

GS GEOGRAPHY SERIES · BOOK 2 OF 4

Indian Physical Geography

Complete notes on the physical geography of India for the UPSC Civil Services Examination: Prelims and General Studies Paper I (Mains)

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INDIAN GEOGRAPHY

PRELIMS · GS PAPER I

The Himalaya: Formation, Structure and Ranges

Across the whole north of India runs a wall of rock some 2,400 km long, carrying the highest summits on Earth. It was built in the last fifty million years from the floor of a vanished ocean, it is still rising, and it still shakes. This chapter explains how the Himalaya were made, how the great faults inside them divide the mountains into belts, and how each belt appears on the map as a named range, from the Karakoram in the north to the low Shiwalik hills at the edge of the plains and the Purvanchal hills along the Myanmar border.

SYLLABUS

PRELIMS

Indian and World Geography: Physical Geography of India (the Himalayan mountain system, its ranges, peaks and hills of the North-East)

MAINS · GS PAPER I

Salient features of India's physical geography; important geophysical phenomena such as earthquakes; location of key physical features (mountain ranges). GS III: disaster management (seismic hazard)

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01 The Himalaya at a Glance	02 Origin: From the Tethys to the Roof of the World
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13 Why the Himalaya Are Arcuate	14 Earthquakes and the Seismic Gap
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This chapter covers:

- the extent, shape and signs of youth of the Himalaya, and the closing of the Tethys Sea as India drifted north;
- the older geosyncline explanation and the modern plate-tectonic explanation, and the phases in which the ranges rose;
- the Indo-Gangetic trough, the Indus–Tsangpo suture, the three great thrusts (MCT, MBT, MFT) and the syntaxial bends;
- each longitudinal division as a set of named ranges: Trans-Himalaya, Greater Himalaya, Lesser Himalaya, Shiwaliks with their duns, and Purvanchal;
- a north–south profile and comparison of the ranges, why the system is arc-shaped, and its earthquakes and seismic gap.

The next chapter divides the Himalaya from west to east into regions, and covers their valleys, glaciers, passes and significance.

The Himalaya at a Glance

The **Himalaya** (Sanskrit *hima*, snow, and *alaya*, abode) is not one ridge but a **system of parallel and converging ranges**, separated by deep valleys and plateaus. In the strict sense it runs for about 2,400 km from the Indus gorge in the west to the Brahmaputra (Dihang) gorge in the east. Its width falls from about **400 km in Kashmir to about 150 km in Arunachal Pradesh**. Taken with the Trans-Himalayan ranges and the Purvanchal hills, it forms the northern and north-eastern mountain wall of India.

- **Bounded by** the Pamir knot, Karakoram and Hindu Kush in the north-west, the Tibetan Plateau in the north and the Indo-Gangetic plain in the south. The southern edge is sharp, the northern edge merges with Tibet.
- **Countries:** India, Nepal, Bhutan, China (Tibet) and Pakistan; most of the main ranges lie in India, Nepal and Bhutan.
- **Shape:** an arc whose **convex side faces south**, towards India. Its trend changes along its length (table below).
- **Slopes:** the folds are asymmetrical. Southern faces are steep and northern faces gentler, which gives a **hogback** look to many ridges and is one reason the classic routes up Everest exist on both sides but differ in character.
- **Height pattern:** in the east the ranges rise abruptly from the plains, so Kangchenjunga stands only about 100 km from the Bengal plain; in the west they rise in steps, and the snowy peaks lie 150–200 km back from the plains.



Fig. 3.1 The Himalaya seen from the International Space Station, looking south across the Tibetan Plateau. Makalu and Everest rise in the centre; the haze-filled plains lie beyond.

PART OF THE ARC	GENERAL TREND OF THE RANGES
Jammu & Kashmir, Ladakh, Himachal Pradesh, Uttarakhand	North-west to south-east
Nepal, Darjeeling and Sikkim	Nearly east-west
Bhutan and Arunachal Pradesh	South-west to north-east
Nagaland, Manipur, Mizoram (Purvanchal)	North-south, convex to the west

Why the Himalaya Are Called Young Fold Mountains

The Himalaya are among the youngest major mountain systems on Earth. They are built of folded and thrust rock that is still being squeezed, so both internal (endogenic) and external (exogenic) forces are very active. The evidence is visible on any journey into the hills:

- **Deep gorges and V-shaped valleys:** the land rises so fast that rivers can only cut down, not widen their valleys.
- **Antecedent rivers and U-turns:** the Indus, Sutlej and Brahmaputra are older than the ranges they cross, and they bend sharply where the arc bends.
- **Parallel ranges** of folded rock that erosion has not yet worn down, with **steep, unstable slopes** that fail as landslides.
- **Frequent earthquakes**, hot springs and measured uplift, all signs that the mountain-building has not stopped.

Origin: From the Tethys to the Roof of the World

About 250 million years ago all the continents were joined in a single landmass, **Pangaea**, surrounded by the ocean Panthalassa. As Pangaea broke up, a northern block, **Laurasia (Angaraland)**, made of today's North America, Europe and most of Asia, separated from a southern block, **Gondwanaland**, made of South America, Africa, the Indian Peninsula, Australia and Antarctica. Between them lay a long arm of the sea, the **Tethys**. Rivers from both sides poured sediment into it for tens of millions of years, building thick layers of sand, mud and lime on its floor.

India began to move away from the rest of Gondwana about 150 million years ago, first with Madagascar, Antarctica and Australia and then alone after about 90 million years ago. Between about 70 and 50 million years ago it became the fastest-moving plate known, travelling north at some **15–18 cm a year**. The ocean floor in front of it, the **Neo-Tethys**, was swallowed beneath Asia at a subduction zone, where it fed a chain of volcanoes and granite bodies along the Asian margin. Around 66 million years ago India passed over the Réunion hotspot, and the outpouring of basalt built the Deccan Traps (Chapter 02).

When the ocean was used up, roughly

50–55 million years ago, the Indian continent met Asia. Continental crust is too light to sink far into the mantle, so the collision could not end with one plate neatly diving beneath the other. Instead the sediments of the Tethys and slices of India's own crust were folded, broken and stacked into thrust sheets, while Indian crust was pushed beneath southern Tibet, roughly doubling the crust there to about 70 km. India has since slowed to about **4–5 cm a year**, but it has never stopped (see *Physical Geography*, Chapters 07 and 08).

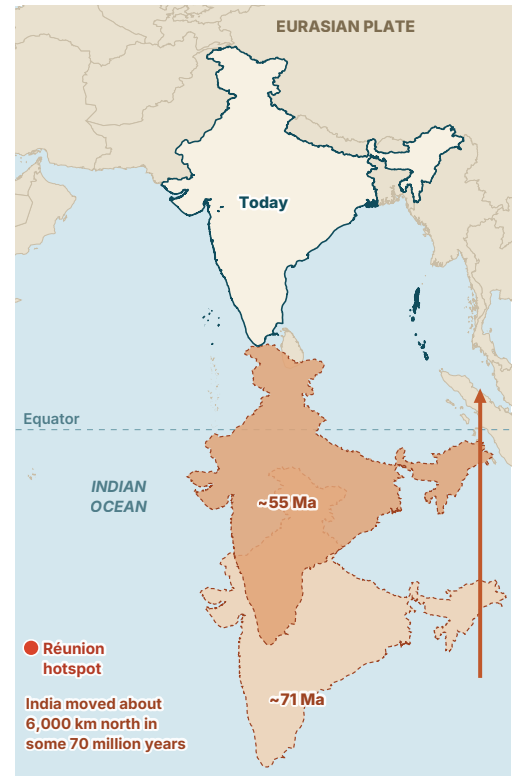


Fig. 3.2 India's journey north: schematic positions of India about 71 and 55 million years ago. The Deccan lavas erupted as India passed over the Réunion hotspot.

Two Explanations: the Geosyncline View and the Plate-Tectonic View

Before plate tectonics, the Himalaya were explained by the **geosyncline theory**. A geosyncline is a long, slowly sinking trough of shallow sea in which great thicknesses of sediment pile up. In **Leopold Kober's** version of the 1920s, the Tethys was such a trough lying between two rigid **forelands**, Angaraland to the north and Gondwanaland to the south. When the forelands moved towards each other, the sediments were squeezed into two **marginal ranges**: the **Kunlun** on the northern side and the **Himalaya** on the southern side. The less disturbed block left between them, the **Tibetan Plateau**, was the **median mass** (*Zwischengebirge*). In 1924 the Swiss geologist **Émile Argand** took a step towards the modern view: he argued that India had been pushed under Asia, which explained why Tibet stands so high.

The Older Explanation: Kober's Geosyncline Model

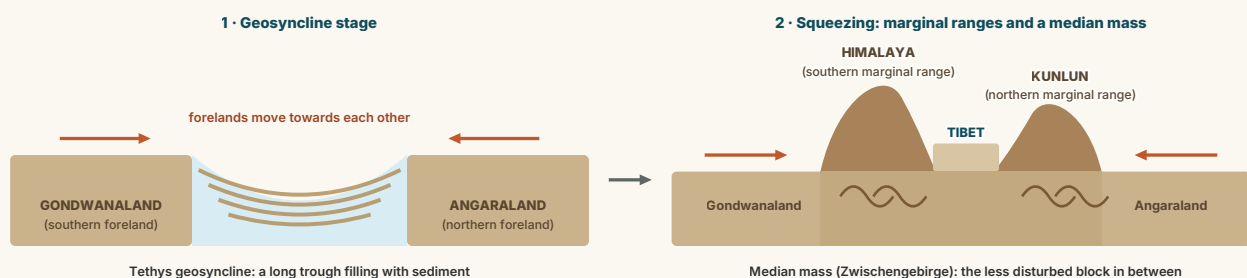


Fig. 3.3 In the geosyncline view the Tethys trough was squeezed between two forelands that moved closer, throwing up marginal ranges on both sides with Tibet left as a median mass. The idea explained folding but not the force that moved the forelands.

Plate tectonics, accepted from the late 1960s, keeps the Tethys and its sediments but supplies the mechanism: the forelands are lithospheric plates moved by mantle convection, slab pull and ridge push; the "squeezing" is the closure of an ocean by subduction and then a **continent–continent collision**.

POINT	GEOSYNCLINE (KOBER) VIEW	PLATE-TECTONIC VIEW
Where the sediment lay	In the Tethys geosyncline, a long subsiding trough	On the continental shelf of India and the floor of the Neo-Tethys ocean
Driving force	Forelands moved towards each other, cause unexplained	Plate motion driven by mantle convection, slab pull and ridge push
Fate of the ocean floor	Not considered	Subducted beneath Asia; scraps survive as ophiolites in the suture
Tibet	A median mass between two marginal ranges	Asian crust thickened and raised as Indian crust slid beneath it
Status today	Of historical value; terms like geosyncline and foreland remain in use	Accepted; confirmed by GPS, seismology and rock dating

From Ocean to Mountains: Four Stages in the Making of the Himalaya

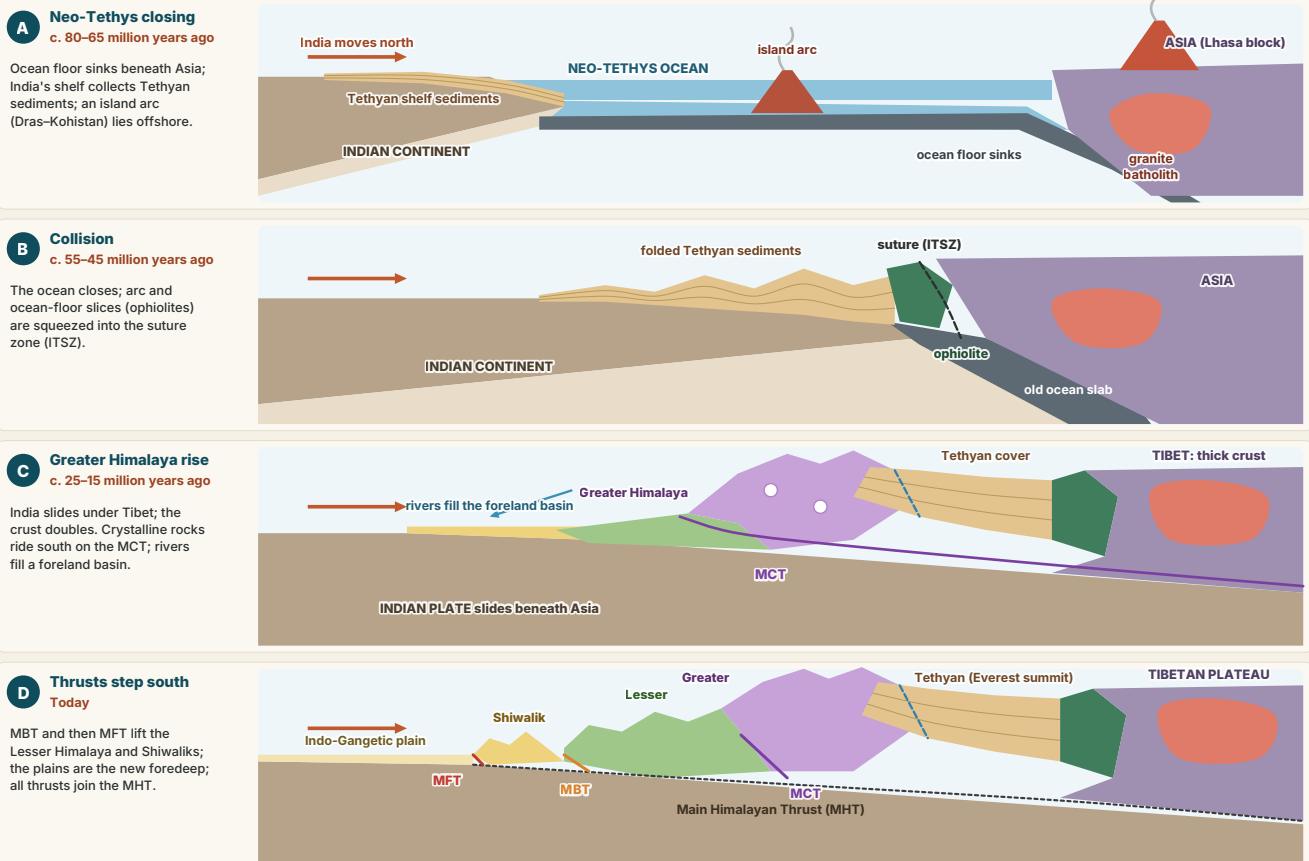


Fig. 3.4 A: the Neo-Tethys sinks beneath Asia, feeding an arc of volcanoes and granite. B: the ocean closes and the suture forms. C: Indian crust slides under Tibet and the Greater Himalayan crystalline slab is driven south on the Main Central Thrust. D: the thrust front steps south to the MBT and MFT, raising the Lesser Himalaya and the Shivaliks. Schematic, not to scale.

CORRECTING COMMON ERRORS

Some notes place the **Dras volcanic arc** in the Oligocene. The Dras–Kohistan arc was an island arc inside the Neo-Tethys in the **Cretaceous** (roughly 110–80 million years ago) and was jammed into the suture during the collision. Others say Tibet was raised by "upthrusting of the southern block of the Eurasian plate"; the plateau

owes its height mainly to **crustal thickening** as Indian crust was driven beneath it. And the Himalaya are not the only young chain: the Alps belong to the same Alpine–Himalayan belt and are of similar age.

PRELIMS POINTER · AN OCEAN FLOOR ON TOP OF THE WORLD

The summit pyramid of **Mount Everest is made of marine limestone** of Ordovician age (roughly 450–470 million years old) containing fossils of trilobites and crinoids, laid down on the floor of a sea long before the Himalaya existed. The famous **Yellow Band** below the summit is a layer of marble. Fossil ammonites (*shaligrams*) of the Tethys are collected along the Kali Gandaki in Nepal and in Spiti.

03 Phases of Uplift and a Range Still Rising

The Himalaya did not rise in one event. Indian textbooks traditionally describe **three phases of uplift**, each building one of the main ranges. Modern dating of thrust movement and of the rocks themselves confirms the order: the mountain front has **stepped southward over time, each new thrust forming in front of the last**.

PHASE	TRADITIONAL TIMING	WHAT ROSE	MODERN EVIDENCE
First	Late Eocene to Oligocene (after collision)	The central axis: the Greater Himalaya and the Tethyan ranges behind it	Thickening and metamorphism of crust from about 45 million years ago; the crystalline core was driven up along the MCT , mainly 23–15 million years ago
Second	Middle Miocene	The Lesser Himalaya (Pir Panjal, Dhauladhar, Mahabharat) and the Potwar plateau	The MBT took over as the main active thrust from roughly 10 million years ago
Third	Late Pliocene to Pleistocene	The Shiwaliks, made of debris from the rising ranges	Siwalik sediments (about 18–1 million years old) were folded and lifted along the MFT , active through the last couple of million years

Each new range was built partly from the waste of the one behind it. Rivers draining the Greater Himalaya filled a trough in front of them; that fill was later caught up and thrust upward as the front moved south. The present trough in front of the Shiwaliks, the Indo-Gangetic plain, is simply the latest such foredeep (Section 04).

Still Rising: What the Instruments Show

- **Convergence:** GPS stations show India moving north-north-east towards Eurasia at about **4–5 cm a year**. Roughly **2 cm a year** of this is taken up across the Himalaya itself; the rest is absorbed by Tibet and the ranges of Central Asia.
- **Uplift:** parts of the High Himalaya rise by a few millimetres a year; GPS on and around Everest records about **2 mm a year**. Erosion removes much of this, so the mountains grow more slowly than the rock rises.
- **Height of Everest:** a joint China–Nepal survey announced in December 2020 fixed the summit at **8,848.86 m**.
- **Sudden change:** during the 2015 Gorkha earthquake (Mw 7.8) the land around Kathmandu rose by nearly a metre within a minute, while the high peaks dropped slightly.

IN THE NEWS · NEW FINDINGS ON HOW THE HIMALAYA GROW

Everest and a captured river (2024): a study in *Nature Geoscience* argued that about 89,000 years ago the **Arun** river captured a Tibetan river system; the faster erosion that followed lightened the crust, which rebounded, lifting Everest by an estimated **15–50 m**.

A tearing plate (2025): a seismic study of 462 stations published in *Communications Earth & Environment* (August 2025) found that the Indian plate beneath Tibet is **splitting along a north–south line near 90–92°E**. West of the tear the Indian lithosphere slides under Tibet intact; east of it the lower, mantle part peels away from the crust. The tear lines up with north–south rifts such as Yadong–Gulu and Cona–Sangri.

A plateau pulling apart (2025): the **Tingri earthquake** of 7 January 2025 (Mw 7.1, near Shigatse) was caused by **normal faulting** on a north–south fault. High, thickened Tibet is spreading east–west under its own weight even as India pushes north.

04 The Indo–Gangetic Trough

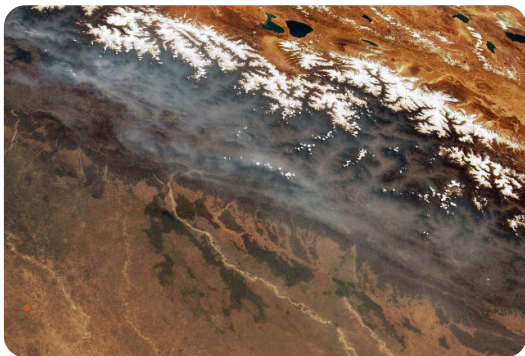


Fig. 3.5 From the ISS: the Sharda river and the horseshoe-shaped Pilibhit Tiger Reserve on the plains, with the Himalayan front rising abruptly to the north.

