JustTeach

A-LEVEL GEOGRAPHY RESOURCE FILE

Water & Carbon Cycles

Tim Bayliss | Simon Ross

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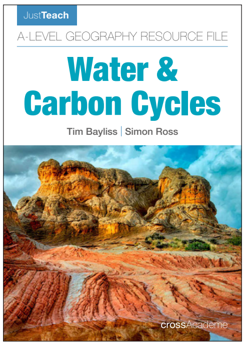

Series Editor: Simon Ross

Water & Carbon Cycles

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TOPIC 1

Lesson ideas for teachers

The systems approach

The water and carbon cycles are best understood through a systems approach and students need to understand this important concept in physical geography.

Resource 1 describes the systems approach and introduces students to the concept of open and closed systems. Students will mostly be concerned with the functions of open systems, so they need to be familiar with a number of key terms, such as inputs, outputs, stores, flows, processes and feedbacks. These are defined in Resource 1.

Student activities

1. Students could draw their own version of Figure 1 in Resource 1 using the information in the text to add annotated labels describing the different aspects of a system.
2. Students could consider the value of a systems approach in understanding the water balance and budgeting for water usage.

Equilibrium and feedback

Open systems tend to adjust themselves to flows of energy and/or matter by modifying the interrelationships between different elements of the system, so that input and output flows balance each other out, resulting in a steady state for the system, known as dynamic equilibrium. This kind of adjustment is a type of self-regulation, and much of physical geography can be understood in part as the study of self-regulating systems.

The concept of feedback is probably one of the most important aspects of systems theory. It is critical that students understand it. Feedback occurs when one element of a system changes because of an outside influence. This will upset the dynamic equilibrium, or state of balance, and affect other components in the system. As Resource 2 explains, it is possible to identify positive and negative feedbacks; both have the potential to trigger significant change within physical systems.

Student activities

3. Using Resource 2, Figure 2, students could explain how a negative feedback cycle operates and why it may promote dynamic equilibrium. Students could be asked to consider the operation of negative feedbacks in other natural systems, such as coastal systems.
4. Using Resource 2, Figure 3, students could explain how a positive feedback cycle can result in significant and possibly dramatic change in the Arctic (see also Resource 4).

Lesson ideas for teachers (continued)

Global physical systems

Finally, in terms of global geographical systems, students should be able to identify the basic characteristics of, and connections between, the four major physical subsystems of the Earth – the, atmosphere, biosphere, hydrosphere and lithosphere.

Student activity

5 With reference to Resource 3, Table 1, students could work in pairs or small groups to suggest connections between the four major physical subsystems.

Sea ice near Kulusuk, Greenland

Students should be aware of the trend in recent years of a decline in the Arctic sea ice winter maximum, as illustrated with alarming clarity by iconic NASA satellite images. This photograph can be used to introduce to students the various aspects of systems theory such as inputs, outputs, transfers and feedbacks.

Student activity

6 Students could attempt to apply systems theory and terminology to the photograph by adding labels and annotations.

Resources

1 The systems approach

2 Equilibrium and feedback

3 Global physical systems

4 Sea ice near Kulusuk, Greenland

Online materials

1 An introductory presentation on systems:
https://prezi.com/waun8urselvh/water-and-carbon-cycles-as-natural-systems/

2 A summary of the main features of the atmosphere:
http://nationalgeographic.org/encyclopedia/atmosphere/

3 A summary of the main features of the biosphere:
http://nationalgeographic.org/encyclopedia/biosphere/

4 A summary of the main features of the hydrosphere:
http://nationalgeographic.org/encyclopedia/hydrosphere/

5 A summary of the main features of the lithosphere:
http://nationalgeographic.org/encyclopedia/lithosphere/

The systems approach

A **systems approach** helps us to consider the 'whole picture' by understanding the components and transfers of the physical and human world around us. Such an approach enables us to consider interrelationships and to comprehend the causes and impacts of change caused by both internal and external factors.

