Instructional Segment for Fundamental principles of our atmosphere, weather systems, and the nature of storms and storm systems

| Using maps and data to predict wind patterns, frontal boundaries and movement, and precipitation. | |
|---|---|
| **Student Science Performance** | |
| **Grade or course-Earth Science HS** | **Title**<br>Making and Interpreting Weather Maps |
| **Topic:** Fundamental principles of our atmosphere, Weather systems, and the nature of storms and storm systems | |

**Performance Expectation for GSE:**

**SES5. Obtain, evaluate, and communicate information to investigate the interaction of solar energy and Earth's systems to produce weather and climate.**

a. Develop and use models to explain how latitudinal variations in solar heating create differences in air pressure, global wind patterns, and ocean currents that redistribute heat globally.

b. Analyze and interpret data (e.g., maps, meteograms, and weather apps) that demonstrate how the interaction and movement of air masses creates weather.

c. Construct an argument that predicts weather patterns based on interactions among ocean currents, air masses, and topography.

d. Analyze and interpret data to show how temperature and precipitation produce the pattern of climate regions (zones) on Earth.

e. Construct an explanation that describes the conditions that generate extreme weather events (e.g., hurricanes, tornadoes, and thunderstorms) and the hazards associated with these events.

f. Construct an argument relating changes in global climate to variation to Earth/sun relationships and atmospheric composition.

Additional notes on student supports

**Performance Expectations for Instruction:**

The GSE for Earth Systems requires that students continually develop and use models to better explain concepts across the various instructional segments. Students will also be provided models and asked to interpret and analyze data from these models that will further reinforce core concepts. In Earth Systems, models commonly consist of scaled and unscaled 2 and 3-dimensional surface and cross-sectional maps.

This lesson will utilize the mapping and modeling skills gained throughout the year to develop a weather map. Initially the students will focus on the history of weather maps and then learn how to create their own.

**Materials**

Topographic Map of USA

Color pencils and/or markers

***Students will continuously obtain, evaluate, and communicate information. This is not a linear process. Students will communicate through writing and discussions to allow for formative assessment. This benefits the teacher, student, and whole group to guide instruction to clarify misconceptions or extend content.***

| ***Engaging Learners*** | **Phenomenon**<br>Students will read about the Sea Island Storm of 1893.<br>Have students or teacher research and share findings on: 1893 Sea Islands Hurricane as well as the history of communication. |
|---|---|

| | |
|---|---|
| | The goal of this segment is making and interpreting weather maps. There is a reason for accurate weather mapping, so we will start with some history before there were satellites to aid in tracking hurricanes. Some probing questions for the students are:<br>(1) Why did so many people die in the 1893 Sea Island Hurricane?<br>(2) Do you think that the people on Sea Island had an indication that there was a hurricane coming?<br>*Teacher Note:* We are leading up to the importance of understanding weather maps. |
| | *Obtaining*<br>Students obtain a list of significant hurricanes to impact the United States prior to the launch of weather satellites.<br><br>*A list can be found at the* *Hurricane Research Division*<br>Have students or teacher research and share findings: *List of Atlantic Hurricanes*<br><br>*Teacher Note:* Some significant storms that impacted the Georgia Coast were the Sea Island Storm of 1893, 1824, 1854, 1884, 1893 (a second storm) 1898, 1940, 1947. One of the worst storms to impact the continental US was in Galveston TX in 1900. Students often struggle with understanding what life was like before technology. |
| | *Evaluating*<br>Students will evaluate the different forms of communication for weather events during the times prior to satellites and radios. |
| | *Communicating*<br>Students will write a diary entry as if they lived on the coast during one of the storms prior to satellite imaging and radios.<br><br>*Teacher note: be sure that students have researched history of communication.* |
| **Exploring** | *Obtaining*<br>Students will construct an experiment to show the unequal heating and cooling of the earth. After this is complete and data shared with all groups. Student will communicate their findings in a report that explains how latitudinal variations in solar heating create differences in air pressure, global wind patterns, and ocean currents that redistribute heat globally.<br><br>Students will then obtain weather maps from their location from local media or the National Weather Service. |

| | |
|---|---|
| | *Communicating*<br>Students will work in small groups to make a weather map. Have each group's map indicate a coming air mass that would change the weather in that area (warm front or cold front and high and low pressures). The students should note the latitude and longitude of the locations and how the weather would change because of these.<br><br>*Teacher Note:* Students can discuss how latitudinal variations in solar heating create differences in air pressure, global wind patterns, and ocean currents that redistribute heat globally from SES5a. Depending on your students, the students that understand the larger picture of weather could do locations from around the world in this activity, while the students that struggle focus on the local areas.<br><br>Have students or teacher research and share findings to help students with symbols, language, and interpretation of weather maps.<br>● Weather Prediction, Storms<br>● Interpreting Visible and Infrared Satellite Imagery<br>● Determining Surface Wind Direction<br>● Identifying Troughs and Ridges<br>● Brief "Tour" of a Low-Pressure System |
| | *Evaluating*<br>Students will present their maps to the class and compare the way each group depicted the approaching weather event. |
| | ***Formative Assessment of Student Learning*** |
| ***Explaining*** | *Obtaining*<br>The class will either visit one of the local meteorologist at a news station or have the person come to visit. Many of them love to meet with students and share their field.<br><br>*Teacher note:* Through a google search, you will be able to find options for contacting a local meteorologist or even someone from the NWS or The Weather Channel which is housed in Atlanta to come and visit the school. |
| | *Evaluating*<br>Have the meteorologist discuss how they forecast the weather, interpret the maps that they present on the nightly news and provide examples. This person is also a good resource as a career path in STEM. |
| | *Communicating*<br>Students will ask questions to a professional in the field. |
| ***Elaborating***<br>Applying Model to Solve a Problems | **Phenomenon**<br>Students will watch an approaching thunderstorm and discuss the importance again of weather maps and tracking weather. What air masses are a part of the map in relation to where the thunderstorms occur?<br>Have students or teacher research and share findings: Approaching thunderstorm time lapse video |

