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GEOGRAPHY

UPSC Civil Services — Complete Edition 2027

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PART I — WORLD PHYSICAL GEOGRAPHY (Unit 10)

Chapter 1 Plate Tectonics & Geomorphology

1.1 Micro-Topic Map — PYQ Coverage

Micro-Topic / Theme	Year (Marks)	Key Conceptual Thread
Continental Drift theory — evidences (Wegener)	2013	Jigsaw fit, fossils (Mesosaurus, Glossopteris), palaeomagnetism, rock-type match, palaeoclimate
Circum-Pacific Zone (Ring of Fire) — geophysical characteristics	2020 (10M)	40,000 km arc; 75% volcanoes; 90% earthquakes; Pacific Plate subduction
Mantle plume — definition and role in plate tectonics	2018 (10M)	Hot upwelling column → intraplate volcanism (Hawaii, Deccan Traps via Réunion plume)
Formation of Indonesian & Philippine archipelagos	2014	Ocean-ocean subduction → volcanic island arcs
Tsunamis — genesis, propagation, consequences	2025 (10M)	Undersea earthquakes M>7 | ITEWC (INCOIS, Hyderabad) | 2004 Indian Ocean Tsunami
Changes in shape/size of continents & ocean basins	2025 (15M)	Sea-floor spreading, Wilson Cycle, passive vs. active margins

1.2 Plate Boundaries — Types & Examples

Boundary Type	Movement	Feature Formed	Example
Divergent	Plates move apart	Mid-ocean ridge, rift valley	Mid-Atlantic Ridge; East African Rift
Convergent — Ocean-Ocean	Two oceanic plates collide	Island arc, deep trench	Mariana Trench; Philippines Arc
Convergent — Ocean-Continent	Oceanic subducts under continental	Fold mountains, trench, volcanoes	Andes; Peru-Chile Trench
Convergent — Continent-Continent	Both continental plates collide	Tall fold mountains (no volcanism)	Himalayas — India + Eurasian plate
Transform / Conservative	Plates slide horizontally past each other	Fault zone; earthquakes; no new crust	San Andreas Fault (California)

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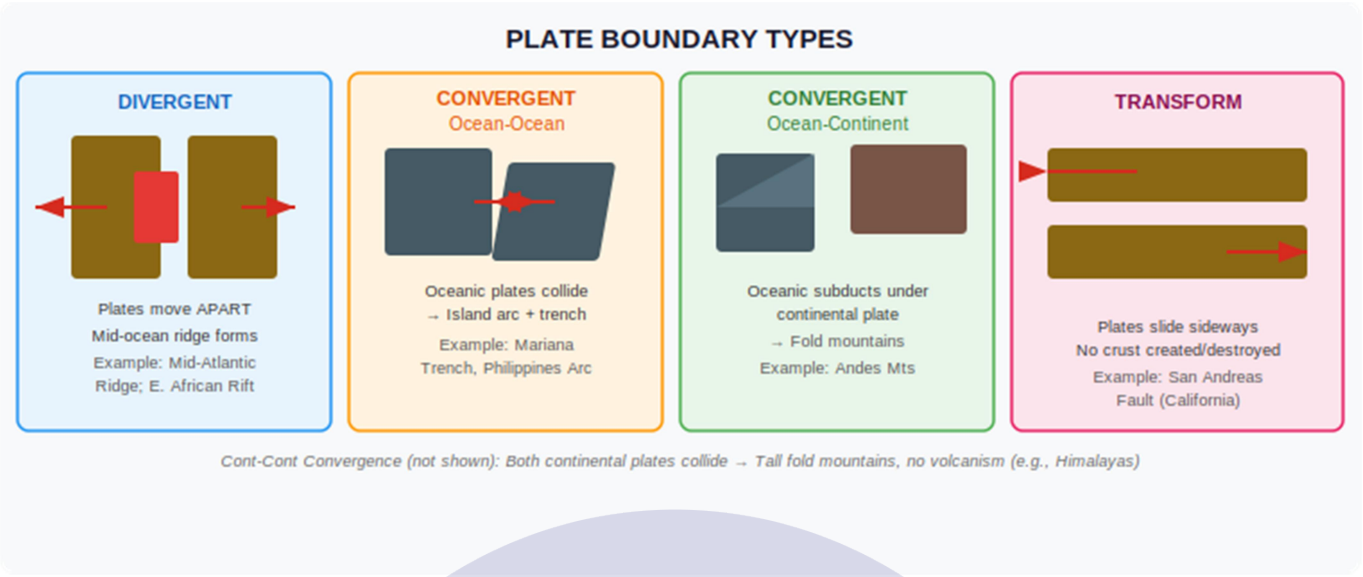

Figure 1.1 — The four main plate boundary types with movement directions and landforms formed

1.3 Mantle Plume, Ring of Fire & Tsunamis — Key Facts

Aspect	Detail
Mantle Plume	Narrow column of anomalously hot mantle rock rising independently of plate boundaries → hotspot volcanism | Examples: Hawaii (Pacific), Réunion (→ Deccan Traps 66 Mya), Yellowstone, Iceland
Ring of Fire — Extent	Aleutians → Japan → Philippines → Indonesia → New Zealand → W. Americas (Andes–Rockies–Cascades)
Ring of Fire — Stats	40,000 km arc | 75% of world's volcanoes | 90% of world's earthquakes
Tsunami Triggers	Undersea earthquakes (M>7, <50 km depth) | Submarine landslides | Volcanic eruptions
Wave Behaviour	Deep ocean: 700–800 km/h, height <1 m → Near coast: slows, surges to 30 m+
2004 Indian Ocean	Mw 9.1 Sumatra; 14 nations; 2.3 lakh deaths → triggered India to set up ITEWC (INCOIS, Hyderabad)
India's Vulnerable Coasts	Andaman & Nicobar | Tamil Nadu | Kerala | Andhra Pradesh — Bay of Bengal amplifies waves

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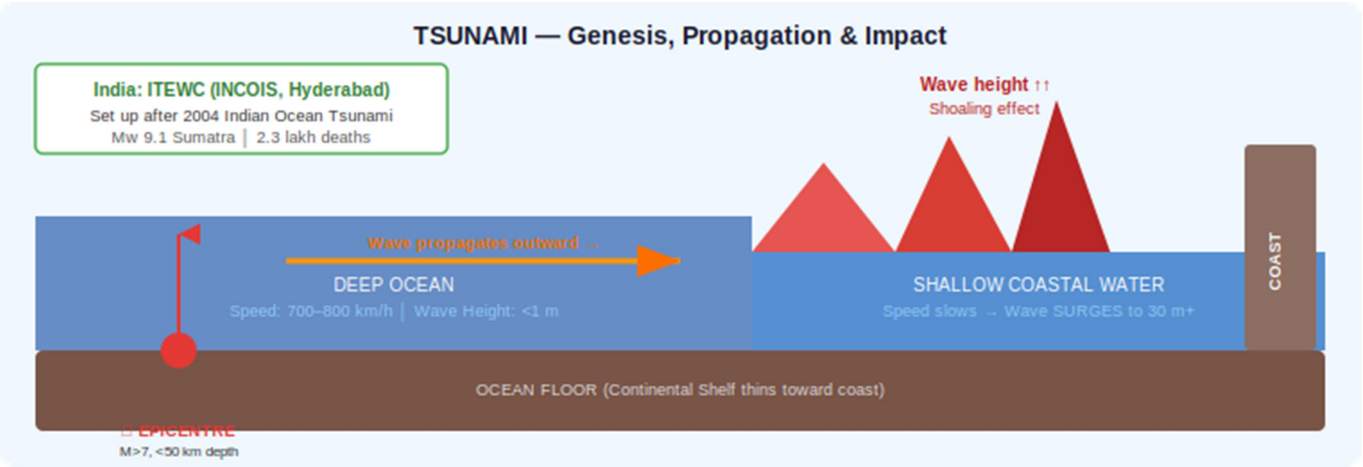

Figure 1.2 — Tsunami: genesis, propagation from deep to shallow water, and coastal impact

Chapter 2 Mountains, Volcanoes, Rocks & Landforms

2.1 Micro-Topic Map — PYQ Coverage

Micro-Topic / Theme	Year (Marks)	Key Conceptual Thread
Fold mountains along continental margins — link to earthquakes & volcanoes	2014	Subduction/collision zones → sediment folding; correlated with seismicity & volcanism
Mountain alignment & impact on local weather	2021 (15M)	Orographic rain, rain shadow (Leh, Tibet), foehn/chinook, monsoon trapping
Global volcanic eruptions in 2021 — regional environmental impact	2021 (10M)	La Palma, Nyiragongo, Semeru, Etna — SO□, ash, displacement, aviation disruption
Primary rocks — characteristics and types	2022 (10M)	Igneous (intrusive: granite; extrusive: basalt); Sedimentary; Metamorphic; rock cycle
Landslides: Himalayas vs. Western Ghats — causes & mitigation	2013, 2016, 2021	Himalayas: young fragile geology + seismicity; W. Ghats: laterite + heavy monsoon
Fjords — formation and why picturesque	2023 (10M)	U-shaped glacial valley flooded by sea after deglaciation; Norway, NZ, Chile, Alaska

