PROPOSITIONS OF THE PhD THESIS

Characterization of the runoff regime and its stability in the Danube catchment

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I. Introduction

By its size, the River Danube is only on the second place in Europe after River Volga, but one of the most international rivers in the world. The Danube and its tributaries collect their waters from the territory of 20 countries, whose life and history – in spite of the different social and political traditions – is more or less defined by this river. Due to this geogreaphical connection, it was an natural necessity, that the countries sharing the Danube Catchment – against the actual political disagreements – must have to cooperate in the science of the hydrology.

The first steps of this collaboartion persisting today, were in 1971, when the – at that time – 8 Danube countries began the interoperation for the development of the first Hydrological Monograph of the Danube River. This work was finalized in 1986 by the publication of the German-language version of the Monograph. Since 1987, the aim of the Regional Hydrological Cooperation of the Danube Countries in the frame of IHP UNESCO is to improve and update the Monograph by jointly compiled and published follow-up volumes on selected topics of common interest.

In my Phd thesis, which was mostly prepared in the frame of the above mentioned cooperation, I used a natively and internationally spreading methodology for the investigation of the whole Danube Catchment, which creating an overall picture about the characteristic features of the runoff regime in the Danube Basin.

II. The aims of the investigation

The main purpose of executing of my PhD thesis is the investigation of the runoff regime of the Danube and its tibutaries by a uniform methodology. The primary task was the characterization of the runoff regime and the specification of its stability in the whole catchment. The results of this work are presented ina follow-up volume of the above mentioned Danube Monograph. The essential porpuses of the thesis are the following:

- the general description of the geographical and hydrological conditions of the Danube Basin in hungarian language
- the most complete collection of the existing methodologies of runoff regime characterization and stability investigation
- the investigation of the runoff regime of the Danube and its tributaries by using a uniform methodology

- characterization of the runoff regime in the Danube Catchment and the introduction of its spatial variability
- definition of the runoff regime stability in the Danube Basin
- investigation of the changes of runoff regime stability along the Danube and Tisza
- the introduction of temporal changes of the stability on the Danube and its tributaries
- the exploration of the possible temporal changes of monthly runoff – as the first indications of climate chamnge – on the Danube and Tisza.

III. Methodology of investigations

At the investigation of the runoff regime of a river, we have to recognize as detailed as possible the geographic, climatic and hidrologic features of its basin, together with the anthropogenic activities. The typization of runoff regime – the classification of the rivers (river sections) by a property of seasonal changes of runoff – has a long history. For my work I had to survey and process all the native and international literature dealing with the Danube Catchment. I must collected possibly all the characterization methodologies ever used in the world. These information provided the appropriate basis for me to complete my own runoff regime classification and stability investigation.

At the definition of the runoff regime types and the stability in the Danube Catchment, I used the methodology worked out by B. NOVÁKY. This method is using relatively new mathematical statistical procedures, which were applied with its preliminaries for many regions in Europe, e.g. for the whole the territory of Hungary. The database of this investigation was built up by the monthly mean discharge values of the measuring stations on the Danube and its tributaries. The monthly mean runoff data series were given by the competent experts of the respective countries of the Danube Basin. The application of the above mentioned methodology on newer and wider database, created the conditions for identification of the rivers or river sections with similar runoff regime features (the characterization of the ruoff regime) and for the computation of the runoff regime stability (the comparison of the occurence of a hydrological event in a given year with the many years' average). The temporal and spatial characteristic of the results were explorated by simple statistical investigations, while the reasons of differences are searched by the means of the geographical and hydrological features, introduced in the thesis.

IV. The results of the investigations

The results and statements of my investigations are the following:

1. The Danube Monograph was published in 1986, in the frame of the Hydrological Cooperation of the Danube Countries. This publication is the greatest international summary of knowledge about the Danube River Basin. It was originally published in German and in Russian language, the quadrilingual version – which was the complemention by the English and French languages – was completed three years later. Because of the continuous development of science and researcsh methodologies since the time of the publishment of the original version, follow-up volumes are created in English or German languages. All of these publications have no Hungarian version, so I compiled ***the geographic summary of the Danube Catchment in Hungarian language***. The primary sources of my work were the Danube Monograph itself, together with its follow-up volumes, but I processed other literatures and books of this topic of course. I always would like to present the newest available scientific results (e.g. the simplified hydrogeological map of the Danube Basin), or I created some additional investigations (e.g. the precipitation map of Danubian subcatchments).

