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9 to 20 May 2005

Water resources in Bulgaria during the 1982 - 1994 drought period - quantitative investigations

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Water Resources in Bulgaria during the 1982-1994 drought period - quantitative investigations

Presented by: Dr. Elena Kirilova Bojilova

Water Resources in Bulgaria during the 1982-1994 drought period - quantitative investigations

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Content of the study

- Information data base
- Analysis of the multi-annual variations
- Definition of the 1982-1994 drought period
- Comparative and probabilistic estimations
- Basic results
- Scenarios for climate change influence
- Recommendations
- Acknowledgement


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Danube
Black
Sea
SERBIA &
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Adriatic
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SOFIA
SKOPJE
Maritsa
TIRANË
F.Y.R.O.
MACEDONIA
İstanbul
Vardar
Tyrrhenian
Sea
ALBANIA
GREECE
Aegean
Sea
TURKEY
Ionian
Sea
ATHENS
125
km
mi
Mediterranean Sea

Information data base

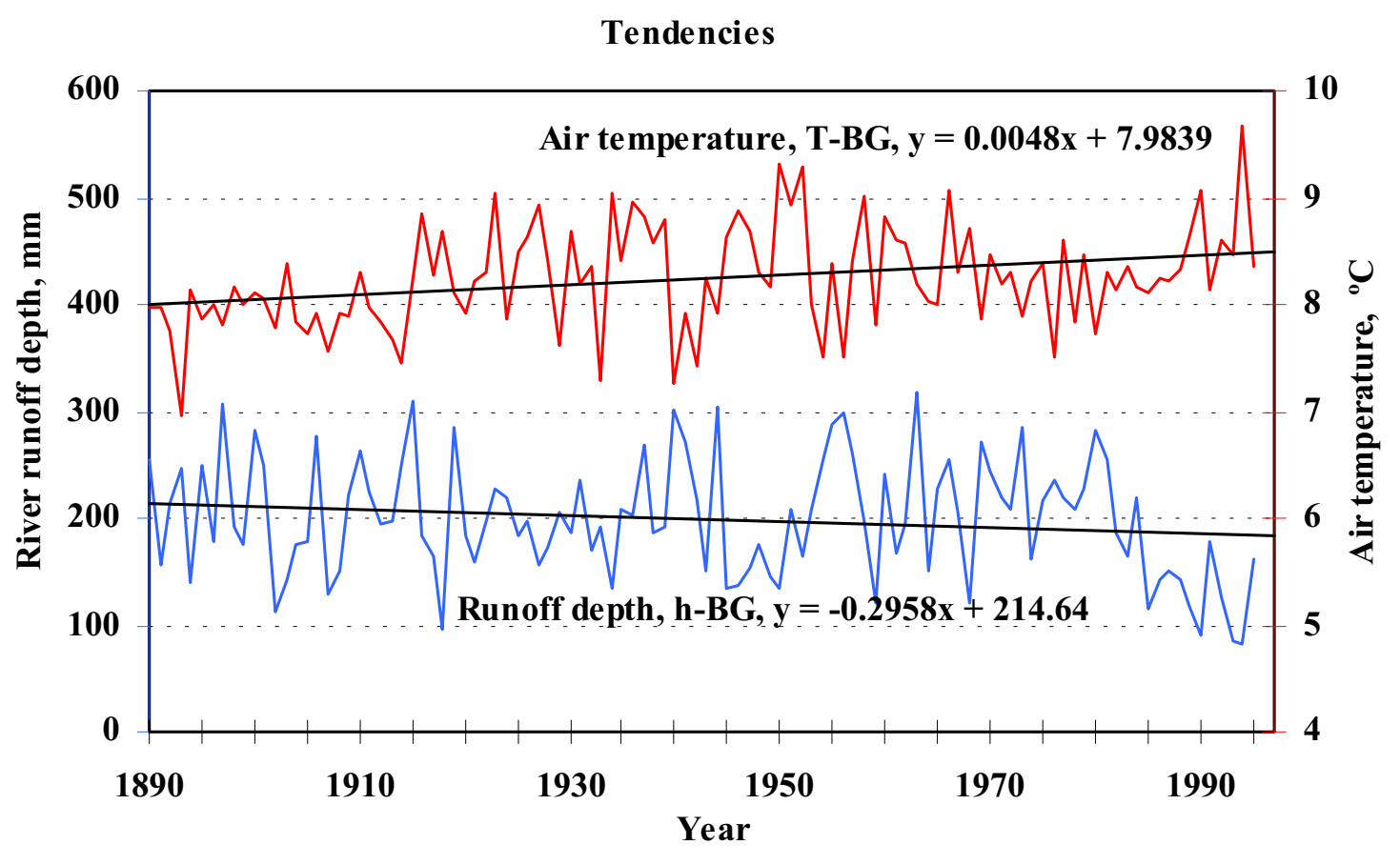
- A full investigation of the total annual runoff for 1960-1996 period was made (44 hydro-meteorological stations).
- Long data series for 16 hydrometeorological stations for whole territory of Bulgaria were obtained. The series were extended using correlative relationships back up to 1890.
- Data series for precipitation (300 stations) and air temperature (169 stations) for the hole territory of Bulgaria were used.

