01 Physical & World Geography

1. Geomorphology

1. INTERIOR OF EARTH

- **Structure of the Earth**
  - **Crust:**
    - Continental (35 km, granitic) → e.g., Himalayas.
    - Oceanic (5–10 km, basaltic) → denser.
  - **Mantle:**
    - 2900 km, silicate-rich; asthenosphere partially molten → plate movement zone.
  - **Core:**
    - Outer core (liquid Fe–Ni) → creates magnetic field.
    - Inner core (solid Fe–Ni) → very dense.

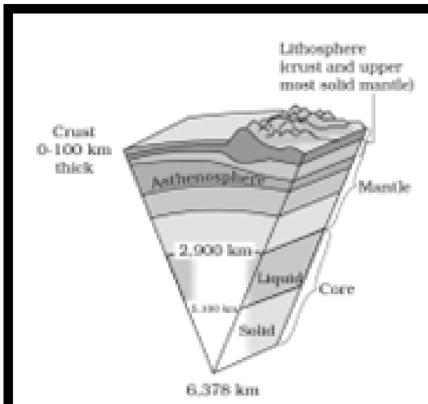
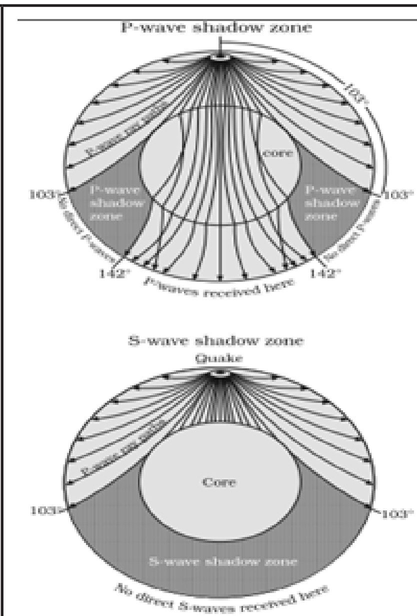


Figure 3.4 : The interior of the earth

- **Evidence of Earth Interior**

Seismic Waves:	Seismic Waves: Seismic Waves – Most Reliable Evidence • **P-waves (Primary):** Travel through solids + liquids → speed increases in denser layers. • **S-waves (Secondary):** Travel only through solids → their absence in outer core = liquid outer core. • **Shadow Zones:** ➤ P-wave shadow (103°–142°) → refraction at core–mantle boundary. ➤ S-wave shadow (beyond 103°) → confirms liquid outer core. • **Wave Speed Changes:** Reveal layer density → e.g., sharp increase at Moho indicates mantle composition change.	 Figure 3.2 (a) and (b) : Earthquake Shadow Zones

Volcanic & Magma Materials	• Lava brings mantle samples to surface → ultramafic composition (Mg, Fe-rich). • Gases (SO_2, CO_2, H_2O vapour) indicate deep chemical processes.
Magnetic Evidence	• Earth's Magnetic Field: Generated by convection in liquid outer core (geodynamo). • Paleomagnetism: Ancient magnetic signatures show pole reversal + crust movement, supporting internal layering.
Heat Flow (Geothermal Gradient)	• Heat increases with depth (~33°C per km near surface). • High heat flow zones → tectonic plate boundaries, volcanic belts. • Low heat flow → stable shield areas (Peninsular India).
Temperature, Pressure & Density	• Temperature: Increases with depth (geothermal gradient). • Pressure: Maximum at core → several million atmospheres. • Density: Heaviest at core (Fe–Ni), lightest at crust.

2. Theories explaining distribution of continents and oceans

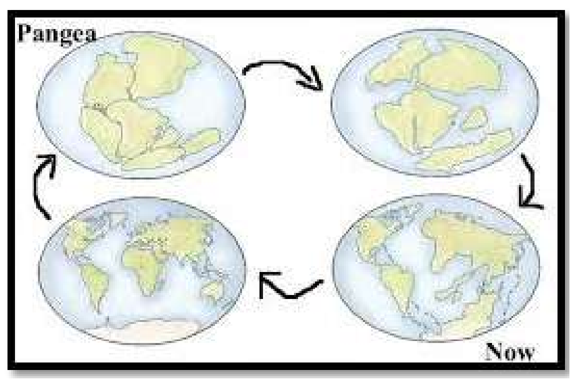
- **A.Continental Drift Theory**

Basic Idea

- All continents were once a single supercontinent Pangaea, surrounded by a universal ocean Panthalassa.
- Around 200 million years ago, Pangaea broke apart → continents drifted to present positions.

Key Evidence

- Coastlines match: South America ↔ Africa fit → shared geology.
- Fossils match: Mesosaurus (Brazil ↔ S. Africa) → Glossopteris (India–Australia–Antarctica).
- Glacial deposits: India–Australia–S. Africa → once near South Pole.
- Mountain chains: Appalachians (USA) ↔ Caledonians (Europe) → same origin.
- Climatic clues: Coal in Antarctica → tropical past; coral reefs in temperate zones → continent shift.



Weakness

- Proposed forces (tidal pull, Earth's rotation) → too weak → mechanism rejected.

Significance

- Introduced idea of mobile continents → paved way for Sea-Floor Spreading & Plate Tectonics.

B. Sea Floor Spread Theory (Harry Hess, 1962)

Core Idea / Meaning

- **Ocean floors are not fixed → New crust forms at mid-ocean ridges → Spreads outward → Old crust destroyed at trenches.**

Key Evidence

- **Mid-Atlantic Ridge:** Youngest rocks at ridge → Older outward.
- **Magnetic Stripes:** Symmetrical magnetic bands → Pole reversals recorded in new crust.
- **Ocean Floor Age:** No rocks >200 million yrs → Continuous recycling.
- **Heat Flow:** Highest at ridges → Confirms magma upwelling.
- **Earthquakes & Volcanoes:** Concentrated along ridges & trenches → Active tectonic zones.

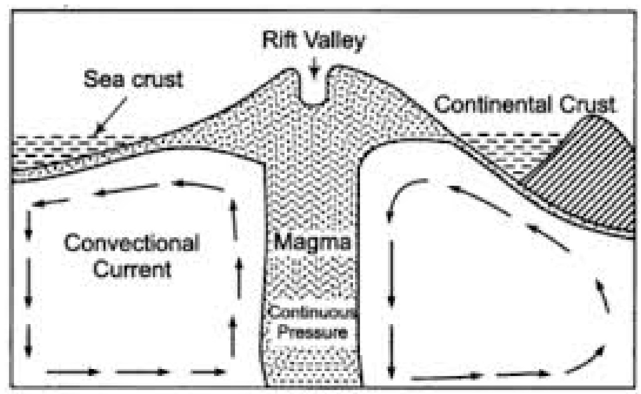


Fig. Sea Floor Spreading

Process (Arrow-Linked)

- Mantle convection → Magma rises → Sea-floor spreads → Plates move → Old crust subducts at trenches.

Significance

- **Provided mechanism for continental drift → Foundation for Plate Tectonics Theory.**

C. Plate Tectonics Theory (McKenzie, Morgan — 1960s)

Core Idea / Meaning

- **Earth's lithosphere is broken into rigid plates → Plates move over semi-molten asthenosphere → Interactions create all major landforms.**

Key Components

- **Lithospheric Plates:** 7 major + several minor (e.g., Indian Plate, Pacific Plate).
- **Asthenosphere:** Weak, plastic layer → allows plate movement.
- **Plate Boundaries:** Convergent, divergent, transform.

Types of Plate Movements

1. Convergent (→←)

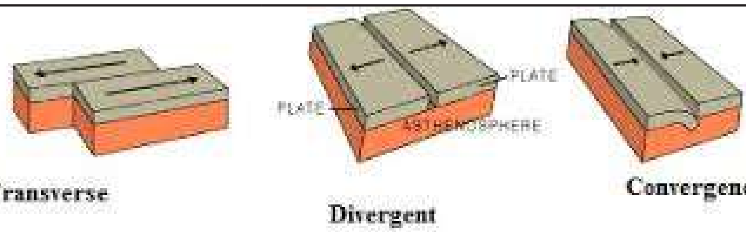
- **Plates collide → Fold mountains (Himalayas), Volcanic arcs (Andes), Trenches (Marianas).**

2. Divergent (←→)

- **Plates move apart → Mid-ocean ridges (Mid-Atlantic Ridge), Rift valleys (East African Rift).**

3. Transverse (↑↓)

- **Plates slide past → Earthquakes (San Andreas Fault).**



Evidence

- **Sea-floor spreading patterns.**
- **Magnetic stripes → symmetric on both sides of ridges.**
- **Distribution of earthquakes & volcanoes around Ring of Fire.**
- **Fit of continents + matching fossils & geology.**

Significance

- **Unified explanation for mountains, ocean basins, earthquakes, volcanoes, rift valleys, island arcs.**
- **Most comprehensive theory of Earth's dynamics → foundation of modern geomorphology.**

3. Earthquakes

Meaning

- **Sudden release of stress along faults → seismic waves shaking Earth's crust.**

Key Points / Features

- **Types:** tectonic (major), volcanic, collapse, induced
- Focus (origin) + epicentre (surface point)
- Measured by magnitude (Richter/Mw) & intensity (MMI)
- Occur along plate boundaries; intra-plate also possible

Evidence / Examples (India)

- Himalayan quakes (Nepal 2015, Kashmir, Uttarakhand)
- Peninsular intraplate: Latur 1993, Kutch 2001

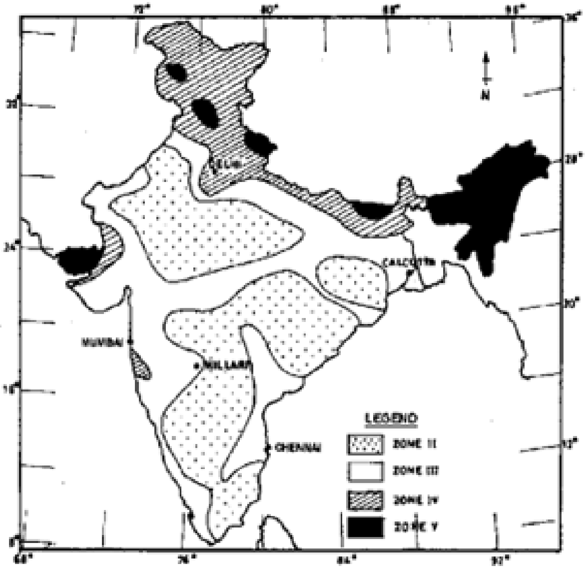
Process

- **Stress builds → Rocks deform → Rupture along fault → Energy released → Seismic waves → Ground shaking**

Significance

- **Major hazard → loss of life, infrastructure collapse, landslides.**

- **Seismic zones of India**

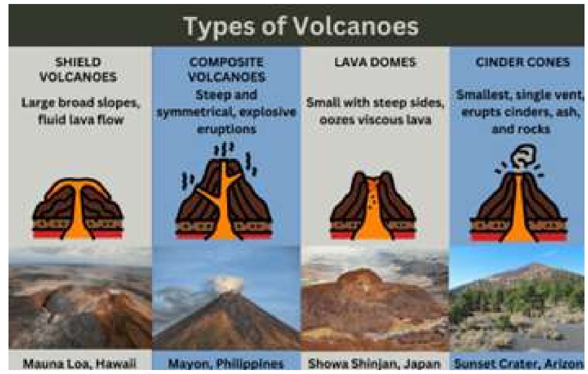


2. Tsunami

- **Core Idea**
  - **Long-wavelength sea waves generated by sudden vertical displacement of ocean floor.**
- **Key Features**
  - **Causes:** undersea quake, landslide, volcanic eruption, meteor impact
  - **Travels fast in deep ocean; grows in height near coast**
  - **Arrives as series of waves, not a single wave**
- **Evidence / Examples (India)**
  - **2004 Indian Ocean Tsunami → severe impact on Andaman–Nicobar & Tamil Nadu**
  - **Potential threat along Makran Subduction Zone**
- **Significance**
  - **High-impact coastal hazard → requires early warning, evacuation planning.**

3. Volcanic Activity

- **Meaning**
  - **Magma rises from mantle/crust → erupts as lava, ash, gases.**
- **Types**
  - **Shield Volcanoes**
    - Broad, gently sloping; formed by fluid basaltic lava



- Quiet, non-explosive eruptions
- Example: Hawaiian volcanoes

- **Composite or Stratovolcanoes**
  - Steep, conical; alternating lava + ash layers
  - Highly explosive due to viscous magma
  - Example: Mt. Fuji, Mt. St. Helens
- **Cinder Cone Volcanoes**
  - Small, steep cones built from pyroclasts (cinders, ash)
  - Short-lived eruptions; found on volcanic flanks
  - Example: Parícutin (Mexico)
- **Dome or Acid Lava Volcanoes**
  - Dome-shaped; very viscous, silica-rich lava
  - Violent eruptions; slow lava movement
  - Example: Lassen Peak
- **Fissure Volcanoes**
  - Erupt through long cracks (fissures), not central vents
  - Large volumes of basalt → lava plateaus
  - Example: Deccan Traps (India), Icelandic eruptions
- **Caldera Volcanoes**
  - Large depression formed after explosive eruption + roof collapse
  - Can host lakes or renewed activity
  - Example: Yellowstone Caldera
- **Submarine (Underwater) Volcanoes**
  - Occur along mid-ocean ridges; pillow lavas
  - Can grow to form islands
  - Example: Surtsey (Iceland)
- **Mud Volcanoes**
  - Erupt mud, water, gases, not lava
  - Associated with petroleum/gas fields
  - Example: Baratang (Andaman & Nicobar, India)

Evidence / Examples (India)

- Deccan Traps (fissure eruptions)
- Barren Island (active volcano) in Andaman Sea
- Narcondam (dormant)

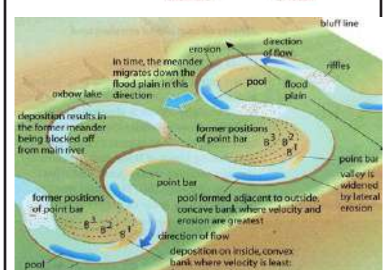
4. Landforms

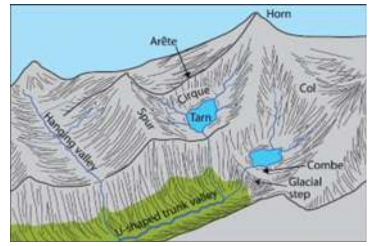
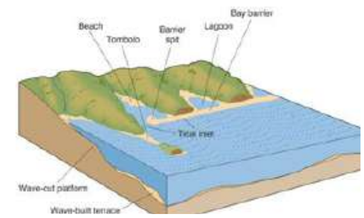
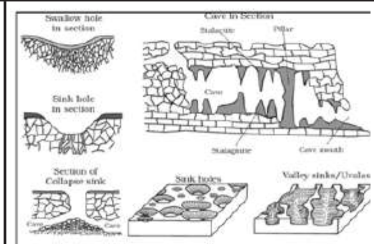
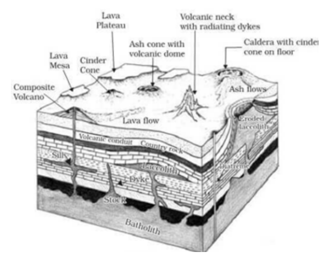
Landforms = physical features shaped by erosion, deposition, weathering, tectonics, volcanism. Form varies with agent + process + structure.

Key Points

- **Classified by agents:** River (Ganga valley), Wind (Thar Desert), Glacier (Himalayas), Sea (Konkan coast), Karst (Meghalaya limestone), Volcanic (Deccan Trap), Structural (Narmada rift)
- Each agent → unique erosional + depositional forms (e.g., rivers → gorges & deltas; wind → yardangs & dunes)
- Controlled by rock type (Basalt–Deccan), slope (Himalayan steep gradients), climate (arid Thar), structure (faulted Narmada), time
- India shows all major landform types → from Himalayan U-valleys to coastal lagoons (Chilika) and volcanic plateaus (Deccan)

Various Types of Landforms

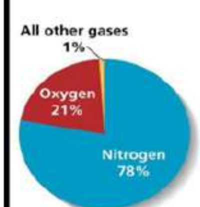
Agent	Depositional Landforms	Erosional Landforms	Diagram
River (Fluvial)	Floodplain, Natural levees, Point bars, Delta, Alluvial fans	V-shaped valley, Waterfall, Gorge/Canyon, Potholes, Meanders (erosional side), River terraces	 
Wind (Aeolian)	Sand dunes (Barchan, Longitudinal), Loess	Deflation hollows, Yardang, Zeugen, Mushroom rock	

Glacier (Glacial)	Moraines (lateral, medial, terminal), Drumlins, Eskers, Outwash plains	Cirque, Arête, Horn, U-shaped valley, Fjord	
Sea/Waves (Marine)	Beaches, Spits, Bars, Tombolos, Lagoons	Cliffs, Wave-cut platforms, Sea caves, Arches, Stacks	
Karst (Solution)	Stalactites, Stalagmites, Pillars, Travertine deposits	Sinkholes, Dolines, Uvalas, Poljes, Limestone pavements	 Various Karst topography features
Volcanic	Lava plateaus, Shield cones, Ash beds	Calderas (collapse), Volcanic necks, Dyke/sill exposure (after erosion)	

2.Climatology

A. Basics of Atmosphere

- **Composition of the Atmosphere**



Gas	Percentage by Volume
Nitrogen (N_2)	78.084
Oxygen (O_2)	20.946
Argon (Ar)	0.934
Carbon dioxide (CO_2)	0.037
Neon (Ne)	0.00182
Helium (He)	0.00052
Methane (CH_4)	0.00015
Krypton (Kr)	0.00011

- **Structure of the Atmosphere**
  - **Troposphere**

- Lowest layer; up to ~12 km (higher at equator, lower at poles)
- Temperature decreases with height
- Weather phenomena, clouds, water vapour present

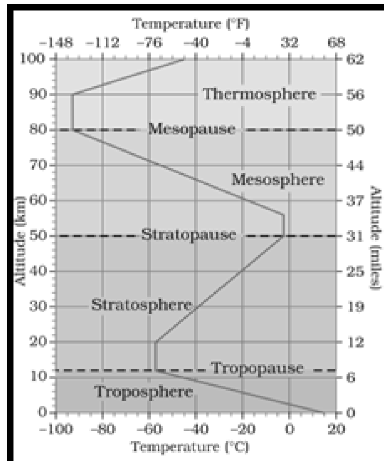


Figure 8.1 : Structure of atmosphere

- **Stratosphere**
  - 12–50 km
  - Temperature increases due to ozone layer
  - Clear, stable; ideal for aircraft; absorbs UV radiation
- **Mesosphere**
  - 50–80 km
  - Temperature decreases; coldest layer
  - Meteors burn up here
- **Thermosphere**
  - 80–400 km
  - Temperature rises sharply; ionosphere present
  - Radio wave propagation; auroras occur
- **Exosphere**
  - Above ~400 km
  - Extremely thin; merges into outer space
  - Mostly hydrogen and helium

B. Solar Radiation & Heat Budget

- Earth maintains a balance between incoming solar radiation (insolation) and outgoing terrestrial longwave radiation.
- About 100 units of solar energy reach the Earth–atmosphere system (conceptual value used for clarity).
- 30 units reflected back → by clouds, atmosphere, and Earth's surface (planetary albedo ≈ 30%).
- 51 units absorbed by Earth's surface → warms land and oceans.

■ Basic Terms

1. Insolation

- Incoming solar radiation received by Earth.
- Controls temperature, seasons, and climate patterns.

2. Solar Constant

- Amount of solar energy received at top of atmosphere per unit area (~1361 W/m^2).
- Actual insolation at surface varies due to angle, clouds, distance.

3. Albedo

- Percentage of solar radiation reflected back without heating Earth.

- 19 units absorbed by atmosphere → mainly by water vapour, ozone, dust.
- Surface releases energy through terrestrial radiation, convection, conduction, and latent heat.
- Atmosphere sends part of this longwave radiation back to surface via greenhouse effect, keeping Earth warm.
- Overall balance: Incoming = Outgoing over long periods → maintains global temperature.

4. **Heat Budget (Earth's Energy Balance)**
   - Balance between incoming solar radiation and outgoing terrestrial radiation.
   - Determines Earth's temperature stability.
5. **Terrestrial Radiation**
   - Longwave infrared radiation emitted by Earth's surface at night or after heating.

