Earth and Space Science

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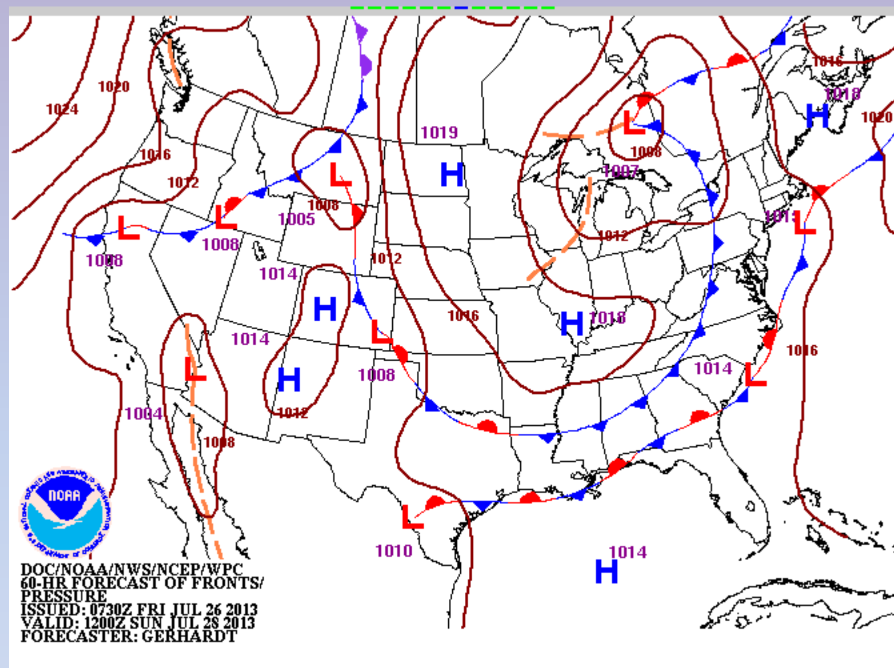
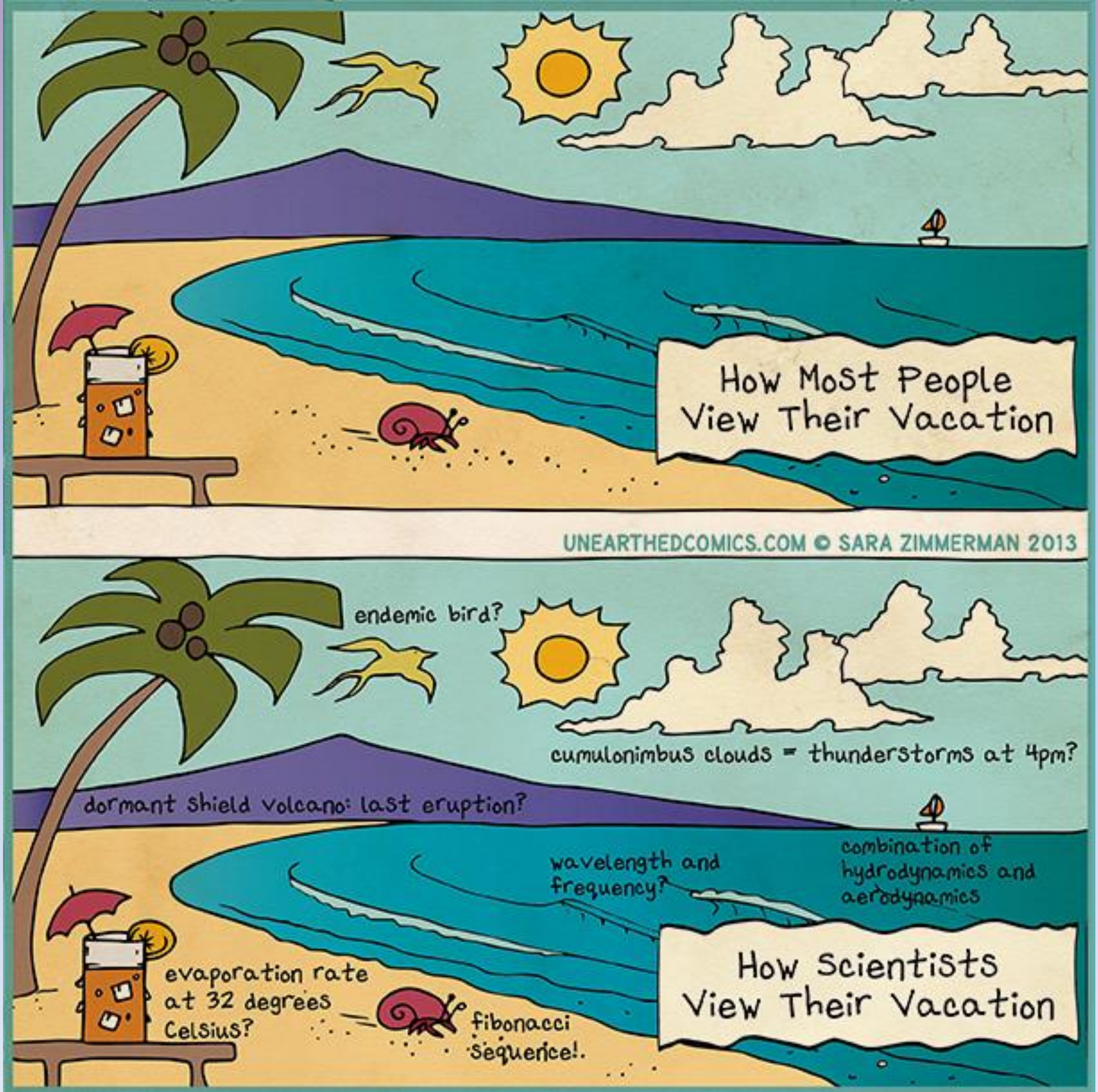
3.3 Earth Structure, Processes and Cycles

Explain how parts are related to other parts in weather systems, solar systems, and earth systems, including how the output from one part can become an input to the other part. Analyze the processes that cause the movement of material in the Earth's systems. Classify Earth's internal and external sources of energy such as radioactive decay, gravity, and solar energy.

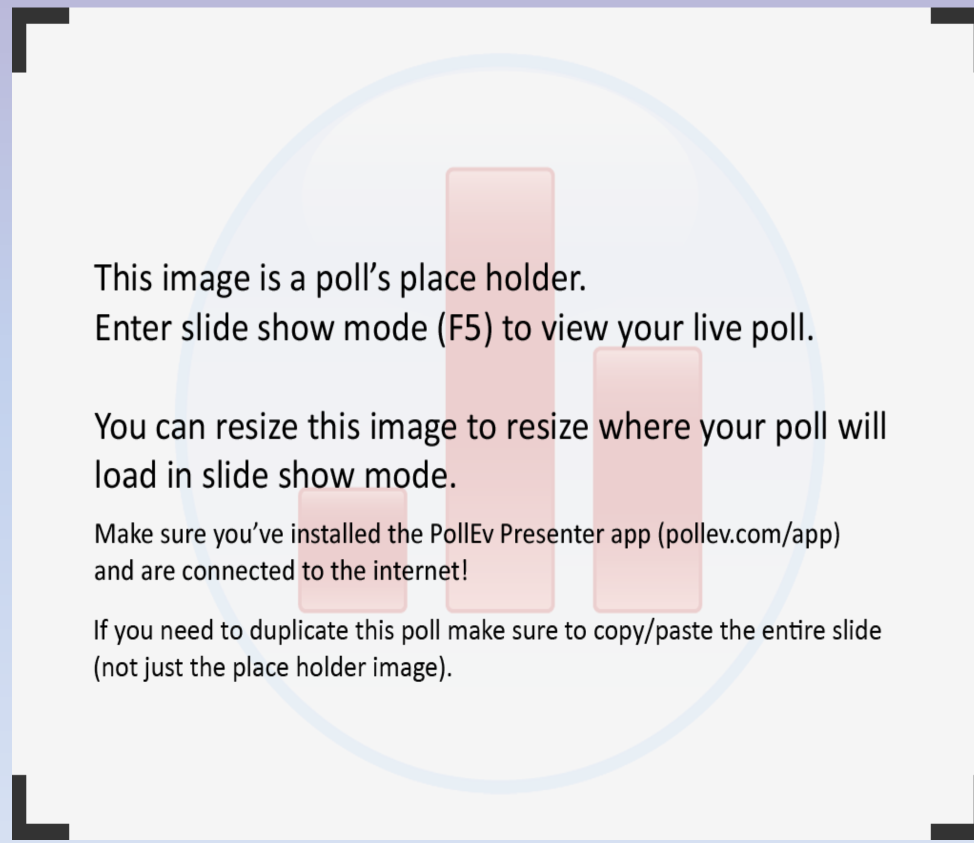
(note: LiveWeb, a free powerpoint download, must be installed to run web pages)

http://www.hpc.ncep.noaa.gov/basicwx/day0-7loop.html

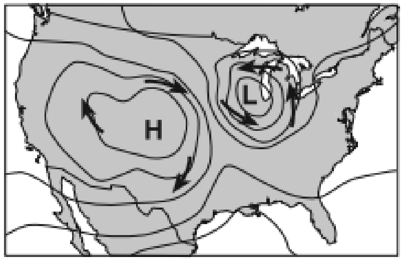



How Most People
View Their Vacation
UNEARTHEDCOMICS.COM © SARA ZIMMERMAN 2013
endemic bird?
cumulonimbus clouds = thunderstorms at 4pm?
dormant shield volcano: last eruption?
wavelength and
frequency?
combination of
hydrodynamics and
aerodynamics
evaporation rate
at 32 degrees
Celsius?
fibonacci
sequence!.
How Scientists
View Their Vacation

Humid air is:
more/less
dense than dry air



43 The arrows on which map best show the pattern of surface winds around these two pressure centers?



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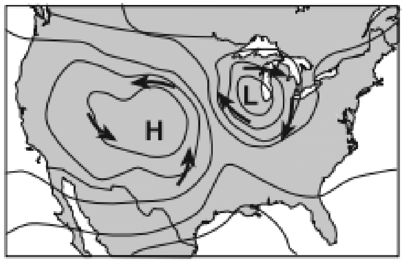

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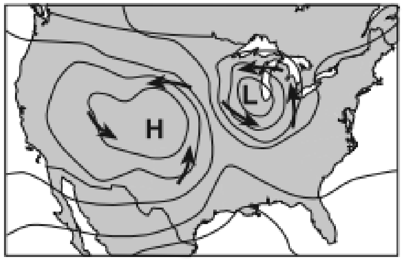

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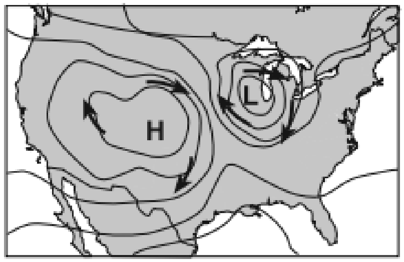

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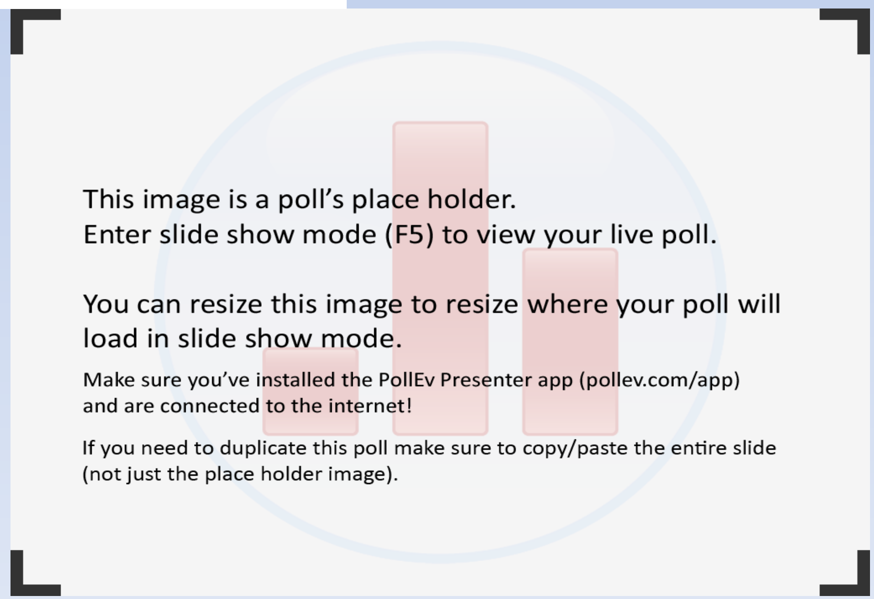

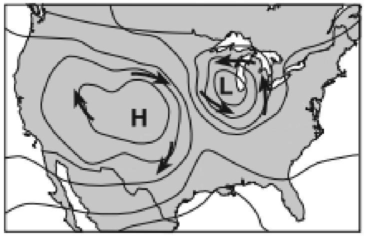

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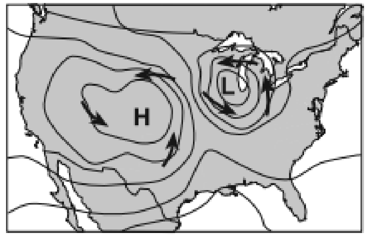

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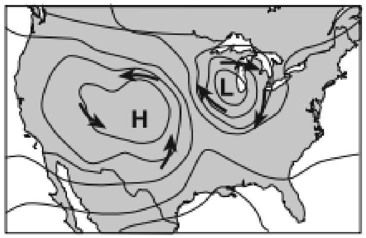

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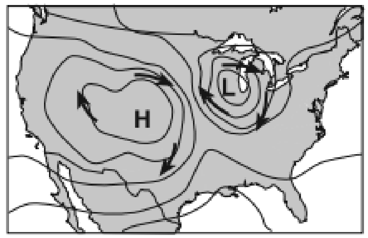
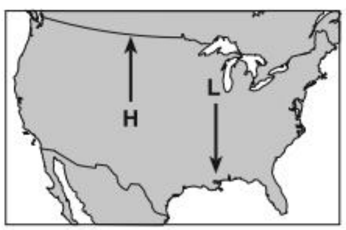


(4)

4 The arrows on which map show the most likely path in which these two pressure centers will move over the next few days?



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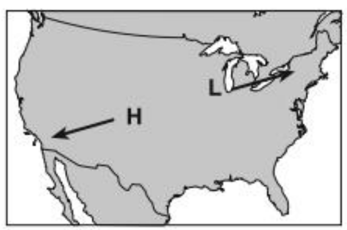

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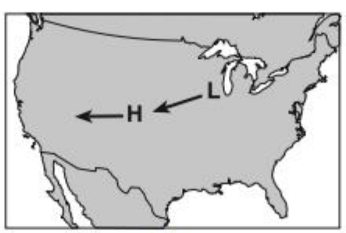

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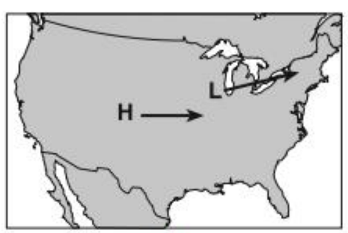

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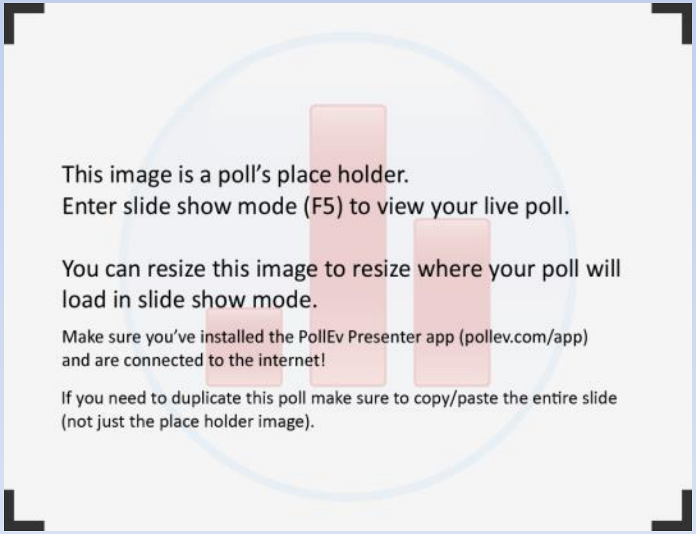
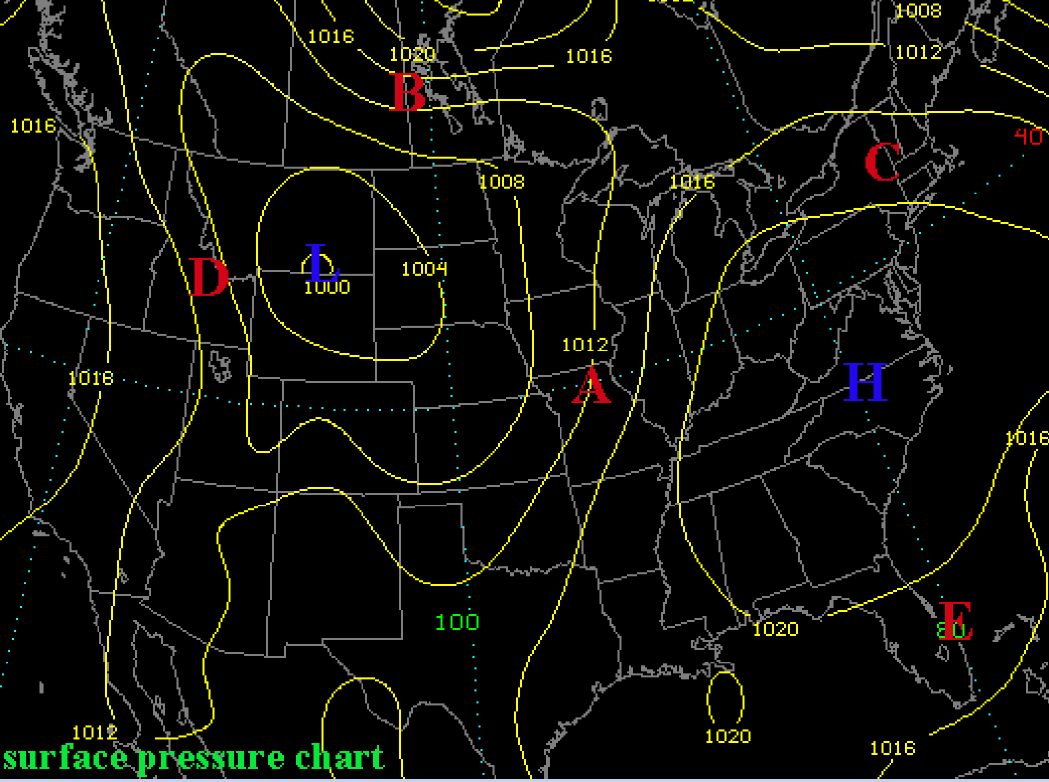
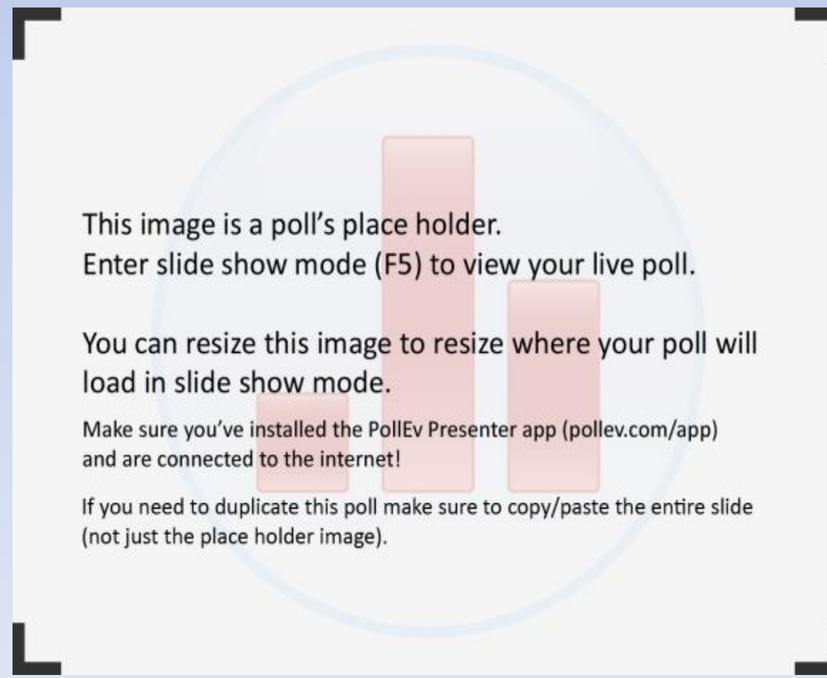




At which red letter would you expect the fastest velocity winds?



Density

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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Floating Bag

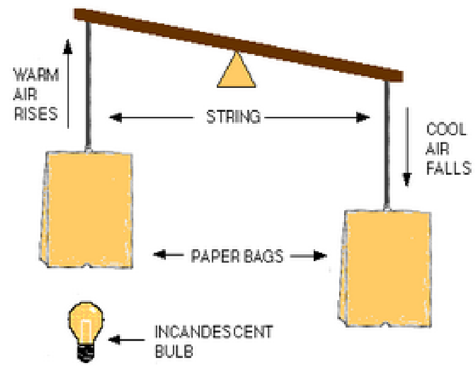
Material List:

1. yardstick
2. block of wood
3. 2 medium sized paper grocery bags
4. needle
5. string
6. scissors
7. Incandescent lamp

Change in air density with change in temperature

Procedure:

Open the grocery bags and poke a hole in the center of each bag's bottom. Cut two strings of equal length and tie a knot at one end of each string. Insert the strings through the holes in the bags and tie the loose end exactly 1" from each end of the yardstick. Set the block of wood on the corner of a desk so the yardstick will move freely without obstructions. Be careful to make sure the yardstick is perfectly balanced. Place the incandescent lamp under one of the grocery bags and turn it on. Watch what happens.



Scientific Principle:

The incandescent bulb will produce heat. The warmer air stream will replace the colder air that is in the bag. As the colder air is replaced with the warmer air, the bag becomes lighter and will rise. This demonstrates that warm air is less dense than cold air, and that cold air of equal volume will weigh less than warm air. Since cold air is heavier than warm air, cold air will fall pushing the warmer air up.

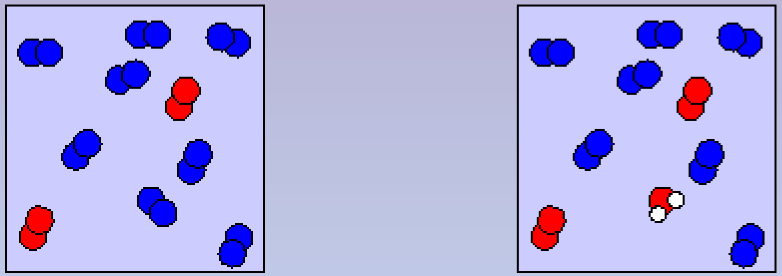
Related Pages:
[Convection Home Page]
[Aeronautics Activities]
[Aerospace Activities Page]
[Air Density]
[Aerodynamics Index]

Calculating density of pepsi and diet pepsi:

http://www.youtube.com/watch?v=Q4EBOE4pJyw

Summers in PA are lovely: humid and hot and sometimes feel like pea soup.
Let's think about the densities of humid vs. dry air.

Consider two containers, each with 10 molecules of gas, at identical T and P.



Density = mass/volume

$\rho = m/v$

The molecular weights of O_2 (in red), N_2 (in blue) and H_2O are about 32, 28, and 18 atomic mass units, respectively. Substituting a water molecule for either an oxygen or a nitrogen molecule, then, will decrease the total mass of air in the container by 10 atomic units.

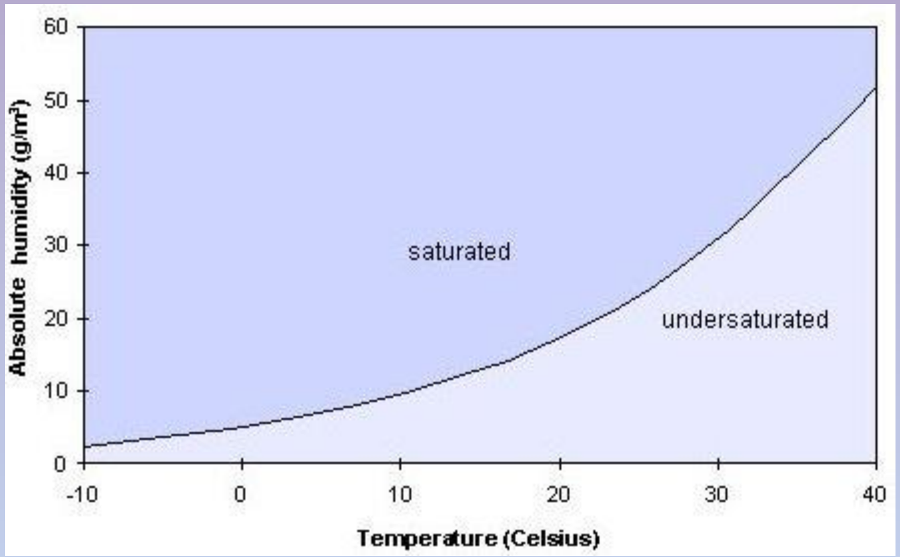
Volume remains constant, so the density of water-containing air must be less than the density of dry air because the mass has decreased.

