Prototype

DLESE Teaching Boxes

Essentials of Weather

Digital Library for Earth System Education

Essentials of Weather

Overview of the box

Overview: About this teaching box

This Teaching Box is an online assembly of interrelated learning concepts, digital resources, education standards, and lesson plans that explore basic elements of weather. It is meant to provide an inquiry-based exploration of winds, clouds, and extreme weather events. It is divided into the following units:

- Introductory activity
- The ways of wind
- Counting on clouds
- Culminating activity

Each unit has a set of supporting concepts and education standards correlated to the National Science Education Standards and California State Science Content Standards, lesson plans to teach the concepts, and a summary list of resources used in the box.

Goals of the teaching box: By the end of the teaching box, students will have constructed an understanding of some of the basic elements, forces and processes involved in weather: temperature, pressure, density, convection, differential heating, and condensation, and how these elements combine to create the dynamics of wind and clouds. In the culminating activity, students will research an extreme weather event, its occurrence in a particular area, and a specific incidence of it. Taken as a whole, the lessons within the teaching box demonstrate the inter-relatedness of earth's processes thus reinforcing the overarching concept of **Earth as a system**.

Appropriate for: High school, grades 9-12

Time to complete:
As a whole, this Teaching Box can take 14 - 16 class periods.

Overview: Concepts and standards for this box as a whole

The concepts and education standards are organized below according to the lesson that supports them.

Introductory activity

<table>
<tr><th>Concepts</th><th>Education Standards Supported</th></tr>
<tr><td>

The elements that create everyday weather are the same elements that cause extreme weather.
Extreme weather can cause catastrophic damage to the environment and property and cause the loss of lives.

</td><td>
National Science Education Content Standards:
Grades 9 to 12: Standard D - Earth & Space Science
http://www.nap.edu/readingroom/books/nses/html/6e.html#es
Energy in the earth system: Heating of earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents.
<hr>
California Standards: Earth Sciences: Grades 9 - 12: Energy in the Earth System
http://www.cde.ca.gov/be/st/ss/scearth.asp

Standard 5.Heating of Earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. As a basis for understanding this concept:

a. Students know how differential heating of Earth results in circulation patterns in the atmosphere and oceans that globally distribute the heat.

Standard 6. Climate is the long-term average of a region's weather and depends on many factors. As a basis for understanding this concept:

a. Students know weather (in the short run) and climate (in the long run) involve the transfer of energy into and out of the atmosphere.
</td></tr>
</table>

Ways of wind

Lesson	Concepts	Education Standards Supported
Lesson 1, 2, 3, 4	• The sun's energy is the driving force that ultimately causes weather. • The surface of Earth heats unevenly because of its tilt to the sun • Uneven heating of Earth's surface by the sun creates air temperature differences, which result in air density differences from location to location.	**National Science Education Content Standards: Grades 9 to 12: Standard D - Earth & Space Science** http://www.nap.edu/readingroom/books/nses/html/6e.html#es ***Energy in the earth system:*** Heating of earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. **California Standards: Earth Sciences: Grades 9 - 12: Energy in the Earth System** http://www.cde.ca.gov/be/st/ss/scearth.asp **Standard 5.**Heating of Earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. As a basis for understanding this concept: a. Students know how differential heating of Earth results in circulation patterns in the atmosphere and oceans that globally distribute the heat. **Standard 6.** Climate is the long-term average of a region's weather and depends on many factors. As a basis for understanding this concept: a. Students know weather (in the short run) and climate (in the long run) involve the transfer of energy into and out of the atmosphere.
Lesson 1: Convection's role in creating wind	• The sun provides the energy to create convection currents on our planet.	**California Content Standards: Earth Sciences - Grades 9 to 12: Energy in the Earth System** http://www.cde.ca.gov/be/st/ss/scearth.asp **Standard 4.** Energy enters the Earth system primarily as solar radiation and eventually escapes as heat. As a basis for understanding this

	• Warming causes molecules to move faster, bump into one another, and spread apart. Therefore there are fewer molecules within a given space, resulting in lower density. • Air that is less dense (lighter) than surrounding air will rise and air that is more dense (heavy) will sink. • Air is a fluid (similar to water) and moves because of these differences in temperature and density. The continual cycling of air is called a convection current. • Winds are the horizontal movement of air as the atmosphere acts to equalize density differences in adjacent air masses caused by unequal heating • Convection cells occur in the atmosphere at different scales.	concept: a. Students know the relative amount of incoming solar energy compared with Earth's internal energy and the energy used by society. b. Students know the fate of incoming solar radiation in terms of reflection, absorption, and photosynthesis.

	Large scale convection cells occur in the atmosphere causing the prevailing winds.	
Lesson 2: The roles of pressure and differential heating in wind	• There is a direct correlation between density and pressure. As density increases, pressure increases. • Density differences create areas of high and low pressure. Areas with high density (more molecules) have higher pressure. • Winds blow from high to low pressure and create air mass characteristics and boundaries (fronts) • Winds are the horizontal movement of air as the atmosphere acts to equalize pressure and density differences in adjacent air masses caused by unequal heating.	**National Science Education Content Standards:** **Grades 9 to 12: Content Standard B:** http://www.nap.edu/readingroom/books/nses/html/6e.html#csb912 ***Conservation of Energy and the Increase in Disorder:*** Heat consists of random motion and the vibrations of atoms, molecules, and ions. The higher the temperature, the greater the atomic or molecular motion. **California Content Standards: Earth Sciences - Grades 9 to 12: Energy in the Earth System** http://www.cde.ca.gov/be/st/ss/scearth.asp **Standard 4.** Energy enters the Earth system primarily as solar radiation and eventually escapes as heat. As a basis for understanding this concept: a. Students know the relative amount of incoming solar energy compared with Earth's internal energy and the energy used by society. b. Students know the fate of incoming solar radiation in terms of reflection, absorption, and photosynthesis.
Lesson 3: Wind at the	• Winds are the horizontal movement of air as the atmosphere	**California Standards: Earth Sciences: Grades 9 - 12: Energy in the Earth System**

seashore	acts to equalize pressure and density differences in adjacent air masses.
	
	• Land gains and loses heat more quickly than water.
	
	• Land and sea breezes develop in response to differential hearing of the land and sea surface.
	  ○ During the day, the land heats up more quickly than the sea causing a low pressure over the land with warm air rising, while at sea cool air sinks creating higher pressure. This convection system results in a breeze at the surface from the sea to the land (sea-breeze).
	  ○ In the evening, the land cools off more quickly than the sea with the cool air sinking over the land causing high pressure, while at sea a low pressure area develops. This
		http://www.cde.ca.gov/be/st/ss/scearth.asp
		
		Standard 5. Heating of Earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. As a basis for understanding this concept:
		
		5b. Students know the relationship between the rotation of Earth and the circular motions of ocean currents and air in pressure centers.
		
		Standard 6. Climate is the long-term average of a region's weather and depends on many factors. As a basis for understanding this concept:
		
		b. Students know the effects on climate of latitude, elevation, topography, and proximity to large bodies of water and cold or warm ocean currents.

	convection system results in a breeze at the surface from the land to the sea (land-breeze).	
Lesson 4: Global wind patterns and convection	• There is an indirect correlation between latitude and the receipt of Sun's energy – Over a year, the tropical latitudes 0-30° receive most of the sun's energy, the polar latitudes (60°-90°) the least. As a result the poles are colder than the equator. • Air moves from areas of higher pressure to lower pressure (often resulting from unequal heating). The simplest case is a convection current. • On Earth, convection currents occur on many difference scales due to relative differences in temperature in adjacent air masses. • In areas of vertical air motion – at 0°, 30°, 60°, and 90° latitudes – there is very little wind at the Earth	**National Science Education Content Standards: Grades 9 to 12: Standard D - Earth & Space Science** http://www.nap.edu/readingroom/books/nses/html/6e.html#es ***Energy in the earth system:*** Global climate is determined by energy transfer from the sun at and near the earth's surface. This energy transfer is influenced by dynamic processes such as cloud cover and the earth's rotation, and static conditions such as the position of mountain ranges and oceans. **California Standards: Earth Sciences: Grades 9 - 12: Energy in the Earth System** http://www.cde.ca.gov/be/st/ss/scearth.asp **Standard 5.**Heating of Earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. As a basis for understanding this concept: 5b. Students know the relationship between the rotation of Earth and the circular motions of ocean currents and air in pressure centers.

	surface.
	
	• In the Northern Hemisphere, winds move clockwise, outward, and downward around a High pressure system. Winds move counterclockwise, inward, and upward around a Low pressure system.
	
	• Air movement is influenced by Earth's rotation.
	
	• At the Earth's surface, air moving over relatively long distances appears to veer (be deflected) from its intended path.
	    o Air movement is deflected due to the Earth's rotation known as the Coriolis Effect or Force
	
	    o Winds deflect to the right of motion (clockwise) in the Northern Hemisphere. And winds deflect to the left of motion (counter-clockwise)	

	in the Southern Hemisphere. • The boundaries between air masses of different characteristics (Highs and Lows) are known as fronts.	

Counting on clouds

Lesson	Concepts	Education Standards Supported

Lesson 1: How Clouds Form	• Air cools as it rises.
	  ○ Rising air occurs with low pressure and leads to cloud development. Clouds are often present with low pressure systems (e.g. cold front).
	  ○ Sinking air is associated with high pressure, and leads to dissipating clouds or no cloud development resulting in few or no clouds.
	
	• Clouds form when: 1) there is enough water vapor (water in gas form) to change to liquid droplets or ice; 2) the air is cooled enough from vertical lifting; and 3) there are particles (sand, dust, salt) onto which water vapor can condense.
		National Science Education Content Standards: Grades 9 to 12: Standard D - Earth & Space Science
		http://www.nap.edu/readingroom/books/nses/html/6e.html#es
		Energy in the earth system:
		
		• Heating of earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents.
		• Global climate is determined by energy transfer from the sun at and near the earth's surface. This energy transfer is influenced by dynamic processes such as cloud cover and the earth's rotation, and static conditions such as the position of mountain ranges and oceans.
		
		--- 	
		
		California Standards: Earth Sciences: Grades 9 - 12: Energy in the Earth System
		http://www.cde.ca.gov/be/st/ss/scearth.asp
		
		Standard 6. Climate is the long-term average of a region's weather and

	• Precipitation occurs when cloud droplets grow large and heavy enough to overcome the rising air creating the cloud. • Some of the water in clouds falls as precipitation or snow over oceans and land. • Clouds are transported by the wind. • Clouds are part of the global water transport cycle.	depends on many factors. As a basis for understanding this concept: a. Students know weather (in the short run) and climate (in the long run) involve the transfer of energy into and out of the atmosphere. b. Students know the effects on climate of latitude, elevation, topography, and proximity to large bodies of water and cold or warm ocean currents.
Lesson 2: Exploring Cloud Types	• Air cools as it rises. • Clouds form at different altitudes depending on the temperature and density. • Clouds are divided into groups mainly based on the height of the cloud's base	**National Science Education Content Standards:** **Grades 9 to 12: Standard D - Earth & Space Science** http://www.nap.edu/readingroom/books/nses/html/6e.html#es ***Energy in the earth system:*** • Heating of earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. • Global climate is determined by energy transfer from the sun at and near the earth's surface. This energy transfer is influenced by dynamic processes such as cloud cover and the earth's rotation, and static conditions such as the position of mountain ranges and

	above the Earth's surface. - **Clouds with vertical growth** include Cumulus and Cumulonimbus clouds and can grow to heights in excess of 39,000 feet (12,000 meters). - **High clouds** are made of ice crystals and include Cirrus, Cirrostratus, and Cirrocumulus clouds. The base of a high cloud form above 20,000 feet (6,000 meters). - **Middle clouds** are made of ice crystals and water droplets and include Altostratus and Altocumulus clouds. The base of a middle cloud above the surface can be anywhere from 6,500 to 20,000 feet (2,000 to 6,000 meters). - **Low clouds** consist of water droplets and include Stratus, Stratocumulus, and Nimbostratus clouds. The base of a low cloud is from the surface to 6,5000 feet (2000 meters).	oceans. **California Standards: Earth Sciences: Grades 9 - 12: Energy in the Earth System** http://www.cde.ca.gov/be/st/ss/scearth.asp **Standard 6.** Climate is the long-term average of a region's weather and depends on many factors. As a basis for understanding this concept: a. Students know weather (in the short run) and climate (in the long run) involve the transfer of energy into and out of the atmosphere. b. Students know the effects on climate of latitude, elevation, topography, and proximity to large bodies of water and cold or warm ocean currents.
Lesson 3: Global Cloud Patterns	- Clouds form when: 1) there is enough water vapor (water in gas form) to change to liquid droplets or ice; 2) the air is cooled enough from vertical	**National Science Education Content Standards: Grades 9 to 12: Standard D - Earth & Space Science** http://www.nap.edu/readingroom/books/nses/html/6e.html#es

	lifting; and 3) there are particles (sand, dust, salt) onto which water vapor can condense. • Precipitation occurs when cloud droplets grow large and heavy enough to overcome the rising air creating the cloud. • Some of the water in clouds falls as precipitation or snow over oceans and land. • Clouds are transported by the wind. • Clouds are part of the global water transport cycle. • Infrared satellite images show infrared radiation emitted from Earth: ○ The coldest features of an infrared satellite image, are shown in the lightest shades of gray and the warmest features are shown in the darkest	***Energy in the earth system:*** • Heating of earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. • Global climate is determined by energy transfer from the sun at and near the earth's surface. This energy transfer is influenced by dynamic processes such as cloud cover and the earth's rotation, and static conditions such as the position of mountain ranges and oceans. --- **California Standards: Earth Sciences: Grades 9 - 12: Energy in the Earth System** http://www.cde.ca.gov/be/st/ss/scearth.asp **Standard 6.** Climate is the long-term average of a region's weather and depends on many factors. As a basis for understanding this concept: a. Students know weather (in the short run) and climate (in the long run) involve the transfer of energy into and out of the atmosphere. b. Students know the effects on climate of latitude, elevation, topography, and proximity to large bodies of water and cold or warm ocean currents.

	shades of gray. ○ The tops of the deepest clouds tend to be much colder than Earth's surface or lower clouds, so they typically show up as the lightest features (or colored features)	

Overview: Lessons in this box

Lessons in this box:

Introductory activity: In this introductory activity, students will explore various extreme weather events through images and video. Through class discussion of these events, students will gain an appreciation of the power of Earth's atmosphere and the impact it has on the environment and mankind.

