Primary
8-11

education resource pack

IS OZONE GOOD OR BAD?

The discovery of the Antarctic ozone hole

Teacher guide and student worksheets

climate change initiative education resource pack – IS OZONE GOOD OR BAD?
https://climate.esa.int/en/educate/

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

The ESA Climate Office welcomes feedback and comments
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Produced by the ESA Climate office

IS OZONE GOOD OR BAD? Overview

The discovery of the Antarctic ozone hole

Fast facts

Subjects: Geography, Science, Earth Science

Age range: 8–11 years old

Type: reading, practical activity

Complexity: easy to medium

Lesson time required: 3 hours

Cost: low (5–20 euros)

Location: indoors/outdoors

Includes the use of: sunscreen, UV beads, Internet

Keywords: ozone, the ozone hole, ultraviolet (UV) light, greenhouse gas, pollutant, experiment, satellite

Brief description

In this set of activities, students will learn about ozone and the impacts – good and bad – it has on life on Earth.

The first activity gives an overview of these effects, outlines how ozone is measured and introduces the story of the Antarctic ozone hole.

There is a practical activity investigating the effectiveness of sunscreen.

In the final activity, students use real satellite data to explore how ozone concentration has varied across the world over the last couple of decades.

Intended learning outcomes

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

Summarise the effects of ozone in different parts of the atmosphere on life on Earth.

Outline the story of the Antarctic ozone hole, including the role of satellite observations in monitoring its recovery.

Relate the parts of an experimental model to the real-life situation it represents.

Evaluate the effectiveness of an experimental method.

Carry out a practical activity following instructions and recording results systematically.

Use the Climate from Space web application to explore changes to global ozone concentrations.

Select key information from a range of sources to present a concise summary of independent research.

Summary of activities

	Title	Description	Outcome	Prior learning	Time
1	Why does ozone matter?	Comprehension exercise based on a story relating ozone measurement to real life	Summarise the effects of ozone in different parts of the atmosphere on life on Earth. Outline the story of the Antarctic ozone hole, including the role of satellite observations in monitoring its recovery.	None	30–60 minutes
2	How good is my sunscreen?	Practical activity using UV beads to investigate the protective effect of various types of sunscreen	Relate the parts of an experimental model to the real-life situation it represents. Evaluate the effectiveness of an experimental method. Carry out a practical activity following instructions and recording results systematically.	None	60–90 minutes
3	The ozone hole	Research activity using Climate from Space web application	Use the Climate from Space web application to explore changes to global ozone concentrations. Select key information from a range of sources to present a concise summary of independent research.	An introduction to the topic, e.g. Activity 1	30–60 minutes + research (home learning) and feedback time

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 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/en/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. It is possible to navigate from here to other parts of the ESA Climate Change Initiative website 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. Climate from Space (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.

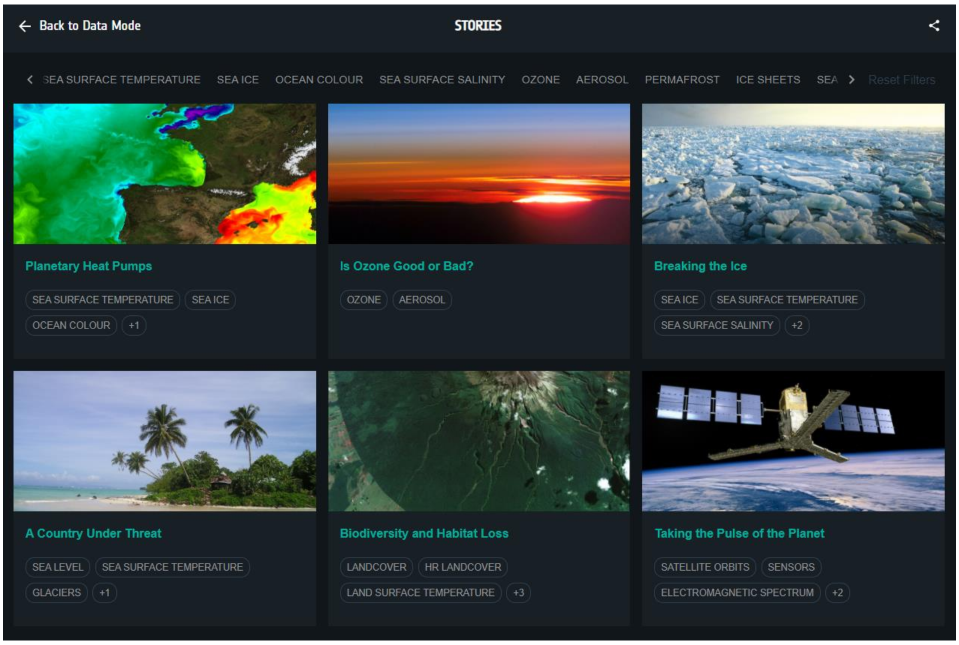


Figure 1: Stories in Climate from Space (Source: ESA CCI)

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.