| | |
|---|---|
| | Ask: How can you explain the movement of the storm? If this were viewed on a map, how would it look? How do large air masses play a part in why thunderstorms develop? How are large air masses depicted on models such as maps and computer?<br><br>*Teacher note: The documents on Winds came from this source: Local and General Winds, Utah State University.*<br><br>Have students read the handout: Local and General Winds and discuss what they know about unequal heating of the earth and its effects on weather. Have small groups or pairs of students summarize the article into their own words providing labels on sketches. Give each group time to discuss with other groups their understandings from their summary and then revise their documents.<br><br>Provide the handout, Local Winds, and have students discuss how this meshes with what they have learned about General Winds. Now they are beginning to see how the general unequal heating of the Earth's surface affects them locally.<br>*Teacher note: This handout contains two sections-- Local Winds and Slope and Valley Winds. Depending on time, use them together or in separate lessons.*<br><br>Have students recognize that the unequal heating of the Earth's surface produces effects on latitude and altitude. Have them generalize what they know to topographical maps of their area to see where wind patterns occur. What role does topography play in weather?<br><br>Now that students are familiar with mapping and weather. Have them use their knowledge and skills to work in small groups on the exercise, Slope and Valley Winds Exercise.<br><br>Have students discuss how the major air masses move the weather across the United States. Have them describe the global wind patterns and the resulting weather that occurs in those paths. Can they determine why this weather is a pattern?<br><br>What role do oceans play in the weather? Why do the global air masses happen?<br>Have students relate the unequal heating of the land, air, and water to the movement of water vapor and air causing the resulting weather.<br><br>Challenge groups of students to construct an explanation of the "Big Picture" of what causes weather and argue what they think is the major factor (water from the ocean, major air masses, topography, other). Have them research their choice and present their findings to the class. |

| | |
|---|---|
| | **Phenomenon:**<br>Cities produce urban "heat islands" where roads, parking lots, and rooftops warm in the sun. This not only raises the city's temperature, but it can affect the weather, producing thunderstorms in some cities or altering storm tracks in others.<br>Ask students to research how weather is impacted by large cities. Have them collect data of temperatures and precipitation of urban, suburban and rural communities near each other and compare the differences. Have them look at long term data to find out how construction and other factors have had an impact on global climates and weather. Have them construct arguments based on their evidence and research about the advantages and disadvantages of large construction areas versus conservation of land areas and the impact on climate in the future.<br>Have them predict how weather and climate could change over the next century while including data of trends to support their prediction.<br>*Teacher Note: be sure that students understand the difference between weather and climate.* |
| | **Phenomenon:**<br>Global Climate Zones<br>This article explains the global climate zones, where they are located, and the kind of weather associated with each zone. Have students determine what factors cause this weather: topography, ocean, air masses, longitude, latitude or a combination of these. Have them discuss and argue their thinking after conducting research to construct their explanations. |
| | |
| | *Obtaining*<br>Students will obtain maps of the United States.<br>One source is USA Topographic Map. |
| | *Evaluating*<br>Students will make their own weather map.<br>Have students or teacher research and share findings.<br>Have students work with the paper map before producing the map digitally and then transferring that information onto the paper map with proper labels and marking.<br><br>*If there is not a color printer available, use the paper map with color markers or pencils.*<br><br>Have students or teacher research and share findings: *High School Earth Science Weather Forecasting* |
| | *Communicating*<br>Students will post their maps in the classroom or hallway with a narrative of the weather at various locations. |

| *Evaluation* | ***Assessment of Student Learning*** |
|---|---|
| | The teacher should have students look at data from years that exhibit changes in weather (such as years that are El Nino) and describe why the change in weather occurs.<br><br>Be sure that expectations for student-made maps and projects are explained at the beginning. Use rubrics for grading arguments based on evidence and meteorological evidence. Journaling allows students to write about their thinking and review their notes for patterns and deeper understanding of concepts. |
| *SEP, CCC, DCI* | **Science Essentials** |
| Science and Engineering Practices | ● Asking questions and defining problems.<br>● Developing and using models<br>● Planning and carrying out investigations<br>● Analyzing and interpreting data<br>● Using mathematics and computational thinking<br>● Constructing explanations (for science) and designing solutions (for engineering)<br>● Engaging in argument from evidence<br>● Obtaining, evaluating, and communicating information |
| Crosscutting Concepts | ● Patterns<br>● Cause and effect<br>● Scale, proportion, and quantity<br>● Systems and system model<br>● Energy and matter<br>● Structure and function<br>● Stability and change |
| Disciplinary Core Ideas | **ESS2.D: WEATHER AND CLIMATE**<br>● The foundation for Earth's global climate system is the electromagnetic radiation from the sun as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems and this energy's reradiation into space. |

