

## Laboratory Exercise #8 - Introduction to Atmospheric Science: Global Circulation and Weather Makers

### Section A - Global Atmospheric Circulation:

To understand weather you need to understand how the atmosphere is organized. As discussed in lecture the how the atmosphere is organized in the northern hemisphere into three circulation cells (Figure 1). Additionally, we discussed how winds move within these circulation cells, which govern the direction in which weather systems mitigate over time (Figure 1). Examine Figure 1 and answer the following questions regarding global circulation patterns. Additionally, refer to section D from last week's lab and the lecture note for a discussion of high and low pressure. Note that in areas where winds collide the atmosphere is characterized by surface convergence (C) and in areas where winds move away from each other this is defined as surface divergence (D). Low pressure is associated with convergence of winds at the earth's surface and high pressure occurs with surface divergence.

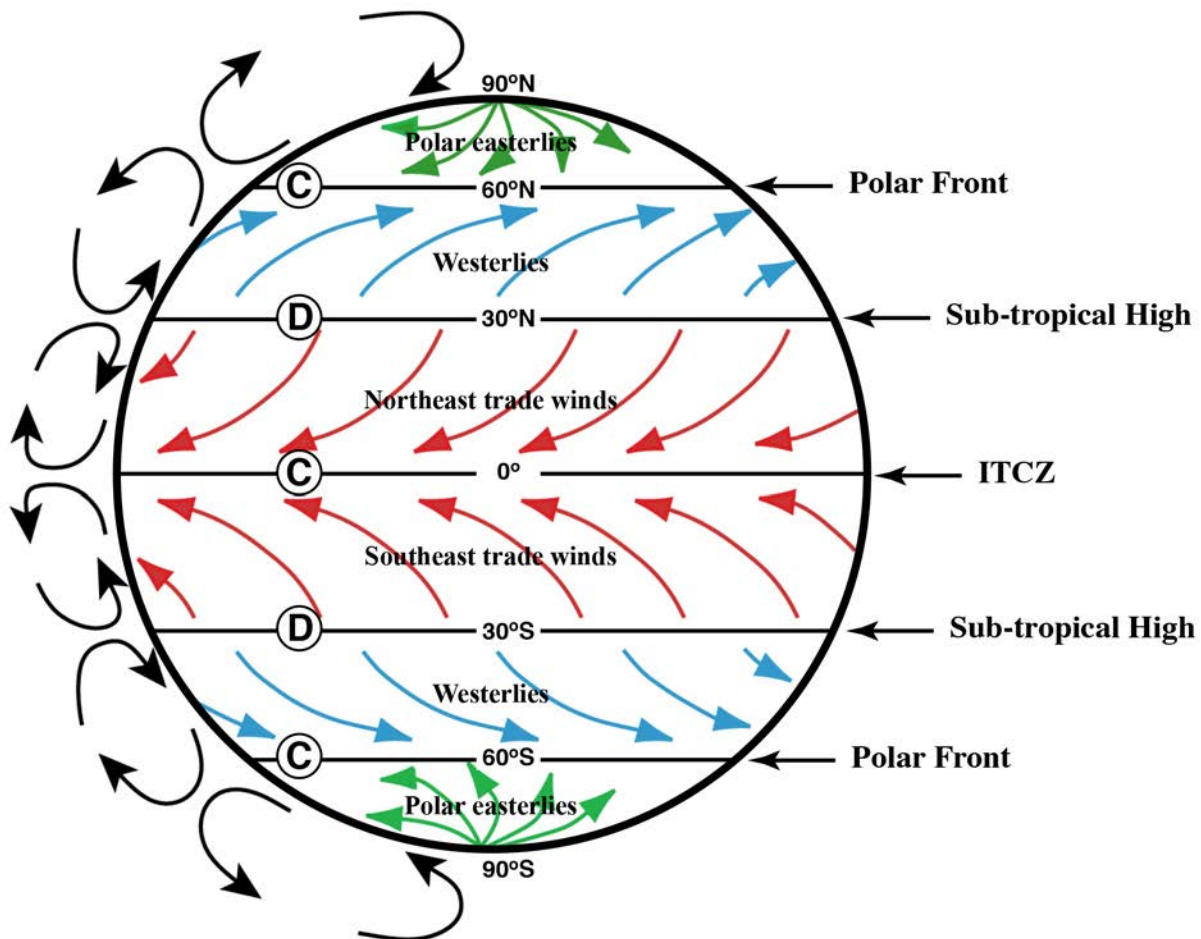


Figure 1. Idealized global atmospheric circulation (C= surface convergence, D= surface divergence).

The Hadley circulation cell dominated in the lower latitudes and is the cell between the equator and 30° degrees latitude as is illustrated on the left side of Figure 1.

QUESTIONS:

1. Indicate the location of the center of the Hadley Cell on the left side of Figure 1 with an H.
2. At the equator the tendency is for surface ---- convergence or divergence ?
3. Describe the vertical movement of air at the equator ---- sinking or rising ?
4. What is the name of the atmospheric feature present at the equator?
5. Is the feature in question #4 an area of --- high pressure or low pressure ?
6. Towards which direction does the weather between the latitudes of 0 and 30° move?
7. What is the latitude of Laredo, Texas in degrees \_\_\_\_\_?

