Chapter 14

Forecasting the Weather:

Forecasting the Weather:

- The study of weather forecasting is called meteorology.
- Those who forecast weather are called meteorologists.

Air Speed and Air Pressure

- There is a relationship between air speed and its related pressure. It states:
- As the air speed increases the pressure will decrease.
- That principle is called Bernoulli’s principle that states that:
    - *Where the air speed of a fluid is high, the pressure is low and where the speed of a fluid is low the pressure is high.*

North American Weather Systems

- Weather at the equator is easy to predict due the fact that the conditions do not change that often; it is generally warm and humid.
- We can say the same about the weather conditions at the poles; it is generally cold and dry.
- The mid latitude regions are much more difficult to predict because the weather conditions change so often.
- A weather system is a set of temperature, wind, pressure, and moisture conditions that exist for a certain region and moves as a unit for a period of days.

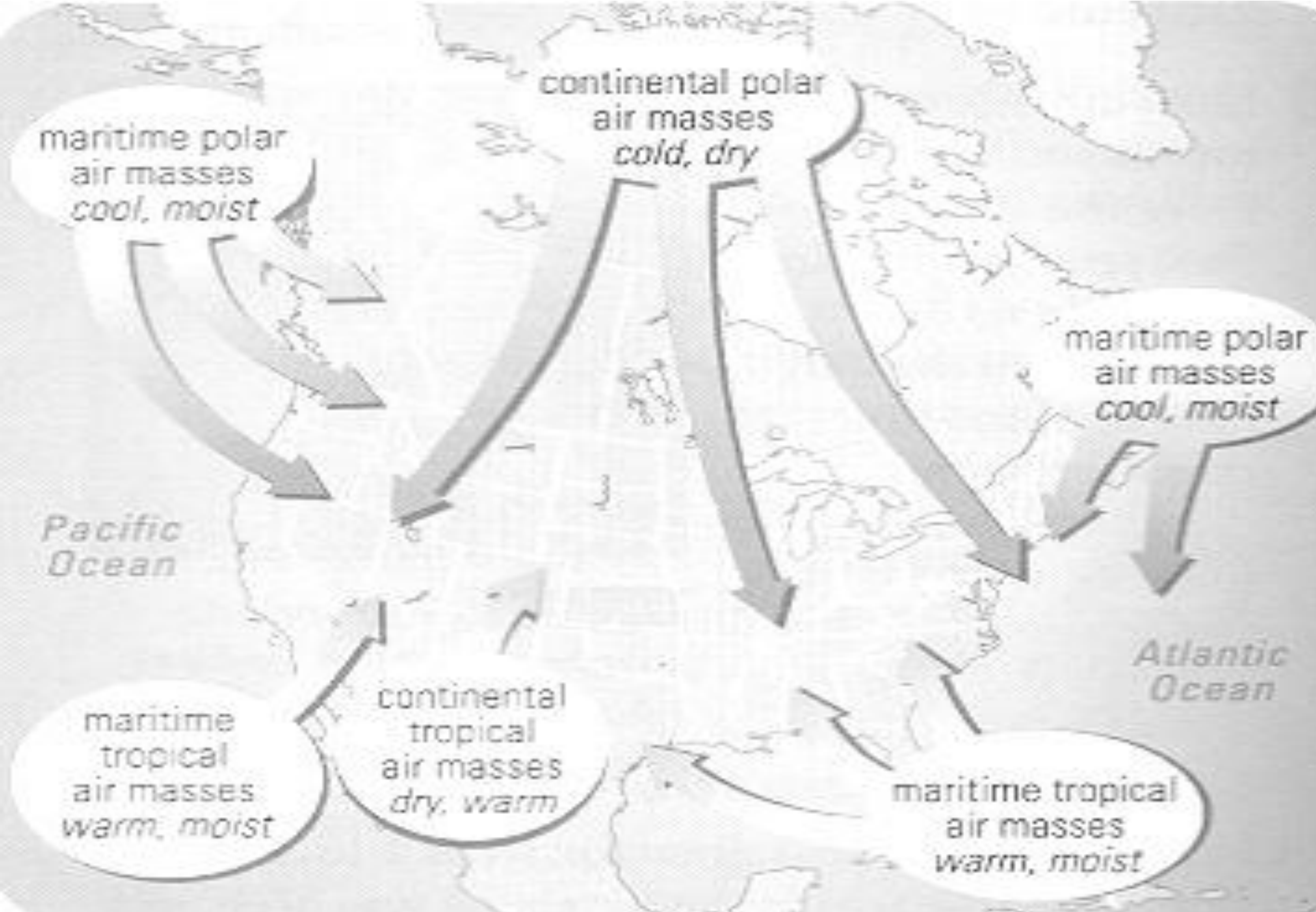
Air Masses

- An air mass is a large body of air in which the temperature and moisture content at a specific altitude are fairly uniform.
- They may be as small as 100 km up to 1000 km across.
- These air masses affect the regional weather conditions in their respective areas.
- Where these weather conditions meet in the mid latitudes and interact it creates the weather systems we see on a day-to-day basis in Canada.

6 NORTH AMERICAN AIR MASSES

Air Masses	Temperature	Moisture Content	Where they form	Direction they move
Maritime Polar (West Coast)	Cool	moist	Over North Pacific Ocean	Northwest to southeast
Maritime Polar (East Coast)	Cool	moist	Over North Atlantic Ocean	Northeast to southwest
Continental Polar	Cold	dry	Over mid-polar Regions of N.A.	North to south

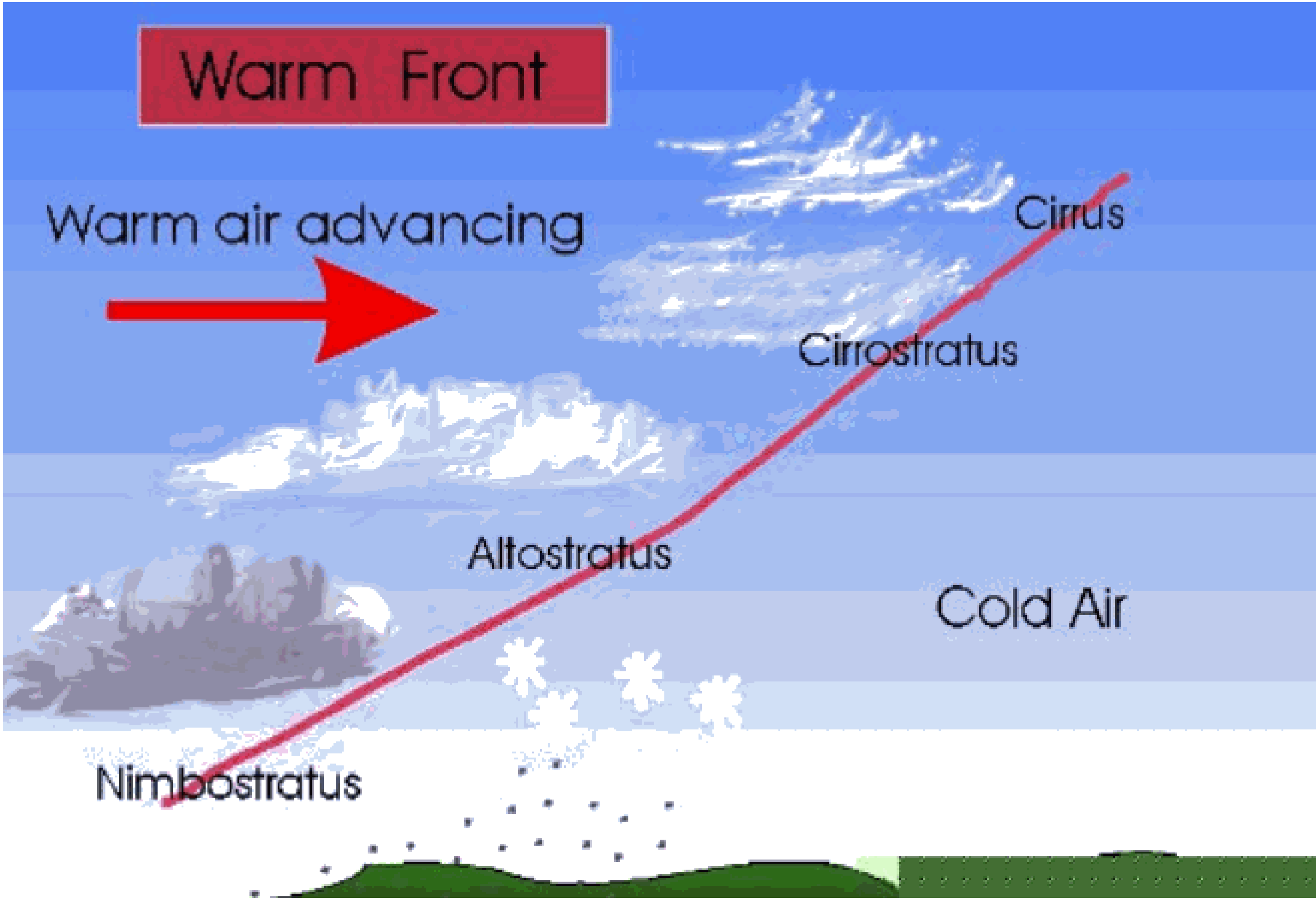
Maritime Tropical (West Coast)	warm	moist	Over South Pacific Ocean	Southwest to northeast
Maritime Tropical (East Coast)	warm	moist	Over South Atlantic Ocean	Southeast to northwest
Continental Tropical	warm	dry	Over mid-southern U.S. & northern Mexico	South to north


continental polar
air masses
cold, dry
maritime polar
air masses
cool, moist
maritime polar
air masses
cool, moist
Pacific
Ocean
Atlantic
Ocean
maritime
tropical
air masses
warm, moist
continental
tropical
air masses
dry, warm
maritime tropical
air masses
warm, moist

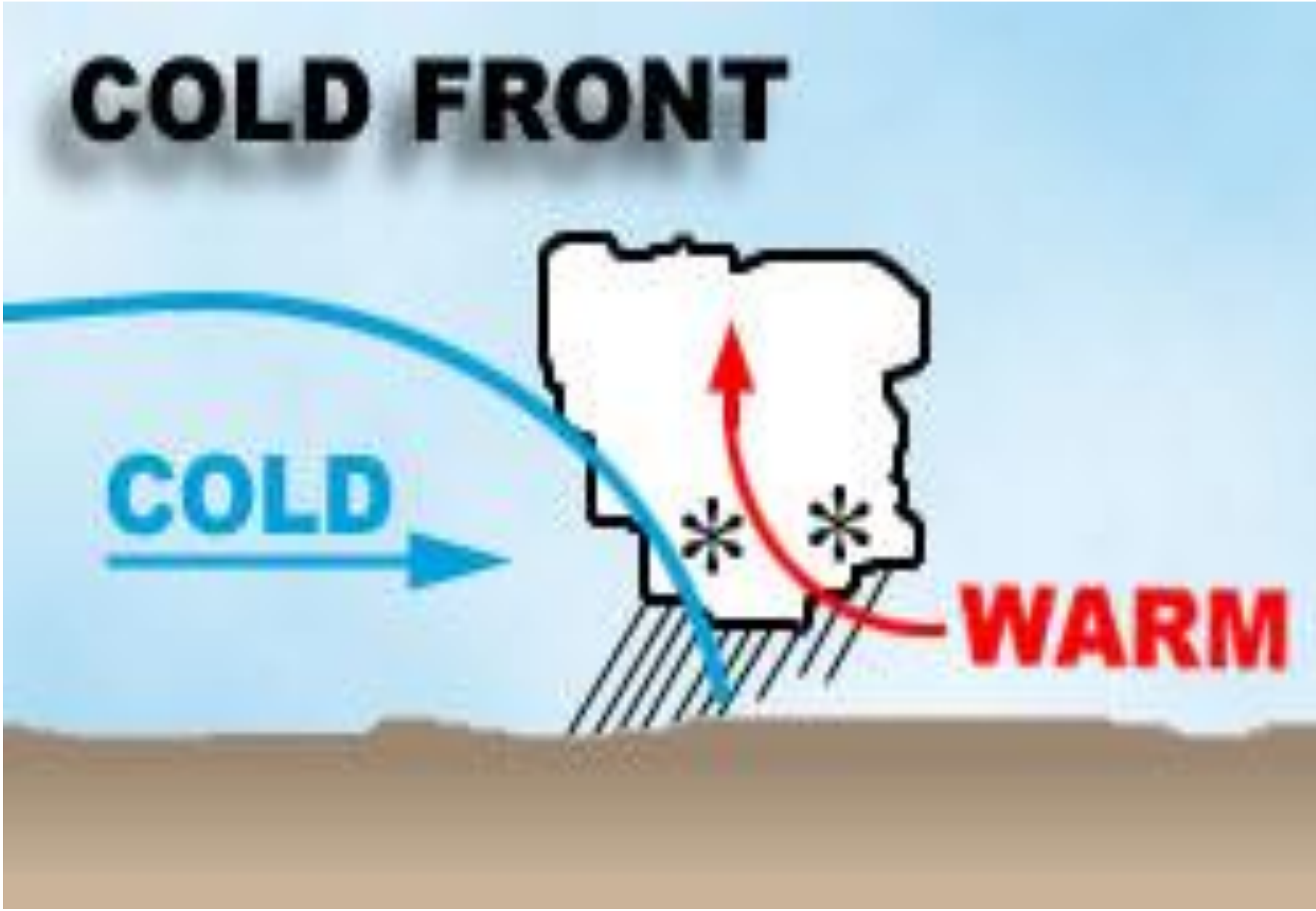
Front

- ***Low-Pressure Systems:*** *tend to bring cloudy skies and stormy weather Fig 2 p 547*
- ***Front*****:** the boundary between a cold air mass and a warm air mass
- Warm front: the leading edge of a warm air mass
- Cold front*:*the leading edge of a cold air mass