2.2 Volcano Classification

Type	Formation	Characteristics	Examples
Shield	Hotspot / divergent; basaltic lava	Broad, flat, gently sloping; non-explosive	Mauna Loa (Hawaii), Deccan Plateau
Composite / Stratovolcano	Subduction zones; alternating lava & pyroclastics	Tall, steep, highly explosive	Mt. Fuji, Vesuvius, Pinatubo, Mt. St. Helens
Cinder Cone	Small vent; pyroclastic fragments only	Steep sides, small, short-lived	Parícutin (Mexico)

Type	Formation	Characteristics	Examples
Caldera	Collapse after massive eruption empties magma chamber	Large bowl-shaped depression	Yellowstone (supervolcano), Toba (Indonesia)
Fissure / Lava Plateau	Lava from linear fissures (not point vents)	Flat, broad flood basalt plains	Deccan Traps, Siberian Traps, Columbia Plateau

2.3 Rock Classification — Igneous · Sedimentary · Metamorphic

Category	Sub-types & Formation	Key Examples	UPSC Relevance
Igneous (Primary)	Intrusive/Plutonic — slow cooling, coarse-grained | Extrusive/Volcanic — rapid cooling, fine-grained	Granite (intrusive); Basalt, Rhyolite (extrusive)	Deccan basalt → regur/black soil; Aravalli granites; mineral deposits
Sedimentary	Clastic (sandstone, shale) | Chemical (limestone, rock salt) | Organic (coal, chalk)	Sandstone, Limestone, Shale, Coal, Gypsum	Fossils; petroleum traps; Gondwana coal beds; sedimentary aquifers
Metamorphic	Heat & pressure | Foliated (schist, slate, gneiss) | Non-foliated (marble, quartzite)	Marble (Rajasthan), Quartzite, Schist, Slate	Makrana marble; gem/mineral deposits

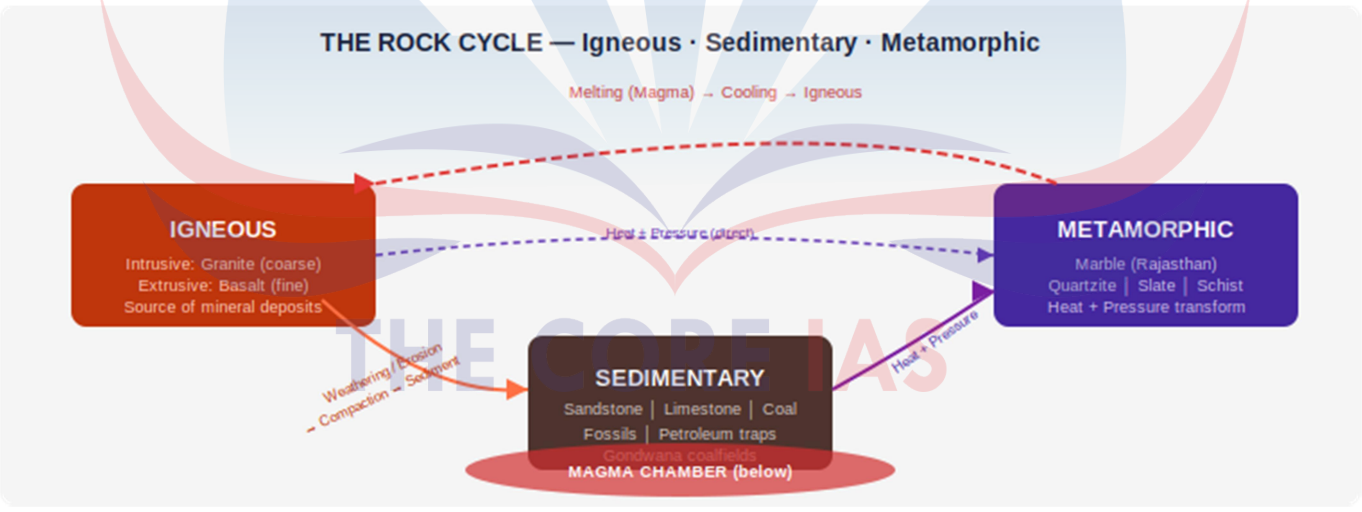

Figure 2.1 — The Rock Cycle: interconversion pathways between Igneous, Sedimentary & Metamorphic rocks

2.4 Landslides — Himalayas vs Western Ghats

Parameter	Himalayan Region	Western Ghats Region
Geological Factor	Young fold mountains; fragile lithology; loose debris; active tectonics	Ancient crystalline rocks topped with laterite — structurally weaker on steep slopes

Parameter	Himalayan Region	Western Ghats Region
Triggering Factor	High-intensity monsoon; earthquakes; glacial meltwater; cloudbursts	Intense SW monsoon (>3,000 mm/yr); slope undercutting; toe erosion
Human Factors	HEP blasting; deforestation; road-cutting (NH-1, NH-2); tunnelling	Road cuttings; quarrying; tourism infrastructure; forest encroachment
Notable Events	Kedarnath 2013 | Chamoli 2021 | Joshimath 2023 | Sarchu 2022	Munnar 2018 | Idukki 2020 | Taliye-Ratnagiri 2021 | Malin 2014
Mitigation Strategy	NDMA bio-engineering; ISRO early warning systems; slope stabilisation	ESZ regulation; controlled plantation; drainage improvement; construction ban

Aspect	Detail
Fjord — Definition	Long, narrow, deep sea inlet formed when a glaciated U-shaped valley is flooded by sea after post-Ice Age deglaciation
Formation Process	Glacier carves U-shaped valley → glacier retreats → sea level rises post-Ice Age → seawater fills valley → fjord
Key Features	Very deep (Sognefjord, Norway: 1,308 m) | Steep near-vertical walls | Narrow width | Hanging valleys | Waterfalls
Global Distribution	Norway (world's finest) | New Zealand (Fiordland NP) | Chile (Patagonia) | Alaska | Greenland | Canada
Ecological Value	Marine biodiversity hotspots | Oxygen-rich cold water | Salmon & cod fisheries | UNESCO WHS (Norwegian Fjords)

Chapter 3 Climatology

3.1 Micro-Topic Map — PYQ Coverage

Micro-Topic / Theme	Year (Marks)	Key Conceptual Thread
Naming of tropical cyclones	2013 (5M)	WMO / RSMC New Delhi; 13 countries × 13 names = 169; in use since April 2020
Tropical cyclones confined to specific seas — why	2014	SST ≥ 26.5°C | Coriolis (>5° lat.) | Weak wind shear | Pre-existing low pressure
IMD colour-coded weather warnings	2022 (10M)	Green (watch) | Yellow (aware) | Orange (prepared) | Red (action)
Urban Heat Island — causes	2013 (5M)	Impervious surfaces | Less vegetation | Anthropogenic heat | Urban canyon effect
Temperature inversion — phenomenon and effects	2013 (5M)	Radiation | Subsidence | Frontal | Advection | Valley/Katabatic types
Hot deserts at 20–30°N on western continental sides	2013 (10M)	Subtropical highs | Cold ocean currents | Offshore trade winds | Continentality

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Micro-Topic / Theme	Year (Marks)	Key Conceptual Thread
El Niño — unusual climatic events	2014	Walker Circulation | SST anomaly in E. Pacific | Weak Indian monsoon | ENSO
Air mass concept & macro-climatic change	2016 (12.5M)	cP, cT, mP, mT, cA, mE | Source regions | Fronts | Mid-latitude cyclones
Sea surface temperature rise & cyclone formation	2024 (10M)	Every 1°C SST rise → ~10% intensification; rapid intensification increasing
Aurora Australis & Aurora Borealis — triggers	2024 (15M)	Solar wind → magnetosphere → O_2 /N_2 ionisation at 100–300 km → photons
Twisters — why mostly near Gulf of Mexico	2024 (15M)	Warm Gulf air + cold Canadian air + dry line + jet stream wind shear → Tornado Alley

3.2 Tropical Cyclones — Naming & Genesis Conditions

Aspect	Detail
Naming System	WMO RSMCs assign names from pre-approved country lists. RSMC New Delhi names N. Indian Ocean cyclones from 169 names (13 countries × 13 names each) — operational since April 2020
Genesis Conditions	SST ≥ 26.5°C to depth of 50 m | Coriolis effect (>5° from equator) | Atmospheric instability | Mid-troposphere humidity | Weak vertical wind shear | Pre-existing low-pressure disturbance
Why NOT at Equator	Coriolis force is zero at the equator — no spinning mechanism for cyclonic circulation to develop
SST & Intensity Link	Every 1°C rise in SST intensifies a cyclone by ~10%; rapid intensification is increasing with climate change
IMD Warnings	Green — Watch (no action) | Yellow — Be Aware | Orange — Be Prepared (Alert) | Red — Take Action (High Impact)
Cyclone Name Examples	India: Phailin, Amphan, Tauktae, Biparjoy | Pakistan: Bulbul | Bangladesh: Nisarga | Myanmar: Mocha

