Rice Air Curriculum

By:

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Online:
< http://cnx.org/content/col11200/1.1/ >

C O N N E X I O N S

Rice University, Houston, Texas

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Chapter 1

Rice Air Curriculum - Introduction[1]

The Rice Air Curriculum, developed by Dr. Daniel Cohan and Kavita Venkateswar of Rice University, aims to engage young children in scientific inquiry and hands-on measurement of the atmosphere. The lessons enable students to apply math and science to explore the challenge of air pollution in their own community.

1.1 Content:

The curriculum is aimed at 5th-grade level math or science classes and consists of seven lessons:

1. Introduction to the Atmosphere: States of matter; Intro to the atmosphere
2. Physical Properties of the Atmosphere: Layers of the atmosphere; Temperature; Wind; Begin GLOBE measurements
3. Atmospheric Gases and Their Cycles: Composition of the atmosphere; Water cycle, clouds & humidity; Oxygen cycle; Carbon cycle
4. Stratospheric Ozone: Dual nature of ozone; Stratospheric ozone layer
5. Tropospheric Ozone and Other Air Pollution: Tropospheric ozone; Particulate matter; Air Quality Index
6. Climate Change: Greenhouse gases; Climate change; Carbon footprint; Alternative sources of energy; End GLOBE measurements
7. Analyzing GLOBE Data: Graphing and analysis of student-collected data

The curriculum involves students in air pollution and meteorology measurements using protocols developed by the GLOBE Program (Global Learning and Observations to Benefit the Environment; www.globe.gov). The GLOBE protocols used here—cloud cover, humidity, surface and air temperature, wind direction, and surface ozone—are specifically aimed at elementary students. For Texas classrooms, this curriculum covers many of the Texas Essential Knowledge and Skills (TEKS) tested on the Texas Assessment of Knowledge and Skills (TAKS) exam. Targeted TEKS are listed in the front of this package and at the top of each lesson.

1.2 Goals:

This curriculum is an inquiry-based program. This means that the lessons are not completely based on lecture and rote memorization of facts. Instead, under the guidance of an instructor, students are given enough background knowledge and tools to explore relationships within the data they collect. In particular, students will create their own experimental hypotheses regarding how air pollution relates to the weather conditions that they measure. The Lessons also engage students in activities such as brainstorming exercises, in-class demonstrations, and computer games to boost their understanding of Earth Science.

[1] This content is available online at <http://cnx.org/content/m34366/1.3/>.

The content and activities cover important science and math learning objectives to build students' knowledge base. At the same time, the experience of engaging in scientific inquiry is intended to spur students toward a curiosity and excitement for ongoing pursuit of scientific learning.

1.3 Materials Provided:

Each Lesson contains a Teacher's Guide, student worksheets, and an answer key. The Teacher's Guide includes the following material:

- Objectives for the Lesson
- Targeted science and math TEKS (for TAKS exam in Texas)
- Background information on the topic
- Key vocabulary
- Expected student outcomes
- Resources for additional information and activities
- Step-by-step guide listing the discussions and activities to be conducted

Depending on available time, teachers may omit some of the listed activities, or utilize the outside resources for additional enrichment. Teachers may also choose to spread a Lesson over more than one day. However, teachers must plan ahead to handle the logistics of the GLOBE measurements (Lessons 2-6), which are designed to be taken during the first five minutes and last five minutes of an hour.

The student worksheets serve as a journal for students to record their ideas, observations, and results as they proceed through the lessons. This allows students to keep their work in one place and provides an assessment tool for teachers to gauge student progress.

In addition to the Teacher's Guides, Student Worksheets, and Answer Keys, the Curriculum provides you with the following resources:

- GLOBE Instruction Manual, summarizing GLOBE measurement protocols used in this curriculum
- Worksheet for recording daily measurements, along with Cloud Guide used by the worksheet
- 5th grade Science and Math TEKS learning objectives covered by curriculum
- Pre/post-quiz of 10 retired TAKS questions related to curriculum (optional)
- Teacher and student surveys to provide feedback about the curriculum (Please send to: Prof. Daniel Cohan, Dept. of Civil & Environmental Engineering, Rice University, 6100 Main St. MS 317, Houston, TX 77005)

1.4 Implementation:

Lessons are intended to be done in sequence. However, the lessons are designed so that they can either be done all at once, or they can be taught one at a time, spread out over the course of an entire year. Teachers may choose to omit some components if they have already been covered at other points of the school year.

1.5 Acknowledgments:

This curriculum development was funded as part of a National Science Foundation CAREER award to Professor Cohan. We gratefully acknowledge guidance and review of the curriculum development by Lauren Topek and Markeshia Ellis of the Houston Independent School District; C. J. Thompson of the Rice Elementary Model Science Laboratory; and Dr. Janice Bordeaux at Rice.

Comments: The Rice Air Curriculum is intended to evolve with the support of feedback from teachers. We encourage you to share suggestions by email (cohan@rice.edu; http://cohan.rice.edu) or by mailing back the surveys.

Chapter 2

Rice Air Curriculum - GLOBE Overview Instruction Manual[1]

2.1 Overview:

The Rice Air Curriculum involves students in air pollution and meteorology measurements using protocols developed by the GLOBE Program (Global Learning and Observations to Benefit the Environment). The GLOBE protocols used are—cloud cover, humidity, surface and air temperature, wind direction, and surface ozone. The notes below are summarized from the full GLOBE protocols available online at www.globe.gov.

2.2 Setting Up a Measurement Station:

It is very important that a measurement station is set up. The station should be set up in an open area (at least 30 feet from the nearest building). Set up a bench or table that is about 1 meter off the ground where the measurement tools can be placed. The instruments placed on the table should not be exposed to direct sunlight.

Wind Vane:

1. Assemble the wind vane by placing the pointer on the vane.
2. Place the wind vane on the table or bench. (If it is possible, set up the wind vane in an even higher place to get a more accurate measurement of the true wind direction.)
3. Use a compass the find magnetic North and align the base of the wind vane to match true North.
4. Students can now read the direction of the wind. (Since the end of the pointer with the larger area is blown away from the wind direction, the pointer will point towards the direction of wind i.e. if the sharp end points toward the wind, the wind is coming from the north).

[1] This content is available online at <http://cnx.org/content/m34365/1.5/>.

Figure 2.1

Cloud Charts:

The cloud chart kit includes several activities that you may do with your students in order to familiarize them with different types of clouds. Please pick one activity to do with them before they start taking measurements in Lesson 2.

Please hang up the cloud chart in the classroom so that students may look at it for reference when they write down what types of clouds they see in the sky during each measurement that they take.

Figure 2.2

Example 2.1

Digital Hygrometer/Thermometer:

1. Place the instrument on the table when students go outside to set up the ozone strip.
2. Record the current temperature and the relative humidity.
3. When students go back outside to scan the ozone strip, record the current temperature and the relative humidity.
4. Return the instrument to the classroom and store in a dry place.

NOTE: This instrument can be damaged by condensation. So, if it is wet outside, record 100% relative humidity as an approximation and do not use the instrument that day.

Figure 2.3

Infrared Thermometer (IRT):

1. Wrap the IRT in the thermal glove provided or place it outside 30 minutes before taking measurements (so it can adjust to the outside temperature). [Note: The thermal glove is an oven mitt, cut to provide an opening for the front of the thermometer]
2. Point the IRT at the surface students want to measure the temperature of and pull the trigger. The temperature will pop up on the display – record this value.
3. Have students choose three places they would like to take the surface temperature of and record these temperatures. Some recommendations are a grassy area or a concrete area. Students may hypothesize about what surfaces have lower or higher temperatures compared to each other, and how this might relate the amount of surface ozone measured. Students will use this data along with other measurements during Lesson 7.
4. Students must take these three temperature measurements both when the ozone strip is exposed and when it is read.

Figure 2.4

Zikua Ozone Scanner and Ozone Strips:

The ozone strips (Eco-Badge Test Cards) are chemically sensitive strips that change color in the presence of ozone.

Figure 2.5

The Zikua Ozone Scanner is an optical reader designed to measure the concentration level of surface ozone after an ozone strip has been exposed for one hour. The ozone scanner consists of

- an LCD display on the face of the unit
- a sliding on/off switch, top right on the unit face
- two command buttons on the top of the unit: the left button is used for scrolling, the right for selecting values
- a slot on the left side of the unit which accepts your Eco Badge Test Card
- a screen brightness adjustment screw located on the back of the unit to adjust the LCD display screen

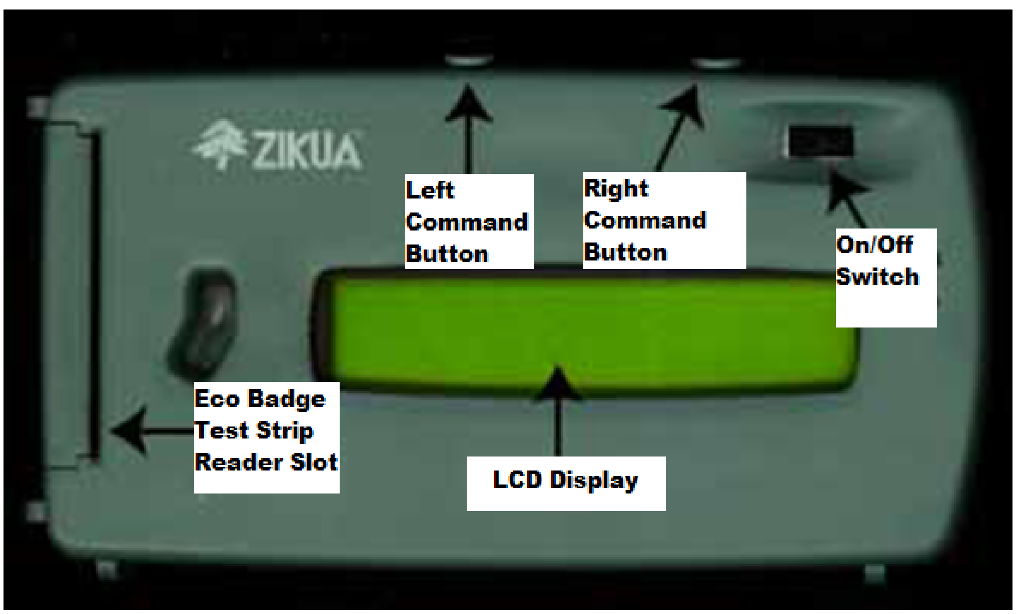

Figure 2.6

Before use, duration and measurement settings must be chosen:

1. Press the left button until the LCD shows the Settings command:

Figure 2.7

1. Press the right button to specify the Settings command. Press the right button repeatedly to scroll through duration options. You want to choose 1 HOUR.

Figure 2.8

1. When the test duration you want to use is displayed, press the left button. Press the right button repeatedly to scroll through measurement options. Select PPB (Parts per billion).

Figure 2.9

The Zikua then must be calibrated:

1. Calibrating the Zikua uses an unexposed Test Card for a reading to establish a baseline standard for reading exposed Test Cards. This is important and should be performed each time you begin a new series of Zikua readings and then every fifteen to twenty tests.
2. Select the calibration command. From the Settings display, scroll through the command options (by pressing the left button repeatedly) until the following display appears:

Figure 2.10

1. Press the right button. The LCD shows:

Figure 2.11

1. Insert an unexposed one hour Test Card, printed side up, into Zikua's Test Card slot. A number appears in the lower right side of the LCD.
2. Press the left and right buttons at the same time to save your calibration. Remove the unexposed Test Card from the slot. The number 171 (a range of 168 to 174 is acceptable) will now appear in the lower right hand corner of the display.

Now, the Zikua and the Eco-Badge Test Cards are ready to be used:

Please read Teacher Support available on pages 3-4 of the GLOBE Surface Ozone Protocol http://www.globe.gov/tctg/ozone.pdf?sectionId=15&rg=n&lang=EN. This discusses the logistics of placing the test card in the measurement station and then reading it, and also the general care and use of the Zikua Ozone Scanner.

Once the Test Card has been exposed for one hour, the Zikua can be used to read it:

Insert the exposed Test Card with the printed side facing up into the Test Card slot.

Zikua reads the card and displays its reading in the lower right of the LCD.

It is important to read the handheld scanner in a shaded area with the scanner placed on a level, stable surface. The scanner should be outside for at least five minutes before it is used so that it can adjust to outside conditions.

Chapter 3

Rice Air Curriculum - Targeted TEKS (Texas Essential Knowledgle and Skills)[1]

NOTE: The Texas Assessment of Knowledge and Skills (TAKS™) was implemented in Texas beginning in spring 2003. The Rice Air Curriculum targets many of the TEKS (Texas Essential Knowledge and Skills) that are covered on this exam. Below can be found a list of the 3rd, 4th, and 5th grade TEKS that are targeted.

3.1 Math TEKS that will be targeted in this curriculum

3.1.1 (a) Introduction.

(1) Within a well-balanced mathematics curriculum, the primary focal points at Grade 5 are comparing and contrasting lengths, areas, and volumes of two- or three-dimensional geometric figures; representing and interpreting data in graphs, charts, and tables; and applying whole number operations in a variety of contexts.

3.1.2 (b) Knowledge and skills.

(2) Number, operation, and quantitative reasoning. The student uses fractions in problem-solving situations.

(5) Patterns, relationships, and algebraic thinking. The student makes generalizations based on observed patterns and relationships. The student is expected to:

- (A) describe the relationship between sets of data in graphic organizers such as lists, tables, charts, and diagrams;

(11) Measurement. The student applies measurement concepts. The student measures time and temperature (in degrees Fahrenheit and Celsius). The student is expected to:

- (A) solve problems involving changes in temperature; and
- (B) solve problems involving elapsed time.

(13) Probability and statistics. The student solves problems by collecting, organizing, displaying, and interpreting sets of data. The student is expected to:

- (A) use tables of related number pairs to make line graphs;

[1] This content is available online at <http://cnx.org/content/m34383/1.1/>.

- (C) graph a given set of data using an appropriate graphical representation such as a picture or line graph.

(14) Underlying processes and mathematical tools. The student applies Grade 5 mathematics to solve problems connected to everyday experiences and activities in and outside of school. The student is expected to:

- (A) identify the mathematics in everyday situations;
- (B) solve problems that incorporate understanding the problem, making a plan, carrying out the plan, and evaluating the solution for reasonableness;
- (D) use tools such as real objects, manipulatives, and technology to solve problems.

(15) Underlying processes and mathematical tools. The student communicates about Grade 5 mathematics using informal language. The student is expected to:

- (A) explain and record observations using objects, words, pictures, numbers, and technology; and
- (B) relate informal language to mathematical language and symbols.

(16) Underlying processes and mathematical tools. The student uses logical reasoning. The student is expected to:

- (A) make generalizations from patterns or sets of examples and nonexamples; and
- (B) justify why an answer is reasonable and explain the solution process.

3.2 Science TEKS that will be targeted in this Curriculum

3.2.1 Objective 1 – Student will demonstrate an understanding of the nature of science

(3.1, 4.1, 5.1) Student conducts field and laboratory investigations following home and school safety procedures and environmentally appropriate and ethical practices

- Demonstrate safe practices during field and laboratory investigations

(5.2) Students uses scientific methods during field and laboratory investigations

- (a) plan and implement descriptive and simple experimental investigations including asking well-defined questions, formulating testable hypotheses, and selecting and using equipment and technology
- (b) collect information by observing and measuring
- (c) analyze and interpret information to construct reasonable explanations from direct and indirect evidence
- (d) communicate valid conclusions
- (e) construct simple graphs, tables, maps, and charts using tools (including computers) to organize examine, and evaluate information

(3.3, 4.3, 5.3) Student uses critical thinking and scientific problem solving to makes informed decisions

- (a) analyze, review, [and critique] scientific explanations, including hypotheses and theories, as to their strengths and weaknesses using scientific evidence and information
- (b) draw inferences based on information [related to promotional materials] for products and services
- (c) represent the natural world using models and identify their limitations

5.4 Student knows how to uses a variety of tools and methods to conduct scientific inquiry

- (a) collect and analyze information using tools

3.2.2 Objective 3 – Student will demonstrate an understanding of the physical sciences

(4.6) Student knows that change can create recognizable patterns

- (a) identify patterns of change such as in weather and objects in the sky

(4.7) Conduct tests, compare data, and draw conclusions about physical properties of matter including states of matter, conduction, density, and buoyancy

3.2.3 Objective 4 – Student will demonstrate an understanding of the earth sciences

(5.6) Student knows that some change occurs in cycles

- (b) identify the significance of the water, carbon, and nitrogen cycles

(3.11) Students knows that the natural world includes objects in the sky

- (a) identify and describe the importance of gases in the atmosphere in the local area, and classify them as renewable, nonrenewable, or inexhaustible

(3.6) Student knows that forces cause change

- (b) identify that the surface of the Earth can be changed by forces such as glaciers

(5.5) Student knows that a system is a collection of cycles, structures, and processes that interact

- (a) describe some cycles, structures, and processes that are found in a simple system
- (b) describe some interactions that occur in a simple system

(4.6) Student knows that change can create recognizable patterns

- (a) identify patterns of change such as in weather and objects in the sky

3.2.4 TEKS Revisions

> NOTE: TEKS has been revised for the 2010-2011 year. Everything listed above is included in the new TEKS. The following below are either new objectives that have been added, or that have become more detailed. Those new objectives that will also be covered in this new curriculum are listed below:

(5.3) The study of elementary science includes planning and safely implementing classroom and outdoor investigations using scientific processes, including inquiry methods, analyzing information, making informed decisions, and using tools to collect and record information, while addressing the major concepts and vocabulary, in the context of physical, earth, and life sciences. Districts are encouraged to facilitate classroom and outdoor investigations for at least 50% of instructional time.

(5.4) In Grade 5, investigations are used to learn about the natural world. Students should understand that certain types of questions can be answered by investigations and that methods, models, and conclusions built from these investigations change as new observations are made. Models of objects and events are tools for understanding the natural world and can show how systems work. They have limitations and based on new discoveries are constantly being modified to more closely reflect the natural world.

(5.3) Scientific investigation and reasoning. The student uses critical thinking and scientific problem solving to make informed decisions. The student is expected to:

- (a) in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, including examining all sides of scientific evidence of those scientific explanations, so as to encourage critical thinking by the student;
- (b) evaluate the accuracy of the information related to promotional materials for products and services such as nutritional labels;
- (c) draw or develop a model that represents how something works or looks that cannot be seen such as how a soda dispensing machine works; and
- (d) connect grade-level appropriate science concepts with the history of science, science careers, and contributions of scientists.

(5.7) Earth and space. The student knows Earth's surface is constantly changing and consists of useful resources. The student is expected to:

- (c) identify alternative energy resources such as wind, solar, hydroelectric, geothermal, and biofuels

Chapter 4

Rice Air Curriculum - Teacher Survey[1]

In the **Links Box** you can find two teacher surveys:

a. **Teacher Survey** – to completed after the curriculum has been taught
b. **Teacher Training Survey** – to be completed after GLOBE Instrument Training

Please return these surveys to Dr. Dan Cohan of Rice University (cohan@rice.edu)

[1]This content is available online at <http://cnx.org/content/m34384/1.1/>.