Warm front



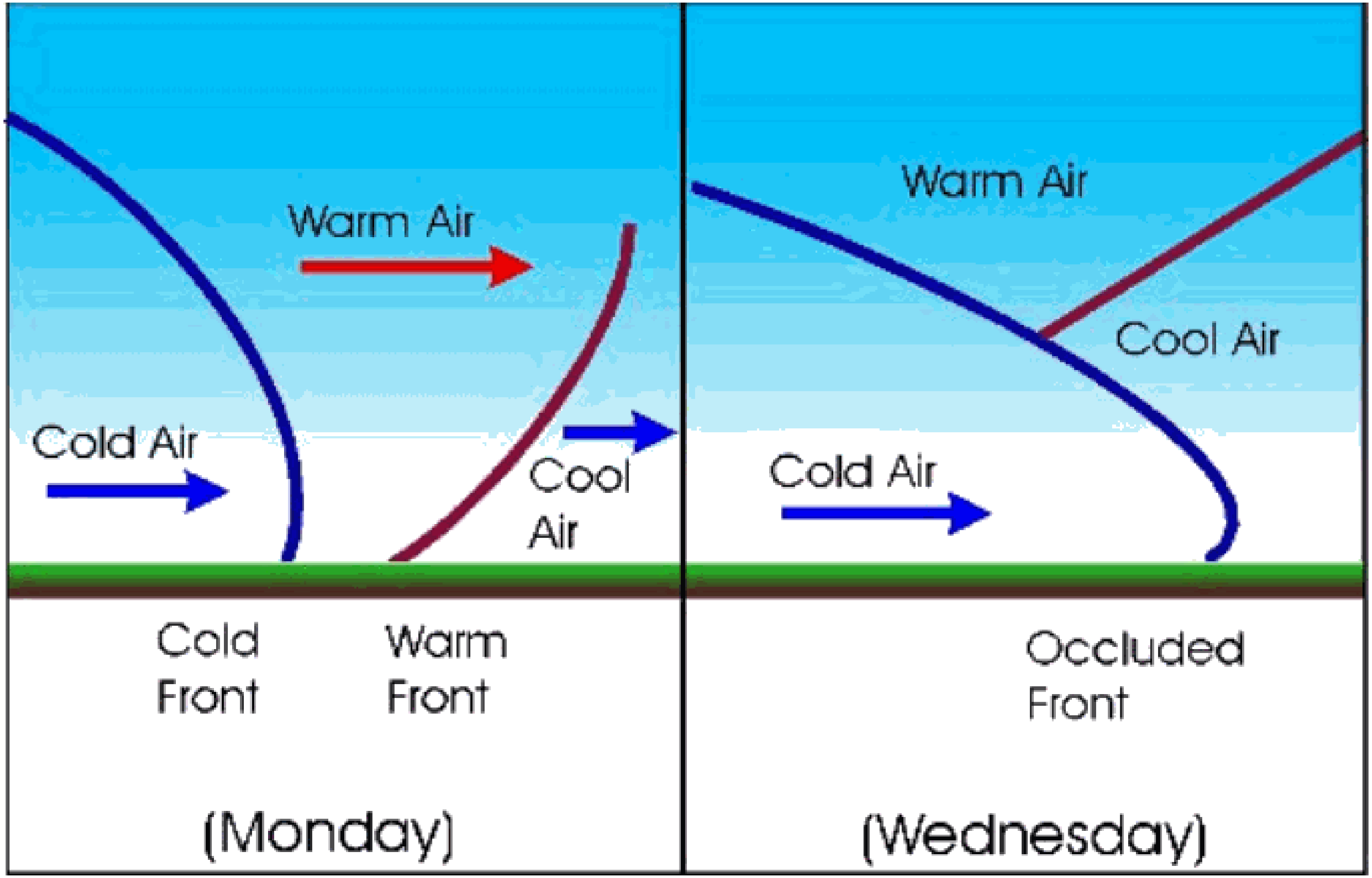
Warm Front
Warm air advancing
Cirrus
Cirrostratus
Altostratus
Cold Air
Nimbostratus


COLD FRONT
COLD
WARM

Occluded front

- forms when a cold front catches up with a warm front; the warm air is lifted above the earth's surface and is cut off from the cooler air below

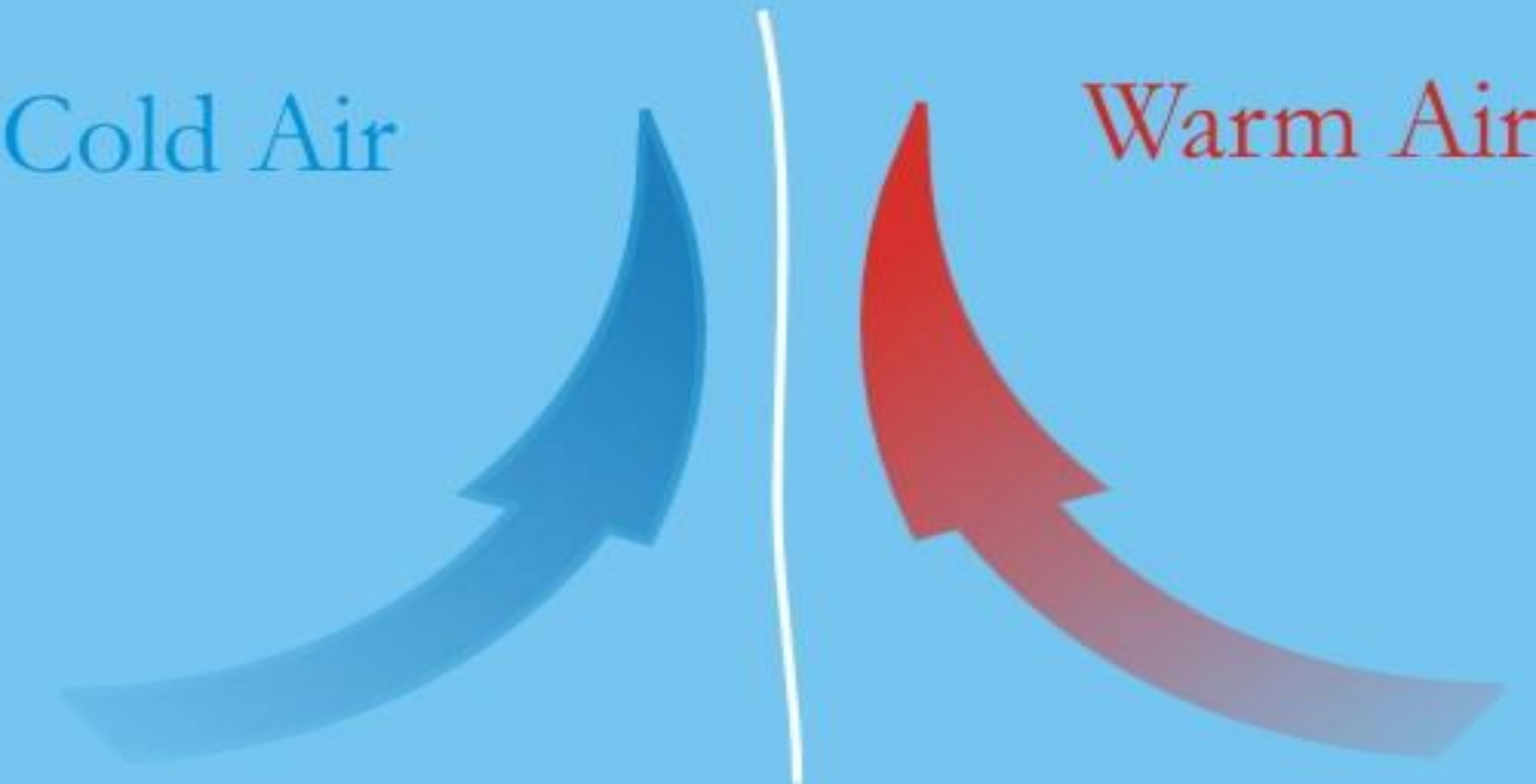
Occluded front – cross-section



Stationary Fronts:

- A stationary front occurs when the boundary between a warm air mass and a cold air mass remains fairly still for some time. This results in fairly stable weather.
- The front will remain that way until the faster moving jet stream air pulls up the air. (at that time a low pressure cyclone may start to form)

Cross Section of a Stationary Front



Low Pressure Systems:

- Results from a warm air mass coming in contact with a cold air mass.
- The two masses of air do not mix well so a front (boundary) forms between them.
- At the start of the low pressure system the front is not moving.
- Air in the jet stream pulls air up from both air masses creating low-pressure regions near the ground.
- This low-pressure region then starts pulling air in from the surface.
- The rising air begins to swirl in a counterclockwise direction due to the Coriolis effect.

Low Pressure Systems:

- As the jet stream continues to pull more air up more air is pulled into the low pressure area.
- The warm air front rises bringing moisture with it and the cold air front pushes under the warm air.
- A large region of precipitation develops ahead of the warm front because the jet stream is pulling more air away.
- Where the cold front is pushing the warm front upward considerable cumulonimbus cloud formation occurs bringing heavy rain or other precipitation.

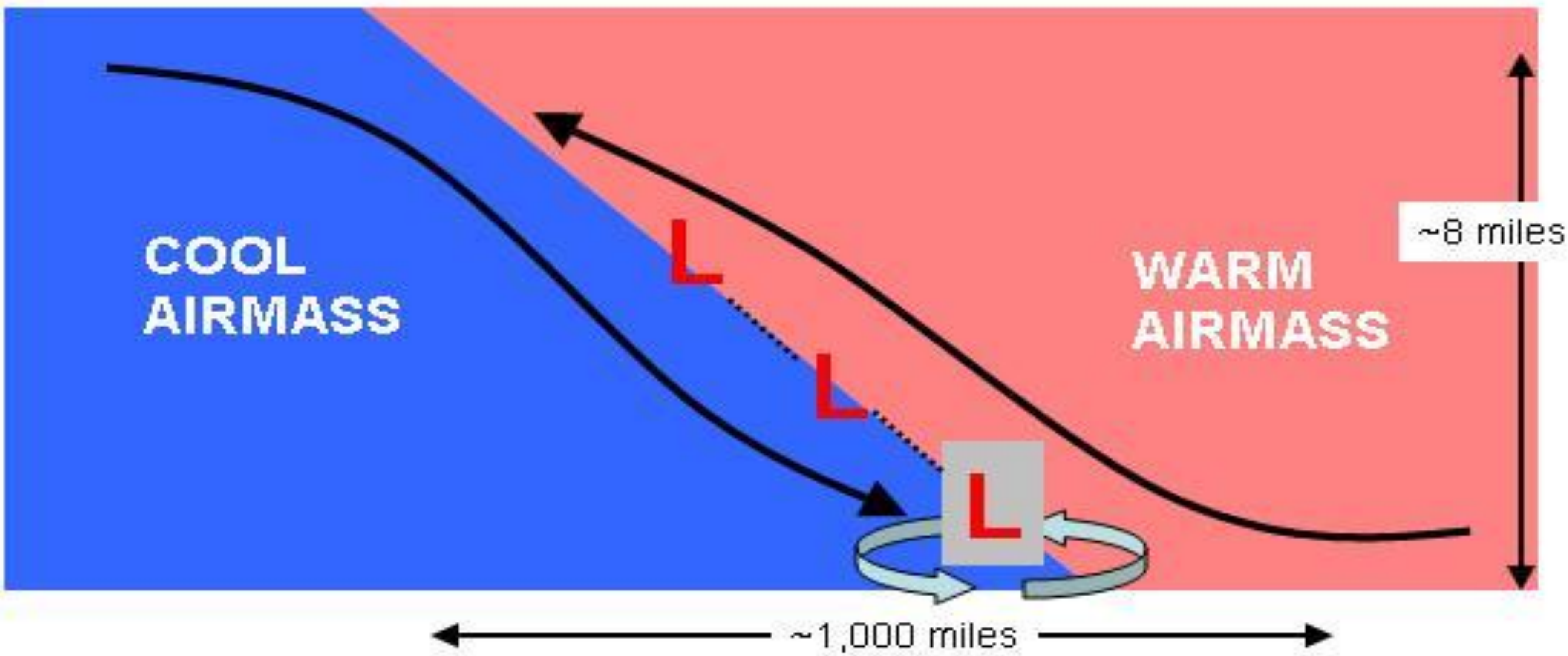
Low Pressure Systems:

- As the two fronts continue to swirl together they will reach a point where the cold front catches up to the warm front.
- At this point an occluded front forms.
- This is a single front and indicates that the storm is weakening.
- Finally the storm ends as the flow of air upward from the low-pressure area stops.
- There is no more pushing up of warm air.

