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→ INVESTIGATING WATER QUALITY

Mini Case Study for Climate Detectives

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FAST FACTS

Subject: Science; Biology

Age range: 14-18 years old

Type: Project activity

Keywords: Water Quality; Climate Change; Cyanobacteria; Earth Observation; Science; Biology

Brief description

The mini case studies for Climate Detectives are intended to help teachers to identify the topic that their Climate Detectives team will investigate and to guide them during the different phases of the project. In the template, teachers will find some suggestions of data that students can collect and analyse. The suggestions are not exhaustive, and the teachers may decide on their own specific focus within a given research area. The mini case study should be used in conjunction with the teacher guide and not as a standalone document.

This case study is dedicated to the topic of **Water Quality** and students will investigate how climate change may impact water quality regarding cyanobacteria in lakes.

LEARNING OBJECTIVES

- Be able to work scientifically by collecting and analysing data, making careful observations, looking for patterns and relationships
- Recognise some of the impact of climate change in water resources
- Identify Cyanobacteria as bacteria that obtain energy via photosynthesis
- Understand how Earth observation satellites can be used to monitor Water Quality

About Climate detectives

Climate Detectives is a school project for school students run by the European Space Agency (ESA) in collaboration with the national European Space Education Resource Offices (ESEROs) throughout Europe.

In this project students will embrace the role of Climate Detectives while learning about Earth's environment. For that they will identify a local climate problem (Phase 1), investigate it by using real satellite images or their own ground measurements (Phase 2), and finally propose actions to help reduce or monitor the problem (Phase 3).

CLIMATE DETECTIVES

Topic: Lakes and Climate

Research Question

How does climate change impact water quality regarding cyanobacteria in lakes?

START HERE

Does the question fit the theme of climate?

Yes. It examines how a change in climate may impact the water quality of lakes.

Is the question focused on a single problem or issue?

Yes. It is focused on water quality related with the development of cyanobacteria.

Is the question too broad or too narrow?

No. It identifies a local scale problem but establishes links to a wider global issue.

Is the question clear and concise?

Yes. It is clearly defined and possible to investigate, making use of satellite observations and ground measurements.

Is the answer to the question too readily available?

No. It involves analysis of data as well as desk research and gathering information from secondary sources.

A – Introduction to the topic (PHASE 1)

Setting the scene

"Understanding the complex behaviour of lakes in a changing environment is essential to effective water resource management and mitigation of climate change effects." ESA CCI Lakes project

The Luxembourg government published an alert in September 2021 about cyanobacteria in the biggest lake in Luxembourg, the Esch-Sur-Sûre Dam. The Water Syndicate of the Esch-Sur-Sûre Dam (SEBEL) comment on the situation:

"Since 1986, a progressive increase in Cyanophyceae has been observed in the Esch-sur-Sûre dam. The waters are classified as "meso-eutrophic", which means that the blooms observed are essentially due to an excessive supply of nutrients such as nitrogen and phosphorus.
The interaction between different forms of nutrients and Cyanophyceae blooms is very complex and still a subject of debate. Other meteorological factors such as climate change, stagnant waters and increasing temperatures as well as decreasing flows in summer have further favoured Cyanophyceae over other phytoplankton species. This phenomenon that we observe in the dam is also observed worldwide."

This case study is about that event. Climate Detective teams from Luxembourg can choose this lake or another body of water in the country. Teams from a different country are encouraged to investigate a body of water local to them.

Figure 1

↑ Satellite data can help monitor the growth and spread of cyanobacterial blooms. In this image captured by Copernicus Sentinel-3 the green algae blooms swirling in the Lake Erie (North America) are clearly seen because they have accumulated at the water surface. This image contains modified Copernicus Sentinel data (2020), processed by ESA, CC BY-SA 3.0 IGO

Background information

What are cyanobacteria?
Cyanobacteria are bacteria that obtain energy via photosynthesis. They absorb light using phycobilin pigments (photosynthetic pigments), which give them their unique blue-green colour, to convert carbon dioxide and water into oxygen and glucose. Cyanobacteria converted the early Earth's oxygen-poor atmosphere to the oxygen-rich atmosphere of today.
Cyanobacteria, alongside algae, form the base of the aquatic food web. This article from the Microbiology Society illustrates the important role that microorganisms, such as cyanobacteria, play as primary producers in the food chain.
The name cyanobacteria refer to their colour (from Ancient Greek **κυανός** (kuanós) meaning 'blue'), giving them their other name, "blue-green algae".

