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:**
  - **fgihrig@msn.com ; h. 303-526-1750**
  - **Announcements:**
    - **Logistics: bathrooms, breaks, no open containers**
    - **other**
- **Paul Belanger:**
  - **PEBelanger@glassdesignresources.com**
  - **c. 303-249-7966; h 303-526-7996**
- **Jim Keller:**
  - **kellerjb10@aol.com**
  - **H 303-526-0867 c 303-503-9711**

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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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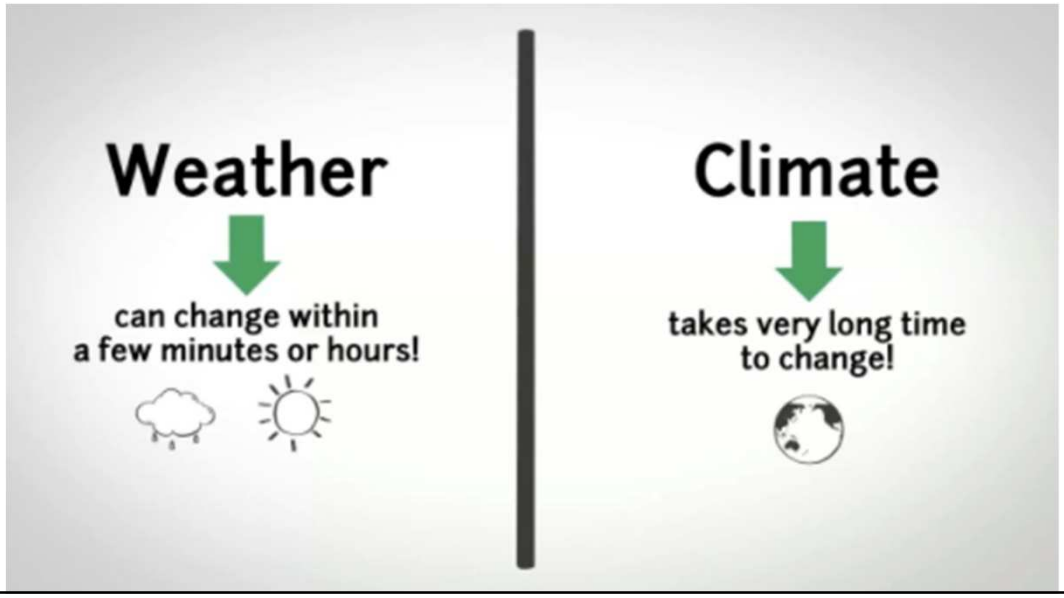
Weather vs. Climate



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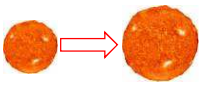
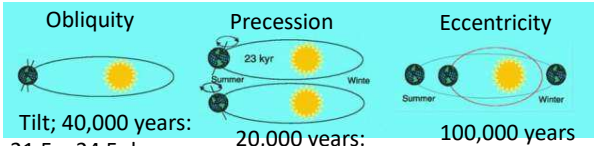
What determines Earth's Longer-term climate

- **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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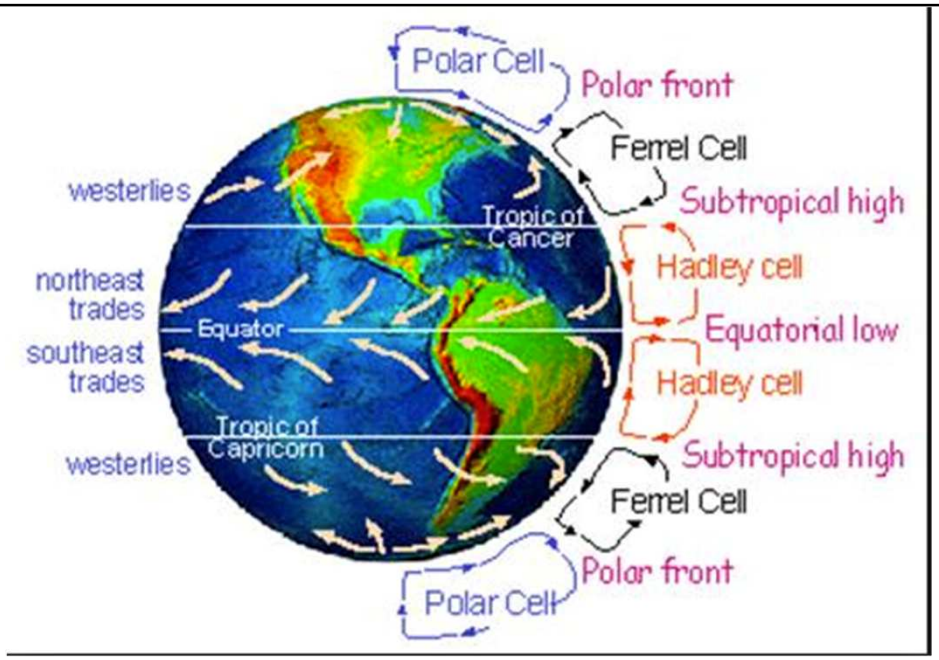

