Today's Topics

Wednesday, September 30, 2020 (Week 6, lecture 18) – Chapter 8.

A. Earth's atmosphere

B. Greenhouse effect

C. Temperature of the Earth vs time

Earth's Atmosphere

The atmosphere forms the outer layer of the planet.

→ It's what you see from outer space.

→ It's where most of life is (plus oceans).

→ It's where we live.

Primary Composition

78 % nitrogen gas (N_2)

21 % oxygen gas (O_2)

1 % argon gas (Ar)

0.04% carbon dioxide gas (CO_2)

0-4% water vapor (H_2O) – variable

Trace gases

Neon (Ne)

Helium (He)

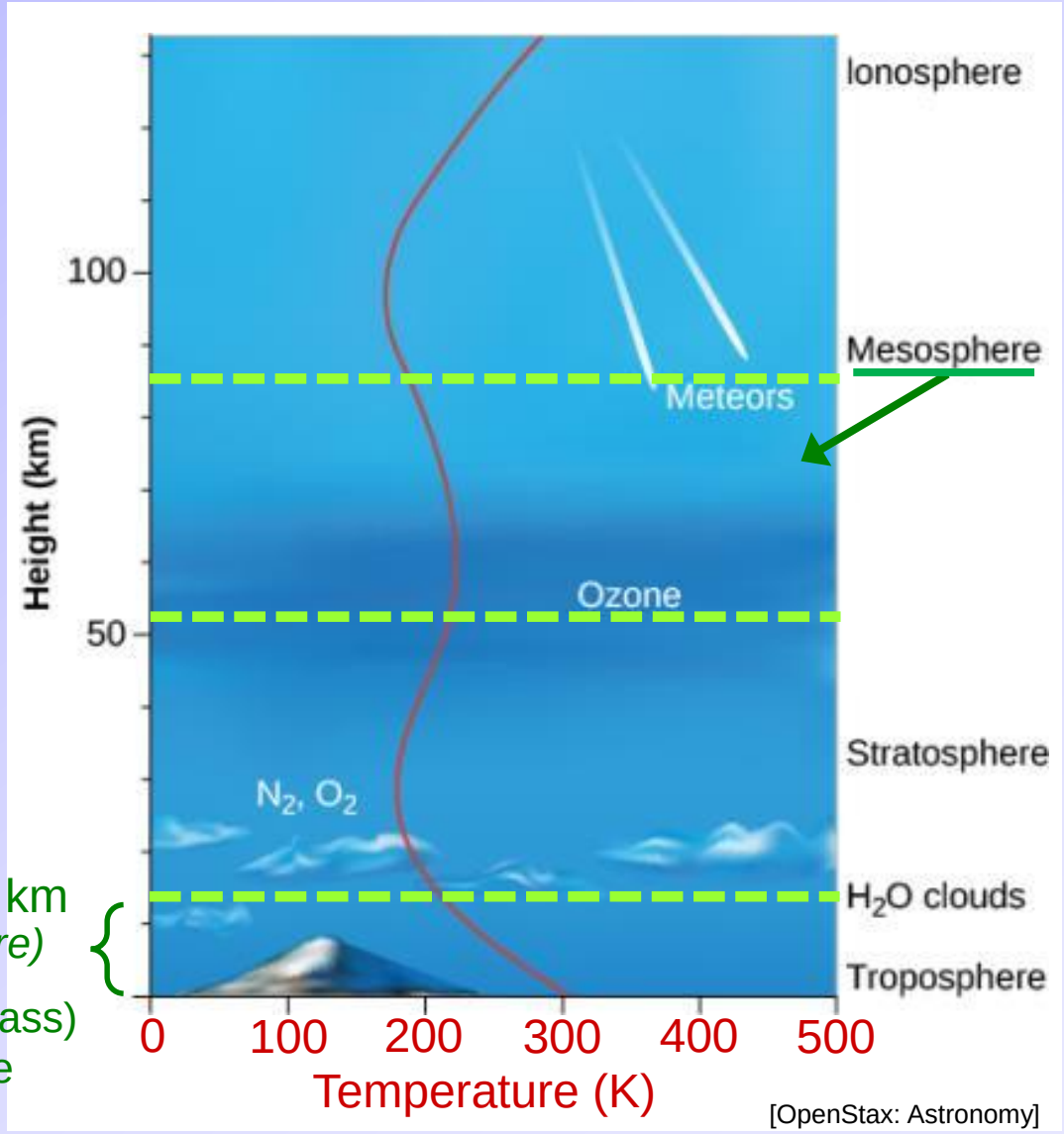
Methane (CH_4)