- Any imbalance (↑ greenhouse gases, ↓ albedo) → warming; (↑ aerosols, ↑ volcanic dust) → cooling.
- Latitudinal imbalance: Surplus heat in tropics and deficit in poles → drives winds, currents, monsoon systems.
- Heat budget explains climate zones, ocean–atmosphere circulation, and long-term climate change trends.

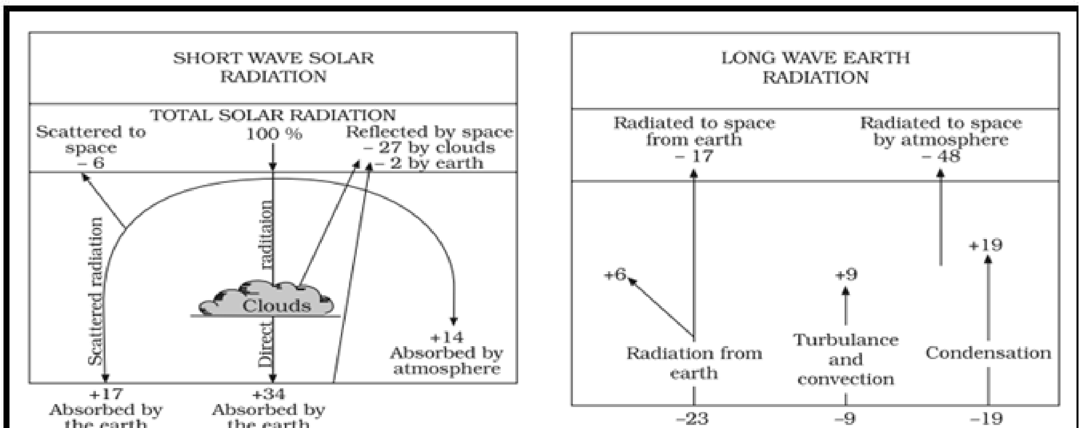


Figure 9.2 : Heat budget of the earth

Factors Affecting Temperature Distribution

- **Latitude:** Controls angle of insolation; temperature decreases poleward.
- **Altitude:** Higher altitude → thinner air → lower temperature (environmental lapse rate).
- **Distance from the Sea (Continentality):** Oceans moderate temperature; interiors show extremes.
- **Ocean Currents:** Warm currents raise coastal temperatures; cold currents lower them.
- **Wind & Air Masses:** Winds carry temperatures of their source regions; modify local climate.
- **Cloud Cover:** Clouds reduce daytime heating and reduce nighttime cooling.
- **Slope & Aspect:** South-facing slopes (in NH) receive more insolation → warmer.
- **Land–Water Contrast:** Land heats/cools faster; oceans heat/cool slowly → affects seasons.

- **Nature of Surface (Albedo):** High albedo (snow, ice) → lower temperature; low albedo (vegetation, oceans) → higher temperature.
- **Vegetation Cover:** Dense vegetation reduces temperature via evapotranspiration.
- **Urbanisation:** Concrete, traffic, industries trap heat → Urban Heat Island effect.
- **Atmospheric Circulation:** Subsiding air (high pressure) → warm; rising air (low pressure) → cool.
- **Clouds, Dust, Aerosols:** Scatter/absorb radiation → reduce surface temperature.
- **Seasonal Sun Path:** Tilt of Earth causes variation in insolation across seasons.

Temperature Inversion

Meaning

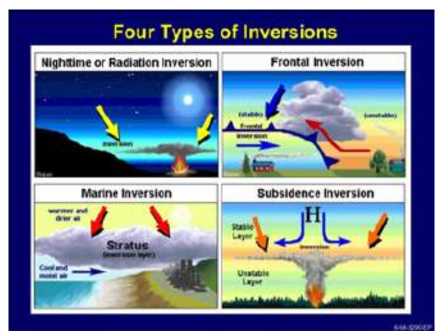
- A condition where temperature increases with height, reversing the normal lapse rate.

Key Points / Features

- Warm air overlays cooler air near the surface → stable atmosphere.
- Suppresses vertical mixing; traps pollutants, fog, smog.
- Common in winter nights, valleys, and high-pressure conditions.

Types of Inversion

- Radiation Inversion – Night cooling of ground → cool air trapped below warm layer.
- Advection Inversion – Warm air moves over a cold surface (e.g., cold ocean).
- Subsidence Inversion – Air sinking in high-pressure systems warms above cooler surface air.
- Valley Inversion – Cold dense air drains downslope and gets trapped in valleys.



Favourable Conditions

- Clear skies
- Calm winds
- Long winter nights
- Dry air
- Valley topography

Examples (India)

- Delhi winter smog
- North Indian valleys (Dehradun, Kashmir)
- Indo-Gangetic plain during winter

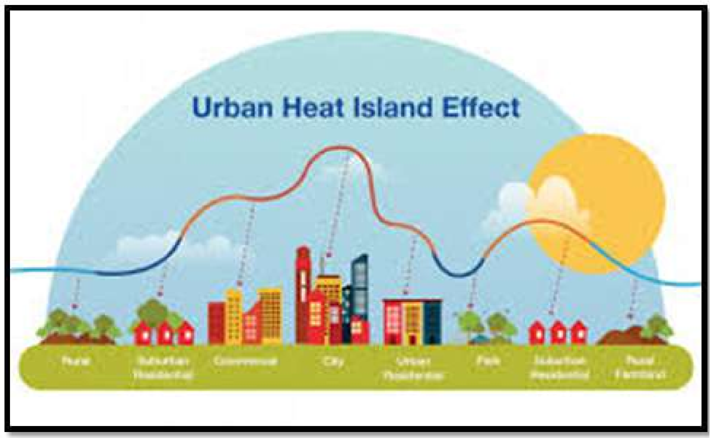
Implications / Significance

- Enhances air pollution and fog formation
- Affects aviation and visibility
- Impacts weather stability and local climate

Urban Heat Island Effect: Causes, Impacts and Solutions

Introduction

- Urban Heat Island (UHI) refers to the phenomenon where urban areas experience higher temperatures than surrounding rural regions due to human activities and land-use changes. According to the IPCC, UHI can raise city temperatures by 1–3°C during the day and up to 12°C at night, worsening the impacts of climate change, especially in megacities.



Causes of UHI

- **Surface Modification:** Replacement of natural vegetation with asphalt, concrete, and buildings which absorb and retain heat.
- **Reduced Vegetation Cover:** Loss of tree canopy reduces shade and evapotranspiration cooling.
- **Anthropogenic Heat Release:** Heat from vehicles, industries, and air conditioners.
- **Air Pollution & Greenhouse Gases:** Smog and suspended particles trap outgoing long-wave radiation.
- **Urban Morphology:** Tall buildings and narrow streets create a "canyon effect," limiting heat dissipation.

Impacts of UHI

- **Environmental**
  - Altered local climate and increased energy demand for cooling.
  - Degradation of air quality due to temperature inversion.
  - Reduced biodiversity in urban ecosystems.
- **Social**
  - Increased incidence of heat-related illnesses (heat strokes, cardiovascular issues).
  - Exacerbates vulnerability of marginalized urban populations.

- **Economic**
  - Higher electricity bills due to air conditioning demand.
  - Strain on urban water and power supply.
- **Indian Context**
  - Delhi, Mumbai, Chennai, Bengaluru record significant UHI intensity.
  - Example: A 2021 study found Delhi's central business districts up to 7°C hotter than surrounding rural areas.
  - Rising UHIs intensify heat waves, already a growing concern due to climate change.

Mitigation and Adaptation Strategies

- **Urban Greening**
  - Increasing green spaces, rooftop gardens, and tree cover.
  - Protection and rejuvenation of urban wetlands.
- **Cool and Reflective Surfaces**
  - Use of cool roofs, reflective paints, and permeable pavements.
- **Urban Planning and Design**
  - Wider roads, green belts, and climate-sensitive zoning.
  - Vertical gardens and sustainable building codes.
- **Technological Solutions**
  - Smart city designs with climate modeling.
  - Use of GIS and remote sensing to map UHI zones.
- **Policy Measures**
  - National Cooling Action Plan (2019) aims to reduce cooling demand and promote passive cooling.
  - Integration of UHI mitigation into Smart Cities Mission and AMRUT.

C. Atmospheric Pressure & Pressure Belts

Air Pressure & Circulation

- Air pressure = weight of air column per unit area; decreases with height.
- Isobars = lines joining equal pressure.
- Winds move from high → low pressure; driven by pressure gradient + modified by Coriolis force.

Pressure Belts (Thermal & Dynamic)

Equatorial Low (0–5° N/S)

- High insolation → warm, rising air → low pressure.
- Convergence of NE & SE trades → ITCZ.
- Weak horizontal winds → doldrums.

Subtropical High (25–35° N/S)

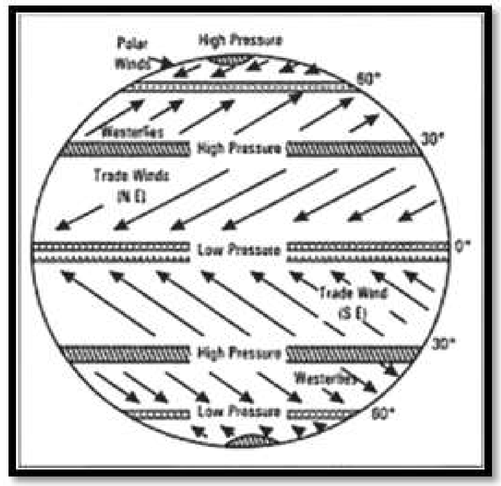
- Descending air from upper troposphere → high pressure.
- Stable, dry, anti-cyclonic → deserts located here.
- Known as horse latitudes.

Subpolar Low (60–65° N/S)

- Divergence caused by rotation + meeting of westerlies and polar winds.
- More regular in Southern Hemisphere.

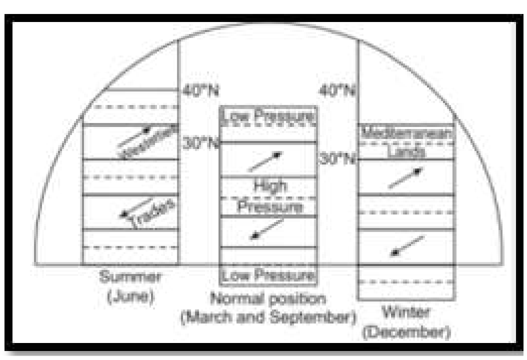
Polar High (90° N/S)

- Very cold, dense air → high pressure.



Seasonal Shifting of Pressure Belts

- Caused by apparent north–south movement of the Sun due to Earth's tilt (23.5°).
- All pressure belts shift northward in June–July and southward in December–January.
- Equatorial Low / ITCZ moves 5–20° north in Northern summer → critical for monsoon formation.
- Subtropical Highs shift poleward in summer → bring dry, stable conditions over subtropics.
- Subpolar Lows also migrate poleward/equatorward seasonally, affecting westerlies.
- Polar Highs remain largely unchanged (least shifting).
- Land–water contrast strengthens shift in Northern Hemisphere (more landmass).



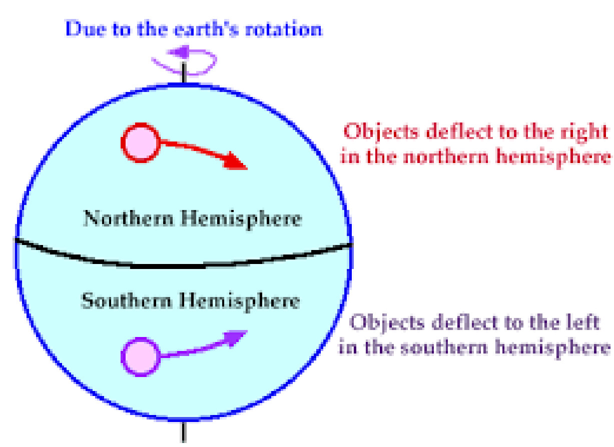
Climatic Impacts

- **Mediterranean Climate:**
  - Summer: Subtropical high lies over Mediterranean → dry summers.
  - Winter: Belt shifts south → westerlies bring rainfall → winter precipitation.
- **Monsoon System (South Asia):**
  - ITCZ shifts north in June → draws moist SE trades → SW monsoon.
  - Retreats south in winter → NE monsoon sets over Tamil Nadu.
- **Desert Climate Stability:**
  - Subtropical highs shift but remain dominant → persistent aridity.
- **Global Wind Reversal Zones:**
  - Shifting belts alter trade winds, westerlies, and tropical convergence zones.

Coriolis Force

Meaning

- Apparent deflection of moving air/water due to Earth's rotation.



Key Characteristics

- Not a real force—an apparent effect caused by rotation.
- Acts only on moving objects (wind, currents, aircraft).
- Alters direction, not speed.
- Stronger for higher wind speed and higher latitude.
- **Formula:** $2\omega v \sin\theta$ (depends on velocity & latitude).

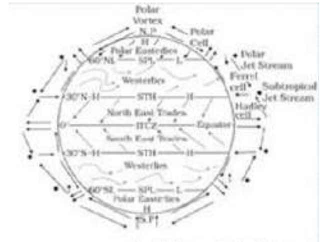
Climatic Importance

- Shapes global wind belts (trades, westerlies, polar winds).
- Responsible for rotation of cyclones/anticyclones.
- Influences ocean currents, jet streams, pressure systems.
- Essential for geostrophic wind formation (balance with pressure gradient).

Tri-cellular Atmospheric Circulation

Core Idea

- Global circulation explained through three cells per hemi-sphere formed by differential heating + Earth's rotation.


Simplified general circulation of the atmosphere

1. Hadley Cell (0°–30°)

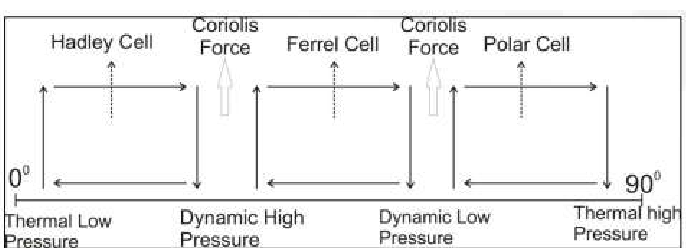
- Strong heating at equator → air rises → divergence aloft.
- Air moves poleward, cools, sinks at 30° → forms subtropical highs.
- Surface return flow from 30° → 0° = Trade Winds.
- Produces tropical rain belts (ITCZ) and subtropical deserts.

2. Ferrel Cell (30°–60°)

- Air rises at subpolar lows (60°) due to convergence of westerlies & polar easterlies.
- Moves aloft toward 30° → descends in subtropical highs.
- **Surface flow:** Westerlies in mid-latitudes.
- Acts as a transitional, mechanically driven cell.

3. Polar Cell (60°–90°)

- Cold dense air sinks at poles → forms Polar Highs.
- Surface flow toward 60° = Polar Easterlies.
- Air rises at 60° (subpolar lows) → completes the cell.



Key Features

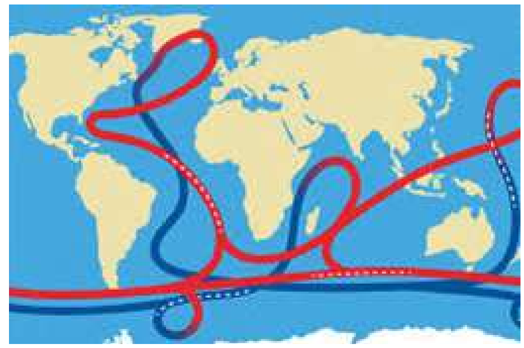
- Provides global distribution of pressure belts, wind belts, and climate zones.
- Explains trade winds, westerlies, polar winds, and jet stream interaction.
- Drives heat transfer from equator → poles.

Atlantic Meridional Overturning Circulation (AMOC)

Meaning

- Large system of ocean currents carrying warm surface water northward & cold deep water southward in the Atlantic.
- Driven by temperature–salinity gradients (thermohaline circulation).

Significance



- Climate Regulator – Transfers heat from tropics to the North Atlantic → moderates Europe's climate.
- Monsoon Influence – Impacts rainfall patterns in South Asia, West Africa, and Amazon.
- Carbon Sink Support – Enhances CO_2 uptake in the North Atlantic.
- Nutrient Transport – Supports marine ecosystems via deep-water formation.
- Sea-Level Control – Weak AMOC raises sea levels along US East Coast.

Risks / Drivers of Weakening

- Global Warming → warming of North Atlantic reduces density → weakens sinking.
- Ice Melt from Greenland → freshens ocean water → suppresses deep-water formation.
- Increased Precipitation & River Runoff → lowers salinity in the North Atlantic.
- Arctic Amplification → accelerates warming → reduces density contrast.
- Ocean Heat Uptake → disrupts temperature gradients.

Implications (Global & Regional)

- **Global Climate Impacts**
  - Weaker poleward heat transport → cooler Europe, hotter tropics.
  - Altered jet streams, storm tracks, and polar vortex behaviour.
- **Monsoon & Rainfall Impacts**
  - Indian Monsoon Weakening → reduced rainfall, drought risk.
  - West African Monsoon shifts → Sahel drought patterns.
  - Amazon drying → rainforest dieback risk.
- **Marine & Ecological Impacts**
  - Collapse of nutrient circulation → affects fish stocks in North Atlantic.
  - Changes in Atlantic hurricane intensity and tracks.

- **Sea-Level Rise**
    - AMOC slowdown → regional sea-level rise along US east coast & Gulf of Mexico.

■ **Worst-Case Scenario**

- Severe cooling in Northern Europe ("mini ice age").
- Disruption of monsoons → global food-security threats.
- Strong warming in tropics → more heatwaves.
- Abrupt climate shifts → irreversible tipping-point impacts.

D. Air Masses & Fronts

1,Air Mass

■ **Meaning**

- A large body of air with uniform temperature, humidity, and stability over a wide horizontal area.
- Forms over broad, homogeneous source regions like oceans, deserts, tundra.

■ **Types / Classification** By Moisture • Continental (c) – dry (forms over land). • Maritime (m) – moist (forms over oceans). By Temperature • Tropical (T) – warm. • Polar (P) – cold. • Arctic/Antarctic (A) – extremely cold.	• Major Air Mass Types • cT – hot, dry (deserts). • mT – warm, moist (tropical oceans). • cP – cold, dry (interior high latitudes). • mP – cool, moist (North Atlantic/North Pacific). • cA – very cold, very dry (polar interiors).

Significance

- Controls temperature changes, heat waves & cold waves.
- Drives front formation → source of temperate cyclones.
- Determines rainfall patterns (monsoon moisture, frontal rain).
- Influences storm tracks, fog, visibility, and aviation weather.
- Key to understanding regional climate zones and seasonal transitions.

2.Front

■ **Meaning**

- A boundary between two contrasting air masses (temperature, humidity, density).
- Marks a zone of sharp weather changes.

Types / Classification

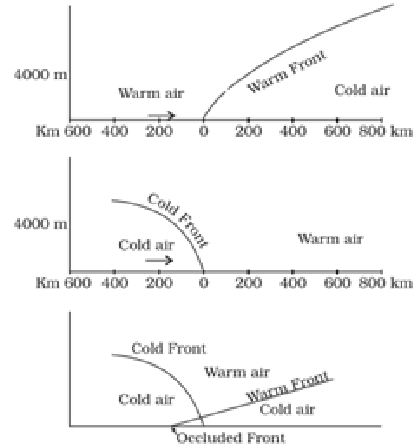


Figure 10.8 : Vertical Sections of : (a) Warm Front: (b) Cold Front: (c) Occluded Front

Cold Front

- Cold air advances and pushes warm air upward.
- Steep slope; fast movement.
- Causes intense but short-duration rain, thunderstorms.

Warm Front

- Warm air moves over retreating cold air.
- Gentle slope; slow movement.
- Produces widespread, steady rainfall and cloud layers.

Stationary Front

- Neither air mass advances.
- Cloudy, wet, prolonged weather.

Occluded Front

- Cold front overtakes warm front; warm air lifted aloft.
- Common in temperate cyclones; complex precipitation.

Significance

- Generates mid-latitude cyclones and major rainfall systems.
- Controls abrupt temperature shifts, storms, fog formation.
- Essential for weather forecasting, aviation safety, and climate analysis.

