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**SPATIAL DISTRIBUTION OF DUST STORMS
IN THE SOUTHERN REGION OF KAZAKHSTAN
IN THE CONTEXT OF MODERN CLIMATE CHANGE**

Abstract. Problems of modern climate change and assessment of their consequences IPCC (2021-2023) according to the latest assessment reports, there is an increase in dangerous weather phenomena that cause significant social and economic damage in various regions of the Earth. In this article, various climatic factors affecting the state of dust storm formation associated with modern climate change were studied. It was established that the longest (72 hours) duration of dust storms at the Aral Sea station in the southern region of Kazakhstan in the period from 2005 to 2022 was recorded in May 2018. The values of meteoroparameters at that time, that is, its dependence on weather conditions, quantitative indicators of solar activity (Wolf number), bioclimatic indicators, as well as the conditions of macrocirculation formation, were considered, and it turned out that there was an important correlation relationship between the number of days when dust storms were most observed and the Wolf number ($r = 1.00$), Wangenheim-GIRs circulation forms, including the e Form ($r = 0.49$), El- Niño indices ($r = 0.47$ as a result of the analysis, it was determined that the prolonged Observation of dust storms was associated with the north-western cold front.

Keywords: dust storm, Wolf number, bioclimatic indicators, atmospheric circulation, correlation coefficient, indexes.

Introduction. Dust storms are dangerous weather phenomena. Dust storms are when a large amount of dust and sand rises into the air by the wind, clouding of the atmosphere and a significant deterioration in visibility. Transportation of a large amount of thick dust or sand by strong winds is a characteristic phenomenon of deserts and steppes, as a result of which wind destruction or soil deflation occurs [1].

Systematic monitoring of dust storms in the network of meteorological stations dates back to 1936. The first work on the climatological generalization of these observations for certain areas of Central Asia took place in the 60s of the last century. The description of the spatial distribution of dust storms for northern Kazakhstan was considered by A. S. Uteshev and O. E. Semenov (1967, 1977) and Yu.M. Chirkov (1970), for the South-East – L. P. Fedyushina (1972), for the West and south-west – A. P. Agarkova (1972) [2-6].

The zoning of the entire flat territory of Kazakhstan by the number of days with dust storms in a year was performed by E. A. Seredkina (1960), L. P. Fedyushina and O. E. Semenov (1970). O. E. Semenov and L. P. Tulina (1978) published a detailed schematic map of the number of days with dust storms in a

year for the territory of Kazakhstan. Shardakova and L. V. Usmanova (2006) analyzed the state of dust storm phenomena near the South Aral Sea in 1990-2000 due to a decrease in the level of the Aral Sea [7-10].

The first attempt to collect data on the dust storm regime in the territory of Central Asia, which included Turkmenistan, Uzbekistan and South Kazakhstan in the period 1951-1955, was made by N. N. Romanov in 1960. In addition to analyzing the recurrence and duration of dust storms during this period, N. N. Romanov classified synoptic conditions for the development of dust storms and made recommendations for predicting them. He noted that in the main part of Central Asia, the north, northeast and northwest winds promote the formation of dust storms, and in the southern part (in Turkmenistan) this role is played by the East and southeast winds. In a later period, the entire Central Asian territory was zoned. So, S. A. Sapozhnikova (1970) compiled a map of the number of days with dust storms for the arid region of the USSR. The map of L. V. Klimenko and L. A. Moskaleva (1979) shows the distribution of the number of days with dust storms on the territory of the USSR. A. N. Zolotokrylin (1996) from 1936 to 1985 tried to diagnose the geographical distribution of repeated dust storms in the Turanian lowland according to surface observations at 65 meteorological stations. When comparing these maps, stable and variable features of the geographical distribution of dust storms in Central Asia are distinguished. A. N. Zolotokrylin noted that a distinctive feature of the spread of dust storms in the territory under consideration is the stable isolation of large foci in Turkmenistan and the East Aral region and their attachment to sandy fields [11-14].

In most of the territory, a significant decrease in the recurrence of dust storms was found in the period 1970-2000. However, since the late 1970s, against the background of a negative trend in the recurrence of dust storms in most of the territory, the recurrence of dust storms near the Aral Sea, south of Lake Balkhash and north of the Caspian Sea began to increase. Foci of high repeatability of dust storms in Central Karakum remain, but its intensity has decreased [15].

The spatio-temporal distribution of dust storms in the southern regions of Kazakhstan in the period from 2005 to 2022 and the meteorological conditions of the longest observed dust storm in this period were considered in the previous article [16].

One of the meteorological values that occupies an important place during a dust storm is wind speed. Studies by many scientists have shown that the wind regime is one of the main meteorological factors that cause dust storms. The higher the wind speeds, the greater the amount of dust and sand is carried over a larger area. The higher the wind speeds, the greater the danger of dust storms [17].

In the considered territory, meteorological factors have their own impact on the formation of dust storms. A long dust storm depends on the amount of precipitation, that is, a long rainless period, the amount of rainless and rainy days in a month, and the height of the snow cover in the Cold 3 months of the year [18].

The dependence of the dust storm on the height of the snow cover is associated with time and space. In the south of Aktobe region, the number of days of dust storms in April depends on the height of snow cover in January and February. The dependence of dust storms on the height of snow cover shows that the height of snow cover in the Shalkar district in the first ten days of February and in the first and third ten days of January is closely related to the recurrence of storms in April. In the east of Atyrau region, dust storms in August depend on the height of the snow cover in the third ten days of February and the first ten days of January. And in the south of the Turkestan region, dust storms that occur in April are closely related to the third ten days of March. In connection with such studies, we can conclude that the recurrence of particularly dangerous dust storms in individual areas is influenced by the snow cover of the past winter. This dependence is an important factor in the development of methods for predicting dust storms [19].

A. L. Chizhevsky showed that during the period of increased solar activity, natural disasters and epidemics occur on earth. From this, conclusions were drawn about the impact of the 11-year cycle of solar activity on climatic, geological and social processes on earth. According to the research of A. L. Chizhevsky, it was established that known solar storms cause large catastrophic, that is, Stormy phenomena [20].

Atmospheric circulation is one of the factors of climate change. Climate change has a significant impact on the economic activity of a person, his living conditions and directly on the health of people. The

variability of atmospheric circulation is the cause of changes in atmospheric pressure, wind, air temperature and humidity in different regions of the Earth.

The use of atmospheric circulation indices proposed by Wangenheim-Geers for the northern hemisphere is considered one of the main forms used in both science and practical applications. It is valid for assessing the contribution of atmospheric circulation to climate change.

