

Atmosphere and Weather

AP Environmental Science

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Dr. E

Origin of Modern Atmosphere

- original atmosphere surrounded the homogenous planet Earth and probably was composed of H and He
- second atmosphere evolved from gases from molten Earth
 - H_2O , CO_2 , SO_2 , CO , S_2 , Cl_2 , N_2 , H_2 , NH_3 , and CH_4
 - **allowed formation of oceans and earliest life**
- modern Atmosphere
 - evolved after Cyanobacteria started photosynthesizing
 - oxygen produced did not reach modern levels until about 400 million years ago

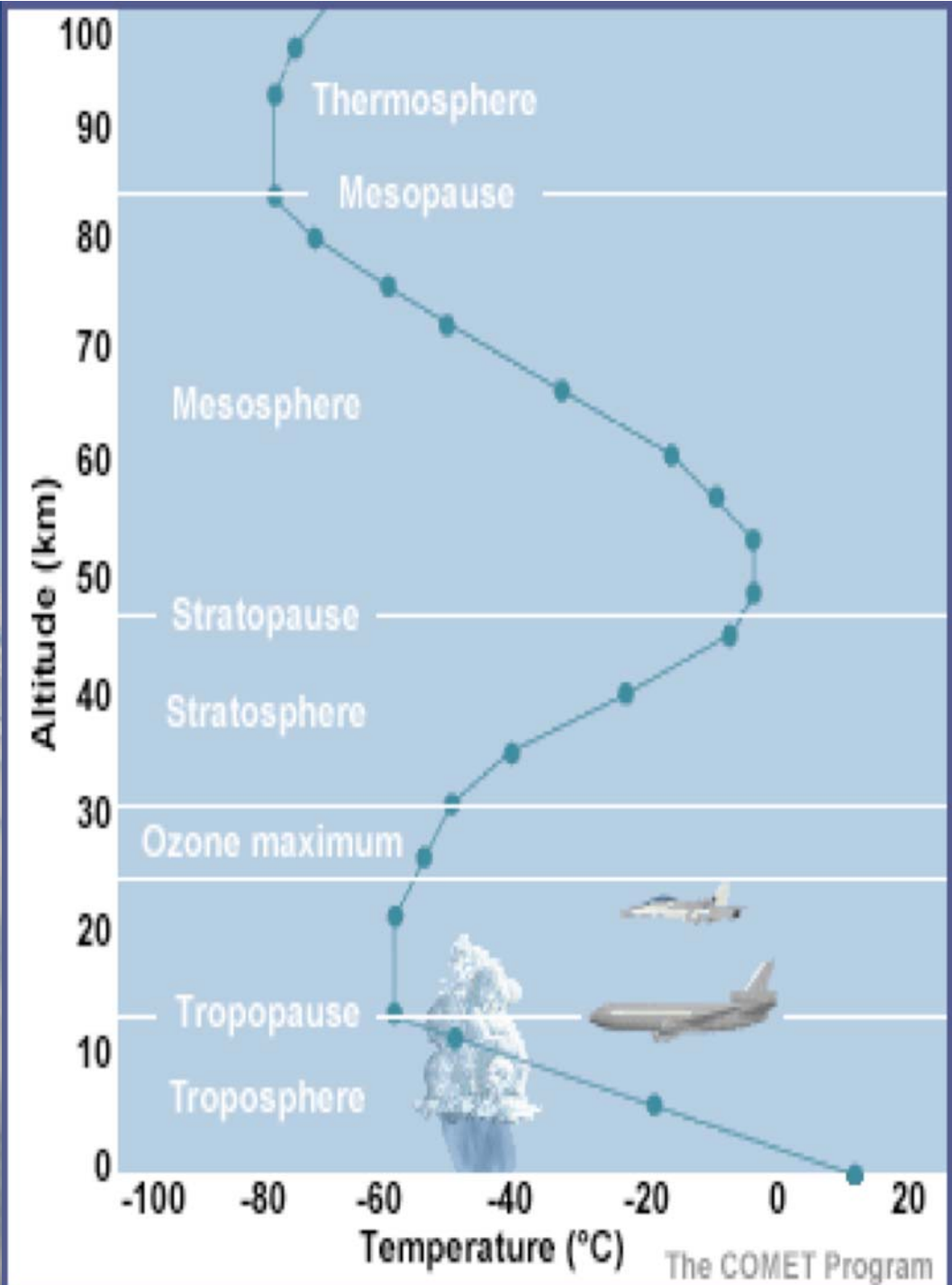
Earth's Atmosphere

A photograph of Earth's atmosphere from space. The image shows a thin, glowing layer of the atmosphere against the blackness of space. The atmosphere appears as a bright blue and orange band, with the orange part closer to the Earth's surface and the blue part higher up. The Earth's surface is visible as a dark, curved horizon at the bottom of the frame.

- compared to the size of the Earth (10^4 km), the atmosphere is a thin shell (120 km).

Atmosphere Layers

- Exosphere
- Thermosphere
- (Ionosphere)
- Mesosphere
- Stratosphere
- Troposphere



Troposphere

- 8 to 14.5 kilometers high (5 to 9 miles)
- most dense
- the temperature drops from about 17 to -52 degrees Celsius
- almost all weather is in this region

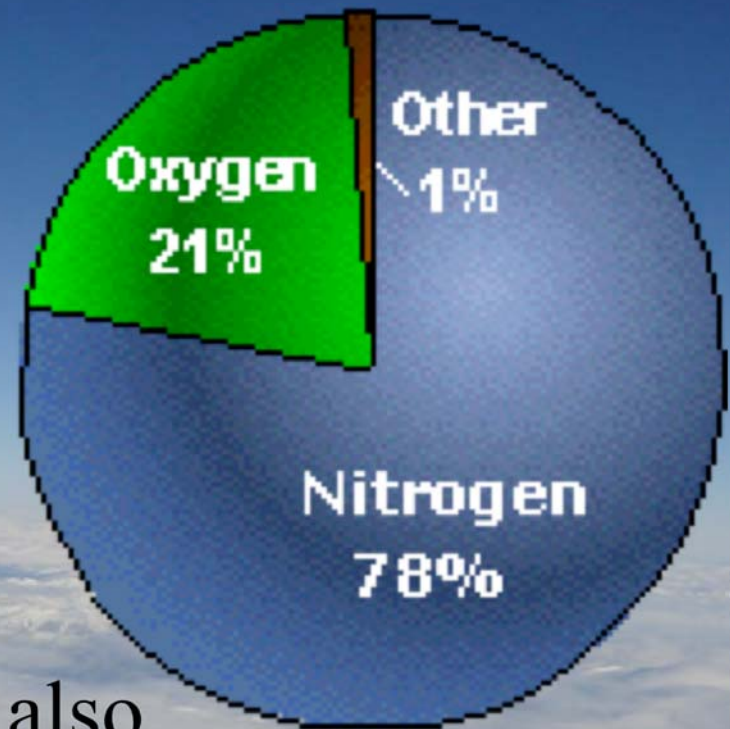


Stratosphere

- extends to 50 kilometers (31 miles) high
- dry and less dense
- temperature in this region increases gradually to -3 degrees Celsius, due to the absorption of ultraviolet radiation
- ozone layer absorbs and scatters the solar ultraviolet radiation
- ninety-nine percent of "air" is located in first two layers
- every 1000-m 11% less air pressure

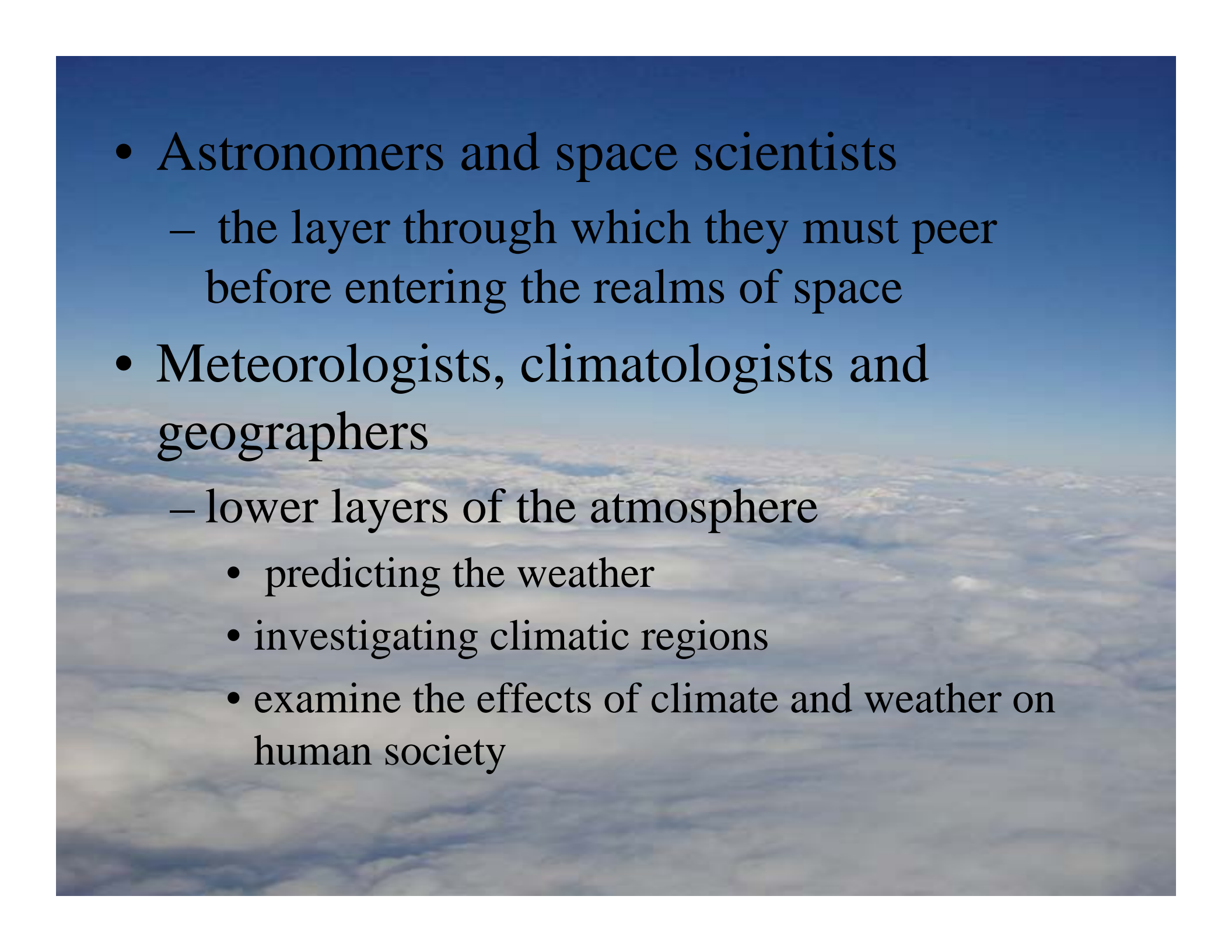
Composition

- Nitrogen (N_2 , 78%)
- Oxygen (O_2 , 21%)
- Argon (Ar, 1%)
- myriad of other very influential components are also present which include the Water (H_2O , 0 - 7%), "greenhouse" gases or Ozone (O_3 , 0 - 0.01%), Carbon Dioxide (CO_2 , 0.01-0.1%),

