SCENARIOS FOR NATURAL DEVELOPMENT OF THE HYDROLOGICAL PROCESSES IN BULGARIA CONSIDERING ANTHROPOGENEOUS IMPACT

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***Abstract*:** In the previous studies of the research team the multi-annual variations of precipitation, air temperature and river runoff in Bulgaria were analysed. The investigation was made for the whole territory of the country. The parameters of the drought period (1982-1994) were taken into consideration in time of analysis. The main objective of this paper is to make an accurate evaluation of the water resources in Bulgaria. The basic element of this investigation is the quantitative aspect due to its strong natural relations to the climatic conditions.

In the research double-mass curves of the number of Wolf and global air temperature anomalies on the Northern hemisphere are executed. Using this basis five different periods were obtained in which the linear approximation of the gradients can be obtained. Number of scenarios is presented with different levels of solar activity, using available information database for the solar activity since XVII century. For the different scenarios, the comments are made. As a result of this investigation, the choice for the most probable scenario was made.
***Keywords*:** anthropogeneous impact, empirical relationships, solar activity, scenarios, natural development, river runoff.

SZENARIOS FÜR DIE NATÜRLICHE ENTWICKLUNG DER HYDROLOGISCHEN VORGÄNGE IN BULGARIEN BEI BETRACHTUNG DER ANTROPOGENISCHEN EINWIRKUNG

***Zusammenfassung*:** In den vorhergehenden Studien des Arbeitsteams wurden die jährlichen Variationen des Niederschlags, der Lufttemperatur und des Flußabflusses in Bulgarien analysiert. Die Untersuchung handelte sich für das ganze Territorium des Landes. Bei der Behandlung wurden die Parameter von der Dürre-Periode 1982–1994 berücksichtigt. Das Hauptziel dieser Studie ist eine genauere Einschätzung der Wasserresoursen des Landes gemacht zu werden. Die Hauptgrundlage dieser Untersuchung ist eine quantitive Betrachtung der Klimabedingungen.

Bei der Untersuchung wurden “double-mass curves” von der Wolfzahl und der Temperaturanomalien für die Nordhalbkugel weitverwendet. Auf diesem Grund wurden 5 verschiedenen Perioden mit verschiedenen Gefällen ihrer Linearaproximation bestimmt. Die Zahl der Szenarios ist durch verschiedene Niveau der Sonnenaktivität bestimmt. Dafür wurden die zugänglichen Daten seit dem 18. Jahrhundert benutzt.

Für die verschiedenen Szenarios werden entschprechende Komentarien gemacht. Als ein Ergebnis von dieser Untersuchung wurde amwahrscheinlichste Szenario gewählt.
***Schlüßelwörter*:** Antropogenische Einwirkung, Empirische Beziehungen, Sonnenaktivität, Szenario, natürliche Entwicklung, Flußabfluss.

Introduction

The reports of the Intergovernmental Panel on Climate Change (IPCC report, 1996 and 1994) were taken into consideration. On the basis of scientific researches for influence of solar activity into climate, two main groups of scenarios for climate change influence were elaborated. The first group includes scenarios for tendencies and analogies to the natural development,

which is the subject of investigation presented in another paper for this Conference – “Scenarios For Natural Development Of The River Runoff In Bulgaria” from the same research team. The scenarios are in the next gradation: neutral - basic model for comparison; weakly pessimistic - with the trend values for river runoff (*Q*) and precipitation (*P*) in the middle of the present century; medium pessimistic - using the trend values for river runoff and precipitation in the end of the new century (2100); pessimistic - using the values of *Q* and *P* for the period of deepest depression 1982-1994; strong pessimistic - using the trend values for 2050 plus absolute deviations from the deepest depression with trend values in the middle of depression period (1988), and the strongest pessimistic scenario - using the trend values in 2100 plus absolute deviations from the deepest depression (1982-1994) with trend values in the middle of depression period, 1988. For orientation concerning the possibility of appearance for the analysed scenarios, the approximate probabilistic estimations for the discharge, precipitation as and average values for different time intervals are presented (Gerassimov et al., 2001a).

The second group presents scenarios with consideration of natural and anthropogeneous factors using the empirical relationships. This group of scenarios is the topic of this presentation. In these scenarios the double mass curves analysis for number of Wolf (Waldmeick, 1961; Trends'93, 1994) and global temperature anomalies of the North hemisphere were executed, and five periods with linear approximation using constant gradients were obtained. Four scenarios of the Intergovernmental Panel on Climate Change with fixed concentration of CO_2 are examined (Gerassimov et al, 2001b). The scenarios in this group are based on the average level of solar activity for

- XX century;
- XIX century;
- Trend estimation from 1700 to 2000, and
- Trend estimation for the last two centuries.

Scenarios with consideration of natural and anthropogeneous factors

The mathematical examination of the double-mass curves analysis was widely used. This apparatus for the number of Wolf (Waldmeick, 1961; Foukal, 1990) $X_i = \sum_1^i W_i$ and global temperature anomalies (in ^0C) of the Northern hemisphere (Lean, 1988) ΔT - $y = \sum_1^i (\Delta T + 1).100$ was applied. On its basis five periods with linear approximation applying constant gradients $G_{j,k} = \sum_j^k y_i / \sum_j^k X_i$ were estimated. These five periods are presented in Table 1.