**Additional Supports for struggling learners:**

**The following supports are suggestions for this lesson and are not the only options to support students in the classroom. These supports target students that struggle with science material, this lesson or a previous lesson. These are generalized supports and do not take the place of IEP accommodations as required by each student's Individualized Education Program.**

**General supports for the following categories:**

| Reading: | Writing: | Math: |
|---|---|---|
| 1. Provide reading support by reading aloud or doing partner reads<br>2. Have the teacher model what they are thinking when reading the text<br>3. Annotate the text with students so that they may refer to it as they work through the lab | 1. The teacher can provide a sentence starter for the students.<br>2. The teacher can give students an audience to write to (i.e. Write a letter to your sibling explaining this topic).<br>3. The teacher can provide constructive feedback during the writing process to help students understand the expectations. | 1. Provide calculators as needed.<br>2. Provide graph paper as needed. |

**Supports for this specific lesson if needed:**

**Performance expectations for instruction:**

1. The teacher should provide information to students in various formats to reach as many students as possible.
2. The students should be given adequate time to complete each part of the lesson.
3. The students should be allowed to express their knowledge in various formats.
4. The teacher should be sure to provide multiple ways for the students to communicate their knowledge of the material.

**Engage:**

1. The teacher should provide a text to speech program or a video to engage students that struggle with reading.
2. Remind students of the time period of when the hurricane occurred. The teacher should ask students what it would be like to be without computers, radar and cell phones.

3. The teacher should give students resources to find a list of the hurricanes that have impacted the US prior to satellites.
4. The teacher should provide students with an organizer to record their research, observations and questions.
5. The teacher can have students come up with a list of questions that will allow them to evaluate the different types of technology that were available to communicate during weather events.
6. The teacher should be sure to provide multiple ways for the students to communicate their knowledge of the material. These formats could include writing, drawing or creating a presentation.

**Exploring:**

1. The teacher should provide a template for students to plan their investigations.
2. If needed the teacher can do a demo on how to plan an investigation. The teacher may do this by making a PB&J (use peanut butter only if there is not student allergic to peanuts in class) using only student instructions. This may lead to the teacher doing things like trying to get Jelly out of a closed jar. The teacher should not do anything that they are not instructed to do by the students.
3. The teacher should be sure to provide multiple ways for the students to communicate their knowledge of the material. These formats could include writing, drawing or creating a presentation.
4. The teacher should have guidelines in place for group work that gives students expectations for how to work with one another, how to respectfully agree or disagree with one another and how to distribute work in the group.
5. The teacher should provide a rubric to the groups for self-evaluation. This will allow students to show ownership of their work.
6. Students may need to review concepts such as air pressure, wind patterns and ocean currents as they work.
7. The teacher should be walking around and working to correct misconceptions as the students work.
8. The teacher should give students resources to find information on the topics that students need to use to read weather maps.
9. The teacher should provide an organizer for students to record their research, observations and questions that they have as they work.
10. The teacher can have students complete a gallery walk of all the maps that were created for this assignment. Then have the students revise their weather maps as needed.

**Explaining:**

1. The teacher should prepare students for visitors and field trips. Some students may experience anxiety when things change and being prepared for changes may lessen the anxiety.
2. The teacher should consider giving students an organizer to record thoughts on during the speech and generate questions.
3. The teacher should consider having students generate questions for the visitor prior to the visit.

**Elaborating:**

1. The teacher should consider showing a video of an approaching thunderstorm. Then have students make observations of what is occurring.
2. The teacher then should ask students to describe what they have seen and felt in real life when a thunderstorm is approaching.

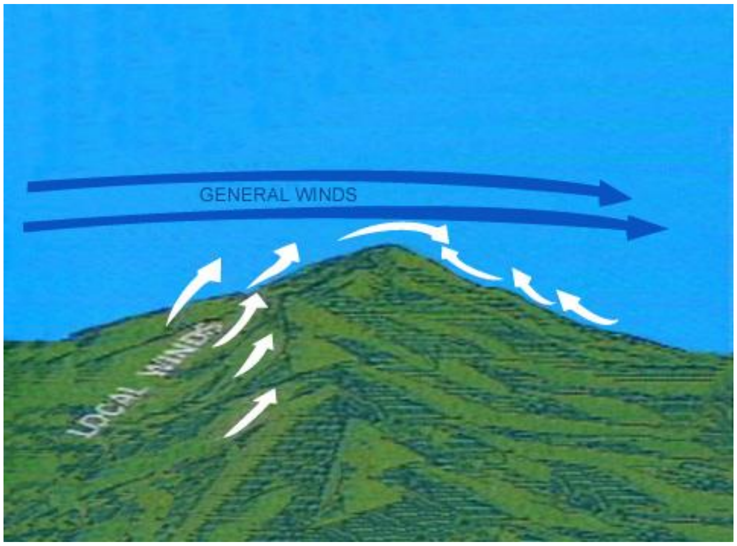
3. The teacher should consider using a text to speech program or doing a read aloud of the article to help struggling readers.
4. The teacher should have guidelines clearly established for discussions. The teacher should provide multiple formats for students to give their summary. These formats could include in writing, verbal summary or drawing.
5. The teacher should consider having students generate questions and assisting students in choosing questions that are the most important. These questions could be used to guide the students research.
6. The teacher should consider giving students resources to use in their research.
7. The teacher should use intentional and flexible grouping.
8. The teacher should consider providing students with a rubric to assess their own work.
9. The teacher should remind students of the parts of a scientific argument.
10. The teacher should have students complete a formative assessment and then review, re-teach or enrich as needed.
11. The teacher may need to help students link the trends and patterns.
12. The teacher can have students refer to models/maps that they have looked at during the lesson. The students can use this to evaluate their model.

