NATS 101
Section 13: Lecture 14

Air Pressure

What is pressure?

The concept was already introduced early in the course, so let’s review a bit…

What is pressure?

Blaise Pascal

Pressure (P) is the force per unit area (A)

$$P = \frac{F}{A}$$

SI Units: m^{-1} kg s^{-2}= Pa (Pascal)

The typical unit of atmospheric pressure is millibars

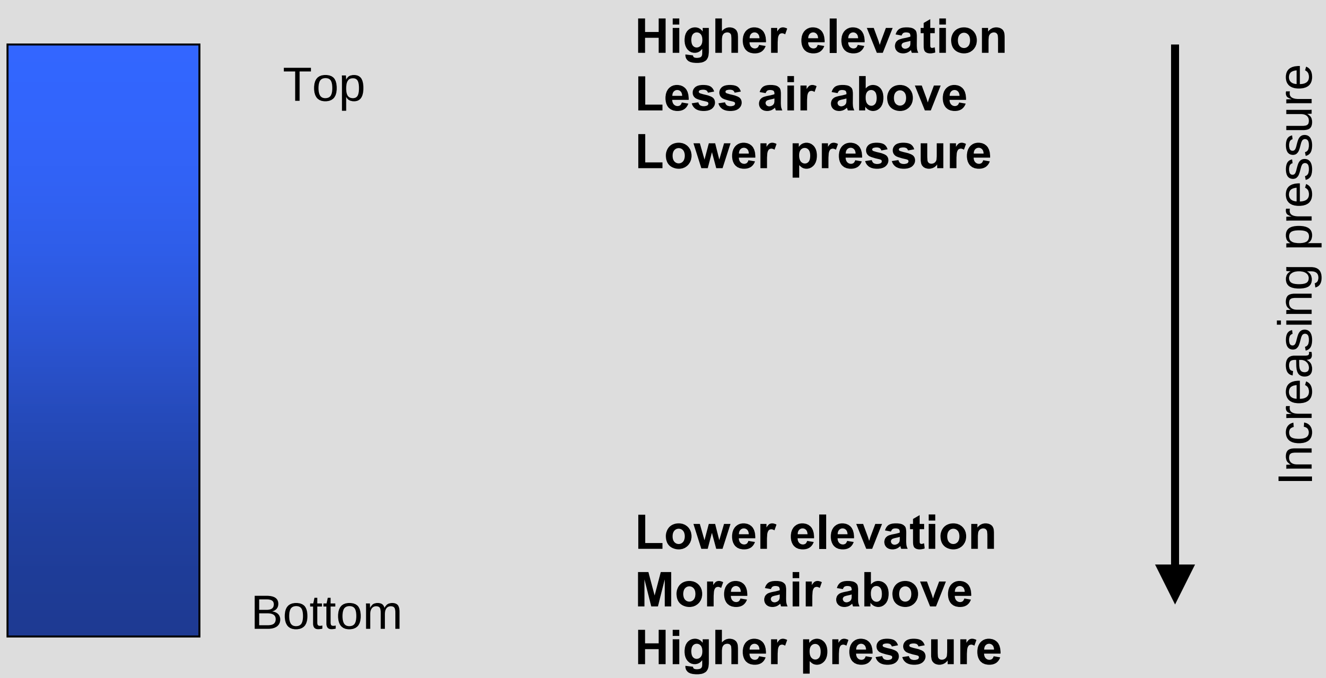
1 mb = 100 Pa

The air pressure at the surface of the Earth at sea level is defined as 1 Atmosphere (Atm):

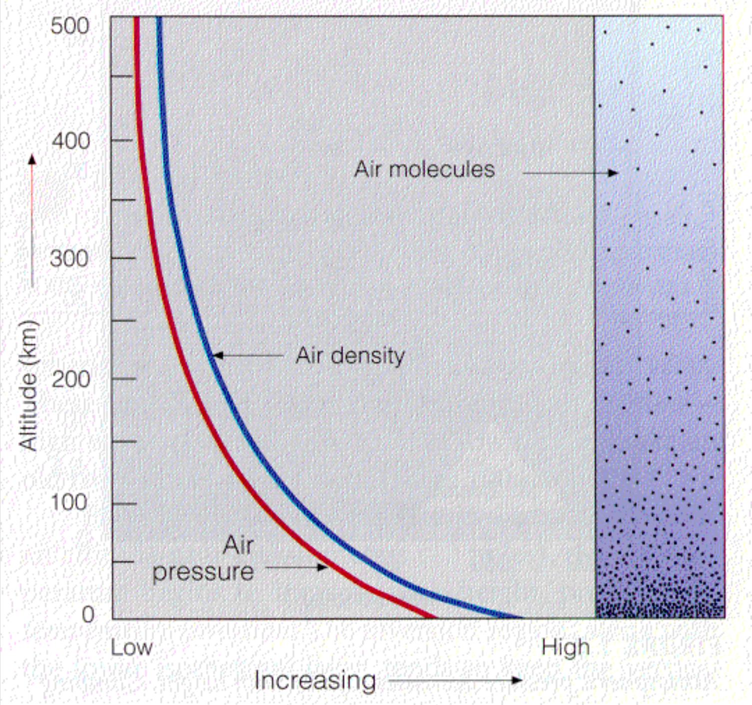
"Atmosphere" → 1 Atm = 1013 mb = 29.92 in Hg

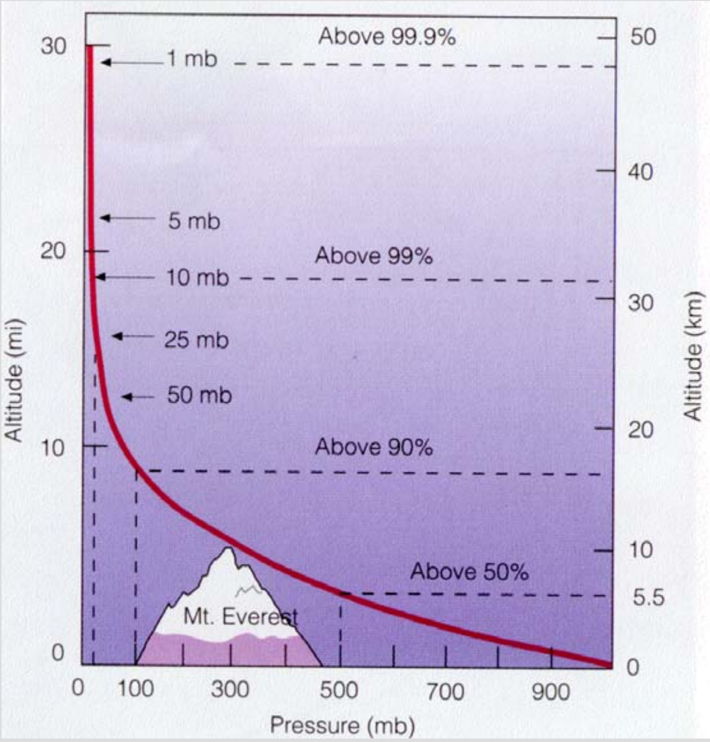
Air pressure

Given the mathematical definitions we've already discussed, ***air pressure can be thought of as the weight of a column of air above you***.



Change in density and pressure with height





Density and pressure decrease ***exponentially*** with height. For each 16 km in altitude, the pressure decreases by a factor of 10..

Ideal Gas Law: Form for Atmosphere

$$P = \rho R T$$

P **= Pressure (Pa or mb)**

V **= Volume (m^3)**

ρ = Density of the gas (kg m^{-3})

R = Constant (dependent on the specific gas or gas mixture)

T = Temperature (K)

