Unit 2
Atmosphere

Background

Introduction

The atmosphere consists of an envelope of gases whose composition has remained relatively stable through most of Earth's history. Differential heating and rotation of our planet contribute to the dynamic nature of our atmosphere, and consequent changes in force, pressure, and temperature create climate zones, weather patterns, and storms on our planet. Physical and chemical reactions in the atmosphere help shape life on Earth. In relatively recent history, human activities are believed to be influencing the dynamic balances in the atmosphere, causing global surface temperatures and precipitation patterns to change.

Essential Questions

What key functions does the atmosphere serve that enable life to exist on the planet?

How does the atmosphere shape Earth's climate and weather?

What can cause the dynamic balance in the atmosphere to change and what influence do humans have?

Content

Unit 2 focuses on the chemical and physical characteristics of the envelope of gases surrounding our planet that make life possible. The text for Unit 2 introduces the composition and layers of the atmosphere, how particular gases in the atmosphere heat Earth, how interactions between variables impact the heating process, how rising carbon dioxide levels affect the cycling of carbon, a building block for life on the planet, and how moving and circulating air causes weather and climate. The many processes that influence weather and climate are covered. Questions are raised about the dynamic aspect of the climate and which physical factors control climate and interact with one another. This lays a foundation for Unit 12: Earth's Changing Climate.

The Unit 2 video illustrates the process of doing atmospheric field research and shows how scientists go about collecting and verifying field data to address hypotheses. Part One shows Pieter Tans discussing important concepts in greenhouse gases and regulation of atmospheric temperature, interaction between the atmosphere and oceans, and long-term green house gas data summaries. Part Two features Kerry Emanuel discussing hurricanes.

Background

Learning Goals

During this session, you will have an opportunity to build understandings, skills, and dispositions.

a. Knowledge

i. The atmosphere is one of Earth's critical systems that makes life possible on our planet.

ii. The atmosphere is dynamic because of the number of factors that affect the gaseous envelope, such as pressure and temperature, which change with altitude and latitude due to Earth's rotation.

iii. Atmospheric CO_2 levels are controlled by the dynamic balance among living and inorganic processes that make up the carbon cycle.

iv. Positive and negative feedback interactions between variables, such as temperature, vegetation, and precipitation, drive atmospheric changes.

v. Severe weather is the result of interactions among atmospheric variables concentrated in a specific geographic region.

b. Skills

i. Atmospheric science is an interdisciplinary study because of the complex interactions of the various Earth systems.

ii. A spatial approach is critical when studying the atmosphere because of the dynamic, circulating, three-dimensional nature of the atmosphere.

iii. Both spatial and temporal dimensions need to be considered in order to understand feedback mechanisms.

c. Dispositions

i. Human actions are influencing key dynamic balances in the atmosphere.

ii. Human activities have changed the concentrations of heat-trapping substances in the atmosphere.

Key Concepts

Atmospheric layers

Greenhouse gases

Atmospheric pressure

Radiative balance

Global mean temperature

Ozone depleting chemicals

Positive and negative atmospheric

Feedback mechanisms

Global carbon cycle

Atmospheric circulation

FACILITATOR: These concepts correspond roughly to the sections of the unit. There are a number of other concepts that could be included. It is best to start with the author's major ideas and then ask for input from the study group for other concepts they would include.

Background

Misconceptions About the Earth's Atmosphere

Examples of common misconceptions pertaining to the atmosphere include the following.

- A common misconception is that land plants generate most of the oxygen in the atmosphere. People do not understand the capacity of the ocean to generate oxygen into the atmosphere for the planet. Research indicates that 75 percent of respondents incorrectly identify forests as generating more oxygen than oceans, when in fact oceans generate 70 percent of the planet's oxygen supply.
- Most people falsely believe that direct sunlight heats the atmosphere. People do not understand the differences or contributions of the three kinds of heat transfer mechanisms—conduction, convection, and radiation—and how they apply to warming the atmosphere. Many, therefore, do not appreciate that the atmosphere is heated from the ground up, even though the original energy comes from the sun.
- Another common misconception is that greenhouse gases make up a major portion of the atmosphere. In fact, the major constituents in the atmosphere are nitrogen and oxygen, which compose 99 percent by volume. Gases like water vapor and carbon dioxide, which are present in minute amounts, receive much of the public's attention because they operate as greenhouse gases that absorb radiation.