Why do cyanobacteria develop?
Cyanobacteria are important as primary producers of organic matter and as providers of oxygen for other aquatic and terrestrial life, but they may also contribute to the mortality of other organisms - in cases of intense blooms. The term bloom is used for events when phytoplankton – algae or cyanobacteria that live in aquatic environments – grow much faster than they are removed (by grazing or other decay). Blooms become a problem when they disturb the balance in the food web, decay too rapidly (causing low oxygen), or produce toxic substances. Unfortunately, species of cyanobacteria which are most likely to form blooms are also those that create significant problems, including accumulation at the water surface during calm weather ('scums') and sometimes being toxic. This causes problems for drinking water supply and recreation. High water temperatures have been associated with cyanobacterial bloom development in temperate and semiarid regions. Increasing temperatures because of climate change favours the growth of certain types of cyanobacteria, thus increasing the risks associated with the blooms. Though temperature is a factor affecting the growth kinetics of bacteria, the availability of nutrients such as phosphorus is a primary condition for algae and cyanobacteria growth.[1]

According to IPCC Interactive Atlas, climate change in Western Europe induces temperature increase and more hydrological drought, causing a reduction in river discharges and lake water inflows. This may provide an advantage for cyanobacteria to grow faster than other phytoplankton and deteriorate water quality.

Research about cyanobacteria development

As an initial activity and for students to build knowledge related with the topic, the following activities are suggested:

- To watch **short documentaries** or **videos** on the topic
- To conduct **web research** to explore factors favouring cyanobacteria development and the link with climate change. The IPCC Interactive Atlas gives regional information about climate change. Here teams will find information about algae blooms and the use of remote sensing to detect and follow these events
- Research **local media** and search for articles exposing the problem in their communities
- Check for any **reports** that could help identify suitable information. For example, check this report from the World Health Organisation that presents the level of cyanobacteria in water considered unhealthy
- Contact **local research organisations** working on this subject to ask for information and for local expert support

[1]https://www.researchgate.net/publication/330944730_Cyanobacteria_Growth_Kinetics

Investigation plan

Now that the topic and the research question have been discussed, it is time to plan which data the team need to collect. The final step in Phase 1 of Climate Detectives is the submission of an investigation plan. You can find ideas for data collection in section B, which may help you with submitting your investigation plan.

B – Data collection and analysis (PHASE 2)

To investigate the topic of water quality and the development of cyanobacteria, students can collect and analyse data from several sources.

Satellite Data

Information from satellites observing Earth can be used to monitor lakes and other bodies of water. Using Copernicus Sentinel-2 satellite data and a water quality analysis script, we can see the cyanobacteria problem in Esch-sur-Sûre lake, Luxembourg, in September 2021.

For this exercise we will be making use of EO Browser (https://apps.sentinel-hub.com/eo-browser/) an online tool that provides free access to satellite images from different Earth Observations missions. Here and here you can find more information about how to use EO Browser.

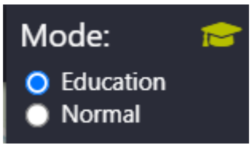
To know more about

Copernicus Sentinel-2 is a two-satellite mission. Each satellite carries a high-resolution camera that images Earth's surface in visible, near infrared and shortwave infrared comprising 13 spectral bands. The mission is mostly used to track changes in the way land is being used and to monitor the health of our vegetation. While it was optimised for land applications, it is also a valuable tool for monitoring ocean colour and biological activity. Read more on the story "Sentinel-2 catches eye of algal storm".

