



HIGHS AND LOWS

TEACHER'S GUIDE

Project ATMOSPHERE

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Foreword

This guide has been prepared to introduce fundamental understandings about the guide topic. This guide is organized as follows:

Introduction

This is a narrative summary of background information to introduce the topic.

Basic Understandings

Basic understandings are statements of principles, concepts, and information. The basic understandings represent material to be mastered by the learner, and can be especially helpful in devising learning activities in writing learning objectives and test items. They are numbered so they can be keyed with activities, objectives and test items.

Activities

These are related investigations. Each activity typically provides learning objectives, directions useful for presenting and completing the activity and questions designed to reinforce the learning objectives.

Information Sources

A brief list of references related to the guide topic is given for further study.

Introduction: Highs and Lows

"What is the weather?" and "What is the weather going to be?" These questions are frequently asked by people because weather and its changes strongly influence our activities and lives. The informed choices that can be made when we are aware of current and anticipated weather range from selecting appropriate clothing for the day to those that might be related to work and recreation. Less frequent, but certainly important, are the decisions and actions we can take to reduce the extent of property damage, and the number of injuries and lives lost due to hazardous weather occurrences.

Adequate answers to questions we might have about weather can often be found on the day's weather map. Prominent on the maps appearing on television, in newspapers and available on the Internet are the words "High" and "Low" or the letters "H" or "L". These words or letters are symbols for centers of broad-scale weather systems. The systems and their locations are the key to describing and understanding probable weather conditions throughout the map area. They also provide information that enables meteorologists to predict possible atmospheric conditions up to a day or so in advance.

The Highs and Lows or H's and L's on maps represent centers of broad regions of relatively high or low surface air pressure. We can think of air pressure as the weight of a column of air above a unit area. Highs and Lows govern atmospheric conditions throughout their expanses. Highs are generally fair weather systems. Changing and stormy weather conditions are associated with Lows.

Mid-latitude Highs and Lows tend to move generally from west to east, changing the weather at locations in their paths. Highs are followed by Lows and Lows are followed by Highs in an endless procession. No two Highs or two Lows are exactly alike, but they share enough characteristics in common that descriptive models of each can be employed to make sense of the weather.

The purpose of this guide is to introduce you to descriptive models of Highs and Lows. As a result of successfully completing this guide, you will be able to:

1. Describe in general terms (a) descriptive models of Highs and Lows and (b) the weather associated with each.
2. Apply these models to interpret weather maps and to describe probable current and future weather at different locations on a weather map.

Basic Understandings

Weather Systems

1. The weather of middle latitudes is dominated by broad-scale weather systems called **Highs** and **Lows**.
2. Highs and Lows are regions of relatively high and low surface air pressure, respectively. Air pressure can be thought of as the weight of a column of air per unit area (e.g. pounds per square inch).
3. Highs are generally fair-weather systems hundreds or even thousands of kilometers across. Lows, typically less expansive, exhibit changeable and often stormy weather conditions.
4. Highs and Lows display circulation and structural patterns organized around their pressure centers. The weather at a specific place depends to a large extent on its location relative to the centers of nearby Highs or Lows.
5. In middle latitudes, Highs and Lows tend to migrate, one following the other, from west to east across the continent with their paths showing north or south swings.
6. Weather at particular locations under the influence of migrating Highs and Lows will often change in predictable sequences depending on the paths of the pressure centers.
7. Highs and Lows are atmospheric features that last for several days or sometimes a week or longer. Mid-latitude Highs tend to persist for longer periods of time than do Lows.
8. Highs and Lows are modified by the effects of Earth surfaces over which they travel. They become more humid when traveling over bodies of water and warm or cool depending on the temperatures of the underlying surface.

Weather Characteristics of a High

9. Highs (or H's) depicted on surface weather maps typically mark the high-pressure centers of air masses. Air masses are broad expanses of air in which temperatures and humidity are relatively uniform in the horizontal.
10. Air masses form when air resides for a substantial period of time over a fairly uniform land or water surface. The overlying air gradually takes on the temperature and moisture characteristics of the underlying surface.