2. In my the PhD thesis, I created ***the possibly most complete collection of the methodologies of runoff regime tipization and stability investigations*** used all around the world. Together with the hungarian literature of the topic, I present the impressioning Russian typifying school (A. A. VOJEJKOV, M. I. LVOVICS), the widely known typization system of M. PARDÉ, and some other studies, which were never published in Hungarian language (e.g. the detailed description in hungarian language of the caracterization system of F. GRIMM). In my thesis I review the methodologies of the runoff regime stability computations, and I give a deatiled description of runoff regime characterization and stability determination methodologies of B. NOVÁKY, that I used in my investigations.

3. The earlier investigations on runoff regime were delt with only a catchment, a country or a smaller region. This study refers a wide area, a catchment of which so me smaller

regions, there were some more or less detailed researches, but this is the first investigation ***on the whole Danube Basin prepared by using a uniform methodology***. For the investigation, monthly mean discharge data series were needed, which were collected in the frame of the above mentioned hydrological cooperation. I characterized the runoff regime of the Danube and its tributaries by using the methodology of B. NOVÁKY on 206 measuring stations. The computetion of stability indices were executed on the basis of the same methodology and data series.

4. ***The characterization of the runoff regime in the Danube Catchment*** was carried out on the basis of the methodology established by B. NOVÁKY and introduced in the methodology chapter of the thesis. The runoff regime types were defined in accordance with the common experience that the highest monthly runoff usually occurs during the period between the end of the winter and the beginning of the summer, and the lowest monthly runoff falls between the end of the summer and the end of autumn in the Danube Basin. The 206 measuring station of the whole basin were classified by their runoff regimes into eight main types and 17 runoff regime sub-types, which are displayed on a map. In the upper regions of the catchments, the types do belong to the catchments, but along the downstream sections of the main rivers (Danube, Sava, Tisza, Maros, Körös) the runoff regime classes do characterize not the catchments but the river stretches themselves, because of the complexity of influences.

   The dates of the hydrological events chosen for the classification are changing on a wide scale within the year. The occurance of the two most important events, the first highest and the first lowest monthly mean discharges, are following well the specifications of the global climate type of the whole Danube Basin: the high water occurs in the first half of the year and the low water period is in the second half of the year. This general pattern is modified by many local effects (eg. climatical effects, geological conditions), when the highest discharges come from October to August, while the lower water occurs from July to March on the Danube and its tributaries.

   The territorial distribution of the runoff regime types is determined by the climatical and meteorological circumstances together with the orographical conditions of the Danube Basin. The appearance of the mediterranean climatical conditions is conspicuous on the Upper Sava Basin, where they create a highly modified runoff

regime, highly differing from the surrounding territories. These effects are perceptible on some neighbouring catchments (eg. Rába, Mura) too.

The output of my characterization are compared with the results of some earlier investigations. The rivers of some territories are placed into same runoff regime types in more investigations (eg. the rivers of the southern slopes of the Northern-Carpathians and the south-western foreground of the North-eastern Carpathians, or the River Siret and its tributaries). In some cases, there is no runoff regiem type border between the same catchments in contrast with the earlier investigations (eg. at Rába). Moreover it can be declared, that we have to get more or less similar results of investigations on the same territories, by using similar physio-geographical indices (eg. monthly mean discharges, climatic and orographical factors).

5. ***The runoff regime stability in the Danube Catchment*** was carried out on the basis of the methodology established by B. NOVÁKY, too. By using the equations defined in the methodological chapter of the thesis, I calculated nine stability indices of each station (for the first, second and third highest and the first, second and third lowest monthly mean discharges; and for three cumulative events created from the individual events). The five most important events are displayed on maps.

