Weather and Climate
Jim Keller & Paul Belanger

Classroom assistant: Fritz Ihrig

Week 1: January 15th , 2019

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INTRODUCTIONS – Part 1

- **Fritz Ihrig; classroom assistant, liaison to OLLI:**
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  - **Announcements:**
    - **Logistics: bathrooms, breaks, no open containers**
    - **other**
- **Paul Belanger:**
  - **PEBelanger@glassdesignresources.com**
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- **Jim Keller:**
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INTRODUCTIONS – part 2

- **Intro**:
  - Yourselves – what brought you here
  - Jim Keller:
  - Paul Belanger:
    - http://denverclimatestudygroup.com/ (OLLI tab)
    - Web page - 11 year history; Resume in "About" tab
    - Facebook - https://www.facebook.com/denverclimatestudygroup/

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Weather and Climate

- **The following are screenshots OR supplemental slides for you to reinforce the first week's coverage**
- **Weekly email with slides for notes – please print or review;**
- **also posted at http://denverclimatestudygroup.com/?page_id=24**

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Weather vs. Climate

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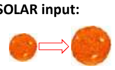
What determines Earth's Longer-term climate

- **Primary Influences (3):**
  1. **SOLAR input:**



0.9% less
100 My ago

& sunspots

Tilt; 40,000 years:
21.5 – 24.5 degrees

20,000 years:
summer season

100,000 years
400,000 years

  2. **Greenhouse Gases (GHGs)**
  (gases that absorb radiation in or out)

  3. **Albedo**
  (reflectivity:30-85%)

- **Feedbacks:** INTERNAL dynamics and responses
  - e.g. higher water vapor in atm. due to heating of atm

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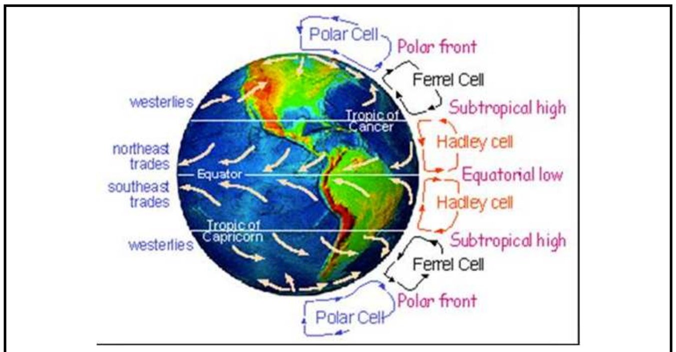

http://maps.unomaha.edu/Peterson/geog1000/Notes/Notes_Exam1/Seasons&Climate.htm

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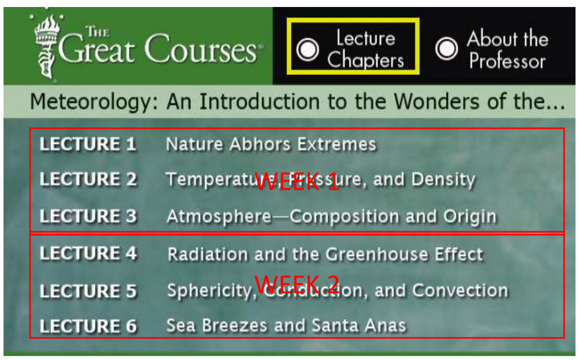

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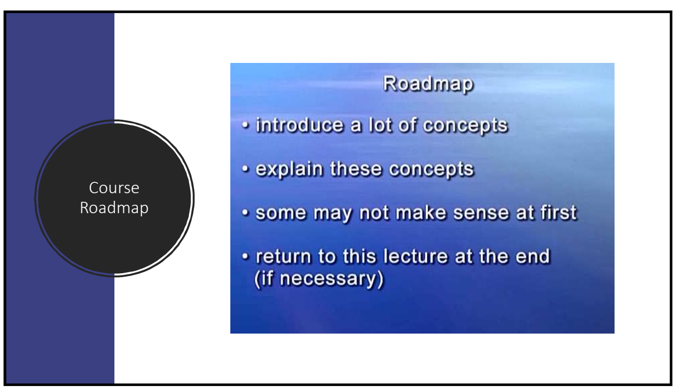

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Lecture 1

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Lecture one covered by following slides

- DVD – introduction first 5 minutes or so
- DVD – The Perfect Storm: minute 16 onward: we won't have time to show but I'll stay to show at 11:30 for 10 minutes IF SO DESIRED

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Terminology week 1:

- Adiabatic: https://en.wikipedia.org/wiki/Adiabatic_process
  - In meteorology it will be used mostly in the relationship of temperature and pressure: cooling or heating as a result of pressure changes. An expansion or compression of a parcel of air without exchange of heat with the air around it.
- Knot: = 1.15 mile/h https://en.wikipedia.org/wiki/Knot_(unit) = 1.15 mph
- Time reference: Greenwich mean time = Z or Zulu
  - Each hour on a globe = 15 degrees longitude: 24 * 15 = 360 degrees
  - Denver at 105 degrees west = PLUS 7 HOURS(105° W/7)
- Wind direction:
  - Where it comes from determines it's name
  - E.g. Southwesterly wind – comes from the SW; Northerly – from the North, etc.

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More information as FYI
Knot as a unit of speed

Origin of the "KNOT":
- = 1 nautical mile per hour
- If travelling at 1 knot = 1 minute of geographic latitude in one hour
- 60 nautical miles per degree latitude – 69 statute miles
- https://en.wikipedia.org/wiki/Knot_(unit)

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Terminology week 1 – continued:

- Pressure is force per unit area: 14.7 pounds per square inch,1013 millibar atmospheric pressure at sea level. 12 pounds per square inch in Denver, still below 82% of the atmosphere.
- Temperature: degrees Celsius = degrees Fahrenheit minus 32 and that number divided by 1.8 (212 Fahrenheit – 32 =180; 180/1.8 = 100 Celsius)
- Density, pounds per cubic foot: 62.4 for liquid water, 0.081 for air and .050 for water vapor at 1013 mbar and 32 F

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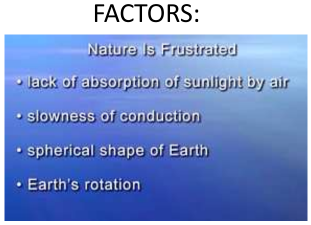
Imbalances - stresses

- Temperature differences make pressure differences
  - Pressure differences drive wind
  - Purpose of wind to reduce temperature differences and to blow themselves out
- Lightning – electrical imbalances

FACTORS:



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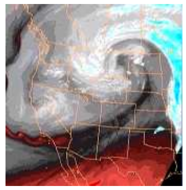
Water vapor and shear

- Wind change over distance – shear creates spin
  - Horizontal wind shear
  - Vertical wind shear
- Fluids of different densities do not want to mix
  - The result: A FRONT



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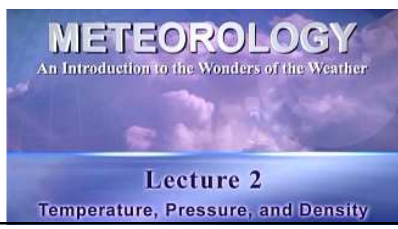
Temperature, Pressure, and Density

Lecture 2



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Temperature, Pressure, and Density

Lecture 2

- What Temperature measures
- Pressure decreases with height
- Density overlooked

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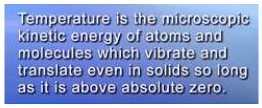
Temperature

Fahrenheit vs. degrees Celsius (°C)
18 degrees F per 10 degrees C

- 32 °F = 0 °C
- 50 °F = 10 °C
- 68 °F = 20 °C
- 86 °F = 30 °C
- 104 °F = 40 °C
- -40 °F = -40 °C



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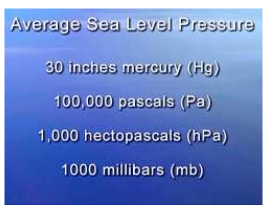
Other Temperature and Atmospheric Pressure information

- 0 °C = freezing point for impure water
- 100 °C = boiling point at sea level for impure water
- 15#/ in^2
- 30 inches mercury or 1000 millibars



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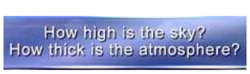
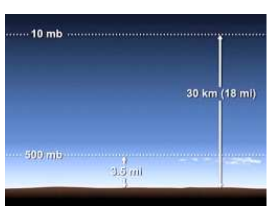
Earth’s size: Radius

- 6500 km = 4000 mile radius
- You will hear a lot about the 500 millibar (mb) level and the 10 mb level





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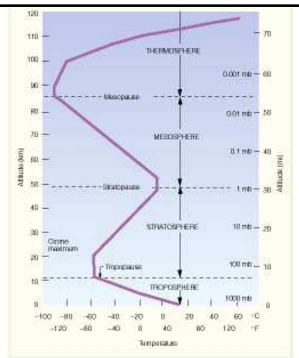
Temperature changes in the atmosphere



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Density

density
mass divided by volume

- Ideal gas law

Ideal Gas Law

$p = \rho RT$

p = pressure (Pa)

ρ = density (kg/m³)

T = temperature (K)

R = proportionality constant

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ADIABATIC WARMING AND COOLING

At the same pressure, warm air is less dense than cold air.

