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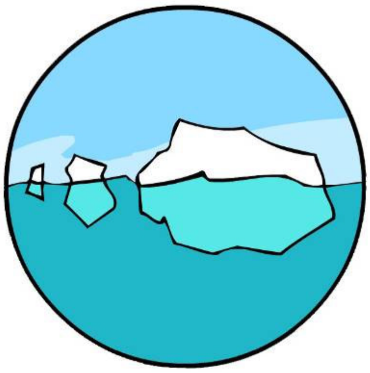

Water and Ice on Earth

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Theoretical note

Distribution of water and ice

When it was first created, the Earth was endowed with 1 400 million km^3 of water. This volume has not changed since that time. Water can be found in three forms: liquid, gas (steam or water vapour) and solid (ice and snow).

However, despite this immense overall volume of water, fresh water is rare, because 97.5% of all of the water found on Earth is saltwater.

Water is distributed between 5 interconnected reservoirs:

• **Oceans**;	*Saltwater* (97.5%: 1 385 $\times 10^{15}$ m^3)
• **Snow and ice deposits** (ice caps and glaciers); • **Land water** (rivers and streams, lakes, underground water, moisture in the soil); • **The biosphere** (plants and animals); • **The atmosphere** (water circulating in the evaporation-precipitation cycle).	*Fresh water* (2.5%: 36 $\times 10^{15}$ m^3)

Fresh water is a rare commodity. What's more, a large proportion of it is trapped in ice caps and glaciers. In particular, the Antarctic contains approximately 90% of the ice on land, or 70% of all the fresh water on Earth. Fresh water that is not frozen can be found mainly in underground water then, in descending order, in lakes, moisture in the soil, the atmosphere, rivers and streams and, finally, in living organisms.

The bottom line is that the amount of fresh water available for humans represents just 0.3% of all of the water on Earth. This water is found in waterways, lakes, rivers, streams and in shallow *phreatic* deposits of water.

The water cycle

On Earth, water is found in solid, liquid and gaseous form. Water has been evaporating, condensing and precipitating in a continuous cycle for the past billion years.

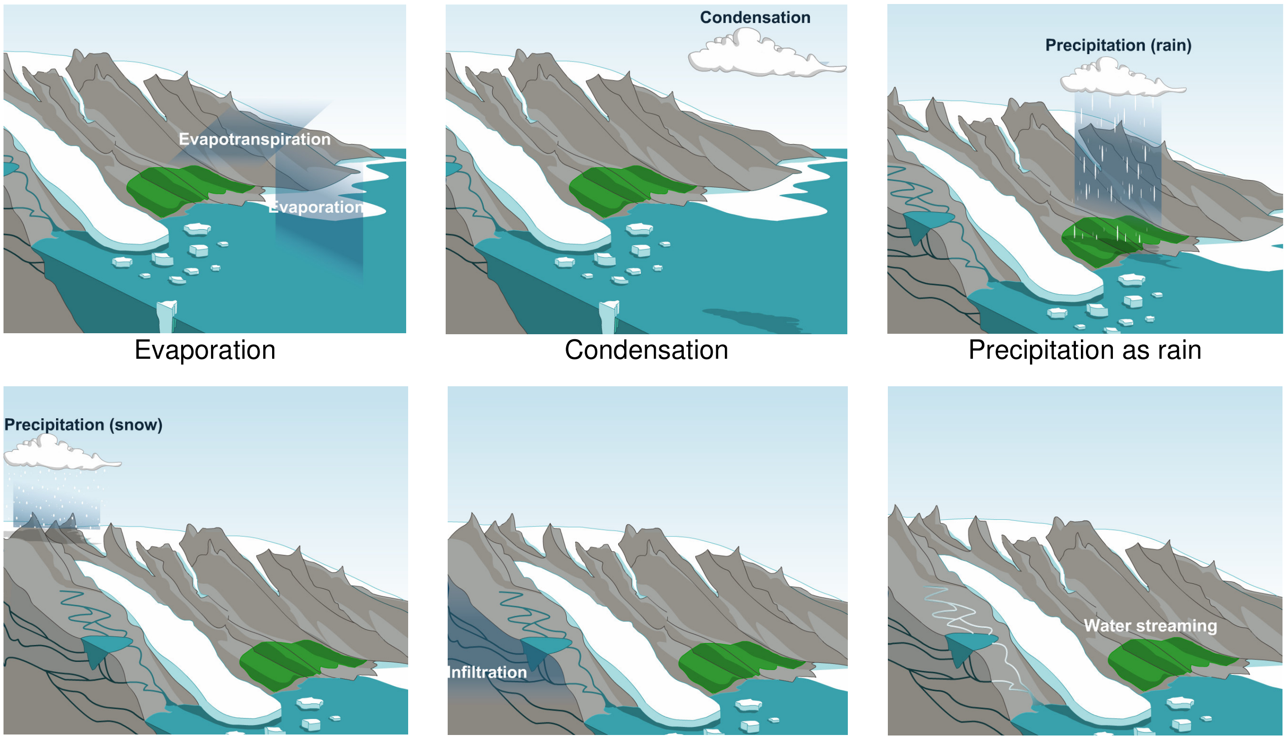
The action of the sun makes water evaporate from the oceans, lakes and all expanses of water. Added to this water vapour contained in the air is the water vapour produced by plants: *evapotranspiration*.

