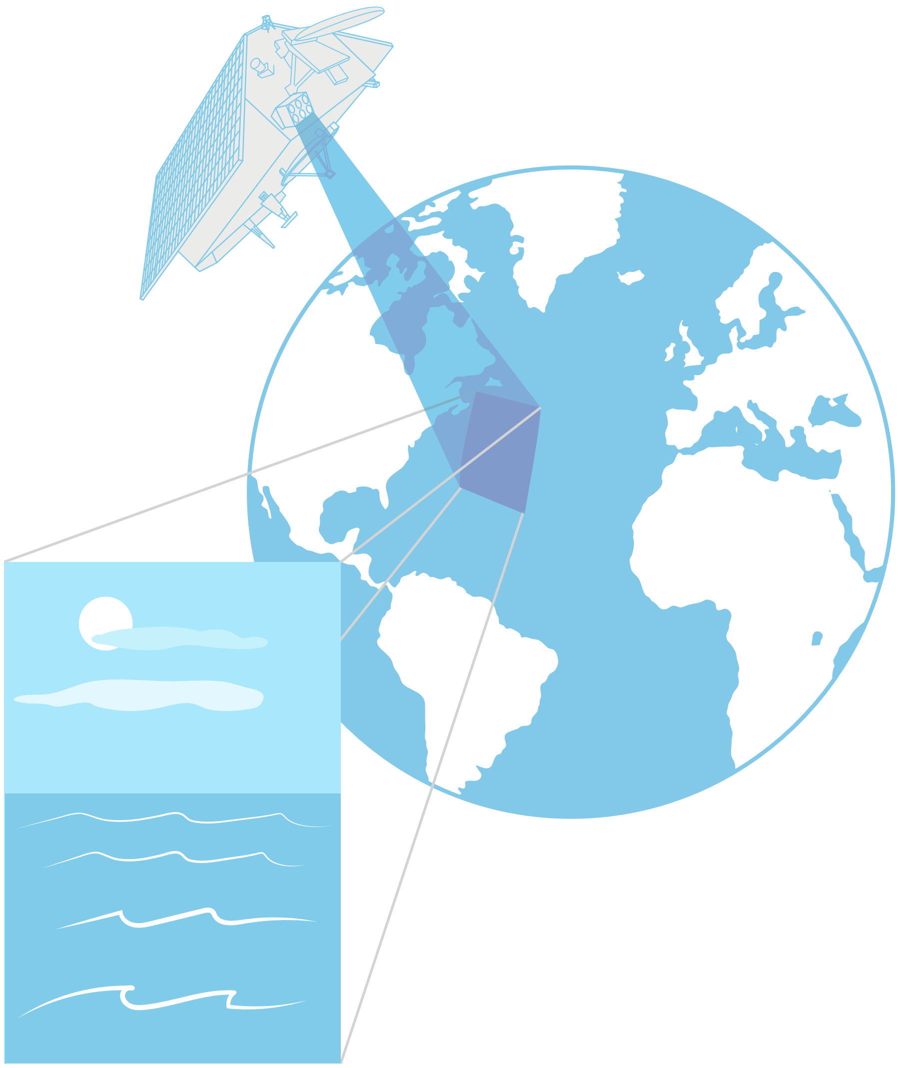
teach with space

→ HIGHWAYS OF THE OCEANS

Sea currents and the connection to climate



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→ HIGHWAYS OF THE OCEANS

Sea currents and the connection to climate

Fast facts

Subject: Geography, Science, Physics
Age range: 12-15 years old
Type: student activity
Complexity: easy
Lesson time required: 45 minutes for each activity
Cost: low (0 -10 euros)
Location: indoors
Includes the use of: multimedia module; computer and internet
Keywords: Earth observation, Sea currents, Sea surface temperature, Climate, Geography, Science, Physics

Brief description

In this set of activities students will use an multimedia module to learn about sea currents, the highways of the oceans, and how they are important for understanding local climates. Using a hands on activity they will investigate what causes ocean currents. They will also use satellite images to analyse the temperature of the sea surface and understand why satellite observations are useful for monitoring sea currents.

Learning objectives

- Elaborate on global ocean and air currents and discuss what they mean to the climate.
- Identify local and global weather processes and climatic phenomena and their causes.
- Use tools available on the internet to collect and analyse satellite data.
- Understand how Earth observation can be used to monitor oceans.
- Interpret sea surface temperature maps.

