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ABSTRACT

Of the dissertation for the degree of Doctor of Philosophy

ASSESSMENT OF DISTRIBUTION REGULATIONS OF METEOROLOGICAL PARAMETERS IN GANJA-KAZAKH REGION AND THEIR IMPACT ON FLIGHTS

Speciality: 5411.01 – Meteorology

Field of Science: Geography

Applicant: **Mahmud Fikrat Suleymanov**

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The dissertation work was carried out at the National Hydrometeorology Department of the Ministry of Ecology and Natural Resources of the Republic of Azerbaijan at the Scientific Research Institute of Hydrometeorology.

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Disposable Dissertation Council BFD 1.23 created on the basis of the Dissertation Council ED 1.23 of the Supreme Attestation Commission under the President of the Republic of Azerbaijan operating at the Institute of Geography of the National Academy of Sciences of Azerbaijan.

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GENERAL DESCRIPTION OF THE WORK

Relevance and extent of research of the topic. Since the beginning of the XXI century, the role of aviation transport in the direction of passenger and cargo transportation has increased significantly, and its modern technical support capabilities have expanded even more. With the integration of air space of Azerbaijan to international airlines, the air transport sector has developed as an integrated part of the States economy. In this regard, a lot of work has been done, the fleet has almost been completely renewed, and critical international agreements have been signed. The rapid development of the aviation infrastructure increased the demand for aviation meteorological support and made the solution to the problems arising in the meteorological safety of flights more urgent.

The objective of the work is the assessment of the impact of meteorological conditions and hazardous atmospheric phenomena on flights operated in the Ganja-Gazakh region. Hazardous weather phenmenons have a negative impact on the efficiency of both aviation and various sectors of the economy. Thus, every year, emergency situations caused by hazardous meteorological phenomena of various scales occur in these areas. Analysis of the causes of occurrence, recurrence, and continuity of these incidents or accidents is an urgent issue and requires a scientific approach and research.

The explored area being one of the strategic regions of Azerbaijan, the intensity of small and large-scale aviation flights is expected to increase in the future. Therefore, the exploration and evaluation of the aero-climatic characteristics of the area are extremely important. Recently, anomalous atmospheric phenomena caused by the influence of global and regional climate changes, including lightning, hail, strong storms, and extreme temperatures, which are hazardous for aviation and agriculture, are also manifested in the studied area. These issues also make the study of the problem posed in the dissertation very relevant. This shows that the

dissertation is dedicated to one of the actual problems of aviation meteorology and climate science.

Purpose and objectives of the research. The purpose of the dissertation work is to evaluate the meteorological conditions, hazardous weather phenomena and their current changes in the Ganja-Gazakh region, to develop relevant recommendations and proposals for aviation flights. To achieve this goal, the following tasks have been resolved:

– Developing an electronic database of statistical characteristics of meteorological elements and events in the studied area;

– Analysis of the dynamics of changes of meteorological elements relatively to the multi-year norm;

– Studying the changing trend of hazardous meteorological phenomena and the occurences caused by them;

– Definition and specification of the Landing / Take-off directions at the existing and designing airports based on the analyses of actual meteorological elements;

– Investigation of the aviation occurences related to adverse meteorological conditions and prepare relevant recommendations.

Research methods. Mathematical-statistical, comparative analysis, geographic interpolation methods, modern computer technologies and software (ArcGIS) capabilities were widely used in the research work.

The main provisions of the dissertation submitted for defence:

1. The results of the study of the influence of modern climate changes on the statistical parameters of air temperature and their impact on aviation flights.

2. Results obtained from the study of wind speed and direction indicators on the territory and their impact on flights, the calculation of wind shear distribution percentages by height and the assessment of the degree of danger.

3. Atmospheric precipitation, the dynamics of multi-year change of rainy and snowy days and the results obtained from the assessment of their impact on flights.

4. Results obtained from the assessment of the impact of hazardous meteorological phenomenon on aviation flights.

The scientific novelty of the study:

– The effect of climate changes on the air temperature regime in the researched region has been determined and their effect on the flight parameters of aircraft has been evaluated;

– The average and maximum indicators of the wind as well as the prevailing winds have been determined, to design runways take off- landing directions of future airports. The percentage of distribution of wind slides by height and the severtity of hasard have been assessed;

– Spatio-temporal variations of atmospheric precipitation, recurrence, and continuity of rainy and snowy days has been evaluated.

– The multi-year trend of lightning, hail, and fog events has been analyzed and the impact on flights has been evaluated;

– In order to assess the probability of aircraft icing, monthly and average annual heights of 0^0C, -10^0C, -20^0C, -30^0C isotherms have been analyzed by region, and average heights have been recorded by season.

The theoretical and practical significanse of the research. The results of the conducted research can be used in the construction of new airports in the area, in the establishment of airport runways, and in the implementation of adaptation processes in various areas of the economy affected by modern climate changes in the future.

Approbation and application of the research. The main results of the dissertation were reported and discussed at the following republican and international conferences: "Globalization and Geography" international scientific-practical conference (Baku, April 26-27, 2012), International scientific conference on regional problems of hydrometeorology and environmental monitoring (Kazan, October 2–5, 2012), "Development of the science of geography in the years of independence", Republican Scientific Conference (Baku, December 16, 2013), International scientific and technical conference “Modern problems of water management,

environmental protection, architecture and construction" Water Management Institute, (Tbilisi, 25–27 July, 2021) published and discussed at conferences:

14 scientific works, including 9 scientific articles and 5 theses, have been published on the topic of the research work.

The entity where the dissertation was developed. The dissertation work was developed at the National Hydrometeorology Department of the Ministry of Ecology and Natural Resources of the Republic of Azerbaijan at the Scientific Research Institute of Hydrometeorology.

The volume, structure and main content of the dissertation. The thesis consists of 4 chapters, introduction, conclusion and proposals, 112 titles of literature list, abbreviations and symbols, 50 tables, 15 graphs, 14 pictures and 153 pages. Introduction - 4 pages, chapter I - 12 pages, chapter II - 49 pages, chapter III - 26 pages, chapter IV - 45 pages, conclusion and suggestions - 2 pages, list of literature - 11 pages, abbreviations and signs - 1 page. It consists of 207610 symbols without tables, graphs, pictures and bibliography.

THE MAIN CONTENT OF THE RESEARCH

In the introduction, information is given about the relevance and degree of development of the topic, the goals and objectives of the research, methods, the main terms defended, the scientific novelty of the research, the theoretical and practical significance of the research, its approval and application, and the structure of the dissertation.