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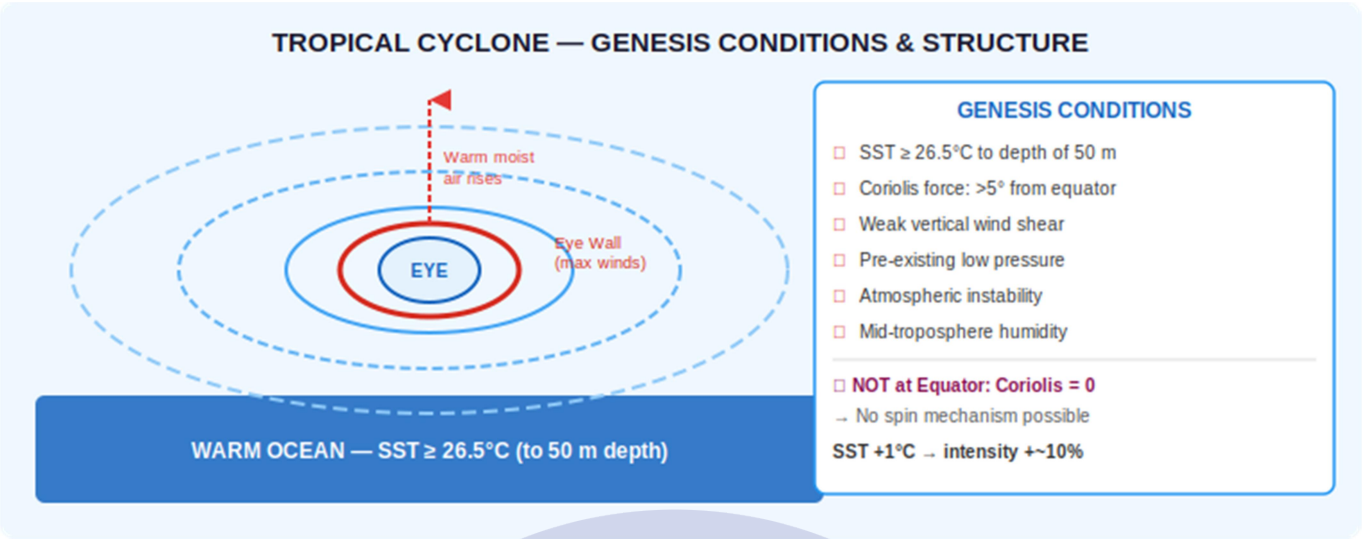

Figure 3.1 — Tropical Cyclone structure & the six genesis conditions (SST, Coriolis, low shear, etc.)

3.3 Urban Heat Island & Temperature Inversion

Aspect	Detail
UHI — Definition	A city significantly warmer than surrounding rural areas — typically 1–3°C warmer, up to 10°C at night
UHI — Causes	Dark impervious surfaces absorb more radiation | Less vegetation (less evapotranspiration) | Anthropogenic heat (vehicles, AC, industry) | Urban canyon traps longwave radiation
UHI — Effects	Higher cooling energy demand | Enhanced smog formation | Disrupted precipitation patterns | Heat-related illness | Nocturnal warming worsens smog
UHI — Mitigation	Cool/reflective roofs & pavements | Urban forests (Miyawaki) | Green & blue roofs | Permeable pavements | Urban wind corridor planning
Indian Examples	Delhi (~5°C warmer than rural surroundings) | Mumbai | Bengaluru | Chennai — all show measurable UHI

Inversion Type	Mechanism	Effect on Weather
Radiation	Clear calm nights → rapid ground cooling → surface air colder than air above	Frost, valley fog, smog trapping
Subsidence	Subsiding air under subtropical highs (20–30°N/S) warms by compression	Cloudless, dry, stable — explains hot deserts
Frontal	Warm air overrides cold air at frontal zone	Stratiform cloud, steady drizzle
Advection	Warm moist air moves over cold surface (Pacific air over cold California Current)	Coastal sea fog (San Francisco, Atacama)
Valley / Katabatic	Cold dense air drains into valleys at night	Frost hollows, radiation fog in valleys

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Key Concept Delhi winter smog = radiation inversion + stubble-burning aerosols + low wind speed + urban canyon. GRAP (Graded Response Action Plan) activated when AQI crosses 400.

3.4 Hot Deserts · ENSO · Air Masses

ENSO Condition	Mechanism	India Impact	Global Effect
Normal Year	Strong trade winds; cold upwelling off Peru; Walker Circulation active	Good SW Monsoon	Normal global rainfall patterns
El Niño	Trade winds weaken/reverse; warm water shifts to E. Pacific; Walker Circulation weakens	Deficit monsoon; drought in India	Droughts in Australia, SE Asia; floods in Ecuador & Peru
La Niña	Stronger trades; extra warm water in W. Pacific; stronger Walker Circulation	Excess monsoon; Gangetic plain floods	Floods in Australia; droughts in Peru
Positive IOD	Warm W. Indian Ocean, cool E. Indian Ocean — amplifies monsoon	Strengthens SW Monsoon	Affects E. Africa rainfall; Australia drought

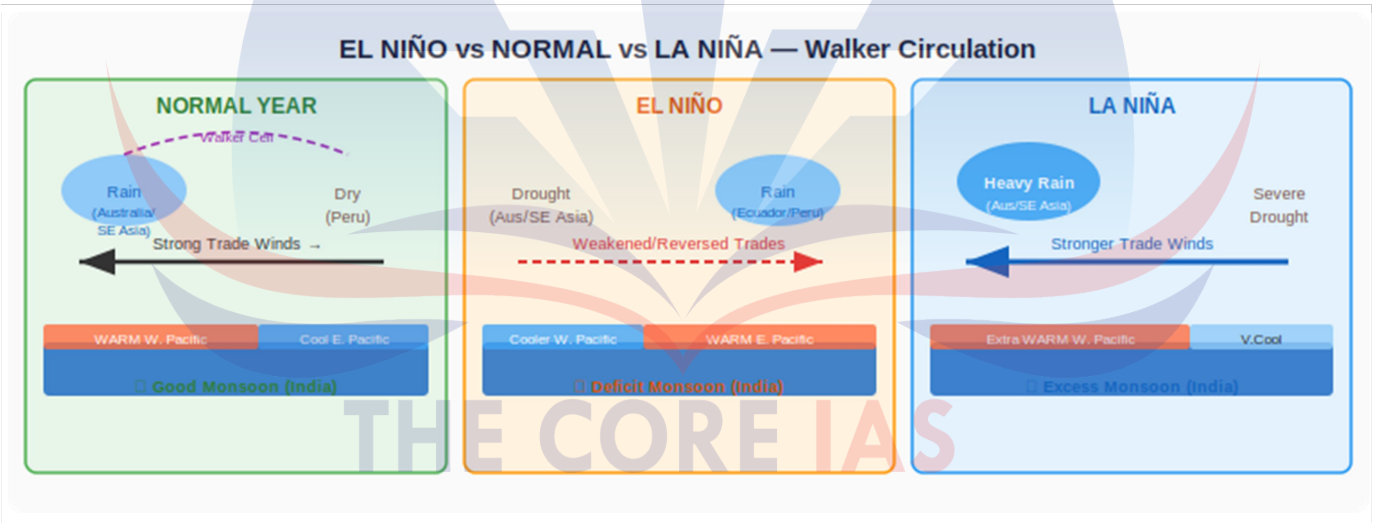

Figure 3.2 — ENSO: Walker Circulation under Normal, El Niño & La Niña conditions and India's monsoon impact

Air Mass	Symbol	Source Region	Characteristics & Weather Impact
Continental Polar	cP	N. Canada, Siberia	Cold, dry | Blizzards to N. America & Europe | Polar vortex outbreaks
Continental Tropical	cT	Sahara, Arabian Desert	Hot, dry | Heat waves | Dust storms (Haboob)
Maritime Polar	mP	N. Atlantic, N. Pacific (high latitude)	Cool, moist | Fog, drizzle to NW Europe & Pacific coast

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Air Mass	Symbol	Source Region	Characteristics & Weather Impact
Maritime Tropical	mT	Gulf of Mexico, tropical Atlantic/Pacific	Warm, moist | Drives monsoons, hurricanes | Key to Tornado Alley
Continental Arctic	cA	Arctic/Antarctic ice sheets	Extremely cold, dry | Polar vortex outbreaks | Freeze events
Maritime Equatorial	mE	Equatorial oceans	Warm, very moist | Fuels ITCZ rainfall | Tropical cyclones

