HENRY
Hydraulic Engineering Repository

Ein Service der Bundesanstalt für Wasserbau

Conference Paper, Published Version

Marko, Adamovic

Possible impacts of climate change on Iron Gate I dam

Dresdner Wasserbauliche Mitteilungen

Zur Verfügung gestellt in Kooperation mit/Provided in Cooperation with:
Technische Universität Dresden, Institut für Wasserbau und technische Hydromechanik

Verfügbar unter/Available at: https://hdl.handle.net/20.500.11970/103705

Vorgeschlagene Zitierweise/Suggested citation:
Marko, Adamovic (2009): Possible impacts of climate change on Iron Gate I dam. In: Technische Universität Dresden, Institut für Wasserbau und technische Hydromechanik (Hg.): Wasserkraftnutzung im Zeichen des Klimawandels. Dresdner Wasserbauliche Mitteilungen 39. Dresden: Technische Universität Dresden, Institut für Wasserbau und technische Hydromechanik. S. 217-225.

Standardnutzungsbedingungen/Terms of Use:

Die Dokumente in HENRY stehen unter der Creative Commons Lizenz CC BY 4.0, sofern keine abweichenden Nutzungsbedingungen getroffen wurden. Damit ist sowohl die kommerzielle Nutzung als auch das Teilen, die Weiterbearbeitung und Speicherung erlaubt. Das Verwenden und das Bearbeiten stehen unter der Bedingung der Namensnennung. Im Einzelfall kann eine restriktivere Lizenz gelten; dann gelten abweichend von den obigen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Documents in HENRY are made available under the Creative Commons License CC BY 4.0, if no other license is applicable. Under CC BY 4.0 commercial use and sharing, remixing, transforming, and building upon the material of the work is permitted. In some cases a different, more restrictive license may apply; if applicable the terms of the restrictive license will be binding.

Possible impacts of climate change on Iron Gate I dam

Adamovic Marko

The research was dedicated to foreseeing the possible impacts of climate change on *Iron Gate I Dam*. Finished in 1964 on the Iron Gate gorge, on the Danube river, as a joint-venture of the Romanian/Yugoslavian governments, one of the largest hydro-plants successfully serves today to the both countries.

During the research, simulations with the IPCC scenario A1B and hydrological transformations (the method of gradual convergence) were used on calculating the Danube river flow in the near future. Also data collected with LISFLOOD driven by HIRHAM-HadAM3H/HadCM3 and IPCC scenario A2 (Dankers and Feyen, 2008), contribute considerably to the analysis of impacts of climate change on Danube river basin. Reductions of water availability, hydropower potential, summer tourism and general crop productivity are certainly appearances which are to be expected in this area as the final outcome.

Key words: IPCC scenarios A1B, A2; method of gradual convergence

1 Introduction

Iron Gate I is the largest dam on the Danube river and one of the largest hydro power plants in Europe. It is located on the Iron Gate gorge, between Romania and Serbia, in the south-eastern part of Europe. Its annual mean air temperature is 11°C and annual amount of precipitation about 700 mm. Apart from its primary relevance for the European history, economics, politics, demographics, cultural and environmental heritage, the Danube basin is very interesting from a climatic point of view because it bears at least a twofold direct relevance to the Mediterranean region. Firstly, it is the fact that Danube runoff gives a relevant contribution of freshwater flux into the Mediterranean sea, and secondly, it depends mostly on precipitated water of Mediterranean origin, because of the geographical position and the complex orography of the basin (*Speranza, 2002*). The Danube basin is in the eastern section of the considered RCM (Regional climate model).

The Danube catchment encompasses continental climate, as it is land-dominated by advection from the surrounding land areas. This part of Danube catchment is greatly affected by the Mediterranean climate on the one hand, as it is mentioned above. On the other, the Dinaric-Balkan mountain chains in the west and the Carpathian mountain bow in the north and east, present distinctive morphological and climatic regions and barriers. These mountain chains receive the highest annual precipitation (1000-3200 mm per year), while the outer basin, such as Pannonian basin and the lowlands, are very dry(350-600 mm per year).

The paper is structured as follows. In section 2, basic information about the Danube basin, the data considered in this study and the concepts behind the diagnostics tools employed in the auditing are presented. In sections 3 and 4, there will be presented and discussed the main results on the intercomparison and verification of the models, respectively regarding the yearly climatology of the precipitation, evaporation, water balance and runoff. In section 5 there will be drawn conclusions.

2 Data and methods

2.1 Notes on the Danube River Basin

The location of the study area of Danube river basin considered by certain model and scenarios are shown in Figure 1.

