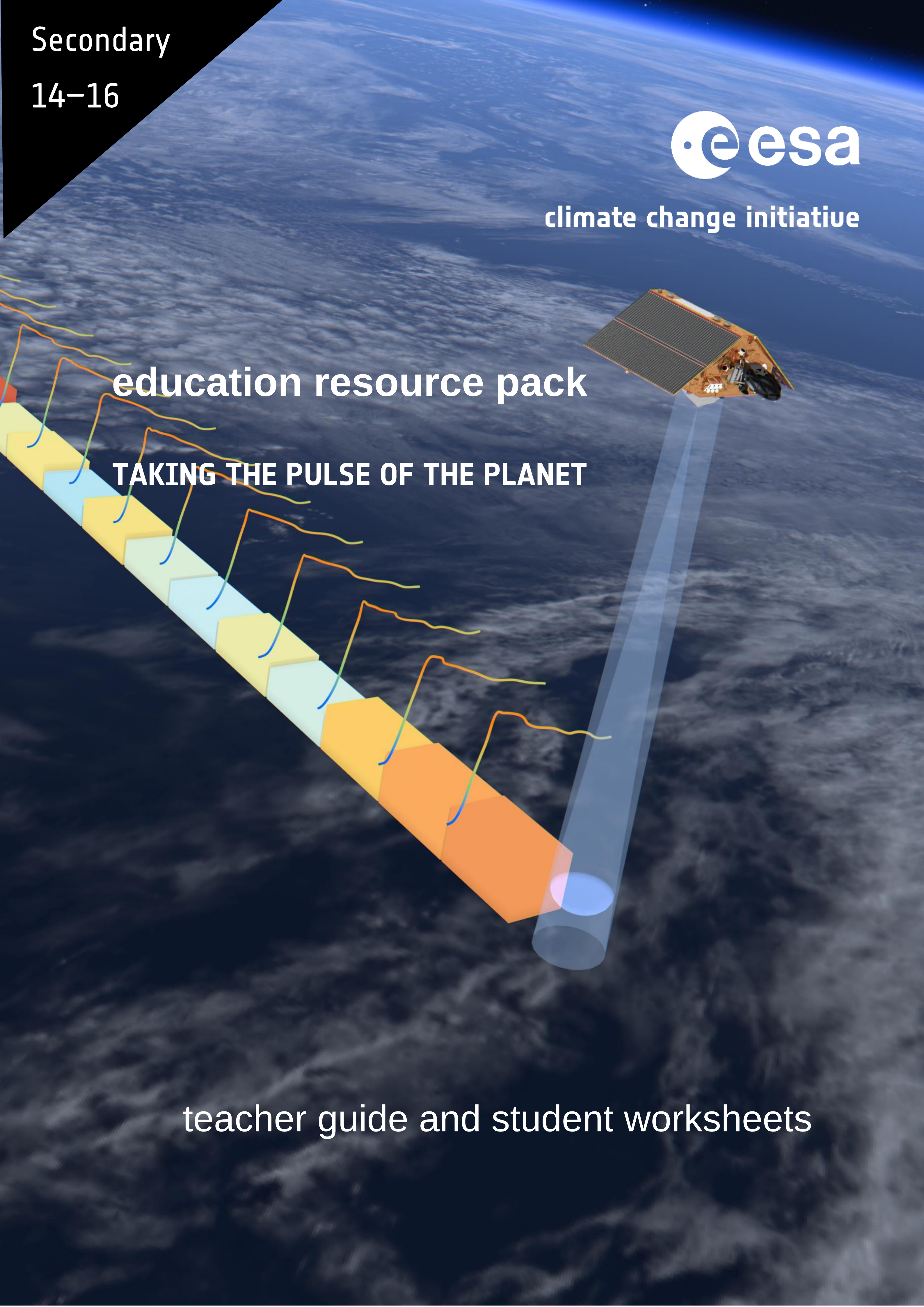

Secondary

14–16

esa

climate change initiative

education resource pack

TAKING THE PULSE OF THE PLANET

teacher guide and student worksheets

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climate change initiative education resource pack –
TAKING THE PULSE OF THE PLANET (Upper Secondary)
https://climate.esa.int/educate/

Activity concepts developed by University of Twente (NL) and
National Centre for Earth Observation (UK)

The ESA Climate Office welcomes feedback and comments
https://climate.esa.int/helpdesk/

Produced by the ESA Climate office

TAKING THE PULSE OF THE PLANET: Overview

Fast facts

Subject(s): Geography, Science, Earth Science

Age range: 14–16 years old

Type: mathematical, IT and research activities

Complexity: medium to advanced

Lesson time required: 4 hours

Cost: low (5–20 euro)

Location: indoors

Includes the use of: Internet, smartphone/camera, calculator

Keywords: remote sensing, platform, sensor, satellite, orbit, geostationary, polar, sun-synchronous, footprint, resolution, spatial, temporal

Brief description

In this set of activities, students will learn about how data is collected by sensors and how the orbit of a satellite affects the detail that can be obtained.

A text-based activity introduces the concept of remote sensing and looks at how sensors and satellites in different orbits can be matched to the intended application.

