LONG-TERM DISCHARGE PROGNOSIS OF RIVERS IN THE DANUBE RIVER BASIN

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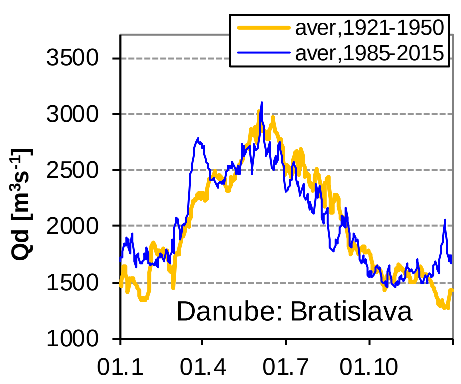
Abstract

In this study, the changes in statistical characteristics of the selected rivers in the Danube basin were identified using analysis of the daily, monthly and annual time series. In the second part, the relationship between runoff and North Atlantic Oscillation phenomena (NAO), as well as AO and ENSO phenomena were discussed. The third part of this study is devoted to the long-term prediction of the discharge by applying stochastic methods.

Data

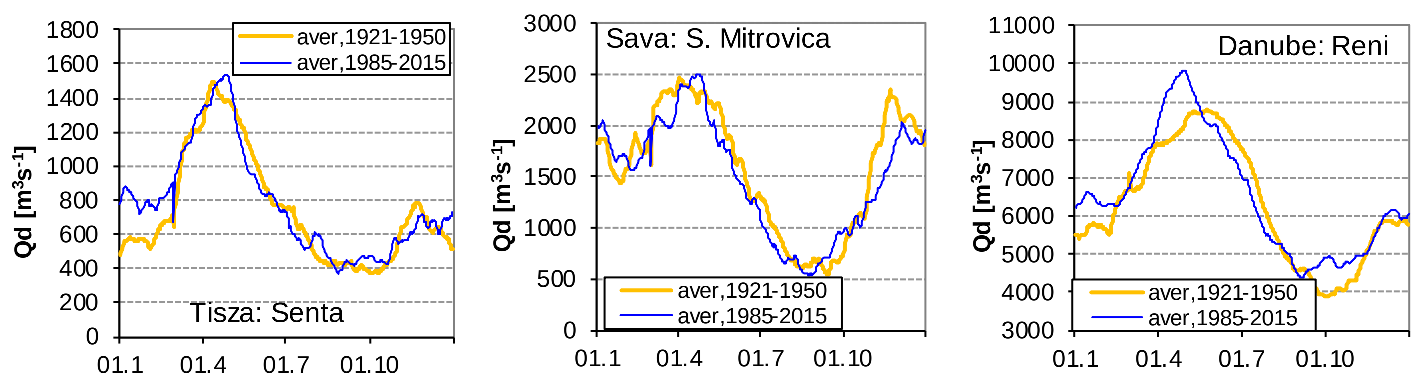
To analyze the long-term runoff variability, the daily discharge series from four water gauge stations: Danube: Bratislava gauge with 131,338 km^2 (Slovakia - SK); Tisza: Senta with 141,715 km^2 (Serbia - SR); Sava: Sremska Mitrovica with 87,966 km^2 (Serbia - SR); and Danube: Reni with 805,700 km^2 (Ukraine - UA) were used (Fig. 1), (period 1921-2018).

1. Statistical analysis, autocorrelations and spectral analysis



In the first part of the study, we focused on changes in statistical characteristics of the average daily discharge of the four studied rivers (Fig. 2) in two periods. There are higher discharges in winter season at Bratislava and Senta and in spring season at Reni in the new period 1985–2015 (blue colour).

Fig. 2. Comparison of the average daily discharge regime in two different 30-year periods.



The spectral and auto-correlation analysis of the selected four rivers show that the yearly discharge series include cyclic components, which are to be removed from the time series before the analysis of the long-term trends. The significant cycles are 2.4; 3.6; 5; 14; 21-22 and 28-29; ...; years.

