Climate change

D4.3 · SL and HL

A changed climate acts through biological mechanisms

Connect forcing, feedback, habitat, timing and inheritance

Shared D4.3 covers human causes, feedbacks, boreal carbon, polar habitats, nutrient upwelling, range shifts, coral reefs and sequestration.

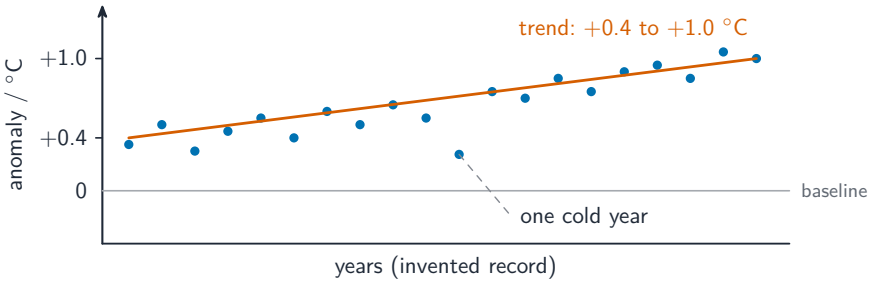
AHL: phenology, disrupted synchrony, completed insect generations and selection on inherited variants.

All numerical records and plotted models are invented teaching examples. Named research is linked separately in the handout.

Separate a short-term state, a baseline and a causal explanation

1. **Weather and climate.** A local cold or hot day does not alone establish or refute a long-term global trend.
2. **Anomaly.** A difference from a stated baseline. $+0.4 \rightarrow +1.0$ degrees Celsius means a rise of 0.6 degrees, not an absolute temperature of 0.6.
3. **Inference.** Ice-core correlation can involve feedback or common drivers. Radiative physics, other observations and models support greenhouse causation.

Climate is the trend, not one year



One cold year sits below the line

Name sources without confusing emission rate and concentration

Gas / process	Contribution and limitation
Carbon dioxide	Fossil burning and land-use change transfer stored carbon; vegetation/oceans can absorb some but not all emissions
Methane	Fuel leaks, anaerobic landfills/rice and ruminant microbes contribute
Concentration	Depends on removal as well as emission input
Radiation	Greenhouse gases absorb and emit infrared; they do not form a solid roof

Natural greenhouse warming and an enhanced effect are compatible

Increasing gas concentrations change radiative transfer

The natural greenhouse effect warms the surface relative to a world without it. Human increases change this energy balance further.

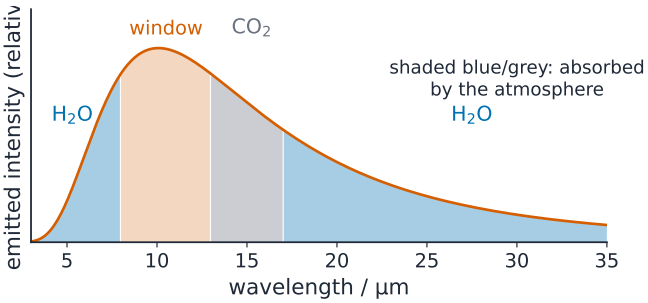
Past natural climate changes do not exclude present human influence. Ozone depletion is a different process.

A surface reflection budget isolates one component; it omits outgoing radiation and other terms needed to infer temperature.

Calculate reflected share using incoming power as the denominator

1. **First model.** Incoming 200, reflected 50: absorbed 150 power units; reflected fraction $50/200 = 25\%$.
2. **Practice.** Incoming 240, reflected 72: absorbed 168; reflected share 30%.
3. **Boundary.** Incoming 180, reflected 36: absorbed 144; share 20%. None of these alone is a complete planetary-temperature model.

