Nexus Island- ESA Extension

A game-based teaching resource on the exploration of ecosystems

embl.org/ells

EMBL Science Education and Public Engagement

About the European Space Agency (ESA)

Exploring Space for Europe and Beyond
The European Space Agency (ESA), consisting of 23 Member States, serves as Europe's gateway to space. Established in 1975, ESA has been leading space exploration, developing cutting-edge technologies, and addressing global challenges to improve society and the economy. Its activities encompass satellite launches, astronaut missions, and the development of applications in Earth Observation, navigation, and telecommunications that greatly benefit life on Earth.

Credit: ESA-SJM Photography

Teacher's guide

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Introduction

Learning objectives:

- Describe how Earth Observation satellites monitor ecosystems
- Associate Earth Observation satellite monitoring with the different frequencies of the electromagnetic spectrum
- List facts about the European Union's Copernicus programme
- Identify differences between Copernicus satellites
- Explain the term in-situ measurements and describe how algae blooms can be investigated locally from the ground
- Identify how in-situ measurements and satellite data work together to complement each other in monitoring ecosystems
- Communicate and collaborate as a group

Links to Curriculum

Subjects	**Related topics**
Technology, Biology, Physics, Earth Sciences, Geography, Social Sciences, Ecology, Chemistry	Algae, Phosphorous/ Nitrogen Cycle in a Lake/Water Body, Nitrogen and Phosphorous as Nutrients, Eutrophication, Water Quality, Food Chain, Risks, Disaster and Emergency Management, European projects for humanity, Electromagnetic spectrum, the Human Eye, Space, Satellites, Remote Sensing, Climate Change, Biodiversity, Coastal Protection, Marine Pollution, Ocean Currents, Sustainable Development Goals (SDGs)...

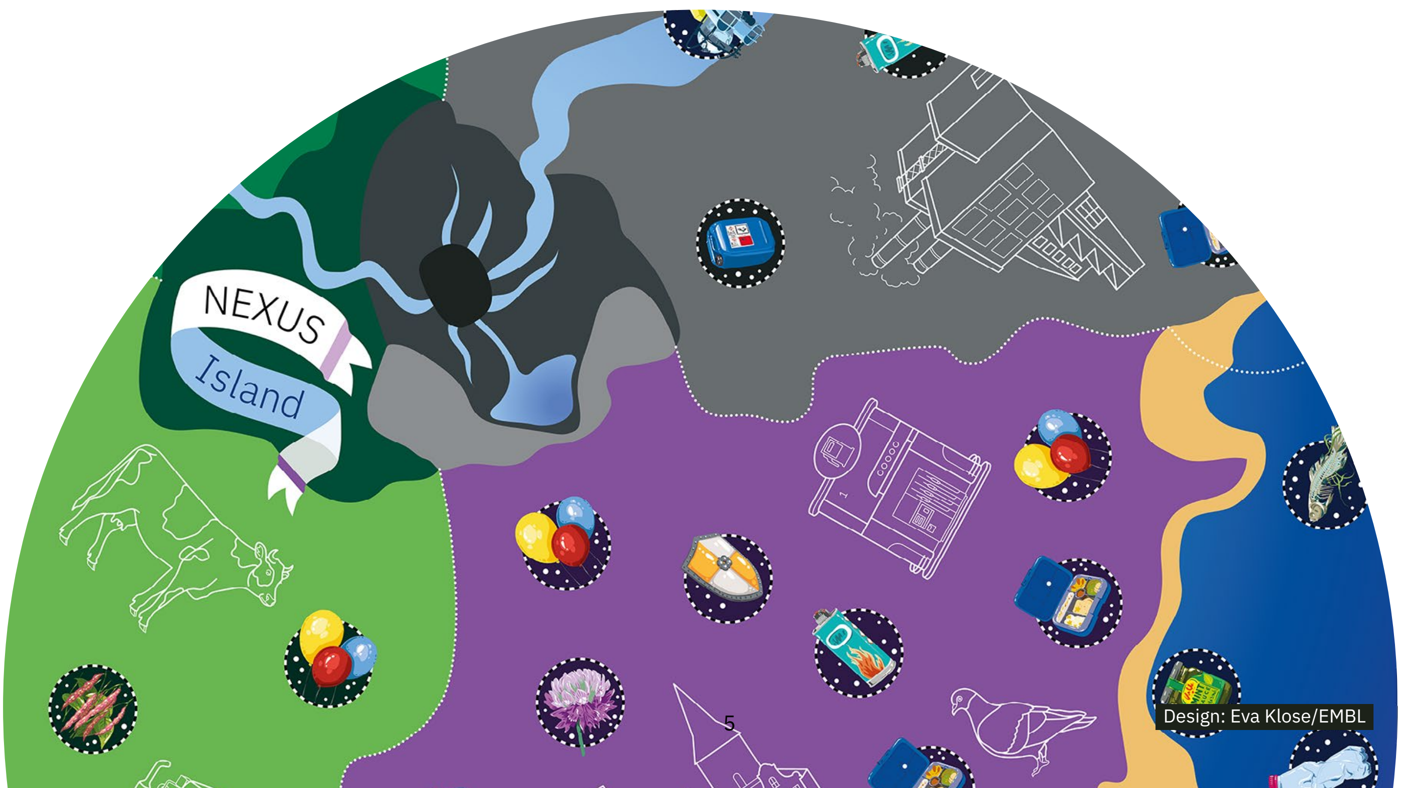
How to use the additional ESA cards for the Nexus Island game?

