

## AIR TEMPERATURE IN THE REPUBLIC OF NORTH MACEDONIA

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### Abstract

Air temperature is a measure of temperature at different levels of the Earth's atmosphere. It is governed by many factors, including incoming solar radiation, humidity and altitude. When discussing surface air temperature, the annual atmospheric temperature range at any geographical location depends largely upon the type of biome, as measured by the Köppen climate classification.

Air temperature describes the process of measuring a current local temperature for immediate or later evaluation. Datasets consisting of repeated standardized measurements can be used to assess temperature trends.

Temperature varies greatly at different heights relative to Earth's surface and this variation in temperature characterizes the four layers that exist in the atmosphere. These layers include the troposphere, stratosphere, mesosphere, and thermosphere.

The aim of this paper was to analyze air temperature in the Republic of North Macedonia over the span of 10 years, measured in 26 different cities. Considering the fact that North Macedonia has a decent geographical position and also the relief, the extent and direction of the mountain slopes and their height are important climatic factors which also effect on the air temperature of our country.

*Keywords:* Air temperature; North Macedonia; Climatic factors; Minimum; Maximum.

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### Introduction

Atmospheric air is slightly heated directly by solar radiation. The main source of its warming is the Earth's surface and objects. The basic factors for transferring heat from the soil to the air are:

Heat flow — represents a thermally conditioned vertical exchange of air. In contact with the heated surface, the air warms up, becomes lighter, and rises.

Heat advection — is a horizontal movement of air masses, during which heat transfer from subtropical regions occurs in our latitudes.

Turbulence — represents the disorderly swirling movements of air in different directions within the main air stream. Depending on the initial causes, it can be dynamic and thermal. Radiation at the Earth's surface also contributes to air heating. The atmosphere is poorly permeable to long-wave radiation and absorbs a significant part of it. Evaporation, or rather water vapor entering the atmosphere, is also a source of latent heat that is released during the condensation of water vapor.

On the other hand, air cooling occurs for several reasons- adiabatic cooling is the primary cause. As air rises, it falls into conditions of lower atmospheric pressure and expands. The expansion of the air occurs at the expense of the thermal energy it contains.

Other, less important reasons are: Radiation of heat; Heat transfer in contact with a colder surface.

## Climate factors

The climatic features of the Republic of North Macedonia depend directly on several climatic factors. The most important climatic factors include:

- *Geographical position;*
- *Relief;*
- *The proximity of the surrounding seas;*
- *Impact of general circulation;*
- *Spread of air pressure etc.*

The geographical position of the Republic of North Macedonia is considered a very important climatic factor. It is located somewhat closer to the equator where permanent summers reign and somewhat further from the North Pole where permanent winters also reign. From this, it can be seen that the territory of the country lies in the middle climate zone of the northern hemisphere.

The relief, the extent and direction of the mountain slopes, and their height are important climatic factors. Sharr Mountain with Korab, Deshat, and Jabllanica prevented the department of Mediterranean influences from the West. The same obstacles to the influences of the Mediterranean climate from the south are the mountains Kozhuf, Nixhe, and Bellasica. A part of Sharri with Mount Luboten and Skopje's Montenegro also prevents the influence of the cold continental climate from the north.

The proximity of the sea basins is also an important factor for the country's climate, even though North Macedonia does not have direct access to the sea, because it is under the influence of the side seas, since the Aegean Sea by air distance is located in the south at a distance of about 60 km, while the Adriatic Sea in the west is about 80 km.

The influences of the Mediterranean climate enter from the south through the valley of Vardar and into Strumica. The same influences from the Adriatic through the valley of Drin enter the Dibra Valley. The western winds that blow from the Atlantic Ocean towards the east in our country bring spring and autumn rains.

## Average annual temperature

The heating state of the atmosphere is first manifested through the air temperature. It is an important climatic element and because it is very simple to measure, its distribution is much better known than the distribution of the individual components of the warm balance of the atmosphere. The heating state over any area for climatic needs is more simply expressed through the daily average and annual air temperature.

The daily movement of air temperatures represents the temperature change within **24 hours**. It appears as a result of the acceptance and emission of warmth in the soil-air-soil relationship. The increase in air temperatures begins at sunrise when the surface of the earth begins to receive more warmth than global radiation, about what it loses. The maximum values of air temperatures reach **14-15h**. After this moment, the air temperatures begin to decrease. The minimum temperature occurs before sunrise. In North Macedonia under normal conditions, the maximum temperature occurs at **2 and 4 p.m.**, while the minimum is around **4 and 6** in the morning.