The first chapter of the dissertation work is dedicated to **"Physical-geographical conditions of the territory, climatic characteristics of the region and meteorological information provision of researches**". The studied area is located in the west of the republic, on the northeastern slope of the Lesser Caucasus Mountains. One of the factors affecting the development and operation of air transport in the Ganja-Gazakh region is the variety of

relief conditions of the area. The large amplitude of the relief of the area on plains, foothills, low and high mountain zones is very favorable for population settlement and land acquisition.

The studied area starts from the watershed of the Shahdag-Murovdag ridges covering the northeastern slope of the Lesser Caucasus and continues to the foothill plains in the north. It has a mountainous relief with a complex structure, the absolute height of which varies from 500-600 m to 3000-3300 m. The highest peaks are Gamish (3724 m) and Hinaldag (3367 m)[1].

The territory is hydrographically rich, distinguished by the abundance of rivers and belongs to the Kura river basin. Kura, Agstafachay, Tovuzchay, Shamkirchay, Zayamchay, Ganjachay, Goshgarchay, Kurekchay, Hasansuchay, Akhinchachay, Karachay, etc., Shamkir, Yenikend, Agstafachay, Cogaz reservoirs, Goygol, Candargol, Maralgol, etc. lakes, artificial water basins (channels) create the hydrographic network. Many rivers are widely used for irrigation and water supply. Relief has a great role in the formation of climate in the studied area. As in many areas, surface structure, solar radiation, and air masses entering the area play a key role in the formation of climate in the studied area. Mountain systems in the area have a great influence on air circulation processes and incident solar radiation. Active temperatures in the area fluctuate between 3500-4500^{0}C. Depending on the altitude, the heat resources in the high areas decrease and the climate is cold in the high mountain zone. Active temperatures in high areas are only 2000-3500^{0}C[2].

The amount of total solar radiation is unevenly distributed over the territory. The average temperature of July is 17-26^{0}C, and the absolute maximum (until 2014) reaches 39-41^{0}C. Winter is mild and warm, the average temperature in January is close to 0^{0}C. The

[1] Museyibov, M.A. Physical geography of Azerbaijan / M.A. Museyibov. - Baku: Maarif, -1998. - 400 p.

[2] Agroclimatic atlas of Azerbaijan / editor. A.C. Eyyubov - Baku: -1993. -104 p.

absolute minimum temperature is minus 17-26^{0}C. Continuous snow cover is not formed. Summer is relatively cool. Winter is cold.

Continuous snow cover is observed in areas above 1300-1400 m. The amount of annual precipitation is between 290-740 mm[3]. The amount of total cloudiness fluctuates between 5.0 and 6.3 points during the warm and cold periods of the year. Depending on the altitude, there is a complete difference between the cold period and the warm period of the year. In the warm period of the year, the amount of total cloudiness at the altitudes of 200, 500, 1000 m is relatively small compared to the cold period. However, at a height above 1500 m, the amount of total cloudiness in the warm period is greater than in the cold period. The reason for the change in the amount of total cloudiness depending on the height between the warm and cold periods of the year can be attributed to the uneven distribution of air temperature and humidity.

At the same time, the amount of total solar radiation at different heights above sea level (200, 500, 1000, 1500, 2000, 2500, 3000, 3500, 4000 m) was examined for the studied area. The amount of annual total solar radiation varies between 124.5-147.9 kcal/cm^2, depending on the altitude.

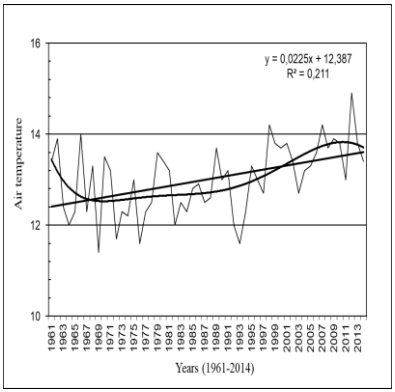
The second chapter of the thesis work is dedicated to "**Regional change trend of air temperature, wind parameters and evaluation of their impact on flights**".

Since air temperature is the most important indicator of climate, its changes have a strong impact on the dynamics of other parameters and dangerous hydrometeorological phenomena. Observations on air temperature, study of its impact on various sectors of the economy, especially aviation, and investigation of adaptation possibilities are one of the important problems for the studied area. An analysis of the multi-year dynamics of the average annual air temperature covering

[3] Mahmudov, R.N. Modern climate changes and dangerous hydrometeorological events / R.N. Mahmudov. - Baku: Polygraphic Center of MAA, - 2018.-231 p.

the years 1961-2014 of Agstafa, Dashkasan, Shamkir, Gadabey, Ganja and Goygol-resort meteorological stations in the studied area was carried out. According to the results obtained during the conducted research, an increase in the average air temperature can be observed for each station during the years 1961-2014 (Graph 1). During the period 1991-2014, the average air temperature increased compared to the multi-year norm (1961-1990). This increase was 0.7^0C in Agstafa, 0.9^0C in Dashkasan, 0.9^0C in Shamkir, 0.5^0C in Gadabey, 0.9^0C in Ganja and 0.7^0C in Goygol-kurort[4].

In general, the average temperature increase in the region was 0.8^0C. The analysis of the distribution of the average air temperature in the studied area by seasons showed that the positive increase was 0.6^0C in the winter season, 0.7^0C in the spring season, 1.0^0C in the summer season, and 0.8^0C in the autumn season. The obtained results show that the increase in the average air temperature is most observed in the summer months compared to other seasons.



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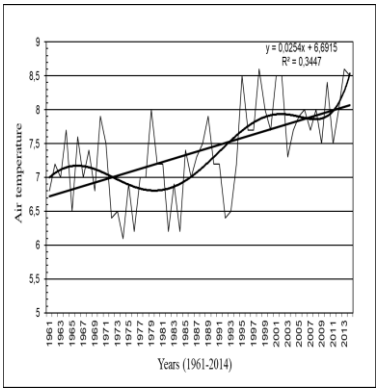
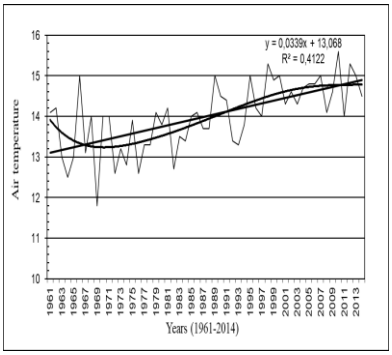


b)

[4] Suleymanov, M.F. Change in surface air temperature regime and its potential impact on the conditions of TAKE-OFF and Landing of aircraft in Ganja-Gazakh region // — Almaty: Hydrometeorology and ecology Quarterly scientific and technical journal, - 2021. No. 4, - p. 48-52.