Extended Data Series		
Drainage basin	Hydrometeorological stations	Since year
Danube	Ogosta river near Misia town	1914
	Vit river near Teteven town	1922
	Rosiza river near Sevlievo town	1922
	Iantra river near Cholakovzy village	1922
	Rusenski Lom river near Bojichen village	1922
Black Sea	Provadia river near Sindel	1922
	Kamchia river near Grozdevo village	1922
	Veleka river Zvezdech (no extension)	1937
Aegean	Struma river near Rajdavyza	1919
	Sovolanska Bustriza, Sovolano village	1919
	Struma river near Marino-pole village	1919
	Topolniza river near Poibrene village	1914
	Maritza river near Plovdiv town	1909
	Striama river near Bania village	1914
	Chepelarska river near Bachkovo village	1909
	Maritza river near Harmanli town	1909

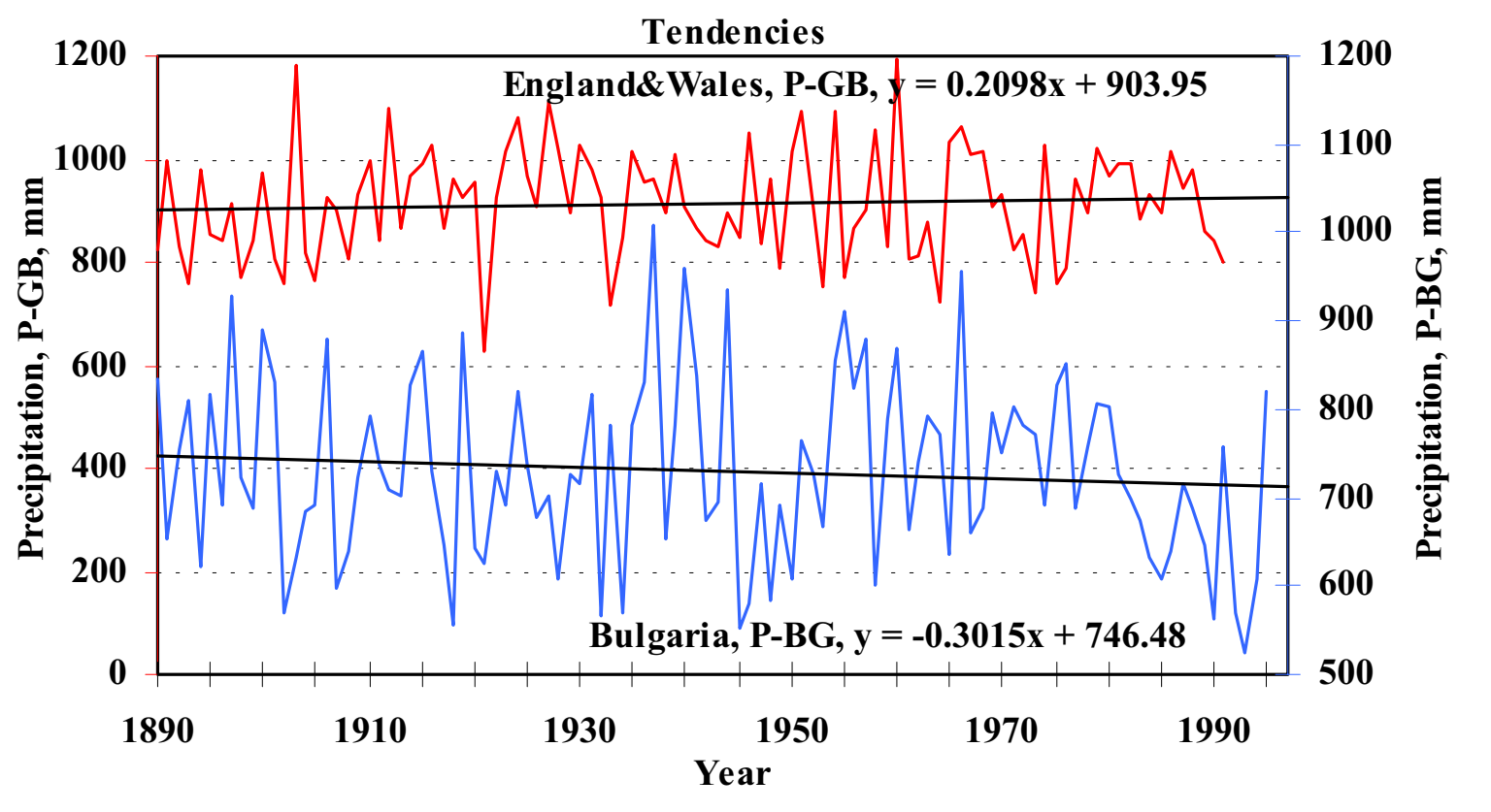
