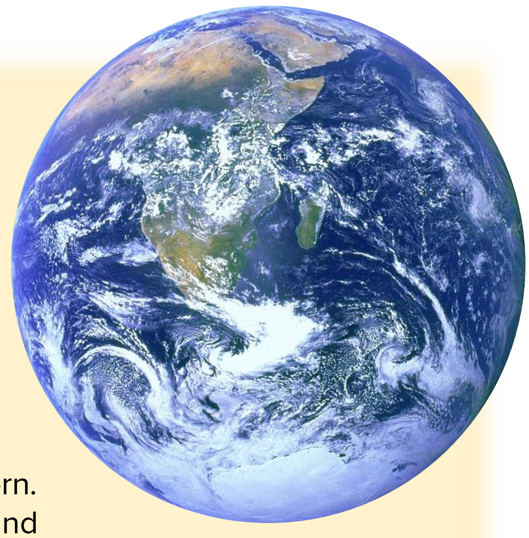
MODULE 2

What's the Air Forecast?

Human Impacts, Weather, and the Story of a Code Red Day

Module Overview



This photograph of Earth, commonly known as "The Blue Marble," was taken by the crew of the Apollo 17 spacecraft. When humans first began taking pictures of Earth from space in the 1960s, air and water pollution had already become huge problems in the United States. Photographs like this one, as well as books like Silent Spring by Rachel Carson, inspired people to take action to save the planet. In 1970 the first Earth Day was held and the Clean Air Act was signed. The modern environmental movement was born. Since then, humans have done a lot to both damage and protect the Earth and its air. In this module, students will investigate a "bad air day" to understand the sources and types of man-made air pollution, focusing on ozone, a common contributor to bad air days in the region. They will also learn about weather, and the complex ways in which weather and air pollution interact. In doing so, they will use the same sophisticated computer models that meteorologists use to predict both the weather and air pollution. Students will also take a historical look at how air quality has changed over time, using both the Air Quality Index (AQI) and EPA data as guides. As a culminating activity, students will use what they have learned to create an air quality report to inform the public about whether their air is safe to breathe.

Anchor phenomenon: A hazy day that occurred in Washington D.C. in July, 2018.

Pacing

- 9 activities + summative assessment project
- Approximately 11-13 45-60 minute class periods + assessment project

Module Contents

When to Teach This Module

Finding the right place within a science scope and sequence to investigate air pollution with students can be tricky. Below you will find some information about the module that can help you decide where this it might fit into your own plans for student leaning:

- **Connection to Weather:** This module includes a significant connection to weather concepts, but it *does not* go into detail about those concepts. As such, the module would be a great addition to a weather module – either during or after – to incorporate human impacts on Earth's atmosphere. Activity 8 is designed to be a refresher on weather topics and vocabulary, so even if students have studied weather in a previous year, they should be able to engage with the topics of this module.

- **Connection to Natural Resource Usage:** Air pollution is very much a story about human population and the consequences of how we use natural resources. While the module itself does not go into detail about kinds of natural resources, it would fit well as a part of a larger investigation of fossil fuels, and how our usage of those fuels affects the environment. The module is a great way to incorporate human impacts on the environment into a unit on these resources.

Standards Overview

Middle School NGSS standards alignment

Performance Expectations

Focus PE:

MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems. [Clarification Statement: Examples of evidence include grade-appropriate databases on human populations and the rates of consumption of food and natural resources (such as freshwater, mineral, and energy). <u>Examples of impacts can include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change</u>. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions for the actions society takes.]

Background PE:

MS-ESS3-3. Apply scientific principles to design a method for monitoring ~~and minimizing~~ a human impact on the environment.* [Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land).]

Science & Engineering Practices

Focus SEP: Developing and Using Models
Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.

- ~~Develop or~~ **modify a model—based on evidence – to match what happens if a variable or component of a system is changed.**
- **Use** ~~and/or develop~~ **a model of simple systems with uncertain and less predictable factors**.
- ~~Develop and/or~~ **use a model to predict and/or describe phenomena**.

