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Five Decades of Temperature Change in Bangladesh: Trends in Mean Temperature, Day-to-Day Variability, and Abrupt Temperature Shifts, 1975-2024

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Abstract

Long-term warming and short-term thermal variability are distinct climate properties, yet their joint evolution in Bangladesh has received limited attention. We analyzed daily average dry-bulb temperature observations obtained from the Bangladesh Meteorological Department for 43 stations during 1975–2024; 24 long-record stations were retained after reproducible quality control and completeness screening. Day-to-day temperature variability (DTV) was defined as the absolute difference between genuinely consecutive calendar days, and station-standardized 1991–2020 anomalies were aggregated to an equal-station observational network index. Sen slopes and Mann-Kendall tests were supplemented by trend-free prewhitening, Hamed-Rao variance-corrected Mann-Kendall inference, breakpoint screening, multiplicity adjustment, geographic weighting and fixed-station-network sensitivities. Annual mean temperature increased by 0.086°C decade^{-1} (95% CI 0.029 to 0.144; TFPW $p < 0.001$; Hamed-Rao $p = 0.004$), whereas annual mean DTV changed by -0.004°C decade^{-1} (95% CI -0.013 to 0.007; $p = 0.605$ and 0.442, respectively). The primary DTV ≥ 3°C event frequency also showed no statistically detectable trend (-0.411 equivalent days yr^{-1} decade^{-1}; TFPW $p = 0.196$; Hamed-Rao $p = 0.101$). The absence of a statistically detectable mean-DTV trend persisted after excluding three breakpoint-flagged stations, geographic reweighting and a strict fixed 3-station panel. The retained Bangladesh station network therefore warmed without a parallel long-term trend in mean consecutive-day temperature variability.

1. INTRODUCTION

Anthropogenic climate change is usually summarized through changes in mean temperature and the frequency or intensity of extremes, but these measures do not fully describe how temperature evolves from one day to the next. High-frequency temperature variability is a distinct property of climate: two regions can experience comparable long-term warming while displaying very different short-term thermal behavior. Long instrumental records and model-based studies have long suggested that high-frequency variability need not change in step with the mean state (Karl et al. 1995; Moberg et al. 2000). Consequently, a complete description of regional warming requires attention not only to whether temperatures are rising, but also to whether the sequence of daily temperatures is becoming more or less variable.

Day-to-day temperature variability (DTV) provides a direct measure of that short-timescale behavior. In its simplest form, DTV is the absolute difference in temperature between two consecutive days. This quantity captures the magnitude of the thermal transition experienced from one day to the next, rather than the absolute temperature on either day. Short-term temperature variability is increasingly recognized as relevant to human and socioeconomic systems: multi-country epidemiological evidence links temperature variability with mortality risk (Guo et al. 2016), and global economic analysis indicates that greater day-to-day variability can reduce regional economic growth independently of annual mean temperature (Kotz et al. 2021). These impact studies do not all use exactly the same DTV definition as the present work, but they establish an important point: variability at short time scales carries information that annual or seasonal mean temperature alone cannot represent.

DTV must also be distinguished from diurnal temperature range (DTR). DTR is the difference between maximum and minimum temperature within the same calendar day, whereas DTV measures the transition between successive days. The two quantities therefore describe different components of the thermal climate. A region may simultaneously experience rising mean temperature, decreasing DTR, stable mean DTV and changing frequencies of large interday transitions. Conflating these metrics can obscure whether climate change is altering the thermal level, the within-day amplitude, or the continuity of temperature from one day to the next.

International research on consecutive-day temperature change has expanded rapidly. Zhou et al. (2020) examined sudden day-to-day changes exceeding 10°C and found decreasing frequencies across many historically active mid- and high-latitude regions, emphasizing the role of topography, circulation and strong winds. Wang et al. (2025) used essentially the same absolute consecutive-day temperature-difference concept employed here and showed pronounced seasonal and regional structure in observed and reanalysis DTV across China. Shi and Wu (2025) demonstrated that urbanization can modify observed DTV trends and that the direction of the effect varies geographically. Hamal and Pfahl (2025) linked extreme day-to-day changes to changes in air-mass transport and synoptic circulation, while their future-climate analysis showed strong latitude- and season-dependent responses (Hamal and Pfahl 2026). At the global scale, Chen et al. (2025) reported declining average day-to-day differences in maximum and minimum temperature from 2000–2022 while population exposure continued to increase. In contrast, Liu et al. (2026), using percentile-defined extreme day-to-day changes, found increasing frequency and intensity across many low- and mid-latitude regions. These apparently different results are not contradictory: they use different metrics, thresholds and climatic regimes, and together they show why both the mean behavior and the upper tail of consecutive-day change should be evaluated explicitly rather than inferred from warming alone.

