Q.1) Why is the Circum-Pacific Belt known as the most active seismic and volcanic region in the world? Discuss the tectonic settings responsible for this activity. (150 words, 10 marks)

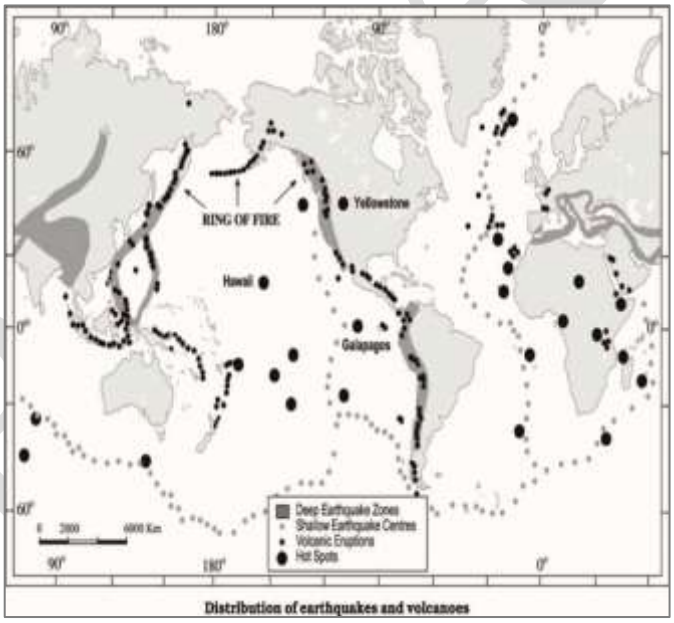
Introduction

The Circum-Pacific Belt, also known as the **"Ring of Fire"**, encircles the Pacific Ocean and accounts for over **75%** of the world's active volcanoes and **90%** of earthquakes, due to its complex tectonic environment.

Body

Reasons for high seismic and volcanic activity

1. **Subduction of oceanic plates:** The Pacific Plate and other oceanic plates are subducting beneath continental plates, leading to intense earthquake and volcanic activity.
2. **Presence of multiple convergent boundaries:** Regions like the Andes, Japan, and Indonesia experience frequent seismicity due to constant plate collision.
3. **Accumulated strain and sudden release:** The constant movement leads to stress accumulation in rocks, resulting in sudden energy release during earthquakes.
4. **Formation of island arcs and trenches:** Features like the Mariana Trench and Aleutian Islands are direct results of subduction processes that foster both volcanism and seismicity.



Distribution of earthquakes and volcanoes

Tectonic settings responsible

1. **Oceanic-continental subduction zones:** Nazca Plate subducting beneath South America forms the Andes and triggers frequent earthquakes.
2. **Oceanic-oceanic subduction zones:** The Pacific Plate subducting under the Philippine Sea Plate forms deep-sea trenches and island arcs.
3. **Transform fault boundaries:** The San Andreas Fault in California causes lateral movement and frequent shallow earthquakes.
4. **Multiple plate junctions:** Regions like Japan lie at the intersection of four tectonic plates, increasing seismic complexity.
5. **Ring-shaped tectonic convergence:** The continuous loop of interacting plates around the Pacific leads to persistent and intense geodynamic activity.

Conclusion

The Circum-Pacific Belt exemplifies how tectonic interactions—especially subduction and transform boundaries—create a **dynamic geological zone**. Understanding its structure helps **mitigate disaster risk** through better prediction and **resilient infrastructure** in vulnerable regions.

