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Understanding the Meteorology
Behind Climate Change



Understanding the Meteorology Behind Climate Change

September 14, 2026



Agenda

1. Welcome
2. Review of Public Act 103-0837
3. Understanding the Meteorology Behind Climate Change
4. Resources and Questions
5. Next Steps

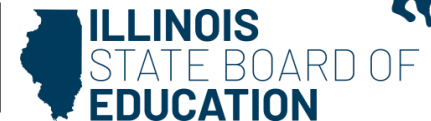
Understanding the Meteorology
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Public Act 103-0837

Beginning with the 2026-27 school year, every public school shall provide instruction on climate change, which shall include, but not be limited to, **identifying the environmental and ecological impacts of climate change on individuals and communities and evaluating solutions for addressing and mitigating the impact of climate change and shall be in alignment with State learning standards, as appropriate.**

The State Board of Education shall, subject to appropriation, prepare and make available multi-disciplinary instructional resources and professional learning opportunities for educators that may be used to meet the requirements of this subsection (b).



Understanding the Meteorology Behind Climate Change



The Process: Part 1

We will discuss basic meteorology, including the meteorological processes, using the precipitation ladder.

The Process: Part 2

We will discuss the basics behind the Greenhouse Effect, increased greenhouse gases, and Earth's atmospheric temperature rise.

The Process: Part 3

We will discuss why the increasing temperatures could increase storm strength.

We will discuss other possible climate change impacts.

Part 1 - Brief Intro

Weather vs. Climate vs. Forecast

Averages

TFWOWO

Precipitation Ladder

Definitions

Weather – the state of the current sensible conditions. Temperature, wind speed and direction, precipitation, visibility, etc.

Climate - climate is the long-term average of temperature, precipitation, and other weather variables at a given location.

Forecast – the projected state of the sensible weather conditions.

Definitions – shorter!

Weather – What it is.

Climate – What it was.

Forecast – What it will be.

Let's try a few!

Which is it – Number 1

**Tomorrow, the high
temperature will be 88°F.**

Number 1 - Answer

**Tomorrow, the high
temperature will be 88°F.**

FORECAST

Which is it – Number 2

It's windy.

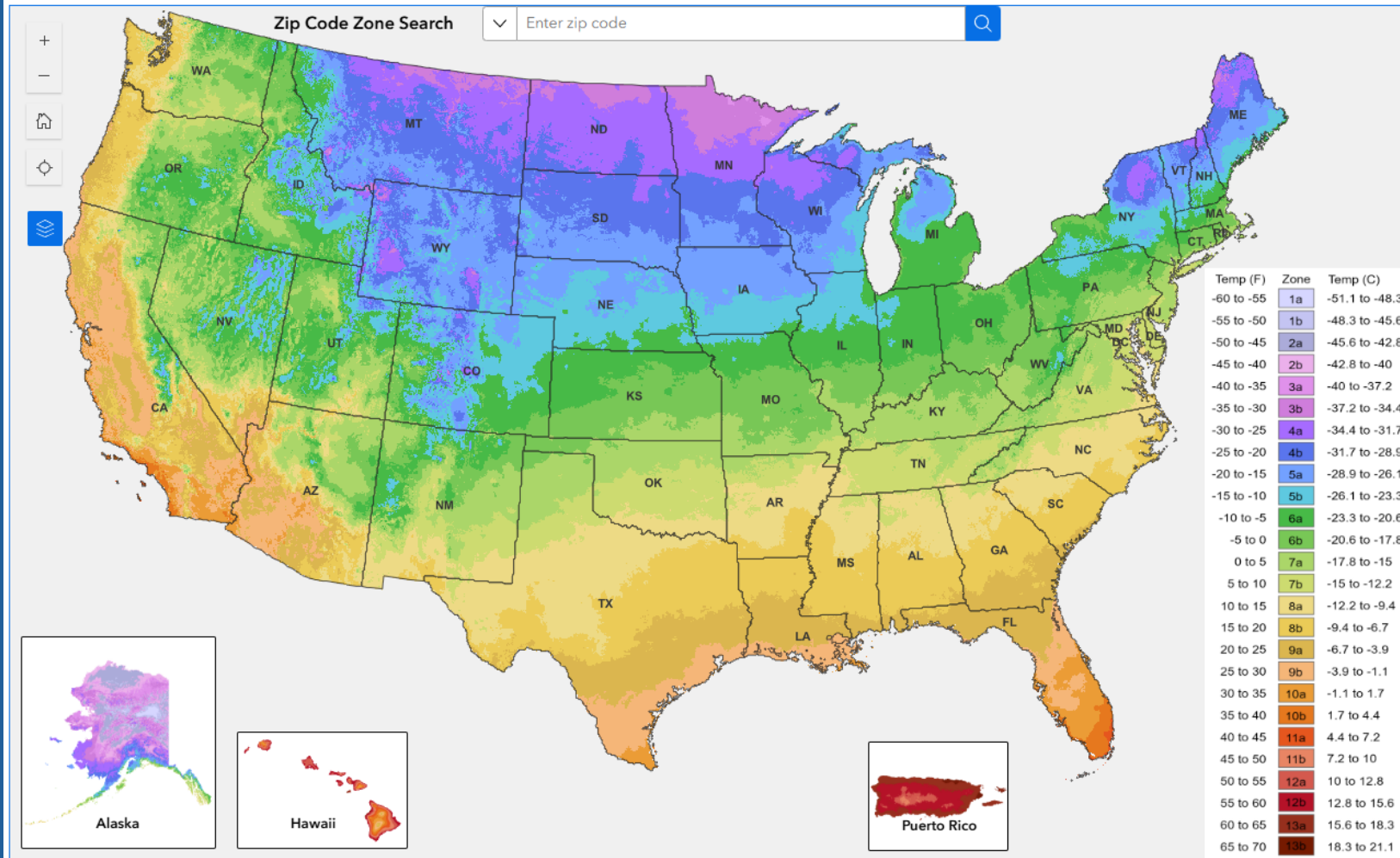
Number 2 - Answer

It's windy.

WEATHER

Which is it - Number 3

2023 USDA Plant Hardiness Zone Map



Number 3 - Answer

CLIMATE

Which is it - Number 4

**Planning an outdoor
Wedding in September.**

Number 4 - Answer

CLIMATE

FORECAST

WEATHER

Averages

Every 10 years, the averages are recalculated using the previous 30 years.

Previous Averages:	1981 – 2010
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Current Averages:	1991 – 2020
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Next Period*:	2001 – 2030
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***This will commence January 1, 2031.**

TFWOWO

**We are going to learn several meteorological processes.
TFWOWO is “The Fabulous World of Weather Opposites”!**

In many of these processes, if we change the operative words to their opposite, the statement remains true!

Warm air rises.

Cold air sinks.

As air rises, it cools

As air sinks, it warms.

Keep this in mind. It will come in handy!

The Precipitation Ladder

- 11. Precipitation**
- 10. Droplet Growth**
- 9. Buoyancy/Cloudiness**
- 8. Condensation**
- 7. Saturation**
- 6. Humidification**
- 5. Cooling**
- 4. Expansion**
- 3. Ascent**
- 2. Dirty Air**
- 1. Water Vapor**

Water Vapor

Water vapor is the most abundant trace gas in the atmosphere. It can vary from near zero (it can't be zero) to as much as 4%.

The amount is dependent on any moisture advection*, the moisture on the surface beneath, and the air temperature.

***Advection is the horizontal movement of a property.**

Dirty Air

Without “dirty air” there would be no rain clouds! Even the cleanest air contains about 1,000 dust particles per cubic meter.

Not all sizes and shapes will do! Certain types of sea salts and clay make the best condensation nuclei.

Ascent

Ascent is very important to the precipitation process because it impacts expansion. Ascent and expansion impact cooling. Can you see the trend?

There are four main types of ascent. Let's look at each.

Ascent - Convergence

Convergence is just like it sounds. It is air meeting at the same place at the same time.

The air coming in from different directions can't go around the other air, but it must go somewhere. It goes up.

Ascent by convergence.

Ascent - Convection

Warm air rises. Cold air sinks. Think of a hot air balloon.