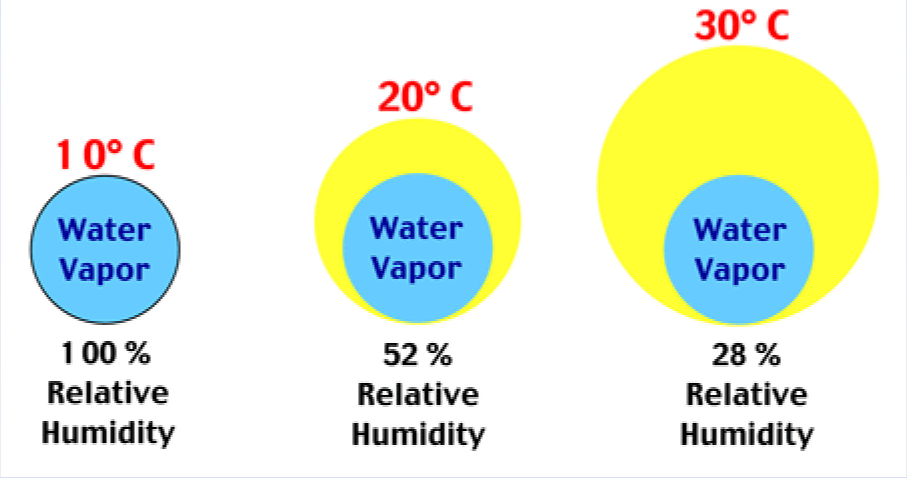
How we 'feel' temperature and humidity isn't always how scientific equipment 'measures' them!

(Same is true of temperature…)

(Amadeo Avogadro discovered in the early 1800s that a fixed volume of gas at the same temperature and pressure would always have the same number of molecules no matter what gas is in the container.)

Humidity:
Absolute and Relative





Relative Humidity = ratio of water content to water content required for saturation (at given T & P)

What does this graph show us about the relationship between humidity and temperature?

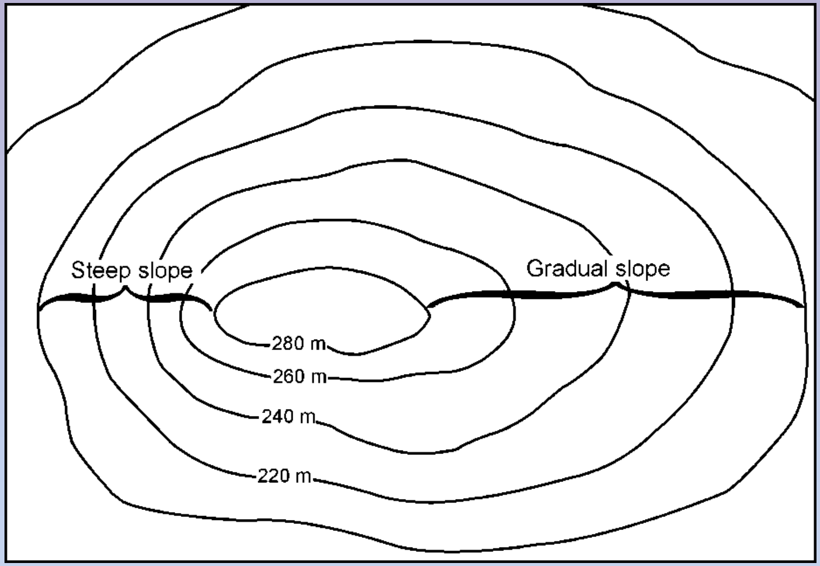
1. At higher T, more water vapor is required for saturation

   (Warm air is able to 'hold' more water vapor than cold air)

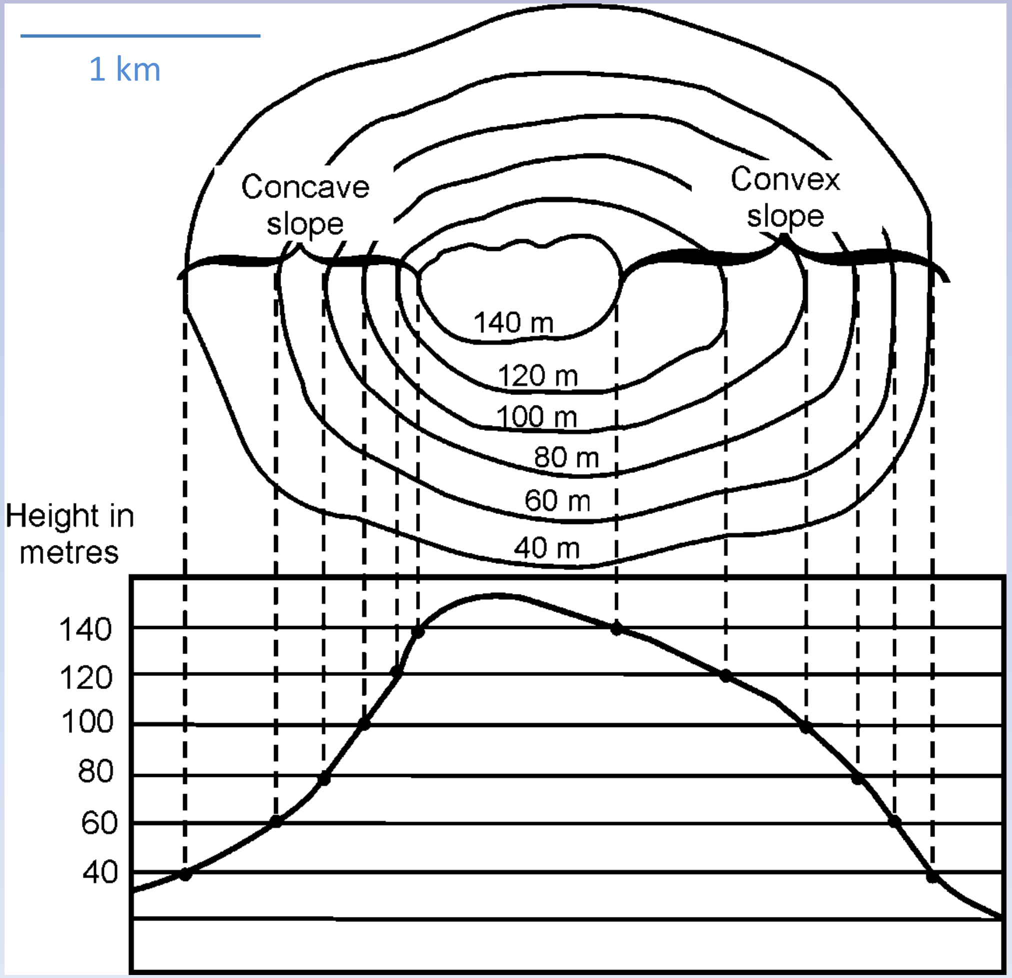
   – temperature and absolute humidity are positively correlated

2. The line = dewpoints

Gradient



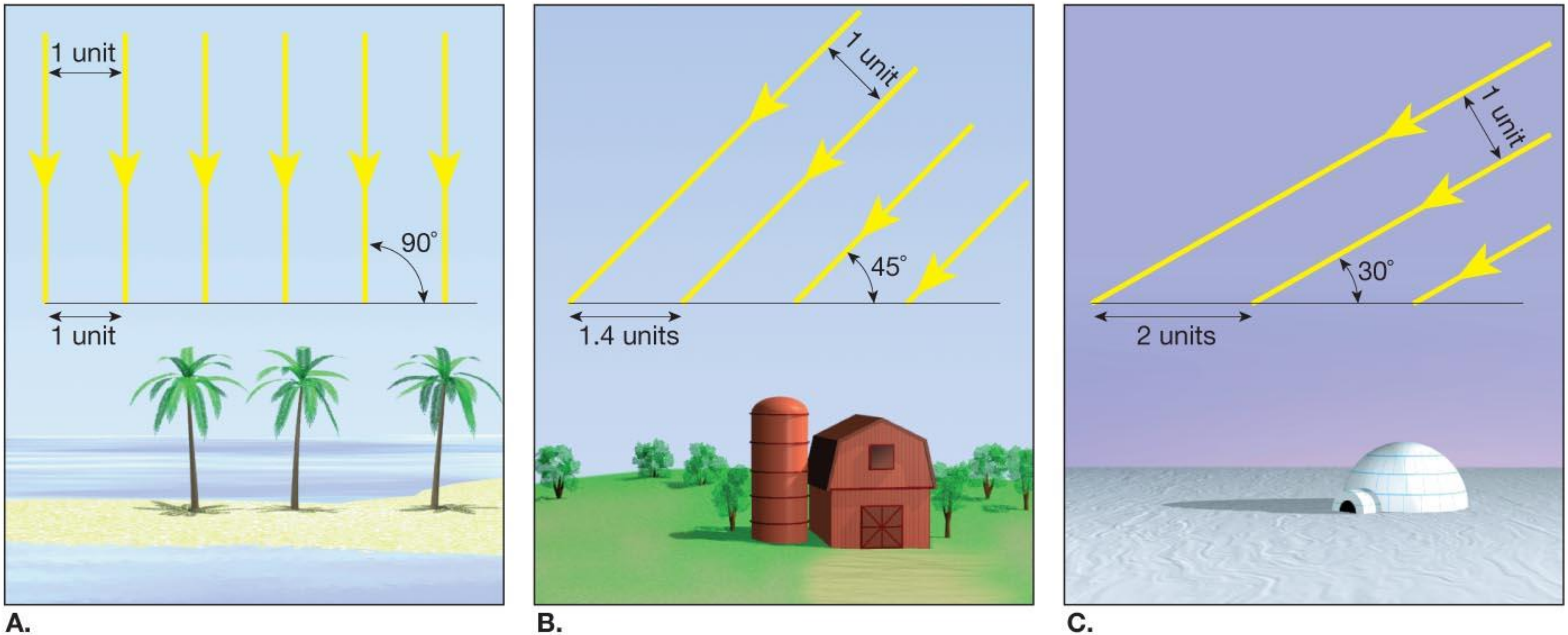
Calculate the slope/gradient



100m/1000m = 0.1
100m/1250m = 0.08

What creates weather?

Variations in the amount of solar radiation due to earth's tilt drive many of our weather patterns



Ideal Gas Law

$$PV = nRT$$

n = number of moles
R = universal gas constant = 8.3145 J/mol K
P = pressure
V = volume
T = temperature

Pressure and volume are inversely proportional to temperature.

This law is demonstrated with soda bottles/balloons/compressed gas tanks…

In meteorology, we typically don't think about a gas in terms of volume, we tend to think about gases in terms of density (mass per unit volume). Using density instead of volume gives us the common form of the **Ideal Gas Law** in atmospheric science:

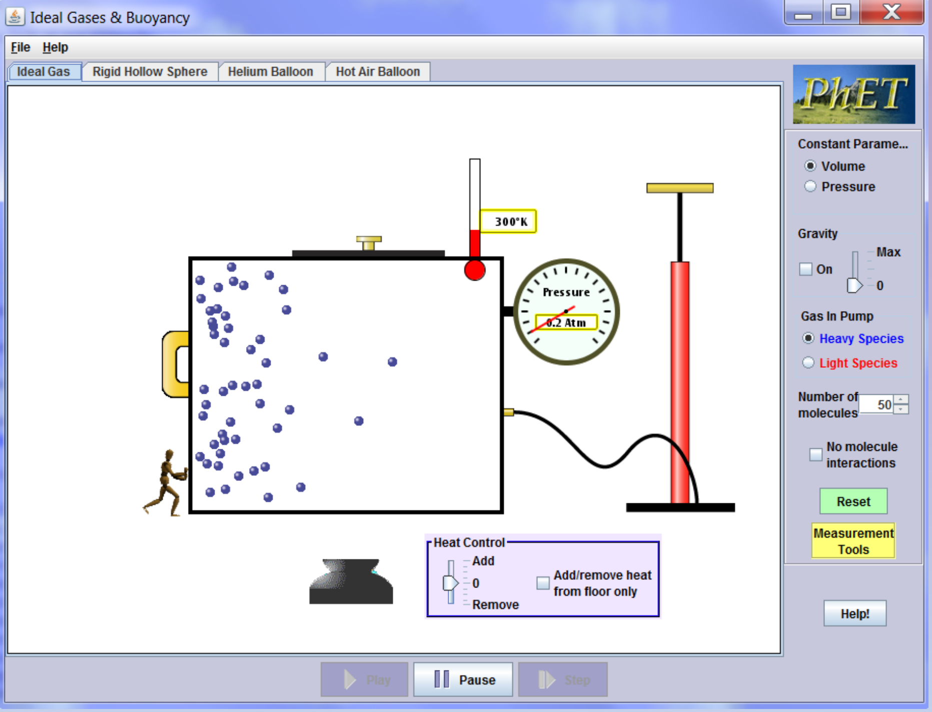
$$P = \rho R T$$

ρ = density
R = universal gas constant = 8.3145 J/mol K
P = pressure
T = temperature

We instinctively 'know' that warm air rises. This is directly related to the change in density with temperature.

We can also change the density of a gas by altering the pressure, while T remains constant (compressed gases).

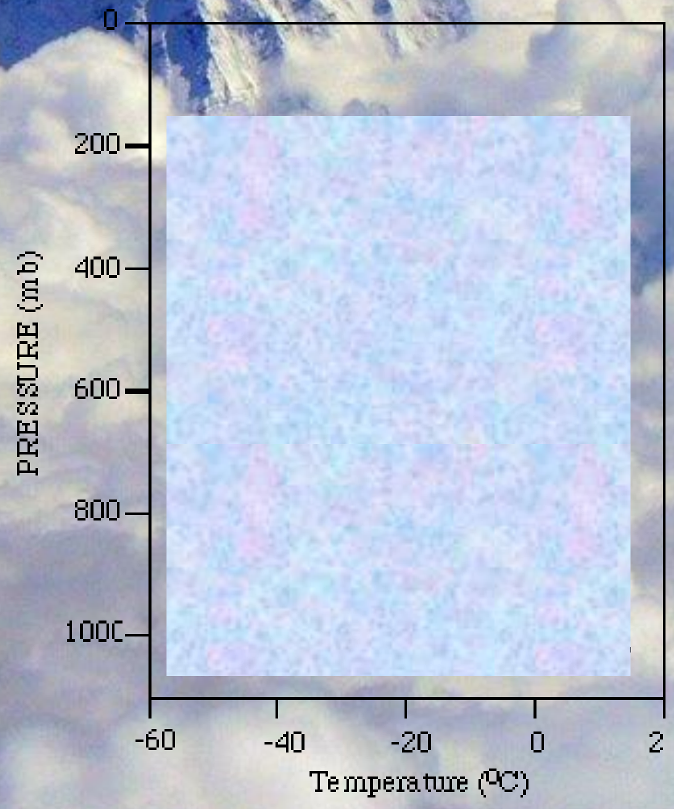
Think about varying temperature in the atmosphere, what accompanying changes happen to density?



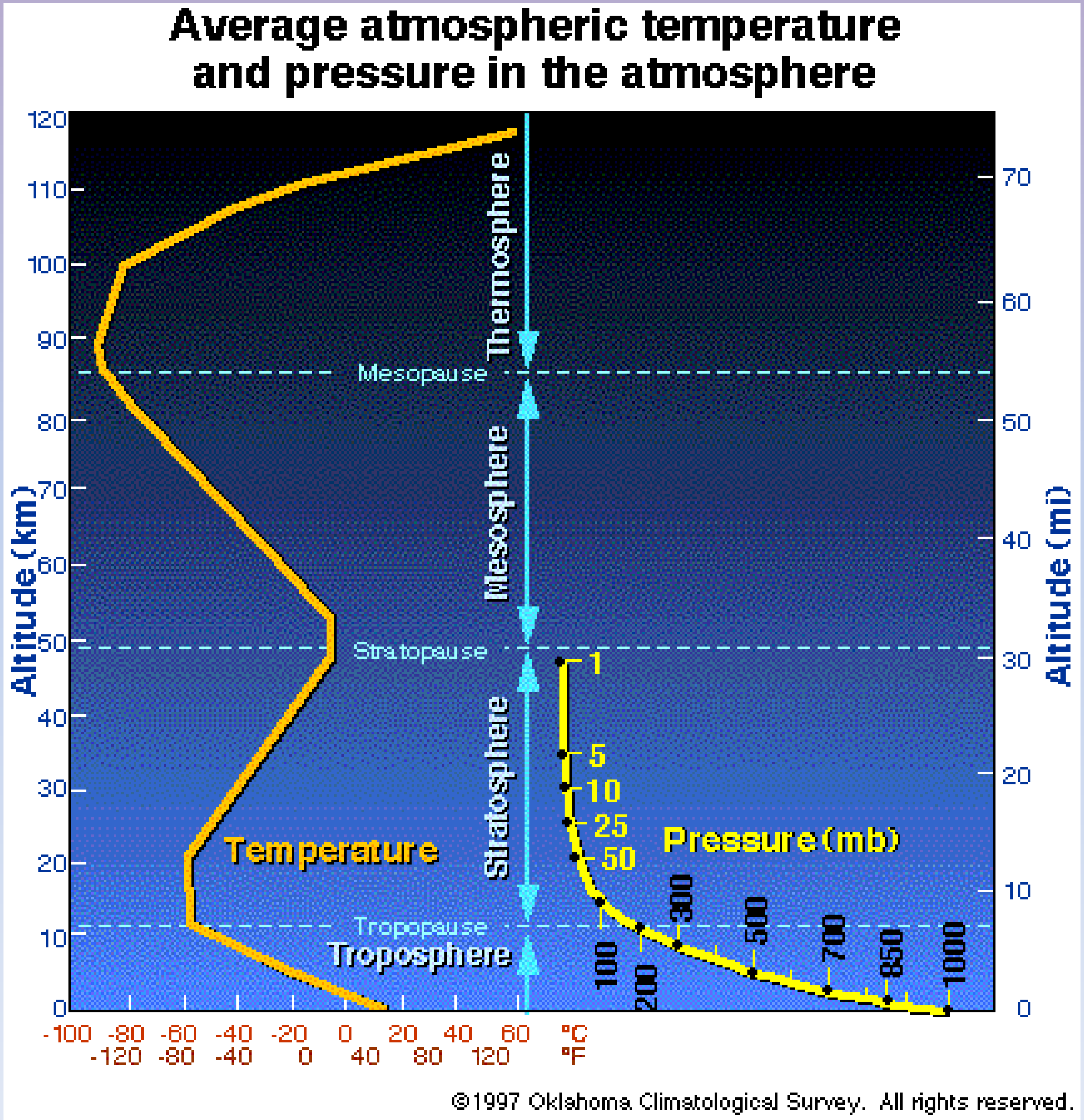
Ideal Gases & Buoyancy
File
Help
Ideal Gas
Rigid Hollow Sphere
Helium Balloon
Hot Air Balloon
PhET
300°K
Pressure
0.2 Atm
Constant Parame...
Volume
Pressure
Gravity
On
Max
0
Gas In Pump
Heavy Species
Light Species
Number of molecules
50
No molecule interactions
Reset
Measurement Tools
Heat Control
Add
0
Remove
Add/remove heat from floor only
Help!
Play
Pause
Step

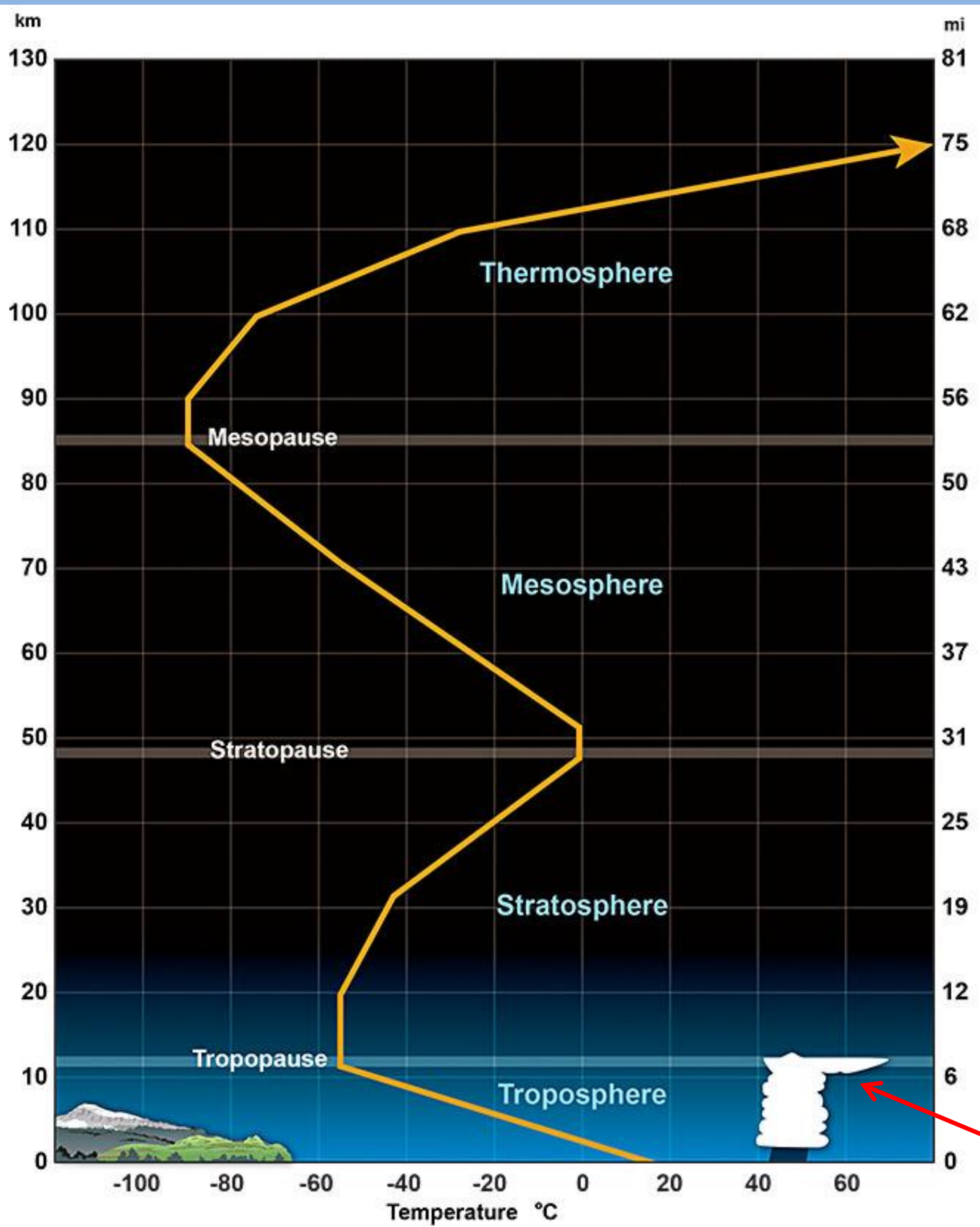
Think about climbers of Mt. Everest…what variations in T and P must they contend with?

What would you expect the relationship between temperature and pressure to look like in the troposphere (the lowest part of the atmosphere)?



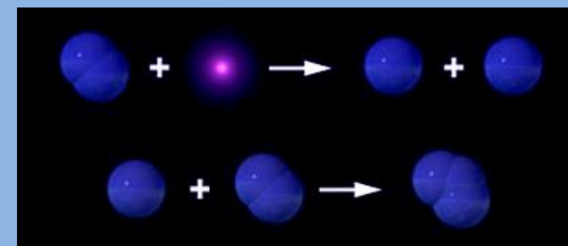
The Upper Atmosphere





STRATOSPHERE:

In this region the temperature increases with height. Heat is produced in the process of the formation of ozone and this heat is responsible for temperature increase with altitude.



If you're wondering why these processes "absorb" UV light, it is because they create **exothermic** reactions. Essentially, oxygen and ozone convert UV light to heat.

Increase in temperature with height means warmer air is located above cooler air. This prevents "convection" as there is no upward vertical movement of the gases. As such the location of the bottom of this layer is readily seen by the 'anvil-shaped' tops of cumulonimbus clouds.

