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Climatological Normals of General Santos City, South Cotabato, Philippines (1991–2020): Analysis of Temperature, Rainfall, Humidity, and Atmospheric Parameters

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Abstract-This paper characterizes the climatological normals of General Santos City, South Cotabato, Philippines, for the 1991–2020 World Meteorological Organization (WMO) standard reference period, using published data from the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). The analysis is descriptive in scope and is based on the twelve-monthly normal values (n = 12) derived by PAGASA from the underlying 30-year observational record for the General Santos synoptic station. Because daily and monthly observations were unavailable, trend, anomaly, and extreme-value analyses were not performed. Rainfall, maximum and minimum temperatures, relative humidity, vapor pressure, dew point, mean sea level pressure, prevailing wind direction and speed, cloud amount, and thunderstorm and lightning frequency were summarized using descriptive statistics, seasonal grouping, diurnal temperature range (DTR) computations, and Pearson correlation analysis. The station records an annual cumulative rainfall of 958.1 mm distributed across 106 rainy days. June is the wettest month (101.9 mm), whereas February is the driest (53.0 mm). The mean annual temperature is 27.9°C, with the highest monthly maximum occurring in April (34.3°C) and the lowest in July and August (31.7°C); the annual mean DTR is 9.75°C. Because the correlations were computed across the twelve-monthly normal values rather than interannually, they reflect seasonal covariation rather than interannual or long-term relationships: rainfall covaries positively with relative humidity ($r = 0.91$) and negatively with mean temperature ($r = -0.77$). Prevailing monthly wind direction shifts from northeasterly during the dry season (December–March) to southerly during the wet season, consistent with the documented Philippine monsoon reversal. These results establish an updated station-level climatological baseline for General Santos City that may support subsequent work in agricultural planning, disaster risk reduction, and climate vulnerability assessment in the SOCCSKSARGEN region.

Keywords: Climatological normals, climate baseline, General Santos City, rainfall, temperature, relative humidity, diurnal temperature range, PAGASA, monsoon, Philippines

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I. INTRODUCTION

Climate is one of the most important factors that determines a region's ecological stability, economic vitality, and public health. Understanding these long-term statistical properties of atmospheric parameters such as climatological normal is essential for regional planning in agriculture, water resource management, infrastructure development, and disaster risk reduction [1]. The World Meteorological Organization (WMO) defines climatological normal as period averages computed over at least three consecutive 10-year periods, with 1991-2020 serving as the current standard reference period [2].

The Philippines, a tropical archipelago in the western Pacific, experiences a climate shaped by a complex

interaction among the Northeast Monsoon (Hanging Amihan), the Southwest Monsoon (Hanging Habagat), the tropical cyclones that affect the country every year, the Inter-Tropical Convergence Zone (ITCZ), and local topography. The Philippine climate has been described in detail at national and regional scales using PAGASA observations, including analyses of long-term trends and daily extremes in precipitation and near-surface temperature [3]. PAGASA classifies the climate of the country into four types based on rainfall distribution [4], which makes localized climatological studies important for region-specific decision-making.

General Santos City, situated in the SOCCSKSARGEN region of Mindanao (6°03'25.85″N, 125°06'11.19″E, elevation 132.2 m), is one of the major urban and agricultural centers of the southern Philippines. The city is a hub for tuna fishing, pineapple cultivation, and agro-industrial activity, all of which are sensitive to rainfall seasonality and temperature [5]. Although nationwide analyses of rainfall extremes exist [6]; detailed descriptive evaluations of individual synoptic stations in Mindanao remain sparse. Consequently, published station-level climatological baselines for General Santos City remain limited despite its economic significance.

This study provides a focused and explicitly bounded analysis of the 1991–2020 climatological normals published by PAGASA for the General Santos synoptic station. This present work converts these tabulated values into an interpreted station climatology by: (1) grouping monthly records into monsoon-defined seasons used in Philippine climatology; (2) quantifying the diurnal temperature range; (3) describing seasonal covariation among reported parameters; and (4) contextualizing these patterns within the documented regional atmospheric processes.

Due to data availability limits, this study does not establish long-term climatic trends, anomalies, extreme value distributions, or climate change signals. The daily and monthly observations underlying the normals were not accessible; the dataset consists strictly of the twelve derived monthly normal values and the annual summary row. Where the text refers to a "baseline," it denotes a reference climatology for the 1991–2020 period against which future studies utilizing full instrumental records may be compared.

The primary objectives of this study are: (1) to describe the monthly and annual distribution of rainfall, temperature, humidity, pressure, wind, cloud amount, and thunderstorm frequency at the General Santos synoptic station for 1991–2020; (2) to characterize the seasonal structure of that distribution in relation to the Philippine monsoon system; (3) to quantify the seasonal covariation among the reported variables and to state explicitly what such covariation can and cannot demonstrate; and (4) to situate the resulting station climatology within the existing Philippine climate literature.