This is followed by mathematical work exploring factors affecting the amount of detail that is visible in a satellite image.

In the final activity, students use the Climate from Space web application to explore a range of climate variables during El Niño and La Niña events.

Intended learning outcomes

Having worked through these activities, students will be able to:

List the key components of a remote sensing system.

Describe the benefits and drawbacks of different satellite orbits for monitoring the Earth and its climate.

Create an infographic to convey research in an engaging way.

Analyse a digital image to determine the resolution of the image.

Consider how sensors are adapted for use on satellite platforms.

Suggest reasons for differences in the resolution of data collected by different instruments.

Use climate data to identify El Niño and La Niña events.

Explain how these events have global effects and investigate the human and societal impact of one such effect.

Summary of activities

	Title	Description	Outcome	Prior learning	Time
1	Taking the pulse of the planet	Reading and research on orbits used by remote sensing satellites	List the key components of a remote sensing system. Describe the benefits and drawbacks of different satellite orbits for monitoring the Earth and its climate. Create an infographic to convey research in an engaging way.	None	1½ hours
2	What can we see from space?	Exploring the footprint and resolution of images using a camera and the Climate from Space web application	Analyse a digital image to determine the resolution of the image. Consider how sensors are adapted for use on satellite platforms. Suggest reasons for differences in the resolution of data collected by different instruments.	Calculations involving direct proportionality, SI units	1 hour
3	El Niño and La Niña	Using satellite data to explore a climate cycle	Use climate data to identify El Niño and La Niña events. Explain how these events have global effects and investigate the human and societal impact of one such effect.	None	1½ hours

Times given are for the main exercises, assuming full IT access or/and distribution of repetitive calculations and plots around the class. They include time for sharing results but not the presentation of outcomes as this will vary depending on the size of the class and groups. Alternative approaches may take longer.

Practical notes for teachers

The **material required** for each activity is listed at the start of the relevant section, together with notes about any preparation that may be required beyond copying worksheets and information sheets.

Worksheets are designed for single use and can be copied in black and white.

Information sheets may contain larger images for you to insert into your classroom presentations, additional information for students, or data for them to work with. These resources are best printed or copied in colour but may be reused.

Any **additional spreadsheets, datasets or documents** required for the activity may be downloaded by following the links to this pack from https://climate.esa.int/educate/climate-for-schools/

Extension ideas and suggestions for **differentiation** are included at appropriate points in the description of each activity.

Worksheet answers and sample results for practical activities are included to support **assessment**. Opportunities for you to use local criteria to assess core skills such as communication or data handling are indicated in the relevant part of the activity description.

Health and safety

In all activities, we have assumed you will continue to follow your usual procedures relating to the use of common equipment (including electrical devices such as computers), movement within the learning environment, trips and spills, first aid, and so on. Since the need for these is universal but the details of their implementation vary considerably, we have not itemised them every time. Instead, we have highlighted hazards particular to a given practical activity to inform your risk assessment.

Some of these activities use the Climate from Space web application or other interactive websites. It is possible to navigate from these to other parts of the ESA Climate Change Initiative site or that of the host organisation and thence to external websites. If you are not able – or do not wish – to limit the pages students can view, do remind them of your local Internet safety rules.

Climate from Space

ESA satellites play an important role in monitoring climate change. The Climate from Space web application (cfs.climate.esa.int) is an online resource that uses illustrated stories to summarise some of the ways in which our planet is changing and highlight the work of ESA scientists.

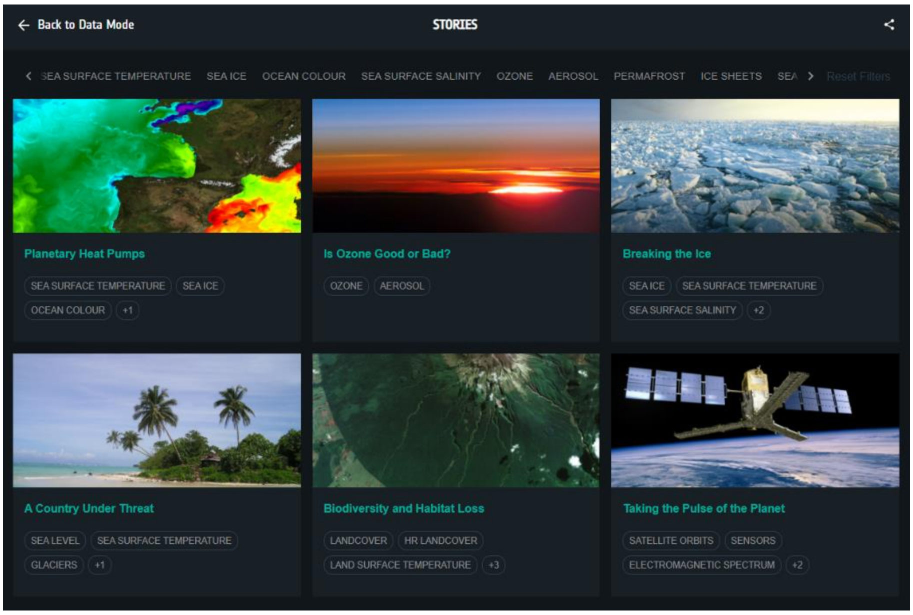


Figure 1: Stories in the Climate from Space web application (Source: ESA CCI)

ESA's Climate Change Initiative programme produces reliable global records of some key aspects of the climate known as essential climate variables (ECVs). The Climate from Space web application allows you to find out more about the impacts of climate change by exploring this data for yourself.

