THE MINISTRY OF ECOLOGY AND NATURAL RESOURCES OF THE REPUBLIC OF KAZAKHSTAN

REPUBLICAN STATE ENTERPRISE KAZHYDROMET

SCIENTIFIC RESEARCH CENTER

ANNUAL BULLETIN OF SURFACE WIND MONITORING ON THE TERRITORY OF THE REPUBLIC OF KAZAKHSTAN FOR 2024

Photo from the archive of the RSE "Kazhydromet"

ASTANA, 2025

CONTENT

CONTENT

BRIEF SUMMARY

Surface wind pattern for 2024

- In 2024, Kazakhstan's wind patterns were characterized by marked regional heterogeneity. The highest wind speeds were observed in the northern, central, and southeastern regions, where they reached 40 m/s in places, while winds were significantly weaker in the west and south. Overall, strong winds (≥ 15 m/s), classified as hazardous meteorological phenomena, were frequent across most of the territory.
- Anomalies in mean annual wind speed ranged from positive in the north and east to negative in the south and west, reflecting a strengthening of the wind regime in the north-eastern part of the country and a weakening in the south-west.
- The number of days with strong winds varied significantly across regions, from around 30 days in the south to more than 170 days in the southeast, highlighting the contrasting wind patterns across the country.

Seasonal activity at 95th percentile

- An analysis of seasonal anomalies in average wind speed and the number of days above the 95th percentile revealed that positive deviations predominated in winter, with the highest number of days with extreme winds. Wind activity weakened in spring, but increased again in summer and fall, particularly in the eastern and southeastern regions of the country.

Long-term data and linear trends

- According to the analysis of long-term linear trends, the largest increase in average wind speed and the number of days with strong winds is observed in the north-eastern and central regions of the country, especially in spring and summer.
- A decrease in wind activity is observed mainly in the western and partially northwestern regions, while the eastern and southern regions demonstrate weakly expressed or statistically insignificant changes.

INTRODUCTION

Wind is a key factor influencing the redistribution of heat and moisture across the planet, as well as the dynamics of atmospheric processes associated with climate change. Changes in the nature and strength of wind flows can lead to significant shifts in climatic conditions, influencing weather events, ecosystems, and human activity. In recent decades, significant changes have been observed in global and regional wind systems, requiring more careful monitoring and analysis to understand the impacts of climate change and help various economic sectors adapt to new conditions.

Wind is considered the primary resource for wind energy. Therefore, wind distribution data is important for determining locations for wind turbine installations and optimizing their operation.

Wind conditions play a significant role in the design of buildings and infrastructure. High-rise buildings, bridges, and other structures must withstand wind loads, especially in regions prone to strong winds. Wind distribution is also considered when designing ventilation and the microclimate around buildings.

Wind influences evaporation, seed and pollen dispersal, and precipitation. For example, in arid regions, wind can accelerate water evaporation, negatively impacting agricultural crops. Winds can also transport soil, causing erosion, requiring protective measures such as shelterbelts. Wind speed also determines the intensity of snow transport, causing the redistribution of snow masses on the surface and, consequently, spatial heterogeneity of soil moisture during snowmelt.

Wind distribution significantly influences the spread of pollutants, including industrial emissions, wildfire smoke, and radioactive particles. Understanding wind patterns allows us to predict and monitor risk areas for populations and ecosystems, as well as develop measures to prevent or minimize the impacts of pollution.

This issue of the bulletin describes the characteristics of surface wind conditions and provides historical information on trends that have occurred since 1979. To ensure comparability of results, data are used since 1979, when wind measurements began to be carried out universally using an anemorumbometer.

Responsible for the release: Head of the Department of Meteorological Research and Calculations Zhezdibaeva B.T. Leading research associates A.A. Abilkadi, A.B. Smagulova, and A.E. Zhaxybaeva also participated in the preparation of the bulletin.

1. DESCRIPTION OF THE SURFACE WIND MODE

Surface wind. In Kazakhstan, wind patterns are characterized by significant spatial and temporal variability due to the topography, continental climate, and atmospheric circulation patterns. In areas with rugged terrain (mountains, valleys, and low hills), as well as in coastal zones of large bodies of water, a variety of local winds are observed—mountain-valley winds, breezes, foehn winds, and others—which differ in their formation mechanisms and manifestation patterns.

The average surface wind speed decreases consistently from north to south, which is a climatic pattern for the lowland Kazakhstan. A certain zonality exists here, clearly evident in the territorial distribution of average long-term annual wind speeds. The eastern coast of the Caspian Sea and several mountainous regions of the republic, characterized by distinct local wind conditions, are particularly prominent.

In the main steppe and forest-steppe regions of Kazakhstan, average annual wind speeds typically range from 4.5 to 5.0 m/s. As one moves south, average wind speeds decrease in central regions. A further decrease in wind activity is observed in the Kazakhstan folded region and adjacent uplands, where the complex topography weakens horizontal air movement. In the southern desert massifs, average annual wind speeds decrease to 3-4 m/s. Approaching the mountain ranges located in the south, southeast, and east of Kazakhstan, wind speeds decrease to 2-3 m/s. In these areas of the republic, as in other parts, there are pockets of elevated annual wind speeds. These include areas such as the Zhetisu Gates (Zhalanashkol 7.2 m/s), the Kordai Pass (5.4 m/s), and the Shokpar Pass (5.0 m/s).

