FLOW REGIMES SPATIAL VARIABILITY

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ABSTRACT. Flow regimes spatial variability. This study investigates the spatial distribution of annual flow regimes within the Tur River basin, using 29-year records (1979-2007) of mean monthly flow, for 7 gauging stations. A multivariate, statistical classification of regime "shape" and "magnitude" is used to group annual regimes. The classification revealed two "shape" classes with different timing of major flow peaks and three "magnitude" classes. These results suggest regime "shape" is controlled by the seasonal distribution and nature of hydroclimatic inputs. As such, a framework can be provided around which to test hypotheses, making regional classification an important tool for hydrological research, particularly over large and complex geographical domains.

Keywords river flow; regimes; hydroclimatology; clusters; classification.

1. INTRODUCTION

A river flow "regime" defines the bound variability in runoff over the hydrological year. The nature of seasonal behavior is dependent upon hydroclimatic processes and basin characteristics; hence, the flow regime is often used as the basis for regionalization (i.e. determination of hydrologically similar areas).

A sketch for identifying the types of river flow "regime" in Romania was published in the "Geografie Fizică" manual developed by V. Mihailescu (1936). Methodical studies of this kind have been made since 60's.

For Romania, the types of river flow "regime" are determined by the presence of the Carpathians, which prints a vertical zonality to the physicogeographical factors, and the climatic effects of the Black Sea. So, we identified three major types of hydrologic regime (macro-tips) – carpathian, peri-carpathian and Ponto-Danube – and twelve minor types (mezotipuri) depending on regional differences (I. Ujvari, 1980). The criteria used in the analysis and separation were the types of arrangements relating to high waters, floods, low waters, the flow distribution during the year and river water sources (nival, pluvial).

This paper aims to characterize the nature and geography of a river basin regime thus, infer the key factors determining spatial variations in the annual

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runoff regimes. This aim is achieved through some specific objectives: develop a new robust and sensitive regime classification methodology, and identify flow regime "regions".

Left tributary of the Tisza River upper basin, the Tur River (Fig. 1), lies in the north part of Romania, starting from the high volcanic mountains of Oaş and Gutâi to the lower plains of the Someş River, with a direction of flow from East to West. We analyzed the basin only upper from Turulung (the last hydrometrical station with long-term data), to have hydrological control over the runoff.

