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TEMPORAL VARIABILITY OF ARTVIN MONTHLY TOTAL PRECIPITATION FROM 1949 TO 2020

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ABSTRACT
Precipitation variability is one of the most important hydrological phenomena affecting the whole world. Human impacts and climate change are gradually altering the spatial and temporal pattern of precipitation. In this study, the temporal variability of monthly total precipitation in Artvin province was analyzed. Artvin is one of the provinces with high rainfall in Türkiye, which is significantly affected by climate change. 1949-2020 was determined as the study period. Wild Binary Segmentation (WBS) and Window-Based Change Point Detection (WBCPD) methods were used as multiple change point detection methods to examine temporal variability. After determining the sub-periods, the temporal variability of precipitation was analyzed comparatively in terms of basic statistical parameters, precipitation anomaly time series, and long-term seasonal averages. As a result of the findings, 1956 and 1985 were identified as the change years. Three sub-periods were determined according to the change years. While the averages of the three sub- periods show a gradual increase, the negative direction of the linear slopes is remarkable. The highest maximum rainfall (about 325 mm) was observed in the third period and the lowest maximum rainfall (about 225 mm) was observed in the second period. In the long-term seasonal averages, a significant divergence was found between the three sub-periods. In the sub-periods, the lowest precipitation was observed in July and August, and the highest precipitation was observed in January and December.

Keywords: Precipitation variability, Artvin, Multiple Change Point

1. INTRODUCTION

Water is of great importance for the preservation of ecological balance and the continuity of life. The main input of water resources of great importance in different parts of the world is precipitation. As a result of global warming, climate change, and increasing anthropogenic effects, the movement of water around the world has started to differ. Precipitation, which is one of the important components of the hydrological cycle, shows spatial and temporal changes because of these effects. These changes need to be analyzed, observed, and evaluated from a cause-effect perspective. It is possible to develop sustainable policies by predicting climatic changes. Beyond considering precipitation variability as a regional problem, it is necessary to know that its global change affects the whole world.

The temporal variability of precipitation, which is investigated within the scope of the study, is one of the important phenomena investigated by the science of hydrology. Precipitation follows a certain pattern in time. While there is low precipitation at certain times of the year, there is high precipitation in some months. When the months with little or no precipitation are examined, the stability between years may be a sign of drought. Similarly, considering the months with high precipitation, the risk of flooding increases over the years. In addition to predictable hazards, rainfall follows a highly variable temporal pattern. This can lead to wasted financial resources and ineffective agricultural strategies. Therefore, it is quite important to investigate temporal variability. There are many studies in the literature on the temporal variability of precipitation (Curtis et al., 2001; Dai, 2012; Habte et al., 2023). There are studies in which rainfall variability has been examined in Türkiye (Blöschl et al., 2019; Buyukyildiz, 2023; Koycegiz & Buyukyildiz, 2022, 2023; Köyceğiz & Büyükyıldız, 2019; Koycegiz & Buyukyildiz, 2021; Panagos et al., 2017; Turkes, 1996).

In this study, the variability of monthly total precipitation data obtained from the Artvin province meteorological station was analyzed. The study period was 1949-2020. Change point detection methods were used to analyze the temporal variability of precipitation. To the determined break years, sub-periods were formed. The rainfall variability of the sub-periods was analyzed.

2. STUDY AREA AND DATA

Artvin, a province with high rainfall, was selected as the study area. Located in the Black Sea region of Türkiye, Artvin has a mountainous geography. The surface area of Artvin is 7436 km^2. Artvin has a warm and rainy climate near the coast. However, as the elevation increases, snowfall becomes dominant. A large part of Artvin is covered with forests. Evergreen coniferous forests are quite abundant. The Çoruh River, a part of which is located within the borders of Artvin province, is a river with high hydroelectric potential.

