ГОДИШНИК НА СОФИЙСКИЯ УНИВЕРСИТЕТ „СВ. КЛИМЕНТ ОХРИДСКИ“
ГЕОЛОГО-ГЕОГРАФСКИ ФАКУЛТЕТ
Книга 2 – ГЕОГРАФИЯ
Том 110

ANNUAL OF SOFIA UNIVERSITY “ST. KLIMENT OHRIDSKI”
FACULTY OF GEOLOGY AND GEOGRAPHY
Book 2 – GEOGRAPHY
Volume 110

DATA FOR THE 1989–2004 PERIOD FROM METEOROLOGICAL STATION ZEMEN AND ITS APPLICATION IN AGROCLIMATOLOGY AND GEOMORPHOLOGY

HRISTO POPOV[1], PETKO BOZHKOV[1], ALEXANDAR PEICHEV[2],
ALEXANDAR SARAFOV[3]

[1] *Department of Climatology, Hydrology and Geomorphology*
e-mails: hpopov@gea.uni-sofia.bg; petko_bozhkov@abv.bg
[2] *Manager of Zemen training and scientific base, Faculty of Geology and Geography*
e-mail: obskn@abv.bg
[3] *Department of Landscape Sciences and Environmental Protection*

Hristo Popov, Petko Bozhkov, Aleksandar Peichev, Alexandar Sarafov. DATA FOR THE 1989–2004 PERIOD FROM METEOROLOGICAL STATION ZEMEN AND ITS APPLICATION IN AGROCLIMATOLOGY AND GEOMORPHOLOGY

Collected data form meteorological station Zemen is analyzed. In the presented study authors emphasize on their application in agroclimatology and geomorphology. An attempt is made to determinate periods with certain conditions for development and activity of different environmental processes and phenomena, some of which have influence on the landscape and, therefore, on economic and social activities in the study area. Climate conditions are comment as factor for weathering and activity for different slope and erosion processes.

Key words: Zemen, agroclimatology, climate regime, geomorphological processes.

INTRODUCTION

Solar radiation is an exogenous source of energy, which in action with atmospheric circulation transforms Earth’s surface and determines the development of sequence of processes. Their action, regime and frequency form specific character of each given place. Some hydrologic and geomorphic phenomena are caused by meteorological conditions and characteristics of local climate which are hazardous for the economy. They affect given economic aspects related with the environment – agriculture, transport, insurances of farmland and against the risk of natural disasters etc. This requires analysis of climate and its elements on a global and regional scale.

The perennial observations of climatic elements provide opportunity to analyze the information by methods of statistics and to interpret the results. Climate changes and fluctuations can be revealed by evaluation of data from different time periods describing a given area.

The following paper has regional character. The study object is part of Struma valley located between Zemenska, Konjavska and Rudini Mountains (Fig. 1). The valley floor has elevation about 600 m and it is altered by two main tributaries – Treklyanska and Blateshnitsa

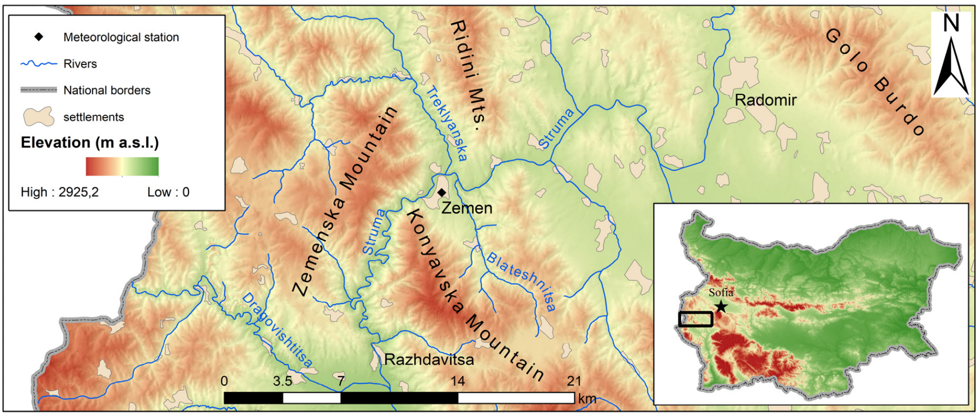


Fig. 1. Location of the study area and meteorological station Zemen

River. Presented results characterize southern parts of Kraishte region including Zemen Gorge, located between Konjavska and Zemenska Mountains.

The aim of the presented research is to apply the daily meteorological data from station Zemen in agroclimatological and geomorphological studies. For this reason, analysis of daily meteorological data is performed. This required accomplishment of several tasks – summarizing the existing datasets, tracking the regime of climatic elements and computation of several indexes.

