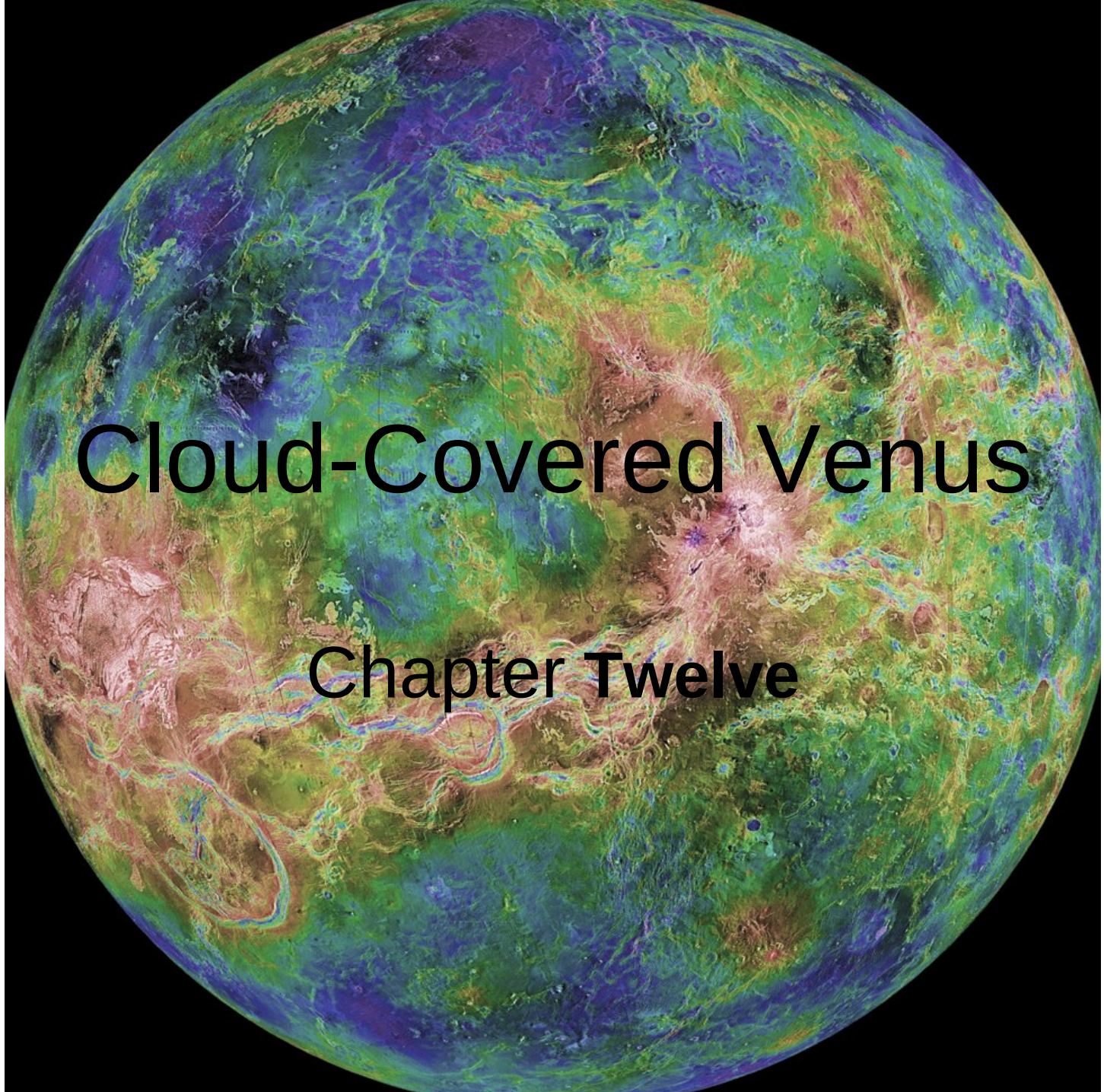


Cloud-Covered Venus

Chapter **Twelve**

ASTR 111 – 003 **Fall 2006**
Lecture 11 Nov. 13, 2006

Introduction To Modern Astronomy I

Introducing Astronomy
(chap. 1-6)

Planets and Moons
(chap. 7-17)

Ch7: Comparative Planetology I
Ch8: Comparative Planetology II
Ch9: The Living Earth
Ch10: Our Barren Moon
Ch11: Sun-Scorched Mercury

Ch12: Cloud-covered Venus
Ch13: Red Planet Mars

Ch14: Jupiter and Saturn
Ch15: Satellites of Jup. & Saturn
Ch16: Outer World
Ch17: Vagabonds of Solar System

