An investigation of Afro-Eurasia precipitation anomalies in relation to climate change

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Abstract

Changes in precipitation will be one of the most critical factors determining the overall impact of climate change. Spatial-temporal variations in rainfall affected runoff, soil moisture, and underground water reserves. The analysis of precipitation trend is important in climate-change studies for planning and effective water resource management. In this study, long-term annual and seasonal trends of precipitation were identified for region 15° W to 135° E over period of 1982-2016 Using CHIRPS precipitation data. The statistical significance of trends is assessed by the Mann-Kendall test. Our target in this research is to investigate the trend of precipitation and to know how it changes during the period.

Introduction

Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems. Evidence of observed climate change impacts is strongest and most comprehensive for natural systems. In many regions, changing precipitation or melting snow and ice are altering hydrological systems, affecting water resources in terms of quantity and quality. Changes in precipitation will not be uniform. The high latitudes and the equatorial Pacific are likely to experience an increase in annual mean precipitation under the RCP8.5 scenario. In many mid-latitude and subtropical dry regions, mean precipitation will likely decrease, while in many mid-latitude wet regions, mean precipitation will likely increase under the RCP8.5 scenario[1, 2]. Space and time variability analysis of regional precipitation is crucial for water resource management, at a regional level, and for numerous environmental and socio-economic systems, particularly for the agricultural sector. The variability of the precipitation field depends on many factors, including the thermodynamic structure of the atmosphere, the orography and the interaction with the large-scale atmospheric circulation[3]. Kampata et al (2008), Chaouche et al (2010) and Xu, et al (2010) are some examples of the researchers who have investigated precipitation trends in different areas [4-6]. Therefore, our target in this research is to investigate the trend of precipitation and to know how it changes during the period.

Material and methods

To study the long-term annual and seasonal trends of precipitation and determine the anomalies in the Afro-Eurasia region, daily mean precipitation data were obtained from the CHIRPS¹ reanalysis archive[7]. All fields have a spatial resolution of 0.5° latitude × 0.5° longitude. A trend is a significant change over time exhibited by a random variable, detectable by statistical parametric and non-parametric procedures.

Mann-Kendall test for trend

Mann-Kendall test is a statistical test widely used in analysis of trend in climatological time series. There are two advantages of using this test. First, it is a nonparametric test and does not require the data to be normally distributed. Second, the test has low sensitivity to abrupt breaks due to inhomogeneous time series. According to this test, the null hypothesis $H_0$ assumes that there is no trend (the data is independent and randomly ordered) and this is tested against the alternative hypothesis $H_1$, which assumes that there is a trend. Mann-Kendall test is a nonparametric test for identifying trends in time-series data. This test assumes that there exist only one data values for a time period. When multiple data points exist for a single time period, the median value will be used.

¹Climate Hazards Group InfraRed Precipitation with Station data
The initial value of the Mann-Kendall statistic $S$ is assumed zero. If the data asset value from a later time period is higher than a data value from an earlier time period, $S$ is increased by 1. The net result of increments and decrements yields the final value of $S$. This method is more suitable for non-normally distributed and censored data and is less influenced by the presence of outliers in the data\cite{8, 9}. As it is a rank-based procedure, it is robust to the influence of extremes and good test for skewed data.

The MK test statistic $S$ is given by:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(x_j - x_k)$$

Where $n$ indicates the number of observations and $x_j$ is the value of $j$th observations and $sgn(x_j - x_k)$ is the sign function, which can be defined as:

$$sgn(x_j - x_k) = \begin{cases} +1, & \text{if } (x_j - x_k) > 0, \\ 0, & \text{if } (x_j - x_k) = 0, \\ -1, & \text{if } (x_j - x_k) < 0, \end{cases}$$

The mean $E(S)$ and variance $V(S)$ of the $S$ statistic are given by:

$$E(S) = 0$$

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i (t_i - 1)(2t_i + 5)}{18}$$

Where $t_i$ the number of ties for the $i$th value and $m$ is the number of ties values. Therefore, the standardized $Z$ statistic can be computed as follows:

$$Z = \begin{cases} \frac{S - 1}{\sqrt{V(S)}}, & \text{if } S > 0, \\ 0, & \text{if } S = 0, \\ \frac{S + 1}{\sqrt{V(S)}}, & \text{if } S < 0. \end{cases}$$