   It can be declared, that the runoff regime stability of the minimum events is larger that of the maximun events in the Danube Basin. The stability of the high situated catchments is higher. They usually described by summer runoff, with water coming from the melting glaciers. The most stable part of the Danube Catchment is the territory of the highest ridges of the Eastern Alps, the subcatchments of Inn. The possible reason – together with the high elevation – is climatic, because this is one of the most stable wet area of the Catchment (defined by precipitation and snowmelt). The most unstable territories of the Danube Catchment are in the Rába and – at some hydrological evevnts – in the Mura Basin. The most possible reason is climatic again, because this area is the crossing region of the three determinig climate types, the atlantic, continental and mediterranean effects.

6. ***The changes of the runoff regime stability along the rivers*** were investigated on some stations of Danube and Tisza for the first highest and first lowest monthly mean discharge events. The changes of the runoff regime stability is decreasing downstream along the Danube. On the upstream section, the incoming tributaries causing

spectacular changes (eg. the income of River Inn between Hofkirchen and Achleiten), while on the downstram section the stability changing effect of the tributarties is negligible. The stability of the investigated hydrological events more or less gradually decreasing along down the Tisza. The effects of the incoming tributaries are slighter than it is on the Danube, they can be seen only at the minimum event. The stability indices of the hydrological events are approaching together just like at the Danube, but the long, close going pattern of the Danube is can not seen on the Tisza.

7. ***The temporal changes of the runoff regime stability*** are defined by the methodology established in the study of B. NOVÁKY – M. SZALAY (2001). The temporal changes are investigated on some 100-year-long data series of the Danube Catchment for the first highest and first lowest monthly mean discharge events.

   The stability indices are rather diversified at the first highest monthly mean discharge event. On the chosen stations of the Danube can be arranged into three groups: the uppermost station, Hofkirchen has the most unstable value, the patterns of the three middle data series, Achleiten, Kienstock and Bratislava are roughly similar, while the data series of the bottommost station, Nagymaros has an intermediate stage. The data series of the Tisza and some of its tributaries show different pattern, but there are some similarities too. The stability values of Tisza, Zagyva and Maros are approaching together towards to the end of the investigated time period, while the Sajó behaving a bit different from them. Among the investigated rivers of the Bavarian Basin, Iller has continuously decreasing stability, while the values of Regen are increasing until the middle of the time period, after that they are decreasing too.

   At the first lowest monthly mean discharge event the five Danubian stations – except the uppermost, Hofkirchen – show rather uniform pattern. The stability values of the four stations are all the time in the stable zone and show similar picture. The values of Hofkirchen are always more unstable than the others, but it is approaching to the others. In the case of Tisza and its tributaries the picture is very diversified again. The Tisza and Maros are more or less similar, while Sajó goes its own way again, but here the Zagyva is joining it. The stability of Iller is higher than the stability of Regen almost in the whole time period. The previous has an increasing value at the beginning of the perion, but later it is gradually decreasing, while the latter is becoming more and more stable in most of the time period.

The most possible reasons of these significant temporal variabilities of the runoff regime stability are the anthropogenic activities (eg. river regulations, reservoir constructions) on the catchments of the Danube and its tributaries.

8. In the thesis, the results of some hungarian and international research are interpereted about ***the possible effects of climate change in the Danube Catchment***. The processes, which affecting Hungary directly, were investigated by the VAHAVA Working Group of the Hungarian Academy of Sciences, while in international level, the work of IPCC has to be emphasized. The directions of the possible climatical changes are introduced by the achievements of these complex studies.
   The exploration of ***the already perceptible processes of climate change on the Danube and its tributaries*** is based on the investigation of monthly mean data series of two hungarian measuring stations. The 100-year-long (1901-2000) data series of Danube/Nagymaros and Tisza/Vásárosnamény are separated into a 70- and a 30-year-long periods, because the results of the more intensive changes of the end of the XX. century can be explored in this way. At the Danube, there were not so extensive changes in the 30-year-long period compared to the 70 years time. The tendencies showed a decrease of runoff in the summer period, and an increase at wintertime. At Tisza, the results were a bit complicated, but there was a slight increase in winter too. There were more spectacular changes around the runoff maxiumun in spring: from the previous months of the maximum (February-March), a part of the waterflow is moving into June and July. The possible reasons can be the increase of winter-flow (the flowed mass of water in winter is missing in spring), or the increasing of precipitation in spring and at the beginning of summer in the Upper-Tisza Basin, which is forcasted by some climate models.
   In sum, it can be declared, that in these sections of Danube and Tisza, a slight increaser of runoff can be noticed, in agreement with the wellknown climate change scenarios. The increase of summer flow of Tisza is harmonizig less with these forecasts, but there are some supporting scenarios too.