11. Warm surfaces produce warm air masses and cold surfaces produce cold air masses. Dry air masses form over land areas and humid air masses form over bodies of water. Dry, cold air masses form over Central Canada. The Gulf of Mexico is a source of warm, humid air masses. Air masses from the North Pacific Ocean or North Atlantic are humid and cool.
12. Sooner or later, air masses move away from their source regions. They carry their temperature and humidity characteristics with them and display internal circulations around their high-pressure centers.
13. Air near the centers of surface Highs flows outward towards lower pressure. The Earth's rotation plus the frictional effects of the surface cause the air to spiral outward. In the Northern Hemisphere the spiral is clockwise as seen from above. In the Southern Hemisphere, it is counter-clockwise.
14. The circulation in Highs has a sense of rotation opposite to that of the Earth's rotation, so it is called anticyclonic. Since this circulation and relative high atmospheric pressure co-exist, Highs are also commonly called **anticyclones**.
15. Air sinks from above within Highs and replaces the outward spiraling air.
16. Sinking air in Highs is warmed by compression. Clouds, if present, vaporize and clear skies tend to prevail.
17. Air pressure varies little in a broad region about the center of a High so that winds are light and sometimes calm.
18. The horizontal circulation within Highs transports colder air from higher to lower latitudes in regions generally to the east of the pressure center. In the western flanks, warmer air flows from lower to higher latitudes.
19. In North American winters, cold Highs tend to track from the northwest towards the southeast. In summer, warm Highs tend to drift slowly from west to east and can stall for several days or even weeks.
20. The generally clear and relatively calm conditions in Highs favor night-time cooling and the possible formation of dew, frost, or fog.

Weather Characteristics of a Low

21. Lows (or L's) appearing on surface weather maps mark a weather system organized around a center of relatively low pressure. The low-pressure center is typically located along a boundary (front) between air masses that have contrasting temperatures and/or humidity.

22. Lows are weather systems characterized by a variety of weather including cloudy and stormy conditions, warm and cold sectors, air-mass boundaries called fronts (labeled warm, cold, or stationary depending on their movement), and rapidly changing conditions over short distances across frontal boundaries.
23. Air flowing towards the center of a surface Low is deflected by the Earth's rotation and the frictional effects of the surface to produce an inward spiral. In the Northern Hemisphere, this spiral is counter-clockwise as seen from above. In the Southern Hemisphere, it is clockwise.
24. The circulation in Lows has a sense of rotation that is the same as that of the Earth's rotation, so it is called cyclonic. Because this circulation and relative low pressure co-exist, Lows are commonly called ***cyclones***.
25. Air spiraling into Lows also produces upward motion. Rising air expands and cools, clouds form and precipitation can develop.
26. Within Lows, horizontally, changes in air pressure are typically greater than those found in Highs; thus, Lows tend to have significantly higher wind speeds.
27. In winter over North America, the principal tracks of Lows and their stormy conditions are over the coterminous 48 states. Cyclogenesis (the formation of a Low) tends to occur over the Pacific Ocean, the Gulf of Mexico, on the Great Plains just east of the Rocky Mountains, and off the mid-Atlantic coast.
28. Winter storms tend to track towards the east and northeast, exiting North America through New England and Maritime Canada.
29. Winter Lows are generally more intense than summer Lows primarily because of greater temperature contrasts between neighboring air masses. Central pressures are lower and winds are stronger.
30. In spring and early summer, Lows over the Great Plains are often accompanied by lines of thunderstorms, some of which may be severe.
31. In summer, over North America, the principal storm track is across southern Canada.

Activity: Air Motion - The High and Low of It

Introduction

Weather can be fair or stormy. Generally, fair weather is associated with high surface air pressure while stormy weather is associated with low surface air pressure. Broad-scale areas of high or low surface pressure dominate weather in middle latitudes and are simply called **Highs** and **Lows**.

Highs and Lows are regions where air pressures are higher or lower compared to surrounding areas and are typically hundreds or even a thousand or more kilometers across. On a weather map, a large "High" or "H" symbolizes the location of highest pressure in a High whereas a large "Low" or "L" symbolizes the position of lowest pressure in a Low. Highs and Lows generally travel from west to east while exhibiting at least some motion toward the north or south. As they travel, they bring changes in the weather at places in their paths.

This activity investigates: (1) the horizontal and vertical air motions in Highs and Lows, and (2) the impacts of these motions on weather at locations under the influence of Highs and Lows.