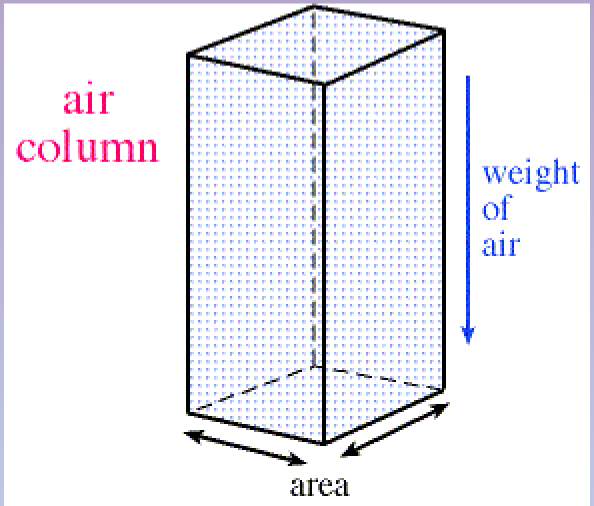
The ***atmospheric pressure*** can be thought of as the weight of the air above you pushing down on some area

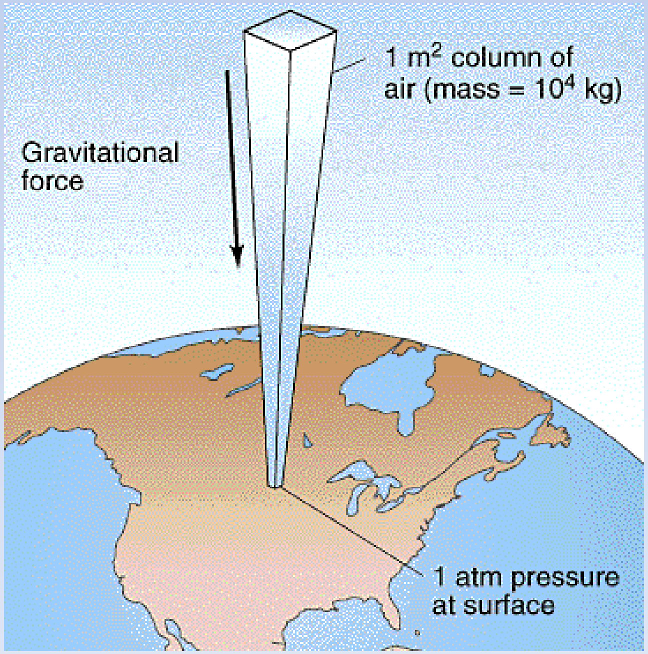
Weight of the air at sea level

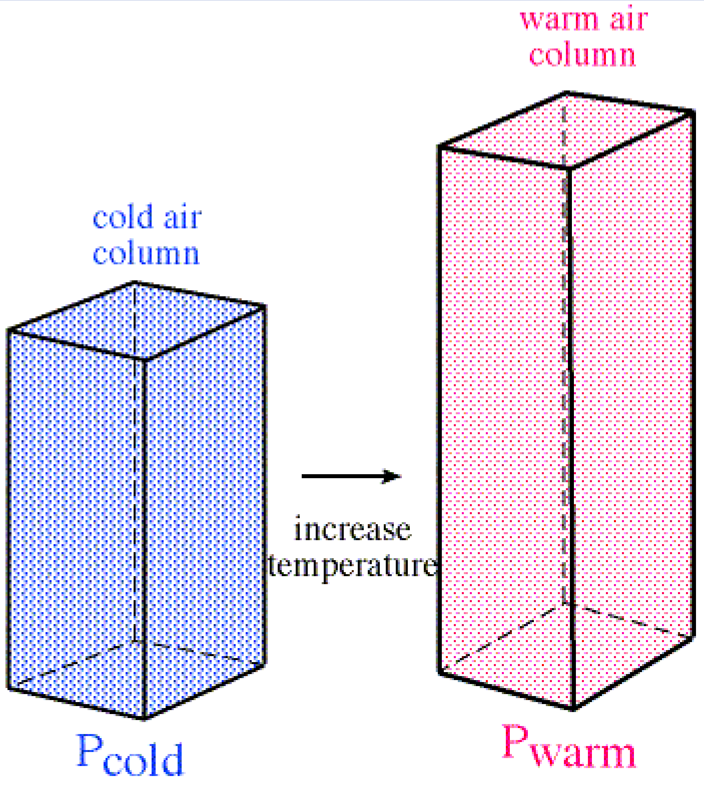
14.7 pounds per square inch

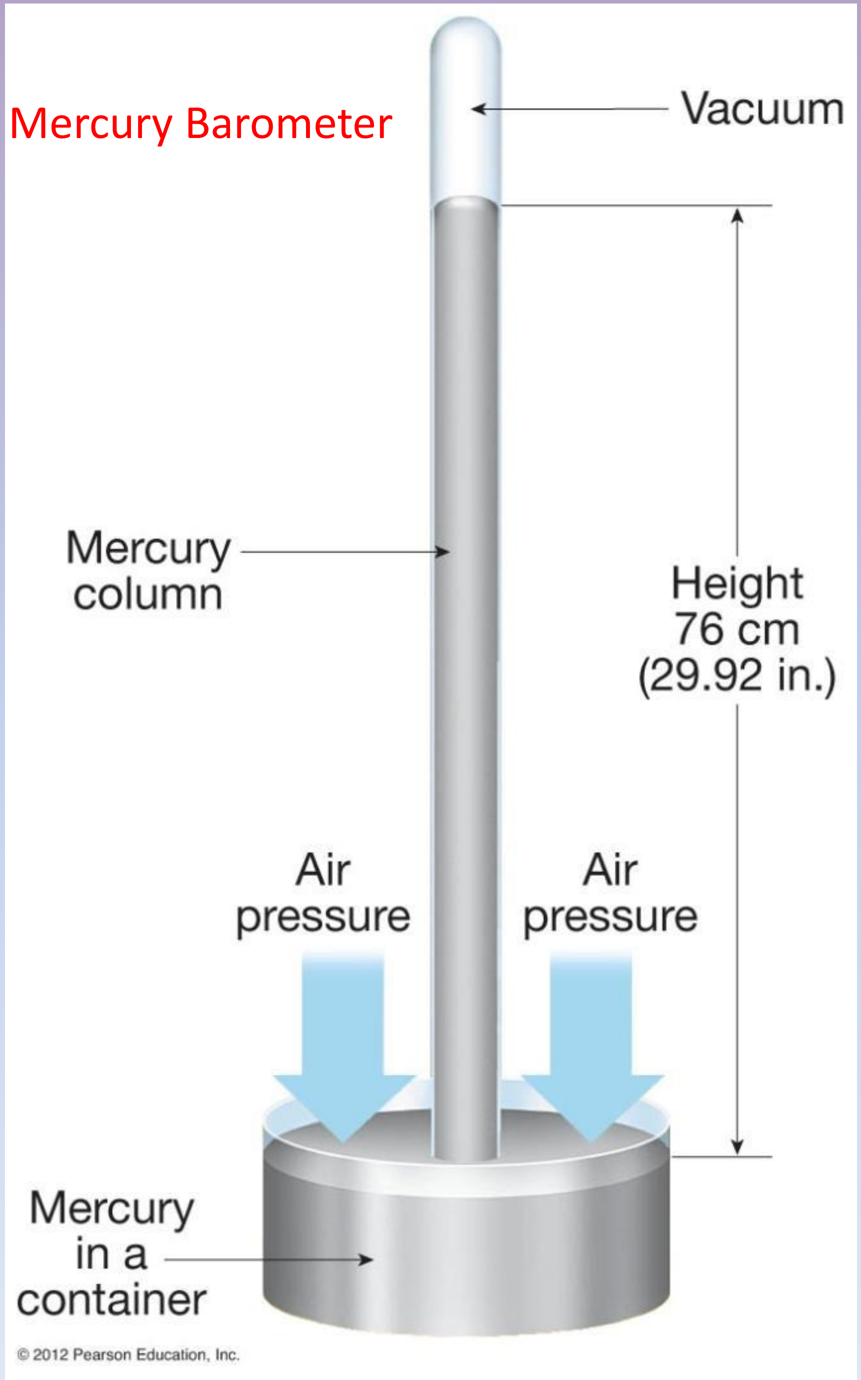
1 kilogram per square centimeter

1013.2 millibar

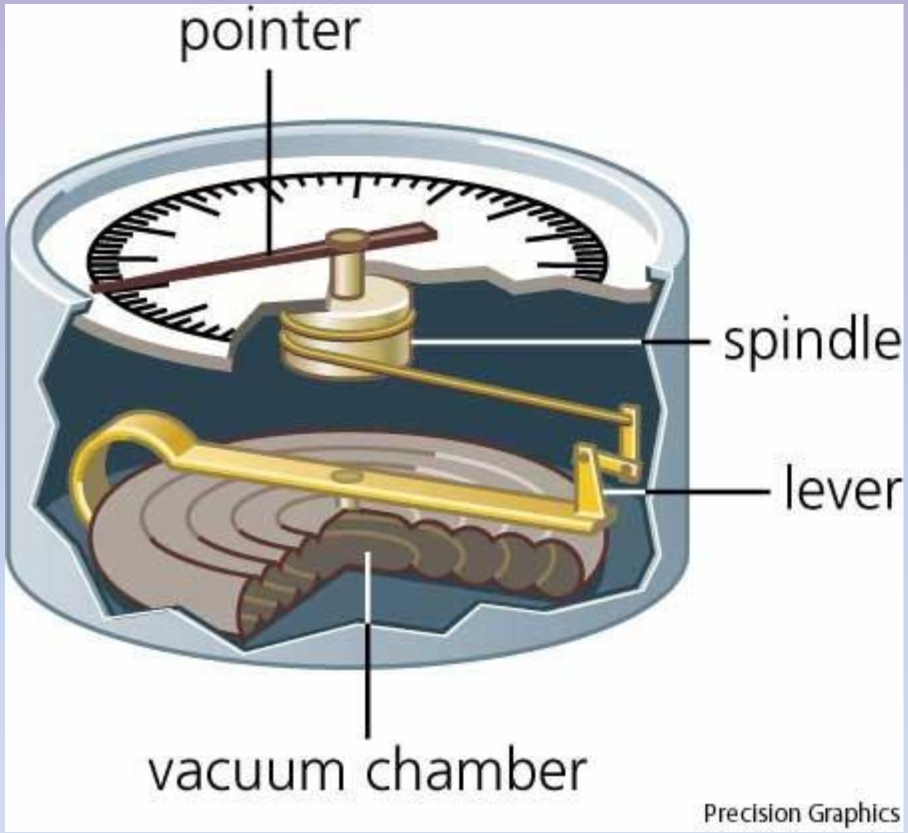








Aneroid Barometer



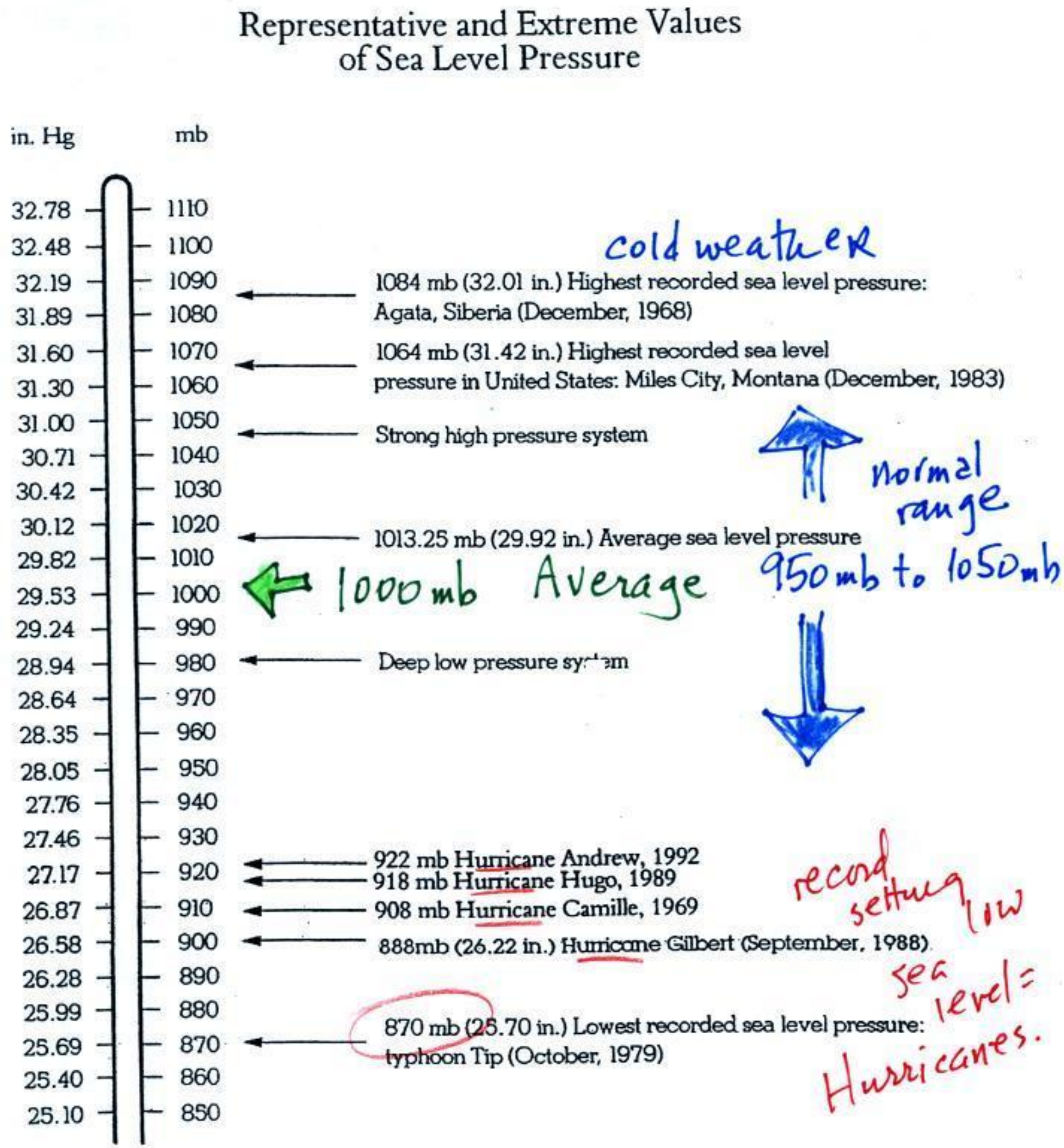
AT SEA LEVEL:
1013.25 mb = 29.92 inches of Hg

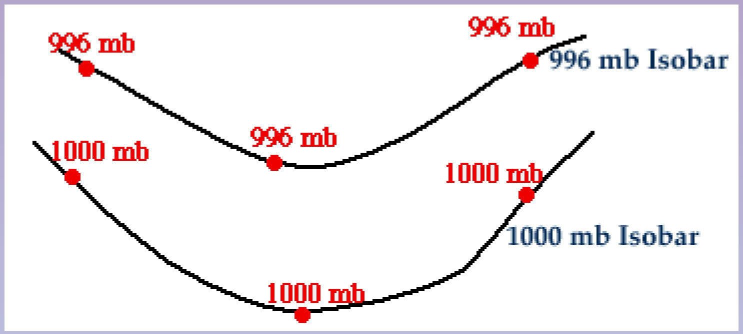
Let’s check current barometric pressure:

http://w1.weather.gov/obhistory/KPHL.html

http://www.localweather.com/weather/maps/currents/pressure/us.html

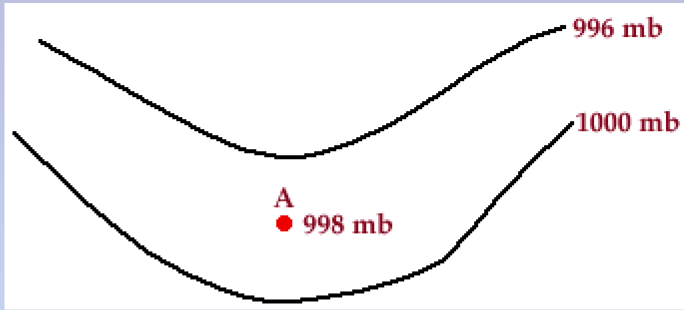
What are some of the highest and lowest atmospheric pressures ever recorded?

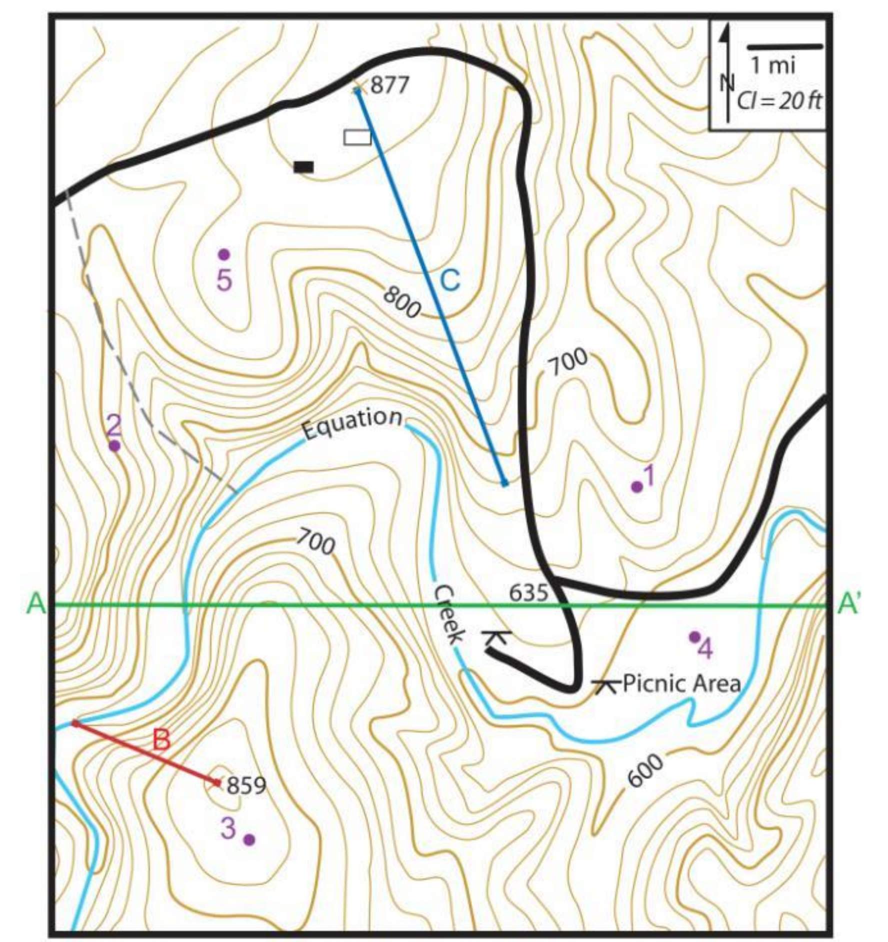




Contouring pressure gradients is identical to contouring land elevations

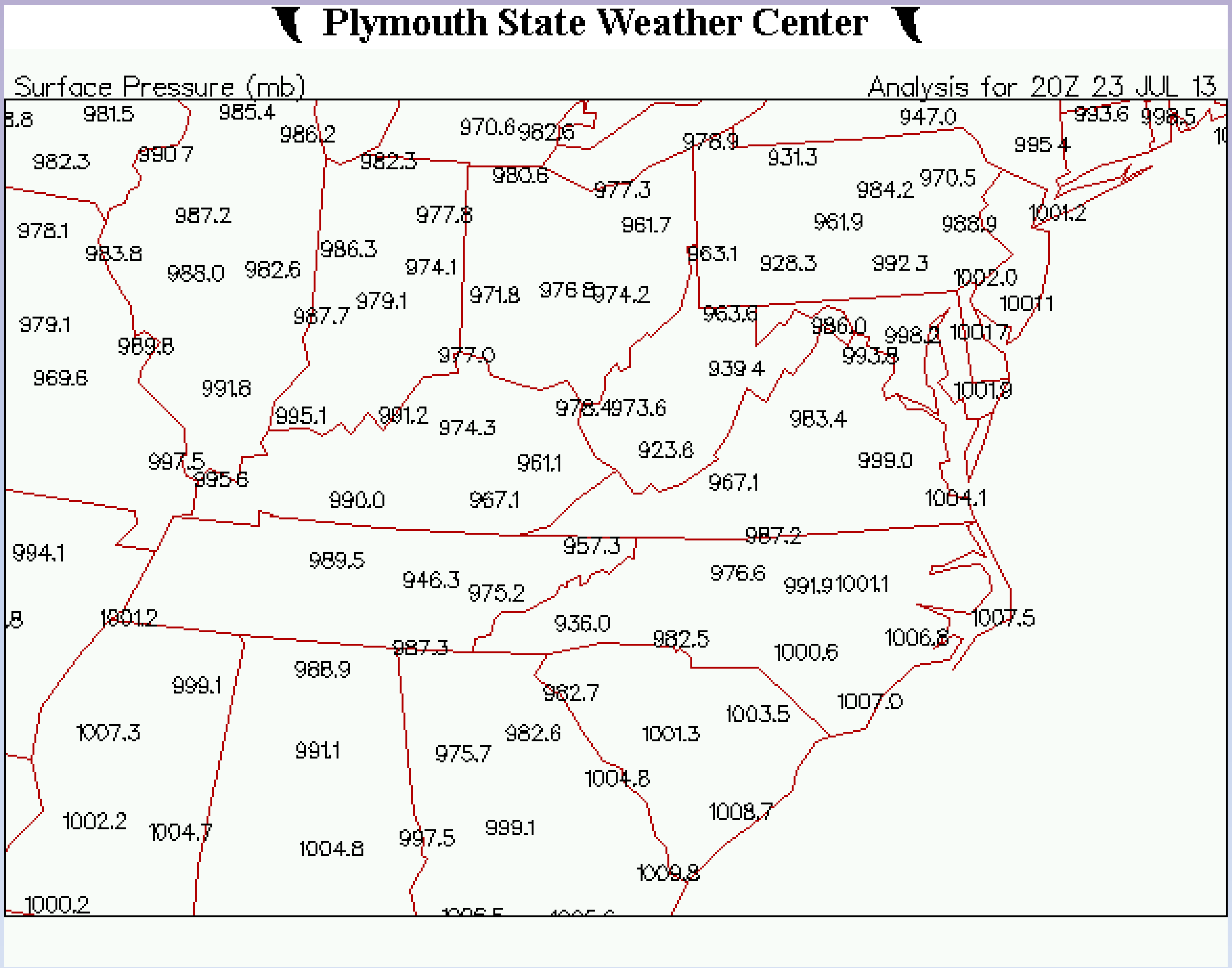
Each isobar represents a line of equal pressure.





Topographic Map of Math State Park

Pressures are recorded and then isobars representing lines of equal pressure can be drawn:



(intervals of 10 in this example)

Wind

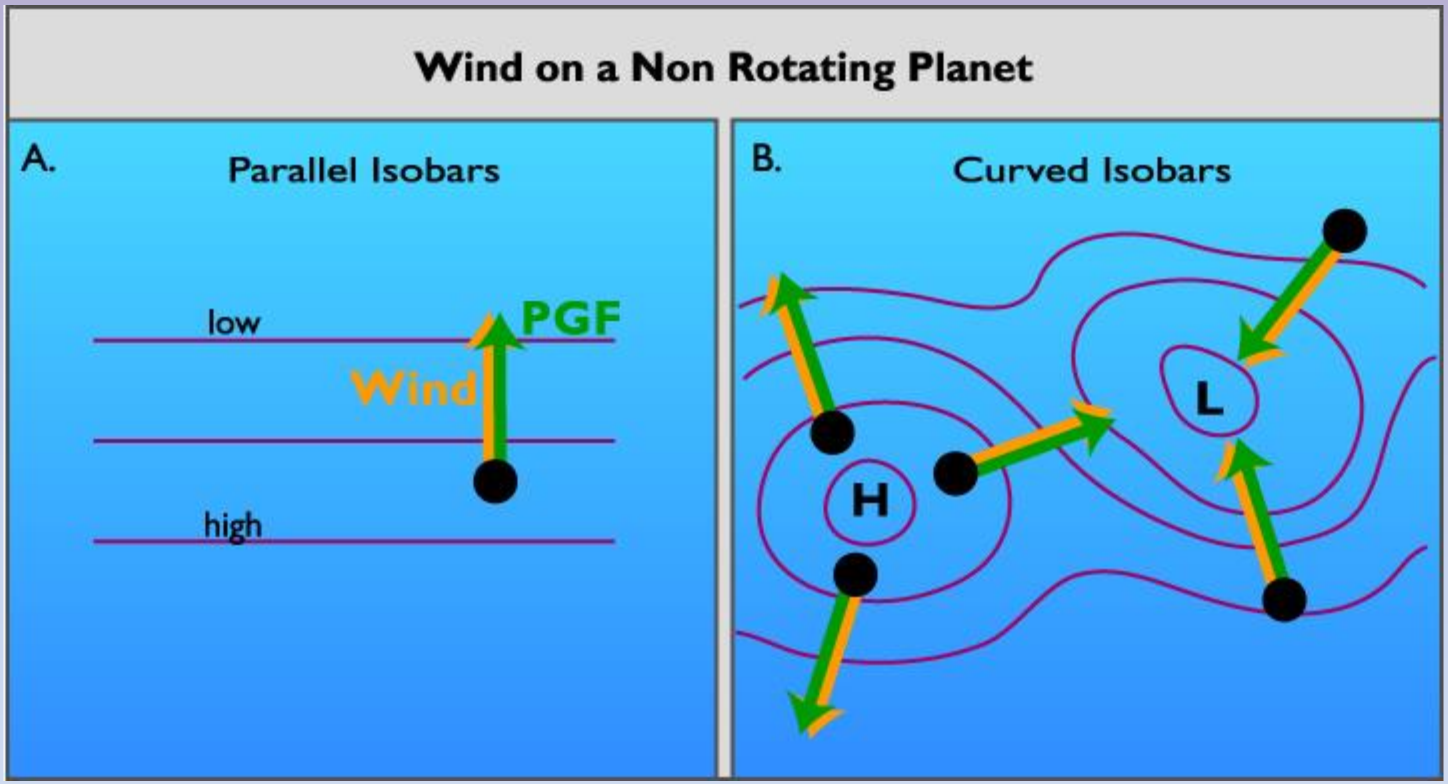
- Horizontal movement of air
  - Out of areas of high pressure
  - Into areas of low pressure

What is the ultimate driving force for winds?