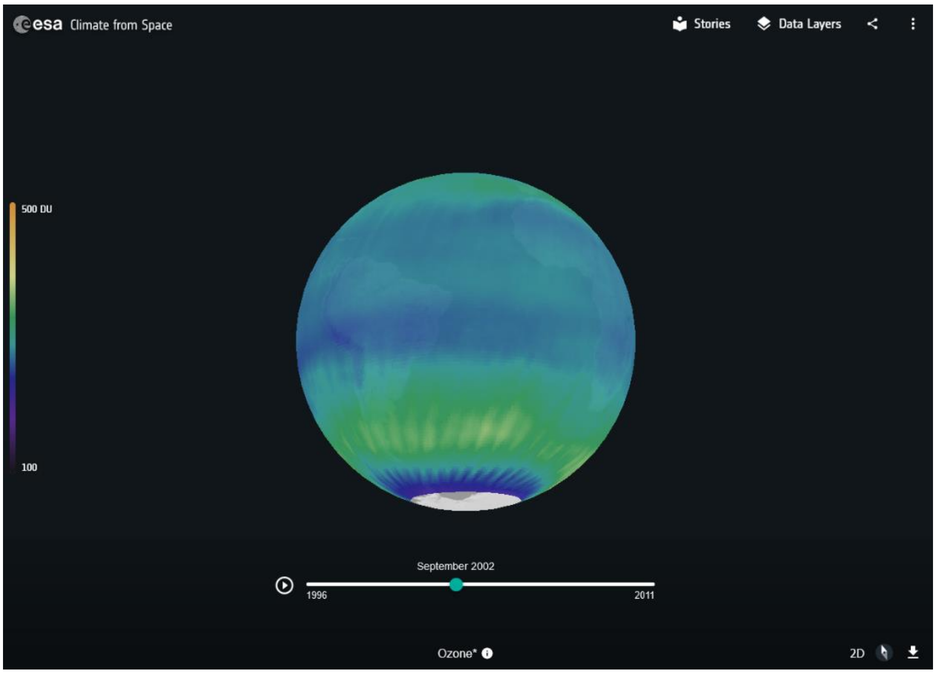


Figure 2: Exploring ozone levels in the Climate from Space web application (Source: ESA CCI)

Ozone in the atmosphere: background information

Greenhouse gases

Light from the sun passes through our atmosphere and warms the Earth. The Earth, in turn, radiates heat into outer space. Greenhouse gases in the atmosphere let in sunlight but trap the heat it produces, reducing the cooling effect (Figure 3). Ozone, a form of oxygen (O_3), is one such greenhouse gas.

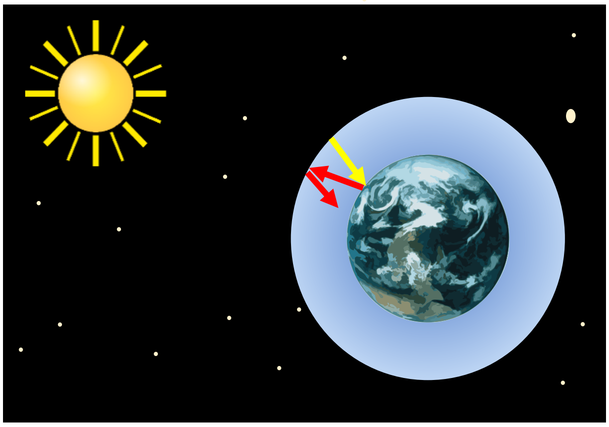


Figure 3: The greenhouse effect
(Source: Suhyb Salama, University of Twente)

Ozone and ultraviolet light

Invisible ultraviolet (UV) light from the sun causes sunburn and skin damage. It is categorised as UVA (low energy), UVB (medium energy) and UVC (highest UV energy). Ozone high in the atmosphere (20–50 km) absorbs all the UVC radiation but allows some UVA and UVB through.

UVA creates ozone by splitting oxygen molecules (O_2) into individual atoms, which quickly react with other oxygen molecules to form ozone (O_3). UVB destroys ozone by splitting it up into an oxygen molecule and individual atoms, which pair up to form more oxygen molecules (Figure 4).

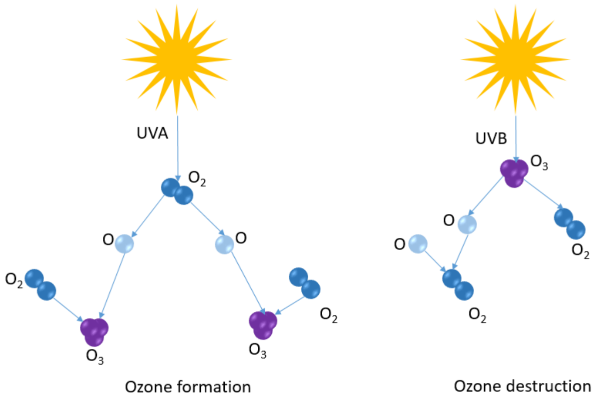


Figure 4: Natural creation and destruction of ozone
(Source: Suhyb Salama, University of Twente)

These two processes would usually balance out, but other chemicals, such as those emitted during the burning of fossil fuels, can affect how quickly ozone is created and destroyed. This leads to a reduction in the amount of ozone high in the atmosphere and leaves a higher concentration of ozone nearer the surface (Figure 5). Ground-level ozone can cause breathing difficulties and even lung damage, particularly for people who already have conditions such as asthma.