Chapter 5

Rice Air Curriculum - Student Survey[1]

In the **Links Box**, you can find a student survey. Please have students complete this after the curriculum has been taught.

Please return this survey to Dr. Dan Cohan of Rice University (cohan@rice.edu)

[1]This content is available online at <http://cnx.org/content/m34381/1.1/>.

Chapter 6

Rice Air Curriculum - Student Pre/Post Quiz[1]

In the **Links** box, you can find the Student Pre/Post Quiz. All questions on the quiz are based on the 5^{th} grade TAKS test. Teachers are recommended to give this short quiz to students before and then after the curriculum is taught to see how students improve. Answers should not be given to the students until after the second time they take the quiz.

[1] This content is available online at <http://cnx.org/content/m34382/1.1/>.

Chapter 7

Rice Air Curriculum - Lesson 1 (Student): Introduction to the Atmosphere[1]

7.1 Overview

Today, you will begin to learn about the atmosphere—the air that surrounds Earth. Even though the atmosphere is mostly invisible gases, it plays important roles in protecting the Earth, regulating its temperature, and helping to sustain life. At the end of the lesson, your teacher will show you some cool tools that will let you measure the weather and air pollution outside your school and learn more about the air around you!

7.2 Demonstration: Glass of ice and water and the Three States of Matter

Your teacher will show you a glass of ice and water to demonstrate the three states of matter.

Exercise 7.1
What solid do you see in this demonstration?

Exercise 7.2
What liquid do you see in this demonstration?

Exercise 7.3
Even though water vapor gas in the air is invisible, how do we know it exists? (Hint: Think about why the water droplets form on the outside of the glass.)

7.3 Discussion

Gases. Your teacher will help you brainstorm other examples that demonstrate that air exists, even though most gases are invisible.

Exercise 7.4
What are examples of things you can observe to see that air really does exist?

Atmosphere. Your teacher will share with you some interesting facts the atmosphere and help you brainstorm why the atmosphere is so important.

[1] This content is available online at <http://cnx.org/content/m34380/1.1/>.

Exercise 7.5

What are some examples of why the atmosphere is so important for life on Earth?

Figure 7.1

Chapter 8

Rice Air Curriculum - Lesson 1 (Teacher): Introduction to the Atmosphere[1]

NOTE: Suggested Time: 60 minutes. Science TEKS: 3.11, 5.3, 5.4, 5.5. Math TEKS: 5.11, 5.14, 5.15.

8.1 Objective

The atmosphere, air pollution, and meteorology may be fairly new topics for the students, so the first day's discussions and brief demonstrations provide an opportunity to gauge their incoming knowledge. This will help teachers identify any common misconceptions to address by the end of the curriculum.

A demonstration with ice water and associated discussion will help students review three states of matter—solid, liquid, and gas—and examples of how the transfer of heat energy can cause transitions between these states. Students should then begin to think of the atmosphere around them as a mixture of gases. How do we know that air actually exists—that what surrounds us is not just empty space? Inflating a balloon and discussing how they perceive the air with their senses will help students explore this question. Teachers will also introduce the various measuring tools to the class, explain how they work, and organize students into teams for the measurements.

Students should leave with a sense of wonder about the atmosphere around them and motivated to learn more about its importance. Interesting facts in the "Background Information" section can help the teacher achieve this goal.

8.2 Background Information

Matter is anything that takes up space, and is what makes up everything that we see. Solids, liquids and gases are three states of matter. A **solid** has both a fixed volume and fixed shape. A **liquid**takes the shape of whatever container that it is in, but has a fixed volume. **Gases**, however, do not have a fixed volume—they spread out to take up space, like in a balloon.

Students should recognize examples of transitions between states of matter and the role of heat energy in causing them. Adding heat energy can convert a solid to a liquid, or a liquid to a gas. Removing heat energy can turn a gas to a liquid, or a liquid to a solid. The condensation in the ice water demonstration

[1] This content is available online at <http://cnx.org/content/m34377/1.1/>.

provides a visual example, as the cold glass condenses water vapor (gas) from the air to form liquid water on the outside of the glass.

Air is a fascinating gas. Every breath we take (~1 liter) has 10^{22}**molecules** of **air**! That is about as many stars as exist in the universe. Interestingly, if you could make a box with sides the width of a human hair, it could still have trillions of air molecules inside. However, these air molecules are so small that air appears "invisible" to the naked eye. Air molecules do scatter light, especially at blue wavelengths, which gives the sky its color. Particles suspended in the air can both scatter and absorb light, creating a hazy appearance when the air is polluted (Figure 1).

Figure 8.1: Figure 1. Houston on a hazy day (L) and on a clear day (R)

Credit: http://www.jpl.nasa.gov/news/features.cfm?feature=423

The air around the Earth is called the **atmosphere**. Viewed from space (Figure 2), we see that the atmosphere is very thin compared to the Earth overall. However, the atmosphere is vitally important to life on Earth. It contains the air that animals breathe and that plants use for photosynthesis; absorbs UV radiation; regulates the planet's temperature; blocks meteors from crashing onto our surface; and is where weather occurs.

The mass of the atmosphere (about 1.1×10^{19} pounds, or 5.1×10^{18} kilograms) can best be understood by considering **atmospheric pressure**, which is the pressure exerted by the weight of the atmosphere above a given point. Atmospheric pressure averages 14.7 psi (pounds per square inch) at sea level. This means that if you drew a square one inch wide and one inch long on the Earth's surface, the column of air rising above that square into space would weigh 14.7 pounds! The higher you travel in the atmosphere, the lower the density of air, but there is no definite boundary where the atmosphere ends and outer space begins.

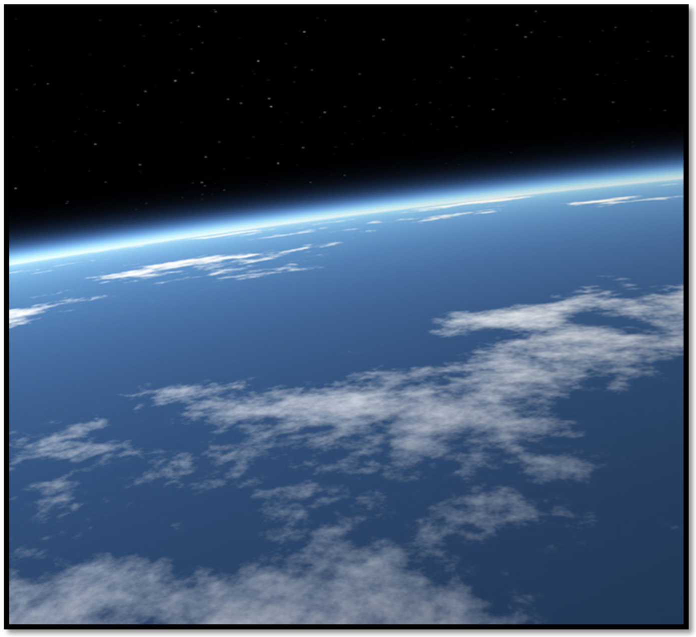

Figure 8.2: Fig. 2. From space, the atmosphere appears as a thin blue line between Earth and outer space.

Credit: http://www.adventures.com.sg/

8.3 Materials (for a class of 25)

- Water glass (1 per class)
- Water (Enough to fill the glass)
- Ice
- 1 Hot plate (if possible)
- Access to Brainpop.com
- Computer
- Balloons (1 per student)

8.4 GLOBE instruments (described in GLOBE measurement protocols at www. globe.gov):

- Ozone strips (1 per class)
- Ozone Scanner (1 per class)
- Hygrometer (1 per class)
- Infrared Thermometer (1 per class)
- Cloud Charts (1 per class)
- Wind Vane (1 per class)
- Thermal Glove (1 per class)

8.5 Vocabulary

- Matter
- Solid
- Liquid
- Gas
- Air
- Temperature
- Heat Energy
- Thermometer
- Atmosphere
- Molecules
- Atmospheric Pressure

8.6 Demonstration: The Three States of Water (Step 2 of Lesson Plan)

This demonstration is geared toward introducing students to three states of matter, and how transfers of heat energy can change the state of matter.

1. In a clear glass, put in cold water and ice.
2. Condensation should form on the outside of the glass.
3. Explain or let your students try to explain what states of matter they see. In this example, the water is a liquid and the ice is a solid. The "wetness" on the outside of the glass is a liquid that forms as the water vapor (gas) from the outside air cools and condenses onto the glass.
4. It is strongly recommended that you use a hot plate to demonstrate gas as the third state of matter, and how heat energy can change the state of matter. Heating a pot of water until it begins to steam, you can explain to students that heat energy from the hot plate is converting some of the liquid water into the gas (steam) that is being released.
5. Ask students to explain what transfers of heat energy are causing the changes in states of matter that they are observing.

Figure 8.3

Credit: http://www.acornadvisors.com

8.7 Step-by-Step Suggested Lesson Plan

Note: Page numbers listed in the Student Activity column refer to Student worksheets.

Instructor Activity	Student Activity
Explain the purpose of the curriculum. Let the students know that they will be learning about the Earth's atmosphere, air pollution, and meteorology.	
Demonstration: The Three States of Water (ice-water demonstration on previous page)	Students observe the demonstration and answer questions (p. 1)
Optional Video: "States of Matter" on Brainpop.com.	Students watch and take notes
Demonstration: Ask the class to blow up balloons, and ask them what is filling up the space inside.	Students participate in balloon activity and learn that air is a gas
Brainstorming: Ask students why they cannot see the air around them. Then, ask them to describe experiences that they have had that demonstrate that air exists. For example, blowing warm air on a mirror (warm air condenses onto cool surface), seeing wind turn a pinwheel or windmill, blowing bubbles underwater, etc.	Students brainstorm other examples that show air exists and write down examples (top of p. 2)
Discussion/Brainstorming: Share with students interesting facts from the "Background Information" section about the air and the atmosphere to pique their interest about the atmosphere. Brainstorm with students about why the atmosphere, though so thin, is actually quite important.	Students discuss, ask questions, and answer questions at bottom of p. 2.
Demonstration: Introduce each measuring tool to the students, and invite questions from the students as they pass around the tools. Let students know how each tool works, and that they will get to use them to measure air pollution and meteorology.Ozone stripsOzone scannerInfrared thermometer gunHygrometerCloud chartsWind vaneThermal glove	Students interact with each other and with the teacher as they handle each instrument and learn how each one works in preparation for Lesson Two. Students fill in instrument names and what they measure (p.3)

Table 8.1

8.7.1 Expected Outcomes:

1. Students are reacquainted with the three states of matter.
2. Students seek out examples of how transfers of heat energy can cause the state of matter to change.
3. Students identify examples that demonstrate the existence of air and the importance of the atmosphere.

4. Though students may not understand exactly how the measuring instruments work, they become familiar with each instrument to help prepare them for the measurements in the following class periods.
5. Students should complete Lesson One Journal Activities.

Chapter 9

Rice Air Curriculum - Lesson 2 (Student): Physical Properties of the Atmposphere[1]

9.1 Overview

Today, you will take your first measurements outside! You will be measuring the amount of ozone in the air, the humidity, the wind direction, the air temperature, and the temperature of some surfaces. You will also be able to observe the types of clouds that are in the sky. You will take these measurements at both the beginning and at the end of the class.

You will also be learning about the layers of the atmosphere and about two physical properties of the atmosphere: temperature and wind.

9.2 Label the layers of the atmosphere

What is something that you might find in each layer?

1.
2.
3.
4.
5.

[1] This content is available online at <http://cnx.org/content/m34378/1.1/>.

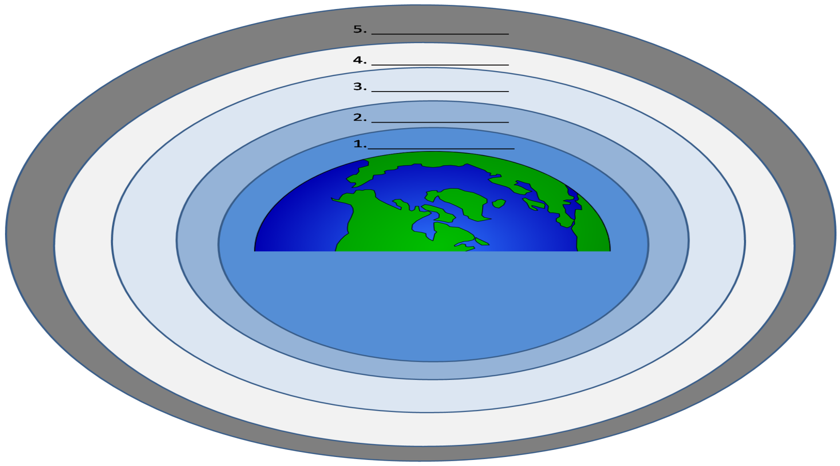

Figure 9.1

9.3 Temperature

Which instruments do we use to measure temperature?

What is an urban heat island? What causes it to occur?

9.4 Wind

Which instrument do we use to measure wind direction?

What causes the wind to blow?

9.5 You have begun measuring surface temperature and air temperature with your GLOBE measurements.

Which instruments did you use to measure surface temperature and air temperature?

What types of objects did you measure for surface temperature?

Which object had the warmest surface temperature? Why do you think that object was warmer than the other objects?

Chapter 10

Rice Air Curriculum - Lesson 2 (Teacher): Physical Properties of the Atmposphere[1]

NOTE: Suggested Time: 65 minutes. Science TEKS: 3.11, 4.6, 5.3, 5.1, 5.2, 5.4, 5.5, 5.6 .Math TEKS: 5.11, 5.14, 5.15.

10.1 Objective

Students will begin to take the following measurements outside—the amount of ozone in the air, surface temperature and air temperature, types of clouds in the air, humidity, and wind direction. These measurements will continue for five class periods. At this point in time, students do not have enough knowledge to analyze the results they get. Creating hypotheses, drawing conclusions, and communicating their findings about the trends in data will occur later in the course. However, you can involve the students in experimental design by helping to select exactly where to take the measurements.

Students will spend a lot of this lesson getting familiar to the tools they will be using to take measurements at the beginning and end of the class. Teachers should refrain from explaining too much about how the instruments work, unless necessary, so as to allow students the freedom to explore on their own how to make the measurements Students will be introduced to the layers of the atmosphere and will learn about two of the tangible properties of the atmosphere that they will be measuring with their GLOBE instruments: temperature and winds.

10.2 Background Information

The Earth's atmosphere is divided into five layers. The first layer, closest to earth's surface, is the **troposphere**. This is where all of our weather occurs—clouds, wind, lightning, hurricanes, rain, snow, and tornadoes. Because air density is greatest near the surface and diminishes with height, the troposphere contains about 80% of the atmosphere's mass. All of the air we breathe is in the troposphere, so it is here that air pollution is of greatest concern. Temperature is typically warmest near the ground and cools with height in the troposphere, which helps drive the weather and the mixing of pollutants.

The next layer is the **stratosphere**. This is where ultraviolet radiation from the sun reacts with oxygen to form ozone gas and the ozone layer. The oxygen and the ozone layer protect us from the cancer-causing ultraviolet radiation. This absorption of radiation causes temperatures to increase with height in the stratosphere,

[1] This content is available online at <http://cnx.org/content/m34374/1.1/>.

in contrast to cooling with height in the troposphere. This temperature pattern causes the stratosphere to be very stable; in other words, air rises and sinks very slowly in this layer.

The next layer is the **mesosphere**, which stops meteors and other fragments of things that come from space. The next layer is the thermosphere, where space shuttles orbit the earth. Finally, the last layer is the exosphere, which is the outermost portion of our atmosphere and is the layer in which satellites orbit the Earth. Outside of this layer lies space.

Layers of the Atmosphere

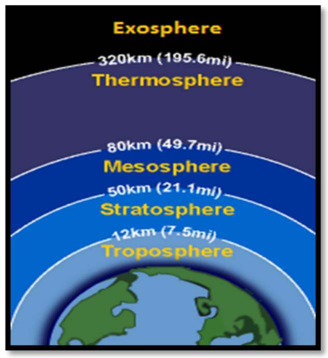

Figure 10.1: http://earthscience.files.wordpress.com/2007/04/atmosphere.gif[2]

The two most obvious ways that we experience the atmosphere are through its temperature and its winds. **Temperature** is a physical property that measures how "hot" or "cold" something is. Microscopically, it is a measure of the average kinetic energy or speed of the molecules that make up the system. Temperature can be measured in Kelvin, Celsius, and Fahrenheit.

The GLOBE instruments will allow students to measure both the **surface temperature** (the temperature of Earth's surface or other objects) and the **air temperature** (the temperature of the air). Air and surface temperature measurements are not always equal at a given location. That's because surfaces tend to change temperature more quickly than the air, warming more quickly during the day and cooling more quickly at night. Some surfaces warm more quickly than others due to their color and composition, and this can affect the temperature of the air above them. You may want to have students experiment with measuring the temperatures of different surfaces outside.

An **urban heat island** occurs when a metropolitan area is significantly warmer than surrounding rural areas. This happens because surfaces like asphalt and concrete warm up quickly and conduct their heat to the air; by contrast, much of the energy absorbed by vegetation dissipates by evapotranspiration (the sum of evaporation and plant transpiration from the Earth's surface to the atmosphere). Waste heat from our use of energy adds to the heat island.

[2] http://earthscience.files.wordpress.com/2007/04/atmosphere.gif

A typical urban heat island temperature profile

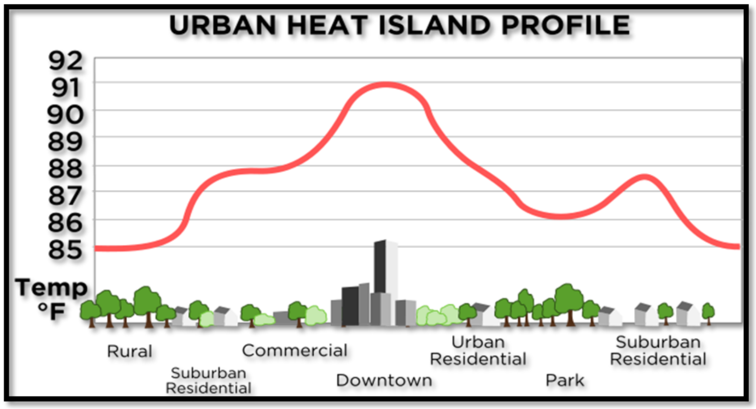

Figure 10.2: Credit: http://commons.wikimedia.org/wiki/File:Urban_heat_island.svg

Differences in temperature due to the Sun's uneven heating of the Earth are the driving force behind **wind**, or moving air. A classic example of how temperature differences cause the wind to blow is the sea breeze. On summer days near the coast, the land warms faster than the sea. This creates a wind circulation pattern in which near the ground wind blows from sea to land. At night, a "land breeze" may blow in the opposite direction as the land cools more quickly than the sea.