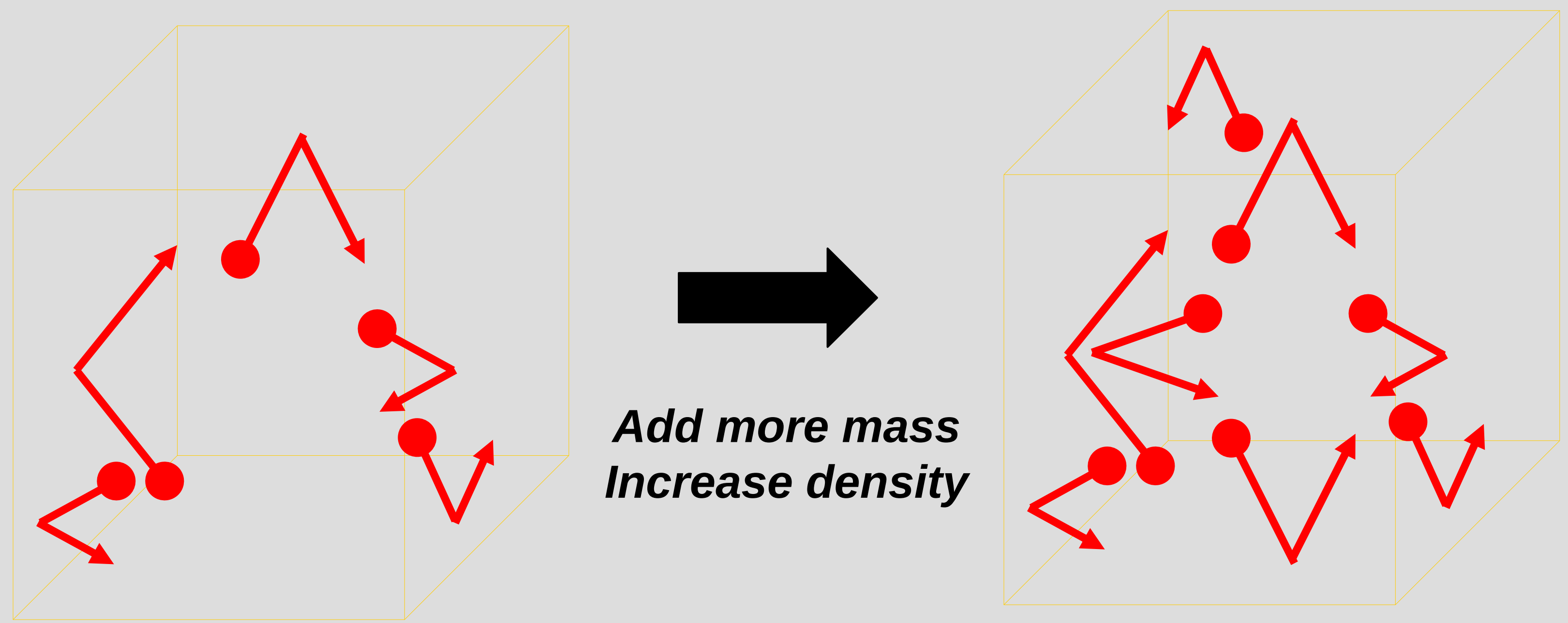
Ideal gas law can be broken down into two parts if either the temperature, density, or pressure is held constant.

Boyle's Law: temperature constant

Charles' Law: density constant

Pressure constant

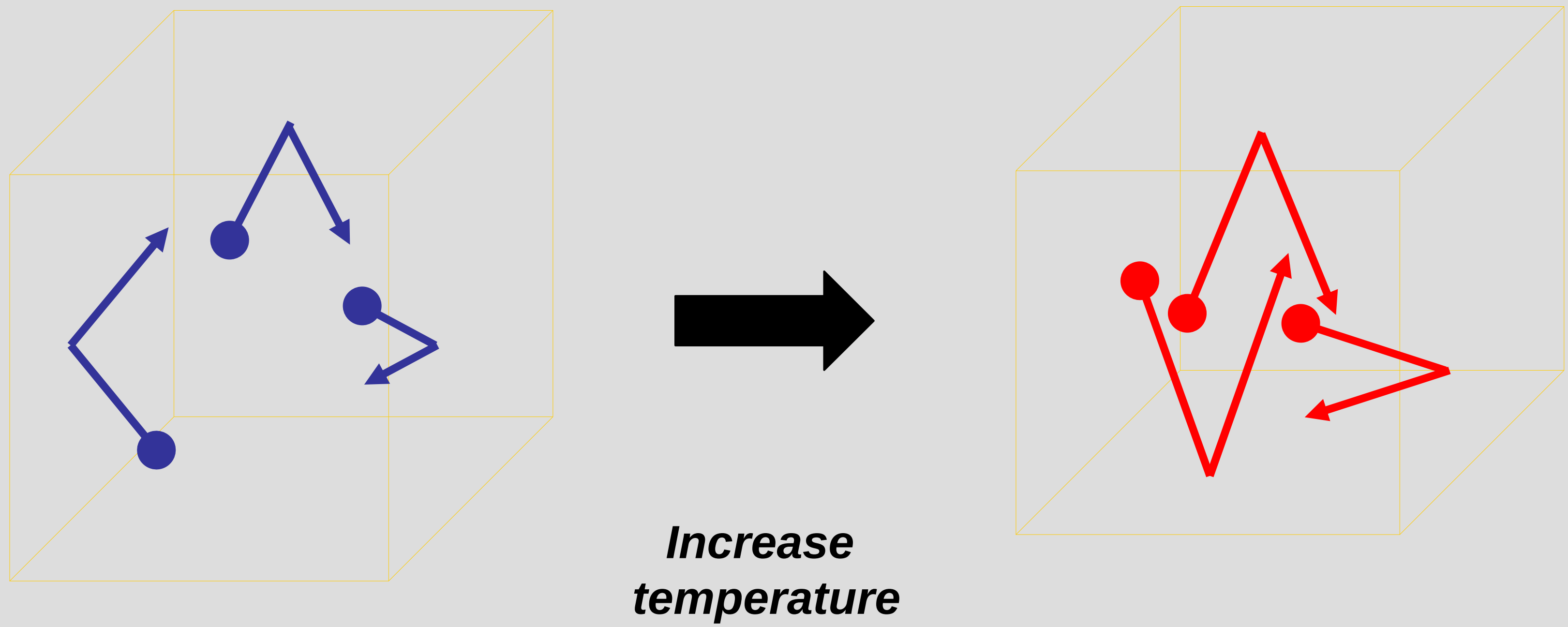
Boyle's Law: temperature constant



Adding more molecules, or increasing the density, increases the number of collisions on the walls of the box → Pressure increases.

PRESSURE IS PROPORTIONAL TO DENSITY

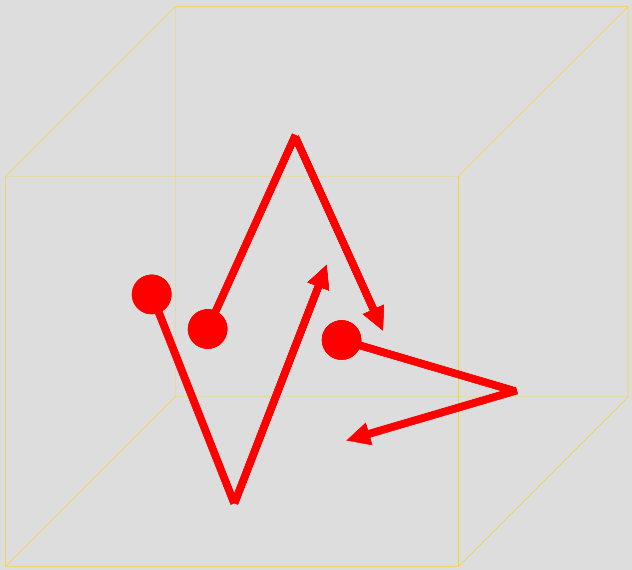
Charles' Law: density constant

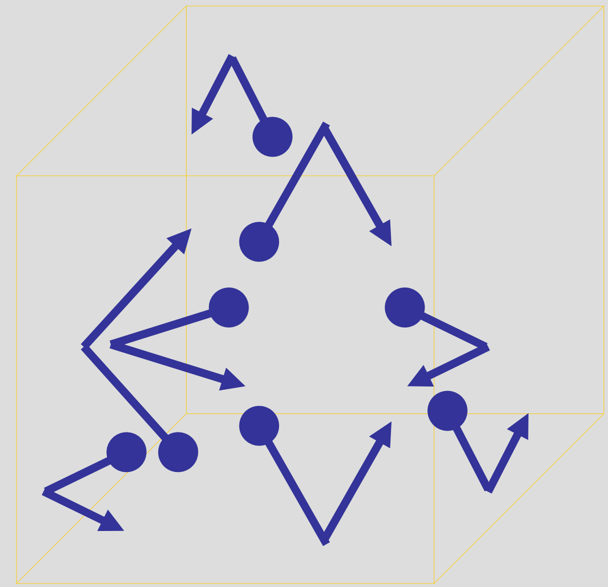


Increasing the temperature increases the kinetic energy of the molecules in the box, so they collide with the walls with more force. → Pressure increases.

PRESSURE IS PROPORTIONAL TO TEMPERATURE.

