Regional Analysis of theHydrological Regimes and Their Stability in the Mediterranean Zone

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INTRODUCTION

At large scale of space, the main climate characteristics that are prevalent in the countries belonging to the Mediterranean European zone are influenced by the Mediterranean and oceanic circulation as well and/or the continental climate. These determine the "macro-types" of hydrological regimes. Each of these "macro-types" encompasses "subtypes" of river flow regimes, the occurrence of which is considerably controlled by the physiographical properties of specific sub-areas. Among these, the altitude plays the most important role as it expresses the variation in altitude of a particular macro-type of the climate and it implicitly reflects the configuration of the river network, channel and slope gradients, soil and land cover.

This paper describes the regime types at a finer scale from the Mediterranean zone of Europe, concentrating on the following aspects:

- Types of the regimes defined by the timing of the high and low flow phases;
- Regionalisation of the "micro-types"
- Stability of the river flow regimes.

REGIME TYPES IN THE MEDITERRANEAN ZONE.

The FRIEND-AMHY available data on the flows allowed characterising the river regime in several zones of the Mediterranean area. The classification of the hydrological regimes (types of regimes) was done by assessing the discriminant periods defined by the first, the second and the third highest and lowest monthly values of flows noted MAX1, MAX2, MAX3 and MIN1, MIN2, and MIN3 respectively (Figure 1)

For the analysis of the types of the river flow regime regimes defined by the timing of the high and low flow phases as indicated by the discriminant periods the following sources have been used:

- FRIEND-AMHY data base;
- Data on mean monthly discharges at gauging stations published in the hydrological yearbooks

The lengths of the data series concerning the mean monthly discharges are very

different ranging from 20-80 years. Nevertheless, the short series of data having at last 15 years record have been considered for the assessment of the occurrence of the discriminant discharges as in these periods dry and wet years have been observed so that the selected series have been considered as representatives ones.

Relying upon the available data at the stations considered in the countries belonging to this area (Italy, France, Greece, Romania, Spain and Yugoslavia), the discriminating periods, which define a particular river flow regime, have been assessed. In the following tables the zones of specific river flow regime types are presented for the considered countries in the Mediterranean area from Europe.

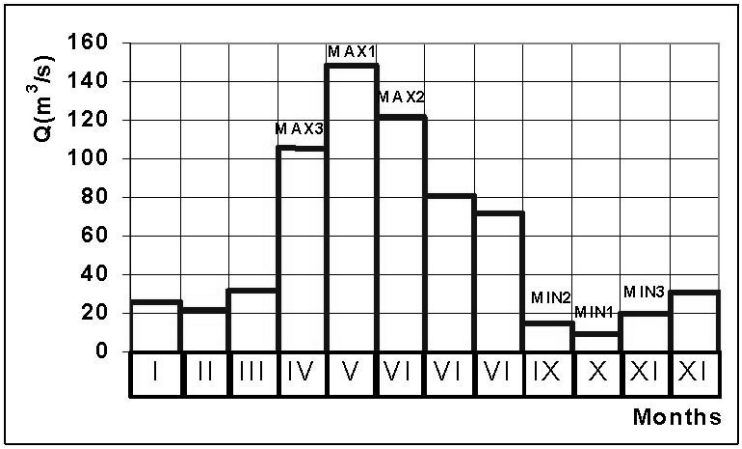

Fig. 1 Discriminant periods

Table 1. Types of flow regime and the discriminant periods in Italy

Zone	REGIMETYPE	Meanaltitude (m)	MAX1	MAX2	MAX3	MIN1	MIN2	MIN3
1	Pluvial central West	400 –600	XII - III	XI - III	XI - III	VII - IX	VII - IX	VII - IX
2	Pluvio-nival central	1000 -1500	I - IV	II - V	I - IV	VIII - X	VIII - X	VII - IX
3	Nivo-pluvial high altitude	1400 -1800	II - V	XII - III	III - VI	VIII - X	VIII - X	VIII - X
4	Pluvial central East	400 –800	XII - III	XI - III	XI - III	VII - IX	VII - IX	VII - IX
5	Pluvial South - East	800 - 1000	XII - III	I - IV	I - IV	VII - IX	VII - IX	VII - IX