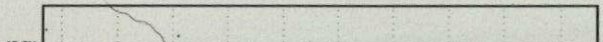

Figure 1 *Study area defined by the regional climate model* (blue points are taken into consideration)

Prior to the assessment of changes of water resources of the Danube river and their impacts on Iron Gate I dam, including the climate change effects, there was determined the terrain's spatial regionalization. Having been aware of the climatic-hydrologic and hydrographic homogeneity of regions, the whole territory of Serbia was divided into 20 units basins. The part of Danube basin in its eastern part, was subject of the research. For this balance unit, the main components of the balance equation of the water that included into the calculation are: precipitation P (mm), flow Q (m^3/s), runoff depth h (mm), evaporation E (mm) and annual air temperature T (°C). All these components were taken into the calculation for the two time frames of analyses: 1961-1990 and 2071-2100 as the mean annual values, including monthly precipitation values. In order to foresee the effects and impacts of climate change on Iron Gate I dam, certain correlation relationships were established according to the data from 1961-1990. Afterwards, it is assumed that those relationships will continue to work and be useful also for the next century, although some changes of the climatic elements (precipitation and temperature) are bound to happen. On the basis of the assessment of climate units in the XXI century and with help of the established relationships, the water flow of Danube river and runoff depth were defined for this century.

2.2 Data Sets

The following data sources, relative to the 1961-1990 time frame have been used for the purposes of this analysis:

1. Annual values of Temperature (T), Precipitation (P), Evaporation (E) from Regional Climate Model taken within the boundaries of the hydrologic homogeneous unit basin in Serbia.
2. Daily discharge of the Danube river at the near-sea Ceatal Izmail station obtained in order to get clearer picture about climate changes till the end of this century.

2.3 Notes on the Theoretical Framework

By imposing mass conservation for water, extrapolation of the hydrological parameters of the water balance equation was done in the following steps. First, using the data from the 1961-1990 of the A1B scenario, for the homogeneous region, relationships were established between runoff depth h, total precipitation and evaporation (by evaporation it is meant the total evaporation, thus including transpiration).

The first between:

- runoff depth-h
- total precipitation-P $h = P - m \cdot E$
- evaporation-E

that is: $h = \Theta \cdot P$

with the parameters: $\Theta = \frac{h}{P}$

coefficient of the runoff depth reduction – $m = 1$

The second one between:

- evaporation-E
- precipitation-P $E = a + b \cdot P + c \cdot T$
- air temperature-T

For the requirements of the extrapolation in the period of the 2071-2100, the data as are precipitation $P^{2071\text{-}2100}$ and air temperature $T^{2071\text{-}2100}$ were used, and implemented in the next equation in order to get conditional evaporation for the same period.

$$E^{2071-2100} = a + b \cdot P^{2071-2100} + c \cdot T^{2071-2100}$$

The first approximation of the runoff depth for the 2071. is shown in the next equation:

$$h^{2071} = \Theta \cdot P^{2071}$$

The reduction coefficient:

$$m^{2071} = P^{2071} - h^{2071}$$

If this condition is not fulfilled, the correction of the conditional h^{2071}, i. e. E^{2071} is performed by the method of the gradual convergence (approximation) until such values are obtained which must satisfy the balance equation:

$$h^{2071} = P^{2071} - E^{2071}$$

3 Results

The considered data sets are analyzed in terms of their representation of the hydrological balance over the Danube basin in its eastern part where the Iron Gate is located, by focusing on the long-term mean, on the interannual variability. For this impact model, by suitable averaging over the calendar years, the yearly time series of the accumulated basin integrated fields (*P*, *T*, *E*) were defined as the outset. The results show that in the last quarter of this century we can expect the deficit in all those fields mentioned above and, as its worst consequence, the decrease of the Danube river flow in this area. The hydrographs for each time frame (1961-1990 and 2071-2010) according to the scenario A12 and the correlations between them are shown in following figures (Figure 2, 3, 4). The analysis of the simulations driven by the HIRHAM-HadAM3H/HadCM3 and IPCC scenario A2 (Dankers and Feyen, 2008) at the Ceatal Izmail station, also show that the Danube river flow and its hydrological catchment balance will face a lot of changes (Figure 5).

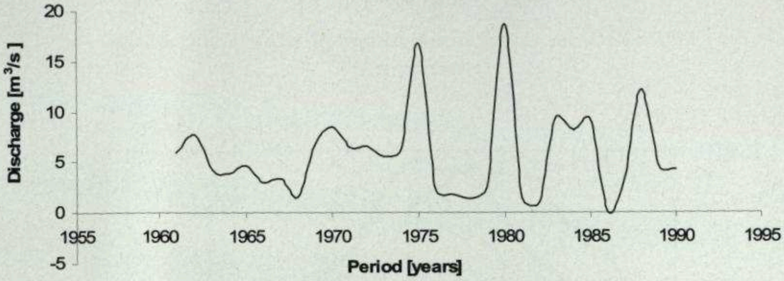

Figure 2. Danube Discharge Hydrograph according to the A1B scenario (1961-1990)