- <u>Cyclogenesis</u>: the process of forming a cyclone
- Cyclone : a low-pressure system that rotates counterclockwise (in the Northern Hemisphere) and usually brings cloudy, stormy weather

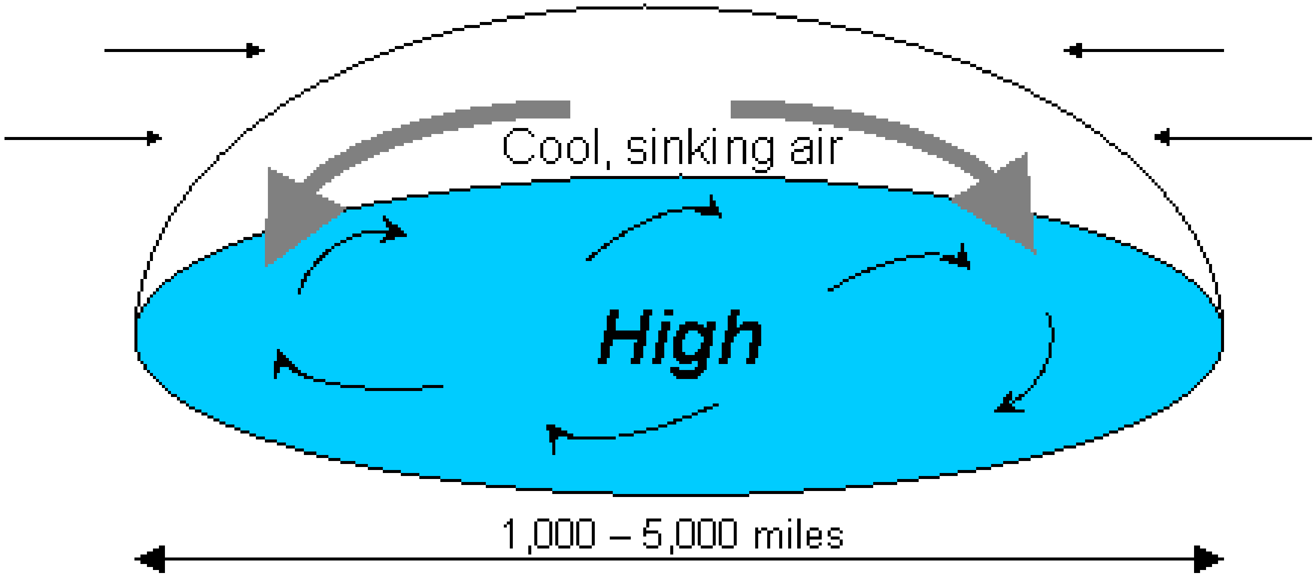
The cyclone gets it's energy from warm air rising and cool air sinking

SIDE VIEW



High-Pressure Systems:

- **An anticyclone** is a high-pressure system that spins clockwise (in the Northern Hemisphere) and usually brings clear skies
- Instead of the air rising creating a region of low pressure the air falls thus creating a high-pressure system.
- In central Canada and the Arctic regions there are **cold high-pressure systems** that result from the cold dry Arctic air falling and bringing with it clear skies and cold temperatures.
- **Warm high-pressure systems:** form at 30° latitude, when air in the equatorial convection currents that are heading northward becomes colder and more dense and moves downward, toward the surface.



Anticyclone

Questions:

- **p. 549:**
  - **1, 2, 3, 4, 5, 6**

Regional Weather:

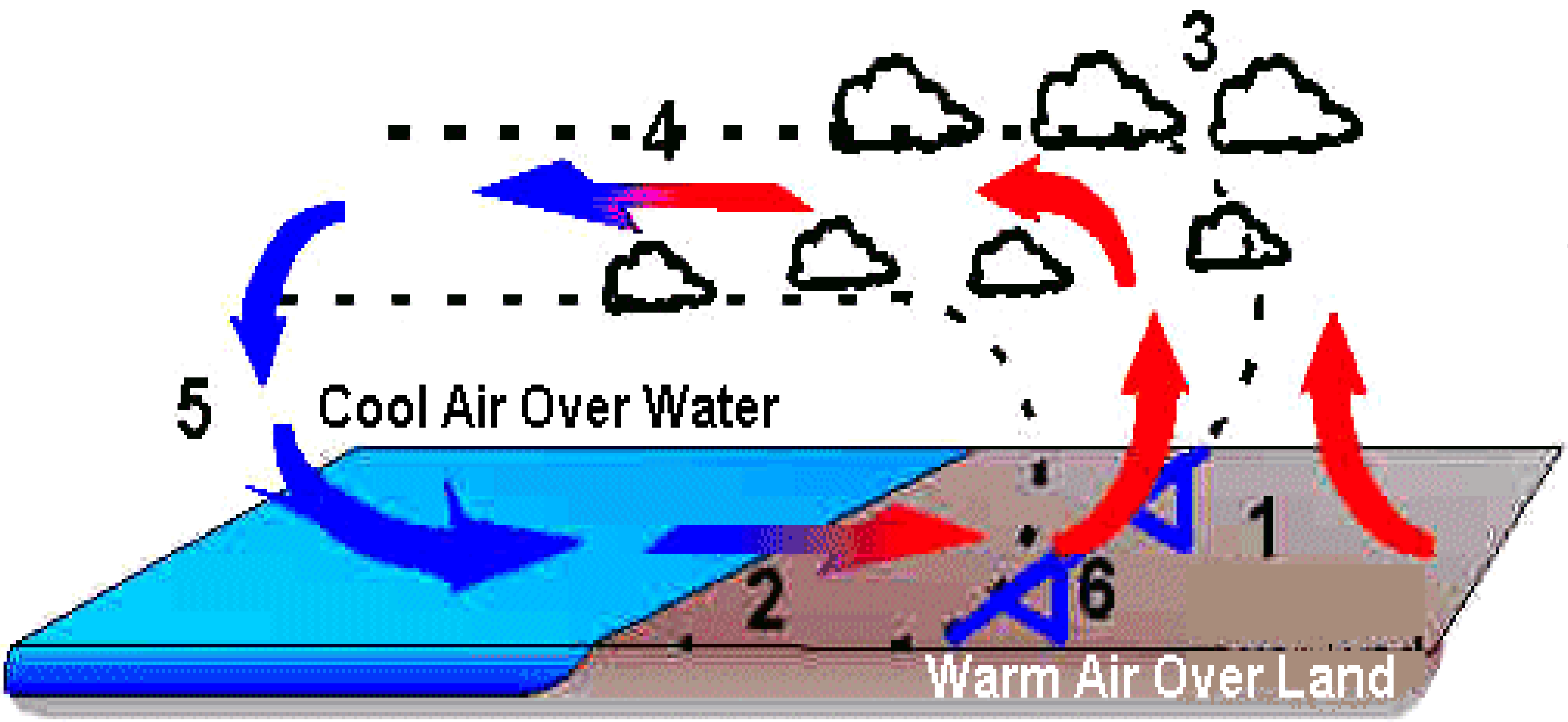
Thermals:

- A thermal is a local convection current set up during the day.
- On a clear, sunny day, solar energy warms the land. The land absorbs the energy and converts it into heat, which warms the nearby air. The warm air expands, becomes less dense and rises. The rising warm air is replaced by cooler, denser air which sets up a convection current.
- Thermals are generally weaker in early morning when they are just forming or toward sunset as the convection currents weaken.

Sea Breeze:

- A thermal that forms near a sea, an ocean or a lake is called a sea breeze.
- In early morning, solar energy warms the land faster than the water. Warm air above land rises and moves out over the water. Warm air is replaced by cooler air from above the water which sets up a convection current that moves air from the water toward the land.

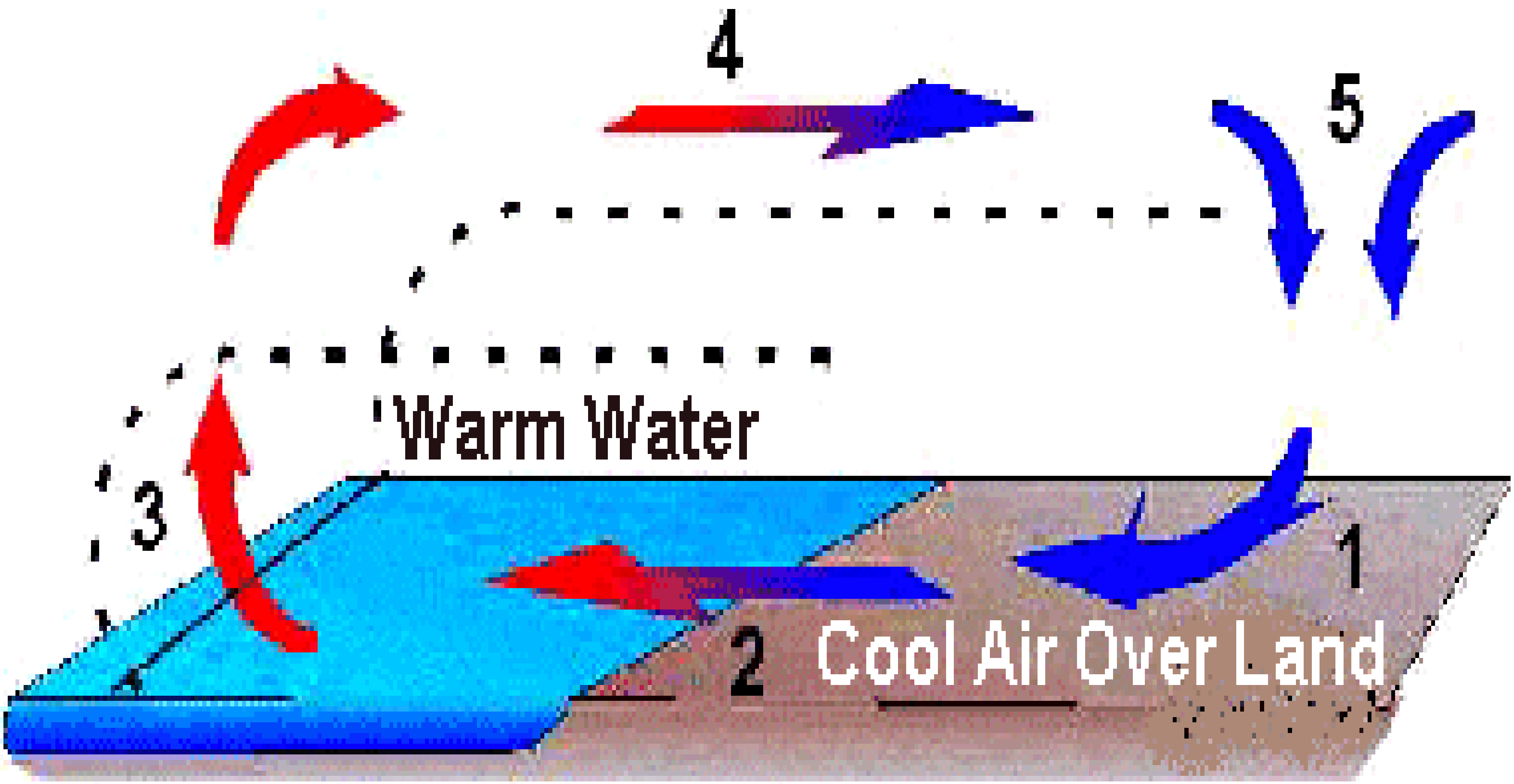
Sea Breeze Circulation



Land Breeze:

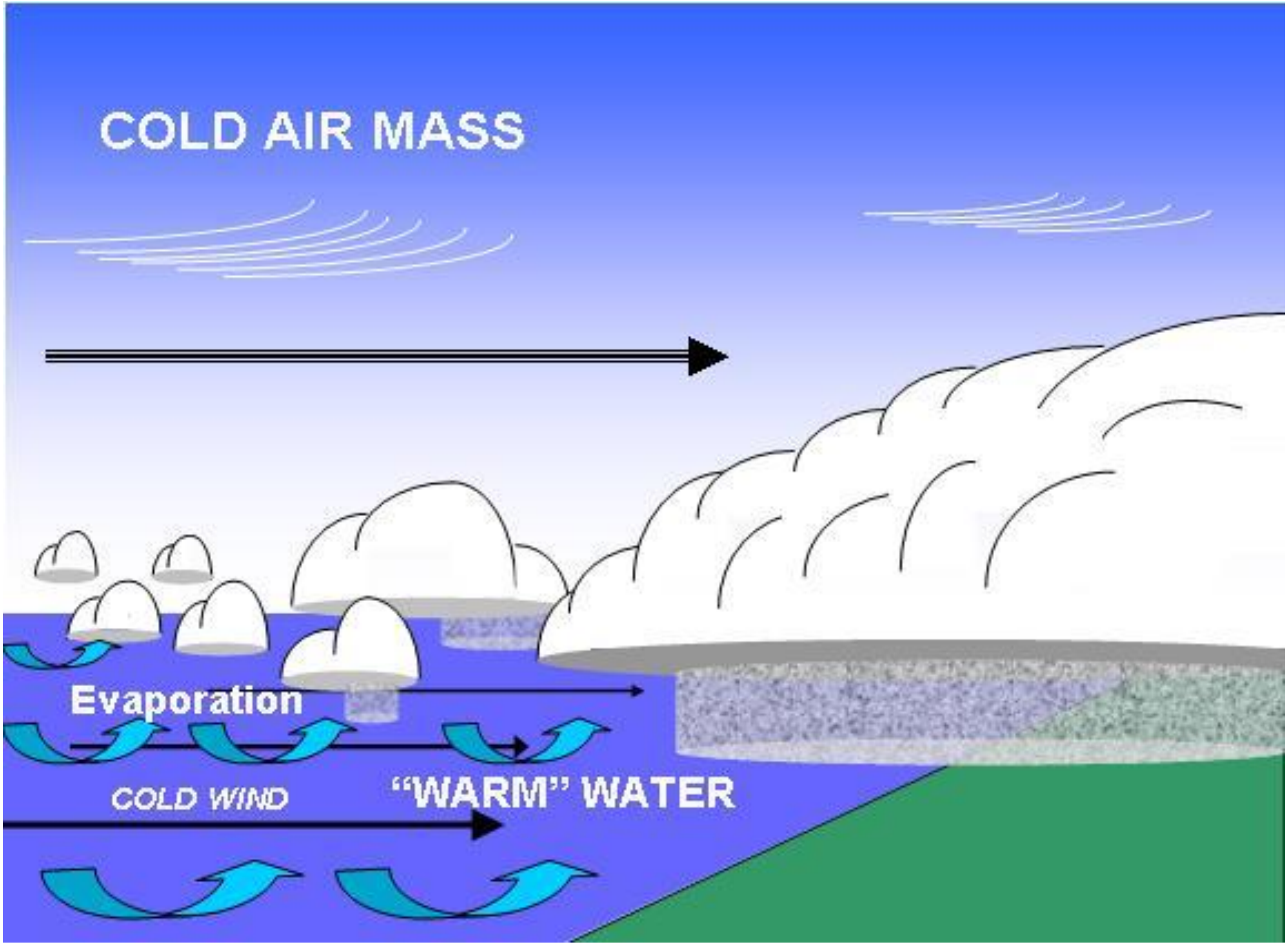
- Reverse of a sea breeze where the land cools faster than the ocean.
- A convection thermal that flows from the land toward a large body of water.
- As the sun sets, the land cools down faster than the water. Warmer air above water rises and moves in over the land. Warm air is replaced by cooler air from above the land which sets up a convection current that moves air from the land toward the water.

Land Breeze Circulation



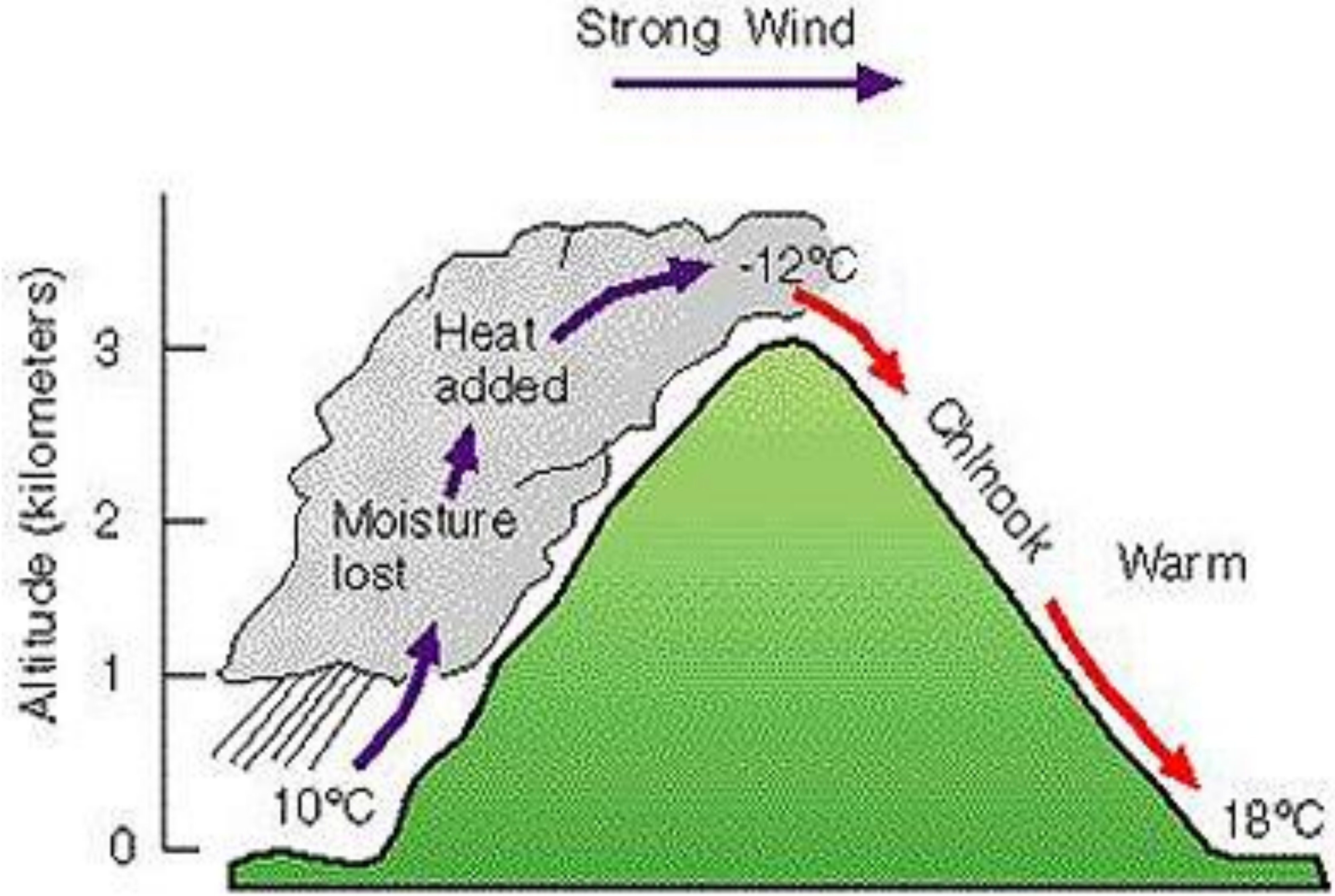
Lake Effect Snow

- When an air mass moves across a large body of water it picks up moisture.
- In winter, water tends to be warmer than the surrounding land and air.
- Moisture-laden air mass warms and rises as it travels across the water. When it reaches the far side of the body of water, temperature is lower, and the moisture becomes snow.
- The mean annual snowfall is greater on the downwind side of a large lake where the prevailing winds tend to produce precipitation.


COLD AIR MASS
Evaporation
COLD WIND
"WARM" WATER

Chinook Winds:

- On the windward side of a mountain, orographic lifting causes water vapour in the air to condense, thereby releasing energy and warming the air.
- As the air sinks on the leeward side of the mountains it loses its moisture and gains heat.
- The air that sinks on the leeward side is warm and dry and is called a chinook. (In the Canadian Rockies this happens on the east side of the mountains)
- This warm dry air can create summer like conditions during the winter months.


Strong Wind
Altitude (kilometers)
3
2
1
0
Heat
added
Moisture
lost
-12°C
Chinook
Warm
10°C
18°C

Precipitation:

Precipitation:

- It can be defined as water that reaches the ground as either a solid or a liquid.
- Occurs when air reaches its saturation point and the water vapour in the air condenses to form liquid droplets. When many droplets join together they become heavy enough to fall to the surface.
- The type of precipitation that reaches the surface depends on the temperature in the atmosphere, and, more importantly, the temperature near the ground
- Liquid forms: drizzle, rain and dew
- Solid forms: frost, freezing rain, ice pellets (sleet), snow and hail.

Drizzle:

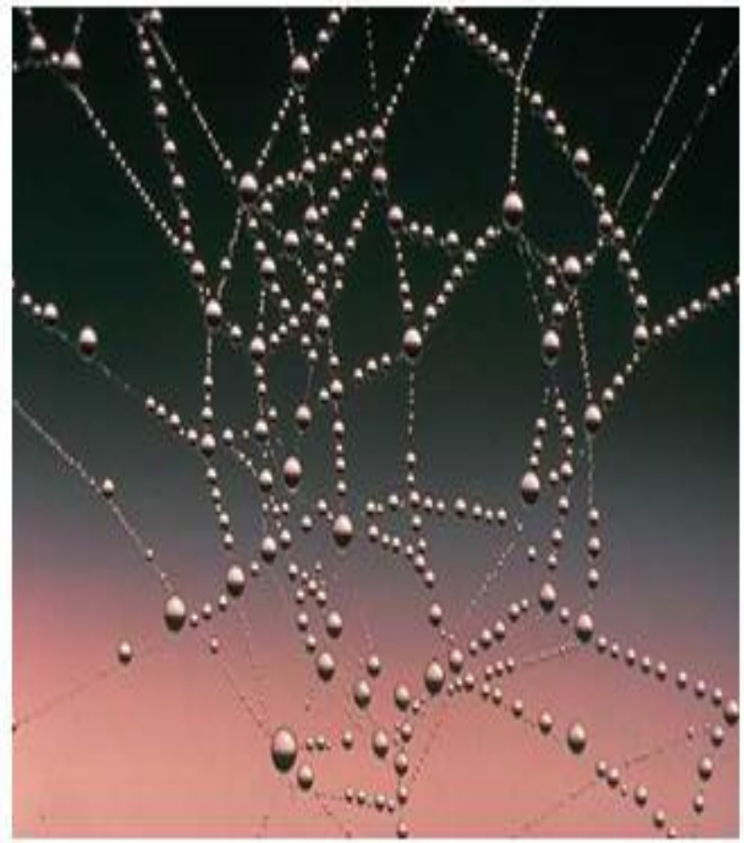
- Drizzle is fine water droplets between 40 μm and 0.5 mm in diameter.
- Depending on the intensity of the precipitation, both rain and drizzle can be classified as light, moderate or heavy.

Rain:

- Rain consists of falling water with a diameter between .5 mm and 5 mm.
- If the droplet is larger it will break into pieces as it falls through the air.

