National Aeronautics and
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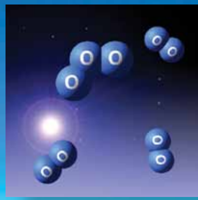

Our Protective Atmosphere

An Educator's Classroom Activity Guide

- STUDENT EDITION -

Earth System Science Curriculum Content

GRADE LEVEL: 6 – 8

On the Cover

Pictured on the cover is the Aura satellite, that studies the Earth's atmosphere.

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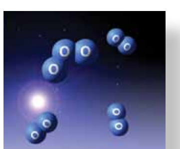
Scientific Enterprise and Inquiry. Credit: Dave Hamilton

Layers of Earth's upper atmosphere. Credit: NASA

Vehicles Emit Carbon Dioxide. Credit: C. Holm



Ozone Molecules in the Stratosphere. Credit: NASA

Science On a Sphere. Credit: NASA Kennedy Space Center

The Process of Scientific Enterprise and Inquiry

Vocabulary

Belief – confidence or conviction that something is true or exists even though it has not (or can not) been immediately proved through observations or measurements.

Conclusion – the outcome of a result that follows from a given hypothesis.

Fact – a truth that can be verified from actual experience or observation.

Hypothesis – an initial explanation for a set of facts that can be tested using observations or measurements.

Idea – a belief, opinion, thought, conviction, or concept developed by the mind.

Inference – a conclusion that incorporates many lines of reasoning, including observation, experiment, and theory.

Law – a generalization that is based on observations or measurements that consistently hold true for a given theory.

Observation – the act of noting and recording something we can see, hear, touch, taste, smell, or measure.

Opinion – confidence in a belief or conclusion that has not been proven valid through observation or measurement.

Theory – a body of knowledge that is organized systematically to explain an event, set or class of events, or other phenomena. For a hypothesis to become a theory, scientists must prove, or confirm, the hypothesis is valid through repeated observations, measurements, or experiments that give strong evidence for its validity.

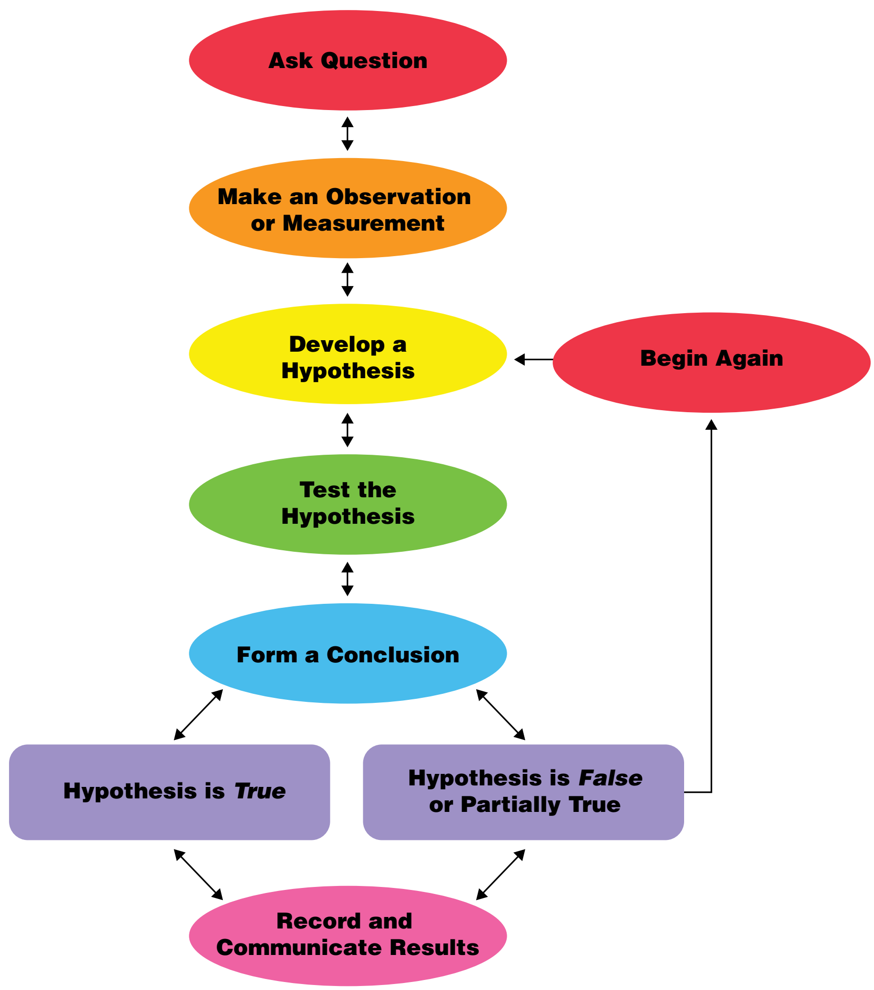
Reading Material

Scientists make observations, collect data, and conduct experiments to acquire new knowledge, correct existing knowledge, and investigate phenomena that are at present not well understood.

The process of scientific enterprise and inquiry must be conducted in a specific way for new knowledge to be accepted as "fact" by the scientific community. This process is how we distinguish a "fact" from an "idea," "opinion," or a "belief."

So how do we set about demonstrating, or proving, that an idea, opinion, or a belief is a fact? First, we define a fact as a truth that can be verified from actual experience or observation. Note that ideas, opinions, and beliefs need no such verification. The process of scientific enterprise and inquiry is what separates facts from everything else.

The scientific method of conducting scientific enterprise and inquiry



This simple flow chart illustrates the method scientists use to determine whether new knowledge can be verified as a fact.

Credit: NASA

- Ask a question
- Make an observation or measurement
- Develop a hypothesis that explains the meaning of the observation or measurement
- Test the hypothesis by gathering evidence or performing an experiment, and then analyze and interpret the data
- Form a conclusion based on the results—accept or reject your hypothesis
- Record your observations, hypothesis, interpretation, and conclusion
- Communicate the results

Ask a question

The first step in any scientific enterprise is to ask a question. For example, a scientist might wonder whether the ozone hole that exists in the stratosphere above the Earth's Antarctic region is continuing to grow. The scientist would then ask the question, "Is the Ozone Hole Continuing to Increase in Size?"

Make an observation or measurement

The next step would be for the scientist to make observations or measurements. An observation is the act of noting and recording something. An observation is something we can see, hear, touch, taste, smell, or measure. The observations or measurements are called "data." These data should be recorded.

Develop a hypothesis

After scientists make their observations or measurements, they develop a hypothesis that explains the meaning of the observation. If, for example, the ozone hole was observed to be bigger in 2006 than in 2005, a scientist might form the following hypothesis: The ozone hole is increasing in size.

Test the hypothesis

To test the hypothesis that the ozone hole is increasing in size, a scientist would collect more data by making additional observations and measurements. If the scientist made measurements in 2007 and every measurement that year showed larger values for the size of the ozone hole, then the scientist would interpret that data as supporting his or her hypothesis.

Form a conclusion

Next, the scientist forms a conclusion about the hypothesis. Because the evidence (or data) in our hypothetical case supports the hypothesis, the scientist would conclude that the ozone hole is increasing in size.

Record and communicate the results

Scientists publish the results of their experiments and studies in professional journals so that other scientists have access to the information. In this way, new knowledge can be added to what is already known about the subject of scientific inquiry in question. In this case, we are trying to add new knowledge to what is already known about the ozone hole.

The ozone hole is a region in the stratosphere is exceptionally depleted of ozone. The ozone hole forms each spring over the Antarctic. Ozone in the stratospheric layer of the Earth's atmosphere protects us from ultraviolet (UV) rays, which can be harmful to humans, plants, and animals on the Earth.

NASA's Aura satellite is designed to answer questions about changes in our life-sustaining atmosphere. Aura's four instruments study the atmosphere's chemistry and dynamics. The Ozone Monitoring Instrument (OMI) aboard Aura measures ozone levels in the atmosphere.

In the activities that follow, you will be the scientist. Using data obtained with OMI, you will use the methods of scientific enterprise and inquiry to explore the ozone hole in more depth.

Resources

Visit NASA's Ozone Hole Watch Website to learn more about the ozone hole and find out what a Dobson Unit is: http://ozonewatch.gsfc.nasa.gov/facts/hole.html.

Activity 1a: Ask a question and make an observation

Procedure

Ask the following question:

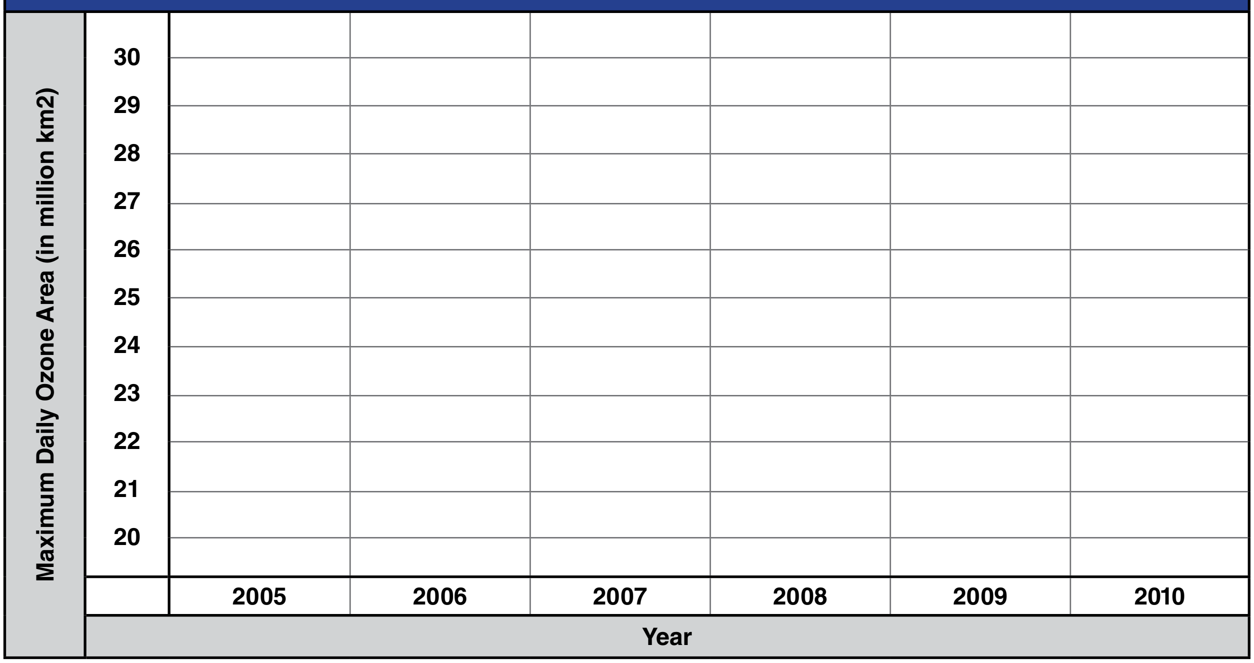
"Is the ozone hole increasing in area?"

