ATM S 103

Hurricanes and Thunderstorms

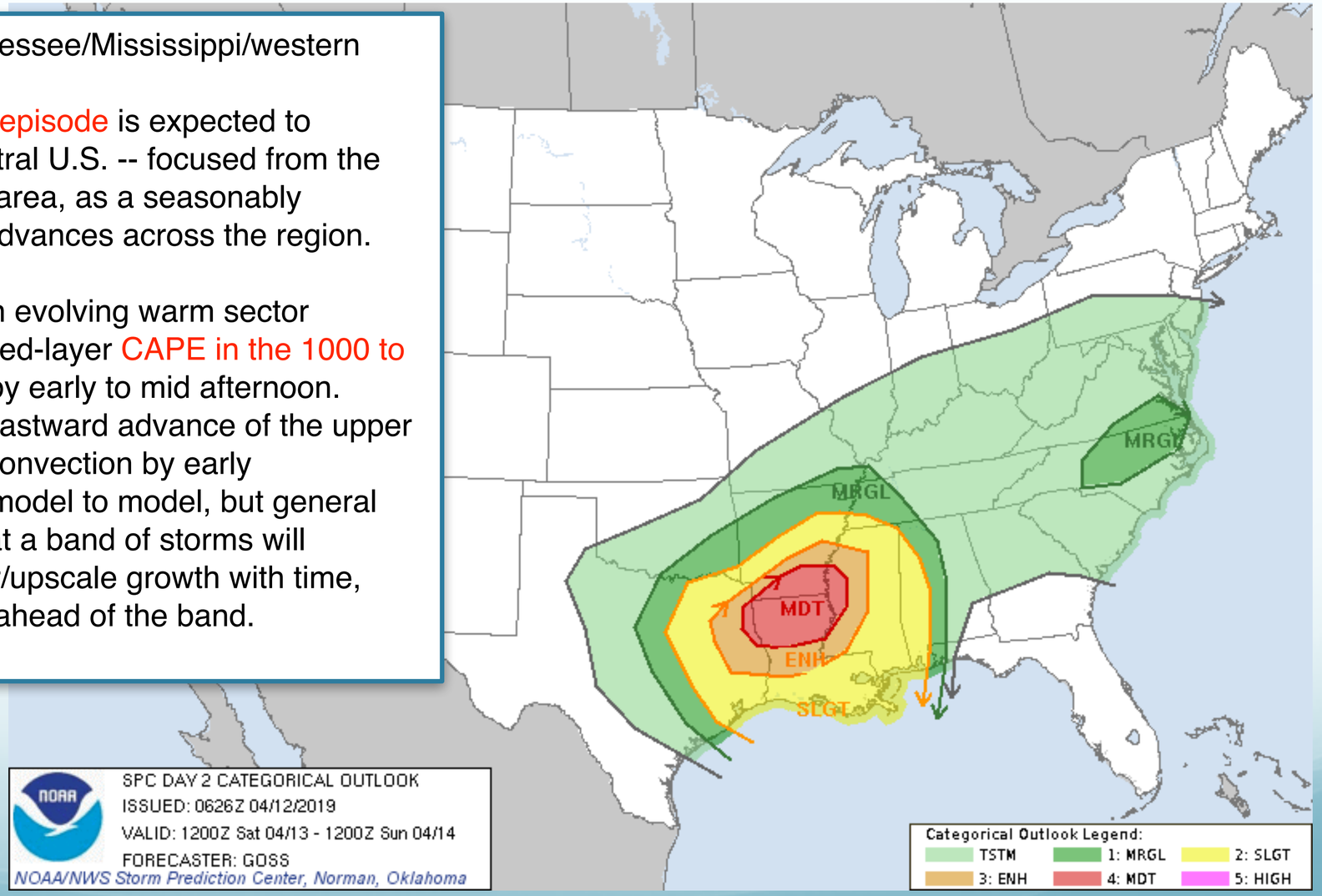
Their Science and Impacts

Outlook for Saturday

...east Texas eastward to southwest Tennessee/Mississippi/western Alabama...

A potentially significant severe weather episode is expected to evolve across portions of the south central U.S. -- focused from the Arklatex to the lower Mississippi Valley area, as a seasonably strong southern-stream storm system advances across the region.

With a moist low-level airmass within an evolving warm sector undergoing ample daytime heating, mixed-layer CAPE in the 1000 to 2000 J/kg range is expected to evolve by early to mid afternoon. Increasing ascent associated with the eastward advance of the upper system should result in an increase in convection by early afternoon. CAM guidance varies from model to model, but general consensus appears reasonable -- in that a band of storms will develop near the front, with some linear/upscale growth with time, while more cellular convection evolves ahead of the band.



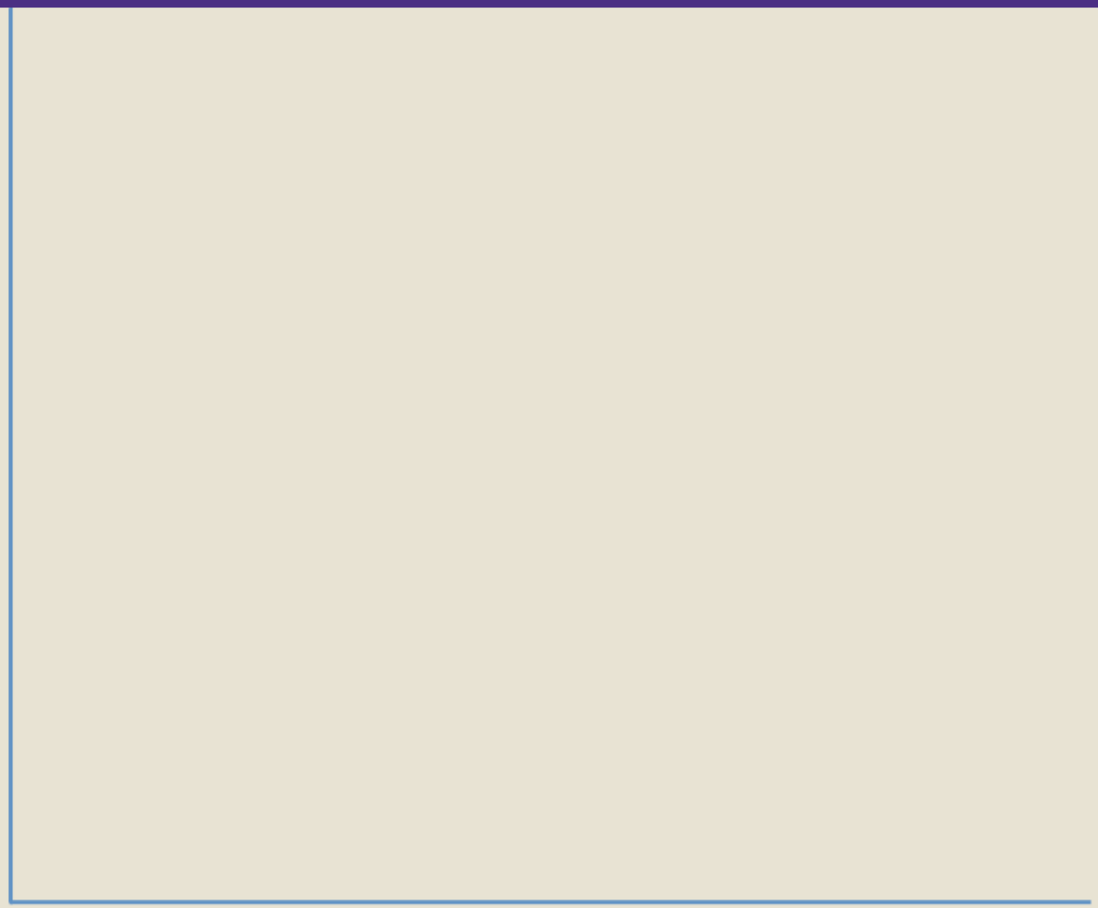
Which of the following is NOT true?

Latent heat from evaporation powers thunderstorms

In a stable atmosphere, an air parcel that is pushed up will be back down

An unstable atmosphere is rare as it will trigger air motions that will make the atmosphere stable again

In a conditionally unstable atmosphere, if you push an air parcel up high enough, it will become positively buoyant



Answer: Latent heat from condensation (not evaporation) powers thunderstorms

- In a stable atmosphere, an air parcel that is pushed up will be back down
- An unstable atmosphere is rare as it will trigger air motions that will make the atmosphere stable again
- In a conditionally unstable atmosphere, if you push an air parcel up high enough, it will become positively buoyant

Topics for today

- What shapes the clouds?
- How do clouds and moisture affect atmospheric stability?

What Shapes the Clouds?

- Key factor: *atmospheric stability*
- *Stable case: Stratus clouds* form in stable air that is uniformly lifted over a broad region by a low pressure center or ...
- *Unstable case: Cumulus clouds* form when the clouds rise in localized patches because they are warmer than their environment

Stability

“Stable”

When pushed to the left or right, the ball will eventually comic to its original position

“Unstable”

A slight change in the position of the ball will make it to move away from its original position

Assessing stability: overall strategy

- Consider an air parcel at rest, in equilibrium with its surroundings.
- What is the *feedback* on the parcel if it is pushed up or down?

Stable Case: Negative Feedback

When the parcel is pushed *up* a bit, it becomes

- Slightly *colder* than its surroundings
- So it *sinks* back down (and oscillates about its original position).

