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A Synoptic-to-Mesoscale and In-Situ Diagnosis of the 13 August 2026 Protracted Rainfall Event over Lafia, North-Central Nigeria

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Abstract

A protracted convective storm event in Lafia, Nasarawa State, on 13 August 2026, in a region already flagged for elevated flash-flood risk. Using ERA5T reanalysis with an independent station record from the Trans-African Hydro-Meteorological Observatory, this study reconstructs the storm's synoptic priming, verifies its rainfall against independent products, and establishes when convective initiation began relative to surface rainfall. CAPE and 925 hPa moisture flux convergence at Lafia show active convection consuming instability from around 23:00 UTC on 12 August, roughly seven hours before the rain-cooled downdraft reached the surface. The station's five-minute record corroborates the findings: a brief pulse of rain at 02:45-03:00 UTC precedes a two-hour dry lull, then the main burst, peaking at 5.17 mm per five minutes at 05:55 UTC, coincident with a pressure rise to 99.81 kPa and a 2.5-degree temperature drop within a single hour, the classic signature of a mature mesoscale convective system. Independent of any reanalysis or satellite product, the station's own multi-day record confirms 13 August as anomalous, with daytime temperature and solar radiation suppressed by roughly a third to a half and relative humidity at or above 95.7 percent throughout. Verification against three gridded and satellite products shows all three substantially underestimating the measured total, recovering 66, 20, and 15 percent of the gauge value, respectively, consistent with rainfall concentrated below their resolution. These findings place convective initiation several hours ahead of surface rainfall and point to a lead time that near-real-time monitoring of convective precursors could exploit for early warning.

Keywords: convective initiation, mesoscale convective systems, moisture flux convergence, TAHMO, West African monsoon

1. Introduction

Lafia, the capital of Nigeria's Nasarawa State, is in the southern savanna belt and is about 200 km southeast of Nigeria's capital city, Abuja. The city of Lafia and the entire middle belt of Nigeria lie within the transition zone separating the moist south-westerly airflow and the drier north-easterly airflow from the Sahara. Across this belt, rainfall is delivered overwhelmingly by mesoscale convective systems rather than by steady frontal rain, and squall lines organised along the leading edge of African easterly waves account for the majority of the wet-season total (Fink and Reiner, 2003). This type of storm event is capable of releasing rainfall that could have been expected over a week or a month in just a single day. Such was the downpour of the 13th of August, 2026, in Lafia, which resulted from a convective system that formed over the city.

The timing of the event was not incidental. In the days beforehand, an advisory covering thirteen Nigerian states between 11 and 20 August 2026 named Nasarawa among the states carrying the highest flash-flood risk on the basis of forecast rainfall intensity, soil moisture, drainage capacity and terrain (Legit.ng, 2026). Nasarawa's state emergency management agency had separately already flagged Lafia Local Government Area as one of four flood-prone areas warranting an intensified early-warning campaign ahead of the peak rainy season, and residents of Kwanka, a community within Lafia LGA that has suffered repeated flood damage, had appealed for government intervention months before the storm arrived (Tori.ng, 2026). The 13 August event therefore struck a city that had already been named, in advance, as vulnerable, rather than one caught unaware.

Lafia's land surface has itself been changing quickly. A recent remote-sensing characterisation of the city found that its land surface temperature has risen as vegetation cover has been lost and the built-up footprint has expanded, consistent with a developing and intensifying urban heat island (Abimbola et al., 2025). Whether this land-surface trajectory measurably shapes individual storms is a question raised, but not settled, by the wider literature: an ensemble of convection-permitting simulations over Lagos found that the urban footprint alone increased rainfall over that city by 20 to 30 percent relative to an otherwise identical run in which the city was replaced by forest, through a chain running from reduced evapotranspiration to a stronger heat island to enhanced convergence (Doan et al., 2023). That result rests on a single, coastal megacity whose relevant circulation, an urban-enhanced sea breeze, has no analogue in Lafia, an interior city roughly 400 km from the coast, and a recent systematic review of WRF applications to extreme rainfall in Nigeria found that convection-permitting simulation of mesoscale convective systems in the country's interior Guinea Savanna belt remains largely unstudied by comparison (Onyejuruwa et al., 2025). Testing whether an analogous mechanism operates at an interior city such as Lafia requires convection-permitting simulation paired with a land-surface sensitivity experiment, an approach beyond the scope of the present analysis; this study instead focuses on what an observational diagnosis,

combining reanalysis and an independent station record, can establish about the storm's synoptic priming, its true convective timing, and its verified rainfall total.

A storm's surface rainfall record and its true convective initiation are not the same thing. The general thunderstorm and mesoscale convective system literature draws a sharp distinction between a storm's initiation, when updrafts first begin to organise, and its later, mature stage, when a rain-cooled downdraft reaches the surface and produces the heaviest rainfall and the sharpest pressure and temperature signature of the whole event (Byers, 1949; Houze, 2004); for organised tropical systems, this initiation stage can precede the mature stage by several hours. In the Sahel specifically, the mature-stage signature has been documented directly at the surface, with pressure rises of up to 8 hPa and temperature drops of 2 to 14 degrees Celsius accompanying the downdraft of Sahelian mesoscale convective systems (Provod et al., 2016). Whether the 13 August 2026 Lafia event fits this pattern, and when its convective initiation actually began relative to the surface rainfall it eventually produced, is a central question this study answers.

Convective initiation and organisation over West Africa is itself strongly modulated by the African easterly jet and the easterly waves that propagate along it: squall-line initiation is systematically favoured ahead of easterly-wave troughs (Fink and Reiner, 2003), and low-level moisture flux convergence, most commonly diagnosed at 925 hPa, is one of the most widely used precursors of convective initiation precisely because, unlike surface rainfall, it can signal the initiation stage before rain reaches the ground (Banacos and Schultz, 2005). A large share of nocturnal Sahelian rainfall is tied to the diurnal migration of the Inter-Tropical Front (Vizy and Cook, 2018), and the frequency of the most intense Sahelian storms has roughly tripled since 1982 alongside strengthening land-surface temperature gradients at the desert margin (Taylor et al., 2017), underscoring that West African convection, including nocturnal and early-morning events such as the Lafia case, is shaped by synoptic conditions that a purely daytime or surface-rainfall-based account can miss.

This study addresses four questions using ERA5(T) reanalysis and an independent in-situ station record. First, what synoptic-to-mesoscale conditions primed the atmosphere over Lafia ahead of the 13 August 2026 event? Second, how well do independent gridded and satellite precipitation products, namely CHIRPS, GPM IMERG-Late and ERA5T, verify against in-situ ground truth for this event? Third, when did convective initiation actually begin at Lafia, and how does this compare with the storm's later, mature, surface-rainfall-producing stage? Fourth, does 13 August 2026 stand out from the days immediately around it in the station's own independent surface climate record? Answering these questions provides a coherent, cross-verified account of the event's synoptic priming, its true convective timing, its measured rainfall, and its anomalous character.

