Atmosphere and climate change

Topic 6 · SL

One year and a long-term target

Paris Agreement

Adopted December 2015; signing opened April 2016.

Well below 2 °C; pursue efforts towards 1.5 °C.

WMO report on 2024

Calendar year 1.55 ± 0.13 °C above 1850–1900.

One annual value does not establish a long-term target breach.

Composition and layers

Dry air

About 78% nitrogen, 21% oxygen and 0.9% argon.

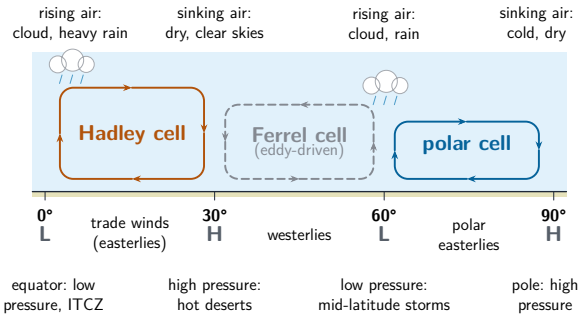
NOAA global 2024 CO_2: about 422.8 ppm; water vapour excluded from dry air.

Temperature profile

Troposphere: most weather; temperature usually falls upwards.

Stratosphere: **ozone** absorbs UV; temperature rises upwards.

Three circulation cells



one hemisphere, idealised zonal mean; heights not to scale

Link rising and sinking air to pressure and surface winds.

Heat and surface winds

Pressure and motion

Equatorial ascent; subtropical descent; ascent near 60°; polar descent.

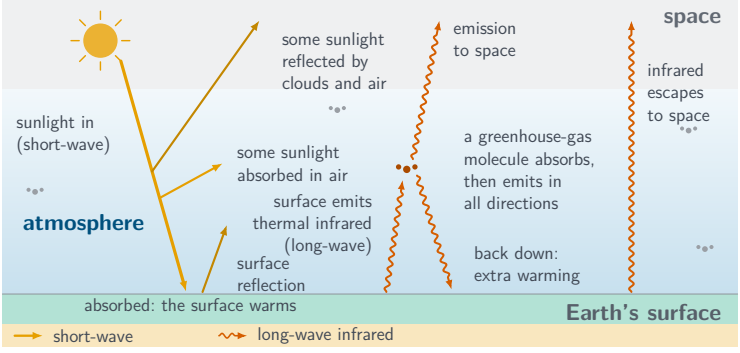
Hadley and polar cells redistribute heat; Ferrel circulation is indirect and eddy-driven.

Wind directions

Rotation deflects right in the north and left in the south.

Trade/polar easterlies; mid-latitude westerlies. Names describe where winds come from.

Radiation and greenhouse gases



Selected pathways, not a complete flux budget: both atmosphere and surface absorb solar radiation.

Trace the energy mechanism

Solar and surface radiation

Incoming solar includes visible, near-infrared and **ultraviolet**.

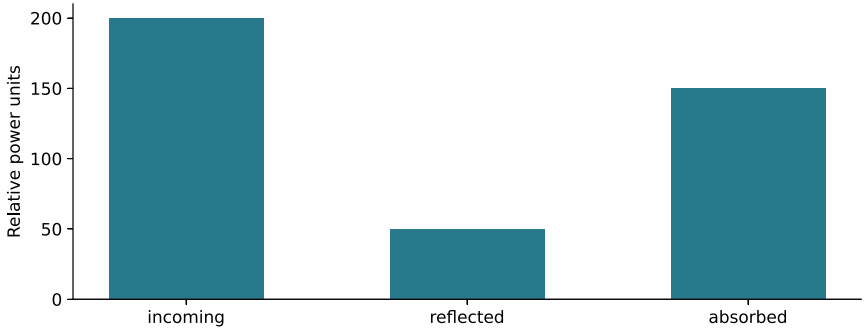
A warmed surface emits new thermal-infrared photons.

Atmospheric interaction

Greenhouse gases absorb and emit infrared in all directions.

Some infrared escapes; downward emission contributes to surface heating.

A surface albedo model



200 incoming − 50 reflected = 150 absorbed; this surface boundary excludes atmospheric absorption.

Albedo and absorbed power

1. **Invented givens.** Incoming 340 W/m^2, **albedo** 0.30.
2. **Reflected.** $340 \times 0.30 = 102$ W/m^2.
3. **Absorbed.** $340 - 102 = 238$ W/m^2.