Using the measurements contained in the "Ozone Hole Area" and "Minimum Ozone" tables as your data, fill out the "Maximum Daily Ozone Hole Area versus Year for 2005–2010" and "Minimum Daily Ozone Value versus Year for 2005–2010" plots.

Ozone Hole Area (million km^2) Maximum Daily			Minimum Ozone (DU) Minimum Daily	
Year	**Date**	**Value**	**Date**	**Value**
2005	11 September	26.9	19 September	102
2006	24 September	29.3	08 October	82
2007	13 September	24.8	24 September	104
2008	12 September	26.5	04 October	100
2009	17 September	24.0	26 September	94
2010	25 September	22.2	01 October	118

The Ozone Monitoring Instrument (OMI) aboard NASA's Aura satellite collected the data contained in this table. Credit: NASA/Ozone Hole Watch.

Plot: Maximum Daily Ozone Hole Area versus Year for 2005–2010



Plot: Minimum Daily Ozone Value versus Year for 2005–2010

Minimum Daily Ozone Value (in DU*)	2005	2006	2007	2008	2009	2010
200						
195						
190						
185						
180						
175						
170						
165						
160						
155						
150						
145						
140						
135						
130						
125						
120						
115						
110						
105						
100						
95						
90						
85						
80						
75						
70						

Year

* DU is an abbreviation for Dobson Units

Question

Review the plots you created for 2005–2010.

Do these plots indicate that the area of the ozone hole is increasing, decreasing, or staying the same?

Activity 1b: Form a hypothesis

Procedure

Use the plots you made in Activity 1a to analyze and interpret what the data reveal about the question you are investigating.

Write a hypothesis that explains what the observations mean.

Activity 1c: Test your hypothesis

Procedure

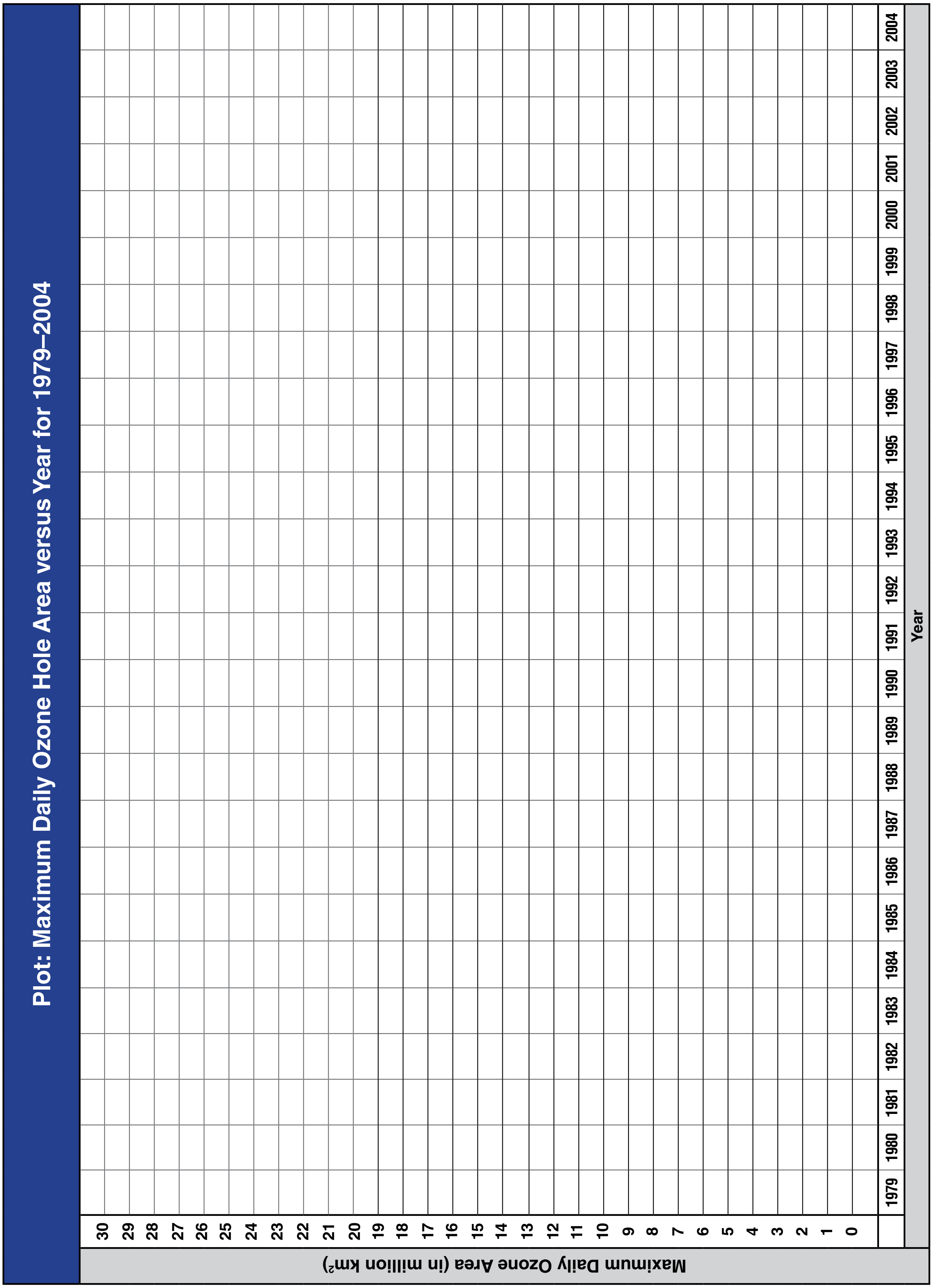
Gather additional evidence that will either support or refute your hypothesis.

Using the measurements contained in the “Ozone Hole Area and Minimum Ozone” table from 1979–2004 as your data, fill out the “Maximum Daily Ozone Hole Area versus Year” and “Minimum Daily Ozone Hole Value versus Year for 1979–2004” plots.

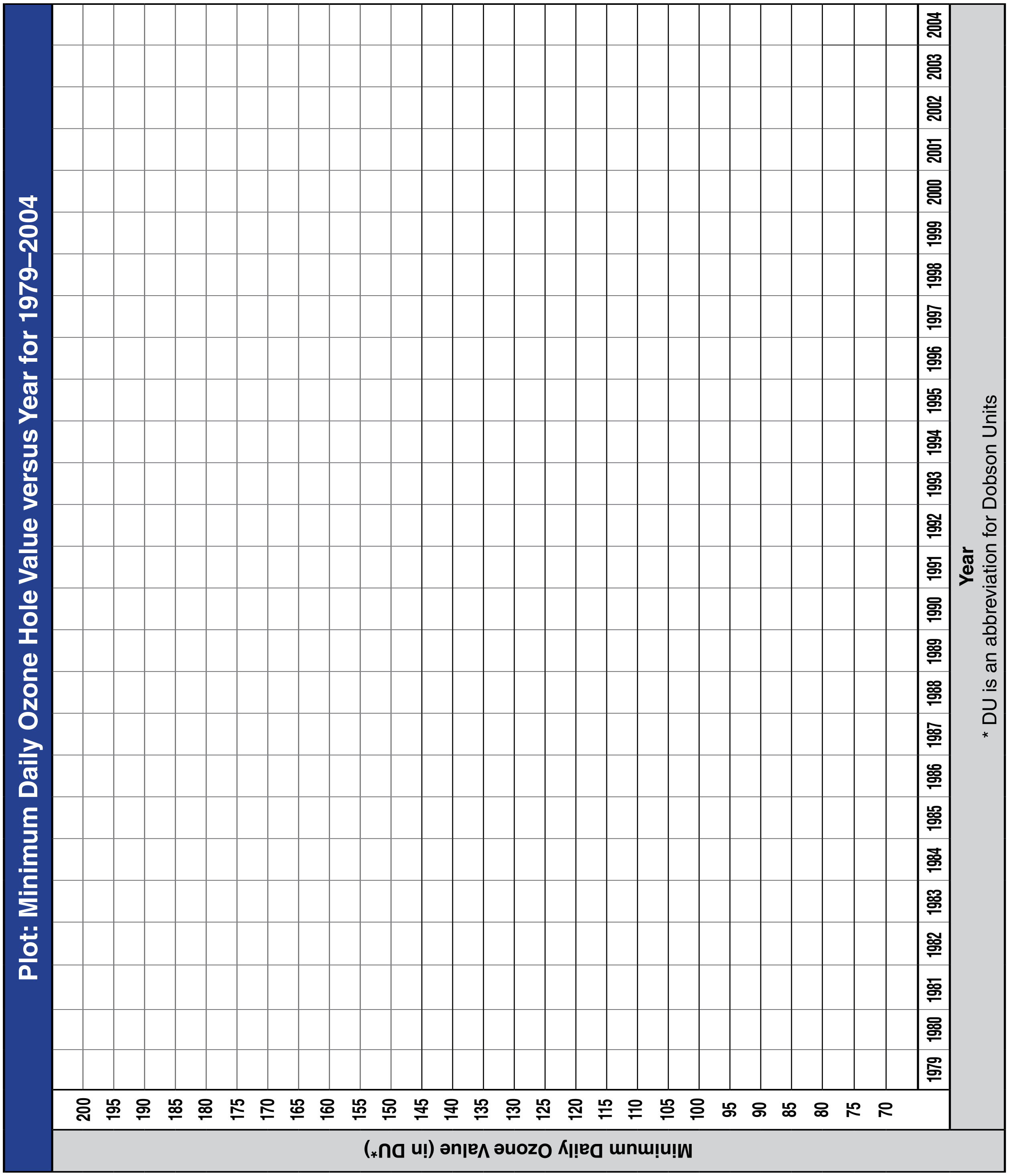
Ozone Hole Area ($million\ km^2$) Maximum Daily		
Year	**Date**	**Value**
1979	17 September	1.1
1980	27 October	3.3
1981	10 October	3.1
1982	02 October	10.8
1983	17 October	12.2
1984	24 September	14.7
1985	03 October	18.8
1986	06 October	14.4
1987	29 September	22.5
1988	20 September	13.8
1989	03 October	21.7
1990	19 September	21.1
1991	04 October	22.5
1992	27 September	24.9
1993	19 September	25.8
1994	30 September	25.2
1995	no data	no data
1996	07 September	26.9
1997	27 September	25.1
1998	19 September	27.9
1999	15 September	25.8
2000	09 September	29.9
2001	17 September	26.5
2002	19 September	21.9
2003	24 September	28.4
2004	21 September	22.7