**Evaluating:**

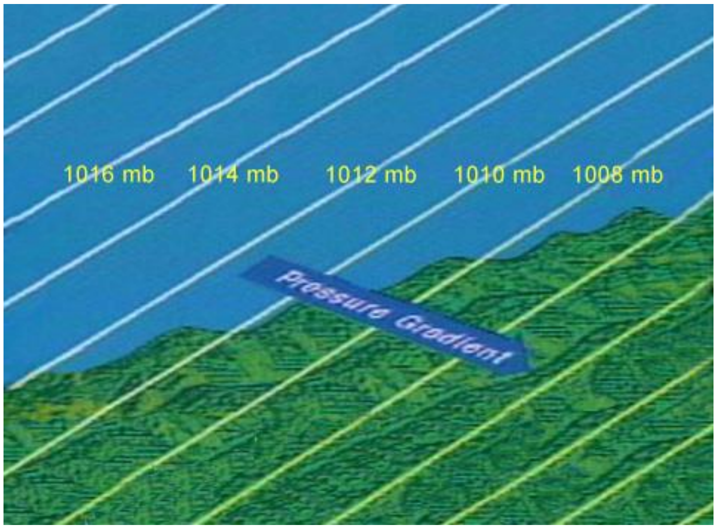
1. The teacher should be sure to provide multiple ways for the students to communicate their knowledge of the material. These formats could include writing, drawing or creating a presentation.
2. Students may need additional time to construct their explanation.

## General Winds

**All winds** are the result of temperature differences, thus, pressure gradients between different areas. This can be on a very large scale, such as over many hundreds of miles, or on a very small scale, such as a few inches.

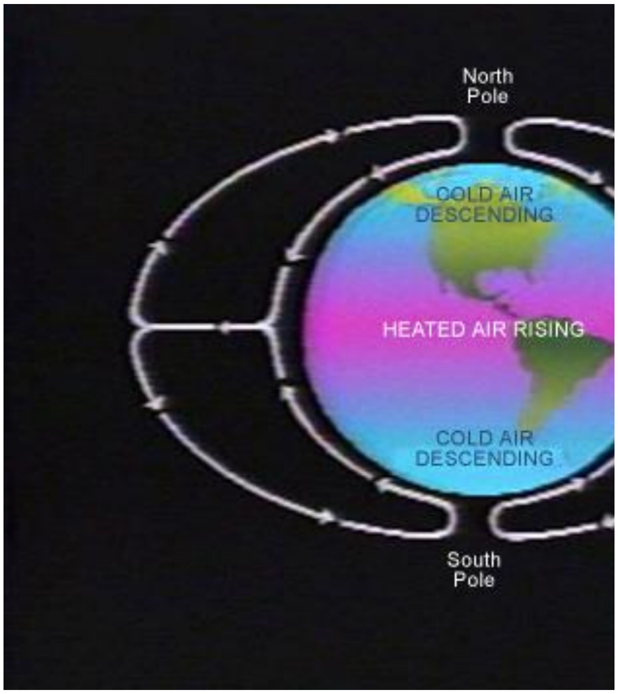


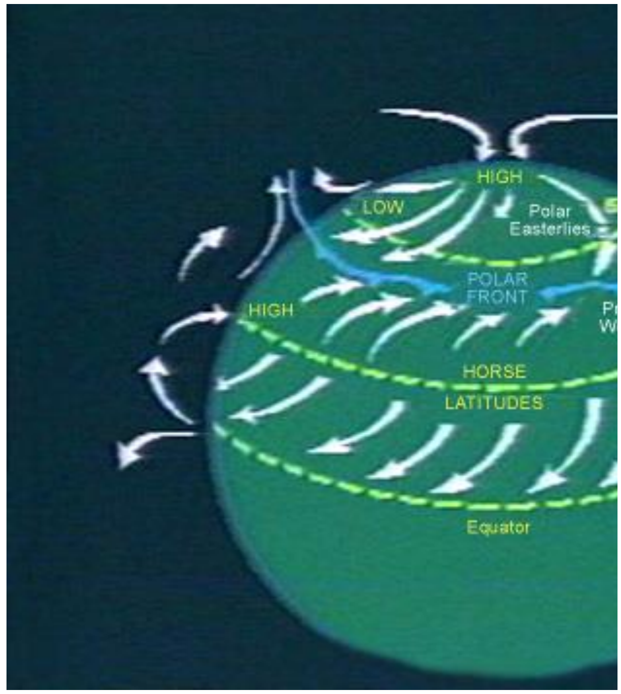

Here we see that upslope local winds, produced by warm air rising over the terrain, meet and mix with the general winds. The general winds in the lower layers of the atmosphere will be further modified by locally induced convective winds.




In the above figure, we see the general wind blowing across the terrain from an area of high pressure to an area of lower pressure. Close to the terrain, the general air flow will become modified by the roughness of the surface.