In this study, monthly total precipitation data obtained from the meteorological observation station of Artvin province were used. The period 1949-2020 was determined as the study period. The number and coordinates of the Artvin meteorological station and the basic statistical information of the data used are given in Table 1. Accordingly, the mean and standard deviation of the monthly total precipitation data for the period 1949-2020 were 55.58 mm and 41.63 mm, respectively. The maximum monthly total precipitation was 342.30 mm in January 1989.

Table 1. Coordinates and fundamental statistical values of Artvin meteorological station

Station No	**Latitude**	**Longitude**	**Min (mm)**	**Mean (mm)**	**Max (mm)**	**Std. Dev. (mm)**
17045	41°10'30.7"N	41°49'07.3"E	0.20	55.58	342.20	41.63

3. METHODOLOGY

3.1. Wild Binary Segmentation (WBS)

BS has a long history in change point detection algorithms (Scott & Knott, 1974; Sen & Srivastava, 1975). This method transforms into a multiple change point detection method by repeating single change point methods in different sub-segments. First, the first change point is detected in the data set. Then it is checked whether there are change points in the two separated groups. A schematic representation of this method is given in Figure 1. However, a more useful version, Wild BS (WBS), is proposed by (Fryzlewicz, 2014). The main advantages of WBS are its ease of implementation and low computational complexity. However, the initial detection of a single change point in the whole period reduces the success of some functions. There is also a tendency to detect change points in sub-segments far from the origin. In the WBS method, the most appropriate one among the possible breakpoints determined according to a certain threshold value is preferred. This process is then repeated recursively. In this study, a threshold value of 2 is preferred.

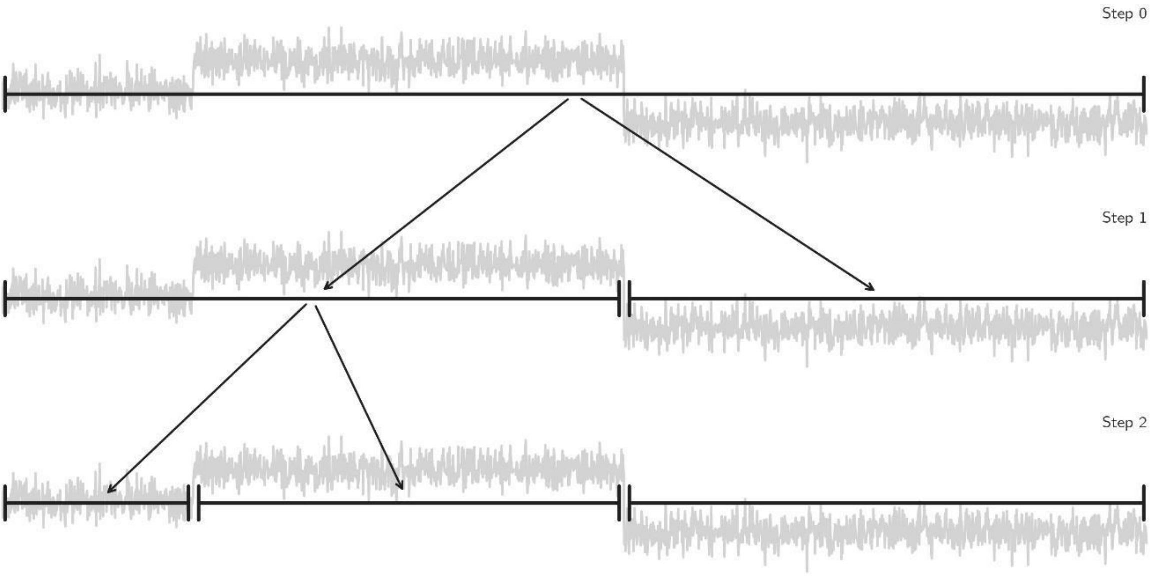

Figure 1. Schematic illustration of the WBS method (URL-1)

3.2. Window-Based Change Point Detection (WBCPD)

Window-based change point detection method, also known as the sliding window method in the literature, is frequently used in signal segmentation problems (Liu et al., 2022; Moradi et al., 2022; Wang et al., 2020). In this method, statistics calculated along a sliding window are compared with a discrepancy measure. In this study, a penalty value of 0.5 was chosen. When the specified threshold value is exceeded, if similar statistical features are observed within the window, the breakpoint is determined. Among the important advantages of the WBCPD method is its ease of implementation, the fact that it can be applied regardless of whether the number of breakpoints is known or not and that it can be applied to single or multiple breakpoint detection problems (URL-2).