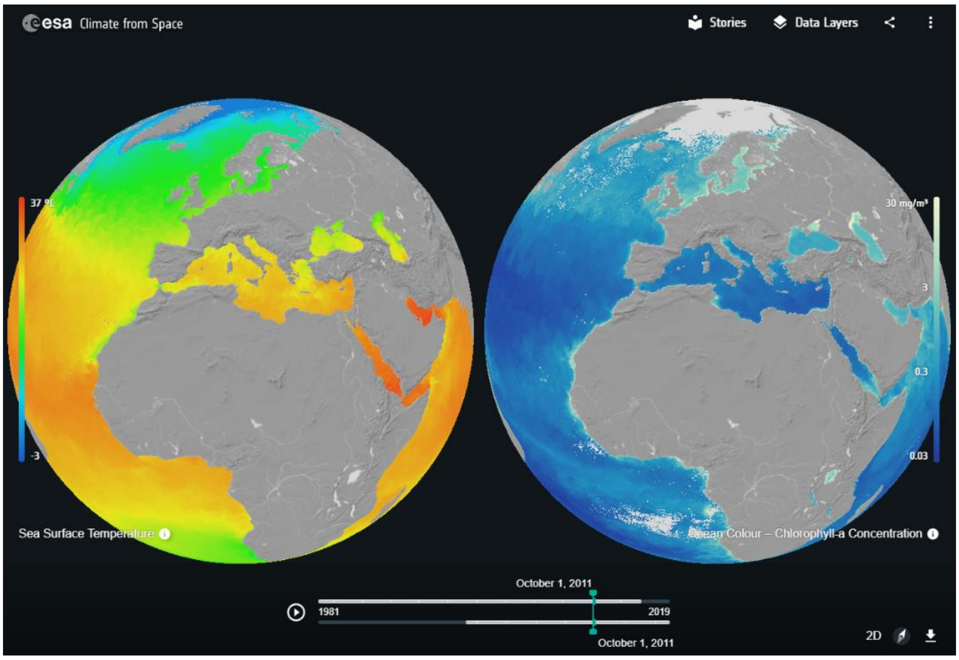


Figure 2: Comparing sea surface temperatures and ocean colour in the Climate from Space web application (Source: ESA CCI)

Monitoring the Earth from space: background information

Earth observation and remote sensing

Earth observation is the process of collecting data about the Earth. Particularly in Europe, the term is often used to refer to collecting measurements using sensors on satellites. Another term often used for collecting data in this way is 'remote sensing' – taking measurements from a distance. Earth observation scientists also use data collected from instruments on the ground, on (or in) the sea, and in the atmosphere to calibrate the satellite sensors and check they are working properly.

The satellite advantage

A key use of Earth observation is monitoring the climate. The climate system is complicated, and understanding it requires measurements from across the globe, so space is the ideal vantage point from which to collect data: it would take an army of ground-level observers to collect the information in a single satellite image. Space-based instruments can also collect data from remote or inaccessible places such as the polar regions and the middle of the ocean. A further advantage of satellites is that they can make measurements at regular intervals over a period of years. Thanks to overlapping measurements from several families of satellite instruments, we now have detailed records, covering decades, for many of the key aspects of the climate that scientists and policy makers call Essential Climate Variables (ECVs).

The first two activities in this pack focus on the view that a satellite has, exploring the types of orbit available and considering the balance between height and the level of detail that sensors can supply. The orbits are described on Information sheet 1 (pages 20 and 21). Student worksheet 2.1 (page 16) guides students through calculating resolutions using simple mathematics and data from a smartphone. The teacher notes for the activity (pages 11–13) support discussion comparing this theoretical situation with sensors in orbit, so we have not included additional detail here.

Earth observation for climate

Our climate is the product of interacting variables which create natural cycles that play out over a day, a year, decades or thousands of years. We monitor ECVs to help us understand how they change, interact and contribute to these cycles. Earth observation data from satellites makes a major contribution to our understanding of the processes driving climate change. It is used to model the climate to help us assess future change and the possible impact of actions we might take to mitigate its effects.

The final activity in this pack gives students the opportunity to explore the complexity of the climate using actual satellite data to investigate one of these natural cycles: the El Niño and La Niña events that arise in the South Pacific. If you are not familiar with how these arise, see the animation referenced in the notes for the activity (on page 14) – it is far easier to understand than static text!

You can find activities focusing on the sensors used on satellite platforms in the companion pack *Taking the Pulse of the Planet (Lower Secondary)* which is also available from https://climate.esa.int/educate/climate-for-schools/.