Compared to the general wind speed distribution across Kazakhstan, the eastern coast of the Caspian Sea stands out in terms of wind strength. Here, average long-term annual wind speeds reach 5-6 m/s, and in the Fort Shevchenko area, due to local orographic effects, even 8.3 m/s. This is primarily due to the intense presence of cyclones here, originating from the west and south of the Caspian Sea. It is also significant that the energy transfer of air masses over the vast surface of the Caspian Sea does not decrease as sharply in the surface layer as it does on land in rugged terrain. The significant thermal difference between the Caspian Sea and the adjacent sandy deserts during the warm season in turn leads to a general increase in wind speeds in the coastal zone, which is reflected in local breeze circulation.

The general decrease in wind speeds from north to south in Kazakhstan is due to seasonal baric circulation conditions and orography. In the central regions, the decrease in wind speeds is due to the frequent prevalence of anticyclonic conditions, accompanied by atmospheric droughts and calm weather. The topography of the Kazakh folded country, Tarbagatai, and adjacent highlands further reduces the speed of surface air transport.

In desert areas, moderate wind speeds are formed under the influence of a weakly expressed baric gradient of the summer Central Asian thermal depression, which leads to a weakening of cyclonic processes and a high frequency of calm weather, especially pronounced at night due to radiative cooling.

Low wind speeds in the east, southeast, and south of Kazakhstan are due to the rugged mountainous terrain of the Altai, Zhetisu, and Tien Shan mountains, which create vast zones of

wind calm. The exceptions are narrow intermountain passes and mountain passes, where localized wind intensification is observed.

Increased wind activity in the forest-steppe and steppe zones of Northern Kazakhstan is explained by frequent cyclonic processes with precipitation and thunderstorms, accompanied by snowstorms. However, the flat terrain does not impede wind development, unlike mountainous areas.

Strong winds (≥15 m/s) are an important characteristic of the wind regime, and the number of days with strong winds is also of great importance.

In the flatlands of Kazakhstan, strong winds are primarily observed in late winter and spring, and are less common in summer. The exception is the south and southeast of the country, where the annual maximum number of days with strong winds occurs in spring and summer, and the minimum in winter. It should be noted that the incidence of strong winds increases significantly in open terrain. In various climatic regions of Kazakhstan, strong winds have been observed primarily in winter.

The number of days with strong winds in Kazakhstan fluctuates quite widely—from 5 to 70 on average per year. The desert zone has the fewest such days; in some areas, where strong winds are determined by local conditions, the number of days increases significantly.[1]The administrative-territorial regions are shown on the map below.

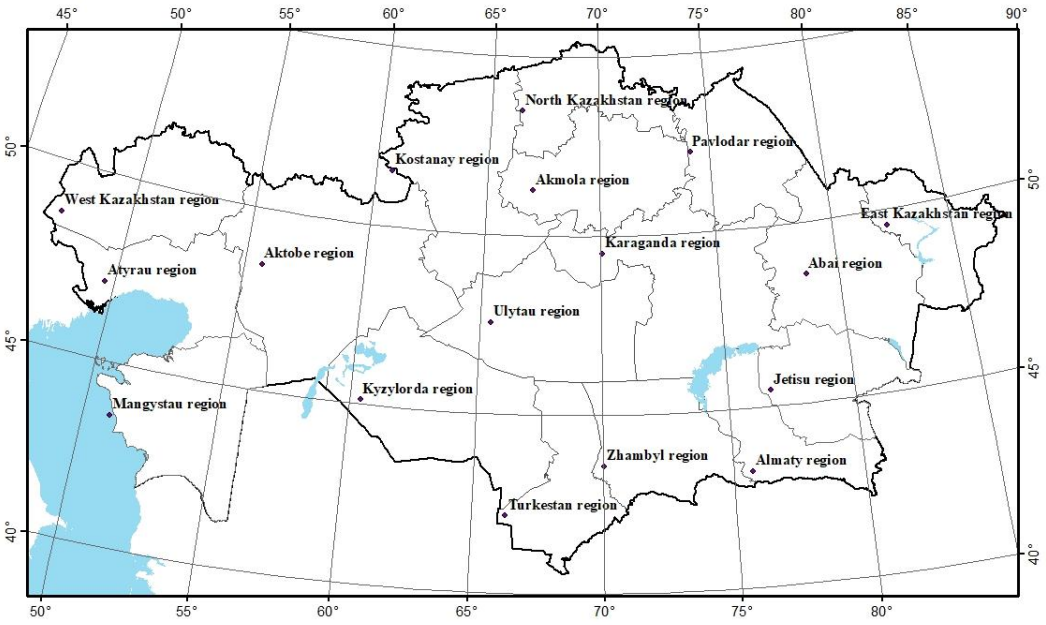


Figure 1. Map of the administrative-territorial regions of the Republic of Kazakhstan

[1]Uteshev A. S. (ed.). Climate of Kazakhstan. – L.: Gidrometeoizdat, 1959. – 360 p.

