Energy flow in global systems slide deck

Science 10

Unit D: Energy flow in global systems

Solar energy and life

One energy source for many systems

- Sunlight supplies energy for photosynthesis and heats Earth's surface unevenly.
- Uneven heating drives atmospheric and hydrologic processes that shape climate.



Solar radiation drives photosynthesis, weather, and climate

Two paths from sunlight

- Photosynthesis stores energy from light in chemical compounds.
- The same sunlight can warm the ground, move air, and drive phase changes.
- The Sun powers most surface climate and most food webs. Heat from inside Earth and the tides are the exceptions.

Key terms

solar radiation

Electromagnetic energy emitted by the Sun.

photosynthesis

Process that uses light energy to form energy-rich molecules from carbon dioxide and water.

climate

Long-term patterns and ranges of weather conditions.

adaptation

A heritable structural, physiological, or behavioural trait that improves survival or reproduction.

Climate and life

- Climate is the long-term pattern of weather over decades.
- People and other species meet extremes with shelter, insulation, water storage, or seasonal movement.
- A trait passed on in a population is different from one animal coping for a single week.
- Housing, fur, and behaviour are responses you can point to in a specific climate.



Solar radiation drives photosynthesis, weather, and climate

Solar source

- One afternoon of sunshine can grow grain and also start a breeze.
- Follow chemical energy from a plant to an animal, and follow heating into moving air.
- Sunlight drives most of the climate at Earth's surface and most food webs. Tides and heat from inside Earth are separate sources.
- The carbon in a leaf came from carbon dioxide; light supplied only the energy.



Solar connections

- Trace solar energy through one living system and one climate process.
- A complete answer traces a physically plausible chain and separates energy transfer from matter cycling.



Solar radiation drives photosynthesis, weather, and climate

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Migco, Village Milo Alberta, public domain

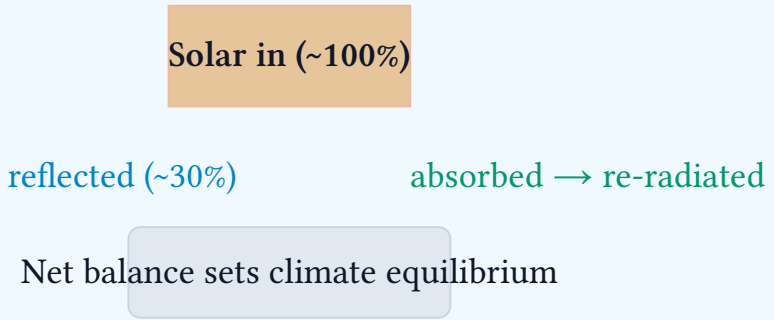
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Net radiation budget

One hundred units of sunlight

- About 30 of 100 incoming solar-energy units are reflected by clouds, atmosphere, and surfaces.
- The absorbed portion is later transferred and emitted as longwave radiation.



Terms in the energy budget

- Incoming sunlight, reflected sunlight, and outgoing infrared radiation all belong in the budget.
- Reflected radiation bounces straight back to space without warming Earth.
- Use one set of units, or one set of percentages, for the whole calculation.

Key terms

radiation budget

Accounting of incoming, reflected, absorbed, and outgoing radiation.

albedo

Fraction of incoming radiation reflected by a surface.

shortwave radiation

Mostly visible and near-visible solar radiation arriving at Earth.

longwave radiation

Infrared radiation emitted by Earth and its atmosphere.

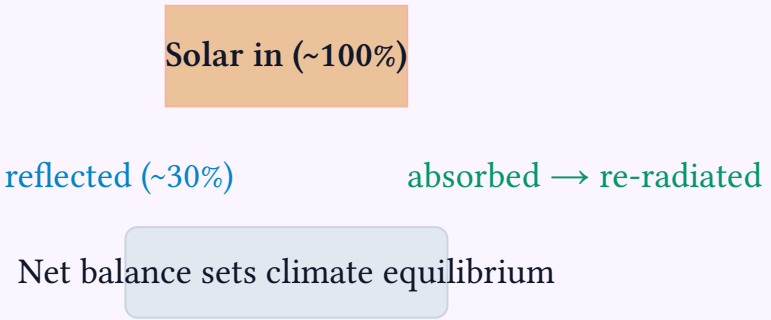
Key terms

net radiation

Incoming absorbed radiation minus outgoing radiation.

Radiation budget

- State incoming radiation, outgoing radiation, and the net as percentages of the same total.
- Shortwave radiation arrives from the Sun. Longwave radiation leaves from Earth.
- The net is what remains after you subtract what leaves.