Pressure is constant

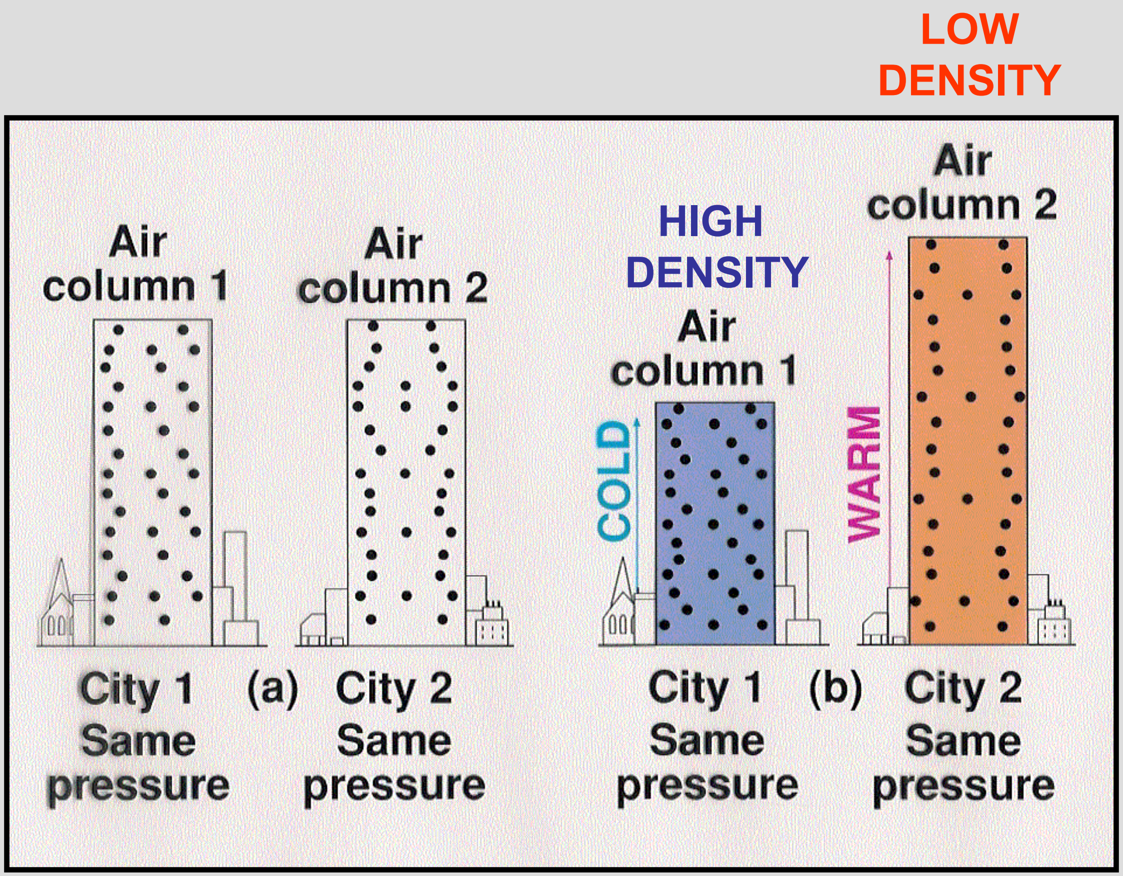




Hotter temperature: fewer number of molecules required to exert same pressure because they have more kinetic energy

Colder temperature: greater number of molecules required to exert same pressure they have less kinetic energy.

TEMPERATURE IS *INVERSELY* PROPORTIONAL TO DENSITY (e.g. 1/ρ)

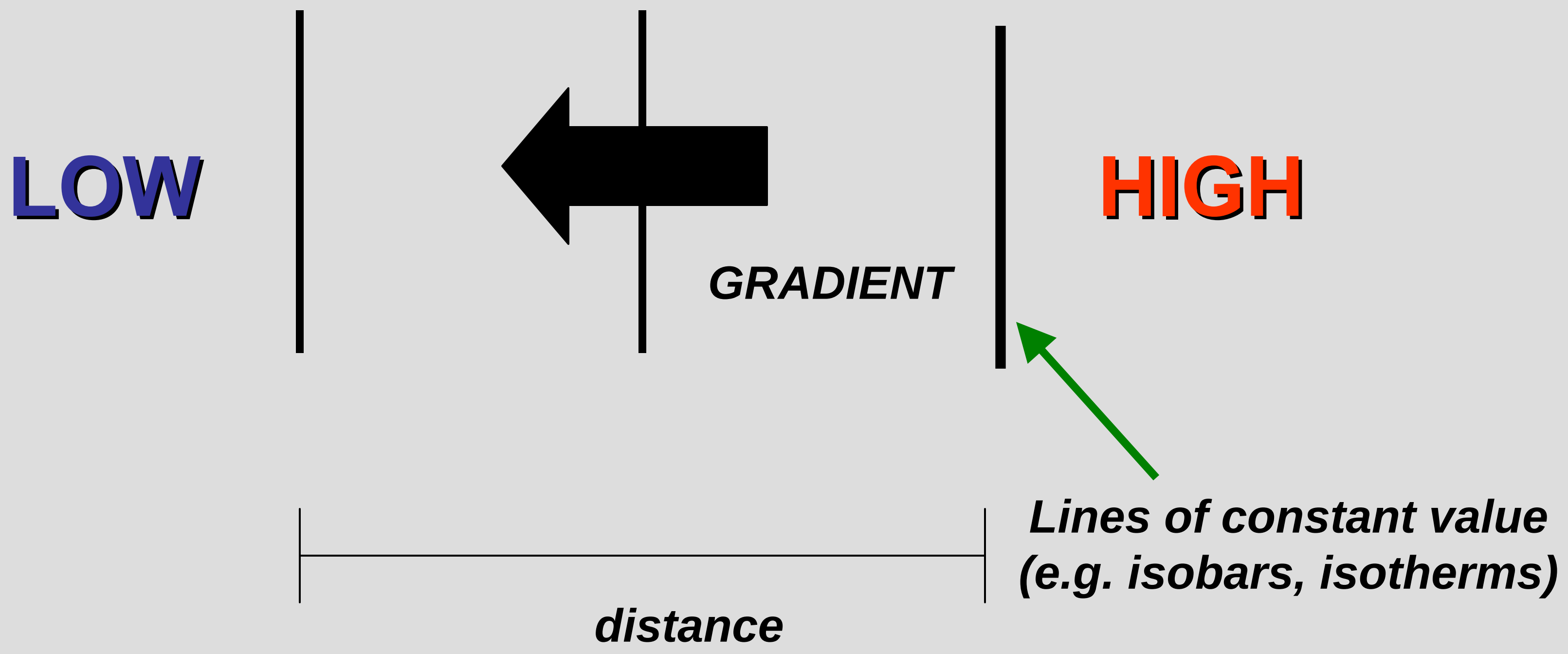


Cool column of air above City #1 → density increases and column shrinks.

Warm column of air above City #2 → density decreases and column expands.

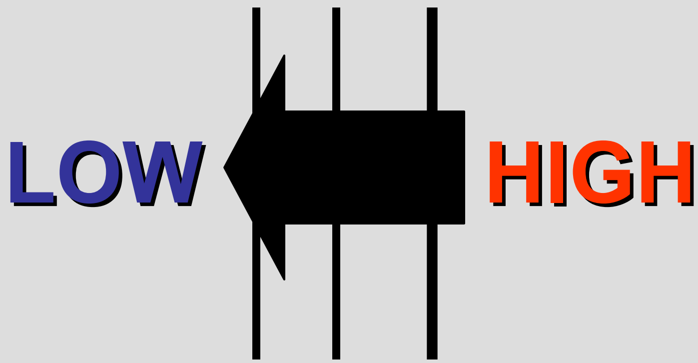
CREATES DIFFERENCES IN PRESSURE BETWEEN THE TWO COLUMNS AT THE SAME HEIGHT, OR A PRESSURE GRADIENT.

<u>Gradient</u>: The change in the value of a quantity over a distance.



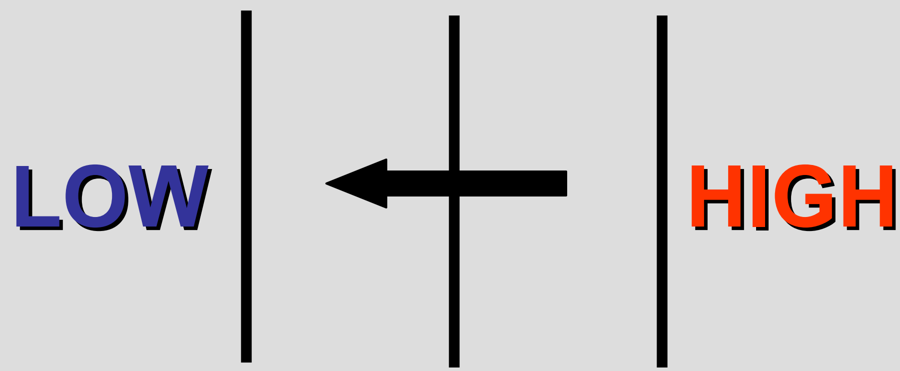
CONCEPT IS FUNDAMENTAL TO UNDERSTANDING DYNAMICS OF THE ATMOSPHERE!

