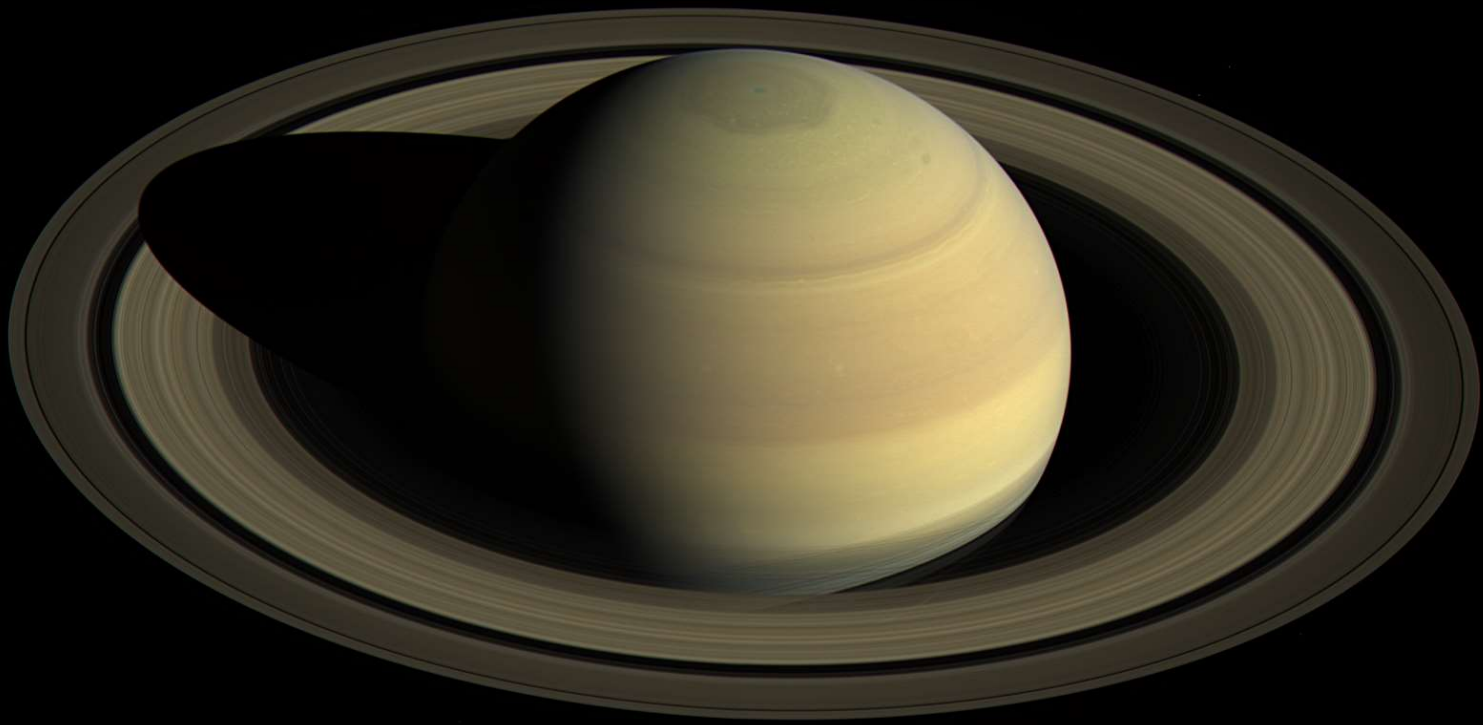
AST 2002
Introduction to Astronomy



A Few Quick Things…

E-mailing me: Must have AST2002 in the subject

Mary Hinkle, Graduate Teaching Assistant:
Office Hours: Mon 1:30-3:00pm. PSB 316

My office hours: Mon 3:00-4:00pm. PSB 308
Tue 3-4 pm. PSB 308

First Mid-term – ScanTron results are in…

Next Knights Under the Stars Event – Thur 22nd Feb 7-8:30pm

Anonymous iClicker Response

The Mid-term average was 69% … why?

A. The exam was too hard

B. Not enough homework – not enough familiarity with the material

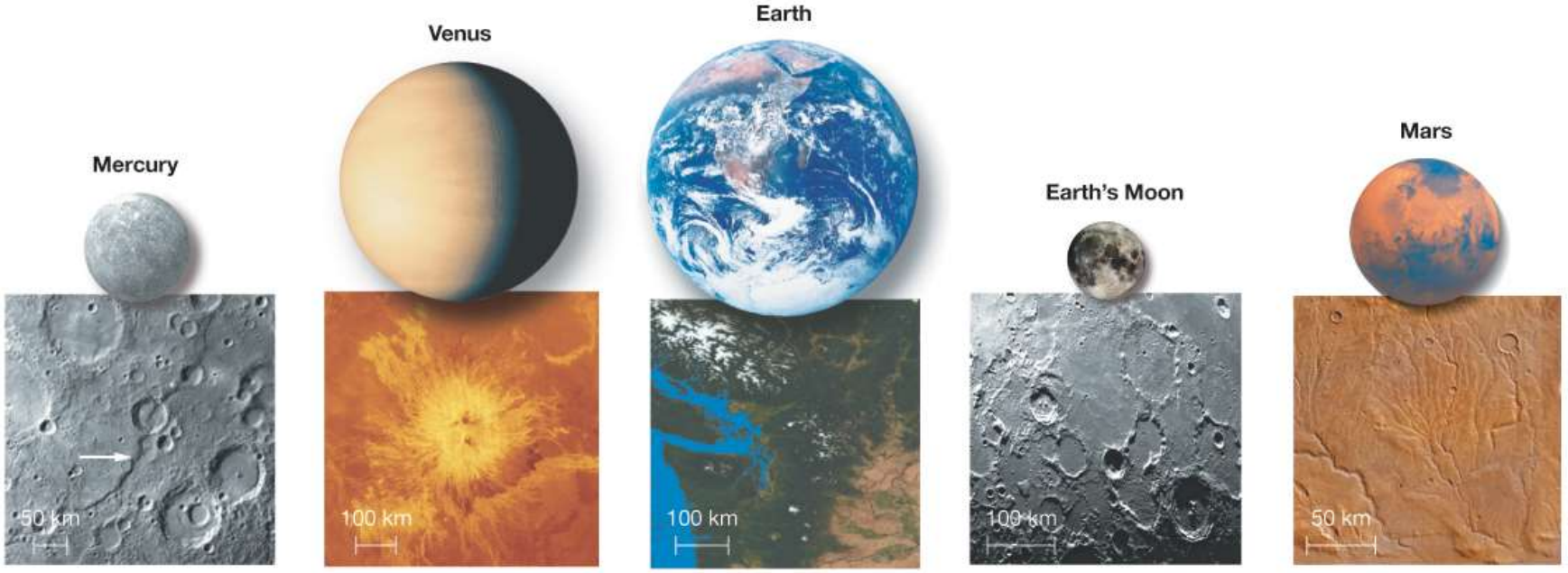
C. I didn't study enough, or haven't been doing enough reading

D. I am using the OpenStax book, which isn't being used enough

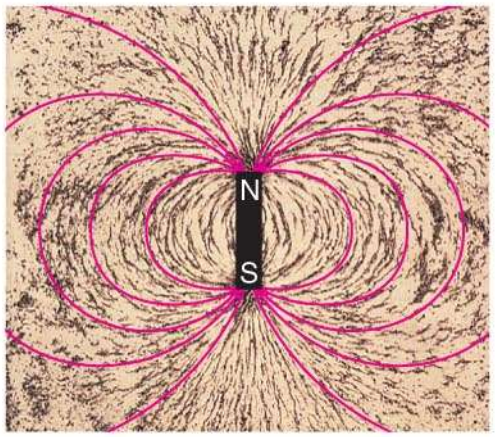
E. The lectures are going over my head … but I'm refusing to come to office hours or ask questions

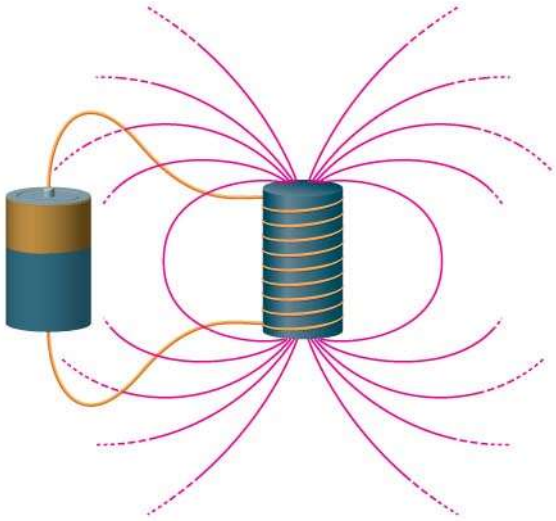
Comparative Planetology

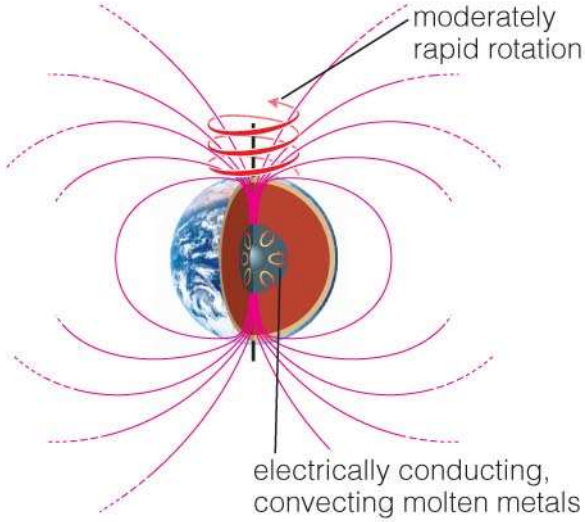
Why have the surfaces of planets turned out so differently, even though they formed at the same time from the same materials? *What processes are shaping these surfaces?*



Planetary Magnetic Fields



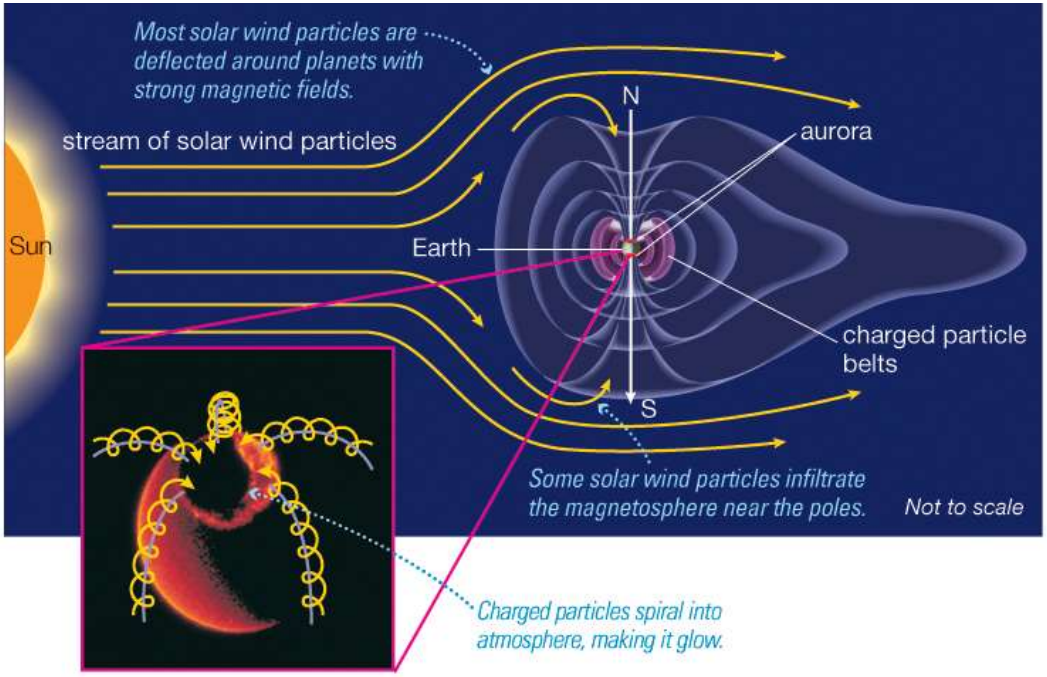




- Moving charged particles create magnetic fields.
- A planet's interior can create magnetic fields if:
  - its core is electrically conducting (iron-nickel works well)
  - Its core is convecting (liquids work well)
  - Rotating (IMPORTANT: No Rotation = No magnetic field)

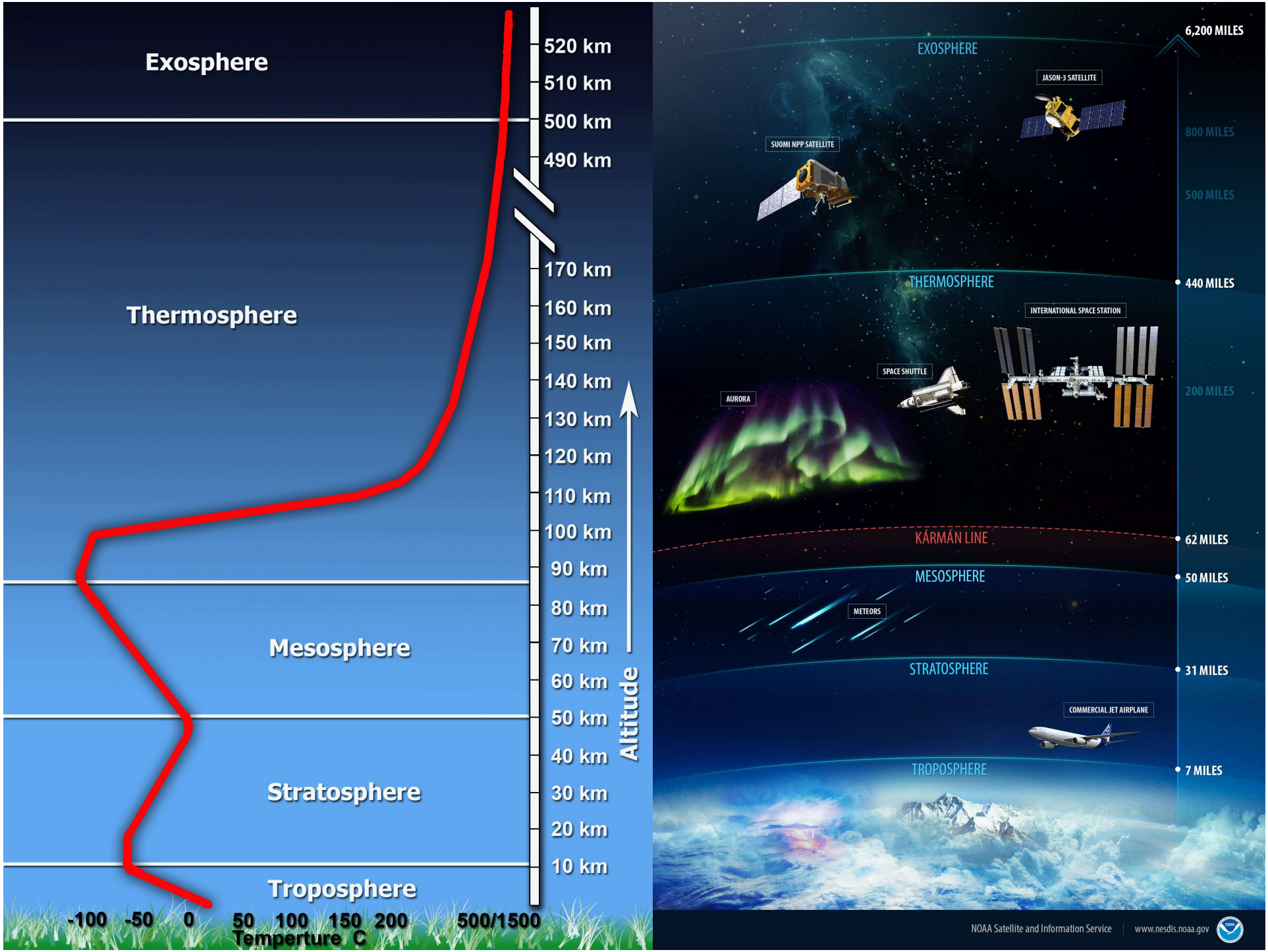
Earth's Magnetosphere

- The majority of solar wind particles are deflected by Earth's magnetosphere
- The charged particles can enter at the poles, generating the aurorae.