Bangladesh is an especially relevant setting for such an analysis because the country's long-term warming signal is well established, yet the literature has concentrated on other dimensions of temperature change. Shahid (2010), using observations from 17 stations during 1958–2007, reported nationally averaged warming of mean, maximum and minimum temperature, with stronger warming in winter. That work provided an important baseline for understanding Bangladesh's changing thermal climate, but it focused on the temperature level and seasonal mean behavior rather than the magnitude of transitions between consecutive days.

Subsequent Bangladesh studies substantially broadened the picture but still left the interday-variability dimension largely unresolved. Shahid et al. (2012) analyzed DTR at 18 stations during 1961–2008 and showed that within-day temperature range exhibited strong seasonal and regional structure even while maximum and minimum temperatures increased. Imam et al. (2022) revisited DTR over Bangladesh for 1981–2015 and further characterized its spatial and temporal variability. Imran et al. (2023) evaluated 29 temperature- and precipitation-extreme indices from a high-resolution gridded observational dataset for 1981–2020, documenting substantial changes in warm and cold extremes. Haider et al. (2024) used 26 stations during 1975–2019 to examine trends, modified trends, sub-trends, homogeneity and

conventional climate-extreme indices, providing one of the most comprehensive recent station-based assessments of Bangladesh climate change. These studies are valuable precisely because they establish that warming, DTR and standard extremes are changing in complex ways; however, none of those metrics directly quantifies the absolute change in mean temperature from one day to the next.

The literature has also moved toward impact-oriented thermal indicators. Kamal et al. (2024) showed that wet-bulb globe temperature and the number of days associated with high or extreme heat-stress risk have increased across Bangladesh, with especially important changes during the pre-monsoon and monsoon seasons. Such work demonstrates the growing societal relevance of Bangladesh's changing thermal environment, but heat-stress indices combine temperature with humidity, radiation and wind and therefore characterize a different aspect of thermal conditions from DTV. Taken together, the Bangladesh evidence is now strong on warming, DTR, standard temperature extremes and heat stress, but comparatively weak on whether the temporal continuity of daily temperature itself has changed over multiple decades.

That gap matters scientifically. A warmer climate does not necessarily imply a more volatile climate from one day to the next. Mean DTV may increase, decrease or remain broadly stable while the background mean rises. Moreover, the mean of the DTV distribution and its upper tail need not move together: typical interday variability could remain stable even if the most abrupt transitions become more or less frequent. For Bangladesh, distinguishing among these possibilities is important because it clarifies what kind of thermal change has actually occurred and provides a more complete observational baseline for later work on health, agriculture, energy demand, atmospheric circulation and climate-model evaluation. The purpose of the present analysis is therefore not to introduce a new variability metric, but to apply a clearly interpretable and increasingly relevant metric to a long national station record in which it has received limited direct attention.

Long-term DTV analysis also places unusually high demands on data quality. Absolute differences between adjacent days can respond sharply to observation-time changes, station relocation, instrumentation changes and other discontinuities; Moberg et al. (2000) specifically noted the sensitivity of consecutive-day variability measures to changes in observing practice. Recent Climate Research work likewise demonstrates that homogenization can materially change estimated long-term temperature trends (He et al. 2023). For this reason, the present study treats station homogeneity, changing station composition and serial dependence as central inferential issues rather than peripheral technical checks. The primary station-network results are accompanied by breakpoint-exclusion, geographic-weighting, fixed-station-panel and serial-dependence-adjusted sensitivity analyses.

Accordingly, this study evaluates whether five decades of warming across a long-record Bangladesh station network were accompanied by a parallel monotonic trend in mean DTV during 1975–2024. It also assesses whether the frequency of operationally defined abrupt interday transitions changed, whether DTV trends differed by season and station, and whether the main conclusions remained stable under alternative treatments of station composition, inhomogeneity and serial correlation. By placing long-term

warming and consecutive-day variability within the same observational framework, the study addresses an underexamined dimension of Bangladesh's changing thermal climate and establishes a reproducible baseline for future process-based and impact-oriented research.

2. MATERIALS and METHODS

2.1 Study area and BMD observations

Bangladesh lies in the humid tropical South Asian monsoon region and exhibits pronounced seasonal temperature contrasts across a relatively compact geographic domain. The daily average dry-bulb temperature observations analyzed in this study originate from the Bangladesh Meteorological Department (BMD), Climate Division, Agargaon, Dhaka-1207, Bangladesh. The working data were supplied as comma-separated station-by-month files. Supporting BMD daily maximum- and minimum-temperature records were used only for quality-control corroboration. The available files do not document the historical observation schedule or formula used by BMD to derive daily average temperature; this uncertainty is therefore acknowledged as a measurement limitation.

Station labels in the analysis archive preserve the source-file spelling. For manuscript presentation only, several unambiguous names were standardized to current BMD usage (e.g. Barishal, Bogura, Cumilla, Jashore and Maijdi Court); station codes and coordinates were unchanged.