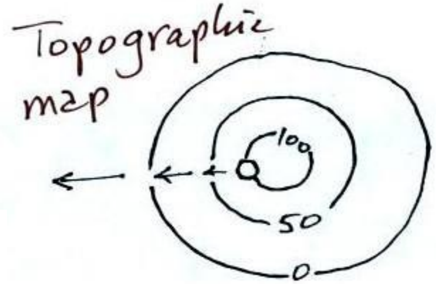
Wind

Controls on wind:

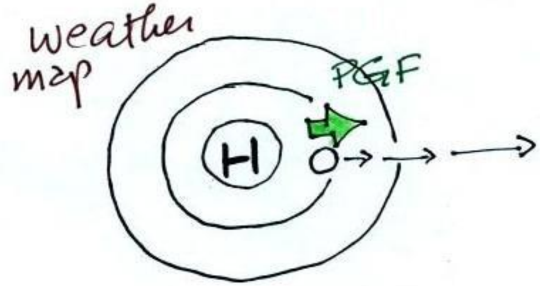
- Pressure gradient force (PGF)
  - Isobars – lines of equal air pressure
  - Pressure gradient – pressure change over distance
- Coriolis force (CF)
  - Apparent deflection in the wind direction due to Earth’s rotation
  - Deflection is to the right in the Northern Hemisphere and to the left in the Southern Hemisphere
- Friction (F)
  - Only important near the surface
  - Acts to slow the air’s movement



(no Coriolis force acting)

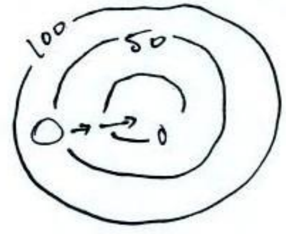


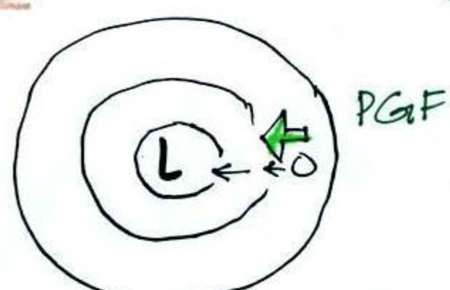
PGF is a little like a rock on a hill. A rock will always roll downhill (from H altitude toward L altitude)



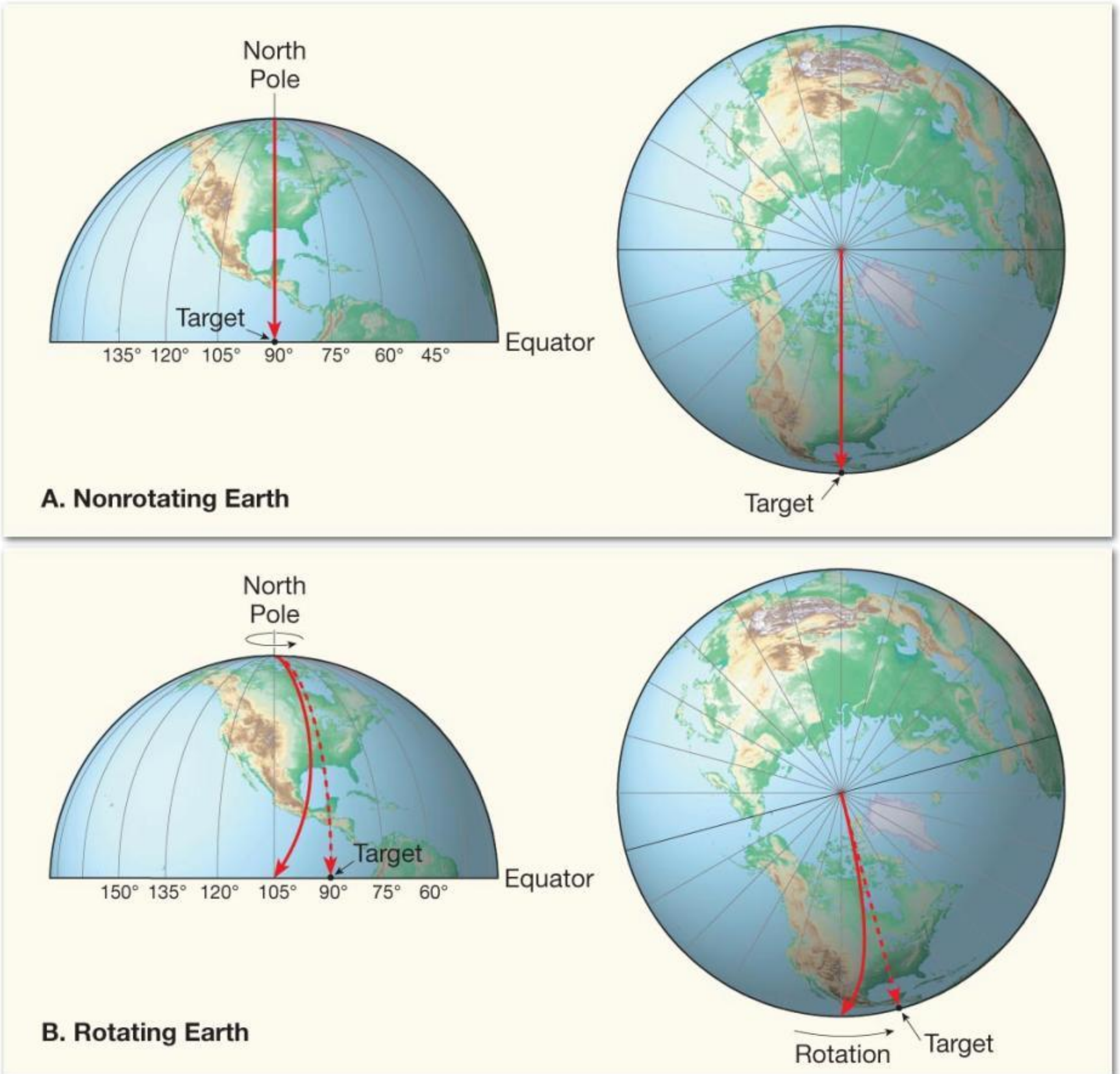
☆ (1) PGF can start stationary air moving

(2) PGF is perpendicular to the contours, always points toward Low.





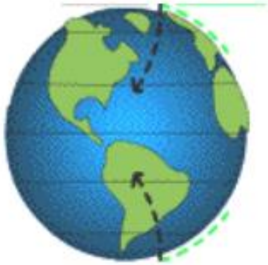
The Coriolis effect



Veers trajectories to the right

(Northern Hemisphere)

Coriolis Demonstration



Students should work in pairs or small groups and take turns so each student has a chance to try this activity.

Materials

- stiff paper such as a manila folder, cut into circles about 8 " (about 20 cm) in diameter
- corrugated cardboard cut into squares about 10" (about 25 cm) on a side
- push pin or thumb tack
- ruler
- pencil

Procedure

1. Push the pin through the center of the paper circle and pin the circle in the center of the cardboard so that it can rotate freely.
2. Place the ruler so that it crosses the center of the circle.
3. Have one student practice smoothly turning the circle counter-clockwise while holding the ruler in place. The rotation represents the spinning of the earth from the point of view of looking down from the north pole (counter-clockwise rotation) or looking up from the south pole (clockwise rotation). The ruler will allow the second student to draw a straight line while the earth is turning.
4. To model the effect of Coriolis in the northern hemisphere, have the second student draw a straight line at a constant rate along the ruler from the center of the circle to the edge (from the pole to the equator) while the circle is being turned counter-clockwise.
5. Repeat the action, this time drawing a straight line from the edge of the circle to the center (from the equator toward the pole) while the circle is being turned counter-clockwise.

You should notice a definite curve to the line, despite the fact that the drawing was linear. Repeat the demonstration by rotating the opposite direction to model Coriolis in the southern hemisphere; you should be able to draw some conclusions about the direction of apparent deflection in the northern hemisphere versus the southern hemisphere.

Questions: What happened to the line as you rotated the cardboard?

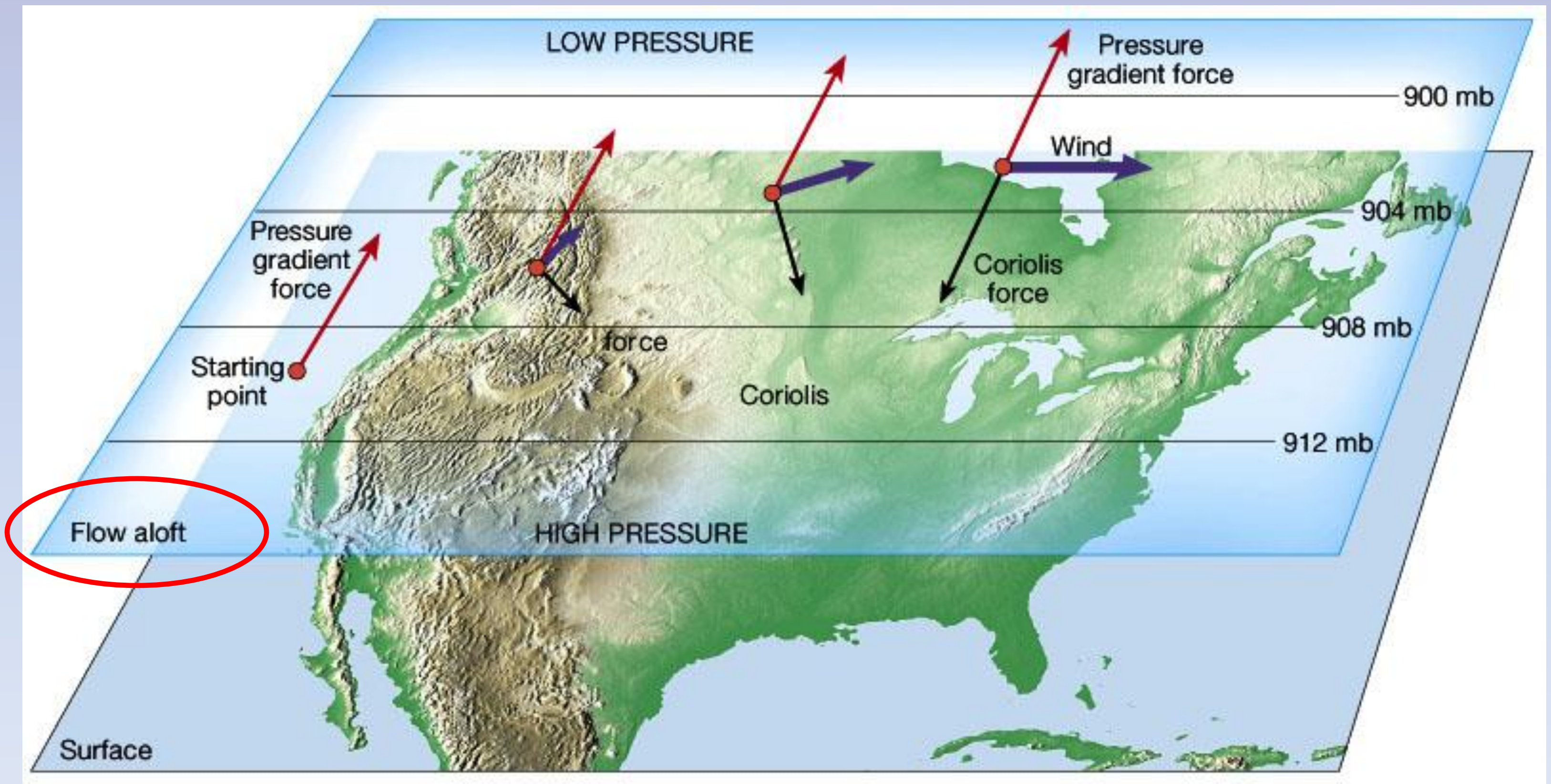
What happens to the line as you get further toward the edge?

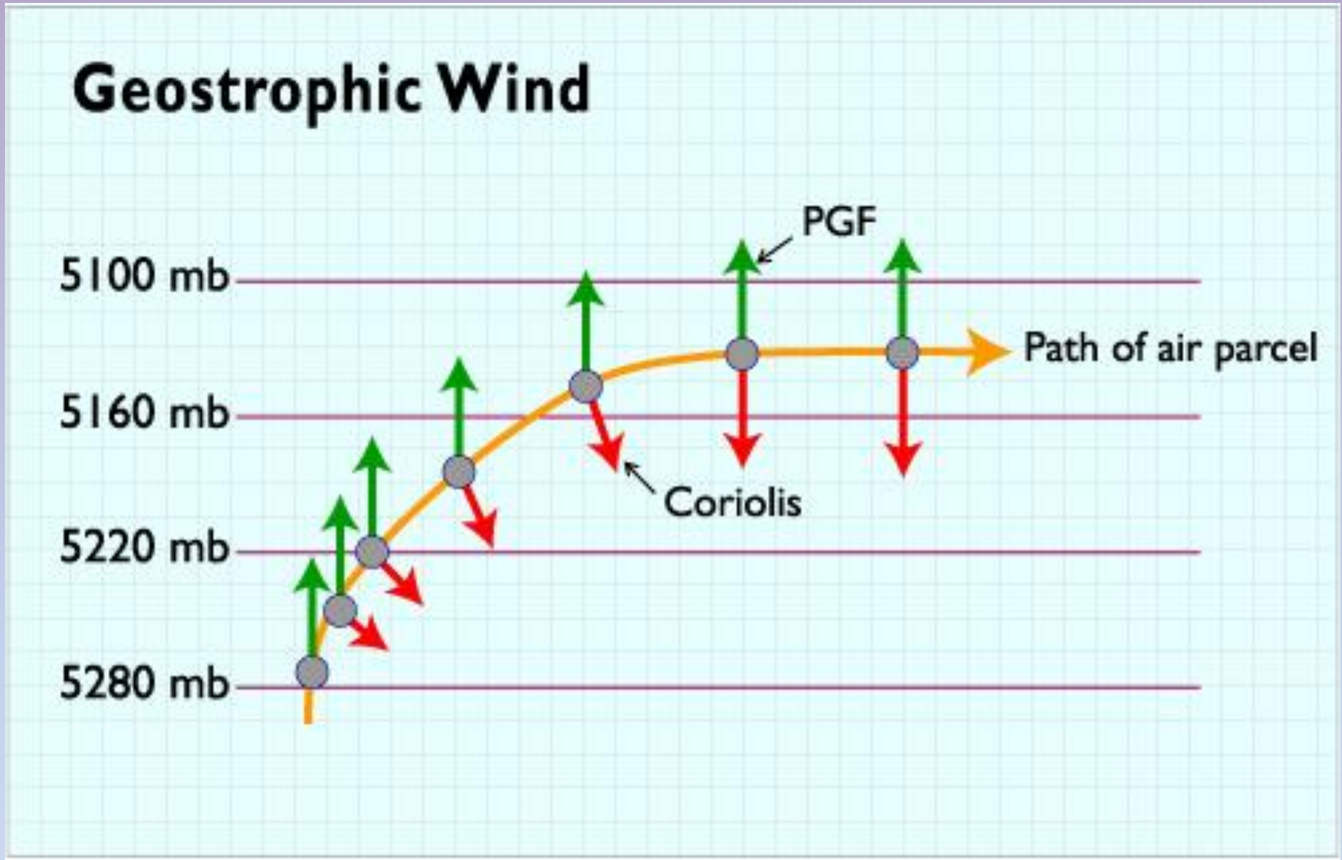
What happens if you spin it fast or slow?

Look at a satellite image, observe the pattern of clouds or storm systems, and describe how Coriolis might help explain their motion.

You can do the same demonstration as above with an inflatable globe and a washable marker, or a solid globe and a piece of chalk. This is a more realistic way to demonstrate the Coriolis effect.

Friction is most important near the ground and less important higher in the atmosphere. If we consider winds aloft, an important wind is the **geostrophic wind**. The geostrophic wind is a wind that parallels the isobars. At first this may seems incorrect, but let's think about it for a moment. If the PGF forces winds from high to low pressure and the CF deflects the winds, there may come a time when the winds are deflected 90° from their initial direction. If the PGF exactly balances the CF, the the geostrophic winds will flow parallel to the isobars.



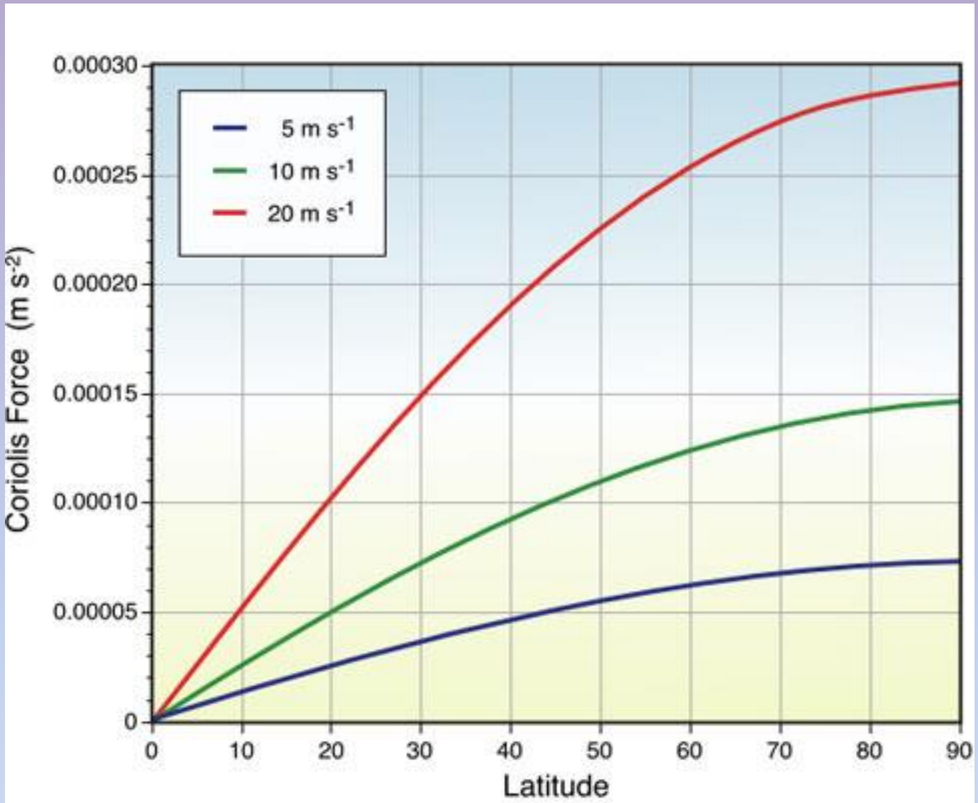


The Coriolis effect increases in magnitude until it balances the pressure gradient force – resulting in wind moving parallel to the isobars

Which force is not accounted for here? Friction!

Geostrophic winds are upper-level winds and are not affected by friction.

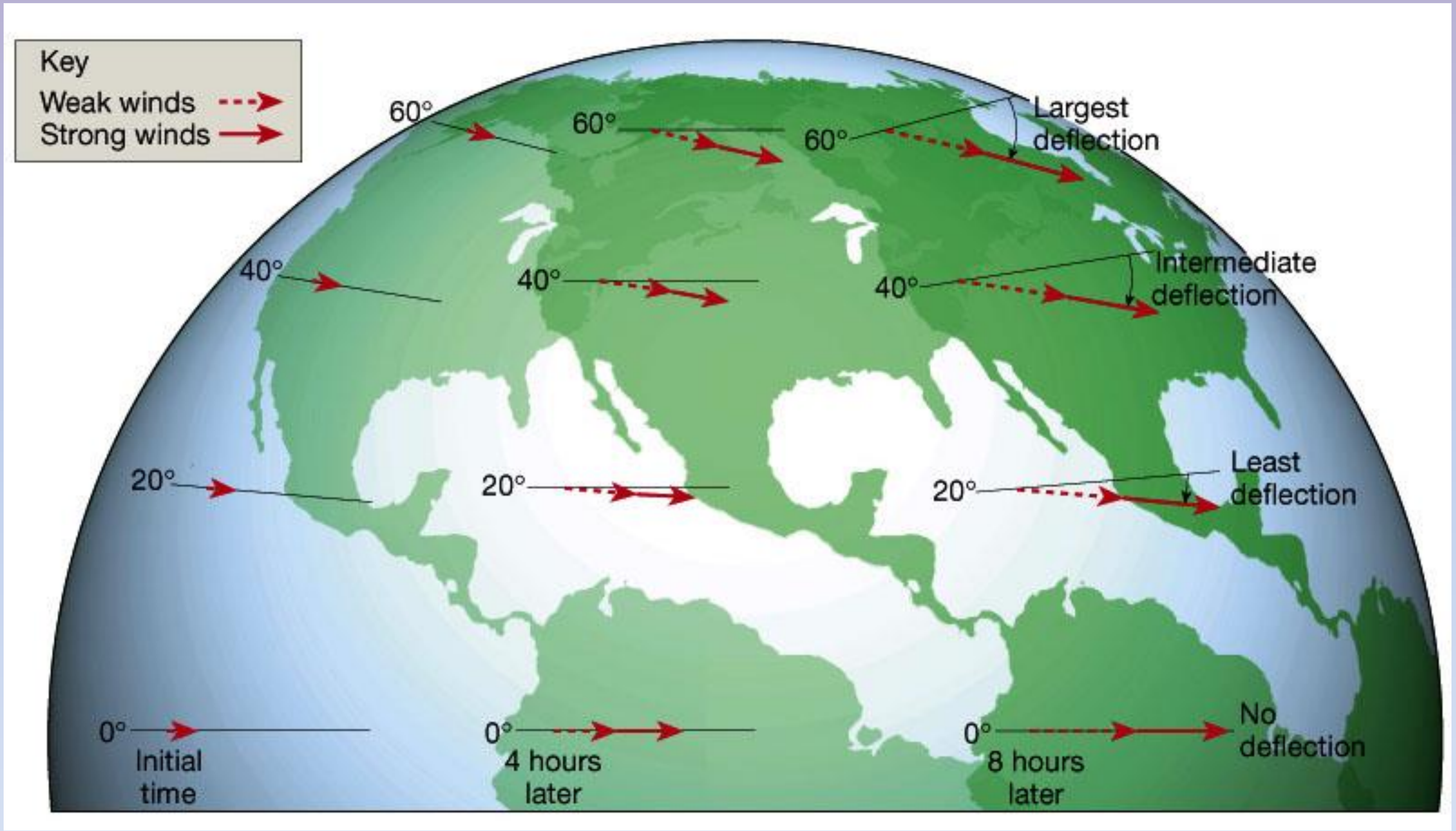
Summarize the relationship between Coriolis and latitude/wind speed

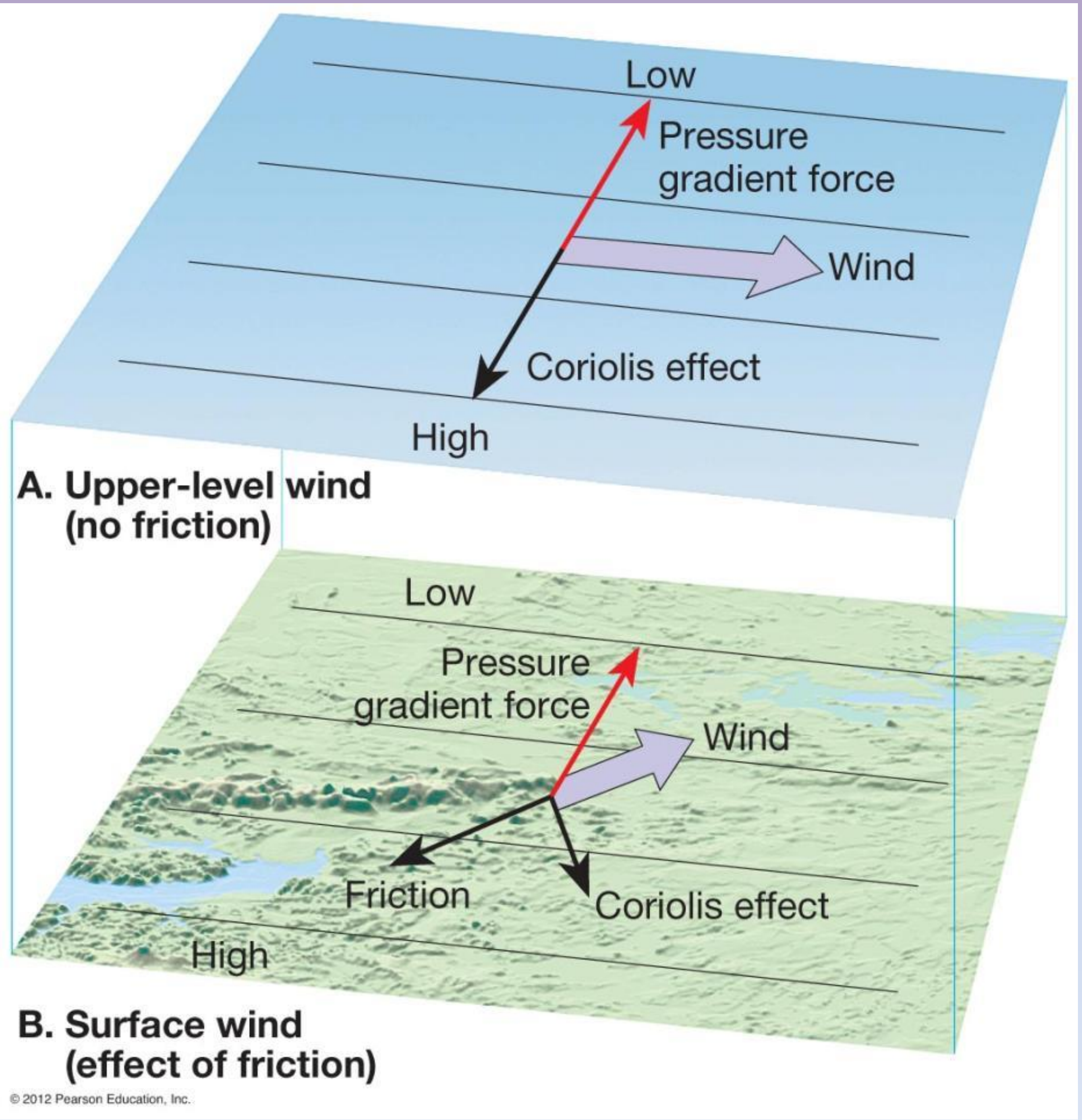


1. As latitude increases, so does the Coriolis effect. The Coriolis affect is zero at the equator and is maximal at the poles this has to do with angular momentum.
   - Angular momentum acts perpendicular to the axis of rotation. The plane is tangent at the equator, therefore the Coriolis effect is zero.

2. The greater the wind speed, the greater the Coriolis effect.

Coriolis effect stronger at higher latitudes



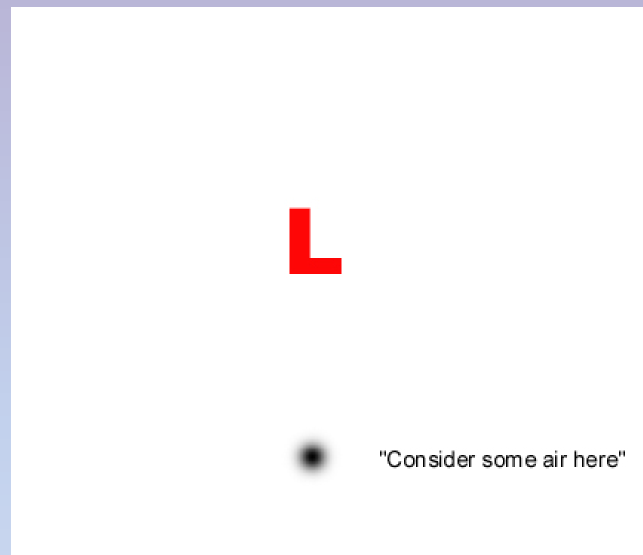


PGF and CF are balanced in upper level winds – the geostrophic balance

Friction acts to weaken the CF. CF no longer balances PGF in surface winds – the wind blows at an angle across isobars

Notice how the PGF vector always heads perpendicular to the isobars?