Air is only capable of holding a limited quantity of vapour. This amount is reduced when the temperature and atmospheric pressure are low. At altitude, the excess vapour condenses round particles of dust suspended in the air to form clouds. So, clouds are not made up of water vapour, but of drops of water held in suspension.

With the action of the wind, these clouds move. When they are over the continents and the oceans, clouds cause precipitation in the form of rain, snow or hail, depending on the temperature of the air.

The water released in this way will then follow various routes that all lead, at lesser or greater speeds, back to the oceans.

When rain falls on the land, part of the water percolates into the soil and joins the phreatic deposits below the ground. Another part of the water ends up in ice caps and will finish its cycle as icebergs. The final part of the rain runs over the surface of the land, feeding streams, small rivers and then major rivers, before returning to the oceans and seas.



Evaporation | Condensation | Precipitation as rain

Precipitation as snow | Percolation | Run-off

Figure 1– The various stages in the water cycle[1]

Ice in its various forms

The *cryosphere* designates all of the areas on the surface of the planet where water is found in its frozen form. Land ice, or ice that originates on land, should be distinguished from sea ice:

Land ice, or ice that originates on land

This ice is made from fresh water.

- The great ice caps or *"inlandsis"* of the Antarctic and Greenland;
- Small icecaps, such as in Iceland and the Canadian Arctic;
- Mountain glaciers;
- The enormous platforms of floating ice attached to the coast of Antarctica: ice-shelves;
- The icebergs that become detached from the ice-shelves and some glaciers;
- Frozen water in the ground of Arctic tundra: *permafrost*;
- Water frozen in winter on the surface of lakes and rivers;
- Seasonal expanses of snow.

[1] All of the illustrations in this file are taken from animations at the Educapoles website: www.educapoles.org

Sea ice

The sea ice (also known as pack ice) can be permanent or seasonal. Made from seawater, this ice is salty, although its salt concentration diminishes over time.

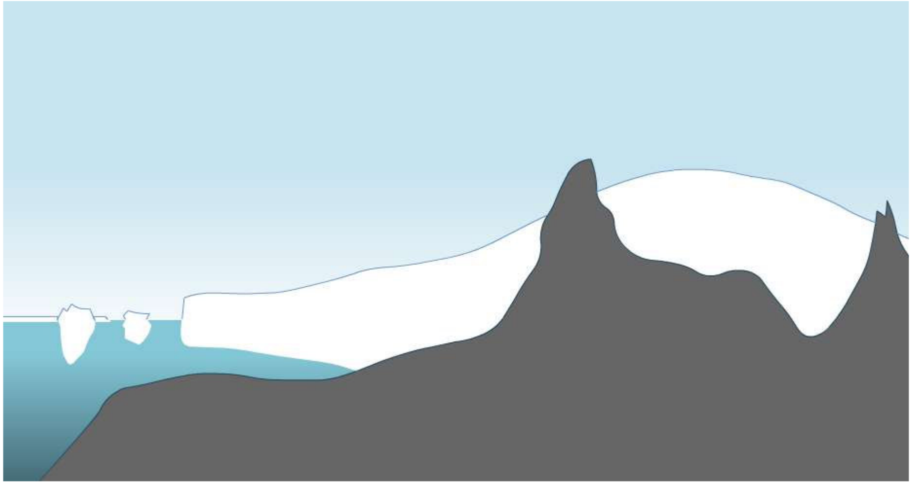


Figure 2 – Cross-section of the Antarctic: sea ice, icebergs, ice shelf, glacier, inlandsis (from left to right).

Icecaps

An icecap is a thick layer of ice that covers a rocky base. Overall, an icecap is dome-shaped at the top, rather than flattened. Icecaps are formed by the accumulation of snow falling over tens of thousands of years.

The two largest icecaps are called *inlandsis*. These icecaps cover the Antarctic and Greenland. There are also much smaller icecaps, such as in Iceland and the Canadian Arctic. However, even the *inlandsis* in Greenland is dwarfed by the 2 immense Antarctic icecaps which, put together, are bigger than Europe (14 million km^2, or 25 times larger than France).