The intended outcome is an updated and explicitly bounded climatological reference for General Santos City for use by local government units, farmers, urban planners, and researchers.

II. Methods and Procedure

A. Data Source

The primary dataset used in this study is the Climatological Normals table for General Santos, South Cotabato, prepared by the Climatology and Agrometeorology Division (CAD) of PAGASA [7].

The normals were derived by PAGASA from an underlying observational record spanning the WMO standard 30-year reference period 1991–2020 (representing approximately 360 station-months per parameter). However, the dataset accessible for this study comprises only the published summary table: twelve monthly normal values per parameter and an annual summary row. All statistical metrics derived in this paper, e.g., means, range, standard deviations, diurnal temperature ranges, and correlation coefficients, were computed using n = 12 monthly values rather than the underlying 360 monthly observations. The underlying observations were not obtained, and no result in this paper should be read as resting on them.

The parameters included in the dataset are monthly normal values for: rainfall amount (mm), number of rainy days, maximum and minimum temperatures (°C), mean temperature (°C), dry bulb and wet bulb temperatures (°C), dew point temperature (°C), vapor pressure (mb), relative humidity (%), mean sea level pressure (MSLP, mb), prevailing wind direction (16-point compass), wind speed (m/s), mean cloud amount (oktas), and the number of days with thunderstorms and lightning.

B. Data Processing and Analysis

Data processing, tabulations, and statistical evaluations were conducted in Microsoft Excel (Versions 2019 and 365). These analytical procedures include the following:

Data screening: The twelve-monthly values for each parameter were verified for completeness and for physical consistency before analysis. No missing values were present. Consistency checks confirmed that: (1) mean temperature remained within the reported monthly maximum and minimum bounds; (2) dew point did not exceed dry bulb temperature; and (3) monthly rainfall amounts and rainy-day counts summed exactly to PAGASA-supplied annual row (958.1 mm and 106 days). No values were excluded, interpolated, or adjusted.

Descriptive statistics: Arithmetic means, ranges, and standard deviations were computed across the twelve-

monthly normals for each parameter. These dispersion measures describe the amplitude of the mean annual cycle, i.e., how much the parameter varies from month to month within an average year, and are not estimates of interannual variability, which cannot be obtained from normals. Annual totals and averages were verified against the PAGASA-supplied annual row.

Seasonal grouping: Based on the Coronas climate classification [8] and updated typologies by Cinco et al. [3], the twelve months were partitioned into three distinct seasons: (1) Dry season (December–March, NE Monsoon/Amihan); (2) Transitional period (April–May); and (4) Wet season (June–November, SW Monsoon/Habagat and ITCZ). Seasonal statistics were computed as unweighted arithmetic means of the constituent monthly normals, except for seasonal rainfall totals, which represent cumulative sums. Because each season comprises only two to six monthly values, no inferential comparison between seasons was attempted.

Diurnal temperature range: The monthly mean DTR was computed as the arithmetic difference between the normal monthly maximum and the normal monthly minimum temperature. Because the metric is derived from two monthly mean extremes rather than from paired daily extremes, this quantity is the range of the mean daily cycle and is smaller than the mean of daily DTRs.

Correlation analysis: Pearson product-moment correlation coefficients (r) and coefficients of determination (R^2) were computed in Microsoft Excel (CORREL function) across rainfall, mean temperature, relative humidity, vapor pressure, thunderstorm frequency, and number of rainy days.

The sample for every coefficient reported in this paper is the set of twelve-monthly normal values (n = 12, df =10), not the approximately 360 underlying monthly observations. A correlation computed across twelve monthly normals measures the degree to which two variables move together over the course of the mean annual cycle, i.e., seasonal covariation. This correlation does not quantify interannual co-variability, establish a direct causal or physical mechanism, or scale to daily, event, or multi-year dynamics. Consequently, two distinct seasonal variables may show high correlation simply due to shared annual timing, regardless of whether a direct physical linkage exists.

Statistical significance was benchmarked using a two-tailed t-test on r with df = 10, following Wilks [9]; the critical values are r = 0.576 at $\alpha = 0.05$ and r = 0.708 at $\alpha = 0.01$. All reported *p*-values correspond to this test. However, given that the sample consists of twelve serially dependent monthly values from a single mean annual cycle, these *p*-values serve as indicative benchmarks rather than formal hypothesis tests. Because consecutive months exhibit autocorrelation, the effective degrees of freedom are fewer than the nominal ten.

Prevailing wind direction: PAGASA provides a single modal prevailing wind direction (16-point compass) for each month, which was tabulated to identify low-level seasonal circulation shifts. This dataset does not constitute a comprehensive wind-frequency analysis. A single monthly modal direction per month conveys no information about the distribution of direction, the proportion of time the prevailing direction is obtained, or the speeds associated with each sector. A defensible wind-frequency characterization for this station requires sub-monthly observational data and is typically visualized via a wind rose; thus, no such characterization is attempted here, and the wind results below are interpreted only as evidence of a seasonal shift in the modal direction.

