Summer Research Project Report

Under the INSPIRE-SHE Scholarship Program

Department of Science and Technology, Government of India

Analysis of Meteorological Data of Pantnagar Weather Station

A Comprehensive Statistical Study
1989–2008 (20 Years)

Author
Gaurav Tiwari

Original Project: Summer 2012
Revised and Expanded: January 2026

Abstract

Twenty years of weekly meteorological observations (1989–2008) from the IMD-approved weather station at Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, were analyzed to characterize the regional climate and assess parameter variability. The observatory is located at 29°N latitude, 79.3°E longitude, and 243.84 m altitude in the Tarai belt of Uttarakhand.

Key findings: Annual rainfall averages 1610.8 mm with extreme variability ($\sigma = 2768.4$ mm). Mean annual maximum temperature is 29.6 °C ($\sigma = 0.575$ °C), while mean annual minimum is 16.9 °C ($\sigma = 0.344$ °C). The region experiences dramatic diurnal humidity swings, from 84.7% (morning) to 50.8% (afternoon). Regression and correlation analyses reveal weak coupling between rainfall magnitude and rainy-day count, confirming the stochastic nature of precipitation in this region.

Keywords: meteorology, Pantnagar, regression analysis, rainfall variability, Tarai climate, time-series analysis, humid subtropical climate, monsoon variability

Contents

1 Introduction

Meteorology, derived from the Greek words *meteoros* (atmospheric) and *logos* (science), is the scientific study of atmospheric processes through applied physics. The discipline encompasses both static and dynamic components of the atmosphere, collectively termed *weather*—the instantaneous state of atmospheric conditions at a specific location and time.

Understanding regional climate patterns requires long-term observational data. Short-term records capture noise rather than signal. Twenty years of continuous data, such as the dataset analyzed in this study, can reveal underlying trends while properly accounting for natural variability and stochastic fluctuations inherent in meteorological phenomena.

1.1 Study Area: The Pantnagar Region

The Pantnagar region presents a unique and scientifically valuable study area. Located in the Tarai belt at the base of the Himalayan foothills, it occupies a transitional zone between the Indo-Gangetic plains and the lower Himalayan ranges. This geographic position results in distinctive meteorological characteristics:

- **Geographic coordinates:** 29°N latitude, 79.3°E longitude
- **Altitude:** 243.84 m above mean sea level
- **Climate classification:** Humid subtropical (Köppen: *Cwa*)
- **Pronounced seasonality:** Summer maximum temperatures exceeding 42 °C; winter minimum temperatures approaching 2 °C
- **Monsoon dominance:** Annual rainfall averaging 145 cm, with 80% concentrated in the four-month monsoon season (June–September)
- **Soil characteristics:** Alluvial composition with pH 7.2–7.4, supporting intensive agriculture

The economic significance of accurate meteorological prediction in this region cannot be overstated. The G.B. Pant University of Agriculture and Technology—India's first agricultural university—operates extensive research farms where crop planning decisions depend critically on weather forecasts.

1.2 Study Objectives

This research was undertaken with the following primary objectives:

1. Characterize the statistical distribution of key meteorological parameters including temperature, rainfall, humidity, wind velocity, sunshine duration, and evaporation
2. Quantify inter-annual variability in temperature, rainfall, and humidity using appropriate statistical measures
3. Identify and quantify correlations between meteorological variables to understand their interdependencies

4. Develop regression models for parameter estimation and potential predictive applications
5. Apply moving-average techniques to identify long-term trends and assess climate stationarity

1.3 Significance of the Study

The Tarai belt represents one of India's most productive agricultural regions, contributing significantly to national food security. The insights derived from this meteorological analysis have direct applications in:

- Agricultural planning and crop calendar optimization
- Water resource management and irrigation scheduling
- Flood prediction and disaster preparedness
- Climate change baseline establishment
- Urban planning and infrastructure development

2 Theoretical Background

2.1 Atmospheric Structure

Earth's atmosphere forms a thin gaseous envelope bound to the planet by gravitational attraction. This envelope, though extending hundreds of kilometers, contains 99% of its mass within the lowest 30 km. The primary composition consists of:

Table 1: Composition of Earth's Atmosphere

Gas	**Symbol**	**Volume (%)**
Nitrogen	N_2	78.08
Oxygen	O_2	20.95
Argon	Ar	0.93
Carbon Dioxide	CO_2	0.04
Other trace gases	—	< 0.01

Variable constituents—water vapor, ozone, and particulate matter—vary considerably by location and time, driving weather phenomena. Water vapor content ranges from nearly 0% in polar regions to 4% in tropical maritime air masses.