Ways of wind has four lessons in this sequence:

Lesson 1. *Convection's role in creating wind:* In this lesson students will investigate the connection between the heat, density, the movement of a fluid (air) and how this creates convection. The lesson concludes with a discussion of larger scale convection currents and wind.

- Activity 1. Pie pan convection: 30 minutes
- Activity 2. Currents in water: 30 minutes; extension: 30 minutes

Lesson 2. *The roles of pressure and differential heating in wind*: This lesson is composed of both class demonstrations and hands-on activities during which students learn how pressure, density, and differential heating play a role in creating wind.

- Activity 1. What is pressure: 20 minutes
- Activity 2. Differential heating of land and water from solar radiation: 90 minutes (can be shortened to 45 minutes)

Lesson 3. *Wind at the seashore*: This lesson is pulls together the concepts of lesson 1 and 2 by exploring winds at the seashore. Through classroom discussion and activities, students learn how differential air temperatures set up day and night time wind patterns near an ocean.

- Activity 1. Pressure and winds at the seashore (day): 30 minutes
- Activity 2. Pressure and winds at the seashore (night): 20 minutes

Lesson 4. *Global wind patterns and convection*: This lesson is composed of hands-on and kinesthetic activities during which students learn how winds move in global patterns and from high to low pressure systems.

- Activity 1. Follow the air around globally : 20 minutes
- Activity 2. Follow the air around highs and lows: 45 minutes

Counting on clouds has two lessons in this sequence:

Lesson 1. *How clouds form*: In this lesson students will investigate the conditions that must be present for a cloud to form: cooling of air, water vapor, and condensation nuclei. **Class activity: 40 minutes, extension: 20 minutes**

Lesson 2. *Exploring cloud types*: During this lesson students will relate cloud types to the various kinds of weather events. **Class activity: 30 minutes**

Lesson 3. *Global cloud patterns*: During this lesson students will investigate global patterns of precipitation-producing clouds and storms using real-world infrared satellite images. **Class activity: 40 minutes**

Culminating activity: At the end of the unit, students will research an extreme weather event, its occurrencein a particular area, and a specific incidence of it. The unit will end with a weather summit at which the students present the results of their research. **Class activity to describe the project - 40 minutes; Student research: 15 - 20 minutes per class period for 4 - 8 class periods (or this project could be completed during homework sessions); Student demonstrations: 40 - 90 minutes**

Overview: Prerequisites

Students should understand the following concepts. (The links provide information.)

- The sun is the primary source of heat energy for the Earth
  http://www.ucar.edu/learn/1_1_2_5t.htm

- Seasons occur due to earth-sun interactions in orbit.
  http://www.windows.ucar.edu/tour/link=/earth/climate/cli_seasons.html&edu=high
- The atmosphere is organized in layers, each with unique characteristics.
  http://www.ucar.edu/learn/1_1_2_2t.htm
- Composition and structure of the atmosphere
  http://www.ucar.edu/educ_outreach/webweather/basic5.html
- Water has three phases, each with unique characteristics.
  http://www.ucar.edu/learn/1_1_2_3t.htm

Introductory activity: Weather Happens!

In this introductory activity, students will explore various extreme weather events through images and video. Through class discussion of these events, students will gain an appreciation of the power of Earth's atmosphere and the impact it has on the environment and mankind.

Concepts:

- The elements that create everyday weather are the same elements that cause extreme weather.
- Extreme weather can cause catastrophic damage to the environment and property and cause the loss of lives.

Science education standards supported:

National Science Education Content Standards:
Grades 9 to 12: Standard D - Earth & Space Science
http://www.nap.edu/readingroom/books/nses/html/6e.html#es
Energy in the earth system: Heating of earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents.

California Standards: Earth Sciences: Grades 9 - 12: Energy in the Earth System
http://www.cde.ca.gov/be/st/ss/scearth.asp

Standard 5.Heating of Earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. As a basis for understanding this concept:

a. Students know how differential heating of Earth results in circulation patterns in the atmosphere and oceans that globally distribute the heat.

Standard 6. Climate is the long-term average of a region's weather and depends on many factors. As a basis for understanding this concept:

a. Students know weather (in the short run) and climate (in the long run) involve the transfer of energy into and out of the atmosphere.

Materials:

- Computer with connection to the internet
- Projector

Advance preparation: Choose a variety of examples of extreme weather from the online resources below and check their links prior to class. Note: Read through the Culminating Activity to decide when to start students on their culminating project.

Time needed: Teacher prep: 15 minutes; Student activity: 30 - 45 minutes

Procedure:

Start the class with some thought questions, such as "Where would you rather live – Florida or Kansas? What are some positives and negatives about the weather in each place?" *(Answers will be provided in italics: Hurricanes and tornadoes)*

Show images and information from some of these sites about hurricanes to motivate students.

- http://www.nationalgeographic.com/eye/hurricanes/hurrintro.html
  Forecasters talking about tornadoes, pictures of damage
- http://www.nationalgeographic.com/forcesofnature/interactive/index.html?section=h (click hurricane icon top left if necessary) Choose the Hurricane icon (upper left), then Case Studies (right), then select a hurricane (one of the numbers, top left), and scroll through the pictures and video. The site has background information on hurricanes and an activity in which students set the conditions and see if a hurricane forms.
- http://www.nationalgeographic.com/eye/hurricanes/phenomena.html
  Brief information on how hurricanes form
- http://meted.ucar.edu/hurrican/strike/text/anatomy1.htm
  More information on how hurricanes form

Access the following links about the hurricane hunters.

- What is it like to fly into a hurricane? http://www.aoml.noaa.gov/hrd/tcfaq/H3.html
- Follow a 'cyberflight' through a hurricane. http://www.hurricanehunters.com/cyberfly.htm
- Frequently asked questions about flying through hurricanes. Examples: Are the aircraft's wings specifically reinforced? How much money do you make? Do you carry parachutes? http://www.hurricanehunters.com/faq.htm#dangerous.

Discuss what the class has seen. Ask students what the threats associated with a hurricane as it approaches land and makes landfall.

(Strong winds, coastal storm surge, and inland flooding rains. Tornadoes is also correct, although not discussed in the cases. For more information, see http://www.aoml.noaa.gov/hrd/tcfaq/tcfaqL.html.)

Transition to tornadoes. Access the following site and listen to a meteorologist describing a wild day during a tornado.

- http://www.nationalgeographic.com/eye/tornadoes/tornintro.html
  Forecasters talking about tornadoes, pictures of damage
- http://iwin.nws.noaa.gov/iwin/videos/videos.html
  video/audio of several tornadoes (skip the first one)

Show images from some of the sites below. Then discuss what the class has seen.

- http://www.nationalgeographic.com/forcesofnature/interactive/index.html
  Scroll through the pictures and video. As a class work through the activity, Cause your own tornado, in which students set the conditions and see if a tornado forms.
- http://www.spc.noaa.gov/misc/spencer/spendmg.htm
  - Explore some of the maps and photos of damage in Spencer, South Dakota, May 30, 1998
  - Point out how construction techniques (lack of anchoring) made some some buildings vulnerable [photo numbers 6, 8, 9, 10, 15, etc.]
- http://www.nationalgeographic.com/eye/tornadoes/phenomena.html
  Click on the video link on the right, then select a player to see video/audio about how tornadoes form.
- http://www.pbs.org/wgbh/nova/tornado/
  This NOVA site has information, interviews, and activities about tornadoes.

Closing the activity :

1. Discuss with the students what key words did they see or hear that describe what happens when a tornado forms. *(Rising motion, wind shear, rotation inside storm, downdrafts, collision of different air streams in and below thunderstorms.)* Explain that over the next few days, we will unravel some of the fundamental causes of extreme weather events such as these.
2. Discuss some of the common elements between hurricanes and tornadoes *(Students may well focus on the damage caused by both events and this is just fine. Eventually elicit a response that deals with the commonality of strong wind.)* Ask what wind is. *(Movement of air)* Explain that our real investigation is what makes air move. Any thoughts? *Students have probably heard that warm air rises, but chances are that they are not clear about why.* We'll begin by exploring this in **The Ways of Wind, Lesson 1**.

Ways of wind

Ways of wind: Introduction

Approach

Students explore the essential ingredients for weather: temperature, pressure, density, convection, and differential heating. They investigate how these elements combine to create the dynamics of wind on local and global scales.

Lesson Sequence

Lesson 1. *Convection's role in creating wind:* In this lesson students will investigate the connection between the heat, density, the movement of a fluid (air) and how this creates convection. The lesson concludes with a discussion of larger scale convection currents and wind.

- Activity 1. Pie pan convection: 30 minutes
- Activity 2. Currents in water: 30 minutes; extension: 30 minutes

Lesson 2. *The roles of pressure and differential heating in wind*: This lesson is composed of both class demonstrations and hands-on activities during which students learn how pressure, density, and differential heating play a role in creating wind.

- Activity 1. What is pressure: 20 minutes
- Activity 2. Differential heating of land and water from solar radiation: 90 minutes (can be shortened to 45 minutes)

Lesson 3. *Wind at the seashore*: This lesson pulls together the concepts of lessons 1 and 2 by exploring winds at the seashore. Through classroom discussion and activities, students learn how differential air temperatures set up day and night time wind patterns near an ocean.

- Activity 1. Pressure and winds at the seashore (day): 30 minutes
- Activity 2. Pressure and winds at the seashore (night): 20 minutes

Lesson 4. *Global wind patterns and convection*: This lesson is composed of hands-on and kinesthetic activities during which students learn how winds move in global patterns and from high to low pressure systems.

- Activity 1. Follow the air around globally : 20 minutes
- Activity 2. Follow the air around highs and lows: 45 minutes

Ways of wind: Concepts

Teaching the concepts:

The concepts and education standards are organized below according to the lesson that supports them.

Lesson	Concepts	Education Standards Supported
Lessons 1, 2, 3, 4	The sun's energy is the driving force that ultimately causes weather. The surface of Earth heats unevenly because of its tilt to the sun Uneven heating of Earth's surface by the sun creates air temperature differences, which result in air density differences from location to location.	**National Science Education Content Standards: Grades 9 to 12: Standard D - Earth & Space Science** http://www.nap.edu/readingroom/books/nses/html/6e.html#es ***Energy in the earth system:*** Heating of earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. **California Standards: Earth Sciences: Grades 9 - 12: Energy in the Earth System** http://www.cde.ca.gov/be/st/ss/scearth.asp **Standard 5.**Heating of Earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. As a basis for understanding this concept: a. Students know how differential heating of Earth results in circulation patterns in the atmosphere and oceans that globally distribute the heat. **Standard 6.** Climate is the long-term average of a region's weather and depends on many factors. As a basis for understanding this concept:

		a. Students know weather (in the short run) and climate (in the long run) involve the transfer of energy into and out of the atmosphere.
Lesson 1: Convection's role in creating wind	The sun provides the energy to create convection currents on our planet. Warming causes molecules to move faster, bump into one another, and spread apart. Therefore there are fewer molecules within a given space, resulting in lower density. Air that is less dense (lighter) than surrounding air will rise and air that is more dense (heavy) will sink. Air is a fluid (similar to water) and moves because of these differences in temperature and density. The continual cycling of air is called a convection current. Winds are the horizontal movement of air as the atmosphere acts to equalize density differences in adjacent air masses caused by unequal heating Convection cells occur in the atmosphere at different scales. Large scale convection cells occur in the atmosphere causing the prevailing winds.	**California Content Standards: Earth Sciences - Grades 9 to 12: Energy in the Earth System** http://www.cde.ca.gov/be/st/ss/scearth.asp **Standard 4.** Energy enters the Earth system primarily as solar radiation and eventually escapes as heat. As a basis for understanding this concept: a. Students know the relative amount of incoming solar energy compared with Earth's internal energy and the energy used by society. b. Students know the fate of incoming solar radiation in terms of reflection, absorption, and photosynthesis.
Lesson 2: The roles of pressure and differential heating in wind	There is a direct correlation between density and pressure. As density increases, pressure increases. Density differences create areas of high and low pressure. Areas with high density	**National Science Education Content Standards: Grades 9 to 12: Content Standard B:** http://www.nap.edu/readingroom/books/nses/html/6e.html#csb912 ***Conservation of Energy and the Increase in Disorder:*** Heat consists of random motion and the vibrations of atoms, molecules, and ions. The

	(more molecules) have higher pressure. Winds blow from high to low pressure and create air mass characteristics and boundaries (fronts) Winds are the horizontal movement of air as the atmosphere acts to equalize pressure and density differences in adjacent air masses caused by unequal heating.	higher the temperature, the greater the atomic or molecular motion. **California Content Standards: Earth Sciences - Grades 9 to 12: Energy in the Earth System** http://www.cde.ca.gov/be/st/ss/scearth.asp **Standard 4.** Energy enters the Earth system primarily as solar radiation and eventually escapes as heat. As a basis for understanding this concept: a. Students know the relative amount of incoming solar energy compared with Earth's internal energy and the energy used by society. b. Students know the fate of incoming solar radiation in terms of reflection, absorption, and photosynthesis.
Lesson 3: Wind at the seashore	Winds are the horizontal movement of air as the atmosphere acts to equalize pressure and density differences in adjacent air masses. Land gains and loses heat more quickly than water. Land and sea breezes develop in response to differential heating of the land and sea surface. • During the day, the land heats up more quickly than the sea causing a low pressure over the land with warm air rising, while at sea cool air sinks creating higher pressure. This convection system results in a breeze at the surface from the sea to the land (sea-breeze). • In the evening, the land cools off more quickly than the sea with the	**California Standards: Earth Sciences: Grades 9 - 12: Energy in the Earth System** http://www.cde.ca.gov/be/st/ss/scearth.asp **Standard 5.**Heating of Earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. As a basis for understanding this concept: 5b. Students know the relationship between the rotation of Earth and the circular motions of ocean currents and air in pressure centers. **Standard 6.** Climate is the long-term average of a region's weather and depends on many factors. As a basis for understanding this concept: b. Students know the effects on climate of latitude, elevation, topography, and proximity to large bodies of water and cold or warm ocean currents.

	cool air sinking over the land causing high pressure, while at sea a low pressure area develops. This convection system results in a breeze at the surface from the land to the sea (land-breeze).	
Lesson 4: Global wind patterns and convection	There is an indirect correlation between latitude and the receipt of Sun's energy – Over a year, the tropical latitudes 0-30° receive most of the sun's energy, the polar latitudes (60°-90°) the least. As a result the poles are colder than the equator. Air moves from areas of higher pressure to lower pressure (often resulting from unequal heating). The simplest case is a convection current. On Earth, convection currents occur on many difference scales due to relative differences in temperature in adjacent air masses. In areas of vertical air motion – at 0°, 30°, 60°, and 90° latitudes – there is very little wind at the Earth surface. In the Northern Hemisphere, winds move clockwise, outward, and downward around a High pressure system. Winds move counterclockwise, inward, and upward around a Low pressure system. Air movement is influenced by Earth's	**National Science Education Content Standards: Grades 9 to 12: Standard D - Earth & Space Science** http://www.nap.edu/readingroom/books/nses/html/6e.html#es ***Energy in the earth system:*** Global climate is determined by energy transfer from the sun at and near the earth's surface. This energy transfer is influenced by dynamic processes such as cloud cover and the earth's rotation, and static conditions such as the position of mountain ranges and oceans. **California Standards: Earth Sciences: Grades 9 - 12: Energy in the Earth System** http://www.cde.ca.gov/be/st/ss/scearth.asp **Standard 5.**Heating of Earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. As a basis for understanding this concept: 5b. Students know the relationship between the rotation of Earth and the circular motions of ocean currents and air in pressure centers.

	rotation. At the Earth's surface, air moving over relatively long distances appears to veer (be deflected) from its intended path. • Air movement is deflected due to the Earth's rotation known as the Coriolis Effect or Force • Winds deflect to the right of motion (clockwise) in the Northern Hemisphere. And winds deflect to the left of motion (counter-clockwise) in the Southern Hemisphere. The boundaries between air masses of different characteristics (Highs and Lows) are known as fronts.	