A sea breeze circulation on a summer day

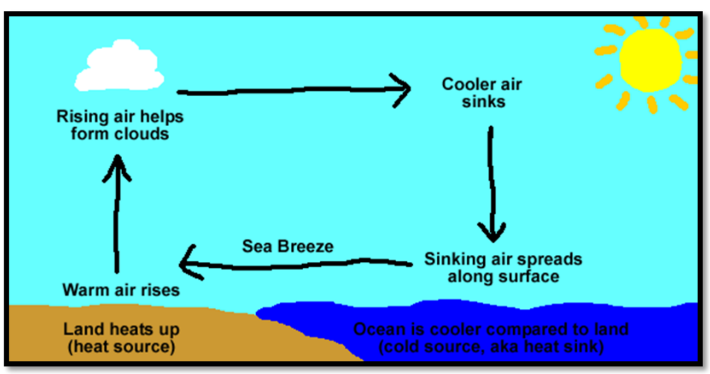

Figure 10.3: Credit:http://www.prh.noaa.gov/hnl/kids/activities.php

Students will use the wind vane to discover from what direction the wind is blowing. Though students will not directly measure wind speed, they can get a sense of it by feeling the wind blow and checking wind speed in weather reports.

10.3 Regarding GLOBE Measurements

Teachers should have already been trained in the following GLOBE protocols: Surface Ozone, Cloud, Humidity, Surface and Air Temperature, Wind Direction. An Instruction Manual has been included so that you may review how to set up and use each measuring tool. It also may be helpful to review the protocols (available at www.globe.gov) as you prepare for this lesson. Each day, beginning with today (Day Two) students will take all six measurements at the beginning and end of their class periods. Remember that there must be one hour between the measurements. For a teacher whose class periods are less than an hour, students from different classes can take the measurements.

Data sheets for students to record all of their results in an organized way are included in this handbook. It is recommended that the teacher split their classes into six groups or teams, and that each group takes turns using a different instrument. This way, all measurements can be taken at the same time. Small groups allow students to be more hands-on with the measuring tool.

It is important to choose a good spot for the class to take the measurements. All measurements should be taken in a consistent location. If your class is interested in comparing measurements in different parts of the school, the curriculum can be adapted for teams to split up and test different parts of the school, or for different classes to compare data. Doing so can enable students to develop and test hypotheses regarding how air pollution and weather conditions vary by location and time of day. This does however require more time and organization on the part of the teacher.

10.4 Vocabulary

- Atmosphere
- Troposphere
- Stratosphere
- Mesosphere
- Thermosphere
- Exosphere
- Ultraviolet Radiation
- Surface Temperature
- Air Temperature
- Fahrenheit
- Celsius
- Urban Heat Island
- Wind
- Sea Breeze

10.5 Outside Resources

- GLOBE measurement protocols: www.globe.gov
- More information about urban heat islands can be found online in The Encyclopedia of Earth (http://www.eoearth.org/article/Heat_island).
- A thermal image of Houston from a NASA sensor, showing warmer and cooler parts of the city: www.harc.edu/Projects/CoolHouston/HeatIsland/

10.6 Materials (for a class of 25)

- Computer/projection screen
- Access to Brainpop.com
- Hygrometer (1 per class)

- Infrared Thermometer (1 per class)
- Ozone Test Strips (1 per class)
- Ozone Scanner (1 per class)
- Wind Vane (1 per class)
- Thermal Glove (1 per class)
- GLOBE Measurement Data Sheets (1 per student)

10.7 Step-by-Step Suggested Lesson Plan

Instructor Activity	**Student Activity**
Measurements. Take your students outside and conduct the GLOBE protocols listed above. Students should set up the ozone strip, take the air and surface temperatures, observe the sky for clouds, and measure humidity and wind direction. This first time, take the measurements one at a time to make sure that the students are using the tools correctly and are getting accurate results.	Students help choose where measurements will be taken, especially for the multiple surfaces that will be measured for surface temperature. They take measurements and record their results on their data sheets.
Discussion. Discuss what is found in each of the five layers of the atmosphere – example: where the weather, ozone layer, and space shuttles can be found.	Students listen, ask questions, and fill out picture (p.2)
Discussion. Discuss the meaning of temperature, and how urban heat islands show that cities can affect their own temperature. Make sure that students can distinguish between surface and air temperature.	Students answer questions in journals: (top of p.3)
Optional Video. Brainpop.com: "Temperature." Complete online quiz as a class.	Students watch video and participate in quiz (Note: quizzes are online, not in worksheets).
Discussion about wind. What have their experiences been with wind? Explain the sea breeze as an example of how differences in temperature drive the winds.	Students answer questions in journals (bottom p.3).
Optional Video. Brainpop.com: "Wind." Complete online quiz as a class.	Students watch video and participate in online quiz.
Student work time.	Complete worksheets (p.4).
Measurements. Take your class outside, and scan the ozone strip. Also, have students retake the surface and air temperature and humidity measurements so that they can be averaged with those from the beginning of the class.	Students take measurements and write down their results on their data sheets.

Table 10.1

10.7.1 Expected Outcomes

1. Students measure ozone and meteorology conditions for the first time.

2. Students label the five layers of the atmosphere and know what can be found in each layer of the atmosphere.
3. Students can draw and describe an urban heat island.
4. Students can draw and label the components of a sea breeze circulation.
5. Students should complete Lesson Two Journal Activities.

Chapter 11

Rice Air Curriculum - Lesson 3 (Student): Atmospheric Gases and their Cycles[1]

11.1 Overview

You have already learned a little about Earth's atmosphere – its five layers, and some of its important properties like temperature and wind. Now we wonder, What types of gases make up the air around us? Today, we will learn about some of the important types of gases that make up the atmosphere. We will also learn about the cycles that enable those substances to move around the Earth and its atmosphere.

Exercise 11.1

What are the five main gases that make up the atmosphere?

11.2 Water Cycle

Each of the words below is a process in the water cycle. Define each word and label it in the figure below.

1) **Evaporation:**
2) **Transpiration:**
3) **Condensation:**
4) **Precipitation:**
5) **Infiltration:**

[1]This content is available online at <http://cnx.org/content/m34372/1.1/>.

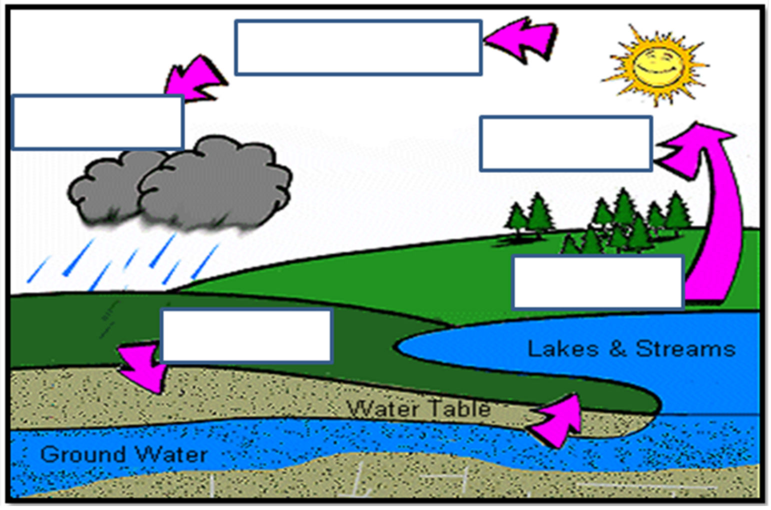

Figure 11.1: Credit: http://www.dnr.state.wi.us/org/caer/ce/eek/earth/groundwater/images/groundwater.gif

11.3 Humidity

Exercise 11.2
Humidity is a measurement of how much ________________________ is in the air.

Exercise 11.3
Which instrument do we use to measure humidity?

11.4 Clouds

Exercise 11.4
In what layer of the atmosphere do you find clouds?

Exercise 11.5
Which types of clouds did you see outside today?

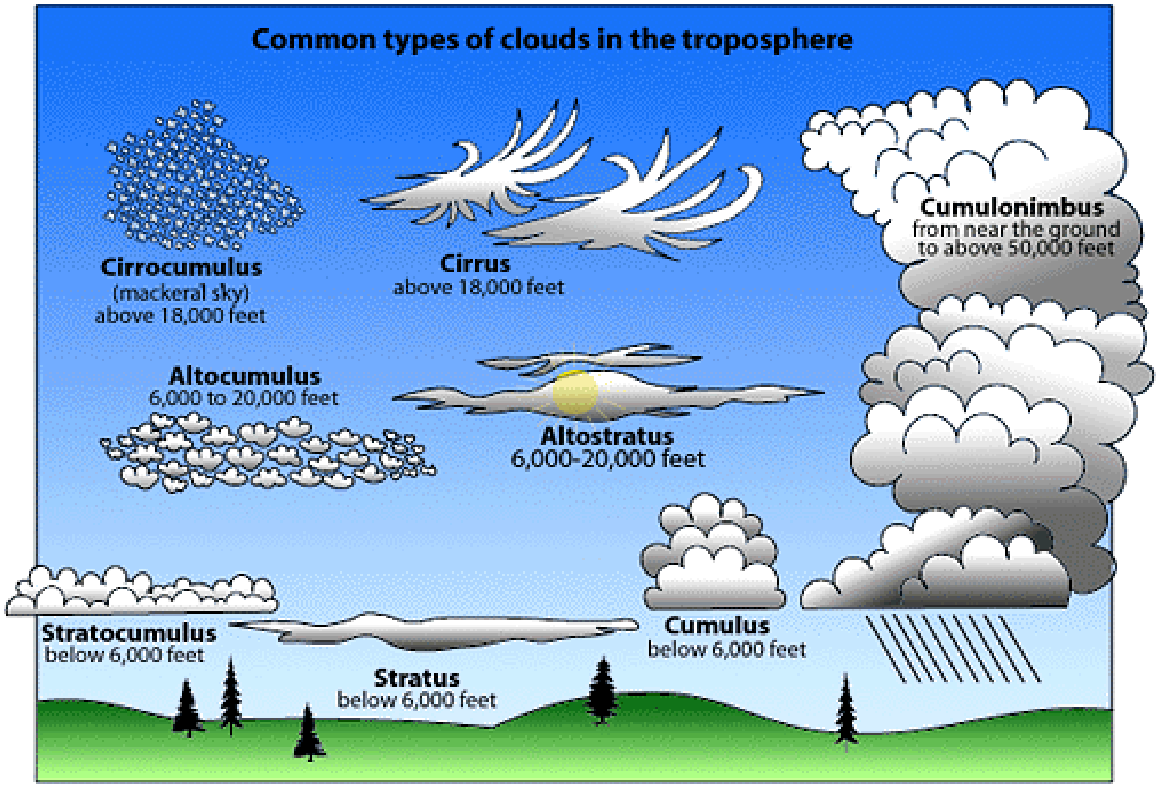

Figure 11.2: Credit: http://www.stmarysmedia.co.uk/jb01/project/images/cloudchart.gif

11.4.1

11.5 Oxygen Cycle

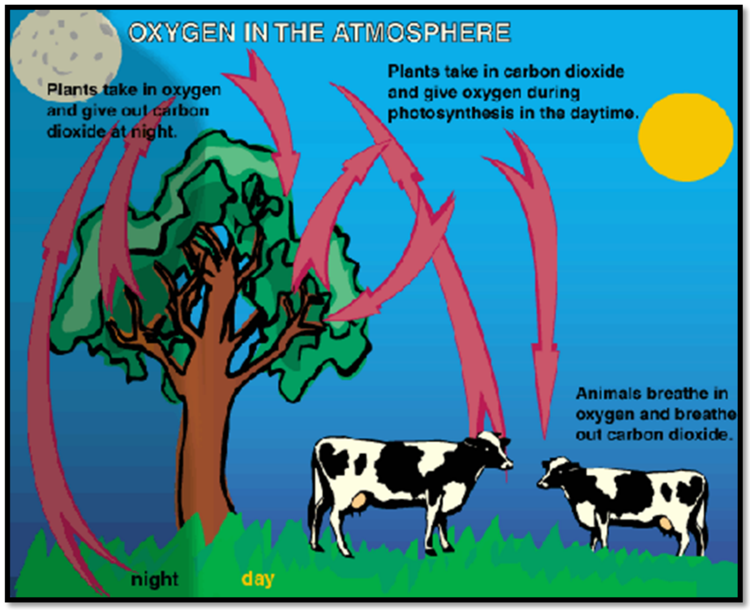

Figure 11.3: Credit: http://www.kidsgeo.com/geography-for-kids/0160-the-oxygen-cycle.php

Exercise 11.6
What percent of the atmosphere is made up of oxygen?

Exercise 11.7
Why is oxygen important to animals?

11.5.1

11.6 The Carbon Cycle

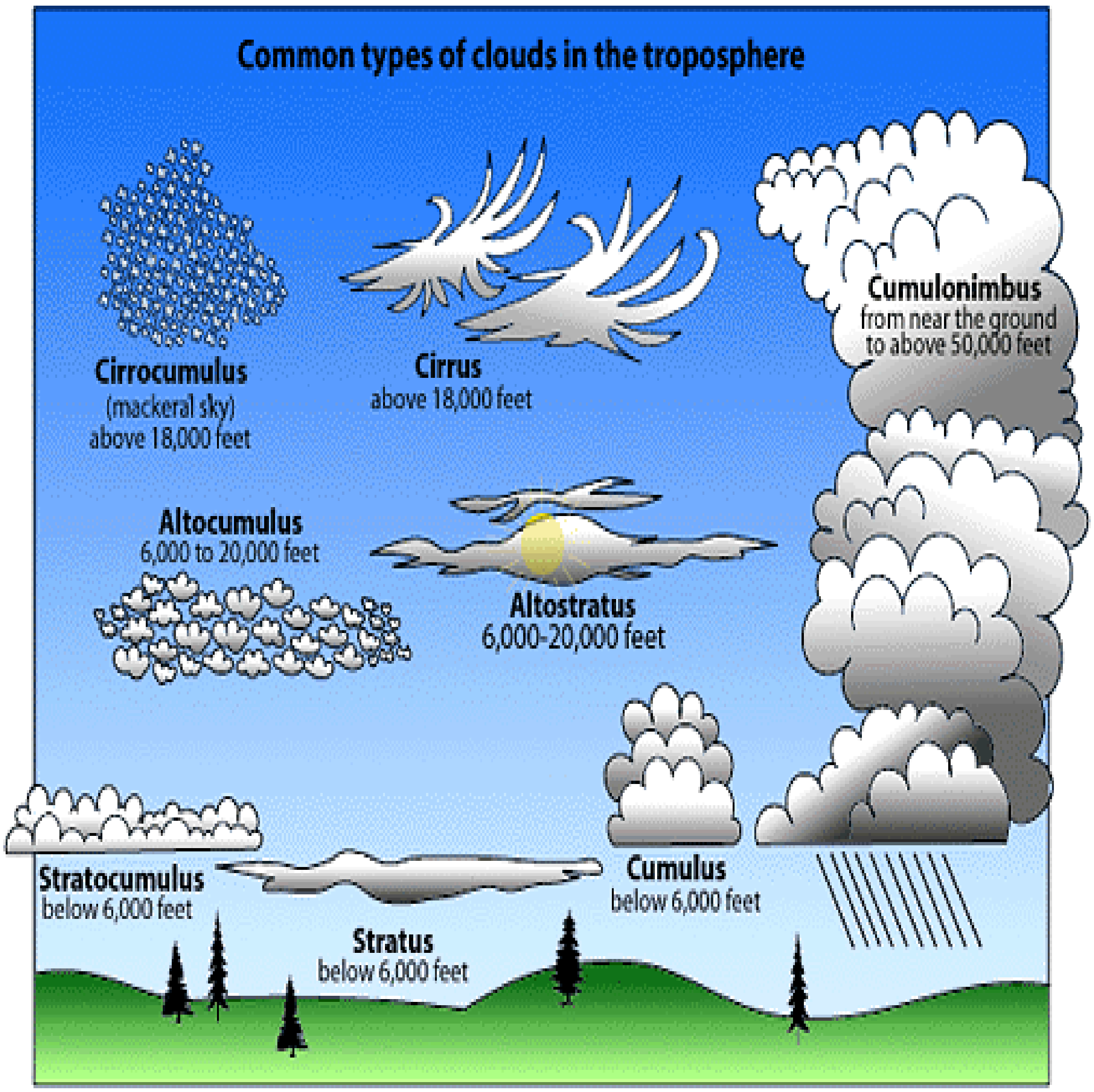

Figure 11.4: Credit: http://www.windows.ucar.edu/tour/link=/earth/climate/images/carboncycle_jpg_image.html&edu=ele

Exercise 11.8
In which process do plants take carbon dioxide from the atmosphere?

Exercise 11.9

In which process do plants, animals, and roots release carbon dioxide into the atmosphere?

Exercise 11.10

How do autos and factories affect the carbon cycle?

What did you find cool or surprising that you learned about the atmosphere today?

Chapter 12

Rice Air Curriculum - Lesson 3 (Teacher): Atmospheric Gases and their Cycles[1]

NOTE: Suggested Time: 90 minutes. Science TEKS: 3.11, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6. Math TEKS: 5.11, 5.14, 5.15

12.1 Objective

Now that students have a basic knowledge of the physical structure of the atmosphere, this lesson goes into much further detail about the most common gases that make up the atmosphere. The significance of the water cycle, the oxygen cycle, and the carbon cycle will be covered. The gases discussed today compose the vast majority of air molecules in the atmosphere; in later lessons, students will learn about air pollutants that greatly affect our health and environment even in very small quantities.

12.2 Background Information

The **atmosphere** is made up of five main gases – nitrogen (N2), oxygen (O2), argon (Ar), water vapor (H2O), and carbon dioxide (CO2). There are many other gases in very trace amounts, some of which are called air pollutants if they harm the health of humans, plants, or animals, and some of which are greenhouse gases that trap in the Earth's warmth.

To visualize the composition of the atmosphere, suppose you gathered 100 random molecules of dry air. Most likely, 78 of them would be nitrogen molecules (N2), 21 of them would be oxygen molecules (O2), and 1 of them would be an argon molecule (Ar). Depending on how warm and humid the air is, zero to four of the 100 molecules would be replaced by molecules of **water vapor** (H2O).

Now suppose that you could randomly choose 1 million molecules of air. Almost all of them (about 999,610 molecules) would be the gases we listed above: nitrogen (N2), oxygen (O2), argon (Ar), and water vapor (H2O). About 385 of them would be carbon dioxide (CO2). This is less than one-tenth of 1 percent of the Earth's atmosphere, but in Lesson 6 we'll see it has a huge effect on Earth's climate. Most of the other air pollutants that we'll study in later lessons have concentrations of less than 1 part per million, so we might not even see one in our collection of 1 million air molecules. However, we'll learn later that these air pollutants can have important effects on our health and environment.

[1] This content is available online at <http://cnx.org/content/m34375/1.1/>.

The main gases of the atmosphere undergo important cycles that are vital to life on Earth. The most apparent of these cycles is the **water cycle**, which includes all the movements of water between Earth's atmosphere, bodies of water, and underground. The total amount of water on Earth is constant, but water is continually moving to different locations and changing its form (solid, liquid, or gas).