In these investigations, my set targets were fullfilled. As a result of my work, a general description of the geographical and hydrological conditions of the Danube Basin in hungarian language was prepared, together with the characterization of the runoff regime and its stability investigation, by using a new methodology. This work can be easily repeated, so the results of

my thesis can make a suitable base for latter climate change investigations, when the long-term data series of the needed hydrographical parameters will be available.

V. The list of own publications

Publications in journals

- Kovács P. (2002): *A Duna-vízgyűjtőbeli országok XXI. Hidrológiai Konferenciája* (Bukarest, 2002. szeptember 2-6.), Vízügyi Közlemények 2002/2. füzet. pp. 290-298.

- Kovács P. (2009): Vízjárástípusok és a vízjárás stabilitása a Duna vízgyűjtőterületén. Vízügyi Közlemények, Várható megjelenés: 2009. utolsó negyedéve

Independent publications

- Kovács P. (2006): *Characterization of the runoff regime and its stability in the Danube Catchment.* The Danube and its Catchment – A Hydrolgical Monograph, Follow-up volume No. XI., Regional Cooperation of the Danube Countries (RCDC) in the frame of International Hydrolgical Programme (IHP) of UNESCO, VITUKI, Budapest. 40 p.

Conference abstracts

- Kovács P., Nováky B. (2004): *Characterization of the runoff regime and its stability in the Tisza Catchment*. In: *Conference abstracts*. XXIInd Conference of Danubian Countries on the Hydrological Forecasting and Hydrological Bases of Water Management, Czech National Committe for the International Hydrolgical Programme (IHP) of UNESCO. Brno, Czech Republic. pp. 172.

- Kovács P., Gulyás M. (2005): *Characterization of the runoff regime and its stability in the Danube Catchment.* General Assembly 2005, European Geosciences Union (EGU), Vienna, Austria.

- Kovács P. (2006): *Characterization of the runoff regime and its stability in the Danube Catchment.* In: S. Bruk – T. Petkovic (eds.) (2006): *Conference abstracts*. XXIIIrd Conference of Danubian Countries on the Hydrological Forecasting and Hydrological Bases of Water Management. National Committe of Serbia for the International Hydrolgical Programme (IHP) of UNESCO. Belgrade, Serbia. pp. 134.

Other studies and publications

- Kovács P. (2002): *A Duna-vízgyűjtőbeli országok NHP keretében folyó hidrológiai együttműködésének rendkívüli szakértői értekezlete* (Bukarest, 2002. szeptember 1.), NHP/OHP Híradó 2002/3. VITUKI, Budapest. pp. 15-16.

- Kovács P. (2002): *A XXI. Duna-konferencia* (Bukarest, 2002. szeptember 2-6.), NHP/OHP Híradó 2002/3. VITUKI, Budapest. pp.17-19.

- Kovács P. (2002): *A Duna-vízgyűjtő vízmérlegének elkészítésével foglalkozó szakértői munkacsoport tanácskozása* (Pozsony, 2002. október 24-25.), NHP/OHP Híradó 2002/4. VITUKI, Budapest. pp. 2-3.

- Kovács P. (2009): *Characterization of the runoff regime and its stability in the Danube Catchment*, Springer Publications, Ljubljana, Slovenia. 40 p. (under edition)