Table 2. Types of flow regime and the discriminant periods in France

Zone	REGIME TYPE	MAX1	MAX2	MAX3	MIN1	MIN2	MIN3
1	Pluvial oceanic west	XII - II	XII - III	I - III	VIII - X	VII - IX	VII - IX
2	Pluvial oceanic south-eastern	I - IV	I - III	I - IV	VII - IX	VIII - X	VIII - X
3	Pluvial Mediterranean	I - IV	I - IV	I -IV	VII - IX	VII - IX	VII- IX
4	Nivo-pluvial Massif Central	I - IV	I - IV	I - IV	VIII - IX	VII - IX	VII - IX
5	Pluvial- Vosges	XII - II	XII - III	XII - III	VII -IX	VII -IX	VII -IX
6	Nival- French Alps	V - VI	V - VI	IV - VI	XII - II	XII - II	XII - II
7	Pluvio nival Alps	I - IV	I - IV	I - IV	VII -IX	IX - XI	VII - X
8	Glaciar - High Alps	VI - VII	VI - VII	V - VII	II - III	II - III	I - III

Table 3. Types of flow regime and the discriminant periods in Romania

Zone	REGIME TYPE	MAX1	MAX2	MAX3	MIN1	MIN2	MIN3
1	Southern Plain	MAX1	MAX2	MAX3	MIN1	MIN2	MIN3
2	Western Carpathian	II-IV	II-IV	II-IV	IX-XI	VII-X	VII-X
3	Central Plateau	III-IV	III-IV	III-V	IX-XI	VIII-XI	VIII-XI
4	Moldavian Plateau	III-IV	III-V	III-V	VIII-X	VIII-X	VIII-X
5	Carpathian Mountains	IV-VI	IV-VI	IV-VII	XII-II	XI-II	XI-II
6	South-western Carpathian	II-V	II-VI	II-VI	VIII-X	IX-XI	IX-XII
7	Dobrodgean	IV-VI	IV-VII	IV-VII	VIII-X	IX-X	VII-XI

The existence of different zones, which are quasi-homogeneous as physiographical properties, especially expressed by their mean altitudes, allows to carry out a hydrological regionalisation of the river flow regime types. In Figure 2 and Figure 3 the regionalization of the river flow regimes of France and Romania are presented as a title of example.