As the Himalaya grew, their great weight pressed down on the edge of the Indian plate, which bent like a loaded plank. In front of the mountains a long, deep **foreland basin** (foredeep) formed, curving with the arc. Rivers from the new ranges, joined later by some from the Peninsula, filled it with gravel, sand and silt. The result is the **Indo–Gangetic–Brahmaputra plain**, one of the largest alluvial plains on Earth.

The fill is **thickest, several kilometres, next to the mountain front** and thins southward to a few hundred metres near the Peninsula, exactly as a bent plate predicts.

Spurs of the Peninsular basement run under the alluvium as **buried ridges**, such as the Delhi–Haridwar ridge and the Faizabad ridge.

- Older ideas treated the trough differently. **Eduard Suess** called it a foredeep in front of the folds; **Sidney Burrard** thought it was a deep rift or crack in the crust, an idea now rejected because gravity and drilling show a flexed, sediment-filled basin.
- The trough is still sinking and still filling; the plain is in effect the **youngest foredeep** of the Himalaya, as the Siwalik belt was before it.

The plains themselves (Bhabar, Terai, Bhangar and Khadar, and their regional divisions) are described in Chapter 05.

05 Structure: Suture, Thrusts and Syntaxes

Seen in a north–south section, the Himalaya are a stack of rock slices piled onto India, each slice bounded by a great fault. Every major thrust dips **north** and joins at depth a single gently dipping fault surface, the **Main Himalayan Thrust (MHT)**, along which India slides beneath the mountains. Knowing these lines is the key to the ranges, because each belt of rock between two faults forms one of the longitudinal divisions.

A North–South Section Through the Himalaya

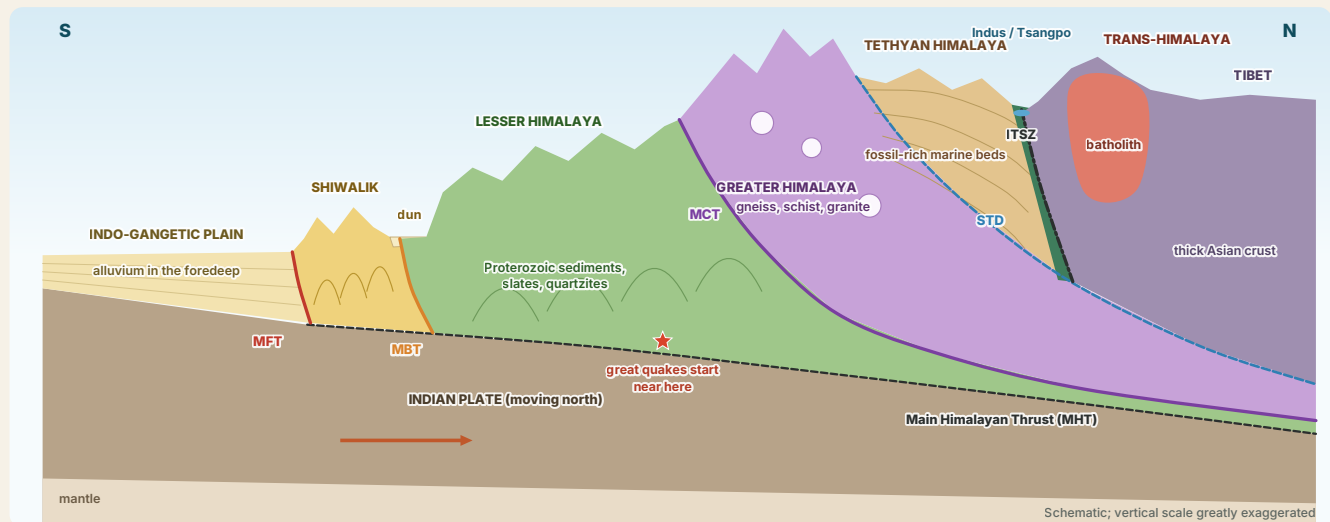


Fig. 3.6 From south to north: the alluvium of the foredeep, the Shiwalik sheet above the MFT, the Lesser Himalaya between the MBT and the MCT, the crystalline Greater Himalaya capped by the South Tibetan Detachment (STD), the Tethyan sediments, the Indus–Tsangpo suture with ophiolite and the granite belt of the Trans-Himalaya. All thrusts root in the MHT, where great earthquakes start.

LINE (NORTH TO SOUTH)	TYPE	WHAT IT SEPARATES	KEY POINTS
Indus–Tsangpo Suture Zone (ITSZ)	Suture: the scar of the closed ocean	Asian plate (Ladakh–Kailas granites, Karakoram) to the north; Indian plate (Tethyan Himalaya) to the south	Holds ophiolites (ocean floor) such as those of Nidar and Spongtang in Ladakh; the Indus in Ladakh and the Yarlung Tsangpo in Tibet follow it
South Tibetan Detachment (STD)	North-dipping normal fault	Tethyan sediments above; Greater Himalayan crystallines below	Moved at the same time as the MCT, letting the hot core squeeze out southward
Main Central Thrust (MCT)	Thrust, moderate north dip	Greater Himalaya above; Lesser Himalaya below	Brings high-grade gneiss over low-grade sediments; zone of crushed rock and many landslides (Joshimath lies near it)
Main Boundary Thrust (MBT)	Thrust, steeper near the surface	Lesser Himalaya above; Shiwalik molasse below	Runs along the foot of the Mussoorie and Dhauladhar ranges; the duns lie just south of it
Main Frontal Thrust (MFT), also Himalayan Frontal Fault	Youngest thrust, at the mountain front	Shiwaliks above; Indo-Gangetic alluvium below	Marks the boundary of mountain and plain; great earthquakes have broken through to the surface here

CLEARING A COMMON MISCONCEPTION

Notes often call the MCT a "synclinal basin" containing the Kashmir, Kangra and Kathmandu valleys. The **MCT is a fault plane**, not a valley. The Kashmir valley is a broad basin between the Pir Panjal and the Greater Himalaya, Kangra is a strike valley at the foot of the Dhauladhar, and Kathmandu sits on a thrust sheet in the Lesser Himalayan belt (Chapter 04). Also, the **Tethyan Himalaya and the Zaskar range lie south of the suture**, on the Indian plate, even though they are usually grouped with the "Trans-Himalaya".

Syntaxial Bends: the Two Knots

At both ends the ranges stop advancing south and swing sharply round. These sharp knee-bends are the **syntaxial bends** (syntaxes) of the Himalaya:

- The **western syntaxis** centres on **Nanga Parbat (8,126 m)**, where the north-west-trending ranges swing sharply round to the south-west and the Indus cuts a gorge about 7 km below the summit.
- The **eastern syntaxis** centres on **Namcha Barwa (7,782 m)**, where the ranges turn south into the Mishmi and Purvanchal hills, and the Yarlung Tsangpo wraps round the peak in the **Great Bend** before entering India as the Dihang (Siang).

Both knots are among the fastest-rising places on Earth. Their rocks have been pushed up from depths of 20–30 km within the last few million years, helped by the rapid erosion of the deep river gorges that cut through them. The Brahmaputra's U-turn is therefore a product of the **syntaxial bending of geologically young mountains**, a point UPSC has tested.



Fig. 3.7 Nanga Parbat (8,126 m), the western anchor of the Greater Himalaya. Its Rupal face rises about 4.6 km above its base, one of the highest mountain walls on Earth.



Fig. 3.8 Namcha Barwa (7,782 m) from the west. The Yarlung Tsangpo loops round it through one of the deepest gorges on Earth.

IN THE NEWS · A MEGA-DAM IN THE EASTERN KNOT

In July 2025 China began building a hydropower project of about **60 GW** on the lower Yarlung Tsangpo in Medog county, where the river drops steeply round the eastern syntaxis before entering Arunachal Pradesh. India has raised concerns about downstream flows and about building such a project in one of the most seismic parts of the Himalaya: the **1950 Assam–Tibet earthquake (Mw 8.6)** struck this very region.

06 The Longitudinal Divisions

From north to south the Himalayan system is divided into parallel belts, each running the length of the arc:

1. **Trans-Himalaya** (Tibetan Himalaya): Karakoram, Ladakh, Zaskar and Kailas ranges.
2. **Greater Himalaya** (Himadri, Inner or Central Himalaya): the highest, snow-covered range.
3. **Lesser Himalaya** (Himachal, Middle or Lower Himalaya): Pir Panjal, Dhauladhar, Mussoorie, Nag Tibba and Mahabharat ranges.
4. **Shiwaliks** (Outer Himalaya): the foothills, with the duns behind them.
5. **Purvanchal** (Eastern Hills): the southward continuation along the Myanmar border.

07 The Trans-Himalaya

The **Trans-Himalaya** are the ranges immediately north of the Greater Himalaya. Most of their length lies in Tibet, hence the name Tibetan Himalaya; in India they occupy Ladakh and the north of Jammu & Kashmir and Himachal Pradesh. They stretch about 1,000 km east–west within the Indian sector, and are about **40 km wide at the ends and up to 225**

km in the middle. They lie in the rain shadow of the Greater Himalaya, so they form a **cold desert** of bare, brown slopes.

CORRECTING A COMMON ERROR

Many notes give the Trans-Himalaya an "average elevation of 3,000 m". That figure fits only the lowest valley floors. The **ranges themselves crest at about 5,500–6,000 m**; even the Indus valley at Leh is about 3,500 m high, and the Ladakh range averages close to 6,000 m.

The Himalayan Ranges and the Great Faults That Divide Them

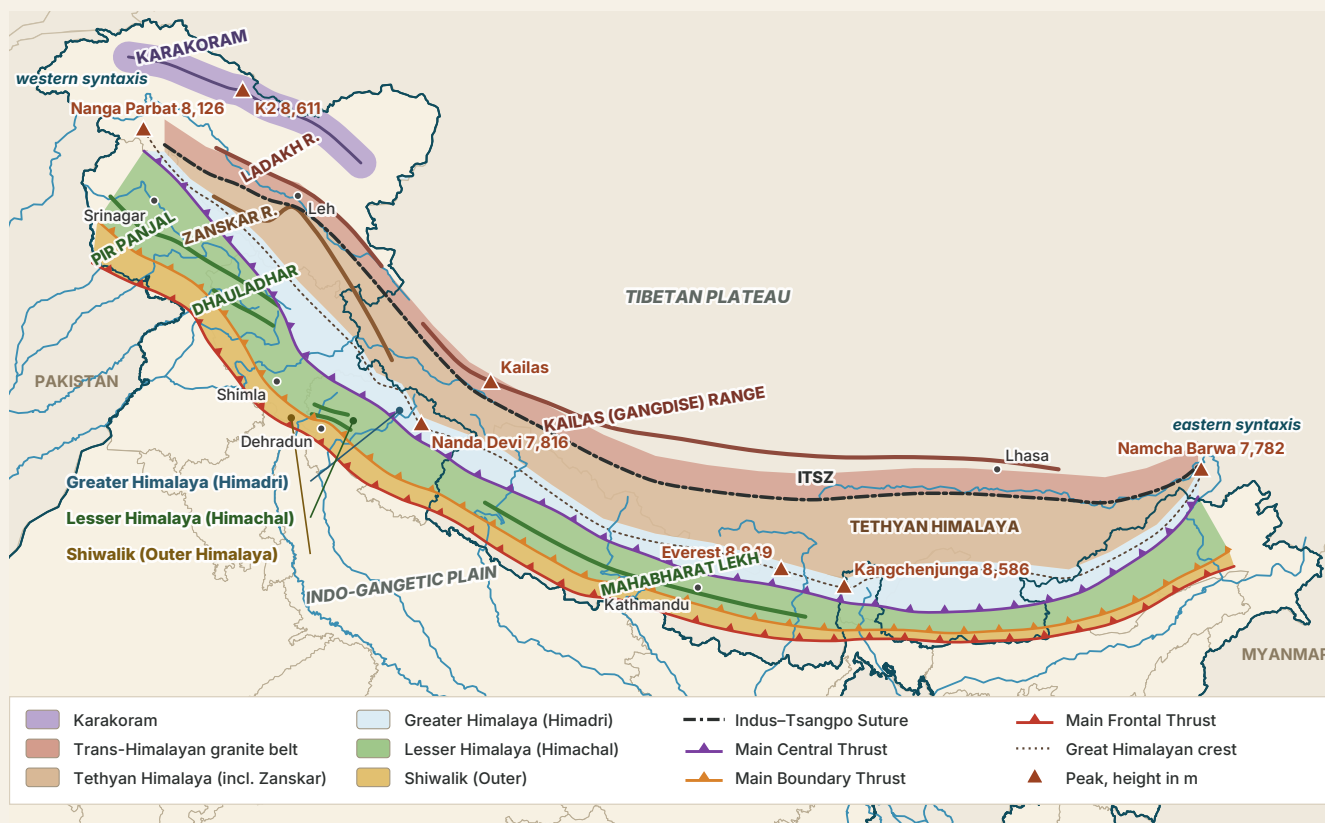


Fig. 3.9 Each coloured belt is bounded by a major fault: the Shiwaliks between the MFT and MBT, the Lesser Himalaya between the MBT and MCT, the Greater Himalaya above the MCT, and the Tethyan belt and Trans-Himalayan granites on either side of the Indus-Tsangpo suture. Fault traces and range lines are approximate.

Karakoram Range

- The **northernmost** range of India, also called **Krishnagiri**. It stretches about 500 km south-east from the Pamir along India's frontier with China (and Afghanistan through the Wakhan corridor) and forms the watershed between India and Central Asia (Turkistan).
- Home to **K2 or Godwin-Austen (8,611 m)**, the highest peak of India and second highest in the world, and three more eight-thousanders: Gasherbrum I, Broad Peak and Gasherbrum II.
- Holds some of the largest glaciers outside the polar regions, including **Siachen**, Baltoro, Biafo and Hispar (Chapter 04). Granite batholiths form its core; geologically it belongs to the Asian side of the collision.
- North-east of it lies the high **Ladakh plateau**, broken into the Aksai Chin, Lingzi Tang, Soda, Depsang and Chang Chenmo plains.

Ladakh Range

- Runs south-east for about 370 km between the **Indus and Shyok** valleys, from Baltistan to the Tibetan border; it is often described as a south-eastern offshoot of the Karakoram.

- Made of the **Ladakh batholith**, granite that crystallised beneath the volcanoes of the Asian margin before the collision. It has an even crest with few outstanding peaks; Khardung La and Chang La cross it.

Zaskar Range

- Lies south of the Indus, parallel to the Greater Himalaya, separating the Zaskar valley from the Indus valley; its crest is mostly 5,500–6,500 m. **Stok Kangri** (about 6,150 m), seen from Leh, belongs to it.
- Built of fossil-bearing **Tethyan sedimentary rocks** south of the suture. Many Indian texts extend it south-east into Garhwal and assign **Kamet (7,756 m)** to it.

Kailas Range

- The continuation of the Ladakh range in western Tibet (Gangdise in Chinese), carrying the sacred **Mount Kailas**, about 6,638 m (older Indian texts give 6,714 m).
- Near Kailas and Lake Manasarovar rise four great rivers: the **Indus** (Senge Khabab) on the north side, the **Sutlej**, the **Karnali** (Ghaghara) and the **Yarlung Tsangpo** (Brahmaputra).



Fig. 3.10 K2 (8,611 m) in the Karakoram, highest peak of India, with the Godwin-Austen glacier at its foot.



Fig. 3.11 From Khardung La on the granite Ladakh range, looking south over the Indus valley (the suture) to the Zaskar range.



Fig. 3.12 The Zaskar range above Padum: folded Tethyan sediments in a high, dry valley.

08 The Greater Himalaya (Himadri)

The **Greater Himalaya**, also called the **Himadri**, Inner or Central Himalaya, is the most continuous and loftiest range of the system. It runs for about 2,500 km from Nanga Parbat to Namcha Barwa, ending abruptly at the two syntaxes. Its **average height is about 6,000 m** and its crestral belt is about 25 km wide. It carries almost all the great peaks, most of them under permanent snow, and feeds the glaciers of the Ganga, Yamuna and many other rivers.

- **Rocks:** a **crystalline core** of gneiss, schist and granite, including young leucogranites formed by melting deep in the thickened crust, overlain in the north by metamorphosed Tethyan sediments. This explains the old textbook line that it is "made of the oldest rocks", which is why UPSC once asked which Himalayan range is the oldest.
- **Structure:** asymmetrical folds, steep southern faces and gentler northern slopes; rivers such as the Indus, Sutlej, Alaknanda, Kali, Arun and Brahmaputra cross it in tremendous gorges.
- **Peaks:** nine of the world's ten highest summits, all except K2, stand on this range. It is unbroken except where antecedent rivers cut through it.

PEAK	HEIGHT (M)	LOCATION	NOTE
Everest (Sagarmatha, Qomolangma)	8,849	Nepal–China (Tibet)	Highest on Earth; named after George Everest, Surveyor General of India; fixed as highest by the Great Trigonometrical Survey in the 1850s
Kangchenjunga	8,586	Sikkim–Nepal	Highest in the Indian Himalaya and third highest in the world; some Indian texts give 8,598 m

Makalu, Lhotse, Cho Oyu	8,485 / 8,516 / 8,188	Nepal–China	All in the Everest massif area
Dhaulagiri, Annapurna, Manaslu	8,167 / 8,091 / 8,163	Nepal	The Kali Gandaki gorge runs between Dhaulagiri and Annapurna
Nanga Parbat	8,126	Gilgit-Baltistan (Indian territory under Pakistan's occupation)	Western end; "naked mountain", standing alone
Nanda Devi	7,816	Uttarakhand (Chamoli)	Highest peak lying wholly within India; Nanda Devi National Park is a World Heritage Site
Kamet; Trisul	7,756; 7,120	Uttarakhand	Garhwal–Kumaon giants
Namcha Barwa	7,782	Tibet, at the eastern syntaxis	Eastern end; Brahmaputra bends round it
Kangto	about 7,060	Arunachal Pradesh–Tibet	Highest point of Arunachal Pradesh

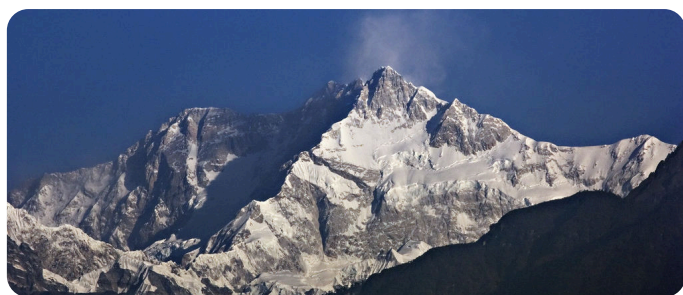


Fig. 3.13 Kangchenjunga (8,586 m) on the Sikkim–Nepal border, the highest peak of the Indian Himalaya.

