LLI SPRING 2020
BASIC WEATHER CHAPTER FOUR

STABILITY, CLOUDS, PRECIPITATON

Time Permitting: Intro to Fronts and Thunderstorms

NWS WEATHER BALLOON LAUNCH

Weather

- **DATE: TBD, if enough interest will be scheduled.**
- **TIME: 2400 GMT (6 pm DST 5pm CST). Be at NWS 15 mins prior to launch**
- **LOCATION: NATIONAL WEATHER SERVICE OFFICE**
- **2485 SOUTH POINT ROAD**
- **GREEN BAY, WI**
- **The NWS Weather Office is immediately across the street from Austin Straubel Airport. Park in the visitor parking lot and enter building front entrance. The Balloon Launch will take place outdoors, rain or shine, and this will be followed by a tour of the NWS facilities.**

Chapter 4
Objectives

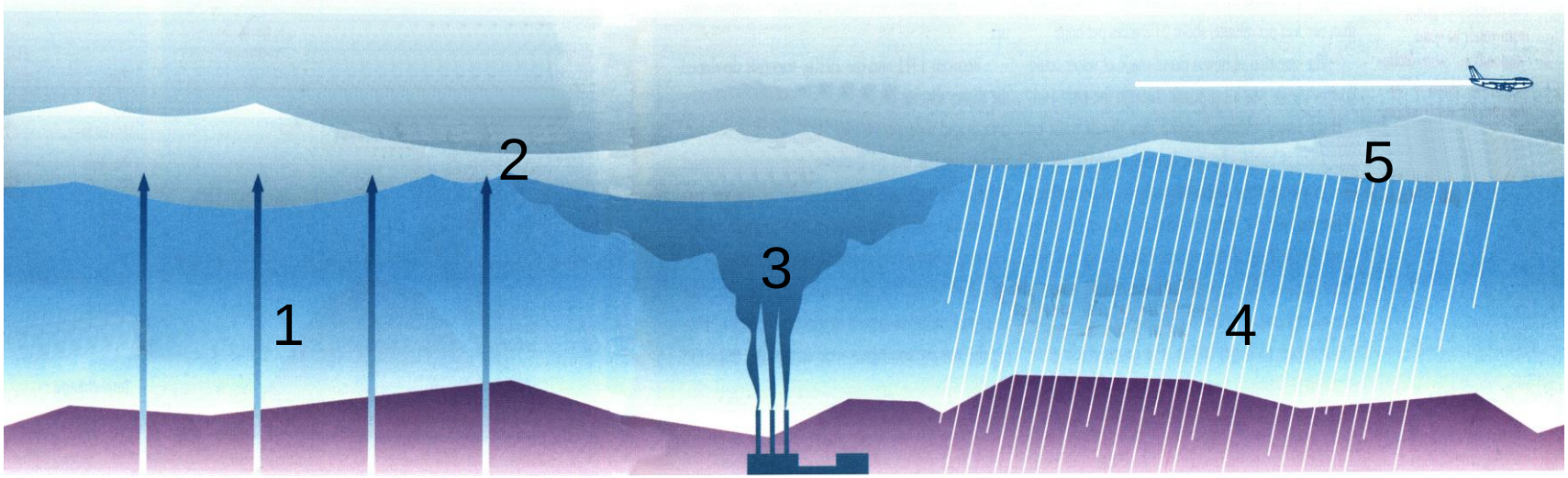
- Be familiar with the concept of stability.
- Understand the four lifting processes.
- Know what a lapse rate and stability are.
- Recognize common clouds and what they indicate.
- Be familiar with the various forms of precipitation.
- Understand Air Masses and Fronts
- Introduce Polar Front Theory and Cylogenesis
- Know the general movement of weather systems in the mid-latitudes of North America
- Know the basics of thunderstorm formation

Atmospheric Stability/Instability

- **Stability:**
  - **when there is relatively little vertical movement.**
  - **an air parcel (imaginary particle that is enclosed by a membrane) and resists being pushed up or down.**
- **Instability:**
  - **when there is significant vertical movement (convection) .**
  - **an air parcel tends to continue rising or falling when pushed up or down.**
- **An example of stable air is a temperature inversion when warm air is ABOVE cooler air. Forms a “lid” on the atmosphere**

STABLE AIR

For clouds to form, something has to keep pushing the air upward until it cools to the Dew Point.



1. Air flowing into the center of a low pressure area rises.
2. Air cools to Dew Point, water vapor condenses into cloud droplets; air rising uniformly over hundreds of square miles, clouds are flat and cover sky over large area.
3. Visibility under clouds poor - pollutants, haze or fog not being cleared out by slowly rising air. An inversion forms a "lid".
4. Precipitation likely to be light, falling over wide area and lasting for hours.
5. Without strong updrafts, airplanes have smoother ride.

Stability

•clouds tend to be in layers that are **not very thick compared to how spread-out they are**; FLAT CLOUDS called Stratus
•any precipitation is usually light to moderate and steady; and
•the wind is light to moderate and steady

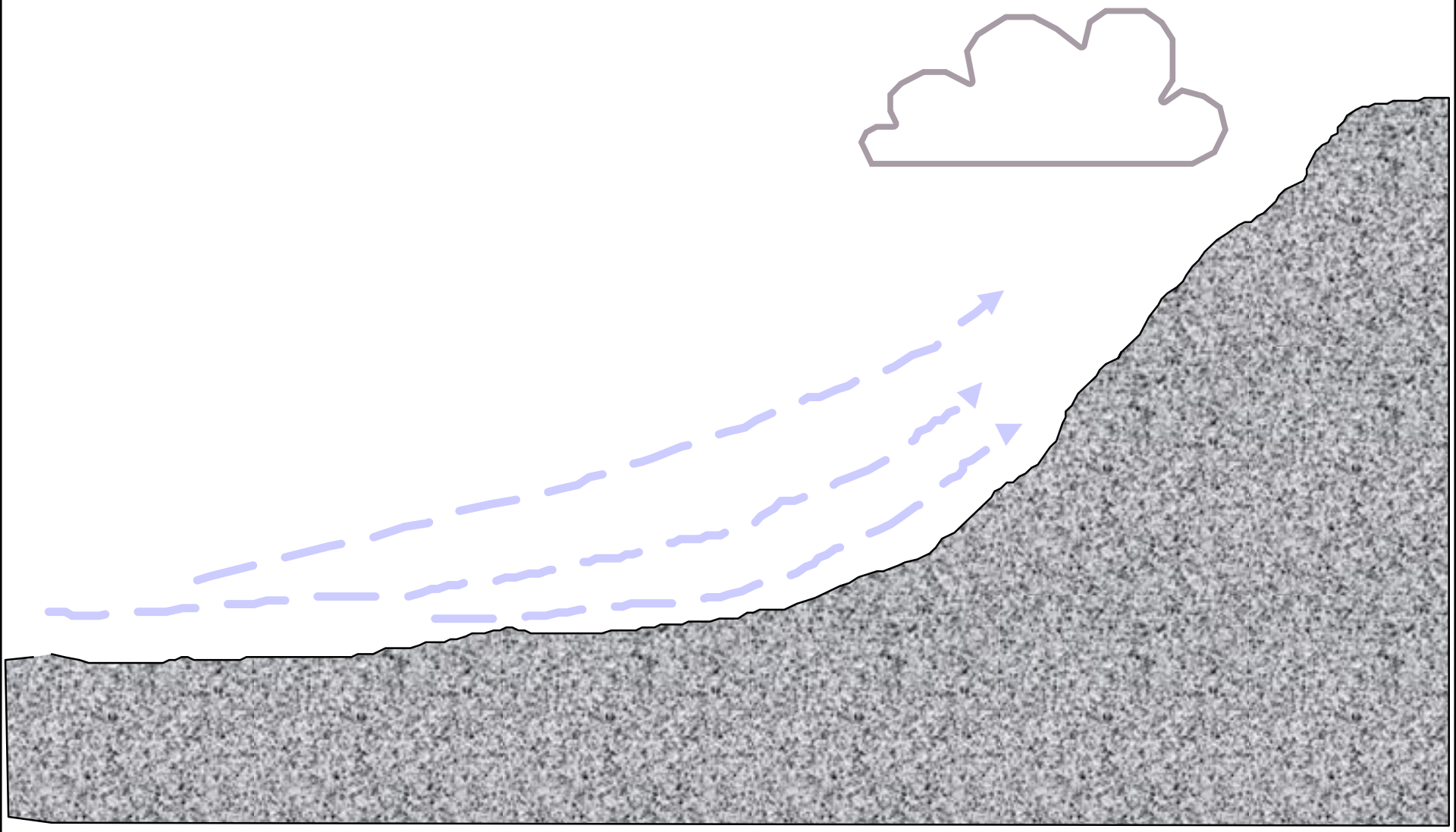
Instability

•clouds tend to **be puffy with high vertical development** (sometimes towering seen in **thunderstroms**);
•**precipitation is usually heavy with significant changes in intensity**; and
•the **winds are gusty and shift direction** frequently.

What causes air to rise?
Lifting Processes

- **The four lifting processes are:**
- **Lifting processes cause vertical air movement-convection.**
  - **Orographic Lifting-mountain lifting-Chinook winds**
  - **Frontal Wedging- a warm air mass is forced up by more dense colder air mass**
  - **Surface Convergence-air blows into a low pressure area and rises**
  - **Localized Convective Lifting-air parcel rises because it is warmer and less dense than surrounding air**

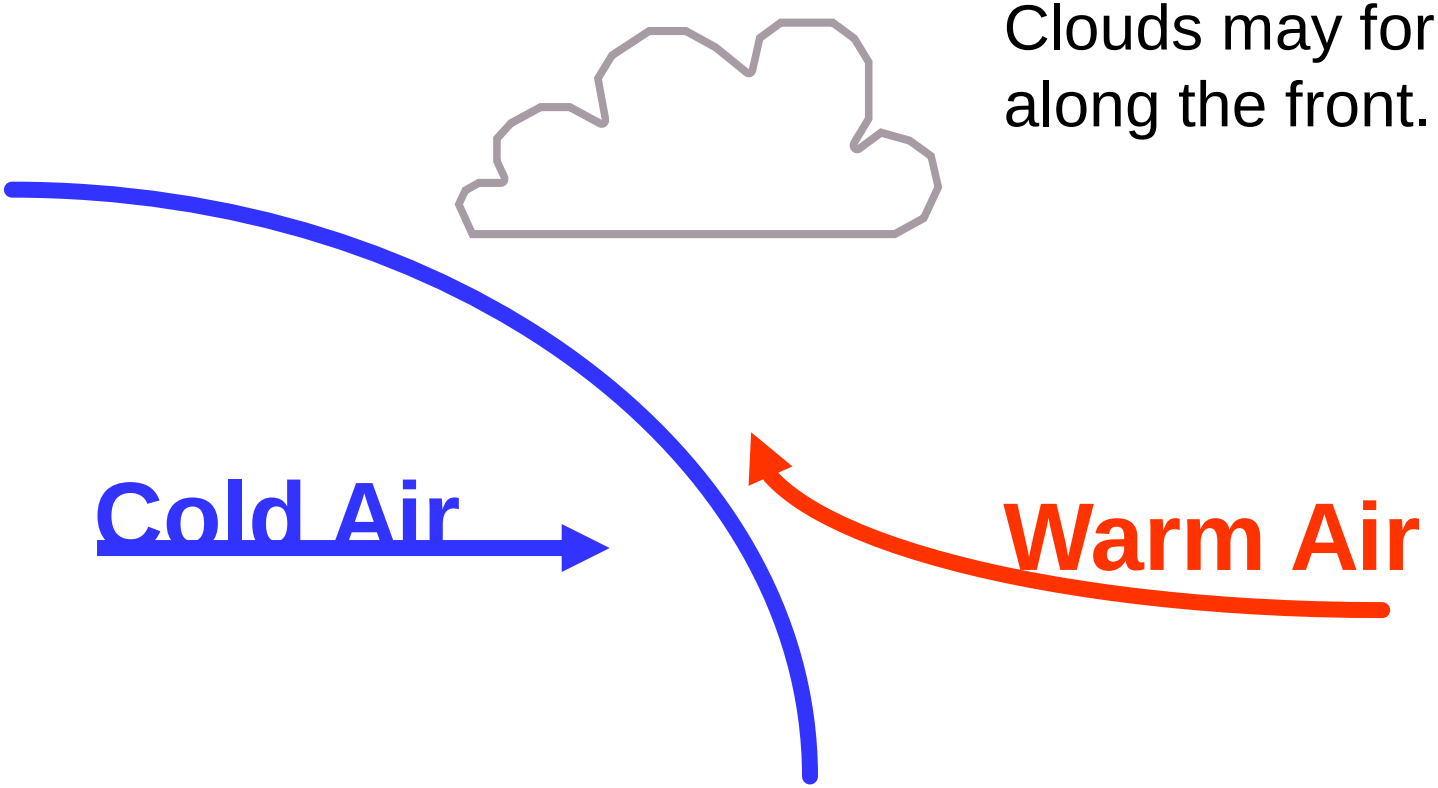
Orographic Lifting



Lenticular Cloud Over Hills

•The shape of the cloud is formed by **orographic lifting** (**the air cools and water vapor in the air condenses).**
•On **the other side of the hill (mountain) the air sinks (the air warms and the water droplets evaporate).**
•Lenticular clouds worrisome to pilots in airplanes in the mountains, because it can signal turbulent air. There can be **strong downward gusts, called Rotors**

