CLIMATE AND METEOROLOGICAL CONDITIONS IN MAVROVO NATIONAL PARK IN R. MACEDONIA

Biserka DIMISHKOVSKA, Jovan DIMISHKOVSKI, Nikola DIMISHKOVSKI

Abstract: *The area of Mavrovo National Park, which was the subject of the analysis presented in this paper and for which the climate and the meteorological conditions was analyzed covers the mountainous areas of Mount Bistra massif as well as the territory of the Radika river catchment area which influence the creation of an individual (mountain) climate. The influence of the Radika River basin on the other climatic regions in the western parts of the Republic of Macedonia was also analyzed. Several groups of factors have an influence upon the analyzed area: physical-geographical, radiation, circulation as well as local factors.*

The air temperature (with all its parameters), the rain and the characteristics of the wind field (through the wind roses) as well as the specific atmospheric phenomena were analyzed as the major climate elements and phenomena which influence the ecological conditions.

In addition to medium and extreme values of air temperature, the elements of the air temperature with their specific parameters were also analyzed within the characteristics of the air thermal regime: the number of extremely cold days, (maximum temperatures <-10□C), the number of icy days, the number of frost days (air temperatures below 0□C), the number of summer days (temperatures with T max >=25□C), and the number of tropical days (days with air temperature higher than 30° C), as well as their spatial distribution in the analyzed area.

The rain was analyzed via average monthly and annual quantities displayed in tables and on graphs.

The characteristics of the wind and the wind field were analyzed through wind occurrence roses and average wind velocity roses.

The analyses were conducted based on available data obtained at meteorological stations in the Mavrovo National Park as well as in the territory near the park published in specialized literature.

Keywords*: Human environment, waste management, waste types, recycling, landfilling, incineration, hazardous waste.*

1. INTRODUCTION

The region for which the climate and the meteorological conditions were analyzed covers the mountainous regions of the Mavrovo National Park massif (influencing the creation of a special mountain climate). There are several groups of factors that create the climate characteristics such as: the physical-

geographic factors, the radiation factors, the circulation factors as well as the local factors.

The data obtained by the meteorological observational network for defining the climate and the meteorological conditions (Table 1) and their parameters in the territory of the Mavrovo National Park were analyzed. These data were recorded at the following stations: Lazaropole, Mavrovi Anovi, Popova Shapka, Gostivar, Kichevo, Debar, including also a number of rain-measuring stations, Fig.1.

No.	Station name	Station type	H_S(m)	A	l
1	Tetovo	Regular	462	42^0 00'	20^0 58'
2	Gostivar	Regular	525	41^0 48'	20^0 55'
3	Debar	Regular	675	41^0 31'	20^0 32'
4	Krushevo	Regular	1230	41^0 22'	21^0 15'
5	Mavrovo	Main	1240	41^0 42'	20^0 45'
6	Lazaropole	Main	1332	41^0 32'	20^0 42'
7	Popova Shapka	Main	1750	42^0 01'	20^0 53'

Table 1. Types of meteorological stations with altitudes and geographical coordinates used for climate evaluation of Mavrovo National Park

Fig. 1. Network of main, common and rainfall measuring stations

The territory of the Mavrovo National Park encompasses the region of the western parts of the Republic of Macedonia at an altitude from 525m to 2250m (Mount Bistra), as well as up to 2764 m. (in the Radika river catchment area at Korab mountain).

In this territory, there is the boundary between the modified-continental pluviometric regime and the continental pluviometric regime. It covers the

mountain massifs of the upper parts of Radika river and the highest parts of the National Park Mavrovo.

The northwest part of the territory of the Republic of Macedonia (parts of the Korab and Deshat mountains and parts of the Bistra and Shara Moauntain) has an influence upon the distinguishing of the air masses from west and northwest compared to the air masses that are created inside the territory of the Republic of Macedonia. These influence the modification of the air masses that come from the Mediterranean and are transformed through the territory of Albania (most frequently rich in moisture) compared with the other air masses that are transported from north and northeast, in the territory of the Republic of Macedonia. The transformation of these air masses takes place particularly in the course of the winter part of the year when there is maximum precipitation (in the course of November), while in the continental pluviometric regime, the main maximum occurs in the course of May. In addition to the influence of these mountain massifs on the transformation of the air masses through reduction of their humidity, the mountain massifs also influence the average changes of air temperature and other climate conditions creating a special type of a mountain climate (Mediterranean-continental, moderate and mountainous, moderate and mountainous, i.e. subalpine and alpine climate).

2. SPATIAL AND TIME DISTRIBUTION OF METEOROLOGICAL - CLIMATIC ELEMENTS

The air temperature (with all its parameters), the rain and the characteristics of the wind field (through the wind roses) and the specific atmospheric phenomena were analyzed as the major climate elements and phenomena which influence the ecological conditions.

