Chapter 7: Why Is The Climate Changing?

March 16 & 18, 2026

Quiz 3

7.1. Context of the Recent Warming

7.2. The First Suspect: Plate Tectonics

7.3. The Sun

7.4. The Earth's Orbit

7.5. Unforced Variability

7.6. Greenhouse Gases

7.7. Putting It Together

Terms

Problems

7.1. Context of the Recent Warming

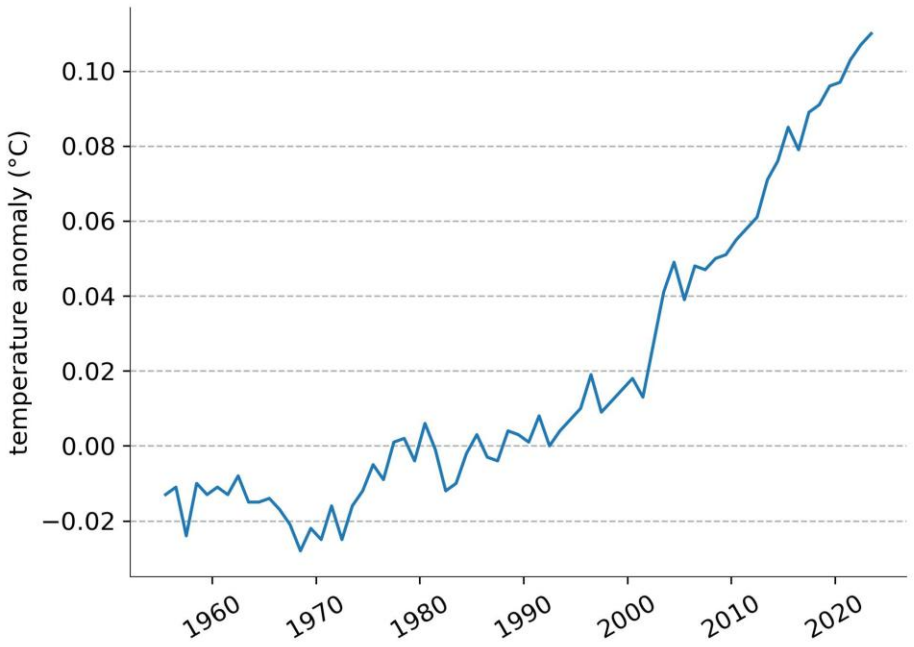

Fig. 2.8: Ocean temperature anomaly (°C) of top 2 km of world ocean.

- Evidence shows Earth climate is changing (warming)!
- Is observed warming caused by humans, by natural processes, or by some combinations?
- **Conclusion:** GHG released by humans are leading cause of recent warming.

7.2. The First Suspect: Plate Tectonics

Earth landmasses are moving, with rate on order of mm/yr over millions of yrs

- **Plate Tectonics** = responsible for arrangement of continents (e.g., earthquakes, volcanism, tsunamis):
- **Geography** matters = ice sheet growth needs land at high latitudes and cool summer T.
- **Ice sheets** matter = high albedo reflects sunlight (ice-albedo feedback).
- **Continents matter** = they affect ocean circulation.
  - ✓ ~30 mil yr ago Antarctica separated from S. America, opening Drake passage and created circumpolar vortex, climatically isolating Antarctica.
  - ✓ Continents indirectly affect climate by regulating atmospheric CO_2 via altering rainfall patterns, exposing new rock, and chemical weathering.

7.3. The Sun

- Solar constant (S) introduced as a control of climate (?)
- Over last ~5 bil yr, Sun burned hydrogen and produced helium via fusion.
- Rate of fusion increased as buildup of helium increased density of Sun's core.
- **Result**: over time Sun increased in brightness by ~30 %.
- 11-yr cycle with S varying by ~0.1 % (~1 W/m^2) -- little influence on climate (too small for the slow feedbacks)
- Conclusion: evidence suggests Sun output increased over millennia, but changed little over past few hundred yr.