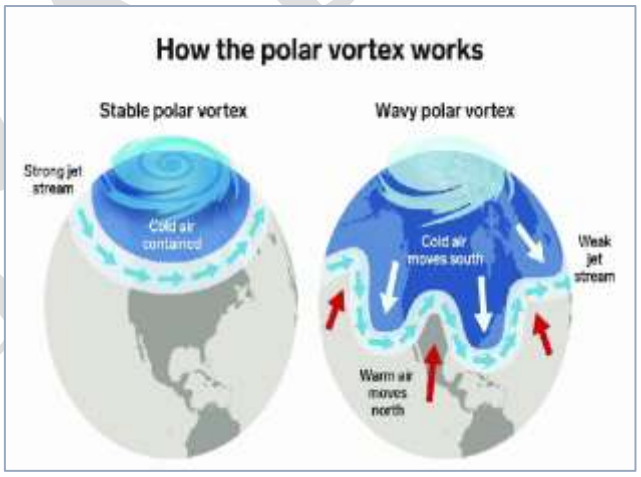
Q.2) What is the Polar Vortex? Explain its role in influencing extreme weather patterns in the mid-latitudes. (150 words, 10 marks)

Introduction

The Polar Vortex is a **large, low-pressure, cyclonic circulation** of cold air located near the Earth's poles in the stratosphere. It plays a crucial role in modulating weather patterns, especially in mid-latitudes.

Body

Characteristics of the Polar Vortex



1. **Location and structure:** Centered around the Arctic and Antarctic, it exists in both the troposphere and stratosphere, more stable in the latter.
2. **Seasonal behavior:** It strengthens during winter and weakens or breaks apart in summer.
3. **Wind direction:** It circulates counterclockwise in the Northern Hemisphere and confines frigid air near the poles.
4. **Temperature gradient driver:** Formed by the steep temperature difference between the polar and mid-latitude regions.

Role in influencing extreme weather

1. **Sudden Stratospheric Warming (SSW):** Disruption of the vortex causes warm air to rise and displace cold air southward, leading to cold waves in North America and Eurasia.
2. **Jet stream disturbance:** A weakened vortex causes the jet stream to meander, bringing prolonged cold spells, storms, or heatwaves to mid-latitudes.
3. **Increased snowfall events:** Displaced polar air meets moist systems, increasing chances of heavy snow, as seen in the **US blizzards of 2021**.
4. **Blocking patterns:** Vortex disruption can lead to atmospheric blocking, trapping weather systems and causing **prolonged droughts or floods**.
5. **Temperature extremes:** Both cold snaps and unseasonal warm spells in temperate zones can arise due to the vortex-induced jet stream fluctuations.

Conclusion

The Polar Vortex is a key player in **global climate dynamics**. Its weakening, often linked to **Arctic amplification**, leads to erratic mid-latitude weather. Monitoring its behavior is essential for accurate seasonal forecasting and disaster preparedness.

Q.3) Compare and contrast the timber industry in tropical and temperate regions with respect to forest type, extraction methods, and environmental impact. (150 words, 10 marks)

Introduction

The timber industry varies significantly between tropical and temperate regions due to differences in **ecology, governance, and economic practices**. Below is a comparative analysis across key dimensions.

Body

Comparison of Timber Industry: Tropical vs Temperate Regions

Aspect	Tropical Regions	Temperate Regions
Forest Type	Dense, evergreen, multilayered forests with high biodiversity. (**e.g. teak, mahogany**)	Deciduous or coniferous forests with fewer species and more uniform stands. (**e.g. pine, oak**)
Extraction Methods	Selective logging using manual/semi-mechanized tools; often informal or illegal	Mechanized logging (clear-cutting, shelterwood); more planned and regulated
Infrastructure	Poor access and monitoring; difficult terrain	Well-developed transport and monitoring systems
Biodiversity Impact	High species loss; slow regeneration; habitat fragmentation	Lower species impact; some loss in habitat but often reversible
Soil & Water Impact	Severe erosion, increased runoff, disruption of nutrient cycles	Controlled erosion; watershed occasionally affected by clear-cutting
Carbon Footprint	Major contributor to global carbon emissions from deforestation	Lesser emissions; carbon offset through reforestation efforts

Governance & Policy	Weak enforcement of regulations; corruption common	Stronger legal frameworks and better policy enforcement
Sustainability	Low due to illegal logging and overexploitation	Higher due to regulated practices and sustainable forest management

Conclusion

Tropical regions face greater ecological and governance challenges, while temperate forestry benefits from better management. Ensuring **global timber sustainability** requires bridging this gap through policy reforms, responsible trade, and stronger international cooperation.