During the e-form, significant precipitation deficit zones are observed in the meridional area along the Volga River from the Caspian Sea. The reason for the lack of precipitation in this air is the location of the High Ridge in the troposphere and the mixing of this ridge with the edge, sometimes the center of the Siberian anticyclone on earth. After that, positive pressure anomalies are created and the anticyclogenesis process is intensified. Even in a warm half-year, the distribution of precipitation will be the same as the distribution of winter precipitation. In the western and southwestern regions of Kazakhstan, precipitation will be below normal [21].

The main feature of long thermobaric waves of form E is their stationary nature. Located on a high ravine, that is, it affects the western and southwestern regions of Kazakhstan, that is, due to the import of dry air masses into these regions, the air temperature increases, and as the temperature increases, the soil moisture decreases, creating conditions for the formation of dust storms [22].

Among the phenomena of a planetary scale occurring in the Earth-atmosphere system - the ocean, El Niño-South oscillation (Southern occurrence Index - SOI) has been of great interest in recent years. They explain the annual intermediate changes in atmospheric pressure, wind and precipitation on the earth's surface, which have opposite signs of anomalies in the tropical regions of the eastern and western hemispheres. With the Southern Oscillation of the atmosphere, the phenomena of El Niño and La Niña are closely related. Therefore, they are considered by El Niño-South oscillation as a single phenomenon. ENUT-monitoring with several indices [23].

In the process of considering the microcirculatory conditions of dust storms in the South Kazakhstan region in the period from 2005 to 2022, the connection with the El Niño phenomenon during the period of the storm was studied [24].

According to research by A. P. Agarkova (1950-1969) in the study area studied was observed that dust storms often occur against a temperate and weak background of small areas covering one or more areas. The nature of its occurrence is determined not only by the state of the paving surface but also depends on the direction and intensity of atmospheric processes that have developed on the Earth's surface and altitude [25].

The relevance of the research work is that in the last decade there are significant changes in climatic characteristics and resources, which are determined by the relative and socio economic systems. Among the most dangerous weather phenomena are droughts and dust storms, therefore, due to the unfavorable consequences of dust storms, the problem of studying the conditions for the occurrence and spread of this phenomenon remains relevant. The study of dust storms not only allows us to predict it, but also effectively helps to combat it, that is, to carry out anti-erosion measures, insure the national economy, and much more. The purpose of the research work is to consider the spatial distribution of dust storms in the southern region of Kazakhstan in the period from 2005 to 2022 in the context of modern climate change.

As objectives of the study, the spatio-temporal distribution of dust storms in the southern region of Kazakhstan for the period 2005-2022 was determined and the dependence of the longest observed dust storms for these years on meteorological conditions, quantitative indicators of solar activity (Wolf number), bioclimatic indicators, as well as macrocirculation conditions was determined.

Materials and research methods. To determine the conditions for the formation of dust storms at the Kyzylorda, Aral Sea, Kyzylkum, Ashysay, Zhosaly stations located in the south of Kazakhstan, the values of the weather parameters during their longest observation in the period from 2005 to 2022 (based on complementing the values in the previous article), that is, its dependence on weather conditions, quantitative indicators of solar activity (Wolf number), bioclimatic indicators, as well as the conditions of macrocirculation formation were studied.

The object of the study was the Stations of the Aral Sea, Kyzylorda, Kyzylkum, Zhosaly, Ashysai in the southern region of the Republic of Kazakhstan. South Kazakhstan is a region that occupies a large valley from the Aral Sea in the west to the Zhetysu Alatau in the East and from Lake Balkhash in the North and the Betpakdala desert to the border of Kazakhstan in the South. Kyzylorda region is located in the southern part of Kazakhstan. It borders South Kazakhstan to the East and Southeast, Karaganda to the



Figure 1 – Map-scheme of the research area

North, Aktobe region of the Republic of Kazakhstan to the Northwest, and the Republic of Uzbekistan to the South. Due to the fact that one of the largest environmental disasters – the Aral Sea problem – is located in the Kyzylorda region, all areas of the region are considered environmentally catastrophic zones. The territory of the region is located in the east of the Aral Sea in the lower reaches of the Syrdarya River, the main part is located in the Turan lowland. The west of the region is adjacent to the Aral Sea, in the south-east there are North-Western Spurs and Foothill plains of the Karatau Ridge, in the north-west there are wide valleys of mountain sands of the Aral Karakum. On the Left Bank of the Syrdarya there is a wide range of hilly-Ridge sands of Kyzylkum, cut through the dry channels of the Zhanadarya and arid Darya. On the right bank there are Hills (Yegizkara), sandy areas (Aryskum, etc.), shallow basins occupied by salt marshes. In the north there are hilly sand massifs (lesser Badger and Aral buckwheat). In the South-East, the North-Western Spurs of the Karatau Ridge are included in the territory of the region. On a wide concave plain, which gradually descends from the edge of the Turanian lowland to the center, there are a number of large sandy massifs intersecting with clay Plains. Karakum near the Aral Sea is located in the north-east of the Aral Sea, in the south it is bordered by the Syrdarya River. Most of the desert territory is located within the Aral and Kazalinsky districts of the Kyzylorda region. In general, the climate of this belt is characterized by long hot summers, cold winters for these latitudes, extremely dry air, little cloudiness, little precipitation distributed unevenly throughout the year, and a slight snow cover. This climatic regime is determined by the location of the region in the center of the Eurasian continent of the Kyzylorda region, on the northern edge of the inner tropical deserts of Asia, the peculiarities of atmospheric circulation, the nature of the Earth's surface and other factors. To the north, it allows cold air masses to freely enter the region and cool down suddenly, especially in winter. There is a drought characteristic of the climate of the region, where there is little precipitation, not exceeding 190 mm. Precipitation is unevenly distributed throughout the seasons, occurring mainly in the winter and spring months, accounting for 60% of the total precipitation. Frequent and strong winds blow throughout the region, with an average annual speed of 3.1-6.0 M/s. In winter, these winds blow away the snow cover, causing deep freezing of the soil, and in summer, dust storms are observed. Basically, the entire territory of the region is characterized by frequent and strong winds of the northeast direction [2].

In the process of carrying out the work, generally accepted methods of processing mathematical, statistical and climatological data were used.

As bioclimatic indicators, the Effective temperature according to Missenard and the "heat heat" index proposed by Stedman were calculated.

Bioclimatic indices determine the features of the thermal structure of the medium of a physical nature and are an additional indicator of the state of the thermal Valley. The degree of inconvenience caused by the excess of heat is usually determined by one or more biometeorological temperature indices. In

practice, effective temperature is often used. By itself, it gives the temperature of the still standing air, saturated with water vapor. In determining the effective temperature, the Missenard method is widely used. Effective temperature is widely used in the climatic assessment of thermal effects, environmental discomfort, and in treatment. The importance of effective temperature as a bioclimatic indicator is that it continues to be used both in the Warm Period and in the cold period.