The remainder of this manuscript is organised as follows. Section 2 describes the study area, data sources and methodology in full, including the diagnostic used to establish the storm's convective initiation time. Section 3 presents the results, Section 4 discusses their implications, and Section 5 concludes and offers recommendations for future work.

2. Methodology

2.1 Study area

Lafia (8.49°N, 8.52°E) is the capital of Nasarawa State in Nigeria's Middle Belt, roughly 200 km southeast of the federal capital, Abuja, at an elevation of approximately 180 to 200 m above sea level. The city sits within the Southern Guinea Savanna vegetation belt, in a transition zone between the moisture-laden south-westerly monsoon flow that dominates the wet season and the drier continental air that advances from the north in the dry season. Under the Koppen climate classification the area falls within the tropical wet-and-dry (Aw) regime, with a single wet season running from roughly April to October and a pronounced dry season for the remainder of the year; the wet season itself is punctuated less by steady frontal rain than by discrete, often intense mesoscale convective systems, consistent with the wider West African pattern (Fink and Reiner, 2003).

Rainfall characteristics across twelve stations in Nigeria's Guinea Savanna belt, including Lafia, show a statistically detectable, though only moderately explained ($R^2 = 0.41$), positive trend in Lafia's own rainfall series over a multi-decade record, alongside shifting rainy-season onset and cessation dates at a majority of the stations studied (Buba et al., 2017). This indicates that Lafia's rainfall regime is itself in a period of change, and provides useful climatological context for treating an individual high-impact event such as the 13 August 2026 storm as informative in its own right. The city has also urbanised rapidly, with its built-up footprint expanding and vegetation cover correspondingly declining over the past two decades, accompanied by a measurable rise in land surface temperature consistent with a developing urban heat island (Abimbola et al., 2025).

2.2 ERA5 pressure-level and single-level reanalysis

Hourly ERA5 fields were retrieved from the Copernicus Climate Data Store (Hersbach et al., 2020) for 10-14 August 2026, a five-day window bracketing the event, on a 0.25° grid over a West Africa domain bounded by 25°N-5°S and 20°W-25°E. The pressure-level request returned geopotential, zonal and meridional wind, specific humidity and temperature on 19 levels from 1000 to 200 hPa; the single-level request returned 2 m dewpoint and temperature, 10 m wind, mean sea-level pressure, and ERA5's own convective available potential energy diagnostic.

These files carry an expver value of '0005' throughout, identifying them as ERA5T, the preliminary, near-real-time extension of ERA5 rather than the final, fully quality-controlled release. ERA5T typically trails real time by about five days; the final release for this event is not expected until roughly two to three months after it occurred. Differences between ERA5T and final ERA5 are usually small, but ideally the diagnosis in Sections 3.1 and 3.3 would be re-run against final ERA5 once it becomes available.

2.3 August climatology

A 26-year August climatology (2000-2025) of geopotential, wind and specific humidity at 850 and 600 hPa was retrieved from the same CDS pressure-level monthly-means product, on the same domain, to give the event composite in Section 3.1 a climatological baseline to be compared against.

2.4 CHIRPS daily precipitation

Daily precipitation for 10-14 August 2026 was retrieved from the Climate Hazards Center's CHIRPS-2.0 archive (Funk et al., 2015) at its native 0.05° resolution, clipped to the same domain as the ERA5 fields above. CHIRPS's fully quality-controlled final product carries a roughly three-week latency and was not yet available for these dates at the time of retrieval; the faster "prelim" product (typical latency about two days, built from satellite input with a provisional station adjustment) was used instead.

2.5 GPM IMERG-Late half-hourly precipitation

Half-hourly precipitation for 10-14 August 2026 was retrieved from NASA GES DISC's IMERG-Late Run, algorithm version V07C (Huffman et al., 2024), at 0.1° resolution, and summed into daily totals. IMERG's fully gauge-calibrated Final Run is not produced until roughly 3.5 months after the fact; the Late Run (typical latency about 14 hours, satellite-only, no gauge adjustment) was used in its place.

2.6 ERA5T total precipitation

A supplementary single-level CDS request, separate from the fields listed in Section 2.2, returned hourly total-precipitation accumulations for the same domain and window, summed into daily totals for comparison against CHIRPS and IMERG-Late in Section 3.2. This request inherits the same ERA5T status described in Section 2.2.

2.7 TAHMO 13 August five-minute rain gauge

A genuine in-situ rain gauge record for 13 August 2026 was obtained from the Trans-African Hydro-Meteorological Observatory (TAHMO) automatic weather station at the Federal University

of Lafia permanent site, at the station's native 5-minute resolution. TAHMO is an independently operated pan-African research network (van de Giesen et al., 2014). The station recorded zero precipitation on the other four days in the event window (10, 11, 12 and 14 August), cross-checked in Section 3.2 against what each gridded product independently shows at the same point. The exported record spans 02:45-11:00 UTC on 13 August; every reading in that window is used directly in Section 3.3 to test for convective initiation.

2.8 TAHMO 11-14 August hourly multi-variable surface record

A second TAHMO export from the same station provided hourly air temperature, relative humidity, station pressure, solar radiation, wind speed and wind direction spanning 11 to 14 August 2026, a 96-hour window bracketing the event by roughly one day on either side. This record is used for the convective-initiation-timing diagnostic in Section 2.11, which draws on its pressure and temperature traces around the event itself, and the multi-day comparative characterisation in Section 2.12, which compares 13 August against the three flanking days across all four scalar surface variables. Wind speed and direction on 13 August carry a five-hour data gap, from 07:00 to 11:00 UTC, spanning the storm's most intense rainfall; this is treated in Section 3.3 as a data limitation rather than as evidence in its own right, since an instrument interruption during heavy rain is at least as plausible an explanation as a genuine calm.

2.9 Synoptic-to-mesoscale diagnostic framework

Four diagnostics were computed from the ERA5(T) fields described in Section 2.2, covering the 72 hours before through 24 hours after the event.

The Inter-Tropical Discontinuity (ITD) was located, at each longitude across the domain, as the latitude at which 925 hPa specific humidity drops from at-or-above a conventional 8 g/kg moist threshold, scanning south to north, to below it, the boundary between the moist monsoon air mass to the south and the drier air to its north. The African Easterly Jet (AEJ) core was located as the latitude and longitude of the strongest (most negative) zonal wind at 600 hPa within its climatological 5-15°N band and a 0-15°E box overlapping Lafia's meridian; any accompanying African Easterly Wave signature was sought in the same field following the trough-identification approach of Fink and Reiner (2003).

