Atmospheric Motions

- **Horizontal Motions:** parallel to Earth's surface (the everyday wind)
- **Vertical Motions:** perpendicular to Earth's surface (up/down)

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- **Atmosphere is a collection of ideal gases → $P = \rho RT$; P and therefore ρ decrease exponentially with altitude**

Poll Question

The atmosphere has a mass of 5.2x10^18 kg, and thus feels a force due to gravity of ~5x10^19 Newtons,

Visual settings | Activate | Show results | Show correct | Lock | Clear results | Fullscreen

When poll is active, respond at **PollEv.com/thornton211** Text **THORNTON211** to **22333** on

- Therefore, it is continually falling to the surface due to gravity and being replenished above from space
- Therefore, it feels the force due to friction which balances gravity
- 1 and 2
- Neither 1 nor 2

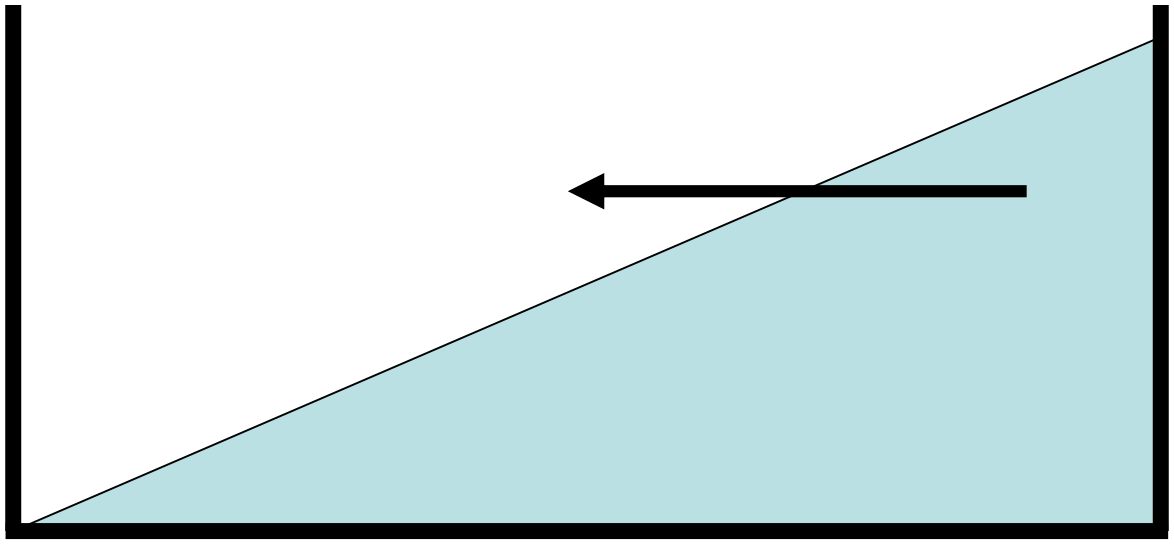
Next | Previous

Total Results: 0

Making Air Move

Pressure Gradient Force (PGF)

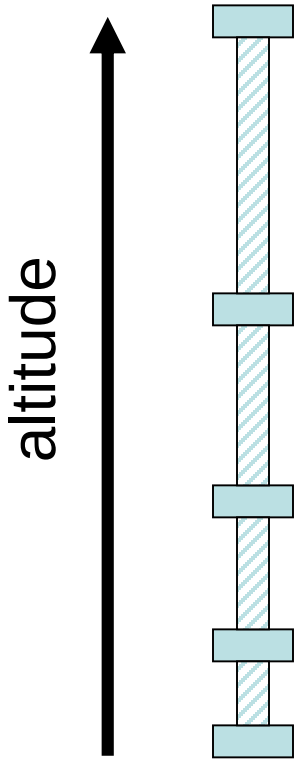
Air/water will move from a region of high pressure to low pressure



Water in a tub with horizontal pressure gradient

Pressure versus Altitude

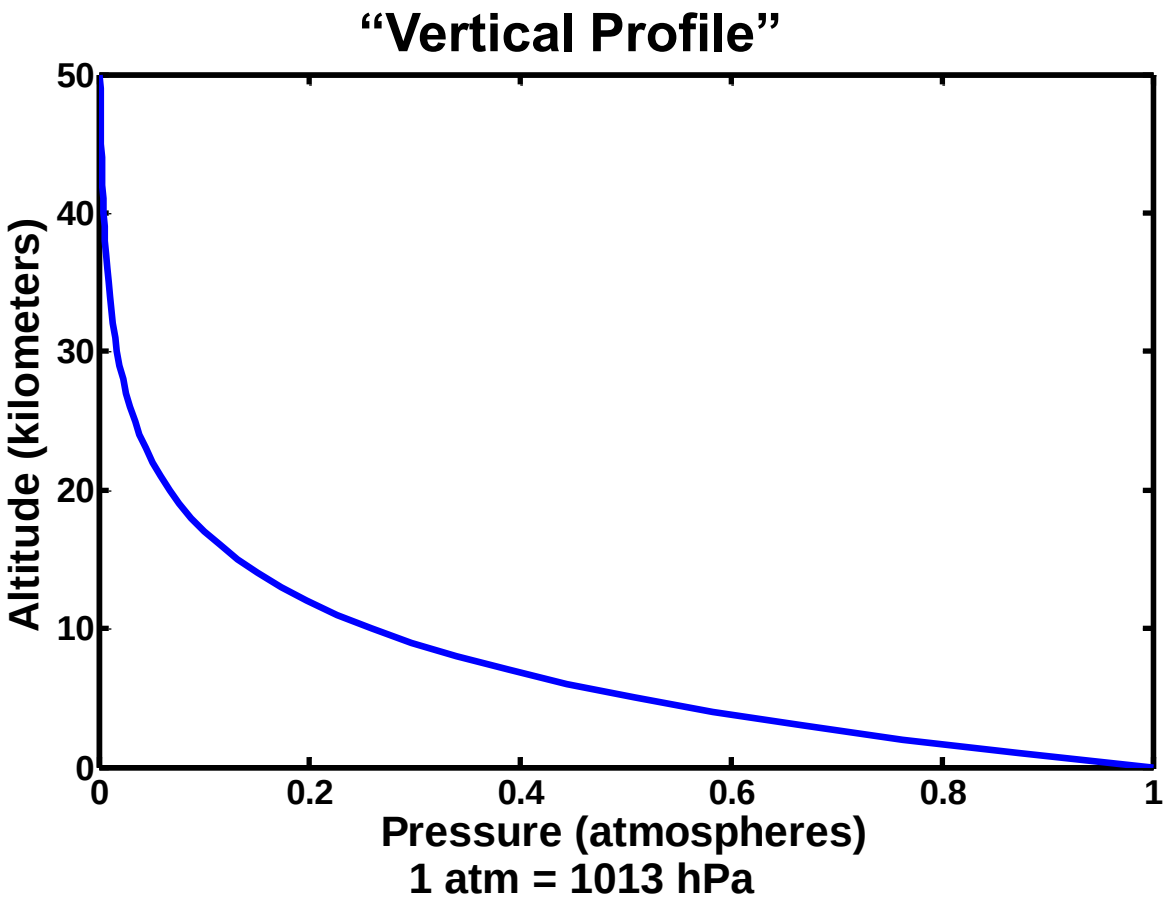
Gases (air) are *compressible* fluids



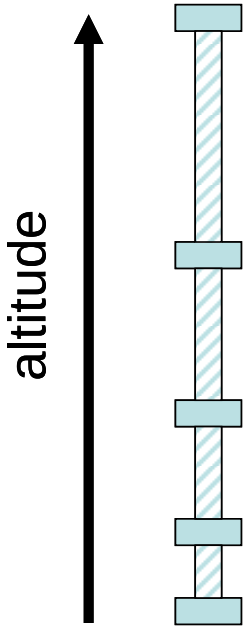
Expect Pressure to *decrease* with altitude (height above ground)

"Compressible" **equal-mass** bricks of air stacked on each other

Pressure Decreases Exponentially w/Altitude



Gases (air) are *compressible* fluids, unlike liquids.