2.2 Quality control and station eligibility

The raw average-temperature file contained 43 station series. Calendar dates were reconstructed from station-year-month blocks, and invalid calendar cells were ignored. Quality control recoded 51 exact 0.0°C values as missing. Thirty coincided with missing supporting maximum and minimum temperatures; the remainder had positive maximum temperatures but missing minimum temperatures and several occurred in repeated patterns inconsistent with plausible daily averages. All 169 exact 37.8°C average-temperature entries were also recoded as missing: 168 had both supporting maximum and minimum values missing, the remaining case exceeded the reported maximum temperature, and repeated 37.8°C runs extended to 96 days. Record-level QC logs are supplied in the reproducibility package.

Two Rangpur month blocks labelled 2023-04 and 2023-07 were corrected to 2024-04 and 2024-07 because each occupied the corresponding position in the otherwise chronologically ordered 2024 sequence. Duplicate auditing identified 122 duplicate station-date records: 91 in Kumarkhali (90 conflicting and one identical/missing) and 31 identical/missing duplicates in Tetulia. Both stations were independently excluded by the long-record eligibility criteria, so no retained station contained an unresolved conflicting duplicate.

A station was eligible when its source record began in 1975 or earlier, extended through 2024, and retained at least 90% of the 18,263 expected daily observations after QC. Annual temperature metrics

required at least 90% daily coverage within each year; DTV and abrupt-event metrics required at least 90% of possible within-year consecutive-day DTV opportunities. Leap years used 366 expected daily observations/opportunities and other years used 365. These criteria retained 24 stations and excluded 19.

2.3 Day-to-day variability and abrupt-transition metrics

For station s and calendar date t, DTV was calculated only when temperatures were available on both date t and the immediately preceding calendar date:

$$DTV_{s,t} = |T_{s,t} - T_{s,t-1}|.$$

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A complete daily calendar was explicitly reindexed before differencing, so no DTV value was formed across a missing day. Annual station mean DTV was the mean of valid consecutive-day pairs. The primary abrupt-transition threshold was DTV ≥ 3°C. To retain comparability across station-years with occasional missing pairs, event counts were expressed as an equivalent annualized frequency: the observed event proportion among valid DTV opportunities multiplied by the number of calendar days in that year. Trend units are therefore equivalent days yr^{-1} $decade^{-1}$. Thresholds of 2.5 and 4°C were sensitivity outcomes; 3°C is an operational study threshold and is not claimed to be a universal climatological cutoff.

2.4 Network construction and seasons

To reduce bias from varying annual station availability, each retained station's annual outcome was converted to an anomaly from its own 1991–2020 mean. A baseline required at least 24 valid annual values (80% of the 30-year reference period); all 24 retained stations satisfied this requirement. For each year, the network anomaly was the arithmetic mean of available station anomalies, and the reported network value was that anomaly plus the arithmetic mean of station baselines. This quantity is interpreted as a station-standardized observational network index, not an area- or population-weighted national climate surface. Annual contributors ranged from 17 to 24 stations.

Seasons were winter (December-February), pre-monsoon (March-May), monsoon (June-September) and post-monsoon (October-November). December was assigned to the following winter year, giving a complete winter series for 1976–2024. Station-season DTV required at least 90% of expected seasonal DTV opportunities.

2.5 Trend inference, serial dependence and multiplicity

Monotonic trends were summarized using Sen's slope and tested using the Mann-Kendall statistic (Mann 1945; Sen 1968). These rank-based procedures provide distribution-light inference for climatic trends and do not require normality of the annual series. Slope uncertainty is reported as 95% Theil-Sen confidence intervals. The reported Theil-Sen confidence intervals summarize slope uncertainty from the

original annual series and are not presented as autocorrelation-adjusted intervals; sensitivity of significance inference to serial dependence was evaluated separately using TFPW and Hamed-Rao procedures. Statistical significance was evaluated at $\alpha = 0.05$ while interpreting effect magnitude, uncertainty and robustness jointly.

Serial dependence was addressed in two complementary ways. First, every national and seasonal series was analyzed with trend-free prewhitening (TFPW) following the logic of Yue et al. (2002): the Sen trend was removed, lag-1 correlation was estimated from the detrended series, the AR(1) component was removed, and the trend was restored before Mann-Kendall inference. Second, we independently applied the Hamed-Rao modified Mann-Kendall variance correction for autocorrelated data (Hamed and Rao 1998), implemented on Sen-detrended ranks with significant rank-autocorrelation lags contributing to the variance inflation factor. Sen slopes from the original series remained the principal effect-size estimates; TFPW and Hamed-Rao p-values were treated as complementary serial-dependence-adjusted sensitivity analyses.

The analysis hierarchy comprised three primary network outcomes: annual mean temperature, annual mean DTV and DTV ≥ 3°C event frequency. DTV ≥ 2.5°C and DTV ≥ 4°C were threshold sensitivities. For the three abrupt thresholds, both TFPW and Hamed-Rao p-values were evaluated with Benjamini-Hochberg false-discovery-rate and Bonferroni adjustments (Benjamini and Hochberg 1995). Station-level FDR correction was performed separately within each 24-test scientific family for mean temperature, mean DTV and DTV ≥ 3°C.