MATERIALS AND METHODS

Daily data from 1989 to 2004 about air temperature, soil temperature in various depths, precipitation, and snow cover retention from meteorological station in town of Zemen (property of Sofia University "St. Kliment Ohridski") is analyzed. The station is placed at 620 m above sea level and has geographic coordinates N 42° 28' 27.8", E 22° 44' 56.44" (Fig. 1).

Preliminary preparation of the study was related with digitizing of the meteorological diaries and their transformation in form of spreadsheets. The data set is analyzed using statistical parameters – maximum, minimum, standard deviation, arithmetic mean (average). Tables and charts are made, showing the regime and inner annual change in climatic elements. Duration of periods with low and high air temperatures, number of days with snow cover and its retention period are calculated. Standard agroclimatological indicators concerning the duration of period with air temperature above 0, 5, 10 and 15 °C (Hershovich, 1984) are calculated along with indexes of Thorntwait (Topliiski, 1998, 2000, 2006; Topliiski et al., 1995).

The available information is interpreted in terms of climatic geomorphology and exogenous processes. The estimated periods with transition of soil temperature above 0 °C characterizes frost weathering and the occurrence of days with soil temperature equal or above 20 °C influences the chemical weathering rates (Barry, 1994).

Authors realize the short duration of the study period and, therefore, we compare the results with existing data concerning even shorter observational periods (Stoychev, 1986; Todorov, 1989; Topliiski, Peichev, 1993; Velchev et. al., 1993).

RESULTS

AIR TEMPERATURE. MEAN MONTHLY AND ANNUAL TEMPERATURE

Comparing the mean annual temperature for two periods of time from the selected station we observe an increase of 8.8 (1981–1988) to 9.1 °C (1989–2004). This warming is related with higher summer temperatures during the second period (1989-2004). In June we observe the greatest warming with increase of 16.6 to 17.4 °C (Fig. 2). In July and August, the warming is less pronounced than in June as mean temperature in both months rise above 19 ° C. In spring months, we observe increase of temperatures in March with more than 1 °C – from 3.6 to 4.7 °C. In April and May values of mean monthly temperatures remain almost the same.

In the autumn months we observe different tendencies in temperature variance. In September mean monthly temperatures decrease with about a degree – from 15.3 up to 14.5 °C (Fig. 1). In October we estimate raise from 9.4 to 10.3 °C (Fig. 2).

This different tendency is observed in the winter months. In December and January air temperature decrease (Fig. 2). In December the decrease of mean monthly temperature is more than one degree (from 0.6 to 0.7 °C) as the values remain negative. In January the temperature drops down is not well defined as the temperature decreases from –1.3 to –1.9 °C (Fig. 2). There is warming in February when the mean monthly air temperature rises from –0.9 up to 0.1 °C (Fig. 2).

Increase of average annual temperature amplitudes give us reason to assume that in the period 1989–2004 the continental influence on the climate in the study area is emphasized.

Even if short, the observation period of extreme temperatures gives us grounds to estimate their average values. They help us to characterize deviation of average values of air tempera-

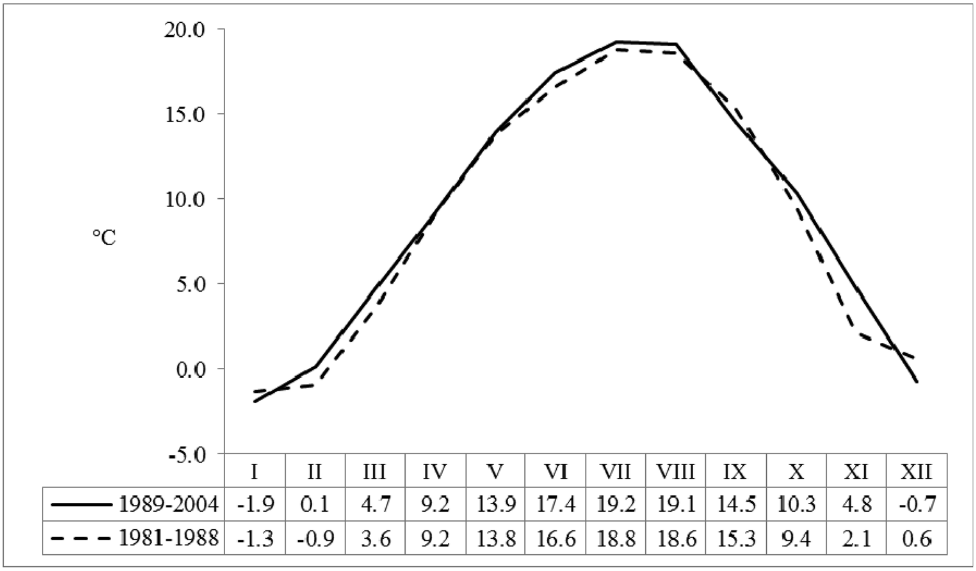


Fig. 2. Mean monthly and annual temperatures during the periods 1989–2004 and 1981–1988 (after Topliiski, Peichev, 1993)

tures. Summer maximal temperatures are of greatest importance to the analysis. They influence directly on agriculture and local economy and indirectly on the development of some natural phenomena, presenting a hazard for the local community.

