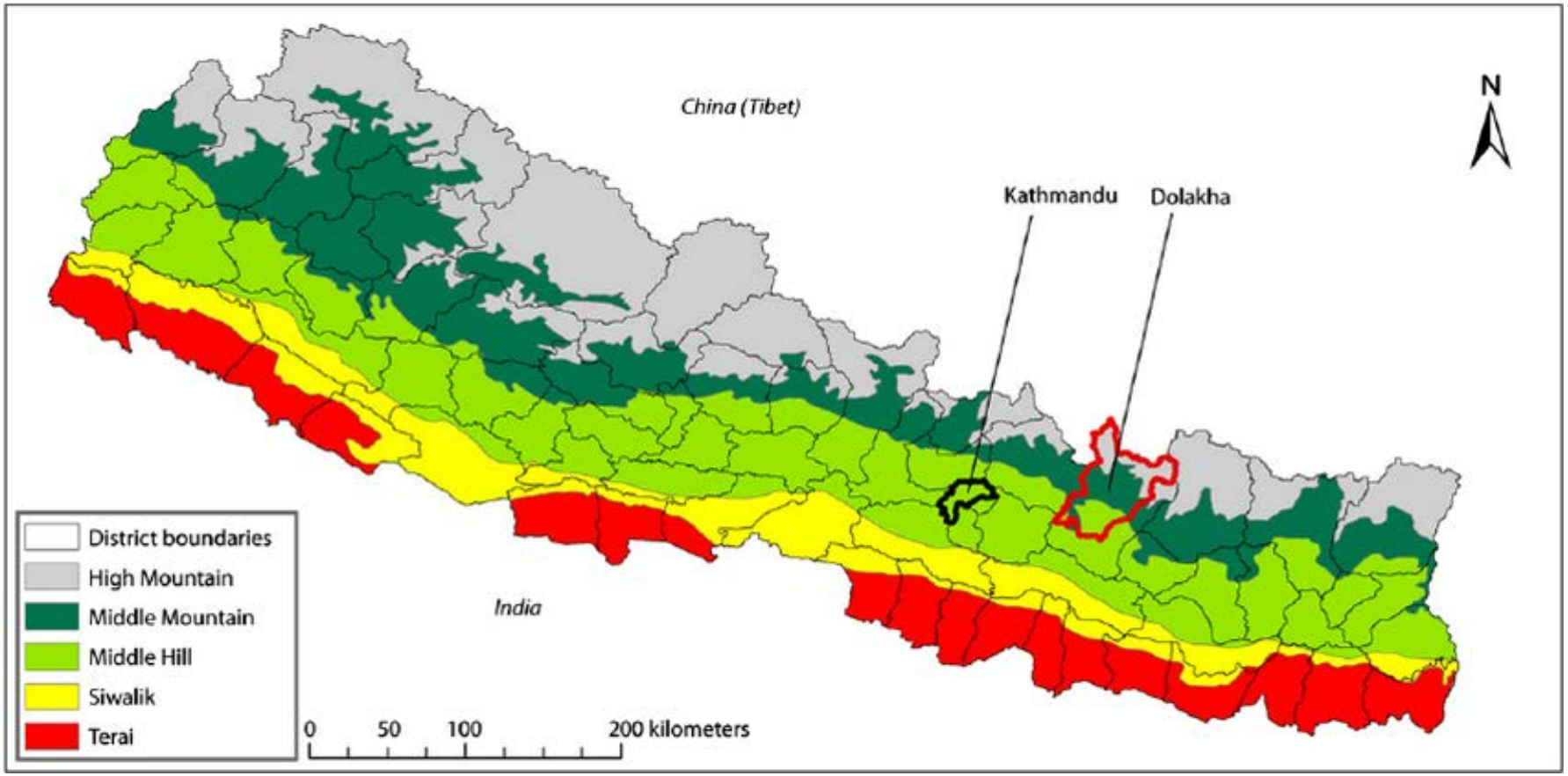
Hydrological Processes in Different Climatic Zone

- Climatic zones of Nepal
- River system of Nepal
- Different between Watershed and Basin

Climatic zones of Nepal



The topological features of Nepal are so persistent along the length of the country that cross - section do not differ radically. Nepal is usually divided into five topographical region from South to North as follows :-

1. Terai Region - 60 to 200m - Tropical Climate
2. Siwalik Ranges - 300 to 1500m - Mesothermal Climate
3. Middle Mountains - 1500 to 2500 - Mesothermal Climate
4. High Mountains - 2000 to 4000m - Microthermal Climate
5. High Himalaya Region - 4000 to 8848m - Alpine Climate

Sub tropical

Five major climatological zones in Nepal there are :

1. Subtropical
2. Warm Temperature
3. Cool Temperature
4. Alpine
5. Arctic

Precipitation occurs in Nepal major two times they are :