The "Nexus Island" game and the provided ESA cards offer great flexibility and can be easily adapted to suit your and your students' needs. Before using the additional ESA content to play the game with your students, you will need to print it double-sided on A3 sheets of paper, ensuring that the printer flips the paper on the short edge.

Tip: Laminate the cards to increase their durability. You can print the worksheet for students so that they can take notes while playing the game.

To use the ESA cards in the Nexus Island game, follow the steps described in the “Preparation and Setup” chapter of the EMBL Nexus Island Teacher Guide (starting at page 18). In addition to the Definition Cards and the Organism Cards, you will have four Earth Observation Cards. By following the story below, you will guide your students to explore Nexus Island and investigate the events unfolding. Using the ESA cards, students will be engaged in discovering the importance of Earth Observation data monitored from space to address the events occurring on day two.

They will deepen their knowledge of Earth Observation by reading and studying the cards. On day three, they will be able to explain which satellite can help with each occurring event, and some may even be able to suggest strategies for using satellites to predict and prevent events such as algal blooms. Due to its great flexibility, you can adapt the story to focus on a single event (e.g., an algal bloom, oil spill, or mass die-off of seagrass), or you can mention all of them in one context to emphasize the interactions between them.



Design: Eva Klose/EMBL

Story with ESA extension

Part 1

It’s the year 2028 and we are part of a scientific mission to explore the ecosystem of this beautiful island. It is a gorgeous day, and we are about to step onto the shores for the first time. Our inflatable boat rubs against the bottom of the shallow waters of the coastline. We hear the calls of birds in the distance. The boat docks – we climb out together and make our way to the shore. Standing on the coast of Nexus Island, we can tell that the island is made up of four distinct regions with varying degrees of human influence: an untouched pristine region, an agricultural site, an industrial zone along a riverbed, and a city. After taking a first peek at the new surroundings, we check the study notes: our first task today is to identify the organisms living on the island and learn more about them.

To explore the island in the short time we have, we divide into four research teams. Each research team will cover one of the four quadrants of the island and look for clues to find all the inhabitants in said quadrant. To get started, we have received a deck of cards, which will help us learn as much as possible about each of the organisms present in the quadrants. It might be helpful to mark where exactly we found the different organisms by placing the respective cards on the organisms' exact location to remember where we saw them.

Part 2

All of a sudden, a huge thunderstorm with heavy rain hits the island. We all rush to seek shelter. Our clothes are wet. The heavy rain soaks the soil of the farmlands with water carrying chemicals like fertilisers and herbicides. The rainfall is so strong that the water even washes these chemicals into the sea and other parts of the island.

As soon as the worst is over, we rush out to check what happened in our parts of the island. In our teams, we start to investigate the impact of the rain. How did the rain affect the farming quadrant and did the chemicals manage to spread to other parts of the island too? How are the organisms we have just identified across the island affected by the chemical run off?

It’s time to analyse the samples we have collected to understand what is going on. We have also received some brand-new satellite images from our Earth Observation satellites: Echo Explorer, SuperSharp Snapper and AquaPalette Analyst. These satellites have been continuously monitoring the island and the surrounding ocean from space.