Existing data allows estimation of two parameters. In average of absolute maximal temperatures, the maximum is in July – 36.2 °C and the minimum is in January – 11.9 °C. Months from June to September are with average values above 30 °C (Table 1).

Maximum of average maximal temperatures is in August (27.7 °C) and the minimum is in December (3.5 °C). In June, July and August the values of this parameter are above 25 °C (Table 2).

Two parameters are calculated for the minimal temperatures. These parameters provide data about the extent of severity of winter and the possibility of rapid decrease of temperature in other months of the year.

Table 1

Average of absolute maximal air temperatures (°C) during the period 1989–2003*

Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Average	11.9	15.4	21.9	23.9	28.7	32.0	36.2	34.1	30.0	26.8	21.2	13.0	24.7
Standard deviation	2.6	3.4	2.3	3.1	2.6	2.3	3.2	3.1	2.8	2.5	2.4	3.6	1.4

*No data available for 2004.

Table 2

Average maximal air temperatures (°C) during the period 1989–2003*

Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Average	3.7	6.6	11.4	15.6	20.9	25.1	27.0	27.7	22.0	17.5	10.5	3.5	16.2
Standard deviation	2.4	3.2	3.1	2.7	2.4	1.7	1.2	2.7	1.7	2.0	3.0	2.7	1.4

*No data available for 2004.

Table 3

Average of absolute minimal air temperatures (°C) during the period 1989–2003*

Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Average	–16.3	–14.8	–8.3	–4.7	2.0	5.3	7.1	6.5	0.8	–4.0	–9.3	–14.6	–4.3
Standard deviation	4.9	3.7	3.0	2.1	2.3	2.6	2.6	2.1	1.8	1.8	3.0	3.6	1.8

*No data available for 2004.

Table 4

Average minimal air temperatures (°C) during the period 1989–2003*

Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Average	–6.7	–5.1	–1.0	3.2	7.9	11.4	12.7	11.6	7.5	4.2	–0.2	–4.3	2.9
Standard deviation	3.2	2.3	2.1	1.7	1.5	1.6	1.5	1.3	1.1	1.6	1.6	2.1	0.4

*No data available for 2004.

Minimum of average absolute minimal air temperatures is observed in January (–16.3 °C) and the maximum is in July (7.1 °C). Negative values (under –4 °C) are estimated in all months of the cold half of the year including April. Only months from May to September we have positive values of this parameter (Table 3).

Average monthly minimal temperatures are important agroclimatic parameter. Its minimum is in January (–6.7 °C) and the maximum is in July (12.7 °C). Negative values of this parameter are registered in cold half year as they last from November (–0.2 °C) to March (–1°C). In January and February average minimal values are under –5 °C (Table 4).

FROST

Frosts (hoarfrosts and rimes) are phenomena which are closely related with the decrease of air temperature and sublimation of water vapor in atmosphere on a surface and objects.

They are considered to be risk from agricultural standpoint. Frosts in later autumn are extremely dangerous for the vegetation of plants.

Available information from station Zemen for the period 1989–2004 shows most frequent appearance (formation) of frosts in March. In several years there are several days with frost in the beginning of May. First autumn frosts are formed in the end of September and the beginning of October.

In the winter months the formation of frost is related with absence of snow cover. From November to February are observed about 10 days with rimes each month (Table 5).

Table 5

Average monthly and annual number of days with frosts (1989–2004)

Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Days	9.4	10.3	10.7	4.1	0.6	0.0	0.0	0.1	1.5	6.8	10.2	10.1	61.2

SOIL TEMPERATURE

Soil temperature varies in depth as the air temperature changes during the day and the year. Maximum of mean soil temperature is in July and August (between 22 and 24 °C) and the minimum is January – the only month with negative values (Table 6). Mean annual soil temperature varies from 11.5 at a depth of 10 cm to 12.1 °C at 5 cm depth. Temperature amplitude also decreases in depth from 23.4 °C to 21.7 °C.

