The WATER CYCLE

WHERE'S OUR WATER?

Water exists as:
- *Liquid*
- *Solid*
- *Gas*

Hydrosphere – *Oceans 96.5% of the total water – salty! Also water in lakes, rivers and wetlands.*

Lithosphere – *soil water and groundwater – almost a third of our fresh water*

Earth's water

Atmosphere – *water vapour and clouds – the amount is tiny at 0.001% of the total water on Earth!*

Cryosphere – *snow, ice and permafrost – over two thirds of our fresh water*

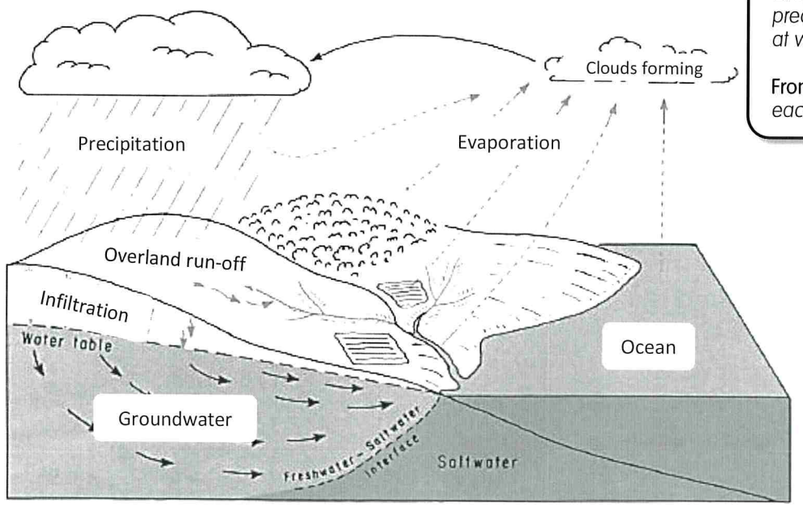
Water can go from liquid to gas (evaporation), gas to liquid (condensation), ice to gas (or gas to ice) – sublimation, freeze to ice and melt back into liquid water.

ARE WE CHANGING THINGS?

Humans are emitting greenhouse gases – resulting in climate change. The stores of water (and also the flows) are changing – for example, decrease in ice which increases the store within the oceans. Warmer air can hold more water – so humidity and cloud cover could increase.

THE WATER CYCLE AT THE HILLSLOPE LEVEL

- **Evaporation:** *The Sun provides energy – to* **evaporate** *water from the oceans, from the land surface, and from vegetation.*
- **Condensation:** *The water vapour rises and* **condenses** *to form clouds and, therefore, precipitation.*
- **Precipitation:** *The precipitation falls on the land – some is* **intercepted** *by trees (some will drip off to the ground or run down the trunks as* **stemflow**, *and some will evaporate). Some will* **infiltrate** *into the soil and eventually* **percolate** *into rock to form the groundwater below (flowing underground). Some will flow through rivers and eventually flow into stores, such as lakes, and eventually the ocean.*
- **Transpiration:** *Trees and vegetation* **transpire** *– water flows through the plants from the soil into the air.*
- *We can see that many of these are stores and flows!*



WHAT ARE SYSTEMS?

Inputs

Stores (components) and flows (transfers) and processes

Outputs

Most systems are driven by the Sun. Systems are either **open** *or* **closed**.

Open systems *have* **inputs and outputs of energy and material**. **Closed systems only transfer energy** *in and out.*

The water cycle is a closed system overall, but small-scale drainage basins are open systems.

There are four linked open systems – the atmosphere, the hydrosphere (water), the lithosphere (rock) and the biosphere (living world).

If the **inputs and outputs are balanced**, *the system is in a state of* **dynamic equilibrium**.

Processes called **feedback** *change the equilibrium –* **positive feedback** *pushes the system* **away** *from the previous equilibrium and* **negative feedback** *restores the system* **back** *towards the previous equilibrium.*

WHY DOES IT RAIN?