→ Summary of activities

Summary of activities					
	Title	Description	Outcome	Requirements	Time
1	Ocean in motion	Ocean currents and how they connect remote places. The great Pacific garbage patch.	To identify main ocean currents. To understand what drives ocean currents and how ocean currents have a global influence.	None	45 minutes
2	How does water sink?	A practical experiment to model water movements and investigate how deep ocean currents are created.	To understand that deep ocean currents are driven by differences in the water's density, which is controlled by temperature and salinity.	Activity 1	45 minutes
3	Feeling the heat	Analysing measurements of sea surface temperature taken by satellites.	To describe and understand the general distribution of sea surface temperatures.	None	45 minutes

→ HIGHWAYS OF THE OCEANS

Sea currents and the connection to climate

→ Introduction

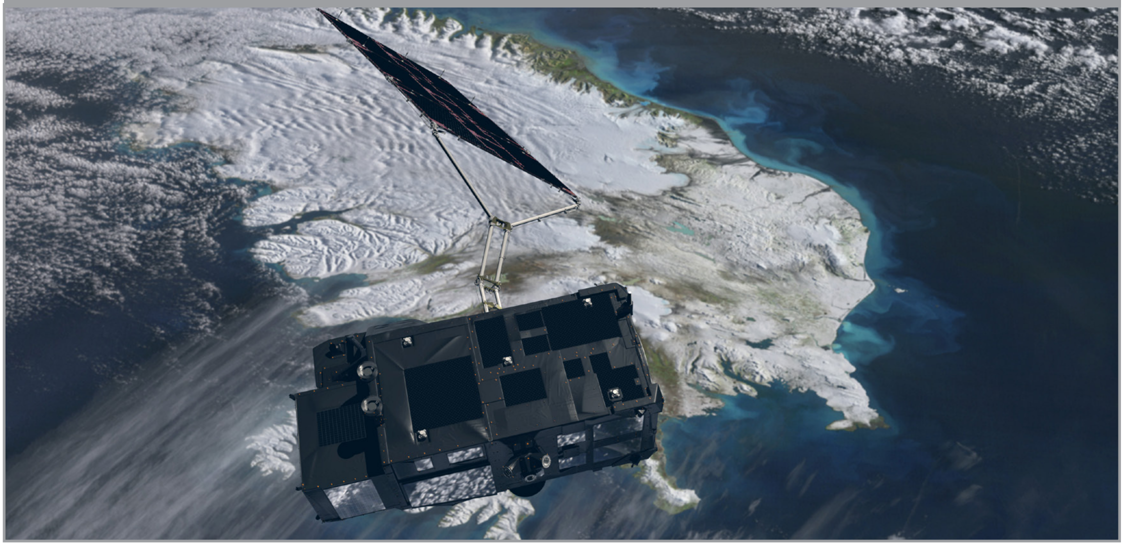
Covering 71% of the planet, the oceans are intrinsically linked to our weather and climate. They are also essential for global transport and provide a wealth of resources. What happens far out to sea has a direct impact on societies all over the world.

Ocean currents are driven by surface winds, differences in water density due to salinity and temperature variation, and by Earth's rotation. Ocean circulation and the ocean's capacity to accumulate and slowly release the energy it receives from the Sun play a crucial role in moderating the climate.

The oceans directly absorb the majority of solar heat, retaining it for much longer periods of time than either the land or the atmosphere. The equator receives much more energy from the Sun than the polar regions. The major ocean currents, together with the wind, help redistribute this energy around the world.

Satellites in combination with in-situ instruments provide important information to understand and monitor the oceans. Through Earth observation, scientists have been able to model and monitor global sea surface temperatures in unprecedented detail over the last decades. Considering that oceans are vast reservoirs of heat, measuring the sea surface temperature can improve our understanding of global warming and climate change.

Figure 1



↑The European satellite Sentinel-3 carries a suite of state-of-the-art instruments, including an infrared radiometer to provide global maps of sea surface temperature for monitoring climate change, ocean and weather forecasting.

→ Activity 1: Ocean in motion

In this activity, students will explore an multimedia module to learn about sea currents and how they connect remote places on our planet. Students will learn that winds and Earth's rotation are the main causes of surface currents. At the end, students will discuss ocean pollution, and debate possible actions to lessen the problem.

