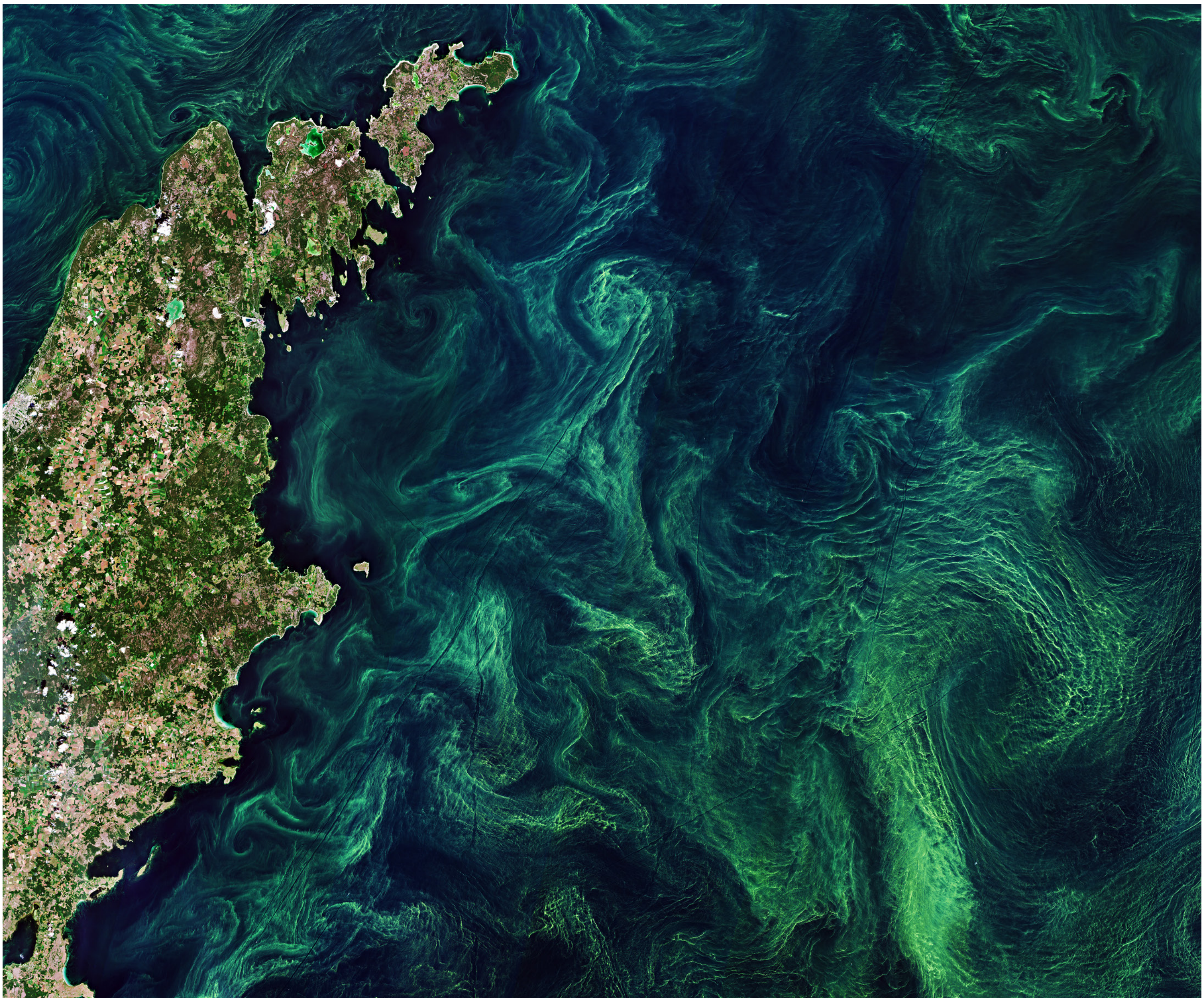
teach with space

→ COPERNICUS BROWSER CASE STUDY: ALGAL BLOOMS FROM SPACE

EARTH OBSERVATION IN THE CLASSROOM



Baltic Blooms.
Credit: Contains modified Copernicus Sentinel data (2019), processed by ESA

Learning Objectives:

- Define algal blooms and identify their potential causes and effects on ecosystems and society.
- Describe the benefits of using satellite imagery from the Copernicus Sentinel-2 mission to detect and monitor algal blooms, including its ability to provide large-scale, frequent, and detailed observation.
- Use the Copernicus Browser to locate, analyse, and interpret satellite data related to algal blooms.
- Investigate patterns in algal bloom development over time and examine the relationships between environmental factors and bloom intensity.
- Assess the strengths and limitations of satellite data compared to ground-based observations for monitoring algal blooms.

Brief Description:

This activity supports teachers in guiding their students to investigate algal blooms and their impacts using satellite imagery. It includes exercises for data collection and analysis, which can be adapted to the specific focus chosen by the teacher and students. By using satellite data from the Copernicus Sentinel-2 mission, students will examine the factors contributing to algal bloom formation, learn to detect and analyse these phenomena and reflect on their impacts on ecosystems and society.

Note! This activity is designed to complement the Copernicus Browser Teacher Guide, which provides more details about the tool and its features.

Fast Facts:

Subject: Geography, Biology, Physics, Environmental Sciences

Age range: 12-18 years old

Type: Student Activity

Complexity: Adaptable

Lesson time: 60 minutes

Cost: N/A

Location: Indoor

Requirements: Internet access and an electronic device (such as a tablet or laptop)

Keywords: Water Quality, Algal Blooms, Satellites, Satellite Imagery, Climate Change, Cyanobacteria, Earth Observation, Copernicus Browser, Photosynthesis, Hands-On Learning

What is Copernicus Browser?

