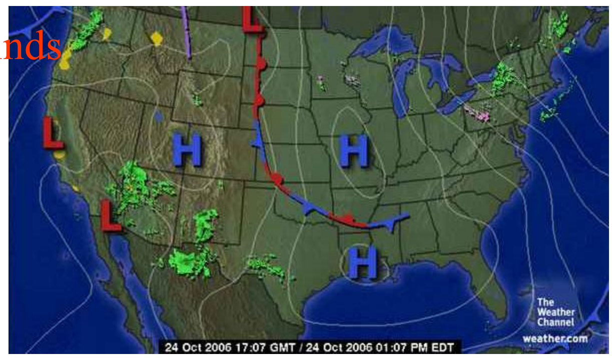
Chapter 6: Air Pressure

Measuring air pressure

Variations due to temperature and water vapor

Development of pressure systems

Generation of winds

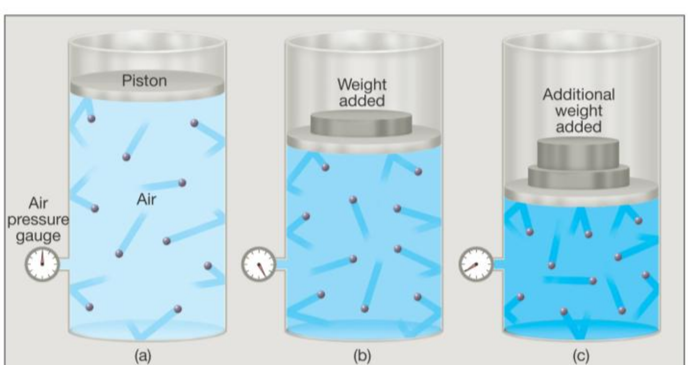


Understanding Air Pressure:

-pressure exerted by the weight of air above

-force exerted against a surface by the continuous collision of gas molecules

-sea level pressure (slp) = 14.7 lbs/in^2, 1kg/cm^2

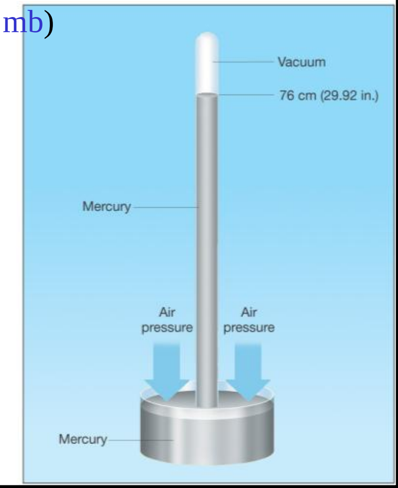


Measuring Air Pressure:

Newtons: unit of force (F = ma, **kg m/s^2**)

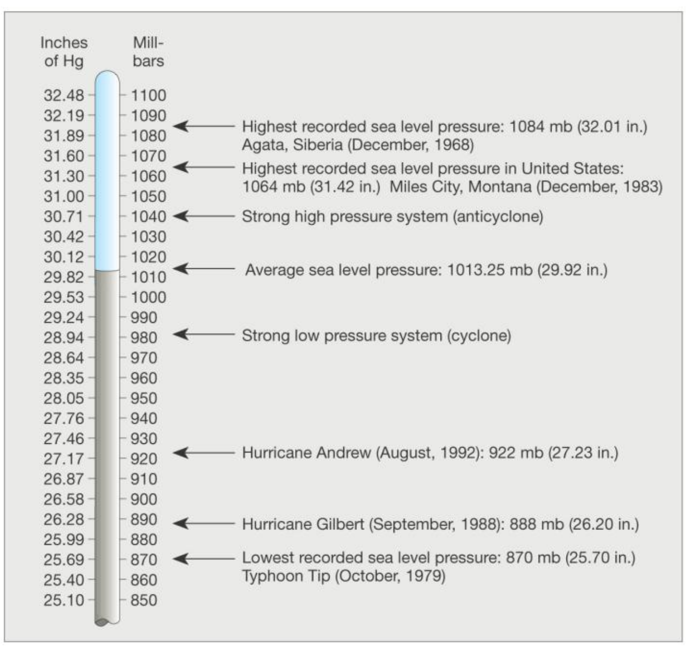
slp: 101,325 Newtons

100 Newtons = 1 milibar (slp = 1013.25 mb)



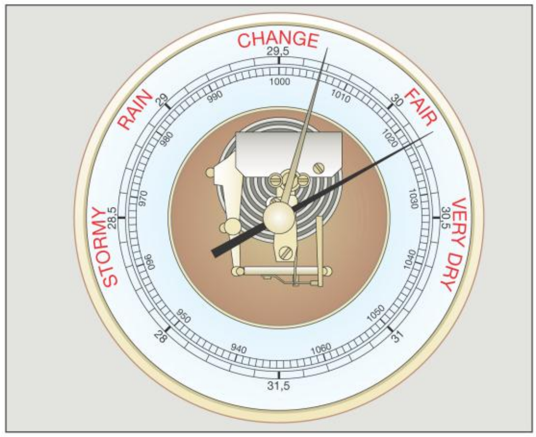
Inches of Mercury: mercury barometer

slp = 29.92 in of mercury



Measuring Air Pressure:

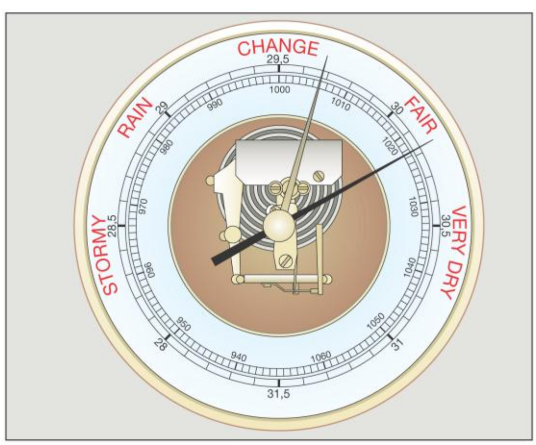
aneroid barometer: metal chamber changes shape based on pressure, changes lever locations



Measuring Air Pressure:

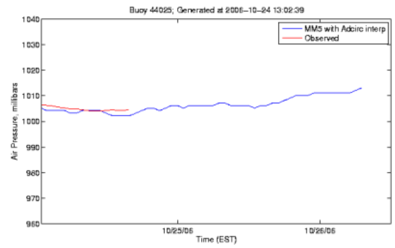
Rising pressure: fair and dry

Falling pressure: rainy, wet, stormy



Measuring Air Pressure:

barograph: continuous log of aneroid barometer measurements



Digital barographs

Pressure Changes With Altitude:

Density decreases w/ altitude

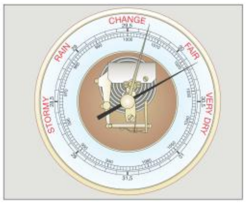
Weight of overlying column of air decreases with altitude

Pressure decreases w/ altitude

halves ~ every 5 km

TABLE 6-1 U.S. standard atmosphere

Height (km)	Pressure (mb)	Temperature (° C)
50.0	0.798	-2
40.0	2.87	-22
35.0	5.75	-36
30.0	11.97	-46
25.0	25.49	-51
20.0	55.29	-56
18.0	75.65	-56
16.0	103.5	-56
14.0	141.7	-56
12.0	194.0	-56
10.0	265.0	-50
9.0	308.0	-43
8.0	356.5	-37
7.0	411.0	-30
6.0	472.2	-24
5.0	540.4	-17
4.0	616.6	-11
3.5	657.8	-8
3.0	701.2	-4
2.5	746.9	-1
2.0	795.0	2
1.5	845.6	5
1.0	898.8	9
0.5	954.6	12
0	1013.2	15



Pressure Altimeter: aneroid barometer marked in meters

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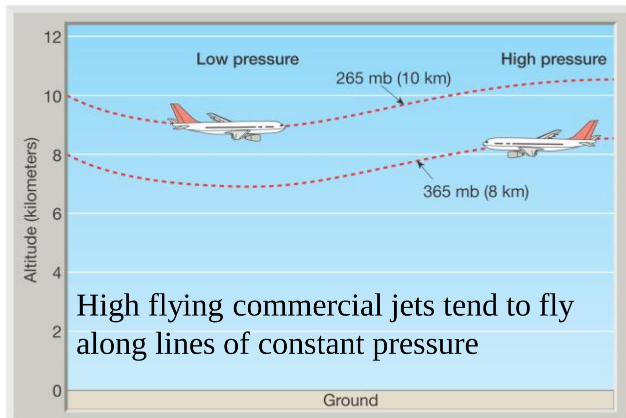
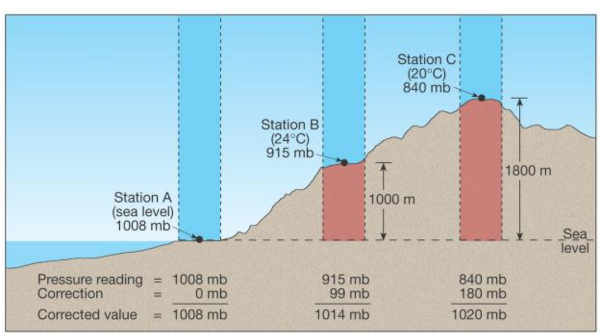


High flying commercial jets tend to fly along lines of constant pressure

Adjusting to Sea-Level Pressure



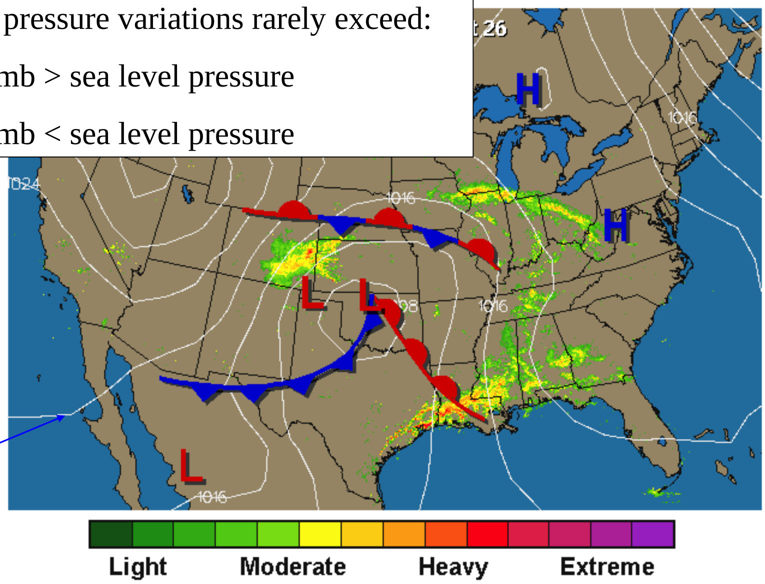
Correction depends on temperature

Horizontal Variations in Air Pressure:

Horizontal pressure variations rarely exceed:

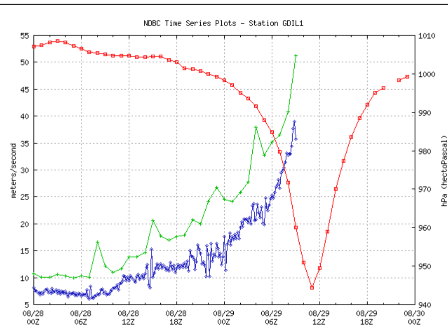
30 mb > sea level pressure

60 mb < sea level pressure



Isobars

Horizontal Variations in Air Pressure:



Pressure Changes with Temperature

Cold air mass temperatures

Low kinetic energy

Slow moving molecules

Closer together

Higher Pressure

Pressure Changes with Temperature

Warm air mass temperatures

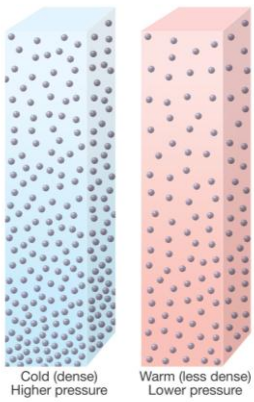
High kinetic energy

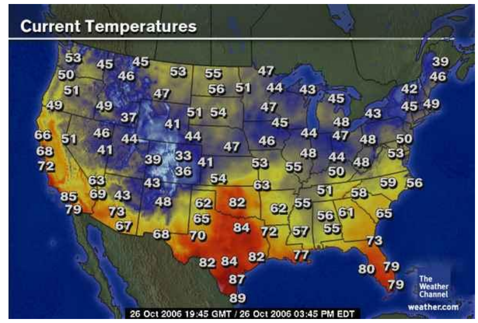
Fast moving molecules

Further apart

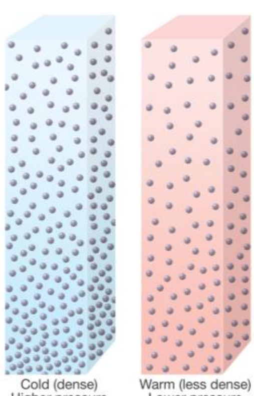
Low Pressure

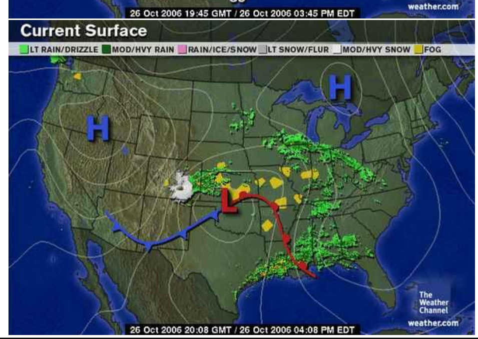
Pressure Changes with Temperature





Pressure Changes with Temperature





Pressure Changes with Water Vapor

1 atomic mass unit (u) ≈ 1.66053886 × 10^{-27} kg

1 **H** Hydrogen 1.00794																	2 **He** Helium 4.003
3 **Li** Lithium 6.941	4 **Be** Beryllium 9.012182											5 **B** Boron 10.811	6 **C** Carbon 12.0107	7 **N** Nitrogen 14.00674	8 **O** Oxygen 15.9994	9 **F** Fluorine 18.9984032	10 **Ne** Neon 20.1797
11 **Na** Sodium 22.989770	12 **Mg** Magnesium 24.3050											13 **Al** Aluminum 26.981538	14 **Si** Silicon 28.0855	15 **P** Phosphorus 30.973761	16 **S** Sulfur 32.066	17 **Cl** Chlorine 35.4527	18 **Ar** Argon 39.948
19 **K** Potassium 39.0983	20 **Ca** Calcium 40.078	21 **Sc** Scandium 44.955910	22 **Ti** Titanium 47.867	23 **V** Vanadium 50.9415	24 **Cr** Chromium 51.9961	25 **Mn** Manganese 54.938049	26 **Fe** Iron 55.845	27 **Co** Cobalt 58.933200	28 **Ni** Nickel 58.6934	29 **Cu** Copper 63.546	30 **Zn** Zinc 65.39	31 **Ga** Gallium 69.723	32 **Ge** Germanium 72.61	33 **As** Arsenic 74.92160	34 **Se** Selenium 78.96	35 **Br** Bromine 79.904	36 **Kr** Krypton 83.80
37 **Rb** Rubidium 85.4678	38 **Sr** Strontium 87.62	39 **Y** Yttrium 88.90585	40 **Zr** Zirconium 91.224	41 **Nb** Niobium 92.90638	42 **Mo** Molybdenum 95.94	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.07	45 **Rh** Rhodium 102.90550	46 **Pd** Palladium 106.42	47 **Ag** Silver 107.8682	48 **Cd** Cadmium 112.411	49 **In** Indium 114.818	50 **Sn** Tin 118.710	51 **Sb** Antimony 121.760	52 **Te** Tellurium 127.60	53 **I** Iodine 126.90447	54 **Xe** Xenon 131.29
55 **Cs** Cesium 132.90545	56 **Ba** Barium 137.327	57 **La** Lanthanum 138.9055	72 **Hf** Hafnium 178.49	73 **Ta** Tantalum 180.9479	74 **W** Tungsten 183.84	75 **Re** Rhenium 186.207	76 **Os** Osmium 190.23	77 **Ir** Iridium 192.217	78 **Pt** Platinum 195.078	79 **Au** Gold 196.96655	80 **Hg** Mercury 200.59	81 **Tl** Thallium 204.3833	82 **Pb** Lead 207.2	83 **Bi** Bismuth 208.98038	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
87 **Fr** Francium (223)	88 **Ra** Radium (226)	89 **Ac** Actinium (227)	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (263)	107 **Bh** Bohrium (262)	108 **Hs** Hassium (265)	109 **Mt** Meitnerium (266)	110 (269)	111 (272)	112 (277)	113	114				