Analysis of the multi-annual variations

- *The aims* of the analysis are to estimate the 1982-1994 drought period and to investigate the water resources in Bulgaria.
- The objective of the analysis of the chronological variations of the river runoff and the elements of the water balance – precipitation and evaporation, is to obtain the tendency and some possible changes in the future under different scenarios for global climate change.
- *Data* for 10 full solar cycles, precipitation over England & Wales and temperature anomalies in the Northern hemisphere were used.

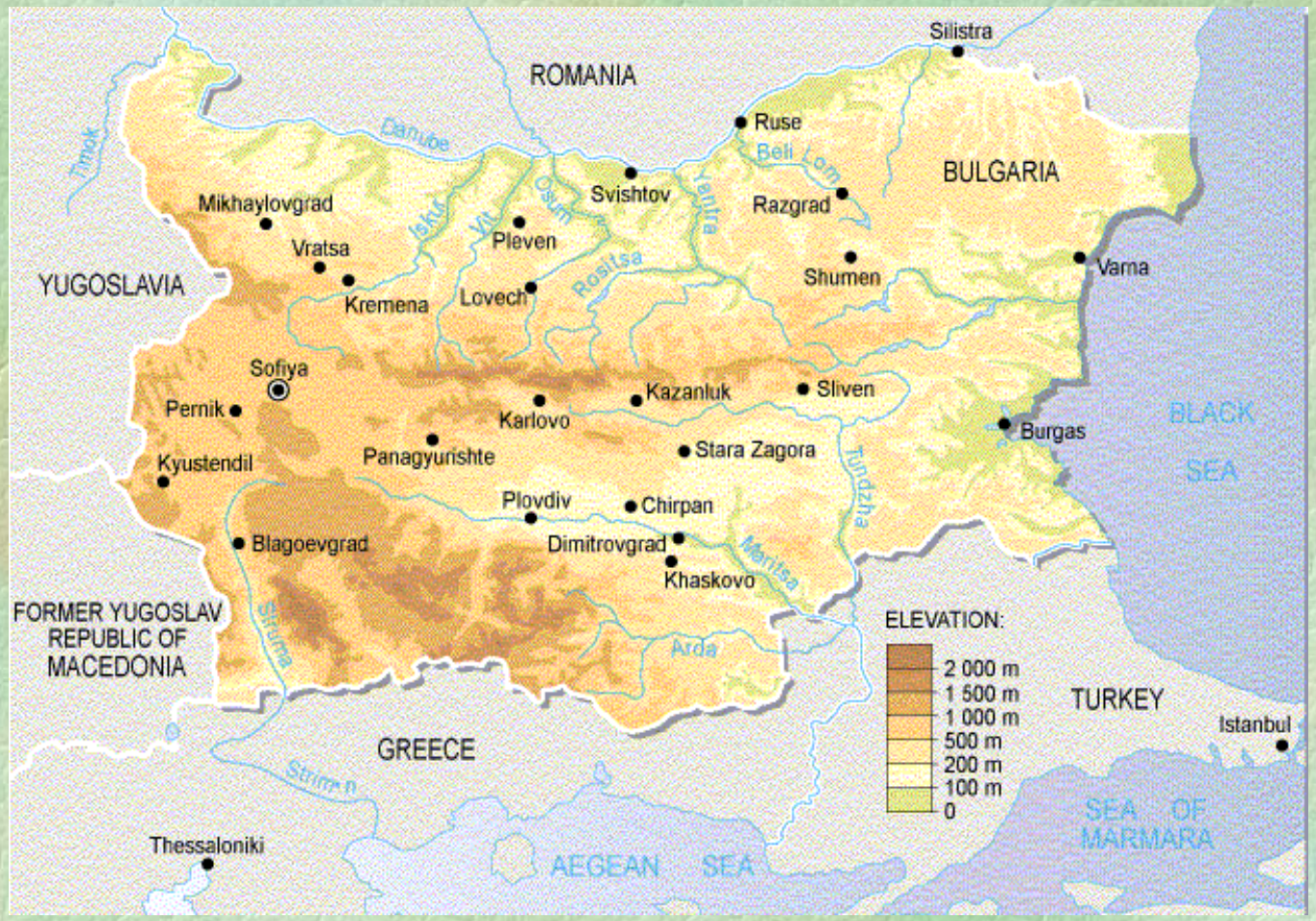
Chronological graphs of annual values for air temperature and river runoff depth for Bulgaria and respective linear trend lines.