As a blob of air becomes warmer than the air that surrounds it, it will rise. It will continue to rise until it cools to the temperature of the surrounding air.

Ascent by convection.

Ascent - Frontal Lift

Air lifted by a front.

What is a front?

Fronts

A front is the border between air masses.

What is an air mass?

Air Mass

An air mass is a blob of air with similar temperature and moisture characteristics.

We have two basic temperatures, cold and warm.

We have two basic moisture characteristics, dry and moist.

Our common air masses are the combination of these different temperature and moisture profiles.

Air Mass Names

Dry air is called continental. (Canada)

Moist air is called maritime. (Gulf of Mexico)

Cold air is called Polar. (Canada)

Warm air is called Tropical. (Gulf of Mexico)

Air masses are labeled by the moisture profile, then temperature characteristics. The moisture profile is a lowercase letter and the temperature is an uppercase letter.

cP Air Mass

Cold, dry air from Canada is continental polar air, labeled cP.

Cold air is more dense than warm air.

mT Air Mass

Warm, moist air from the Gulf of Mexico is maritime tropical air, labeled mT.

Dry air is more dense than moist air.

mP and cT Air Masses

Maritime polar air is cool and moist. We sometimes see this type of air with winter and spring storms.

Continental tropical air isn't too common in the Midwest. It is more common in the Plains.

Our two main “weather-making” air masses are cP and mT.

Air Mass Density

We mentioned cold air is more dense than warm air and dry air is more dense than moist air.

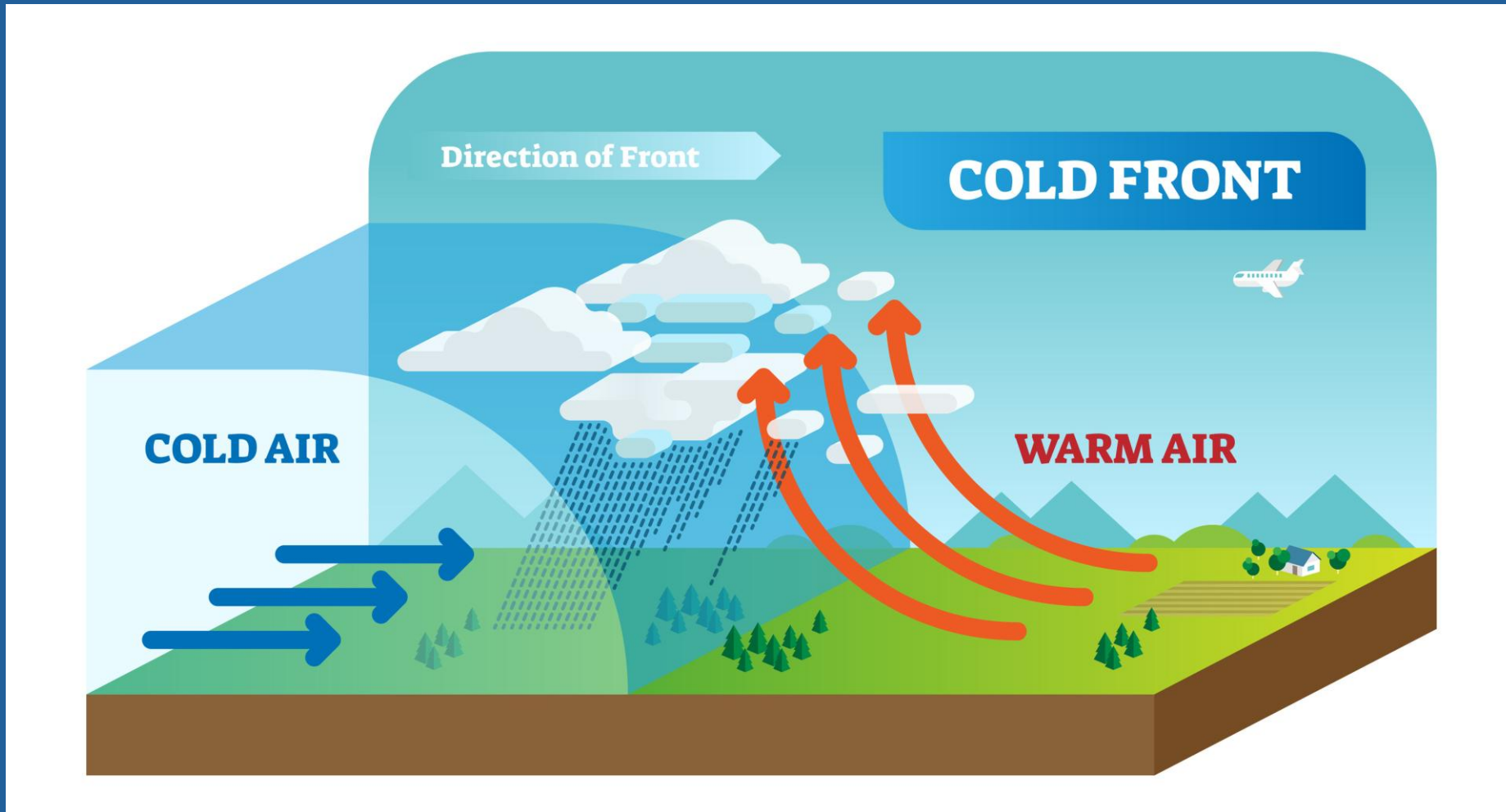
cP air is cold and dry. mT air warm and moist. Therefore, cP air is more dense than mT air.

**Remember, a front is the border between air masses.
When cP air and mT air collide, the cP air forces the mT air up.**

Ascent by frontal lift.