Getting Ready (45 minutes)

Activity One: Assessing Prior Knowledge, Questions, and Related Experiences

FACILITATOR: Distribute index cards to the study group. On the first card, participants indicate something they know about the atmosphere. On the second, they write one question they have about atmospheric systems. And on the third card, they describe a direct experience that they have had that relates to the atmosphere. For example an individual might write:

The atmosphere is made up of high and low pressure air masses that move around and cause weather.

How thick or thin is the atmosphere?

When the air has more moisture it feels more oppressive or thicker.

Getting Ready (45 minutes)

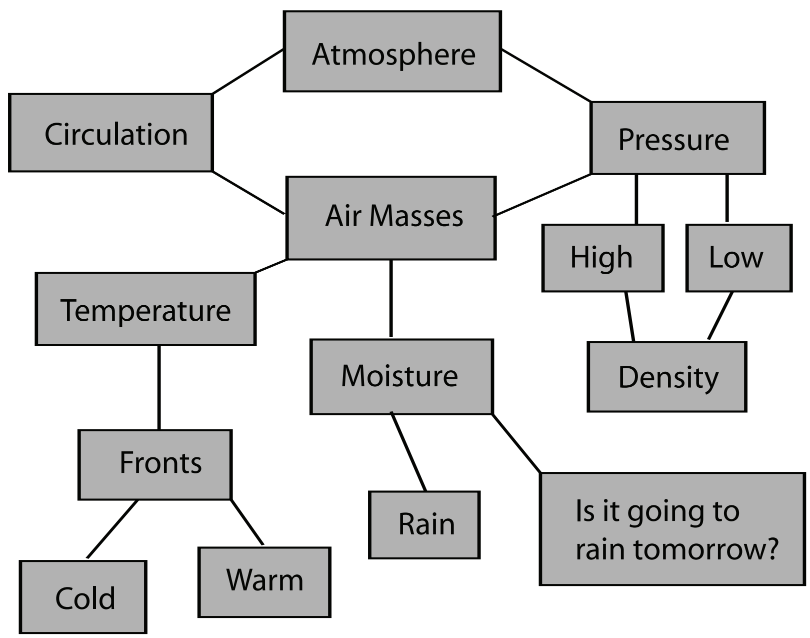

Figure 2.1 An example of a study groups' idea collection, with major subjects identified and the addition of the major focus ideas of the video. This activity links individual pre-existing knowledge with that of other members of the group and the unit content.

Activity Two: Current Events and Editorial Cartoons

Participants will share an article that they have found that is related to the week's topic. All the group members will share their headlines for the articles. The leader should ask a few people to summarize their articles and ask for comments from others with related articles. As the group discusses the articles, a participant should record key concepts and make a list. (Participants may choose to bring in a cartoon or an editorial that is related to the week's topic instead of an article.)

Activity Three: On-line Computer Simulation

Participants will share their diagrams of the carbon cycle. Discuss the results of running the simulation to 2100. Discuss what is necessary to reach the goal of 550 parts per million of carbon dioxide.

Activity Four: Demonstrating the Carbon Cycle

All living organisms are based on the carbon atom. Carbon can help form solid minerals, plants, and animals, and can be dissolved in water or carried around the world through the atmosphere as carbon dioxide gas. The movement of carbon through the Earth's interconnected systems is known as the carbon cycle. The paths taken by carbon atoms through this cycle are extremely complex and may take millions of years to come full circle. Carbon may be stored for extended periods (the "sinks") and eventually released to the atmosphere (the "source"). The triggers of those sources (the "release agents") are also part of the carbon cycle.

Getting Ready (45 minutes)

Materials

- At least 15 black balloons to represent carbon. One red balloon (equals 48 black balloons) and one white balloon (represents 66,000 black balloons). Balloons should be filled with air.
- String or tape to attach balloons.
- Large index cards that identify the principal carbon reservoirs (Atmosphere; Land Biomass (plant or animals); Ocean; Fossil Fuel; Rock).
- Drawing paper and markers.