"Compressible" bricks of air stacked on each other

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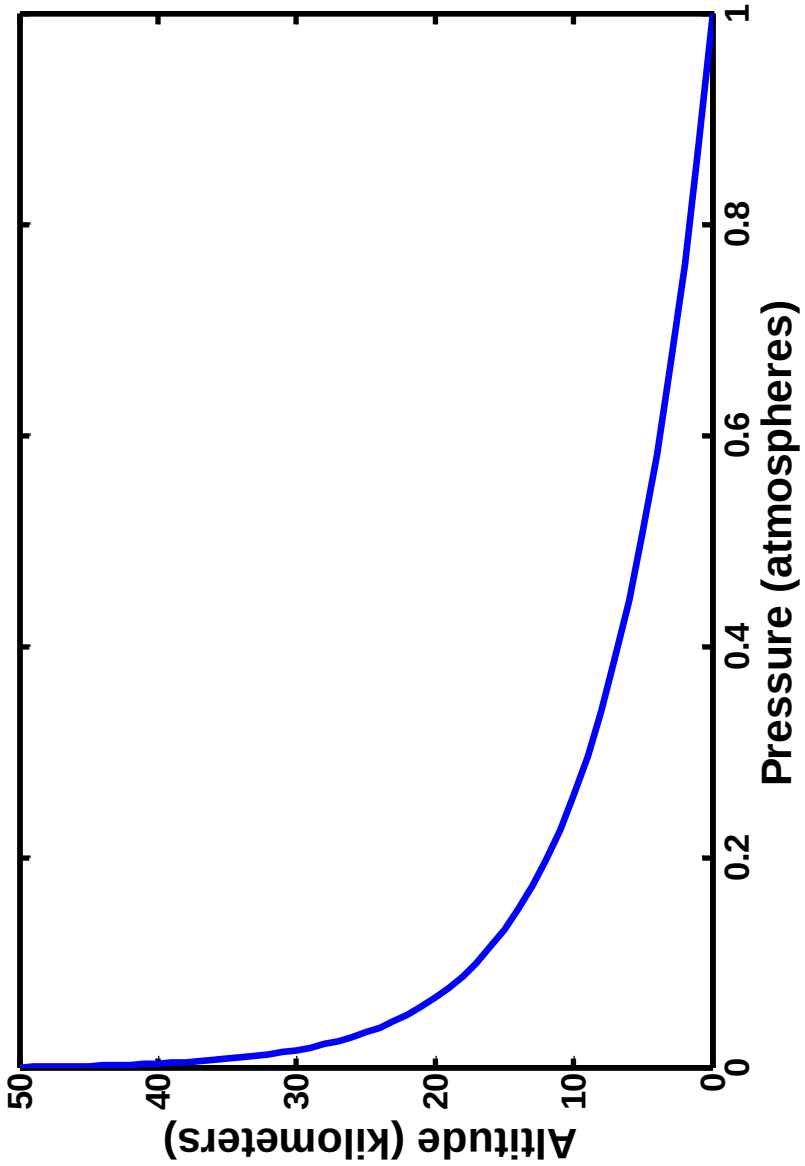

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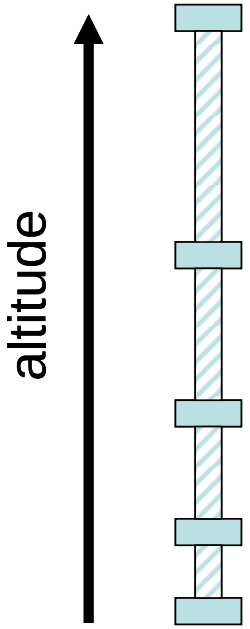

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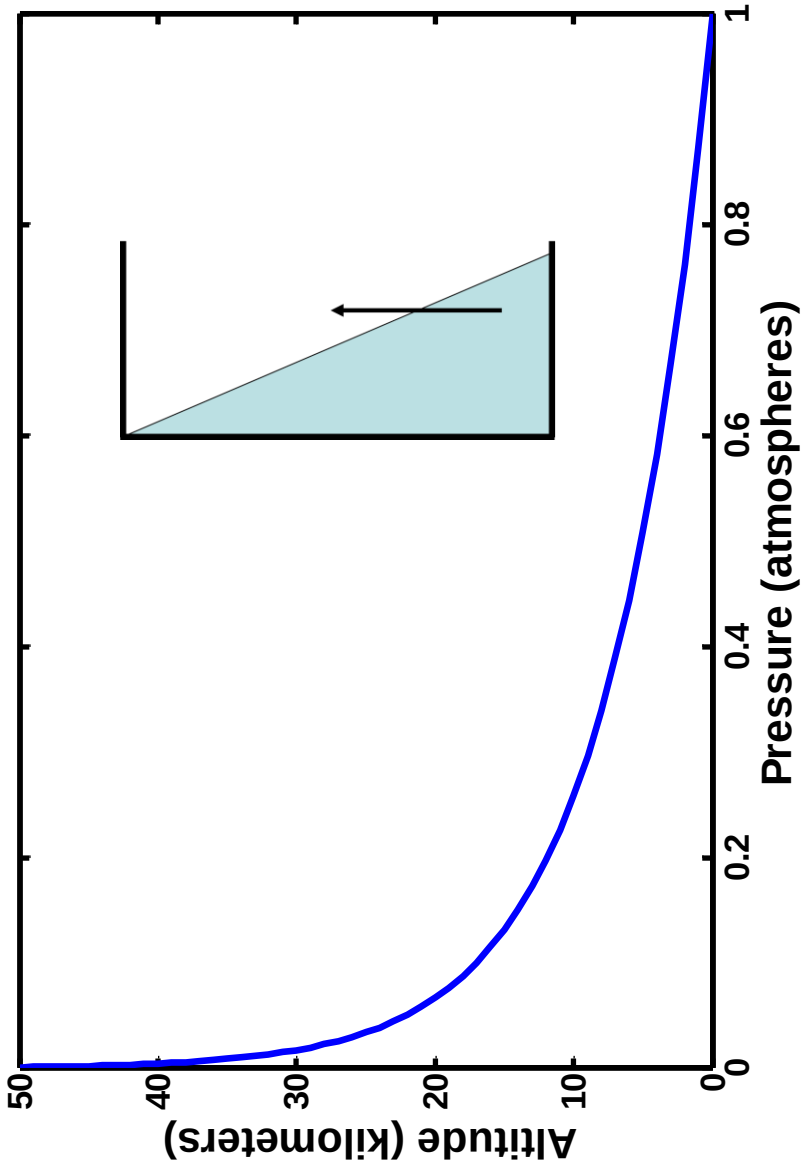

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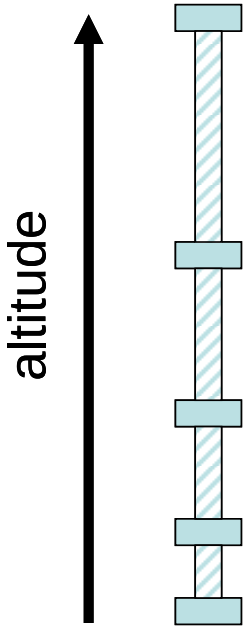