Upon completing this activity, you should be able to:

- Describe the general air motions and weather conditions associated with a high pressure system, or High.
- Describe the general air motions and weather conditions associated with a low pressure system, or Low.
- Based upon the locations of the centers of Highs and Lows, as shown on a weather map, predict general wind directions and weather conditions for different locations.

Materials

- Pencil

Procedure: Construction of a Model High Pressure System

1. Turn to **Figure 1**, a High. Lightly draw a circle about 3 cm or so in diameter around the large "H" appearing on the map.

2. Place the map flat on your desk. If possible, stand up. (This exercise works better standing up.) Bring the thumb and fingertips of your non-writing hand close together and place them on the circle you drew.
3. Rotate your hand slowly clockwise, as seen from above, and gradually spread out your thumb and fingertips as your hand turns. Do not rotate the map. Practice this until you achieve as full a twist as you can comfortably.
4. Place your thumb and fingertips back in your starting position on the circle. Mark and label the positions of your thumb and fingertips 1, 2, 3, 4, and 5, respectively.
5. Slowly rotate your hand clockwise while gradually spreading your thumb and fingertips. Go through about a quarter of your twisting motion. Stop, mark, and label the positions of your thumb and fingertips on the map. Follow the same procedure in quarter steps until you complete your full twist.
6. Connect the successive dots for each finger and your thumb using a smooth curved line. Place arrow heads on the lines to show the directions your thumb and fingertips moved.
7. The spirals represent the general flow of surface air that occurs in a typical **High** pressure system.

Procedure: Construction of a Model Low Pressure System

1. Turn to **Figure 2**, a Low. Lightly draw a circle about 3 cm or so in diameter around the large "L" shown on the map.
2. Again, if possible, stand up. Place your non-writing hand flat on the map with your palm covering the circle.
3. Practice rotating your hand counter-clockwise as seen from above while gradually pulling in your thumb and fingertips as your hand turns until they touch the circle. Do not rotate the map. Practice until you achieve a maximum twist with ease.
4. Place your hand back in the spread position on the map. Mark and label the positions of your thumb and fingertips 1, 2, 3, 4, and 5, respectively.
5. Slowly rotate your hand counter-clockwise while gradually drawing in your thumb and fingertips. Stopping after quarter turns, mark and label the positions of your thumb and fingertips. Continue the twist until your thumb and fingertips are on the circle.

6. Connect the successive dots for each finger and your thumb using a smooth curved line. Place arrow heads on the lines to show the directions your thumb and fingertips moved.
7. The spirals represent the general flow of surface air that occurs in a typical **Low** pressure system.

Investigations: Characteristics of High & Low Pressure Systems

Directions: Refer to the Activity Introduction and the Model Highs and Lows you constructed to complete the following questions.

1. Moving in the direction towards the center of a **High**, the surface atmospheric pressure [(increases)(decreases)]. When moving towards the center of a **Low**, the surface atmospheric pressure [(increases)(decreases)].
2. Which of the following best describes the surface wind circulation around the center of a High pressure system (as seen from above)?
 - a) counterclockwise and spiraling outward
 - b) counterclockwise and spiraling inward
 - c) clockwise and spiraling outward
 - d) clockwise and spiraling inward
3. Which of the following best describes the surface wind circulation around the center of a Low pressure system (as seen from above)?
 - a) counterclockwise and spiraling outward
 - b) counterclockwise and spiraling inward
 - c) clockwise and spiraling outward
 - d) clockwise and spiraling inward
4. On your desk, repeat the hand twists for the High and Low pressure system models. Note the vertical motions of the palm of your hand. For the High, the palm of your hand [(rises)(falls)] during the rotating motion, whereas for the Low, the palm of your hand [(rises)(falls)] during the rotating motion.
5. The motions of your palms during these rotations represent the directions of vertical air motions in Highs and Lows. Vertical motions in a High are [(upward)(downward)] while vertical motions in a Low are [(upward)(downward)]. Note that horizontal surface winds in a High and Low are considerably stronger than vertical air motions.