Closing the budget

- From a simple 100-unit model, calculate the radiation that was absorbed and the net radiation.
- Subtract the reflected portion, keep the percentages consistent, and say whether the system gained or lost energy.



Closing the budget

- Calculate absorbed and net radiation from a simple 100-unit model.
- A complete answer subtracts reflected energy, keeps one set of units or percentages, and interprets the sign of the net.

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NASA/Apollo 17 crew; taken by either Harrison Schmitt or Ron Evans, The Earth seen from Apollo 17, public domain

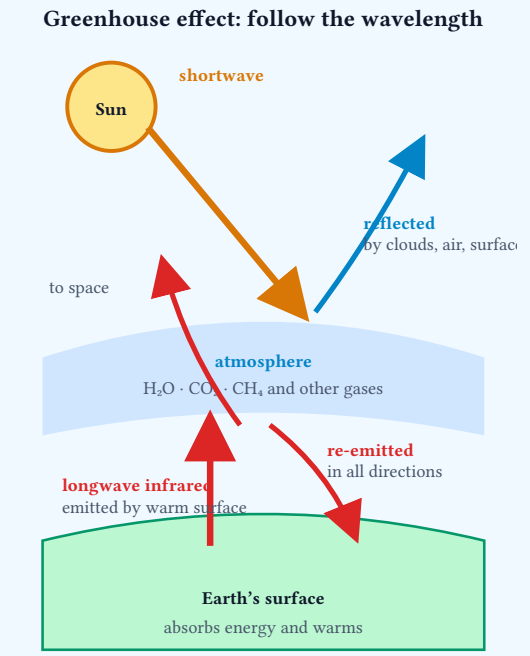
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Unit D: Energy flow in global systems

Earth systems and the greenhouse effect

Earth’s temperature and the atmosphere

- Earth’s surface absorbs solar radiation and emits infrared radiation.
- Greenhouse gases absorb and re-emit some outgoing in-frared radiation, changing the rate of energy loss to space.



enhouse gases are not a solid lid; they absorb and emit infrared ener

Effects of greenhouse gases

- Greenhouse gases matter because they absorb and emit infrared radiation.
- That changes how fast energy leaves, and therefore the temperature at which incoming and outgoing energy balance.
- On a diagram, label the reservoirs and the arrow directions. Say the energy is slowed on its way out to space.

Key terms

atmosphere

The layer of gases surrounding Earth.

hydrosphere

All water on, under, and above Earth's surface.

biosphere

All living organisms and the regions they inhabit.

greenhouse gas

A gas that absorbs and emits infrared radiation.

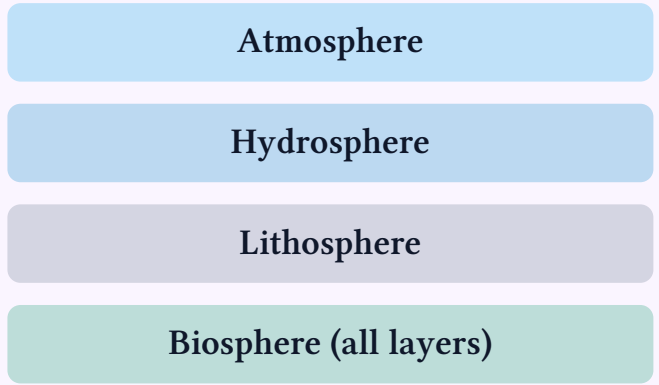
Key terms

greenhouse effect

Atmospheric warming caused by absorption and re-emission of infrared radiation.

Earth spheres

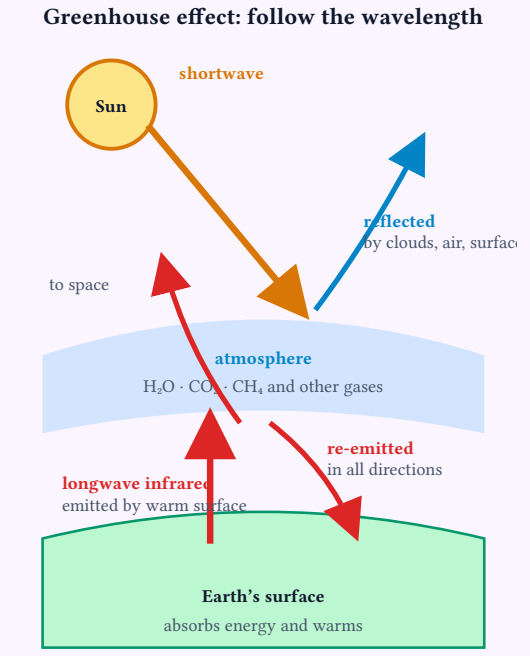
- Air, water, rock, and life trade materials.
- Water leaves a lake as vapour. Rock weathers into soil. Plants take in carbon.
- Draw the reservoirs and the arrows, and say which boundary you are using.
- A missing arrow is a missing transfer, and that matters.