The Ferrell circulation cell dominated in the middle latitudes and is the cell between 30° and 60° degrees latitude. Finally the Polar circulation cell dominated in the high latitudes and is the cell between 60° and 90° degrees latitude. Both of these circulation cells are illustrated on the left side of Figure 1.

8. Indicate the location of the centers of the Ferrell and Polar Cells on the left side of Figure 1 with an F and P.
9. Laredo is close to the boundary between which two atmospheric circulation cells?  
\_\_\_\_\_
10. Around Laredo the vertical movement of air is ---- sinking or rising ?
11. Around Laredo the tendency is for surface ---- convergence or divergence ?
12. What is the name of the atmospheric feature present close to Laredo?
13. Is the feature in question #12 an area of --- high pressure or low pressure ?

14. Towards which direction does the weather between the latitudes of 30 and 60° move?
15. At 60° latitude the tendency is for surface ---- convergence or divergence ?
16. Describe the vertical movement of air at 60° latitude is ---- sinking or rising ?
17. What is the name of the atmospheric feature present at 60° latitude?
18. Is the feature in question #17 an area of --- high pressure or low pressure ?
19. On Figure 2 indicate the locations of the ITCZ, Subtropical High and Polar Front with a highlighter.

### **Section B - Remote Sensing of the Atmosphere:**

Modern meteorologists use space based tools to enhance their understanding of how the atmosphere behaves. There are three major satellite observations routinely used in meteorology.

#### **1. Visible Satellite Imaging**

This type of imagery allows meteorology to see large scale patterns of clouds over large distances of the planet. This imagery uses the visible light part of the electromagnetic spectrum and therefore is good for only daytime observations

#### **2. Infrared Satellite Imaging**

For both day and night-time viewing infrared (IR), or heat, imagery is more useful. Intensity of emitted IR radiation is directly related to temperature. Colder objects show up as white with warmer objects black.

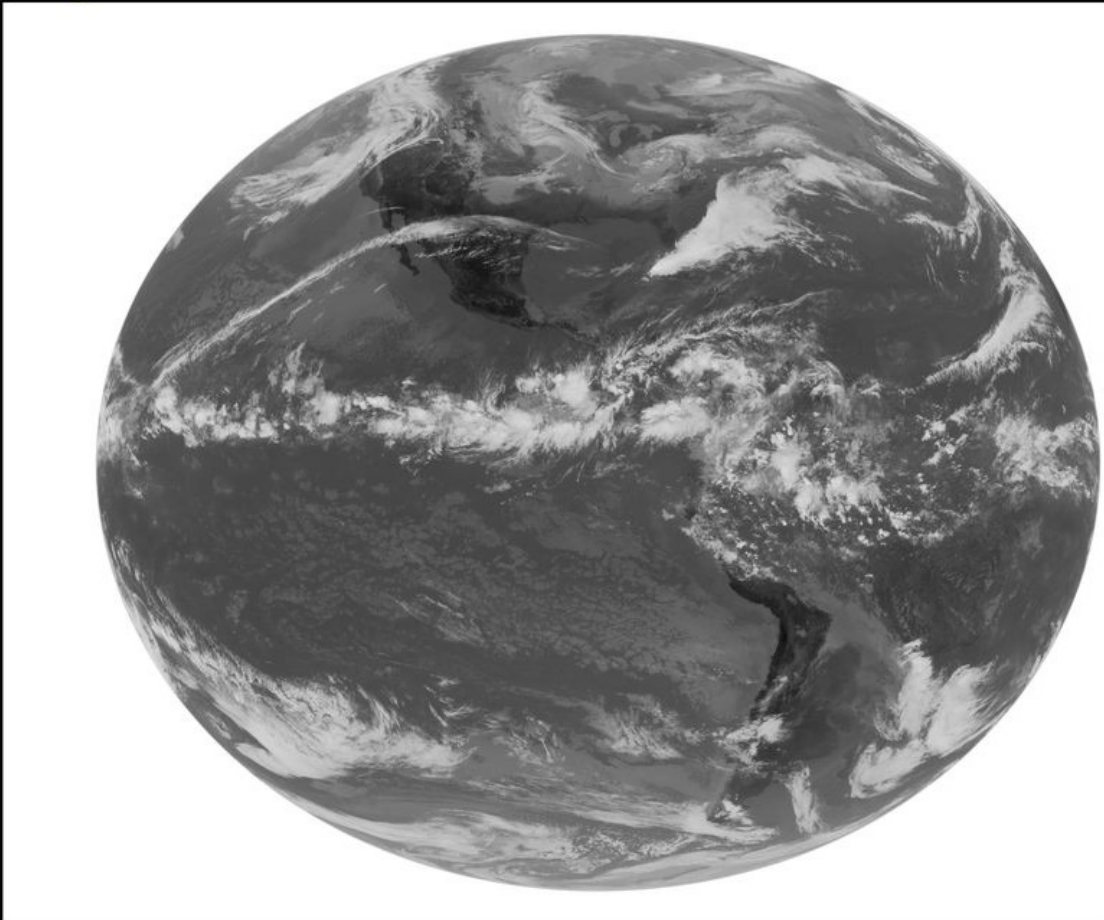
- High clouds can have extremely cold cloud tops showing up as white on the image
- Low clouds have warmer temperatures and will appear gray on the image. Snow cover can also show up as a gray in an IR image
- Areas without cloud cover show up as black indicating the earth's surface, which is warmer than overlying clouds.