Background SEP: Obtaining, evaluating, and communicating information
Obtaining, evaluating, and communicating information in 6–8 builds on K–5 experiences and progresses to evaluating the merit and validity of ideas and methods.

- Integrate qualitative and/or quantitative scientific and/or technical information in written text with that contained in media and visual displays to clarify claims and findings.
- Communicate scientific and/or technical information (e.g. about a proposed object, tool, process, system) in writing and/or through oral presentations.

Disciplinary Core Ideas

Focus DCI: ESS 3.C: Human Impacts on Earth Systems
Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

Background DCI: ESS 2.D: Weather and Climate
Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. ~~These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns~~.

Crosscutting Concepts

Focus CCC: Patterns – Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.

- Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems.
- Graphs, charts, and images can be used to identify patterns in data.

Background CCC: Systems and System Models – A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.

NGSS 5th Grade Standards alignment

Performance Expectations:

Focus PE:

5-ESS3-1. Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.

Science & Engineering Practices

Focus SEP: Developing and Using Models
Modeling in 3–5 builds on K–2 experiences and progresses to building and revising simple models and using models to represent events and design solutions.

- Develop and/or use models to describe and/or predict phenomena.

Background SEP: Obtaining, evaluating, and communicating information
Obtaining, evaluating, and communicating information in 3–5 builds on K–2 experiences and progresses to evaluating the merit and accuracy of ideas and methods.

- Read and comprehend grade-appropriate complex texts and/or other reliable media to summarize and obtain scientific and technical ideas and describe how they are supported by evidence.
- Compare and/or combine across complex texts and/or other reliable media to support the engagement in other scientific and/or engineering practices.
- Combine information in written text with that contained in corresponding tables, diagrams, and/or charts to support the engagement in other scientific and/or engineering practices.
- Obtain and combine information from books and/or other reliable media to explain phenomena or solutions to a design problem.
- Communicate scientific and/or technical information orally and/or in written formats, including various forms of media as well as tables, diagrams, and charts

Disciplinary Core Ideas

Focus DCI: ESS3.C: Human Impacts on Earth Systems
Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments. (5-ESS3-1)

ESS 2.A: Earth Materials and Systems
Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather.

Focus CCC: Patterns – Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.

- Similarities and differences in patterns can be used to sort, classify, communicate and analyze simple rates of change for natural phenomena and designed products.
- Patterns of change can be used to make predictions.
- Patterns can be used as evidence to support an explanation.

Background CCC: Systems and System Models – A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

- A system can be described in terms of its components and their interactions.

Virginia Standards of Learning (SOLs) alignment

Science & Engineering Practices	
5.1 (e)	Developing and using models. The student will… • develop models using an analogy, example, or abstract representation to describe a scientific principle or design solution • identify limitations of models
6.1 (e)	Developing and using models. The student will… • use, develop, and revise models to predict and explain phenomena • evaluate limitations of models
Content Standards	
6th Grade 6.9	6.9 The student will investigate and understand that humans impact the environment and individuals can influence public policy decisions related to energy and the environment. Key ideas include c) major health and safety issues are associated with air and water quality
6th Grade 6.7	6.7 The student will investigate and understand that air has properties and that Earth's atmosphere has structure and is dynamic. Key ideas include a) air is a mixture of gaseous elements and compounds; b) the atmosphere has physical characteristics; e) atmospheric measures are used to predict weather conditions; and f) weather maps give basic information about fronts, systems, and weather measurements.
Earth Science ES.11	ES.11 The student will investigate and understand that the atmosphere is a complex, dynamic system and is subject to long-and short-term variations. Key ideas include b) biologic and geologic interactions over long and short time spans change the atmospheric composition; c) natural events and human actions may stress atmospheric regulation mechanisms; and d) human actions, including economic and policy decisions, affect the atmosphere.
Earth Science ES.12	ES.12 The student will investigate and understand that Earth's weather and climate are the result of the interaction of the sun's energy with the atmosphere, oceans, and the land. Key ideas include b) weather patterns can be predicted based on changes in current conditions; d) models based on current conditions are used to predict weather phenomena