Minimum Ozone (DU) Minimum Daily	
Date	**Value**
17 September	194
16 October	192
17 March	176
02 November	170
06 October	154
03 October	144
24 October	124
06 October	140
05 October	109
30 September	162
07 October	108
05 October	111
06 October	94
11 October	105
25 September	104
30 September	73
no data	no data
05 October	103
24 September	99
06 October	86
29 September	97
29 September	89
22 September	91
20 September	131
26 September	91
30 September	116

The Total Ozone Mapping Spectrometer (TOMS) Earth Probe collected the data contained in this table. Credit: NASA/Ozone Hole Watch.



Plot: Maximum Daily Ozone Hole Area versus Year for 1979–2004
Maximum Daily Ozone Area (in million km²)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004
Year



Question

Review the plots you created for 1979–2004.

Do these plots indicate that the area of the ozone hole is increasing, decreasing, or staying the same?

Activity 1d: Form a conclusion

Procedure

Use all of the plots you created in activities 1a and 1c to analyze and interpret what all of the data reveal about the question you are investigating and form a conclusion.

Write your conclusion based on the evidence contained in the plots you created.

Activity 1e: Record and communicate your results

Procedure

Gather together the question you are investigating, the plots in which you recorded your measurements, your hypothesis, and conclusion.

Assume that a scientific journal is interested in publishing the results of your study. Use the information you have gathered to prepare a summary of your results. In scientific research, a summary is called an "abstract." Also include the source of your data (spacecraft and instrument).

Title: ____________________

Author(s): ____________________

Affiliation: (your school): ____________________

Abstract ____________________

Unit II

Understanding the Layers of Earth’s Atmosphere

Vocabulary

Atmosphere – a thin layer of gases that surrounds our planet.

Mesosphere – the atmospheric layer that lies above the stratosphere and below the thermosphere.

Stratosphere – the atmospheric layer that lies above the troposphere and below the mesosphere.

Thermosphere – the atmospheric layer that lies above the mesosphere.

Troposphere – the layer of the atmosphere that lies closest to the Earth’s surface.

Mean sea level – a measure of the average height of the ocean’s surface.

Reading Material

Earth’s Atmosphere

Earth’s atmosphere is a thin layer of gases that surrounds our planet. Three quarters of the atmosphere lies within about 11 km (6.8 miles) of the Earth’s surface and becomes thinner as the distance from Earth’s surface increases.

Like a protective cocoon, the atmosphere protects life on Earth by absorbing most of the harmful ultraviolet (UV) radiation that comes from the sun. Our atmosphere also keeps the Earth’s surface warm, by keeping heat from radiating out into space, and reduces temperature extremes between day and night.

Exposure to even small amounts of UV rays can result in a sunburn. According to the World Health Organization (http://www.who.int/uv/health/en/), exposure to UV radiation over time can lead to premature aging of the skin, skin cancer, cataracts that can cause blindness, and suppression of the body’s immune system. Without an atmosphere, UV rays would bombard our planet’s surface and make it a place where life could not thrive.

Atmospheric Layers

Earth’s atmosphere can be divided into four main layers. The troposphere is the layer closest to the Earth’s surface. Above that is the stratosphere. Higher still is the mesosphere. And the highest layer is the thermosphere. These layers are defined on the basis of temperature, chemical composition, air movement, and air density.

Troposphere

The troposphere begins at the Earth’s surface and extends about 9 to 14.5 kilometers (5 to 9 miles) high, varying with latitude and time of year. The densest part of the atmosphere, the troposphere, contains between 80 and 90 percent of all the “air” in the atmosphere. Nearly all of the Earth’s weather occurs in the troposphere, where the temperature drops with distance away from our planet’s surface—from about 17 degrees Celsius (63 degrees Fahrenheit) to –52 degrees Celsius (–61 degrees Fahrenheit). The troposphere, or lower atmosphere, is where ozone is an air pollutant because it causes damage to plants and animals when inhaled.

Stratosphere

The stratosphere begins just above the troposphere and extends from about 9 to 14.5 kilometers (5 to 9 miles) to 50 kilometers (31 miles) above Earth’s surface. This part of the atmosphere is drier and less dense than the layer below it. The temperature in the stratosphere increases gradually with altitude to –3 degrees Celsius (27 degrees Fahrenheit) due to the absorption of UV radiation. A layer of ozone in the stratosphere, or upper atmosphere, is beneficial because ozone in the stratosphere absorbs ultraviolet light that could cause damage to life on the surface.

Mesosphere

The mesosphere lies above the stratosphere and below the thermosphere. This atmospheric layer takes its name from the Greek words “mesos,” meaning middle, and “sphaira,” or ball. The mesosphere begins about 50 kilometers (30 miles) above the Earth and extends to about 85 kilometers (50 miles) away. Temperatures here are cold and get extremely cold in the upper mesosphere, falling as low as –100 degrees Celsius (–148 degrees Fahrenheit). This frigid layer of the atmosphere is also the least understood. Elusive red sprites, blue jets, and elves are just a few of the mysterious, large-scale electrical discharges that occur in the mesosphere, high above storm clouds. Noctilucent clouds also form in the mesosphere. These elusive night-shining clouds, the highest clouds in the Earth’s atmosphere, are made of water-ice crystals and become visible when sunlight from below the horizon illuminates them.

Thermosphere

The thermosphere begins about 90 kilometers (56 miles) above the Earth and extends to above 600 kilometers (370 miles) high. The largest atmospheric layer, the thermosphere is where most of our satellites and the International Space Station orbit our planet. The colorful dancing lights, known as aurora, also form in the thermosphere. Most importantly, the thermosphere absorbs extreme ultraviolet (EUV) photons from the sun before they reach the Earth’s surface. Due to the absorption of EUV rays, temperatures in the thermosphere increase with altitude, at times rising to as much as 1,500 degrees Fahrenheit (2,730 degrees Celsius). Carbon dioxide that makes its way into the thermosphere acts as a coolant, shedding heat by way of infrared radiation.

Fun Facts About the Atmosphere

- The layers of the atmosphere are not always the same height all around the Earth and they expand and contract with temperature fluctuations throughout the year.
- The troposphere, the lower atmosphere, contains 99% of the atmosphere’s water vapor.
- The troposphere and stratosphere contain 99.9% of the total mass of the atmosphere.
- All atmospheric layers exchange gas and energy all the way out to the magnetosphere, the region surrounding Earth where our planet’s magnetic field dominates.

Activity 2a: Layers of the Atmosphere Worksheet

Procedure

Each of the 10 sentences below describes a particular layer of the Earth's atmosphere. Fill in the blank with the letter that indicates the atmospheric layer that most closely matches the layer's description.

(A) Thermosphere **(B) Mesosphere**
(C) Stratosphere **(D) Troposphere**

1. A protective layer of UV-absorbing ozone lies within the ________________ layer.
2. The colorful dancing lights, known as aurora, form in the ________________ layer.
3. Nearly all weather happens in the ________________ layer.
4. The night-shining, polar mesospheric clouds form in the ________________ layer.
5. We live in the ________________ layer.
6. The International Space Station orbits the Earth in the ________________ layer.
7. The coldest atmospheric temperatures occur in the ________________ layer.
8. Ozone is considered an air pollutant in the ________________ layer.
9. Noctilucent clouds, the highest clouds in the Earth's atmosphere, form in the ________________ layer.
10. An astronaut returning from the Earth to the moon will first encounter the ________________ layer.