3.Frontogenesis

Meaning

- The process of formation or strengthening of a front due to increasing contrast between two air masses.

Key Conditions

- Strong temperature gradient between adjacent air masses.
- Convergence of unlike air masses (warm–cold).
- Horizontal temperature differences sharpen with time.
- Occurs mainly in mid-latitudes where air masses frequently meet.

Mechanisms

- Convergence → pushes contrasting air masses together → sharper boundary.
- Differential heating/cooling → increases temperature contrast.
- Topographic influence → mountains force air masses to meet.
- Dynamic uplift (cyclonic conditions) → tightens thermal gradient.

Weather Effects

- Enhances cloud formation, uplift, precipitation.
- Leads to development/intensification of temperate cyclones.
- Associated with rapid weather changes along the front.

Significance

- Key process in mid-latitude weather systems.
- Helps forecast storms, frontal rain, cold waves, warm spells.
- Critical for aviation and synoptic meteorology.

E. Cyclones

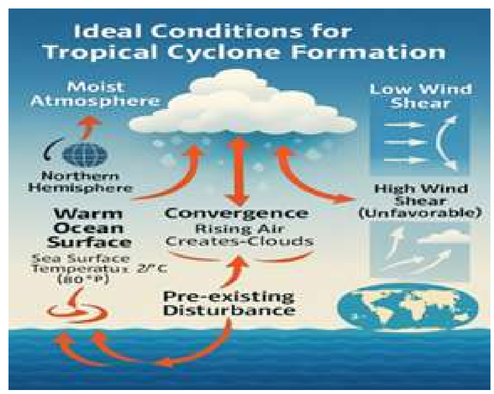
Meaning

- Large, rotating low-pressure systems with inward spiraling winds.
- Air rises at center → clouds, rain, storms.

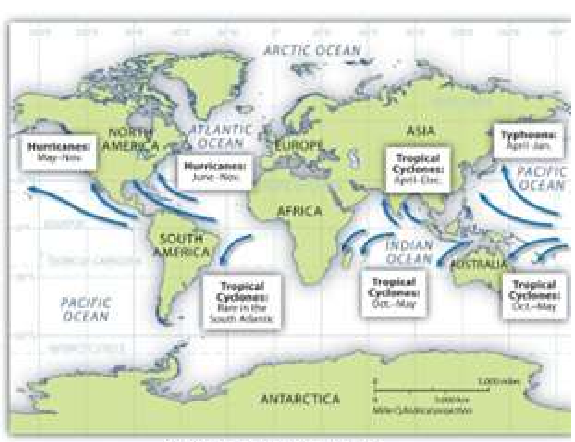
1.Tropical Cyclones

- **Meaning**
- Intense low-pressure systems over warm tropical oceans with spiralling winds, heavy rain, and a central calm eye.

Conditions Required



- Sea surface temperature > 26.5°C (deep layer of warm water).
- High humidity in lower–middle troposphere.
- Strong Coriolis force (hence form between 5°–30°).
- Low vertical wind shear (allows organized convection).
- Pre-existing low-pressure disturbance / easterly wave.
- Upper-level divergence to evacuate rising air.



Significance of Tropical Cyclones

- Transfer heat and moisture from oceans to the atmosphere, balancing Earth's energy system.
- Drive vertical and horizontal heat redistribution, reducing tropical energy surplus.
- Play a key role in global atmospheric circulation and maintaining pressure belts.
- Trigger large-scale rainfall events, influencing seasonal patterns (including monsoon variability).
- Enhance ocean mixing, bringing nutrients to surface waters.
- Contribute to cloud formation and global hydrological cycle.
- Shape coastal landforms through wave action, sediment redistribution, and storm surges.

2.Extra-Tropical Cyclone

Meaning

- Large low-pressure systems forming in mid-latitudes (35°–65°) where warm tropical air meets cold polar air.

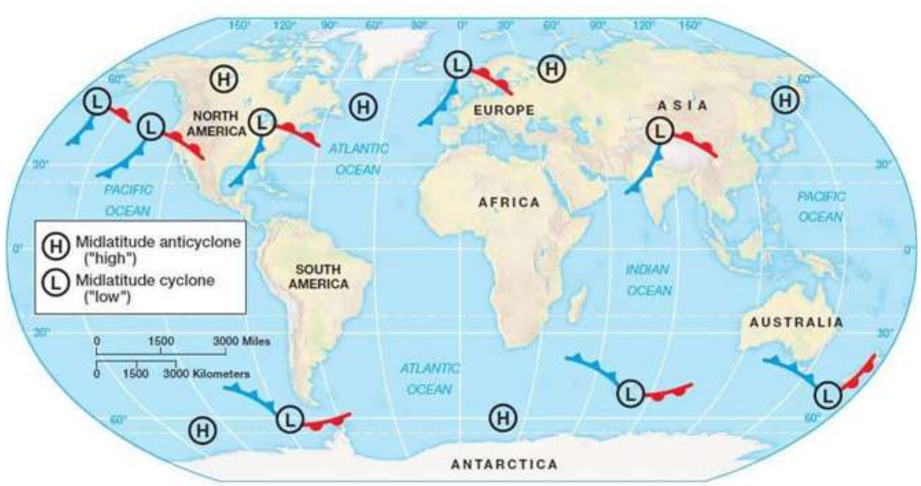
Formation Conditions

- Strong temperature contrast along the polar front.
- Active westerlies and upper-air divergence.
- Presence of Rossby waves supporting cyclogenesis.

Structure

- Have warm front + cold front meeting at the center.
- Cold air wedges under warm air → frontal uplift.
- Wide cloud bands; no eye (unlike tropical cyclones).

FOR FORMATION YOU CAN REFER DIAGRAM OF FRONTOGENESIS



Associated Weather	Significance
• **Warm front:** steady rain, overcast sky. • **Cold front:** intense rain, thunderstorms, sharp temperature drop. • **Occlusion:** widespread precipitation, snow in high latitudes.	• Major driver of mid-latitude weather systems. • Bring winter rainfall to NW India (Western Disturbances). • Key for heat redistribution between tropics and poles. • Influence aviation, shipping, agriculture, and snowfall patterns.

F. Clouds and Forms of Precipitation

1.Clouds

Meaning

- Visible masses of tiny water droplets or ice crystals formed by condensation in the atmosphere.

Classification (By Height & Appearance)

- High Clouds (above 6 km) – composed mostly of ice
  - Cirrus (Ci) – thin, wispy; fair weather.
  - Cirrostratus (Cs) – thin veil; halo around sun/moon.
  - Cirrocumulus (Cc) – small white ripples.
- **Middle Clouds (2–6 km)**
  - Altostratus (As) – grey, uniform; light rain.
  - Altocumulus (Ac) – white/grey patches; atmospheric instability.
- **Low Clouds (below 2 km)**
  - Stratus (St) – layered, dull; drizzle/fog-like.
  - Stratocumulus (Sc) – low lumpy clouds; light rain.
- **Vertical Development (surface to 12–13 km)**
  - Cumulus (Cu) – cauliflower-shaped; fair weather.
  - Cumulonimbus (Cb) – tall thunderstorm clouds; lightning, hail, heavy rain.

2.Precipitatin

Forms of Precipitation

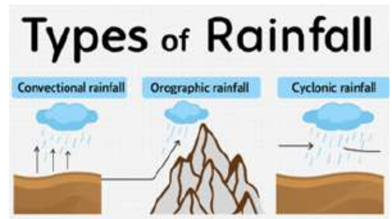
- **Rain:** Liquid water droplets >0.5 mm; formed by condensation and coalescence.
- **Drizzle:** Very fine droplets <0.5 mm; from low stratus clouds.
- **Snow:** Ice crystals form directly from vapour; below-freezing conditions.

- **Sleet:** Frozen raindrops or ice pellets; temperature inversion layers.
- **Hail:** Ice balls formed by strong updrafts inside cumulonimbus clouds.
- **Glaze / Freezing Rain:** Supercooled raindrops freeze on contact with cold surfaces.
- **Dew:** Condensation on cold surfaces during clear nights (surface phenomenon).
- **Frost:** Ice crystals deposited directly by sublimation on freezing surfaces.
- **Fog / Mist:** Cloud at ground level; formed by cooling and condensation near the surface.

Types of Rainfall

1. Convectional Rainfall

- Occurs when intense surface heating causes warm, moist air to rise.
- Rapid uplift → condensation → heavy, short-duration rain.
- Common in equatorial regions (afternoon showers).
- Associated with cumulonimbus clouds, thunderstorms.



2. Orographic (Relief) Rainfall

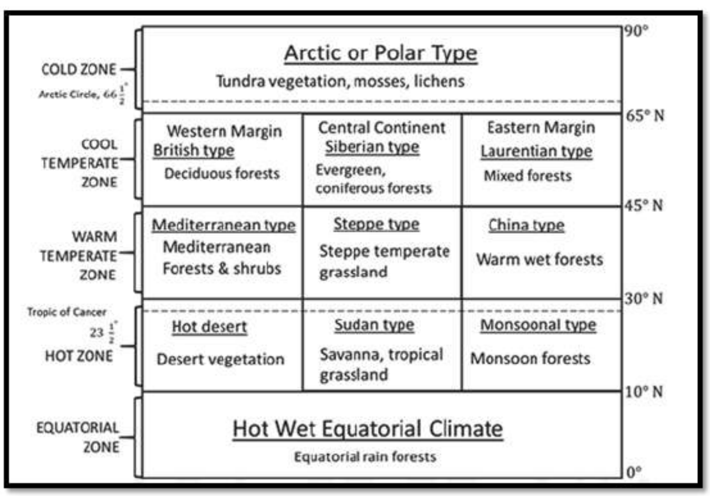
- Moist air forced to rise over mountains/hills.
- Windward side → cooling → condensation → heavy rainfall.
- **Leeward side → dry descending air → rain shadow.**
- **Examples:** Western Ghats (windward heavy rain; leeward rain shadow).

3. Cyclonic (Frontal) Rainfall

- **Caused by lifting of warm air over cold air along fronts.**
- **Warm Front:** gentle, widespread, steady rain.
- **Cold Front:** intense, short-lived rainfall.
- Dominant in mid-latitudes (temperate cyclones) and tropical cyclones.

Climatic Zone	Latitude (approx.)	Climatic type	Rainfall regime	Natural Vegetation
Equatorial Zone	00-100N and S	1. Hot, wet equatorial	rainfall all year round: 200cm	Equatorial rain forests
Hot Zone	100-300N and S	1. (a) Tropical Monsoon (b) Tropical Marine 2. Sudan Type 3. Desert: (a) Saharan type (b) Mid-latitude type	Heavy summer rain : 150cm Much summer rain :175cm Rain mainly in summer :75cm Little rain : 15cm	Monsoon forests, Savana (tropical grassland), Desert vegetation and scrub

Warm Temperate Zone	300-450N and S	1. Western Margin (Mediterranean type) Central Continental (Steppe type) Eastern Margin: (a) China Type (b) Gulf Type (c) Natal Type	Winter Rain : 90cm Light Summer rain: 50cm Heavier Summer rain: 115cm	Mediterranean Forests and shrub Steppe or Temperate Grassland, Warm, Wet forests and Bamboo
Cool Temperate Zone	450 - 650 N and S	Western Margin (British Type) Central Continental (Siberian Type) 10. Eastern Margin (Laurentian Type)	More rain in autumn and winter : 75cm Light Summer rain: 60cm Moderate Summer Rain: 100cm	Deciduous Forests, Evergreen Coniferous forest, Mixed Forest, (Coniferous & Deciduous)
Cold Zone	650 - 900 N and S	11. Arctic or Polar	Very light summer rain: 25cm	Tundra, mosses and lichens
Alpine Zone	At high altitudes (above 3000m)	12. Mountain Climate	Heavy Rainfall (Variable)	Alpine Pastures, conifers, fern, snow



3. Oceanography

A. Oceanic Relief and Submarine Landforms

1.Major Ocean Relief

1. Continental Shelf

- Submerged edge of continents; shallow, gently sloping.
- Rich in fisheries, oil & gas.
- Widest in Arctic Ocean; narrow in Pacific.

2. Continental Slope

- Steep drop after the shelf; boundary between continental crust & oceanic crust.
- Features canyons carved by turbidity currents.

3. Continental Rise

- Gentle slope formed by deposition of sediments at the base of the continental slope.
- Connects slope to abyssal plains.

4. Abyssal Plains

- Flat, deep ocean floors (4,000–6,000 m).
- Created by sediment covering uneven crust.
- Among Earth's flattest surfaces.

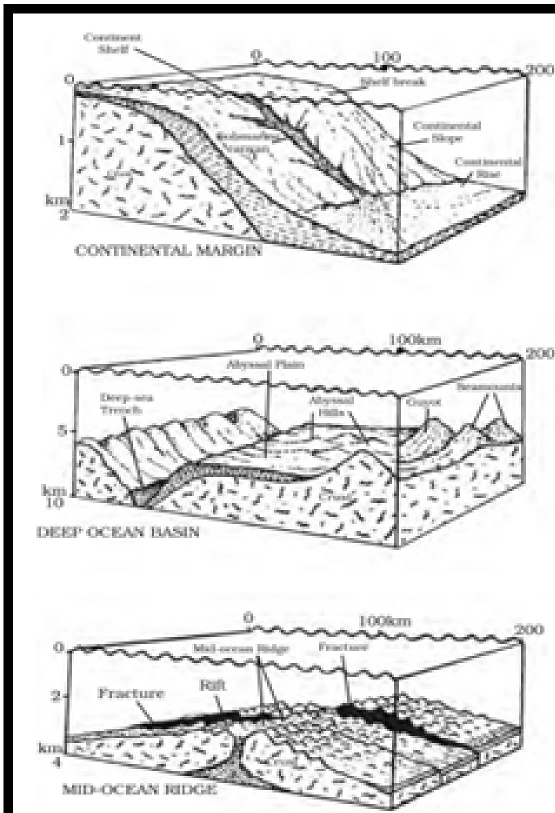


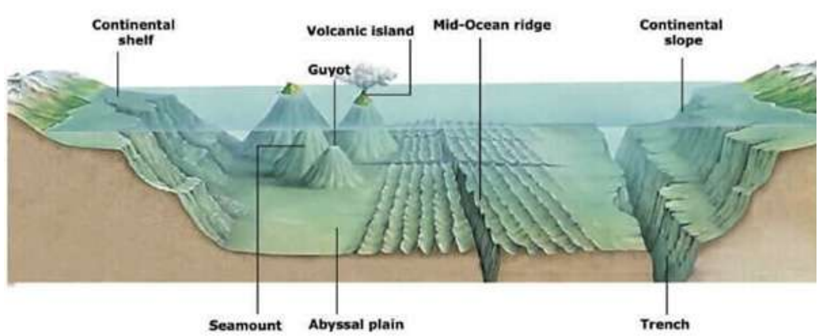
Figure 13.2 : Relief features of ocean floors

5. Mid-Ocean Ridges

- Underwater mountain chains formed by divergent plate boundaries.
- High volcanic and seismic activity; central rift valley.
- **Example:** Mid-Atlantic Ridge.

6. Deep Sea Trenches

- Long, narrow, deepest parts of ocean; formed by subduction.
- **Highest depth:** Mariana Trench (~11,000 m).
- Associated with strongest earthquakes.



2.Minor Ocean Relief

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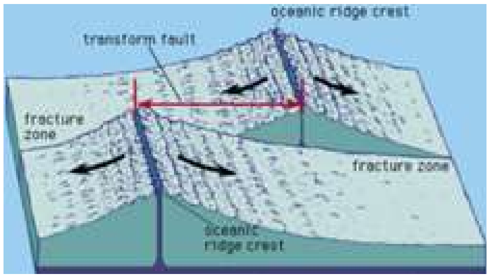
<tr><th>Feature</th><th>Explanation</th></tr>
<tr><td>
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Ridges

- Long, narrow mountain chains on the ocean floor.
- Formed due to tectonic plate divergence (seafloor spreading).
- Example: Mid-Atlantic Ridge.
- Often associated with volcanic activity and new crust formation.

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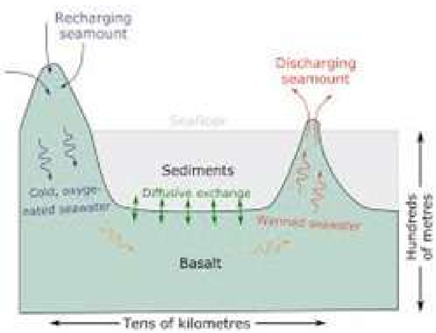
<tr><td>
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Seamounts

- Submarine volcanic mountains rising from the seafloor.
- Do not reach the ocean surface (unlike islands).
- Often form near tectonic plate boundaries or hotspots.
- Rich in marine life due to nutrient upwelling.

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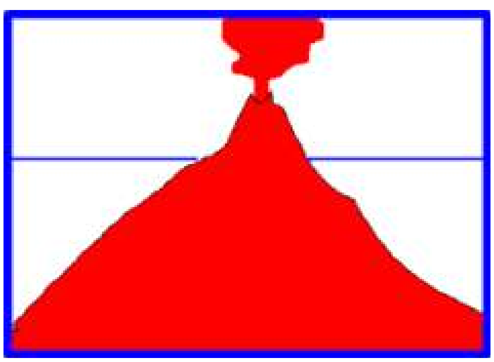
<tr><td></td><td>

Guyots

- Flat-topped seamounts.
- Once volcanic islands eroded by waves, then submerged.
- Found mostly in Pacific Ocean.
- Important for studying sea level changes.

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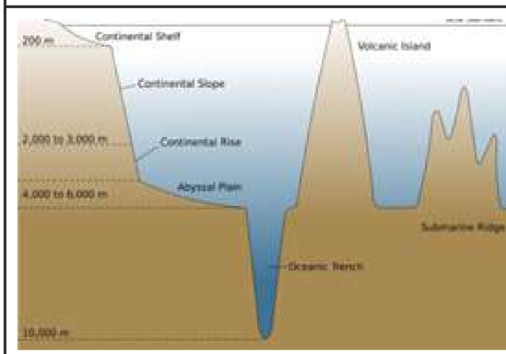
<tr><td>
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Trenches

- Deep, narrow depressions in the ocean floor.
- Formed by subduction of one tectonic plate under another.
- Example: Mariana Trench (deepest point on Earth).
- Associated with strong earthquakes and volcanic activity.

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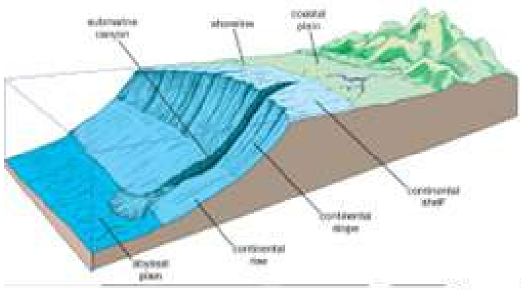
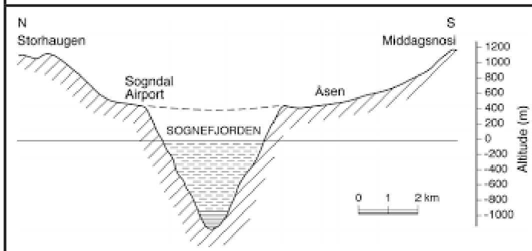


Submarine Canyon

- Deep valleys cut into continental slopes.
- Formed by river erosion during low sea levels or turbidity currents.
- Example: Hudson Canyon (off New York).
- Serve as routes for sediments from land to deep sea.

Coral Reefs

- Structures formed by colonies of tiny marine organisms (corals).
- Found in warm, shallow, sunlit waters.
- Three main types: fringing reef, barrier reef, atoll.
- Example: Great Barrier Reef (Australia).



Fjords

- Narrow, deep, steep-sided inlets of the sea.
- Formed by glacial erosion and later submerged by sea-water.
- Common in Norway, New Zealand, Canada.
- Provide natural harbors but are limited to glaciated coasts.

