Q.1) Compare and contrast tropical and extratropical cyclones in terms of their origin, structure, and impact. (150 words, 10 marks)

Introduction

Cyclones are intense low-pressure systems forming under different atmospheric conditions. **Tropical and extratropical cyclones** vary fundamentally in their **origin, structure**, and **nature of impact** on both environment and human society.

Body

Difference between Tropical and Extra-Tropical Cyclones

1. Origin

Tropical Cyclones

- Form over warm tropical oceans between 5° and 20° latitude.
- Derive energy from the latent heat of condensation over warm waters (≥26.5°C).
- Typically originate in regions with low vertical wind shear and high humidity.
- Common in late summer and early autumn (e.g., Indian Ocean cyclones).

Extratropical Cyclones

- Develop in mid to high latitudes (30°–60°) over both land and oceans.
- Form due to the interaction of contrasting air masses (cold and warm fronts).
- Fueled by baroclinic instability and upper-level jet streams.
- Can occur throughout the year, with higher frequency in winter.

2. Structure

Tropical Cyclones

- Possess a **warm-core structure** and are highly symmetrical.
- Characterized by an eye at the center, surrounded by the eyewall with maximum winds.
- Vertical development is deep with strong convection.
- Lack frontal boundaries; the system is a unified warm air mass.

Extratropical Cyclones

- Exhibit a **cold-core structure** and are asymmetrical.
- Associated with distinct warm and cold fronts.
- Typically have a tilted vertical structure and weaker convection.
- Form a comma-shaped cloud pattern, with strong temperature gradients.

3. Impact

Tropical Cyclones

- Cause intense rainfall, storm surges, and high-velocity winds.
- Can result in large-scale devastation in coastal areas.
- Examples: Cyclone Fani (2019), Hurricane Katrina (2005).

Extratropical Cyclones

- Produce widespread precipitation (including snow), temperature shifts, and strong winds.
- Impacts are less intense but spread over larger areas.
- Examples: Nor'easters in North America, European windstorms.

Conclusion

While both tropical and extratropical cyclones are powerful atmospheric systems, they differ significantly in genesis, structure, and consequences. Understanding these distinctions is essential for improving disaster preparedness and climate resilience strategies.

Q.2) Describe the role of fluvial processes in the evolution of erosional and depositional landforms. (150 words, 10 marks)

