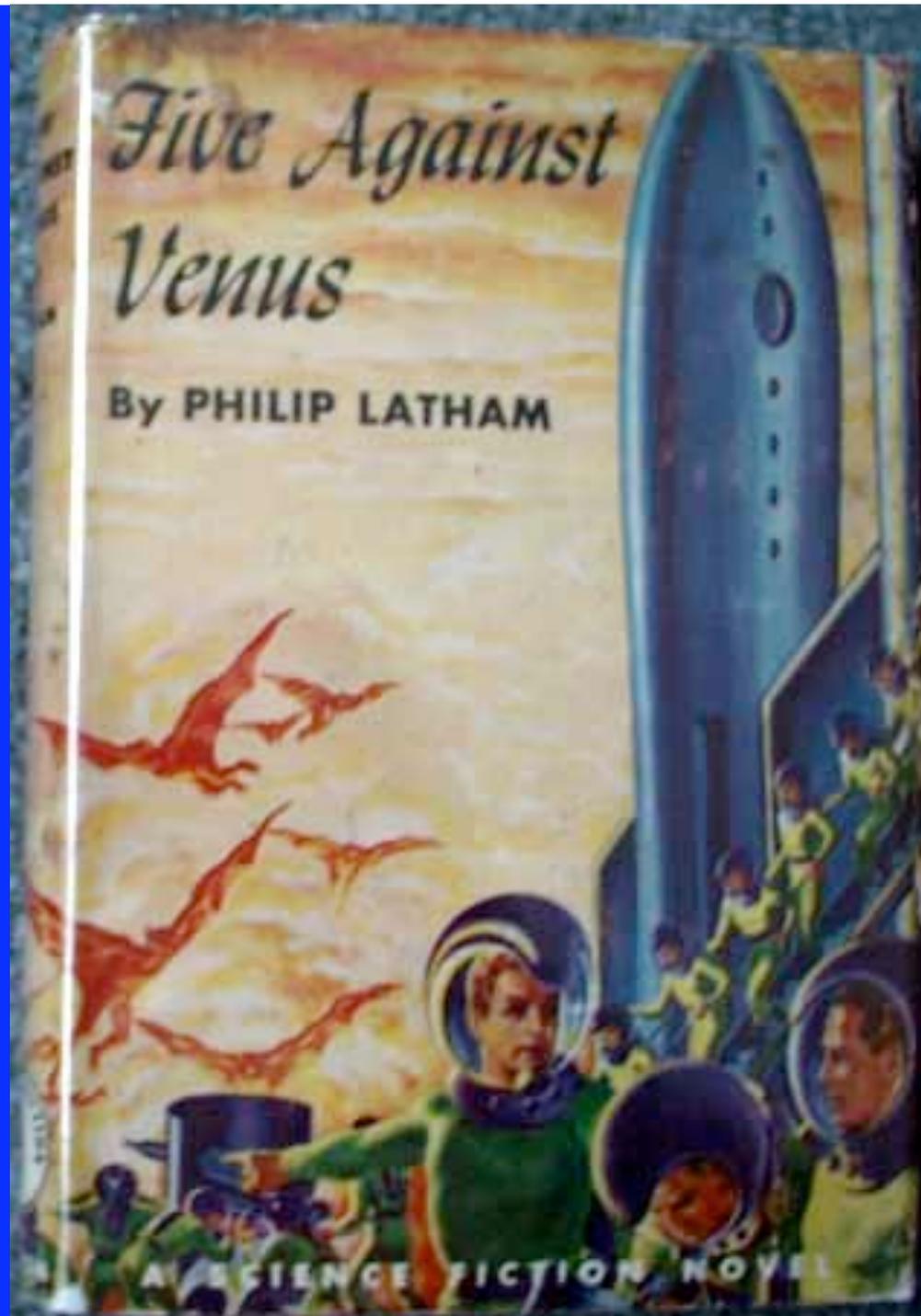
liquid: No. No ices. No atmosphere

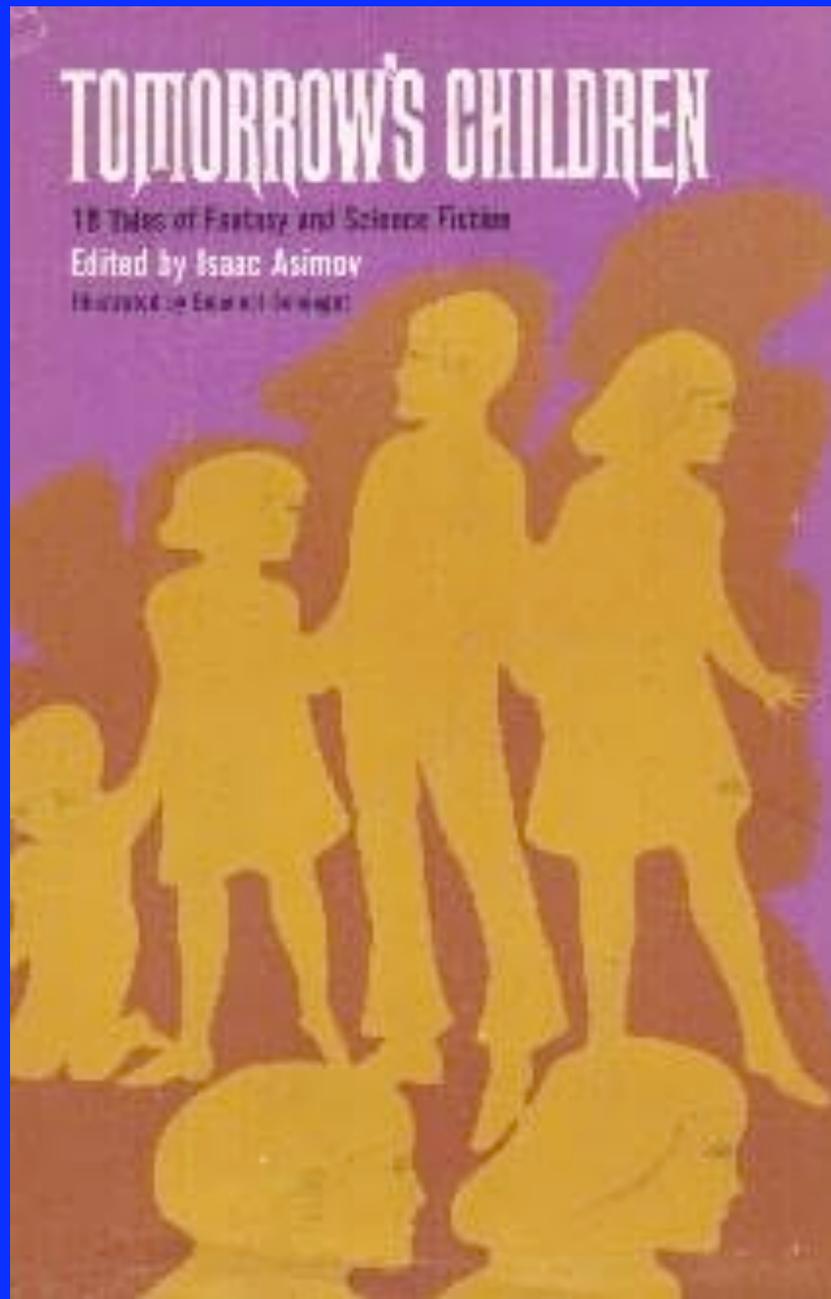
stability: Probably reasonable but no data on temperature variations as specific locations on Moons





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"They were all nine years old, and if there had been a day, seven years ago, when the sun came out for an hour and showed its face to the stunned world, they could not recall."