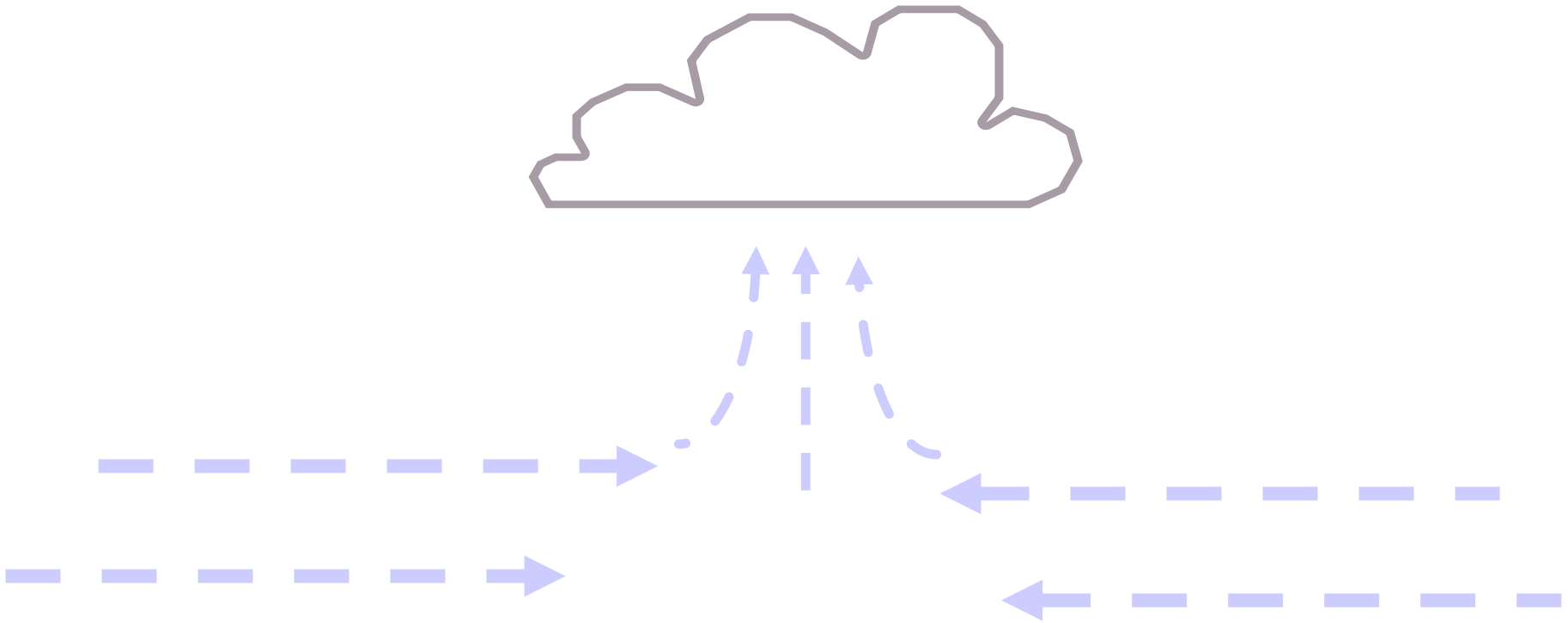
Lifting by Frontal Wedging
warm air rises over cold air



•Advancing wedge of a cold air mass forces warmer air aloft or **Warm air overtakes a retreating mass of cold air**.

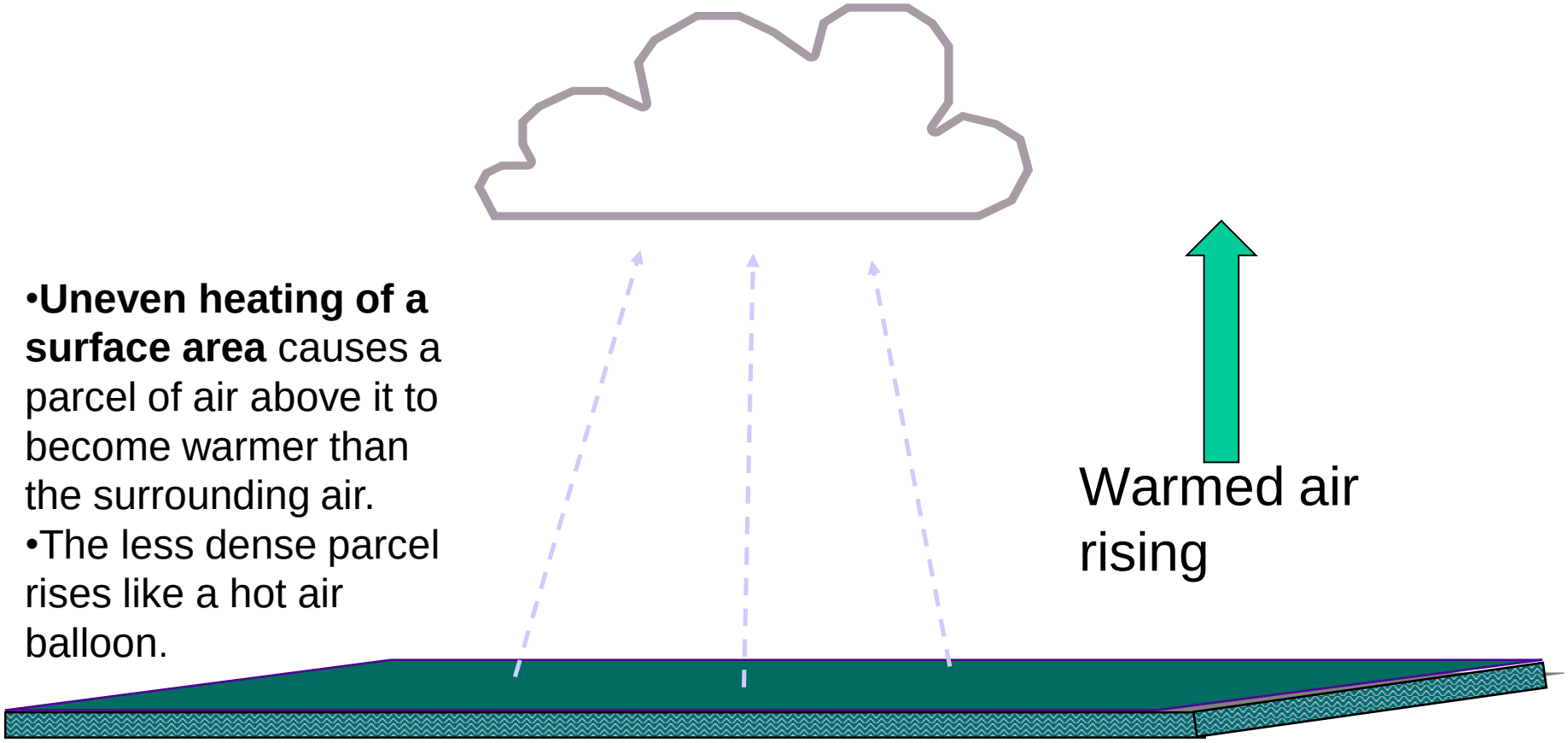
Lifting by Surface Convergence

in a low pressure system, air is forced upward, cools as it rises and condenses into a cloud



Localized Convective Lifting

uneven heating of surface e.g. black asphalt causes rising air which then cools and can form a cloud



•**Uneven heating of a surface area** causes a parcel of air above it to become warmer than the surrounding air.
•The less dense parcel rises like a hot air balloon.

Environmental Lapse Rate

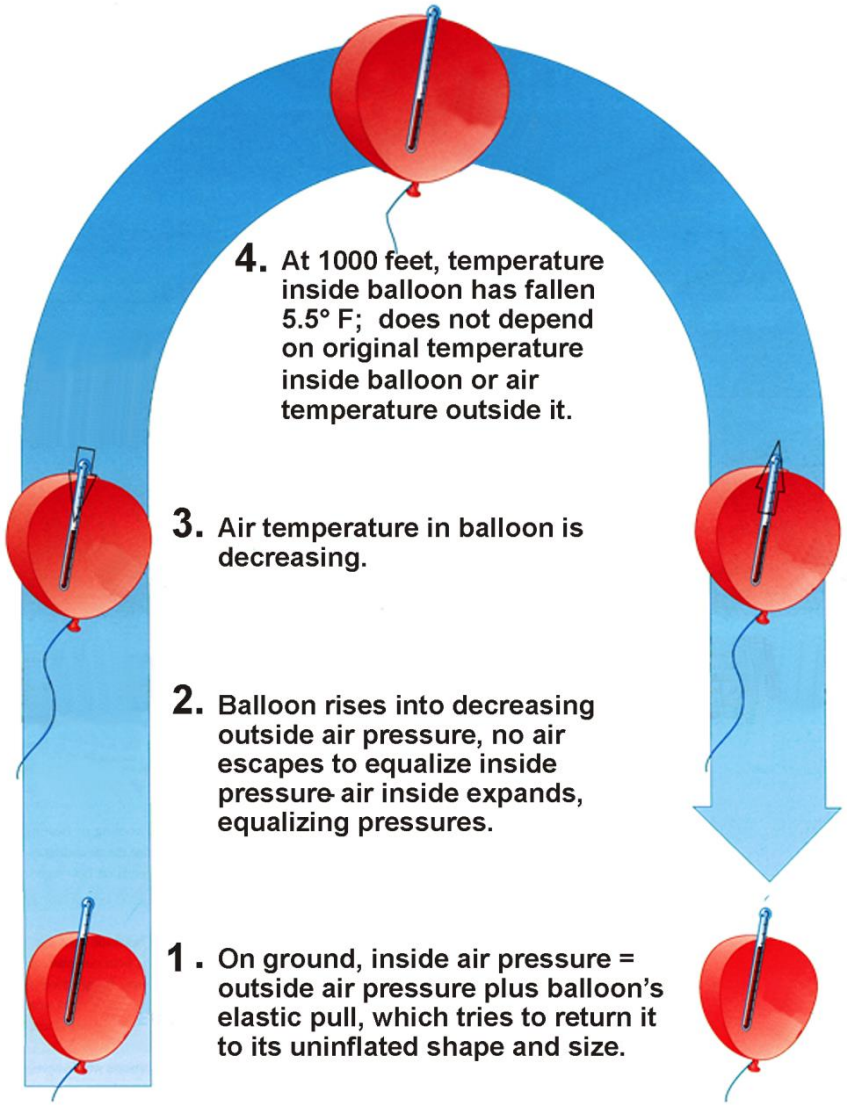
- **The Environmental Lapse Rate applies to a stationary (NO vertical movement) column of air.**
  - **The rate varies with atmospheric conditions at different times and places.**
  - **Actual rates are determined by observations made by weather balloons and satellites.**
  - **Think of a mountain climber with a thermometer.**
- **The <u>average</u> rate is -3.5^0 F per 1000 ft.**
  - **- means the air cools with increasing altitude.**
  - **The rate is + if there is a temperature inversion. The ELR becomes positive when descending (a negative, negative) and the temperature increases.**

Adiabatic Lapse Rates

- **Adiabatic Lapse rates apply to air parcels that move up or down.**
  - **Air parcels cool when they rise only because they expand.**
  - **Air parcels warm when they sink only because they compress.**
- **Adiabatic means:**
  - **No heat is added to or removed from the air parcels. The heating is the result of expansion or compression of the air.**
  - **The surrounding air does not cause this cooling and warming. It is simply the result of the lifting process. Remember the Ideal Gas Law: PV=nRT**
  - **The pressure falls with rising altitude, so T must decrease to comply with Ideal Gas Law**
- **Examples of adiabatic processes are:**
  - **A tire hand pump gets warm from the compression of air.**
  - **Air escaping from a tire valve is cold because it is expanding.**
  - **Childhood example of C02 cylinder powered model car. After the cylinder was puncture and car raced ahead, ice crystals formed on cylinder**

Rising and Sinking Balloon

THINK OF THE BALLOON AS AN "AIR PARCEL"



4. At 1000 feet, temperature inside balloon has fallen 5.5° F; does not depend on original temperature inside balloon or air temperature outside it.

3. Air temperature in balloon is decreasing.

2. Balloon rises into decreasing outside air pressure, no air escapes to equalize inside pressure- air inside expands, equalizing pressures.

1. On ground, inside air pressure = outside air pressure plus balloon's elastic pull, which tries to return it to its uninflated shape and size.

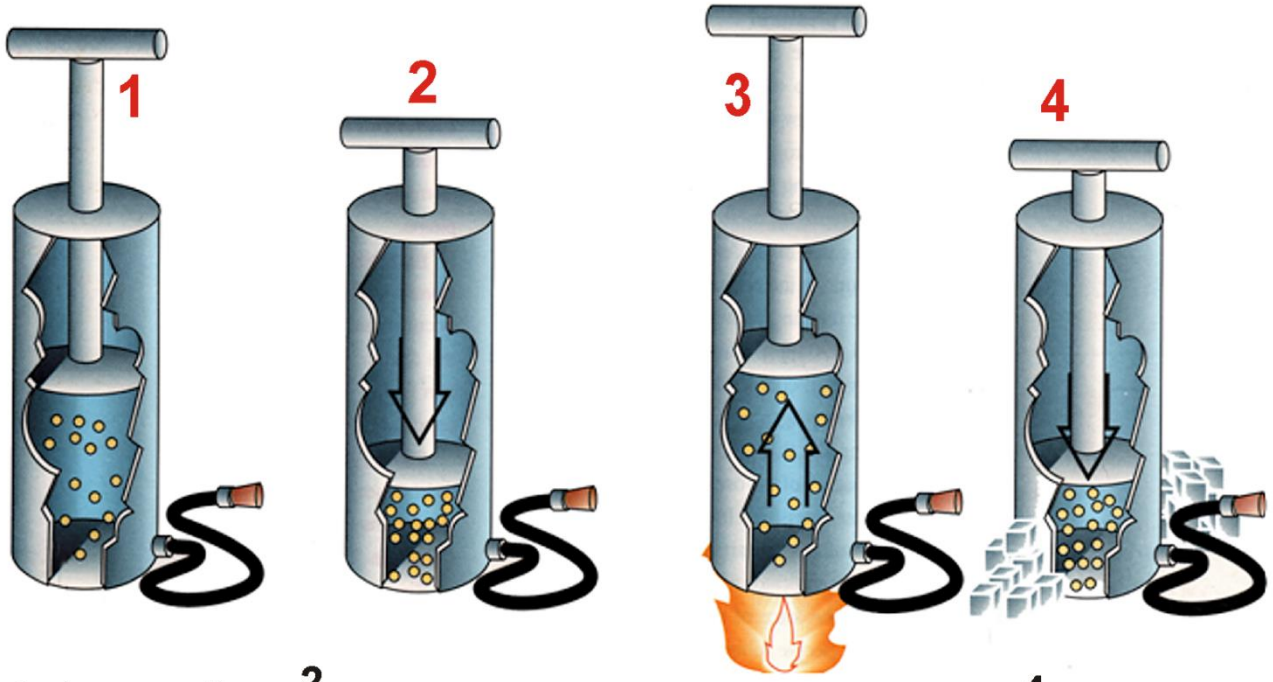
5. Going down, increasing outside air pressure squeezes balloon, compressing air inside; air temperature inside balloon is increasing.