Activity 1: TAKING THE PULSE OF THE PLANET

In this comprehension activity, students are introduced to the concept of remote sensing and explore the use of satellites in different orbits to monitor components of the Earth's climate system. Confident readers could carry out this activity as a standalone homework exercise, and the final research task may be done individually or in pairs/groups.

Equipment

- Information sheet 1 (2 pages)
- Student worksheet 1
- Climate from Space web application: *Taking the Pulse of the Planet* story (optional)
- Internet access

Exercise

1. Read Information sheet 1 as a class or ask students to read it individually or in groups. As they read, students should note any questions they wish to ask and complete the 'Types of orbit' section of Student worksheet 1.
    - You can find an animated version of the final image on the information sheet at https://www.esa.int/ESA_Multimedia/Videos/2020/11/Sentinel-6_orbit/(lang)
    - You could supplement the text with material from the Climate from Space story *Taking the Pulse of the Planet*, particularly the galleries on slide 2 (which shows a series of historical pictures of the Earth from space, including the Blue Marble image) and slide 3 (which shows a selection of satellites and how they communicate with the ground).
2. Check answers to 'Types of orbit' as a class, and discuss any questions arising from the reading.
   Students completing this exercise at home may also wish to refer to the ESA article on types of orbit:
   https://www.esa.int/Enabling_Support/Space_Transportation/Types_of_orbits.
3. Ask students to answer the remaining questions on the worksheet.
    - If students struggle to think of applications, refer them to any work they have done using dataloggers, encourage them to think about how drones might be used, and to consider how animal migrations are tracked.
    - Good starting places for the research task are the description of the Copernicus Sentinel satellites at https://www.esa.int/Applications/Observing_the_Earth/Copernicus/The_Sentinel_missions and the comprehensive list of ESA Earth observations at https://www.esa.int/Applications/Observing_the_Earth/Highlights/Earth_observation_missions
    - You may wish to allocate satellites to be investigated or allow students to choose one that is of interest.
    - Similarly, you may wish to give specific dimensions for the completed work or/and allow students to include interactive elements.

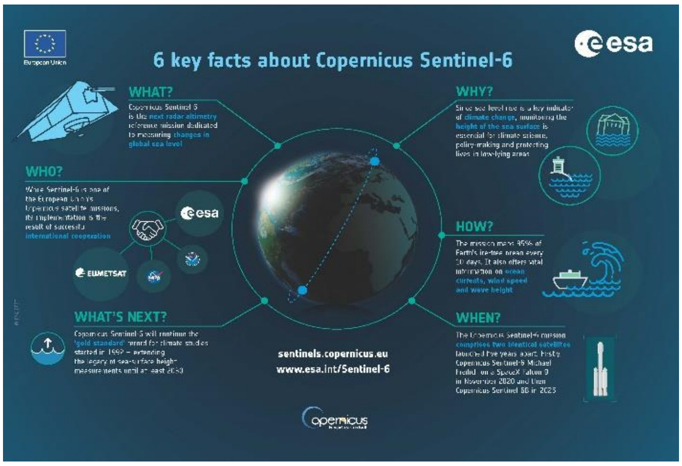


Figure 3: Sample infographic (Source: ESA)

- You might wish to show students the infographic in Figure 3 as an example. A high-resolution version can be downloaded from https://www.esa.int/ESA_Multimedia/Images/2020/09/Six_key_facts_about_Copernicus_Sentinel-6#.X8T7Fd3QZQY.link

4. Students could present the results of their research to each other in a poster session, peer-evaluating the infographics against pre-agreed criteria.

Worksheet answers

Types of orbit

1	Always view the same hemisphere of the globe	GEO
2	Pass over most places on Earth	LEO
3	Can take many pictures of a single place each day	GEO
4	Produce detailed images	LEO
5	Are used for remote sensing	GEO/LEO
6	Help monitor land cover	LEO
7	Support weather forecasts	GEO

The answers above correspond to the information given in the story on Information sheet 1 but data from LEO satellites may be used to support local weather forecasts.

Remote sensing

There are many possible answers, but some examples are given below:

Sensor	Platform	Application
Video camera	Drone	Traffic monitoring
Heart-rate monitor	Wristband	Athletics coaching
GPS sensor	Tag	Tracking bird migration
Motion sensor	Buoy	Wave height/conditions
Temperature sensor	Wall	Weather station

Find out more

Individual answers.

Activity 2: WHAT CAN WE SEE FROM SPACE?

This activity challenges students to think about factors affecting the amount of detail possible in data collected from space. Calculations based on the information about a digital image taken in the classroom with an everyday camera allow students to revise mathematical ideas about similar triangles or proportionality. Investigating the resolution of data sets in the Climate from Space web application introduces the wide range of ECVs that can be measured from space.

Equipment

- Student worksheet 2 (2 pages)
- A metre rule or tape measure
- Smartphone or digital camera
- Calculator
- Image-processing software with which students are familiar
- Climate from Space web application (cfs.climate.esa.int)

Preparation

Go to ESA's Earth observation image of the week collection (esa.int/ESA_Multimedia/Sets/Earth_observation_image_of_the_week/(result_type)/images) and download an image to introduce the lesson. You might choose the most recent image or one related to where you live or to other work the students are doing.