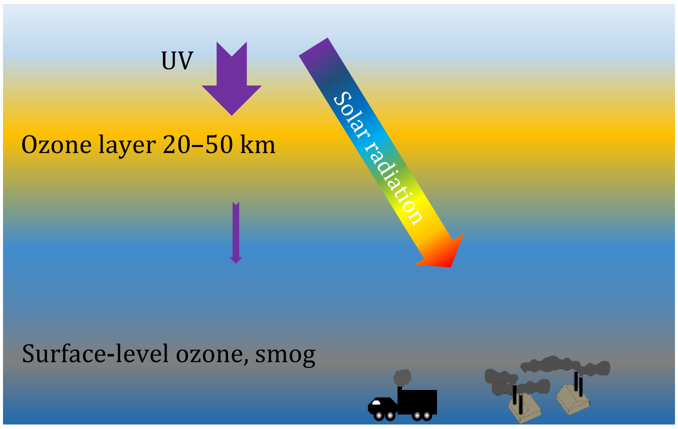


Figure 5: 'Good' and 'bad' ozone
(Source: Suhyb Salama, University of Twente)

It is important to remember that 'good' ozone in the upper atmosphere and 'bad' ozone lower down are both the same substance.

Ozone measurements

We can put instruments to measure ozone at ground level (e.g. in weather stations), in the air (on planes or balloons) or on satellites. Satellites allow us to measure ozone over the entire globe every day by using UV-sensitive cameras: the dimmer the UV, the more ozone in the atmosphere.

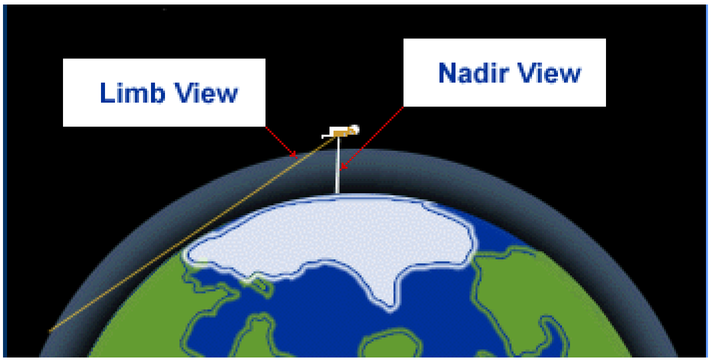


Figure 6: Nadir view versus limb view (Source: ESA)

If the camera looks straight down (nadir view in Figure 6) it measures the total amount of ozone in the atmosphere. This is shown in the Climate from Space web application as 'total ozone'. Looking sideways through the atmosphere (limb view in Figure 6) gives information about ozone concentration at different heights – an ozone profile – that we can use to compare 'good' and 'bad' ozone.

The ozone available in the atmosphere is measured in Dobson units. 100 Dobson units is a concentration equivalent to a one-millimetre-thick layer of ozone at the surface of the Earth (at standard temperature and pressure). The unit is named after Gordon Dobson, a researcher from the University of Oxford, who built the first instrument to measure ozone concentration from the ground.

The ozone hole

In 1979, engineers received the first data from a new instrument on an American satellite. The sensor recorded ozone levels over Antarctica so low that they were discounted as instrument errors. Not long afterward, a team of British scientists at an Antarctic research station published ground-based results that showed similar ozone levels. The low values recorded by satellites were not wrong after all.

The 'hole' in the ozone layer quickly gained the attention of the media and policy-makers while scientists tried to identify what was causing it. They identified a group of gases called chlorofluorocarbons (CFCs), which were, at that time, widely used in aerosols, fire extinguishers, fridges and air conditioners. Although mostly harmless at ground level, CFC molecules high in the atmosphere release chlorine atoms, when hit by solar radiation, and a single atom of chlorine can split many ozone molecules. Ozone concentrations were falling worldwide and, thanks to the movement of air around the planet, particularly over Antarctica.

In 1987, severe limits on CFC emissions were agreed at an intergovernmental conference in Montreal. The gases have largely been replaced by safer alternatives since then and the ozone layer is recovering. But it is a slow process: CFCs stay in the atmosphere for a very long time so ozone concentration is not expected to return to 1980 levels until 2030–2060. The Montreal Protocol is a successful example of how satellite-based climate data can deliver information upon which world leaders can base an international agreement to protect the global environment.

Activity 1: WHY DOES OZONE MATTER?

The story in this activity introduces ozone as an invisible gas that protects life on Earth if it is high in the sky but harms people's health once it is close to the surface. Confident readers may be able to read the story themselves, perhaps in preparation for the lesson. In the classroom, you can use material from the related Climate from Space story to supplement the text.

Equipment

- Information sheet 1
- Student worksheet 1
- Climate from Space online resource: *Is Ozone Good or Bad?* story (optional)