## General circulation due to earth's rotation and unequal heating



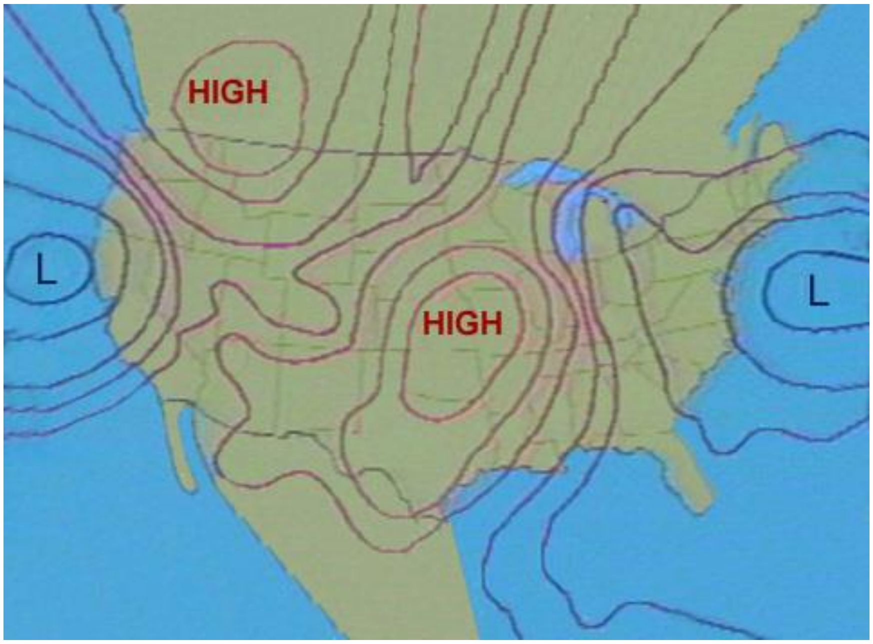




To better understand general winds, we should discuss the general circulation of air around the earth. This mass of moving air is our atmosphere--a gaseous mantle encasing the earth, held there by gravity, and rotating with the earth. See the graphics above. Several natural forces interact to produce continual movement of this air, thus producing wide and varied weather patterns.

The surface of the earth is not heated uniformly by the sun, and the resulting unequal heating of the atmosphere causes compensating air motions which tend to reduce the horizontal temperature differences. As the air moves from the equatorial regions toward the polar regions, it is affected by the earth's rotation. In the Northern Hemisphere, the air is deflected to the right as the earth rotates on its axis. This deflection force-is called the Coriolis force.

The uneven heating and cooling at all latitudes, due to seasonal and day-night cycles, modifies the large-scale circulation pattern. Uneven heating and cooling, due to the distribution of land and sea areas, is another important factor. These and other factors are responsible for producing a series of wind belts that circle the earth at various latitudes. One of these wind belts is called the prevailing westerlies. Closer to the North Pole, high pressure is maintained, and easterly winds occur. We are primarily concerned with latitudes between 30 degrees and 60 degrees North. In the graphic above, arrows indicate air flowing out of the south and west. This is the region where we have the prevailing westerlies.

At some latitudes the air tends to "pile up" to cause belts of high surface pressure. These belts are never uniform, but instead consist of a series of rather large pressure cells. Some of the pressure cells are relatively fixed, such as the polar high, while others are migratory. Our weather is closely related to the location and movement of these primary pressure cells and other smaller scale pressure patterns.




Large scale pressure systems and fronts.

On the graphic above illustrates a surface pressure map over the United States for a particular time. There are cells of high pressure and cells of low pressure on this weather map. The lines that you see on the map are called isobars which are drawn through points of equal air pressure. These isobars outline the areas of high and low pressure.

Typically, pressure cells move from west to east across the United States. However, at times they move in other directions, which further complicates weather patterns. The circular isobars over Mississippi indicate a low-pressure cell, or in this case, a hurricane that has moved inland from the Gulf of Mexico.

A boundary between two air masses or different temperatures and other characteristics is called a weather front. The figure shows both a short warm front extending to the east coast and a longer cold front extending into Texas.



Return to Instructional Segment

## Local Winds

**Local winds** are small scale convective winds of local origin caused by temperature differences. Local terrain has a very strong influence on local winds, and the more varied the terrain, the greater the influence.

**Convective winds** are all winds - up, down, or horizontal - that develop as a result of local temperature differences.