2. MATERIALS AND METHODS OF RESEARCH

An analysis of wind activity in the Republic of Kazakhstan was conducted using surface wind speed data for 2024, taking into account long-term changes since 1979. The source material was observations obtained from ground-based meteorological stations of the state network of the Republican State Enterprise "Kazhydromet" for the period 1979-2024. Wind speed and direction are recorded using an M-63 anemorumbometer, installed on a mast at a height of 10-12 m, which complies with international standards for minimizing surface influence and ensuring the reliability of measurements in the surface layer of the atmosphere.

The study calculated key wind regime characteristics, including maximum wind speed, wind speed anomalies, the number of days with strong winds (defined as wind speeds exceeding 15 m/s), and the 95th percentile of wind speed and the number of days with strong winds, allowing for the assessment of extreme wind events.[2].

The anomaly was calculated as the difference between the actual value for 2024 and the corresponding climate norm for the period 1991–2020. The number of days with strong winds was calculated based on daily wind speed data, with only those days in which the maximum wind speed exceeded the established threshold being taken into account.

To assess long-term variability and identify trends, a least-squares linear regression method was used. This approach allows one to determine the rate of change in time series, identifying positive and negative trends by region and season. The statistical significance of the identified trends was verified using statistical tests, using a standard significance level of $p < 0.05$. This ensures that the detected changes are not random, but rather systemic. A similar methodology has been used in a number of climate studies, including the calculation of wind loads in Russian regions.[3], analysis of long-term wind speed trends in China[4], assessing global changes in surface wind speed based on reanalysis data, and studying wind activity trends in Turkey[5].

For visual analysis, maps of indicator distribution and trends were created using geographic information systems. The resulting trend values and their statistical significance are grouped by season (winter, spring, summer, fall) and presented in summary tables.

[2]Report on climate features in the Russian Federation for 2022. – Moscow: Roshydromet, 2023. – P. 76–80.

[3]Zhabelov S. T., Khokonov I. M., Kadyrova A. A., Niyazov I. A. Complex analysis of wind time series // European Science. - 2020. - No. 5 (54). - P. 20-23.

[4]Wu J., Shi Y. Changes in surface wind speed and its different grades over China during 1961-2020 based on a high-resolution dataset // International Journal of Climatology. – 2021. – T. 42. – No. 7. – P. 3954–3967.

[5]Dadaser-Celik F., Cengiz E. Wind speed trends over Turkey from 1975 to 2006 // International Journal of Climatology. – 2013. – T. 34. – No. 6. – P. 1913–1927.

3. FEATURES OF THE SURFACE WIND REGIME

3.1 Maximum speed and average annual speed norm winds across Kazakhstan in 2024

The spatial distribution of maximum wind speeds for 2024 revealed significant regional differences due to both climatic features and orographic conditions in the country (Table 3.1). In 2024, extreme winds were observed at meteorological stations in the Republic of Kazakhstan primarily in the northern, central, and southeastern regions of the country. At these stations, maximum wind speeds reached 30 m/s and above, which corresponds to the category of very strong and storm-force winds capable of causing natural hydrometeorological impacts on infrastructure and ecosystems. Table 3.1 presents the meteorological stations that recorded wind speeds of 30 m/s and above. Maximum wind values, average wind speed anomalies, and the number of days with speeds ≥ 15 m/s are provided in the appendix.

Table 3.1-Maximum wind speed values ≥30 m/s recorded at meteorological stations of the Republic of Kazakhstan in 2024year

No.	Weather station	Region	Wind speed, m/s
1	Yesil	Akmola	30
2	Zhaltyr	Akmola	30
3	Rodnikovka	Aktobe	30
4	Aksengir	Almaty	30
5	Ertis	Pavlodar	30
6	Aktogay	Pavlodar	30
7	Bayanaul	Pavlodar	31
8	Ereimentau	Akmola	33
9	Taiynsha	North Kazakhstan	33
10	Taraz	Zhambyl	34
11	Rodnikovskoye	Karaganda	34
12	Korneevka	Karaganda	34
13	Sharbakty	Pavlodar	34
14	Chkalov	North Kazakhstan	34
15	Shokpar	Zhambyl	36
16	Zhalanashkol	Zhetisu	40

The highest wind speed of 40 m/s was recorded at the Zhalanashkol weather station (Zhetisu region), indicating extreme wind conditions in this area. These extreme wind conditions are due to the climatic and orographic features of this region. Zhalanashkol is located in an area with a pronounced mountainous topography, which enhances wind flow due to the acceleration of air masses as they pass through mountain passes and gorges. A particularly significant factor is the weather station's location near the Zhetisu Gates—a narrow intermountain pass between the Zhetisu Alatau and Tarbagatai ridges, where an aerodynamic effect is created that contributes to the intensification and persistence of strong winds. Moreover, the historical maximum wind speed

recorded at this weather station between 1979 and 2024 is 60 m/s and was observed in 1979, 1982, and 1983. This highlights the region's persistent tendency to experience very strong and dangerous winds.