Water molecule lighter than N_2 and O_2

Adding water vapor displaces heavier molecules

Air pressure decreases

Airflow and Pressure:

Keep in mind atmosphere is 3Dimensional

Regions of Convergence = pressure increases

Regions of Divergence = pressure decreases

Summarize:

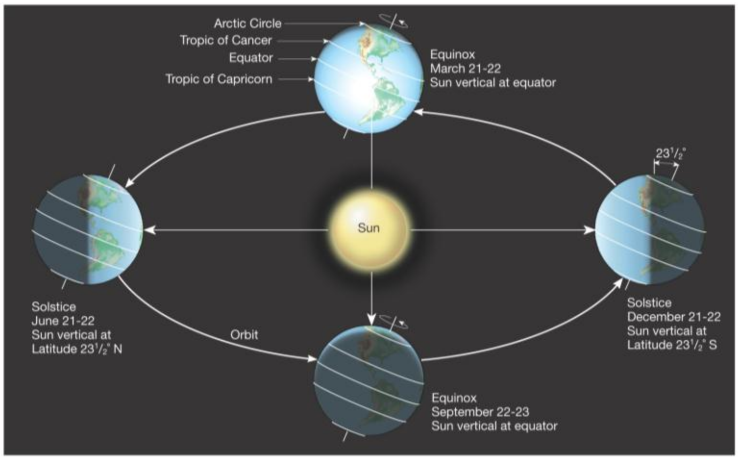
Cool, dry = high pressure

Warm, moist = low pressure

<u>Wind</u>:

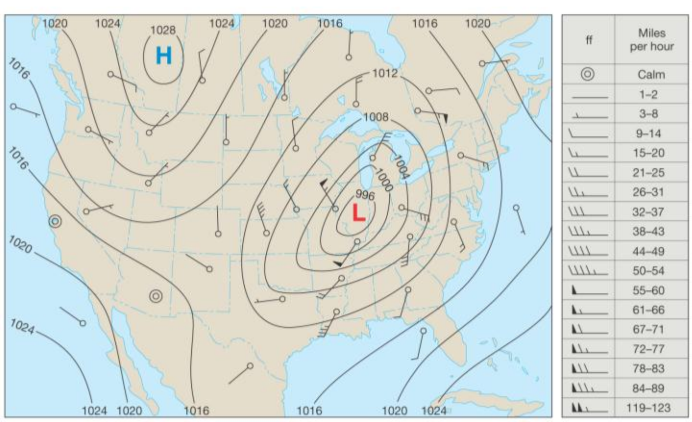
Horizontal movement (advection) of air

Results from horizontal differences in air pressure



<u>Factors Affecting Wind</u>:

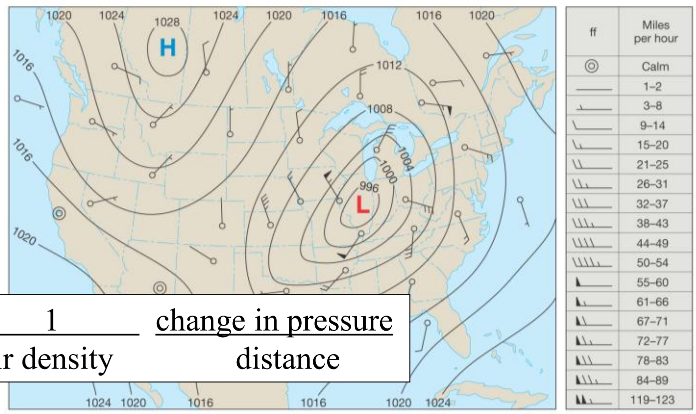
1. **The pressure gradient force**
2. **The Coriolis force**
3. **friction**



Pressure Gradient:

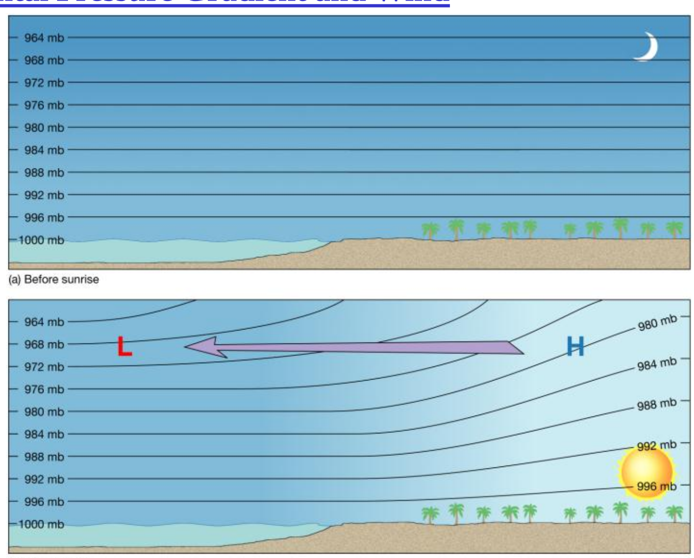
Pressure change occurring over a given distance

Closely spaced isobars = steep pressure gradient, stronger winds

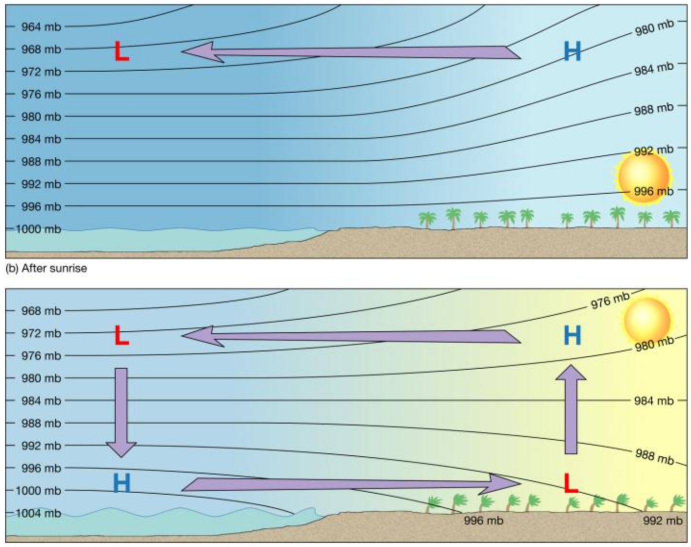


$$\text{PGF} = \frac{1}{\text{air density}} \; \frac{\text{change in pressure}}{\text{distance}}$$

Horizontal Pressure Gradient and Wind



Horizontal Pressure Gradient and Wind



(b) After sunrise

(c) Sea breeze established

Vertical Pressure Gradient

balanced by gravitational force

hydrostatic balance or equilibrium

large scale vertical movements are slow

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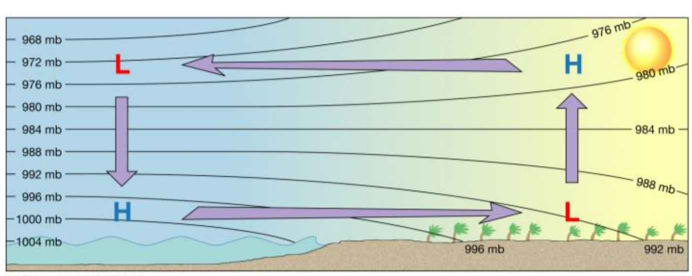
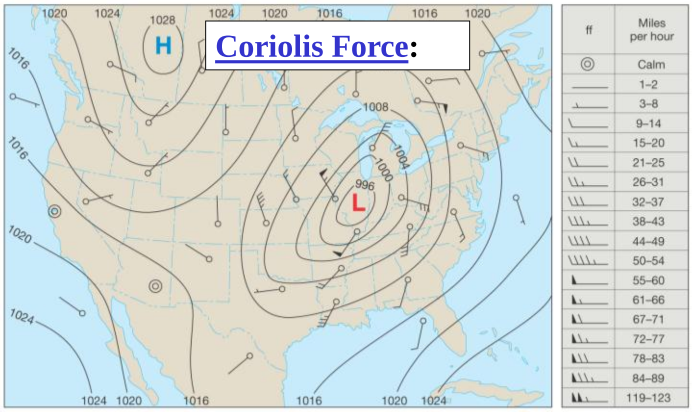
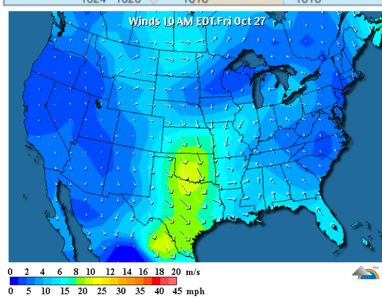
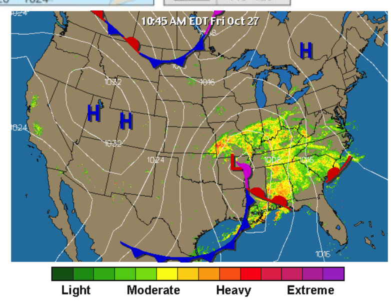


(c) Sea breeze established

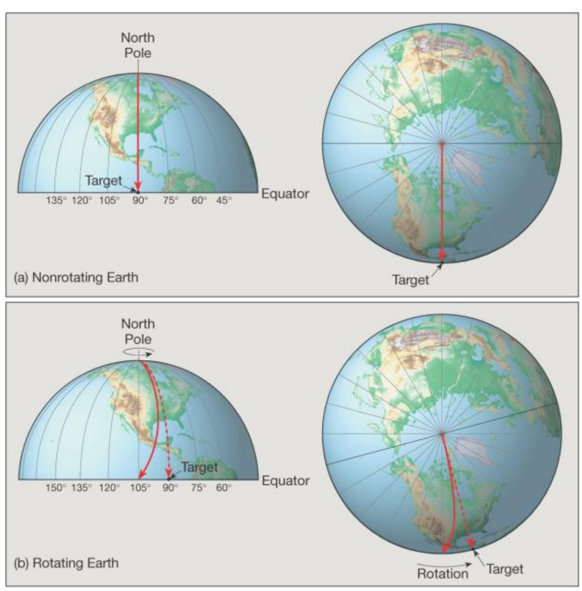
Coriolis Force:



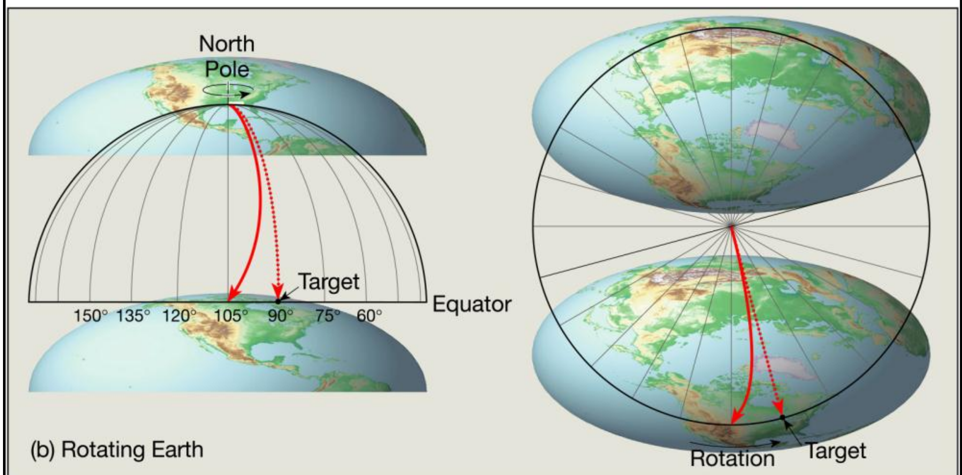




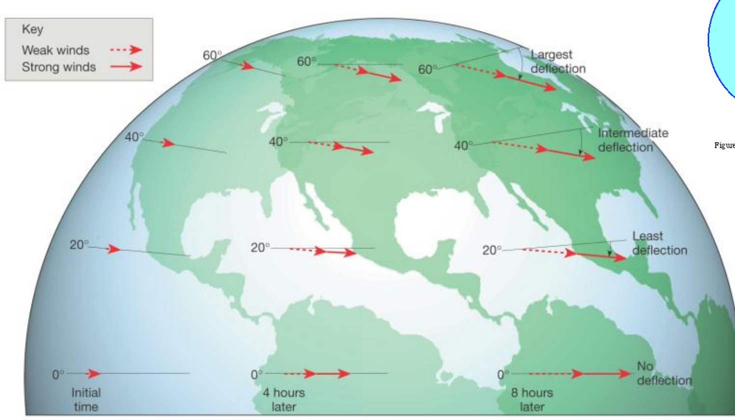
Coriolis Force:



Coriolis Force: Ex. 1hr move from pole to equator



Equatorial Circumference 40,076 km



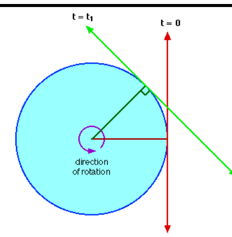


Figure 2: Change in the direction of "East" in a rotating system.

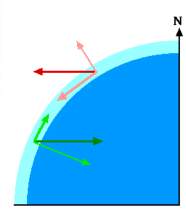


Figure 3: Coriolis deflection broken into radial and tangential (North/South) components. The view is of a cross-section of the Earth. The bold arrows are the actual deflection (red for eastbound, green for westbound), and the pale arrows are the radial and tangential components.

Coriolis Force:

$$Fc = 2\nu\Omega \ \sin(\phi)$$

ν = wind speed

Ω = angular velocity

ϕ = latitude

F = m(kg)a(m/s^2)

F/m = a (m/s^2)

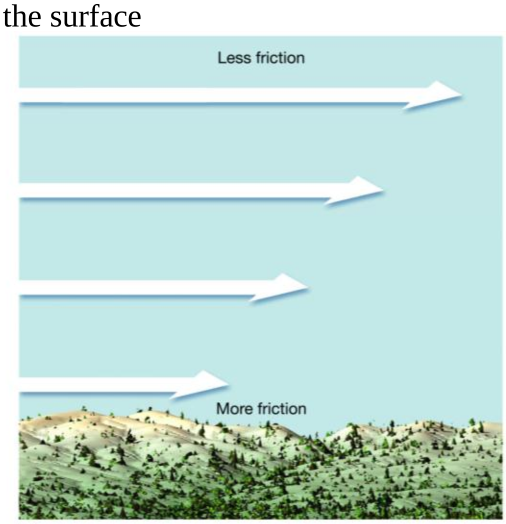
TABLE 6-A Coriolis force for three wind speeds at various latitudes

Wind Speed		Latitude (ϕ)			
		0°	20°	40°	60°
(m/s)	(kph)		Coriolis Force (cm/s^2)		
5	18	0	0.025	0.047	0.063
10	36	0	0.050	0.094	0.126
25	90	0	0.125	0.235	0.316