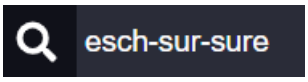
Exercise

1. Open EO Browser

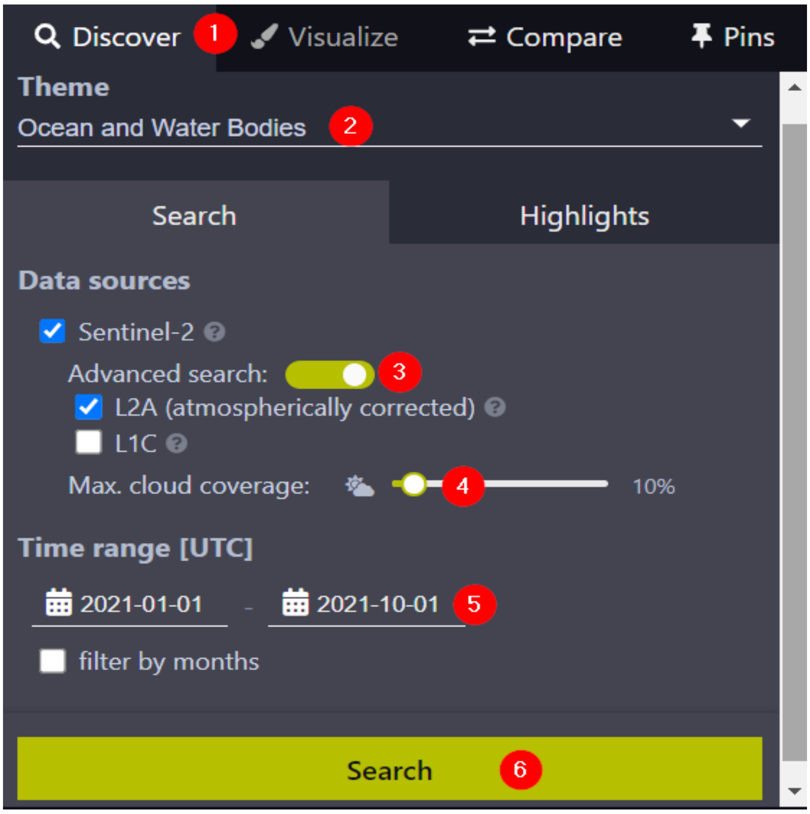
2. On the top right corner of your EO Browser screen, click on the academic hat icon and choose Mode: Education



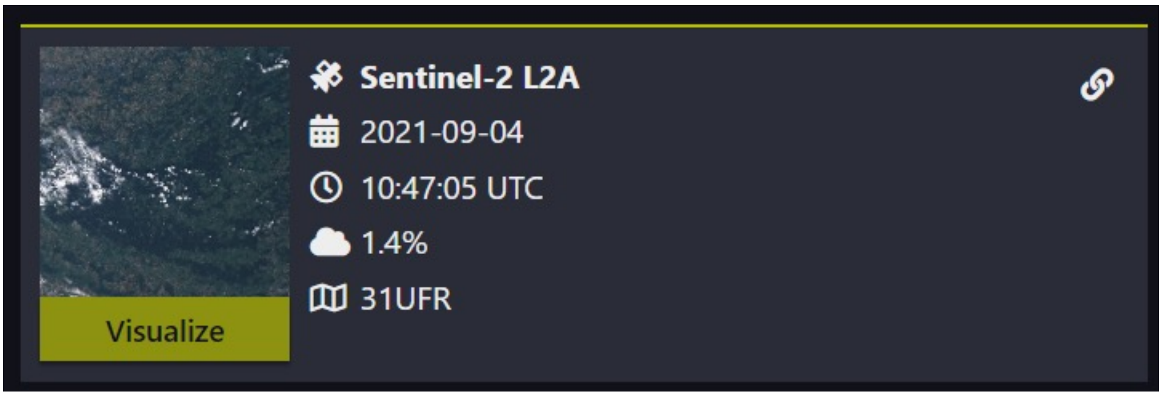
3. Select the location of the lake in the search field