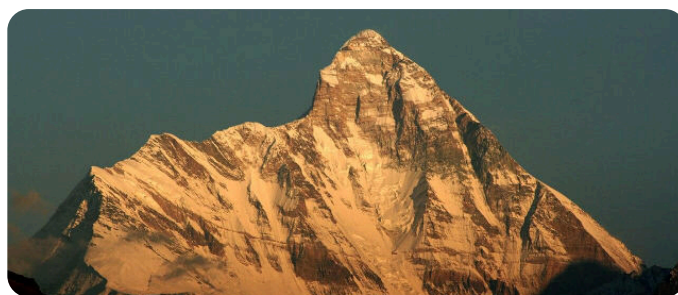


Fig. 3.14 Nanda Devi (7,816 m) at sunrise, the highest mountain lying entirely within India.

09 The Lesser Himalaya (Himachal)

South of the Himadri lies the **Lesser Himalaya**, also called the **Himachal**, Middle or Lower Himalaya. Its ranges are generally **3,700–4,500 m** high, with some peaks above 5,000 m that stay snow-covered, and the belt is about **50–80 km wide**. It runs roughly parallel to the Greater Himalaya, but in the west it splits into several ranges, some parallel and some transverse.

- **Rocks:** mostly old, poorly fossiliferous sediments altered by low-grade metamorphism, such as slates, quartzites, limestones and phyllites, with volcanic rocks (the **Panjal Traps**) in the Pir Panjal.
- **Slopes:** southern faces are steep and often bare, northern slopes gentler and better forested.
- **People:** the most welcoming part of the mountains. Most **hill stations** lie here: Shimla, Mussoorie, Nainital, Almora, Ranikhet, Dalhousie, Dharamshala and Darjeeling. It also holds the great valleys of Kashmir, Kangra, Kullu, Kathmandu and Pokhara (Chapter 04).

RANGE	WHERE	FEATURES
Pir Panjal	Jammu & Kashmir and Himachal Pradesh	Longest and most important range of the Lesser Himalaya, over 300 km from the Jhelum to the upper Beas; rises above 5,000 m; crossed by the Jhelum, Chenab and Kishanganga; Banihal and Pir Panjal passes, with the Jawahar, Banihal–Qazigund and Atal tunnels piercing it
Dhauladhar	Himachal Pradesh	The south-eastern continuation of the Pir Panjal beyond the Ravi; rises abruptly behind Dalhousie and Dharamshala; Hanuman Tibba (about 5,900 m) near Manali is its highest point

Mussoorie and Nag Tibba ranges	Uttarakhand (Garhwal)	Mussoorie ridge (about 2,000 m) overlooks the Doon; Nag Tibba (3,022 m) is the highest peak of the Lesser Himalaya in Garhwal
Mahabharat Lekh	Nepal	The continuation of the Mussoorie range across Nepal, cut through by the Karnali, Gandak and Kosi
Eastern ranges	Sikkim, Bhutan, Arunachal Pradesh	Narrow and pressed close to the Greater Himalaya; hill tracts named after the Dafla (Nyishi), Miri, Abor (Adi) and Mishmi peoples

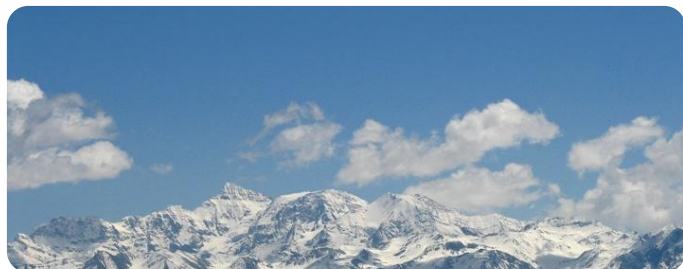


Fig. 3.15 The snowy Pir Panjal seen from Khajjiar in Chamba, Himachal Pradesh.



Fig. 3.16 The Dhauladhar wall rising sharply behind Dharamshala in the Kangra valley.

10 The Shiwaliks and the Duns

The **Shiwaliks** (Outer Himalaya) are the lowest and southernmost range, lying between the Lesser Himalaya and the plains. They run for about 2,400 km from the **Potwar plateau** to the Brahmaputra valley, are **10–50 km wide** (widest in Himachal Pradesh, under 15 km in Arunachal Pradesh) and are mostly **900–1,100 m high**.

- **Rocks:** the waste of the higher ranges, carried down by rivers and laid in the old foredeep: conglomerates, sandstones and clays of Miocene to early Pleistocene age (a molasse). They are only partly consolidated and erode very easily. They are famous for **vertebrate fossils**, including early apes, elephants and giraffes.
- **Form:** folded into simple anticlines (ridges) and synclines (valleys); the southern face is steep, the northern gentler.
- **Continuity:** an almost unbroken chain from the north-west to the Gandak; discontinuous beyond, and nearly absent for 80–90 km where the **Tista and Raidak** valleys cut a gap. East of it they are thin or missing, replaced by the duars.
- **Forest and erosion:** forest cover thins from east to west with falling rainfall. In Punjab and Himachal Pradesh the bare southern slopes are gashed by seasonal torrents called **chos** (Hoshiarpur district is the classic case), which spread sand onto farmland.

REGION	LOCAL NAME OF THE OUTER HILLS
Jammu	Jammu Hills
Himachal Pradesh, Punjab, Haryana	Shiwalik (Siwalik) Hills; Morni Hills in Haryana
Uttarakhand and the Uttar Pradesh–Nepal border	Dhang Range and Dundwa Range
Nepal	Churia (Chure) Hills
Arunachal Pradesh foothills	Often listed as the Dafla, Miri, Abor and Mishmi hills (names that really cover tribal hill tracts spanning the outer and lesser ranges)

Duns and Duars

Duns (doons) are flat-floored longitudinal valleys between the Shiwaliks and the Lesser Himalaya. When the Shiwaliks rose they blocked streams draining the higher ranges and ponded them into temporary lakes. The lakes filled with

gravel, sand and silt; later the rivers cut gaps through the Shiwaliks, the lakes drained, and broad valley floors were left behind.

Duns of the Western Himalaya and How They Formed

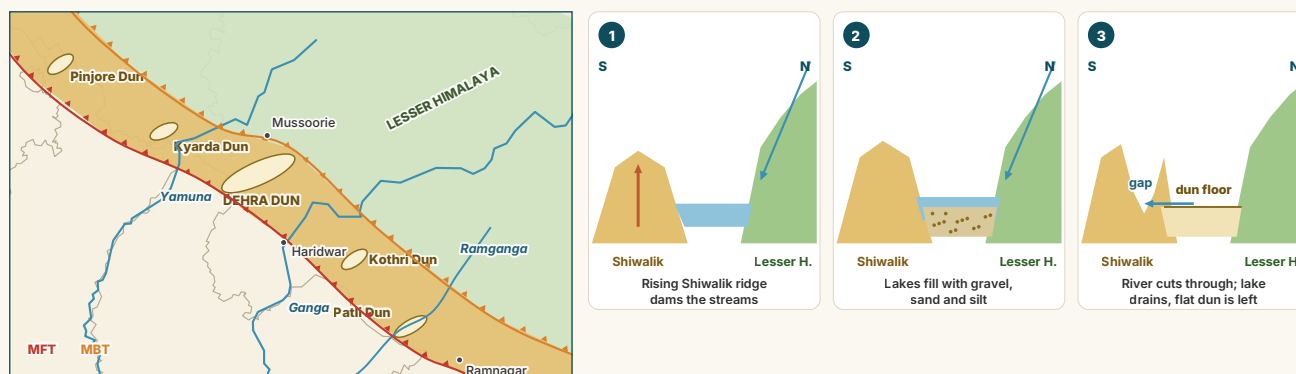


Fig. 3.17 Left: the duns (cream) lie between the MFT and the MBT, inside the Shiwalik belt (tan) and at the foot of the Lesser Himalaya; the Yamuna and Ganga cut through the Shiwaliks on either side of the Dehra Dun. Right: a rising ridge dams the streams, the lakes fill with sediment, and the river finally cuts through to leave a dun. Duns and lines are approximate.

- **Dehra Dun** in Uttarakhand is the largest and best known: about 75 km long from the Yamuna in the west to the Ganga in the east and some 20–25 km across, between the Shiwaliks and the Mussoorie range.
- Others: **Patli Dun** along the Ramganga in Corbett National Park, **Kothri Dun** near Kotdwar, **Kyarda Dun** near Paonta Sahib, **Pinjore Dun** in Haryana, and **Udhampur** and **Kotli** duns in the Jammu region. The inner Terai valleys of Nepal (Chitwan, Dang) are of the same kind.
- **Duars** (Dooars, "doors" or gateways to Bhutan) are the corresponding foothill plains in northern West Bengal (Western Duars) and Assam (Eastern Duars). With well-drained gravelly soils and heavy rain they became a major tea belt.



Fig. 3.18 The low, scrub-covered Shiwalik hills seen from Chandigarh.

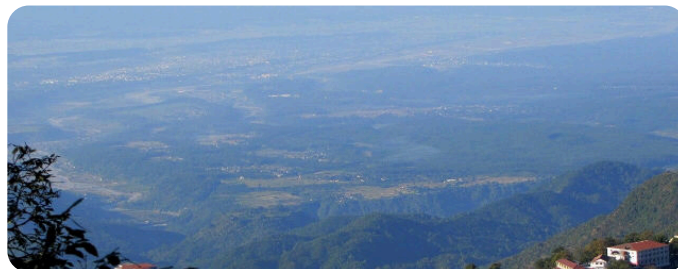


Fig. 3.19 The Doon valley from Landour above Mussoorie, with the Shiwalik ridge on the far side.

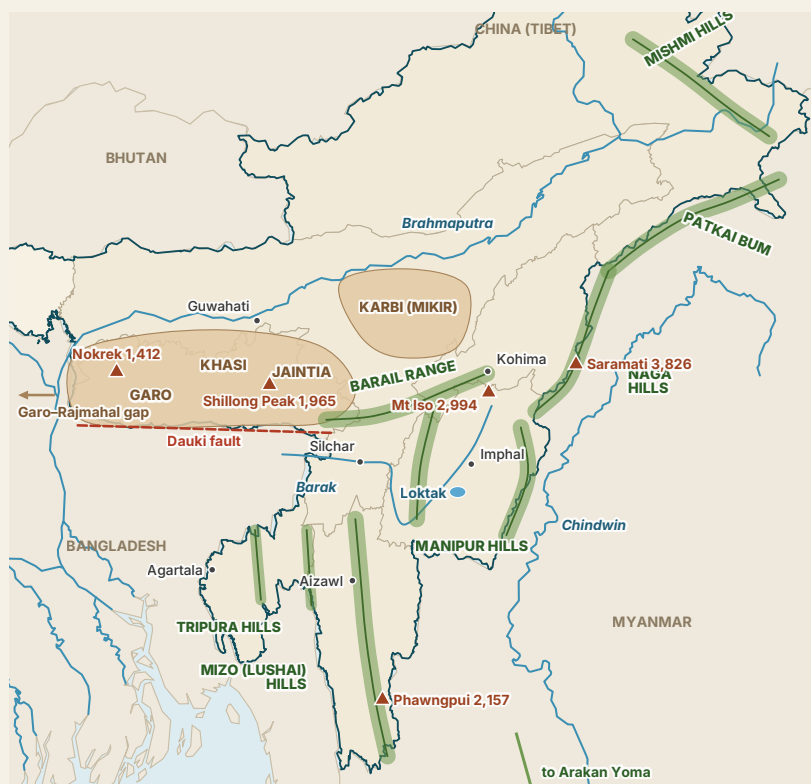
11 Purvanchal: The Eastern Hills

Beyond the Dihang gorge the Himalaya turn abruptly south. The low ranges that continue along India's eastern border, from Arunachal Pradesh to Mizoram, are the **Purvanchal** or Eastern Hills. They are arranged in an arc **convex to the west** and continue south into Myanmar as the **Arakan Yoma**, and under the sea as the ridge of the Andaman and Nicobar Islands (Chapter 07).

- **Origin:** they are young folds and thrust slices formed where the Indian plate moves obliquely beneath the Burma (Myanmar) plate. Their rocks are mostly **Tertiary sandstones and shales**, with slivers of ocean floor (the **Naga–Manipur ophiolites**) along the eastern border.
- **Relief:** mostly below 2,500 m, much lower than the main Himalaya, and divided into many ridges and valleys by fast rivers. Heavy rain keeps them densely forested; shifting cultivation (*jhum*) is widespread.

- **Drainage:** rivers of Nagaland and Arunachal join the Brahmaputra; those of southern Manipur and Mizoram feed the Barak (Meghna system); eastern Manipur drains to the Chindwin, a tributary of the Irrawaddy.

The Purvanchal Hills and the Meghalaya Plateau



The eastern hills, north to south

- **Mishmi Hills**
Arunachal; where the arc turns south
- **Patkai Bum**
Arunachal–Myanmar border; sandstone
- **Naga Hills**
Nagaland; Saramati 3,826 m
- **Barail Range**
divides Naga and Manipur hills
- **Manipur Hills**
ring the Imphal valley (Loktak)
- **Mizo (Lushai) Hills**
Mizoram; Phawngpui 2,157 m
- **Tripura Hills**
low N–S ridges; Jampui
- **Arakan Yoma**
continues the arc into Myanmar

Not part of Purvanchal

Garó, Khasi, Jaintia and Karbi (Mikir) hills are blocks of the old Peninsular plateau, cut off by the Garó–Rajmahal gap. The Dauki fault marks their southern edge.

- Purvanchal ranges (young folds)
- Peninsular-block plateau
- - - Dauki fault
- ▲ Peak, height in m

Fig. 3.20 The Purvanchal ranges (green) curve along the Myanmar border, convex to the west. The Garó, Khasi, Jaintia and Karbi hills (brown) look like part of the same hill country but are blocks of the Peninsular plateau. Positions of ranges and peaks are approximate.

HILLS (NORTH TO SOUTH)	STATE	FEATURES
Mishmi Hills	Arunachal Pradesh	Where the arc turns south at the eastern syntaxis; Dibang and Lohit valleys
Patkai Bum	Arunachal Pradesh–Myanmar border	Strong sandstone ridges; with the Naga hills forms the watershed between India and Myanmar ; Pangsau pass (Stilwell Road)
Naga Hills	Nagaland (and Manipur)	Saramati (3,826 m) , highest in Nagaland, on the Myanmar border; Japfu near Kohima; Dzükou valley
Barail Range	Assam (Dima Hasao), Nagaland, Manipur	Separates the Naga hills from the Manipur hills; Haflong, Assam's only hill station, stands on it
Manipur Hills	Manipur	Ring the oval Imphal valley and Loktak lake ; Mt Iso (Tenipu, about 2,994 m) is the highest point of Manipur
Mizo (Lushai) Hills	Mizoram	Parallel north–south ridges, mostly below 1,500 m; Phawngpui (Blue Mountain, 2,157 m) in the south
Tripura Hills	Tripura	Low north–south ridges such as Jampui, where Betling Sib (about 930 m) is the state's highest point

THE MEGHALAYA LINK: LOOKS LIKE PURVANCHAL, IS NOT

The **Garó, Khasi and Jaintia hills** of Meghalaya and the **Karbi Anglong (Mikir) hills** of Assam are not young folds. They are blocks of the ancient **Peninsular plateau** (Archaean gneiss and granite), separated from the Chotanagpur–Rajmahal area by the **Garó–Rajmahal gap**, which was filled by Ganga–Brahmaputra alluvium. The

Dauki fault bounds the plateau on the south. Nokrek (1,412 m) is the highest point of the Garo hills and Shillong Peak (about 1,965 m) of the Khasi hills (Chapter 06).

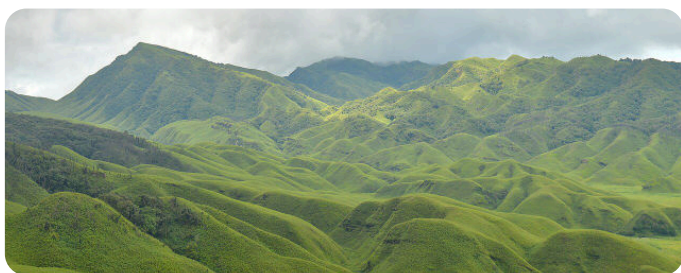


Fig. 3.21 Dzukou valley on the Nagaland–Manipur border in the Naga hills: rolling grassy ridges of the Purvanchal.

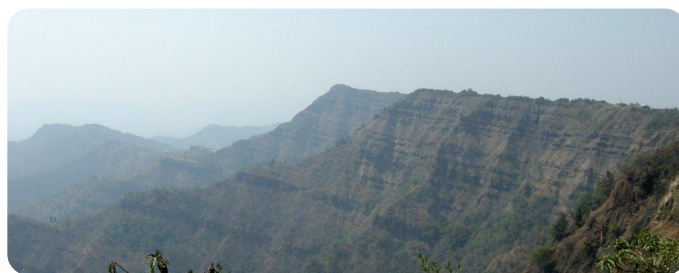


Fig. 3.22 Steep, forested north–south ridges of the Mizo (Lushai) hills near Hmuifang, Mizoram.

12 The Ranges Compared

A walk from the plains of Uttar Pradesh to the Tibetan Plateau crosses every belt in turn, each with its own height, width and rock. Fig. 3.23 shows the pattern in a single profile, and the table sums it up.

From the Plains to Tibet: a Generalised North–South Profile

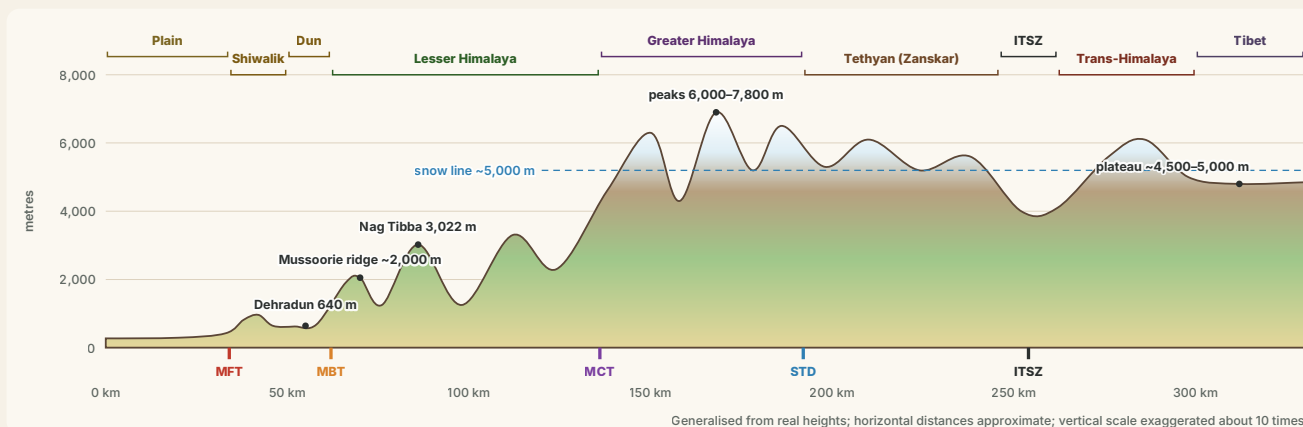


Fig. 3.23 A generalised profile through Garhwal into Tibet. Height jumps at each major thrust: a step at the MFT into the Shiwaliks, a second at the MBT into the Lesser Himalaya, and the great rise across the MCT into the Greater Himalaya. Behind the main crest the Tethyan ranges and Tibet stay high.