In 2024, strong winds of 15 m/s and higher were observed across a significant portion of the territory (Figure 3.1). Winds of 15 m/s and higher are considered hazardous meteorological phenomena according to regulatory documents.[6], was observed almost everywhere.

Only in certain areas of the Atyrau, Turkestan, Almaty, and Zhetisu regions were relatively low maximum wind speeds observed in the year under review—9-14 m/s. These values were recorded locally, as strong winds were also observed in the same regions.

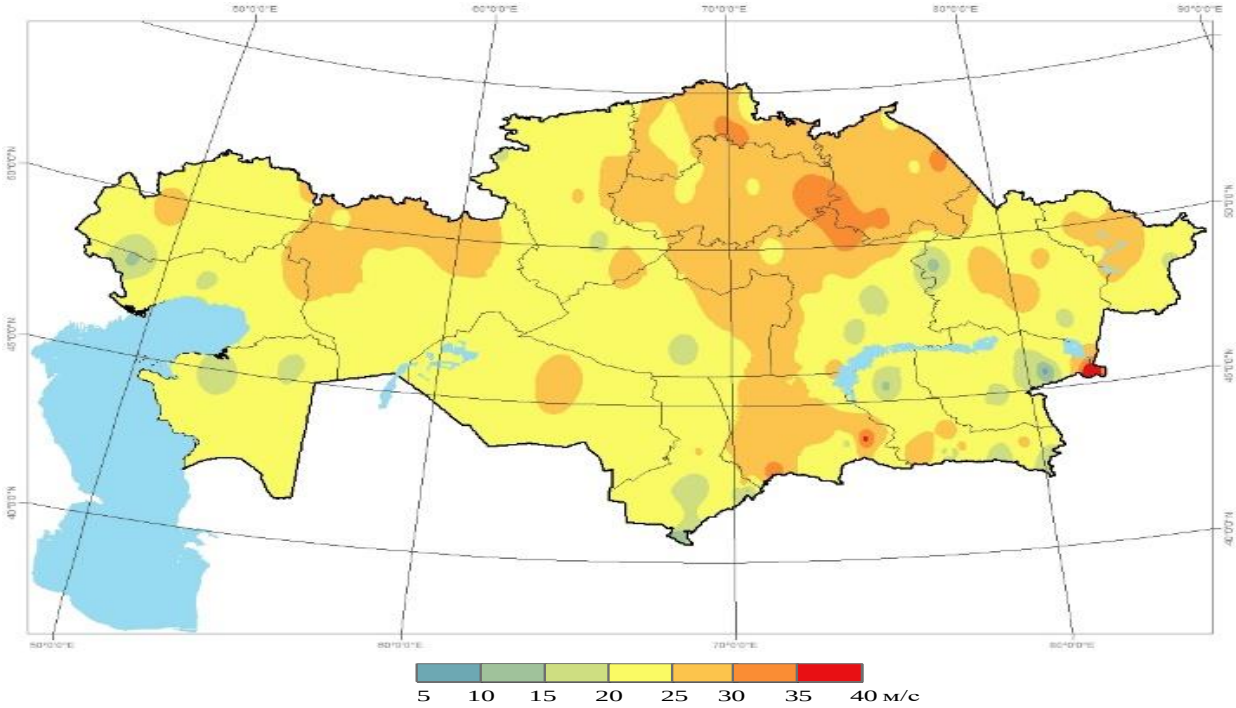


Figure 3.1 –Maximum wind speed for 2024

An analysis of anomalies in the average annual surface wind speed for 2024 in relation to the climate norm for the period 1991-2020 made it possible to identify the features of the spatial distribution and nature of deviations in the wind regime in the territory of the Republic of Kazakhstan (Figure 3.2).

In 2024, maximum positive wind anomalies ranged from +0.5 to +2.0 m/s. The largest positive deviations were recorded in the North Kazakhstan region (+2.0 m/s), Abay region (+1.6 m/s), Almaty region (+1.3 m/s), and Ulytau region and certain areas of West Kazakhstan region (+1.2 m/s). This indicates a persistent trend toward increasing average annual wind speeds in the northern, western, and eastern regions of the country, as well as in several southern and central territories.

At the same time, negative anomalies reflecting a weakening of average annual wind speeds were observed in a number of regions. The most pronounced anomalies were observed in the Zhetisu region (-1.4 m/s), West Kazakhstan (-1.3 m/s), and in the Zhambyl, Pavlodar, and

[6]Rules for the provision of information by the National Hydrometeorological Service, Order of the Minister of Ecology, Geology and Natural Resources of the Republic of Kazakhstan dated July 23, 2021, No. 267

North Kazakhstan regions, where values reached -1.1 m/s. Thus, in the West Kazakhstan region, a mixed trend was observed – a combination of areas with increased wind speeds and zones with weakening winds.