The Water Cycle

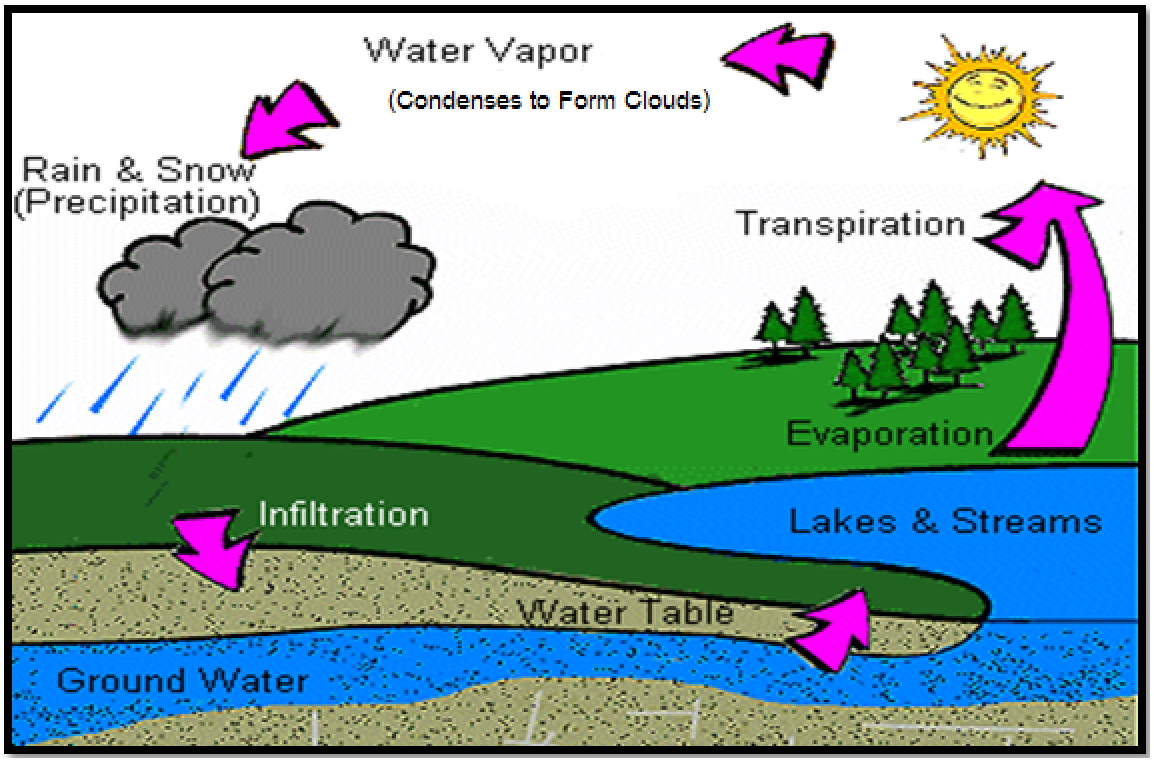

Figure 12.1: Credit: http://www.dnr.state.wi.us/org/caer/ce/eek/earth/groundwater/images/groundwater.gif

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The following steps make up the water cycle. Energy from the Sun **evaporates** liquid water from lakes and oceans to become water vapor gas in the air. Plants also release water vapor to the atmosphere by **transpiration**. The water vapor **condenses** back to liquid water higher in the troposphere, because the cooler air there cannot hold as much water vapor as warm air (recall condensation on a cold glass of water). This **condensation** occurs on small particles, forming **clouds**. Clouds can also form on the ground – this is called fog.

As more water vapor condenses and the cloud droplets grow large enough, the water can fall as **precipitation** (rain, snow, or hail). Precipitation varies in type and amount in different parts of the world. Oceans, rivers, and lakes store this water. **Infiltration** allows some of the water to move underground into the groundwater and water table. Other water evaporates from the bodies of water, starting the water cycle all over again.

The water cycle plays an integral role in the measurements students are taking. **Humidity** is the measure of the amount of water vapor in the air. The hygrometer that the students are using measures **relative humidity**: the ratio of the amount of water vapor in the air to the maximum amount that the air could hold at its current temperature, expressed as a percentage. Students are also observing **cloud types** in the GLOBE measurements.

Cloud Types

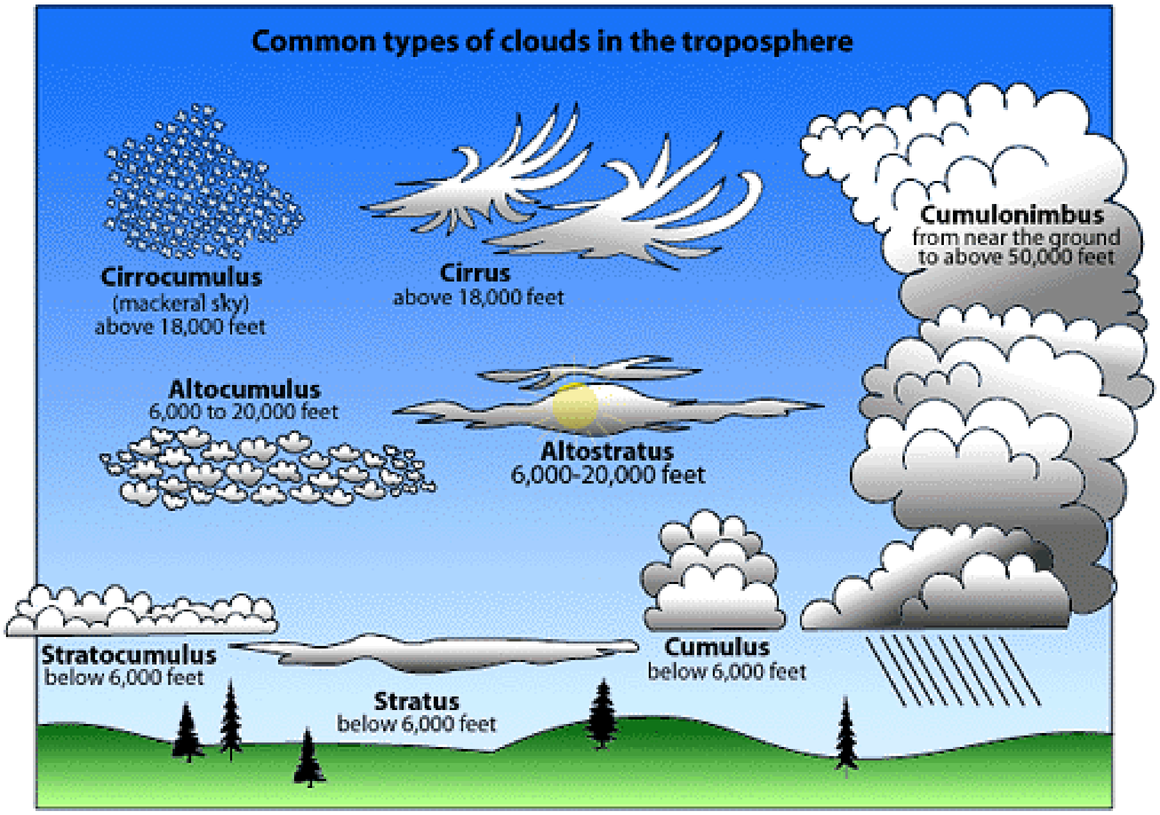

Figure 12.2

The **oxygen cycle** is critically important to sustaining the life on earth – without it, none of us would be alive! During **photosynthesis**, plants absorb carbon dioxide and sunlight and release oxygen to the atmosphere. Humans and other animals use the oxygen in the air. After the oxygen is used by the body, it is breathed back out as carbon dioxide in a process called respiration. Plants also consume some oxygen and release carbon dioxide through **respiration**.

The Oxygen Cycle

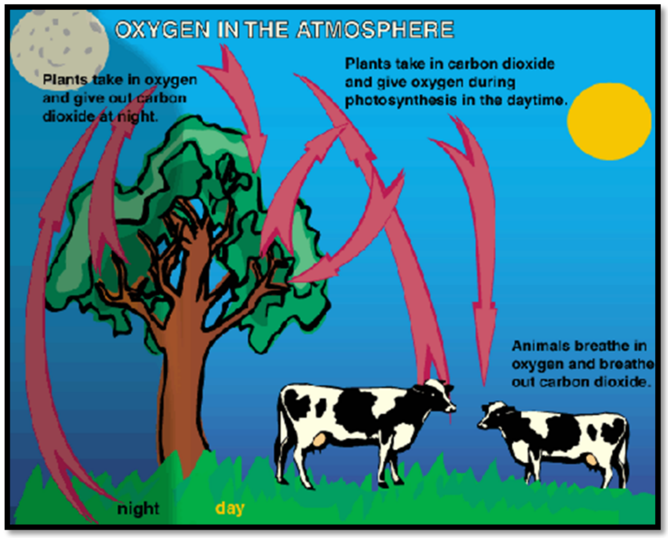

Figure 12.3: Credit: http://www.kidsgeo.com/geography-for-kids/0160-the-oxygen-cycle.php

The oxygen cycle is closely intertwined with the carbon cycle. The **carbon cycle** is how all of the carbon atoms that exist move around on the earth and in the atmosphere. In **photosynthesis**, plants absorb sunlight and carbon dioxide in order to grow. The carbon is stored in the plants as sugars, starches, and other compounds. Animals eat these plants or other animals and the carbon moves into them. These animals, and humans too, release the carbon dioxide into the atmosphere when they breathe out. When plants and animals die, they decay, and the carbon is returned to the air or ground, where some of it can be reused by plants or small microorganisms. Over millions of years, some of the carbon can transform into fossil fuels. When these fossil fuels are burned by cars or factories, carbon dioxide is released into the air.

Despite its small concentration, carbon dioxide plays an important role – it acts as a greenhouse gas, keeping the Earth warm; plants use it for photosynthesis; and it is released when we breathe out or material decays. We will discuss carbon dioxide in much greater detail in Lesson 6.

The Carbon Cycle

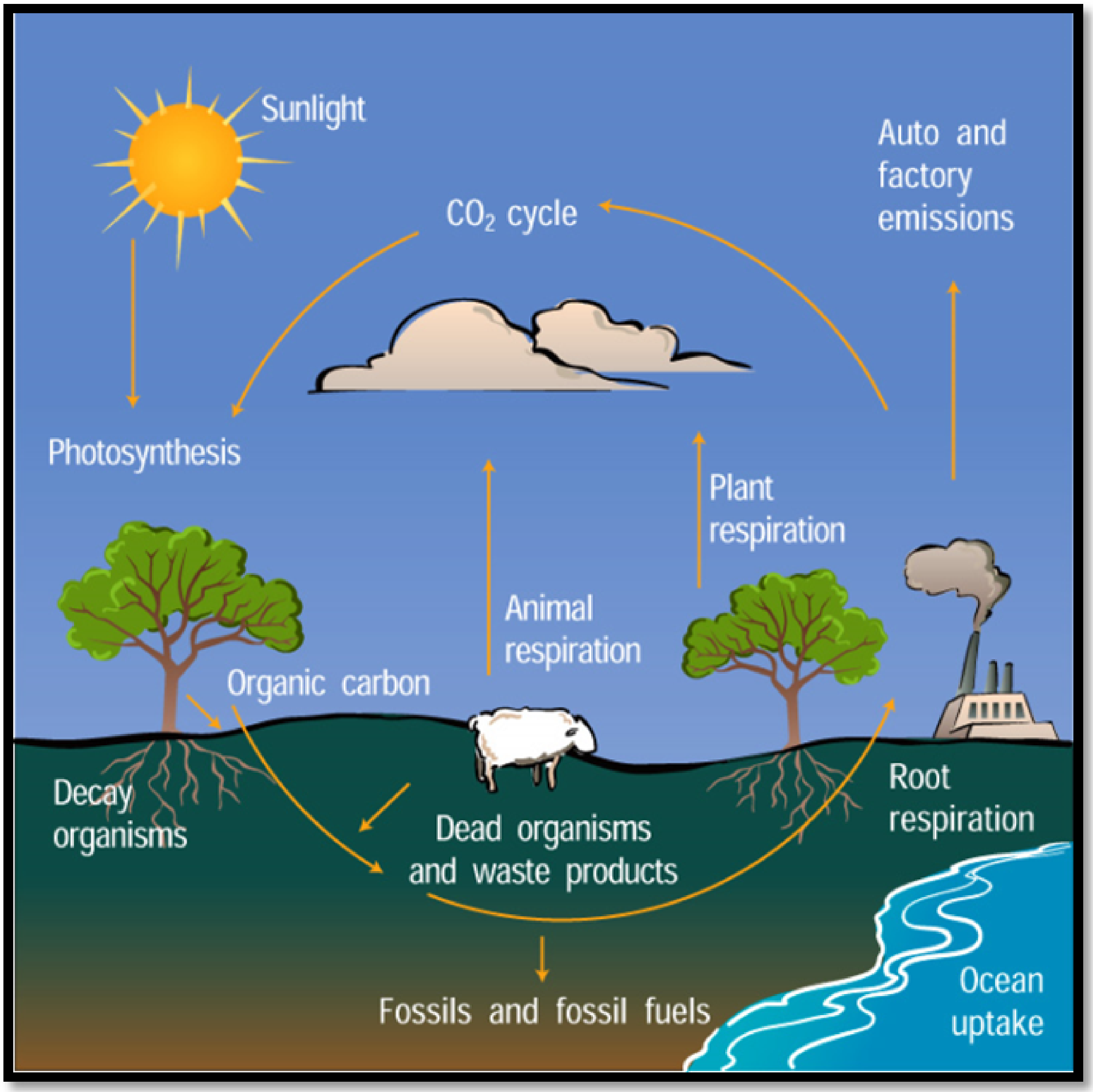

Figure 12.4: Credit: http://www.windows.ucar.edu/tour/link=/earth/climate/images/carboncycle_jpg_image.html&edu=ele

12.3 Vocabulary

- Clouds
  - Water Cycle
  - Carbon cycle
  - Oxygen cycle
  - Humidity

- Relative Humidity
- Precipitation
- Condensation
- Evaporation
- Infiltration
- Transpiration
- Cirrus
- Cumulonimbus
- Cumulus
- Stratus
- Surface Water
- Respiration
- Photosynthesis

12.4 Materials (for a class of 25)

- Hygrometer (1)
- Infrared Thermometer (1)
- Ozone Test Strip (1)
- Ozone Scanner (1)
- Wind Vane (1)
- Thermal Glove (1)
- Cloud Charts
- GLOBE Data Sheets
- Computer
- Projection Screen
- Access to Brainpop.com
- 101 Cloud Activities
- Cotton Balls
- Various Art Supplies

12.5 Step-by-Step Suggested Lesson Plan

Instructor Activity	**Student Activity**
Measurements. Take your students outside and conduct the GLOBE protocols. Students should set up the ozone strip, take the air and surface temperature, observe the sky for clouds, and measure humidity and wind direction.	Students take measurements.

continued on next page

Review. Take a few minutes to review what students have already learned about the atmosphere (e.g. its importance, layers, temperature, and wind).	
Discussion. Next, introduce students to the 5 main gases that make up the atmosphere (nitrogen, oxygen, argon, water vapor, and carbon dioxide), using information from the "Background Information" section. You can have students pretend to be different types of air molecules to visualize ratios of molecules (for example, about one-fifth of air molecules are oxygen). Explain the concept of a "cycle", and point out that we'll be discussing cycles that affect three of the main gases: water, oxygen, and carbon.	Students answer journal question: (p.1)
Water Cycle Video and Discussion. Introduce the water cycle with the Brainpop.com video: Water Cycle (Optional: accompanying Brainpop quiz and activity). Explain the processes of evaporation, transpiration, condensation, precipitation, and infiltration. Ask students for examples of types of precipitation.	Students watch video (and participate in optional quiz and activity), participate in discussion, and fill out journal questions (p. 2)
Humidity Discussion. Ask students to recall the Water in Three States Demonstration from Lesson One (or, repeat the demonstration). Remind them that the water that condensed on the glass came from water vapor in the air. Explain that humidity is a measure of how much water vapor the air contains. Hold up the GLOBE hygrometer to remind them of how they are measuring humidity.	Students answer journal questions (top of p. 3)
Clouds discussion. Give a short lecture about clouds. Teach the students about the different types of clouds, how they are formed, and where they are found. Students should be somewhat familiar with recognizing clouds, as they have already done a bit with the GLOBE protocol.	Students answer journal questions: (bottom of p. 3)

continued on next page

Pick 1 cloud activity to do with the class, from the 101 Cloud Activities in the GLOBE kit. Students may split into smaller groups to do the activities and play the games.	Students complete cloud activity.
Art Activity (optional): Ask the class to draw a model of the water cycle. Make sure that they can name all parts of the cycle. Cotton balls can be used to create the clouds, and they should be able to differentiate between different shapes of clouds. You can hang these models up in the classroom for future reference. Students may use construction paper, markers, crayons, glue and scissors to create the model. The following parts of the water cycle should be clearly shown and labeled on the model: evaporation, transpiration, condensation, precipitation, and infiltration. The following types of clouds should be created with the cotton balls: cumulus, stratus, cirrus, cumulonimbus.	Students complete art activity.
Discussion of oxygen and carbon cycles. Explain to students the importance of the oxygen cycle and carbon cycle and the key processes in each. Point out how the two cycles are very closely related, with photosynthesis and respiration playing important roles in each.	Students answer journal questions (p. 4-5).
Give students 3 minutes to complete the worksheets.	Students answer journal question (p. 6)
Take your class outside, and scan the ozone strip. Also, retake the surface and air temperature, and the humidity so that students can take the average of these measurements in order to supplement their ozone measurements.	Students take measurements.

Table 12.1

12.5.1 Expected Outcomes

1. Students will be able to list the gases of the atmosphere and the relative abundance of each.
2. Students should be able to draw and label a diagram of the water, oxygen, and carbon cycles and explain in a few sentences the importance of each.
3. Students should complete Lesson Three Journal Activities.

Chapter 13

Rice Air Curriculum - Lesson 4 (Student): The Dual Nature of Ozone - Stratospheric Ozone[1]

13.1 Overview

Ozone is a gas that is quite interesting because of its dual or "two-sided" nature. Ozone high up in the stratosphere naturally protects Earth from the Sun's harmful ultraviolet light. However, ozone that forms close to the ground is a major air pollutant. This type of ozone can hurt humans and our surrounding environment.

Today, we will focus on the good ozone, which is called stratospheric ozone. You will learn a lot more about the "bad ozone" air pollution near the ground during Lesson Five.

13.2 Ozone

Exercise 13.1
What does it mean that ozone is "Good up high, Bad nearby"?

Exercise 13.2
Can you think of another example of something that is good to have in one place, but bad to have somewhere else?

Exercise 13.3
Label the stratosphere, troposphere, and ozone layer in the diagram.

[1]This content is available online at <http://cnx.org/content/m34371/1.1/>.