Exercise

1. Show the students the image of part of the Earth from space and discuss what it shows. How easy is it to tell the scale of the image? Are there any particular features that help? How? What is the smallest feature students think would be visible in the image?
2. Explain that satellite images are more useful if we know the scale and resolution – the distance on the ground corresponding to the length of a pixel in the image – and ask students to work through the instructions and questions on Student worksheet 2.
   Students will need to use the information on satellite orbit heights from the previous activity and will need to take care with units.
   Question 13 is optional.

Worksheet answers and sample results

How big a picture can your camera take?

The answers to questions 1, 2 and 4 below are sample results obtained using the camera on a simple smartphone. You could give this data to students unable to carry out the practical themselves.
Answers to questions 3, 5 and 6 are based on the sample data, so are for guidance only: student suggestions should match the figures they obtain in their calculations.

1. 1.25 m   2. 1.5 m

3. a) Footprint is 250 m so the object could be, for example, a running track.
   b) 8330 m – a small town
   c) 333 km – about the distance between London and Paris
   d) 583 km – Amsterdam to Berlin

What can your camera see?

4. 2560 pixels

5. 4.88×10^{-4} m/pixel (i.e. about 0.5 mm/pixel)

6. a) Resolution is 9.76 cm so the object could be, for example, lane markings.
   b) 3.26 m – cars
   c) 130 m – large buildings such as factories
   d) 228 m – fields

Cameras in space

7. In principle, yes and absolutely if it is a 'proper' camera: the cameras used by astronauts on the ISS are no different to those used on Earth.
   In practice, there are several limitations students may think of. These include:

   - A phone camera on a rapidly moving platform may not have a fast enough shutter speed to prevent blurring.
   - A cheap sensor may not collect enough light to produce a clear image.
   - Large differences in contrast might affect automatic exposure times, leading to images that are dark or washed out.
   - Any shortcomings in the optics may be enhanced, leading to aberrations at the edges of the image, for example.
   - Exposure to cosmic radiation may lead to tracks in images and 'dead' pixels.

   In addition, some students may be aware that the sensors on some satellites are sensitive to different regions of the electromagnetic spectrum to those detected by normal cameras.

8. Students may mention:

   - The structure needs to be able to survive the stress of launch.
   - Any air-filled cavities need to be well-sealed as the satellite will be in a vacuum.
   - All components must function across the wide range of temperatures in low Earth orbit – from about 120°C in direct sunlight to −150 °C in the Earth's shadow.
   - Any adjustments to focus, aperture, shutter speed, etc. will need to be made by remote control.
   - Similarly, the camera needs to include a data transmitter rather than a memory card.

Measuring other quantities

9. How often pictures are taken – students unable to answer this question should be encouraged to move on to the next and come back to this having looked at some data sets in the Climate from Space web application.

10. 4 km, monthly

11. The resolution of the sensors used may be different.
    Students may also notice that we have monthly or annual data from satellites that, according to the information in the previous activity, collect data every ten days or so. Data may be averaged over an area (in the same way as it is averaged over time) to give more reliable measurements.

12. Cloud cover will affect many measurements.
    Land cover type may also affect others: for example, it is not possible to get soil moisture measurements for densely forested areas using the same techniques as for grassland.

Challenge

13. a) The distance is $0.25 \times 2 \times \pi \times 6400 \div 360$ in each direction
    so about 27.9 km × 27.9 km.

    b) The size of the pixel in the north–south direction remains the same but the east–west distance decreases as you move away from the equator.
    A circle around the Earth at latitude θ has a radius of $6400 \times \cos\theta$ km.
    At 40º N, a 0.25º pixel would be about 21.2 km × 27.9 km.

Activity 3: EL NIÑO AND LA NIÑA

In this activity, students explore some datasets in the Climate from Space web application in greater detail to support understanding of El Niño and La Niña events and research into their impacts.

Equipment

- Student worksheet 3 (2 pages)
- Internet access
- Climate from Space web application (cfs.climate.esa.int)

Exercise

1. Ask students why weather forecasters and climate scientists give ranges and probabilities rather than fixed predictions. Elicit the ideas of natural variability, that Earth's climate system is complex, and that there are natural cycles of various lengths (daily, seasonal, multi-annual) to be considered. In this lesson, students are going to see how satellite observations help us to monitor one such cycle and its impacts.

2. Ask students to read through the instructions for the first task on Student worksheet 3.1.

3. Show the beginning (to 2:05 minutes) of the ESA El Niño and La Niña animation, and get students to use it to complete the task. You might also want them to give the correct sequence of letters in each box.
   The animation can be found on slide 7 of the Climate from Space web application story *Planetary Heat Pumps* or on the ESA website at http://www.esa.int/ESA_Multimedia/Videos/2018/12/El_Nino_and_La_Nina

4. Check answers as a class before asking students to explore the data available in the Climate from Space web application as described on the worksheet. They may do this individually, in pairs or in small groups as appropriate for the class. You may wish to give additional information about some of the datasets available – for example, defining the term 'anomaly' as the difference from the usual or average value.