The Copernicus Data Space Ecosystem Browser is an online application that provides easy and free access to satellite imagery from different Earth Observation (EO) missions. It provides ready-to-use satellite images and pre-configured visualisations. The browser can be accessed from a desktop browser or a mobile device

How to use Copernicus Browser for Education?

The Copernicus Browser is a powerful tool for STEM education, making it easy to bring real-world environmental data into the classroom. It supports classroom investigations and projects like Climate Detectives, helping students investigate global changes through satellite imagery. Whether you're teaching geography, physics, biology or environmental sciences, this tool provides a hands-on way to explore Earth's transformation over time.

With the Copernicus Browser, it is possible to explore satellite images of almost any location, such as a city, a glacier, deserts, rainforests, or even a volcano. These images can be viewed in true colour, just as they appear to the human eye, or through different satellite modes that highlight key environmental factors like vegetation health, chlorophyll levels in water, air pollution patterns, etc.

The *compare function* and *time-lapse* features allow us to track changes on Earth over time using data from the Sentinel satellites, which have been monitoring the planet since 2014. It is possible to create series which show landscapes evolve with the seasons, measure the area of deforestation, or analyse the impact of natural disasters like volcanic eruptions. Images in different formats can be downloaded for further study and classroom activities.

By integrating the Copernicus Browser into lessons, environmental science can be turned into an interactive experience, giving students the tools to explore, analyse, and understand the world around them, like real scientists.

Algal bloom in the Baltic Sea downloaded from the Copernicus Browser platform

How to use this resource?

This student activity is designed to guide students through the investigation of algal blooms using satellite data from the Copernicus Sentinel-2 mission. Use the following steps to effectively implement the activity in the classroom.

Introduction to the Topic

Begin by familiarising students with the basics of algal blooms, their causes, and their impacts on ecosystems and society. Use the provided background information to set the context for the investigation. Students can also build knowledge related to the topic by watching short documentaries or videos or by conducting web research.

- *What are Algal blooms?*
- *Why do algal blooms develop?*
- *Do you think algal blooms could help us or cause problems to us in any way?*
- *What are the main problems caused by algal blooms?*
- *How does climate change impact the water quality in relation to algal blooms?*

Get to know the Copernicus Browser

Before starting this activity, it is recommended to understand and test the Copernicus Browser tool, which can be done by consulting the Copernicus Browser Guide. It is also recommended that each student create an account/log in to the Copernicus Browser before beginning the activity, as this may take up time. Instructions for creating an account are provided in the 'Getting Started on the Copernicus Browser' section below.

Data Collection and Analysis

Students will use the Copernicus Browser to locate and analyse satellite imagery of algal blooms in specific regions. Guide students in selecting time frames and zooming into the desired areas. Encourage them to identify visible patterns in algal bloom development over time, focusing on seasonal changes.

Discussion and Reflection

After gathering data, students should reflect on their findings by answering the guided questions provided in this resource. These will help them analyse algal bloom patterns, consider the potential environmental triggers, evaluate the limitations of satellite data, and explore the broader impacts of blooms on ecosystems and society. Facilitate this process by encouraging deeper analysis, fostering group discussions, and prompting students to consider both the scientific and societal aspects of their finding

Background Information

Teacher Part

What are Algal blooms?

Algal blooms are rapid increases in the population of algae in water bodies, often resulting in dense, visible patches on the surface. These blooms can involve both true algae (such as green algae, diatoms, and dinoflagellates) and cyanobacteria (commonly known as blue-green algae, though they are actually bacteria). Algal blooms can appear in green, blue-green, brown, or reddish colours. They typically occur in both freshwater and marine environments and are usually caused by a combination of factors, including:

- Nutrients: High levels of nutrients, particularly nitrogen and phosphorus, often from agricultural runoff, wastewater, or fertilizers, fuel algae growth.

- Sunlight: Abundant sunlight supports photosynthesis, enabling algae to reproduce more rapidly.
- Temperature: Warmer water temperatures often accelerate algae growth.
- Stagnant water: Calm, slow-moving water provides ideal conditions for blooms to form.

While some algal blooms are harmless, others can be detrimental to ecosystems, human health, and local economies. Harmful algal blooms (HABs) can produce toxins that affect aquatic life, contaminate drinking water, and pose risks to humans through contact or consumption of affected seafood.

In addition, large algal blooms can deplete oxygen levels in the water as they die and decompose, leading to dead zones where aquatic life struggles to survive. This oxygen depletion can create long-lasting consequences for ecosystems, such as the loss of biodiversity and the disruption of food chains.

Climate change is expected to worsen this problem by increasing water temperatures and altering nutrient levels, making algal blooms more frequent and severe. These changes are likely to have a greater impact on fisheries, tourism, and local economies worldwide.

Earth Observation Data using Satellites

Earth Observation (EO) involves the collection, analysis, and presentation of data to better understand our planet. This data can be gathered by remote sensing platforms, such as satellites, or directly from the ground. Ground-based measurements, known as 'ground data' or 'in-situ' (on the spot), are essential for validating satellite measurements. Together, these two types of data complement each other, providing a more accurate picture of our planet's environment.

From above, satellites collect data from all around the world, even from very remote places. By doing so, they provide a global perspective and ensure frequent and continuous measurements. The data collected by satellites can be converted into actionable information, which can be used to monitor environmental factors such as air pollution, map deforestation and urban growth, Earth's temperature changes and enable rapid and resilient crisis response after natural or man-made disasters. Recognising the importance of this data, ESA continues to have Earth Observation as a key priority and has developed the Sentinel satellites for the European Union's Copernicus programme, the largest environmental monitoring initiative in the world.