Exercise

1. Discuss with students how they behave in different ways in different places – the classroom and the playground, for example. Explain that they are going to listen to or read a story about a gas that does the same. They should be listening/looking out for information about what it does where.
2. Read the story on Information sheet 1 to or with the class, pausing to check understanding at appropriate places.
   You could illustrate the text with material from the Climate from Space story of the same title as follows:
   - The second gallery picture on slide 2 shows the sun as we see it and how it would appear if we could see ultraviolet light.
   - The animation on slide 3 shows ozone measurements. Note that the 'hole' shows as an irregular dark blue or purple area (low concentration). The sharp-edged circles with the sea in grey and the continent of Antarctica in white are times and places for which we have no data (see next bullet point).
   - The section of the video on slide 4 from 0:18 to 0:33 shows how a satellite collects information for the whole Earth over several days and why there is a data gap at the poles.
   - The next section of this video (up to about 1:20) shows how ozone moves around the planet. This may be helpful if students ask why ozone emissions cause a problem in a place where not many people live and no one needs a fridge.
   - The first gallery picture on slide 2 is a slice through the atmosphere showing ozone in blue. If you are moving quickly to Activity 3 it may be better not to show this as the colour used to show ozone in this picture corresponds to that used in the web application to represent a fairly low concentration.
3. Ask students to complete the table on Student worksheet 1, working individually or in groups. Those who complete this task quickly could do one or more of the following:
   - Carry out the supplementary calculation.
   - Make a list of other facts they remember from the story or/and things they want to ask about.

- Search the text for information about additional comprehension questions such as: What has caused the hole in the ozone layer above Antarctica? What have people been doing to fix it? How do satellites measure ozone in the atmosphere?

4. As a class, check the ideas students have put in the table, discussing any extra, missing or misplaced points. You could end the session by getting students to vote on whether they think ozone is more good than bad or more bad than good, and asking some to articulate their reasoning.

Worksheet answers

Is ozone good or bad?

	Ozone **high in the atmosphere**	Ozone **at the Earth's surface**
How they are **different**	Good Created naturally Protects us from UV radiation	Bad Created by pollution Causes lung problems
How they are **the same**	Same gas Can be measured by satellites	

Measuring ozone

300 Dobson units is equivalent to a 3 mm layer of ozone at the surface of the Earth.

Activity 2: HOW GOOD IS MY SUNSCREEN?

An experiment using UV-sensitive beads to examine the protection sunscreen offers against harmful ultraviolet radiation.

Equipment

- UV-sensitive beads, preferably purple or dark pink as these give a clearer range of shades – 5 or 6 for each group (different groups can have different colours, but all the beads used by any one group should be the same colour)
- Petri dish or another flat open container – one per group
- UV torch – one per group (optional)*
- Coloured pencils (same colour as beads) – one for each student
- A selection of sunscreens with different protection factors (for example SPF 20, 30 and 50) or/and water resistance – each group will need a small amount of one type in a small container (e.g. gallipot)
- Beakers of water – one per group
- Sharpie or another fine permanent marker – see preparation, below
- String and sticky labels (optional) – see preparation, below
- Towels for wet hands and to deal with any spills
- A copy of Student worksheet 2 (2 pages) for each student, perhaps with extra copies in case of spills

*UV (blacklight) torches allow you to carry out the experiment indoors or when the weather is poor, and control the amount of light to which the beads are exposed. They are generally too low-powered to damage eyesight and are, therefore, safe to use – but do check the manufacturer's leaflet and give the safety instruction below. As well as adding to the cost of the experiment, they make the situation one step further removed from real life so it is better to use natural light whenever possible.

Preparation

Each group will need a way of identifying individual beads. You can mark numbered segments on the dishes to be used, or thread each bead onto a piece of string and use sticky labels for the numbers, as shown in Figure 7 in the sample results section below. The latter method may make it easier for students to handle the beads.

Health and safety

If working outdoors, ensure that the students are protected against the sun with caps and sunscreen.

Instruct students not to put anything – including their fingers! – in their mouths.

Students should not look directly at the sun or shine UV torches at each other.

Check beforehand if parents are aware of allergies their child may have to any particular brand or sunscreen ingredient and choose/allocate samples accordingly.

Ensure there is material available to deal with spills.

Exercise

1. Distribute the UV beads and get students to take them outside to see what happens. (A sunny windowsill is sometimes sufficient.) How long does it take for the beads to develop a strong colour today?
2. Explain that UV light from the sun makes the beads change colour, just as it can cause our skin to darken or burn (but much faster!). We can use the colours to make a scale to measure how much UV light reaches a certain place. Ask students to do this by following the instructions for making a colour scale at the start of Student worksheet 2.1.
3. Outline the experiment: we are going to use these beads to compare different types of sunscreen. How well do they last? Which type gives the most protection?
4. Distribute the pots of sunscreen and beakers of water. Depending on the age and ability of the students, you may want to take them through the instructions or leave them to use the information at the bottom of Student worksheet 2.1. The blank line is for the use of students who come up with a set-up of their own. (In the sample results shown in Figure 7, bead 6 was covered in sunscreen, swooshed in the water and then wiped off – equivalent to using a towel after a swim.)
5. While students leave their set of beads in the sun, discuss how the experiment models real-life situations. Ask them to complete the exercise at the bottom of Student worksheet 2.1, drawing arrows to match each set-up with a corresponding description. If there is time, you could also discuss the concept of a control.
6. When the beads have been in the sun for enough time – long enough for bead 1 to get as dark as possible is good – ask students to assess the colour of each bead and record it in the results table on Student worksheet 2.2. They should then use the guidance on the worksheet to write a conclusion.
   You may wish to initiate a discussion on what does it mean to say a sunscreen works well.
7. Combine groups, or gather results from the class as a whole, so students can compare their results with those obtained by other groups using a different sunscreen. Ask why it is important to compare beads that have been treated the same way when completing the second table.You may wish to get students to produce an appropriate graph of their results or/and the combined results showing SPF against a colour-scale number.
8. The final section of Student worksheet 2.2 includes questions that can form the basis of a class discussion. You could assess learning by asking students to produce a sun safety leaflet that uses the results of their investigation to help people choose the right sunscreen and explain how to use it well.