III. Results

A. Data Tables and Statistical Summaries

Tables 1 (a) and 1 (b) present the complete set of monthly climatological normals for General Santos City (1991–2020). All subsequent tables and figures are derived from these twelve-monthly values.

Table 1 (a). Monthly Climatological Normals — General Santos, South Cotabato, Philippines (1991–2020)

Month	Rainfall (mm)	Rain Days	Max Temp (°C)	Min Temp (°C)	Mean Temp (°C)
JAN	96.9	9	32.3	22.6	27.5
FEB	53.0	7	32.9	22.8	27.9
MAR	55.3	6	34.0	23.0	28.5
APR	54.1	6	34.3	23.5	28.9
MAY	72.2	8	33.5	23.6	28.5
JUN	101.9	12	32.2	23.1	27.7
JUL	98.1	11	31.7	22.8	27.2
AUG	91.3	11	31.7	22.8	27.3
SEP	83.3	10	32.2	22.8	27.5
OCT	99.6	10	32.6	22.8	27.7
NOV	77.5	8	32.8	23.0	27.9
DEC	74.9	8	32.6	23.0	27.8
ANNUAL	**958.1**	**106**	**32.7**	**23.0**	**27.9**

Table 1 (b). Monthly Climatological Normals — General Santos, South Cotabato, Philippines (1991–2020)

Dry Bulb (°C)	Wet Bulb (°C)	Dew Point (°C)	Vapor Press. (mb)	RH (%)	MSLP (mb)	Wind Dir.
27.4	24.4	23.3	28.6	79	1009.6	NE
27.7	24.4	23.1	28.4	76	1009.9	NE

28.3	24.7	23.4	28.7	75	1009.9	NE
28.8	25.2	23.9	29.7	75	1009.4	S
28.4	25.3	24.2	30.3	78	1009.3	S
27.6	25.0	24.1	30.0	82	1009.5	S
27.1	24.7	23.9	29.7	83	1009.5	S
27.2	24.7	23.9	29.6	82	1009.7	S
27.4	24.8	23.8	29.6	81	1009.7	S
27.6	24.9	23.9	29.8	81	1009.3	S
27.8	25.0	24.0	29.8	80	1008.7	S
27.7	24.7	23.7	29.3	79	1008.6	W
27.7	**24.8**	**23.8**	**29.5**	**79**	**1009.4**	**S**

Source: PAGASA, Climatology and Agrometeorology Division (CADS/CAD/PAGASA)

Table 2 shows the monthly diurnal temperature range (DTR) alongside seasonal classifications. March exhibits the widest DTR at 11.0 °C, whereas July and August display the narrowest at 8.9 °C, yielding an annual mean DTR of 9.75 °C. This seasonal pattern, characterized by expanded ranges during dry months and contracted ranges at the peak of the wet season, is consistent with the moderating effect of cloud cover on both daytime heating and nocturnal cooling. This radiative mechanism was established globally by Dai et al. [10] and is further examined in Section III-C.

Table 2. Monthly Diurnal Temperature Range (DTR)

Month	Max Temp (°C)	Min Temp (°C)	DTR (°C)	Season
JAN	32.3	22.6	9.7	Dry
FEB	32.9	22.8	10.1	Dry
MAR	34	23	11	Dry
APR	34.3	23.5	10.8	Transition
MAY	33.5	23.6	9.9	Transition
JUN	32.2	23.1	9.1	Wet
JUL	31.7	22.8	8.9	Wet
AUG	31.7	22.8	8.9	Wet
SEP	32.2	22.8	9.4	Wet
OCT	32.6	22.8	9.8	Wet
NOV	32.8	23	9.8	Wet
DEC	32.6	23	9.6	Dry
MEAN DTR			**9.75**	

Table 3 contrasts the three monsoon-defined seasons: dry (December–March), transitional (April–May), and wet (June–November). The wet season accounts for 551.7 mm, or 58% of annual rainfall, displaying both the highest mean number of rainy days per month (10.3) and relative humidity (81.5%). The transitional period records the highest mean maximum temperature (33.9 °C) and peak thunderstorm activity (5.5 days/month). Although the dry season receives the lowest rainfall, its monthly mean of 70.0 mm remains non-negligible. Because seasonal values represent unweighted averages across subsets of two to six months, these contrasts are interpreted descriptively without formal significance testing.