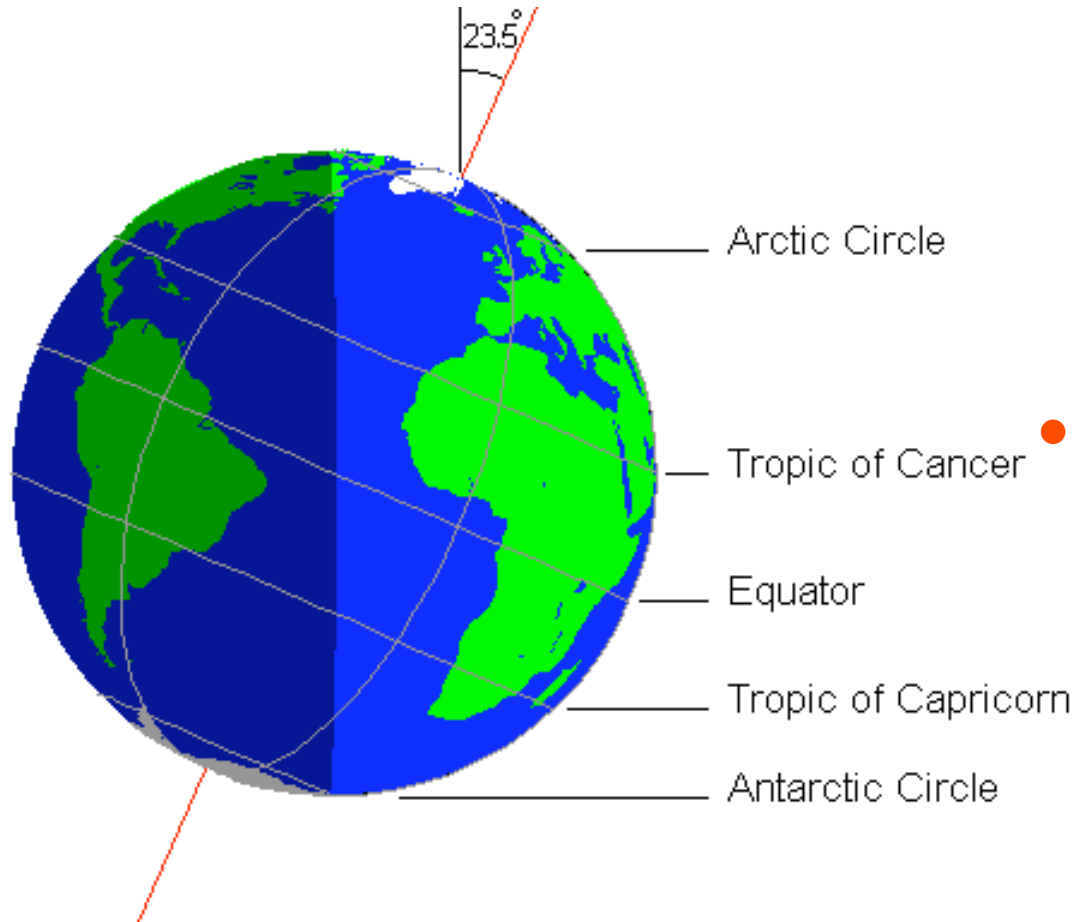


Importance of the Atmosphere

- Physicists
 - physical properties and processes that take place between the radiant energy and atmospheric gases
- Chemists
 - behavior of the chemical materials in the atmosphere
 - the ways in which lightning causes the formation of substances
 - chemistry of the ozone layer and of chemicals introduced from industrial processes

- 
- Astronomers and space scientists
 - the layer through which they must peer before entering the realms of space
 - Meteorologists, climatologists and geographers
 - lower layers of the atmosphere
 - predicting the weather
 - investigating climatic regions
 - examine the effects of climate and weather on human society

Seasonal Changes

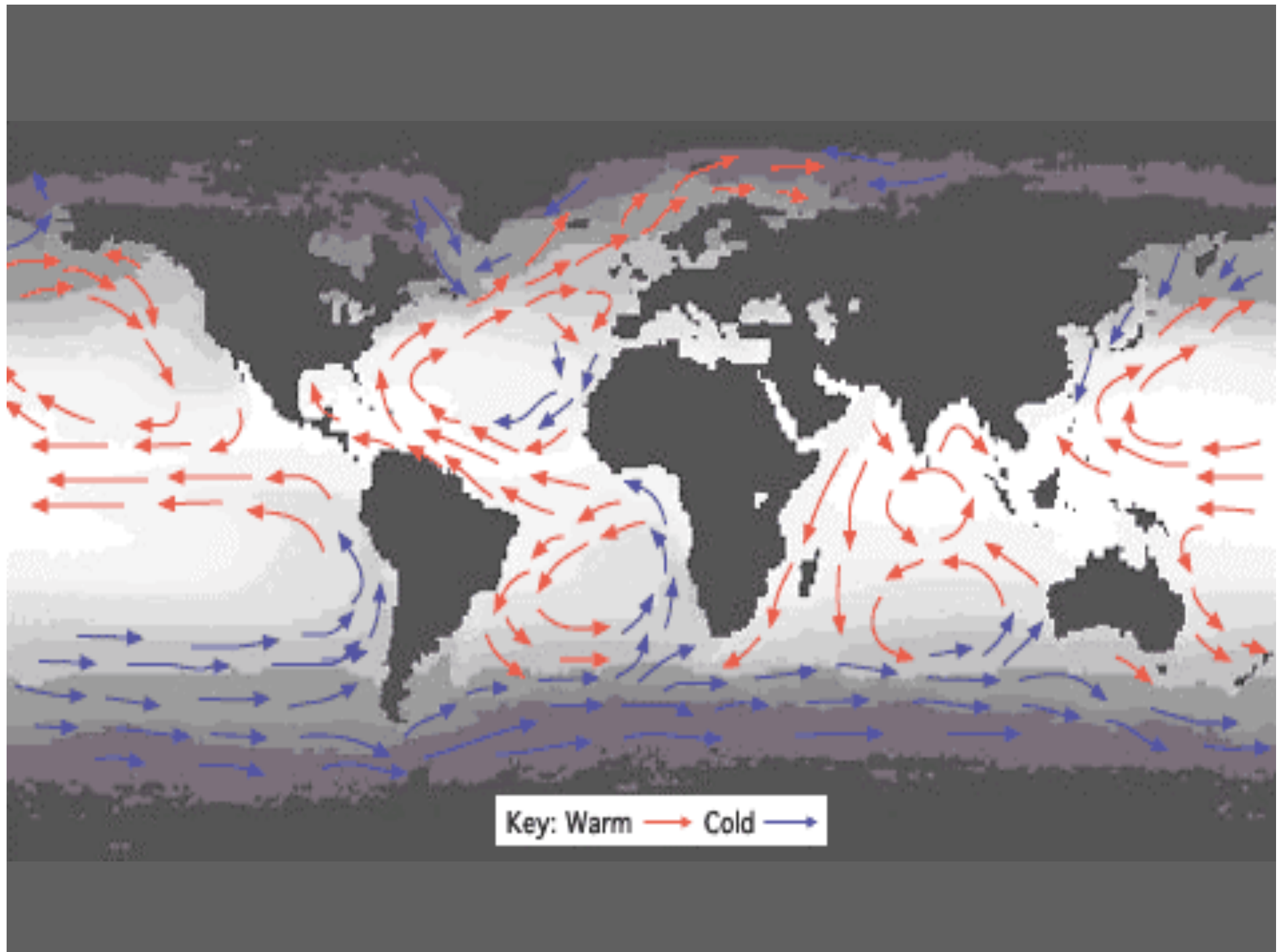


- Occur because the earth's axis is tilted
- Creates opposite seasons in the northern and southern hemisphere
- Factor that determines global air circulation patterns



Ocean Currents

- Sea-surface temperature influences air temperature as the ocean exchanges heat with the overlying atmosphere.
- It also influences evaporation rates which are generally higher where sea-surface temperature is higher



Ocean Currents

- There are two type of Ocean Currents:
- **1. Surface Currents--Surface Circulation**
- These waters make up about 10% of all the water in the ocean.
- These waters are the upper 400 meters of the ocean.

Ocean Currents

- 2. Deep Water Currents
- These waters make up the other 90% of the ocean
- These waters move around the ocean basins by density driven forces and gravity.
- The density difference is a function of different temperatures and salinity
- These deep waters sink into the deep ocean basins at high latitudes where the temperatures are cold enough to cause the density to increase.