"All Summer in a Day"
by Ray Bradbury

**On Venus,
Have We
Got a Rabbi!**



by William Tenn

Venus: Jungle Planet?

- Long imagined by science fiction writers to be a tropical planet with lots of water vapor
- This conclusion was made in 1918: clouds= H_2O ?
- In 1922, already clear that this was not so



<http://i4.photobucket.com/albums/y141/igallo/SkyPeopleArt.jpg>

Possibility of Life in the Inner Solar System

What do we know about Venus?

Cloud covered at all times!

Mass = 0.815 Earth mass

Surface Gravity = 0.91 Earth

Average Density = 5.25 g/cm^3

Distance from Sun = 0.723 AU



Physical Data

Property	Venus	Earth	Mars
Distance from the Sun	108 million km	150 million km	228 million km
Rotation period	243 days	24 hours	24.37 hours
Equatorial radius	6052 km	6378 km	3379 km
Mass	$4.87 \times 10^{24} \text{ kg}$	$5.97 \times 10^{24} \text{ kg}$	$6.42 \times 10^{23} \text{ kg}$
Density	5240 kg/m^3	5520 kg/m^3	3940 kg/m^3

For comparison

Possibility of Life in the Inner Solar System

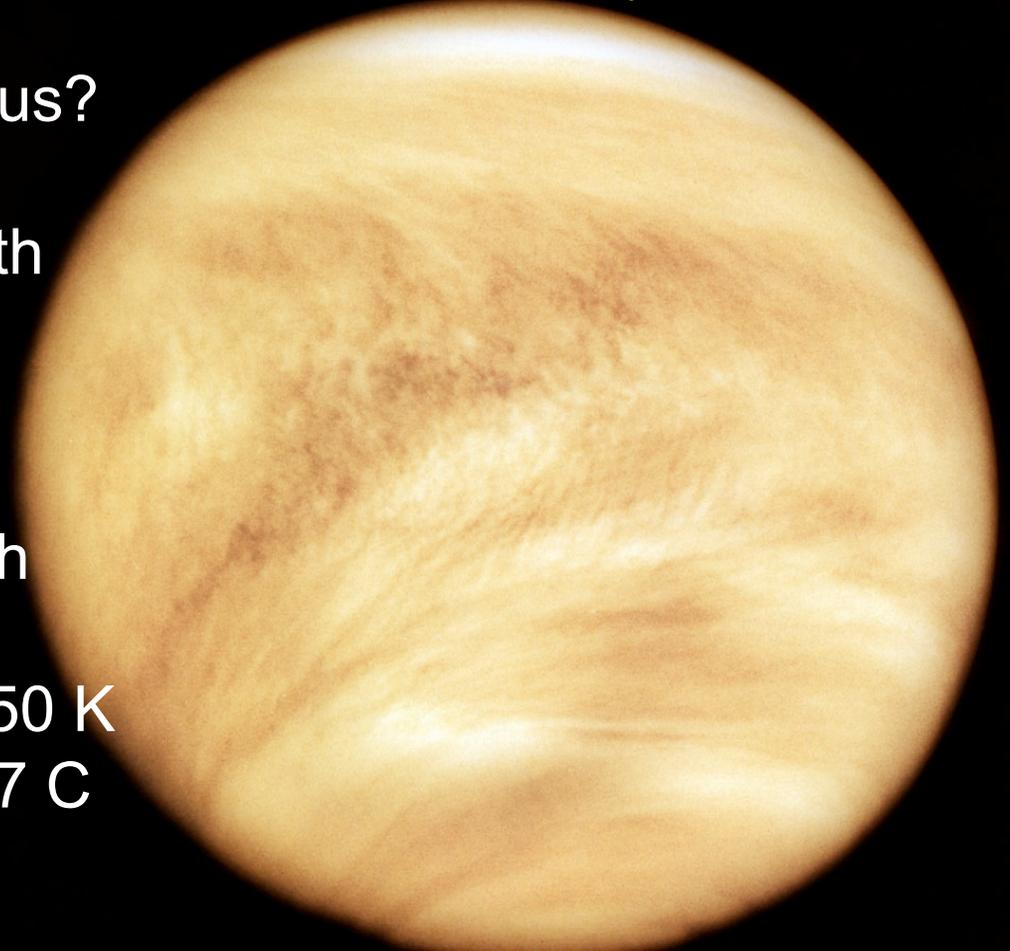
What do we know about Venus?

Energy from Sun = 1.9 x Earth

No moons

Equatorial radius = 0.95 Earth

“Expected Temperature” = 350 K
= 77 C



Physical Data

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For comparison

Features of Venus



No significant magnetic field



Retrograde rotation with a long period of 243 Earth days. Rotation axis is inclined by 177° to the plane of the ecliptic

Rock crust
Rock mantle

Wind speeds in the upper atmosphere over 100m/s

One revolution around the Sun lasts 224,70 Earth days

Core of molten iron-nickel

6052 km

Surface viewed from Earth shows no structure and has the highest albedo of all planets

Pressure at the surface about 92 bar, temperature about 460°C

Clouds 45-65 km altitude

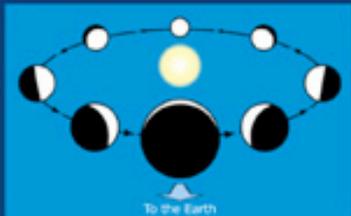
Active volcanoes

Equatorial highland

Impact craters

Coronae

© Calvin J. Hamilton



Venus phases



Venus from Earth



Dense atmosphere with sulphur dioxide clouds and greenhouse effect, composed of roughly 96,5% carbon dioxide and 3,5% nitrogen



Cloud Structure

Strange Rotation

- Relative to stars, Venus rotates once per 243 Earth days!
Year is only 225 days long
- Rotation is retrograde; Venus basically rotates upside down
Tilt of 177 degrees, only 3 deg from vertical
- Could it be caused by collisions?
Probably not; more likely gravitational effect of Earth on Venus's atmosphere

Possibility of Life in the Inner Solar System

Venus has been visited by probes:

Mariner 2 flyby in 1962

- measured surface temperature
- tried to measure magnetic field

Venera 3 crashed into planet in 1966

- no data returned

Venera 4 entered atmosphere in 1967 and parachuted down but died before getting to the ground.