Dew:

- Dew forms when the air cools and water vapour in the air condenses on a cool surface like the grass in the early morning.
- If the surface is very cold the water vapour sublimates resulting in frost.



Dew on a spider web (photo: U.S. Fish and Wildlife service)

Freezing Rain:

- When raindrops that are close to freezing strike a cold object on or near the ground.
- They freeze instantly.

Freezing Rain

Ice Pellets: (Sleet)

- This is a solid form of water.
- They form when snow falls through a region of warm air and partially melts.
- They then fall through a colder region of air and refreeze.
- These ice pellets are hard enough to bounce off the ground when they strike.

Snow:

- Snow is formed when water vapour crystallizes on tiny particles of dust.
- The ice crystals grow and combine to form snowflakes.
- Snow forms only when the air temperature has cooled below 0° C.
- If the temperature remains cold the snow falls to the ground as dry snow.
- If the snowflakes pass through a region of warmer air they can melt slightly and fall to the ground as wet snow.

Hail:

- Hail is a solid form of water that is created in cumulonimbus clouds high in the troposphere.
- Frozen raindrops move up and down in highly active thunderclouds, each cycle they become larger in diameter.
- They will remain suspended in the air currents until they are too heavy then they fall to the ground.
- Some hailstones can have as much as 20 layers of ice.

Hail

Questions:

- **Page 557,**
  - **#1, 2, 3, 4, 5, 6**

Humidity:

Humidity:

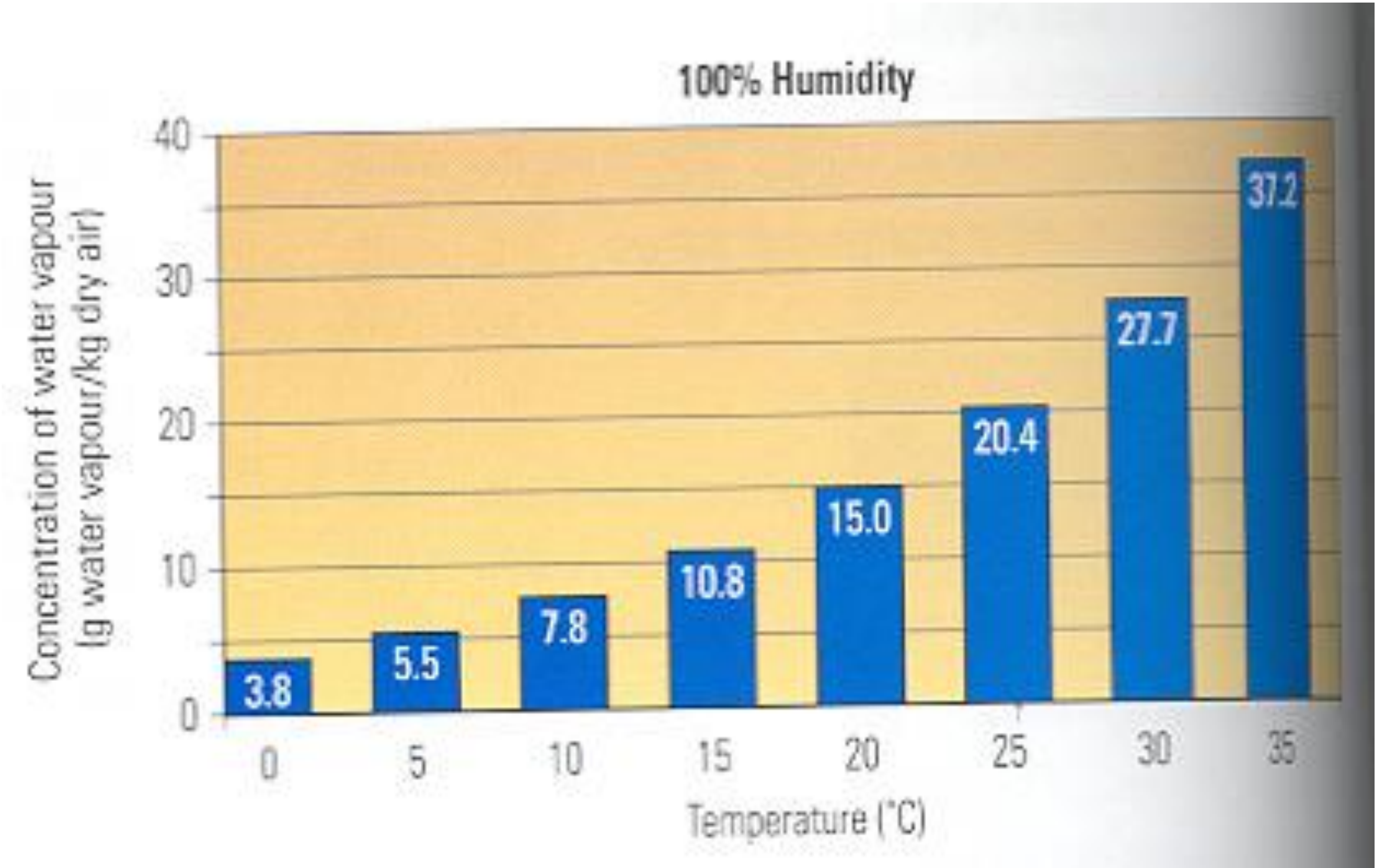
- Humidity is the measure of water vapour that is in the atmosphere.
- It affects how comfortable we feel.
- If the humidity is low we feel comfortable but if it is high we find that there is no way to keep cool
- Clouds formed when the humidity is low generally evaporate quickly but if they form when the humidity is high they will linger for a very long time.

- Low humidity = Evaporation can occur from bodies of water
- High humidity = Evaporation cannot occur; condensation can occur producing clouds &/or fog

Relative Humidity:

- Relative humidity is the measure of the amount of water vapour actually in the air as a percentage of the maximum amount of water vapour the air could hold at that temperature.
- Warm air can hold more moisture than cold air.
- *Figure 1 (p.558)* shows the maximum concentration of water vapour in dry air (in g/kg) at different temperatures to give 100% humidity = *saturated air*

Figure 1



100% Humidity
Concentration of water vapour (g water vapour/kg dry air)
40
30
20
10
0
3.8
5.5
7.8
10.8
15.0
20.4
27.7
37.2
0
5
10
15
20
25
30
35
Temperature (°C)

Saturated Air:

- Saturation of air occurs when the air is holding the maximum amount of water vapour it can at that temperature – its relative humidity is 100%

Dew and the Dew Point:

- Dew is water vapour that has condensed on colder objects such as grass in the early morning
- Dew forms when the relative humidity is 100% - the temperature at which dew forms is called the dew point.
- At night the ground radiates energy into the atmosphere, and objects at ground level cool down quickly.
- When the temperature of these objects is at or below the dew point the water vapour in the air condenses out as droplets on the plants, etc.

Dew and the Dew Point:

- When the skies are cloudy the earth radiates energy and the clouds absorb it.
- The clouds in turn radiate some energy back to the ground keeping the surface temperature higher. That is why dew forms mainly on nights when the skies are clear.
- Steam on a bathroom mirror or water on the outside of a cold glass forms in the same way as dew.

Calculations involving relative humidity:

- Ex1: If the concentration of water vapour at 0^oC is 1.9 g/kg of dry air, what is the relative humidity?
- See figure 1 Figure 1 (p.558)

- Relative humidity = $\dfrac{\text{concentration}}{\text{max concentration}} \times 100\%$

$$= \frac{1.9 \text{ g/kg}}{3.8 \text{ g/kg}} \times 100\%$$

$$= 50\%$$

Calculations involving relative humidity:

- Example 2: Determine the concentration of water vapour in air at 20^{o} C when the relative humidity is 50%
- See Figure 1 (p.558)
- Maximum concentration= 15.0 g/kg
- $$\text{Concentration} = \frac{(\text{Relative Humidity})\ (\text{Max conc.})}{100}$$

$$= \frac{(50)\ (15.0\ g/kg)}{100} = 7.5\ g/kg$$

Determining Relative Humidity:

- To determine relative humidity you would use a psychrometer.
- An instrument that uses two thermometers, one dry and open to the air, the other covered with gauze that is made wet when you wish to use the instrument.
- It works on the principle that dry air will cool the wet gauze faster than damp air.
- To operate the device simply wet the gauze and then spin it.

Determining Relative Humidity:

- After a few minutes check the temperature of both thermometers.
- In general the temperature of the wet thermometer will be lower than the dry one .
- Subtract the wet thermometer value from the dry one and then use the table to determine the relative humidity.
- When the air is saturated (100% humidity) both thermometers will have the same temperature reading; if not saturated, the wet-bulb will have a lower reading than the dry-bulb

Table 1 Determining Relative Humidity

Dry-bulb temperature (°C)	Difference between wet-bulb and dry-bulb temperatures (°C)									
	1	2	3	4	5	6	7	8	9	10
	Relative humidity (%)									
10	88	77	66	55	44	34	24	15	6	
12	89	78	68	58	48	39	29	21	12	
14	90	79	70	60	51	42	34	26	18	10
16	90	81	71	63	54	46	38	30	23	15
18	91	82	73	65	57	49	41	34	27	20
20	91	83	74	67	59	53	46	39	32	26
22	92	83	76	68	61	54	47	40	34	28
24	92	84	77	69	62	56	49	43	37	31
26	92	85	78	71	64	58	51	46	40	34
28	93	85	78	72	65	59	53	48	42	37
30	93	86	79	73	67	61	55	50	44	39

Subtract the wet-bulb temperature from the dry-bulb temperature, and find the column that corresponds to the temperature difference. Go down that column to the row for the dry-bulb temperature to find the relative humidity.

Determining Relative Humidity:

- Ex 3: The air temperature in a classroom is 22° C and the wet-bulb temperature is 17° C. Determine the relative humidity of the room.
- 22° C - 17° C = 5° C
- Look for 22° C on the left side and look for 5° C. The intersection is the relative humidity 61%

Effects of Humidity

- The amount of humidity in the air affects many things such as frost or dew forming on the ground in the early morning. It also affects how we feel.

High humidity

- Normally, when a person perspires, evaporation of perspiration removes heat from the body and cools it down
- If the relative humidity is high evaporation does not occur as quickly, making the person feel uncomfortable.

Low humidity

- In winter when the air is dry, evaporation occurs quickly because the air can hold a lot more moisture, so the skin can become uncomfortably dry. (humidifiers add moisture to the air in homes)

Questions:

- **p. 561**
  - **# 1, 3, 4, 5, 6, 7, 8, 9, 10, 11**
- **p. 563**
  - **# 2, 3, 4, 6**

Weather Forecasting Technology

Weather Forecasting Technology

- Today weather forecasting is accurate for about three days.
- This is due to the technology and methods we now use for gathering weather information.
- There are a number of things that haven’t changed but computer technology has allowed us to generate better and more accurate models of how weather systems will move.

Weather Forecasting Technology

- Things such as forecasting temperature, wind speed, atmospheric pressure, and humidity have remained the same. The main difference with these items is our ability to get this information distributed quickly to those who need it.
- Weather satellites and aircraft have greatly improved our ability to collect data.

Weather Satellite

- An orbiting spacecraft that regularly gathers weather-related data and images and relays them to weather stations on the ground

Low-orbit satellites

- Orbit about 1000 km above the poles
- Low level satellites travel around the poles every two hours collecting data using infrared and microwave energies.
- Gather data that is used to detect changes in air temperature and water vapour at different levels of the atmosphere, as well as global wind patterns.

High-orbit satellites

- Orbit about 36,000 km above the equator
- High level satellites detect electromagnetic radiation from various levels of the atmosphere.
- Provide images using visible light, useful in observing cloud cover.
- Infrared heat images which show amount of infrared radiation from Earth's atmosphere and Earth's surface features.
- The combined efforts of all these satellites provide a comprehensive image of the earth's weather.

Radar systems

Doppler radar

- Works like a police radar system.
- Radio waves are sent out from antennas on the radar instrument and bounce off water drops and ice particles back to the instrument.
- Detects the direction and speed at which air masses are moving.

Weather Balloons

- Helium-filled balloons that are launched up to 30 km high two or more times per day from weather stations across North America or from airplanes above the ocean.
- Carry instruments that collect data on temperature, pressure, humidity and ice-crystals
- Can also be used to determine speed and direction of upper level winds (using radar systems).

