

ATM S 103

# Hurricanes and Thunderstorms

Their Science and Impacts

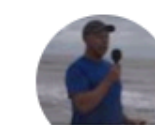


Claudio Bottari (from <http://www.severe-weather.eu>)



# Last Saturday

- <https://www.today.com/video/at-least-4-dead-after-15-tornadoes-touch-down-from-texas-to-alabama-1491492931985>



**Bob Pack**  
@BobPackWX



Power of nature from Franklin TX @KBTXErika @KBTXShel

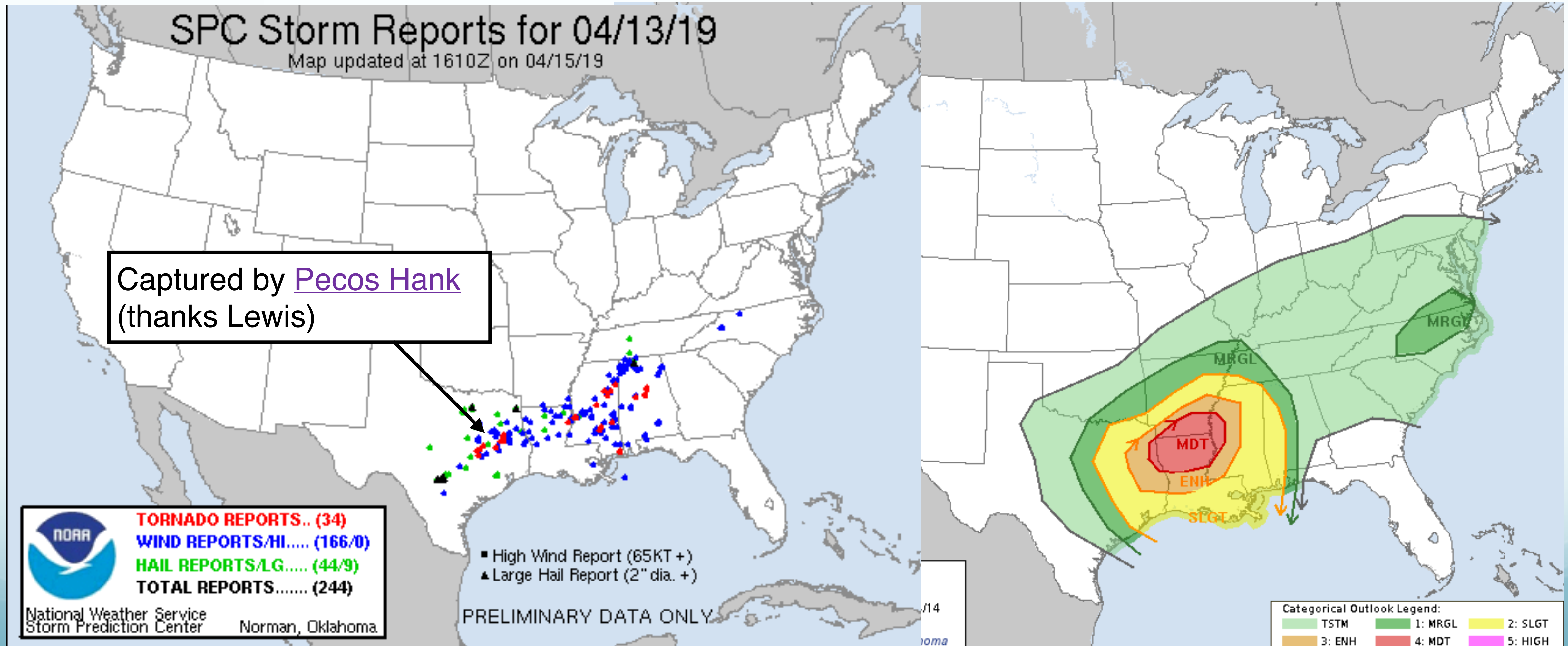
♡ 128 12:50 PM - Apr 13, 2019

💬 130 people are talking about this





# Last Saturday



# W Which of the following is NOT associated with a typical thunderstorm breakout?

high dew point  
near the surface

strong heating of the  
surface by sun lights

stable atmosphere

upward motion near  
the surface



# Answer

- high dew point near the surface (correct)
- strong heating of the surface by sun lights (correct)
- stable atmosphere (**wrong**) —> **conditionally unstable atmosphere**
- upward motion near the surface (correct)

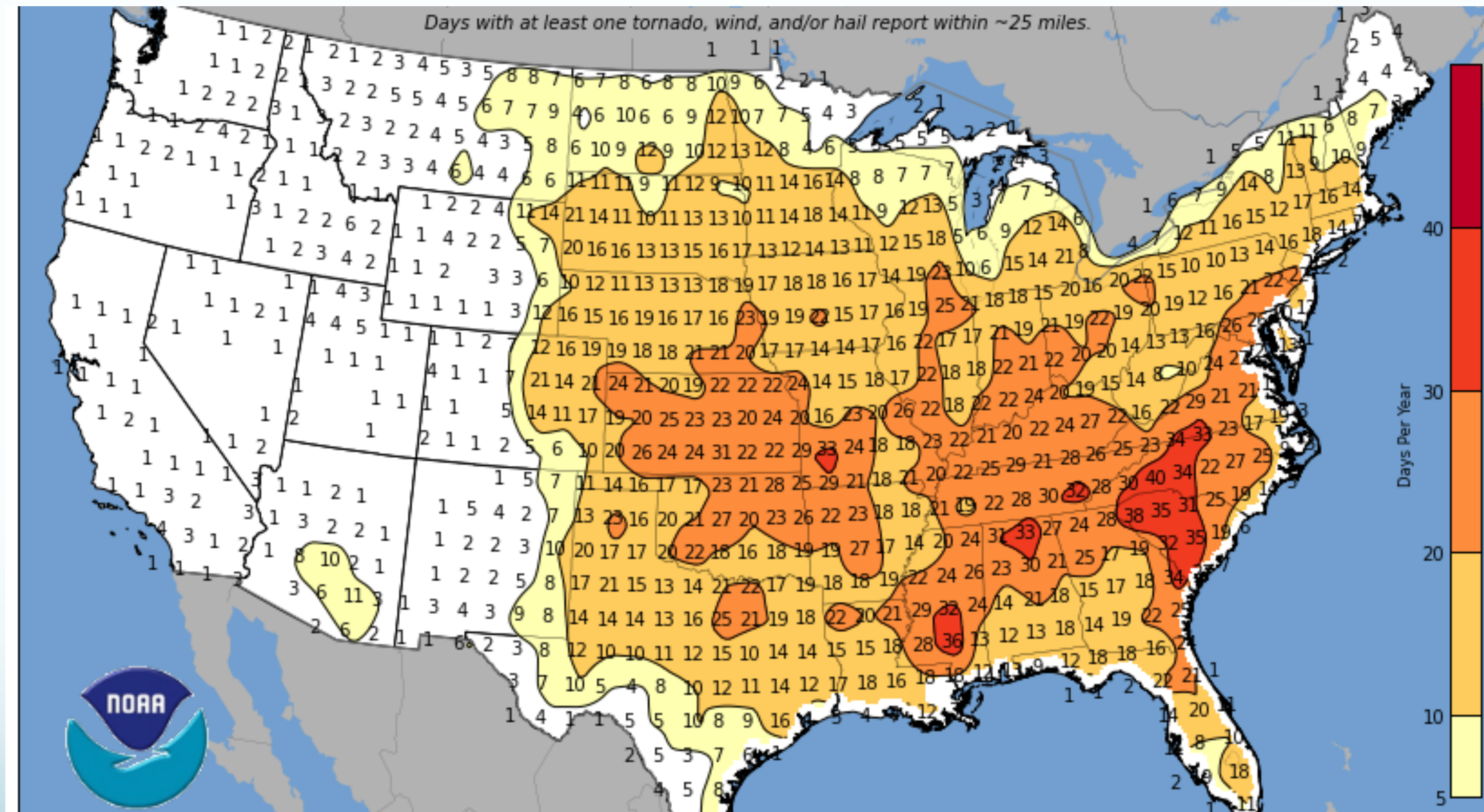


# Topics for today

- What are the key ingredients required to produce thunderstorms?



# Annual average days with a severe thunderstorm





# Where do the numbers come from?

- Need observers or observational evidence available after the fact
- There must be a “box” size associated with these numbers.
- NOAA uses “within 25 miles”
  - Severe weather reports within a 50 x 50 mile box
  - Severe T-storm: 1” hail or 50 knot (58 mph) winds
- Will show plots for period 2003 – 2012
  - Biased toward population centers
  - Biased toward areas with trees (???)



# W Why are the severe weather statistics biased toward areas with trees?

Few people live where there are trees.

Trees show high-wind damage better than grasslands.

Tree emit more moisture than grasslands during photosynthesis.