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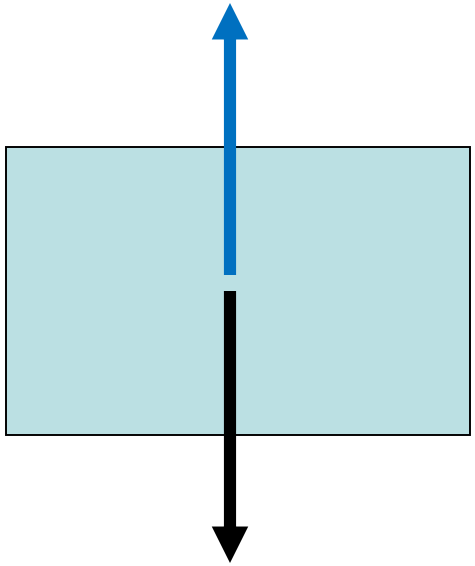
Barometric Law — “Hydrostatic Equation”

Pressure Gradient Force [because $P(z_1) > P(z_2)$]



Z_2 – higher altitude

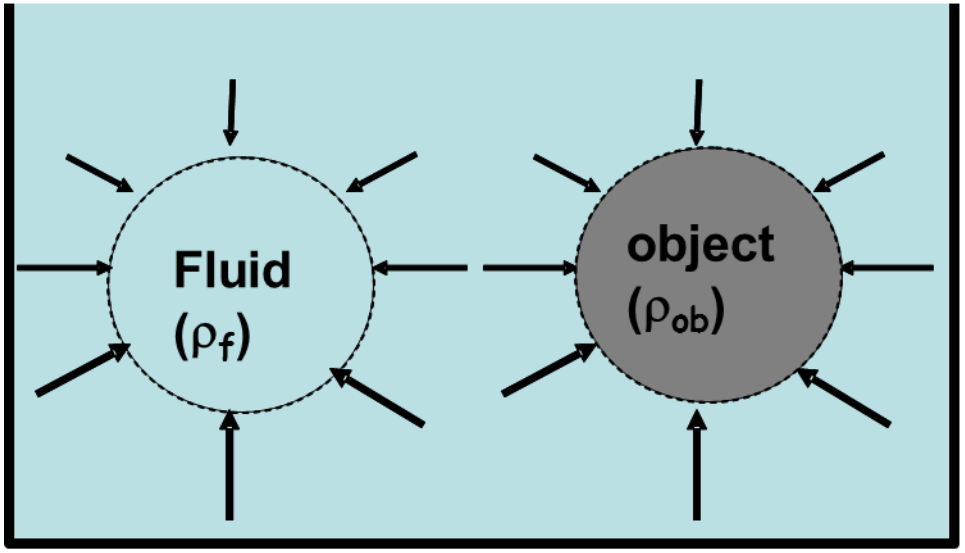
Z_1 –low altitude

Gravitational Force

The atmosphere’s tendency to be forced into space by pressure gradient, is balanced by force due to gravity (on average).

Making Air Move in Vertical: Buoyancy

$$F_{buoy} = PGF - F_g$$



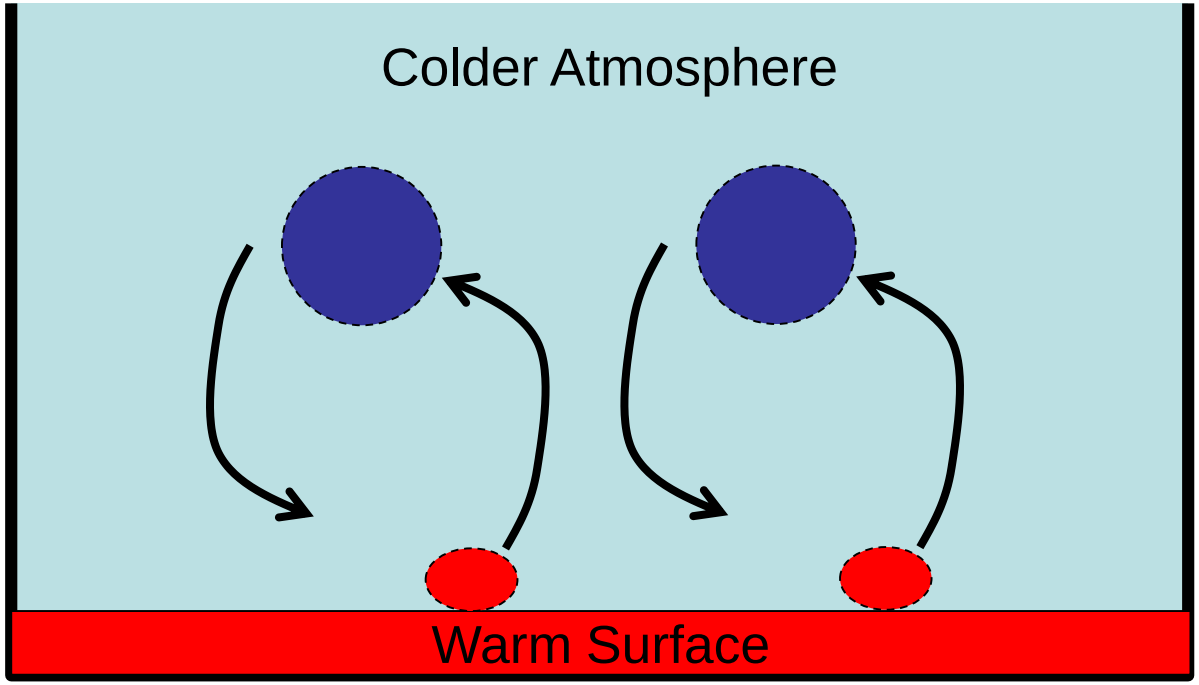
An object feels "buoyant force (F_{buoy})" if its density (ρ_{ob}) is *different* from the surrounding fluid's (ρ_f).