Ways of wind: Lesson sequence

Lesson 1: Convection's role in creating wind

Activity 1. Pie pan convection

In this lesson students will investigate the connection between the heat, density, the movement of a fluid (air) and how this creates convection through two activities. The lesson concludes with a discussion of larger scale convection currents and wind.

Online Resource:

- http://www.exploratorium.edu/snacks/pie_pan_convection/index.html

Materials:

- A copy of the instructions for each team of students: http://www.exploratorium.edu/snacks/pie_pan_convection/index.html
- Aluminum pie-pan
- Hot plate
- Dye or food coloring: any color will do
- Tap water
- Bottle of liquid hand soap or shampoo that has a pearly or metallic appearance. Look for the following ingredient on the label: glycol stearate, glycol distearate or glycerol stearate. Good brands to try are Softsoap® and Walgreen's Liquid Soap.

Advance Preparation: Read through the procedure for the experiment; gather the materials needed for the students

Time needed: Teacher preparation: 20 minutes; Student activity: 30 minutes

Procedure:

Students will create convection cells using soapy water, food coloring, and a heat source using this resource: http://www.exploratorium.edu/snacks/pie_pan_convection/index.html.

1. To introduce the concept of convection, ask students to imagine that they are in the kitchen. They take out a pot and fill it half way with water. They put it on the stove and turn the stove onto high. What happens to the water? Why? *(The water will boil.)*

2. Explain that the water at the bottom of the pot heats up first. This causes it to expand. Since the warmed water has a lower density than the water around it, it rises up through the cooler, dense water. When the water reaches the top of the pot, it cools and increases in density, which causes it to sink back down to the bottom. This rising and sinking movement (cycling) is a convection current.
3. Divide students into teams of two.
4. Provide each team with a set of instructions and materials.
5. Have the students follow the instructions under "Assembly" and "To Do" .
6. When the students are finished, have them describe the movement of the soapy water as it heated.

Closing the activity: Discuss with the class how the soapy water moved throughout the experiment. As the solution heated up, it became less dense and rose to the top in columns. The warm liquid cooled and sunk to the bottom. The regions where the fluid rises and sinks are convection cells.

Lesson Vocabulary: Convection, current, density, temperature, fluid

Lesson 1: Convection's role in creating wind

Activity 2. Currents in water

Online Resources:

- Teacher's guide: http://www.ucar.edu/learn/1_1_2_7t.htm This activity is part of a larger activity entitled "Atmospheric Processes - Convection."
- Student guide: http://www.ucar.edu/learn/1_1_2_7s.htm This activity is Part 1 of the student guide.
- Currents in water Student Worksheet

Materials:
For the class:

- Pitchers or jugs for water
- A source of very hot water, such as an electric teakettle, hot plate and regular kettle, or coffee maker (hot tap water is usually not hot enough)

For each team of students:

- Clear plastic plant saucer 8 to 10 inches wide. Caution: DO NOT use saucers with concentric raised rings on the inside bottom; radial ridges are okay
- Pitchers or jugs for hot and cold water
- Food coloring
- Small container for food coloring (a small cup would work fine)
- Medicine dropper or pipette
- Four Styrofoam cups
- Dump buckets

Advance Preparation: Read through the procedure for the experiment; gather the materials needed for the students

Time needed: Teacher instructions - 15 minutes; Student activity - 30 minutes

Procedure:

Working in groups of 4, students will conduct various experiments to trace currents when water is not heated evenly. In the first experiment, they will observe the movement of a drop of food coloring in still water. Then they will conduct variations to the experiment in which they have a heat source and add food coloring to the set-up in various locations. Students will be asked to observe (draw) and record what happens to the drop as it sits in the tray. At the end, students should be able to describe the effect that hot water under the center of the saucepan has upon currents. They should also be able to describe the heat transfer that is taking place (convection).

1. Review the teacher guide: http://www.ucar.edu/learn/1_1_2_7t.htm before class. Students will perform the experiment and the variations in Part 1
2. Print out the student guide for each student: http://www.ucar.edu/learn/1_1_2_7s.htm
3. Divide the students into teams of 4
4. Have the student teams follow the instructions in the 'procedure section' of the student guide
5. Have each students fill out the Currents in water Student Worksheet.

Closing the activity:

- Have students finish student worksheet questions as homework if they need more time
- Discuss as a class what the teams have observed.
- Discuss the relationship between the activities and planet Earth. Ask where circulation like this would occur on Earth. *(Takes place in fluids that are heated unevenly, for example, the atmosphere, the hydrosphere [oceans], and even in molten portions of the lithosphere [magma].)*

- Explain to the students that air moves in the same way as water when it is heated.
- In the next lesson, we will further explore the relationship between temperature, density, and convection in air and water.

Modifications for Alternative Learners: Limited language students should be able to rely on drawings and diagrams for explanations.

Extension: Demonstrate the Preliminary Exercise in the Teacher's Guide: http://www.ucar.edu/learn/1_1_2_7t.htm (the procedure is provided after Part 1's instructions). This exercise demonstrates the concept of density and temperature in water using an aquarium.

Lesson 1: Activity 2. Currents in water Student Worksheet

Observe the movement of the food coloring as it moves through the water

1. Draw your observations an overhead view of the water's motion (as you are looking down on the pan)
   - Show the movement of the colored water (currents) and its relationship to the hot water or heat source for convection
   - Include an explanation about the motion of the water.

2. Now draw the currents in a side view.

3. What effect does the hot water in the center under the saucepan have upon the currents?

4. What type of heat transfer is taking place? How do you know?

Lesson 2: The roles of pressure and differential heating in wind

Activity 1. What is pressure

This lesson is composed of both class demonstrations and hands-on activities during which students learn how pressure, density, and differential heating play a role in creating wind.

Materials:

- Balloon or bicycle tire's inner-tube
- Bike pump
- Safety goggles

Advanced Preparation:

Gather the materials together; read through the procedure before class

Time needed: Teacher Prep - 10 minutes; Class demonstration - 20 minutes

Procedure:
Introduce the idea of pressure by asking students: What words are often used by meteorologists talk about winds and weather systems? You often see Hs and Ls on weather maps right? What are do they stand for? High and low what? *(Elicit the response of pressure.)*

1. Inflate a bicycle tire with a pump or inflate a balloon.
2. While you're inflating the balloon/tire, ask the class what's happening *(Air is going into the balloon/tire, the pressure is increasing, the balloon/tire is getting bigger).* As you add more molecules into a given space (volume), does the pressure increase or decrease? *(It increases because there are more molecules. The pressure inside the balloon/tire is greater than the surrounding air.)*
3. Pop the balloon or use a pen to release the pressure from the tire. If possible have the students feel the air being released from the tire.
4. Ask the students what happened when the balloon popped or the tire's pressure was released. *(Emphasize that the pressure is equalizing suddenly; the air moved from the balloon/tire to the surrounding room. Before the balloon / tire was popped, the pressure gradient was high between the inside of the balloon/tire and the surrounding air.)*

5. Review with the class what happened with the balloon/tire. *(you filled the balloon / tire with more air, the pressure inside increased and was greater than the pressure of air in the room, then the pressure was suddenly released when you popped the balloon/tire)*
6. Ask the class: which direction does air move when there is a pressure gradient (high to low pressure, or low to high) *(From the balloon to the surrounding air - from high pressure to low pressure)*
7. What is this movement of air is called? *(Wind!)*

Closing the activity: Summarize to your students: From the previous lesson, we've learned that convection influences wind and today we've learned that pressure influences wind. What does temperature have to do with weather? We'll see in this next activity.

Lesson 2: The roles of pressure and differential heating in wind

Activity 2. Differential heating of land and water from solar radiation

This activity illustrates how dark land surfaces, light land surfaces, and water all heat at different rates. Students will learn that water heats more slowly than land and therefore the surface of the Earth heats at different rates, causing our weather.

Online Resource: Which Gets Hotter, Land or Water http://www.geosociety.org/educate/lessonplans/land-watertemp_lab.pdf

Materials:

- 3 identical waterproof containers (1–2 cup size plastic containers, U-shaped dishes, large Styrofoam cups, etc.)
- 3 thermometers
- Large reflector lamp and ring stand with at least a 100-w bulb
- Black or dark brown sand, white sand and water, all at room temperature. The sand needs to be dry.
- Stop watches or a large clock with second hand

Advanced Preparation:

Read through the procedure before class; gather the materials for the student activity together

Time needed: Teacher Prep - 15 minutes; Class activity - 90 minutes (Teacher tip: if you don't have block scheduling, try 30 minutes of heating and 15 minutes of cooling)

Procedure:

Introduce the concept of solar radiation and differential heating and cooling of land and water by asking if anyone has ever walked barefoot on the beach on a sunny day. What did they notice about the temperature of the dry sand as they walked along the beach and in and out of the water? Which material felt warmer? *(Dry sand)* Which material felt cooler? *(The wet sand and the water, which is why we go in to cool off!)* Why? *(An example, wet sand: The sun's energy goes into evaporating the water in the sand before it begins to actually raise the sand's temperature.)*

In this activity, students will use water (at room temperature), light soil, dark soil, and a reflector lamp to explore how, even at a small scale, water heats up much more slowly than land. Students will measure the temperature of the heating and cooling of each material in Celsius every 5 minutes for approximately 70 minutes. Then they will graph their results.

1. Print out the activity, "Which Gets Hotter: Land or Water?" http://www.geosociety.org/educate/lessonplans/land-watertemp_lab.pdf for yourself. It comes with teacher instructions and student procedures and worksheets. Make copies of the student procedures and worksheets for your class.
2. Have the students follow the instructions to set up the activity.
3. Divide the students into groups of 2 or 4.
4. Check the set up of each team's equipment to make sure set up is correct (most importantly that the heat source is directly over all three cups evenly!). Make sure each group has a reliable timekeeper and that they all know how to read the thermometers.
5. The students follow the student procedures to measure the temperature of the heating and cooling of each material in Celsius every 5 minutes for approximately 70 minutes.
6. Get the students started on creating their graphs by drawing on the board a large example graph with time on the x axis and temperature on the y axis.
7. Discuss the questions on the worksheets with your students.

Closing the activity: This activity may lead to a discussion about how continents will be warmer than oceans when heated by the sun. This is a good lead in to the next lesson where you explore high- and low-pressure centers due to the temperature differential between land and water.

Lesson 3: Wind at the seashore

Activity 1. Pressure and winds at the seashore (day)

This lesson pulls together the concepts of Lessons 1 and 2 by exploring winds at the seashore. Through classroom discussion and activities, students learn how differential air temperatures set up day and night time wind patterns near an ocean.

Online Resource: Simple drawing of land and ocean

Materials:

- Overhead projector or LCD project

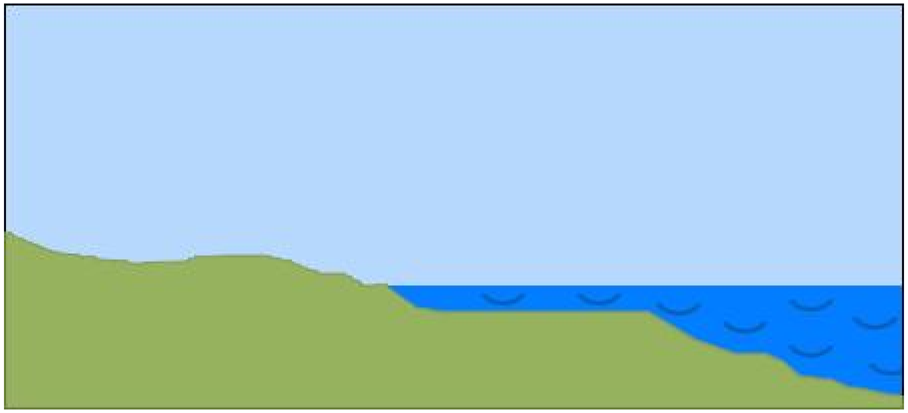
Advanced Preparation:

- Read through the procedure before class
- Make an overhead slide of the simple land - ocean drawing or use an LCD projector to show the drawing
- Make a copy of the simple drawing of land and ocean for each student

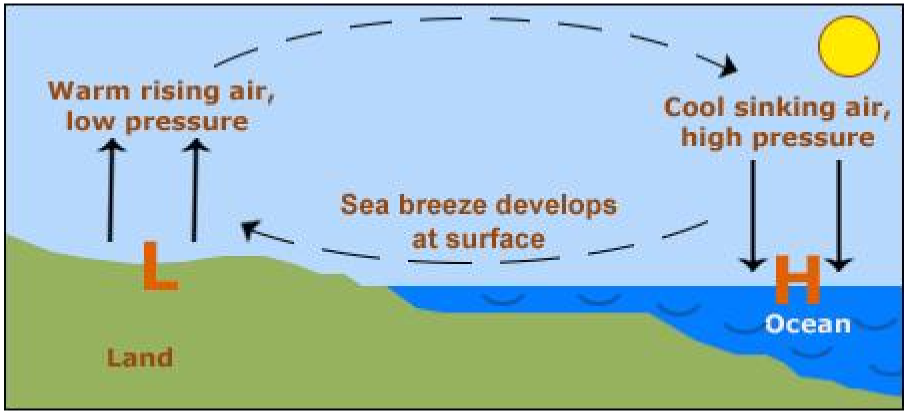
Time needed: Teacher preparation - 10 minutes; Class activity - 30 minutes

Procedure:

To introduce this activity, ask the students if they have ever been to the beach. Was it breezy? Why? *(Note: if the students quickly understand the process, these steps can be condensed.)*



1. In your own words, tell the students: "Let's explore how wind is created when next to large bodies of water and see if we can apply the information we've learned over the past two lessons to this illustration."
2. Hand out the simple drawing of land and ocean to the students
3. Ask your students: If the sun heats an area with both land and ocean, where will the high- and low-pressure areas form during the day? Let's see if we can figure this out.
4. From the previous lesson, which heated more quickly – land or water? *(We learned that land heats up more quickly than water/ocean. Label the land with the word 'warmer', and the ocean with the word 'cooler')*
5. As the air warms does it become more dense or less dense? *(It becomes less dense.)*
6. What happens when the air heats up? Does it sink or rise? Why? *(It rises, because the heated air is less dense than the air above it. Draw an arrow pointing up from the land.)*
7. Since there is lower density air above the land, is there high pressure or low pressure? Think about the balloon activity, as the balloon was filled, the pressure increased, and so did the air's density. Outside of the balloon, the air was lower density and lower pressure. *(so Low density = low pressure. There is low pressure over the land. Draw the low pressure symbol 'L' on the land)*
8. What is happening to the air over the ocean? *(Air over the ocean starts to cool and sink toward the ocean. Draw an arrow pointing down towards the ocean)*
9. Since the air is sinking towards the ocean, does this mean the density of the air is higher or lower? *(It's higher, which means the pressure is higher)*
10. Now we can draw the high pressure symbol (H) to our drawing and connect the rising arrow and sinking arrows together into a circle.