Satellite Data to Detect Algal Blooms

In this activity, we will use data from the Copernicus Sentinel-2, which is a two-satellite mission. Each satellite carries a high-resolution camera, allowing for the capture of super-sharp images of Earth. It is possible to take detailed images down to a 10 m resolution, even though Sentinel-2 is orbiting at a height of 786 km above our heads. The Sentinel-2 satellites can detect visible, near-infrared, and shortwave infrared light, and they photograph almost the entire Earth in just five days.

The satellite images are used to monitor changes in land use and to keep track of vegetation health. Although Sentinel-2 is mostly optimised for land applications, it also delivers data for monitoring ocean colour and biological activity. This makes it useful for detecting and observing seagrass and algal blooms from space.

Monitoring the development of potentially harmful blooms can be done by measuring their density and the area they cover, combined with data on currents, temperature, and salinity. Sentinel-2 captures light reflections from algae to identify different types based on their unique colours. These data can be obtained not only from Sentinel-2 but also from other satellites to maximize the understanding of ecosystems.

Getting Started on the Copernicus Browser

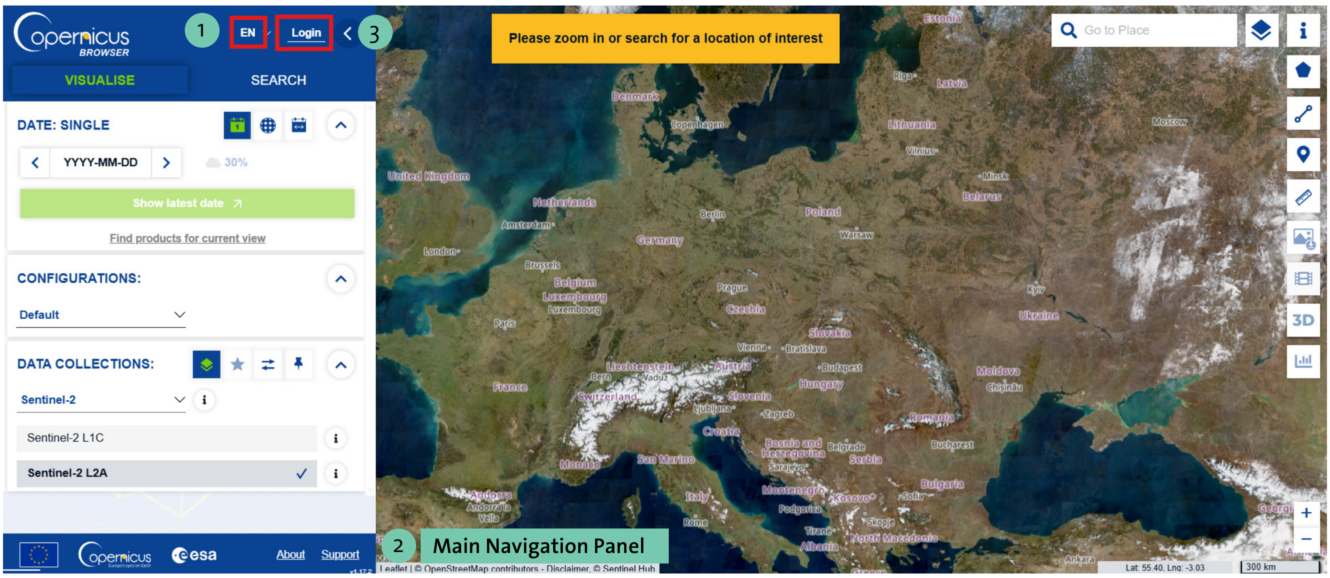
We strongly encourage you to ensure that each student has an account on Copernicus Browser before beginning the activity, as this may otherwise take up considerable lesson time. Instructions for creating an account are provided below:

1. Go to the Copernicus Browser, which can be accessed using the following link: https://browser.dataspace.copernicus.eu/

   The Copernicus Browser is available in different languages.

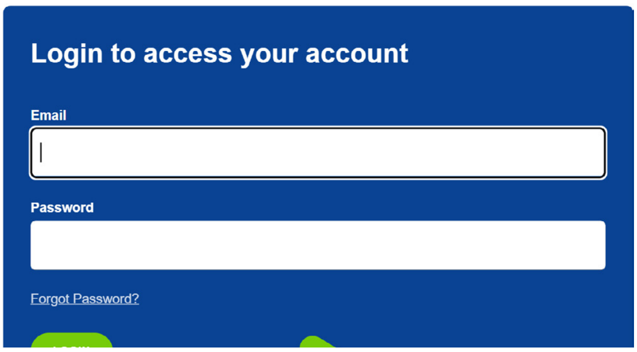
2. Select the language (1) in the Main Navigation Panel.

3. On the top right of the Main Navigation Panel, click on the login button (3).



Note: To complete this resource, you need an account. While it is possible to use the Copernicus Browser to download satellite images without a user account, some features of the map toolbar, such as the time-lapse function and saving pins (as needed in this resource), require you to be logged in.

Please also note that it may take some time to receive the verification email. We therefore recommend signing up before starting this activity.

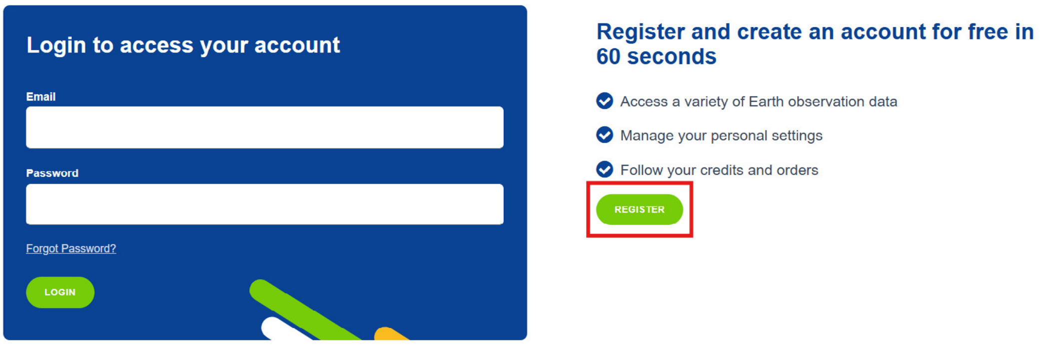


How to register on the Copernicus Browser:

Creating an account on the Copernicus Browser is free. To create an account, please follow this link: https://browser.dataspace.copernicus.eu/

1. Click on ''Login'':

2. A popup window will appear. Scroll to the bottom and click on "Register" at the bottom in green.



3. You will then be directed to a registration form that you need to fill out. After registration, you will receive a verification email. Note that it may take some time to receive it.