- measured composition of atmosphere and pressure



Possibility of Life in the Inner Solar System

Mariner 5 flyby 4,000 km above atmosphere in 1967

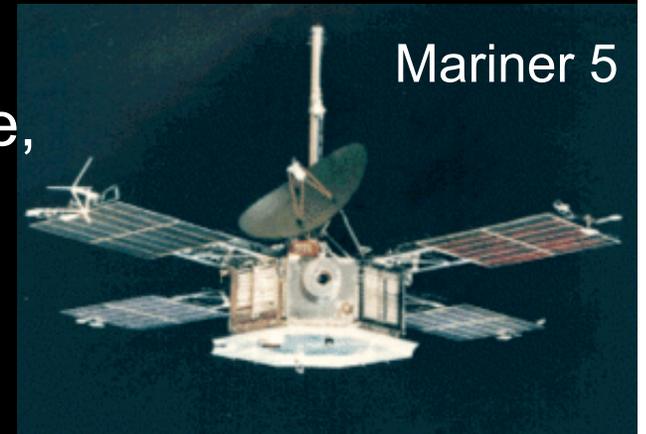
- Measured pressure profile of atmosphere

Venera 5 and 6 (1969) entered atmosphere, descended and were crushed about 20 km above surface

- returned more atmospheric data

Venera 7 (1970) supplied temperature data from the surface for 23 minutes.

Venera 8 (1972) sent surface temperature data for 50 minutes.



Possibility of Life in the Inner Solar System

Mariner 10 (1974) flyby with images of clouds.

Venera 9 and 10 (1975) sent back the first images of the surface.

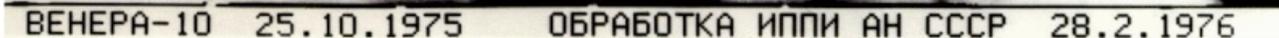
- images
- surface temperature, pressure, wind



Venera 10



ВЕНЕРА-9 22.10.1975 ОБРАБОТКА ИППИ АН СССР 28.2.1976

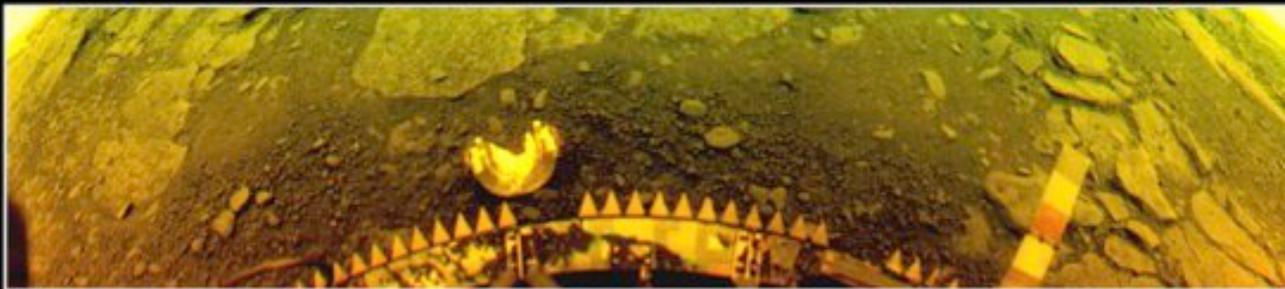


ВЕНЕРА-10 25.10.1975 ОБРАБОТКА ИППИ АН СССР 28.2.1976

Possibility of Life in the Inner Solar System

Venera 11 and 12 (1978)

Venera 13 and 14 (1982) made
first color picture of surface



Color as seen on the surface of Venus

Color with atmospheric effects removed



Possibility of Life in the Inner Solar System

Venera 15 and 16 (1983) did radar mapping of surface from orbit.

Russian Vega Program (1985) put two aerobots (balloons) in atmosphere. Second lasted for 2 Earth days.

- Atmosphere temperature, pressure, winds.

Magellan Probe (1990-1994) mapped surface of Venus with radar imaging

Venus Express (European – 2006 to present) imaging the clouds on Venus from Orbit.



Lightning on Venus

- Lightning was detected by Venera 11, 12, and Venus Express
- Even thunder was detected!
- What might have caused this?

Not a photo!



Ongoing Volcanic Activity?

- Some evidence for: might cause lightning, change in sulfur dioxide levels from 1978 to 1986
- But, no new lava flows
- 167 volcanos > 100 km across! All extinct?



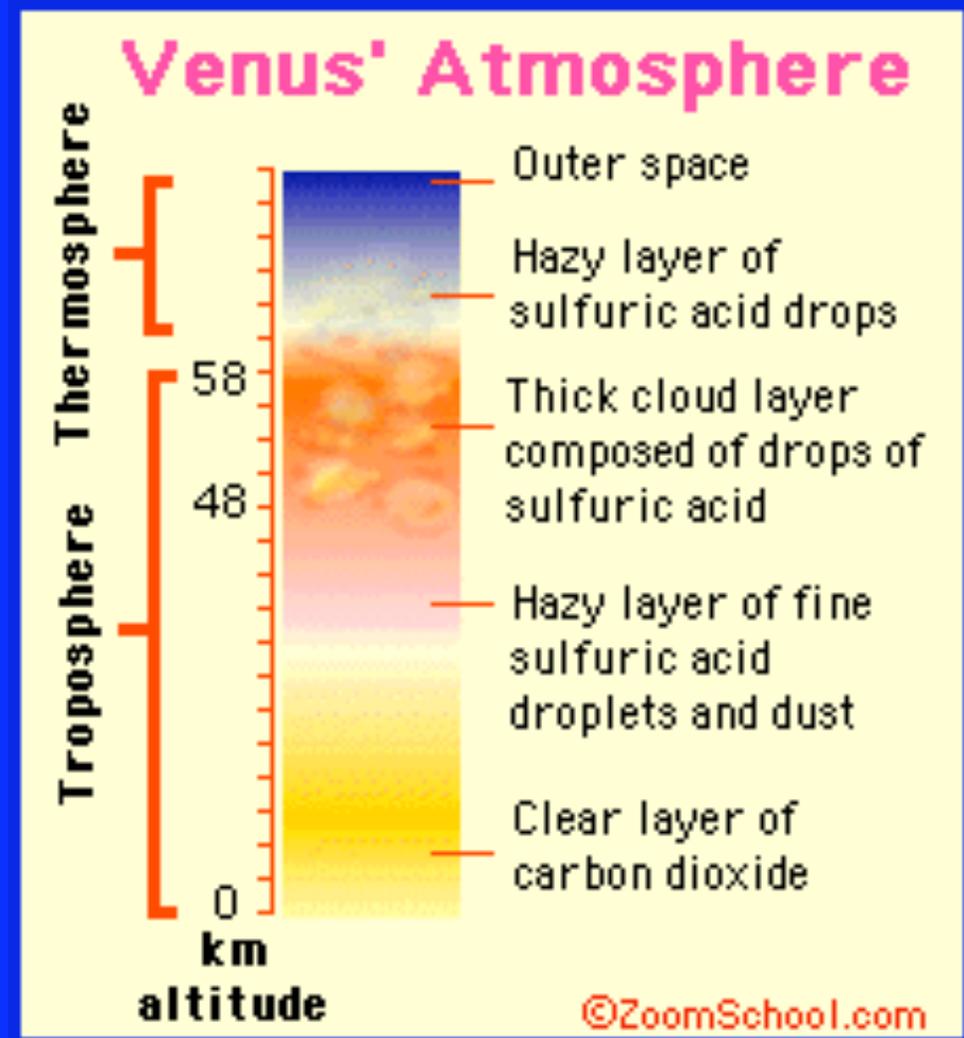
<http://www.spacedaily.com/images/venus-volcano-surface-artwork-desk-1024.jpg>