Consider 4 little parcels of air in a high pressure system


L
"Consider some air here"

Quick review for the Northern Hemisphere:

Around a HIGH pressure center, winds move

a. clockwise
b. counterclockwise

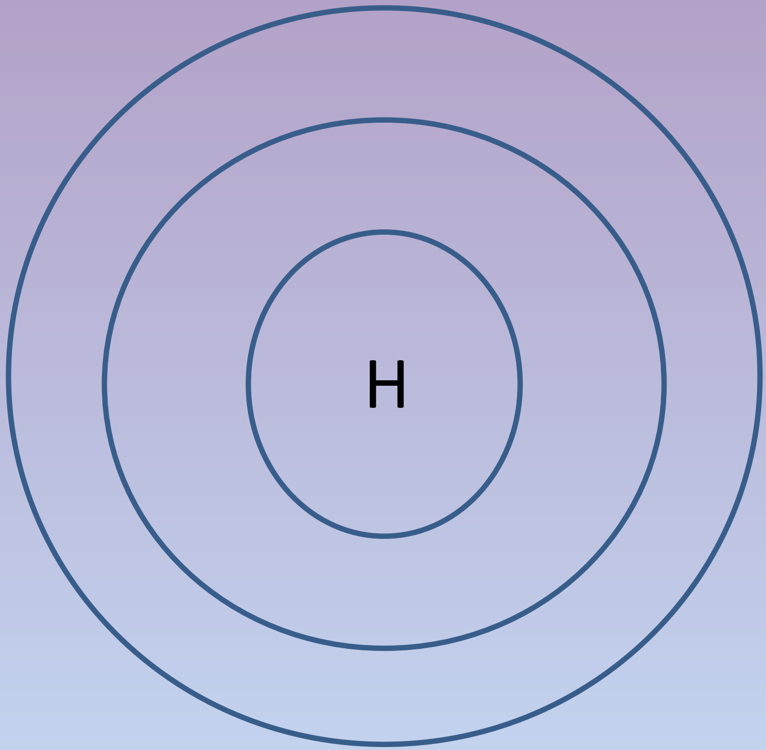
Around a LOW pressure center, winds move

a. clockwise
b. counterclockwise

There is no need to ‘memorize’ this, in fact, it is more fun to prove it to yourself with practice ☺ Just remember two simple facts:

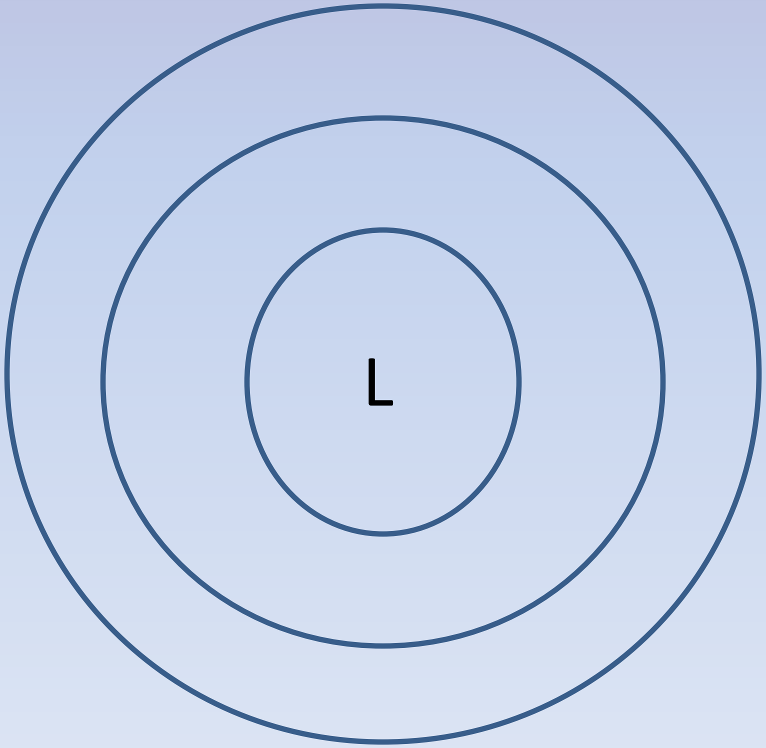
1. Winds move from high to low pressure.
2. Winds are deflected to the right in the Northern Hemisphere.

3. Target practice!



Your arrow wants to cross the isobars perpendicularly – that is the steepest gradient.

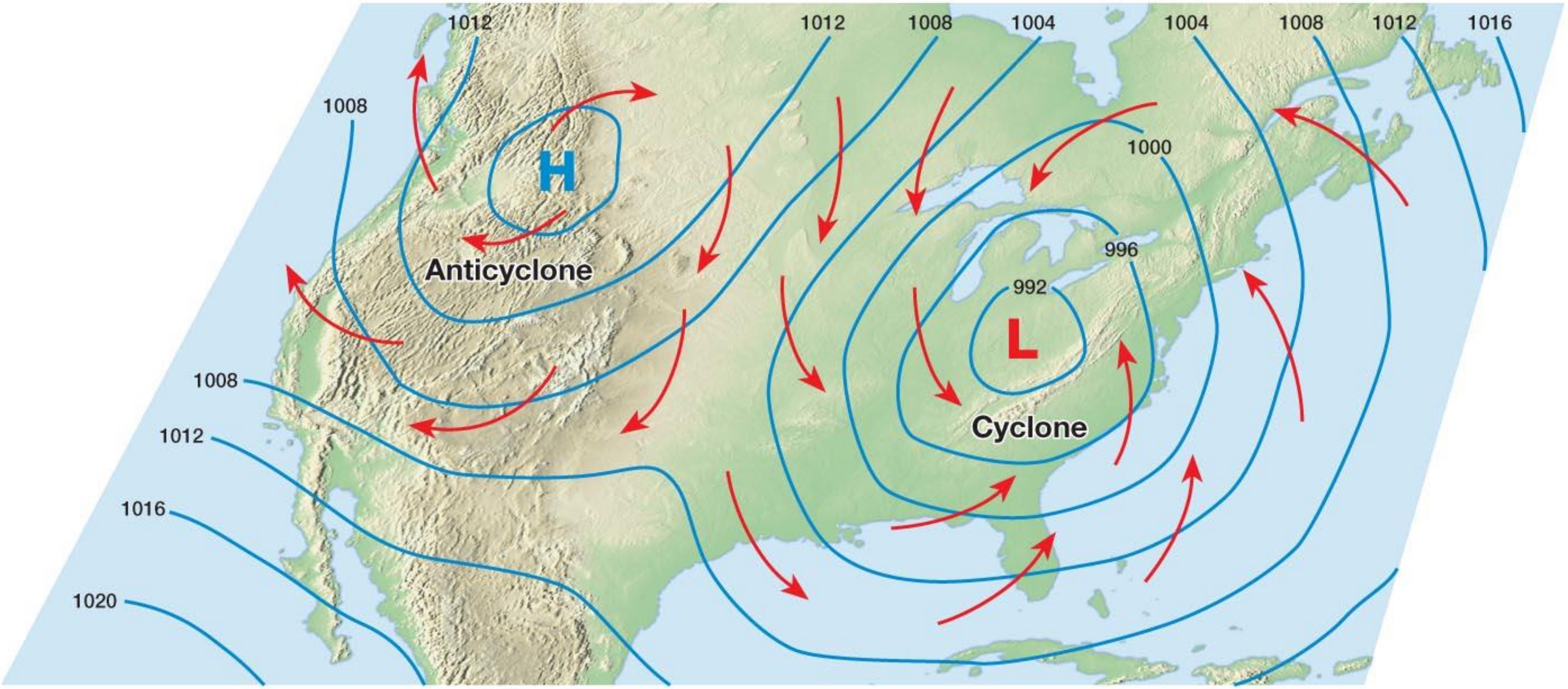
But coriolis deflects to the right…



Remember: things always move from high to low (like the ball rolling down the hill or into the bottom of a bowl).

Coriolis deflects the air movement to the right.

Did your circulation systems result in these patterns?

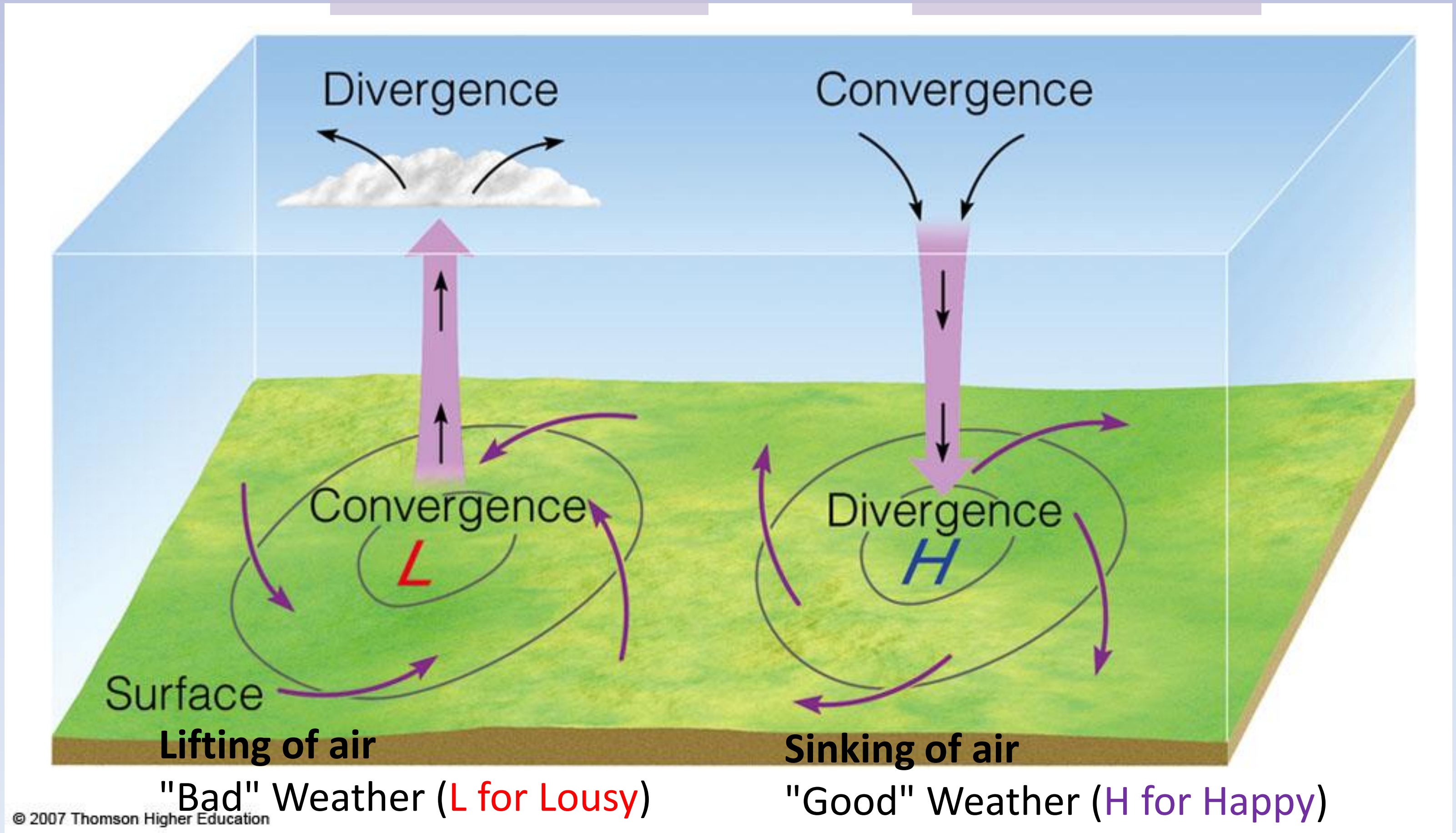


But if the air is converging on a low pressure area, wouldn't that lead to a high pressure area?

-For a low pressure system to exist for very long, compensation must occur aloft.

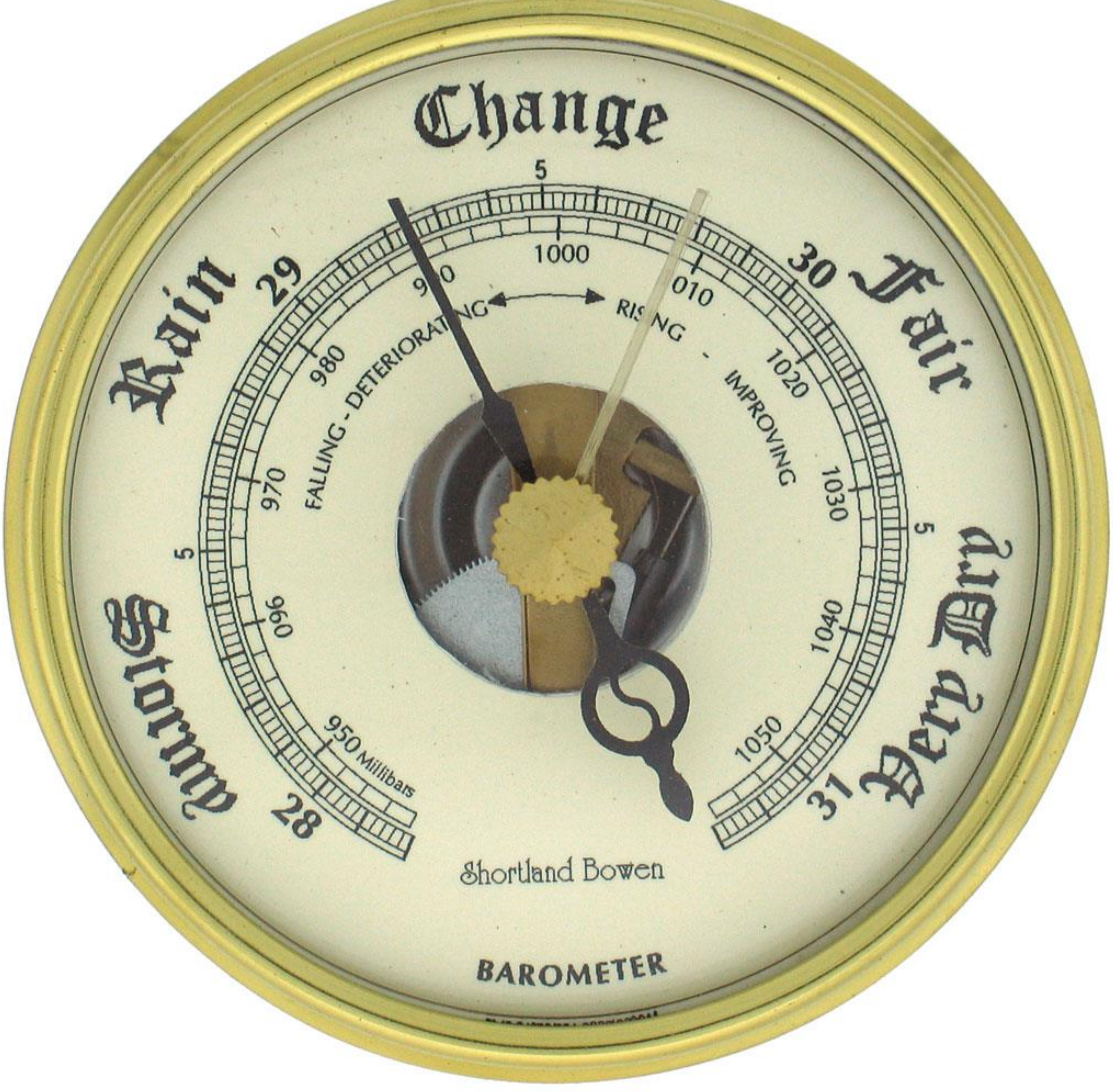
Clouds
-rising air cools, water vapor condenses

No clouds
-sinking air warms, no condensation



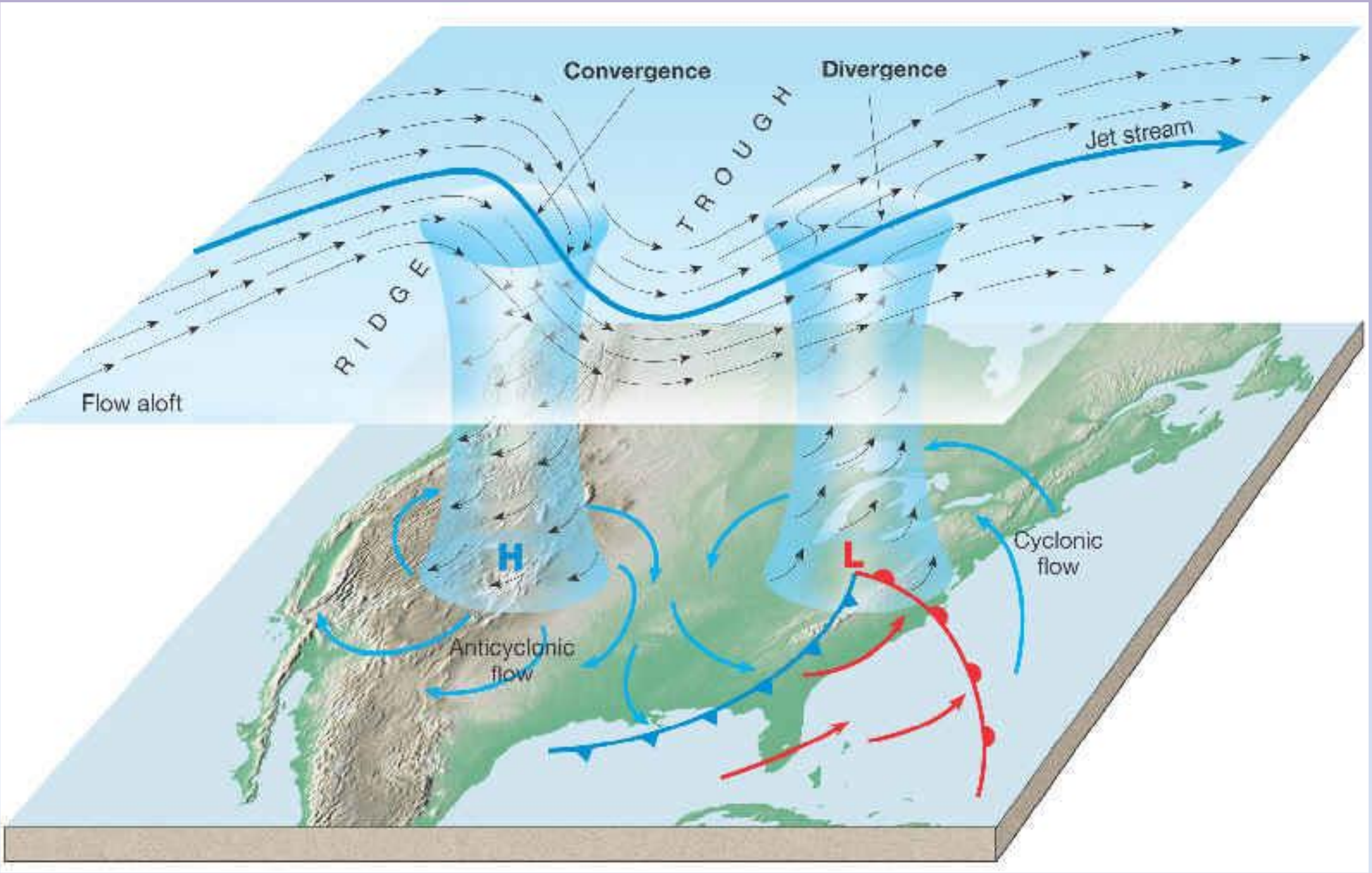
Lifting of air
"Bad" Weather (L for Lousy)

Sinking of air
"Good" Weather (H for Happy)

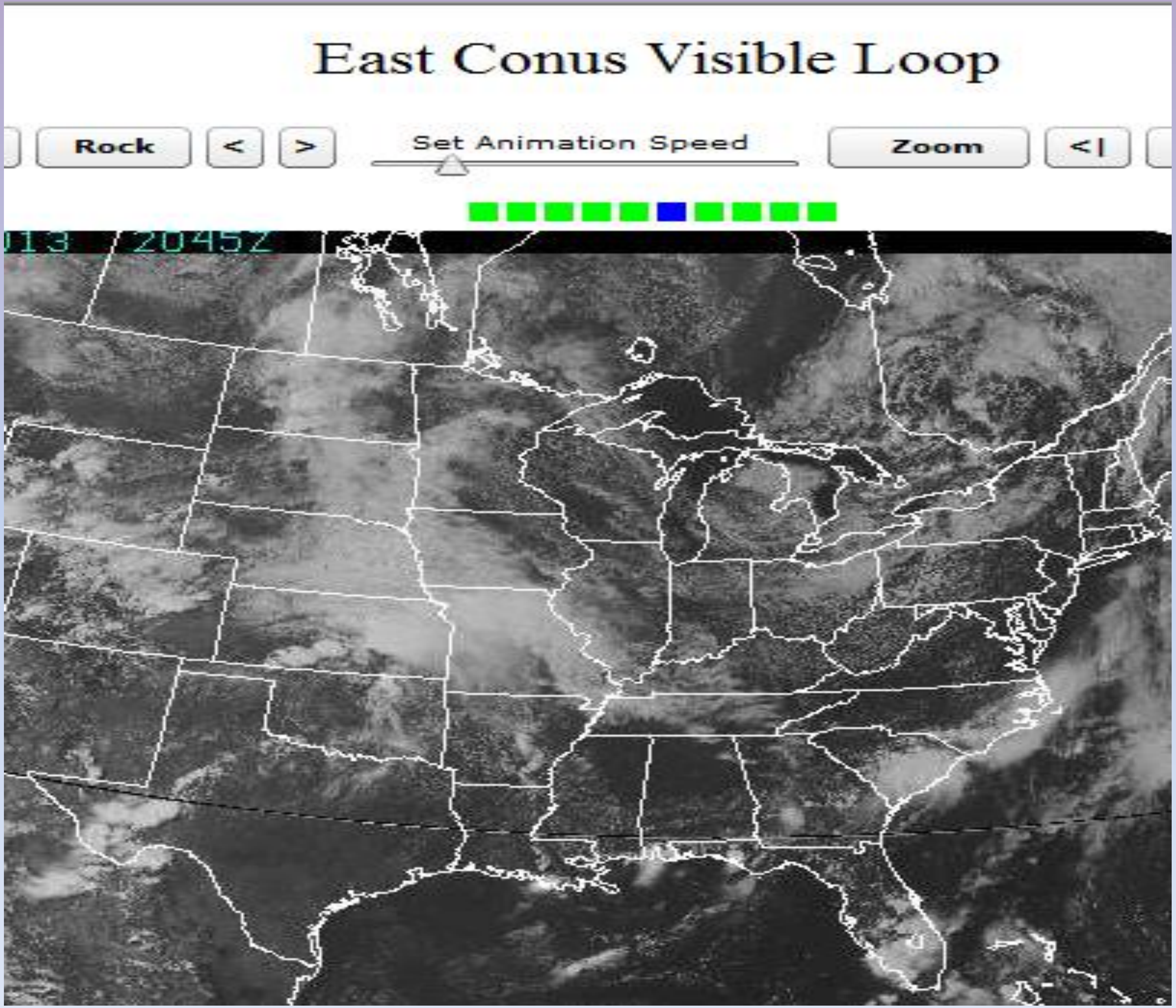


Change
Rain
Fair
Stormy
Very Dry
28
29
30
31
5
950 Millibars
960
970
980
1000
1010
1020
1030
1040
1050
FALLING - DETERIORATING
RISING - IMPROVING
Shortland Bowen
BAROMETER

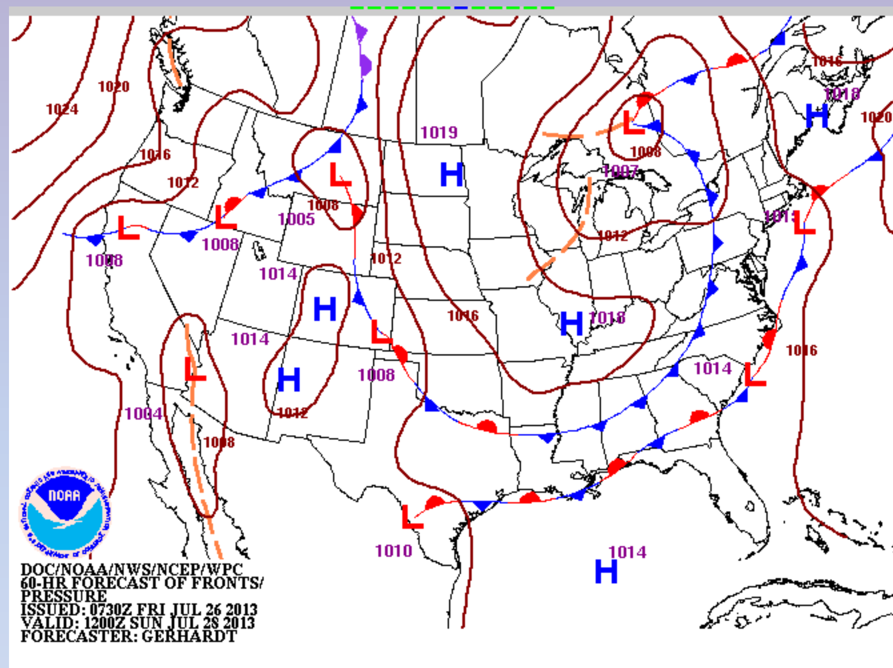
This upper level activity is what creates the Jet Stream