Circle the correct answer:

1.	Thunderstorms and hurricanes occur in the…	*mesosphere*	*troposphere*
2.	Satellites orbit the Earth in the…	*thermosphere*	*stratosphere*
3.	The densest layer of the atmosphere is the…	*mesosphere*	*troposphere*
4.	Large-scale electrical discharges occur in the…	*stratosphere*	*mesosphere*
5.	Temperatures fall as low as –100 degrees Celsius (–148 degrees Fahrenheit) in the…	*mesosphere*	*stratosphere*

Activity 2b: Locate and Label the Layers of the Earth's Atmosphere

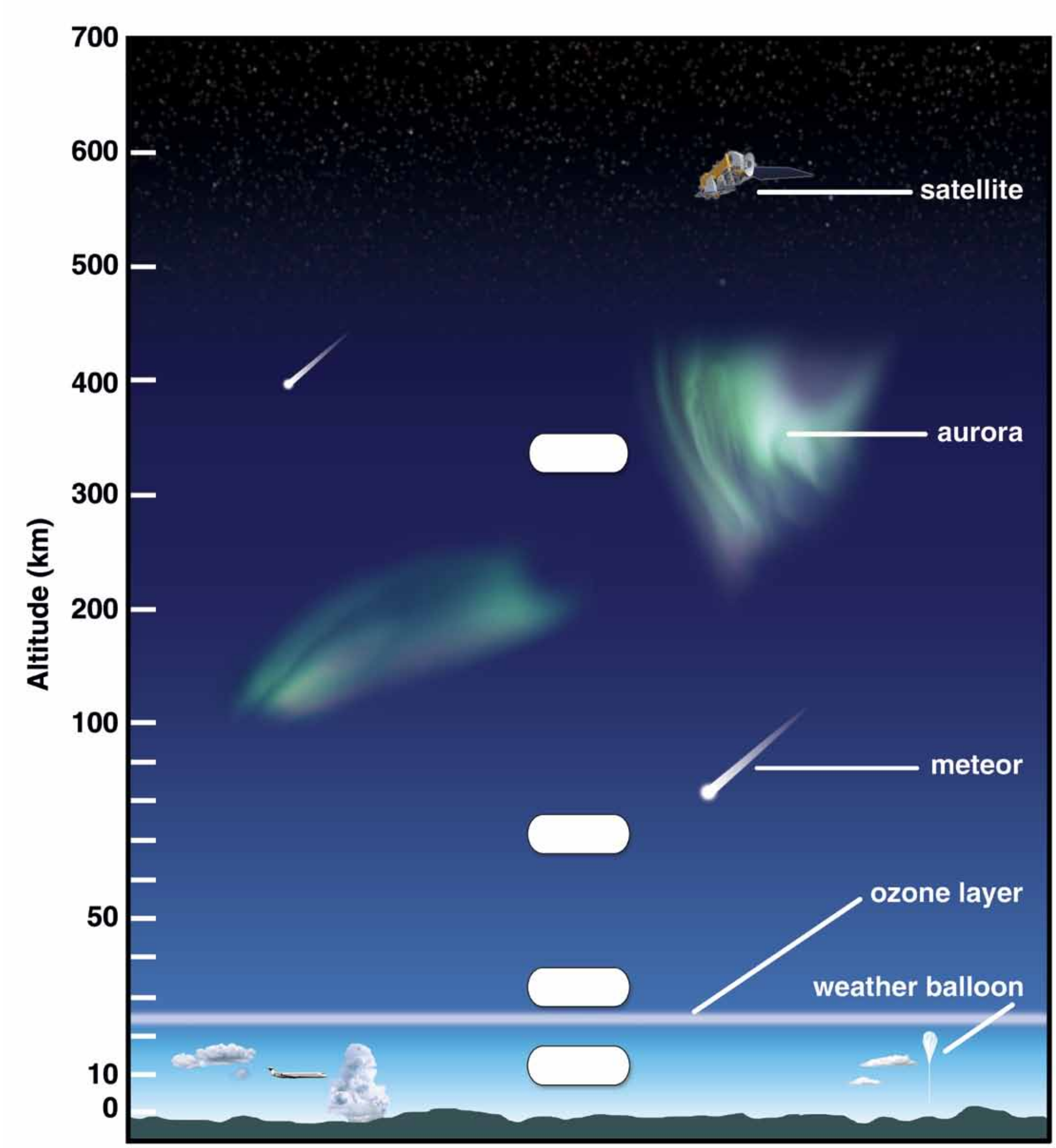
Procedure

Using the "Altitude and the Earth's Atmosphere" image, choose the label that corresponds to each layer of the atmosphere.

(A) Thermosphere **(B) Mesosphere** **(C) Stratosphere** **(D) Troposphere**

Altitude and the Earth's Atmosphere

One distinguishing characteristic of each layer of the atmosphere appears on the right of this image. The numbers along the left in this image represent the approximate height above the Earth's surface at which each identifying characteristic occurs.



Credit: NASA

Activity 2c: Discover What Lies or Flies in the Earth's Atmospheric Layers

Procedure

Use the data contained in the "Altitude and the Earth's Atmosphere" image to answer the following questions:

1. The peak of Mt. Everest, the world's highest mountain, lies about 8.8 km (5.5 mi.) above mean sea level. Does Mt. Everest reach into the stratosphere? Yes ______ No ______
2. Commercial airplanes typically fly at an altitude from 9.8–12.2 km (6.1–7.6 mi.). Do airplanes ever leave the troposphere? Yes ______ No ______
3. The Concorde turbojet-powered supersonic passenger airliner could reach a cruising altitude of 18.3 km (11.4 mi.). Could the Concorde fly in the stratosphere? Yes ______ No ______
4. The U-2 high-altitude reconnaissance aircraft, or spy plane, reaches altitudes above 21.3 km (13.3 mi.). Can U-2 spy planes ever fly in the mesosphere? Yes ______ No ______
5. Can U-2 spy planes fly near the protective layer of ozone in the stratosphere? Yes ______ No ______
6. NASA's space shuttles orbit at altitudes of 185–644 km (115–400 mi.). Can space shuttles fly in the thermosphere? Yes ______ No ______

Match the following items to their correct altitudes using the "Altitude and the Earth's Atmosphere" image:

1. Mt. Everest
2. Commercial airplanes
3. Concorde
4. U-2 spy plane
5. Space shuttle

Unit III

Air Pollution and Nitrogen Dioxide

Vocabulary

Nitrogen oxides – a family of gases that includes NO_2 and is produced during the combustion of coal and gasoline.

Nitrogen dioxide (NO_2) – a gas with one nitrogen atom and two oxygen atoms.

Ozone (O_3) – a gas made of 3 oxygen atoms that is unhealthy to breathe.

Parts per billion (ppb) – a quantity-per-quantity measure that describes small values.

Smog – a mix of air pollutants from the combustion of fuel that react in sunlight to form unhealthy levels of ozone in and near cities.

Reading Material

The quality of the air we breathe depends on the amount of toxic or harmful chemicals that make their way into the atmosphere.

Nitrogen, oxygen, and argon account for more than 99% of the gases in the atmosphere. Dry air consists of about 78% nitrogen (N_2), 21% oxygen (O_2), 0.9% argon (Ar), 0.04% carbon dioxide (CO_2), and small amounts of other gases. The amount of water vapor in the atmosphere changes, or varies, but is about 1% on average. Ozone exists in the atmosphere in very small amounts and is measured in parts per billion (ppb). One part in one billion is a very small number that is equivalent to one raindrop diluted into 250 barrels, each holding 55 gallons of rainwater.

Air pollution causes air to become unhealthy to breathe and can make humans and other living organisms sick or even shorten their lives. According to the World Health Organization, 2.4 million people die each year because of air pollution.

Air pollution is made up of toxic gases and tiny particles. The culprits of air pollution include ozone, particulate matter, sulfur dioxide, nitrogen dioxide, carbon monoxide, and lead, according to the 1977 National Ambient Air Quality Standards.

Nitrogen dioxide (NO_2) is a toxic, foul-smelling gas that forms in the atmosphere when fuel is burned at a high temperature, such as when gasoline is burned in the engines of cars. NO_2 is reddish-brown in color, so it contributes to the brown color of the haze that often envelops cities.

According to the U.S. Environmental Protection Agency (EPA), the health effects of NO_2 include the irritation of eyes, nose, and throat, the worsening of asthma symptoms, and an increased risk of respiratory infections, especially in young children. The EPA's National Ambient Air Quality Standards lists 53 ppb as the average 24-hour limit for NO_2 in outdoor air.

Natural sources of NO_2 include forest fires, lightning, plants, soil, and water. Combined, natural sources make up only about 1% of the total amount of NO_2 found in cities. The overwhelming majority of NO_2 comes from the production of electricity, industrial boilers, and the tailpipes of cars and other vehicles as they burn their fuel.

High concentrations of NO_2 play a major role in producing ground-level ozone, the major component of "smog." NO_2 belongs to the family of nitrogen oxides. Nitrogen oxides can react with other pollutants in the air and sunlight to form ozone. Ozone is unhealthy to breathe, worsens asthma symptoms, and causes inflammation of the linings of the lungs, leading to coughing and chest pain.

The EPA regulates the amount of nitrogen oxides released from vehicles and factories to decrease the concentration of NO_2 and the formation of high levels of ground-level ozone. These regulations have been successful and, according to the EPA, measured NO_2 concentrations in the air have decreased by 40% since 1980.

Consequently, average ozone levels for the U.S. have decreased since the 1980s and shown a notable decline after 2002. Scientists expect this trend to continue, with NO_2 concentrations in the air expected to continue to decrease in the next decade because of these regulations.

During our investigation of NO_2 as a pollutant in the air we breathe, we will examine NO_2 levels in the U.S., where we live, and investigate how NO_2 levels have changed over time.

Activity 3a: Investigating NO_2 air pollution where you live

Procedure

Use the image labeled "Tropospheric NO_2 in January 2005" to answer the following questions.