Krypton (Kr)

Ozone (O_3)

Earth as seen from Apollo 17

Structure of the Atmosphere



[OpenStax: Astronomy]

Troposphere: 0-12 km
(passenger jets fly here)

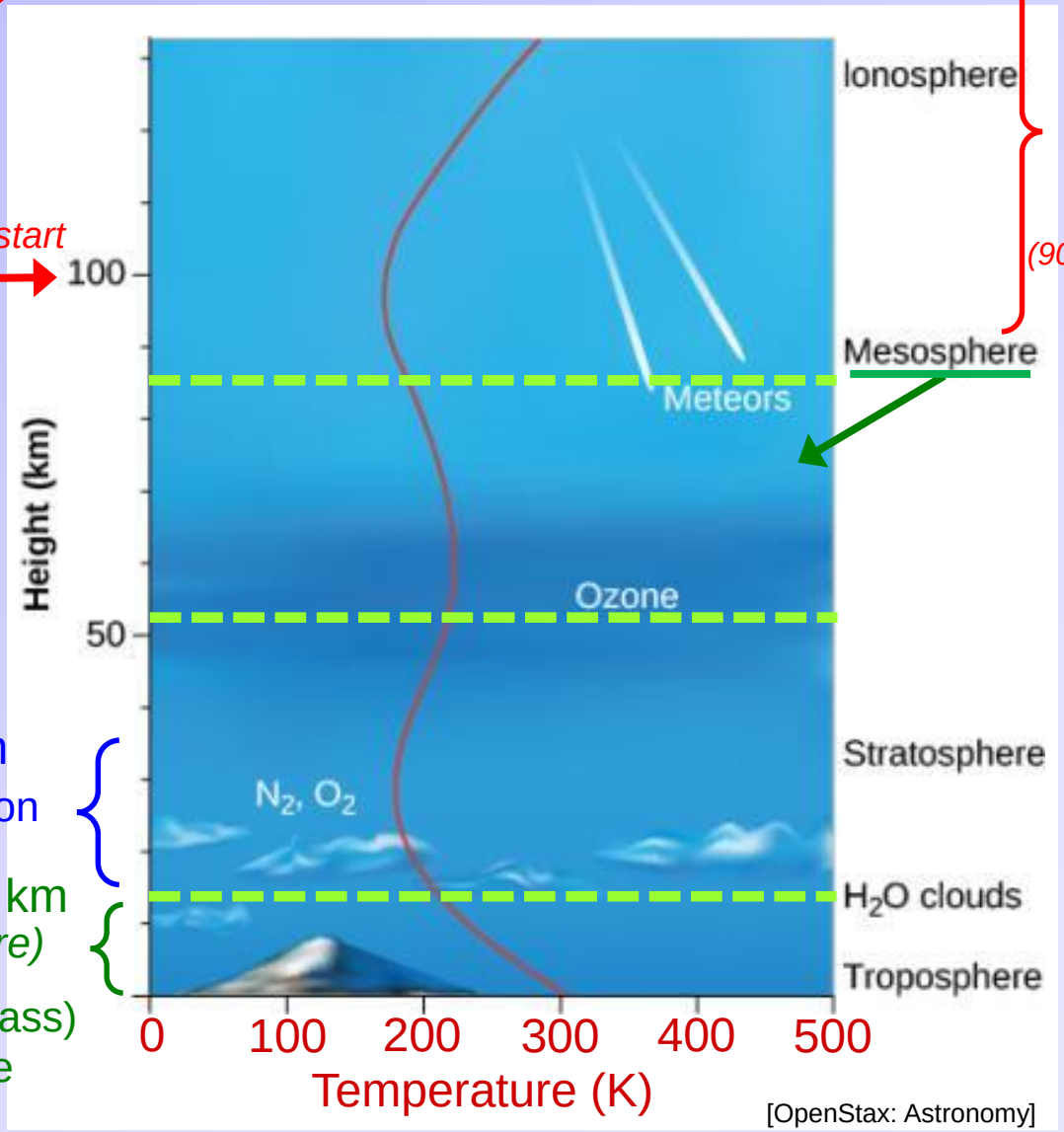
→ 80% of atmosphere is here (by mass)
→ Most weather events happen here