Ocean Currents

Ocean Currents are influenced by two types of forces

1. Primary Forces--start the water moving

1. Solar Heating

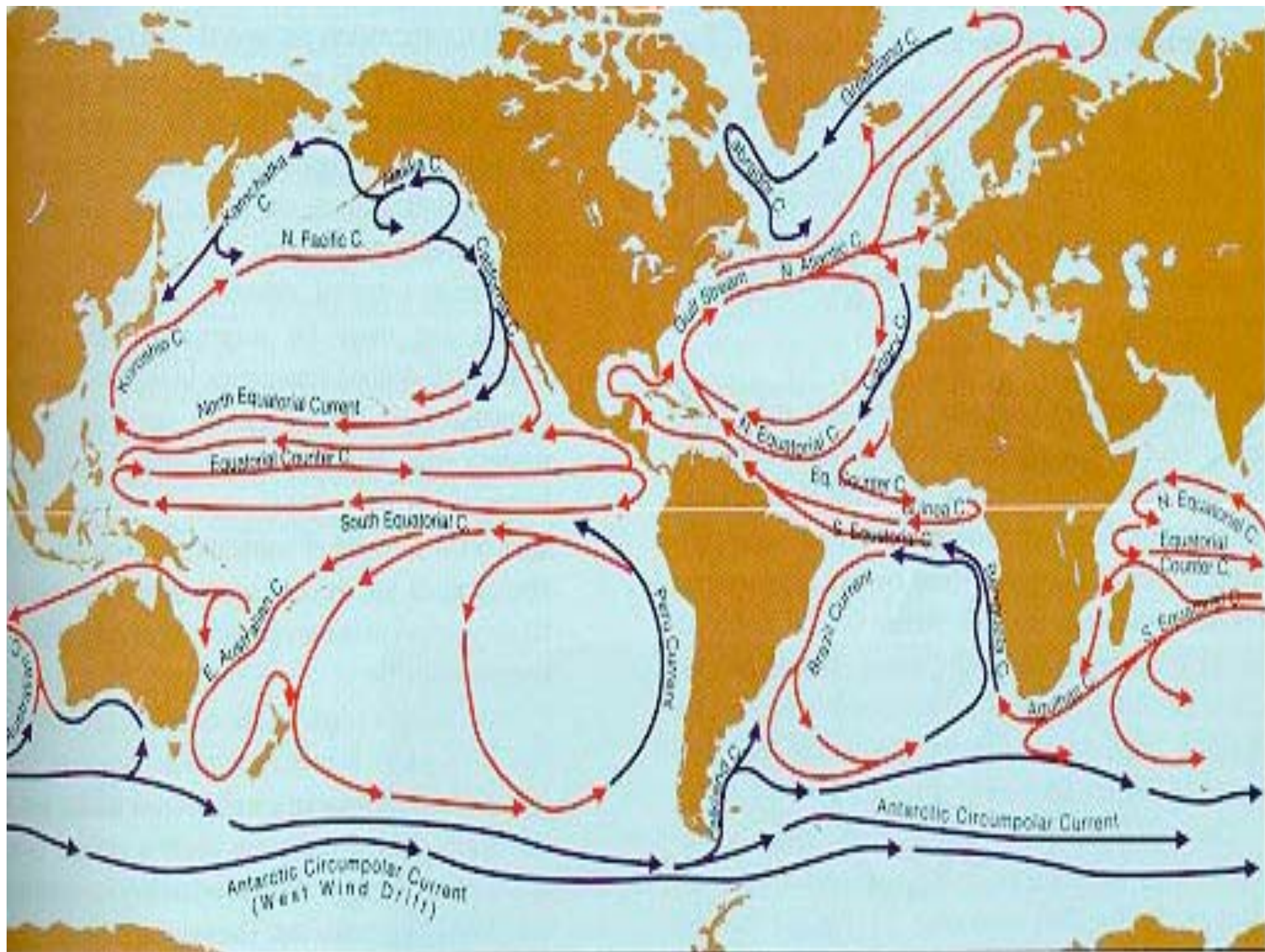
2. Winds

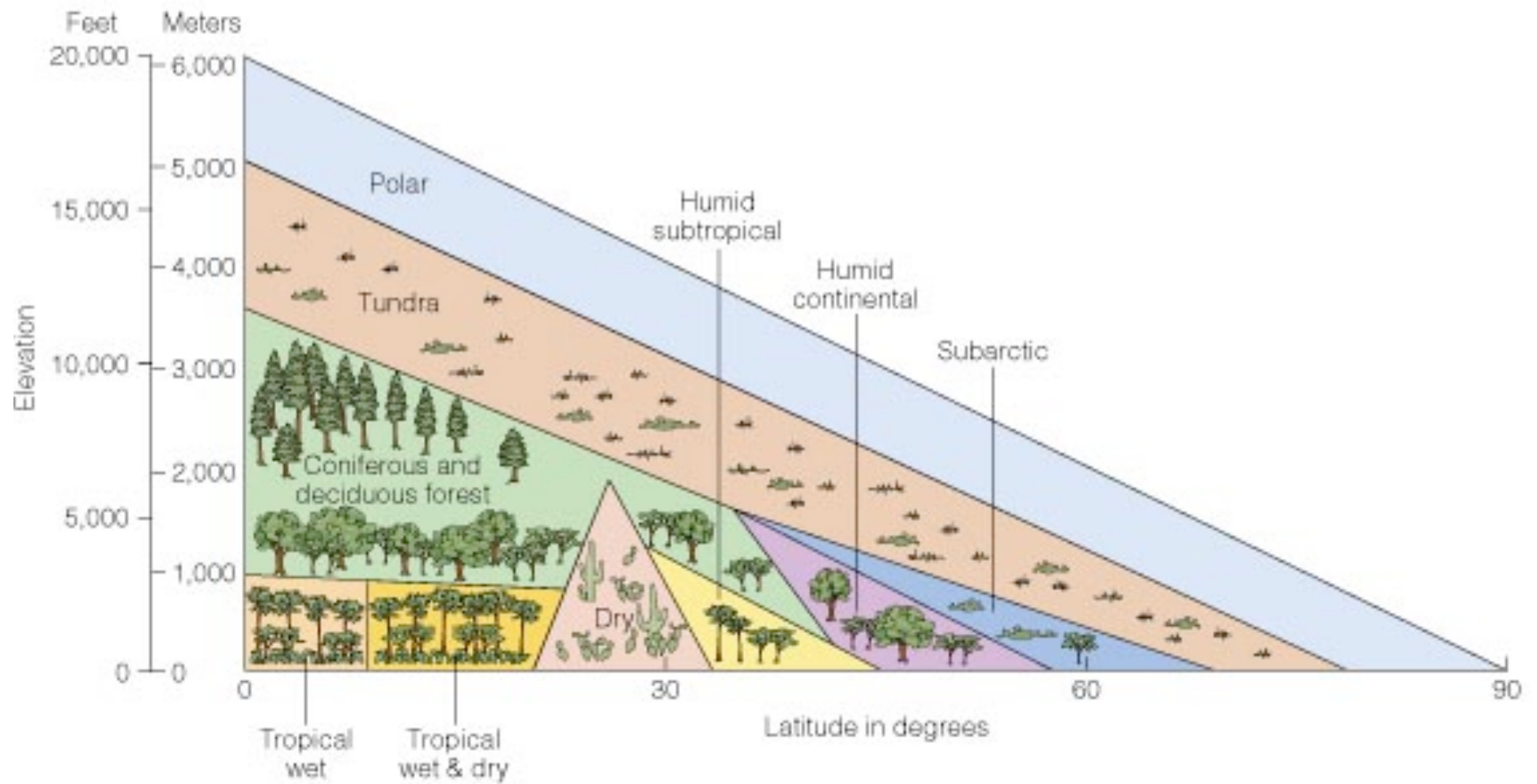
3. Gravity

4. Coriolis

2. Secondary Forces--influence where the currents flow

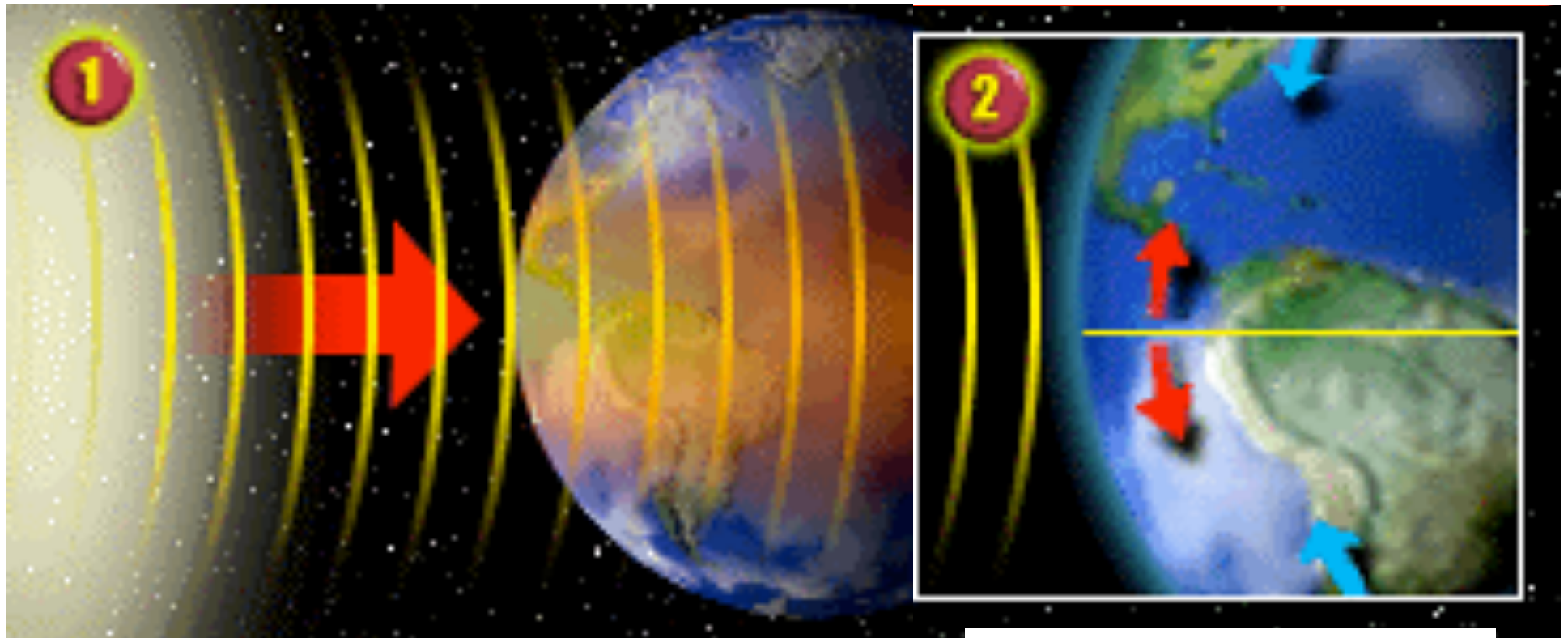






Air Temperature

- As solar energy reaches the Earth, equatorial regions heat up more than the poles.
- Warm air and water at the equator travel poleward while cold air and water at the poles travel equatorward in an attempt to equalize this temperature contrast.
- It is the atmosphere's continual struggle for temperature balance that brings us our changing weather.



1

Energy imbalance

Solar energy heats equator more than the poles.

