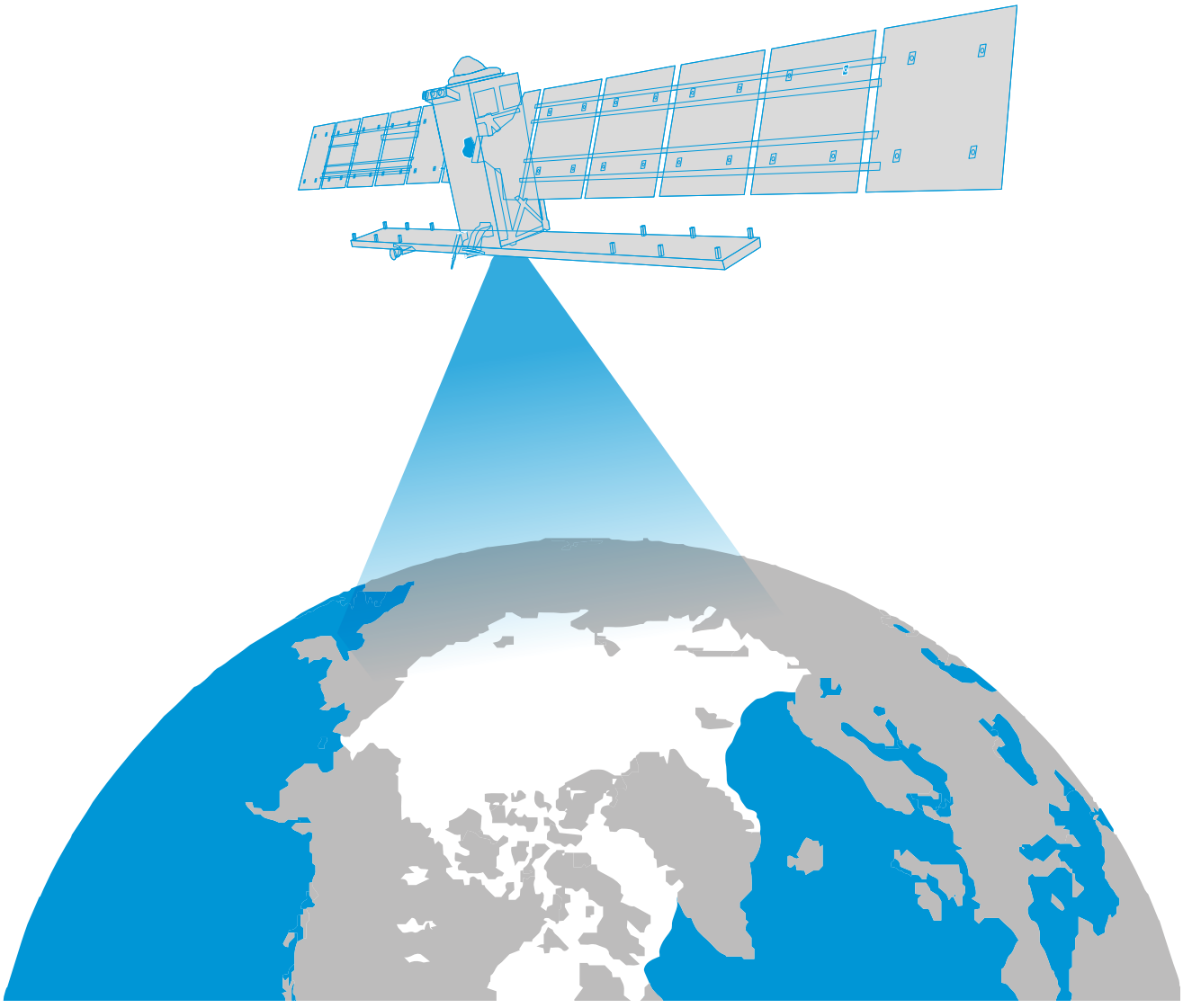
Geography | G04

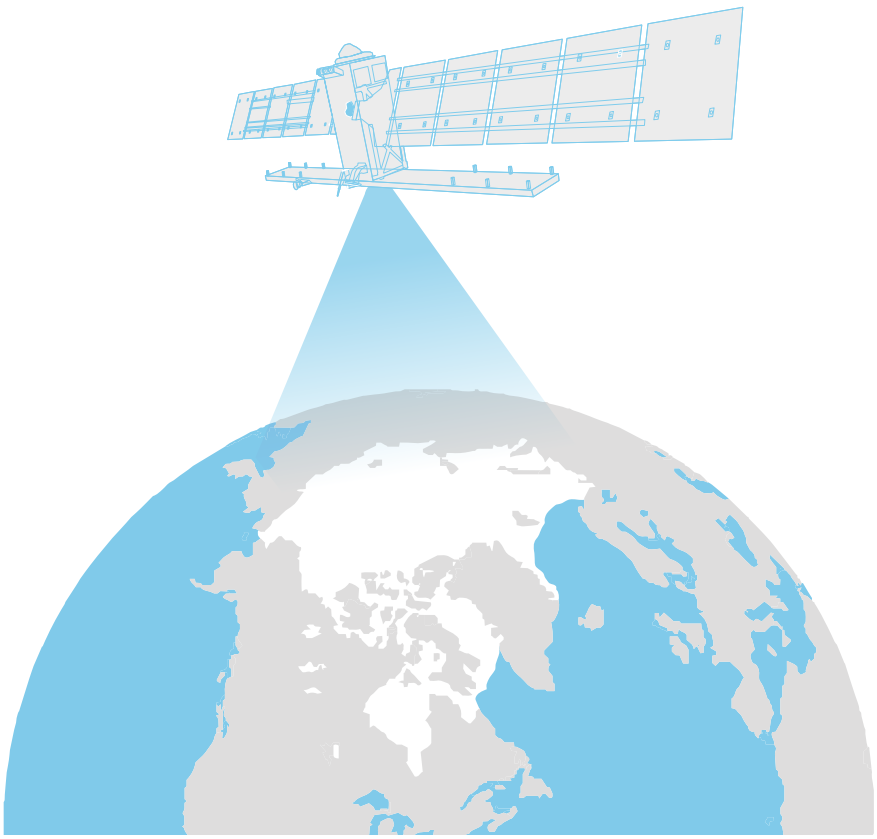
teach with space

→ SEA ICE FROM SPACE

Investigating Arctic sea ice and its connection to climate



teacher guide & student worksheets



Teacher guide

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→ SEA ICE FROM SPACE

Investigating Arctic sea ice and its connection to climate

Fast facts

Subject: Geography, Science
Age range: 13-17 years old
Type: student activity
Complexity: easy
Lesson time required: 30 minutes for each activity
Cost: low (0 -10 euros)
Location: indoors
Includes the use of: ice, computer, internet
Keywords: Earth observation, sea ice, Arctic, climate, climate change, geography, science

Brief description

In this set of activities students will investigate Arctic sea ice. First, they will perform a hands-on activity to find out what happens 'when the ocean freezes'. Then, they will use satellite images to analyse the sea ice concentration and extent and how these parameters have changed in the last decades. They will learn where in the world it is possible to find sea ice and analyse up-to-date and long-term satellite data about sea ice concentration in the Arctic. This activity deals with one of the most important indicators scientists have to study climate change and its possible consequences.

Learning objectives

- Learn what sea ice is and where it can be found on Earth.
- Understand the importance of sea ice and its relation to Earth's climate.
- Understand how human actions and physical processes interact to influence and change landscapes, environments, and the climate.
- Use tools available on the internet to collect and analyse satellite data.
- Understand how Earth observation satellites can be used to characterise and monitor sea ice.

→ Summary of activities

Summary of activities					
	Title	Description	Outcome	Requirements	Time
1	When the ocean freezes	Compare freshwater ice with sea water ice using a hands-on experiment.	Understanding what happens when salt water freezes and the importance of sea ice.	None	30 minutes
2	Sea ice today	Sea ice in the world and analyses of up-to-date satellite data about sea ice concentration in the Arctic.	Learning where on Earth we can find sea ice and how to analyse satellite data about sea ice concentration.	Knowledge about ocean currents is desirable	30 minutes
3	Sea ice through the seasons	Analyse long-term data about sea ice.	Identifying short and long-term trends that help to characterise and monitor sea ice.	Activity 2	30 minutes

→ SEA ICE FROM SPACE

Investigating Arctic sea ice and its connection to climate

→ Introduction

Each year, the polar oceans experience the formation and then melting of vast amounts of sea ice. This seasonal cycle of sea ice is one of the most dynamic components of Earth's climate system.