- Adiabatic expansion and compression: a parcel of air not exchanging heat with the air around it will cool on expansion and warm on compression. A Chinook wind coming down from the mountains warms at 5.5 F per 1000 feet of decent. https://en.wikipedia.org/wiki/Chinook_wind

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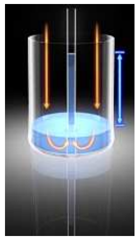
Barometer



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NATURAL FORCES

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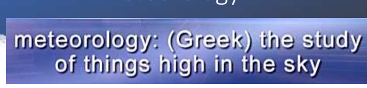
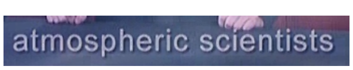
Meteorology



- Meteorologists – atmospheric scientists



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LECTURE 3 Atmosphere—Composition and Origin

Lecture 3

Lecture 3

Atmosphere: Composition and Origin

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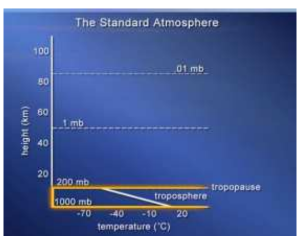
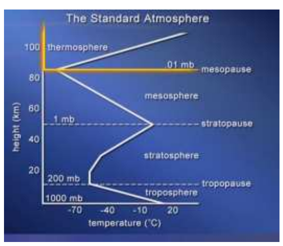
Air – The Standard Atmosphere





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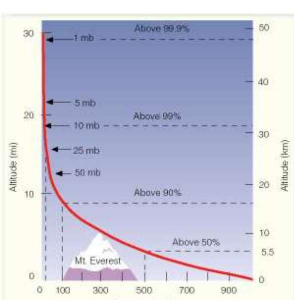

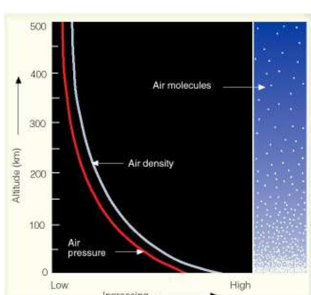

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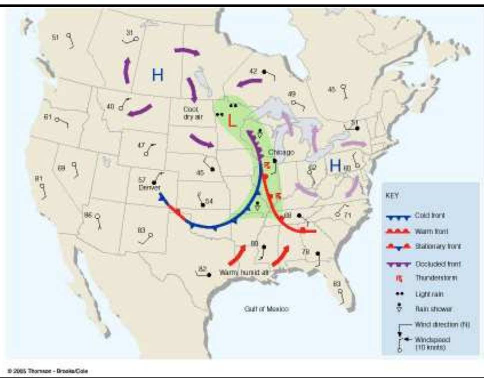

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Density: Mass per unit volume

- Key concept:

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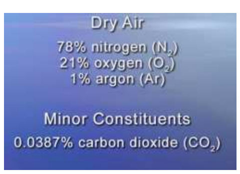
What is Air

- Dry Air



- If a Basketball arena holds 25,000 people
  - 20000 = N_2
  - 5000 = O_2
  - 250 = Ar
  - 10 CO_2 – just THE PLAYERS (but other GHGs too)
  - 387 OUT OF A MILLION at time of this video –now 410 out of a million

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If interested in more detail:

TABLE 1.1 Composition of the Atmosphere Near the Earth's Surface

PERMANENT GASES			VARIABLE GASES			
Gas	Symbol	Percent (by Volume) Dry Air	Gas (and Particles)	Symbol	Percent (by Volume)	Parts per Million (ppm)*
Nitrogen	N_2	78.08	Water vapor	H_2O	0 to 4	
Oxygen	O_2	20.95	Carbon dioxide	CO_2	0.037	375*
Argon	Ar	0.93	Methane	CH_4	0.00017	1.7
Neon	Ne	0.0018	Nitrous oxide	N_2O	0.00003	0.3
Helium	He	0.0005	Ozone	O_3	0.000004	0.04†
Hydrogen	H_2	0.00006	Particles (dust, soot, etc.)		0.000001	0.01–0.15
Xenon	Xe	0.000009	Chlorofluorocarbons (CFCs)		0.00000002	0.0002

*For CO_2, 375 parts per million means that out of every million air molecules, 375 are CO_2 molecules.