Q.4) Describe the major erosional and depositional landforms formed by glaciers. Support your answer with suitable examples. (250 words, 15 marks)

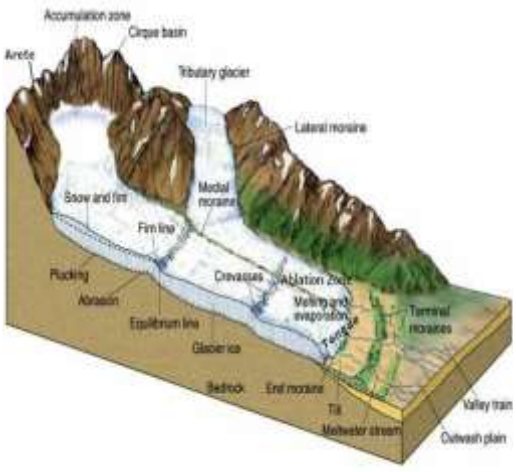
Introduction

Glacial landforms are features created by the **action of glaciers** through processes of erosion and deposition. These landforms are found in both current glaciated regions (like **Antarctica**, **Greenland**, and **the Alps**) and relict glaciated landscapes (e.g. **Himalayas**, **Scandinavian** highlands).

Body

Major Erosional Landforms

1. **Cirque:** A bowl-shaped depression carved into a mountain by the head of a glacier. Example: **Corrie Lochan** in the Cairngorms, Scotland.
2. **Arete:** A narrow ridge formed between two adjacent cirques. Example: **Knife Edge** in Mount Katahdin, USA.
3. **U-shaped Valley:** Formed by the down-valley movement of glaciers, replacing a former V-shaped river valley. Example: **Yosemite** Valley in California.
4. **Hanging Valley:** A tributary valley that enters a U-shaped valley at a higher elevation, often with waterfalls. Example: **Bridalveil Falls**, Yosemite.
5. **Roche Moutonnée:** A rock formation smoothed by glaciers on one side and plucked on the other. Example: Found in Lake District, England.



Erosional and Depositional forms

Major Depositional Landforms

1. **Moraine:** Accumulations of debris (till) deposited by a glacier. Types include lateral, terminal, and ground moraines. Example: Terminal moraine in the Snout of **Gangotri Glacier**.
2. **Drumlin:** Smooth, elongated hills made of glacial till shaped by ice flow. Example: Drumlins in the **Valparai region**, Tamil Nadu.
3. **Esker:** A winding ridge formed by glacial meltwater streams depositing sediments under the ice. Example: **Kettle Moraine region, USA**.
4. **Kame:** Irregularly shaped mounds of sand and gravel formed by glacial meltwater. Example: Found in parts of **Alberta, Canada**.
5. **Outwash Plain:** A flat area composed of sediments deposited by glacial meltwater beyond the terminal moraine. Example: **Sandur plains** in Iceland.