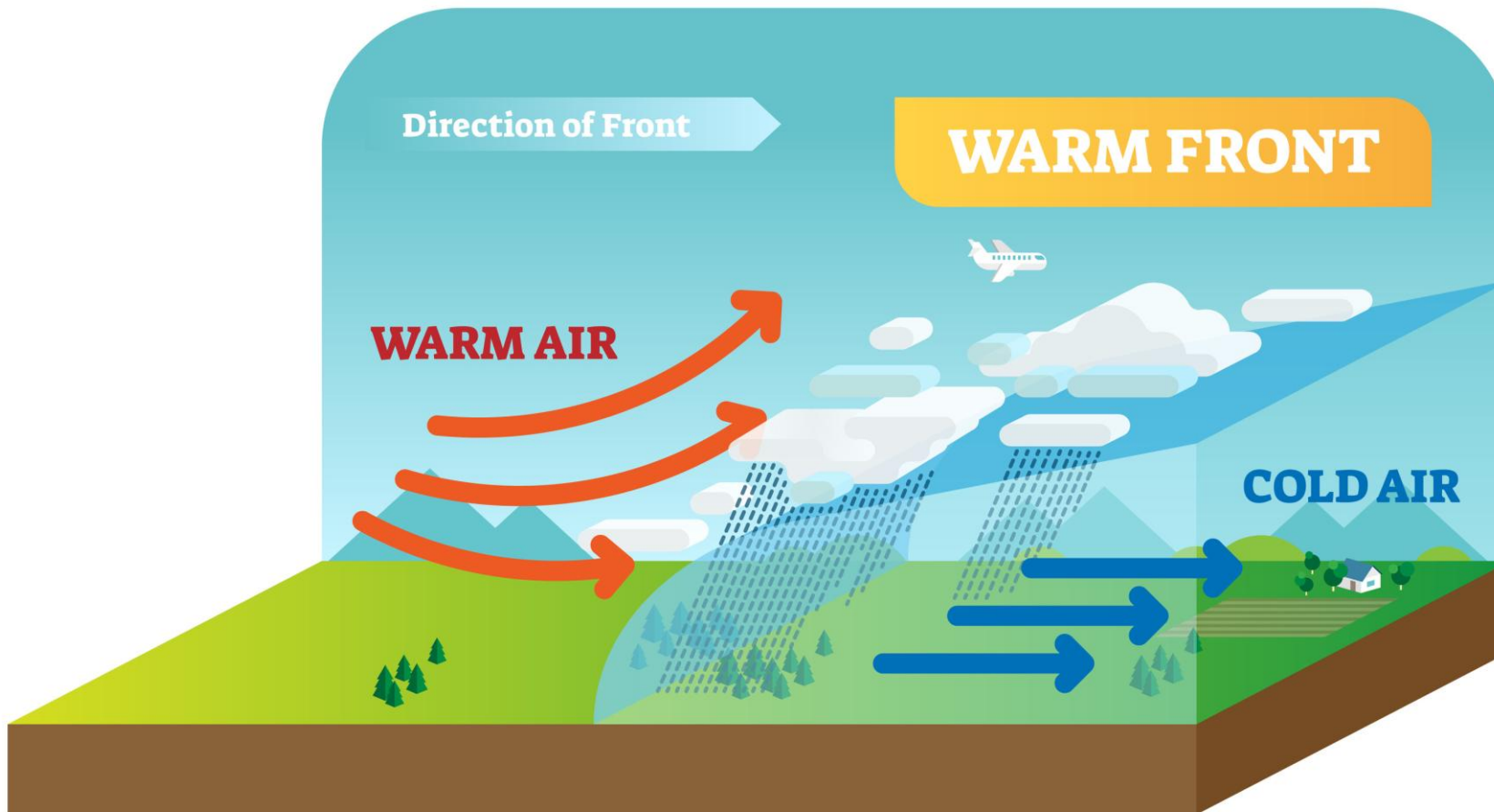
Cold Front

A cold front is where cP air collides with mT air.

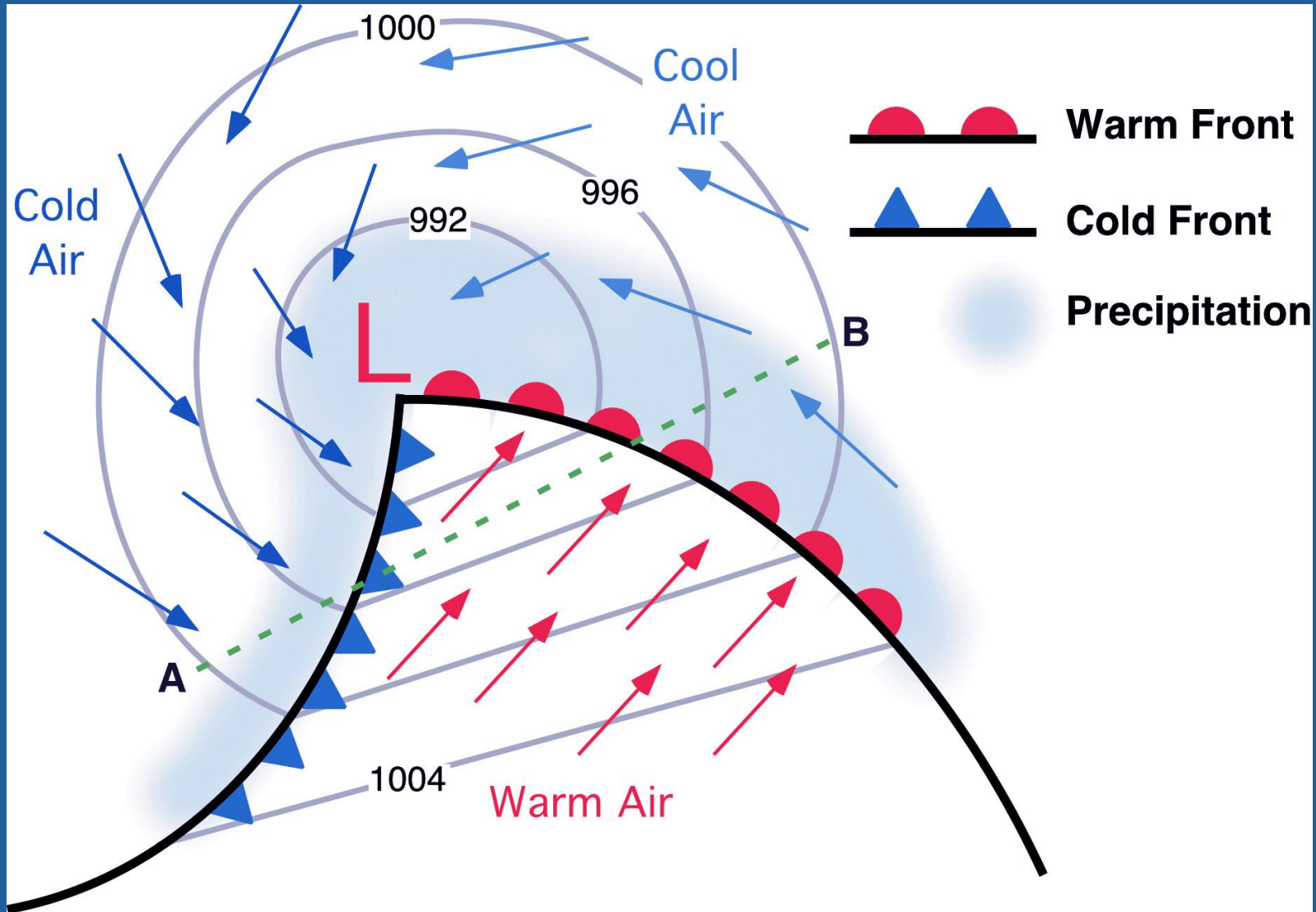


Warm Front

A warm front is where mT air moves into a region.



Fronts on Maps



Ascent - Physical Lift

This is also known as orographic lift. This is lift caused by land/topographical features. This does exist in Illinois, but not very much!

As horizontally moving air (wind) approaches topographical features, it cannot go around the feature, and it cannot go under the feature. It must go over the feature.

Ascent by physical features.

Expansion

No matter the lifting process, the result is the rising air must change its pressure to remain in equilibrium with the surrounding air. Pressure decreases with altitude, so the atmospheric pressure of the rising air must also decrease.*

What versus Why*

We interrupt this presentation for a quick aside. These processes are rooted in some deep science that we do not have time to fully investigate. Many of the things I have presented, and have yet to present, will only be shown from the “what” perspective. We, unfortunately, do not have time to delve into the “why.” I, however, hope you do investigate the “why”!

Now back to our program. So, what is atmospheric pressure?

Atmospheric Pressure

Pressure is defined as force per unit area. Air has weight. All the gases in the atmosphere push down with a force of 14.7 lbs. per square inch at sea level. Some common pressure units with their equivalencies:

**14.7 psi = 1013.25 mb = 29.92 inHg = 760 mmHg
all approximate to 1 atmosphere (1 atm)**

**So why does pressure decrease with altitude?
Gravity!**

Cooling

As air rises, it cools. To understand the cooling processes, we must get to some chemistry!

Let's look at the Universal (or Ideal) Gas Law.

Universal Gas Law

$$PV = nRT$$

P = Pressure in Pascals or atmospheres

V = Volume in cubic meters or liters

n = Amount of a substance measured in moles

R = Universal Gas Constant

T = Temperature in Kelvin

For demonstration purposes, we can consider n and R as constants and they can be dropped from the equation.

UGL – Modified for Demo

$$PV=T$$

The power of the equal sign is shown here as anything happening to one side of the equation must happen to the other side if the equation, so the equal sign remains true.

We stated previously as air rises, the pressure (P) must decrease. If we measure the same volume of air, meaning volume (V) stays constant, as the pressure drops, the temperature must also drop for the equation to remain true.

Check-in Number 1

Here is where we are.

Warm air rises. As it rises, it expands and cools.

Now the water vapor and dirty air become important. More on this in a minute.

Humidification

Sounds like humidity!

There are several types of humidity. For demonstration purposes, we will be using relative humidity. This is a generally misunderstood weather parameter that doesn't tell us as much as most people think it does!

Relative Humidity

This is defined as the amount of moisture an air parcel is holding relative to how much it could hold.

Relative humidity is calculated using the air temperature and the dew point temperature, expressed in a percentage.

Temperature is defined as the average kinetic energy of molecules. Dew point temperature is defined as the temp the air must be cooled to, to achieve saturation.