Take a look at the satellite cards to explore the specific capabilities of each satellite. What useful data can each satellite provide about the events happening around the island? How can we use this data to take action?

Story with ESA extension-Continued

Part 3

From the satellite data, we see changes in the colour of the sea around the island. These coloured stains seem to have increased every day. The satellite data, therefore, confirms our predictions: the runoff of chemicals from the island into the sea triggered a harmful bloom of algae in the ocean surrounding our island. There is also the possible danger of contamination of the mussel-growing farms which are on the shoreline. Additionally, it seems some oil spills were spotted from space.

While collecting the samples on the shores, we also realised that there are vast amounts of dead seagrass that have been washed onto the beaches around the island. This might aggravate the damaging effects on the whole ecosystem and the inhabitants of the island. This is alarming!

We decide to come together, exchange information and discuss measures to stop the detrimental effects of the chemical wash off and to help the island ecosystem recover.

Fact sheets

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Earth Observation

Earth Observation (EO) involves the collection, analysis, and presentation of data to better understand our planet. These observations can be made locally at ground level or acquired from remote sensing platforms such as satellites. 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.

Credit: EUMETSAT 2002

Man-made satellites that are launched into space and placed in orbit around Earth play a crucial role in EO. By continuously acquiring images of our planet from orbit, satellites have become powerful scientific tools, enabling a better understanding of the Earth and its environment.

From above, satellites can collect data on locations all around the world, even reaching places too remote to visit in person. By doing so, they provide a global perspective and ensure frequent measurements. Recognising the power of this data, ESA has made Earth Observation a key priority. The primary goals of ESA in Earth Observation are to provide valuable information about the environment, monitor the climate, and manage resources effectively. To achieve these goals, ESA uses satellites to monitor Earth and combines this with ground data for a better understanding of the planet. These efforts aim to enhance the well-being of people across the world.

Satellites See with Different “Eyes"

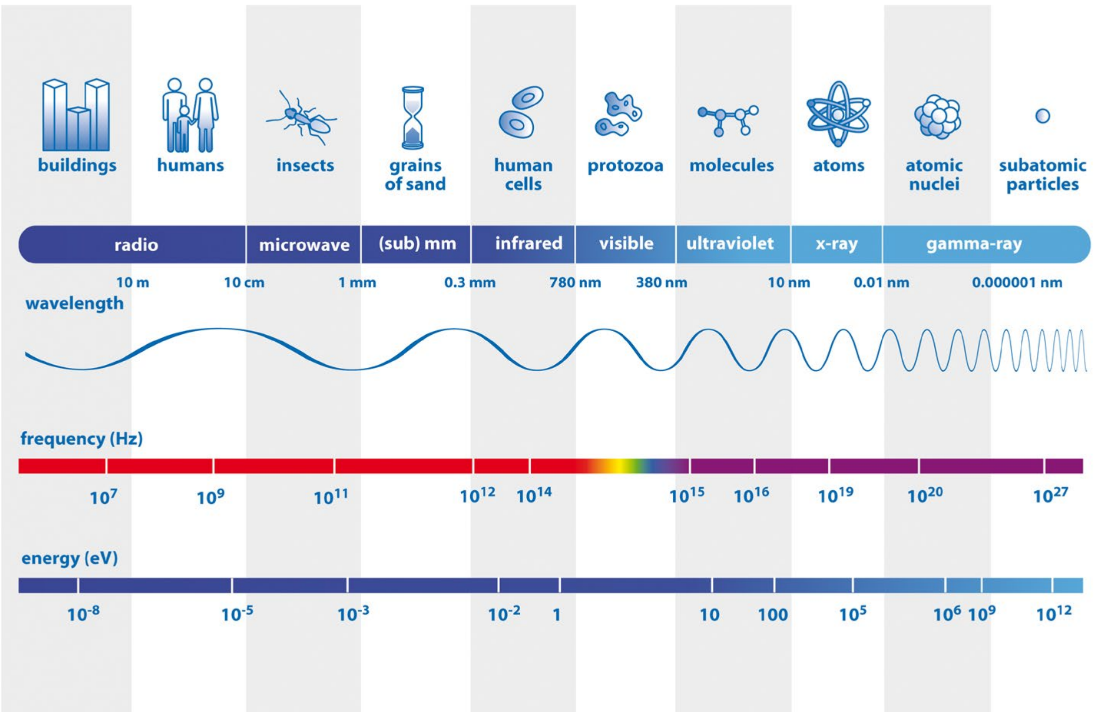
The single location where we can learn the most about our planet is found nowhere on Earth but high up above it !