6. Back on ground, balloon has regained the 5.5° F in temperature it lost going up.

Expanding the balloon means the air inside is doing work, which requires energy. The energy comes from the air molecules, decreasing the temperature.

Air: Heated, Cooled, Under Pressure

now imagine pump being moved up and down the atmosphere: what would happen?



1.
Pump's plunger won't fall all the way down since air pressure under it applies upward force, holding it up.

2.
Push down on plunger - squeezes molecules below together - air pressure under plunger increases - let go and this pressure pushes plunger back up.

3.
Heat pump's bottom - heat makes air molecules move faster, increasing pressure - plunger rises.

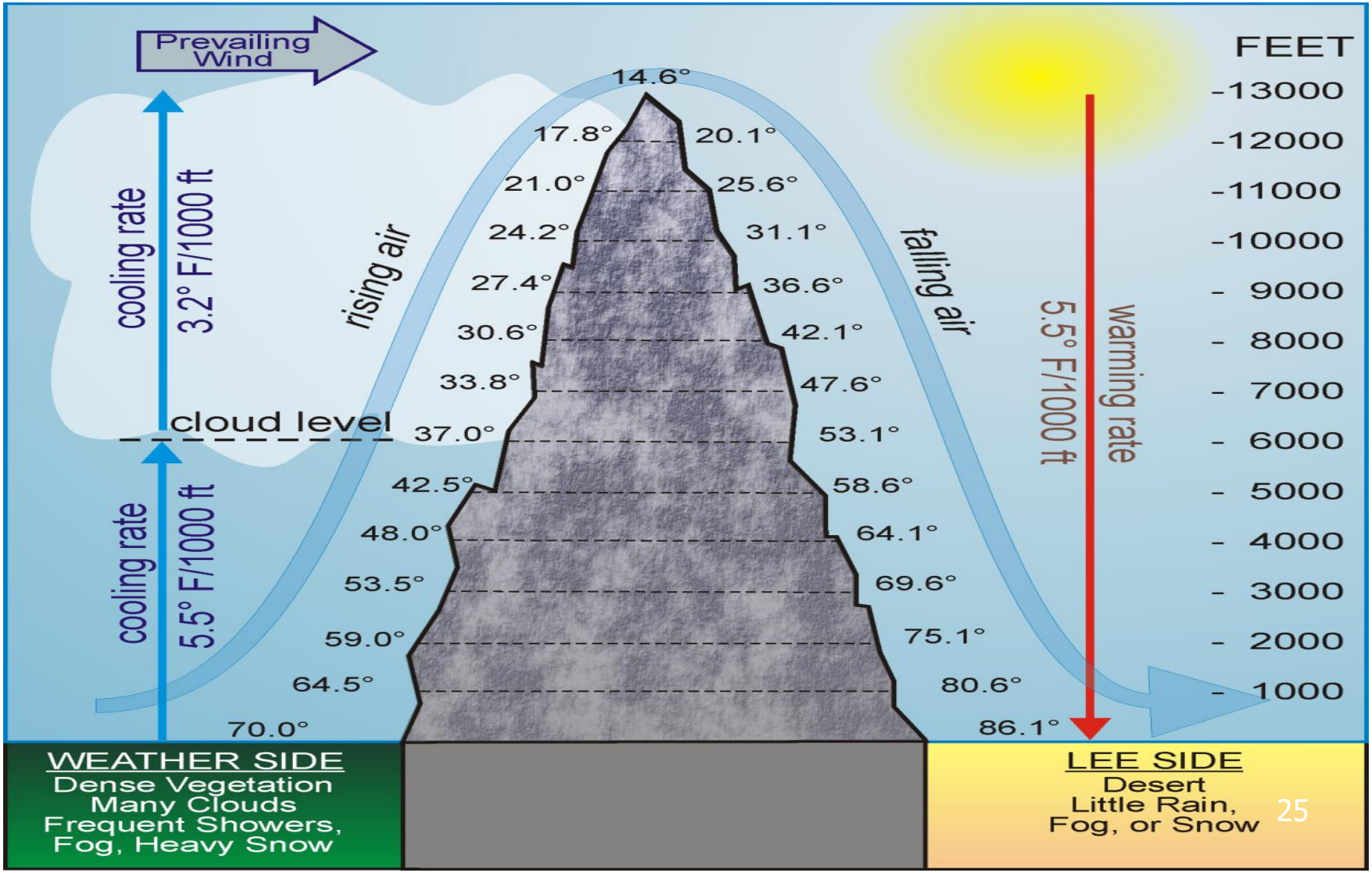
4.
Cool off pump - air molecules slow down - pressure decreases - plunger falls.

A more complicated process can occur when air is pushed up a mountain and sinks on the other side

•On the **windward side of the mountain the rising air cools at the dry adiabatic lapse rate (5.5^{0}F/1000ft)** until its temperature drops to the **Dew Point (the condensation level).**

•air continues to cool but at the lower **wet adiabatic lapse rate (3.2^{0}F/1000ft).**

•When the air sinks on the **leeward side of the mountain it warms at the higher dry adiabatic lapse rate (5.5^{0}F/1000ft)** all the way down because the **air having lost moisture never becomes saturated.**



Adiabatic Warming and Cooling in Wyoming

- **Animated video showing the mountain effects of heating and cooling on cloud formation and dissipation:**
- **https://www.youtube.com/watch?v=XH_M4jItiKw**
- **1:42 mins.**

Types of Stability/Instability weather associated

- **Stability and Instability refer to the vertical motion of air:**
  - **stable – little vertical movement-fair weather**
  - **unstable – a lot of vertical movement-tendency to storms, esp. thunderstorms**
  - **TYPES of Stability:**
    - **Absolute Stability-most stable condition, rising air cools**
    - **Absolute Instability-rising air warms**
    - **Conditional Stability-rising air is stable when unsaturated and unstable when saturated. Major problem for meteorologist…how much water vapor is in the air aloft?????**

Clouds

- **Clouds form when rising air cools to and below Dew Point.**
  - **Recall Dew Point is that temp at which air is saturated with water vapor.**
- **Clouds are visible clusters of:**
  - **water droplets or ice crystals;**
  - **formed by condensation or deposition**
  - **Formed when rising air cools below dew point**
- **Clouds are indicators of atmospheric conditions:**
  - **Flat layered clouds indicate stability. (stratus clouds)**
  - **Lumpy piled-up clouds indicate instability (cumulus)**

Cloud Classification

- Different types of clouds:
  - indicate weather patterns; and
  - serve as forecasting aids.
- Clouds are classified using two basic criteria:
  - Shape
  - Height

Cloud Shapes

- **Cirrus – thin wispy fibers or veil-like patches**
- **Stratus – layered or stratified sheets**
- **Cumulus – piled-up or lumpy; cauliflower-like structure with flat base**
- **Combinations**
  - **Cirrostratus**
  - **Stratocumulus**
- **Other Descriptive Characteristics:**
  - **Nimbo or Nimbus – cloud producing precipitation**
  - **Fracto or Fractus - fragmented, shredded by winds**

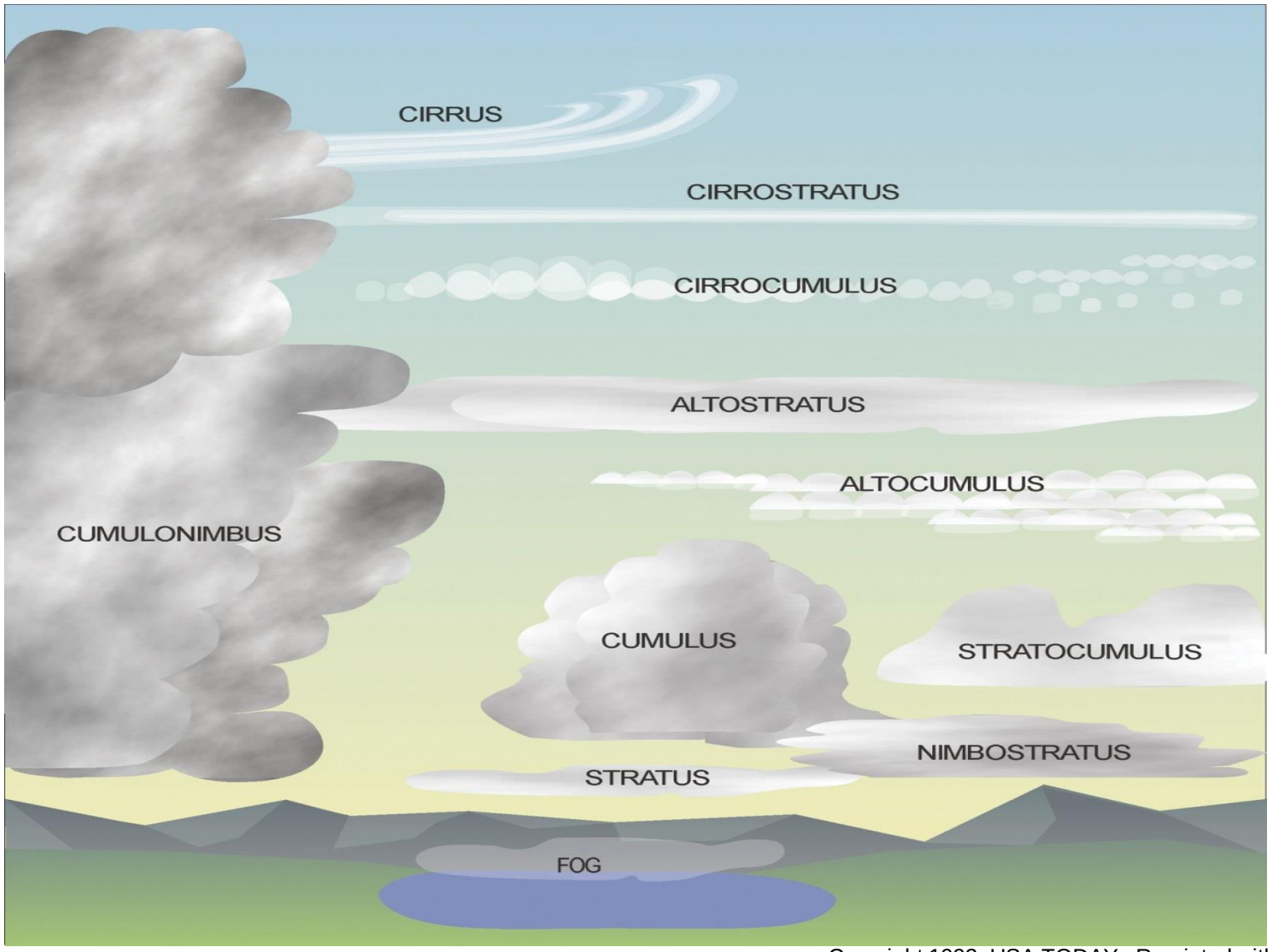
Cloud Base Height Chart

		Clouds of Vertical Development	
HIGH above 20,000ft	Cirrus (Ci) Cirrostratus (Cs) Cirrocumulus (Cc)		Cumulonimbus (Cb) from near ground to above 50,000ft
MIDDLE 20,000ft to 6,500ft	Altostratus (As) Altocumulus (Ac)	Cumulus (Cu) Bases 1,500ft Tops 16,000ft	
LOW below 6,500ft	Stratocumulus (Sc) Nimbostratus (Ns) Stratus (St)		

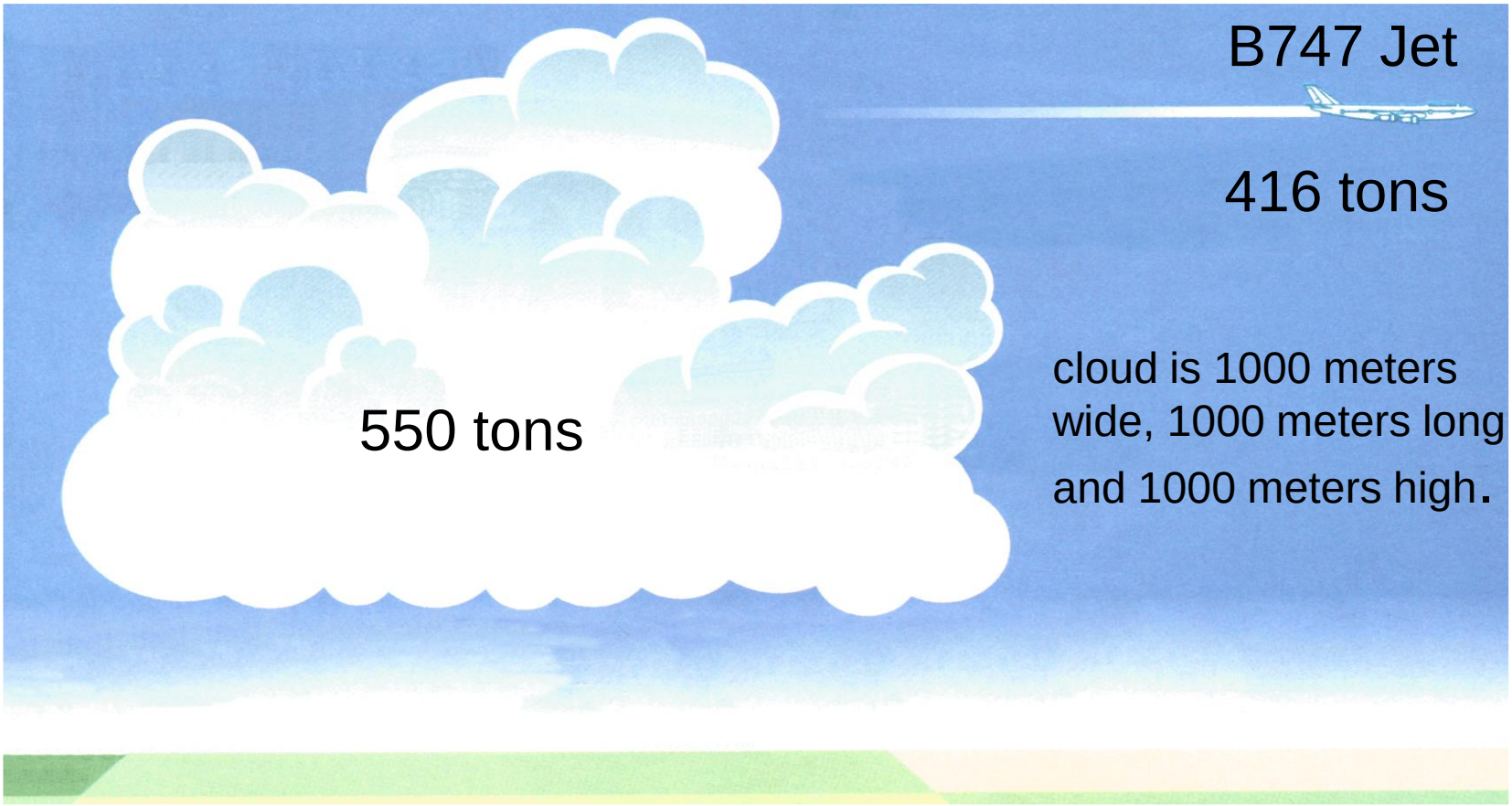
- Remember that the cloud base is at the height where rising air cools to its Dew Point and water vapor condenses into cloud droplets.