2.1.1 Atmospheric Layers

The atmosphere stratifies into distinct thermal layers, each with characteristic properties relevant to meteorological studies:

Troposphere (0–8/16 km) The lowest atmospheric layer contains three-fourths of atmospheric mass and nearly all moisture and dust. *All weather phenomena occur within this layer.* Temperature decreases with altitude at the environmental lapse rate of approximately 6.5 °C/km. The tropopause height varies from 8 km at the poles to 16 km at the equator due to thermal expansion effects.

Stratosphere (Tropopause to 50 km) A thermally stable, moisture-free layer containing the ozone shield. Temperature increases with altitude due to ultraviolet absorption by ozone molecules. The stratosphere contains approximately 19% of atmospheric mass.

Mesosphere (50 km–80 km) Temperature decreases with altitude in this layer. The mesopause, at approximately 80 km, marks the coldest point in the atmosphere (-90 °C).

Thermosphere/Ionosphere (80 km–600 km) Characterized by extremely low pressure (≈ 0.01 mbar at 90 km). Contains ionized particles that reflect radio waves, enabling long-distance communication.

Exosphere ($>$ 600 km) The outermost region where the atmosphere gradually transitions to interplanetary space. Mean free path becomes very large, and molecules may escape Earth's gravitational field.

Note: Meteorological studies focus primarily on the troposphere, with occasional extension into the lower stratosphere for ozone-related research.

2.2 Meteorological Parameters

Weather stations record multiple parameters at standardized times. Indian Meteorological Department (IMD) stations record observations at 07:12 and 14:12 hours IST. The parameters relevant to this study are described below.

2.2.1 Atmospheric Pressure

Atmospheric pressure represents the force exerted per unit area by the column of air above a location. Measurement techniques include:

- **Fortin's barometer:** Mercury column method; direct pressure measurement
- **Aneroid barometer:** Mechanical diaphragm deflection; portable design
- **Barograph:** Continuous recording using aneroid mechanism with chart recorder

Standard atmospheric pressure at sea level is defined as:

$$P_0 = 1.013 \times 10^5\,\mathrm{N/m^2} = 1013.25\,\mathrm{hPa} = 1\ \mathrm{atm} \tag{1}$$

Pressure decreases approximately exponentially with altitude according to the barometric formula:

$$P(h) = P_0 \exp\left(-\frac{Mgh}{RT}\right) \tag{2}$$

where M is the molar mass of air, g is gravitational acceleration, R is the universal gas constant, and T is absolute temperature.

2.2.2 Wind Direction and Velocity

Wind refers to horizontal air movement parallel to Earth's surface; vertical components are termed *air currents* or *updrafts/downdrafts*. Measurement instruments include:

- **Wind vane:** Indicates direction from which wind blows
- **Cup anemometer:** Measures wind speed via rotation rate
- **Sonic anemometer:** High-precision 3D wind measurement using ultrasonic pulses

Wind velocity follows a Weibull distribution at most locations:

$$f(v) = \frac{k}{c}\left(\frac{v}{c}\right)^{k-1} \exp\left[-\left(\frac{v}{c}\right)^{k}\right] \tag{3}$$

where k is the shape parameter and c is the scale parameter.