Venus Data

table 12-1 Venus Data

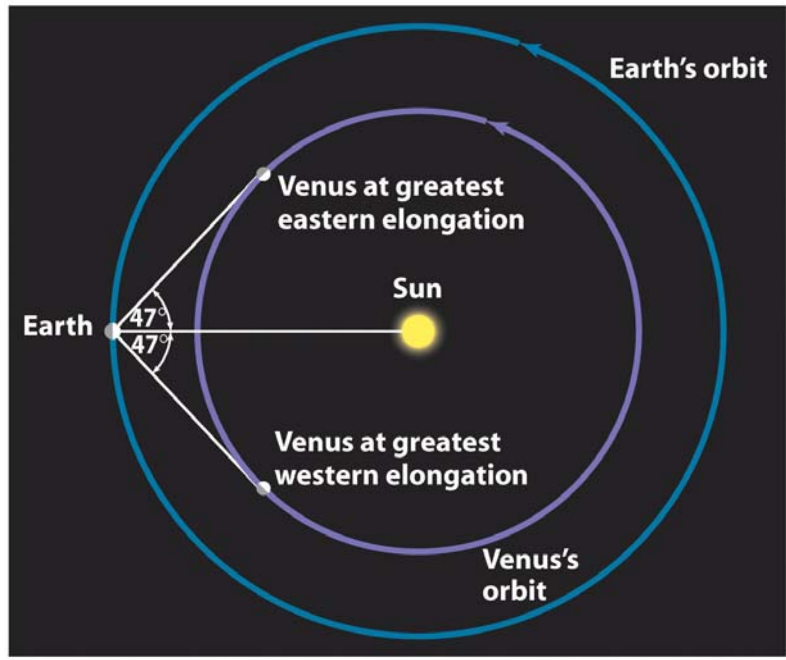
Average distance from Sun:	0.723 AU = 1.082×10^8 km
Maximum distance from Sun:	0.728 AU = 1.089×10^8 km
Minimum distance from Sun:	0.718 AU = 1.075×10^8 km
Eccentricity of orbit:	0.0068
Average orbital speed:	35.0 km/s
Orbital period:	224.70 days
Rotation period:	243.01 days (retrograde)
Inclination of equator to orbit:	177.4°
Inclination of orbit to ecliptic:	3.39°
Diameter (equatorial):	12,104 km = 0.949 Earth diameter
Mass:	4.868×10^{24} kg = 0.815 Earth mass
Average density:	5243 kg/m^3
Escape speed:	10.4 km/s
Surface gravity (Earth = 1):	0.91
Albedo:	0.59
Average surface temperature:	460°C = 860°F = 733 K
Atmospheric composition (by number of molecules):	96.5% carbon dioxide (CO_2) 3.5% nitrogen (N_2), 0.003% water vapor (H_2O)

Guiding Questions

1. What makes Venus such a brilliant “morning star” or “evening star”?
2. What is strange about the rotation of Venus?
3. In what ways does Venus’s atmosphere differ radically from our own?
4. Why do astronomers suspect that there are active volcanoes on Venus?
5. Why is there almost no water on Venus today? Why do astronomers think that water was once very common on Venus?
6. Does Venus have the same kind of active surface geology as the Earth?

Brilliant “Morning Star” and “Evening Star”

- At its greatest eastern and western elongations, Venus is about 47° from the Sun



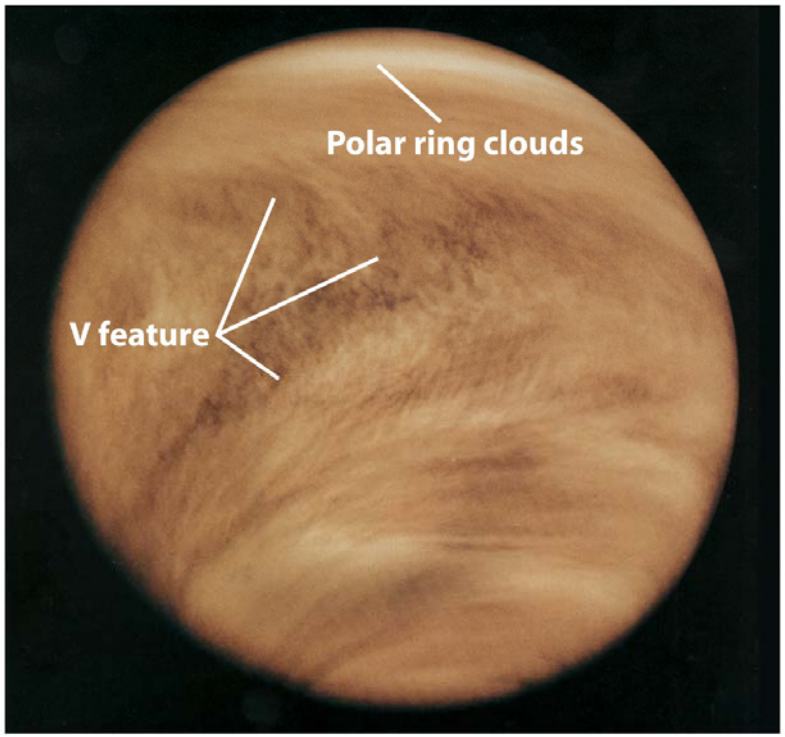
- **Morning Star**:
  - at greatest western elongation
  - rises nearly 3 hours before the Sun
  - High in the eastern sky at dawn
- **Evening Star**
  - At greatest eastern elongation
  - High above the western horizon after sunset

Brilliant “Morning Star” and “Evening Star”