Chronological graphs of annual values for precipitation sums over Bulgaria and England&Wales and respective linear trend lines.



- The water regime in Bulgaria is described over the three main units in relation to climate, hydrographical conditions and natural variations :
  - Danube hydrological zone;
  - Black Sea hydrological zone;
  - Aegean hydrological zone.
- The river runoff is assessed as a total runoff of all river estuaries or a country boundaries of Bulgaria for minimum temporal interval of one calendar year.


ROMANIA
Silistra
Ruse
Danube
Beli Lom
BULGARIA
Svishtov
Razgrad
Mikhaylovgrad
Iskur
Vit
Osum
Pleven
Yantra
Vratsa
Rositsa
Shumen
Varna
YUGOSLAVIA
Kremena
Lovech
Sofiya
Kazanluk
Sliven
Pernik
Karlovo
BLACK
SEA
Burgas
Kyustendil
Panagyurishte
Stara Zagora
Tundzha
Plovdiv
Chirpan
Blagoevgrad
Dimitrovgrad
Maritsa
Khaskovo
FORMER YUGOSLAV
REPUBLIC OF
MACEDONIA
Struma
ELEVATION:
2 000 m
1 500 m
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500 m
200 m
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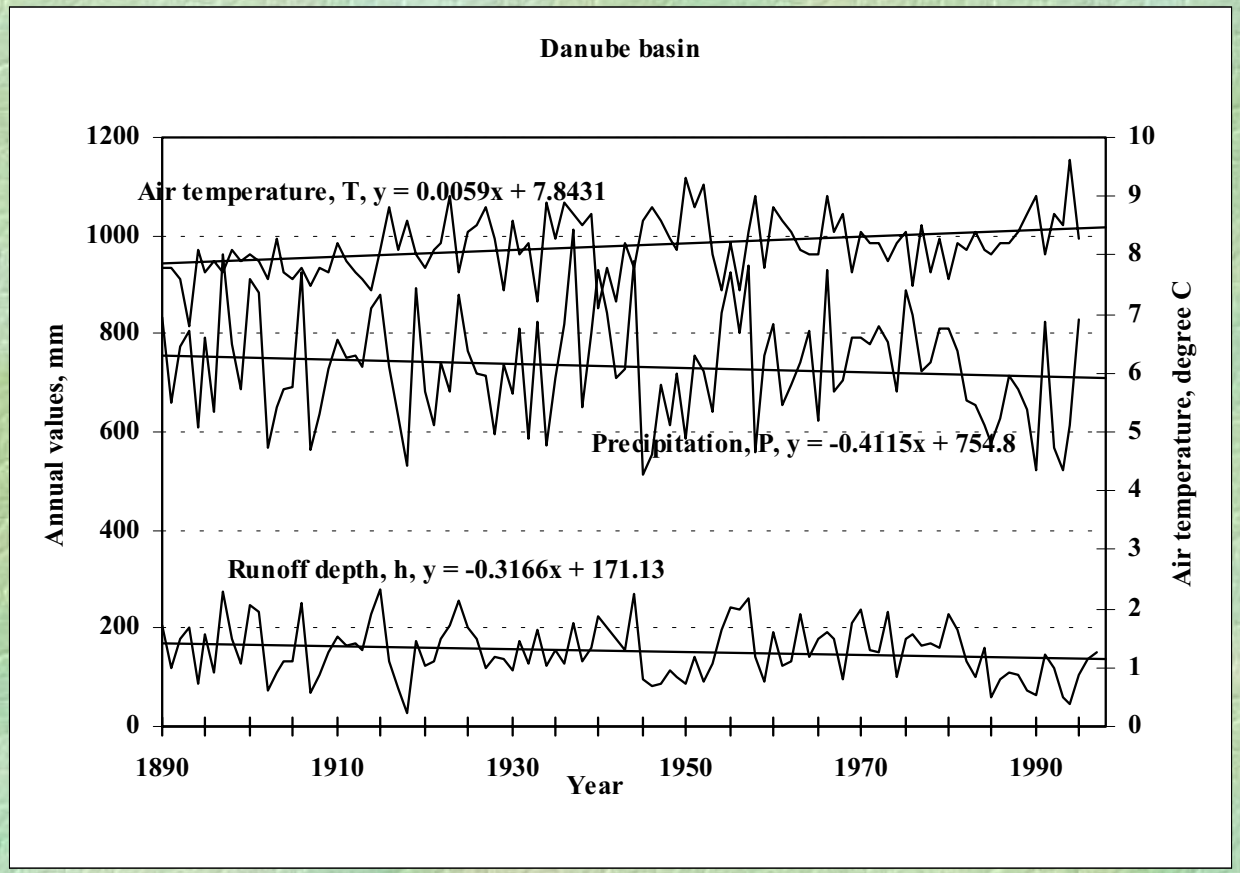
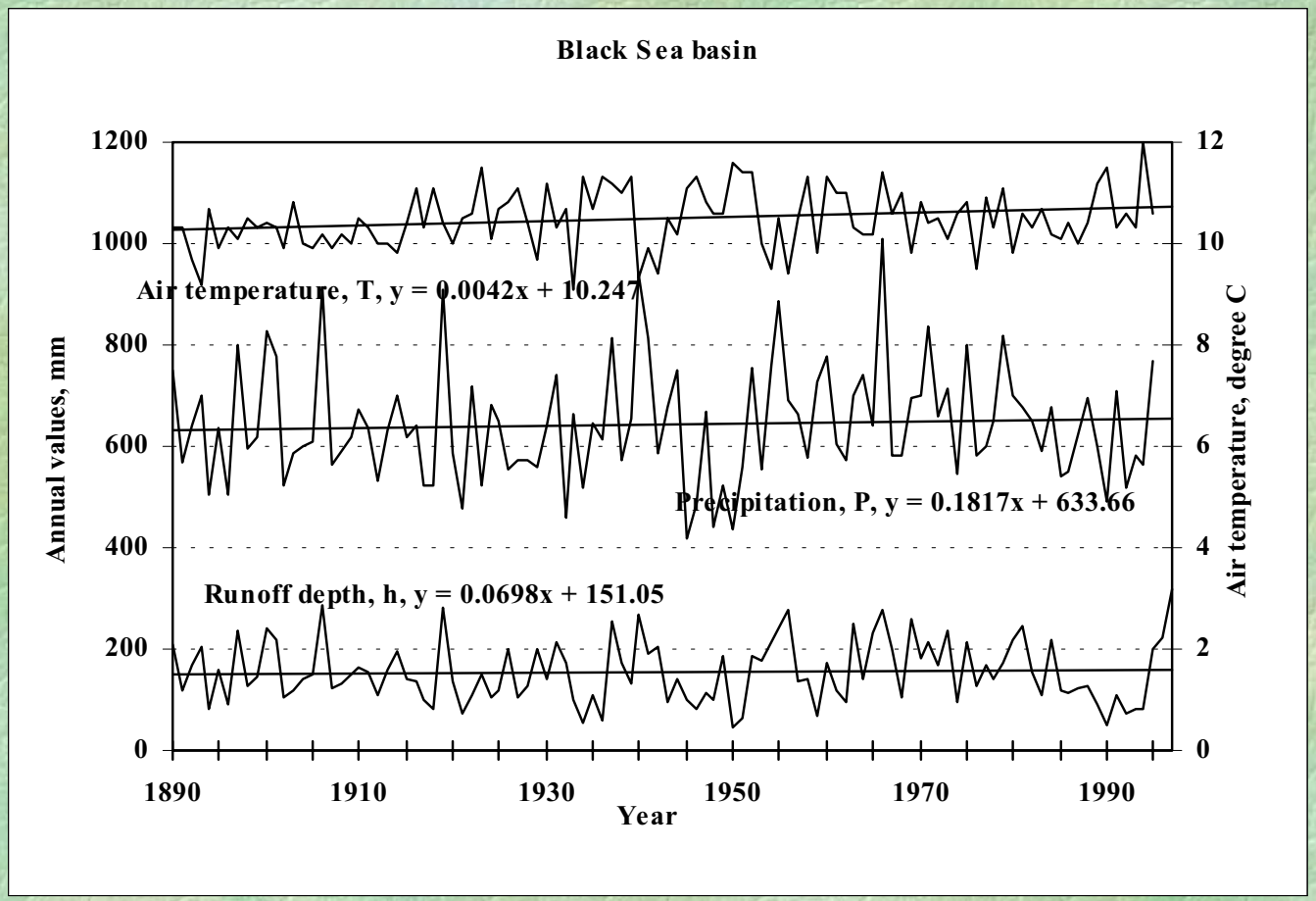
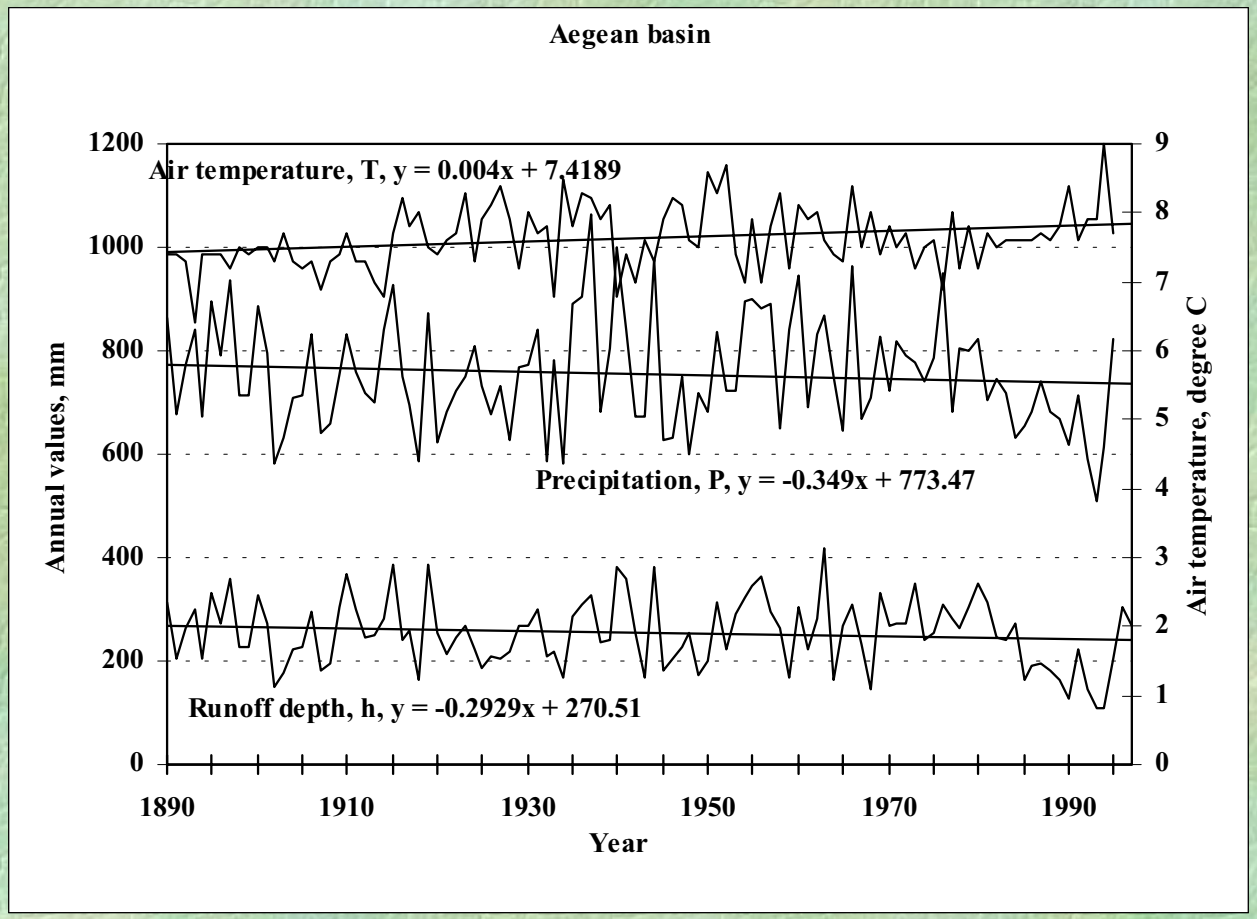
Arda
TURKEY
Istanbul
GREECE
Strimon
SEA OF
MARMARA
Thessaloniki
AEGEAN SEA