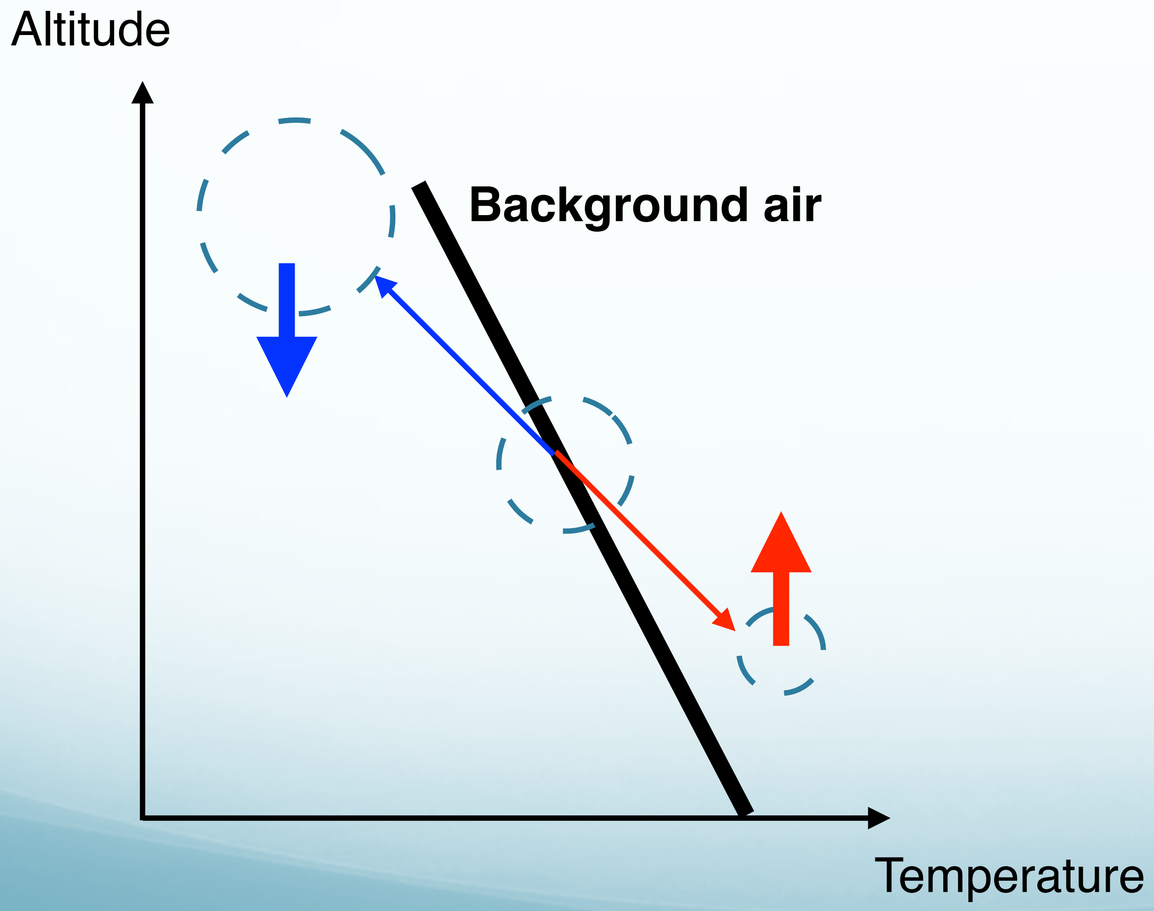
Unstable Case: Positive Feedback

When the parcel is pushed *up* a bit, it becomes

- Slightly *warmer* than its surroundings
- It continues to *rise*
- Becoming even warmer than its surroundings
- And rising even faster.

Atmospheric stability

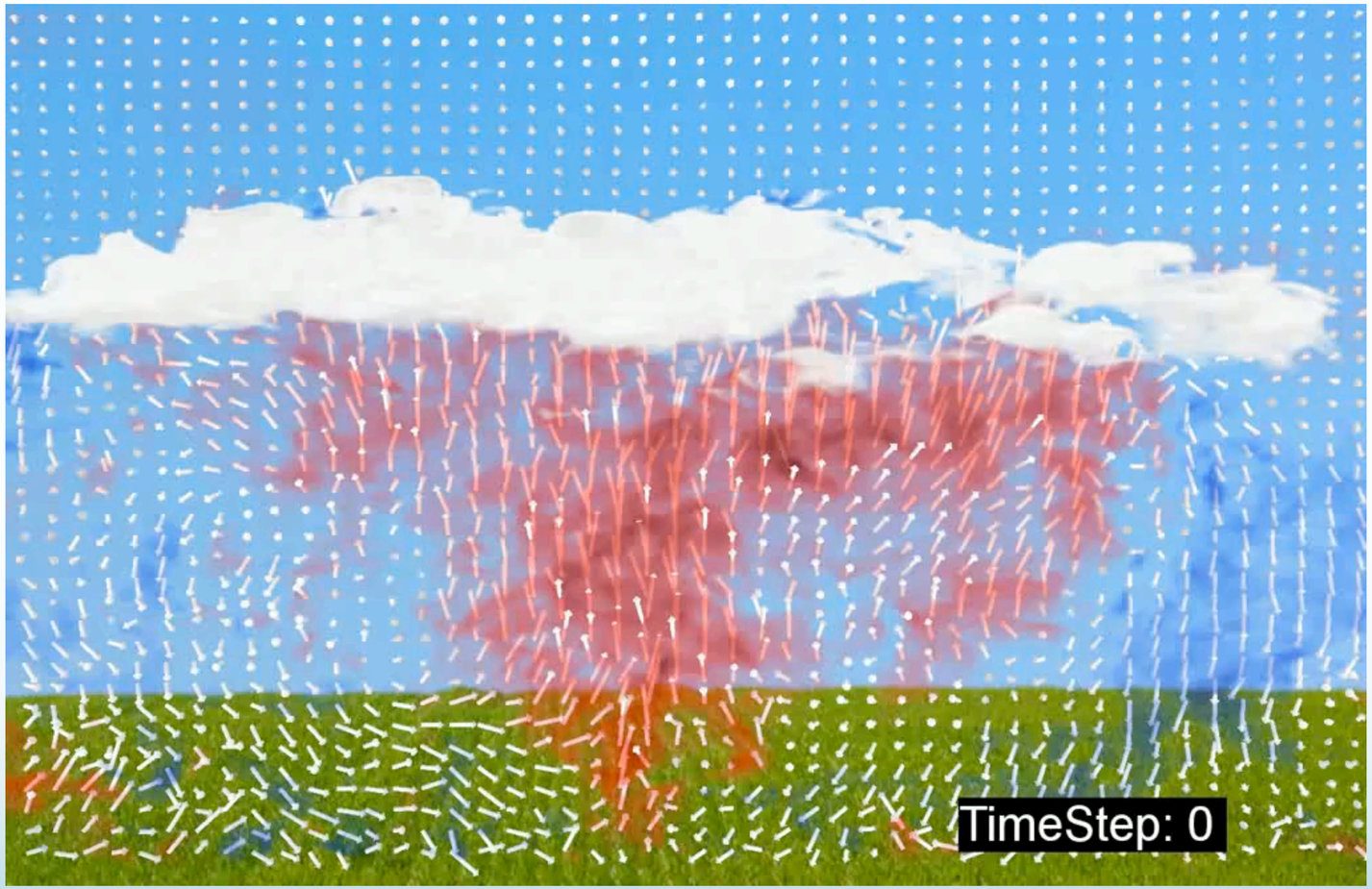
"Stable"



Creating unstable conditions

- The sun can heat the ground.
  - That heat gets transferred to air near the surface, tending to make an unstable environmental lapse rate.
  - But warm air starts to rise transferring heat upward
  - The layer of air near the ground never gets strongly unstable
  - Vertical velocities in the heated rising air are weak (2 m/s or 4 mph)

Rising (red) and Sinking (blue) Motions in Fair Weather Cumulus



Maximum updraft speeds about 2 m/s (4 mph, fast walk)

Clouds formed by rising motions in an unstable environment near the ground created by solar heating.

Compare to a thunderstorm

Unstable ascent through a deep layer creates thunderstorms. How?

Conditional instability allows moist, but unsaturated air to be *stable to small* vertical displacements, but dramatically *unstable to large* ones.

Cloudy (Saturated) Parcels

What happens if a *rising air* parcel *is saturated* (contains a cloud)?