Structure of the Atmosphere

International Space Station orbits at 400 km

Often defined as start of "outer space"

Aurora occurs here (90-150 km)



[OpenStax: Astronomy]

Ozone layer: 15-35 km

→ Blocks most UV radiation

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Structure of the Atmosphere

[NASA, International Space Station]

Origin of Atmospheric Gases

Nitrogen (N_2): 78 %

Outgassing from Earth interior via volcanoes

→ Nitrogen does not react easily.


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→ Oxygen is very reactive and is continually replenished.


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CO_2 is released by outgassing, organic decomposition, respiration.

CO_2 is released by ***combustion/oxidation*** (fossil fuels, wildfires).

→ CO_2 reacts when dissolved in water: reaction with calcium → limestone.


[Wikipedia]

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[Wikipedia]

Water (H_2O): 0-4 %

Water vapor comes primarily from ***ocean evaporation***.

→ Water is mildly reactive, excellent catalyst.


[Wikipedia: Tiago Fioreze]

Ozone (O_3): trace quantities

Ozone is created-destroyed by ***UV light***: $O_2 + UV \rightarrow 2O$, $O_2 + O \rightarrow O_3$, $O_3 + UV \rightarrow O_2 + O$

Atmospheric Temperature

The Greenhouse Effect

Comparison with Venus & Mars

	 [NASA] **Venus**	 [NASA] **Earth**	 [ESA] **Mars**
Nitrogen	3.5 %	**78 %**	2.6 %
Oxygen	trace	**21 %**	0.17 %
Argon	0.005 %	1 %	1.9 %
Carbon dioxide	**96.5 %**	0.04 %	**95 %**
water	trace	0-4 %	0.03 %

Earth's atmosphere is **not** CO_2 because of ***life***

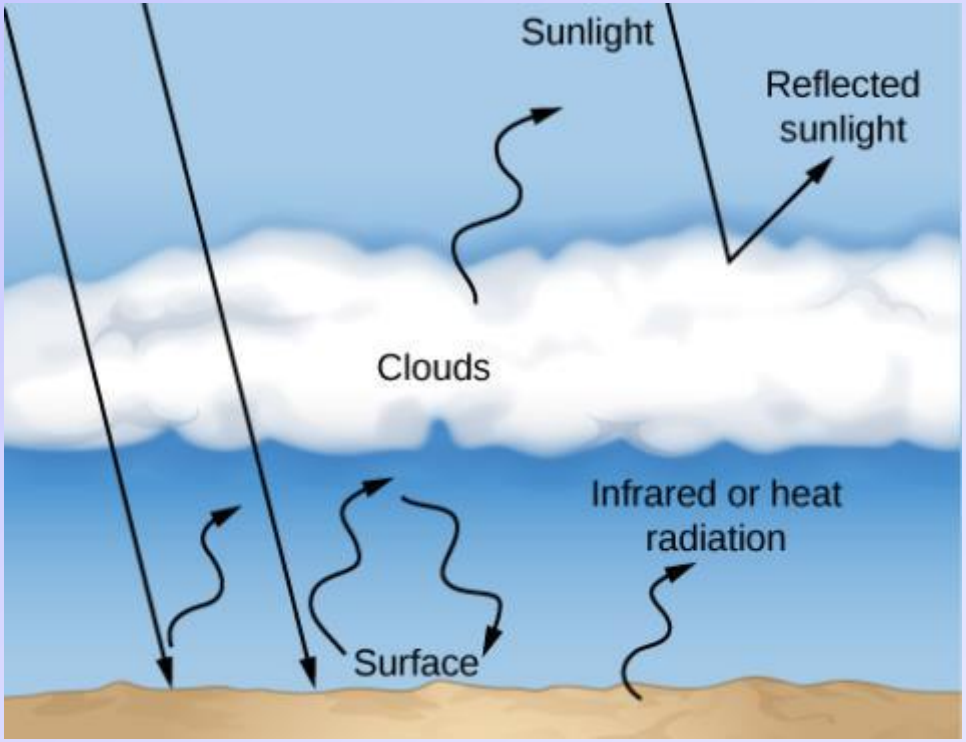
The Martian and Venusian atmospheres are dominated by **carbon dioxide**.