Table 3 (a). Seasonal Summary Table

Season	Months	Avg Rainfall (mm)	Total Rain (mm)
DRY SEASON	**Dec – Mar**	70.03	280.1
TRANSITIONAL	**Apr – May**	63.15	126.3
WET SEASON	**Jun – Nov**	91.95	551.7

Table 3 (b). Seasonal Summary Table

Avg Rainy Days	Avg Max Temp (°C)	Avg Min Temp (°C)	Avg Mean Temp (°C)	Avg RH (%)	Avg Tstm Days
7.5	32.95	22.85	27.93	77.25	2.25
7	33.9	23.55	28.7	76.5	5.5
10.3	32.2	22.88	27.55	81.5	5

Collectively, Tables 1 through 3 describe a coherent annual cycle. Rainfall rises from a February minimum (53.0 mm) to its June maximum (101.9 mm), whereas maximum temperature peaks earlier in April (34.3°C) before declining as cloud amount increases. Relative humidity scales from 75% in the driest months to 83% at the height of the wet season, while thunderstorm frequency reaches its maximum in May. The modal wind shifts direction from northeasterly from January through March to southerly from April through November, with a westerly direction recorded in December.

Figure 1 illustrates monthly rainfall, which normally exhibits a broadly bimodal distribution. A primary rainfall maximum occurs in June (101.9 mm), aligning with the onset of the Southwest Monsoon, followed by a secondary cluster spanning from July through October. These wet periods are separated by a drier interval from February through April. Notably, January yields higher rainfall (96.9 mm) than the subsequent dry-season months; while orographic enhancement of Northeast Monsoon moisture represents a plausible driver, climatological normals alone are insufficient to confirm this mechanism over competing hypotheses.

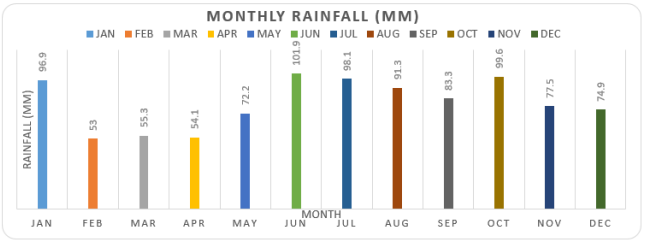


Fig. 1. Monthly Rainfall (mm)

Figure 2 shows the maximum, minimum, and mean temperature normals. Maximum temperature peaks in April (34.3°C) and reaches its minimum in July and August (31.7°C), coinciding with peak cloud cover (6 oktas). Minimum temperature exhibits remarkable stability, varying only 1.0°C across the entire year (22.6–23.6°C). Mean temperature tracks maximum temperature closely, peaking in April–May and declining slightly throughout the wet season.

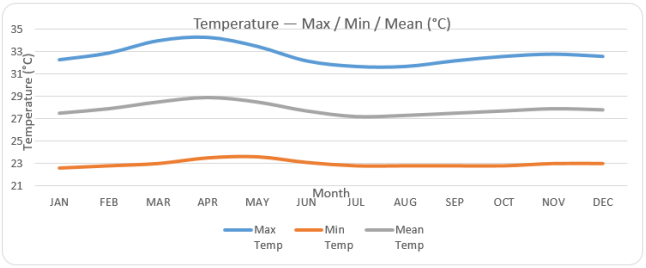


Fig. 2. Temperature — Maximum, Minimum, and Mean (°C)

Figure 3 illustrates monthly relative humidity varying between 75% in March and April and 83% in July. The narrow 8-percentage-point annual range indicates that the station remains humid throughout the year, with no month approaching dry conditions in absolute terms. The vertical axis is scaled to the observed range; readers should note that the absolute variation is modest.

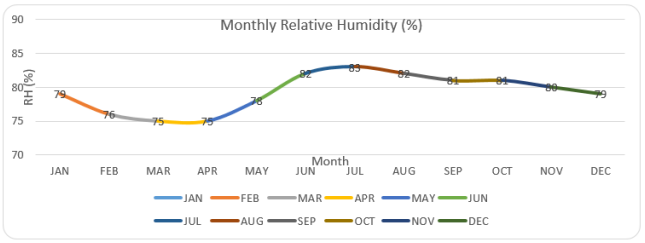


Fig. 3. Monthly Relative Humidity (%)

Figure 4 compares monthly thunderstorms and lightning days. The two series are nearly identical, as would be expected given that lightning is a defining feature of thunderstorm activity and satellite observations confirm their close co-occurrence at tropical land stations [11]. Both parameters peak in May (7 thunderstorm days, 8 lightning days). This maximum occurs during the pre-monsoon transition, when temperatures and vapor pressure approach their annual highest but monthly rainfall totals have not yet reached their peak. This atmospheric configuration is consistent with strong convective instability, although summary normals alone cannot quantify instability metrics directly [12].