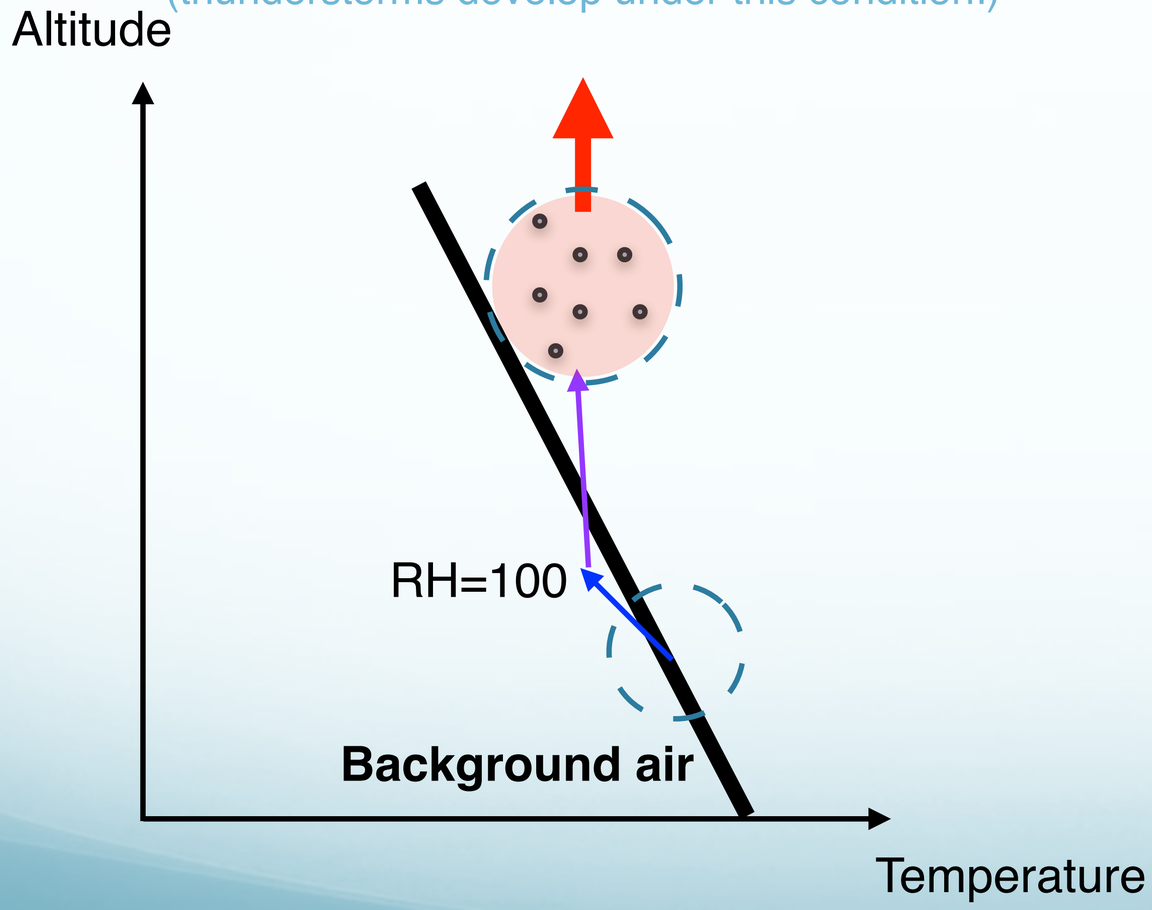
- As it cools due to expansion, *water vapor condenses*
  - Forming new droplets
  - Enlarging existing droplets
- *Latent heat is released* as the vapor condenses.
- Latent heat partially offsets the cooling accompanying the parcel's expansion as it encounters lower pressures aloft.

A rising cloudy parcel cools at a different rate: the *moist adiabatic lapse rate*.

Atmospheric stability

"Conditionally unstable"

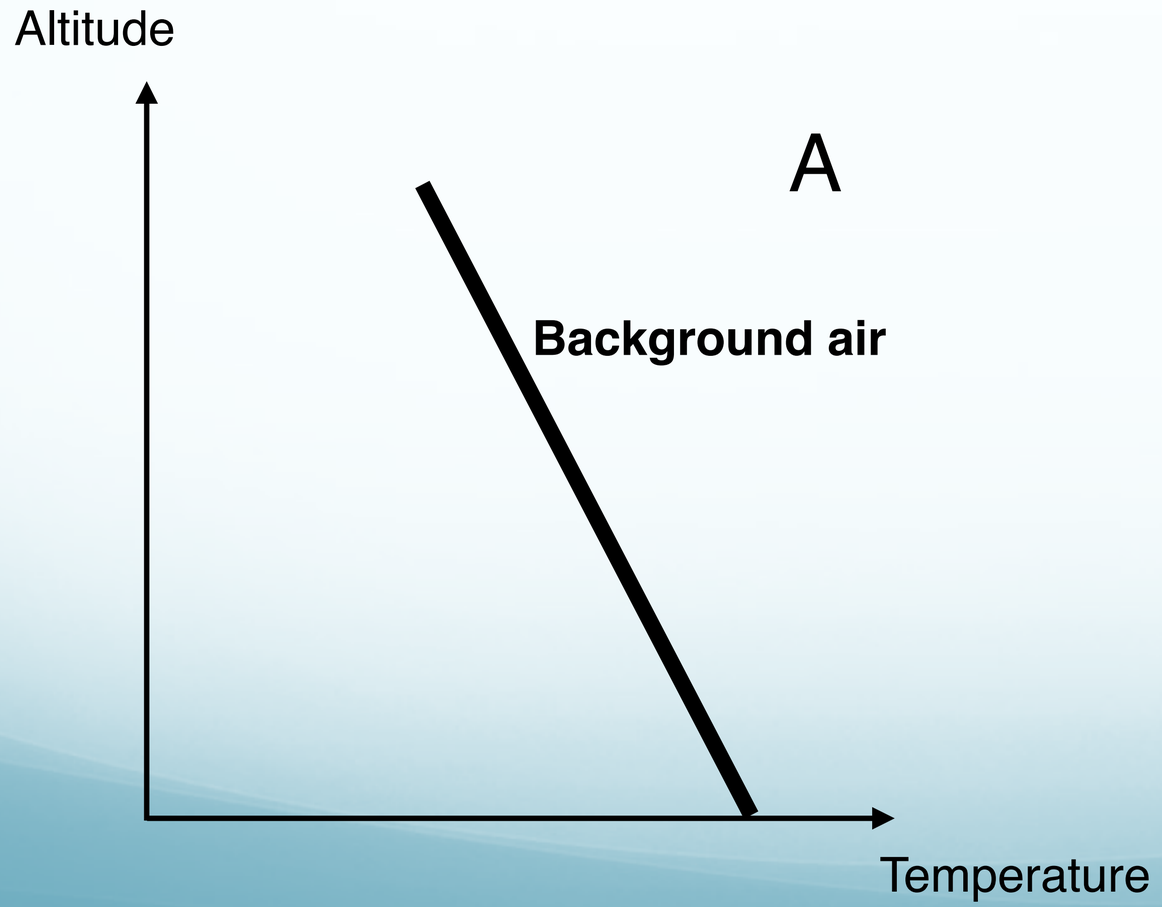
(thunderstorms develop under this condition!)

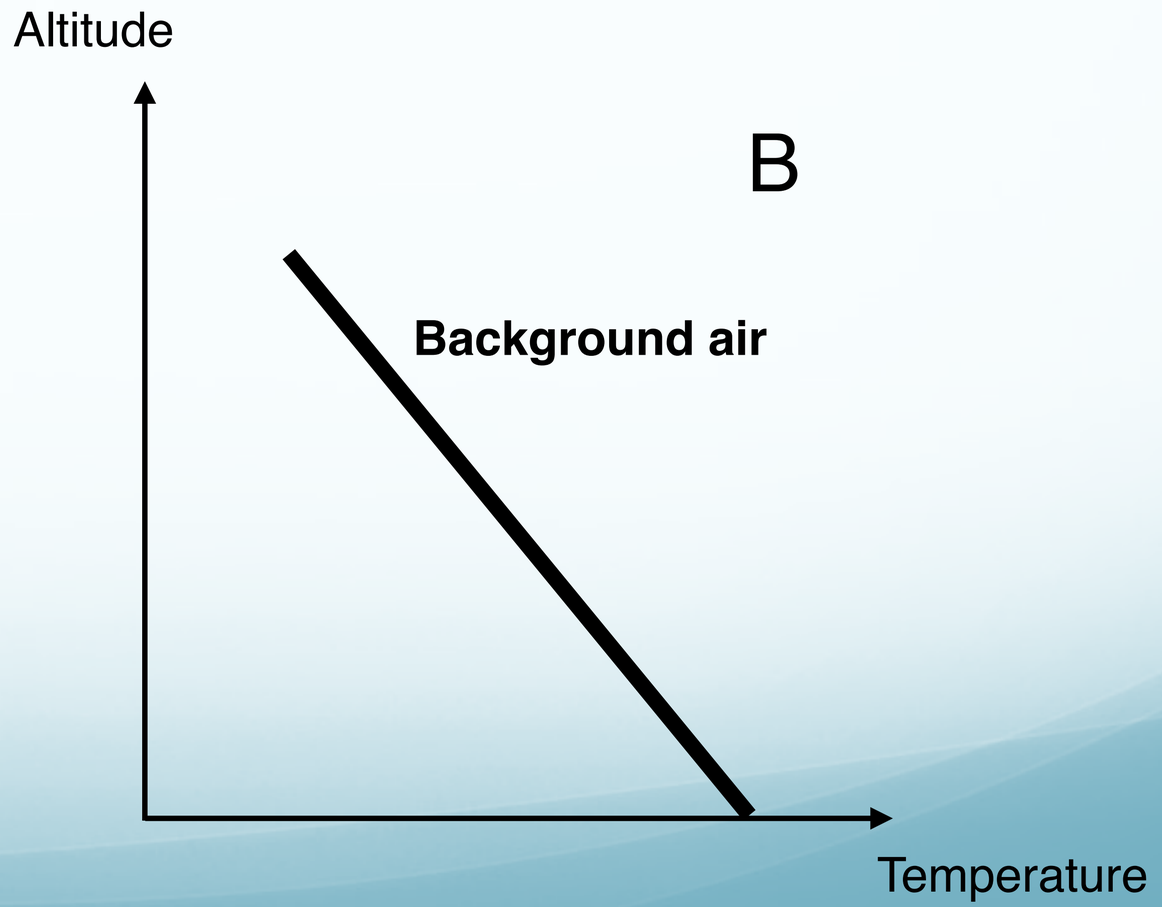


How do we measure atmospheric stability?