The effective temperature according to Missenard is calculated using the following formula:

$$ET = t - 0,4 (t - 10) (1 - f/100), \tag{1}$$

where t – air temperature, °C; f – relative humidity, %.

Another index used to assess the effects of heat is the "heat" index, proposed by Stedman. It is widely used in the United States. Stedman's "heat" index is determined by the following formula:

$$HI = - 42,379 + 2,04901523t + 10,14333127f - 0,224754t \cdot f - 0,00683783t^2 - 0,05481717f^2 + 0,00122874t^2 + 0,00085282t \cdot f^2 - 0,00000199t^2 \cdot f, \tag{2}$$

where HI – heat index; t – air temperature, °C; f – relative humidity, %.

In the process of carrying out the work, generally accepted methods of processing mathematical, statistical and climatological data were used.

Research results. In the southern regions of Kazakhstan, the longest duration of dust storms in the period from 2005 to 2022 was recorded at the Aral Sea station in May 2018.

The dust storm began on May 26 at 11:00 local time and ended on May 29 at 11:00, that is, with a total duration of 72 hours. These days, at different times, a dust storm was also registered at the Kyzylorda station. In the process of considering meteorological conditions during these dust storms, data were obtained on air and soil temperatures, air humidity, wind speed and direction, visibility distance, as well as the amount of precipitation and the height of snow cover during the period of the storm.

The values of meteorological values during dust storms in the Aral Sea for the period from May 26 to 29, 2018 are given in the figures below (figure 2-4).

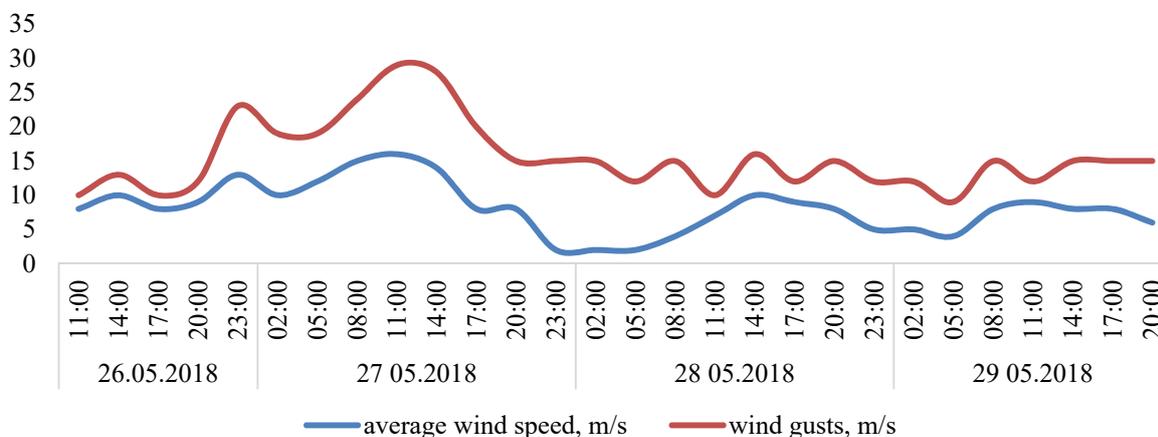


Figure 2 –Average wind speed and gusts during the longest observed dust storm at the Aral Sea station

According to figure 2, the dust storm, which began on May 26, intensified on May 27, and on this day the maximum value of the average wind speed (16 m/s) was observed, and the acceleration was 29 M/s. In later terms, the wind slowed down and only reached a high value again by the time the dust storm stopped. In most cases, the wind was from the north, north-west direction.

In the initial period of the beginning of the dust storm, the values of air temperature and soil temperature were higher, that is, at 11:00 on May 26, the temperature of the air was higher than 30 °C, and the temperature of the soil was 45 °C. That is, high air and soil temperatures create favorable conditions for the formation of dust storms.

Air humidity was observed as the inverse of air temperature and decreased at high wind speed values. When the wind speed increased, that is, when the dust storm intensified (on May 27 at 11:00 and 14:00 hours), the meteorological visibility distance was equal to 2.0 m.

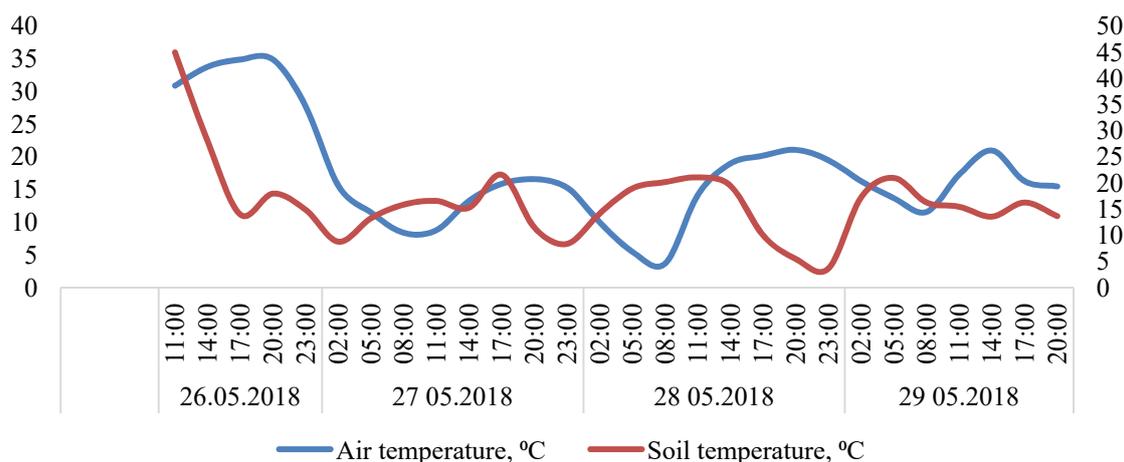


Figure 3 – Distribution of air and soil temperatures during the longest observed dust storm according to the Aral Sea station