Questions

1. Identify five states where NO_2 is found in the highest concentrations.

   __________, __________, __________, __________, __________,

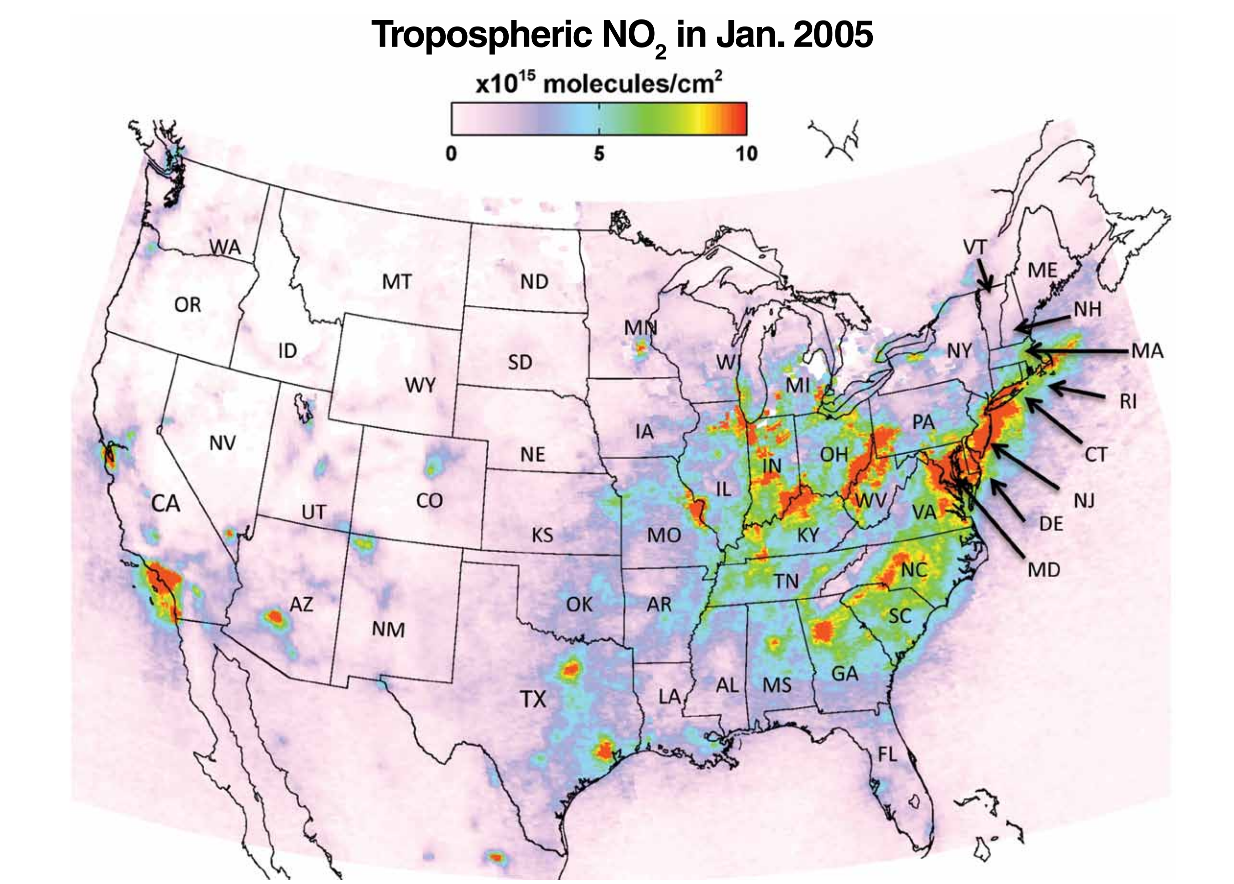
2. What is one possible explanation of why NO_2 is higher in Los Angeles, CA, than in the state of Oregon, just north of California?

   ____

3. Identify five states where NO_2 is found in the lowest concentrations.

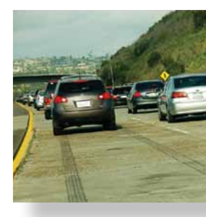
   __________, __________, __________, __________, __________,

4. What is the level of NO_2 where you live? ________________



This image shows the level of tropospheric NO_2 present in the atmosphere in the U.S. in January 2005.
The Ozone Monitoring Instrument aboard the Aura satellite collected the tropospheric NO_2 data contained in this image.

Credit: NASA



Activity 3b: Comparing NO_2 pollution levels on weekdays versus on weekends and holidays

Procedure

Use the data contained in the "Tropospheric NO_2 on Weekdays" and "Tropospheric NO_2 on Weekends and Holidays" images to investigate how NO_2 levels change from weekdays to weekends and holidays.

Chart your observations

City	NO_2 Value Weekdays	NO_2 Value Weekends/Holidays
Los Angeles, CA		
Chicago, IL		
Houston, TX		
Washington, D.C.		

Questions

1. Are tropospheric NO_2 levels higher on weekdays or on weekends and holidays in the following cities?

   Los Angeles, CA; ____________ Chicago, IL; ____________

   Houston, TX; ____________ Washington, D.C. ____________

2. Are tropospheric NO_2 levels higher on weekends and holidays than on weekdays in the following states?

   California ____________ Oregon ____________

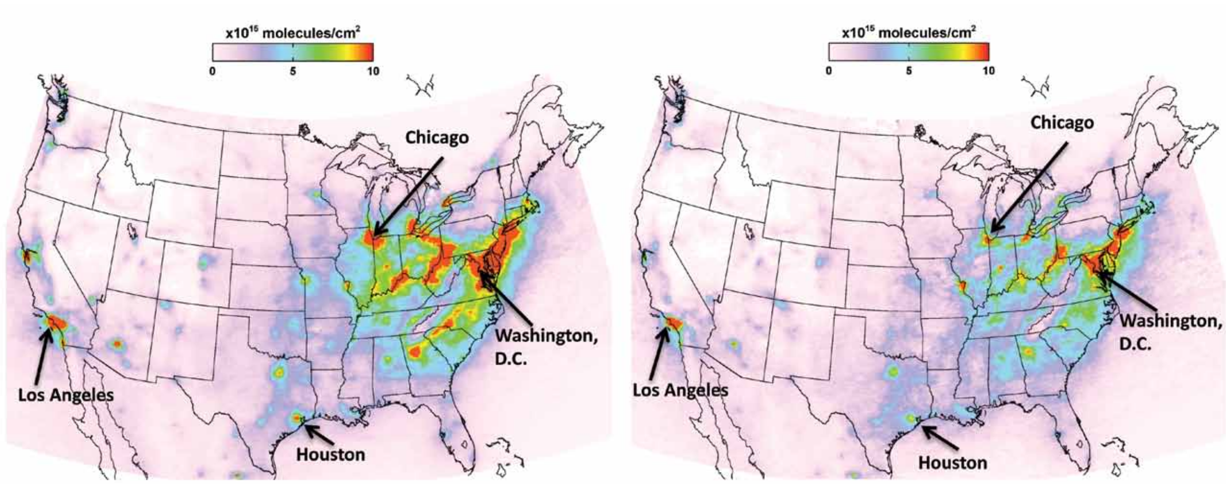
   Texas ____________ Illinois ____________

3. What change do you notice in NO_2 levels from weekdays to weekends and holidays? ____________

4. What do you think could be responsible for the change of NO_2 levels from weekdays to weekends and holidays? ____________

Tropospheric NO_2 on Weekdays

Tropospheric NO_2 on Weekends and Holidays



These side-by-side images show the level of tropospheric NO_2 present in the atmosphere in the U.S. on weekdays and on weekends and holidays, respectively. The Ozone Monitoring Instrument aboard the Aura satellite collected the tropospheric NO_2 data contained in this image.

Credit: NASA

Activity 3c: Explore how NO_2 pollution levels have changed over time

Procedure

Use the data contained in the "Tropospheric NO_2 in Jan. 2005" and "Tropospheric NO_2 During Jan. 2009" images to answer the following questions about how levels of NO_2 in the atmosphere have changed over time.

Questions

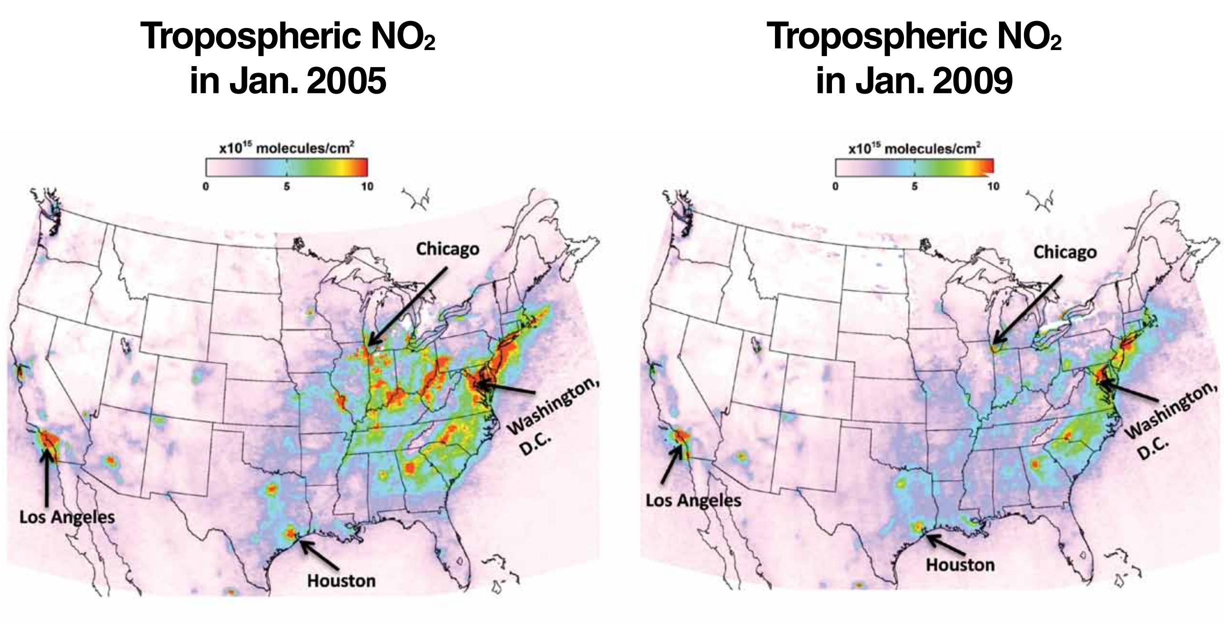
1. Have levels of tropospheric NO_2 increased or decreased from 2005 to 2009 in the following cities?

