

Climate, weather, tides, cyclones and storm-surge history of the Indian Sundarban (West Bengal)

1) Why Sundarban weather feels “different”

The Indian Sundarban sits right on the land–sea interface of the Ganga–Brahmaputra–Meghna delta.

Three big controls shape its climate and daily weather:

1. **The Bay of Bengal heat engine** (very warm sea-surface temperatures most of the year)
2. **The South Asian monsoon system** (seasonal wind reversal + moisture transport)
3. **A macrotidal, multi-channel estuary** (strong tides + salinity gradients + sediment and water exchange)

So, even if Kolkata is hot, the Sundarban often feels **more humid, wind-influenced, salt-affected, and storm-sensitive**—with sharp microclimatic differences between exposed mudflats, mangrove interiors, embanked croplands, and open estuarine water.

2) Baseline climate “with numbers” (1991–2020 normals)

Because the Sundarban is a watery archipelago (few long-term stations inside the core delta), it’s standard to use **nearby IMD coastal stations** as reference points:

- **Diamond Harbour (IMD station id 42811)** – Hooghly estuary margin / gateway zone
- **Digha (IMD station id 42901)** – open coast reference on the Bay of Bengal side

These IMD “Extreme & Climatological Data” tables provide month-wise **mean temperature, mean rainfall, rainy days, and occurrence-days of thunder/fog**, etc.

2.1 Month-wise climate table (IMD normals, Period: 1991–2020)

(A) Diamond Harbour (42811) – Monthly means

From IMD climatological table:

Month	Mean Temp (°C)	Mean Rainfall (mm)	Rainy Days	Thunder Days	Fog Days
Jan	13.9	25.4	1.1	0.4	15.3
Feb	17.9	29.1	1.3	0.8	7.0
Mar	22.8	32.7	1.7	2.3	2.7
Apr	25.8	34.0	2.9	4.6	0.1
May	26.8	34.3	6.1	6.6	0.0
Jun	27.2	33.5	12.2	7.3	0.0
Jul	26.8	32.1	16.7	6.7	0.0
Aug	26.8	32.2	17.0	6.9	0.0
Sep	26.5	32.4	13.2	7.3	0.0
Oct	24.6	32.3	6.1	3.4	0.4
Nov	19.9	30.2	1.6	0.7	1.8
Dec	15.1	26.8	0.5	0.3	10.8
Annual	22.8	31.3	80.4	47.4	38.1

Note: IMD’s “Mean Rainfall (mm)” is shown month-wise; the **annual rainfall total** is given separately as **1739.0 mm**.

(B) Digha (42901) – Monthly means

From IMD climatological table:

Month	Mean Temp (°C)	Mean Rainfall (mm)	Rainy Days	Thunder Days	Fog Days
Jan	13.9	25.6	1.1	0.2	4.9
Feb	18.1	28.2	1.3	1.7	3.6
Mar	22.9	31.3	1.8	4.2	1.1
Apr	25.7	32.7	3.5	8.4	0.0
May	26.7	33.5	6.2	10.6	0.0
Jun	27.1	33.1	10.2	10.1	0.0
Jul	26.7	32.0	13.7	9.6	0.0
Aug	26.5	31.8	14.1	10.6	0.0
Sep	26.2	32.1	12.1	11.0	0.0
Oct	23.9	31.8	7.5	7.6	0.2
Nov	19.1	29.8	1.8	0.6	0.4
Dec	14.5	26.9	0.6	0.2	1.9
Annual	22.6	30.7	73.9	74.6	12.1

IMD gives **annual rainfall** here as **1759.6 mm**.

Quick interpretation:

- Rainfall totals are similar (~1.74–1.76 m/year), but **thunder-day frequency is much higher at Digha** in these normals (open-coast convection + sea-breeze interactions) while **fog is far higher at Diamond Harbour** (river/estuary moisture + winter inversions).

3) Season-wise climate of the Sundarban delta (India)

3.1 Winter (Dec–Feb): “cool”, very humid, fog-prone

Weather character

- Cooler nights, mild days; humidity stays high due to tidal water + wetlands.
- Frequent **radiation fog / haze** especially along estuarine margins and inland embanked areas.

What IMD normals show

- Fog days peak in **Jan & Dec** at Diamond Harbour (10–15 fog-days/month in the normals).
- Winter rainfall is low (mostly western disturbances’ weak influence + occasional coastal lows).