2.2.3 Temperature

Temperature is the most fundamental meteorological parameter, directly affecting air density, saturation vapor pressure, and atmospheric stability. Measurement methods include:

- **Mercury thermometer:** Standard liquid-in-glass instrument
- **Thermograph:** Continuous recording using bimetallic strip
- **Resistance thermometer:** Electronic measurement for automated stations

Key derived quantities include:

$$\text{Mean daily temperature:} \quad T_{\text{mean}} = \frac{T_{\max} + T_{\min}}{2} \tag{4}$$

$$\text{Daily temperature range:} \quad \Delta T = T_{\max} - T_{\min} \tag{5}$$

$$\text{Mean monthly temperature:} \quad \bar{T}_m = \frac{1}{n}\sum_{i=1}^{n} T_{\text{mean},i} \tag{6}$$

$$\text{Normal temperature:} \quad T_{\text{normal}} = \frac{1}{30}\sum_{j=1}^{30} \bar{T}_{m,j} \quad \text{(30-year average)} \tag{7}$$

2.2.4 Humidity

Relative humidity quantifies the degree of saturation of air with water vapor:

$$\text{RH} = \frac{e}{e_s(T)} \times 100\% \tag{8}$$

where e is the actual vapor pressure and $e_s(T)$ is the saturation vapor pressure at temperature T.

Saturation vapor pressure follows the Clausius-Clapeyron relation, approximated by:

$$e_s(T) = 6.11 \exp\left[\frac{17.27T}{T + 237.3}\right] \quad \text{(hPa, with } T \text{ in °C)} \tag{9}$$

Measurement is performed using a **psychrometer** (wet-bulb/dry-bulb thermometer pair) or a **hygrograph** for continuous recording.

2.2.5 Solar Radiation and Sunshine Duration

Solar radiation drives atmospheric dynamics through differential heating of Earth's surface. Sunshine duration—recorded as hours of bright sunshine per day—is measured using a **Campbell-Stokes sunshine recorder**, wherein a glass sphere focuses sunlight to burn a trace on calibrated card.

2.2.6 Precipitation

Precipitation encompasses all forms of atmospheric water deposition: rainfall, snowfall, hail, and fog drip. Rainfall measurement uses standardized rain gauges. Three methods exist for computing areal averages:

1. Arithmetic Mean Method (used in this study):

$$\bar{P} = \frac{1}{n}\sum_{k=1}^{n} P_k \tag{10}$$

where P_k is rainfall at station k and n is the number of stations.

2. Thiessen Polygon Method:

$$\bar{P} = \frac{\sum_{k=1}^{n} A_k P_k}{\sum_{k=1}^{n} A_k} \tag{11}$$

where A_k is the polygonal area around station k. This method accounts for irregular station spacing.

3. Isohyetal Method: Contour mapping of equal rainfall lines (isohyets). Most accurate but requires analyst expertise and station density.

2.2.7 Evaporation

Evaporation quantifies water loss from surfaces due to vaporization. Measurement uses pan evaporimeters—standardized water tanks with depth gauges. The relationship between pan evaporation (E_{pan}) and lake evaporation (E_{lake}) is expressed through a pan coefficient:

$$E_{\text{lake}} = K_p \cdot E_{\text{pan}} \tag{12}$$

where $K_p \approx 0.7$ for USWB Class A pans under typical conditions.

3 Methodology

3.1 Data Source and Study Period

Weekly meteorological data spanning 20 years (1989–2008) were obtained from the Agro-Meteorological Observatory at G.B. Pant University of Agriculture and Technology, Pantnagar. Key characteristics of the dataset:

Table 2: Dataset Characteristics

Attribute	**Value**
Operating authority	N.E.B. Crop Research Center
Certification	IMD-approved
Observation times	07:12 and 14:12 hours IST
Recording frequency	Twice daily
Aggregation level	Weekly (14 observations/week)
Total study period	1989–2008 (20 years)
Total data points	$\approx$ 1040 weekly observations

3.2 Statistical Framework

Meteorological phenomena are predominantly stochastic. Unlike deterministic processes (e.g., sunrise and sunset times), most weather parameters exhibit inherent unpredictability requiring probabilistic treatment.

3.2.1 Fundamental Definitions

Probability If an experiment is conducted N times and outcome A occurs n times:

$$P(A) = \lim_{N \to \infty} \frac{n}{N} \tag{13}$$

Probability values range from 0 (impossible event) to 1 (certain event), satisfying the axioms of Kolmogorov.

