Introduction to Air Quality from Space

Description: A collection of worksheets and resources for teachers and pupils exploring the topic of air quality from space.

Age range: Suitable for 11-13 year olds (Year 7 - 9).

List of worksheets:

1. What is air pollution? ~20 minutes

- This worksheet will help you to discover what air pollution is, which are the major global air pollutants and where they come from.
- 1x worksheet, 1x information sheet,1x answer sheet

2. How do Satellites Monitor Air Quality? ~ 10 minutes

- This worksheet will help you to learn about satellites and how they monitor air quality.
- 1x worksheet, 1x answer sheet

3. Air pollution from space. ~ 30 minutes

- This worksheet will help you to learn how to interpret some satellite data air pollution maps and develop a better understanding of the spatial distribution of the air pollutant tropospheric ozone.
- 1x worksheet, 1x figure sheet, 1x answer sheet

4. Air quality resource list.

- A list of online interactive air quality tools (including air quality from space), what they include and some examples of quick starter questions for them.
- 1x resource list

What is Air Pollution?

AIM: This worksheet will help you to discover what air pollution is, which are the major global air pollutants and where they come from.

1. What is air pollution? *Fill in the gaps.*

Air pollution describes anything in the _____ which causes _____ when breathed in. Air pollution can be both very small particles or different _____ in the air. The sources of air pollution can be either man-made (_____) or _____ . Air pollution in the atmosphere can be measured at the _____ or higher up by using instruments on _____ , _____ and satellites.

surface anthropogenic natural ballons aircraft air gases harm

2. What are the sources of air pollution? *Sort the words into the table.*

Power Plants Agriculture Volcanic Eruptions Cleaning Chemicals Plants Wood Burning Stoves

NATURAL SOURCES	ANTHROPOGENIC SOURCES

Cars & Other Vehicles Forest Fires Desert Dust Fireworks Sea Salt Spray Industrial Processes

3. What are the major air pollutants? *Read the 'Air Pollutants Description' and fill in the table.*

Pollutant	Chemical Symbol or Acronym	Sources/How is it produced?	Health Impact
Nitrogen Dioxide			
Ground Level Ozone			
Carbon Monoxide			
Particulate Matter			
Sulfur Dioxide			
Black Carbon			

Air Pollutants Description

Description of pollutants from the World Health Organisation (WHO)

https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/ambient-air-pollution/pollutants/types-of-pollutants

Particulate Matter

Particulate matter (PM) are inhalable and respirable particles composed of sulphate, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water. Particles with a diameter of less than 10 microns (PM10), including fine particles less than 2.5 microns (PM2.5) pose the greatest risks to health, as they are capable of penetrating peoples' lungs and entering their bloodstream. Sources of PM include combustion engines (both diesel and petrol), solid-fuel (coal, lignite, heavy oil and biomass) combustion for energy production in households and industry, as well as other industrial activities (building, mining, manufacture of cement, ceramic and bricks, and smelting).

Black Carbon

Black carbon is a major component of PM2.5 and driver of climate change, also known as a "short-lived climate pollutant." SLCPs persist in the atmosphere for a shorter period compared to CO2. Despite its short atmospheric lifetime, black carbon is one of the largest contributors to global warming after CO2. It also known to decrease agricultural yields and accelerate glacier melting.

Ground-level Ozone

Ground-level ozone is one of the major components of photochemical smog and a key health risk linked to breathing problems, asthma, reduced lung function and respiratory diseases. It is a secondary pollutant, meaning that it is not directly emitted. Instead, it is produced when carbon monoxide (CO), methane, or other volatile organic compounds (VOCs) are oxidized in the presence of nitrogen oxides (NOx) and sunlight. In addition to their role as ozone precursors, CO, VOCs and NOx are dangerous air pollutants themselves. Major sources of NOx and VOCs include emissions from motor vehicle exhaust, industrial facilities, and chemical solvents. Major sources of methane include waste and the fossil fuel and agricultural industry. Aside from its health impacts, tropospheric ozone is a short-lived climate pollutant and one of the most important greenhouse gases.

Nitrogen dioxide

Nitrogen dioxide, mainly emitted by power generation, industrial and traffic sources, is an important constituent of particulate matter and ozone. There is growing evidence that independently, it can increase symptoms of bronchitis and asthma, as well as lead to respiratory infections and reduced lung function and growth. Evidence also suggests that NO2 may be responsible for a large disease burden, with exposure linked to premature mortality and morbidity from cardiovascular and respiratory diseases.