Satellites, orbiting far above our planet, offer us a unique perspective, allowing us to observe and study Earth in ways that are impossible from the ground. While our human eyes can only see what we call visible light - comprising all the colours of the rainbow we encounter every day - satellite instruments can sense other types of light that are invisible to us.

Light is electromagnetic waves that can have a wide range of wavelengths. These wavelengths are organised into the “electromagnetic spectrum”. This spectrum helps us group light into categories such as visible light, infrared, radio waves, microwaves, and X-rays. Shorter wavelengths, like X-rays, have higher energy, while longer wavelengths, like radio waves, have lower energy.

The visible light our eyes can detect has wavelengths ranging from 400 to 700 nanometres. Within this range, each colour we see corresponds to a specific wavelength. For instance, red light has longer wavelengths, while violet light has shorter ones. Our eyes detect these wavelengths, and our brains interpret them as the colours we see.

Although we can’t see most parts of the electromagnetic spectrum, we have created devices that can. We all use these devices e.g., while listening to the radio, connecting to Wi-Fi, using microwaves to heat our food, or having an X-ray scan to see inside our bodies. Satellites use this same principle, detecting wavelengths beyond our vision. It’s as if they see the world through different "eyes," giving us a broader view of our planet.



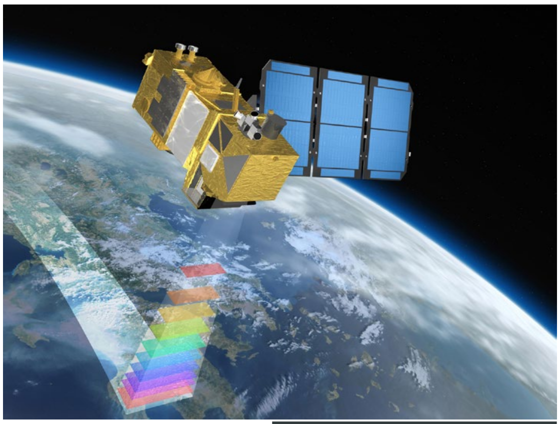
Satelite data

Satellites use a variety of sensors to capture different types of data, including optical instruments that detect visible light. This data is often visualised as images of Earth, similar to photographs. However, it is important to note that since the raw data is digital, it can be further processed with advanced computer software to reveal additional insights or patterns that may not be immediately visible in the images, enabling more detailed analysis. This is done e.g., to monitor coastal erosion.

Credit: ESA/ATG medialab

Figure 1. ESA - Sentinel-1 radar vision

The data collected by satellites is converted into actionable information, which can be used to monitor environmental factors such as air pollution, map deforestation and urban growth, measure Earth's temperature and enable rapid and resilient crisis response after natural or man-made disasters. To harness this potential, ESA has developed the Sentinel satellites for the Copernicus programme. Copernicus is the Earth observation component of the European Union's Space programme. It provides accurate, timely and easily accessible information to improve the management of the environment, understand and mitigate the effects of climate change and ensure civil security.



Credit: ESA/ATG medialab

Figure 2. ESA - Sentinel-2 - visible vision

Sentinel-1 and Sentinel-2 carry different types of sensors and therefore provide us with different kinds of data. In the case of Sentinel-1, we get colourless radar images, whereas Sentinel-2 provides us with colourful optical images.

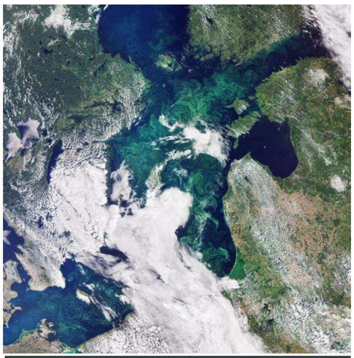
The Sentinel satellites weigh about 1-2 tons each and travel at around 28,000 km/h, orbiting the Earth approximately every 100 minutes. The rapid orbit enables them to capture frequent imagery and data using the state-of-the-art, specialised instruments carried by each satellite. Best of all, the collected imagery and data are freely available to everyone, offering you the opportunity to become an Earth observer yourself!

