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ANALYSIS OF PRECIPITATION SERIES AND DOUBLE MASS CURVE

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Abstract: The examination of precipitation series and the application of the double mass curve constitute pivotal components in the fields of hydrology and climatology. This research paper endeavors to ascertain the double mass curve, validate the consistency of the scrutinized data series, and subsequently utilize the double mass curve to rectify the discrepancies in the precipitation data. Such inconsistencies may arise from alterations in data collection methodologies or from physical changes that influence the underlying relationships. Upon the adjustment and homogenization of the data, we advance to the substantive statistical analysis, which employs the Simple Mass Curve as a visual trend tool, while fundamentally relying on frequency methods for the computation of design values.

Keywords: precipitation, double mass curve, temperature, catchment area

1. INTRODUCTION

Precipitation monitoring is very important for the efficient management of water resources, flood forecasting, etc., and precipitation of the countries is the main source of water for the hydrological system [1]. The coverage and accuracy of existing instruments are inherently limited, and achieving extensive coverage with rain gauges incurs substantial costs. Although advancements in satellite meteorological products, from TRMM to GPM, have significantly enhanced both coverage and spatial-temporal resolution, measurement errors and sampling uncertainties continue to constrain their applicability [2].

The objectives of this study were to analyze the long-term rain gauge records from 1991 to 2020 at two stations, Deva and Lugoj, situated at the extremities of the Bistra River basin, and to assess the homogeneity of the rain gauge data series between these two stations. This element is vital to ensure that the discrepancies identified in the data are ascribed to genuine climatic variations rather than external influences.

2. THE CASE STUDY

The Bistra River originates in the Țarcu Mountains, with a length of 46.2 km and a catchment area of 908 km². From an ecological, economic and hydrological point of view, the river network of Bistra catchment area is very important. It plays an essential role in the local ecosystem through the water resources offered, and from a tourist point of view, Bistra River offers a multitude of landscapes and recreational areas.

The main tributary of the Bistra River is the Rusca River, which originates from the Padeș Peak at 1359 meters altitude and has an area of 160 km² and a length of 21 km.

Altitude plays an important role in the distribution of temperature and precipitation (the higher the altitude, the lower the temperature and, usually, the greater the precipitation).