Danube basin
Air temperature, T, y = 0.0059x + 7.8431
Precipitation, P, y = -0.4115x + 754.8
Runoff depth, h, y = -0.3166x + 171.13
Annual values, mm
Air temperature, degree C
Year
1200
1000
800
600
400
200
0
10
9
8
7
6
5
4
3
2
1
0
1890
1910
1930
1950
1970
1990


Black Sea basin
Air temperature, T, y = 0.0042x + 10.247
Precipitation, P, y = 0.1817x + 633.66
Runoff depth, h, y = 0.0698x + 151.05
Annual values, mm
Air temperature, degree C
Year
1200
1000
800
600
400
200
0
12
10
8
6
4
2
0
1890
1910
1930
1950
1970
1990


Aegean basin
Air temperature, T, y = 0.004x + 7.4189
Precipitation, P, y = -0.349x + 773.47
Runoff depth, h, y = -0.2929x + 270.51
Annual values, mm
Air temperature, degree C
Year
1200
1000
800
600
400
200
0
9
8
7
6
5
4
3
2
1
0
1890
1910
1930
1950
1970
1990

Definition of the drought period

- The chronological structure of the 1982-1994 drought period is executed in relative units (the norm for runoff and precipitation are divided to the values of 106-year norms).
- The values of lower quartile (25% probability of non-exceedance) which may be used as stronger limit of drought were applied (Table 1).