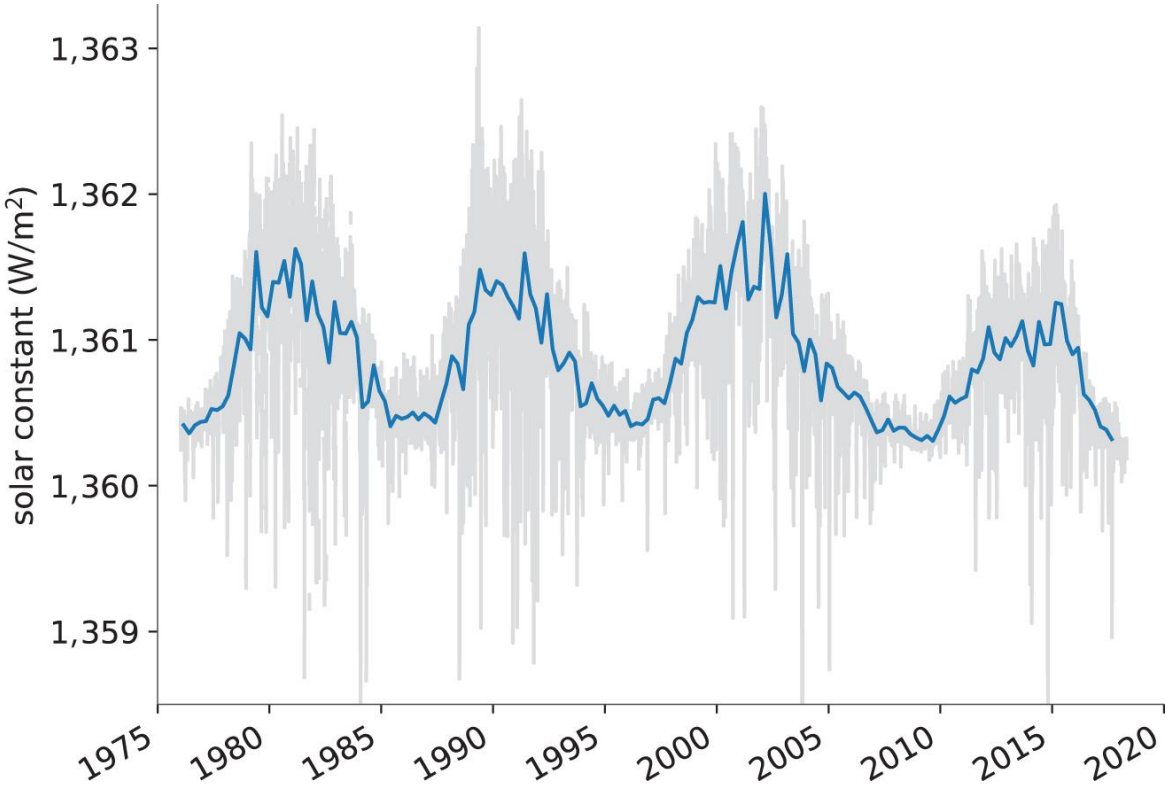

Fig. 7.1: Satellite measurements of S (in W/m^2) over last few decades. Seasonal changes in Earth-Sun distance (r) have been removed.

7.4. The Earth's Orbit

S determined <u>not</u> just by power emitted by Sun (P), but also by Earth-Sun distance (r).

$S = P / a = P / (4 \times \pi i \times r^2)$, so S inversely related to r.

Earth orbits is <u>not</u> a perfect circle, but rather an ellipse that varies over ~100,000-yr cycle.

Eccentricity = ratio of length of ellipse to width of ellipse*:*

As eccentricity increases (more elliptical), average r increases and average S decreases.

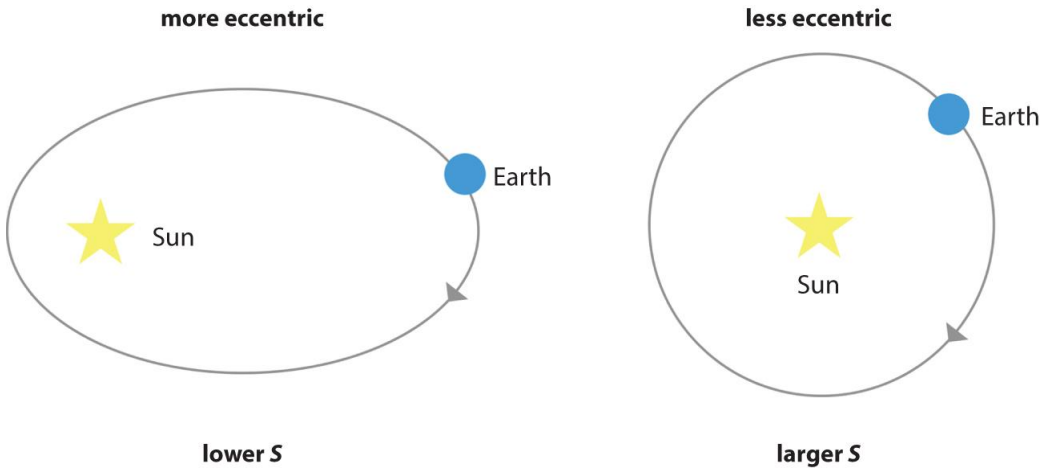

Fig. 7.2: Schematic illustrating how eccentricity of Earth's orbit varies with period of ~100,000 yr.