Although sea ice is found primarily in the polar regions, it influences our global climate. Sea ice changes the reflectivity of the ocean and acts as a barrier to the exchange of heat and moisture between the ocean and the atmosphere. The seasonal changes of polar sea ice also play a significant role in global ocean circulation. As ice forms, the salinity and density of the surface water increase. Cold, dense, polar water sinks and moves along the ocean bottom toward the equator, while warm water travels from the equator towards the poles. As ice melts it sends a flux of fresh water into the upper ocean; this decreases the salinity and density of the water, and the lighter, less dense water forms a fresh layer at the surface.

The seasonal sea ice cycle affects not only climate but also human activities like shipping as well as biological habitats. The Arctic ecosystem is home to many organisms, from microscopic bacteria, phytoplankton and algae, to large animals like polar bears and seals that depend on sea ice for their survival.

Satellites give us a unique overview of the polar regions, providing measurements that were previously impossible to acquire in such hostile and remote areas. Different types of sensors, from optical to passive microwave or infrared sensors, can be used to observe and monitor sea ice. Several European Space Agency (ESA) missions have studied or are studying sea ice on Earth. Among them are ESA's CryoSat satellite, an Earth Explorer mission, and the Copernicus Sentinels, a family of satellites developed to monitor our fragile planet.

Figure 1

↑ ESA's Cryosat satellite is dedicated to measuring polar sea ice thickness and monitoring changes in the ice sheets that blanket Greenland and Antarctica.

With this set of activities and by analysing real satellite data on sea-ice concentration in the Arctic, students will be stimulated to think about the importance of sea ice and why scientists study it. Students will understand that although it may not directly affect each of us, the influence of sea ice on the Earth is global.

→ Background

What is sea ice?

Sea ice is simply frozen seawater. In contrast to icebergs or glaciers that originate on land, sea ice forms, grows and melts in the ocean. The formation of sea ice is a complex process that is influenced by the basic properties of water and ice. The salt content of water influences the freezing point: the higher the salt content, the lower the freezing point.

Figure 2

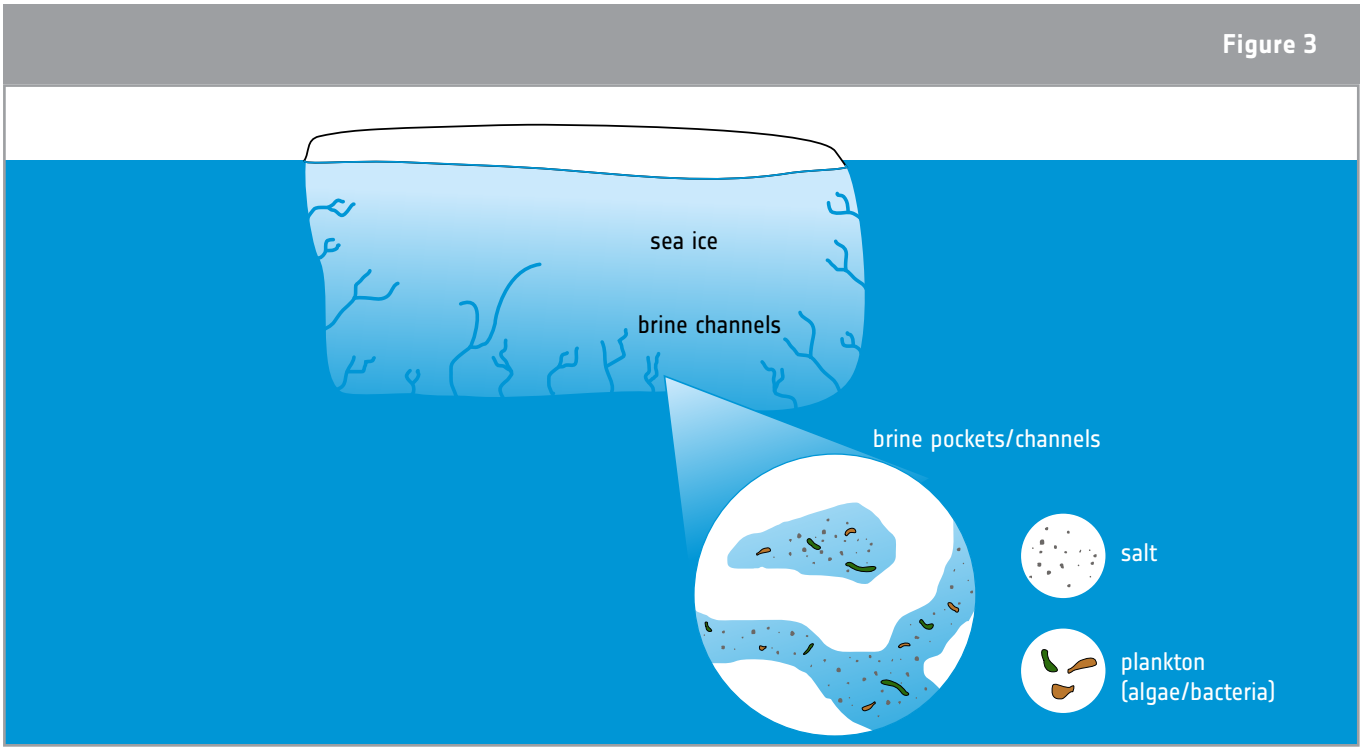
↑ Every year the Arctic Ocean experiences the formation and then melting of vast amounts of ice that floats on the sea surface.