Except for the medium and extreme values of air temperature, the elements of the air temperature with their specific parameters were also analyzed within the characteristics of the thermal regime of the air: the number of extremely cold days, (maximum temperatures <-10°C), the number of icy days, the number of frozen days (air temperatures below 0°C), the number of summer days (temperatures with T max >=25°C), and the number of tropical days (days with air temperature higher than 30° C), as well as their spatial distribution in the analyzed area. The rain characteristics and the wind phenomena were also analyzed through wind roses, occurrence roses and average wind velocity roses. Analyzed were data from the meteorological stations near the mountainous regions of Mavrovo National Park, as well as Radika river basin along with the data on the Mavrovo National Park (Lazaropole and Mavrovi Anovi) and the data available for the region in the vicinity of the analyzed area: Popova Shapka, Gostivar, Kichevo, Debar.

One of the major components of the climate is the air temperature. It mostly influences the forest biocenoses and the flora, as well as all the areas of human existence.

The analysis of the thermal air regime was carried out on the basis of the results on the temperature measured at the meteorological stations located in the Mavrovo National Park (Lazaropole and Mavrovi Anovi), as well as on the basis of the total data which exist for the territory of the Republic of Macedonia, including data on climatic parameters like number of frozen, summer, tropical and extremely cold days and other.

The average monthly and annual air temperatures were measured in the period 1971-2000 at the meteorological stations, Fig. 2.

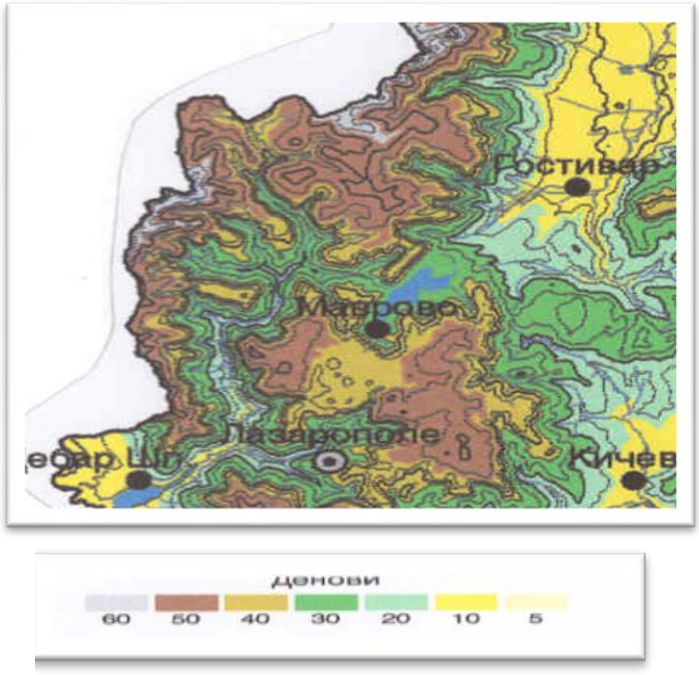

Fig. 2. Map of average annual air temperature (1971-2000)

Under the influence of the climate factors which condition the climate (astronomical, circular, orthographic in anthropogenic) the change of the annual air temperature depending on the altitude has the following temperature gadient: f(x)=1440.6x+2111.8. (temperature gradient Fig.3).

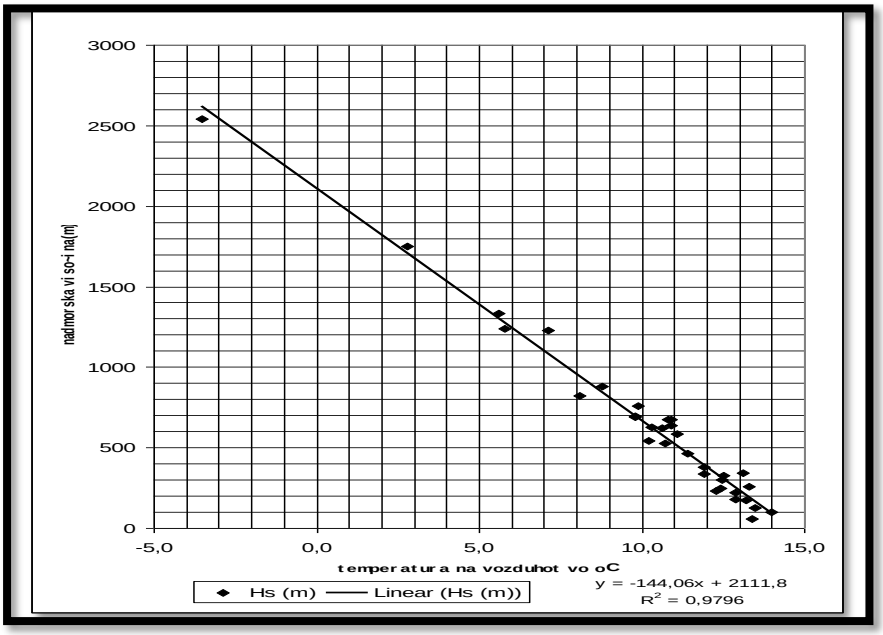

Fig. 3. Functional dependence of the average annual air temperature and the altitude for the territory of the Republic of Macedonia (1971-2000)

Thus, for example, at an altitude of 700 m, the average annual air temperature is 10° C, while at the altitude of 1400 m, it is 5° C. An isothermal map was drawn based on the temperature gradient, as well as on the functional dependence on the altitude. At altitudes higher than 2100 m, the average annual air temperature continues to drop down to 0 ^{o}C, while at an altitude of 2500m, it is -2.5 ^{o}C. On the aforementioned mountains, at an altitude higher than 1900 m, there prevails the so-called sub-alpine or alpine climate which is the most severe climate in the territory of the Republic of Macedonia (Filipovski Gj. et al. 1996).