Lapse rate

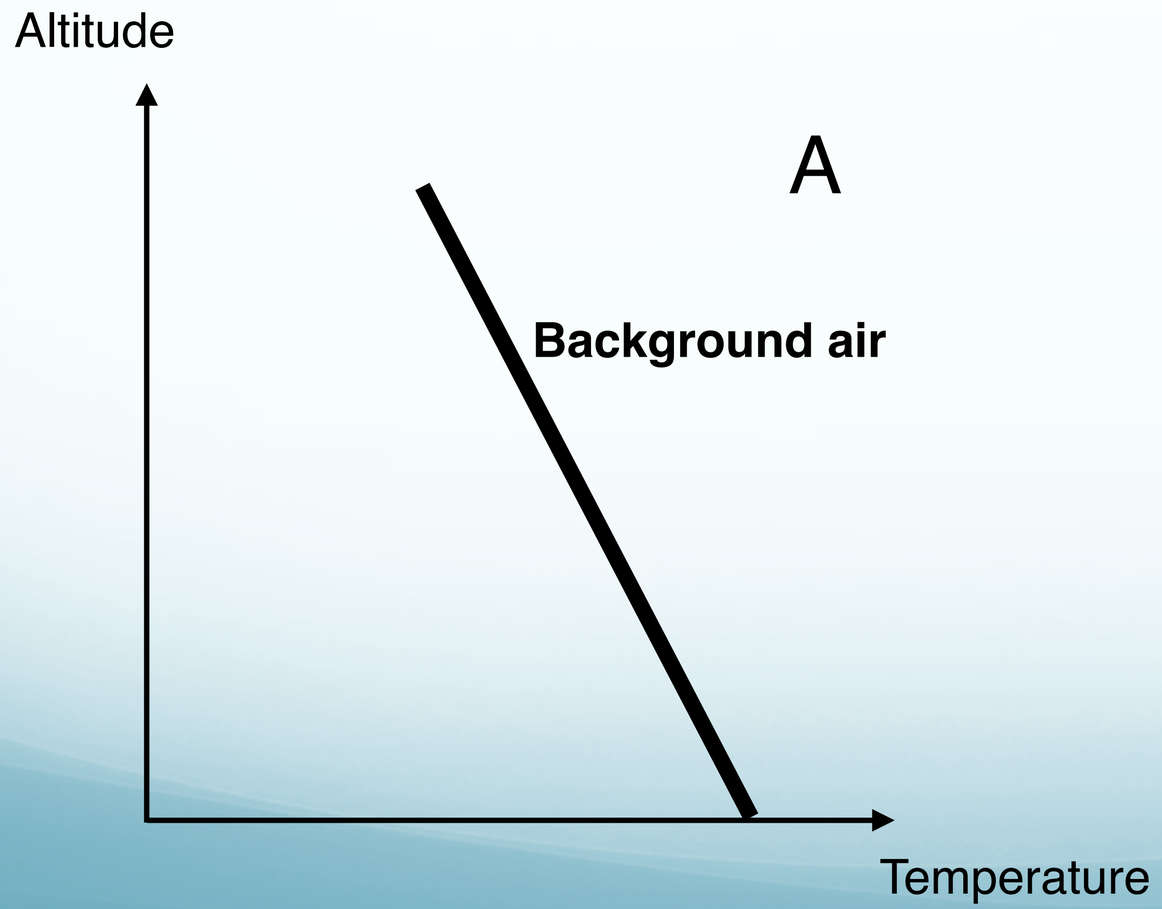
Environmental lapse rate: the rate at which background air temperature drops with height (varies depending on where you are)