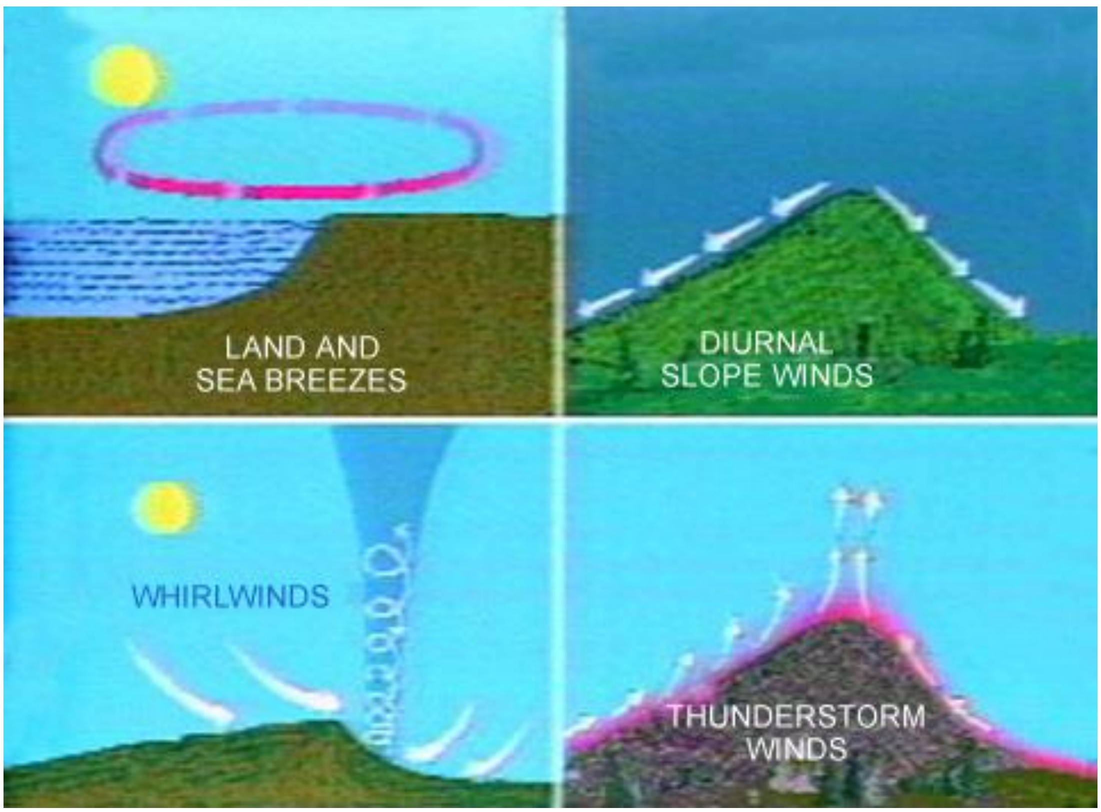
## Ways that Local Winds Develop

Some ways in which local winds develop are:

1. Convection from daytime heating.
2. Unequal heating and cooling of the surface.
3. Gravity, including downdrafts.

## Common Local Winds

Winds of local origin, convective winds, can be as important in fire behavior as the winds produced by the large-scale pressure patterns. In many areas, they are the predominant winds in that they overshadow the general winds. If their interactions are understood and their patterns known, local convective winds can be predicted with reasonable accuracy.




**Common local winds**

Some common local, convective winds are:

**1. Land and Sea Breezes**

We discussed the surface properties that cause land surfaces to become warmer than water surfaces during the daytime. As a result of this local-scale temperature and pressure difference, a sea breeze begins to flow inland from over the water, forcing the warm air over the land to rise and to cool adiabatically. In the absence of strong general winds, this air flows seaward aloft to replace air which has settled and moved toward shore, and thus completes the circulation cell. The surface sea breeze begins around mid-morning, strengthens during the day, and ends around sunset.

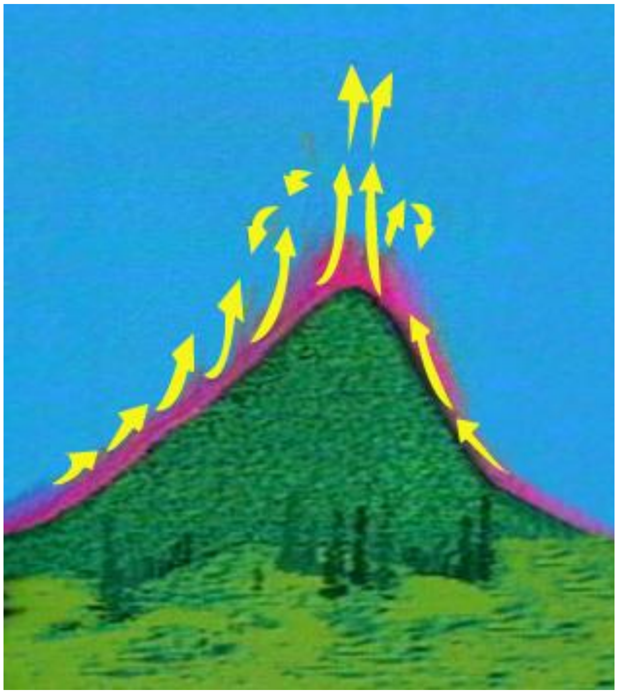
The land breeze at night is the reverse of the daytime sea breeze circulation. At night, land surfaces cool more quickly than water surfaces. Air in contact with the land then becomes cooler than air over adjacent water. Again, a difference in air pressure develops over the land and the water causing air to flow from the land to the water. The air must be replaced, but return flow aloft is likely to be weak and diffuse and is diminished in the prevailing general winds. The land breeze begins 2 to 3 hours after sunset and usually ends shortly after sunrise.

Another combination of convective winds results in slope winds. Slope winds are local diurnal winds present on all sloping surfaces. They flow upslope during the day as the result of surface heating, and downslope at night because of surface cooling. Slope winds are produced by the local pressure gradient caused by the difference in temperature between air near the slope and air at the same elevation away from the slope.

During the daytime, the warm air sheath next to the slope serves as a natural chimney and provides a path of least resistance for the upward flow of warm air. The layer of warm air is-turbulent, increasing in depth as it progresses up the slope. This process continues during the daytime as long as the slope is receiving solar radiation. When the slope becomes shaded or night comes, the process is reversed.