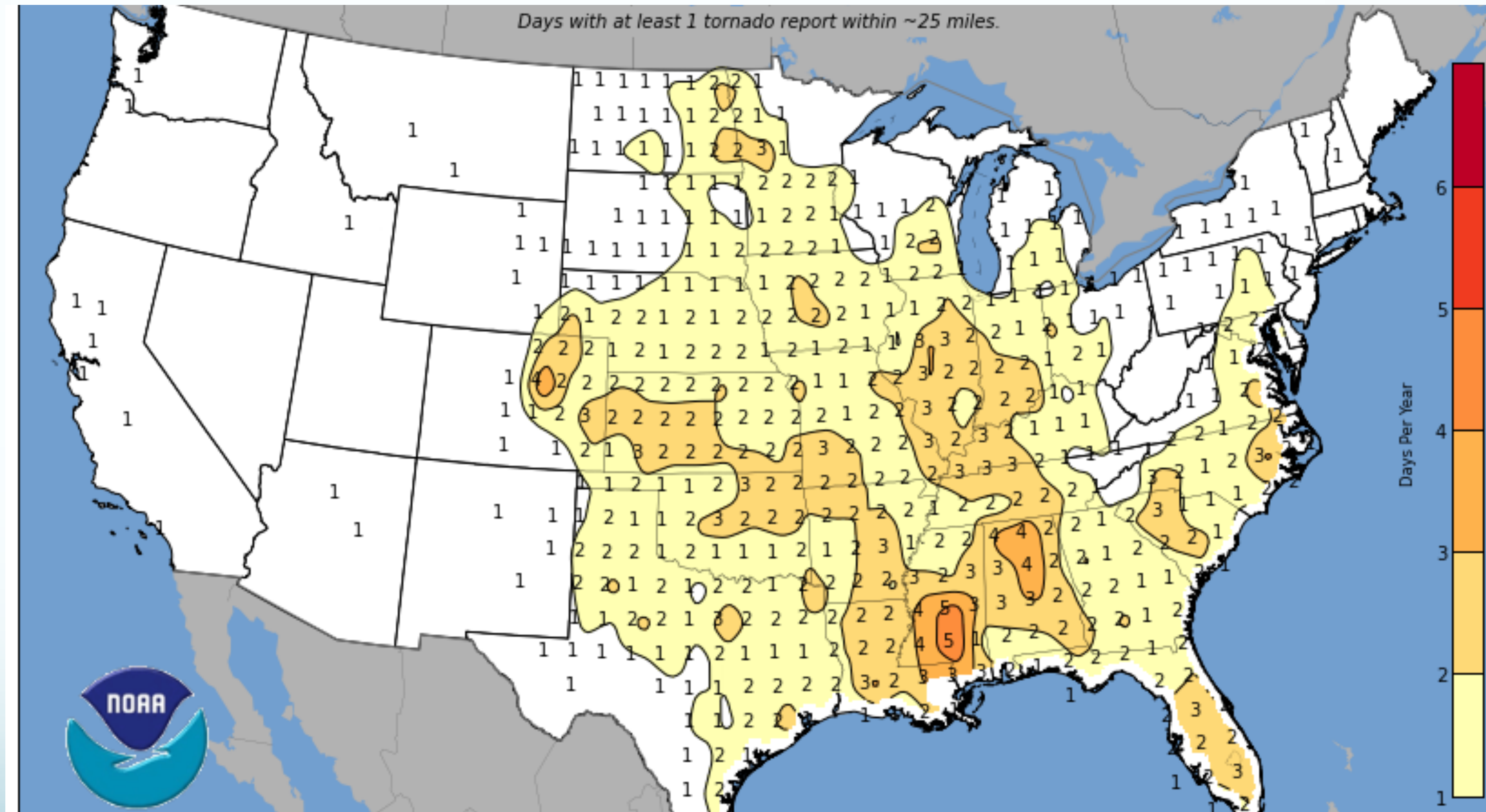
Answer: trees show high wind damage better than grasslands.