The difference between the highest and lowest value of air temperature during 24 hours represents the daily temperature amplitude or daily temperature fluctuation.

The annual average temperature indicates in which part of the temperature scale the annual average air temperature is occurring. In our Republic, it ranges from **15°** in Valandovo and Dojran to **0.5°C** in Koka e Selanikut, while worldwide it ranges from **30°C** in the subtropical deserts to **-30°C** in the Antarctic.

The annual variation represents the difference between the average temperatures of the warmest and coldest months of the year.

The air temperature depends on the relief (height and extent of the mountains), proximity to the seas, movement of air masses, and flora. Air temperature with the height decreases from the following reasons:

- With the height of the air, the content of dust and other particles that absorb heat from solar radiation decreases;
- At altitude, the air has a small absorption power of radiant energy and it changes proportionally with the density of the air, while the density decreases with the altitude;
- The surface of the earth, which is heated by the sun's rays, also heats the terrestrial air, it decreases with height and is minimal on the tops of the mountains;
- Warm air heated by the substrate rises, comes to the rarest layer of air, expands and cools according to the laws of thermodynamics.

At the latitude where North Macedonia is located, the hottest month is July, while the coldest is January. The regions in which the air temperature changes with the increase in altitude, with all connections present homogeneous thermal regions. The average air temperature in North Macedonia reaches **11.5°C**. Average annual temperatures with higher values up to **14.5°C** in North Macedonia have been recorded in the lower reaches of the Vardar River and the Gevgelija-Valandovo, Dojran, and Tikves valley. These areas are under the great influence of the Aegean Sea.

With an average annual temperature of **14.5 to 13°C**, the distinguished are the Strumica-Radovish, Veles, Skopje, Stip, and Kocani valley. Temperatures from **13 to 12°C** are characteristic of the Kumanovo, Polog, Pelagonia, Dibra, and Ohrid-Struga valleys. Temperatures from **12° to 11°C** are characteristic of the Kriva Palanka, Delcevo, Kicevo, and Makedonski Brod valley. The Prespa valley is characterized by an average annual temperature of **11° to 10°C**.