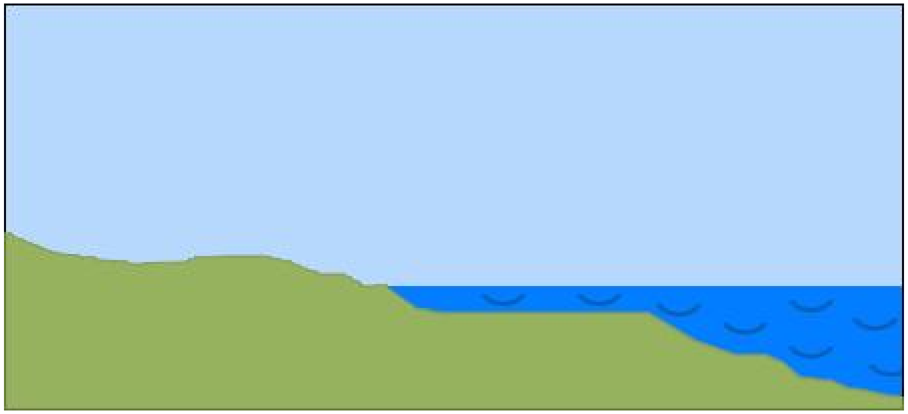


Closing the activity: Ask the students: What does this circle of arrows remind you of? *(a convection cell)*. During the day, you would feel wind from the ocean on your face. What happens at night? *(This leads into the next activity.)*

Worksheet: Simple drawing of the land and sea during the daytime

This is an illustration of the land and sea. The sun is shining and it is late morning.

If the sun heats an area with both land and ocean, where will the high- and low-pressure areas form during the day?



Lesson 3: Wind at the seashore

Activity 2. Pressure and winds at the seashore (night)

Online Resource: Simple drawing of land and ocean at night

Materials:

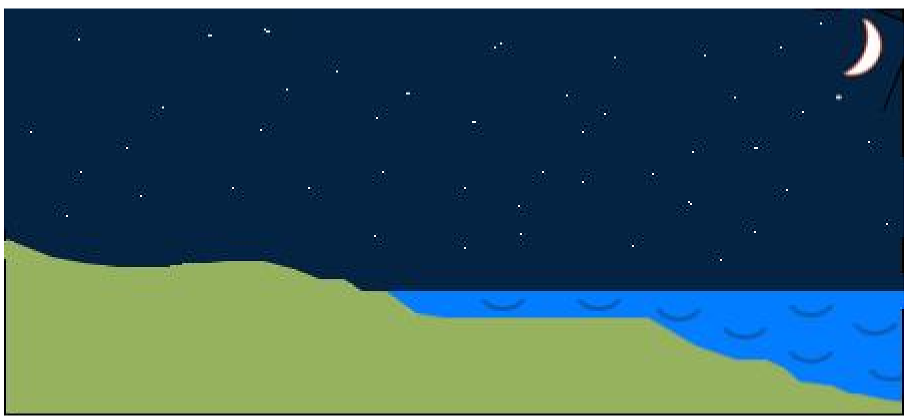
- Overhead projector or LCD project

Advanced Preparation:

- Read through the procedure before class
- Make an overhead slide of the simple land - ocean drawing or use an LCD projector to show the drawing
- Make a copy of the Simple drawing of land and ocean at night for each student

Time needed: Teacher preparation - 5 minutes; Class activity - 20 minutes

Procedure:



1. Let's return to the drawing of land and ocean; but now at night. How would the map differ if it were evening? How would the land and sea surface respond to the cooling? Where is the cool air sinking? *(Solids heat up but also cool down more quickly than liquids.*
2. During the evening, where would the high pressure develop? *(High pressure develops over the cool land surface)*

3. And the low pressure forms where? *(Over the water)*
4. Which direction does the convection cell circulate at night? If you were looking at the ocean, would you feel the breeze on your face? *(The convection cell is opposite of one drawn earlier. Air moves from the land out to the ocean at the surface; you would feel the breeze from behind you*

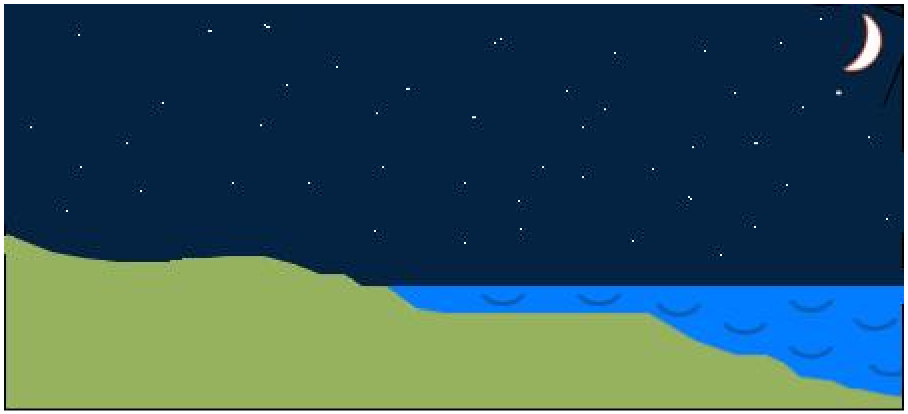
Closing the activity: Ask the students: We have looked at how convective cells are created on a small scale. When we talk about the air warming up during the day in the global sense, what is the heat source? *(The sun)* So in a simple world, we would just have one giant convection current. But there are complications:

1. The surface that is receiving heat is not all made up of the same material and therefore radiates – we've learned that the past two activities.
2. The Earth is not flat, nor does it stay still; it rotates

In the next lesson, we will explore these issues and see how convective forces work on a global scale.

Worksheet: Simple drawing of the land and sea at night

How would the land and sea surface respond to the cooling in the evening? During the evening, where would the high pressure develop?



Lesson 4: Global wind patterns and convection

Activity 1. Follow the air globally

This lesson is composed of hands-on and kinesthetic activities during which students learn how winds move in global patterns and from high to low pressure systems. In this activity, students explore global temperature distribution and how winds move in global patterns.

Online Resource:

- Blank world map: http://www.eduplace.com/ss/maps/pdf/world_cont.pdf
- Simplified global temperatures and convection cells map: http://www.ucar.edu/learn/images/solcirc.gif
- Global temperature, atmospheric circulation, and trade winds map: http://www.ucar.edu/learn/images/fastcirc.gif
- Coriolis Effect graphic at: http://www.atmosphere.mpg.de/media/archive/2847.gif, part of (scroll to step 3): http://www.atmosphere.mpg.de/enid/2f91975b7bb39340e12f4e0ff5e772d2,55a304092d09/18y.html

Advanced Preparation:

- Read through the activity
- Make two copies of the blank world map: http://www.eduplace.com/ss/maps/pdf/world_cont.pdf for each student
- Either have computer w/internet connection and projector ready, or make overheads of the online resources

Time needed: Teacher preparation - 10 minutes; Class activity - 20 minutes

Procedure:

1. In your own words, start the activity with: **"Let's compare the temperatures at the extremes on Earth (the equator and the poles)."** Where are the highest and the lowest temperatures? Can you predict the global wind pattern from what you know about differential heating and pressure? *(Yes, let's try!)* "If you were a parcel ("piece") of air moving from the equator to the poles or the poles to the equator, would you go straight north? Let's find out."
2. **"First, let's review the main relationships between air temperature, density, pressure, and convection.** What happens to air when it is heated or cooled?"

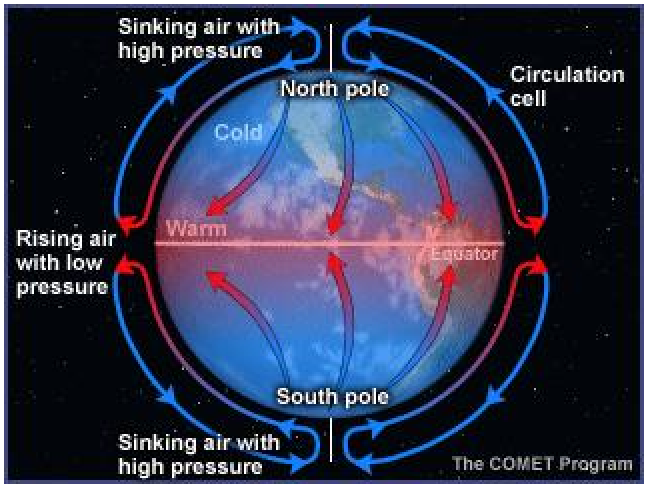
   Elicit a response that indicates an understanding of the following concepts:

   - When air is heated, it expands and rises, resulting in lower pressure over a given area.

- When air is cooled, it contracts and descends/sinks, resulting in higher pressure over a given area.
- Convection and convection cell circulations are the names given to air systems in which air is warmed, causing it to expand, become less dense, and rise; and in cooler nearby locations, air cools, contracts, and more dense and sinks.
- Convective cell motions occur at all scales on Earth, wherever there is a gain or loss of heat resulting in a temperature and pressure gradient.

3. Hand out two copies of the blank world map: http://www.eduplace.com/ss/maps/pdf/world_cont.pdf to each student. Describe to the students: **"Let's look at the extremes on Earth.** Our objective is to examine a simplified, non-rotating Earth and determine where the high- and low-pressure systems exist because of temperature conditions at the Earth's surface. **Think about where the coolest and warmest temperatures are on Earth based on how much sun they receive annually."**

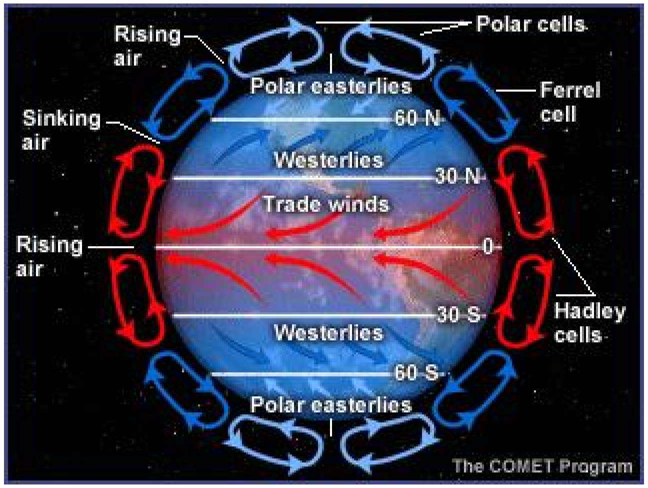
   Have the students draw where the coolest and warmest temperatures are on Earth. Then have them label along the edge of the map (using arrows) where they expect warm air to rise and cool air to sink. Have them connect the rising and sinking air regions with horizontal winds creating a "convection cell." (*The students' maps should look something like the figure below:*).



   source:http://www.ucar.edu/learn/images/solcirc.gif

4. Explain: **"With this approach we have two large convection cells that appear on our simplified Earth, one in the Northern Hemisphere and one in the Southern Hemisphere moving continuously between the poles and the equator.**

Unfortunately, things are not this simple. Because the Earth spins and the air changes temperature as it moves from its source region, this idealized one-cell model is really a three-cell model. Let's examine a map of the three convective cells in each hemisphere". Draw on the board or on an overhead slide the globe and the three Hadley Cells (with arrows) from the global atmospheric circulation map below.



source: http://www.ucar.edu/learn/images/fastcirc.gif

In your own words explain as you draw: "Note the Hadley Cells on the global map. They are one of the three large convections cells that form in the atmosphere between the equator and 30 degrees north and south (N/S), where warm, moist rising air from the equator cools and sinks, creating descending, dry, high-pressure air masses. In addition, relatively warm air at 60 degrees north and south creates a persistent low resulting in two more convection cells between 90-60 degree N/S and 60-30 degrees N/S." Have your students draw the Hadley Cells on the second blank map you handed out to them earlier.

5. Ask your students: **"How can we predict the basic global wind patterns knowing the position of these high and low systems?** Do you ever get the doldrums (feel sluggish)? Who has heard of the trade winds? What are they and why they do they have this name?"

   Explain: "Air that moves vertically (for example, the areas where air is rising [low pressure at the equator] and sinking [high pressure at 30° N/S]) results in very little wind at the Earth's surface. At the equator, this condition is known as the doldrums. It's an area of generally low pressure where rising warm, humid air condenses and forms clouds. This area is known as the ITCZ (Intertropical Convergence Zone) because two Hadley Cells converge there.

There’s another region with very little wind (calm conditions) at 30° latitude. This is where sailors used to get stuck for weeks with no wind to power their sails. The region was called the horse latitudes, because sailors would throw their horses overboard or eat them after running out of food and water for them.

Remember that wind is the horizontal movement of air at the Earth’s surface between regions of high and low pressure." Have students note the general direction of the winds (bottom branch of the Hadley cell) from 30° N/S to the equator and label this: "Trade winds". Also have them draw the westerlies and polar easterlies.