Effect of Friction

Greatest near surface

Negligible a few km above the surface



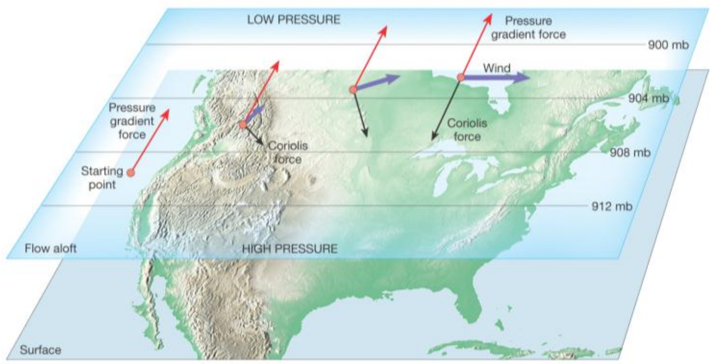
(a)

Winds Aloft and Geostrophic Flow

pressure gradient force = (balanced by) coriolis force

geostrophic balance, reach equilibrium, no acceleration

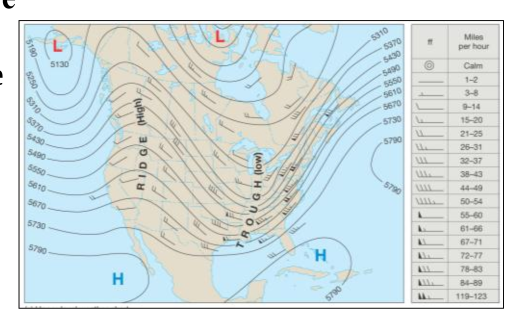
geostrophic winds flow in a straight line parallel to isobars

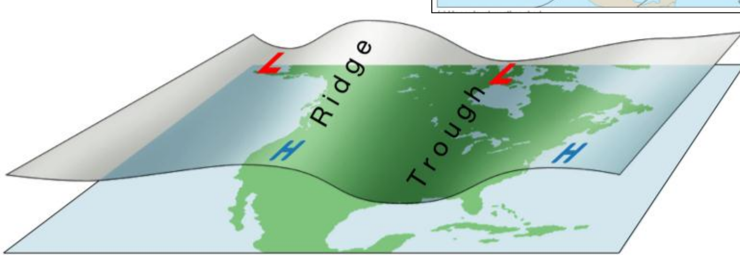


Upper Level Geostrophic Winds

Ridge = high pressure

Trough = low pressure



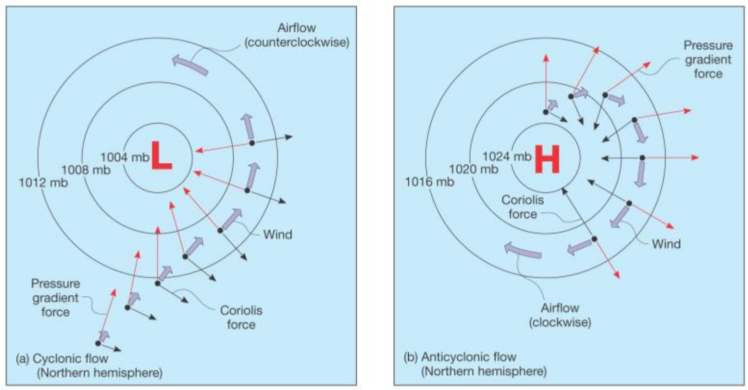


(b) Representation of upper-level chart

Geostrophic Winds

High = anticyclones, clockwise flow (NH)

Low = cyclones, counter clockwise flow

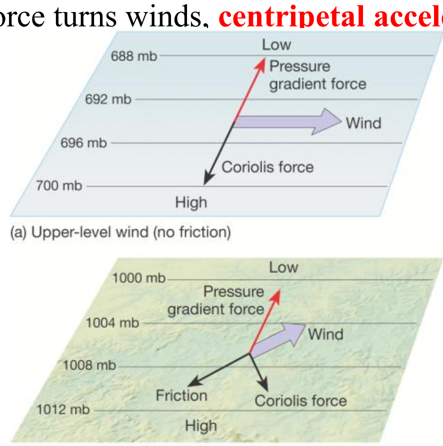


Gradient Winds

Near the surface friction slows winds

pressure gradient force exceeds **corriolis force**

Unbalance force turns winds, **centripetal acceleration**



(a) Upper-level wind (no friction)

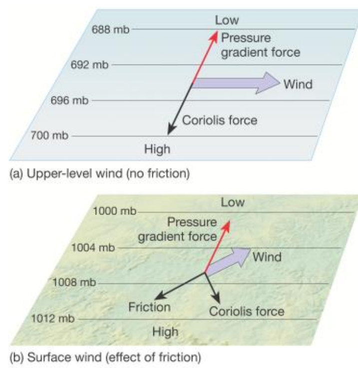
(b) Surface wind (effect of friction)

Surface Winds

Friction = reduces speed, weakens coriolis force

ocean = 2/3 geostrophic speed (10-20° isobars)