RH Examples

Temp = 75°F and Dew Point Temp = 50°F

$$RH = 41.4\%$$

Temp = 98°F and Dew Point Temp = 70°F

$$RH = 40.6\%$$

RH Examples - Impact

Temp = 75°F and Dew Point Temp = 50°F

Heat Index = 74.1°F

Temp = 98°F and Dew Point Temp = 70°F

Heat Index = 105.6°F

Dew Point Temperature

Dew Point (°F)	How it Feels
>75°	Oppressive
70-75°	Very Humid
65-69°	Humid
60-64°	Slightly Humid
55-60°	Comfortable
<55°	Dry

Saturation

The air is holding all the water vapor that it can. When the temperature and dew point are equal, the relative humidity (RH) is 100%. There are two main ways to achieve saturation. Both processes will cause the temp and dewpoint temp to get closer together.

The first way is to add moisture to the atmosphere. This will increase the dew point.

The second way is to cool the air temp.

Supersaturation

To form a cloud, the air typically has to become a bit more saturated than just saturated. It can become supersaturated. The dew point temperature will be slightly higher than the air temperature.

There are variabilities in this process. If the condensation nuclei (dirty air) are of a correct quantity and composition, condensation can occur below saturation.

Condensation

Condensation of water onto condensation nuclei begins at a particular altitude known as the cloud base or lifting condensation level. Water molecules attach to the particles and form cloud droplets which have a radius of about 20 micrometers (0.02 mm, 0.00002m) or less.

Cloud droplets forming leads to...

Clouds

Clouds are composed tremendous numbers of cloud droplets, or ice crystals, or both. Because of their small size and relatively high air resistance, they can remain suspended in the air for a long time, particularly if they remain in ascending air currents. The average cloud droplet has a terminal fall velocity of 1.3 cm per second in still air. To put this into perspective, the average cloud droplet falling from a typical low cloud base of 500 meters/1,650 feet would take more than 10 hours to reach the ground.

Clouds Have Weight

According to the US Geological Survey, a fair-weather cumulus cloud weighs around 1.1 million pounds! (1,100,000 lbs.)

Cumulonimbus clouds can weight up to 1 billion pounds! (1,000,000,000 lbs.)

Massive systems like large hurricanes and mid-latitude low pressure systems and weigh up to 1 trillion pounds! (1,000,000,000,000 lbs.)

Check-in Number 2

- 11. Precipitation**
- 10. Droplet Growth**
- 9. Buoyancy/Cloudiness**
- ~~**8. Condensation**~~
- ~~**7. Saturation**~~
- ~~**6. Humidification**~~
- ~~**5. Cooling**~~
- ~~**4. Expansion**~~
- ~~**3. Ascent**~~
- ~~**2. Dirty Air**~~
- ~~**1. Water Vapor**~~

Buoyancy or Cloudiness

Not all clouds produce precipitation. It is a very small percentage that do. To get from a cloud to rain, there must be a continuation of the process.

We must increase the cloud water content before we can expect any precipitation.

This requires a continuation of the lifting process. Remember...lifting air cools. Cooling air humidifies because the temp is getting closer to the dew point.

Latent Heat

As water vapor condenses into liquid water, it releases heat. This release of heat can help keep the rising parcel of air warmer than the air surrounding it.

Warm air rises. Rising air cools. Cooling air humidifies, etc. The process can continue.

Rising air is said to have a positive buoyancy.

Droplet Growth

Cloud droplets can grow to a larger size in three ways.

1) Continued condensation - slow

2) Collision and coalescence - faster

3) Ice crystals are present in a cloud - fastest

Precipitation

The drops have grown to a sufficient size to be able to make it to the ground without evaporating.

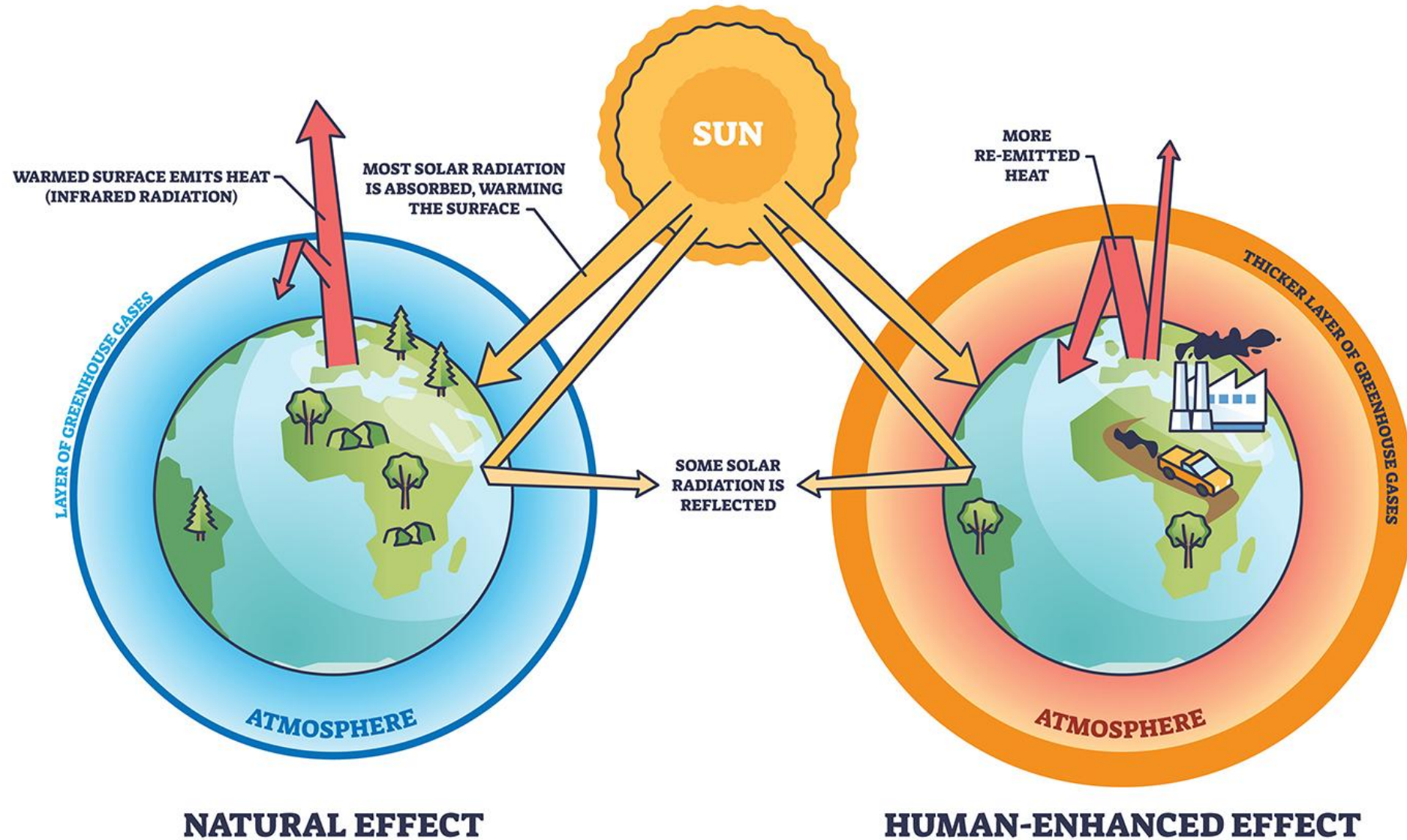
Typical raindrop size is in the range of 0.2 (drizzle) to 5 mm (big ol' FAT rain) (0.008 to 0.20 inch).