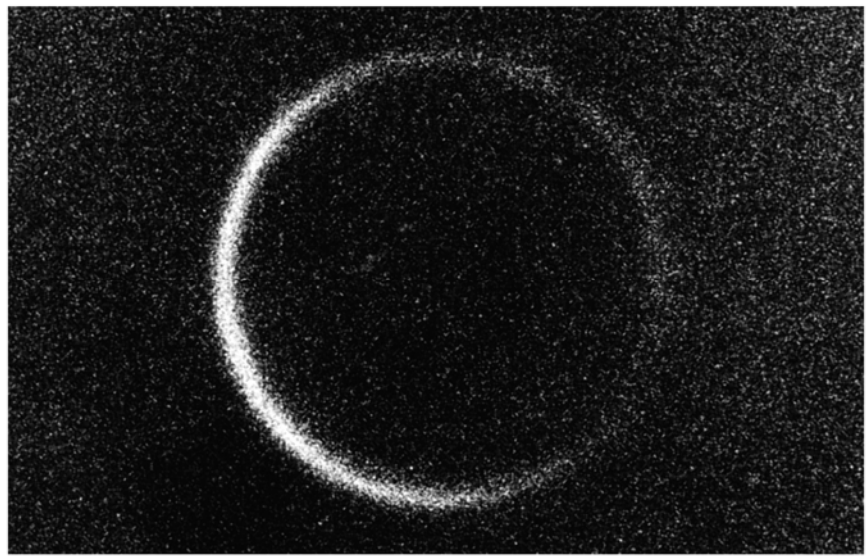
- It is the brightest object in the sky except the Sun and the Moon
  - Venus is relatively large
  - Close to the Sun
  - Close to the Earth
  - Strongly reflect the Sunlight by its cloudy atmosphere

Thick Cloud Cover of Venus

- Venus is similar to the Earth in its size, mass, average density, and surface gravity
- It is covered by unbroken, highly reflective clouds that conceal its other features from Earth-based observers