   Los Angeles, CA; ____________ Chicago, IL; ____________

   Houston, TX; ____________ Washington, D.C. ____________

2. Have levels of tropospheric NO_2 increased anywhere in the U.S. from 2005 to 2009? ____________________________

3. Overall, have NO_2 levels increased, decreased, or stayed the same in the eastern U.S. from 2005 to 2009? ____________________________



These side-by-side images show the level of tropospheric NO_2 present in the atmosphere in the U.S. in January 2005 and January 2009, respectively. The Ozone Monitoring Instrument aboard the Aura satellite collected the tropospheric NO_2 data contained in this image.

Credit: NASA

Activity 3d: Comparing NO_2 pollution levels and population density in the U.S.

Procedure

Use data contained in the "Population in 2009 for Various Cities and States" chart, the "Tropospheric NO_2 During Jan. 2005" image, and the "City Lights at Night" map to compare NO_2 levels with the population density in different cities and states.

Questions

1. Where in the U.S. are the NO_2 levels the highest? ______________
2. Where in the U.S. are the NO_2 levels the lowest? ______________
3. What are the 2005 tropospheric NO_2 levels for the following cities?

   Chicago, IL ________ Houston, TX ________

   Los Angeles, CA ________ New York City ________

   Washington, D.C. ________
4. What are the 2005 tropospheric NO_2 levels for the following states?

   Nevada ________ Oregon ________

   South Dakota ________ Maine ________
5. Do the tropospheric NO_2 levels tend to increase or decrease where people are crowded together in cities? ______________
6. Do the tropospheric NO_2 levels tend to increase or decrease where people are spread out throughout the area of a state? ______________
7. What is your interpretation of why pollution levels are much higher in the eastern U.S. than in the western and central U.S.? ______________

Population in 2009 For Various Cities and States

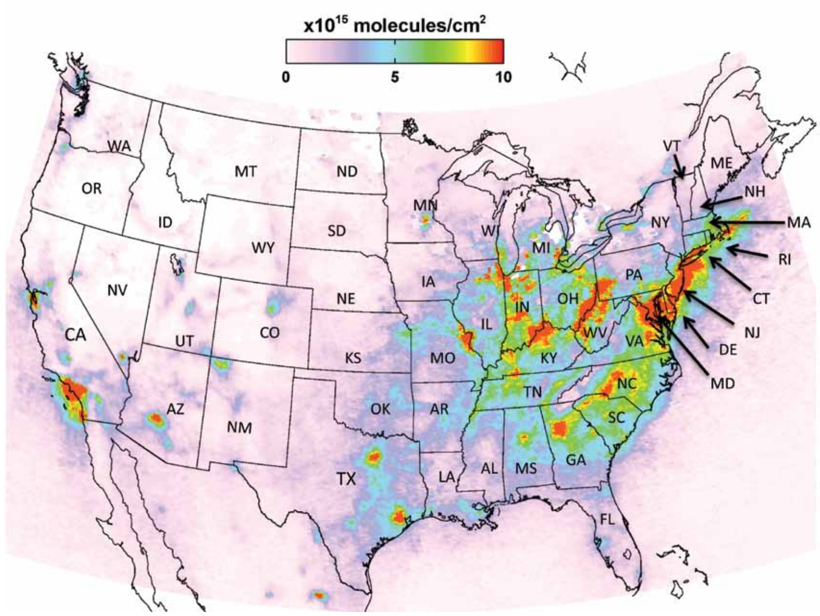
City	2009 Population	State	2009 Population
Chicago, IL	2.9 million	Nevada	2.6 million
Houston, TX	1.9 million	Oregon	3.8 million
Los Angeles, CA	3.7 million	South Dakota	812,383
New York City	8.4 million	Washington, D.C.	599,657

City Lights at Night

Credit: DMSP data – U.S. Air Force Weather Agency; DMSP data processing – NOAA's National Geophysical. Data Center; DMSP and MODIS image composite – NASA.

This image of Earth's city lights at night shows the spatial distribution, or arrangement, of human settlements. White areas of light show urbanized areas where population is typically large.

Tropospheric NO_2 in Jan. 2005



Credit: NASA

This image shows the level of tropospheric NO_2 present in the atmosphere in January 2005.
The Ozone Monitoring Instrument aboard the Aura satellite collected the tropospheric NO_2 data contained in this image.

Extended Learning Activity (Optional)

Visit the EPA website (http://www.epa.gov/airtrends/nitrogen.html) and learn about the trends in NO_2 levels in the U.S. since 1980.

Unit IV

Investigating the UV-Ozone Connection

Vocabulary

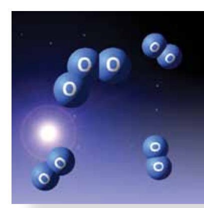
Equator – the imaginary great circle around the Earth that is the same distance from the North and South Poles and divides the Earth into northern and southern hemispheres.

Latitude – an imaginary line joining points on the Earth's surface that are all of equal distance from the equator.

Ozone – a colorless gas in the atmosphere that is made up of three oxygen atoms.

UV – ultraviolet rays from the sun.

UV index – a measure of the intensity of ultraviolet rays using a scale of 0 to 11+.



READING MATERIAL

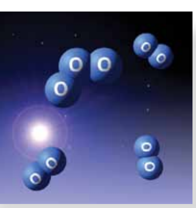
Our atmosphere protects us from most of the sun's harmful rays. Ozone is a gas that exists in our atmosphere in very tiny amounts. Most of the ozone in our atmosphere is found in the stratosphere—a layer of the atmosphere many miles above our heads. Ozone in the stratosphere protects us from damaging ultraviolet (UV) rays by absorbing most of them. However, a small amount of UV still makes it to the Earth's surface.

Some exposure to the sun's rays can have a beneficial effect. One important benefit comes from the production of vitamin D when our skin is exposed to the sun's rays. Vitamin D helps our bodies absorb calcium, which helps to form and maintain strong bones. However, as little as 5-15 minutes of exposure 2-3 times a week is enough to produce the amount of vitamin D your body needs. Brief exposure to UV rays on sunny days produces vitamin D, but too much exposure to UV rays can have harmful effects.

Too much exposure to UV rays can have both immediate and long-term effects on our skin. In the short-term, skin exposed to UV rays can burn. A 'sunburn' can happen within minutes or over the course of several hours. Over the long term, UV exposure can result in premature ageing of your skin, skin cancer, and damage to your eyes.

Calculating your exposure to UV rays depends on several things. One important factor is how directly the sun's rays shine upon you. The angle of the sun changes from winter to summer. During the winter, the sun is lower in the sky, which lowers the UV exposure. The sun is more directly overhead during the summer, which raises the UV exposure.

Cloud cover also affects your UV exposure. Did you know that you can get a sunburn even on a cloudy day? Although clouds will absorb and scatter many of the UV rays that make it into the lower atmosphere, some UV rays will still pass through clouds.



To inform people about the risk one can expect from UV rays, the National Weather Service and the U.S. Environmental Protection Agency (EPA) have developed the UV Index. The UV Index is a measure of the intensity of UV rays, and the daily forecast is a prediction of the UV Index.

The daily UV Index predicts UV intensity using a scale of 0 to 11+, with 0 representing minimal risk and 11+ posing an extreme risk of UV exposure.

UV Strength	UV Index
Low	0 - 2
Medium	3 - 5
High	6 - 7
Very High	8 - 10
Extreme	11 +

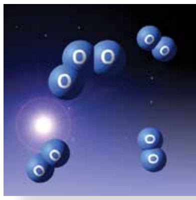
Calculating the daily UV Index depends on several factors. The thickness of the ozone layer in the stratosphere is the most important factor. Other factors include the amount of cloud cover, your elevation, and how high the sun is in the sky.

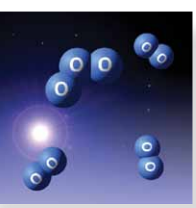
UV strength is higher when the sun is more directly overhead, as it is in the summer. In addition, the sun is highest in the sky at about noon each day. UV strength is the highest between the hours of 11 a.m. and 4 p.m., and everyone should avoid prolonged exposure during those hours.

Your skin type also affects your risk due to UV exposure. People with lighter skin burn more easily than those with darker skin. For example, on a day for which the UV Index is forecast to be a 7, a light-skinned person would have a high risk of sunburn while a dark-skinned person would have a low risk.

You can protect your eyes and skin from the effects of UV exposure by wearing a wide-brimmed hat, sunglasses that block both “UVA” and “UVB” rays, and sunscreen with a sun protective factor (SPF) of at least 15. Always wear sunscreen when swimming because water reflects UV rays and increases your risk of UV exposure.

The ozone layer protects us from nearly all of the UV rays from the sun. Without the ozone layer, life on the Earth could not exist on land. Scientists surmise that if two-thirds of the ozone layer were to disappear, the UV rays falling on cities in the continental U.S., like Washington, D.C., would be strong enough to result in sunburn in just five minutes and would have harmful effects on plants, animals, and humans.