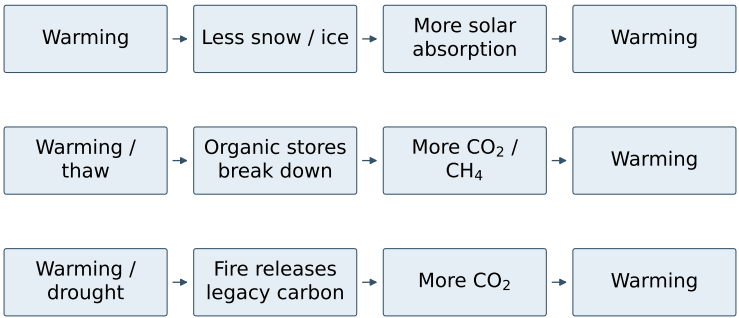
Which gases absorb infrared?



A window from 8 to 13 μm lets radiation escape

Close each feedback through its effect on warming

Three reinforcing pathways; each row returns to warming



Positive means reinforcing, not beneficial or numerically above zero.

Trace ice loss and thawed organic matter through different mechanisms

1. **Reflectivity.** Less snow/ice exposes darker surfaces; more solar absorption promotes warming and further melting.
2. **Decomposition.** Thaw exposes organic matter; aerobic decomposition releases carbon dioxide, while suitable low-oxygen conditions can support methane production.
3. **Limit.** Previously frozen material need not already contain all the gas later produced. Moisture, oxygen and temperature constrain rates.

Distinguish regional exchange from the global net carbon balance

1. **Peat, drought and fire.** Warming/drying can increase decomposition; fire releases stored carbon and damaged vegetation may take up less.
2. **Deep ocean.** Ventilation can bring carbon-rich deep water toward the surface; warming lowers gas solubility, while circulation and biology also affect exchange.
3. **Boundary.** These feedback pathways do not imply every region responds alike or that the whole modern ocean automatically becomes a net carbon source.

A standing carbon store is not automatically a current sink

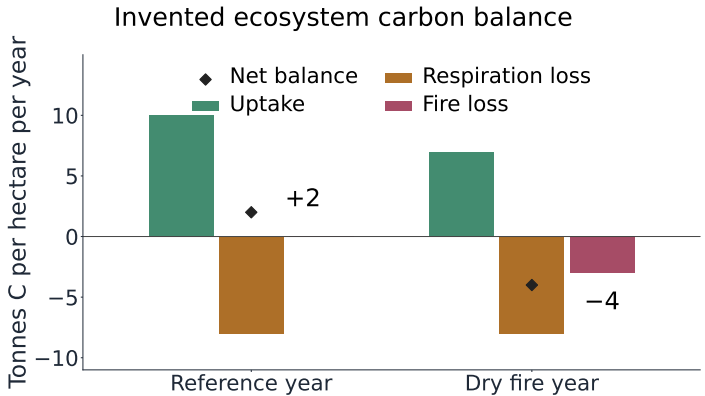
Judge net flux over a boundary and an interval

Warmer conditions, less winter snowfall and drought can stress taiga trees, reduce production and contribute to browning.

Severe or frequent fire can combust vegetation and legacy soil carbon before stores rebuild. Walker and colleagues used radiocarbon evidence to examine such losses.

Repeated loss can reinforce warming and hinder recovery. A one-year source observation alone does not prove permanent ecosystem collapse.

Keep uptake, respiratory loss and combustion separate



Positive net balance is retention by this defined model ecosystem.

Interpret the sign after applying a consistent carbon-mass balance

1. **Reference year.** Uptake 10, respiration 8, fire 0 tonnes C per hectare/year: net $+2$.
2. **Dry fire year.** $7 - 8 - 3 = -4$ tonnes C per hectare/year; a source. Without fire, $7 - 8 = -1$ under the same conditions.
3. **Units and inference.** Carbon mass is not carbon-dioxide mass. Measure multiple years and account for excluded exchanges before generalizing.