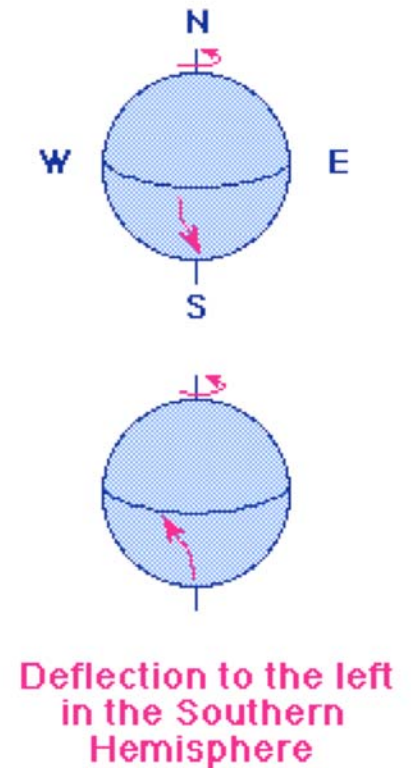
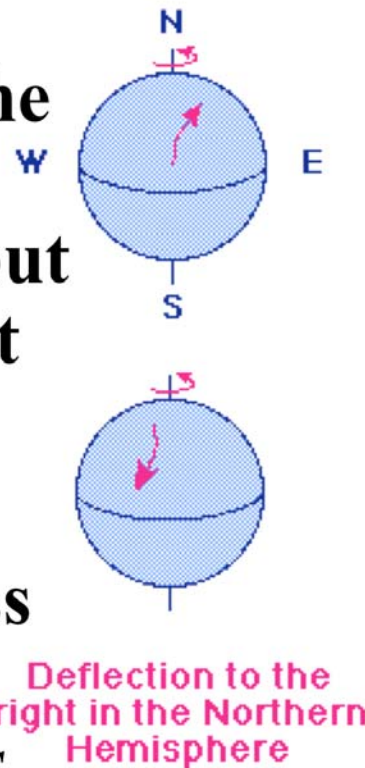
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Balancing act

Warm air, water flows to colder poles while cold air, water flows to warmer equator.

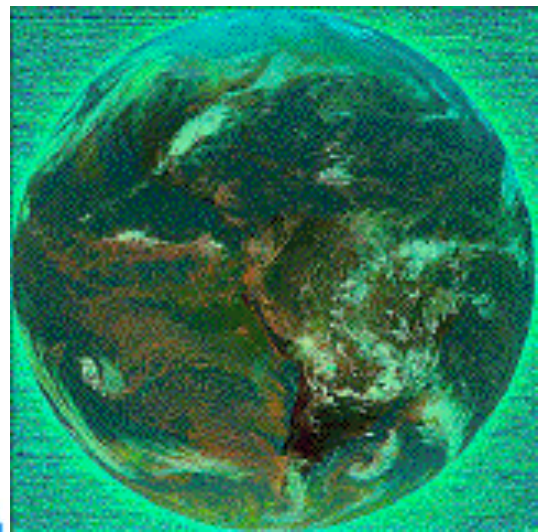
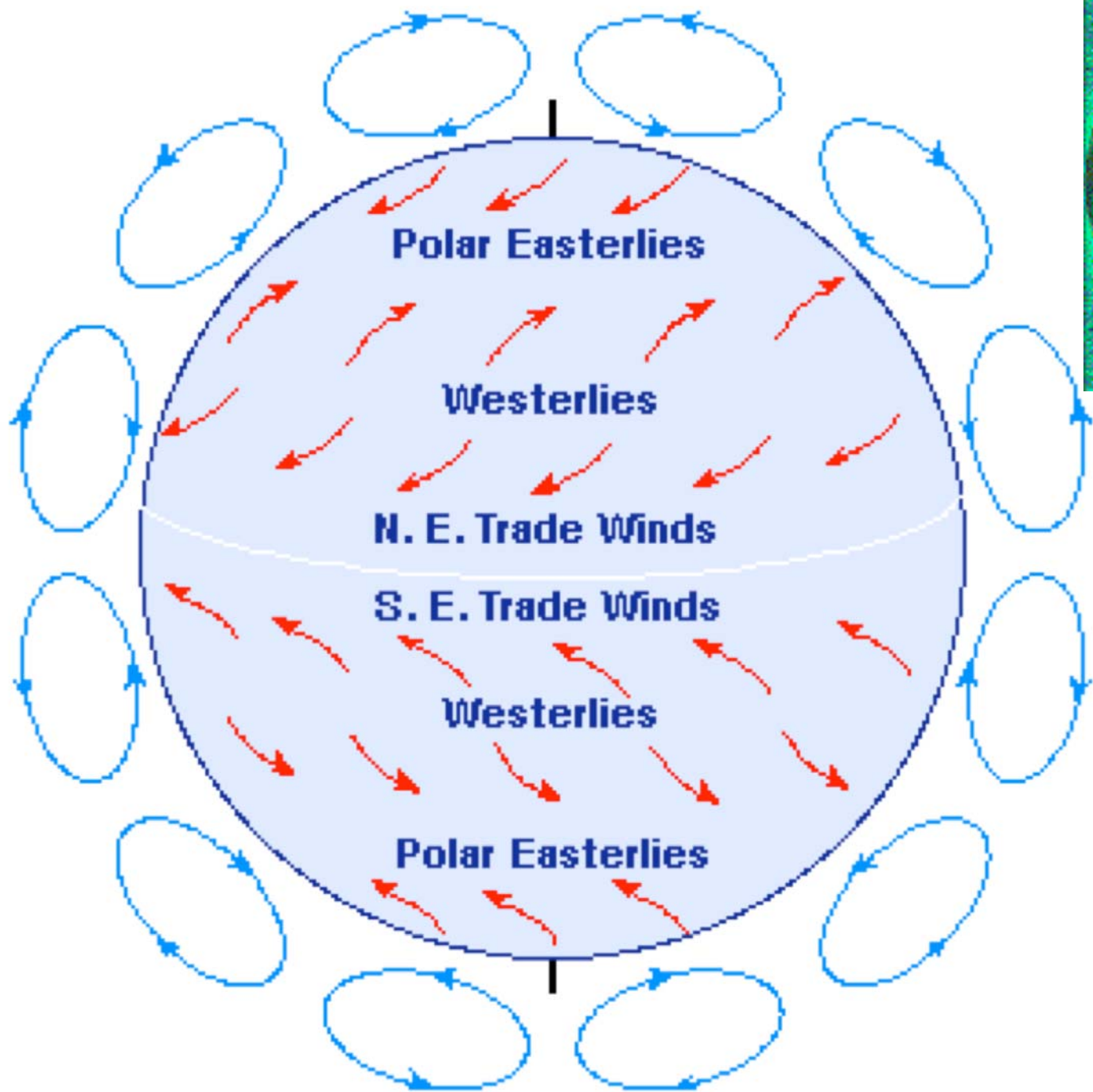
Coriolis Effect

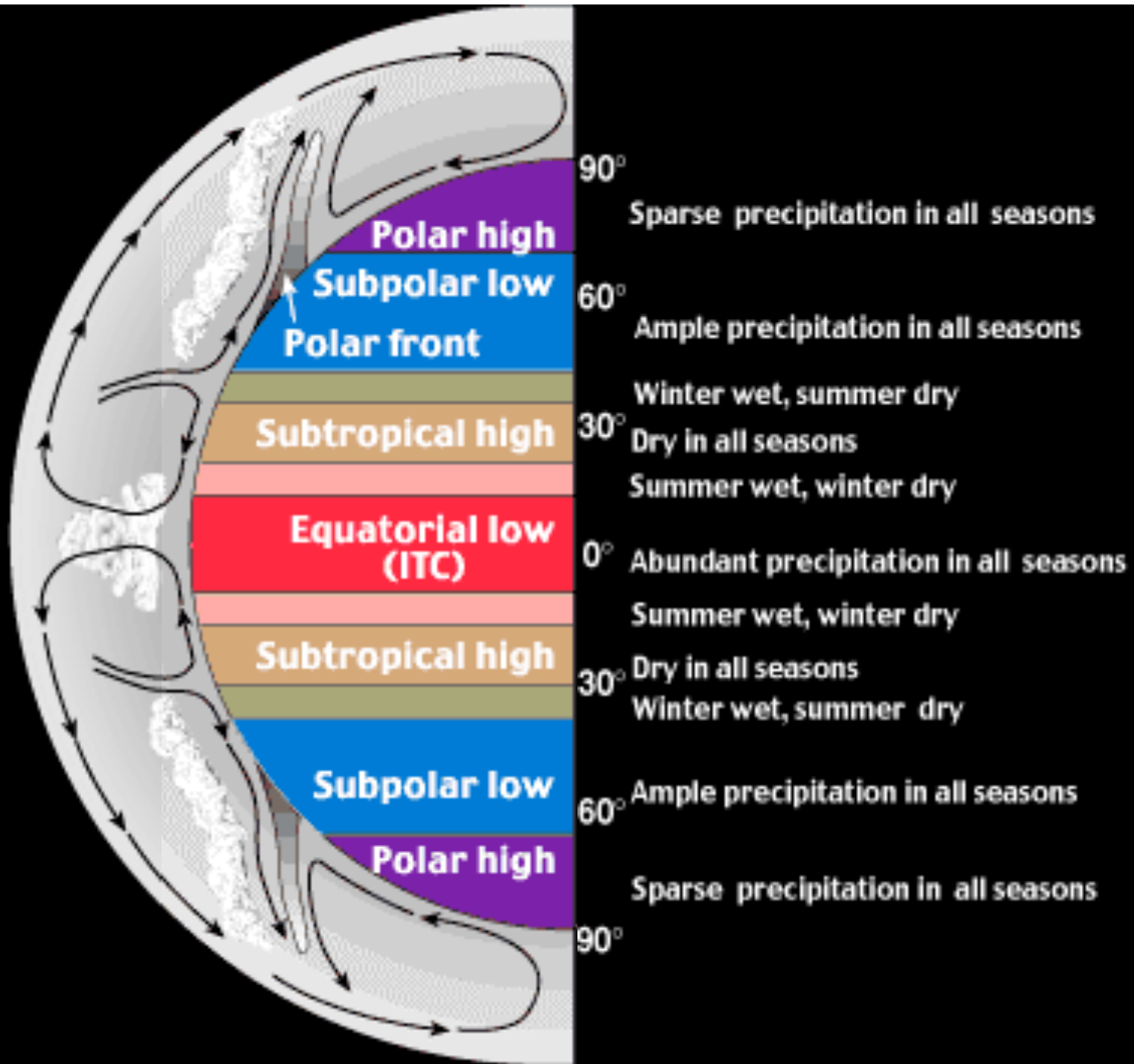
- The Earth is a spinning globe where a point at the equator is traveling at around 1100 km/hour, but a point at the poles is not moved by the rotation.
- This fact means that projectiles moving across the Earth's surface are subject to *Coriolis forces* that cause apparent deflection of the motion.