Part 2 - Greenhouse

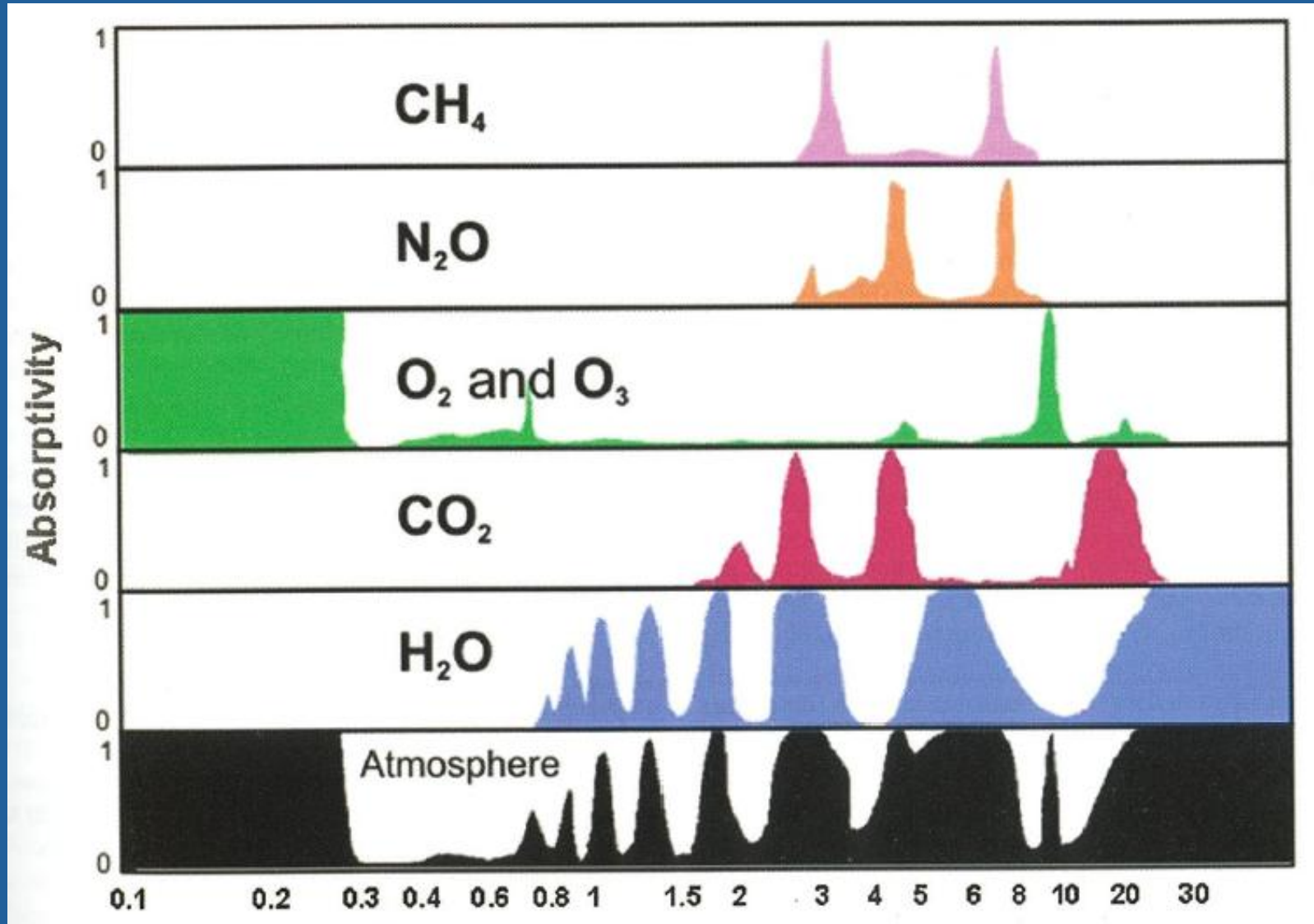
We'll discuss the Greenhouse Effect.

We'll discuss greenhouse gases and what role they play.