Atmospheric Temperature

The Greenhouse Effect

How it works:

- **Sunlight** penetrates atmosphere and ***heats surface***.
- The heated surface re-radiates in the **infrared**.



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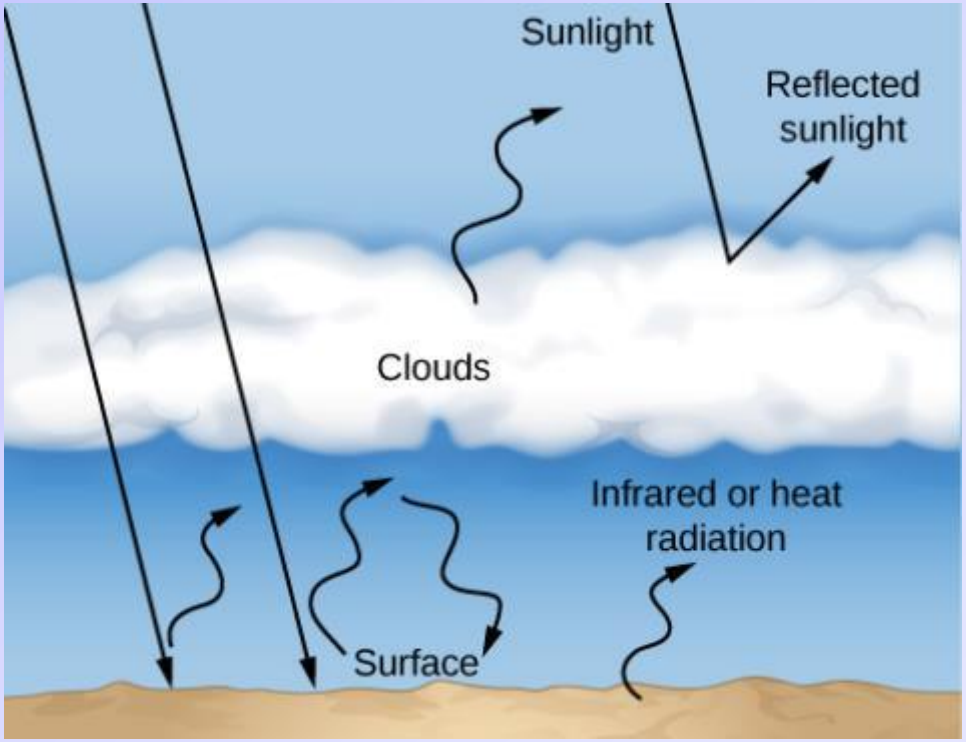
- The infrared radiation is **absorbed, stored, converted to heat**, and re-radiated by **greenhouse gases.**

→ ***Infrared light is trapped*** in lower atmosphere and has difficulty exiting the planet.

Note: **Clouds** also help block the re-radiation of infrared radiation.