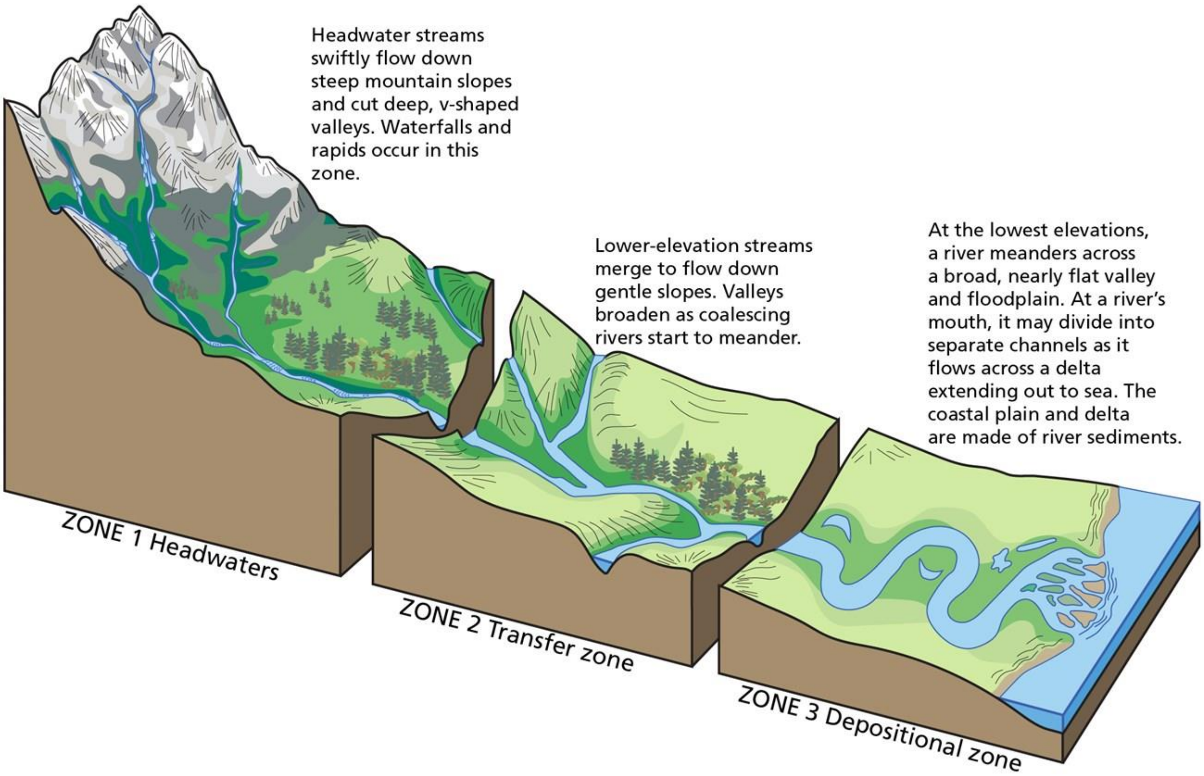
Introduction

Fluvial processes—comprising **erosion, transportation**, and **deposition by running water**—are dominant in sculpting the continental landscape. They actively contribute to the **formation and transformation of both erosional and depositional landforms**, particularly in riverine regions like the Indo-Gangetic plains and Peninsular India.

Body

Fluvial Erosional Landforms and Their Evolution

- In the **youthful stage**, rivers like the **Teesta** and **Alaknanda** exhibit rapid vertical erosion forming **deep V-shaped valleys**.
- **Gorges and canyons** like the **Gandikota Canyon** (Pennar River, Andhra Pradesh) are carved through resistant rock.
- **Waterfalls** such as **Dhuandhar Falls** (Narmada River, Madhya Pradesh) and **Jog Falls** (Sharavathi River, Karnataka) result from differential erosion of rock strata.
- **Potholes** in riverbeds, seen in **Bhedaghat (Narmada)**, develop by eddying currents.
- **River capture** events, such as those along the Chambal-Yamuna system, reshape drainage patterns through headward erosion.



Fluvial Depositional Landforms and Their Evolution

- In the **mature and old stages**, rivers like the **Ganga**, **Godavari**, and **Brahmaputra** slow down and deposit silt, forming **extensive floodplains**.
- **Meanders** and **oxbow lakes**, such as those found in **Bihar's Kosi Basin**, are formed by lateral erosion and channel migration.
- **Natural levees** are built by silt deposition during flooding, particularly along the **Hooghly River** in West Bengal.
- **Deltas**, such as the **Sundarbans Delta** formed by the Ganga-Brahmaputra system, are depositional features formed at river mouths.
- **Point bars** and **braided channels**, visible in the **Yamuna and Kosi rivers**, form due to fluctuating discharge and sediment load.

Conclusion

Fluvial processes play a **transformative role in landscape development**, influencing agriculture, settlement, and biodiversity. Understanding their impact is crucial for **flood control**, **sustainable river management**, and **land use planning** in India's riverine zones.

Q.3) Analyse the link between plate tectonics and the spatial distribution of natural hazards. Illustrate with diagrams (150 words, 10 marks)