Table 1. Periods with constant gradients

Periods	n	$\overline{W}$	C	G
1854-1877	24	49,8	288	1,367
1878-1937	60	38,6	296	1,928
1938-1947	10	65,0	308	1,663
1948-1960	13	100,8	318	1,141
1961-1995	35	71,9	338	1,501

The number of the years in the different periods is from ten to sixty. Respectively, the value of the solar activity is between 38,6 up to 108,8. The values of the gradients are in the range from 1,141 to 1,928.

On the basis of the points, the empirical relationship is estimated:

$$G = \frac{a}{W^{\alpha}} + b.(C - 200) \quad (1)$$

where C is the concentration of CO_2 in ppm;

a, b, α are empirical constants.

Furthermore, after estimation of the empirical constants and with application of $\Delta T = f(G)$ with weighting factor of the errors one can receive the next relationship:

$$\Delta T = \frac{1{,}086}{W^{0,15}} + 7{,}052.10^{-5}.W.(C - 200) - 1{,}175\,. \quad (2)$$

Using the trend linear estimations between the precipitation (*mm*) over the Great Britain ($P_{GB} = 0{,}2098.x + 904$) and global temperature anomalies ($\Delta T = 0{,}0055.x - 0{,}317$) is obtained:

$$P_{GB} = 38{,}2.\Delta T + 918{,}1\,. \quad (3)$$

On the basis of the trend linear estimations between air temperatures (^0C), precipitation (*mm*) on Bulgaria with global temperature anomalies and precipitation over Great Britain the following relationships are received:

$$T_{BG} = 0{,}8727.\Delta T + 7{,}66\,, \quad (4)$$

$$P_{BG} = 2045{,}53 - 1{,}437.P_{GB}\,. \quad (5)$$

The average discharge layer (*mm*) for Bulgaria is estimated in the same manner with equation:

$$h_{BG} = 0{,}981.P_{BG} - 517{,}7\,. \quad (6)$$

In the present research, four different scenarios of the Intergovernmental Panel of Climate Change IPCC (A, B, C, C and D) with concentration of CO_2 in 2100 are as follow (see Table 2 for more comprehensive summary):

Table 2. Scenarios with different concentration of CO_2

Scenarios	$C_{CO_2}(ppm)$
I-A)	820
II-B)	560
III-C)	490
IV-C and D)	430

In this study everyone from these scenarios will be combined with different level of solar activity – such as $\overline{W} = 63{,}2; 38{,}8; 78\ and\ 91$. These different scenarios are presented in the following part of this paper.

Scenarios with average level of solar activity of XX century with $\overline{W} = 63{,}2$

Using the equations given above, the received results for chosen scenarios are presented in Table 3. The group of scenarios is with average level of solar activity $\overline{W} = 63{,}2$ **.**

Table 3. Scenarios with $\overline{W} = 63{,}2$

Scenarios	$^{*}C_{CO_2}$	ΔT	P_{GB}	δ_p	T_{BG}	P_{BG}	δ_p	h_{BG}	δ_h
	(ppm)	(^0C)	(mm)	$(\%)$	(^0C)	(mm)	$(\%)$	(mm)	$(\%)$
A	820	2,17	1001	8,6	9,55	607	-15,8	77,9	-58,9
B	560	1,01	957	3,8	8,54	670	-7,0	139,9	-26,2
C	490	0,70	945	2,5	8,27	688	-4,6	156,8	-17,3
CD	430	0,43	933	1,4	8,04	702	-2,6	170,9	-9,8

Legend:

$^{*}C_{CO_2}$, ppm is the concentration of CO_2;

$\Delta T(^0C)$ are global temperature anomalies for Northern hemisphere;

$T_{BG}(^0C)$ is air temperature over Bulgaria;

$P_{GB}, P_{BG}, (mm)$ are the precipitation sums over Great Britain and Bulgaria respectively;

$h_{BG}(mm)$ is discharge layer over Bulgaria;

$\delta_P(\%)$ is relative deviation for the precipitation;

$\delta_h(\%)$ is relative deviation for the discharge layer.

The basic values for comparison are in fact the trend values in the middle period 1961-1990. The values are presented in Table 4.

Table 4. Basic values for comparison

Parameters	Values
$\Delta T^0(^0C)$	0,10
$P^0{}_{GB}(mm)$	921,8
$T^0{}_{BG}(^0C)$	8,39
$P^0{}_{BG}(mm)$	720,9
$h^0{}_{BG}(mm)$	189,5

Comment. This scenario with extremely high concentration of green house gases has catastrophic influence over the water resources of Bulgaria and is almost impossible to expect. The scenario B is an average scenario and is possible to appear. The scenarios C and CD with the most probable increase of the concentration of CO_2 - they show possible decrease of the precipitation and river runoff even with the lower temperatures compared with the basis values.