Greenhouse Effect



Greenhouse Gases



methane

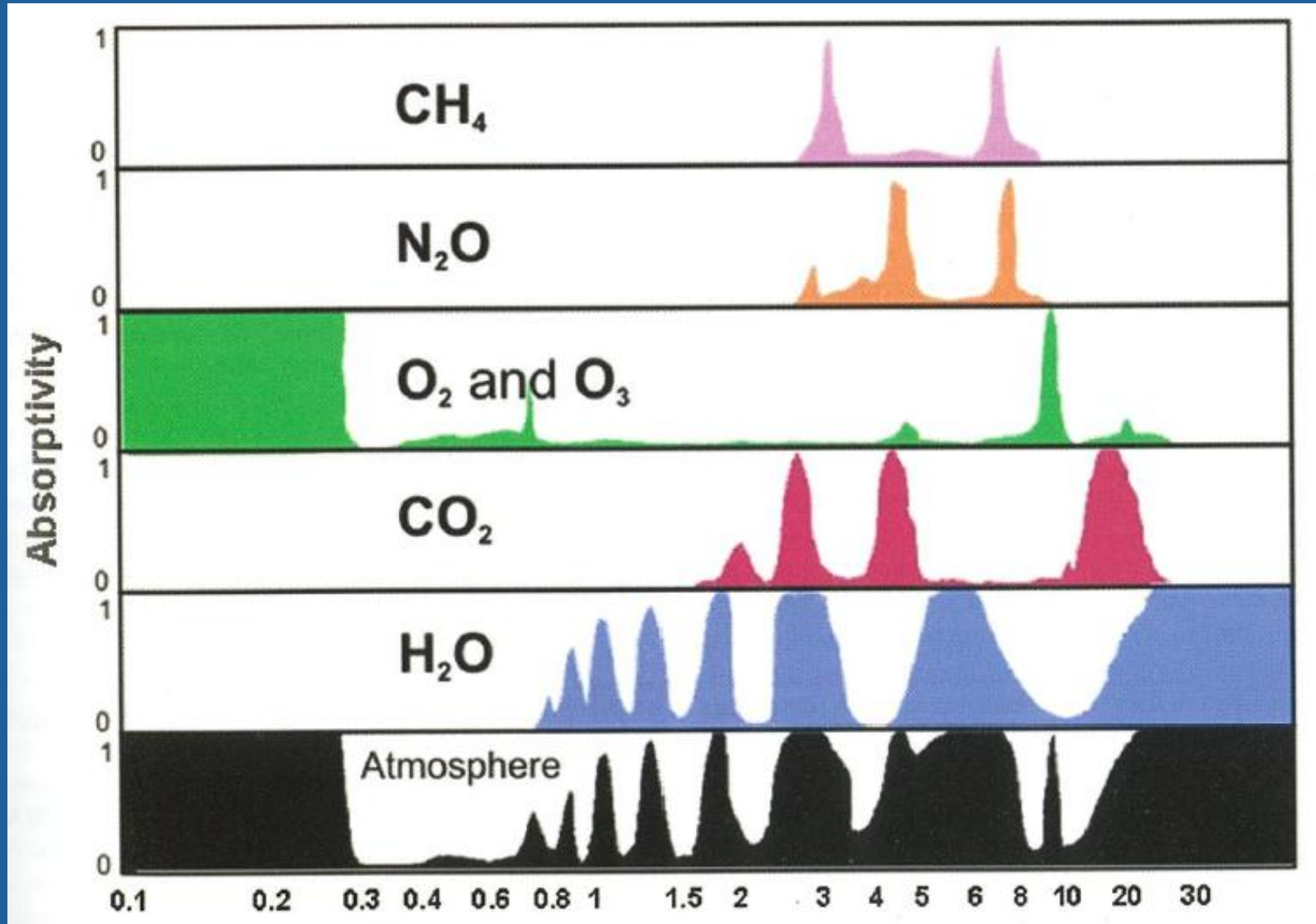
nitrous oxide

oxygen and ozone

carbon dioxide

water vapor

Graph Units



UV

.01 to .4 microns

Visible

.4 to .7 microns

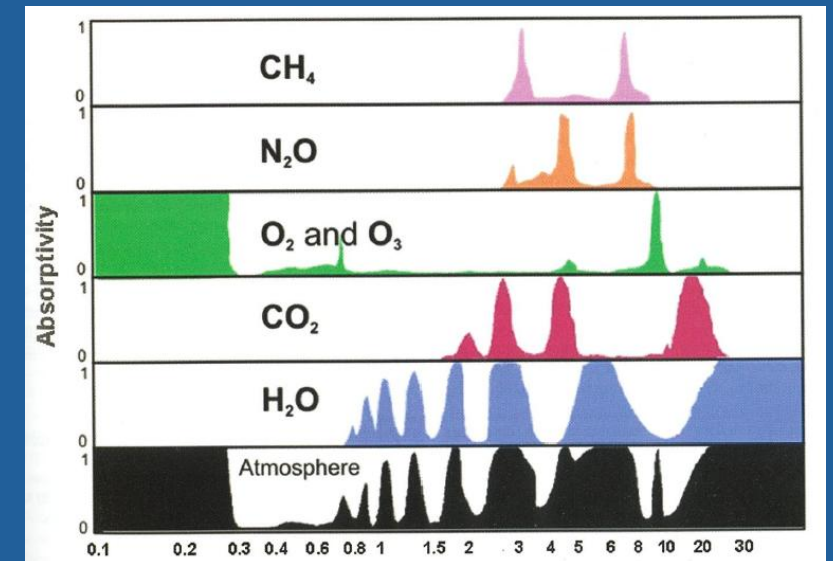
IR

.7 to 1000 microns

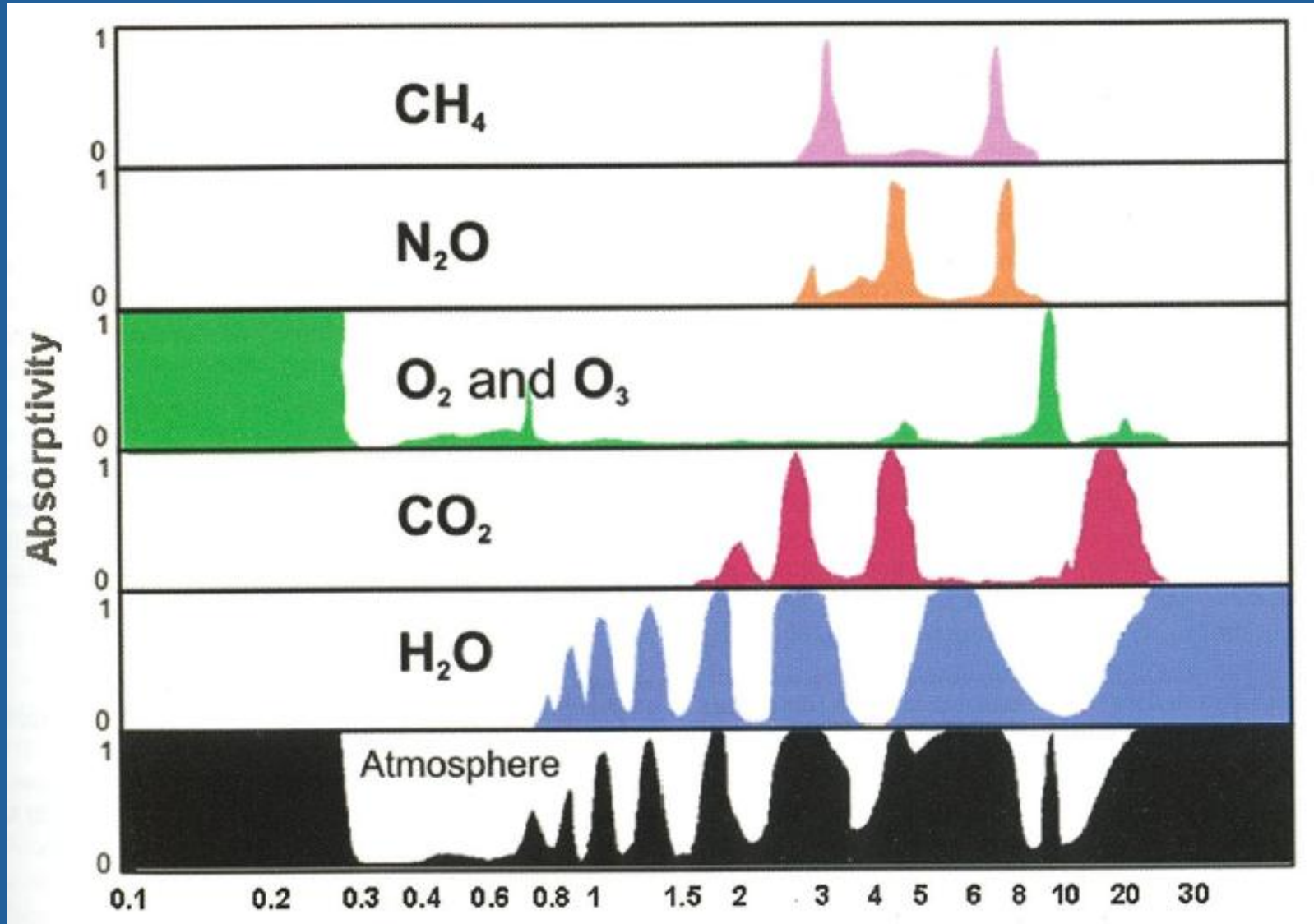
**1 mm =
1000 microns**

Earth Emissions

Earth re-emits solar energy in the thermal infrared spectrum, specifically between 4 microns and 100 microns. The primary wavelengths causing greenhouse issues fall heavily in 15 micron band (absorbed by CO₂) and the 8 to 13 micron range (absorbed by methane, water vapor, and ozone).



Re-emission Areas



8 to 13 microns

8 to 13 microns

15 microns

8 to 13 microns

Blackbody Radiation

All material objects absorb and emit electromagnetic radiation. The distribution of photon energies and fluxes emitted depend primarily on the object's temperature. This phenomenon is known as blackbody radiation.

If an object absorbs MORE energy than it emits, the temperature of the object will increase.

Using the TFWOWO – If an object absorbs LESS energy than it emits, the temperature of the object will decrease.

Check-in Number 3

We have discussed the Precipitation Ladder to gain a basic understanding of how precipitation forms.

We have briefly discussed the Greenhouse Effect to gain a basic understanding of why the atmosphere is warming.

Now we will start “add heat” to the weather equation and look at the potential impacts.