After familiarising yourselves with the Copernicus Browser and collected Copernicus Sentinel-2 data to analyse an algal bloom, you can begin a discussion and reflection on the activity using the following questions and answers. Students can work first in small groups, or a discussion with the whole class after each part of the Copernicus Browser exercise can be encouraged.

Questions and answers from the student worksheet

1. A) Did you find any boats in the satellite images? How did you identify them as boats?

Yes, boats were visible in the satellite imagery. They appeared as small, elongated shapes with contrasting colours against the water. They also had visible streams in the algal bloom left by their movement.

The trails in the algal blooms created by the boats' movement were clear indicators. Additionally, their placement in typical boating areas and their elongated shapes made them distinguishable from other objects.

The boats appear lightly blurry, with small details like passengers or specific features not visible. However, their general shape is still recognisable.

B) Based on your observations, how detailed do you think the satellite's resolution is? Can you estimate the size of objects the satellite might be able to capture clearly?

The key takeaway is the reasoning behind the estimation. The actual resolution of Sentinel-2 is 10 meters per pixel. This means that each pixel on the screen corresponds to 10 meters on the ground.

The boats shown on the satellite image have different sizes. By counting the pixels, you can estimate the size of the ships. Thinking about bigger container ships, the sizes you are estimating can be between 15-300 m. While they appear blurry, their general shape is visible, suggesting the satellite can capture objects at least this size. Since the details are unclear, the resolution isn't fine enough for small features. A reasonable estimate for the resolution would be between 10 and 20 meters.

2. A) In which months did you observe algal blooms?

Algal blooms were observed during the warmer months in the Northern Hemisphere, particularly in late spring and summer, from April to August.

B) In which month(s) was the bloom most intense?

The blooms were most intense in mid-to-late summer, particularly in July and August when water temperatures peaked, and sunlight levels were highest.

C) In which month(s) were there no signs of any blooms?

There were no visible signs of algal blooms in the colder months in the Northern Hemisphere, such as December, January, and February.

3. A) What might have triggered the algal bloom?

Warm water temperatures and stagnant water conditions might have triggered the algal blooms, as they are mainly present during the warmer months. The Baltic Sea also seems to be surrounded by agriculture, so the algal blooms may have been triggered by an increase in nutrients (nitrogen and phosphorus) in the water due to agricultural runoff.

B) How does climate change affect algal blooms?

Global warming worsens algal blooms by increasing water temperatures. Warmer water allows algae to grow faster and for longer periods, making blooms more frequent and severe. Additionally, because warm water is less dense than cold water, it is less likely to sink, trapping nutrients near the surface and providing algae with more fuel to grow.

At the same time, higher temperatures reduce the amount of oxygen water can hold, as gases like oxygen dissolve less effectively in warm conditions. When algae die and decompose, they further deplete oxygen levels, creating low-oxygen or "dead zones" that can harm aquatic life. As climate change continues to drive rising temperatures, these effects are becoming more prolonged.

C) What could be some of the limitations of satellite data compared to ground data and vice versa?

Satellite Data Strengths: Provides large-scale, consistent, and frequent observations, enabling the monitoring of wide areas and patterns over time.
Satellite Data Limitations: Limited in capturing subsurface blooms, species identification, or fine-scale details. Cloud cover can also reduce accuracy.
Ground Data Strengths: Allows for precise, localized measurements, such as nutrient concentrations, water clarity, and species identification.
Ground Data Limitations: Labor-intensive and time-consuming, with limited spatial coverage. Requiring direct human data collection.

D) What impact could the algal bloom have on society and ecosystems?

Algal blooms negatively impact society by:

- Damaging fisheries through oxygen depletion/toxin production, killing aquatic life.
- Contaminating drinking water and seafood with toxins harmful to human and animal food chains.
- Affecting tourism by making water bodies unsafe and unsightly.
- Creating economic losses in sectors like fishing and tourism.

E) What strategies can help reduce the risk of algal blooms?

Answers may include:

- Raise Public Awareness about the topic and the use of free satellite data: Educate society and inform local policymakers about algal blooms and areas most at risk by using satellite imagery to demonstrate the scale and seasonal patterns of the problem. Visual data from tools like the Copernicus Browser can be a powerful way to communicate the issue. Freely available satellite data (such as Sentinel-2 imagery) help local authorities, researchers, and students monitor and predict algal bloom occurrences and empower local action.
- Advocate for Sustainable Practices: Encourage the reduction of fertilizer in agriculture

and use practices reducing the run-off of fertilizer and nutrients, e.g., by using adapted application systems or advancing the selection of crops. Encourage industrial practices to reduce nutrient runoff (as improving wastewater management). Satellite data can be used to monitor the effectiveness of these interventions over time.

- Support Water Monitoring Efforts: Combine ground-based monitoring (e.g., Secchi disks and nutrient testing) with satellite data to ensure comprehensive tracking of water quality.

Introduction to the topic - Setting the Scene

Student Worksheet

Imagine yourself on a very hot summer day. The sun is scorching, but it's too risky to go swimming because there's a lot of blue-green algae in the sea and rivers nearby. Some species of algae kill fish and aquatic life by using up the oxygen in the water, and certain types even produce toxins that can make people and animals sick if they touch or drink the contaminated water.