1. Summer or Monsoon Season
2. Winter Season

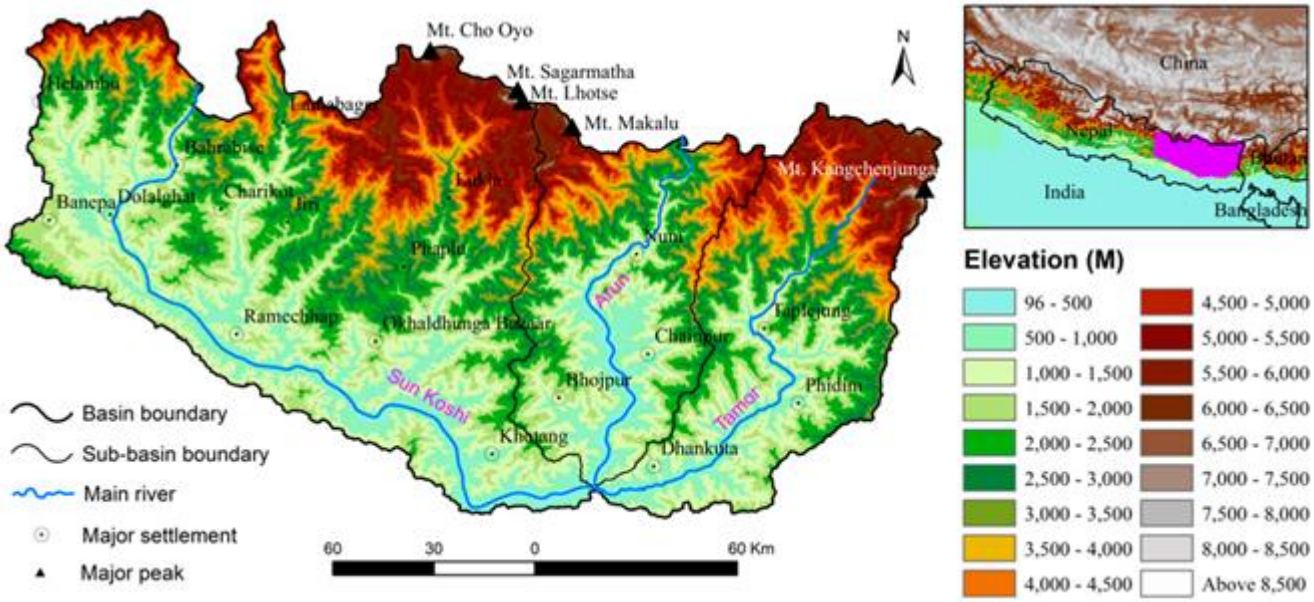
River System of Nepal

- Nepal is rich in water resources. There are about 6000 rivers in Nepal having drainage area of 191000 sq. km, 74% of which lies in Nepal alone. There are 33 rivers having their drainage areas exceeding 1000 sq. km. Drainage density expressing the closeness of spacing of channels is about 0.3 km/sq. km. If this natural resource is properly harnessed, it could generate hydropower; provide water for irrigation, industrial uses and supply water for domestic purposes. Based on the nature of their sources and discharge, they can be broadly classified into three main river system and its categories which are.
- The first category consists of perennial rivers that originate in the Himalayas and carry snow fed flows with significant discharge even in the dry season. This includes the Koshi Gandak and Karnali river systems.
- Second categories originate from Mahabharat range which includes Babai, West Rapti, Bagmati, Kamala, Kankai and Mechi etc. Streams and rivulets originating mostly from the Chure hills.
- Third category; these rivers cause flash floods during monsoon rains and remain without any flow or very little flow during the dry season.

A basin is a contiguous area that drains to a common outlet. It is the area around a stream that actually sends water into the stream.

River system of Nepal

Koshi


Mt. Cho Oyo
Mt. Sagarmatha
Mt. Lhotse
Mt. Makalu
Mt. Kangchenjunga
Phelambu
Bahrabise
Banepa
Dolalghat
Charikot
Jiri
Lukla
Phaplu
Num
Arun
Ramechhap
Okhaldhunga
Chainpur
Taplejung
Bhojpur
Phidim
Sun Koshi
Tamor
Khotang
Dhankuta
N
Basin boundary
Sub-basin boundary
Main river
Major settlement
Major peak
60
30
0
60 Km
China
Nepal
India
Bangladesh
Elevation (M)
96 - 500
500 - 1,000
1,000 - 1,500
1,500 - 2,000
2,000 - 2,500
2,500 - 3,000
3,000 - 3,500
3,500 - 4,000
4,000 - 4,500
4,500 - 5,000
5,000 - 5,500
5,500 - 6,000
6,000 - 6,500
6,500 - 7,000
7,000 - 7,500
7,500 - 8,000
8,000 - 8,500
Above 8,500

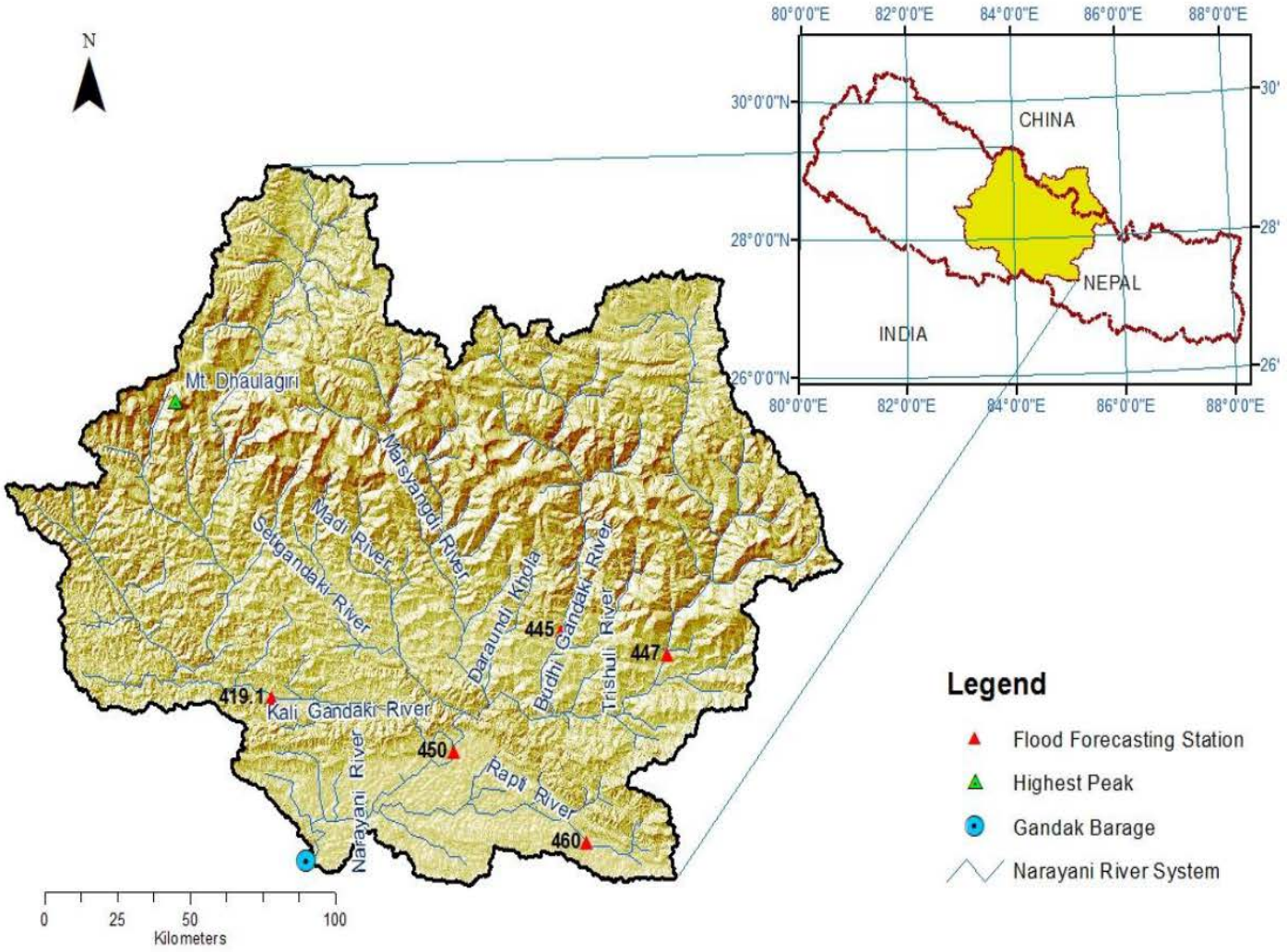
Koshi

- The river system of eastern Nepal is occupied by the Koshi River Basin, which is also known as the Sapta Koshi River, i.e., a network of seven major rivers flowing through the Koshi River Basin. All these seven rivers, namely, the Tamor River, the Arun River, the Dudh Koshi River, the Likhu River, the Tama Koshi River, the Sun Koshi River, and the Indrawati River, from east to west, originate from the High Himalaya. Among the tributaries, the Sun Koshi-Bhote Koshi, the Tama Koshi, and the Arun River originate in Tibet.

Kosi River

- The Kosi river system is the largest river system in Nepal and widest among all that have their origin in the Himalayan excepting the Brahmaputra and Indus. **This river rises at the Tibet region of China at an altitude of 5400m and the joins the Ganga near Kursela(Bihar) after traveling about 720Km.**It is drained by the Kosi River, which has seven tributaries. It is locally known as the Sapt Kosi, which means seven Kosi rivers (Tamur, Likhu Khola, Dudh Kosi, Sun Kosi, Indrawati, Tama Kosi, and Arun). **The total drainage area is 74500 sq Km of which 40000 sq Km in Nepal, 33000 sq.Km in Tibet (China) and 11000sq.Km in India.** The principal tributary is the Arun, which rises about 150 kilometers inside the Tibetan Plateau which contribute 37% from total water. Similarly Sun Kosi contributes 44% and Tamor contributes 19 % from total water.