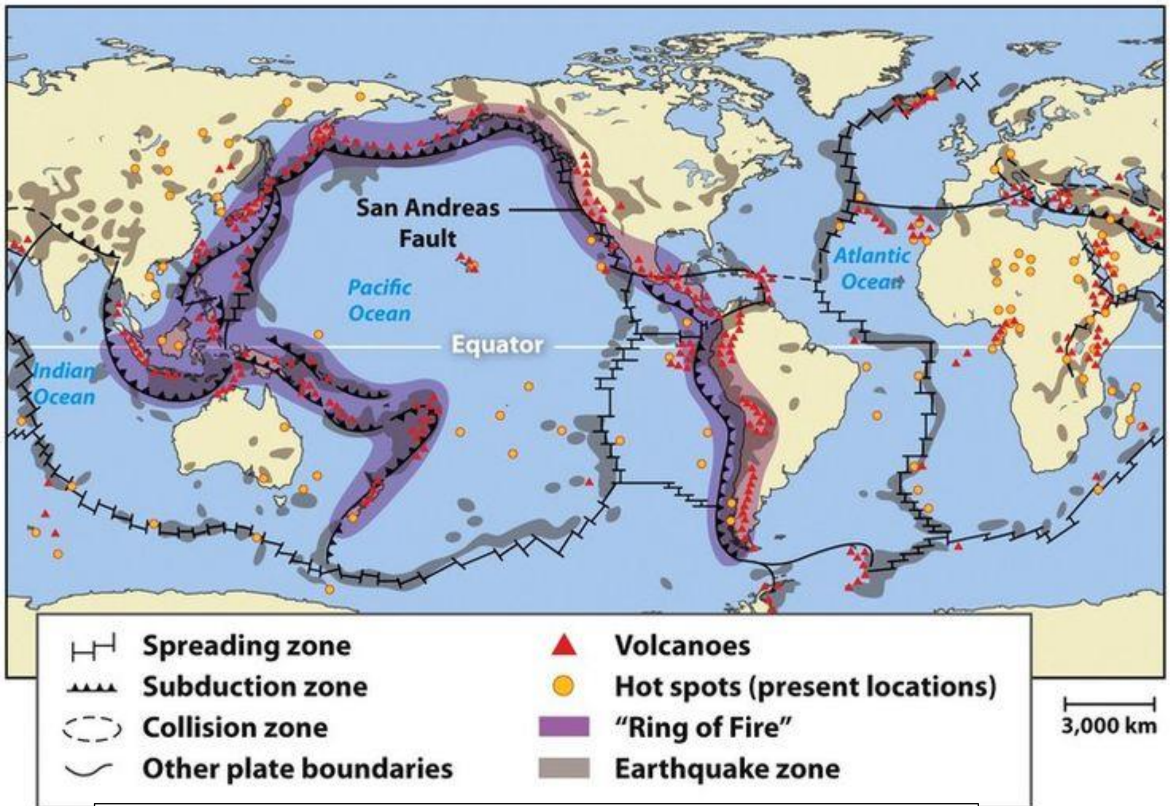
Introduction

The **theory of plate tectonics**, which describes the movement and interaction of lithospheric plates, offers a comprehensive explanation for the **spatial concentration of natural hazards**. Most seismic and volcanic activities occur along **active plate margins**, shaping global hazard patterns.

Body

Types of Plate Boundaries and Corresponding Hazards

- **Convergent Boundaries** (e.g., **Indian Plate and Eurasian Plate**) produce intense **earthquakes** and **mountain building**. The **Himalayan region** is highly prone to seismic hazards (e.g., 2015 Nepal earthquake).



Reference Diagram: Practice drawing similar diagram by hand

- **Divergent Boundaries**, such as the **Mid-Atlantic Ridge**, are marked by **volcanic eruptions** and **shallow earthquakes** due to magma upwelling.
- **Transform Boundaries**, like the **San Andreas Fault**, cause **strike-slip earthquakes** from horizontal plate motion.
- **Subduction Zones**, like the **Sunda Trench**, generate **megathrust earthquakes** and **tsunamis** (e.g., **2004 Indian Ocean tsunami**).

- **Intraplate Activity**: Re-activation of ancient faults leads to events like the **1993 Latur Earthquake** in stable Peninsular India.

Indian Context of Tectonic Hazards

- **Himalayan Frontal Thrust (HFT)**: Most active seismic belt due to plate convergence.
- **Andaman-Nicobar Islands**: Prone to **tsunamis and earthquakes** due to subduction of Indian Plate under Burma Plate.
- **Kutch and Western Ghats**: Known for minor intraplate seismicity.

Conclusion

The **distribution of tectonic hazards** is not random but corresponds closely with **plate boundaries**. Recognising these patterns is vital for **hazard zoning**, **infrastructure resilience**, and **disaster risk reduction**, particularly in vulnerable regions like the Himalayas and coastal belts.

Q.4) Differentiate between igneous, sedimentary, and metamorphic rocks in terms of formation, characteristics, and utility. (150 words, 10 marks)

Introduction

Rocks, the basic building blocks of the Earth's crust, are classified as **igneous**, **sedimentary**, and **metamorphic** based on their **origin** and **transformation processes**. Each type holds unique features, origins, and socio-economic significance.

