The Science of Climate Change

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What Causes Climate Change?
Everything emits radiation energy

units: Watts per square metre (Wm$^{-2}$)

Cool things: long wavelength or thermal radiation, e.g. us $\sim 300$ K

Hot things: short wavelength radiation, e.g. the sun $\sim 6000$ K

Temperature in Kelvin = Temperature in °C + 273.15
The Electromagnetic Spectrum

Penetrates Earth Atmosphere? Y N N Y

Wavelength (meters)
- Radio: $10^3$
- Microwave: $10^{-2}$
- Infrared: $10^{-5}$
- Visible: $0.5 \times 10^{-6}$
- Ultraviolet: $10^{-8}$
- X-ray: $10^{-10}$
- Gamma Ray: $10^{-12}$

About the size of...
- Buildings
- Humans
- Honey Bee
- Pinpoint
- Protozoans
- Molecules
- Atoms
- Atomic Nuclei

Frequency (Hz)
- $10^4$
- $10^8$
- $10^{12}$
- $10^{15}$
- $10^{16}$
- $10^{18}$
- $10^{20}$

Temperature of bodies emitting the wavelength (K)
- 1 K
- 100 K
- 10,000 K
- 10 Million K

Figure from NASA.
IR thermometer activity
Earth’s Radiation balance in space

Absorbed Solar or Shortwave Radiation \( \frac{S}{4} \times (1 - \alpha) \)

\( \alpha \) is “albedo” – the proportion of incoming solar radiation reflected back

- There is a balance between heating from absorbed sunlight and cooling to space through thermal/longwave radiative energy

- \( \frac{S}{4} (1 - \alpha) = OLR \quad S \approx 1361 \text{ Wm}^{-2}, \alpha \approx 0.3, OLR \approx 239 \text{ Wm}^{-2} \)

- How does it balance? Why is Earth’s average temperature \( \sim 15^\circ \text{C} \)?

- **Scratch Energy Balance Activity**
Forcing and response: a natural experiment
Clouds affect radiation fluxes
Radiation fluxes affect clouds

Feedback/response activity
Water vapour and climate
Water Vapour causes an amplifying positive Feedback loop

$\uparrow CO_2$ → $\uparrow$ Water vapour → $\uparrow$ Net Heating → $\uparrow$ Temperature → $\uparrow$ Water vapour → $\uparrow$ Greenhouse effect and more absorption of sunlight

SSM/I Satellite data, Dec 2006

Sea Surface Temperature (°C)

Column Water Vapour (mm)
Climate simulations

• Scientists put all the physics of the atmosphere, oceans and land into complex computer simulations
• Many millions of lines of code are used to calculate the equations and pass information between grid cells
• These simulations are used to:
  – understand why climate has changed in the past
  – project how climate will change over future decades and centuries
How will climate change over your lifetimes?
Summer 2003 European heatwave temperatures normal by the 2040s, cool by 2060s
Warming will be greater over the land and greatest in the Arctic

Change in average surface temperature (1986–2005 to 2081–2100) RCP 8.5 Scenario
Arctic sea ice extent is projected to diminish over the 21st century.

94% decrease in September and 34% decrease in February for the RCP8.5 scenario (IPCC 2013, WG1 Fig. 12.29).
Intensification of heavy rainfall

Hurricane Harvey

Philippines

Coverack, Cornwall
Sea-level rise will continue to rise for centuries

$CO_2$ increase stops here
Summary

• Climate has always changed
• Greenhouse gases such as carbon dioxide are at their highest levels for at least the last 800,000 years
• This pollution from human activity is amplifying the natural greenhouse effect
• This is heating the planet by impeding outgoing infrared cooling to space
• Substantial changes in global temperature and rainfall patterns are projected using computer simulations
• Predicting regional climate change is a challenge
• What can we do to avoid dangerous climate change?