STRONG GRADIENT

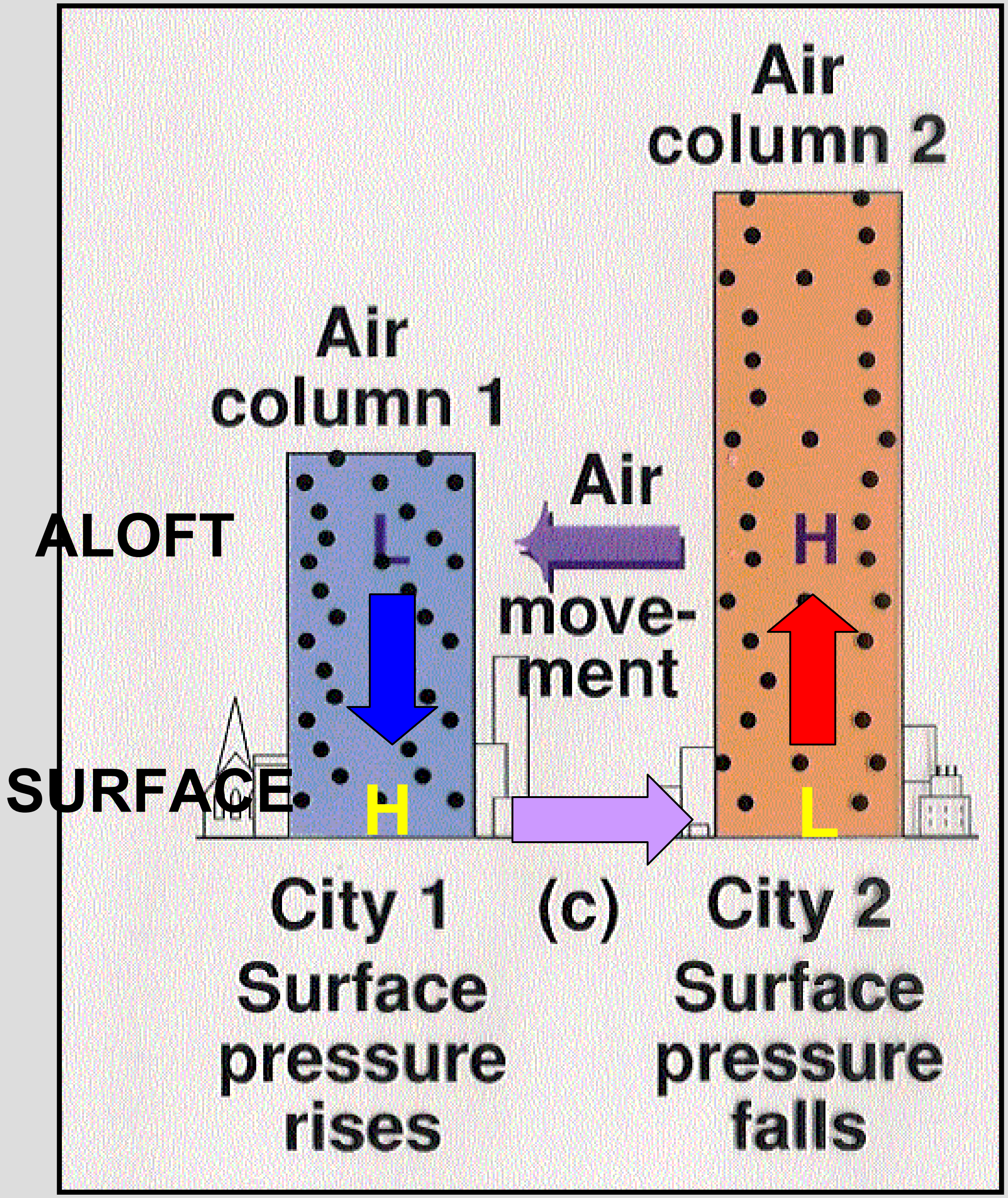


Large change over a short distance.

WEAK GRADIENT



Small change over a large distance



ALOFT

Cold column → relatively less air above. LOW PRESSURE.

Warm column → relatively more above. HIGH PRESSURE

Result: Air moves from warm column to cold column, changing the total amount of mass of air in each.

SURFACE

Cold column → more mass above. HIGH PRESSURE

Warm column → less mass above. LOW PRESSURE.

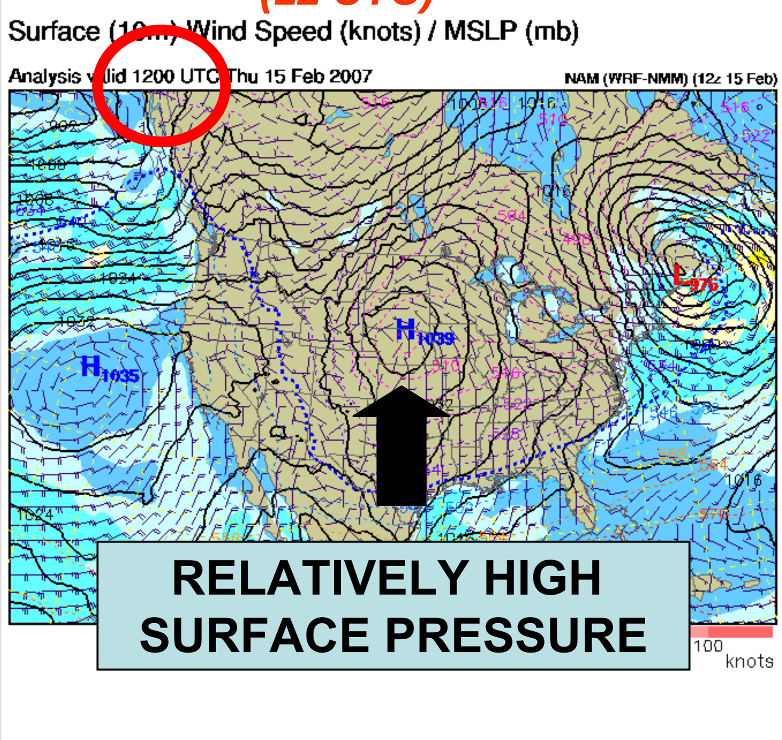
Another Flashback…

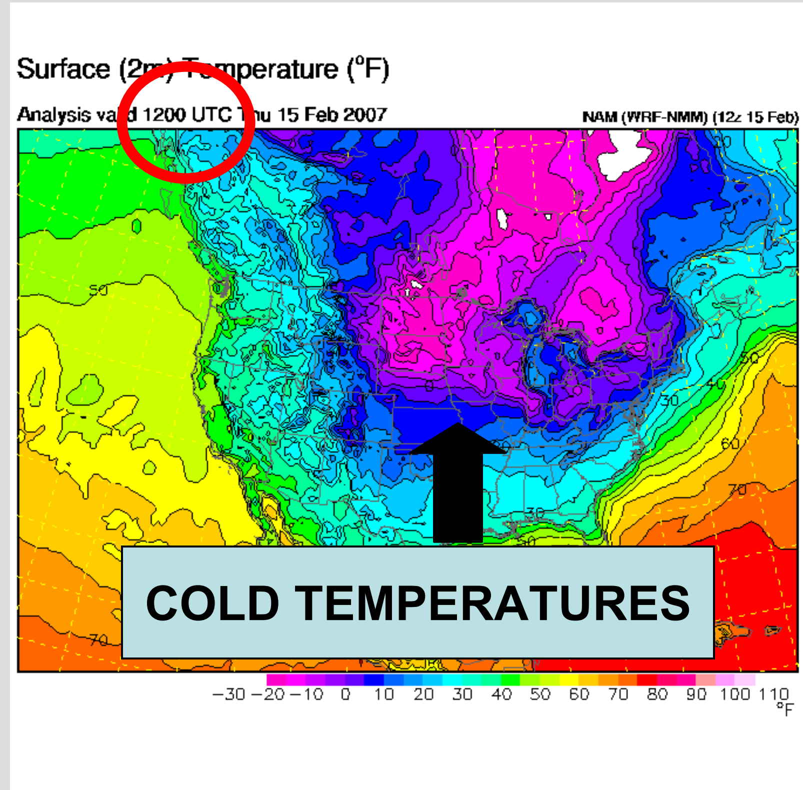
CONVECTION

MASS MOVEMENT OF FLUID OR GAS

Surface Pressure and Temperature

ABOUT SUNRISE (12 UTC)