Decision

This is not the complete surface heat budget; infrared, sensible and latent heat also matter.

Compare gases and aerosols

Gases

CO_2: fossil fuels, cement and land use; no single lifetime.

CH_4: leaks, ruminants, rice and wastes; roughly decade-scale perturbation decay.

Other agents

N_2O from nitrogen cycling; halocarbon effects depend on compound.

Water vapour is modelled as a feedback; aerosols can scatter or absorb sunlight.

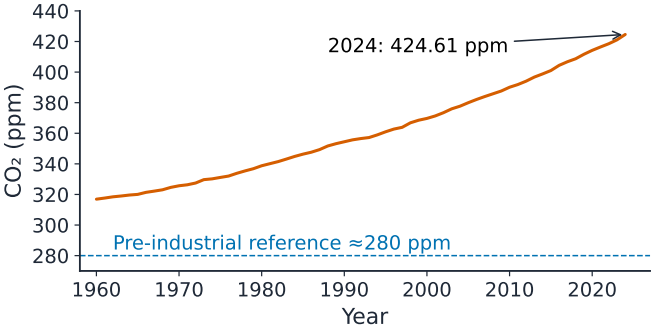
A stated-horizon comparison

1. **Assigned metric.** Invented 100-year methane factor = 28 per equal mass of CO_2.
2. **Assigned emission.** 2 tonnes methane $\times$ 28 = 56 tonnes CO_2-equivalent.
3. **Interpret.** Time-integrated comparison, not lifetime or instantaneous heat.

Decision

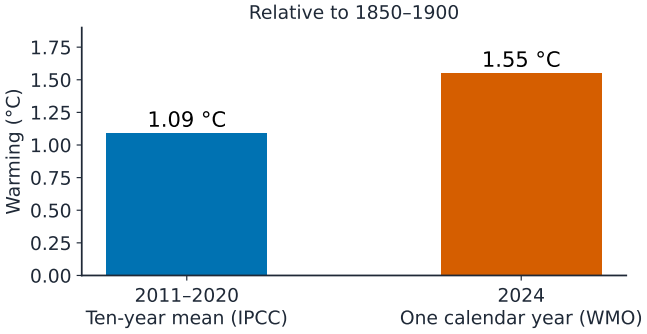
Equal CO_2-equivalent values do not mean identical time profiles or interchangeable policy needs.

Measured concentration is not annual emissions



NOAA Mauna Loa station annual means, 1960–2024; global averages and seasonal peaks differ.

Two reported warming statistics



Different averaging periods: do not infer a warming rate or Paris breach from these two bars.

Independent lines of evidence

Instruments and change

Stations, satellites, oceans, glaciers and biological timing.

Sea level: thermal expansion and land-ice loss; floating sea ice has little direct effect.

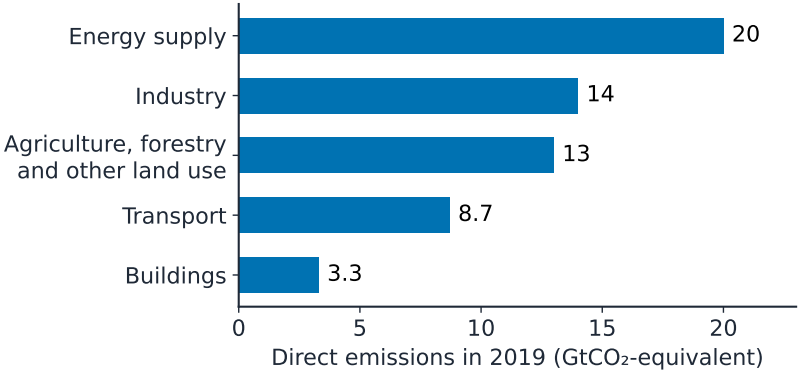
Past climates

Ice-core bubbles preserve ancient air; isotopes provide temperature-related proxies.

Tree rings, pollen and sediments require calibration and dating; not all directly measure CO_2.

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Direct sector emissions in 2019



IPCC rounded estimates total 59 $GtCO_2e$; allocating electricity to end users changes sector shares.

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State the accounting boundary

Different measures

Annual versus cumulative; total versus per person.