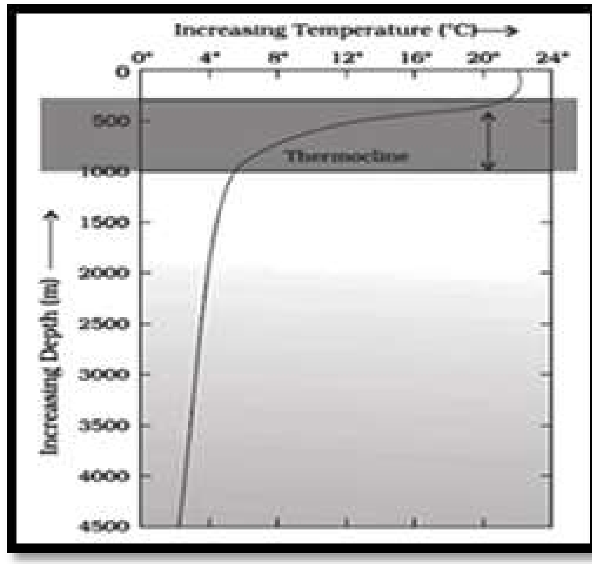
B. Temperature, Salinity & Density

1. Temperature of Oceans

Key Points	Factors Affecting Temperature of ocean
• Sun is the main heat source; insolation varies with latitude, season, cloud cover, and angle of rays. • Daily range very small (~1°C); annual range larger (max in August, min in February in N. Hemisphere). • Temperature decreases from equator → poles and from surface → depth.	• Latitude – higher latitudes → lower temperature. • Land–water distribution – NH oceans warmer than SH. • Winds – offshore winds cause upwelling → cooling; onshore winds → warming. • Ocean currents – warm currents raise temperature; cold currents lower it. • Local factors – storms, cloud cover, evaporation, sea shape.

Vertical Distribution

- Surface warm layer → rapid decline up to 1000 m (thermocline) → slow decline below.
- Photic zone (0–1000 m) – ~90% marine life.
- Aphotic zone – cold, dark, uniform temperature at depth.



2. Density of Ocean Water

Factors Affecting Density

- Temperature – inversely related; colder → denser.
- Salinity – directly related; higher salt → higher density.
- Pressure – directly related but minor effect.

Vertical Pattern

- **Follows temperature trend:** density increases sharply across thermocline, then stabilises.

salinity of Oceans

Meaning

- Total salt content in 1 kg seawater; measured in parts per thousand (‰); average 33–37‰.
- Salt derived mainly from river inflow and chemical weathering.

Factors Controlling Salinity

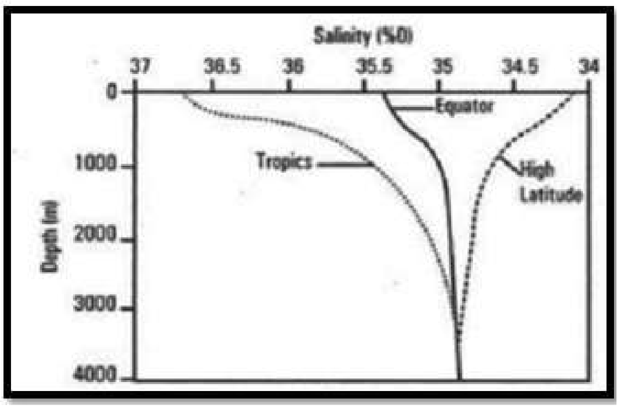
- Evaporation – high evaporation → high salinity (subtropics).
- Precipitation – high rainfall → low salinity (equator).
- Freshwater inflow – rivers/glacial melt reduce salinity (Bay of Bengal, Baltic Sea).
- Wind – onshore ↑ salinity; offshore ↓ salinity.
- Pressure systems – high pressure → clear skies → high salinity.
- Currents – warm currents ↑; cold currents ↓ salinity patterns.

Horizontal Distribution

- Equator – low salinity (rainfall).
- Tropics (20–30°) – highest salinity (evaporation).
- Temperate latitudes – moderate–low.
- Polar regions – lowest (melting ice).
- Enclosed seas depend on freshwater input, not latitude (Baltic low; Dead Sea extremely high).

Vertical Distribution

- Highly variable; halocline (200–1000 m) shows rapid salinity change.
- Polar regions – increases with depth; mid-latitudes – decreases with depth; equator – low at surface, higher below, low again at bottom.



Significance of Salinity

- Controls density, vertical mixing, and thermohaline circulation.
- Influences freezing/boiling point, evaporation rate.
- Regulates marine life distribution and biochemical cycles.
- Affects waves, currents, pressure, and overall ocean dynamics.
- Key driver of major ocean currents and climatic patterns.

C. Tides & Ocean Currents

1.Tides

Meaning

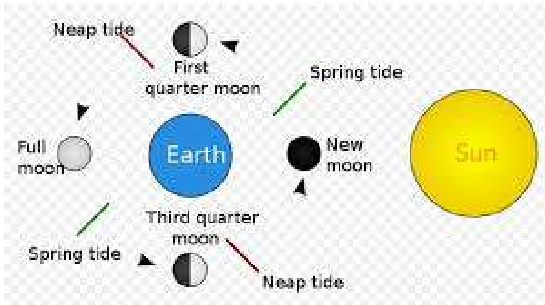
- Periodic rise and fall of sea level due to gravity of Moon & Sun + Earth's rotation.
- High tide = water rises; Low tide = water falls; Tidal range = difference between high & low tide.

Formation

- Moon's gravity strongest on the side facing the Moon → high tide.
- Opposite side: centrifugal force → second high tide.
- Time between two tides = 12 hrs 26 min.

Types of Tides

- Spring Tide – Sun, Moon, Earth in a line (Syzygy); highest tides (New moon & Full moon).
- Neap Tide – Sun & Moon at right angles (Quadrature); lowest tides (Half-moon).
- Perigean/Apogean Tides – Moon closest (perigee) → stronger tides; farthest (apogee) → weaker.



Importance

- Transport & deposition of coastal sediments.
- Determines littoral zone width & coastal landforms.
- Basis for tidal energy and tidal navigation.
- Influences fishing, estuaries, delta morphology & marine life.

2.Ocean Current

Meaning

- Large-scale movement of ocean water in definite direction.
- Classified as warm and cold; also by speed: drifts, currents, streams.

Factors Behind Origin of Ocean Currents

A. Earth's Rotation

- Coriolis force deflects currents: right in NH, left in SH.
- Rotation generates equatorial current and counter-equatorial current.

B. Ocean-Water Factors

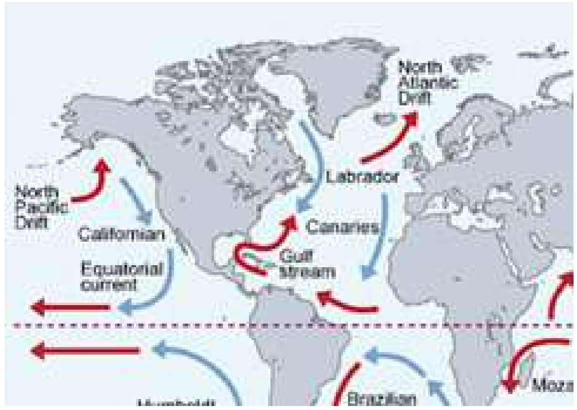
- Temperature differences (warm water moves poleward).
- Salinity differences (high-salinity water sinks → density currents).
- Density differences (temperature + salinity combined).

C. Atmospheric Factors

- Planetary winds (trades, westerlies) drive surface currents.
- Monsoon winds reverse currents in North Indian Ocean.
- Rainfall/Evaporation cause local sea-level differences → minor flow.

Factors Modifying Ocean Currents

- Coastline shape – currents deflect/bifurcate (e.g., Brazil coast → Gulf Stream & Brazilian Current).
- Submarine relief – ridges deflect currents.
- Seasonal changes – strong in Indian Ocean due to monsoon.


North
Atlantic
Drift
Labrador
North
Pacific
Drift
Californian
Canaries
Gulf
Stream
Equatorial
current
Brazilian

02 HUMAN GEOGRAPHY

1. Distribution of Key Natural Resources across the world (including South Asia and the Indian sub-continent)

A. Water Resource

Status

- **Global Distribution**
- **Earth's water:** 97% oceans, 3% freshwater.
- **Freshwater:** 69% glaciers/ice, 30% groundwater, 1% surface water.
- **Uneven distribution:** abundant in equatorial & temperate zones; scarce in arid regions.

Major Water-Rich Regions

- Amazon Basin, Congo Basin, Himalayan Rivers, Great Lakes, SE Asia, Europe (Rhine–Danube).
- **Countries with surplus:** Brazil, Russia, Canada, China, Indonesia.

Water-Scarce Regions

- West Asia, North Africa, Central Asia, Australia, Southwestern USA, Sahel.

India

- 4% global water, 17% population → water-stressed.
- **Major basins:** Ganga, Godavari, Krishna, Indus, Brahmaputra, Narmada, Cauvery.
- **Himalayan rivers:** perennial; Peninsular rivers: seasonal.
- **Problems:** over-extraction, interstate disputes, pollution, rainfall variability, climate change.

Issue of Water Scarcity Around the World

CORE IDEA

- Only 2.5% of Earth's water is freshwater; <1% is usable.
- 4 billion people face severe water scarcity for at least one month/year (UN).
- 700 million people could be displaced by water stress by 2030 (UN-WWDR).
- 40% of global population lives in water-stressed regions.
- Agriculture uses 70% of global freshwater; industry 20%, domestic 10%.

- 21 of the 30 most water-stressed countries lie in West Asia & North Africa.
- Global groundwater extraction: ~1,000 km^3/year; India, China, USA top users.
- Cape Town (2018) & Chennai (2019) reached near "Day Zero".

KEY CAUSES

- Physical Water Scarcity – Arid climates with rainfall <200 mm/year (e.g., Saudi Arabia, UAE, Libya).
- Economic Water Scarcity – Lack of infrastructure despite availability (e.g., Ethiopia, DRC; <50% have access to clean water).
- Overuse in Agriculture – Inefficient irrigation consumes 70% freshwater (e.g., India's Punjab over-extraction).
- Population Growth & Urban Pressure – Megacities like Mexico City & Cairo pumping more groundwater than recharge.
- Groundwater Depletion – India extracts 25% of world's groundwater, leading to rapid water table fall (NASA GRACE data).
- Pollution of Rivers & Lakes – 80% of wastewater globally released untreated (e.g., China's Hai River; India's Ganga & Yamuna).
- Climate Change – Extreme droughts (Horn of Africa, Australia) + shrinking glaciers (Himalayas losing 28% ice since 1980s).
- Declining Per Capita Availability – Global avg dropped from 6,000 m^3 (1900) to ~2,000 m^3 (2020).

Impacts

- Decline in agriculture → food insecurity.
- Groundwater depletion → land subsidence (Jakarta, Mexico City).
- Health crises from unsafe water.
- Conflicts: Nile Basin, Indus Basin, Jordan Basin.
- Economic losses in industry & energy production (hydropower).
- Urban water emergencies (Cape Town "Day Zero", Chennai crisis).

B. Mineral Resource

Introduction

- Mineral resources are naturally occurring inorganic substances with definite chemical composition and economic value.
- Unevenly distributed due to geological history, tectonics, and rock formation processes.
- Form the backbone of industry, energy security, manufacturing, and strategic technologies.
- Global distribution shows clear patterns: Precambrian shields (metals), fold belts (non-ferrous minerals), sedimentary basins (fossil fuels).

1.World: Distribution of key mineral like Iron, Copper and Bauxite

1. Iron Ore – World Distribution

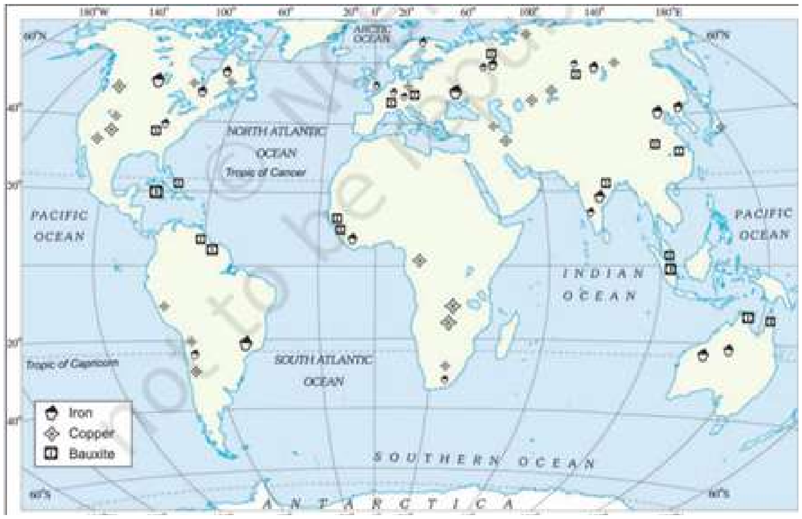
- **Concentrated in Precambrian shields and sedimentary belts.**
- **Top producers:** Australia, Brazil, China, India, Russia.
- **Major belts:**
  - Australia: Pilbara (Hamersley Range) – world's largest high-grade reserves.
  - Brazil: Carajás (Amazon Shield) – rich hematite.
  - China: Liaoning, Hebei (largest consumer).
  - India: Odisha–Jharkhand–Chhattisgarh belt.
  - Russia/Ukraine: Kursk Magnetic Anomaly, Krivoy Rog.
- **Export giants:** Australia & Brazil; import giants: China, Japan, South Korea.

2. Copper – World Distribution

- **Linked to fold mountains, igneous intrusions, volcanic belts, porphyry copper deposits.**
- **Top producers:** Chile, Peru, China, DRC, USA.
- **Major belts:**
  - Chile: Atacama Desert (Escondida) – world's largest.
  - Peru: Andes copper belt.
  - USA: Arizona (Morenci), Utah.
  - DRC/Zambia: Copperbelt region – Africa's major deposit.
  - China: Jiangxi, Yunnan.
- **High-grade ores in Andes, African Copperbelt, Western USA.**

3. Bauxite – World Distribution

- **Derived from tropical/subtropical weathering of rocks → laterites.**
- **Top producers:** Australia, Guinea, China, Brazil, India.
- **Major belts:**
  - Australia: Weipa, Darling Range – world's largest reserves.
  - Guinea: Boké region – highest-grade bauxite globally.
  - China: Shanxi, Henan.
  - Brazil: Trombetas, Pará.
  - India: Odisha (Koraput), Gujarat, Maharashtra.
- **Export leaders:** Australia, Guinea; major consumers: China.



2.Distribution of Mineral oil and Coal

Mineral Oil (Petroleum) – World Distribution

Global Pattern

- **Concentrated in sedimentary basins, continental shelves, and Tethyan belt.**
- **Highly uneven:** Middle East holds ~48% of global reserves.

Major Regions

- Middle East (Largest) – Saudi Arabia (Ghawar), Iraq, Iran, UAE, Kuwait, Qatar.
- North America – USA (Texas, Gulf of Mexico, Alaska), Canada (oil sands).
- South America – Venezuela (Orinoco Belt), Brazil (offshore Santos Basin).
- Eurasia – Russia (Volga–Urals, West Siberia), Kazakhstan, Azerbaijan.
- Africa – Nigeria, Angola, Libya, Algeria (Sahara basin).
- Asia-Pacific – China, Indonesia, Malaysia, Brunei.
- Europe – North Sea (UK–Norway).

Production Leaders

- USA, Saudi Arabia, Russia, Iraq, Canada.

2. Coal – World Distribution

Global Pattern

- Found in ancient continental platforms, Gondwana basins, and younger Tertiary deposits.
- Coal-rich regions formed during Carboniferous period.

Major Regions

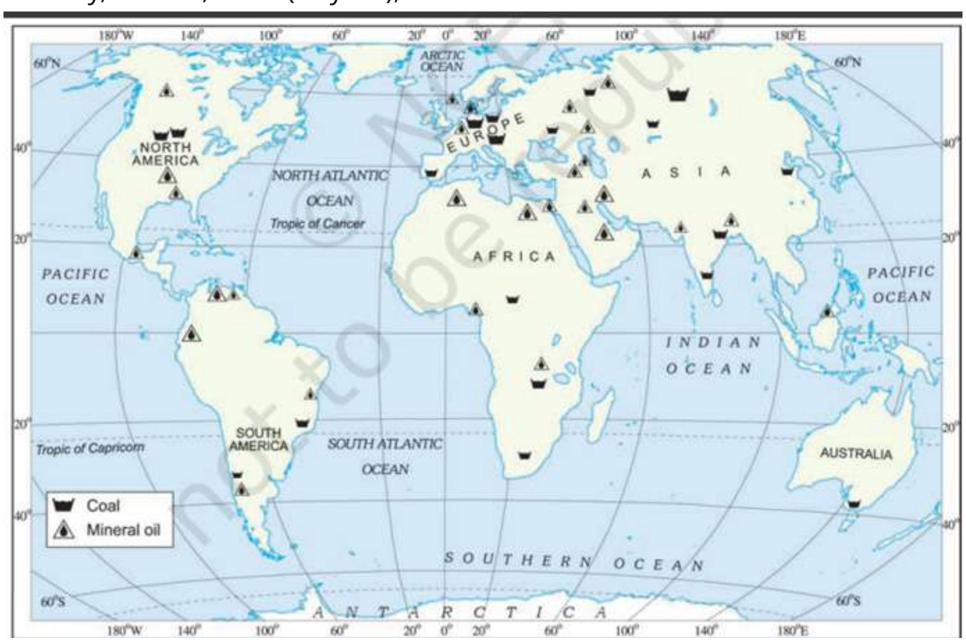
- Asia – China (Shanxi, Inner Mongolia), India (Jharkhand, Odisha, Chhattisgarh), Indonesia.
- North America – USA (Appalachian, Interior Basin, Powder River Basin).
- Europe – Russia (Kuznetsk Basin), Germany, Poland, Ukraine (Donbas).
- Australia – Queensland, New South Wales (major exporter).
- Africa – South Africa (Witbank).

Production Leaders

- **China (~50%), India, Indonesia, Australia, USA.**

Types by Region

- **Anthracite:** USA (Pennsylvania), Russia.
- **Bituminous:** China, India, Australia, USA.
- **Lignite:** Germany, Greece, India (Neyveli), USA.



3. Global Challenges in Mineral Resource Management

- **Resource Depletion:** Non-renewables shrinking → deeper, costlier exploration → declining ore grades.
- **Environmental Impact:** Mining → deforestation → water/air pollution → GHG emissions → climate stress (e.g., Amazon mining damage).
- **Geopolitical Conflicts:** Mineral hotspots → tensions (e.g., South China Sea oil/gas, Africa's diamonds & gold).
- **Illegal Mining:** Unregulated extraction → ecological damage + human rights abuse (e.g., DR Congo cobalt, Brazil Amazon, India sand mining).

- **Economic Dependency:** Mineral-export economies → price shocks → instability (e.g., Venezuela, Nigeria, Saudi Arabia).

Global Trends in Mineral Resource Use

- **Renewable Energy Transition:** Solar/wind shift ↓ fossil fuel demand → ↑ demand for lithium, cobalt, nickel for EVs & batteries.
- **Circular Economy:** Recycling & reuse ↑ → reduced mining pressure (e.g., aluminum, copper, gold recycling growth).
- **Sustainable Mining:** Clean tech → lower emissions → stricter regulations → push for ethical, low-impact mining.

2.Factors responsible for the location of primary, secondary, and tertiary sector industries in various parts of the world

What Are Primary, Secondary & Tertiary Industries (Ultra-Short)

- **Primary Industries:** Extract natural resources → farming, fishing, forestry, mining.
- **Secondary Industries:** Convert raw materials → manufacturing, processing, construction.
- **Tertiary Industries:** Provide services → transport, IT, banking, tourism, education.

Factors Responsible for Location of Primary Industries	Factors Responsible for Location of Tertiary (Service) Industries	Factors Responsible for Location of Secondary (Manufacturing) Industries
• Natural Resources Availability: Minerals → mining clusters (e.g., Australia's iron ore belt). • Climate & Soil: Favourable agro-conditions → crops (e.g., coffee in Brazil, tea in India–Assam). • Water Availability: Irrigation + fishing → river/coastal regions. • Topography: Plains → agriculture; Mountains → forestry & pastoralism. • Labour Needs: Seasonal, low-skilled labour → dense rural regions.	• Raw Materials: Bulk inputs → steel near coal-iron (e.g., Pittsburgh, Jamshedpur). • Energy Supply: Coal, hydro, oil → energy-heavy industries (e.g., Norsk Hydro in Norway). • Transport Connectivity: Ports/rail/highways → lower cost (e.g., Japanese coastal industries). • Market Proximity: Large consumer markets → FMCG clusters (e.g., US, EU, India metros).	• Urbanization: Cities → demand for services → hospitals, banking, education. • Skilled Workforce: Knowledge & IT → talent hubs (e.g., Bengaluru, Singapore). • Infrastructure: Telecom → transport → digital networks → service efficiency. • Market Access: Dense population → service consumption. • Government Policies: IT parks, incentives (e.g., India's STPI scheme).