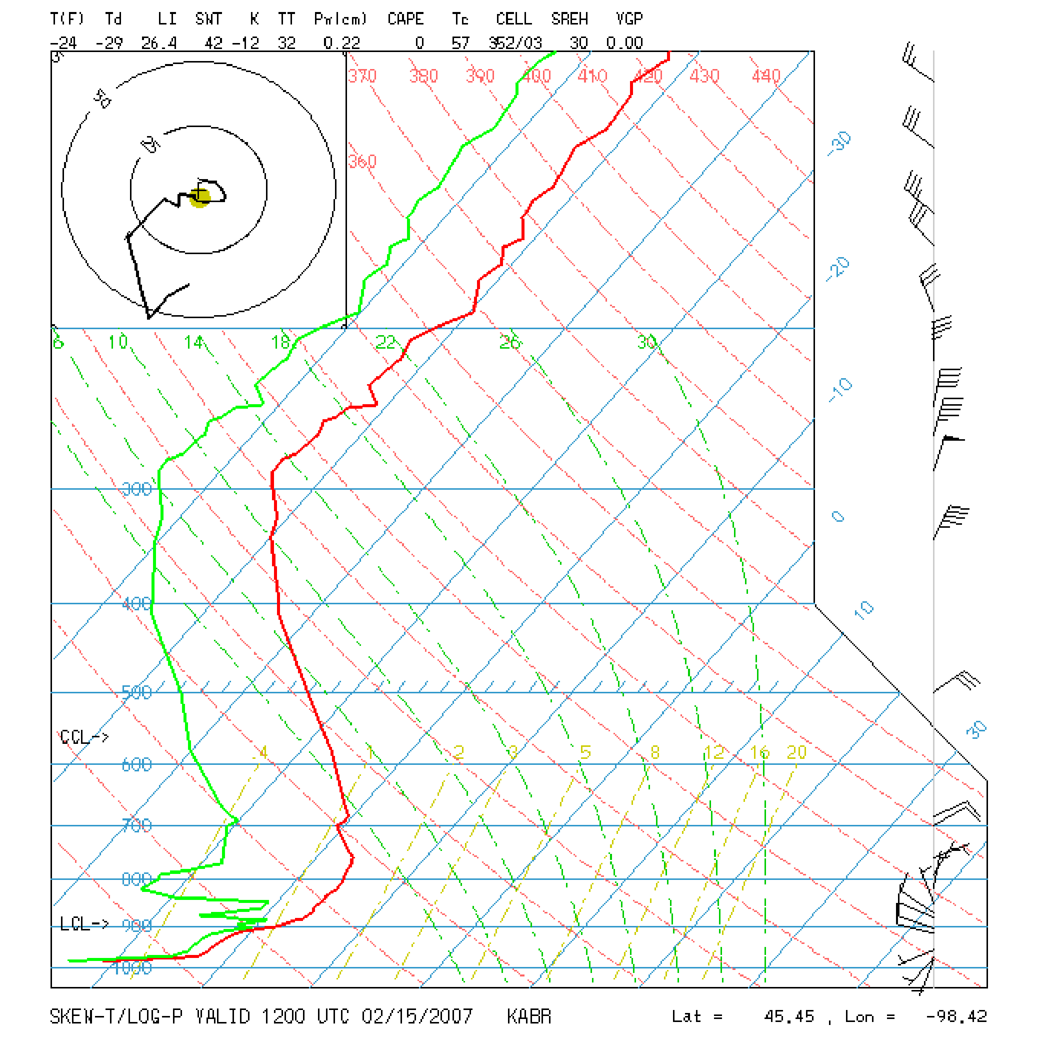




High pressure at the surface is typically associated with cold temperatures.

In winter this cold, dense air originates over the interior of continents (e.g. Siberia and Canada). ***Remember why?*** **So the highest surface pressures typically occur there.**

Upper Air Sounding Under Arctic High

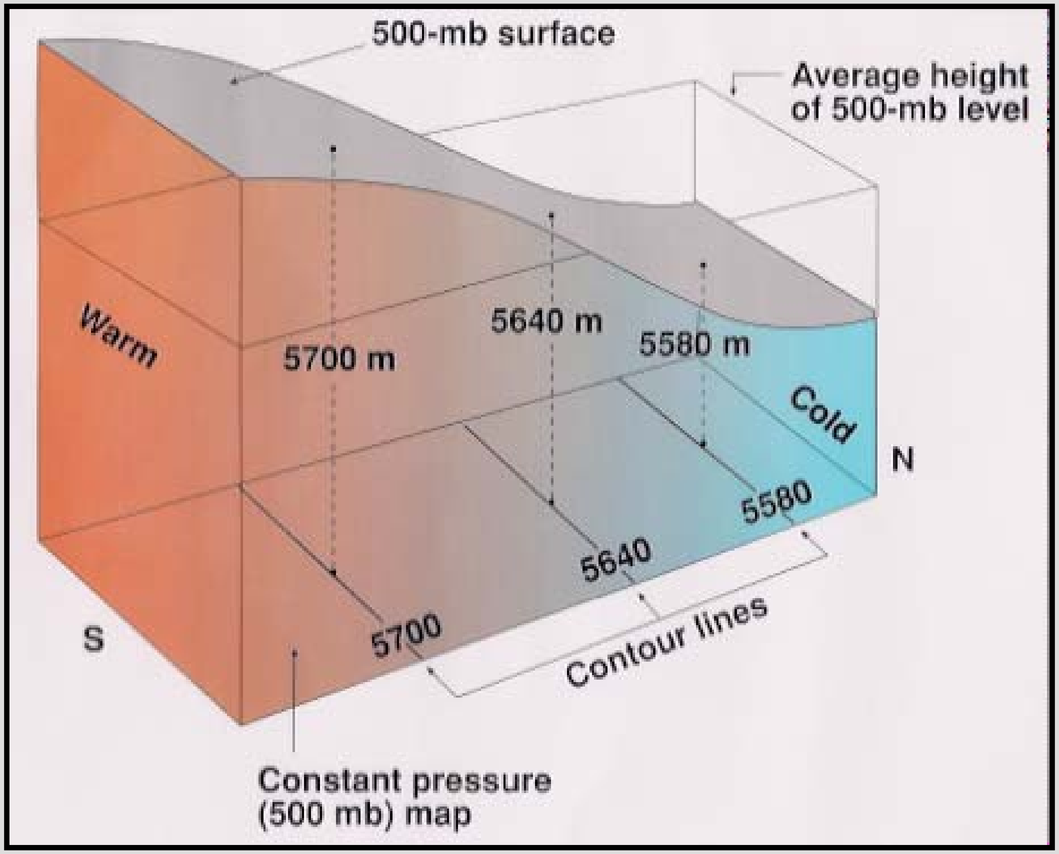


Another flashback:

What is the process that makes the surface temperatures so low in a situation like this?

Hint: no wind + no clouds…

Upper Level Charts

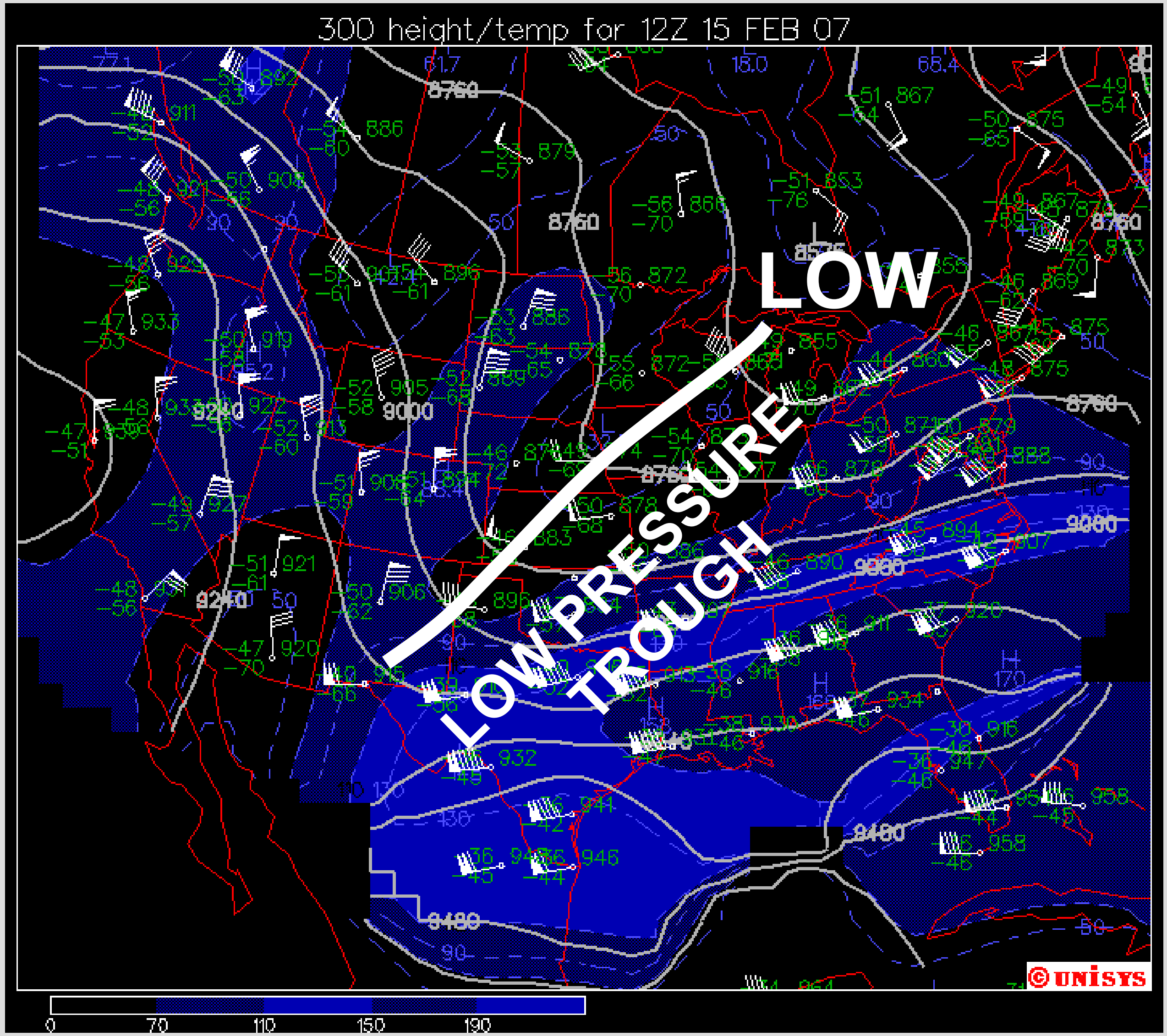


Based on the height of a pressure surface in the atmosphere.