Narayani


N
80°0'0"E
82°0'0"E
84°0'0"E
86°0'0"E
88°0'0"E
30°0'0"N
28°0'0"N
26°0'0"N
CHINA
NEPAL
INDIA
Mt. Dhaulagiri
Marsyangdi River
Madi River
Setgandaki River
Daraundi Khola
Budhi Gandaki River
Trishuli River
445
447
419.1
Kali Gandaki River
450
Rapti River
Narayani River
460
0
25
50
100
Kilometers
Legend
Flood Forecasting Station
Highest Peak
Gandak Barage
Narayani River System

Narayani

- The river network of central Nepal is occupied by the Gandaki River system, which is popularly known as Narayani. The river network forming Narayani comprises the Trishuli River, the Budhi Gandaki River, the Marsyangdi River, the Seti Gandaki River, and the Kali Gandaki River. Among these rivers, some parts of the Kali Gandaki River and the Budhi Gandaki River and major parts of the Trishuli River lie in Tibetan territory and flow down through the Himalayan range to Nepal.

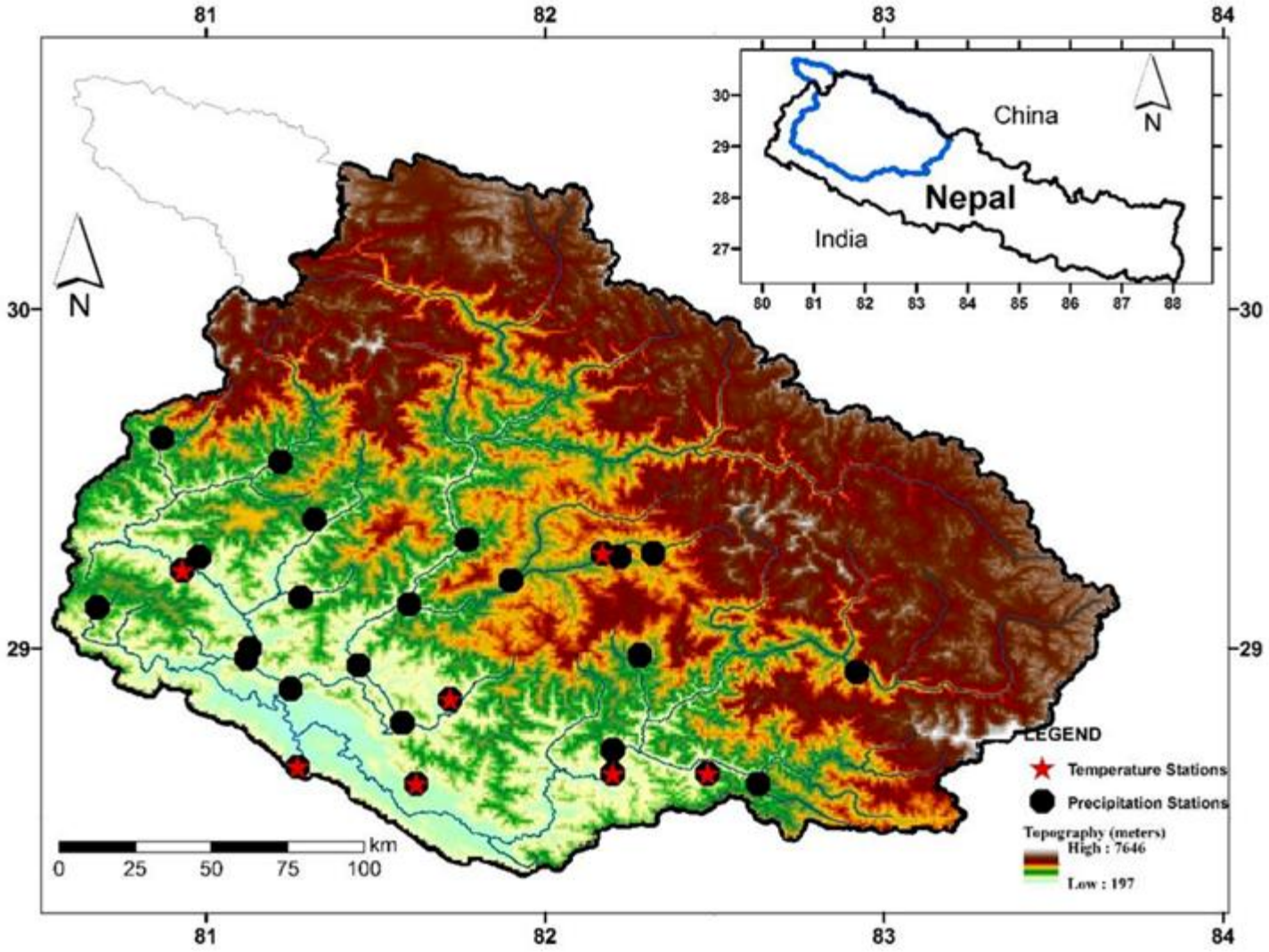
Narayani River

- The Narayani River drains the central part of Nepal. **It rises of 7620 m in Tibet and enters Nepal at Rasuwa District.** It has seven major tributaries (Daraudi, Seti, Madi, Kali, Marsyandi, Budhi, and Trisuli). The Kali, which flows between the Dhaulagiri Himal and the Annapurna Himal is the main river of this drainage system. In the south there lies a deep gorge of 8200ft, the deepest gorge. This basin has relatively high flow during dry season. Finally Kali Gandaki and Trisuli join at NarayanGhat to form Narayani (Gandaki). **The river enters into the plain at Tribeni (Bihar) and after for another 300 Km it joins the Ganga. The total drainage of the Gandaki is 46,300Sq.Km of which 7620 sq Km is in India**

Narayani River

- Narayani basin is one of the key river systems of Nepal that originates from Tibetan Plateau in the north from China and drains almost central to western part of Nepalese territory. The river system is also known as Gandak and ends up at Gandak Barrage at the India-Nepal boarder. The basin extends from 27°21'N to 29°29.7'N in latitude and from 82°52.6'Eto 85°48E' longitude. The highest elevation of the basin relief is 8167m asl which is the highest peak of Mt. Dhaulagiri within the basin. The outlet point of the basin is at the India-Nepal boarder at an altitude of 103m asl as depicted from Google Earth. The Narayani River System is the combination of seven big rivers namely Kaligandaki, Marsyangdi, Budhigandaki, Setigandaki, Madi, Trisuli, and Daraudi. The total basin area as computed from SRTM 90 meter resolution DEM data for the outlet point is found to be 36490 km^2. About 12 percent of land area for the basin is in the territory of China

Karnali Basin



Karnali Basin

- The Karnali River is about 507 km in length and is formed by the joining of Mugu Karnali and Humla Karnali at Galwa. The West Seti River and the Bheri River are the main tributaries of the Karnali River. The Kawari River and the Tila River are other minor tributaries of the Karnali River, which originate from the glaciated region of Nepal, whereas the Humla Karnali River originates in Tibet.