Sundarban-specific notes

- Cold stress for fish/prawn seed is generally limited compared to north India, but sudden cool spells can affect **disease dynamics in brackish aquaculture** (especially when water exchange is restricted).

3.2 Pre-monsoon / “Kalbaisakhi” & Nor’wester season (Mar–May)

This is one of the most important seasons for **high-impact short-duration hazards**.

Key processes

- Strong surface heating → instability
- Sea-breeze fronts interacting with dry/hot continental air

- Thunderstorms, squalls, lightning, isolated hail (more inland), and **violent gust fronts**

Signals in IMD normals

- Thunder days rise sharply from March onward; at Digha they are very high in Apr–May.
- Rainfall increases before monsoon onset (Apr–May rain is often convective + storm-linked).

Cyclone link

- Bay of Bengal has a known **pre-monsoon cyclone window (Apr–May)** (see cyclone climatology section below).
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3.3 Southwest monsoon (Jun–Sep): humid, cloudy, rain in pulses

Weather character

- Persistent humidity, heavy cloud cover.
- Rainfall often arrives in **multi-day spells** associated with monsoon lows/depressions moving inland.

What the station normals show

- Most rainy days occur Jun–Sep (e.g., Diamond Harbour ~12–17 rainy days/month during Jun–Aug).
- Peak monthly rainfall totals in the monsoon core months (Jul–Sep).

Sundarban hydrology

- Freshwater influx from upstream + local rainfall reduces salinity seasonally.
 - Turbidity and sediment loads rise; creek and estuary dynamics can shift quickly after strong discharge episodes.
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3.4 Post-monsoon / Retreating monsoon (Oct–Nov): cyclone peak, surge-sensitive season

This is the **highest-risk season for severe cyclones** impacting the West Bengal–Bangladesh coast. RSMC/IMD climatology notes that Bay of Bengal cyclones strike **Odisha–West Bengal more often in October**, with seasonal shifts further south later in the year.

Weather character

- Clearer skies return between systems, but humidity remains high.
- Short bursts of extreme rainfall and gale winds occur when cyclonic systems approach.

Sundarban-specific hazard

- **Storm surge + high tide coincidence** can trigger embankment breaches, saline inundation, and long-term waterlogging.
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4) Tidal dynamics of the Indian Sundarban: what matters for ecology + disasters

4.1 The Sundarban is macrotidal and “tide-dominated”

The delta is carved by a dense network of tidal creeks and estuaries; tides propagate inland and interact with channel geometry (convergence/shalowness) and river discharge.

A numerical study of tidal propagation in the Hooghly estuary reports amplification of tidal range from **~5 m near the mouth (off Sagar Island)** to about **5.6 m** further upstream near Hooghly Point (order ~80 km inland), driven by convergence effects.

4.2 Spring–neap cycle, tidal asymmetry, and residual transport

Even without a cyclone, tides generate:

- Strong bidirectional currents that move fine sediment, nutrients, detritus
- Flood/ebb dominance patterns that influence channel siltation and erosion
- Salinity intrusion patterns (especially in the dry season)

These are not just “oceanography details”—they decide:

- where mangroves expand/retreat,
- where mudflats build up,
- and where embankments face chronic scouring.

4.3 Tide–surge interaction: why timing is everything

Storm surge impacts are dramatically amplified when:

- a cyclone makes landfall near spring tide,
- surge coincides with peak astronomical tide,
- and water is funneled into estuaries (estuarine “surge penetration”).

This is why two cyclones of similar wind strength can create very different flood outcomes in the Sundarban.

5) Cyclone climatology for West Bengal–Sundarban sector

5.1 Cyclone formation and landfall patterns (Bay of Bengal)

RSMC/IMD summarizes that:

- Over **60%** of Bay of Bengal tropical cyclones strike India’s east coast,
- ~30% strike Bangladesh/Myanmar,
- and Bay cyclones more often strike **Odisha–West Bengal in October**.

For basin-scale long-term cyclone track data, **IBTrACS (NOAA/NCEI)** is the standard global best-track archive merging multiple agencies.

5.2 What has changed (signal vs noise)

Peer-reviewed work on the North Indian Ocean indicates changes in cyclone characteristics in recent decades (e.g., intensity, rapid intensification, seasonality), but results differ by metric, period, and dataset. A recent Climate Dynamics paper specifically discusses “changing status” of tropical cyclones over the north Indian Ocean.