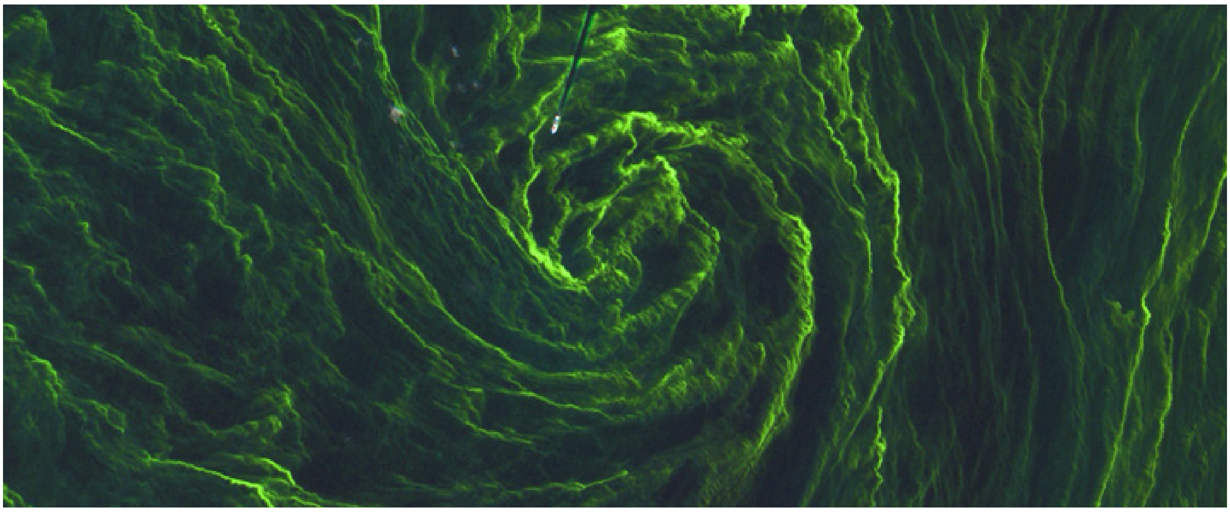
In Europe, algal blooms are a major issue. They cost over 900 million euros annually to the EU's tourism and fishing industries. Algae naturally grow in all parts of the world every year. They need sunlight, carbon dioxide, and certain nutrients to grow, like nitrogen and phosphorus. When these conditions are just right, they multiply quickly and form large green patches on the water, known as “algal blooms”.

Did you know?

Nutrients like nitrogen and phosphorus are vital for aquatic ecosystems, but excessive amounts can lead to eutrophication (the process in which a water body becomes overly enriched with nutrients), causing harmful effects.

Phosphorus, often in the form of phosphate, is the key nutrient for eutrophication in fresh waters and is considered the "limiting nutrient" that controls the growth rate of algae and aquatic plants.

In this activity, you will explore how satellites can be used to study algal blooms, focusing on real-world examples, like the Baltic Sea. You will also learn practical skills to investigate algal blooms in your local communities, helping you understand and address this environmental issue.



Sentinel-2A captured this detailed image of an algal bloom in the middle of the Baltic Sea on 7 August 2015.
CREDIT Copernicus Sentinel data (2015)/ESA

Data Collection and Analysis
Exercise: Case-study: Detection of Algal blooms in Finland

Earth Observation (EO) involves the collection, analysis, and presentation of data to better understand our planet. Algal blooms can be investigated locally from the ground by taking so-called in-situ measurements, but scientists also use satellites to keep an eye on these blooms from space. Earth Observation data can, therefore, be divided into two categories: 'Ground data,' which is collected on Earth, and 'Satellite data,' which is gathered from space. Both data categories complement each other. Using this information, scientists can develop strategies to protect public health, ecosystems and safeguard the fishing and tourism industries.

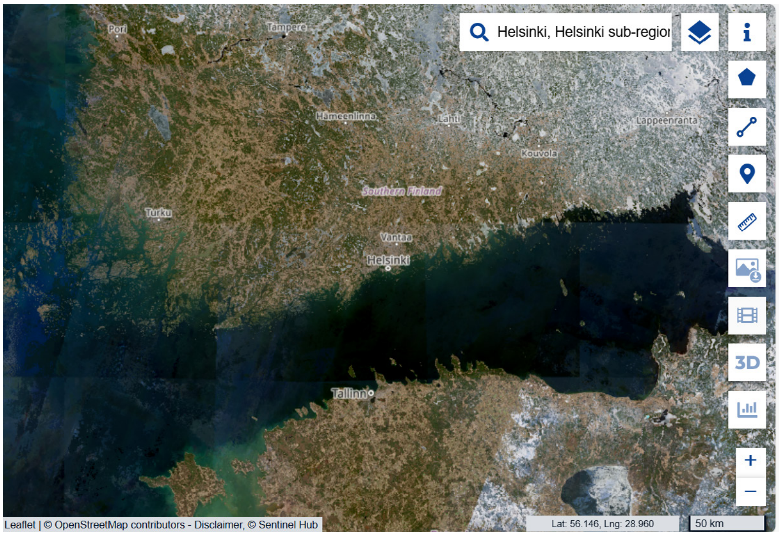
Did you know?

The European Union's Copernicus Programme provide satellite data freely available to everyone, offering everyone the opportunity to access data. Helping to map algal blooms and providing critical information for marine operations are just some of the ways that the Sentinel satellites are used for Europe's Copernicus environmental monitoring programme. The Sentinel Satellites also monitor our land, ice and atmosphere to understand large-scale global dynamics.

Please follow the numbered instructions in blue to get started.