#### **3. Water Vapor Satellite Imagery**

Water vapor absorption of IR radiation is particularly strong at certain wavelengths and can provide an estimate of moisture in the middle levels of the troposphere.

In today's lab we will use only IR satellite images as seen in Figure 2 on the following page.

First GOES-15 Full Disk Infrared Image  
 26 April 2010 1730 UTC  
 10.7 um -- Longwave IR Window



### Section C - Encoding the Weather - Reading and Developing a Station Model

Meteorologists need to encode vast amounts of data onto a map. To do this they have developed symbols and a systematic method for depicting weather data, which is referred to as a station model. Figure 3 is a sample station model with instructions on how to read it and Figure 4 is a map symbol key for weather maps.

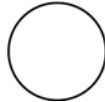
In today's lab we will focus on how to read and encode sky cover, air temperature, dew point temperature and weather conditions. For a basic station model (Figure 4) realize that the temperature is indicated to the upper left of the circle that represents the station and dew point temperature is indicated to the lower left of the circle. **Both air and dew point temperatures are indicated *without the degrees symbol or the letter F indicating Fahrenheit*.** Weather conditions are indicated with the appropriate symbol, from Figure 3, between the temperature and dew point numbers. If no significant weather is happening, like a nice sunny day, then no weather symbol is needed. Finally, sky cover is indicated by filling in the circle as indicated in Figure 3.

Let us begin with the data that your recorded from last's week's lab.

Copy the conditions at the end of Lab 7 for 12/14/19 at 16:00 hours.

Air Temperature \_\_\_\_\_ °F      Sky Cover \_\_\_\_\_  
 Dew Point Temperature \_\_\_\_\_ °F

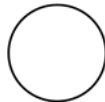
20. Construct a station model for the above conditions using the circle below.



Copy the conditions at the end of Lab 7 for 7/22/04 between the hours of 19:00 and 20:00.

Air Temperature \_\_\_\_\_ °F      Sky Cover \_\_\_\_\_  
 Dew Point Temperature \_\_\_\_\_ °F      Weather \_\_\_\_\_

21. Construct a station model for the above conditions using the circle below.



### Surface Station Model


<b>Temperature (°F)</b>  <b>Weather</b>  <b>Dewpoint Temp. (°F)</b>	<div style="text-align: center;">           45            ••            29            </div>	<b>Sky Cover</b>	<b>Data at Surface Station:</b> - Temperature 45 °F - Dewpoint Temp. 29 °F - overcast - weather - light rain
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Figure 3. Example of how a meteorologist encodes weather data. In this lab we will encode only air and dew point temperatures, weather conditions, and sky cover.


















Sky Cover	Fronts and Radar	Selected Weather Symbols
 clear	 cold front	• Rain (see note below)
 1/8	 warm front	⚡ Rain shower
	 stationary front	⚡ (Thunderstorm
 3/8	 occluded front	' Drizzle
 4/8	 trough	* Snow (see note below)
 5/8	 squall line	⚡ Snow shower
 broken	 dry line	❄ Freezing rain
 7/8		❄ Freezing drizzle
 overcast		☁ Fog
 obscured		∞ Haze
<b>NOTE:</b> multiple rain or snow symbols indicate intensity, i.e. light (2 symbols), moderate (3 symbols), heavy (4 symbols)		☁ Smoke
		⚡ Dust or Sand
		⚡ Blowing Snow

Figure 4. Key for symbols used on a weather map. Especially note the symbols for sky cover, fronts, and weather.

22. When air and dew point temperature are close the atmosphere is humid (relative humidity close to 100%); whereas, if the dew point is greatly lower than the air temperature the atmosphere will have a low relative humidity. Comment on the relative moisture content in the atmospheres between the dates of 07/22/04 and 12/14/19.

### **Section D – Introduction to Weather Makers**

To understand the occurrence of storms, and for that matter fair, sunny weather, we need to learn about how air moves within the atmosphere. The movement of air is driven by differences in atmospheric pressure that occur within the atmosphere. Most people that have even casually glanced at a weather map from the television or internet notices the presence of areas of high pressure (**H**) and low pressure (**L**) depicted on weather maps.

Atmospheric pressure can be measured in either millibars or inches of mercury. Typically, areas of high pressure will exceed approximately 30 inches of mercury ( $\approx 1015$  millibars of pressure). Atmospheric pressure is indicated on a weather map as isobars or lines of equal pressure. The conventions for plotting and reading isobars are exactly the same as those for contour lines; refer back to laboratory exercise 2! Figure 5 shows a simplified weather map illustrating an area of low and high pressure. Generally, areas of high and low pressure are defined on a weather map as enclosed circular regions.

Remember that air rises associated with low pressure and sinks associated with high pressure, which controls the weather we experience on a day-by-day basis. Also recall that air temperature normally decreases with increasing altitude within the lowest level of the atmosphere. From last week's lab we learned about the inverse relationship between temperature and humidity; i.e. with increasing temperature humidity will decrease and vice versa.