Potential Impacts

“Stormier” Storms

“Floodier” Floods

“Hottier” Hots? “Warmier” Colds

“Droughtier” Droughts

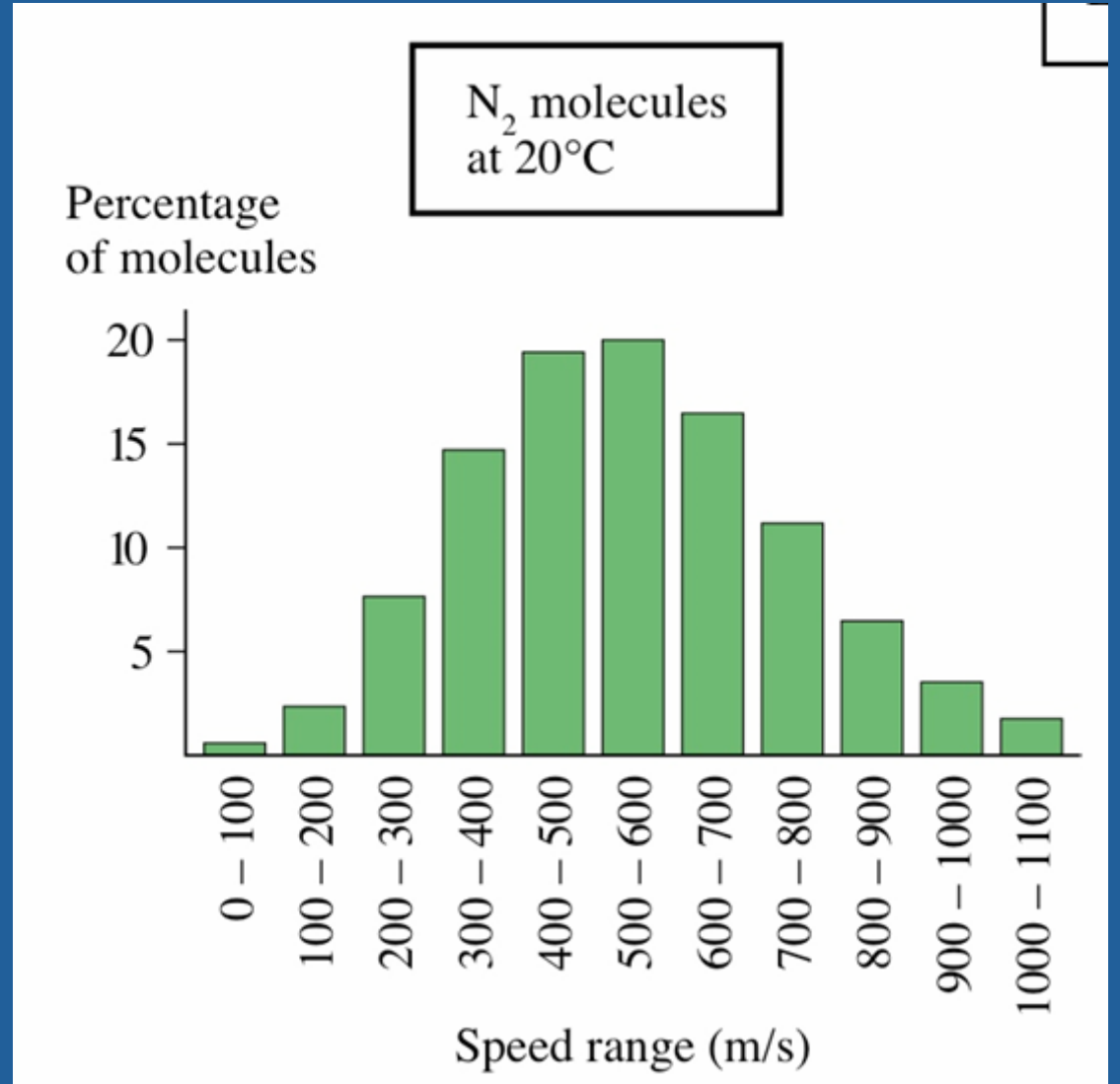
Increased Heat – Part 1

Warm air is able to “hold” more moisture than cooler air.

The warmer the air, the more moisture it can potentially contain.

How Heat Impacts Molecules

Remember...temperature is the measure of the average kinetic energy of the molecules.



Increased Heat – Part 2

Warmer air means potentially more moisture. Warm, moist air is “storm fuel.”

Where does this impact the Precipitation Ladder?

Here is the potential for “stormier” storms and “floodier” floods.

- 11. Precipitation**
- 10. Droplet Growth**
- 9. Buoyancy/Cloudiness**
- 8. Condensation**
- 7. Saturation**
- 6. Humidification**
- ~~5. Cooling~~**
- ~~4. Expansion~~**
- ~~3. Ascent~~**
- ~~2. Dirty Air~~**
- ~~1. Water Vapor~~**

Increased Heat – Part 3

Warmer air means potentially more moisture. Moist air doesn't cool as efficiently as dry air. Water has a tremendous heat capacity,* so much of the energy that could be used to heat the air is used to heat the water vapor.

*** Heat capacity is the amount of heat required to raise the temperature of an object/substance 1°C.**

Part 3 – “Hottier” Hots

This may seem counterintuitive, as a warmer atmosphere will allow more water vapor to evaporate into it. More water vapor means more energy to heat. However, more moisture also means less cooling.

Starting out with warmer temperatures (overnight lows) mainly due to additional surface moisture means we have less “distance” to get to higher daytime highs and higher daily mean temperatures.

Water Impact on Temps

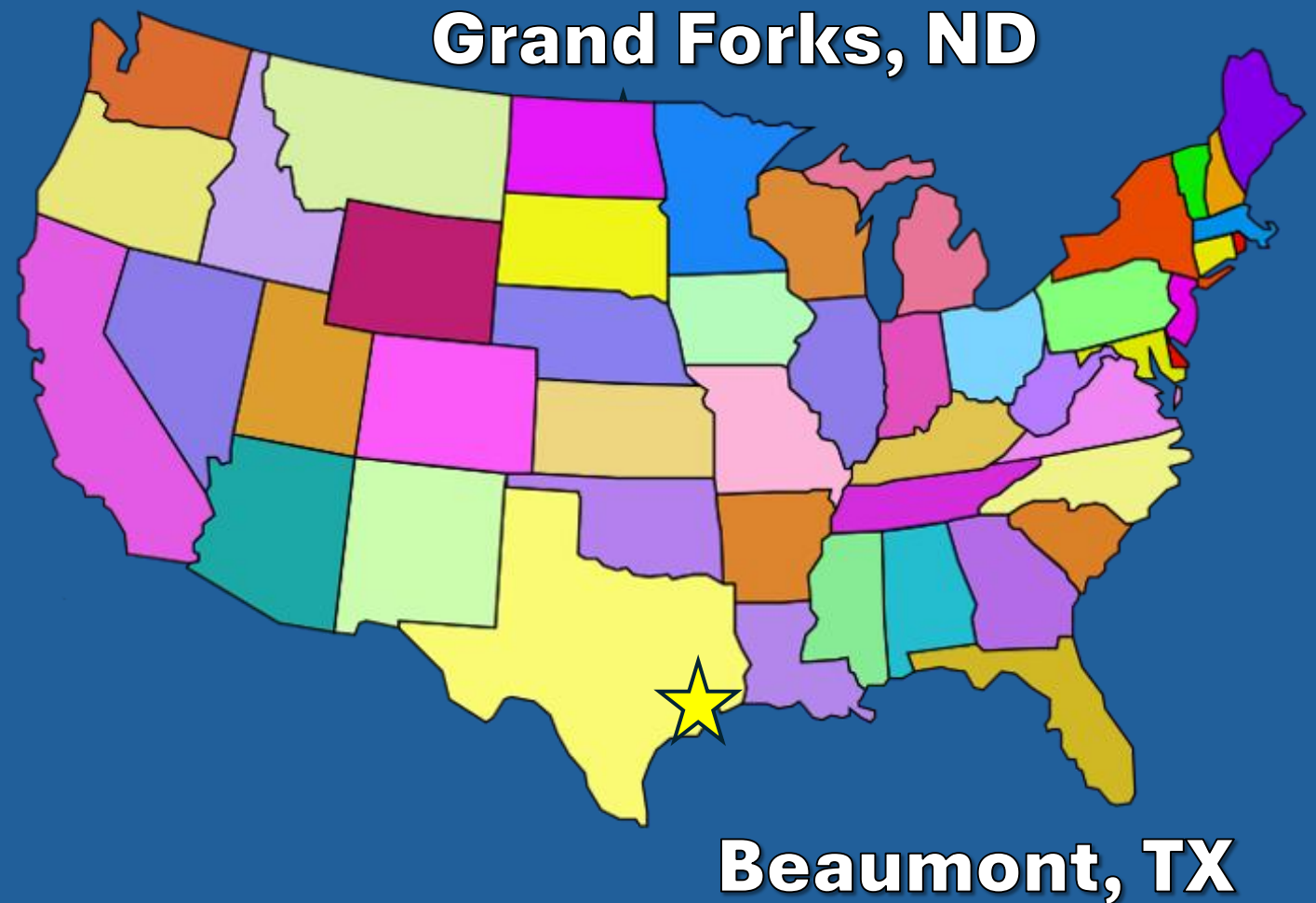
All-time Record Highs (Lows)

Grand Forks, ND

109°F. (-43°F)

Beaumont, TX

108°F. (10°F)