Common Core State Standards alignment

Literacy Standards	
RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
RST.6-8.4	Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.
RST.6-8.7	Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).
SL.8.1	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly.
Math Standards	
6.RP.A.1	Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities.
6.RP.A.3	Use ratio and rate reasoning to solve real-world and mathematical problems, e.g., by reasoning about tables of equivalent ratios, tape diagrams, double number line diagrams, or equations.
7.RP.A.3	Use proportional relationships to solve multistep ratio and percent problems. Examples: simple interest, tax, markups and markdowns, gratuities and commissions, fees, percent increase and decrease, percent error.

5E Module Flow

Activity 1 (Engage): What's That in the Sky?
Timing: 30-45 minutes
Purpose: Introducing the anchor phenomenon
- ✓ Students will make observations and hypotheses, and ask questions to better understand the anchor phenomenon

Activity 2 (Explain): What is Weather?
Timing: 1-2 class periods
Purpose: Building background knowledge of weather terminology to determine if the phenomenon could be natural
- ✓ Students will understand the primary characteristics used to describe weather
- ✓ Students will use weather data to determine if the phenomenon is natural or man-made

Activity 3 (Explore): Pollution, Power Plants, and People
Timing: 60 minutes
Purpose: Determining whether the phenomenon may be man-made by looking at how humans impact the environment.
- ✓ Students will use maps to identify connections among air quality, population, and electricity production

Activity 4 (Explain): The Criteria Air Pollutants
Timing: 45-60 minutes
Purpose: Building understanding of different kinds of air pollution and their sources, including the 6 criteria pollutants, in order to identify the pollutant causing the phenomenon
- ✓ Students will define air pollution
- ✓ Students will know there are different kinds of air pollution, and some are more important for us to consider
- ✓ Students will identify the pollutant that caused the Code Red Day in DC

Activity 5 (Explain): O_3, Oh My! Getting to Know Ozone
Timing: 30 minutes
Purpose: Understanding ozone and its role in air quality
- ✓ Students will understand what ozone is from both a general and chemical perspective
- ✓ Students will understand the different between beneficial (stratospheric) and harmful (tropospheric) ozone

Activity 6 (Explore): Air Quality in the DC/Baltimore Region
Timing: 2 class periods
Purpose: Understanding the Air Quality Index (AQI) and using it to explore air pollution and air quality issues at the local level

- ✓ Students will learn to interpret the Air Quality Index (AQI)
- ✓ Students will research current and historical AQI data from the DC/ Baltimore area
- ✓ Students will identify the major air pollutants in the DC/Baltimore area and analyze data to show how they have changed over time

Activity 7 (Explore): Air Pollution Trends and the Clean Air Act
Timing: 1-2 class periods
Purpose: Understanding how humans can have a positive impact on air quality by investigating how air quality has changed since the Clean Air Act

- ✓ Students will interpret graphs to determine how air quality in the US has changed over time
- ✓ Students will use the Clean Air Act to discuss whether humans have a positive or negative impact on the planet

Activity 8 (Elaborate): Smog City: How Weather Affects Air Quality
Timing: 45 minutes
Purpose: Determining how air quality and weather interact, along with how humans affect air quality

- ✓ Students will understand how different weather conditions affect AQI
- ✓ Students will understand how emissions from various sources and population affect AQI

Activity 9 (Elaborate): Making an Air Quality Prediction
Timing: 45-60 minutes
Purpose: Appplying knowledge about air quality and weather to a real world situation

- ✓ Students will be able to make an AQI prediction using data from a variety of information sources including weather conditions

Activity 10 (Evaluate): Creating an Air Quality Report
Timing: variable, minimum two class periods
Purpose: Showing student understanding of module objectives

- ✓ Students will create an air quality report based on an AQI forecast and weather conditions

Module Materials

Activity 1 (Engage): What's That in the Sky?