Sample results

Making a colour scale

There is an example of a completed colour scale on Student worksheet 2.1.

Setting up your experiment

Bead	What to do with it
1	Nothing (this is the **control**)
2	Cover it in sunscreen
3	Cover it in sunscreen, dip it in the water for 1 second
4	Cover it in sunscreen, dip it in the water for 5 seconds
5	Cover it in sunscreen, swoosh it about in the water for 5 seconds
6	

This bead is like …
me when I've been sitting outside for a little while (the sunscreen has worn off a bit)
me without sunscreen
me after a swim
me when I've been running around in the sun (getting quite sweaty!)
me with sunscreen on

Results

The results below were obtained using purple UV beads exposed to light from a UV torch for about 30 s. (The beads may take several minutes to develop similar colours in weak sunlight.) The sunscreen used was SPF 15 and nominally waterproof. Bead 6 was covered in sunscreen, swooshed in the water, then wiped off – equivalent to using a towel after a swim.

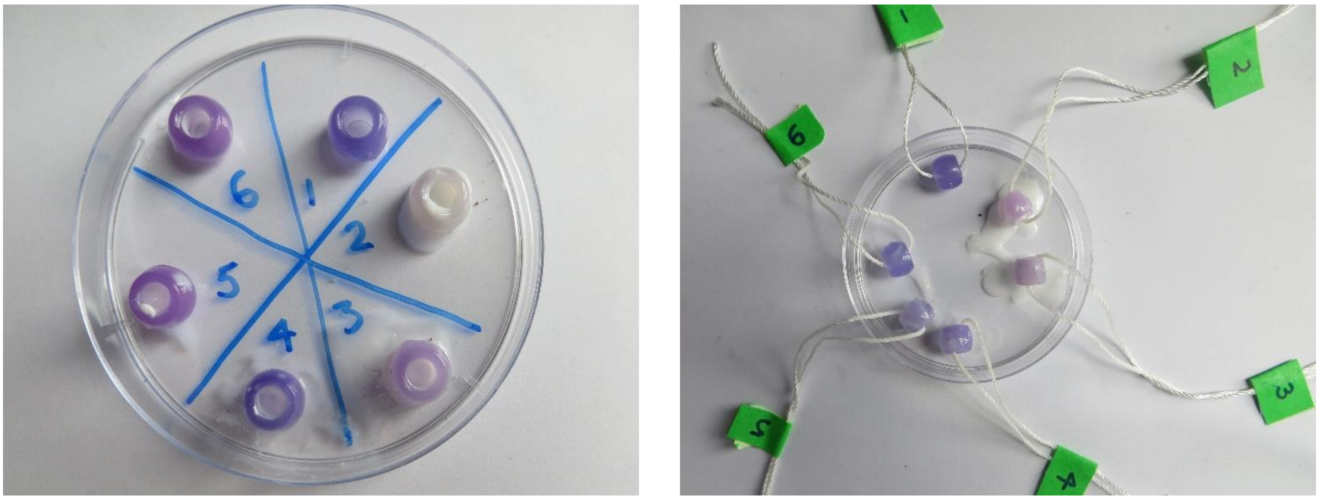


Figure 7: Two different methods for labeling UV sensitive beads (Source: ESA CCI)

Bead	What we did with it	Colour-scale number
1	Nothing (this is the **control**)	10
2	Covered it in sunscreen	2
3	Covered it in sunscreen, dipped it in the water for 1 second	4
4	Covered it in sunscreen, dipped it in the water for 5 seconds	5
5	Covered it in sunscreen, swooshed it about in the water for 5 seconds	6
6	Cover it in sunscreen, swooshed it about in the water for 5 seconds and wiped off	8

Conclusion

The answers to these questions will depend on students' criteria for 'working well'. A reasonable measure would be if beads 4 and 5 have a relatively low number, as this indicates that the sunscreen probably offers protection after some time and a 'swim'.

In discussing these conclusions, it is worth bringing out the need to reapply sunscreen regularly and that this is even more important if you've been active or swimming.

Students may want to carry out an additional experiment to test how long the protection lasts – re-exposing the beads and recording the colour at intervals of, say, an hour without applying any more sunscreen. When discussing the results of such an investigation, remember that the beads are not as porous as skin.

Comparing SPFs

The results shown are comparing bead 4 for three different lotions. They give some evidence that a higher SPF offers more protection, but there appears to be no difference between SPF 30 and SPF 50.

SPF	Colour-scale number
15	5
30	4
50	4

Of course, if only three types of sunscreen are used, it is likely that each has been tested by several groups. Averaging the results obtained by all groups using SPF 15, all groups using SPF 30 and all groups using SPF 50 is likely to eliminate an issue like this.

Nonetheless, discussing potential reasons for it (different amounts of sunscreen applied by different groups, different ways of measuring 5 seconds, variation in colour scale between groups, or different beads) can lead to a fruitful evaluation of the method used, and may lead to suggestions for improving the experiment in the future.