A short transition period occurs as a slope goes into shadow: the upslope winds die, there is a period of relative calm, and then a gentle, smooth downslope flow begins. Downslope winds are very shallow and may not be represented by a 20-foot surface wind speed. The cooled denser air is stable, and the downslope flow tends to be quite smooth and slower than upslope winds. The principal force here is gravity. Downslope winds usually continue throughout the night until morning, when slopes are again warmed by solar radiation. The times during which winds change from downslope to upslope and vice versa can depend on aspect, time of year, slope percent, current weather conditions, and other lesser factors.

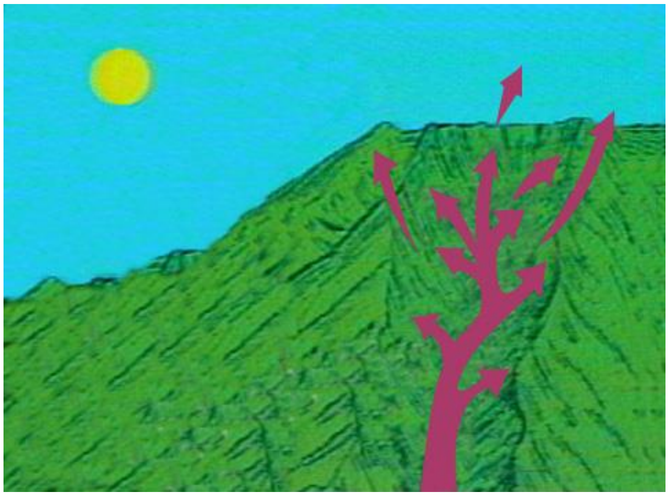
**2. Slope and Valley Winds**



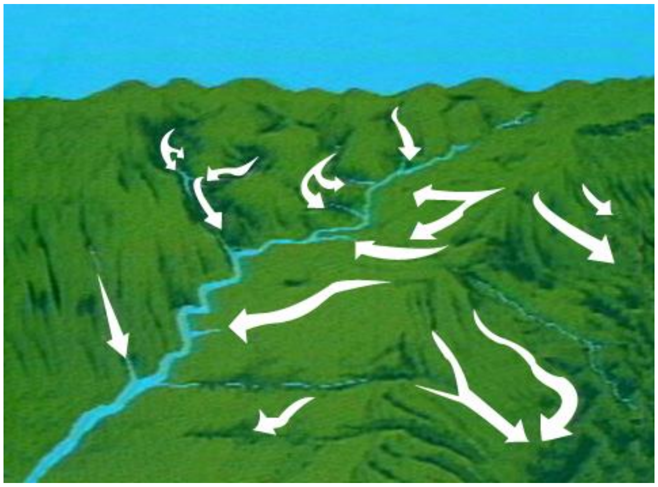
**3. Thunderstorm downdrafts** **4. Whirwinds**

### Slope and Valley Winds

**The figure below illustrates the valley winds. During the day, air in mountain valleys and canyons tends to become warmer than air at the same elevation over adjacent plains or larger valleys, thus creating a pressure gradient and resulting in upvalley winds. The main difference between upslope winds and upvalley winds is that the upvalley winds do not start until most of the air mass in the valley becomes warmed. Usually this is middle or late afternoon, depending largely on the size of the valley. These winds reach their maximum speeds in early afternoon and continue into the evening.**



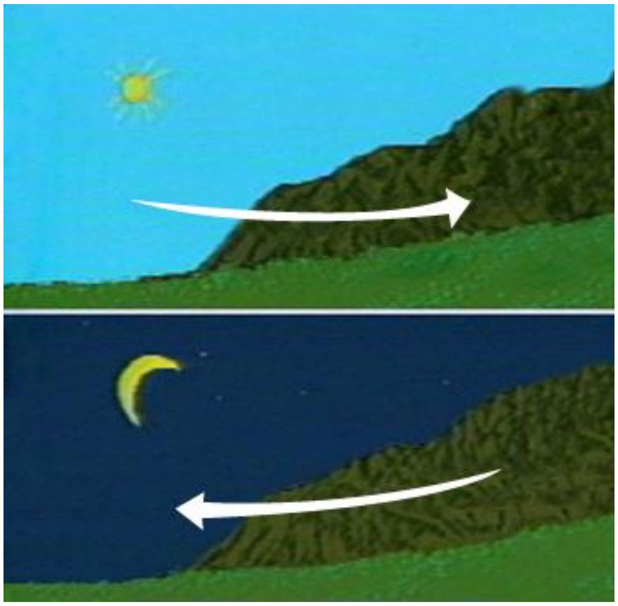
**The transition from upvalley to downvalley flow takes place in the early night. The transition is gradual: first the downslope winds, then a pooling of cool, heavy air in the valley bottoms. The cool air in the higher valley bottoms will flow to lower elevations and increase in velocity as the pool of cool air deepens. This continues through the night and diminishes after sunrise.**