### **THEREFORE:**

Low Pressure – Has rising air and as the air rises it cools. As the air cools the humidity increases until it reaches 100%. When the humidity reaches 100%, water vapor condenses to form clouds and precipitation.

**Or Low Pressure = Stormy Weather**

High Pressure – Has sinking air and as the air sinks it warms up. As the air warms up the humidity decreases, cloud formation is prevented and the weather is fair.

**Or High Pressure = Fair Weather**



In the northern hemisphere at the earth's surface the winds will spiral away from the center of a high pressure system in a clockwise manner (Figure 5). Conversely, winds spiral in toward the center of the low-pressure system in a counterclockwise fashion (Figure 5). Always remember that air moves from areas of high pressure to areas of low pressure.

From a careful examination of all of the above concepts you should be able to predict the weather associated with a high and low-pressure system.

Areas of high pressure (**anti-cyclone**) are obvious on a satellite image in that these areas lack a significant cloud cover. Relative large areas of low pressure have extensive cloud cover. Remember that there are two types of low pressure systems (**cyclones**), which are defined based on the latitudes in which they form.

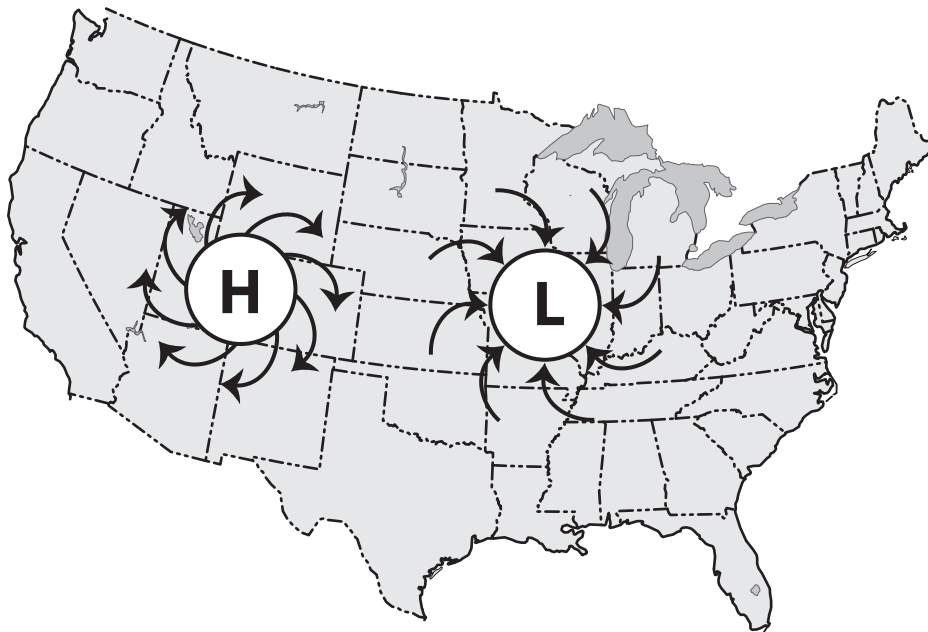


Figure 5. Map of North America showing air circulation around a low and high pressure system.