reenhouse gases (H_2O, CO_2, CH_4) trap outgoing longwave radiatic

Greenhouse effect

- The surface absorbs sunlight and gives off infrared radiation.
- Carbon dioxide, methane, and water vapour absorb some of that infrared and emit it again.
- The planet warms until energy leaving matches energy absorbed.
- The effect is wavelength-specific. Calling it a blanket around Earth is only a rough comparison.



enhouse gases are not a solid lid; they absorb and emit infrared ener

An exchange between spheres

- Trace one matter transfer and one energy transfer through at least two Earth systems.
- A complete answer names the reservoirs, points the arrows the right way, and says the energy is slowed on its way out.

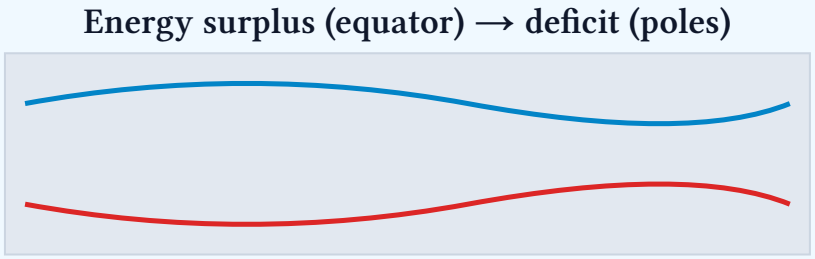
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Unit D: Energy flow in global systems

Global energy transfer and climate zones

Energy surplus at the equator

- Low latitudes receive more concentrated solar radiation on average than high latitudes.
- Atmospheric circulation and ocean currents move thermal energy toward higher latitudes.



Hadley, Ferrel, and polar cells redistribute heat

Energy transfer toward the poles

- Without air and ocean currents moving energy, the equator would run hotter and the poles colder.
- Moving air and moving water carry thermal energy toward higher latitudes.
- Show both paths on the diagram. Tomorrow’s local weather comes from a forecast; a climate zone describes the long-term pattern.

Key terms

latitude

Angular distance north or south of the equator.

atmospheric circulation

Large-scale movement of air driven by heating differences and Earth's rotation.

ocean current

Persistent movement of ocean water that transfers matter and energy.

energy surplus

A region or period where absorbed energy exceeds outgoing energy.

Key terms

energy deficit

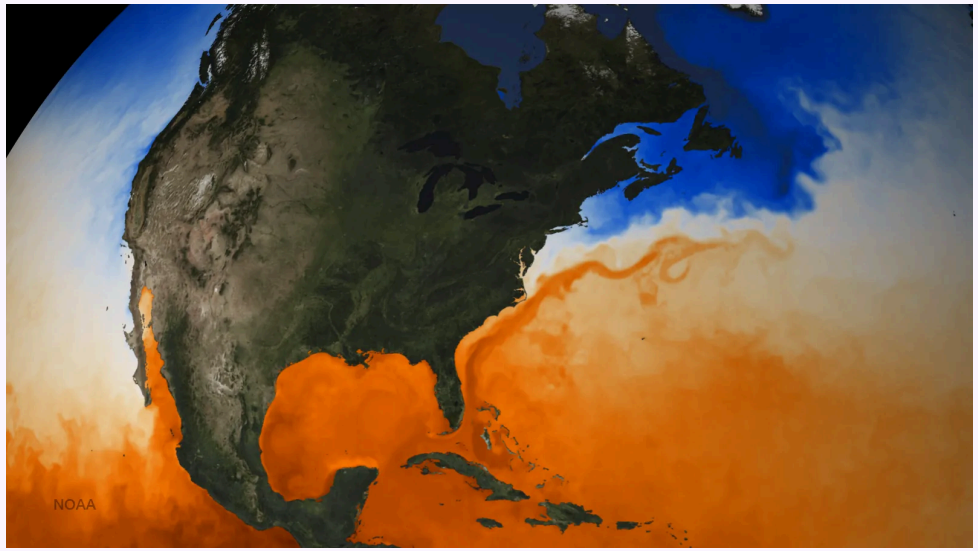
A region or period where outgoing energy exceeds absorbed energy.