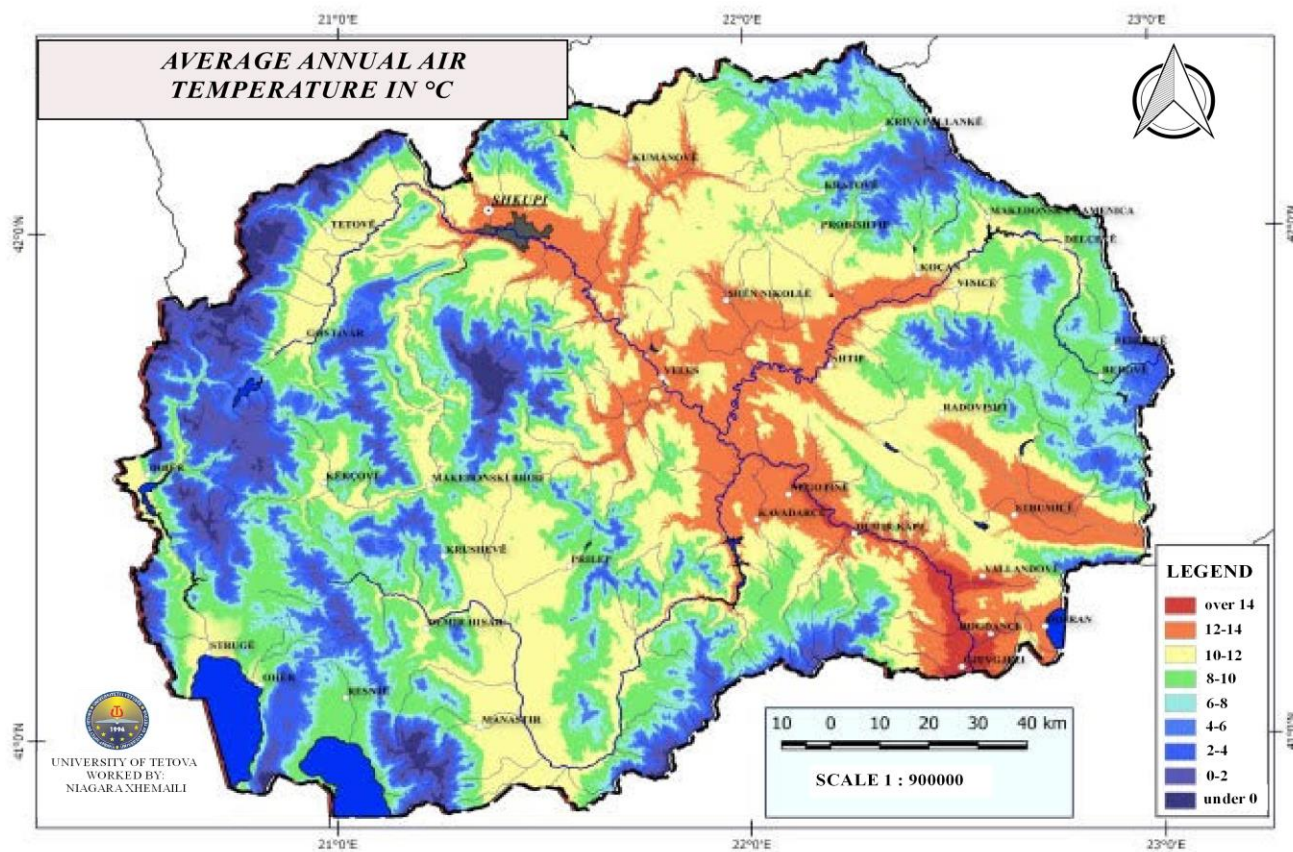
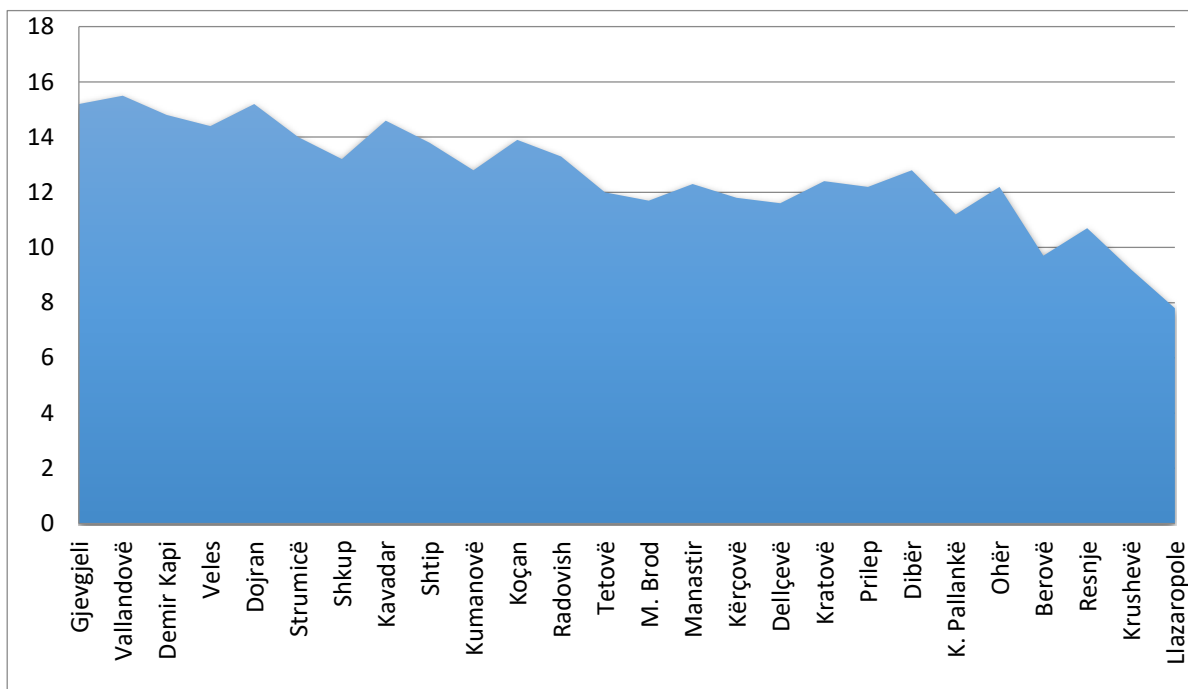
Temperatures from **10 to 9°C** are characteristic for the Berovo and Krusevo valleys, about **8°** for the area of Mavrovo and Lazaropole, from **4-5°C** for *Kodra e Diellit*, and an average annual temperature from **-1 to 0°C** in *Koka e Selanikut*.