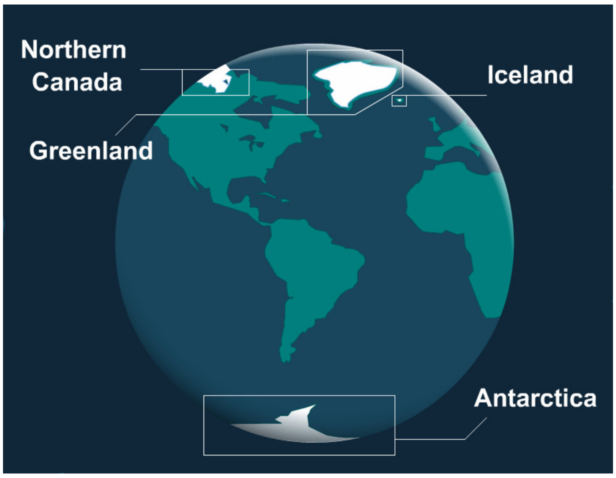


Figure 3 – The icecaps.

In cold regions that have a continental base, any snow that falls does not melt and instead accumulates year after year. The snow crystals are compacted under the weight of the upper layers and the permanent compacting of the snow gradually turns it into ice. In the end, an icecap is created.

On the surface of the icecap (or glacier), there is fresh snow that has just fallen. Then, deeper down, the *névé*, i.e. the compacted snow. Deeper still comes pure ice – i.e. snow that has become so compacted that the air bubbles have become virtually invisible.

As a result, the ice in glaciers and icecaps is not frozen water (as you would find in a freezer), but compacted snow.

The Antarctic icecap and the surrounding ocean act like an immense conveyor belt:

- Water evaporates above the ocean;
- Precipitation falls on to the continent in the form of snow;
- The snow builds up, compacts and is converted into ice. It then moves little by little towards the edge of the icecap, where *outlet glaciers*, acting like rivers, channel and accelerate the movement of the ice towards the ocean;
- This network of glaciers feeds enormous coastal platforms of floating ice: *ice-shelves*;
- Chunks of ice break off regularly from end of these ice-shelves. These are called *icebergs* and they melt gradually as they drift into warmer waters – and the whole cycle begins again.

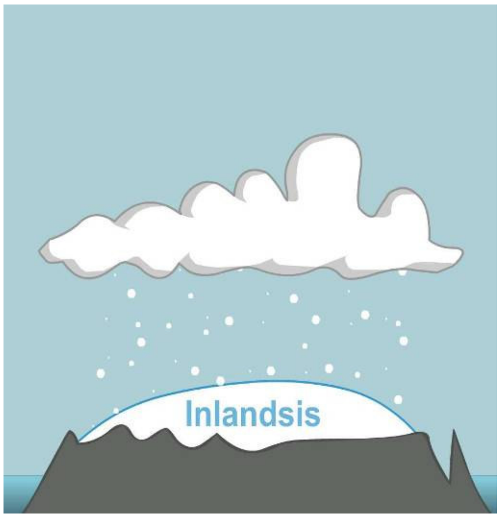


Figure 4 – Formation of an inlandsis

It takes 800 000 years for the snow that falls at the South Pole to find its way back to the ocean.