Equipment

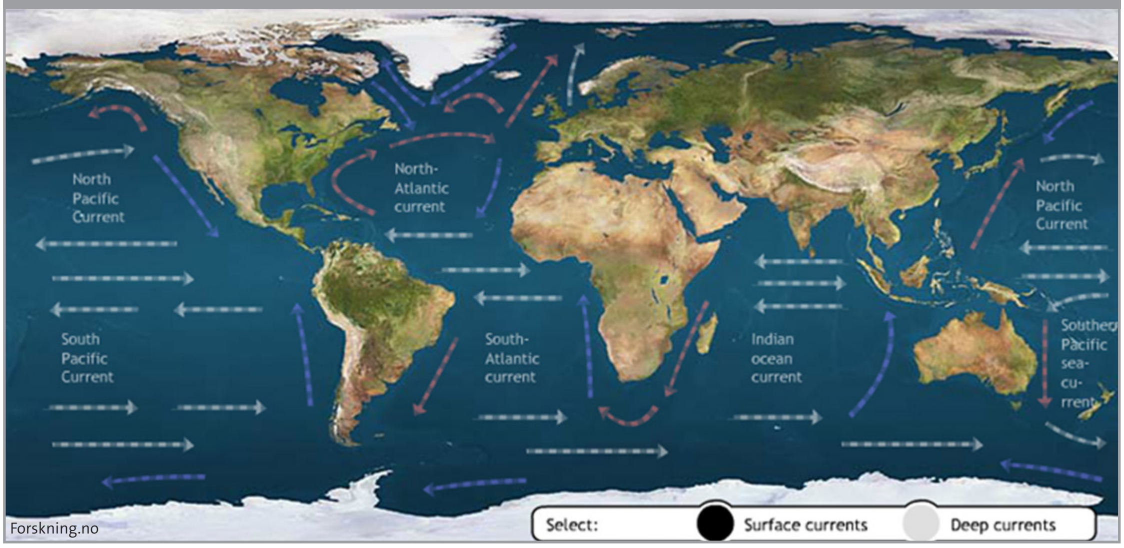
- PC and multimedia module "Sea_currents.exe" by Forskning.no and/or other information sources

Exercise

To introduce the topic, ask students to imagine dropping a message in a bottle into the ocean at a given location. Students should then answer question 1 on the student worksheet. Discuss in small groups where they think the bottle would wash up as a result of ocean currents. When the bottle is thrown into the Atlantic Ocean in Florida, the Gulf Stream will transport it eastwards towards Europe and Northern Africa. Then it will either follow the Canary current to the South, or the Norwegian Atlantic current to the North. The bottle will reach destination 2 or 4.

Students then work with the multimedia module, either in groups of two or independently. Teachers can also analyse the module with the whole class with a projector . Students answer question 2 on their worksheet while exploring slides 1 (Figure 2) to 3 of the module.

Figure 2



↑Sea currents, multimedia module.

Answers exercise 2

2. a. Identify two countries/cities that are affected by currents: one related to a warm current (red arrows), and another to a colder current (dark blue arrows).

    - UK – Norwegian Atlantic stream – warm current
    - Florida (USA) – Gulf stream – warm current
    - Canary Islands – Canary current – cold current

c. How are surface currents powered?

Surface currents in the ocean are primarily driven by the wind.

d. Identify a wind current and write down the sea surface current/s it powers.

- West wind belt (northern hemisphere westerlies): north Atlantic current.
- Northeast trade winds: northern equatorial current.

e. Try to answer the question from slide 3: why are both winds and ocean currents deflected to the right in the Northern Hemisphere?

The Earth rotates on its own axis, and because of that circulating air is deflected. Instead of circulating in a straight pattern between the poles (high pressure areas) and the equator (a low-pressure area), the air deflects toward the right in the Northern Hemisphere and toward the left in the Southern Hemisphere. This effect is called the Coriolis effect. The Coriolis effect deflects the circulating air that causes the movement of the water's surface. Therefore, it also deflects the surface ocean currents to the right in the Northern Hemisphere and to the left in the Southern Hemisphere.

Discussion

The millions of tonnes of plastic ending up in the oceans every year are a global challenge. Teachers can use the exercise about a message in a bottle to make an analogy with the transport of plastic and waste by ocean currents. In small groups, students investigate where plastic would end up from the beach closest to their home town based on the knowledge they have acquired about oceans currents and investigate the Great Pacific garbage patch.

Students discuss their expectations and answer question a) and b) from the discussion. In the "Did you know" section students can discover some examples of what the European Space Agency is doing to respond to this global challenge.

→ Activity 2: How does water sink?

Winds drive ocean surface currents. However, ocean currents also flow thousands of metres below the surface. In this activity, students will investigate why these masses of water sink to form the deep ocean currents.

Equipment

- Two 250ml beakers
- Coloured ice cubes
- 1 teaspoon
- Salt
- Water

Health and Safety

- Students should wet fingers before touching ice cubes.
- Coloured water/ice could stain fingers/clothes/tables.

Exercise

As a starting point, students discuss in small groups their expectations about why they think ocean water sinks to form deep ocean currents. After answering question 1, students set-up the experiment. Instructions for doing the experiment are provided in the student worksheet.

Discussion

Beaker 1 contains salt water, which has a higher density than the fresh water in beaker 2. Therefore, the coloured water from the melting ice cubes accumulates as a layer on top of the water in beaker 1 (see figure 3). In beaker 2, the melting water is colder than the water in the beaker, and therefore students can see how the coloured water is sinking. This creates some turbulence and mixing, resulting in colouring of all the water in the beaker. Students should compare their expectations to the question, "How does the ocean water sink to form deep ocean currents?" to their answer to question 4 of the discussion.