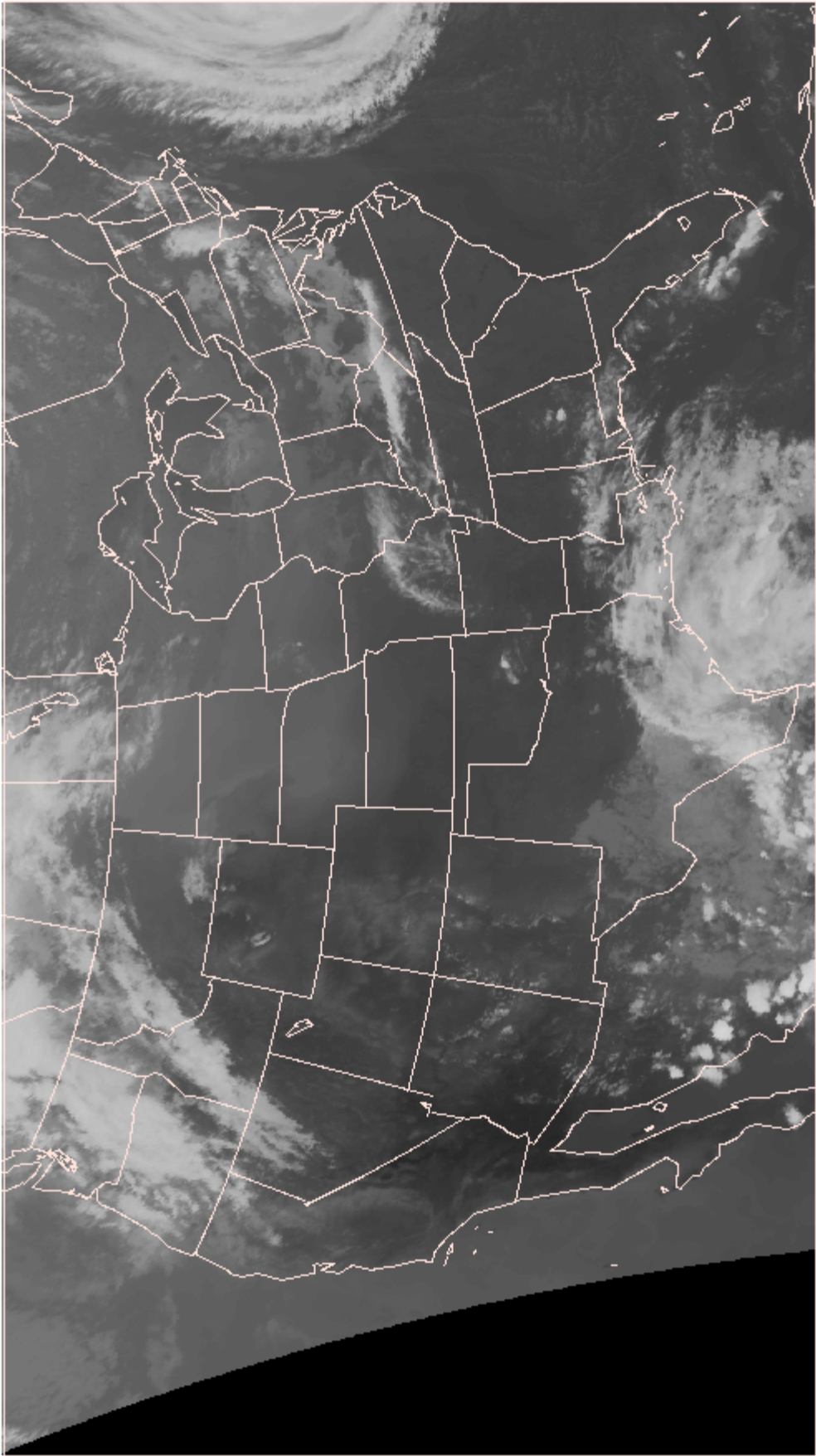
### QUESTION

23. Draw one circle with an H on pg. 9 to indicate an area of high pressure. Also draw arrows around the H like in Figure 5.



0015Z 20 SEP 2010

Infrared Image



NCEP/INWS/NDAA

**Tropical cyclones** form in the low latitudes, typically between 8 to 25° degrees away from the equator. Tropical low-pressure systems in the Atlantic basin tropical low-pressure systems develop off the coast of Africa as well as in the Caribbean Sea. Additionally, tropical systems can develop in the Gulf of Mexico. Since these systems require warm water their formation is seasonally limited. Hurricane season in the Atlantic and Gulf basins begins on June 1 and extends through November 30 with a peak in tropical activity around mid-September. These systems typically move from east to west, which is consistent with the prevailing movement of wind in the low latitudes. Occasionally, steering winds can cause a tropical cyclone to turn towards the north and this is when these system pose the greatest danger to the continental United States.

Tropical low-pressure systems have rising air with abundant rainfall. There are different types of tropical low-pressure systems depending upon the intensity of the system. For example, a tropical disturbance is nothing but a poorly organized cluster of thunderstorms. A tropical depression is an area that has begun to organize into a coherent low pressure zone with relatively weak winds less than 39 miles per hour. A tropical storm has winds between 39 to 74 miles per hour versus a hurricane with winds >74 miles per hour and as these systems intensify they become better organized. Note that you will only see an eye and spiral rain bands with a well-developed hurricane (Figure 6). Tropical disturbances through tropical storms look more like a large, ill-defined cluster of thunderstorms.

Occasionally, the South Texas coastline is struck by a tropical storm or hurricane that makes landfall in this region. Once a tropical low-pressure system makes landfall (moves onto land) the wind speed rapidly decreases. However, the danger is not over in that a minimal tropical storm over land can still produce prodigious amounts of rain (Tropical Storm Allison in 2001 produced over 3 feet of rain in Houston). Unlike typical thunderstorms discussed previously, tropical systems can spread heavy rain over a wide geographic area. The last hurricane to make landfall over South Texas was Dolly in July 2008. Last summer's Hurricane Havey actually made landfall over Houston causing massive flooding.