†Stratospheric values at altitudes between 11 km and 50 km are about 5 to 12 ppm.

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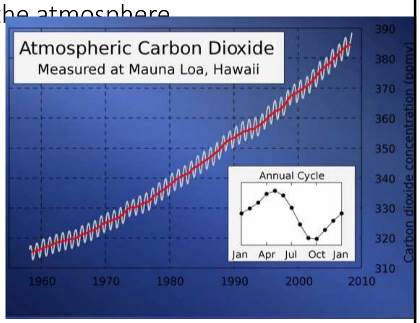
Keeling curve: documentation of added fossil fuel CO2 to the atmosphere

2019 value = 410 ppm



- https://en.wikipedia.org/wiki/Keeling_Curve

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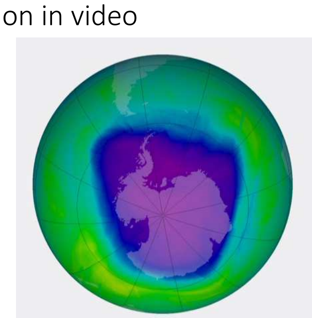
Ozone hole discussion in video

Notes: Ozone hole has been reduced but it's still there!

Addressing this issue AND acid rain shows that WE CAN MAKE A DIFFERENCE!

Links:
- https://en.wikipedia.org/wiki/Ozone_depletion
- http://www.theozonehole.com/
- https://earthsky.org/earth/2018-ozone-hole-slightly-above-average



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Why is Ozone hole restricted to southern hemisphere

- Cl – South polar stratospheric vortex – deadly to ozone
- Ozone protects us from UV
- Ozone bad for health at sea level

- 1987 Montreal protocol
- Substitutes good for ozone but huge Green House Gases (GHGs)

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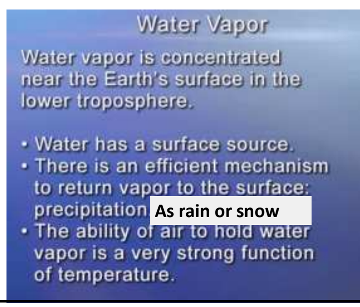
Water vapor discussion



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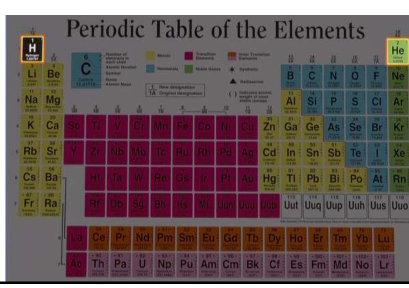
Warm air holds more water vapor than cold air



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Early atmosphere

- Oxygen absent
- Higher CO2 – most went to bicarbonate and carbonates
- Photosynthesis 3 billion years ago by cyanobacteria– used CO2 made oxygen

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Ideal gas law but also Avogadro number

Ideal Gas law: https://en.wikipedia.org/wiki/Ideal_gas_law

- PV = nRT
  - P = Pressure
  - V = Volume
  - T = Temperature
  - n = # moles
  - R = a number = ideal gas constant

Avogadro number: https://en.wikipedia.org/wiki/Avogadro_constant

- 6.022 atoms per mole
- Important in the estimating of the density of air as influenced by WATER VAPOR!

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Avogadro number:

- https://en.wikipedia.org/wiki/Avogadro_constant
  6.022 atoms per mole
  Important in the estimated the density of air as influenced by WATER VAPOR! **WATER VAPOR IS LIGHTER THAN AIR!!!!!**
- TAKE AWAY: **WATER VAPOR IS LIGHTER THAN AIR!!!!!**
- **Next slides try to explain why**

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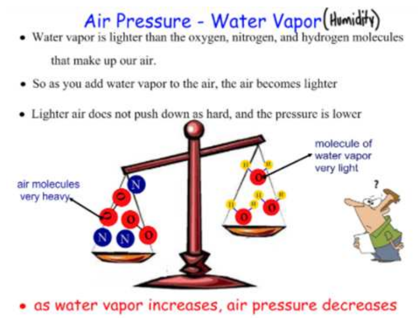