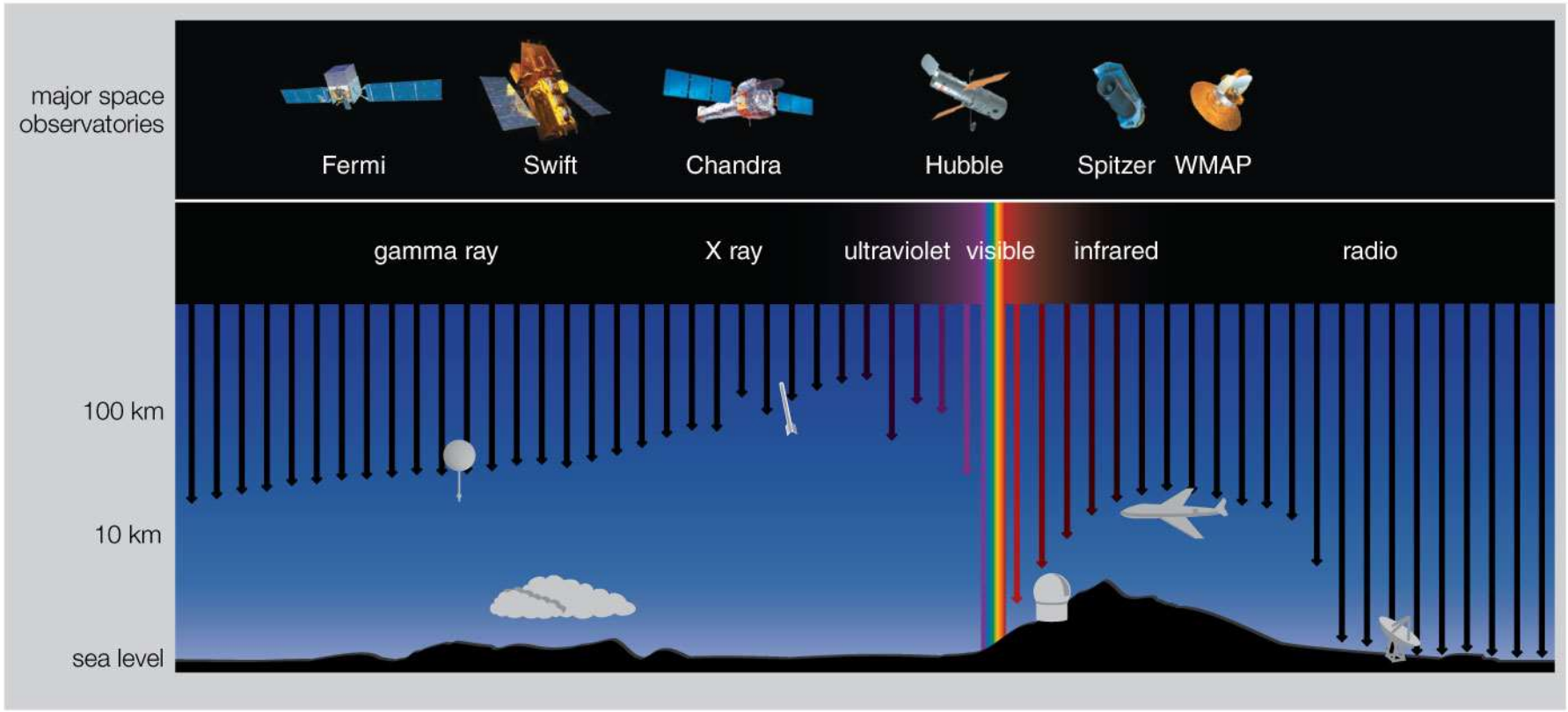


a This diagram shows how Earth's magnetosphere deflects solar wind particles. Some particles accumulate in charged particle belts encircling our planet. The inset is an ultraviolet image of a ring of auroras around the North Pole; the bright crescent at its left is part of the day side of Earth.

b This photograph shows the aurora near Yellowknife, Northwest Territories, Canada. In a video, you would see these lights dancing about in the sky.


Exosphere
Thermosphere
Mesosphere
Stratosphere
Troposphere
520 km
510 km
500 km
490 km
170 km
160 km
150 km
140 km
130 km
120 km
110 km
100 km
90 km
80 km
70 km
60 km
50 km
40 km
30 km
20 km
10 km
Altitude
-100 -50 0 50 100 150 200 500/1500
Temperture C
6,200 MILES
EXOSPHERE
JASON-3 SATELLITE
SUOMI NPP SATELLITE
800 MILES
500 MILES
THERMOSPHERE
440 MILES
INTERNATIONAL SPACE STATION
SPACE SHUTTLE
AURORA
200 MILES
KÁRMÁN LINE
62 MILES
MESOSPHERE
50 MILES
METEORS
STRATOSPHERE
31 MILES
COMMERCIAL JET AIRPLANE
TROPOSPHERE
7 MILES
NOAA Satellite and Information Service
www.nesdis.noaa.gov

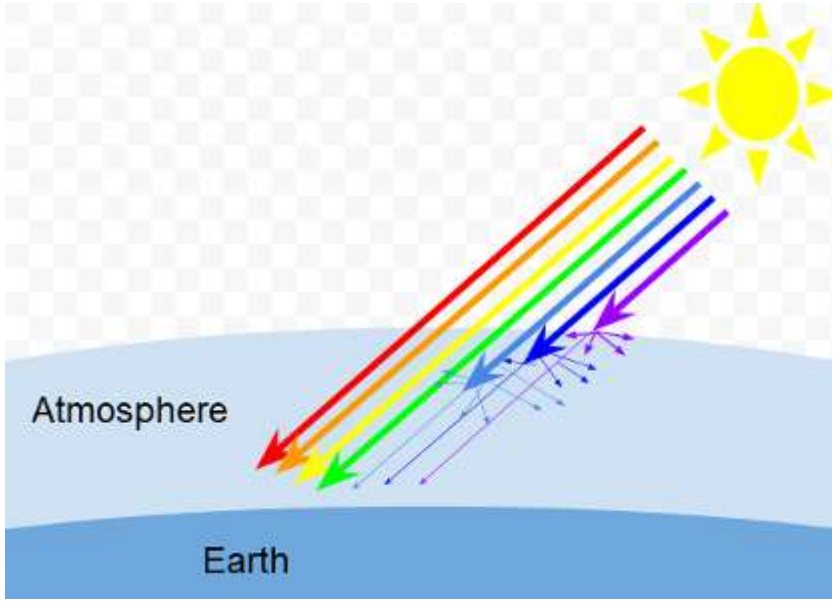
Protection from Radiation

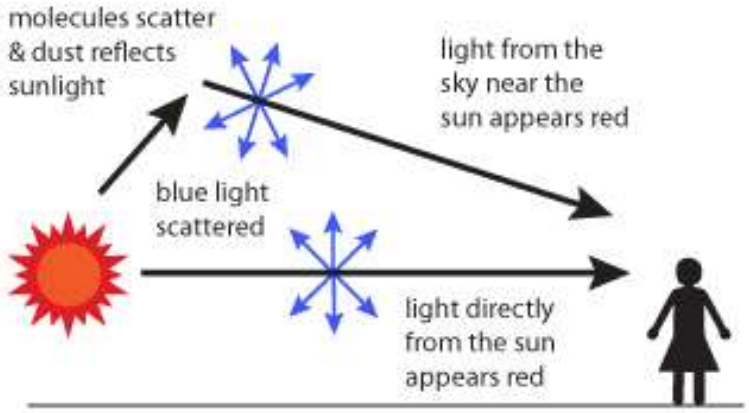


- Earth's atmosphere absorbs light at most wavelengths
  - Ozone (O_3) absorbs UV. Most X-rays don't make it to the ground
- Most meteoroids usually burn up in the mesosphere

Why is the Sky Blue? And Sunsets Red?

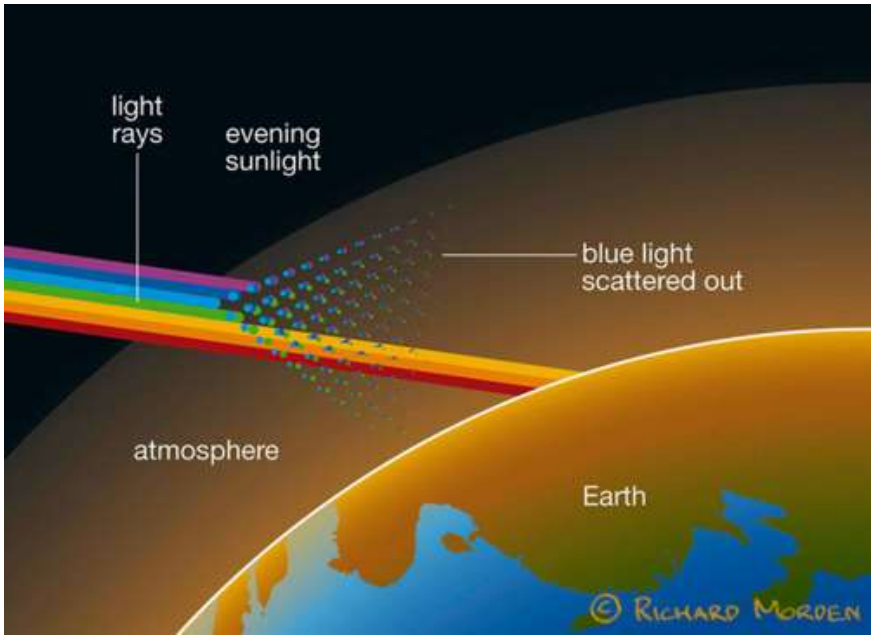
Blue particles are scattered more effectively so appear to be coming from every direction



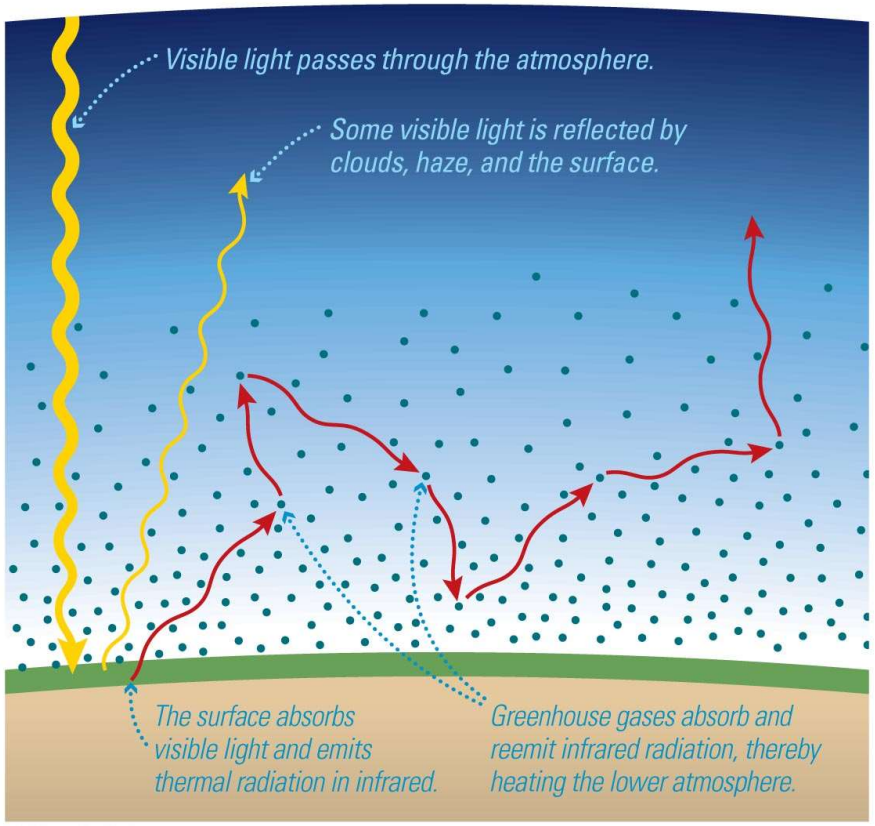


At Sunset, the suns rays have to travel through more atmosphere so more of the blue light never reaches you.

In addition, dust particles (smog) scatters red particles



What is the Greenhouse Effect?



Light from the Sun heats the Earth Surface

- ~50% heating caused by visible light

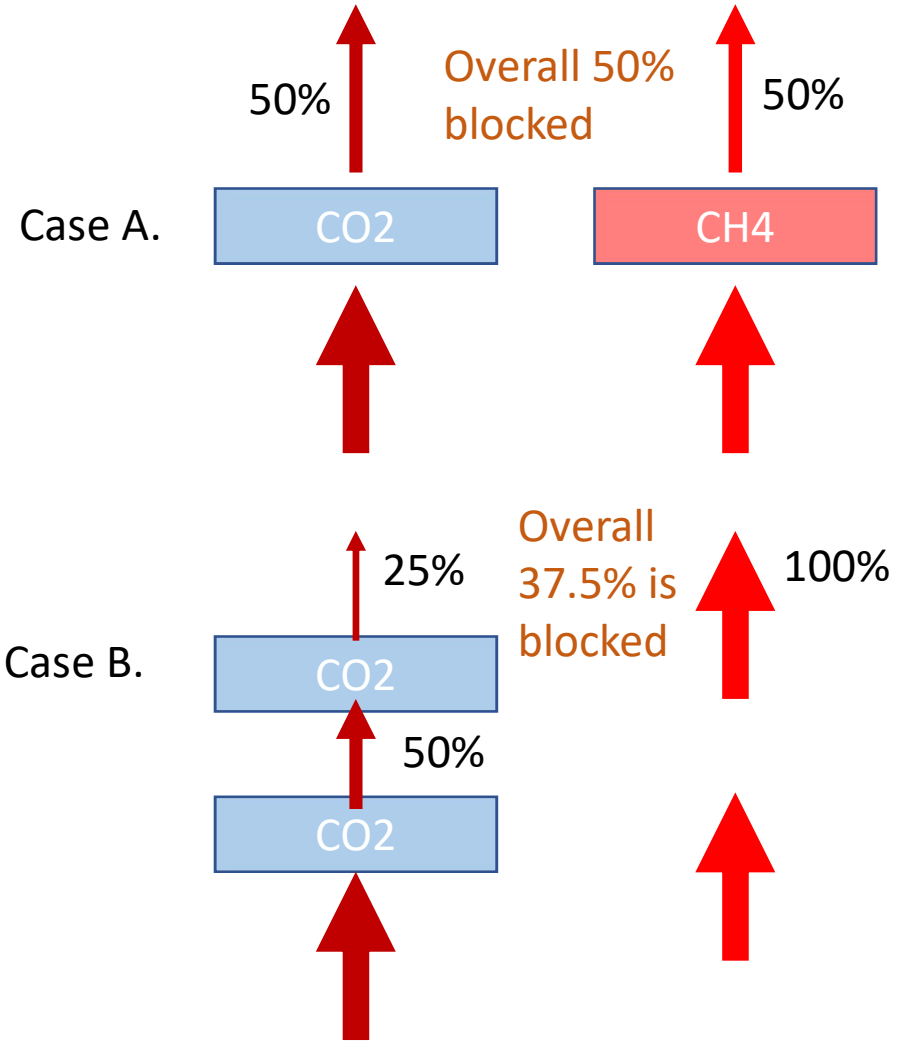
The Earth, at ~300 K emits light in the infrared region

- Molecules that absorb infrared light in the atmosphere re-irradiate it in random directions.
- As a result, that infrared light can't escape

What are Greenhouse gases?

- Any gas that absorbs infrared
- Greenhouse gas: molecules with two different types of elements (CO_2, H_2O, CH_4)
- Not a greenhouse gas: molecules with one or two atoms of the same element (O_2, N_2)

Explanation why different greenhouse gases are more problematic



Lets say that each 'block' represents a certain concentration of a gas in the atmosphere.

Each one might block say 50% of light escaping at a particular IR wavelength

In case A, two different wavelengths are blocked by 50%. Case A is worse!