Will object in this figure rise or sink? Floating Bowling Balls

Buoyant Force and Vertical Motions

Heating a Fluid From Below → Convection

Warm surface air → less dense →"buoyant" → rises

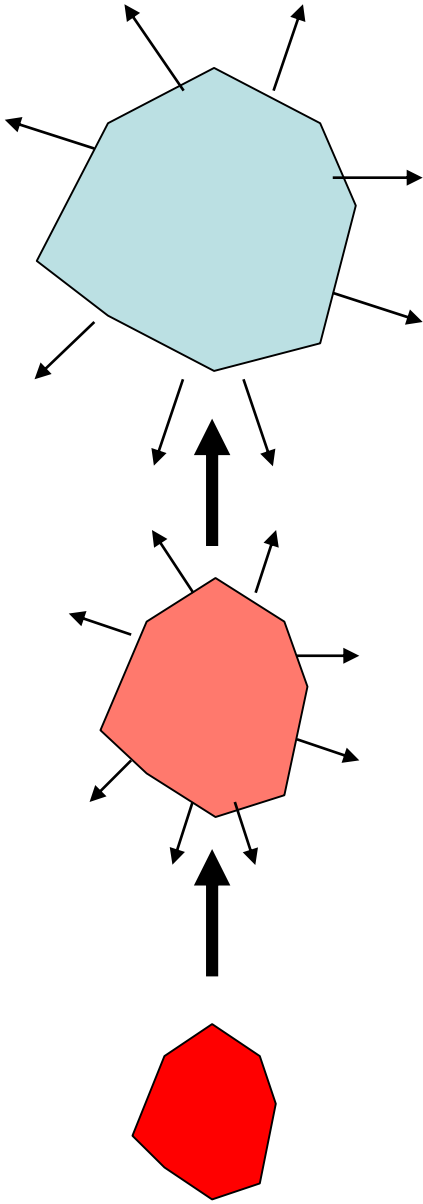


Rising air expands → does *work* → gives energy to surroundings

Convection: transfer of heat via motions of a fluid

Important Concepts in Vertical Motions

- An air parcel that rises → ***expands*** due to lower surrounding pressure



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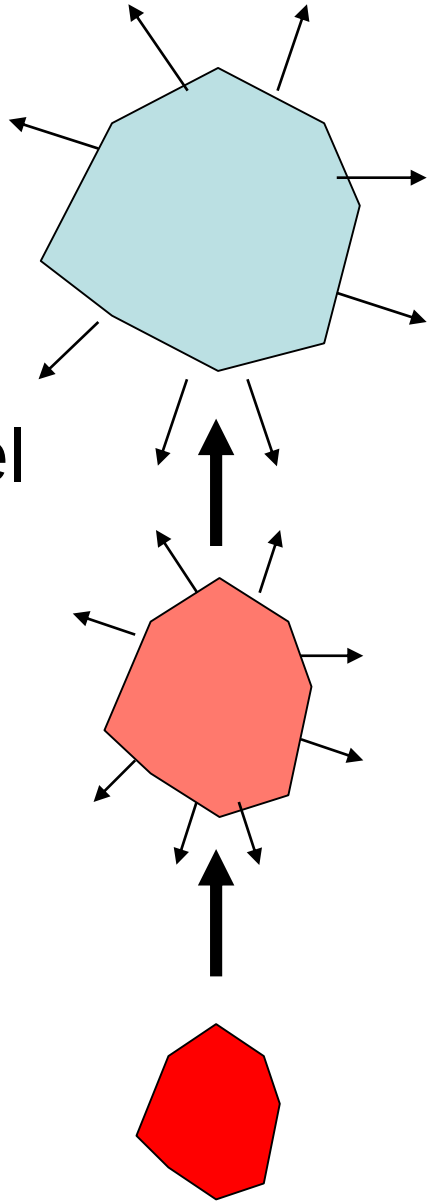

Important Concepts in Vertical Motions

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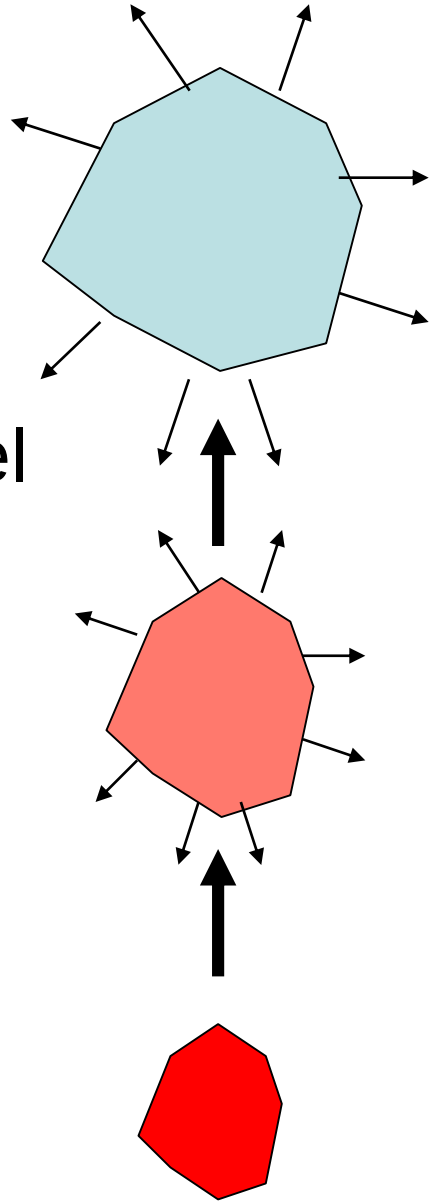
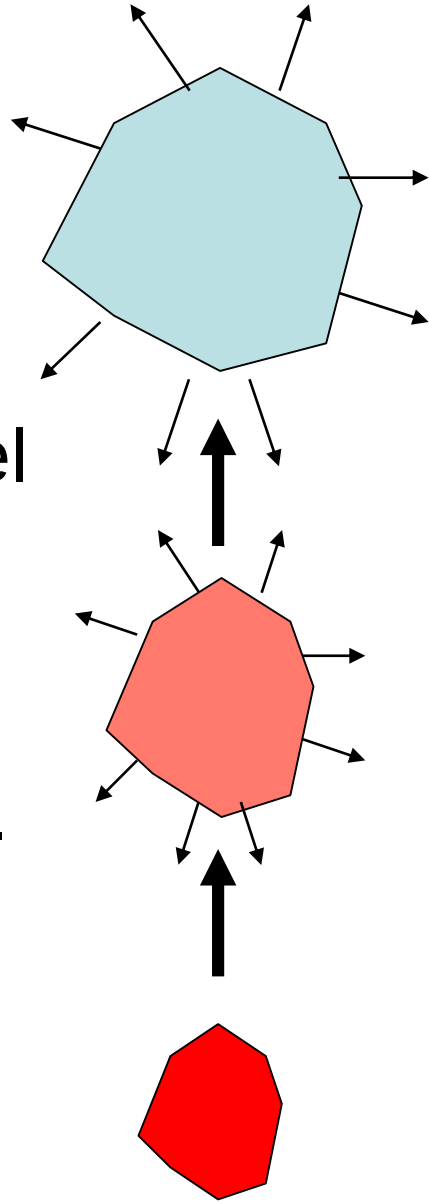
- EXPANSION requires WORK by the parcel
- Air parcel doing WORK, loses Energy, →Temperature of parcel goes down (because it gives heat to surrounding air).