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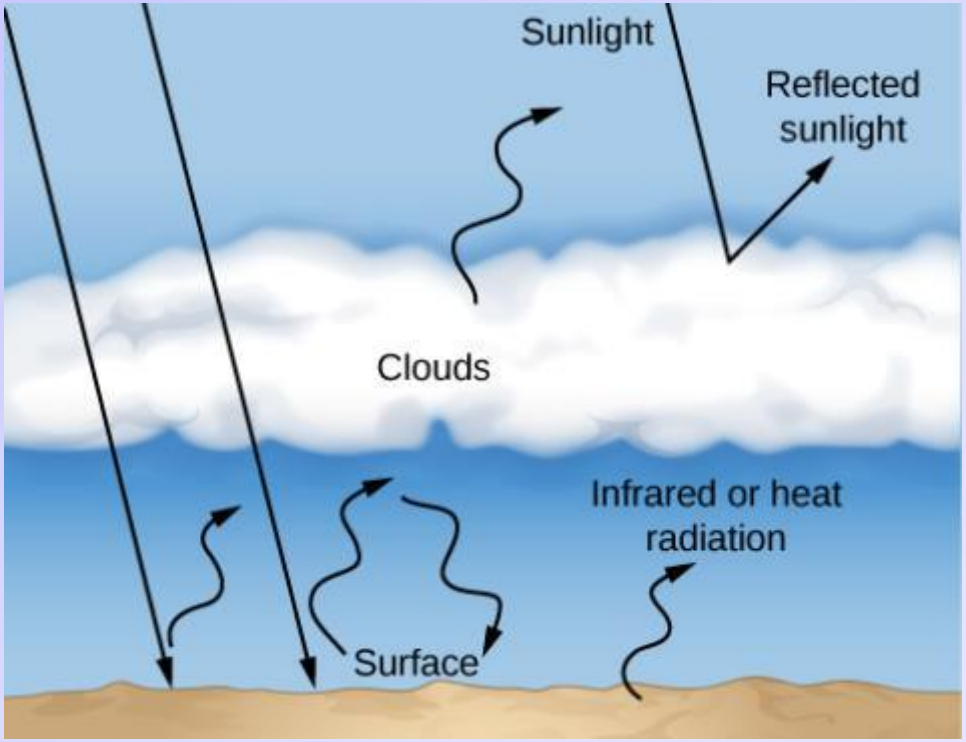
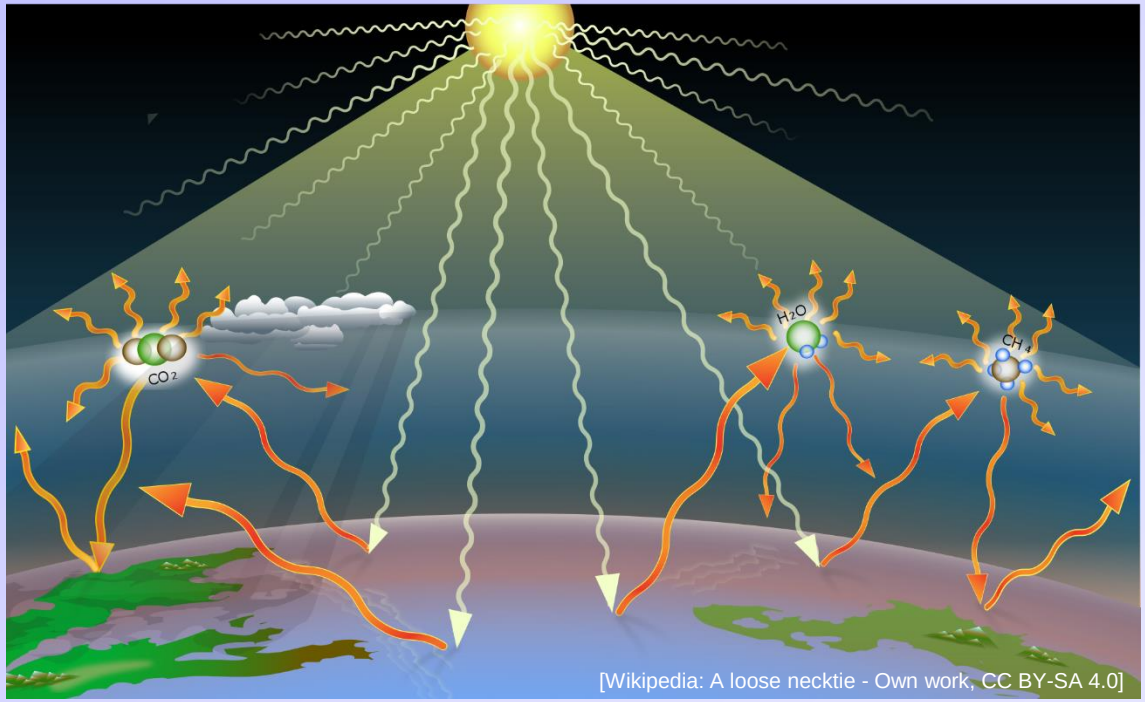