2.6 Homogeneity and network-composition sensitivities

Complete station-history metadata sufficient for formal relative homogenization were unavailable. We therefore used statistical breakpoint screening as a diagnostic sensitivity rather than automatically correcting series. For each station and annual outcome series separately, Sen-detrended annual mean-temperature and mean-DTV series were screened using the Pettitt test (Pettitt 1979), a standardized-normal-homogeneity (SNHT-form) maximum-shift statistic (Alexandersson 1986), and the Buishand cumulative-deviation Q statistic (Buishand 1982). SNHT-form and Buishand p-values were obtained from 4,999 permutations. For a given station-outcome series, a strong candidate-break flag was assigned when at least two of the three breakpoint tests produced $p < 0.01$ and their candidate break years fell within a five-year window. A station was flagged for the homogeneity sensitivity if either annual mean temperature or annual mean DTV met this strong-break rule. Primary outcomes were then recomputed after excluding flagged stations. These absolute screens identify candidate discontinuities but cannot prove an instrumental break without reference series and metadata.

Two network-composition sensitivities were added. First, stations were assigned to four broad geographic strata defined by 24 °N and 90.5 °E; station anomalies were averaged within strata and then averaged equally across available strata. Second, fixed-station panels were constructed to remove changing station composition entirely. Applying the same ≥ 90% annual temperature and DTV coverage criterion in every study year yielded a strict balanced panel of Dhaka, Ishurdi and Rajshahi. A relaxed ≥

80% fixed panel was also examined as a diagnostic; because it contained breakpoint-flagged Mymensingh and Satkhira, we additionally evaluated the corresponding 5-station panel after removing those flagged stations. The relaxed panels are sensitivity analyses and do not replace the 90% primary design.

2.7 Software and reproducibility

Analyses were performed in Python 3.13.5 using NumPy 2.3.5, pandas 2.2.3 and SciPy 1.17.0. The reproducibility package contains cleaning and DTV-construction scripts, breakpoint and trend analyses, the Hamed-Rao and fixed-network sensitivity code, QC and station audits, derived analytical data, numerical results, figure-generation scripts, software-version records and raw-file checksums. Original BMD observations are not redistributed because unrestricted redistribution permission was not established.

Detailed station audits, breakpoint diagnostics, threshold multiplicity results, fixed-network sensitivities, seasonal analyses and station-level results are provided in Online Resource 1.

3. RESULTS

3.1 Analytical network and DTV distribution

The 24 retained stations contributed 429,206 valid daily mean-temperature observations and 428,955 valid consecutive-day DTV pairs. Overall station completeness ranged from 93.8 to 100.0%. Daily mean temperature averaged 25.59°C. DTV was right-skewed (skewness 1.94), with mean 0.882°C, median 0.6°C, 95th percentile 2.5°C and 99th percentile 3.8°C. Eight valid DTV pairs exceeded 10°C; excluding them did not alter the central network conclusions.

Table 1
Summary of the analytical station network and study data. DTV = day-to-day temperature variability.

Characteristic	Value
Raw station series	43
Retained long-record stations	24
Excluded stations	19
Study period	1975–2024 (50 year)
Valid daily mean-temperature observations	429,206
Valid consecutive-day DTV pairs	428,955
Retained-station completeness	93.8–100.0%
Annual network contributors	17–24 stations
1991–2020 baseline support	24 of 24 retained stations

3.2 Warming without a parallel trend in mean DTV

The station-standardized observational network warmed clearly during 1975–2024 (Fig. 2A). Annual mean temperature had a Sen slope of 0.086°C decade^{-1} (95% CI 0.029 to 0.144). Classical Mann-Kendall inference gave $p = 0.004$, TFPW gave $p < 0.001$, and the Hamed-Rao modified test gave $p = 0.004$. Thus the warming inference was not sensitive to the serial-correlation treatment.

Mean annual DTV did not change in parallel with the background warming (Fig. 2B). Its Sen slope was −0.004°C decade^{-1} (95% CI -0.013 to 0.007), with classical $p = 0.437$, TFPW $p = 0.605$ and Hamed-Rao $p = 0.442$. The data therefore provide no statistically detectable monotonic trend in mean consecutive-day temperature variability over the retained network.

For the primary abrupt-transition threshold, DTV ≥ 3°C frequency had a Sen slope of -0.411 equivalent days yr^{-1} decade^{-1} (95% CI -0.842 to 0.128). The trend was not statistically detectable under classical ($p = 0.099$), TFPW ($p = 0.196$) or Hamed-Rao ($p = 0.101$) inference (Fig. 2C).

