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1. INTRODUCTION

When you look at a surface weather map, what do you see? Most people see a two dimensional map of the United States with lines and symbols that provide an indication where atmospheric pressure is high or low, where adverse weather conditions may be occurring, etc. Many people fail to realize that a two-dimensional weather map is actually a physical representation of three-dimensional atmospheric conditions at a specific point in time. Visualizing this two-dimensional image in three-dimensional form requires abstract thinking. However, once that is accomplished many of the meteorological concepts and processes conveyed by a weather map become easier to understand.

This paper presents a method for transforming an abstract concept (a 2-dimensional weather map) into a physical model (a 3-dimensional representation of the weather map) to help students better understand key meteorological concepts and processes conveyed by the surface weather map. A similar concept was used by Wellner (1997) to model geologic formations.

2. MATERIALS

- a) Surface weather map
- b) Foam core board: a 30" x 40" sheet for each group is plenty (for a less expensive alternative, you could substitute corrugated cardboard or foam trays found at supermarkets in the meat and produce departments)
- c) X-acto knife (if you are uncomfortable with your students using X-acto knives, I suggest you go with the corrugated cardboard or foam tray option, in which case you can use

scissors – if you do use X-acto knives, eye protection should be required)

- d) Glue stick or adhesive spray
- e) Metal straight edge (if using an X-acto knife)

3. PROCEDURES

3.1 Preparation

Find a suitable surface weather map, i.e., one that shows good contrast between high pressure and low pressure (a good website for finding surface weather maps is:

<http://www.hpc.ncep.noaa.gov/dailywxmap/index.html> - the map shown in Figures 1-4 is from this website and is dated February 13, 2005). If necessary, reduce or enlarge the weather map such that it fills an 8.5" x 11" sheet of paper, then make enough photocopies of the weather map for each group. The number of copies needed will depend on the number of isobars on the map – one map is needed for each isobar on the map plus one additional map to serve as the base. One suggestion that will make this project even more interesting is to use a series of consecutive daily weather maps – giving each group a map from a different day – this will allow your students to track the progress of a weather system (for example, a low pressure) over the course of several days.

3.2 Making the Model

- a) Firmly glue copies of the weather map side-by-side onto the foam core board (butt the maps up against one another to maximize your use of the foam core board).
- b) Using the metal straight edge to guide the Exacto knife, carefully cut along the edges of the map. When stacked on one another, your maps should all be the same size.

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- c) Take one of the maps that is glued to the foam board and, leaving it as it is, place it on a table – this will serve as your base map (Figure 1).
- d) On the second map, find the lowest pressure on the map (it will likely have an “L” for low pressure). Cut along the isobar (line of equal air pressure) that circles the low pressure (Figure 2) [**Hint:** if you use an Exacto knife to cut along the isobar, be sure to place a piece of cardboard underneath to prevent cuts on your tabletop]. When you have cut out that area of the map, there will be a hole in your map. Stack that map on top of your base map (Figure 3).
- e) On the third map, find the isobar representing the next lowest surface pressure (it will be the next isobar outward from the center of the low pressure). After cutting along that isobar, there will be an even bigger hole in your map. Stack this map on top of the other two. You will begin to notice how they fit together in a layered pattern. [**Hint:** As you progress, you may find it is best to glue the layers together.
- f) Continue with this procedure until your three-dimensional map is complete (Figure 4). Notice that isobars indicate changes in air pressure in four millibar (mb) increments of atmospheric pressure. By convention, isobars will always be drawn for even multiples of 4 mb (i.e., ...992 mb, 996 mb, 1000 mb, 1004 mb, ...).

4. RESULTS & DISCUSSION

4.1 Prominent Weather Map Features

The features that are probably most conspicuous on the three-dimensional map are the high and low pressures. Areas of high pressure tower above all else; it is no wonder that broadcast meteorologists often refer to high pressures as “mountains” or “domes” of air. Perhaps even more prominent are the areas of low pressure. Low pressures appear as valleys, and are sometimes referred to as “depressions” or “troughs.” Thus, when low pressures are gaining strength, meteorologists will often mention that the area of low pressure is “digging deeper.”

When looking at their three-dimensional models, students may misinterpret the heights of

the various layers of their model (Figure 4) as being related to the height or top of the atmosphere. However, the layers themselves have nothing to do with the height or top of the atmosphere, but rather the concentration of, and therefore the pressure exerted by, air molecules above that surface. Where the layers of the model are stacked high (high pressure), there is simply a high concentration of air molecules; where there are very few layers to your model (low pressure), there is a low concentration of air molecules. So the “hole” that is formed in the model by the low pressure does not represent “nothing,” but rather a lower concentration of air molecules. You may also want to reinforce the concept that, in trying to reach equilibrium, the atmosphere is constantly moving air molecules from areas of higher pressure to the areas of lower pressure.