5. Students may continue straight on to using the web application to try to identify El Niño and La Niña events, or you may ask them to first share their ideas about how each type of event would show in given datasets.

6. Once students have had time to see if they can identify events, show the remainder of the animation. This will give them the opportunity to check their answers and give them material to use to start the mind map for the first task in the 'Effects of El Niño and La Niña' section of Student Worksheet 3.2.

7. The detailed research or/and production of a podcast could be set as homework. Students without access to technology could produce notes to use when making a recording in school, write a script, or present their findings in a different format.

You could use the audio files to assess student understanding of this phenomenon, or the segments could be used for assessment/peer assessment of science communication skills against local criteria or criteria agreed by the students.

Worksheet answers

What causes El Niño and La Niña?

Normal year	G E B
El Niño	H I D
La Niña	F C A

El Niño and La Niña from space

The table below shows only those items suggested by the video. Students may add others, particularly if they already have a good handle on the topic.

Data layer	El Niño	La Niña
Sea surface temperature	Cooler water by South America's Pacific coast, a band of warm water across the Pacific	A plume of cooler water from South America across the Pacific
Ocean colour	High chlorophyll concentrations by South America's Pacific coast	Low chlorophyll concentrations, or narrower extent of phytoplankton in this region
Sea level	Sea levels higher than usual (positive anomalies/red colour) across the Pacific	A belt of ocean with sea levels lower than average (negative anomalies, blue)
Cloud	Belt of cloud above the band of warm water	No marked band of cloud

Identifying El Niño and La Niña

Events classed as moderate, strong or very strong from 1990, in decreasing order of strength:

El Niño: 2015–16,1997–98, 1991–92, 2009–10, 2002–03, 1994–95

La Niña: 2010–11, 1999–2000, 2007–08, 1998–99, 2011–12, 1995–96

Effects of El Niño and La Niña

Individual responses.
Students might investigate South American fisheries, Australian droughts, floods or fires, or effects further afield (see video animation).

Worksheet 1: TAKING THE PULSE OF THE PLANET

Types of orbit

Do the statements below apply to satellites in a geosynchronous equatorial orbit (GEO), those in a sun-synchronous geosynchronous low Earth orbit (LEO), or both? Use ideas from Information sheet 1 to help you decide.

1. Always view the same hemisphere of the globe ________________________
2. Pass over most places on Earth ____________________________________
3. Can take many pictures of a single place each day _____________________
4. Produce detailed images ____
5. Are used for remote sensing ______________________________________
6. Help monitor land cover ____
7. Support weather forecasts ____

Remote sensing

The story on Information sheet 1 focuses on using cameras mounted on satellites to observe the Earth's climate. However, other combinations of sensors and platforms can be used to monitor a huge variety of things.
How many can you think of? Record some ideas in the table below.

Sensor	Platform	Application

Satellite research

Research a named Earth observation satellite and produce an infographic about it. Your infographic should include:

- an image or drawing of the satellite
- the orbit in which the satellite travels
- what the sensor(s) on the satellite detect(s) or/and is/are used to measure
- who operates the satellite and the purpose of the mission
- when the satellite was launched and its (expected) lifespan
- other satellites carrying out work related to that of this one.

You may include any other information you wish – but remember that your infographic should remain attractive and easy to read.

Worksheet 2: WHAT CAN WE SEE FROM SPACE?

How big a picture can your camera take?

1. Choose a noticeboard or a window. How wide is it? ______________________

2. How far away from it do you have to stand so that it just fits into a photograph?

   ____

Take the photograph.
The size of the object in your image is the **footprint** of your camera at this distance.

3. Use these measurements to help you work out what you could take a picture of if you used the same camera and the same settings but mounted it on:

a) a drone flying 300 m above the ground ______________________________

____

b) an aircraft at 10 000 m ____

____

c) the International Space Station (ISS) at 400 km _________________________

____

d) a satellite in low Earth orbit. ____

____

What can your camera see?

Download the photograph you took and open it in image-processing software.

4. How many pixels wide is the image? ______________________________

5. Use this and the answer to question 1 to find the scale of your image in m/pixel.

   ____

6. Now work out the smallest object the camera could see if it were mounted on:

a) a drone ____

____

b) an aircraft ____

____

c) the ISS ____

____

d) a satellite in low Earth orbit. ____

____

Cameras in space

7. Do you think you would really be able to see this far and make out these details if your camera were in these places? Why? ______________________________

____

8. What do you think might be different about the cameras used by satellites? What effect would this have on the images they produce?

____

____

Measuring other quantities

The scale of the image in m/pixel is referred to as the **spatial resolution**. If we are using satellite images to monitor change, **temporal resolution** is also important.

9. What do you think 'temporal resolution' means? ______________________________

Open the Climate from Space web application (cfs.climate.esa.int). Click on the Data Layers symbol (top right) then pick Ocean Colour from the list. Click the **i** button next to the title of the visualisation (bottom left).