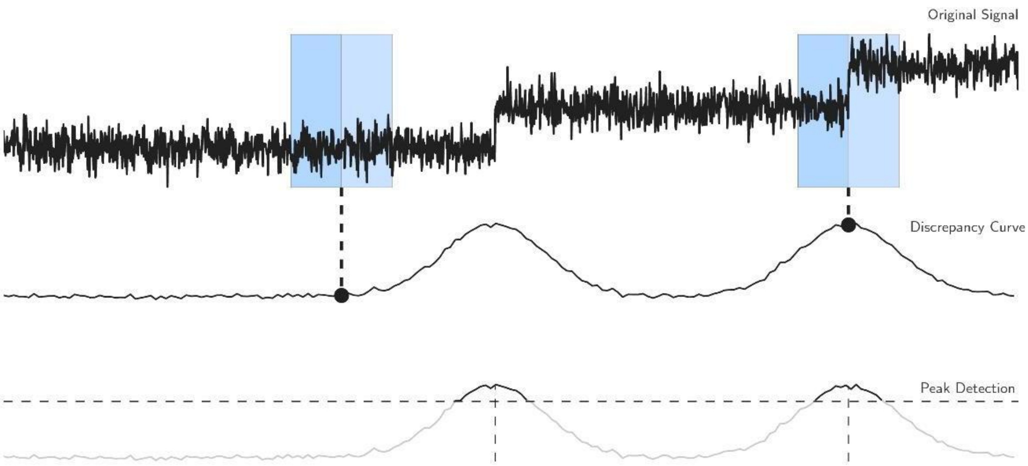

Figure 2. Schematic illustration of the WBCPD method (URL-2)

4. APPLICATION RESULTS

Change point detection methods are frequently used in rainfall variability studies. However, WBS and WBCPD are relatively new methods used in hydrology. Break points were determined because of analyzing the monthly total precipitation of the Artvin meteorological station with WBS and WBCPD methods. The results obtained are given in Table 2.

Table 2. Change points of Artvin precipitation data to WBS and WBCPD methods

Methods	Change Points (Year)
WBS	1985 (Sep)
WBCPD	1956 (Jul), 1985 (Sep)

According to Table 2, the WBS method detected one break point and WBCPD detected two break points. All results of the methods were considered due to the limited breakpoint detection. Accordingly, the years 1956 and 1985 were determined as breakpoints. The first period is Jan 1949-Dec 1956, the second period is Jan 1957-Dec 1985, and the third period is Jan 1986-Dec 2020. The maximum and average values according to the determined sub-periods are given in Figure 3.

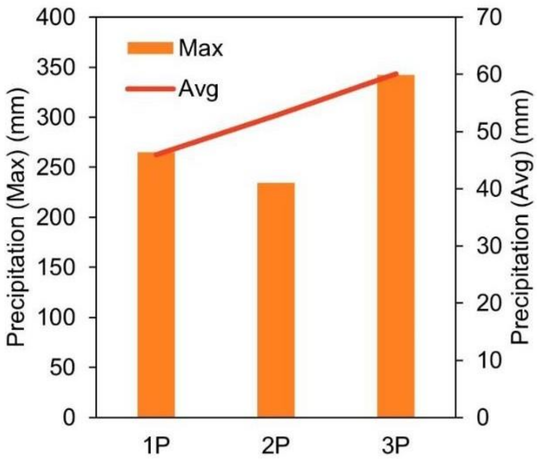

Figure 3. Monthly maximum and average precipitation by sub-period

According to Figure 3, the lowest maximum rainfall was obtained in the second period (about 230 mm) and the highest in the third period (about 340 mm). When the averages are analyzed, there is an increasing trend throughout the period. The average values increased from around 40 mm to around 60 mm during the three periods.