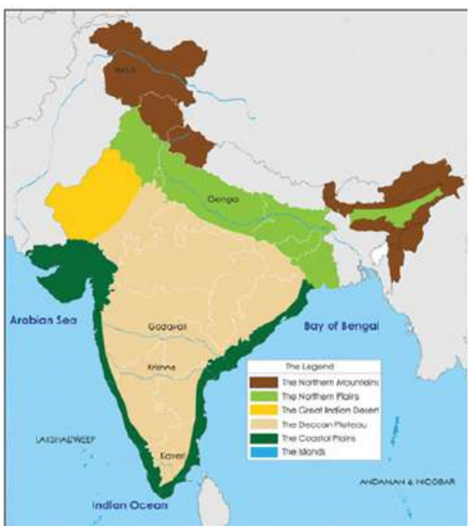
• Market Demand: Proximity to raw-material demand centres.	• Skilled Labour: Tech & precision work → skilled belts (e.g., Germany's engineering hubs). • Capital Availability: Finance + technology → industrial growth (e.g., Silicon Valley capital ecosystem). • Industrial Climate: Policies, SEZs, low taxes → favourable investment. • Agglomeration: Industrial clusters → shared services & suppliers (e.g., Detroit auto cluster).	• Global Connectivity: Airports, trade links → finance & tourism hubs (e.g., Dubai, London). • Quality of Life: Safety, lifestyle → attracts high-end service industries.

03 INDIAN & MAHARASHTRA GEOGMGRAPHY

1.Physiographic Divisions of India & Maharastra

India

- **India is divided into six major physiographic divisions, shaped by tectonics, climate, and river systems.**
  (1) The Himalayan Mountains
  (2) The Northern Plains
  (3) The Peninsular Plateau
  (4) The Indian Desert
  (5) The Coastal Plains
  (6) The Islands



1. The Northern & North-Eastern Mountains

- Includes Himalayas (trans, greater, lesser, Shivalik) + NE hills (Purvanchal).
- Formed by Indo-Eurasian collision; young, fold mountains.
- **Features:** high peaks, deep gorges, glaciers, passes, fertile valleys.
- **Importance:** climate barrier, perennial rivers, hydro-power, biodiversity hotspots

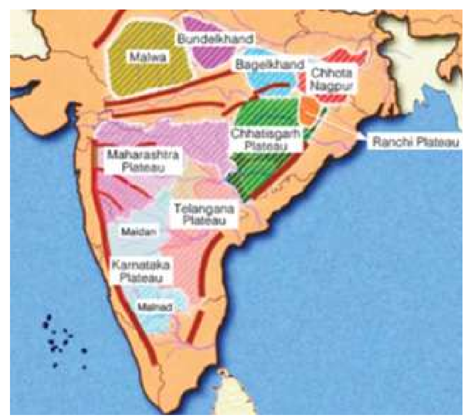
2. The Northern Plains

- Formed by sediments of Indus–Ganga–Brahmaputra rivers.
- Extensive alluvial plains with bhabar, terai, bangar, khadar.
- Highly fertile; India's major agricultural belt.
- Flat relief aids transport, urbanisation.

3. The Peninsular Plateau • Oldest landmass; part of Gondwana; stable block of hard rocks. • Includes Deccan Plateau, Central Highlands, Northeastern Plateau. • **Features:** lava plateaus (Deccan Traps), rift valleys (Narmada, Tapti), escarpments, mesas. • Rich in minerals; major river basins (Godavari, Krishna, Mahanadi).	**4. The Indian Desert** • **Thar Desert:** western Rajasthan. • Arid climate, sand dunes (barchans, longitudinal), scarce vegetation. • Luni is only major river; inland drainage. • Extends into Rann of Kachchh.
5. The Coastal Plains • **Western Coastal Plain:** narrow, steep (Konkan, Kannad, Malabar), estuaries, lagoons. • **Eastern Coastal Plain:** wide, deltaic (Godavari–Krishna–Cauvery), dunes, beaches. • Supports ports, fisheries, agriculture, tourism.	**6. The Islands** • **Andaman & Nicobar:** volcanic + submerged ridges; dense forests, biodiversity. • **Lakshadweep:** coral atolls; lagoons, reefs; low-lying. • Strategic significance for defence & maritime trade.

Significance of India's Peninsular Location

- Ensures long coastline (~7,500 km) → boosts trade, ports, fisheries, tourism.



- Provides maritime advantage in Indian Ocean, connecting West Asia, Africa, and Southeast Asia.
- Acts as a bridge between East and West, shaping India's role in global trade routes since ancient times.
- Controls sea lanes of communication (SLOCs) in the Indian Ocean → strategic leverage.
- Moderates climate through maritime influence (peninsular climate, reduced extremes).
- Facilitates monsoon mechanism via land–sea thermal contrast.
- Promotes rich marine biodiversity (coral reefs, mangroves, backwaters).
- Offers access to energy resources (offshore oil & gas in Mumbai High, KG Basin).
- Critical for India's blue economy: shipping, fishing, minerals, renewable ocean energy.
- Strengthens defence and naval presence through bases in Andaman–Nicobar & Lakshadweep.
- Enhances India's role as net security provider in the Indian Ocean Region (IOR).

Climate Change and the Himalayan Ecosystem

Importance of the Himalayan Ecosystem

- **Source of major rivers:** Ganga, Brahmaputra, Indus.
- **Contains largest glacier mass outside poles – the "Third Pole".**
- Supports ~1.3 billion people in India, Nepal, Bhutan, Pakistan, Bangladesh.
- Global biodiversity hotspot (Himalayan + Indo-Burma zones).
- Provides hydropower, forests, agriculture, tourism, cultural heritage.

Observed Impacts of Climate Change

- **Glaciers & Snow**
  - Rapid glacial retreat (~0.5 m water equivalent loss annually).
  - Expansion of glacial lakes → rising GLOF risks.
  - Shorter snow-cover duration altering meltwater cycles.
- **Water Resources**
  - Higher monsoon flows, lower summer flows → seasonal imbalance.
  - Reduced groundwater recharge; altered base flow of rivers.
- **Ecosystems & Biodiversity**
  - Upward shift of vegetation zones; loss of medicinal plants.
  - Threat to Snow leopard, red panda, Himalayan musk deer.
  - Invasive species encroaching higher altitudes.
- **Disasters**
  - Increased flash floods, landslides, avalanches, cloudbursts.
  - Fragile slopes → heightened vulnerability.
- **Livelihoods & Communities**
  - Apple belts shifting upward in HP & Uttarakhand.
  - Stress on pastoralism, agriculture, tourism.
  - Rising outmigration due to declining carrying capacity.
- **Future Risks**
  - 1/3–1/2 of Himalayan glaciers may vanish by 2100.
  - Rivers may reach peak water, leading to long-term scarcity.
  - Rising risk of water conflicts, energy shortages, climate migration.

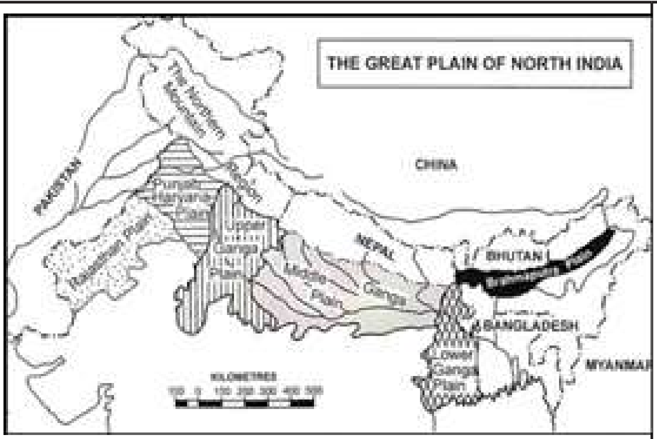
Government & Institutional Measures

- NMSHE under NAPCC for Himalayan sustainability.
- NAFCC for state-level climate adaptation.
- INCCA for climate research and assessments.
- ICIMOD for Hindu Kush Himalayan cooperation.
- SAPCCs focused on mountain state vulnerabilities.

Way Forward

- Strengthen glacier & river monitoring (remote sensing + field stations).
- Build disaster-resilient infrastructure; regulate construction on fragile slopes.
- Promote ecosystem-based adaptation (forests, wetlands, springs).
- Ensure sustainable tourism and regulate pilgrimage pressure.
- Empower local communities; use indigenous knowledge.
- Encourage regional cooperation for shared rivers & transboundary ecosystems.

Gangetic Plains (Indo-Gangetic Plains)



Formation

- Created by alluvial deposition from Himalayan rivers (Ganga, Yamuna, Ghaghara, Gandak, Kosi, Son).
- **Features layered alluvium:** Bhangar (old) & Khadar (new).

Subdivisions

- Upper Ganga Plains – Haryana, Western UP; better drainage, drier.
- Middle Ganga Plains – Central & Eastern UP; high fertility, dense population.
- Lower Ganga Plains – Bihar, West Bengal; abundant silt, flood-prone.

Major Landforms

- Bhabar – coarse sediments along foothills; porous belt.
- Terai – marshy belt south of bhabar; dense forests, high water table.
- Bhangar – old alluvium terraces; calcareous kankar nodules.
- Khadar – fresh deposits; renewed fertility; floodplains.

■ **Key Characteristics** • Flat terrain; slope ~15–20 cm/km. • Highly fertile alluvial soils → rice, wheat, sugarcane. • Rich groundwater; numerous canals. • Frequent floods (Kosi, Ghaghara) and river meandering. • **Dense rural and urban settlements; major cities:** Delhi, Kanpur, Lucknow, Patna, Kolkata.	■ **Economic Significance** • India's agricultural heartland (food grains, sugarcane, oilseeds). • **Industrial hubs:** Kanpur (leather), Kolkata (port), Noida–Ghaziabad (manufacturing). • **Dense transport network:** railways, highways, inland waterways.
■ **Environmental Issues** • River pollution (Ganga), groundwater depletion (Western UP). • Floods and erosion (Bihar), siltation, waterlogging. • Deforestation in Terai; wetland loss, urban pressure.	

Coastal Region of India

- India has a coastline of ~7,516 km along the Arabian Sea, Bay of Bengal, and Indian Ocean, forming diverse coastal landscapes.

■ **Western Coastal Plains** • Narrow (10–80 km), steep, backed by Western Ghats. • **Subdivisions:** ➤ Konkan Coast – Maharashtra–Goa; rocky cliffs, estuaries.	1. **Eastern Coastal Plains** • Wide (up to 120 km), flat, low-lying, backed by Eastern Ghats. • **Subdivisions:** ➤ Northern Circars – Andhra Pradesh; deltas, beaches.

- Kannada Coast – Karnataka; moderate width, ports (Mangaluru).
- Malabar Coast – Kerala; lagoons, backwaters (Vembanad), coconut plantations.

- **Characteristics:**
  - Drowned/coastal submergence → estuaries ideal for ports. High rainfall; lateritic soils; plantation crops (spices, rubber).
  - Strong monsoon waves, coastal erosion.

- Coromandel Coast – Tamil Nadu; cyclones, winter rainfall.

- **Characteristics:**
  - Large deltas: Mahanadi, Godavari, Krishna, Cauvery.
  - Highly fertile alluvium; rice bowl regions.
  - More prone to cyclones, storm surges, floods.

Islands (Associated Coastal Systems)

- **Andaman & Nicobar:** tectonic–volcanic origin, mangroves, coral reefs.
- **Lakshadweep:** coral atolls, lagoons, low elevation, high vulnerability.

Major Coastal Landforms

- Lagoons (Chilika, Pulicat), estuaries, sand dunes, spits, bars, mudflats, mangroves.
- Marine national parks (Gulf of Mannar, Sundarbans).

Economic Significance

- **Ports:** Mumbai, Kochi, Chennai, Visakhapatnam, Paradip.
- **Fishing & aquaculture:** rich EEZ (2.3 million sq km).
- **Minerals:** offshore oil & gas (Mumbai High, KG Basin), ilmenite, monazite.
- **Agriculture:** rice, coconut, arecanut, spices.
- **Tourism:** beaches, backwaters, islands.

Environmental Issues

- Coastal erosion (Kerala, Tamil Nadu, Odisha).
- Cyclones & storm surges (Bay of Bengal).
- Mangrove loss, wetland degradation, coral bleaching.
- Pollution from ports, industries, oil spills.
- Sea-level rise & saltwater intrusion.

Environmental Issues

- Coastal erosion (Kerala, Tamil Nadu, Odisha).
- Cyclones & storm surges (Bay of Bengal).
- Mangrove loss, wetland degradation, coral bleaching.
- Pollution from ports, industries, oil spills.

Government Initiatives

- Sea-level rise & saltwater intrusion.
- ICZM (Integrated Coastal Zone Management).
- CRZ Regulations for development control.
- Sagarmala Project for port-led development.

	• National Coastal Mission under NAPCC. • Mangrove & Coral Reef Conservation schemes.

Maharashtra Physiography

PHYSIOGRAPHIC DIVISIONS OF MAHARASHTRA

- **Maharashtra has three major physiographic regions:** Konkan, Western Ghats, and the Deccan Plateau (including Vidarbha, Marathwada, and Madhya Maharashtra).
- **Konkan (Coastal Lowlands):**
  - Narrow coastal strip between Arabian Sea and Western Ghats.
  - Characterised by lateritic soils, creeks, estuaries, and heavy rainfall.
  - Moderated climate due to proximity to the sea.
- **Western Ghats (Sahyadri Range):**
  - Runs north–south parallel to the coast; steep western escarpment.
  - Elevation 900–1600 m; source region for major rivers (Godavari, Krishna).
  - High rainfall on windward side; cool climate in hill stations (Mahabaleshwar, Matheran).
- **Deccan Plateau Region:**
  - Largest physiographic division; basaltic lava plateau.
  - Includes three sub-regions:
    - Madhya Maharashtra: Rainshadow zone; low rainfall; fertile black soils in some pockets.
    - Marathwada: Semi-arid plateau; undulating terrain; drought-prone.
    - Vidarbha: Eastern plateau with undulating plains; moderate rainfall; rich in forests (Satpura, Melghat).

- **River Basins:**
  - Godavari, Krishna, Bhima, Tapi, and Wardha–Wainganga basins shape the plateau.
  - Wide valleys and black soil plains characterise interior regions.
- **General Characteristics:**
  - High relief in Ghats → steep slopes and waterfalls.
  - Flat-topped plateaus (mesa, butte landforms) common in Deccan.
  - Coastal–Ghat–Plateau contrast creates marked variation in climate and vegetation.

2.Climate of India & Maharastra

Introduction

- India's climate is governed by monsoon winds, Himalayas, and land–sea contrast, creating marked seasonal variation.
- India → Tropical Monsoon Climate with distinct wet & dry seasons.
- Controlled by latitude, relief, monsoon winds, jet streams, and cyclonic systems.

CONTROLLING FACTORS OF INDIA'S CLIMATE

- **Latitude**
  - Tropic of Cancer divides India → tropical south & sub-tropical north.
  - Southern India → smaller temperature range; Northern India → sharp seasonal contrast.
- **Altitude**
  - Himalayas (avg. >6000 m) → block cold Central Asian winds → keep winters milder.
  - High mountains → support temperate, alpine climates; plains remain tropical.
- **Relief (Mountains, Ghats, Plateaus)**
  - Western Ghats → heavy rain on west-facing slope → rainshadow on interior Deccan.
  - Himalayas → force uplift of monsoon winds → intense rainfall in foothills.
  - NE Hills funnel Bay monsoon → extreme rainfall at Mawsynram/Cherrapunji.
- **Monsoon Winds**
  - Southwest monsoon → main source of rainfall (June–Sept).
  - Northeast monsoon → rainfall to TN coast (Oct–Dec).
  - Seasonal reversal of winds → defines wet vs dry seasons.
- **Land–Sea Contrast**
  - Land heats faster in summer → low pressure → draws moist winds from ocean.

- Land cools faster in winter → high pressure → dry northeast winds dominate.

- **Jet Streams**
  - Subtropical Westerly Jet (STWJ) → winter weather; drives Western Disturbances.
  - Tropical Easterly Jet (TEJ) → linked with monsoon onset and strength.
- **El Niño–La Niña (ENSO)**
  - El Niño → weak monsoon, drought tendencies.
  - La Niña → stronger monsoon, flooding risk.
- **Western Disturbances**
  - Extra-tropical storms from Mediterranean region.
  - Bring winter rain to north India → crucial for Rabi wheat.
- **Tropical Cyclones**
  - Mainly Bay of Bengal → influence rainfall in eastern & southern coasts.
  - Pre- and post-monsoon cyclones modify monsoon behaviour.
- **Indian Ocean Conditions**
  - Somali Jet, Arabian Sea SST, Bay depressions → modify rainfall distribution.
  - Warm ocean currents increase moisture supply to monsoon winds.

MAJOR CLIMATE SEASONS IN INDIA

1. Hot Weather Season (March–May)

- Strong heating → NW India >45°C; Loo winds blow.
- North → intense low pressure develops.
- **Local storms:** Kalbaisakhi, Nor'westers, Mango showers, Blossom showers.
- Peninsular India → moderate due to proximity to sea.

2. Southwest Monsoon Season (June–September)

- **Onset:** Kerala → moves northwards rapidly.
- **Mechanisms:** ITCZ shift, Tibetan plateau heating, Somali jet, warm seas.
- Arabian Sea branch → heavy rain on Western Ghats; Konkan–Goa.
- Bay of Bengal branch → heavy rain in NE India (Mawsynram/Cherrapunji).
- Monsoon depressions from the Bay bring rain to central–north India.

3. Retreating Monsoon Season (October–November)

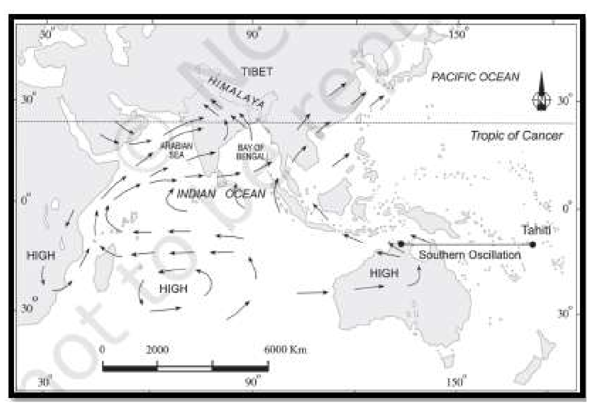
- Withdrawal of SW monsoon → clear skies, rising temperature + humidity.
- Northeast monsoon brings rainfall to Tamil Nadu & coastal AP.

- Bay cyclones strike east coast (Odisha–AP–TN).
- Ideal period for Rabi crop sowing in north India.

4. **Cold Weather Season (December–February)**
   - Cool, dry air; low temperatures in northern plains.
   - Western Disturbances bring light winter rain to Punjab–Haryana & snowfall in Himalayas.
   - Clear skies → strong radiation → cold waves in NW India.
   - Peninsular India → mild dry winter.

INDIAN MONSOON

- The Indian monsoon is a seasonal reversal of winds driven by land–sea temperature contrast and the shifting ITCZ.
- It brings nearly 75% of India's annual rainfall, shaping agriculture, rivers, and climate.
- **Key drivers of monsoon:**
  - Differential heating of land and ocean → low pressure over NW India in summer.
  - Northward shift of ITCZ.
  - Tibetan Plateau heating → strong thermal low.
  - Somali Jet and warm Arabian Sea.
  - Formation of monsoon depressions in the Bay of Bengal.
  - Mountain barriers (Himalayas, Western Ghats).
- **Onset of Southwest Monsoon (June–September):**
  - Begins over Kerala around June 1.
  - Splits into Arabian Sea branch (heavy rain on Western Ghats, Konkan) and Bay of Bengal branch (NE India, Ganga valley).
  - Causes widespread rainfall across India with variations due to relief.
- **Withdrawal / Retreating Monsoon (October–November):**
  - Winds retreat from NW India, shifting southwards.
  - Clear skies and rising temperatures in north India.
  - Northeast Monsoon brings major rainfall to Tamil Nadu and coastal Andhra Pradesh.
  - Cyclones from the Bay of Bengal strike the east coast.