6. In a High pressure system, air flows
- downward and outward in a clockwise spiral.**
 - downward and inward in a counter-clockwise spiral.**
 - upward and outward in a clockwise spiral.**
 - upward and inward in a counter-clockwise spiral.**
7. In a Low pressure system, air flows
- downward and outward in a clockwise spiral.**
 - downward and inward in a counter-clockwise spiral.**
 - upward and outward in a clockwise spiral.**
 - upward and inward in a counter-clockwise spiral.**
8. The weather associated with a **Low** can be significantly different than that of a **High**. The differing vertical motions account for some of these differences. Vertical motions lead to temperature changes in the rising or sinking air. The temperature changes occur because air warms when it is compressed and cools when it expands. (That is why a bicycle pump heats up as it compresses air and why air coming out of a tire valve cools as it expands while rushing from the higher pressures in the tire into the lower pressure of the atmosphere.) In the open atmosphere, air pressure is less at increasing altitudes. Consequently, air expands and cools when **[(ascending)(descending)]**. Air is compressed and warms when **[(ascending)(descending)]**.
9. In a **Low**, air generally exhibits ascending motion. The rising air experiences **[(increasing)(decreasing)]** atmospheric pressure. The ascending air **[(expands)(is compressed)]** and its temperature **[(increases)(decreases)]**.
10. In a **High**, air displays descending motion. The sinking air experiences **[(increasing)(decreasing)]** atmospheric pressure. Consequently, the descending air **[(expands)(is compressed)]** and its temperature **[(increases)(decreases)]**.
11. Most clouds form by the cooling of air. Air, if sufficiently cooled, will become saturated with water vapor. Continued cooling will result in condensation, cloud formation, and possible precipitation. The vertical motion in a **[(High)(Low)]** often leads to cloud formation.
12. Warming causes clouds to evaporate. Cloudy air is saturated with water vapor. With sufficient warming, it will become unsaturated and existing cloud particles (water droplets or ice crystals) will evaporate. The vertical motions in a **[(High)(Low)]** produce warming, promote cloud dissipation, and lead to clear skies.

13. Descending air in a **High** leads to **[(fair)(stormy)]** weather and ascending air in a **Low** tends to make weather **[(fair)(stormy)]**.
14. The broad horizontal expanses of Highs and Lows cover large geographical areas such that their circulations transport colder air from higher latitudes and warmer air from lower latitudes. Consequently, in a High, air to the east of the system's center is generally **[(colder)(warmer)]** than air to the west.
15. In a Low, air to the east of the system's center is generally **[(colder)(warmer)]** than air to the west.
16. Turn to Figure 1, the HIGH, examine the model High you constructed on the map. The High is centered over Kansas City. The hand-twist model of a High indicates the sky is probably **[(clear)(cloudy)]** at Kansas City.
17. Surface winds at Denver are probably from the general direction of **[(north)(south)]**, and temperatures are **[(higher)(lower)]** than those in Indianapolis.
18. The center of the High is forecast to be near Indianapolis tomorrow. The weather at Kansas City tomorrow will probably be most like the weather occurring in **[(Indianapolis)(Denver)(Dallas)(Minneapolis)]** today.
19. Turn to Figure 2, the LOW, examine the model Low you constructed on the map. Now the Low is centered over Kansas City. The hand-twist model of a Low indicates that the sky is probably **[(clear)(cloudy)]** at Kansas City.
20. Surface winds at Denver are probably from the general direction of **[(north)(south)]**, and temperatures are **[(higher)(lower)]** than those in Indianapolis.

21. In the table below, describe the typical characteristics of Highs and Lows. Within each box, the related question number is listed for easy reference.

| | HIGH | LOW |
|----------------------------------------------------------------------------------------------|-------------|------------|
| Pressure Change Towards Center [(<u>increase</u>)(<u>decrease</u>)] | 1 | 1 |
| Surface Winds Around Center [(<u>clockwise</u>)(<u>counterclockwise</u>)] | 2 | 3 |
| Surface Winds relation to Center [(<u>inward</u>)(<u>outward</u>)] | 2 | 3 |
| Vertical Motion at Center [(<u>up</u>)(<u>down</u>)] | 5 | 5 |
| Temperature Change of Vertically Moving Air [(<u>increases</u>)(<u>decreases</u>)] | 10 | 9 |
| State of the Sky Around Center [(<u>clear</u>)(<u>cloudy</u>)] | 12 | 11 |
| General Weather Conditions [(<u>fair</u>)(<u>stormy</u>)] | 13 | 13 |

