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Temporal trend and statistical analysis of monthly, seasonal and annual rainfall in Silchar, Assam

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ABSTRACT

Effective planning for water harvesting, irrigation management, hydro-related projects, and resolving climate change challenges requires an understanding of patterns in climatic factors, such as rainfall. This study uses Sen's Slope and the Mann-Kendall test to determine statistical significance in its temporal trend analysis of monthly, seasonal, and annual rainfall in Silchar, Assam. The results show a distinct upward trend in yearly precipitation over the research period, with a Z value of +4.83 and a magnitude of +56.05 mm/year. Significant rising trends were noted for the months of May through August, with June showing the largest shift at +13.40 mm/year. Furthermore, the data shows that the pattern significantly intensifies before and after the monsoon season. A decreasing pattern in rainfall was identified over the 37-year period from 1984 to 2021. The Rainfall Anomaly Index (RAI) and the Standardized Precipitation Index (SPI) were used to measure the frequency of dry and wet years in order to further characterize the rainfall patterns. During the study period, there were years that were moderately to excessively wet, as indicated by both SPI and RAI. No exceptionally or severely dry periods were found, but during the research years, there were more dry periods than rainy ones. June produced the biggest percentage of annual rainfall (18.39%), while January contributed the lowest percentage (0.30%), according to a comprehensive statistical examination of monthly rainfall. The monsoon season had the highest percentage of yearly precipitation (63.51%). These findings have important ramifications for the management of agricultural water resources and water resources in general. They also offer important information for strategic planning and adaptation strategies in the face of changing climate circumstances.

1. Introduction

The greatest environmental issues facing the planet and civilization are without a doubt climate change and its variability (AghaKouchak et al., 2020; Gelata et al., 2023; Gupta et al., 2021; Tang et al., 2022; Yang & Xing, 2022). Precipitation and temperature are two of the most crucial variables that are regularly used to trace the extent and scale of climate change and variability, among the problems given by this climate change (Umar et al., 2019). In many countries of the world, including India, rapid economic development and population growth have raised questions about the availability and quality of natural resources (Rani et al., 2022). India needs a comprehensive evaluation of climate change that takes into account both the long-term and short-term effects of the anthropogenic and natural causes of global warming (i.e., variations in meteorological parameters) (Pingale et al., 2014). The high temporal heterogeneity of rainfall distribution reflects the possibility of extreme events such as drought and flood, which must be addressed for proper watershed management (Saini et al., 2022).

In order to develop the best adaptation strategies for the sustainable use of natural resources like water, information on the magnitude, length, and frequency of

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extreme events (such as floods and droughts) as well as trends in various hydro-meteorological variables is necessary (Akhtar et al., 2021). The hydrologic cycle depends heavily on precipitation, and variations in its pattern would have a direct impact on the area's water resources (Praveen et al., 2020). Rainfall amount and frequency affect the flow of streams and demands (particularly agricultural), runoff dispersion, moisture levels in the soil, and groundwater reserves. Understanding the issues related to floods, droughts and the availability of water for diverse applications with respect to future climatic scenarios would be made easier by trend analysis of rainfall at various spatial scales (Bora et al., 2022; Goyal, 2014).

A wide variety of approaches may be used to assess climate change's consequences. A number of researchers over the last few years have employed parametric and nonparametric statistical techniques to examine shifts in meteorological time series throughout the nation. In this study, statistical trend analysis techniques such as the Mann-Kendall (MK) test (Kendall, 1975; Mann, 1945) and Sen's slope estimator (Sen, 1968) were used. Regional disparities in precipitation can be much larger, with significant spatial and temporal variation between climatically different regions, even though precipitation variability on inter-annual to millennial time scales appears to be more or less consistent between climate models and climate reconstructions (Yue et al., 2002). As a consequence of this, it has been suggested that the observations of past climate made at the global or continental dimensions may not be as relevant for planning purposes at the local or regional scale.

In the past, several parametric (linear regression, F-test, and T test) and non-parametric (Mann-Kendall test, modified Mann-Kendall, Sen's slope estimator, and Kruskal-Wallis test) approaches were used to assess climatic variability (Mahmood et al., 2019; Swain et al., 2022). Non-parametric tests are applied for trend analysis more often than parametric tests owing to the multiple benefits that non-parametric tests bring. They have fewer assumptions than parametric tests. They are distribution-free techniques that assume the data points do not have the same probability distribution (Gelata et al., 2023; Nguyen et al., 2022; Yang & Xing, 2022). In addition, unlike parametric tests, non-parametric tests are not adversely affected by outliers when trying to identify trends. MK test as a tool for determining the trend has been use in a global scale (Gadedjisso-Tossou et al., 2021; Kessabi et al., 2022; Khaniya et al., 2020; La Sorte et al., 2021, 2021; Lana et al., 2022; Mallick et al., 2021; Rathnayake, 2019; Umar et al., 2019) and also in India (Ahmed et al., 2022; Akhtar et al., 2021; Gupta et al., 2021; Kalidoss et al., 2017; A. Kumar et al., 2023; Maharana et al., 2021; Panda & Sahu, 2019b; Rawat et al., 2020; Rayadurgam & Rao, 2021; Singh & Kumar, 2022). MK test has also been employed to find the climatic trends like precipitation in the regional scale like North East Region (NER) of India and also in the states within NER (Bora et al., 2022; Borah et al., 2022; Choudhury et al., 2012; Das & Joshi, 2012; Gharphalia et al., 2018; Gogoi & Rao, 2022; Singh & Kumar, 2022).

Numerous recent studies have examined the main patterns and unpredictable nature of yearly precipitation in great detail, including those from India. On the other hand, information regarding the patterns and fluctuations of intense daily precipitation occurrences at the regional level is still notably lacking. To increase forecast accuracy, these data must take into consideration a range of region-specific features and how they interact with climatic variables at both spatial and temporal dimensions. Thus, it is crucial to look at past records of climatic variations and changes across India's regions. These assessments can help address climate change difficulties while addressing social and economic concerns. Because there is a dearth of sophisticated equipment and a poor network of meteorological observatories, scientists have mostly depended on a small climate database and have paid little attention to regional climate changes. The extent of study conducted in this field has been hampered by the lack of access to advanced technology. Nevertheless, regional and local trend assessments can be very helpful for focused development and adaptation efforts intended to lessen the effects of climate change. This research uses strong statistical approaches to analyze rainfall statistics from 1984 to 2021 in order to improve knowledge of the climatic variability characteristic of Silchar. This strategy aims to close the current gaps in regional climate data and offer vital insights required for policies of mitigation and adaptation to the changing climate.