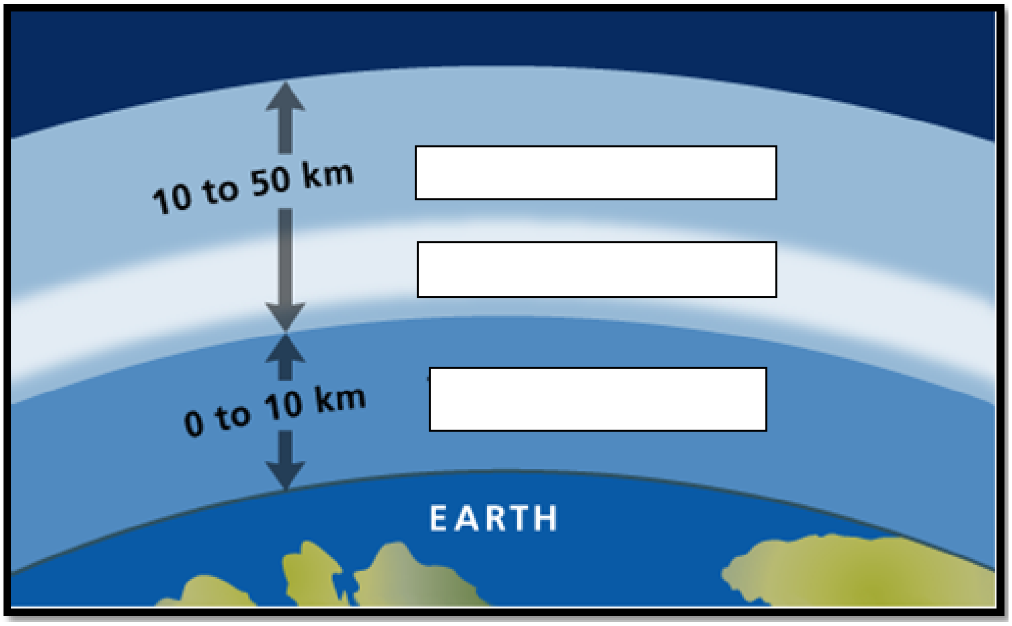

Figure 13.1

Exercise 13.4
What did you learn about the ozone layer in the video?

Exercise 13.5
In the map that your teacher showed, where was the ozone hole?

Chapter 14

Rice Air Curriculum - Lesson 4 (Teacher): The Dual Nature of Ozone - Stratospheric Ozone[1]

NOTE: Suggested Time: 65 minutes. Science TEKS: 3.11, 4.6, 5.1, 5.2, 5.3, 5.4, 5.5. Math TEKS: 5.11, 5.14, 5.15

14.1 Objective

Students have already learned about the most common gases in the atmosphere. Now they will begin to learn about how other substances in the atmosphere can strongly affect their health and the environment, even in minute concentrations. In this lesson, students will learn about stratospheric ozone and the difference between this high-level ozone (which protects the Earth from ultraviolet radiation) and low-level ozone (which is an air pollutant).

[1]This content is available online at <http://cnx.org/content/m34379/1.1/>.

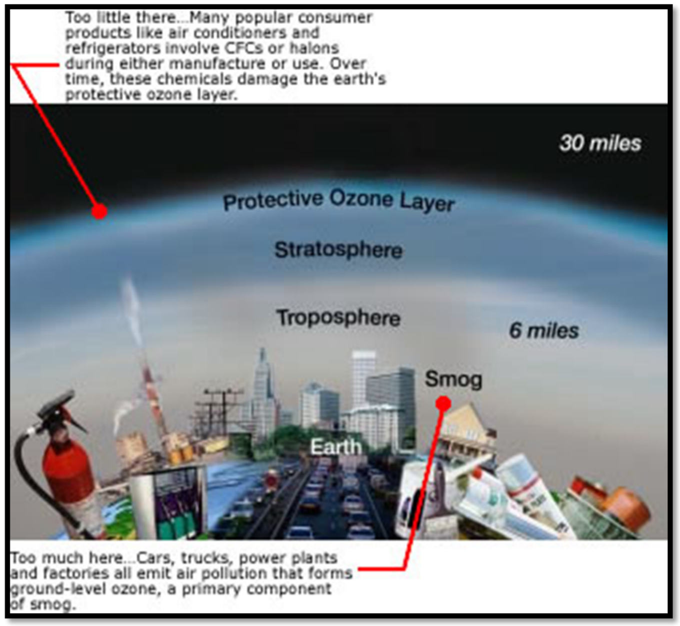

Figure 14.1: Stratospheric ozone forms naturally and protects us from ultraviolet radiation. Tropospheric ozone forms from air pollutant emissions and harms human health.Credit: U.S. EPA: "Ozone Good Up High, Bad Nearby"

14.2 Background Information

Most of the oxygen in the atmosphere, and the type that we need to sustain life, has two atoms per molecule (O2). **Ozone**, by contrast, has three oxygen atoms (O3). Ozone forms naturally in the stratosphere when intense ultraviolet radiation from the Sun splits an oxygen molecule (O2) into two O atoms. Each O can then combine with another O2 to form O3. [Note: The concept of molecules composed of atoms is above the 5th grade level; for your explanation to students, you can state that the Sun's intense UV radiation splits oxygen to form ozone].

About 90 percent of the ozone in the Earth's atmosphere is found in what is known as the **ozone layer** in the stratosphere (about 10-30 miles above Earth's surface). The ozone layer absorbs most of the Sun's **ultraviolet radiation** to shield us from these damaging rays. Ultraviolet rays can cause a range of negative effects: they can cause cancer, burn skin, damage eyes, weaken the human immune system, and harm both plants and animals. In fact, estimates show that a one percent reduction in the ozone layer results in a two to five percent increase in the number of cases of cancer!

Certain air pollutants can damage the ozone layer. The most dramatic depletion of the ozone layer is the **Antarctic ozone hole**. In the early 1980s, scientists discovered major thinning of the ozone layer above Antarctica during springtime . In fact, they observed nearly 70% less ozone than had been found there previously! Scientists realized that the depletion of the ozone layer is caused by the release of certain chemicals such as **chlorofluorocarbons** (CFCs) into the atmosphere. Just a few decades ago, CFCs were used in air conditioners, aerosol sprays, and cleaning products. When CFCs reach the stratosphere, they react with the sunlight to release chlorine atoms, which can destroy ozone molecules. In 1989, an international agreement known as the **Montreal Protocol** was signed to ban the most destructive ozone-depleting gases and preserve the ozone layer. If the agreement is adhered to, it is hoped that the ozone layer will completely recover by 2050.

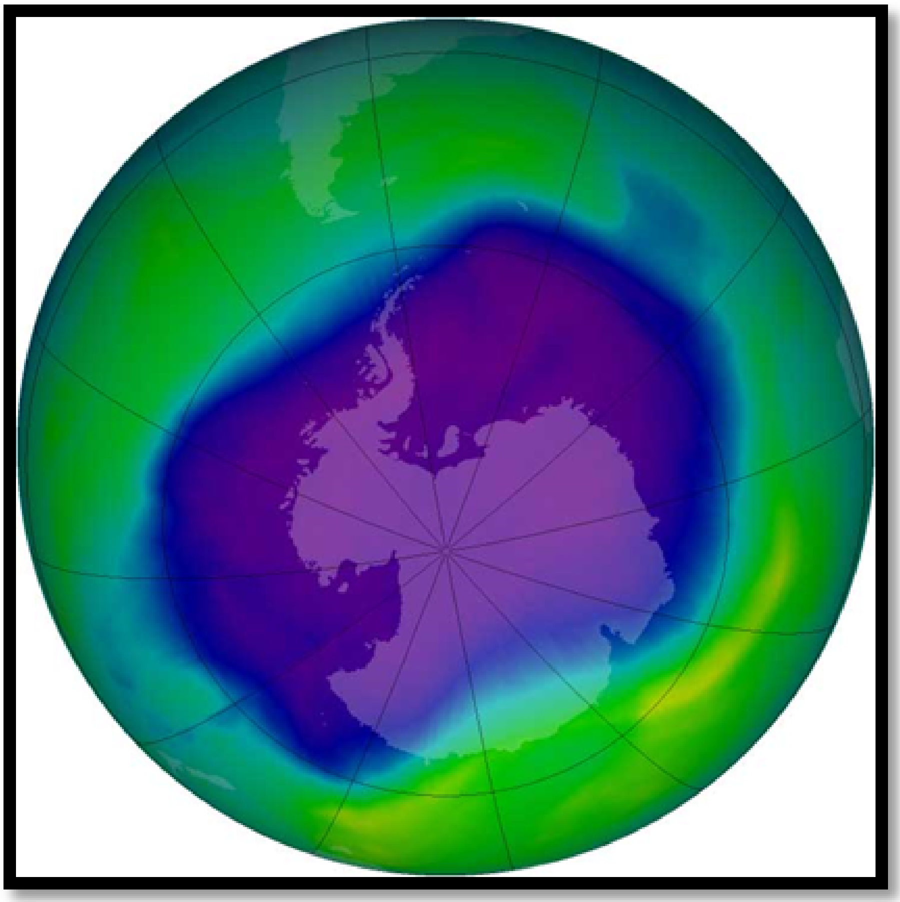

Figure 14.2: From September 21-30, 2006 the average area of the ozone hole was the largest ever observed. In this image, from Sept. 24, 2006, the Antarctic ozone hole was equal to the record single-day size of 11.4 million square miles.Credit: http://www.nasa.gov/centers/goddard/news/topstory/2006/ozone_record.html

As we have seen, the ozone layer in the stratosphere is a vital layer of protection for the Earth. This layer that contains most of the atmosphere's ozone is far above the air that we breathe every day, and even above the altitude where most airplanes fly. However, when ozone forms near the surface in the troposphere, where humans breathe, it is an air pollutant that can harm our lungs and the natural environment. This tropospheric ozone is the same molecule as in the stratosphere. However, in the troposphere, ozone forms in very different ways than in the stratosphere. We'll learn more about tropospheric ozone and other air pollutants in Lesson Five.

14.3 Additional Resources

More information about good and bad ozone can be found at **http://www.epa.gov/airnow/gooduphigh** - a booklet by the EPA called Good Up High, Bad Nearby. Other great resources regarding ozone can be found at:

1. http://www.epa.gov/ozone/strathome.html.
2. http://www.windows.ucar.edu/tour/link=/Earth/Atmosphere/ozone_overview.html&edu=mid
3. http://www.clean-air-kids.org.uk/ozonehole.html
4. Comic strip from US EPA illustrating the two types of ozone: http://www.epa.gov/ozone/sciencem/missoz/index.html.

14.4 Vocabulary

- ozone
- ozone layer
- ultraviolet rays
- Antarctic ozone hole
- Chlorofluorocarbons (CFCs)
- Montreal Protocol
- Environmental Protection Agency
- Asthma
- Cancer
- Tropospheric ozone
- Stratospheric ozone

14.5 Materials (for a class of 25)

- Hygrometer (1 per class)
- Infrared Thermometer (1 per class)
- Ozone Test Strips (1 per class)
- Ozone Scanner (1 per class)
- Wind Vane (1 per class)
- Thermal Glove (1 per class)
- Cloud Charts (1 per class)
- GLOBE Measurement Data Sheets (1 per student)
- Computer
- Access to Brainpop.com
- Projection screen

14.6 Step-by-Step Suggested Lesson Plan

Instructor Activity	Student Activity
	continued on next page

Measurements. Take your students outside and conduct the GLOBE protocols. Students should set up the ozone strip, take the air and surface temperature, observe the sky for clouds, and measure humidity and wind direction.	Students take measurements and write down their results on their data sheets.
Discussion. Ask students to think of examples of things that are good in one location, but bad somewhere else (e.g., a lion in a zoo, the flame of a candle, etc.). Explain that ozone is a gas that is "Good Up High, Bad Nearby": up high it shields Earth from radiation, but nearby it is harmful to breathe. (See "Background Information" for details and links to resources).	Students participate in brainstorming and answer related questions on p. 1.
Video. "Ozone Layer" on Brainpop.com provides a good overview of stratospheric ozone.	Students watch video and answer related questions (p. 2)
Discussion: Go into more detail about "good" stratospheric ozone. Ex: How ozone is formed, where the layer can be found, and how it protects our health from UV rays.	Students listen and answer questions: (p. 3)
Visual. Show students a picture of the ozone hole. Explain that the hole occurs over Antarctica each September, and that the Montreal Protocol has banned some of the air pollutants (CFCs) that cause it.	Students listen and answer question: (p.3)
Measurements. Take your class outside, and scan the ozone strip. Also, retake the surface and air temperature, and the humidity so that students can take the average of these measurements to supplement their ozone measurements.	Students take measurements and write down their results on their data sheets.

Table 14.1

14.6.1 Expected Outcomes

1. Students can explain the "dual" nature of ozone – it can act as both a major air pollutant and as a layer of protection for the Earth.
2. Students can define stratospheric ozone, know how it is formed, and know the causes and effects of ozone depletion.
3. Students complete Lesson Four Journal Activities.

Chapter 15

Rice Air Curriculum - Lesson 5 (Student): Tropospheric Ozone and Other Air Pollutants [1]

15.1 Overview

Yesterday we learned about the "good" ozone layer high in the stratosphere that protects us from ultraviolet rays. However, ozone can also form near the surface of the Earth where we breathe. This ozone is a harmful air pollutant that can irritate our lungs. Today you will learn about how "bad" low-level ozone is created, its harmful effects, and how we can prevent its creation.

Exercise 15.1
Can you remember a day when you could see that the air was polluted? Describe what you saw that indicated the air was polluted that day.

NOTE: Ozone and some other air pollutants are invisible. Thus, you may not always be able to see if the air is polluted. The EPA' Air Quality Index helps tell us how clean the air really is each day. We'll learn more about the Air Quality Index later in this lesson.

15.2 Air Pollution

Exercise 15.2
Is all air pollution visible, or is some of it invisible?

Exercise 15.3
What are some things that emit pollution into the air?

Exercise 15.4
What are some effects of air pollution on humans and the environment?

15.3 What is the Air Quality Index?

This Internet Activity will help us learn about the Air Quality Index. This index tells us about the quality of the air, even if air pollution is invisible.

[1] This content is available online at <http://cnx.org/content/m34367/1.1/>.

1. Type **http://airnow.gov/index.cfm?action=aqikids.index** into the address bar of the internet browser on your computer.
2. Click on the cloud that says **"What is the AQI?"** Click "next" to read each section so you can answer all of the following questions.

- What does the Air Quality Index measure?
- What color means the best air quality?
- What color means the worst air quality?

3. Now click on the link "Air Pollution & Health." After you read each page, click "Next" to read the next page.

- What health word goes with a "Green" AQI?
- What does EPA recommend that active kids should do on a Red AQI ("Unhealthy") day?

15.3.1

15.4 Ozone Scavenger Hunt

1. Type http://**www.airnow.gov**/ into the address bar of the internet browser on your computer.
2. Below the map on the homepage there is a link that says "Ozone Now". Click on it. You should be able see the "Current Hour AQI." How does it look? Are there any areas in the United States that look very badly polluted? Color the map as you see it:

Figure 15.1

1. If you look below the map on the screen, you can watch an animation that shows how the Air Quality Index has changed over the course of the day. What time of day has the most green areas indicating clean air? What time of day has the most air pollution?
2. Press the "Back" button to return to the homepage. Click on the map of the United States. Click on Texas. Scroll down until you see Houston-Galveston-Brazoria, TX.
3. Look under the column "Current AQI." What is the current AQI number for Houston-Galveston-Brazoria? What color does this correspond to? Is it safe to exercise outside?
4. What is tomorrow's forecast? What color does this correspond to? Will it be safe to exercise outside tomorrow?
5. Click on Houston-Galveston-Brazoria, TX. Click on "yesterday's summary" for ozone. Look at the Ozone: 1-hour Average Peak Concentration. What was the highest ozone concentration measured in the Houston region yesterday? Where did it happen?

15.5 Smog City 2

1. Go to **http://www.smogcity2.org/smogcity.cfm?preset=ozone** in your internet browser.

Current emission factors and weather conditions are causing ground-level ozone in Smog City 2 to reach "Unhealthy" levels. The Air Quality Index (AQI) level for ozone is now Red. By following the scenarios below, see how emissions factors, temperature, and sunlight impact ozone levels. The weather factors that you will be able to change around are the following: clouds/sky cover, wind, and temperature. The emission factors that you will be able to change are the following: the amount of energy sources, cars and trucks, off-road vehicles, consumer products, and industries.

Scenario 1: Emissions Factors

Use only the emission controls to reduce the ozone levels to "Yellow" on the AQI, which is "Moderate" air quality. Do not change the weather controls.

a) Which emission factor affects ozone the most?
b) Which emission factor has the smallest effect on ozone?

Scenario 2: Weather Factors

Return all emission controls and population control to the middle. These conditions result in an "Unhealthy for Sensitive Groups" value, or "Orange" AQI.

a) Increase temperature to 110F. How does the increase in temperature affect ozone levels?
b) Now try increasing the cloud cover. How does the increase in cloud cover affect ozone levels?
c) Now try increasing the wind speed. How does the increase in wind speed affect ozone levels?

15.6 Hypotheses

We saw in Smog City 2 how changes in meteorology caused ozone pollution to increase or decrease. Now let's think about what patterns we expect to see in our daily ozone and meteorology measurements.

A hypothesis is an educated guess about the results that we expect to find in a scientific experiment. Even though we haven't finished all of our outdoor measurements, we can make hypotheses about how we expect the ozone and meteorology measurements to be related.

Fill in the table below with your hypotheses about your ozone and meteorology measurements.

a) Check **"positive correlation"** if you think that ozone concentrations will be higher on days when that meteorological measurement is high.
b) Check **"negative correlation"** if you think that ozone concentrations will be lower on days when that meteorological measurement is high.
c) Check **"no correlation"** if you think the measurements are not related.

We will evaluate our hypotheses when we analyze all of our measurements in Lesson 7.

	Positive Correlation	Negative Correlation	No Correlation	Reasoning
Ozone and Air Temperature				
Ozone and Humidity				
Ozone and Cloud Cover				

Figure 15.2

Chapter 16

Rice Air Curriculum - Lesson 5 (Teacher): Tropospheric Ozone and Other Air Pollutants [1]

NOTE: Suggested Time: 150 minutes. Science TEKS: 3.11, 4.6, 5.1, 5.2, 5.3, 5.4, 5.5. Math TEKS: 5.11, 5.14, 5.15

16.1 Objective

NOTE: This lesson may take longer than previous lessons, due to 3 internet activities that allow student exploration as they learn about air pollution. It may be divided into two class periods as necessary.

During Lesson Four, students learned about the "dual" nature of ozone, and in particular stratospheric ozone. Today, students will learn about tropospheric or low-level ozone, which is a very harmful air pollutant. Students will learn about how it is created, and how it affects our health. Students will find ways to learn more about air pollution in their own communities, such as by checking the EPA's Air Quality Index. These explorations will give students a much better understanding of low-level ozone, which they are measuring each day through the GLOBE protocols. Students will also learn about ways that they can help prevent the creation of ground-level ozone.

With this background knowledge, students will spend the second half of class discussing with other students and with the teacher what they have learned about air pollution, ozone, surface temperature, air temperature, humidity, clouds, and wind direction. Students will be asked to create hypotheses regarding what they think the relationships are between the GLOBE measurements they take every day. For example, do they think that on days that that the air temperature is warmer there will be more ozone measured in the air or vice-versa? Today, students will write down the trends they think they will see in their GLOBE measurement data. By the end of the curriculum, on Day Seven, they can use their data to either refute or support their initial conjectures.