© Ben Evans/Huw Evans Agency

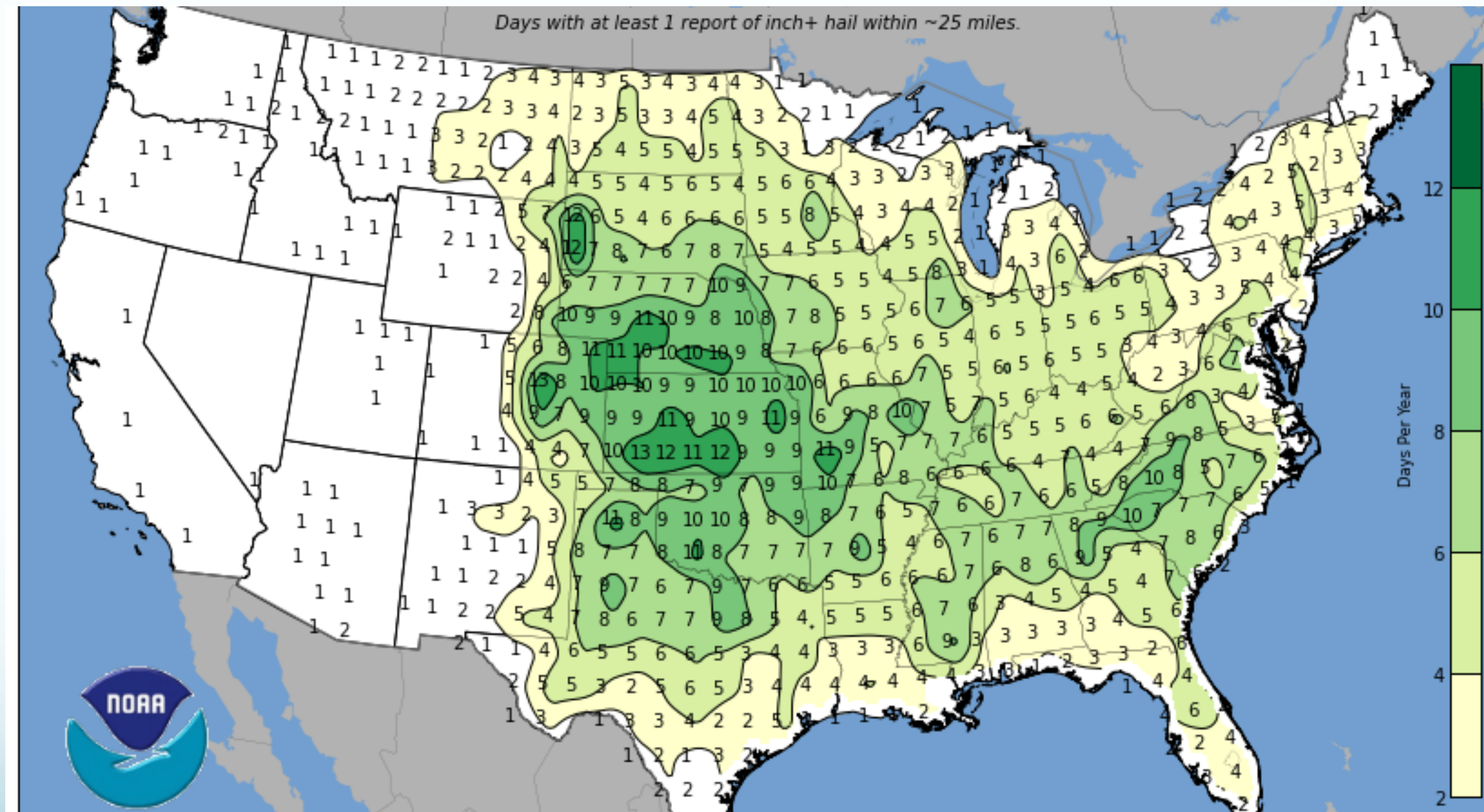


# Annual average days with a tornado



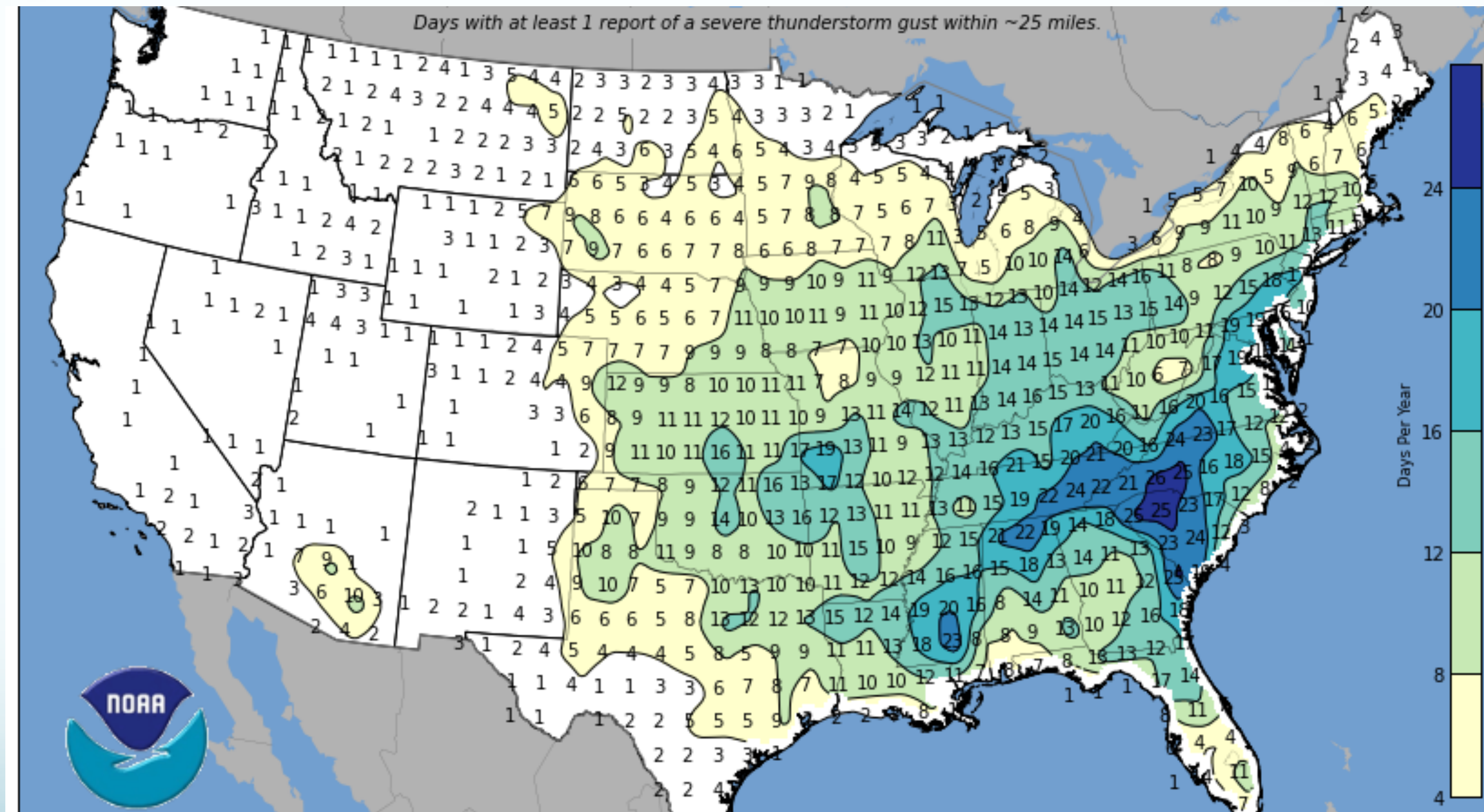


# Annual average days with $> 1''$ hail





# Annual average days with wind gusts (> 50 knots)





# What conditions favor thunderstorms?

# Thunderstorm Ingredients

## 1. A suitable lapse rate

- Conditionally unstable beginning 1 or 2 km above the surface and continuing through a deep layer.
- Why not “dry” (unsaturated) unstable?



# **W Why can't we expect a deep dry-unstable layer to provide the main factor promoting instability aloft on thunderstorm days?**

Because then there would be no clouds aloft.

Because minor disturbances would trigger motions in the unstable layer that would remove or greatly reduce the instability.