Body

Igneous Rocks – Formed from Magma or Lava

- **Formation**: Solidified from molten magma, either below (intrusive) or on the surface (extrusive).
- **Key Features**: **Hard, crystalline, non-layered** and lack fossils. Texture varies with cooling rate.
- **Examples**: **Granite** (intrusive, Rajasthan), **Basalt** (extrusive, Deccan Plateau).
- **Utility**: Extensively used in **roads, buildings, monuments**, and **crushed stone aggregates**.

Sedimentary Rocks – Formed from Deposited Material

- **Formation**: Created by **weathering, transportation, deposition**, and **lithification** of sediments in layers.
- **Key Features**: **Layered**, may contain **fossils**, and are generally **softer** and porous.
- **Examples**: **Sandstone** (Vindhyan Basin), **Limestone** (Chhattisgarh), **Coal** (Jharkhand).
- **Utility**: Vital for **building materials**, **cement industry**, and **fossil fuels** like coal and petroleum.

Metamorphic Rocks – Transformed by Heat and Pressure

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- **Formation**: Arise when igneous or sedimentary rocks undergo **recrystallization** due to **extreme pressure and temperature**.
- **Key Features**: Often **banded**, more **dense and crystalline**, and resistant to erosion.
- **Examples**: **Marble** (metamorphosed limestone, Makrana), **Schist**, **Gneiss** (found in Himalayan belt).
- **Utility**: Used in **architecture**, **sculpture**, **decorative stone**, and **flooring**.

Conclusion

The three rock types contribute differently to **landform evolution**, **mineral resource formation**, and **economic activities**, making them fundamental to both physical geography and human development.

Q.5) Discuss the global significance of atmospheric pressure belts in determining weather patterns and oceanic currents. (250 words, 15 marks)

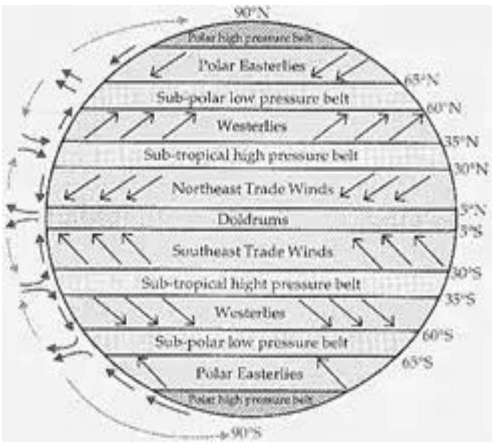
Introduction

The Earth's atmospheric pressure belts form a complex yet organized system that regulates **global wind circulation, weather patterns, and oceanic currents**. These belts, shaped by latitudinal solar energy distribution and Earth's rotation, are instrumental in crafting the planet's diverse climates and marine dynamics.

Body

Pressure Belts and Global Weather Systems

- The **Equatorial Low-Pressure Belt (0°–5° N/S)** is driven by intense insolation, causing **warm, moist air to rise**, leading to **daily convectional rainfall**—supporting dense equatorial rainforests like the **Amazon** and **Congo**.
- The **Subtropical High-Pressure Belts (25°–35° N/S)** are zones of **descending dry air**, responsible for **arid climates**—e.g., **Sahara**, **Arabian**, and **Thar** deserts. These regions receive **<250 mm annual rainfall**.



- The **Subpolar Lows (55°–65° N/S)** promote the formation of **temperate cyclones**, impacting the **British Isles**, **Japan**, and **Canada's east coast**, with frequent low-pressure storm systems.
- The **Polar Highs (above 80° N/S)** are cold and stable, where **dense air descends**, contributing to **polar desert conditions**, with mean temperatures remaining below 0°C year-round.

- The **seasonal shift** of these belts drives phenomena like the **Southwest Monsoon**, as the **ITCZ** (Inter-Tropical Convergence Zone) moves northwards, bringing ~70% of India's annual rainfall between June and September.