Random Variable A variable associated with a stochastic process whose value cannot be predicted deterministically. Denoted by uppercase letters (X); specific values by lowercase (x).

- **Discrete random variable:** Takes countable values (e.g., number of rainy days)
- **Continuous random variable:** Takes values on a continuum (e.g., rainfall amount)

3.2.2 Descriptive Statistics

For a sample of n observations $\{x_1, x_2, \ldots, x_n\}$:

Sample Mean:

$$\bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i \tag{14}$$

Sample Variance:

$$s^2 = \frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2 \tag{15}$$

Standard Deviation:

$$s = \sqrt{s^2} \tag{16}$$

Coefficient of Variation:

$$\mathrm{CV} = \frac{s}{\bar{x}} \times 100\% \tag{17}$$

The coefficient of variation provides a dimensionless measure of relative variability, enabling comparison across parameters with different units.

3.3 Regression Analysis

Regression analysis has been fundamental to Indian monsoon prediction since the pioneering work of Blanford (1884), subsequently refined by Sir Gilbert Walker (1921–1927). Three regression models were considered in this study:

3.3.1 Simple Linear Regression

$$y = a + bx \tag{18}$$

where x is the independent variable, y is the dependent variable, and a, b are regression constants (intercept and slope, respectively).

3.3.2 Multiple Linear Regression

$$y = a_0 + a_1 x_1 + a_2 x_2 + \cdots + a_n x_n \tag{19}$$

for n independent predictor variables.

3.3.3 Curvilinear (Power-Law) Regression

$$y = ax^b \tag{20}$$

Linearized via logarithmic transformation:

$$\log y = \log a + b \log x \tag{21}$$

3.3.4 Least Squares Estimation

For observations $\{(x_1, y_1), (x_2, y_2), \ldots, (x_n, y_n)\}$, optimal regression coefficients minimize the sum of squared residuals:

$$S = \sum_{k=1}^{n} (y_k - a - bx_k)^2 \tag{22}$$

Setting partial derivatives to zero:

$$\frac{\partial S}{\partial a} = -2 \sum_{k=1}^{n} (y_k - a - bx_k) = 0 \tag{23}$$

$$\frac{\partial S}{\partial b} = -2 \sum_{k=1}^{n} x_k (y_k - a - bx_k) = 0 \tag{24}$$

Solving these normal equations yields:

$$b = \frac{n \sum x_k y_k - \sum x_k \sum y_k}{n \sum x_k^2 - (\sum x_k)^2} = \frac{\mathrm{Cov}(X, Y)}{\mathrm{Var}(X)} \tag{25}$$

$$a = \bar{y} - b\bar{x} \tag{26}$$

For multiple regression with n predictors, the residual sum:

$$S = \sum_{k=1}^{N} \left(y_k - a_0 - \sum_{j=1}^{n} a_j x_{jk} \right)^2 \tag{27}$$

generates $n + 1$ normal equations, solved via matrix methods.

3.4 Correlation Analysis

The Pearson correlation coefficient quantifies the strength and direction of linear association between two variables:

$$r = \frac{\sum_{k=1}^{n}(x_k - \bar{x})(y_k - \bar{y})}{\sqrt{\sum_{k=1}^{n}(x_k - \bar{x})^2} \cdot \sqrt{\sum_{k=1}^{n}(y_k - \bar{y})^2}} \tag{28}$$

Equivalently:

$$r = \frac{\text{Cov}(X, Y)}{s_X \cdot s_Y} \tag{29}$$

Interpretation:

- $r = +1$: Perfect positive linear correlation
- $r = -1$: Perfect negative linear correlation
- $r = 0$: No linear correlation (note: does not preclude nonlinear relationships)
- $|r| > 0.7$: Strong correlation
- $0.4 < |r| < 0.7$: Moderate correlation
- $|r| < 0.4$: Weak correlation

The coefficient of determination, $R^2 = r^2$, represents the proportion of variance in the dependent variable explained by the independent variable.

3.5 Moving Average Analysis

To identify long-term trends while filtering short-term fluctuations, centered moving averages were computed:

$$\bar{x}_t^{(k)} = \frac{1}{k} \sum_{i=-(k-1)/2}^{(k-1)/2} x_{t+i} \tag{30}$$

where k is the window size (3-year and 5-year windows were used in this study).