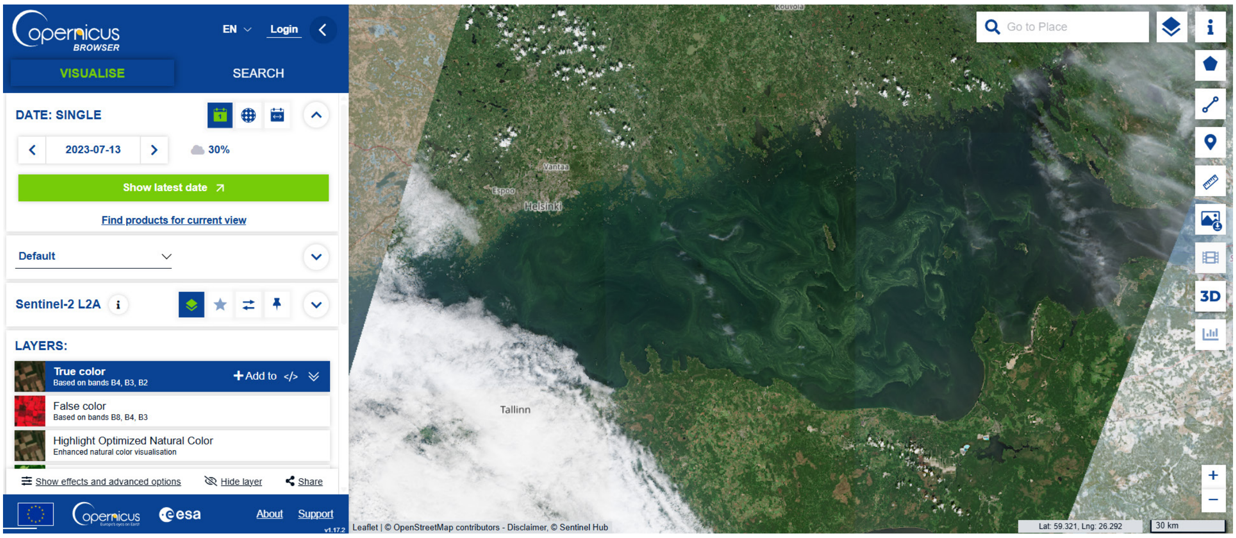
Collecting Data

1. Navigate to Helsinki, the capital of Finland.

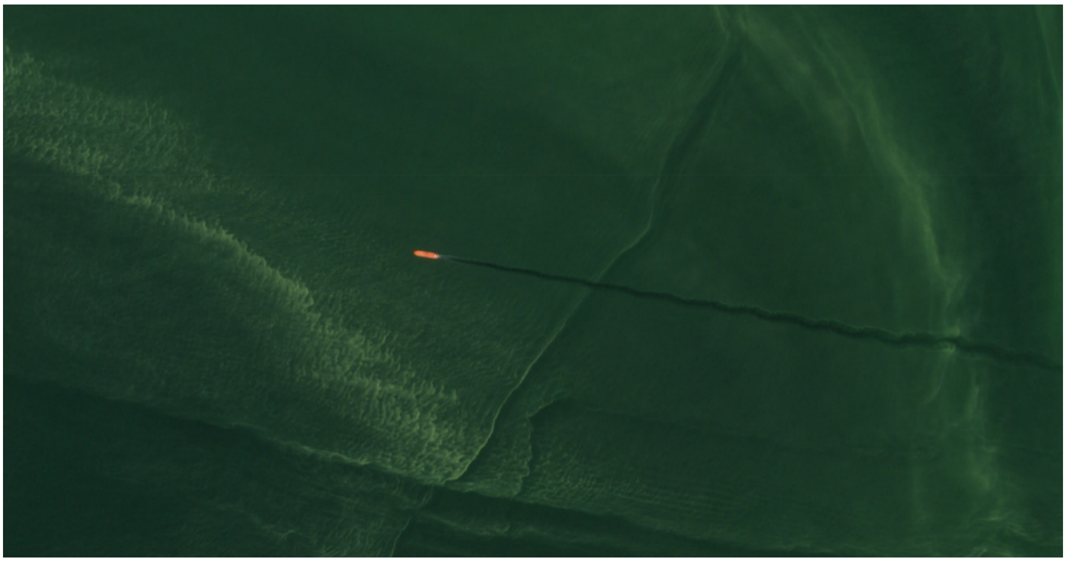


The body of water near Helsinki is the Gulf of Finland, an arm of the Baltic Sea located between Finland to the north and Estonia to the south.