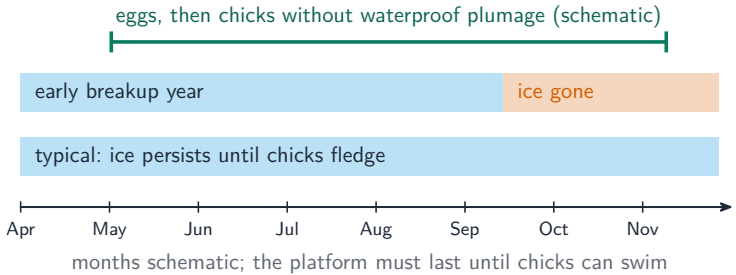
Locate the platform, season and biological dependence

Organism / ice	Mechanism and evidence boundary
Landfast sea ice	Attached to a coast or fixed feature; distinct from drifting sea ice and land-based glaciers
Emperor penguin	Early Antarctic platform breakup can precede waterproof chick plumage
2022 regional study	Satellite evidence of probable failure at four of five studied Bellingshausen Sea colonies
Walrus	Resting near benthic shelf-feeding areas; retreat can increase travel or crowd coastal haulouts

Avoid turning a regional mechanism into an unsupported universal claim

1. **Penguins.** The study does not say every Antarctic colony failed or every chick was directly observed.
2. **Walruses.** Crowded disturbance can threaten calves/yearlings through trampling. Walruses feed on benthic organisms, not the ice platform.
3. **Scale.** Timing, persistence and location matter. Annual ice area alone does not fully specify breeding or feeding access.

Sea ice and breeding

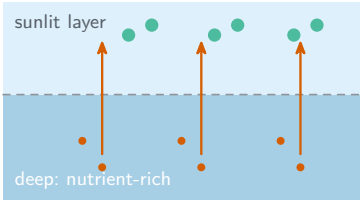


The chicks still lack waterproof plumage

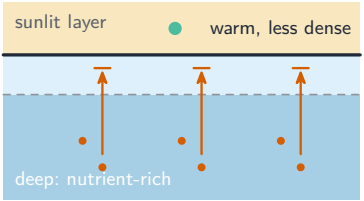
Follow vertical supply to production and a food-chain consequence

1. **Supply.** Upwelling/mixing can deliver deep nutrients to sunlit surface water. Winds, currents, temperature and salinity affect supply.
2. **Stratification.** A warmer, less dense surface layer can limit vertical mixing. If nutrients limit growth, reduced delivery can lower primary production.
3. **Invented comparison.** 500 $\rightarrow$ 400 production units is a 20% fall. At assumed 10% transfer, next-level supply is 50 $\rightarrow$ 40; this is not a universal efficiency or direct fish-catch prediction.

Warming and ocean nutrients



mixing reaches nutrients



warmer surface: stronger stratification

phytoplankton • nitrate, phosphate warm water does not make nitrate; it reduces delivery

Few phytoplankton grow

Leading and trailing edges can respond differently

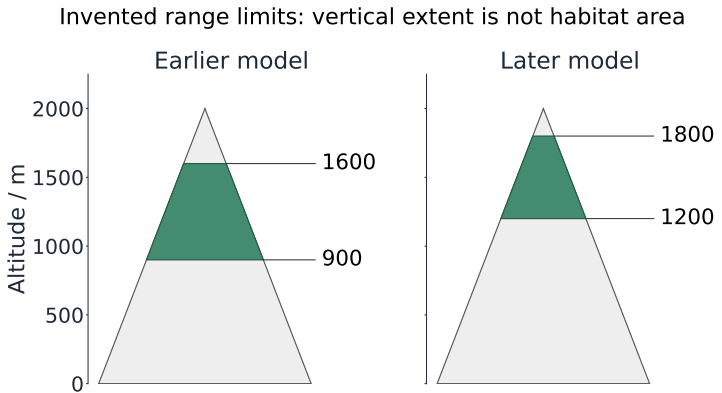
Range movement is not an individual tree walking north

Establishment at a cooler leading edge and loss at a warmer trailing edge depend on dispersal, soil, partners, competitors and habitat barriers.

Freeman and Class Freeman's New Guinea resurveys documented upslope bird shifts; near summits, available habitat may shrink.

Quebec tree inventories reported predominantly northward changes with varied responses and lag. Eastern US seedling/adult comparisons also found patterns consistent with contraction.

Compare both boundaries before claiming an unchanged range size



An invented vertical extent does not measure actual habitat area.