Lack of Tectonics

- Unlike Earth, Venus does not have active plate tectonics
- Partly because Venus is smaller (easier to cool, so crust is thicker).
- Partly because lack of water makes crust stiffer
- Therefore, mantle builds up stress and undergoes catastrophic resurfacing
Last one ~500 million years ago

Atmosphere

- 90x Earth pressure
=our ocean, 1 km deep
- 300 km/hr winds
- Very inhospitable

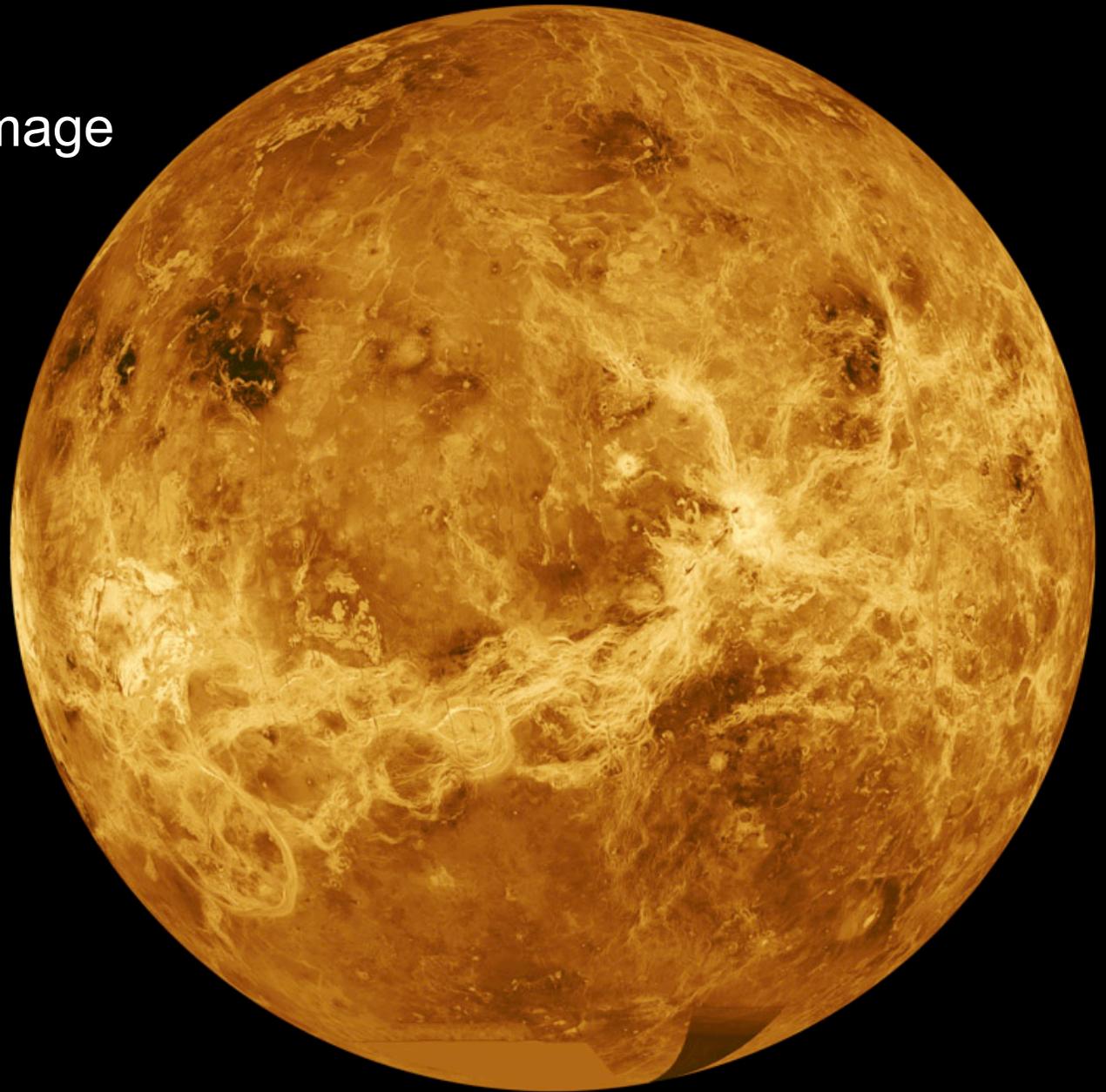


