Climate basics – the scientific consensus & IPCC

Climate warming in context
Radiative forcing
Warming projections
Annual anomalies of global land-surface air temperature relative to 1961-90 mean
Northern Hemisphere temperature estimates from tree rings and other sources relative to 1961-90 mean

Recent temperature changes are unprecedented

Data from 10 studies, with darker colors representing greater consensus
The so-called “hockey stick” curve
For longer records we turn to ice cores
Antarctic ice sheet
Ice coring in Antarctica
Temperature & CO$_2$ from Dome C ice core (Antarctica)

Temperature difference from last 1000-yr mean

Past 100 yr not included on graphs
Overlay of temperature & CO$_2$ from Dome C ice core

Temperature difference from last 1000-yr mean
Greenhouse effect – trapping of infrared radiation emitted by the Earth

**NATURAL WARMING**

(1) Sunlight brings energy into the climate system; most of it is absorbed by the oceans and land.
(2) Heat (infrared energy) radiates outward from the warmed surface of the Earth.
(3) Some of the infrared energy is absorbed by greenhouse gases in the atmosphere, which re-emit the energy in all directions.
(4) Some of the infrared energy further warms the Earth.
(5) Some of the infrared energy is emitted into space.

**AMPLIFIED WARMING**

(6) Higher concentrations of CO₂ and other "greenhouse" gases trap more infrared energy in the atmosphere than occurs naturally. The additional heat further warms the atmosphere and Earth's surface.
Global-climate radiative forcing

Warming effect of greenhouse gases partially offset by aerosols
Current radiative forcing, enhanced greenhouse effect

Radiative forcing of climate between 1750 and 2005

Radiative Forcing Terms

- Long-lived greenhouse gases
  - CO₂
  - N₂O
  - CH₄
  - Halocarbons

- Human activities
  - Stratospheric (-0.05)
  - Tropospheric
  - Ozone
  - Stratospheric water vapour
  - Surface albedo
  - Land use
  - Black carbon on snow
  - Direct effect
  - Cloud albedo effect
  - Linear contrails

- Natural processes
  - Solar irradiance
  - Total net human activities

Radiative Forcing (watts per square metre)
Precipitation changes over the past century

**Palmer Drought Severity Index**

PDSI is an index of drought – measures the cumulative local deficit in surface land moisture.

PDSI is based on hydrologic accounting of previous precipitation & estimates of moisture drawn into the atmosphere (based on temperature).
What caused climate changes before the industrial era, e.g. ice ages?

T: tilt (or obliquity) of the Earth’s axis
E: eccentricity of the orbit (due to variations in the minor axis of the ellipse),
P: precession, changes in the direction of the axis tilt at a given point of the orbit.
Today’s greenhouse gas concentrations are at unprecedented levels.
Are industrial era increases in atmospheric $\text{CO}_2$ & other greenhouse gases caused by human activities?

Human-caused sources in orange
Natural sources & sinks in teal

Human-caused $\text{O}_3$ in orange
Natural $\text{O}_3$ in teal
Global surface temperature anomalies from observations (black) & simulations with both anthropogenic & natural forcings

Simulating Earth’s climate with numerical computer models

Comparison with natural natural forcings only
Can 20th century warming be explained by natural variability?
Projections of future climate depend on emissions
Continental-scale projections of warming