FEATURE	TRANS-HIMALAYA	GREATER HIMALAYA	LESSER HIMALAYA	SHIWALIKS	PURVANCHAL
Other names	Tibetan Himalaya	Himadri, Inner, Central	Himachal, Middle, Lower	Outer Himalaya	Eastern Hills
Typical height	Crests 5,500–6,000 m; K2 8,611 m	Average about 6,000 m; Everest 8,849 m	3,700–4,500 m	900–1,100 m	Mostly below 2,500 m; Saramati 3,826 m
Width	40 km at ends, up to 225 km in middle	Crest belt about 25 km	50–80 km	10–50 km	Varies; ranges narrow
Rocks	Granite batholiths (Karakoram, Ladakh, Kailas); Tethyan sediments (Zaskar)	Gneiss, schist, granite; Tethyan limestone on top	Slates, quartzites, limestones, Panjal volcanics	Conglomerate, sandstone, clay (molasse)	Tertiary sandstone and shale; ophiolites

Bounding faults	North of and around the ITSZ	Above the MCT, below the STD	Between MBT and MCT	Between MFT and MBT	Indo-Burman thrusts
Typical features	Cold desert, Siachen glacier, salt lakes	Highest peaks, glaciers, gorges	Hill stations, large valleys, forests	Duns, chos, fossils, landslides	Jhum, dense forest, Loktak

PRELIMS POINTER · EAST AND WEST ARE NOT ALIKE

The Himalaya are **narrower in the east** (about 150 km) than in the west (about 400 km). In the east the ranges rise abruptly from the plains, the Lesser Himalaya are squeezed against the Himadri and the Shiwaliks nearly vanish; heavier rain makes river erosion dominant and forests dense. In the west the climb is gradual, through a series of wide ranges and valleys. The regional contrasts are taken up in Chapter 04.

13 Why the Himalaya Are Arcuate

On the map the Himalaya bow south in a smooth arc between the two syntaxes. Several reasons are given, and they work together:

- **Push at the two corners:** the north-western and north-eastern corners of the Indian plate pushed hardest into Asia, pinning the ends of the range at Nanga Parbat and Namcha Barwa. The middle lagged behind, so the belt bowed southward between the two anchors.
- **A slight anticlockwise turn of India** during its drift, pivoting about its north-western corner, kept the western end fixed while the east swung round.
- **Geometry of a sphere:** a fault plane dipping into a sphere meets its surface along a curve, the same reason island arcs are curved (press a dent into a ping-pong ball and its edge is an arc).
- **Resistance:** the rigid Peninsular block in front and the strong Tibetan and Pamir blocks behind confined the deformation to a curved belt.

The Bowed Arc and the Knots at Its Ends

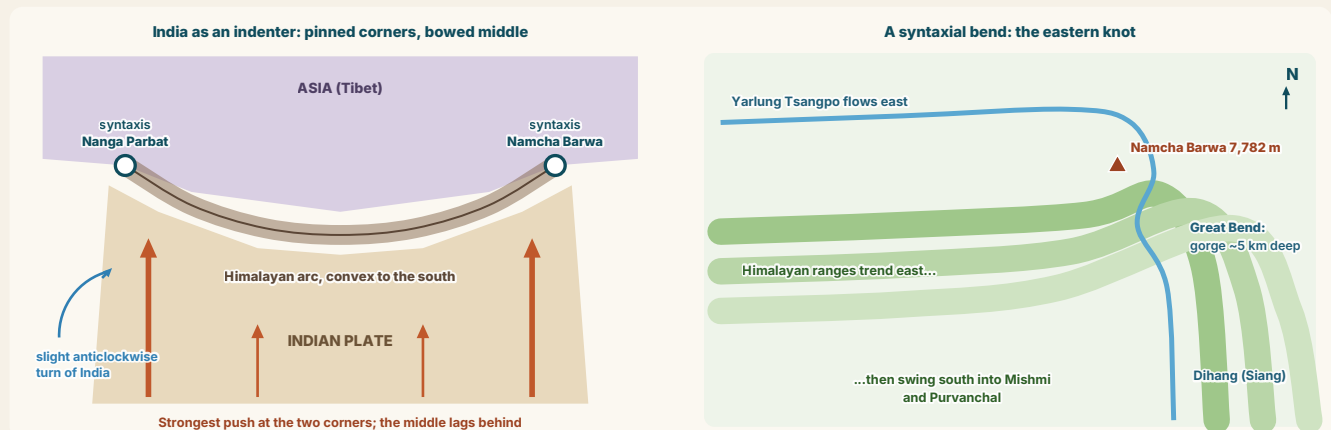


Fig. 3.24 Left: the strongest push came at the corners of the Indian plate, pinning the ends and leaving an arc convex to the south. Right: at the eastern syntaxis the ranges swing from an eastward trend, and the Yarlung Tsangpo turns sharply round Namcha Barwa to become the Dihang. Schematic.

The same logic in reverse explains the **Purvanchal**: at India's north-eastern corner the plate slides obliquely past and beneath Myanmar, and the ranges there bow outward to the **west**.

14 Earthquakes and the Seismic Gap

The 2 cm a year of convergence across the Himalaya is not taken up smoothly. The shallow part of the Main Himalayan Thrust stays **locked** for centuries while strain builds up, then slips by several metres in a great earthquake that starts deep beneath the Lesser Himalaya and tears southward towards the front. Earthquake mechanisms and India's seismic zones are explained in *Physical Geography*, Chapter 11; here only the Himalayan pattern is needed.

Great Earthquakes of the Himalayan Arc and the Central Seismic Gap

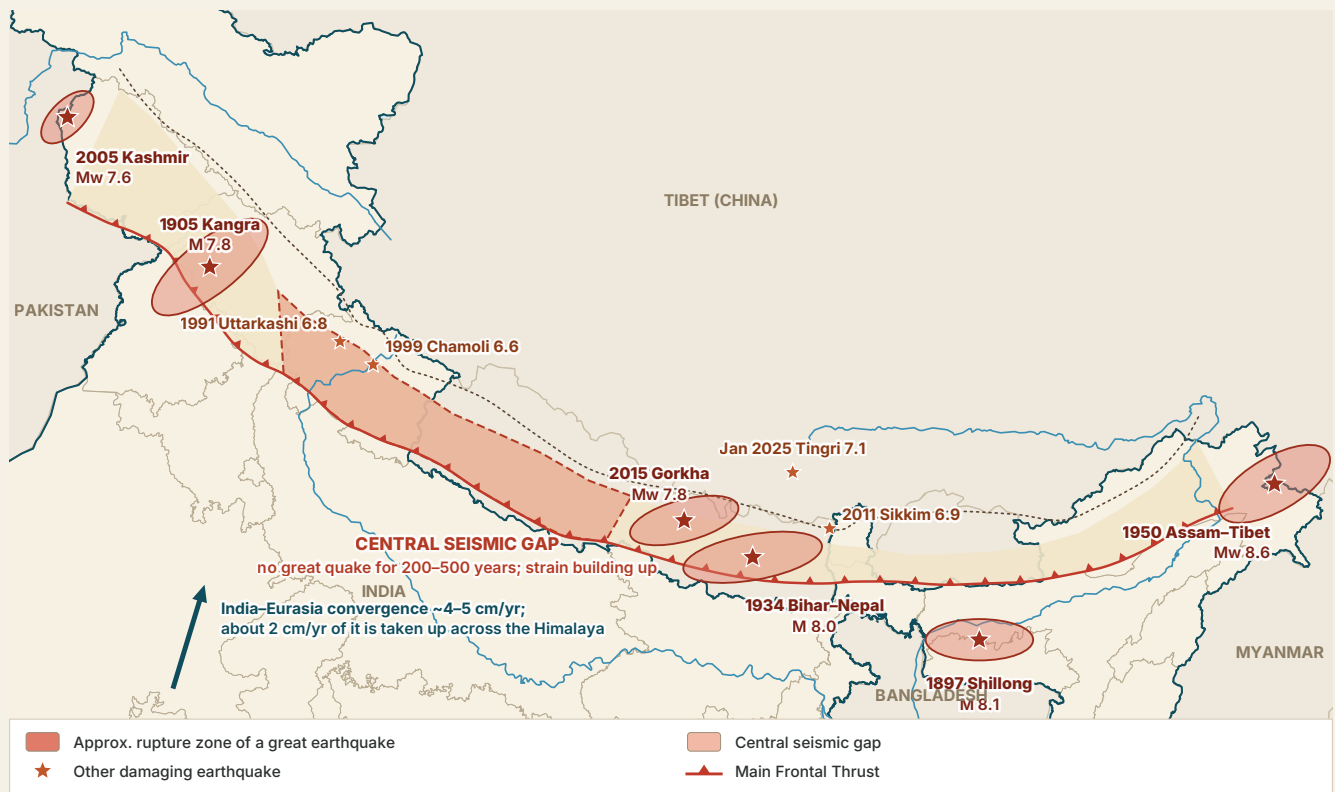


Fig. 3.25 Great earthquakes have ruptured most of the arc in the last 130 years, but the stretch between the 1905 Kangra and 1934 Bihar–Nepal ruptures, under Himachal Pradesh, Uttarakhand and western Nepal, has had no great earthquake for centuries. Rupture zones are approximate.

- **Great earthquakes** (magnitude 8 or close to it): 1897 Shillong (on the Meghalaya plateau), 1905 Kangra, 1934 Bihar–Nepal, 1950 Assam–Tibet (Mw 8.6, the largest on land in the instrumental era), and more recently 2005 Kashmir and 2015 Gorkha.
- A **seismic gap** is a stretch of an active fault that has not had a large earthquake for a long time although its neighbours have. It is not safe; it is **overdue**.
- The **Central Seismic Gap** spans roughly 700 km between the 1905 and 1934 ruptures. Trenches across the MFT suggest its last great rupture may have been around 1505. At 1.5–2 cm a year, five centuries store enough slip for an earthquake of **magnitude 8 or more**, under a region that now holds dense towns, dams and highways.
- The 2015 Gorkha earthquake broke only a deep 150 km patch at the eastern end of this belt and did not reach the surface, so most of the stored strain remains.

IN THE NEWS · ENTIRE HIMALAYAN ARC PUT IN THE NEW ZONE VI

The **Bureau of Indian Standards** released a revised earthquake design code, **IS 1893 (2025)**, in late November 2025. Its new seismic zonation map, built by probabilistic hazard assessment that models individual faults and locked segments, creates a new highest category, **Zone VI**, and places the **entire Himalayan arc from Jammu & Kashmir and Ladakh to Arunachal Pradesh** in it. About 61% of India's area now falls in moderate to high hazard zones. The code also recognises that ruptures on the Himalayan Frontal Thrust can extend south into foothill towns such as Dehradun.

USING THIS CHAPTER IN MAINS

GS Paper I questions on the Himalaya link origin, structure and present-day hazard. A strong answer:

- opens with a crisp statement of the collision (Tethys closure, about 50 million years ago) and a quick labelled sketch: the four-stage cross-section or the section with MFT, MBT, MCT and ITSZ;
- explains features through structure: three phases and thrusts stepping south, the foredeep that became the plains, arcuate shape and syntaxes, duns behind the Shiwaliks, the Purvanchal as an oblique-convergence belt;
- uses current evidence (GPS convergence, the 2025 plate-tearing study, the 2025 Tingri earthquake, the central seismic gap, BIS Zone VI) and ends with what it means for building codes, dams, tunnels and towns in the hills.



Previous Year Questions

Prelims

2022

Consider the following pairs:

Peak — Mountains

1. Namcha Barwa — Garhwal Himalaya
2. Nanda Devi — Kumaon Himalaya
3. Nokrek — Sikkim Himalaya

Which of the pairs given above is/are correctly matched?

☐ a 1 and 2

☒ b 2 only

☐ c 1 and 3

☐ d 3 only

Answer: (b). Namcha Barwa is at the eastern syntaxis in Tibet; Nokrek is the highest point of the Garo hills (Meghalaya plateau).

2017

Consider the following statements:

1. In India, the Himalayas are spread over five States only.
2. Western Ghats are spread over five States only.
3. Pulicat Lake is spread over two States only.

Which of the statements given above is/are correct?

☐ a 1 and 2 only

☒ b 3 only

☐ c 2 and 3 only

☐ d 1 and 3 only

Answer: (b). The Himalaya cover far more than five states and UTs (J&K, Ladakh, HP, Uttarakhand, Sikkim, West Bengal, Arunachal, plus Purvanchal); the Western Ghats cross six states.

2013

Consider the following pairs:

1. Nokrek Biosphere Reserve : Garo Hills
2. Logtak (Loktak) Lake : Barail Range
3. Namdapha National Park : Dafla Hills

Which of the above pairs is/are correctly matched?

☒ a 1 only

☐ b 2 and 3 only

☐ c 1, 2 and 3

☐ d None

Answer: (a). Loktak lies in the Imphal valley amid the Manipur hills; Namdapha is in the Patkai foothills of eastern Arunachal, not the Dafla hills.

2012

When you travel in Himalayas, you will see the following:

1. Deep gorges
2. U-turn river courses
3. Parallel mountain ranges
4. Steep gradients causing land-sliding

Which of the above can be said to be the evidence for Himalayas being young fold mountains?

☐ a 1 and 2 only

☐ b 1, 2 and 4 only

☐ c 3 and 4 only

☒ d 1, 2, 3 and 4

Answer: (d). All four reflect rapid, continuing uplift (Section 01).

2011

The Brahmaputra, Irrawaddy and Mekong rivers originate in Tibet and flow through narrow and parallel mountain ranges in their upper reaches. Of these rivers, Brahmaputra makes a "U" turn in its course to flow into India. This "U" turn is due to

- a Uplift of folded Himalayan series
- b Syntaxial bending of geologically young Himalayas**
- c Geo-tectonic disturbance in the tertiary folded mountain chains
- d Both (a) and (b) above

Answer: (b). It turns round Namcha Barwa at the eastern syntaxis (Section 05).

1994

The Himalayas are formed of parallel fold ranges of which the oldest range is

- a the Siwalik Range
- b the Lesser Himalayas
- c the Great Himalayan Range**
- d the Dhauladhar Range

Answer: (c). The Greater Himalaya rose first, then the Lesser Himalaya (with the Dhauladhar), and the Shiwaliks last.

Mains

2025

GS I · 15 MARKS

Discuss how the changes in shape and sizes of continents and ocean basins of the planet take place due to tectonic movements of the crustal masses.

Approach: Lead with the Himalaya: India's drift, Tethys closure, collision, crustal doubling under Tibet and the new Indo-Gangetic foredeep (Sections 02–04); contrast opening oceans such as the Atlantic and Red Sea.

2021

GS III · 15 MARKS

Discuss about the vulnerability of India to earthquake related hazards. Give examples including the salient features of major disasters caused by earthquakes in different parts of India during the last three decades.

Approach: Himalayan source (locked MHT, 2 cm a year of convergence, central seismic gap, Section 14); cases such as Uttarkashi 1991, Chamoli 1999, Kashmir 2005, Sikkim 2011, plus Latur and Bhuj; end with codes and Zone VI.

2015

GS III · 12.5 MARKS

The frequency of earthquakes appears to have increased in the Indian subcontinent. However, India's preparedness for mitigating their impact has significant gaps. Discuss various aspects.

Approach: The hazard is structural, not new: thrusts and the seismic gap (Sections 05, 14). Then gaps in code enforcement, retrofitting, hill-town planning, early warning and awareness, with 2015 Gorkha as context.

2014

GS I · 10 MARKS

Why are the world's fold mountain systems located along the margins of continents? Bring out the association between the global distribution of fold mountains and earthquakes and volcanoes.

Approach: Convergent margins collect and squeeze sediment; the Himalaya (continent–continent: quakes, no volcanoes) against the Andes (ocean–continent: both). Sketch Fig. 3.6.

INDIAN GEOGRAPHY

PRELIMS · GS PAPER I

The Indian Monsoon

For four months every year a wind that has crossed the Equator sweeps over India from the south-west and brings about three-quarters of the country's rain. When it is late, weak or patchy, reservoirs run low, kharif sowing slips and food prices rise; when it is strong, rivers flood. No single cause explains it. Land and sea, the swing of the ITCZ, the heated Tibetan Plateau, jet streams high above Asia and the surface of three oceans all play a part, and the balance between them changes from year to year.

SYLLABUS

PRELIMS

Indian and World Geography: Physical Geography of India (mechanism of the monsoon, ITCZ, jet streams, Tibet, El Niño, IOD and MJO, onset, advance, branches, breaks and withdrawal, the north-east monsoon, IMD forecasts and rainfall categories)

MAINS · GS PAPER I

Salient features of India's physical geography; important geophysical phenomena; changes in critical geographical features and their effects; GS III: rain-fed agriculture and monsoon dependence, floods and droughts

CONTENTS

01	Meaning of the Monsoon	02	Pressure, Winds and the Driving Factors
03	The Classical Thermal Theory	04	The ITCZ and the Air-Mass View
05	Jet Streams and the Monsoon	06	The Tibetan Plateau as a Heat Source
07	Ocean Drivers: Mascarene High, ENSO, IOD, MJO	08	Onset of the Monsoon
09	Advance and the Two Branches	10	Monsoon Trough, Depressions and Breaks
11	Withdrawal and the North-East Monsoon	12	Characteristics and Variability
13	Forecasting the Monsoon	14	Monsoon, Agriculture and the Economy
15	The Changing Monsoon	16	Previous Year Questions

This chapter covers:

- the meaning of the monsoon, the pressure and wind pattern over India in January and July, and the factors that build, start, vary and end the south-west monsoon;
- the classical thermal theory and its limits, the ITCZ and air-mass views, the jet streams (STJ, TEJ and the Somali jet), the Tibetan Plateau, the Mascarene High, ENSO, the IOD, EQUINOO and the MJO;
- onset over Kerala and IMD's criteria, the normal dates of advance and withdrawal (revised in 2020), the Arabian Sea and Bay of Bengal branches, the monsoon trough, depressions, active spells and breaks;
- withdrawal and the north-east monsoon of Tamil Nadu, the long-period average and IMD's rainfall categories, recent seasons from 2019 to 2026, forecasting and Mission Mausam;
- the monsoon's role in farming and the economy, and how the monsoon is changing.

The next chapter follows the year through India's four seasons, the western disturbances, the distribution of rainfall and the climatic regions of India.

01 Meaning of the Monsoon

The word **monsoon** comes from the Arabic *mausim*, "season", the word Arab sailors used for the winds that carried their ships to India in one half of the year and home in the other. A **monsoon** is a **seasonal reversal of the prevailing wind**, with a wet season under winds that blow onto the land from the sea and a dry season under winds that blow off the land. The general idea and the world's monsoon regions are covered in *Physical Geography*, Chapter 17; this chapter is about how the system works over India.

- India has two monsoons. The **south-west monsoon** (June–September) blows from the Indian Ocean and brings most of the year's rain. The **north-east monsoon** (October–December, continuing as the dry winter flow into early spring) blows off the land and is dry over most of the country, but it gives Tamil Nadu and the south-east coast their main rainy season (Section 11).
- The June–September season gives India about **three-quarters of its annual rainfall**; its long-period average over the country is 868.6 mm.
- The monsoon is a **double system**: when moist air streams in from the south-west at the surface, air flows out at the top of the troposphere towards the south. Winds high above India in July blow from the east, the reverse of the surface winds.
- South Asia is the clearest monsoon in the world because it combines the largest continent, a warm ocean to the south and the highest plateau on Earth. Nowhere else does the rain belt travel so far from the Equator.