Habitat for microscopic life

Sea ice contains little salt, as most of it is rejected as the ice forms. The salt ions do not fit in the crystal structure of water ice and for that reason the salt is expelled. The salt that is rejected is either forced out into the surrounding water, or trapped in small pockets or channels between ice crystals. These are called brines. The high concentration of salt prevents the brines from freezing.

The brines in sea ice consist not only of salt, but also trap microorganisms like plankton. Different processes wash out of brines that make it possible for photosynthetic algae to grow on the bottom of the sea ice. The algae serves as food for small animals in the ocean and even for whales. During winter, when there is no sunlight in the Arctic, the organisms are not active. During spring, when light becomes available for photosynthesis, and throughout the summer, when the waters warm, sea ice melts and releases algae cells and tiny animals back to the sea that become food for larger animals.

Figure 3



↑ Brine channels in sea ice consist of a very salty liquid and are a micro-habitat for ice algae.

Sea ice measurements

Since 1979, different satellites have provided a continuous record of Earth's sea ice cover. The data collected by satellite instruments is usually processed into digital picture elements, or pixels. One pixel may cover an area of 25 km x 25 km or smaller. Scientists calculate the amount of sea ice in each pixel.

When analysing data about sea ice it is important to understand which measurement values are being used. The **sea ice area** is the measured area of sea ice within one pixel.The **sea ice concentration** is the percentage of the pixel covered with ice. This can be calculated by dividing the sea ice area by the area of the pixel. For example, if 62,5 km² of a 625 km² pixel were covered with ice, the sea ice concentration would be 10%. Many scientists work with another value called the **sea ice extent**. The extent determines if there is ice cover or not for the whole pixel by applying the following rule: if the sea ice concentration is greater than 15%, there is sea ice.

Table 1

Sea ice measurements for a 25 km x 25 km pixel			
Sea ice area	12,5 km²	100 km²	562,5 km²
Sea ice concentration	2%	16%	90%
Sea ice extent	No sea ice since sea ice concentration is < 15%	625 km²	625 km²

↑ Table 1: Summary of different sea ice measurements for a pixel that represents an area of 25 km x 25 km. (Blue represents water and white represents sea ice).

When scientists decide to use one of these measurements, they have to consider different aspects. While the area might appear as the 'most correct' measure, how this data is acquired is relevant. Most satellite data provides scientists with information about the mixture of surface conditions appearing within an image pixel. In the months during which ice melts, the melt water on the ice might be mistaken as open water. This means that the sea ice concentration and fraction of the ocean covered with sea ice may be underestimated. During the winter months the ice concentration may be overestimated due to the ability of the sensor to resolve small cracks, or leads, within the sea ice pack.

→ Activity 1 – When the ocean freezes

In this activity, students will understand some properties of sea ice by comparing ice blocks made from freshwater and salt water.

This activity must be completed over two days, as the water needs enough time to freeze.

Equipment

- Student worksheet for each group
- Two 250 ml jars or cups
- Teaspoon
- Tray
- Measuring jar
- Table salt
- Food colouring

Exercise

Start the activity by asking students if they know what sea ice is and why they think it is important to study sea ice. Students will be asked this question again in the discussion of the activity.