Table 2
Primary trends and threshold sensitivities. Confidence limits are 95% Theil-Sen intervals. DTV = day-to-day temperature variability; CI = confidence interval; TFPW = trend-free prewhitening; HR = Hamed-Rao modified Mann-Kendall; eq. days = equivalent days.

Class	Outcome	Sen slope (95% CI)	Unit	Classical p	TFPW p	HR p
Primary	Annual mean temperature	0.086 (0.029, 0.144)	°C decade⁻¹	0.004	< 0.001	0.004
Primary	Annual mean DTV	-0.004 (-0.013, 0.007)	°C decade⁻¹	0.437	0.605	0.442
Primary	Abrupt DTV ≥ 3°C	-0.411 (-0.842, 0.128)	eq. days yr⁻¹ decade⁻¹	0.099	0.196	0.101
Sensitivity	Abrupt DTV ≥ 2.5°C	-0.555 (-1.238, 0.208)	eq. days yr⁻¹ decade⁻¹	0.160	0.301	0.162
Sensitivity	Abrupt DTV ≥ 4°C	-0.272 (-0.486, -0.053)	eq. days yr⁻¹ decade⁻¹	0.016	0.020	0.016

3.3 Threshold and robustness analyses

The 2.5°C threshold also showed no statistically detectable trend (Sen slope − 0.555 equivalent days yr⁻¹ decade⁻¹; TFPW p = 0.301; Hamed-Rao p = 0.162). The 4°C threshold showed a nominal decline of -0.272 equivalent days yr⁻¹ decade⁻¹ (95% CI -0.486 to -0.053; TFPW p = 0.020; Hamed-Rao p = 0.016). Its multiplicity status depended on serial-correlation treatment: the three-threshold Benjamini-Hochberg adjusted p-value was 0.060 for TFPW but 0.049 for Hamed-Rao. This method dependence, together with the homogeneity sensitivity below, makes the ≥ 4°C result secondary rather than evidence for a general decline in abrupt transitions.

Breakpoint screening strongly flagged Mymensingh (candidate break approximately 1986), Patuakhali (1987) and Satkhira (1988). After excluding those stations, the warming slope increased to 0.114°C decade⁻¹ and remained highly detectable (TFPW p < 0.001; Hamed-Rao p < 0.001). Mean DTV was − 0.001°C decade⁻¹ (TFPW p = 0.959; Hamed-Rao p = 0.894), and the primary ≥ 3°C event slope was − 0.222 equivalent days yr⁻¹ decade⁻¹ (TFPW p = 0.605; Hamed-Rao p = 0.296). The ≥ 4°C slope weakened to -0.173 equivalent days yr⁻¹ decade⁻¹ and was no longer detectable (TFPW p = 0.228; Hamed-Rao p = 0.108).

Geographic reweighting also preserved the central result: annual mean temperature increased by 0.096°C decade⁻¹ (Hamed-Rao p < 0.001), mean DTV changed by -0.003°C decade⁻¹ (p = 0.532), and DTV ≥ 3°C changed by -0.423 equivalent days yr⁻¹ decade⁻¹ (p = 0.141).

The strict fixed-station panel, requiring the same ≥ 90% complete stations in all 50 years, contained only Dhaka, Ishurdi and Rajshahi. Despite its limited geographic coverage, it again showed warming (+ 0.130°C decade⁻¹; Hamed-Rao $p < 0.001$) with essentially zero mean-DTV trend (+ 0.0002°C decade⁻¹; $p = 0.973$) and no detectable ≥ 3°C event trend (-0.275 equivalent days yr⁻¹ decade⁻¹; $p = 0.408$). A relaxed 7-station ≥ 80% fixed panel did show declining DTV (-0.0145°C decade⁻¹; $p = 0.020$), but it contained breakpoint-flagged Mymensingh and Satkhira. Removing those two produced a 5-station fixed panel with a DTV slope of -0.0012°C decade⁻¹ ($p = 0.776$). This contrast identifies station homogeneity as the main sensitivity of the fixed-panel result rather than a failure of the primary network conclusion.

Table 3
Robustness of the three primary outcomes. Values are Sen slopes per decade with Hamed-Rao p-values in parentheses. DTV = day-to-day temperature variability. The column n gives the number of stations retained in each station-based sensitivity; for geographic reweighting, it gives the number of geographic strata. Temperature and DTV slopes are in °C decade⁻¹; event slopes are in equivalent days yr⁻¹ decade⁻¹.