The Monsoon Arrives in Kerala



Fig. 12.1 Monsoon clouds over the Chalakudy river, Thrissur district, Kerala. Kerala is the first part of the mainland to receive the south-west monsoon, around 1 June on average.

CLEARING A COMMON MISCONCEPTION

"Monsoon" is often used to mean "the rains". Strictly it is the wind system. The winter monsoon is also a monsoon, even though it is dry over most of India. In the same way, a "break in the monsoon" does not mean the winds have stopped: the south-westerlies keep blowing, but the rain-producing systems shift away (Section 10).

02 Pressure, Winds and the Driving Factors

The two monsoons are two opposite pressure patterns (Fig. 12.2).

- **January.** Cold, dense air over the land gives high pressure over north-west India, about 1019 hPa, with the stronger Siberian High beyond the Himalaya. Pressure falls towards the warmer seas and the Equator, where the ITCZ now

lies, south of the Equator. Winds blow outwards from the land: down the Ganga plain from the north-west, and from the north-east over the peninsula and the Bay of Bengal. They are dry except where they cross the Bay before reaching the Coromandel coast.

- **July.** The land is now the low. A shallow **heat low**, with pressure below about 998 hPa, lies over the Thar and Pakistan, and a long trough of low pressure, the **monsoon trough**, runs from it to the head of the Bay of Bengal. Pressure rises steadily southwards across the ocean to the **Mascarene High** near 30°S. Air moves down this gradient from the southern hemisphere, crosses the Equator and reaches India from the south-west; over the Ganga plain it arrives from the east.

Pressure and Winds over India: January and July

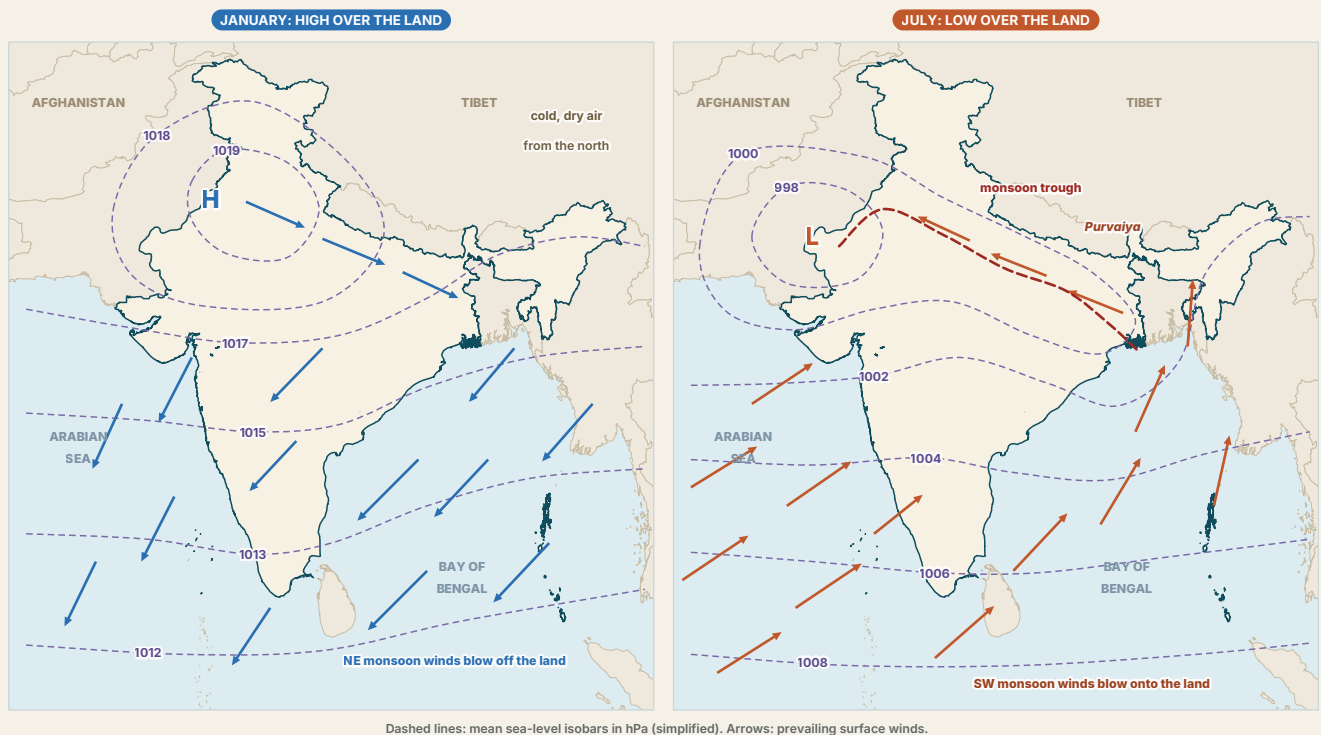


Fig. 12.2 In January high pressure over the north-west sends dry winds off the land. In July a heat low and the monsoon trough over the north draw moist air from the oceans; the Bay of Bengal branch turns west up the Ganga plain and is felt there as an easterly (purvaiya).

The pressure maps describe the monsoon; they do not explain it. Modern accounts bring in several interacting factors, which can be grouped by what they do (Fig. 12.3). The rest of this chapter takes them one by one.

What Builds, Starts, Varies and Ends the South-West Monsoon

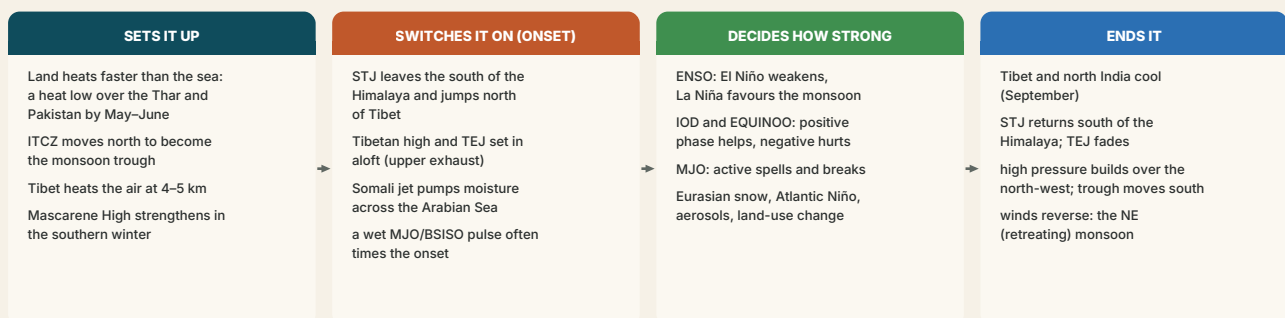


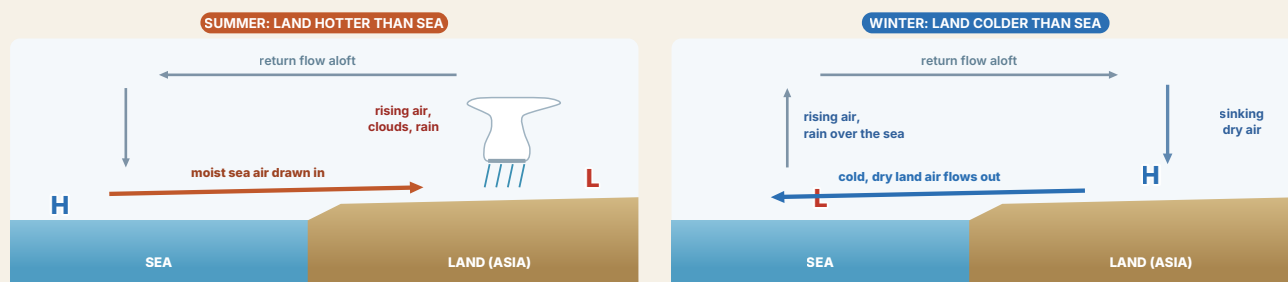
Fig. 12.3 No single factor makes the monsoon. Heating of land and plateau and the northward shift of the ITCZ set the stage; changes in the upper-air jets switch it on; ocean–atmosphere patterns decide how strong it will be; cooling of the plateau and the return of the westerly jet end it.

The Classical Thermal Theory and Its Limits

The first scientific account came from the English astronomer **Edmond Halley**, who in 1686 explained the monsoon as a result of the **differential heating** of land and sea. This is the **thermal (classical) theory**: the monsoon is a **land and sea breeze on the scale of a continent and a season** (Fig. 12.4).

- **Summer.** When the Sun is overhead near the Tropic of Cancer, the land of Asia heats far faster than the ocean. Low pressure forms over the land and relatively high pressure over the sea, so moist air flows in from the sea, rises over the land and gives rain.
- **Winter.** The land loses heat faster than the sea. High pressure builds over the continent and dry air flows out towards the warmer ocean.

The Thermal Concept of the Monsoon



Halley's idea: the monsoon is a land and sea breeze on the scale of a continent and a season.

Fig. 12.4 The classical model: the land is the low in summer and the high in winter, and the wind reverses with the season.

Why the Thermal Theory Is Not Enough

- **Timing.** North-west India is hottest in May and early June, yet the rain arrives only later, and once the rains begin the land cools while the monsoon circulation grows stronger. A pure land-sea contrast cannot explain this.
- **The hottest land is the driest.** The heat low over the Thar is shallow and capped by sinking air; it pulls in winds but gives almost no rain.
- **The burst and the breaks.** The sudden onset, the long dry spells in July and August and the pulses of heavy rain have no place in the model.
- **The rain does not fall like a sea breeze.** Much of it comes from moving lows and depressions and from relief, not from a steady inflow of air.
- **Year-to-year changes.** The land heats up every summer, yet some monsoons fail and others flood; these swings follow the oceans of the Pacific and Indian basins, not the land alone.
- The model also ignores what happens in the upper troposphere, which observations after the Second World War showed to be central.

The land-sea contrast still matters: it is the base on which the other factors act. Its modern form looks at the heating of the whole air column, above all over the Tibetan Plateau (Section 06), rather than at surface temperature alone.

The ITCZ and the Air-Mass View

From the 1950s the German meteorologist **Hermann Flohn** and others put forward a **dynamic concept**: the monsoon is the result of the **seasonal migration of the planetary pressure and wind belts** that follows the overhead Sun (*Physical Geography*, Chapter 17). In this view the monsoon is not a separate wind at all but a modified trade wind.

- The **Inter-Tropical Convergence Zone (ITCZ)**, where the trade winds of the two hemispheres meet, moves north in the northern summer and south in winter. Over most of the world the shift is small, but over the Indian Ocean and

Asia it is enormous: from about 10°–15°S in January to about 20°–25°N over India in July, a swing of some 40° of latitude (Fig. 12.5).

- When the ITCZ moves north, the **south-east trades** of the southern hemisphere are drawn across the Equator. The Coriolis force turns them to their right, and they arrive over India as **south-westerlies**. These deflected trades are sometimes called the **equatorial westerlies**.
- Over India the summer ITCZ takes the form of the monsoon trough. Its summer position is called the **Northern ITCZ (NITCZ)**; the winter position south of the Equator, the **Southern ITCZ (SITCZ)**.
- In winter the ITCZ moves south of the Equator and the north-east trades, reinforced by outflow from the cold land, re-establish themselves as the **north-east monsoon**. After crossing the Equator they turn left and reach Indonesia and northern Australia as a north-west monsoon.

The ITCZ over the Indian Ocean in July and January

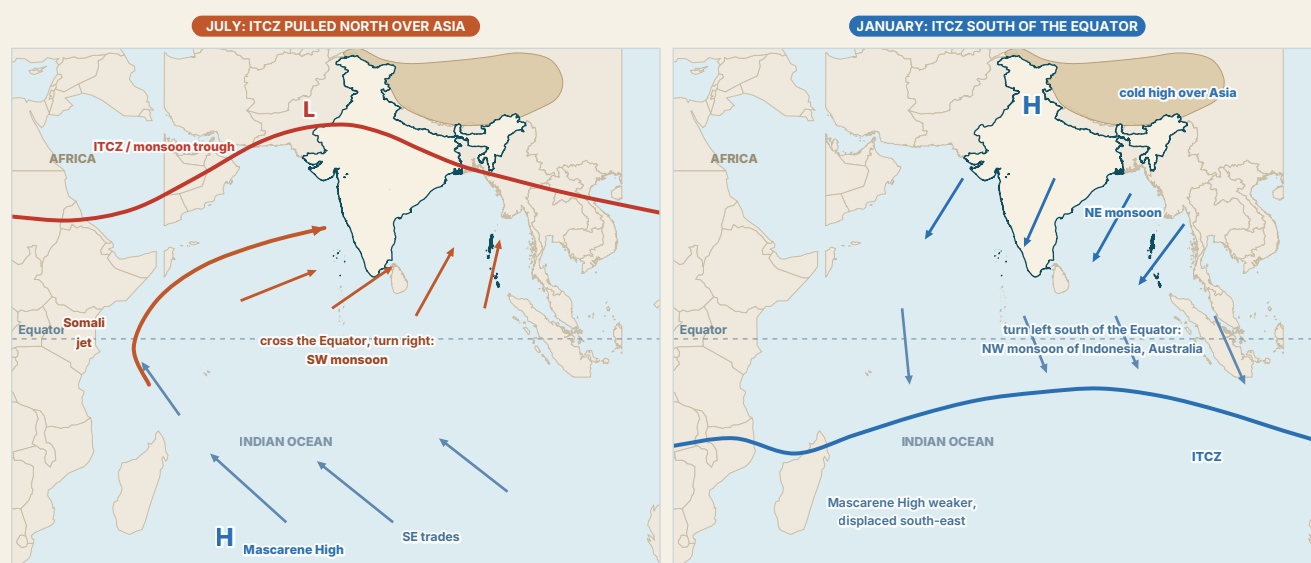


Fig. 12.5 In July the ITCZ lies over north India as the monsoon trough, and south-east trades from the Mascarene High cross the Equator, many of them along the Somali coast, to become the south-west monsoon. In January it lies south of the Equator and winds blow out of Asia.

The Air-Mass Interpretation

The same picture can be described in terms of air masses (*Physical Geography*, Chapter 19). The south-west monsoon is warm, moist **maritime tropical air** from the southern Indian Ocean; the winter monsoon is dry **continental air** from Asia. Older texts described the leading edge of the moist air as a "monsoon front" along which rain fell. That idea has been dropped: there is no true front, and most monsoon rain comes from lows, depressions, convection and relief inside the moist air mass.

The ITCZ view explains the reversal and its link with the Sun better than the thermal theory, but it still leaves questions: why the ITCZ jumps so far north over Asia and nowhere else, and why the onset is so sudden. The answers lie in the upper air.

95 Jet Streams and the Monsoon

Jet streams are narrow belts of very fast wind near the top of the troposphere; their causes and types are explained in *Physical Geography*, Chapter 19. Three jets matter for India: the **subtropical westerly jet (STJ)**, the **tropical easterly jet (TEJ)** and the low-level **Somali jet** (Fig. 12.6).

Winter: the STJ South of the Himalaya

- From about October to May the STJ, at about 12 km (around 200 hPa), flows over the subtropics of Asia. West of the plateau, over Afghanistan and the Pamir, the Himalaya–Tibet block **splits it into two branches**. The **southern branch**, the stronger one, runs along the southern edge of the Himalaya at about 25°–30°N; the weaker northern branch passes north of Tibet. They rejoin over eastern China.
- Air **sinks beneath the southern branch** over north-west India and Pakistan. Sinking air warms and dries, so winter there is settled and dry, with high pressure at the surface and light winds blowing off the land.
- The same jet steers the **western disturbances** that bring winter rain and snow to the north-west (Chapter 13).
- Through March, April and May the southern branch weakens but stays in place. As long as it does, the subsidence beneath it caps the heat low and the monsoon cannot set in. This is why April and May are hot and largely rainless over the north despite intense heating.

The Northward Jump

In late May or early June the southern branch weakens sharply and vanishes, and the jet re-forms **north of the Tibetan Plateau, near 40°N**, often within a few days. With the westerlies gone from above north India, the upper-air pattern switches to its summer form and the monsoon can advance quickly; this abrupt change lies behind the "burst" of the monsoon. In autumn the process runs in reverse: the jet returns south of the Himalaya, and the monsoon withdraws.

The Tropical Easterly Jet (TEJ)

- Once the STJ has moved north, a strong easterly current appears in the upper troposphere over southern Asia. Identified by the Indian meteorologist **P. Koteswaram** in the 1950s, the **tropical easterly jet** blows **from east to west at about 14–16 km (100–150 hPa)**, with its core near 10°–15°N over the peninsula, from South-East Asia across India and the Arabian Sea to Africa. It lasts from June to September, with typical core speeds of 25–40 m/s.
- It is the southern flank of the **Tibetan anticyclone**, the upper-level high that forms over the heated plateau (Section 06). Over India the upper troposphere is then warmer to the north than to the south, the reverse of normal, and this reversed temperature gradient produces easterly winds aloft.
- The TEJ acts as an **exhaust**: it carries away air that rises over India and the Bay of Bengal, and the air sinks again far to the south and west, over the southern Indian Ocean and eastern Africa, where it helps to sustain the Mascarene High.
- A strong, well-placed TEJ goes with a vigorous monsoon and active depressions; a weak TEJ with breaks and poor rain. Studies over recent decades have reported a **weakening of the TEJ**, linked to a smaller temperature contrast between land and ocean.

The Somali Jet (Findlater Jet)

- Near the surface, at about **1–1.5 km**, a narrow, fast current of air crosses the Equator along the coast of Kenya and Somalia and turns north-east across the Arabian Sea towards the Western Ghats. It was mapped in the 1960s by the British meteorologist **J. Findlater** and is called the **Somali jet** or Findlater jet. Mean core speeds in July are about 15–20 m/s, stronger in surges.
- The East African highlands guide the cross-equatorial flow into this channel, so a large share of the moisture that reaches India crosses the Equator here. A strong Somali jet means vigorous rain on the west coast.
- Its friction drives the **Somali Current** north along the coast in summer; this reverses in winter. The current and the winds cause strong **upwelling** of cold water off Somalia and Oman, which cools the western Arabian Sea in July and August.