2. Materials and Methods

2.1. Brief description of study area

Silchar is the second largest town in the southernmost point of Assam and one of the most stable areas in the North-East. It has a height of 35 meters above mean sea level and may be found between the longitudes 92°24' East and 93°15' East and the latitudes 24°22' North and 25°8' North East. The landscape around the city consists of a flat alluvial plain with scattered tiny hills (called tilla in the area), wetlands, and streams. Silchar has a borderline tropical monsoon climate that gets a little too warm during the winter season. Winters are warm and dry, with chilly to pleasant mornings; meanwhile, the rainy season starts early when the monsoon comes into the area in March (Pre-monsoon), leading to rainfall for seven months of the year. Temperatures range from a high of 31.9°C (89.4°F) to a low of 22.8°C (73°F) and rainfall averages 25 days a month during the monsoon season, which typically begins in June and lasts until September.

2.2. Meteorological Data and Analysis

This article examined precipitation patterns and their climatic variability throughout 37 years. Data from 1984 to 2021 were obtained from the local weather station and the NASA website. Analysis of the seasonal rainfall pattern was performed by classifying the monthly data as either winter (January–February), pre–monsoon (March–May), monsoon (June–September), or post–monsoon (October–December). Both descriptive and trend analysis were used to analyse the data. The methodological framework of the analysis is presented in Figure 1. The procedures that were followed in order to calculate the coefficient of variation (C_V), the standard precipitation index (SPI), and the rainfall anomaly index (RAI) are detailed in Table 1.

2.1.1 Statistical analysis of rainfall

Computation of descriptive statistics such as minimum, maximum, standard deviation (SD), mean (M), Skewness (C_S), coefficient of variation (C_V), and kurtosis (C_K) were performed in order to examine the rainfall data collected throughout the study area and determine the variability and distribution of the variable. The rainfall time series were analysed by using the Mann-Kendall trend test and Sen's slope to determine the dispersion around the mean and identify any discernible patterns. We may be able to get some understanding of the dispersion of data points around the mean by using the coefficient of variation. A greater level of spatial variation is indicated by a C_V value that is higher, and vice versa. Rainfall data from collected meteorological records was analyzed using C_V to identify monthly, seasonal, and yearly variations. C_V is used to classify the degree of variability of rainfall events as less ($C_V < 20\%$), moderate ($20\% < C_V < 30\%$), and high ($30\% < C_V < 40\%$), very high ($40\% < C_V < 70\%$) and extremely high ($70\% < C_V$) (Asfaw et al., 2018; Mehta & Yadav, 2021).

2.2.2 Standardized Precipitation Index (SPI)

The Standardized Precipitation Index, often known as SPI, has been applied to the precipitation variable in order to estimate how wet or dry conditions are expected to be. The SPI can monitor this wet or dry condition on a range of time scales, from sub-seasonal to inter-annual (Kaur et al., 2022). Negative and positive SPI values indicate drought and wet conditions, respectively; as dryness or humidity increases, these values become more negative or positive, respectively (Chaulagain et al., 2023). A minimum of 30 years of long-term rainfall data is required to calculate SPI because shorter ones are unlikely to capture the signals of climatic variability (Saini et al., 2020).The SPI measures the extent to which the actual precipitation record deviates from what would be expected given a normal distribution and fitted probability distribution.

2.2.3 Rainfall Anomaly Index (RAI)

The rainfall anomaly index is a measure used to assess the deviation of precipitation from the normal pattern in a particular area over a specified period of time (Aryal et al., 2022). Studying the impacts of climate change on several

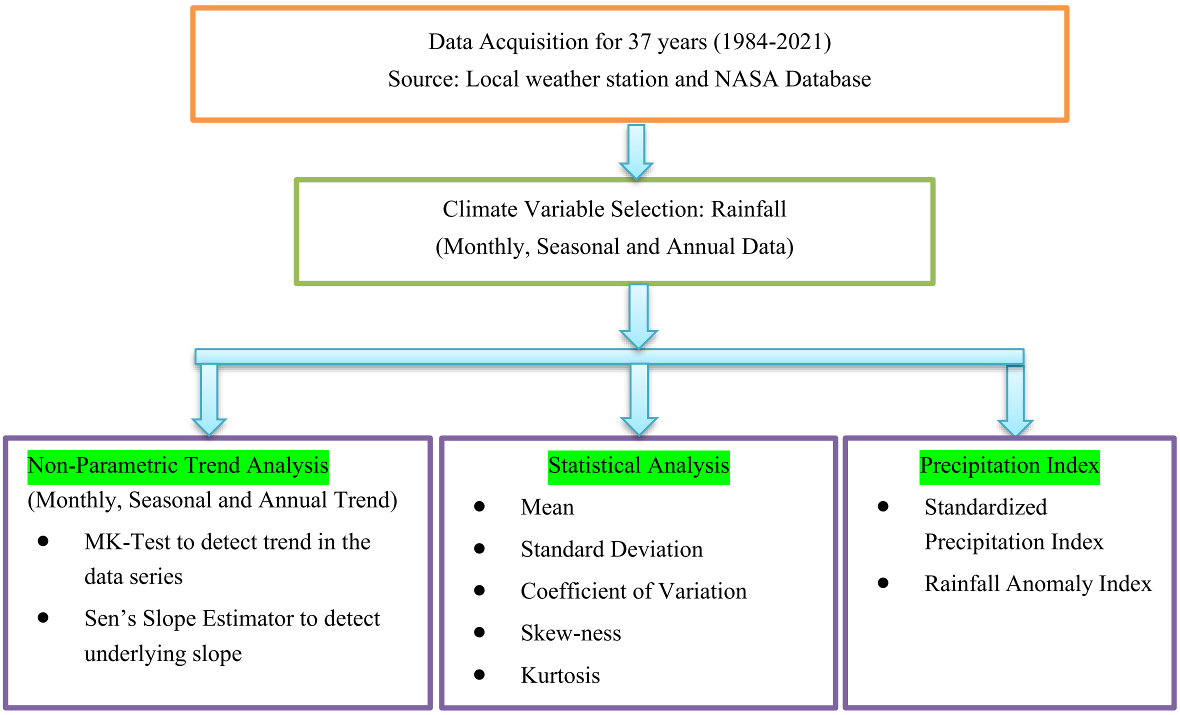


Figure 1. Methodological framework of the study

fields, such as the agricultural sector, access to water resources, and environmental protection, requires having the capability to collect and interpret rainfall data. Precipitation anomalies in Silchar were analyzed by estimating RAI during the research period of 37. years. A variable's anomaly is its deviation from the climatological normal and the normal is typically computed by running climatology for at least 30 years (the climate normal period) (Baig et al., 2022). Positive and negative precipitation anomalies indicate that it rained more or less than the baseline