Current cloud cover



http://www.goes.noaa.gov/GSSLOOPS/ecvs.html

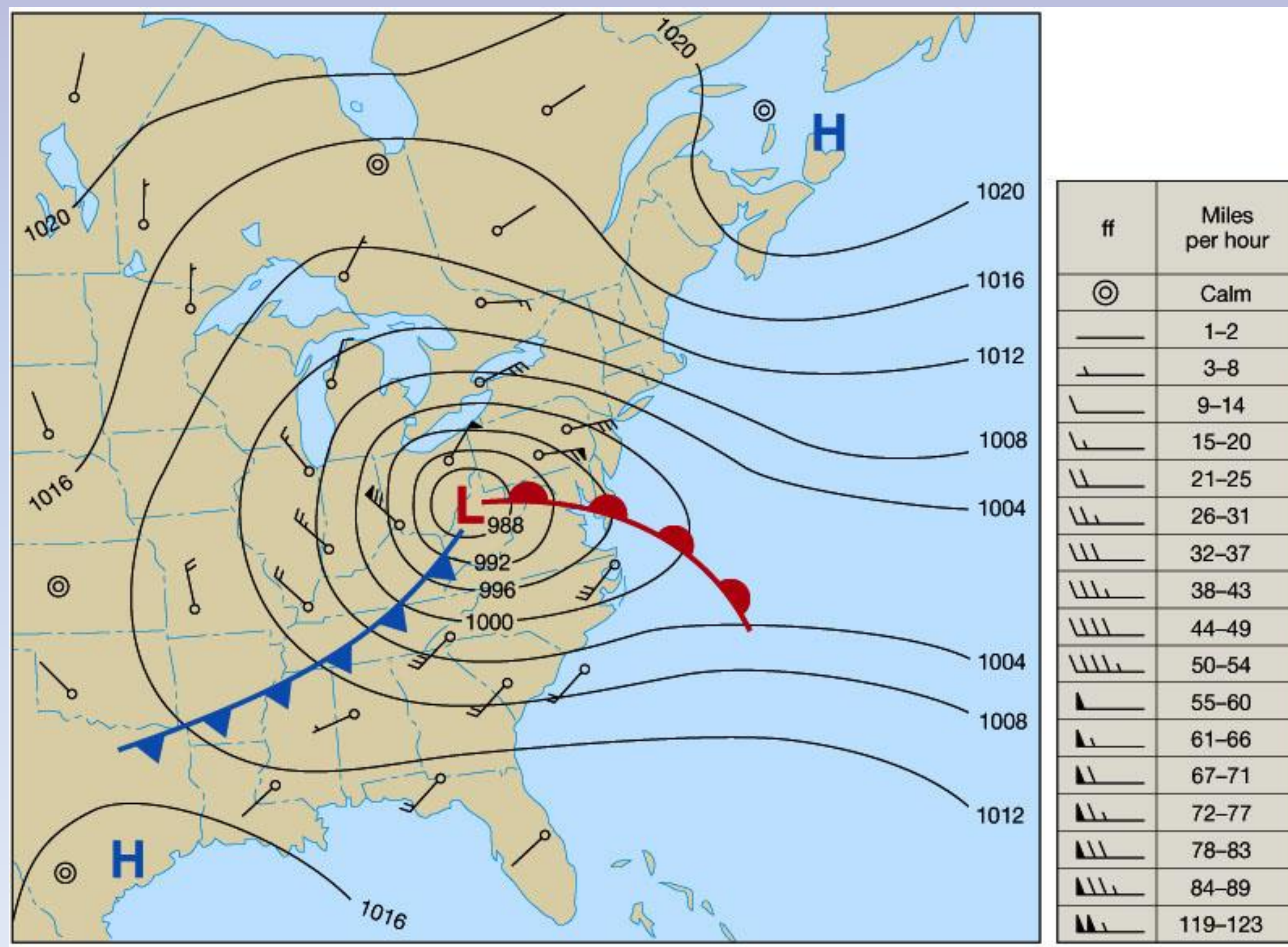

DOC/NOAA/NWS/NCEP/WPC
60-HR FORECAST OF FRONTS/
PRESSURE
ISSUED: 0730Z FRI JUL 26 2013
VALID: 1200Z SUN JUL 28 2013
FORECASTER: GERHARDT

Fronts

- Boundary that separates air masses of different *densities* *(like the lava lamp)*
  - Air masses retain their identities
  - Warmer: less dense air forced aloft
  - Cooler: more dense air acts as wedge

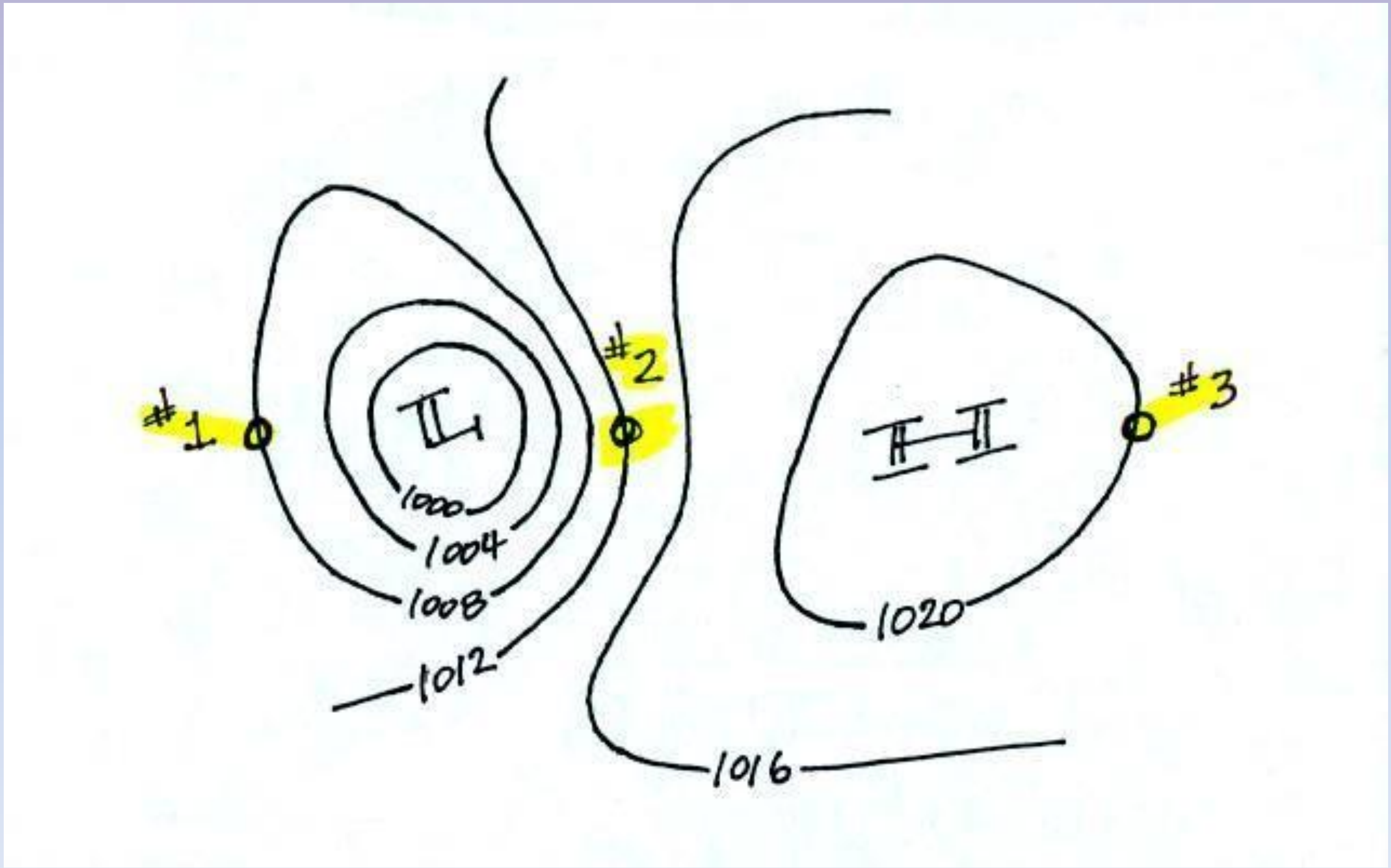
Why do we often see a warm front along the eastern half and a cold front along the western half of a low pressure system?

Think about where these winds are coming from…

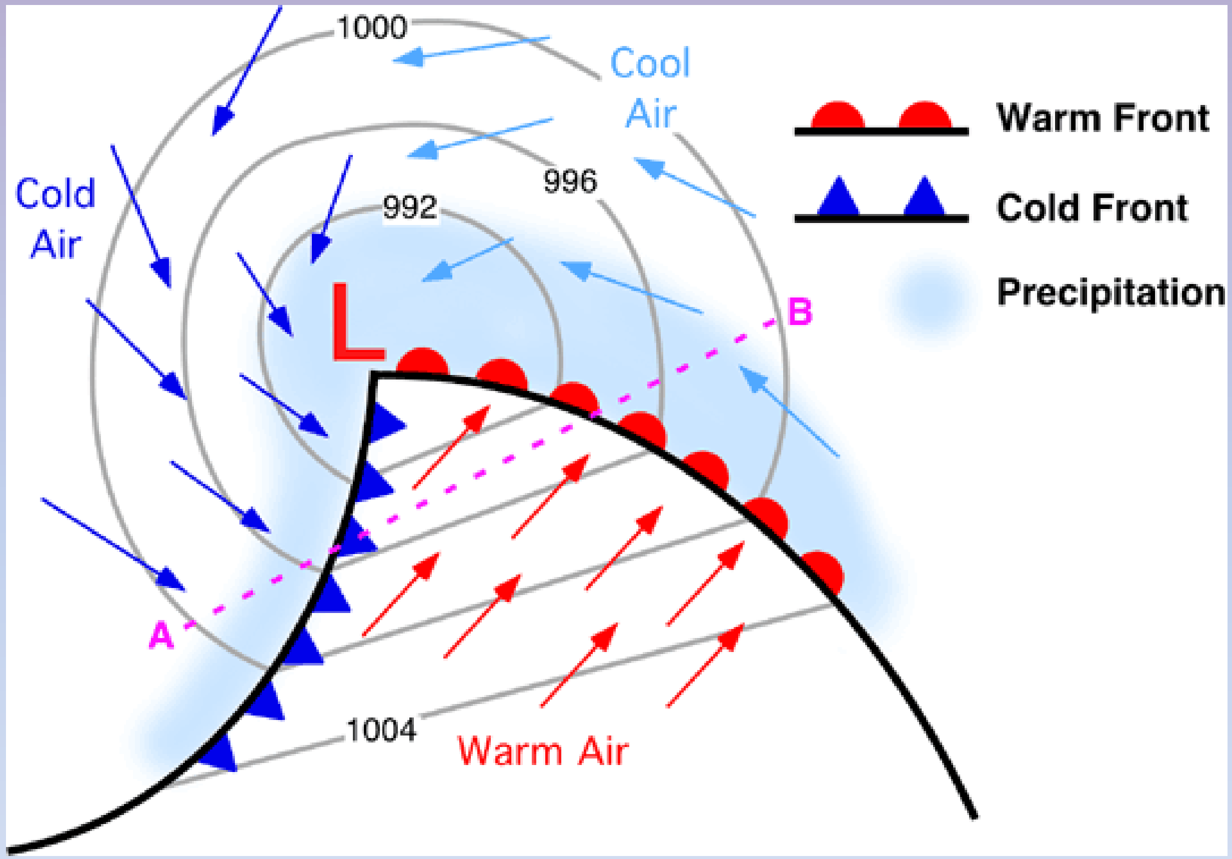


Which way are the winds blowing at 1, 2, 3?

See! You CAN predict the weather ☺

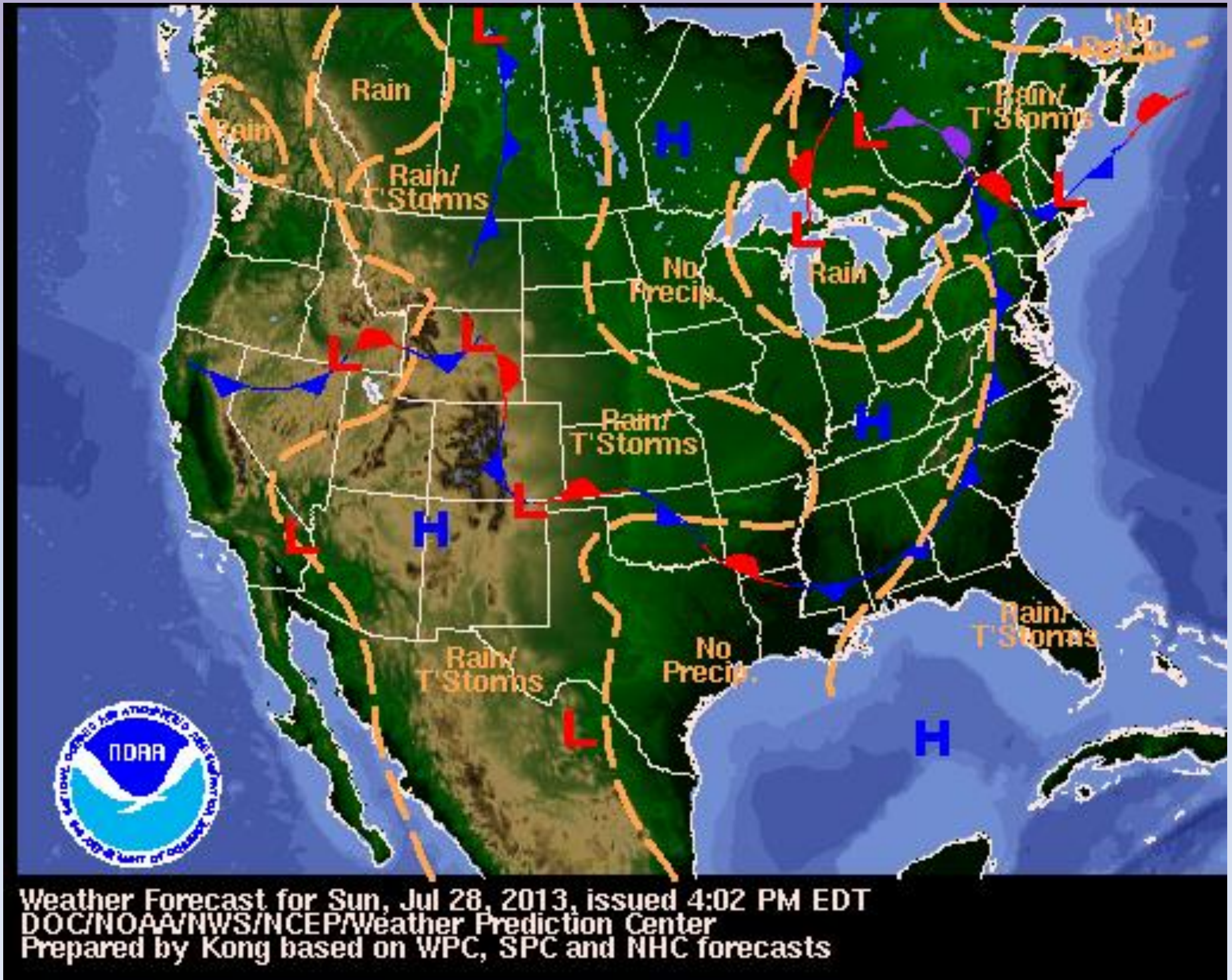


Let’s explore the change in winds a bit further:



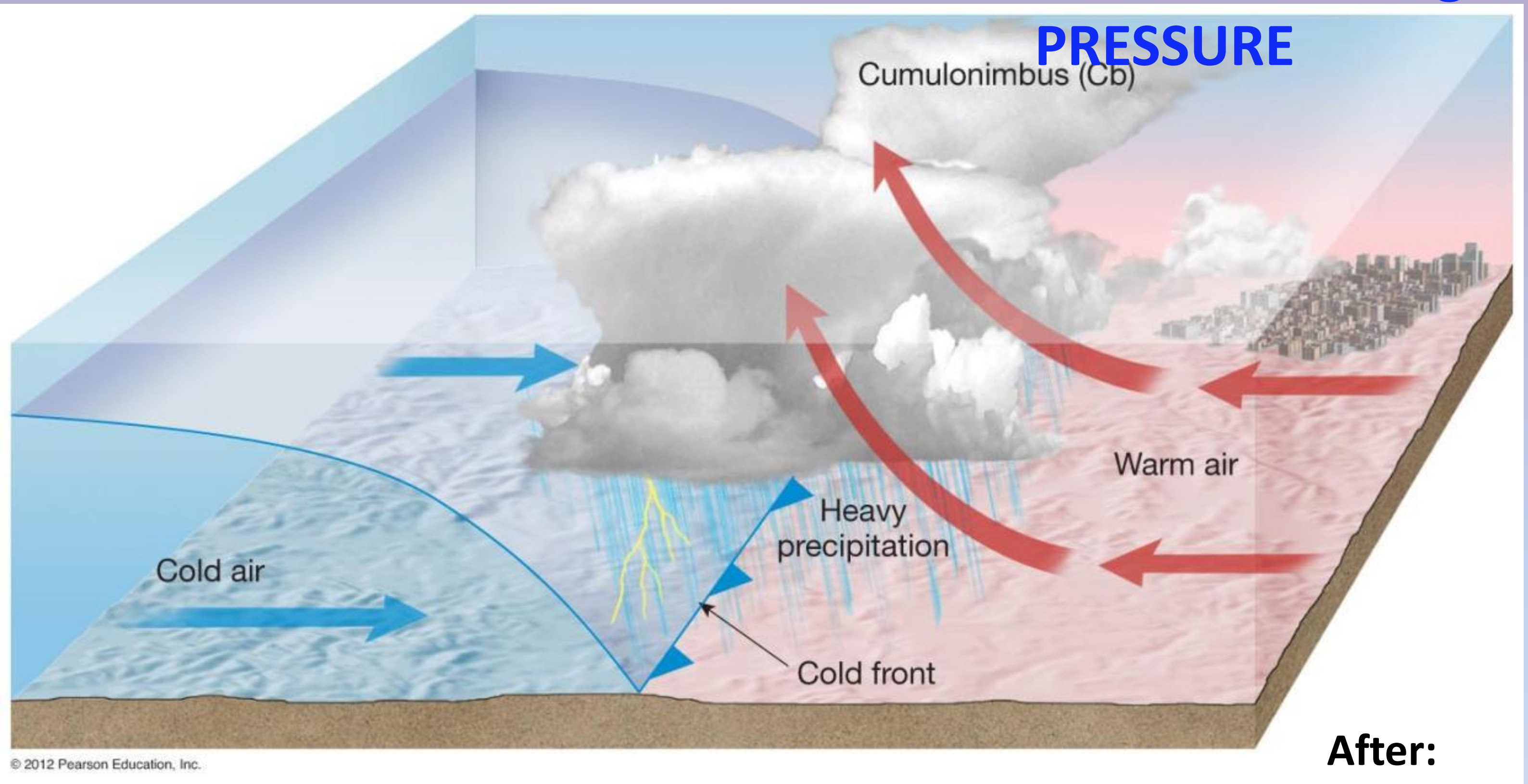
Because they need cold air to form, cold fronts often originate from the northerly direction so the winds shift to northerly winds after the front passes.

On Sunday Philadelphia set an ALL TIME record for rainfall in a 24-hr. period at over 8 inches.
What was going on??



Cold front

Behind the cold front is an area of cooler, sinking air and HIGH PRESSURE



Cumulus: a pile

During:
- Cold air replaces warm air
- Shown on a map by a line with triangles
- Twice as steep (1:100) as warm fronts
- Advances faster than a warm front
- Associated weather is more violent than a warm front
  - Intensity of precipitation is greater
  - Duration of precipitation is shorter

After:

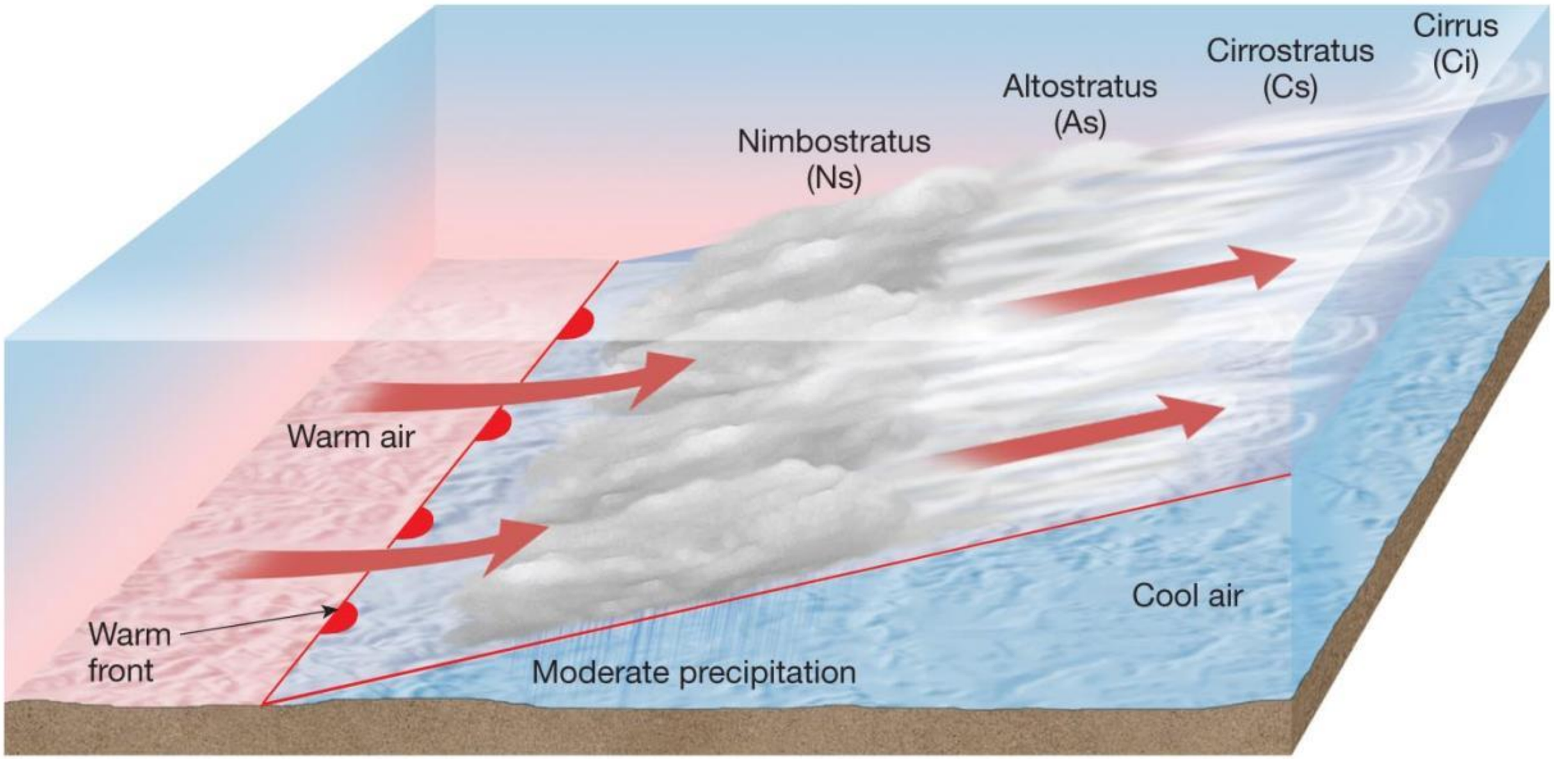
Weather behind the front is dominated by
- Cooler air mass
- Subsiding air
- Clearing conditions

http://www.youtube.com/watch?v=huKYKykjcm0

Blue skies http://www.youtube.com/watch?v=kEc16BjfrvI

Warm front

Behind the warm front is an area of warm, rising air and LOW PRESSURE



Stratum:
a layer

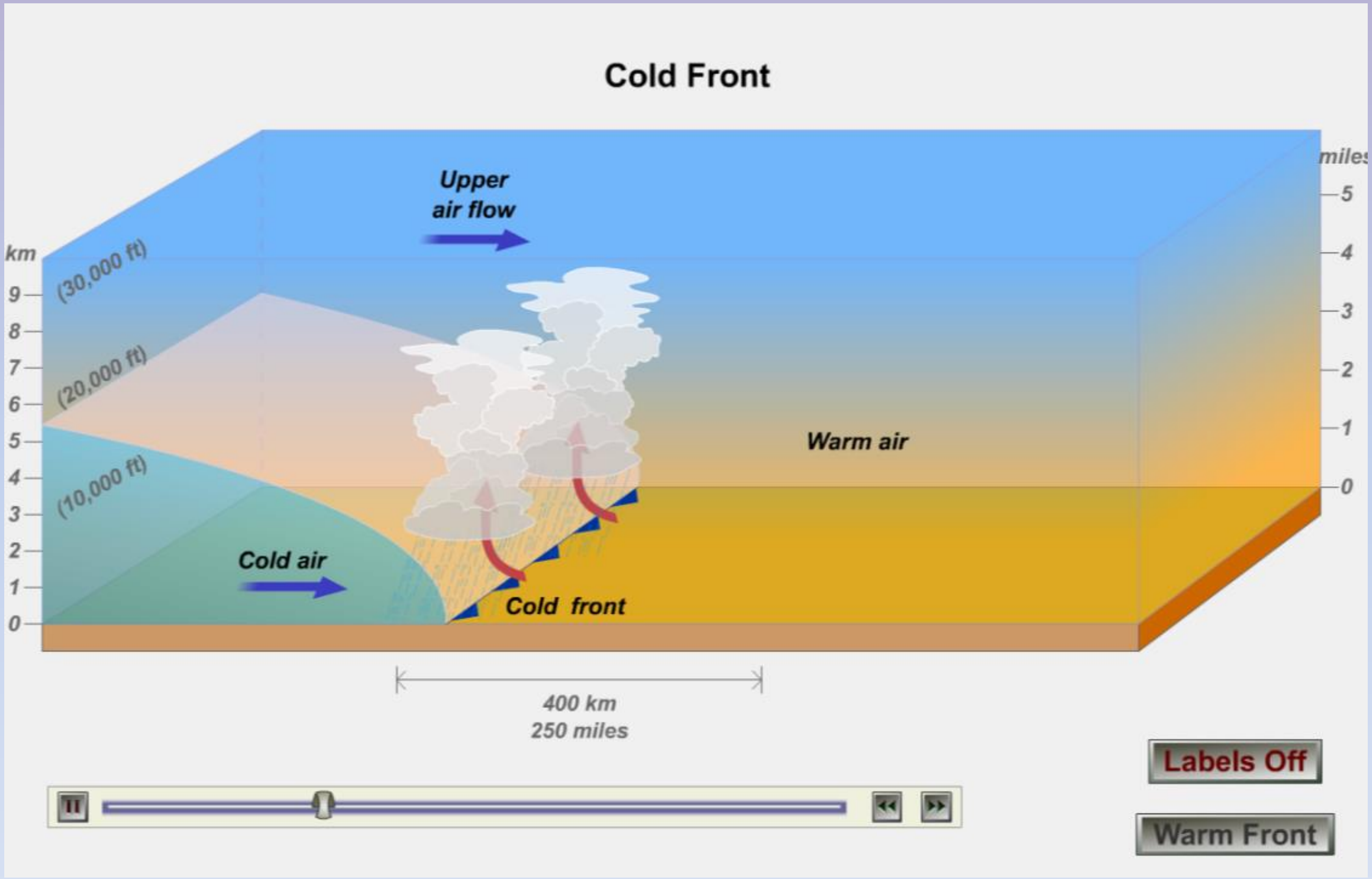
Cirrus:
a curl

During:
Warm air replaces cooler air
Shown on a map by a line with semicircles
Small slope (1:200)
Clouds become lower as the front nears
Slow rate of advance
Light-to-moderate precipitation
Covers larger geographic area

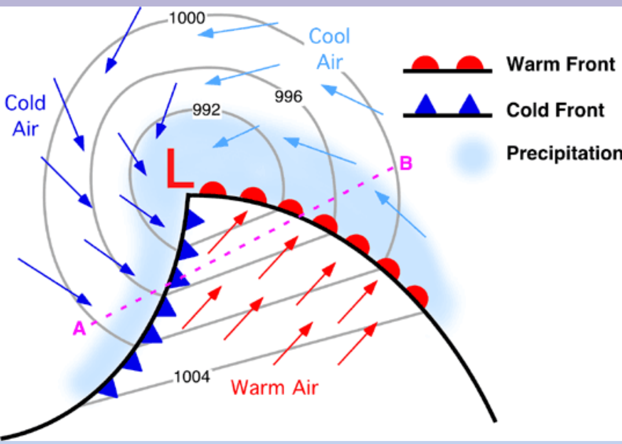
After:

A warm front brings gentle rain or light snow, followed by warmer, milder weather.