Solar energy/radiation leaves more slowly and the atmosphere heats up.

Greenhouse Gases

Primary Greenhouse Gases on Earth

- Water, H_2O (+ clouds)
  → contribution: 36-72 %
- Carbon dioxide, CO_2
  → contribution: 9-26 %
- Methane, CH_4
  → contribution: 4-9 %
- Ozone, O_3
  → contribution: 3-7 %



[Wikipedia: A loose necktie - Own work, CC BY-SA 4.0]

<u>Other greenhouse gases</u>

- Nitrous oxide (N_2O)
- Chlorofluorocarbons (CFCs).

The Greenhouse Effect

comparison with Mars & Venus

	 [NASA] **Venus**	 [NASA] **Earth**	 [ESA] **Mars**
Temperature **with** *greenhouse effect*	470° C	15° C	– 50° C
Temperature **without** *greenhouse effect* (estimate)	– 40° C	– 16° C	– 56° C

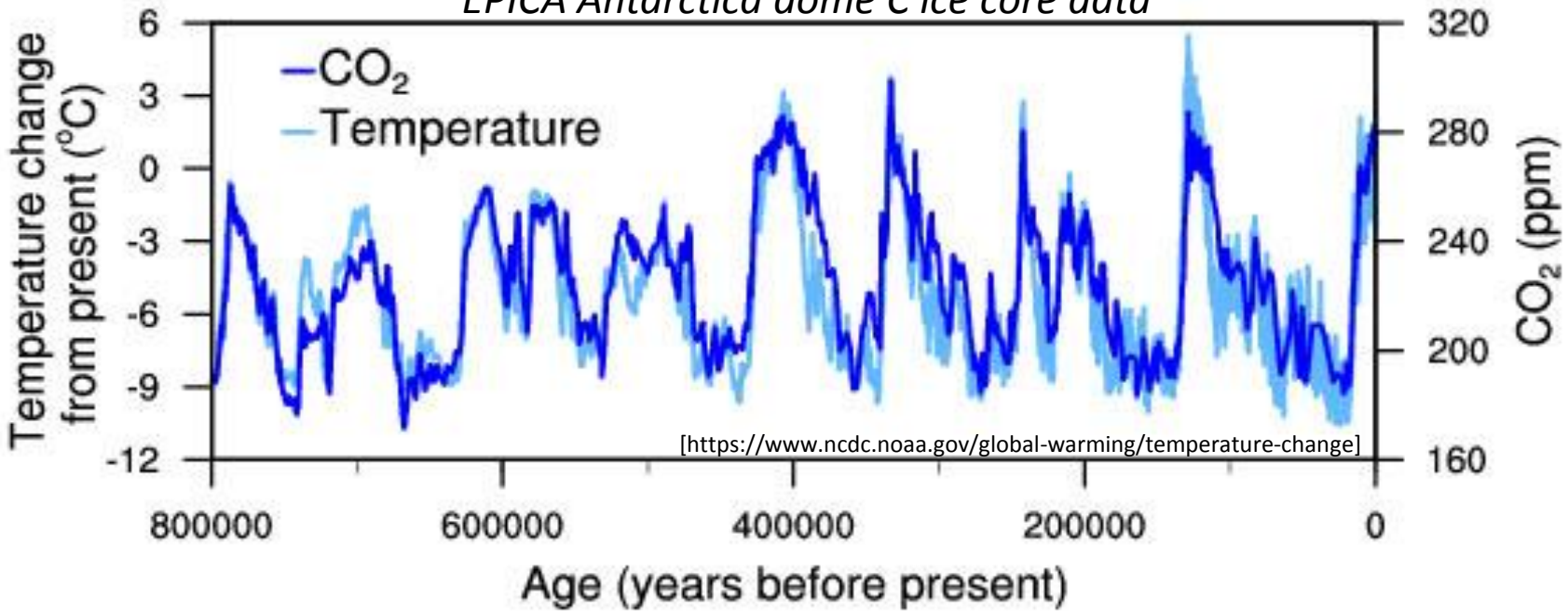
low temperature predicted because of high albedo. i.e. it's fairly reflective