Karnali Basin

The Karnali Basin is located on the western part of Nepal between 28° 19' N to 30° 27' N latitudes and 80° 33' N to 83° 42' N longitudes encompassing 21 districts, some wholly and some partly. out two-thirds of the sub basin lies in the Mid-Western Development Region while the remaining one-third lies in the Far-Western Development Region. Karnali is a perennial trans-boundary river originating from the Himalayas on the Tibetan plateau. It rises in the southern slopes of the Himalayas in Tibet, in the glaciers of Mapchachungo, **The catchment area of Karnali at Chisapani is approximately 45,390 km^2** (NDRI, 2009) **and is roughly in a shape of rectangle with length 230 km and width 200 km.** The river flows south through one of the most remote and least explored areas of Nepal.

The Karnali River basin starts from the high mountains and carries snow fed flows where it integrates most of the river systems covering small to medium scale rivers situated in the mid-western and far-western regions. The headwaters of Karnali River lies about 230 km North from Chisapani (mainstream Karnali River length) covering mountainous ranges with altitude more than 5,500 m up to an elevation above 7,700 m.

Major portion of the basin, especially the upper areas are within 15 to 45 degrees, with some steep areas having slopes greater than 60 degrees. However, the low lying areas in the Terai are below 15 degree slope. The Karnali River at Chisapani drains the entire Karnali Basin consisting of its main tributaries Humla Karnali, Mugu Karnali, Tila, Seti, Bheri, Thuli Gad, Geruwa, Kauriala and a number of minor ones (Dulal and Bhattarai, 2014). According to the nature of soil in the region, Karnali River with its tributaries tend to carry huge amount of sediment load during the rainy season in the form of sands, coarse gravels, cobbles and boulders. (GEOCE, 2004).

Processes of Precipitation

Introduction

- All forms of water that reach the earth from the atmosphere is called Precipitation.
- The usual forms are rainfall, snowfall, frost, hail, dew. Of all these, the first two contribute significant amounts of water.
- Rainfall being the predominant form of precipitation causing stream flow, especially the flood flow in majority of rivers. Thus, in this context, rainfall is used synonymously with precipitation.

Precipitations Types and forms

Four Basic Condition to be satisfied:

Accumulation of Moisture of sufficient intensity

Cooling of air to the dew point Temperature

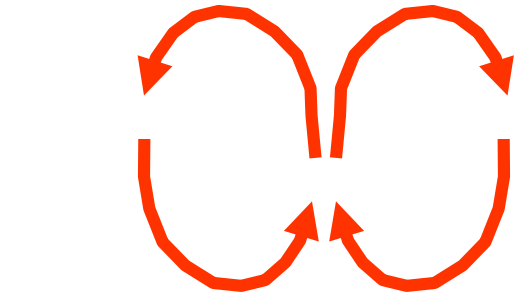
Condensation

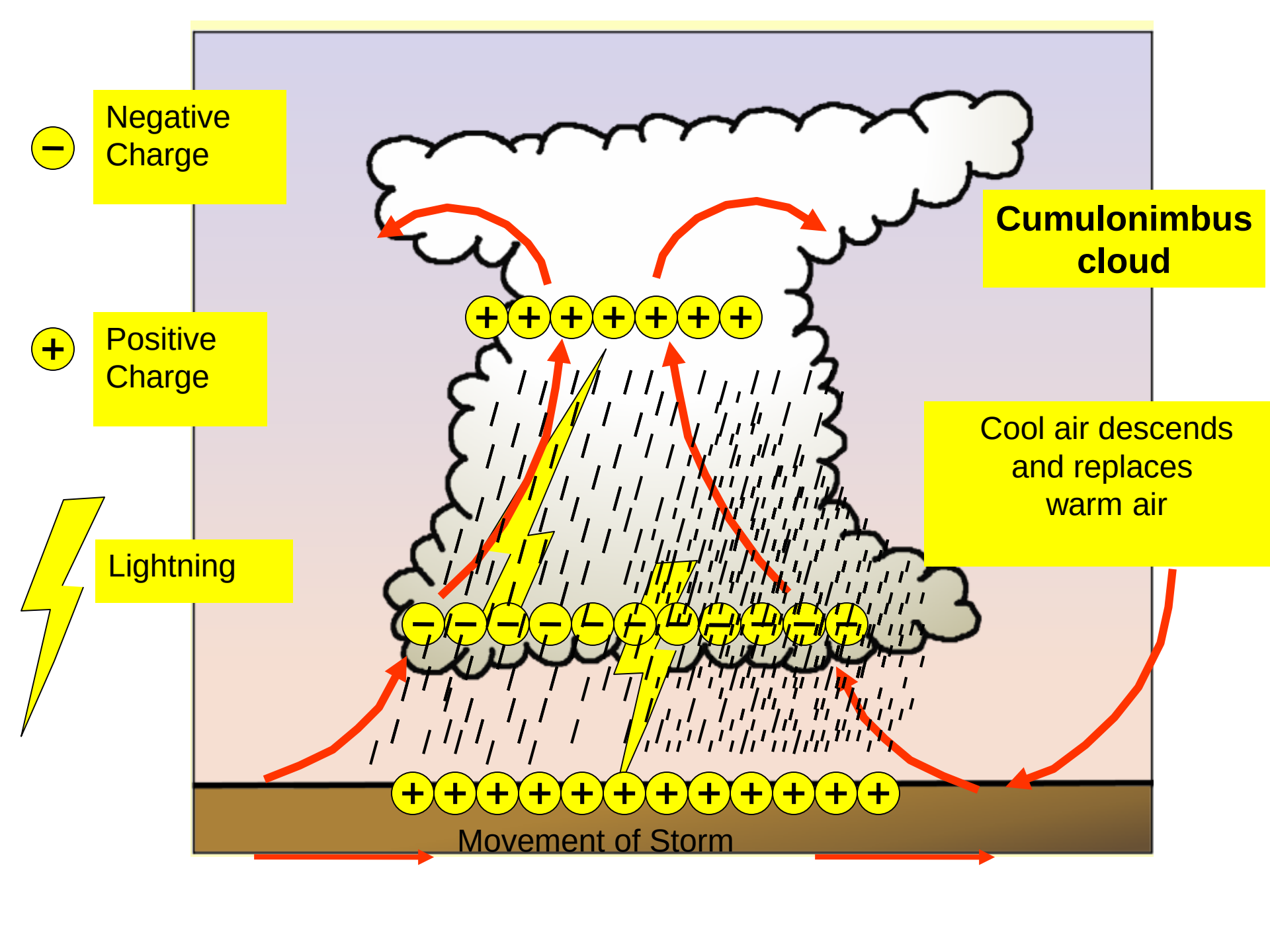
Growth of small water droplets to precipitable size

Convectional Rain

- During summer days the earth's surface can becomes very hot.
- This can cause an intense warming of the air making it very buoyant.
- The air rises quickly.
- As it does so it expands and cools. The air can no longer hold
- the moisture; condensation takes place and rain forms.

- The cool air then falls and
- is caught and dragged back
- upward by more rising air
- forming a convection cell.