Monitoring Marine Ecosystems with Sentinel Satellites

The Sentinel satellites play a crucial role in monitoring the health of marine environments by providing detailed, real-time data on key ecological indicators. They track biodiversity changes, such as seagrass populations in shallow waters, which are essential for coastal protection and carbon storage. The satellites also help identify sources of marine pollution, including oil spills, by detecting ship movements. Additionally, they monitor algal blooms, which can deplete oxygen levels in water and create dead zones, threatening marine life. They also measure sea surface temperature, monitor suspended sediments, and track ocean currents, which can be used to further assess the risk of algal blooms. Collectively, these data contribute to more effective management and protection of marine ecosystems.

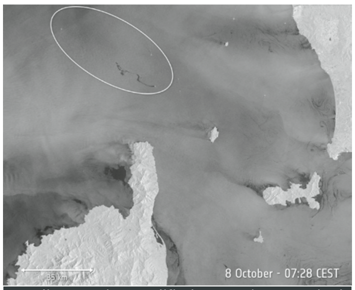
Credit: contains modified Copernicus Sentinel data (2019), processed by ESA

Baltic blooms (Sentinel-2)



Credit: contains modified Copernicus Sentinel data (2019), processed by ESA

Algae bloom detected from space by Sentinel-3

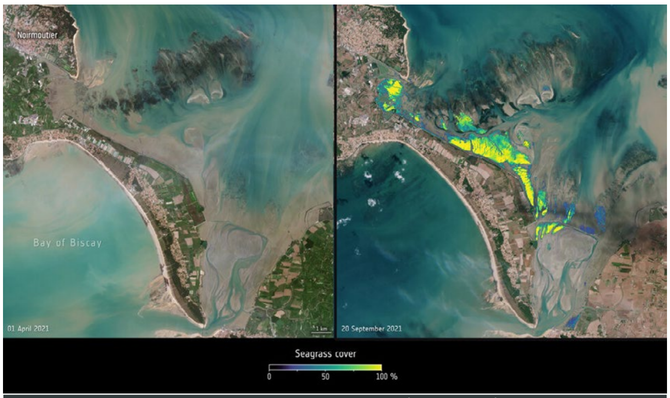


Credit: contains modified Copernicus Sentinel data (2018), processed by ESA

Oil spill detected from space using Sentinel-1

Credit: contains modified Copernicus Sentinel data (2021), processed by ESA

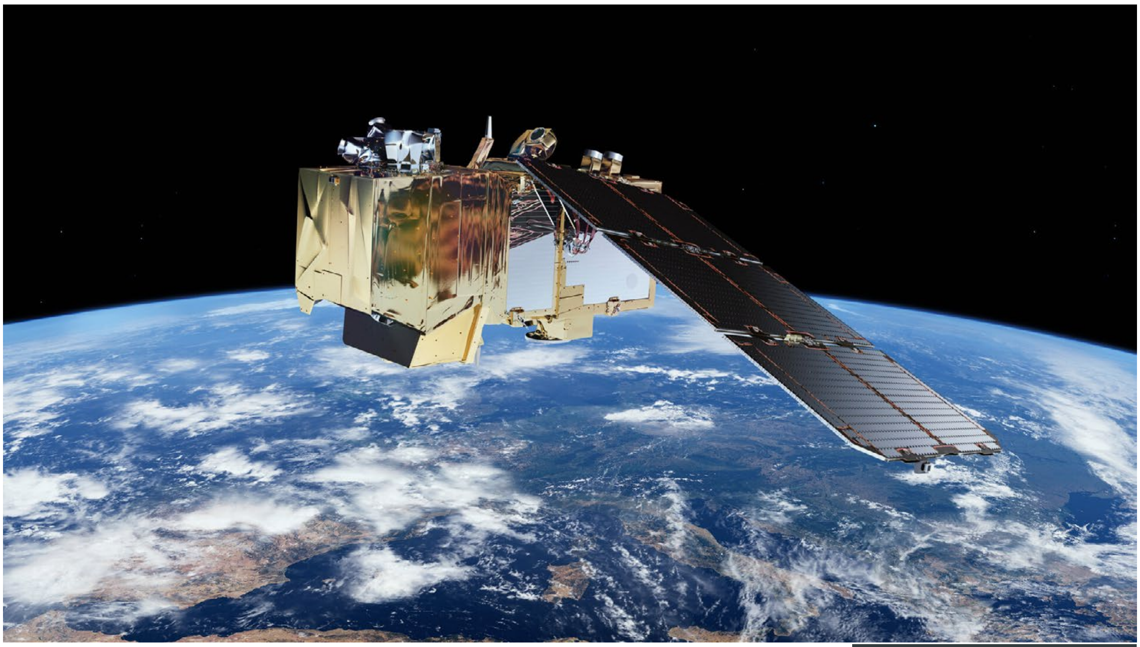
Suez Canal traffic jam seen from space using Sentinel-1