16.2 Background Information

An **air pollutant** is any gas or particle in the air that causes harm to living things or the environment. Depending on the type of pollutant, the impacts can include respiratory ailments, cancer, birth defects, heart

[1] This content is available online at <http://cnx.org/content/m34373/1.1/>.

disease, and damage to the environment. Air pollution has these major effects even though it constitutes only a tiny fraction of air molecules. Most air pollutants have a concentration less than one molecule per million air molecules.

There are many types of **air pollution**. This lesson focuses on the example of **tropospheric ozone** (also called "low level ozone") because it can be measured by students, it has been linked to serious respiratory health effects, and because many cities such as Houston exceed federal standards for tropospheric ozone and must find ways to reduce it.

Power plants, factories, vehicles, and other sources do not directly emit ozone into the air. Instead, tropospheric ozone (also called "low level ozone") forms when emissions of other gases (specifically, nitrogen oxides (NOx) and hydrocarbons (also known as volatile organic compounds, VOCs)) react in the atmosphere in the presence of heat and sunlight. The actual chemical reactions are very complex, but you can think of it in a simplified form as:

Nitrogen Oxides + Hydrocarbons + Heat + Sunlight = Tropospheric Ozone

So to reduce the amount of ozone air pollution that forms in the troposphere, we must find ways to reduce emissions of nitrogen oxides and hydrocarbons from sources like vehicles and industries.

Tropospheric ozone has very different effects than stratospheric ozone. Ozone in the stratosphere protects Earth from the Sun's ultraviolet rays (see Lesson Four). Even though only about 10% of Earth's ozone is in the troposphere, it is here that humans and animals can breathe it in as a harmful air pollutant. Tropospheric ozone can have the following health effects, even at concentrations of just 75 parts per billion (i.e. 75 ozone molecules per 1 billion air molecules):

1. Make people more sensitive to allergens
2. Aggravate asthma
3. Damage and inflame the lungs, making it harder to breathe
4. Irritate the respiratory system - coughing and irritation in the chest

Children and the elderly are especially sensitive to these health effects. Tropospheric ozone can also interfere with photosynthesis, stunting the growth of some types of plants.

Normal lung tissue (left) and lung tissue exposed to high levels of ozone

Figure 16.1: Credit: US EPA. More information about tropospheric ozone can be found in the US EPA booklet Good Up High, Bad Nearby (http://www.epa.gov/airnow/gooduphigh).

Normal lung tissue (left) and lung tissue exposed to high levels of ozone

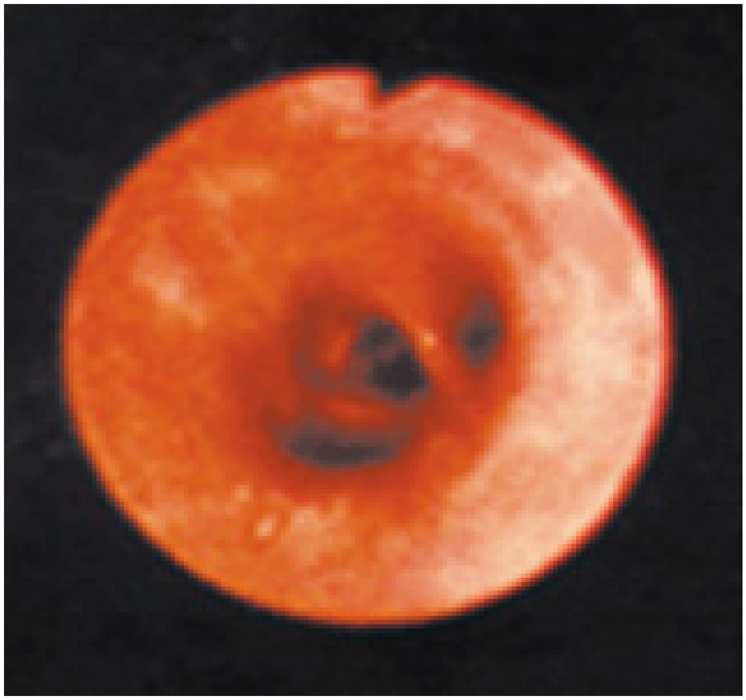

Figure 16.2: Credit: US EPA. More information about tropospheric ozone can be found in the US EPA booklet Good Up High, Bad Nearby (http://www.epa.gov/airnow/gooduphigh).

The Houston region has long struggled to meet federal air quality standards for ground-level (tropospheric) ozone. Large amounts of emissions from vehicles and industries (including numerous petrochemical facilities) and hot weather contribute to Houston's ozone pollution. Though cleaner cars and industries have greatly improved ozone levels in Houston, they continue to exceed federal limits. The U.S. EPA recently lowered the ozone limit from 85 parts per billion to 75 parts per billion, because scientists found that health impacts can occur even at these low levels. This lower limit will make it even more challenging for Houston to reduce emissions sufficiently to attain the ozone standard.

In addition to tropospheric ozone, there are many other types of **air pollutants** that can cause harm to living things or the environment. Some air pollutants are gases that are virtually invisible. Most occur in very small concentrations (typically less than 1 molecule per million air molecules), but they can still have major impacts on our health and the environment. In Lesson 6, we will see how some of these gases can warm the planet.

Other air pollutants are **particles**: microscopic liquids or solids like dust or soot suspended in the air. When the air looks "hazy" like in the picture below, it is mostly due to particles scattering and absorbing light. Scientists have learned that high levels of particles in the air can cause cardiovascular and respiratory disease.

Houston on a hazy day (L); Houston on a clear Day (R)

Figure 16.3: Credit: http://www.jpl.nasa.gov/news/features.cfm?feature=423

The sources of air pollutants are widely varied and include manmade and natural processes. For example, particles are emitted by **manmade sources** like diesel engines and smokestacks, and by **natural sources** such as volcanoes and windblown dust. Cows actually produce 80 million metric tons per year of **methane**, which can warm the planet and help form tropospheric ozone.

The **Environmental Protection Agency** posts **Air Quality Index** numbers to tell us how clean the air is in each part of the country each day. More information about this can be found at **http://airnow.gov/index.cfm?action=aqibroch.index**. In the Houston Chronicle, the weather page shows the ozone levels from the day before and a forecast of today's ozone levels. Online, the Houston Chronicle has a "current air quality" map that you can click on. That takes you to an interactive map, where they can click on each monitor and see its meteorology and air pollution conditions. For the Westbury schools, the Bayland Park monitor (#13 in the bottom map) would be the closest to their campus. This map is available at http://weather.chron.com/US/TX/Houston.html.

Air Quality Index

Air Quality Index Levels of Health Concern	Numerical Value	Meaning
Good	0-50	Air quality is considered satisfactory, and air pollution poses little or no risk.
Moderate	51-100	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.
Unhealthy for Sensitive Groups	101-150	Members of sensitive groups may experience health effects. The general public is not likely to be affected.
Unhealthy	151-200	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.
Very Unhealthy	201-300	Health alert: everyone may experience more serious health effects.
Hazardous	> 300	Health warnings of emergency conditions. The entire population is more likely to be affected.

Figure 16.4: Credit: http://airnow.gov/index.cfm?action=static.aqi#haz

The following AQI ranges correspond to certain ranges of ozone concentration in parts per billion (ppb). This can give students a sense of how their GLOBE ozone measurements (in ppb) relate to AQI levels, though technically the AQI is based on 8-hour averaged concentrations of ozone.

Air Quality Index	Ozone Concentration (ppb)*
0-50	0-59
51-100	60-75
51-100	76-95
151-200	96-115
201-300	116-374
>300	>374

Table 16.1

NOTE: *These numbers were calculated by using the EPA's conversion calculator, which can be found at http://www.airnow.gov/index.cfm?action=aqi.aqi_conc_calc.

16.3 Additional Resources

The EPA provides reading material through Project A.I.R.E:

1. Air pollution http://www.epa.gov/region01/students/pdfs/rd_airpol.pdf
2. Health effects http://www.epa.gov/region01/students/pdfs/rd_health.pdf
3. Weather and air quality http://www.epa.gov/region01/students/pdfs/weather.pdf
4. Ozone http://www.epa.gov/region01/students/pdfs/ozone.pdf
5. Automobiles and air pollution http://www.epa.gov/region01/students/pdfs/rd_auto.pdf

Figure 16.5: Loss of healthy green color, smaller size, and rough texture show the effects of ozone pollution on a leaf. Ozone interferes with the process of photosynthesis in plants. Credit: http://streaming.discoveryeducation.com/

16.4 Materials (for a class of 25)

- Hygrometer (1 per class)
- Infrared Thermometer (1 per class)
- Ozone Test Strips (1 per class)
- Ozone Scanner (1 per class)
- Wind Vane (1 per class)
- Thermal Glove (1 per class)
- Cloud Charts (1 per class)
- GLOBE Measurement Data Sheets (1 per student)
- Access to computer (enough for two or three students to share a computer)
- Access to UnitedLearning.com
- Access to Brainpop.com
- Projection Screen

16.5 Vocabulary

- Ozone
- Ultraviolet radiation
- Air pollution
- Oxygen atoms

- Tropospheric ozone
- Stratospheric ozone
- Environment
- Surface temperature
- Air temperature
- Humidity
- Clouds
- Wind direction
- Environmental Protection Agency
- Air Quality Index
- Air pollutants
- Particles
- Manmade sources
- Natural Sources
- Methane

Step 6 in Lesson Plan

Figure 16.6

Step 7 in Lesson Plan

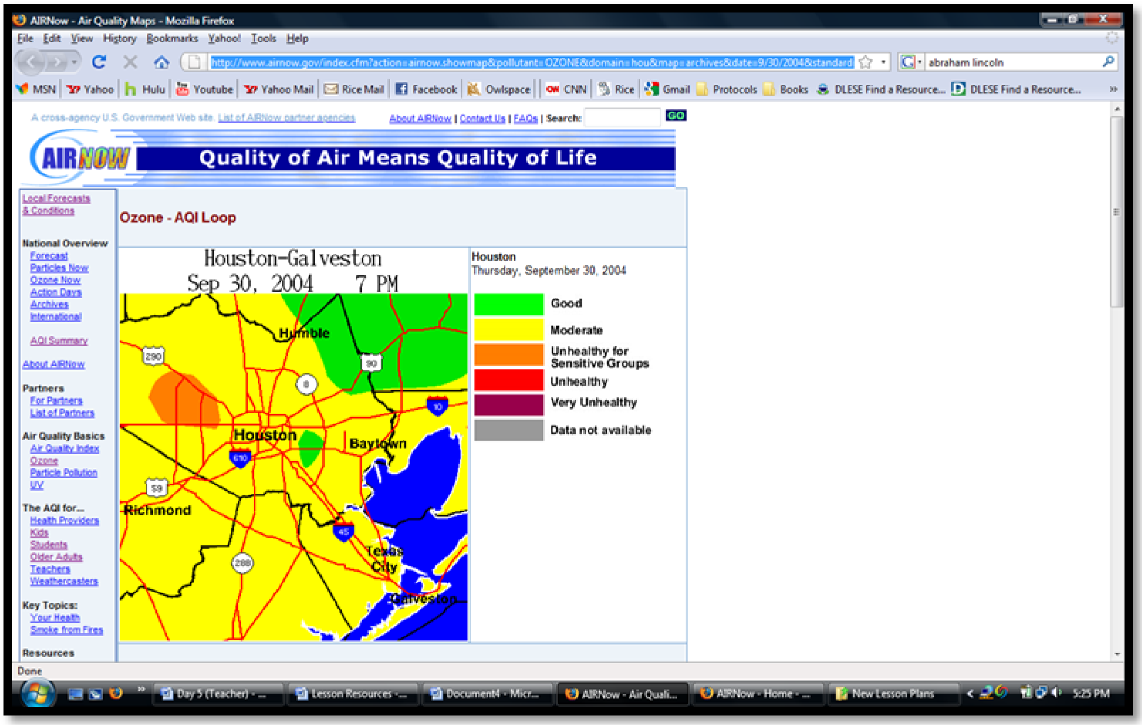

Figure 16.7

Step 8 in Lesson Plan

Figure 16.8: http://www.smogcity2.org/smogcity.cfm?preset=ozone

16.6 Explanation of Controls and Settings

Students will be able to change around the levels of the following factors:

The weather factors that students will be able to change around are the following: clouds/sky cover, wind, and temperature. The emission factors that students will be able to change are the following: the amount of energy sources, cars and trucks, off-road vehicles, consumer products, and industries. Students will also be able to change the population of their city.

Consumer Products-	This includes paint thinner, charcoal lighter fluid, glue or other adhesives, gasoline Levels: 1 2 3 4 5
Industry –	This includes manufacturing facilities, power plants, oil refineries/storage/distribution centers, food and agricultural processing Levels: 1 2 3 4 5

Area Name:	**Choices Included in the Area:**
Population – Population in Smog City 2 affects air quality. Changing population, as shown by the "total emissions" chart and the emission sources in the cityscape, affects VOCs, NO_x and SO_2. The compounds react to form ground-level ozone and particle pollution. When temperatures are cool, changing population also changes the usage of wood-burning stoves, which emit particle pollution	In Smog City 2, you can increase the population from near-zero to about two million people. Levels: 1 2 3 4 5

Figure 16.9

Weather Conditions	Choices Included in the Area:
Sunlight :	Clear -Partly Cloudy - Cloudy
Inversion Layer:	No inversion - Low inversion - High inversion
Wind Speed:	Calm - Light Breeze - Breezy - Windy
Maximum Daily Temperature:	30ºF - 40 ºF - 50ºF - 80ºF - 90ºF - 100 ºF - 110 ºF

Emission	Choices Included in the Area:
Energy Sources –	Some energy sources produce more smog-producing emissions than others.(level 1 is cleaner sources like a wind or solar technology, level 3 produces more smog like a coal-fired power plant) Levels: 1 2 3
Cars and Trucks –	This includes Passenger vehicles (all sizes), large and medium trucks, motorcycles Levels: 1 2 3 4 5
Off Road Vehicles –	This includes airplanes, trains, power boats, earth movers, tractors, harvesters, forklifts, bulldozers, backhoes Levels: 1 2 3 4 5

Figure 16.10

NOTE: An inversion is when air temperature increases with height. This inhibits pollutants from mixing vertically, which can cause very polluted conditions near the ground.

16.7 Step-by-Step Suggested Lesson Plan

Instructor Activity	Student Activity
	continued on next page

Measurements. Take your students outside and conduct the GLOBE protocols. Students should set up the ozone strip, take the air and surface temperature, observe the sky for clouds, and measure humidity and wind direction.	Students take measurements and record their data.
Review. Take one minute to review stratospheric, "good" ozone. Remind students that this ozone high in the atmosphere protects Earth from the Sun's ultraviolet radiation.	Students listen.
Brainstorm. Brainstorm with students about ways to classify air pollutants, to help students recognize the diverse nature of air pollution. Specifically: 1. Some are visible (particles that form haze), while others are invisible gases; 2. Their origin can be manmade (factories, cars), natural (wildfires, volcanoes), or in between (e.g., emitted by cattle raised by humans); 3. Some affect health, others affect climate. Ask students whether they know of health effects that can be caused by air pollution.	Students participate in discussion and answer questions on p. 1-2.
Discussion. Explain that even though there are many air pollutants, we will focus on tropospheric or "bad" ozone because students can measure ozone and it causes serious impacts. Discuss how low-level ozone is formed from other pollutants reacting in sunlight, and its negative health effects.	Students listen
Optional video. As a summary of the "dual" nature of ozone covered in Lesson Four and Lesson Five, you may show the class the **video** clip entitled *Ozone: Harmful and Helpful,* available at **http://player.discoveryeducation.com /index.cfm?guidAssetId=E320368D-9247-4FDC-9949-B7E8983E67E&blnFromSearch=1 &productcode=US**.	Students watch video.

continued on next page

Online Activity 1: Air Quality Index. This activity guides students to explore the meaning of EPA's Air Quality Index in a fun and simple way. Teachers will act as a guide, answering questions but also letting students explore and learn on the computer on their own.	Students complete online activity, following instructions and answering questions on journal p. 3.
Online Activity 2: Ozone Scavenger Hunt. This activity leads students on an "Ozone scavenger hunt" to explore recent, current and forecast air quality conditions across the country and in their home town. The activity uses EPA's AirNow website, **http://www.airnow.gov/**. The Journal worksheets guide students through the scavenger hunt.	Students complete online activity, following instructions and answering questions on journal p. 4-5
On-line Activity 3: Smog City 2 simulation. Students will be able to try out a simulation about tropospheric ozone levels on EPA's website for kids. This simulation allows students to change the levels of various factors in order to see how it affects the Air Quality Index and the amount of ozone during an entire day. Use the chart given to make sure that students understand each level of each factor – for example, that Level 1 of Sky Cover means "sunny", and that Level 3 means "cloudy." The lesson will help students think about hypotheses of measurement correlations (next step).	Students complete online activity, following instructions and answering questions on journal p. 6-7.
Hypotheses based on measurements. Now that students understand how tropospheric ozone forms, they will create hypotheses regarding expected relationships between the daily GLOBE measurements. For example, do they think that on days that that the air temperature is higher there will be more ozone measured in the air? Let students make these hypotheses on their own in their journals – they have learned enough to make some educated guesses. Students will write down the trends they think they will see in their GLOBE measurement data. On Day Seven, they will use their final data to either refute or support their initial hypotheses.	Students think about relationships between ozone and meteorology based on what they've learned in class and in Smog City 2 simulation, and fill out chart with their hypotheses (p. 8).

continued on next page

Take your class outside, and scan the ozone strip. Also, retake the surface and air temperature, and the humidity so that students can take the average of these measurements in order to supplement their ozone measurements.	Students take measurements and record data on their data sheets.

Table 16.2

16.7.1 Expected Outcomes

1. Students will begin to appreciate the diverse nature of air pollution and brainstorm ways to classify different types of air pollutants.
2. Students will be able to define tropospheric ozone, and will understand how this is ozone is created and how it effects our health.
3. Students will know how to read the EPA's Air Quality Index. Using this knowledge, they will be able to read local and national ozone maps, and will also know the relation between AQI index values and ozone concentration in units of parts per billion (ppb).
4. Students will create hypotheses regarding what they think the relationships are between the GLOBE measurements they take every day.

Chapter 17

Rice Air Curriculum - Lesson 6 (Student): Climate Change[1]

17.1 Overview

Today, you will be taking your last GLOBE measurements – measuring the amount of tropospheric ozone in the air, the type of cloud cover, the surface and air temperature, wind direction, and humidity.

We are going to learn about global warming, which occurs when Earth's climate becomes warmer. Certain gases in the atmosphere, like carbon dioxide, are called greenhouse gases because they trap in Earth's warmth. Without them, most of Earth's surface would be frozen. However, emitting more of these gases to the atmosphere can contribute to global warming. You will learn about some of the possible impacts of global warming today.

Energy efficiency and alternative sources of energy can help reduce emissions of greenhouse gases. For example if cars can use gasoline more efficiently, less air pollutants and greenhouse gases will be released into the air.