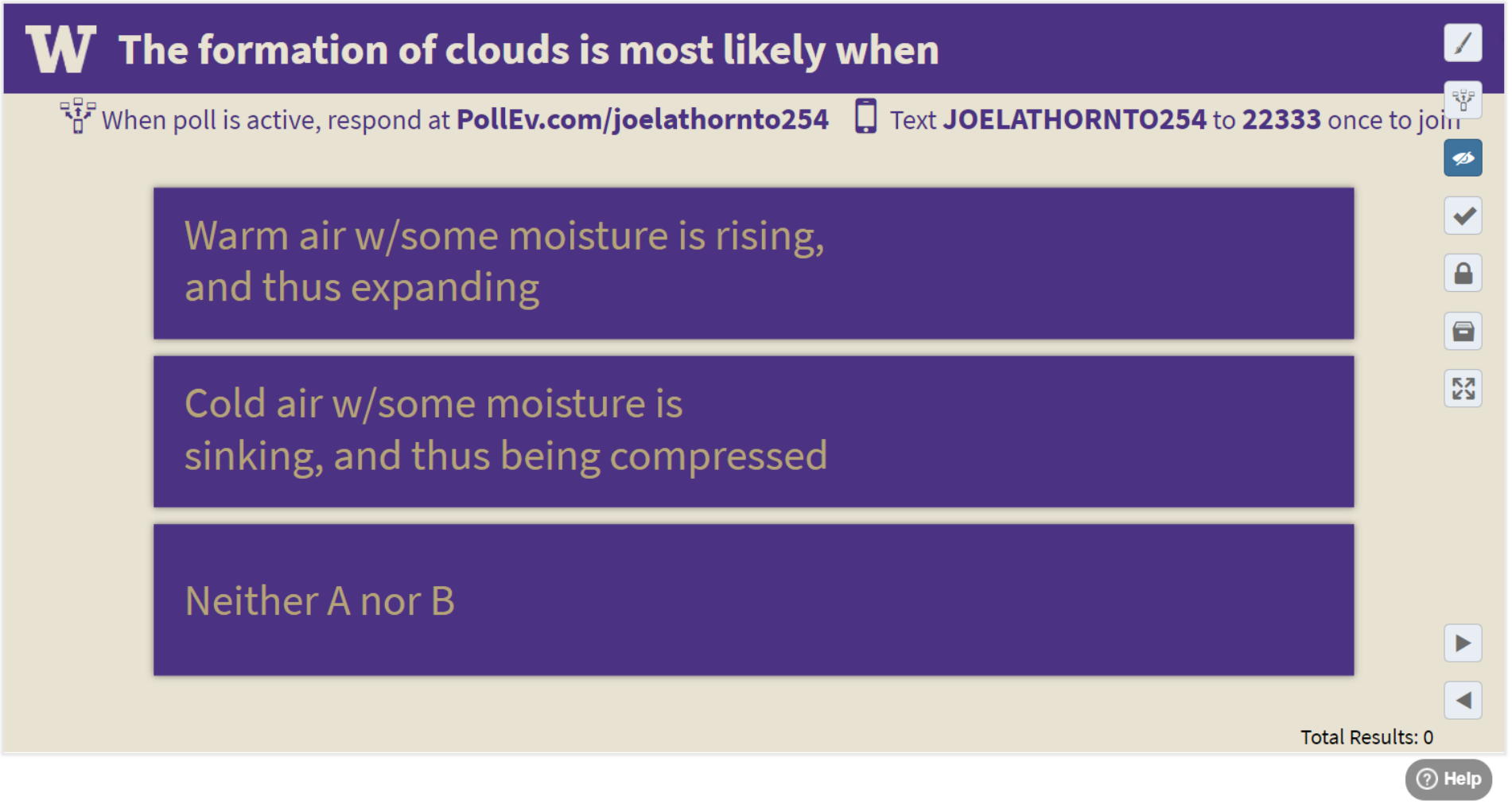


Important Concepts in Vertical Motions

- An air parcel that rises → ***expands*** due to lower surrounding pressure
- EXPANSION requires WORK by the parcel
- Air parcel doing WORK, loses Energy, →Temperature of parcel goes down (but does transfer heat to surrounding altitude).
- Sinking motions are opposite (sinking parcel → compressed → warms)

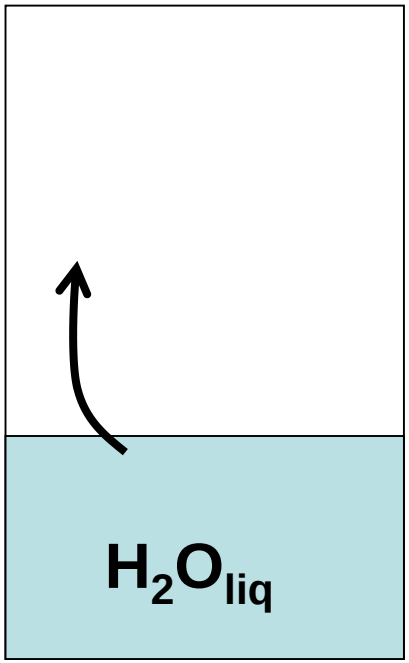


Poll


The formation of clouds is most likely when
When poll is active, respond at PollEv.com/joelathornto254
Text JOELATHORNTO254 to 22333 once to join
Warm air w/some moisture is rising, and thus expanding
Cold air w/some moisture is sinking, and thus being compressed
Neither A nor B
Total Results: 0
Help