Table 1. Method of estimation of C_V and rainfall indices

Characteristics	Method	Reference
Coefficient of Variance (C_V)	$CV=\frac{\sigma\times 100}{\mu}$ where, C_V = coefficient of variation; σ = standard deviation and μ = the average precipitation.	(Asfaw et al., 2018)
Standard Precipitation Index (SPI)	$SPI = (P-P^*) / \sigma$ where P = precipitation; p* = average precipitation and σ = standard deviation of precipitation.	(Baig et al., 2022; Saini et al., 2020)
Rainfall Anomaly Index (RAI)	$RAI=3\left[\frac{N-\overline{N}}{\overline{M}-\overline{N}}\right]$ for positive anomaly $RAI=-3\left[\frac{N-\overline{N}}{\overline{X}-\overline{N}}\right]$ for the negative anomaly Where, N = the current annual/seasonal/monthly precipitation; $\overline{N}$ = the average annual/seasonal/monthly precipitation of historical series; $\overline{M}$ = the average of ten highest annual/seasonal/monthly precipitation; $\overline{X}$ = the average of ten lowest annual/seasonal/monthly precipitation; $N-\overline{N}$ = positive anomaly and negative anomaly based on positive or negative values.	(Aryal et al., 2022; Chahal et al., 2021)

Table 2. Interpretation of dry and wet condition of rainfall by SPI value (Mckee et al., 1993)

SPI Value	**Interpretation**
SPI < -2.0	extremely dry
-2.0 < SPI < -1.5	severely dry
-1.5 < SPI < -1.0	moderately dry
1.0 < SPI < 1.5	moderately wet
1.5 < SPI < 2.0	very wet
2.0 < SPI	extremely wet

Table 3. Interpretation of intensity of the rainfall anomaly index (RAI) (Rooy, 1965)

RAI Value	**Interpretation**
SPI < -4	extremely dry
-4 < SPI < -2	severely dry
-2 < SPI < 0	moderately dry
0 < SPI < 2	moderately wet
2 < SPI < 4	very wet
4.0 < SPI	extremely wet

2.2.4 Mann-Kendall Test

Non-parametric Mann-Kendall Test (MK-test) was used to determine the significance of the rainfall time series data over the study period of 37 years (1984-2021). MK-Test has been used by many researchers to find the existence of significant and non-significant trends in climatic parameters like rainfall (Ahmed et al., 2022; Jain & Kumar, 2012; Kessabi et al., 2022; Mallick et al., 2021; Panda & Sahu, 2019a; Sharma et al., 2021). The MK statistic is computed using the given formula:

$$S=\sum_{i=1}^{N-1}\sum_{j=i+k}^{N}\operatorname{sgn}\left(x_j-x_i\right)$$

Where, *N indiactes* the number of data points. Assuming $(x_j - x_i) = \vartheta$, the value of sgn (ϑ) is computed as follows:

$$\operatorname{sgn}(\theta)=\begin{cases}1 \text{ if } \theta>0\\ 0 \text{ if } \theta=0\\ -1 \text{ if } \theta<0\end{cases}$$

For large samples (N>10), normal distribution is used to conduct the MK-test (Helsel & Hirsch, 2002) with the variance and mean as under:

$$E[S]=0$$

$$\operatorname{Var}[S]=\frac{N(N-1)(2N+5)-\sum_{k=1}^{n} t_k(t_k-1)(2t_k+5)}{18}$$

Where, *n* is the number of tied (zero difference between compared values) groups and t_k the number of data points in the K^{th} tied group. The standard normal deviate (*Z*-statistics) is then computed as (Helsel et al., 2020) follows:

$$Z=\begin{cases}\frac{S-1}{\sqrt{\operatorname{Var}(S)}} & \text{If } S>0\\ 0 & \text{If } S=0\\ \frac{S+1}{\sqrt{\operatorname{Var}(S)}} & \text{If } S<0\end{cases}$$

Where, Z>0 indicates the rising trends and Z<0 indicates the falling trends.

2.2.5 Sen's Slope Estimation

Sen's Slope method was used to identify the underlying magnitude of the trend (Lettenmaier et al., 1994; Panda & Sahu, 2019a; Partal & Kahya, 2006; Singh & Kumar, 2022; Yue et al., 2002). This method computes the slopes (T_i) of all data pairs as given below:

$$T_i=\frac{x_j-x_k}{j-k} \text{ for } i=1,2,\ldots, N$$

Where, x_j and x_k *represent* data values at times j and k (j > k).

The slope estimate provided by Sen is the median of these N different values of T_i, and it is calculated as follows:

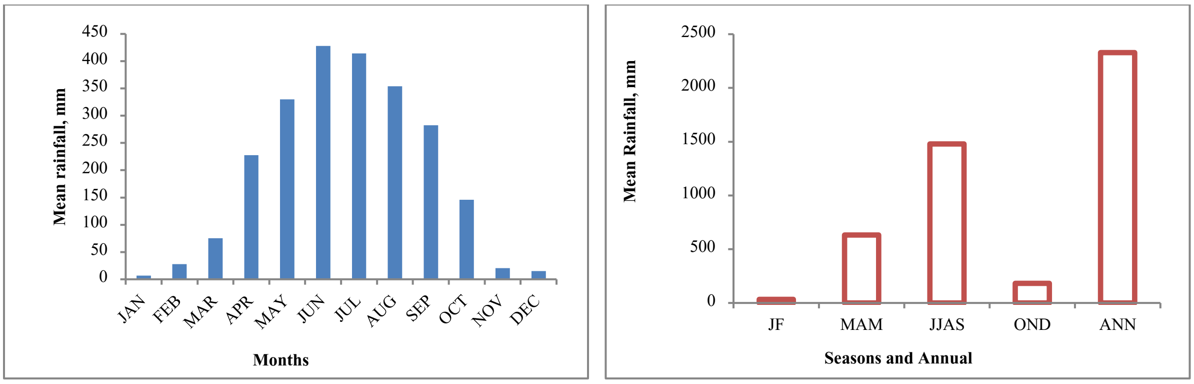
$$Q=\begin{cases}T_{\frac{N+1}{2}} & N \text{ is odd}\\ \frac{1}{2}\left(T_{\frac{N}{2}}+T_{\frac{N+2}{2}}\right) & N \text{ is even}\end{cases}$$

Where, Q>0 denotes the magnitude of the rising trend and Q<0 denotes the magnitude of the descending trend.