Sulfur dioxide

Sulfur dioxide (SO2) is primarily produced from the burning of fossil fuels (coal and oil) and the smelting of mineral ores that contain sulphur. Exposure to SO2 affects the respiratory system and the function of the lungs, and causes irritation of the eyes. Inflammation of the respiratory tract from SO2 can aggravate asthma and chronic bronchitis, as well as increases the risk of infection, leading to increased hospital admissions and visits to emergency rooms. SO2 also combines with water in the air to form sulfuric acid - the main component of acid rain.

Carbon monoxide

Carbon monoxide (CO) a colourless and odourless gas, which at high levels can be harmful to humans by impairing the amount of oxygen transported in the bloodstream to critical organs. Although high concentrations of CO are more of a concern indoors, emissions outdoors, particularly in developing countries can be high. New evidence also reveals that long-term exposure to low concentrations is also associated with a wide range of health effects. The main sources of ambient CO include motor vehicle exhaust and machinery that burn fossil fuels.

What is Air Pollution? - Answers

AIM: This worksheet will help you to discover what air pollution is, which are the major global air pollutants and where they come from.

1. What is air pollution? **Fill in the gaps.**

Air pollution describes anything in the **air** which causes **harm** when breathed in. Air pollution can be both very small particles or different **gases** in the air. The sources of air pollution can be either man-made (**anthropogenic**) or **natural**. Air pollution in the atmosphere can be measured at the **surface** or higher up by using instruments on **balloons**, **aircraft** and satellites.

surface natural ballons harm aircraft air gases anthropogenic

2. What are the sources of air pollution? **Sort the words into the table.**

NATURAL SOURCES	ANTHROPOGENIC SOURCES
Desert Dust Plants Forest Fires Sea Salt Spray Volcanic Eruptions	Cars & Other Vehicles Industrial Processes Fireworks Power Plants Cleaning Chemicals Agriculture (Forest Fires) Wood Burning Stoves

3. What are the major air pollutants? ***Read the 'Air Pollutants Description' and fill in the table.***

Pollutant	Chemical Symbol or Acronym	Sources/How is it produced?	Health Impact
Nitrogen Dioxide	NO_2	Power generation, industry, traffic	Bronchitis, asthma, respiratory infections and reduced lunch function.
Ground Level Ozone	O_3	VOCs + NOx in the presence of sunlight.	Asthma, reduced lung function, respiratory diseases.
Carbon Monoxide	CO	Motor vehicle exhausts and machinery that burns fossil fuels.	Reduces how much oxygen can be transported to organs.
Particulate Matter	$PM_{2.5}$ or PM_{10}	Combustion engines, solid-fuels e.g. coal, industry.	Can enter lungs and bloodstream.
Sulfur Dioxide	SO_2	Burning fossil fuels and mineral ore smelting.	Reduces lung function, eye irriation,asthma, chronic bronchitis, respiratory infections.

How do Satellites Monitor Air Quality?

AIM: This worksheet will help you to learn about satellites and how they monitor air quality.

What is a satellite?

Man-made satellites are used in many different areas of our lives and scientific research. A satellite is an object that goes around (orbits) a planet. Satellites can be natural e.g. the moon, or they can be man-made. The first man-made satellite put into space was in 1957 and was very simple. Now, man-made satellites are much more complex and can tell us a lot about different processes on the Earth's surface.