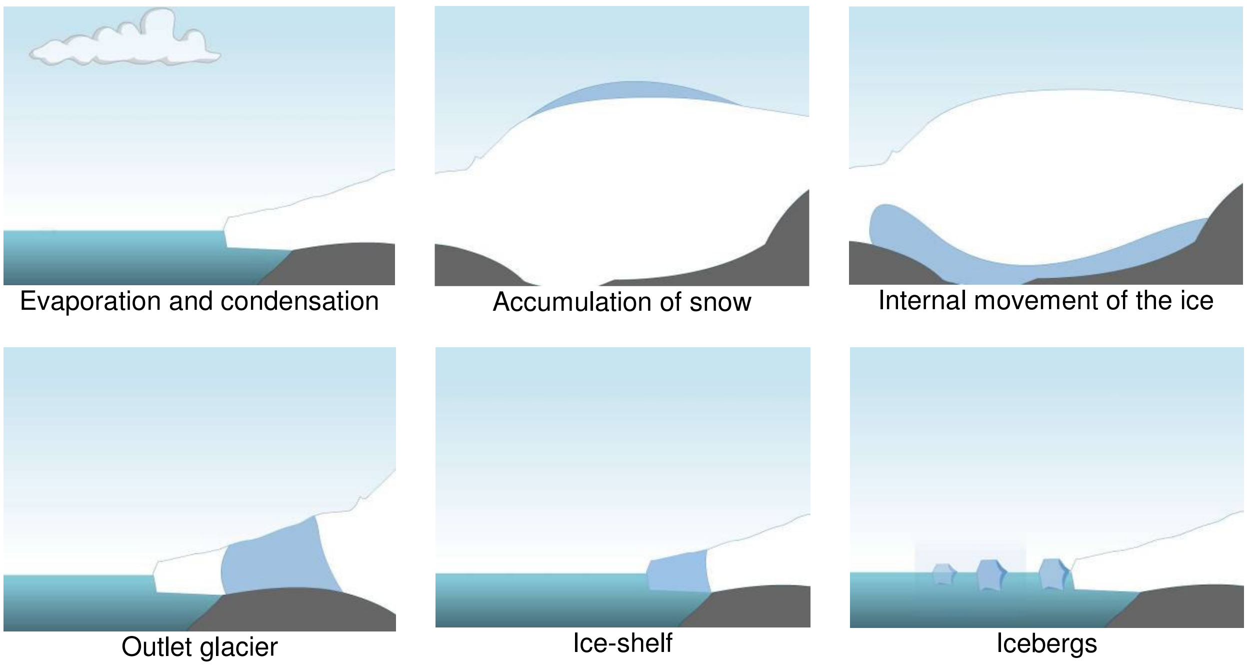


Figure 5 – The conveyor belt of the Antarctic inlandsis.

Polar glaciers

Inside an *inlandsis*, the ice moves from the centre towards the outside. This flowing movement is very slow at first, but is speeded up at the edges of the icecap in the Antarctic or Greenland by huge glaciers. These are called *outlet glaciers* and they can move at relatively high speeds: some moving at 2 to 3 km per year. The *toe* end of these glaciers feeds an *ice-shelf* or takes the form of a *tongue* of ice that floats on the water. There are also glaciers that move in valleys of ice at the heart of the icecap. These are called *ice-streams* and they flow on a bed of ice.

A glacier is like a river of ice, which often flows imperceptibly, driven by its own weight, along a slope or valley. The ice has the special property of melting at a temperature that is lower than 0°C when it is subjected to high pressure. This principle partly explains the movement of a glacier down a slope: because the ice that is in contact with the ground is under such high pressure caused by the total mass of the glacier, it melts and creates a film of lubricating water that enables the glacier to slide along the slope under the sheer force of the glacier's weight.

Ice-shelves

Numerous *ice-shelves* are found around the Antarctic icecap, covering at least 30% of the coast. These are immense platforms of ice that float on the ocean while still being solidly anchored to the continent. The smaller ice-shelves cover just a few hundred km^2. But the largest, the Ross ice-shelf, has an area equivalent to the whole of France.

Figure 6 – The Antarctic ice-shelves.

What are the dynamics of ice-shelves?
At the edges of the inlandsis, glaciers channel the ice from the interior of the continent towards the ocean. When the ice reaches the water, it floats, thereby creating platforms that remain anchored to the continent. Overall, the total area of an ice-shelf remains constant, because numerous glaciers supply it continuously with ice, while right at their extremities, pieces of ice are becoming detached regularly and falling into the ocean, forming icebergs.

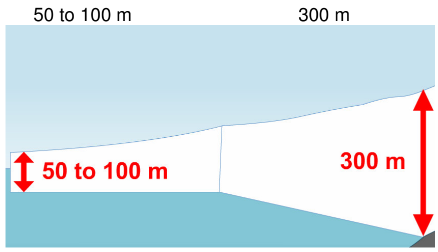


Figure 7 – The dimensions of an ice-shelf.

An ice-shelf is approximately 300 metres thick at the point where it is anchored to the coast. Its thickness then gradually reduces, ending with a *barrier*, or a vertical cliff of ice, 50 to 100 metres high.

Icebergs

The extremity of an ice-shelf or tongue of ice is constantly being moved around by the tides and gnawed at by the seawater. This makes it fragile as a result. Fractures appear and chunks fall off regularly to be carried away by the ocean as *icebergs*. This is known as the glacier *calving* icebergs.

An iceberg is made up of fresh water. As the density of ice is 0.8 to 0.9, an iceberg floats on the ocean and the part showing above the water only represents about 1/7 to 1/8 of its total volume. While most icebergs measure a few dozen to a few hundred metres in length, the largest tabular icebergs recorded in Antarctica have been measured at over 300 km long by 100 km wide.

When an iceberg breaks away, it drifts off into the ocean for two or three years, during which time it is nibbled at by the sea water, toppling over regularly and finally disintegrating. If an iceberg runs aground on its travels, its lifespan may be as long as ten years.

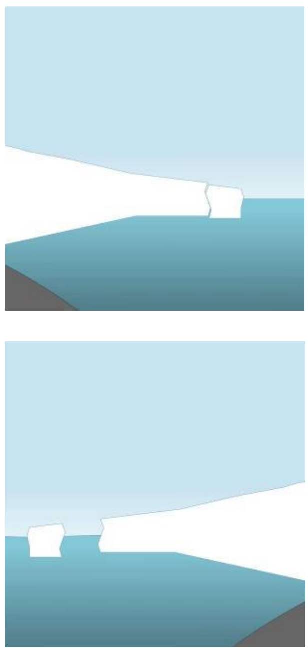


Figure 8 – Calving of an iceberg.