3.6 Software Tools

Analysis was performed using the following software environment:

- **SPSS:** Statistical analysis and visualization
- **Mathematica:** Complex calculations and symbolic computation
- **Microsoft Excel:** Data manipulation and moving average calculations
- **LaTeX:** Document preparation and typesetting

4 Results

4.1 Temperature Analysis

Temperature exhibited the lowest inter-annual variability among all parameters studied, reflecting the stabilizing influence of the land-sea thermal system and consistent solar forcing at this latitude.

Table 3: Annual Temperature Statistics (1989–2008)

Parameter	Mean	Std Dev	Min	Max	CV (%)
Maximum Temperature (°C)	29.6	0.575	28.3	30.4	1.94
Minimum Temperature (°C)	16.9	0.344	16.3	17.5	2.04

Weekly Extremes:

- Maximum recorded: 42 °C (pre-monsoon summer)
- Minimum recorded: 2.4 °C (winter)
- Intra-annual range: ∼40 °C

Key Finding: The contrast between low inter-annual variability ($\sigma < 0.6\,°C$) and extreme intra-annual range (∼40 °C) is characteristic of the continental Tarai climate. This pattern allows reliable long-term agricultural planning while demanding crop varieties tolerant of both heat and cold stress.

4.2 Rainfall Analysis

Rainfall exhibited extreme variability, confirming its stochastic nature and the dominant role of monsoon dynamics in determining annual totals.

Table 4: Annual Rainfall Statistics (1989–2008)

Statistic	Annual Rainfall (mm)	Rainy Days
Mean	1610.8	78
Standard Deviation	2768.4	11.8
Minimum	831.2 (1992)	63
Maximum	3218.6 (2000)	100
Coefficient of Variation	172%	15.1%

Critical Finding: Weak correlation between total rainfall and number of rainy days ($r < 0.4$). This implies high uncertainty in daily precipitation intensity, even when rainy-day count is accurately predicted. The coefficient of variation of 172% indicates that annual rainfall may deviate from the mean by more than 170% in extreme years.

Seasonal Distribution: Approximately 80% of annual rainfall occurs during the four-month monsoon period (June–September), with July and August contributing the largest shares.

4.3 Humidity Analysis

The region exhibits dramatic diurnal humidity variation, characteristic of the Tarai belt's humid subtropical climate.

Table 5: Relative Humidity Statistics (1989–2008)

Observation Time	**Mean RH (%)**	**Min (%)**	**Max (%)**
Morning (07:12 hrs)	84.7	81.7	86.9
Afternoon (14:12 hrs)	50.8	44.5	56.0
Diurnal Swing	**33.9**	—	—

The ∼34 percentage-point average diurnal swing reflects rapid morning evaporation in the subtropical climate. This pattern has significant implications for:

- Morning conditions favor fungal diseases in crops
- Afternoon drying aids harvest activities
- Irrigation scheduling must account for high afternoon evaporative demand

4.4 Additional Parameters

Table 6: Secondary Meteorological Parameters (1989–2008)

Parameter	**Mean**	**Min**	**Max**
Sunshine Duration (hrs/day)	7.37	6.40 (2008)	7.97 (1989)
Wind Velocity (km/h)	4.75	2.94	7.03
Daily Wind Range (km/h)	—	0.8	30.0
Evaporation (mm/day)	4.85	3.92	5.41

Observations:

- **Sunshine duration** shows a declining trend from 7.97 hrs/day (1989) to 6.40 hrs/day (2008), potentially indicating increased cloud cover or pollution
- **Wind velocity** is generally low (mean 4.75 km/h), with occasional high gusts up to 30 km/h during convective events
- **Evaporation** averages nearly 5 mm/d, representing significant water demand for agricultural operations

4.5 Regression Results

Regression analysis was performed to explore predictive relationships between meteorological variables.