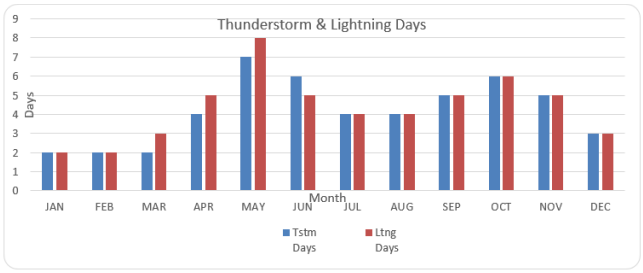


Fig. 4. Thunderstorm & Lightning Days

Figure 5 shows mean sea level pressure (MSLP) across the year. Pressure remains remarkably stable, ranging only from 1008.6 mb to 1009.9 mb, which has a total annual range of 1.3 mb. The minima occur in the late wet season (October–December), which is consistent with the lower pressures associated with monsoon and tropical disturbances in the region. The vertical axis of Figure 5 is expanded to resolve this variation, and the apparent amplitude of the curve should not be interpreted as a meteorologically large pressure fluctuation.

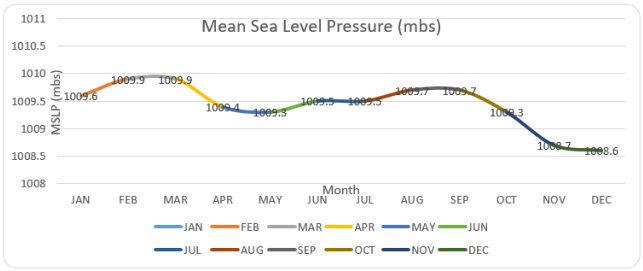


Fig. 5. Mean Sea Level Pressure (mb)

Figure 6 illustrates two measures of atmospheric moisture. Vapor pressure ranges from 28.4 mb in February to 30.3 mb in May, peaking just before the onset of the wet season, and dew point temperature follows the same shape (23.1°C in February to 24.2°C in May). Both indicate that near-surface moisture content is greatest during the pre-monsoon transition. That the thunderstorm maximum coincides with this moisture maximum is consistent with a convective interpretation, but coincidence in the monthly normals does not by itself demonstrate the causal link.

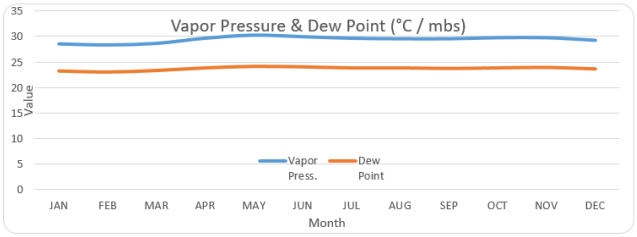


Fig. 6. Vapor Pressure (mb) and Dew Point Temperature (°C)

Figure 7 illustrates monthly diurnal temperature range (DTR) values. DTR peaks during the dry season in March (11.0°C) and reaches its annual minimum during the wet season in July and August (8.9 °C). The conventional explanation for this pattern is radiative: increased cloudiness during wet months reduces incoming solar shortwave radiation by day while retarding outgoing longwave radiation at night, effectively compressing the diurnal range from both ends. Dai et al. [10] established this global mechanism empirically using observational datasets, and the pattern observed accords directly with this mechanism.

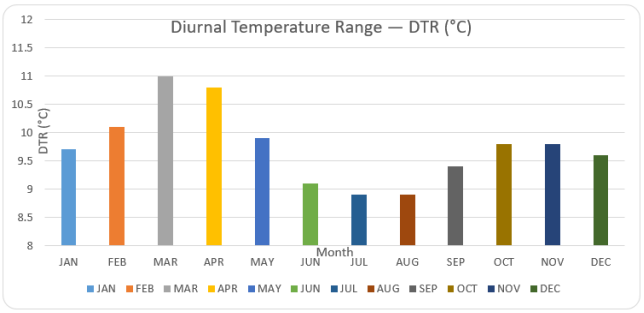


Fig. 7. Diurnal Temperature Range, DTR (°C)

Figure 8 shows the number of rainy days per month, ranging from 6 in March and April to 12 in June. June has both the highest rainfall total and the highest rainy-day count, which indicates that its rainfall is distributed across many days rather than concentrated in a few. The mean rainfall per rainy day in June (8.5 mm) is close to the annual mean (9.0 mm), supporting that reading, though the normals contain no information on daily rainfall intensity or on the frequency of heavy-rainfall events.

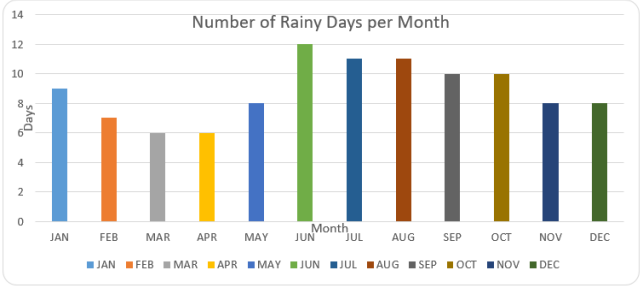


Fig. 8. Number of Rainy Days per Month

Table 4 presents the correlation matrix. As noted in Section II-B, all coefficients describe seasonal covariation across the twelve-monthly normals.