# Answer

- Tiny initial motions in a dry unstable layer will grow, moving air around in a way that acts to reduce the instability.
- Therefore, we never get dry layers that are very strongly unstable.



# Thunderstorm Ingredients

## 2. Adequate low-level moisture

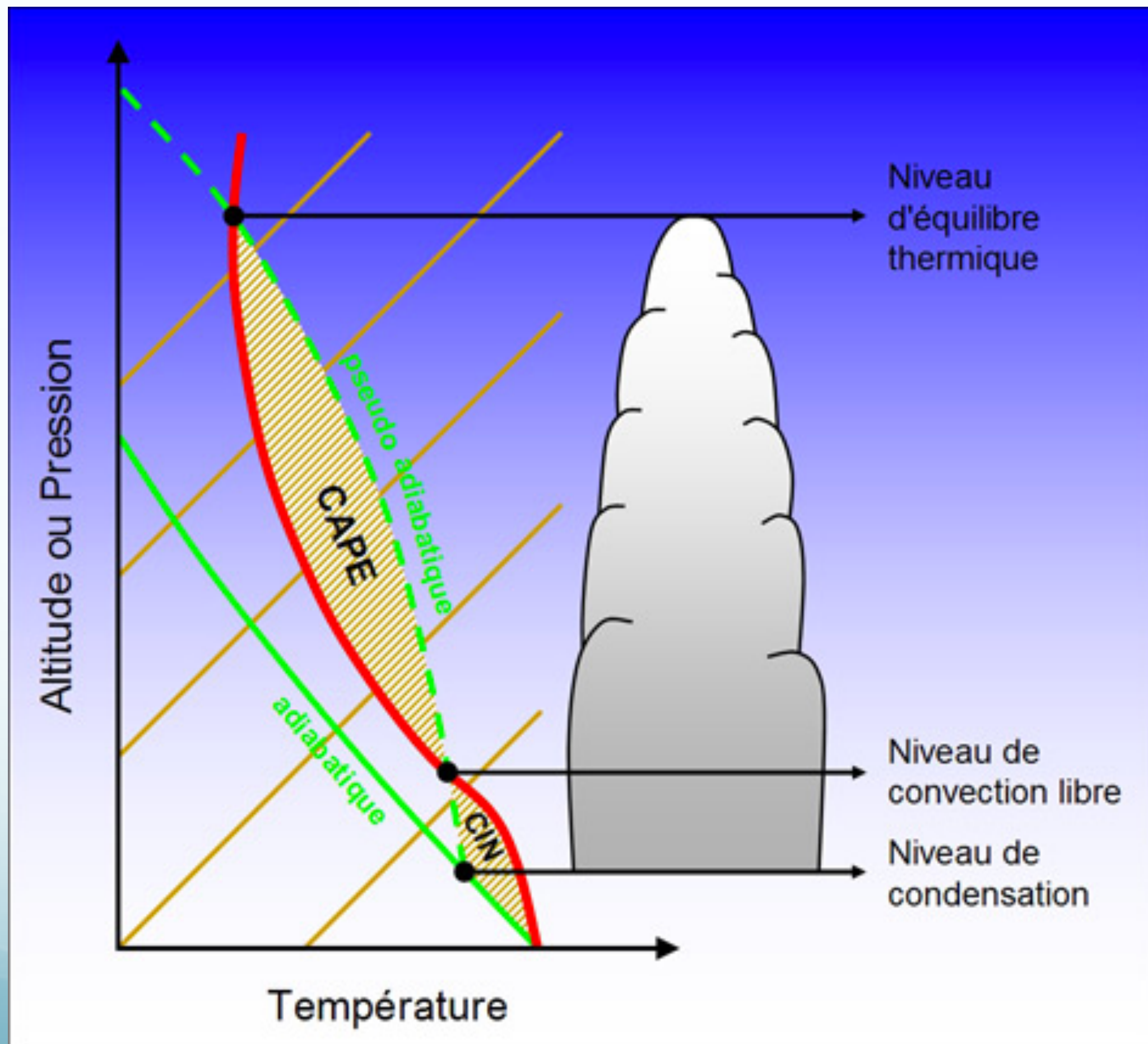
- Must be able to saturate an air parcel with modest lifting of the surface air
  - RH can't be too low.
- Need to be able to get a lot of latent heat released as the parcel rises after it saturates.
  - Dew points can't be too low.

# Ingredients 1+2 Determine:

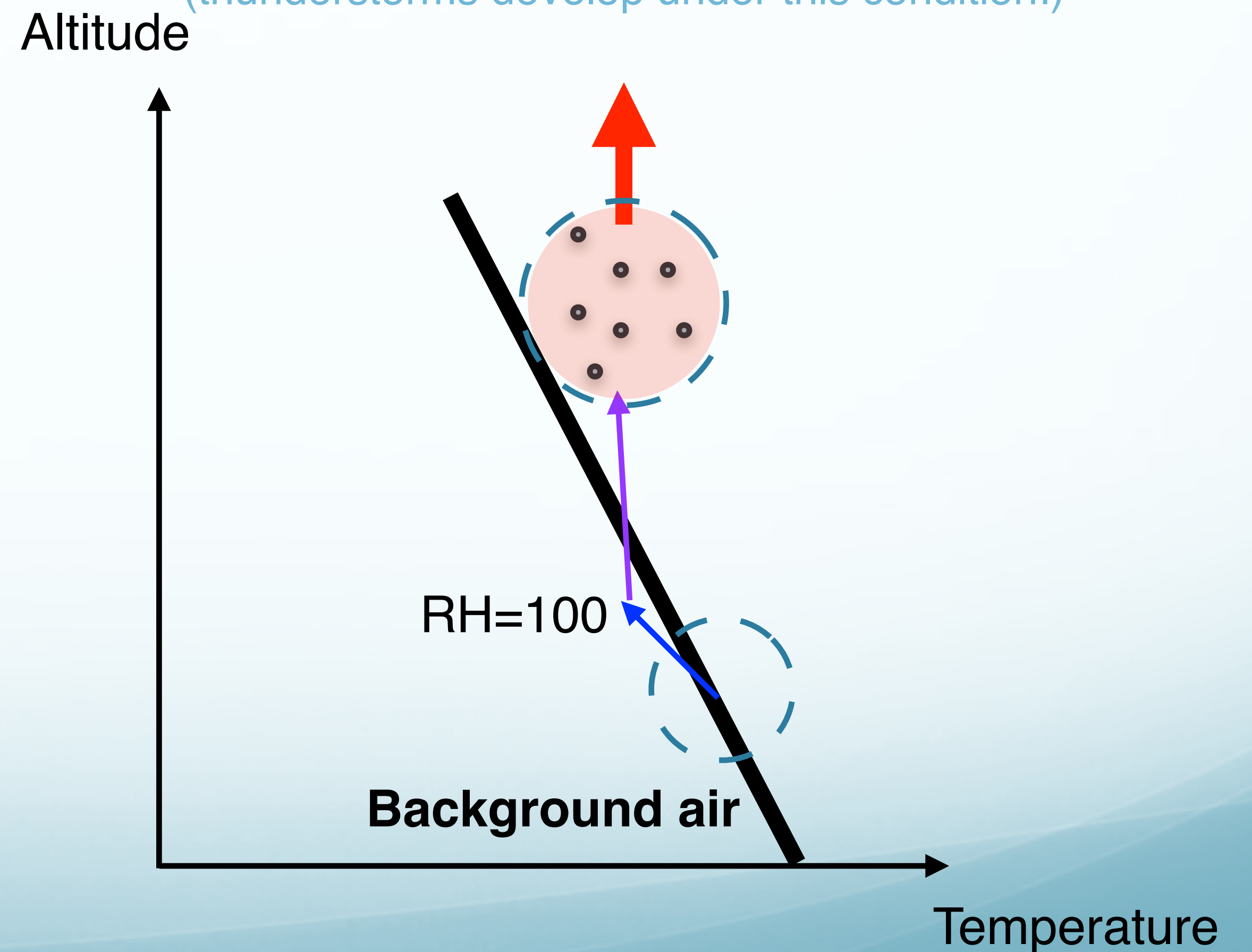
- **CAPE** (Convective Available Potential Energy)
  - The total energy that can be released while a rising air parcel is warmer than its environment.
- **CIN** (Convective Inhibition)
  - The work (energy) required to get an air parcel up to the level where it can start rising freely.