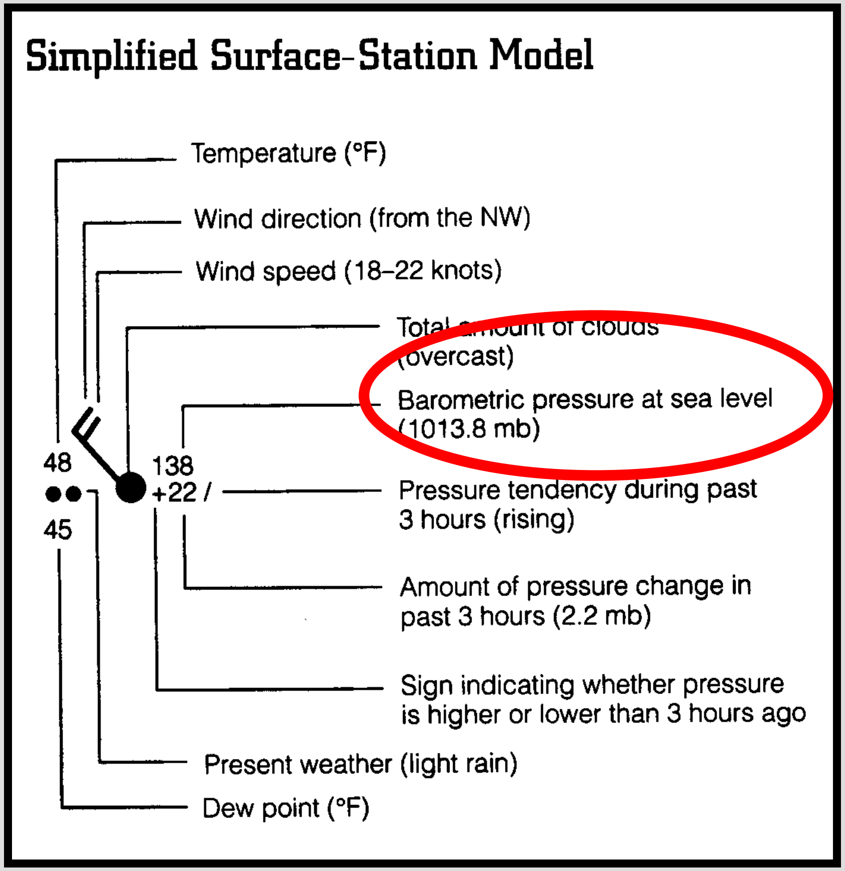
Warmer Column: Pressure surface is higher

Colder Column: Pressure surface is lower.

Upper Level Chart for Surface Arctic High Example (300-mb)



Flashback
Sea-Level Pressure in Station Models

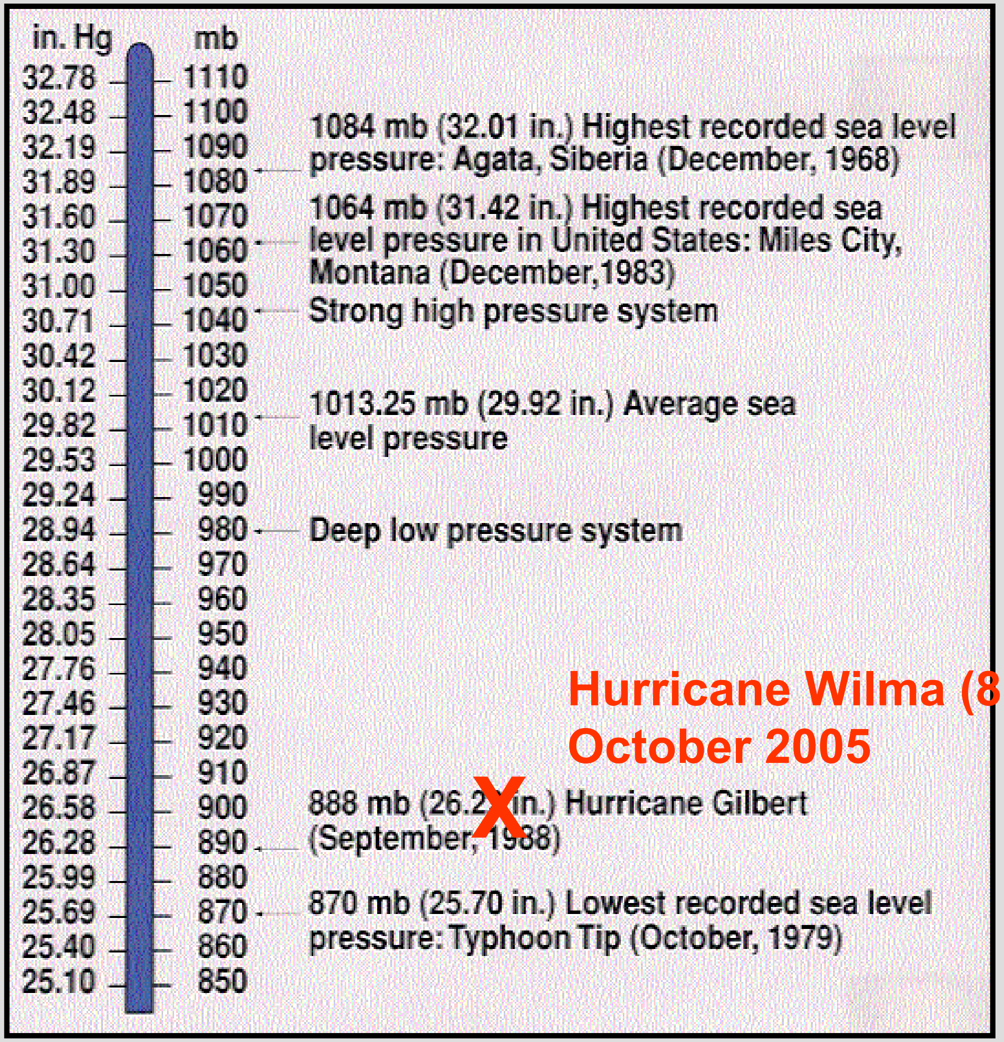


Two "tricks" to the pressure reading:

You have to know the "typical" range of sea level pressure on Earth to be able to plot it right (which we talked about before)

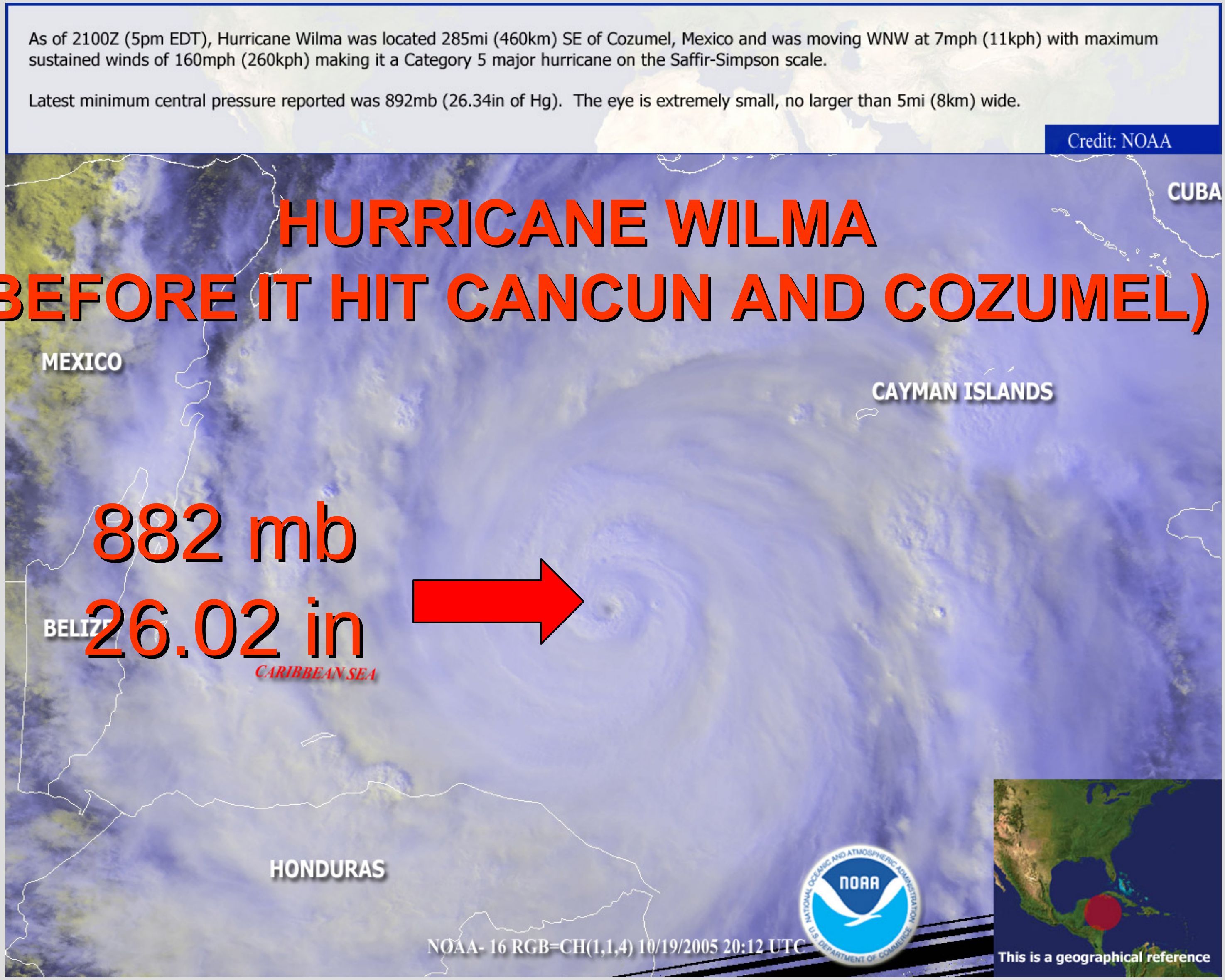
This reading has been adjusted to account for the altitude of the station.