Common Cloud Types

Google “NOAA Cloud Chart”
https://www.weather.gov/media/owlie/cloud_chart.pdf



Weight of a Cloud?



A cloud like this has 0.5 gram of liquid water in each cubicmeter. If we multiply 1000 x 1000 x 1000 x 0.5, we find the clouds liquid water weighs about 500 million grams. This is about **550 tons**.

Cirrus

- Cirrus clouds are thin and wispy with a filament appearance.
- filaments are hooked they are called “mares’ tails”.
- Cirrus clouds usually indicate **immediately stable fair weather** but can precede a warm front bringing a **weather change within 24 hours**
- Cirro type clouds are composed of **ice crystals. No precipitation (too cold).**

Cirrostratus Clouds

veil-like appearance; can produce halos around moon/sun; indication of a warm front approaching within 12 to 24 hours

Cirrocumulus

•Cirrocumulus clouds appear as thin and lumpy small white flakes or globules: **mackerel sky** because of their **likeness to bands of fish scales**.

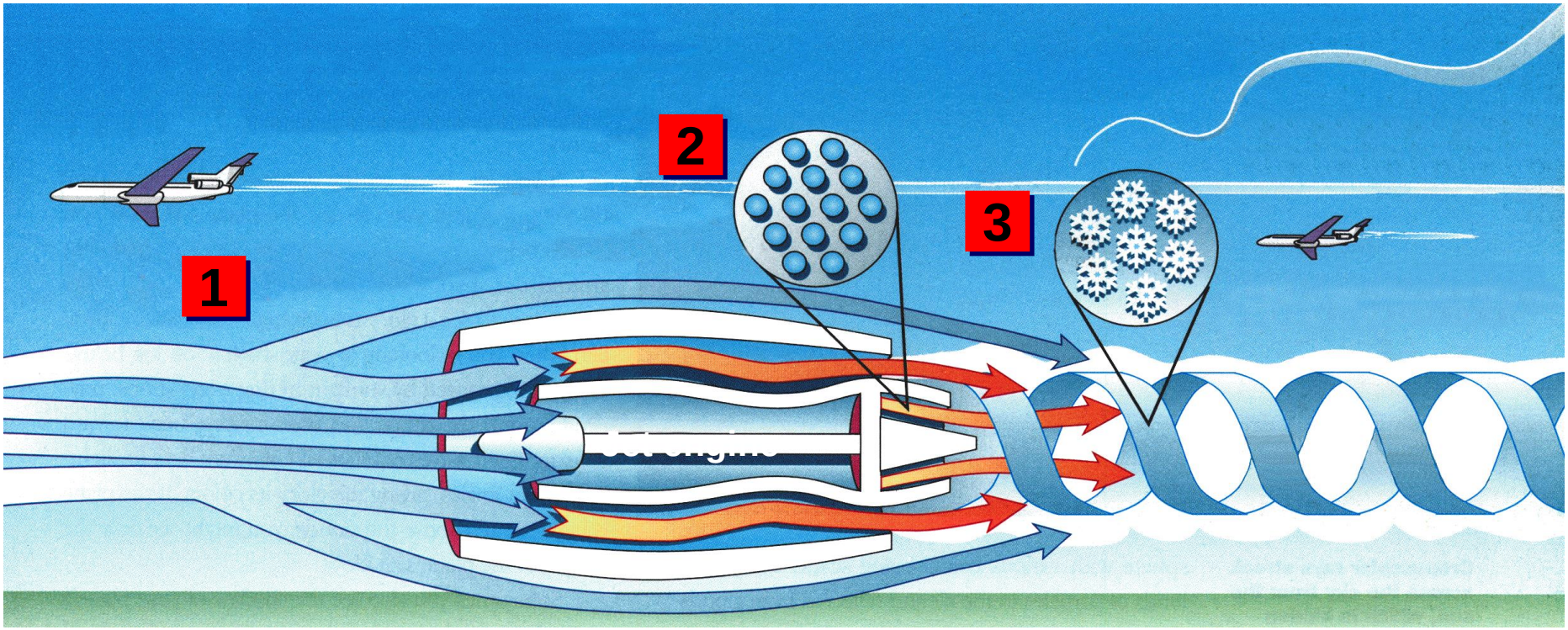
•can send **mixed messages:** winter often indicate fair cold weather.

•**If they are part of a lowering thickening cloud pattern they warn of deteriorating weather.**

Contrails

streams of ice crystals formed by high altitude aircraft

Contrails



Contrails - long streaks of clouds - formed by airplanes flying from 25,000 to 40,000 feet above the Earth.

- **1. If outside air is close to 100% relative humidity. (very little water vapor, because its so cold).**
- **2. …the added water vapor from the engines' exhaust makes it 100%.**
- **3. Clouds of ice crystals form.**

- **Winds of differing speeds or directions push contrails into wavy lines.**
- **If air is humid enough, the clouds (contrails) can last an hour or more and spread out.**
- **Disturbed air created by wings twists contrails, mixing warm, humid exhaust with the cold air.**

Altostratus: flat, sheetlike

While light precipitation may accompany them, when they are **associated with a warm front and thicken into darker nimbostratus, precipitation is likely to be long lasting.**

Altocumulus

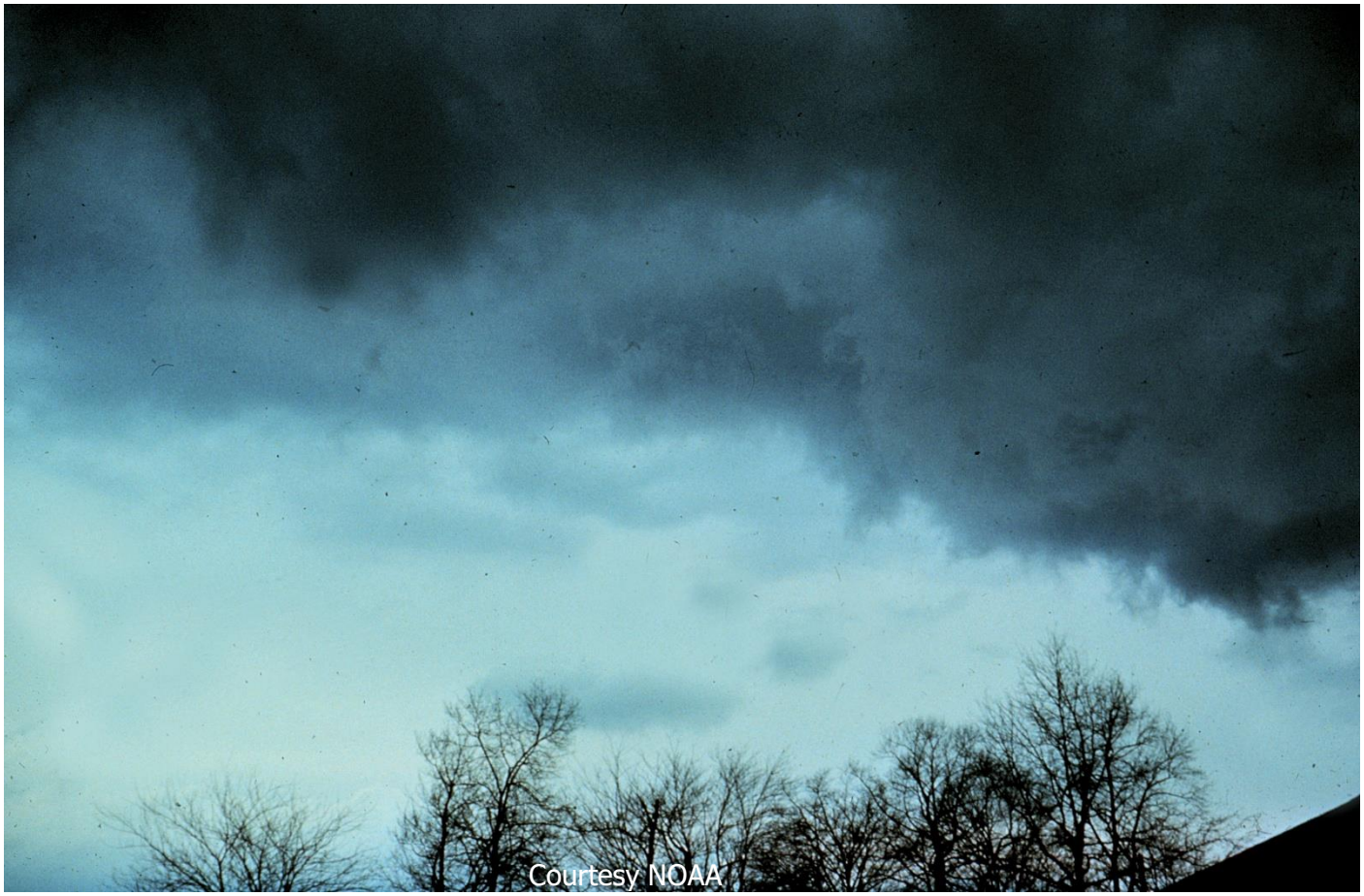
•Altocumulus are **fluffy and lumpy** appearing as a layer of flattened globules. **composed of water droplets** **not** associated with precipitation.

Stratocumulus

often foretell rain preceding a front.

Nimbostratus Clouds

- stable conditions **main producer of precipitation**.
- precipitation: **light to moderate, widespread and long-lasting**.



Stratus

•**stable** conditions and are a **main producer of precipitation**: **light to moderate, widespread and long-lasting**.

Cumulus Clouds “friendly clouds”

“fair weather clouds” that are convectively generated and can reach heights of 16,000 feet.

typically appear in the morning, grow during the day and dissolve at night.

Cumulonimbus Clouds “unfriendly”

billowy mountainous looking heaps can extend to the upper edges of troposphere (**50,000 feet) or more: dramatic examples of atmospheric instability**, associated with thunderstorms , can have ANVIL shape

Precipitation

- Most clouds do not produce precipitation.
  - The water droplets and ice crystals fall so slowly they evaporate.
  - Only “large” water droplets and ice crystals fall fast enough to reach the ground.
- The formation of “large” drops and ice crystals is complicated.
  - The Bergeron Process- 40 sec.video shows process

Water Vapor moves with Air

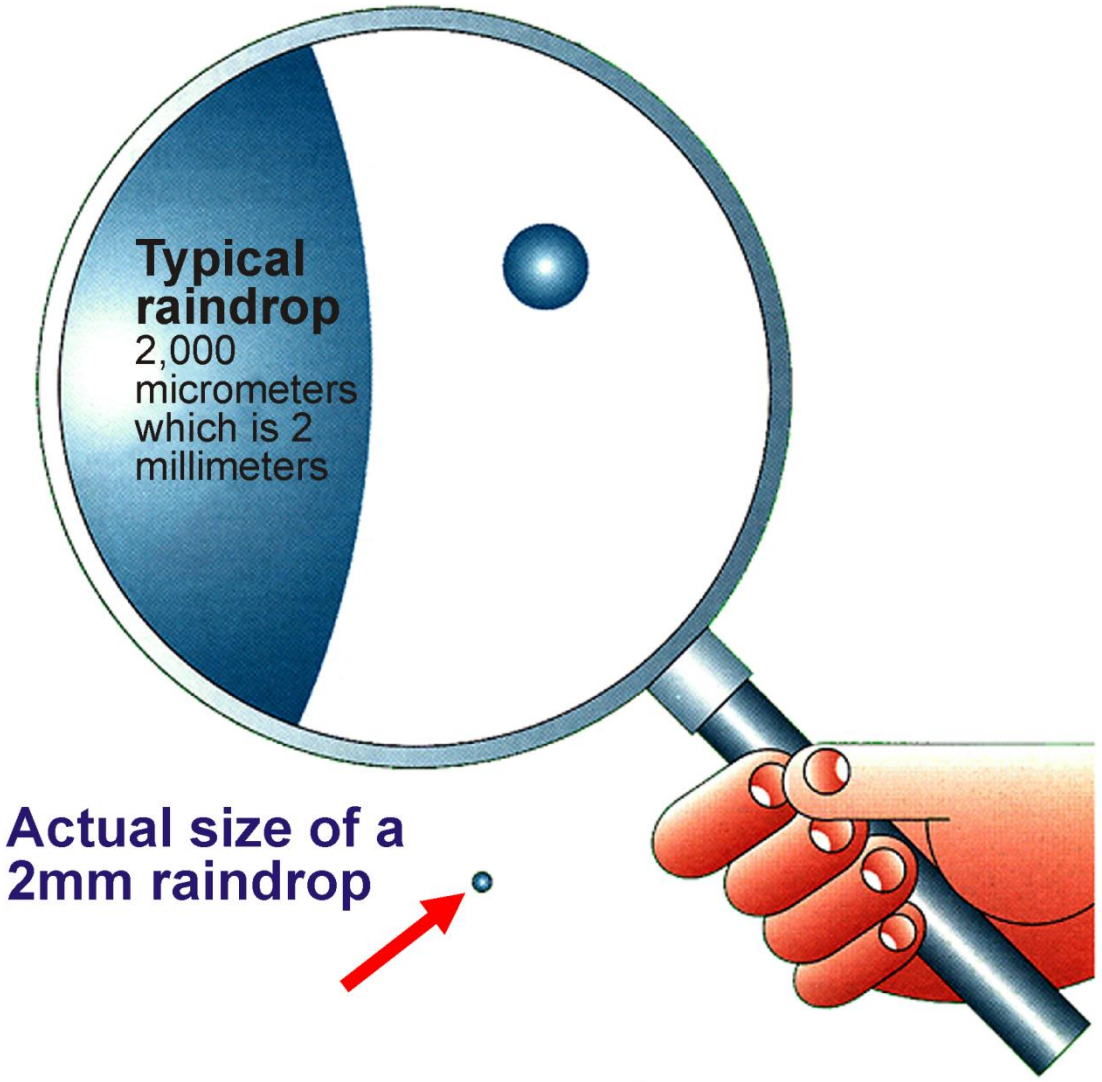
- Water vapor forms above moist areas
- Warm air near the ground absorbs water vapor
- Water vapor in rising air cools
  - Condenses (dew point) - forms clouds
  - Winds move the clouds
  - At some point rain falls from the clouds
- Water on the ground can now vaporize and repeat the cycle

Forms of Precipitation and Deposits

- **Liquids**
  - **Rain, Drizzle and Mist**
  - **Freezing Rain**
- **Solids**
  - **Sleet (Ice Pellets)**
  - **Hail**
  - **Snow**
- **Deposits**
  - **Rime- we see it in our freezers that need defrosting**
  - **Glaze**

Cloud Drop & Rain Drop

A million cloud drops are needed to make one raindrop.