3.5 Auroras & Tornadoes

Aspect	Detail
Auroras — Mechanism	Solar wind (charged particles) → hits Earth's magnetosphere → deflected to poles → collides with O_2 & N_2 at 100–300 km → electron excitation → photon emission (light)
Aurora Colours	Green — oxygen at ~100 km | Red — oxygen at >200 km | Blue/Purple — nitrogen | Pink — mix
Aurora Borealis	Northern Lights: Norway, Canada, Alaska, Iceland, Finland (Aurora Oval 65–72°N)
Aurora Australis	Southern Lights: Antarctica, S. America tip, New Zealand — India's Maitri Station (Antarctica) has observed
India Relevance	Intense CMEs → visible in Ladakh/Himalayas; affects GPS, satellites, power grids
Tornado Formation	Warm moist air (mT — Gulf of Mexico) meets cold dry air (cP — Canada) → supercell thunderstorm → mesocyclone → tornado touchdown
Why Gulf of Mexico?	1. Gulf SST ~29°C → unlimited warm moist air | 2. Flat Great Plains — no barrier for cold Canadian air | 3. Dry line where Gulf air meets Rockies desert air | 4. Jet stream provides wind shear for rotation
Tornado Alley	Texas → Oklahoma → Kansas → Nebraska → S. Dakota | 1,000+ tornadoes/year — world's highest density

Chapter 4 Oceanography

4.1 Micro-Topic Map — PYQ Coverage

Micro-Topic / Theme	Year (Marks)	Key Conceptual Thread
Factors for ocean currents; influence on climate, fishing, navigation	2015	Planetary winds, Coriolis, THC density, bottom topography, temperature
Forces influencing ocean currents — fishing industry role	2022 (15M)	Cold-warm convergence zones → upwelling → nutrients → rich fisheries (Grand Banks, Peruvian)
Ocean currents vs. water masses —	2019	Warm currents: moderate climate, rainfall; Cold

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Micro-Topic / Theme	Year (Marks)	Key Conceptual Thread
impact on marine life & coasts		currents: fog, aridity, upwelling fisheries
Oceanic salinity variations and multi-dimensional effects	2017	Evaporation, precipitation, river inflow, ice melt/freeze; Dead Sea, Red Sea, Bay of Bengal
Dead Zones — consequences on marine ecosystems	2018 (10M)	N/P runoff → algal bloom → decomposition → O_2 depletion → hypoxia; Gulf of Mexico, Baltic Sea
Global warming & coral bleaching	2019 (10M)	SST rise 1–2°C → zooxanthellae expelled → white skeleton; 4th mass bleaching 2022-23
Mangrove depletion — coastal ecology importance	2019	Blue carbon, coastal protection (50–70% wave energy), fisheries nursery, biodiversity
Ocean resources to meet world resource crisis	2014 (10M)	Fisheries, polymetallic nodules (CIOB), methane hydrates, OTEC, tidal energy, marine biotech

4.2 Major Ocean Currents

Current	Type	Region	Climate / Fishery Significance
Gulf Stream	Warm	W. Atlantic → NW Europe	Keeps UK/Scandinavia 5–10°C warmer than latitude; supports N. Atlantic Drift
Kuroshio	Warm	E. Japan, N. Pacific	Japan's climate moderator; major tuna & albacore fishery
Labrador	Cold	W. Greenland → NE USA	Grand Banks cod fishery — mixes with Gulf Stream
Humboldt (Peru)	Cold	W. South America	World's most productive fishery (anchovy); causes Atacama Desert
Benguela	Cold	W. Africa, S. Atlantic	Namib Desert; anchovy/sardine fishery; dense coastal sea fog
Canary	Cold	NW Africa, N. Atlantic	Reinforces Sahara aridity; sardine fishery
N. Atlantic Drift	Warm	N. Atlantic	Keeps N. European ports ice-free year-round
Agulhas	Warm	SE Africa, Indian Ocean	SE Africa rainfall; rogue waves near Cape of Good Hope
Somali Current	Seasonal	E. Africa coast	Reverses with monsoon; upwelling feeds Arabian Sea productivity

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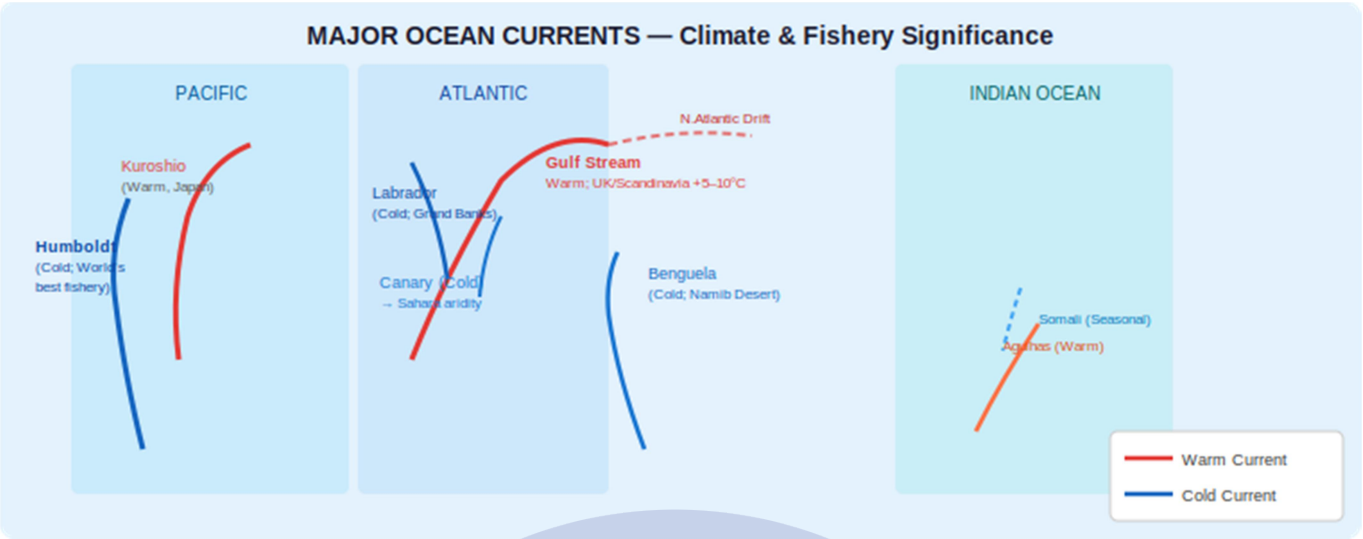

Figure 4.1 — Major ocean currents: warm (red) and cold (blue) with climate & fishery significance

4.3 Salinity · Dead Zones · Coral Bleaching · Mangroves

Aspect	Detail
Salinity — Evaporation ↑	Higher evaporation → higher salinity | Red Sea (~40‰), Persian Gulf, Mediterranean
Salinity — Precipitation ↑	High rainfall dilutes → lower salinity | Equatorial belt, Bay of Bengal
Salinity — River Inflow ↑	Fresh water input → lower salinity near river mouths | Bengal coast (Ganga, Brahmaputra)
Salinity — Ice Dynamics	Ice melt → ↓ salinity (polar summer) | Ice freezing → excludes salt → ↑ salinity nearby (polar winter)
Dead Zones — Formation	N/P fertilizer runoff + sewage → algal bloom → bacterial decomposition → O_2 depletion → hypoxia (<2 mg/L)
Dead Zones — Examples	Gulf of Mexico (~22,720 km² — largest annual dead zone) | Baltic Sea | Bay of Bengal | Black Sea
Coral Bleaching — Cause	SST rise 1–2°C above seasonal max for 4+ weeks → zooxanthellae expelled → white skeleton → death if prolonged
Coral Bleaching — Events	1998 | 2010 | 2015-16 | 2022-23 (4th global — 54+ countries); Great Barrier Reef most affected
India's Reefs	Andaman & Nicobar | Lakshadweep (atoll reefs) | Gulf of Mannar | Gulf of Kutch — all under bleaching threat
Mangroves — Functions	Coastal protection (50–70% wave energy reduction) | Blue carbon (3–5× tropical forests/ha) | Fisheries nursery (80% of commercial species)
India's Mangroves	Sundarbans (largest, UNESCO WHS) | Bhitarkanika (Odisha) | Pichavaram (TN) | Godavari-Krishna delta
MISHTI Scheme (2023)	Mangrove Initiative for Shoreline Habitats & Tangible Incomes — 540 km² plantation target

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PART II — DISTRIBUTION OF RESOURCES (Unit 11)

Chapter 5 Water

Micro-Topic / Theme	Year (Marks)	Key Conceptual Thread
India well-endowed with freshwater yet suffering scarcity	2015	4% world freshwater; 18% population; uneven distribution; inefficient irrigation
Effective management of land & water resources	2016 (12.5M)	PMKSY, watershed development, Hariyali, NWDPRA
Micro-watershed development in drought-prone areas	2016 (12.5M)	Ridge-to-valley, check dams, farm ponds, contour bunding
Water harvesting in urban areas — groundwater solution	2018 (15M)	Rooftop RWH, percolation pits; TN mandatory norm; Bengaluru pilot
Water stress — how & why it differs regionally	2019 (15M)	Falkenmark Indicator; NW India (overexploitation) vs. NE India (excess); peninsular drought
World freshwater crisis — availability & access	2023 (10M)	<1% global water freshwater accessible; 2.2 billion lack safe water; SDG 6
Groundwater decline in Gangetic valley — food security	2024 (15M)	Punjab 156.9% extraction of recharge; GRACE satellite data; crop diversification needed