10. What are the spatial and temporal resolutions for this data?

____

11. Explore the spatial and temporal resolution of some of the other datasets. Why do you think there are differences? ______________________________

____

12. As you looked through the data, you may have noticed that there are places where the grey base map shows through because there is no data. Why do you think this sometimes happens? ______________________________

____

Challenge

13. Some quantities have the spatial resolution given in degrees, rather than metres. Given the radius of the Earth is 6400 km, what pixel size does a spatial resolution of 0.25º correspond to:

a) at the equator? ______________________________

____

b) where you live? ______________________________

____

Worksheet 3: EL NIÑO AND LA NIÑA

What causes El Niño and La Niña?

The statements A–I describe the movement of water and air across the southern Pacific Ocean.
Some describe a normal year, some an El Niño event, and others a La Niña event.
Write the letter for each statement in the appropriate row of the table.

A. A tongue of cold water travels east to west across the surface of the ocean.
B. Cold, nutrient-rich water rises from ocean depths along the coast of South America.
C. In the Eastern Pacific, cold water rises more quickly than in a normal year.
D. There is increased cloud cover across the Pacific.
E. This pushes warm surface water towards Australia.
F. Trade winds are stronger than usual.
G. Trade winds blow east to west.
H. Trade winds weaken.
I. Warm water builds up near the Americas.

Normal year	
El Niño	
La Niña	

El Niño and La Niña from space

Open the Climate from Space web application (cfs.climate.esa.int).
Click on the Data Layers symbol (top right) and look at the list of options.

1. Which data layers do you think will show changes during El Niño or/and La Niña?
2. What patterns or trends would you expect to see in each case?

Record your thoughts in the table below.

Data layer	El Niño	La Niña

Identifying El Niño and La Niña

Check you understand how the controls in the Climate from Space web application help you to look more closely at particular places or times.

1. Explore some or all of the data layers you decided would show changes.
2. Identify one or more El Niño and La Niña events.
3. Write the years when they occurred below. If an event spans parts of two consecutive years, give both.

El Niño ____

La Niña ____

Effects of El Niño and La Niña

El Niño and La Niña do more than changing rainfall patterns across the Pacific Ocean.

1. Carry out some rapid research into the effects these events have on countries and communities across the world. Sketch a mind map to show what you discover.

2. Choose one of these effects and carry out some more focused research into the consequences of it during or after a particular El Niño or La Niña event.

3. Record a report about this event to form part of a podcast about climate cycles. Your segment should:

   - be an audio file no more than three minutes in length
   - include a brief explanation of what El Niño or/and La Niña is/are
   - explain how the climate event leads to the effect you are describing
   - describe the impact on people, the environment or/and industry.

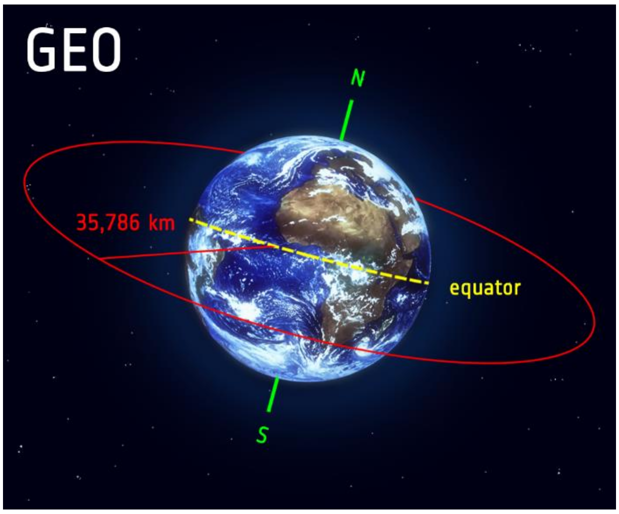
Information sheet 1: TAKING THE PULSE OF THE PLANET

The famous 'Blue Marble' image of the Earth (Source: NASA)

'The Blue Marble' is the name given to a picture of Planet Earth taken by the crew of Apollo 17. It is one of the most widely reproduced photos of all time. The blue water of the seas and oceans dominate the image but when we take a closer look, we can see much more: the yellow Sahara sand, the dark green tropical rainforests, the white of clouds over the oceans and ice and snow covering Antarctica. Similar pictures taken by cameras on satellites in orbit around the Earth are now part of our daily life: for example, they appear on many TV weather forecasts.

Scientists use the term **remote sensing** to describe observing objects from a distance. A remote sensing system needs a **sensor** (in the example above, this is the camera) and a **platform** (in this case, the satellite). **Earth observation** scientists who monitor our planet from space use many types of sensor mounted on different types of satellites, combining them in various ways depending on what they want to find out. Here we focus on how the type of satellite affects the data the instruments on it can collect.