Scenarios with decreased level of solar activity - average for XIX century $\overline{W} = 38{,}8$

In the Table 5 the four created scenarios are presented. They are for the case of decreased level of solar activity - $\overline{W} = 38{,}8$ using average results for XIX century.

Table 5. Scenarios with $\overline{W} = 38{,}8$

Scenarios	$*C_{CO_2}$	ΔT	P_{GB}	δ_p	T_{BG}	P_{BG}	δ_p	h_{BG}	δ_h
	(ppm)	(^0C)	(mm)	$(\%)$	(^0C)	(mm)	$(\%)$	(mm)	$(\%)$
A	820	1,15	962	4,4	8,66	663	-8,0	133	-29,9
B	560	0,44	935	1,4	8,04	702	-2,6	171	-9,8
C	490	0,25	928	0,7	7,88	712	-1,6	181	-4,5
CD	430	0,08	921	-0,1	7,73	722	0,2	191	0,8

Comment. These are optimistic scenarios in direction of solar activity. In them the air temperatures over Bulgaria are lower then the basis values excluding scenario A. The last scenario CD is with increase in precipitation and river runoff even in context of increasing concentration of CO_2. Only in these optimistic scenarios for case of CD we can expect increase in precipitation $\delta_p = 0{,}2\%$ and discharge $\delta_h = 0{,}8\%$.

Scenarios with increased level of solar activity using trend for 1700 - 2000 $\overline{W} = 78$

In the Table 6 the four scenarios are presented. They are for the case of increased level of solar activity - $\overline{W} = 78$ using trend estimations for 1700-2000.

Table 6. Scenarios with $\overline{W} = 78$

Scenarios	$*C_{CO_2}$	ΔT	P_{GB}	δ_p	T_{BG}	P_{BG}	δ_p	h_{BG}	δ_h
	(ppm)	(^0C)	(mm)	$(\%)$	(^0C)	(mm)	$(\%)$	(mm)	$(\%)$
A	820	2,42	1011	9,7	9,77	593	-17,2	64,0	-66,2
B	560	1,19	963	4,5	8,70	662	-8,2	132	-30,3
C	490	0,85	951	3,2	8,40	679	-5,8	148	-21,9
CD	430	0,57	940	2,0	8,16	695	-3,6	164	-13,5

Comment. The presented scenarios are pessimistic scenarios for precipitation and discharge for Bulgaria, especially scenario A. The scenario A has no analogy in the natural development of hydrological processes up to now.

Scenarios with increased level of solar activity using trend from the last two centuries - $\overline{W} = 91$**, the strongest pessimistic (black) scenarios**

In the Table 7 the discussed scenarios are explained. These scenarios are characterised with increased level of solar activity $\overline{W} = 91$. Here we received the strongest pessimistic (black) scenarios. In this group the trend estimation for the last two centuries were applied.

Comment. The scenarios A with 13,5 % increase of precipitation over Great Britain is drastically for water resources of Bulgaria – 93 % decrease of the river runoff and – 24,8 % of precipitation. These scenarios with increased level of solar activity are the strongest pessimistic (black) scenarios for water resources in Bulgaria.

Table 7. Scenarios with $\overline{W} = 91$

Scenarios	$*C_{CO_2}$	ΔT	P_{GB}	δ_p	T_{BG}	P_{BG}	δ_p	h_{BG}	δ_h
	(ppm)	(^0C)	(mm)	$(\%)$	(^0C)	(mm)	$(\%)$	(mm)	$(\%)$
A	820	3,36	1046	13,5	10,59	542	-24,8	14	-93
B	560	1,69	983	6,6	9,13	633	-12,2	103	-45,6
C	490	1,24	965	4,7	8,74	659	-8,6	129	-31,9
CD	430	0,86	951	3,2	8,41	679	-5,8	148	-21,9

Drawing a general conclusion for most possible scenarios for Bulgaria

From the presented four scenarios for different concentrations of CO_2 we can exclude the extreme scenario A. The other three scenarios we can accept as equally probable. We need to take into consideration one scenario CD with the lowest values of CO_2 concentration and solar activities giving slight increase of the precipitation and river discharge (+ 0,2 and + 0,8 %, respectively).

If we combine the present research and the study of "Scenarios for natural development of the river runoff in Bulgaria" we can receive wide range of nine possible scenarios for Bulgaria. The first group are scenarios for tendencies and analogies to the natural development. The second group includes scenarios with consideration of natural and anthropogeneous factors with application of empirical relationships. So, we can conclude that from nine scenarios only CD has slight increase in precipitation and river runoff. The other eight scenarios show low values of these parameters.

Furthermore, we have probability of 89 % for decrease in the precipitation and discharge over Bulgaria, so there are no reasons for optimistic expectations. The most possible for the near future development is the model 1 (from "Scenarios for natural development of the river runoff in Bulgaria") - weakly pessimistic scenario, using the trend values for river runoff and precipitation in the middle of new century (2050). This scenario has the biggest frequency and probability of occurrence in the context of normal distribution of the frequencies. This is a medium pessimistic estimation, and it can be proposed for future hydro-technical design, constriction works and utilization of the water resources.

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