Analysis of the average number of days of characteristic air temperatures was made as follows: average annual number of summer days (days with maximum air temperature >= 25°C), average annual number of tropical days (days with maximum air temperature >= 30°C), average annual number of icy days (days with maximum air temperature <0°C), average annual number of ice days (days with a minimal air temperature <0°C). Their special distribution is shown in Figures 4,5,6,7.

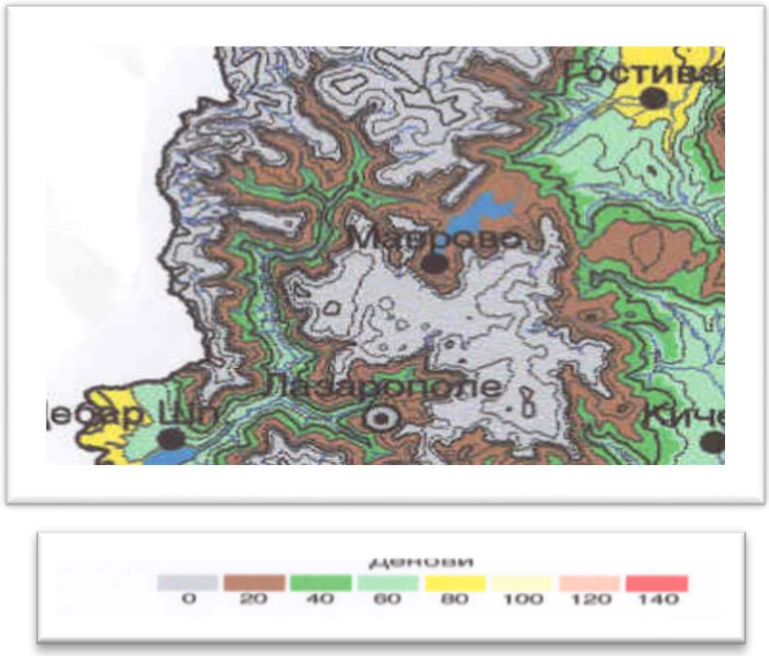

Fig. 4. Map of average annual number of summer days (days with maximum air temperature >= 25°C), 1971-2000

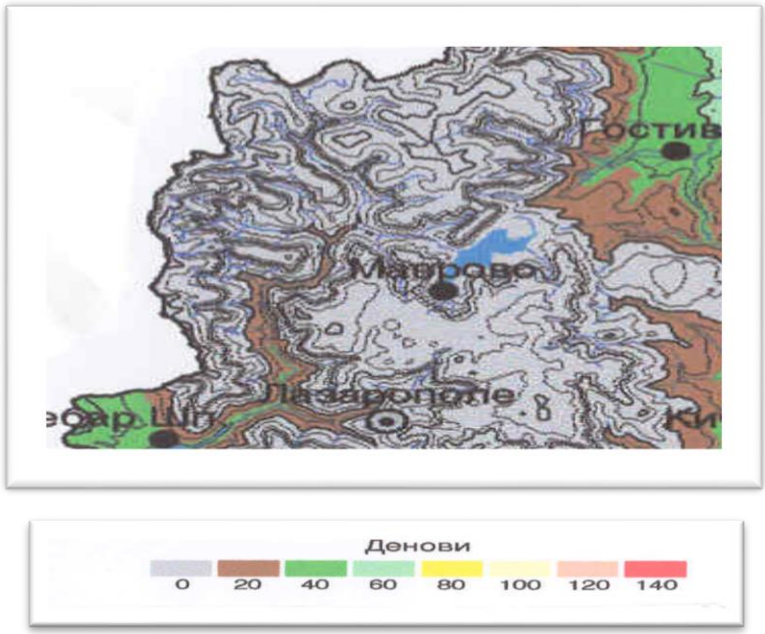

Fig. 5. Map of average annual number of tropical days (days with maximum air temperature >= 30°C), 1971-2000