# CAPE and CIN



“Conditionally unstable”  
(thunderstorms develop under this condition!)



# Observations

- CAPE and CIN are determined from the vertical profiles of temperature and humidity.
- These are observed by weather balloons launched twice daily world wide.

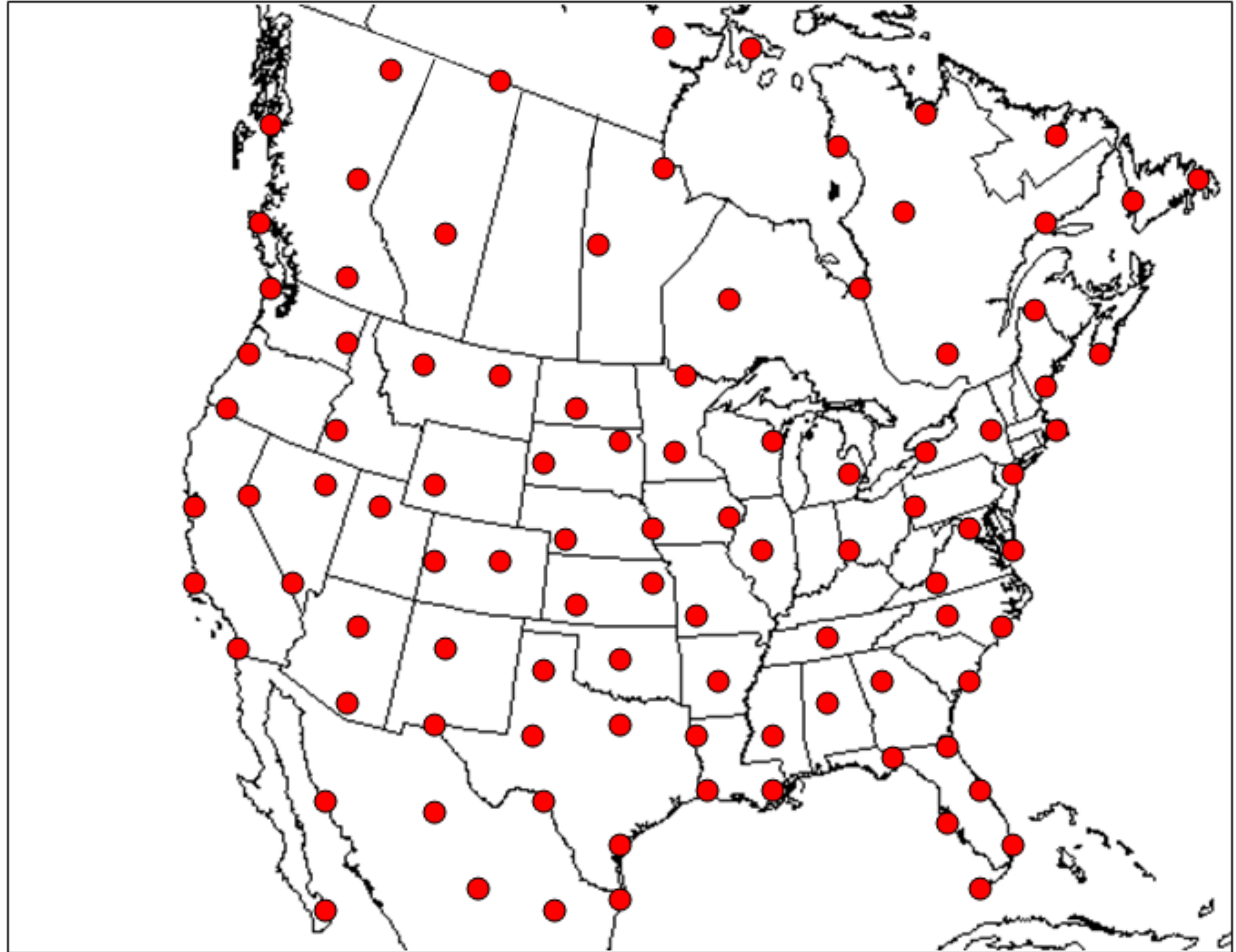


# Weather Balloon Launch

National Weather Service

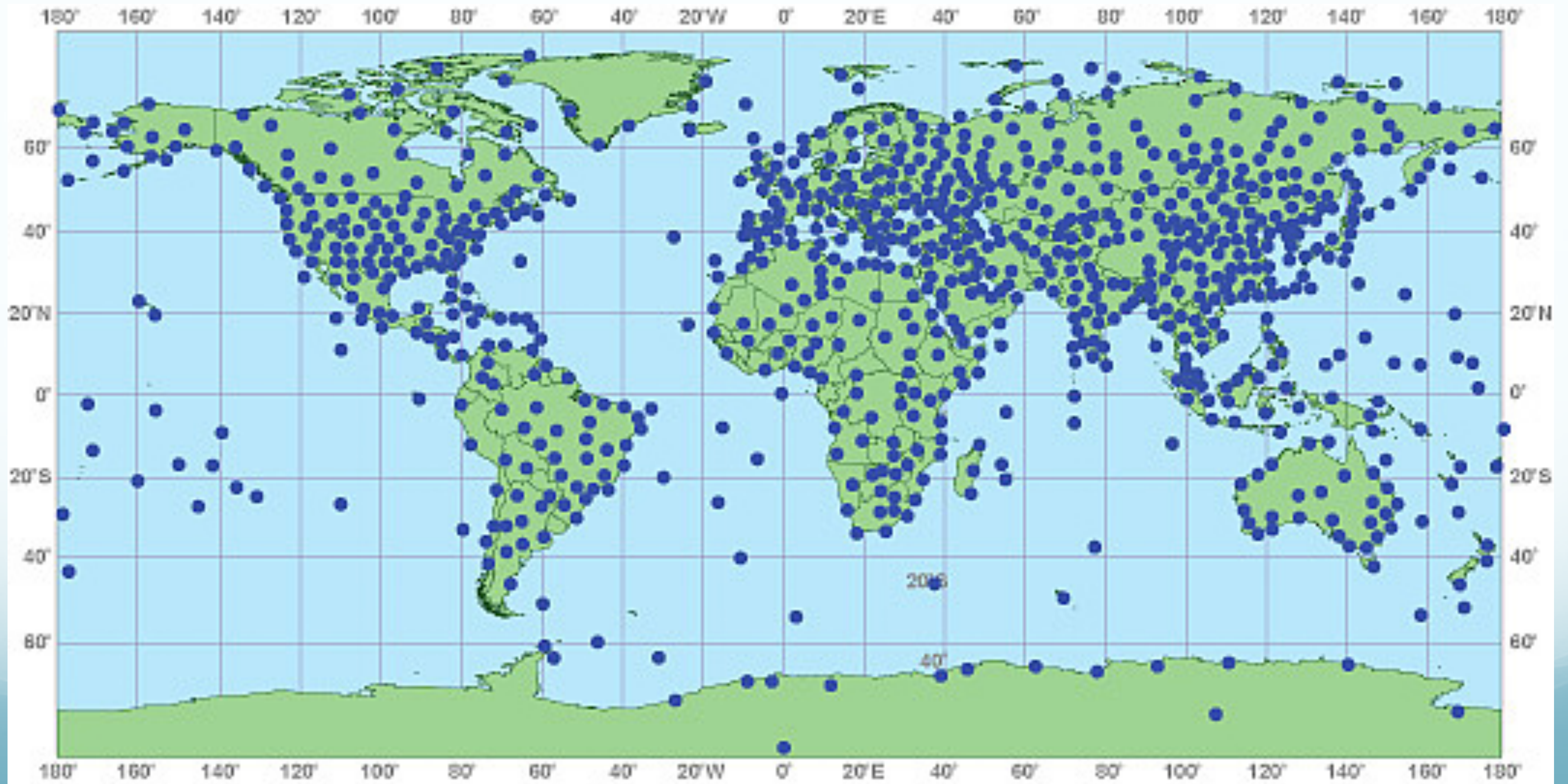


# North American Weather Balloon Network



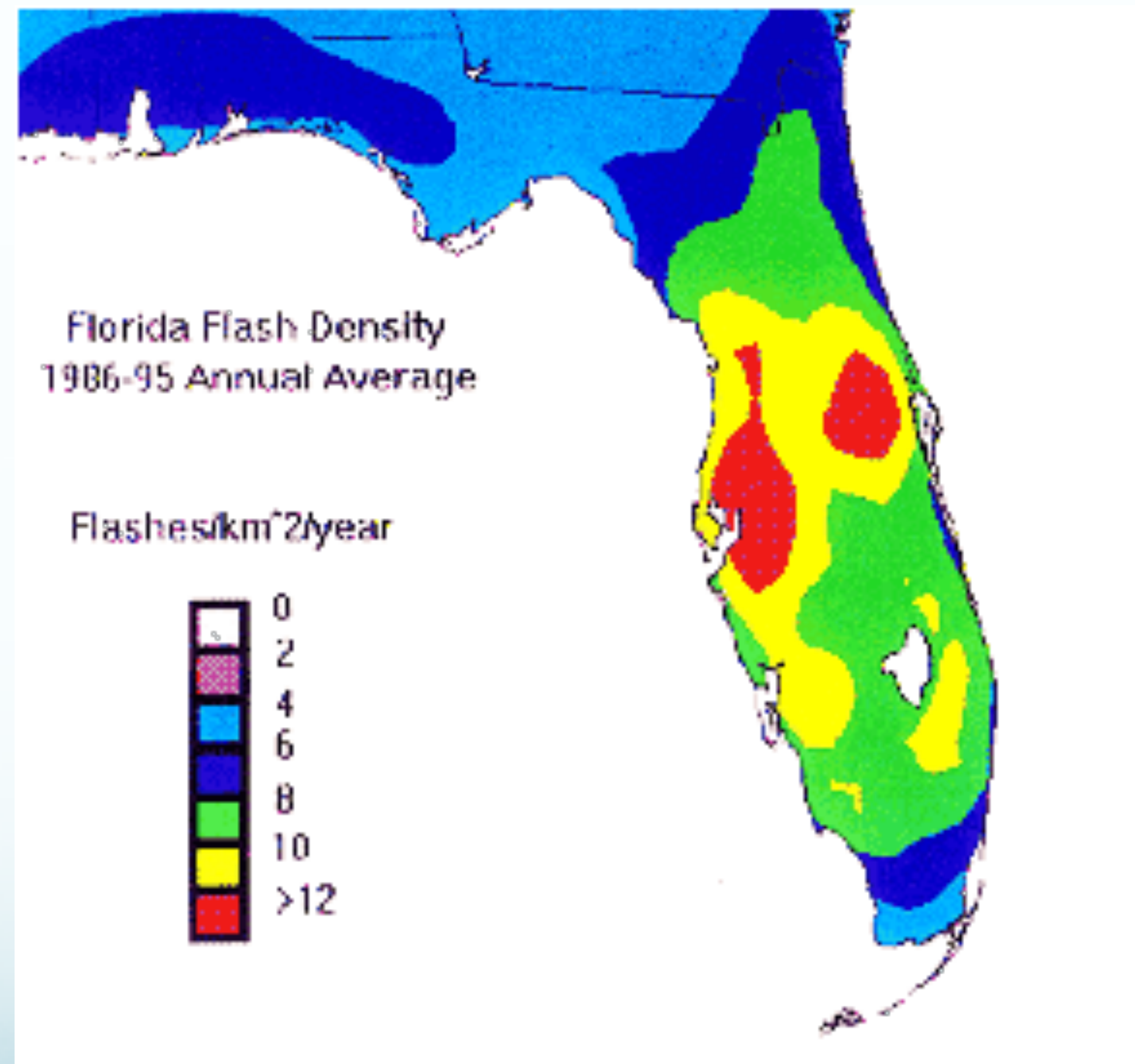


# All over the world





# Florida: lots of thunderstorms and lightning



Number of flashes per square kilometer, per year

# Thunderstorm development in Florida

## Satellite loop

- Note fair weather cumulus develops over the land by mid-morning
- Thunderstorms are triggered at the leading edge of sea breeze as it penetrates inland.



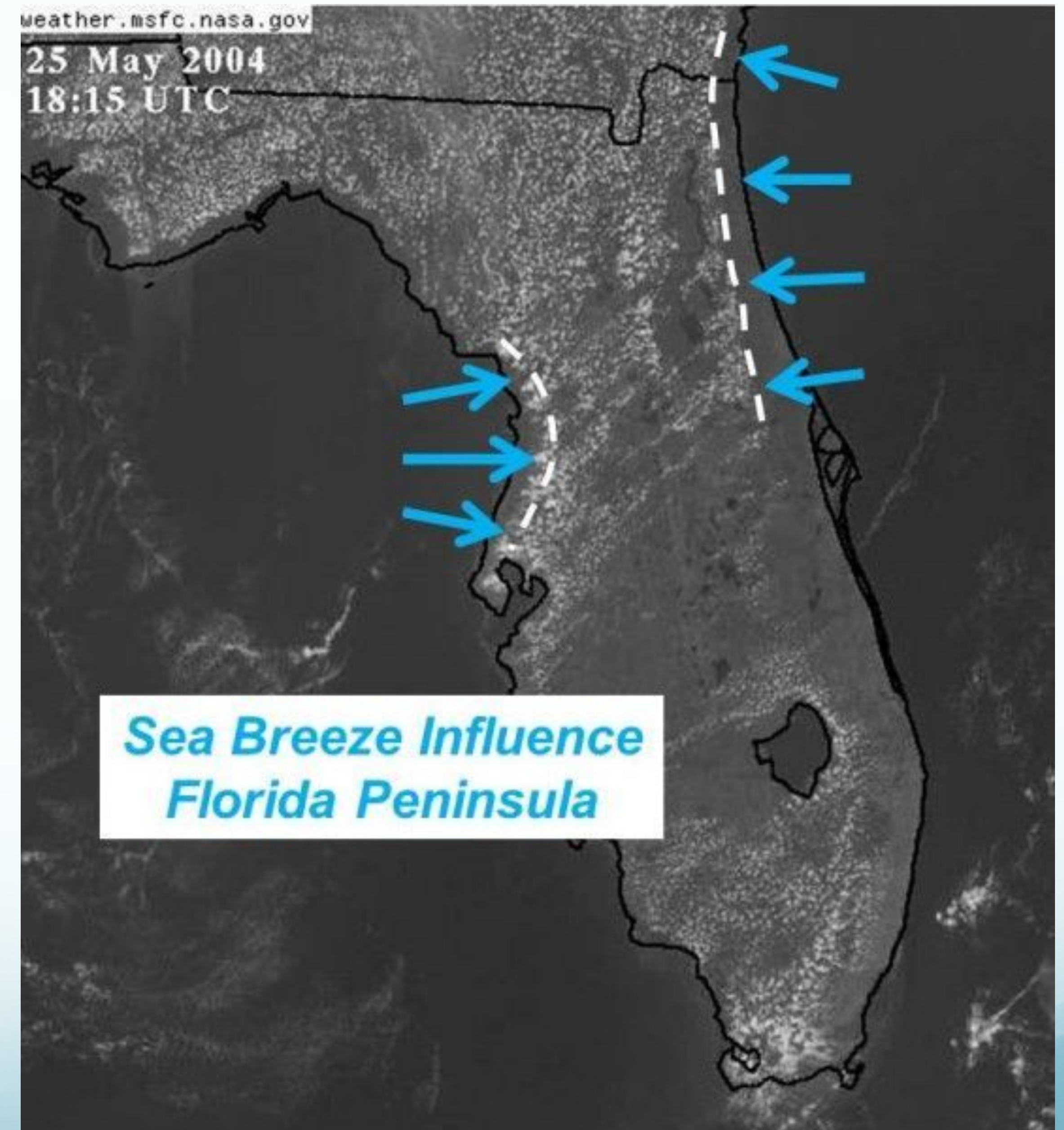
# **W** Why do thunderstorms **START** to develop most frequently between noon and 2 PM over the Florida Peninsula?

The hottest time of the day is typically between noon and 2PM.

The dew point hits hits daily minimum between noon and 2PM.