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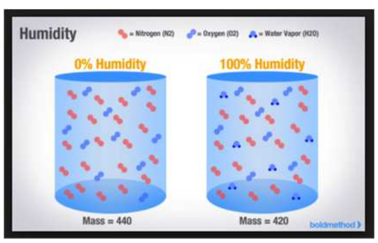
NOTE: EQUAL NUMBER OF MOLECULES!
ON THE RIGHT – LIGHTER MOLECULES OF H20
REPLACE HEAVIER MOLECULES

$N_2 = 28$
$O_2 = 32$
$H_20 = 18$



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• TAKE AWAY:

- adding H_2O VAPOR decreases density – i.e. makes air lighter

- it's why storms are associated with LOWS (low Pressures)

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Water vapor

The amount of water vapor
that the atmosphere can hold
DOUBLES FOR EVERY 10°C

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~ DOUBLES FOR EVERY 10°C

Table 1 Specific humidity of a kilogram of air (at average sea level pressure)

Temp. (°C)	Temp. (°F)	Grams of water vapor per kg of air (g/kg)
-40	-40	0.1
-35	-31	0.2
-30	-22	0.3
-25	-13	0.51
-20	-4	0.75
-10	14	1.8
0	32	3.8
5	41	5
10	50	7.8
15	59	10
20	68	15
[illegible]	77	[illegible]
30	86	27.7
[illegible]	95	35
40	104	49.8

What is the volume of 1 kg of air?

Answer: At sea level:
95 cm x 95 cm x 95 cm = .8562 m^3)
or **about 1 cubic meter**

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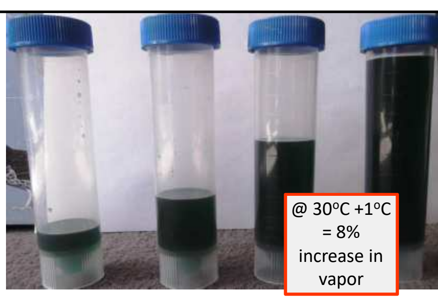
~ DOUBLES FOR EVERY 10°C



@ 30°C +1°C = 8% increase in vapor

10°C = (50°F)	20°C = (68°F)	30°C = (86°F)	40°C = (104°F)
7.8 cc	15 cc	27.7 cc	49.8 cc

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T, P and V relationships with density

$PV = nRT$

$P = dRT$

- Temperature: INCREASES
  - V increases and thus
  - Density decreases
- Pressure: INCREASES
  - V decreases and thus
  - Density increases
- Volume: INCREASES
  - T decreases and thus
  - Density Decreases

P = PRESSURE
V = VOLUME
T = TEMPERATURE

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T, P and V relationships with density

$PV = nRT$

- IF we increase T, and we let V increase then P must decrease: $PV = nRT$: = less dense air
  - Heated air rises because it's less dense
  - Conversely cold air sinks
- If we increase Pressure and hold the V to the same then T must increase that results in less dense air: $PV = nRT$
- However if we increase P without changing T then V decrease resulting in denser air: $PV = nRT$
- expand without T changing then
  - V decreases and thus

P = PRESSURE
V = VOLUME
T = TEMPERATURE
Density = mass / Volume

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JIM – NOT SURE WHETHER WE'LL HAVE TIME TO GO OVER THIS OR LEAVE IT AS HANDOUT AND TELL CLASS WE WILL GO OVER LATER

HOWEVER:
Changes in the composition of medium can also cause density to change

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EXTRAS - THE PERFECT STORM

- WILL SHOW AFTER CLASS FOR THOSE INTERESTED – ABOUT 10 MINUTES

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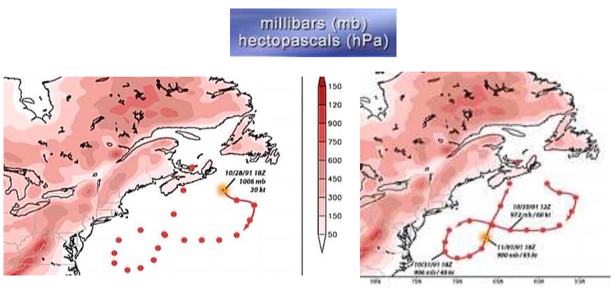

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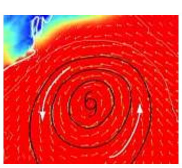
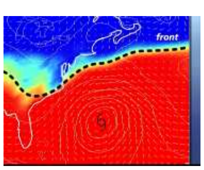
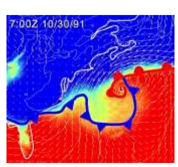
Drop in pressure – increase wind speed

- Wind goes from high pressure to low pressure areas = pressure gradient – changes in pressure
- Isobars – lines of = pressure







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