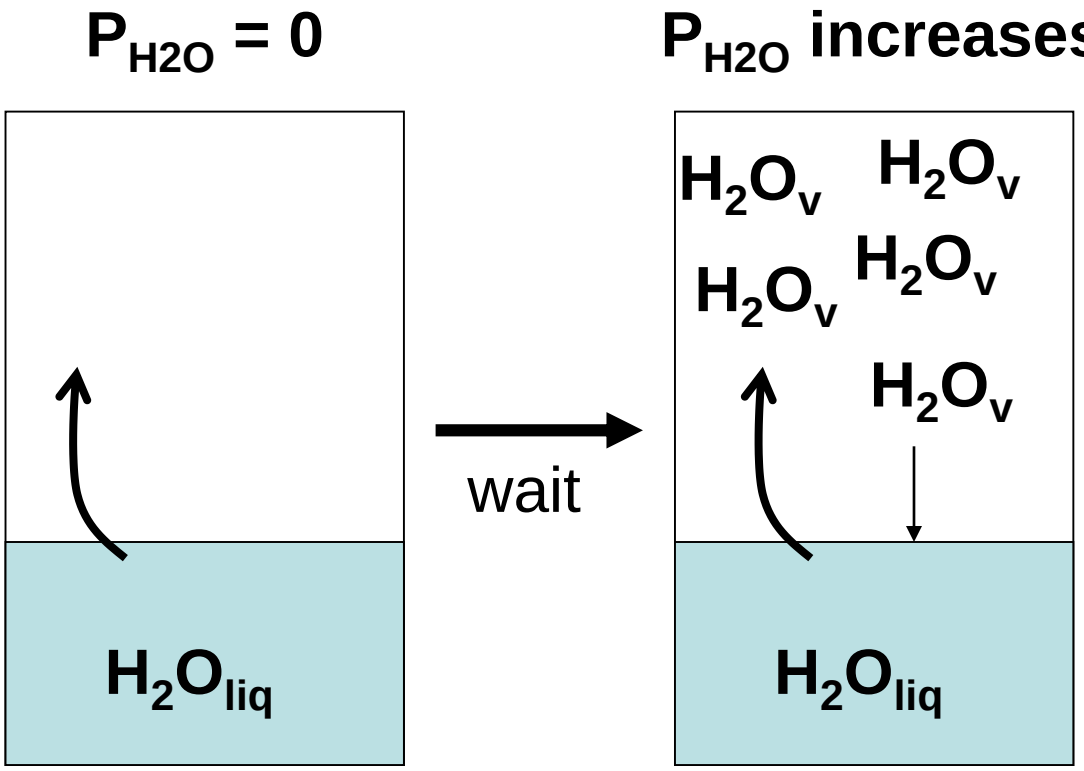
Saturation Vapor Pressure of Water

$P_{H2O} = 0$



Start: H_2O_{liq}
w/dry air above

Saturation Vapor Pressure of Water



Start: H_2O_{liq} w/dry air above

Middle: net evaporation

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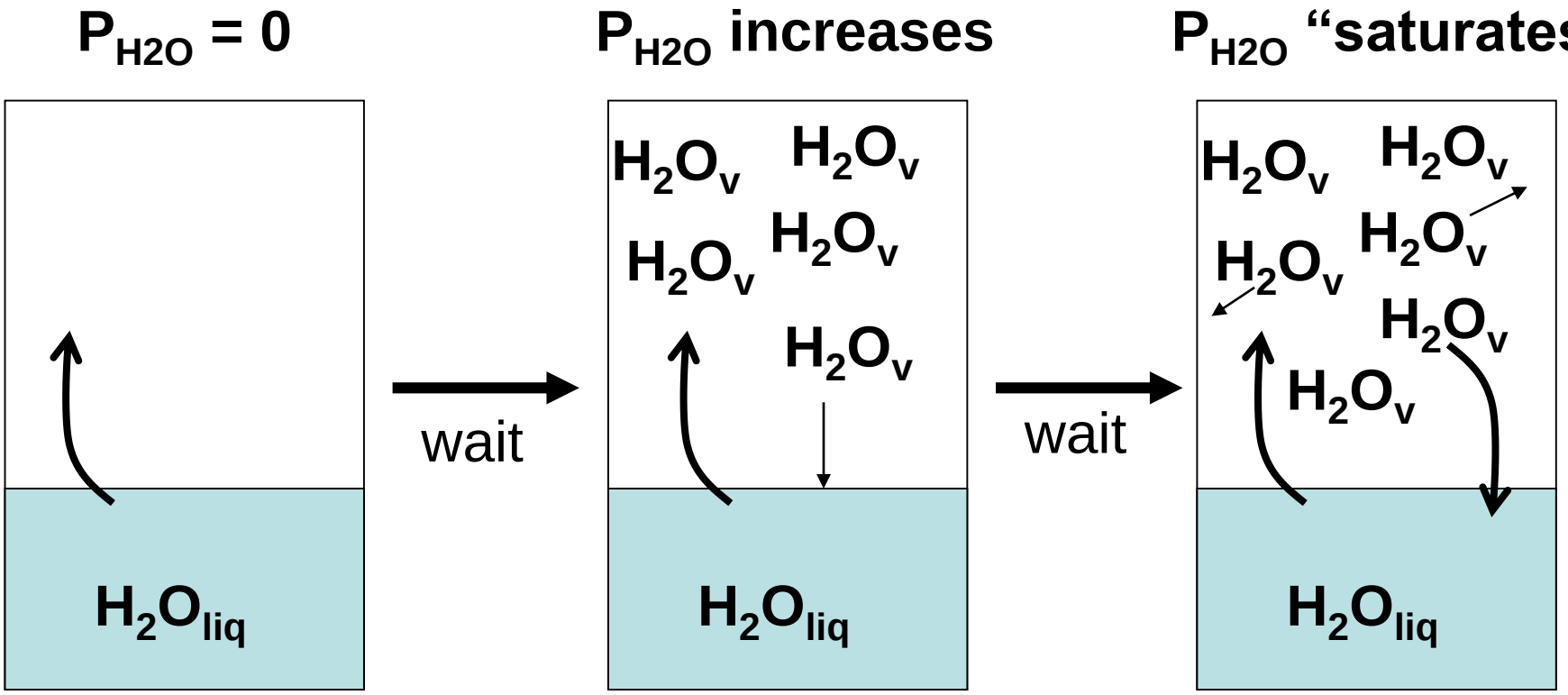


Start: H_2O_{liq} w/dry air above

Middle: net evaporation

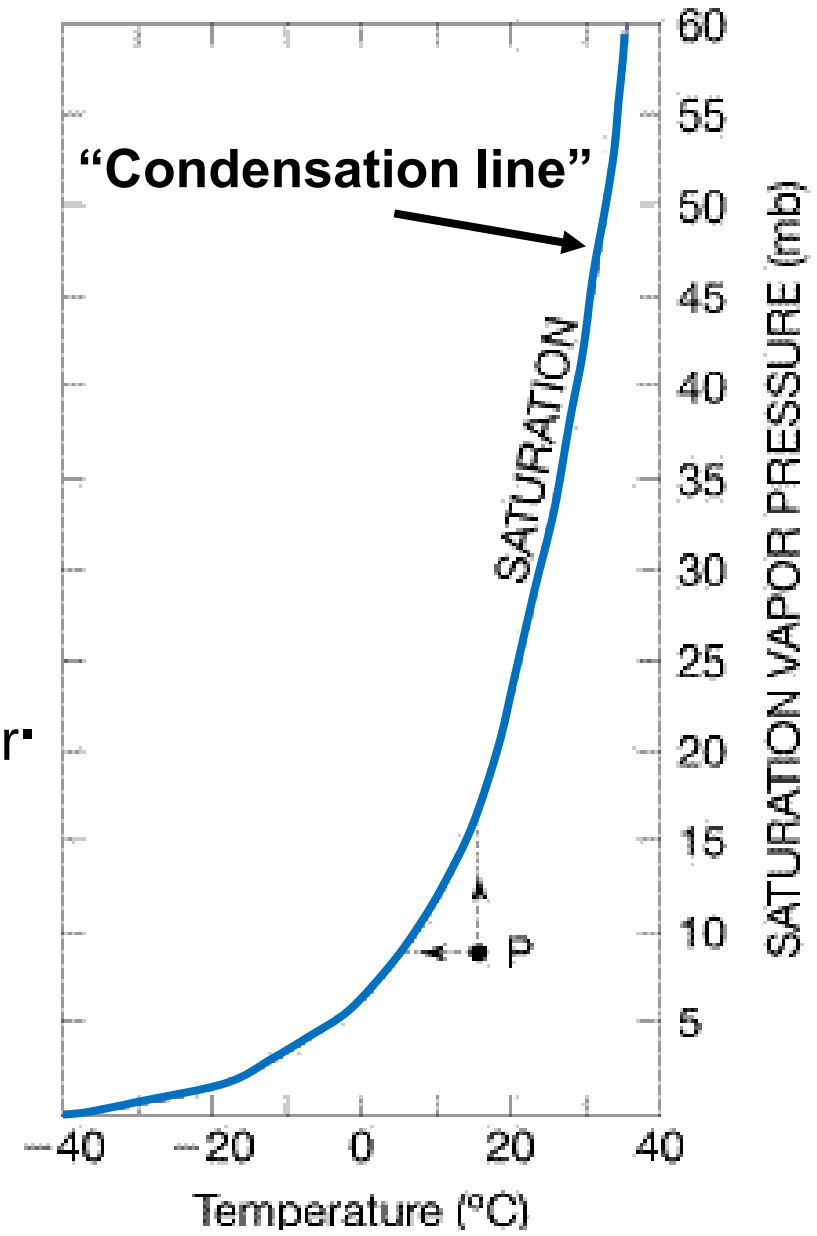
End: condensation equals evaporation

"Equilibrium"

Saturation Vapor Pressure of Water

Is the maximum amount of H_2O_{vapor} that "air can hold"