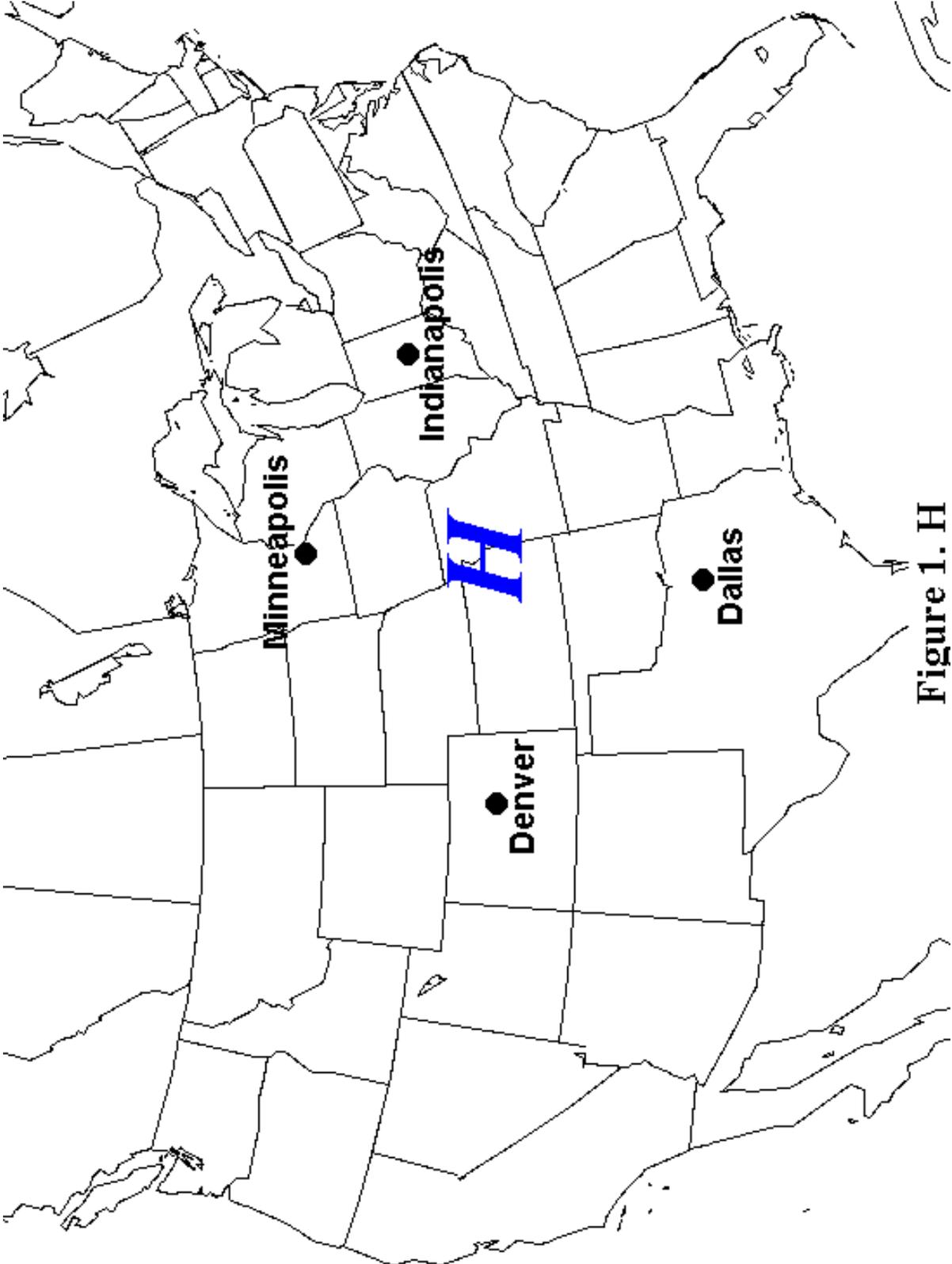


Figure 1. H

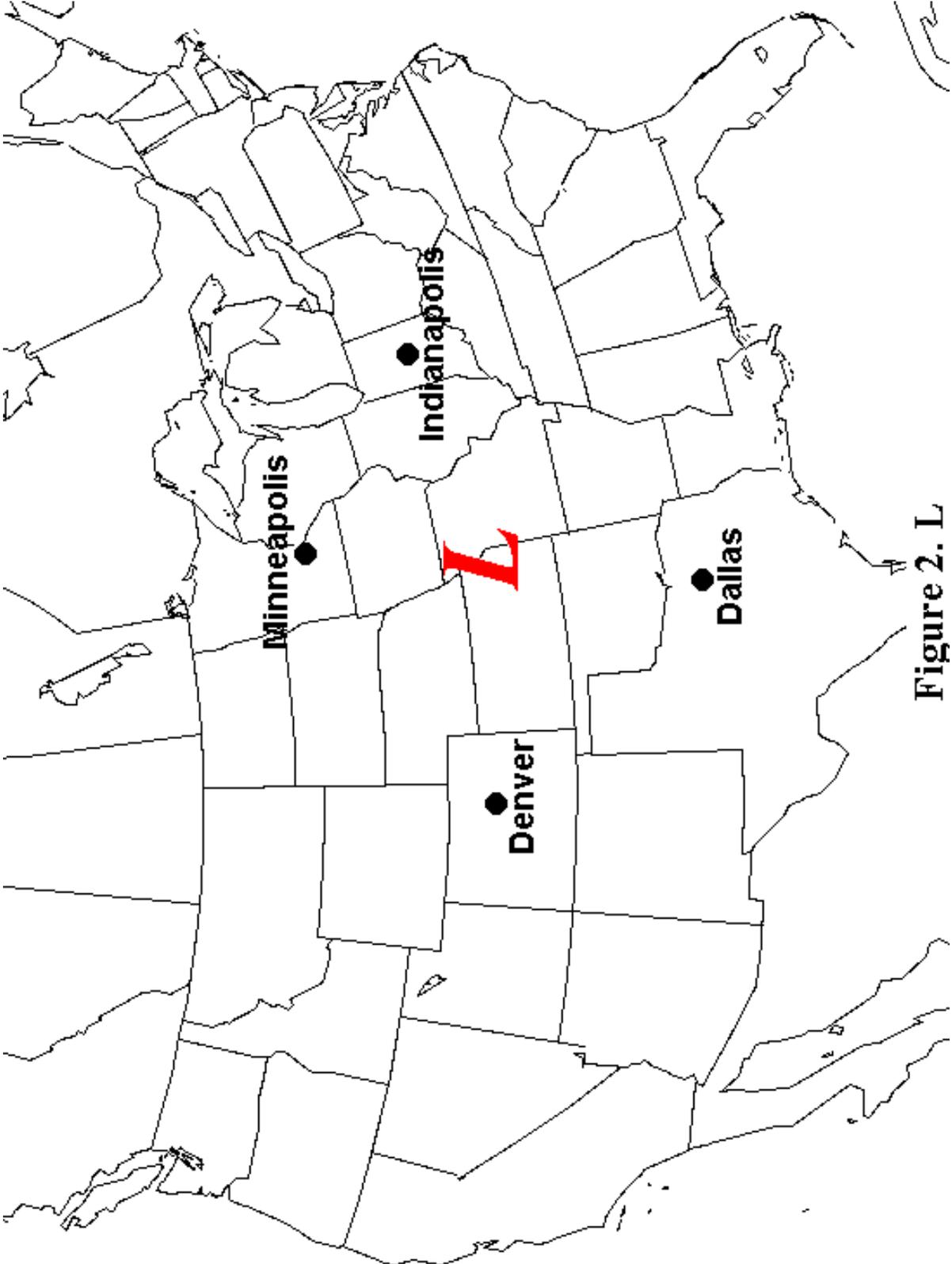


Figure 2. L

Real World Applications

Our hand-twist models of Highs and Lows provide mechanisms to explain why Highs are generally termed “fair weather” systems and Lows are called “stormy” weather systems. We will consider a real example to apply these models.

On the following page, **Figure 3** is a visible satellite image of cloud patterns across the coterminous U.S. at 1815Z on 15 April 2011. 1815Z or 1815 UTC (Universal Time Coordinated) is four hours ahead of Eastern Daylight Time, so the image was from 2:15 PM EDT (1 PM CDT, 12 noon MDT, 11 AM PDT, etc.) on the 15th. On visible satellite imagery at this midday time across the country, thick clouds appear bright white. Land surfaces appear generally gray and water surfaces (ocean and lakes) are darker.