50% of half = 25% for each

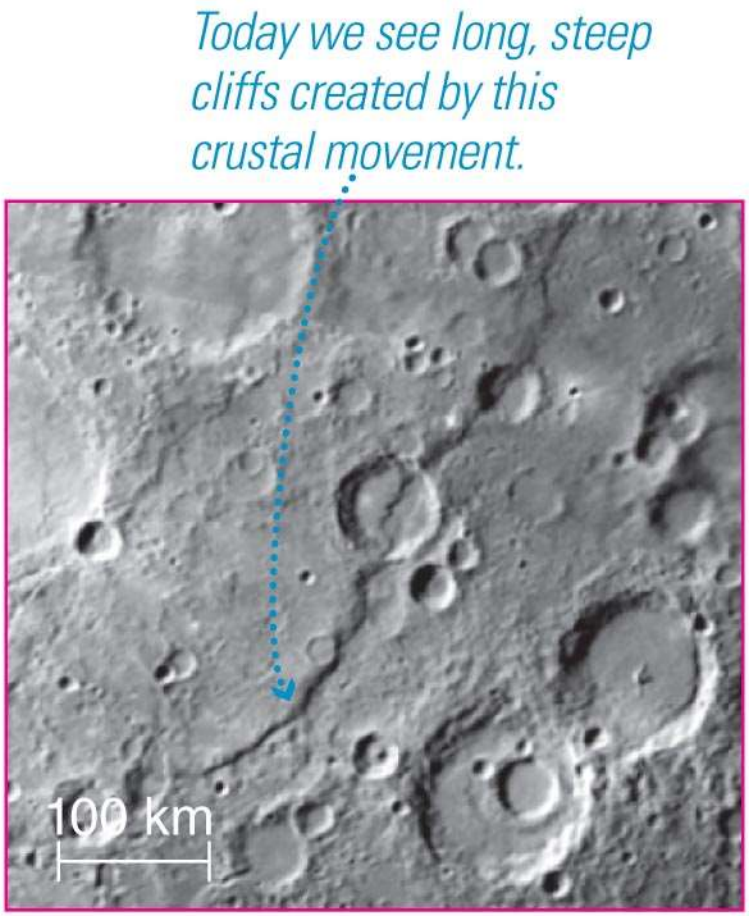
In case B, only one wavelength is blocked twice…

100% of half gets through = 50%
25% of half gets through = 12.5%
67% through, 37.5% blocked

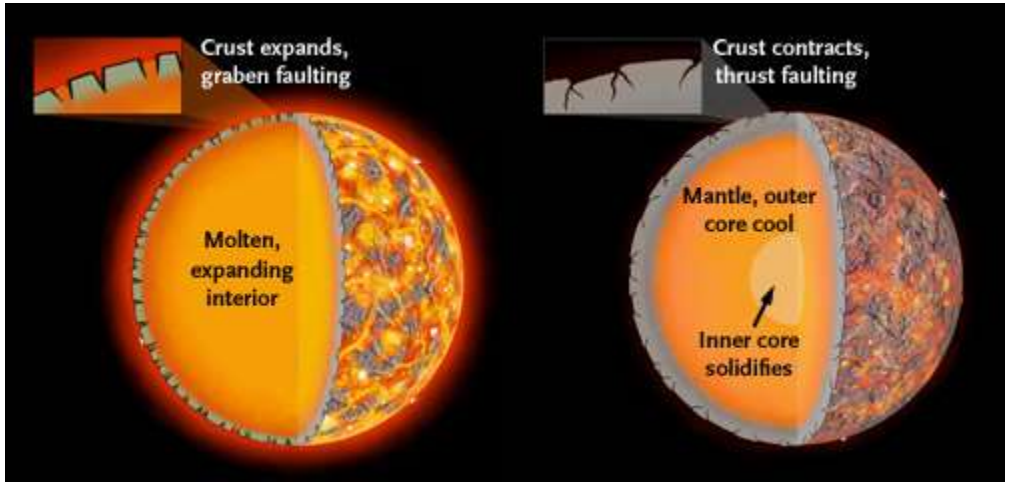
How did the Lunar Mare Form?

- Large impact occurred during ‘Late Heavy Bombardment’
  - Sufficient to crack the lithosphere
- Radioactive decay peaked around 3-4 billion years ago…
  - Some volcanic activity 3 billion years ago must have flooded lunar craters, creating *lunar maria*.
- The Moon is now geologically dead.

Tectonics on Mercury

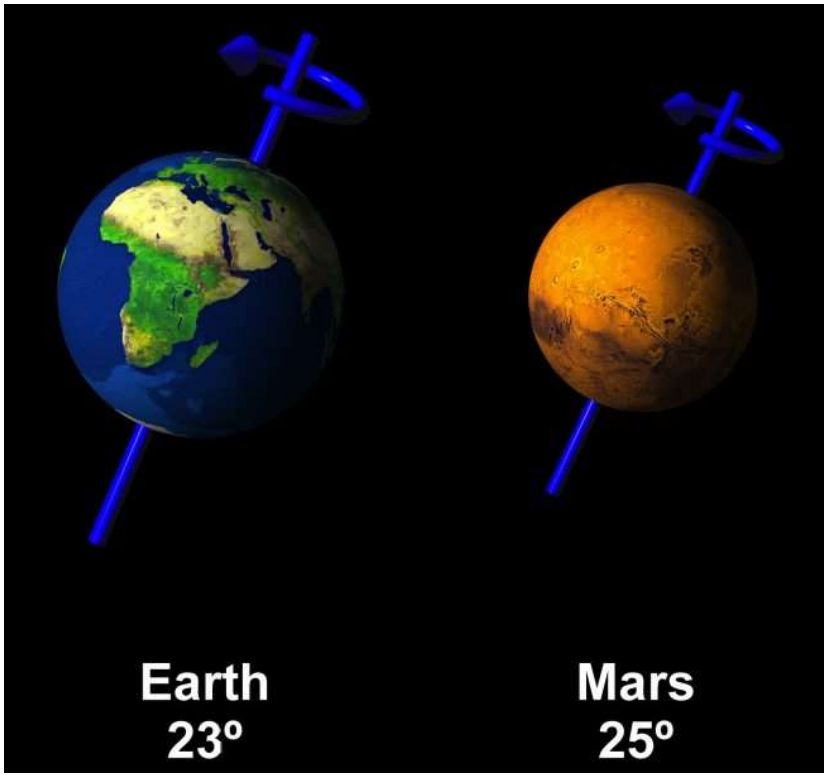


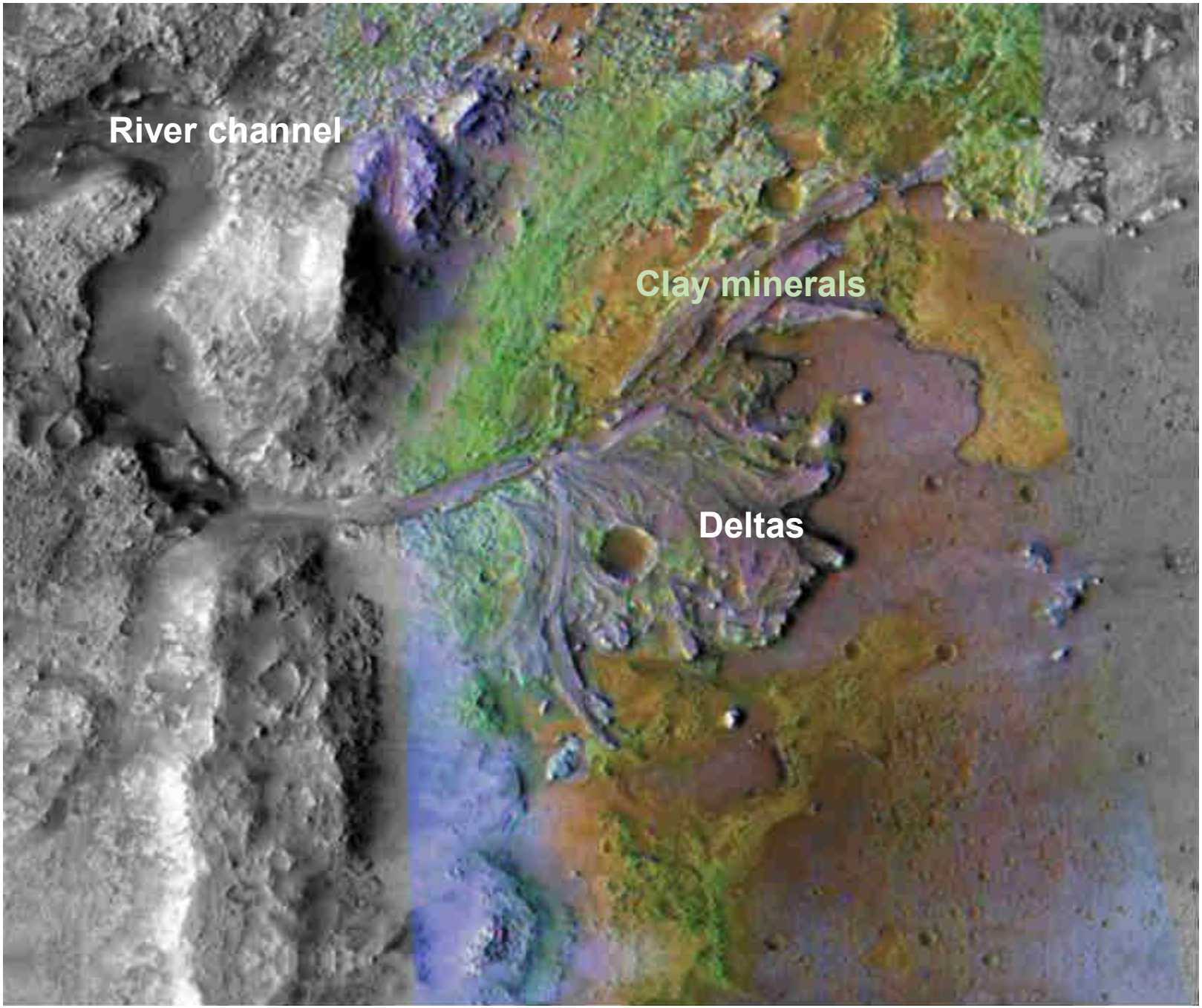
- Long cliffs indicate that Mercury shrank early in its history.



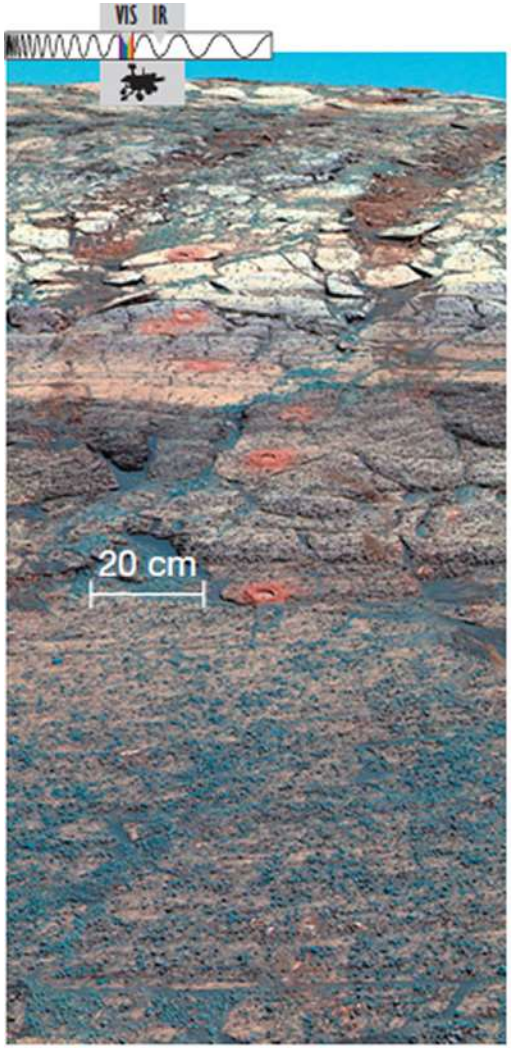
Mars versus Earth

- 50% Earth's radius, 10% Earth's mass
- 1.5 AU from the Sun
- Axis tilt about the same as Earth
- Similar rotation period
- Thin CO_2 atmosphere: little greenhouse
- Main difference: Mars is SMALLER




River channel
Clay minerals
Deltas

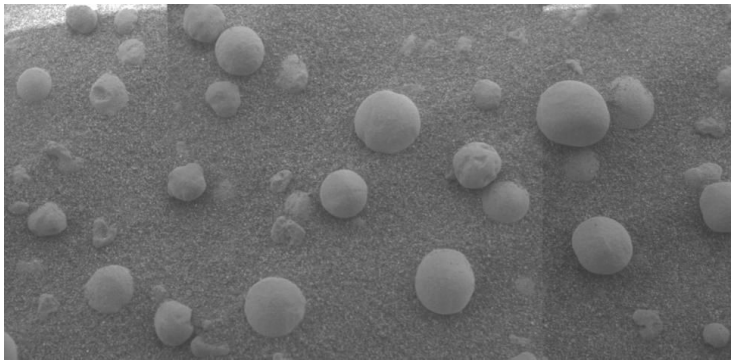
Evidence of “hematite” Blueberries



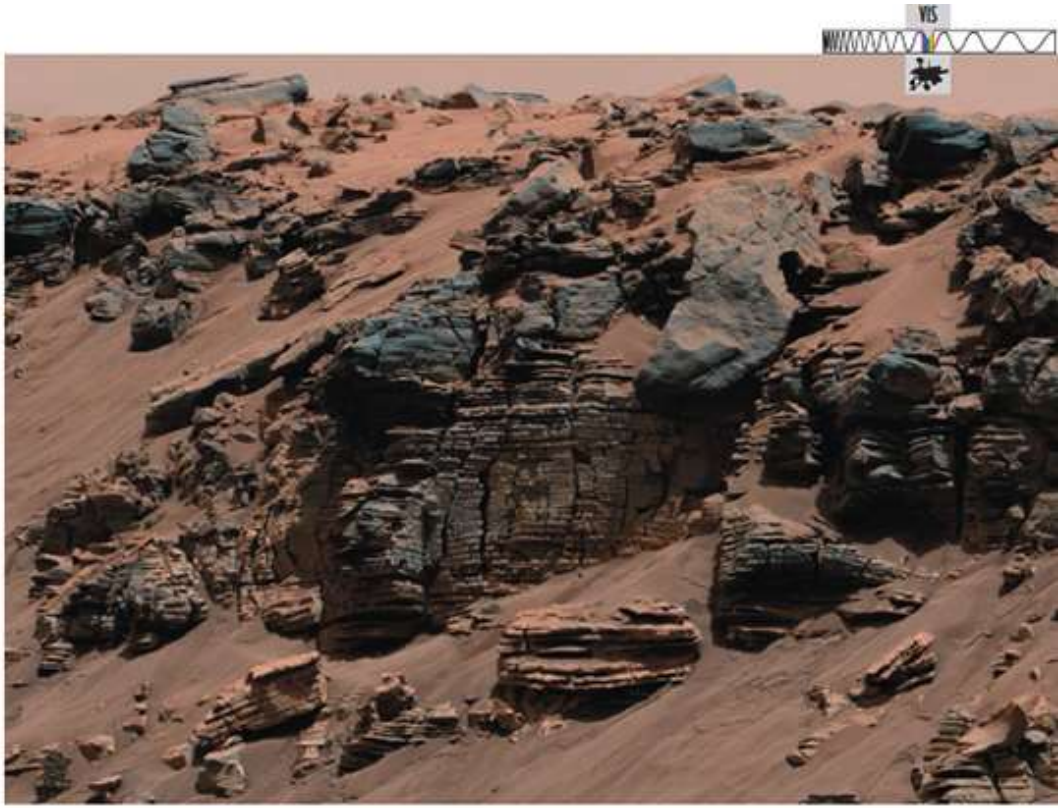
Mars (Endurance Crater)

Earth (northern Arizona)

- 2004 *Opportunity* rover provided strong evidence for abundant liquid water on Mars in the distant past.
- The mineral hematite, typically formed in a salty water environment.



Evidence of Sedimentary Rock Layering



b The even layers of the foreground rocks in this image from *Curiosity* are characteristic of sediment deposited over time in the delta of a river that emptied into a lake.

Curiosity also found these layered rocks, characteristic of sedimentation by water.

Summary of Last Time & Today's Topics

Chapter 7: Earth and the Terrestrial Worlds

- Earth as a Planet
  - Why is Earth geologically active?
  - What processes shape Earth's surface
  - How does Earth's atmosphere affect the planet?
- The Moon and Mercury: Geologically Dead
  - Was there ever geological activity on the Moon or Mercury?
- Mars: A Victim of Planetary Freeze-Drying
  - What geological features tell us that water once flowed on Mars
  - Why did Mars change?
- Venus: A Hothouse World
  - Is Venus Geologically Active?
  - Why is Venus to Hot?
- Earth as a Living Planet
  - What unique features of Earth are important for life?
  - How is human activity changing our planet?
  - What makes a planet habitable?

iClicker Question

Question: Why is the sky blue?

A. The sky reflects light from the oceans.
B. Oxygen atoms are blue.
C. Nitrogen atoms are blue.
D. Air absorbs red light.
E. Air molecules scatter blue light more than red light.