Cloudy Venus

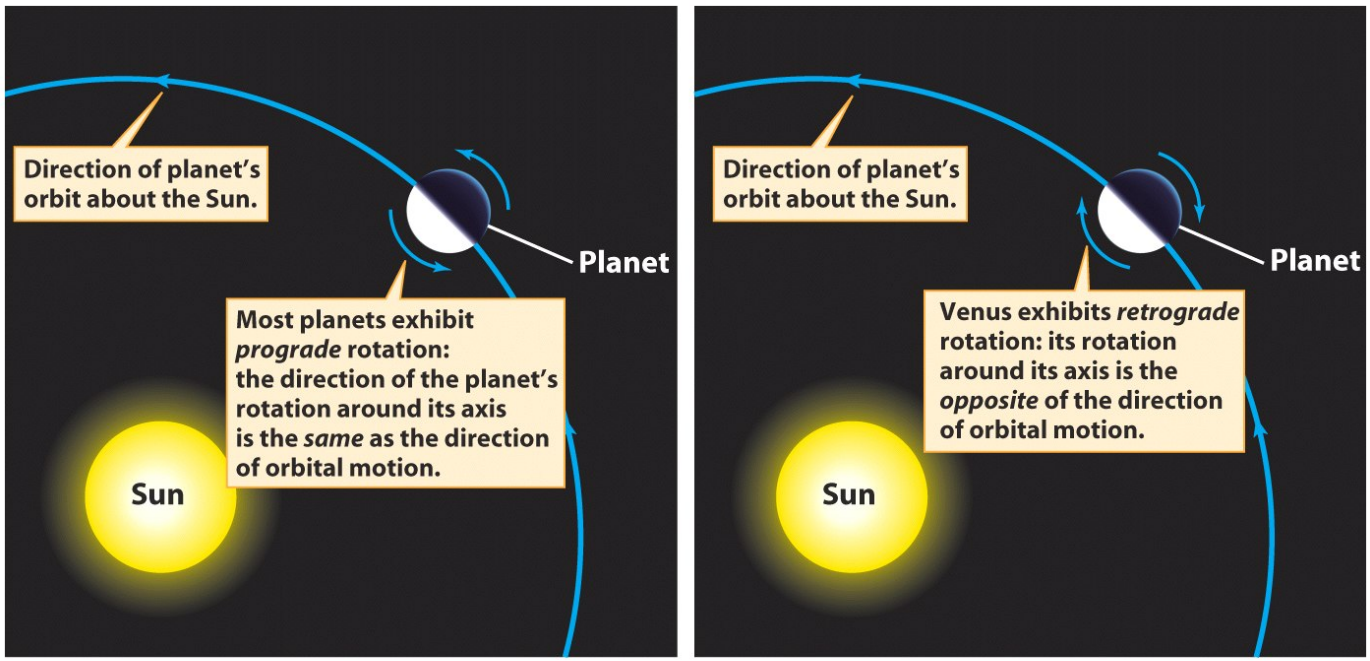


Crescent Venus

The ring indicates atmosphere

Peculiar Rotation

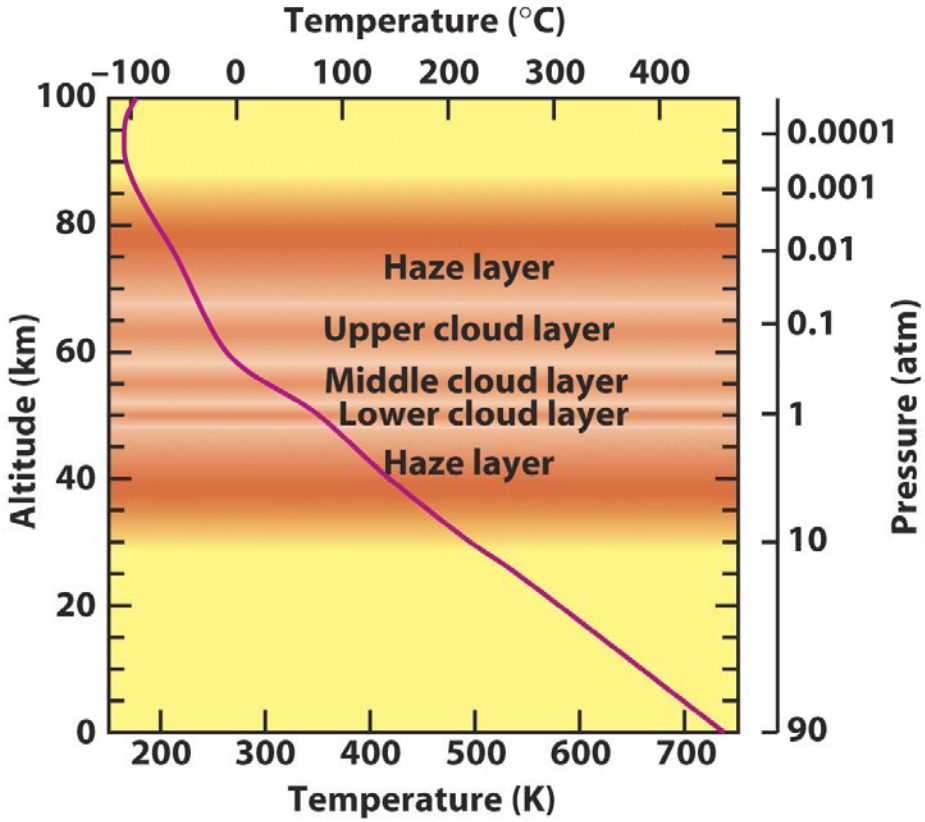
- Rotation is **retrograde**: rotation is opposite of the direction of orbital motion
  - Orbit motion around the Sun: counterclockwise
  - Venus's rotation on its axis: clockwise
  - Planets and satellites have **prograde** rotation except Venus, Uranus and Pluto