Soil temperature regime depends on temperature of surface air. Transition of temperature between 0 °C determines the process of frost weathering, which leads to disintegration of bedrock in depth. Presence of such temperature transition and the duration of periods with temperature transitions are important conditions for the activation and action of cryogenic processes. Study focusing on relation between variations in soil surface temperature and the activity of slope processes in the alpine zone of Pirin Mountains is conducted in the period from 2011 to 2015 (Kenderova et al., 2015). Authors present data from daily measurements

Table 6

Mean monthly and annual soil temperatures (°C) at different depths (1989–2004)

Depth (cm)	Months												Average
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
0	–0.4	1.6	6.5	10.7	16.0	21.1	23.8	22.8	17.2	12.8	6.0	0.4	11.8
2	–0.4	1.3	5.7	10.4	15.8	20.5	23.2	22.9	17.3	12.8	6.1	0.7	11.7
5	–0.4	1.0	5.7	10.5	15.3	20.3	22.9	22.2	17.4	12.7	6.2	1.0	12.1
10	–0.4	0.8	5.2	9.9	14.6	19.3	22.1	21.9	17.1	12.5	6.2	1.2	11.5

of soil temperature in depth of 3–5 cm. However, the readings describe another altitude zone, thus they cannot be compared with our result.

Analysis of meteorological data revealed three periods with soil temperature transitions between 0 °C – frost free period, period with single temperature transition and period with two transitions.

Minimum of soil surface temperature is observed before sunrise when radiation balance is negative and the maximum appears to be at noon when the height of the Sun is at its peak (Penkov, 1992). Therefore, the single temperature transition is defined by the readings in 7 and 14 h local time. In rare cases with positive soil temperatures in the morning the single temperature transition occurs in the evening, hence it is defined by readings from 14 and 21 h local time. In cases with negative soil temperature in 7 and 21 h and positive values (≥ 0.1 °C) in 14 h two temperature transitions exist.

Soil temperature transition is observed in 5 to 6 moths per year – from October and April (Table 7, 8). Number of days with single transition is different in each month and it rapidly decreases in depth (Table 7). Similar tendency is observed in number of days with two temperature transitions (Table 8). Maximum number of days with single soil temperature transition is in February and the minimums are two – in April and October (Table 7). Days with two temperature transitions are less than days with single transition, as their maximum is in January and the minimum is in October (Table 8). Data shows melting and freezing in the topsoil between 0 and 5 cm, thus there are conditions for soil creep in this layer after each freeze – thaw cycle.

Table 7

Average number of days with single soil temperature transition between 0 °C (1989–2004)

Depth (cm)	Months												Annual
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
0	10.4	12.9	9.5	1	–	–	–	–	–	1.3	4.8	9.7	49.6
2	3.9	8.4	5.1	0.1	–	–	–	–	–	0.4	2.3	4.8	25
5	1.9	3.4	2.1	0.1	–	–	–	–	–	–	0.9	1.6	10
10	0.5	1.8	0.6	–	–	–	–	–	–	–	0.1	0.7	3.7

Table 8

Average number of days with two soil temperature transitions between 0 °C (1989–2004)

Depth (cm)	Months												Annual
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
0	7.8	7.6	3.7	–	–	–	–	–	–	0.1	1.5	7.1	27.8
2	1.4	4.3	1.6	–	–	–	–	–	–	–	0.6	2.3	10.2
5	0.4	1.3	0.4	–	–	–	–	–	–	–	0.2	0.4	2.7
10	–	0.4	0.1	–	–	–	–	–	–	–	–	0.1	0.6

Table 9

Average number of days with soil temperature above 20 °C (1989–2004)

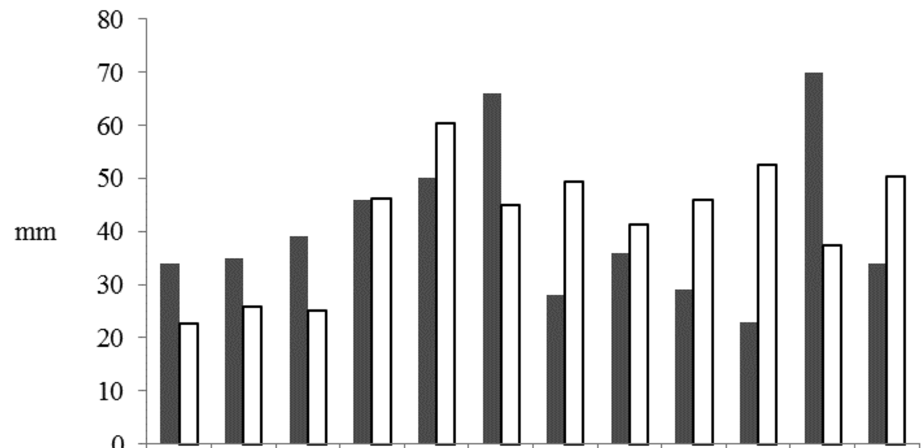
Depth (cm)	Months												Annual
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
0	–	–	–	0.1	2.5	18.3	22.4	24.4	4.3	0.6	–	–	72.6
2	–	–	–	–	0.9	14.9	22.8	25	3.3	0.2	–	–	67.1
5	–	–	–	0.9	13.5	23.1	24.4	2.6	0.2	–	–	–	64.7
10	–	–	–	–	0.4	9.6	21.1	22.2	2.6	0.3	–	–	56.2