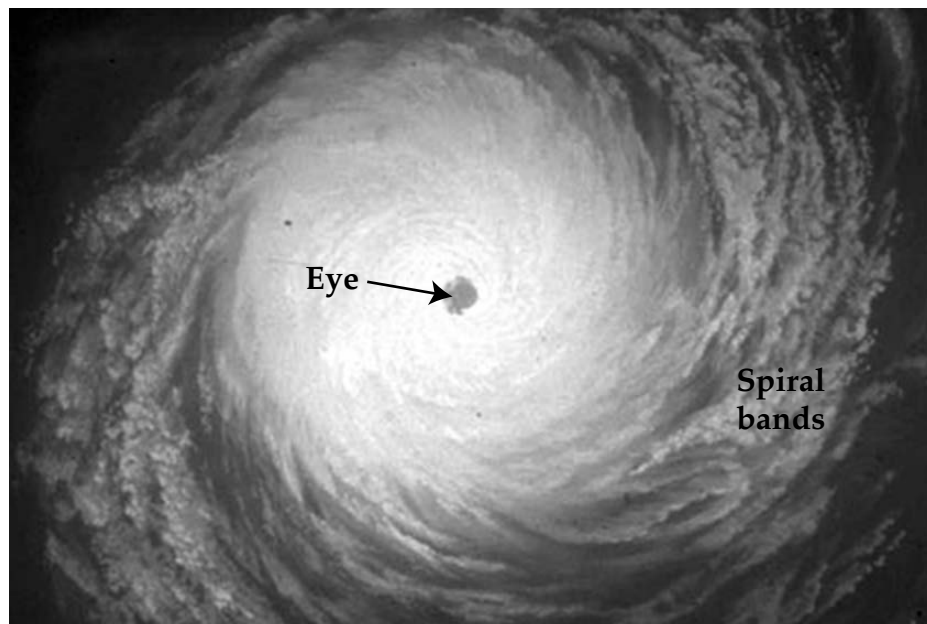


Figure 6 (previous page). A well developed tropical cyclone (hurricane) with a characteristics eye and outer spiral rain bands.

### QUESTIONS

24. Draw a line on pg. 9 at  $30^{\circ}$  latitude. This represents the boundary between the low and middle latitudes.
25. On pg. 9 there is an example of both a well developed (hurricane) and poorly developed (tropical depression) tropical cyclone on the satellite image. Circle and label these systems. Note that the hurricane recurved to the north and moved into the middle latitudes, which these systems sometimes do. Note that only half of the hurricane is shown on this image.
26. Contrast the wind speed and degree of organization of a hurricane, tropical storm, and tropical depression.
27. How do tropical cyclones generally move? From west to east or east to west? Explain.
28. When is hurricane season in the Atlantic Basin \_\_\_\_\_?
29. When a tropical cyclone makes landfall is the danger over? Explain.

The second type of cyclone, a **mid-latitude cyclone** actually marks the boundary between the temperate air of the mid-latitudes and the polar air of the high latitudes. This boundary between warm (temperate) and cold/cool (polar) air has three components (central low pressure system, cold front, and warm front). These systems, with adjacent high pressure systems, move west to east across the continental United States. Remember that a mid-latitude cyclone consists of three components: central low pressure area; a cold front that extends to the south and west of the central low; and a warm front that is located to the north and east of the center of the system (Figure 7). Refer to Figure 3 for the symbols used for a cold and warm front.

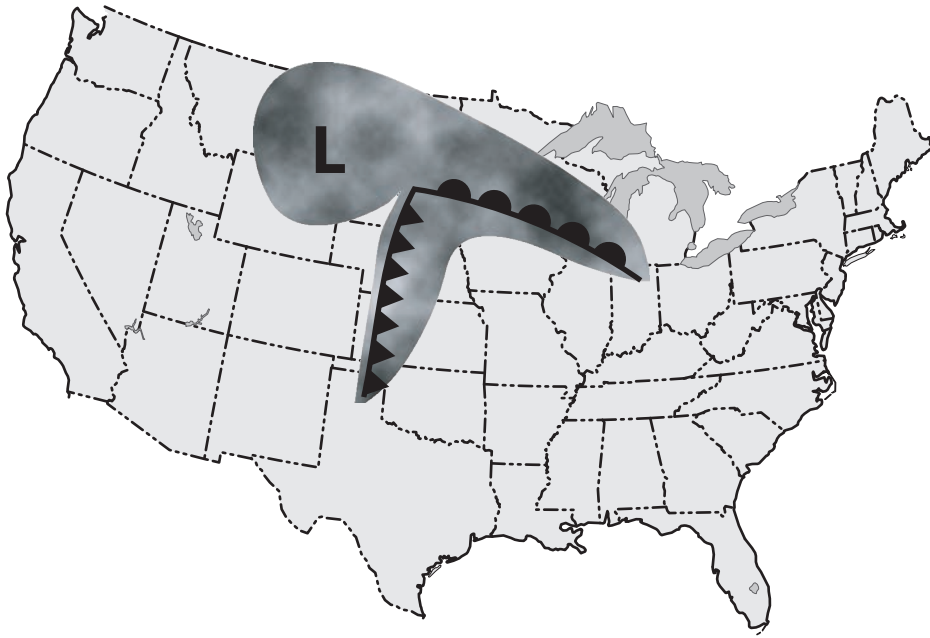


Figure 7. A representative mid-latitude cyclone showing position of fronts and cloud cover associated with this system.

Initially, instability in the boundary between temperate and polar air along the polar front will cause a low-pressure system to develop. Atmospheric instability (i.e. colder air over warmer air) will serve as the triggering mechanism causing air to rise and resulting in the development of a low-pressure system.

Once the low pressure is developed, cold air will begin to move counterclockwise around the northwestern side of the low-pressure system (in the northern hemisphere). This cold air will encounter the warm temperate air to the south of the low-pressure system forming a boundary between these two air masses. This boundary is referred to as a cold front and is always located to the west and south of the central low-pressure system (Figure 7). In profile view a cold front has a steep geometry where air is rapidly rising up over the front (Figure 8). This results in the development of cumulonimbus clouds that can produce intense precipitation ( $> 1$  inch per hour) in the form of thunderstorms that form in a line along the length of the cold front. However, cold fronts tend to move rapidly (up to 50 miles per hour) and therefore the resulting precipitation generated from the passage of a cold front lasts only a few hours at most.