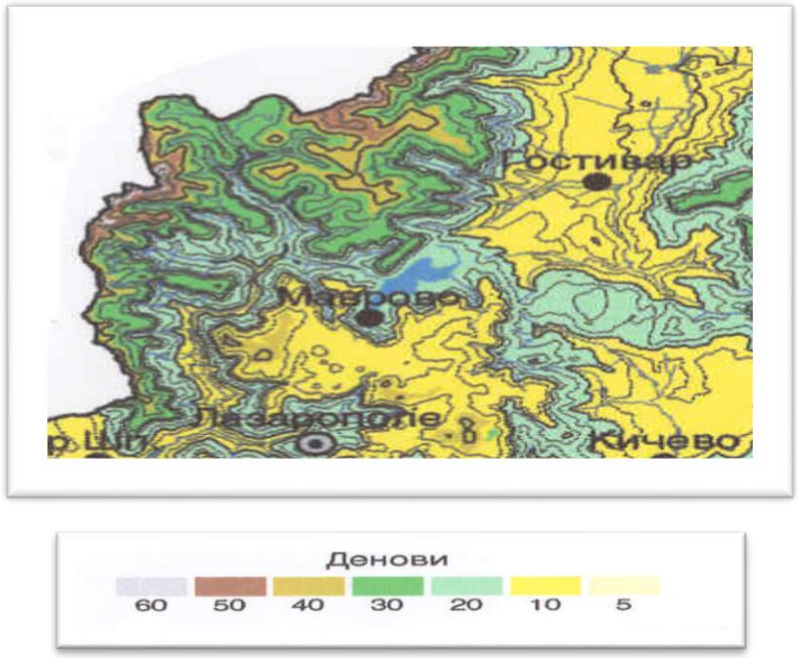

Fig. 6. Map of average annual number of icy days (days with maximum air temperature <0°C), 1971-2000

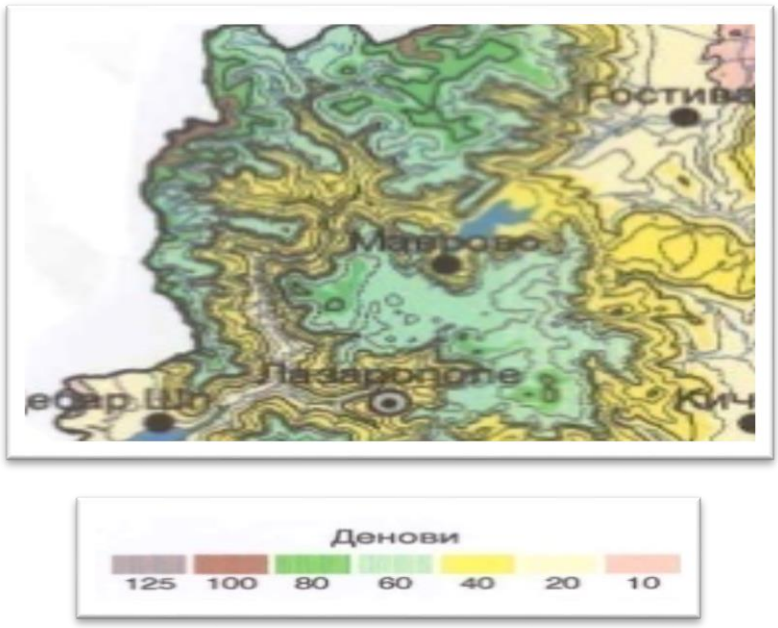

Fig. 7 Map of average annual number of icy days (days with minimal air temperature <0°C), 1971-2000

The average monthly, the average monthly maximum, the average monthly minimal, the absolute monthly maximal and the absolute monthly minimal air temperature in ^{0}C for Debar, Mavrovi Anovi and Lazaropole, were analyzed.

According to the results from the network of meteorological stations in Mavrovo National Park (main, regular and a specific number of rain-measuring stations) using methods that are usual for this type of work (examination of homogeneity of series, interpolation of data, reduction of the series to the same number of years (FHM Institute, 1964) and establishing a correlated "annual rains sum" – "altitude" relation, we drew an annual isothetic map. From that map, we can separate regions with the same spatial quantities of rainfall during the year, as well as during specific months and seasons. In the subsequent text, for the purposes of this research, data obtained at meteorological stations in the region as well as data from the local meteorological stations which gravitate toward the analyzed territory, are shown. As a characteristic of the rainfall and pluviometric regime, the average values of rainfall are displayed in the subsequent text.