Possibility of Life in the Inner Solar System

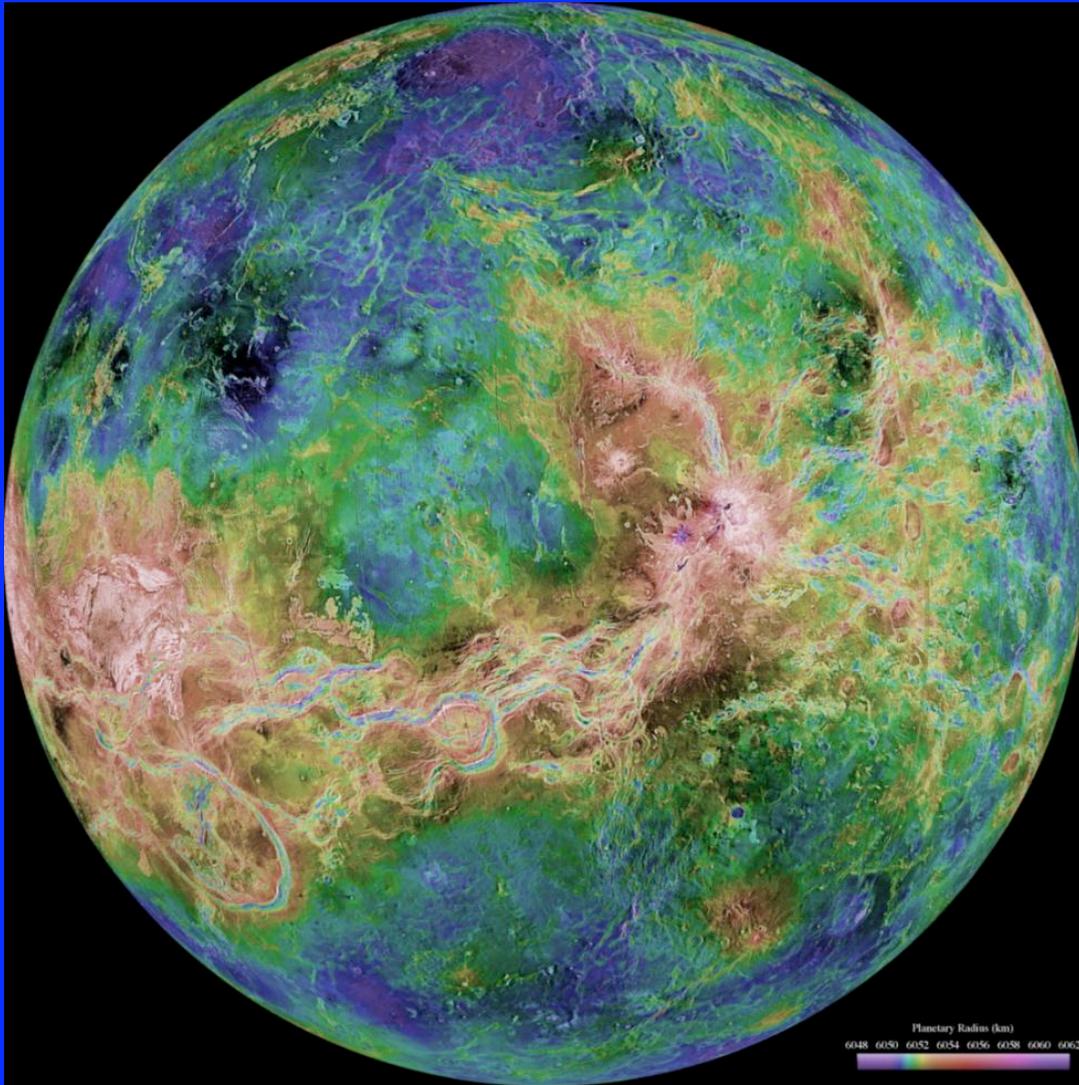
Magellan radar image
of the surface of
Venus

Radar can see
through the
clouds to
measure the
altitude of the
land

Light colors are
higher altitude.



Magellan Radar Mapping

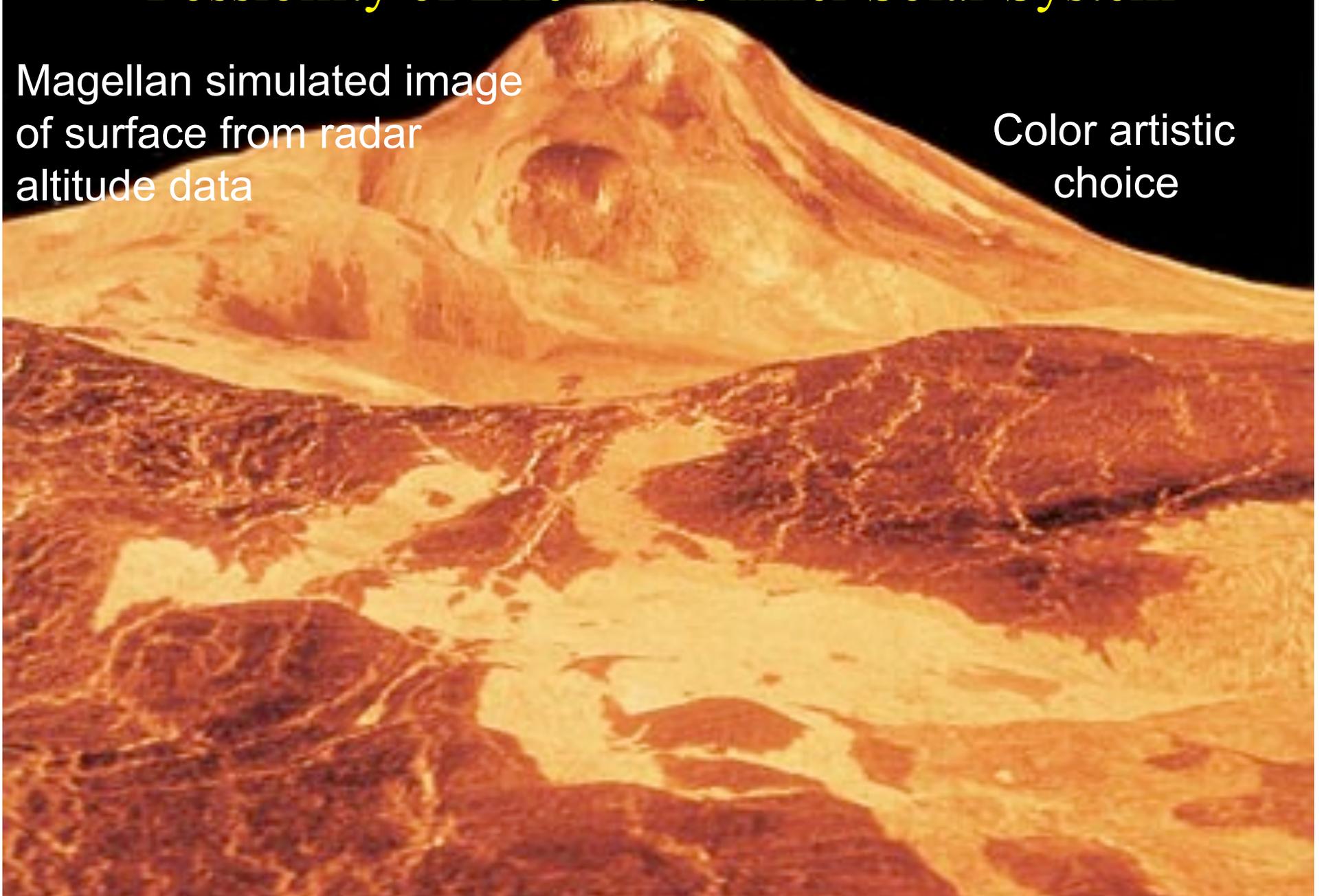


Mapped full surface
of Venus
Found high mountains:
Maxwell Montes, 11 km
Everest: 9 km
Mountain ranges, so
likely tectonic activity
in past.
But nothing at all now...