Average duration of the period with single soil temperature transition between 0 °C is 149 days while the period with single transition last 96 days. Average date of beginning of temperature transition for the study period is 4th of November even though in given years it begins in the second half of October (1990, 1991, 1993, 1997, 2000, 2001). The latest date of beginning of soil temperature transition is 26th of November (1996). Average end date of this period is 2nd of April. However, in particular years the end of the period is in the first half of March (1989, 1991, 2001) or it extends to the end of April (1992). Period with two temperature transitions begins 18 days later (average date of beginning 22nd of November) and ends a month earlier (average end date 8th of March) than the period with single transition. Therefore, the frost free period extends between 2nd of April and 4th of November and it lasts 216 days. In this period soil creep and other slope processes are result of transformation of rainfalls into surface and underground flow which leads to excessive moisture. Chemical weathering processes including karstification are intense in this period and act upon summits and slope of mountains near the town of Zemen.

During the frost free period we differentiate subperiod with average soil temperature over 20 °C which "influences chemical weathering rates" (Barry, 1994). This subperiod lasts approximately 129 days. Average date of beginning of this period is 20th of May although in some cases it begins earlier in April (9.04.1998). The end of the period is in the last 10 days of September, but its duration is frequently extended up to the first 10 days of October (in 1989, 1990, 1991, 1992, 1994 и 1997, 1998 and 2003). Due to this reason average end date of the subperiod is 26th of September. Maximal number of days with soil temperature ≥20 °C is in July and August (Table 9). High air temperature leads to low groundwater level, reduced amount of soil moisture and drought which limits the processes of chemical weathering. We assume that they are most intensive in the beginning (in June) and in the end of the period (September and October) when precipitation is larger than summer rainfalls. Heavy rainfalls in July and August can trigger this type of geomorphological processes. Such rainfalls are observed from 1989 to 1992 and in 1994, 1996, 1997, 1998 and 2002.

PRECIPITATIONS

Precipitation regime in the study area has two maximums and two minimums. During the first reference period (1981–1988) precipitation maximums are in November and June and the minimums are in July and October (Topliiski, Peichev, 1993). During the second period (1989–2004), there are some differences in the monthly distribution of the rainfall quantities. In January, February and March we observe less monthly rainfall sums than in the first reference period (1981-1988). Rainfall sums in April are not altered. However, the rainfalls in May are increased with more than 10 mm when primary precipitation maximum occurs. Monthly precipitation sums in June, July and August during the second period are between 40 and 50 mm, whereas in the first period we observe increased rainfalls in June (66 mm) and less precipitation in other summer months (Fig. 3). There are also changes in the average precipitation quantities in the last 4 month of the year (Fig 3). Precipitation sum in September is increased by nearly 60%. Rainfalls in October are doubled as they formed the secondary maximum. Rainfalls in November are halved and currently they formed secondary minimum, whereas during the first period we observed maximum of precipitation in this month. Precipitation in December is increased by 50%, reaching sum of 50 mm (Fig. 3). The annual



	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
■ 1981-88	34	35	39	46	50	66	28	36	29	23	70	34
□ 1989-04	23	26	25	46	61	45	49	41	46	53	37	50

Fig. 3. Monthly precipitation during the first (1981–1988) and the second (1989–2004) observation period

precipitation sum for the first period (1981–1988) is 490 mm, while in the second observation period (1989–2004) it is increased up to 502 mm.

According to Topliiski, Peichev (1993) average number of days with rainfall between 1981 and 1988 covers about 1/3 of the year. Most of the rainfalls during that period fall in May and November and minimal quantities falls in August and September. During the sec-

Table 10

Number of days with rain (1989–2004)

Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Average	2.2	2.7	3.6	8.3	9.7	7.5	6.4	5.8	6.7	6.1	5.9	4.3	65.9
Standard deviation	1.5	1.6	2.2	3.4	3.6	4.0	2.7	4.0	4.4	3.1	3.3	3.0	18.9

ond period most of the rainfalls are observed in May, April and June (Table 10). Rarely rain falls in January and February.