4.5.1 Rainfall vs. Rainy Days

The relationship between total annual rainfall (P) and number of rainy days (N):

$$P = a + bN \tag{31}$$

Table 7: Regression Results: Rainfall vs. Rainy Days

Parameter	**Value**
Correlation coefficient (r)	0.38
Coefficient of determination (R^2)	0.14
Regression slope (b)	24.3 mm/day

The weak correlation ($r = 0.38$) confirms that rainy-day count explains only 14% of the variance in annual rainfall, underscoring the importance of intensity variations.

5 Discussion

5.1 Climate Characterization

The Pantnagar climate exhibits three defining characteristics that collectively shape the regional environment and constrain agricultural practices:

5.1.1 Temperature Stability with Extreme Seasonality

Year-to-year mean temperatures vary by less than 1 °C, yet seasonal range exceeds 40 °C. This pattern:

- Enables reliable long-term agricultural planning
- Demands crop varieties tolerant of both heat stress (>40 °C) and cold stress (<5 °C)
- Necessitates distinct cropping seasons (Kharif, Rabi, Zaid)

The low inter-annual variability suggests that temperature-based planning can rely on climatological normals with reasonable confidence.

5.1.2 Rainfall Unpredictability

The coefficient of variation of 172% for annual rainfall indicates that precipitation in any given year may deviate from the historical mean by more than 170%. This extreme variability:

- Poses significant challenges for water resource management
- Increases risk for rain-fed agriculture
- Necessitates irrigation infrastructure as risk mitigation
- Complicates reservoir operation and flood control

The weak correlation between rainfall amount and rainy-day count further compounds uncertainty, as even accurate prediction of rainy-day frequency provides limited information about total precipitation.

5.1.3 Humidity Dynamics

The 34 percentage-point diurnal humidity swing affects multiple aspects of regional agriculture:

- **Disease management:** Morning conditions (RH $> 80\%$) favor fungal pathogens
- **Evapotranspiration:** Afternoon conditions drive high evaporative demand
- **Harvest timing:** Afternoon drying aids grain harvest and processing
- **Irrigation scheduling:** Peak demand occurs during low-humidity afternoon hours

5.2 Methodological Considerations

5.2.1 Spatial Averaging

The arithmetic mean method for rainfall averaging, while computationally simple, assumes uniform station weighting. For a single-station dataset like this, the limitation is moot. For regional studies involving multiple stations, Thiessen polygon or isohyetal methods would provide superior accuracy by accounting for irregular station spacing.

5.2.2 Temporal Stationarity

Moving average analysis (3-year and 5-year windows) revealed no statistically significant long-term trends in temperature or rainfall over the 20-year period. This suggests:

- Climate stationarity during 1989–2008
- The 20-year dataset captures natural variability without significant trends
- Longer records (30+ years) would be needed to assess climate change impacts

5.2.3 Limitations

Several limitations should be noted:

1. Single-station analysis precludes spatial variability assessment
2. 20-year period may be insufficient for detecting gradual climate trends
3. Weekly aggregation masks sub-weekly variability
4. Missing data handling (if any) was not explicitly documented in source records

5.3 Comparison with Regional Studies

The findings are consistent with other studies of Tarai belt climatology:

- Rainfall variability exceeds that of peninsular India
- Temperature patterns align with humid subtropical classification
- Diurnal humidity patterns match theoretical expectations for continental locations

6 Conclusions

Analysis of 20 years of meteorological data (1989–2008) from the Pantnagar weather station reveals the following key findings:

1. **Temperature:** Highly predictable on an annual basis ($\sigma < 0.6\,°C$) despite extreme seasonal variation (range $\sim$40 °C). Inter-annual stability enables reliable agricultural planning.

2. **Rainfall:** Highly unpredictable (CV = 172%). Weak correlation with rainy-day count ($r = 0.38$) indicates intensity uncertainty even when occurrence frequency is known. This represents the primary source of agricultural risk in the region.

3. **Humidity:** Consistent diurnal pattern with $\sim$34% swing from morning (84.7%) to afternoon (50.8%). This predictable pattern can be exploited for disease management and irrigation scheduling.

4. **Sunshine and Evaporation:** Relatively stable parameters with low inter-annual variability. A potential declining trend in sunshine duration warrants further investigation.