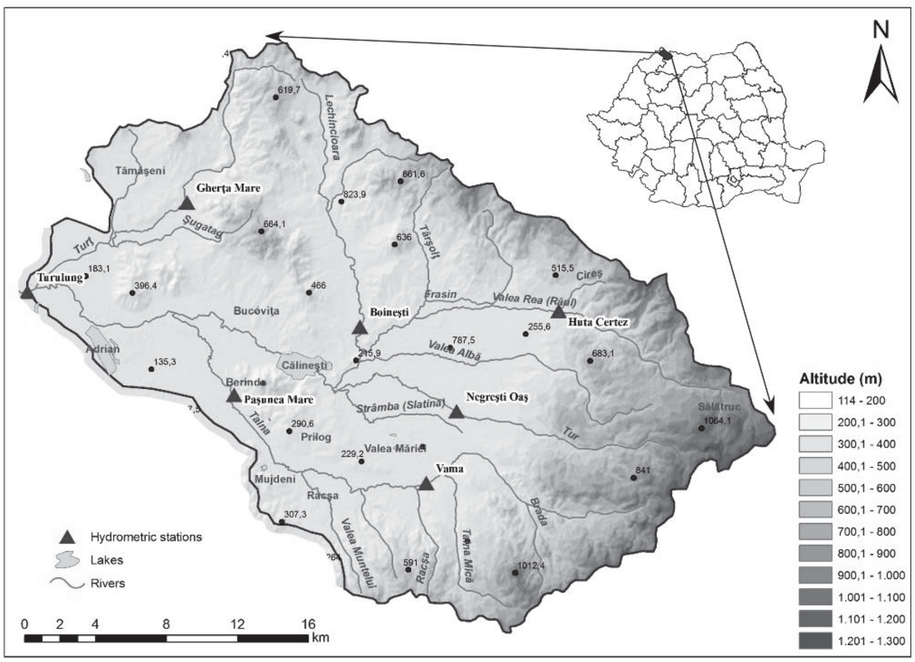

Fig. 1. ***Tur River basin***

2. DATA

Long-term (1979-2007; 29 hydrological years) monthly records were obtained for 7 hydrometric stations within the Tur River basin from the Romanian Water Authority, "Someş - Tisa" Branch. Stations were selected to provide a relatively uniform spatial coverage across the basin.

The long-term flow regime for each of the 7 stations was estimated by calculating mean monthly runoff for all years. The most frequent month of minimum flow was identified as August. Thus, runoff time series were divided into hydrological years commencing in September. This ensured that the rising limb, annual peak and flow recession were included within the same 12-month period. Throughout the paper, station years are referred to by the calendar year in which they begin.

Used hydrometric stations and data Tur River (1979-2007)*

River name	Hydrometric station	Altitude	Area	Mean	$\overline{Q}_{min}$	$\overline{Q}_{max}$	Stand. Dev.
		m	km^2	m^3/s	m^3/s	m^3/s	m^3/s
Tur	Turulung	130	733	10,817	0,232	53,80	2,870
Talna	Pasunea Mare	137	170	2,311	0,097	9,530	0,456
Turt	Gerta Mare	149	36,6	0,486	0,007	2,710	0,170
Tur	Negresti Oas	238	38	0,888	0,008	3,740	0,142
Valea Rea	Huta Certeze	285	61	1,659	0,059	6,990	0,231
Talna	Vama	192	51	1,205	0,067	4,620	0,173
Lechincioara	Boinesti	185	84,6	1,009	0,000	5,530	0,306

** Romanian Water Authority, „Someş - Tisa" Branch*

3. REGIME CLASSIFICATION METHODOLOGY

The "flow regime" defines the bound variability in river discharge over the hydrological year. Since it is important to assess both the size and timing of discharge events, a methodology is adopted which employs multivariate techniques to separately classify regimes according to their "shape" and "magnitude". The classification procedure used is similar to that devised by Donna Bower & D. M. Hannah (2002) and by S. R. Kansakar et al. (2002).

Simplified, the method supposes that, the "shape" classification identifies stations with a similar form of annual average regime hydrograph, regardless of the absolute magnitude of runoff; while the "magnitude" classification is based upon four runoff indices (i.e. the mean, minimum, maximum and standard deviation of mean monthly runoff observations) for each station, regardless of their timing.

To classify flow regime "shape" independently of "magnitude", the 12 monthly observations for each station were standardized separately using z-scores, STANDARDIZE formula in Ms Excel 2003.

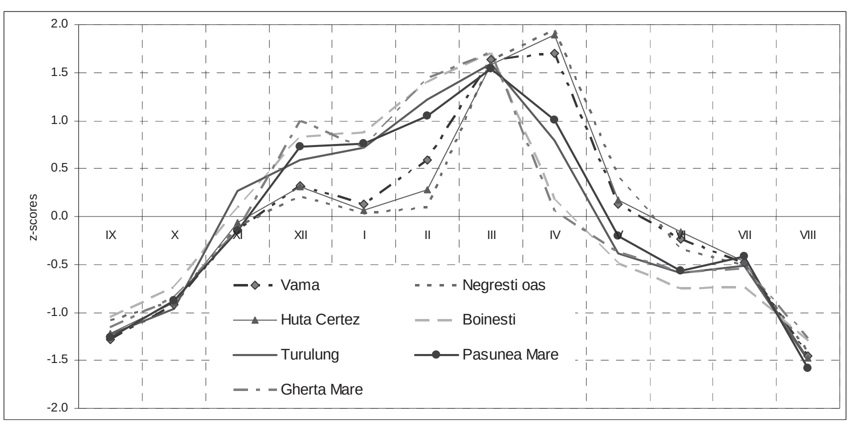

Fig. 2. ***Standardized flow data z-scores***

The four "magnitude" indices were derived for the long-term regime, for each station; here also it was necessary to standardize between indices (to control for differences in their relative values) by expressing each index as z-scores across the 7 stations.