Range of Sea Level Pressure



Hurricane Wilma (882 mb, 26.04 in)
October 2005

HURRICANE WILMA
(BEFORE IT HIT CANCUN AND COZUMEL)



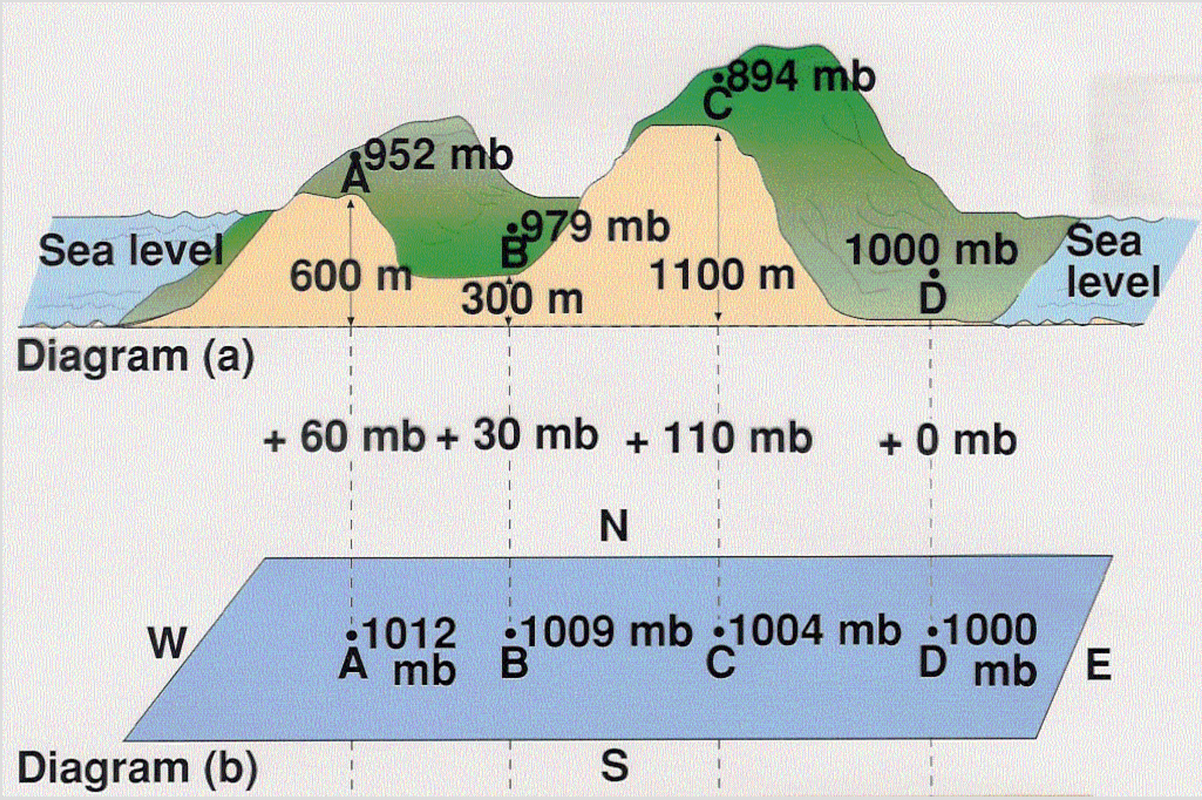
882 mb

26.02 in

NOAA image

OBVIOUSLY…We're not taking barometer readings on a ship in the eye of that monster!! We'll talk about how they do with dropsondes—and why hurricanes have such low pressure—later in the semester.

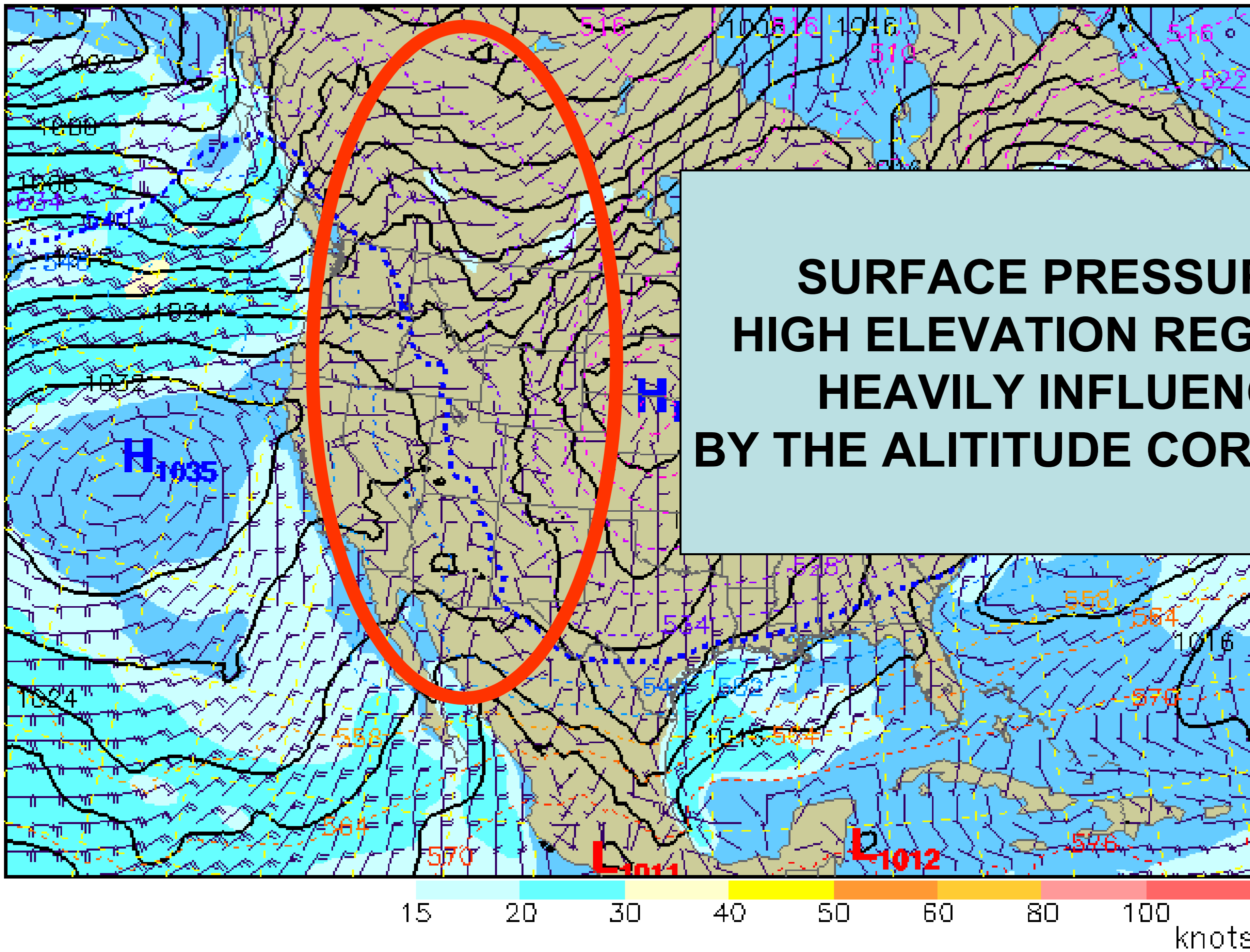
Station sea level pressure
Altitude Adjustment



The altitude adjustment for the pressure is about 10 mb for every 100 m increase in elevation. Not perfect…and may introduce error!