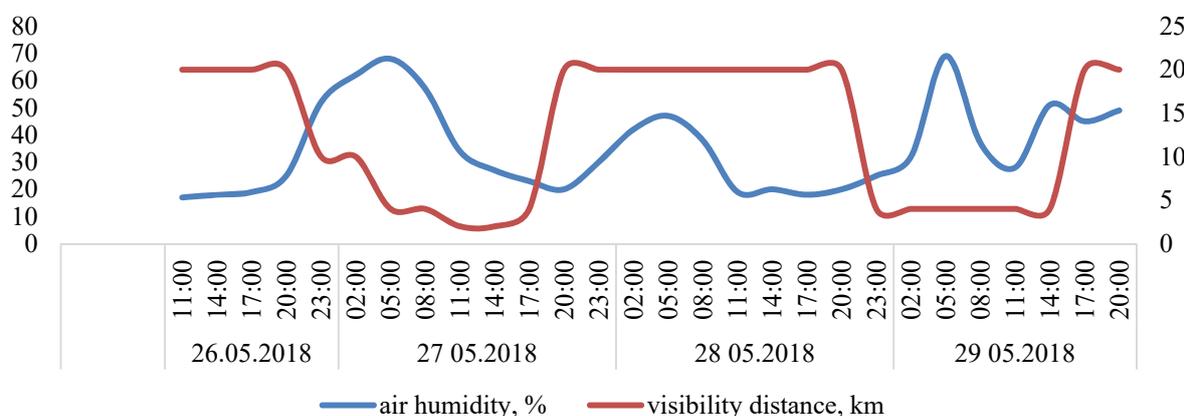


Figure 4 –Air humidity and visibility distance during the longest observed dust storm according to the Aral Sea station

The amount of precipitation (mm) and the height of snow cover at the Aral Sea station in December-May 2017-2018 (table 1).

Table 1 –The amount of precipitation in December-may (mm) and the height of the snow cover at the Aral Sea station for 2017–2018 years

Decada	12/2017		01/2018		02/2018		03/2018	04/2018	05/2018	General
	ΣR	H	ΣR	H	ΣR	H	ΣR	ΣR		
1 decada	5,6	0	13,2	6	3,5	17	8	–	–	30,3
2 decada	0,2	3	0,4	13,1		17	2	–	–	2,6
3 decada	10,3	5	14,1	15	6,8	16	4,4	0,4	–	36
For the moon	16,4		27,8		10,3		15,2	0,4	–	70,1
		3		11		17				10

Note. H is the height of the snow cover; ΣR is the amount of precipitation.

As shown in table 1, the Aral Sea station received 16.4 mm in December 2017, 27.8 mm in January 2018, 10.3 mm in February, 15.2 mm in March, 0.4 mm in April, and no precipitation at all in May. The height of the snow cover in December 2017 is very low, that is, only 3 cm, because in 1 decada there was no snow cover. At the same time, the average height of the snow cover also showed small values for January and February, that is, it was 11 cm in January and 17 cm in February. Due to such a small amount

of precipitation in winter, the degree of soil moisture was also low. Accordingly, the pavement surface quickly dried up, which affected the formation of dust storms, that is, a long absence of precipitation created conditions for the formation of storms.

Thus, a long dust storm depends on the amount of precipitation, that is, a long rainless period, in addition to the height of the snow cover in the winter months, as well as on solar activity (Wolf number).

The distribution of quantitative indicators of solar activity (Wolf number) during the longest observed dust storm for 2018 is given (figure 5).

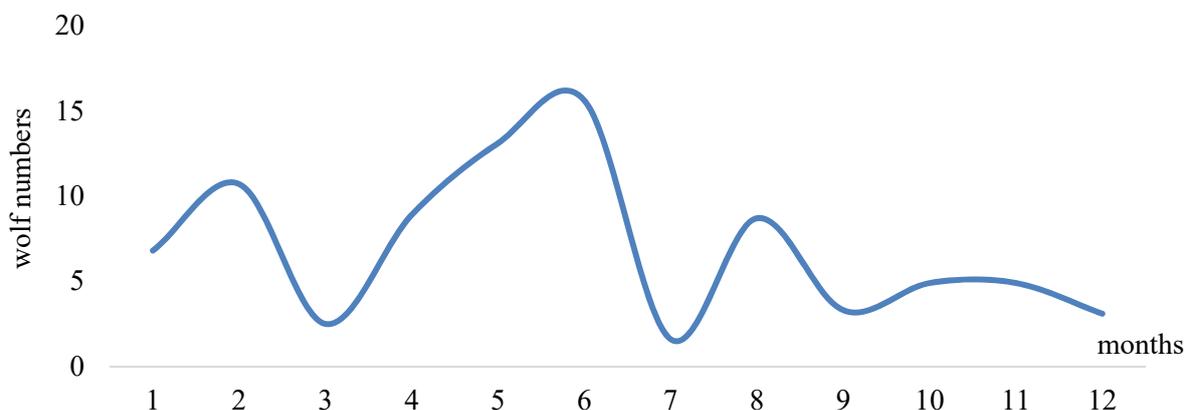


Figure 5 –Distribution of The Wolf number in 2018

As shown in figure 5, the increase in solar activity in 2018, when the longest dust storm was observed, falls on the spring months, especially in May and June, that is, during these months the value of The Wolf number increased to 13.1-15.3. The longest observed dust storm was observed at the Aral Sea station in 2018 in the period from May 26 to 29, according to which quantitative indicators of solar activity also showed high values during this period. From this it can be concluded that as the number of wolves increases, the repeatability of dust storms is more likely.

To assess the role of Wolf number 2005-2022. The coefficient correlation between the series of quantitative indicators of solar activity and the number of days in which dust storms were observed was calculated for the warm season. The values of The Wolf number and the average number of days during which dust storms were observed were taken as quantitative indicators of solar activity (table 2).

Table 2 – Correlation relationship between the number of days dust storm and the wolf numbers in the 2005-2022 years

Correlated dimensions	Months						
	3	4	5	6	7	8	9
South Kazakhstan region							
r (Wolf number; number of days)	0,39	0,42	0,53	0,35	0,39	0,30	-0,11
Aral Sea station							
r (Wolf number; number of days)	0,47	0,44	1,00	0,64	0,53	0,46	-0,13
<i>Note.</i> 1) CS is the number of days; 2) for N = 17 samples, the correlation coefficient is 0.45 at a confidence level of 95 % ($\alpha = 0.05$) [26].							

According to table 3, in 2005-2022. in determining the correlation relationship between the number of days when dust storms were observed in the South Kazakhstan region for a warm period and the wolf numbers, the correlation relationship is important when, according to the data given in Lakin's book "biometrics", the critical value of the correlation coefficient for 17 years is equal to 0.45. Accordingly, for the South Kazakhstan region, the correlation coefficient (0.53) was significant in May in the generally considered years. And the values of the coefficient correlation between the average number of days during which dust storms were observed at the Aral Sea station and the wolf numbers, especially in March-August, showed a positive sign and direct relationship (0.44-1.00). That is, the high values of the number

of days on which the dust storm was observed also correspond to the high values of the wolf numbers, and it can be seen that a very important direct relationship was observed, especially in May, when the correlation coefficient had a very high (1.00) indicator. Therefore, it can be concluded that the indicators of solar activity had a significant impact on the dust storms that occurred in this area.