http://maps.unomaha.edu/Peterson/geog1000/Notes/Notes_Exam1/Seasons&Climate.htm

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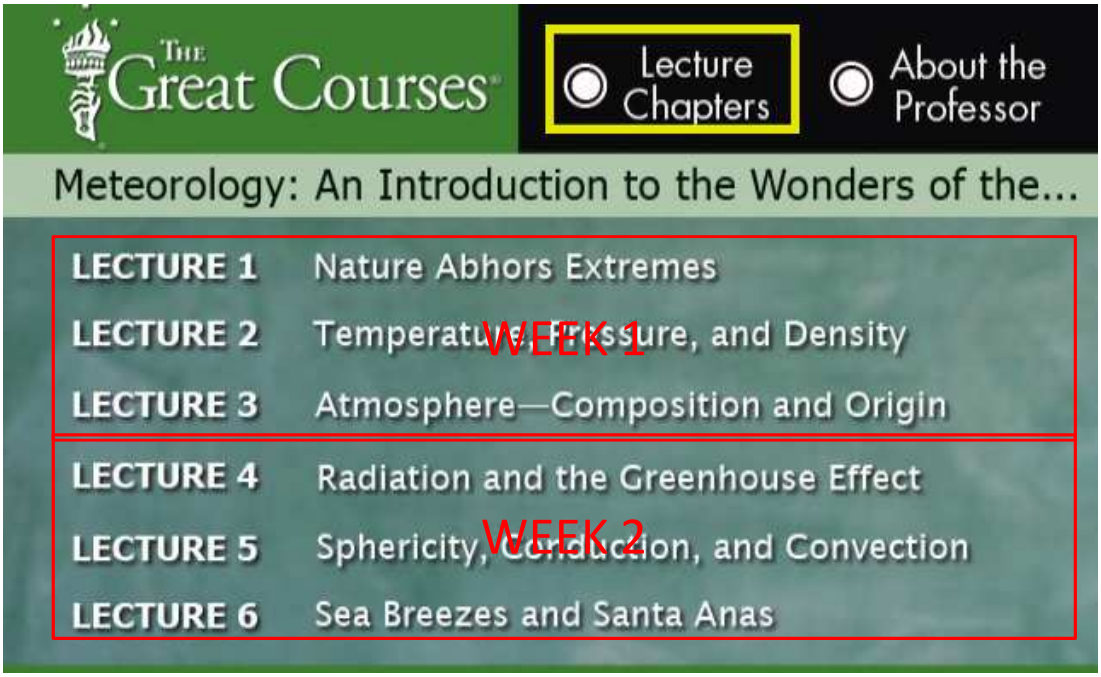

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Course Roadmap

Roadmap

- introduce a lot of concepts
- explain these concepts
- some may not make sense at first
- return to this lecture at the end (if necessary)

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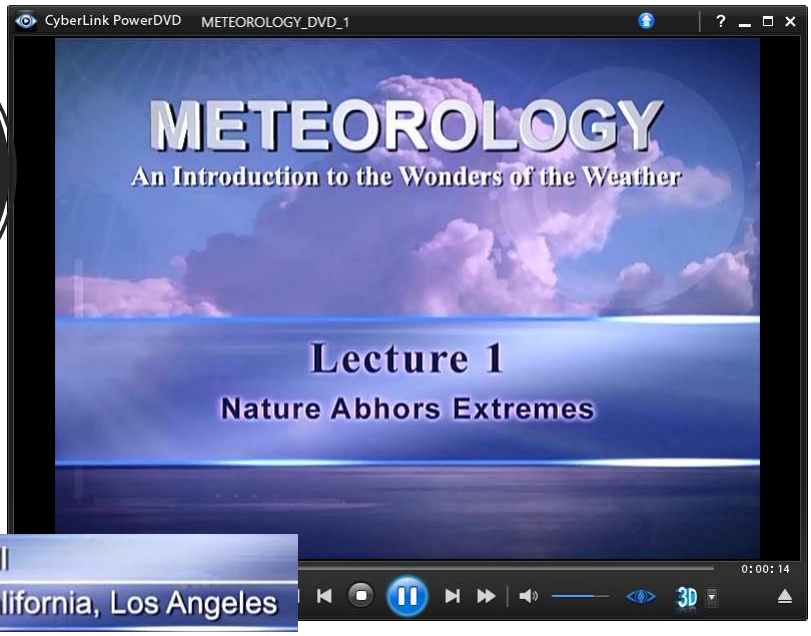
Lecture 1