Figure 3

↑ Experimental results: the coloured melting fresh water accumulates on the top of the more dense salt water in beaker 1 (left).

To conclude and link with Activity 1, teachers can show students slides 5 to 8 from the multimedia module.

Extension – The Gulf Stream current

Teachers can use the Gulf Stream current example and ask students to answer the question from slide 9 from the multimedia module: "How can the ocean's currents be affected by the ice melting?", and explore possible impacts on the climate.

The Gulf Stream current, which carries warm surface water northwards from the Gulf of Mexico to the sub-polar ocean east of Greenland, is very important for the climate in Europe. The coastal waters of Europe are a few degrees warmer than waters at the equivalent latitude in the North Pacific. These warm waters mix with surrounding water, and cool and sink as they reach the Arctic. If this circulation pattern were disturbed by melted ice in the Arctic, there could be a profound effect on the strength and direction of this current. This current could become weaker or even stop.

Students should be able to explain that ice consists of freshwater, and as ice melts there is an influx of freshwater into the surrounding ocean. This reduces the salinity and, consequently, the density of the water. Students should be able to explain why, therefore, global warming can affect sea currents and the impacts this may have. Students should understand that combining satellite measurements along with ground measurements, can produce a unique view of ocean-surface circulation, helping us to predict how our planet will react to a changing climate.

→ Activity 3: Feeling the heat

In this activity, students will use satellite images to analyse the temperature of the sea surface. Students will investigate the relation between ocean currents and the sea surface temperature (SST), and understand the importance of monitoring the temperature of the oceans.

Equipment

- PC and internet access

Exercise

To introduce the topic, ask students to answer question 1 on their worksheets. Students should be able to identify the heating from the Sun as the main mechanism responsible for the distribution of the temperature of the sea.

Then students analyse measurements of the sea surface. For that they download the latest Sea Surface Temperature image from the website of University of Wisconsin-Madison Space Science and Engineering Center (see Links section). Guide students so they conclude that temperature varies by latitude, from the warm region along the equator to the cold regions near the poles. The large areas of sea ice around Antarctica appear in shades of grey, indicating no data were collected.

Students can identify the western coasts of South America, and Africa as well as the Norwegian coast as areas that deviate from the general behaviour of the distribution of the sea temperature. In the western coast of South America and South Africa, the water is colder due to the Humboldt current and Benguela current, respectively. The temperature of the water in the Norwegian coast is warmer when compared with other place at the same latitude due to the influence of the Gulf Stream.

Teachers can show again the multimedia module from Activity 1 (slide 1) for students to identify the effects of the ocean currents in the SST image that they downloaded.

As a final exercise, students analyse the seasonality in sea surface temperatures. Before starting the exercise, students should discuss their expectations regarding the changes of the sea surface temperature with seasons. In order to complete the exercise, students download one SST image for each season. Teachers can choose to download the images in advance and complete the exercise with the whole class, or in small groups with a printed version of the images.

Students can also analyse the animation from ESA's Climate Change Initiative (see Links section) showing changes in global sea-surface temperature between 1991 and 2010. They can investigate the seasonality as well as possible changes of the sea surface temperature.

Students conclude that the seasonality in sea surface temperatures is largest in mid-latitudes and lowest in the tropical ocean near the equator. This seasonality derives from changes in atmospheric conditions such as winds and temperature. Since the sea surface is in direct contact with the atmosphere, its temperature follows atmospheric seasonal patterns. Teachers can also ask students to compare oceanic seasons with respect to their atmospheric equivalents, and discuss the high heat capacity of water.

→ HIGHWAYS OF THE OCEANS

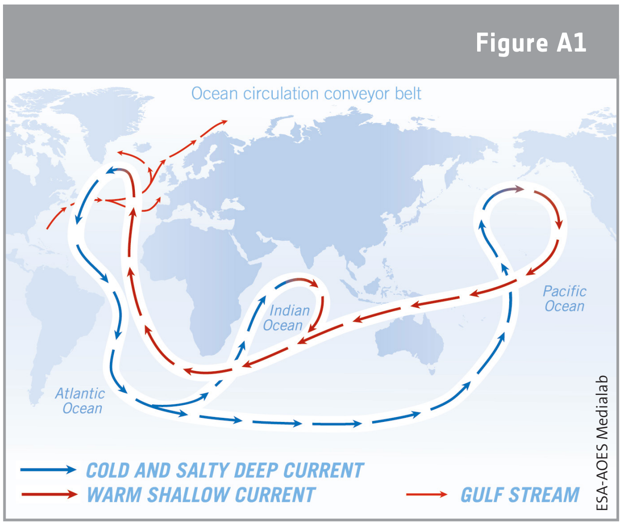
Sea currents and the connection to climate

Ocean currents transport warm and cold water over enormous territories. Many of these currents have a major influence on the climate on land. Satellites are important tools for monitoring of oceans, surveying current changes, and contributing to increased knowledge about the pattern of ocean currents.