Greenhouse effect is small because Mars has a thin atmosphere.

Temperature of the Earth
vs
Time

Temperature of the Earth: past 800k years

EPICA Antarctica dome C ice core data



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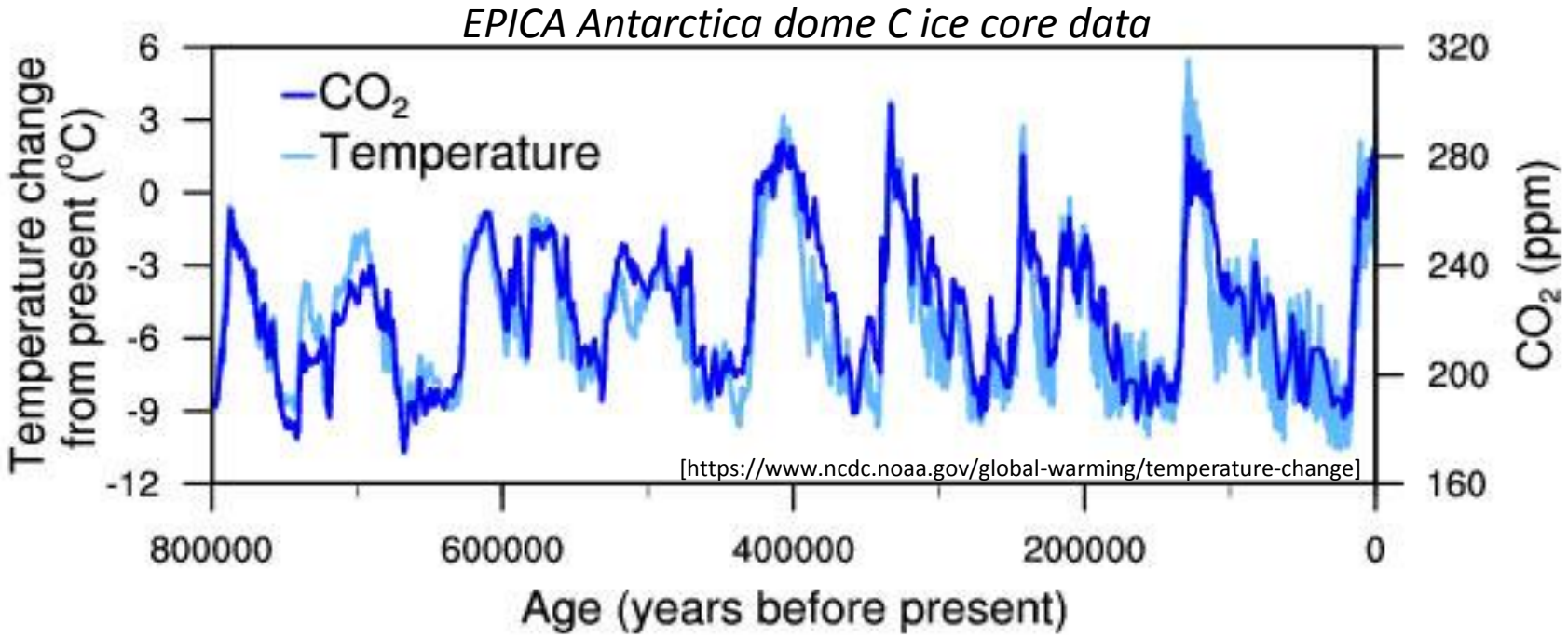