Condensation: *When air rises it expands and cools, and the water vapour condenses (around condensation nuclei) to form clouds and eventually precipitation.*

Orographic: *Air rises over mountains (orographic/relief precipitation), due to the heat of the ground (convectional) and at warm/cold fronts (frontal).*

Frontal: *You get different types of rainfall and precipitation at each type – the faster the air rises, the heavier the rainfall.*

SYNOPTIC GEOGRAPHY

Hot deserts, coasts and glacial: *How could processes change?*
Hazards: *how could storms/wildfires change?*
Ecosystems: *how could marine ecosystems be affected?*
Urban climate: *changes to urban rainfall.*
Population, health and well-being: *spread of disease, limits to growth.*
Resources: *water security.*

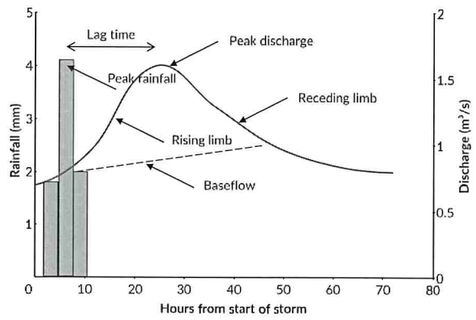
THE WATER BALANCE (BUDGET)

- *We can calculate the water balance of both catchments and the soil. We use the equation:*
  Precipitation = discharge + evaporation ± storage change
- **The soil moisture budget** *changes throughout the year based on changes in precipitation, potential evaporation and the uptake from plants. In the UK, rainfall is highest in the autumn and winter, when soil moisture and groundwater recharges. In the summer, potential evaporation is highest, and plants are using lots of water!*
- **River flow** *also changes throughout the year – called the regime. When it rains, water travels to the channel via the surface. When it doesn't rain, rivers flow because of their base flow – from the soil and groundwater. Some rivers dry up entirely in the summer.*

THE FLOOD HYDROGRAPH

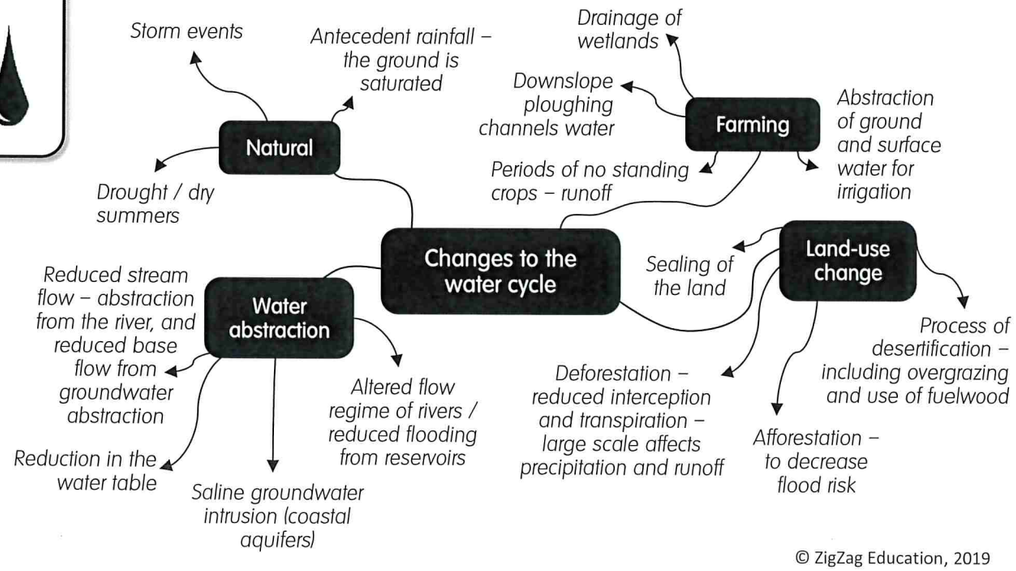
A representation of river flow – how the river flow changes after precipitation.

- **Natural factors:** *If the river responds quickly to precipitation – high peak flow and short lag time – we say that the hydrograph is 'flashy'. The hydrograph may be flashy due to natural factors, based on the shape, size, relief and geology of the drainage basin.*