Depending on the effective temperature value, a person's sense of heat was determined according to the following table (table 3).

Table 3 –Feeling of heat in a person due to the value of the effective temperature (°C)

Effective temperature	>30	30-24	24-18	18-12	12-6	6-0
Feeling	Very hot	Hot	Warm	Norm warm	Cool	Norm
Impact	Strong	Normal	Suitable	Suitable		

The effective temperature course on the Missenard of May 2018, when the longest dust storm was observed at the Aral Sea station, is given (figure 6).

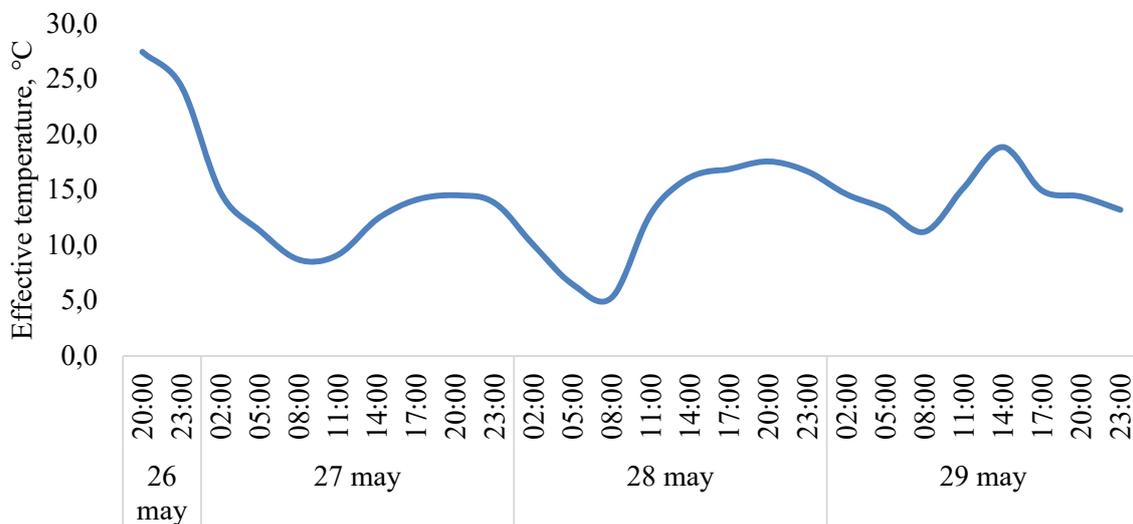


Figure 6 –Distribution of the Effective temperature course on the Missenard on the days when the longest dust storm was observed

According to figure 6, in May, when the longest dust storm was observed at the Aral Sea station in 2018, there was no significant change in the course of effective temperatures along the Missenard. In May, the effective temperature value at the time of the beginning of the dust storm was 27.4 °C, that is, it did not exceed 30 °C. This temperature is estimated to be a hot temperature according to the degree to which a person feels heat and is considered normal according to the effects it has.

Depending on the value of the HI index, the hazard category is determined according to the Table (table 4).

Table 4 –Hazard category depending on the value of the HI index

HI index value	Danger category	Possible deviations in the upper risk groups
27-32	Noteworthy	Presence of weakness in physical activity
32-41	Extreme caution	Muscle twitching, heat and sun passing, diseases of blood vessels from heat
41-54	Dangerous	Muscle inflammation, sun and heat transition
>54	Especially dangerous	Heat or sun pass

The course of the "heatstroke" Index according to Stedmen for May, when the longest dust storm of 2018 was observed at the Aral Sea station (figure 7) is given.

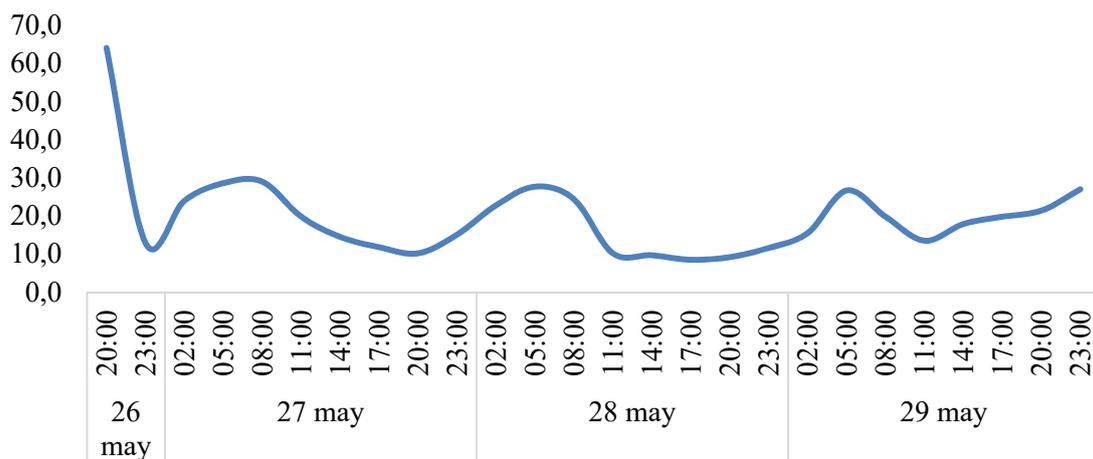


Figure 7 –The days when the longest dust storm was observed Stedman's "heat heat" indexes gait distribution

Figure 7 shows the course of the Stedmen thermal index for May, when the longest dust storm was observed in 2018 at the Aral Sea station. On May 26, when the longest dust storm began in 2018, the maximum indicator of the Stedman "heat" index was 64.1, therefore, according to the degree of danger, this day is considered the most dangerous and most likely to be observed heat or solar transition in terms of possible fluctuations in the upper risk groups.

During the consideration of microcirculation cases of dust storms in the South Kazakhstan region for the period from 2005 to 2022, data from the Wangenheim-Girst indices E, C, W were obtained.

The relationship between the number of observed days during the longest observed dust storms of the warm season of 2018 in the southern regions of Kazakhstan and the values of the Wangenheim-Girs meridional (E and C) and zonal (W) indices is shown in the following figure (figure 8).