- The average temperature of the Earth has varied by **$\Delta T \approx 12°$ C** over the past 800,000 years.

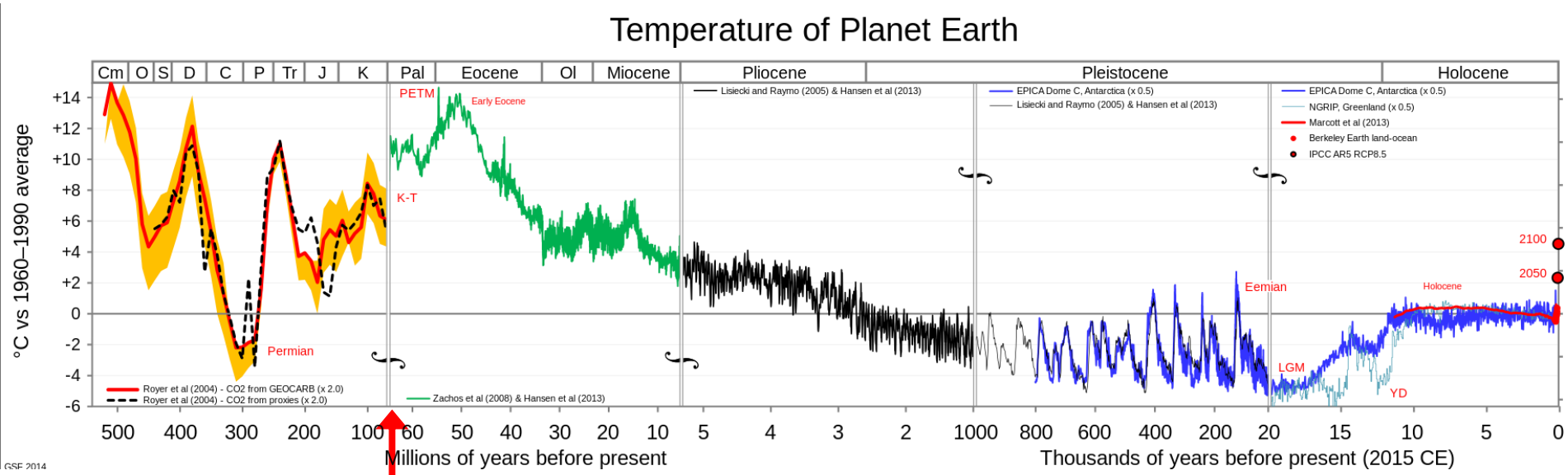
  → *The temperature of the Earth is relatively stable.*

- The temperature **varies on a 100,000 year** characteristic timescale.

  → *Temperature cycle <u>probably</u> due in part to variations in the Earth's orbit.*

- **Relative isotope abundances** in ice from ice cores (^{18}O vs ^{16}O and ^{2}H vs ^{1}H) can serve as **proxies for global temperature**.

Temperature of the Earth: past 540 M years



[Wikipedia: By Glen Fergus - Own work; data sources are cited]

end of the dinosaurs
Hypothesis: giant asteroid impact on Yucatan peninsula (Mexico)

- Temperature estimates for the past 0.5 billion years are harder to measure.
- Less short term fluctuations, but also larger long term changes.

→ **$\Delta T \sim 18°$ C.**