Surface (10m) Wind Speed (knots) / MSLP (mb)

Analysis valid 1200 UTC Thu 15 Feb 2007 NAM (WRF-NMM) (12z 15 Feb)

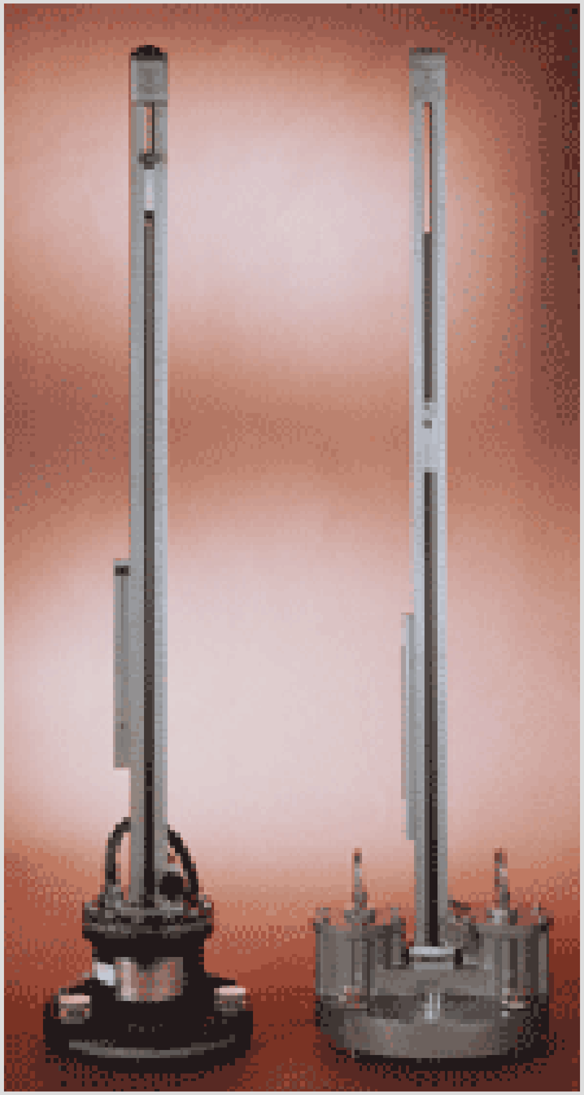


SURFACE PRESSURE IN HIGH ELEVATION REGIONS IS HEAVILY INFLUENCED BY THE ALITITUDE CORRECTION!

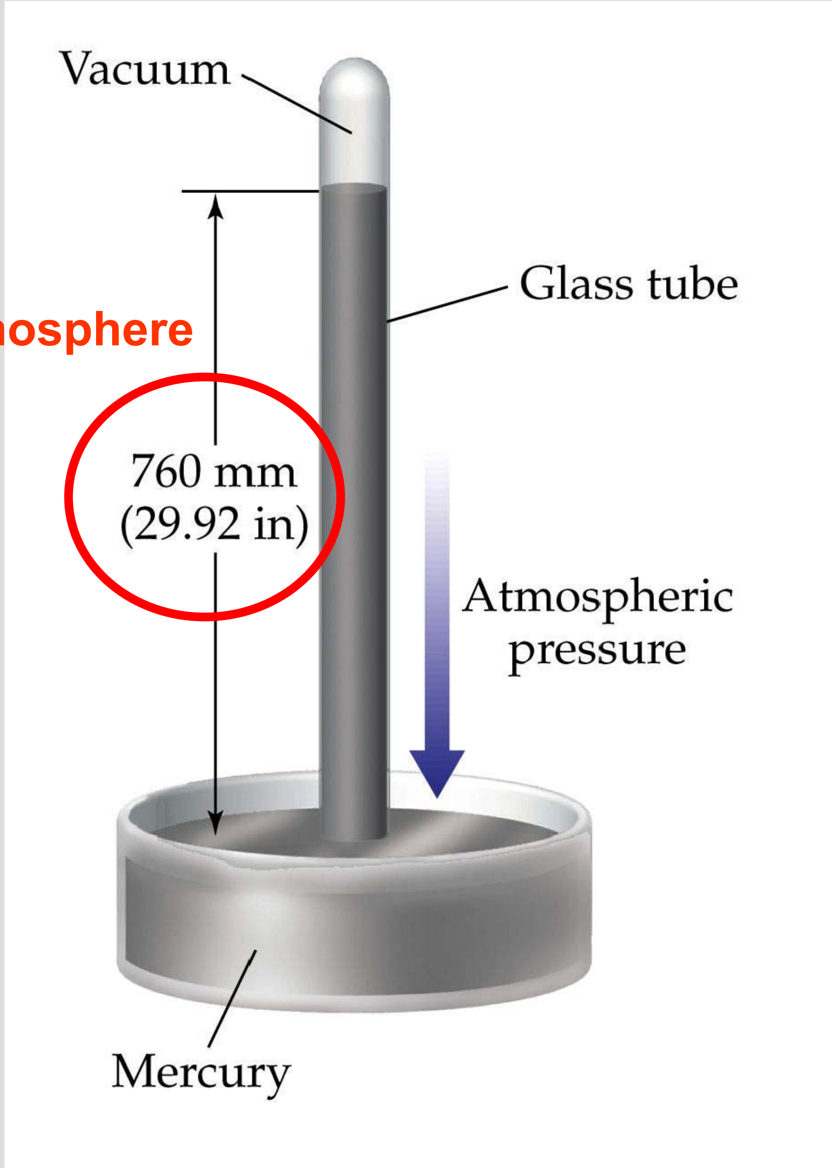
Measuring Air Pressure

Mercury barometer
Aneroid barometer

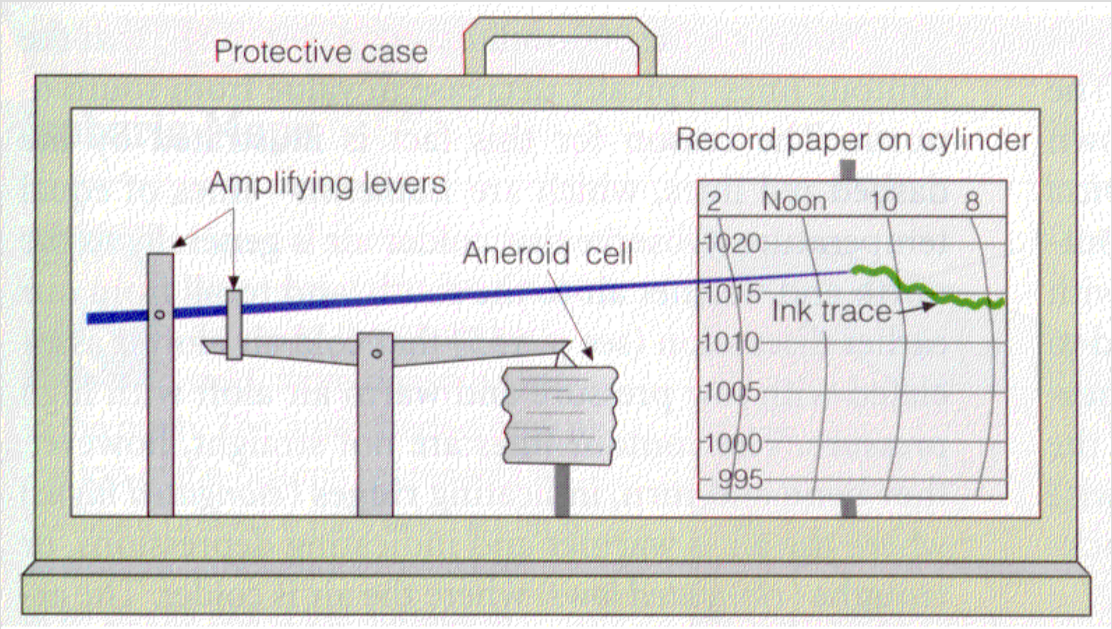
Mercury Barometer



One atmosphere



Aneroid Barometer



Aneroid cell is partially evacuated
Contracts as pressure rises
Expands as pressure falls
Changes recorded by revolving drum

Summary of Lecture 14

Reviewed the basic concepts of pressure from earlier in the course.

Ideal gas low relates pressure to density and temperature. Breaking this down (Boyles law, Charles law, etc.) we find:

- **Pressure is proportional to density**
- **Pressure is proportional to temperature**
- **Temperature is inversely proportional to density**

Heating (cooling) a column of air expands (contracts) it and decreases (increases) density. The pressure gradient will force air to go from high to low pressure.

The example of an Arctic high was used to illustrate these concepts. At the surface, high pressure is associated with very cold temperatures.

Upper air charts show the height of a pressure surface above the ground. In the Arctic high example, because the air is cold it had a relatively low height at 300-mb.

Station model sea-level pressure must be adjusted for altitude.

Air pressure can be measured using a mercury barometer and aneroid barometer.

Reading Assignment and Review Questions

Reading: Chapter 8, pp. 202-216 (8th ed.)
pp. 204-208 (9th ed.)