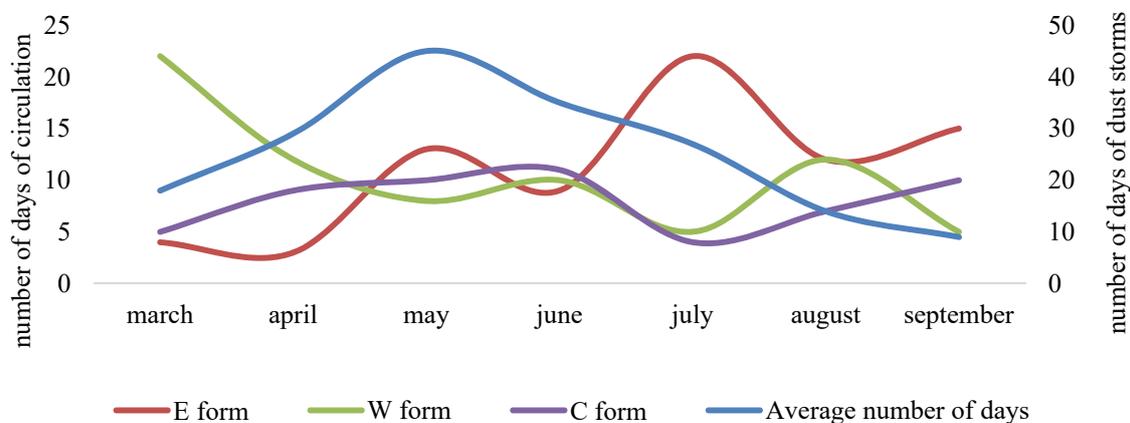


Figure 8 –Relationship between the Wangenheim-Girs indices and the number of days of the longest observed dust storm

According to figure 8, when determining the relationship between the Wangenheim-Geers indices for three forms (E, C, W) and the dust storm gait for the longest observed year (2018), The Shape e gait for the longest observed dust storm gait is approximately directly propotional, i.e. the gait of both values was higher in May. The course of form C is also approximately close to the course of the longest observed dust storm. And the course of form W was the opposite of the course of the longest observed dust storm.

The relationship between the values of the Wangenheim-Girs form E index and the number of days when dust storms were observed in the southern regions of Kazakhstan in the warm season in 2018 is shown (figure 9).

According to figure 9, the number of days of the longest observed dust storm in the warm season in 2018 and the course of the e-form of circulation are approximately similar. The similarity is especially well expressed in April-May, that is, the longest observed dust storm, which lasted 72 hours, coincides with the March of the May period and the course of the e-Form (13 days).

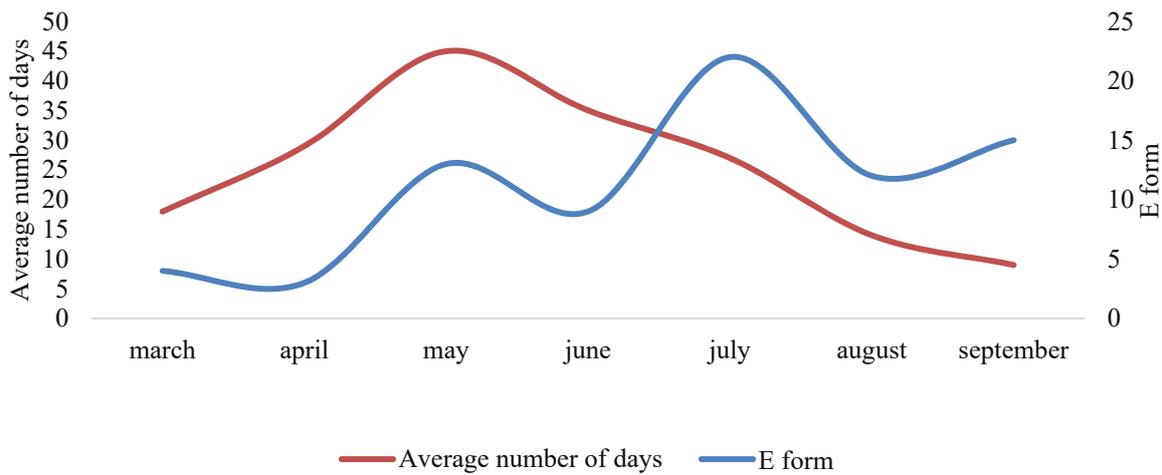


Figure 9 –Relationship between Wangenheim-Geers e-form indices and the number of days of the longest observed dust storm

To assess the role of the circulating factor during a more detailed consideration of the above-mentioned relationship, it is necessary to study the results of 2005-2022. the correlation coefficient between the number of days when dust storms were observed in the Warm Period and the form E was calculated (table 5).

Table 5 –The correlation between the number of days in which the dust storm was observed and the form E

Correlated dimensions	Months						
	3	4	5	6	7	8	9
South Kazakhstan region							
<i>r</i> (Form E; number of days)	0,06	0,22	0,42	0,23	-0,13	-0,14	-0,04
Aral Sea station							
<i>r</i> (Form E; number of days)	0,12	0,40	0,49	0,03	-0,03	-0,31	-0,20
<i>Note.</i> 1) CS is the number of days; 2) for N = 17 samples, the correlation coefficient is 0.45 at a confidence level of 95 % ($\alpha = 0.05$) [26].							

According to Table 5, 2005-2022. in determining the correlation relationship between the number of days when dust storms were observed in the South Kazakhstan region for the Warm Period and the e-form indices, the correlation relationship is important when, according to the data given in Lakin's book "biometrics", the critical value of the correlation coefficient for 17 years is 0.45, that is, the e-form affected the dust storms that occurred in the general region approximately in May (0.42).

According to the Aral Sea station in 2005-2022. the correlation coefficient between the number of days of a dust storm and the form E in April and May, the values of which are positive and Direct, was observed, that is, high values of the indices of the Form e corresponded to high values of the number of days of a dust storm, especially in May, it can be seen that a very significant relationship was observed, that is, the correlation coefficient was equal to 0.49.

The relationship between the values of the El Niño indices during dust storms and the number of days when dust storms were observed in the southern region of Kazakhstan for the considered years is shown (figure 10).

As shown in figure 10, for the period 2005-2022 by the region studied. In determining the relationship between the El Niño index travel and the number of days in which a dust storm was observed, The Travels of both values roughly coincide.

Discussion. To assess the role of the microcirculation factor in a more detailed study of the relationship between the El Niño Southern Oscillation and the number of days observed in dust storms, the correlation coefficient between the macroscale atmospheric circulation indices and the number of days observed in dust storms was calculated for the warm season. The values of El Niño (SOI) and the number of days in which dust storms were observed were taken as macroscale circulation indices (table 6).