6. Ask the students: **"Notice that the westerlies and polar easterlies are curved on the global graphic. Why? Because the Earth is spinning, which is known as the Corliolis Force.** It is sometimes called the Coriolis Effect because it is not a true force, but rather an effect caused by the Earth’s constant motion."

   Use the Coriolis Effect graphic at: http://www.atmosphere.mpg.de/media/archive/2847.gif (this is part of a larger page: http://www.atmosphere.mpg.de/enid/2f91975b7bb39340e12f4e0ff5e772d2,55a304092d09/18y.html).

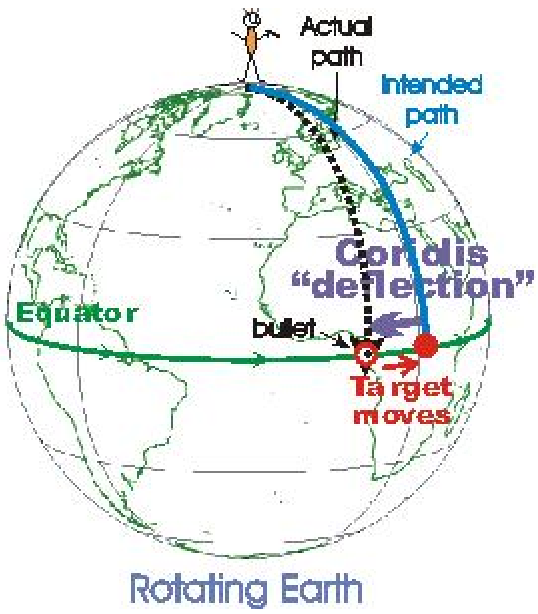


Figure by Schlanger ©

Give students this analogy: Assume a plane takes off from some northern location in the U.S. *(pick one from your area)* and flies several hours due south *(pick another location)*. When the plane arrives, the destination city has moved east due to the Earth's rotation. To really reach the destination due south, the plane actually has to fly a curved path to where the city will be when the plane lands. This is what happens with the air "turning to the right."

Explain that the trade winds are winds resulting from air moving horizontally from 30° N/S to the equator. Again, because the Earth is spinning, the winds are deflected to the right of the straight path you would expect them to take in the Northern Hemisphere and to the left in the Southern Hemisphere. This reliable belt of stronger winds helped sailors move quickly between ports of trade, hence the name 'trade winds' for this area of the globe's wind patterns.

7. Explain: **"The westerlies develop due to prevailing winds between 30 and 60° N/S.** These winds form because air moving from 60° to 30° is deflected to the right of motion in the Northern Hemisphere and to the left of motion in the Southern Hemisphere. The resulting motion is a belt of winds that move out of the west.

Closing the activity: Discuss with your students: "What do the westerlies have to do with the general movement of storms we see in our country? *(In general, weather systems move from west to east across the U.S.)* Has anyone ever noticed that flights going from the east coast to the west coast take longer than the reverse? *(That's because they're flying against the winds. When going from west to east, the westerlies give the plane a boost.)*

Lesson 4: Global wind patterns and convection

Activity 2. Follow the air around highs and lows

This is a kinesthetic activity that shows students the effects of the Coriolis Force on winds around high and low-pressure systems. It helps students understand that in the Northern Hemisphere, high-pressure systems rotate in a clockwise direction and that low-pressure systems rotate in a counterclockwise direction.

Online Resource:

- Kinesthetic Activity Support Document
- Blank map of the United States: http://www.eduplace.com/ss/maps/pdf/us_nl.pdf
- Animations of horizontal and vertical motions: http://meted.ucar.edu/hazwx/2_2_4.htm

Advanced Preparation:

- Read through and try the activity in the Kinesthetic Activity Support Document before class

- Make two copies of the blank map of the United States for each student
- Prepare computer with internet connection and projector to show: Animations of horizontal and vertical motions: http://meted.ucar.edu/hazwx/2_2_4.htm

Time needed: Teacher preparation - 10 minutes; Class activity - 45 minutes

Procedure:
The Kinesthetic Activity Support Document provides step-by-step directions for completing the hand motions for the kinesthetic portion of the activity and explains why rotations are opposite for high and low-pressure systems even though both are due to the Coriolis Effect.

1. Tell students that they will do a hands-on activity that helps them remember the movements of winds around high and low-pressure systems in the Northern Hemisphere.
2. Hand out two copies of blank map of the United States to each student and have them write an **'H'** on one map and an **'L'** on the second map. (This activity also works well in student pairs where one does the high pressure and one does the low pressure).
3. Follow the instructions to complete the kinesthetic activity.

Closing the activity: After the activity (or as an alternative), show the simple animations of horizontal and vertical motions in atmospheric high and low pressure systems at http://meted.ucar.edu/hazwx/2_2_4.htm. The site also has great explanations of the key concepts of pressure gradients, isobars on weather maps, and the strength of the wind.

Closing the unit:

Explain that by now, everyone should know that air moves and what causes it to move. Discuss the concepts before moving on to the next unit, Counting on Clouds.*(The existence of air masses with different temperature, density, and pressure.)*

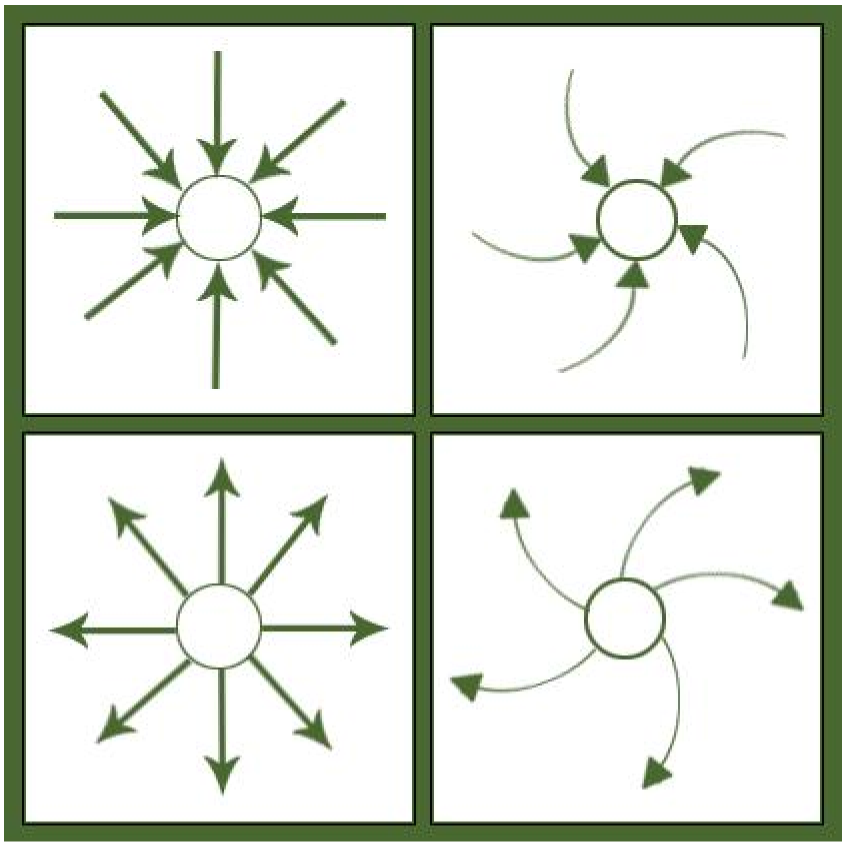
Ask those who are wearing glasses to remove them and breathe on them. What happens. *(They get misty.)* Not only is water in your breath, it's also a major component of air. What form is the water is in. *(Water vapor)* What happens as that water vapor cools and condenses? *(It rains!)* But what do we see in the sky before the rains begin? (*Clouds*)

We'll continue studying weather by exploring clouds.

Kinesthetic Activity: Movement of Air in High and Low-Pressure Systems

Overview
This activity helps students **feel** how high and low-pressure systems spin. The motion is due to deflection resulting from the Coriolis Force. In the Northern Hemisphere, it causes high-pressure systems to rotate clockwise and low-pressure systems to rotate counter clockwise. The direction for rotation is opposite in the Southern Hemisphere.

The reason for this deflection is relatively simple. Air rises in the center of low-pressure systems and is replaced by air rushing in from surrounding higher-pressure areas. (Remember that nature abhors a vacuum.) As the air moves in to the center, it deflects to the right.



Upper left: What would happen without the Coriolis Force
Upper right: The effect of the Coriolis Force on motion

The same thing is true for high-pressure systems in the Northern Hemisphere.

Lower left: What would happen without any Coriolis Force.
Lower right: Overall motion with Coriolis Force.

ACTIVITY FOR LOW-PRESSURE SYSTEMS
Teacher: Practice the activity several times in advance. Then demonstrate it and have your students go through the following procedure.

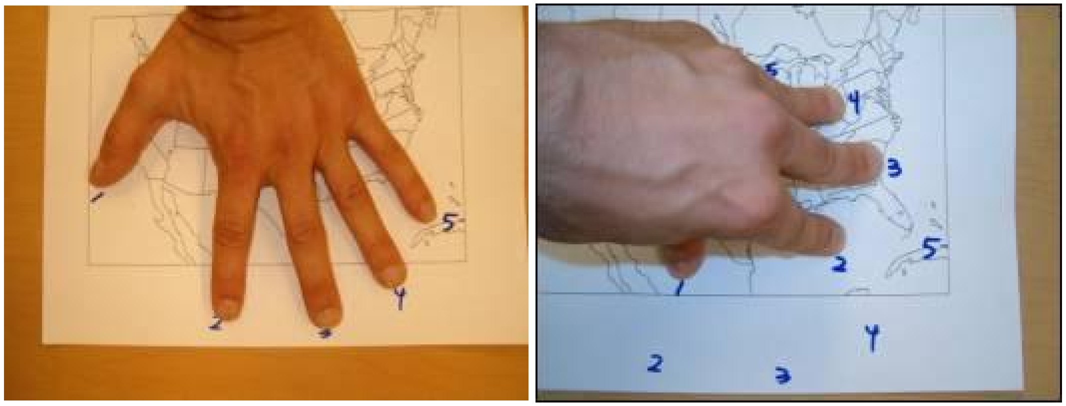
Stand over your desk with the map flat in front of you. Put your left hand on the map with your fingers facing at you (your thumb points to the left). Twist your hand counter clockwise (to the left), bringing your fingers closer and closer together until all your fingers touch.

Do it again but this time, when you're at the starting position, write a number on the map at the end of each finger (1, 2, 3, 4, 5).

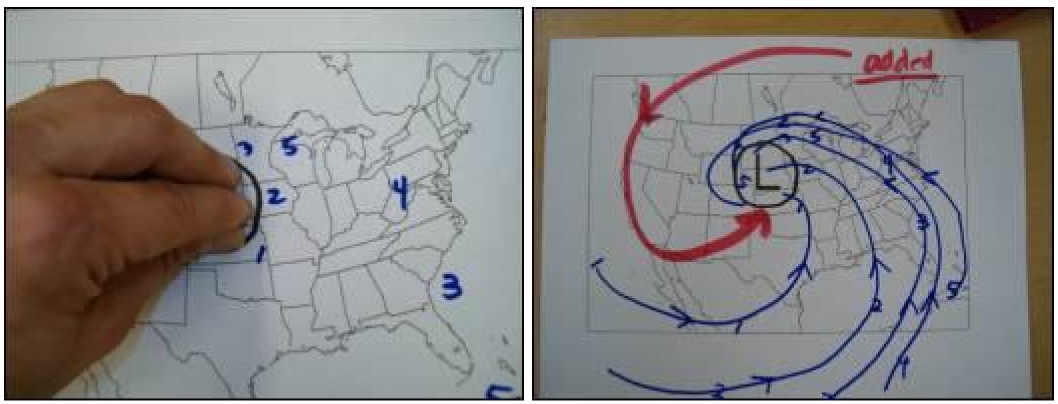
Then move your fingers 1 – 2 cm, stop and write a new number again for each finger (1, 2, 3, 4, 5). Repeat this until your fingers are together in the center of the low. Note that your hand has risen as you've pulled towards the center. This is how low-pressure centers behave.

Now connect all of the 1s and 2s, etc. and put arrows on the lines toward the center. Note that the winds are moving counterclockwise towards the center of a low (in the Northern Hemisphere).

More detailed instructions
Left: Start with your hand flat over the circle with the L (low) on it. Your hand will be in an awkward position (your fingers are pointing at your body).
Right: As you move your hand counterclockwise, your hand will begin to arch up from your wrist.



Left: As you continue up, rotating counterclockwise, your fingers will end up in a circle with the L (low).
Right: This is what you should see when you connect the numbers (the pink arrow adds emphasis and clearly completes the rotation of the wind).



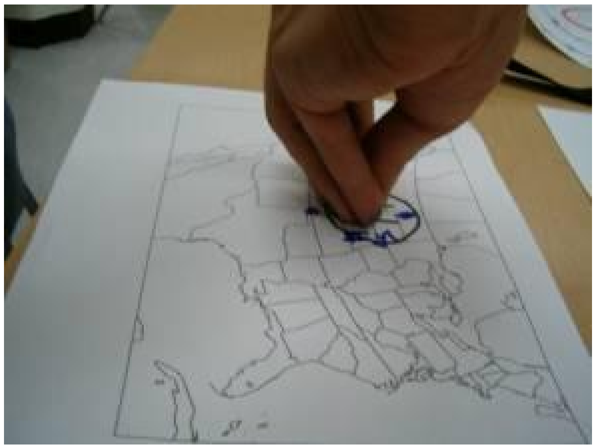
ACTIVITY FOR HIGH-PRESSURE SYSTEMS
Start with your hand in the end position of the low-pressure system (fingers drawn together in a circle around the high, with your palm facing away from you to start). You'll see that the air sinks at the center of the high-pressure area and that it moves out in a clockwise fashion.

Do it again but this time, when you're at the starting position, write a number on the map at the end of each finger (1, 2, 3, 4, 5).