5.2 Water Scarcity Data & Global Models

Metric	Global	India
Water Stress Rank	—	13th most water-stressed nation (WRI Aqueduct 2019)
Safe Drinking Water Access (SDG 6.1.1)	2.2 billion lack safely managed water (2022)	~35 million still lack access
Groundwater Extraction	—	~251 BCM/year — world's largest extractor (FAO)
Per Capita Availability	—	~1,486 m³/capita/year (near stress threshold of 1,700 m³)
Falkenmark Indicator	<1,700 m³/capita = Water Stress | <1,000 m³ = Water Scarcity	India approaching scarcity in NW states

5.4 Groundwater Depletion — State-wise Trends

State / Region	Depletion Status	Key Causes
Punjab	Extraction at 156.9% of annual recharge; table falling >1 m/year	Paddy cultivation, free electricity, flood irrigation — unsustainable triad
Haryana	2,200+ villages with water table >30 m; extraction ~136% of recharge	Urbanisation, deep borewells, canal seepage reducing
Rajasthan	2–4 m/year decline in many arid districts	Hard rock aquifers, arid climate, groundwater-dependent farming
Tamil Nadu	64% blocks semi-critical or worse	Urban demand surge, borewell overdraft, low recharge in dry years
Delhi NCR	Depth fallen from ~20 m to >40 m in 20 years	Concrete surfaces, illegal extraction, poor urban recharge
India Overall	~4 cm/year national average fall (GRACE satellite data)	Climate change, heat-driven irrigation demand, inefficient cropping patterns

Chapter 6 Land

Land Issue	Description	Key Region(s)
Desertification	Loss of productive capacity — wind erosion, salinity, drought	Thar Desert (Rajasthan), Kutch (Gujarat)
Soil Erosion	Topsoil removal by water & wind — reduces fertility	Shivalik Hills, Eastern Ghats
Waterlogging & Salinity	Over-irrigation → salt accumulation — reduces crop yield	Punjab, Haryana, W. Uttar Pradesh
Deforestation	Forest clearing for agriculture, mining, infrastructure	Jharkhand, Chhattisgarh, NE India
Shifting Cultivation (Jhum)	Traditional tribal practice → deforestation & erosion	Nagaland, Meghalaya, Mizoram
Mining-induced Degradation	Land stripping, overburden dumping, acid drainage	Odisha (Keonjhar), Jharkhand (Dhanbad)
Urban Encroachment	Conversion of agricultural & wetland land for urban use	Peri-urban Delhi, Bengaluru, Chennai outskirts
Land Fragmentation	Sub-division of holdings reducing economic viability	Bihar, E. UP, Maharashtra (Vidarbha)
Tenurial Insecurity	No formal land ownership for tribes, women, tenant farmers	Odisha, MP tribal belts, Andhra Pradesh
Wasteland Expansion	Degraded, abandoned land — erosion, salinity, or neglect	Bundelkhand, Ladakh, W. Rajasthan

Case Studies — Water & Land Conservation

- **Ralegan Siddhi:** Anna Hazare watershed model, Maharashtra — community-led water conservation transformed drought-prone village
- **Hiware Bazar:** Maharashtra — 400% groundwater rise through participatory watershed management
- **Sukhomajri:** Haryana — first social fencing model; hill catchment + villager cooperative management
- **Pani Panchayat:** Maharashtra — equitable irrigation rights per family, not per land holding
- **Neeru-Meeru:** Andhra Pradesh — tank revival programme recovering traditional water bodies
- **Kudumbashree:** Kerala — women collectives lease fallow land for collective farming; land + livelihood model

Chapter 7 Energy

Energy Resource	Type	Major States	Key Facts & Data
Coal	Conventional	Jharkhand, Odisha, Chhattisgarh, WB, MP	Gondwana coalfields (97% of India's coal) | 4th largest reserves globally | 75%+ domestic energy
Crude Oil	Conventional	Assam, Gujarat, Mumbai High, Rajasthan	India imports ~85% of crude | Mumbai High = largest offshore producer (since 1974)
Natural Gas	Conventional	Assam, Tripura, KG Basin, Gujarat	Cleaner fuel; growing use in city gas distribution & power generation
Uranium	Nuclear	Jharkhand (Jaduguda), Meghalaya, Telangana	Limited domestic reserves; imports from Kazakhstan, Canada; Lithium found in J&K (2023)
Hydro Power	Renewable	HP, Uttarakhand, Sikkim, Arunachal, Kerala	High Himalayan & Western Ghats potential; seasonal flow challenges
Solar Energy	Renewable	Rajasthan, Gujarat, MP, Maharashtra, AP	750+ GW potential | Fastest growing | ISA, KUSUM, Rooftop Solar
Wind Energy	Renewable	Tamil Nadu, Gujarat, Maharashtra, Karnataka	695 GW onshore potential at 120 m hub height | Concentrated in 8 coastal/hilly states
Biomass	Renewable	Punjab, Haryana, Bihar, UP, WB	25–30 GW potential | Used for bio-CNG and power generation
Tidal	Renewable	Gulf of Kutch & Khambhat, Sundarbans	~11 m tidal range at Khambhat | No commercial plant yet in India

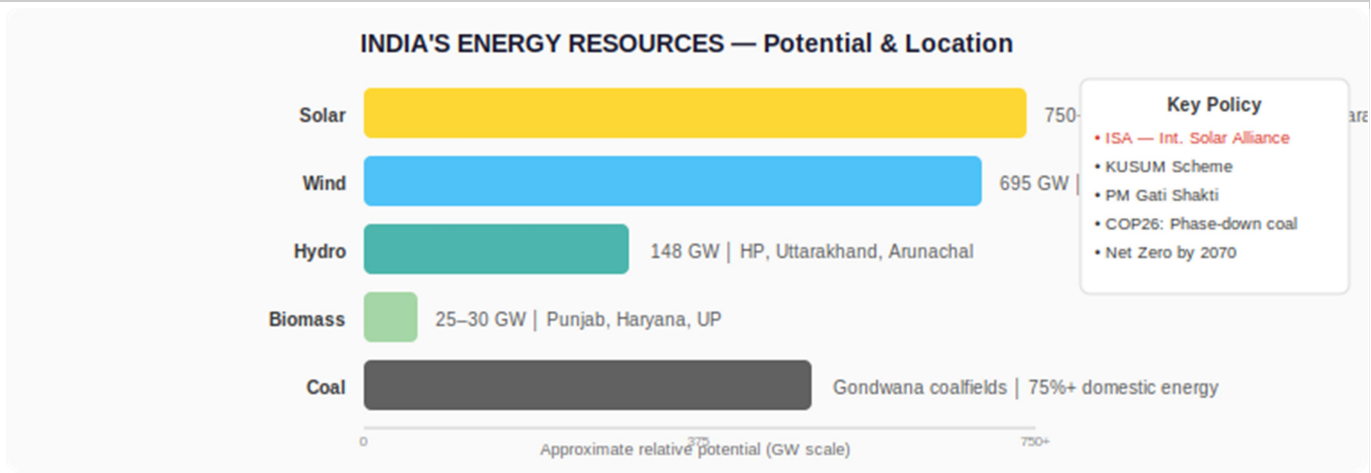

Figure 7.1 — India's Energy Resource Potential: Solar (750+ GW), Wind (695 GW), Hydro (148 GW) and Coal

7.2 Clean Coal Technologies

Clean Coal Technology	Description	Benefit
Supercritical/Ultra-supercritical Boilers	Higher steam temperature & pressure than conventional plants	30–45% efficiency vs. 25–30% conventional; reduces CO□ per unit of power
Coal Washing	Removes ash/sulphur before burning	Reduces ash content by 10–15%; lowers railway transport cost
Fluidised Bed Combustion (FBC)	Burns crushed coal in fluidised particle bed with air	Burns low-grade coal; significantly reduces SO□ & NOx emissions
IGCC (Integrated Gasification Combined Cycle)	Converts coal to syngas before combustion	Higher efficiency; easier carbon capture; reduced particulate pollution
Carbon Capture & Storage (CCS)	Captures CO□ from flue gas; stores underground	Potential 80–90% CO□ reduction per plant; key for net-zero coal
Flue Gas Desulphurisation (FGD)	Removes SO□ from flue gases of coal power plants	Mandatory under MoEFCC norms since 2015 for all Indian thermal plants

Key Concept Just Transition: India committed to 'phase-down' (not phase-out) of coal at COP26. Coal employs 4 million+ directly — social protection is essential alongside energy transition.