Negative Charge
Positive Charge
Lightning
Cumulonimbus cloud
Cool air descends and replaces warm air
Movement of Storm

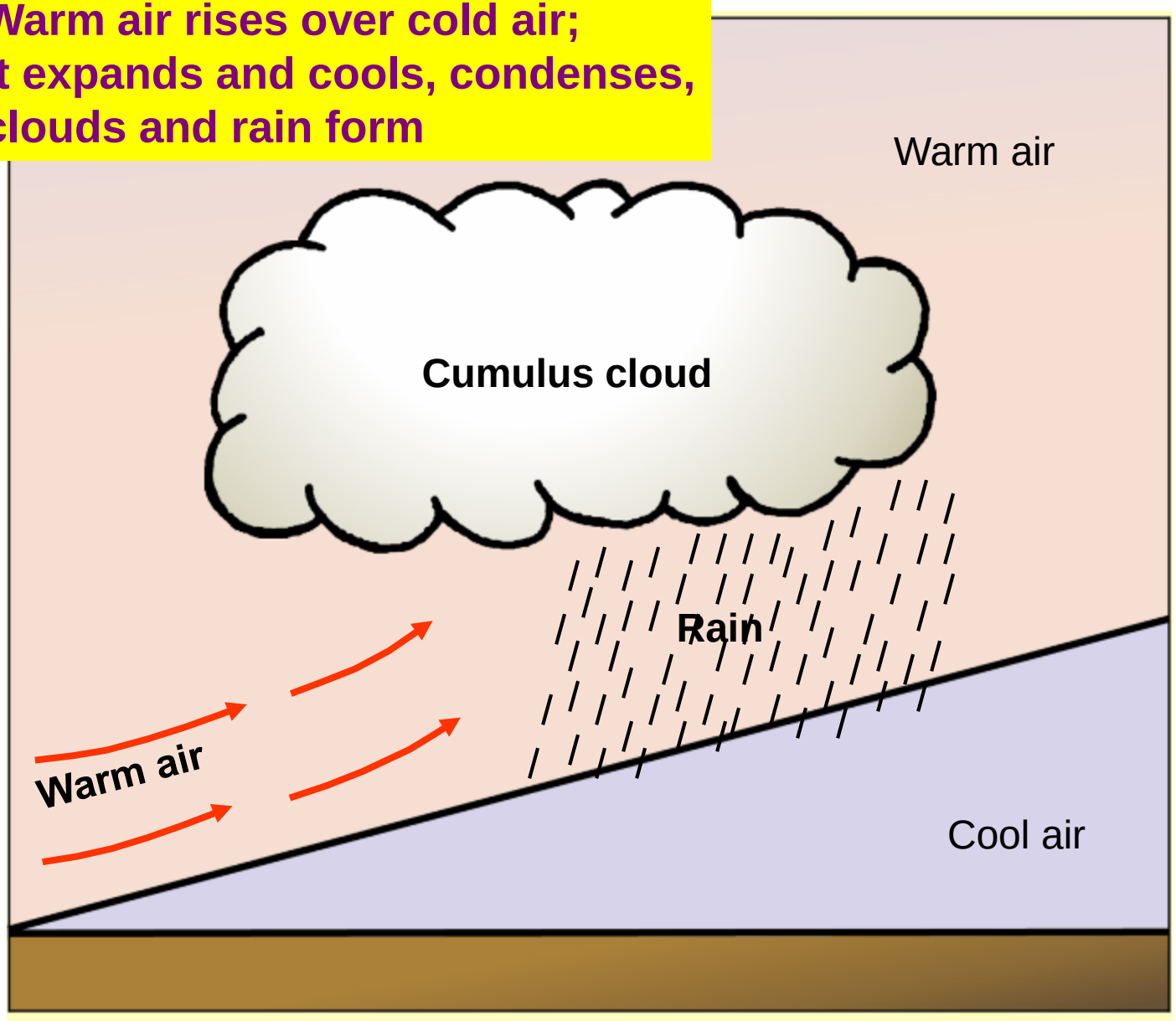
Cyclonic (Frontal) Rain

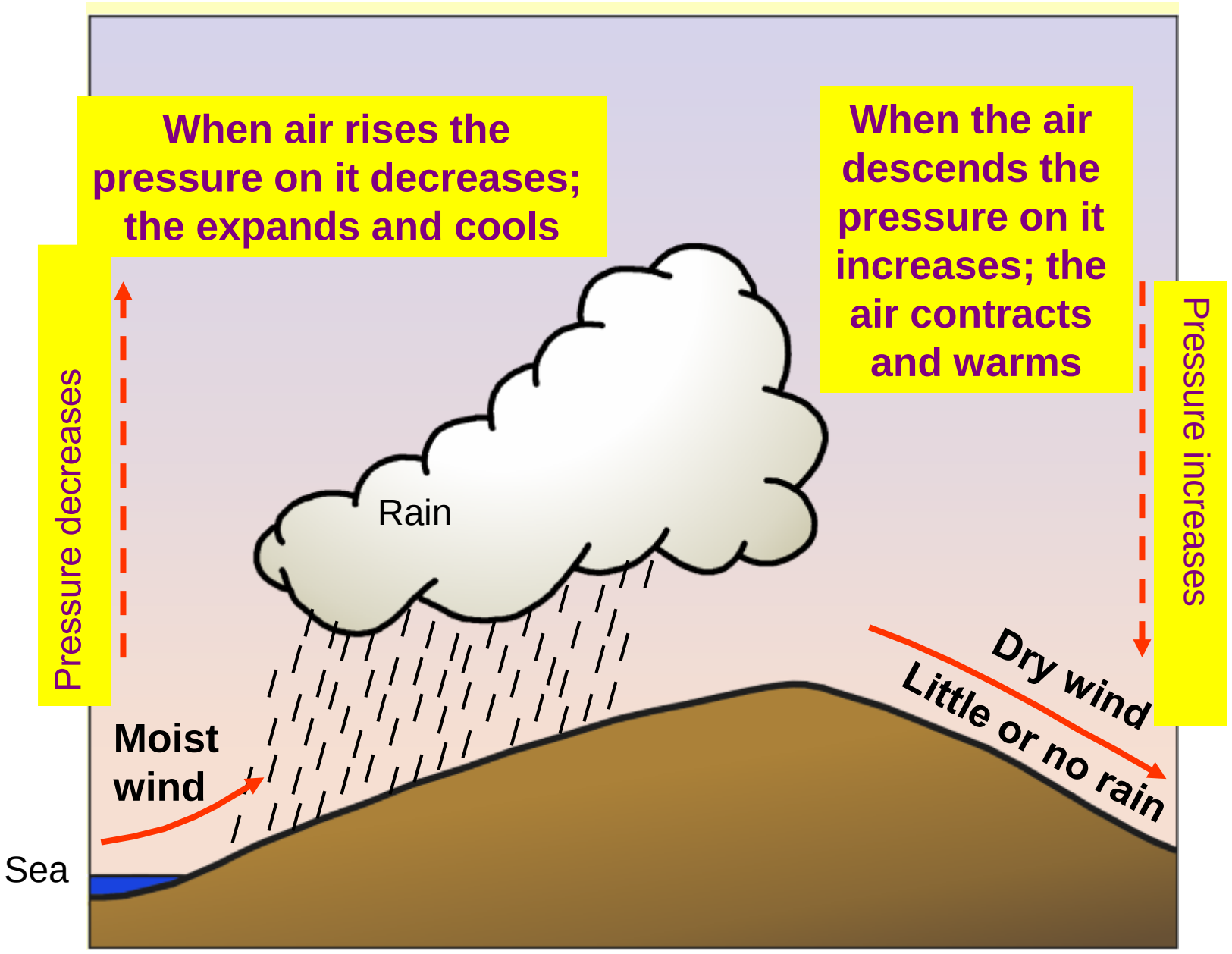
- A warm air mass tries to force into a cold air mass.
- The warm air is lighter and less dense than the cold air and so is forced to rise over it.
- As the warm air rises it expands and cools and so rain forms.