- ❒ Handouts: I See, I Think I Wonder, Investigation Tracker
- ❒ Materials needed: Computer & projector
- ❒ Optional materials: Air Quality Champion Interview

Activity 2 (Explain): What is Weather?

- ❒ Handouts: Visual vocabulary sheets
- ❒ Materials needed: Computer & projector, Resources for students to research weather terms (student computers with internet access, textbooks, library books, etc.)
- ❒ Optional materials: Chart paper & markers, I Have, Who Has game cards

Activity 3 (Explore): Pollution, Power Plants, and People

- ❒ Handouts: Human Activities and the Earth
- ❒ Materials needed: Computer & projector
- ❒ Optional materials: Student computers, chart paper

Activity 4 (Explain): The Criteria Air Pollutants

- ❒ Handouts: The Criteria Air Pollutants (foldable or regular), Reading: *The Region's Air Quality Reached Unhealthy Code Red Levels on Monday*
- ❒ Materials needed: Computer & projector, air pollution information stations, sources of air pollution signs
- ❒ Optional materials: scissors

Activity 5 (Explain): O_3, Oh My! Getting to Know Ozone

- ❒ Materials provided: Ozone: Good Up High, Bad Nearby (graphic organizer)
- ❒ Materials needed: Computer & projector, speakers
- ❒ Optional materials: Student computers

Activity 6 (Explore): Air Quality in the DC/Baltimore Region

- ❒ Handouts: Air Quality Index reading, Historical AQI Data Investigation, AQI Through the Years
- ❒ Materials needed: Computer & projector, "The Air Quality Today in <blank> is" posters
- ❒ Optional materials: Student computers (highly recommended), graph paper

Activity 7 (Explore): Air Pollution Trends and the Clean Air Act

- ❒ Handouts: Air Pollution Summary
- ❒ Materials needed: Computer & projector, speakers, Pollutant Trends Graphs
- ❒ Optional materials: Student computers (highly recommended), How Much Pollution is Too Much (handout)

Activity 8 (Elaborate): Smog City: How Weather Affects Air Quality

- ❒ Handouts: Save Smog City From Ozone
- ❒ Materials needed: Computer & projector
- ❒ Optional materials: Student computers (highly recommended)

Activity 9 (Elaborate): Making an Air Quality Prediction

- ❒ Handouts: AQI prediction guide
- ❒ Materials needed: Computer & projector
- ❒ Optional materials: Student computers (highly recommended)

Activity 10 (Evaluate): Creating an Air Quality Report

- ❒ Handouts: Project guidelines, Grading rubric
- ❒ Materials needed: n/a
- ❒ Optional materials: Student computers (highly recommended), video recording devices

Ozone

Ozone is a gas found in different parts of the atmosphere. Ozone in the upper atmosphere, or stratosphere, helps protect the Earth from the sun's harmful rays. In the lowest level of the atmosphere, the troposphere, exposure to ozone also can be harmful to both human health and some plants. For this reason, ozone is often described as being "good up high and bad nearby" (U.S. EPA, 2003a). Most ground-level ozone forms in the air from chemical reactions involving nitrogen oxides (NOx), volatile organic compounds (VOCs), and sunlight. Ozone levels are typically highest during the afternoon hours of the summer months, when the influence of direct sunlight is the greatest. These highest levels occur during what is known as the "ozone season," which includes at least the spring and summer months but whose time frame varies by state (U.S. EPA, 2003b).

Variations in weather conditions play an important role in determining ozone levels. Daily temperatures, relative humidity, and wind speed can affect ozone levels. In general, warm dry weather is more conducive to ozone formation than cool wet weather. Wind can affect both the location and concentration of ozone pollution. NOx and VOC emissions can travel hundreds of miles on air currents, forming ozone far from the original emissions sources. Ozone also can travel long distances, affecting areas far downwind. High winds tend to disperse pollutants and can dilute ozone concentrations. However, stagnant conditions or light winds allow pollution levels to build up and become more concentrated.