You will also be able to calculate your "carbon footprint." A carbon footprint tells you how much carbon dioxide is emitted as a result of your day [U+2010] to [U+2010] day actions. It can also tell you how you could change your actions so that fewer pollutants are released into the air.

17.2 Interactive Map: Global Warming Impacts

1. Go to **www.nationalgeographic.com**. Click on "Environment" on the left-hand side of the screen. Then click on the "Effects of Global Warming," found in the dark green box entitled "Environment Topics." Scroll down and click on "Interactive: Map of Impacts."

> NOTE: (The direct link is: http://environment.nationalgeographic.com/environment/global-warming/gw-impacts-interactive.html)

2. You should see a world map on the screen. On the map, you can see the effects global warming can have around the world if the climate continues to warm. Mark and write down three effects that you find interesting on the map below.

[1] This content is available online at <http://cnx.org/content/m34376/1.1/>.

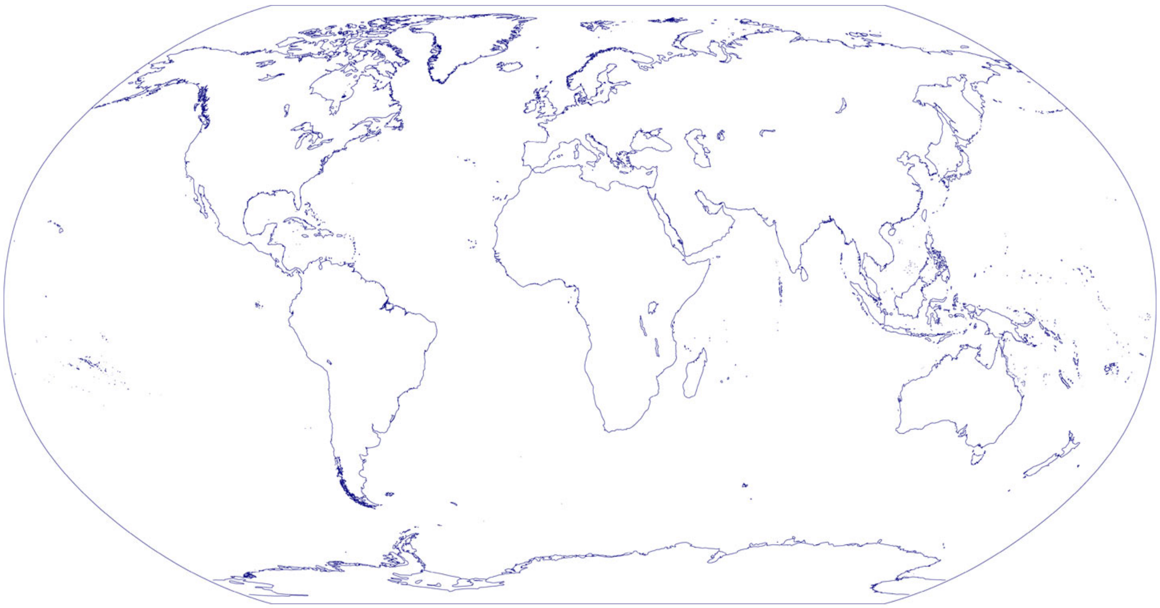

Figure 17.1

Exercise 17.1
Click on one of the impacts to go into more detail. What does it say?

17.3 Measuring Your Carbon Footprint

1. Go to www.epa.gov/climatechange/kids/calc/index.html

2. Follow the instructions on the screen, and answer the questions that pop up.

3. On each screen, you can answer "Yes" if you will take that action, "No" if you will not, or "I already do this" if you are already taking this action. You can learn about each action by following the "Find out more" link.

4. When you have completed answering all of the questions, "Your Summary" will come up on the screen. Fill in the blanks with your results:

Exercise 17.2
Based on what you're already doing, you're avoiding ____________lbs of CO2 per year.

Exercise 17.3
This is equivalent to the emissions from driving a car ____________ miles.

Exercise 17.4
If you take the additional actions that you checked above, you will avoid another ___________lbs of CO2 per year.

Exercise 17.5
This is equivalent to the emissions from driving a car ____________ miles.

Exercise 17.6
Make a list of actions you could take to reduce your carbon footprint.

Chapter 18

Rice Air Curriculum - Lesson 6 (Teacher): Climate Change[1]

NOTE: Suggested Time: 80 minutes. Science TEKS: 3.6, 3.11, 4.6, 5.2, 5.3, 5.4, 5.5. Math TEKS: 5.11, 5.14, 5.15.

NOTE: (Teachers) The greenhouse effect is considered an 8th grade topic in Texas. For 5th grade classrooms, you may consider omitting or simplifying Step 2 of the lesson plan.

18.1 Objective

By now, students have learned how minute quantities of air pollutants in the atmosphere can affect their health. Today they will learn how small amounts of certain gases can also affect the planet's climate. Students will learn how greenhouse gases like carbon dioxide keep the Earth at a livable temperature, and how increasing amounts of these gases may cause the climate to change. Students will compute their carbon footprint and discuss alternative sources of energy. Students should come away with a sense of their own impact on the environment and what they can do to reduce the creation of more emissions.

18.2 Background Information

The **greenhouse effect** is the warming of the Earth caused by certain gases in the atmosphere. The Figures on the next page show how this works. First, sunlight shines onto the Earth's surface. The Earth absorbs some of this solar energy and radiates its own heat energy back toward space. **Greenhouse gases** are chemicals in the atmosphere that prevent some of the Earth's heat from escaping into space, while letting sunlight pass through. Greenhouse gases include water vapor, carbon dioxide, methane, and chlorofluorocarbons.

The greenhouse effect is very beneficial to life on Earth because it warms the planet and moderates temperature extremes. Without greenhouse gases, the surface of the Earth would be too cold for liquid water! (For an interactive animation of the greenhouse effect, visit **http://environment.nationalgeographic.com/environment/global-warming/gw-overview-interactive.html**)

[1]This content is available online at <http://cnx.org/content/m34369/1.1/>.

Greenhouse effect

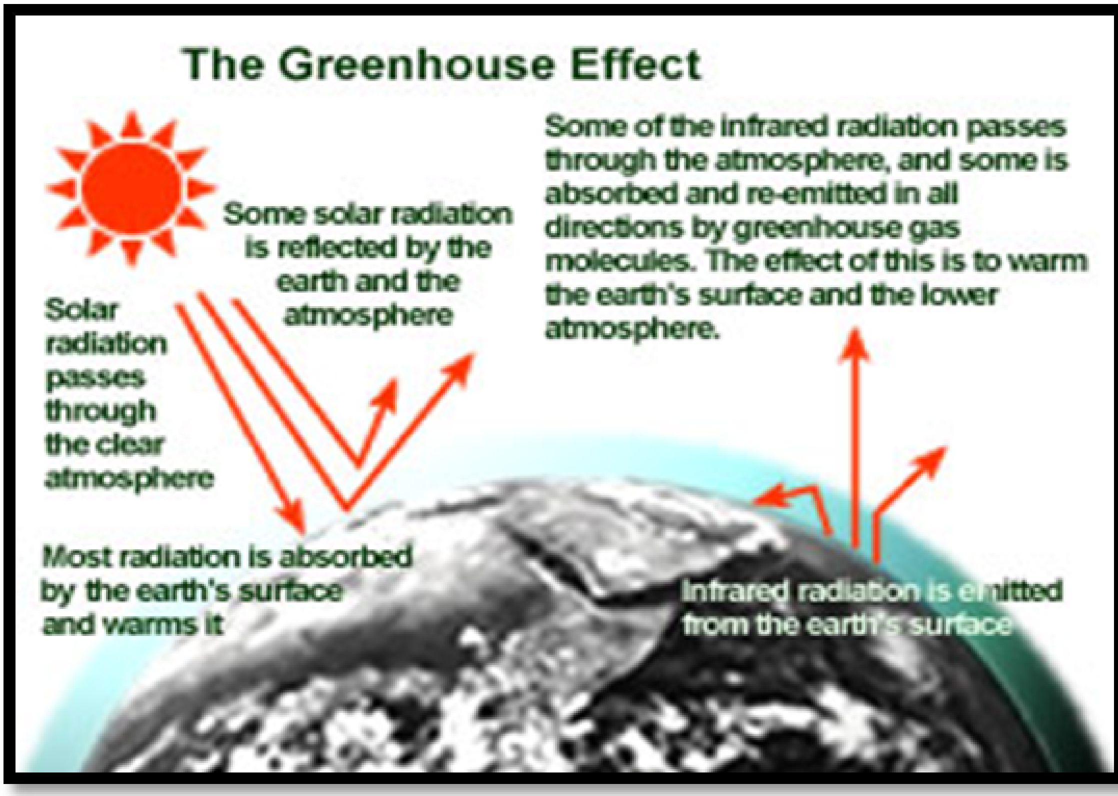

Figure 18.1: Credit: http://www.epa.gov/climatechange/kids/greenhouse.html

While the greenhouse effect is necessary for most life on Earth, increasing levels of greenhouse gases can cause Earth's temperature to rise. This is what scientists believe is currently happening to our planet. The burning of fossil fuels and the loss of forests have caused levels of greenhouse gases like carbon dioxide to increase significantly over the past century. Many greenhouse gases remain in the atmosphere for decades. As a result, more and more heat is being trapped in the Earth's atmosphere, which is causing the Earth's climate to warm.

Global warming is the increase in the average air temperature of Earth. Most climate scientists believe that the Earth's average temperature has been rising over the past century, and that most of this warming has been caused by manmade emissions of greenhouse gases, such as the burning of fossil fuels.

Global warming can make it difficult for humans and natural ecosystems to adapt, especially if temperatures rise rapidly. Warm temperatures can melt major ice sheets and cause ocean water to expand, which could cause sea levels to rise significantly. Weather patterns could shift and become more extreme, with severe floods in some region and severe droughts in others. According to the Intergovernmental Panel on Climate Change, 11 of the 12 hottest years since thermometer reading became available occurred between 1995 and 2006!

Atmospheric carbon dioxide concentrations have been increasing in recent decades

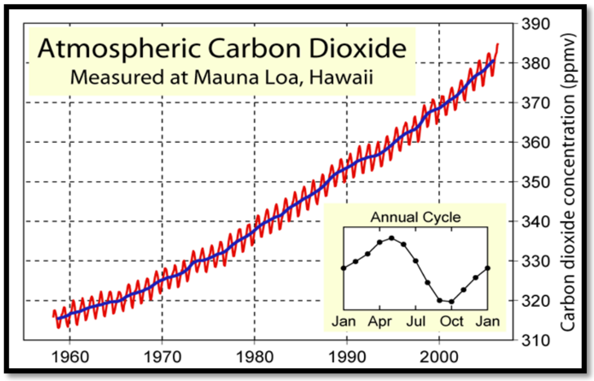

Figure 18.2: Credit: http://www.globalwarmingart.com/wiki/Image:Mauna_Loa_Carbon_Dioxide_png

Global temperatures and sea levels have been rising

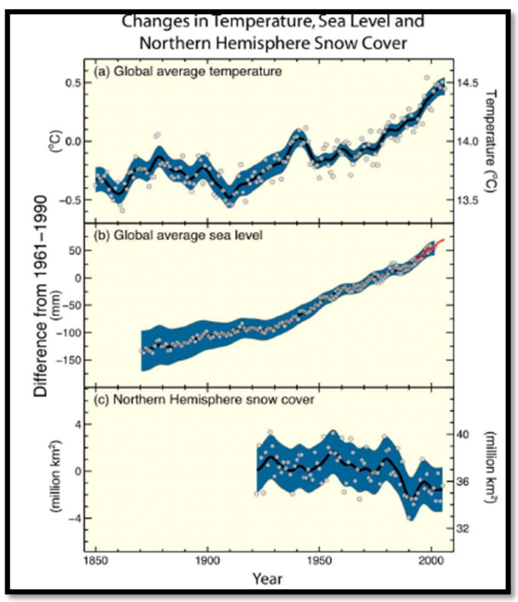

Figure 18.3: Credit: Intergovernmental Panel on Climate Change

So what can we do to prevent global warming? Burning of fossil fuels (coal, oil, and natural gas) is the biggest source of greenhouse gases. Fossil fuel use can be reduced by energy efficiency and conservation, and by switching to **alternative sources of energy** such as wind, solar, or nuclear power.

One way to calculate your impact on the environment and contribution to the heating of the earth is the "**Carbon footprint**." A carbon footprint tells you how much carbon dioxide is emitted as a result of your day-to-day lifestyle and actions. It can also tell you what actions could reduce the amount of pollutants are released into the air. Toward the end of this lesson, students will compute their own carbon footprints using an EPA computer program online.

18.3 How can we keep our air clean and reduce our carbon footprint?

- Walk, bike or take the bus
- Look out for energy-efficient appliances and light bulbs
- Ask your parents to make sure that the air conditioner is in good condition
- Shut off the lights when you are not in the room, and turn off your electronic appliances when they are not in use.
- Save water! Turn off the water when it is not in use, and only do the laundry or run the dishwasher with a full load of clothes or dishes.
- Set the thermostat so that your heater or air conditioner run less while you are away.

18.4 Additional reading materials:

1. **Greenhouse Effect**
http://www.epa.gov/region01/students/pdfs/greenhouse.pdf
http://www.windows.ucar.edu/tour/link=/earth/interior/greenhouse_effect.html
2. **Causes and Effects of Global Warming**
http://environment.nationalgeographic.com/environment/global-warming/gw-causes.html
http://environment.nationalgeographic.com/environment/global-warming/gw-effects.html
3. **Clean Fuels**
http://www.epa.gov/region01/students/pdfs/rd_clean.pdf

18.5 Materials (for a class of 25)

- Hygrometer (1 per class)
- Infrared Thermometer (1 per class)
- Ozone Test Strips (1 per class)
- Ozone Scanner (1 per class)
- Wind Vane (1 per class)
- Thermal Glove (1 per class)
- Cloud Charts (1 per class)
- GLOBE Measurement Data Sheets (1 per student)
- Computers
- Projection Screen
- Access to Brainpop.com

18.6 Vocabulary

- Low-level ozone
- Greenhouse effect
- Global warming

- Atmosphere
- Carbon footprint
- Alternative fuels
- Alternative energy
- Greenhouse effect
- Greenhouse gases

18.7 Step 4 in Lesson Plan

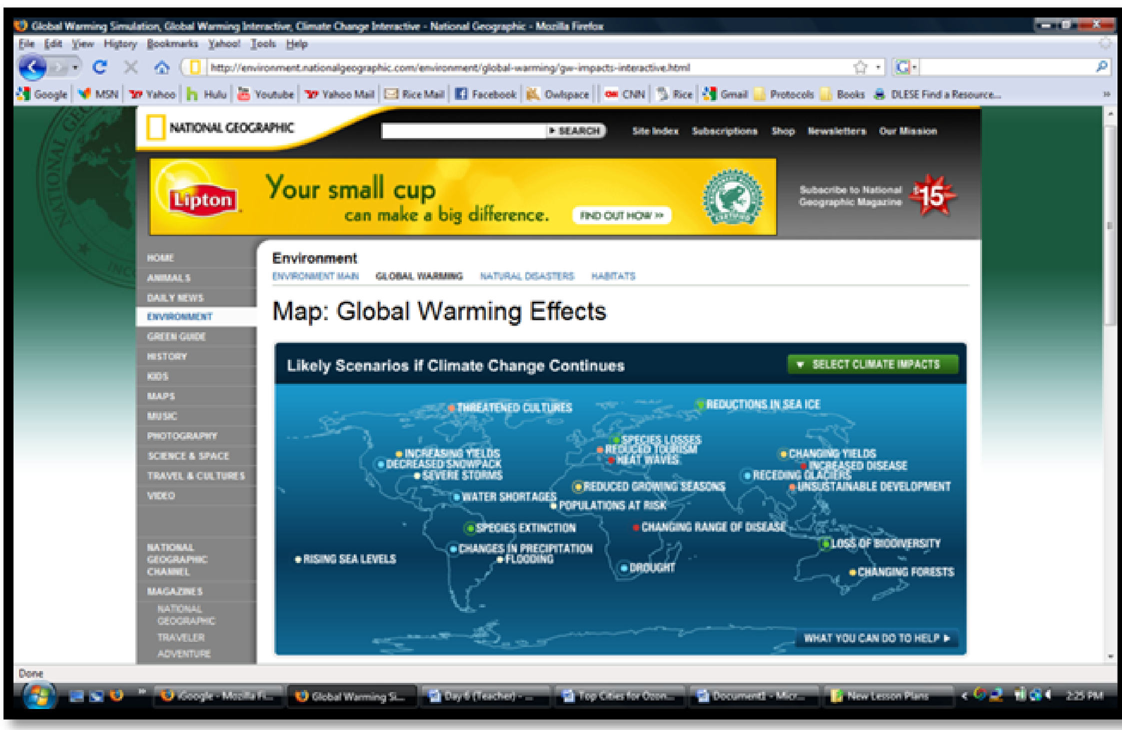

Figure 18.4: http://environment.nationalgeographic.com/environment/global-warming/gw-impacts-interactive.html

18.8 Step-by-Step Suggested Lesson Plan

Instructor Activity	Student Activity
	continued on next page

Measurements. Take your students outside and conduct the GLOBE protocols. Students should set up the ozone strip, take the air and surface temperature, observe the sky for clouds, and measure humidity and wind direction.	Students take measurements and write down results on data sheets.
(Optional: Above 5th grade learning objectives). Ask students to brainstorm examples of something in balance, such as a budget. Explain that Earth maintains a balance between solar energy absorbed from the Sun and heat energy that Earth sends back to space. Greenhouse gases trap in some of Earth's heat energy and make the planet warmer. Draw a picture like the one on p. 2 to illustrate this. Make it clear that the greenhouse effect is good for Earth to some extent, but that increasing amounts of greenhouse gases can change the climate. Optional video: "Greenhouse effect" on Brainpop.com	Students brainstorm examples, participate in discussion, and watch video.
Ask students how scientists could measure if climate is changing. Discuss some of the evidence that the climate is warming, such as rising CO2 levels, temperatures, and sea level (see p. 3).	Students discuss measurements that could indicate a changing climate.
Online Activity. Next, guide students to an interactive map of global warming impacts at: http://environment.nationalgeographic.com/environment/global-warming/gw-impacts-interactive.html. Guide students to answer related questions in journals.	Students visit website to explore some of the impacts of global warming worldwide, and answer related questions in their journal. (p. 2)
Online Activity. Guide students to compute their carbon footprint at: http://www.epa.gov/climatechange/kids/calc/index.html. This carbon footprint calculator helps students discover how much carbon emissions result from their actions, and how much those emissions can be reduced by simple changes. Ask students what actions they think are most doable for reducing their carbon footprint.	Students compute carbon footprint and answer related questions in journal (p. 3)
	continued on next page

Take your class outside, and scan the ozone strip. Also, retake the surface and air temperature and humidity so that students can take the average of these measurements to supplement their ozone measurements.	Students take measurements and write down their results on their data sheets.