Credit: contains modified Copernicus Sentinel data (2018, 2021), processed by ESA

Sea grass detected from space by Sentinel-2

Copernicus Sentinel-2 SuperSharp Snapper



Credit: ESA/ATG Medialab

Figure 3. Sentinel-2

Copernicus Sentinel-2 is a two-satellite mission. Each satellite carries a high-resolution camera, allowing for the capture of supersharp 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 the entire Earth in just five days!

The supersharp satellite images are used to monitor changes in land use and to keep track of vegetation health. Although it is mostly optimised for land applications, Sentinel-2 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.

Copernicus Sentinel-3 AquaPalette Analyst

Figure 4. Sentinel-3

The two-satellite mission Copernicus Sentinel-3 orbits at a height of 814 km and images the entire Earth every 27 days, with a particular focus on oceans. The satellites excel at measuring ocean colour, making them exceptionally useful for monitoring the development of algal blooms. By tracking ocean currents and winds, Sentinel-3 even monitors the movement of these blooms. However, compared to Sentinel-2, Sentinel-3 is less effective at observing smaller areas in fine detail.

The Sentinel-3 satellites carry four instruments to monitor Earth. These instruments include a sensor to monitor ocean and land colour, a radiometer to measure sea and land surface temperature, a synthetic aperture radar altimeter that measures the height of Earth's surface features (such as sea level and ice sheets), and a microwave radiometer that detects natural microwave emissions to provide data on atmospheric water content, soil moisture, and ocean salinity. Together, these instruments provide data to enhance our understanding of large-scale global dynamics in the oceans, on land, in ice-covered regions, and within the atmosphere.

Copernicus Sentinel-1 Echo Explorer

Figure 5. Sentinel-1

Copernicus Sentinel-1 is the first satellite of the Sentinel series and orbits at a height of 693 km. It is designed as a constellation of two satellites orbiting 180° apart, allowing Sentinel-1 to map the entire Earth every six days.

To provide continuous data delivery and transmission to Earth, the Sentinel-1 satellites are equipped with a radar instrument, enabling them to map Earth's surface day-and-night, through all weather conditions. The radar uses microwaves that can penetrate through clouds, while many other wavelengths are either reflected or absorbed by them. In contrast, other satellites, like Sentinel-2 and Sentinel-3, cannot see through clouds or at night. Sentinel-1 also only provides black-and-white images as the satellites do not observe visual light.

The radar is called the C-band Synthetic Aperture Radar (SAR) and delivers data which include key information for a broad range of global monitoring applications. Sentinel-1 delivers data to tackle and understand climate change, support forest, water and soil management, gives insights into sea-ice mapping and extent, and assist in humanitarian aid and crisis situations. For example, Sentinel-1 is highly useful for monitoring waterbody pollution, such as oil spills, and for tracking ships to ensure maritime security.

Did you know?

Algae blooms can be also investigated locally from the ground by taking so-called in-situ measurements, which may include:

- Measuring water transparency
- Researching water quality
- Characterizing key algae species
- Analysing nutrient or oxygen concentrations

In-situ data are used to complement satellite imagery and help to improve future instruments for Earth observation from space.

Credit: ESA - Sirio Sechi

ESA astronauts Matthias Maurer and Pedro Duque taking in-situ samples during their training

Take Home Message

For Earth Observation, satellites and ground-based data (so called in-situ measurements) work together to monitor ecosystems locally and globally. Satellites provide valuable insights into our planet by using advanced instruments to detect visible and invisible changes such as heat, atmospheric composition, and vegetation health. ESA's Sentinel satellites, developed for the Copernicus Programme, play a key role in this process by continuously observing Earth, enabling quick detection of environmental changes in ecosystems like wildfires, floods, and oil spills. Over time, their long-term monitoring reveals the effects of Climate Change, including glacial retreat, sea level rise, and ocean acidification. Satellites also track phenomena like algae blooms and seagrass health, which are crucial for marine resources. Sentinel data is freely available to all, so everyone is empowered to explore, track, and contribute to solving the world's most pressing environmental issues.