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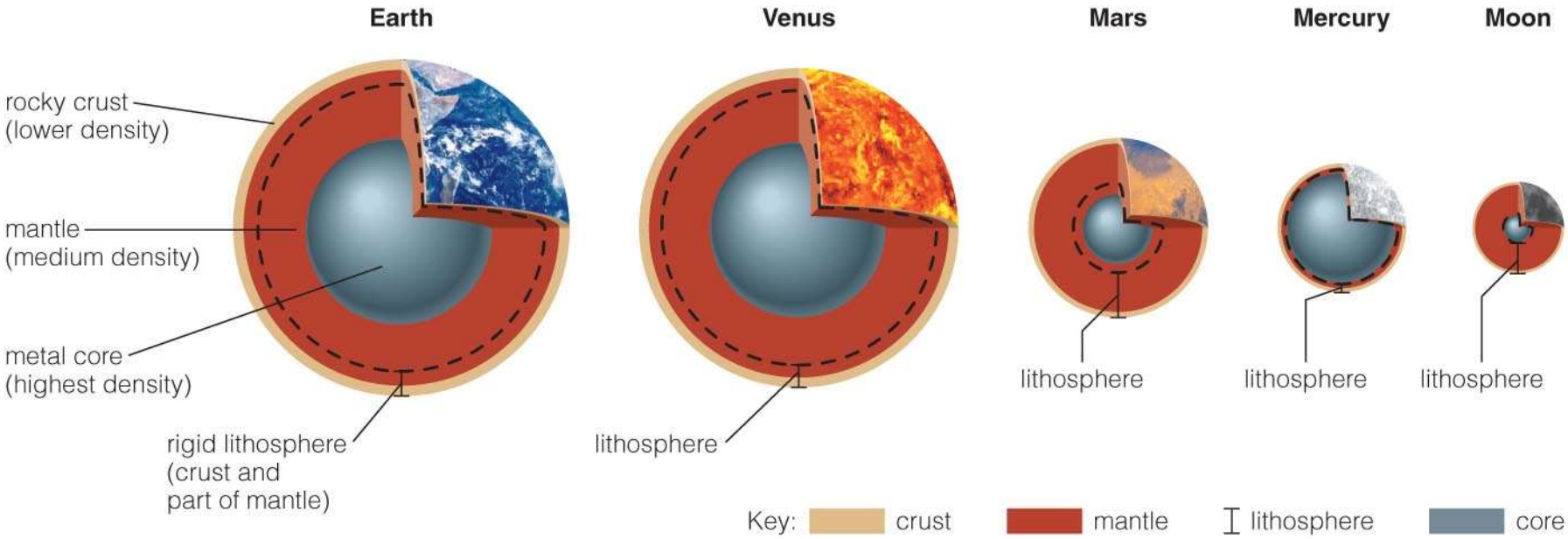
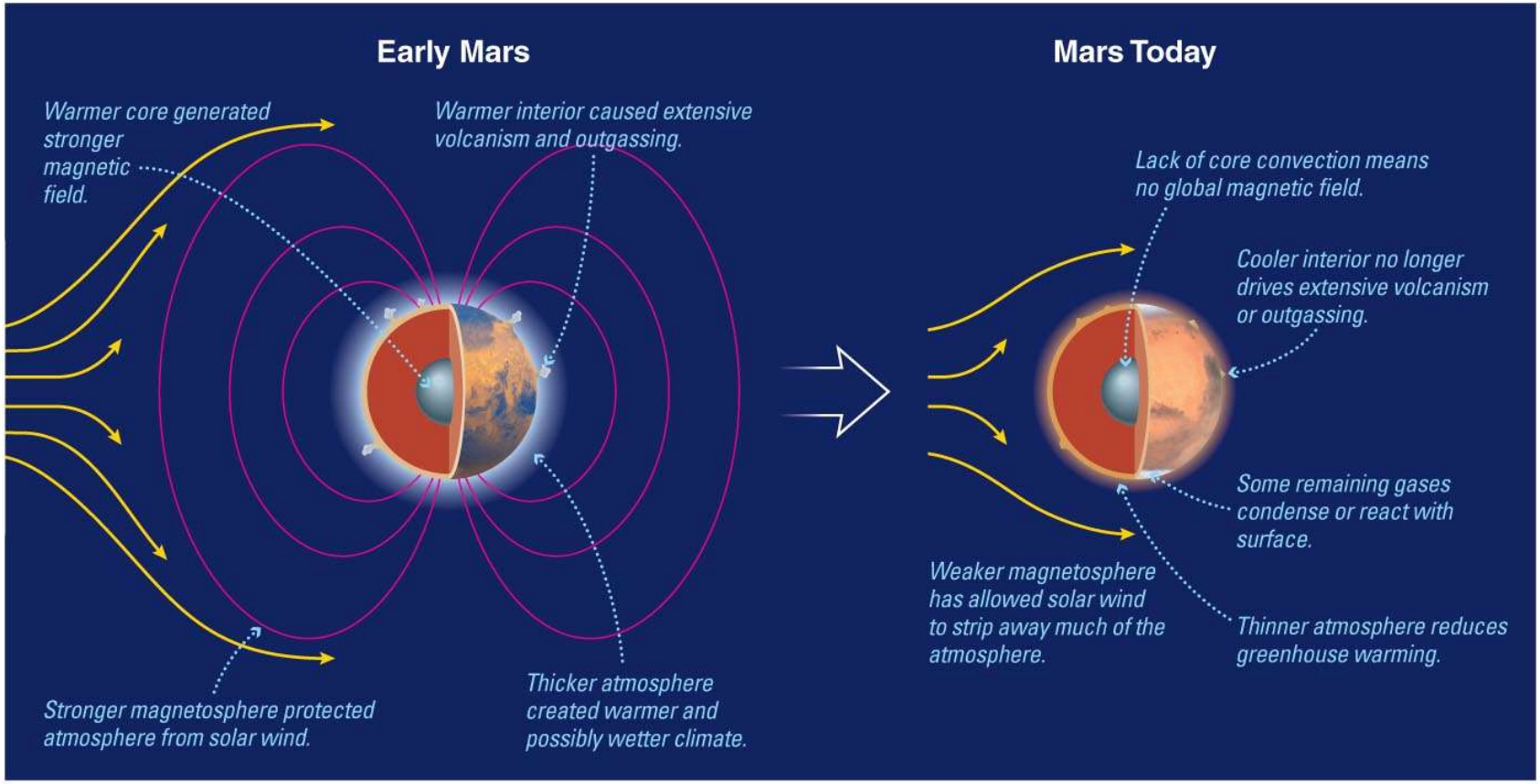
Why did Mars change?



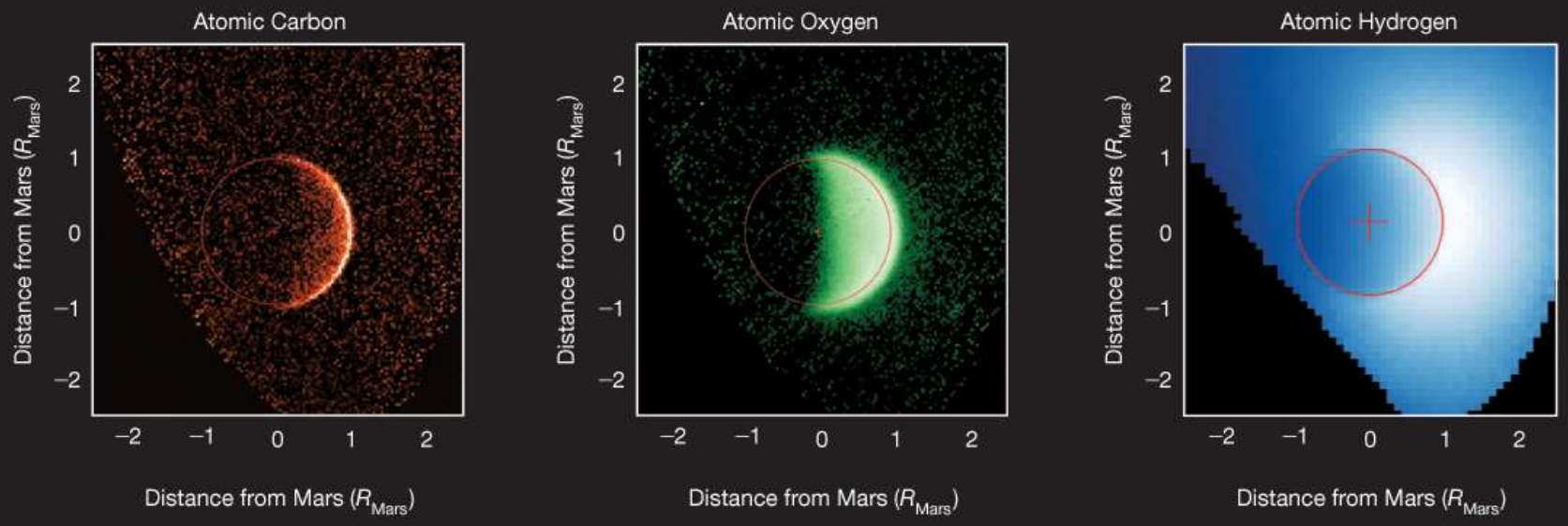
- Mars should have had similar composition from outgassing
  - we can see volcanoes
- We see evidence for water in the past…
- Mars has not had widespread surface water for 3 billion years.
- The greenhouse effect probably kept the surface warmer before that.
  - Mars must have lost its atmosphere sometime in the past. Why?

Mars Lost its Magnetosphere



- Somehow Mars lost most of its atmosphere.
- Magnetic field may have preserved early Martian atmosphere.
- Solar wind may have stripped atmosphere after field decreased because of interior cooling.

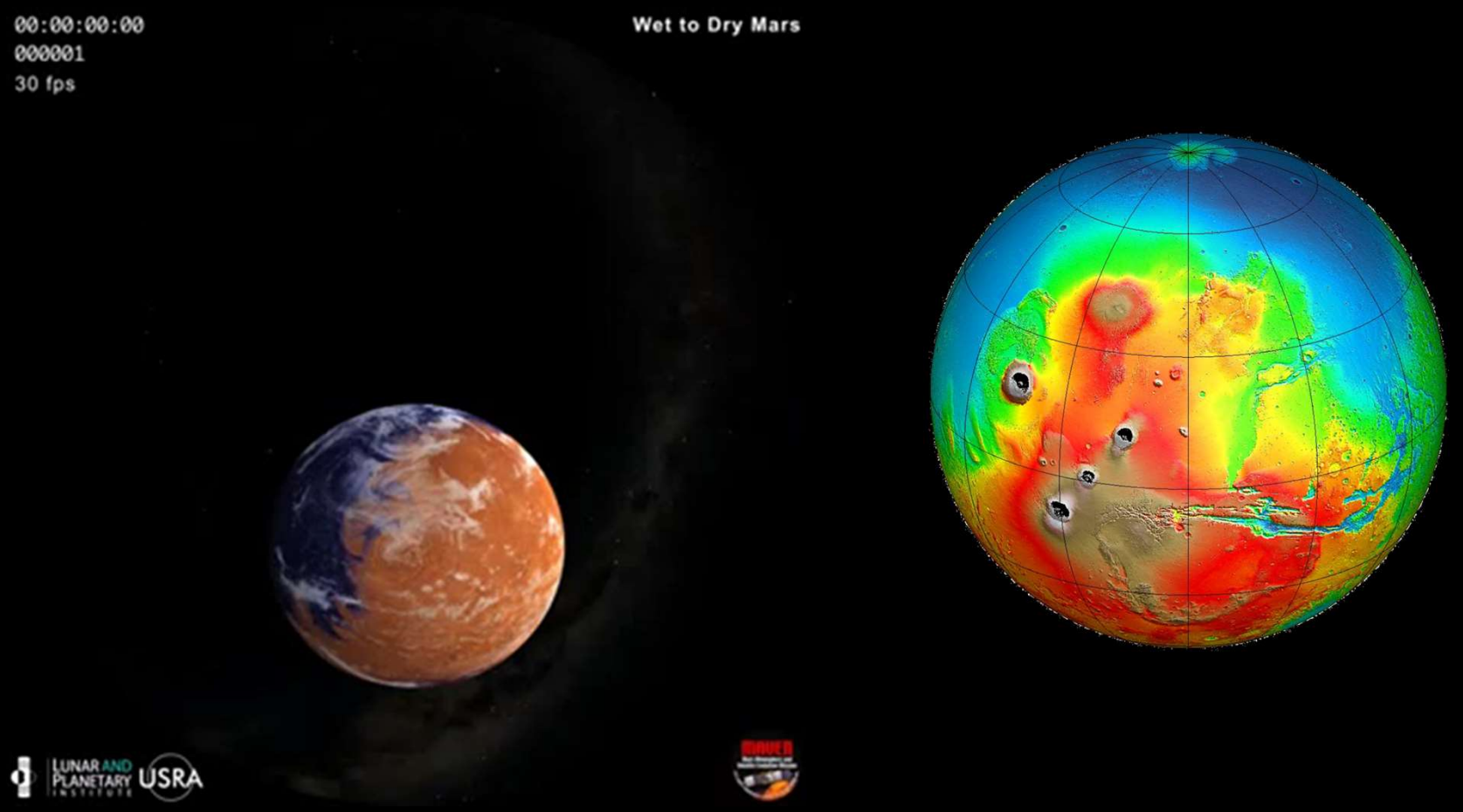
Stripping of Mars' Atmosphere by the Solar Wind – *In Action*



- The *MAVEN* spacecraft is measuring the loss of Mars' atmosphere today.
  - Can literally see CO_2 → C + O.
- Also measured Argon-36 vs. Argon-38 ratios
  - Lighter isotope is sputtered more efficiently

Transition from Wet to Dry Mars

https://www.youtube.com/watch?v=nFBVBG5nEpw



What have we learned about Mars?

- What geological features tell us that water once flowed on Mars?
  - Dry riverbeds, eroded craters, and rock-strewn floodplains all show that water once flowed on Mars.
  - Mars today has ice, underground water ice, and perhaps pockets of underground liquid water.

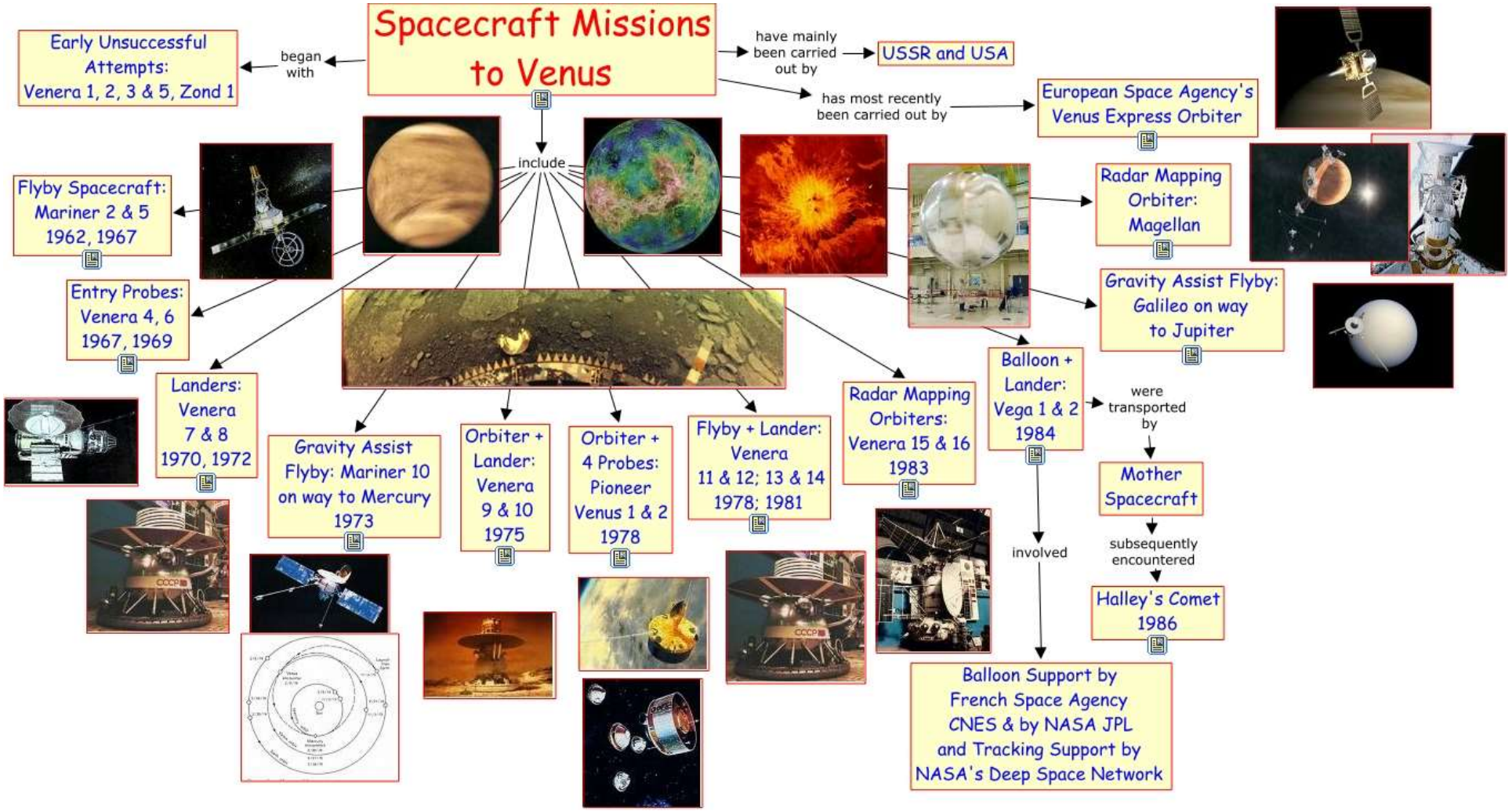
- Why did Mars change?
  - Mars's atmosphere must have once been much thicker for its greenhouse effect to allow liquid water on the surface.
  - Somehow Mars lost most of its atmosphere, perhaps because of a declining magnetic field.