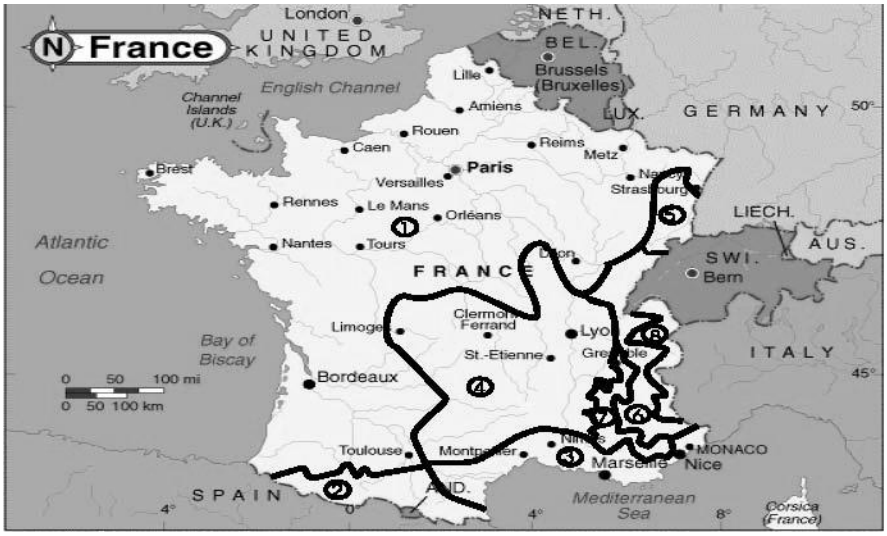

Fig. 2. Flow regime type regionalisation in France

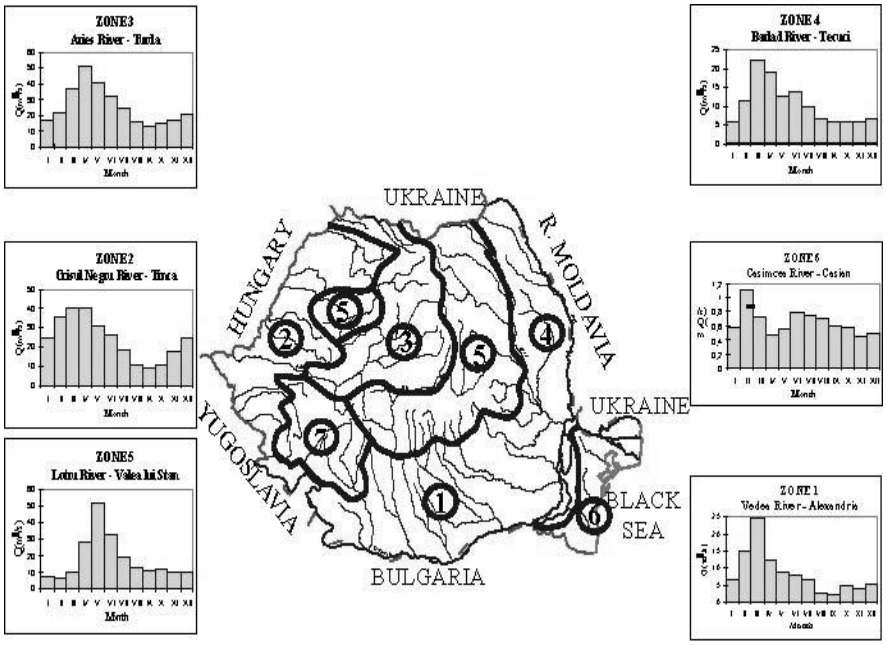

Fig. 3. Flow regime type regionalisation in Romania

Table 4. Types of flow regime and the discriminant periods in Yugoslavia

Zone	REGIME TYPE	MAX1	MAX2	MAX3	MIN1	MIN2	MIN3
1	North plain - low altitude.	II-III	II-IV	II-V	VIII-X	VIII-X	VIII-X
2	South-eastern zone - Juzna Morava River	III-IV	II-IV	II-V	VIII-IX	VIII-X	VIII-X
3	Eastern zone.	III-IV	II-IV	II-V	VIII-IX	VIII-IX	VIII-X
4	South-western zone.	IV-V	IV-V	III-V	VIII-IX	VIII-IX	VIII-X
5	Central zone - Zapadna Morava River basin	III-IV	III-V	III-V	VIII-IX	VIII-X	IX-X
6	Southern zone - high altitude.	IV-V	IV-V	III-V	VIII-IX	IX-X	VIII-X

Table 5. Types of flow regime and the discriminant periods in Spain

Zone	Regime type	MAX1	MAX2	MAX3	MIN1	MIN2	MIN3
1	Western and south-western zone	XII-III	XII-III	XII-IV	VIII-IX	VIII-IX	VII-IX
2	Central zone of transition	I-V (IV)	I-V	I-VI	VIII-IX	VII-IX	VII-X
3	Eastern and south-eastern zone.	II-V	II-VI	II-VI	VI-VIII	VII-IX	VII-IX