**Table 1.** Average monthly and annual air temperature in °C (2010-2020 period)

Place of measurement	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Gevgelija	5,4	7,5	10,5	15,2	20,4	24,8	27,0	26,6	22,2	15,2	11,0	7,2	16,0
Valandovo	5,6	7,7	10,8	15,6	20,5	24,7	27,2	26,9	22,6	16,9	11,8	7,4	16,5
Demir Kapija	4,1	6,8	10,3	15,4	20,1	24,4	26,7	26,4	22,1	16,1	11,0	5,9	15,8
Veles	3,8	6,2	9,8	14,9	20,1	24,1	26,9	26,1	21,9	15,9	10,4	5,7	15,4
Dojran	5,6	7,4	9,1	14,8	19,9	24,2	26,7	26,6	22,4	16,8	12,1	7,7	16,2
Strumica	3,6	5,9	9,8	14,9	19,7	23,7	25,8	25,3	21,2	15,2	10,0	5,0	15,0
Skopje	2,4	5,0	8,7	14,1	19,0	22,1	25,2	25,0	20,5	14,3	9,1	4,0	14,2
Kavadar	3,5	6,1	9,7	15,3	20,1	24,2	26,6	26,7	22,3	16,0	10,9	6,0	15,6
Stip	3,3	5,8	9,3	14,3	19,3	23,3	25,7	25,4	21,2	15,4	10,1	5,2	14,8
Kumanovo	2,4	4,8	8,3	13,6	18,4	22,3	24,3	24,1	19,8	14,1	9,0	4,1	13,8

Kocani	3,5	6,1	9,7	14,6	19,4	23,2	25,2	25,0	21,0	15,4	10,2	5,3	14,9
Radovis	3,1	5,4	8,7	13,6	18,6	22,7	24,9	24,6	20,4	14,9	9,8	5,0	14,3
Tetovo	1,7	3,9	8,1	13,3	17,8	21,4	23,4	22,9	18,7	13,0	8,3	3,4	13,0
M. Brod	2,4	4,7	7,7	12,1	16,8	20,1	22,2	22,0	18,2	13,1	8,8	4,1	12,7
Bitola	1,3	4,4	8,1	12,9	17,6	21,7	23,8	23,6	19,2	13,4	8,9	3,8	13,3
Kicevo	1,1	4,4	7,8	12,3	16,9	20,6	22,6	22,3	18,4	13,2	8,7	4,1	12,8
Delcevo	1,0	3,9	7,3	12,2	17,2	20,7	22,6	22,3	18,0	12,7	8,3	3,8	12,6
Kratovo	2,4	4,7	8,0	12,6	17,4	20,9	23,2	23,7	19,4	14,3	9,4	4,6	13,4
Prilep	1,0	4,3	7,7	12,5	17,5	21,4	23,6	23,6	19,1	13,6	8,9	4,0	13,2
Debar	2,7	5,0	8,3	13,0	17,8	21,6	24,2	24,0	20,0	14,6	9,5	4,7	13,8
K. Palanka	1,3	3,7	6,8	11,2	16,4	20,0	22,0	24,0	18,0	12,7	8,0	4,0	12,2
Ohrid	3,7	5,1	7,6	11,8	16,4	20,4	22,8	22,7	18,9	13,8	9,7	5,8	13,2
Berovo	0,2	2,5	5,4	10,1	15,0	18,5	20,3	19,9	15,9	10,7	6,8	2,7	10,7
Resen	2,2	3,5	6,0	10,7	15,4	19,2	21,2	20,7	16,9	12,1	8,1	4,4	11,7
Krusevo	0,6	1,4	4,1	8,5	13,7	17,6	19,9	19,9	16,2	11,1	6,9	2,5	10,2
Lazaropole	-0,3	0,3	3,2	7,3	12,2	15,7	17,9	17,7	14,1	9,6	5,7	1,1	8,8

**Graph.1.** Average annual air temperature in °C (2010-2020 period)



**Map 1.** Average annual air temperature in °C

## Absolute minimum and maximum air temperatures

The absolute minimum air temperature is lower than  $-14^{\circ}\text{C}$  even in the warmest regions of North Macedonia. So, for example in Valandovo, the temperature is  $-14.1^{\circ}\text{C}$ , in Gevgelija  $19.5^{\circ}\text{C}$  and Demir Kapija up to  $-22.0^{\circ}\text{C}$ . Temperatures between  $-20$  and  $-25^{\circ}\text{C}$  are present in the Tikves, Strumica-Radovis, Skopje, Debar, Ovce Pole, Pelagonija, Kumanovo, and Kriva Palanka valleys. Temperatures lower than  $-25^{\circ}\text{C}$  occur in the Polog, Kicevo, Prespa, and Koçani valleys, and temperatures lower than  $-30^{\circ}\text{C}$  occur in the Berovo valley.