The examination of precipitation anomalies allows the emergence of trends that are difficult to observe in hydrometeorological time series. For this reason, an anomaly time series was created to analyze the sub-periods of Artvin monthly total precipitation (Figure 4). Accordingly, a significant decreasing trend is observed in the first period. There is also a decreasing trend in the second and third periods. However, the trend in these periods is not as severe as in the first period. It is observed that there are jumps in the third period. It can be stated that rainfall variability increased in the last period. Towards the last years of the time series, it is seen that the precipitation anomaly is in a narrower range. This may be a sign of a decreasing stable trend.

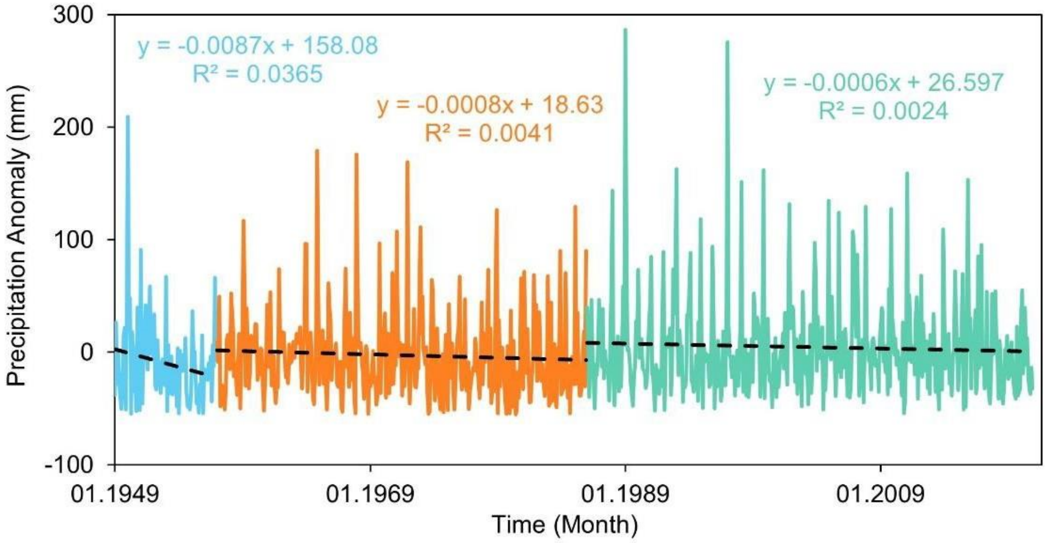

Figure 4. Sub-period rainfall anomalies and linear regression equations

Seasonal trends were analyzed by taking the long-term monthly averages of the sub-periods separated according to the breakpoints. Figure 5 shows the long-term seasonal averages. Accordingly, August was the month with the lowest precipitation for the first and third periods. The month with the lowest precipitation for the second period is July. It is quite remarkable that in November and December, when high precipitation is received (over 60 mm), the first period receives very low precipitation (about 40 mm). In January, the precipitation of the first period suddenly increased (from around 40 mm to 85 mm). The precipitation of the second period suddenly decreased. From this point of view, it can be stated that the sub-periods have significant differences. The third period had the highest precipitation (about 100 mm) in January. In other months, the averages of the three periods were close to each other.