On that basis, relative humidity and rainy days show the strongest seasonal covariation ($r = +0.95$, $p < 0.01$), followed by vapor pressure and thunderstorm frequency ($r = +0.93$, $p < 0.01$). Rainfall covaries positively with relative humidity ($r = +0.91$) and with rainy-day frequency ($r = +0.91$), and negatively with mean temperature ($r = -0.77$); relative humidity likewise covaries negatively with mean temperature ($r = -0.84$). All of these exceed the nominal $\alpha = 0.01$ critical value of 0.708. Because successive monthly normals are serially dependent and the effective degrees of freedom are fewer than the nominal ten (Section II-B – Data Processing and Analysis), this threshold is used only as an indicative benchmark. It shows that these associations are strong across the mean annual cycle, not that they have been confirmed by a formal hypothesis test. Stated differently, the wetter months of an average year are also cooler and more humid. Whether this relationship holds between wetter and drier years at this station is a separate question that these summary data cannot address. Notably, atmospheric moisture and thunderstorm activity covary strongly with each other, whereas neither correlate strongly with monthly rainfall totals ($r = 0.38$ and $r = 0.39$, respectively). Because both coefficients fall below the nominal $\alpha = 0.05$ critical threshold ($r = 0.576$), no statistically significant seasonal association is detected at this sample size ($n = 12$). However, given the serial dependence among twelve monthly values, the lack of a detectable correlation should not be interpreted as definitive proof that no relationship exists. One plausible interpretation is that monthly rainfall volume at this station is driven less by near-surface moisture availability than by synoptic-scale circulation features that govern the duration and presence of rain-bearing systems—though the present dataset cannot confirm this mechanism.

Table 4 (a). Correlation Matrix (Pearson r)

	Rainfall	Mean Temp	Rel. Humidity
Rainfall	**1.000**	**-0.769**	**0.906**
Mean Temp	**-0.769**	**1.000**	**-0.841**
Rel. Humidity	**0.906**	**-0.841**	**1.000**
Vapor Press.	0.376	0.048	0.485
Thunderstorms	0.395	0.038	0.455
Rainy Days	**0.914**	**-0.805**	**0.948**

Table 4 (b). Correlation Matrix (Pearson r)

Vapor Press.	Thunderstorms	Rainy Days
0.376	0.395	**0.914**
0.048	0.038	**-0.805**
0.485	0.455	**0.948**
1.000	**0.931**	0.426
0.931	**1.000**	0.439
0.426	0.439	**1.000**

B. Rainfall Distribution

Total annual rainfall at General Santos City is 958.1 mm, which is spread over 106 rainy days. Monthly rainfall ranges from 53.0 mm in February to 101.9 mm in June (Table 1). The annual distribution shows a roughly bimodal pattern; rainfall is suppressed during the dry season (December–March), peaks in June alongside the onset of the Southwest Monsoon, and reaches a secondary peak in October (99.6 mm).

The seasonal grouping shows a clear monsoon signature, i.e., mean monthly rainfall during the wet season (June–November) is 91.95 mm, compared with 70.03 mm during the dry season (December–March) and 63.15 mm during the transitional months (April–May) (Table 3). This pattern is consistent with the Type III Philippine climate classification, characterized by relatively even rainfall distribution throughout the year with a short dry spell from December to April [4].

The frequency of rainy days follows the same seasonal gradient, ranging from 6 days in March and April to 12 days in June, which indicates more frequent rain-producing systems during the wet season. Even the driest month, February, records 53.0 mm. The absence of a genuinely dry month is characteristic of low-latitude maritime stations near the western Pacific warm pool [13].

C. Temperature Regimes

The mean annual temperature for General Santos City is 27.9°C (Table 1). Maximum temperature peaks in April at 34.3°C, coinciding with the period immediately preceding SW Monsoon onset, when solar radiation is near-overhead and cloud cover remains relatively low (5 oktas). Conversely, the lowest maximum temperatures occur in July and August (both 31.7°C), falling at the height of the SW Monsoon when cloud cover reaches 6 oktas.

Minimum temperatures are remarkably stable throughout the year, varying by only 1.0°C - from 22.6°C in January to 23.6°C in May. Thermal buffering by the adjacent water bodies (Sarangani Bay and the Celebes Sea), combined with the station's low latitude and consequently small annual variation in insolation, provides the standard explanation for this narrow range [14]. While the present data are consistent with this mechanism, they do not test it, as no direct comparison was made with an inland station at the same latitude.

The mean diurnal temperature range (DTR) averages 9.75°C annually. It is lowest in July to August (8.9°C), when cloud cover and rainfall are most intense, and expands to its highest in March (11.0°C), when clear-sky conditions prevail. The negative relationship between DTR and rainfall is consistent with the findings of Dai et al. [10], who showed globally that cloud cover and precipitation systematically reduce DTR.