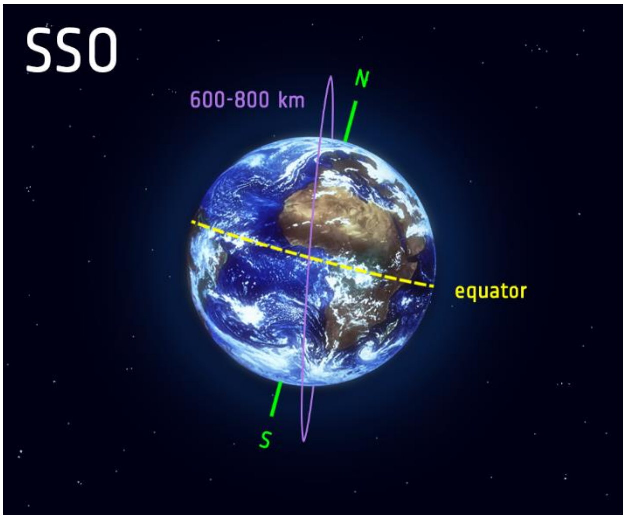
Types of orbit



A geosynchronous equatorial orbit (GEO) (Source: ESA)

Many of the images in weather forecasts come from instruments around 36,000 km above the surface of the Earth. The satellites carrying them travel at the same rate as the planet rotates and so they are always above the same point in the world. Satellites in such a **geosynchronous equatorial orbit** (GEO) are referred to as **geostationary satellites**. A GEO allows the camera to take many pictures of the same location every day so meteorologists can track how weather systems develop.

Not all satellites are geostationary. Others can look at the entire globe by travelling from pole to pole. These **polar-orbiting** satellites are in a **low Earth orbit** (LEO) at an altitude of about 700 km. Polar-orbiting satellites take only about a hundred minutes to go around the globe and their path crosses the equator about fourteen times every day.



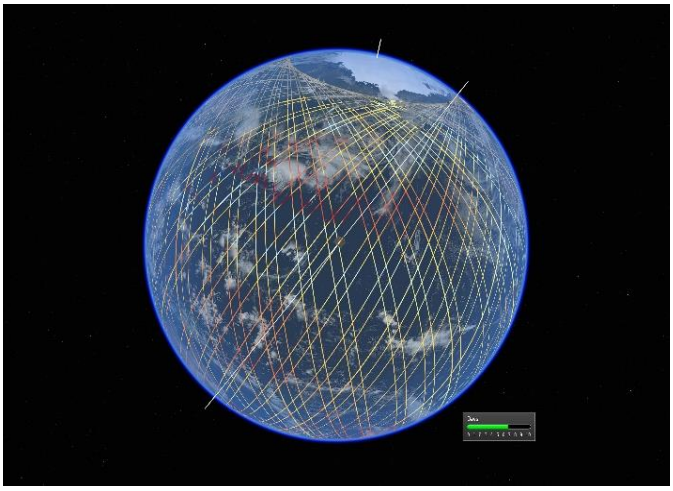
A sun-synchronous orbit (SSO) is a special type of low-Earth orbit (LEO) (Source: ESA)

Most polar-orbiting satellites follow a very specific path called a **sun-synchronous orbit** (SSO). They do not go right over the poles, but their orbit is slightly tilted. As a result, each time they pass over a particular point on the equator, the local time is approximately the same.

For most places on Earth, the cameras on board sun-synchronous polar-orbiting satellites can take only one picture per day. However, the images are more detailed than those taken from geostationary satellites because the camera is much closer to the Earth. Another advantage of using an SSO is that, because all the images of a certain place are taken at the same time of day, the pictures are not affected by the variations in light intensity and direction that happen naturally over the course of a day. This makes it possible to see other changes accurately, something that is essential for observing climate and measuring quantities known as essential climate variables (ECVs). ECVs indicate the health of our planet, in the same way that taking your pulse can tell a doctor about your health.

Using satellite observations

The European Space Agency, one of the world's leading space organisations, has collected satellite data for over forty years, most of it using sun-synchronous polar-orbiting satellites. This long record is extremely valuable. For instance, it allows us to see what global warming has done to our planet and is particularly useful in showing what is happening in remote regions. This is important because inaccessible oceans, mountains, tropical rainforests, savannahs and polar regions are among the areas that are most vulnerable to climate change.



The Copernicus Sentinel 6 satellite takes around one hundred minutes to make a single orbit and so 'sees' 95% of the Earth's ice-free oceans at least once every ten days (Source: ESA)

Links

Resources

Climate from Space web application
https://cfs.climate.esa.int

Climate for schools
https://climate.esa.int/educate/climate-for-schools/

Teach with space
http://www.esa.int/Education/Teachers_Corner/Teach_with_space3

Investigating El Niño with LEO Works
https://www.esa.int/SPECIALS/Eduspace_Weather_EN/SEML1PVO1FG_0.html

ESA space projects

ESA Climate Office
https://climate.esa.int/

Space for our climate
http://www.esa.int/Applications/Observing_the_Earth/Space_for_our_climate

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

Earth Explorers
http://www.esa.int/Applications/Observing_the_Earth/The_Living_Planet_Programme/Earth_Explorers

Copernicus Sentinels
https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Overview4

Extra information

Types of orbit
https://www.esa.int/Enabling_Support/Space_Transportation/Types_of_orbits

El Niño diagrams
https://www.esa.int/ESA_Multimedia/Images/2018/08/El_Nino

More Earth from Space videos
http://www.esa.int/ESA_Multimedia/Sets/Earth_from_Space_programme

ESA Kids
https://www.esa.int/kids/en/learn/Earth/Climate_change/Climate_change