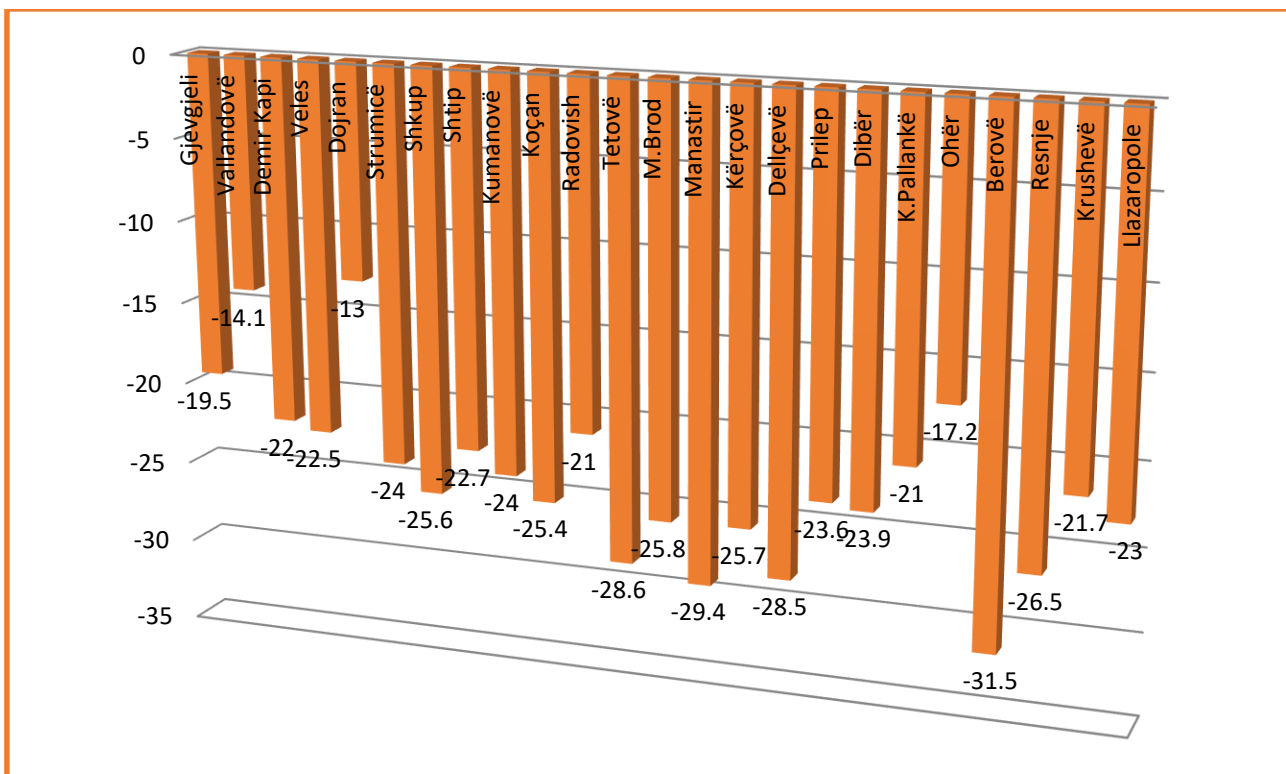
Absolute maximum air temperatures were recorded in southern Anavardar, while the highest values were also recorded in other areas. The highest temperatures in North Macedonia at  $44.5^{\circ}\text{C}$  were recorded in Demir Kapija in 1952, then similar temperatures were also recorded in Gevgelija at  $45.3^{\circ}\text{C}$ , Valandovo at  $43.4^{\circ}\text{C}$ , Ovce Pole at  $42.5^{\circ}\text{C}$  and Veles  $43.4^{\circ}\text{C}$ . Absolute maximum air temperatures of  $34-40^{\circ}\text{C}$  were also recorded in: the Polog, Kicevo, Ohrid-Struga, Kocani, and Pelagonija valleys. In North Macedonia, many days with an average temperature of  $30^{\circ}\text{C}$  have been recorded. Such days appear from April to the beginning of November. These days are most frequent in July and August. The average annual number of tropical days is higher in southern Anavardar, while towards the interior they decrease. For example, in the Gevgelija and Valandova valley, the number of these days is 73, in Skopje valley 53, in Polog 35, etc.