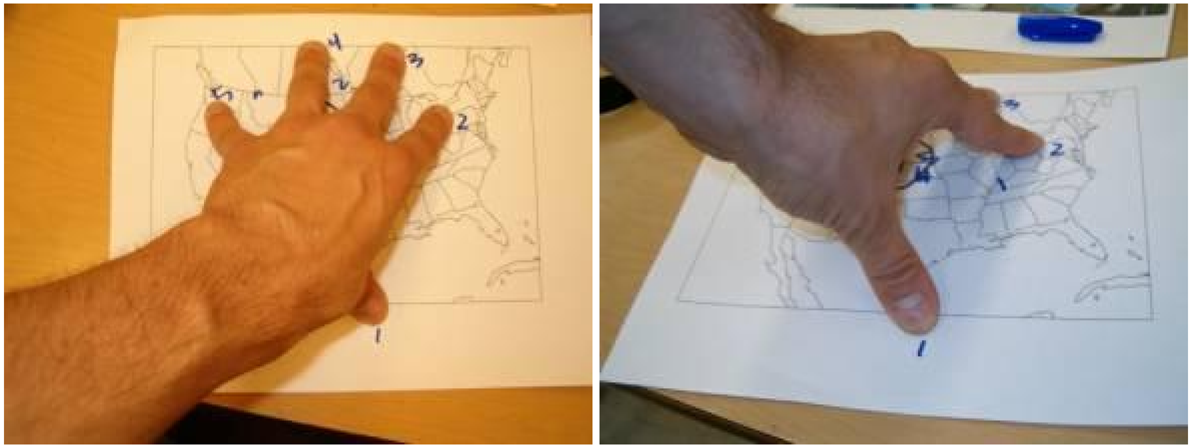
Then move your fingers 1 – 2 cm, stop and write a new number again for each finger (1, 2, 3, 4, 5). Repeat this until your fingers are flat on the paper.

Now connect all of the 1s and 2s, etc. and put arrows on the lines toward the center. Note that the winds are moving clockwise away from the center of a high (in the Northern Hemisphere).

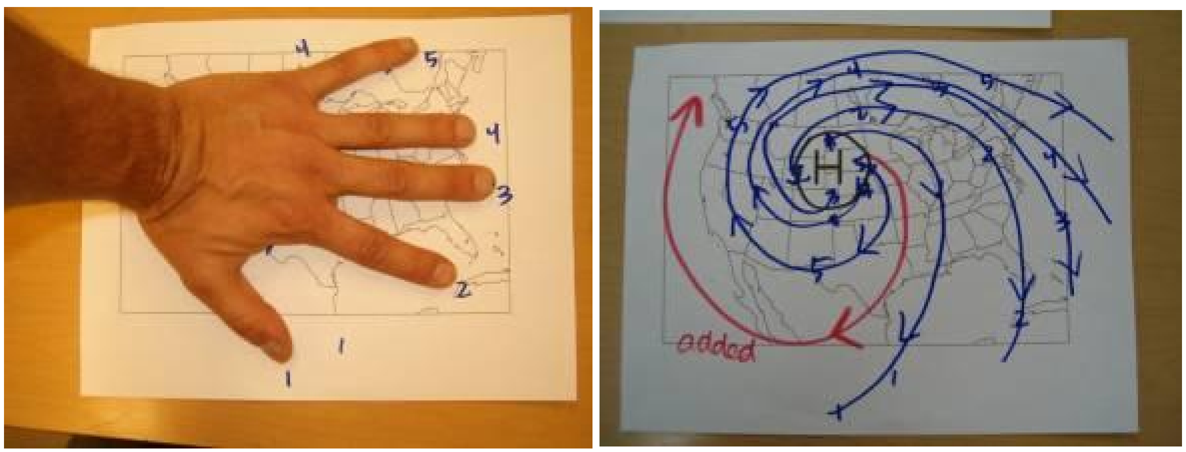
More detailed instructions
Left: Your hand is turned away from you at the start. Write a number (1-5) for each finger
Right: Turn your hand clockwise and down. As you move incrementally, write the numbers for each finger.



Left: As you rotate clockwise, your fingers spread apart.
Right: A view from the side.



Left: Do this until your hand is flat. Keep adding the numbers (1-5 for each finger).
Right: Connect the numbers and add the arrows.



Ways of wind: Teaching and learning resources used in this box

Student Worksheets and On-line resources used in Lesson 1

Currents in Water Student Worksheet
http://teachingboxes.org/jsp/teachingboxes/weather2/wind/L1A2StudentWorksheet.doc

---

Pie-Pan Convection
http://www.exploratorium.edu/snacks/pie_pan_convection/index.html
In this activity, students observe fluid motion and the formation of convection cells as a solution of soap and water is heated. This procedure can be performed as a demonstration by the teacher, or older students can conduct the experiment themselves. A list of materials, instructions, and a description of the convective process are included.

Teacher Guide to Atmospheric Processes: Convection
http://www.ucar.edu/learn/1_1_2_7t.htm
This instructor guide provides background material for a two-part activity in which students observe convective currents in water and learn that air can behave as a fluid. Students will understand that temperature changes can cause density changes in water, learn that the same phenomenon happens in air, and understand that temperature-driven density changes will produce currents in a fluid medium. The student guide has an overall description of the activity, a list of materials, the procedure and observations and questions for both parts. Materials provided in the instructor guide include learning goals, alignment to national standards, grade level/time, details on materials and preparation, procedure, assessment ideas, and modifications for alternative learners.

Atmospheric Processes: Convection
http://www.ucar.edu/learn/1_1_2_7s.htm
In this two-part activity, students observe the phenomenon of convection and the fact that air can behave as a fluid like water, only less dense. They should understand that convection currents are found in many places and on many scales, such as huge convection currents in the atmosphere, oceans, and even in the Earth's interior, or as smaller convection currents that can be found in a cup of hot cocoa or a fish tank. Lists of materials, instructions, variations on the experiments, observations, and questions are provided. This activity can be performed as a demonstration by the teacher, or older students can conduct the experiments themselves.

On-line resources used in Lesson 2

Which Gets Hotter, Land or Water?
http://www.geosociety.org/educate/lessonplans/land-watertemp_lab.pdf
This activity illustrates how dark land surfaces, light land surfaces and water all heat at different rates. Students determine whether land or water absorbs heat more quickly and how this difference affects weather and climate.

Worksheets in Lesson 3

Student Worksheet: Simple drawing of land and ocean
http://teachingboxes.org/jsp/teachingboxes/weatherEssentials/wind/sequence/L3A1_blankLandSea.htm

Student Worksheet: Simple drawing of land and ocean at night
http://teachingboxes.org/jsp/teachingboxes/weatherEssentials/wind/sequence/L3A2_LandSeaNight.htm

On-line resources used in Lesson 4

Blank World Map: http://www.eduplace.com/ss/maps/pdf/world_cont.pdf is part of: Education Place: Outline Maps
http://www.eduplace.com/ss/maps/index.html
This page from Education Place's Social Studies Center lists a selection of outline maps for use in the classroom or at home. Sample maps include Africa: Political; Africa: Political and Physical; California's Regions; Colonial America, 1776; Eastern Hemisphere; Southern Asia: Political; United States: Postal Abbreviations; United States: Climate; The United States in 1860. It contains also five maps with different views of the world.

Simplified global temperatures and convection cells map: http://www.ucar.edu/learn/images/solcirc.gif is part of: Introduction to the Atmosphere
http://www.ucar.edu/learn/1_1_1.htm
This site provides a brief overview of the properties associated with the atmosphere, the thin envelope of air that surrounds our planet and is a mixture of gases, each with its own physical properties. It will help students to recognize that while ninety nine percent of the atmosphere is made up of nitrogen and oxygen, the rest is made up of trace gases that can have a large impact on atmospheric processes. The site serves as a reference for and includes links to seven classroom activities.

Global temperature, atmospheric circulation, and trade winds map: http://www.ucar.edu/learn/images/fastcirc.gif is part of: Teacher Guide to Atmospheric Processes: Convection
http://www.ucar.edu/learn/1_1_2_7t.htm
This instructor guide provides background material for a two-part activity in which students observe convective currents in water and

learn that air can behave as a fluid. Students will understand that temperature changes can cause density changes in water, learn that the same phenomenon happens in air, and understand that temperature-driven density changes will produce currents in a fluid medium. The student guide has an overall description of the activity, a list of materials, the procedure and observations and questions for both parts. Materials provided in the instructor guide include learning goals, alignment to national standards, grade level/time, details on materials and preparation, procedure, assessment ideas, and modifications for alternative learners.

Weather Basics: Local Circulation
http://www.atmosphere.mpg.de/enid/2f91975b7bb39340e12f4e0ff5e772d2,55a304092d09/18y.html
This resource explains the basic forces behind atmospheric circulation on a local scale. Topics include phenomena that help to drive circulation, such as solar heating, gravity, pressure, the coriolis effect, and friction. Two types of local circulation patterns are also discussed: mountain and valley breezes; and land and sea breezes. Photos and diagrams are provided to augment the written discussion, and links to related websites are also included.

Blank map of the United States: http://www.eduplace.com/ss/maps/pdf/us_nl.pdf is part of: Education Place: Outline Maps
http://www.eduplace.com/ss/maps/index.html
This page from Education Place's Social Studies Center lists a selection of outline maps for use in the classroom or at home. Sample maps include Africa: Political; Africa: Political and Physical; California's Regions; Colonial America, 1776; Eastern Hemisphere; Southern Asia: Political; United States: Postal Abbreviations; United States: Climate; The United States in 1860. It contains also five maps with different views of the world.

Pressure: Surface Highs and Lows
http://meted.ucar.edu/hazwx/2_2_4.htm
This tutorial provides basic information about high and low atmospheric pressure systems at the Earth's surface. Topics include how pressure varies with altitude, how pressure systems are depicted on maps, and some properties of high and low pressure systems.

Kinesthetic Activity Support Document
http://teachingboxes.org/jsp/teachingboxes/weatherEssentials/wind/sequence/Kinesthetic%20Activity.html

Counting on clouds

Counting on clouds: Introduction

Approach

Through these lessons, students learn how to make a cloud and how clouds form, the varieties of cloud types and what weather is commonly associated with differing cloud types, and explore global cloud patterns. By the end of this unit, students will be able to describe how clouds form, typical weather associated with the cloud types, and that clouds are part of the global water transport cycle.

Lesson Sequence

Lesson 1. *How clouds form*: In this lesson students will investigate the conditions that must be present for a cloud to form: cooling of air, water vapor, and condensation nuclei. **Class activity: 40 minutes, extension: 20 minutes**

Lesson 2. *Exploring cloud types*: During this lesson students will relate cloud types to the various kinds of weather events. **Class activity: 30 minutes**

Lesson 3. *Global cloud patterns*: During this lesson students will investigate global patterns of precipitation-producing clouds and storms using real-world infrared satellite images. **Class activity: 40 minutes**

Counting on Clouds: Concepts

Teaching the concepts:

The concepts and education standards are organized below according to the lesson that supports them.

Lesson	Concepts	Education Standards Supported

Lesson 1: How Clouds Form	• Air cools as it rises.
	  ○ Rising air occurs with low pressure and leads to cloud development. Clouds are often present with low pressure systems (e.g. cold front).
	  ○ Sinking air is associated with high pressure, and leads to
		National Science Education Content Standards:
		Grades 9 to 12: Standard D - Earth & Space Science
		http://www.nap.edu/readingroom/books/nses/html/6e.html#es
		Energy in the earth system:
		• Heating of earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents.

	dissipating clouds or no cloud development resulting in few or no clouds. • Clouds form when: 1) there is enough water vapor (water in gas form) to change to liquid droplets or ice; 2) the air is cooled enough from vertical lifting; and 3) there are particles (sand, dust, salt) onto which water vapor can condense. • Precipitation occurs when cloud droplets grow large and heavy enough to overcome the rising air creating the cloud. • Some of the water in clouds falls as precipitation or snow over oceans and land. • Clouds are transported by the wind. • Clouds are part of the global water	• Global climate is determined by energy transfer from the sun at and near the earth's surface. This energy transfer is influenced by dynamic processes such as cloud cover and the earth's rotation, and static conditions such as the position of mountain ranges and oceans. --- **California Standards: Earth Sciences: Grades 9 - 12: Energy in the Earth System** http://www.cde.ca.gov/be/st/ss/scearth.asp **Standard 6.** Climate is the long-term average of a region's weather and depends on many factors. As a basis for understanding this concept: a. Students know weather (in the short run) and climate (in the long run) involve the transfer of energy into and out of the atmosphere. b. Students know the effects on climate of latitude, elevation, topography, and proximity to large bodies of water and cold or warm ocean currents.

	transport cycle.	

Lesson 2: Exploring Cloud Types	• Air cools as it rises.
	
	• Clouds form at different altitudes depending on the temperature and density.
	
	• Clouds are divided into groups mainly based on the height of the cloud's base above the Earth's surface.
	
	  ○ **Clouds with vertical growth** include Cumulus and Cumulonimbus clouds and can grow to heights in excess of 39,000 feet (12,000 meters).
	  ○ **High clouds** are made of ice crystals and include Cirrus, Cirrostratus, and Cirrocumulus clouds. The base of a high cloud form above 20,000 feet (6,000 meters).
	  ○ **Middle clouds** are made of ice crystals and water droplets and include Altostratus and Altocumulus clouds. The base of a middle cloud above the surface can be anywhere from
		National Science Education Content Standards: Grades 9 to 12: Standard D - Earth & Space Science
		http://www.nap.edu/readingroom/books/nses/html/6e.html#es
		Energy in the earth system:
		
		• Heating of earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents.
		• Global climate is determined by energy transfer from the sun at and near the earth's surface. This energy transfer is influenced by dynamic processes such as cloud cover and the earth's rotation, and static conditions such as the position of mountain ranges and oceans.
		
		--- 	
		
		California Standards: Earth Sciences: Grades 9 - 12: Energy in the Earth System
		http://www.cde.ca.gov/be/st/ss/scearth.asp
		
		Standard 6. Climate is the long-term average of a region's weather and depends on many factors. As a basis for understanding this concept:
		
		a. Students know weather (in the short run) and climate (in the long run) involve the transfer of energy into and out of the atmosphere.
		b. Students know the effects on climate of latitude, elevation, topography, and proximity to large bodies of water and cold or warm ocean currents.