Atmospheric transfer

- Low latitudes gain more solar energy than the poles, so air moves to even that difference out.
- Earth's rotation bends large-scale winds and helps set broad climate bands.
- A jet stream and a local storm are both moving air, at different scales.
- One day's weather can still disagree with the climate zone printed on the map.

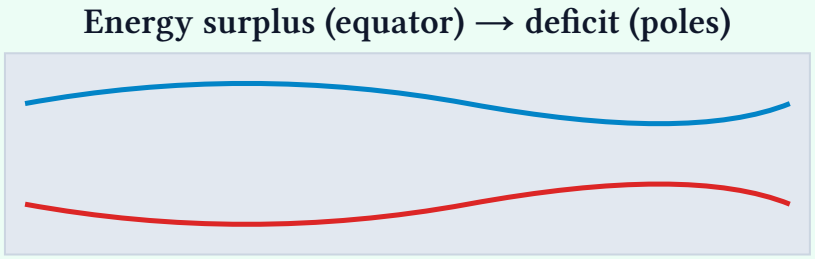
Ocean and climate

- Surface currents carry warm or cold water along coasts.
- Wind drives much of that surface flow. Temperature and saltiness help drive deeper flow.
- A coast can be milder than inland places at the same latitude.
- Currents move energy. The equator still gets extra energy and the poles still get less.



Surplus to deficit

- Annotate a world diagram with energy surplus, deficit, and two transport pathways.
- A complete answer shows the latitude pattern and arrows for both air and ocean transport.



Hadley, Ferrel, and polar cells redistribute heat

Image credits

NOAA, The Gulf Stream Seen Through Sea Surface Temperature (NESDIS 2016-06-03), public domain

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Factors affecting solar input

Winter shadows

- At a lower solar angle, the same incoming energy spreads over a larger surface area.
- Shorter winter days also reduce the time available for solar-energy input.

Angle of Sun	season, latitude, day length
Albedo	ice/snow reflect more than forest
Clouds and aerosols	scatter and absorb incoming solar radi

Axial tilt and seasons

- Earth’s tilt changes the solar angle and the length of the day.
- Axial tilt is the main cause of the seasons; distance from the Sun plays a minor part.
- A lower Sun spreads the same beam over more ground and sends it through more air.
- Name the mechanism, such as reflection or a longer path through the air.

Key terms

solar angle

Angle at which sunlight strikes a surface.

albedo

Fraction of incoming radiation reflected by a surface.

day length

Time between sunrise and sunset at a location.

aerosol

A small solid particle or liquid droplet suspended in air.

Surface solar energy

- A low Sun spreads the same beam over more ground.
- Longer days mean more hours of input.
- Bright surfaces reflect more. Clouds and particles can scatter or absorb.
- Seasons follow the tilt of Earth's axis. Earth's distance from the Sun barely changes them.

Angle of Sun	season, latitude, day length
Albedo	ice/snow reflect more than forest
Clouds and aerosols	scatter and absorb incoming solar radi

Factor and mechanism

- Match each factor to reflection, absorption, scattering, or how long the energy arrives.
- Name the physical mechanism. ‘It increases’ is a start; an explanation also names the cause.

Angle of Sun	season, latitude, day length
Albedo	ice/snow reflect more than forest
Clouds and aerosols	scatter and absorb incoming solar radi

Factor and mechanism

- Match each factor to reflection, absorption, scattering, or duration of input.
- A complete answer names a physical cause for the change.

Angle of Sun	season, latitude, day length
Albedo	ice/snow reflect more than forest
Clouds and aerosols	scatter and absorb incoming solar radi

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Uneven heating and phase changes

Sand and lake water cooling

- After sunset, dry land often changes temperature faster than a nearby large body of water.
- Equal energy input can produce different temperature changes because materials have different specific heat capacities.



Temperature and energy

- Temperature measures how fast particles are moving on average. It is only part of the energy change.
- The same mass and the same energy input can still produce different temperature changes in different materials.
- During a phase change, energy can go in while the thermometer stays still.

Key terms

specific heat capacity

Energy required to raise one unit mass of a substance by one degree Celsius.

phase change

A change of state without a change in chemical identity.

heat of fusion

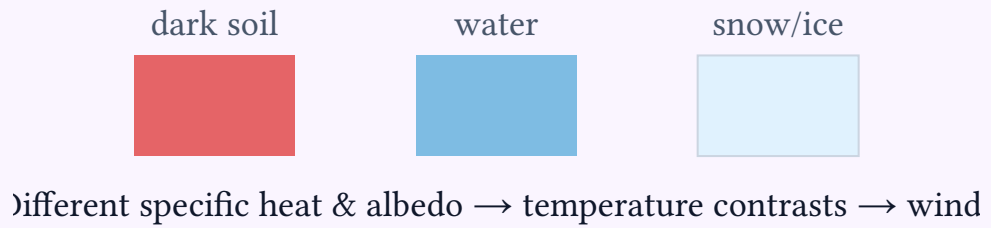
Molar energy required for melting at the melting point.

heat of vaporization

Molar energy required for vaporization at the boiling point.