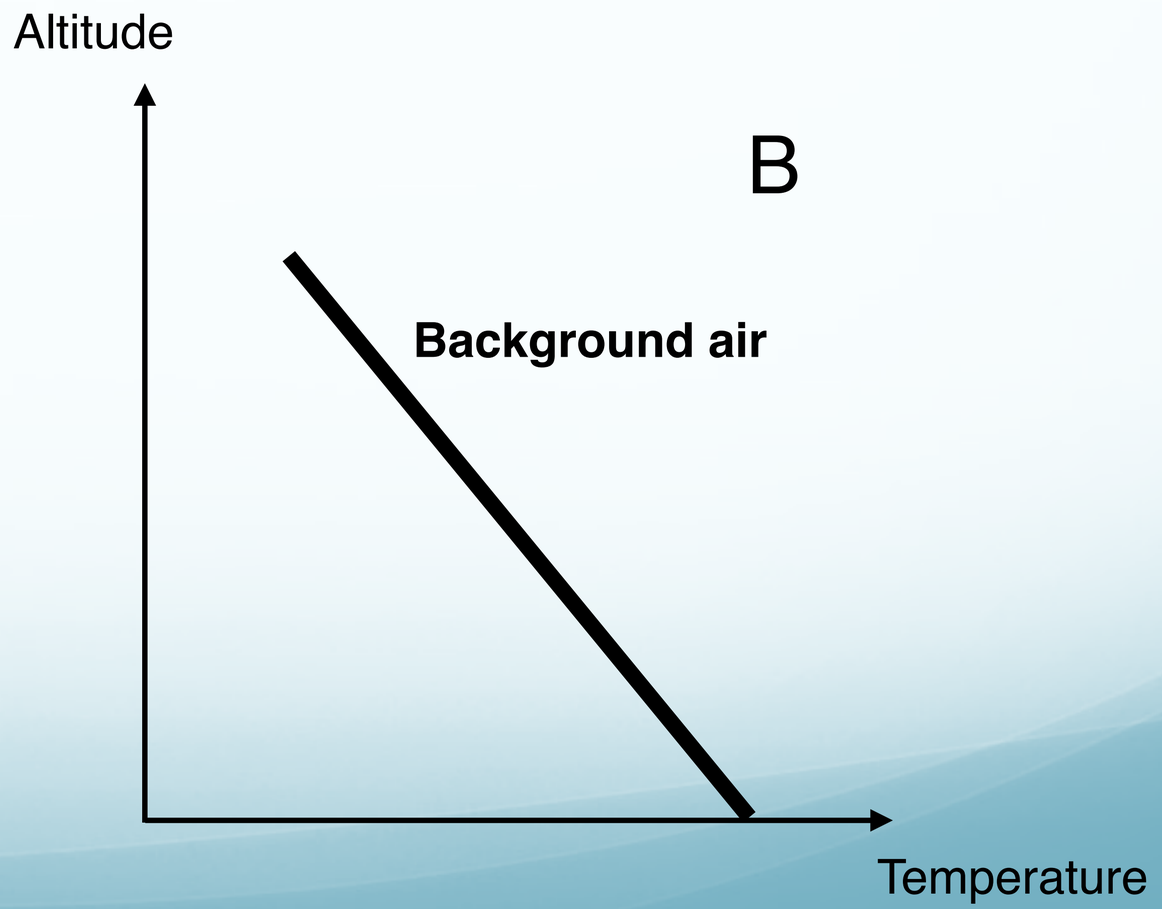




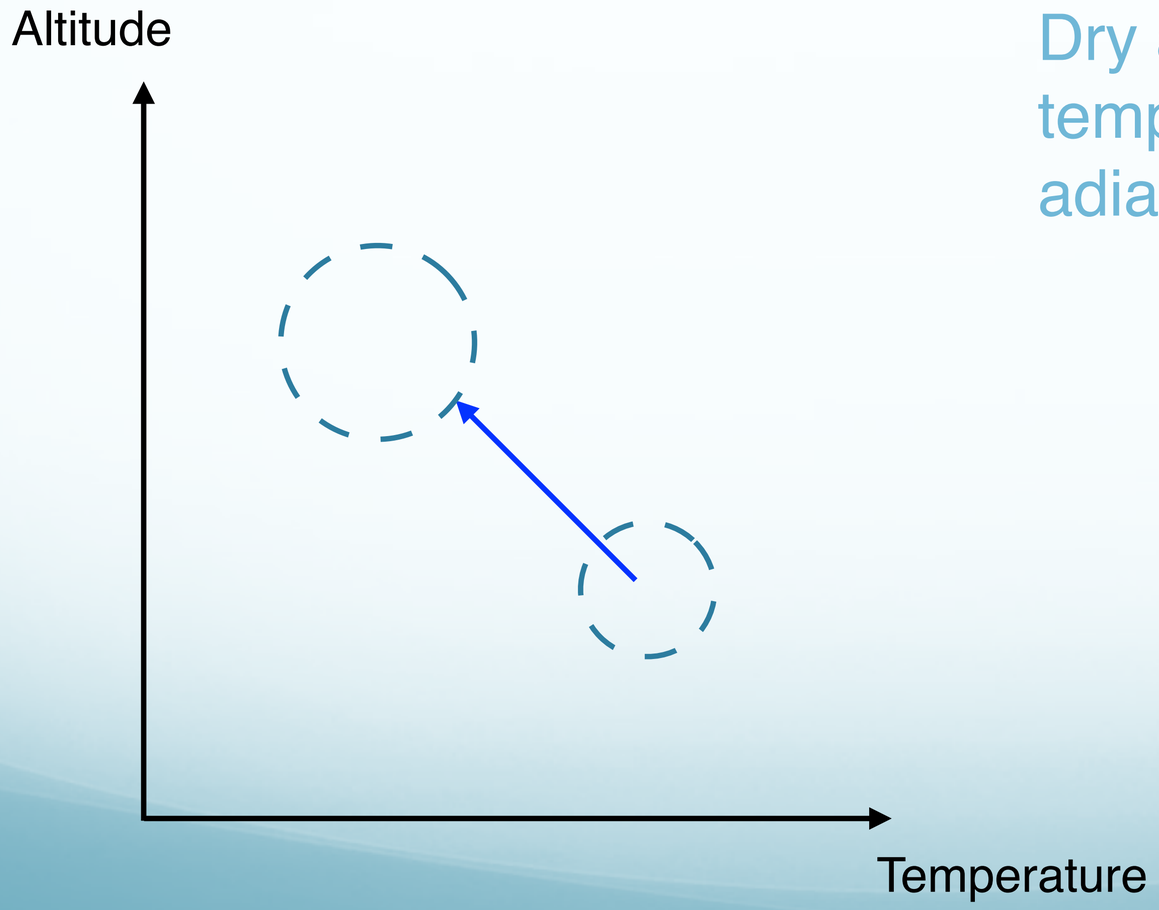
Lapse rate

Environmental lapse rate: A < B



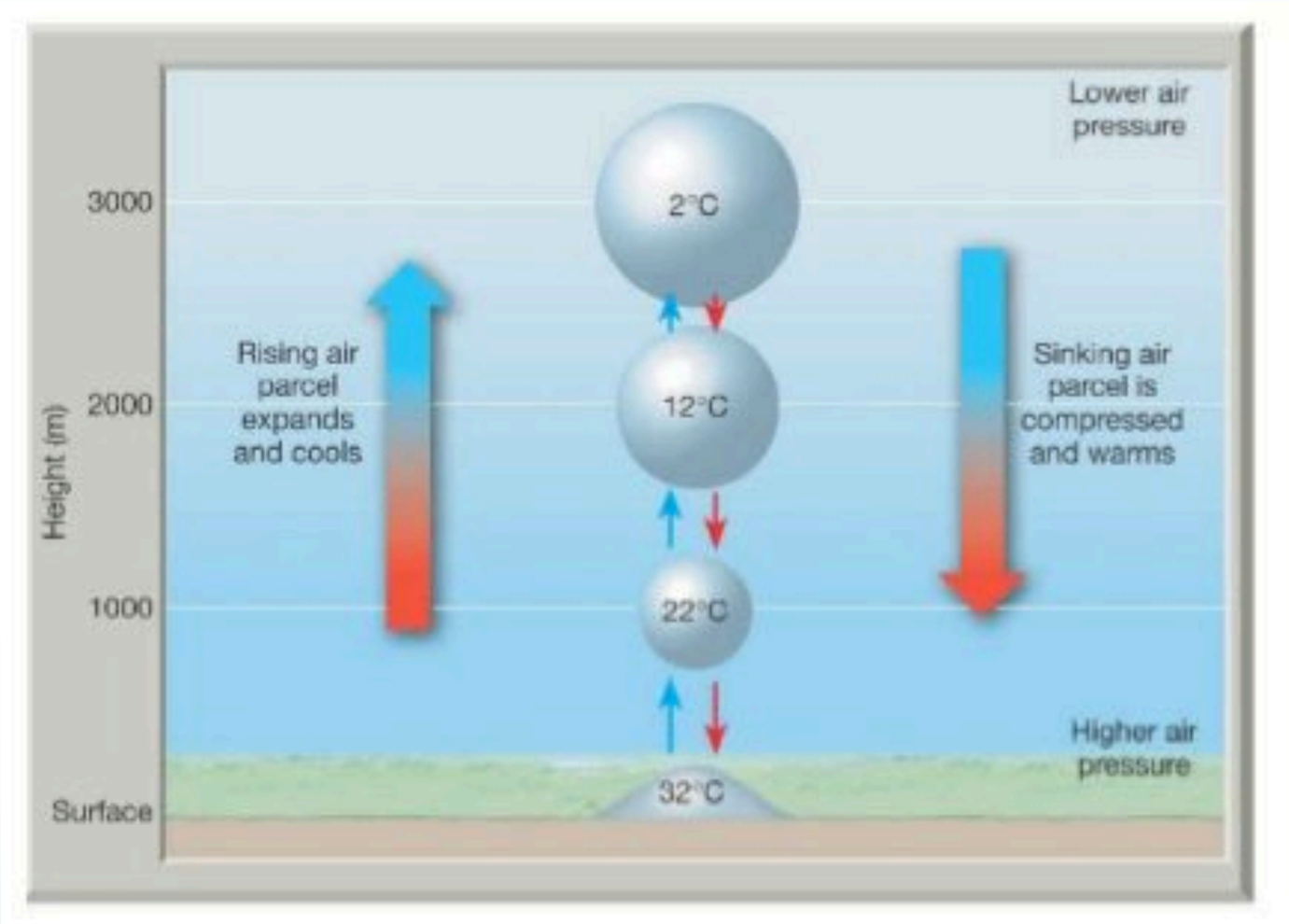


Lapse rate

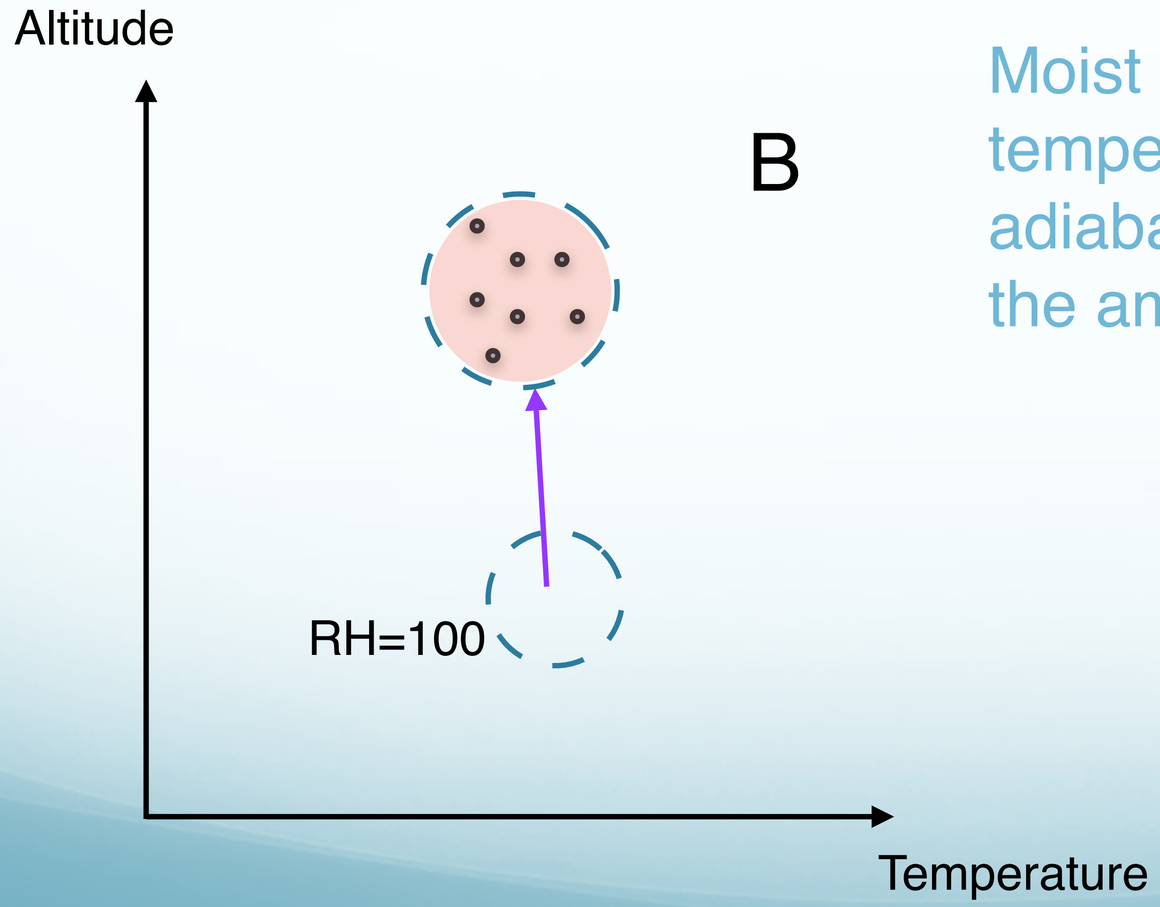


Dry adiabatic lapse rate: the rate at which temperature drops in an air parcel as it is adiabatically raised up (always 10 ^{o}C/km)