We used, cluster analysis, that refers to methods which attempt to group cases in such a manner that the members of each group are, in some sense, "close" to one another. Several variables may be chosen for the analysis, and the differences in these variables between two cases determine the "distance" between the two cases. Hierarchical clustering was performed using five methods (single, average and complete linkages, centroid and Ward). This exploratory analysis revealed that different algorithms identify different classes.

Ward's method was found to yield the most informative and evenly-sized classes, while other methods tended to produce unevenly-sized clusters that did not well characterize regional hydrological patterns. This method (also known as incremental sums of squares) says that the distance between two groups is proportional to the change in the within group sum of squares which re-sults when the two groups are combined. In other hydrological regionalization studies the Ward's method was also found to give the most robust and physically realistic clusters. "Shape" and "magnitude" were both classified using hierarchical, agglomerative cluster analysis (Ward's method).

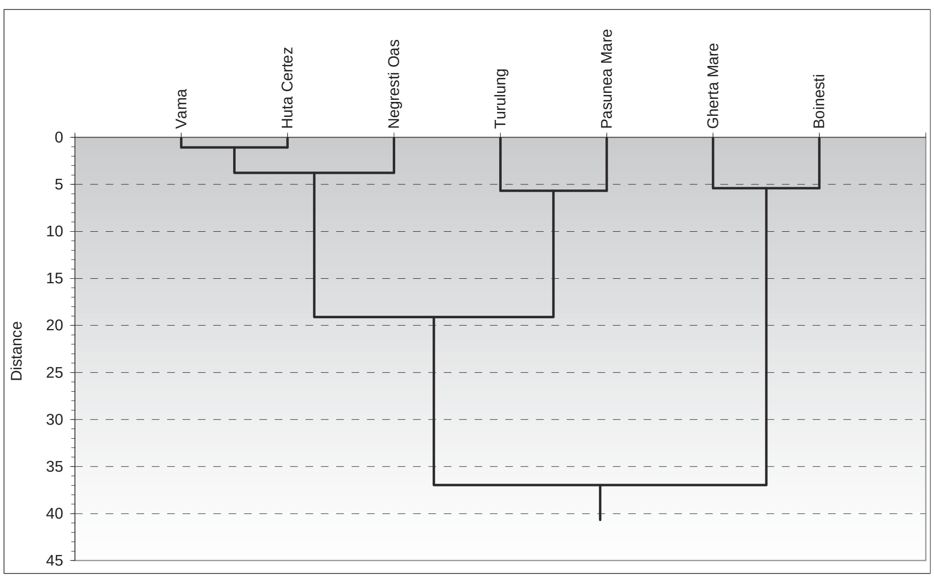

Fig. 3. *"Shape" dendogram (WinSTAT)*

The data were computed using partitional clustering and hierarchical clustering algorithms, in MATLAB software, we also tried the MsExcel WinSTAT add-in with similar results. For the hierarchical clustering, Euclidian distances and Ward's method linkage were used and returned three clusters.