Permafrost

All around the Arctic Ocean, the land is covered by stunted and treeless vegetation called *tundra*, where the ice never goes away. The ice is found in the form of ground that has been frozen to the core for thousands of years. This is called *permafrost*. Just a thin surface layer melts in the spring. The permafrost has been known to reach some record depths: 450 m in Spitzbergen, 740 m in the North American Arctic, 800 to 1600 m in the Russian Arctic.

Pack ice

Pack ice forms where the surface of the ocean freezes; this means that pack ice is made up of salty water.

There are two types of pack ice:

- Permanent pack ice that does not melt during the summer. This ice is made up of sea water that is several years old (3 to 3.5 m) thick. This is the type of pack ice found in the centre of the Arctic Ocean.
- Pack ice that forms with the cold of the winter and is added to the permanent pack ice. This seasonal pack ice (1 to 3 m thick) covers the whole of the Arctic basin and forms right round Antarctica for a distance of several hundred kilometres. When the summer returns, it breaks up again and disappears.

Pack ice is like a gigantic jigsaw puzzle made up of large pieces of ice (*floes*) of very irregular sizes. Driven by the ocean currents and the winds, these floes are constantly jostling with one another, creating compression ridges or, the opposite, open *leads* of water. This means that the pack ice presents a chaotic landscape, with compression ridges rising in places up to 10 or 20 metres in height (*hummocks*). There can also be flat areas, some large, some small.

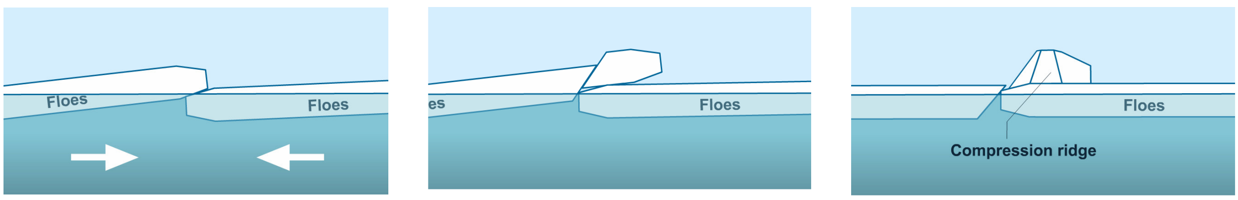


Figure 9 – Pack ice: sequence of the overlapping of two floes.

Figure 10 – Pack ice: appearance, then freezing over of a lead.

Climate warming, ice melting and ocean levels

The current climate warming is increasing the rate at which the ice is melting. Does that contribute to the level of the oceans rising?

According to Archimedes' principle, floating ice displaces a volume of water equivalent to the amount of water it will provide when it melts. This means that melting pack ice or an ice-shelf that breaks up into icebergs do not directly raise the level of the oceans because they are already floating. But doesn't this melting ice have any effect?

As far as pack ice is concerned, the answer is clear-cut; there is an effect caused by the modification of the *albedo*. When the ice melts, its white, highly reflective surface is replaced by the surface of the sea, which is much darker. This difference in colour increases the absorption of heat by the oceans, which in turn speeds up the melting of the pack ice, and so on; this is a perfect example of *positive retroaction*. As it happens, this increased absorption of heat causes the oceans to expand and so does indeed play a part in the rising of the water.

Scientists are not so clear-cut about ice-shelves. However, it would appear that the recent collapse of several ice-shelves in the Antarctic peninsula has allowed for a speeding up in the movement of the glaciers that were feeding them and hence create a greater flow of "dumped" continental ice into the ocean. Yet it is this continental ice (which by definition does not float) whose melting is feeding the oceans (mountain glaciers, inlandsis).

As for the polar icecaps, the situation is far from clear: the icecap covering Greenland could well begin to melt in the coming years (in fact, some researchers claim it is already doing so); the icecap covering the Antarctic peninsula could also become involved over the next few decades because part of it is located on a rocky base below sea level and hence is in contact with the ocean; finally, the largest icecap of them all, in eastern Antarctica, shouldn't be affected for another 200 years or so.

It should be pointed out, however, that during the last period of the Earth's history when there was no ice at the poles (50 million years ago), the average temperature was only 6°C higher than it is now. Yet forecasts for the year 2100 made by the United Nations predict a rise anywhere between 1.4 and 5.8ºC. If the polar icecaps were to melt, the level of the oceans would rise by 70 metres. Very fortunately, however, the extraordinary size of the Antarctic icecaps give them a degree of inertia that will make their thawing extremely slow. If this inertia were to be combined with a dramatic reduction in the emissions of greenhouse gases, the thawing process could maybe be counteracted altogether…

Teaching note

Pupils are aware of water in all three of its forms. Yet they only use the word "water" for its liquid form. Ice and snow are often perceived as totally separate matter, while the term "steam" is often used incorrectly, even by adults. In fact, like all gases, water vapour is invisible. What we see coming out of a saucepan boiling on the stove is steam: tiny droplets of water in liquid form. Water vapour is present in the air all around us. This is demonstrated in winter, when condensation becomes visible on the windows. These drops do not appear by magic, but are produced from the humidity in the air which, when it comes into contact with cold, is converted into liquid water.