Dry adiabatic lapse rate

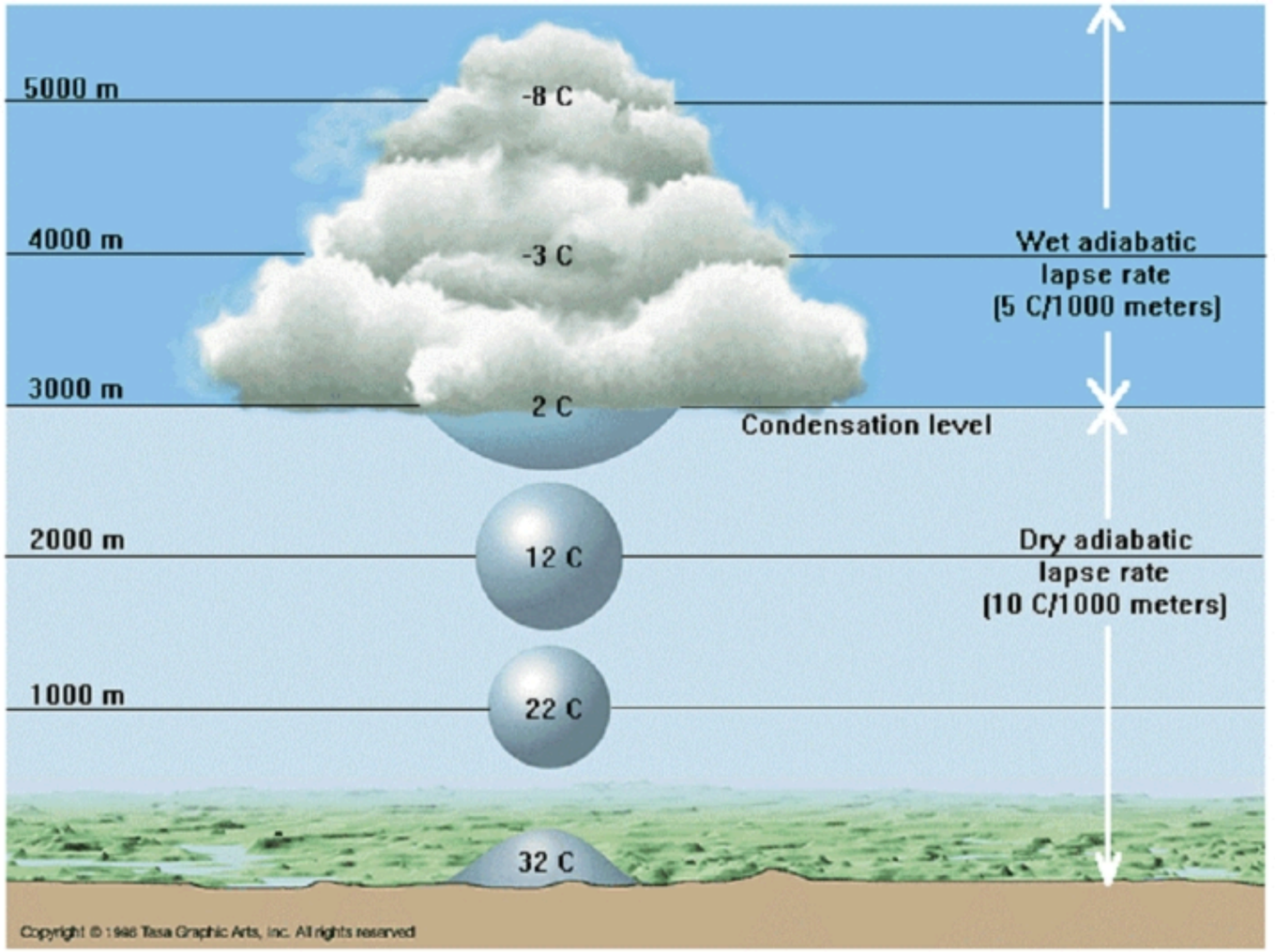


Lapse rate



Moist adiabatic lapse rate: the rate at which temperature drops in a saturated parcel as it is adiabatically raised up (varies depending on the amount of water vapor, less than 10 oC/km)

Dry vs. moist adiabatic lapse rate



Lapse rate: the rate at which temperature drops with height

- Environmental (or background) lapse rate: how fast the background air temperature drops with height (varies depending on where you are)
- Dry adiabatic lapse rate: how fast temperature drops in an air parcel as it is adiabatically raised up (always 10 ^{o}C/km)
- Moist adiabatic lapse rate: how fast temperature drops in a saturated air parcel as it is adiabatically raised up (varies depending on the amount of water vapor, less than 10 ^{o}C/km)

In a stable atmosphere, the background lapse rate is greater than the dry adiabatic lapse rate

True

False

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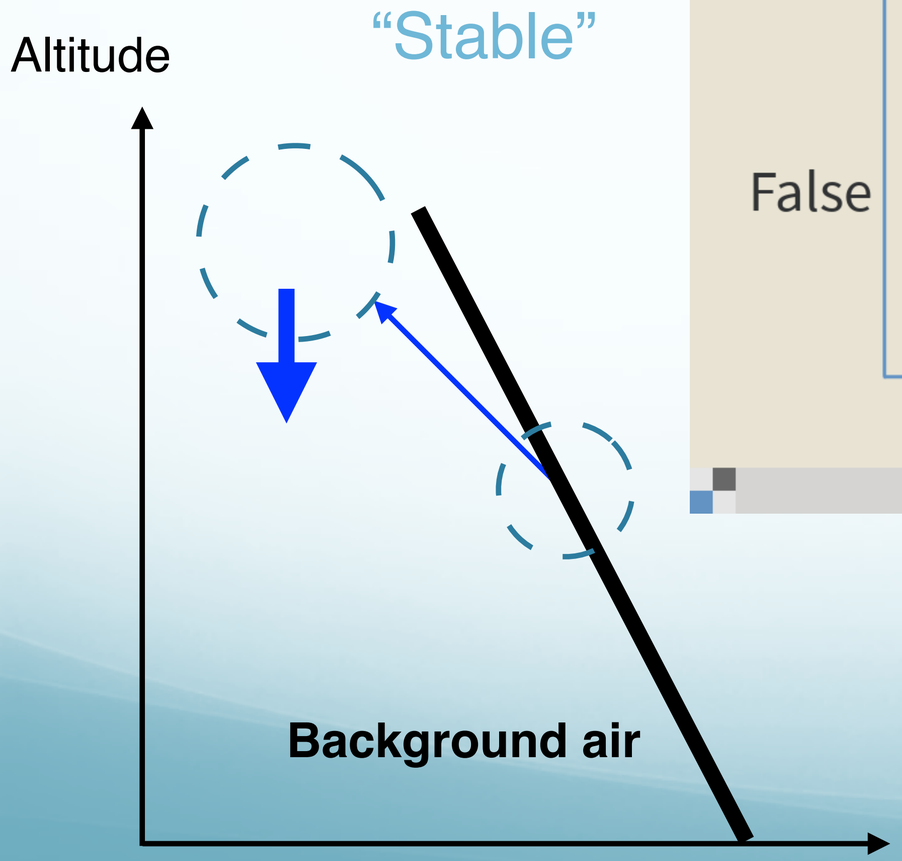
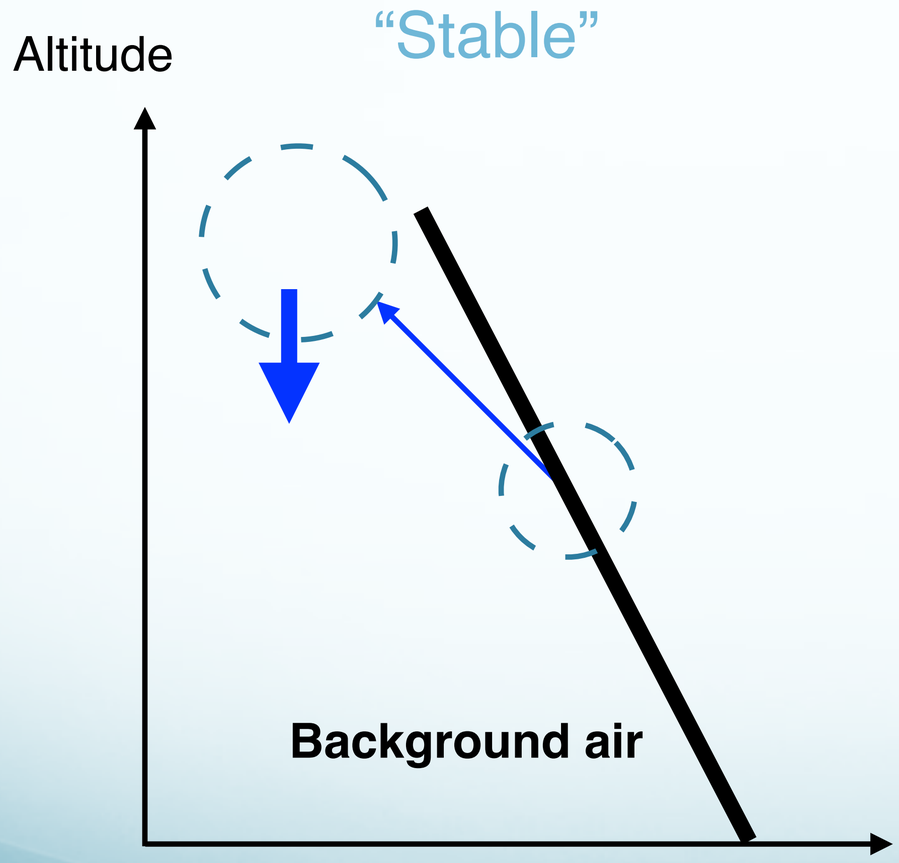
Total Results



Answer: False



Dry adiabatic lapse rate is greater than the background lapse rate in a stable situation

Which of the following is the largest in a conditionally unstable atmosphere?

- Background lapse rate
- Dry adiabatic lapse rate
- Moist adiabatic lapse rate

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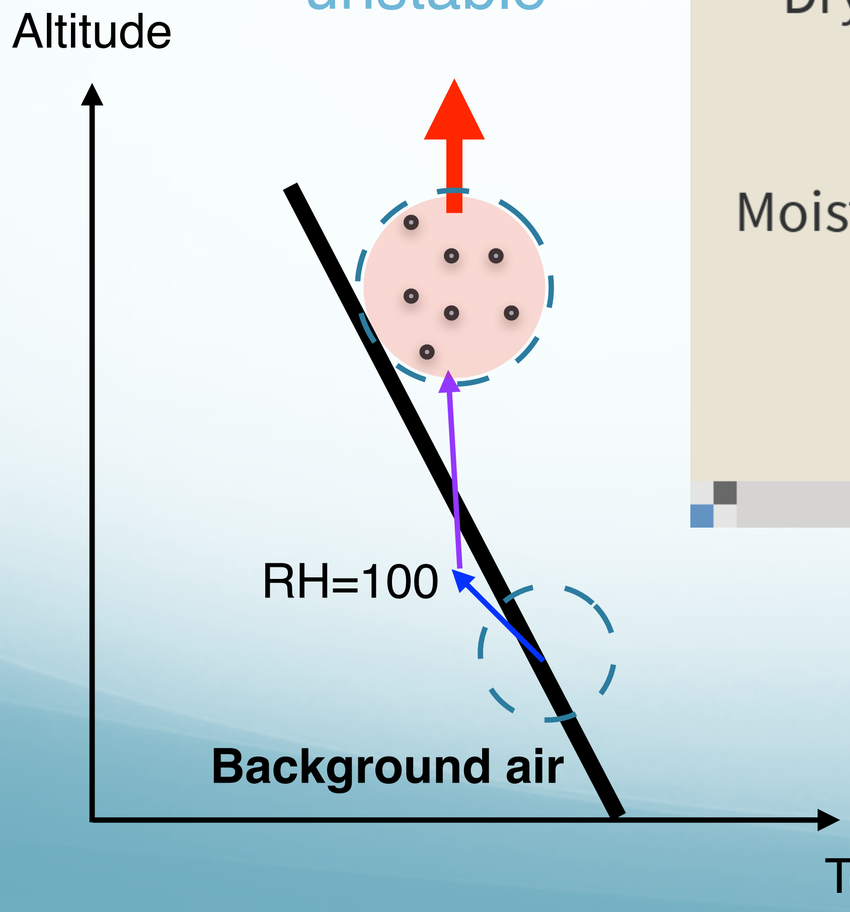
Total Results