- **Monsoon variability:**
  - Breaks in monsoon → temporary dry spells.
  - Active spells → heavy rainfall phases.
  - Influenced by El Niño (weak monsoon) and La Niña (strong monsoon).
  - Western Disturbances modify rainfall in north India.
  - IOD (Indian Ocean Dipole) affects monsoon strength.
- **Orographic influence:**
  - Western Ghats cause heavy rainfall on windward slope and a rainshadow on the Deccan plateau.
  - NE hills channel moist winds → extremely heavy rain (Mawsynram, Cherrapunji).
  - Himalayas block cold winds and uplift monsoon winds.
- **Significance:**
  - Controls Kharif agriculture and water resources.
  - Influences hydropower, groundwater recharge, and river regimes.
  - Determines drought and flood patterns across India.

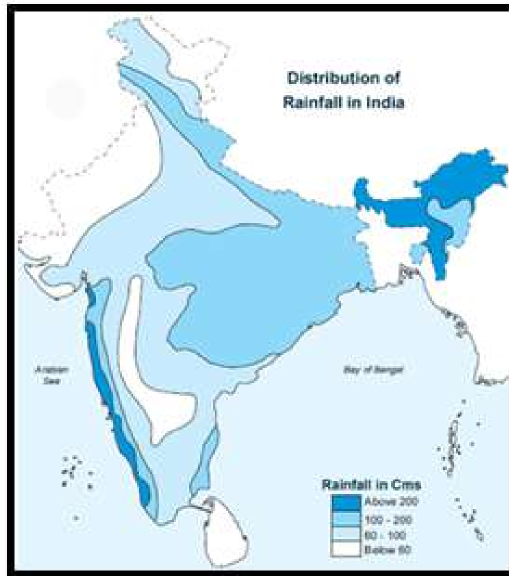
FACTORS AFFECTING THE INDIAN MONSOON

- **Land–sea heating contrast:** Creates low pressure over NW India → pulls moist winds.
- **ITCZ shift:** Moves north in summer → draws monsoon flow.
- **Tibetan Plateau heating:** Strong thermal low strengthens circulation.
- **Jet streams:** Easterly jet aids onset; westerly jet shifts north to allow monsoon entry.
- **Arabian Sea & Bay SST:** Warm seas → high moisture supply.
- **Monsoon depressions:** Bay lows bring widespread rain inland.
- **ENSO:** El Niño weak monsoon; La Niña strong monsoon.
- **Indian Ocean Dipole:** Positive IOD boosts monsoon.
- **Relief features:** Himalayas block cold winds; Western Ghats cause orographic rain.
- **Snow cover:** High Eurasian snow weakens monsoon; low snow strengthens it.

Rainfall Pattern in India

- India receives most of its rainfall from the Southwest Monsoon (June–September), contributing about 75% of annual rainfall.
- Rainfall is highly uneven, controlled by monsoon winds, relief, latitude, and cyclones.
- **Very high rainfall areas (>200 cm):** Western Ghats (windward), Northeast India (Mawsynram, Cherrapunji), Andaman–Nicobar Islands.

- **High to moderate rainfall (100–200 cm):** Bengal–Odisha coast, Himalayan foothills, eastern and central India.



- **Low rainfall (50–100 cm):** Deccan plateau rainshadow (Karnataka, Telangana, Maharashtra), leeward Eastern Ghats.
- **Very low rainfall (<50 cm):** Thar Desert (Jaisalmer, Barmer), cold deserts of Ladakh.
- **Seasonal pattern:**
  - Southwest Monsoon (Jun–Sep): Main rainy season, caused by monsoon depressions and orographic uplift.
  - Northeast Monsoon (Oct–Dec): Important for Tamil Nadu and coastal Andhra Pradesh.
  - Winter rainfall: Western Disturbances bring light rain to Punjab, Haryana, western UP.
  - Pre-monsoon showers: Kalbaisakhi, Nor'westers, Mango showers help farmers.
- **Orographic effects:** Western Ghats cause heavy rainfall on the west-facing slope; eastern Deccan stays dry.
- **Northeast hills channel moist winds → some of the heaviest rainfall on Earth.**
- **Himalayas uplift moist winds → heavy rainfall in foothills.**
- **East–west gradient:** Rainfall decreases from Assam/Bengal (150–200 cm) to Rajasthan (<50 cm).
- **Cyclonic rainfall:** Bay of Bengal cyclones affect Odisha–AP–TN; Arabian Sea cyclones sometimes affect Gujarat–Konkan.
- **Rainfall variability:** Monsoon breaks, active phases, El Niño and La Niña cycles lead to droughts in NW/Central India and floods in NE/Bihar/Assam.

Maharashtra Climate

CLIMATE OF MAHARASHTRA — SHORT NOTES

- **Maharashtra has a tropical monsoon climate with clear seasonal contrast.**
- **Three main seasons:** Summer (Mar–May), Monsoon (Jun–Sep), Winter (Oct–Feb).
- **Summer:**
  - Very hot and dry, especially in Vidarbha (>45°C).
  - Coastal Konkan remains moderate due to sea influence.
- **Southwest Monsoon:**
  - Heavy rainfall in Konkan (200–300 cm; Mumbai, Ratnagiri).

  - Western Ghats receive very high rainfall.
  - Rainshadow region (Madhya Maharashtra, Marathwada) gets low rainfall (50–100 cm).
  - Vidarbha receives moderate rainfall mainly from Bay depressions.
- **Winter:**
  - Cool and dry; minimum temperatures drop in interior districts.
  - Coastal region remains mild; interior experiences cold nights.
- **Rainfall pattern:**
  - West → very high rainfall;
  - Ghats → maximum;
  - East (Marathwada–Vidarbha) → low to moderate.
  - Highly uneven due to topography and monsoon winds.
- **Humidity:**
  - High in coastal belt; low in interior plateau.
- **Cyclonic influence:**
  - Occasional cyclones in Konkan; interior rarely affected.

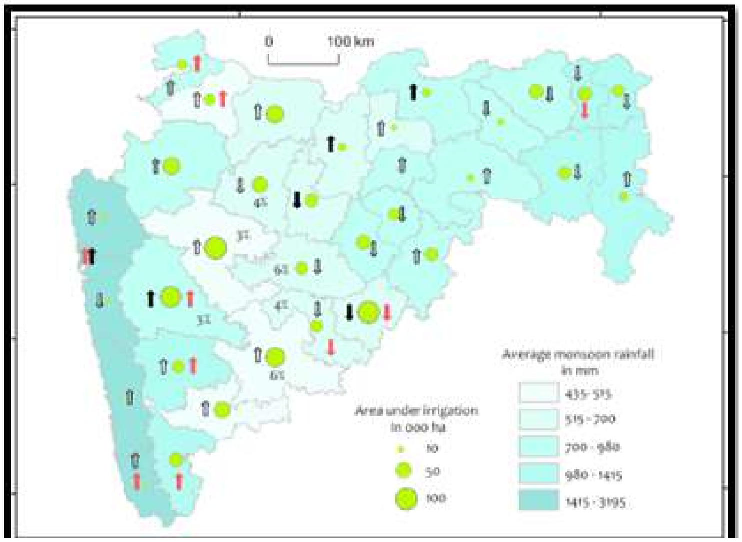
INFLUENCE OF TOPOGRAPHY ON CLIMATE OF MAHARASHTRA

- Western Ghats act as a major climatic barrier, blocking the Southwest Monsoon and creating sharp rainfall contrasts.
- Konkan (west of Ghats) gets very high rainfall due to orographic uplift of moist monsoon winds.
- Leeward side (Madhya Maharashtra & Marathwada) lies in the rainshadow zone, receiving low rainfall and experiencing dry conditions.
- Vidarbha plateau is far from the Ghats → receives moderate rainfall mainly from Bay depressions, not direct monsoon impact.
- Altitude differences create temperature variation: Ghats remain cooler; interior plateau gets high summer heat.
- Coastal topography moderates temperature → Konkan has less seasonal variation.
- Plateau interiors heat up strongly in summer due to open, dry terrain → higher temperature extremes.
- Valleys and basins (like Bhima basin) trap heat → warm conditions in summer, mild winters.
- Topographic orientation influences wind flow, humidity levels, and localized rainfall patterns.

RAINFALL PATTERN IN MAHARASHTRA

- Maharashtra’s rainfall is mainly from the Southwest Monsoon (June–September).

- Rainfall distribution is highly uneven due to the Western Ghats and plateau topography.
- **Konkan Coast:**
  - Very high rainfall (200–300+ cm) due to orographic uplift.
  - Heavy continuous monsoon spells; frequent flooding.
- **Western Ghats:**
  - One of the wettest belts in the state (up to 400 cm).
  - Steep slopes enhance orographic rainfall.
- **Madhya Maharashtra (leeward side):**
  - Lies in the rainshadow zone → low rainfall (50–100 cm).
  - Districts like Pune, Solapur, Ahmednagar receive limited monsoon rain.



- **Marathwada:**
  - Low and erratic rainfall (60–90 cm).
  - High drought frequency due to monsoon variability.
- **Vidarbha:**
  - Moderate rainfall (100–125 cm).
  - Rain mainly from Bay of Bengal depressions moving westward.
- **Seasonal Distribution:**
  - June–July: Maximum rainfall across most regions.
  - August: Decrease in intensity.
  - September: Weakening monsoon.
  - Post-monsoon (Oct–Nov): Light rain in few districts; Marathwada occasionally receives remnant cyclone rains.
- **Cyclonic Influence:**
  - Konkan may receive heavy rains from Arabian Sea cyclones.
  - Marathwada and Vidarbha sometimes receive rainfall from Bay cyclone remnants.
- **Overall Trend:**
  - West → very high rainfall;
  - Ghats → maximum;

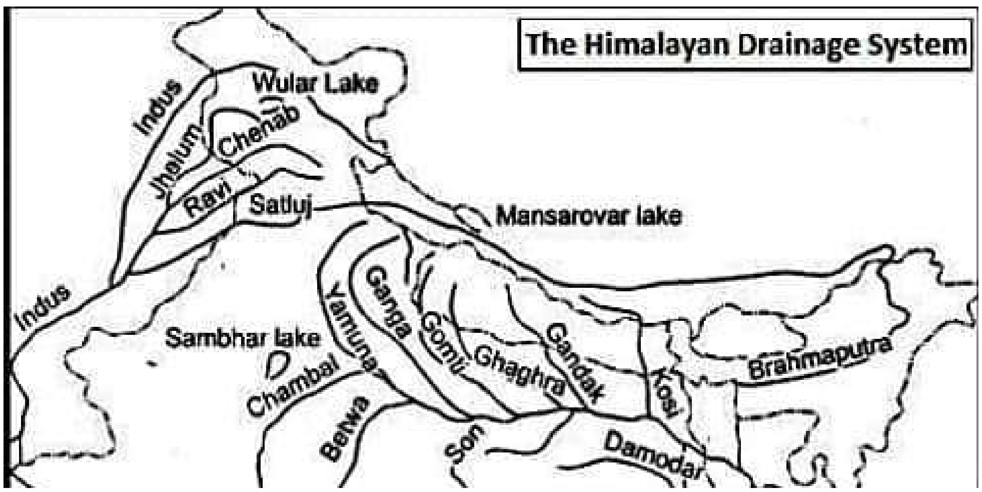
- Interior → low;
- Eastern plateau → moderate.

2.Drainage System

- India's river system forms a vast drainage network shaped by Himalayan and Peninsular geology, supporting agriculture, water supply, ecosystems, and civilisation across the subcontinent.
- It includes perennial Himalayan rivers and seasonal Peninsular rivers, each with distinct origins, flow patterns, and geomorphic features.

Himalayan River System

- Large, perennial rivers originating from Himalayan glaciers & snowfields, flowing through deep gorges and broad alluvial plains.



Key Characteristics

- Perennial flow (glacial + rainfall-fed).
- Extensive meandering, floodplains, and alluvial deposits.
- High erosive power; form gorges in Himalayas and deltas in plains.
- Major geomorphic features: oxbow lakes, levees, braided channels.
- Crucial for irrigation, agriculture, hydropower.

Significance

- Support India's most fertile regions (Indo-Gangetic Plains).
- Provide perennial irrigation & drinking water.
- Basis of major hydropower projects (Tehri, Nathpa Jhakri).
- Influence climate, agriculture, and settlement patterns.

Major River Systems

- **Indus System**
  - Origin: Lake Mansarovar (Tibet).
  - Tributaries: Jhelum, Chenab, Ravi, Beas, Sutlej (western); Shyok, Gilgit, Zanskar (upper).
  - Flows through India → Pakistan; forms a large delta at Karachi.

- **Ganga System**
  - Origin: Gangotri Glacier (Uttarakhand) as Bhagirathi.
  - Major tributaries:
    - Left-bank: Gomti, Ghaghara, Gandak, Kosi.
    - Right-bank: Yamuna, Son.
  - Largest river basin in India; forms the Sundarbans delta with Brahmaputra.
- **Brahmaputra System**
  - Origin: Chemayungdung Glacier (Tibet) as Tsangpo.
  - Enters India through Arunachal as Siang/Dihang.
  - Major tributaries: Subansiri, Lohit, Manas, Dhansiri.
  - Joins Ganga in Bangladesh forming world's largest delta

Peninsular River System

- Ancient, seasonal rivers flowing over the stable Peninsular Plateau, dominated by rainfall rather than glacial melt.

Key Characteristics

- Seasonal flow (monsoon-fed).
- Fixed courses; flow through shallow valleys and mature landscapes.
- Mostly non-perennial except a few (Godavari headwaters, Narmada stretches).
- Narrow floodplains, fewer meanders compared to Himalayan rivers.
- Major east-flowing rivers form large deltas.

Significance

- Irrigation through major projects (Nagarjuna Sagar, Sardar Sarovar, Hirakud).
- Support agriculture in Deccan, TN, coastal Andhra & Odisha.
- Basis for hydropower (Sharavathi, Periyar) and drinking water supply.
- Delta regions are major rice-growing belts and host key ports.

1. East-Flowing Rivers (into Bay of Bengal)

- **Key Characteristics**
  - Flow eastward across gently sloping Peninsular surface.
  - Form large deltas (Godavari, Krishna, Cauvery, Mahanadi).
  - Longer courses, larger drainage basins.
  - More perennial influence due to Western Ghats' rainfall.
  - Major agricultural belts along deltas (rice bowls).
- **Major Rivers**
  - **Godavari – largest Peninsular river; tributaries:** Manjira, Pranhita, Indravati.
  - **Krishna – major tributaries:** Tungabhadra, Bhima.
  - **Cauvery – originates in Western Ghats; fertile TN delta.**
  - Mahanadi – Chhattisgarh–Odisha; large delta at Cuttack.
  - Subarnarekha & Baitarani – shorter systems draining Odisha–Jharkhand region.

2. West-Flowing Rivers (into Arabian Sea)

- **Key Characteristics**
  - Short, swift, steep gradients due to Western Ghats' proximity to coast.
  - Form estuaries, not deltas (submerged/coastal relief).
  - High hydropower potential; narrow drainage basins.
  - Often seasonal, except regulated stretches.
- **Major Rivers**
  - Narmada – rift valley river; straight course; Dhuandhar Falls.
  - Tapti – flows parallel to Narmada; Satpura origin.
  - Luni – inland drainage; ends in Rann of Kachchh.
  - Periyar, Bharathapuzha, Sharavathi – short, swift, Western Ghats rivers.

Himalayan vs Peninsular Rivers

Feature	Himalayan Rivers	Peninsular Rivers
Origin	Glaciers & snowfields (perennial)	Peninsular Plateau (rain-fed)
Flow Type	Perennial; uniform discharge	Seasonal; high monsoon flow
Valleys	Deep gorges, V-shaped (youthful stage)	Broad, shallow valleys (mature stage)
Course	Long, meandering	Shorter, fixed courses
Erosion/Deposits	High erosion; large alluvial deposits	Mostly erosional; limited alluvium
Floodplains	Wide floodplains; Bhabar–Terai–Bhangar–Khadar	Narrow floodplains
Deltas	Large deltas (Ganga–Brahmaputra)	Large deltas only in east-flowing rivers
Tributaries	Numerous, large tributaries	Fewer, smaller tributaries

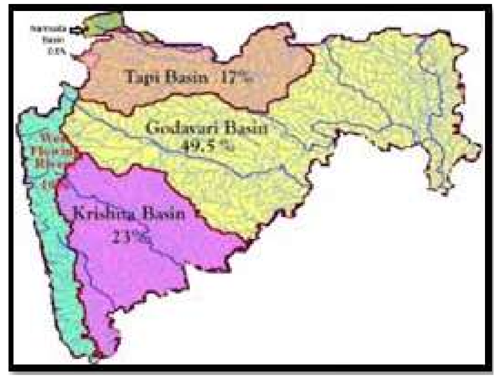
Direction of Flow	Mostly north → south or west → east	East-flowing (Bay) > West-flowing (Arabian Sea)
Hydropower	High potential in upper reaches	Moderate; mainly western ghat rivers
Navigation	Better due to perennial flow	Limited (seasonal flow, rapids)
Examples	Indus, Ganga, Brahmaputra	Godavari, Krishna, Cauvery, Narmada, Tapti

DELTAS IN THE EASTERN COAST OF INDIA

- The eastern coast has broad, well-developed deltas because rivers flow slowly over flat coastal plains before entering the Bay of Bengal.
- Formed mainly by large peninsular rivers and Himalayan rivers depositing huge sediment loads.
- **Ganga–Brahmaputra Delta:**
  - World's largest delta; shared by India and Bangladesh.
  - Highly fertile; forms the Sundarbans mangrove region.
- **Mahanadi Delta:**
  - Located in Odisha; large and actively growing.
  - Known for rice cultivation and repeated flooding.
- **Godavari Delta:**
  - Wide, fertile delta in Andhra Pradesh.
  - Supports dense agriculture and aquaculture.
- **Krishna Delta:**
  - Formed near Vijayawada–Machilipatnam region.
  - Highly irrigated; sugarcane and paddy major crops.
- **Cauvery Delta:**
  - Known as the "Granary of South India".
  - Fertile alluvial plains in Tamil Nadu (Thanjavur region).
- **General Characteristics of Eastern Coast Deltas:**
  - Soft alluvial soils → high agricultural productivity.
  - Prone to cyclones, flooding, and sedimentation changes.
  - Broad distributaries create fan-shaped or arcuate deltas.
  - Dense settlement and intensive agriculture dominate.

Maharashtra

Major River basins in Maharashtra



- **Maharashtra has five major river basins:** Godavari, Krishna, Bhima, Tapi, and Wardha–Wainganga.
- **Godavari Basin:**
  - Largest river basin in Maharashtra.
  - Originates at Trimbak (Nashik) in Western Ghats.
  - Major tributaries: Pravara, Purna, Manjra, Wainganga, Wardha.
  - Supports agriculture across Nashik, Ahmednagar, Jalna, Nanded.
- **Krishna Basin:**
  - Originates near Mahabaleshwar.
  - Tributaries in Maharashtra: Koyna, Warna, Panchganga, Dudhaganga.
  - Supports paddy, sugarcane, and horticulture in Satara–Kolhapur–Sangli.
- **Bhima Basin:**
  - Major tributary of Krishna; originates near Bhimashankar.
  - Flows through Pune, Solapur.
  - Tributaries: Mula, Mutha, Ghod, Sina.
  - Key for irrigation and drinking water (Pune region).
- **Tapi Basin:**
  - Originates in Satpura Range (Multai, MP) but flows through northern Maharashtra.
  - Tributaries in state: Purna, Girna, Panjhra.
  - Influences Jalgaon, Dhule; forms fertile alluvial plains in parts.
- **Wardha–Wainganga (Pranhita) Basin:**
  - Major sub-basin of the Godavari system.
  - Wardha originates in Multai (MP) and Wainganga in Seoni (MP).
  - Cover eastern Maharashtra (Nagpur, Chandrapur, Gadchiroli).
  - Dense forests and good groundwater availability.
- **West-flowing Coastal Rivers (minor):**
  - Short, swift rivers draining Konkan directly into the Arabian Sea.
  - Examples: Vaitarna, Ulhas, Savitri, Shastri, Vashishti.