	6,500 to 20,000 feet (2,000 to 6,000 meters). ◦ **Low clouds** consist of water droplets and include Stratus, Stratocumulus, and Nimbostratus clouds. The base of a low cloud is from the surface to 6,5000 feet (2000 meters).	
Lesson 3: Global Cloud Patterns	• Clouds form when: 1) there is enough water vapor (water in gas form) to change to liquid droplets or ice; 2) the air is cooled enough from vertical lifting; and 3) there are particles (sand, dust, salt) onto which water vapor can condense. • Precipitation occurs when cloud droplets grow large and heavy enough to overcome the rising air creating the cloud. • Some of the water in clouds falls as precipitation or snow over oceans and land.	**National Science Education Content Standards: Grades 9 to 12: Standard D - Earth & Space Science** http://www.nap.edu/readingroom/books/nses/html/6e.html#es ***Energy in the earth system:*** • Heating of earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. • Global climate is determined by energy transfer from the sun at and near the earth's surface. This energy transfer is influenced by dynamic processes such as cloud cover and the earth's rotation, and static conditions such as the position of mountain ranges and oceans. **California Standards: Earth Sciences: Grades 9 - 12: Energy in the Earth System** http://www.cde.ca.gov/be/st/ss/scearth.asp **Standard 6.** Climate is the long-term average of a region's weather and depends on many factors. As a basis for understanding this concept: a. Students know weather (in the short run) and climate (in the long run)

	- Clouds are transported by the wind. - Clouds are part of the global water transport cycle. - Infrared satellite images show infrared radiation emitted from Earth: - The coldest features of an infrared satellite image, are shown in the lightest shades of gray and the warmest features are shown in the darkest shades of gray. - The tops of the deepest clouds tend to be much colder than Earth's surface or lower clouds, so they typically show up as the lightest features (or colored features)	involve the transfer of energy into and out of the atmosphere. b. Students know the effects on climate of latitude, elevation, topography, and proximity to large bodies of water and cold or warm ocean currents.

Counting on clouds: Lesson sequence

Lesson 1: How Clouds Form

During this lesson students will investigate the conditions that must be present for a cloud to form: cooling of air, water vapor, and condensation nuclei.

Online Resource:

- Cloud in a bottle activity: http://www.weatherwizkids.com/cloud1.htm
- Local and Global Precipitation Patterns: http://funnel.sfsu.edu/courses/gm309/labs/global_precip/global_precip.html
- GOES Satellite Imagery : http://rsd.gsfc.nasa.gov/goes/
- Global Cloud Patterns: http://funnel.sfsu.edu/courses/gm309/labs/global_clouds/global_clouds.html

Materials:

- 2-liter clear plastic pop bottle
- Matches
- Warm water
- LCD Projector and computer / Overhead projector and transparency slides

Advanced Preparation:

- Read through the activity before class
- Gather the materials for the activity so that students can work in teams of two
- Set up projector and
- Set up computer to URLs in online resources or make transparencies

Time needed: Teacher preparation - 20 minutes; Class activity - 40 minutes, Extension - 20 minutes

Procedure:

The 'Cloud in a Bottle' activity at http://www.weatherwizkids.com/cloud1.htm is an excellent way to engage students on the subject of clouds. The site has good discussion questions. During this activity students will learn that water vapor must have something to condense on in order to form the droplets that make up clouds. Many things can serve as condensation nuclei, such as dust, pollen, salt from ocean spray, and smoke.

1. Ask students if they have ever walked or flown through a cloud. *(Hint, fog is a cloud on the ground.)* If so, what it feel like? What is a cloud is made o? What conditions are necessary to form clouds? Well, let's see...
2. Without giving the answers, Split the students into teams of two and have them perform the experiment in the Cloud in a Bottle activity, making observations along the way. First, they will try to produce a cloud by just cooling warm air. Then they will repeat the experiment using smoke to provide the nuclei necessary for cloud formation.
3. At the end of the experiment, have students answer the following questions based on their observations.
    1. In all of the trials, the jar contained warm liquid water and air. Where did the water vapor come from? *(The water changed phase from liquid to gas when the air in the closed bottle warmed due to the compression of molecules into a smaller volume.)*
    2. Did a cloud form the first time you put the lid over the mouth of the jar? How about the second and third times? *(Likely no, yes)*
    3. Based on your observations and answers, what else is necessary besides moisture and cool air for cloud formation? *(A particulate for the water vapor to condense on. Meteorologists refer to these as CCN or cloud condensation nuclei.)*
4. As a class, discuss the key things needed to produce a cloud. *(Cooling the air and some kind of particulate, also know as an aerosol. Aerosols are very small insoluble particles suspended in a gaseous medium, in this case, smoke.)*
5. In your own words, "So how can we cool the air? Think back to what we have just learned. Where would you expect to see clouds? *(Where there is rising motion!)* Remember that the atmosphere is less dense and therefore colder with height. Have you ever escaped the summer heat by going into the mountains? Earlier, we learned some of the places that this can occur: at low-pressure systems, where winds converge (such as at the ITCZ), or where land is heated (recall the sea breeze)."

Closing the activity: After discussing the cloud in a bottle experiment, show the image of the Earth at: http://funnel.sfsu.edu/courses/gm309/labs/global_precip/global_precip.html and additional images and animations (movies) from the GOES Satellite Imagery site: http://rsd.gsfc.nasa.gov/goes/. Students should notice cloud patterns occurring across the globe and that clouds are most noticeable across areas of low pressure where air is rising - at the equator and about 60 degrees.

Extension or Homework: To reinforce the principles involved in cloud formation, ask the students the following questions, then as a class, compare the students' answers with the answers provided on San Francisco State University’s site on global cloud patterns: http://funnel.sfsu.edu/courses/gm309/labs/global_clouds/global_clouds.html:

- What is a cloud? *(check answer by clicking on Question #1)*
- How do clouds form? *(check answer by clicking on Question #2)*
- How can air cool enough to form clouds? *(check answer by clicking on Question #3)*
- How can it rise (in more detail)? *(check answer by clicking on Question #4)*

- How do clouds produce precipitation? *(This question extends the students understanding of clouds and rain. Check answer by clicking on Question #5)*

(It's all about vertical motion! As air rises, expands, and cools, it condenses onto the particulates in the air, forming a cloud.)

Lesson 2: Cloud Types

During this lesson students will relate cloud types to the various kinds of weather events.

Online Resources:

- WW2010 Cloud Types: http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/cld/cldtyp/home.rxml
- S'COOL Cloud Chart: http://asd-www.larc.nasa.gov/SCOOL/Cloud_ID.html
- Windows to the Universe: Clouds Types: http://www.windows.ucar.edu/tour/link=/earth/Atmosphere/clouds/cloud_types.html
- Cloudman's Mini Cloud Atlas: http://www.cloudman.com/atlas.htm
- Cloud Observation: http://serc.carleton.edu/introgeo/field_lab/examples/clouds.html
- The Stories Clouds Tell: http://www.ucar.edu/sciencestore/item86.htm

Materials:

- Computer w/ internet connection
- LCD projector

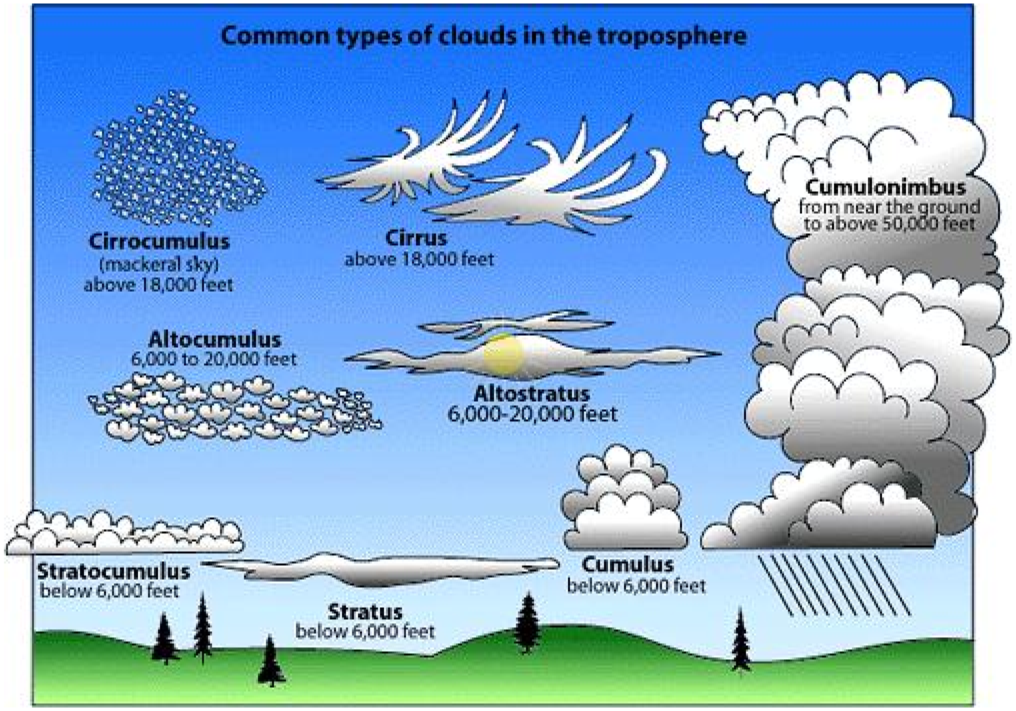
Advanced Preparation:

- Read through the procedure
- Prepare the computer and projector

Time needed: Teacher preparation - 10; Class activity - 30 minutes

Procedure:

1. **Project the site:** WW2010 Cloud Types page and show students the common cloud classifications and heights at which they are typically found in the atmosphere. Alternatively, print out the cloud chart from S'COOL for the students. Additional sites to consider: Windows to the Universe Clouds Types site and Cloudman's Mini Cloud Atlas



Source:http://www.ucar.edu/educ_outreach/webweather/images/cloudchart.gif

2. For each cloud type, ask the students what they see and have them create a list of the cloud types and write a description for each one.
3. As a class, discuss the type of weather related to each cloud type.
4. Once students have created their chart, have students observe and identify the types of clouds that are outside your classroom. Use the Cloud Observation activity to guide the activity.

Alternate procedure: If a computer and projector is not available, "The Stories Clouds Tell" provides photos of clouds types and nice illustrations of how each cloud type is formed. The book comes with a slide show and is available from the National Center for Atmospheric Research at http://www.ucar.edu/sciencestore/item86.htm.

Closing the activity: Discuss the cloud types that are normally seen in your area. This will lead into the next lesson on exploring global cloud patterns.

Lesson 3: Global Cloud Patterns

During this lesson students will investigate global patterns of precipitation-producing clouds and storms using real-world infrared satellite images.

Online Resource:

- http://funnel.sfsu.edu/courses/gm309/labs/global_clouds/CloudsQ6.html
- http://funnel.sfsu.edu/courses/gm309/labs/global_clouds/CloudsQ7.html
- http://funnel.sfsu.edu/scripts/mwir_archloop.html

Materials:

- LCD Projector and computer
- Computers for students to work in teams

Advanced Preparation:

- Read through the activity before class, particularly the information on global patterns and infrared satellite images.
- Gather the materials for the activity so that students can work in small teams.
- Set up projector and computer to URLs in online resources

Time needed: Teacher preparation - 20 minutes; Class activity - 40 minutes

Procedure: This activity has two sections; an introduction section completed as a class, then a small group activity to explore global precipitation through animations of

1. Discuss with students how we can see global patterns of precipitation-producing clouds and storms. Use the answer from Question #6 of San Francisco State University's site on clouds: http://funnel.sfsu.edu/courses/gm309/labs/global_clouds/CloudsQ6.html.
2. Describe to students what infrared satellite images show using San Francisco State University's site on clouds Question #7 as a guide: http://funnel.sfsu.edu/courses/gm309/labs/global_clouds/CloudsQ7.html.
3. Have students in teams explore the weather image viewer located at: http://funnel.sfsu.edu/scripts/mwir_archloop.html. This is a very nice viewer of whole globe weather images (infrared) for the past 2+ years that can build animation loops for up to 14 days.
4. Demonstrate to the students how to build an animation loop.

- Select your current year and month
- Select five days before your current day that you are teaching and 18z. (e.g. if today is the 28th, select the 24rd). Time on this viewer is in Universal Coordinated Time, otherwise known as zulu time. Pacific Standard Time is 8 hours behind zulu time, Mountain Standard Time is 7 hours behind, Central Standard Time is 6 hours behind, and Eastern Standard Time is 5 hours behind. For example, choosing 18z on the viewer will show images from 10 A.M. in Pacific Standard Time.
- Choose an animation length of 5 days.
- Choose 6 hours for the interval between images.
- Click on **Build Animation**. It will take a moment for the viewer to build the sequence.
- In the viewer area, where the global map shows the cloud patterns, you will see the time and date change with each image.
- To get the big picture, click on the **Faster** button multiple times. To study a particular cloud formation, such as storm approaching the coast, click on the **Stop** button, then step through the animation by individual images by clicking on **Next** or **Prev**.

5. Have the students explore other months at the same days, and different years for the same month using the viewer. Some questions to pose the students could be: What was last year's weather like in this month? Was there a lot of cloud cover? What was the weather like in southern California, Michigan, and Florida in September this year? last year? Would you want to vacation in either of these places during this time. Why?

Closing the activity: After the students have explored various time periods, discuss with them some of these questions:

- What general patterns of cloudiness can you make out in these images, at least at this time of year?
- Do these patterns of cloudiness offer any insight into any of the patterns of precipitation?
- Can you spot any patterns of temperature changes revealed in these animations? If so, how might you account for them?

Counting on clouds: Teaching and learning resources used in this box

On-line resources used in Lesson 1

Cloud in a Bottle
http://www.weatherwizkids.com/cloud1.htm
In this activity, students create artificial clouds inside a plastic bottle. This activity can be performed as a demonstration by the teacher, or older students can conduct the experiment themselves. A list of materials, procedures, and an explanation of the cloud-forming process are provided.

Exploration Activity: Local and Global Precipitation Patterns
http://funnel.sfsu.edu/courses/gm309/labs/global_precip/global_precip.html
In this activity, students investigate and compare seasonal precipitation patterns in the San Francisco Bay area with locations at similar latitudes and geographic situations in the southern hemisphere. They will also characterize the pattern of annual average precipitation versus latitude for the earth as a whole. They must understand the concept of latitude, know the names of latitude zones used by meteorologists and geographers, be able to estimate latitudes on a map or globe, and be able to construct and interpret graphs. A list of materials, instructions, study questions, and references are provided.

GOES Project Science
http://rsd.gsfc.nasa.gov/goes/
This collection of GOES satellite imagery features still pictures and movies of weather phenomena and landforms. The collection is divided into east and west sectors. A selection of "scrapbooks" archives images from previous GOES missions. Links to news and information are also included.

Exploration Activity: Global Cloud Patterns
http://funnel.sfsu.edu/courses/gm309/labs/global_clouds/global_clouds.html
In this activity, students characterize some global patterns of deep, cold-topped clouds visible on global infrared satellite images. They will apply these characterizations to answer questions about local and global patterns of precipitation. The questions concern what clouds are and how they form, atmospheric cooling, rising air, precipitation, and the use of remote satellite imagery to see precipitation-producing clouds and storms. They will also create animated global infrared satellite images and answer some questions concerning them.