5. **Wind:** Low mean velocity (4.75 km/h) with high daily variability (range 0.8–30 km/h). Not a limiting factor for most agricultural operations.

These findings support the classification of Pantnagar as a **humid subtropical climate** (Köppen: *Cwa*) with monsoon characteristics and extreme rainfall variability typical of the Indo-Gangetic Tarai belt.

6.1 Recommendations

Based on this analysis, the following recommendations are proposed:

1. **Agricultural risk management:** Given rainfall unpredictability, irrigation infrastructure development should be prioritized over rain-fed agriculture expansion

2. **Continued monitoring:** Extension of the observation record beyond 2008 would enable climate change impact assessment

3. **Spatial network:** Additional stations within the Pantnagar region would enable spatial variability characterization

4. **Sub-daily analysis:** Hourly data would enable improved understanding of diurnal cycles and extreme event characteristics

Data Availability

The following datasets are publicly available for download:

- Complete 20-year weekly meteorological data (1989–2008)

- Yearly aggregated data with analytical graphs and moving averages

- Rainfall moving average calculations
- Temperature moving average calculations

Data files are available at: `https://gauravtiwari.org/summerproject/`

Acknowledgments

This research was conducted under the **INSPIRE-SHE Scholarship Program**, Department of Science and Technology, Government of India. The author thanks the Agro-Meteorological Observatory at G.B. Pant University of Agriculture and Technology, Pantnagar, for providing access to meteorological records.

Special thanks to the faculty of the Department of Mathematics for guidance during the summer research project.

References

1. Blanford, H.F. (1884). On the connection of the Himalayan snowfall with dry winds and seasons of drought in India. *Proceedings of the Royal Society of London*, 37, 3–22.
2. Walker, G.T. (1921–1927). Correlation in seasonal variations of weather. *Memoirs of the India Meteorological Department*, various volumes.
3. Weisner, C.J. (1983). *Hydrometeorology*. Chapman & Hall Ltd., London.
4. Reddy, P.J. (2006). *A Textbook of Hydrology*. Laxmi Publications, India.
5. Sharma, M.A. & Singh, J.B. (2010). Use of Probability Distribution in Rainfall Analysis. *New York Science Journal*, 3(9), 40–49.
6. India Meteorological Department (2015). *Climate of India*. IMD, Pune.
7. Peel, M.C., Finlayson, B.L., & McMahon, T.A. (2007). Updated world map of the Köppen-Geiger climate classification. *Hydrology and Earth System Sciences*, 11, 1633–1644.

A Statistical Formulas Summary

A.1 Descriptive Statistics

$$\text{Sample Mean:} \quad \bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \tag{32}$$

$$\text{Sample Variance:} \quad s^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2 \tag{33}$$

$$\text{Standard Deviation:} \quad s = \sqrt{s^2} \tag{34}$$

$$\text{Coefficient of Variation:} \quad \text{CV} = \frac{s}{\bar{x}} \times 100\% \tag{35}$$

A.2 Correlation and Regression

$$\text{Pearson Correlation:} \quad r = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \cdot \sum(y_i - \bar{y})^2}} \tag{36}$$

$$\text{Linear Regression:} \quad y = a + bx \tag{37}$$

$$\text{Slope:} \quad b = \frac{\text{Cov}(X, Y)}{\text{Var}(X)} \tag{38}$$

$$\text{Intercept:} \quad a = \bar{y} - b\bar{x} \tag{39}$$

A.3 Moving Average

$$\bar{x}_t^{(k)} = \frac{1}{k}\sum_{i=-(k-1)/2}^{(k-1)/2} x_{t+i} \tag{40}$$

B Observation Station Details

Table 8: Pantnagar Meteorological Station Specifications

Attribute	**Specification**
Station Name	Agro-Meteorological Observatory
Institution	G.B. Pant University of Agriculture & Technology
Location	Pantnagar, District Udham Singh Nagar, Uttarakhand
Latitude	29°0′0″N
Longitude	79°18′0″E
Altitude	243.84 m AMSL
Certification	IMD-approved
Operating Unit	N.E.B. Crop Research Center
Observation Times	07:12 hrs and 14:12 hrs IST