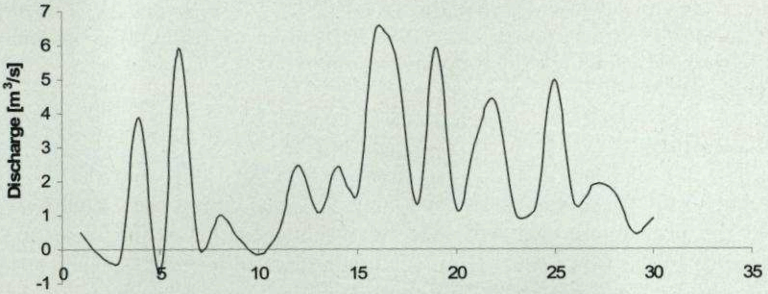

Figure 3. Danube Discharge Hydrograph according to the A1B scenario (2071-2100)

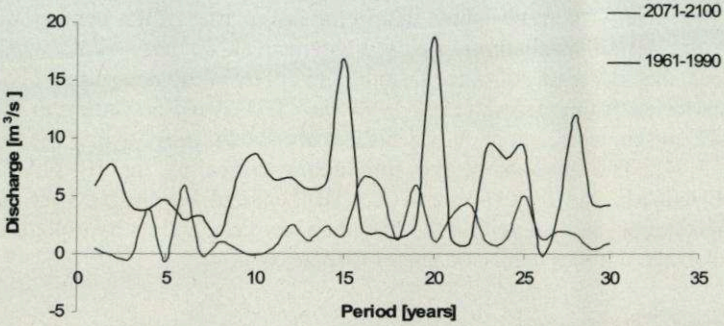

Figure 4. Cross-correlation Hydrograph of the Danube discharge

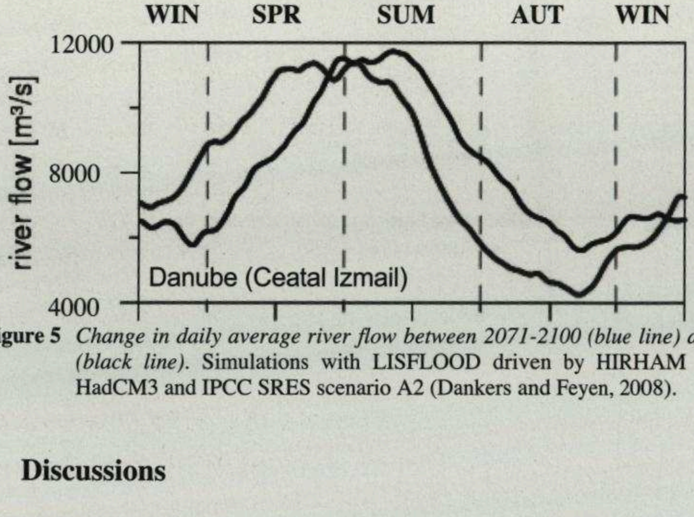

Figure 5 *Change in daily average river flow between 2071-2100 (blue line) and 1961-1990 (black line).* Simulations with LISFLOOD driven by HIRHAM - HadAM3H/ HadCM3 and IPCC SRES scenario A2 (Dankers and Feyen, 2008).

4 Discussions

According to all these results, by analyzing and calculating the Danube river flow in the near future, we will face many changes that will have a great consequence to the Iron Gate I dam, accumulation and its ecosystems. During the summer and autumn there will be much less water in the river bed. Furthermore, if we take into account predictions made by IPCC which say that the south-east Europe will face temperature growth of 0.2 degrees in the next two decades for the range of SRES scenarios, it makes the whole problem much more complicated and alarming.

Precipitations peak in the early summer months and in November, which gives more often a secondary maximum, is the typical feature of the observed climatalogy of the precipitation of the Danubian region. The minima of precipitation are also clustered in two periods of the year, namely February and the summer months. The latter minimum is a signature of the influence of the typical Mediterranean summer (Figure 6.).