Inhalation exposure to ozone can cause many harmful health effects. Examples include respiratory effects, such as difficulty breathing, coughing, and airway inflammation. For people with lung diseases such as asthma, emphysema, and chronic obstructive pulmonary disease (COPD), these effects can lead to emergency room visits and hospital admissions. Ozone exposure also is likely to cause premature death from lung or heart diseases. In addition, evidence indicates that long-term ozone exposure may lead to the development of asthma and permanent lung damage (U.S. EPA, 2013).

People most at risk from breathing air containing ozone include people with asthma, children, older adults, and people who are active outdoors, especially outdoor workers. In addition, people with certain genetic characteristics, and people with reduced intake of certain nutrients, such as vitamins C and E, are at greater risk from ozone exposure. Research also indicates people with certain health conditions, such as obesity or diabetes, may be at increased risk of ozone-related health effects. Elevated concentrations of ozone can also affect some vegetation and ecosystems (U.S. EPA, 2013).

Trends in Ozone Levels in the US

Between the 1978-1980 and 2014-2016 averaging periods, ambient ozone concentrations decreased significantly. The 8-hour ozone levels in 2014-2016 were the second lowest on record. However, despite reductions in ambient concentrations of ozone over the past quarter century, ozone concentrations above the health-based air quality standards remain one of the most persistent air pollution problems in many parts of the U.S.

Adapted from: *Ozone Concentrations*, Report on the Environment, US EPA,
https://cfpub.epa.gov/roe/indicator_pdf.cfm?i=8

AQI Basics

What is the U.S. Air Quality Index (AQI)?

The U.S. AQI is EPA's index for reporting air quality.

How does the AQI work?

Think of the AQI as a yardstick that runs from 0 to 500. The higher the AQI value, the greater the level of air pollution and the greater the health concern. For example, an AQI value of 50 or below represents good air quality, while an AQI value over 300 represents hazardous air quality.

For each pollutant an AQI value of 100 generally corresponds to a concentration equal to the level of the short-term national ambient air quality standard (NAAQS) for protection of public health. AQI values at or below 100 are generally thought of as satisfactory. When AQI values are above 100, air quality is unhealthy: at first for certain sensitive groups of people, then for everyone as AQI values get higher.

The AQI is divided into six categories. Each category corresponds to a different level of health concern. Each category also has a specific color. The color makes it easy for people to quickly determine whether air quality is reaching unhealthy levels in their communities.

AQI Basics for Ozone and Particle Pollution

Daily AQI Color	Levels of Concern	Values of Index	Description of Air Quality
Green	Good	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Yellow	Moderate	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Orange	Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Red	Unhealthy	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Purple	Very Unhealthy	201 to 300	Health alert: The risk of health effects is increased for everyone.
Maroon	Hazardous	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected.

Five Major Pollutants

EPA establishes an AQI for five major air pollutants regulated by the Clean Air Act. Each of these pollutants has a national air quality standard set by EPA to protect public health:

- ground-level ozone
- particle pollution (also known as particulate matter, including PM2.5 and PM10)
- carbon monoxide
- sulfur dioxide
- nitrogen dioxide

Adapted from *AQI Basics*, Air Now. https://www.airnow.gov/aqi/aqi-basics/

Quantities and the Earth's Atmosphere

The vast majority of Earth's atmosphere is made up of just two gases: nitrogen or N_2 (78%) and oxygen or O_2 (21%). Trace gases such as argon (1%), water vapor (1%), carbon dioxide (0.04%), and others are also present in very small amounts. Pollutants may be harmful at even smaller amounts. To describe these very small amounts of gases, scientists use the measures parts per million (ppm) and parts per billion (ppb). One percent is equal to one part per hundred or 10,000 parts per million. Similarly, one part per million equals 0.0001%.