7.4 Venus: A Hothouse World

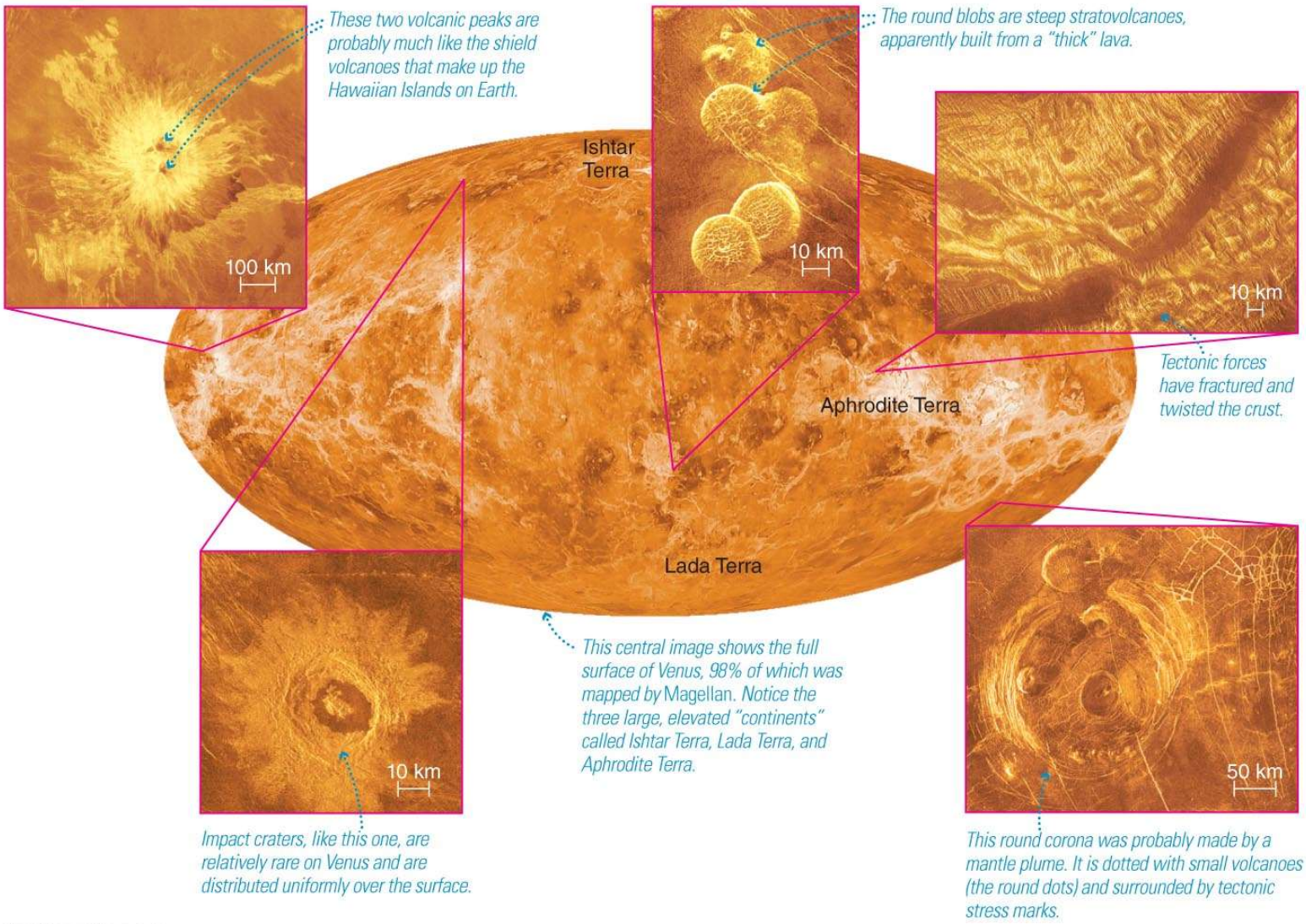
Our goals for learning:

- Is Venus geologically active?
- Why is Venus so hot?

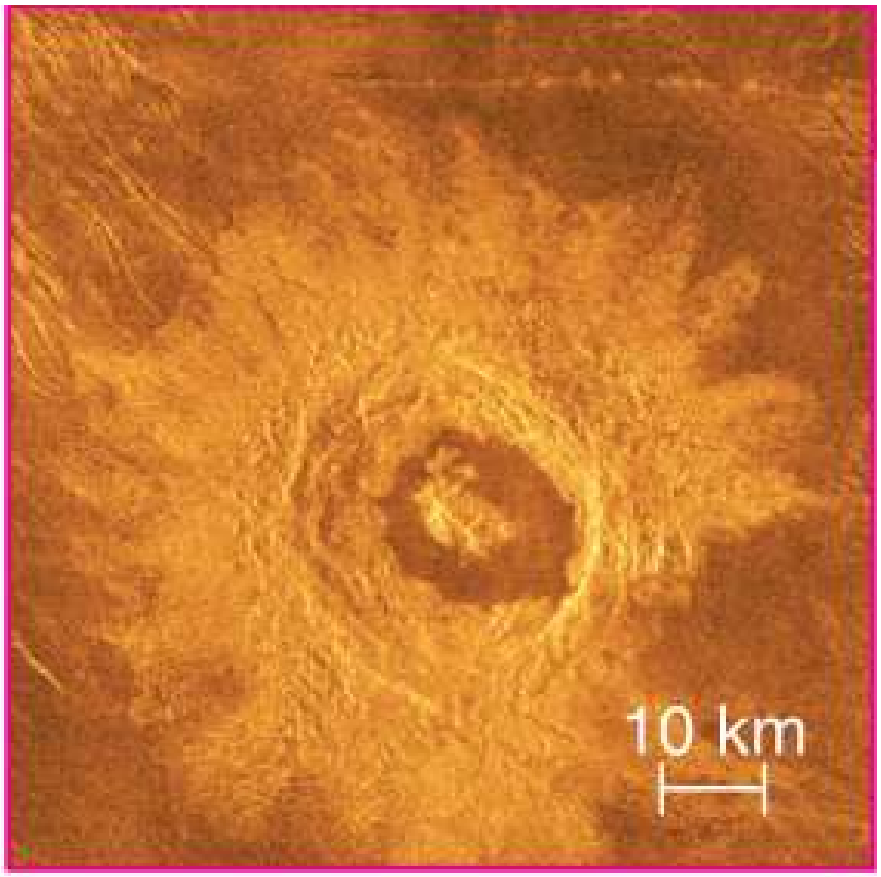
Missions to Venus



Is Venus geologically active?

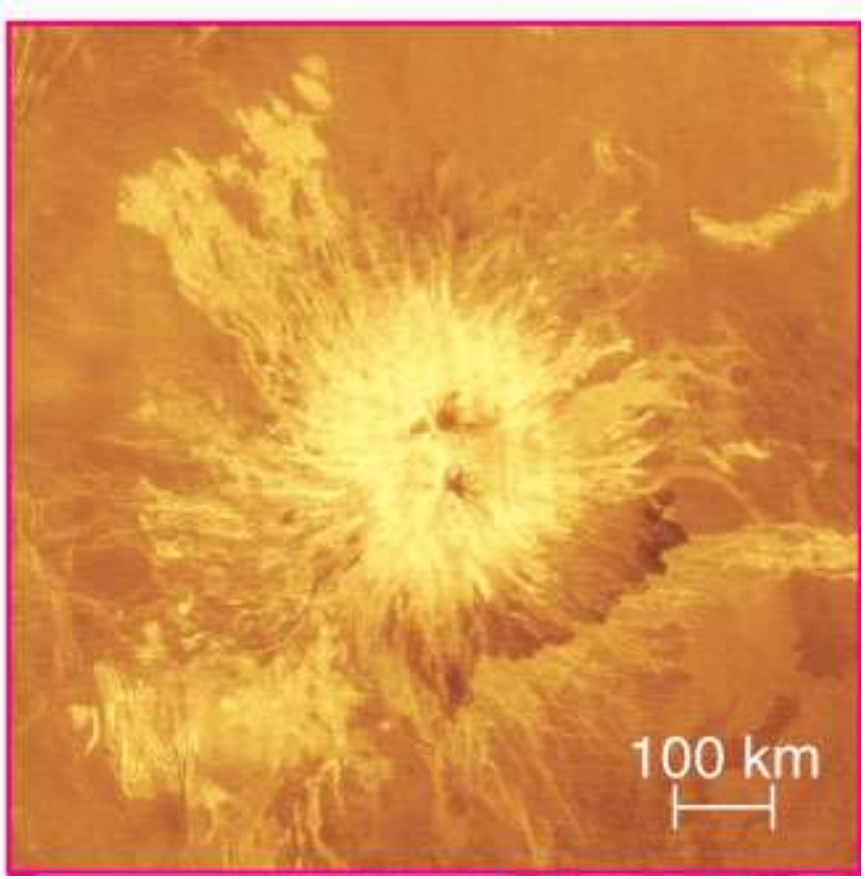


Cratering on Venus



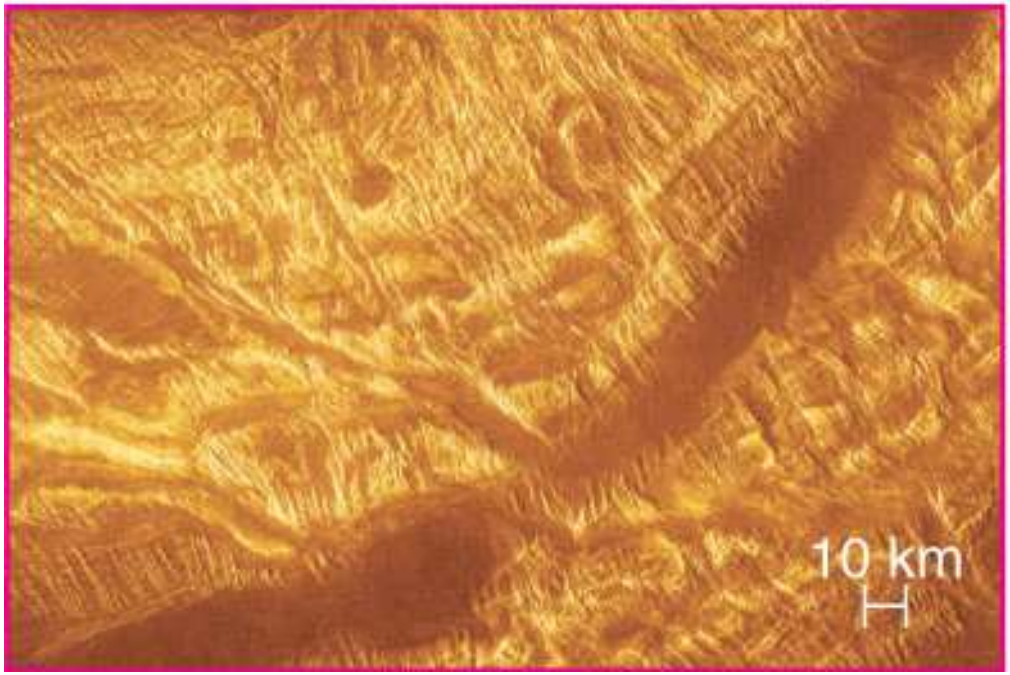
- Impact craters, but fewer than Moon, Mercury, Mars
  - Surface is young
- Massive resurfacing event seems to have happened 750 million years ago

Volcanoes on Venus



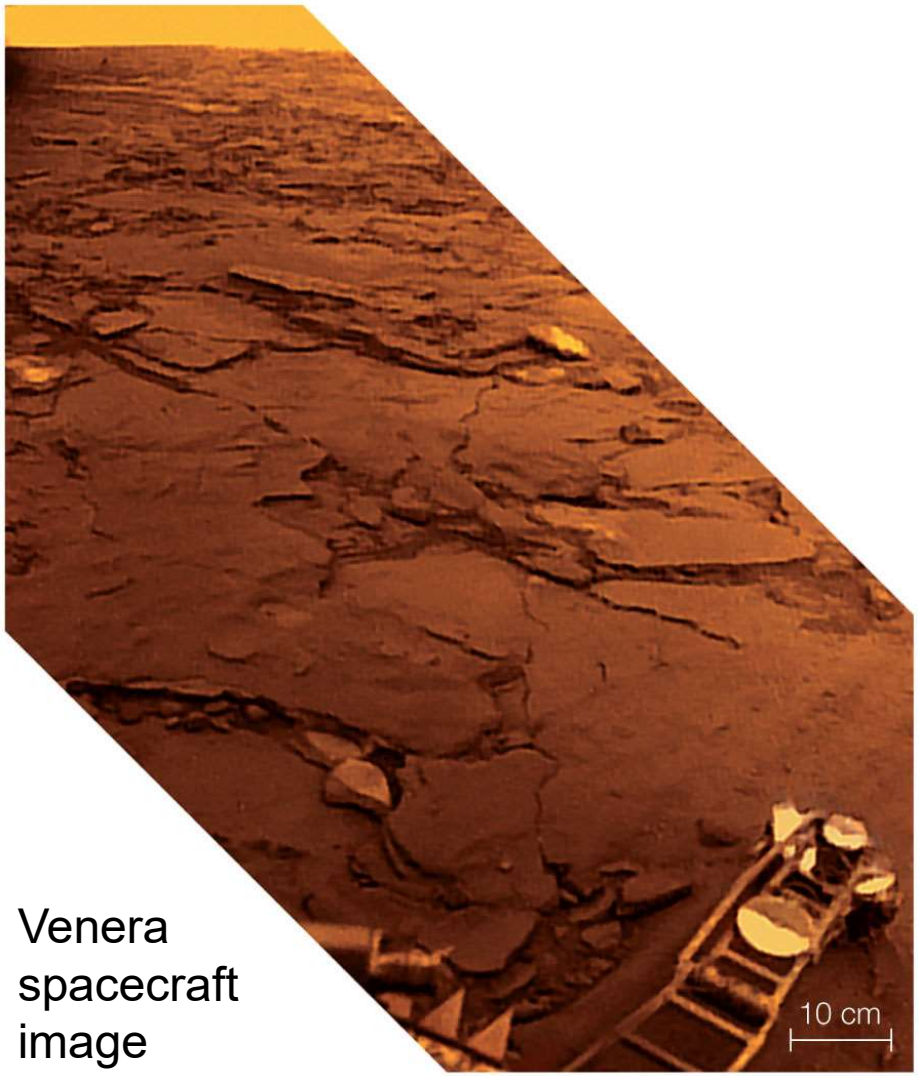
- Many volcanoes
- Evidence some were active as recently as 180 million years ago

Tectonics on Venus



- Fractured and contorted surface indicates tectonic stresses
- Lithosphere may have had the water baked out of it so thicker and stiffer

No Erosion on Venus



Venera spacecraft image

- Photos of rocks taken by lander show little erosion
- Makes sense since there is virtually no winds, or any rain on Venus

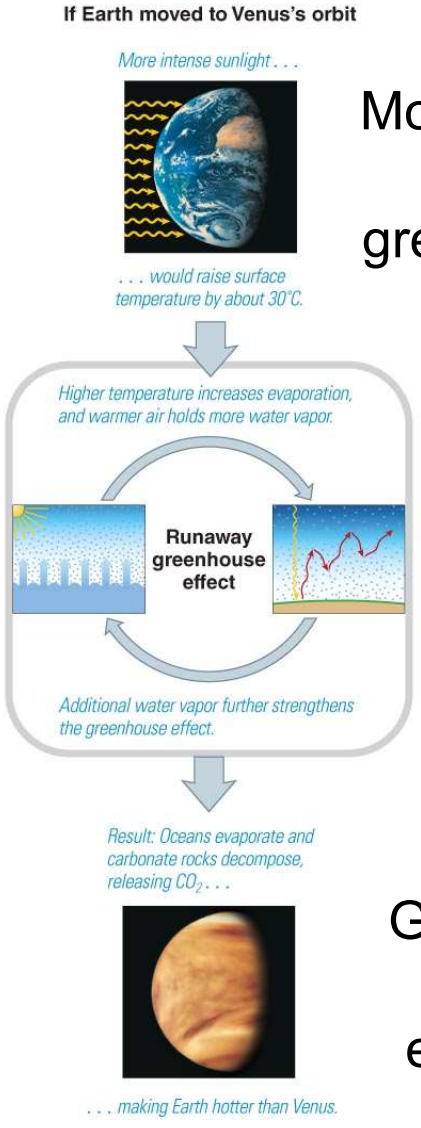
Why is Venus so hot?