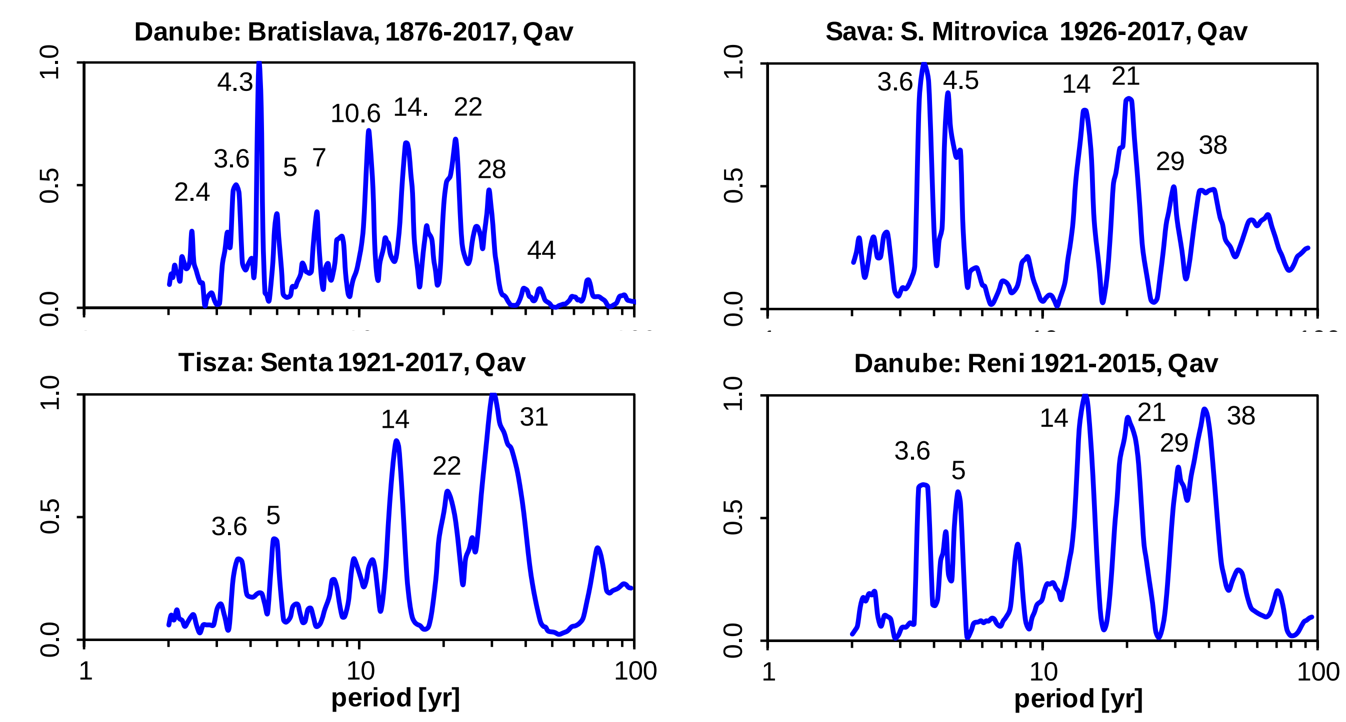


Fig. 3. The combined periodograms of the average annual discharges of the selected rivers.

2. Relationship between annual runoff and NAOw phenomena

From the cross-correlation graphs (Fig. 4) it follows that there exists a significant correlation between the discharge time series and the North Atlantic Oscillation winter index (NAOw) time series (negative ones for -1, 0, +1 year lags and positive ones for -2, and 7 year lags). From it follows that the NAO phenomenon has significant effect on the annual runoff fluctuations in the Danube basin. The length of the cycles of about 3.6 years, which was found in the flow rates, is probably related to the Southern Oscillation, expressed by the SO index. The length of cycles of about 2.47 years may be related to QBO oscillation. The length of the cycles of about 14 years is related to the North Atlantic Oscillation, expressed by the NAO index.

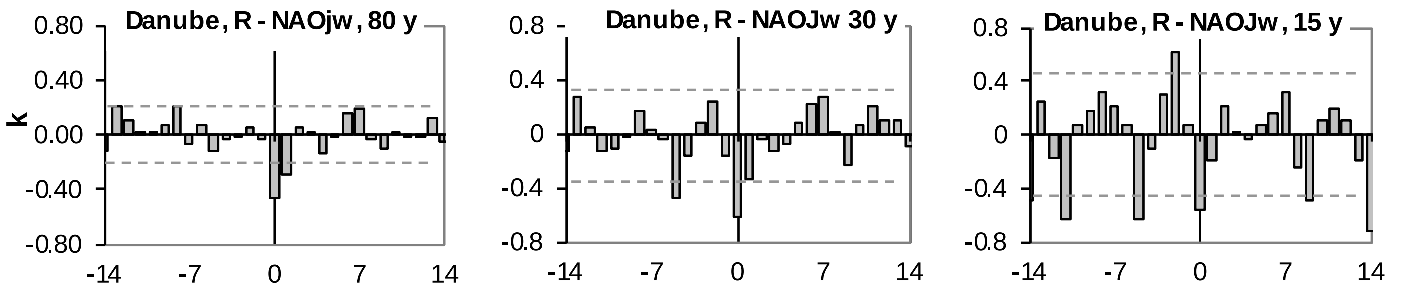


Fig. 4. The cross-correlogram coefficients (k) of the Danube discharge at Reni station and of NAO phenomena (NAO index according to Jones) for the periods: 1936–2015, 1981–2010, and 1996–2010.