(a) Prograde rotation (b) Retrograde rotation

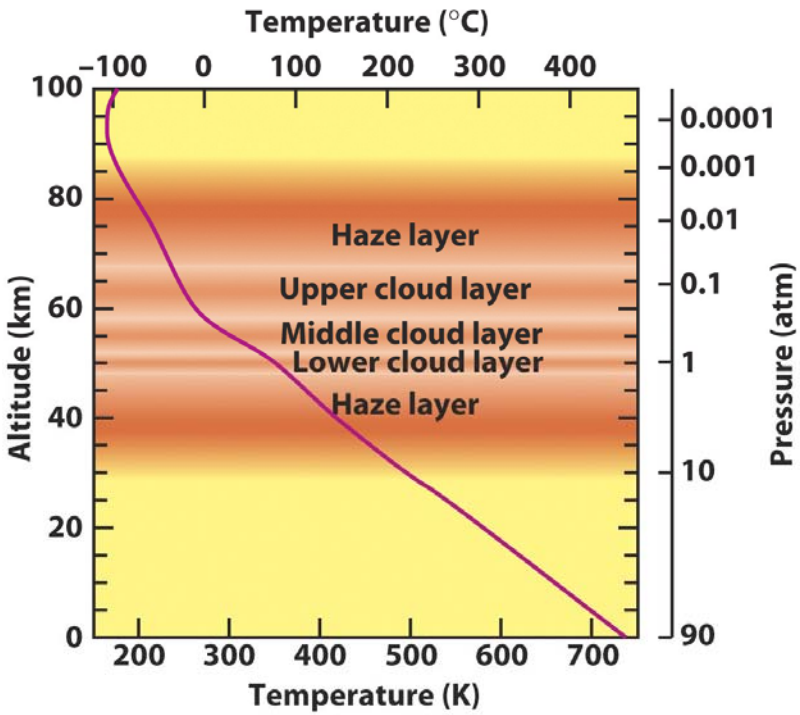
Atmosphere

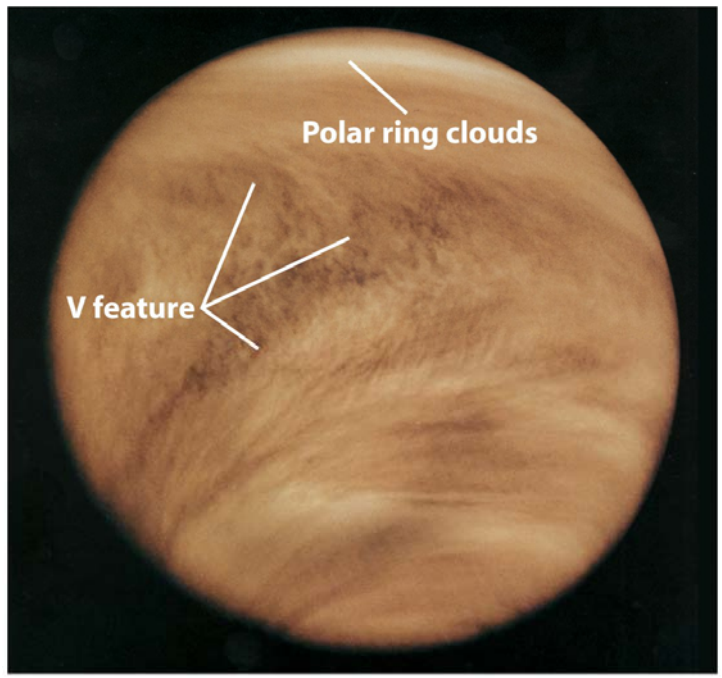
- Measured by Spacecraft and their landing probes
- Composition:
  - Mostly carbon dioxide: 96.5%
  - Remaining is Nitrogen: 3.5%
- Surface Temperature: 460°C in both dayside and night-side
- Density
  - Very high, 90 atm at the surface
- Both temperature and pressure decrease as altitude increases



Atmosphere

- Dense greenhouse gas CO_2 raises the surface temperature by more than 400°C
- Venus has three layers of high-altitude clouds from 48 km to 68 km
- Venus's clouds consist of droplets of concentrated sulfuric acid (H_2SO_4: highly corrosive).





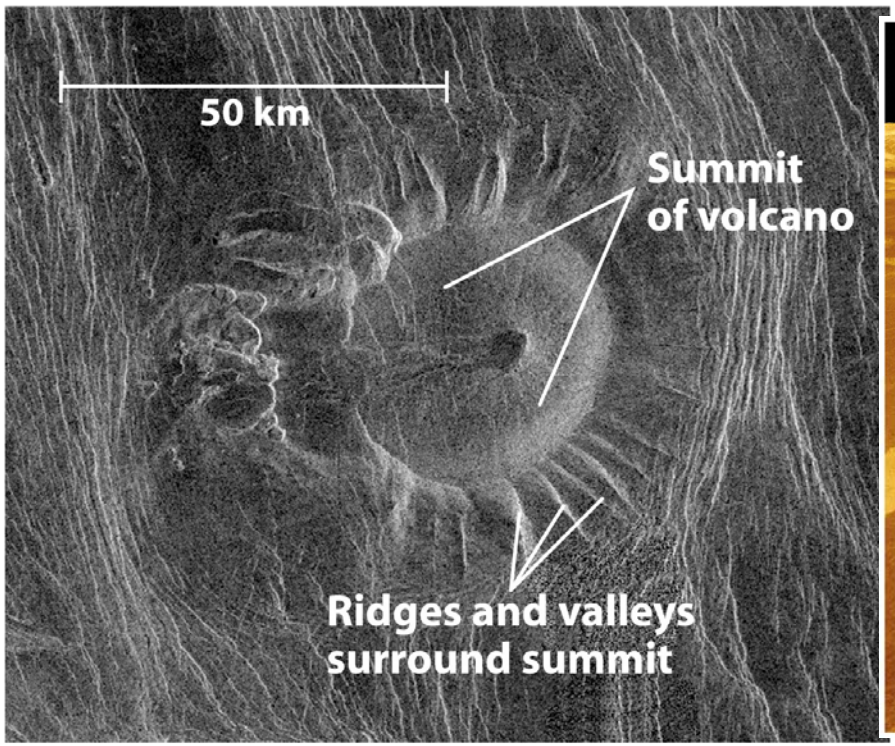
Venus's Clouds

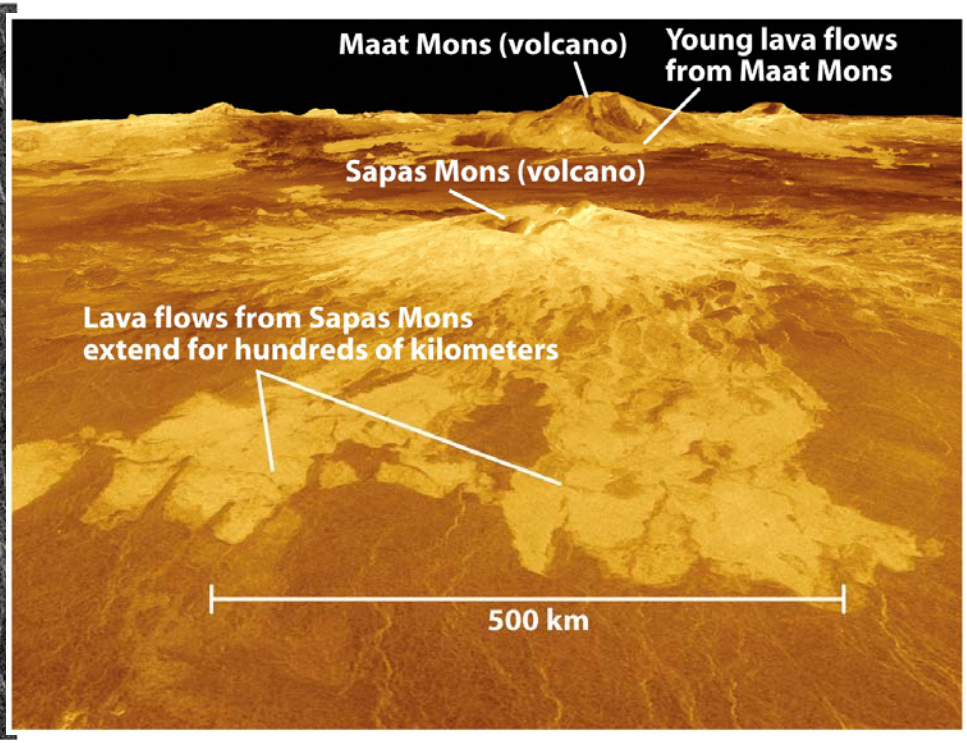
- Sulfuric acid in the clouds come from the sulfurous gas injected into the atmosphere by volcano
- **Hot-spot volcanism**: a hot region beneath the planet's surface extrudes molten rock over a long period of time, e.g., the Havaiian volcanoes
- Ongoing volcanic activity
  - Unexpected high level of sulfuric acid in 1978, and steadily declined over the next years
  - Clouds may be replenished by active volcanoes