Liquid Precipitation varying severity

Drizzle

Diameter < .02 inch, falling close together.

Rain

Diameter > .02 inch, or smaller drops widely separated.

Light Drizzle
visibility more than 5/8 mile

Moderate Drizzle
visibility from 5/16 to 5/8 mile

Heavy Drizzle
visibility less than 5/16 mile

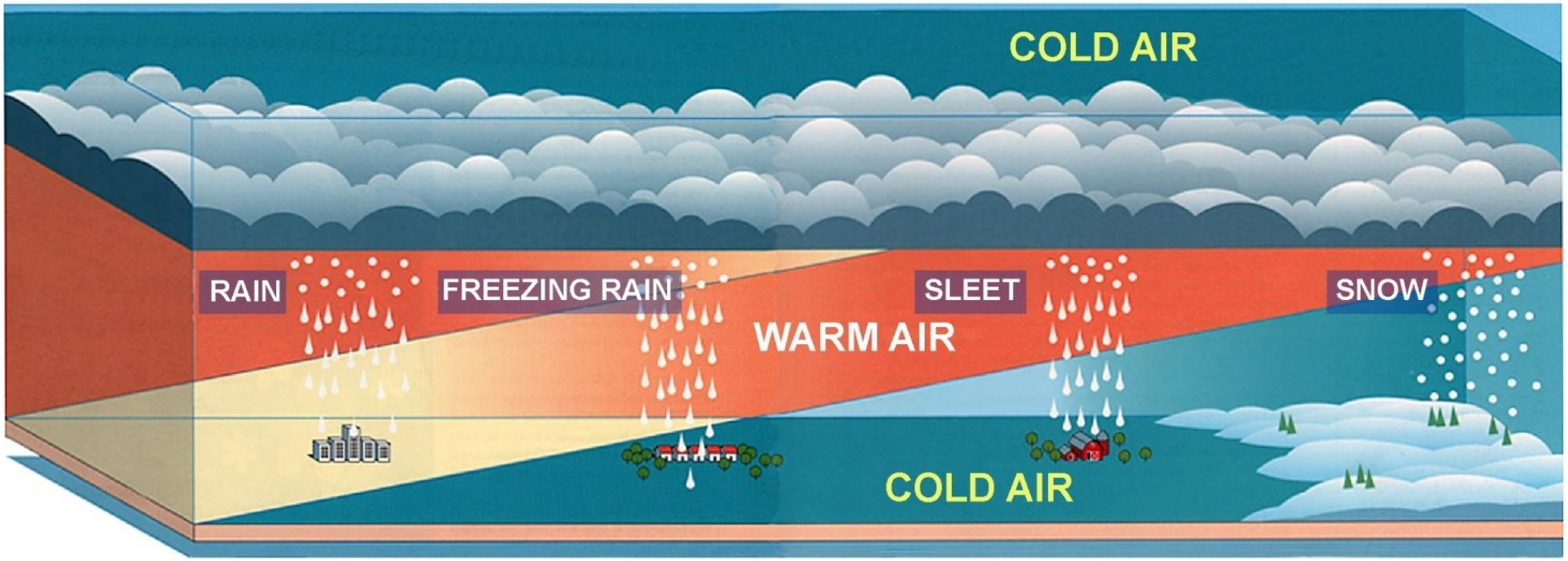
Light Rain
0.1 inch or less in an hour; individual drops easily seen

Moderate Rain
0.11 to 0.30 inches per hour; drops not clearly seen

Heavy Rain
more than 0.30 inches per hour; seems to fall in sheets, reducing visibility

Air Layers and Precipitation

showing the various forms of precipitation
the types of precipitation depends on the ambient temperature through which it falls



Snow begins falling from clouds...

...falls into warm air, melts into rain

Snow melts

...cools below freezing in cold air

...becomes ice when it hits something

Snow melts

...refreezes into sleet during long journey in cold air

Snow falling into cold air never melts

WHAT IS A WEATHER FRONT?

- **A WEATHER FRONT--transitional zone between two air masses.**
- **Recall: an Air Mass is a large body of air that has similar characteristics of temperature and humidity and remain constant.**

Temp---Humidity	US Examples
cP Continental Polar cold - dry	Northern Canada
mP Maritime Polar cool - moist	Coast of Alaska
mT Maritime Tropical warm - wet	Coast of California
cT Continental Tropical hot - dry	US Desert SW
A Arctic very cold-dry	Above Artic Circle
E Equatorial warm – moist	Equatorial Regions

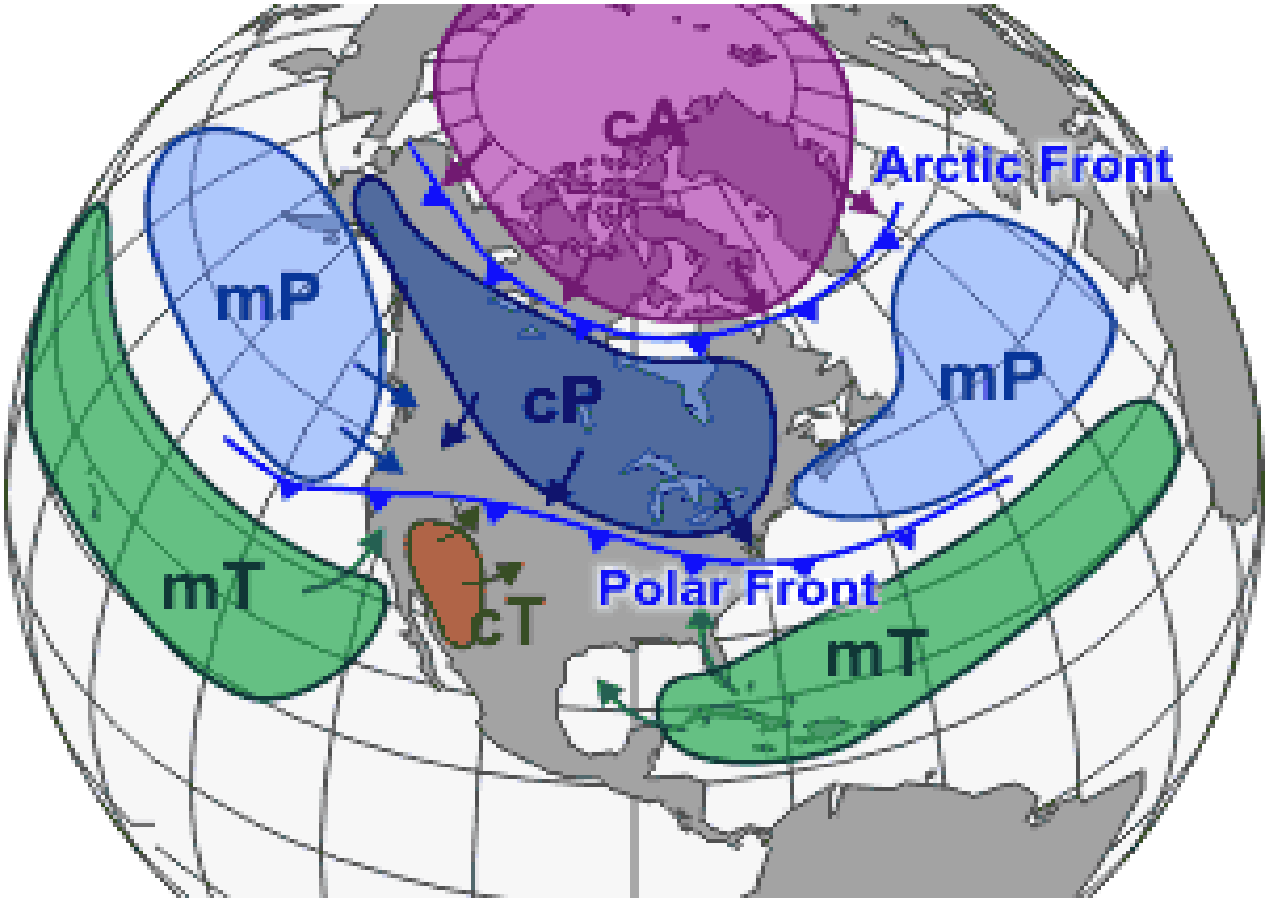
Air Masses-large body of air with permanent uniform horizontal temp and humidity

Humidity		Temp---
cP	Continental Polar	cold - dry
mP	Maritime Polar	cool - moist
mT	Maritime Tropical	warm - wet
cT	Continental Tropical	hot - dry
A	Arctic	very cold
E	Equatorial	warm - moist

Major Air Masses over North America

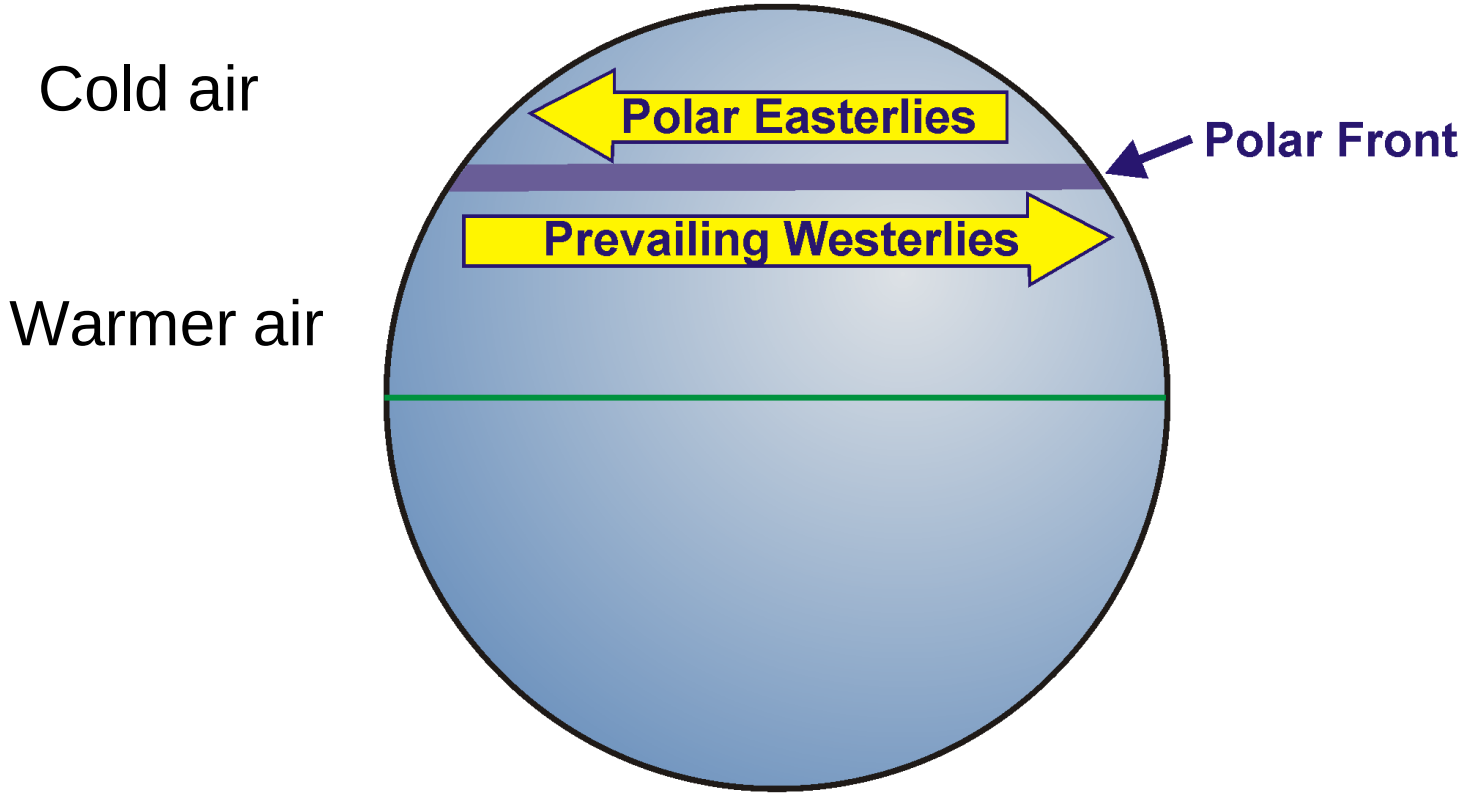
Weather

A or cA – forming over the Arctic
cP – forming over Canada
mP- forming over the North Pacific
mT – forming over the subtropical Pacific and Atlantic Oceans
cT – forming over the SW USA



Polar Front Theory

explains how mid-latitude storms develop along the Polar Front.