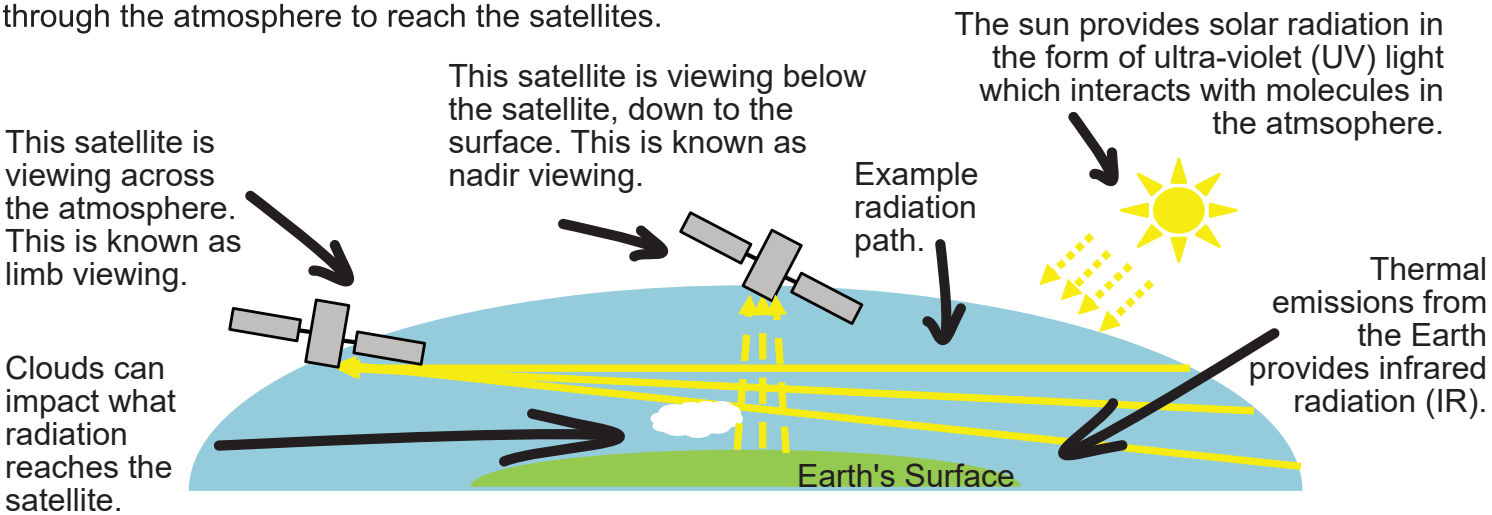
Some satellites have instruments on board which can monitor air quality. The instruments monitor which wavelengths of radiation reach the instrument after passing though the atmosphere. Atmospheric scientists can then use this data to calculate the concentrations of different gases in the atmosphere.

How do satellites move around the Earth?

Satelliets orbit the Earth. An orbit is the curved path that the satellite takes around the Earth due to gravity.

How do satellites monitor air quality?

The diagram below shows how satellites monitor air quality by observing the radiation which passes through the atmosphere to reach the satellites.



Can you define these words?

Limb viewing	
Orbit	
Satellite	
Solar radiation	
Nadir viewing	

How do Satellites Monitor Air Quality? - Answers

AIM: This worksheet will help you to learn about satellites and how they monitor air quality.

What is a satellite?

Man-made satellites are used in many different areas of our lives and scientific research. A satellite is an object that goes around (orbits) a planet. Satellites can be natural e.g. the moon, or they can be man-made. The first man-made satellite put into space was in 1957 and was very simple. Now, man-made satellites are much more complex and can tell us a lot about different processes on the Earth's surface.

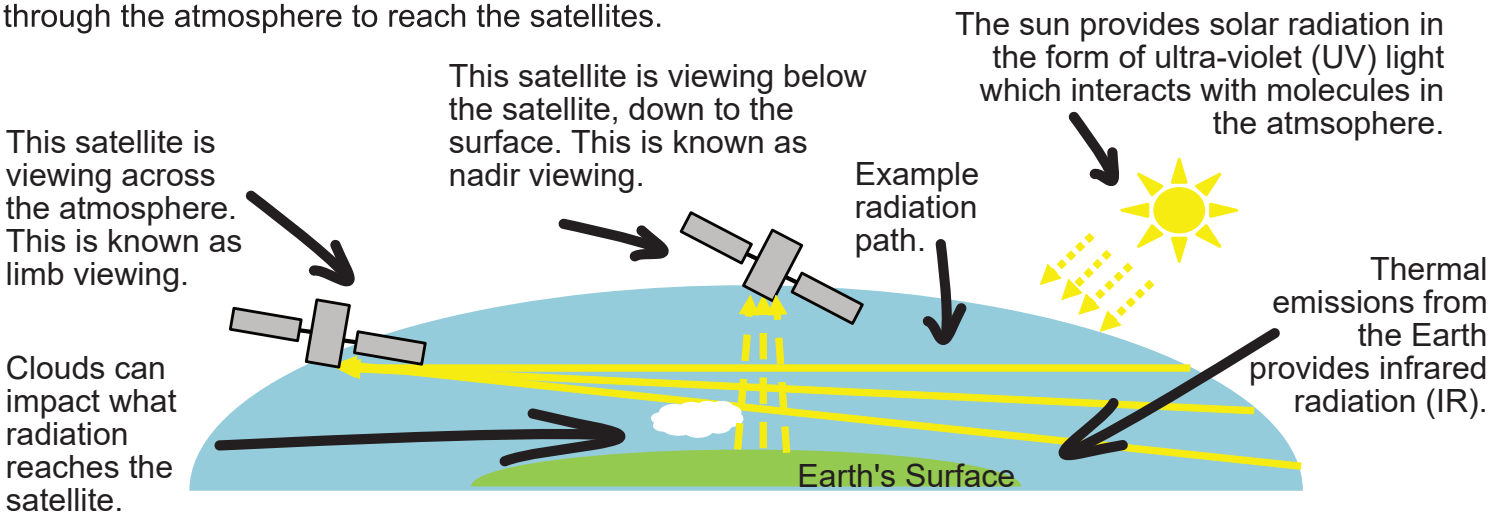
Some satellites have instruments on board which can monitor air quality. The instruments monitor which wavelengths of radiation reach the instrument after passing though the atmosphere. Atmospheric scientists can then use this data to calculate the concentrations of different gases in the atmosphere.