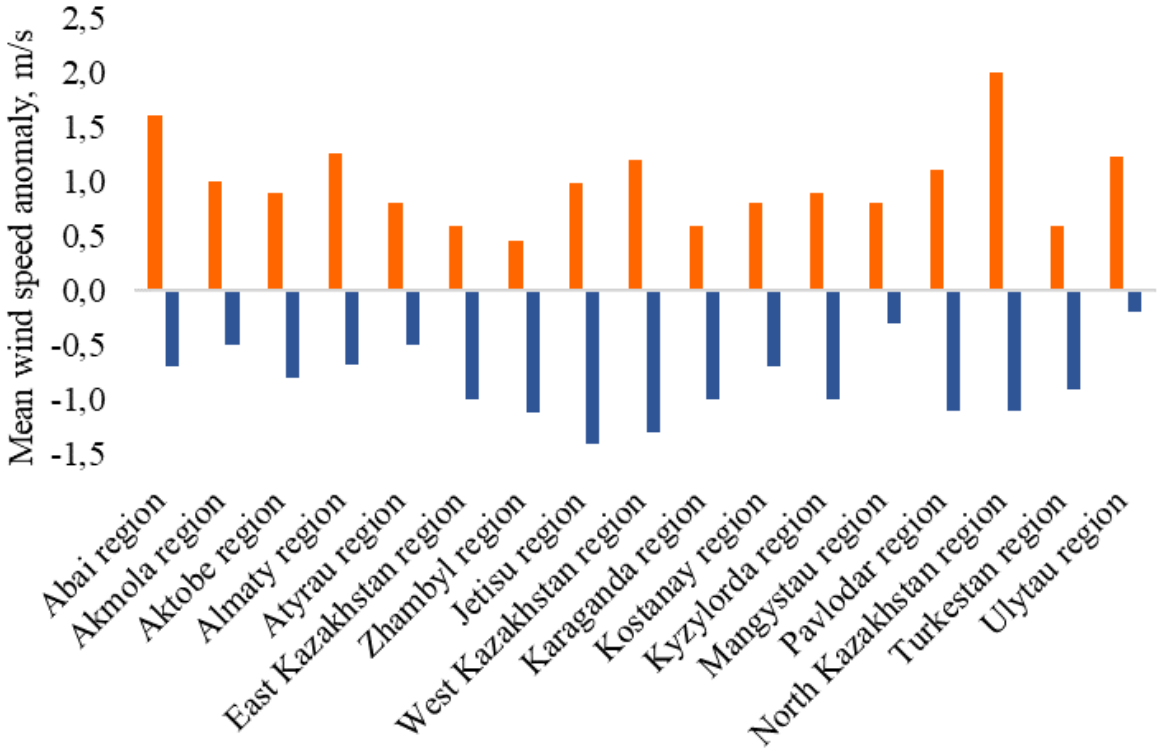


Figure 3.2 –Regional variations of anomalies of average annual surface wind speed in the Republic of Kazakhstan for 2024

3.2 Number of days and anomalies of the number of days of strong wind

The number of days with strong winds is an important indicator of wind conditions and reflects the intensity of wind activity in a region. An increase in the number of such days impacts natural processes, infrastructure, agriculture, and public safety. Frequent strong winds exacerbate the negative impacts of various natural and man-made disasters, affecting the lives of residents and the health of ecosystems.

The spatial distribution of days with wind speeds ≥ 15 m/s within Kazakhstan varied (Figure 3.3). The highest number of such days was observed in the northern, southern, and southeastern regions of the country.

The maximum values vary from 31 days (Turkestan region) to 177 days (Zhetisu region), which indicates significant spatial heterogeneity of conditions conducive to the formation of strong winds.

The highest number of days with surface wind speed ≥15 m/s in 2024 was recorded in Zhetisu (177 days), Kyzylorda (163 days), North Kazakhstan (156 days) and Akmola (126 days) regions, while the minimum values were noted in Turkestan (31 days), Mangystau (41 days) and Zhambyl (46 days) regions.

Analyzing data from individual weather stations, the fewest days with strong winds were observed at the Almaty, Zhalanash, and Mynzhylki stations (Almaty Region)—only one day each.

There were also observation points where winds of 15 m/s or more were not observed throughout the year.