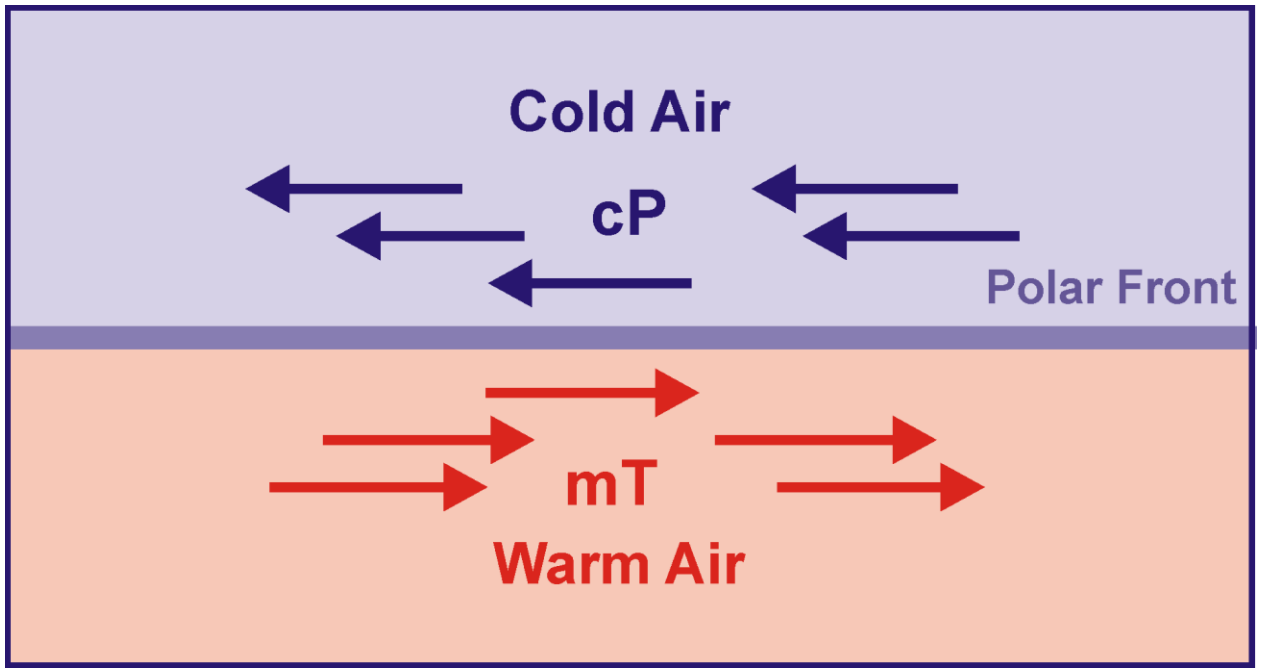
- After World War I Norwegian meteorologists developed the Polar Front Theory:
  - the theory is **based on surface weather data**; and
  - **explains how mid-latitude storms develop along the Polar Front**.
- The **Polar Front separates colder air masses to the north and warmer air masses to its south**:
  - The **Polar Easterlies are in the cold air mass**; and
  - The **Prevailing Westerlies are in the warmer air mass.**

Cyclogenesis-1 Polar Front

the **process of forming a cyclone (a system of air spiraling inward at the surface)**. **mid-latitude storm** cyclogenesis typically begins at the Polar Front.

Cold Canadian air

Moist air off CA coast



Polar Easterlies

Prevailing Westerlies

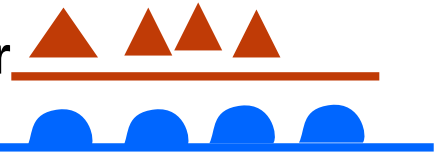
- For the **continental United States the Polar Front most often separates cP and mT air masses.**
  - **continental polar air (cP) - on the north side with Polar Easterlies blowing from east to west**
  - **maritime tropical air (mT) – on the south side with Prevailing Westeries blowing from west to east**
- The Polar Easterlies and the Prevailing Westerlies are **flowing parallel to one another in opposite directions**.

Weather forms along fronts

Front-the transition zone between air masses

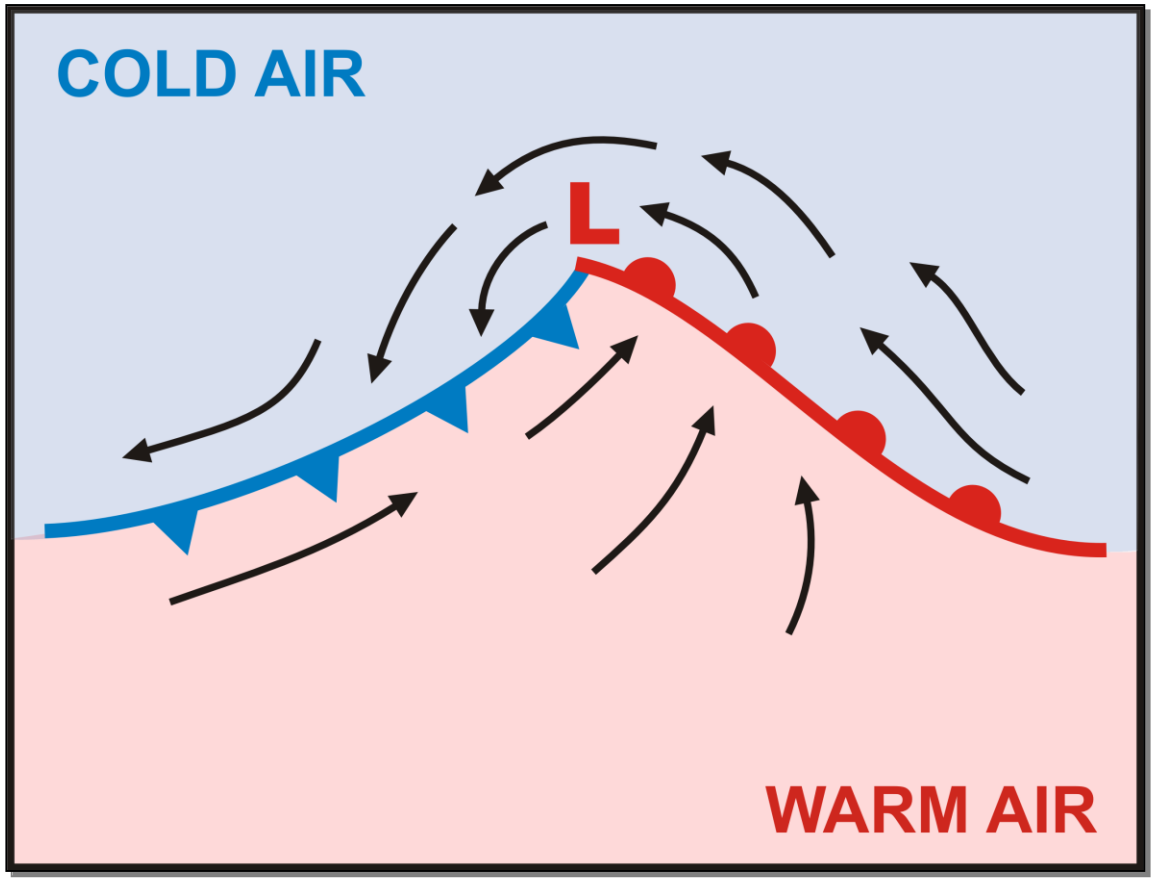
Along the boundary between cold and warm air masses

- **Low pressure areas can form**
- **The boundary is distorted into fronts**
  - **Warm front – advancing warm air**
  - **Cold front – advancing cold air**
  - **Fronts move and bring weather with them**



Formation of Fronts

Cyclogenesis is the name for the process of forming a cyclone (a system of air spiraling inward at the surface).
Recall in a low pressure system air spirals inward in a counterclockwise manner

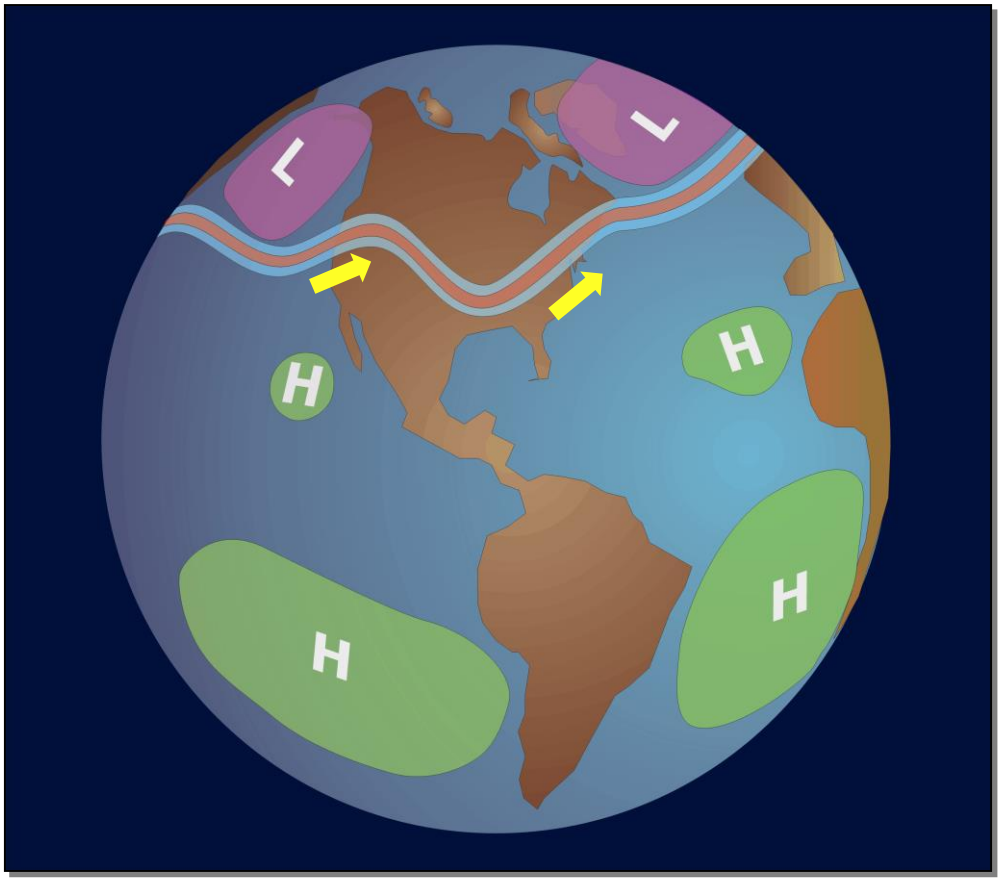


Weather Systems

- **Global patterns dictate a general direction**
  - **How weather systems move is predictable**
  - **e.g. in Mid-Latitudes of N. America, the Prevailing Westerlies have a major impact on weather systems.**
- **But weather forecasting is all about**
  - **WHEN the weather will get to you**
  - **and its specific path-South or North of you???**
- **METEOROLOGISTS CAN PREDICT WITH A HIGH DEGREE OF ACCURACY THAT CERTAIN WEATHER CONDITIONS ARE APPROACHING. THEY CANNOT, WITH THE SAME ACCURACY, TELL YOU THE EXACT TIME OR PATH THE CONDITION WILL TAKE.**

Global Systems
the Jet Stream "steers" weather systems

Jet Stream dictated by yellow arrows



JET STREAM

MAJOR EFFECT ON OUR WEATHER SYSTEMS BY STEERING THE LOW AND HIGH PRESSURES FARTHER NORTH OR FARTHER SOUTH.

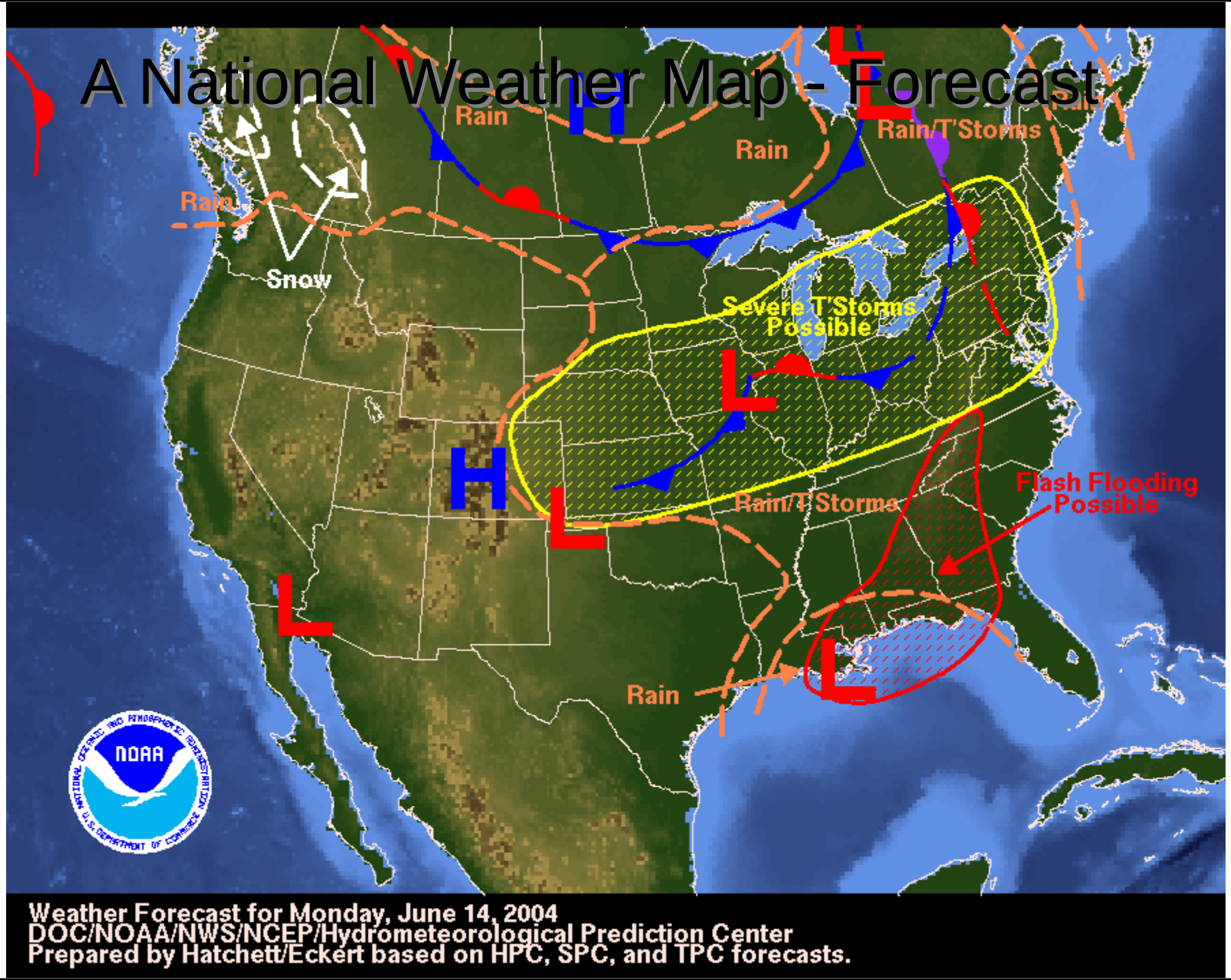
Advancing Weather Systems

- **Highs and Lows tell about weather occurring elsewhere**
- **Systems move in predictable patterns**
- **Weather maps**
  - **can show forecasts-the future**
  - **current conditions**
- **Isobar (lines of equal pressure) spacing**
  - **Show wind intensity**
  - **When isobars are closer, winds are stronger**

What is a Weather Map?