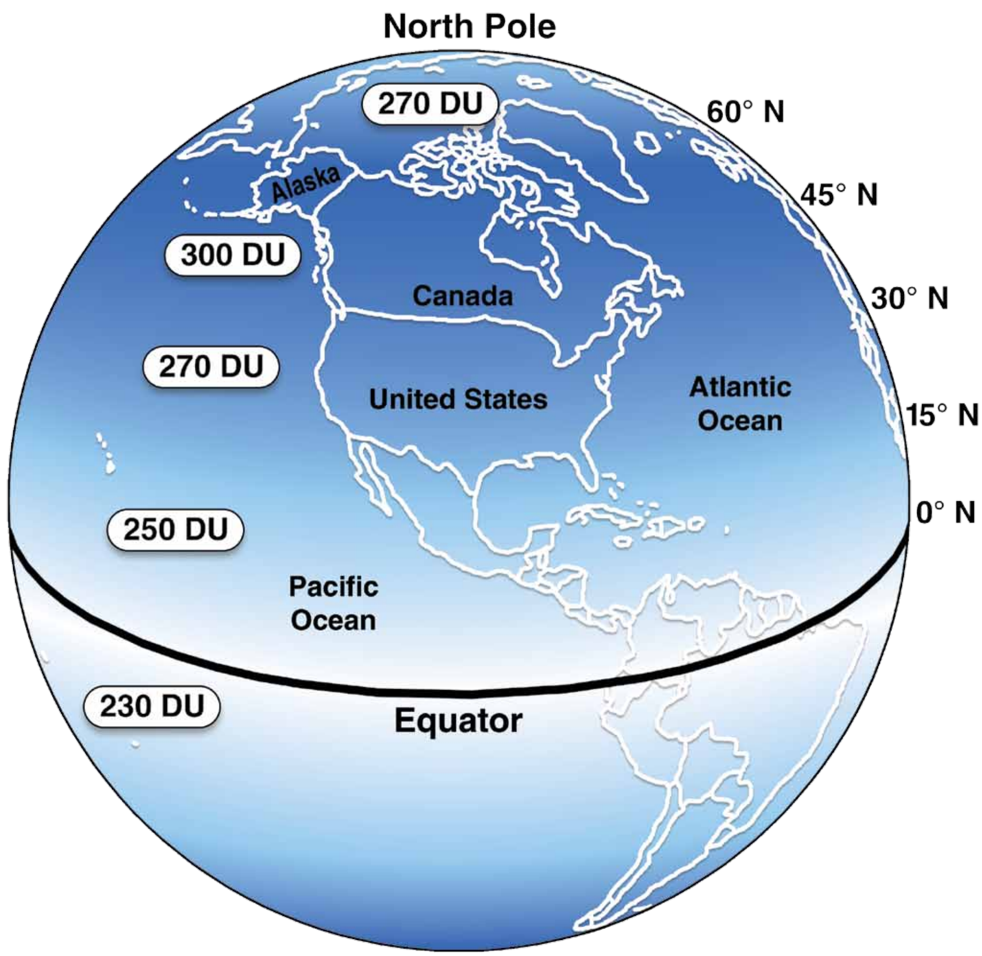
Activity 4a: Investigate how the thickness of the ozone layer varies with distance from the Earth's equator

Procedure

Use the Stratospheric Ozone image to answer the following questions:

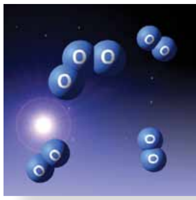
1. What is the value of stratospheric ozone near the equator? ______________
2. What is the value of stratospheric ozone in the United States? ______________
3. What is the value of stratospheric ozone in Canada? ______________
4. Where is the stratospheric ozone layer the thickest? ______________
5. What country shown has the greatest protection from UV rays? ______________

Stratospheric Ozone



This image shows stratospheric ozone in Dobson Units (DU) in summer at various latitudes. The higher the amount of stratospheric ozone, the higher the DU. The Ozone Monitoring Instrument aboard NASA's Aura satellite collected the stratospheric ozone data contained in this image.

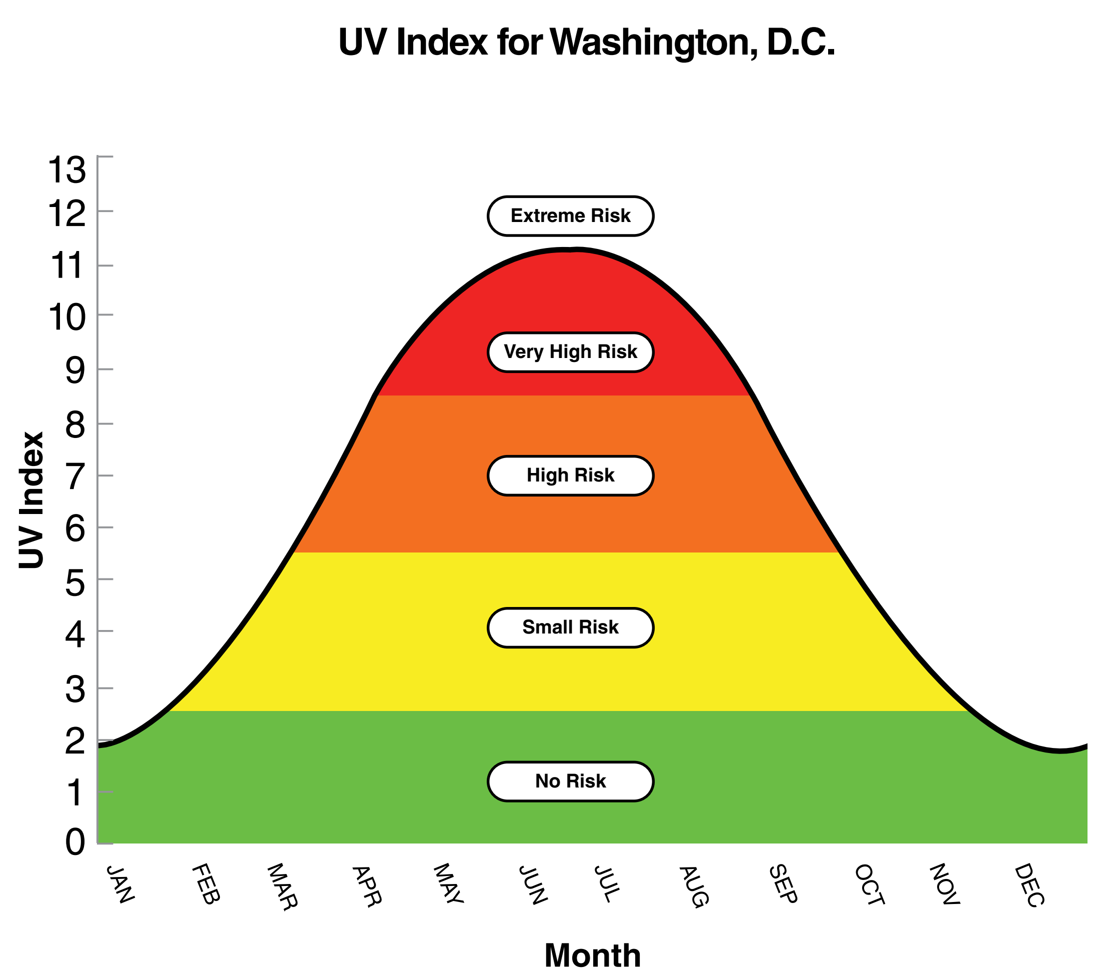
Credit: NASA



Activity 4b: Chart Seasonal Changes in the UV Index

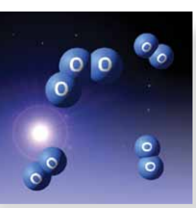
Procedure

Use the UV Index chart and the UV Exposure chart to identify how the UV index (and your risk of exposure to UV) varies from month to month throughout the year in Washington, D.C.



This image shows how the UV Index for Washington, D.C., varies over the course of one year.
Data for this plot were taken on sunny days at local noon.

Credit: NASA



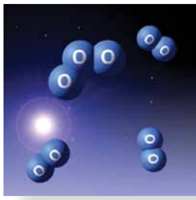
Procedure:

Observe and record the UV index for each month in Washington, D.C. Then observe and record the corresponding UV exposure risk.

Month	UV Index	UV Exposure Risk
January		
February		
March		
April		
May		
June		
July		
August		
September		
October		
November		
December		

Questions:

1. When you visit Washington, D.C., in summer on a sunny day, is it a good idea to protect your skin from UV exposure? Yes ______ No ______
2. When you visit Washington, D.C., in winter on a sunny day, is it a good idea to protect your skin from UV exposure? Yes ______ No ______
3. When you visit Washington, D.C., in summer on a cloudy day, is it a good idea to protect your skin from UV exposure? Yes ______ No ______
4. When you visit Washington, D.C., in winter on a cloudy day, is it a good idea to protect your skin from UV exposure? Yes ______ No ______

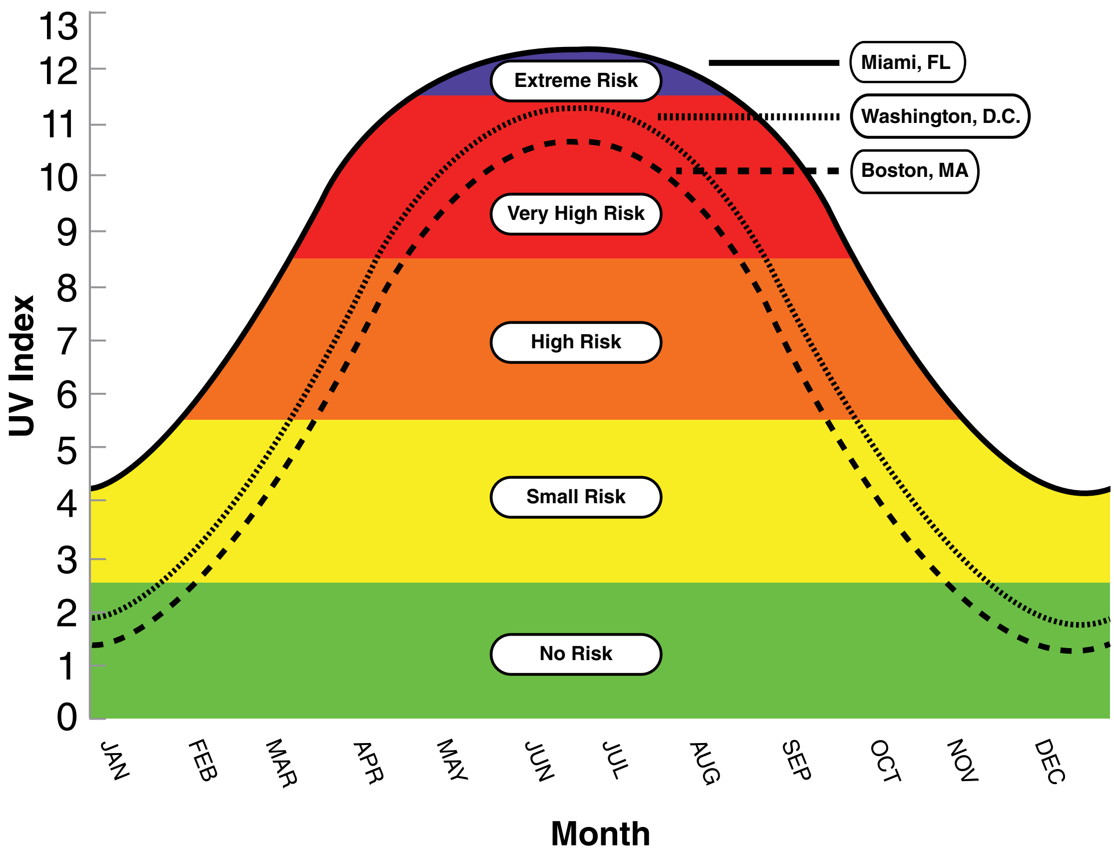


Activity 4c: Compare the UV Index in Different Cities in the U.S.