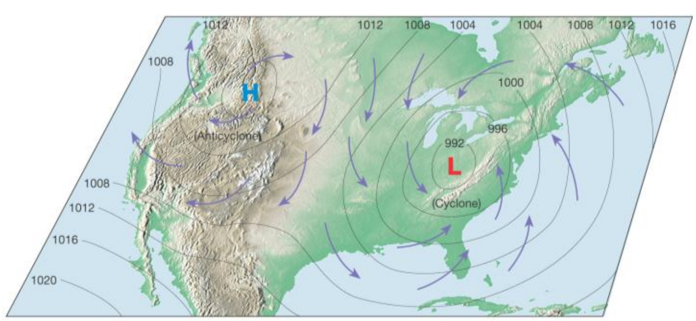
rugged terrain = 1/2 geostrophic speed (45° isobars)



Surface H & L Pressure Systems

High = **divergence**, net flow of air away from the center

Low = **convergence**, net flow of air toward the center

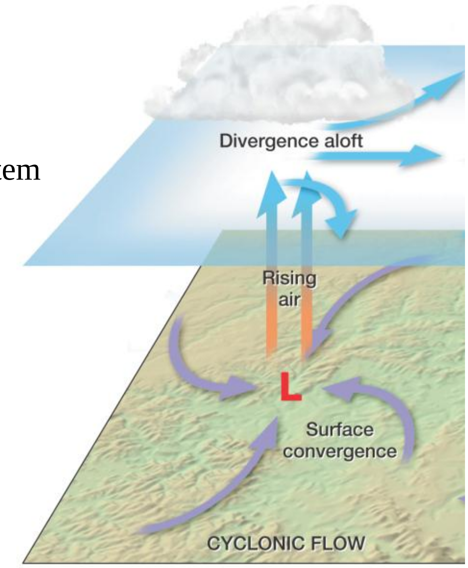


Low Pressure System: vertical motion

surface convergence

rising column of air (**inc pres**)

divergence aloft to maintain system

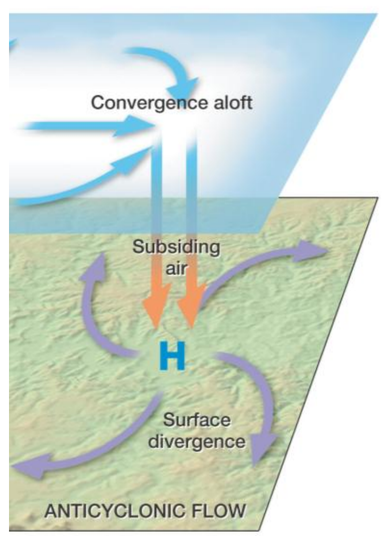


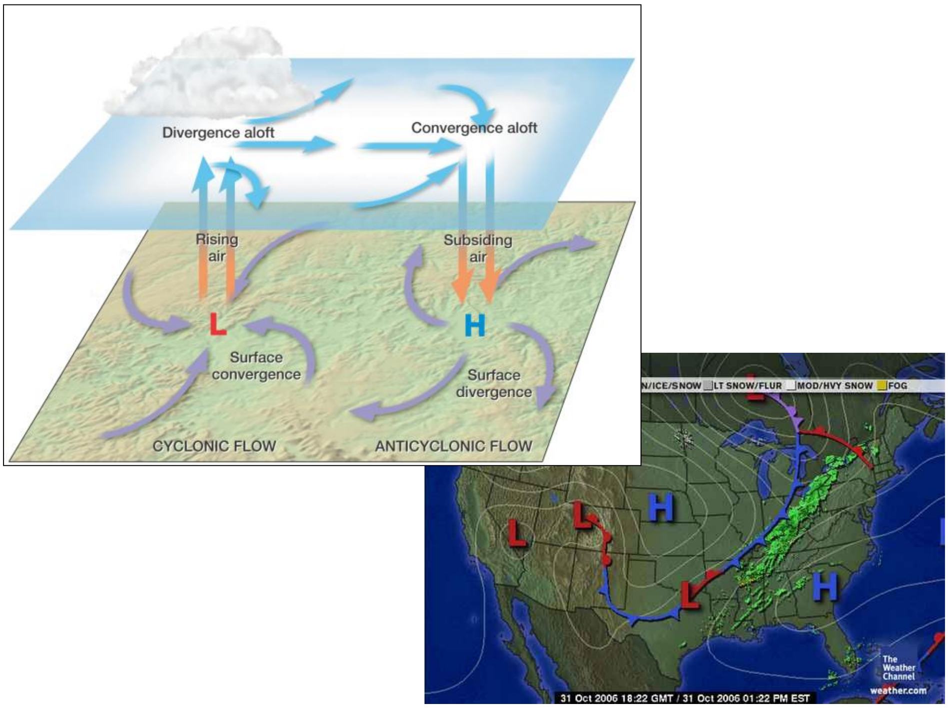
High Pressure System: vertical motion

surface divergence

descending column of air
(**adiabatic warming, clear skies**)

convergence aloft to maintain system

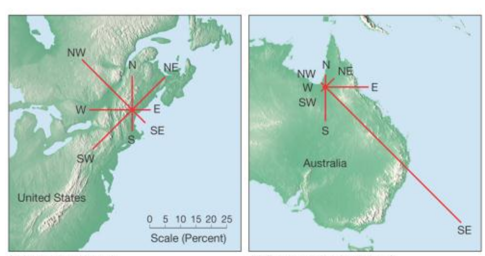




Wind Measurement

Wind Vane
Prevailing Wind
Cup Anemometer
Aerovane

Wind Rose



(a) Westerlies (winter) (b) Southeast Trades (winter)