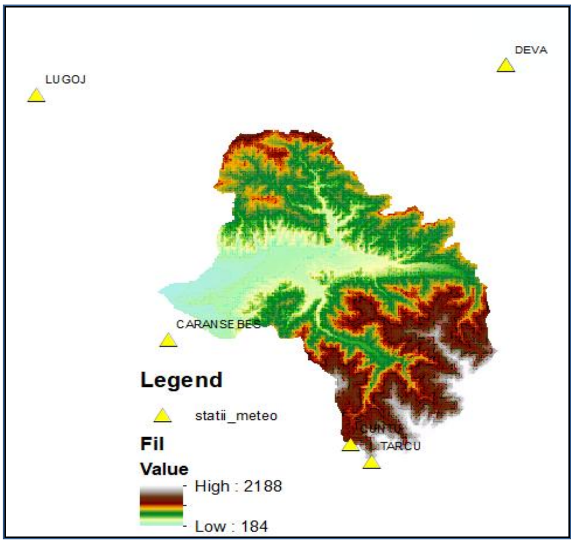

Figure1. Location map of the study area

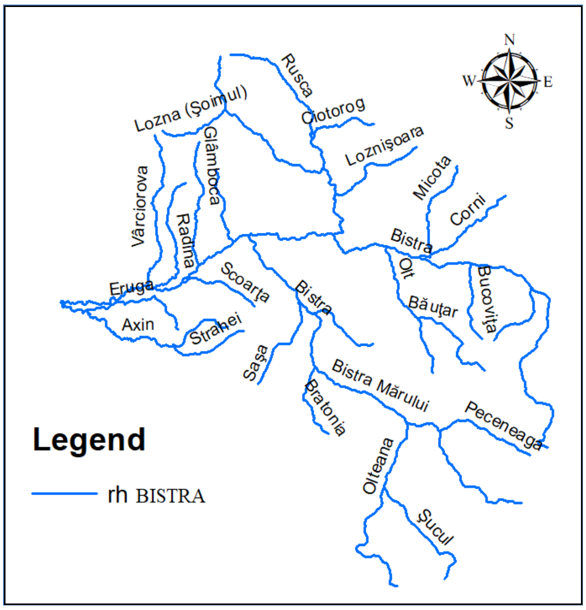

Figure 2. The hydrographical network of River Bistra

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The basin surfaces have an average slope with very high values, between 300 and 400 m/km. The water course has high falls in its mountainous sector, reaching an average of 80 m/km before reaching the town of Bucova.

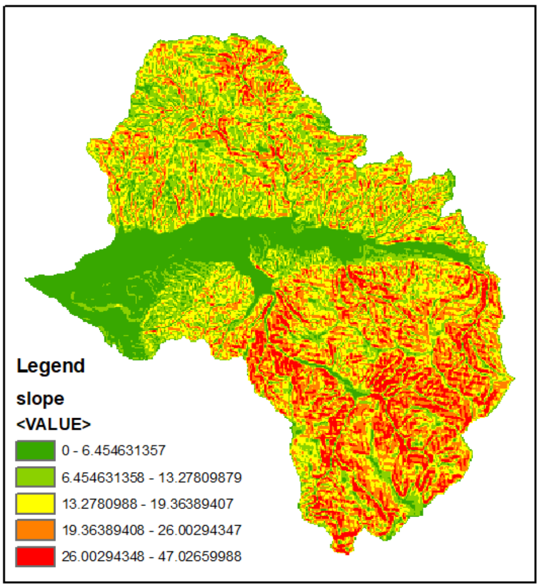

Figure 3. The slope of Bistra catchment

In the spring area, the slope exceeds 10-15%, in the hilly area with values between 5-10%, and in the lower area, close to the outlet, it has values below 5%. The terrain of the Bistra River Basin is predominantly formed by forests and semi-natural areas, the water bodies, artificial surfaces and agricultural areas (figure 4).

The climate encountered in the Bistra River Basin is temperate continental, manifested by hot summers and cold winters.

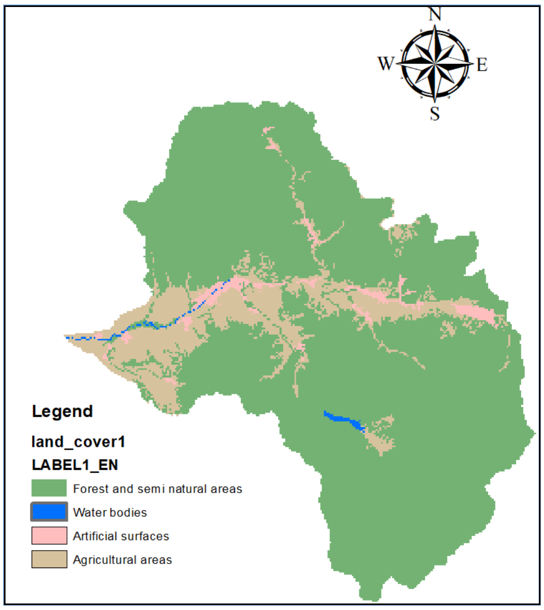

Figure 4. The land cover of River Bistra

3. RESULTS AND CONCLUSIONS.

Essentially, the analysis of precipitation series begins with checking the homogeneity using the Double Mass Curve to validate the quality of the data [3]. The mass curve is used to detect the influence of anthropogenic factors and climate change in the data series used for hydrological modeling. If the mass curve is not characterized by "jumps", then the flow formation process in the studied area is homogeneous and vice versa.[8]

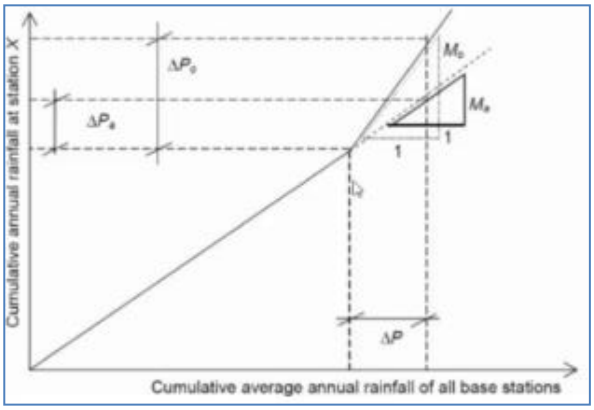

Figure 5. The double mass curve

$$P_a = P_o \frac{M_a}{M_o}$$

Where:

Mo - Slope of the line before the breakpoint.