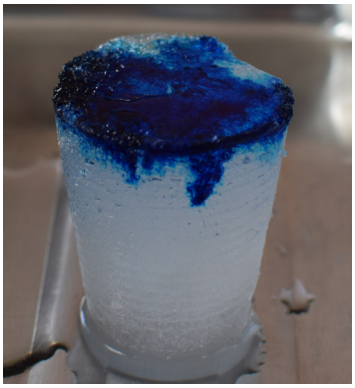
Students will study two samples – one of fresh water and one of salt water – and compare the differences between regular freshwater ice and salt water ice using a couple drops of food colouring on each type of ice.

Instructions for the preparation and exercise are provided in the student worksheet. Teachers can choose to do activity 2 and activity 3 on the same day as the samples are prepared and discuss activity 1 on the second day. It is also possible to perform activity 1 as a demonstration.

Plastic cups may be easier to use, as students can cut the cup to remove the ice. If reusable plastic jars or plastic beakers are used, students might need to place them in warm water for a while to release the ice from the jar. The ice should be placed on trays to catch melt water.

It is possible to extend the hands-on activity below by adding another sample made of at least 5 teaspoons of salt dissolved in 200ml of fresh water. This will not freeze completely due to the high salt concentration and visualises why the brines do not freeze.

Results

	Freshwater ice	Salt water ice
Before adding food colour	Clear and mostly transparent	Foggy and porous structure
After adding food colour	Food colouring does not penetrate the ice and runs down the side of the ice or accumulates on the top	Food colouring penetrates the ice cube and channels become visible 

↑ Table 2: Summary of the results

Discussion

Students should observe that salt water ice appears foggy, while freshwater ice is usually clear. After adding the food colouring students can identify the channels (brines) formed in salt water ice.

Freshwater and salt water ice have very different structures. When freshwater freezes, the water molecules arrange in a hexagonal crystal structure. If there is salt in the water, however, the salt ions do not fit in the crystal structure of water ice and for that reason the salt is expelled and concentrates in small pockets or channels.

Students should be able to conclude that sea ice plays a fundamental role in the polar ecosystem as it serves as the habitat for many organisms, from microorganisms to large animals. Depending on the students' level of knowledge, they could also explore how the formation of sea ice can change the salinity of the surrounding water, which may impact ocean currents.

→ Activity 2 – Sea ice today

In this activity, students will learn about the global distribution of sea ice. They will also analyse up-to-date satellite data about sea ice concentration in the Arctic.

Equipment

- PC and internet access
- Student worksheet for each group

Exercise

Before analysing real data, students discuss their expectations regarding where they anticipate to find sea ice in the Northern Hemisphere. For that students analyse a map from the Northern Hemisphere and indicate the areas where they expect to find sea ice (Figure A2 from student worksheet). The locations are 1, 3, 4 and 8. The other areas are influenced by the Gulf Stream, which is an Atlantic ocean current that carries warm water northwards, prevents the water from freezing. Depending on the students' level of knowledge, the "Highways of the Oceans" resource (see links section) can be a good basis for this enquiry. In the Southern Hemisphere, sea ice can be found around Antarctica.

On the University of Bremen (Germany) website (https://seaice.uni-bremen.de/sea-ice-concentration), students can find up-to-date data about sea ice concentration in the Arctic. The data is derived from JAXA's (Japan Aerospace Exploration Agency) Advanced Microwave Scanning Radiometer 2 instrument on-board the GCOM-W satellite.

When describing the sea ice concentration, students should understand that a concentration of 0% indicates unfrozen water (open ocean). There is an area around the North Pole that is not imaged by the satellite, and there is no way to know what the actual concentration is within this area, so the area is represented by a dark grey circle. They should point out where on the map sea ice can be found and read from the legend how the concentration of the sea ice is distributed and differs.

In the links section you can find more links to platforms that provide access to sea ice data, including some from ESA satellites. A new candidate Copernicus Imaging Microwave Radiometer (CIMR) mission is currently being developed to provide future continuity in measurements of sea ice concentration in the Arctic Ocean and in the Southern Ocean around Antarctica.

Students should conclude that satellites are extremely useful for monitoring remote locations where we typically find sea ice. Teachers may discuss some of the properties of the electromagnetic spectrum and the different sensors and techniques satellites use with older students. For example, radar technology allows satellites to "see" during the night as well as through clouds. This ability is very important in monitoring sea ice, taking into consideration polar darkness (long winters) and cloudy conditions at the polar regions.