KONKAN RIVERS (MAHARASHTRA)

- Konkan rivers are short, swift, west-flowing rivers draining directly into the Arabian Sea.
- Originate in the Western Ghats and descend steeply, forming narrow valleys.
- **Major Konkan Rivers:**
  - Vaitarna River: Flows through Nashik–Palghar; major source of Mumbai's water supply.
  - Ulhas River: Rises near Karjat; flows through Thane; forms Thane Creek.
  - Savitri River: Origin near Mahabaleshwar; flows via Mahad; empties into the Arabian Sea.
  - Kundalika River: Known for white-water rafting at Kolad; small but fast-flowing.
  - Patalganga River: Industrial belt river near Khopoli–Rasayani.
  - Vashishti River: Major river of Ratnagiri district; forms backwaters near Chiplun.
  - Jagbudi River: Flows through Khed–Dapoli region in Ratnagiri.
  - Shastri River: Flows near Rajapur; joins the sea near Jaigad.
  - Terekhol (Tiracol) River: Forms part of the Maharashtra–Goa boundary.
  - Gad, Kajvi, Bharja, Muchkundi: Smaller swift-flowing coastal streams.
- **Characteristics of Konkan Rivers:**
  - Short length but high velocity due to steep gradient.
  - Seasonal flow → heavy discharge in monsoon, low flow in summer.
  - Create narrow estuaries, creeks, and backwaters along the coast.
  - Important for fisheries, water transport (creeks), and local irrigation.

PROBLEMS OF RIVER POLLUTION IN MAHARASHTRA

- Industrial effluents from Pune, Thane, Tarapur MIDC → chemicals & heavy metals contaminate Mula–Mutha, Ulhas.
- Untreated city sewage from Pune, Nashik, Nagpur → high BOD → foul smell & health risks.
- Agricultural runoff in Godavari & Krishna basins → fertilisers/pesticides flow into rivers → eutrophication.
- Ganesh idol immersion in Mumbai, Pune, Nashik → plaster, paints, POP → toxic sediment.
- Solid waste dumping along nallas and riversides → plastics, garbage → block flow & degrade water.
- Encroachment near Mithi, Godavari, Bhima → reduced river width → concentrates pollution.
- Low monsoon flow in Marathwada & Solapur region rivers → less dilution → higher pollutant load.
- Inadequate STPs in growing cities → untreated sewage continues entering rivers.
- Reservoir stagnation in Ujjani, Gangapur, Mulshi → algal blooms → low oxygen levels.
- Pollution → fish deaths & loss of aquatic life → affects farmers, fishermen, and local ecosystems.

SOILS IN INDIA

- Soil = weathered rock + organic matter → shaped by rainfall, parent rock, relief, and time.
- India's diverse geology + climate → formation of varied soil types → basis for agriculture patterns, vegetation, and land use.
- India has 8 major soil types due to contrasting physiography

Major Soil Types

1. ALLUVIAL SOIL

- **Origin:** River-borne sediments → Indo-Gangetic plains + deltas.
- **Distribution:** Punjab–Haryana–UP–Bihar–Bengal; Krishna–Godavari–Cauvery deltas.
- **Nature:** Loamy to clayey; deep profile (up to several meters).
- **Nutrients:** Rich in potash, phosphoric acid; low in nitrogen; moderate humus.
- **Texture Variation:** Coarse in upper reaches → finer toward the sea.
- **Types:**
  - Khadar → newer, silty, highly fertile, deposited annually.
  - Bangar → older, calcareous kankar nodules, less fertile.
- **Hydrology:** Excellent moisture retention, well-drained.
- **Crops:** Wheat, rice, maize, sugarcane, jute, pulses.
- **Significance:** Supports India's food bowl regions.

2. BLACK SOIL (REGUR)

- **Origin:** Weathering of basalt in Deccan Trap.
- **Distribution:** Maharashtra, Gujarat, MP, parts of Andhra & Karnataka.
- **Nature:** Clayey (40–60% clay); deep cracks in summer → aeration.
- **Nutrients:** Rich in lime, iron, magnesia; poor in nitrogen & phosphorus.
- **Properties:** High moisture retention → sticky when wet, hard when dry.
- **Sub-types:**
  - Deep black (≥1m depth) → superior for cotton.
  - Medium black → cereals & oilseeds.
- **Crops:** Cotton, sugarcane, sorghum, sunflower, groundnut.
- **Significance:** Ideal for cotton → "Black Cotton Soil belt."

3. RED SOIL

- **Origin:** Weathering of granite & gneiss.
- **Distribution:** TN, Karnataka, AP, Odisha, Chhattisgarh.
- **Nature:** Sandy to clayey; porous; well-drained.
- **Nutrients:** Iron-rich (red colour), low humus; deficient in NPK.

SOILS OF MAHARASHTRA

- **Maharashtra's soils are mainly formed from Deccan basalt, monsoon processes, and river deposition.**
- **The state has four major soil types:** Black Soil, Laterite Soil, Alluvial Soil, and Coastal Soil (with local sub-types).
- **Black Soil (Regur):**
  - Most widespread soil type in Maharashtra.
  - Found in Vidarbha, Marathwada, Khandesh, Solapur, Ahmednagar, Pune.
  - Deep, clayey, moisture-retentive; cracks in summer.
  - Highly suitable for cotton, soybean, sorghum, pulses.
- **Medium and Deep Black Soils:**
  - Deep black → in river basins of Godavari, Krishna, Tapi.
  - Medium black → plateau regions.
  - Fertile but need fertilisers for nitrogen and phosphorus.
- **Laterite Soil:**
  - Found in Western Ghats and Konkan uplands.
  - Formed by heavy rainfall and leaching; reddish, porous.
  - Supports cashew, coconut, rubber, horticulture with manure.
- **Coastal Alluvial Soil:**
  - Occurs along Konkan Coast.
  - Sandy to loamy; rich in organic matter in creek areas.
  - Suitable for rice, fruits (mango, kokum), coconut.
- **River Alluvial Soil (Limited extent):**
  - Found near Bhima, Godavari, Krishna river valleys.
  - Fertile, light-textured; suitable for sugarcane, vegetables, fodder crops.
- **Red Soil Pockets:**
  - Present in parts of Bhandara, Gondia, Chandrapur.

  - Low in humus; supports millets, pulses, and coarse grains.
- **Saline and Alkaline Soils:**
  - Found in low-lying, poorly drained tracts of Solapur, Ahmednagar.
  - Formed due to evaporation and faulty irrigation practices.
- **pH:** Slightly acidic to neutral.
- **Sub-types:**
  - Red loamy → better fertility.
  - Red sandy → low water retention.
- **Crops:** Millets, pulses, groundnut, cotton, vegetables.
- **Human Intervention:** Needs fertilizers + irrigation for high productivity.

4. LATERITE SOIL

- **Origin:** Intense leaching under high rainfall + high temperature.
- **Distribution:** Western Ghats, Eastern Ghats, NE states, parts of Bengal.
- **Nature:** Porous, coarse, brick-like when dry.
- **Nutrients:** Rich in iron and aluminium; low in organic matter & nitrogen.
- **Formation Process:** Leaching → silica removed → iron/alumina left behind.
- **Crops:** Tea, coffee, rubber, cashew, coconut (with inputs).
- **Use:** Laterite blocks used as building material.
- **Limitation:** Low fertility → needs manuring.

5. ARID SOIL

- **Origin:** Mechanical weathering in dry climate.
- **Distribution:** Rajasthan, Kutch, western Haryana.
- **Nature:** Sandy, loose, low humus; high evaporation.
- **Nutrients:** Rich in soluble salts; low organic carbon.
- **Presence of Calcium:** Calcareous; gypsum nodules common.
- **Colour:** Yellowish-brown due to low moisture.
- **Crops:** Bajra, guar, sesame (with irrigation).
- **Special Note:** Indira Gandhi Canal → converts parts to cultivable land.

6. FOREST / MOUNTAIN SOIL

- **Origin:** Mechanical weathering on steep slopes.
- **Distribution:** Himalayas, NE hills, Western Ghats highlands.

- **Nature:** Thin, immature, acidic; rich humus under forest cover.
- **Variability:**
  - Higher altitudes → acidic, humus-rich.
  - Lower altitudes → alluvial mix.
- **Erosion Risk:** High due to slope.
- **Crops:** Tea, apple, cardamom, spices.
- **Significance:** Supports dense forest ecosystems.

7. **SALINE / ALKALINE SOIL**

- **Origin:** Poor drainage, high evaporation, over-irrigation.
- **Distribution:** Arid/semi-arid regions of Punjab, Haryana, Rajasthan, UP.
- **Nature:** White salt crusts; hard kankar layer; pH high.
- **Salinity Sources:** Sodium chloride, sodium carbonate.
- **Effects:** Poor structure → low permeability.
- **Reclamation:** Gypsum, deep ploughing, flushing with water.
- **Crops:** Limited; tolerant crops include barley, cotton (after treatment).

8. **PEATY / MARSHY SOIL**

- **Origin:** Waterlogging + accumulation of organic matter.
- **Distribution:** Kerala, Bengal Sundarbans, parts of Bihar.
- **Nature:** Dark, highly organic, acidic, saline patches.
- **Nutrients:** High humus but poor minerals.
- **Hydrology:** Poor drainage → anaerobic decomposition.
- **Crops:** Rice, jute, coconut (in improved areas).
- **Environmental Role:** Carbon-rich → acts as carbon sink.

Soil Erosion and Land Degradation

Definition

- **Soil Erosion:** Removal of the topsoil by natural forces like wind, water, or by human activity.
- **Land Degradation:** Decline in land productivity and ecosystem health due to natural or human-induced processes such as erosion, salinization, waterlogging, and deforestation.

Causes of Soil Erosion and Land Degradation

Natural Causes

- **Water erosion:** Runoff, floods, riverbank erosion.

- **Wind erosion:** Especially in arid and semi-arid regions (Rajasthan, Gujarat).
- **Seismic and climatic events:** Landslides, droughts, desertification.

■ Anthropogenic Causes

- **Deforestation:** Reduces soil binding by roots.
- **Overgrazing:** Removes vegetation cover.
- **Unsustainable agriculture:** Excessive tilling, shifting cultivation, monocropping.
- **Industrial and mining activities:** Open-cast mining, quarrying.
- **Urbanization and infrastructure projects:** Land conversion, excavation.
- **Overuse of fertilizers and pesticides:** Decline in soil fertility.

■ Extent of the Problem in India

- **According to ISRO's Desertification and Land Degradation Atlas (2021), ~30% of India's land (96.4 million hectares) is undergoing degradation.**
- **States worst affected:** Rajasthan, Maharashtra, Gujarat, Karnataka, Jharkhand, Odisha, Madhya Pradesh.
- **Soil erosion by water alone accounts for more than 10% of degraded land.**

■ Impacts

- **Agricultural Impact:** Decline in soil fertility, crop productivity, and food security.
- **Ecological Impact:** Desertification, loss of biodiversity, increased floods and droughts.
- **Economic Impact:** Reduced farm income, higher input costs, mining-related damage.
- **Social Impact:** Rural distress, migration, conflicts over land and water.
- **Climate Impact:** Degraded soils release carbon, contributing to global warming.

■ Measures Taken in India

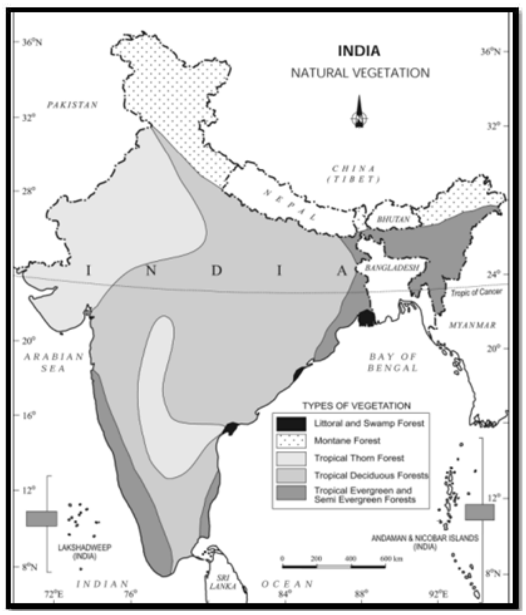
- **Policy and Institutional**
  - National Action Plan for Combating Desertification and Land Degradation (NAPCD).
  - National Afforestation Programme and Green India Mission.
  - National Watershed Development Project for Rainfed Areas (NWDPRA).
  - Soil Health Card Scheme.
  - Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) – for efficient irrigation.
  - India is a signatory to the UNCCD (United Nations Convention to Combat Desertification); committed to restore 26 million ha degraded land by 2030.
- **Technological and Community Measures**
  - Contour bunding, terracing, afforestation, shelter belts to reduce erosion.

- ➤ Rainwater harvesting and check dams to conserve soil moisture.
- ➤ Agroforestry and mixed cropping to improve soil structure.
- ➤ Organic farming and reduced chemical inputs to preserve fertility.

■ Way Forward

- Strengthen integrated watershed management at local level.
- Incentivize sustainable agriculture and crop diversification.
- Promote community-led soil conservation projects.
- Strict regulation of mining and deforestation.
- Use of remote sensing and GIS for mapping and monitoring degraded land.
- Stronger convergence between MGNREGA, afforestation schemes, and irrigation projects.

4.Natural Vegetation in India



- Natural vegetation = plant communities grown without human interference.
- India’s climate diversity → distinct vegetation zones from tropical forests to alpine meadows.
- Determined by rainfall → temperature → soil → altitude gradients.

1. TROPICAL EVERGREEN FORESTS

- **Where:** Western Ghats (Malabar), NE states (Assam, Meghalaya, Nagaland), Andaman–Nicobar.
- **Climate:** Rainfall >200 cm; temperature 25–27°C; humidity >75%.
- **Structure:** 4–5 layer stratification → emergent trees → canopy → understory → shrubs → herbs.
- **Features:** Dense, dark, evergreen; trees don’t shed simultaneously.
- **Species:** Rosewood, mahogany, rubber, ebony, cinchona.

- **Creepers & epiphytes:** Orchids, ferns, bamboo.
- **Soil:** Lateritic but nutrient-poor due to leaching.
- **Wildlife:** Lion-tailed macaque, Malabar civet, hornbill, hoolock gibbon.
- **Significance:** High biodiversity; difficult to exploit due to dense growth.

2. **TROPICAL DECIDUOUS (MONSOON) FORESTS**

■ **A. Moist Deciduous**

- **Where:** Eastern India (Jharkhand, Odisha), Himalayan foothills, NE plateau, Western Ghats' leeward side.
- **Rainfall:** 100–200 cm.
- **Features:** Shed leaves for 1–2 months in dry season; open canopy.
- **Species:** Sal, teak, shisham, bamboo, mahua.
- **Soil:** Alluvial, clayey, fertile.
- **Wildlife:** Elephants, bison, deer species.
- **Importance:** Major commercial timber sources.

■ **B. Dry Deciduous**

- **Where:** Central India (MP, Chhattisgarh), rainshadow regions (Maharashtra, Karnataka).
- **Rainfall:** 70–100 cm.
- **Features:** More open, shorter trees, thorny mixes.
- **Species:** Palash, khair, babul, tendu.
- **Human Use:** Fuelwood, tendu leaves for bidi.

3. **TROPICAL THORN FORESTS**

- **Where:** Rajasthan, Gujarat, Haryana, Deccan interior.
- **Rainfall:** <70 cm; high evapotranspiration.
- **Vegetation:** Open scrub → thorny trees → xerophytes (acacia).
- **Species:** Babool, kikar, date palm, cactus, ber.
- **Features:** Thick bark, small leaves → reduce water loss; deep roots.
- **Soil:** Sandy, saline, poor humus.
- **Wildlife:** Blackbuck, Indian wild ass (Little Rann of Kutch).
- **Significance:** Indicator of desertification zones.

4. MONTANE FORESTS

A. Himalayan Moist Temperate (1500–3000 m)

- **Climate:** Cool summers; severe winters; 100–200 cm rainfall.
- **Species:** Oak, chestnut, deodar, blue pine, spruce.
- **Features:** Thick forests; mixed coniferous; high timber value.
- **Wildlife:** Himalayan black bear, red panda.

B. Himalayan Dry Temperate

- **Where:** Inner Himalayas (Ladakh, Lahaul-Spiti).
- **Rainfall:** Low; cold desert.
- **Species:** Juniper, birch, fir, pine.
- **Soil:** Thin, gravelly.
- **Adaptations:** Needle leaves, conical shape to shed snow.

5. ALPINE & SUB-ALPINE VEGETATION

- **Where:** Above 3000–5000 m in Himalayas.
- **Vegetation Zones:**
  - Sub-alpine → 3000–4000 m → dwarf shrubs (rhododendron).
  - Alpine meadows → 4000–5000 m → grasses, mosses, lichens.
- **Climate:** Short growing season; long snow cover.
- **Wildlife:** Snow leopard, ibex, Himalayan tahr.
- **Human Use:** Summer grazing areas → bugyals (Uttarakhand).

6. LITTORAL & SWAMP FORESTS

A. Mangroves

- **Where:** Sundarbans, Godavari-Krishna delta, Mahanadi, Andamans.
- **Conditions:** Tidal range, brackish water, muddy saline soils.
- **Adaptations:** Aerial roots (pneumatophores), stilt roots.
- **Species:** Sundari (dominant in Sundarbans), rhizophora, avicennia, nipa palm.
- **Wildlife:** Royal Bengal tiger, crocodile, mudskipper.
- **Significance:** Cyclone buffer; carbon sink; nursery for fish.

B. Freshwater Swamp/Marsh Forests

- **Where:** Bihar Terai, Assam, coastal lagoons.
- **Features:** Periodically flooded; rich vegetation.

- **Species:** Cane, pandanus, swamp palm.

Determinants of Vegetation

- Rainfall → Temperature regime → Soil type → Altitude → Humidity → Sunlight availability → Resulting vegetation zone.

Ecological Significance

- Regulates monsoon cycles.
- Supports endemic flora/fauna in biodiversity hotspots.
- Prevents soil erosion and maintains watershed systems.
- Helps in carbon sequestration and climate moderation.

FOREST COVER IN INDIA

INTRODUCTION

- India's forest cover reflects climatic zones + conservation efforts → crucial for ecology, biodiversity, and livelihoods.
- Forest Cover = land >1 ha with tree canopy density ≥10% (as per ISFR).
- Classified into → Very Dense (>70%), Moderately Dense (40–70%), Open Forest (10–40%).
- Tree Cover refers to scattered trees outside recorded forests.

Distribution Pattern

- **Highest forest cover:** Mizoram, Arunachal Pradesh, Meghalaya, Manipur, Nagaland.
- **Largest area:** Madhya Pradesh > Arunachal Pradesh > Chhattisgarh > Odisha.
- **Western Ghats:** High evergreen cover.
- **Himalayas:** Moist → dry temperate → alpine transitions.
- **Central India:** Deciduous sal & teak belts.
- **Desert/Deccan interiors:** Sparse/open forests.

Key Features

- India's forest cover ~one-fourth of geographic area (clubbed with tree cover).
- Dense forests mainly in NE India + Western Ghats + Himalayan foothills.
- Open forests widespread in Central India due to degradation.
- **Mangroves:** Major belts in Sundarbans, Godavari–Krishna, Mahanadi deltas.

Importance

- Monsoon regulation → evapotranspiration → local rainfall.
- Biodiversity hotspots (Western Ghats, Himalayas, NE).

- Erosion control → flood moderation.
- Livelihoods for tribals → NTFP (tendu, bamboo, lac).
- Carbon sink → climate mitigation.

SOCIAL FORESTRY

- Social forestry emerged to meet rural fuelwood needs & reduce pressure on natural forests by involving communities.
- Forestry practiced outside traditional forests → on community lands, farm lands, wastelands, roadsides.
- **Aim:** Community participation in growing trees for fuel, fodder, small timber, and ecological balance.