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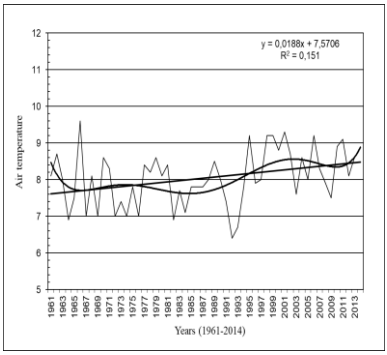

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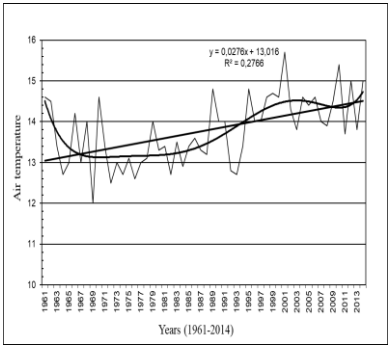

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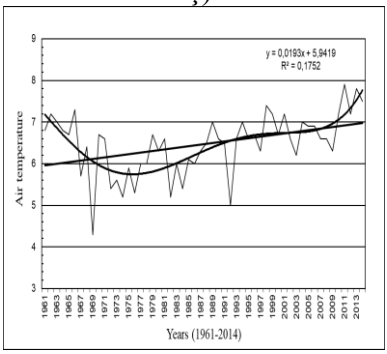


e)

Source: on the basis of archival data of the National Hydrometeorological Service, developed by challenger M.F. Suleymanov.

Graph 1. The multi-year course of the average annual temperature (^{0}C) for the years 1961-2014 a) Agstafa b) Dashkasan, c) Shamkir c) Gadabey, d) Ganja e) Goygol-resort. (−)-linear distribution (^^^^)-polynomial distribution.

The absolute maximum temperature in the area in July is 41^{0}C in Agstafa, 34^{0}C in Dashkasan, 39^{0}C in Shamkir, 35^{0}C in Gadabey, 41^{0}C in Ganja, and 30^{0}C in Goygol-resort. The absolute minimum temperatures for stations in January (1881-2014) were -26^{0}C in Agstafa, -24^{0}C in Dashkasan, -17^{0}C in Shamkir, -25^{0}C in Gadabey, -18^{0}C in Ganja, and -24^{0}C in Goygol-resort. The statistical

significance of the homogeneity of the ranks by year was checked by Fisher and Student criteria.

When determining the statistical significance of the variation of the average monthly values of the air temperature with Student's and Fisher's criteria, some months were significant in parallel with both criteria, while others were insignificant. Statistically significant months are II,III,X in Agstafa, I,III,VI,VIII,X in Dashkasan, III,VI,VIII,X in Shamkir, X in Gadabay, I,III,VI,VIII,X in Ganja, and III,VIII in Goygol resort. for months. The statistical significance of the homogeneity of the ranks by year was analyzed with a 5% guarantee of Fisher and Student criteria. Mean square deviations of the analyzed temperature series were distributed in the intervals of 1.4-1.7. In 1991-2014, the variation coefficients of average monthly air temperature anomalies (1961-1990) relative to the multi-year norm were distributed in the range of 0.6-1.6.

An increase in air temperature causes a decrease in air density, which in turn increases the range of Aircraft. An increase in the run-off distance can also lead to a decrease in the aerodynamic characteristics of the aircraft, deviation from the take-off runway, and an accident. The higher the air temperature and the lower the atmospheric pressure, the faster the descent speed. The change in running distance compared to standard conditions is calculated by the following formula[5]:

$$L_{EN} = L_{st.EN} \frac{T}{T_{st}} \frac{p_{st}}{p}$$

Here, L_{EN} and L_{st}. EN – running distances at actual T and standard T_{st} temperatures, respectively; p and pst represent actual atmospheric pressure and standard pressure, respectively. According to our calculations, the fact that the actual air temperature is 10^0C different from the standard atmospheric temperature causes a 3.5% change in the running distance on the earth's surface. The horizontal

[5] Leshchenko, G.P. Aviation meteorology / G.P. Leshchenko. - Kirovograd: Publishing House of GLAU, - 2009. - 488 p.

length of the runway of Ganja International Airport located in the studied area is 3300 m. However, taking into account the current trend, we recommend that the horizon length of the airports planned to be built in the region in the future should be 0.2-0.4 km larger than the existing airports. Taking into account the approximate height of the area above sea level, we suggest the length of runways in the range of 3500-3700 m. At the same time, it will make the flights economically profitable.

Also, in the second chapter, the effect of wind parameters on flights was assessed. Taking into account the influence of wind parameters on aviation flights, multi-year wind observation data on the territory was studied. Per meteorological stations located in the Ganja-Gazakh region, the multi-year dynamics of the average annual wind speed during 1961-2014 was analyzed. According to the linear trend, with the exception of Shamkir and Gadabay, a decrease in the average annual wind speed is observed in other areas.

Table 1

Anomalies of average monthly wind speed in 1991-2014 with respect to multi-year norm (1961-1990) (m/s)

Stations	Months												
	01	02	03	04	05	06	07	08	09	10	11	12	Yearly
Agstafa	-0.5	-0.2	-0.2	-0.5	-0.4	-0.4	-0.8*	-0.8*	-0.6	-0.6	-0.6	-0.6	-0.5
Dashkasan	-0.5	-0.4	-0.3*	-0.5*	-0.3	-0.5	-0.6*	-0.5	-0.5	-0.6	-0.5	-0.7*	-0.5
Shamkir	0.0	0.4	0.5	0.3	-0.1	-0.2	-0.1	0.0	0.1	0.1	0.0	-0.1	0.1
Gadabay	1.2*	1.5	1.8*	1.3*	1.5*	1.5*	1.4*	1.5*	1.6*	1.6*	1.7*	1.7*	1.6
Ganja	-0.6	-0.4	0.0	-0.4	-0.6	-0.2	-0.4	-0.4	-0.5	-0.5	-0.8	-0.9	-0.5
Goygol-resort	-0.5	-0.4	-0.5	-0.4	-0.5	-0.3	-0.3	-0.3	-0.2	-0.1	-0.3	-0.7*	-0.4

Source: on the basis of archival data of the National Hydrometeorological Service, developed by challenger M.F. Suleymanov.