Table 1: Chronological Structure of the Drought Period in Relative Unit (K) for River Runoff (h) and Precipitation (P) with Comparison to 106-Year Norms - $K = X_K / \overline{X}$

Chronological Structure														
Drainage basin	*	**	Years from 1982 to 1995												
			82	83	84	85	86	87	88	89	90	91	92	93	94	95
Bulgaria	h	.80														
	P	.90														
Aegean	h	.82														
	P	.89														
Danube	h	.71														
	P	.89														
Black Sea	h	.72														
	P	.87														

*Element; **Boundary quartile 25%.

Definition of the drought period

- The *river runoff* for Danube basin forms one more competitor 13-year drought period:1983-1995.
- For the *runoff* in the Aegean basin and Bulgaria the strongest limit gives 11-year drought period - 1985-1995.
- Furthermore, the *shorter periods* with more severe drought for the runoff with significance for the whole country are:
  - 1983-1994, *n=12 years* and;
  - 1985-1994, *n=10 years*.

- The probable chronological characteristics of the period 1982-1994 along with estimates of theoretical approximation of empirical distribution curves $P\left(X\langle X_P\right)$ are presented in Table 2, based on the 106-year period 1890-1995. The theoretical probabilistic curves are lognormal with correction $\ln\left(x \pm a\right) = N\left(X\langle X_P\right)$.

Table 2: Probabilistic chronological structures for the drought period 1982-1994 $P(X\langle X_P),\%$.

Probabilistic Chronological Structures														
Basin		**Years 1982-1994**												
	*	*82*	*83*	*84*	*85*	*86*	*87*	*88*	*89*	*90*	*91*	*92*	*93*	*94*
Bulgaria	*h*	47	32	70	4.6	16	21	17	5.6	0.76	40	8.2	0.44	0.26
	P	41	31	18	12	21	46	36	24	4.3	61	5.0	1.4	11
Aegean	*h*	51	46	65	7.7	17	21	15	7.5	0.9	38	3.1	0.19	0.23
	P	50	39	13	17	25	48	26	21	9.0	37	5.0	0.4	8.0
Danube	*h*	41	20	62	1.7	18	25	23	5.9	2.7	54	34	1.7	0.44
	P	28	26	16	7.8	18	47	38	23	3.1	81	6.3	1.9	16
Black Sea	*h*	58	26	86	32	31	38	41	15	0.83	28	5.0	11	11
	P	55	34	62	17	21	45	70	36	7.6	74	12	31	25

- From Table 2 we may notice that the 13-year period has rather large availability of dry years with low probability of occurrence. For example, for this short period with probability fewer than 20% only three cases are normally expected. Besides precipitation for the Black Sea zone where such cases are two and for the runoff they are five, for the other two zones and for the whole country such cases are from 6 to 8.

- Moreover, in this period some years with very low runoff occur (1990, 1993 and 1994) having excessively small probability of occurrence – from 0.19 to 0.9 %, i.e. with return period 526-111 years, surpassing the basic period of approximations (106 years). These unfavorable combinations lead to strong decrease of runoff during the investigated period.

Comparative & probabilistic estimations

- From the 106-year data series some 13-year periods are presented.
- In Table 3 the estimate for the probable period is given in which is possible to observe the average value $\overline{X}$ *(n=13 years)*. The sustainable standard deviation of the average value is assessed - $\sigma_{\overline{X}n} = \sigma_X (N = 106)/\sqrt{n}$ and for the standardized deviations $t = (\overline{X}_n - \overline{X}_N)/\sigma_{\overline{X}_n}$ based on the Student distribution are received the probable samples of size 13 years *P(t)*, and also the return period - $N = n / P(t)$.

Table 3: Deviation of 13-year average values for the runoff and precipitation in relation to their 106-year average values

$$\varepsilon = \left(\frac{\overline{X}_{13}}{\overline{X}_{106}} - 1 \right) 100,\%$$

and return period N (in *years*).