It is possible to identify **open** and **closed** systems. Considered in their entirety, the water and carbon cycles are both closed systems in that there are no inputs (gains) or outputs (losses). However, at a more local scale – say, a river basin or a forest – they can be considered as open systems, with both inputs and outputs transferring energy and matter beyond the system's boundary (see below).

There are several key concepts in the understanding of a systems framework:

- **Inputs** – the movement of energy or materials into a system from outside;
- **Outputs** – the movement of energy or materials out of a system;
- **Stores** – the amount of the total material held within parts of the system. For example, soils are a major store of carbon within the terrestrial carbon system. These stores are usually expressed in units of mass. For example, the total global soil carbon storage is estimated at 1500–2400 PgC (petagrams of carbon). One petagram is equal to one quadrillion grams, or one trillion kilograms!
- **Flows** (or **fluxes**) – the transfers of energy or material between the stores. When measured, they are commonly expressed as Pg per year;
- **Processes** – the physical mechanisms that drive the flows of energy and material between stores. For example, one of the key processes that drive the flux of carbon from the atmosphere to the vegetation store is photosynthesis;
- **Feedback** – the return 'loop' where the outputs and consequences have a positive or negative impact on the inputs, altering the subsequent operation of the system (see Resource 2 for more detail).

The water balance – an example of a systems approach

The use of systems enables us to quantify stores and transfers and to establish a 'budget' for the system as a whole. An example of this is creating a **water balance** for a drainage basin where we measure inputs (rainfall) and losses (evaporation and runoff) of water from the catchment. More detailed understanding of the system requires understanding of the internal processes that produce throughputs in the system. For example, to understand the runoff from a catchment, we might study the role of rainfall infiltration into the soil and the way in which it becomes either soil water storage or runoff.

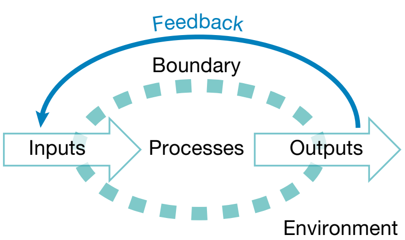

Figure 1 *Basic elements of an open system*

Equilibrium and feedback

Open systems tend to adjust themselves to flows of energy and/or matter by modifying the interrelationships between different elements of the system. In many natural systems, this leads to a balanced steady state known as **dynamic equilibrium** where the inputs and outputs balance one another. This kind of adjustment is a type of self-regulation, and much of physical geography can be understood in part as the study of self-regulating systems.

Feedback is probably one of the most important aspects of systems theory, and understanding it is crucial. Feedback occurs when one element of a system changes because of an outside influence. This will upset the dynamic equilibrium, or state of balance, and affect other components in the system.

- **Negative feedback** occurs when a **system** acts by lessening the effect of the original change and ultimately reversing it. Figure 2 illustrates a negative feedback cycle starting with a slight increase in surface temperature, say as a result of climate change, which eventually corrects itself.

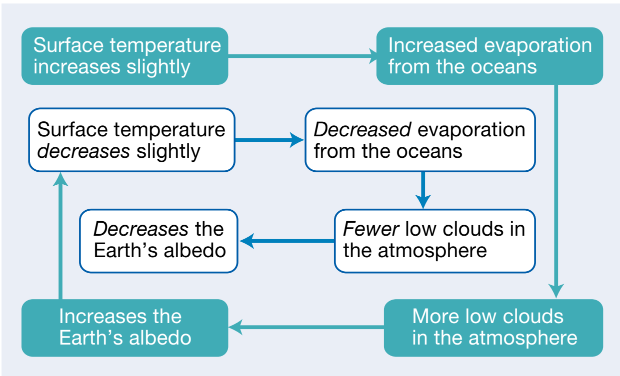

Figure 2 *A negative feedback cycle*

- **Positive feedback** occurs within a **system** where an initial change causes a further, or snowball, effect, continuing or even accelerating the original change. Figure 3 illustrates a positive feedback cycle, also initiated by an increase in surface temperature.