In the data of the monthly average, annual maximum, and absolute minimum air temperature, it can be seen that the influence of the Mediterranean climate on the thermal regime in the areas of the Republic of North Macedonia is lost in the summer months for the reasons already mentioned.

**Table 2.** Absolute minimum monthly and annual air temperature in  $^{\circ}\text{C}$  (2010-2020 period)

Place of measurement	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Gevgelija	-19.5	-15.0	-10.7	-3.0	2.5	8.0	8.4	9.0	2.4	-4.0	-9.5	-10.0	-19.5
Valandovo	-12.5	-14.1	-9.5	-0.7	1.9	8.0	10.5	8.8	4.2	-0.1	-10.5	-12.0	-14.1
D.Kapija	-22.0	-19.2	-16.7	-2.5	1.4	5.7	7.8	6.1	2.1	-3.1	-9.4	-14.5	-22.0
Veles	-22.5	-17.0	-11.3	-2.8	-0.5	7.4	7.3	7.0	2.8	-3.0	-11.5	-12.4	-22.5
Dojran	-13.0	-12.5	-7.2	-0.5	5.0	8.0	12.3	11.5	5.0	1.5	-3.5	-7.6	-13.0
Strumica	-24.0	-20.0	-11.0	-2.5	-2.0	4.0	6.1	5.8	0.1	-6.4	-11.0	-18.2	-24.0
Skopje	-25.6	-22.0	-15.1	-6.0	-1.6	3.2	5.8	7.0	-0.6	-4.2	-11.0	-17.9	-25.6
Stip	-22.7	-18.4	-15.4	-3.3	1.4	4.4	6.3	5.9	1.0	-3.9	-9.9	-16.4	-22.7
Kumanovo	-24.0	-17.6	-11.5	-3.5	-2.0	5.5	5.9	5.0	0.2	-4.3	-12.8	-16.1	-24.0
Kocani	-25.4	-18.0	-16.0	-3.7	-5.0	1.2	7.0	4.9	-0.6	-4.5	-11.5	-18.7	-25.4
Radovis	-21.0	-18.8	-13.1	-4.5	1.0	2.2	6.4	6.9	0.7	-1.8	-9.8	-15.2	-21.0
Tetovo	-28.6	-25.0	-14.6	-3.5	-1.0	0.8	4.6	4.0	-2.5	-5.0	-14.2	-20.8	-28.6
M.Brod	-24.6	-25.8	-16.5	-5.6	-1.8	1.2	4.0	2.4	-4.0	-7.2	-13.0	-25.0	-25.8
Bitola	-29.4	-27.7	-18.0	-3.5	-1.6	0.7	4.8	5.0	-2.4	-7.1	-15.3	-23.8	-29.4
Kicevo	-23.5	-25.7	-16.8	-2.5	-0.3	1.0	5.0	5.5	-1.0	5.0	-11.3	-17.2	-25.7
Delcevo	-26.7	-28.5	-18.6	-6.0	-1.5	-1.5	3.5	2.0	-2.5	-5.5	-14.5	-22.5	-28.5
Prilep	-23.6	-21.9	-15.8	-3.0	-0.1	2.2	5.2	5.3	0.4	-5.0	-11.0	-20.8	-23.6

Debar	-23.9	-20.4	-15.0	-4.2	-0.5	5.0	6.0	5.9	2.0	-7.5	-13.0	-19.0	-23.9
K.Palanka	-21.0	-17.0	-13.0	-4.0	-0.6	1.3	5.0	5.1	-0.5	-4.1	-11.6	-17.0	-21.0
Ohrid	-17.2	-16.1	-16.0	-5.4	-0.2	2.3	4.7	5.0	2.4	-5.2	-8.0	-14.9	-17.2
Berovo	-31.5	-24.5	-23.7	-7.7	-4.0	-1.8	1.7	1.0	-4.6	-8.5	-18.6	-23.7	-31.5
Resen	-26.5	-23.9	-22.0	-8.5	-1.5	0.0	3.2	3.0	-5.4	-8.0	-10.1	-20.5	-26.5
Krusevo	-19.5	-21.7	-16.7	-9.6	-1.6	0.0	4.5	4.0	-1.5	-7.4	-12.0	-18.7	-21.7
Lazaropole	-23.0	-22.0	-18.5	-13.4	-5.0	-3.4	1.3	1.4	-4.5	-10.6	-15.5	-19.5	-23.0