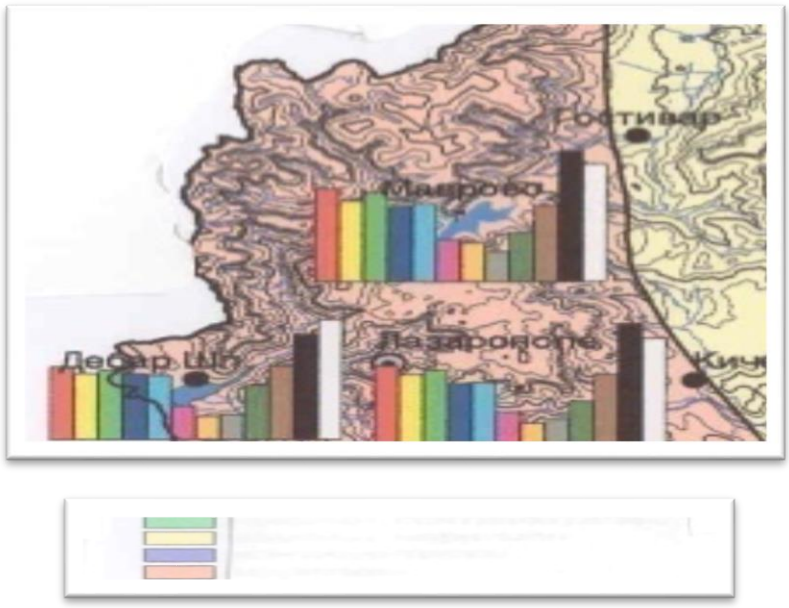

Fig. 8. Map of pluviometric regimes, with histograms of meteorological stations from Mavrovi Anovi, Lazaropole and Debar, 1971-2000

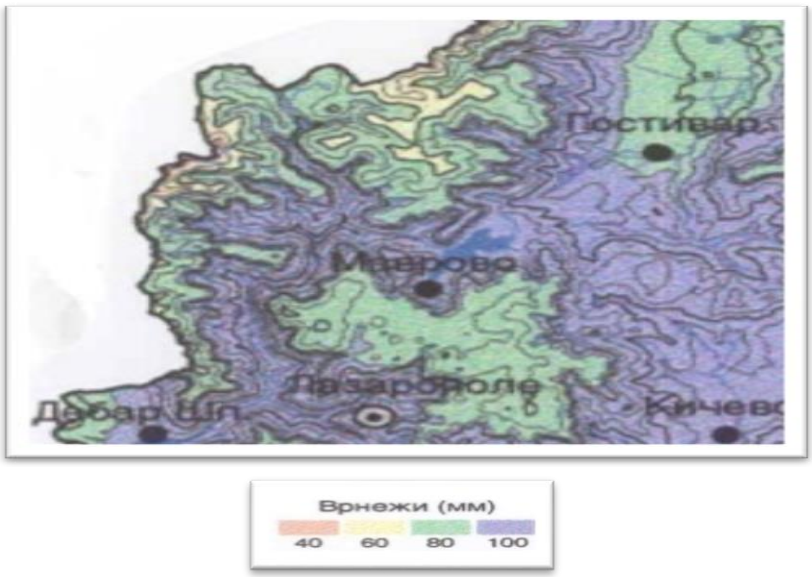

Fig. 9. Map of monthly rainfall quantities for the month of January, 1971-2000

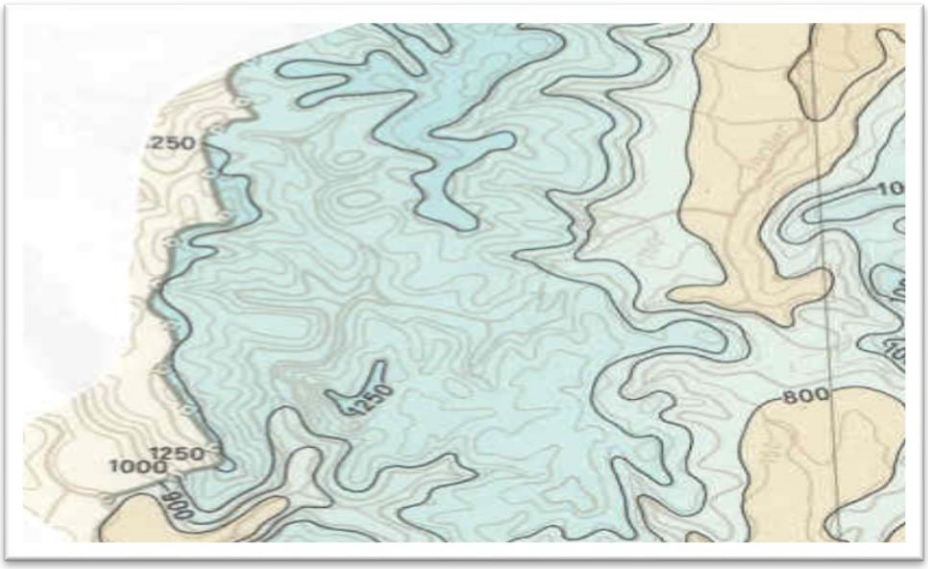

Fig. 10. Map of annual rainfall sums in mm, 1971-2000

According to the average annual isothetic map, most of the territory of the analyzed region is characterized by a quantity of rainfall which is around 600 to 800 mm. At the higher mountain massifs, the annual sum of rainfall is about 700 to 900 mm as well as up to 1050 mm, while at the altitude of 1800 m, there is a reduction of the annual sum of rainfall.

Several factors influence the wind: the gradient of the air pressure, the deviation force and the force of friction. Orography also has a significant influence on the surface wind field besides the influence of the change to the air masses, i.e. the configuration of the prevailing wind flows at the mountain massifs.

The average wind flow in Mavrovo National Park in the Republic of Macedonia is displayed on maps with wind roses, Fig.11.