These changes in state involve complex phenomena that can really only be understood at a molecular level and hence are beyond the reach of pupils at primary school. Going from one state to another corresponds to a change from a molecular structure relative to the state of atomic excitation. However, simple experiments make it possible to highlight certain forms of behaviour associated with changes in state and some of the properties of solids, liquids and gases. It is these types of behaviour and these principles that are studied at primary school.

The water cycle is often studied in too simplistic a way, without taking account of the time factor, the spatial dimension, interaction between the hydrosphere and other of the Earth's compartments, or even the role that the cycle has on our ways of life. In a systemic approach, emphasis would be placed on points that are not studied very much, but which are nonetheless essential:

- Some water molecules evaporate before they touch the ground, whereas others take 800 000 years, which is the maximum period of time water spends in the Antarctic icecap, before returning to the atmosphere;
- Movements by water molecules on Earth can be very irregular – some travel several thousand kilometres;
- Water can become charged with particles. It also dissolves certain types of matter, is involved in erosion, and plays an important role in heat exchange and in the absorption of CO_2;
- Water is the source of life and is also the main constituent of all living beings. Humans need it and interfere in the very heart of the water cycle (diverting water courses, building dams, increasing evaporation through industry, irrigation, etc.).

In our own area, the supply of water appears to be inexhaustible. That's what many children still think, because they are not aware that the water we drink has been the same for millions of years.

The words that designate water in its solid form are often confusing: glacier, iceberg, icecap, pack ice, ice-shelf, etc. Particular attention needs to be paid to the individual feature of each of these terms. Is it saltwater? Fresh water? How are icebergs and pack ice formed? What are their specific features?

Objectives

To be able to
- Put an experiment in place.
- Explore natural phenomena.
- Ask others questions, ask oneself questions.
- Isolate variables.
- Use measuring instruments (thermometers) and illustrations (diagrams, graphs).
- Process information and data.
- Use information and communication technology to exchange data and observations.

To have understood and retained the fact that
- The same quantity of water has existed on Earth for a billion years. This water goes through a never-ending cycle.
- Fresh, drinkable water is a rare commodity on Earth.
- Fresh water freezes at 0℃. Saltwater freezes at a temperature lower than 0℃.
- With pack ice, it is the surface of the ocean that has frozen; this means that pack ice is made up of saltwater. The surface of pack ice is chaotic.
- There are immense icecaps that cover continents. This glace is made up of compacted snow.
- A glacier is the equivalent of a river of ice which, as a result of its weight, slides down a slope, usually on a thin film of water at ground level.
- An iceberg is a large chunk of ice that becomes detached from an ice-shelf and which floats.
- Only a small part of the volume of an iceberg can be seen above the surface of the water.
- When floating ice thaws, it does not make the level of the oceans rise.

Proposed activities

"Earth sciences experiments" file

- The water cycle
- The properties of ice
- Icebergs
- The movement of glaciers
- Frost shattering

Research questions and working directions to be taken

Why do icebergs float?

Work on the buoyancy of icebergs.
- Watch the "Icebergs" animation in class (can be viewed at the Educapoles website: www.educapoles.org), then start a discussion about what the children understand of the origins and dynamics of icebergs.
- An iceberg floats because it has less density than water. Make a large ice cube from fresh water in the freezer, then float it in a large transparent tub of water. Estimate the proportion of the volume of the ice jutting up out of the water. Highlight the fact that an iceberg floats and that only a small part is visible above the surface of the water. Broach the notion of density by showing that water takes up more space when it is frozen because it can make a plastic bottle burst in the freezer, whereas the weight of the water has not changed. Can the volume sticking out of the water vary? Try to affect the iceberg and modify the proportion out of the water: simulate the ageing of the iceberg as the result of the action of the water by digging out part of the ice cube and by changing its shape; change the density of the ice by making an ice cube from saltwater (which is more dense than fresh water), if possible using ice from outside (less dense than pure ice).

Can the salt content of saltwater (in an ocean) be recovered?

- If you live close to an ocean, it will be possible, using evaporation, to determine the quantity of salt dissolved in a litre of water. Is there 2 times as much salt in 2 litres of water? Make a comparison with the water from a lake or pond. For classes located far away from the ocean, the teacher can prepare in advance a solution of fresh water and coarse salt equivalent to seawater (34 to 35 g/l). This level of salinity is also close to the salinity of blood or tears.
- How do you build a system that enables fresh water to be separated from the salt without using a saucepan? Develop a system in class, for example a system using the sun.