→ Activity 3 – Sea ice through the seasons

In this activity, students will discuss their expectations regarding seasonal changes in sea ice and analyse long-term data about sea ice extent.

Equipment

- Student worksheet for each group

Exercise

Before analysing real data, students discuss their expectations. They should conclude that they expect seasonal changes in sea ice extent and that there might be a decrease of sea ice extent over several years due to rising global temperatures.

After analysing up-to-date data showing sea ice values (activity 2), students will first investigate how the sea ice extent changes in the course of one year and then how it changes over several years. Teachers can find monthly maps of sea ice at https://climate.copernicus.eu/sea-ice and download the original image.

The E.U. Copernicus Marine environment monitoring service (http://marine.copernicus.eu/science-learning/ocean-monitoring-indicators/catalogue/) also provides graphics and data about the Northern Hemisphere sea ice extent for different years. Teachers are advised to download the most up-to-date data available.

The graphics in the annex, from the E.U. Copernicus Marine Service Information, show the sea ice extent mean and trend in the Northern Hemisphere between 1993 and 2017 and the Northern Hemisphere sea ice mean for 2012, 2014 and for the 1993-2014 period.

By analysing the graphics in the annex students should conclude that Artic sea ice extent reaches a summer minimum in September and winter maximum in March. Students can also conclude that the long-term trend (annual mean) over the 1993-2017 period indicates that Arctic sea-ice extent has declined at a rate of approximately 6% per decade.

It is also very important to understand the relationship between global warming and the melting of sea ice and land ice and the consequences. This is one of the goals of "The greenhouse effect and its consequences" set of activities, which explores in detail global warming and the effects of melting sea and land ice on sea level and albedo (see links section).

Extension – Classroom debate: Consequences of an ice-free Arctic

As an extension of this activity, students can debate the consequences of an ice-free Arctic ocean and what the implications are for Earth's climate and for human activities (for example, global shipping routes). They will discuss different positions from economic and environmental perspectives.

A possible shipping route through the Arctic leads to quicker transportation of goods between Europe and Southeast Asia. There are several impacts: a shorter route can be seen as more sustainable, as less fuel is needed. However, increased shipping traffic means more ship noise or potential oil spills, which can affect the Arctic environment. And while shipping routes are often possible in the summer, they cannot be reliably planned due to annual changes in the Arctic.

These are just a few points that can be discussed with students. In general, it is important to consider that sea ice plays a key role in Earth's climate.

→ SEA ICE FROM SPACE

Investigating Arctic sea ice and its connection to climate

The Arctic is the most northerly area of the globe. In the Arctic Ocean, areas are entirely or partly covered by sea ice most of the year, which makes it a challenge for explorers and scientists to access the area for research. Since 1979 satellites have been monitoring sea ice. Different kinds of technologies have been used to achieve this goal. Looking at the Arctic from space allows us to acquire measurements and track changes in areas that were previously impossible.

Figure A1

↑ Thin sea ice in the Arctic.

In this set of activities, you will use satellite images to analyse sea ice concentration and extent and how these parameters have changed dramatically in the last decades. In this way you will analyse one of the most important indicators scientists have to study climate change and its possible consequences. You will work like a real climate scientist!

Did you know?

About 12% of the world's oceans are covered by sea ice. Even though sea ice occurs primarily in the polar regions, it influences our global climate. Sea ice changes the reflectivity of the ocean and acts as a barrier to the exchange of heat and moisture between the ocean and the atmosphere. Sea ice also has a significant role in global ocean circulation. Changes in sea ice are one of the biggest challenges for scientists trying to predict Earth's changing climate.

→ Activity 1 – When the ocean freezes

In this activity, you will investigate some properties of sea ice by comparing ice blocks made from freshwater and salt water. You will also discuss the importance of sea ice.

Equipment

- Two 250ml jars or cups
- Table salt
- Teaspoon
- Food colouring
- Measuring jar
- Tray

Exercise

Note: Steps 1 to 4 to be done the day before

1. Fill each jar with about 200 ml of tap water.
2. In one of the jars, add 1.5 teaspoons of salt and stir until all the salt dissolves.
3. Label the containers.
4. Put them in the freezer overnight.
5. Take the two ice blocks out of the jars and place them on the tray with the top side up. Describe their appearance in table 1.
6. What do you think will happen if you add food colouring to the ice blocks? Will the food colouring behave the same way on both blocks? Write your prediction below.