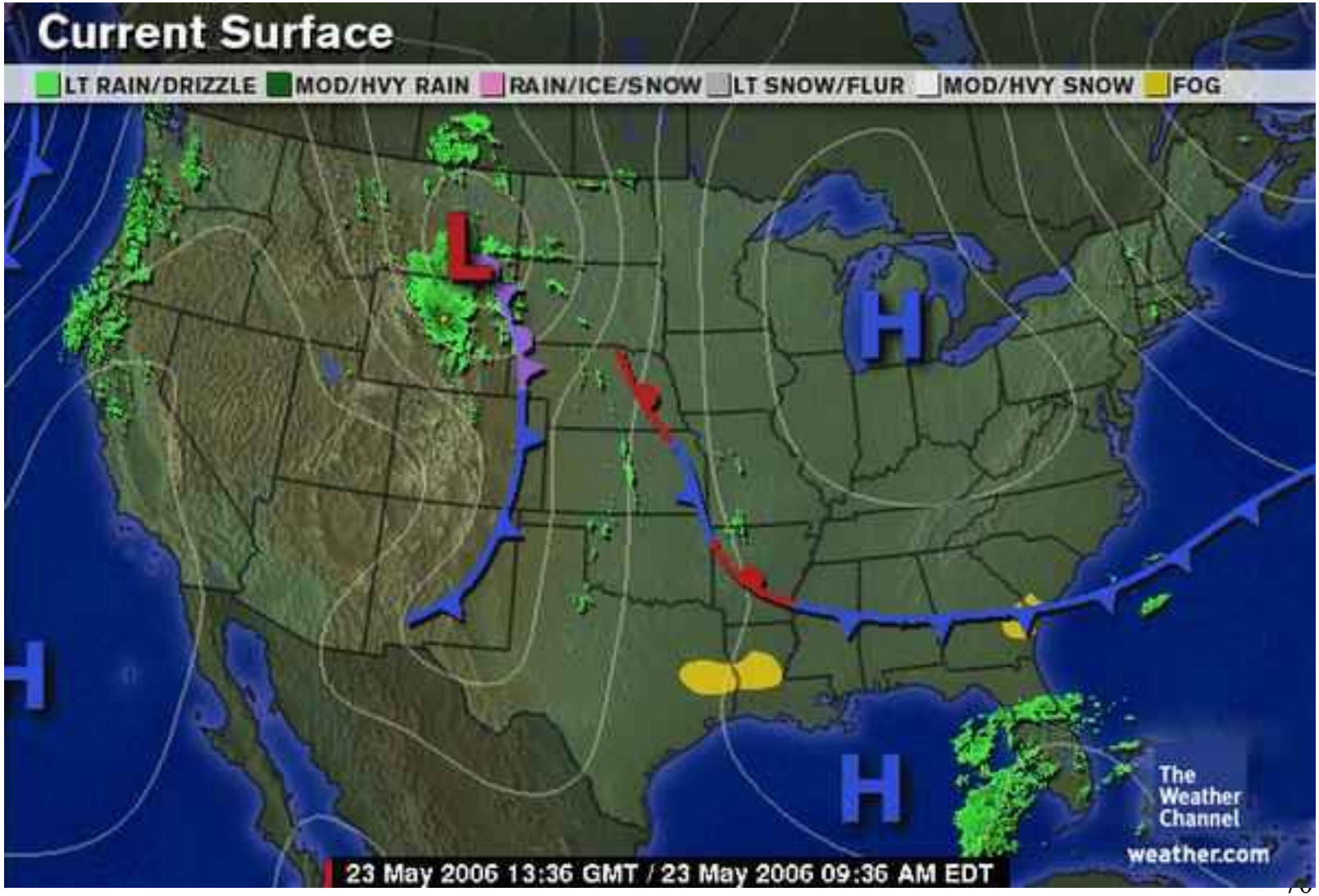
- 1. A map of an area that shows specific weather conditions or information about weather
- 2. Can show current conditions (current map) or what the weather will be like in the future (forecast map)
- 3. Data from multiple sources are used to create the most accurate maps.

A National Weather Map - Forecast

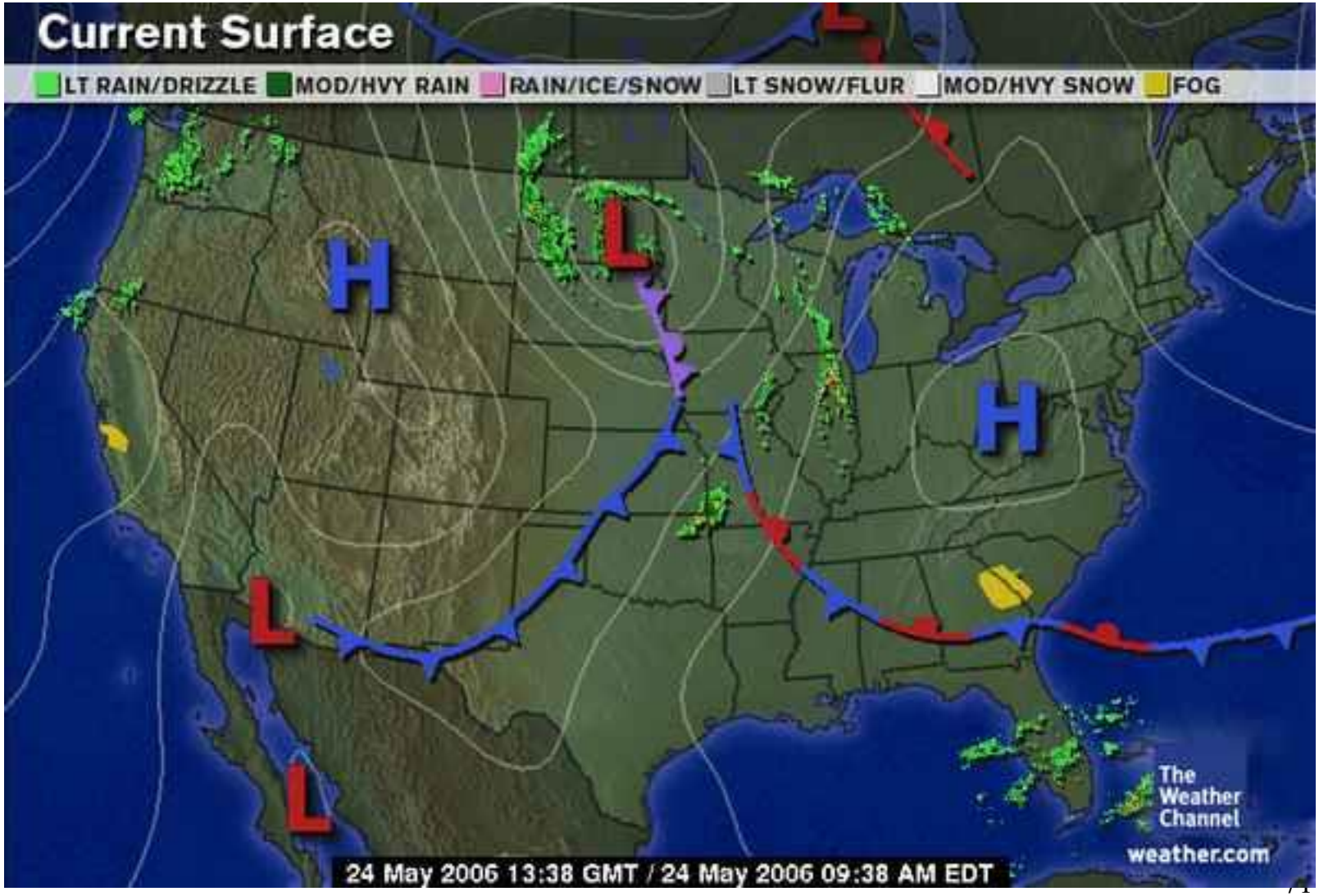


Weather Forecast for Monday, June 14, 2004
DOC/NOAA/NWS/NCEP/Hydrometeorological Prediction Center
Prepared by Hatchett/Eckert based on HPC, SPC, and TPC forecasts.

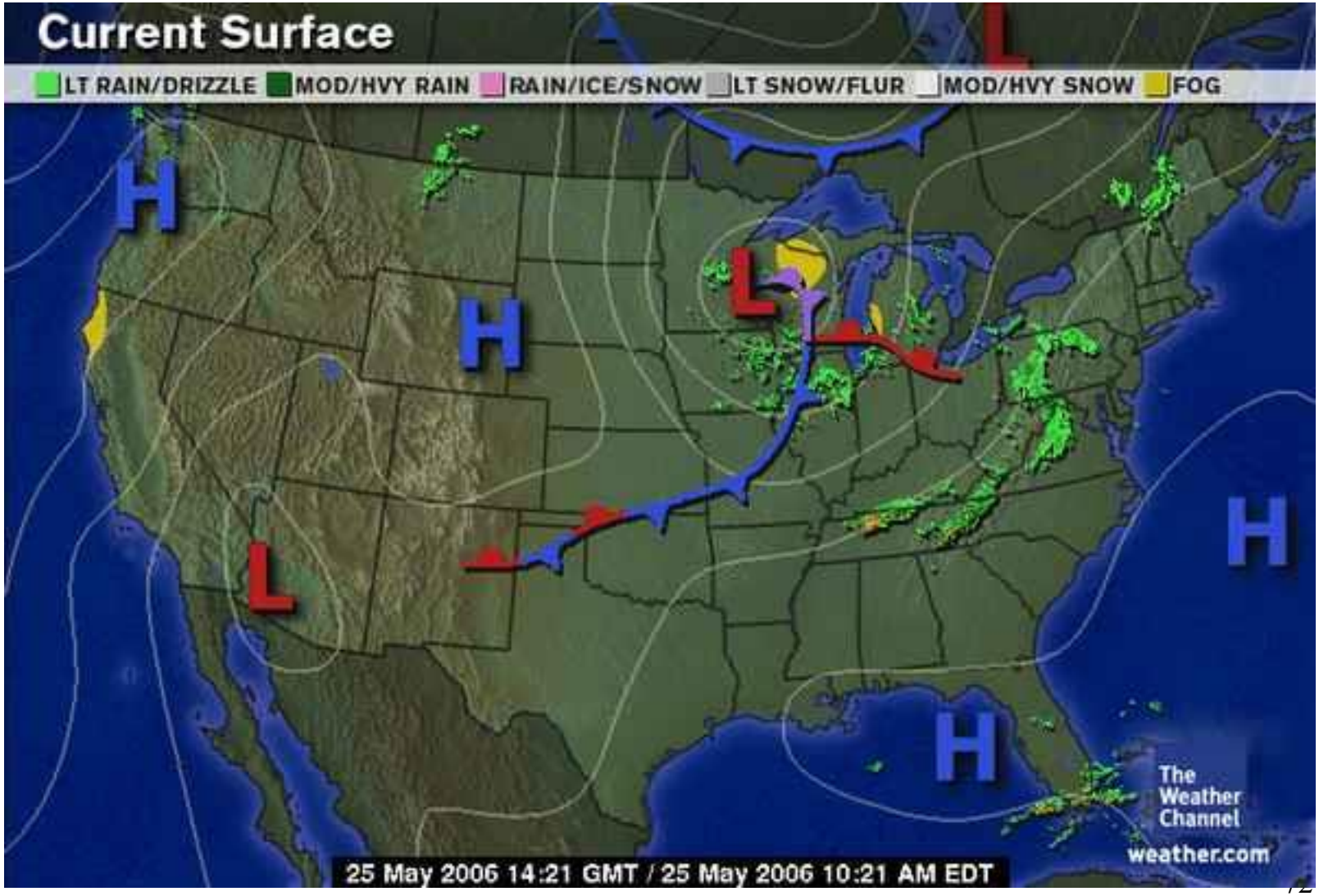
CURRENT SURFACE WEATHER MAP
DAY 1- NOTE: Low over Rockies-MT/WY