How do satellites move around the Earth?

Satelliets orbit the Earth. An orbit is the curved path that the satellite takes around the Earth due to gravity.

How do satellites monitor air quality?

The diagram below shows how satellites monitor air quality by observing the radiation which passes through the atmosphere to reach the satellites.



Can you define these words?

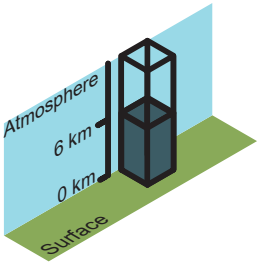
Limb viewing	When the satellite observes radiation across the atmosphere.
Orbit	The curved path a satellite takes around the Earth due to gravity.
Satellite	An object which orbits a planet.
Solar radiation	UV radiation produced by the sun.
Nadir viewing	When the satellite observes radiation directly below the satellite.

Air Pollution from Space

AIM: This worksheet will help you to learn how to interpret some satellite data air pollution maps and develop a better understanding of the spatial distribution of the air pollutant tropospheric ozone. This worksheet requires the air pollution maps on reference sheet 'Air Pollution from Space - Maps'.

Tropospheric Ozone is an air pollutant, however it is not emitted directly from man-made or natural sources. It is produced by the reaction of other gases in the air in the presence of sunlight and so is called a secondary pollutant. The word "tropospheric" indicates that the ozone is in the lowest layer of the atmosphere, the closest layer to the surface, the troposphere.

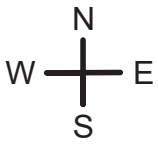
Tropospheric ozone can be monitored by satellites orbitting the Earth. Figures 1 and 2 show examples of tropospheric ozone data from satellites. They show a sub-column of ozone data (diagram right), between the surface and around 6km above the surface.



Sub-column diagram

Use the following sentence starters to interpret figure 1:

Use an online world map or atlas to look up country names to give details to your answers.
Use tropospheric ozone values in dobson units (DU) to give details to your answers.
Remember your compass directions when giving details to your answers.



1. Between 2005 and 2017 average European tropospheric ozone is highest ....

2. Between 2005 and 2017 average European tropospheric ozone is lowest ....

Use the following sentence starters to interpret figure 2:

1. Between 2005 and 2017 average European tropospheric ozone is highest in the season of .....

2. Between 2005 and 2017 average European tropospheric ozone is lowest in the season of .....

3. In the country of ..... average European tropopsheric ozone changes between the seasons by .....

4. EXTENSION : ***Using the introduction paragraph complete the following sentence starter.***

Average European tropopsheric ozone is highest in the season of ..... because .....

Air Pollution from Space - Maps

Figure 1 - Averaged European Ozone 2005-2017 (DU). Atmospheric column data between the surface to around 6km above the surface.