Ground-Based Technology

Instrument	**Weather factor measured**
• Thermometer	• Current minimum & maximum temperatures
• Anemometer	• Wind speed & direction
• Aneroid barometer	• Atmospheric pressure
• Rain Gauge	• Rainfall
• Hydrometer	• Relative humidity

Computer Technology

- Data from weather satellites, aircraft, weather balloons and ground-based instruments are gathered, stored and analyzed by computer software
- Computers linked to satellite communication systems allows information to be sent around the world

Weather System

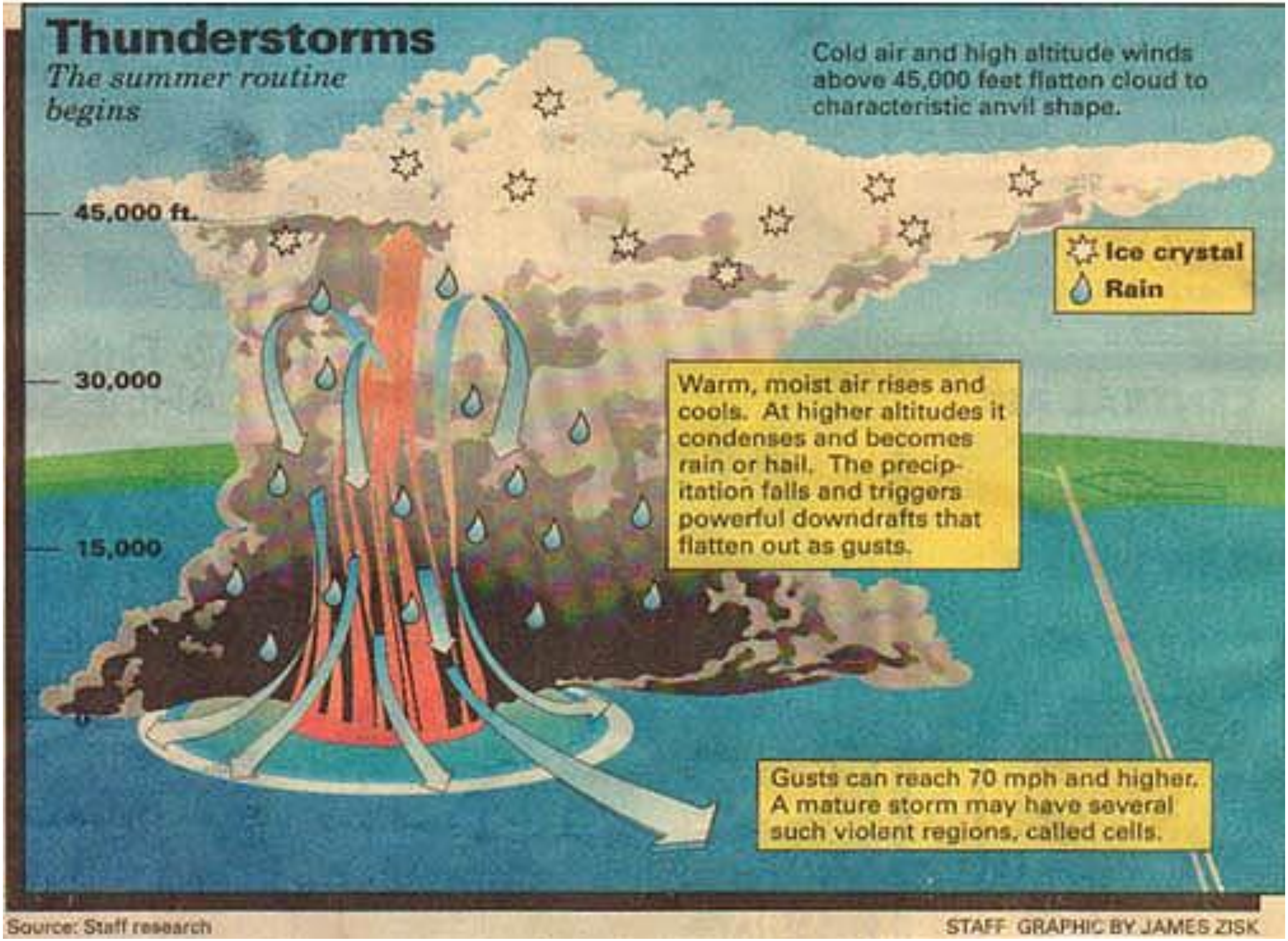
- **Weather System:** a set of temperature, wind, pressure and moisture conditions for a certain region, that moves as a unit over a period of days

Thunderstorms

- A storm with lightning, thunder, heavy rain and sometimes hail.
- Two conditions necessary :

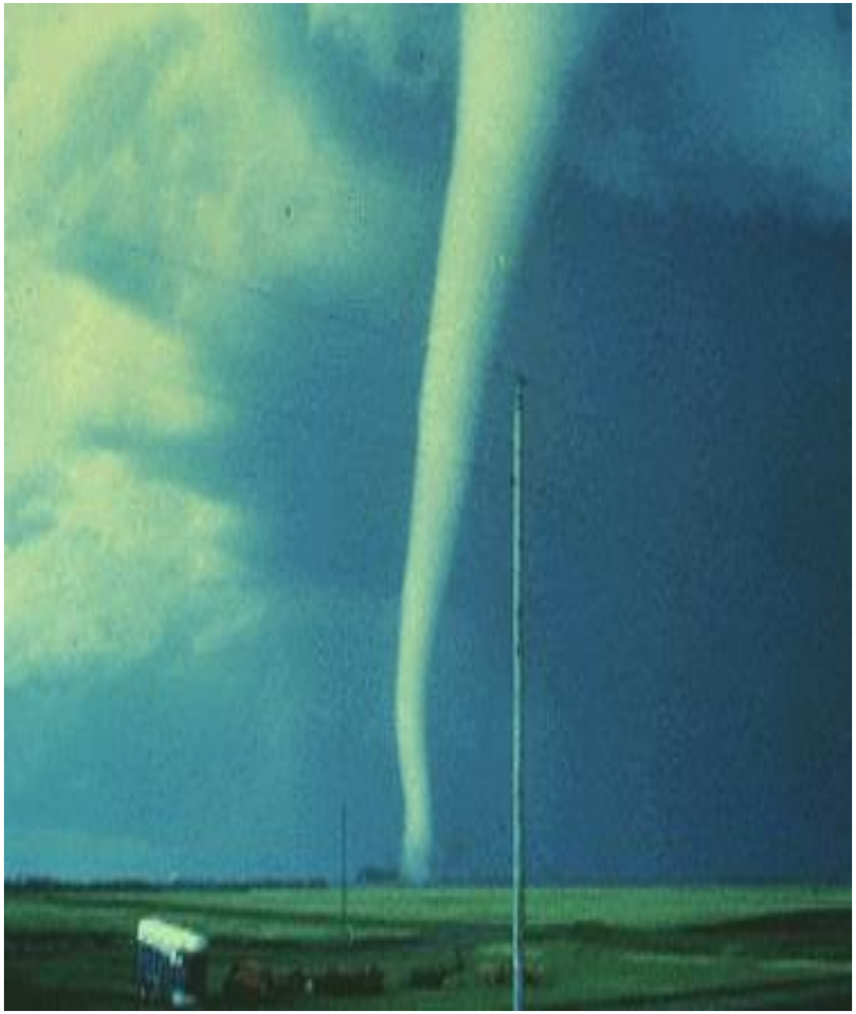
  1. moisture is needed to form clouds and precipitation.
  2. uplift of air must be strong in order to produce clouds reaching high into the atmosphere.

Times-Picayune, 6-12-89



Tornadoes:

- Form in the most severe thunderstorms.
- Fast rising air begins spinning, forming a funnel of air and moisture.
- Rising air causes a pressure difference that increases with speed.
- Travel at speeds of up to 100 km/h.
- At the centre of the funnel cloud wind speeds can reach 500 km/h.
- Tornado Alley in the US stretches from Texas to Nebraska and averages 65 tornadoes a year.



Floods:

- Excess of water from rain, rivers, or oceans that form over land that cannot soak up any more water.

2 Types:

- **Flash**
- **Broadside**

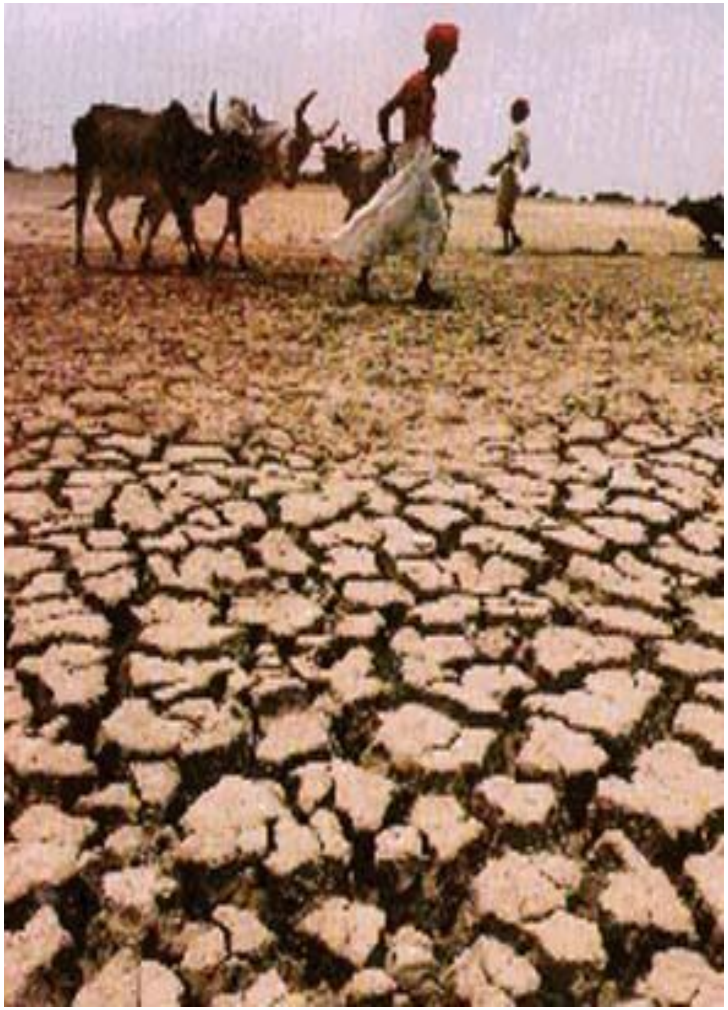
Floods

- **[Flash](#) - quick onset; difficult to predict, little or no warning. (eg. Badger, NL)**

- **<u>Broadside</u> – cover a large land area; seasonal, predictable floods (eg. Monsoon Flooding)**

Drought:

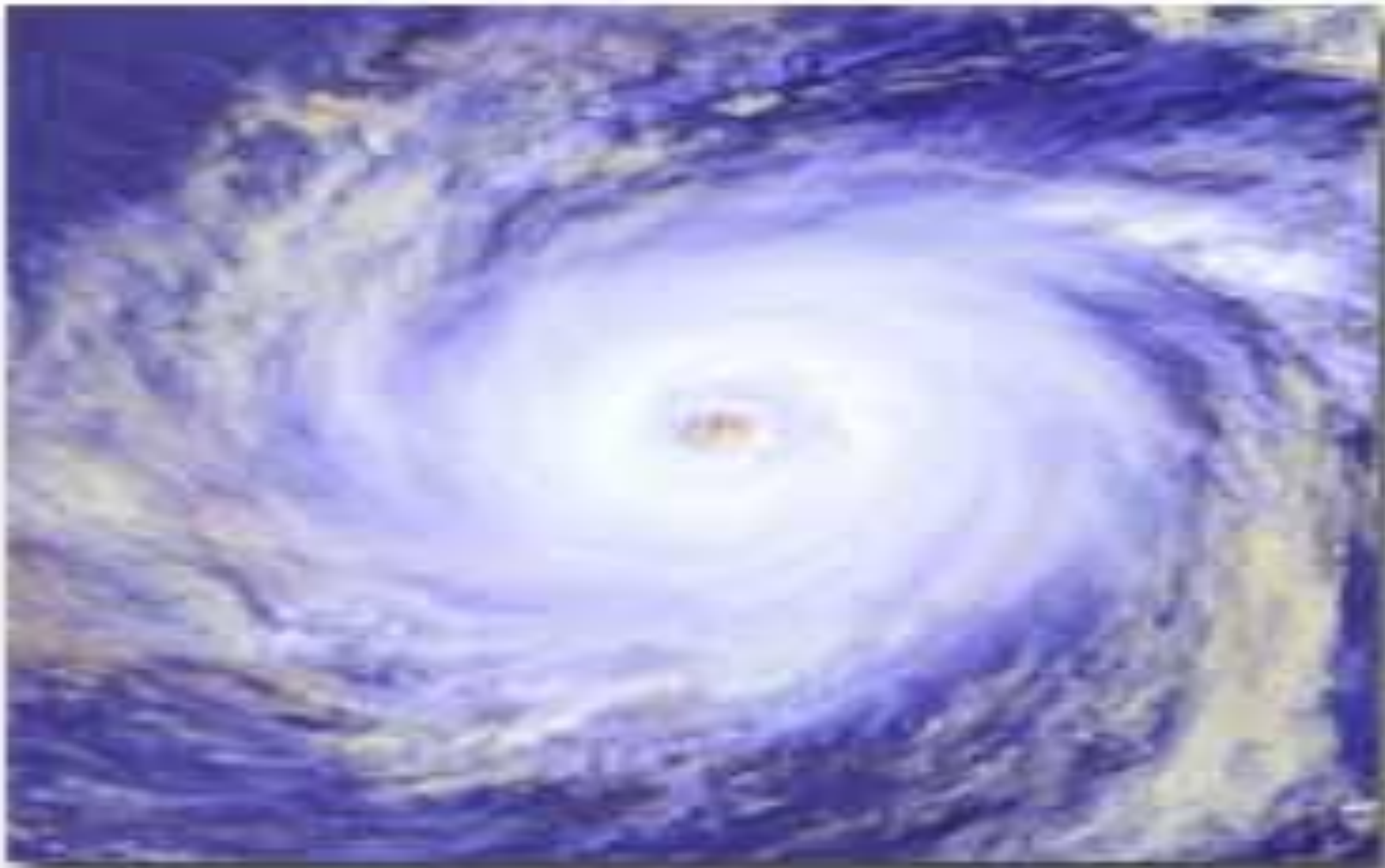
- occurs whenever precipitation is very low over a long time period
- common in areas at or near 30° latitude (high pressure areas with low average yearly rainfall)
- eg. Dust Bowl of 1930's in the prairies



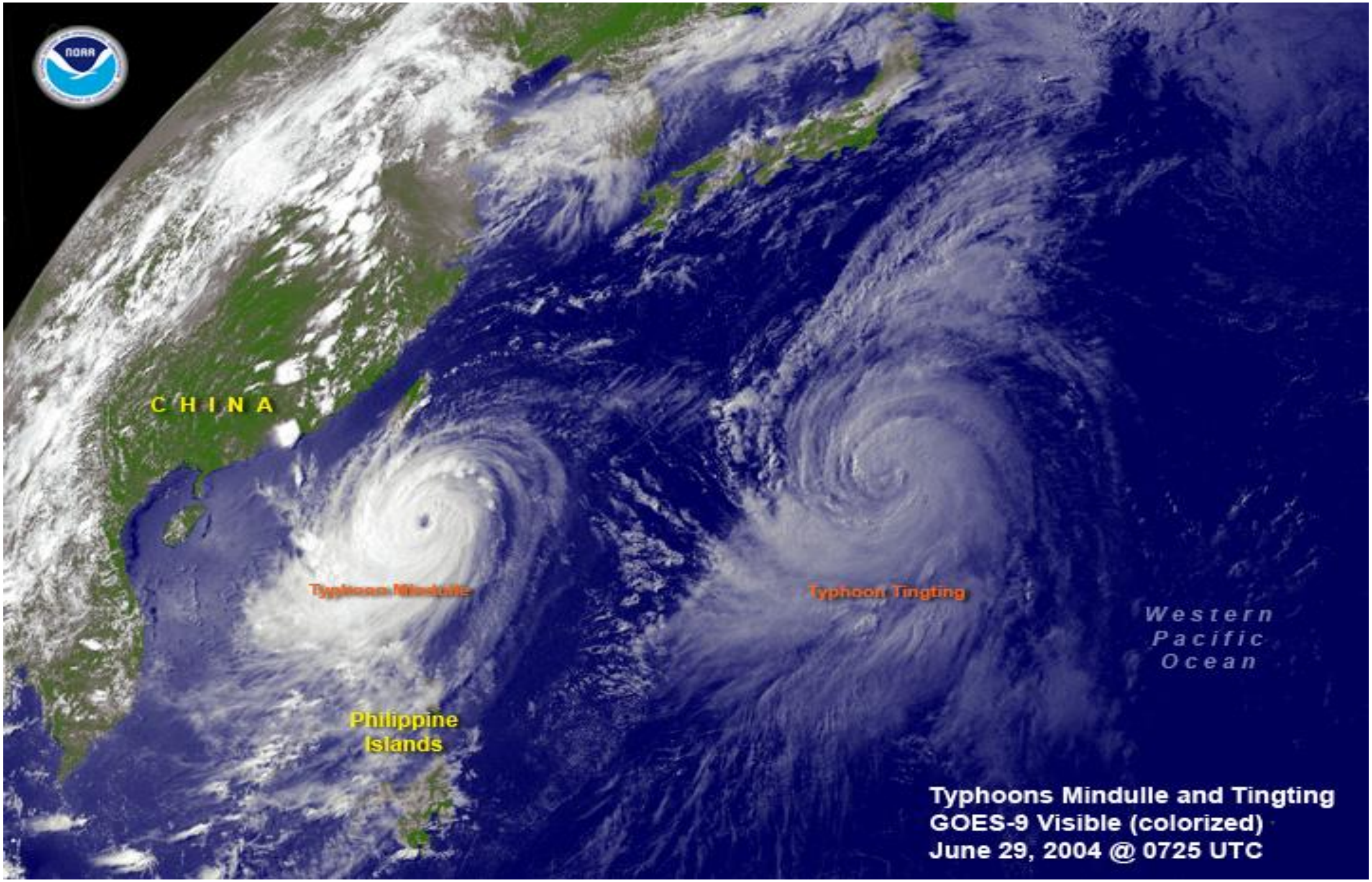
Hurricane, Typhoons and Tropical Cyclones

- All are cyclones: massive high-energy low pressure systems which have resulted from the large amounts of energy from hot, tropical marine air masses spinning off of equatorial ocean areas.
- The names are different due to the regions in which they are found.
- Hurricanes: eg. western Atlantic Ocean, Caribbean Sea, Gulf of Mexico, Eastern Pacific Ocean
- Typhoons: eg. Northwestern Pacific Ocean, China Sea
- Tropical Cyclone: eg. Indian Ocean, area around Australia
- When wind speeds reach 62 km/h it is called a tropical storm, at speeds of 119 km/h it is officially a hurricane.

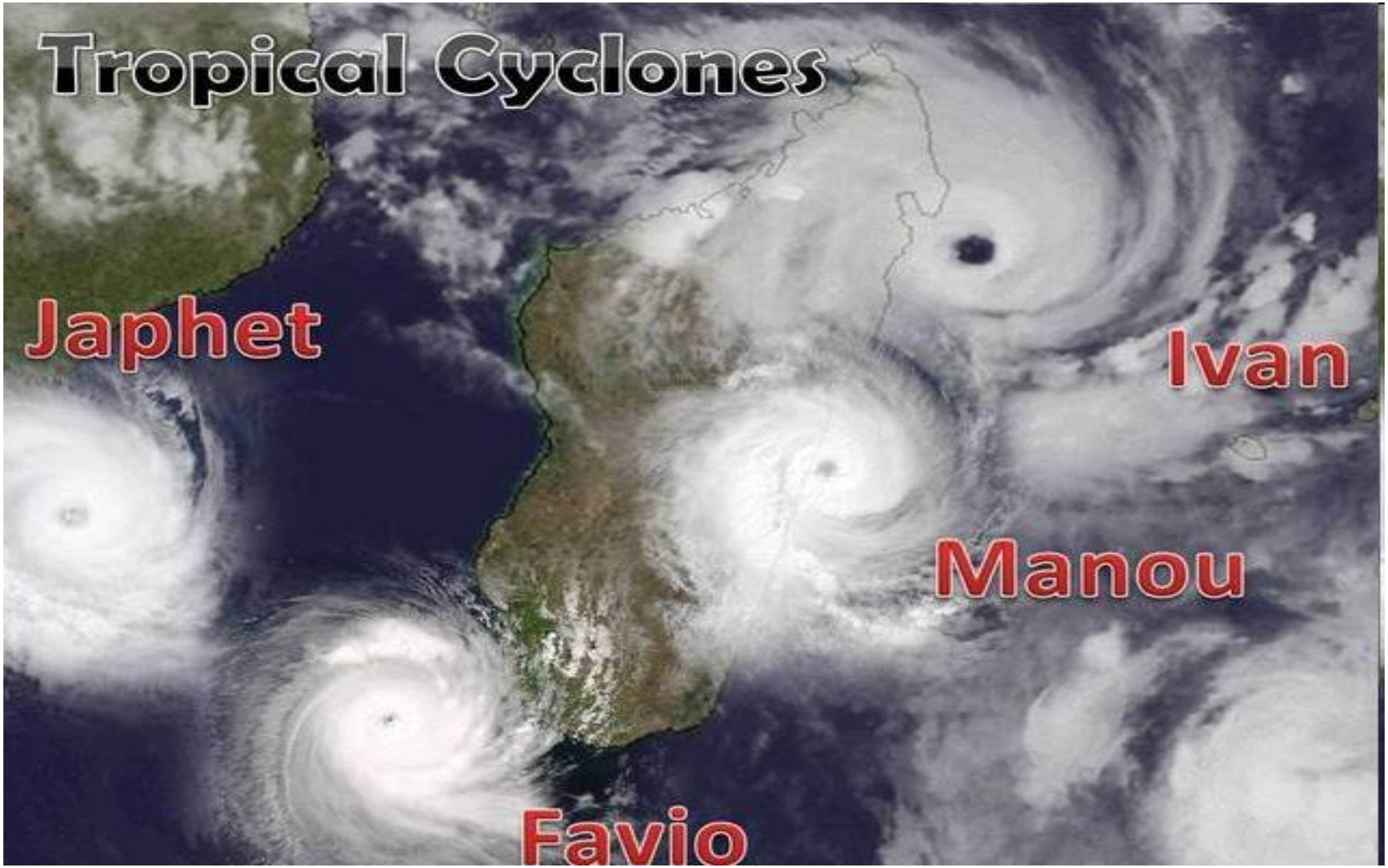
Hurricane



Typhoon

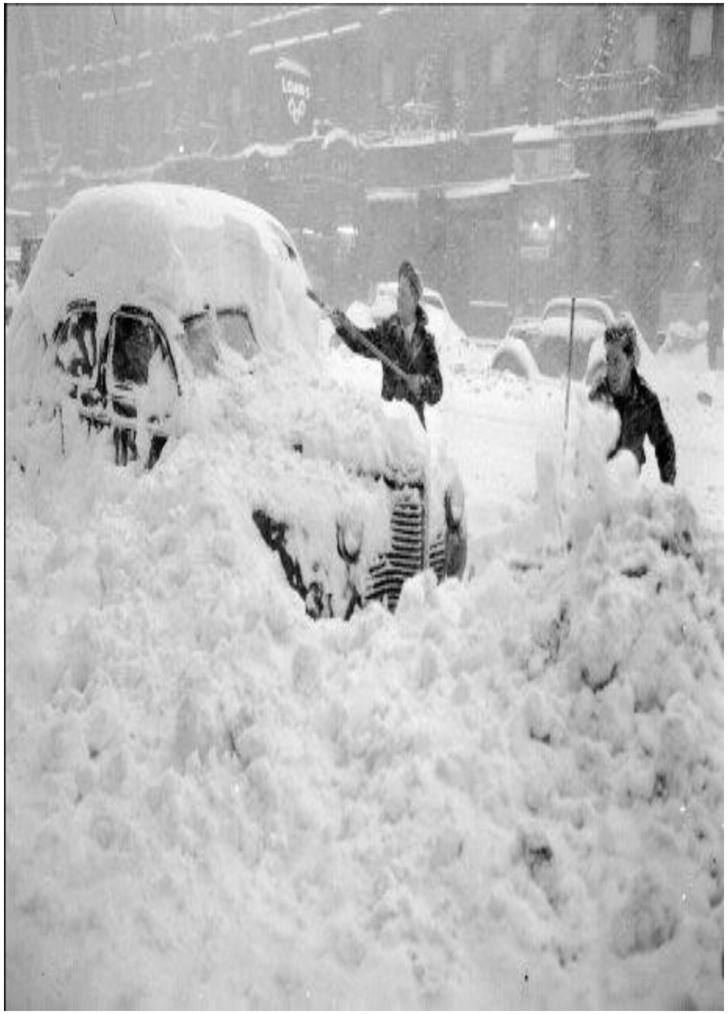

CHINA
Typhoon Tingting
Western Pacific Ocean
Philippine Islands
Typhoons Mindulle and Tingting
GOES-9 Visible (colorized)
June 29, 2004 @ 0725 UTC

Tropical Cyclones



Blizzards

- Severe snow storms with strong winds (> 55 km/h), low temperatures, an visibility less than 0.2 km.
- Can develop when a warm moisture-laden air mass moves northward and meets a cold Arctic air mass, under a strong jet stream.