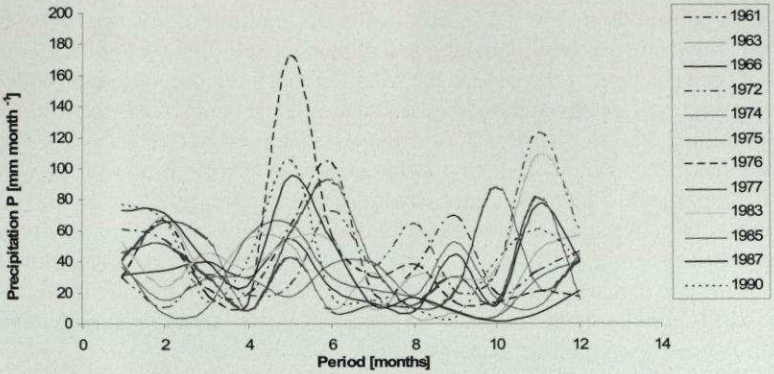

Figure 6. Monthly long-term accumulated precipitation over the study area of the Danube catchment

As a result of all that, as has been mentioned above, this part of Europe will face with worse conditions (high temperatures, droughts) in a region already vulnerable to climate variability, than those of 2003 when Europe was hit by an incredible heat wave. But the story does not end here. Reductions of water availability, hydropower potential, summer tourism and general crop productivity are certainly appearances which we can expect in this area with a stress on the following problems:

- Reduced flow which will have consequent decreases in power generation;
- Lower Danube flow which reduces water supply, water quality and recreation activities in the upstream part of the river;
- Lower water tables will cause some shallow wells to go dry up;
- Warmer river temperatures will have an effect on cold-water species, such as trout, and directly will affect biodiversity; and
- Increased demand for irrigation and a change in crop types due to a longer growing season.

5 Conclusions

This paper has intercompared and verified certain RCM in its representation of the hydrological balance over the Danube river basin along Iron Gate gorge, for the time frame 1961-1990 and 2071-2100 according to the IPCC SRES scenario A1B. For matters of completeness, it has also considered the outputs of the HIRHAM - HadAM3H/ HadCM3 and IPCC SRES scenario A2. The Danube has been chosen as a case study because of its multiple relevance for socio-economical, as well as environmental and climatic level. This part of the Danube river basin has a direct relevance to the Mediterranean region, since it provides a relevant input of freshwater to the sea, as well as being fuelled mostly by precipitations due to the water of Mediterranean origin. The hydrological balance has been computed in two different, but in principle equivalent ways. The first approach, which has a more hydrological nuance, relies on establishing relationships between annual averages of the hydrological balance parameters (E, P, T) in order to get relevant coefficients. The second approach, which is more typically meteorological, relies on the calculation of the E for the time frame 2071-2100 by using the previous coefficients and getting runoff depth (h) and discharge (Q) as the final outputs.

The results are very troublesome since according to these simulation the discharge in this part of the Danube basin will decrease over 50 % with a great consequences to the Iron Gate I dam and its accumulation.

So on, when talking about climate change, a question always arise: Should we adapt to the climate change, or should we mitigate it? Maybe the answer is in mitigation while doing adaptation. According to the Danube River and the dam Iron Gate I, the works for fighting reservoir related bank erosion in order to preserve the dam and accumulation have already been started. Also protection of the natural resources and the ecosystem, which urged the performance actions of restoration of nature and reintegration of temporarily occupied lands and landscape improvement (like maintenance of verdure spots), started to happen. Pushing and raising the problem of climate change to the surface, what should be reality and the global prime issue, is a way to get community involved in order to preserve its existence.

Acknowledgments. I wish to thank S. Prohaska for the generous help in hydrological calculations and V. Djurdjevic for providing me with the necessary modeling data inputs.

References

Brunetti, M., M. Maugeri, T. Nanni, I. Auer, R. Böhm, and W. Schöner, (2006): Precipitation variability and changes in the greater Alpine region over the 1800–2003 period, *J. Geophys. Res.*, 111, D11107, doi:10.1029/2005JD006674

Dankers, R., and L. Feyen, (2008): Climate change impact on flood hazard in Europe: An assessment based on high-resolution climate simulations, *J. Geophys. Res.*, 113, D19105, doi:10.1029/2007JD009719

Filipovic B., Krunic O., Lazic M., (2005), Regionalna Hidrogeologija Srbije, Faculty of Mining and Geology, Belgrade, pp. 14-17

Lucarini V., R. Danihlik, I. Kriegerova, and A. Speranza, (2007): Does the Danube exist? Versions of reality given by various regional climate models and climatological datasets, Journal of Geophysical Research, 112, D13103, doi: 10.1029/2006JD008360

Prohaska S., Ristic V., (2002): Hidrologija kroz teoriju i praksu, Faculty of Mining and Geology, Belgrade, pp. 157-161

Speranza A., (2002): The hydrological cycle of the Mediterranean Basin, Proceedings of the Interreg IIC Conference Drought-Monitoring, Mitigation, Effects, Villasimius (Cagliari), 21-23 September 2000, Eds G. Monacelli and E. Giusta., pp. 103-106.

Author:

Undergraduate student, Mr. Adamovic Marko
Department of Hydrogeology, Faculty of Mining and Geology,
University of Belgrade,
Bulevar Zorana Djindjica 127, Belgrade, Serbia
+381-64-614-85-39
damdamrgf@yahoo.com