If you live in an area where there is no fresh water, how do you go about getting some?

- In Antarctica, there are only a few rivers in the summer on the Antarctic peninsula and the lakes that do exist beneath the icecap are inaccessible. How do humans go about obtaining fresh water? Work in class to find possible methods: melt some snow; use a desalination unit.
- Have a debate in class about the fact that 1/3 of the world's population does not have access to drinking water. Make a list of the reasons and the solutions. Is the desalination of seawater a viable solution?
- Living a long way from a source of fresh water has many consequences on ways of life. What are they? List the consequences. Which populations on Earth do not have access to drinking water? Create a computer graphic.

How is pack ice formed?

Do you know what pack ice is? When you walk on pack ice, are you on the sea or on the land? Is sea ice made from fresh water or saltwater?

- Watch the "The Pack Ice" animation (www.educapoles.org) in class. Set up experiments designed to understand pack ice better (formation, strength of the ice, movement ice floes, thawing, etc.). For example, place a large transparent container of water in a freezer and work on the layer of ice that forms on the surface.

How does a glacier move?

Do you know what a glacier is? Some pupils may even have seen a glacier before. Do you know how they work?

Work on glaciers.

- Watch the "Polar Glaciers" animation (www.educapoles.org) in class. Then do the experiment with the steel wire passing through the ice (see the "experiments teaching dossier" for the experiment called "The properties of ice").
- Compare various photographs of glaciers. Find their common points and any differences. Identify the various parts of the glacier.
- Find recent and old postcards of glaciers and compare them. Start a discussion in class about the retreat of glaciers and the effects of climate warming on them, as well as more generally on the planet and humans.

When floating ice melts, does it raise the level of the oceans?

Some forms of ice float on water (pack ice, icebergs). Do you think that if they melt the level of the oceans will rise?

- Using a container of water and ice cubes, ask the children to think up an experiment that shows whether the level of the sea rises when floating ice melts.
- Have the class search for information about the rise in sea levels caused mainly at the moment by the thermal expansion of ocean waters and, secondarily, by the melting of continental ice.
- Work with the class to envisage the effects on Earth of a rise in ocean levels caused by climate warming (melting of continental glaciers, expansion of oceans): coastal villages flooded, displacement of populations, refugee camps, cereal-growing areas destroyed, famines, disease, ruined economies, need to rebuild using new techniques, rich countries better prepared than poor countries, thus causing a widening of the gap between North and South. What solutions should be adopted to counteract the rise in ocean levels and to provide protection against it happening?

What steps/action should be taken in my region?

- Identify causes of water wastage. Estimate the quantity of water used daily in the toilets at school. Is there a way of economising part of that water?
- Organise a “well week”: in all the school and for a whole week, only use a single tap (the well), preferably located outside the building. How would daily life be organised then?
- Carry out historical research into the supplying of drinking water to towns and villages. Present this research to other classes.
- Research ways of economising on the use of water in the region (industry, separate units for waste water and rainwater, recovering rainwater for watering gardens, etc.).
- Invite an expert in glaciology or hydrology to come and present information about his or her research activities.

Example of teaching/learning sequence

The properties of ice

Objectives

To be able to
- Put an experiment in place.
- Ask others questions, ask oneself questions.
- Isolate variables.
- Abide by an experiment protocol.
- Report on the results of the experiment.

To have experience of
- Cognitive illustration tools (graphs, tables, organisation charts, computer graphics, etc.).
- Measuring instruments (thermometers).

To have understood and remembered
- Some of the properties of ice.
- The difference between fusion and freezing.
- The effects of salt on the freezing point.

1. Starting point (15 minutes)

Bring two identical plastic bottles into class: one full of liquid water, the other split, containing frozen water (bottle filled with water and placed for 24 hours in the freezer). Discussion.

2. Collecting illustrations (45 minutes)

Using magazine, select ten or so photos showing water in its solid form (glacier, skating rink, ice cube in a glass, snow, iceberg, etc.). Ask the pupils to explain in a few lines about the way the ice was formed in each situation.

3. Putting a research method in place (15 minutes)

Knowledge common to the class and questions

Write on the blackboard what the pupils know about ice.
Highlight any questions that need to be raised.

4. Study of cognitive illustration tools - graphs, tables, organisation charts, computer graphics - (several sequences of 45 minutes)

Reference can be made here to certain methods for teaching mathematics that make it possible to work on these parallel skills that are important for science.

5. Experiment 1: freezing and fusion (90 minutes)

Give the pupils 3 experiments (working in groups and in a workshop) to broach the issues of fusion and freezing.