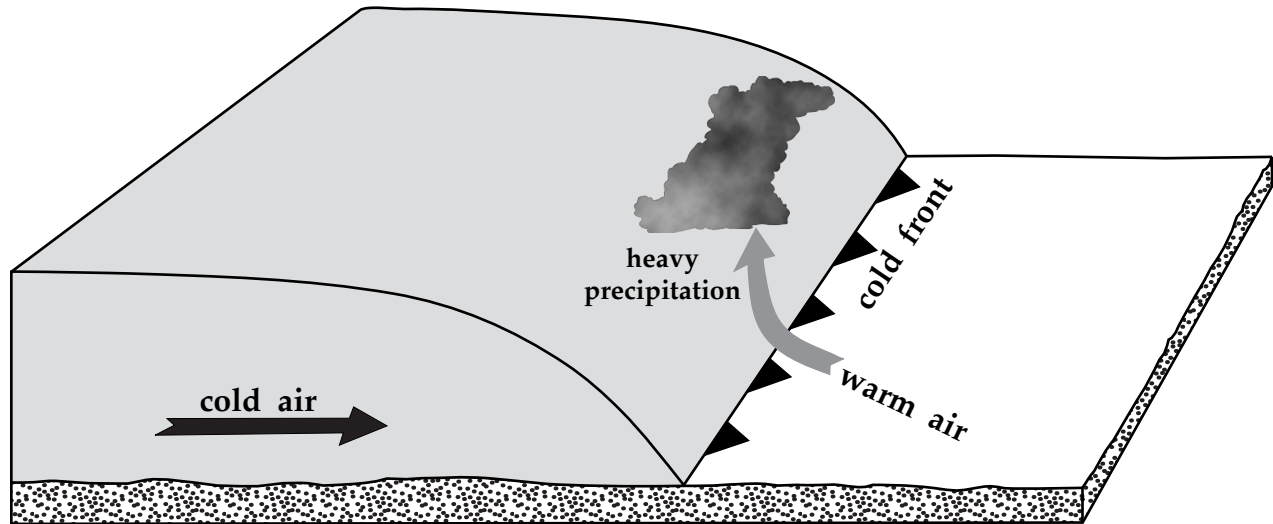


Figure 8. Profile view of a cold front.

Additionally, warm, temperate air will begin to move counterclockwise around the central low pressure system. This warm temperate air will encounter cooler air to the north forming a boundary referred to as a warm front (Figure 4). In profile view, warm fronts (Figure 9) have a gently sloped geometry where warm air is slowly rising up over the front surface below which the air is cooler. This results in the development of low-lying stratus or nimbostratus clouds that produce low intensity precipitation ( $< 0.1$  inch per hour; *e.g.* drizzle). Warm fronts tend to move slowly and therefore the resulting precipitation generated from the passage of a warm front can last for days.

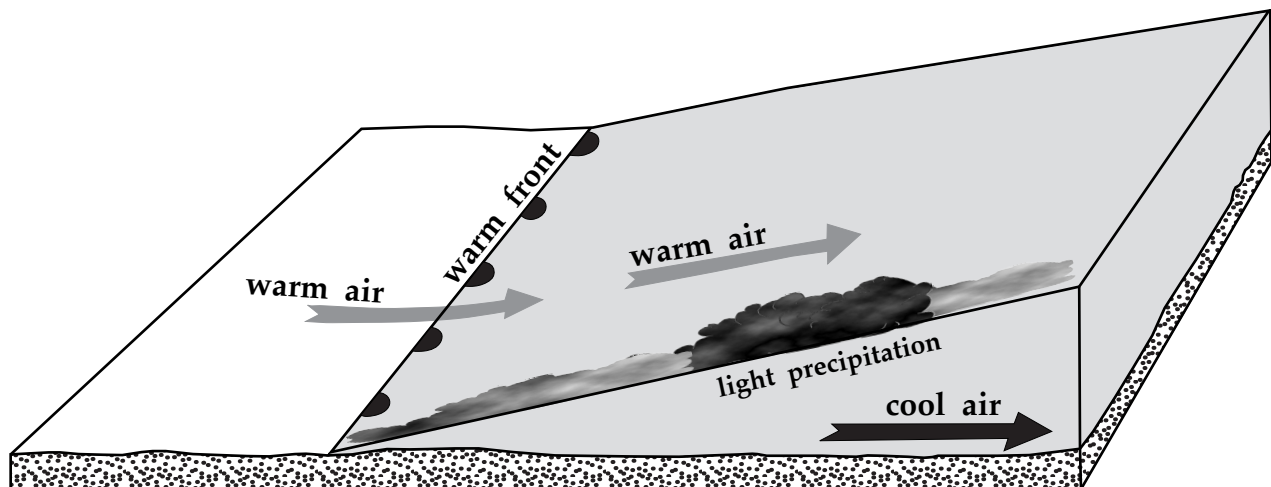


Figure 9. Profile view of a warm front.

Finally, the area between the cold and warm front to the southeast of the central low pressure system is referred to as the warm sector where the weather is typically fair but warm and humid resulting from the southly flow of air towards the low pressure area. To the west of the cold front weather rapidly clears and cooler and drier air is present.