Chapter 8 Agriculture & Agro-Resources

Micro-Topic / Theme	Year (Marks)	Key Conceptual Thread
Blue Revolution — problems & pisciculture	2018 (15M)	PMMSY | Overfishing | IUU | Cold chain gap

Micro-Topic / Theme	Year (Marks)	Key Conceptual Thread
strategies		| India = 2nd largest producer globally
Pulses — cultivation advantages (Int'l Year 2016)	2017	N-fixation | Low water use | Soil health | Protein security | India: largest producer & importer
British tea gardens not succeeding beyond Darjeeling — why	2014	Unique terroir: altitude + mist + acidic soil + cool temp + GI Tag 2004
Green Revolution bypassing eastern India — why	2014	Weak irrigation | Fragmented holdings | Sharecropping | Absent credit | No research extension
Non-farm primary activities & physiographic link	2025 (10M)	Fishing (coast) | Forestry (hills) | Mining (Deccan) | Pastoralism (arid zones) | Sericulture (Karnataka, WB)
Rubber-producing countries & environmental issues	2022 (15M)	Thailand, Indonesia, Malaysia, Vietnam, India (Kerala 90%) | Monoculture deforestation | Smallholder volatility

Aspect	Detail
Blue Revolution — India	2nd largest fish producer globally | ₹1.75 lakh crore sector | exports ~₹60,000 cr (2022-23)
PMMSY (2020)	₹20,050 crore | 22 MT fish production target by 2024-25 | 55 lakh employment
Pulses — N Fixation	Root nodules with Rhizobium bacteria fix atmospheric N_2 → saves 20–30 kg N/ha; reduces chemical fertiliser need
Darjeeling Tea Terroir	1,000–2,500 m altitude + morning mist + cool 10–30°C + well-drained acidic soil → slow growth → muscatel flavour ('Second Flush')
Green Revolution Bypass	Punjab/Haryana had: assured canal irrigation + consolidated holdings + MSP enforcement + PAU research | East India lacked all four
Natural Rubber	Equatorial: >1,500 mm rain, 20–35°C, well-drained laterite soil | India = 4th globally (7%) | Kerala = 90% of India's production
Rubber — Env. Issues	Monoculture deforestation (displaces rainforest biodiversity) | Pesticide/herbicide use | Water-intensive processing effluent

Chapter 9 Arctic Resources & India

Aspect	Detail
Why Arctic Matters Globally	13% of undiscovered oil | 30% of undiscovered natural gas (USGS) | Rare earths | Freshwater | Opening of Northern Sea Route (NSR) — cuts Europe-Asia shipping by ~40%

Aspect	Detail
India's Scientific Engagement	Himadri Research Station, Svalbard, Norway (est. 2008) | Observer in Arctic Council since 2013 | Research on monsoon-Arctic teleconnection & ice-core paleoclimate
India's Economic Interests	Energy cooperation with Russia (Rosneft, Gazprom) | Rare earth & mineral access | NSR for faster trade routes
India's Strategic Interests	Balance China's 'Polar Silk Road' ambitions | Strengthen polar governance presence | Align with Russia, Nordic countries on access
Arctic Policy 2022 — 6 Pillars	1. Science & Research | 2. Climate & Environment | 3. Economic & Human Development | 4. Transportation & Connectivity | 5. Governance & International Cooperation | 6. National Capacity Building
Challenges	No direct Arctic access | Observer status — no voting right | Expensive extreme-weather operations | NATO vs. Russia-China geopolitical tensions
Arctic vs Antarctic	Arctic = sea ice → melting raises albedo/climate risk but NOT sea level | Antarctic = land ice → melting DIRECTLY raises sea level (Thwaites 'Doomsday Glacier' — potential 3 m+ rise)

Chapter 10 Mineral Resources

Aspect	Detail
Gondwanaland Heritage	Gondwana coal (Damodar, Son, Mahanadi, Godavari — 97% of India's coal) | Iron ore (Jharkhand, Odisha) | Mica | Bauxite | Copper | Manganese | Lithium deposit discovered in J&K (2023)
India's Mineral Richness	4th largest coal reserves globally | 2nd largest manganese | Significant iron ore (7th globally) | Rare earths on Odisha coast
Mining's GDP Share	Only ~1.3–2% of GDP despite vast reserves — far below potential
Why Low GDP Contribution	Regulatory complexity (MMDR Act, EC Stage I/II, Forest Clearance) | Forest/tribal land overlap → social conflict | Illegal mining displacing legal industry | Technology gap | Infrastructure bottleneck | Low value addition (raw ore not processed)
MMDR Amendment 2021	Composite licence, auction-based allocation | Critical Mineral Mission 2024 | National Mineral Exploration Trust

Parameter	Onshore Oil	Offshore Oil
India Examples	Digboi (Assam, 1889 — oldest) | Barmer (Rajasthan — Cairn) | Ankleshwar, Cambay (Gujarat)	Mumbai High (largest producer, 1974) | KG Basin D6 | Cauvery offshore
World Examples	Permian Basin (Texas) | W. Siberia | Middle East giant fields	North Sea | Gulf of Mexico | Brazil pre-salt (Santos Basin) | Caspian Sea
Extraction Technology	Conventional wells | Directional drilling | EOR	Jackup rigs (shallow) | Semi-submersibles | FPSOs | Subsea

Parameter	Onshore Oil	Offshore Oil
		systems
Challenges	Land acquisition | Groundwater contamination | Gas flaring	Higher cost | Weather hazards | Deep-water tech | Major oil spill risk

Chapter 11 Geopolitics of Resources

Dimension	India–Africa	South China Sea
Strategic Importance	30% of world mineral reserves | 65% of remaining arable land | Fast-growing 1.4 billion market	$3.37 trillion/year trade (50% of global merchant shipping) | Energy imports highway for Japan, S. Korea, China
Resources at Stake	Oil (Nigeria, Angola, Mozambique LNG) | Cobalt (DRC) | Platinum (S. Africa) | Lithium	Estimated 125 bn barrels oil | 500 trillion cubic feet gas | 10% of global fish catch
Key Disputes / Competition	China's BRI ($170 bn+) vs. India's grants-based South-South model	China's Nine-Dash Line (90% of SCS) vs. Vietnam, Philippines, Malaysia, Brunei, Taiwan EEZ claims
Legal Framework	Lines of Credit | IAFS Summits (2008, 2011, 2015) | AU joined G20 under India's 2023 Presidency	UNCLOS 2016 ruling — Nine-Dash Line invalid; China rejects
India's Role	Non-interference principle | Skill-transfer approach | Diaspora linkages (3 million+)	ONGC Videsh blocks in Vietnam's EEZ | FONOPs support | Quad & AUKUS frameworks | Rules-based order

Chapter 12 Regional Geography & Planning

Aspect	Detail
Definition	Spatial planning for specific sub-national regions to address balanced development, resource utilisation, and regional disparities — bridges national goals and local needs
Why Needed in India	High regional income disparities | Over-concentration of industry & population in metro cities | Resource-rich but underdeveloped areas (Odisha, Chhattisgarh) | Migration pressure on cities
Types	Metropolitan (Delhi NCR — NCRPB) | Tribal Sub-Plan (ITDAs) | Hill Area (Western Ghats, NE) | Command Area (Bhakra-Nangal) | Special Economic Regions (DMIC, AKIC)
Aspirational Districts	NITI Aayog 2018 | 112 districts | 49 KPIs across 5 themes (Health, Education, Agri-WR, Financial Inclusion, Infrastructure) | Delta ranking | 3Cs: Convergence + Collaboration + Competition

Aspect	Detail
Geospatial Technology	GIS, Remote Sensing (Cartosat, Sentinel), GPS, AI/ML, Drones — applications in agriculture, urban planning, disaster management, defence | Geospatial Policy 2022 | SVAMITVA scheme
Key Institutions	NITI Aayog | TCPO (Town & Country Planning Organisation) | NCRPB | State Planning Boards
Challenges	Inter-state disputes | Poor coordination across governance levels | One-size-fits-all national models | Data scarcity at regional scale

Chapter 13 Urbanisation

Problem Area	Description	Value-Added Concept / Keyword
Slum Proliferation	65+ million people in slums with poor WASH access	Subaltern Urbanism · Informal Settlements · Right to City
Housing Shortage	~18 million unit shortage for EWS/LIG groups	Affordable Housing Deficit · Rental Housing Vacuum
Traffic & Pollution	Rising PM2.5, inadequate public transport, high vehicle density	Urban Commuter Crisis · Motorisation without Mobility
Water Scarcity	Bengaluru, Chennai approaching Day Zero scenarios	Urban Hydrological Stress · Aquifer Overdraft
Waste Management	India generates 62 million tons solid waste annually	Landfill Urbanism · Circular Economy Lag
Urban Flooding	Chennai, Mumbai, Gurugram flood regularly — wetland encroachment	Concrete Jungle Effect · Urban Wetland Erasure
Urban Heat Island	City temperatures 1–5°C above surroundings — health & energy impact	Anthropogenic Heat · Green Deficit City
Inequitable Growth	Gated communities vs. migrant ghetto; dual urbanism	Dual Urbanism · Socially Unjust Cities
Governance Deficit	Fragmented jurisdiction, weak municipal finances, multiplicity of bodies	3Fs Deficit: Funds · Functionaries · Functions (74th Amendment)

13.2 Urban Case Studies

Case Study	City	Innovation	Why It Matters for Answers
Janmarg BRTS	Ahmedabad	India's first full-fledged BRT with segregated bus lanes & e-ticketing	Inclusive Mobility · Smart Urban Transport Model
Indore Waste Model	Indore, MP	7× India's cleanest city — door-to-door collection + public behavioural change	Swachh Bharat success story · Behavioural Change Communication
Magarpatta	Pune	Farmers became equity	Planned Urbanisation · Land