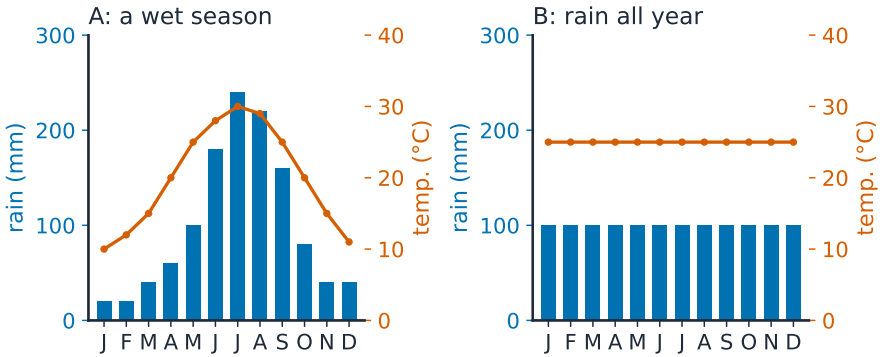
Territorial versus consumption-based; fossil CO_2 versus all greenhouse gases.

Planetary boundary

Common CO_2 control value: 350 ppm; 2024 global value exceeds it.

Different from a Paris temperature target or proof every **tipping point** is crossed.

Read a monthly climate graph



Invented sites: bars show rain; lines show temperature.

Read climate distributions

Invented monthly observations

A: rainfall varies 20–240 mm/month, total 1200 mm/year; temperature 10–30 °C.

B: rainfall 100 mm/month, temperature 25 °C throughout; same 1200 mm/year.

Interpret the pattern

A has a 20 °C monthly temperature range; B has 0 °C.

Equal annual rainfall does not establish equal dry-season stress or runoff.

Ecosystems: mechanism and context

Great Barrier Reef, 2024

Marine heat stress caused widespread bleaching.

Loss of symbiotic algae reduces energy supply; bleaching need not mean immediate death.

Range and productivity

Some cooler regions gain growing-season length, with water/nutrient limits.

Fragmentation and movement rates constrain species responses.

Tuvalu and unequal vulnerability

Named adaptation evidence

UNDP reported handover of 7.3 ha reclaimed land in October 2024.

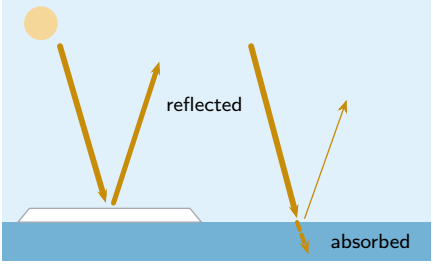
Raised land can reduce specific coastal risks.

Evaluate limits

Exposure, sensitivity and adaptive capacity vary within societies.

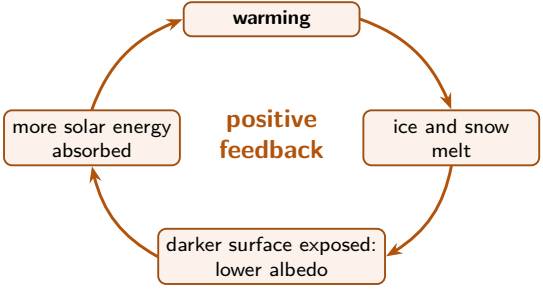
Maintenance, future sea level, ecology, rights and finance remain important.

Ice-albedo amplification



ice and snow
high albedo:
most sunlight reflected

open water
low albedo:
most sunlight absorbed



amplifies the change;
not a beneficial outcome

Positive means amplifying, not beneficial; a feedback alone does not locate a tipping threshold.

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Feedback is not a dated collapse prediction

Amplifying and stabilising

Ice loss, water vapour and **permafrost** carbon can amplify warming.

Warmer bodies emit more; plant uptake is constrained by water, nutrients and disturbance.

Tipping elements

Component changes may become self-sustaining.

State mechanism, uncertainty and timescale; thresholds are not one universal date.

Mitigation and adaptation

Mitigation

Reduce emissions or increase net atmospheric removal.

Clean energy, methane-leak reduction and protecting carbon stores.

Adaptation

Reduce exposure or vulnerability to impacts.

Flood defences, warnings and changed planting dates; some actions do both.

Avoided emissions versus removal

Point-source capture

Capturing fossil or cement process CO_2 avoids some new emissions.