- Venus has reflective sulfuric acid clouds
  - **HIGHER ALBEDO**
- Receives less heat from sunlight than Earth

- The greenhouse effect on Venus keeps its surface temperature at 470°C.
- But why is the greenhouse effect on Venus so much stronger than on Earth?
- Venus has a very thick carbon dioxide atmosphere with a surface pressure 90 times that of Earth.
- Thick carbon dioxide atmosphere produces an extremely strong greenhouse effect. (Runaway Greenhouse Effect)
- Too hot for liquid water…

→ On Earth, carbon dioxide dissolves in water, and can react to form carbonates, slowly removing it from the atmosphere

The Runaway Greenhouse Effect

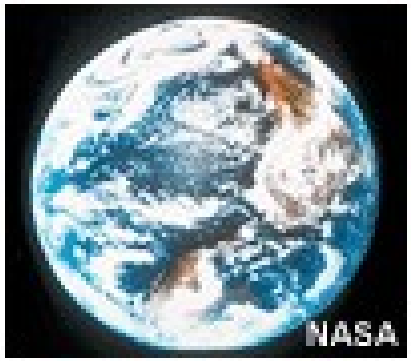


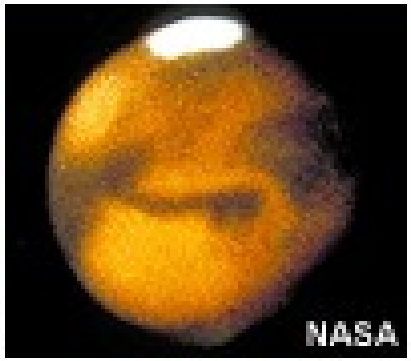
More evaporation, stronger greenhouse effect

Greater heat, more evaporation

- The more CO_2 in the atmosphere, the more heating occurs
  - Less liquid water available to dissolve and remove CO_2 by forming carbonate rocks
- The runaway greenhouse effect would account for why Venus has so little water.

The Atmospheres of Venus & Mars





	Venus	Earth	Mars
Surface pressure relative to Earth (bars)	90	1	0.007
Major greenhouse gases (GHG)	CO_2	H_2O, CO_2	CO_2
Temperature if no GHG (°C)	-46	-18	-57
Actual temperature (°C)	477	15	-47
Temperature change due to GHG	+523	+33	+10

iClicker Question

Question: If Earth was more reflective (had a higher albedo) what would happen to its temperature?

A. It would go up
B. It would go down
C. It wouldn't change

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7.5 Earth as a Living Planet

Our goals for learning:

- What unique features of Earth are important for life?
- How is human activity changing our planet?
- What makes a planet habitable?

What unique features of Earth are important for life?

1. **Surface liquid water**
2. **Atmospheric oxygen**
3. **Plate tectonics**
4. **Climate stability**

What unique features of Earth are important for life?

1. **Surface liquid water**
2. Atmospheric oxygen
3. Plate tectonics
4. Climate stability

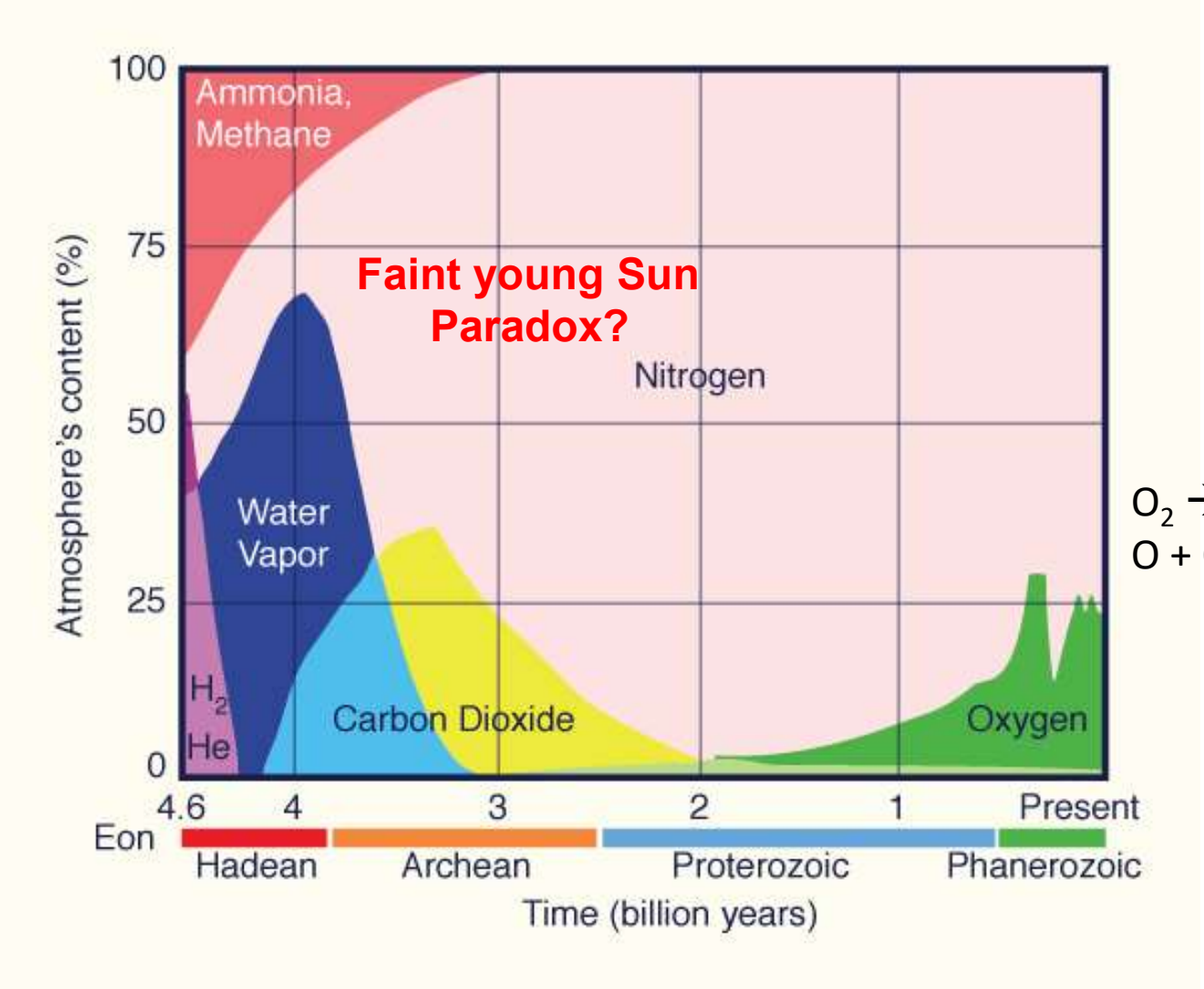
Earth's distance from the Sun and moderate greenhouse effect make liquid water possible.

What unique features of Earth are important for life?

1. Surface liquid water
2. **Atmospheric oxygen**
3. Plate tectonics
4. Climate stability

PHOTOSYNTHESIS (plant life) is required to make high concentrations of O_2, which produces the protective layer of O_3.

Oxygen on Earth is Due to Photosynthesis (Life!)



$O_2 \rightarrow O + O$

$O + O_2 \rightarrow O_3$

Banded Iron Formation

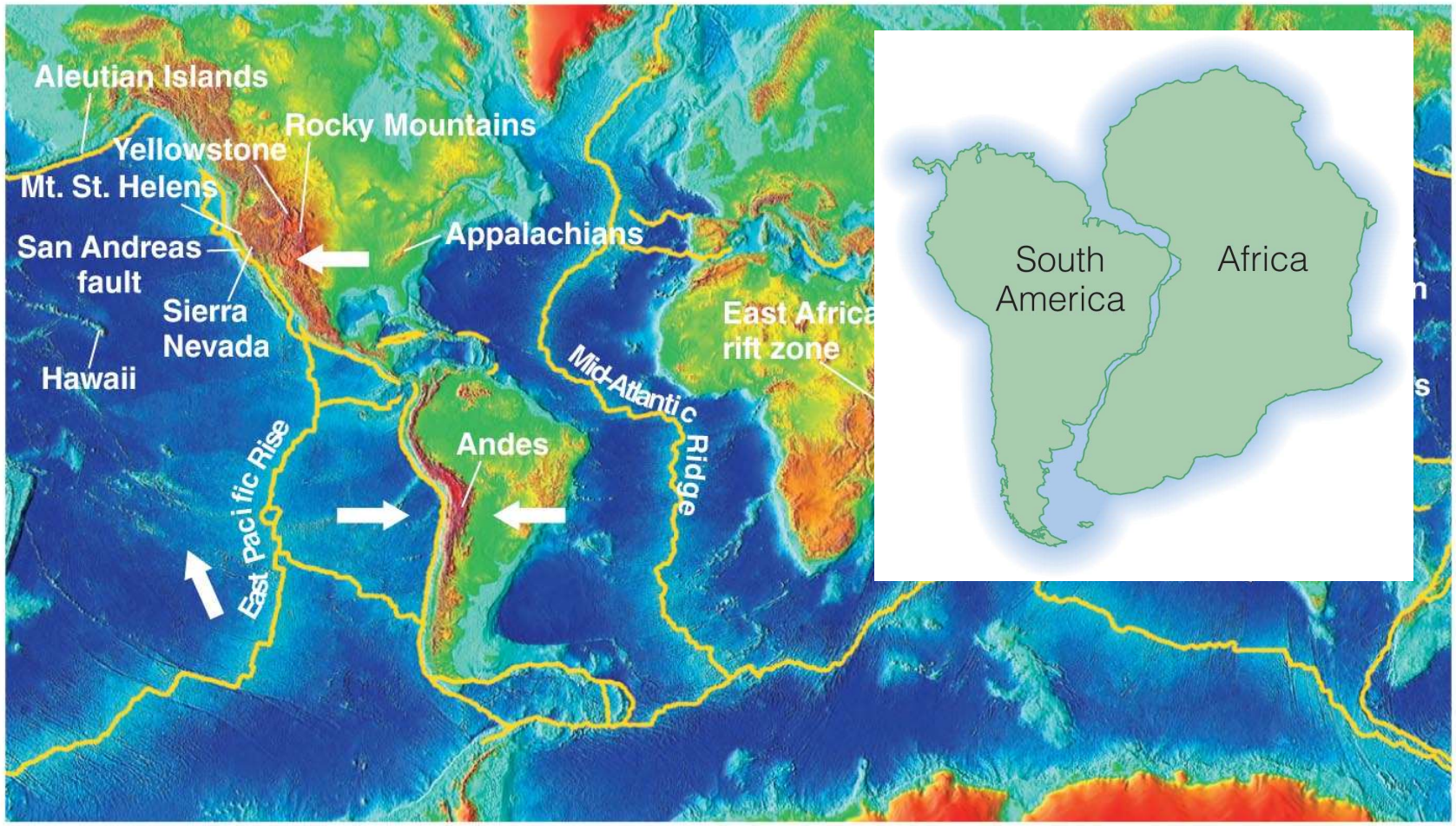
1.8-2.5 billion years ago

What unique features of Earth are important for life?

1. Surface liquid water
2. Atmospheric oxygen
3. **Plate tectonics**
4. Climate stability

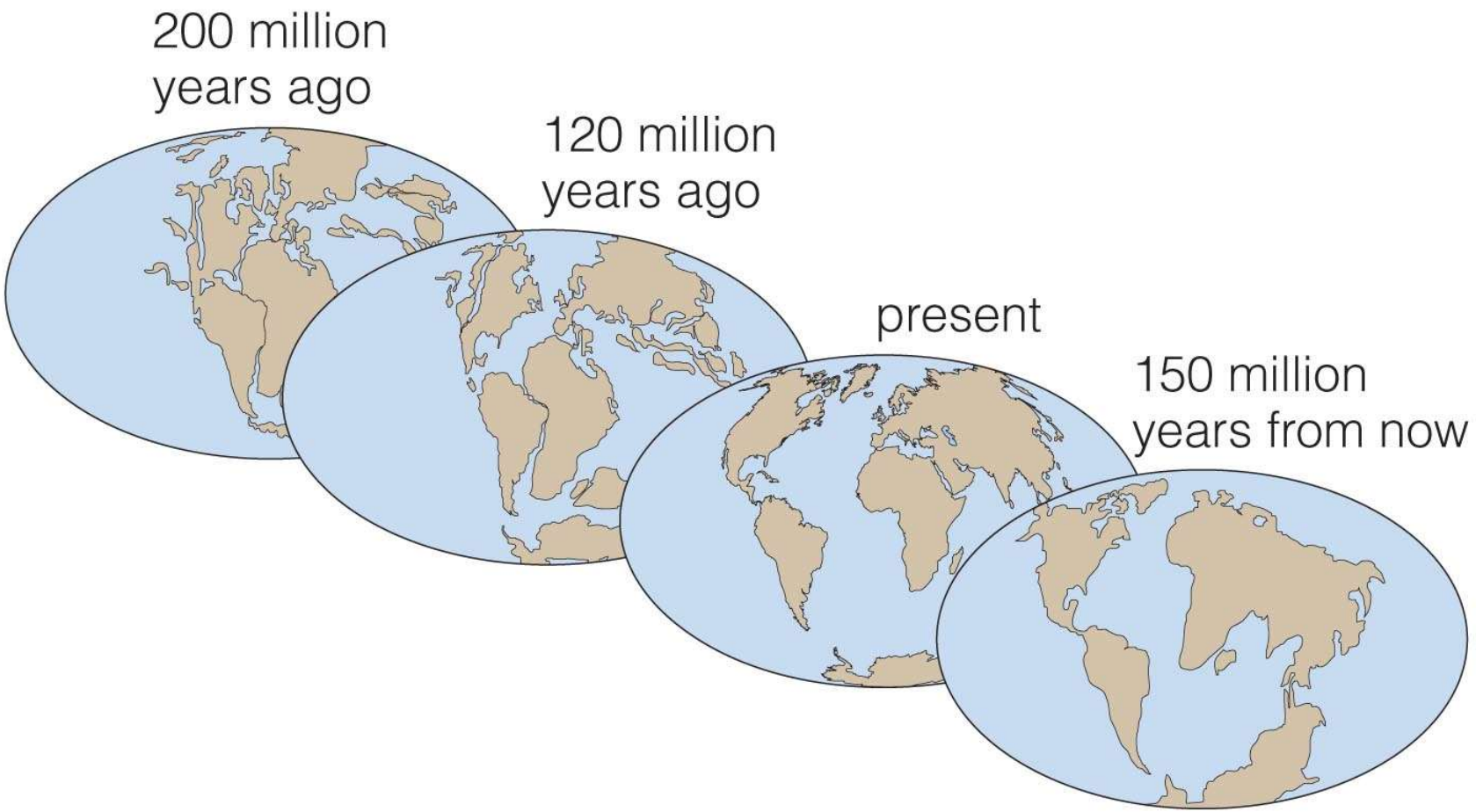
Plate tectonics is an important step in the carbon dioxide cycle.

Continental Motion

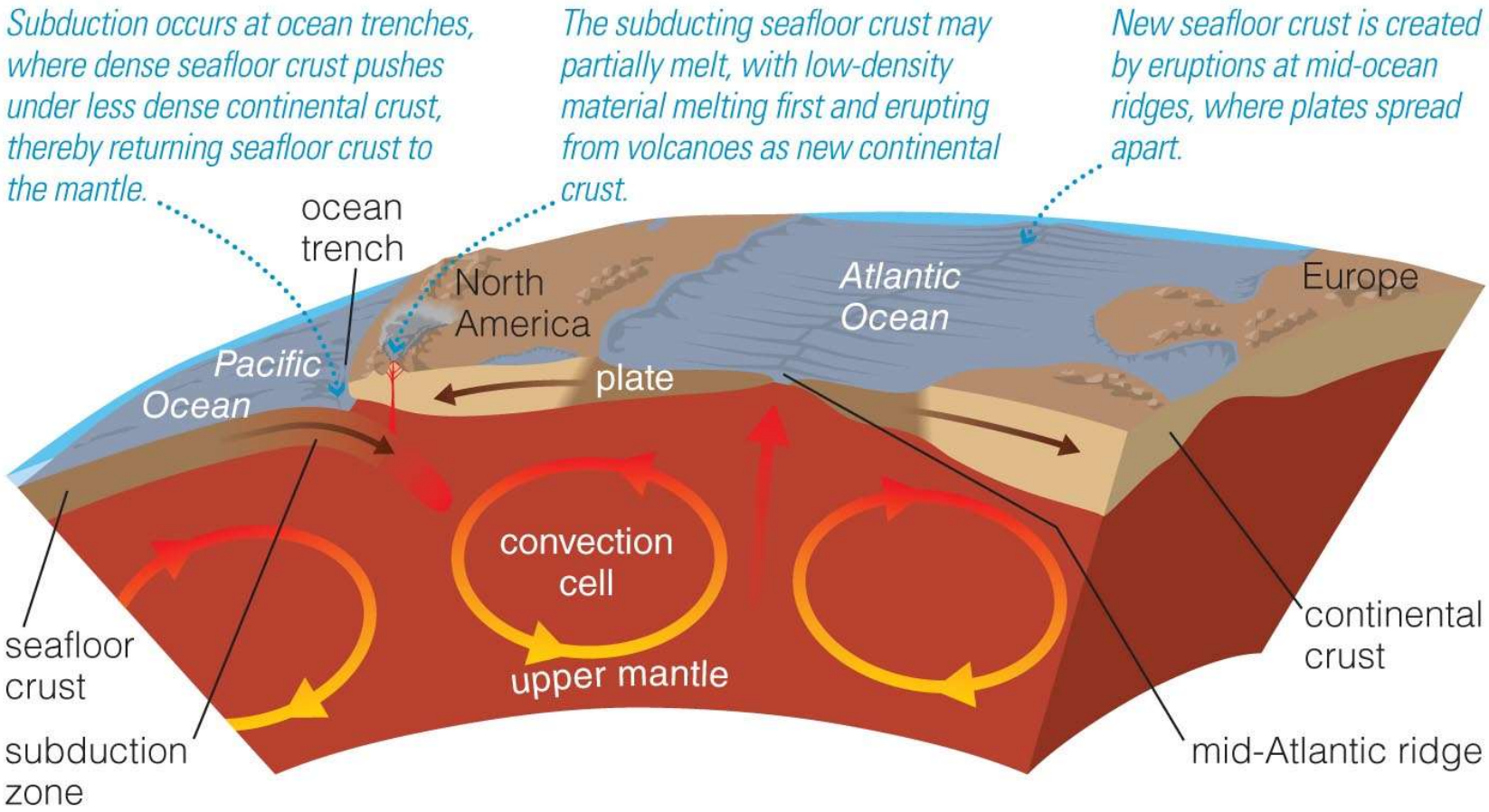


Motion of continents can be measured with GPS.