- Set up identical containers, each containing the same quantity of a different type of water: distilled water, tap water, salty water, sweetened water, etc. Place them in the freezer and measure the temperature at which the water freezes in each container. Create a table. The distilled fresh water solidifies or freezes 0℃. The salty or sweetened water (solutions) freezes at a temperature below 0℃, and is lower the more the solution is concentrated.
- As it freezes, water expands, but its weight does not change. Pour some fresh water into a container, filling it half full. Make a mark to show the level of the water and weight the container and water. Place the container in a freezer for 24 hours, then observe that the volume has increased, while the weight has not changed.
- Place a salad bowl of crushed ice on a radiator. Insert a thermometer into the ice and take a reading of the temperature every minute. Make a graph of the readings. Highlight the fact that the temperature rises to 0℃, which is the fusion temperature for ice. It then remains constant during fusion for as long as the water and ice coexist: making the ice fuse requires energy (taken from the source of heat and the ambient air), which is therefore no longer available to increase the temperature of the water. Once the ice has melted, the temperature starts to rise again.

6. Experiment 2 (90 minutes)

The children need to identify the parameters that may have an effect on the fusion of an ice cube, by varying one parameter after another.

How do you make ice melt? How do you speed up the melting process? How do you slow it down? The pupils must answer these three questions. For each one, draw curves of the changes in temperature over time.

- How do you make an ice cube melt? You need to apply heat to the ice cube to make it melt. Measure the fusion time for an ice cube under various conditions: in the shade, in the sun, in the sun on black cardboard, immersed in cold water, immersed in hot water, in the hot air stream of a hair-dryer, in a microwave, etc. Ask the children to explain why there are differences in the fusion times.
- How do you speed up the melting process of an ice cube? For example by crushing the ice cube to increase the surface area of heat transfer, or by sprinkling it with salt.
- How do you preserve an ice cube? Wrap an ice cube in different materials that are better or worse conductors of heat. Place the ice cube in a container filled with various insulating materials. Add a layer that reflects light.

7. Experiment 3 (90 minutes)

What action does salt have on ice? Why is salt used to melt ice on the roads in winter? Highlight the action of salt on the freezing point of water by providing the class with two experiments:

- One experiment is simple: two ice cubes on a sheet of black paper, one salted, one not (the black paper absorbs the light and returns it to the ice cubes in the form of heat). The salted ice cube melts more quickly because its freezing point is less than 0℃. You can also use two fresh water ice cubes and put salt on one of them.
- The second experiment is more ambitious: place a glass of water in a salad bowl, surround the glass in a mixture of 1/5 coarse salt and 4/5 crushed ice, cover with a cloth. The water in the glass with melt. This is because the salt lowers the fusion point of the ice, which melts more quickly than the ice without salt. To melt, the ice draws heat from the ambient air, the temperature of which falls to a value equal to the new fusion point (down to minus 10℃ or minus 15℃), which freezes the water in the glass. Measure the temperature in the crushed ice. At the same time, conduct the experiment with ice and no salt.

8. Evaluation - assessment (90 minutes)

Produce a scientific poster on one of the experiments.

Resources

Websites

- http://www.educapoles.org: Educapoles, the educational website of the International Polar Foundation provides learning activities about the polar regions and climate warming.
- http://www.unesco.org/water/: Unesco's "water" portal. In addition to a large amount of information, there are also a number of useful tools for teachers: the international hydrology glossary in several languages, a photo library from which visitors can select photos about water, country by country, etc,
- http://www.wateryear2003.org: The UN's official website for the International Year of Freshwater – 2003. The site comes up in English, but can also be selected in French or Spanish. An "education corner" with interesting, fun items to browse through, most of which are currently in English.
- http://www.pseau.org/index_en.php: Website for the "Water Solidarity" programme aimed at promoting exchanges between North and South on the topic of water. Well-endowed database dealing with water, plus descriptive sheet for each item. Teaching documents for downloading.
- http://nsidc.org/cryosphere/: The National Snow and Ice Data Center (NSIDC) is a resource for data and information about all forms of snow and ice.
- http://www.cnn.com/TECH/science/9902/03/antarctic.ice.sheet/: The NASA has developed 3-D computer animation showing the retreat of the west Antarctic ice sheet over 20,000 years, speeded up into a few minutes of dramatic video footage.
- http://visibleearth.nasa.gov/view_set.php?categoryID=509: This site from NASA provides satellite photos of Ice and Snow from all over the world. Clicking a link under a photograph will take you to a site that describes the photo and has links to larger images. The larger images are truly stunning, even though the thumbnail may appear somewhat dull. Unless otherwise noted, all images and animations made available through Visible Earth are not copyrighted.
- http://www.teachersdomain.org/9-12/sci/ess/watcyc/index.html: How quickly is Earth's climate changing? What effect does El Niño have on the global weather system? What can ice cores from Greenland tell us about Earth's climatic history? How does the atmosphere change as altitude increases? How do we predict the intensity of a hurricane? Explore these questions and more in this collection of Water Cycle, Weather, and Climate resources.