Convective available potential energy (CAPE) was computed at the Lafia grid point (8.49°N, 8.52°E) from the full 19-level ERA5 column, using the virtual-temperature-corrected formulation of Doswell and Rasmussen (1994) shown in equation 1, evaluated with MetPy's parcel-lifting routines rather than re-derived numerically, so that the published formulation is applied unmodified.

$$CAPE = g \int_{Z_{LFC}}^{Z_{EL}} \left(\frac{T_{v,parcel}(z) - T_{v,env}(z)}{T_{v,env}(z)} \right) dz \quad 1$$

Surface moisture flux convergence (MFC) was computed at 925 hPa at the same Lafia grid point using the formulation of Banacos and Schultz (2005), as shown in equation 2.

$$MFC = -\nabla \cdot (q\mathbf{V}) = -(\mathbf{V} \cdot \nabla q + q\nabla \cdot \mathbf{V}) \quad 2$$

Finally, mean geopotential height, wind and specific humidity at 850 and 600 hPa were composited across the 96-hour event window and differenced against the 2000-2025 August climatology described in Section 2.3, following the general diagnostic approach Vizu and Cook (2023) used for the closely analogous Damergou Gap storm events on the Niger-Nigeria border.

2.10 Multi-source precipitation verification

The 24-hour precipitation totals for 13 August 2026 described in Sections 2.4-2.6 (CHIRPS, IMERG-Late, ERA5T) were compared pairwise across the full domain and at the single Lafia grid point. No NiMet or NASEMA rain-gauge record is used anywhere in this study; consequently, the domain-wide statistics below treat each of the three gridded/satellite products as a reference in turn against each of the other two, rather than validating any of them against independent ground truth. At the single Lafia point, however, all three products are additionally verified against the TAHMO station gauge described in Section 2.7; this point-only comparison is reported alongside, not instead of, the pairwise domain-wide statistics, since a single station cannot support a domain-wide statistic on its own. Before each domain-wide pairwise comparison, the candidate field was bilinearly interpolated onto the reference field's native grid. The CHIRPS prelim GeoTIFFs used here do not always carry a nodata tag in their own file metadata even though ocean pixels within the bounding box are still filled with CHIRPS's standard -9999 sentinel value; these were identified and masked explicitly, together with any residual negative value, before computing any domain-wide statistic.

Continuous agreement between each pair of products was summarised with the root-mean-square error (equation 3), mean bias (equation 4), and Pearson correlation coefficient (equation 5), following Wilks (2019), where P and O denote the candidate and reference precipitation fields respectively and n is the number of valid grid cells compared.

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^n (P_i - O_i)^2} \quad 3$$

$$Bias = \frac{1}{n} \sum_{i=1}^n (P_i - O_i) \quad 4$$

$$r = \frac{\sum_{i=1}^n (P_i - \bar{P})(O_i - \bar{O})}{\sqrt{\sum_{i=1}^n (P_i - \bar{P})^2} \sqrt{\sum_{i=1}^n (O_i - \bar{O})^2}} \quad 5$$

Categorical skill at rainfall thresholds of 1, 10, 25, 50 and 75 mm per 24 hours was summarised with the probability of detection (POD) of equation 6, false alarm ratio (FAR) of equation 7, and critical success index (CSI) of equation 8, following Roebber (2009), where H, M and F are respectively the counts of hits, misses and false alarms at a given threshold: a hit is a grid cell where both candidate and reference meet or exceed the threshold, a miss is a cell where only the reference does, and a false alarm is a cell where only the candidate does.

$$POD = \frac{H}{H + M} \quad 6$$

$$FAR = \frac{F}{H + F} \quad 7$$

$$CSI = \frac{H}{H + M + F} \quad 8$$

2.11 Convective initiation timing diagnostic

Section 3.1 reconstructs the synoptic-to-mesoscale evolution of the 13 August 2026 event. This section develops a method for identifying the atmosphere's convective initiation, distinct from the storm's later, mature, cold-pool stage described in Section 3.3, using two independent lines of evidence.

The first is the pre-storm evolution of CAPE and 925 hPa moisture flux convergence at the Lafia grid point, already computed for Section 3.1 following the methods described in Section 2.9, examined here at hourly resolution across the pre-storm and storm period. A sustained rise in MFC together with a drawdown in CAPE, rather than a single pre-storm CAPE peak considered in isolation, is the reanalysis-based signature of active convection already consuming the instability that MFC continues to build beneath it, and was used here as the primary reanalysis-based precursor evidence of convective initiation.

The second is the TAHMO Federal University of Lafia station's own hourly pressure and temperature record (Section 2.8) and its independent 5-minute rainfall record (Section 2.7), examined together across the same window. Following the West African cold-pool signature documented by Provod et al. (2016), a pressure minimum (a pre-storm mesolow) followed by a pressure rise (a mesohigh, marking the arrival of the storm's rain-cooled downdraft at the surface)

and a coincident sharp temperature drop were used as the surface signature of the storm's mature stage, distinct from and later than its initiation. The station's own 5-minute rainfall record was examined in full to check directly for any early, weak rainfall that a coarser, hourly or daily-total analysis would miss.

2.12 TAHMO multi-day comparative characterisation

The hourly, six-variable TAHMO record described in Section 2.8, spanning 11 to 14 August 2026, was used to place the event day in the context of the two days immediately before it and the one day immediately after. For each of the four days, the daily maximum and minimum temperature, minimum relative humidity, maximum and minimum station pressure, and maximum solar radiation were computed and compared, on the logic that a genuinely anomalous convective day should be detectable in a station's own record purely by contrast with its immediate surroundings, independent of any reanalysis or satellite product. Wind speed and direction were inspected but are reported qualitatively only, because the station's own wind record carries the data gap noted in Section 2.8 across the most active hours of the storm itself.

3. Results

3.1 Synoptic-to-mesoscale reconstruction of the 13 August 2026 event

The four diagnostics described in Section 2.9, and also shown graphically in Figure 1, point to a coherent, textbook-consistent pre-convective evolution during the day before the storm's heaviest rainfall on 13 August. CAPE at the Lafia grid point built from around 550-1000 J/kg through 10-11 August to a peak of approximately 1660 J/kg on the evening of 12 August (14:00-18:00 UTC), roughly 12-18 hours before the storm's heaviest rainfall arrived, before declining through the storm itself to 460-850 J/kg by 14 August. The AEJ core at 600 hPa, as shown in Figure 1, weakened over the same pre-storm window, reaching a local minimum of about 14.6 m/s around 12 August 17:00-13 August 01:00, essentially coincident with peak CAPE, a weak-background-wind, high-instability configuration consistent with the conditions under which West African convection is most readily amplified rather than suppressed.

Moisture flux convergence at 925 hPa over Lafia peaked at approximately $10 \times 10^{-7} \text{ kg kg}^{-1} \text{ s}^{-1}$ around 13 August 00:00-03:00, the clearest single signal in the four diagnostics of low-level convergence building directly ahead of the storm. The AEJ then re-intensified sharply, as seen in Figure 1, through the storm's most active daytime hours, from its 12-13 August minimum up to a peak of roughly 22 m/s at 13 August 12:00-18:00, before relaxing back toward 17-20 m/s by 14 August.