Orographic Rain

- Upland areas force the warm moist air upward, where it cools.

**Warm air rises over cold air;
it expands and cools, condenses,
clouds and rain form**




When air rises the pressure on it decreases; the expands and cools
When the air descends the pressure on it increases; the air contracts and warms
Pressure decreases
Pressure increases
Rain
Moist wind
Dry wind
Little or no rain
Sea

Precipitation Formation

- For precipitation to form, millions of cloud droplets must somehow coalesce into drops large enough to sustain themselves during their descent.
- The two mechanisms that have been proposed to explain this phenomenon are:
  - the **Bergeron process**, which produces precipitation from cold clouds (or cold cloud tops) primarily in the middle latitudes, and
  - the warm cloud process most associated with the tropics called the **collision-coalescence process**.

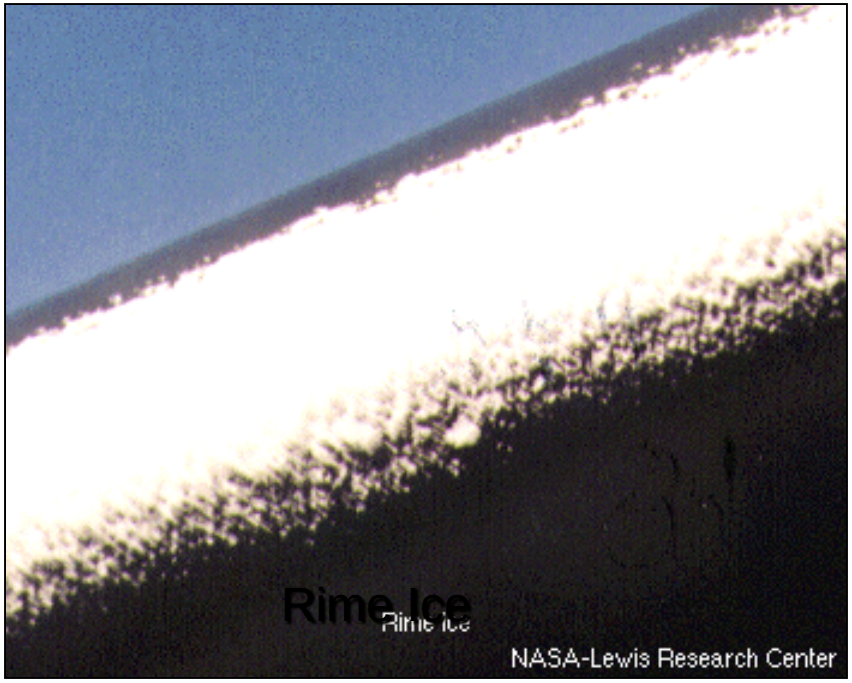
Collision Coalescence Process

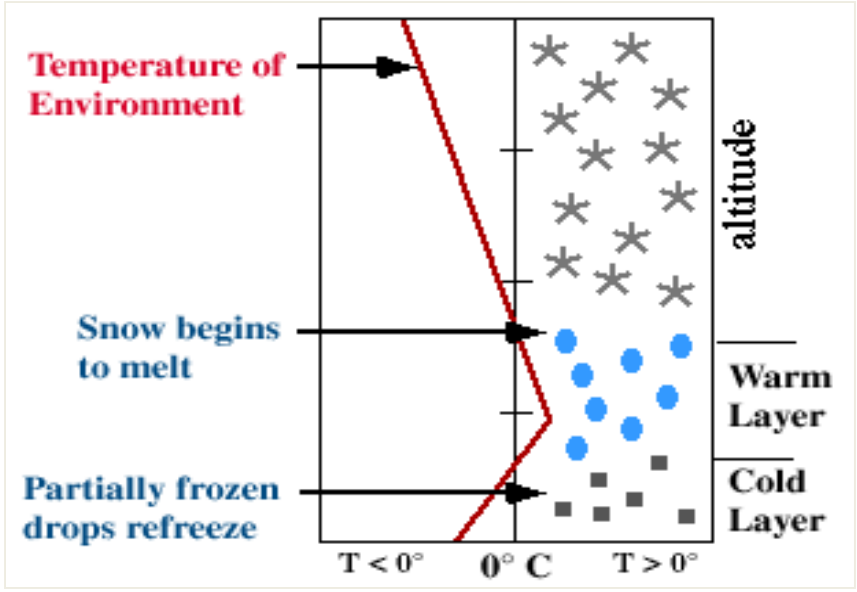
Precipitation Types

- The two most common and familiar forms of precipitation are:
  - **rain** (drops of water that fall from a cloud and have a diameter of at least 0.5 millimeter) and
  - **snow** (precipitation in the form of ice crystals or, more often, aggregates of ice crystals).

Precipitation Types (cont.)

- Other forms include:
  - **sleet** (falling small particles of ice that are clear to translucent),
  - **glaze** (formed when supercooled raindrops turn to ice on colliding with solid objects),
  - **hail** (hard, rounded pellets or irregular lumps of ice produced in large cumulonimbus clouds), and
  - **rime** (a deposit of ice crystals formed by the freezing of supercooled fog or cloud droplets on objects whose surface temperature is below freezing).
  - **drizzle** (smaller droplets of rain, yet larger than mist)
  - **mist** (smallest water droplets visible)
  - **gaupel** (watery hail)