Carbon Reservoirs

1. Briefly review the carbon cycle as presented in the Unit 2 text. Explain that one black balloon represents 1 carbon unit.
2. Assign five locations within the room for the different carbon reservoirs. Place identifying signs in each location.
3. Place the following number of balloons in each location:

   1 black balloon in the Atmosphere location. (Indicate that this represents all the carbon in the atmosphere in the form of carbon dioxide gas.)

   4 black balloons in the Land Biomass location.

   1 red balloon and 2 black balloons in the Ocean reservoir.

   7 black balloons in the Fossil Fuel reservoir. (Note that fossil fuel carbon is not part of the current carbon cycle flows unless people bring it to the surface.)

   1 white balloon in the Rock reservoir.
4. Ask participants if they agree with the number of balloons in each location and to offer any changes they think should be made with an appropriate explanation.

Questions for Discussion

1. Describe two important “sinks” (parts of Earth that store carbon), two important “sources” (parts of Earth that release carbon), and one important “release agent” (conditions that trigger release) for carbon.
2. Currently it seems that CO_2 sources are out of balance with CO_2 sinks. If more CO_2 is produced than sinks can remove, CO_2 in the atmosphere increases. What might happen if the reverse were true and sinks took up more CO_2 than sources released?
3. Why is knowledge about the carbon cycle important for helping scientists understand global climate change?

The Video (45 minutes)

Activity Four: Watch the Video

As you watch the video, think about the following focus questions.

1. Why is CO_2 the key greenhouse gas that is monitored when there are other greenhouse gases in the atmosphere?
2. Why does scientist Tans believe the role of carbon, cycling through natural systems, like the oceans and forests, is important when talking about CO_2 as a greenhouse gas?
3. What factors cause greenhouse gas concentrations to vary over the globe?
4. What factors go into the selection of places to monitor greenhouse gases?
5. Why do scientists focus on understanding sinks instead of concentrating solely on humans' role as a source of CO_2?
6. What is significant about the two questions Professor Emanuel from MIT poses?
7. Why does hurricane researcher Emanuel distinguish between using models to make forecasts and using models to understand phenomena better?
8. Why is sea spray a confounding factor in understanding how hurricanes work?
9. What is the evidence that hurricanes cause the mixing of ocean currents and how do large computer models accounted for this?
10. How does Emanuel explain evidence that 50 million years ago the temperature in the tropics was the same as today but the temperature in polar regions was much warmer?

Activity Five: Discuss the Video

Discuss the following questions about the video.

1. In what ways do humans influence the role that natural ecosystems play as a sink for CO_2?
2. Do hurricanes affect the climate in important and profound ways?
3. When models behave differently than the real world, how does the inconsistency help scientists?
4. What is the value of long term monitoring?
5. Why should scientists continue to monitor CO_2 concentrations in the same way when there are new and different questions that have emerged that can't be answered by the old way of monitoring?

FACILITATOR: Refer back to the Misconception section and Activity One: Assessing Prior Knowledge. Has the video contributed to the participants' new understanding of concepts? Are there any changes the participants would make to the arrangement of their cards from Activity One?

Going Further (60 minutes)

Activity Six: The Effect of Surface Type on Heating

In this activity, participants will form their own conclusions as to how different surface and cover types affect heating.

Learning Goals

Participants will be able to:

1. Identify at least three factors that affect the heat-trapping ability of a greenhouse.

2. Explain the factors that are important in the atmosphere's heat trapping ability.

3. Describe the influence of albedo on the Earth's temperature.

Materials for Each Group of Four Participants

- Six 1-liter bottles
- Six thermometers
- Tape
- White paint and brushes
- Three cups of dark soil
- Three cups of white sand
- Water and dump buckets
- One 150-watt floodlight bulb
- Portable reflector lamp
- Stand to support lamp set-up
- Graph paper

FACILITATOR: To save time, prepare the model greenhouses in advance. Each team will need six bottles (experimental chambers). The upper third of three of the bottles for each group should be painted white.