Calculate boundary shifts and contraction separately

1. **Earlier/later limits.** 900–1600 m $\rightarrow$ 1200–1800 m. Lower edge rises 300 m; upper rises 200 m.
2. **Extent.** 700 $\rightarrow$ 600 m; reduction $100/700 \times 100 \approx 14.3\%$.
3. **Evaluation.** Area requires topographic habitat mapping. Match survey effort, season and detection; juvenile/adult contrasts are not identical to repeated boundary tracking.

Separate the two mechanisms before explaining reef consequences

Pressure	**Mechanism and boundary**
Heat stress	Disrupts coral–photosynthetic-symbiont association or pigments; bleaching can be reversible
Added carbon dioxide	Lowers seawater pH/carbonate availability; can hinder skeleton formation
Acidification	pH decrease, not necessarily pH below 7
Ecosystem effect	Loss of cover/structure affects shelter, feeding and food webs; pollution/disease also matter

A bleached coral is stressed rather than automatically dead

The animals and their wider habitat can have different recovery times

Prolonged or repeated stress can kill corals and impair recovery; loss of habitat complexity affects other reef organisms.

The chemistry of acidification is distinct from heat-induced symbiont loss. Their effects can interact.

Reducing local pollution may improve resilience, but it does not itself remove global greenhouse-gas forcing.

Compare actions using the same boundary, baseline and timescale

Approach	Potential benefit and accounting limit
Mitigation / adaptation	Address drivers / reduce harm; one project can contribute to both
Afforestation / regeneration	New forest establishment / recovery of cover; uptake must exceed losses and disturbance
Plantations / native recovery	Growth rate, biodiversity, water demand, reflectivity and reversal risk differ
Peat restoration	Waterlogging can reduce oxidation; methane and other fluxes still require accounting

Carbon sequestration is a net additional storage claim

Planting a seedling does not guarantee permanent storage

Include respiration, soil disturbance, harvest, fire and what would otherwise happen. Avoid replacing a baseline with a gross uptake total.

Peat forms in temperate/boreal wetlands and suitable tropical systems. Rewetting can preserve carbon while also changing methane emissions.

Evaluate effectiveness, cost, equity and uncertainty. Neither non-native plantations nor native regeneration is automatically best for every place and objective.

Name the event, cue and response window

1. **Events.** Budburst, flowering, bud set, seasonal growth, migration and nesting are phenological observations.
2. **Cues.** Temperature patterns, accumulated warmth, snowmelt and photoperiod can influence timing. Day length at a fixed latitude/date does not lengthen because of warming.
3. **Distinction.** Unequal cue responses can change overlap. An individual's timing response may be plasticity rather than genetic evolution.

A shared ecosystem does not guarantee shared timing cues

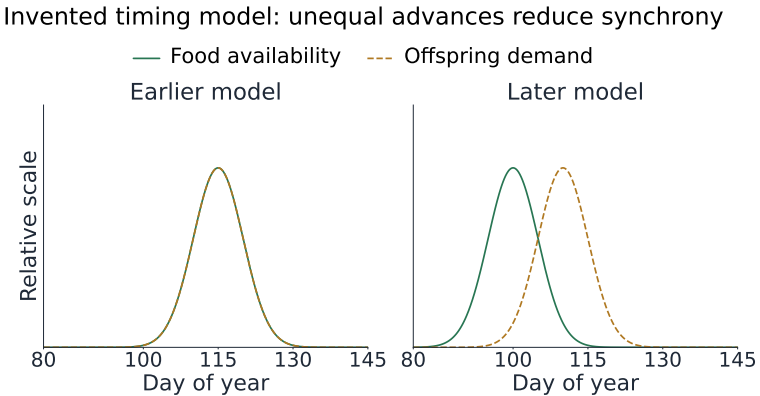
Compare Arctic plants/reindeer and forest birds/caterpillars

Earlier warmth/snowmelt can advance Arctic mouse-ear chickweed, Cerastium arcticum; migrating reindeer, Rangifer tarandus, may not adjust arrival equally.

Reindeer face multiple cues and route constraints, not only photoperiod, and consume multiple plants. Reduced overlap with high-quality growth can affect nutrition/reproduction.