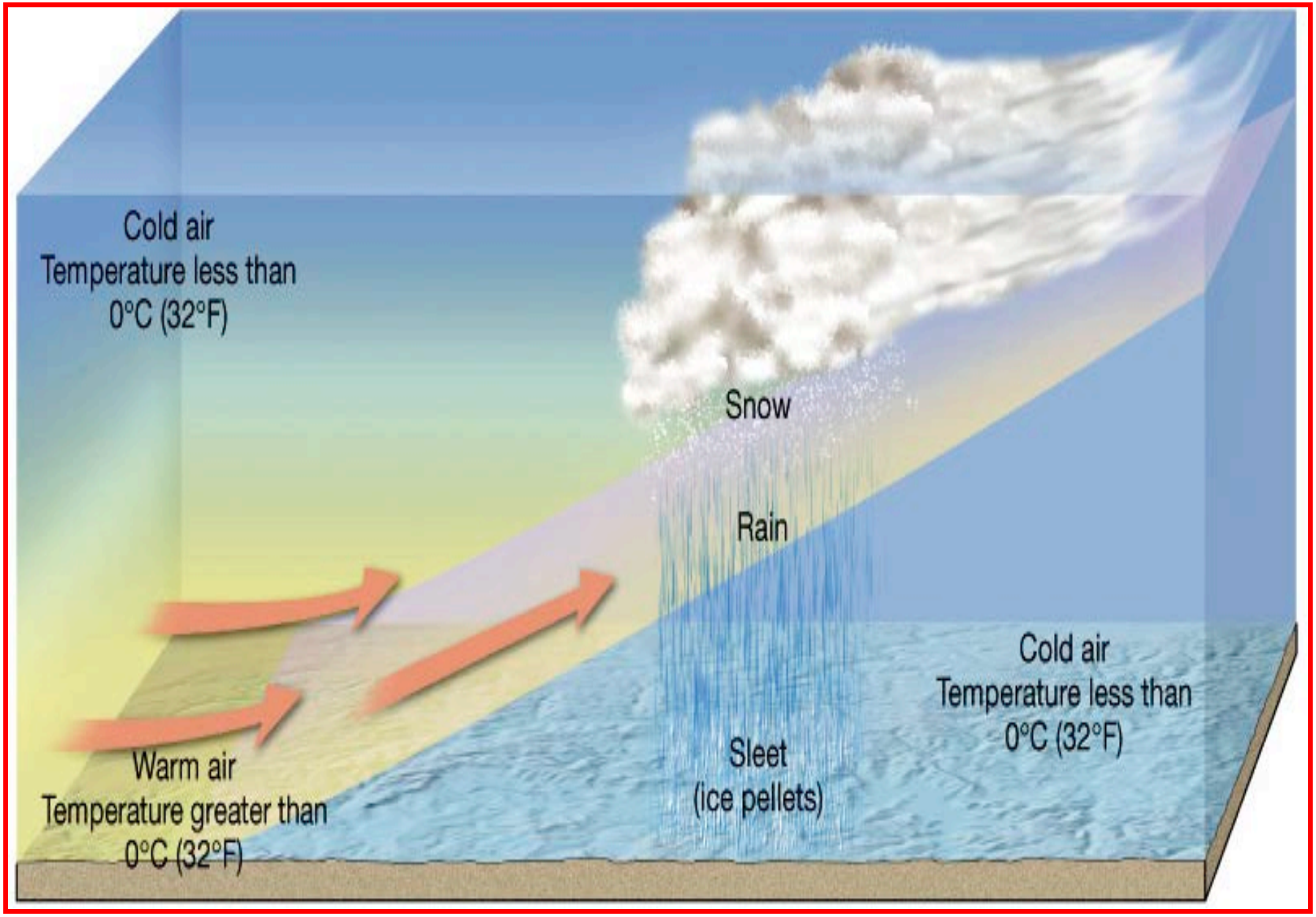




Sleet formation

Table 5–4 Types of precipitation

Type	Approximate Size	State of Water	Description
Mist	0.005 to 0.05 mm	Liquid	Droplets large enough to be felt on the face when air is moving 1 meter/second. Associated with stratus clouds.
Drizzle	Less than 0.5 mm	Liquid	Small uniform drops that fall from stratus clouds, generally for several hours.
Rain	0.5 to 5 mm	Liquid	Generally produced by nimbostratus or cumulonimbus clouds. When heavy, size can be highly variable from one place to another.
Sleet	0.5 to 5 mm	Solid	Small, spherical to lumpy ice particles that form when raindrops freeze while falling through a layer of subfreezing air. Because the ice particles are small, any damage is generally minor. Sleet can make travel hazardous.
Glaze	Layers 1 mm to 2 cm thick	Solid	Produced when supercooled raindrops freeze on contact with solid objects. Glaze can form a thick coating of ice having sufficient weight to seriously damage trees and power lines.
Rime	Variable accumulations	Solid	Deposits usually consisting of ice feathers that point into the wind. These delicate frostlike accumulations form as supercooled cloud or fog droplets encounter objects and freeze on contact.
Snow	1 mm to 2 cm	Solid	The crystalline nature of snow allows it to assume many shapes, including six-sided crystals, plates, and needles. Produced in supercooled clouds where water vapor is deposited as ice crystals that remain frozen during their descent.
Hail	5 mm to 10 cm or larger	Solid	Precipitation in the form of hard, rounded pellets or irregular lumps of ice. Produced in large convective, cumulonimbus clouds, where frozen ice particles and supercooled water coexist.
Graupel	2 mm to 5 mm	Solid	Sometimes called "soft hail," graupel forms as rime collects on snow crystals to produce irregular masses of "soft" ice. Because these particles are softer than hailstones, they normally flatten out upon impact.

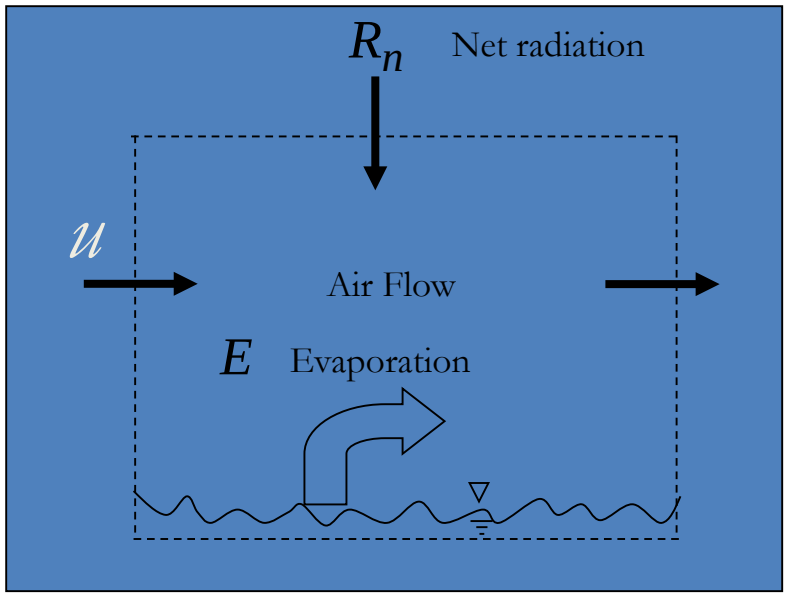

Cold air
Temperature less than
0°C (32°F)
Snow
Rain
Cold air
Temperature less than
0°C (32°F)
Sleet
(ice pellets)
Warm air
Temperature greater than
0°C (32°F)

Evaporation

- **Terminology**
  - **Evaporation** – process by which liquid water passes directly to the vapor phase
  - **Transpiration** - process by which liquid water passes from liquid to vapor through plant metabolism
  - **Sublimation** - process by which water passes directly from the solid phase to the vapor phase

Factors Influencing Evaporation

- Energy supply for vaporization (latent heat)
  - Solar radiation
- Transport of vapor away from evaporative surface
  - Wind velocity over surface
  - Specific humidity gradient above surface
- Vegetated surfaces
  - Supply of moisture to the surface
  - Evapotranspiration (ET)
    - Potential Evapotranspiration (PET) – moisture supply is not limited