WEATHER MAP DAY 2
-Low has moved over Dakotas

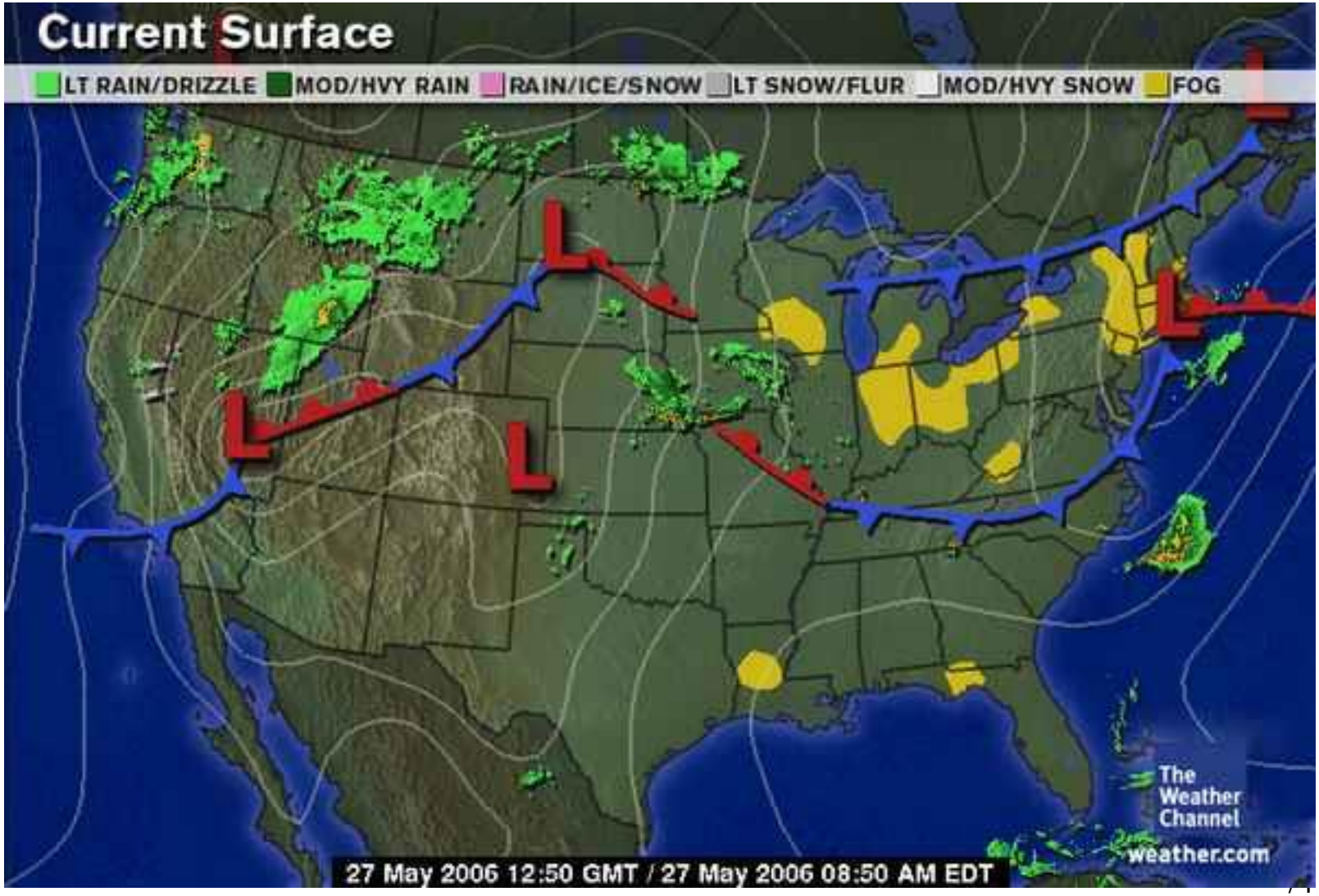


WEATHER MAP DAY 3-
Low has moved over Miss. Valley



WEATHER MAP DAY 4-
Low moved over Michigan NEW Low over MT/WY

WEATHER MAP DAY 5-Low off East Coast

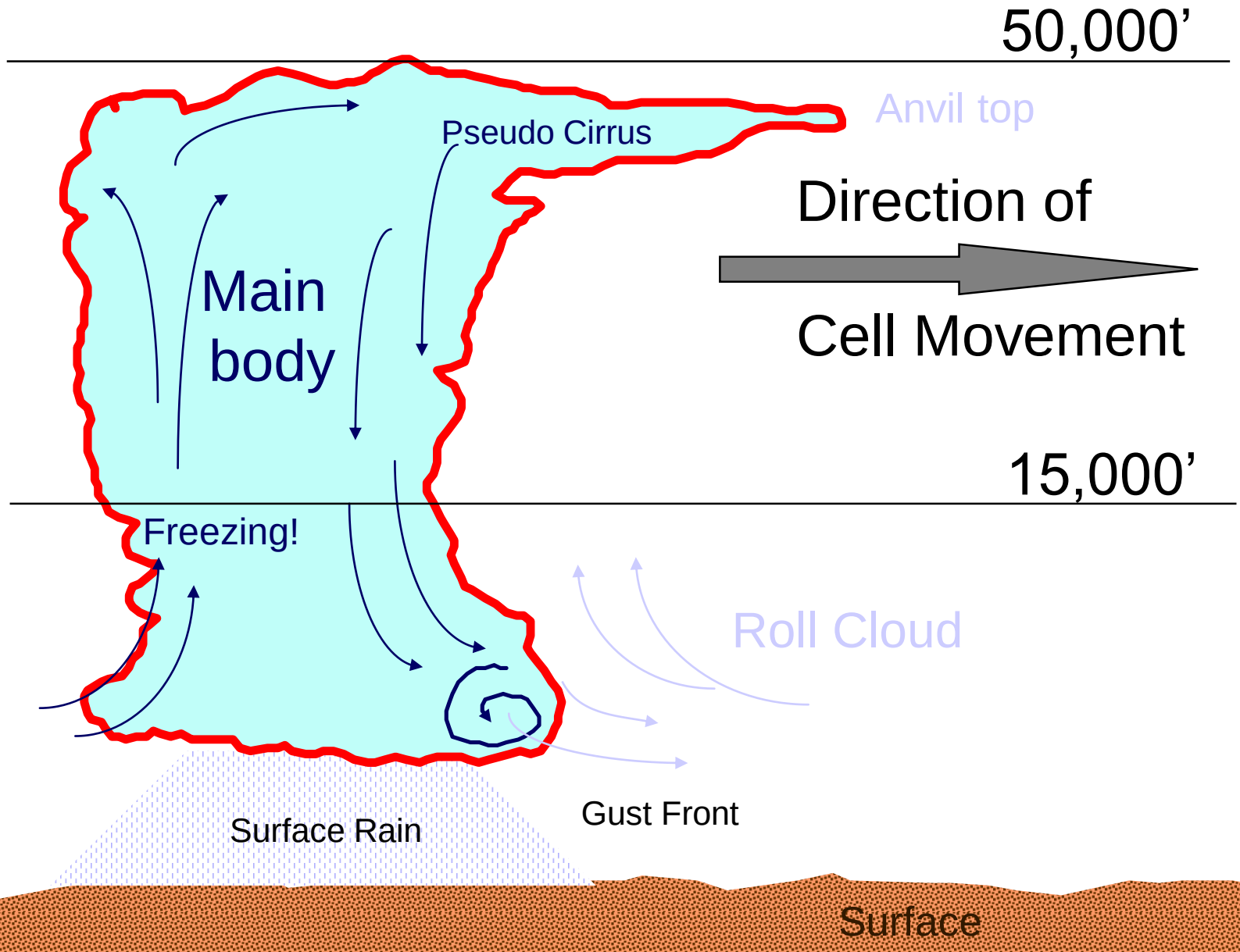


Day 1-5 in Sequence

Weather forms around Lows
Key Questions

- **Pattern of**
  - **Winds: WHICH DIRECTION IS THE WIND FROM?**
  - **Clouds: WHAT TYPES OF CLOUDS ARE WE SEEING AND WHAT IS THE SEQUENCE OF THEM OVER A PERIOD OF HOURS/DAYS?**
  - **Precipitation: Is it raining, snowing, mix?**
  - **Barometric Pressure: IS THE BAROMETER RISING/FALLING? HOW FAST?**
  - **Temperature: Rising or Falling?**
- **The passage of a weather front indicated by:**
  - **Temperature change, wind direction and speed change, change in humidity**

Anatomy of aThunderstorm



Thunderstorms

violent examples of upward air movement generated by temperature imbalances in the atmosphere.

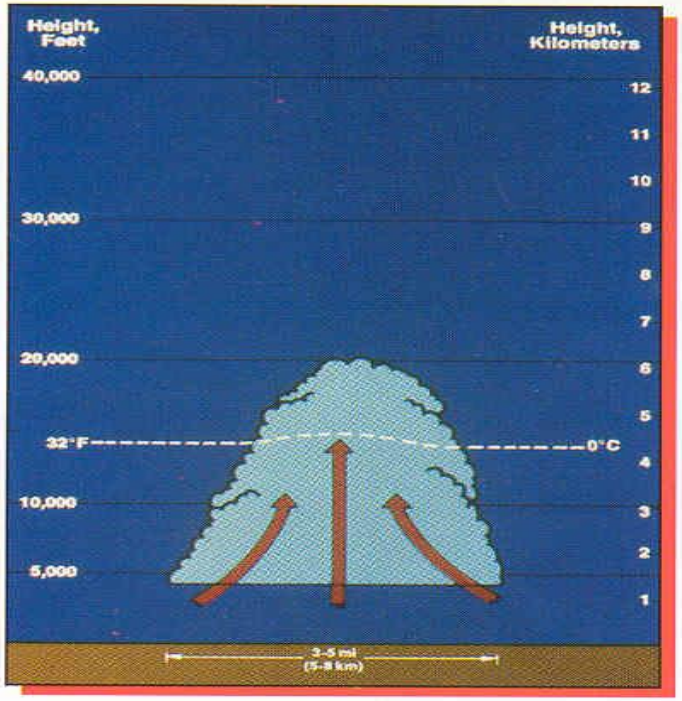
- **Every thunderstorm needs:**
  1. **Moisture-to form clouds and rain**
  2. **Unstable air-warm air than can rise rapidly**
  3. **Lift-cold or warm fronts, sea breezes, mountains or sun's heat capable of lifting air**

- **A Thunderstorm is a storm produced by a cumulonimbus cloud, with lightning, thunder, usually with strong wind gusts, heavy rain, and sometimes hail.**

Thunderstorm Stages

- **Development**
  - **-towering cumulus cloud—rising air**
  - **-usually little, if any rain**
  - **-lasts 10 minutes**
  - **-occasional lightning**
- **Maturation**
  - **Most likely hail, heavy rain, lightning, strong winds, tornadoes**
- **Dissipation**
  - **-Rainfall decreases in intensity**
  - **-can still produce a burst of strong winds**
  - **-lightning remains a danger**

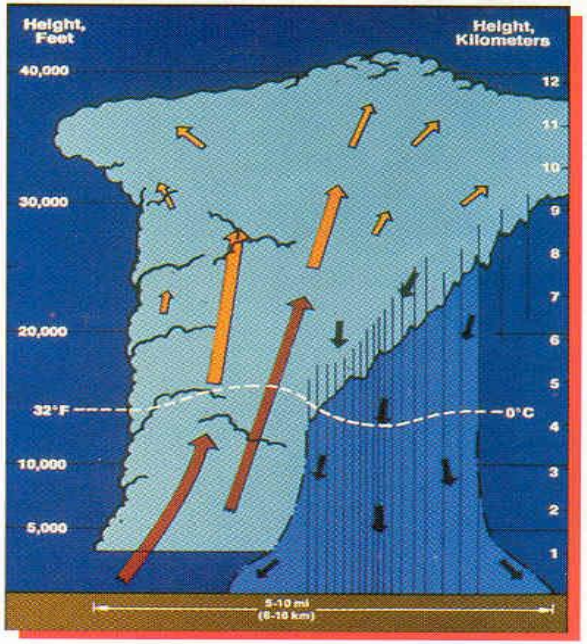
Thunderstorm-development



Developing Stage

- Towering cumulus cloud indicates rising air.
- Usually little if any rain during this stage.
- Lasts about 10 minutes.
- Occasional lightning.

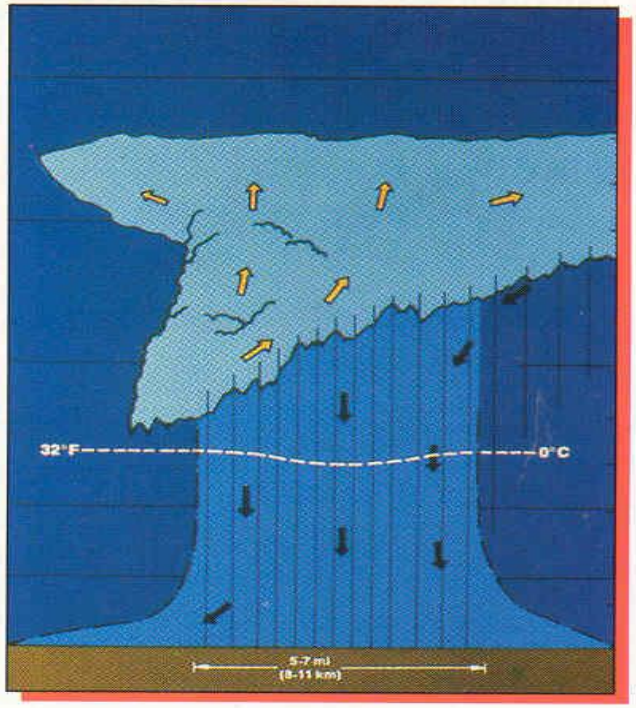
Thunderstorm-maturation



Mature Stage

- Most likely time for hail, heavy rain, frequent lightning, strong winds, and tornadoes.
- Storm occasionally has a black or dark green appearance.
- Lasts an average of 10 to 20 minutes but may last much longer in some storms.

Thunderstorm-dissipation



NOA

Dissipating Stage

- Rainfall decreases in intensity.
- Can still produce a burst of strong winds.
- Lightning remains a danger.

Animation of a Typical Thunderstorm

- https://www.youtube.com/watch?v=bOfOA3PTghM&feature=youtu.be
- **2:20 mins.**

Chapter 4
Summary

- **The weather characteristics of atmospheric stability and instability.**
- **The orographic, frontal wedging, surface convergence, and localized convective lifting processes.**
- **The difference between environmental and adiabatic lapse rates.**
- **The 10 principal cloud types.**
- **The different types of precipitation and how they are produced.**
- **How weather fronts form**
- **How weather systems move in United States**
- **How thunderstorms form and dissipate**

END OF CHAPTER FOUR

THANK- YOU

HOPE TO SEE YOU NEXT FALL!