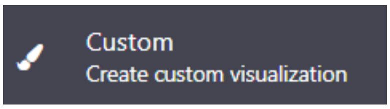
4. On the "Discover" tab (1):
   a. Select "Ocean and Water bodies" theme (2)
   b. Activate the "Advanced search" (3)
   c. Set the "Max cloud coverage" to 10% (4)
   d. Select the desired time range (5)
   e. Press "Search" (6)



5. On the “Visualize” tab, select an image and click on the “Visualize” button



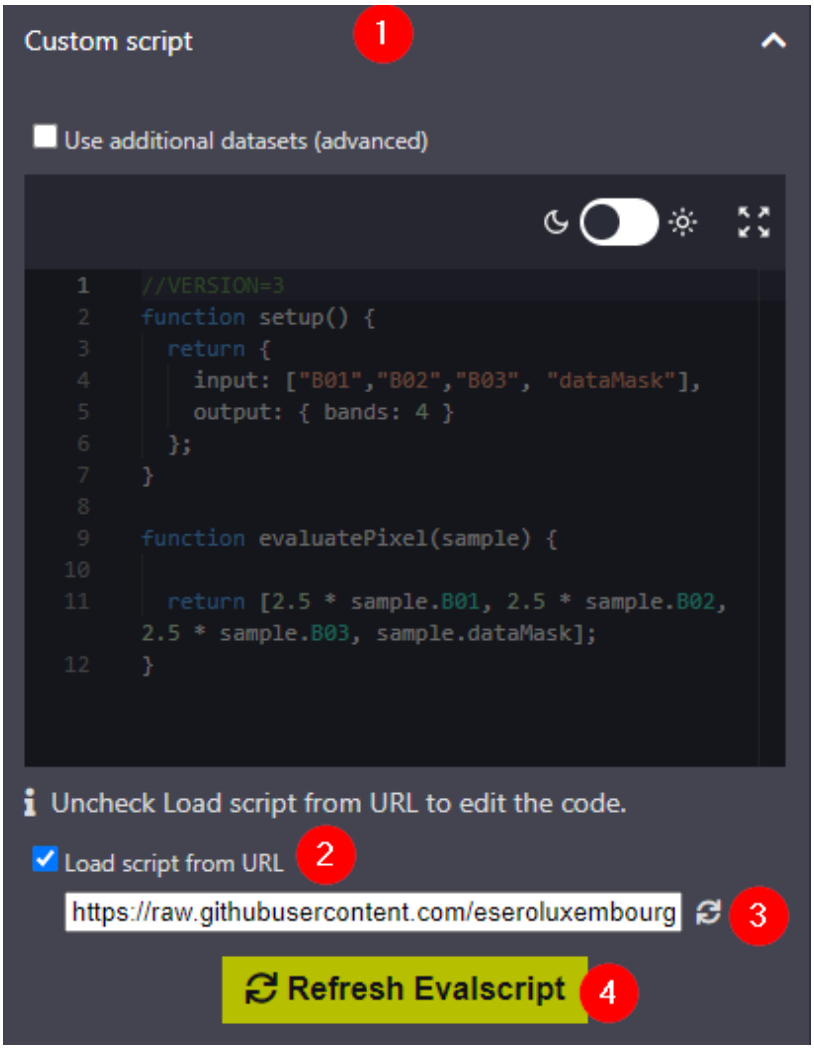
6. Click on the “Custom” button



7. Click on “Custom script” (1), then check the “Load script from URL” box (2)

8. Fill the field with the following URL (3):
https://raw.githubusercontent.com/eseroluxembourg/sentinel-scripts/master/sentinel-2/se2waq/script.js