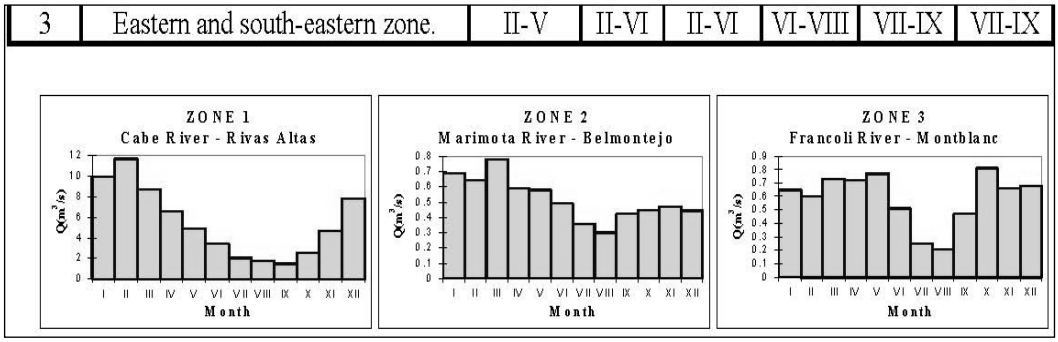

Fig. 4. Mean monthly hydrographs at the gauging stations of catchments that are representative for the three regime types in Spain

As data from only two stations from Greece were available, two distinct river flow regime types have been found (Table 6 and Figure5)

Table 6. Types of flow regime and the discriminant periods in Greece

Zone	Regime type	MAX1	MAX2	MAX3	MIN1	MIN2	MIN3
1	Northern high altitude-temperate influence	II-V	III-VI	III-VI	VIII-IX	VII-IX	VII-X
2	Central zone - Mediterranean influence.	XII-II	II-IV	III-IV	VIII-IX	VII-IX	VII-X

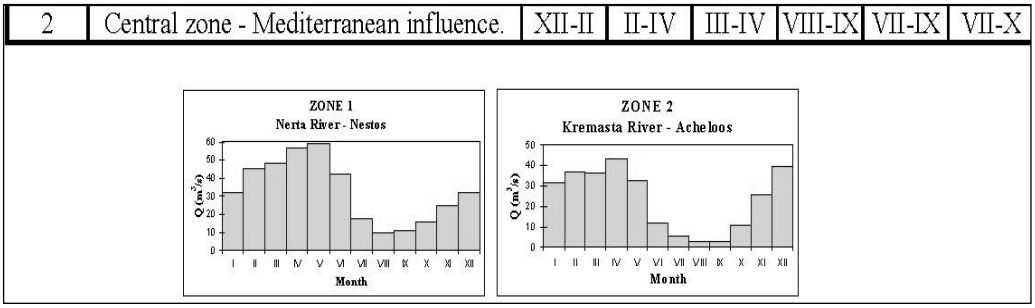

Figure 5. Mean monthly hydrographs at the gauging stations of catchments that are representative for the three regime types in Greece

STABILITY OF THE RIVER FLOW REGIMES

The stability of a certain flow regime may be quantitatively expressed either by the sum of the entropies of the occurrence of the regime characteristics (Shannon and Weaver, 1941), (Krasovskaia, 1995) or by the stability coefficient as determined by (Corbus and Stanescu,1999). According to the latter, the coefficient of stability is determined as follows:

$$CS = FA*CR \quad (1)$$

where: *FA* is the frequency of the occurrence of the discriminant value in *m* subsequent month (m=1.12), CR is the distribution coefficient along the period, given by:

$$CR = \left[\frac{13 - m}{12}\right] \quad (2)$$

In the table 11 the degree of stability of the river regime, function of the ranges of the stability coefficient is presented.

Table 7. The character of the river regime function of the stability coefficient C

FA	CR	CS		Regime character
m		CR = f(m)		
0.9-1.0	1-2	0.69-1.00	0.62-1.00	Very stable
0.8-0.9	2-3	0.56-0.69	0.45-0.62	Stable
0.7-0.8	3-4	0.44-0.56	0.31-0.45	Relatively stable
0.6-0.7	4-5	0.34-0.44	0.20-0.31	Relatively unstable
0.0-0.6	6-12	0.00-0.34	0.00-0.20	Unstable

The advantage of this method stands in the fact that for several combinations of subsequent months, the maximisation of the stability coefficient leads to the assessment of the characteristic period for a discriminant value.