Jet Streams over Asia: Winter and the Summer Monsoon

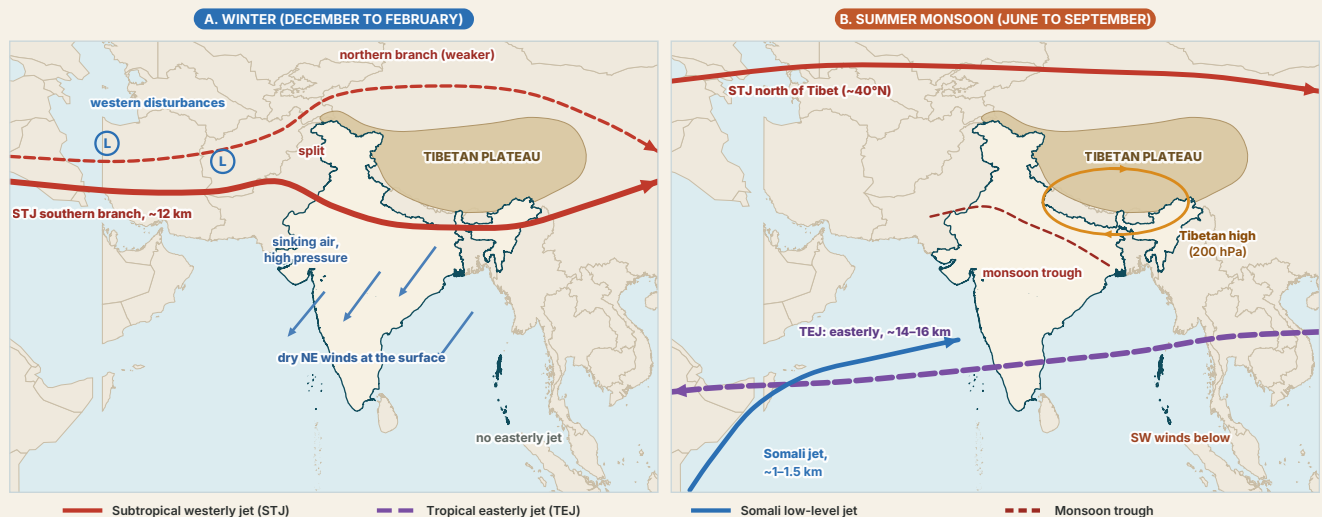


Fig. 12.6 A: in winter the STJ splits west of Tibet; its southern branch over north India steers western disturbances and keeps the air sinking and dry. B: in summer the STJ lies north of Tibet, the Tibetan high builds aloft, the TEJ streams westward over the peninsula, and the Somali jet carries moisture across the Arabian Sea near the surface.

CLEARING A COMMON MISCONCEPTION

Some notes call the TEJ the "African Easterly Jet" and list it, with the Somali jet, among the low-level jets. They are different things. The TEJ is an **upper-tropospheric** jet (100–150 hPa) of the Asian summer; the African Easterly Jet is a **mid-level** jet (about 600–700 hPa) over West Africa that steers the waves that grow into Atlantic hurricanes. Only the Somali jet is a low-level jet, and it runs along East Africa, not across the Sahel.

06 The Tibetan Plateau as a Heat Source

The Tibetan Plateau covers about 2.5 million km² at an average height of more than 4,000 m. In 1958 Koteswaram, and around the same time Flohn, showed that it acts on the atmosphere in two ways: as a **mechanical barrier** and as an **elevated heat source**.

- **Heating.** In May and June the high, dry, sunlit surface heats the thin air directly above it at a height of 4–5 km, a level where over the plains and the ocean there is only free atmosphere. Rain on the plateau's southern and eastern slopes adds latent heat. The column of air over Tibet becomes the warmest in Asia at middle and upper levels.
- **Rising air and the Tibetan high.** The heated air rises. At about 200 hPa it spreads out in a huge clockwise **Tibetan anticyclone**, centred near 30°N. Its southern flank is the TEJ, and its outflow travels south and sinks over the southern subtropics (Fig. 12.7).
- **A complete cell.** Air rising over Tibet and the monsoon trough, flowing out southward aloft, sinking over the southern Indian Ocean and returning north near the surface as the south-east trades and the Somali jet forms a giant overturning **monsoon cell**, in effect a Hadley cell turned round for the summer.
- **Barrier.** In winter the Himalaya–Tibet block splits the STJ and keeps the coldest Siberian air out of India. In summer it walls the monsoon air in on the north, so the moisture is wrung out over the Himalaya and the plains.
- **Winter.** The plateau then cools strongly, a cold high forms over it, and it adds to the outflow of the north-east monsoon.

Tibet as an Elevated Heat Source: A North–South Section

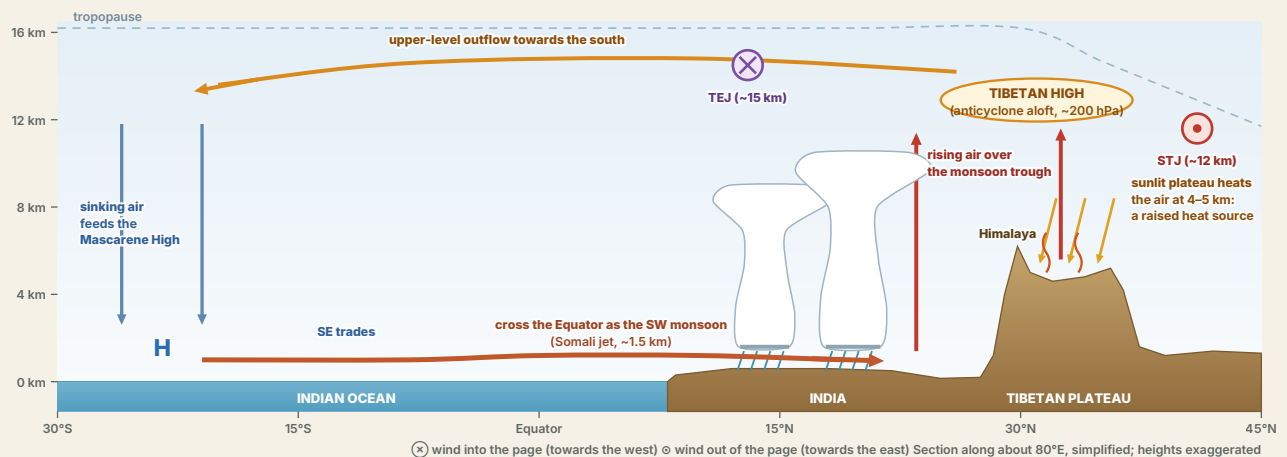


Fig. 12.7 Heating of the plateau and the release of latent heat in monsoon clouds drive rising air over Tibet and north India. Aloft, the Tibetan high spreads air southward in the TEJ; it sinks over the southern Indian Ocean, strengthens the Mascarene High and returns northward near the surface as the south-west monsoon.

Snow, Heating and the Strength of the Monsoon

If the plateau is covered by heavy, late-lying snow, much of the spring sunshine is used to melt it, the land warms later and less, and the circulation is weaker. This link between **Himalayan and Eurasian snow cover** and the monsoon was first noticed in the 1880s by H. F. Blanford, the first head of the India Meteorological Department (IMD), and it is still used: IMD's statements note that winter and spring snow cover over the northern hemisphere and Eurasia is inversely related to the following monsoon. Snow extent over the northern hemisphere in January–March 2026 was slightly below normal, which on its own would have favoured the monsoon; the El Niño of that year overrode it.

THEORY	MAIN IDEA	WHAT IT EXPLAINS	WHAT IT MISSES
Thermal (Halley, 1686)	Land–sea heating contrast; continental sea breeze	Seasonal reversal; onshore summer winds	Delayed rains, burst, breaks, dry Thar, year-to-year swings
Dynamic / ITCZ (Flohn, 1950s)	Seasonal shift of wind belts; deflected SE trades	Cross-equatorial south-westerlies; link with the Sun	Why the shift is so large over Asia; sudden onset
Jet stream (upper air)	STJ must leave north India; TEJ sets in	Timing of onset and withdrawal; dry pre-monsoon	Why the jets change; rainfall amount
Tibetan heat source (Koteswaram, Flohn)	Elevated heating builds the Tibetan high and TEJ	The northward jump, the TEJ, the monsoon cell	Ocean-driven variability
Ocean–atmosphere (ENSO, IOD, MJO)	Remote and local sea-surface patterns shift rising air	Good and bad years; active and break spells	Not deterministic; links change over decades

67

Ocean Drivers: Mascarene High, ENSO, IOD, MJO

Whether a monsoon is generous or poor depends largely on the oceans. The mechanisms of ENSO, the IOD and the MJO are explained in *Physical Geography*, Chapter 22; here the focus is on what they do to India.

The Mascarene High and the Somali Current

- The **Mascarene High** is the subtropical anticyclone of the southern Indian Ocean, east and south-east of Madagascar near 30°S, 50°–60°E. It is strongest in the southern winter, June to August, just when India needs it: it is the source of the south-east trades that cross the Equator.
- A strong Mascarene High steepens the pressure gradient towards the Indian heat low and strengthens the cross-equatorial flow and the Somali jet; a weak or displaced high tends to go with weaker monsoon winds. Sinking air from the TEJ helps to maintain it (Section 06).
- In winter the high weakens and moves south-east as the ITCZ comes south.

ENSO

In an **El Niño** year the rising branch of the Walker circulation moves from the western to the central Pacific, and a compensating zone of sinking air spreads over the Indian region. The monsoon trough and the low-level westerlies weaken, depressions form less often, breaks last longer and rain falls short. A **La Niña** does the opposite. Most of India's worst droughts, such as 1918, 1972, 1987, 2002 and 2009, came in El Niño years, but the link is not a law: roughly four El Niño years in ten have escaped a below-normal season.

The Indian Ocean Dipole and EQUINOO

- The **Indian Ocean Dipole (IOD)** is a difference in sea-surface temperature between the western tropical Indian Ocean and the eastern part off Sumatra. In a **positive IOD** the west is warmer, rising air and cloud shift west, and the Indian monsoon is generally helped; a **negative IOD** tends to weaken it.
- Its atmospheric partner is the **Equatorial Indian Ocean Oscillation (EQUINOO)**, a see-saw of convection between the western and eastern equatorial Indian Ocean described by Indian scientists in 2004. Together, ENSO and EQUINOO account for most extreme Indian monsoons.
- A positive IOD can cancel much of an El Niño's effect, as in 1997 and 2023.

OCEAN STATE	YEARS	MONSOON (% OF LPA)
El Niño with positive IOD	1997, 2023	102, 94: near normal or below normal; the dipole softened the blow
El Niño with neutral or negative IOD	2002, 2009, 2026	81, 78, 87: deficient seasons
Strong positive IOD, neutral Pacific	2019	110: excess rain in September, the latest withdrawal on record
La Niña	2020, 2021, 2022	109, 99, 106: normal to above normal

IN THE NEWS · 2026: EL NIÑO WITH NOTHING TO OFFSET IT

An El Niño developed in June 2026 and strengthened through the season, while the IOD stayed neutral throughout, although forecasts had suggested a positive phase late in the season. The monsoon ended at 87% of the LPA, the weakest since 2015. It is a textbook case of the second row of the table above.

The MJO and the Monsoon's Pulse

- The **Madden–Julian Oscillation (MJO)** is an envelope of enhanced cloud and rain that drifts east along the Equator every 30–60 days, followed by a suppressed phase. In northern summer a related disturbance, the **boreal summer intraseasonal oscillation (BSISO)**, also moves north from the equatorial Indian Ocean across India at roughly one degree of latitude a day.
- Its wet phase over the Indian Ocean often coincides with the onset over Kerala, with **active spells** and with the formation of lows and depressions; its dry phase with **breaks**. It is the main source of skill in IMD's forecasts two to four weeks ahead.
- Other influences studied in India include the **Atlantic Niño** (warming of the eastern equatorial Atlantic, which tends to weaken the monsoon), the **Pacific Decadal Oscillation**, which changes the strength of the ENSO link from

decade to decade, and the heat stored in the upper south-western Indian Ocean, measured as the **ocean mean temperature** down to the 26 °C isotherm.

08 Onset of the Monsoon

The **onset** of the monsoon is the change from the hot, dry pre-monsoon weather to the rainy season, marked by a sudden rise in rain, deep westerly winds and a fall in temperature. The heavy rain with thunder and strong winds that often accompanies it gives the expression "**burst**" of the monsoon.

- The monsoon first reaches the **south Andaman Sea and the Nicobar Islands**; the normal date is about 22 May.
- Onset over the mainland is declared for **Kerala**, normally on **1 June**, with a standard deviation of about a week. It has come as early as 11 May (1918) and as late as 18 June (1972).
- A swirl of low pressure, the **onset vortex**, often forms in the south-east Arabian Sea at the time of onset. Some grow into depressions or cyclones. They can push the monsoon forward, as Cyclone Nisarga did in early June 2020, or draw its moisture away and stall it, as Vayu (2019) and Biparjoy (2023) did when they moved north-west into the Arabian Sea.

How IMD Declares Onset over Kerala

IMD declares the onset with objective criteria based on rain, wind and cloud, not on the first heavy shower (Fig. 12.8).

IMD's Criteria for Monsoon Onset over Kerala

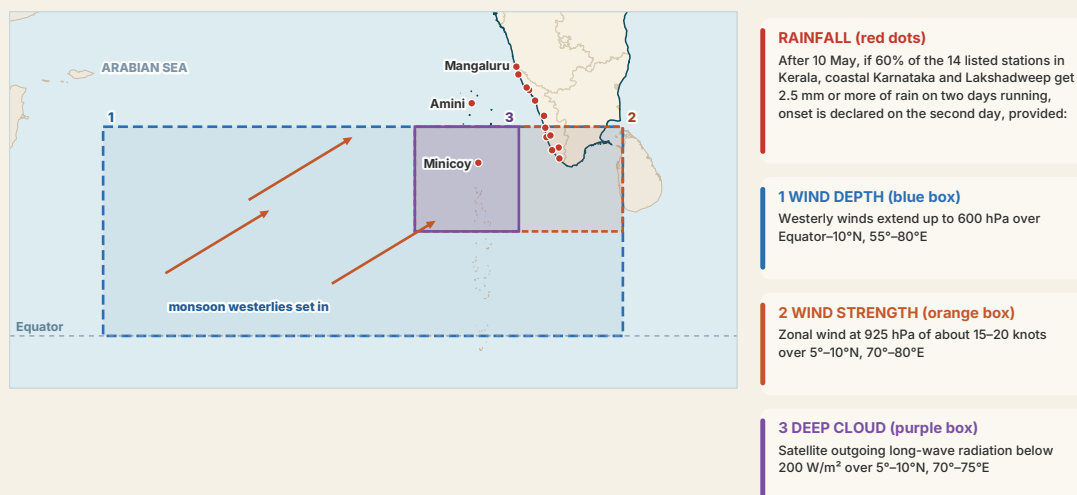


Fig. 12.8 Rain must be widespread at the 14 listed stations, and the westerlies must be deep, strong and accompanied by deep cloud. The rule stops a few heavy pre-monsoon showers from being mistaken for the monsoon.

Forecasting the Onset

IMD has issued an operational forecast of the onset date over Kerala every year since 2005, using a statistical model with an error of ± 4 days and six predictors, such as minimum temperatures over north-west India, pre-monsoon rain over the south peninsula, cloud (outgoing long-wave radiation) over the South China Sea and the south-west Pacific, and winds over the Indian Ocean. It has missed only twice: in 2015, and in 2026, when it forecast 26 May and the monsoon arrived on **4 June**.

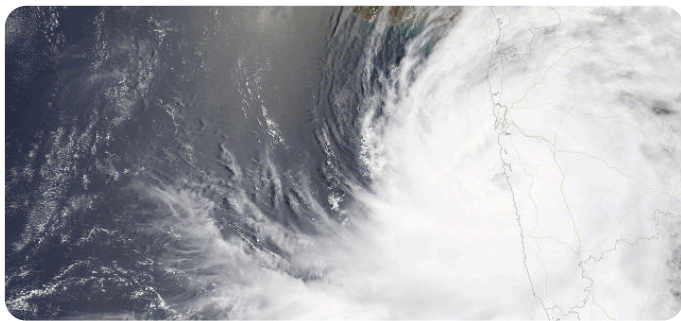


Fig. 12.9 Cyclone Nisarga over the Konkan coast and Maharashtra on 4 June 2020, a day after landfall near Alibag. Onset-phase systems in the Arabian Sea can speed up or stall the monsoon (NASA, MODIS).



Fig. 12.10 The Deccan Queen in the Western Ghats between Mumbai and Pune in the monsoon. The Ghats force the Arabian Sea branch to rise and wring out its moisture.

IN THE NEWS · ONSET IN 2025 AND 2026

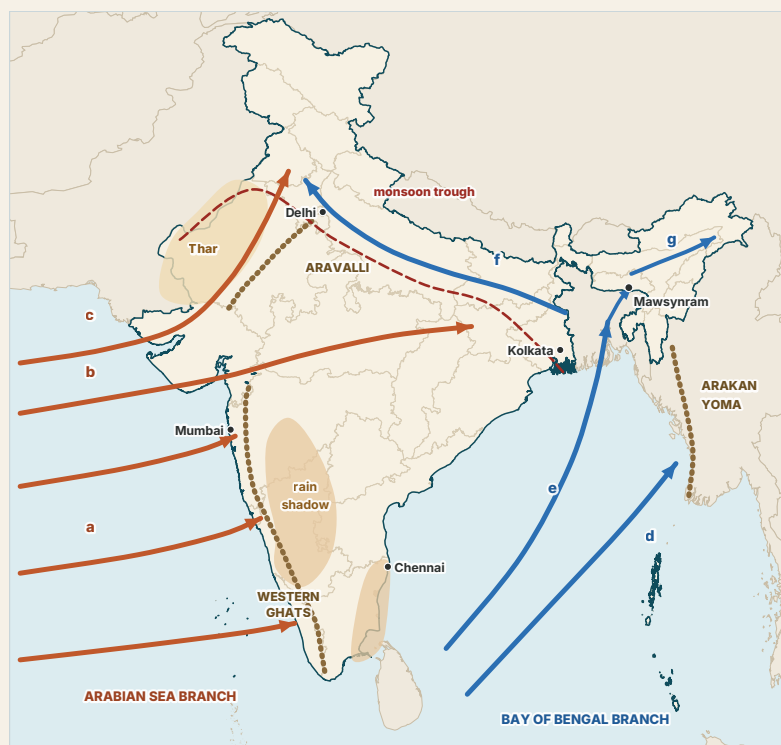
2025: the monsoon reached the Andaman Sea on 13 May and Kerala on **24 May**, eight days before normal and the **earliest onset since 2009** (23 May). It raced over the south and north-east by 29 May, stalled until 16 June, and still covered the whole country by 29 June, nine days early. **2026:** it reached the Andaman Sea on 16 May, six days early, but Kerala only on **4 June**, three days late; it covered the country on 9 July, a day after the normal date.

09

Advance and the Two Branches

After onset the monsoon advances in surges separated by pauses, each surge usually tied to a low or a wet MJO pulse. The tip of the Indian peninsula divides the flow into two branches, the **Arabian Sea branch** and the **Bay of Bengal branch**, which meet again over central and north-west India (Fig. 12.11).

The Two Branches of the South-West Monsoon



ARABIAN SEA BRANCH (the stronger one)

- a** strikes the Western Ghats head-on: heavy orographic rain on the windward slopes, rain shadow inland
- b** enters the Narmada–Tapi gap and reaches central India and the Chotanagpur plateau
- c** crosses Kachchh and Rajasthan parallel to the Aravalli, so it gives little rain; meets the Bay branch over Punjab and Haryana

BAY OF BENGAL BRANCH

- d** strikes the Arakan Yoma of Myanmar
- e** turns north into Bengal and Bangladesh; part is funnelled into the Garo–Khasi hills (Mawsynram)
- f** turned west by the Himalaya and the trough: flows up the Ganga plain from the east (Purvaia); rain falls off from Kolkata towards Delhi
- g** moves up the Brahmaputra valley

WHY SOME AREAS STAY DRY

- Interior Karnataka, Marathwada: lee of the Ghats
- Tamil Nadu coast: in the lee of the Ghats and parallel to the Bay branch, so June–September is its dry season
- Rajasthan: winds parallel to the Aravalli, dry air aloft, and few monsoon lows reach it

Fig. 12.11 The Arabian Sea branch strikes the Western Ghats, pushes up the Narmada–Tapi corridor and crosses Rajasthan; the Bay branch hits Myanmar, swings north into Bengal and the Meghalaya hills, and turns west up the Ganga plain. The two meet over the north-west. Arrows and dry areas are schematic.