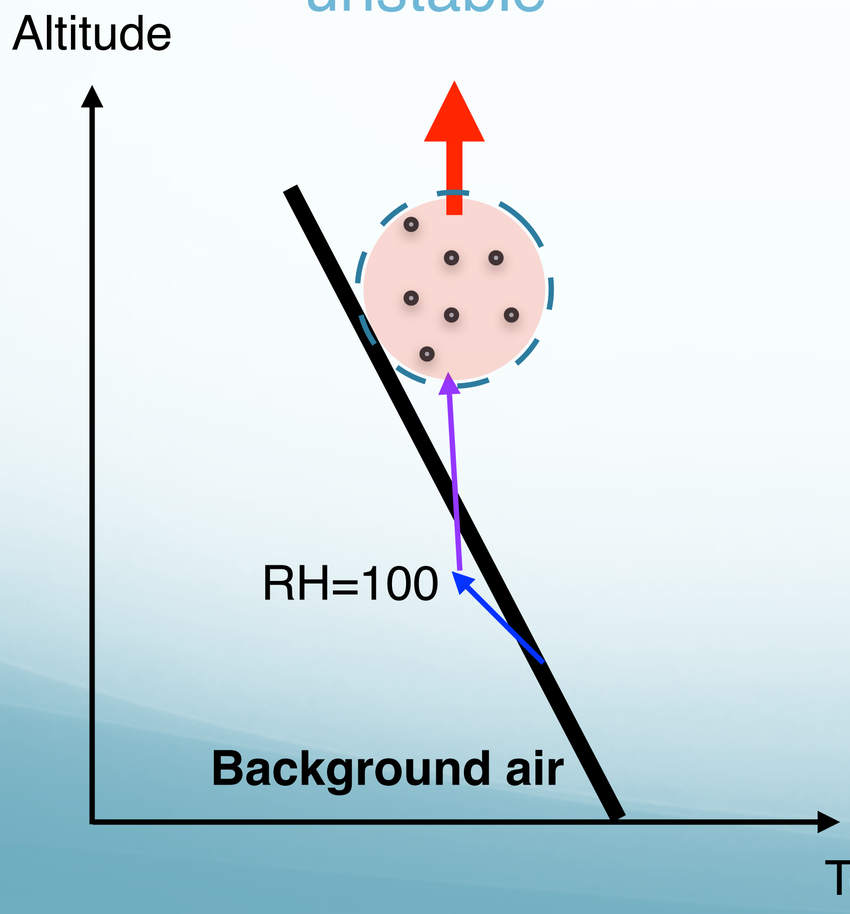
"Conditionally unstable"



Answer: dry adiabatic lapse rate

“Conditionally unstable”

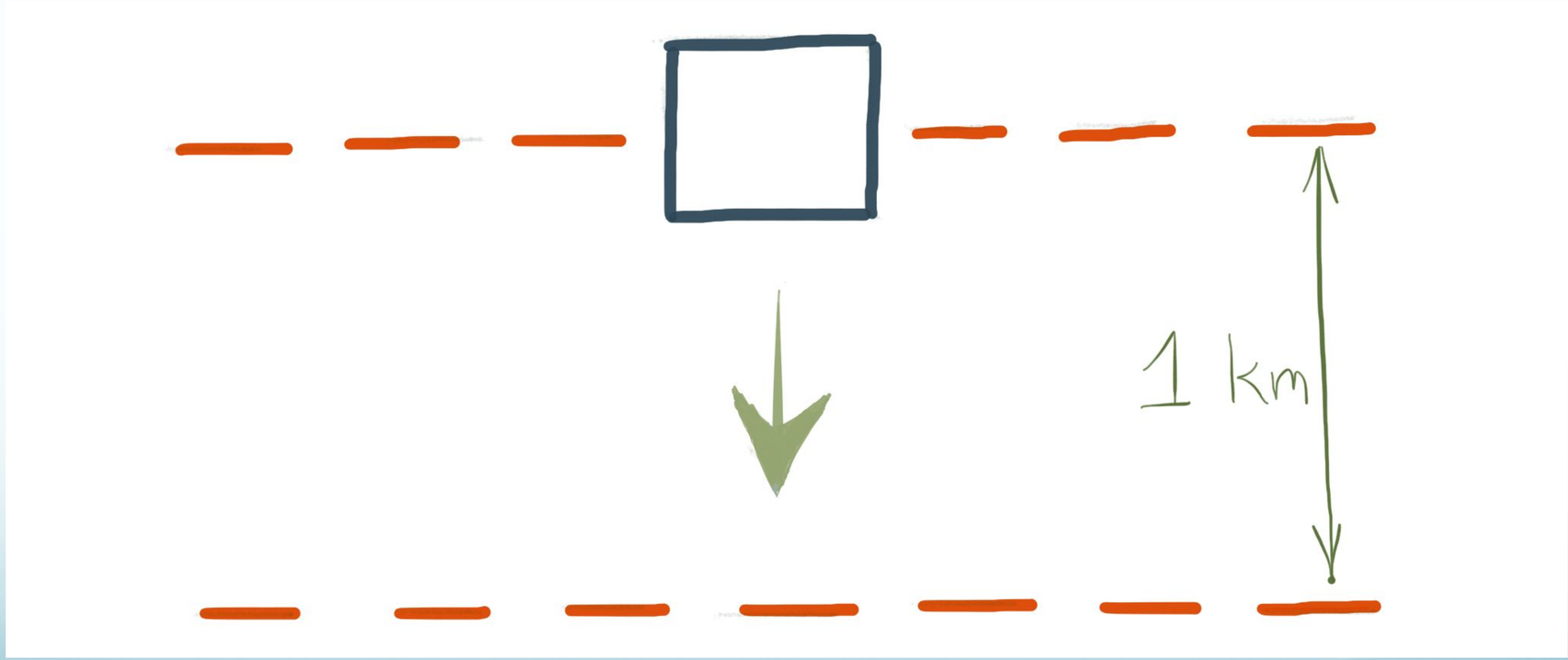
Moist adiabatic lapse rate < Environmental lapse rate < Dry adiabatic lapse rate



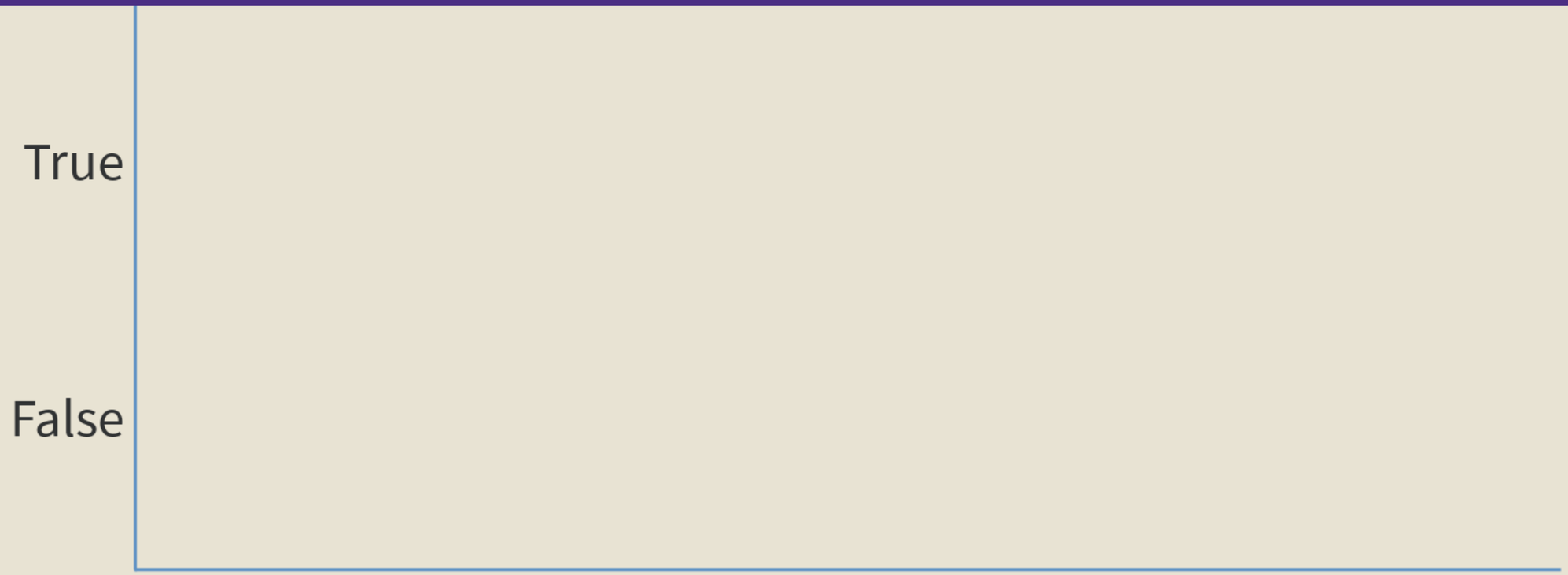
Effect of temperature (via water vapor content) on the moist adiabatic lapse rate

Temperature at 1000 mb	-20 °C	0°C	30°C
Dry Adiabatic Lapse Rate	-10 °C/km	-10 °C/km	-10 °C/km
Latent Heating	+1 °C/km	+3 °C/km	+6.5 °C/km
Moist Adiabatic Lapse Rate	-9 °C/km	-7 °C/km	-3.5 °C/km

The environmental lapse rate is 5° C per km.
A dry air parcel given an initial push downward from a height of 1 km. Will it tend to keep moving downward?