Can Predict how Earth will Look

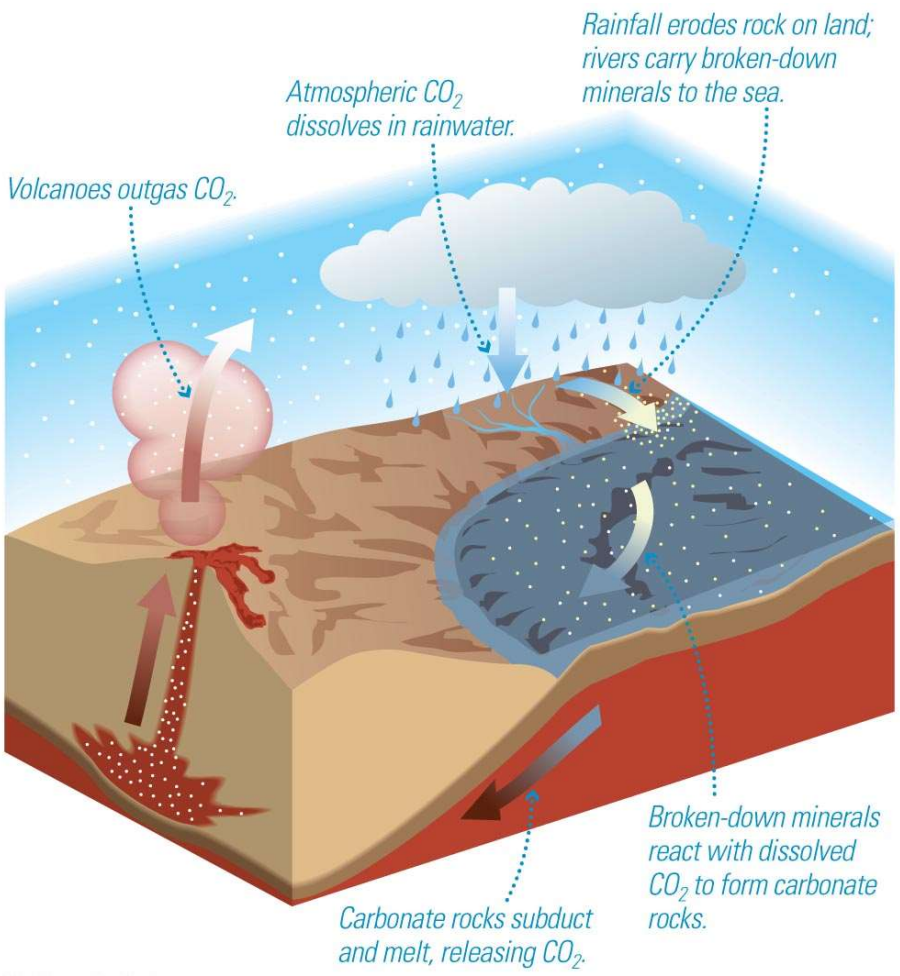


Seafloor Recycling



- Seafloor is recycled through a process known as subduction.
- *Releases Carbonate rocks back into the atmosphere as CO_2.*

The Carbon Dioxide Cycle



1. Atmospheric CO_2 dissolves in rainwater.
2. Rain erodes minerals that flow into the ocean.
3. Minerals combine with carbon to make carbonate rocks on ocean floor.
4. Subduction carries carbonate rocks down into the mantle.
5. Rock melts in mantle and outgases CO_2 back into atmosphere through volcanoes.

Tectonics makes a very slow feedback loop possible…

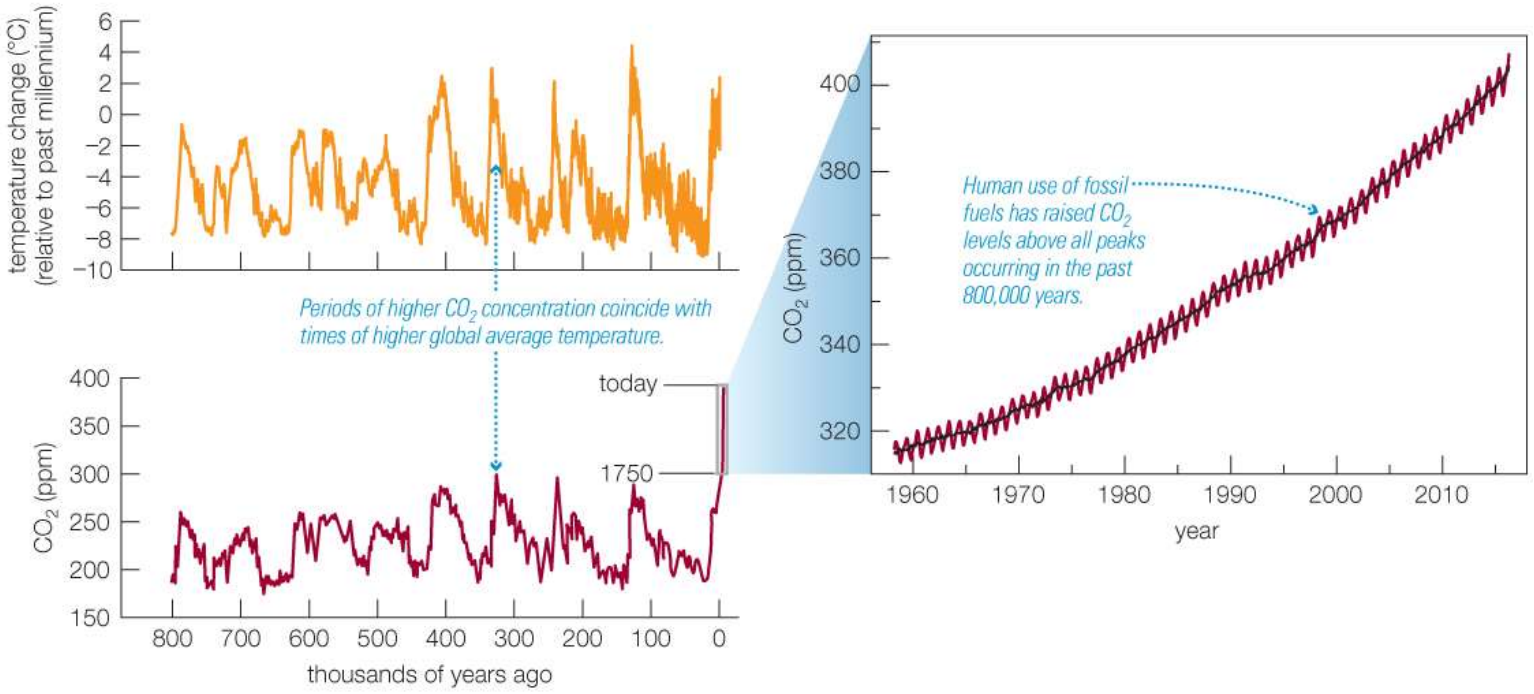
More heat = More rainfall

What unique features of Earth are important for life?

1. Surface liquid water
2. Atmospheric oxygen
3. Plate tectonics
4. **Climate stability**

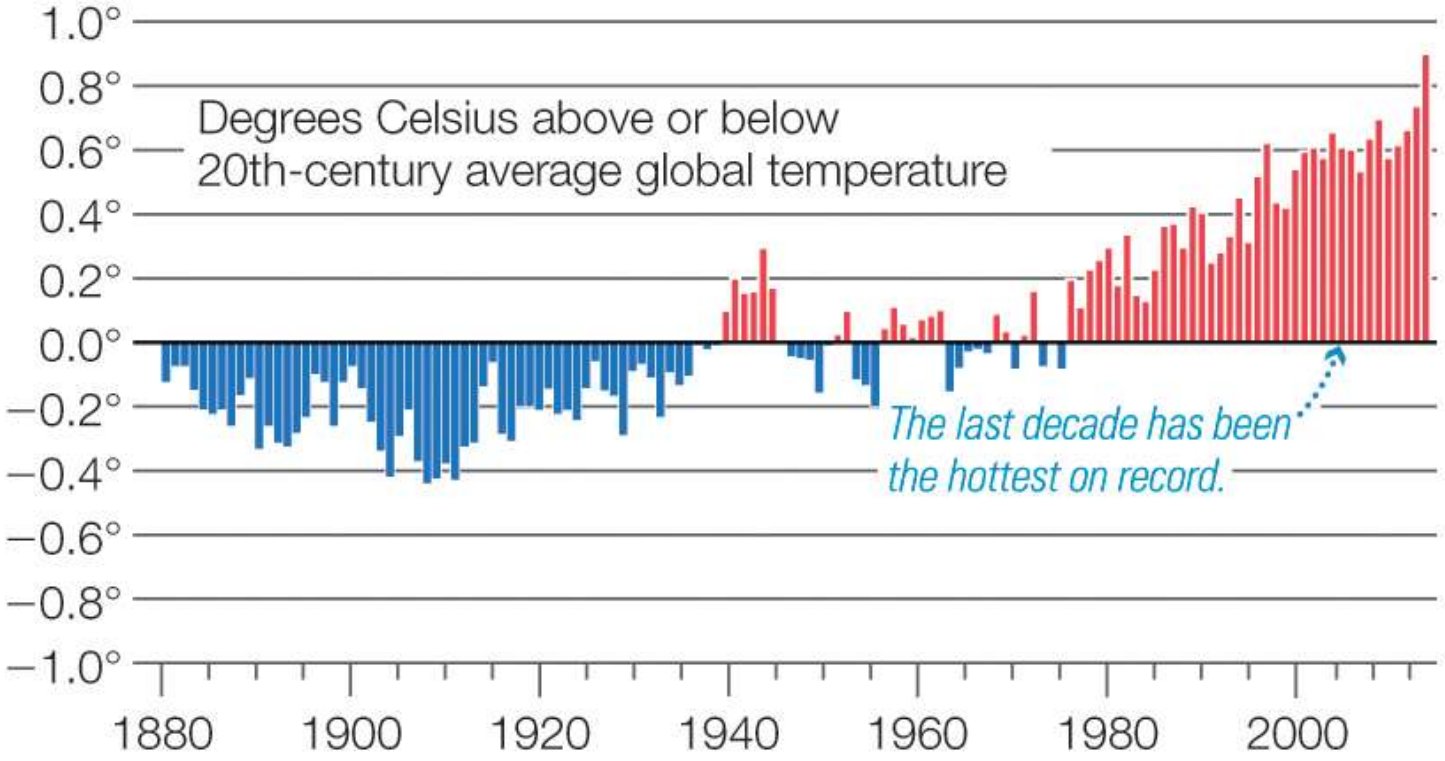
The CO_2 cycle acts like a thermostat for Earth's temperature.

CO_2 Concentration



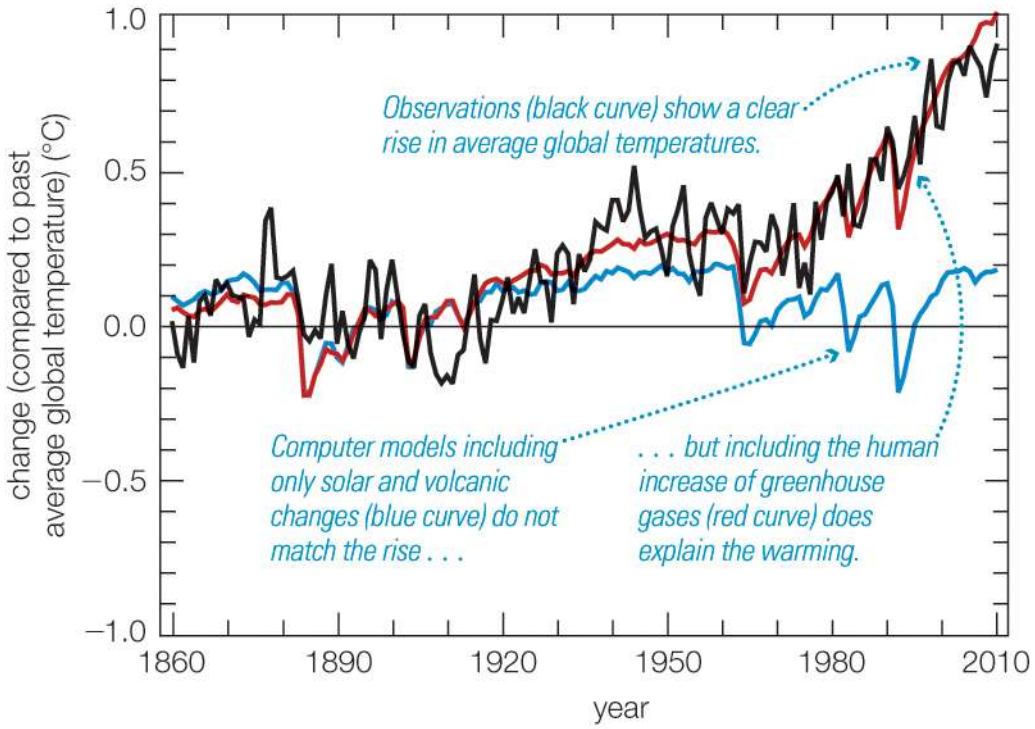
- Global temperatures have tracked CO_2 concentration for the last 500,000 years.
- Antarctic air bubbles indicate the current CO_2 concentration is at its highest level in at least 500,000 years.

How is human activity changing our planet?