Another conspicuous feature on the three-dimensional map is the change in slopes that occur between the various layers across the map. If you use a physical interpretation of a slope, your students will better understand the concept of why wind speeds are sometimes strong and sometimes gentle. The isobars on a weather map are analogous to contours on an elevation map, where isobars are closely spaced there is a large difference in the concentration of air molecules over a short distance (i.e., a steep pressure gradient). Where steep pressure gradients exist, you’ll find strong winds as the atmosphere quickly moves air molecules from an area of high concentration (high pressure) to an area of low concentration (low pressure) in an attempt to reach equilibrium. Conversely, where isobars are widely spaced there is a small difference in the concentration of air molecules over a large distance (i.e., a gentle pressure gradient). Where gentle pressure gradients exist, you’ll find weak winds.

The atmosphere, in a constant attempt to reach equilibrium, moves air molecules from areas of high pressure toward the center of low pressure, going “downhill” similar to a skier. Your inquisitive students may wonder what happens to that air once it “reaches the bottom of the hill” (the center of low pressure). Once that air meets in the center of low pressure it is forced rise through a process called convergence. Converging air carries with it water vapor that will likely condense to form clouds, and potentially precipitation. That is why clouds and oftentimes precipitation are associated with low pressures.

4.2 Making Connections Between the Information Provided by Individual Weather Stations on the 2-D Map and Your 3-D Map

Have your students been trained to read data from individual weather station models (Figure 5) (Smith and Ford, 1994)? **[Note:** A good site for quizzing students on data found on weather station models is found at <http://cimss.ssec.wisc.edu/wxwise/station/page5.html>. If so, have your students make side-by-side comparisons of that information (read from the two-dimensional map) to the features found on their three dimensional map, this will help them make the connections between what they see on a two-dimensional map and what they visualize on a three-dimensional map. I have provided a list of questions (and answers) you can ask your students in the section below. After they have answered the questions with both the two- and three-dimensional maps in front of them as a reference, challenge their abstract thinking abilities by providing them with a completely different surface weather map, then ask them the same questions listed below.

4.3 Potential Questions (and Answers) for Your Students Regarding the Map They Created

- a) Where is surface pressure greatest on this map? (Answer depends on the map used.)
- b) What is the physical interpretation of a surface high pressure? What does it literally mean when there is high pressure over a particular surface? (There is a higher concentration of air molecules above that location relative to surrounding locations.)
- c) Describe the vertical movement of air in the center of a high pressure. (Downward.)
- d) What kind of weather do we normally expect if pressure is high? Why do you expect this type of weather? To what extent is the sky covered by clouds in the center of high pressure (check a weather station model on your map that is located in/near the center of high pressure). (Vertical movement of air is downward, so water vapor at the surface is not lifted into
- e) Describe the horizontal movement of air around a high pressure. Why does it move this way? (Horizontal movement of air is outward. In trying to reach equilibrium, air molecules move outward toward surrounding areas of lower pressure. Actually, you will find that wind movement around a high pressure is outward and clockwise. The clockwise movement is due to the Coriolis Effect, but that might be beyond the scope of what you wish to teach.)
- f) Where is surface pressure least on this map? (Answer depends on the map used.)
- g) What is the physical interpretation of surface low pressure? What does it literally mean when there is low pressure over a particular surface? (There is a low concentration of molecules above that point.)
- h) Describe the vertical air movement in the center of a low pressure. Why does it move this way? (Vertical motion of air is upward, caused by air converging on a single point (the center of low pressure) and, since it cannot go into the ground, the air is forced to rise.)
- i) What kind of weather do we normally expect if pressure is low? Why do you expect this type of weather? To what extent is the sky covered by clouds in the center of low pressure (check a weather station model on your map that is located in/near the center of low pressure). (Because the vertical motion is upward, water vapor at the surface can be lifted into the atmosphere and condensed, forming clouds. If enough moisture is present, precipitation forms.)
- j) Describe the horizontal movement of air found around a low pressure. Why does it circulate this way? (The horizontal circulation of air is inward. In trying to reach equilibrium, the air molecules in the

the atmosphere to be condensed. Therefore, it is difficult for clouds, and thus precipitation, to form. So fair weather is typically associated with high pressure.)

area of high pressure move toward areas of lower pressure. Actually, you will find that wind movement around a low pressure is inward and counterclockwise. The counterclockwise movement is due to the Coriolis Effect, but that might be beyond the scope of what you wish to teach.)

k) Where are the fastest wind speeds found on your map? Why are they found there? (Fastest wind speeds will be located where the isobars are most closely spaced. This is where the pressure gradient is greatest. As a result, air molecules are moving rapidly from an area of greater concentration (high pressure) to an area of lesser concentration (low pressure)).