Mount St. Helens Earth, 1980

Venus's Clouds

- Relatively young lava flows are seen from volcanoes
- The lack of craters on the surface suggests that the entire surface of Venus is no more than a few hundred million years old.





Venusian Volcano by Radar

Climate Evolution

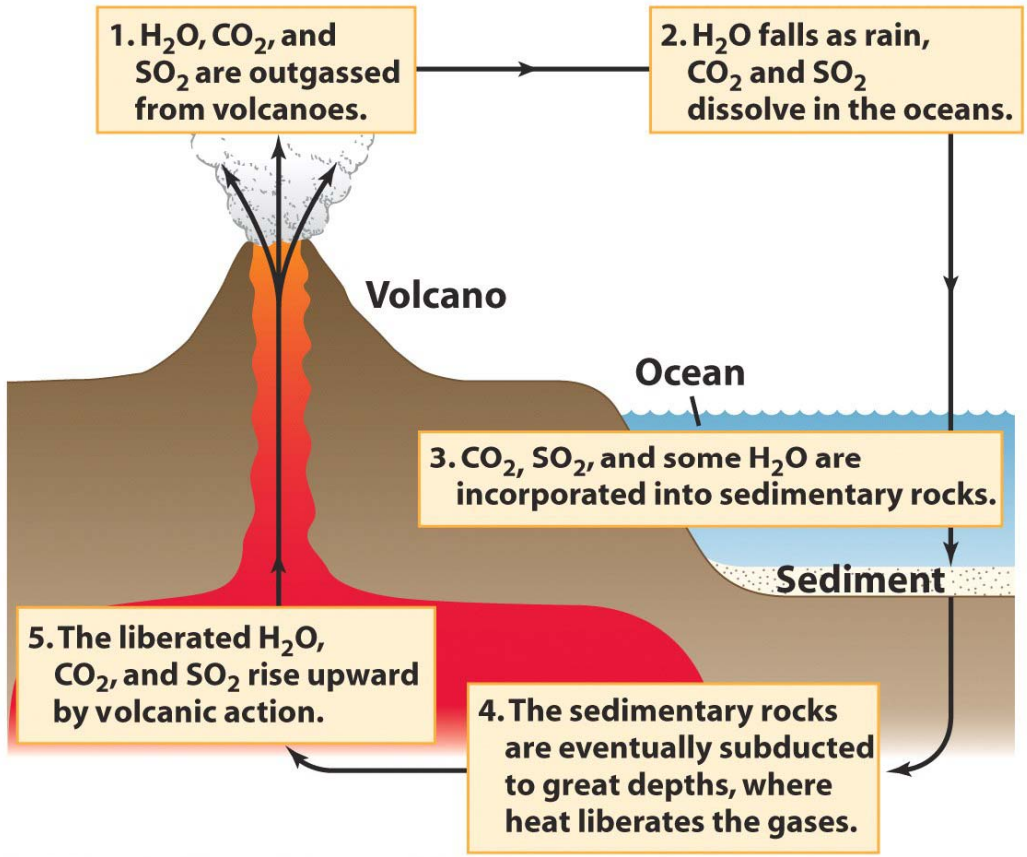
- Venus versus Earth: Similarities
  - Venus and Earth are similar in size, mass, density and surface gravity
  - The early atmospheres of both Venus and Earth were similar in content: water vapor (H_2O), carbon dioxide (CO_2) and Sulfur dioxide (SO_2) that have outgassed from volcanism

- Venus versus Earth: Disparities (now)
  - The Earth has abundant water in its oceans and little carbon dioxide in its relatively thin atmosphere
  - The Venus is very dry and its thick atmosphere is mostly carbon dioxide

Climate Evolution

- **On the Earth**, H_2O and CO_2 are recycled
- Water Vapor falls as rain, forming the oceans

- CO_2 dissolves in the water, falling into the ocean
- CO_2 and H_2O are incorporated into sedimentary rocks
- As a result, most CO_2 is removed from the atmosphere, and locked into the Earth's rocks.