Ma - Slope of the line after the breakpoint

Figure 5 shows the relationship between the rainfall measured at a station (station X) and the average rainfall of the reference stations.

The consistency check consists of an unchanged (consistent) relationship which is represented by a straight line. Any slope break (change in the angle of the line) indicates a change in the data collection regime at Station X; these changes can be caused by moving the station, changing the measuring instruments, changes in the station's environment (e.g. deforestation, high-rise buildings). Next, by applying a correction factor, the data prior to the slope break is adjusted to the current conditions (or vice versa), so that the data series becomes homogeneous (consistent).

By adjusting the inconsistent series, double mass curve ensures that subsequent hydrological and climatic analyses (such as the calculation of the average rainfall per basin or frequency analysis) are based on correct and homogeneous data.

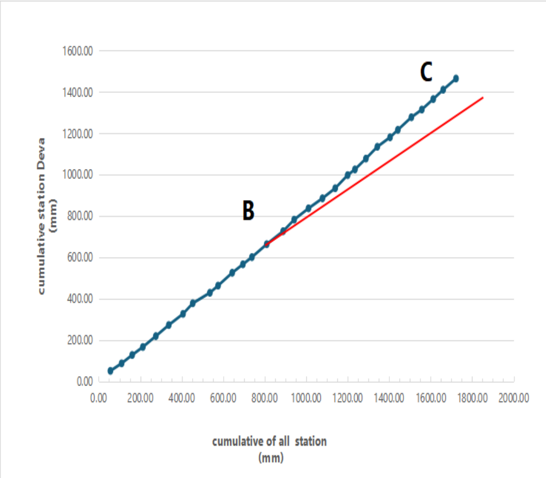

Figure 5. The double mass curve of Deva station

Point B on the data curve is the slope break point. Here, the behavior of the Deva station has changed in relation to the regional average. The segment from Point B to Point C regarding the correct slope of the series reflects the consistent regime of the Deva station after the change. The goal is to adjust the values recorded in the original period to make them correspond to the correct slope stability regime.

In the graphs below, the trends of the average annual precipitation, respectively of the maximum temperatures recorded, have been analyzed. As can be seen in figure 1, the highest amount of precipitation was recorded in 2006, and in 1994 only 65.5 mm was recorded at Deva station. Regarding the maximum temperatures, a linear trend with a slight increase can be observed.

The figure 7 shows that the frequencies decrease rapidly as the interval size increases, indicating a strong positive asymmetry specific to the precipitation data; in the case of maximum temperatures, the distribution appears to be roughly centered in the range of approximately 25 - 37, approximating a normal temperature distribution.