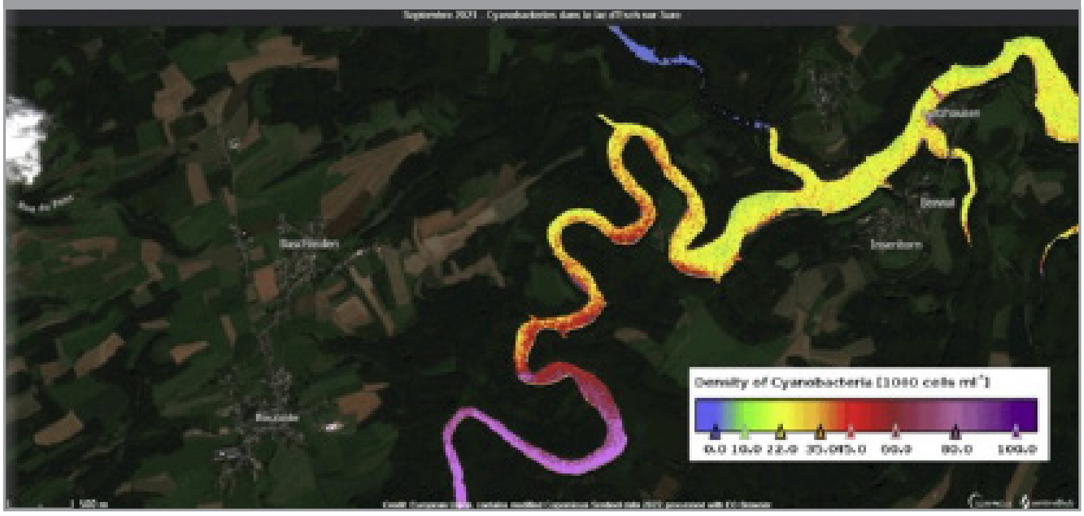
9. Click on the “Refresh Evalscript” button (4)



Results

- September 2021 (see the image directly on EO Browser)

Figure 2

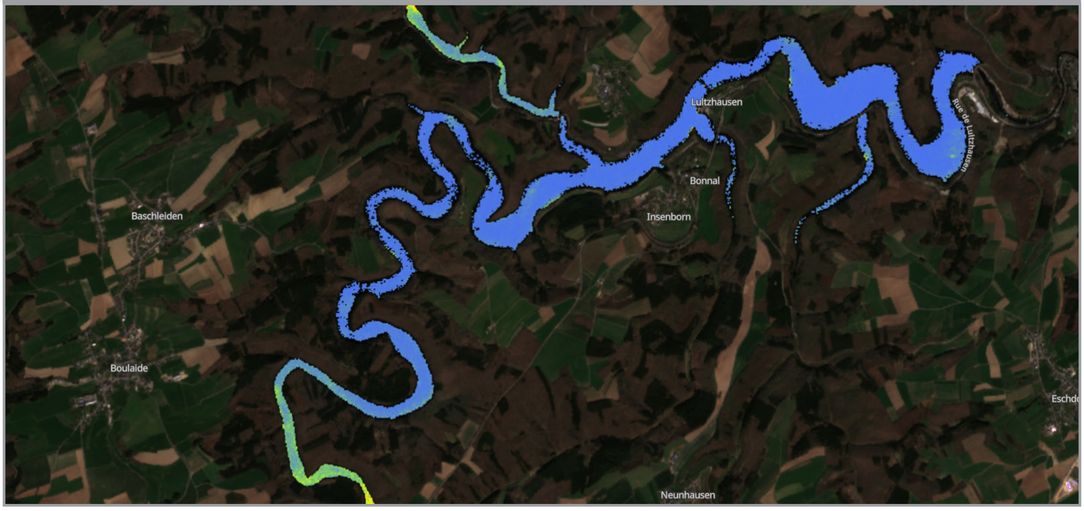


↑Density of Cyanobacteria in Esch-sur-Sûre lake, Luxembourg, in September 2021

Students can repeat the exercise above and get a new image from the same lake in a different season, for example April 2021.

- April 2021 (see the image directly on EO Browser)

Figure 3



↑ Density of Cyanobacteria in Esch-sur-Sûre lake, Luxembourg, in April 2021

Analysis and discussion

After visualising the results, students should compare both images and reflect about what the data shows, as well as noting any differences. Students could investigate how cyanobacteria presence varies over time and how that is related, or not, to, for example, the temperature of the water, weather events and changes in climate.