Sensitivity analysis	n	Mean temperature	Mean DTV	DTV ≥ 3°C
Exclude 3 strong breakpoint flags	21	0.114 ($p < 0.001$)	-0.001 ($p = 0.894$)	-0.222 ($p = 0.296$)
Equal-weight 4 geographic strata	4 strata	0.096 ($p < 0.001$)	-0.003 ($p = 0.532$)	-0.423 ($p = 0.141$)
Strict fixed panel ≥ 90% every year	3	0.130 ($p < 0.001$)	0.000 ($p = 0.973$)	-0.275 ($p = 0.408$)
Fixed panel ≥ 80%, breakpoint flags removed	5	0.160 ($p < 0.001$)	-0.001 ($p = 0.776$)	-0.145 ($p = 0.588$)

3.4 Seasonal and station-level patterns

No season showed a statistically detectable network-wide mean-DTV trend under either TFPW or Hamed-Rao inference. The largest magnitude was pre-monsoon (-0.022°C decade⁻¹; 95% CI -0.050 to 0.007; TFPW $p = 0.088$; Hamed-Rao $p = 0.132$). Winter, monsoon and post-monsoon slopes were smaller. Full seasonal results are provided in Online Resource 1 (Table S5).

Station-level DTV slopes varied across the network: 10 were positive, 13 negative and one zero. After Benjamini-Hochberg correction within the 24-station DTV family, Rangpur showed an increasing DTV slope and Satkhira a decreasing slope. Because Satkhira was also strongly breakpoint-flagged, its station-specific trend is especially sensitive to possible discontinuity. The complete station-level forest plot and FDR results are provided in Online Resource 1 (Fig. S1 and Table S6).

4. DISCUSSION

4.1 Warming without parallel mean-DTV change

The clearest result is the contrast between background warming and mean consecutive-day temperature variability. Across the retained station network, annual mean temperature increased by about 0.086°C decade⁻¹, whereas mean DTV showed no statistically detectable monotonic trend. This central divergence survived two different treatments of serial dependence, exclusion of strongly breakpoint-flagged stations, geographic reweighting, and the strict fixed-station panel. The result is therefore not an artifact of using a single Mann-Kendall implementation or of year-to-year changes in station composition.

The warming magnitude is broadly comparable to earlier Bangladesh estimates, although direct numerical comparison is limited by different periods, station networks, quality control and aggregation. Shahid (2010) reported a national mean-temperature trend of approximately 0.10°C decade⁻¹ over 1958–2007. The present study extends the observation through 2024 but deliberately focuses on whether warming was accompanied by a parallel change in consecutive-day variability.

The lack of a network-wide mean-DTV trend is plausible in the context of the wider literature, where high-frequency variability shows substantial regional and seasonal structure rather than a universal response to warming (Karl et al. 1995; Moberg et al. 2000; Wang et al. 2025). Our result should therefore be interpreted as specific to this Bangladesh observational network, metric and period rather than as evidence for a general climatic law.

4.2 Abrupt transitions and the upper tail

The abrupt-transition analysis is more uncertain than the mean-DTV result. The primary 3°C threshold did not show a statistically detectable trend under classical, TFPW or Hamed-Rao inference. The stricter 4°C threshold declined nominally in the full network, but its multiplicity-adjusted status differed between TFPW and Hamed-Rao and the signal disappeared when three strongly breakpoint-flagged stations were excluded. It should therefore remain a secondary upper-tail observation, not a headline conclusion.

This caution is especially important given recent global results. Liu et al. (2026) reported increasing frequency and intensity of percentile-defined extreme day-to-day changes across many low- and mid-latitude regions, whereas Zhou et al. (2020) identified decreases in sudden day-to-day changes in other settings and definitions. These studies use different variables, thresholds and spatial frameworks from the present fixed 3°C operational threshold. The Bangladesh station-network result neither confirms nor refutes those global patterns; it shows that our primary absolute-threshold series does not establish a general decline.

4.3 Homogeneity, representation and limitations

Historical station homogeneity remains the principal vulnerability of the study. Three retained stations showed concordant strong breakpoint signals, and the relaxed fixed-panel analysis changed materially depending on whether two of those stations were included. This does not invalidate the primary network result—mean DTV remained essentially unchanged after their exclusion—but it demonstrates why more aggressive claims about the upper tail or individual stations would be unsafe. Formal relative

homogenization using verified station histories and appropriate reference series would be preferable if the necessary metadata become available (He et al. 2023).

Other limitations are more conventional. The historical BMD definition and observing schedule for daily average dry-bulb temperature were not documented in the supplied files. Equal-station aggregation and the four-stratum sensitivity do not create an area-weighted national surface, and station coverage is geographically uneven. National trend inference uses only 50 annual observations, while serial-dependence corrections are themselves method-dependent. Abrupt thresholds are operational, and multiple thresholds were examined. Finally, the observational design cannot attribute trends to urbanization, aerosols, irrigation, ENSO, monsoon circulation, land-use change or other mechanisms.

5. CONCLUSIONS

Five decades of observations from the retained Bangladesh station network show clear long-term warming without a parallel monotonic trend in mean day-to-day temperature variability. Annual mean temperature increased by approximately 0.086°C decade^{-1}, while mean DTV changed by only − 0.004°C decade^{-1} and was not statistically detectable under either trend-free prewhitening or Hamed-Rao modified Mann-Kendall inference.