HAIL, HAILSTORMS AND THUNDERSTORMS

Hails are not common phenomena. They are caused by the passage of cold fronts of the second order and the formation of powerful cumulonimbus clouds accompanied by thunder. Number of days with hailstorms for the period 1981-1988 varies between 3 and 5 days per year. Such phenomena are observed in May and June (Topliiski, Peichev, 1993). About 6 days with thunderstorms are observed each year between 1989 and 2004. Their frequency is largest in the spring and summer months, as their maximum is in August (Table 11). Occurrence of thunderstorms in other months of the year is episodic and happens once every 10 years.

Table 11

Number of days with thunderstorms (1989–2004)

Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Average	0.0	0.1	0.1	0.2	1.1	1.2	1.3	1.4	0.4	0.1	0.1	0.2	5.9

SNOWFALLS AND SNOW COVER

Average number of days with snowfalls is approximately 20. Their frequency in largest in December – about 5 days. In January, February and March are observed at least 4 days with snowfall (Table 12). Last snowfall is registered in April and the first one is in November but in some rare cases snow falls are observed in October.

Snow cover act on climate formation, radiation and thermal balance as a canopy on top of the Earth’s surface with its high albedo. Snow cover cools the surface air which leads to temperature inversions. It prevents soil and subsurface parts of plants from freezing. Snow retains the moisture for the beginning of the vegetation period. Forming and melting of the snow is related with snowfalls, air and temperature.

Table 12

Average number of days with snowfall (1989–2004)

Months	I	II	III	IV	X	XI	XII	Annual
Average	4.3	4.1	3.8	1.0	0.4	2.0	5.2	19.5
Standard deviation	2.5	2.0	3.5	1.3	0.9	2.2	2.9	6.7

Table 13

Average monthly and annual number of days with snow cover by months (1989–2004)

Months	I	II	III	IV	X	XI	XII	Annual
Average	11.2	8.6	2.3	0.8	0.2	2.5	8.9	32.1
Standard deviation	7.8	6.9	2.4	0.9	0.7	3.3	5.0	10.1

Maximum number with snow cover is observed in January – about 10 days. In the other winter month snow cover retains for approximately 8 to 9 days (Table 13). In the spring (mainly in March) and autumn (in November) there are between two and three days with snow cover. Even rare snow cover is formed in April and October, but it melts for a day.

AGROCLIMATOLOGIC APPLICATION OF THE DATA

Average date of beginning and end of the period with sustainable preservation of air temperature above 5, 10 and 15 °C, duration of this periods in days and temperature sums accumulated in them are most important agroclimatic parameters. Temperature sums are integral indicator for the thermal conditions during the vegetation period or part thereof (Topliiski, Peichev, 1993).

For the purpose of presented study, we included average duration of period with sustainable preservation of air temperature above 0 °C in days. Tables show decreased average duration of this period (Table 14, 15). However, the temperature sum is increased which

Table 14

Average date of sustainable preservation of air temperature above 0, 5, 10 and 15 °C and average duration of those periods (1981–1988)

Transition	Date	Transition	Date	Temperature. sum	Days
above 0°	20.II	below 0°	26.XII	3285	310
above 5°	24.III	below 5°	3.XI	3124	225
above 10°	21.IV	below 10°	13.X	2755	176
above 15°	29.V	below 15°	16.IX	1936	111

Table 15

Average date of sustainable preservation of air temperature above 0, 5, 10 and 15 °C and average duration of those periods (1989–2004)

Transition	Date	Transition	Date	Temperature. sum	Days
above 0°	13.II	below 0°	12.XII	3452	303
above 5°	19.III	below 5°	14.XI	3300	241
above 10°	21.IV	below 10°	18.X	2852	181
above 15°	25.V	bolow 15°	12.IX	1977	111

is related with the increased air temperature during the period from 1989 to 2004. The decrease of mean monthly temperature in December and January leads to increase of the period with negative temperature with 7 days. This in combination with increased temperature in February and March leads to shift of the beginning (from 26th to 12th of December) and the end (from 20th to 13th of February) of the period with negative air temperature.

Period with sustainable preservation of air temperature above 5 °C is increased by 16 days along with the accumulated temperature sum. This is caused by warming in March and increased mean temperature in November.

Period with sustainable preservation of air temperature above 10 °C is accepted for period of active vegetation for most of the agricultural crops (Hershovich, 1984). According to Hershovich classification the study area is part of Subzone of less thermophilic cultures with moderately warm climate. Conditions in this subzone are suitable for cultivation of beans, sunflower, alfalfa (lucerne), beets, tobacco, flax, oats and potatoes. Average date of beginning of this period remain unchanged – 21st of April. Average end date is shifted from 13th to 18th of November as the temperature sum grows up by 100 °C.

The duration of period with sustainable preservation of air temperature above 15 °C remains the same. Both its beginning and end are shifted by 4 days – from 29th to 25th of May and from 16th to 12th of September (Table 14, 15). Temperature sums are slightly increased.