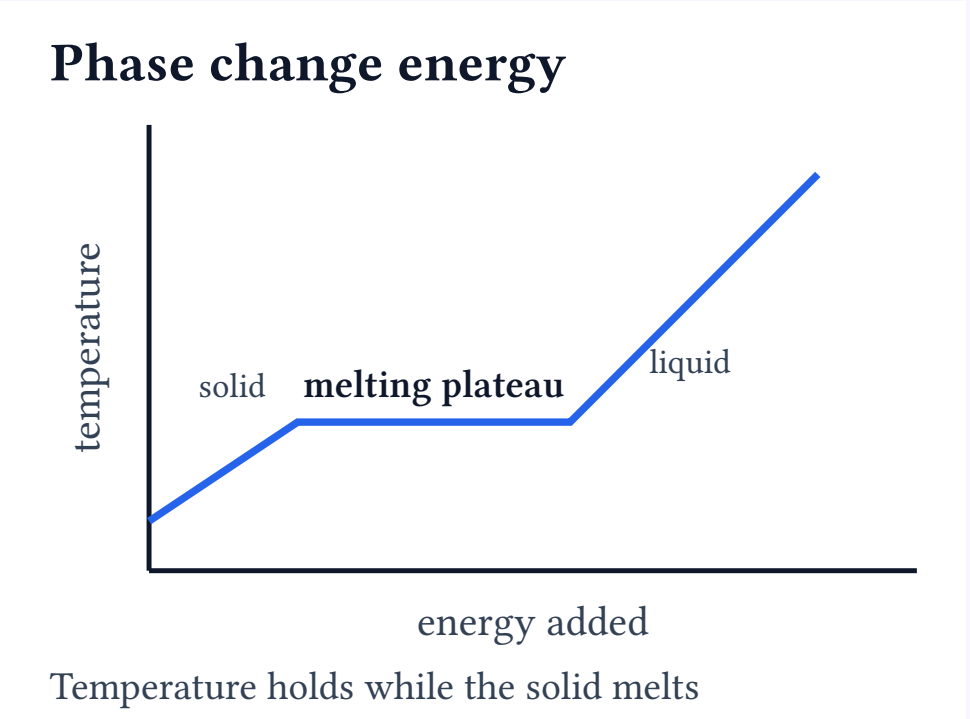
Uneven heating

- Sand and lake water warm by different amounts under the same sunshine.
- A material that warms quickly usually cools quickly too.
- Large lakes change temperature more slowly than nearby dry ground.
- Specific heat capacity is why equal masses can still diverge.



Phase change energy

- Melting ice can absorb energy while the thermometer stays at the melting point.
- Use a temperature-change calculation only while the substance stays in one state.
- Use a fusion or vaporization value when the state itself is changing.
- A full heating path may need both kinds of step, in order.



Temperature holds while the solid melts

Choosing an equation

- Decide whether a scenario uses $Q = mc\Delta t$, molar heat of fusion, or molar heat of vaporization and justify the choice.
- A complete answer names the process, the known quantities, the units, and whether temperature changed or a phase changed.

Image credits

CocoRoux, Sylvan Lake 2014 Beach, CC BY-SA 4.0

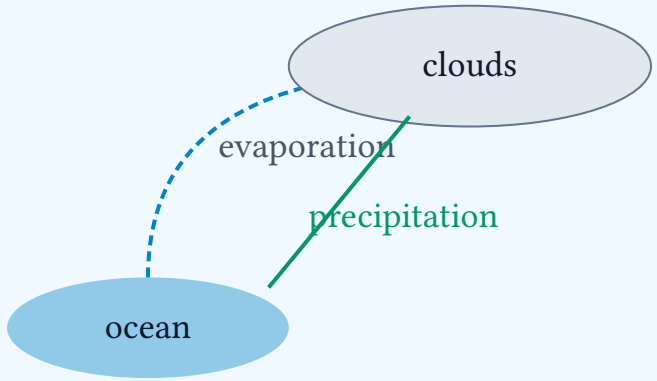
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Unit D: Energy flow in global systems

Hydrologic cycle and climate

Evaporation and condensation

- Evaporation requires energy and can cool the remaining liquid or surface.
- Condensation transfers energy to the surrounding air as water vapour becomes liquid.