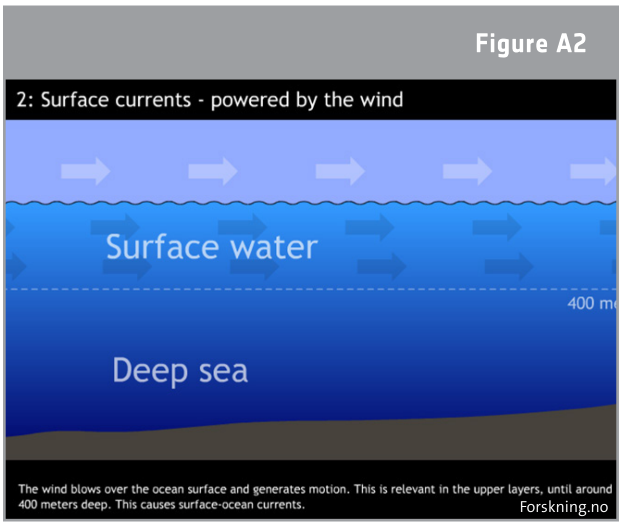
The ocean in constant circulation

The ocean covers about 71% of the globe and is therefore essential to the environment and to life on Earth. These enormous quantities of water are in constant circulation, and transport heat and energy from one area of the globe to another, for instance along the coast of Europe.

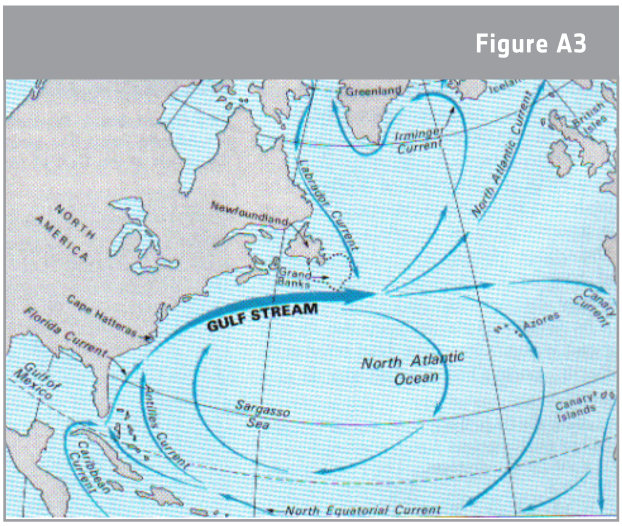
The systems of ocean currents are primarily driven by a combined effect of wind, atmospheric pressure on the surface, and the differences in density between various water masses. This density depends on the temperature and salinity of the water. Therefore, many effects define the 'highways of the oceans'.



↑ Ocean currents have a key role in climate.



↑Surface and deep sea currents.



↑ Gulf Stream current.

→ Activity 1: Ocean in motion

In this activity, you will use an multimedia module to learn about sea currents – the highways of the oceans – and how they connect completely remote places on our planet. You will also learn what drives surface currents and discuss the importance of these highways.

Did you know?


ESA/ATG Medialab

Christopher Columbus used the Gulf Stream current to be able to reach America by sailing from the Canary Islands during his voyages. In the past, exploration and navigation across the Atlantic provided knowledge of this warm current. Today, Earth Observation satellites offer a frequent overview of our entire planet – covered mostly by water – and provide valuable data to monitor and understand this and other ocean currents. Measurements of ocean surface currents are fundamental to a number of practical applications, such as marine search and rescue and emergency response, ship routing, and water pollution monitoring.

Equipment

- PC and multimedia module "Sea_currents.exe" by Forskning.no and/or other information sources

Exercise

1. In this exercise you will explore the ocean currents. Before you start doing that, let us think about currents:

   Imagine that you are in Florida, USA, marked with a  in figure A4, and want to send a message inside a bottle. Where do you expect this message can go? Mark the possible correct answer. Take into account that there can be more than one correct answer. Discuss with your colleagues in the classroom.

   ☐ 1. We will find it on the south-eastern coast of South America (Brazil or Argentina).

   ☐ 2. We will find it in the Canary Islands.

   ☐ 3. We will find it on the south-western coast of Africa.

   ☐ 4. We will find it in north Norway.

   ☐ 5. After some time, the bottle will return to the beach in Florida.

Figure A4

↑Where does the bottle go?

2. You will now start exploring the multimedia module: analyse slides 1 to 3 and answer the following questions:

a) Identify two countries/cities that are affected by currents: one related to a warm current (red arrows), and another to a colder current (dark blue arrows).

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b) Follow the North Atlantic current. Think again about the bottle experiment from question 1 and revise which area/s the bottle can reach.

