

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 counterclockwise 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 counterclockwise 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
 - a) **downward and outward in a clockwise spiral.**
 - b) **downward and inward in a counter-clockwise spiral.**
 - c) **upward and outward in a clockwise spiral.**
 - d) **upward and inward in a counter-clockwise spiral.**

7. In a Low pressure system, air flows
 - a) **downward and outward in a clockwise spiral.**
 - b) **downward and inward in a counter-clockwise spiral.**
 - c) **upward and outward in a clockwise spiral.**
 - d) **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 [(increase)(decrease)]	1	1
Surface Winds Around Center [(clockwise)(counterclockwise)]	2	3
Surface Winds relation to Center [(inward)(outward)]	2	3
Vertical Motion at Center [(up)(down)]	5	5
Temperature Change of Vertically Moving Air [(increases)(decreases)]	10	9
State of the Sky Around Center [(clear)(cloudy)]	12	11
General Weather Conditions [(fair)(stormy)]	13	13

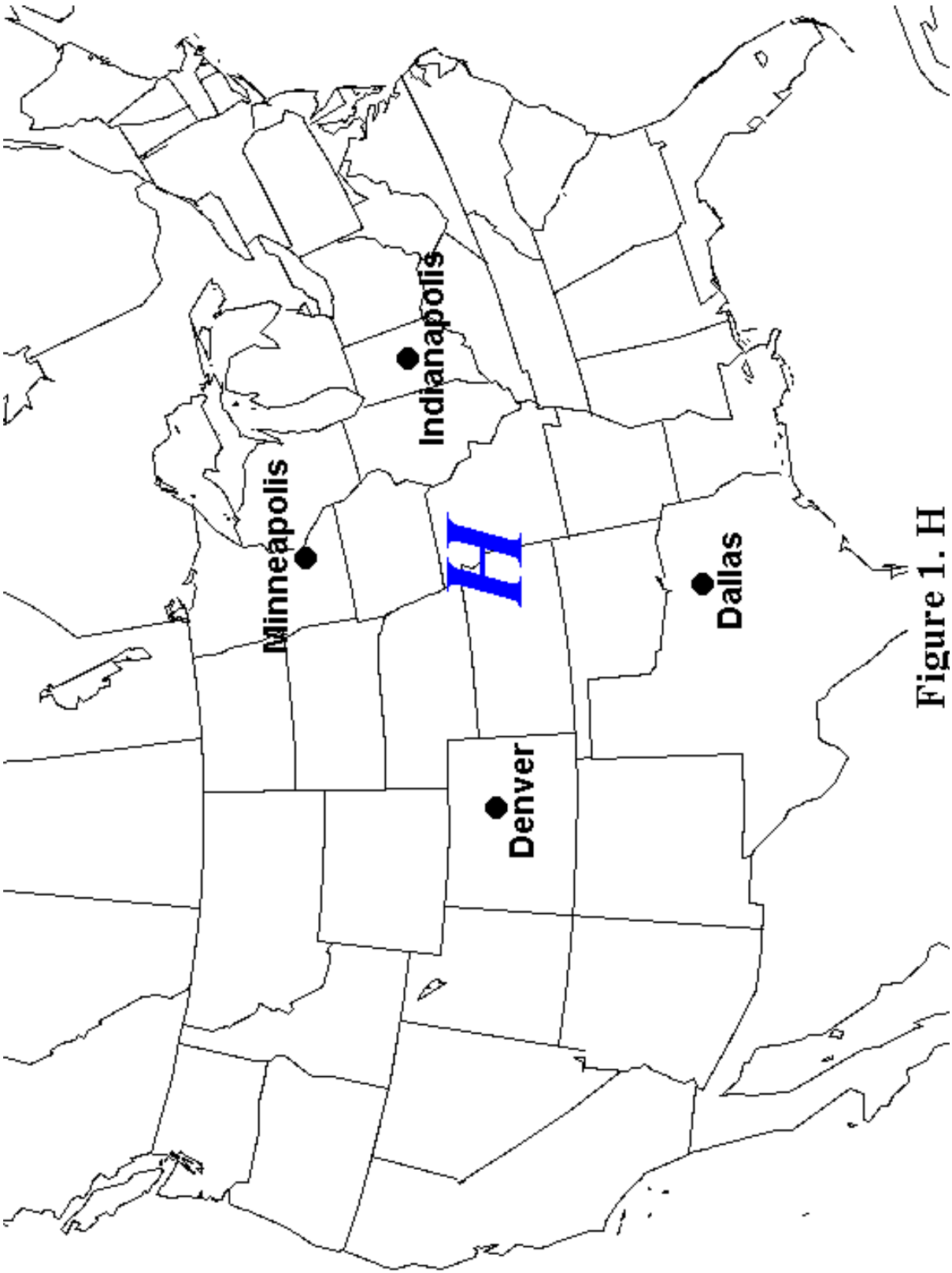


Figure 1. H

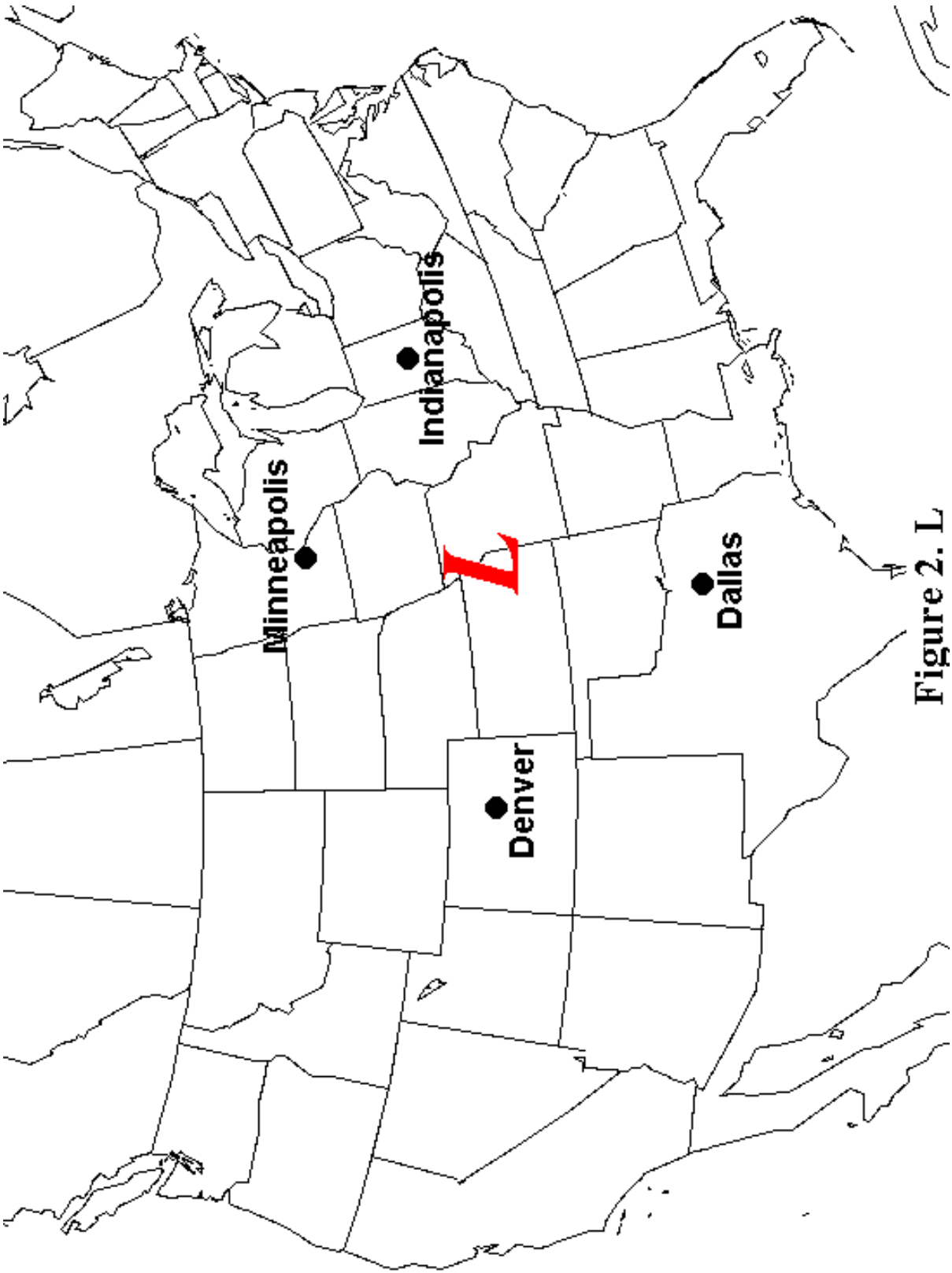


Figure 2. L

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.