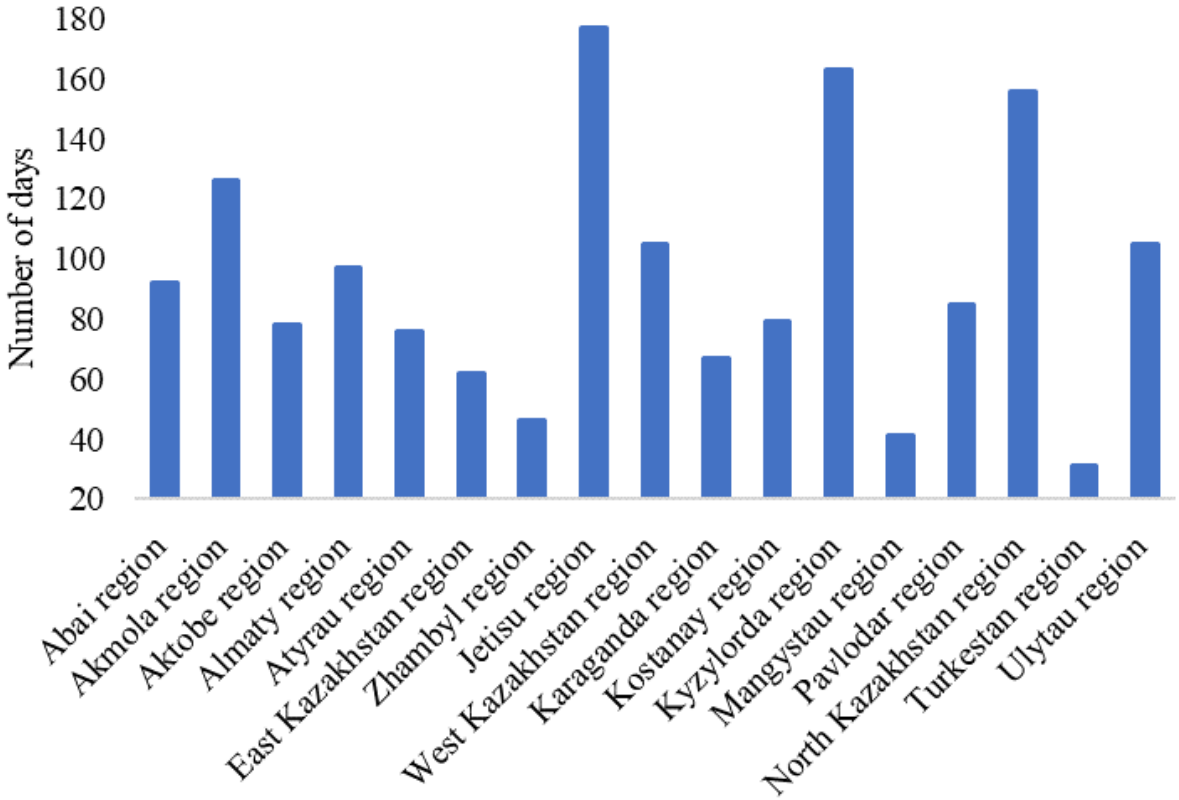


Figure 3.3– The maximum number of days with wind speed ≥15 m/s by administrative regions of the Republic of Kazakhstan for 2024.

Anomalies in the number of days with wind speed ≥ 15 m/s across Kazakhstan in 2024 ranged from -38.4 to +94.2 days (Figure 3.4).

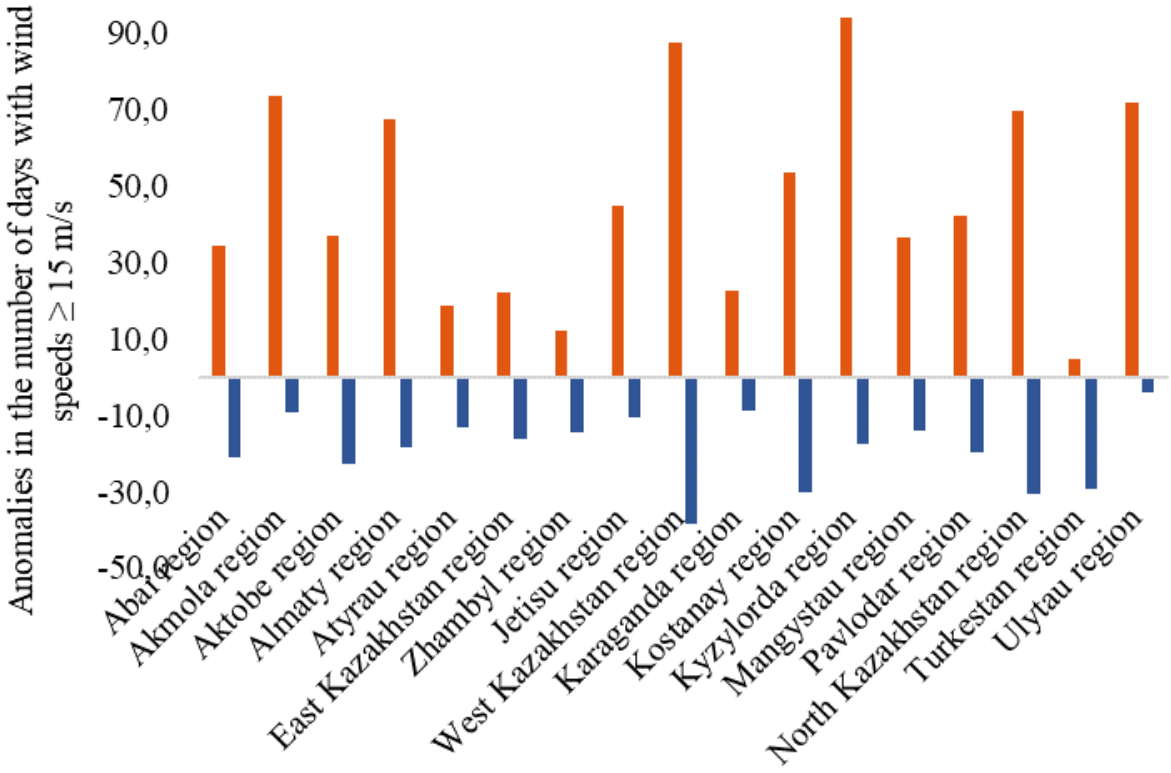


Figure 3.4– Anomalies in the number of days with wind speed ≥ 15 m/s in 2024.