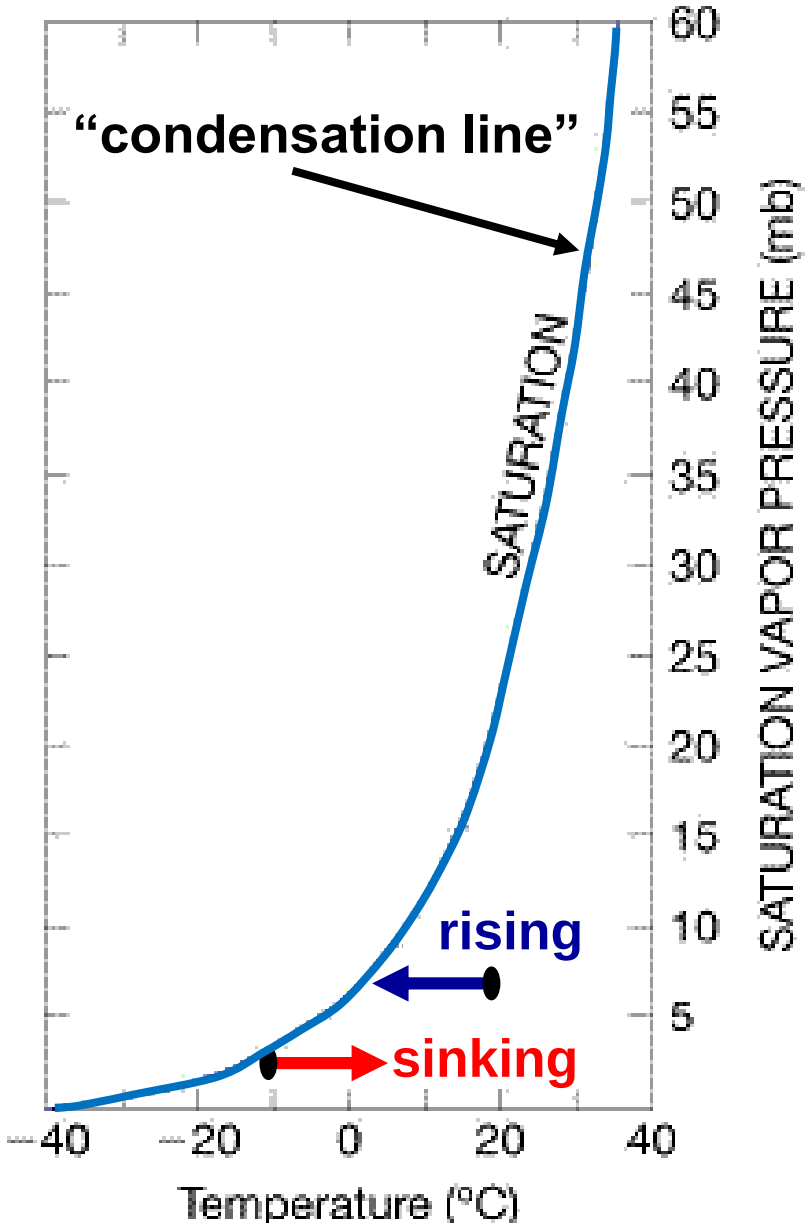
Warmer air can hold *exponentially more* H_2O_{vapor}.



Phase Transitions in Rising/Sinking Air

Rising air (expansion cooling), condensation/precipitation is ***more likely***

Sinking air (compression warming), condensation/precipitation is ***suppressed***.



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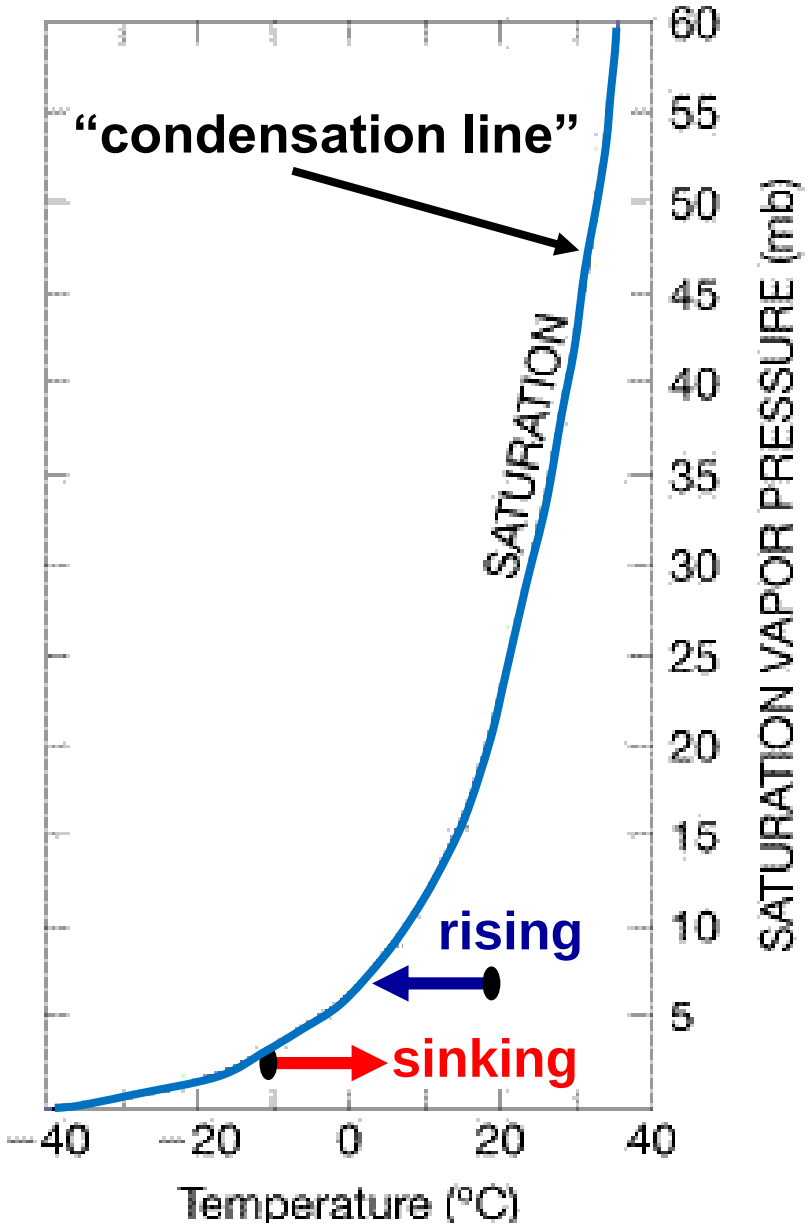

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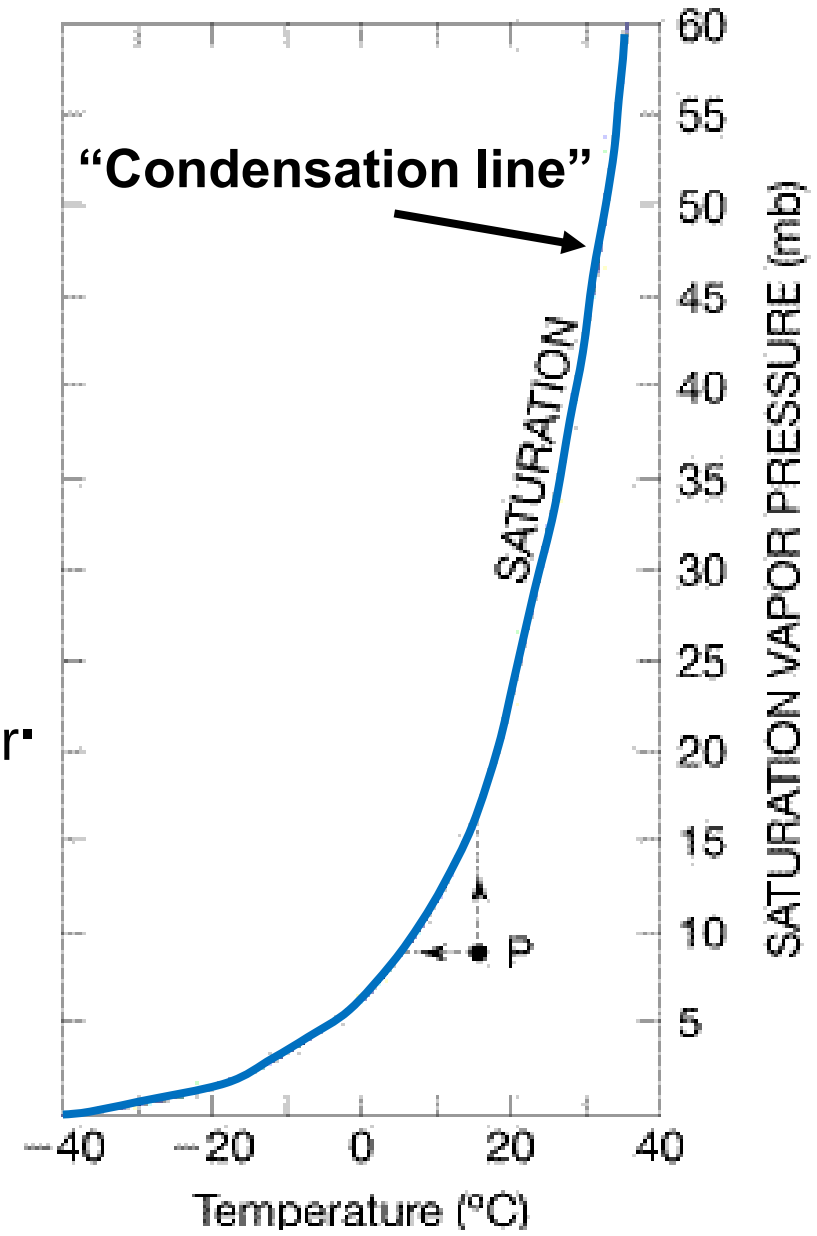
Implications for Greenhouse Effect And Climate Feedback



