

Introduction to Climate Change

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Key concepts, causes, impacts, and responses

1. What Is Climate Change?

Aspect	Description
Definition	Long-term alteration of temperature, precipitation, wind patterns, and other aspects of the Earth's climate system.
Timescale	Measured over decades to millions of years (distinguishes it from short-term weather variability).
Natural vs. Anthropogenic	Natural drivers (volcanic eruptions, solar cycles) have always operated, but the current rapid warming is overwhelmingly driven by human activities.

2. The Science Behind It

2.1 The Greenhouse Effect

- Solar radiation** reaches Earth as short-wave (visible) light.
- Surface absorbs** energy, warms, and re-emits it as long-wave (infrared) radiation.
- Greenhouse gases (GHGs)**—CO₂, CH₄, N₂O, water vapor—absorb and re-emit infrared radiation, trapping heat.
- Result:** Average surface temperature is ~33°C warmer than it would be without GHGs.

2.2 Key Greenhouse Gases & Sources

Gas	Atmospheric Lifetime	Primary Human Sources
Carbon dioxide (CO ₂)	~100-yr	Fossil-fuel combustion, cement production, deforestation
Methane (CH ₄)	12-yr	Livestock, rice paddies, landfills, natural gas extraction
Nitrous oxide (N ₂ O)	114-yr	Synthetic fertilizers, industrial processes

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Gas	Atmospheric Lifetime	Primary Human Sources
Fluorinated gases (SF ₆ , HFCs)	10 ² –10 ⁴ yr	Refrigeration, electronics, fire suppression systems

2.3 Climate Feedbacks

Feedback Type	Mechanism	Effect on Warming
Positive	Ice albedo loss → less reflection → more absorption	Amplifies warming
	Permafrost thaw → CH ₄ release	Amplifies warming
	Water vapor increase → stronger greenhouse effect	Amplifies warming
Negative	Increased cloud cover reflecting sunlight (region-specific)	Can dampen warming, but overall weaker than positive feedbacks

3. Evidence of Current Climate Change

Indicator	Observed Trend (1850–present)
Global mean surface temperature	+1.2°C (relative to pre-industrial)
Ocean heat content	~30% of excess heat stored
Sea level rise	~20 cm (1900–2020)
Arctic sea ice extent	~13% per decade (summer)
Glacial mass loss	>9,000 Gt of ice lost since 1961
Frequency of extreme events	More intense heatwaves, droughts, heavy precipitation

4. Impacts of Climate Change

4.1 Environmental

- **Ecosystem shifts:** Species migrate poleward/upward; biodiversity loss.

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- **Coral bleaching:** Ocean warming + acidification → reef degradation.
- **Ocean acidification:** 30% increase in CO₂ uptake → pH drop, affecting calcifying organisms.

4.2 Societal

- **Human health:** Heat-related mortality, vector-borne diseases, air quality decline.
- **Food security:** Crop yield reductions in tropical/sub