- Antarctic CO_2 bubbles have distinct isotopic signatures (500,000 year record)
- Fossil Fuel (Coal) has a distinct isotopic signature too (e.g., reduced ^{13}C)
- *The recent CO_2 signature matches what would expect if the added CO_2 came from human activity burning coal*

Modeling of Climate Change

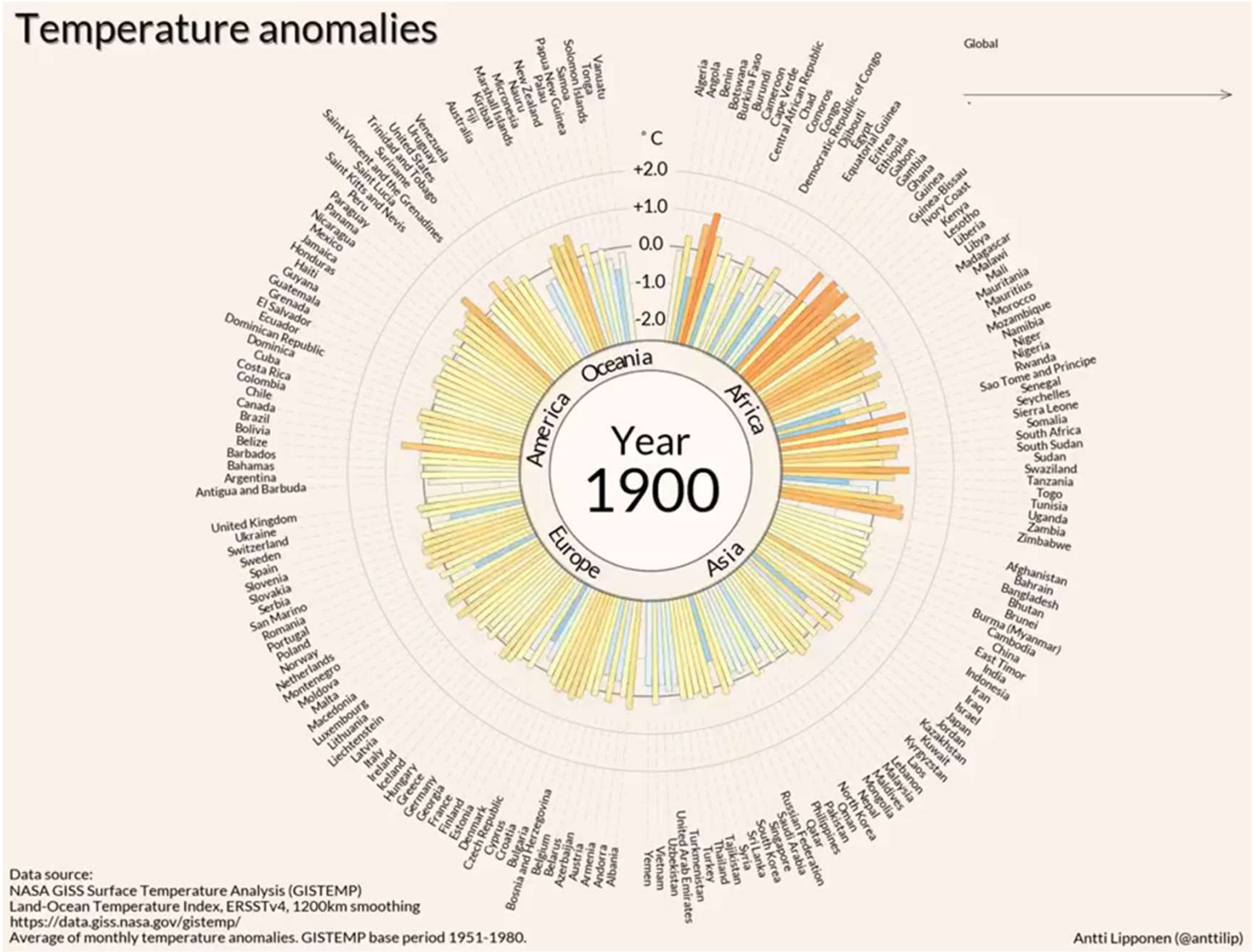


- Models of global warming that include human production of greenhouse gases are a better match to the global temperature rise.
- *Models don't work without greenhouse gas contributions*
- Increased by 0.5°C in the past 50 years.

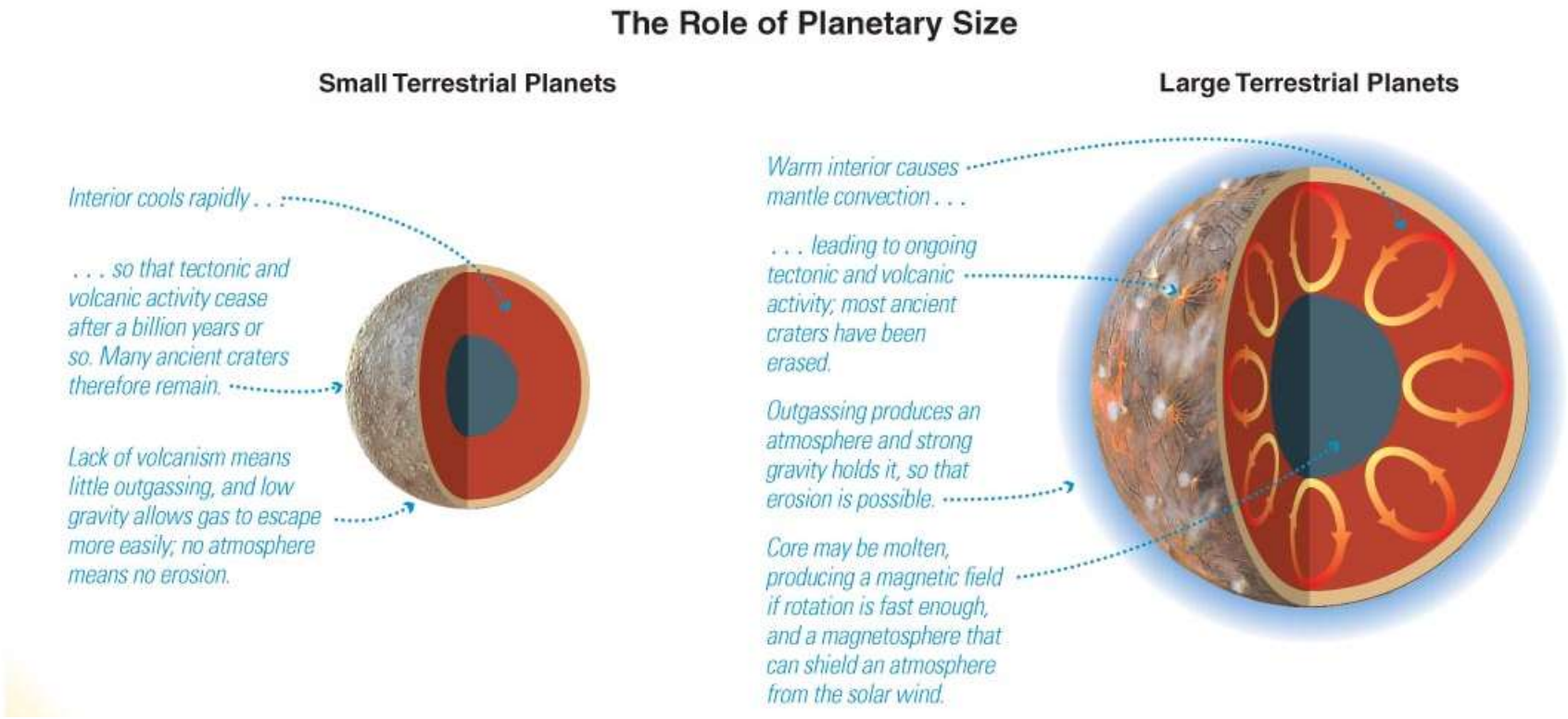
- The concentration of CO_2 is rising rapidly.
- An unchecked rise in greenhouse gases will eventually lead to global warming.

Temperature Anomalies 1900-2016

https://www.youtube.com/watch?v=K4Ra2HR27pQ

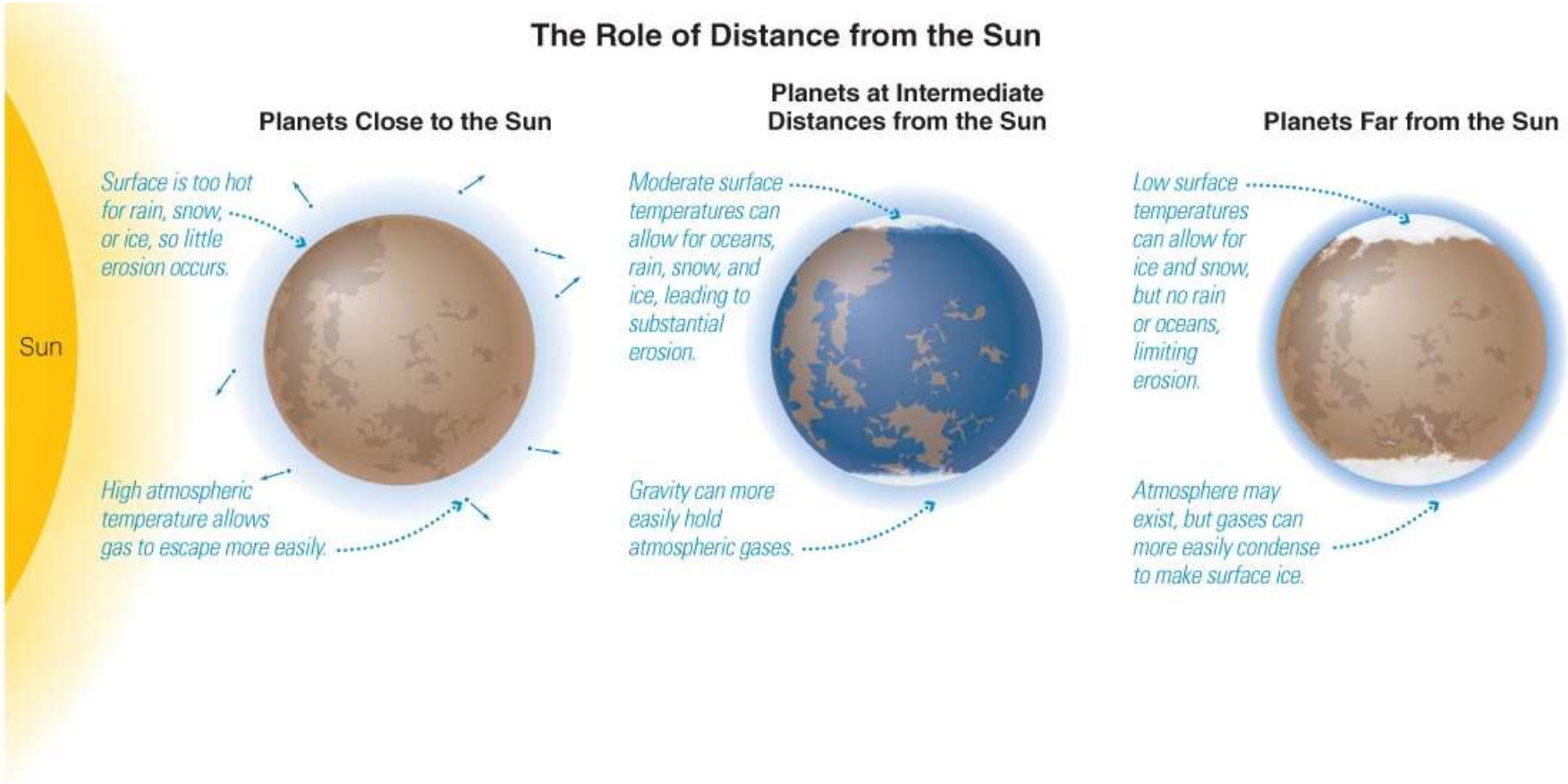


What makes a planet habitable?



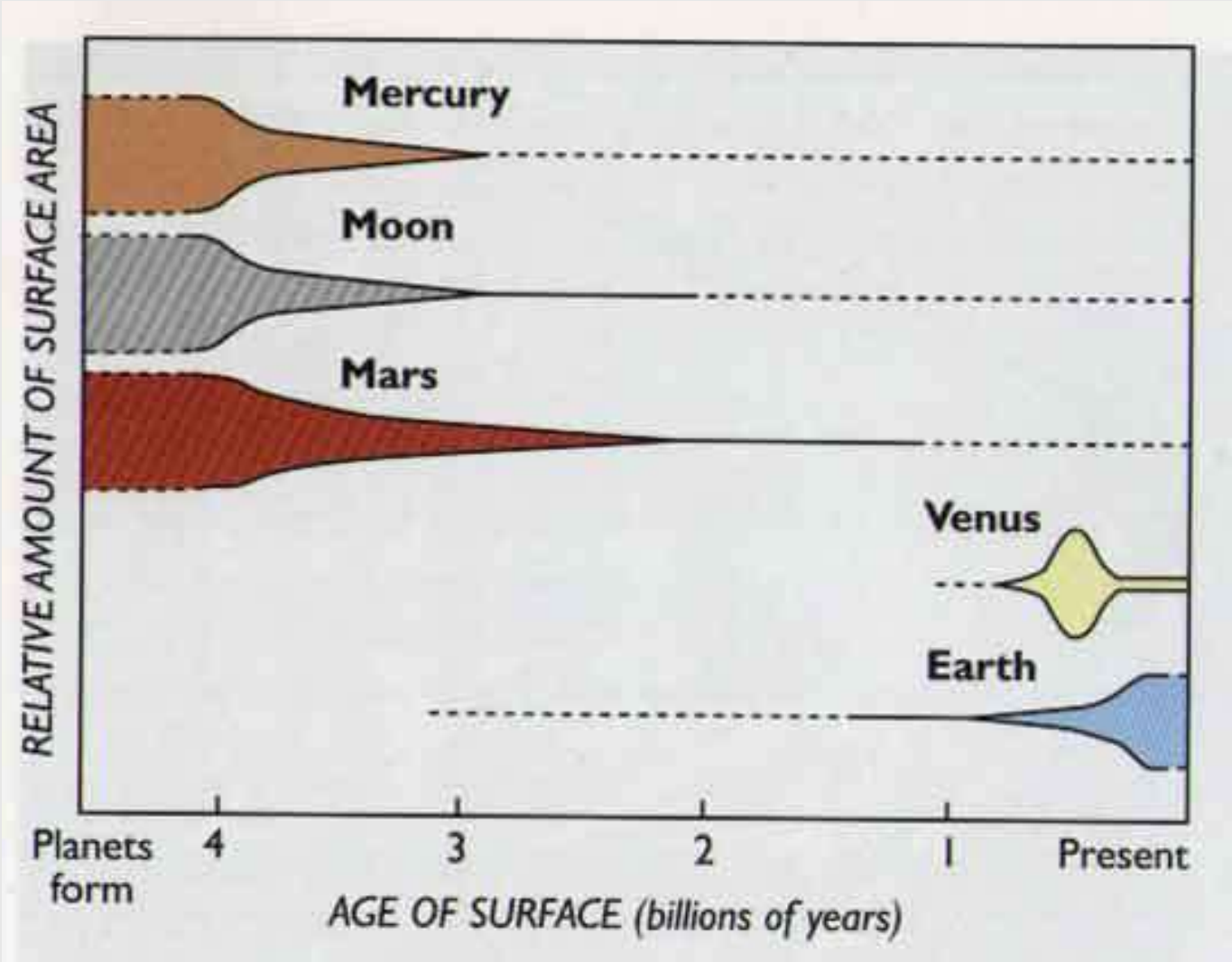
- Must be large enough for geological activity to release and retain water and atmosphere

What makes a planet habitable?

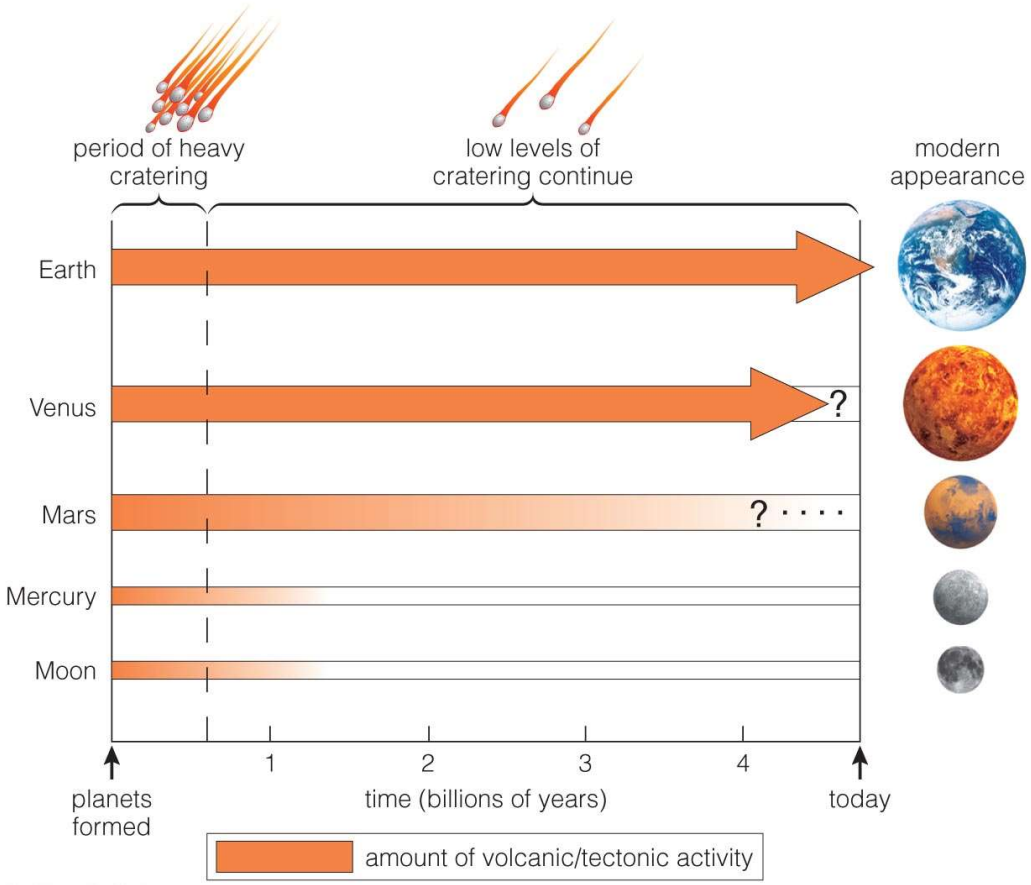


- Must be located at an optimal distance from the Sun for liquid water to exist = *Habitable Zone (Goldilocks Zone)*

Comparative Surface Ages of Terrestrial Worlds



Planetary Destiny



Earth is habitable because it is large enough to remain geologically active, and it is at the right distance from the Sun so oceans could form.

End of Todays Lecture