Note: * indicates statistical significance according to Student's or Fisher's tests.

Comparing the average monthly wind speed values during 1991-2014 with the multi-year norm (1961-1990), it was -0.5 m/s in

Aghstafa, -0.4 m/s in Dashkasan, -0.5 m/s in Ganja, -0.4 in Goygol resort. m/s decrease, 0.1 m/s increase in Shamkir, 1.6 m/s increase in Gadabey[6]. The difference obtained from the comparison of the average monthly wind speed (1991-2014) with the multi-year norm is shown in the mean square deviation values. Quantities of root mean square deviations are distributed in intervals of 0.3-1.1. In 1991-2014, the coefficients of variation of the average monthly wind speed (1961-1990) relative to the multi-year norm were distributed in the intervals of 0.4-1.2. The average annual number of days with strong winds (>15 m/s) in the area, in Agstafa (31 days), Dashkasan (3 days), Shamkir (12 days), Gadabey (9 days), Ganja (26 days) and Goygol resort (3 days) is observed. During the construction of airports, first of all, the direction of the prevailing winds is thoroughly investigated with reference to multi-year climate survey books and observational data. Except for Ganja international airport, no civil airport operates in the studied area.

Table 2

Repetition of prevailing wind direction (%)

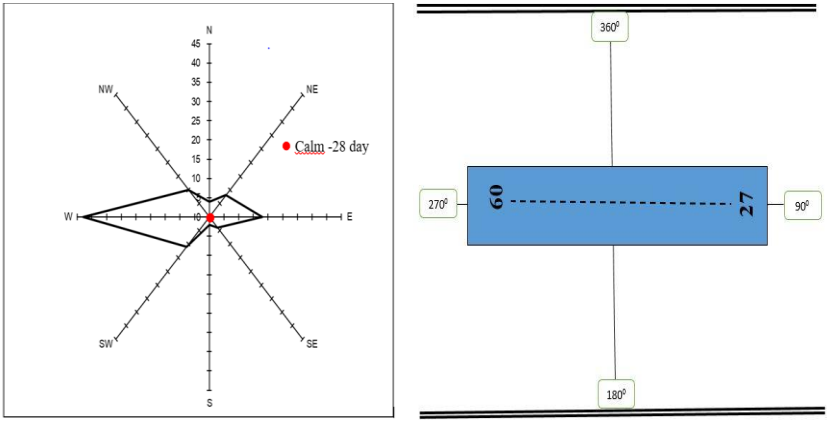
Stations	Yearly (%)								
	Şm	ŞmŞ	Ş	CŞ	C	CQ	Q	ŞmQ	Calm (day)
Agstafa	2.0	3.0	16	13	2.0	22	20	22	-
Dashkasan	12	32	3.0	1.0	4.0	12	30	6.0	-
Shamkir	4.0	8.0	18	4.0	2.0	11	43	10	28
Gadabay	17	17	11	1.0	5.0	26	16	7.0	-
Ganja	2.0	2.0	12	5.0	3.0	18	40	8.0	8.0
Goygol-resort	21	17	1.0	2.0	33	24	1.0	1.0	28

Source: on the basis of archival data of the National Hydrometeorological Service, developed by challenger M.F. Suleymanov.

[6] Suleymanov, M.F. Characteristics of multi-year changes in the wind regime in the Ganja-Kazakh region and assessment of its impact on aviation // - Baku: Works of the Azerbaijan Geographical Society "Geography and natural resources", magazine, - 2018. No. 2, - p. 57-60.

The physical-geographical position of the area, the actual potential for the development of tourism, the wealth of raw materials for the development of the industry can always bring the construction of the airport to the agenda in other regions in the future. As a result of the conducted research, the percentage rate of winds blowing from different directions and stormy days for many years was calculated, and based on this, wind roses were constructed to visually show the direction of prevailing winds.

The direction of the prevailing winds is taken as the basis for the construction of airfields at airports. Since aircraft climbes and descends against oppose to wind direction, the numbers of the courses in the runway are written in the opposite direction of the geographical coordinate.



a) b)

Source: based on archival data of the National Hydrometeorological Service, developed by challenger M.F. Suleymanov.

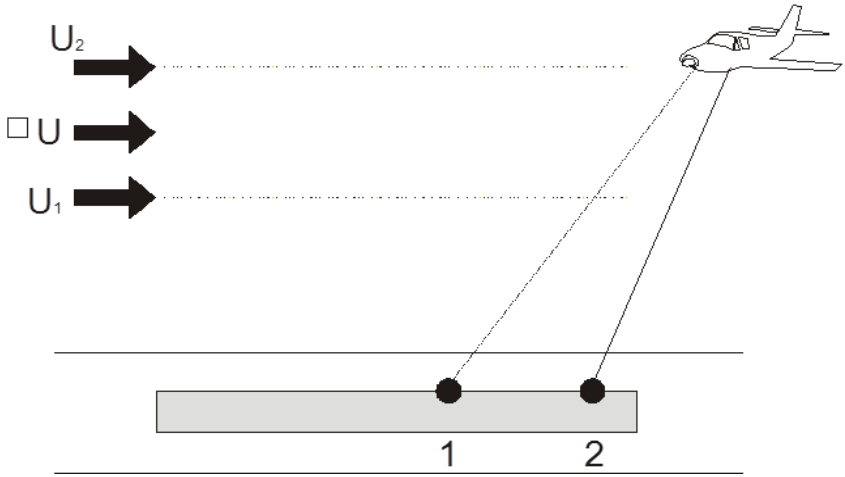
Figure 1. Courses of wind rose and Runway at Shamkir station. a) Wind Rose (%) b) Intended Runway Courses.

According to the results obtained from the analysis of the direction and speed of prevailing winds in the studied area, a wind rose was constructed based on the wind data of the Shamkir

hydrometeorological station in Figure 1, and the flight courses of the runway (090^0-270^0) were determined accordingly. The same pictures were made on other stations. The geographical directions of the runways of other studied areas are recommended as follows: 320^0-140^0 in Aghstafa, 050^0-230 in Dashkasan, 050^0-230^0 in Gadabay, 090^0-270^0 in Ganja, and 180^0-360^0 in Goygol.