Drainage basin	*	1982-1994		1983-1995		1942-1954			
		ε	N	ε	N	ε	N	ε min	N max
Danube	*h*	-36	3250	-38	4333	-14	65	-38	4333
	P	-14	1560	-12	765	-5	50	-14	1560
Black Sea	*h*	-28	433	-26	310	-15	38	-28	433
	P	-6	68	-7	44	-9	138	-9	138
Aegean	*h*	-28	4810	-30	7222	-4	20	-30	7222
	P	-13	1730	-12	1182	-3	30	-13	1730
Total for Bulgaria	*h*	-31	3333	-32	4063	-8	33	-32	4063
	P	-12	1444	-11	812	-5	48	-12	1444

- It is seen that competitive periods for Bulgaria, Danube and Aegean zones are: 1982-1994 - for precipitation and 1983-1995 – for the river runoff (with one year's delay).
- For Black Sea basin, the minimum value of the runoff is for 1982-1994, and for precipitation - 1942-1954.

Results and conclusions

- Since 1981 in Bulgaria *long lasting decrease* in the precipitation combined with increase in the air temperature were observed, which lead to deep depression in the river runoff.
- The 1982-1994 period is characterized with 31% decrease in runoff for Bulgaria with comparison to the norms of the 1890-1996 period. This period is characterized with *very low probability of occurrence*: once in 3333, or once in 1444 years for the runoff and precipitation respectively.

Basic results

- The drought period was preceded with the long wet 1954-1981 period.
- The long 106-year period is characterized with:
  - Increase in the average annual air temperature for Bulgaria in accordance with the trend lines for solar activity, radiation and temperature anomalies in the Northern Hemisphere.
  - Decrease in the precipitation and river runoff for Danube and Aegean Zones and increase for both elements for the Black Sea zone.

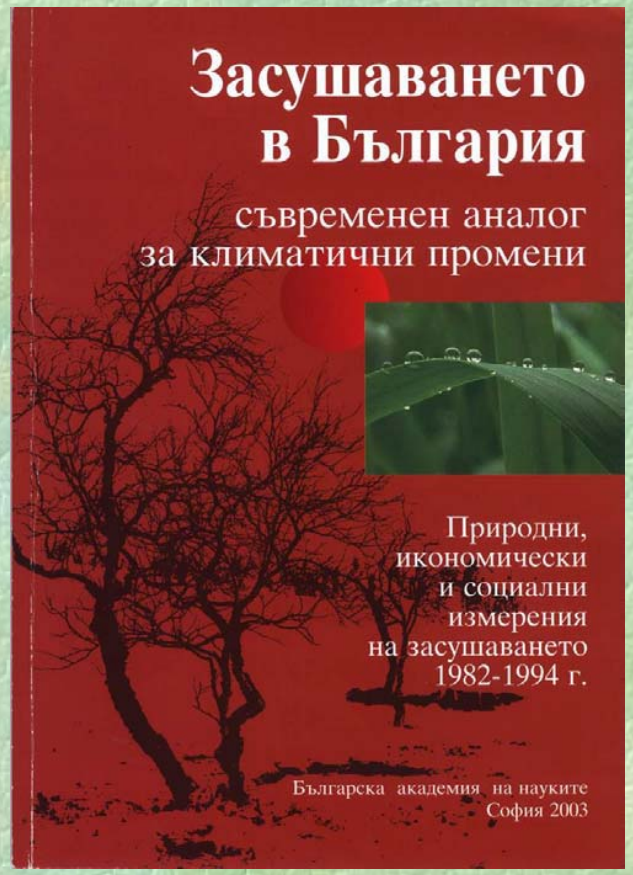
Basic results

- *The depressions* within the drought period are most visible during *1990, 1993* and *1994* when the absolute minimums of the 1890-1996 longer period are observed.
- *The drought period* of 10-14 years with similar parameters of the discussed one (1982-1994) is possible to appear during present century, although it has very low probability of occurrence.

Recommendations

- Rational utilization of the available water accumulated in reservoirs, natural lakes and groundwater resources;
- Economic water utilization by all consumers using legislative and economic actions and stimulus;
- Building of reservoirs with annual and multi-annual regulation of the runoff;
- Water transfer from wet to dry regions.

Acknowledgement



This is to acknowledge that the talk is partly based on the:

Gerassimov, Str., M. Genev, E. Bojilova and T. Orehova 2004, "*Water Resources during the drought*", 85-100, Part IV: Drought impact on water resources, Chapter 8 in Monograph: **Drought in Bulgaria: a contemporary analogue for climate changes**. - (Ashgate Studies in Environmental policy and practice), ISBN 0 7546 4215 1, Printed & Bound by MPG Books Ltd, Bodmin Cornwall, 336 pp.