ıanges move thermal energy through atmosphere, hydrosphere, b

Phase changes move energy

- A phase change moves energy as well as water.
- Evaporation takes energy from the surface. Condensation releases energy to the surrounding air.
- Name the phase and the direction of the arrow before you talk about the climate effect.

Key terms

evaporation

Change from liquid to gas at a surface.

condensation

Change from gas to liquid.

precipitation

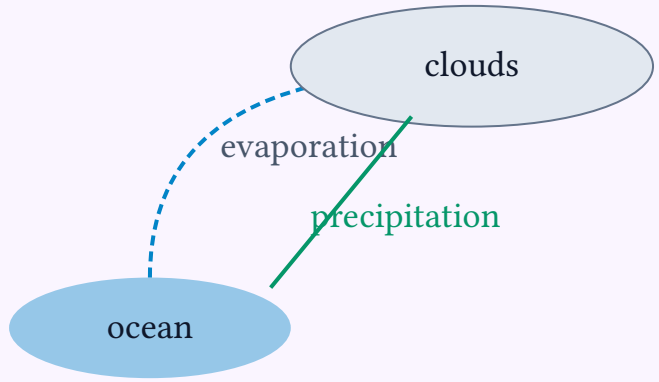
Water that falls from the atmosphere as rain, snow, sleet, or hail.

latent energy transfer

Energy absorbed or released during a phase change without temperature change during the transition.

Hydrologic cycle

- Sunlight evaporates water from oceans, soil, and organisms.
- Vapour travels, then returns as rain or snow.
- Rivers, groundwater, ice, and oceans hold water for very different lengths of time.
- Each change of state moves energy as well as water.



ıanges move thermal energy through atmosphere, hydrosphere, b

Climate link

- Evaporation cools the surface that lost the water.
- Condensation warms the air around the new droplets.
- Vapour can travel a long way before that energy is released.
- The water molecules are matter. The warming and cooling are energy transfer.



Water and energy arrows

- Label a water-cycle diagram with matter movement and energy absorbed or released.
- A complete answer names the phases, points the arrows, and shows energy absorbed at evaporation and released at condensation.

Image credits

Tomascastelazo, Large cloud over Mexican landscape, CC BY-SA 4.0

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Unit D: Energy flow in global systems

Biomes as open systems

Grassland boundaries

- Sunlight, water, organisms, gases, and nutrients cross any chosen biome boundary.
- Matter cycles within and across the boundary while energy flows through and leaves mainly as thermal energy.



Matter and energy exchange

- A biome includes its climate, soils, living communities, and the materials that cross its boundary.
- Matter and energy move between the biome and its surroundings.
- When you model a biome, name what cycles, what flows through, and what the climate allows to live there.

Key terms

biome

A large ecological region characterized by climate and typical communities.

open system

A system that exchanges matter and energy with its surroundings.

matter cycle

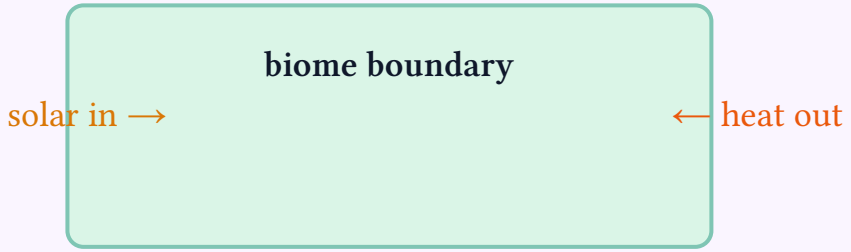
Repeated movement and transformation of matter among reservoirs.

energy flow

One-way transfer and transformation of energy through a system.

Biome inputs and outputs

- A biome boundary is a line people choose for study. Living things cross it freely.
- Light, water, gases, animals, and nutrients cross it.
- Matter can loop among soil, water, air, and organisms.
- Energy arrives mostly as sunlight and leaves mostly as heat.



Matter cycles; energy flows through: compare to cell open system

System inventory

- Choose a biome and draw the boundary you are studying.
- Sort four exchanges into inputs and outputs.
- Say which exchanges are matter, which are energy, and how the climate limits the community.

System inventory

- Choose a biome boundary and classify four exchanges as inputs or outputs.
- A complete answer names the boundary, separates matter from energy, and connects the exchanges to the climate.