Coriolis Effect

- **Since winds are just molecules of air, they are also subject to Coriolis forces.**
- **Winds are basically driven by Solar heating.**
- **Solar heating on the Earth has the effect of producing three major convection zones in each hemisphere.**
- **If solar heating were the only thing influencing the weather, we would then expect the prevailing winds along the Earth's surface to either be from the North or the South, depending on the latitude.**
- **However, the Coriolis force deflects these wind flows to the right in the Northern hemisphere and to the left in the Southern hemisphere.**

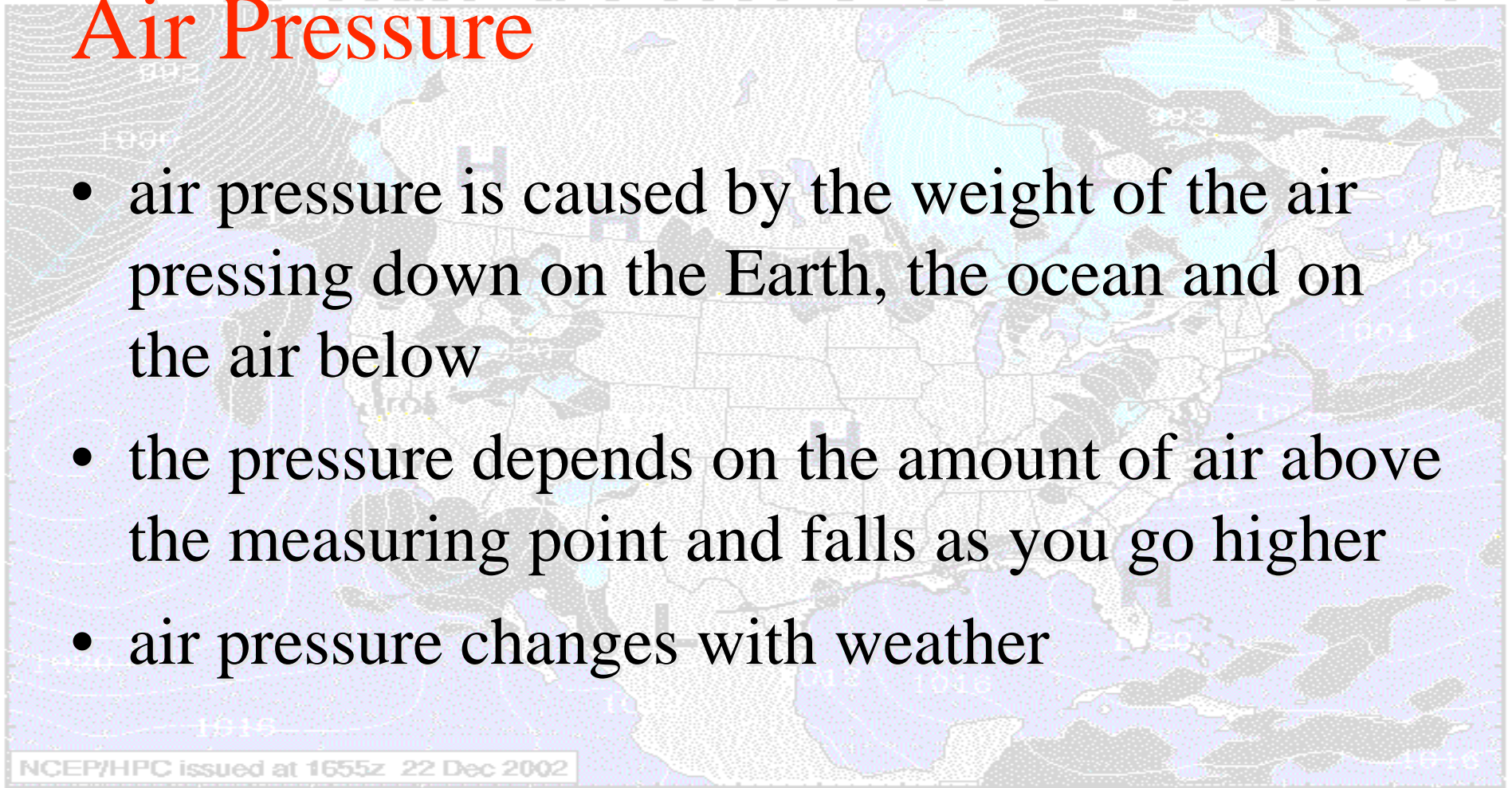




12 hr forecast valid 0000 UTC Mon 23 Dec 2002

Air Pressure

- air pressure is caused by the weight of the air pressing down on the Earth, the ocean and on the air below
- the pressure depends on the amount of air above the measuring point and falls as you go higher
- air pressure changes with weather



Rain

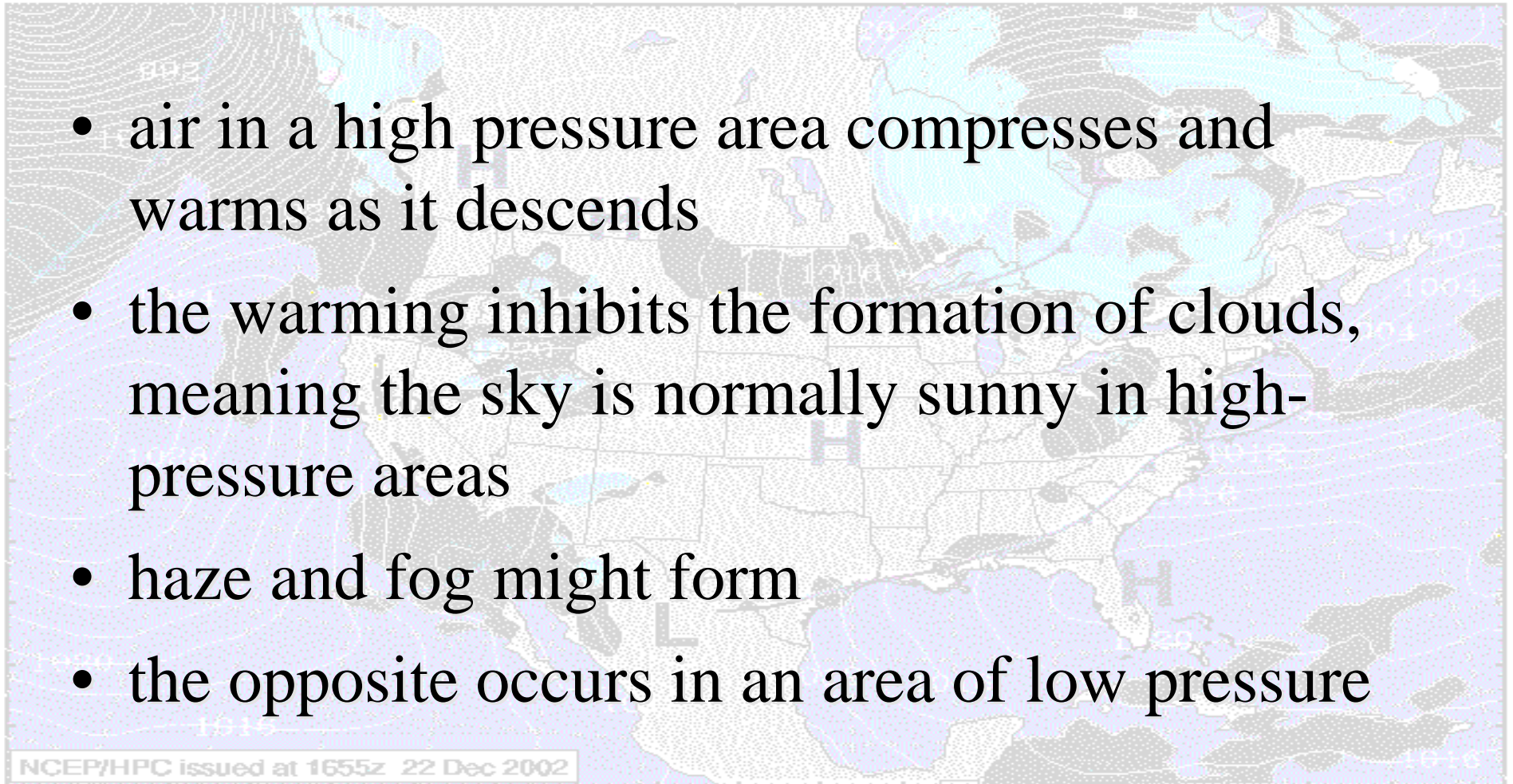
Snow

Wintry mix

... and Weather

12h forecast for 0000 UTC Mon 23 Dec 2002

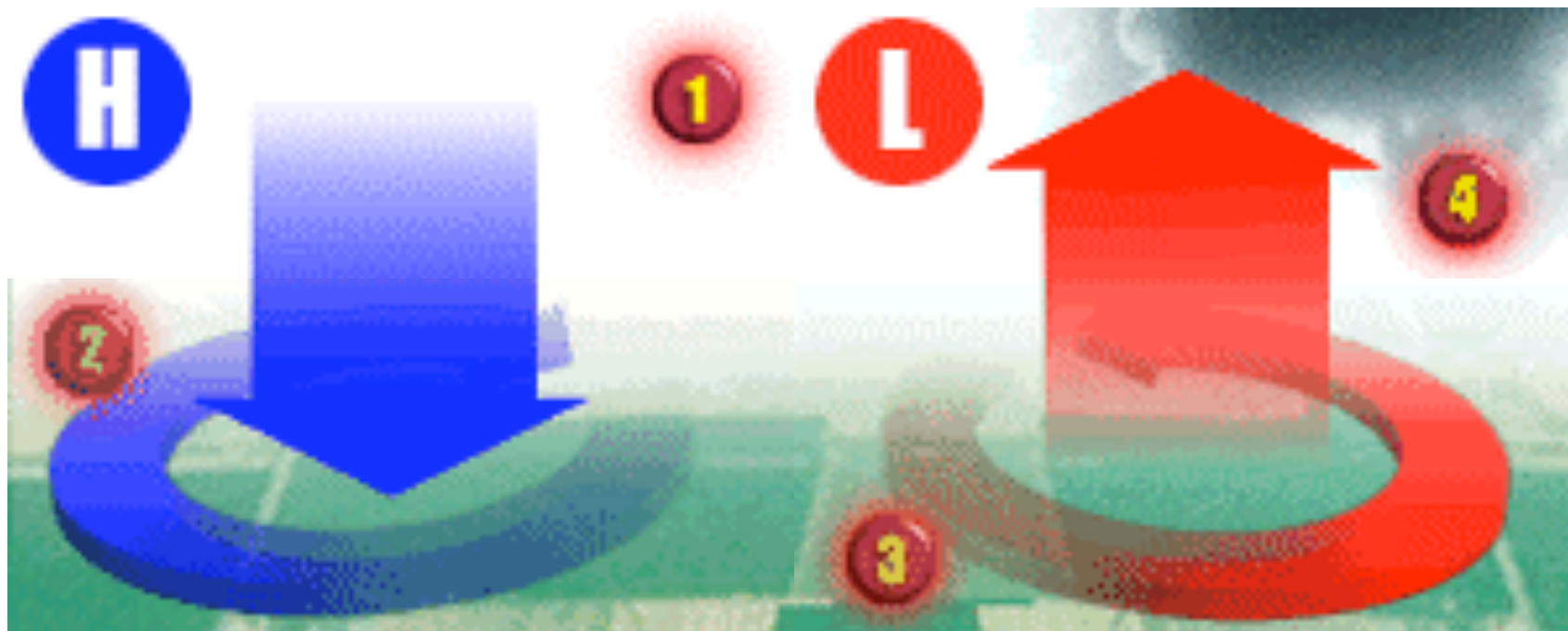
- air in a high pressure area compresses and warms as it descends
- the warming inhibits the formation of clouds, meaning the sky is normally sunny in high-pressure areas
- haze and fog might form
- the opposite occurs in an area of low pressure



Rain

Snow

Wintry mix



1 High pressure at Earth's surface

Air slowly descends...