Robert G. Fovell
University of California, Los Angeles

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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^{o} 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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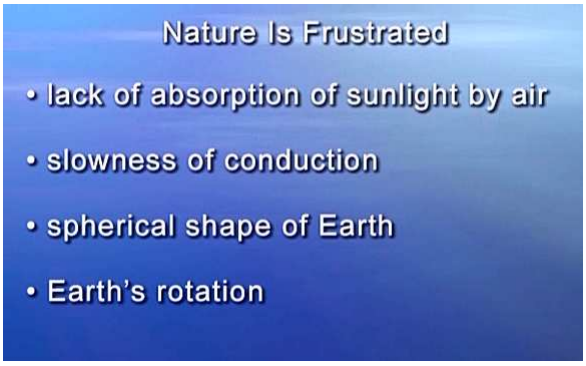
Imbalances - stresses

- 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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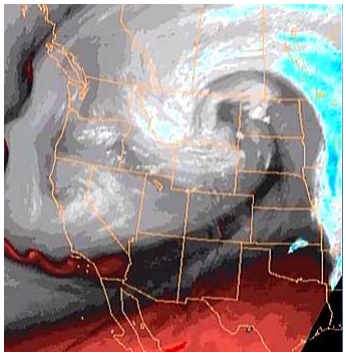
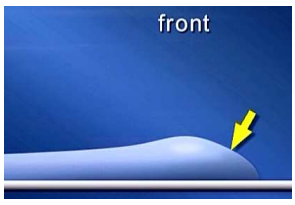
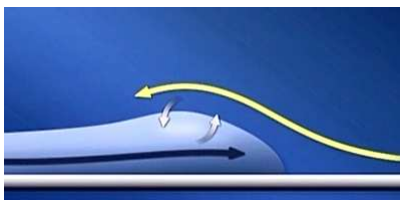
Water vapor and shear



- 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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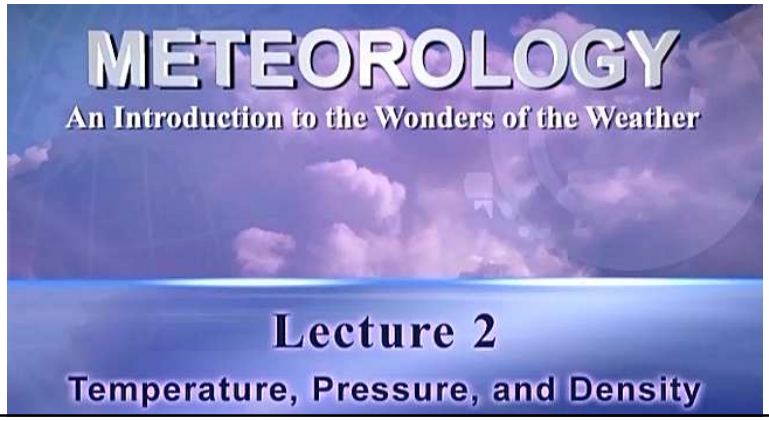
Temperature, Pressure, and Density

Lecture 2



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Lecture 2

Temperature, Pressure, and Density

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

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Temperature

Daniel Gabriel Fahrenheit
1686 – 1736

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

Temperature is the microscopic kinetic energy of atoms and molecules which vibrate and translate even in solids so long as it is above absolute zero.

absolute zero

–273° C

–459° F

0 K

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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

Average Sea Level Pressure

30 inches mercury (Hg)

100,000 pascals (Pa)

1,000 hectopascals (hPa)

1000 millibars (mb)

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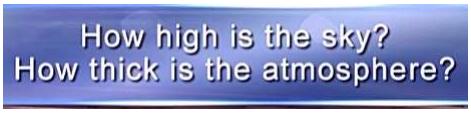
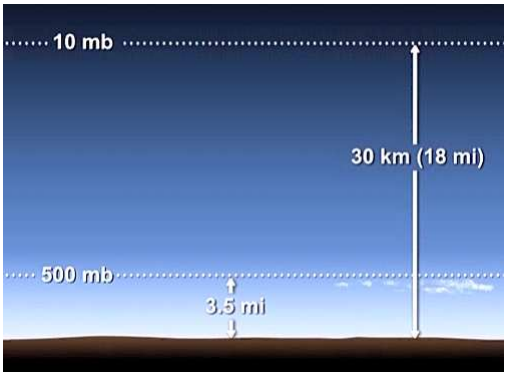
Earth's size: Radius