Influence on Ocean Currents

- **Trade Winds**, flowing from subtropical highs to the equator, push surface waters westward, forming **Equatorial Currents**—e.g., **North and South Equatorial Currents** in the Pacific and Atlantic.
- The **Westerlies** aid in creating **warm currents** like the **Gulf Stream**, warming Western Europe, and **cold currents**like the **California Current**, cooling the U.S. West Coast.
- **Gyres** in the **North Atlantic** and **North Pacific** form due to interactions between trade winds and westerlies, playing a key role in **heat redistribution** across the globe.
- **Upwelling zones**, such as along the **Peruvian coast**, are facilitated by pressure-driven winds, supporting rich fisheries like the **Humboldt Current system**.

Conclusion

Atmospheric pressure belts are not mere theoretical constructs but dynamic engines that **orchestrate Earth's climate**, regulate **global rainfall patterns**, and drive **marine ecosystems**. Understanding their structure and seasonal shifts is essential for **predicting climate anomalies**, managing **agriculture**, and enhancing **disaster preparedness** in a warming world.

Q.6) Explain the process of cloud formation and describe different types of precipitation. (250 words, 15 marks)

Introduction

Cloud formation and precipitation are integral components of the **Earth's hydrological cycle**, playing a crucial role in maintaining ecological balance and supporting human and agricultural systems. They are driven by atmospheric dynamics, thermodynamics, and moisture content.

Body

Cloud Formation: A Step-by-Step Process

1. **Evaporation and Humidification**
   - Water from oceans, lakes, rivers, and soil surfaces **evaporates** due to solar radiation, adding **water vapour** to the atmosphere.
   - This humid air, being lighter, tends to rise.
2. **Cooling Mechanisms of Rising Air**

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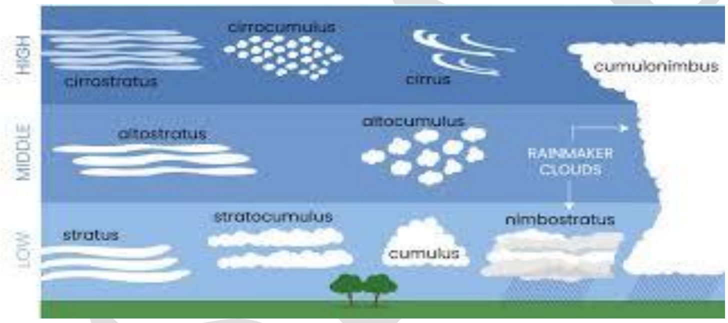
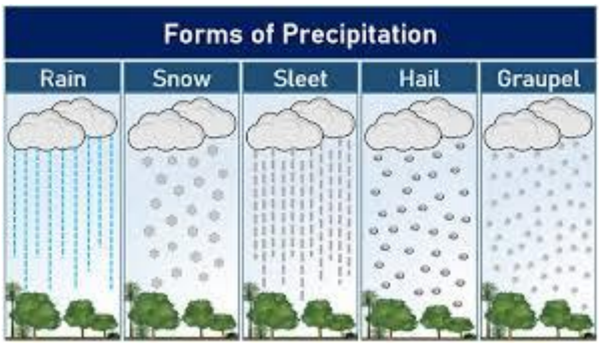
- As air ascends due to **convection (heating), orographic uplift (mountain barrier), frontal uplift (meeting of air masses), or convergence**, it **expands and cools adiabatically**.
- The **dry adiabatic lapse rate** is approximately 10°C per km for unsaturated air.

3. **Reaching Dew Point and Condensation**
    - Upon reaching the **dew point temperature**, air becomes saturated. Excess water vapour begins to **condense** on **condensation nuclei**—tiny particles such as dust, smoke, or sea salts.
4. **Cloud Development**
    - Continued condensation forms **cloud droplets**, which combine to form clouds.
    - The nature of the cloud depends on **altitude, temperature**, and **stability** of the air.
        - *High clouds*: **Cirrus, Cirrostratus**
        - *Middle clouds*: **Altostratus, Altocumulus**
        - *Low clouds*: **Stratus, Nimbostratus**
        - *Vertical clouds*: **Cumulus, Cumulonimbus**



Types of Precipitation

1. **Rainfall**
    - The most common type; occurs when cloud droplets coalesce to a size >0.5 mm and fall under gravity.
    - **Convectional rainfall** is common in equatorial areas; **orographic rainfall** is seen on windward mountain slopes (e.g., Western Ghats); **cyclonic rainfall** occurs during depressions.