3. Results and Discussion

3.1 Statistical analysis of rainfall variability

Table 4 provides information on standard deviation (SD), coefficient of variation (C_V), mean, kurtosis (C_K), and skewness (C_S) of seasonal (June to September) and yearly rainfall events in Silchar throughout the course of a 37-year period of time (1984-2021). Figure 2 illustrates the monthly, seasonal, and yearly mean precipitation that the research region experienced from 1984 to 2021. The coefficient of variation (CV) is 38%, the standard deviation was 877.48 mm, and the mean, or average, for the yearly rainfall data for Silchar is 2328.10 mm. According to the outcomes of the study, June had the most monthly mean rainfall (428.10 mm), which accounted for 18.39% of the annual rainfall. On the other hand, January had the least amount of monthly mean rainfall (6.90 mm), which accounted for only 0.30% of the annual rainfall. The monsoon season (JJAS) had the greatest amount of precipitation (1478.62 mm), which contributed to 63.51% of the total annual precipitation. The pre-monsoon season, represented as MAM, had an average rainfall of 633.22 mm, while the post-monsoon season, represented as OND, had an average rainfall of 181.69 mm. The quantity of precipitation that fell during the winter season (JF) was the lowest of any season, totaling just 34.55 mm and representing 1.48% of the total annual rainfall. The MAM region was responsible for 27.20 % of the yearly precipitation, whereas the OND region was responsible for 1.80 %. The average annual rainfall was also strongly skewed (1.24), with an estimated C_K of 1.49. All of the months and seasons were positively skewed, with C_K values ranging from 0.60 to 2.16. Gogoi and Rao (2022) also identified a positive C_S value of 5.7 for Silchar and Hailakandi over a 38-year study period (1981 – 2017). The leptokurtic distribution is indicated by the positively skewed value. According to the computed Table 4, the average monthly rainfall C_V ranges from 45 % (September) to 137 % (October) (December). The results showed that C_K peaked in March, at 7.14, and flattened out in May, at 0.14.



(a) **(b)**

Figure 2. Profile of monthly, seasonal and annual rainfall from 1984-2021

Table 4. Summarized monthly, seasonal, and yearly precipitation statistics for Silchar (1984-2021)

Months/season	SD	C_V (in fraction)	C_s	C_k	% of annual	Z	Q	Significance
JAN	7.34	1.06	1.58	2.32	0.30	0.53	0.04	NS
FEB	27.03	0.98	1.47	1.77	1.19	0.04	0.03	NS
MAR	61.75	0.82	2.16	7.14	3.24	1.27	0.84	NS
APR	158.67	0.70	1.60	2.62	9.78	2.41	4.44	NS
MAY	151.43	0.46	0.65	0.14	14.17	4.83	10.26	S
JUN	200.23	0.47	1.04	0.82	18.39	4.97	13.40	S
JUL	191.44	0.46	1.38	2.24	17.79	4.34	9.44	S
AUG	161.07	0.46	1.10	1.60	15.20	5.05	9.16	S
SEP	128.24	0.45	1.46	3.28	12.13	3.12	5.21	NS
OCT	92.96	0.64	1.21	1.76	6.27	2.61	3.13	NS
NOV	24.43	1.19	1.59	1.41	0.88	0.14	0.01	NS
DEC	20.81	1.37	2.00	4.15	0.65	0.84	0.06	NS
JF	27.29	0.79	1.23	1.06	1.48	0.89	0.32	NS
MAM	288.62	0.46	1.38	2.37	27.20	4.95	16.56	S
JJAS	552.15	0.37	1.08	1.08	63.51	5.73	36.15	S
OND	99.85	0.55	0.96	1.11	7.80	2.84	4.60	NS
ANN	877.48	0.38	1.24	1.49	100.00	5.83	56.05	S

3.2 Standard Precipitation Index

Figure 3 and Figure 4 (a) depict the wet and dry periods of yearly and seasonal rainfall based on the threshold value of SPI reported in Table 2. Rainfall has varied from being relatively dry to exceptionally wet during the course of the previous 37 years, as shown by the SPI reading for the monsoon season (JJAS) ranging from -1.36 to +2.71. Negative SPI values were consistent from 1984 to 1996 and from 2014 to 2022, and the SPI was found to be positive, having the highest value in 2017.During the monsoon season, very heavy rainfall was discovered to take place in the years 2017, 2019, and 2020 with SPI values more than 2.0. On the other hand, relatively dry spells were discovered to take place in the years 1886, 1991, 1992, 1994, and 1996. In the post monsoon season (OND) also, moderately dry period was seen in 1985, 1993, 1997, 2006 rainfall in five years (1991, 1999, 2010, 2013, and 2021). Most extremely wet period of rainfall was observed in the pre-monsoon period (MAM) with SPI value of +3.01 and +2.99 in the year 2016 and 2017, respectively. The pre-monsoon period also experienced moderately dry periods in 1986, 1989, 1992 and 1995 experienced moderately dry period and the dry periods were consistent from 1984 to 1999, covering a period of 16 years out of the 37 years of observation. Annually, the area of study experienced extremely wet rainfall to moderately wet rainfall. The 2017 SPI for annual rainfall (+3.08) was the greatest on record, indicating that the years 1986, 1992, 1994, and 1996 saw very wet and moderately dry rainfall, respectively. No event of extremely dry (SPI < -2.0) and severely dry (-2.0 < SPI < -1.5) was seen in the study period of 37 years (1984 – 2021). From what could be extracted from the data, it seems that annual SPI is on the rise at most stations (23), and is especially on the rise at 5 stations (statistically significant at the 95% level). During the early part of the rabi season, over 70% of the stations had wet conditions. However, as the season progressed into its middle and latter stages, incrementally drier conditions were seen.