- 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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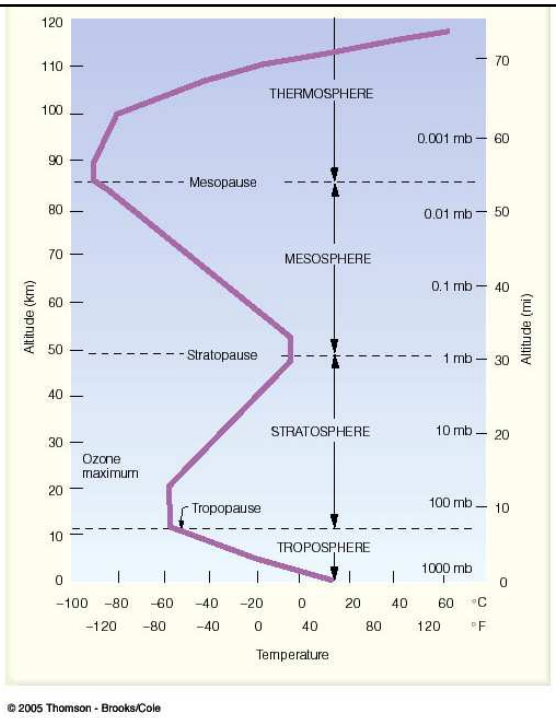
Temperature changes in the atmosphere



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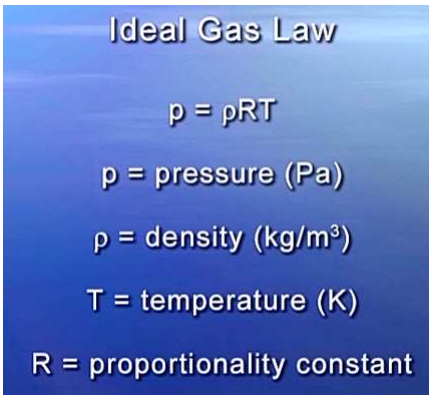
Density

density
mass divided by volume

- Ideal gas law



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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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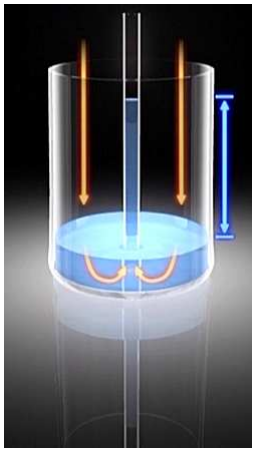
Barometer



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NATURAL FORCES

Nature wants to move mass from high to low pressure.

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Meteorology

meteorology: (Greek) the study of things high in the sky

- 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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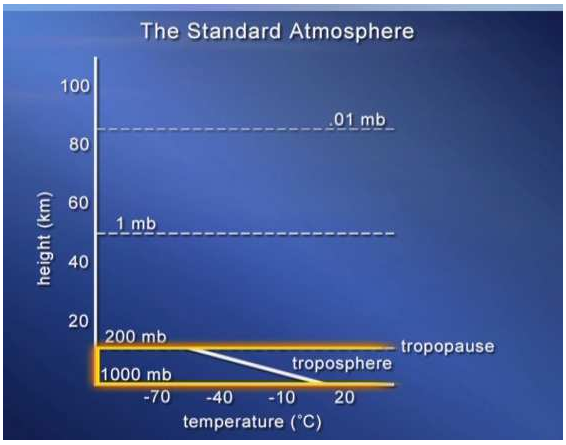
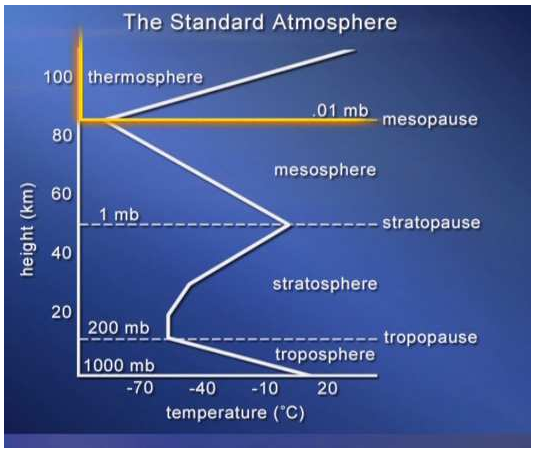
Air – The Standard Atmosphere