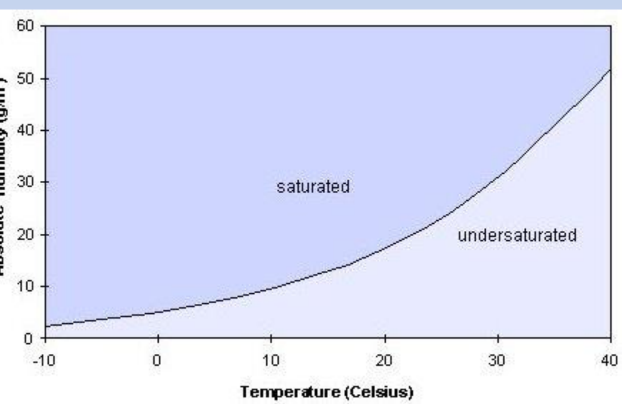
http://www.youtube.com/watch?v=huKYKykjcm0



COLD FRONT or WARM FRONT?



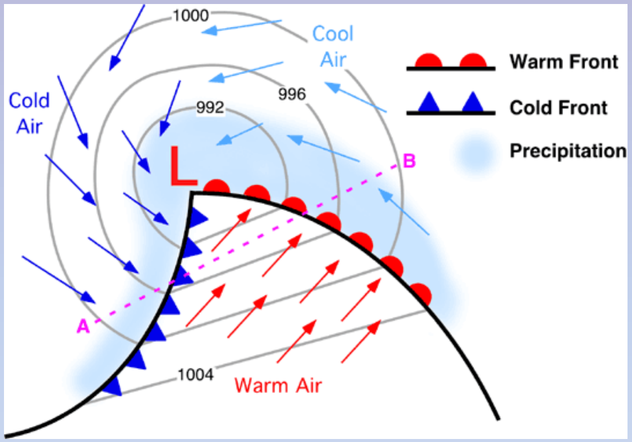
Weather	**Before**	**During Passage**	**After**
Winds	SSW	gusty, shifting	WNW
Temperature			
Pressure			
Precipitation			
Dew point			

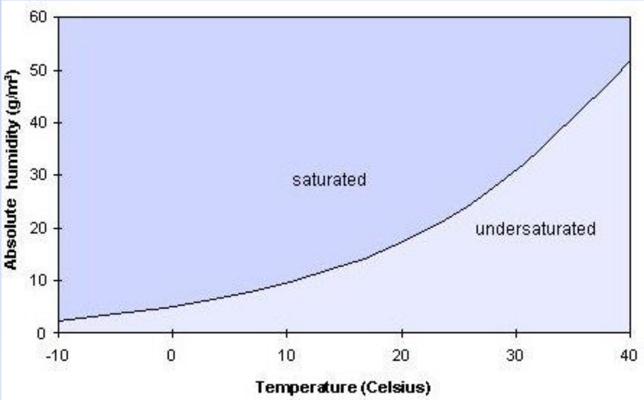


I can name that front in 2 clues, George!

COLD FRONT or WARM FRONT?

Weather	**Before**	**During Passage**	**After**
Winds	SSE	variable	SSW
Temperature			
Pressure			
Precipitation			
Dew point			





After a cold front passes, which of these does not usually occur?

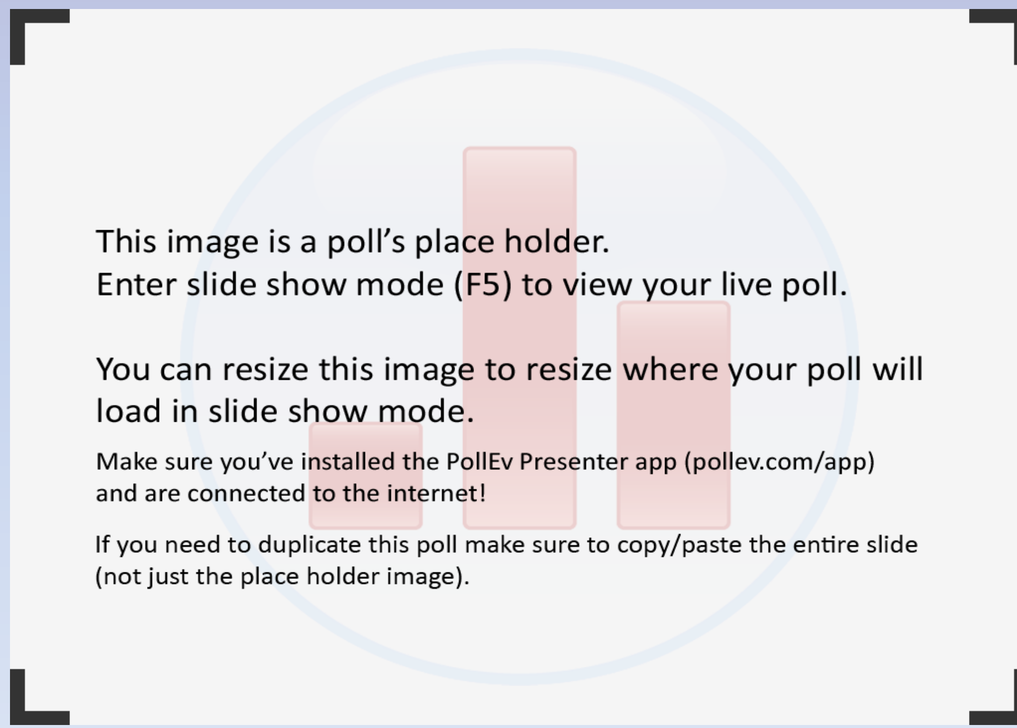
A. Wind direction shift

B. Marked temperature drop

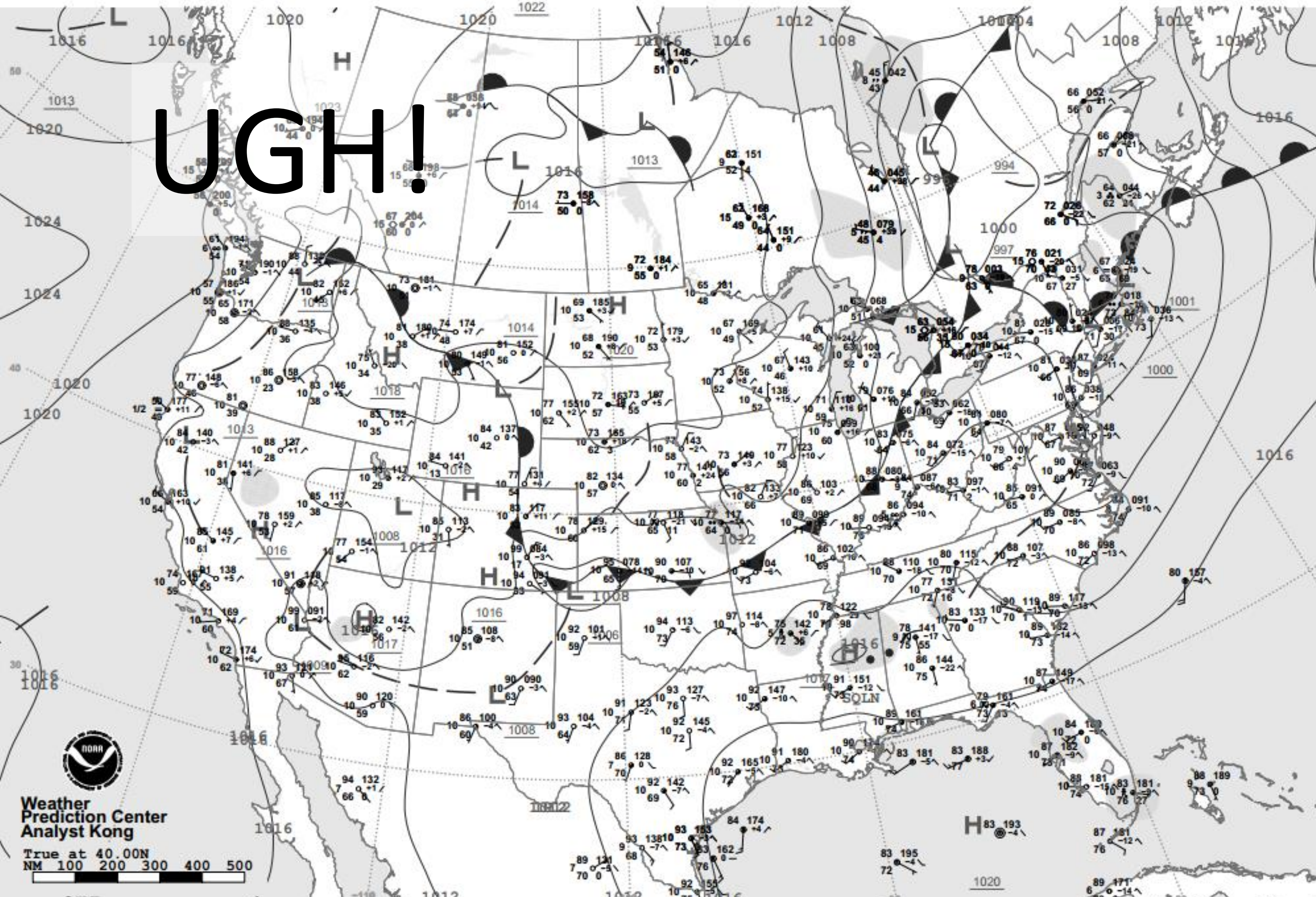
C. Clearing skies

D. Decreased pressure

The passage of a cold front signals the edge of a mass of cooler and heavier air arriving over an area. Since the air more dense, then the pressure would rise, not fall, thus answer D.



UGH!

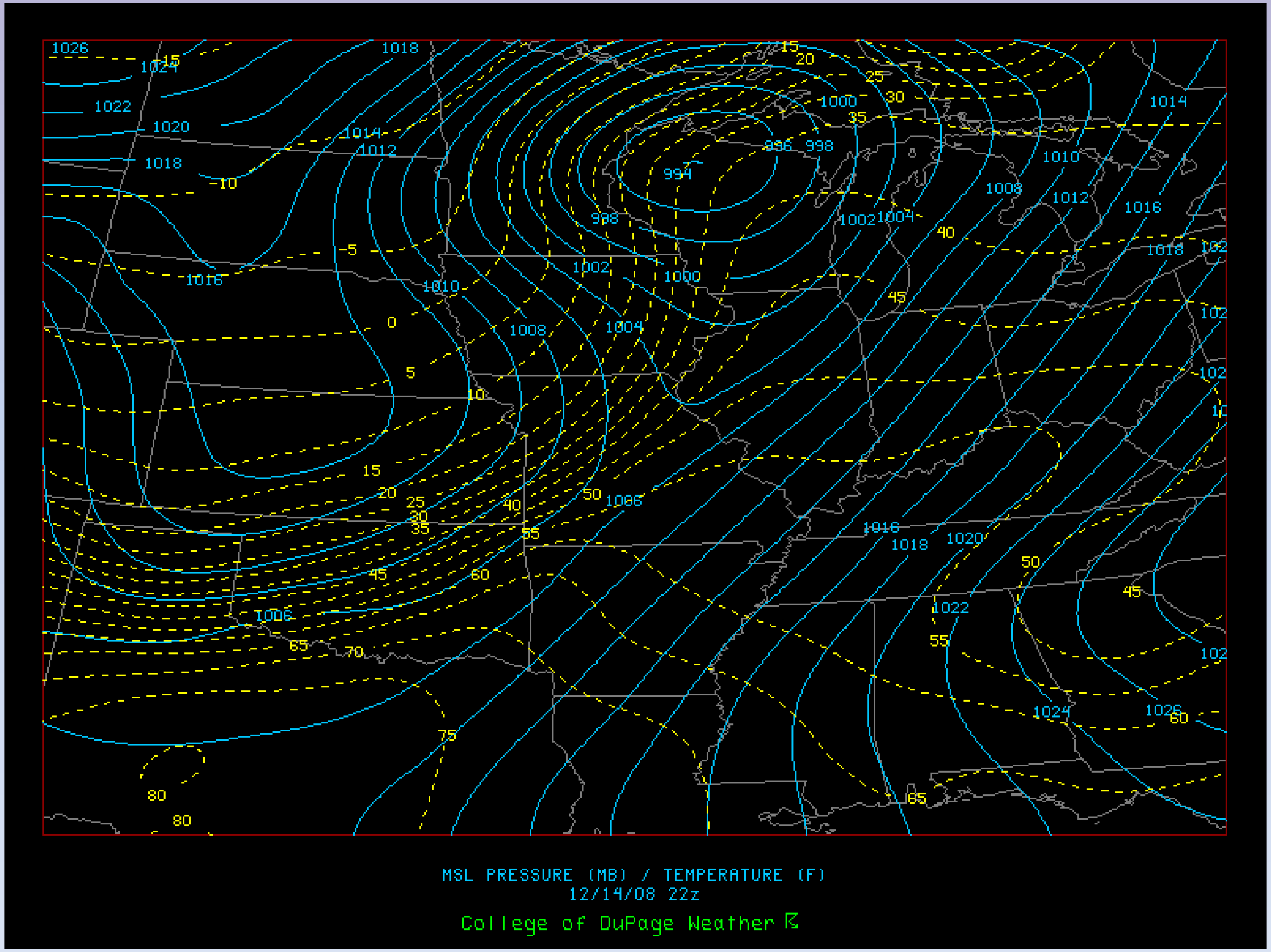


TUE JUL 23 2013 18 UTC

Surface Weather Map and Station Weather

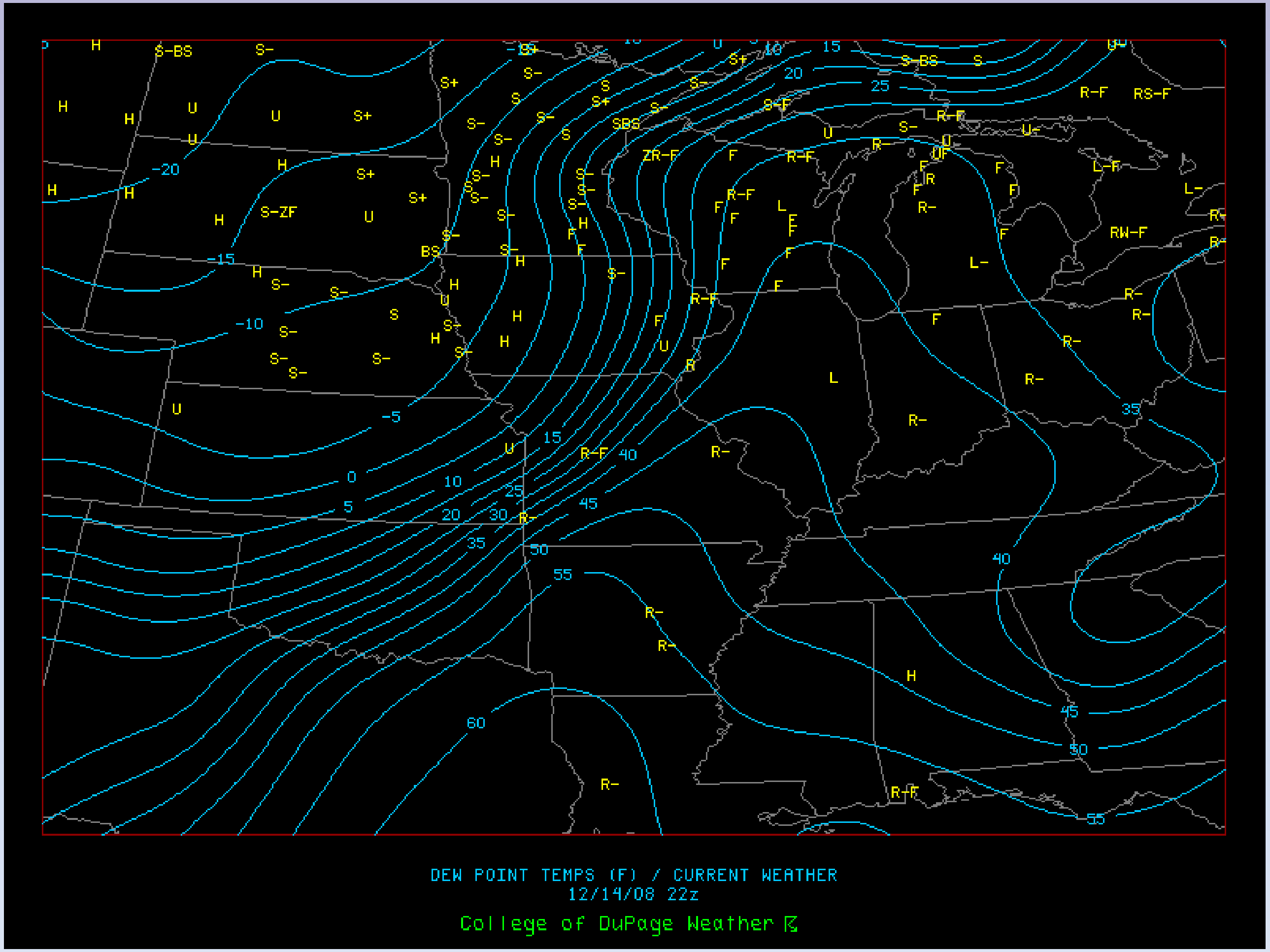
Locating the fronts

- 1st look for a strong temperature gradient or change in temperature (in yellow).
- Do you see one here?
- How to the air masses in the Dakotas compare to those in Kentucky?



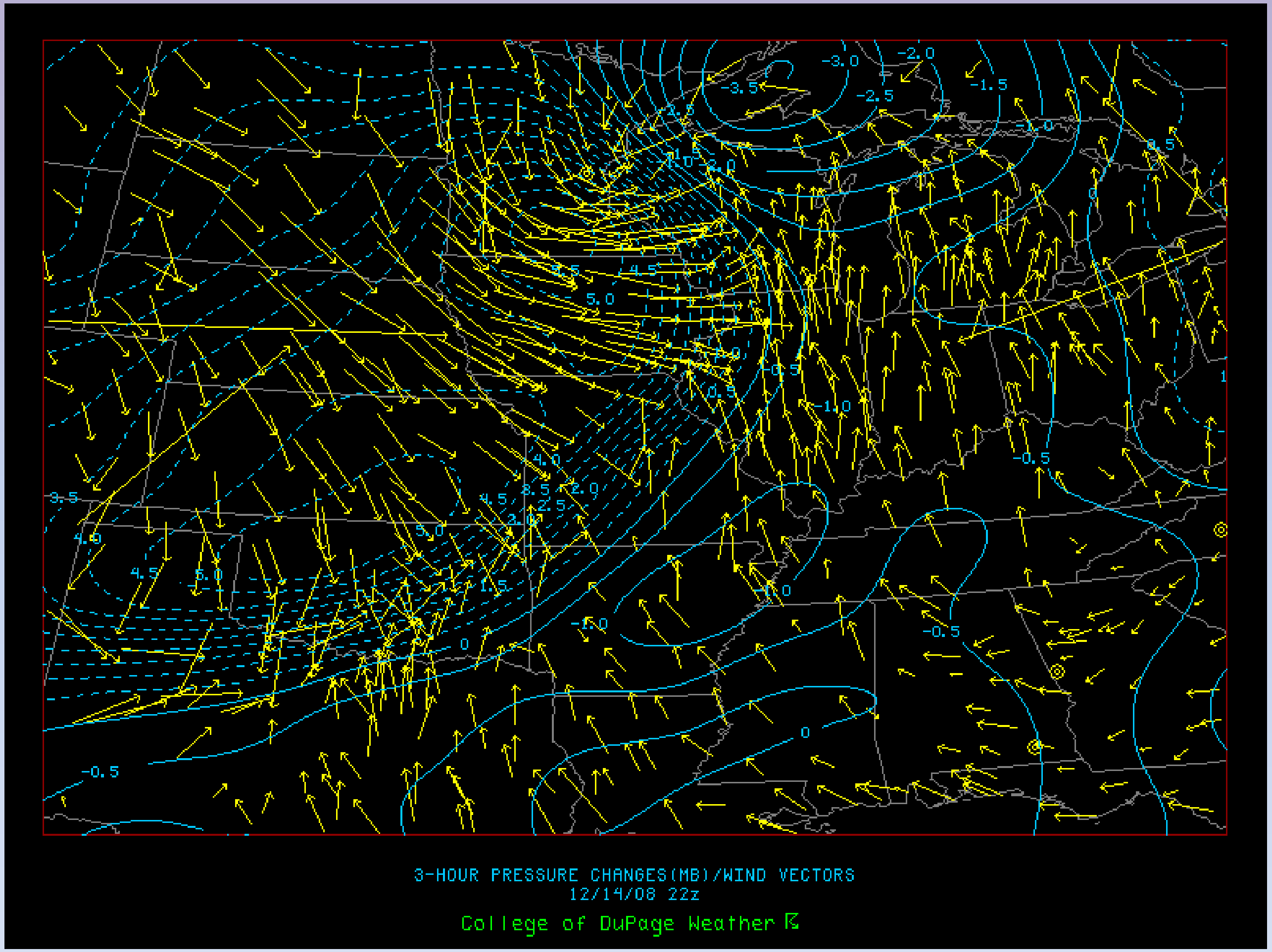
Locating the fronts

- 2nd look for a strong dewpoint gradient, or change.
- Do you see one here?
- How does it compare the temperature gradient in the last slide?



Locating the fronts

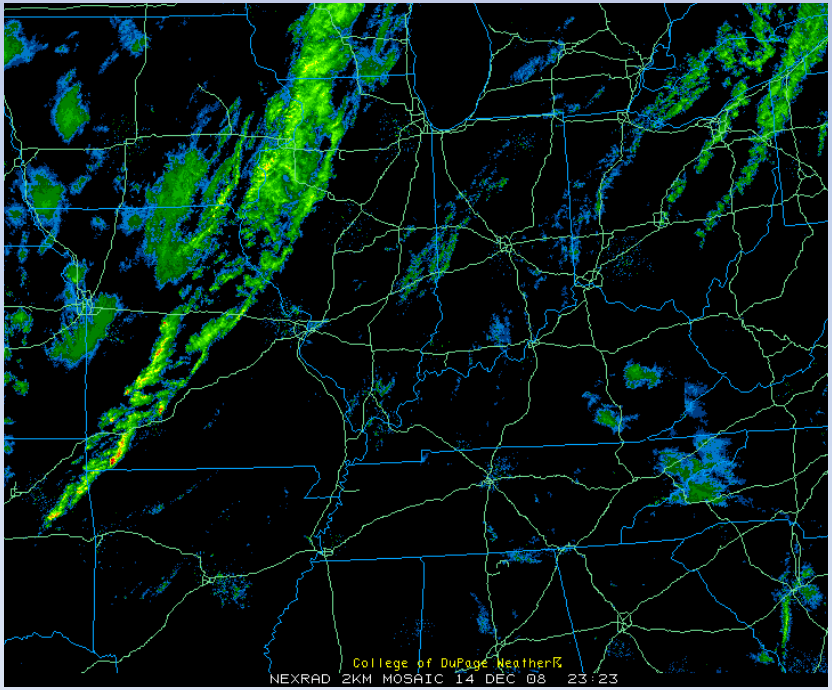
- 3rd look for a strong pressure gradient, or change.
- 4th look for a strong wind shift (the yellow vectors.)
- Do you see these here?