2 High pressure at Earth's surface

...flowing out clockwise at the ground.

3 Low pressure at Earth's surface

Air flowing in counter-clockwise...

4 Low pressure at Earth's surface

...rises and cools, often forming clouds and precipitation.

Humidity

- **relative humidity** is the amount of water vapor in the air compared with the potential amount at the air's current temperature
 - expressed as a percentage
 - depends on air temperature, air pressure, and water availability
- the Earth has about 326 million cubic miles of water
- only about 3,100 cubic miles of this water is in the air as water vapor > clouds > precipitation



1

Equal

Amount of liquid water remains constant as evaporation and condensation cancel each other out.

2

Liquid wins

Amount of liquid water in puddle increases as condensation exceeds evaporation.

3

Vapor wins

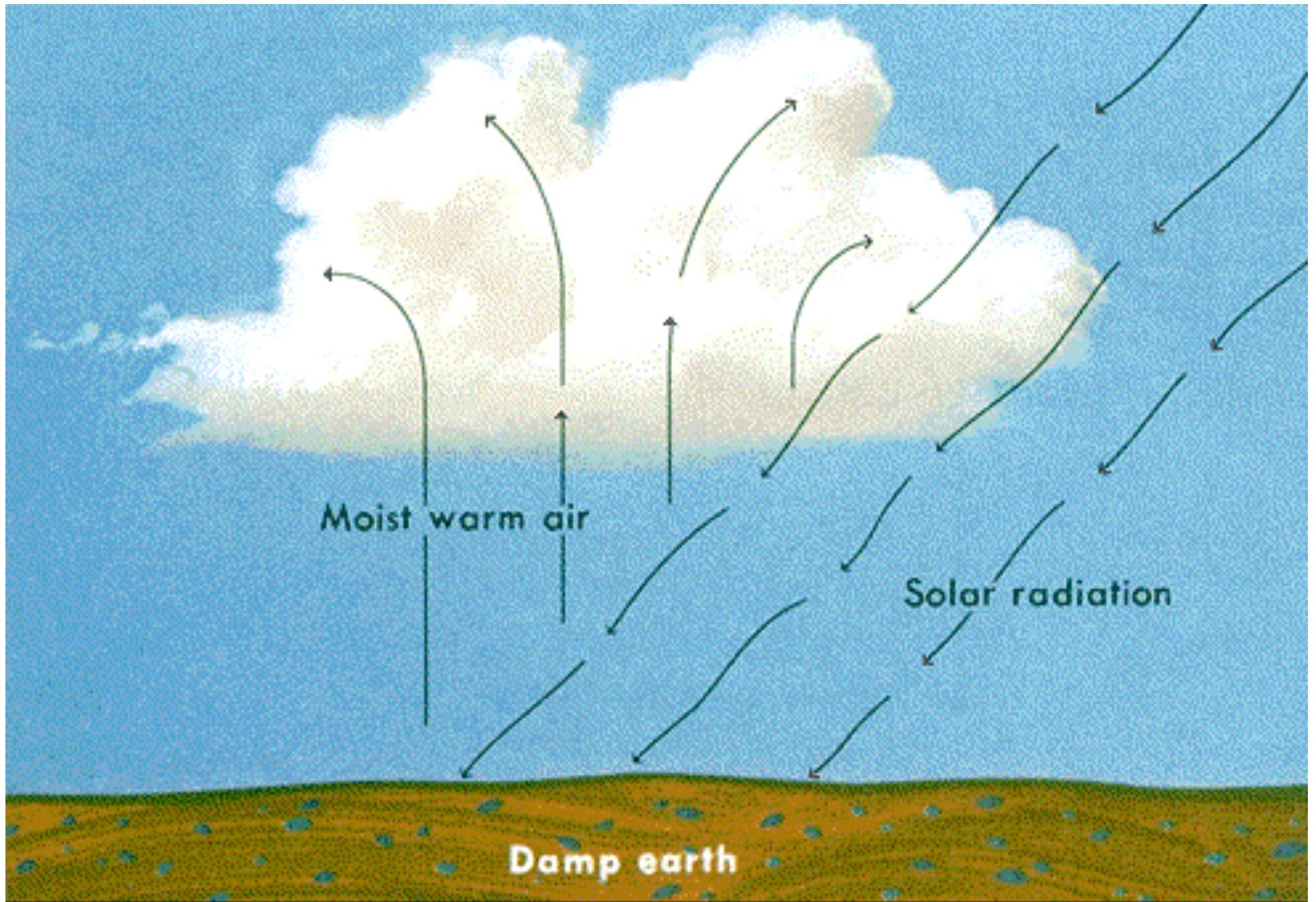
Amount of liquid water in puddle decreases as evaporation exceeds condensation.

Cloud cover

- moisture in the atmosphere forms clouds which cover an average of 40% of the Earth at any given time
- a cloudless Earth would absorb nearly 20 percent more heat from the sun
- clouds cool the planet by reflecting sunlight back into space. This is known as Albedo

However

- clouds reduce the amount of heat that radiates into space by absorbing the heat radiating from the surface and reradiating some of it back down
- the process traps heat like a blanket



▣ By convection

Precipitation

- Air containing water vapor cools in atmosphere and therefore condenses to form droplets of liquid water
 - **Rain**: liquid, falls, $d > 0.5$ mm (sphere)
 - **Freezing Rain**: occurs when drop touches frozen surface
 - **Sleet**: ice pellets, $d < 0,5$ mm, begins as rain but enters air below freezing
 - **Snow**: water deposits in hexagonal nuclei below freezing
 - **Snow Pellets**: grains of ice, $d = 2-5$ mm
 - **Hail**: 5-190 mm in diameter, concentric rings of ice

Winds

- horizontal wind moves from areas of high to low pressure
- vertical wind moves from low to high pressure
- speed is determined by differences in pressure
- Coriolis effect causes winds to spiral from high pressure zones and into low pressure zones

Winds

- wind speed is detected by a anemometer and direction by a weather vane
- wind direction is based on where the wind is coming from: an wind from the east is an easterly
- Beaufort Wind Speed Scale is has a range from 0 for calm to 12 for a hurricane with waves greater than 37 feet