Water Vapor Feedback

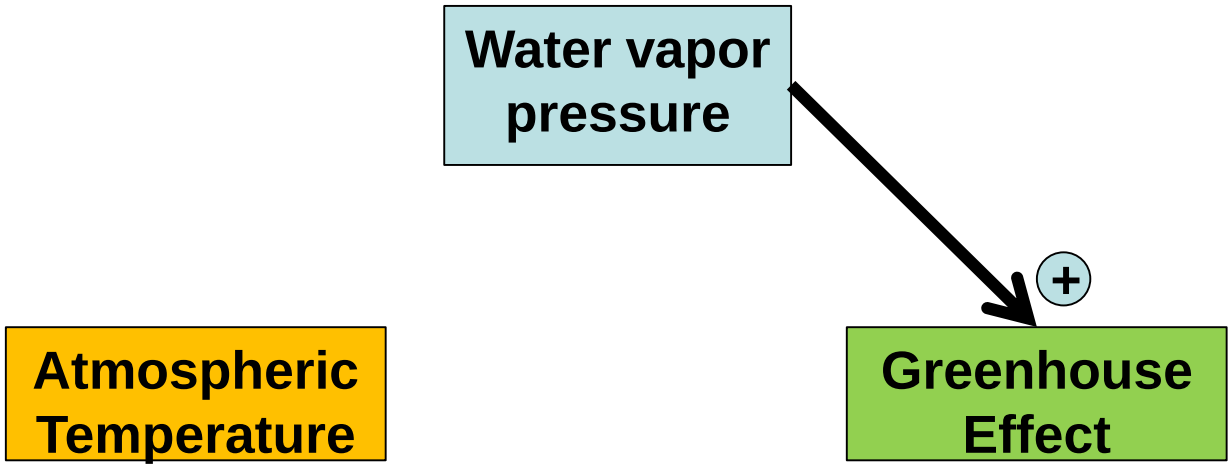
Water vapor pressure

Atmospheric Temperature

Greenhouse Effect

The amount of water vapor in the atmosphere is a *response to the climate*

Water Vapor Feedback



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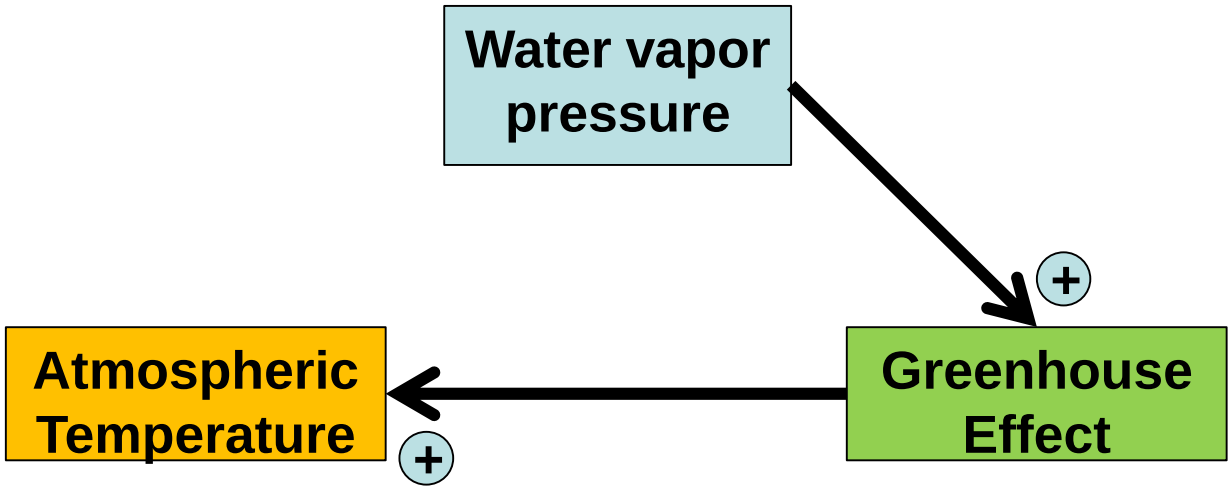

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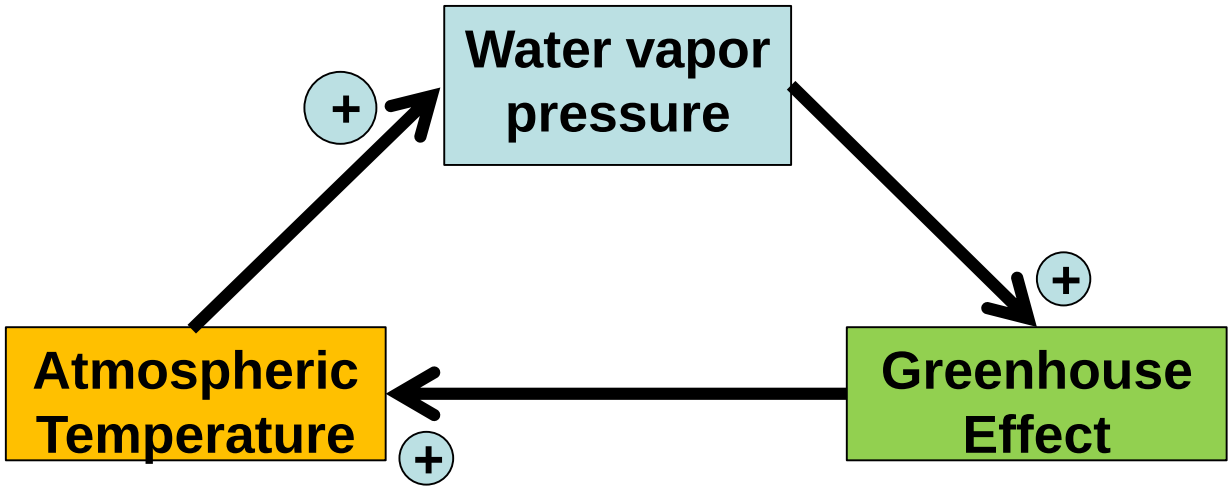

The amount of water vapor in the atmosphere is a *response to the climate*

Vertical Motions Summary

- A warm planetary surface induces ***buoyant forces***, which cause vertical motions, and thus ***convection*** in the atmosphere above it

- ***Rising*** air ***expands*** and therefore ***cools***, while ***sinking*** air is ***compressed*** and therefore ***warms*** (1st Law E = Q + W)

- Vertical motions are coupled to phase transitions of water: ***condensation*** (precip) during ***rising*** motions; ***evaporation*** (drying) during ***sinking*** motions

- The above concepts explain the ***average decrease*** in temperature (T) with altitude (z) in the troposphere:

$$\mathbf{T(z) = T_{surface} - (6.5K/km)*z}$$