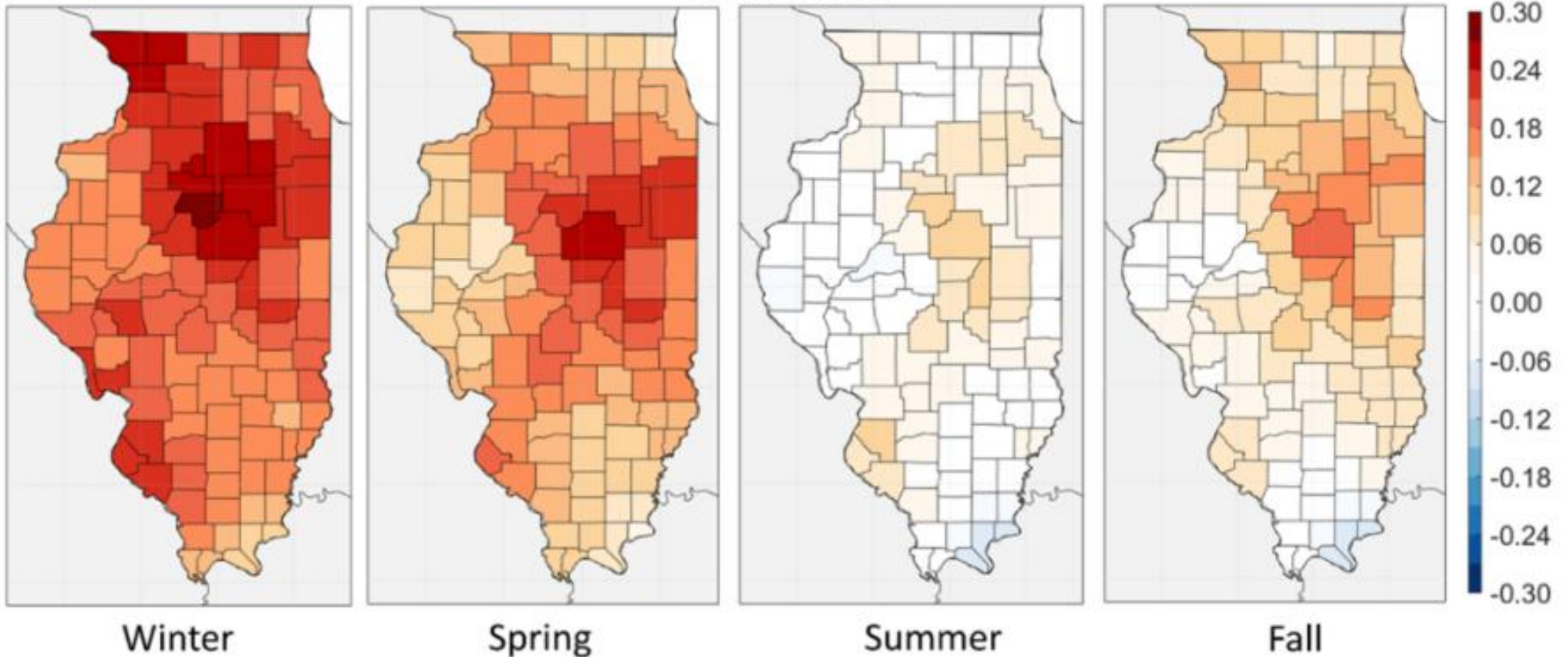
Part 3 – “Warmier” Colds

Starting out with warmer temperatures (overnight lows) mainly due to additional surface moisture means we have less “distance” to get to higher daytime highs and higher daily mean temperatures.

Increased moisture is the main reasons our winter season is getting warmer. The moisture in the air decreases the temperature’s ability to drop.

Temperature Trends

Temperature Trends (°F per decade)
1895 – 2021



Check-in Number 4

~~“Stormier” Storms~~

~~“Floodier” Floods~~

~~“Hottier” Hots? “Warmier” Colds~~

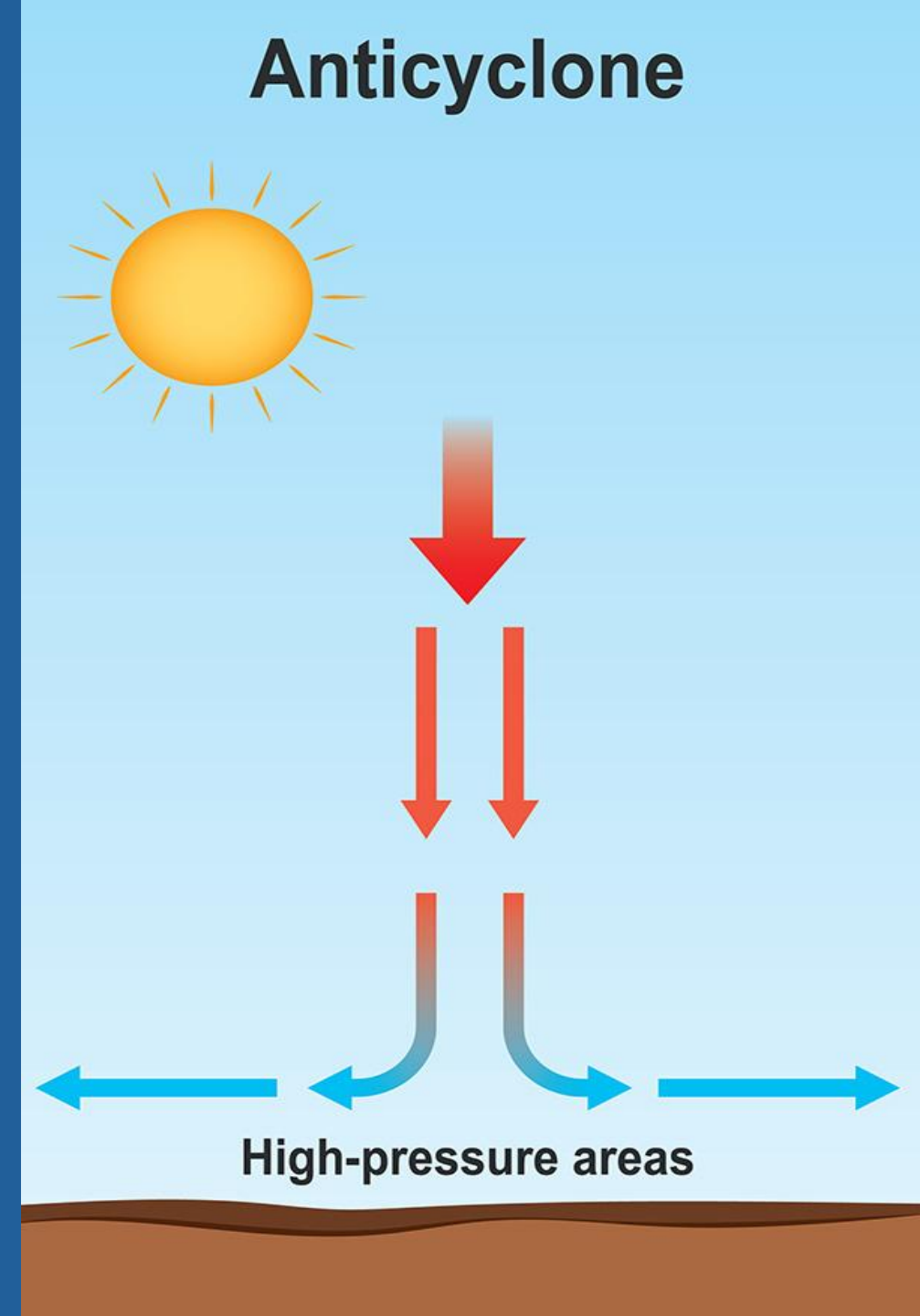
~~“Droughtier” Droughts~~

“Droughtier” Droughts

There is still a lot of debate about the connection between drought and global warming, the current period of climate change. A 2013 NASA study predicts warmer worldwide temperatures will mean increased rainfall in some parts of the world and decreased rainfall in others, leading to both more flooding and more droughts worldwide. **Other scientists question the prediction that there will be more droughts and believe global warming will create a wetter climate around the world.**

Drought Cause

If we are to have an increase in droughts, it will be due to the warming and drying of the air in the lower and mid levels in the atmosphere. The warmer and drier air will resist cloud formation. Therefore, precipitation amounts will be affected.



Climate Data

Past weather data (climatological data) is easier to get than ever before! Your local National Weather Service office webpages have **BUNCHES** of climate data for your area. Five offices cover Illinois.

ILX – Lincoln, IL (Central)

LOT – Chicago, IL (Romeoville) (NE)

LSX – St. Louis, MO (St. Charles) (SW)

PAH – Paducah, KY (West Paducah) (Southern)

DVN – Quad Cities, IA/IL (Davenport) (NW)

What is next?

1. Be sure you have signed in
2. Look for an email from Meagan Budke for materials and slide deck
3. By the end of the week, log in to PD+ to complete the evaluation form and redeem PD hours



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Behind Climate Change



Resources

[ISBE Science Webpage](#)

[IDNR Education Website](#)

[IDNR ENTICE Workshop Webpage](#)



Thank you – Stay Connected

Meagan Budke, ISBE, mbudke@isbe.net

Joe Bauer, IDNR, joe.bauer@illinois.gov