2. Select the date: 13th of July 2023 in the Main Navigation Panel.

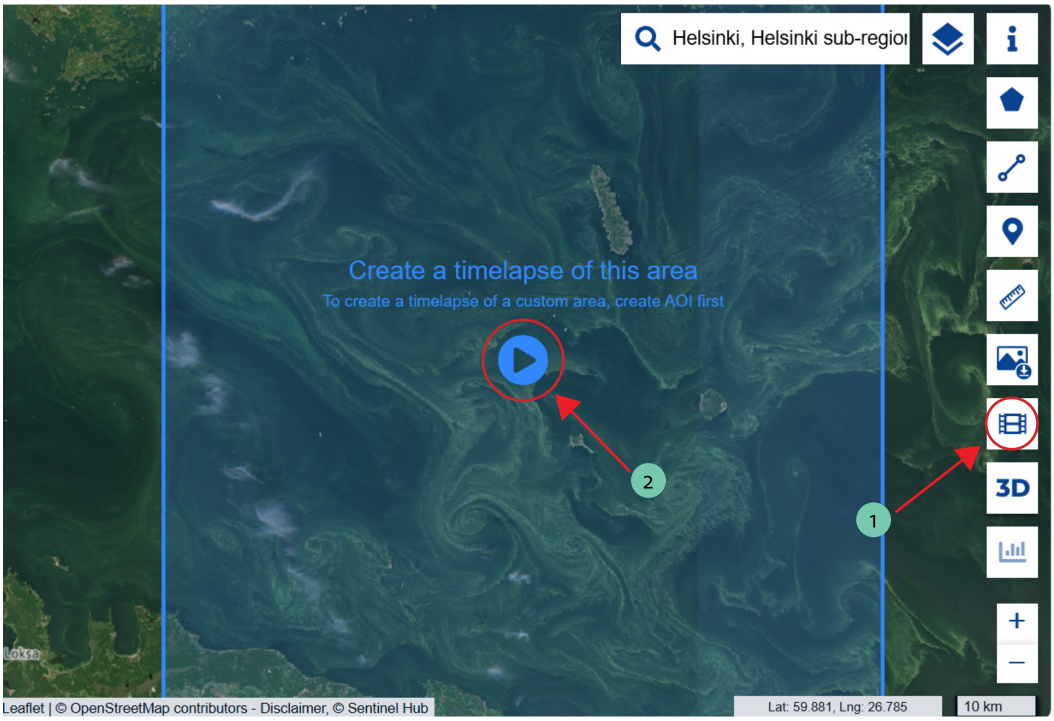


3. Zoom in and explore. Can you find any boats that might be collecting in-situ measurements, even if it's not the one in the picture?

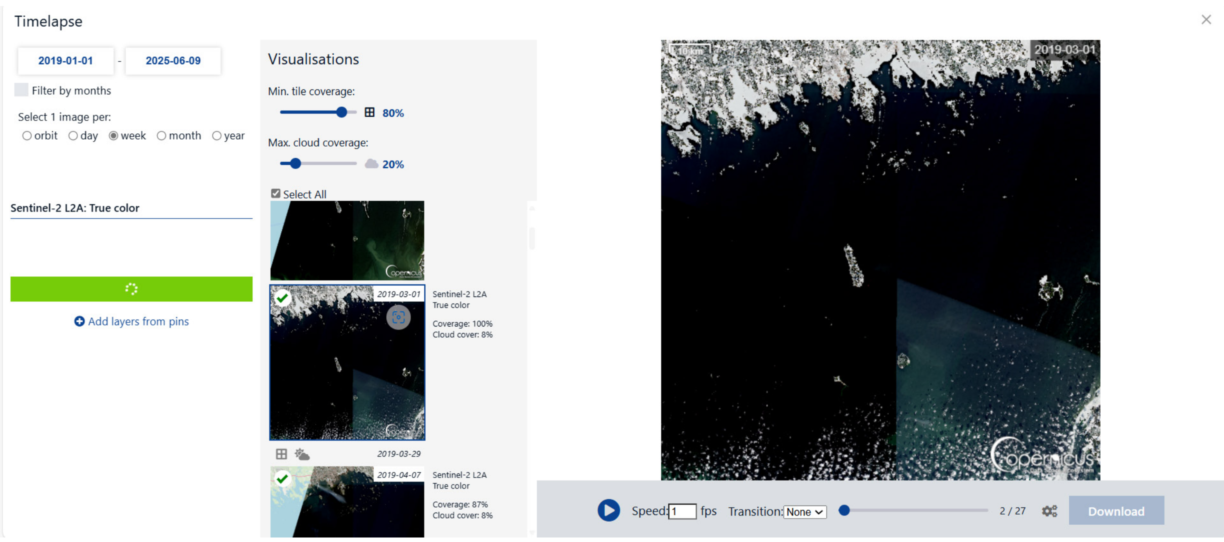


4. Note down what you observe, e.g. how clearly you can see the boats, whether there are many, how you know it is a boat, etc

5. Now create a timelapse by pressing the symbol marked in red and then the play symbol. (Note: You need to be logged in to access this feature.)



6. Set "Min. tile coverage" to "80 %" and "Max. cloud coverage" to "20 %".
Set the dates of the timelapse from 2019-01-01 to 2024-05-12 (or a more current date).
Select 1 image per week.
Press Search.

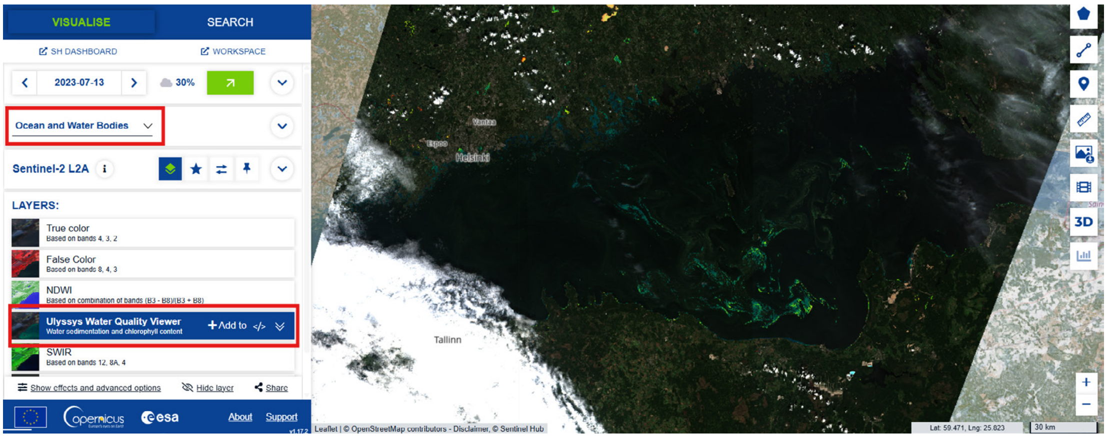


7. Set the speed to what you want (not too fast or you cannot see the dates)

8. Download the timelapse (Optional).
9. Watch the timelapse and note the months when you observe algal blooms every year.
10. Investigate the surrounding land around the Baltic Sea. Is it primarily composed of cities, agricultural areas, industrial production or other types of land use? Note down your observations.