W **The environmental lapse rate is 5° C per km. A dry air parcel given an initial push downward from a height of 1 km. It will tend to keep moving downward.**



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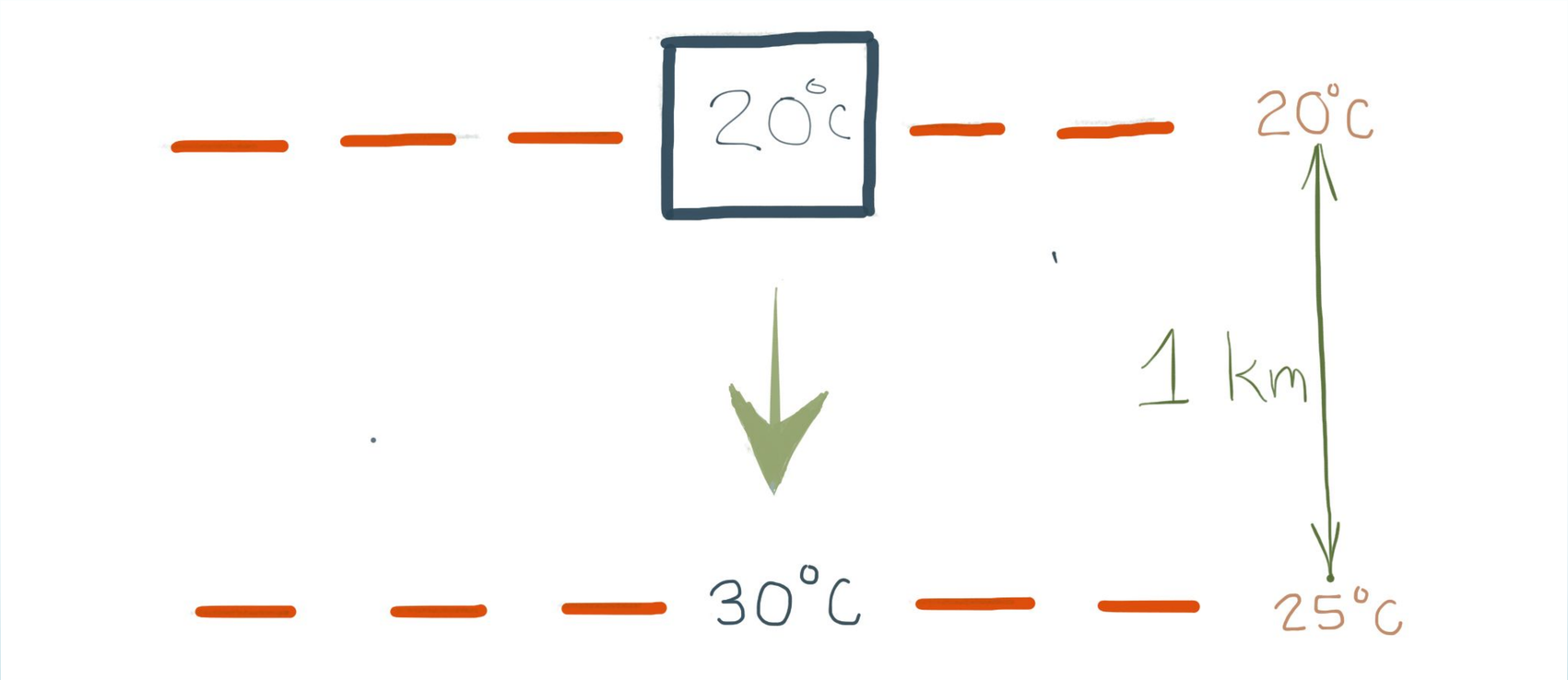
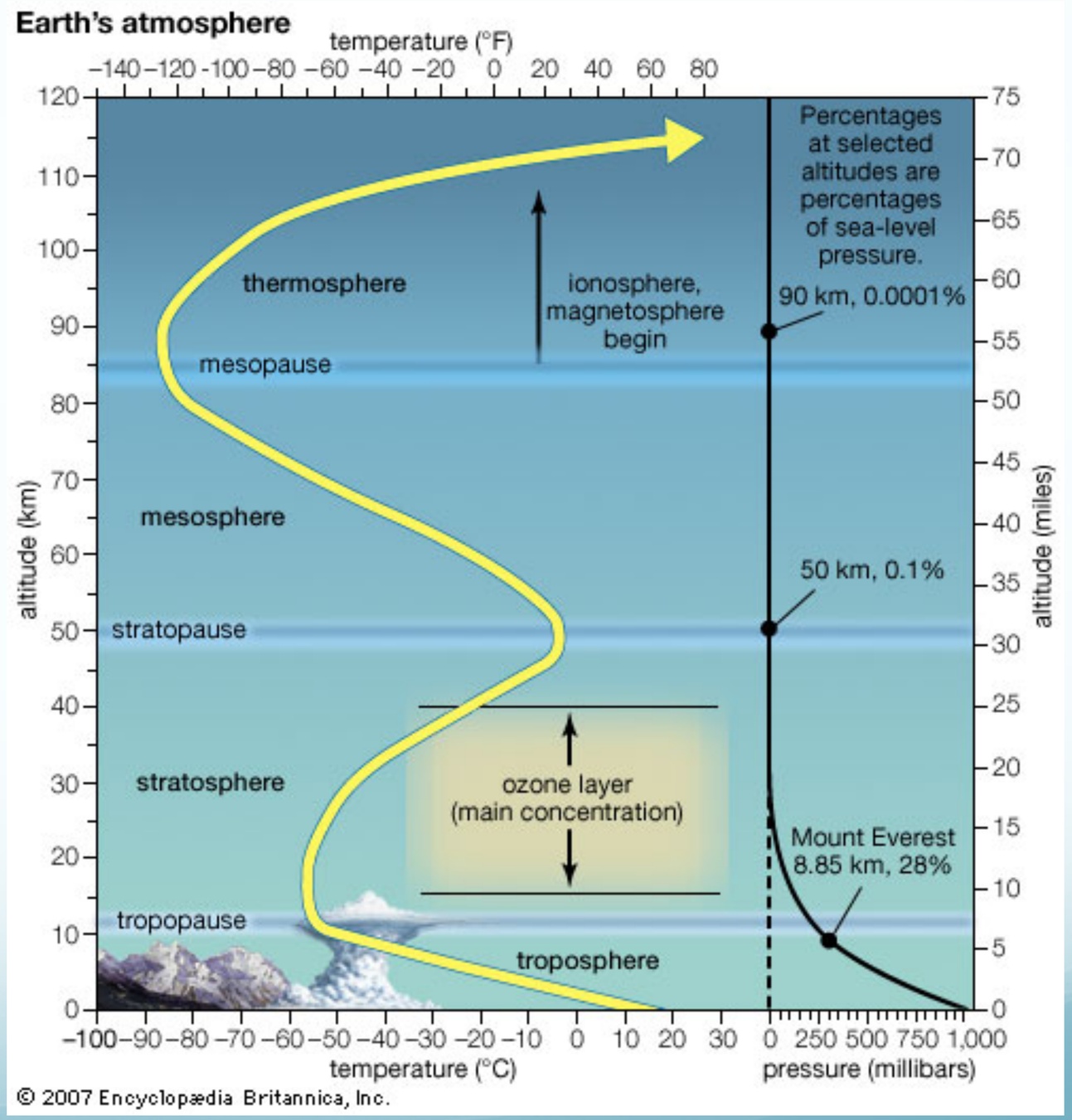
Total Results

False: if the environmental lapse rate is 5° C per km, a dry air parcel given an initial push downward from a height of 1 km will become warmer than its environment.



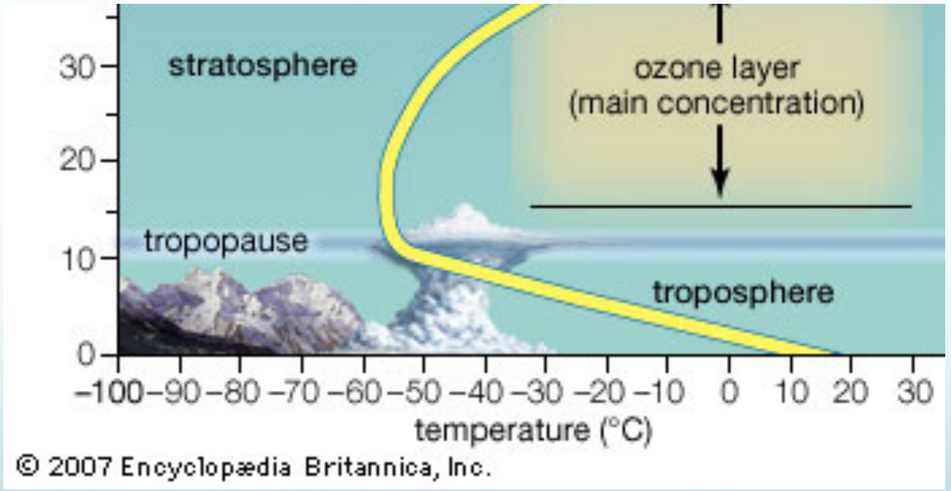
Vertical Profile of Atmospheric Temperature

Which layer in the atmosphere is most stable?



The atmospheric layer that is most stable is the stratosphere.

- The temperature is constant with height in the lower stratosphere.
- It increases with height in the upper stratosphere. (negative lapse rate!)
- Both situations are *very* stable.



Thunderstorm anvil viewed from space.

Why do thunderstorms “stop rising” when they reach the tropopause?

Answer

- Thunderstorm clouds stop rising and spread out when they encounter the *very stable* stratosphere.
- Rising air parcels in the updraft rapidly become colder than their environment as they ascend in the stratosphere.
  - They don’t ascend very far.