Image credits

1brettsnyder, Aspen Parkland in Dry Island Buffalo Jump Provincial Park - panoramio, CC BY-SA 3.0

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Climatographs and biome comparison

Two annual patterns

- A climatograph combines monthly temperature and precipitation on one set of axes.
- Seasonal range and precipitation timing distinguish locations with similar annual averages.



Pair temperature and precipitation curves to classify biomes

Reading a climatograph

- On a climatograph, temperature is a line and precipitation is a set of bars. They use different units.
- A yearly average hides the coldest month and the month when the rain actually falls.
- Compare biomes using the shape of the whole year.

Key terms

climatograph

A graph of monthly average temperature and precipitation for a location.

temperature range

Difference between the highest and lowest values in a period.

annual precipitation

Total precipitation measured over one year.

biome

A large ecological region characterized by climate and typical communities.

Major biomes

- Grassland, desert, tundra, taiga, deciduous forest, and rain forest name broad living regions.
- Give the climate range, then ask what else could move the boundary: soil, fire, or elevation.
- Describe a biome with a range of temperatures and rainfall totals.



Pair temperature and precipitation curves to classify biomes

Climatographs

- Read the temperature line and the precipitation bars before you name a biome.
- A yearly total can hide a dry summer or a harsh winter.
- Compare the coldest month and the wettest months across the whole graph.
- The same biome name can show up where the climate pattern matches, even at another latitude.



Evidence-based biome match

- Compare two climatographs and justify a biome match with temperature and precipitation evidence.
- A complete answer uses values from both axes, describes the seasonal pattern, and rests on more than one measurement.

Image credits

CLS Research Office from Saskatoon, Canada, Quarry of the Ancestors Sep 2009 110, CC BY-SA 2.0

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Human actions and climate evidence

Climate change in two centuries

- Burning fuels, clearing land, and draining wetlands have changed what the air and the biomes do.
- The scientific question is how much of that change is caused by people and how much is natural variability.

- Fossil fuel combustion → CO_2
- Land-use change → CO_2, CH_4
- Ice cores & tree rings → past CO_2 & temperature

le independent lines of evidence support recent anthropogenic wa

Greenhouse gases and past climates

- Carbon dioxide and methane are greenhouse gases because they absorb and emit outgoing infrared radiation.
- Air bubbles trapped in ice cores preserve samples of past atmospheres, while layer chemistry helps reconstruct paleoclimate.
- Tree-ring width and density can date past growing conditions.
- One proxy is only part of the climate record.

Key terms

greenhouse gas

A gas that absorbs and emits infrared radiation in the atmosphere.

paleoclimate

Climate conditions from before instrumental records, reconstructed from proxy evidence.

ice core

A cylinder of ice whose layers and trapped gases preserve evidence of past atmosphere and climate.

dendrochronology

Study of annual tree rings to date events and infer past environmental conditions.

Human actions that change climate

- Burning fuels, draining wetlands, forest fires, and clearing forests all change how much carbon stays in the air or in the land.
- Tie each action to a measurement, such as emissions, ice loss, or sea level, before you call it a cause.

- Fossil fuel combustion → CO_2
- Land-use change → CO_2, CH_4
- Ice cores & tree rings → past CO_2 & temperature

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Paleoclimate archives

- Ice cores hold tiny samples of old air, so past carbon dioxide levels can be compared with temperature over thousands of years.
- Tree rings add a year-by-year record of wet and dry growing seasons from before thermometers existed.



Reading a climate graph

- Describe how atmospheric carbon dioxide has changed since industry expanded.
- Separate one unusual week of weather from a trend that lasts decades.

- Fossil fuel combustion → CO_2
- Land-use change → CO_2, CH_4
- Ice cores & tree rings → past CO_2 & temperature

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Alberta connections

- Forestry, farming, and energy production change land and emissions in different ways.
- A measurement can inform a decision. The decision still depends on what a community values.

- Fossil fuel combustion → CO_2
- Land-use change → CO_2, CH_4
- Ice cores & tree rings → past CO_2 & temperature

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Evidence triad

- Name three human actions that change climate, and one kind of evidence scientists use.
- A complete answer names greenhouse-gas emissions and land use, and uses ice cores or tree rings as evidence of past climate.

Climate evidence retrieval check

- Separate weather from climate in the claim: one cold winter disproves global warming.
- Name one direct modern record and two paleoclimate proxies.
- Climate also changed naturally in the past. Explain why human influence can still drive change today.

Image credits

Dargaud, Ice core extracted at Talos Dome showing an ash layer corresponding to the Toba eruption, CC BY-SA 4.0

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Unit D: Energy flow in global systems

Climate science and decisions

Decisions under uncertainty

- Alberta winters, farming, forestry, and northern communities feel climate variability.
- Science informs choices, and values and perspectives still shape them.