Fig. 11. Wind roses at annual level, 1971-2000

The most common wind directions in Mavrovi Anovi is southwest and northeast, while in the Lazaropole region, the most common winds come from the east and west side.

3. CLIMATE CHANGES IN THE 20th CENTURY AND FUTURE CLIMATE CHANGES

The registered climate changes toward the end of the 20th century continued in the 21st century. These are manifested by low annual and summer sums of rainfalls, increase of the annual air temperatures as well as increased potential evaporation and transpiration. The influence of the climate changes on all components of the hydrological cycle (surface and underground waters, springs, oscillations of the level of natural and artificial accumulations as well as the total water needs) is of a great importance.

Climate fluctuation that occurred during the 20th century also affected the region of the mountain massifs in the northeast part of the territory of the Republic of Macedonia, as well as Mavrovo National Park. An analysis of the air temperature recorded at the meteorological stations of Lazaropole was made for the territory of Mavrovo National Park. The data were compared to those obtained for other parts of the territory of the Republic of Macedonia. Long term air temperature fluctuations were calculated for the period 1926-2005 at an annual level, for the months of January, July, and the summer period of the year. The results are shown in Fig.12- 15.

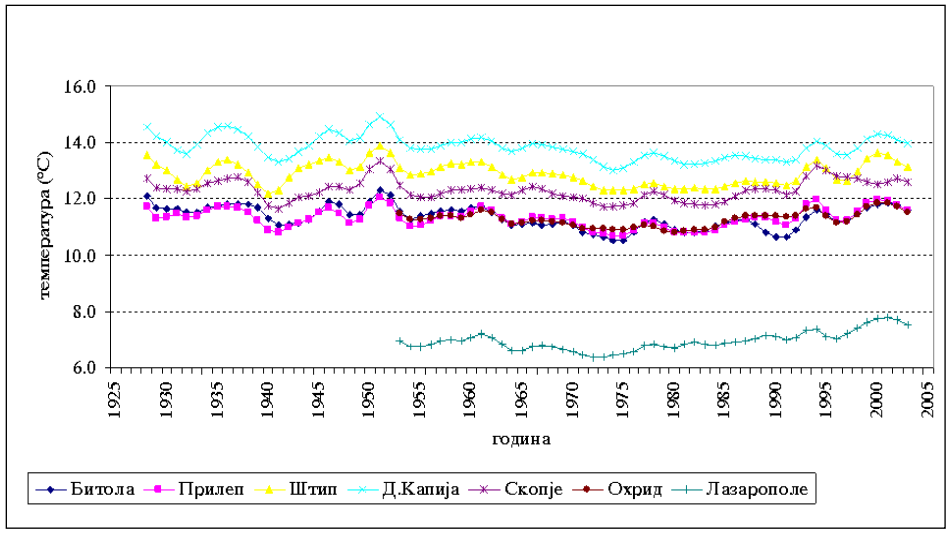

Fig. 12. Multiannual air temperature variations (1948-2005) obtained at Lazaropole meteorological station compared with the other long series of data (Skopje, Bitola, Stip, Prilep, Ohrid and Demir Kapija)

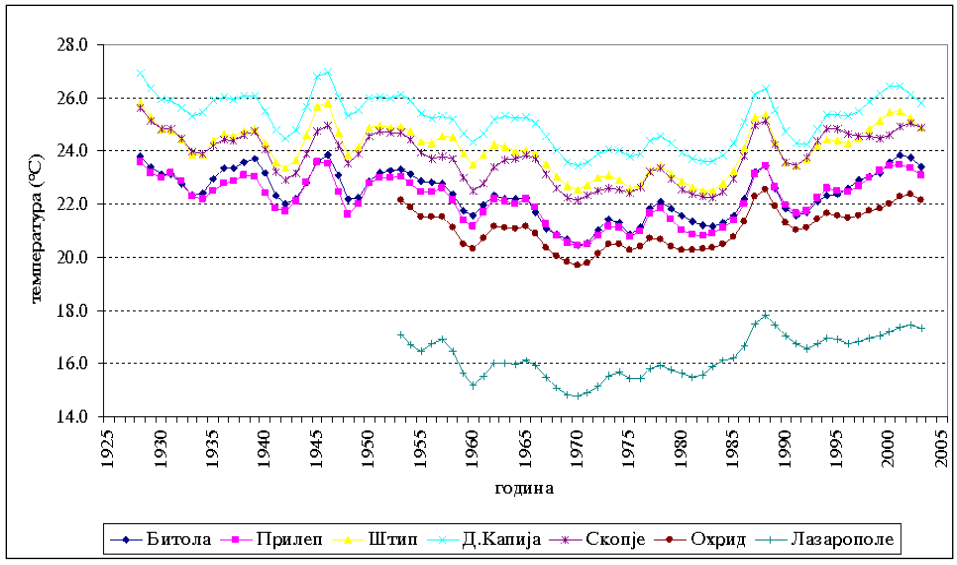

Fig. 13. Multiannual air temperature variations (1948-2005) recorded in July at Lazaropole meteorological station compared to other long series of data (Skopje, Bitola, Stip, Prilep, Ohrid and Demir Kapija) for the rainfall