Typically, in South Texas we are affected by the extreme southern segment of cold fronts connected to mid-latitude cyclones, whose central low-pressure systems are located further to the north. Additionally, South Texas is mainly affected by fronts during the winter when polar air masses move southwards towards the equator.

### QUESTIONS:

30. Look at pg. 9. In the northwestern US there is a mid-latitude cyclone. On the satellite image label the following features:

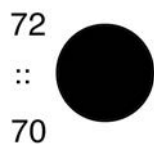
- Central Low Pressure (indicate with an “L”)
- Cold Front (use the proper symbol)
- Warm Front (use the proper symbol)
- Warm Section (indicate with “WS”)

31. Draw arrows around the central low area on Page 9.

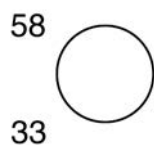
32. Contrast the precipitation intensity and cloud types associated with a cold and warm front.

33. Below are station models associated with the following four areas of weather (High Pressure; Mid-Latitude Cyclone - Cold Front, Warm Front, and Warm Sector). Examine the data in these models and correctly assign to a weather maker.

### Weather Maker





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61  
..  
58



75  
68




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34. Describe how the mid-latitude cyclone will likely move over the next few days. Justify your answer based on your knowledge of atmospheric circulation in the northern hemisphere.
35. Put a dot on pg. 9 representing the city of Chicago. If you were a meteorologist would you predict precipitation for Chicago on September 22, which is two days after the satellite image on page 9 was taken. Explain your answer in detail.

A final type of significant weather maker can occur in areas smaller than the low and and high pressure systems discussed on the previous page. This small scale phenomena is isolated thunderstorms, which can be highly localized.

In South Texas most rain is generated by isolated thunderstorms, which can be thought of as mini-low pressure areas, with rising air that ultimately generates significant rain. Many thunderstorms develop when intense heating of the ground creates extremely warm air that rises into the atmosphere forming puffy cumulus clouds (Figure 10). Warm air rises because it has a lower density then cooler air (this is the principle behind hot air balloons). As the air continues to rise,



tall cumulonimbus clouds can develop, which produce precipitation (Figure 10).

Thunderstorms can produce extremely localized rainfall where it literally can be raining on one side of a street but not the other. Even isolated thunderstorms can generate heavy rain ( $> 1$  inch per hr) and occasional hail as well as other forms of severe weather (e.g. tornados, heavy winds and lightening). One final difference between isolated thunderstorms and cyclones is that while cyclones with frontal systems can last days although they do not typically stay in one place, isolated thunderstorms typically do not last for more than a few hours.

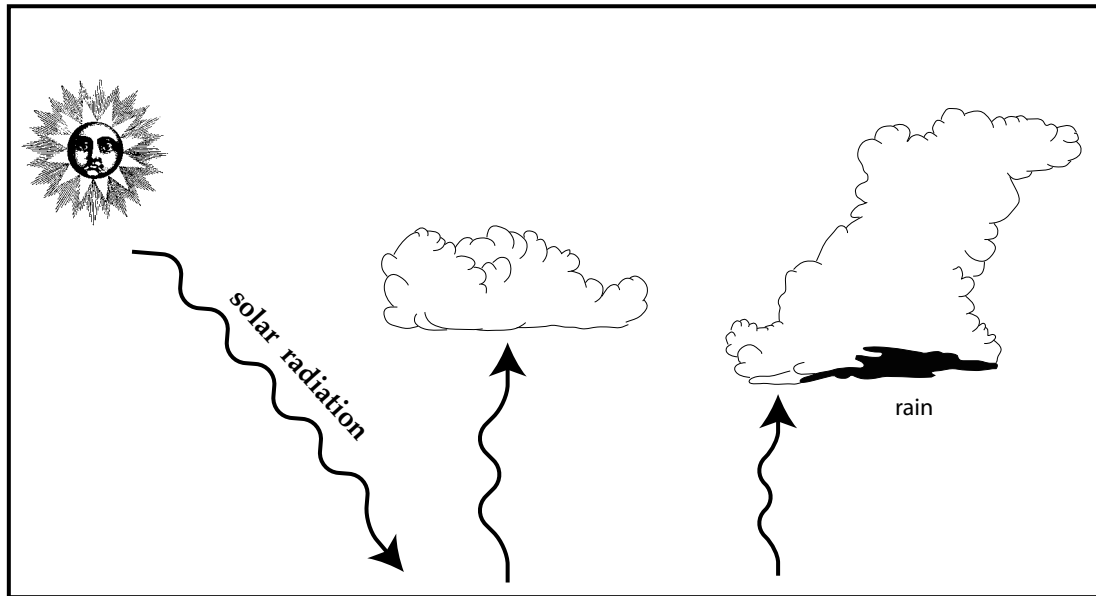


Figure 10. Profile of an initial (center) and mature (right) stage thunderstorm.

## QUESTIONS

36. In northwestern Mexico and the northwest United States there are two areas of thunderstorms that look very different. Indicate where these types of thunderstorms are located below.

Isolated Thunderstorms \_\_\_\_\_

Cold Front Thunderstorms \_\_\_\_\_

37. Which type of thunderstorm will be more likely to be long lasting, the isolated or cold front thunderstorms? Explain your answer.