3.3 Rainfall Anomalies

Figure 4 (b) and Figure 5 demonstrates the seasonal and annual rainfall anomaly indices (RAI) for the geographical region of Silchar, Assam, from 1984 to 2021, respectively. Prior to 2000, RAI was negative for the majority of the year. Some years after 2000 were dry, but all years after 2015 were humid. Years with a positive value indicate rainfall or wet conditions, whereas years with negative values indicate drought. A total of 15 years had a positive RAI, which indicated circumstances that varied from highly wet to humid, and 23 years had a negative RAI, which indicated conditions that ranged from extremely dry to moderately dry. In other words, over a 37-year period, drought years outnumber wet years in terms of numbers. Drought years lasted for 16 years (1984-1999) before 2000, while consecutive wet years were observed from 2016 to 2021, with 2017 having the highest RAI value of +6.85 (Extremely wet) in the later period of analysis. The year 1992 had the largest negative value, with a RAI of -3.82; it was a year that was considered to be very dry. There has never been a year with an exceptionally low RAI value (less than -4). The RAI values for seasonal rainfall were also examined, and it was discovered that the winter period (JF) had the most drought years (24 years) and the fewest wet years (13 years). The pre-monsoon (MAM) season of 2016 had the highest RAI (+6.87) value ever recorded. In the post-monsoon period (JJAS), the year 2017 had the highest positive RAI of + 6.11 > +4, indicating another extremely wet rainfall event. The highest RAI value was discovered in 2017, indicating that 2017 was the wettest year during the study period. The same results were found in an SPI analysis of annual rainfall in Silchar from 1984 to 2021.