Researched area and water gauges

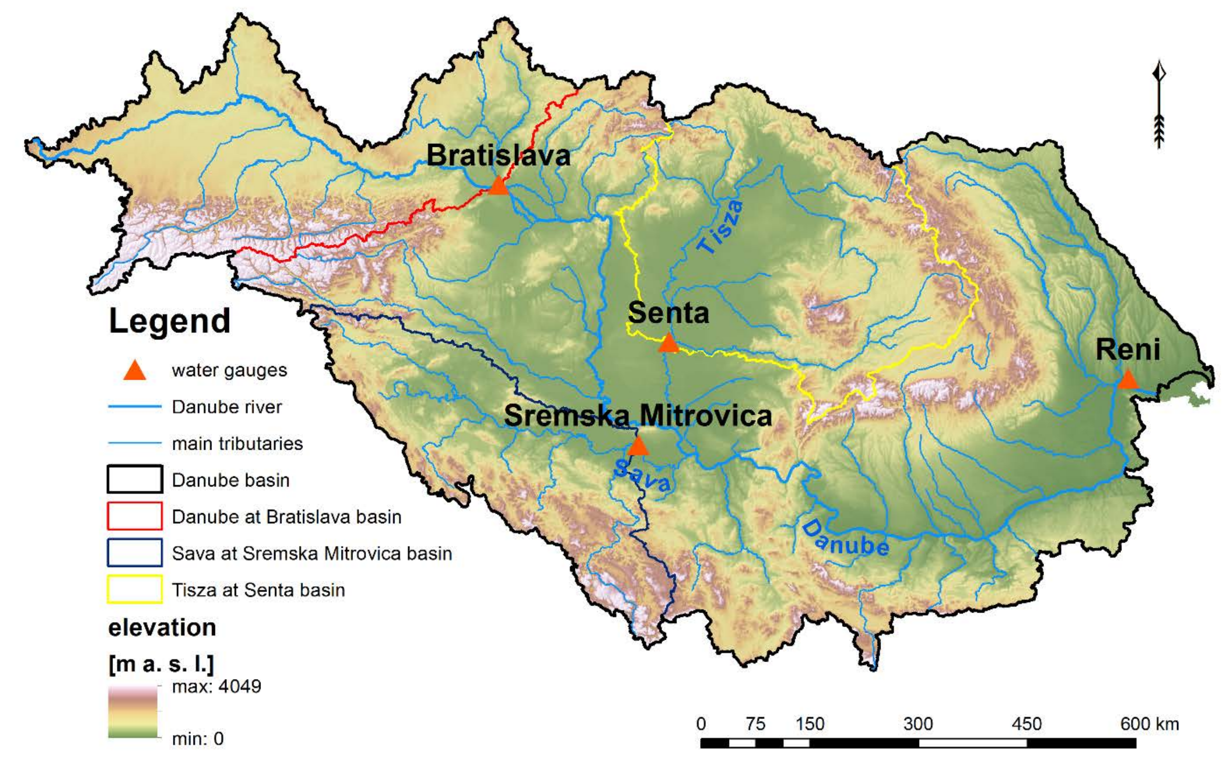


Fig. 1. Researched area of Danube River Basin and selected hydrological gauges along the Danube River

1. Long-term runoff prediction

In order to provide long-term predictions of the annual and monthly discharge series different models were developed: the harmonic models, the linear autoregressive Box-Jenkins models, the combined autoregressive models with the harmonic component and the regressive component expressing the impact of NAO.

The harmonic component of the model is identified in the form:

$$X_t = A_0 + \sum_{j=1}^{m} \left(A_j \cos(\lambda_j t) + B_j \sin(\lambda_j t) \right) + \varepsilon_t \qquad t = 1, ..., N \qquad (1)$$

Here, the parameters A_j, B_j, $j = 1,2, \dots m$ in (1) are estimated by

$$A_j = \frac{2}{N} \sum_{t=1}^{N} x_t . \cos(\lambda_j . t), \qquad (2)$$

$$B_j = \frac{2}{N} \sum_{t=1}^{N} x_t . \sin(\lambda_j . t). \qquad (3)$$

Then, a simple prediction of the stochastic process at time z can be given as

$$x_{N+z} = A_0 + \sum_{j=1}^{m} \left[A_j . \cos\left(\frac{2\pi}{T_j} (N+z) \right) + B_j . \sin\left(\frac{2\pi}{T_j} (N+z) \right) \right]. \qquad (4)$$

On the basis of (1)–(4) a model for predicting the harmonic component of the discharge time series (model PYTHIA) was developed.