Decisions that cite evidence

- Name the evidence before you recommend a climate action.
- Say what is still uncertain, and who would live with the result.
- A transit proposal, for example, still needs emissions data and a list of people affected.

Key terms

Intergovernmental Panel on Climate Change

A United Nations body that assesses published research about climate change. (IPCC)

model

A simplified representation used to explain evidence, test ideas, or make predictions.

perspective

A viewpoint shaped by evidence, experience, responsibilities, and values.

stewardship

Responsible care and management of land, water, living systems, and resources.

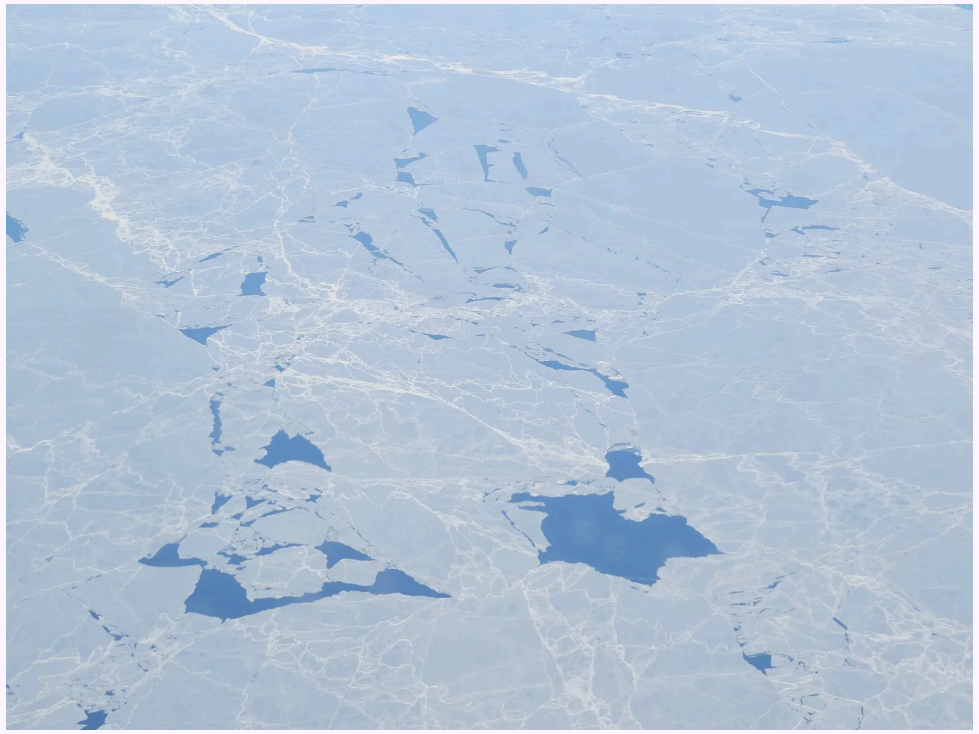
Key terms

biome

A large region with characteristic climate, plants, and animals.

Sensitive biomes and peoples

- Less Arctic ice changes habitats for species and for Indigenous societies that rely on ice for travel and hunting.
- Connect local observations to global energy balance studied earlier in Unit D: Energy flow in global systems.



Global collaboration in science

- Weather agencies, Global Atmosphere Watch, and the IPCC pool measurements and review one another's conclusions.
- Satellites and ground stations record greenhouse gases and changes at Earth's surface.



Limits of knowledge

- Predictions for agriculture, forestry, oceans, and shifting circulation all carry uncertainty.
- Good decisions state assumptions and what would change the conclusion.



Evaluating a proposal

- Take a proposal such as expanding public transit to reduce emissions from transportation.
- List the benefits, the risks, the evidence you still need, and who is affected before you choose.

Multiple perspectives

- Compare the Gaia hypothesis with Indigenous perspectives that see the land as a web of relationships.
- A decision should weigh economic, social, environmental, and cultural consequences together.

Structured debate

- Teams present a course of action to reduce greenhouse gases from goods and people transport.
- The audience should hear the evidence, the limits of the claim, and more than one perspective.

Position with evidence

- Groups defend one transport-emissions reduction strategy using two evidence sources and one limitation.
- A complete answer cites the data, says what is still uncertain, and takes more than one perspective seriously.

Course closure

- Before a final assessment, be ready to read a radiation budget and a biome climatograph again.
- This course connects chemical change, energy technologies, living systems, and the flow of energy across Earth.

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