The Arabian Sea Branch

- The stronger of the two. Its first stream meets the **Western Ghats** almost at right angles. Forced up the steep scarp, it gives very heavy orographic rain on the windward slopes, generally 250–400 cm in the season and much more on the crest. Descending the eastern side, the air warms and dries, leaving a **rain-shadow** over interior Karnataka, Marathwada and Telangana (relief in Chapter 06).
- A second stream enters north of Mumbai and moves along the **Narmada and Tapi valleys** into central India and the Chotanagpur plateau, where it joins the Bay branch.
- A third stream crosses **Kachchh, Saurashtra and Rajasthan**. It blows **parallel to the Aravalli**, which therefore cannot lift it, and dry air and dust above it suppress convection, so western Rajasthan gets little rain. It meets the Bay branch over Punjab and Haryana, and together they bring rain to the western Himalaya.
- Rain on the west coast increases when an **offshore trough** or vortex forms along the coast, or the Somali jet strengthens; it falls off when the winds blow parallel to the coast.

The Bay of Bengal Branch

- Part of it strikes the **Arakan Yoma** of Myanmar; much of the rest is turned north into West Bengal and Bangladesh, arriving from the south and south-east.
- One stream is funnelled into the **Garó and Khasi hills** of Meghalaya, whose south-facing slopes rise sharply above the Bangladesh plain. Mawsynram and Sohra (Cherrapunji) there have among the highest average rainfalls on Earth. Another moves up the **Brahmaputra valley**.
- Blocked by the Himalaya and drawn by the monsoon trough, the main stream turns **west up the Ganga plain**. People in Bhojpur and eastern Uttar Pradesh call this easterly wind **purvaya**. Its moisture is used up as it goes, so rainfall decreases from east to west: Kolkata receives roughly twice the seasonal rain of Delhi.
- The **Tamil Nadu coast** stays fairly dry in June–September: it lies in the rain-shadow of the Ghats for the Arabian Sea branch, and the Bay branch runs parallel to the coast instead of striking it.

The New Normal Dates (2020)

Until 2020 the normal dates came from only 149 stations for 1901–1940. In April 2020 IMD replaced them with dates based on onset data for **1961–2019** and withdrawal data for **1971–2019** (Fig. 12.12).

- Onset over Kerala stays at **1 June**, and the final withdrawal from the south at about **15 October**.
- Advance over Maharashtra, Gujarat, Madhya Pradesh, Chhattisgarh, Telangana, Andhra Pradesh, Odisha, Jharkhand, Bihar and parts of Uttar Pradesh is now **3–7 days later** than before.
- The monsoon now covers the **whole country by 8 July** instead of **15 July**, because it reaches the extreme north-west earlier.
- Withdrawal from the north-west begins about **17 September** instead of **1 September**, and is 7–14 days later across north-west and central India.

STATION	NORMAL ONSET	NORMAL WITHDRAWAL	STATION	NORMAL ONSET	NORMAL WITHDRAWAL
Thiruvananthapuram	1 June	NE monsoon follows	Bhopal	22 June	30 September
Chennai	4 June	NE monsoon follows	Lucknow	23 June	3 October
Guwahati	4 June	14 October	New Delhi	27 June	25 September
Hyderabad	8 June	14 October	Jaipur	1 July	22 September
Mumbai	11 June	8 October	Jaisalmer	8 July	17 September
Kolkata	11 June	12 October	Srinagar area	22 June	24 September

Normal Dates of Onset and Withdrawal of the South-West Monsoon

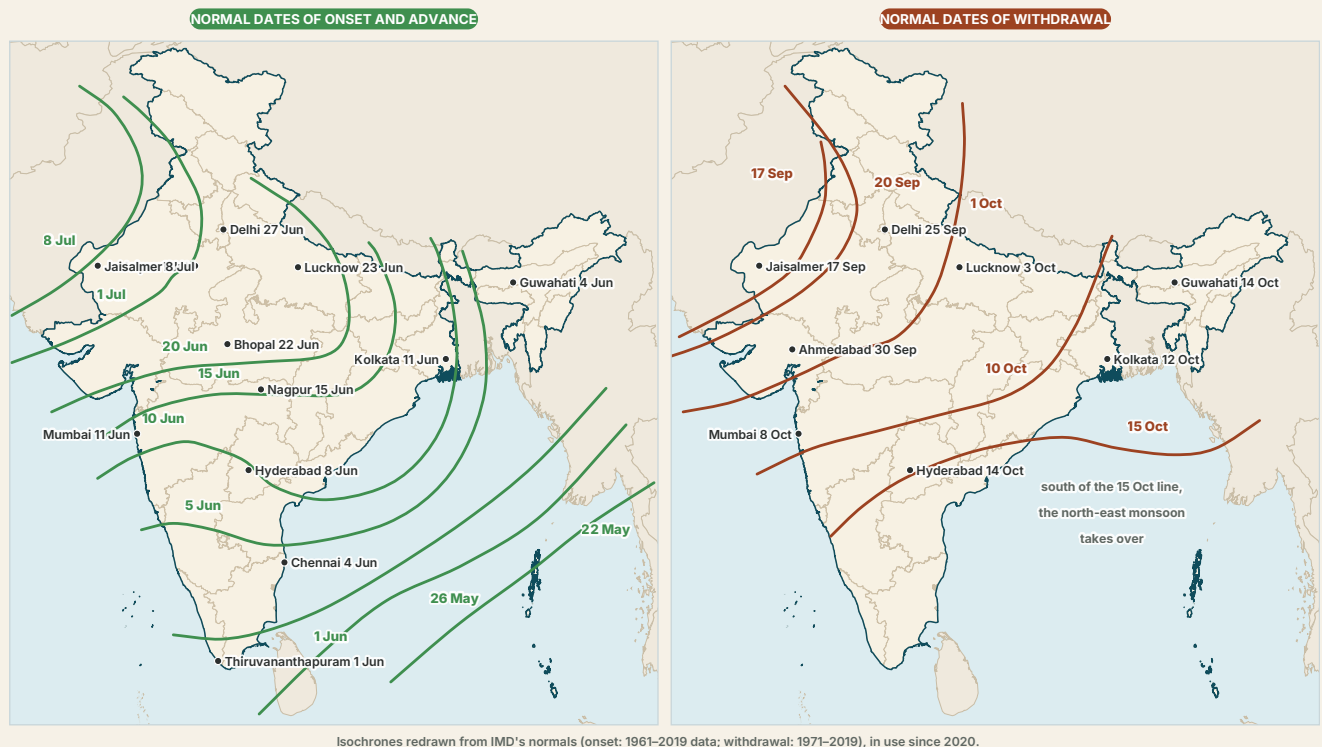


Fig. 12.12 Left: the monsoon reaches Kerala and the north-east first and the far north-west last; the Bay branch is quicker than the Arabian Sea branch north of about 20°N. Right: withdrawal starts in west Rajasthan in mid-September and ends in the south in mid-October, so the season is longest in the south and north-east and shortest in the Thar.



Fig. 12.13 Monsoon rain in Mumbai, which receives the Arabian Sea branch around 11 June.



Fig. 12.14 Northern India on 17 June 2013: a monsoon low and a western disturbance merge into a mass of cloud over Uttarakhand, Himachal Pradesh and the plains, the setting of the Kedarnath disaster (NASA, MODIS).

10 Monsoon Trough, Depressions and Breaks

Once the monsoon is established, its rain is organised by the **monsoon trough**: an elongated belt of low pressure running from the heat low over Pakistan and west Rajasthan, through about Sri Ganganagar, Agra and Prayagraj, to the head of the Bay of Bengal. Its position from day to day decides where it rains (Fig. 12.15).

Rain-Bearing Systems

- **Lows and monsoon depressions.** Most form over the north and north-west Bay of Bengal, or over land near it, and move **west-north-west** across Odisha, Chhattisgarh and Madhya Pradesh towards Rajasthan, steered by the easterlies aloft. They last a few days; the heaviest rain falls in their south-west sector. Their number and tracks largely decide how much rain central and north India receive. A season normally has about 13 lows and depressions, with about 57 days on which one is present.
- **Mid-tropospheric cyclones** over Gujarat and the north-east Arabian Sea, and **offshore troughs and vortices** along the west coast, give bursts of very heavy rain to Gujarat and the Konkan.

- **Relief** adds to all of these: the Western Ghats, the Meghalaya hills and the Himalaya receive far more than the plains around them.
- The frequency of monsoon depressions has fallen since the 1970s while weaker lows have become more common; whether this is a lasting change is still debated.

The Monsoon Trough, Its Shifts and Monsoon Depressions

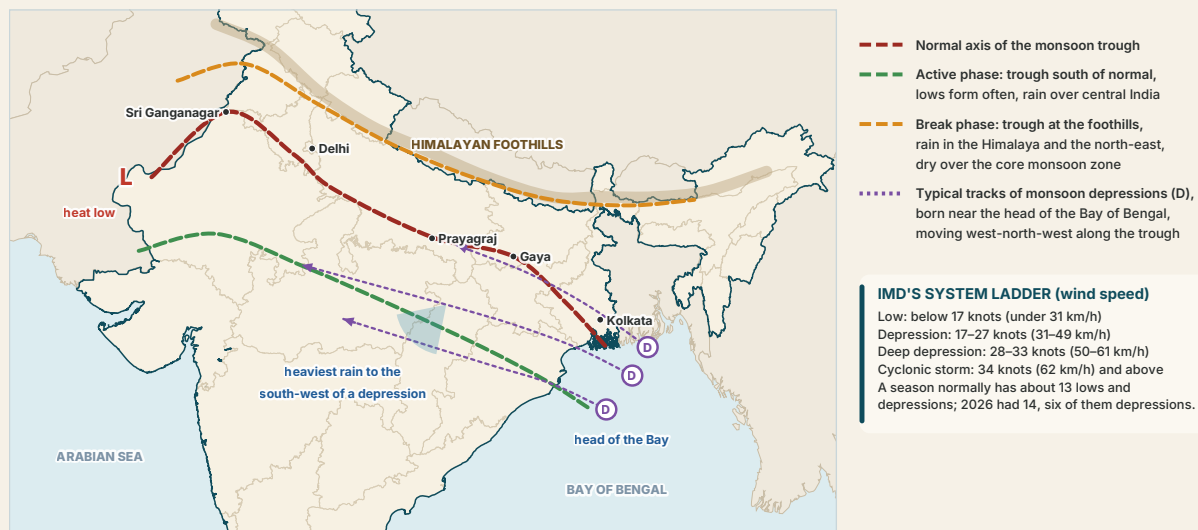


Fig. 12.15 When the trough lies south of its normal position and lows move along it, central India gets heavy rain (active spell). When it shifts north to the foothills, the plains dry out while the Himalaya and the north-east are drenched (break). Depressions born near the head of the Bay move west-north-west along the trough.

Active Spells and Breaks

- Monsoon rain comes in pulses. IMD tracks rainfall over the **core monsoon zone**, the belt from Gujarat to Odisha that holds most of India's rain-fed farmland. An **active spell** is declared when its rainfall is well above normal (standardised anomaly above +1) for at least three days running, and a **break** when it is well below (below –1) for at least three days.
- During a break the **trough moves north to the Himalayan foothills**. Rain stops over most of the plains and central India, while the foothills, the north-east and often the south-east peninsula get heavy rain: rivers such as the Kosi and Brahmaputra flood while the rest of the country waits for rain.
- Breaks are commonest in July and August and last from a few days to two weeks or more. They are linked to the dry phase of the MJO and BSISO, to El Niño, and to shifts of the Tibetan high and the TEJ. On the west coast, dry spells come when the winds weaken or blow parallel to the coast.
- Long breaks cause the worst damage, because they come when crops are in the ground: July 2002, one of the driest Julys on record, and August 2023, the driest August since 1901, are examples.

IN THE NEWS · THE 2026 SEASON, MONTH BY MONTH

No low formed in June 2026 (normally about three do), and June rain was only 65% of normal. Four lows came in July and lingered over central India, which pushed July to 101% and gave Central India above-normal rain that month. August fell back to 84%; a late wet spell lifted September to 92%. Fourteen lows formed in all, six of them depressions. Frequent western disturbances also interacted with monsoon systems over the north, a pattern that raises the risk of cloudbursts and flash floods in the Himalaya.

Withdrawal and the North–East Monsoon

As the Sun moves south in September, the land and the plateau cool, the Tibetan high and the TEJ fade, the STJ returns south of the Himalaya, and high pressure builds over the north-west. The monsoon trough weakens and the south-west monsoon begins to **withdraw**. Withdrawal is much slower and less abrupt than onset.

- IMD declares withdrawal from extreme west Rajasthan, not before 1 September, when **rain stops for five days in a row**, an **anticyclone forms in the lower troposphere** (around 850 hPa) and the air becomes **much drier** on satellite water-vapour images and upper-air soundings.
- The normal start is about **17 September**. The monsoon leaves central India by about 1 October and withdraws from the whole country, the south included, by about **15 October**.
- The clear skies and still-moist ground after withdrawal give hot, humid days over the plains, the "October heat" (Chapter 13).
- Recent withdrawals show the spread: in 2019 it began only on 9 October, the latest on record; in 2025 it began on 14 September, three days early, and was complete on 16 October; in 2026 it began on 19 September, two days late, and was still under way at the end of September.

The North–East (Retreating) Monsoon

- After the south-west monsoon has withdrawn south of about 15°N, usually in the second half of October, winds over the south become north-easterly. Over most of India these winds are dry, because they come off the land. But over the Bay of Bengal they pick up moisture and bring rain to **Tamil Nadu, Puducherry, coastal Andhra Pradesh, Rayalaseema, south interior Karnataka and Kerala**, and to northern and eastern Sri Lanka.
- IMD declares its onset, not before about 10 October, when persistent surface easterlies set in over the Tamil Nadu coast, rain begins there and the easterlies reach up to about 850 hPa.
- Much of the rain comes from **lows, depressions and cyclones** that form over the Bay and cross the coast; October–December is also the main cyclone season of the Bay (Chapter 16; *Physical Geography*, Chapter 20).
- Tamil Nadu receives close to half of its annual rainfall in these three months, the coastal districts more. The October–December normal for the south peninsula is about 334 mm. The rain fills the tanks and reservoirs on which the **samba** rice crop depends.
- El Niño and a positive IOD tend to **strengthen** the north-east monsoon (the Chennai floods of November–December 2015 came during a strong El Niño); La Niña tends to weaken it. In 2025 the north-east monsoon set in on 16 October, the same day the south-west monsoon left the country.

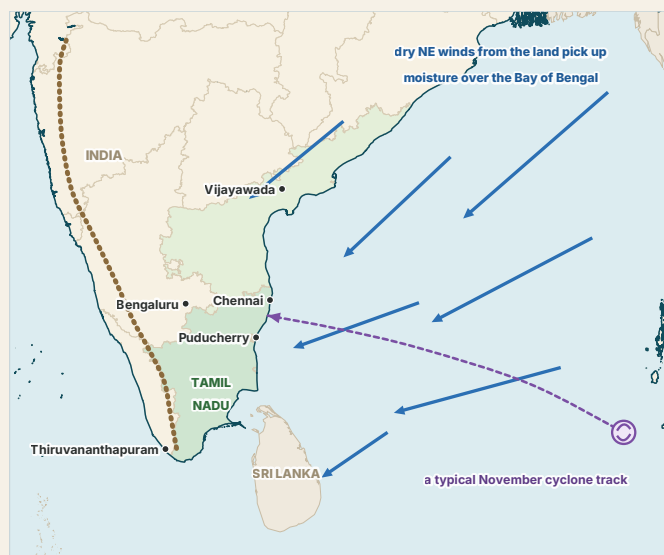


Fig. 12.16 Rain on Anna Salai, Chennai. The city gets most of its rain from the north-east monsoon.

CLEARING A COMMON MISCONCEPTION

The "retreating monsoon" and the "north-east monsoon" are often treated as one thing. The **retreat** is the withdrawal of the south-west monsoon from north to south during September–October. The **north-east monsoon** is the winter circulation that follows, which gives rain to the south-east coast in October–December. The two overlap in time over the south, which is why the terms get mixed.

The North-East Monsoon over South-East India



WHEN AND WHERE

October to December, once the south-west monsoon has withdrawn south of about 15°N. Tamil Nadu, Puducherry, coastal Andhra, Rayalaseema, south interior Karnataka, Kerala; also northern and eastern Sri Lanka.

WHAT BRINGS THE RAIN

North-easterly and easterly winds off the Bay, lifted over the coast and Eastern Ghats; lows, depressions and cyclones that cross the coast, mostly in October–December.

WHY IT MATTERS

Tamil Nadu gets close to half of its annual rain now, its coastal districts even more. It fills the tanks and reservoirs for samba rice. South peninsula normal for October–December: about 334 mm.

Fig. 12.17 In October–December north-easterly winds cross the Bay of Bengal, pick up moisture and rain on the Coromandel coast, helped by lows and cyclones moving in from the east. Tamil Nadu, which is fairly dry in June–September, has its main rainy season.

12 Characteristics and Variability

- **Seasonal reversal** of winds between summer and winter, the defining feature.
- **Pulsating rain.** The rain comes in active spells and breaks, not as a steady fall (Section 10).
- **Uncertain timing.** Onset over Kerala varies by about a week either way, and advance can stall for weeks, as it did in June 2025.
- **Unequal distribution.** Annual totals range from more than 1,100 cm at Mawsynram to under 15 cm in Ladakh and under 20 cm in the far west of Rajasthan. Rain is heaviest where relief lifts the winds and decreases away from the sea and up the Ganga plain (Chapter 13).
- **Duration decreases from south to north:** about four and a half months in Kerala and the north-east, two and a half or less in western Rajasthan.
- **Variability.** The all-India total varies by about 10% from year to year, but a district can swing far more, and the driest regions are the most variable.
- **Unifying influence.** Despite these contrasts, the whole country shares the same rhythm of seasons, the same agricultural calendar and many festivals tied to the arrival of the rains.

The Long-Period Average and IMD's Categories

IMD measures each season against the **long-period average (LPA)**, the mean June–September rainfall over the country for a 50-year base period. Since 2022 the LPA has been **87 cm (868.6 mm)**, based on 1971–2020; earlier values were 88 cm (1961–2010) and 89 cm (1951–2000). The monthly normals are 165.3 mm for June, 280.5 mm for July (the wettest month), 254.9 mm for August and 167.9 mm for September.