The primary DTV ≥ 3°C event series likewise showed no statistically detectable trend. Evidence for a decline in the ≥ 4°C upper tail is fragile because its multiplicity status depends on the serial-correlation procedure and it disappears under the homogeneity-exclusion sensitivity. The most defensible conclusion is therefore not that abrupt changes generally declined, but that long-term warming and mean consecutive-day variability did not exhibit parallel trends across this observational network.

Future work would benefit most from verified BMD station-history metadata, formal relative homogenization and independent comparison with high-quality gridded or reanalysis products. Those additions would address the principal remaining uncertainty more directly than adding methodological complexity to the present trend analysis.

Declarations

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Competing interests

The authors have no relevant financial or non-financial interests to disclose.

Author contributions

Sujana Azmi Polin: Conceptualization; Methodology; Formal analysis; Validation; Visualization; Writing - original draft; Writing - review & editing; Supervision; Project administration; Correspondence. Hameem Ahsan: Methodology; Formal analysis; Data curation; Investigation; Visualization; Writing - review & editing. Both authors read and approved the final manuscript.

Data availability

The original daily meteorological observations analyzed in this study originate from the Bangladesh Meteorological Department (BMD). The observations are not publicly redistributed because unrestricted redistribution permission has not been established. Derived annual metrics, quality-control summaries and supporting analytical outputs are available from the corresponding author on reasonable request, subject to applicable BMD data-use conditions.

Code availability

Analysis code supporting the findings is available from the corresponding author on reasonable request.

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Figures

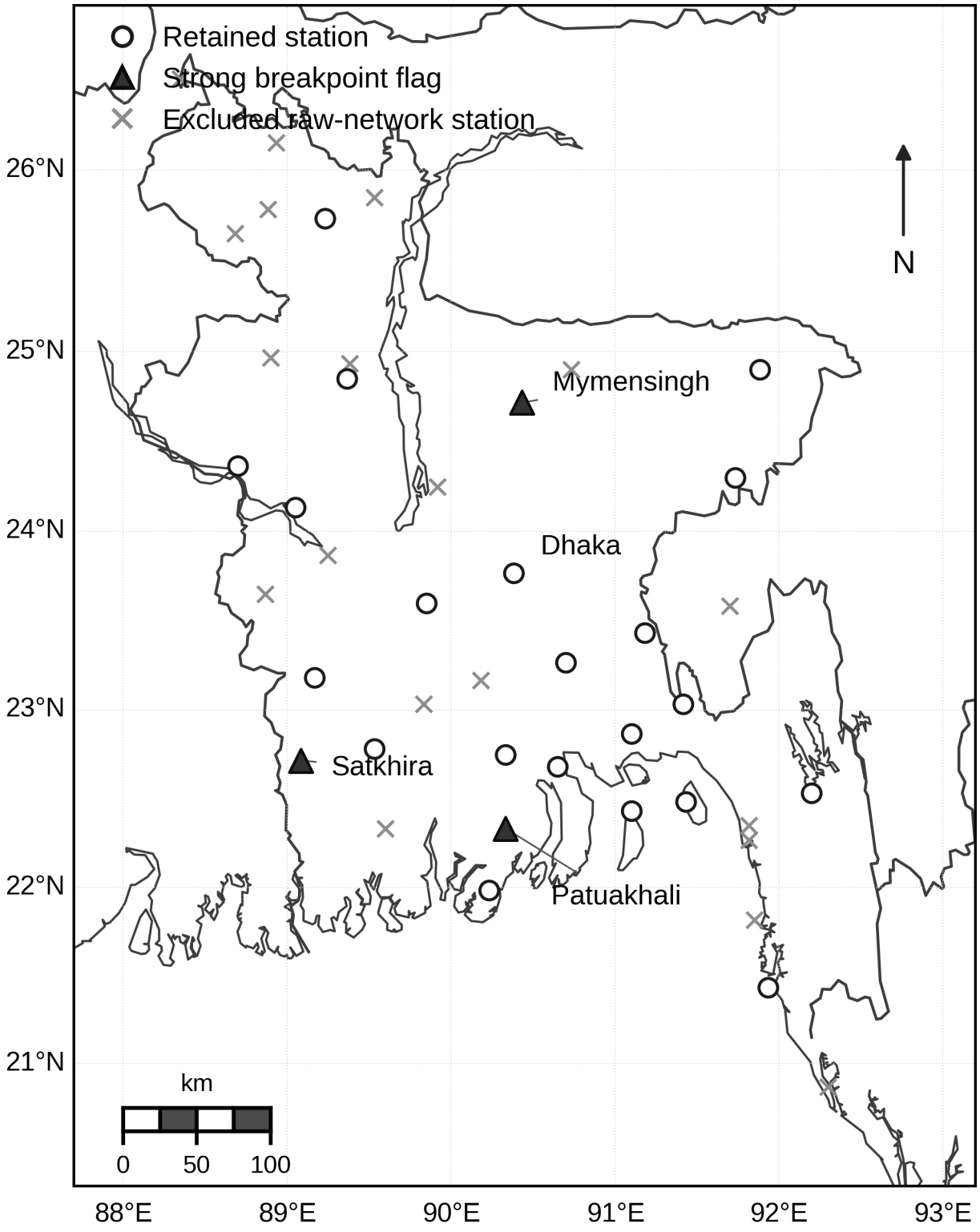


Figure 1

Bangladesh meteorological station network represented in the source data. Open circles denote stations retained in the primary long-record analysis, crosses denote excluded raw-network stations, and filled triangles denote the three retained stations with strong candidate breakpoint flags used in the homogeneity sensitivity analysis