5. CONCLUSION

Many students, including my own, find that a visual representation helps their understanding of abstract concepts. I have used this model building exercise as a tool to help explain to my students some of the

meteorological processes that occur at the earth's surface.

Granted, the forecast issued by the National Weather Service (NWS) takes into account much more than just the meteorological conditions and processes occurring at the earth's surface. However, after completing this exercise, your students can now look at a daily surface weather map and make rudimentary forecasts of atmospheric pressure, pressure tendency (changes in air pressure over a short time frame), wind speed, cloud cover, and perhaps even precipitation and wind direction. Have them compare their forecast (made individually or as a group) to that of the NWS or their local television meteorologist. Perhaps a field trip to the television station or an invitation to the meteorologist to come to your classroom would continue their interest in the weather unit.

6. REFERENCES

Smith, P. Sean and B. A. Ford, 1994. Interpreting weather maps. *Science Activities*. 31:13-18.

Wellner, K. 1997. Modeling geology formations. *Science Scope* 20:34-35.

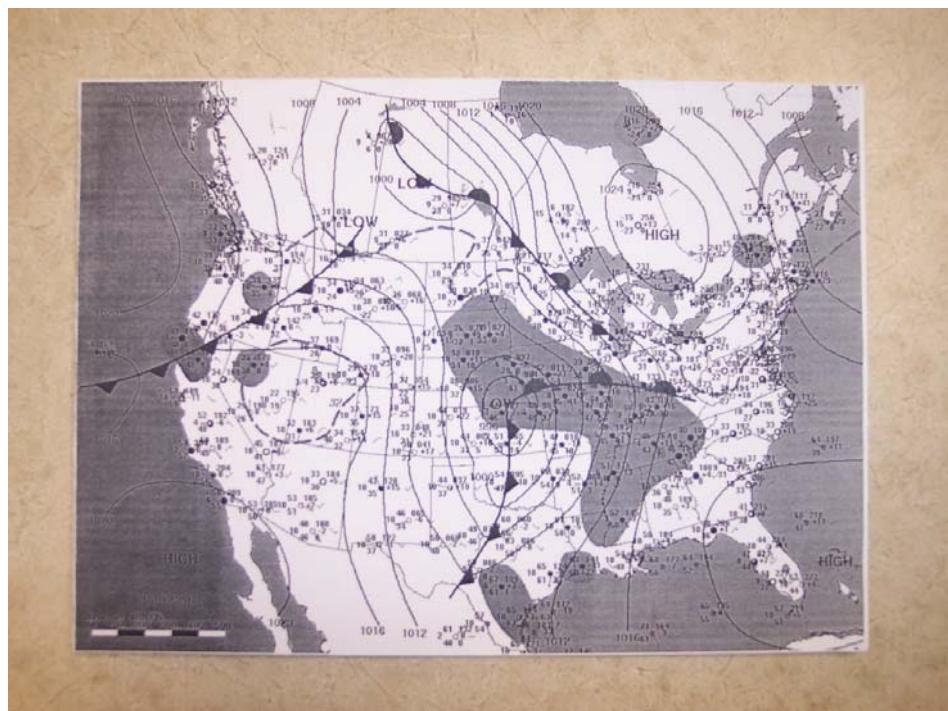


Figure 1. Glue weather maps onto the core board; the first weather map will become your base map.