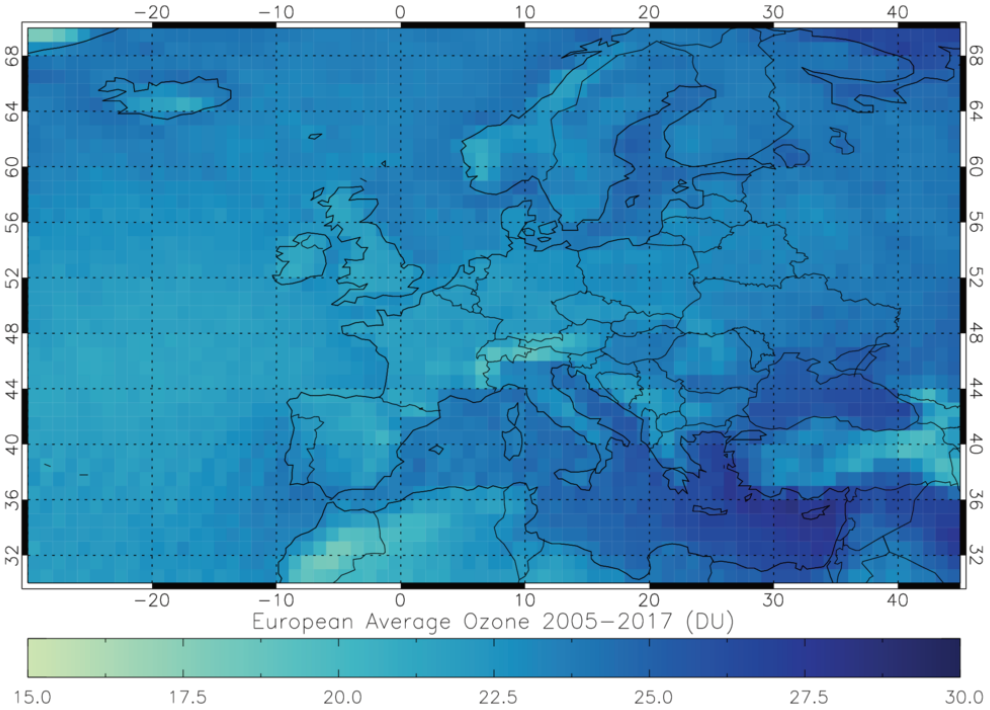
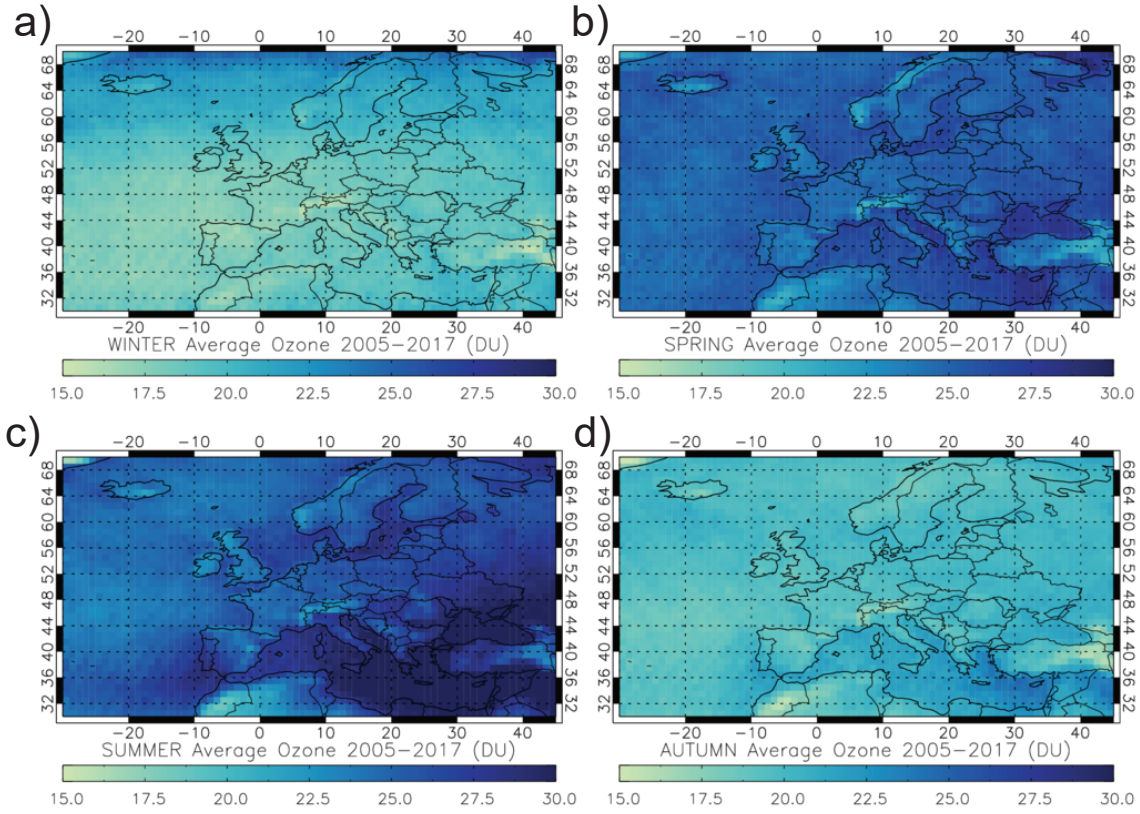