Ready to explore more?

There's plenty more to discover at the ESA Education website! The ESA Education program provides a range of engaging STEM projects for primary and secondary school level students, such as Climate Detectives, CanSat, Mission X, Moon Camp, and AstroPi. Additionally, it offers teaching resources and training opportunities for teachers and educators. You can also connect with your national ESERO (European Space Education Resource Offices) to find out more about activities in your country!

Glossary

Algal Blooms: Rapid growth of algae in water bodies, often triggered by excessive nutrient enrichment, such as nitrogen and phosphorus. Some blooms can be harmful to aquatic life and the environment

Artificial Satellite: A man-made object launched into space and placed in orbit around a celestial body

Copernicus: A European Union programme for environmental monitoring, using satellite data from missions like the Sentinel series

Electromagnetic spectrum: The full range of wavelengths of electromagnetic radiation, from the longest to the shortest wavelength

EO Data: Earth Observation Data collected via remote sensing or ground measurements to monitor Earth's environment, climate, and natural phenomena.

False colour: A processed image that uses colours not corresponding to natural colours, often to visualise data outside the visible spectrum

In-situ Measurements: Data collected directly on the ground or in a specific location, often used to complement satellite data for a more complete understanding

Microwaves: A type of electromagnetic radiation with longer wavelengths than infrared light, used in satellite radar instruments for Earth observation

Near-infrared Light: A part of the electromagnetic spectrum just beyond visible light, often used in satellite imagery for monitoring vegetation and land cover

Ocean Colour: The colour of the ocean as observed in different electromagnetic spectrum bands, primarily influenced by phytoplankton and their chlorophyll concentrations

Oil Spills: The release of liquid petroleum into the environment, often causing harm to ecosystems, which can be detected in waterbodies by using satellite-based radar systems

Radar: A remote sensing technique to generate three dimensional images of Earth's surface, by sending out radio waves for detecting and locating an object by their reflection

Remote sensing: A device that delivers information and data about an object or phenomenon without physical contact and from a distance, often using satellite sensors

Sea Surface temperature (SST): The temperature of the layer of seawater close to the surface (approx. 0,5 m deep)

Sentinel Satellites: A series of Earth-observing-satellites

Shortwave Infrared Light: A type of infrared light used in remote sensing, providing useful data for detecting water content in vegetation and soil

Spectral Band: Specific ranges of wavelengths within the electromagnetic spectrum, which are detected by satellite sensors for different types of observations

Visible Light: The part of the electromagnetic spectrum that humans can see, ranging from violet (shorter wavelengths) to red (longer wavelengths)

Worksheets

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QUESTION 1

Match the Mission Name to the superhero description

A radar superhero that sees through clouds and darkness.	In-situ (Ground Grabber)
Captures super-sharp images and monitors plant and forest health.	Sentinel-3 (AquaPalette Analyst)
Excels at measuring ocean colour and can track the movement of algae blooms	Sentinel-2 (SuperSharp Snapper)
Collects direct environmental data and is great at investigating details.	Sentinel-1 (Echo Explorer)

QUESTION 2

Determine whether the following statements are true or false.

1. Echo Explorer can distinguish different types of algae based on their colour. True/False
2. SuperSharp Snapper can see in more detail than AquaPalette Analyst. True/False
3. In-situ measurements are done on a global scale. True/False
4. SuperSharp Snapper can see at night and through clouds.True/False
5. AquaPalette Analyst track ocean currents and winds. True/False

QUESTION 3

What is Earth Observation (EO) and what are the main two types of EO data?

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QUESTION 4

Which Sentinel satellite would be most helpful for identifying the different types of algae blooms? Explain why?

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QUESTION 5

If scientists wanted to track the movement of an algae bloom across the ocean, which satellite would they use and why?

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QUESTION 6

6A. Write the detail visibility (resolution) for Supersharp Snapper and AquaPalette Analyst:

SuperSharp Snapper: ....

AquaPalette Analyst: ....

QUESTION 6-CONTINUED

6B. Which of the two satellites would be best suited for monitoring large ocean regions, and which one would be better for studying smaller coastal areas?

QUESTION 7

Which event is Echo Explorer great at detecting which may impact algal communities?

QUESTION 8

What is the clear advantage of Echo Explorer compared to SuperSharp Snapper and AquaPalette Analyst?