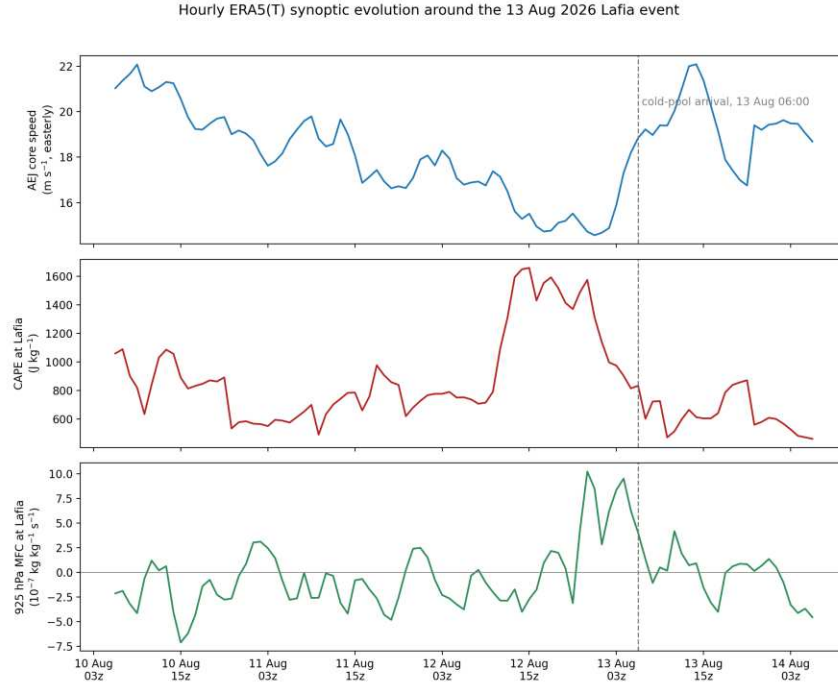


Figure 1. Hourly evolution of the 600 hPa AEJ core wind speed, CAPE at Lafia, and 925 hPa moisture flux convergence at Lafia, 10-14 August 2026 (ERA5T).

The ITD, as on Figure 2, reconstructed from the 925 hPa moisture field at 06:00 UTC on 13 August, sat at a domain-mean latitude of approximately 20°N (range 17.2-22.8°N across the domain), consistent with the well-documented climatological August position of the West African ITD. Its position was not uniform with longitude: directly over Lafia's own meridian (8.52°E) the ITD sat at a local minimum of roughly 17.7-18.5°N, displaced south of the values at longitudes immediately to its east and west (which reach 20.5-22.8°N), consistent with locally enhanced low-level convergence there relative to its surroundings.

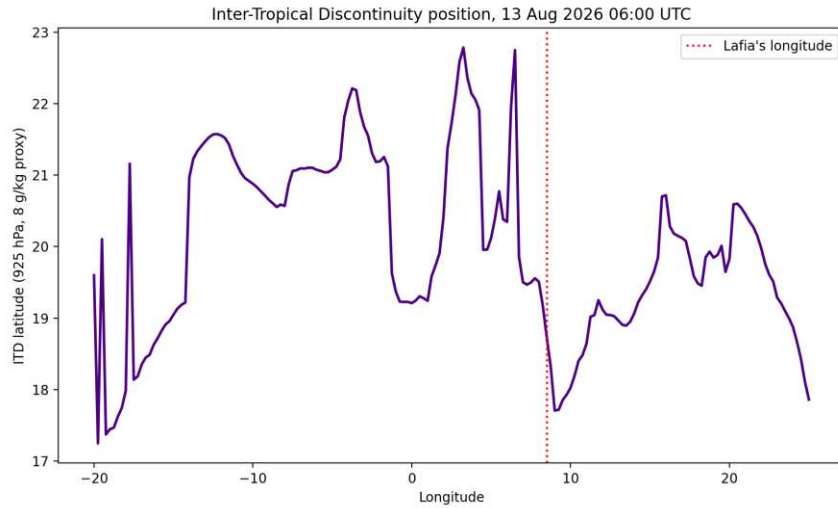


Figure 2. Inter-Tropical Discontinuity position (925 hPa, 8 g/kg proxy) by longitude, 13 August 2026 06:00 UTC (ERA5T).

The 850 hPa composite for the event window ran anomalously high in geopotential height relative to the 2000-2025 August climatology across most of the domain (up to $+187 \text{ m}^2 \text{ s}^{-2}$ locally) is shown on Figure 3, with one notable exception: a negative anomaly pocket north of Lafia, roughly $20\text{-}24^\circ\text{N}$ and $0\text{-}5^\circ\text{E}$, where heights ran as much as $-75 \text{ m}^2 \text{ s}^{-2}$ below climatology. At 600 hPa, as shown in Figure 4, the same broadly positive anomaly pattern was stronger still (up to $+325 \text{ m}^2 \text{ s}^{-2}$), with wind anomalies indicating a modest strengthening of the mean easterly flow relative to climatology across the domain.

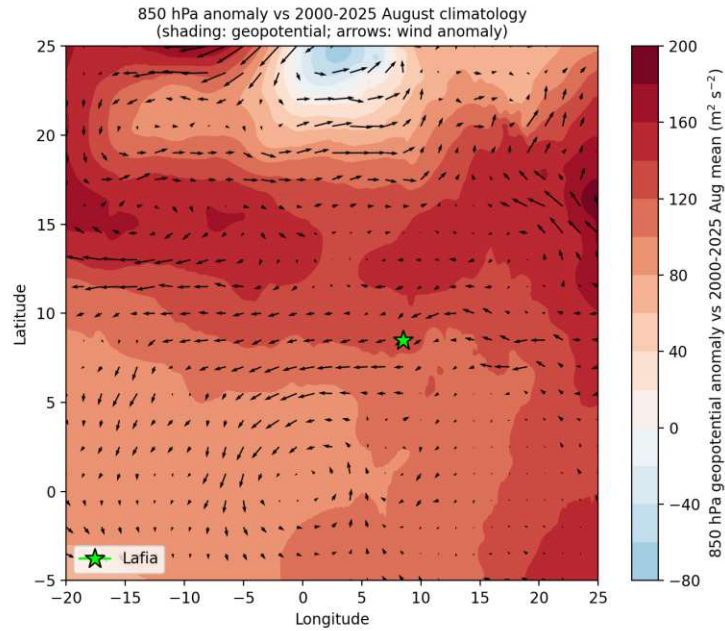


Figure 3. 850 hPa geopotential and wind anomaly, 10-14 August 2026 composite vs. 2000-2025 August climatology (ERA5T).