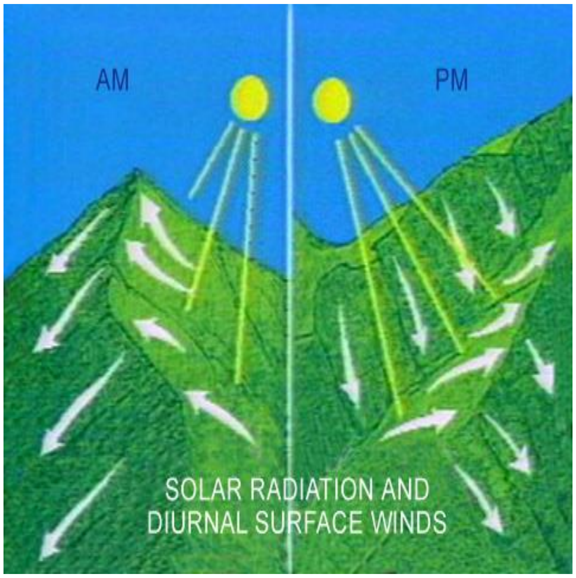


**The velocities of the slope and valley winds vary considerably by terrain and current weather conditions. For example, slope and valley winds develop better under clear skies when the heating and cooling**

processes are more pronounced.

We can give you some broad ranges to indicate typical wind speeds in mountain topography. Upslope winds usually range from 8 to 12 miles per hour, while downslope winds are somewhat less; 2 to 7 miles per hour. Upvalley winds typically are stronger, 12 to 20 miles per hour, while downvalley winds can be 8 to 14 miles per hour.






Diurnal valley winds

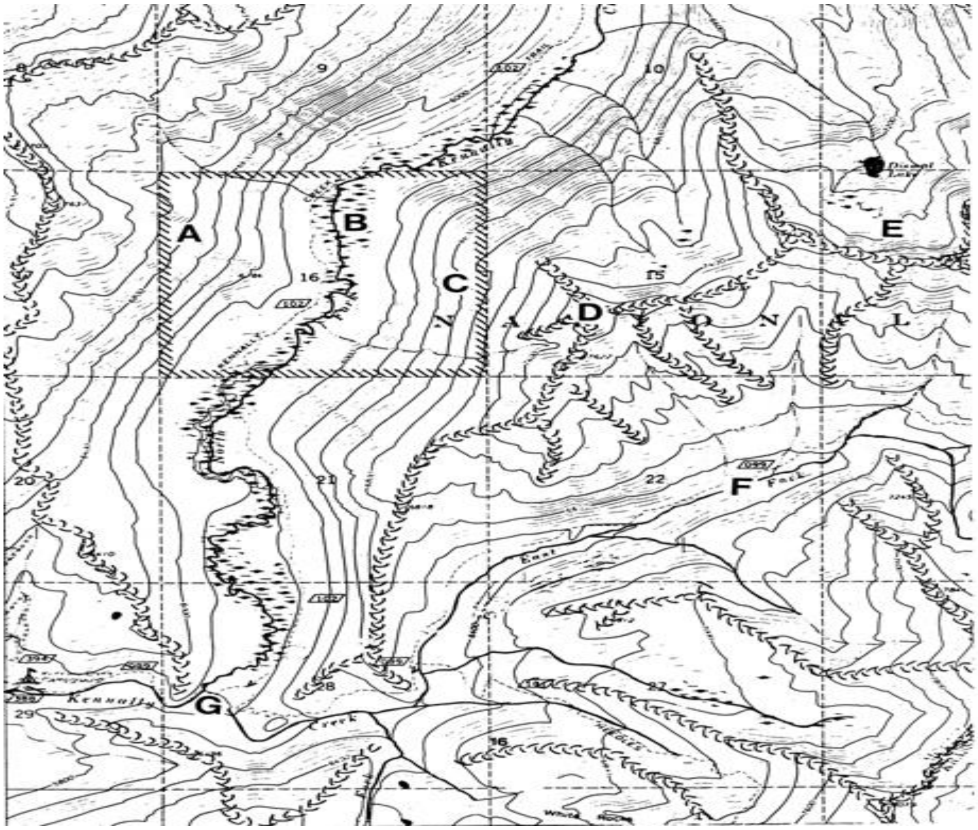
Solar radiation affects slope winds

The illustrations of slope and valley winds to this point might suggest that upslope and upvalley winds occur on all slopes at the same time. This is not usually the case. For one example, see the graphic above. Let's suppose we have a ridge line and canyon parallel to each other running north and south. In the morning, the east aspects will be heated by the sun, but the west aspects are shaded. Upslope winds can occur on the east slopes, while downslope winds occur on the west slopes. As the sun passes overhead and into the afternoon positions, the west slopes become heated and the east slopes become shaded. The slope winds can reverse from those of the morning.

Return to Instructional Segment

## Slope and Valley Winds

Using the map with points A-G, complete the following items relating to local winds in mountainous terrain under clear, warm, midsummer weather conditions.




1. Which slope (give point) will receive the early morning solar heat first, thus, upslope winds start first?
2. Which slope (give point) will receive solar heating latest in the afternoon, thus, upslope winds continue the latest?
3. Which slope (give point) will receive the least solar heating, thus, the lightest upslope winds throughout the day?
4. Which slope (give point) will receive the least solar heating, thus, the lightest upslope winds throughout the day?
5. When will point B receive the strongest downvalley winds?
6. Which point will be most exposed to the general winds?
7. What time of day will upslope winds be strongest at point A?
8. What time of day will upslope winds be strongest at point C?
9. Which direction will winds be at point F at 1500?
10. At which two points will it be most difficult to predict wind directions?

Return to Instructional Segment