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c) How are surface currents powered?

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d) Identify a wind current and write down the sea surface current/s it powers.

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e) Try to answer the question from slide 3: why are both winds and ocean currents deflected to the right in the Northern Hemisphere?

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Discussion

a) You have been thinking about a message in a bottle. But the currents are also moving all the trash we throw into the sea, and this is a lot! Due to currents, plastic travels large distances, and huge amounts can accumulate in certain places. Choose the closest sea coast to your local area. Where do you expect the plastic trash that it is thrown there will be accumulated?

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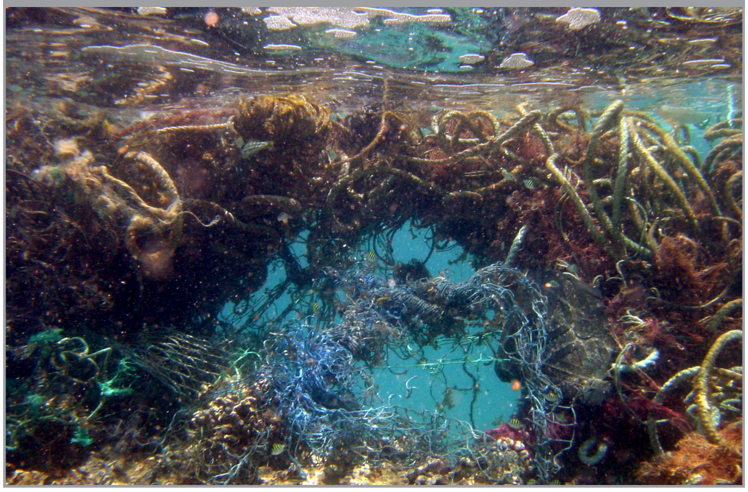
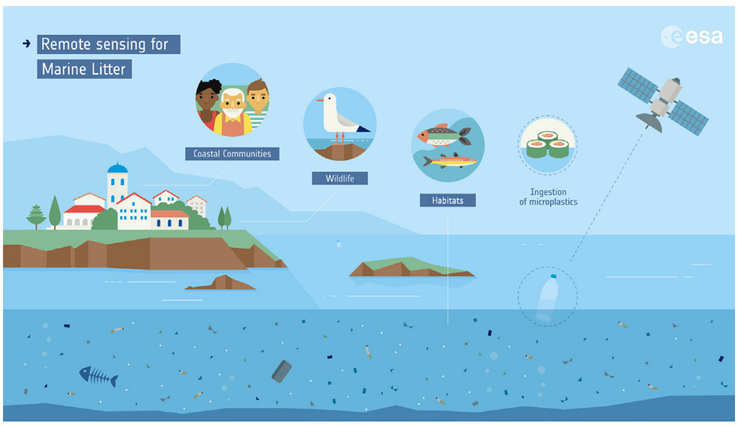
b) Have you ever heard about the Great Pacific garbage patch? It is a massive floating island of plastic between California and Hawaii. Research online to find more information about this "island" and discuss possible actions to mitigate the problem.

Figure A5



↑ Marine debris found in the waters of the Northwestern Hawaiian Islands Marine National Monument.

Did you know?



The European Space Agency (ESA) is investigating technology that would allow satellites to identify the concentration, movement and origin of plastic debris across the world's oceans. Plastics in the ocean can be identified by satellites due to the way floating debris reflects different wavelengths of sunlight, in a similar way to how current satellites can pick out concentrations of phytoplankton, suspended sediments, and water pollution. Satellite measurements have the great advantage of providing global coverage and this can give important insights to scientists to enable them to understand and monitor the problem.

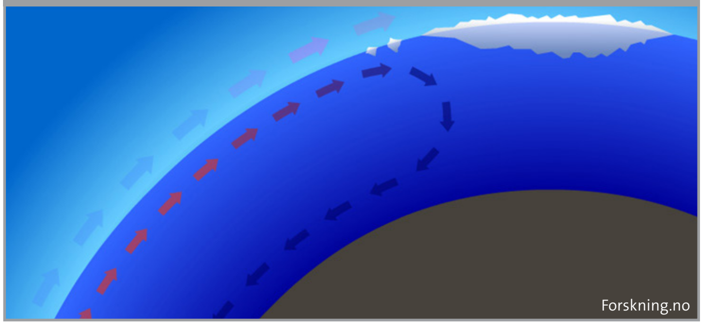
→ Activity 2: How does water sink?

The world's oceans consist of two types of ocean currents: surface currents and deep water currents. In this activity, you will explore why some of these masses of water sink to form the deep ocean currents.

Equipment

- Two 250ml beakers
- 1 teaspoon
- Coloured ice
- Salt
- Water

Figure A6



↑ Sea currents multimedia module, water flow.