Figure 2 - Seasonal averaged European Ozone 2005-2017 (DU). Atmospheric column data between the surface to around 6km above the surface. a) Winter b) Spring c) Summer d) Autumn



All data is provided by the Remote Sensing Group at RAL Space

National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

RAL Space

UKRI Science and Technology Facilities Council

Air Pollution from Space - Answers

AIM: This worksheet will help you to learn how to interpret some satellite data air pollution maps and develop a better understanding of the spatial distribution of the air pollutant tropospheric ozone. This worksheet requires the air pollution maps on reference sheet 'Air Pollution from Space - Maps'.

Use the following sentence starters to interpret figure 1:

Use an online world map or atlas to look up country names to give details to your answers.
Use tropospheric ozone values in dobson units (DU) to give details to your answers.
Remember your compass directions when giving details to your answers.

1. Between 2005 and 2017 average European tropospheric ozone is highest .... across southern Europe, especially over the easter mediterranean. The values peak around 27 DU in the east/south-east Mediterranean. There are also some higher values around the Northern Altantic e.g. around Iceland.

2. Between 2005 and 2017 average European tropospheric ozone is lowest .... in the mountainous regions e.g. in the alps (switzerland and surrounding area), Turkey and Northern Africa. The lowest values here are around 15 DU. The average ozone across the European mainland is around 20-22 DU.

Use the following sentence starters to interpret figure 2:

1. Between 2005 and 2017 average European tropospheric ozone is highest in the season of ..... summer.

2. Between 2005 and 2017 average European tropospheric ozone is lowest in the season of ..... winter/autumn.

3. In the country of ..... average European tropopsheric ozone changes between the seasons by .....

eg. UK - Lowest values in winter, average around 17-20 DU. Increases in spring, to around 22-25 DU, similar in summer. Decreases into winter, average around 20 DU. And then back to the lowest values in winter again.

4. EXTENSION : ***Using the introduction paragraph complete the following sentence starter.***

Average European tropopsheric ozone is highest in the season of ..... because .....

Summer - because ozone is production is related to sunlight and there is more solar radiation in the summer.

Air Quality Resource List

SUMMARY: A list of online interactive air quality tools (including air quality from space), what they include and some examples of quick starter questions for them.

Satellite Monitoring

European Space Agency (ESA)

- Maps with data from the tropospheric Monitoring Instrument (TROPOMI).
- **https://maps.s5p-pal.com/**
- Global Nitrogen Oxide and Carbon Monoxide Maps from May 2018 onwards.

NASA

- Maps and trends with data from the Ozone Monitoring Instrument (OMI)
- Nitrogen Dioxide Trends for US Cities - **https://airquality.gsfc.nasa.gov/no2**
- Nitrogen Dioxide Trend Video for the US - **https://airquality.gsfc.nasa.gov/no2/usa**
- Nitrogen Dioxide Trends for Major World Cities - **https://airquality.gsfc.nasa.gov/no2/world**

Surface Monitoring

DEFRA UK AIR

- Interactive Monitoring Network Map for the UK
- Includes the Automated Urban and Rural Network (AURN) sites.
- **https://uk-air.defra.gov.uk/interactive-map**
- UK Ambient Air Quality (AQ) Map based on air quality models and observations.
- **https://uk-air.defra.gov.uk/data/gis-mapping/**

World Air Quality Index Project – Real-time Air Quality Index

- Interactive air quality monitoring map with data from from over 10,000 stations worldwide.
- **https://waqi.info/**

London Air

- Visualisation of London monitoring sites, comparing mean and peak values.
- **https://www.londonair.org.uk/LondonAir/Data-Visualisations/meanVSpeak.aspx**

Forecasting

DEFRA UK AIR

- Air Pollution Forecast Map for the UK for the next 5 days.
- **https://uk-air.defra.gov.uk/forecasting/**

NASA

- Forecast maps for different pollutants in different global regions from the Global Modeling and Assimilation Office (GMAO).
- **https://fluid.nccs.nasa.gov/cf/classic_geos_cf/**

Quick Starter Qs

- **Where are pollution hot spots around the world?**
- **What is the pollution like in your local area, which pollutants are the biggest problem?**
- **What is the pollution forecast in your local area for tomorrow?**
- **Select a city anywhere in the world, what is the pollution like there today, what was it like 2 years ago?**