QUESTION 9

What are the advantages of satellite data compared to in-situ measurements?

QUESTION 10

How may in-situ measurements complement satellite data?

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Answer Sheet

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QUESTION 1

Match the Mission Name to the superhero description

Answer

A radar superhero that sees through clouds and darkness.	In-situ (Ground Grabber)
Captures super-sharp images and monitors plant and forest health.	Sentinel-3 (AquaPalette Analyst)
Excels at measuring ocean colour and can track the movement of algae blooms	Sentinel-2 (SuperSharp Snapper)
Collects direct environmental data and is great at investigating details.	Sentinel-1 (Echo Explorer)

QUESTION 2

Determie swhether the following statements are true or false.

Answer

1. Echo Explorer can distinguish different types of algae based on their colour. False
2. SuperSharp Snapper can see in more detail than AquaPalette Analyst. True
3. In-situ measurements are done on a global scale. False
4. SuperSharp Snapper can see at night and through clouds. False
5. AquaPalette Analyst track ocean currents and winds. True

QUESTION 3

What is Earth Observation (EO) and what are the main two types of EO data?

Answer

EO data refers to information collected about the Earth's surface, atmosphere, and oceans using satellites and ground-based measurements.
There are two main types:

Satellite data (Remote Sensing): Collected from space, using sensors on satellites to capture images and measurements of the Earth's surface.

In-situ data: Collected directly from the ground or water, such as samples taken for lab analysis.

QUESTION 4

Which Sentinel satellite would be most helpful for identifying the different types of algae blooms? Explain why?

Answer

Satellite data from Sentinel-2 (SuperSharp Snapper) is particularly useful for identifying different types of algae blooms because it can capture colourful images that reveal the unique colour patterns of different algae species. Different types of algae reflect light in distinct ways, and Sentinel-2 can detect these variations, which helps differentiate between algae species.

QUESTION 5

If scientists wanted to track the movement of an algae bloom across the ocean, which satellite would they use and why?

Answer

Scientists would use Sentinel-3 (AquaPalette Analyst) to track the movement of algae blooms across the ocean. Sentinel-3 monitors ocean currents and winds, which are important for understanding how algae blooms move across large bodies of water.

QUESTION 6

6A. Write the detail visibility (resolution) for Supersharp Snapper and AquaPalette Analyst:

Answer

SuperSharp Snapper: 10 meters

AquaPalette Analyst: 300 meters

6B. Which of the two satellites would be best suited for monitoring large ocean regions, and which one would be better for studying smaller coastal areas?

Answer

AquaPalette Analyst (Sentinel-3) would be better suited for monitoring large ocean regions as it has a higher detail visibility/lower resolution (300 meters) but is excellent for observing broad ocean conditions like ocean colour, currents, and large-scale algae blooms across vast areas. SuperSharp Snapper (Sentinel-2), with a lower detail visibility/higher resolution (10 meters), is better suited for studying smaller, more detailed areas such as coastal ecosystems.

QUESTION 7

Which event is Echo Explorer great at detecting which may impact algal communities?

Answer
Echo Explorer excels at detecting ocean oil spills, which, like algal blooms, may appear as ‘dark areas’ on radar images.

QUESTION 8

What is the clear advantage of Echo Explorer compared to SuperSharp Snapper and AquaPalette Analyst?

Answer
Sentinel-1 (Echo Explorer) can see through clouds and darkness.

QUESTION 9

What are the advantages of satellite data compared to in-situ measurements?

Answer
Satellite data provides global coverage, frequent large-scale observations, and can monitor remote areas, while in-situ measurements are limited to smaller areas and are more time-consuming and expensive.

QUESTION 10

How may in-situ measurements complement satellite data?

Answer
In-situ measurements complement satellite data by providing ground truth data. This includes detailed, localized information like chlorophyll concentration and species identification that satellites cannot capture directly. For example, in-situ measurements such as water samples help analyse chlorophyll levels, nutrient concentration, and species identification at a microscopic level - and are therefore used to identify the water quality. This ground-based data helps validate and improve satellite observations, ensuring more accurate monitoring of phenomena like algae blooms. While satellites offer broad, large-scale coverage, in-situ data fills in the finer details that satellites might miss.

Find out more

Contact us

We invite you to contact us to get more information about our activities and how you could collaborate with our team.

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Version 1: April 2025