CATEGORY (COUNTRY AS A WHOLE)	RAINFALL, % OF LPA	CATEGORY (SUBDIVISION, DISTRICT)	DEPARTURE FROM NORMAL
Deficient	Below 90	Large excess	+60% or more
Below normal	90–95	Excess	+20% to +59%
Normal	96–104	Normal	–19% to +19%

Above normal	105–110	Deficient	–20% to –59%
Excess	Above 110	Large deficient / no rain	–60% to –99% / –100%

IMD also issues separate forecasts and normals for four homogeneous regions (north-west, central, south peninsula, and east and north-east India, with LPAs of 587.6, 978.0, 716.2 and 1,367.3 mm) and for the core monsoon zone (826.0 mm).

YEAR	KERALA ONSET	COVERED INDIA	WITHDRAWAL BEGAN	SEASON, % OF LPA	MAIN OCEAN SIGNAL AND NOTES
2019	8 June	19 July	9 October	110	Record positive IOD; very wet September; latest withdrawal
2020	1 June	26 June	28 September	109	La Niña; August 2020 the wettest in 44 years
2021	3 June	13 July	6 October	99	La Niña; long stall before reaching the north-west
2022	29 May	2 July	20 September	106	La Niña (third year); six monsoon depressions
2023	8 June	2 July	25 September	94	El Niño, softened by a positive IOD; driest August since 1901
2024	30 May	2 July	23 September	108	Neutral to La Niña; Central India 119%
2025	24 May	29 June	14 September	108	Earliest onset since 2009; North-west India 127%, highest since 2001; East and North-east 80%
2026	4 June	9 July	19 September	87	El Niño with neutral IOD; deficient; East and North-east India lowest since 1901

Recent Monsoon Seasons

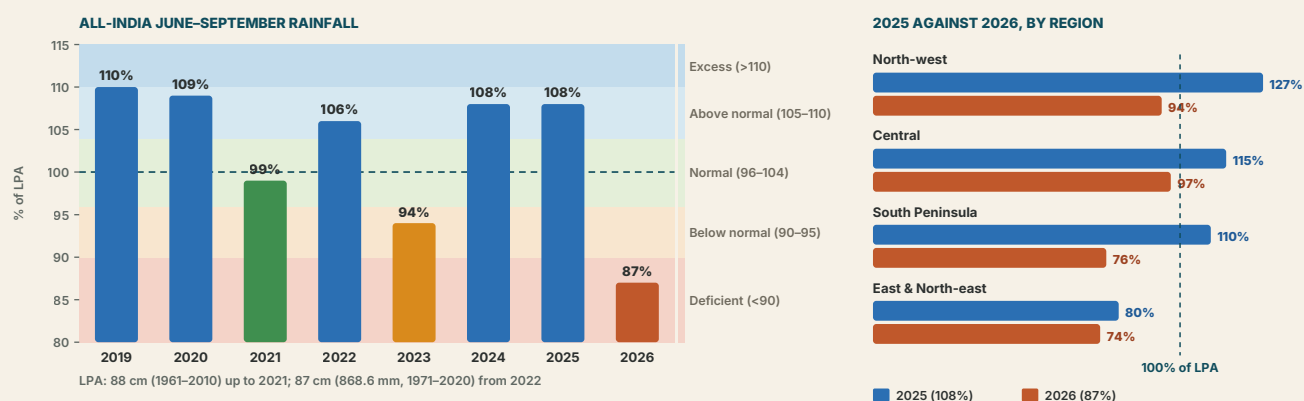


Fig. 12.18 Left: all-India June–September rain since 2019. Six of the eight seasons were normal or better; 2023 and 2026, both El Niño years, fell short. Right: even in a good year (2025) East and North-east India was deficient, and in 2026 it had its lowest rain since 1901.

IN THE NEWS · THE 2026 END-OF-SEASON STATEMENT

India received **759.4 mm, 87% of the LPA**: the fourth lowest since 2001 and the weakest since 2015. North-west India got 94%, Central India 97%, the south peninsula 76% (its fourth lowest since 1901) and East and North-east India 74% (1,016 mm, the lowest since 1901). Seventeen of the 36 subdivisions, covering 42% of the area, were deficient; only Odisha had excess rain. Rain over the core monsoon zone was just below the normal range.

Forecasting the Monsoon

India has forecast its monsoon for longer than almost any country. After the famine of 1877, H. F. Blanford issued the first long-range forecasts in the 1880s, using Himalayan snowfall. His successor **Gilbert Walker** (1904–1924) searched the world's weather records for predictors and in doing so discovered the Southern Oscillation, the atmospheric half of ENSO.

IMD's Long-Range Forecasts

- IMD forecasts the June–September rainfall in **two stages**: a **first-stage forecast in mid-April** for the country as a whole, and an **updated second-stage forecast at the end of May** with forecasts for June, the four regions and the core monsoon zone. Monthly outlooks follow, and at the end of July a forecast for August–September (Fig. 12.19).
- For many years the forecasts used **statistical models** built on predictors such as the North Atlantic–North Pacific sea-surface temperature gradient, equatorial south Indian Ocean temperature, east Asian sea-level pressure, north-west European land temperature and the warm-water volume of the equatorial Pacific.
- Under the **National Monsoon Mission**, launched by the Ministry of Earth Sciences in 2012, the Indian Institute of Tropical Meteorology (IITM), Pune, developed the **Monsoon Mission Coupled Forecasting System (MMCFS)**, a dynamical ocean–atmosphere model. Since 2021 IMD has combined it with other global coupled models in a **multi-model ensemble**, alongside the statistical system.
- Within the season, **extended-range forecasts** look up to four weeks ahead, issued every Thursday and drawing much of their skill from the MJO; medium- and short-range forecasts and nowcasts warn of heavy rain.

IMD's Monsoon Forecast Calendar

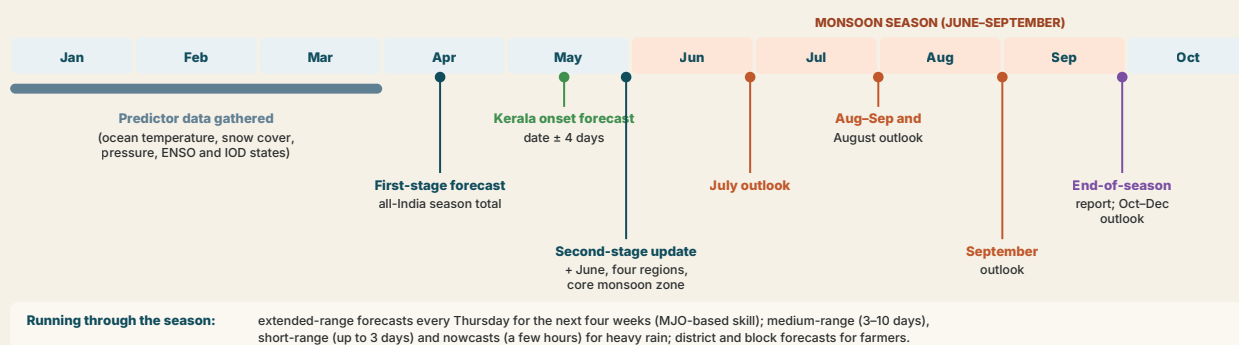


Fig. 12.19 The seasonal forecast is built on ocean and atmosphere conditions up to March, issued in mid-April and updated at the end of May; monthly and regional outlooks and weekly extended-range forecasts follow during the season.

The 2026 forecasts show both the progress and the limits. The April forecast of 92% and the May update of 90% both correctly expected a below-normal season, and the actual 87% was within the stated error, but the onset over Kerala came nine days after the forecast date. The difficulty is built in: the year-to-year signal is small (about 10% of the mean), the atmosphere is chaotic, models struggle to see past the **spring predictability barrier** of ENSO, and breaks and MJO pulses can turn a forecast normal season into a poor one.

Mission Mausam

- Approved by the Union Cabinet in **September 2024** with an outlay of about ₹2,000 crore for its first two years, and launched in January 2025 on IMD's 150th foundation day, **Mission Mausam** aims to make India "weather-ready and climate-smart".
- It is run by IMD, IITM Pune and the National Centre for Medium Range Weather Forecasting under the Ministry of Earth Sciences. It adds Doppler weather radars, wind profilers, radiometers and other observations; builds higher-

resolution models with artificial intelligence and machine learning; and supports research on weather management, including cloud physics and cloud seeding at a cloud chamber at IITM.

- In 2025 IITM introduced the **Bharat Forecast System**, a global weather model with a grid of about 6 km, among the finest of any operational global model.

PRELIMS POINTER

The **ocean mean temperature (OMT)**, the average temperature of the upper south-western Indian Ocean down to the 26 °C isotherm in January–March, was shown by IITM scientists to predict the monsoon better than sea-surface temperature alone. UPSC asked about it in 2020.

14 Monsoon, Agriculture and the Economy

The monsoon has been called the real finance minister of India. Agriculture and allied activities provide about a sixth of the country's gross value added and employ close to half of its workers, and about half of the net sown area is still rain-fed.

- **Kharif sowing** of rice, pulses (tur, moong, urad), oilseeds (soybean, groundnut), cotton, maize and millets follows the onset; a late onset or a long break in July delays sowing and can force a switch to shorter-duration crops.
- **Reservoirs and groundwater.** Monsoon rain refills the storage that serves the rabi season, drinking water and hydroelectric power; the Central Water Commission tracks over 150 major reservoirs weekly. Recharge of groundwater in the alluvial plains depends on it.
- **Prices and demand.** A poor monsoon raises food inflation, particularly of pulses, vegetables and edible oils, cuts rural incomes and demand for goods, and weighs on growth; the Reserve Bank watches the monsoon closely.
- **Hazards.** Intense spells bring floods, landslides and soil erosion; failures bring drought (Chapter 16).
- **Society and culture.** The rains shape the agricultural calendar, migration, festivals and songs across the country: teej, kajari and the songs of the purvaiya in the Gangetic plain, Onam after the rains in Kerala, the Pongal harvest after the north-east monsoon in Tamil Nadu.



Fig. 12.20 Ploughing after the first monsoon showers in the Western Ghats of Maharashtra.



Fig. 12.21 A flooded paddy field in Raichur district, Karnataka, in July 2025, a good monsoon year.

15 The Changing Monsoon

The monsoon is changing, though not in one simple direction.

Fewer Rainy Days, More Extreme Rain

- All-India seasonal rain weakened in the second half of the twentieth century and has partly recovered since the early 2000s, with no clear long-term trend. What has changed more is how the rain falls.
- Over central India, widespread **extreme rain events** (more than 150 mm in a day) roughly tripled between 1950 and 2015, while moderate rain days declined. Warmer air holds about 7% more water vapour per °C, and moisture from

the warming Arabian Sea feeds these bursts. IMD's station reports of very heavy and extremely heavy rain were especially high in 2024 and 2025.

- Dry spells within the season have also lengthened in many areas, so floods and droughts can now affect the same district in one season.

A Shifting Pattern

- A tehsil-level study of the decade 2012–2022 found that about 55% of tehsils, many in traditionally dry Rajasthan, Gujarat, central Maharashtra and Tamil Nadu, received more south-west monsoon rain than in 1982–2011, while about 11%, mostly in the Indo-Gangetic plain, the north-east and the Himalaya, received less.
- The recent seasons fit this: in 2025 North-west India had 127% of its normal, its highest since 2001, while East and North-east India had its second-lowest rain since 1901; in 2026 the east and north-east had its lowest.
- Researchers disagree about the causes and permanence. Some see a westward or north-westward spread of monsoon rain into the arid zone and more depressions tracking across the north; others stress the drying of the Indo-Gangetic plain and the north-east, a weaker land–sea temperature contrast as the Indian Ocean warms faster, and more frequent interaction of monsoon systems with western disturbances over the Himalaya.

Aerosols, Land Use and Global Warming

- **Aerosols.** Sulphate and other reflecting particles from fuel burning cool the land surface and weaken the land–sea contrast, and have been linked to the decline in monsoon rain in the late twentieth century. Absorbing aerosols such as black carbon and dust can warm the air over north India and the Himalayan foothills in spring and change where and when rain falls.
- **Land use.** Irrigation cools and moistens the plains of the north-west; deforestation reduces moisture recycling; cities create heat islands and their paved surfaces turn heavy rain into floods, as in Mumbai in July 2005 and Chennai in 2015.
- **Global warming.** Climate assessments expect South Asian monsoon rain to increase over the twenty-first century as the air holds more moisture, with larger swings from year to year and more extreme rain, even though the circulation itself may weaken.

USING THIS CHAPTER IN MAINS

- **Mechanism answers:** never rely on one theory. Start with the land–sea contrast and the ITCZ shift, add the upper air (STJ jump, Tibetan high, TEJ) and the Somali jet, then the ocean modulators (ENSO, IOD, EQUINOO, MJO). Draw Fig. 12.6 or 12.7; a sketch of the monsoon cell earns marks.
- **Distribution and branches:** use Fig. 12.11 to explain the windward–leeward contrast of the Ghats, Mawsynram, the dry Tamil Nadu coast in summer and the east-to-west decline over the plains.
- **Variability and impact (GS I, III):** quote the LPA (87 cm, 1971–2020), the categories, and the 2025 (108%) and 2026 (87%) seasons; link breaks and El Niño to kharif output, inflation and drought management.
- **Change:** extreme rain events, shifting regional pattern, aerosols and urban flooding; close with forecasting (multi-model ensemble, extended-range forecasts, Mission Mausam) and adaptation such as crop planning, storage and early warning.
- **Culture questions** (purvaiya, monsoon Asia): connect the wind's direction and timing to the farming calendar, festivals and folk songs.



Previous Year Questions

Prelims

2020

With reference to Ocean Mean Temperature (OMT), which of the following statements is/are correct?

1. OMT is measured up to a depth of 26°C isotherm which is 129 meters in the south-western Indian Ocean during January–March.
2. OMT collected during January–March can be used in assessing whether the amount of rainfall in monsoon will be less or more than a certain long-term mean.

Select the correct answer using the code given below:

☐ a 1 only

☒ b 2 only

☐ c Both 1 and 2

☐ d Neither 1 nor 2

Answer: (b). The 26 °C isotherm lies at roughly 50–100 m there, not 129 m; January–March OMT is a useful predictor of the monsoon (Section 13).

2017

With reference to 'Indian Ocean Dipole (IOD)' sometimes mentioned in the news while forecasting Indian monsoon, which of the following statements is/are correct?

1. IOD phenomenon is characterised by a difference in sea surface temperature between tropical Western Indian Ocean and tropical Eastern Pacific Ocean.
2. An IOD phenomenon can influence an El Nino's impact on the monsoon.

Select the correct answer using the code given below:

☐ a 1 only

☒ b 2 only

☐ c Both 1 and 2

☐ d Neither 1 nor 2

Answer: (b). The IOD compares the western and eastern tropical Indian Ocean, not the Pacific; a positive IOD can offset El Niño, as in 1997 and 2023 (Section 07).

2014

The seasonal reversal of winds is the typical characteristic of

☐ a Equatorial climate

☐ b Mediterranean climate

☒ c Monsoon climate

☐ d All of the above climates

Answer: (c). A seasonal reversal of winds is the definition of a monsoon (Section 01).

2012

Consider the following statements:

1. The duration of the monsoon decreases from southern India to northern India.
2. The amount of annual rainfall in the northern plains of India decreases from east to west.

Which of the statements given above is/are correct?

☐ a 1 only

☐ b 2 only

☒ c Both 1 and 2

☐ d Neither 1 nor 2

Answer: (c). The monsoon arrives first in the south and leaves it last; the Bay branch loses moisture as it moves west up the Ganga plain (Sections 09 and 12).

2011

La Nina is suspected to have caused recent floods in Australia. How is La Nina different from El Nino?

1. La Nina is characterised by unusually cold ocean temperature in equatorial Indian Ocean whereas El Nino is characterised by unusually warm ocean temperature in the equatorial Pacific Ocean.
 2. El Nino has adverse effect on south-west monsoon of India, but La Nina has no effect on monsoon climate.
- Which of the statements given above is/are correct?

a 1 only

b 2 only

c Both 1 and 2

d Neither 1 nor 2

Answer: (d). La Niña is a cooling of the central and eastern equatorial Pacific, not the Indian Ocean, and it usually favours a normal or good monsoon (Section 07).

2009

Consider the following statements:

1. In the world, the tropical deserts occur along the western margins of continents within the trade wind belt.
2. In India, the East Himalayan region gets high rainfall from north-east winds.

Which of the statements given above is/are correct?

a 1 only

b 2 only

c Both 1 and 2

d Neither 1 nor 2

Answer: (a). The eastern Himalaya gets its heavy rain from the Bay of Bengal branch of the south-west monsoon, not from north-east winds (Section 09).

2004

Assertion (A): Bangalore receives much higher average annual rainfall than Mangalore.

Reason (R): Bangalore has the benefit of receiving rainfall both from south-west and north-east monsoons.

a Both A and R are individually true and R is the correct explanation of A

b Both A and R are individually true but R is not the correct explanation of A

c A is true but R is false

d A is false but R is true

Answer: (d). Mangaluru, on the windward side of the Western Ghats, gets several times the rain of Bengaluru, which lies in the rain-shadow, although Bengaluru does receive some rain from both monsoons (Sections 09 and 11).

2002

For short-term climatic predictions, which one of the following events, detected in the last decade, is associated with occasional weak monsoon rains in the Indian subcontinent?

a La Nina

b Movement of jet stream

c El Nino and Southern Oscillations

d Greenhouse effect at global level

Answer: (c). El Niño and the negative phase of the Southern Oscillation weaken the monsoon; La Niña usually strengthens it (Section 07).

1996

High temperature and low pressure over the Indian sub-continent during the summer season, draws air from the Indian Ocean leading to the in-blowing of the

a Southeast monsoon

b Southwest monsoon

c Trade winds

d Westerlies

Answer: (b). South-east trades drawn across the Equator are turned right by the Coriolis force and arrive as the south-west monsoon (Sections 02 and 04).

Mains

2023

GS I · 10 MARKS

Why is the South-West monsoon called 'Purvaiya' (easterly) in Bhojpur Region? How has this directional seasonal wind system influenced the cultural ethos of the region?

Approach: Use Fig. 12.11: the Bay branch is turned west up the Ganga plain by the Himalaya and the monsoon trough, so it reaches Bhojpur from the east; then its place in paddy transplanting, festivals, kajari and other folk songs, and the region's agricultural calendar (Sections 09 and 14).

2017

GS I · 15 MARKS

What characteristics can be assigned to monsoon climate that succeeds in feeding more than 50 percent of World population residing in Monsoon Asia?

Approach: Seasonal reversal; a reliable wet season coinciding with high temperatures; rain over fertile alluvial plains and deltas; two or three crops with residual moisture and the winter season; wet-rice cultivation; then note variability, breaks and the need for storage and irrigation (Sections 01, 12 and 14).

2015

GS I · 12.5 MARKS

How far do you agree that the behaviour of the Indian monsoon has been changing due to humanizing landscapes? Discuss.

Approach: Accept local human influences (aerosols, irrigation, deforestation, urban heat islands and urban floods) with examples, but show that most year-to-year variation comes from ENSO, the IOD and the MJO, and that global warming drives the rise in extreme rain (Sections 07 and 15).

2014

GS I · 10 MARKS

Most of the unusual climatic happenings are explained as an outcome of the El-Nino effect. Do you agree?

Approach: Explain how El Niño shifts the Walker circulation and weakens the Indian monsoon, then show its limits with India's record: 1997 and 2023 (positive IOD), deficits without El Niño, and the role of the MJO, IOD and warming (Sections 07 and 12).

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