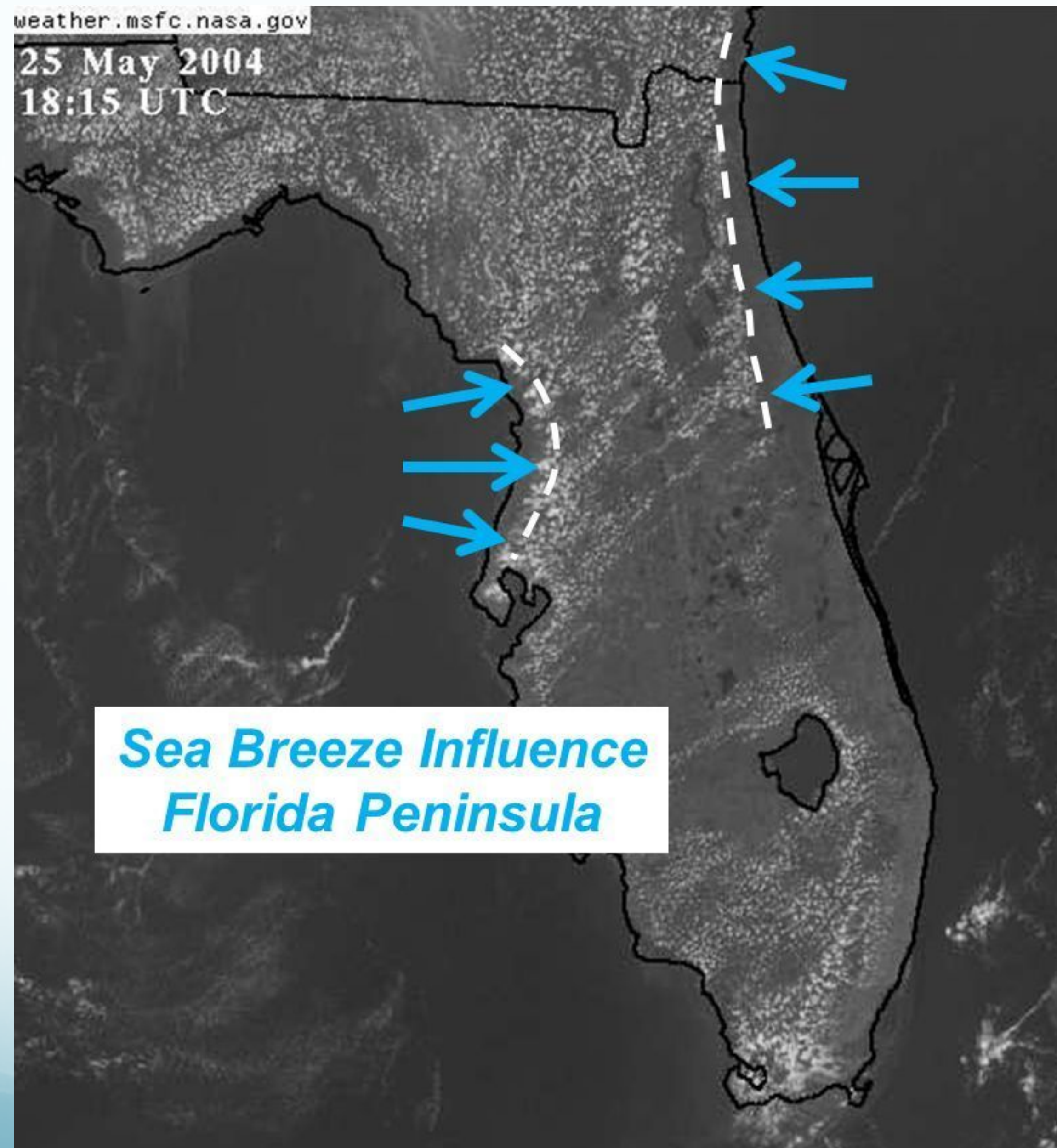
Converging air currents, flowing off the water as the land warms collide, to trigger thunderstorms.

Answer: Colliding onshore winds in the sea breezes meet and force air upward.

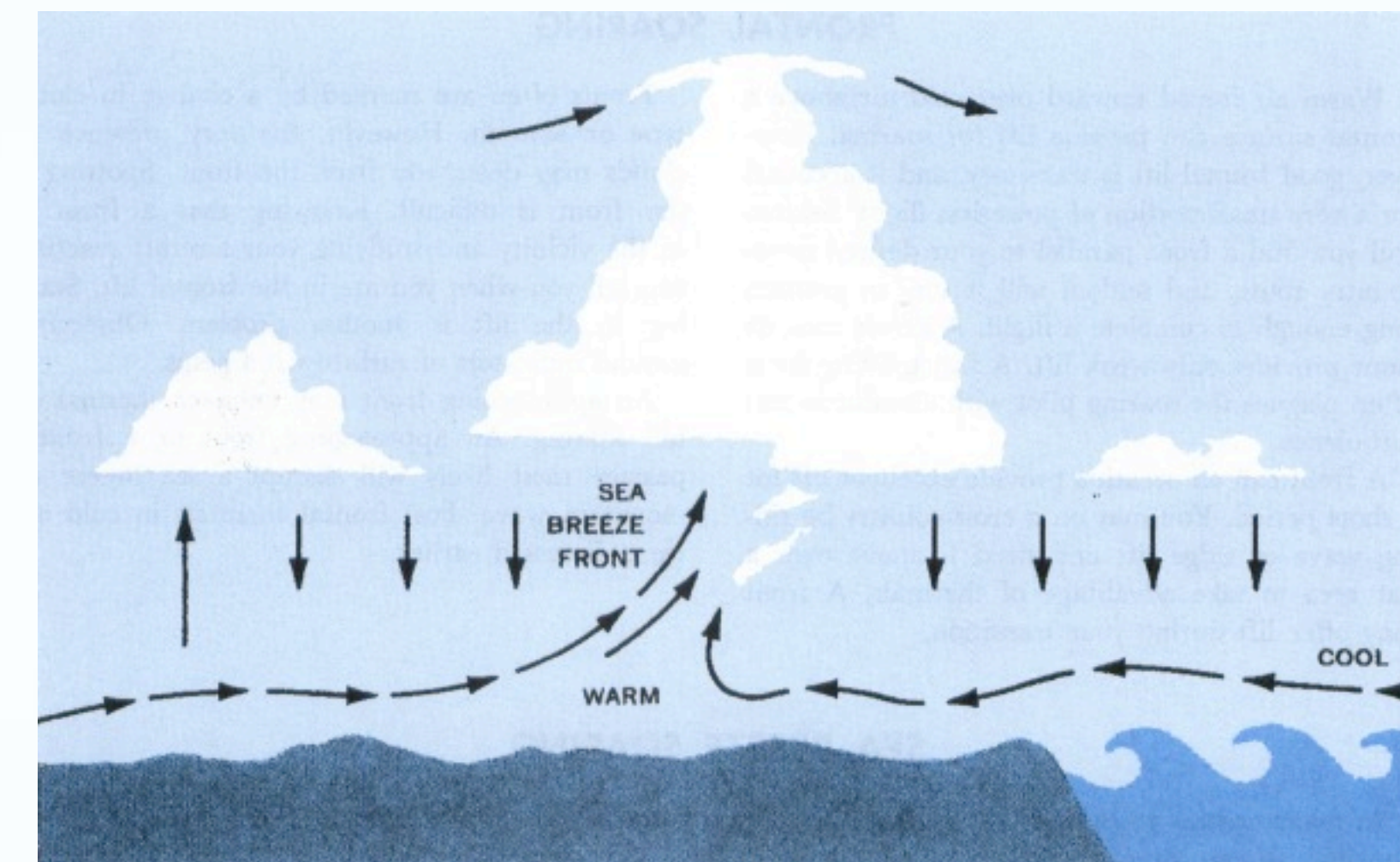




25 May 2004  
18:15 UTC



**Sea Breeze Influence  
Florida Peninsula**



Triggering at sea-  
breeze fronts.



# Thunderstorm Ingredients

## 3. A trigger that lifts the low-level air (overcomes the CIN)

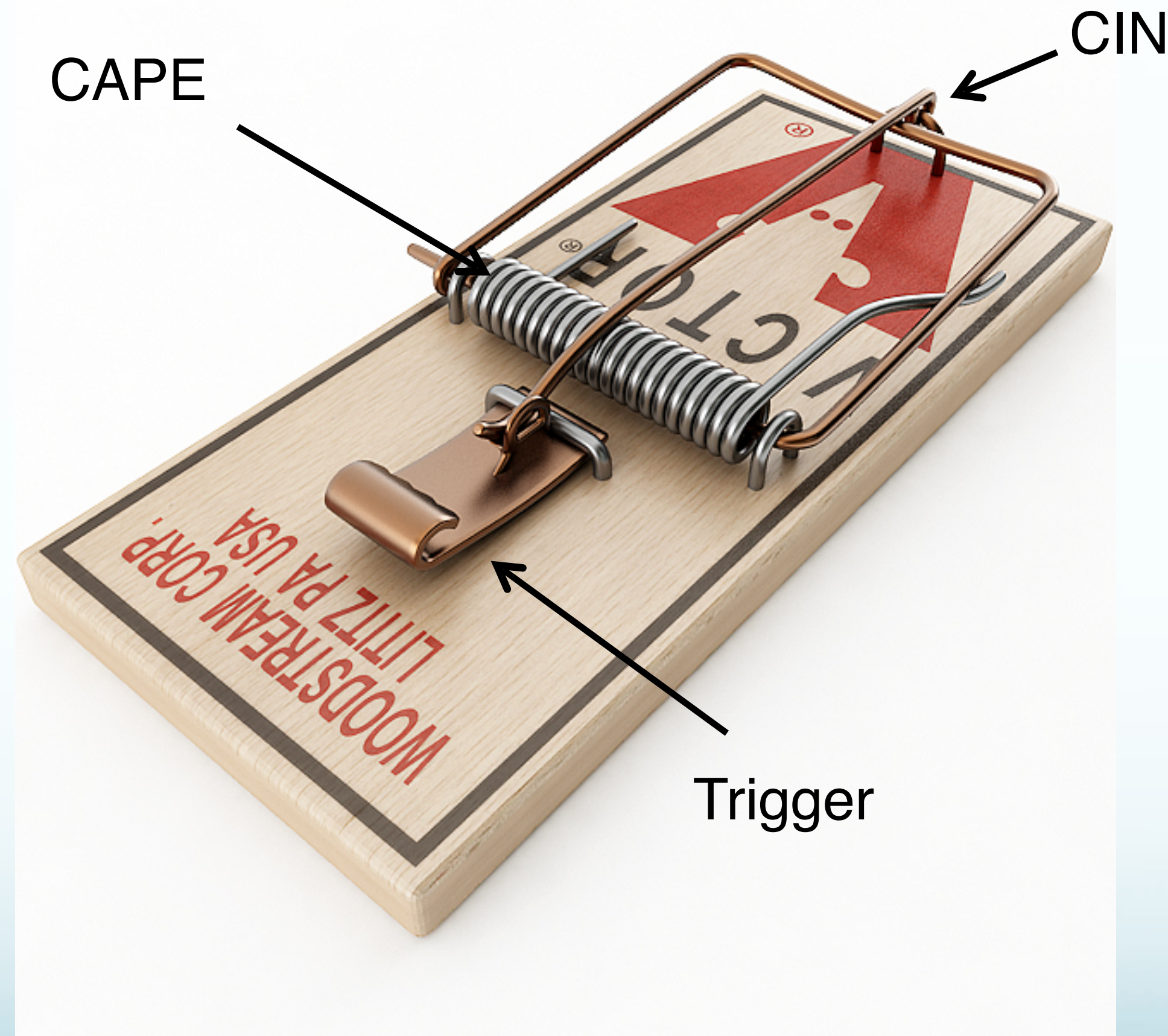
- Surface heating.
  - Parcels start rising if they get hotter and less dense than the air in the layer just above them.
- Lifting at a weather front.
- Lifting of ascending air by mountains
  - This can be driven by solar heating