Also, in the second chapter, the event of wind slide, which is considered a dangerous meteorological phenomenon has been studied. At short distances during the takeoff and landing phases, weakening of the headwind or strengthening of the crosswind can lead to a loss of flight altitude.

Windshears are classified into two types according to their influence on aircraft: vertical and horizontal[7].



Source: developed by contender M.F. Suleymanov using CorelDRAW software.

Figure 2. Vertical wind shear caused by a sharp decrease of headwind during descending 1-Intended landing point, 2-Actual landing point due to wind shear.

[7] Huseynov, N.Sh. A short course of lectures on the discipline "Aviation meteorology" / N.Sh. Huseynov, G.I. Kuliev - Baku: SADA, - 2004. - 95 p

During the climb and descent phases, vertical wind shear is considered to be more hazardous.

Encountering strong vertical wind shear during the descent phase may cause to land the aircraft at the point beside to aiming point of the runway. This, might cause an accident resulted with landing on terrain or excursion of aircraft from runway.

A sharp decrease or relative increase in headwind during the descent phase can lead to a deficiency of a lifting power and a crash before reaching the aiming point. During a wind shear event, the flight crew is advised to facilitate control of the aircraft and return it to the calculated trajectory:

– The crew captain should increase the airspeed during the sharp weakening of the headwind during the takeoff and landing phases;

– The crew captain can compensate for the reduced indicated air speed (IAS) due to the effect of wind shear by increasing the thrust of the engine and changing the pitch angle. According to the instrumental flight rules (IFR), if the measures taken have no result, it is required to go around[8].

The assessment of vertical wind shift in the 0-100 m layer is very important during the meteorological support of flights. In the ICAO guidelines, wind shears are characterized by strength as (0-2 m/s) weak, (2.1-4 m/s) moderate, (4.1-6 m/s) strong, (>6 m/s) strong accepted as strong[9]. The vertical wind shift was taken as a value equal to 30 m, and the horizontal wind shift was equal to 600 m. The vertical wind shear and its variation with height were calculated as follows[10]:

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[8] Safonova, T.V. Aviation meteorology: textbook. / T.V. Safonova. - Ulyanovsk: UVAU GA (I), - 2014. - 215 p.

[9] Manual on Low-level Wind Shear // Doc 9817 AN/449. – Montreal: İCAO, – 2005, – 213 p.

[10] Guliyev, H.I. Aviation meteorology / H.I. Guliyev.- Baku: Polygraphic Center of MAA, - 2019. - 362 p.

$$\beta_s = \frac{|\Delta u_s|}{\Delta h}$$

There $|\Delta u_s|=|u_y-u_a|$-modulus of vector difference of wind in upper and lower layer, m/sec; Δh-he thickness of the considered layer.

According to Table. 3, wind drift in the studied area is observed in all months. Due to its strength and impact on aircraft handling, the area experiences mostly weak and moderate wind shears. Weak 46.7%, moderate 48.2%, strong 2.6%, very strong 2.5% were observed.

Table 3

Replication of wind shear in the 0-100 m surface layer (%)

Power	Months												Year
	01	02	03	04	05	06	07	08	09	10	11	12	
Weak	60	50	48	41	50	27	45	48	44	46	47	54	46.7
Mild	38	47	49	56	46	65	36	52	50	50	46	43	48.2
Strong	2.0	1.0	3.0	1.0	3.0	2.0	8.0	1.0	4.0	2.0	3.0	2.0	2.6
Very Strong	0.0	2.0	0.0	3.0	1.0	6.0	10	0.0	2.0	2.0	4.0	1.0	2.5

Source: Ganja International Airport, on the basis of archival data of "Ganjaaeronavigation" Aeronautical Meteorological Provision Department, developed by claimant M.F. Suleymanov.

The third chapter of the dissertation is devoted to "**Analysis of the trend of regional changes in atmospheric precipitation and their impact on flights**". The regional climate changes that occurred in the studied area did not leave an impact on the atmospheric precipitation. From the analysis of the multi-year course of atmospheric precipitation (1961-2014), it is concluded that, except for Gadabay, a decrease in the total amount of precipitation is observed in other areas. In Agstafa: -18 mm, in Dashkasan: -21 mm,

in Shamkir: -57 mm, in Ganja: -26 mm, in Goygol-resort -33 mm decrease, and in Gadabey there is an increase of 47.8 mm[11].

In general, there is a decrease of 18 mm in the amount of atmospheric precipitation in the region. Differences have emerged from the comparison of the average annual amount of atmospheric precipitation (1991-2014) with the multi-year norm (1961-1990), which are reflected in the mean square deviation values. Mean square deviation values are distributed in intervals of 100-208. Variation coefficients are distributed in intervals of 0.8-5.5.

The average number of rainy days in Agstafa is 80.6 (days); Dashkesan 154.6 (day); Shamkir 138.4 (day); Gadabay 122.8 (day); Ganja 117.6 (day); Goygol-resort is (87.6) days. From the obtained calculations, it is known that the most rainy days in the area are observed in Dashkasan, and the lowest in Aghstafa. Average annual values of duration of rainy days (hours) are distributed by stations as follows: Agstafa 213.3 (hours); Dashkasan 242.3 (hours); Shamkir 284.2 (hours); Gadabey 400 (hours); Ganja 247.4 (hours); Goygol resort 211.9 (hours). Despite the fact that the number of rainy days on the territory is more in Dashkasan, the duration of precipitation is more in Gadabey station.

The fact that the studied area has a complex relief structure has caused an uneven distribution of the snow event in the area. In the relatively high points of the area, in addition to winter, snow events are observed in late autumn and early spring.

It is known that there are enough dangerous situations caused by snow in aviation flights. In particular, heavy snow not only worsens the visibility distance but also reduces the braking effect in the case

[11] Suleymanov, M.F. Analysis of the multi-year change trend of atmospheric precipitation in the Ganja-Gazakh region and its impact on aviation flights // - Baku: Scientific Collections of the National Aviation Academy, -2019. Volume 21, No. 2, – p. 103-110.

of freezing on the runway. Ice accumulation due to heavy snowfall causes a decrease in aerodynamic force in aircraft[12]. With the number of snowy days on the territory, the dynamics of its attendance are somewhat different. Thus, a decrease in the number of snowy days is observed at Agstafa, Shamkir, Dashkasan, and Ganja stations, and an increase and stable dynamics are observed at Gadabey and Goygol. During the continuation of the snowy days, the traffic at Gadabey station is stable, while it is remembered that it decreases in other stations.