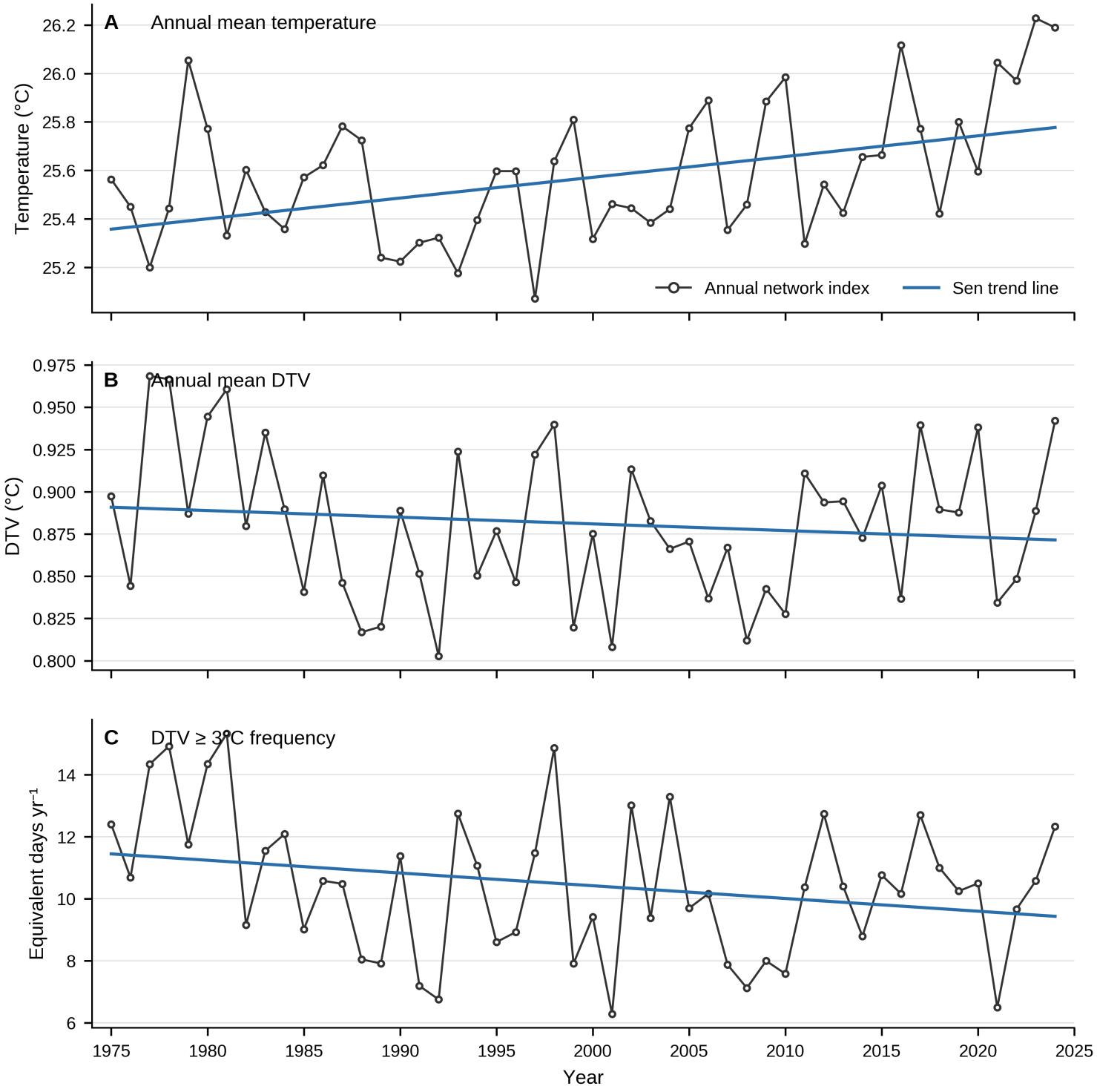


Figure 2

Core station-standardized observational network series, 1975-2024: (A) annual mean temperature, (B) annual mean day-to-day temperature variability (DTV), and (C) annualized frequency of the primary abrupt-transition threshold DTV ≥ 3 °C. Blue lines show Sen trend representations; formal inference is summarized in Table 2

Supplementary Files

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- ESM1.pdf