Activity 3: THE OZONE HOLE

In this activity, students use the Climate from Space web application to explore satellite measurements of ozone across the globe over time and examine changes in the Antarctic ozone hole over the past two decades.

Equipment

- Internet access
- Climate from Space web application
- Student worksheet 3
- Information sheet 3 in colour (can be one per pair of students)
- Presentation software such as PowerPoint

Exercise

1. Review the role of ozone in the atmosphere. You could do this through questioning students about learning from previous activities.
   You may wish to show the ESA video, *Monitoring Ozone* (2:38 – see Links), although this has no narration and the detail of the captions may make it inappropriate for younger or less able groups.
2. Ask students to open the Climate from Space web application and navigate to the ozone data layer. Discuss what the colours in the visualisation mean: blue means less ozone; orange means more ozone (see Figure 8). Note that this colour scale is slightly different to the one used in the images on Information sheet 3.
   You may also wish to introduce the Dobson unit if students did not come across it in Activity 1.
3. Give students some time to explore the ozone data. The Climate from Space web application is fairly self-explanatory but you may wish to display the data layer they need or/and demonstrate the controls.
4. Ask students to answer the questions on Student worksheet 3 using information from the web application or/and Information sheet 3. They may also need to refer to an online map or atlas to be able to identify/name the places with high and low ozone concentrations.
5. Allocate each student or pair of students one of the questions from the end of Student worksheet 3.1 to research online. Alternatively, you could allow students to choose one of these or a similar question of their own. They could carry out the research in class or as a homework activity.
6. Challenge students to present their findings to the rest of the class using a single slide or/and a limited amount of text – say one hundred words.

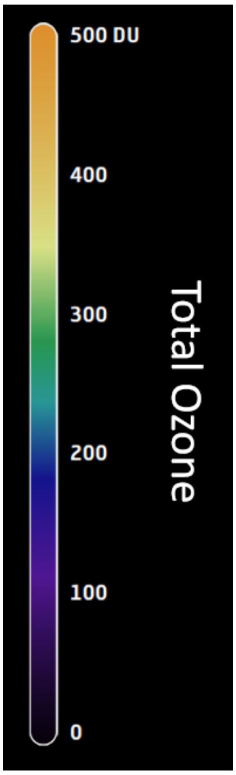


Figure 8: Total ozone colour scale (Source: ESA CCI)

Worksheet answers

Ozone levels around the world

There are many possible answers but some examples are given below.

High ozone concentrations: April 1998, Europe, > 400DU; March 2001, Japan, > 400 DU; March 2007, Alaska, > 400 DU

Low ozone concentrations: October 1997, Antarctica, < 100 DU; December 2001, Pacific Ocean, 100 DU; November 2011, Antarctica, 100 DU

Ozone in Antarctica

The Antarctic ozone hole was largest at the end of 1990s and start of the 2000s.

The observations show ongoing recovery from around 2010.

Find out more

Students may take the given questions in a variety of directions or develop their own questions to research. The notes below include some key points and a place where students who are stuck with one of the suggested questions could start.

- **Is there an ozone hole over the North Pole?**
  A hole in the ozone layer over the North Pole is not very common. However, satellite data showed an unusual reduction in ozone levels above the Arctic in March 2020 following a winter where cold air was trapped in a 'polar vortex'. See, for example: esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-5P/Unusual_ozone_hole_opens_over_the_Arctic
- **What are CFCs?**
  CFCs are chlorofluorocarbons: a group of non-toxic, non-flammable chemicals containing atoms of carbon, chlorine and fluorine. They are used in the manufacture of aerosol sprays, blowing agents for foams and packing materials, as solvents and as refrigerants. See, for example: esrl.noaa.gov/gmd/hats/publictn/elkins/cfcs.html
- **What is the Montreal Protocol?**
  The Montreal Protocol is an international treaty in which it was agreed to phase out the use of substances (mostly CFCs) responsible for ozone depletion. See, for example: en.wikipedia.org/wiki/Montreal_Protocol
- **Which ESA satellites carry instruments that can measure ozone?**

Satellite	*Instrument*	*Launch date*
ERS-2	GOME	1995
Envisat	MIPAS	2002
Envisat	GOMOS	2002
Envisat	SCIAMACHY	2002
Sentinel-5	TROPOMI	2017

Worksheet 1: WHY DOES OZONE MATTER?

Is ozone good or bad?

Use ideas from the story to fill in the table.

	Ozone **high in the atmosphere**	Ozone **at the Earth's surface**
How they are **different**		
How they are **the same**		

Measuring ozone

Ozone is measured in **Dobson units**. One Dobson unit is the same as a layer of ozone $\frac{1}{100}$ mm thick at the Earth's surface. The average ozone concentration in the atmosphere is 300 Dobson units. If all this ozone was at the surface of the Earth, how thick a layer would it make?

____

____

____

Worksheet 2: HOW GOOD IS MY SUNSCREEN?

What you need

- 6 UV-sensitive beads
- Sunscreen
- A beaker of water
- A colour scale

Health and safety

- Wear your sunhat and sunscreen if you are going outside on a sunny day.
- Do not taste anything. Keep your hands away from your mouth.
- Wash your hands when you have finished with the sunscreen.
- Do not look directly at the sun

Making a colour scale

You need a scale like this one so you can compare the colour of your beads.

no UV light →										lots of UV light
0	1	2	3	4	5	6	7	8	9	10

Colour in this box to show the darkest colour your bead went.

no UV light →										lots of UV light
0	1	2	3	4	5	6	7	8	9	10

Leave this box white to show the colour of the bead when it has been in the dark or inside for a while. Shade the boxes in between from light to dark to make your scale.