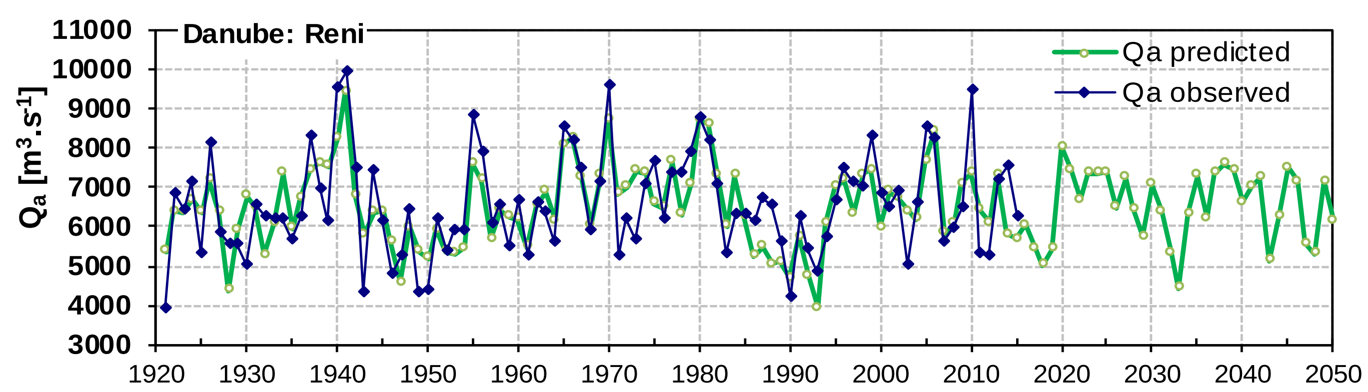


Fig. 5. Average annual discharge prediction (2016-2050) Danube: Reni - harmonic model.

On Fig. 5 long-term annual discharge prediction is presented of the Danube River at Reni station. After low flow discharge period 2015-2016, the wetter years will come . Finally, on Fig. 6 monthly discharge prediction is presented of the Danube River for 5 years ahead.

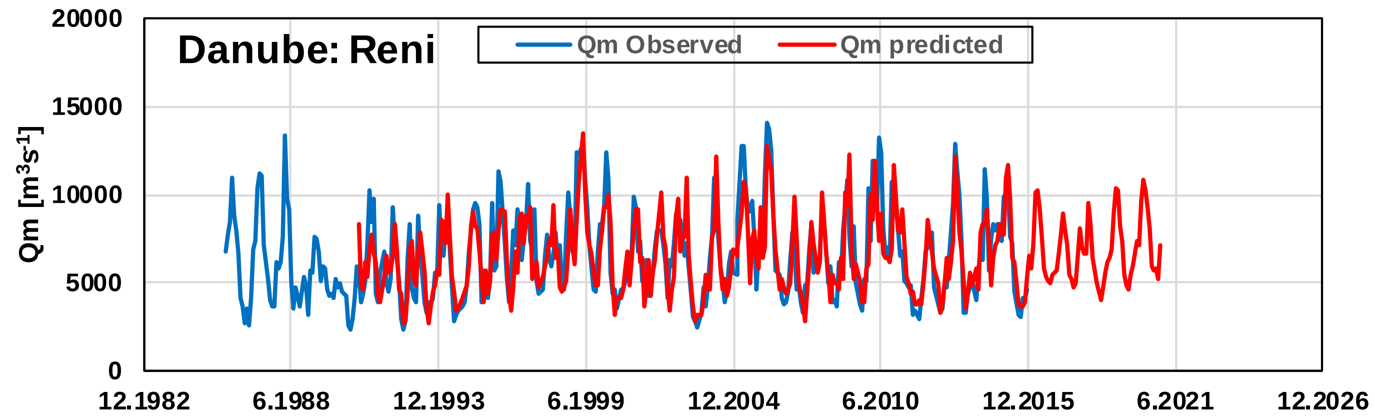


Fig. 6. Average monthly discharge prediction (2016-2020) Danube: Reni - SARIMA model.

Conclusion

The river runoff forecasting is the basic task for the proper water management of the river basins. The hydrological forecasting deals mainly with short-term forecasting of the flow rates development. Similar task is the long-term forecasting of water resources enabling the planning of water resources use in the perspective of several years or even decades.

The long-term forecast or prognosis or prediction of the discharges for several years ahead is based on statistical processing of available historical data including the study of long-term trends and impacts of the teleconnections.

The prediction of the discharges based on PYTHIA model shows that recently the analysed stations are in the low flow period and in short time of 2-3 years they will shift to high flows period where they should remain for several years.

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