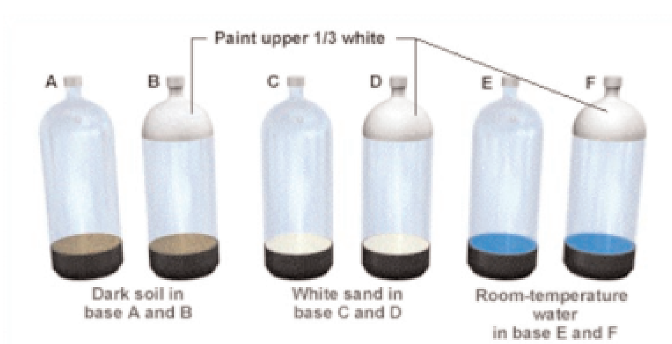

Figure 2.1 Materials Set-up

Going Further

Set-up

1. Label the bottles A, B, C, D, E, and F so that bottles B, D, and F contain the white paint.
2. Fill the base of bottles A and B with dark soil, bottles C and D with white sand, and bottles E and F with room-temperature water.
3. Tape a thermometer (using transparent tape or light-colored masking tape) to the inside of each bottle (facing out).
4. Place the bottle tops in the bases. Make sure the bottles are capped.
5. Make sure the bulbs of the thermometers are just above the top of the bases. If the bulbs are below the base, the thermometer may record the heat absorbed directly by the soil or water, complicating the results.
6. Ask participants to predict which bottle will get hotter. Why? Record predictions.
7. Have each team set up a graph of time (in minutes) versus temperature to record their observations.
8. Each participant should have a specific responsibility during the experiment, either keeping track of the time or recording the temperature for the different bottles.
9. Place the bottles approximately six inches away from the lamp with the thermometer facing away from the light. Record the baseline temperatures.
10. Turn on the light and begin recording the temperatures every two minutes. Continue for at least 20 minutes

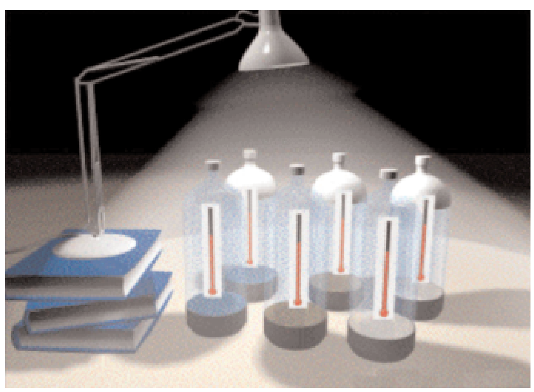

Figure 2.3 Experiment Setup

NOTE: If your lamp is not big enough, six bottles may be too many to have under the light at the same time. The ones further from the light may not get the same intensity of heat as the bottles closer to the light, thereby compromising the experiment. You may have the participants use a sub-set of the bottles at one time. Another technique is to suspend the light in the middle of a circle of containers so they are equidistant from the light.

Observations and Questions

1. Compare the graphed information from data collected using the different bottles.
2. Discuss the results and propose possible explanations.
3. Relate the factors that affect the model greenhouses to the factors that affect the "global greenhouse." Which factors are the same? Which are different?
4. Discuss how this demo relates to the video and text.

Going Further

Activity Seven: Return to Essential Questions

The facilitator should draw the attention of the participants back to the essential questions posed in the Background Section of this unit guide. Discuss how the participants' ideas may have changed in regard to the questions. Discuss the most logical and complete answers to the questions.

Activity Eight: Discuss Supplementary Classroom Activities

If the participants in the study group are teachers, the facilitator should draw the participants' attention to supplementary classroom activities located at the end of this guide. Discuss how teachers would implement these activities in their classrooms and how they would relate them to the topics in this unit.

Between Sessions

Next Week's Topic Overview

Read Unit 3 before the next session. Unit 3 explores the working of ocean currents and circulation patterns and their influence on global climate change. Further details about how global climate change affects the ocean will be found in Unit 12: Earth's Changing Climate and Unit 13: Looking Forward: Our Global Experiment.

Read for Next Session

Read the Unit 3 Professional Development Guide background section. Consider the essential questions as you read the text. The misconceptions section will give you some insight into what misunderstandings people may have about oceans. Consider discussing the topic with your friends or students and discussing common misconceptions.