Ice Storms

- Freezing rain that lasts for several hours.
- Can occur when a warm air mass meets a cold air mass and the cold air mass pushes the warm one upward.
- The moisture in the warm condenses into clouds and ice crystals. As ice crystals fall through air mass they melt to form rain.
- The raindrops fall through cold air mass, cool and then freeze instantly when they hit a cold object on the ground.
- 1998 ice storm in eastern Ontario, southern Quebec and parts of New Brunswick.

Ice Storms

Heat Wave

- A period of more than 3 days at or above 32° C.
- Can occur when southern continental air masses produce long term warm, high pressure systems as they fall over regions in central Canada.

Heat Wave

- Often exaggerated over cities where it may produce a "temperature inversion" which traps warm air and pollution over these regions preventing normal convection from occurring.
- Can feel hotter with high humidity.
- Humidex Scale: combines the temperature and relative humidity to give a temperature indicating how it feels to humans. (Table 1, p. 605)

Extreme Cold

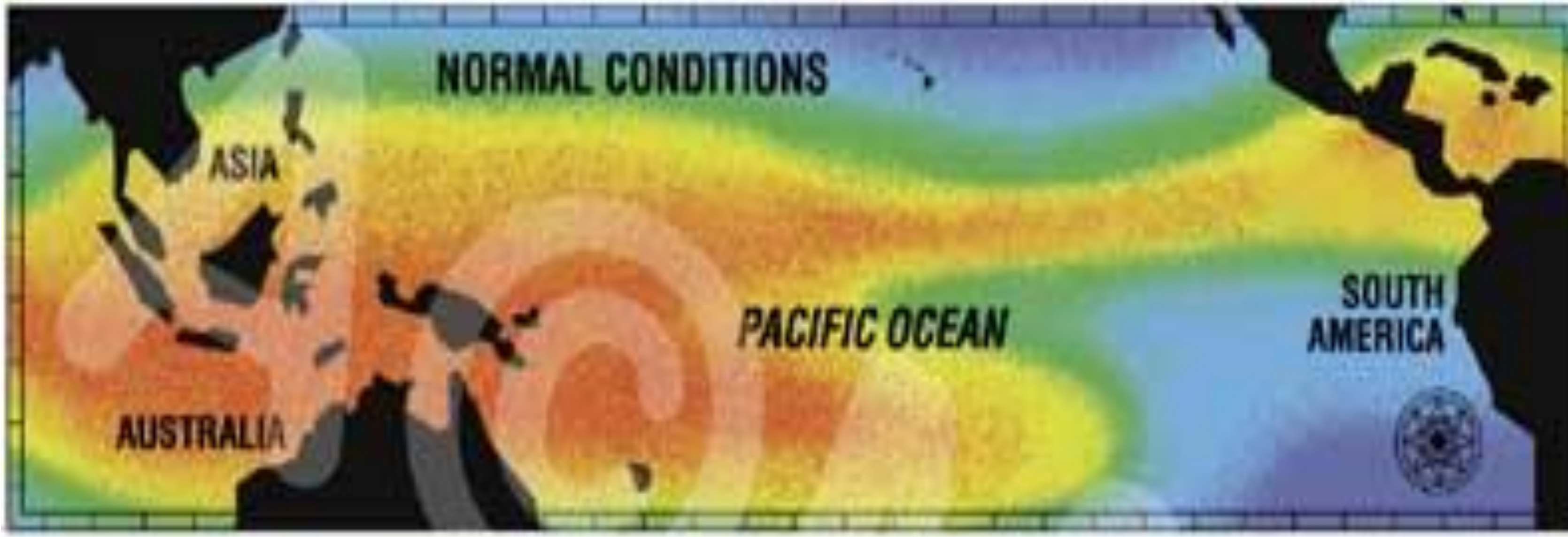
- Can occur when large polar air masses may be drawn southward bringing much cooler than normal temperatures.
- Can feel colder with high winds.
- Wind chill factor: takes into account the cooling effect of wind to indicate what the temperature would feel like with the wind. (Table 2, p. 606 + Fig. 4)

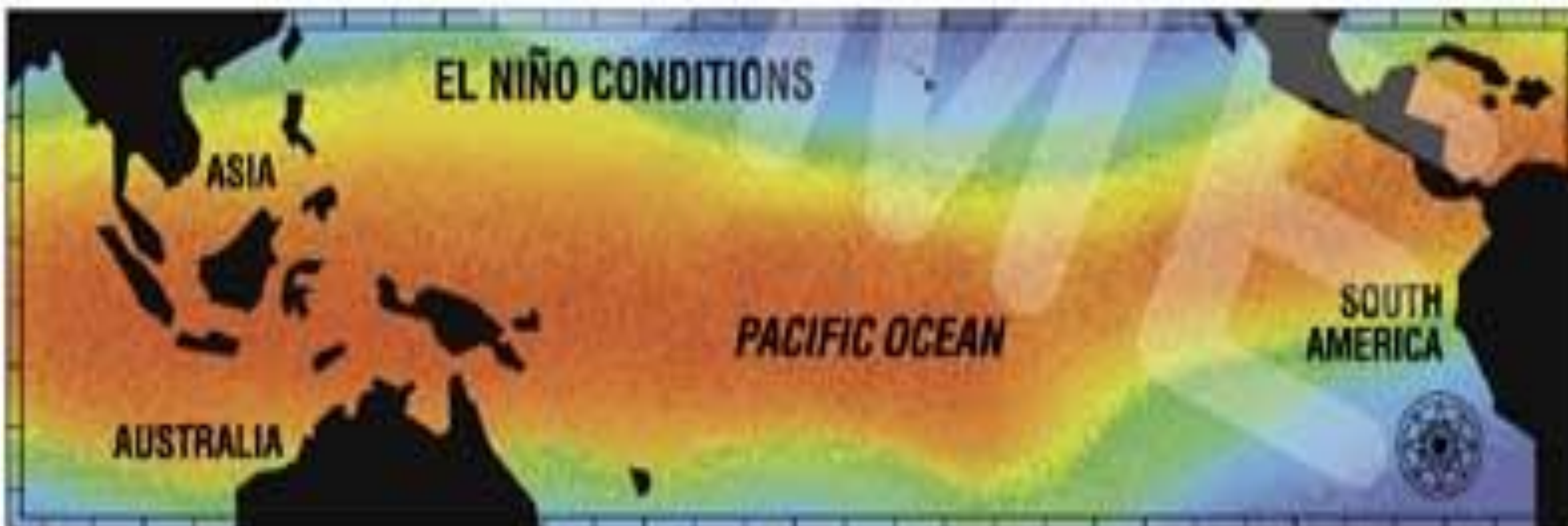
EL Nino and La Nina

- Major changes in the seasonal weather systems in the South Pacific resulting from changes in the ocean convection currents

El Nino:

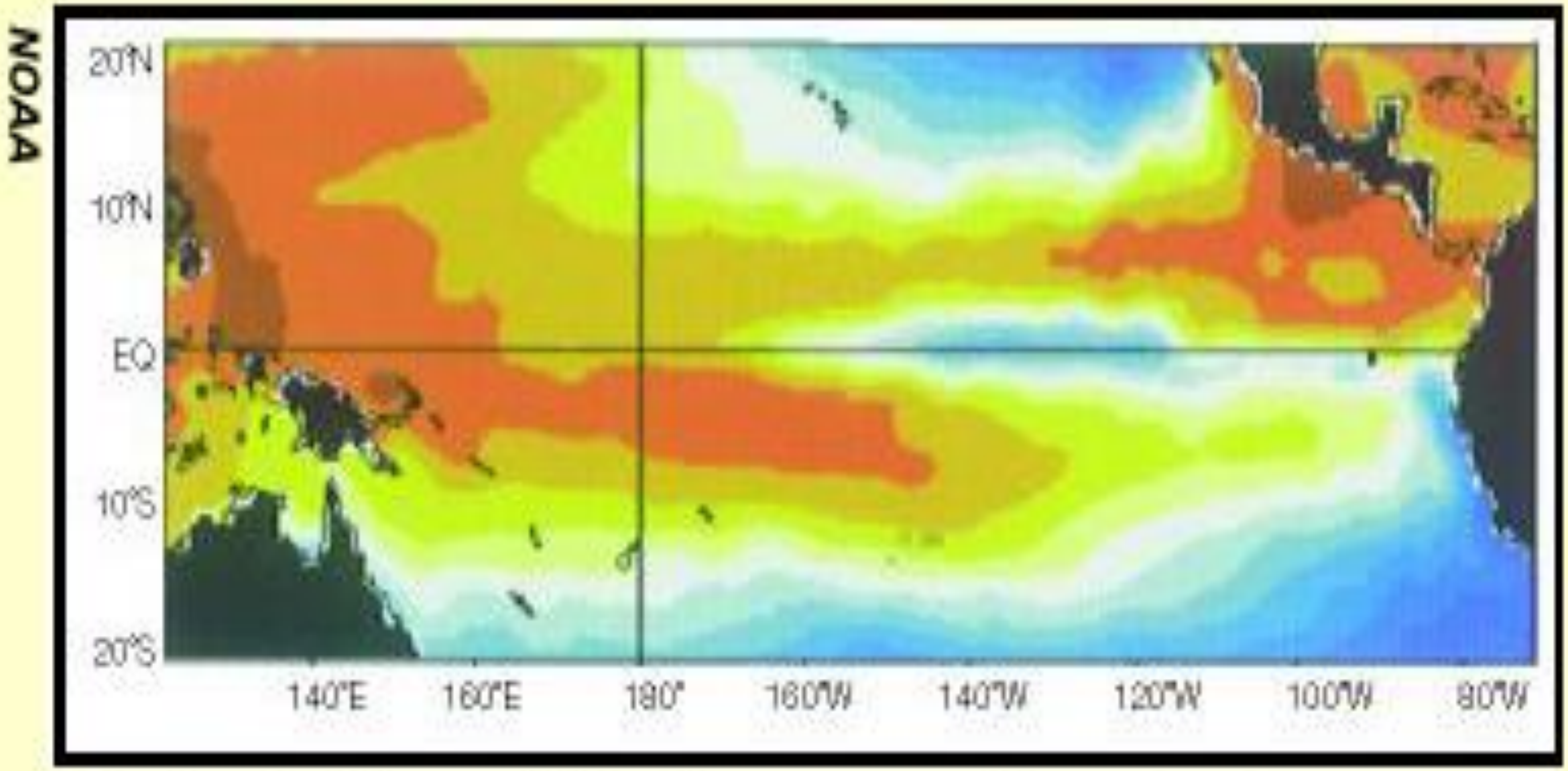
- A shift in the ocean currents, temperatures (water becomes warmer) and atmospheric conditions in the tropical Pacific Ocean.
- Caused by high surface water temperatures and water levels in the western Pacific.
- An abnormal warming of surface ocean waters.
- May result in warm temperatures in Canada (Fig. 3, p. 613).
- Usually occurs once every 3-5 years.


NORMAL CONDITIONS
ASIA
AUSTRALIA
PACIFIC OCEAN
SOUTH
AMERICA


EL NIÑO CONDITIONS
ASIA
AUSTRALIA
PACIFIC OCEAN
SOUTH
AMERICA

La Nina:

- A shift to colder than average ocean temperatures in the Eastern Pacific.
- Caused by low surface water temperatures in the eastern Pacific.
- Cooler than normal sea-surface temperatures.
- May result in colder temperature in Canada.
- Hurricanes develop more easily.



Cool water (shown in blue) has emerged in parts of the equatorial Pacific. Meteorologists predict further cooling leading to the development of La Nina.