Online resources used in Lesson 2

Cloud Types
http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/cld/cldtyp/home.rxml
This tutorial explains common cloud classifications and the Latin root words that have been adapted to create the various names of clouds. The classification is subdivided into high-, low-, and mid-level types, clouds with vertical development, and other, less common types. Each description is accompanied by an example photograph.

S'COOL: Cloud Identification Chart and The Cloud Cookery
http://asd-www.larc.nasa.gov/SCOOL/Cloud_ID.html
This resource provides detailed information about cloud identification, observing, and reporting. It also provides an activity on how to make a cloud in a bottle. French and Spanish versions of the chart are also available. This resource was developed for the S'COOL (Student Cloud Observations On Line) project. S'COOL is a component of NASA's Clouds and the Earth's Radiant Energy System

(CERES) project. S'COOL project participants make ground truth measurements for the CERES experiment. Ground truth measurements are land-based observations to compare with satellite data for the purpose of improving the satellite results.

Windows to the Universe Cloud Types: http://www.windows.ucar.edu/tour/link=/earth/Atmosphere/clouds/cloud_types.html is part of:
Windows to the Universe
http://www.windows.ucar.edu/
Windows to the Universe is a user-friendly learning system pertaining to the Earth and Space sciences. The objective of this project is to develop an innovative and engaging web site that spans the Earth and Space sciences and includes a rich array of documents, including images, movies, animations, and data sets that explore the Earth and Space sciences and the historical and cultural ties between science, exploration, and the human experience. Some of the main resource areas of the site are Our Planet, Our Solar System, The Universe, Myths, Art, Books and Films, Space Missions, People, Headline Universe, Cool Stuff, Data, Geology, Life, and Ask a Scientist. Each topic links to numerous facts, figures, and related sites. There are beginner, intermediate, and advanced options for each topic level. Multiple search engines allow the user to browse by keyword, by educational standards, and the Ask a Scientist archives. Special sections are reserved for kids, with games and fun activities, and teacher's resources, such as a workbook and lesson plans. Updates to Windows to the Universe occur on a regular basis, so resource users are invited to revisit the site regularly to see the resources grow and change.

Cloudman's Mini Cloud Atlas: http://www.cloudman.com/atlas.htm is part of:
Cloudman
http://www.cloudman.com/
This site developed by John A. Day, the 'Cloudman,' is packed with cloud observation resources. The mini-cloud-atlas contains photos & descriptions of 12 basic types of cloud. There is also a cloud formation chart, a cloud gallery, history of clouds, a discovery notebook, articles about weather, activities, photography tips, many annotated photos, and philosophy of meteorology.

Cloud Observation
http://serc.carleton.edu/introgeo/field_lab/examples/clouds.html
This lab activity is part of the Starting Point collection. In this short, serial basic-meteorology lab, students identify different cloud types and estimate cloud cover over a period of several days. This website details learning goals, context for the lab, and teaching notes. A list of teaching materials and links to further resources are also provided.

The Stories Clouds Tell
http://www.ucar.edu/sciencestore/item86.htm
This book is a basic guide to the study of clouds. It features descriptions, photographs, and diagrams of various types of clouds. The book is accompanied by a set of slides. It was produced as part of Project ATMOSPHERE, an educational initiative of the American Meteorological Society.

On-line resources used in Lesson 3

Question #6 and Question #7 about clouds and the Animation of Archived Composite IR Satellite Images are part of:
Exploration Activity: Global Cloud Patterns
http://funnel.sfsu.edu/courses/gm309/labs/global_clouds/global_clouds.html
In this activity, students characterize some global patterns of deep, cold-topped clouds visible on global infrared satellite images. They will apply these characterizations to answer questions about local and global patterns of precipitation. The questions concern what clouds are and how they form, atmospheric cooling, rising air, precipitation, and the use of remote satellite imagery to see precipitation-producing clouds and storms. They will also create animated global infrared satellite images and answer some questions concerning them.

Culminating activity

Culminating activity: Following Dynamic Weather

Through an ongoing investigation of a particular city or region of the country, students will apply what they have learned throughout this teaching box to present their investigative results at their very own weather summit. The purpose of this project is to apply what they have learned throughout the Essentials of Weather teaching box and draw connections between the fundamentals of weather and particular weather phenomena.

Online Resources: Resources to be used in class

Materials:

- Computer w/ internet connection
- LCD projector

Advanced Preparation:

- Read through the procedure
- Prepare the computer and projector
- Have computers with internet connection available for students during their research
- Make copies of the Student Assignment Sheets (MSWord document), this includes project directions and blank data tables.

Time needed: Teacher preparation - 30 minutes; Class activity to describe the project - 40 minutes; Student research: 15 - 20 minutes per class period for 4 - 8 class periods (or this project could be completed during homework sessions); Student demonstrations: 40 - 90 minutes

Procedure:

Overview of the project: Students will select a city or region and track the daily weather for a set number of days. They will also research an extreme weather event that occurred in that region. Applying concepts learned in class, students will describe what conditions caused their weather event and the details surrounding that occurrence. In addition students will design a power point presentation and/or a free-standing board to present to the class at the weather summit displaying what they have discovered and investigated concerning their weather event. The purpose of this project is to apply what they have learned throughout the Essentials of Weather teaching box and draw connections between the fundamentals of weather and particular weather phenomena.

Introduce the project

In your own words begin the activity, "We began this unit by describing the types of extreme weather that meteorologists in Florida and Kansas track during their forecasting (hurricanes and tornadoes). What phenomena have we examined that lead to different weather phenomena?" *(Winds, pressure, differential heating, convection, evaporation, precipitation, clouds, etc.)*

Spend about 10 - 20 minutes with the students brainstorming various extreme weather events and viewing clips of various extreme weather events. Start the student discussion by asking some questions: "What types of extreme weather have you or a family member seen or experienced?" (*tornado? hurricane? drought? flood? thunderstorms and lightening?)* Have you ever wondered what caused these phenomena? Has a recent weather event impacted your community or been in the news? Have them generally describe each type (hurricanes, tornadoes, floods, drought, and thunderstorms/lightning).

Hurricanes

- http://www.nationalgeographic.com/eye/hurricanes/hurrintro.html
- http://www.nationalgeographic.com/eye/hurricanes/effect.html
- http://www.nationalgeographic.com/eye/hurricanes/phenomena.html (some information on how hurricanes form)
- http://www.nationalgeographic.com/forcesofnature/interactive/index.html?section=h, choose the Hurricane icon (upper left), then Case Studies (right), then a hurricane (one of the numbers), and scroll through the pictures and video. The site has background information and an activity in which students set the conditions and see if a hurricane forms.
- http://www.comet.ucar.edu/nsflab/web/index.htm (an interactive site that teaches about hurricanes and lets students investigate a few specific storms)
- http://images.google.com/images?hl=en&lr=&q=hurricane (Google image search on hurricanes)

Tornadoes

- http://www.nationalgeographic.com/eye/tornadoes/tornintro.html
- http://www.nationalgeographic.com/forcesofnature/interactive/index.html?section=h
  Choose the Tornado icon (upper left), then Case Studies (right), then a tornado (one of the numbers), and scroll through the pictures and video. Note: The site has background information and an activity in which students set the conditions and see if a tornado forms.
- http://www.spc.noaa.gov/misc/spencer/spendmg.htm (Damage survey summaries)
- http://www.nationalgeographic.com/eye/tornadoes/phenomena.html, click on the video link on the right, then select a player. (Has video/audio about how tornadoes form)
- http://www.pbs.org/wgbh/nova/tornado/ (NOVA site with information, interviews, and activities about tornadoes)
- http://www.spc.noaa.gov/faq/tornado/ Tornado FAQ from the experts in Oklahoma’s Storm Prediction Center

- http://iwin.nws.noaa.gov/iwin/videos/videos.html (video/audio of several tornadoes)
- http://images.google.com/images?hl=en&lr=&q=tornado (Google image search on tornadoes)

Floods

- http://www.nationalgeographic.com/eye/floods/floodintro.html
- http://meted.ucar.edu/qpf/urbanf/tab1.htm (Overview of floods in urban areas by Colorado experts)
- http://images.google.com/images?hl=en&lr=&q=flood (Google image search on floods)

Drought

- http://news.bbc.co.uk/1/hi/world/south_asia/728124.stm (Pictures of drought)
- http://images.google.com/images?q=drought&hl=en (Google image search on drought)

Thunderstorms and Lightning

- http://wvlightning.com/wxvideo/storms.shtml (Thunderstorm shelf cloud in West Virginia)
- https://www.fin.ucar.edu/ucardil/Orders/EditOrders.jsp (select Natural Disasters in the Browse box)
- http://images.google.com/images?hl=en&lr=&q=thunderstorms (Google image search on thunderstorms)

Explain the project

Teacher note: You can either choose which phenomena students research and have them select a city and specific event or let each student or group select a city and find an extreme weather event that occurred in that region (this may be the more difficult but more rewarding route). This project will work with either student teams or individual effort. If they work in groups, have them establish their group and agree to a topic during the initial session. Modify the project length to fit your schedule.

Here's one example: In your own words, "Over the next two weeks, you will work in teams to select an extreme weather event and a city or region where that event has occurred. You will track the daily weather for daily for two weeks. You will also research this extreme weather event to find out how this type of weather occurs as well as the impact it had on the city or region you choose. Applying the concepts learned in class, you will describe the conditions that caused the weather event, report on the specific incident and the details surrounding it. At the end of this project, the class will hold a weather summit at which your teams will present and discuss their findings. Your findings will be presented in either a PowerPoint presentation and/or a freestanding board to present to the class."

Hand out the Student Assignment Sheets (MSWord document) this includes the project directions and blank data tables.

Start the project

How meteorologists study weather: Explain that weather stations around the world have instruments that constantly collect various types of information. Meteorologists use this information to understand weather phenomena and create weather forecasts. The instruments include thermometers, weather balloons, anemometers, rain gauges, radar, and satellites, etc. Description and pictures of weather observing instruments in the U.S. can be seen at http://www.history.noaa.gov/tools/weathertech.html.

The information from the instruments is uploaded into computer models that create weather maps and predictions of future conditions. Model forecasts are typically made for the next 7-10 days and have fairly accurate reliability for large-scale weather patterns. Reliability declines sharply for many reasons as one goes out in time, including the complexity of the atmosphere. Forecasters rely on model forecasts but add their own value based on their understanding of the weather, especially in their local area.

Tell students that in order to track the weather in a selected city, they will examine weather maps from the U.S. to familiarize themselves with weather map symbols and more information about pressure isobars, temperature contours, high and low pressure regions, various fronts, dew point, and cloud cover. Good sites to explore are: http://vathena.arc.nasa.gov/curric/weather/hsweathr/isobar.html and http://64.55.87.13/dstreme/ (has examples of surface, upper air, radar, and satellite data as well as watches and forecasts, etc.)

Have each group examine U.S. weather maps for a given time period (4-5 days) and predict where certain weather systems will be during those days. Forecast maps are available from various sites, notably the American Meteorological Society's DataStreme's site at http://64.55.87.13/dstreme/. Have the students track the weather in a city for this time period (see tables in Student Sheets). *(Teachers may wish to modify the tables based on whether students will be using a school weather station, the Internet, newspaper, or the T.V. news to collect their data!)*

The following sites provide explanations weather map symbols so students can interpret the weather maps.

- http://64.55.87.13/dstreme/extras/wxsym2.html
- http://ww2010.atmos.uiuc.edu/(Gh)/guides/crclm/tg/wx.rxml

General sites for finding online resources about weather phenomena and extreme weather events

- Digital Library for Earth System Education, DLESE: http://www.dlese.org

- United States Geological Society (USGS): http://www.usgs.gov/, use the search box (upper right)
- National Oceanographic and Atmospheric Administration (NOAA): http://www.noaa.gov/
- National Weather Service, Storm Prediction Center, http://www.spc.noaa.gov/
- NOAA, National Hurricane Center, http://www.nhc.noaa.gov/

Culminating Activity

Student Sheet 1- Assignment with project directions

Name(s) of student(s) ______________________________
This project is due on: ______________________________
Your city is: ______________________________
Your extreme weather event is: ______________________________

Example events

Region	Event	Date
Spencer	Tornado	May 30, 1998
Brookings County	Tornado	June 22, 1997
SW Minnesota	Tornado	March 29, 1998

Part I: Data table

Track the daily weather for _______ days for the city in which your extreme weather event occurred. Use the tracking chart (Student Sheet 2 or Student Sheet 2 Advanced Version) and data at http://www.weather.com. Try hard to make your observations close to the same time each day!

Record the daily temperature, precipitation, and overall conditions including: cloud cover, pressure, relative humidity, wind speed and direction, and comments for each day. Once you have collected the data, create a graph of the high, low, and average temperatures and precipitations for your city.

Example

Date	High/Low/ Avg Temperature ˚F	Precipitation	Conditions	Comments
Thurs. 6/10/04	62°/57°/50°	0 inches	Cloudy	Chance of rain

Part II: Research paper

You will research an extreme weather event and its impact and effects on the Earth and its inhabitants. The paper has two parts.

1. Describe your extreme weather phenomena. Include details like, the conditions that must be present for it to occur, how it forms, when it typically occurs (season, time of day, etc.), and if known, what causes it to end.

2. Include a specific account of an extreme weather incident that occurred in the city for which you are tracking weather. The event must have happened within the last ten years so you can find information about its impact on: the area, the people living there, the environment, the wildlife including vegetation, and the economy. Try to find true stories from people present before, during, and after the event and other information, for example, any warnings issued before the event, any precautions taken, safety awareness or preparedness of the communities involved, response from special services such as the Red Cross, hospitals, clean up assistance, and the government, the damage involved, and what happened after the event.

Part III: Presentation board and Power Point

The presentation at the weather summit is the last part of the unit. Each student or group of students will share what they have discovered about their weather phenomena. The presentations will be made over 2-3 days and must include a PowerPoint presentation (PPT) and/or a freestanding board. The materials in the PPT and on the board must be different (but all relate to the event). The PPT must include 7-10 slides including one with the group's names. All text and pictures on the board must be labeled, and the text must be large so that it can be easily read. The presentations must be organized and informational. Each group should practice their presentation ahead of time. The materials will be evaluated for clarity, organization, information, creativity, and overall appearance. This is an opportunity to share what you have discovered about how your extreme weather event occurs and to share the details of the specific incident that you researched.

Student Sheet 2 – Tracking Weather Data Table

Your Observation site (city):____

Date AND Time	Observer (Name(s))	Hi/Low/ Avg. Temperature (°F)	Precipitation (inches)	Conditions	Comments