Current Events

Bring in a current event article or cartoon related to human impact on the oceans.

Supplementary Classroom Activity

Radiosondes

Background information

A radiosonde is a small package of measurement instruments that is carried upward into the atmosphere by a balloon. The radiosonde is designed to measure the vertical changes in temperature, pressure, and humidity from Earth's surface into the upper atmosphere, approximately 30 km. Eventually, the balloon carrying the radiosonde bursts and the radiosonde falls back to Earth. Radiosondes are launched every 12 hours at numerous weather stations around the world. Dropwindsondes are released from aircraft to collect similar data over oceans.

Air temperature usually decreases with altitude. Earth's surface is heated by the sun during daylight hours and loses that heat at night. The lower atmosphere warms as the surface heats the air next to it during the day. This warming of the atmosphere decreases as one increases in altitude.

Sunlight falls more directly on different parts of Earth during the year, so some places on Earth are warmer than others at times when the sun's rays are more direct. In addition, air masses expand as they rise, causing temperatures to decrease. Scientists divide the atmosphere into different layers whose boundaries are defined by changes in temperature. These layers, from the surface up, are the troposphere, stratosphere, mesosphere, and thermosphere. Temperature generally decreases in the troposphere and mesosphere, but increases in the stratosphere. Sometimes the radiosonde data will show a high-altitude increase of temperature with increasing altitude. This happens when ultraviolet radiation is absorbed by the ozone in the stratosphere.

Radiosondes usually travel to altitudes of 30,000 meters, and so they break before traveling far into the stratosphere. Not all data for all locations shows the temperature increase at the end. Radiosondes typically measure pressure and humidity in addition to temperature. The movement of radiosondes can also be tracked for information on wind speed and direction.

Objectives

Students will be able to:

1. Examine radiosonde data from at least two locations, local and distant, of their choosing to determine how air temperature changes with altitude.
2. Make summary statements about reasons for variability of radiosonde data.
3. Appreciate the multiple ways in which atmospheric data is collected and how methods evolve with changes in technology.
4. Identify and access Web-based resources that share radiosonde data.

Materials

Graph paper, colored pencils, access to the Web

Supplementary Classroom Activity

Procedure

1. Students should make a chart that lists at least two locations with columns under each location for temperature and altitude. Students can plot the data for each location on separate sheets of graph paper or multiple locations on one map using different colors for each location. Students can obtain radiosonde data from the Plymouth State University website, http://vortex.plymouth.edu. Scroll down on the left side under Plymouth Wx Pages to "Make Your Own." Then scroll down to RAOB Soundings and click on Diagrams/Data. Then go to "Check a map or this table for possible station identifiers." You can select a region anywhere in the world and identify a four or five digit or letter code. For Type of Output, select "sounding data." The height will be in meters and the temperature in Celsius. Not all locations will generate complete and suitable data, so students may have to try several identifier codes before turning up data sets that can be compared.

   (Note: Students can also graph the data in Excel.)

2. Temperature should be plotted on one axis and altitude on the other. Plotting altitude vertically makes the most logical sense. Axes and graphs should be labeled.
3. Students can also print off the maps with the data already graphed and create overheard transparencies to overlay one on the other.
4. Discuss the commonalities and differences among the various data sets or graphs.
   a. How does temperature change with altitude?
   b. Can you connect the results with anything you have experienced firsthand? Have you been at different altitudes and noticed changes?
   c. Does the air temperature generally increase or decrease?
   d. Is there a dominant pattern across multiple locations?
   e. How do the data sets vary from location to location?
   f. What factors should you consider in selecting various locations where differences might be more pronounced? For example, do you look at data from different latitudes?
   g. What might account for variations?
   h. Is there an increase in temperature with altitude in lower parts of the atmosphere at any locations you've selected?
   i. How can you explain consistent changes in the data or graphs?
   j. Looking at descriptions of various layers of the atmosphere, how do these layers correspond to the data?
   k. What are the limitations of the equipment used?
   l. What would an inversion look like and what would cause this phenomenon?
   m. Why does anyone care about how temperature changes with altitude? How is the information used?

Notes