Average annual values of the number of snowy days on the territory are distributed by stations as follows: Agstafa 16 (days); Dashkesan 54 (uncle); Shamkir 13.8 (uncle); Gadabay 65.5 (day); Ganja 10 (uncle); Goygol-resort 47.7 (day). From the observational data, it is known that the number of snowy days in the area is observed the most in Gadabay, and the lowest in Ganja. According to stations, the duration of snow is distributed as follows: Agstafa 78.2 (hours); Dashkesan 363.2 (hours); Shamkir 55.7 (h); Gadabay 308.4 (h); Ganja 42.4 (hours); Goygol resort 224.9 (hours). Continuous snow cover is not observed in the plain and foothill regions of the studied area. Starting from 1200-1400 m above sea level, the thickness of the snow cover increases sharply. However, its distribution in individual mountain regions is different depending on local characteristics. The snow thickness is 35-40 cm in the area at 3000 m above sea level. The average multi-year number of snow-covered days is distributed as follows: Agstafa 16 (days), Dashkasan 84 (days), Gadabey 65 (days), Ganja 8 (days), Shamkir 11 (days), and Goygol-resort 87 (days).

During the observations of precipitation in the meteorological support of aviation flights, the intensity of atmospheric precipitation is determined according to its influence on the meteorological visibility distance. As a result of the influence of atmospheric

[12] Bogatkin, O.G. Fundamentals of aviation meteorology / O.G. Bogatkin. - St. Petersburg: RSHU, - 2009. - 338 p.

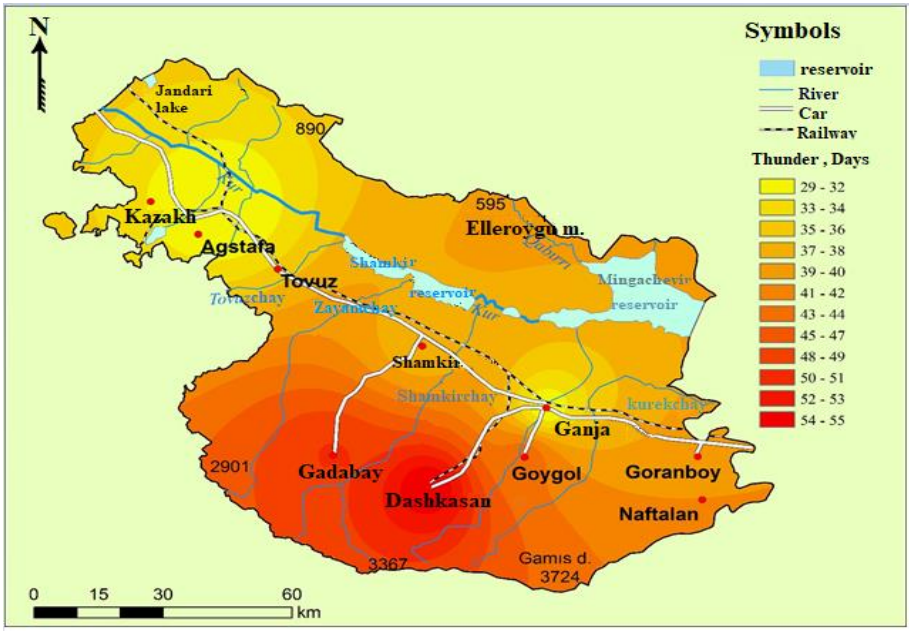
precipitation, if the meteorological visibility distance is reduced to 2000 m, such precipitation is weak, if the visibility distance is 1000-2000 m, its intensity is moderate, if the visibility is less than 1000 m, such atmospheric precipitation is considered as precipitation with strong intensity[13].

It is considered suitable for the location of the area where the airports to be built in the future are located, in relatively heavy rainfall zones. This is because, if the soil is clayey, it may become unusable during intense rainfall. This can cause aircraft's wheel bearings to break and cause an accident.

The fourth chapter of the dissertation is dedicated to the "**Investigation of the impact of hazardous meteorological events on aviation flights**". Despite extensive research, the climatic characteristics of meteorological events hazardous for aviation flights in some areas have not been fully studied yet. Taking these into account, the study of lightning phenomena observed in the Ganja-Gazakh region in modern times and the study of multi-year dynamics are very important in terms of ensuring the safety of flights. For this purpose, a trend analysis of the number of days with lightning and their duration by years was carried out by using the daily values of lightning observations of Agstafa, Dashkasan, Shamkir, Gadabey, Ganja, and Goygol-resort meteorological stations located in the area under review for the years 1981-2014 and corresponding results were obtained. The conducted analyzes show that as a result of the influence of modern climate changes, there is an increase in the number of days with lightning at all stations, and it is in full agreement with the indicator of observed days with lightning in the world. An increase in the average temperature of the air leads to the strengthening of convective processes and the increase of lightning processes. It affects the increase in the frequency and number of lightning events in the increase of convective processes in the area. The average number of days with lightning is 29.4 (days) in Agstafa,

[13] Huseynov, N.Sh. Synoptic meteorology / N.Sh. Huseynov. - Baku: - Polygraphic Center of MAA, - 2012. - 325 p.

55.2 (days) in Dashkasan, 36.3 (days) in Shamkir, 48.9 (days) in Gadabey, 30 (days) in Ganja and 43.5 (days) in Goygol-resort. The dynamics of the number of days with lightning are also observed in the frequency. That is, there is an increase in the duration of lightning at all stations in the area. The average duration of lightning is 36.9 (hours) in Agstafa, 86.0 (hours) in Dashkasan, 46.6 (hours) in Shamkir, 112.9 (hours) in Gadabey, 44.9 (hours) in Ganja, and 71.3 (hours) in Goygol-resort[14].



Source: Prepared by the claimant M.F. Suleymanov using the ArcGis program.

Figure 3. Map scheme of the average number of days with lightning

[14] Huseynov, N.Sh. Suleymanov, M.F. Analysis of multi-year change trend of lightning processes in Ganja-Gazakh region and its impact on aviation flights // - Baku: Scientific Works of the National Aviation Academy, - 2018. No. 1, - p.169-176.