# Thunderstorm Ingredients

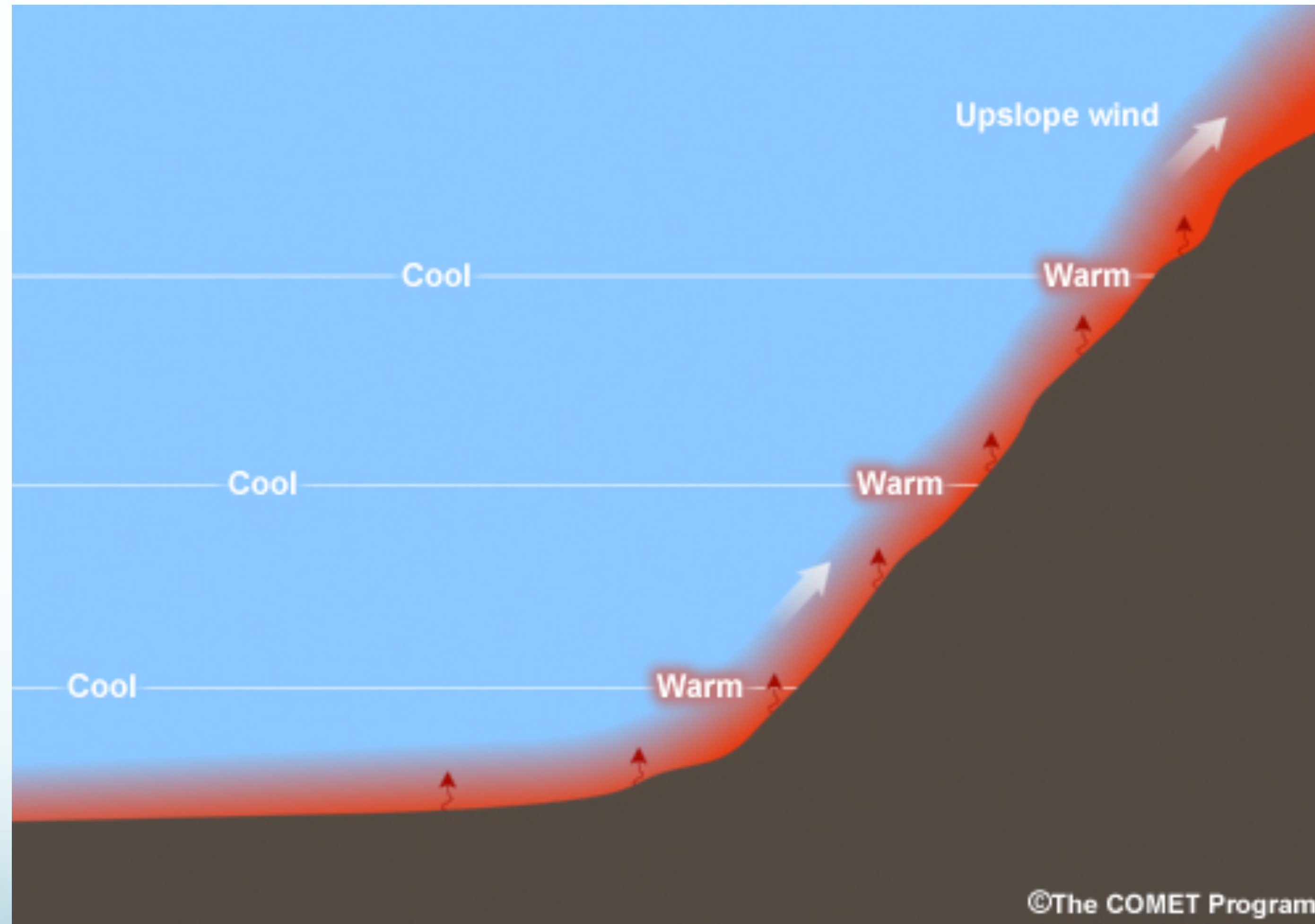
- **CAPE** (Convective Available Potential Energy)
  - The total energy that can be released while a rising air parcel is warmer than its environment.
- **CIN** (Convective Inhibition)
  - The cap that allows lots of CAPE to build up until conditions are ripe for a thunderstorm.
- A **trigger** that lifts the low-level air (overcomes the CIN)

# CAPE, CIN and the Trigger



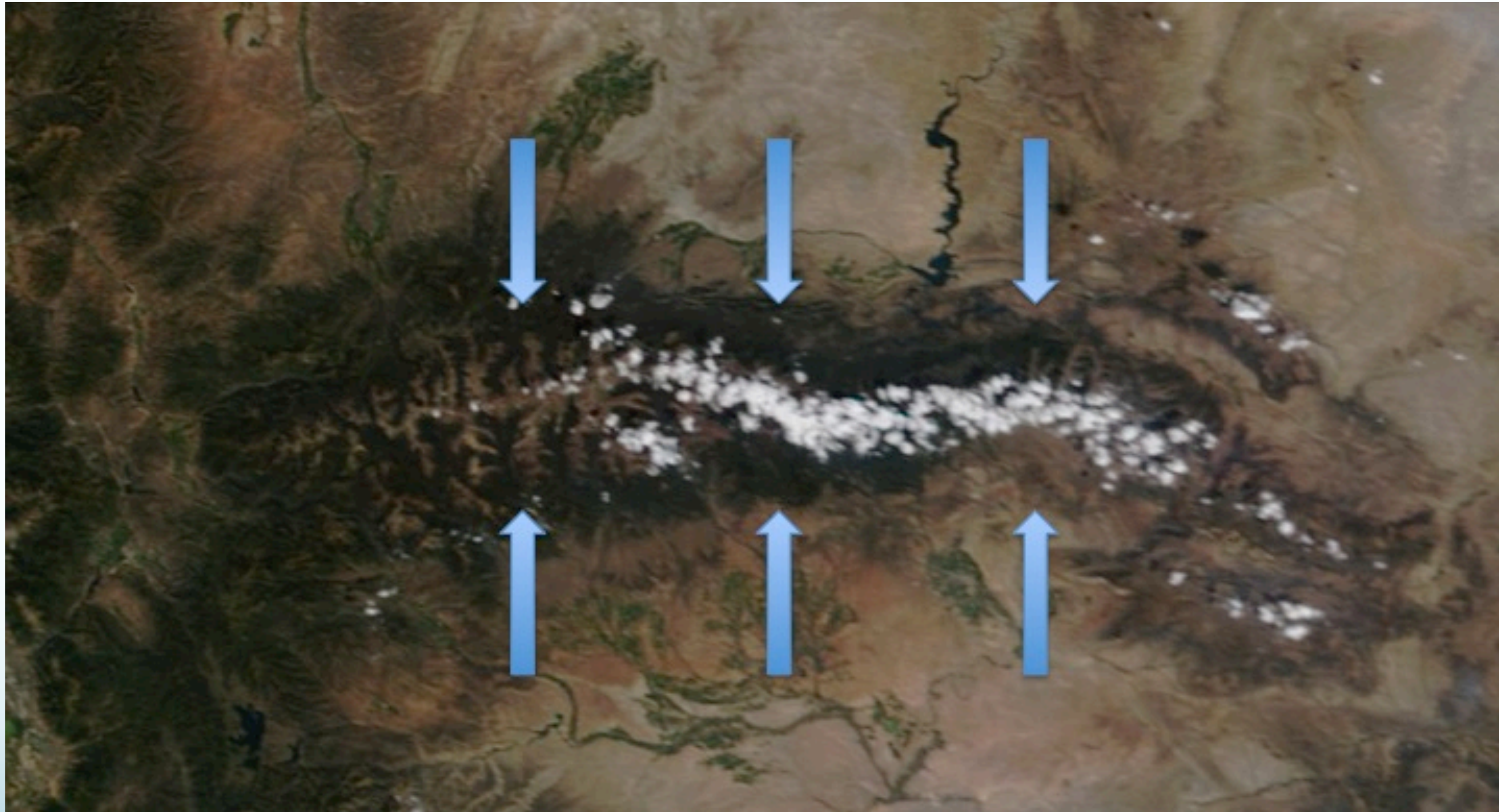


# Another trigger: solar heating moves air upslope





# Clouds over the Uintas





# Upslope clouds near Chongqing, central China





# Triggering by solar heating over flat ground



**W** Air is warmed at the surface, but is not allowed to rise. Will the warming of the air tend to form a cloud?

Yes

No

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Total Results

# Answer: No

- Warming the air will lower the relative humidity, making the air *less* saturated.
- But warm air tends to rise.
- Air warmed at the surface can sometimes rise to sufficient heights that adiabatic cooling forms a cloud.
- If that cloud continues to ascend, it could find itself warmer than its environment in a conditionally unstable layer.
  - If so, it will rise even faster making a deep cumulus cloud that may become a thunderstorm.