7.4. The Earth's Orbit

(2) Timing of closest approach to Sun varies over ~23,000-yr cycle Today Earth closest to Sun during January - winter in NH.

- In ~11,500 yr Earth closest to Sun during July - summer in NH.
- In ~11,500 yr after that Earth closest to Sun during January - winter in NH.
- Cycle known as precession.

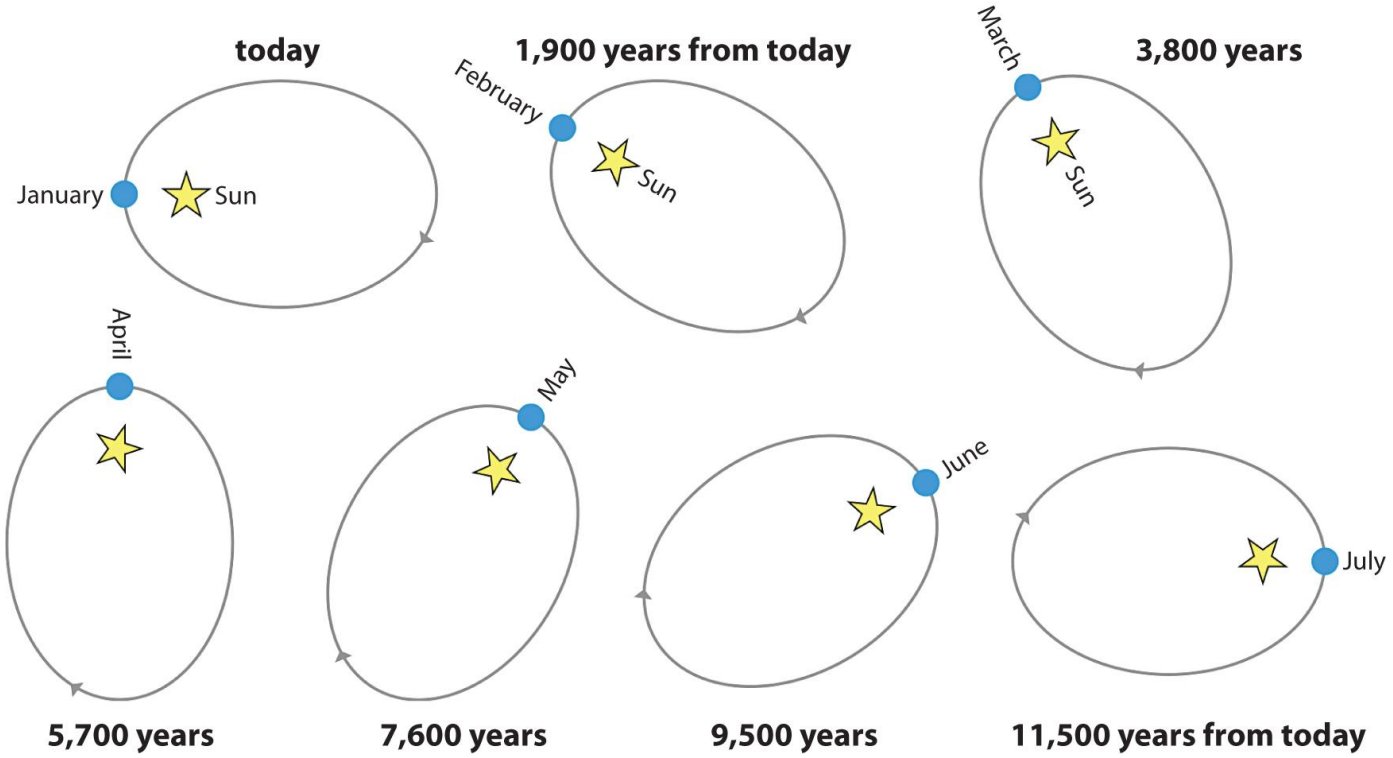

Fig. 7.3: Schematic illustrating how date of closest approach of Earth to Sun varies from January to July over ~11,500 yr.

7.4. The Earth's Orbit

(3) Earth's spin axis tilted from vertical - *currently ~23.5 degrees (**Fig. 7.4**):*

- **Obliquity** = variation in axial tilt angle.
- For Earth occurs over ~41,000-yr cycle with tilt angle range = 22.3 to 24.5 degrees from vertical.
- Obliquity currently decreasing.
- Obliquity and seasonality directly related.