Possibility of Life in the Inner Solar System

Magellan simulated image
of surface from radar
altitude data

Color artistic
choice



Possibility of Life in the Inner Solar System

C. Carr

Venus Express image

Study:
cloud structure
winds
composition
time variations

Possibility of Life in the Inner Solar System

What have we learned from the probes?

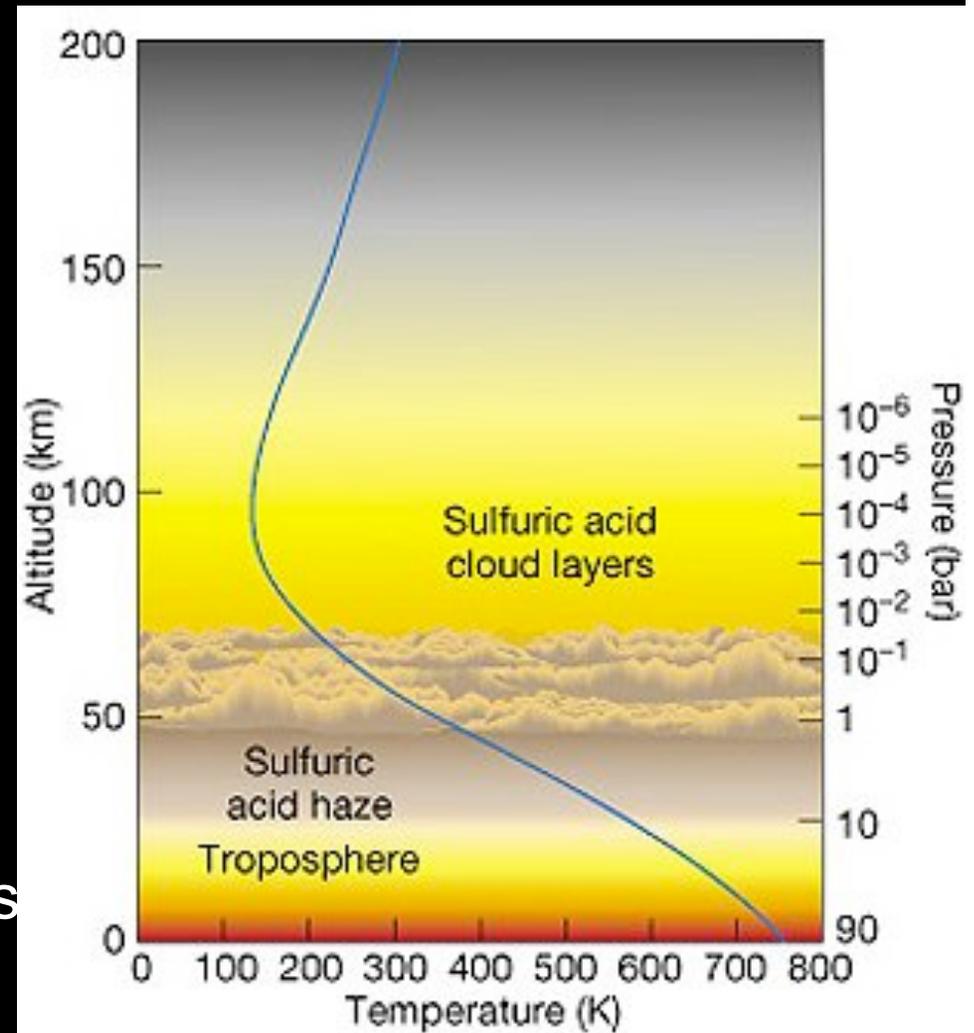
- Most of the surface of Venus is covered by old lava flows but there appears to be little current activity.
- There are rocks, mountains, and canyons
- No evidence of liquid water now or in past. No ice
- Impact craters – It is suggested that the surface may be only 500-700 Myrs old
- No plate tectonic activity
- Surface Temperature = 460 C – and nearly constant



Possibility of Life in the Inner Solar System

What have we learned from the probes?

- Surface pressure = 90 bar
= 90 times Earth
- Composition
 - CO₂: 96.5%
 - N₂: 3.5%
 - SO₂: 0.015%
 - Ar: 0.007%
 - H₂O: 0.002%
 - CO: 0.0017%
 - He: 0.0012%
 - Ne: 0.0007%
- Strong winds and clouds



Lack of Erosion

- Rains of sulfuric acid are frequent
- And yet, practically no erosion!
85% of craters are pristine
- Why? Thought to be because of lack of water, which is needed for erosion.

Possibility of Life in the Inner Solar System

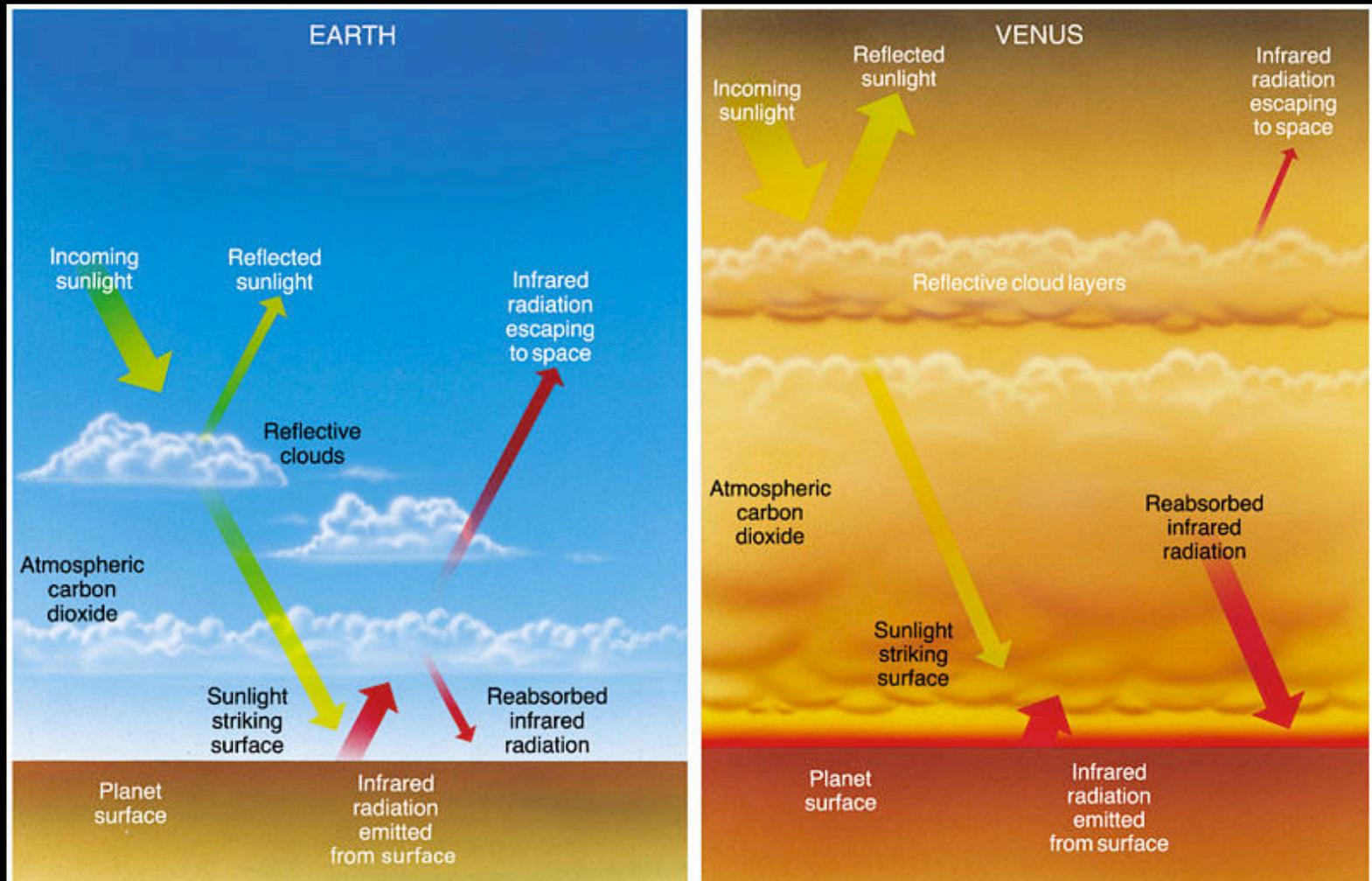
CO₂ and the runaway greenhouse!