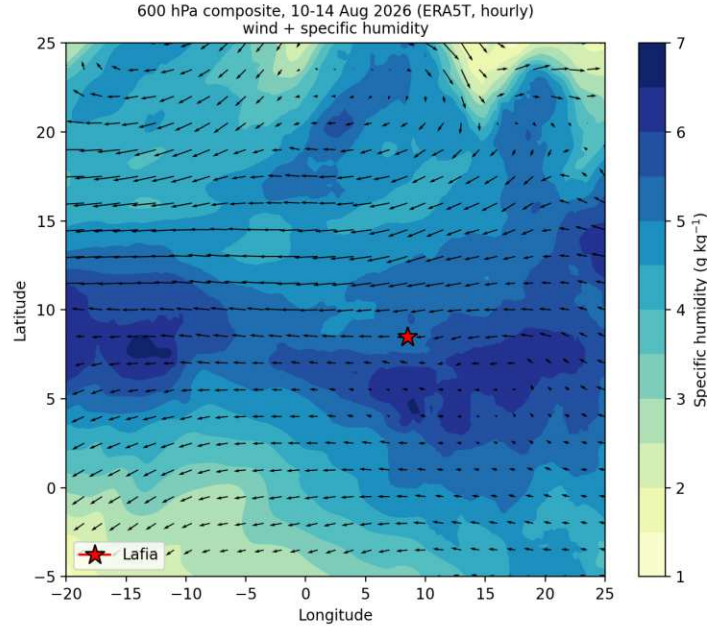


Figure 4. 600 hPa composite wind and specific humidity, 10-14 August 2026 (ERA5T).

These results should be read together with the caveat that the underlying reanalysis is ERA5T, the preliminary, near-real-time product, and that each diagnostic here is a single grid-point or small-box time series rather than a full mechanistic account of the storm; the fine-scale, sub-kilometre structure of the storm itself is beyond what any single-point or small-box reanalysis diagnostic can resolve.

3.2 Multi-source precipitation verification

The TAHMO gauge at Federal University of Lafia recorded a 24-hour total of 78.6 mm on 13 August 2026, and zero on each of the other four days in the event window, corroborated below by the dry-day cross-check against each gridded product's own record at the same point. Against this ground truth, all three gridded/satellite products substantially underestimate the storm's total at the Lafia point, as shown in Figure 5: CHIRPS records 52.1 mm (66% of the gauge total, the closest of the three), IMERG-Late records 15.5 mm (20%), and ERA5T records 11.4 mm (15%). Every product, not just the coarsest one, misses more than a third of what the gauge measured, and the two satellite/reanalysis products miss four-fifths or more.

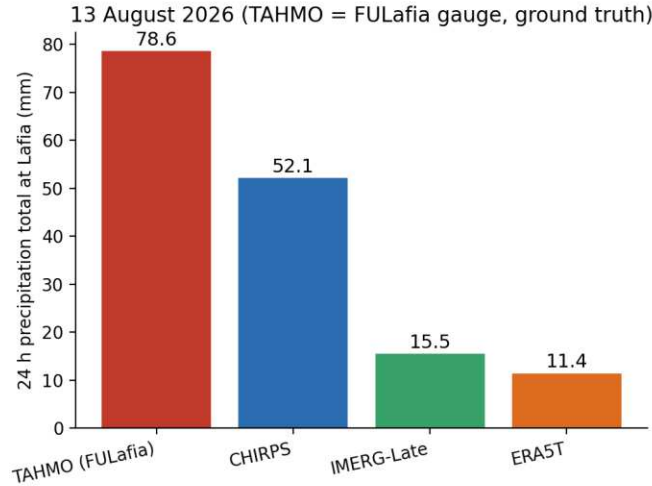


Figure 5. 24-hour precipitation total at the Lafia grid point (8.49°N , 8.52°E), 13 August 2026, by product, with the TAHMO FULafia station gauge as ground truth.

The dry-day cross-check lends confidence to the gauge record rather than undermining it: CHIRPS shows exactly 0.0 mm at the Lafia point on all four other days, matching the gauge exactly, and IMERG-Late's values on those days (0.16-0.38 mm) are close enough to be consistent with measurement/retrieval noise around a true zero. ERA5T is the outlier here as well as at the event peak, showing 0.4-5.2 mm on days the gauge recorded no rain at all, including 5.2 mm on 12 August, one day before the event. Read alongside ERA5T's already-largest underestimate of the 13 August total, this points to a reanalysis whose parameterised convection is not just underestimating the storm's intensity but also getting some of its timing wrong, plausible for a scheme that cannot resolve the sub-grid convective initiation process identified in Section 3.3.

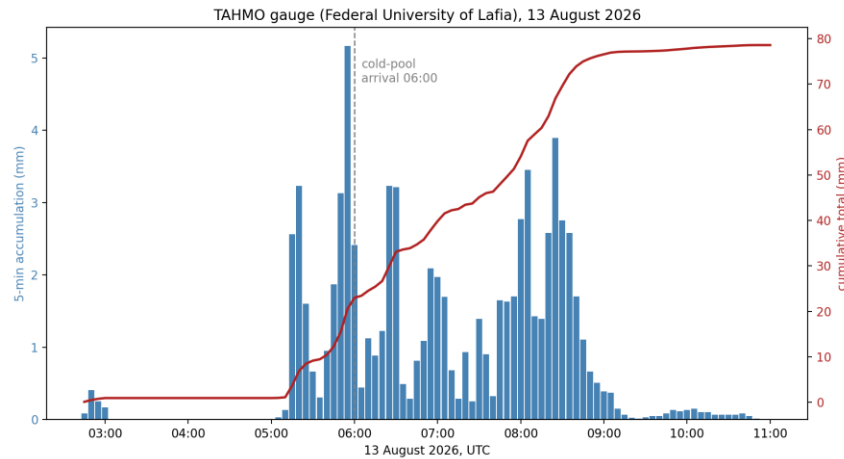


Figure 6. TAHMO FULafia gauge, 5-minute rainfall accumulation and running cumulative total, 13 August 2026. The dashed line marks the arrival of the storm's cold pool at the surface (06:00 UTC).

Domain-wide, the same three gridded/satellite products agree only moderately with each other (a single station cannot support a domain-wide statistic, so TAHMO does not enter this part of the

comparison). CHIRPS and IMERG-Late show the closest correspondence (RMSE 5.70 mm, Pearson $r = 0.572$, mean bias +0.23 mm in the CHIRPS-minus-IMERG direction), CHIRPS and ERA5T agree less well (RMSE 7.00 mm, $r = 0.352$, bias +0.26 mm), and IMERG-Late and ERA5T are the weakest pair (RMSE 8.65 mm, $r = 0.396$, bias -0.05 mm). None of the three mean biases is large in absolute terms, indicating that the point-level underestimate confirmed against TAHMO above is not a simple domain-wide offset between products but something more localised to the storm itself.