In the partitional clustering, Kmeans method returned us one well-separated cluster and two contiguous clusters. Kmeans uses a two-phase iterative algorithm to minimize the sum of point-to-centroid distances, summed over all k clusters:

1. The first phase uses *batch updates*, where each iteration consists of reassigning points to their nearest cluster centroid, all at once, followed by recalculation of cluster centroids. This phase occasionally does not converge to solution that is a local minimum, that is, a partition of the data where moving any single point to a different cluster increases the total sum of distances. This is more likely for small data sets. The batch phase is fast, but potentially only approximates a solution as a starting point for the second phase. (Seber, 1984)
2. The second phase uses *online updates*, where points are individually reassigned if doing so will reduce the sum of distances, and cluster centroids are recomputed after each reassignment. Each of the iteration during the second phase consists of one pass though all the points. The second phase will converge to a local minimum, although there may be other local minima with lower total sum of distances. The problem of finding the global minimum can only be solved in general by an exhaustive (or clever, or lucky) choice of starting points, but using several replicates with random starting points typically results in a solution that is a global minimum. (Spath, 1985)

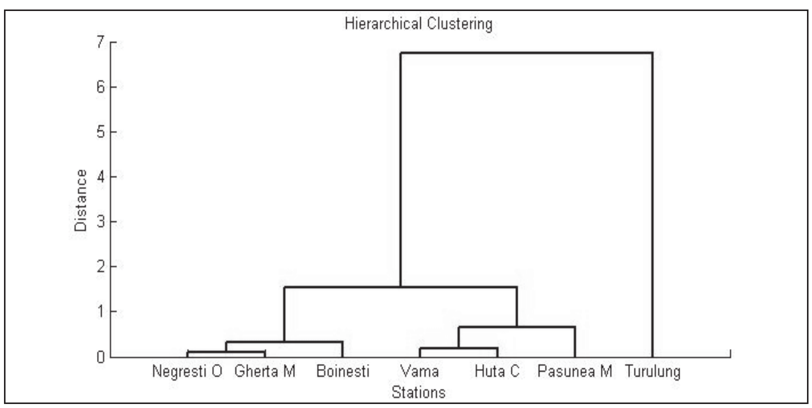

Fig. 4. ***"Magnitude" dendogram (MATLAB)***

Five iterations were computed to find the solution with lowest value of sum of distances. The distance considered is Squared Euclidian, each centroid is the mean of the points in that cluster.

The centroids identified in hierarchical tree (dendogram) were used for the first iteration in kmeans analysis. The Ward's method is the correct hierarchical analog of the kmeans techniques. Contiguity demonstrates that each set of data in the cluster is closer to at least one set of data in its cluster that to any set in another cluster.

The structure of the cluster dendogram was used to decide upon the appropriate number of clusters (i.e. regime classes). Thus, each of the 7 stations was grouped by standardized regime “shape” and relative runoff “magnitude”. The spatial distribution of the “shape” and “magnitude” classes allowed flow regime “regions” to be identified.

In the scientific literature (Ujvari, 1972) the area is represented by two flow regime types, in the high mountain region by the Carpathian Western type and in the lover areas by the Peri-Carpathian Western type, the main difference between them is the moment of the spring maximum runoff, at the lower stations (March) it appears sooner with a month compared to the others (April). The difference is explainable by the runoff supply, in both cases it is mixed from pluvial and nival waters, only the weight differs. This phenomenon can be followed in today’s data series also (Fig. 2).

In case of both classifications (shape and magnitude) we found three clusters represented by three regions in the study area. The difference between them is due mainly to the orography of the region in this case, and also to the computation mechanics. By comparing the results to the scientific literature, the shape classification resembles the most with the traditional classification, only here this new type of classification can follow more finely the small differences impounded by the orography.