The largest positive anomalies in the number of days with wind speed ≥ 15 m/s were observed at the Zhosaly weather stations in the Kyzylorda region +94.2 and at Chapayevo in the West Kazakhstan region +87.7 days.

The largest negative anomaly in the number of days with strong winds in 2024 was recorded at the Aksai meteorological station in the West Kazakhstan region and amounted to -38.4 days, at the Ruzayevka meteorological station in the North Kazakhstan region -30.8 days, and at Arkalyk in the Kostanay region -30.3 days.

3.3 Seasonal anomalies of average wind speed and extreme wind days

Using percentiles allows us to evaluate rare and strong wind events that fall outside the normal range of wind activity and to identify seasonal and spatial patterns in their distribution. For this purpose, the 95th percentile of wind speed was used in the analysis of extreme winds, indicating a value exceeding which wind speed was observed in only 5% of cases.

The spatial distribution of mean wind speed anomalies and the number of days with wind speeds exceeding the 95th percentile by season showed that positive mean wind speed anomalies predominated in winter, while mostly negative anomalies were observed in spring. The number of days with wind speeds above the 95th percentile was similarly highest in winter and lowest in spring (Figure 3.5). Consequently, the cold season saw an increase in the frequency of strong winds, while the spring season was characterized by a decrease in wind activity.

During the winter period, deviations of the average wind speed from the long-term average ranged from -3.0 to +2.4 m/s. The largest positive deviation was recorded at the Zholboldy weather station in the Pavlodar region (+2.4 m/s). The highest negative wind speed

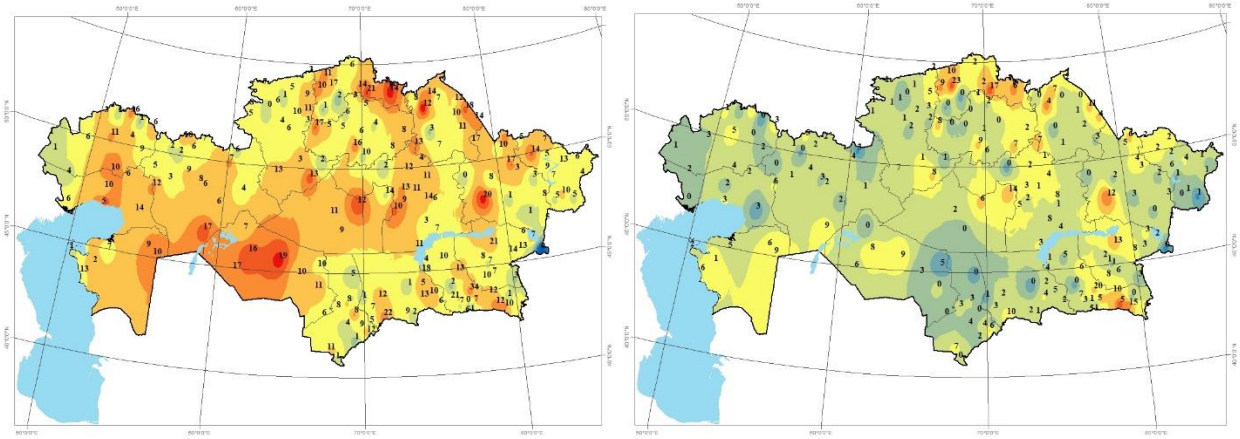
was recorded at the Zhalanashkol weather station in Zhetisu region (-3.0 m/s). During this period, the Kapchagay and Esik weather stations (Almaty region) recorded 34 and 26 days, respectively, with wind speeds above the 95th percentile.

In spring, average wind speed anomalies ranged from +1.9 to -1.7 m/s. The largest positive deviation from the long-term average was recorded at the Chkalovo weather station in the North Kazakhstan region (+1.9 m/s), while the largest negative value was observed at the Zhalanashkol weather station in the Zhetisu region (-1.7 m/s). During the specified period, the maximum number of days exceeding the 95th percentile threshold was recorded at the Sergeevka weather stations in the North Kazakhstan region (23 days) and Esik in the Almaty region (21 days).