Exercise

1. Describe why you think deep water currents are originated by answering the following question:

   How does the ocean water sink to form deep ocean currents?

2. You will now model water movements and investigate how deep ocean currents are caused. Fill two beakers with roughly 200ml of tap water.

3. Mix three teaspoons of salt into one of the beakers (beaker 1) and let it settle until the water is clear. While waiting, answer the following question:

   Prediction: What will happen when you put the ice cubes in the beakers and they start melting?

4. Gently drop one ice cube into each of the beakers.

5. As the ice starts melting, observe and record the behaviour of the fluids. Do not disturb the beakers.

Discussion

1. Describe the differences between what happened in beaker 1 and beaker 2.

2. Are your results similar to your prediction? Explain why or why not.

3. What can you conclude about the density of the water in the beakers in comparison to the cold water released by the melting ice cubes?

4. Based on your observations, what do you think are the main causes of deep ocean currents?

5. Compare your observations and conclusions with what is shown in the multimedia module (slides 5 and 6). Are they similar?

→ STUDENT WORKSHEET

Extension – The Gulf Stream current

Revise all the slides of the sea currents multimedia module. Discuss in small groups the following issues:

1. What may happen to the Gulf Stream current if sea ice continues to melt, and why?

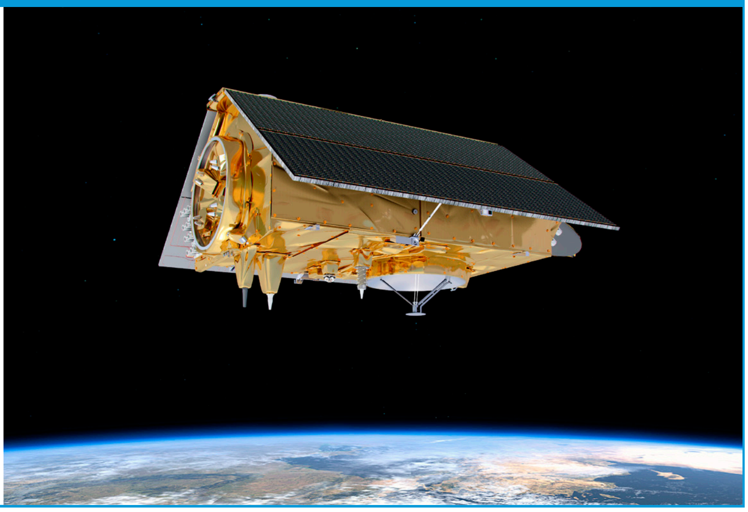
2. Does this have any impact on the climate?

3. How could this affect the economy of the region? For example, Norway's northern coast is very rich in fisheries that provide a major income for many families.

4. How can we monitor the health of the Gulf Stream current?

Did you know?

The European Space Agency is developing a family of innovative satellite missions – the Sentinels – to understand and monitor our planet. Sentinel-6/Jason-CS will map up to 95% of Earth's ice-free ocean every 10 days, providing vital information on sea level variability, wind speeds and wave height for maritime safety. The instruments carried on Sentinel-6 will also measure the ocean surface topography – the hills and valleys of the ocean – to help us to map ocean currents.

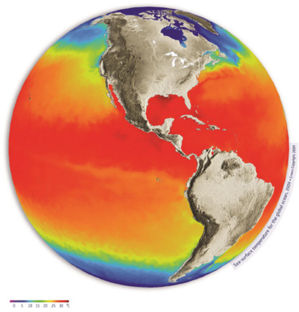


→ Activity 3: Feeling the heat

In this activity, you will use satellite images to analyse the temperature of the sea surface, a key measurement for climate scientists. This is a very important parameter to understand the health of our planet. It also gives indications about sea currents. Measurements of the surface temperature of the water are made from a variety of satellite systems. These types of surface temperature image are called SST – Sea Surface Temperature images.

Did you know?

To measure the sea surface temperature, satellites register different types of light that we cannot see with our eyes. One of these special types of light (or radiation) is called thermal infrared. It is the same radiation registered by night vision cameras. The infrared sensor from the Sentinel-3 satellite provides precise global maps of sea surface temperature. This information is used to monitor oceans and climate change, as well as for weather forecasting.



Equipment

- PC and internet access

Exercise

1. Before you start analysing measurements of the sea surface temperature taken from satellites, discuss in small groups the following questions:

   a) What do you think are the main mechanisms responsible for the distribution of the temperature of the sea? Mark the correct answer(s).