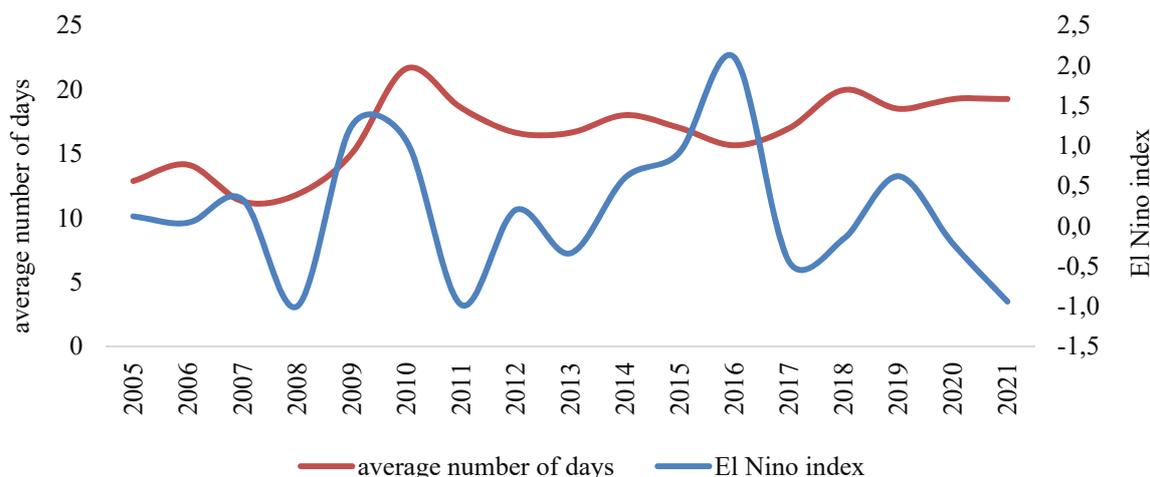


Figure 10 –The relationship between the El Niño indices and the number of days the dust storm was observed

Table 6 –2005-2022 correlation relationship between the number of days when a dust storm was observed for a warm period and the El Niño (SOI) index

Correlated dimensions	Months						
	3	4	5	6	7	8	9
South Kazakhstan region							
<i>r</i> (SOI; number of days)	0,13	0,31	0,42	0,34	0,17	-0,17	-0,03
Aral Sea station							
<i>r</i> (SOI; number of days)	0,25	0,38	0,47	0,34	0,28	0,20	-0,13
<i>Note.</i> 1) CS is the average number of days; 2) for N = 17 samples, the correlation coefficient is 0.45 at a confidence level of 95 % ($\alpha = 0.05$) [26].							

As shown in table 7, for the warm period from 2005 to 2022, the data of the correlation coefficient between the number of days of dust storms and the El Niño (SOI) index for the South Kazakhstan region and the Aral Sea station were calculated. At the stations considered in the southern region of Kazakhstan, the values of the correlation coefficient between the number of days when dust storms were observed in May and the El Niño (SOI) index showed a positive and direct relationship, that is, the high values of the number of days when dust storms were observed also corresponded to the high values of the El Niño (SOI) index, so the correlation coefficient was positive and was equal to 0.42. On the other hand, an important connection was observed in May at the Aral Sea station, that is, the coefficient correlation was equal to 0.47.

According to research by A. P. Agarkova (1950-1969) in the study area studied was observed that dust storms often occur against a temperate and weak background of small areas covering one or more areas. The nature of its occurrence is determined not only by the state of the paving surface but also depends on the direction and intensity of atmospheric processes that have developed on the Earth's surface and altitude [25].

The synoptic state during the longest observed (72 hours) dust storm in the period from May 26 to 29, 2018 was considered, and the analysis of the dust storm (May 27), which struck in those days at the most intense speed (average -16 M/s, perturbation – 29 M/S) was given according to the following maps: a map of the Earth's surface and a map of Baric topography AT₅₀₀ GPA (figure 11).

As shown in figure 11, on the Earth map on May 27, several frontal systems passed through the central and southern regions of Kazakhstan, in connection with which in the Aral Sea and Kyzylorda regions there was an increase in winds, a high recurrence of dust storms, that is, in this regard, the winds that increase during convection, which occurs as a result of uneven heating of the Earth's surface in May-June, and the forced rise of warm air on cold fronts, also cause dust storms in arid regions. On the Baric topography map of the AT500 altitude of May 27, 2018, the territory of the European territory of Western

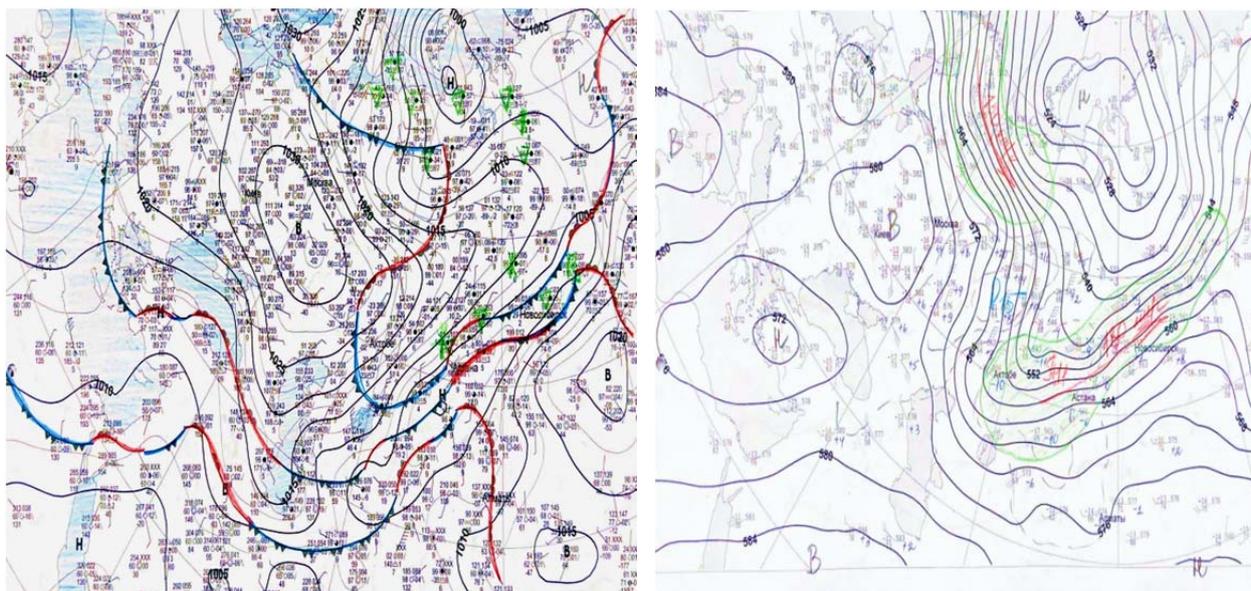


Figure 11 – On May 27, 2018, 12 hours. surface weather map and altitude map at 500 GPA

Europe and Russia, the west of Kazakhstan, coincides with a high ridge with a closed center of the anticyclone. On the territory of the North Sea, a large-scale cyclone is widespread, which is located above the island of Svalbard. A deep ravine extends from it, directed to Western Siberia and eastern Kazakhstan. Between these Baric structures, an intense high frontal zone is formed, which moves medially through the Scandinavian Peninsula to the regions of western Kazakhstan. The location of such Baric structures is characteristic of the north-western penetration.