A positive $Z$ indicates an increasing trend, whereas a negative $Z$ indicates a decreasing trend. To test for either increasing or decreasing monotonic trend at $p$ significance level, the null hypothesis is rejected if the absolute value of $Z$ is greater than $Z_{1-p/2}$, where $Z_{1-p/2}$ is obtained from the standard normal cumulative distribution tables. In this work, the significance level of $p = 0.01$ and 0.05 are applied.

To see change of trend with time, used sequential values, $u(t)$ and $u'(t)$, from the progressive analysis of the Mann-Kendall test. Herein $u(t)$ is a standardized variable that has zero mean and unit SD. Therefore, its sequential behavior fluctuates around zero level. The following steps are applied to calculate $u(t)$ and $u'(t)$:

1. The values of $x_j$ annual mean time series, $(j=1, \ldots, n)$ are compared with $x_k$, $(k=1, \ldots, j-1)$. At each comparison, the number of cases $x_j > x_k$ is counted and denoted by $n_j$.

2. The test statistic $t$ is then calculated by equation

$$t_j = \sum_{i=2}^{j} n_i$$

3. The mean and variance of the test statistic are

$$E(t_j) = \frac{j(j-1)}{4}$$

$$Var(t_j) = \frac{j(j-1)(2j+5)}{72}$$

4. The sequential values of the statistic $u(t)$ are then calculated as

$$U(t) = \frac{t_j - E(t_j)}{\sqrt{Var(t_j)}}$$

The values of $u'(t)$ are computed similarly backward, starting from the end of the series\cite{10, 11}

Results and discussion

A precipitation trend analysis, on different spatial and temporal scales, has been great concern during the past century because of the attention is given to climate change from the scientific community; indicate a small positive global trend, even though large areas are instead characterized by negative trends\cite{1}. It is likely that in a warmer climate heavy rainfall will increase and be produced by
fewer more intense events. This could lead to longer dry spells and a higher risk of floods.

**Anomaly**

The term “anomaly” means a departure from a reference value or long-term average. A positive anomaly value indicates that the observed precipitation was greater than the average precipitation from 1981-2010, while a negative anomaly indicates that the observed precipitation was less than the average precipitation from 1981-2010. Figure 1 shows the anomaly of annual precipitation during the 6 recent years (2011-2016) and year 2017.

![Annual 2011-2016 Precipitation Anomaly VS 1981-2010](image1)

![Annual 2017 Precipitation Anomaly VS 1981-2010](image2)

![Annual 2017 Precipitation Anomaly VS 2011-2016](image3)

Figure 1. The anomaly of annual precipitation over the Afro-Eurasia

This map shows annual precipitation anomalies. Red areas on the map indicate where precipitation was above the long-term normal for the month, and blue areas on the map indicate where precipitation was below normal. Figure 2 shows the trend of precipitation using Mann-Kendall test over the Afro-Eurasia during 1982-2016.

**Conclusion**

A look at various aspects of humane life on Earth shows that they are all affected by weather and climate, and when planning for human life, they recognize these dimensions and pay attention to them as primary necessities. In general, the consequences of droughts, severe and sudden floods, extreme weather events are the evidence of climatic abnormalities that have faced the earth with
various crises. Regarding the effect of changes in temperature and rainfall extremes in a wide range of human activities such as agriculture, environment, water resources management, etc., it is necessary that the impacts of these extreme climatic events in planning future policies and policies in the different sectors should be considered. As a result, by knowing the spatial patterns and temporal variations of climate parameters, one can get an overview of the climate of each location. Therefore, The present study analyzed the rainfall data from 1981 to 2016 over an Afro-Eurasia to determination trend of precipitation. It can be concluded that there is evidence of some change in the trend of precipitation over a region in these periods.

![Image of precipitation analysis]

Figure 2. Trend analysis of precipitation in Afro-Eurasia during the years 1982-2016 using Mann-Kendall test.

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**References**