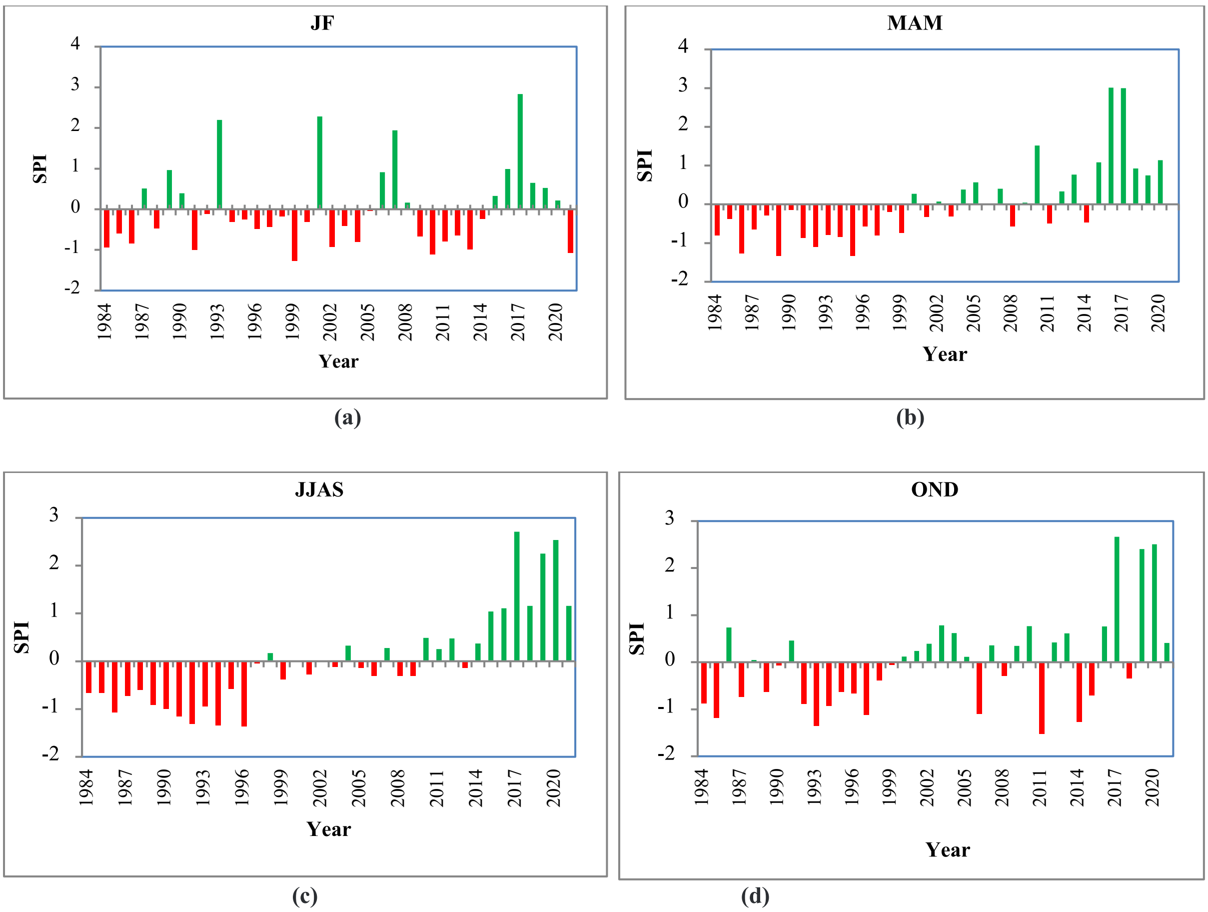


Figure 3. (a), (b), (c) and (d) SPI values of seasonal rainfall from 1984-2021

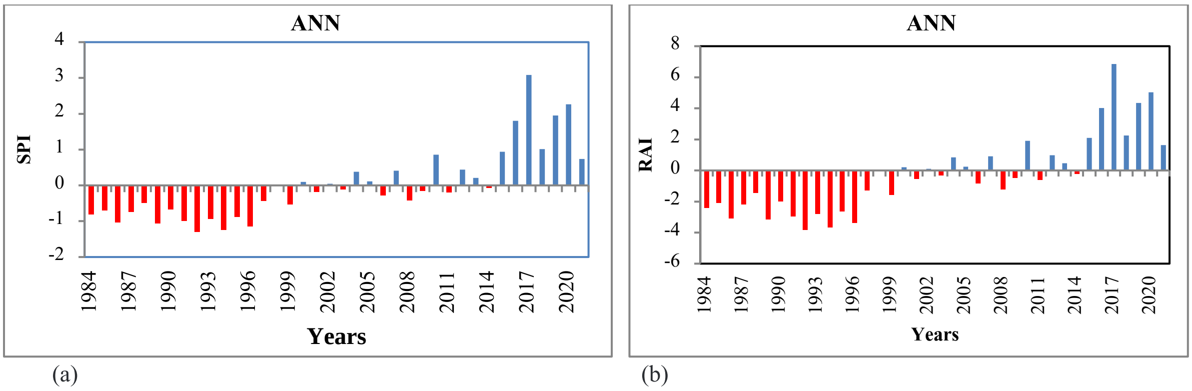


Figure 4. (a) SPI and (b) RAI values of annual rainfall from 1984-2021

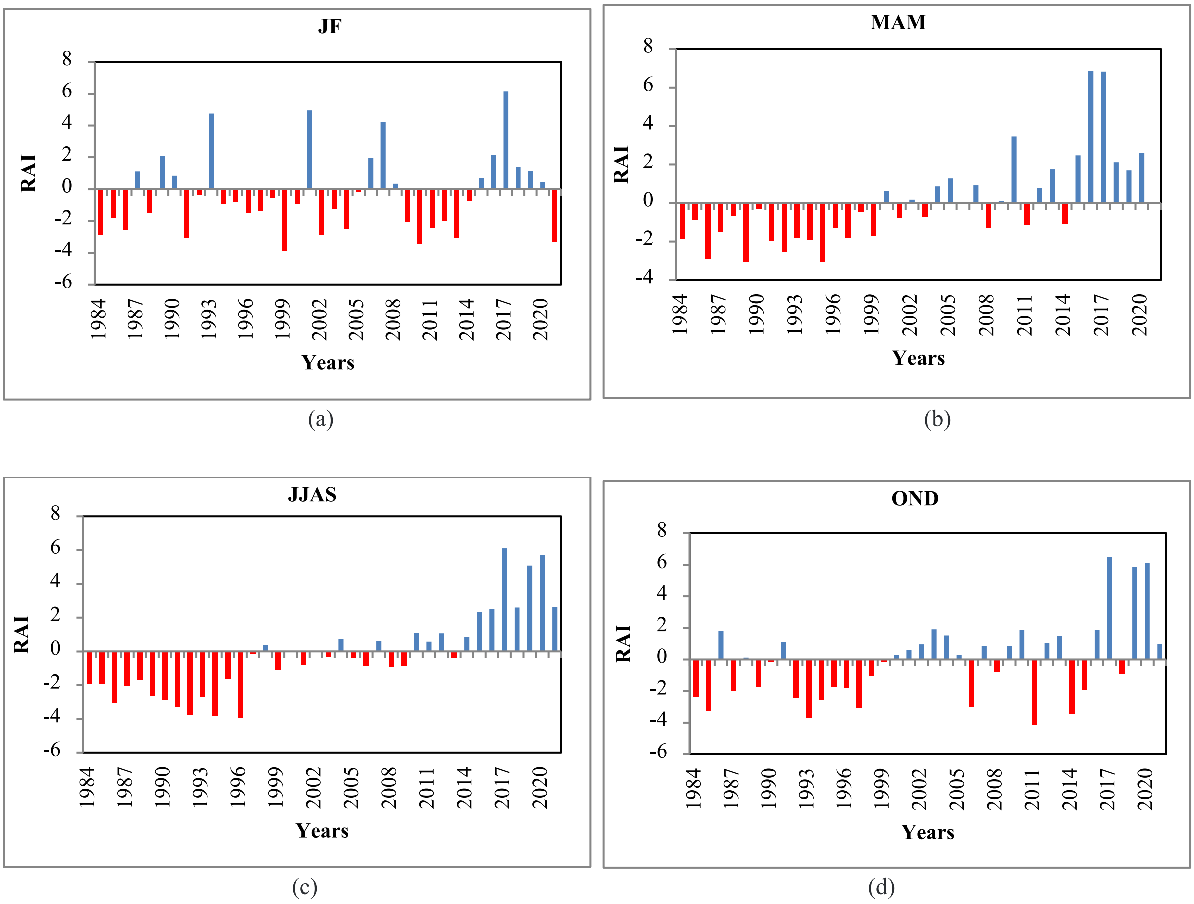


Figure 5. (a), (b), (c) and (d) RAI values of seasonal rainfall from 1984-2021

3.4 Mann-Kendall test statistics of monthly, seasonal and annual rainfall

Table 4 exhibits the Mann-Kendall and Sen's non-parametric approach Z-value as well as the real slopes of the predominant trend (change per year) for monthly, seasonal, and yearly rainfall data at a confidence level of 95%. The monthly average rainfall exhibited both a substantial upward trend and a non-significant downward trend over the course of the study period. The annual and seasonal rainfall profile along with Sen's estimate is given in Figure 6 and Figure 7. The significant positive trend was seen during the months of May, June, July and August. The significant and non-significant value of Z varied from +0.04 to +4.97, while the magnitude of slope ranged from +0.03 to +13.40 mm/year, with the month of June having the greatest value of both Z (+4.97) and Q (+13.40 mm/year). Additionally, the magnitude of the slope as well as the trend was estimated for each season and year between the years 1984 and 2021. An insignificant positive trend was found throughout the winter (JF) and post-monsoon (OND) periods of the 37-year research, but a substantial positive trend was found during the pre-monsoon (MAM) and post- monsoon (JJAS) periods. Z was determined to be +5.73 in the post-monsoon period and +4.95 in the pre-monsoon period. Sen's slope of +36.15 mm/year in JJAS indicates that the change in the monsoon season has increased significantly in the last 37