For the Sundarban risk picture, the most robust story is not just “more cyclones,” but:

- **higher coastal exposure** (population, assets, embankments),
- **sea-level rise + subsidence** increasing baseline water levels,
- and **high-confidence warming** increasing extreme rainfall potential.

6) Storm surge and coastal inundation: what the literature shows

6.1 Typical surge heights in major events

- A numerical modeling study of Cyclone **Aila (2009)** estimated maximum storm surge around **~4 m along the Sundarban region** (ADCIRC-based analysis).

- For Cyclone **Amphan (2020)**, a peer-reviewed synthesis reports the Bengal coast experienced about **3–5 m storm surge above astronomical tide**.

These values should be interpreted as **coast/estuary-wide maxima or event maxima**, not “everywhere surge height.” Local water level depends on bathymetry, channel orientation, and tide phase.

7) Hydrometeorological history (last ~50 years): cyclones & surge-relevant events

You asked for “month-wise and season-wise climate” *plus* “cyclone, storm surge during last 50 years” and an overall **hydrometeorological history, status, trend**. Below is a **risk-focused chronology** emphasizing events that strongly affected the West Bengal delta/Sundarban sector.

Data note: For 1982 onward, IMD/RSMC maintains best-track archives and event documentation; for long historical baselines, IBTrACS is the global reference.

7.1 1970s–1980s: high-impact cyclones remain part of the regional baseline

The 1970 Bhola cyclone is outside your 50-year window but it frames the Bengal delta’s surge vulnerability. For the post-1975 decades, multiple severe cyclones affected the West Bengal–Bangladesh sector; detailed event-by-event surge reconstructions vary by study and dataset (and many older events lack today’s quality of surge observations).

Practical takeaway: Sundarban hazard planning should assume **rare but catastrophic surge events are “normal” in the long-term climatology**, not anomalies.

7.2 1990s–2000s: embankment exposure grows; Aila becomes a turning point

Cyclone Aila (May 2009)

Aila is often considered a modern benchmark for Sundarban embankment-failure risk.

- IFRC noted **~5.1 million people affected** in West Bengal.
- Modeling work estimated **~4 m maximum storm surge** along Sundarban for Aila.

Why Aila matters technically

- Surge water penetrated estuarine channels; embankment breaches produced salinity contamination and prolonged waterlogging—effects that last beyond the “storm day.”

7.3 2010s: Bulbul and the return of strong post-monsoon cyclone risk

Cyclone Bulbul (Nov 2019)

Bulbul made landfall over India and then moved toward Bangladesh; it significantly affected coastal West Bengal and the Sundarban fringe.

Risk lesson

- Post-monsoon cyclones often bring **moderate-to-severe surge + heavy rainfall**, and can cause widespread treefall and infrastructure damage even if peak winds are lower than a super cyclone.

7.4 2020s: compound extremes (surge + rain + sea-level rise baseline)

Cyclone Amphan (May 2020)

Amphan crossed the West Bengal coast across the Sundarban as a very severe cyclonic storm; IMD’s public communication around Amphan reported very high winds at landfall, and a dedicated IMD report exists.

Scientific synthesis reports **3–5 m storm surge above astronomical tide** on the Bengal coast during Amphan.

Cyclone Yaas (May 2021)

IMD/RSMC bulletins and reports document Yaas and its track and warnings for Odisha–West Bengal coasts.

Even when landfall is not directly on the Sundarban core, **water levels can rise in deltaic channels** due to surge and wind setup combined with tide.

Cyclone Remal (May 2024)

IMD national bulletin indicates landfall/impact zone over **Bangladesh and adjoining West Bengal coasts**, with close relevance to Sagar Islands/Canning sector.

Relief assessments document impacts in West Bengal after Remal.

8) Sea level rise and baseline water level: why today's surges start "higher"

A core reason recent cyclones feel more flood-destructive is that **baseline coastal water level is rising**, and parts of the delta also experience **land subsidence** (natural + human-driven).

For the **Diamond Harbour tide gauge**, the PSMSL station provides long sea-level records and documentation.

A derived analysis of monthly mean sea level at Diamond Harbour (using that record) estimates a long-term trend of about **+3.69 mm/year** (with stated uncertainty bounds in that analysis).

Interpretation caution (important):

- Tide-gauge sea level is **relative sea level** (ocean rise + local land motion).
 - In deltas, *relative* sea-level rise can be larger than global mean due to subsidence.
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9) Month-wise "weather narrative" for Sundarban planning (what people experience)

Below is a **practical month-wise hazard + ecology lens** built on the IMD normals and known Bay-of-Bengal seasonality.