Categorical skill against CHIRPS as reference, shown in Figure 7, falls away sharply as the rainfall threshold rises for both candidate products, the expected signature of a convective rather than stratiform rainfall field. At the lightest threshold (1 mm), IMERG-Late reaches a probability of detection of 0.665 and a critical success index of 0.558 against CHIRPS, both noticeably better than ERA5T's 0.510 and 0.412 at the same threshold. By the heaviest threshold tested (75 mm), both products have collapsed to a CSI below 0.05, and ERA5T detects none of CHIRPS's 75 mm-plus cells at all (POD = 0, FAR = 1). IMERG-Late outperforms ERA5T at every threshold tested, consistent with IMERG's satellite-retrieved rain rates resolving localised convective cells more effectively than ERA5T's coarser, physically parameterised precipitation.

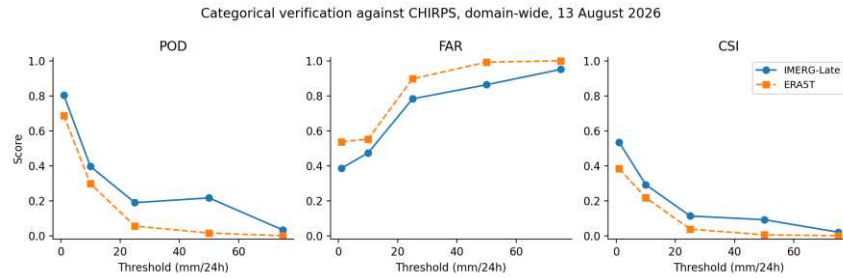


Figure 7. POD, FAR and CSI for IMERG-Late and ERA5T against CHIRPS as reference, domain-wide, 13 August 2026, at five 24-hour rainfall thresholds.

Read together, all three results tell one consistent story. The moderate domain-wide correlations and small domain-wide biases show that all three gridded/satellite products broadly agree on where it rained across the wider West Africa domain on 13 August; the sharp point-level underestimate against TAHMO ground truth, and the equally sharp fall-off in categorical skill at high thresholds, both point to a storm whose most intense rainfall was concentrated at a spatial scale finer than any of the three products' native grids (0.05-0.25°) can fully resolve, exactly what the TAHMO 5-minute record in Figure 6 shows directly: a sharp, short-lived peak (5.17 mm in a single 5-minute interval, around 62 mm/h instantaneous) rather than a spatially smooth, steady rain field.

3.3 Timing of convective initiation

Examined at hourly resolution, the reanalysis record described in Section 3.1 points to convective initiation well before the storm's heaviest surface rainfall. MFC at 925 hPa rose sharply through

the evening of 12 August, from near-neutral values around 20:00-22:00 UTC to a local peak of $1.02 \times 10^{-6} \text{ kg kg}^{-1} \text{ s}^{-1}$ at 23:00 UTC (roughly midnight local time; Nigeria observes UTC+1 year-round), and, after a brief dip at 01:00 UTC ($2.8 \times 10^{-7} \text{ kg kg}^{-1} \text{ s}^{-1}$), remained elevated ($6.2\text{-}9.5 \times 10^{-7} \text{ kg kg}^{-1} \text{ s}^{-1}$) through 02:00-04:00 UTC before collapsing after 05:00 UTC. CAPE fell in step, from 1576 J/kg at 23:00 UTC to 975 J/kg by 03:00 UTC and 601 J/kg by 07:00 UTC, consistent with active convection progressively drawing down the instability that MFC was simultaneously building beneath it, the reanalysis-based signature of ongoing rather than merely impending convection.

The TAHMO station's own, independent record corroborates this directly. Its 5-minute rainfall gauge shows a first, brief pulse of rain, four consecutive 5-minute readings between 02:45 and 03:00 UTC totalling 0.92 mm, a lag of roughly two to four hours after the evening's peak MFC signal that is consistent with the time an initiating cell typically needs to organise and produce its first rain at the surface. A roughly two-hour dry lull followed, from 03:05 to 05:00 UTC, before rainfall resumed at 05:05 UTC and intensified rapidly into the storm's main convective burst, peaking at 5.17 mm per five minutes (an instantaneous rate of roughly 62 mm/h) at 05:55 UTC.

The station's pressure and temperature record shows this later burst as the storm's mature, cold-pool stage. Station pressure sat at a shallow pre-storm minimum of 99.44 kPa from 02:00 to 03:00 UTC, coincident with the first light rain pulse, before climbing steadily to a peak of 99.81 kPa by 08:00 UTC, a rise of 0.37 kPa in five hours. Air temperature fell in step, from 24.6°C at 05:00 UTC to an abrupt 22.1°C at 06:00 UTC, a drop of 2.5°C in a single hour, then held near 22.1-22.8°C through 10:00 UTC before recovering as the storm cleared. This pressure-rise-with-temperature-drop pairing is the classic meso-high and cold-pool signature of a mature mesoscale convective system's rain-cooled downdraft reaching the surface (Byers, 1949; Houze, 2004), directly analogous to the West African cold pools documented by Provod et al. (2016), whose reported pressure rises (up to 8 hPa) and temperature drops (2 to 14°C) bracket the values found here. The station's wind direction record adds a further, tentative detail: recorded wind direction shifted from a consistent south-westerly flow (229-258°) through 02:00-05:00 UTC to 122° at 06:00 UTC, plausibly the leading edge of the storm's outflow boundary passing the station, immediately before the wind sensor's own record falls silent for the next five hours (07:00-11:00 UTC) through the storm's most intense rainfall; this gap is treated as a data limitation rather than as evidence in its own right, since an instrument interruption during heavy rain is at least as plausible an explanation as a genuine calm.