$$1\% = \frac{1}{100} \times \frac{10{,}000}{10{,}000} = \frac{10{,}000}{1{,}000{,}000}$$ 1% = 10,000 ppm

$$\frac{1}{1{,}000{,}000} \times \frac{0.0001}{0.0001} = \frac{0.0001}{100} = 0.0001\%$$ 1 ppm = 0.0001%

Expressed using ppm, the major components of Earth's atmosphere are:

- Nitrogen: 780,800 ppm (78.08%)
- Oxygen: 209,500 ppm (20.95%)
- Argon: 9,340 ppm (0.93%)
- Water vapor: ~10,000 ppm (~1%)
- Carbon dioxide: 410 ppm (0.041%)

Additional sources of background information for teachers:

The Clean Air Act:

- Plain English Guide to the Clean Air Act: https://www.epa.gov/sites/production/files/2015-08/documents/peg.pdf

Acronyms

- NAAQS: National Ambient Air Quality Standards – the is the "safe" level of each pollutant.

Glossary

anemometer – a scientific instrument for measuring wind speed

AQI (Air Quality Index) – a scale for reporting daily air quality. The AQI tells you how clean or polluted the air is in a given location, and what the associated health risks are. The AQI focuses on health effects you may experience within a few hours or days after breathing polluted air.

barometer – a scientific instrument for measuring air pressure

carbon monoxide (CO) - an odorless, colorless gas formed by the incomplete combustion of fuels. Can lead to poisoning because CO molecules will displace the oxygen in red blood cells.

Code Red Day – a day when the air quality index (AQI) is in the red zone (151-200) meaning that the air is unhealthy for everyone to breathe.

criteria pollutant – any one of the six air pollutants that are regulated by the EPA as required by the Clean Air Act. The criteria pollutants are carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide.

dew point - the atmospheric temperature below which water droplets begin to condense and dew can form

humidity – a measure of the amount of humidity in the atmosphere

hygrometer – a scientific instrument for measuring humidity

Inversion – a weather condition wherein a layer of cool air is trapped at the surface by a warmer air layer over it. Inversions can trap air pollution near the surface because the cool air will not rise into the warmer air. Also known as a temperature inversion.

nitrogen dioxide (NO_2) – a highly reactive gas that is a common air pollutant. Nitrogen dioxide primarily comes from burning fossil fuels in power plants, cars, trucks, and other vehicles.

ozone (O_3) - a natural and a man-made gas made of three oxygen atoms that occurs in the Earth's upper atmosphere (the stratosphere) and lower atmosphere (the troposphere). Depending on where it is in the atmosphere, ozone affects life on Earth in either good or bad ways.

particulate matter (abbreviation: PM) **-** a mixture of solid particles and liquid droplets found in the air. Some particles, such as dust, dirt, soot, or smoke, are large or dark enough to be seen with the naked eye. Larger particles are called PM 10, smaller particles are called PM 2.5, based on their diameter in micrometers.

parts-per-billion (abbreviation ppb) – a unit of measure equal to 1 in 1 billion, or 0.0000001%. 1 ppb is also equivalent to 1 µg/liter.

parts-per-million (abbreviation ppm) – a unit of measure equal to 1 in 1 million, or 0.0001%. 1 ppm is also equivalent to 1 mg/liter.

sky condition – a measure of the percentage of the sky covered by opaque clouds.

smog – a haze caused by air pollution. Smog that is made of ground-level ozone is created when sunlight shines on particular kinds of air pollution and nitrogen oxides, especially from automobile exhaust. Smog can also refer to a haze caused by particulate matter pollution.

stratosphere - the layer of the earth's atmosphere above the troposphere, extending from about to about 4-8 miles above the Earth's surface to about 32 miles (50 km)

sulfur dioxide (SO_2) **–**a toxic gas that is often released when coal that contains sulfur is burned in a power plant

troposphere - the lowest region of the atmosphere, extending from the earth's surface to a height of about 4-8 miles (6–10 km), which is the lower boundary of the stratosphere.