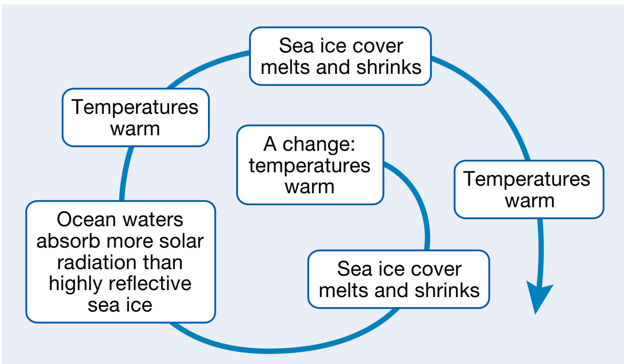

Figure 3 *A positive feedback cycle in the Arctic*

Global physical systems

Component	Characteristics
Atmosphere	▪ A mixture of transparent gases held to the Earth by gravitational force. It mainly consists of nitrogen (78.09%) and oxygen (20.95%) by volume. Other gases include argon, carbon dioxide and traces of hydrogen, neon, helium, krypton, xenon, ozone, methane and radon. ▪ The upper limit is assumed to be 1000 km, but, due to gravity and compression, most of the atmosphere is concentrated near to the Earth's surface. ▪ About 50% of the atmosphere's mass lies within 5.6 km of the surface and 99% within 40 km. ▪ Most of our climate and weather processes operate within 16–17 km of the surface in the zone of the lower atmosphere known as the **troposphere**. ▪ Carbon dioxide absorbs long-wave radiation from the Earth (the **greenhouse effect**) and is important in plant photosynthesis.
Biosphere	▪ Comprises those parts of the Earth's surface and atmosphere where living organisms exist. It is the worldwide sum of all ecosystems. ▪ The biosphere extends from root systems of trees, to the dark environment of ocean trenches, to dense rain forests and relatively barren high mountain summits. It extends to heights of up to ten kilometres above sea level, used by some birds in flight. ▪ The vast majority of species of animals, fungi, parasitic plants and many bacteria depend directly or indirectly on photosynthesis.
Hydrosphere	▪ This is the total amount of water on the planet. ▪ The hydrosphere includes water that is on the surface, underground and in the air. It can be in the form of liquid, vapour or ice. ▪ Liquid water exists on the surface in the form of oceans, lakes and rivers. It also exists below ground – as groundwater, in wells and aquifers. ▪ Water vapour is most visible as clouds and fog. ▪ The frozen part of the Earth's hydrosphere (**cryosphere**) is made of ice: glaciers, ice caps and icebergs.
Lithosphere	▪ The lithosphere includes the crust and the upper mantle – the outermost 'layer' of the Earth's structure. ▪ Tectonic processes such as earthquakes and volcanic eruptions are active within this subsystem.

Table 1 *Characteristics of the atmosphere, biosphere, hydrosphere and lithosphere*

Sea ice near Kulusuk, Greenland

Student questions

The systems approach

1. Study Figure 1 in Resource 1, which illustrates the systems approach concept. Make a copy of the diagram and, using the information in the text, add detailed labels and annotations to describe the different aspects of the system.
2. Consider the value of a systems approach in understanding the water balance and budgeting for water usage.

Equilibrium and feedback

3. Study Figure 2 in Resource 2. Explain how a negative feedback cycle operates and why it may promote dynamic equilibrium. Consider the operation of negative feedbacks in other natural systems, such as coastal systems.
4. Study Figure 3 in Resource 2. Explain how a positive feedback cycle can result in significant and possibly dramatic change to physical systems.

Global physical systems

5. Work in pairs or small groups to suggest connections between the four major physical subsystems.

Sea ice near Kulusuk, Greenland

6. Use annotated labels to apply systems theory and terminology to the photograph in Resource 4.