_____

_____

7. Add some drops of food colouring to the block of freshwater ice and observe what happens. Write your observations in table 1.
8. Add some drops of food colouring to the block of salt water ice and observe what happens. Write your observations in table 1.

Results

	Freshwater ice	Salt water ice
Before adding food colour		
After adding food colour		

↑ Table 1: Summary of the results

Discussion

1. Describe and explain any differences between the two ice blocks before adding food colouring.

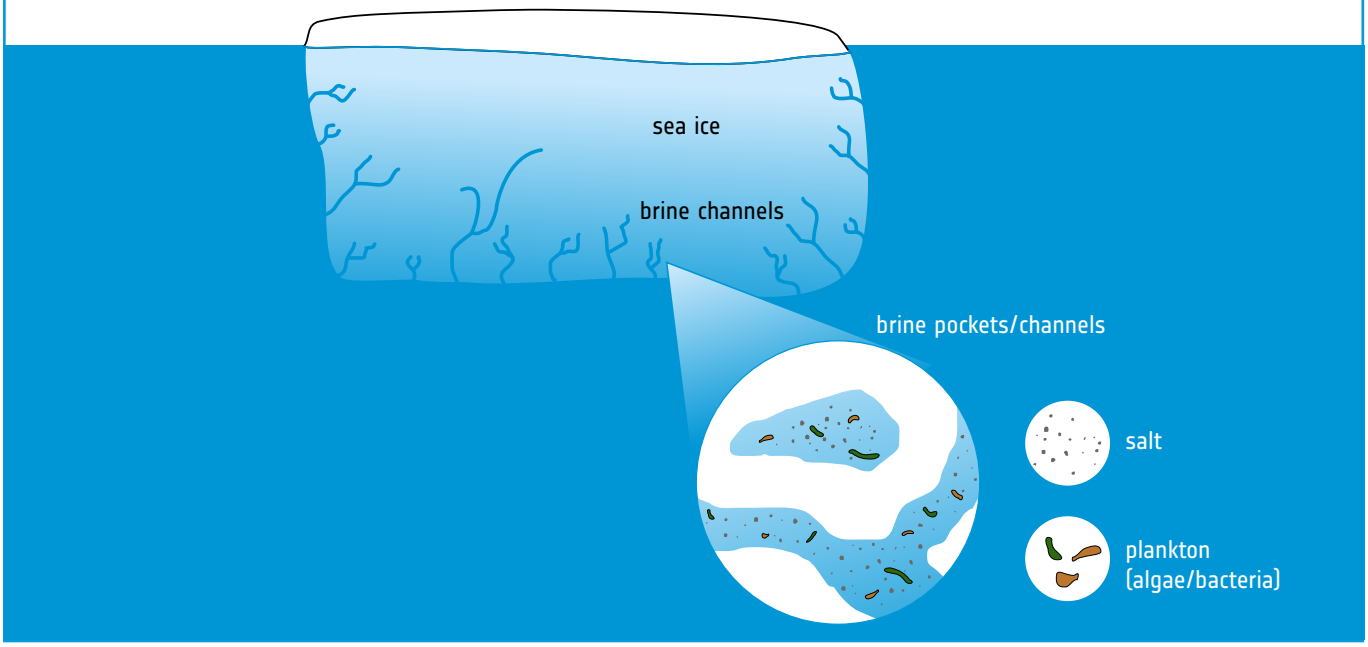
2. Describe the differences between the two blocks of ice after the food colouring was added. Do the results agree with your prediction?

3. In discussion with your group, try to explain any differences you observed after adding the food colouring.

4. Why do you think it is important to study sea ice?

Did you know?

The salt that is dissolved in the oceans accumulates in pockets or channels when the water freezes. These are called brines and consist of water with such high salinity that it does not freeze at all. The brines contain not only salt, but also life! Microorganisms like algae or worms live in the sea ice and are a very important part of the marine food chain. Scientists investigate how life can survive in these extreme conditions to search for extra-terrestrial habitats that may have the potential to harbour life.



→ Activity 2 – Sea ice today

In this activity, you will learn where in the world you can find sea ice. You will also analyse up-to-date satellite data about sea ice concentration in the Arctic.

Exercise

1. Figure A2 shows part of the Northern Hemisphere. Indicate the areas (numbers 1 to 8) where you would expect to find sea ice. Explain why.