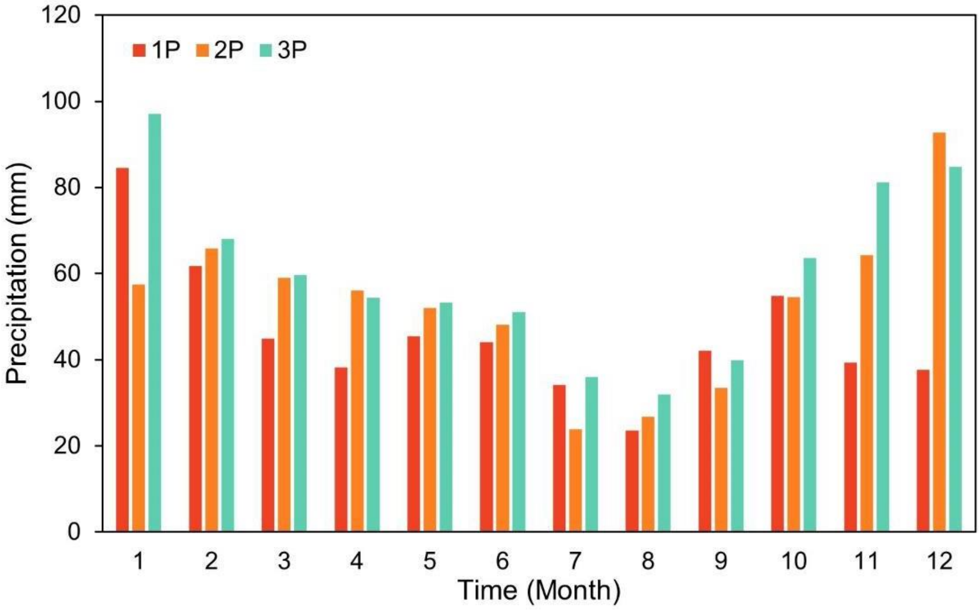

Figure 5. Sub-period seasonal averages of monthly precipitation

5. CONCLUSION

This study, it was aimed to analyze the monthly total precipitation data obtained from the Artvin meteorological station in terms of time variability. Rainfall time series were analyzed by WBS and WBCPD methods, which are among the multiple breakpoint detection methods. Sub-periods were formed according to the breakpoints determined because of the analysis. To reveal the temporal separation in the sub-periods, maximum and average graphs, rainfall anomaly time series, and long-term seasonal averages were created.

As a result of the change point analyses, 1956 and 1985 were determined as the break years. Three sub-periods were formed according to the break years. Accordingly, the averages of the sub- periods show a gradual increase. However, to precipitation anomalies, there is a decreasing slope in all three sub-periods. According to the seasonal averages, the dissociation between the sub- periods was observed quite clearly. Based on the findings, it is clear that climate change and human impacts have a significant impact on precipitation. It is recommended that decision-makers should develop effective policies in terms of water resources and agricultural strategies in light of this information. In the future, it is planned to investigate other environmental impacts of precipitation variability in Artvin province, especially in the agricultural sector.

REFERENCES

Blöschl, G., Hall, J., Viglione, A., Perdigão, R. A. P., Parajka, J., Merz, B., Lun, D., Arheimer, B., Aronica, G. T., Bilibashi, A., Boháč, M., Bonacci, O., Borga, M., Čanjevac, I., Castellarin, A., Chirico, G. B., Claps, P., Frolova, N., Ganora, D., … Živković, N. (2019). Changing climate both increases and decreases European river floods. *Nature,* 573(7772), 108-111. https://doi.org/10.1038/s41586-019-1495-6

Buyukyildiz, M. (2023). Evaluation of annual total precipitation in the transboundary Euphrates–Tigris River Basin of Türkiye using innovative graphical and statistical trend approaches. *Applied Water Science*, 13(2), 1–15.