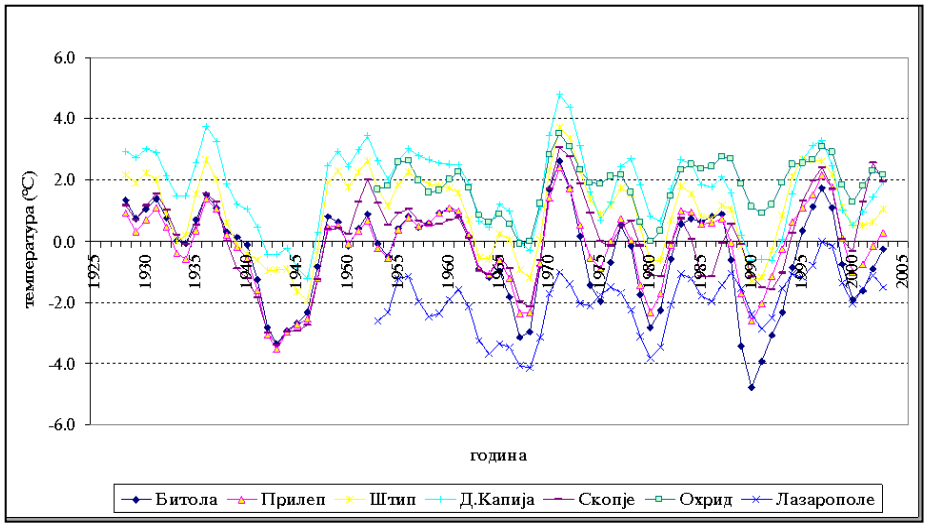

Fig.14. Multiannual air temperature variations (1948-2005) recorded in July at the Lazaropole meteorological station compared to other long series of data (Skopje, Bitola, Stip, Prilep, Ohrid and Demir Kapija)

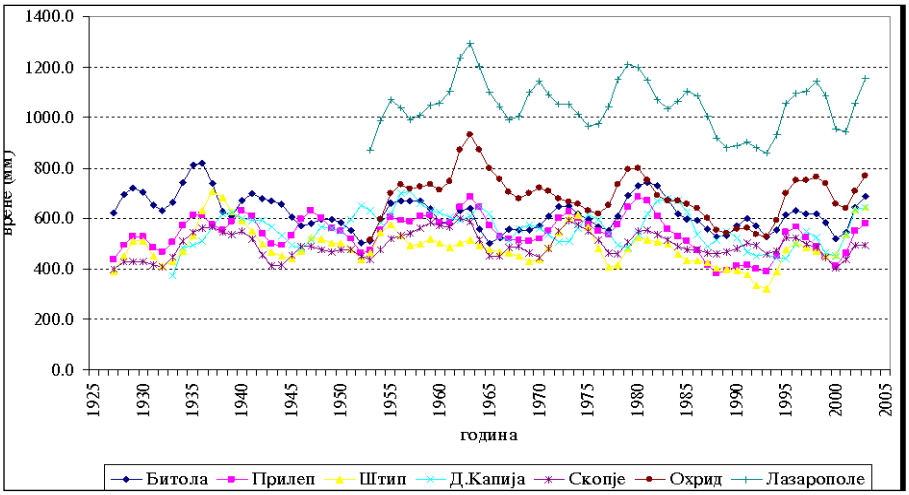

Fig. 15. Multiannual air temperature variations of the annual sums (1948-2005) obtained at the Lazaropole meteorological station compared to other long series of data (Skopje, Bitola, Stip, Prilep, Ohrid and Demir Kapija)

The general conclusion from the analysis is that the climate fluctuations during the 20th century in the territory of the Republic of Macedonia, regarding air temperature and rainfall match (i.e. they have the same sign) and that, in the past years, especially since the seventies of the last century, there have been significant changes with a tendency to increase during the 21st century. The changes include air temperature increase and a decrease in rainfall. This is particularly pronounced during the summer period.

4. CONCLUSION

The climate conditions were analyzed based on published results in appropriate studies, reports and scientific papers through textual interpretation of results that affect and could affect the environmental conditions through the characteristics of the rainfall and the pluviometric regime, the characteristics of the air temperature as well as wind.

Due to the specific physical-geographic and orographic conditions in the mountain parts of the northwest parts of the territory of the Republic of Macedonia, the following types of climate occur:

1. Continental sub-Mediterranean climate (altitude from 300 to 600m),
2. Warm continental climate (altitude from 600 to 900 m),
3. Cold continental climate (altitude from 900 to 1100 m),
4. Sub-mountain continental climate (altitude from 1100 to 1300 m),
5. Mountain continental climate (altitude from 1300 to 1650 m),
6. A region with subalpine climate (altitude from 1650 to 2250 m),
7. A region without tying climate (altitude over 2250 m).