Figure 4 is an analyzed surface weather map for nearly the same time, 1800Z 15 April 2011. Centers of locally highest sea-level pressures are labeled with an H and the pressure value in bold is underlined. For example, the highest pressure is reported in western Quebec Province of Canada, north of New York State is 1037 millibars (mb). The lowest pressure is reported at Kansas City and is 994 mb. The brown curved lines are isobars, lines of equal pressure values, drawn at 4-mb intervals and labeled with associated values. The analyzed isobar pattern gives definition to the field of atmospheric pressure. In addition, boundaries of air masses are shown by fronts associated with the Lows. Warm fronts are bold red curves with half circles on the side towards which the warm air mass is moving. Bold blue curves with triangles designate the direction towards which cold air masses move. The purple curve with alternating half circles and triangles is an occluded front, formed from the combination of warm and cold fronts, showing its movement.

1. Note the locations of the two main Highs centered in Quebec and northern Utah. Comparing those locations on the satellite image shows that regions under the influence of a High are generally [**(clear)(cloudy)**].
2. Consider the areas near the center of the Lows at Kansas City and off the Pacific Coast of Oregon. The satellite image shows that regions under the influence of a Low are generally [**(clear)(cloudy)**].
3. In this example of well-defined Highs and Lows when seen on a satellite image, the general characterization of fair weather Highs and stormy Lows [**(is)(is not)**] consistent with the hand-twist model.

Visible Image

1815Z 15 APR 2011

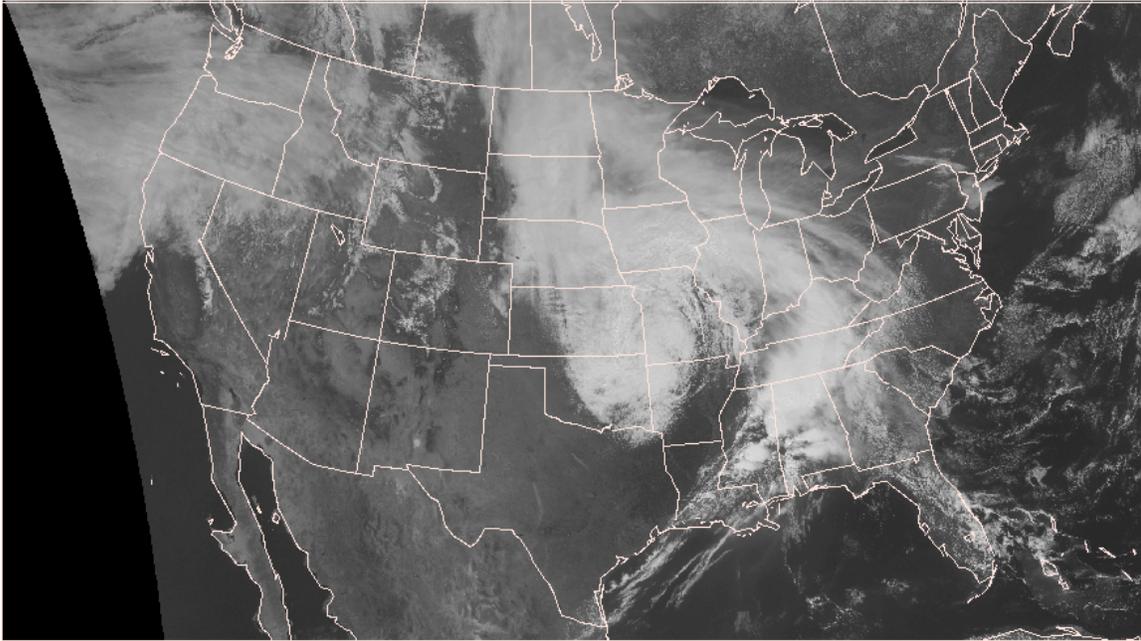


Figure 3. A visible satellite image of the coterminous U.S. at 1815Z (2:15 PM EDT) 15 April 2011 showing cloudy and clear areas. [NOAA/NCEP]