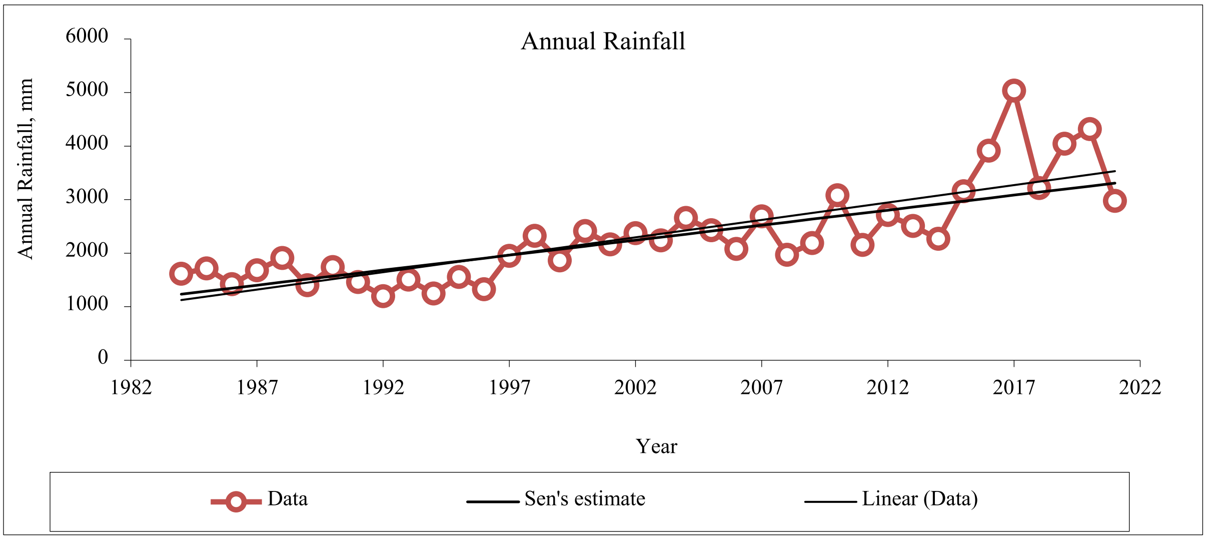
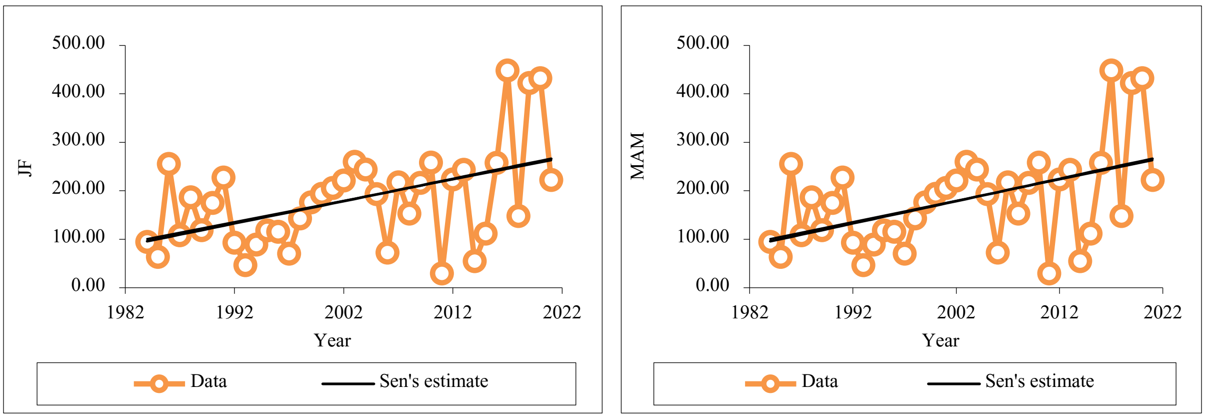
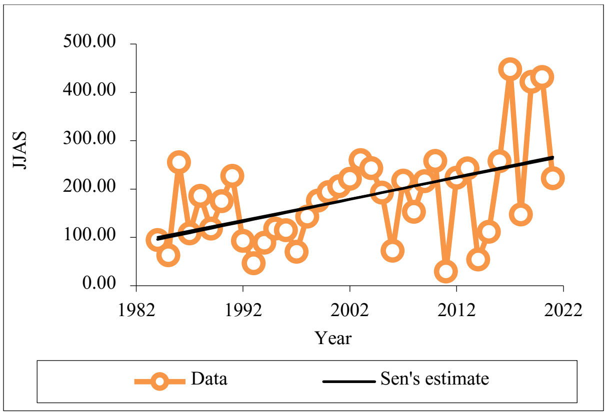


Figure 6. Profile of mean annual rainfall and Sen's estimate from 1984-2021

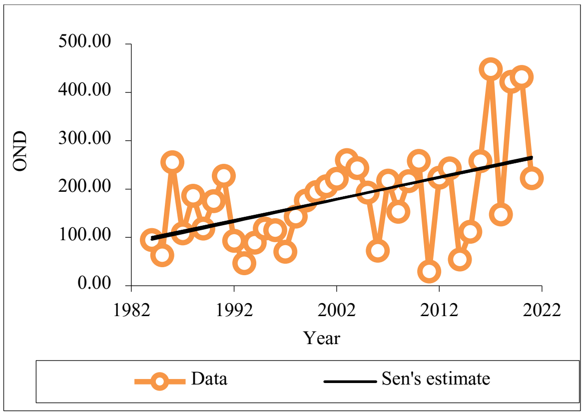


(a) (b)

years. Also, the drastically increasing significant change in the annual rainfall of Silchar was indicated by high Q value of +56.05 mm/year, which is presented in Figure 7. Many researchers have performed trend analysis on the rainfall data in NER of India. There have been accounts of significant and non-significant change in the rainfall trends in NER. The majority of North East Indian districts, according to Ravindranath et al. (2011), are today and in the near future vulnerable to climate change. Choudhury et al. (2012) examined long-term (1983-2010) weather variables to detect trend changes in Meghalaya's mid-altitude. Based on the data, the observed increase in the rate of change in annual rainfall was 3.72 mm $year^{-1}$, which was not statistically significant.