Setting up your experiment

Draw arrows from each bead to the box that best describes what it represents. The arrow for bead 3 has been done for you.

Bead	What to do with it
1	Nothing (this is the **control**)
2	Cover it in sunscreen
3	Cover it in sunscreen, dip it in the water for 1 second
4	Cover it in sunscreen, dip it in the water for 5 seconds
5	Cover it in sunscreen, swoosh it about in the water for 5 seconds
6	

This bead is like …
me when I've been sitting outside for a little while (the sunscreen has worn off a bit)
me without sunscreen
me after a swim
me when I've been running around in the sun (getting quite sweaty!)
me with sunscreen on

Results

What sunscreen did you use? SPF _________ Type ____________________________

Bead	What we did with it	Colour-scale number
1	Nothing (this is the **control**)	
2	Covered it in sunscreen	
3	Covered it in sunscreen, dipped it in the water for 1 second	
4	Covered it in sunscreen, dipped it in the water for 5 seconds	
5	Covered it in sunscreen, swooshed it about in water for 5 seconds	
6		

Conclusion

Do you think the sunscreen you tested worked well? ___________________________

Why do you think so? ____

____

Comparing SPFs

Now compare your results with those of the other groups. You need to make sure you use the results for beads that have been treated the same way.

We are comparing results for bead number __________

Write the SPFs and the colour numbers in this table.

What does this table tell you about the SPF on a bottle of sunscreen?

____

Do any of the results surprise you? Why (or why not)?

____

____

____

SPF	Colour-scale number

Worksheet 3: THE OZONE HOLE

Open the Climate from Space web application (cfs.climate.esa.int).

Click on the Data Layers symbol (top right) then pick Ozone from the list.

Play the animation through several times to check you understand how the controls on the screen help you to look more closely at particular places or times.

Ozone levels around the world

The amount of ozone in the atmosphere changes over time and is different in different places.

Step through the animation and move around the globe until you find a place and time where the ozone level was very high.

Date ____

Place ____

Estimated total ozone _______________________ Dobson units

Now look for a place and time where the ozone level was very low.

Date ____

Place ____

Estimated total ozone _______________________ Dobson units

Ozone in Antarctica

In the 1980s, scientists discovered that the atmosphere above Antarctica contained very little ozone. The pictures on Information sheet 3 show the ozone levels here from 1996 to 2012. Use this data or/and the Climate from Space web application to find out when the Antarctic ozone hole:

was the largest ____

began to recover ____

Find out more

Use the Internet to do some research into ozone in the atmosphere.
You could investigate one or more of these questions:

- Is there an ozone hole over the North Pole?
- What are CFCs?
- What is the Montreal Protocol?
- Which ESA satellites carry instruments that can measure ozone?

Be prepared to present your findings to others in the class.

Information sheet 1: IS OZONE GOOD OR BAD?

Ben lives with his parents on a farm in Australia. At four o'clock every morning, his parents get up so they can milk the cows while it is still cool outside. The bus that brings Ben to school does not pick him up until eight o'clock so he gets to sleep in. He does not need his parents or an alarm to wake him up. The bright sun shining into his bedroom does the job. After breakfast, Ben runs outside to wait for the bus.

His mum is in the yard. 'Have you put your sunscreen on?' she shouts.

Annoyed, Ben answers, 'Yes, Mum!'

But he's lying …

When Ben gets home that afternoon, he's crying. 'My face hurts!' he says. He has sunburn.

His mum is sympathetic but she is angry, too. 'Did you put sunscreen on this morning?' she asks firmly.

'No, I didn't,' Ben admits.

His face is still red and sore at dinnertime, so he decides to find out how the sun burnt his skin.

It turns out that there is a type of sunlight that we cannot see with our eyes but which is very strong – strong enough to burn us. It is called ultraviolet light – UV light for short.