Components

- **Forestry**
  - Trees grown by farmers on private lands.
  - Agroforestry systems → crops + trees (e.g., neem, eucalyptus, poplar).
  - Enhances income → soil fertility → microclimate.
- **Community Forestry**
  - Trees raised on village commons: grazing lands, panchayat lands.
  - Managed by local institutions → joint rights to use produce.
- **Extension Forestry**
  - Tree planting along roads, canals, railways, wastelands, industrial belts.
  - Increases overall green cover.
- **Urban Forestry**
  - Trees in cities → parks, green belts, avenue plantations.
  - Reduces pollution → heat islands → improves urban air quality.

Objectives

- Reduce pressure on natural forests.
- Provide affordable timber, fodder, fuelwood.
- Improve rural ecology & soil health.
- Community empowerment & livelihood support.
- Promote environmental awareness.

Significance

- Supports afforestation and reforestation in degraded lands.

- Improves carbon sequestration & climate resilience.
- Strengthens community participation → decentralised forest governance.
- Enhances biodiversity in rural/urban landscapes.

■ **Example Schemes / Initiatives**

- National Afforestation Programme (NAP).
- Joint Forest Management (JFM).
- Green India Mission.
- Massive plantation drives by states (e.g., MP, UP, Maharashtra).

Resource in India

■ 1.Mineral Resources in India

- India has rich ferrous, non-ferrous, and fuel minerals → supports core industries (steel, power, cement).
- Distribution is uneven → major belts in Jharkhand–Odisha–Chhattisgarh, Rajasthan, Karnataka, Goa

■ **Major Mineral Regions:**

- Bastar Plateau and Chhattisgarh are rich in coal, iron ore, and bauxite.
- Jharkhand, Orissa, and Chhattisgarh are major centers for coal mining.
- Rajasthan is known for its deposits of marble, gypsum, limestone, and copper.
- Karnataka and Goa are significant producers of iron ore.
- Andhra Pradesh and Telangana have deposits of bauxite and limestone.
- Madhya Pradesh has diamond, coal, and bauxite deposits.
- Tamil Nadu has significant limestone reserves, especially in the Cuddalore and Ramanathapuram regions.

CHALLENGES TO MINERAL RESOURCES IN INDIA

- Resource Depletion → high extraction rates in Odisha–Jharkhand belt → shrinking high-grade reserves.
- Uneven Distribution → minerals concentrated in few states → regional imbalance in development.
- Environmental Degradation → mining in Goa, Bellary, Korba → deforestation, soil erosion, polluted water.
- Illegal Mining → sand, iron ore, and manganese theft → loss of revenue → unsafe, unregulated practices.
- Low Technology Levels → outdated machinery → low productivity → high wastage in underground mines.
- Land Acquisition Issues → displacement of tribal communities in Chhattisgarh–Jharkhand → conflicts & delays.
- Regulatory Delays → slow clearances (forest, environment) → project slowdown → high investment risk.
- Infrastructure Gaps → poor roads & rail connectivity in mineral belts → high transport cost → inefficiency.
- Safety Concerns → accidents in coal mines (Jharia, Dhanbad) → inadequate worker protection.
- Global Market Volatility → price swings in iron ore, bauxite → affect exports & mining viability.
- Water Scarcity → mining in drought-prone areas (Vidarbha, Rajasthan) → stress on local water resources.
- Sustainability Issues → abandoned mines → land degradation → long-term ecological damage.

MINERAL RESOURCES IN MAHARASHTRA

- Maharashtra has moderate mineral resources → mainly manganese, coal, bauxite, limestone, iron ore, and minor minerals.
- **Manganese:**
  - Major mineral of the state.
  - Found in Nagpur, Bhandara, Chandrapur districts.
  - Key deposits: Mansar, Ramtek, Saoner → used in steel alloys and batteries.
- **Coal:**
  - Important coalfields in Vidarbha region.
  - Major areas: Wardha Valley (Wani), Kamptee, Ballarpur.
  - Supports power plants like Koradi, Chandrapur TPS.
- **Iron Ore:**
  - Limited reserves compared to central India.

- Found in Chandrapur, Gadchiroli (Surjagad region) → supports small steel units.

- **Bauxite:**
  - Found mainly in Kolhapur, Ratnagiri, Sindhudurg (Konkan belt).
  - Used for aluminium production.
- **Limestone:**
  - Occurs in Yavatmal, Chandrapur, Gadchiroli.
  - Essential for cement plants → Manikgarh Cement, Ultratech.
- **Dolomite:**
  - Found in Chandrapur, Nagpur → used in iron and steel industry.
- **Quartz & Silica Sand:**
  - Found in Buldhana, Nagpur → used in glass and construction industries.
- **Laterite:**
  - Abundant in Konkan → used for bricks and local construction.
- **Minor Minerals:**
  - Black stone, gravel, sand widely extracted in Pune, Nashik, Thane.
  - Clay deposits in Raigad, Ratnagiri.
- **General Features:**
  - Mineral-rich belt mainly in Vidarbha and Konkan.
  - Minerals support industries like cement, aluminium, steel, power, and construction.

CHALLENGES TO MINERAL RESOURCES IN MAHARASHTRA

- Limited reserves → state has fewer large deposits compared to Odisha/Jharkhand → restricts industrial growth.
- Low-grade ores → especially in iron ore (Gadchiroli) and bauxite (Konkan) → reduces extraction efficiency.
- Illegal mining → sand, stone, and minor minerals illegally extracted in Pune, Thane, Raigad → revenue loss.
- Environmental damage → mining in Chandrapur, Gadchiroli, Kolhapur → deforestation, soil erosion, polluted streams.
- Tribal displacement → mining projects in Gadchiroli & Chandrapur → affect forest communities → protests & delays.
- Poor transport infrastructure → remote mineral belts (Vidarbha forests) → high transport cost → low profitability.
- Water scarcity → mining in drought-prone regions like Marathwada & parts of Vidarbha → stress

on local water.

- Regulatory delays → slow forest/environment clearances → project uncertainty → reduced private investment.
- Safety issues → small-scale silica sand and stone quarrying → worker accidents → lack of protective gear.

ENERGY RESOURCES IN INDIA

- India has a diverse energy base → coal, oil, natural gas, nuclear, hydropower, and rapidly growing renewables.
- Energy demand is rising due to urbanisation, industry, and population growth.
- **Coal:**
  - Main energy source (for power & industry).
  - Major fields → Jharia, Raniganj, Talcher, Korba.
  - Key use → thermal power plants (→ most electricity generation).
- **Petroleum & Natural Gas:**
  - Oil fields → Mumbai High, Assam, Cambay Basin.
  - Gas fields → KG Basin, Gujarat, Tripura.
  - Used for transport, petrochemicals, fertilisers.
- **Hydropower:**
  - Major projects → Bhakra–Nangal, Tehri, Hirakud, Sardar Sarovar.
  - Clean renewable source → depends on river basins & monsoon.
- **Nuclear Energy:**
  - Plants → Tarapur, Kudankulam, Kakrapar, Kaiga.
  - Uranium from Jharkhand, Andhra Pradesh.
  - Important for long-term energy security.
- **Renewable Energy:**
  - Solar: Rajasthan, Gujarat, Telangana → fastest-growing.
  - Wind: Tamil Nadu, Gujarat, Maharashtra (→ wind corridors).
  - Biomass: Rural India → biogas, agri waste.
  - Small hydro & tidal: Limited but expanding.
- **Non-commercial Energy (Rural areas):**
  - Firewood, charcoal, dung cakes → still used in many households.

- **Key Challenges:**
  - High import dependence on oil & gas.
  - Coal pollution → environmental concerns.
  - Grid losses, distribution inefficiencies.
  - Need for more renewable integration.
- **Government Initiatives:**
  - National Solar Mission, wind parks, green hydrogen push.
  - Promotion of EVs, energy efficiency, smart grids.

RENEWABLE RESOURCE POTENTIAL IN INDIA

- **India has high renewable energy potential → strong solar radiation, long coastline, good wind corridors, large agro-residues.**
- **Target:** 500 GW renewable capacity by 2030.
- **Solar Energy:**
  - Highest potential zones → Rajasthan, Gujarat, Telangana, Andhra Pradesh.
  - Rajasthan alone has 250–300 sunny days → large solar parks (Bhadla).
  - Rooftop solar growing in urban areas.
- **Wind Energy:**
  - Strong wind corridors → Tamil Nadu, Gujarat, Maharashtra, Karnataka.
  - Offshore wind potential along Gujarat–Tamil Nadu coast.
- **Hydropower:**
  - Himalayan rivers → Uttarakhand, Himachal, Sikkim, J&K.
  - Many small hydro sites across hilly regions.
- **Biomass & Bioenergy:**
  - High potential in Punjab, Haryana, UP, Karnataka → agri residues.
  - Biogas and waste-to-energy expanding in cities.
- **Tidal & Geothermal:**
  - Tidal → Gulf of Kutch, Gulf of Khambhat.
  - Geothermal → Puga Valley (Ladakh).

RENEWABLE RESOURCE POTENTIAL IN MAHARASHTRA

- Maharashtra is among India's top renewable-energy producing states → strong solar, wind, biomass and small hydro potential.

- **Solar Energy:**
  - High irradiation in Marathwada, Vidarbha, Western Maharashtra.
  - Major solar parks → Dhule, Osmanabad, Solapur.
  - Rooftop solar growing in Mumbai–Pune belt.
- **Wind Energy:**
  - Strong wind sites → Satara, Sangli, Kolhapur, Pune (Chalakudy–Satara wind corridor).
  - Maharashtra ranks among top wind-power states.
- **Biomass Energy:**
  - Sugarcane regions → Kolhapur, Sangli, Ahmednagar, Pune → bagasse-based power.
  - Cotton & soybean belt → Vidarbha → biomass briquettes.
- **Small Hydropower:**
  - Available in Western Ghats & Konkan → steep slopes & perennial streams.
  - Potential in rivers like Kundalika, Vashishti, Savitri.
- **Urban Waste-to-Energy:**
  - High potential in Mumbai, Pune, Nagpur, Nashik → large municipal waste generation.

Agriculture

AGRICULTURE IN INDIA

- India is a monsoon-dependent, agrarian economy → agriculture supports over 50% of the population.
- Farming is dominated by small and marginal farmers → fragmented landholdings.
- **Major Agricultural Seasons:**
  - Kharif (Jun–Oct): Rice, cotton, jowar, maize, groundnut → dependent on SW monsoon.
  - Rabi (Nov–Apr): Wheat, barley, mustard, chana → grown in winter with irrigation.
  - Zaid (Apr–Jun): Watermelon, cucumber, fodder crops.
- **Major Crops:**
  - Foodgrains: Rice (East, South), Wheat (North, NW), Millets (Rajasthan, Karnataka).
  - Commercial crops: Cotton (Maharashtra, Gujarat), Sugarcane (UP, Maharashtra), Jute (Bengal).
  - Plantation crops: Tea (Assam, Darjeeling), Coffee (Karnataka), Rubber (Kerala).
  - Oilseeds: Groundnut, mustard, soybean.
  - Horticulture: Mango, banana, potato → India is a global leader.

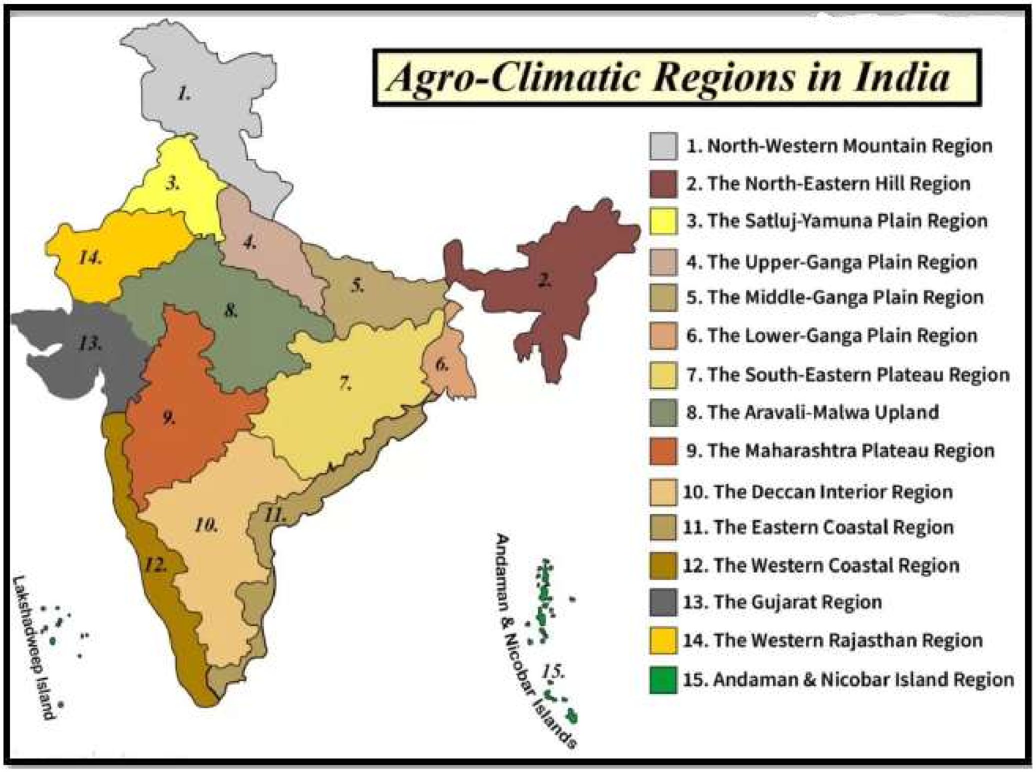
- **Factors Influencing Agriculture:**
  - Monsoon rainfall → uneven → droughts & floods.
  - Soils: Alluvial → wheat & rice; Black soils → cotton; Red soils → millets & pulses.
  - Irrigation: Canal + tube well + tanks → needed for Rabi crops.
- **Regional Patterns:**
  - Indo-Gangetic Plains → highly productive → wheat–rice belt.
  - Peninsular Plateau → millets, pulses, cotton (depends on rainfall).
  - Coastal regions → rice, coconut, spices.

MAJOR CHALLENGES WITH AGRICULTURE IN INDIA

- Monsoon dependence → irregular rainfall causes droughts/floods (Vidarbha, Rajasthan).
- Small & fragmented landholdings → low productivity → high cost per farmer.
- Low irrigation coverage → only about half of farmland irrigated → Rabi crops at risk.
- Soil degradation → overuse of fertilisers, erosion, salinity (Punjab, Haryana).
- Groundwater depletion → heavy tube-well use in UP, Punjab, Haryana → falling water tables.
- Low productivity of major crops → yields lower than global averages (rice, pulses).
- High input costs → seeds, fertilisers, pesticides, diesel → reduce profitability.
- Post-harvest losses → poor storage & cold chain → fruits/vegetables wasted.
- Limited MSP reach → only a few crops effectively procured (mostly wheat, rice).
- Market volatility → price crashes for onion, tomato, cotton → farmer distress.
- Credit issues → dependence on informal lenders → high interest burden.
- Pest & disease outbreaks → locusts, fruit fly, bollworm affect yields.
- Climate change → erratic monsoons, heat waves reduce crop output.
- Lack of diversification → over-reliance on wheat–rice in some states.
- Poor extension services → farmers lack timely information on climate & technology.

AGRO-CLIMATIC ZONES IN INDIA

- Agro-climatic zones are regions grouped based on climate, soil, temperature, rainfall, and cropping patterns.
- India is divided into zones to promote region-specific agriculture, improve productivity, and match crops with local conditions.
- This classification helps in planning irrigation, fertilizers, seeds, and farming practices suited to each zone.



AGRO-CLIMATIC ZONES OF INDIA

1. Western Himalayan Region – Cool climate; apples, temperate fruits; terrace farming in hills.
2. Eastern Himalayan Region – High rainfall; rice, maize, tea; rich biodiversity (NE states).
3. Lower Gangetic Plain – Humid; fertile alluvium; rice–jute; intensive agriculture (WB).
4. Middle Gangetic Plain – High population density; rice–wheat; flood-prone (Bihar–East UP).
5. Upper Gangetic Plain – Irrigated zone; wheat, sugarcane; alluvial soils (West UP).
6. Trans-Gangetic Plain – High input agriculture; wheat–rice, cotton; canal irrigation (Punjab–Haryana).
7. Eastern Plateau & Hills – Undulating plateau; millets, oilseeds; tribal farming (Odisha–Jharkhand).
8. Central Plateau & Hills – Semi-arid; soyabean, pulses; black & red soils (MP–Bundelkhand).
9. Western Plateau & Hills – Rainshadow zone; jowar, cotton; drought-prone (Maharashtra–Karnataka).
10. Southern Plateau & Hills – Warm climate; millets, groundnut, horticulture (TN–Karnataka–AP).
11. East Coast Plains & Hills – Coastal agriculture; rice, coconut; cyclone-prone.
12. West Coast Plains & Ghats – Heavy rainfall; spices, rubber, rice; plantation crops (Kerala–Konkan).
13. Gujarat Plains & Hills – Semi-arid; cotton, groundnut; saline soils in Kutch.
14. Western Dry Region – Very arid; bajra, fodder; desert agriculture (Rajasthan).

15. Islands Region – Humid tropical; coconut, arecanut, fisheries (Andaman–Nicobar, Lakshadweep).

SIGNIFICANCE OF AGRO-CLIMATIC ZONES

- Helps match crops with local climate & soil → improves productivity and sustainability.
- Enables region-specific farming strategies (seeds, fertilizers, irrigation).
- Supports optimal use of natural resources → reduces wastage of water, land, and inputs.
- Encourages crop diversification suited to each zone → reduces risk of crop failure.
- Aids in planning agricultural research & extension services for targeted results.
- Helps reduce regional imbalances by promoting suitable crops in backward areas.
- Supports climate-resilient agriculture → better adaptation to droughts, floods, and temperature extremes.
- Improves food security through efficient zonal planning and higher productivity.
- Assists government in designing schemes, subsidies, and rural development programs based on local needs.

AGRO-CLIMATIC ZONES OF MAHARASTRA

- Agro-climatic zones of Maharashtra are based on rainfall, temperature, soils, and topography, which strongly influence cropping patterns.
- These zones help in region-specific agricultural planning, identifying suitable crops and improving productivity.
- Maharashtra shows high climatic variation → coastal humid belt, Ghat high-rainfall zone, and dry interior plateau.

AGRO-CLIMATIC ZONES OF MAHARASHTRA

- **VRL – Very High Rainfall Zone (Lateritic Soils)**
  - Found in Sindhudurg, Ratnagiri, Raigad coastal belt.
  - Heavy rainfall (300+ cm) → rice, coconut, cashew, horticulture.
- **VRN – Very High Rainfall Zone (Non-Lateritic Soils)**
  - Parts of Thane, Palghar, Mumbai suburbs.
  - High rainfall with mixed soils → paddy, fruits, fisheries.
- **GH – Ghat Zone (Western Ghats)**
  - Covers western slopes of Pune, Satara, Kolhapur.
  - Very high rainfall, steep terrain → horticulture, spices, plantation crops.
- **TRI – Transition Zone I**
  - Includes Nashik, Dhule, Nandurbar.
  - Moderate rainfall → grapes, onions, sorghum, pulses.
- **TR2 – Transition Zone II**
  - Covers Ahmednagar, Jalgaon, Aurangabad belt.
  - Semi-arid → jowar, bajra, cotton, sugarcane (with irrigation).
- **SC – Scarcity Zone**
  - Solapur, Beed, Osmanabad and adjoining areas.
  - Very low rainfall (50–75 cm) → drought-prone → jowar, bajra, oilseeds.
- **AR – Assured Rainfall Zone**
  - Western Vidarbha (Akola, Amravati, Yavatmal).
  - Reliable rainfall (100–120 cm) → cotton, soybean, tur.
- **MR – Moderate Rainfall Zone**
  - Marathwada & Central Plateau areas → Hingoli, Parbhani, Latur.
  - Moderate rainfall → cotton, pulses, oilseeds, coarse cereals.
- **HRM – High Rainfall Zone (Mixed Parent Soils)**
  - Eastern Vidarbha (Bhandara, Gondia, Chandrapur, Gadchiroli).
  - High rainfall + forest soils → paddy, minor millets, horticulture.