2. **Snowfall**
    - Formed when **temperatures are below freezing** throughout the air column, and vapour crystallizes into snowflakes.
    - Common in **temperate and polar regions** and Indian Himalayas during winter.
3. **Hail**
    - Formed in **cumulonimbus clouds** due to **strong updrafts** that repeatedly lift and freeze raindrops, creating **layered ice balls**.
    - Typical in summer thunderstorms; e.g., parts of Central and North India.
4. **Sleet**
    - Occurs when **raindrops freeze into ice pellets** while passing through a sub-zero layer near the surface.
5. **Drizzle and Mist**
    - Drizzle involves **very fine droplets** (<0.5 mm), typical of **stratus clouds**.
    - Mist forms when **condensation occurs near the surface**, reducing visibility.

Conclusion

Understanding the **mechanism of cloud formation** and **diversity of precipitation types** is vital for weather prediction, agriculture, and hydrological planning. With increasing **climate variability**, precipitation patterns are shifting, necessitating enhanced observation and modelling systems for sustainable development and disaster resilience.

Q.7) Explain how glacial processes shape the Earth's surface. Describe the major erosional and depositional landforms formed by glaciers, with suitable examples. (250 words, 15 marks)

Introduction

Glaciers, vast masses of moving ice, act as powerful **geomorphic agents** that erode, transport, and deposit material. Predominantly active in **high latitudes and high altitudes**, glacial processes have played a crucial role in sculpting some of the most dramatic landscapes on Earth.

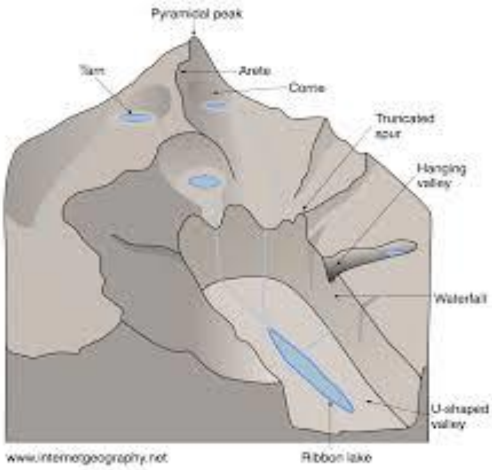
Body

How Glacial Processes Shape the Land

1. **Erosion**
    - Glaciers erode the land through **plucking** (lifting of rocks) and **abrasion** (grinding of rock surfaces by embedded debris).
    - These processes result in deepening, widening, and reshaping of valleys and basins.
2. **Transportation**
    - Glaciers transport **rock debris**, known as **moraine**, over long distances embedded in the ice or carried along its surface and base.

3. **Deposition**
    - As glaciers retreat or melt, they lose energy and **deposit sediments** ranging from boulders to fine silt, shaping a variety of depositional landforms.

Erosional Landforms Formed by Glaciers



- **Cirques (Corries)**: Bowl-shaped depressions formed at glacier heads. *Example: Karakoram ranges.*
- **Arêtes and Horns**: Knife-edged ridges (arêtes) and pyramid-like peaks (horns) formed by erosion from multiple glaciers. *Example: Matterhorn in the Alps.*
- **U-shaped Valleys**: Valleys carved by glaciers with steep sides and flat floors. *Example: Kashmir Valley.*
- **Hanging Valleys**: Tributary valleys left above the main glacial valley. *Example: Valleys in Himachal Pradesh.*

Depositional Landforms Formed by Glaciers

- **Moraines**: Ridges of debris deposited by glaciers—classified into **lateral, medial, terminal**, and **ground moraines**. *Example: Gangotri Glacier moraines.*
- **Drumlins**: Streamlined hills formed beneath glaciers, indicating ice flow direction. *Seen in parts of Europe and North America.*
- **Eskers and Kames**: Sinuous ridges (eskers) and mounds (kames) formed by meltwater streams under glaciers.
- **Outwash Plains**: Flat plains formed by meltwater carrying fine sediments.

Conclusion

Glacial processes have shaped many iconic landscapes, leaving behind both **sculpted terrains** and **depositional features**. In regions like the **Himalayas**, understanding glacial geomorphology is vital for **disaster risk reduction, water resource planning**, and evaluating the impacts of **climate change and glacial retreat**.