Visser and colleagues found an advancing estimated caterpillar peak without equivalent mean laying-date advancement in the studied Hoge Veluwe great tits. Birds can still respond to temperature.

Both events can advance while their mismatch increases



Relative curves show timing; their heights are not comparable masses.

Compare advances and the resulting separation

1. **Earlier invented model.** Food and offspring demand both peak on day 115.
2. **Later model.** Food day 100; demand day 110. Advances 15 and five days; separation increases from zero to ten days.
3. **Evaluation.** Curve width, alternative foods, consumer numbers and weather matter. Laying date and peak chick demand are different events.

Count completed generations rather than every brood

1. **Mechanism.** Suitable warmth and longer season can permit an extra Ips typographus generation; drought can also weaken spruce defences.
2. **Constraints.** Diapause, temperature extremes, hosts, predators and mortality limit outcomes. Temperature and day length influence seasonal activity.
3. **Invented model.** 100 adults $\times$ four reproductive offspring $=$ 400; another completed generation gives 1,600 without resource limits. A sister brood from the original parents is not an offspring generation completed.

Reduced disadvantage can change a population without changing individuals

Tawny owl colour provides evidence of altered selection

Karell and colleagues found stronger survival selection against brown Strix aluco in snowy Finnish winters; the disadvantage diminished as winters became milder.

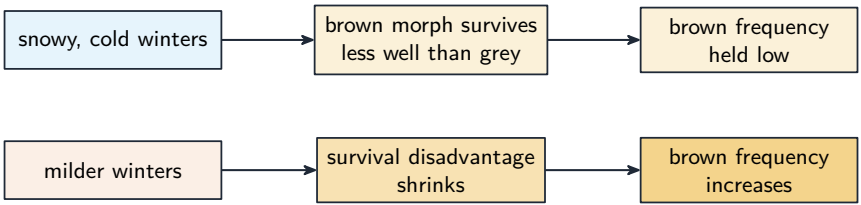
Brown-morph frequency increased, with heritable colour variation allowing population response. A grey owl did not need to turn brown.

The study does not prove camouflage alone caused the difference, or that brown owls are universally fitter in warmth. Physiological links and other mechanisms require evidence.

Count survivors before interpreting the phenotype fraction

1. **Snowy invented winter.** 40 brown $\times$ 0.50 $=$ 20; 60 grey $\times$ 0.80 $=$ 48. Brown survivors $20/68 \approx 29.4\%$, from 40% initially.
2. **Milder model.** Both survival fractions 0.80: 32 brown, 48 grey; $32/80 = 40\%$ brown.
3. **Boundary.** These are survivor phenotype proportions, not direct allele frequencies or a full multigeneration breeding model. Fitness, inheritance and sampling evidence are still needed.

Climate changes selection



schematic of the Finnish tawny owl study; a population response needs heritable colour variation

> The brown frequency increases

Attempt the handout questions before comparing results

Give the pressure, mechanism, consequence and evidence limit

Shared questions cover radiation, feedback, carbon balance, ice platforms, upwelling, ranges, coral mechanisms and management.

Practice carbon: uptake 1,200, respiration 900 and fire 450 kg C per hectare/year. Use the stated boundary and explain the sign.

AHL: evaluate timing mismatch, completed beetle generations and owl survivor proportions without conflating plasticity and evolution.

Check the shared balances and denominators

1. **Radiation.** $240 - 72 = 168$ absorbed units; reflection 30%. With 180/36: absorption 144; reflection 20%.
2. **Carbon.** $1{,}200 - 900 - 450 = -150$ kg C per hectare/year; source over that interval, not proof of permanent collapse.
3. **Ranges/production.** Extent contracts 14.3%; production falls 20%; next-level model supply $50 \to 40$. State units and assumptions.

Check yourself

Separate an observed response from a uniquely demonstrated mechanism

Specify the percentage baseline, model boundary and timescale. Distinguish bleaching from mortality and carbon stock from net flux.

Keep regional and global claims separate; compare sampling effort and alternative explanations before attributing a range change.

AHL: separate cues, event dates, completed generations, plasticity, phenotype proportions and inherited allele-frequency change.