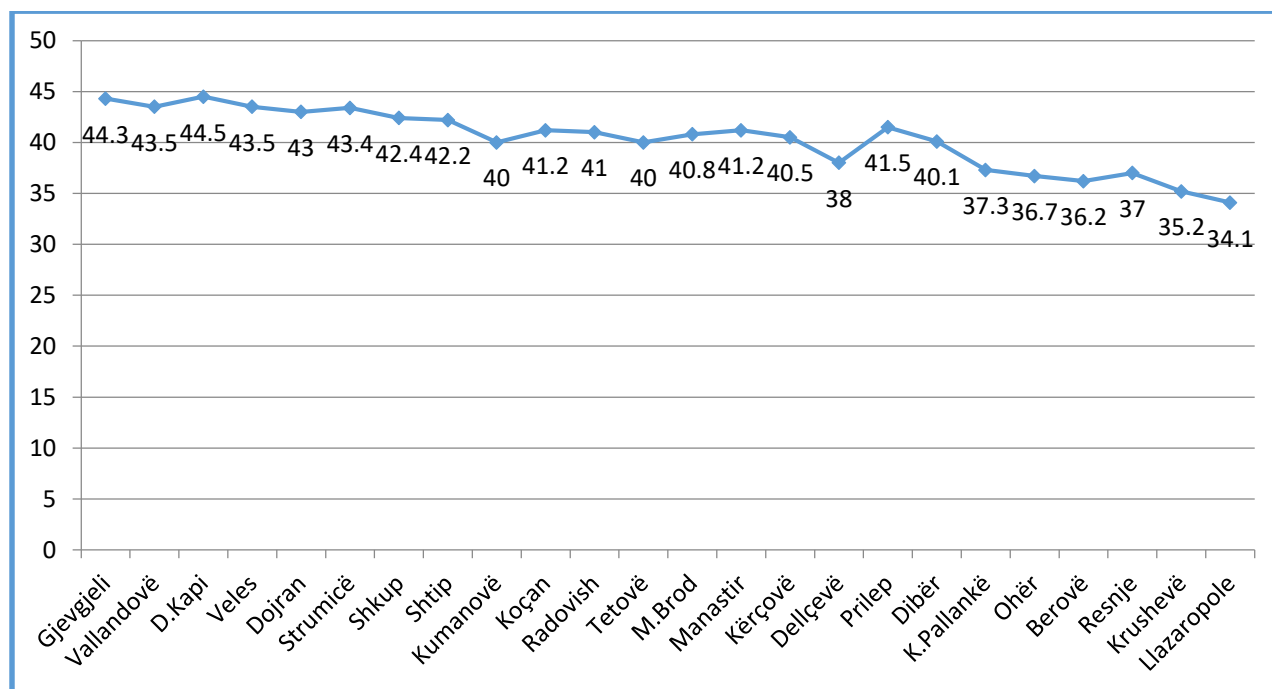


**Graph.2.** Absolute minimum monthly and annual air temperature in °C (2010-2020 period)

**Table 3.** Maximum absolute monthly and annual air temperature in °C (2010-2020 period)

Place of measurement	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Gevgelija	18.0	23.0	30.0	31.0	37.0	38.8	44.3	42.5	37.5	33.0	25.2	21.6	45.3
Valandovo	18.9	23.5	30.0	30.8	36.5	38.2	43.5	42.2	37.5	33.0	24.8	21.4	43.5
D.Kapija	17.9	23.6	31.0	32.2	36.6	40.4	44.5	44.5	38.8	32.4	24.0	20.2	44.5
Veles	19.2	25.4	36.0	29.5	34.5	40.5	42.5	43.5	38.2	34.6	24.0	20.2	43.5
Dojran	17.8	21.5	26.6	30.4	36.0	38.0	43.0	40.6	36.1	30.2	22.8	19.7	43.0
Strumica	19.0	20.9	28.6	30.0	35.5	38.5	43.4	40.5	36.2	32.2	25.0	25.0	43.4
Skopje	19.6	24.0	34.2	29.6	34.7	38.8	42.4	40.6	36.5	33.6	22.8	21.2	42.4
Stip	17.2	20.8	28.1	29.4	35.0	39.4	42.2	41.0	37.0	32.1	23.2	19.3	42.2
Kumanovo	18.5	23.2	34.0	28.6	33.5	37.5	39.4	40.0	36.2	33.0	21.2	20.0	40.0
Kocani	19.2	23.0	32.0	29.4	35.0	36.5	41.2	39.8	36.4	33.4	22.8	21.2	41.2
Radovis	15.6	20.4	25.8	29.0	35.5	38.0	41.0	40.1	35.3	31.4	22.0	17.5	41.0
Tetovo	15.5	21.6	30.0	28.0	34.0	35.8	40.0	38.8	35.6	30.5	21.5	19.0	40.0
M.Brod	16.6	21.4	25.5	27.6	33.2	36.4	40.8	38.9	34.4	30.0	25.3	20.2	40.8
Bitola	18.2	22.6	31.2	29.4	33.0	37.6	41.2	39.0	36.0	30.8	34.0	20.2	41.2
Kicevo	18.0	22.6	24.8	28.5	34.1	35.5	40.5	37.5	35.5	30.0	25.5	19.7	40.5
Delcevo	17.0	19.5	26.4	28.2	32.3	37.0	38.0	36.5	34.0	39.5	26.0	18.5	38.0
Prilep	18.7	21.7	31.9	28.9	33.7	37.7	41.5	39.4	36.6	32.3	23.3	18.8	41.5
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K.Palanka	16.5	20.2	29.6	26.8	31.4	34.0	37.3	36.6	34.4	31.0	22.6	18.0	37.3
Ohrid	15.4	18.4	26.8	25.2	30.2	33.0	36.7	34.4	31.7	27.0	21.8	17.8	36.7
Berovo	14.5	18.4	27.2	26.2	30.6	33.9	36.2	35.8	32.2	29.5	24.5	19.4	36.2
Resen	18.8	19.0	27.0	25.5	30.5	33.8	37.0	35.5	32.5	28.5	20.6	16.6	37.0
Krusevo	14.2	15.8	17.8	21.9	26.5	30.3	35.2	31.1	31.7	24.2	19.1	14.5	35.2
Lazaropole	13.6	14.6	22.4	22.5	26.9	28.8	34.1	31.2	29.8	23.5	20.0	13.4	34.1