The growth of cyanobacteria is strongly related to the availability of nutrients, particularly phosphorus. Nutrients can have a lot of different sources; agriculture and industry are just two examples. It is therefore interesting to investigate the area around the body of water. Are there intensely used fields in the surrounding area? Is there industrial production?

It should be noted that remote sensing of cyanobacteria has its limitations. It is much easier to detect cyanobacteria that accumulate at the water surface, than to identify them from algae when the water is mixed. Thus, measurements from ground observation networks are also essential.

Ground Data

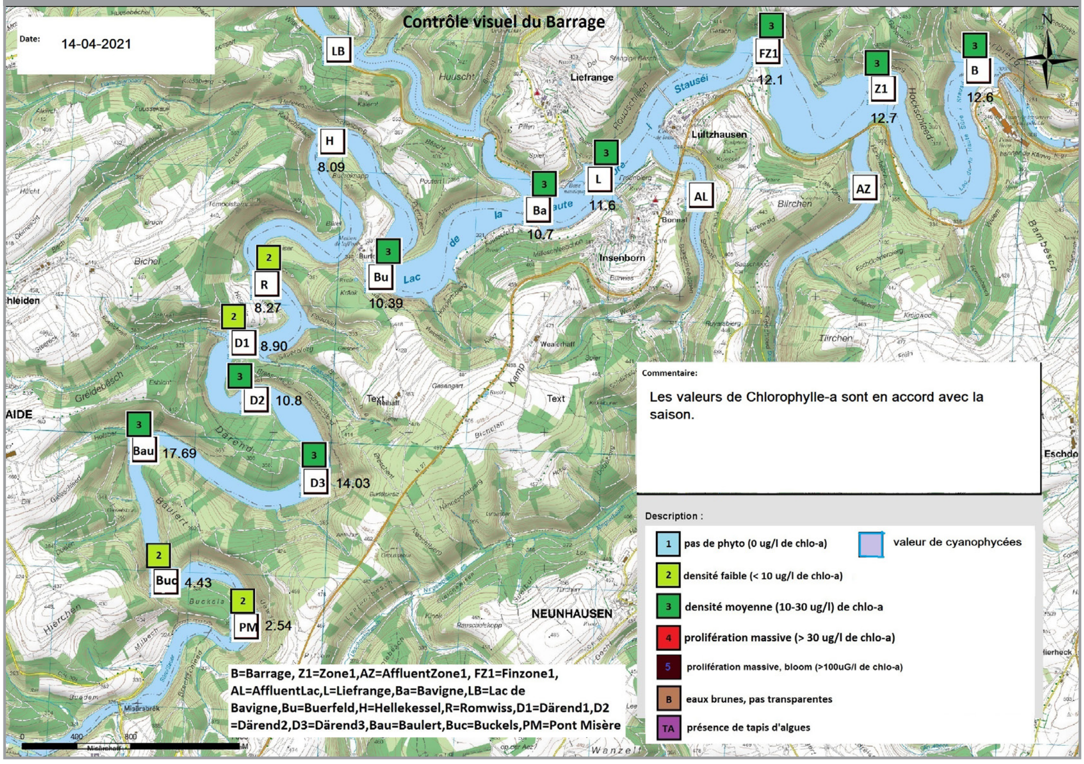
Earth observations can be acquired from remote sensing platforms such as satellites or taken at a ground level. We call those measurements 'ground data' or 'in-situ' (on the spot).

National data

In Luxembourg two organisations provide ground data related with the concentration of cyanobacteria in the water.
a) The Environmental Microbiology and Biotechnology from Luxembourg Institute of Science and Technology (LIST)
b) The Water Syndicate of the Esch-Sur-Sûre Dam (SEBEL)