Conclusion. Considering the conditions for the formation of dust storms in the southern region of Kazakhstan for the period from 2005 to 2022, the following results were summed up:

1. The Longest duration of the dust storm began on May 26, 2018, at 11:00 hours and ended on May 29 at 11:00 hours, that is, the total duration lasted 72 hours. During the initial period of the longest dust storm, that is, on May 26, the air temperature was higher than 30 °C, and the soil temperature was 45°C, the maximum value of the average wind speed was 16 m/s, and the wind speed was 29 m/s, and the visibility distance was reduced to 2 m. The average height of the snow cover is 10 cm, precipitation in April is 0.4 mm, and in May-absolutely no precipitation.

2. The values of the correlation coefficient between the number of days when dust storms were observed at the Aral Sea station and the number of wolves, especially in March-August, were very significant (1.00), especially in May.

3. The effective temperature value according to the Misener indices of May, when the longest dust storm was observed at the Aral Sea station in 2018, was 27.4 °C at the time of the beginning of the dust storm. The maximum indicator of the heat index according to Stedman was 64.1, with a high probability of passing the sun in terms of the degree of danger and possible deviations in the highest risk groups.

4. In the relationship between the Wangenheim-Geers atmospheric circulation indices (E, C, W) and the course of the dust storm in the longest observed year (2018), the importance of form E was found to be especially high ($r = 0.49$) in May.

5. The correlation coefficient between the macro-mass atmospheric circulation Index El Niño (SOI) and the index of the number of days in which dust storms were observed showed that a significant connection was observed in May at the Aral Sea station, that is, the correlation coefficient was equal to 0.47.

6. During the analysis of the synoptic process during a dust storm that struck at the most intense speed (average –16 m/s, permeability – 29 m/s) as of May 27, 2018, it was found that the formation of a dust storm was associated with the penetration of cold northwestern air.

Summarizing the studies carried out, it was proved that the high recurrence rate of dust storms in the south of the country is influenced by meteoparameters. According to the data of the years considered, the

increase in air and soil temperatures, as well as a decrease in air humidity and a decrease in the amount of precipitation and the height of snow cover over the past winter months, influenced the repeatability and duration of dust storms. The results obtained from this research work are somewhat informative when studying climate change in the southern region of Kazakhstan.

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КЛИМАТТЫҢ ЗАМАНАУИ ӨЗГЕРУІ ЖАҒДАЙЫНДА ҚАЗАҚСТАННЫҢ ОҢТҮСТІК АЙМАҒЫНДАҒЫ ШАНДЫ ДАУЫЛДАРДЫҢ КЕҢІСТІКТІК ТАРАЛУЫ

Аннотация. Заманауи климаттың өзгеруі және олардың салдарын бағалау мәселелері IPCC (2021-2023) соңғы бағалау баяндамаларына сәйкес, жердің әртүрлі аймақтарында айтарлықтай элеуметтік және экономикалық зиян келтіретін, ауа райының қауіпті құбылыстарының артуы байқалуда. Берілген мақалада климаттың заманауи өзгеруіне байланысты шанды дауылдың қалыптасу жағдайына әсер ететін әртүрлі климаттық факторлар зерттелді. Қазақстанның оңтүстік өңіріндегі Арал теңізі станциясында 2005-2022 жылдар аралығындағы шанды дауылдың ең ұзақ уақытқа (72 сағат) созылуы 2018 жылдың мамыр айында тіркелгені анықталды. Сол кездегі метеопараметрлердің мәндері, яғни оның ауа райы жағдайларына тәуелділігі, Күн белсенділігінің сандық көрсеткіштері (Вольф саны), биоклиматтық көрсеткіштер, сонымен қатар макроциркуляциялық қалыптасу жағдайлары қарастырылды. Талдау нәтижесінде шанды дауыл ең көп байқалған күндер саны мен Вольф саны ($r = 1,00$), Вангенгейм-Гирс циркуляция формалары, оның ішінде E формасы ($r = 0,49$), Эль-Ниньо индекстері ($r = 0,47$) арасында маңызды корреляциялық байланыс болғаны, сонымен қатар синоптикалық талдау нәтижесінде шанды дауылдың ұзақ байқалуы солтүстік-батыс суық фронтымен байланысты болғаны айқындалды.

Түйін сөздер: шанды дауыл, Вольф саны, биоклиматтық көрсеткіштер, атмосфера циркуляциясы, корреляция коэффициенті, индекстер.

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ПРОСТРАНСТВЕННОЕ РАСПРЕДЕЛЕНИЕ ПЫЛЬНЫХ БУРЬ В ЮЖНОМ РЕГИОНЕ КАЗАХСТАНА В УСЛОВИЯХ СОВРЕМЕННОГО ИЗМЕНЕНИЯ КЛИМАТА

Аннотация. Согласно последним оценочным докладам МГЭИК (2021-2023), в различных регионах Земли наблюдается рост опасных погодных явлений, наносящих значительный социальный и экономический ущерб. Изучены различные климатические факторы, влияющие на образование пыльных бурь в связи с современным изменением климата. Установлено, что на станции Аральского моря в южном регионе Казахстана в мае 2018 года зафиксирована самая продолжительная (72 ч) пыльная буря с 2005 по 2022 год. Рассмотрены значения метеопараметров того времени, т. е. их зависимость от погодных условий, количественные показатели солнечной активности (число Вольфа), биоклиматические показатели, а также условия макроциркуляционного формирования. Анализ показал, что существует значительная корреляционная связь между количеством дней, в течение которых пыльная буря наблюдалась больше всего, и количеством числа Вольфа ($r = 1,00$), формами циркуляции Вангенгейма-Гирса, включая форму E ($r = 0,49$), индексы Эль-Ниньо ($r = 0,47$). В результате синоптического анализа установлено, что продолжительное наблюдение пыльных бурь было связано с прохождением северо-западного холодного фронта.

Ключевые слова: пыльная буря, число Вольфа, биоклиматические показатели, циркуляция атмосферы, коэффициент корреляции, индексы.