Figure A2

↑ Select the areas where you expect to find sea ice.

2. Sea ice is frozen ocean water. Would you also expect to find sea ice in the Southern Hemisphere? If so, where?

3. You will now analyse up-to-date Arctic sea ice concentration with real satellite data. Go to the following link from the University of Bremen, Germany:
https://seaice.uni-bremen.de/sea-ice-concentration

Click to enlarge the image on the left. The different colours indicate different concentrations.

Note: A concentration of 100% (white areas) means that this area is completely covered with sea ice. The unfrozen part of the ocean has a concentration of 0% (purple areas).

a. Identify the areas where you can find sea ice and describe the sea ice concentration.

b. Identify areas 2 and 3 from Figure A2 above in the image. These areas are around the same distance from the North Pole. Is the sea ice concentration similar? If not, explain why.

c. Compare your expectations from question 1 with the analysis of today's ice concentration you have completed in question 3. Did you find ice in the areas you had expected?

4. Why do you think it's important to use satellites to investigate sea ice?

Did you know?

To make sure that data from satellites is accurate, measurements are taken by scientists in the field, either on land, at sea or from the air. These campaigns validate the satellite data and are carried out all over the world, from tropical rain forests to the icy reaches of the Arctic and Antarctica. Also, when instruments to be carried by satellites are developed, the new techniques need to be tested. You can follow some of ESA's campaign teams as they carry out a range of field experiments to support ESA's Earth observation missions and new instrument development at
http://blogs.esa.int/campaignearth

→ Activity 3 – Sea ice through the seasons

Satellites have been observing sea ice for more than three decades. Scientists analyse this data in order to identify short and long-term trends that help to characterise and monitor sea ice. In this activity you will analyse long-term data about sea ice extent and discuss seasonal changes of sea ice.

Exercise

1. Before you start analysing sea ice data, discuss your expectations in small groups:

   a. Do you expect the sea ice extent to change within the year? Why?

   b. In which month(s) do you expect to find the least and the most sea ice?

   c. Do you expect the sea ice extent to change over the years? Why?

2. You will now analyse and compare sea ice variations in different months during the same year. Describe the change of sea ice extent over the course of one year. In which month(s) do you find the least and the most sea ice?

3. You will now analyse and compare the mean annual sea ice extent in different years. Describe the annual mean sea ice extent for different years and compare it with the overall trend.

4. Is your analysis of the seasonal changes and the changes for different years similar to your expectations in question 1? Try to explain any differences.

Did you know?

Sea level is a very sensitive index of climate change. In ice form, sea ice is already contributing its volume to the oceans. Thus when it melts it does not increase the volume of the oceans. However, melting sea ice changes ocean salinity, affecting ocean currents and therefore the global climate system. Melting land ice such as glaciers and ice caps, on the other hand, contribute to the volume of the ocean and rising sea levels. With a focus towards oceans, the Copernicus Sentinel-3 satellite can measure and monitor changes in sea level. This information is essential to understanding our climate as well as the risks to coastal areas vulnerable to rising sea level.

→ Links

ESA resources

ESA classroom resource - Highways of the oceans
esa.int/Education/Teachers_Corner/Highways_of_the_Oceans_-_Sea_currents_and_the_connection_to_climate_TEACH_WITH_SPACE_G02

ESA classroom resource - The greenhouse effect and its consequences
esa.int/Education/Teachers_Corner/The_greenhouse_effect_and_its_consequences_-_Investigating_global_warming_Teach_with_space_G03

ESA space projects

Cryosat mission
esa.int/Our_Activities/Observing_the_Earth/CryoSat

Copernicus Sentinel-1
esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-1

Copernicus Sentinel-3
esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-3

Extra information

ESA app “Climate from Space”
esa.int/Our_Activities/Observing_the_Earth/Space_for_our_climate/Climate_at_your_fingertips

Sea ice data derived from ESA satellite SMOS and others
data.seaiceportal.de

Copernicus marine environment monitoring service
marine.copernicus.eu

Monthly sea ice maps from Copernicus Climate Change service
climate.copernicus.eu/sea-ice

Sea ice: an overview
metoffice.gov.uk/research/climate/cryosphere-oceans/sea-ice/overview

→ Annex

Northern Hemisphere sea ice extent
marine.copernicus.eu/science-learning/ocean-monitoring-indicators/catalogue