North-polar high pressure

Prevailing westerlies

Subtropical high pressure

Trade winds

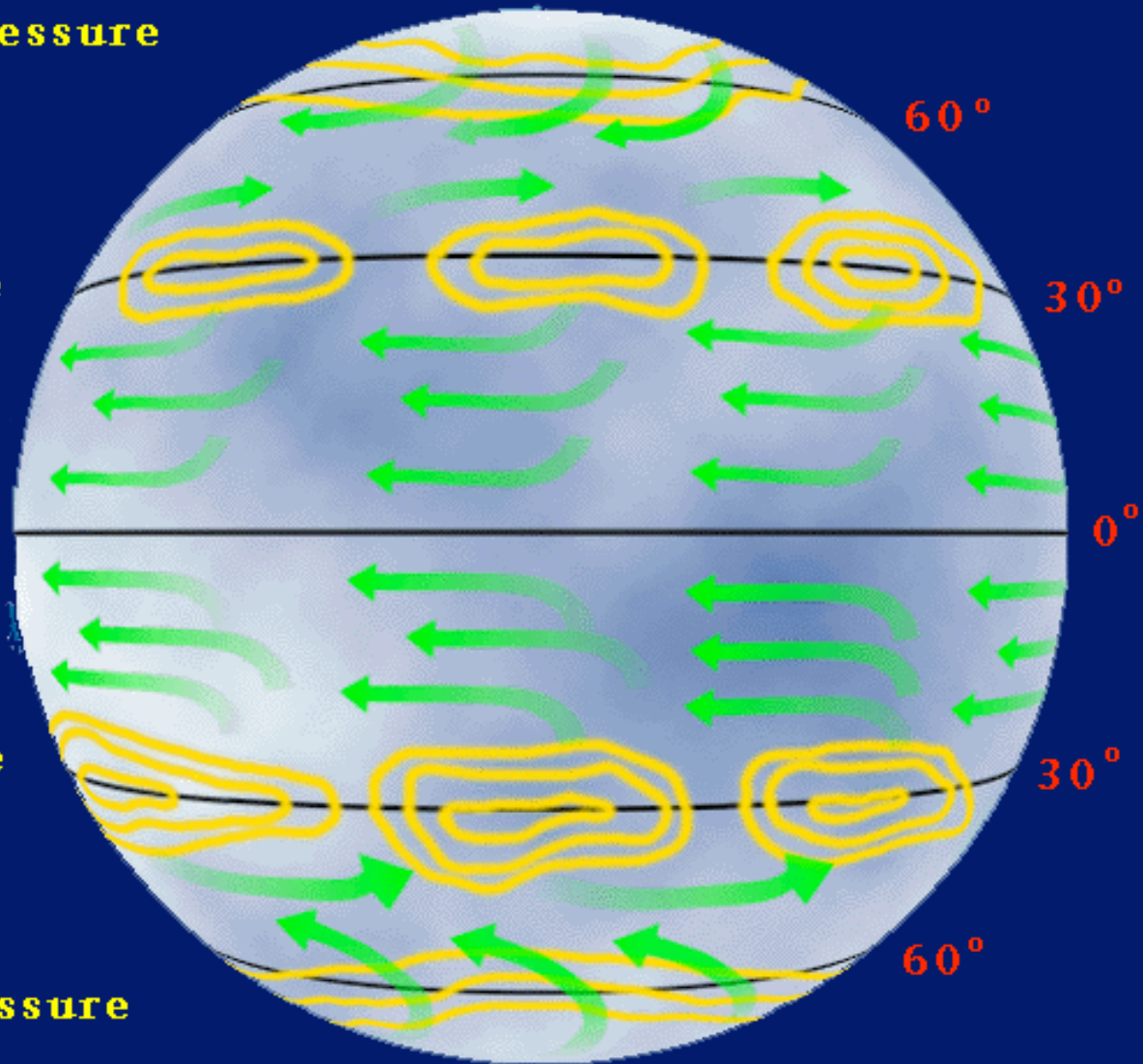
Equatorial low pressure

Trade winds

Subtropical high pressure

Prevailing westerlies

South-polar high pressure



Fronts

Forecast valid 0000 UTC Mon 23 Dec 2002

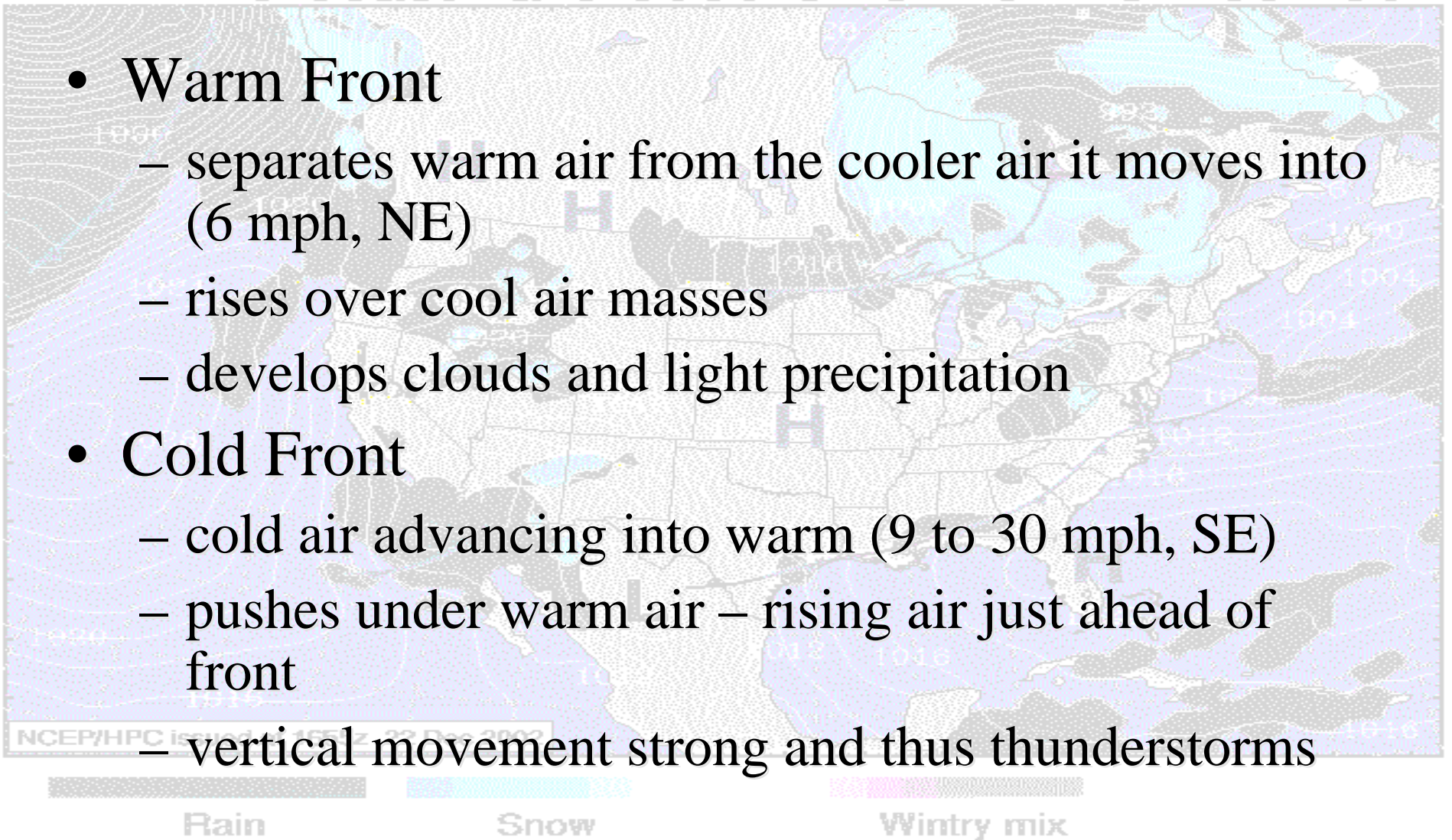
- Warm Front

- separates warm air from the cooler air it moves into (6 mph, NE)
- rises over cool air masses
- develops clouds and light precipitation

- Cold Front

- cold air advancing into warm (9 to 30 mph, SE)
- pushes under warm air – rising air just ahead of front

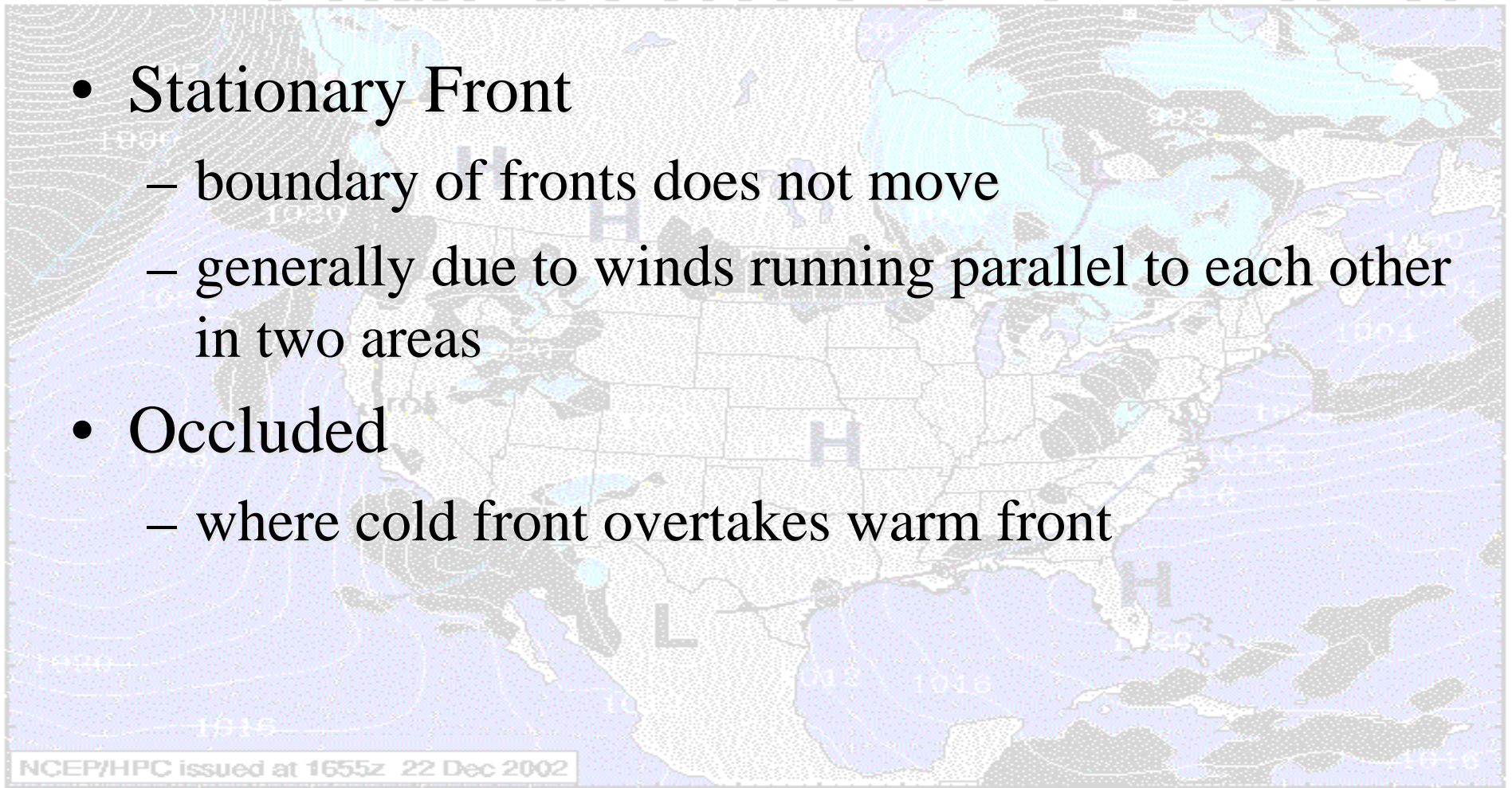
- vertical movement strong and thus thunderstorms



Fronts

Forecast valid 0000 UTC Mon 23 Dec 2002

- Stationary Front
 - boundary of fronts does not move
 - generally due to winds running parallel to each other in two areas
- Occluded
 - where cold front overtakes warm front