D. Humidity, Vapor Pressure, and Dew Point

Ranging from 75% in March and April to 83% in July, the mean annual relative humidity (RH) is 79%. Relative humidity covaries strongly and positively with rainfall across the annual cycle ($r = 0.91$, $p < 0.01$, $n = 12$), indicating that the wetter months of the average year are also the more humid months. This is the expected seasonal signature of a monsoon climate [15]; it does not establish that rainfall amount predicts humidity at shorter timescales or between years.

Vapor pressure follows a similar seasonal pattern, ranging from 28.4 mb in February to 30.3 mb in May, with an annual mean of 29.5 mb. Dew point temperatures remain consistently high year-round (23.1–24.2 °C), reflecting a persistently moist lower atmosphere characteristic of low-latitude coastal stations in the western Pacific [16].

E. Mean Sea Level Pressure

With an annual mean of 1009.4 mb, mean sea level pressure (MSLP) at General Santos varies narrowly between 1008.6 mb in December and 1009.9 mb in February–March. The annual range is 1.3 mb, which is small in absolute terms and should be interpreted accordingly. The slightly higher pressures in February–March are consistent with the seasonal dominance of the subtropical high-pressure belt and Northeast Monsoon flow, and the marginally lower pressures in November–December with residual ITCZ activity and late-season tropical disturbances [17]. These interpretations rest on the general synoptic behavior of the region and are offered as hypotheses; the monthly normals contain no synoptic or upper-air information with which they could be verified.

F. Wind Patterns

The modal monthly wind direction reverses seasonally. The prevailing direction is northeasterly (NE) during the dry season months of January through March, consistent with the Northeast Monsoon (Amihan). The modal direction shifts to southerly (S) from April through November, reflecting the influence of the Southwest Monsoon (Habagat) and the ITCZ. December is reported as westerly (W). This seasonal reversal in the modal direction is consistent with the regional monsoon circulation documented for Mindanao and the

wider Asian monsoon domain [3], [18]. Because PAGASA reports only a single modal direction per month, these twelve values indicate that the reversal occurs but cannot establish its sharpness, its interannual consistency, or the proportion of time the prevailing direction is obtained. Similarly, a single westerly in December cannot fully characterize that month's wind regime.

Mean wind speed averages approximately 2 m/s for most months, decreasing to 1 m/s during June–October. While reduced pressure gradients during the established Southwest Monsoon are a possible explanation, the normals do not permit this to be verified. Mean cloud cover ranges from 5 oktas in the dry season to 6 oktas at the peak of the wet season.

IV. Discussions

The 1991–2020 normals describe a station with a distinctly tropical climate whose annual cycle is governed by the Philippine monsoon system, and which has no month that qualifies as dry. The driest month (February, 53.0 mm) exceeds the conventional dry-month thresholds used in tropical climatology [19]. Relative to the more seasonally extreme stations of Luzon and the Visayas, these characterize General Santos City as having a comparatively even hydrological regime, although a formal inter-station comparison lies beyond the scope of this study.

The April peak in monthly maximum temperature (34.3°C) coincides with the Philippine pre-monsoon heat build-up. Near-zenith solar radiation and low cloud amount are the conventionally cited contributors, and the low reported cloud amount for April (5 oktas) in the present dataset is consistent with the latter contributor. Warming associated with subsidence over the Mindanao uplands has also been proposed as a contributing factor for inland southern Mindanao stations. However, because the present dataset contains no upper-air, radiation, or spatial data, this mechanism is noted strictly as a hypothesis requiring separate investigation.

The thunderstorm maximum in May (7 days) falls within the April–May transition between the NE and S prevailing wind regimes. Lyon and Camargo [20] identified April–May as the principal period of monsoon-onset convection over the Philippine Sea and surrounding areas, and the timing observed here is consistent with that finding. The present data indicate co-occurrence in the mean annual cycle; they do not measure atmospheric instability and cannot demonstrate that the wind-regime transition causes the convective maximum.

The seasonal covariation between rainfall and relative humidity ($r = +0.91$) has a straightforward physical reading: precipitation moistens the near-surface atmosphere, and evapotranspiration from wet soil sustains that moisture [21]. Similarly, the negative association between temperature and rainfall ($r = -0.77$) is consistent with reduced insolation under greater cloud cover and with evaporative cooling during precipitation [22]. Both readings are physically well grounded, and both are consistent with the data. Neither, however, is demonstrated by the correlation coefficients themselves. Rainfall, humidity, and temperature at this station are each strongly seasonal, and variables with a common seasonal cycle will co-vary across twelve monthly normals whether they act directly on one another. These coefficients should be read as a quantitative description of the mean annual cycle, with the physical mechanisms supplied by the established literature rather than established here.

The narrow annual spread in minimum temperature (1.0°C) is consistent with a strong maritime influence from Sarangani Bay and the Celebes Sea. Coastal stations in the western Pacific typically show smaller annual ranges in minimum temperatures than continental stations at comparable latitudes [23], which is the expected result of the greater thermal inertia of the adjacent ocean.