Extra task: Using the Water Quality Filter

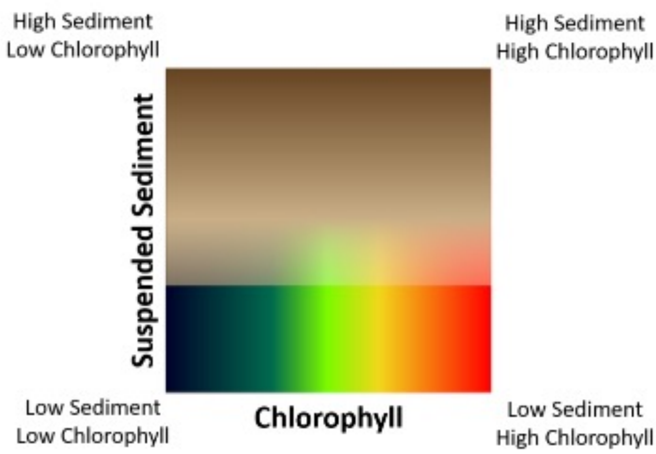
1. Exit the timelapse menu and choose the theme “Ocean and Water Bodies”. Make sure you have a date selected in the calendar or press the button ‘show latest date’. Then choose the layer “Ulyssys Water Quality Viewer”.



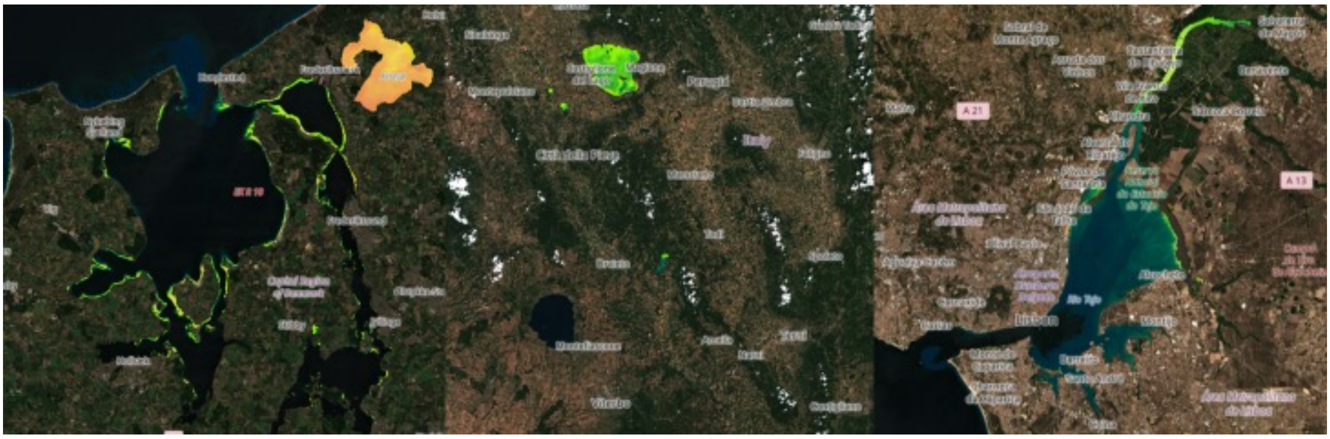
When using the “Ulyssys Water Quality Viewer”, all water pixels are coloured:

- Chlorophyll (plants) is coloured green to red.
- Suspended sediment concentration (dirt) is coloured brown.

Chlorophyll is a pigment found in algae and is known for the process of photosynthesis. High chlorophyll concentrations are marked in red, medium concentrations in green, and low concentrations in dark blue (see palette image on the right).



2. Now go to another country and explore whether you can find any excessive growth of algae in water using the “Ulyssys Water Quality Viewer”. Compare with the “True Colour” visualisation to verify that it is indeed algae and not something else.



Discussion and Reflection

Questions:

1. A) Did you find any boats in the satellite images? How did you identify them as boats?

   B) Based on your observations, how detailed do you think the satellite's resolution is? Can you estimate the size of objects the satellite might be able to clearly capture?

2. A) In which months did you observe algal blooms?

   B) In which month(s) was the bloom most intense?

   C) In which month(s) were there no signs of any blooms?

3. A) What might have triggered the algal bloom?

   B) How does climate change affect algal blooms?

   C) What could be some of the limitations of satellite data compared to ground data and vice versa?

   D) What impact could the algal bloom have on society and ecosystems?

   E) What strategies can help reduce the risk of algal blooms?

→ Links

Background information

Harmful Algal Blooms - Science Education through Earth Observation for High Schools
https://seos-project.eu/marinepollution/marinepollution-c03-p01.html

IPCC Interactive Atlas
https://interactive-atlas.ipcc.ch/regional-synthesis

Toxic cyanobacteria in water
Cyanobacteria in water – World Health Organization

Copernicus Sentinel-2
Copernicus Sentinel-2

Ocean colour & algae blooms
ESA - Ocean colour & algae blooms

ESA's Earth Observation missions
https://www.esa.int/Applications/Observing_the_Earth/ESA_for_Earth

ESA Projects

Climate Detectives project
https://climatedetectives.esa.int/

ESA Resources and other supportive materials

Copernicus Browser Guide

Copernicus Browser Case study: Oil Spills from Space Earth Observation in the Classroom

Investigating Water Quality – Mini Case Study for Climate Detectives
Investigating Water Quality - Mini Case Study for Climate Detectives

EMBL Nexus Island

Copernicus Browser

The Copernicus Data Space Ecosystem Browser
https://browser.dataspace.copernicus.eu/

The ESA Education Office welcomes feedback and comments
teachers@esa.int