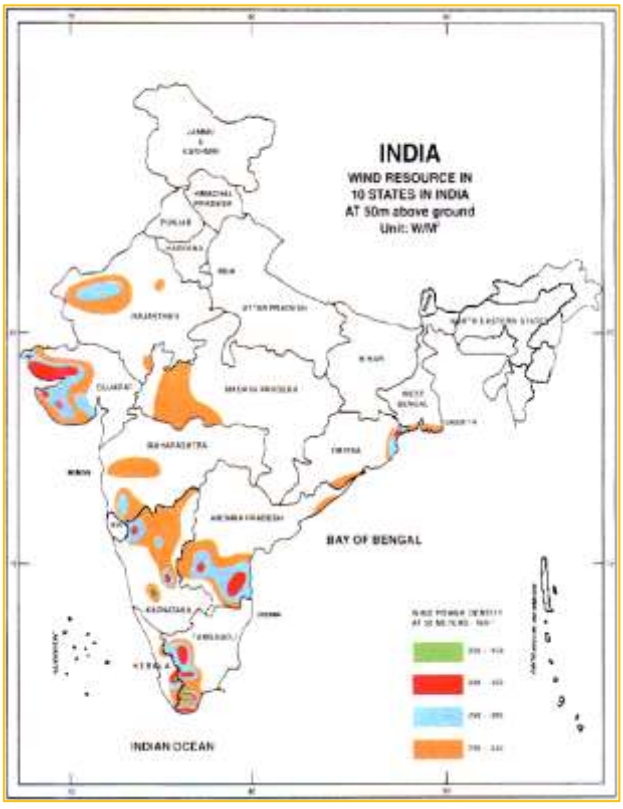
Conclusion

Glacial erosion and deposition shape landscapes uniquely, leaving lasting imprints visible even long after glaciation has ceased. These landforms are **essential for understanding past climatic conditions and glacial extents**.

Q.5) "India has considerable wind energy potential, yet its development remains regionally skewed." Examine the factors responsible for this uneven distribution and suggest measures to ensure balanced growth of wind energy across the country. (250 words, 15 marks)

Introduction

India has an estimated wind energy potential of over **1,000 GW at 120 metres** hub height (as per **NIWE**), yet a large share of installed capacity is concentrated in just a few states like Tamil Nadu, Gujarat, Maharashtra, and Karnataka. This uneven development hinders national energy equity and sustainability.



Body

Factors Responsible for Uneven Distribution

1. **Wind Speed Variation:** High and consistent wind speeds (greater than 6 m/s) are available mostly along the western and southern coasts.
   Example: Tamil Nadu and Gujarat enjoy average speeds **above 7 m/s**, making them more attractive for investment.

2. **Infrastructure and Grid Availability:** Developed states have better transmission networks and grid integration facilities, encouraging more projects.
   Example: ISTS connectivity is more robust in Gujarat than in eastern states.
3. **Land Availability and Policy Support:** States with clear land acquisition policies and single-window clearance systems have attracted more developers.
   Example: Rajasthan and Tamil Nadu have state wind policies and dedicated energy departments.
4. **Private Sector Interest and Investment Climate:** Better ease of doing business and financing options in certain states drive regional focus.
   Example: Southern and western states see higher PPP engagement and FDI inflow in wind energy.
5. **Lack of Awareness and Technical Capacity in Other States:** Several states with wind potential lack trained personnel and investor awareness, delaying project initiation.

Measures for Balanced Growth

1. **High-resolution Wind Mapping and Resource Assessment:** Expand detailed **wind resource surveys** in under-explored states like Odisha, Bihar, and Assam to identify feasible zones.
2. **Strengthening Transmission Infrastructure:** Invest in **green energy corridors** in underserved regions to integrate future wind projects into the national grid.
3. **Uniform Policy Framework and Incentives:** Harmonise state-level policies and offer central incentives (like **Viability Gap Funding** or accelerated depreciation) to attract developers to less-utilized regions.
4. **Promote Offshore and Hybrid Projects:** Develop offshore wind potential (e.g. along Gujarat and Tamil Nadu coasts) and promote **wind-solar hybrids** in lower-wind regions with higher solar irradiance.
5. **Community Engagement and Skill Development:** Involve local communities in land leasing models and build local capacity for maintenance and operation.

Conclusion

Balanced growth of wind energy across India is crucial for **energy security and environmental goals**. As recommended by **NITI Aayog**, coordinated efforts in infrastructure, policy, and regional capacity-building can unlock the sector's potential and ensure inclusive renewable energy development.