Case Study	City	Innovation	Why It Matters for Answers
Township		stakeholders in urban land use — co-op model	Pooling Innovation
Surat Flood Resilience	Surat, Gujarat	Post-2006 floods — Integrated Urban Flood Management with real-time data control	Disaster-Resilient Urban Design · IUFM model
Bhubaneswar One	Bhubaneswar	GIS-based single-window urban management portal for utilities & land records	Smart City Digital Governance · GIS in urban planning
Miyawaki Urban Forests	Delhi NCR	Native micro-forests planted in small urban spaces to fight heat islands	Eco-sensitive Urban Planning · Urban Green Infrastructure

Chapter 14 Locational Factors for Industry

Industry	Traditional Location	Shift / Modern Pattern	Locational Logic
Sugar Mills	UP, Bihar — short crushing season (120 days); 9–10% sucrose	Maharashtra, Karnataka — 180+ day season; 12–14% sucrose; cooperative model	Raw material quality + crushing season length dominates
Cotton Textile	Mumbai, Ahmedabad — colonial origin (port + cotton access)	Tiruppur (knitwear), Surat (synthetic), Erode, Bhilwara — highly decentralised	Ubiquitous raw material + power grid + dispersed market
Petroleum Refineries	Digboi (wellhead, 1901); Barauni, Mathura, Panipat	Jamnagar (world's largest complex), Mangalore, Cochin, Vizag — coastal/market	Crude easy to transport; refined products costlier → market/coastal orientation
Iron & Steel	Jamshedpur, Bhilai, Durgapur, Bokaro — coalfield-raw material based	Vizag, Salem, Hazira — tidewater; imports Australian coking coal	Shift from coalfield → tidewater (import coking coal cheaper than domestic transport)

14.2 Industrial Corridors — India

Industrial Corridor	States Covered	Anchor Port / Node	Key Features & Significance
DMIC (Delhi-Mumbai)	Delhi, UP, Haryana, Rajasthan, Gujarat, Maharashtra	JNPT Mumbai, Mundra Port	Largest ($100 bn) | 24 nodes | Smart cities (Dholera, AURIC) | Japan-India partnership
CBIC (Chennai-Bengaluru)	Tamil Nadu, Karnataka, AP	Chennai Port, Ennore	Electronics, auto, aerospace | Connects IT hubs to manufacturing
AKIC (Amritsar-Kolkata)	Punjab, Haryana, UP, Jharkhand, WB	Kolkata/Haldia Port	Gangetic plain manufacturing belt | Agri-processing + heavy industry
BMIC (Bengaluru-	Karnataka, Maharashtra	JNPT, New	Pharma, automobile, leather |

Industrial Corridor	States Covered	Anchor Port / Node	Key Features & Significance
Mumbai)		Mangalore	Links two major industrial states
ECEC (East Coast)	WB, Odisha, AP, Tamil Nadu	Vizag, Chennai Port	Petrochem, mining, steel | Bay of Bengal maritime integration; SE Asia linkage
PM Gati Shakti (2021)	All India	7 transport modes	GIS-based master plan | Integrates 16 ministries | Reduce logistics cost to <8% of GDP

PART III — GEOPHYSICAL PHENOMENA & CRITICAL CHANGES (Unit 12)

Chapter 15 Climate Change — Trends & Impact

Theme / Trend	Global	India Impact
Temperature Rise	~1.1–1.2°C above pre-industrial (IPCC AR6); 1.5°C breach likely this decade	Heatwaves intensifying; prolonged hot spells in NW & central India
Sea Level Rise	~3.7 mm/year (accelerating); SIDS — Maldives (avg 1.5 m elevation), Tuvalu, Kiribati at existential risk	Coastal erosion along Bengal, Odisha, AP, Kerala coasts; mangrove submergence
Glacier Retreat	Thwaites 'Doomsday Glacier' — potential 3 m+ sea level rise if destabilised	Himalayan glaciers (Third Pole) retreating; Gangotri, Pindari, Milam shrinking; GLOFs
Extreme Weather	More intense cyclones; unprecedented wildfires; 1-in-100-year floods becoming decadal	Cyclone intensification in Bay of Bengal; urban floods; heatwave mortality rising
Agriculture & Food Security	Crop yield decline 2–6% per decade in tropical regions; ocean fisheries declining	Wheat, rice belts at risk; shifting agro-climatic zones; groundwater depletion worsens
Ocean Changes	Warming + acidification (pH fallen 0.1 units since industrial era); dead zone expansion	Coral bleaching (Lakshadweep, A&N) | Dead zones in Bay of Bengal | Fishery disruption

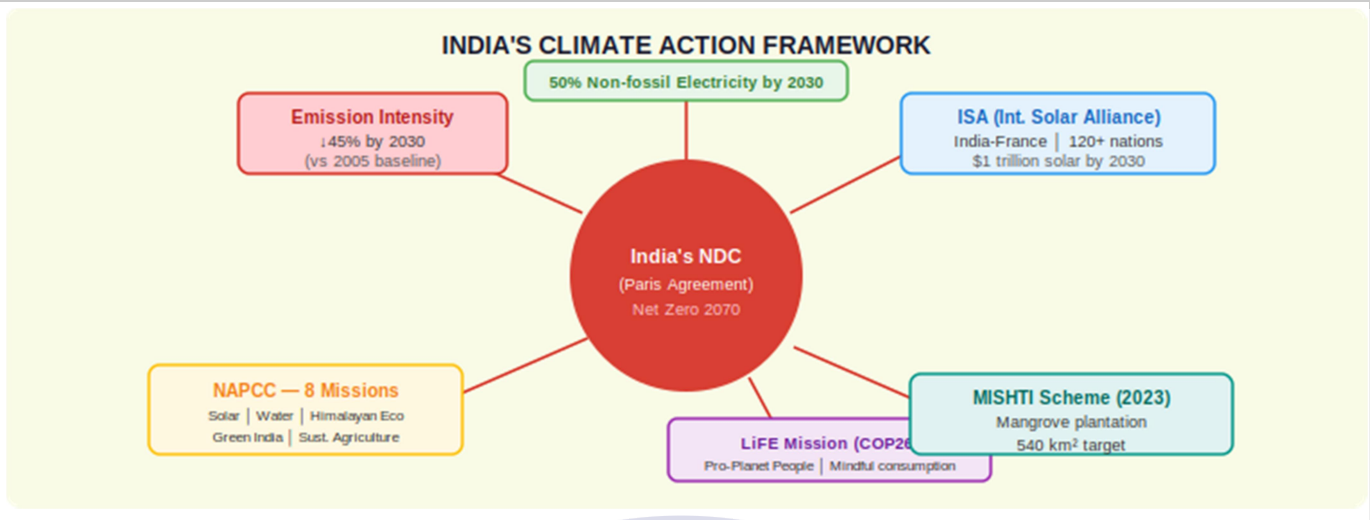

Figure 15.1 — India's Climate Action Framework: NDC commitments, NAPCC missions, ISA & key schemes

15.2 India's Key Climate Initiatives

Aspect	Detail
NAPCC (8 Missions)	Solar | Enhanced Energy Efficiency | Sustainable Habitat | Water | Himalayan Ecosystem | Green India | Sustainable Agriculture | Strategic Knowledge for Climate Change
India's NDC (Paris Agreement)	45% emission intensity reduction by 2030 (vs. 2005) | 50% non-fossil electricity capacity by 2030 | Net Zero by 2070
International Solar Alliance (ISA)	India-France initiative (COP21, 2015) | 120+ member nations | Mobilise $1 trillion solar investment by 2030
LiFE Mission	Lifestyle for Environment — PM Modi initiative at COP26 | 'Pro-Planet People' community | Mindful consumption
MISHTI Scheme (2023)	Mangrove Initiative for Shoreline Habitats & Tangible Incomes — 540 km² plantation target along coastlines
Loss & Damage Fund	Established at COP-27 (Sharm el-Sheikh 2022) for SIDS facing existential climate threat | India supported its creation
Sovereign Green Bonds (2023)	India's first green bond to fund renewable energy and sustainable transport | ₹16,000 crore raised

15.3 Global Climate Frameworks

Global Framework	Key Provision / Milestone
IPCC AR6 (2021-22)	1.5°C breach likely within this decade | Quantified food, water, health, displacement risks globally
Paris Agreement (2015)	Keep warming <2°C; pursue 1.5°C | NDCs submitted by all nations | 5-year Global Stocktake cycle
Glasgow Pact COP26 (2021)	Phase-down (not phase-out) of coal | Methane pledge | $100 bn climate finance (unmet) | Deforestation pledge

Global Framework	Key Provision / Milestone
COP28 Dubai (2023)	'Transition away from fossil fuels' | Triple renewable capacity by 2030 | L&D Fund operationalised | Global Stocktake outcomes
Kunming-Montreal GBF (2022)	30×30 target — protect 30% of land & ocean by 2030 | Halt & reverse biodiversity loss | DSI benefit-sharing