Several potential applications follow from this climatology, and they are stated as potential because none were directly evaluated in this study. The absence of a cold season is consistent with the feasibility of year-round cultivation, which is congruent with the region's established role as a producer of rice, corn, and tropical fruits [5]. The seasonal contrast in prevailing conditions may be relevant to scheduling outside agriculture, like the dry-season months bring relatively clear weather conditions favorable for construction and outdoor activities, while the wet-season months combine higher rainfall with lower mean wind speeds (1 m/s versus 2 m/s), a combination relevant to preliminary wind-energy siting assessment and to aviation planning [24]. However, any operational application of these normals would require analysis at the temporal resolution appropriate to the application, which the monthly normals do not provide.

It is necessary to note what these normals do not capture. Cinco et al. [3] documented national-level Philippine warming on the order of 0.6°C per century over 1951–2010, and it would be natural to suppose that the 1991–2020 normals for this station therefore represent a warmer baseline than the periods that preceded them. The present study cannot support that assumption. Establishing it would require comparing these values against the normals for an earlier reference period at the same station (e.g., 1961–1990), or computing anomalies and trends from the underlying 1991–2020 observational record. Neither the earlier normals nor the station observations were available to the authors, and no such comparison was performed. The values reported here are accordingly presented as a description of the 1991–2020 period alone. Whether they are warmer, wetter, or otherwise different from earlier decades at this station is an open question, and one further complicated by the fact that a 30-year mean at a western Pacific station embeds an unknown contribution from ENSO-related interannual variability, the phase distribution of which differs between reference periods [25].

Subject to the same qualification, these normals may serve as baseline inputs to several planning activities. Monthly rainfall and temperature normals are the

conventional starting point for irrigation scheduling and could inform planning for the February–April dry spell in the city's agricultural hinterland, though operational scheduling additionally requires evapotranspiration estimates and rainfall variability that normals do not supply. The monthly thunderstorm frequencies indicate which months carry the greatest convective risk at General Santos International Airport, offering relevant insight for seasonal risk management without serving as a substitute for the sub-daily climatology required in air traffic operations. The wet-season maxima in vapor pressure and relative humidity identify the months of greatest atmospheric moisture, which is a recognized precondition for fungal crop disease; whether those months coincide with elevated disease incidence in the region's cropping systems was not examined here and would require epidemiological data.

V. CONCLUSIONS

This study has characterized the 1991–2020 climatological normals for the General Santos City synoptic station, South Cotabato, Philippines, using the twelve-monthly normal values published by PAGASA.

Three characteristics define the station's climatology. First, it is uniformly wet: annual rainfall of 958.1 mm is distributed across 106 rainy days and across all twelve months, with no month dry in the climatological sense, making the seasonal contrast one of degree rather than kind. Second, it is thermally narrow: mean annual temperature is 27.9°C, the annual range in monthly minimum temperature is only 1.0°C, and the mean diurnal range of 9.75°C exceeds the annual range of the monthly means, a signature of a low-latitude maritime station where the day-to-night cycle dominates the seasonal one. Third, its seasonality is organized by the monsoon: rainfall, humidity, cloud amount, and prevailing wind direction all shift together between a December–March northeasterly regime and a June–November southerly one, with the April–May transition marked by annual highest temperatures and greatest thunderstorm frequency.

The correlations reported here describe how these variables move together over the course of the mean annual year. They were computed across twelve monthly normals and are therefore measures of seasonal covariation. They are consistent with the physical relationships documented for tropical maritime climates but do not independently establish them. Likewise, the shift in modal monthly wind direction is evidence that a seasonal reversal occurs, but a single prevailing direction per month is not a wind-frequency analysis and does not on its own establish the structure or consistency of the monsoon cycle at this station.

The contribution of this work is therefore a documented and internally consistent reference climatology for General Santos City for the 1991–2020 period, together with an explicit account of what that climatology can and cannot support. The baseline is offered as a potential input to agricultural planning, disaster risk reduction, infrastructure design, and climate adaptation work in the SOCCSKSARGEN region. None of these applications were evaluated here, and each would require subsequent analysis at its own appropriate temporal and spatial resolution.

The principal limitation of this study lies within the dataset itself. Published normals are summary statistics, and the questions of greatest interest for climate adaptation- whether this station is warming, whether its rainfall regime is shifting, or whether extremes are intensifying- require the underlying observations from which the summaries were made. The PAGASA General Santos synoptic station has an instrumental record extending beyond the 1991–2020 reference period. Obtaining that record would permit anomaly and trend analysis using established non-parametric methods such as the Mann–Kendall test and Sen's slope estimator, direct comparison of the 1991–2020 normals against the 1961–1990 period, characterization of rainfall and temperature extremes, and a proper wind-rose analysis at sub-monthly resolution. Furthermore, spatial interpolation with neighboring Mindanao stations would further allow gridded climate products for the region. The present baseline is intended to serve as the reference against which such work can be benchmarked.

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