**Graph.3.** Maximum absolute monthly and annual air temperature in °C (2010-2020 period)

## Discussions and Conclusions

The geographical position of the Republic of North Macedonia is considered a very important climatic factor. The relief, the extent and direction of the mountain slopes, and their height are important climatic factors. Sharr Mountain with Korab, Deshat, and Jabllanica prevent the department of Mediterranean influences from the west. The same obstacles to the influences of the Mediterranean climate from the south are the mountains Kozhuf, Nixhe, and Bellasica.

The difference between the highest and lowest value of air temperature during 24 hours represents the daily temperature amplitude or daily temperature fluctuation.

At the latitude where North Macedonia is located, the hottest month is July, while the coldest is January. The regions in which the air temperature changes with the increase in altitude, with all connection's present homogeneous thermal regions.

The average air temperature in North Macedonia reaches 11.5°C. Average annual temperatures with higher values up to 14.5°C in North Macedonia have been recorded in the lower reaches of the Vardar River and the Gevgelija-Valandovo, Dojran, and Tikves valley.

The absolute minimum air temperature is lower than -14°C even in the warmest regions of North Macedonia. So, for example in Valandovo, the temperature is -14.1°C, in Gevgelija 19.5°C and Demir Kapija up to -22.0°C. In the data of the monthly average, annual maximum, and absolute minimum air temperature, it can be seen that the influence of the Mediterranean climate on the thermal regime in the areas of the Republic of North Macedonia is lost in the summer months for the reasons already mentioned.

## References

- [1]. M. Mustafi; "*Veçoritë fiziko-gjeografike të Pollogut*", Arbëria Design, Tetovë,. 2008.
- [2]. A. Лазаревски;" *Климата во Македонија*", Култура, Скопје, 1993.
- [3]. R. Hamiti; "*Gjeografia fizike e Republikës së Maqedonisë*", Tetovë, 2018.
- [4]. F. Skenderi;" *Klimatologjia*", Shtëpia botuese "Çabej", Tetovë, 2009.
- [5]. S. Laçi;" *Gjeografia e Europës Juglindore*", Shtypshkronja e Shtëpisë Botuese "Lilo", Tiranë, 2007.