January

- Coolest period; fog/haze common (especially estuary margins).
- Low rainfall; high humidity persists.

February

- Gradual warming; fog decreases; comfortable field season.

March

- Rapid warming; thunderstorms begin increasing.
- First lightning-risk season for fishers and field teams.

April

- Hot, humid; intense thunderstorms, squalls; high lightning risk.
- Early heat stress + high evapotranspiration affects soil salinity dynamics in embanked agriculture.

May

- Peak thermal stress; frequent severe thunderstorms; **pre-monsoon cyclone window**.
- Salinity often high before monsoon freshening; cyclone surge at this time can push saline water deep into embanked lands.

June

- Monsoon onset phase; rain becomes more organized; high cloud cover.

July–August

- Core monsoon; maximum rainy days and heavy rainfall totals.
- River discharge + rainfall reduce salinity; turbidity rises; fish nursery dynamics shift.

September

- Monsoon weakens but heavy spells still possible; thunder remains frequent.

October

- Retreating monsoon; **classic cyclone peak for Odisha–West Bengal sector**.
- Clear spells between systems increase diurnal temperature range; humidity stays high.

November

- Transition to drier season; cyclone risk still present though decreasing; pleasant field season returns.

December

- Mild; fog begins rising again; calm weather windows for surveys and restoration works.
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10) “Status and trend” summary: what risk managers should assume now

(A) Climate baseline

- Warm-humid tropical monsoon regime with ~1.7–1.8 m annual rainfall at nearby coastal stations.
- Two high-impact transition seasons: **Apr–May** and **Oct–Nov**.

(B) Tides and estuary physics

- Macrotidal dynamics with tidal amplification in estuaries (Hooghly example: ~5 m to ~5.6 m).
- Surge is not just “coastal”—it can **propagate through estuarine channels**.

(C) Cyclone + surge hazard

- Surge heights in major events can reach several meters (Aila modeling ~4 m; Amphan synthesis 3–5 m above astronomical tide).
- Greatest disaster risk comes from **compound flooding**: surge + tide + heavy rain + river discharge + embankment failure.

(D) Rising baseline water levels

- Tide-gauge–based analyses at Diamond Harbour indicate multi-decadal relative sea-level rise on the order of a few mm/year.
 - This means: **the same cyclone today can flood more deeply than decades ago**, even before considering land-use change.
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11) Bibliography / References (starter list; high-value for a book chapter)

Authoritative data / official sources

1. India Meteorological Department (IMD). *Extreme & Climatological Data (1991–2020)* for Diamond Harbour (42811).
2. India Meteorological Department (IMD). *Extreme & Climatological Data (1991–2020)* for Digha (42901).
3. RSMC New Delhi (IMD). *Landfall climatology (1891–2022)* (web resource).

4. NOAA/NCEI. *International Best Track Archive for Climate Stewardship (IBTrACS)* (dataset description).
5. PSMSL. *Diamond Harbour tide-gauge station documentation and data access*.

Tide/estuary dynamics

6. Savenije, H.H.G. et al. (via Ocean Engineering article page). *Tidal propagation and amplification in Hooghly estuary (convergence effects)*.

Cyclone case studies & surge/inundation science

7. (Aila) *Numerical Study on Storm Surge and Associated Coastal Inundation for 2009 Aila cyclone using ADCIRC* (ScienceDirect page).
8. (Amphan) Springer (peer-reviewed PDF): *Complete study / synthesis on Cyclone Amphan; reports ~3–5 m surge above astronomical tide*.
9. IMD/RSMC. *Cyclone Amphan Report (16–21 May 2020): A Report* (PDF).
10. IMD/RSMC. *Preliminary Report: Cyclone Yaas (May 2021)* (PDF).
11. IMD. *Cyclone Remal national bulletin/advisory* (PDF).

Trend / climatology research

12. *Changing status of tropical cyclones over the north Indian Ocean* (Climate Dynamics article page).
13. *Spatio-temporal behaviours of tropical cyclones over the Bay of Bengal (1971–2020)* (ScienceDirect page).

Sea-level trend (derived visualization using tide-gauge record)

14. SeaLevel.info. *Diamond Harbour MSL trend visualization derived from PSMSL/NOAA station series*.