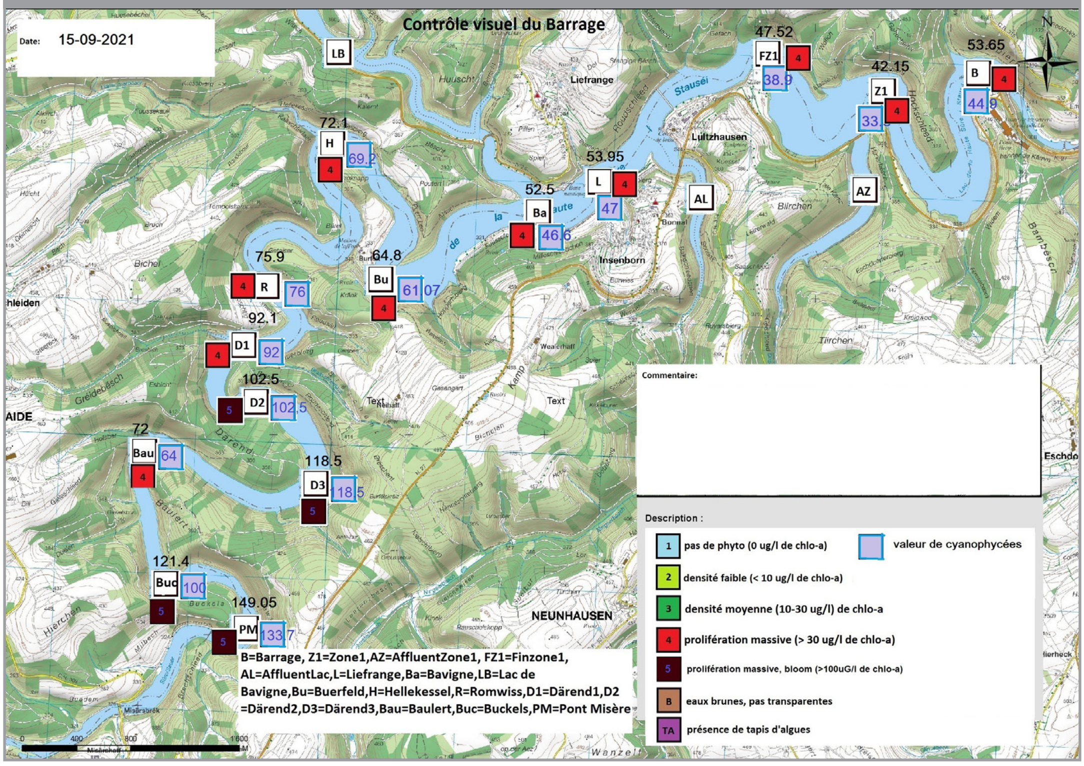
This type of data is very important to validate the measurements being done by satellites. SEBEL onsite observations matches the satellite observations with EO Browser (see figures below). Students should compare their own satellite images with measurements being done by national agencies.

Figure 4



↑ Low cyanobacteria level in April 2021. Credit PURDUE-WILLE Emanuela

Figure 5



↑ High cyanobacteria level in September 2021. Credit PURDUE-WILLE Emanuela

Primary data

This is information that the students measure or calculate for themselves.
There are two main factors limiting cyanobacteria growth: light and nutrient availability. Below, teams can find ideas on how to investigate these factors. Teams can also explore other factors and research about their relation to cyanobacteria. For example, water salinity and water temperature are also important factors that can have an impact on cyanobacteria growth.

Health and safety warning!

Water with a lot of cyanobacteria may cause nuisance (such as bad odour) and health risks! Before visiting lakes and rivers, and taking any measurements, check for water quality warnings from official authorities and discuss how to protect yourself.

Water transparency

The quantity of cyanobacteria and algae influences how deeply light penetrates a water body determines the depth to which aquatic plants can grow. Without light there is no photosynthesis, either by plants, algae or cyanobacteria. Transparency decreases with the presence of molecules and particles that can absorb or scatter light and can help to determine the depth at which photosynthesis is possible. In addition, the colour of water can help determine whether low transparency is caused by algae or other substances, like dissolved organic matter, minerals or organic sediments.

Water transparency can be measured with a **Secchi disk**. A Secchi disk is a disk, 30cm in diameter, that is lowered into the water on a cord. The depth at which the Secchi disk can no longer be seen through the water is known as the Secchi depth. When the water transparency is high, the Secchi depth is also high. When the water transparency is low and cloudy, the Secchi depth is low.