An example of the characterisation of the river flow regime of France from the stability point of view is presented in the Table 8

Table 8. Characterisation of the stability or the types of regimes in France

Zone	R E G I M E T Y P E		MAX1	MAX2	MAX3	MIN1	MIN2	MIN3	Mean MAX	Mean MIN	MEAN
1	Pluvial oceanic wes	CS	0.477	0.445	0.380	0.605	0.548	0.392	0.434	0.515	0.475
		Regime Stability	Stable	Stable	Relat. Stable	Stable	Stable	Relat Stable	Relat Stable	Stable	Stable
2	Pluvial oceanic south eastern	CS	0.373	0.392	0.349	0.569	0.499	0.479	0.371	0.516	0.443
		Regime Stability	Relat. Stable	Relat. Stable	Relat. Stable	Stable	Stable	Stable	Stable	Stable	Relat Stable
3	Pluvial Mediterranea	CS	0.388	0.362	0.342	0.528	0.524	0.403	0.364	0.485	0.425
		Regime Stability	Relat Stable	Relat. Stable	Relat Stable	Stable	Stable	Relat Stable	Relat. Stable	Stable	Relat. Stable
4	Nivo-pluvia Massif.Centr l	CS	0.314	0.300	0.326	0.570	0.566	0.367	0.313	0.501	0.407
		Regime Stability	Relat. Stable	Relat. Unstab	Relat. Stable	Stable	Stable	Relat. Stable	Relat. Stable	Stable	Relat Stable
5	Pluvial-Vosges	CS	0.400	0.307	0.271	0.446	0.417	0.362	0.326	0.408	0.367
		Regime Stability	Relat Stable	Relat. Unstab.	Relat. Unstab	Relat Stable	Relat Stable	Relat Stable	Relat Stable	Relat Stable	Relat Stable
6	Nival-Franch Alps	CS	0.776	0.646	0.427	0.374	0.507	0.374	0.616	0.418	0.517
		Regime Stability	Very Stable	Very Stable	Relat. Stable	Relat. Stable	Stable	Relat. Stable	Stable	Relat Stable	Stable
7	Pluvio nival Alps	CS	0.321	0.442	0.482	0.397	0.595	0.321	0.415	0.438	0.427
		Regime Stability	Relat Stable	Relat Stable	Stable	Relat Stable	Stable	Relat Stable	Relat Stable	Relat Stable	Relat Stable
8	laciar - High Alps	CS	0.672	0.840	0.486	0.756	0.672	0.625	0.666	0.684	0.675
		Regime Stability	Very Stable	Very Stable	Stable	Very Stable	Very Stable	Very Stable	Very Stable	Very Stable	Very stable

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CONCLUSIONS

The significant variation in altitude of a basin subject to the influence of a particular climate leads to a differentiation of several micro-types of flow regimes. If a certain zone is found under the control of the intersection of many atmospheric circulations the micro-regime is a result of their combination with the altitude influence.

• The method of the stability coefficient CS allows to take into account both the length of the discriminant period and the probability of occurrence of a certain regime type in this interval of time. Moreover, this coefficient can numerically express the stability character of the river flow regime, but also it is useful for determining in an objective manner the discriminant periods themselves

REFERENCES BIBLIOGRAPHIQUES

Corbus C., Stanescu V. Al. (1999): *A New Method for determining the stability of the river flow regimes*. In; Annual Seminar of FRIEND-AMHY Group, Cosenza, Italy.

Krasovskaia I. (1995): *Quantification of the stability of the river flow regimes. Hydrological Sciences Journal*, Vol. 40, No. 5.

Shannon, C. E., & Weaver, W. (1941): *The Mathematical Theory of Communication.* University of Ilinois Press, Urbana, USA.

Stanescu V., Al., Ungureanu V.(1997): *Hydrological Regimes in the FRIEND-AMHY Area: Space variability and stability*. In: FRIEND '97-Regional Hydrology: Concepts and Models for Sustainable Water Resource Management. IAHS Publ. No. 246, p. 67-75.