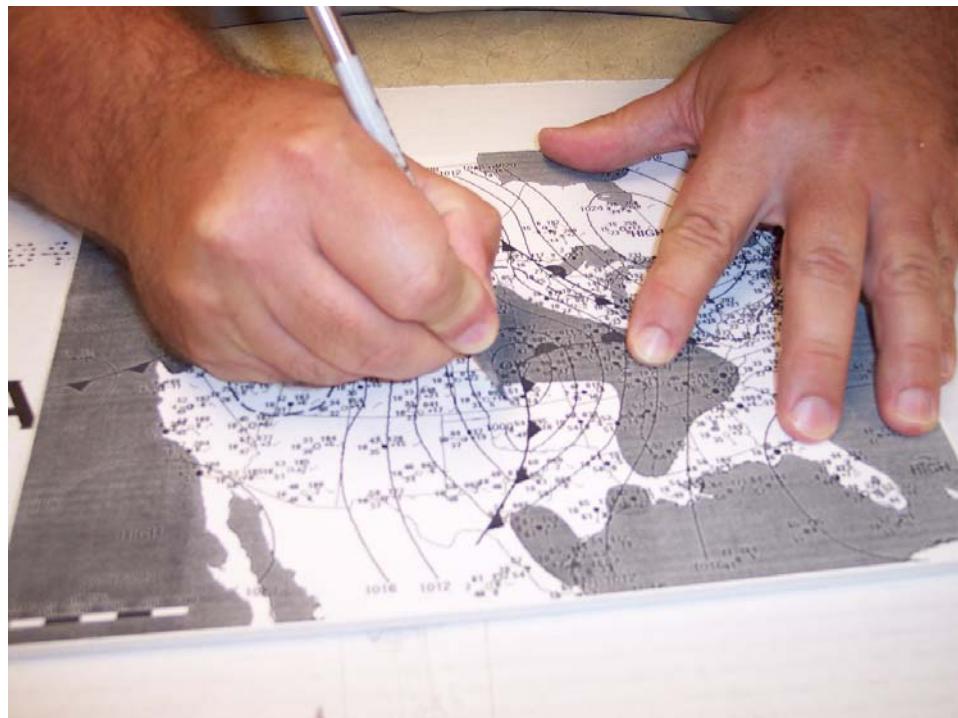


Figure 2. On the second map, cut out the isobar that represents the lowest atmospheric pressure on the map.



Figure 3. After cutting along the isobars, stack each map on top of the previous one. Continue this process with each isobar on the map.

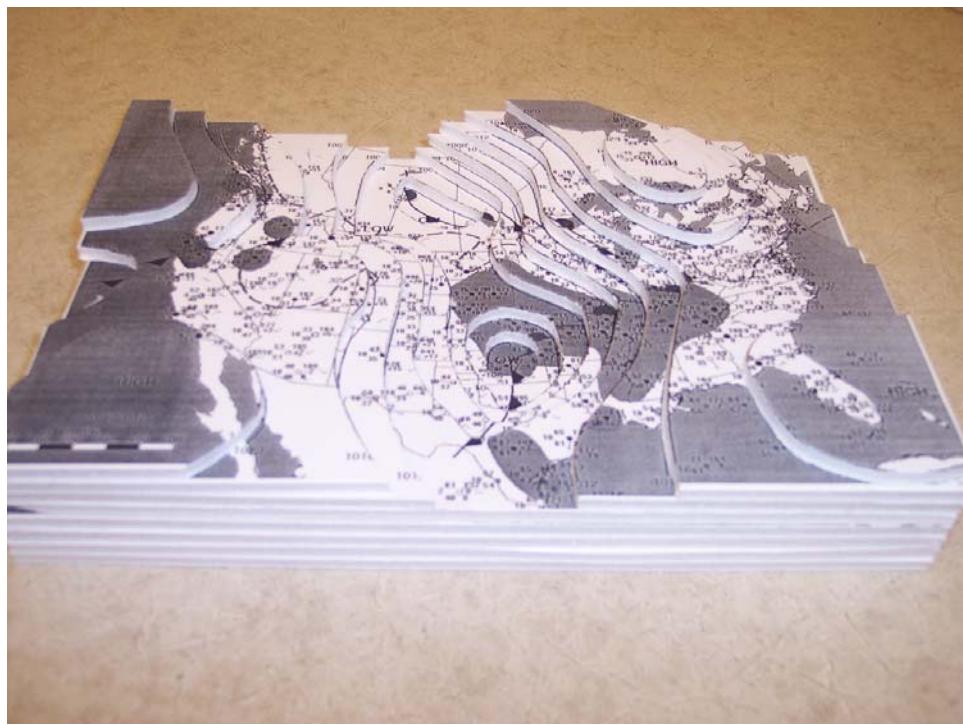


Figure 4. A completed three-dimensional representation of a surface weather map.

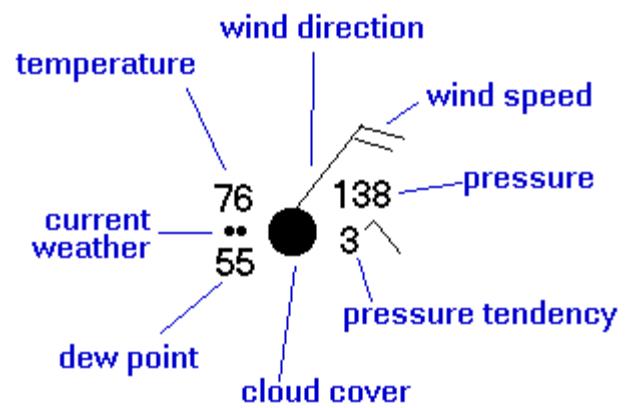


Figure 5. An example of a weather station model with each variable labeled (Courtesy of Steve Ackerman, University of Wisconsin – Madison).