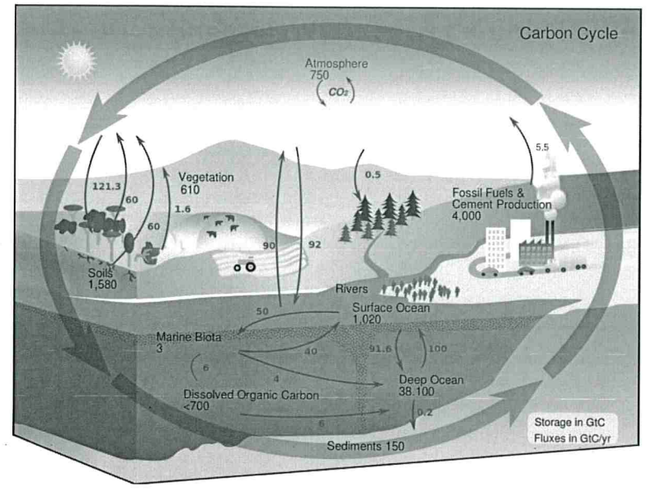


- **Human factors:** *humans can also cause a hydrograph to become flashy – through land-use change, urbanisation, farming practices and deforestation.*

A city increases in size → *Trees are cut down and the land is sealed off* → *Water cannot infiltrate into the ground, interception is reduced* → *Urban surfaces an drains directly into rivers* → *River levels quickly rise as flow increases* → *Flooding results as the rivers overtop*

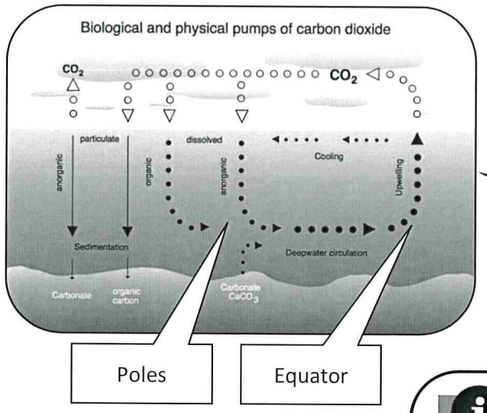


The CARBON CYCLE



THE FAST AND SLOW CARBON CYCLES

- *Carbon can either be organic (from living things), or* **inorganic** *– from rock.*
- *The carbon cycle is a continuous* **process**.
- *There are essentially two carbon cycles – the* **fast** *carbon cycle (months to years) and the* **slow** *carbon cycle (hundreds of years to millennia).*
- *The fast carbon cycles transfer CO_2 between the oceans and* **atmosphere** *(oceanic inorganic carbon pump), and living things quickly store and release carbon.*
- *The slow carbon cycle includes the formation of* **rock**, *including burial and compaction of ocean sediments, and the release of CO_2 from the mantle to the atmosphere by volcanic activity.*
- **Humans** *are very good at altering the carbon cycle.*



PROCESSES WITHIN THE CARBON CYCLE

- **Photosynthesis** *is the process where green plants and phytoplankton use sunlight to convert CO_2 and H_2O into glucose and O_2 – to produce biomass and for respiration – this is* **sequestration**.
- **Respiration** *is essentially the reverse of photosynthesis – plants and animals release energy in the process, along with CO_2.*
- **Decomposition:** *When living things die, their biomass is broken down by* **decomposers**. *Much of the material is respired if there is enough oxygen, but CH_4 is produced in limited oxygen. Not all matter is decomposed – becoming soil humus.*
- **Combustion** *releases stored biomass into the atmosphere – e.g. from trees and plants through wildfires.*
- **Weathering –** *the breakdown of carbonate rock by acidic rainwater which release bicarbonate ions – to later re-form limestone.*

CHANGES TO THE CARBON CYCLE

- *Humans are releasing huge amounts of CO_2 through land-use change, deforestation, and fossil fuel combustion (transport, cooking, and electricity). This dwarfs volcanic activity.*
- *Farming releases CH_4 through livestock and rice farming, and CO_2 from ploughing.*
- *Humans are also increasing the number of wildfires – both deliberately (through rainforest clearance, poaching) and accidentally.*
- *Deforestation releases the carbon stored as biomass.*
- *As population grows and countries develop, the pressures on the land and resources increase!*

SYNOPTIC GEOGRAPHY

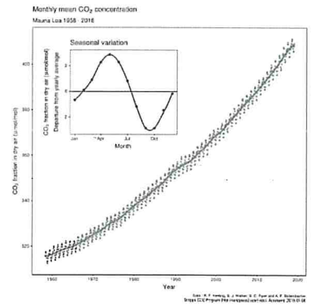
Hot deserts, coasts and glacial: *how could processes change?*
Antarctica: *how could climate change increase vulnerability?*
Urban climate: *the urban heat island.*
Population, health and well-being: *spread of disease, limits to growth.*
Resources: *energy security and the use of fossil fuels and renewables.*

THE CARBON BUDGET

The difference between inputs and outputs. Change from natural processes to human changes. Humans are changing the stores and fluxes – decreased stores of fossil fuels – increased atmospheric and dissolved oceanic carbon.