Curtis, S., Adler, R., Huffman, G., Nelkin, E., & Bolvin, D. (2001). Evolution of tropical and extratropical precipitation anomalies during the 1997-1999 ENSO cycle. *International Journal of Climatology*, 21(8), 961–971. https://doi.org/10.1002/JOC.643

Dai, A. (2012). Increasing drought under global warming in observations and models. *Nature Climate Change*, *3*(1), 52-58. https://doi.org/10.1038/nclimate1633

Fryzlewicz, P. (2014). Wild binary segmentation for multiple change-point detection. *Ann. Statist.*, *42*(6), 2243-2281. https://doi.org/10.1214/14-AOS1245

Habte, A., Worku, W., Mamo, G., Ayalew, D., & Gayler, S. (2023). Rainfall variability and its seasonal events with associated risks for rainfed crop production in Southwest Ethiopia. *Cogent Food & Agriculture*, 9(1). https://doi.org/10.1080/23311932.2023.2231693

Koycegiz, C., & Buyukyildiz, M. (2021). Assessment of Concentration, Erosivity and Seasonality of Precipitation Data for 1970-2019 Period of Karataş Gauging Station. *European Journal of Science and Technology*, 32(32), 118–125. https://doi.org/10.31590/EJOSAT.1040131

Koycegiz, C., & Buyukyildiz, M. (2022). Investigation of precipitation and extreme indices spatiotemporal variability in Seyhan Basin, Turkey. *Water Supply*, 22(12). https://doi.org/10.2166/ws.2022.391

Koycegiz, C., & Buyukyildiz, M. (2023). Investigation of spatiotemporal variability of some precipitation indices in Seyhan Basin, Turkey: monotonic and sub-trend analysis. *Natural Hazards*, 116, 2211-2244. https://doi.org/10.1007/s11069-022-05761-6

Köyceğiz, C., & Büyükyıldız, M. (2019). Temporal trend analysis of extreme precipitation. *Pamukkale University Journal of Engineering Sciences*, 25(8), 956–961. https://doi.org/10.5505/PAJES.2019.86658

Liu, C., Chen, Y. R., Chen, F. H., Zhu, P., & Chen, L. Y. (2022). Sliding window change point detection based dynamic network model inference framework for airport ground service process. *Knowledge-Based Systems*, *238*, 107701.

Moradi, M., Montesino-SanMartin, M., Ugarte, M. D., & Militino, A. F. (2022). Locally adaptive change-point detection (LACPD) with applications to environmental changes. *Stochastic Environmental Research and Risk Assessment*, 36(1), 251–269. https://doi.org/10.1007/S00477-021-02083-0/TABLES/6

Panagos, P., Borrelli, P., Meusburger, K., Yu, B., Klik, A., Lim, K. J., Yang, J. E., Ni, J., Miao, C., Chattopadhyay, N., Sadeghi, S. H., Hazbavi, Z., Zabihi, M., Larionov, G. A., Krasnov, S. F., Gorobets, A. V., Levi, Y., Erpul, G., Birkel, C., … Ballabio, C. (2017). Global rainfall erosivity assessment based on high-temporal resolution rainfall records. *Scientific Reports*, *7*(1), 1-12. https://doi.org/10.1038/s41598-017-04282-8

URL-1: https://centre-borelli.github.io/ruptures-docs/user-guide/detection/binseg/ (accessed on 19 July 2023)

URL-2: https://ctruong.perso.math.cnrs.fr/ruptures-docs/build/html/detection/window.html (accessed on 19 July 2023)

Scott, A. J., & Knott, M. (1974). A Cluster Analysis Method for Grouping Means in the Analysis of Variance. *Biometrics*, 30(3), 507. https://doi.org/10.2307/2529204

Sen, A., & Srivastava, M. S. (1975). On Tests for Detecting Change in Mean. *Ann. Statist.*, 3(1), 98-108. https://doi.org/10.1214/AOS/1176343001

Turkes, M. (1996). Spatial And Temporal Analysis Of Annual Rainfall Variations In Turkey. *International Journal Of Climatology*, 16, 1057-1076.

Wang, Y., Huang, G., Yang, J., Lai, H., Liu, S., Chen, C., & Xu, W. (2020). Change Point Detection with Mean Shift Based on AUC from Symmetric Sliding Windows. *Symmetry,* 12(4), 599. https://doi.org/10.3390/SYM12040599