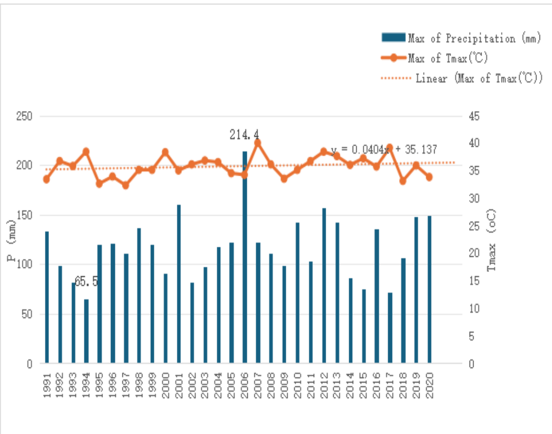

Figure 6. The yearly maximum precipitation and temperature of Deva station

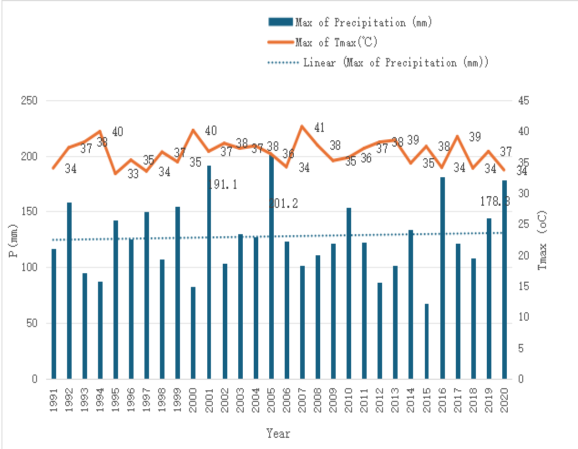

Figure 7. The yearly maximum precipitation and temperature of Lugoj station

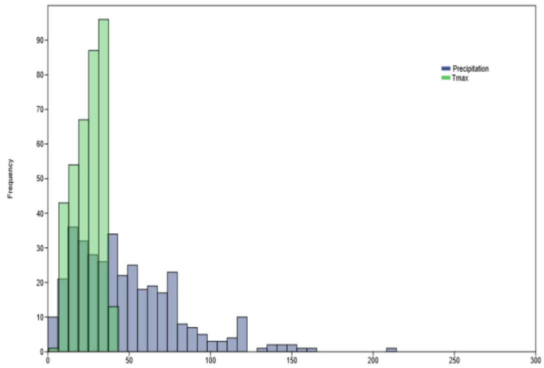

Figure 8. The frequency of precipitation and temperature from Deva station

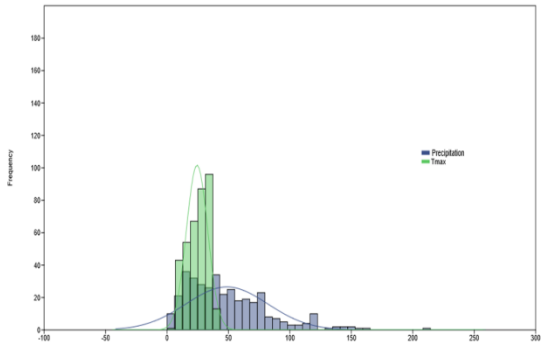

Figure 9. Fit normal – Distribution of numerical data (histogram)

Table 1. Distribution of precipitation and maximum temperatures from Deva station

Histogram

Histogram | Numbers

Bin start	Bin end	Precipitation	95% CI lo	95% CI hi	Tmax	95% CI lo	95% CI hi
0	6.1257	10	4.8236	18.177	1	0.025317	5.5365
6.1257	12.251	21	13.128	31.605	43	31.609	56.705
12.251	18.377	36	25.568	48.873	54	41.303	68.816
18.377	24.503	32	22.173	44.342	67	53.005	82.889
24.503	30.629	28	18.828	39.764	87	71.397	104.16
30.629	36.754	26	17.178	37.454	96	79.799	113.6
36.754	42.88	34	23.865	46.613	13	6.9713	21.946
42.88	49.006	22	13.928	32.784	0	0	3.6701
49.006	55.131	25	16.359	36.293	0	0	3.6701
55.131	61.257	18	10.763	28.035	0	0	3.6701
61.257	67.383	19	11.545	29.231	0	0	3.6701
67.383	73.509	17	9.9883	26.833	0	0	3.6701
73.509	79.634	23	14.734	33.959	0	0	3.6701
79.634	85.76	8	3.471	15.594	0	0	3.6701
85.76	91.886	7	2.8269	14.275	0	0	3.6701
91.886	98.011	5	1.6289	11.561	0	0	3.6701
98.011	104.14	3	0.61986	8.6975	0	0	3.6701
104.14	110.26	3	0.61986	8.6975	0	0	3.6701
110.26	116.39	4	1.0928	10.153	0	0	3.6701
116.39	122.51	10	4.8236	18.177	0	0	3.6701
122.51	128.64	0	0	3.6701	0	0	3.6701
128.64	134.77	1	0.025317	5.5365	0	0	3.6701
134.77	140.89	2	0.24246	7.1726	0	0	3.6701
140.89	147.02	2	0.24246	7.1726	0	0	3.6701
147.02	153.14	2	0.24246	7.1726	0	0	3.6701
153.14	159.27	1	0.025317	5.5365	0	0	3.6701
159.27	165.39	1	0.025317	5.5365	0	0	3.6701
165.39	171.52	0	0	3.6701	0	0	3.6701
171.52	177.65	0	0	3.6701	0	0	3.6701
177.65	183.77	0	0	3.6701	0	0	3.6701
183.77	189.9	0	0	3.6701	0	0	3.6701
189.9	196.02	0	0	3.6701	0	0	3.6701
196.02	202.15	0	0	3.6701	0	0	3.6701
202.15	208.27	0	0	3.6701	0	0	3.6701
208.27	214.4	1	0.025317	5.5365	0	0	3.6701