CLIMATE CLASSIFICATION

According to value of Thorntwait moisture index (*Im*) the study area has dry subhumid climate type C_1, even though value of the thermal efficiency index (PE) is in the range of mesothermal climate type B'_1 (Table 16).

Using computed parameters, we determine the affiliation of the study area to the Köppen climate classification. We should mention that different authors set a different boundary between temperate “C” and cold D climates. We pay attention to both concepts. According to the first one the boundary is determined by –3 °C isotherm (Köppen, 1936), whereas the second idea suggest 0 °C contour line (Russel, 1931). Using the 0 °C isotherm the study area is part of the zone with cold climate with warm summer without dry period (Dfb) (Peel et al.,

Table 16

Precipitation, potential evapotranspiration (PE) and Thorntwait moisture index (*Im*)

Period	Precipitation (mm)	PE (mm)	*Im*
1981–1988	490	598	–18.06
1989–2004	502	612	–17.97

2007). Taking the –3 °C isotherm our area of interest is part of zone with temperate climates with warm summer without dry period (Cfb) (Topliiski, 2006).

CONCLUSIONS

By comparing data from two observation periods we estimated changes in the regime and the mean values of climatic elements. Data from second period (from 1989 to 2004) shows that the climate of the study area is characterized by a colder winter, typical of temperate climate zone. Precipitation regime reveals a shift of the previous November maximum to new one in May. Average annual precipitation is 502 mm, which support the idea of continental climate type.

According to Thorntwait moisture index Struma valley between Zemenska, Konjavska and Rudini Mountains and the Zemen Gorge has dry subhumid climate type C_1. Value of thermal efficiency index determines the climate as mesothermal type B'_1. Using the Köppen classification, the area of interest is characterized with temperate climate with warm summer, without dry period (Cfb).

Sustainable preservation of air temperature above 0, 5, 10 and 15 °C and average duration of those periods creating suitable conditions for agriculture and cultivation of different crops.

Climate conditions trigger various geomorphological processes. Low winter soil temperature triggers frost weathering. Transitions between 0 °C are important conditions for soil creep after each freeze – thaw cycle. Warming in the spring months leads to snow melting. Therefore, soil creep, sheet erosion and other slope processes in this time of the year are result of transformation of rainfalls which leads to excessive moisture. Chemical weathering processes including karstification act mainly in the frost free period. In the subperiod with average soil temperature above 20 °C chemical weathering rates are intense if rainfall occurs. Otherwise a drought period begins.

The intensity and the action of the various exogenous geomorphic processes are related with the regime of climate elements. The relation between different climates and certain processes is expressed by Peltier (1950). The author defines morphogenetic regions in terms of mean annual temperature and rainfall only. Peltier's diagrams provide an opportunity to assess qualitatively the activity of different processes in a particular geographic region. Using the data for the 1989–2004 period from meteorological station Zemen, it is determined that the study area is part of a region with moderate chemical weathering and absent or insignificant frost weathering. This statement is confirmed by the average number of days with soil temperature transition between 0 °C. Slopewash and rill (gully) erosion ("pluvial erosion" according to Peltier) is considered to be dominant processes. However, their action is limited by the type of the vegetation cover, presence or absence of mantle of fallen leaves, the intensity of the precipitation, the frequency of storms, the permeability of the soil etc. Snow melting and heavy rainfalls activates incision of rills and gullies and influence the fluvial processes. Mass movement is considered to be slow or insignificant because of the moderate rate of weathering and the low soil moisture. This is related with the significant number of days with soil temperature above 20 °C in the summer period. Terrain observation and measurement must take place to determine the rates of denudation and accumulation. The geomorphic processes must be monitored and related with particular meteorological situations.

Further studies should be focused on the differences in climate with relation to the aspect and elevation of Struma valley floor and surrounding mountains near town of Zemen in order to reveal local climate features.

SUMMARY

The presented article concerns regime of climate elements in Southern Kraishte region. Published results describe the climate of a part of Struma valley between Zemenska, Konyavska and Rudini Mountains. Daily meteorological data between year 1989 and 2004 form meteorological station Zemen (N 42° 28' 27.8", E 22° 44' 56.44", elevation 620 m) is analyzed. Realizing the short duration of the study period we compared the results with existing data from previous observation period between 1981–1998 (Topliiski, Peichev, 1993).

Comparing the mean annual temperature for two periods of time from the selected station we observe an increase of 8.8 (1981–1988) to 9.1 °C (1989–2004). This warming is related with higher summer temperatures during the second period (1989–2004). Increase of average annual temperature amplitudes give us reason to assume that in period 1989–2004 the continental influence on the climate in the study area is emphasized.