Check residual releases, energy, upstream emissions and durable storage.

Potential removals

DAC with storage or suitable biomass/soil pathways need a negative net balance.

Permanence, leakage, saturation, land and energy requirements matter.

Structural and non-structural adaptation

Structural

Flood barriers, raised buildings, drainage and water storage.

Check maintenance, displaced erosion and residual risk.

Non-structural

Warnings, zoning, standards and emergency planning.

Access, communication, compliance and capacity determine results.

Sponge approaches and national plans

Cities

Permeable surfaces, planted storage and wetlands slow runoff.

Capacity, saturation and blocked outlets limit performance.

Planning

NAPs: medium/long-term priorities, delivery and monitoring.

NAPAs: earlier urgent needs of least-developed countries; not the same as NDCs.

Climate treaties and implementation

Frameworks

UNFCCC 1992; Kyoto 1997 commitments for relevant participating Parties.

Paris successive NDCs, transparency and collective assessment.

Judgement

Targets and procedural duties differ from achieved reductions.

Net-zero global CO_2 pathways are not a universal 2050 all-gas legal deadline.

Carbon prices and cooperation

Tax versus absolute cap

Tax fixes price; response quantity is uncertain.

Absolute-cap trading limits covered quantity; price varies.

Distribution and sovereignty

Revenue use, monitoring, offsets and trade boundaries matter.

Domestic follow-through, finance and technology support international cooperation.

Three kinds of adaptation

structural
flood defences, raised buildings, drainage, water storage

non-structural
early warnings, zoning, building standards, planting dates, plans

ecosystem-based
restore mangroves and wetlands (need space and conditions)

compare lifecycle cost, who benefits and shifted harm: a seawall can move erosion along the shore

Ecosystem-based: restored mangroves

Climate treaties



COP30 met in Belém in 2025

Radiation and ozone

Protective stratosphere

O_2/**ozone** absorb all UV-C and much UV-B; much UV-A reaches ground.

Shorter wavelength means higher photon energy.

Distinct problems

More UV-B damages DNA, eyes, crops and phytoplankton.

Ground-level ozone is the same molecule in a harmful secondary-pollutant context.

Dynamic balance and depletion

Molecules change continually

Ozone formation and destruction rates can balance.

Stable CFCs reach the **stratosphere**; UV releases reactive chlorine.

Polar conditions

Catalysis regenerates chlorine; cold cloud surfaces and spring sunlight matter.

An **ozone hole** is severe seasonal depletion, not empty atmosphere.

Montreal, recovery and Kigali

Controls and evidence

Montreal 1987 controls ODS; finance, alternatives and monitoring support action.

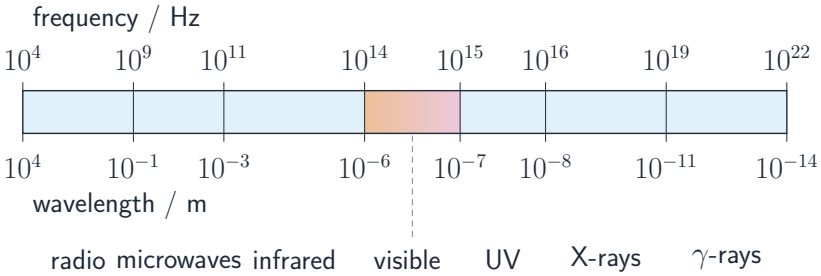
2022 assessment projects conditional recovery, not guaranteed exact dates.

Different metrics

Regional Antarctic loss differs from a global planetary-boundary control.

Kigali 2016 phases down HFCs; HCFC phase-out is a separate ODS measure.

The electromagnetic spectrum



UV-B and UV-C damage living cells; **ozone** absorbs them

Exam tips

Quantities

Station/global; annual/long-term; CO_2/carbon; avoided/removal.

State period, units, boundary and uncertainty.

Evaluate

Trace the mechanism, not only the policy name.

Distinguish agreement, pledge, delivered funding and measured outcome.

Check yourself

Your turn

A surface receives 340 $\mathrm{W/m^2}$ with albedo 0.30. How much is absorbed in the stated solar-only model?

A. 238 $\mathrm{W/m^2}$.
B. 102 $\mathrm{W/m^2}$.
C. 340 $\mathrm{W/m^2}$.