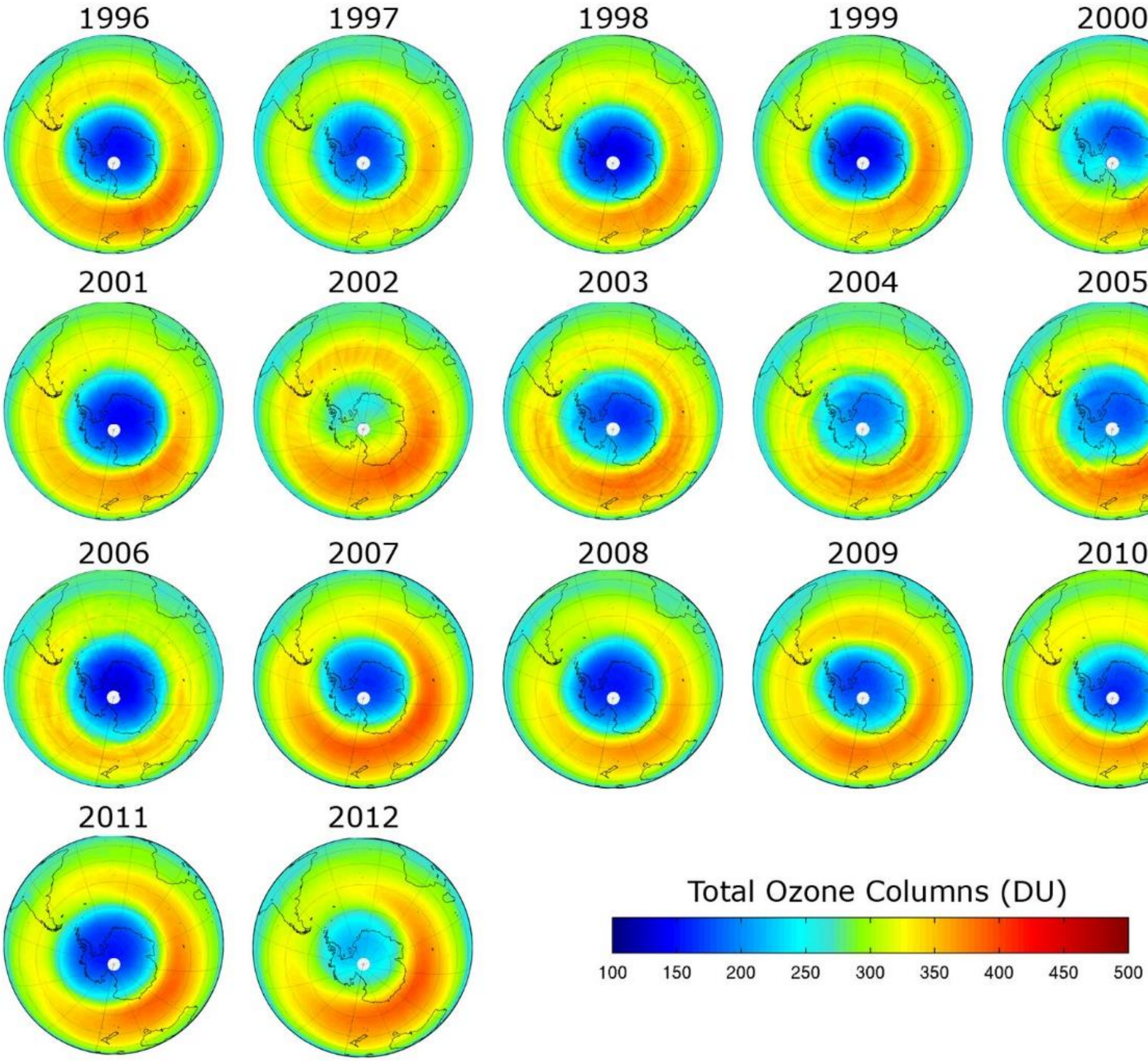
The atmosphere around our planet contains a gas called ozone. A layer of ozone high up in the sky takes in ultraviolet light and changes it to heat, shielding us from the most harmful effects of the ultraviolet light. However, Ben also finds out that air pollution creates ozone lower down in the atmosphere. When ozone is close to the ground, it does not protect us. In fact, it can actually damage our lungs.

A hundred years ago, people started to use gases called CFCs in fridges and spray cans. But then satellites showed there was a hole in the ozone layer over Antarctica, and scientists realised that CFCs destroy ozone. The leaders of every country in the world were shocked by the news and agreed not to use the gases anymore. But CFCs last a long time so, even though the hole has been shrinking since 2000, it will take many more years to close up.

Ben is curious about the satellites. How do they see ozone? He discovers that some satellites have ultraviolet cameras that can measure how much ozone there is in the sky and how high up it is. These cameras can tell the difference between 'good' and 'bad' ozone.

Now Ben now knows about the hole in the ozone layer, he will never forget to put sunscreen on again.

Information sheet 3: THE OZONE HOLE



(Source: BIRA/IASB)

Links

ESA resources

Climate from Space online resource
https://cfs.climate.esa.int

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

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

Monitoring ozone video
http://www.esa.int/ESA_Multimedia/Videos/2017/11/Monitoring_ozone

ESA space projects

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

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

Copernicus Sentinel-5P - TROPOMI
https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-5P/Copernicus_Sentinel-5P_ozone_boosts_daily_forecasts

Extra information

Ozone hole set to close
https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-5P/Ozone_hole_set_to_close

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

Appendix: DID YOU KNOW?

A selection of interesting facts related to the topic that you can use in a variety of ways. You might introduce a lesson with one of them, put on cards to cards to add to displays of student work, pick a point as a discussion starter, use the statements in a true/false quiz …

- There are a number of entirely human-made greenhouse gases in the atmosphere.
- Ground-level ozone is the principal component of smog, which is created from chemical reactions of pollutants with gases in the air.
- In 1920, Gordon Dobson, a researcher from the University of Oxford, was the first to build an instrument to measure ozone concentration from the ground.
- We need some ultraviolet light to stay healthy: our bodies use it to produce vitamin D.
- UVB is more harmful than UVA.
- Sunscreens have a range of sun protection factor (SPFs), but you should make sure to buy one that protects you from UVA and UVB.
- The ozone layer absorbs all the UVC from the Sun that reaches our planet, but welding torches generate it on Earth.
- Many Earth observation satellites are in such orbits that they cannot take measurements directly above the North or South Pole – although they can ‘see’ everywhere else on Earth.