(a) Earth: H_2O, CO_2, and SO_2 are recycled

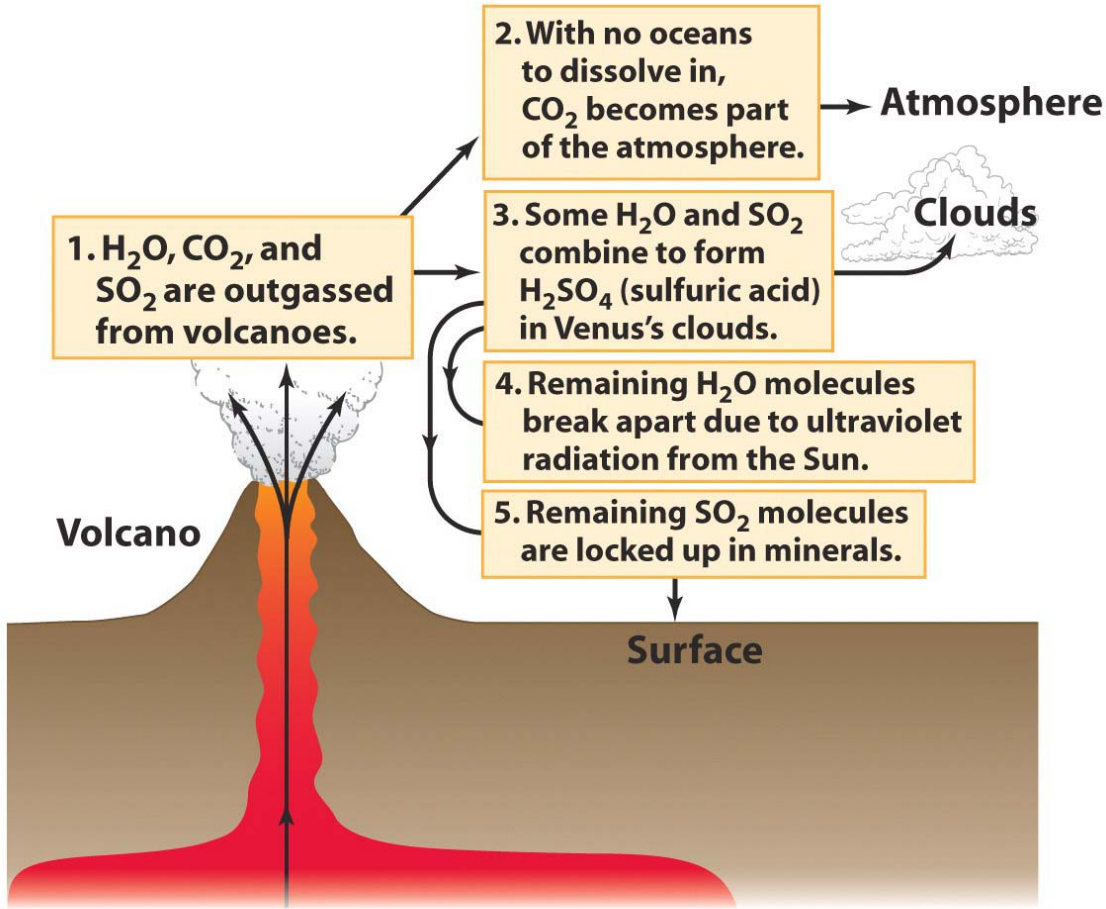
Climate Evolution

- **On the Venus**, the atmosphere experienced a **runaway greenhouse effect**
- In the early history, it may also have liquid ocean
- But temperature is relatively higher, the atmosphere has relatively more water vapor
- The greenhouse effect of the water vapor raised the temperature, and more liquid water evaporated
- This further intensified the greenhouse effect, and raised the temperature even higher
- This runaway process continued until oceans disappeared
- Almost all of the water vapor was eventually lost by the action of ultraviolet radiation on the upper atmosphere

Climate Evolution

- Without ocean to dissolve in, the outgassed CO_2 would accumulate in the Venus's atmosphere