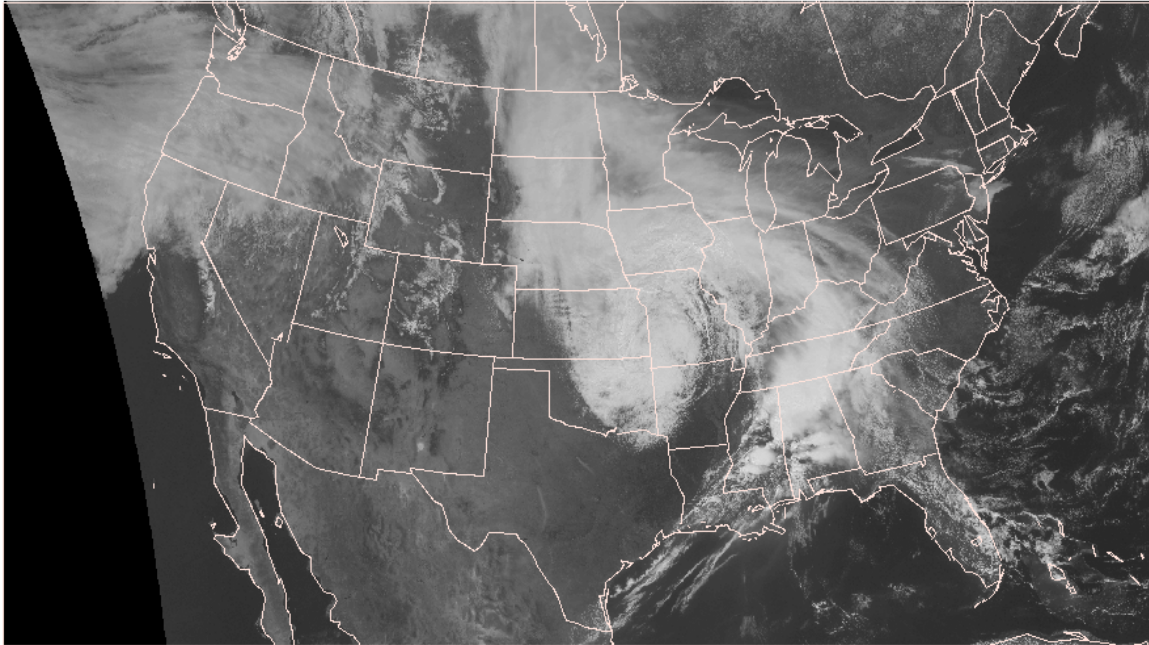


Figure 3. A visible satellite image of the coterminous U.S. at 1815Z (2:15 PM EDT) 15 April 2011 showing cloudy and clear areas. [NOAA/NCEP]

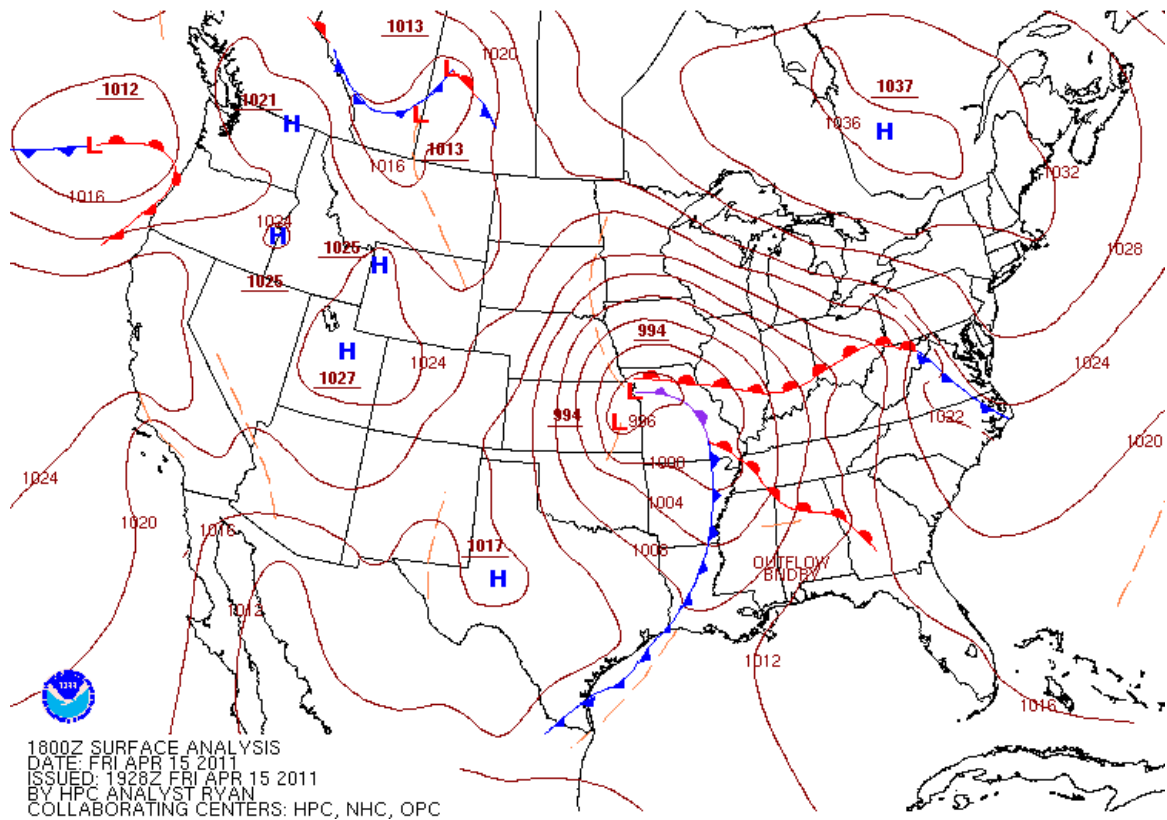


Figure 4. Map of surface weather pressure centers and fronts at 1800Z (2 PM EDT) 15 April 2011. [NOAA/HPC]