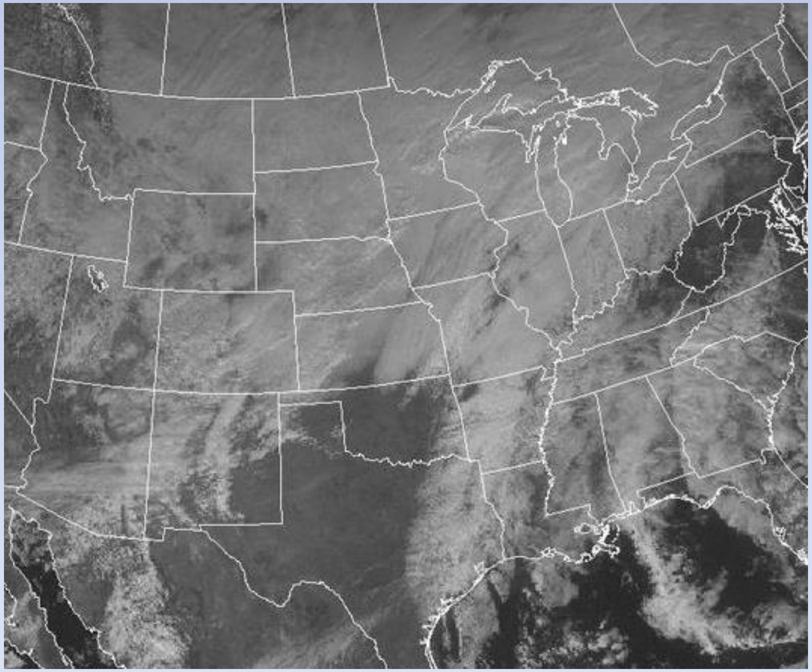


Note: in this image, the dashed blue lines represent pressure increases while the solid blue lines represent pressure decreases. The numbers represent millibars per three hours. The yellow vectors point in the direction the wind is blowing.

Locating the fronts

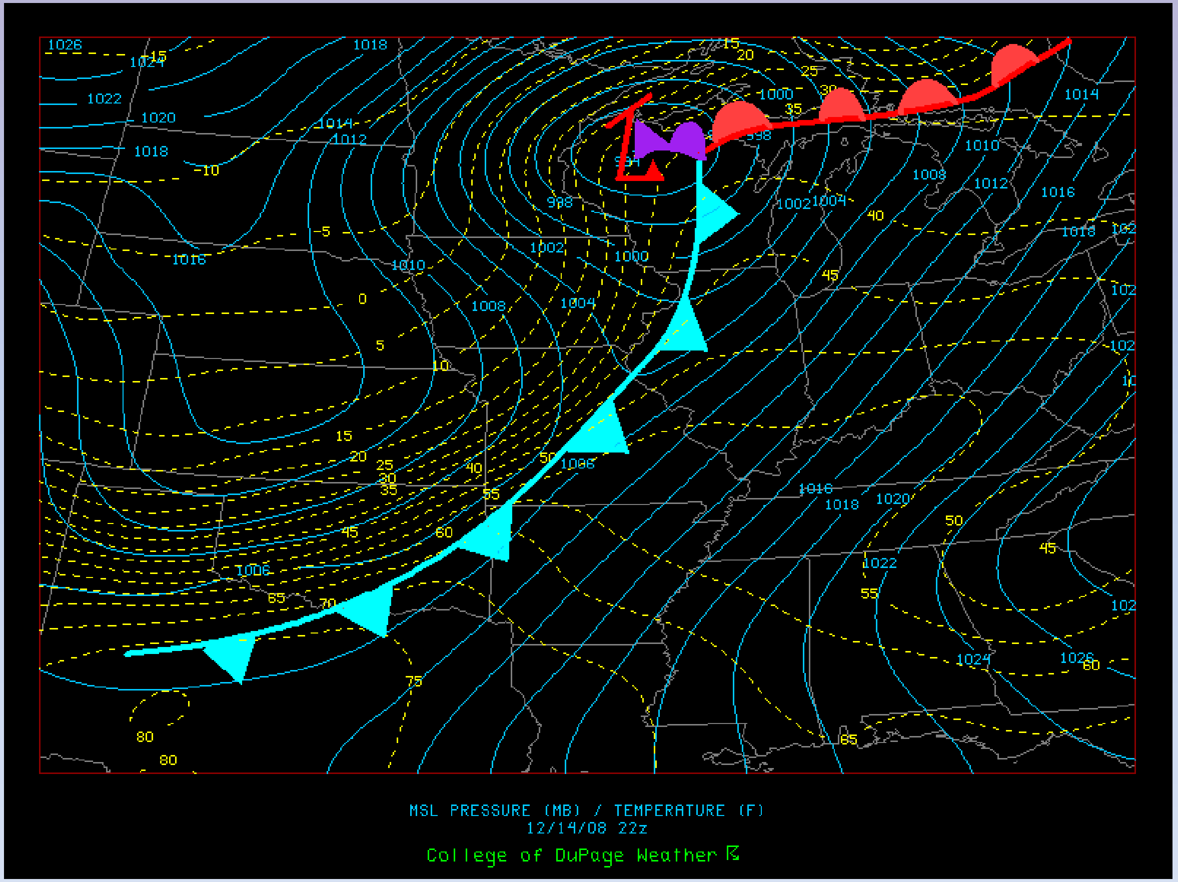
- Check cloud patterns.



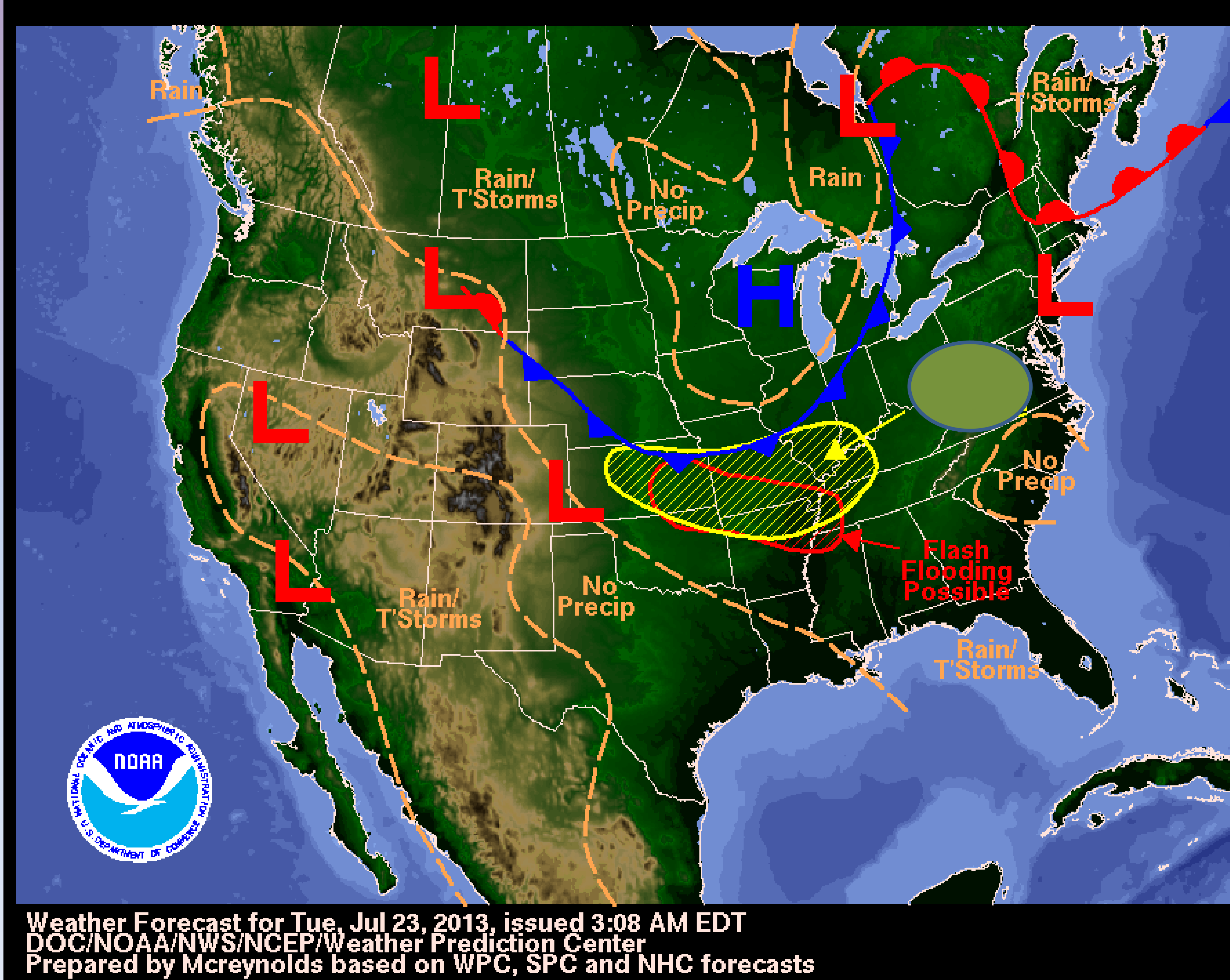


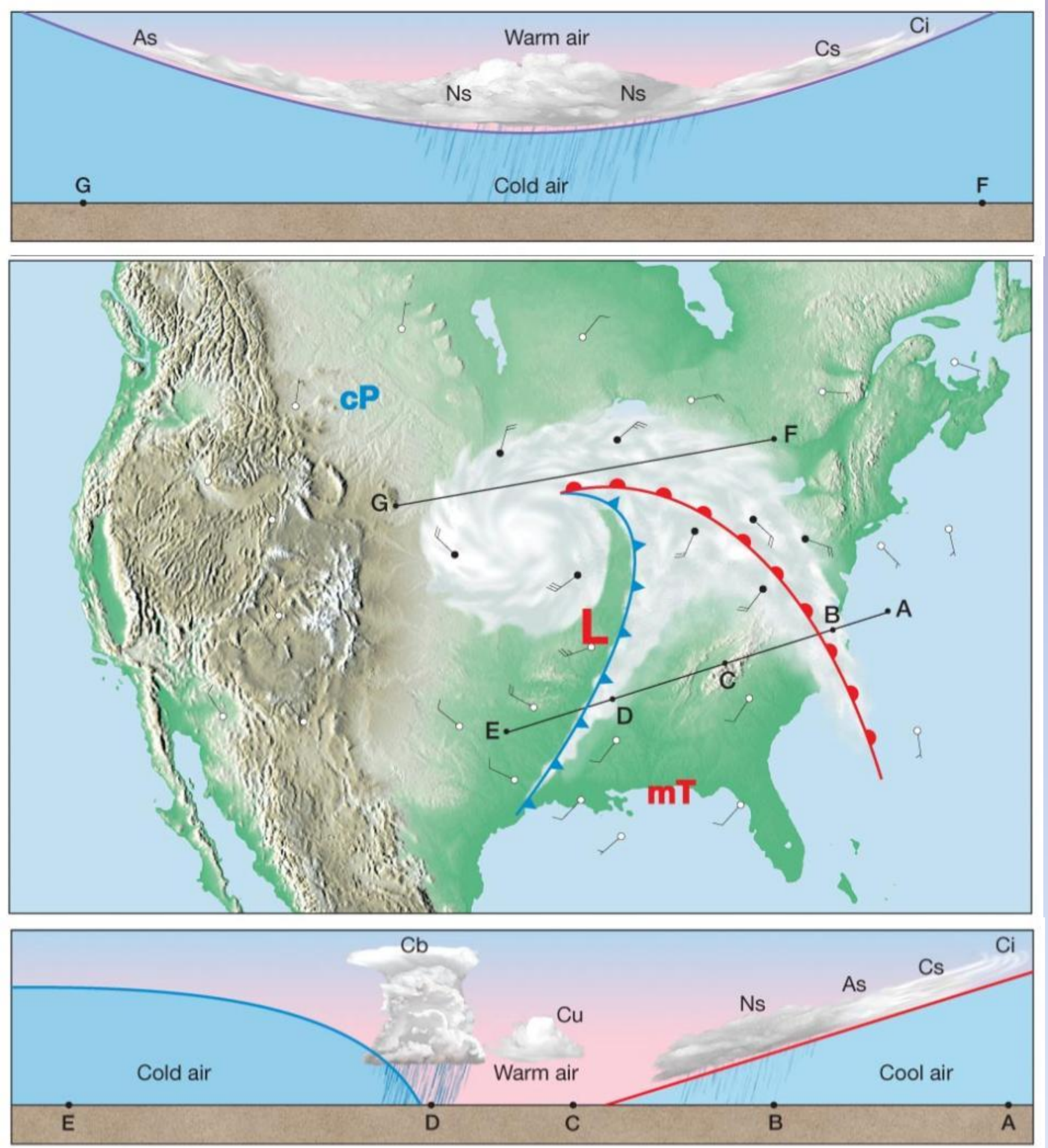
Locating the fronts

- Every cyclone presents unique characteristics.
- While the satellite and radar didn't show the front well, the temperature, wind, and moisture analyses provided a clear cut picture of where this front should be.
- Often, fronts are very subtle and only one rule might be useful.
- I don't expect you to locate fronts, this takes some level of expertise, but understanding HOW they are determined is still helpful, and if you are a weather junky, fun!



In general*, <u>warm fronts are more difficult to discern than cold fronts</u>.* Their transition zones are typically much larger and their effects much more widespread.


Rain
Rain/ T'Storms
No Precip
Rain
Rain/ T'Storms
L
L
L
L
L
L
L
H
No Precip
Flash Flooding Possible
Rain/ T'Storms
No Precip
Rain/ T'Storms
NOAA
Weather Forecast for Tue, Jul 23, 2013, issued 3:08 AM EDT
DOC/NOAA/NWS/NCEP/Weather Prediction Center
Prepared by Mcreynolds based on WPC, SPC and NHC forecasts



What sort of weather and clouds might you expect at the labeled points?

A – Cirrus clouds may extend 1000km ahead of front! Pressure decreases as warm air moves in.

B – Light precip 12-24 hours after cirrus clouds
Rising temps. Change in wind direction to (S/SW).

C – Warm temps, skies clear or partly cloudy

D – Severe weather ensues, winds change direction (N/NW).

E – Blue skies smiling on me. Nothing but blue skies do I see.

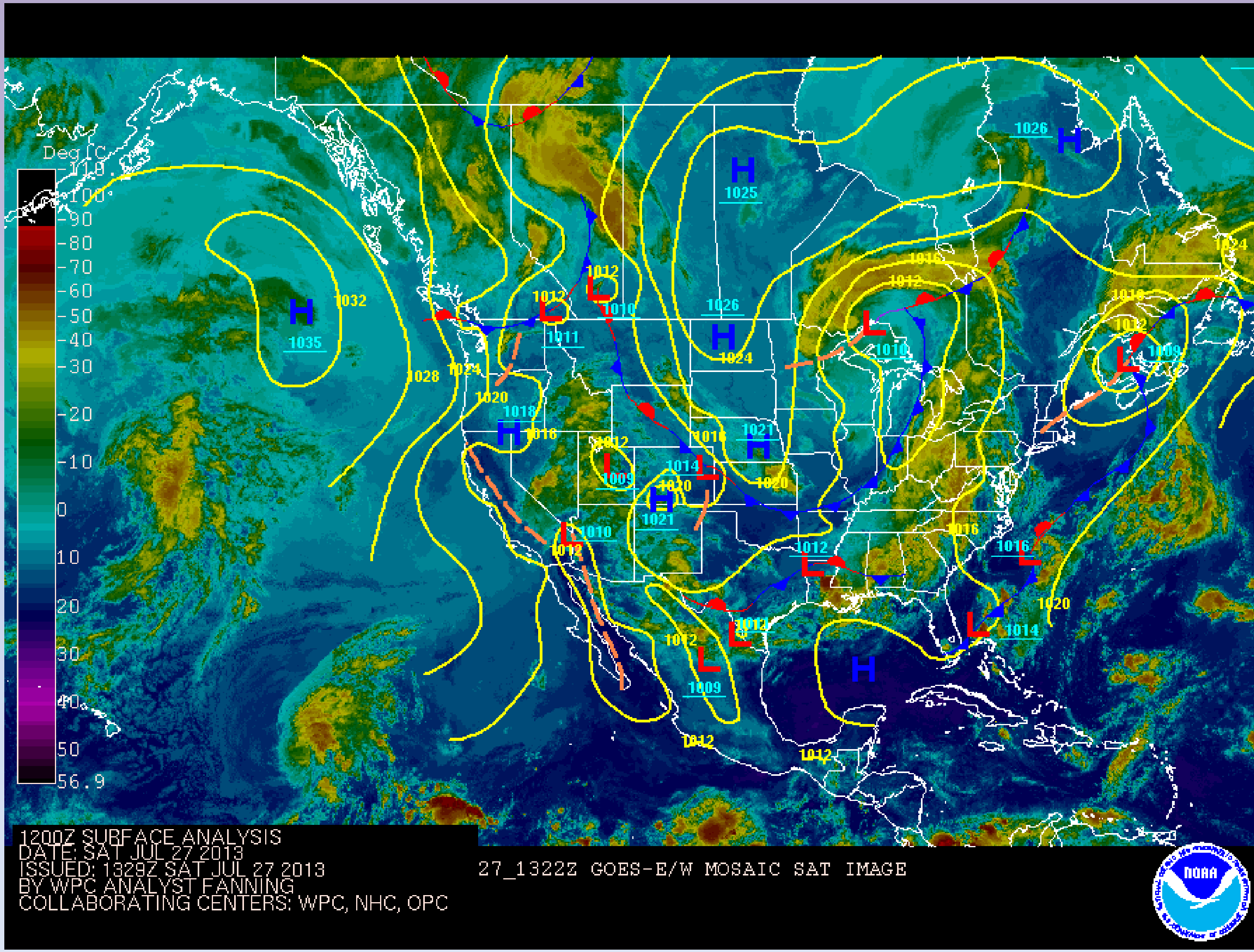
G-F often see worst of the weather, greatest intensity often north of the storm center. In winter, heavy snow, sleet possible.

http://vortex.plymouth.edu/make.html

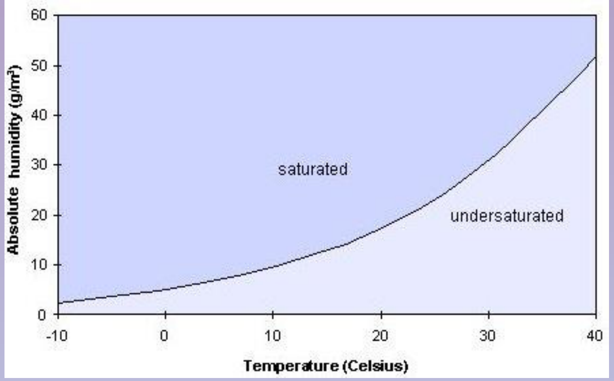
Lets’ make our own weather maps:

http://vortex.plymouth.edu/make.html

Putting it all together…. http://www.hpc.ncep.noaa.gov/sfc/satsfc.gif



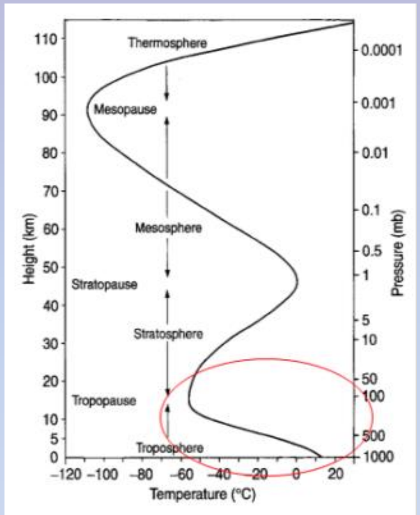
IN SUMMARY:



•At higher temperatures, more water is required for saturation (Warm air is able to 'hold' more water vapor than cold air)

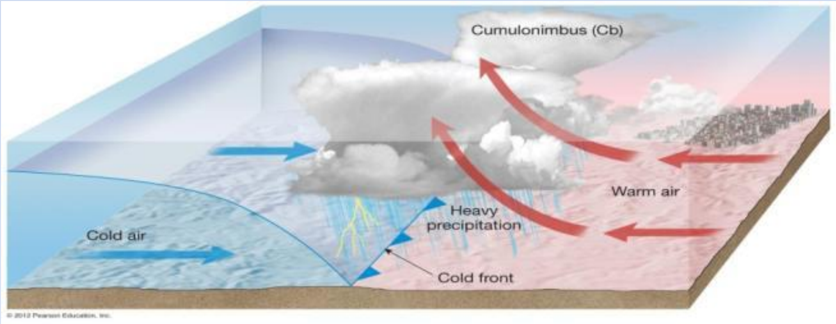
•Temperature decreases with altitude in the troposphere

- as humid air rises and subsequently cools, it will condense to form water droplets if the moisture content is above the point of saturation.

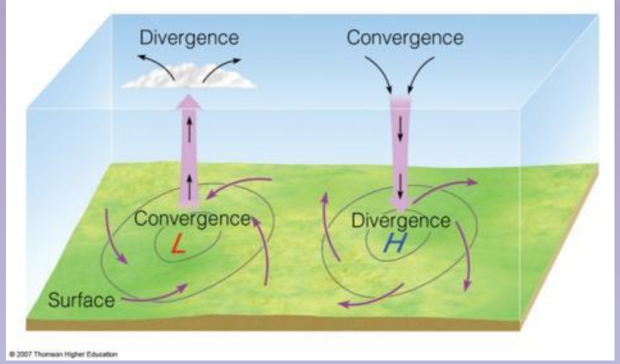


•Cold air is more dense, warm air is less dense.

$$P = \rho R T$$



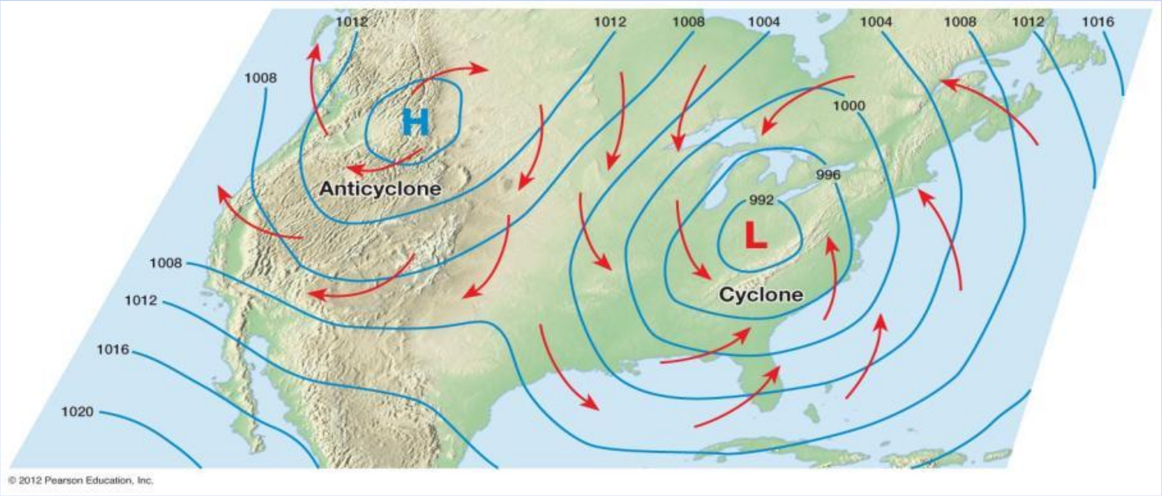
•After a cold front passes, we expect good weather (higher pressure from the cold, dense air mass).



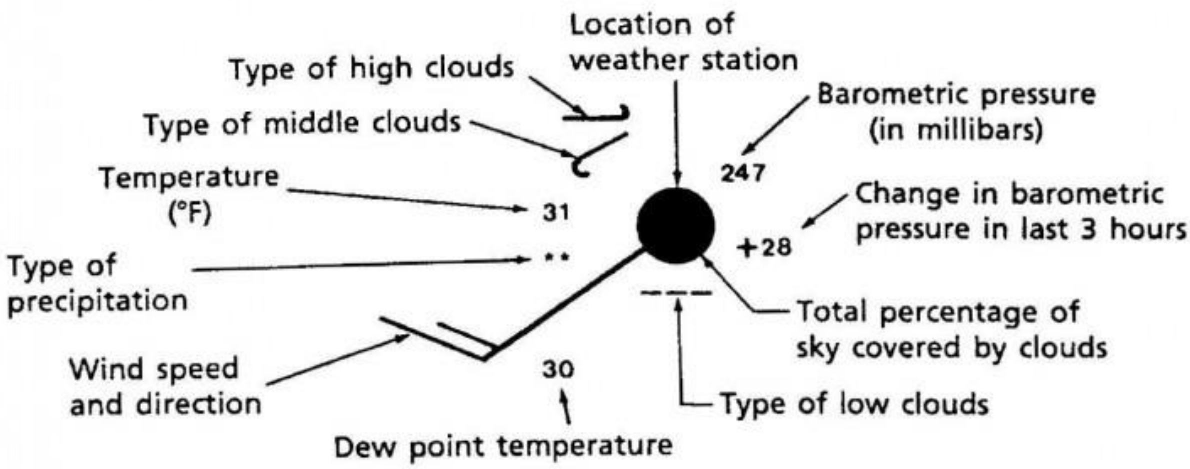
• **High pressure systems associated with good (happy) weather because cooler air from above is descending. ☺ *Blue skies smiling on me…***

• **Low pressure systems associated with bad (lousy) weather because the warm, moist air is rising – and the water vapor condenses. ☹ *Raindrops keep falling on my head…***

• **Coriolis deflects air parcels to the right as they cross the pressure gradient (in the North Hemisphere). This creates cyclonic (counterclockwise) movement around low pressure systems.**



Weather Map Symbols (Simplified Version)



SYMBOLS USED IN PLOTTING REPORT

Precipitation	Wind speed and direction	Sky coverage	Some types of high clouds
Fog	0 calm	No cover	Scattered cirrus
Snow	1–2 knots	1/10 or less	Dense cirrus in patches
Rain	3–7 knots	2/10 to 3/10	Veil of cirrus covering entire sky
Thunder-storm	8–12 knots	4/10	Cirrus not covering entire sky
Drizzle	13–17 knots	½	
Showers	18–22 knots	6/10	
	23-27 knots	7/10	
	48-52 knots	Overcast with openings	
	1 knot = 1.852 km/h	Complete overcast	

Some types of middle clouds	Some types of low clouds	Fronts and pressure systems	
Thin altostratus layer	Cumulus of fair weather	(H) or High (L) or Low	Center of high or low pressure system
Thick altostratus layer	Stratocumulus		Cold front
Thin altostratus in patches	Fractocumulus of bad weather		Warm front
Thin altostratus in bands	Stratus of fair weather		Occluded front
			Stationary front