Table 18.1

18.8.1 Expected Outcomes

1. Students understand the causes and effects of the greenhouse effect.
2. Students understand the causes and effects of global warming.
3. Students compute their carbon footprint and brainstorm ways to reduce carbon emissions.

Chapter 19

Rice Air Curriculum - Lesson 7 (Student): Analyzing GLOBE Data[1]

19.1 Overview

Now that you have finished taking all of your GLOBE measurements, today you will be able to analyze the data you have collected. You have been measuring surface and air temperature, wind, humidity, types of cloud cover, and the amount of ozone outside. Your goal is to understand how the amount of ozone found in the air is related to the measurements. You will be able to do this by doing simple calculations and creating charts, graphs, and pictures to represent your data. This way you can visually see your data in an easy way and look at different trends. For example you will be able to answer the following question:

How does air temperature relate to the amount of low-level ozone in the air? Does ozone increase or decrease when temperature is warmer?

Analyzing the data in this way will help you see whether the data supports the hypotheses you made during Lesson Five. You will then be able to come up with a conclusion that you can share with other students and your teacher.

Good luck!

19.2 GLOBE Measurements

Now that you have finished taking five sets of GLOBE measurements, today you will compile the data you have gotten, and look at it for interesting trends.

Get out your GLOBE Measurement Data Sheets.

- Fill in the "AQI" row with the correct "Health Word" from the chart below.

[1] This content is available online at <http://cnx.org/content/m34368/1.1/>.

AQI Numbers	Ozone Concentration (parts per billion)	Health Word(s)
	0-59 ppb	Good
	60-75 ppb	Moderate
	76-95 ppb	Unhealthy for Sensitive Groups
	96-115 ppb	Unhealthy
	116-374 ppb	Very Unhealthy
	> 300 ppb (usually not shown)	Hazardous

Figure 19.1

- Find the average air temperature on each measurement day by averaging the air temperature from the beginning and end of class. Record your answers, along with each day's ozone concentration, in the chart below.

Average Air Temperature	Ozone Concentration (ppb)

Figure 19.2

- Now we are going to make a graph so we can see how the amount of ozone in the air is related to the average air temperature. On the graph below, Average Air Temperature (^{0} C) is the x-axis, and Ozone Concentration (parts per billion) is the y-axis. Plot the data from the chart above onto the graph below. Draw a dot ([U+25CF]) for each day of measurements.

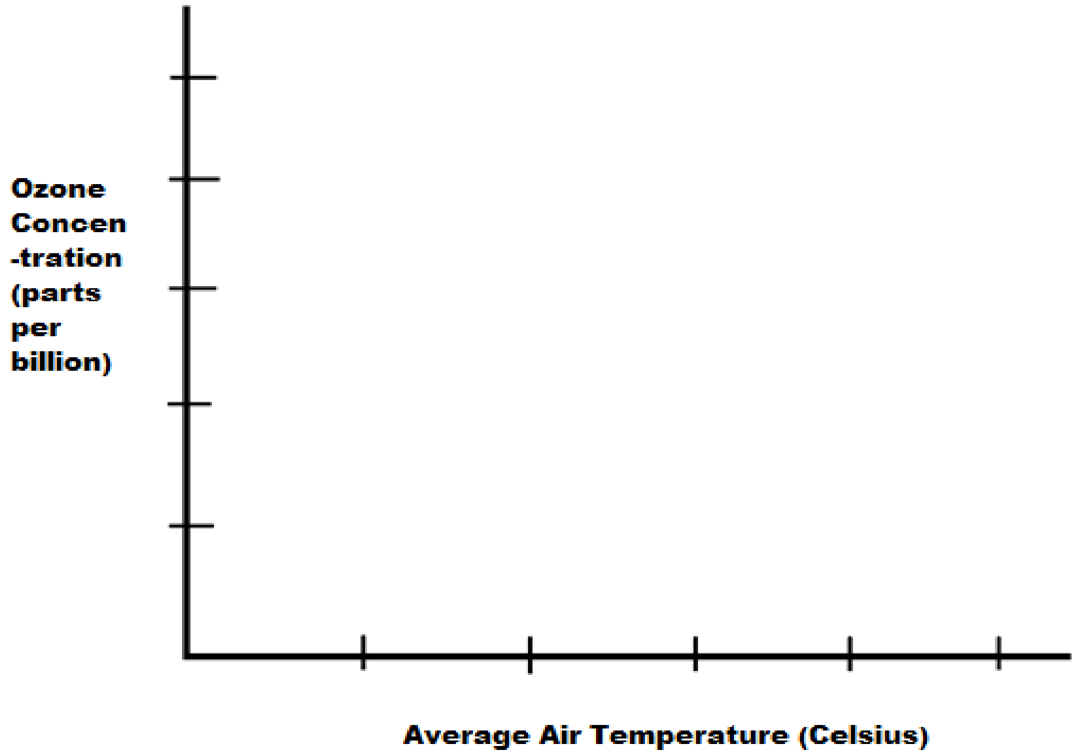

Figure 19.3

- How is humidity related to the concentration of ozone in the air? Let's find out by graphing Humidity (%) on the x-axis and Ozone Concentration (parts per billion) on the y-axis.

- Find the average relative humidity by averaging the relative humidity when the ozone strip was exposed and when the ozone strip was read for each day.
- Record your answers and the ozone concentration for each day in the chart below:

Average Relative Humidity (%)	Ozone Concentration (ppb)

Figure 19.4

- Plot the data from the chart onto the graph below. Draw a dot ([U+25CF]) for each day of measurements.

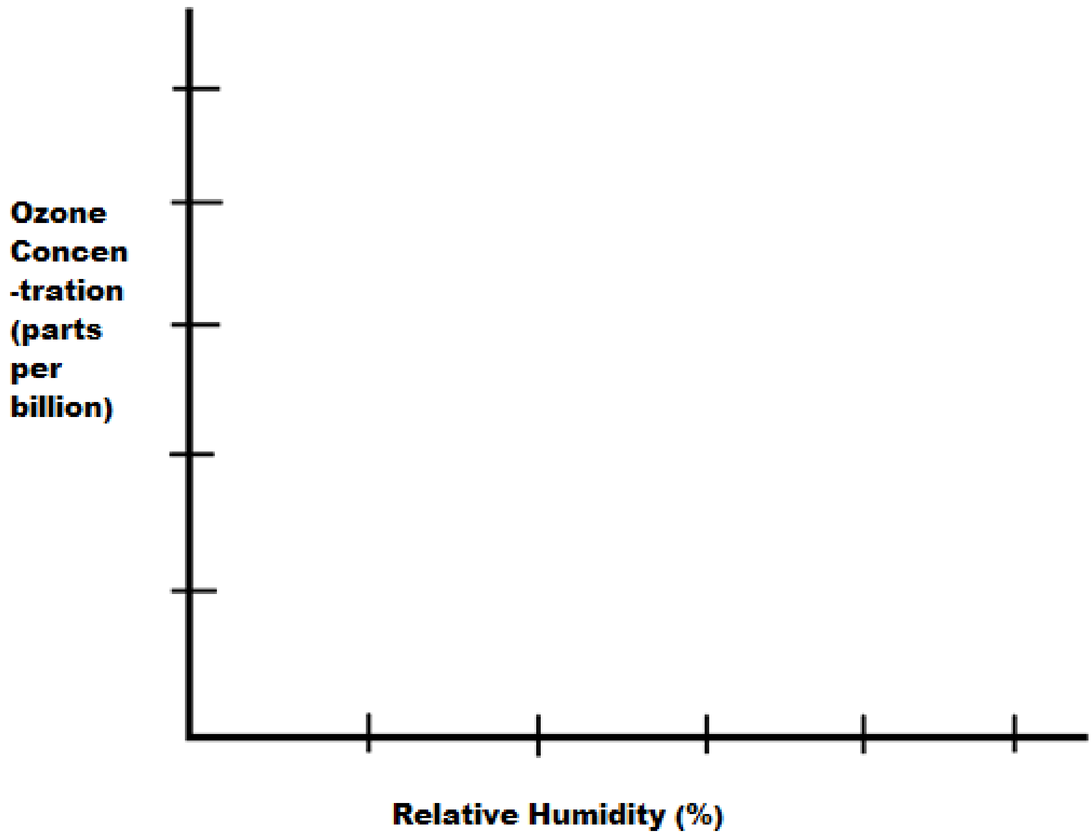

Figure 19.5

- Finally, let's look at the surface temperatures that you took in three different places. Did you perhaps notice that some types of surfaces are consistently hotter or colder than other types of surfaces? Let's create a line graph so that we more easily see if this is true.

- The y-axis of the graph will have surface temperature in Celsius and the x-axis will have the days you took the temperature.
- Color in the Legend below the graph, choosing one color for each surface. For example, you could choose green for Surface Temperature #1, red for Surface Temperature #2, and black for Surface Temperature #3. Write a name for each surface explaining where it was measured (e.g., "grassy field").
- Graph Surface Temperature #1 by drawing 5 dots for the temperature found each day, using the color from your Legend. Connect the dots to create a line graph.
- Then, do the same thing for Surface Temperature #2 and Surface Temperature #3. You will end with three differently-colored lines on your graph.

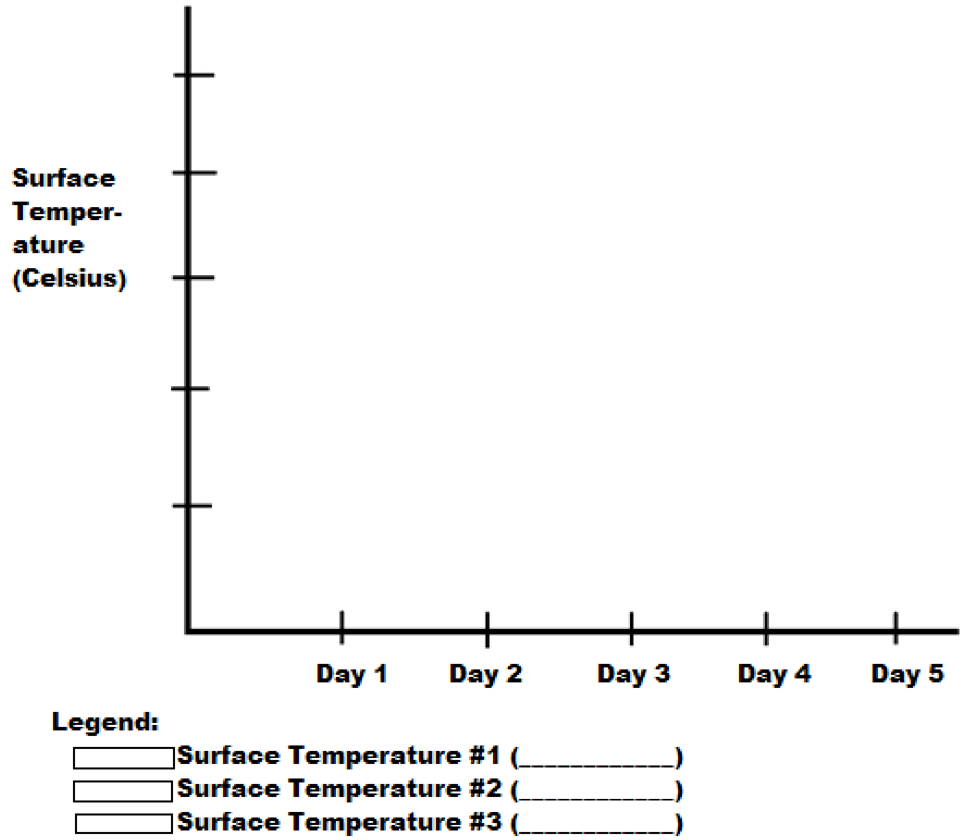

Figure 19.6

- Is there a type of surface that is consistently cooler or warmer than the others? Why is this so?
- Consider your Ozone Concentration versus Average Air Temperature graph. Can you see any relationship between ozone concentration and air temperature? Does ozone increase or decrease when air temperature increases? Fill in the first row of the Table below with your answer.
- Now consider your Ozone Concentration versus Relative Humidity graph. Do you see any relationship between humidity and ozone concentration? Fill in the second row of the Table below with your answer.
- Now look at your Data Sheet. Do you see any relationship between Cloud Cover and ozone concentration? Fill in the third row of the Table below.
- Now look back at the chart you filled in during Lesson Five with your hypotheses. Were your hypotheses supported by the data that you measured?

NOTE: Positive Correlation means that when air temperature, humidity, or cloud cover increased, ozone concentration increased.

NOTE: Negative Correlation means that if air temperature, humidity, or cloud cover increased, ozone concentration decreased.

NOTE: No Correlation means that there is no clear relationship in the data.

	Positive Correlation	Negative Correlation	No Correlation	Reasoning
Ozone and Air Temperature				
Ozone and Humidity				
Ozone and Cloud Cover				

Figure 19.7

19.3 Reflection

Now that you have completed all of the lessons and have analyzed all of your measurements, what have you learned? Take a moment to reflect on your experiences in measuring and learning about the atmosphere.

1. What did you find most fun about the lessons?
2. What were the 3 most interesting facts that you learned?
3. Were you surprised by any of the relationships you found in your data? Remember, five days of measurements is only a beginning for evaluating hypotheses, so it's ok if you found some unexpected relationships.

Chapter 20

Rice Air Curriculum - Lesson 7 (Teacher): Analyzing GLOBE Data[1]

NOTE: Suggested Time: 60 minutes. Science TEKS: 5.1, 5.2, 5.3, 5.6, 5.5. Math TEKS: 5.5, 5.11, 5.13, 5.14, 5.15, 5.16

20.1 Objective

Students have now finished taking the last of their GLOBE measurements. In today's lesson, students will compile and analyze their data. The goal of today's lesson is for students to explore relationships between ozone and the other factors that they measured. Students will analyze the data from the six GLOBE measurements – ozone, cloud cover, humidity, air temperature, surface temperature, and wind direction. They will do this by using simple calculations and by creating charts, graphs, and pictures to represent their data. These calculations and graphs will allow students to see trends in their data. For example, students may find that temperature is positively correlated to the amount of low-level ozone present (as they discovered is true in Smog City 2 in Lesson 5). However, if the data shows no clear trends or atypical correlations (e.g., ozone highest on cool, cloudy days), students must not be discouraged. Instead, explain possible reasons for anomalous results: 1) five days may be too little data for students to find typical relationships between factors, and 2) factors that cannot be measured at one school (e.g., daily fluctuations in emissions; complex wind flow patterns) also affect the creation of low-level ozone. Students should understand that this is also part of experimental design, and that they would probably be able to come up with more accurate conclusions if they took the GLOBE measurements for a much a longer period of time.

After students have reached their conclusions, they will be able to compare them to their original hypotheses. Students will also be given a chance to compare and communicate their findings with other students.

Students will most likely find the following correlations in their data. However, actual results may vary due to the small number of data points collected and factors beyond the scope of these measurements that affect ozone:

[1] This content is available online at <http://cnx.org/content/m34370/1.1/>.

	Positive Correlation	Negative Correlation	No Correlation	Reasoning
Ozone and Air Temperature	V			The higher the temperature, the more ozone is produced. This is one reason why summertime is the time to watch out for unhealthy levels of ozone.
Ozone and Humidity			?	May be positively or negatively correlated depending on complex factors beyond scope of this curriculum. ***Possible reason for positive correlation:*** 1. Water vapor is a precursor of OH radical, which is needed to form tropospheric ozone. ***Possible reasons for negative correlation:*** 1. Higher humidity may be associated with rainy conditions, which disperse pollution and rain-out some ozone precursors. 2. Relative humidity is often inversely correlated with temperature, because air with a given water vapor content has lower RH as temperature increases. Since ozone is positively correlated with temperature, it may be negatively correlated with RH.
Ozone and Cloud Cover		V		More cloud cover tends to reduce ozone levels. Clouds reduce sunlight needed for the chemical reactions that form O3.

Figure 20.1

20.2 Background Information

There is no new background information for this lesson.

20.3 Vocabulary

There is no new vocabulary for this lesson.

20.3.1

20.4 Materials Needed (for a class of 25)

- GLOBE Measurement Data Sheets (1 per student)
- Calculator (If needed)
- Crayons
- Markers
- Pencils
- Butcher Paper
- Ruler
- Construction Paper
- Any other art supplies (If needed to make graphs, charts, tables, pictures)

20.5 Step-by-Step Suggested Lesson Plan

Instructor Activity	**Student Activity**
Tell students that today is the last lesson of the curriculum. Today students will be guided into analyzing their GLOBE data for trends. Tell students they will be able to use the knowledge they have learned in order to see the how the GLOBE measurements they have taken are related.	Students listen
Students will analyze their data. Guide students into calculations and graphing related to the data, following the instructions on the worksheets. You may choose to have some of the work, like the calculations of daily average temperature, to be done as a class.	Students analyze their measurement data to create graphs and answer journal questions: (p.3-6)
Have students share their graphs and conclusions with the class. Suggestion: Create a poster recapping the students' final conclusions and what they have learned over the course of the lessons.	Students share graphs and findings
As a final discussion for students, ask students to tell each other about something that they learned about that they found interesting.	Students complete final reflection journal page: (p. 7)

Table 20.1

20.5.1 Expected Outcomes

1. Students will explore how cloud cover, air temperature, and humidity relate to ozone levels on a given day.
2. Students will build experience graphing data in charts.

Index of Keywords and Terms

Keywords are listed by the section with that keyword (page numbers are in parentheses). Keywords do not necessarily appear in the text of the page. They are merely associated with that section. *Ex.* apples, § 1.1 (1) **Terms** are referenced by the page they appear on. *Ex.* apples, 1

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Module: "Rice Air Curriculum - Lesson 7 (Teacher): Analyzing GLOBE Data"
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Rice Air Curriculum

The Rice Air Curriculum, developed by Dr. Daniel Cohan and Kavita Venkateswar of Rice University with funding from the National Science Foundation, aims to engage young children in scientific inquiry and hands-on measurement of the atmosphere. The lessons enable students to apply math and science to explore the challenge of air pollution in their own community. Students measure air pollution and meteorology conditions on their school campuses using protocols developed by the GLOBE program (www.globe.gov). The curriculum is aimed at 5th-grade level science and math classes and consists of 7 lessons: Introduction to the Atmosphere, Physical Properties of the Atmosphere, Atmospheric Gases and Their Cycles, Stratospheric Ozone, Tropospheric Ozone and Other Air Pollution, Climate Change, and Analyzing GLOBE Data. How to Navigate this Collection: Please start with the "Curriculum Introduction," which serves as an introduction to the other modules of this collection. The 7 lessons each consists of (1) a Teacher Lesson Plan, including information about the topic and a step-by-step lesson plan; (2) a Student Lesson module of activities and questions for the students to complete (including a link to a printable worksheet version); and (3) an Answer Key to each student lesson, available as a link from the Teacher Lesson Plan. The Collection also provides: (1) a GLOBE Overview Instruction Manual describing the GLOBE measurement protocols; (2) a Data Sheet Module with links to printable versions of the measurement data sheets; (3) a list of the Texas Essential Knowledge and Skills (TEKS) learning objectives targeted by this curriculum; and (4) Teacher and Student Surveys, which we request that participating teachers return to Dr. Cohan to help assess and improve this curriculum.

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