A Secchi disk can be built using a 3D-printer or from a recyclable material such as an old record. The water transparency can vary seasonally, so it is important to take numerous Secchi disk readings, for example once a month. Protocols on how to use the Secchi disk to measure water transparency can be readily found online. The Secchi disk has already been used for hundreds of years, and scientists continue to use the measurements to monitor water transparency. If a full-sized Secchi disk is not needed or too large to carry around, see how to build and deploy a Mini-Secchi disk, available through the MONOCLE project.

Scientists also use these measurements to relate to the concentration of phytoplankton in the water and validate measurements being done by satellites!

Nutrients

A natural and healthy amount of nutrients such as nitrogen and phosphorous are essential to the functioning of aquatic ecosystems. The overloading of seas, lakes, and rivers with nutrients can result in a series of adverse effects known as eutrophication. Phosphorus is the key nutrient for eutrophication in fresh waters. It is usually considered the “limiting nutrient”, meaning that the available quantity of this nutrient controls the pace at which algae and aquatic plants grow. The most common form of phosphorus used by biological organisms is phosphate. To measure the phosphates levels in the water teams can use a water quality kit or a phosphate test kit.

Cyanobacteria are less likely to occur in areas where rooted plants are found, because these will take up nutrients needed by both. At the same time, when cyanobacteria are common in a lake, rooted plants are not likely to grow in the water. eams can also investigate the presence of indicator organisms. These are species of plants or animals which live in special conditions and can therefore show, for example, indirectly the amount of nutrients in a lake or along the bank.

Plants which need a lot of nitrogen to grow can therefore be found in areas which have a high concentration of nitrogen. This also applies to animals e.g., insects and even microorganisms. Water quality can be assessed by measuring the presence of chosen organisms in the area being studied.

C – Time to make a difference! (PHASE 3)

Based on the results and conclusions from phase 2, teams decide on actions to be taken to address the climate problem they investigated. What actions could students take as individuals or as a community, to raise awareness and reduce the impact of cyanobacterial blooms in their communities?

→ TASKS AS CLIMATE DETECTIVES

Student Worksheet

A – Introduction to the topic (PHASE 1)

- *What are Cyanobacteria? How does climate change impact the water quality regarding cyanobacteria in lakes?*
- *Why do cyanobacteria develop?*
- *What are the main problems caused by cyanobacteria?*
- *How does the topic that you selected affect/relate to you, your community or local environment?*
- *Describe how you plan to investigate the climate problem and which data you plan to analyse (for the Investigation Plan). For suggestions see below.*

B – Data collection and analysis (PHASE 2)

- *Interview people living around the lake to discuss its evolution over the years in relation to climate change*
- *Analyse different lakes than the one of Esch-sur-Sûre.*
- *Analyse cyanobacteria evolution within a year, over several months.*
- *Compare cyanobacteria evolution on a lake at the same moment in different years.*
- *Investigate the presence of indicator organisms showing the presence of nutrients favouring cyanobacteria*
- *Analyse water transparency over time using a Secchi disk*
- *Relate the presence of cyanobacteria over time to the temperature of water, weather events and changes in climate.*

C – Time to make a difference! (PHASE 3)

Your Climate Detectives work is now complete. What actions could you propose, as individuals and as a community, to make a difference regarding the topic of your investigation?

→ Links

ESA resources

Climate Detectives Teacher Guide
https://climatedetectives.esa.int/teacher-guide/

Climate Detectives classroom resources
https://climatedetectives.esa.int/classroom-resources

Climate for schools – Resources from the Climate Change Initiative
https://climate.esa.int/en/educate/climate-for-schools/

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

Cyanobacteria in water – World Health Organization
https://www.who.int/publications/m/item/toxic-cyanobacteria-in-water---second-edition

Copernicus Sentinel-2

https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-2

Data collection and analysis

EO Browser
https://apps.sentinel-hub.com/eo-browser

Monocle project – Mini-secchi disk
https://monocle-h2020.eu/Sensors_and_platforms/Mini-secchi_disk_en

The ESA Education Office welcomes feedback and comments
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