Chapter 16 Environment vs Development — Mountain Ecosystems

Challenge	Environmental Impact	Restoration / Policy Response
Tourism Overload	Solid waste, sewage, trail erosion, wildlife disturbance — Manali, Mussoorie, Shimla severely affected	Carrying capacity regulation | Eco-permits | Waste management infrastructure | Bhutan 'High Value Low Volume' model
Infrastructure Development	Roads, dams destabilise slopes; fragment habitats (Char Dham Project, Kinnaur roads)	EIA enforcement | Slope stabilisation | Wildlife corridors | Compensatory afforestation
Deforestation & Jhum	Slope farming, firewood cutting → erosion, spring drying, soil degradation	Community forestry | SHGs for fuel alternatives | Terraced farming revival
GLOFs & Cryosphere	Glacier retreat → bare rock; glacial lake formation → GLOF events (Chamoli 2021, Lhonak 2023)	NDMA early warning | ISRO/GSI monitoring | Setback zones near glacial lakes
Over-grazing	Alpine meadow (Bugyal) degradation, soil compaction, loss of endemic flora	Regulated grazing rotation | Community pasture management
PES Model	Unsustainable resource use by mountain communities for survival	Payments for Ecosystem Services — compensate for conservation | HP spring-shed management | CAMPA funds

Chapter 17 Biogeography — Natural Vegetation & Wildlife

Vegetation Type (Champion-Seth)	Climate / Location	Key Species	States
Tropical Wet Evergreen	>200 cm rain | >22°C year-round | No dry season	Dipterocarpus, Mesua, Toon | Multi-canopy dense forest	Kerala, Karnataka, Goa (W. Ghats) | A&N Islands | NE India
Tropical Semi-Evergreen	150–200 cm | Slight dry season | Transitional zone	Mix of evergreen & deciduous — Terminalia, Xylia	S. Karnataka, Odisha, WB (Duars), Assam
Tropical Moist	100–200 cm | 6-month	Teak, Sal, Shisham,	MP, Chhattisgarh,

Vegetation Type (Champion-Seth)	Climate / Location	Key Species	States
Deciduous	dry season | Most extensive type	Bamboo — valuable timber	Jharkhand, Odisha, Maharashtra
Tropical Dry Deciduous	75–100 cm | Long dry season | Open canopy	Teak, Mahua, Palas (Flame of Forest)	Bihar, UP, Deccan plateau
Tropical Thorn Forests	<75 cm | Arid/semi-arid | Xerophytic adaptations	Acacia, Khejri (Rajasthan state tree), Babool	Rajasthan, Gujarat, Punjab, Haryana
Mangrove Forests	Tidal, saline, deltaic coasts	Sundri (Heritiera fomes), Avicennia, Rhizophora	Sundarbans (WB) | Bhitarkanika (Odisha) | Godavari-Krishna delta
Montane / Temperate	900–3,600 m altitude | Himalayan slopes	Oak, Chestnut, Rhododendron, Pine, Deodar, Fir	Uttarakhand, HP, J&K, Sikkim, Arunachal Pradesh
Alpine / Sub-alpine	>3,600 m | Treeline to snowline | Short growing season	Birch, Juniper, Dwarf Rhododendron, Alpine meadows (Bugyals)	High Himalayas — J&K, HP, Uttarakhand, Sikkim, Arunachal

17.2 Key Protected Areas — India

Protected Area	State	Ecosystem	Flagship Species	Special Status
Silent Valley NP	Kerala	Last undisturbed tropical wet evergreen in India	Lion-tailed macaque | Leopard | King cobra | Nilgiri langur	Biosphere Reserve core | Saved from Kunthipuzha dam in 1980s
Periyar Tiger Reserve	Kerala	Moist deciduous + evergreen | Periyar Lake	Tiger | Elephant | Nilgiri tahr | Gaur | Sambar	Tiger Reserve + Elephant Reserve | Model eco-tourism
Anamalai Tiger Reserve	Tamil Nadu	Mixed evergreen + deciduous | Cardamom hills	Tiger | Elephant | Lion-tailed macaque | Nilgiri marten	Tiger Reserve | UNESCO Western Ghats WHS
Namdapha NP	Arunachal Pradesh	Tropical evergreen to alpine | NE India's largest NP	Snow leopard | Tiger | Clouded leopard | Red panda | Hoolock gibbon	Tiger Reserve | Highest biodiversity in NE India
Manas Tiger Reserve	Assam	Alluvial grassland + semi-evergreen | Bhutan transboundary	Tiger | One-horned rhino | Golden langur | Hispid hare	Tiger Reserve + Elephant Reserve + UNESCO WHS
Agasthyamalai	Kerala, TN	Tropical evergreen |	Elephant | Tiger | Lion-	UNESCO

Protected Area	State	Ecosystem	Flagship Species	Special Status
Biosphere		2,000+ flowering plant species	tailed macaque	Biosphere Reserve | Western Ghats UNESCO WHS

Chapter 18 Space & Technology — Juno Mission & NavIC

Parameter	NASA Juno Mission	NavIC (IRNSS)
Overview	Launched Aug 2011; Jupiter orbit since July 2016; solar-powered (3 giant panels) — farthest solar-powered mission	7 satellites: 3 GEO + 4 IGSO | Covers India + 1,500 km beyond borders | ISRO developed
Why Developed / Objective	Jupiter = oldest, largest planet → its composition reveals building blocks of early solar system; proxy for Earth's origin	Kargil War 1999: US GPS denied/degraded → India realised strategic dependency → need for independent navigation system
Key Findings / Services	Fuzzy dilute Jupiter core | Europa sub-ice ocean | Jovian auroras | Magnetic field stronger than expected	SPS — Standard Positioning Service (civilian, <5 m accuracy, free) | RS — Restricted Service (encrypted, defence/strategic)
Relevance to Earth Science	Jupiter's gravity directed asteroid bombardment of Earth 4 Bya — delivering water & organic molecules (origin of life hypothesis)	Strategic autonomy | Higher accuracy over Indian region vs GPS | GAGAN integration for aviation | NavIC 2.0: expanding to 11+ satellites, L1 frequency
Applications	Solar system formation models | Planetary science | Astrobiology (Europa ocean)	NDRF disaster response | Fleet/vehicle tracking | Agriculture precision farming | Banking/telecom time sync | Mandatory in smartphones (India, 2023)

APPENDICES

Chapter A Key Committees, Missions & Agreements

Name	Relevance	Key Finding / Provision
Gadgil Committee (2011)	Western Ghats Ecology Expert Panel	64% of WG = ESA — strict restrictions on mining, quarrying, construction in ESZ
Kasturirangan Committee (2013)	Modified WG plan (more acceptable)	Reduced ESA to 37% (1,64,280 km²) — balance development with ecology
Brundtland Commission (1987)	Sustainable Development definition	'Meets present needs without compromising future generations' ability to meet their needs'
NAPCC & SAPCCs	Climate adaptation — national & state level	8 missions nationally; each state has SAPCC aligned with NAPCC
MISHTI Scheme (2023)	Mangrove protection & community income	540 km² mangrove plantation target along coastlines
Sagarmala Programme (2015)	Port-led coastal development	Port modernisation, connectivity, coastal economic zones; links ECEC corridor
PMMSY (2020)	Blue Revolution 2.0	₹20,050 crore | 22 MT target | 55 lakh employment | Blue Economy flagship
Jal Jeevan Mission (2019)	Rural water supply — Har Ghar Jal	Piped water to all rural households | 15 crore+ connections added by 2024
PM Gati Shakti (2021)	Multimodal logistics national master plan	GIS-based | 16 ministries integrated | 7 transport modes | Reduce logistics cost to <8% GDP
Arctic Policy 2022	India's polar strategy framework	6 pillars: Science | Climate | Economic | Connectivity | Governance | Capacity Building

Chapter B Data Points Quick Reference

Parameter	Data Point	Source / Year
Global avg temp rise	~1.1–1.2°C above pre-industrial level	IPCC AR6, 2021
Sea level rise rate	~3.7 mm/year (accelerating trend)	IPCC, 2022
India's forest cover	21.7% (7.13 lakh km²)	ISFR 2023
India's mangrove cover	4,992 km² (+17 km² since 2021)	ISFR 2023
India's coastline	7,516.6 km total (mainland + island)	Survey of India
India's water stress rank	13th most water-stressed nation	WRI Aqueduct 2019
India's groundwater extraction	~251 BCM/year — world's largest	CGWB / FAO
India's solar potential	>750 GW	MNRE 2023
India's wind potential	695 GW onshore (at 120 m hub height)	MNRE 2023
4th Global Coral Bleaching	2022-23 | 54+ countries affected	NOAA Coral Reef Watch

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Parameter	Data Point	Source / Year
Dead Zone — Gulf of Mexico	~22,720 km² — largest annual dead zone	NOAA 2023
Maldives elevation	Average 1.5 m above sea level (existential SIDS risk)	AOSIS / IPCC
India's fish production	~14.7 MT (2022-23) | 2nd largest globally	PMMSY Report
Mining share of India's GDP	~1.3–2% despite vast Gondwana reserves	Ministry of Mines
Punjab groundwater	156.9% extraction of annual recharge	CGWB / GRACE Data
Falkenmark Indicator	<1,700 m³/capita = water stress | <1,000 = water scarcity	UN / Global standard

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