The climate of this region depends on altitude, orographic, pedologic, bio-geographic factors and local factors, which are considered as constant factors, as well as some variable climate factors, which are manifested by the influence of transport and exchange of air masses, as well as frequency of atmospheric frontal systems, which influence the intensity and type of rainfall.

The influence of small lakes such as Mavrovo lake on the thermal air regime is within the vicinity of 3°C, in the range of a hundred meters (0.8 km) (in spring), up to 2.5 km in fall, in certain days (when the weather is stable) when the water mass of the lake water surface represents a heat accumulator of air temperature.

The lake water surface also influences the relative air humidity in the vicinity and increases the humidity for 10-15%.

Mavrovo lake has its own circulation that depends on the turbulent circulation of the air “from the lake” and “towards the lake”. The lake water surface influences the increase of the velocity of the local wind circulation for 15-20% compared to the situation of a non-existing lake.

The lake water surface also gives rise to an increase of fog, increased rainfall, as well as increased evaporation from the free water surface.

As to the envisaged accumulations Boskov Most and Lukovo Pole, and their influence on the environment, it is necessary to conduct special studies which will lead to conclusions on the future impacts on the environment.

The average annual quantity of rainfall for the average sensitivity of the climate is expected to decrease -3% in 2050, -5% in 2075 and -12% in 2100.

According to specific emission scenarios for Mavrovo National Park, an increase of the rainfall is expected in the winter period by the end of the 21st

century which could rise to 6%, and in all other seasons, a more intensive decrease of rainfall is expected. The most intensive decrease of rainfall of -16% is expected in the summer period.

This climate characteristic will be significantly expressed during the summer period when higher air temperatures, decrease of rainfall, as well as increased aridity and dryness are expected in the territory of the Republic of Macedonia and hence in the Mavrovo National Park. These climate changes will have a significant influence on ecosystems, different types of habitats as well as the fauna.

For detailed research of the microclimate conditions and the influence of topoclimate, orographic and physiogeographic conditions, it is necessary to organize climate-ecological monitoring, process data and create databases.

5. REFERENCES

1. Bergnat K. 2006. Climate Change Scenarios for Macedonia, Nova Gorica.
2. Filipovski et al., 1996 Characteristics of the Climate-Vegetation-Soiled Zones (regions) in the Republic of Macedonia, MASA, Skopje.
3. FHMI, 1973 Climatic Atlas of the Socialist Federal Republic of Yugoslavia, Belgrade.
4. Lazarevski A. 1993. The Climate of the Republic of Macedonia.
5. LSA, 1999. Master Plan for Water Resources in the Republic of Macedonia, Ministry of Development of the Republic of Macedonia.
6. Ristevski et al., 1998 The Climate in the Republic of Macedonia, expert paper, Public Enterprise for Spatial and Urban Planning – Skopje.

NOTES ON THE AUTHOR

Biserka DIMISHKOVSKA Professor, Ph.D. at the Department of Natural and Technological Hazards & Ecology, Institute of Earthquake Engineering and Engineering Seismology (IZIIS), "Ss. Cyril and Methodius" University, P.O. Box 101, 1000 Skopje, Republic of Macedonia, Tel: +389-71 321 568, E-mail: biserka@pluto.iziis.ukim.edu.mk

- **2014, Professor, Ph.D.** Department of Natural and Technological Hazards & Ecology, Institute of Earthquake Engineering and Engineering Seismology (IZIIS) University "Ss. Cyril and Methodius", Skopje, Republic of Macedonia.
- **2009, Associate Professor, Ph.D.** Department of Natural and Technological Hazards & Ecology, Institute of Earthquake Engineering and Engineering Seismology (IZIIS) University "Ss. Cyril and Methodius", Skopje, Republic of Macedonia.
- **2004, Assistant Professor, Ph.D.** Department of Natural and Technological Hazards & Ecology, Institute of Earthquake Engineering and Engineering Seismology (IZIIS) University "Ss. Cyril and Methodius", Skopje, Republic of Macedonia.

- **1993, Assistant. M.Sc.** Department of Natural and Technological Hazards, Institute of Earthquake Engineering and Engineering Seismology (IZIIS), "Ss. Cyril and Methodius" University, Skopje, Republic of Macedonia.
- **1979, Researcher, grad. civil eng.,** Faculty of Civil Engineering, "Ss. Cyril and Methodius" University, Graduated Civil Engineer, Skopje, Republic of Macedonia.
  Specialization (specify), Strazburg, France, 1988.
  Main field: Protection of human environment; analysis of ecological hazards including industrial risks; air pollution due to emission of harmful matter. Water pollution and management, Solid waste management, Investigation of methods for definition of seismic hazard and risk.

Jovan DIMISHKOVSKI "Ss.Cyril and Methodius" University ", Faculty of Mechanical Engineering, Skopje, Republic of Macedonia Phone: +389-77-642-754, E-mail: jovan-rjk@hotmail.com

Nikola DIMISHKOVSKI "Ss.Cyril and Methodius" University, Faculty of Economics, Skopje, Republic of Macedonia Phone: +389-77-642-753, E-mail: dimiskovski93@gmail.com