   ☐ Heating from the Sun

   ☐ Pollution

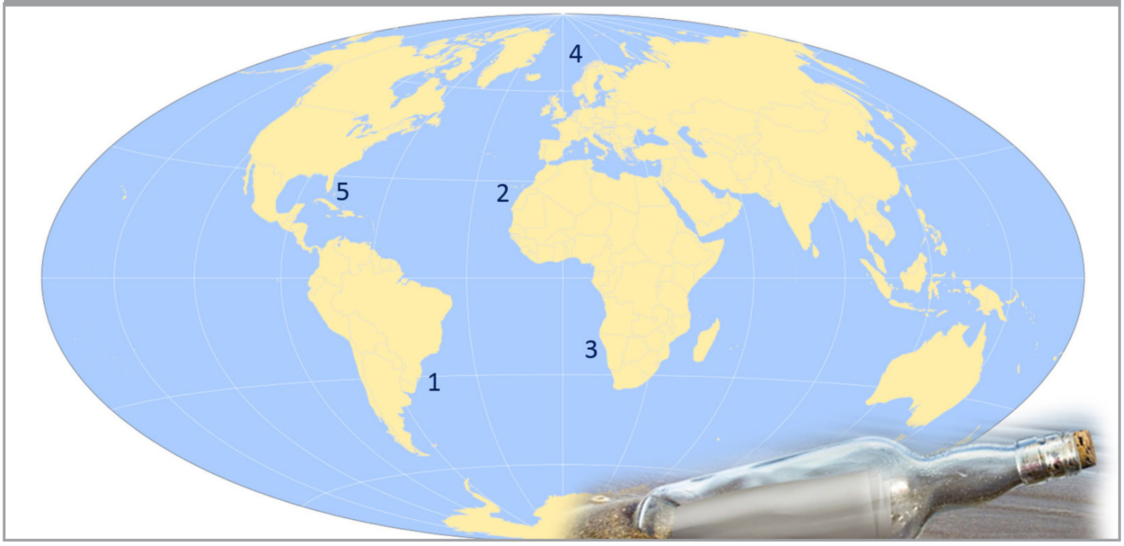
   ☐ The clouds

   ☐ The level of CO_2

b) Where do you expect to find warm water? See figure 7 and identify the beaches with warmer water (order them from warmer to colder).

1- Belem (Brazil), 2- Bleik (Norway), 3- Florida (USA), 4- Tenerife (Spain), 5- Lisbon (Portugal).

Figure A7



↑Localisation of the beaches for task 1.

2. You will now analyse the latest measurement of the sea surface temperature taken by satellites and compare with your expectations.

   a) Open the following link from the University of Wisconsin-Madison Space Science and Engineering Center:

   www.ssec.wisc.edu/data/sst

   Click on "Latest Sea Surface Temperature image" to enlarge and save the picture.

   b) Analyse the sea surface image you have downloaded. Looking at the planet, describe the general distribution of temperatures. Where is it warmer and where is it colder?
   The scale shows the temperature in Fahrenheit (°F). To convert it to Celsius (°C), remember that $T(°C) = (T(°F) - 32) \times 5/9$.

   ____

   ____

   c) Compare your answer to question 2b) with your answer to question 1b). Are your expectations similar to your observations from the SST image? Explain why or why not.

   ____

   ____

d) Some areas deviate from the general behaviour of the distribution of sea temperature. Locate two of them on the map and describe how they differ.

3. You will now analyse and compare SST images from different seasons.

   a) Open the following link: www.ssec.wisc.edu/data/sst/archive. The SST images you see are sorted by date. Download one SST image for each season.

   b) Observe and compare the images. Identify two areas where you detect changes in ocean surface temperature and two areas where the temperature is constant for the different seasons.

4. Are the differences in sea surface temperatures according to seasons similar to your expectations? Explain why and compare your answer to your expectations in question 1a).

→ Links

ESA resources

ESA classroom resources:
esa.int/Education/Classroom_resources

ESA space projects

ESA's Earth Observation missions
esa.int/Our_Activities/Observing_the_Earth/ESA_for_Earth

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

Sentinel-6
esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-6

ESA's Climate Change Initiative
http://cci.esa.int

Extra information

Ocean currents interactive module developed by Forskning.no and translated to English by Nordic ESERO
http://esamultimedia.esa.int/docs/edu/sea_currents_english.zip

University of Wisconsin-Madison Space Science and Engineering Center - Sea Surface Temperature Data
www.ssec.wisc.edu/data/sst

Animation showing changes in global sea-surface temperature between 1991 and 2010, by ESA's Climate Change Initiative
esa.int/spaceinvideos/Videos/2018/05/Global_sea-surface_temperature_1991_2010

Video Sentinel- 3 for oceans
esa.int/spaceinvideos/Videos/2016/02/Sentinel-3_for_oceans

Videos and animations related to ocean's research within ESA
esa.int/Our_Activities/Preparing_for_the_Future/Space_for_Earth/Oceans/ESA_and_Oceans_videos

Science Education through Earth Observation for High Schools (SEOS) Project
lms.seos-project.eu/learning_modules/oceancurrents/oceancurrents-c00-p01.html