In the studied area, it is more appropriate to build the airports that are planned to be built in the future in a relatively favorable area, that is, outside the areas dominated by intense convection zones. If aircraft do not have radio-technical means for identifying lightning centers and radar control from the ground, flights in complex meteorological conditions in lightning activity zones are prohibited. Therefore, restrictions on bypassing a certain distance from thunderclouds apply. If the flight time is switched to visual control, it is allowed to fly 10 km from the side of the thundercloud, 500 m above it, and 30 km from the other if there are two thunderclouds. When driving with the device, it is necessary to pass thunderclouds observed by the onboard radar, 15 km to the side of the radio-echo, 500 m above, and no less than 50 km between two lightning centers. Visual flights from under the thundercloud are allowed only during the day, along the edge of heavy rain zones, over relief and artificial obstacles at a safe distance of 200 m in plains and foothill regions, and 600 m in mountainous and hilly regions[15]. It is forbidden to enter the thundercloud as much as possible during the flight. In the fourth chapter of the dissertation, hail processes were also studied. The number of days with hail is unevenly distributed over the territory[16].

Thus, there is an increase in Ganja, Gadabey, and Dashkasan stations, and a decrease in Goygol-kurort, Aghstafa, Shamkir (1981-2014). The average number of days with hail is 1.1 (days) in Agstafa, 1.2 (days) in Dashkasan, 0.6 (days) in Shamkir, 2.9 (days) in Gadabey, 0.5 (days) in Ganja, and 1.7 (days) in Goygol-resort. With the exception of Shamkir station, according to the linear trend curves, the number of days of hail coincides with its duration.

[15] Annex 3 to the Convention on International Civil Aviation "Meteorological Service for International Air Navigation" // This edition replaces, from November 10, 2016, all previous editions of Annex 3. - Montreal: ICAO, -2016, - 216 p.

[16] Safarov, S.G. Thunderstorm and mudslide phenomena on the territory of Azerbaijan and radar methods of their forecasting / S.G. Safarov. - Baku: Elm, - 2012. - 292 p.

We can accept the decrease in the number of days with hail as a result of climate change. The average annual number of hailstorms differs slightly from the distribution number. Thus, it is 0.2 (hours) in Agstafa, 0.2 (hours) in Dashkasan, 0.09 (hours) in Shamkir, 0.6 (hours) in Gadabey, 0.13 (hours) in Ganja, and 0.2 (hours) in Goygol-resort. In the studied area, the lowest indicator of hail duration is observed in Ganja, and the highest indicator is observed in Gadabay.

Fog belongs to the atmospheric phenomenon that worsens visibility and is very dangerous for aviation. It should be noted that according to ICAO statistics, 62% of air accidents are caused by poor visibility. Fogs are divided into 4 places according to their visibility deterioration, i.e. their intensity: 1. Very strong fogs - visibility distance less than 50 m; 2. Strong fogs - visibility distance 50-200 m; 3. Moderate fogs - visibility distance 200-500; 4. For weak fogs, the visibility distance is 500-1000 m.

During the years 1981-2014, both the number of foggy days and the frequency of foggy days decreased at all stations in the studied area. The average multi-year number of foggy days is 34 (days) in Agstafa, 183.3 (days) in Dashkasan, 24.8 (days) in Shamkir, 21 (days) in Gadabey, 25.4 (days) in Ganja, and 187.4 (days) in Goygol resort[17]. The average annual value of fog duration (hours) is 69.3 (hours) in Agstafa, 1032.4 (hours) in Dashkasan, 64 (hours) in Shamkir, 110.7 (hours) in Gadabey, 66.7 (hours) in Ganja, and 468.1 (hours) in Goygol-resort.

Also, in the fourth chapter, the phenomenon of icing, which is considered a dangerous meteorological phenomenon, and its impact on flights were considered.

Icing is one of the most complex and dangerous atmospheric phenomena and affects the safety and regularity of aircraft flights to a great extent. The intensity of icing is determined by the thickness

[17] Suleymanov, M.F. Study of hazardous atmospheric processes in the Ganja-Gazakh region of Azerbaijan // - Almaty: Hydrometeorology and ecology Quarterly scientific and technical journal, - 2019. No. 1, - p. 27-32.

of the ice that accumulates on the same surface at the same time, depending on the temperature and the wetness of the clouds.

A special table of aircraft icing has been developed by ICAO[18] (Table 4)

Table 4

Intensity of Aircraft icing

Air temperature	Intensity of icing	
0…- 10^0C	Strong acing	>1,0 mm/min
-11…- 20^0C	Mild acing	0,5 -1,0 mm/min
-21…- 30^0C	Poor asing	<0,5 mm/min

Source: ANNEX 3 ICAO, Meteorological Service for International Air Navigation

An icing event can cause a violation of the aerodynamic qualities of the aircraft, a decrease in engine power, a disruption of radio communication, and errors in the indicators of the devices. Flights are prohibited in the zone of strong icing. Heavy icing occurs in cumulonimbus and stratiform clouds, as well as in low-temperature rain. The main parts of the aircraft exposed to icing: engine intake mechanisms, horizontal stabilizer, vertical stabilizer, wing angles of attack, windows of the crew cabin, air pressure receivers, chassis (ranked according to the degree of danger of icing).

To ensure the safety of aircraft during flight, it is recommended to observe the following rules:

- start the anti-icing system in gas-turbine engines when the air temperature is 5^0C and below;

- to activate the anti-icing system before icing, or according to the signal of the transmitter or when icing is detected visually;

[18] Leshchenko, G.P. Meteorological support of flights / G.P. Leshchenko, G.V. Percel, E.G. Leshchenko - Kirovograd: GLAU, - 2010. - 184 p.

- activate all anti-icing systems in precipitation before landing and before entering the cloud in landing mode and when the air temperature is 5^0C and below;

- in the winter period, it is necessary to increase the flight height from the severe icing zone, and in the warm period of the year, to descend to the positive temperature zone. When landing in icing conditions, if the anti-icing system does not activate, it is recommended to reduce the angle of inclination of the wing backs, increase the operating mode of the engine and the speed of descent.

In accordance with the current ICAO requirements, the average annual heights of the 0^0C, -10^0C, -20^0C, -30^0C isotherms for months and seasons have been determined to assess the probability of aircraft icing.

The average height of the 0^0C isotherm in the studied area is 1265 m in winter, 2501 m in spring, 3345 m in summer, and 1439 m in autumn; The average height of the -10^0C isotherm is 1940 m in winter, 4023 m in spring, 4995 m in summer, and 2767 m in autumn; The average height of the -20^0C isotherm is 3551 m in winter, 5689 m in spring, 5710 m in summer, and 4245 m in autumn; The average height of the -30^0C isotherm is 5035 m in winter, 6850 m in spring, 8330 m in summer, and 6110 m in autumn.