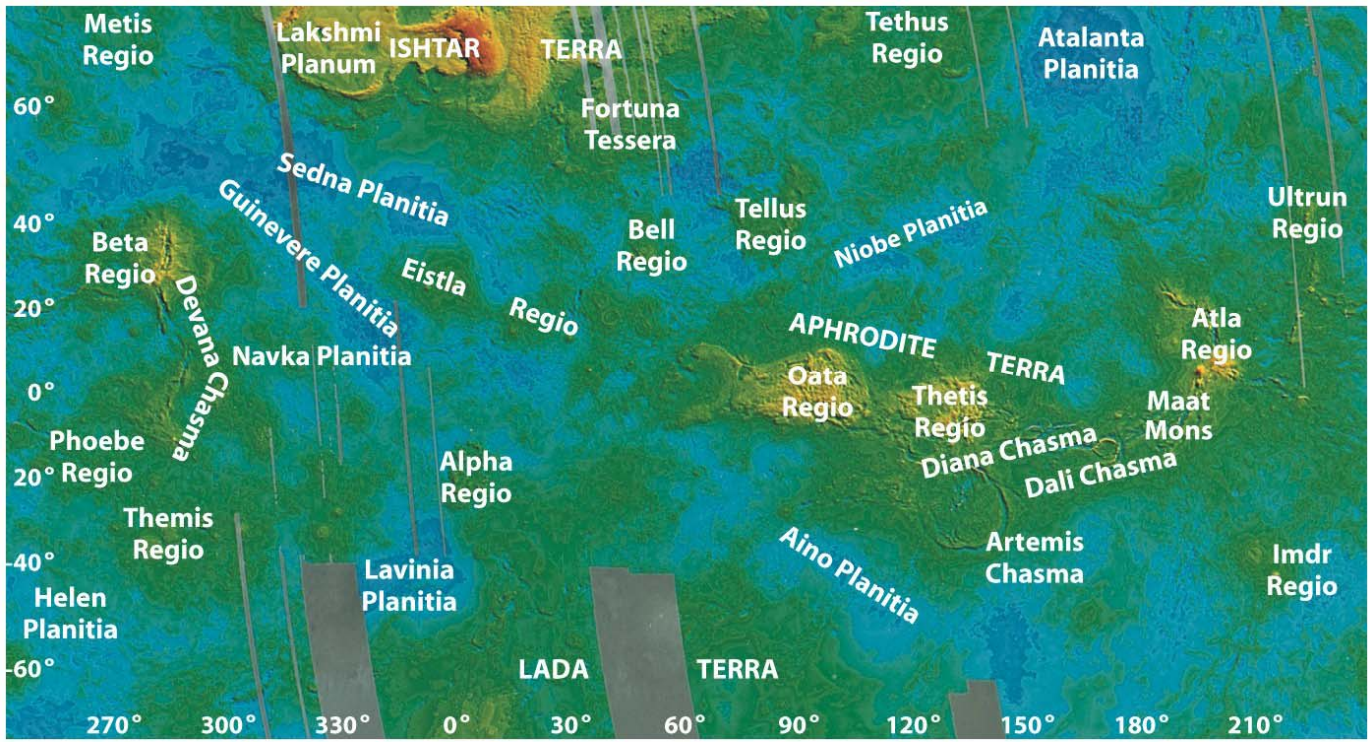
- The Earth has roughly as much carbon dioxide as Venus, but it has been dissolved in the Earth's oceans and chemically bound into its rocks



(b) Venus: H_2O, CO_2, and SO_2 are NOT recycled

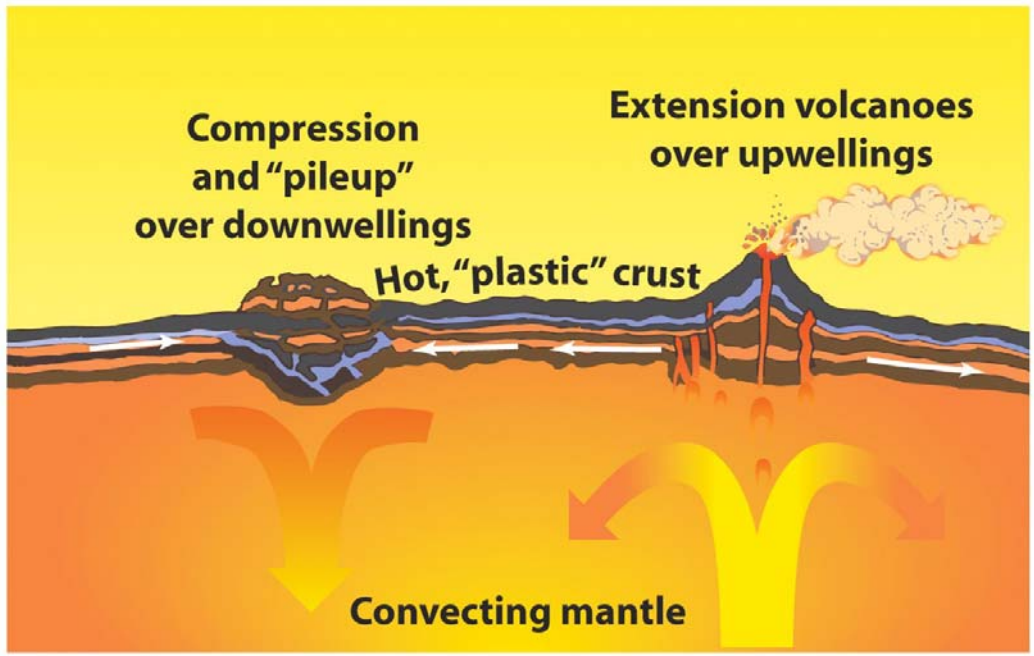
Surface

- The surface of Venus is surprisingly flat, with only a few major highlands and several large volcanoes
- The surface of Venus shows no evidence of plate tectonics (or the motion of large crustal plates)
  - No long chain of volcanic mountains



Interior

- No seismic data available to give a definite answer
- The presence of volcanisms suggests a molten interior
- Venus has no planet-wide magnetic field, possibly due to the fact that Venus rotates too slow
- Venus has no plate tectonics, possibly due to that the crust is too hot and soft to move in rigid plates



(b) Venus: The crust may be too hot and soft to move in rigid plates. The absence of water may limit motions beneath the crust.

Final Notes on Chap. 12

- There are 6 sections in total, all studied