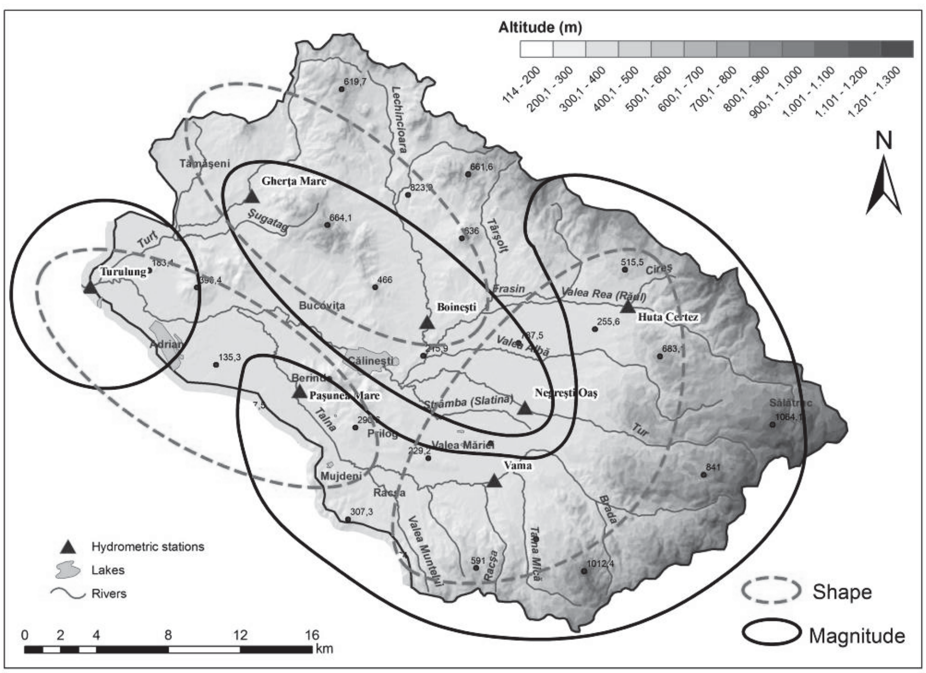

Fig. 5. ***Flow regime regions delimitated by the “shape” and “magnitude” clusters***

4. CONCLUSION AND FURTHER RESEARCH

The spatial distribution of the "shape" and "magnitude" classes allows the identification of flow regime "regions". These results are not only of scientific interest; they have major implications for the assessment and prediction of water resources. To rectify some of the errors which may appear in the computation, a regionalization of precipitation regimes should be conducted, using similar techniques. Also, we should not underestimate the importance of the other runoff influencing factors, like geology, basin characteristics, vegetation, soil and also the significant influence, in the water supply formation, of the temperature.

For a truly robust and quick possibility to assess the flow regime type of a region, the classification must take in to account as many of the runoff components as possible.

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REFERENCES

1. C. R. L. Laize & D. M. Hannah (2008), Seasonal hydroclimatological variability in near-natural UK river basins. Sustainable Hydrology for the 21st Century 15-17 September 2008 (Proceedings of 10th BHS National Hydrology Symposium) University of Exeter.
2. Donna Bower & D. M. Hannah (2002), *Spatial and temporal variability of UK river flow regimes.* FRIEND 2002—Regional Hydrology: Bridging die Cap between Research and Practice (Proceedings of thee Fourth International FRIEND Conference held al Cape Town. South Africa. March 2002). IAHS Publ. no. 274. 2002. ISSN 0144-7815.
3. S. R. Kansakar, D. M. Hannah, J. Gerrard (2002), *Flow regime characteristics of Himalayan river basins in Nepal.* FRIEND 2002—Regional Hydrology: Bridging die Cap between Research and Practice (Proceedings of thee Fourth International FRIEND Conference held al Cape Town. South Africa. March 2002). IAHS Publ. no. 274. 2002. ISSN 0144-7815.
4. Ujvari, I. (1957), *Alimentarea râurilor din R.P.R*, în Meteor. şi Hidrologie, nr. 1.
5. Ujvari, I. (1972), *Geografia apelor României*. Editura Stiinţifică, Bucureşti.
6. Seber, G. (1984). *Multivariate Observations.* Hoboken, NJ: John Wiley & Sons Inc.
7. Spath, H. (1985). *Cluster Dissection and Analysis: Theory, FORTRAN Programs, Examples.* New York: Halsted Press.