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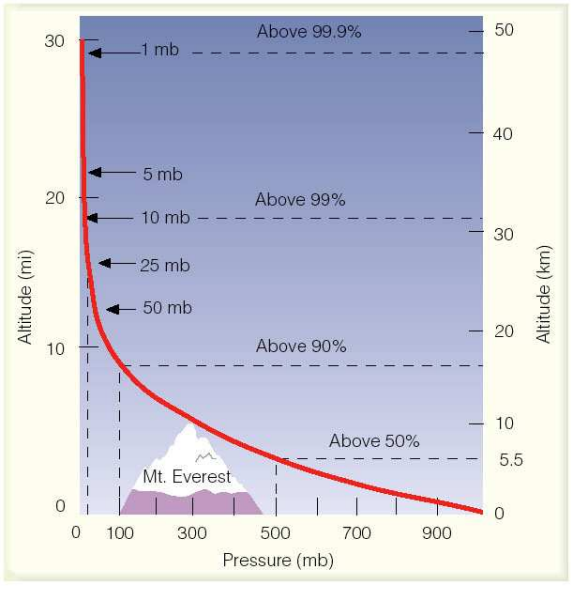

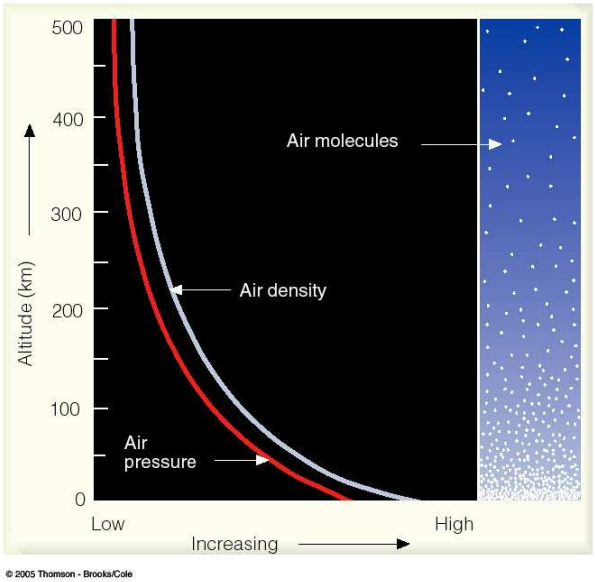

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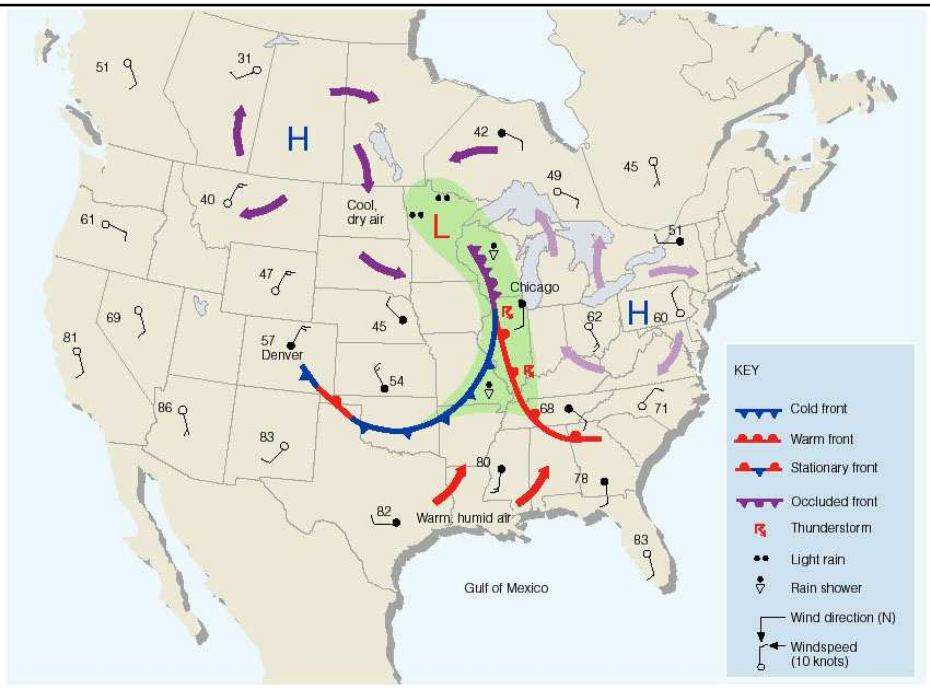

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Density: Mass per unit volume

- Key concept:

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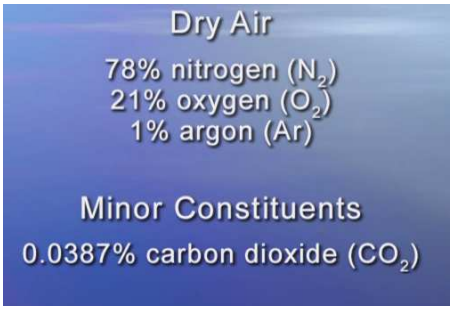
What is Air

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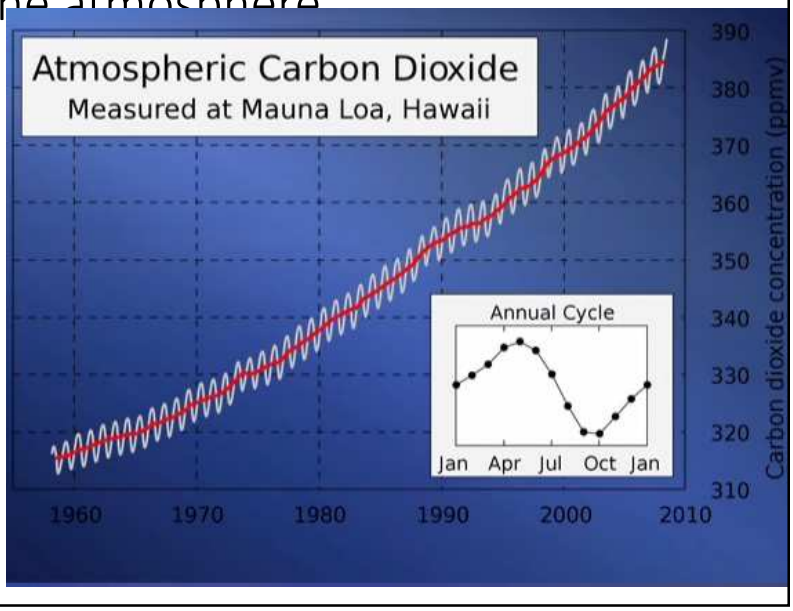
Keeling curve: documentation of added fossil fuel CO2 to the atmosphere

2019 value = 410 ppm



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

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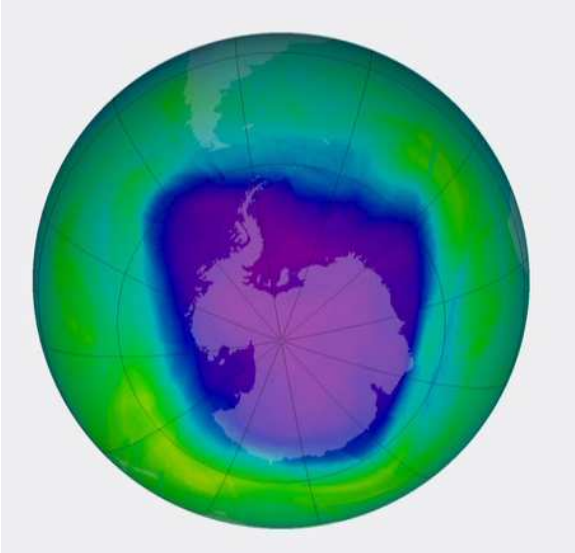
Ozone hole discussion in video

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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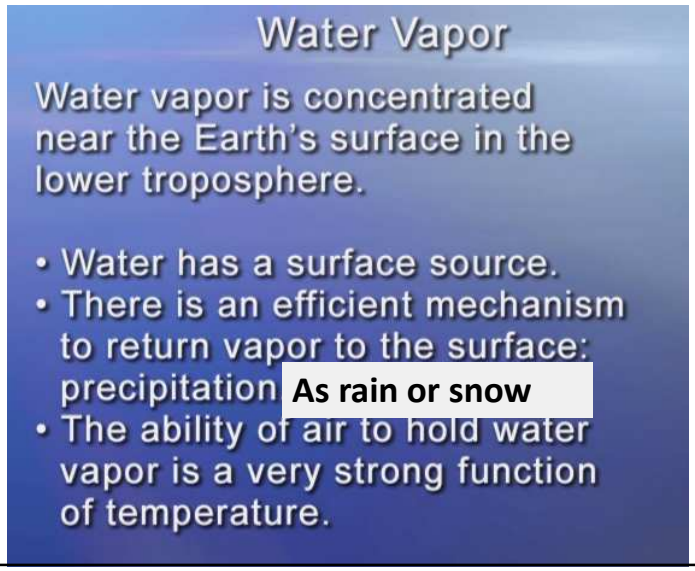
Water vapor discussion