Precipitation regime in the study area has two maximums and two minimums. The annual precipitation sum for the first period (1981–1988) is 490 mm, while in the second observation period (1989–2004) it is increased up to 502 mm.

We applied the results of the analysis of the daily meteorological data in agroclimatological and geomorphological studies. Conditions in the study are suitable for cultivation of beans, sunflower, alfalfa (lucerne), beets, tobacco, flax, oats and potatoes. Frosts are considered to be risk from agricultural standpoint. Available information for the period 1989–2004 shows most frequent appearance (formation) of frosts in March. In several years there are several days with frost in the beginning of May. First autumn frosts are formed in the end of September and the beginning of October.

Collected meteorological data was interpreted in terms of geomorphological studies. Transition of soil temperature between 0 °C is important condition for frost weathering and soil creep after each freeze – thaw cycle. Average duration of the period with single soil temperature transition between 0 °C is 149 days, while the period with single transition last 96 days. Average soil temperature above 20 °C trigger chemical weathering rates especially in

the presence of moisture. This period lasts approximately 129 days. Snow melting and heavy rainfalls creates conditions which activates sheet erosion and incision of rills and gullies and influence the fluvial processes.

REFERENCES

Barry, R. G. 1997. Paleoclimatology, climate system processes and the geomorphic record. – In: Processes and forms in Geomorphology. Edited by David Ross Stoddart, London, Routledge, 187–214.

Hershovich, E. 1984. Agroclimatic resources in Bulgaria, Bulgarian Academy of Sciences, 115 p. (in Bulgarian).

Kenderova, R., G. Rachev, A. Baltakova, D. Krenchev. 2015. Variations in soil surface temperature in the Pirin High Mountain area and their relation with slope processes activity. – *Comptes rendus de l'Académie bulgare des sciences: sciences mathématiques et naturelles*, Tome 68 (8), 1027–1034.

Köppen, W. 1936. Das geographische System der Klimate. – In: Handbuch der Klimatologie, Band 1. Teil C., Verlag von Gebrüder Borntraeger, 1–44.

Peel, M. C., B. L. Finlayson, T. A. Mc Mahon. 2007. Updated world map of the Köppen-Geiger climate classification. – *Hydrology and earth system sciences*, 11 (5), 1633–1644.

Peltier, L., 1950. The geographic cycle in periglacial regions as it is related to climatic geomorphology. – *Annals of the Association of American Geographers*, vol. 40, Issue 3, 214–236.

Penkov, I. 1992. Soil Temperature. – Climatology Manual. Edited by Bistra Vekilska, Sofia, Sofia University Press, 46–54 (in Bulgarian).

Popov, H. D. Topliiski. 2015. Water balance – actualized version of computational scheme of Thorntwait – Mather. LOPS Foundation-2015, Scientific conference with international participation, Sozopol, September, 2011–2012 (in Bulgarian).

Stoichev, N. 1986. Characteristics of temperature regime in Zemen landscape stationary. – *Proceedings of Bulgarian geographical society*, XXIII (XXXIII), 33–42 (in Bulgarian).

Todorov, N. 1989. Brief physical geographical characteristic of the area of Zemen landscape stationary. – *Proceedings of Bulgarian geographical society*, XXVII (XXXVII), 91–102 (in Bulgarian).

Topliiski, D., A. Peichev. 1993. Climate. – In: Physical geographical and landscape studies in the area of Zemen landscape stationary. Edited by A. Velchev, Sofia, Sofia University Press, 40–66 (in Bulgarian).

Topliiski, D., A. Popov. 1995. Climate types in Bulgaria according to Thorntwait moisture index. – *Annual of Sofia University, Faculty of Geology and Geography*, 2 Geography, 87, 117–135 (in Bulgarian).

Topliiski D. 1998. Chronological structure of Thorntwait moisture index in Bulgaria. International scientific conference 100 years geography in Sofia University, 31–38 (in Bulgarian).

Topliiski, D. 2000. Chronological structure of potential evapotranspiration in non-mountainous part of Bulgaria. – *Annual of Sofia University, Faculty of Geology and Geography*, 2 Geography, 90, 39–54 (in Bulgarian).

Topliiski, D. 2006. Climate of Bulgaria. Sofia, "Amstel" Foundation, 364 p.

Velchev, A., P. V. Petrov, D. Topliiski, R. Penin, A. Sarafov, P. B. Petrov, H. Konstantinov, S. Simeonov, N. Todorov, A. Assenov, A. Peichev. 1993. Physical geographical and landscape studies in the area of Zemen landscape stationary, Sofia, Sofia University Press, 250 p. (in Bulgarian).

Received April 2017