(c)



(d)

Figure 7. (a), (b), (c) and (d) Profile of mean seasonal rainfall and Sen's estimate from 1984-2021

Additionally, there was a non-significant increase in precipitation of 1.70 mm during the monsoon months (JJAS), 3.18 mm during the months leading up to the monsoon (MAM), and 1.16 mm in the months after the monsoon (ONDJF).Whereas, Jain et al., (2013) examined trends in monthly, seasonal, and annual rainfall and temperature on the subdivision and regional scale for the NER from 1871 to 2008 and found no significant change in the rainfall pattern. Singh and Kumar, (2022) used monthly data for 150 years (1857-2006) to conduct a detailed analysis of temporal variability in monthly, seasonal, and annual rainfall over northeast India (NEI) by dividing the time series rainfall data into five normal periods of 30 years each: 1857-1886 (P1), 1887-1916 (P2), 1917-1946 (P3), 1947-1976 (P4), and 1977-2006 (P5) (P5). In order to identify the importance of a trend in time series data, parametric tests (such as linear regression) as well as non-parametric tests (such as the Man-Kendall test) were employed. According to the data, monsoon rainfall has decreased significantly but post-monsoon rainfall has increased. Similarly, Bora et al., (2022) investigated the variability and trends in annual and seasonal rainfall in the seven states of North East India from 1901 to 2020, employing non-parametric tests such as Mann-Kendall, trend-free pre-whitening Mann-Kendall, modified Mann-Kendall (MMK), and innovative trend analysis (ITA). The analysis indicated that these seven states had significant differences in their annual and seasonal rainfall. The majority of tests yielded consistent findings. Rainfall patterns in Assam and Meghalaya after the monsoon and rainfall patterns in Arunachal Pradesh before the monsoon, rainfall patterns in Mizoram and Tripura during the winter, and rainfall patterns during the monsoon in Tripura were all notably different from one another. Some researchers have tried to investigate the statistical analysis and trends of rainfall and temperature in Assam but more detailed studies in climatic trends of major city like Silchar, located in the Barak Valley of Assam still needs to be investigated.

Gogoi & Rao, (2022) used Mann-Kendall and Sen slope tests to investigate the spatiotemporal variations of long-term rainfall over Assam in India's north-eastern region from 1981 to 2017. The annual season, the pre-monsoon season, and the monsoon season all demonstrated increasing patterns, but the post-monsoon season and the winter season revealed barely perceptible declining trends. Both the amount of pre-monsoon rainfall and the amount of monsoon rainfall in Assam saw statistically significant increases. Karimganj (36.8%), Hailakandi (31.9%), Silchar (31.9%), and Dhubri (26.5%) were found to be the locations that had the most dramatic variances in rainfall. Das and Joshi (2012) did examined the rainfall pattern in the three South Assam districts of Cachar, Karimganj, and Hailakandi (known as Barak Valley) for short study period of 5 years (2004-2008) and concluded that the annual rainfall in the Barak valley region decreased by 31.58% between 2004 and 2008. Individual month analysis revealed that rainfall decreased in March, April, May, July, and December and seasonally, pre-monsoon and summer monsoon rainfall as a whole decreased, while post-monsoon and winter rainfall increased marginally.

Linear regression, Mann-Kendall, and Sen's Slope test were used by Kalidoss et al. (2017) to examine the long-term trend and magnitude of rainfall and temperature in India from 1901 to 2014. A 5% statistically significant downward trend in summer rainfall was discovered. Furthermore, the variability of the yearly, summer, and monsoon rainfall was lower than that of the variability of the winter and post-monsoon rainfall. Using nonparametric techniques like Mann-Kendall and Sen's slope tests, Akhtar et al. (2021) looked into the monotonic pattern of rainfall in the Karnataka and Tamil Nadu regions during the previous 110 years. It was discovered that Karnataka's declining trend is more significant than Tamil Nadu's.

The conventional statistical Mann - Kendall (MK), modified Mann-Kendall (mMK) method and graphical innovative trend analysis (ITA) approach were used by Mandal et al. (2021) between the years 1901 and 2015 in 36 Indian meteorological subdivisions with the purpose of identifying changes in the historical precipitation. On a seasonal scale, approximately 58.33%, 50%, 69.44%, and 88.88% of the subdivisions were found to experience decreasing trends in the pre-monsoon (Mar-May), monsoon (Jun-Sep), post-monsoon (Oct-Nov), and winter (Dec-Feb) seasons. Saini et al. (2022) attempted to investigate recent rainfall variability using daily rainfall data from 33 well-spread stations in Rajasthan, northwestern India, from 1961 to 2017 using Mann-Kendall, Sen's slope estimator, and simple linear regression test (at 95% confidence level). Rainfall varied greatly between years, ranging from 277 mm in 2002 to 839 mm in 1975, with a mean of 583 mm over this dry-land ecosystem. Baig et al., (2022) also analysed the trend and pattern of precipitation in Coastal Andhra using 36 years of daily and monthly rainfall data (1983–2018). From an average of 161 cm in 1983, the average precipitation declined to 147 cm in 1991, climbed to 181 cm in 2001, and then plummeted dramatically to 91 cm in 2018.According to the Sen, slope, rainfall in the study area is decreasing at a rate of 1.27 cm per year.

Sarkar et al., (2021) also attempted to identify and quantify the impact of climate change on rainfall patterns in West Bengal's Uttar Dinajpur district from 1901 to 2019. Both the Mann-Kendall and Sen's slope forecasts agree with the estimates that rainfall increases before the monsoon, increases during the monsoon, and decreases after the monsoon. The months of January, February, April, May, June, July, August, and December all show a positive ascending trend, whilst the months of March, September, and October show a negative downward trend. Monthly average rainfall peaked in July at 892.1 mm and dropped to a low of 63.3 mm in January. According to the findings, the monsoon season received the most rainfall overall (75.2%), with a coefficient of variance that was 20.4%. The coefficient of variation (C_V) during the winter season was 72.9%, and there was very little precipitation overall (2.87%).

4. Conclusion

Knowledge of rainfall's regional and temporal distribution and varying patterns is essential for effective water resource planning and management. With a Z value of +4.83 and an increase of 56.05 mm/year, the analysis of rainfall data in Silchar, Assam, from 1984 to 2021 shows a clear rising trend in annual precipitation. May to August showed notable increasing tendencies, with June showing the largest rise at 13.40 mm/year. According to the research, this pattern becomes noticeably stronger both before and after the monsoon season. There was also a pattern of declining rainfall over the 37-year period. The Rainfall Anomaly Index (RAI) and the Standardized Precipitation Index (SPI) were used to better define rainfall patterns, and the results showed that there were occasionally years within the study period that were moderately to extremely rainy. There were more dry periods than rainy periods, despite the fact that no very or extremely dry periods were found. The highest proportion of yearly rainfall (18.39%) was recorded in June, while the lowest percentage (0.30%) was recorded in January. The highest proportion of annual precipitation of 63.51% was generated during the monsoon season. The management of water resources in general and agricultural water resources in particular will be greatly impacted by these discoveries. In light of changing climatic conditions, they offer vital insights for strategic planning and adaptation strategies.

5. References

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