# Kinds of Thunderstorms

- **Single cell**
  - “Ordinary” or “air mass” thunderstorm
  - Generates lightning, heavy rain, downbursts.
- **Multi-cell**
  - May be **severe**
    - Severe if hail >1” or winds > 58 mph
  - Seldom makes strong tornadoes
- **Supercell**
  - Relatively long-lived, often **severe**
  - Associated with most strong tornadoes

# Type of Thunderstorm Is Determined By

- The amount by which rising air parcels become warmer than their environment (the CAPE)
- The change with height in the wind's speed and direction in the lowest 5 km above the ground.
  - This is the low-level **wind shear**.



# Thunderstorm Induced Hazards

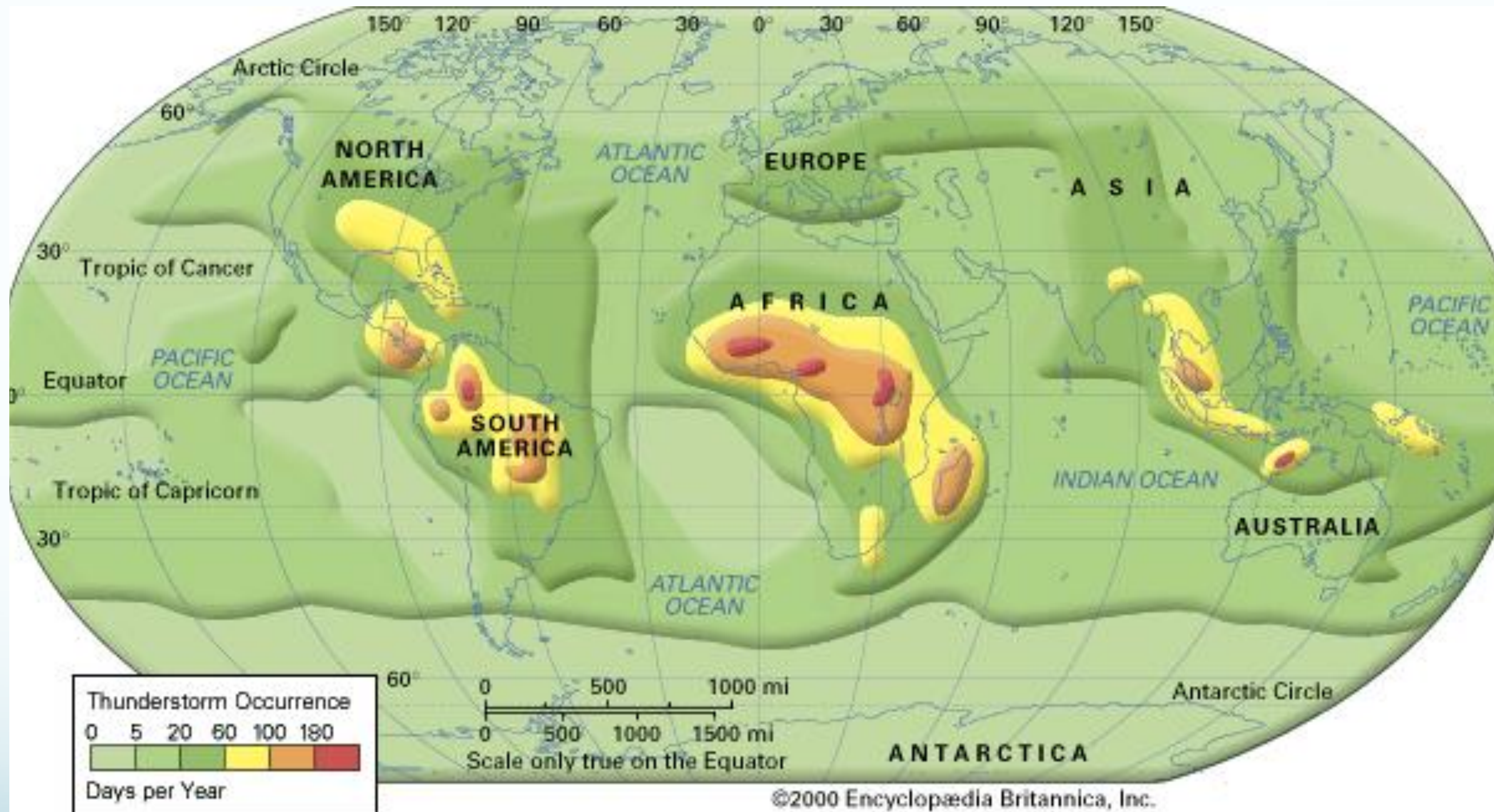
(Yearly-averaged values)

- Tornadoes: 60-65 deaths, 1,500 injuries
- Lightning: 55-60 deaths, 400 injuries
- Flash floods: over 90 deaths
- Hail: over \$1 billion in crop damage
- Winds: can exceed 125 mph

(Source: NOAA Thunderstorms, Tornadoes, Lightning Preparedness Guide, NOAA/PA 201051)

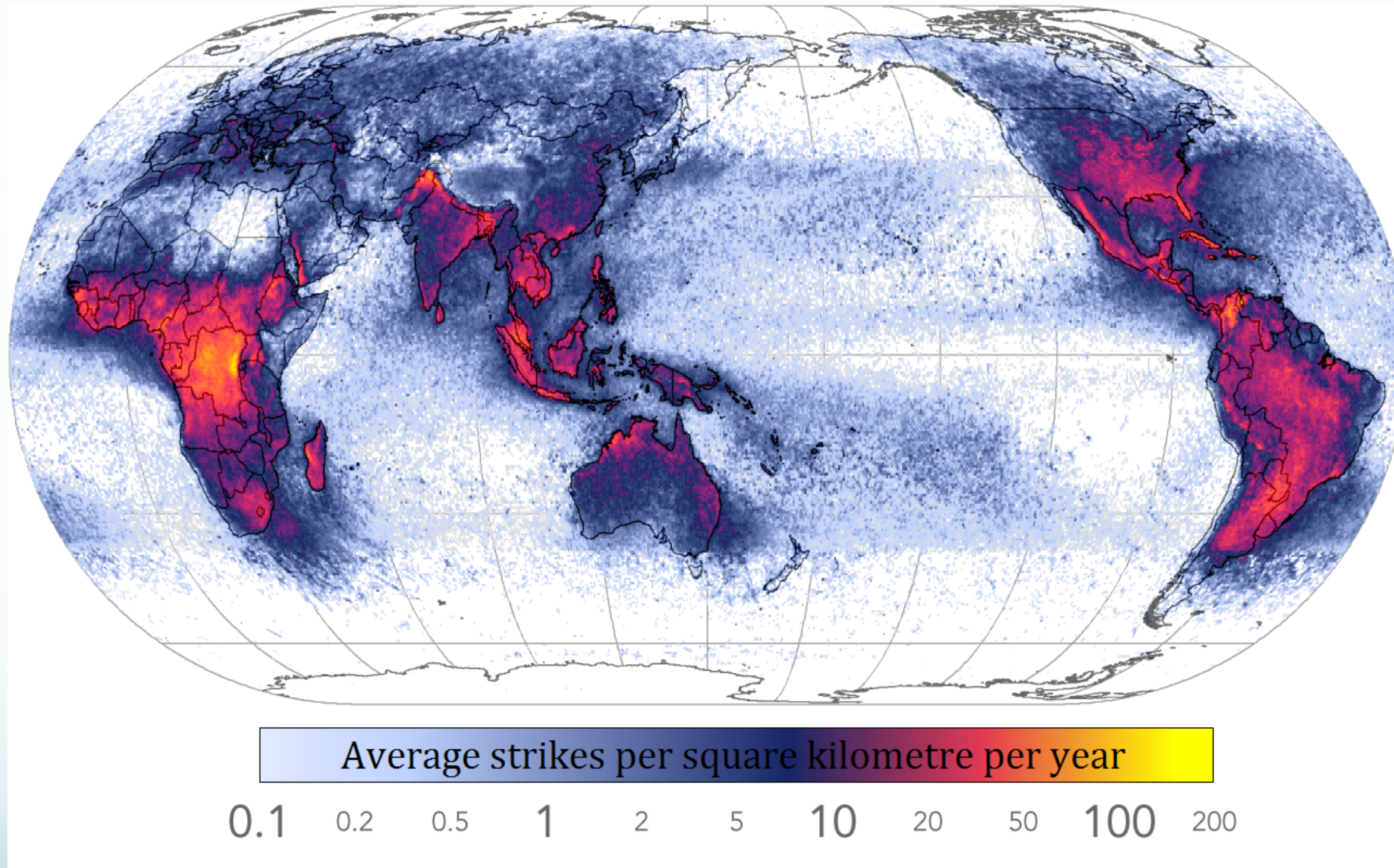


# Thunderstorm Frequency





# Global Lightning Frequency





W

In general, lightning is more common over the ocean than the land.

True

False

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Total Results



Answer: False, lightning is more common over land.