Convective initiation and storm maturity, 13 August 2026 Lafia event

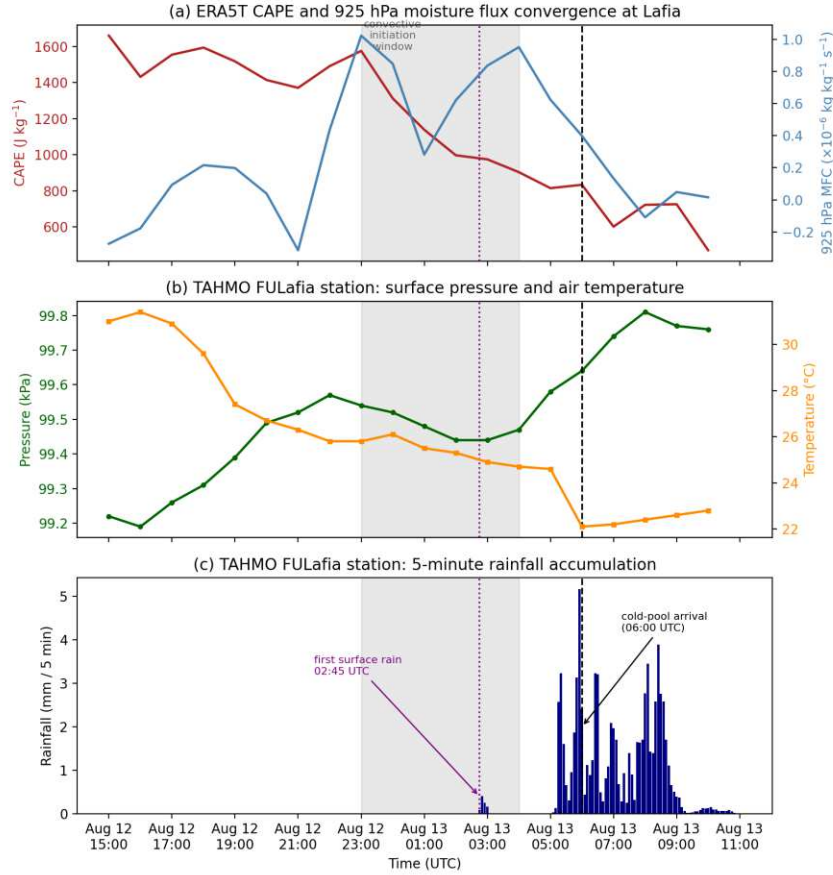


Figure 8. Convective initiation and storm maturity ahead of the 13 August 2026 Lafia event. (a) ERA5T CAPE and 925 hPa moisture flux convergence at Lafia; (b) TAHMO FULafia station surface pressure and air temperature; (c) TAHMO FULafia station 5-minute rainfall accumulation. The shaded band marks the convective initiation window (approximately 23:00-04:00 UTC); the dotted line marks the first surface rain (02:45 UTC); the dashed line marks the arrival of the storm's cold pool at the surface (06:00 UTC).

Read as a single sequence, and illustrated in Figure 8, these two independent lines of evidence place the atmosphere's convective initiation at Lafia in a window from approximately 22:00-23:00 UTC on 12 August (23:00-00:00 local time) through the first light surface rain at 02:45-03:00 UTC on 13 August (03:45-04:00 local time), several hours before the storm's rain-cooled downdraft reached the surface and produced its heaviest rainfall. This finding rests on ERA5T rather than final ERA5, and on a single station rather than a network, and should be read with those caveats in mind.

3.4 TAHMO multi-day surface anomaly of the event

Independent of any reanalysis or satellite product, the TAHMO station's own multi-day record shows 13 August standing out sharply from the three days immediately around it, as illustrated in Figure 9. Daily maximum temperature on 13 August reached only 27.7 $^{\circ}\text{C}$, against 31.2 $^{\circ}\text{C}$ on 11

August, 32.6°C on 12 August and 30.3°C on 14 August, a suppression of 2.6 to 4.9°C relative to the flanking days, consistent with the daytime cloud cover and rain-cooled air the storm produced. Minimum relative humidity on 13 August never fell below 95.7%, against flanking-day minimums of 83.9-88.9%, indicating that the near-surface air stayed close to saturation all day rather than drying out during the afternoon as it did on every other day in the record. Maximum station pressure on 13 August reached 99.81 kPa, higher than any of the three flanking days (99.61-99.75 kPa), the meso-high signature already described in Section 3.3 imprinted on the day's own daily maximum. Solar radiation, the variable least dependent on any single instantaneous reading, was suppressed most dramatically of all: a peak of only 380.8 W/m² on 13 August, against 716.0-897.6 W/m² on the flanking days, a reduction of 46 to 58%, direct, quantitative confirmation of persistent, thick cloud cover through the day consistent with a protracted rather than brief convective event.

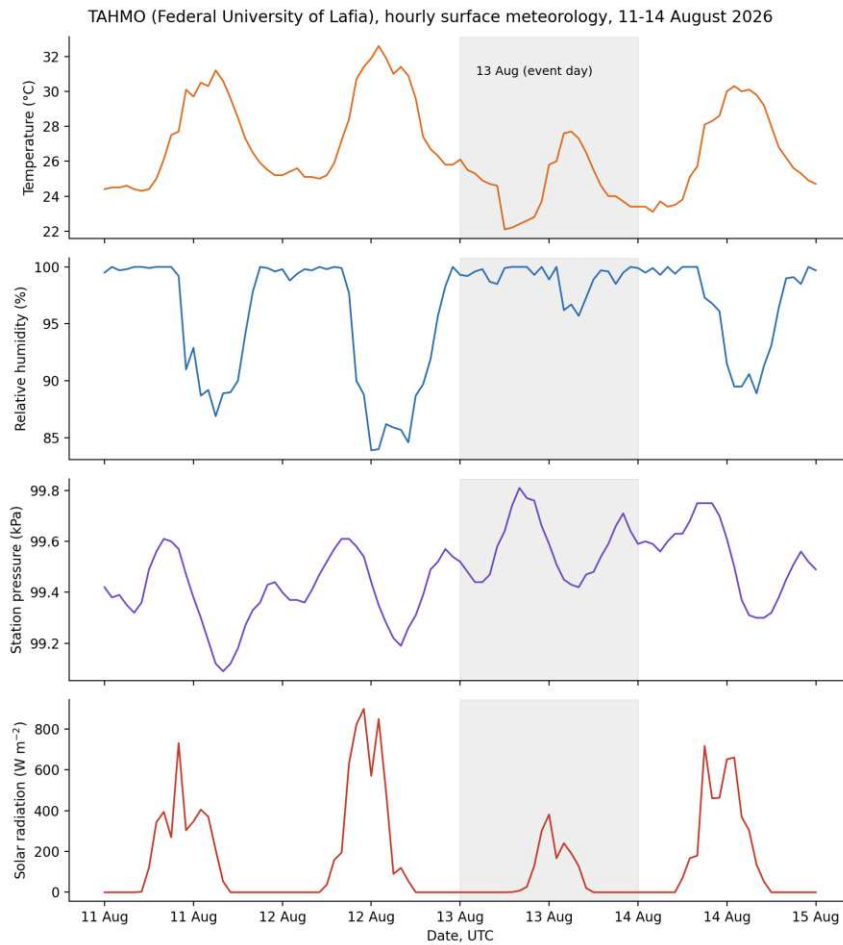


Figure 9. TAHMO FULafia station hourly surface meteorology (temperature, relative humidity, station pressure, solar radiation), 11-14 August 2026. The 13 August event day (shaded) stands out from the three flanking days in all four variables.

The magnitude and consistency of the 13 August anomaly across four physically distinct measurements, recorded at a single station independent of any reanalysis, satellite retrieval or

gridded product used elsewhere in this study, corroborates the event's characterisation as an unusual, high-impact convective day using no data source other than the storm's own immediate surroundings in time.

4. Discussion

Read together, the results in Sections 3.1 through 3.4 show that the atmosphere over Lafia was already actively convecting for at least three hours, and arguably closer to seven if the evening's initial rise in moisture flux convergence at 23:00 UTC on 12 August is counted as the beginning of the process, before the storm's rain-cooled downdraft reached the surface and produced the heaviest rainfall and sharpest pressure and temperature signature of the event. The storm's initiation and its mature, cold-pool stage are therefore separated by several hours, a distinction with a direct bearing on how such events might be monitored.