Table 1 shows the distribution of precipitation and maximum temperatures (T_{max}) from a Deva station, after the corrections established using the double mass curve were applied. The precipitation column shows the frequency (number of occurrences) of the values in the respective class, and the 95% CI lo (lower limit) and 95% CI hi (upper limit) columns show the intervals in which the true population mean is expected to fall, with a probability of 95%.

This analysis is important in hydrology, because it is then used to build a statistical model of the precipitation regime. Ensuring that the collected precipitation data is homogeneous and their statistical adjustment was done using the correction factor. Based on the resulting (homogenized) data series, statistical analysis was performed, being divided into classes (bins) to build Frequency Histograms (Figure 8 and 9) that show the distribution of the variables.

These distributional analyses are essential for hydrological modeling, allowing for the estimation of risks (e.g. frequency of floods or droughts) based on probabilities.

REFERENCES

[1] M. Gosset, M. Alcoba, R. Roca, G. Urbani, S. Cloché, 2018, Evaluation of TAPEER daily estimates and other GPM era products against dense gauge networks in West Africa, analyzing ground reference uncertainty, Q. J. R. Meteorol. Soc., 144, pp. 255-269

[2] Tan, M. L., and H. Santo, 2018, Comparison of GPM IMERG, TMPA 3B42 and PERSIANN-CDR satellite precipitation products over Malaysia. Atmos. Res., 202, 63–76, https://doi.org/10.1016/j.atmosres.2017.11.006

[3] Anderson H. W., 1955, Detecting hydrologic effects of changes in watershed conditions by double-mass analysis. Eos, Transactions American Geophysical Union, 36(1), 1–12. https://doi.org/10.1029/TR036i001p00119

[4] Daniell, T. M. & Daniell, K. A., 2006, Human impacts, complexity, variability and non-homogeneity: four dilemmas for the water resources modeler, Cl. Variability and Change – Hydrological Impacts, IAHS Publ., 308, 10-15.

[5]. A. Serban, 2001, Modelarea seriilor temporale, Ed. HGA, Bucuresti

[6]. Mallick et al. 2021, Analysing the trend of rainfall in Asir region of Saudi Arabia using the family of Mann-Kendall tests, innovative trend analysis, and detrended fluctuation analysis, Theoretical and Applied Climatology, 143(3)

[7] Han, J., Gao, J., & Luo, H., 2019, Changes and implications of the relationship between rainfall, runoff and sediment load in the Wuding River basin on the Chinese Loess Plateau. Catena, 175, 228–235

[8] Gao, P., Li, P., Zhao, B., Xu, R., Zhao, G., Sun, W., & Mu, X., 2017, Use of double mass curves in hydrologic benefit evaluations. Hydrological Processes, 31(26), 4639–4646. https://doi.org/10.1002/hyp.11377

[9] Buishand, T. A., 1982, Some methods for testing the homogeneity of rainfall records. Journal of Hydrology, 58(1–2), 11–27, https://doi.org/10.1016/0022-1694(82)90066-X