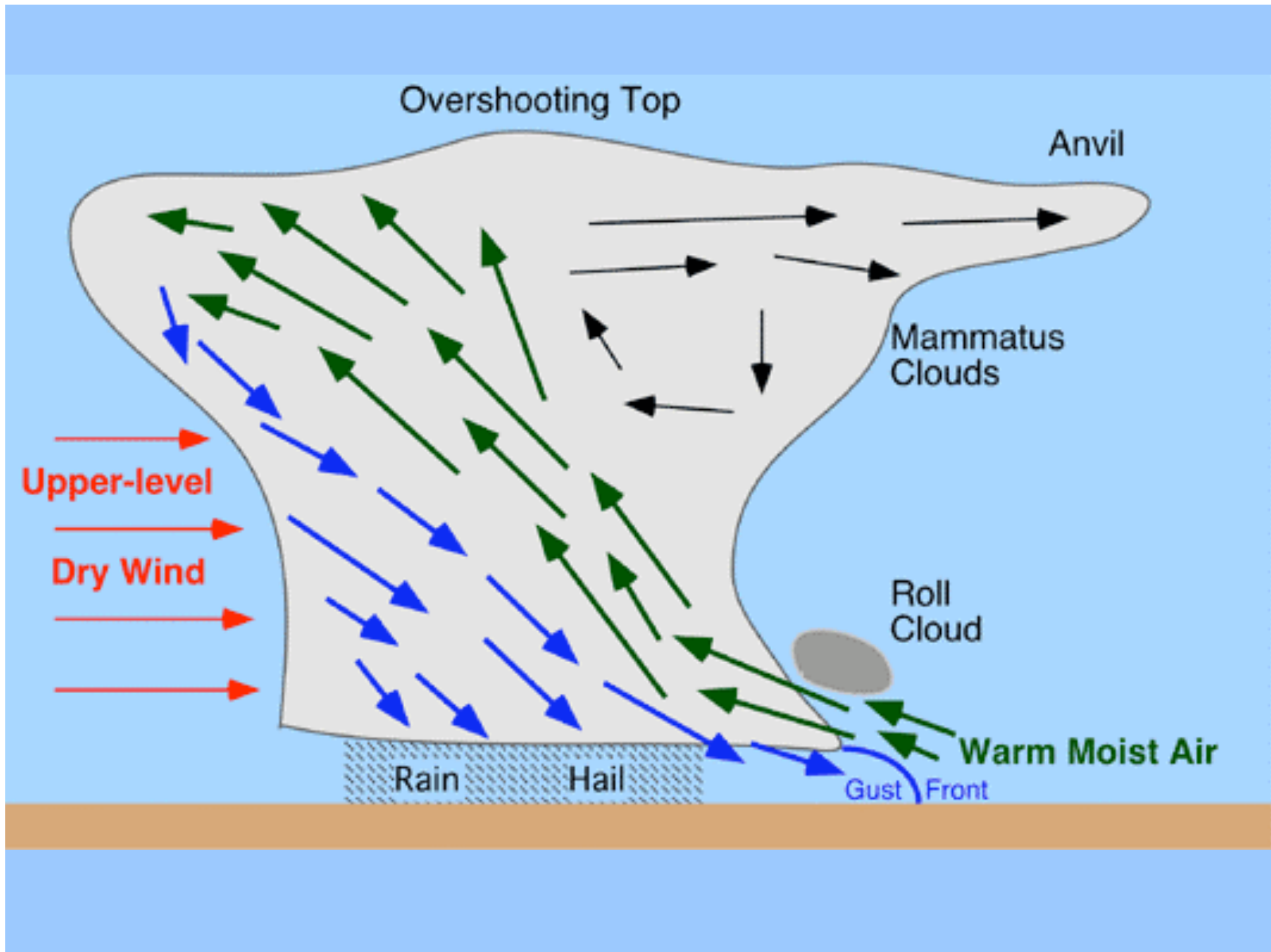
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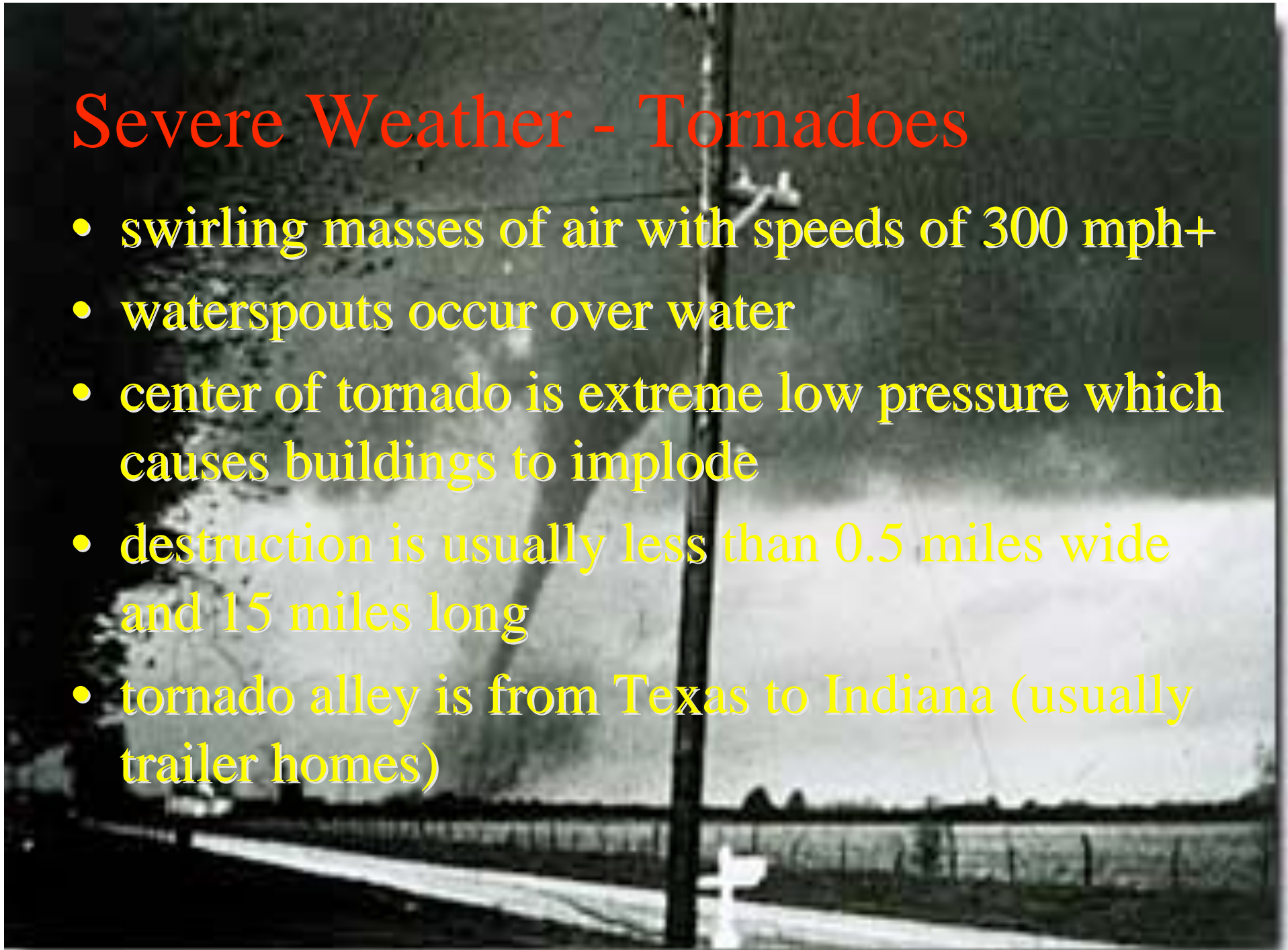
Severe Weather - Thunderstorms

- occur from equator to Alaska
- may have hail, strong winds, lightning, thunder, rain & Z tornadoes
- moist air rises due to frontal zone lifting causing loss of heat leading to cumulus clouds with updrafts
- at 42,000 feet downdrafts and precipitation start
- may last an hour
- severe thunderstorms occur when cold front approaches warm front (which supplies moisture and energy)
 - winds over 60 mph
 - hail > 3/4 inch



Severe Weather - Tornadoes

- swirling masses of air with speeds of 300 mph+
- waterspouts occur over water
- center of tornado is extreme low pressure which causes buildings to implode
- destruction is usually less than 0.5 miles wide and 15 miles long
- tornado alley is from Texas to Indiana (usually trailer homes)



A satellite image of Earth showing a large, swirling hurricane system over the Atlantic Ocean. The hurricane is a prominent white and grey cloud formation with a clear eye. The surrounding ocean is a deep blue, and the landmasses of North and South America are visible in the upper right. The title 'Severe Weather - Hurricanes' is overlaid in red text on the left side of the image.

Severe Weather - Hurricanes

- cause most property damage and loss of life
- winds speeds greater that 74 mph at the center
- begin over warm oceans of the tropics
- solar insolation (water $>80^{\circ}\text{F}$) provides energy for huge evaporation, cloud formation, and atmospheric lifting

A satellite image of Earth showing a large tropical storm system over the ocean. The storm is characterized by a dense, swirling cloud structure with a distinct eye in the center. The surrounding ocean is a deep blue, and the landmasses are visible in shades of green and brown. The text 'Los Mochis' and 'Tucson' are visible in yellow on the landmasses.

Severe Weather - Hurricanes

- stages
 - separate thunderstorms over tropical ocean
 - cyclonic circulation which causes them to pick up more more moisture and heat energy from ocean
 - winds speeds of 23 to 40 mph lead to *Tropical Depression*
 - *Tropical Storms* have lower pressure and higher wind speeds (40-75)
- center is the eye
- rainfall may exceed 24 inches in 24 hours











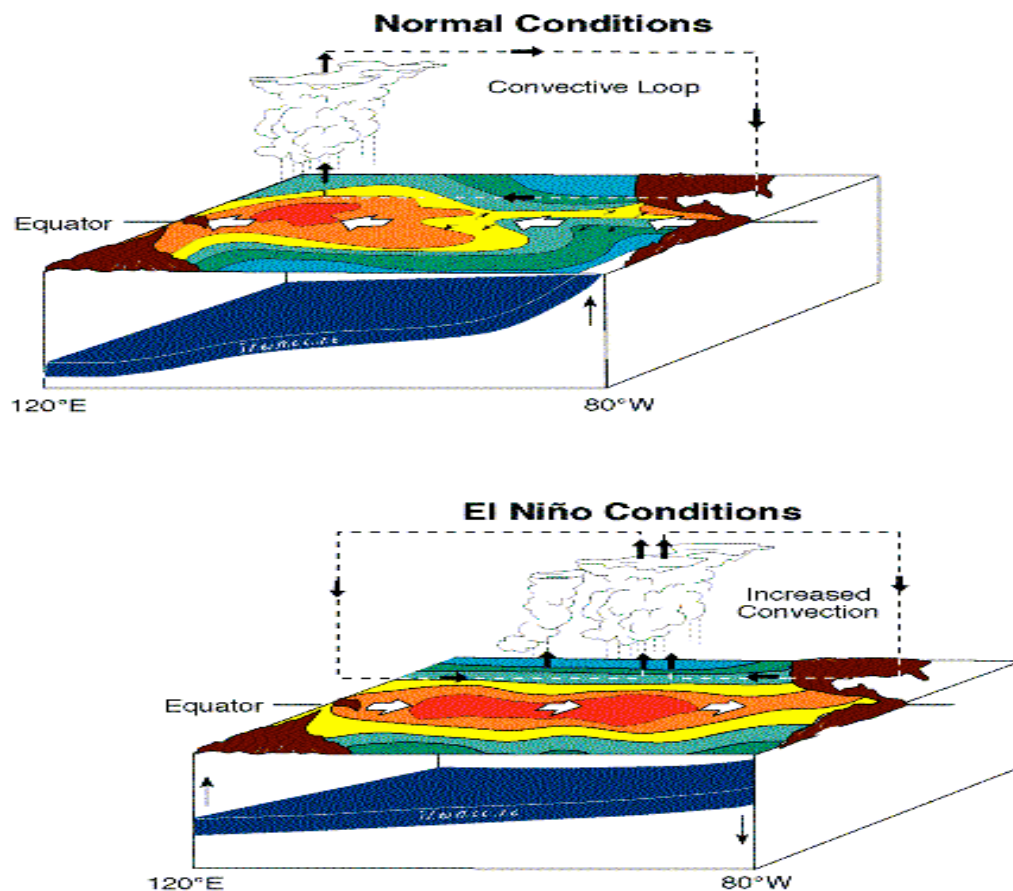






The El-Niño Southern Oscillation

- Occurs every few years
- ENSO's occur when the prevailing westerly winds weaken or cease and surface waters along the South and North American Coasts become warmer
- Upwellings of cold nutrient rich waters are suppressed
- Leads to declines in fish populations



Climate

- **Average long term weather of an area**
 - Seasonal variations and weather extremes averaged over a long period (at least 30 years)
- **2 Main factors**
 - Temperature
 - Precipitation
 - amount
 - distribution