A flood early warning system, similar to that designed for the Sirba River in the Niger Republic, utilizes forecast output or a data signal to forewarn communities and prepare them for action prior to the flood's arrival (Tarchiani et al., 2020). The gap this study documents between convective initiation and the storm's surface maturity, several hours in this case, is exactly this kind of lead time, provided it can be detected in near-real time rather than reconstructed afterward as done here. A moisture flux convergence signal building at a Lafia-representative reanalysis grid point from roughly 23:00 UTC, if monitored operationally, would in principle have offered several hours of warning ahead of the storm's heaviest rainfall. Realising that lead time operationally would require either a genuinely real-time reanalysis-equivalent product or a denser regional observation network than a single station, but the physical basis for it, an MFC and CAPE precursor signal that leads the surface cold-pool signature by several hours, is exactly what Sections 3.1 and 3.3 show for this event.

The multi-source precipitation verification in Section 3.2, read alongside the initiation-timing finding in Section 3.3, also refines what verification should mean for a storm of this kind. All three gridded and satellite products substantially underestimated the TAHMO-measured 24-hour total, and categorical skill collapsed sharply at high rainfall thresholds, both signatures of a storm whose most intense rainfall was concentrated at a spatial and temporal scale finer than any of the three products' native resolution. ERA5T's parameterised convection scheme, in particular, both underestimated the storm's total most severely and produced spurious rainfall on a day (12 August) when the gauge recorded none at all, consistent with a scheme that cannot resolve the sub-grid convective initiation process identified in Section 3.3.

Whether Lafia's own land-surface change (Section 2.1) contributed to this storm's initiation, intensity or location cannot be answered from the reanalysis and station data used here.

Convection-permitting simulation elsewhere in West Africa shows that a city's built-up footprint can measurably enhance convective rainfall through a reduced-evapotranspiration to stronger-heat-island to enhanced-convergence pathway (Doan et al., 2023), but that mechanism was demonstrated for a coastal megacity whose relevant circulation, an urban-enhanced sea breeze, has no analogue in an interior city like Lafia, roughly 400 km from the coast. Testing whether an analogous, sea-breeze-independent mechanism operates at Lafia would require convection-permitting simulation paired with a land-surface sensitivity experiment, an approach beyond the scope of the present, observationally based analysis.

Two limitations bear directly on how these findings should be read. First, all ERA5-based diagnostics in this study use ERA5T, the preliminary, near-real-time release, rather than the final, fully quality-controlled ERA5 product; ideally, the reconstruction in Section 3.1 and the initiation-timing deduction in Section 3.3 would be re-run against final ERA5 once it becomes available. Second, every station-based finding in Sections 3.2 through 3.4 rests on a single TAHMO gauge; a single station can characterise the storm at one point extremely well, as done here, but cannot speak to how far the initiation-timing pattern found at Lafia generalises across the wider region. Neither the reanalysis nor the station-based diagnostics used here can resolve the storm's actual sub-kilometre convective structure, which only a convection-permitting simulation could provide.

5. Conclusion

This study diagnosed the synoptic-to-mesoscale drivers of the 13 August 2026 protracted convective rainfall event at Lafia, Nasarawa State, verified its rainfall against multiple independent gridded, satellite and in-situ sources, and established when convective initiation actually began relative to the storm's surface rainfall.

Using ERA5T reanalysis, the study found a textbook-consistent pre-storm evolution: CAPE built through 10-12 August to a peak of approximately 1660 J/kg on the evening of 12 August, the African easterly jet weakened over the same window, and 925 hPa moisture flux convergence rose sharply that evening. Examined at hourly resolution, that same MFC signal, together with a coincident CAPE drawdown, place the atmosphere's convective initiation at approximately 22:00-23:00 UTC on 12 August, corroborated independently by the TAHMO Federal University of Lafia station's own 5-minute rainfall record, which shows a first, brief pulse of surface rain at 02:45-03:00 UTC on 13 August. The storm's mature stage, the point at which its rain-cooled downdraft reached the surface, produced the sharpest pressure rise (to a peak of 99.81 kPa by 08:00 UTC) and temperature drop (to 22.1°C at 06:00 UTC) in the station's record, and its heaviest rainfall (5.17 mm per five minutes at 05:55 UTC), several hours after true initiation. Independent of any reanalysis or satellite product, the TAHMO station's own multi-day record confirms 13 August as

an anomalous day in its own right, with suppressed daytime temperature and solar radiation, saturated relative humidity, and elevated station pressure relative to the three surrounding days.

Multi-source verification against the TAHMO gauge showed that CHIRPS, IMERG-Late and ERA5T all substantially underestimated the storm's measured 24-hour total (66%, 20% and 15% of the gauge total respectively), with categorical skill collapsing at high rainfall thresholds for both satellite/reanalysis products, evidence that the storm's most intense rainfall was concentrated at a scale finer than any of the three products can resolve.

Together, these findings show that the 13 August event's convective initiation preceded its mature, rain-producing stage by several hours, with the storm's heaviest rainfall and sharpest surface pressure and temperature signature both reflecting its maturity rather than its initiation.

Three recommendations follow. First, operational monitoring of 925 hPa moisture flux convergence and CAPE drawdown at representative grid points could provide several hours of lead time ahead of a storm's surface impact, and is worth testing as a low-cost addition to existing early-warning frameworks in this region. Second, expanding independent in-situ station coverage, of the kind TAHMO already provides at Lafia, would allow the initiation-timing approach used here to be tested across multiple events and locations rather than a single case. Third, convection-permitting simulation paired with an urban and non-urban land-surface sensitivity experiment is needed to determine whether Lafia's documented urban heat island and land-cover change measurably contribute to the initiation, intensity or location of storms such as this one; this remains an open question that observational data alone cannot resolve.

Data and Code Availability

ERA5 and ERA5T reanalysis data are freely available from the Copernicus Climate Data Store (<https://cds.climate.copernicus.eu>), subject to the Copernicus licence to use Copernicus products. CHIRPS precipitation data are freely available from the Climate Hazards Center (<https://www.chc.ucsb.edu/data/chirps>). GPM IMERG data are freely available from NASA GES DISC (<https://disc.gsfc.nasa.gov>), subject to NASA Earthdata registration. The TAHMO station records used in this study (5-minute rainfall for 13 August 2026 and hourly multi-variable surface meteorology for 11-14 August 2026, both from the Federal University of Lafia station. Station ID: TA00461) were obtained directly from TAHMO by the corresponding author and are available from the author on reasonable request, subject to TAHMO's own data-sharing terms.

Funding Declaration

This work receives no funding, either locally or internationally.

Ethics

Not Applicable, as there were no human participants, human data, human tissue, animals, or anima-derived materials involved in this work.

Consent to Participate

Not applicable, no human participants involved in this work.

Consent to Publish declarations

Not applicable. This manuscript contains no individual person's data in any form, including individual details, images, or identifiable information.

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