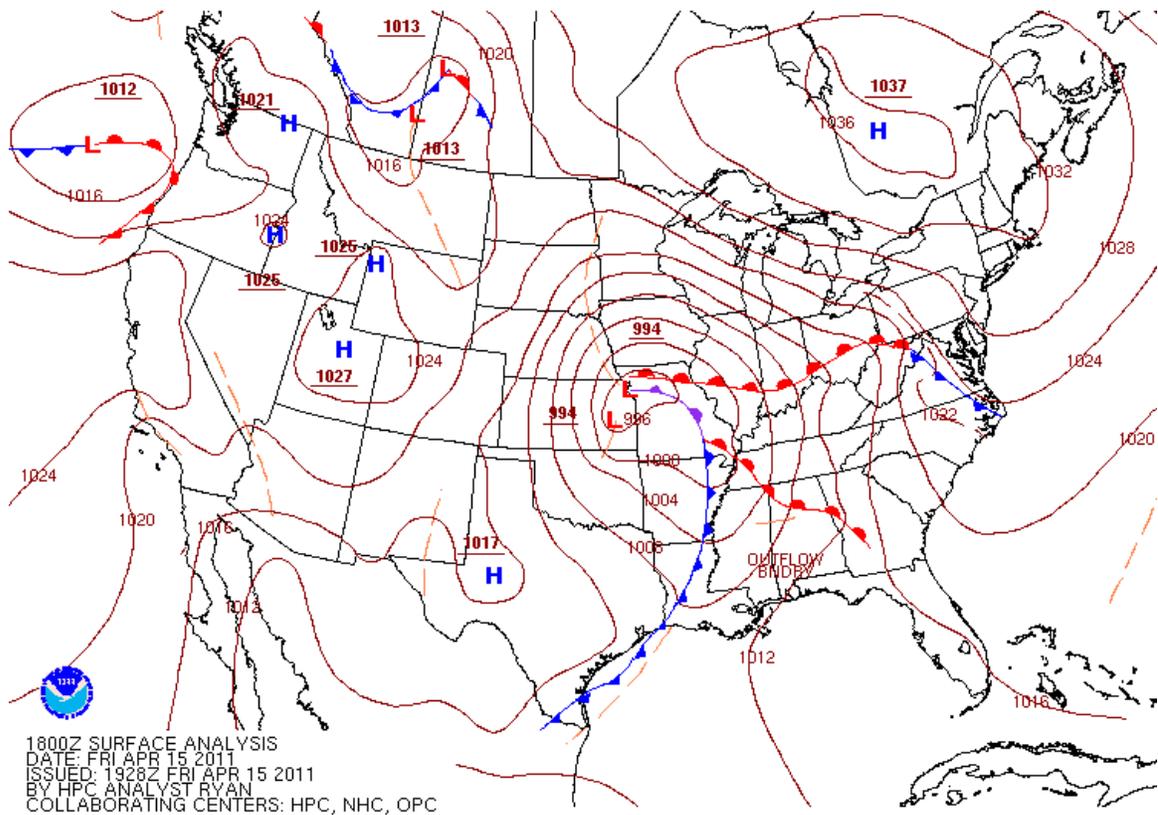


Figure 4. Map of surface weather pressure centers and fronts at 1800Z (2 PM EDT) 15 April 2011. [NOAA/HPC]

Information Sources

Books

Moran, Joseph M. *Weather Studies: Introduction to Atmospheric Science, 5th Ed.* Boston, MA: American Meteorological Society, 2012.

Periodicals

Weatherwise. Bimonthly magazine written in association with the American Meteorological Society for the layperson. *Weatherwise*, 1319 Eighteenth St., NW, Washington, DC 20036.

USA Today. National newspaper with extensive weather page. Available at local newsstands and by subscription.

Radio and Television

NOAA Weather Radio. The voice of the National Weather Service and All Hazards Emergency Alert System. Local continuous broadcasts from over 1000 transmitting stations nationwide.

The Weather Channel. A continuous cable television program devoted to reporting weather. Includes frequent broadcast of local official National Weather Service forecasts.

Internet

DataStreme Atmosphere (www.ametsoc.org/amsedu/dstreme/). Atmospheric education distance-learning website of the AMS Education Program.

JetStream – Online School for Weather (www.srh.noaa.gov/jetstream/). Background weather information site from the National Weather Service.

For the latest NOAA surface map products, see:

<http://www.hpc.ncep.noaa.gov/html/sfc2.shtml>, and for archived maps:

http://www.hpc.ncep.noaa.gov/html/sfc_archive.shtml.