Thick carbon dioxide atmosphere traps the infrared radiation

460 K

versus

350 K



Climate and Temperature

- The thick atmosphere keeps the surface at an almost constant temperature
- No difference between day and night, equator and poles
- Only variation is with altitude
But mountains not high enough to get to Earth-like temperatures

Possibility of Life in the Inner Solar System

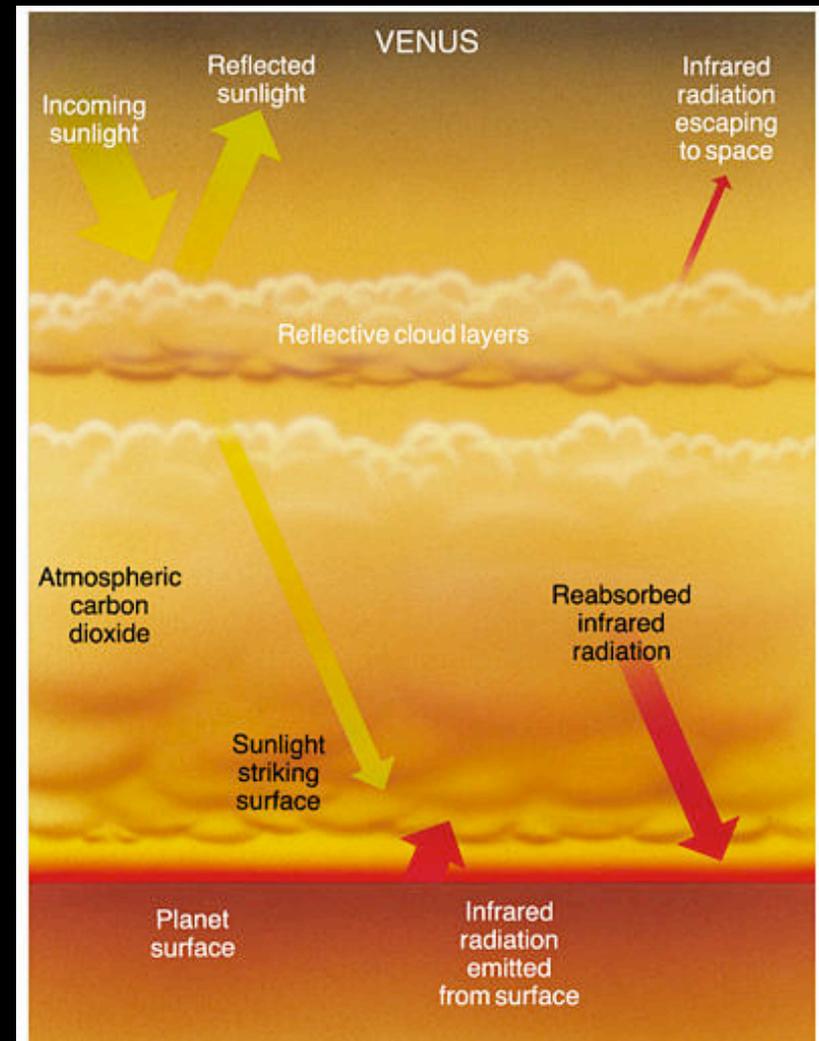
Why is there so much CO₂?

Venus and Earth should have formed in the same way from nearly the same material – should have same rock and gas composition....

But.... Earth had CO₂

The collision that made the Moon -- stripped early Earth atmosphere.

And liquid water -- geological processes to lock CO₂ into rocks



Possibility of Life in the Inner Solar System

The water problem – Venus is dry, very dry!

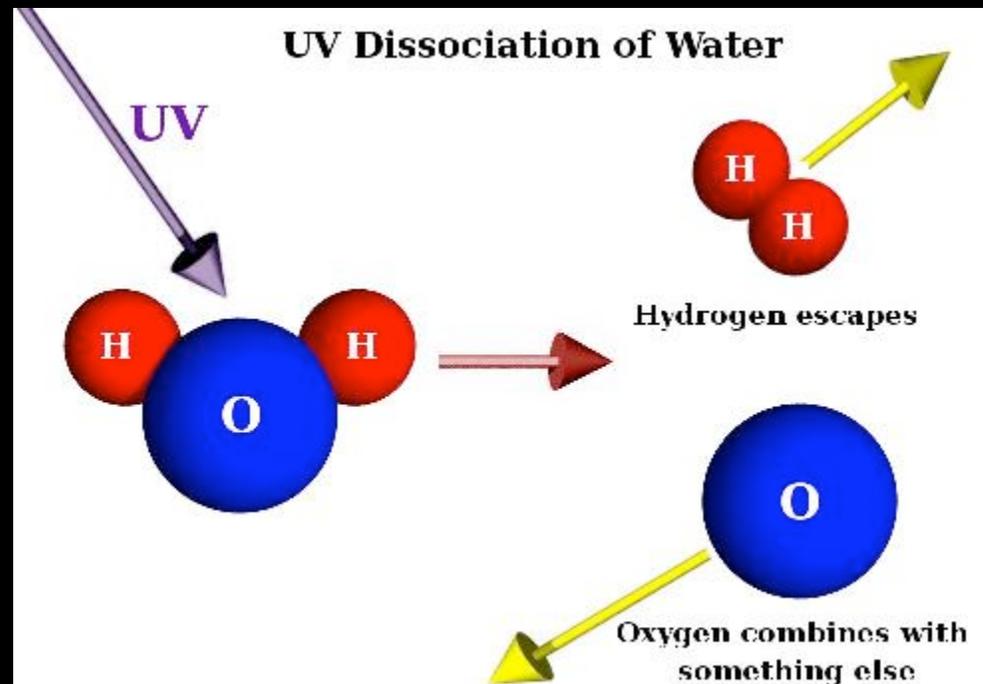
Yes, it is hot so you wouldn't expect liquid water.....