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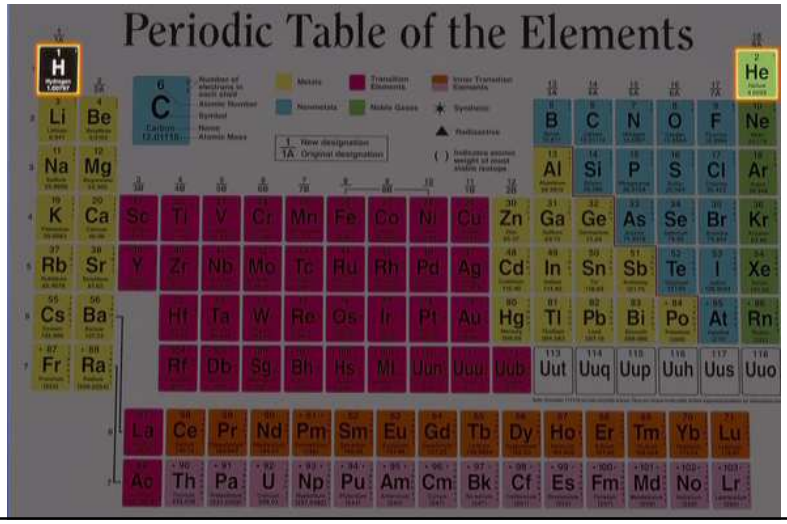
Warm air holds more water vapor than cold air



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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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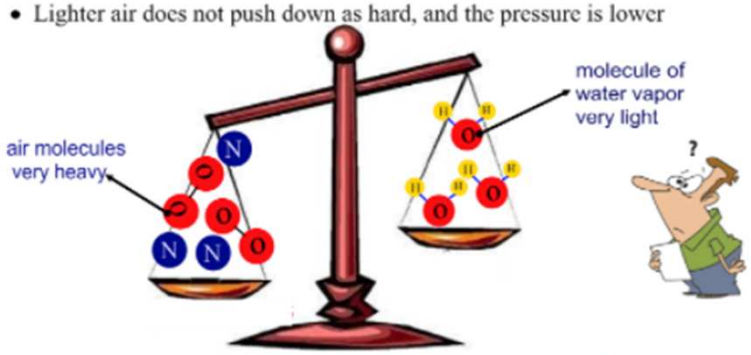
Air Pressure - Water Vapor (Humidity)

- Water vapor is lighter than the oxygen, nitrogen, and hydrogen molecules that make up our air.
- So as you add water vapor to the air, the air becomes lighter
- Lighter air does not push down as hard, and the pressure is lower



- as water vapor increases, air pressure decreases

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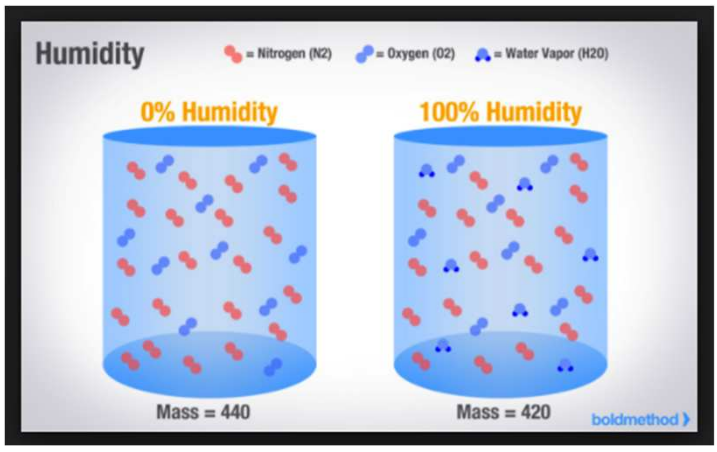
NOTE: EQUAL NUMBER OF MOLECULES!
ON THE RIGHT – LIGHTER MOLECULES OF H20 REPLACE HEAVIER MOLECULES