Changing the budget can have feedback loops (+ve and -ve).

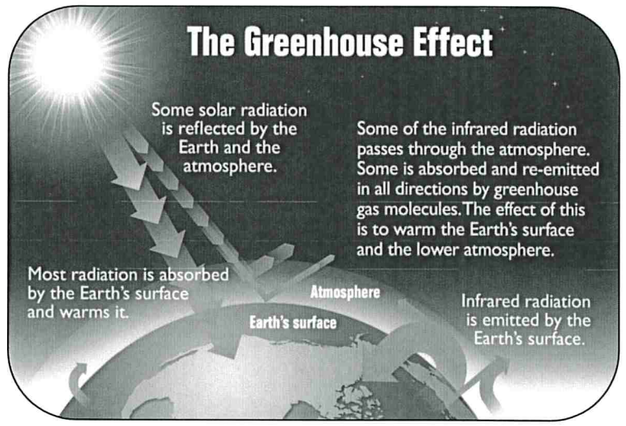
Land:
More CO_2 = more plant growth -> decrease in CO_2 (-ve feedback)
More CO_2 = melting of permafrost -> release of methane (+ve feedback)
Knock-on effects on weather and droughts, agriculture, and ecosystems.



Oceans:
Thermal expansion and melting land ice cause sea level to rise. Acidification from dissolved CO_2 – coupled with increased temperatures – is disastrous for coral reefs. Reduced albedo from melting ice -> decreases albedo -> more warming (+ve feedback).

THE ENHANCED GREENHOUSE EFFECT

- *Gases such as CO_2 and CH_4 are greenhouse gases. They warm the planet by reabsorbing outgoing radiation and re-emit the radiation in all directions.*
- *The greenhouse effect is a natural process, but we're increasing the concentration of greenhouse gases – that's why it's the enhanced greenhouse effect. We're causing radiative forcing: the difference between incoming and outgoing radiation.*



WHERE'S THE CARBON?

Hydrosphere – *dissolved CO2 in oceans, and living animals and plants within the oceans*

Lithosphere – *carbonate rocks, fossil fuels (kerogens) and marine sediments*

Earth's carbon

Atmosphere – *gaseous CO2 – from natural and human sources*

Biosphere – *living plants and animals, soil litter and soil organic carbon, and peat*

Cryosphere – *organic matter locked up in permafrost – frozen ground*

Stores *of carbon are measured in gigatonnes.* **Sinks** *absorb more than they emit, sources of carbon release the carbon faster than they absorb carbon.*

*The movement between the stores (***fluxes***) is measured in gigatonnes per year.*

Atmospheric CO_2 is measured in ppm – parts per **million**.

WHAT ARE SYSTEMS?

Inputs

Stores (components) and flows (transfers) and processes

Outputs

Most systems are driven by the Sun. Systems are either **open** *or* **closed**.

Open systems *have* **inputs and outputs of energy and material**. **Closed systems only transfer energy** *in and out.*

The water cycle is a closed system overall, but small-scale drainage basins are open systems.

There are four linked open systems – the atmosphere, the hydrosphere (water), the lithosphere (rock) and the biosphere (living world).

If the **inputs and outputs are balanced**, *the system is in a state of* **dynamic equilibrium**.

Processes called **feedback** *change the equilibrium –* **positive feedback** *pushes the system* **away** *from the previous equilibrium and* **negative feedback** *restores the system* **back** *towards the previous equilibrium.*

REDUCING OUR IMPACT

There are strong links between the water and carbon cycles, and both are vital for life on Earth. We're causing changes, and we need to limit the effects because of the positive feedback cycles that warming has.

For example, we can:
- ✓ *Increase our use of renewable electricity generation, and use alternative or more efficient transport.*
- ✓ *Reduce CO_2 emissions by using CCS – carbon capture and storage.*
- ✓ *Reduce emissions from land-use change and agriculture – less cattle farming and less ploughing.*
- ✓ *Reduce emissions globally – international trading schemes (e.g. Paris and Kyoto agreements), with implementation at both national and local levels.*