RESULT AND RECOMMENDATIONS

1. The average annual air temperature at the stations located in the research area has increased by 0.5-0.9^{0}C compared to the multi-year norm (1961-1990) in the period after 1991. The average temperature increase in the area was 0.8^{0}C.

2. The temperature increase in the Ganja-Gazakh region was 0.6^{0}C in winter, 0.7^{0}C in spring, 1.0^{0}C in summer, and 0.8^{0}C in autumn. As you can see, the essential temperature increase occurs in the summer months. The conducted analyzes show the increase in air temperature in the future, with the current dynamics, may cause certain problems in aviation flights, which will manifest itself in a decrease in the cargo carrying capacity of aircraft and an increase in

fuel consumption. To prevent this, it is proposed to increase the horizontal length of the newly built runways.

3. During the considered years in the Ganja-Gazakh region, the average wind speed decreased by 0.4-0.5 m/s in Agstafa, Dashkasan, Ganja, and Goygol, and increased by 0.1 and 1.5 m/s in Shamkir and Gadabey, respectively.

4. Based on the analysis of the prevailing wind data, the following runway headings were defined: 320^0-140^0 in Agstafa, 050^0-230^0 in Dashkasan, 090^0-270^0 in Shamkir, 050^0-230^0 in Gadabey, 090^0-270^0 in Ganja, 180^0-360^0 in Goygol.

5. In the studied region, a decrease in atmospheric precipitation was observed compared to the norm (1961-1990). This decrease is in Shamkir: -57.4 mm (16.5%), Ganja: -26mm (9%), Agstafa: -18mm (5%), Goygol Goygol-resort: -33mm (4.8%), Dashkasan: -10mm (1.6%), organized. An increase of 47.8 mm (6.9%) was observed in Gadabey.

6. The number of days with lightning during the considered period in the region increases from 30-40 days in the lowlands and foothills to 50-60 days in the mountainous areas. According to the linear trend curves, the number and duration of thunderstorm days is increasing during the considered period. A decrease in the number of days with hail is observed in Agstafa, Goygol, and an increase in Ganja, Gadabey, Dashkasan and Shamkir.

7. In the considered period, according to the linear trend curves, there is a decrease in the number and duration of foggy days, which are considered a hazardous occurences for aviation. The average number of foggy days in the area varies from 21 days to 138 days.

8. In order to estimate the probability of aircraft icing at the level of isotherms 0^0C, -10^0C, -20^0C, -30^0C, the average annual altitudes for months and seasons were determined.

Published scientific articles on the dissertation work:

1. Suleymanov M.F. The causes of the formation of "Air Gaps" in the atmosphere and the consequences they cause in aviation

flights / Scientific Works of the National Aviation Academy, – Baku: – 2011. No. 1, – p.184-198 (with Juvarov R.P., Safarov S.H., Jafarzade T.R.).

2. Suleymanov M.F. Statistical climate model of the air temperature field in the mountainous regions of Azerbaijan / Scientific Works of the National Aviation Academy, – Baku: – 2012. No. 1, – p. 115-132 (with Safarov S.H., Huseynov G.M., Safarov A.S., Mursalov R.G.).

3. Suleymanov, M.F. Multi-year change trend of dangerous atmospheric phenomena for small aviation on the north-eastern slope of the Lesser Caucasus // "Globalization and Geography" Professor M.A. International Scientific and Practical Conference dedicated to the 85th anniversary of Museyibov's birth, – Baku: BSU, – April 26-27, – 2012, – p. 154-160 (with Safarov S.H.)

4. Suleymanov, M.F., Research and assessment of the long-term trend of wind speed variability in the Greater and Lesser Caucasus // International Scientific Conference on Regional Problems of Hydrometeorology and Environmental Monitoring, – Kazan: KFU, – October –2–5, – 2012, – p. 166-167 (with Makhmudov R.N., Safarov S.G., Safarov A.S.).

5. Suleymanov, M.F. Distribution regularities of the wind regime in the Ganja-Kazakh region // Development of the science of geography in the years of independence, Republican Scientific Conference dedicated to the 70th anniversary of the Department of Physical Geography and the 40th anniversary of the Department of Hydrometeorology, – Baku: BSU, – December 16, – 2013, – p. 620-623.

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7. Suleymanov, M.F. Analysis of the multi-year change trend of lightning processes in the Ganja-Gazakh region and its impact on aviation flights // – Baku: Scientific Works of the National Aviation Academy, – 2018. No. 1, – p. 169-176 (with Huseynov N.Sh.).

8. Suleymanov, M.F. Characteristics of multi-year changes in the wind regime in the Ganja-Gazakh region and assessment of its impact on aviation // - Baku: Works of the Azerbaijan Geographical Society "Geography and natural resources", magazine, – 2018. No. 2, – p. 57-60.

9. Suleymanov, M.F. Study of hazardous atmospheric processes in the Ganja-Gazakh region of Azerbaijan // – Almaty: Hydrometeorology and ecology Quarterly scientific and technical journal, – 2019. No. 1, – p. 27-32.

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11. Suleymanov, M.F. Global climate change and its regional aspects in Azerbaijan // –St. Petersburg: Bulletin of the International Academy of Sciences of Ecology and Life Safety, – 2021. T 26, No. 2, – p. 63-69 (with Makhmudov R.N., Agaev Z.B.).

12. Suleymanov, M.F. Change in surface air temperature regime and its potential impact on the conditions of TAKE-OFF and Landing of aircraft in GANJA-GAZAKH region // – Almaty: Hydrometeorology and ecology Quarterly scientific and technical journal, – 2021. No. 4, – p. 48-52.

13. Suleymanov M. Global climate change and its regional impacts in Azerbaijan // İnternational scientific and technical conference “Modern problems of water management, environmental protection, architecture and construction” – Tbilisi: Water Management Institute , 25 –27 July, – 2021, p.122-128 (Together with R.Mahmudov).

14. Suleymanov, M.F. Study of hazardous atmospheric phenomena in Ganja - Gazakh region // February reports-2022 Creative potential of young people in solving aerospace issues Materials of VII International scientific-practical youth conference, – Baku: MAA, February 2-4, – 2022, – p. 160-164.

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