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



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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
25	77	20
30	86	27.7
35	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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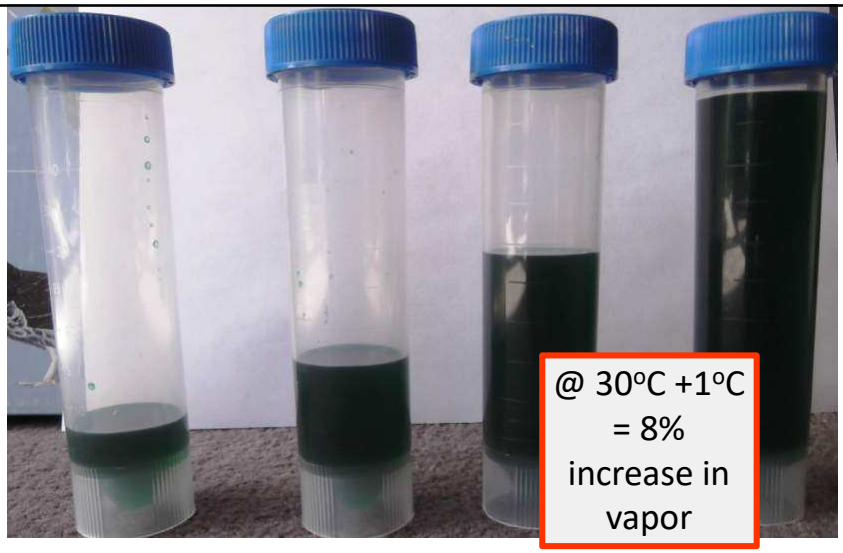
~ DOUBLES FOR EVERY 10°C



10°C = (50°F) 7.8 cc

20°C = (68°F) 15 cc

30°C = (86°F) 27.7 cc

40°C = (104°F) 49.8 cc

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T, P and V relationships with density

$$PV = nR\,T$$

$$P = d\,RT$$

- 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

$$PV = nR\,T$$

- IF we increase T, and we let V increase then P must decrease: PV = nR T: = 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 = nR T
- However if we increase P without changing T then V decrease resulting in denser air: PV = nR T
- 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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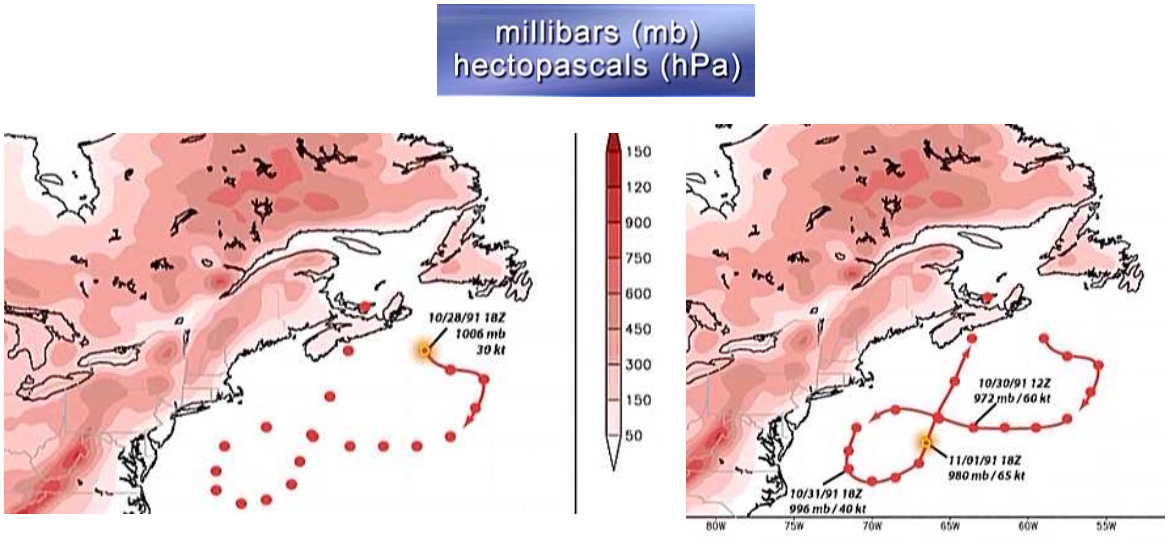

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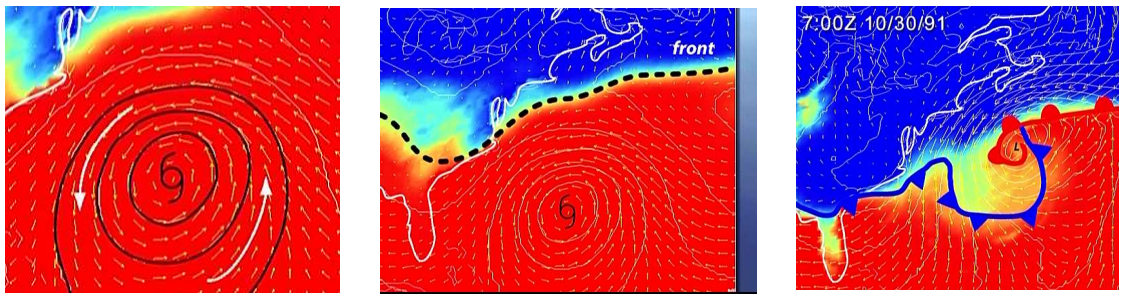
Drop in pressure – increase wind speed

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



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