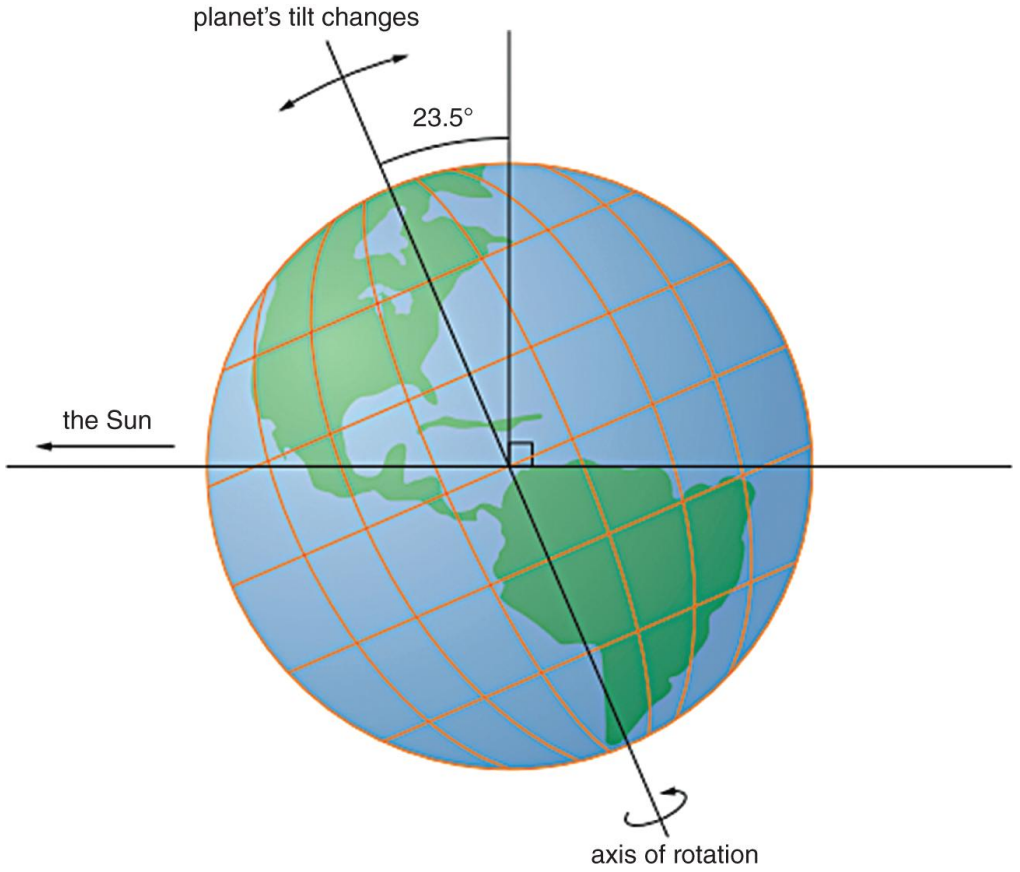

Fig. 7.4: Schematic illustrating how obliquity of Earth (tilt of spin axis away from perpendicular to orbital plane), which varies with period of ~41,000 yr.

7.4. The Earth's Orbit

- Changing date of closest approach to Sun or tilt angle does not change r or S.
- Rather these affect how energy distributed by latitude and season.
- Increasing tilt angle increases amount of sunlight hitting polar regions, decreases amount hitting tropics, in turn increases average albedo.
- Ice sheet growth dependent on high-latitude summer T.
- Orbital variations regulate how sunlight distributed over Earth and over seasons.
- Milankovitch Cycles = orbital variations and climate effects, after mathematician Milutan Milankovitch.

Conclusion: while orbital variations explain glacial advance and retreat over thousands of yr, they do not explain at time scale of modern climate change.

7.5. Unforced Variability

El Niño events = warm phase of several tenths of K.

La Niña events - cool phase of several tenths of K.

ENSO events occur every few yr, lasting ~1 yr (**Fig. 7.5**).

ENSO events linked to worldwide shifts in T and precipitation patterns, having consequences for humanity.

ENSO is dominant and best-known source of unforced variability in climate system, though other modes exist, such as the Pacific Decadal Oscillation (PDO).

https://research.noaa.gov/50-years-of-getting-enso-predictions-mostly-correct/ (2 min video)

Chapter 7: Why Is The Climate Changing?

March 16 & 18, 2026

7.1. Context of the Recent Warming
7.2. The First Suspect: Plate Tectonics
7.3. The Sun
7.4. The Earth's Orbit
7.5. Unforced Variability
7.6. Greenhouse Gases
7.7. Putting It Together
Terms
Problems

TERMS

Eccentricity
Fingerprints
Forced variability
Milankovitch cycles
Obliquity
Outlier
Plate tectonics
Unforced variability