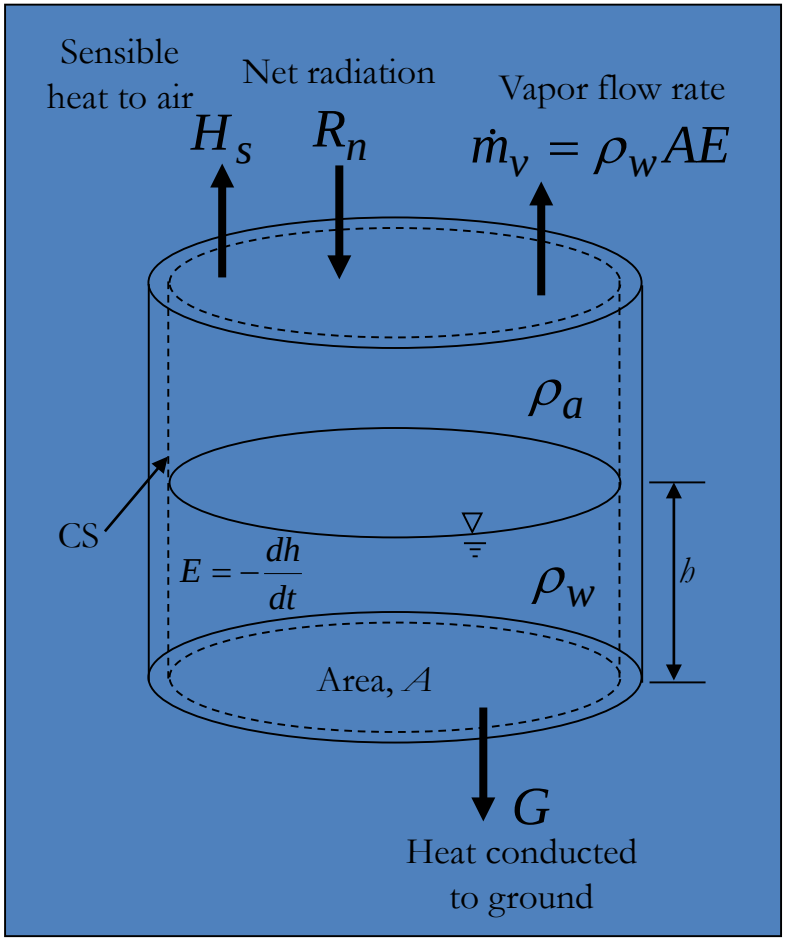


Evaporation from a Water Surface

- Simplest form of evaporation
  - From free liquid of permanently saturated surface

Evaporation from a Pan

- National Weather Service Class A type
- Installed on a wooden platform in a grassy location
- Filled with water to within 2.5 inches of the top
- Evaporation rate is measured by manual readings or with an analog output evaporation gauge



Methods of Estimating Evaporation

- Energy Balance Method
- Aerodynamic method
- Combined method

Evapotranspiration

- **Evapotranspiration**
  - Combination of evaporation from soil surface and transpiration from vegetation
  - Governing factors
    - Energy supply and vapor transport
    - Supply of moisture at evaporative surfaces

Snow melt

- Snowmelt is an integral component of the hydrologic forecasting process in many parts of the world. For flood forecasting, the spatial and temporal evolution of the snowpack, the speed at which it melts, and the impact from the water released are very important.

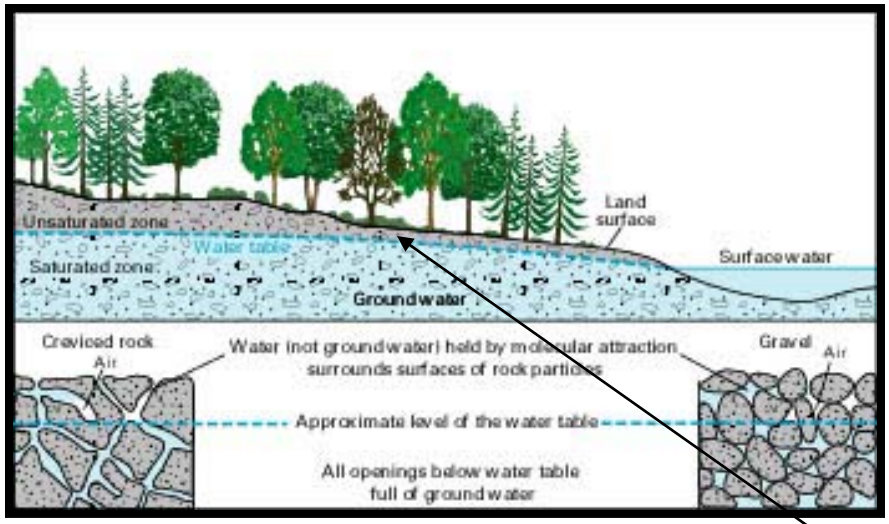
Snow melt process

A. Radiation
  - Short-wave radiation
  - Albedo
  - Long-wave radiation
  - Radiation Balance over snow cover

B. Convective and latent energy exchange

C. Soil heat flux

Occurrence of Ground Water



- Ground water occurs when water recharges the subsurface through cracks and pores in soil and rock
- Shallow water level is called the water table

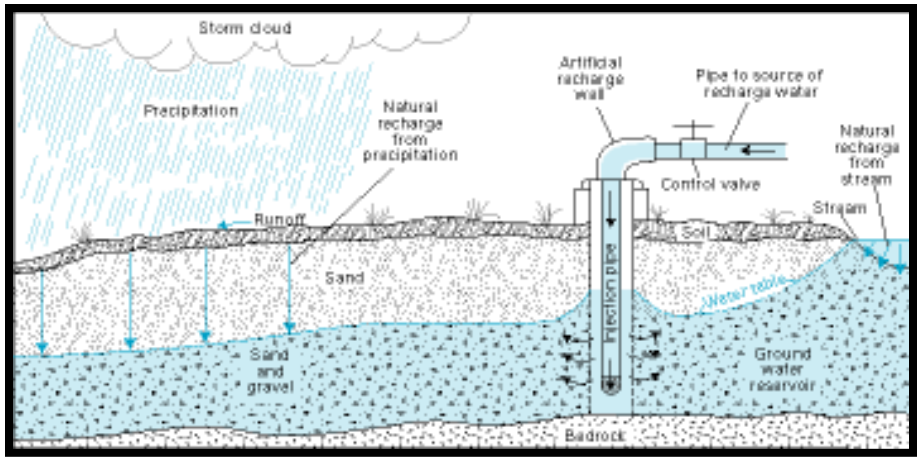
Recharge

Natural

- Precipitation
- Melting snow
- Infiltration by streams and lakes

Artificial

- Recharge wells
- Water spread over land in pits, furrows, ditches
- Small dams in stream channels to detain and deflect water



Runoff process

Runoff is often defined as the portion of rainfall, snowmelt, and/or irrigation water that runs over the soil surface toward the stream rather than infiltrating into the soil. It is sometimes called surface **runoff**.

Meteorological factor affecting runoff

Physical characteristics affecting runoff

Type of precipitation (rain, snow, sleet, etc.)
Rainfall intensity
Rainfall amount
Rainfall duration
Distribution of rainfall over the drainage basin
Direction of storm movement
Precipitation that occurred earlier and resulting soil moisture
Other meteorological and climatic conditions that affect evapotranspiration, such as temperature, wind, relative humidity, and season

Land use
Vegetation
Soil type
Drainage area
Basin shape
Elevation
Topography, especially the slope of the land
Drainage network patterns
Ponds, lakes, reservoirs, sinks, etc. in the basin, which prevent or delay runoff from continuing downstream