But Venus appears to have 1/10,000 as much water as Earth!

Why? Perhaps....

Water is in water vapor which rises to the top of the atmosphere – is split – and hydrogen escapes...

Factors: hot, close to Sun,
and no magnetic field



Possibility of Life in the Inner Solar System

What about Venus in the first few 100 Million years?

WARNING: Little known

Sun dimmer by 30% so less energy input – known

If liquid water was present, $\text{CO}_2 \Rightarrow$ rocks...

Kept atmosphere thin.... Cooler.... Earth-like?

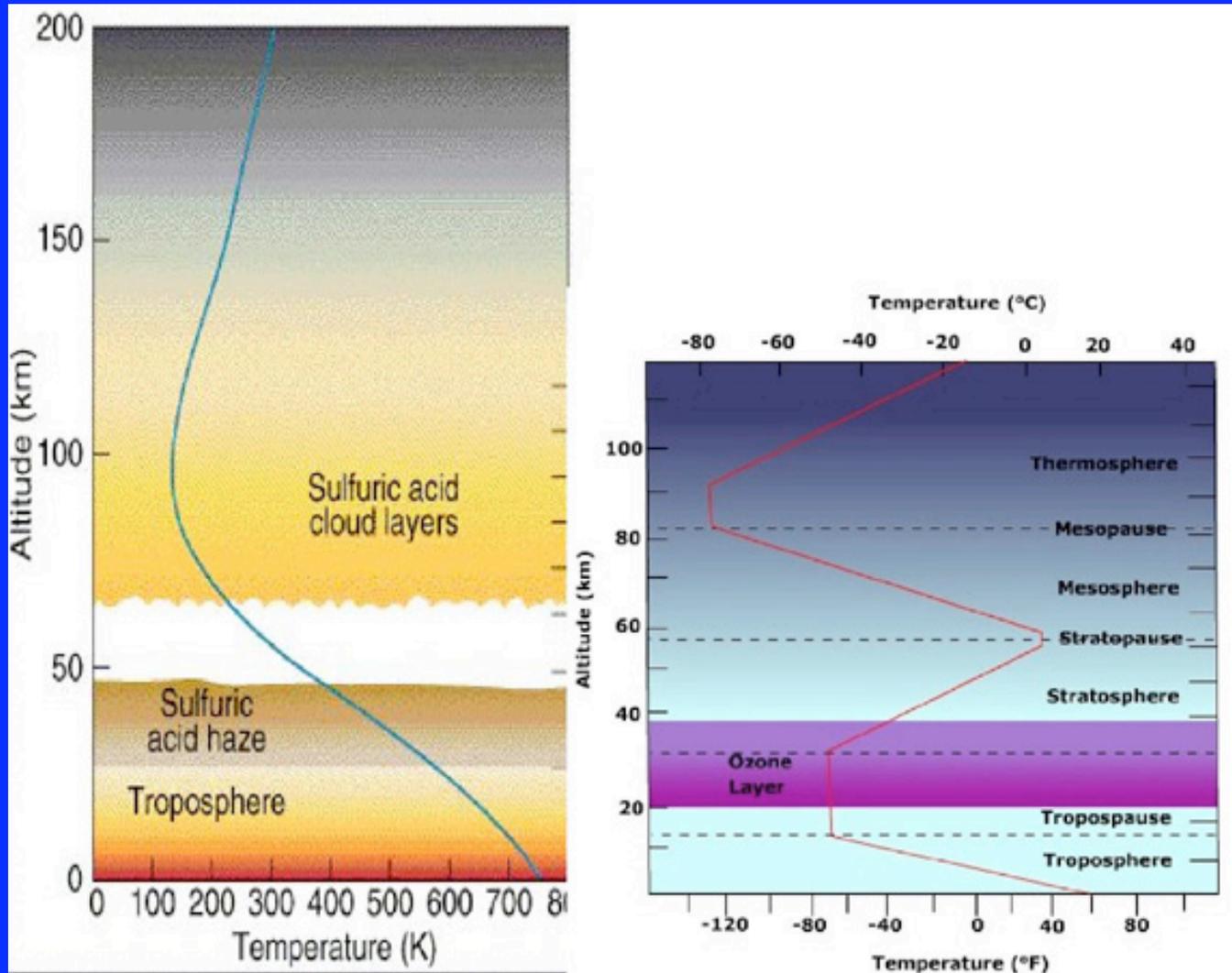
Then, CO_2 grew too thick,
became too hot for liquid water...
no more CO_2 into rocks....
atmosphere increased ... more heat...



Life on Early Venus?

- Since early Sun was less luminous, Venus would have been in the habitable zone
True for >1 billion years
- Might life have evolved then?
- Current surface conditions bad for any life we know
- Might it have gone somewhere?

Venusian Atmosphere?



<http://lasp.colorado.edu/~bagenal/3720/CLASS16/VenusEarth.jpg>

Escape to the Skies?

- Maybe early Venusian bacteria moved into the atmosphere as things heated up?
- Problem: very hostile environment!
Sulfuric acid drops in clouds
High flux of UV radiation
Very little water
- Also tough for Earth microbes that might have been transported by impacts

Possibility of Life in the Inner Solar System

Terraforming Venus

Problems to solve:

Too hot

Too much CO₂

Too little water?



Colonies on Venus?

- Any other prospects?
- At 50 km, temp, pressure is like Earth
- Normal O₂:N₂ mixture floats
- Could have giant floating cities in atmosphere!



Methane_Harvester_final_by_gusti_boucher.jpg

Possibility of Life in the Inner Solar System

Venus versus our checklist:

chemical building blocks: Earth-like origin. Lots of C, N, O.
But currently low on water!

energy: reasonable sunlight. Hot temperatures a problem
for Earth type complex molecules

liquid: No. Too hot for water

stability: Very hot and dry now. Surface may
have episodes of extreme volcanic activity.

Very poor chance for current life.
Small chance of life in the past.



Summary

- Venus may be sort of like Earth, but...
 - Runaway greenhouse
 - Very little water
 - Too much sulfuric acid
- Possible that life emerged early on
 - Tough to imagine it surviving
- We'll need to look elsewhere