Procedure:

Use the UV Index versus Month chart to see how UV exposure from city to city from month to month.

UV Index Versus Month



This image shows how the UV Index varies over the course of the year for three U.S. cities.
Data for this plot were taken on sunny days at local noon.

Credit: NASA

Questions:

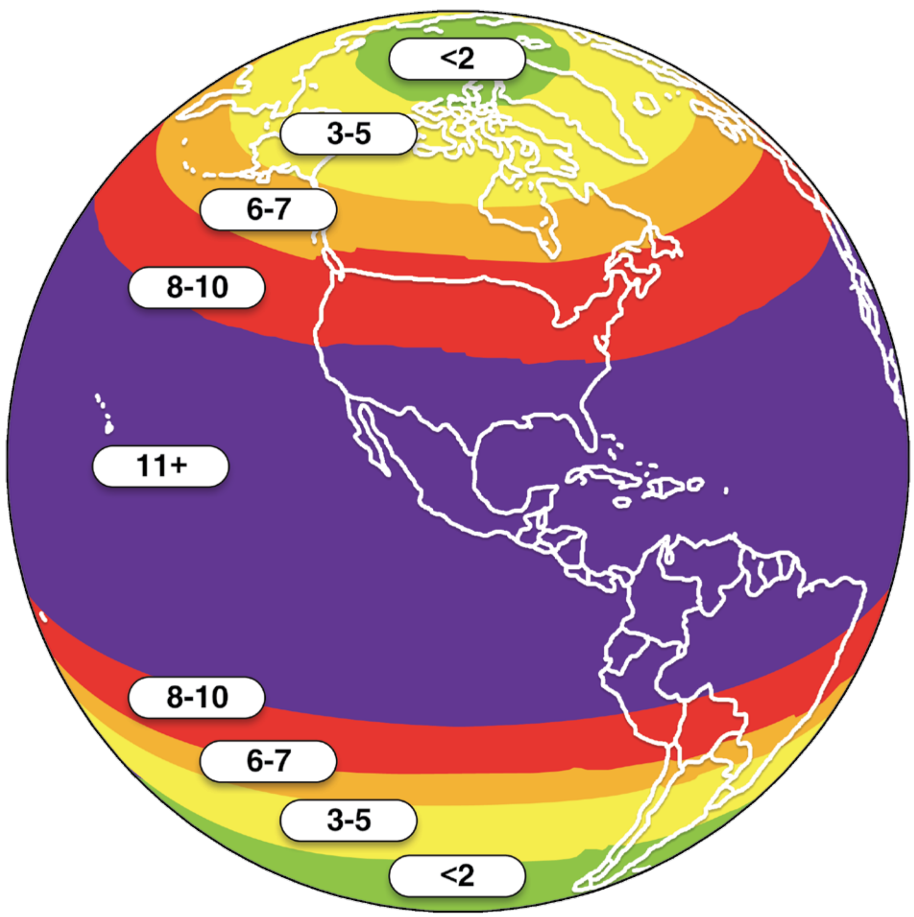
1. Which city has a lower UV exposure? Boston ____ Miami ____
2. Which city has the lower UV exposure? Boston ____ Washington, D.C. ____
3. Which city has the highest UV exposure? ____________
4. Which city has the lowest UV exposure? ____________

Extended Learning Activity (Optional):

Procedure

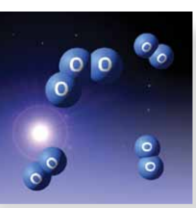
Use the "Present-day Global UV Index" and "Global UV Index with the Ozone Layer Decreased by Half" maps to compare the global UV Index with a scenario in which half of the ozone layer disappears.

Present-day Global UV Index

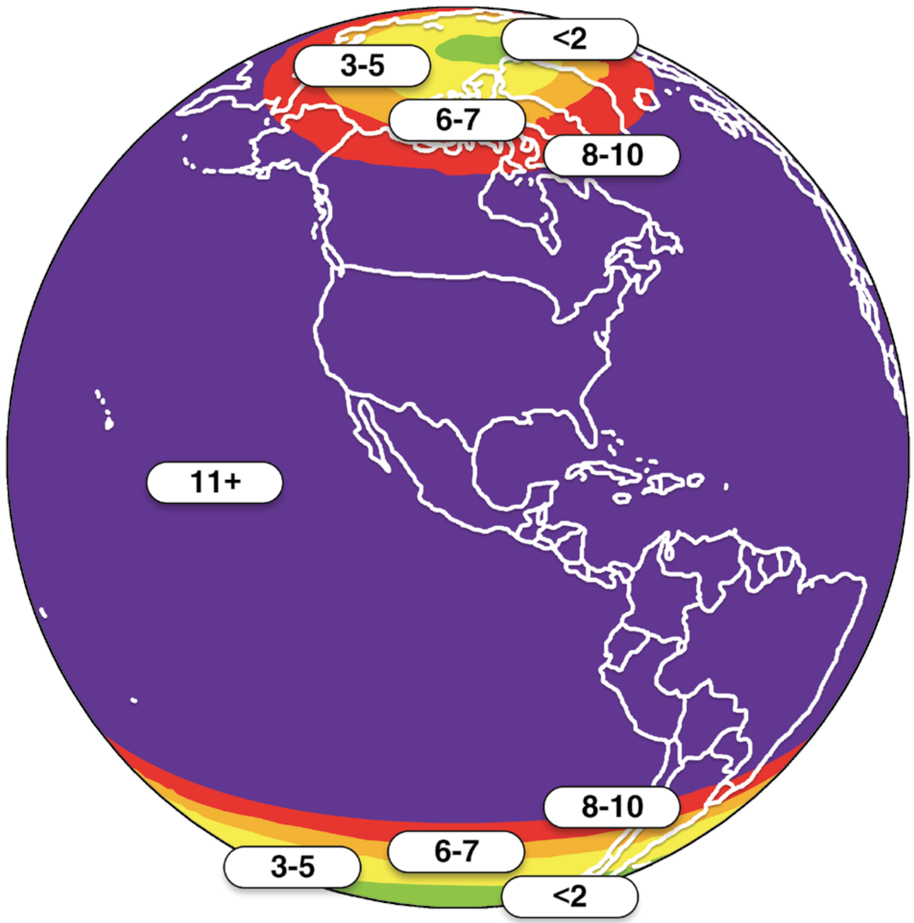


Global UV Index on clear days in summer at local noon with a typical present-day ozone layer.

Credit: NASA

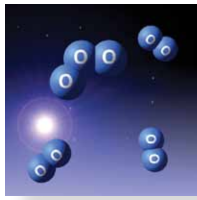


Global UV Index with the Ozone Layer Decreased by Half



Global UV Index on clear days in summer at local noon with a 50% reduction in the ozone layer.

Credit: NASA



Questions:

1. How does UV exposure change over Alaska when the ozone layer is decreased by half?

____

2. Should you protect your skin in summer in the northern continental U.S. with a typical ozone layer? Yes ______ No ______

3. Should you protect your skin in summer in the northern continental U.S. with an ozone layer decreased by half? Yes ______ No ______

4. What do you think the consequences of a 50% reduction in the ozone layer would be for plants, animals and humans on Earth?

____

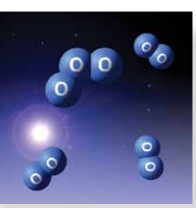
Extended Learning Activity (Optional): UV Index on the Internet

Procedure:

Use the NOAA Lesson Link (http://www.cpc.ncep.noaa.gov/products/stratosphere/uv_index/uvi_map_big.gif) to find out what the current UV index is where you are.

Questions:

1. What is the current UV Index in your area? ______________
2. Given the current UV Index, should you protect your skin? Yes ______ No ______
3. If you travel from Boston to Miami, do you think the UV Index will increase, decrease, or stay the same? ______________



Unit V

Attend the Science On a Sphere Presentation of "Our Protective Atmosphere"

Science On a Sphere (SOS) is an animated globe that can show dynamic, animated images of the atmosphere, oceans, and land of a planet. This extraordinary education and outreach tool describes the environmental processes of the Earth in a visually compelling format that captures the imagination and reinforces content presented in the classroom.

The "Our Protective Atmosphere" SOS presentation brings together the content presented in Units I-IV of the Our Protective Atmosphere formal education module. This docent-led narrated video lecture combines the concepts and data with memorable visuals in a way that is fun and easy for students to understand.

Our atmosphere is a dynamic and complex system that sustains life on the Earth. Understanding how humans affect the air we depend on for life is an important part of Earth system science, both inside and outside the classroom. Understanding how NASA's Earth Observing System satellites monitor and measure the health of the Earth's atmosphere is an integral part of the journey students will take during the "Our Protective Atmosphere" SOS presentation.

Thank you for joining NASA's Earth Observing System satellites on their journey to discover the inner workings of the Earth's atmosphere!

Student Notes

Student Notes

National Aeronautics and Space Administration

www.nasa.gov

NP-2011-05-208-GSFC