During the summer, average wind speed anomalies ranged from positive values at the Chkalovo meteorological station in North Kazakhstan region (+2.2 m/s) to negative values at the Zlikha meteorological station in Kyzylorda region (-1.6 m/s), indicating significant fluctuations in meteorological conditions across different regions of the country. During this period, the Kapchagay and Aksengir meteorological stations in Almaty region recorded a high frequency of days with wind speeds exceeding the 95th percentile, amounting to 36 and 33 days, respectively. Similarly, the Sergeevka meteorological station in North Kazakhstan region recorded 32 days with wind speeds exceeding the 95th percentile, reflecting the widespread occurrence of extreme wind events in this region during the summer.

In autumn, the range of anomalies ranged from +2.1 m/s to -1.3 m/s. The maximum positive deviation was recorded at the Barshatas weather station in the Abai region (+2.1 m/s), while the minimum values were observed at the Saumalkol weather station in the North Kazakhstan region and the Aksai weather station in the West Kazakhstan region (-1.3 m/s), further highlighting regional differences in wind regime changes. During this period, the maximum number of days with wind speeds exceeding the 95th percentile was recorded at the Kapchagay weather station (38 days). Significant values were also recorded at the Esik (26 days) and Aksengir (24 days) weather stations in the Almaty region, reflecting the high intensity of wind activity in this region.

winter…….spring



summer…….autumn

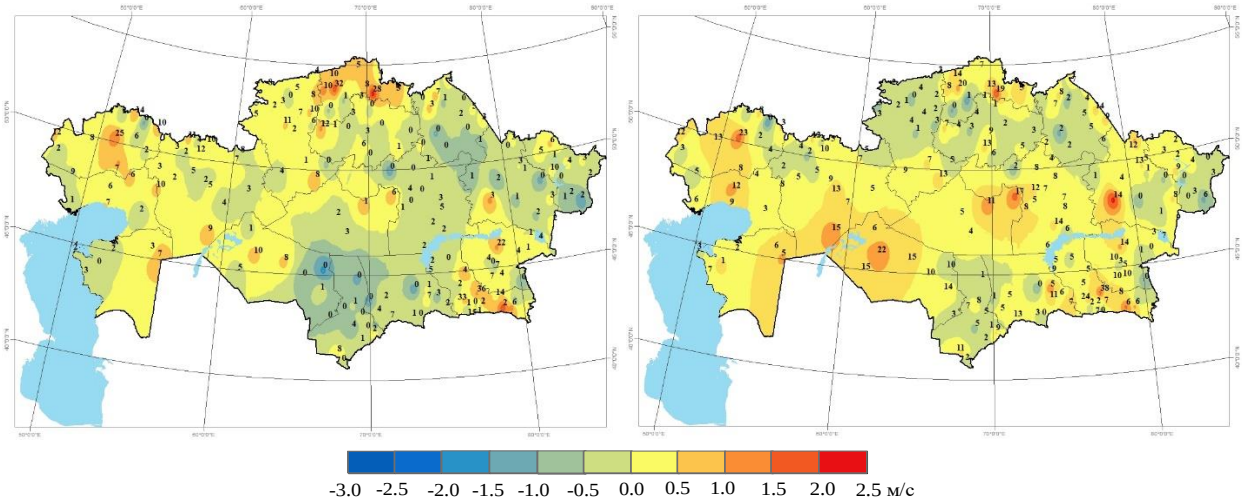


Figure 3.5- Anomalies of average wind speed and the number of days with wind speed exceeding the 95th percentile by season (color – anomaly, numbers – number of days)

4. Long-term changes in wind characteristics

4.1 Long-term trend of average wind speed by season

An analysis of long-term trends in average wind speed was conducted using observational data from 1979 to 2024. Seasonal changes in average annual wind speed were examined to identify the direction and intensity of long-term changes in various regions of the country. A linear trend was used to assess trends, allowing one to determine whether average wind activity is increasing, decreasing, or stable over the period under review.

Long-term changes in the wind regime reflect a tendency towards an increase in average wind speed in summer and a decrease in winter in the territory of the Republic of Kazakhstan (Figure 4.1).

In winter, the spatial distribution of the values of the linear trend coefficient of the average wind speed (m/s over 10 years) showed that the greatest increase was observed at the Barshatas weather station in the Abay region (+0.6 m/s), while a significant decrease was recorded at the Zhalanashkol weather station in the Zhetisu region and Arkalyk weather station in the Kostanay region (-0.8 m/s).

In spring, positive dynamics were noted at the Barshatas weather stations in the Abay region and Chkalovo in the North Kazakhstan region (+0.7 m/s), while the maximum decrease in average wind speed was recorded at the Kulsary weather station in the Atyrau region (-0.8 m/s).

In summer, an increase in average wind speed was observed at the Barshatas weather station in the Abay region (+0.7 m/s), and the most pronounced weakening of winds was noted at the Kulsary weather station in the Atyrau region (-0.7 m/s).

In autumn, the positive trend continued to be observed at the Barshatas weather stations in the Abay region and Chkalovo in the North Kazakhstan region (+0.7 m/s), while at the Arkalyk

and Torgai weather stations in the Kostanay region, negative values of wind speed changes were observed (-0.7 m/s).

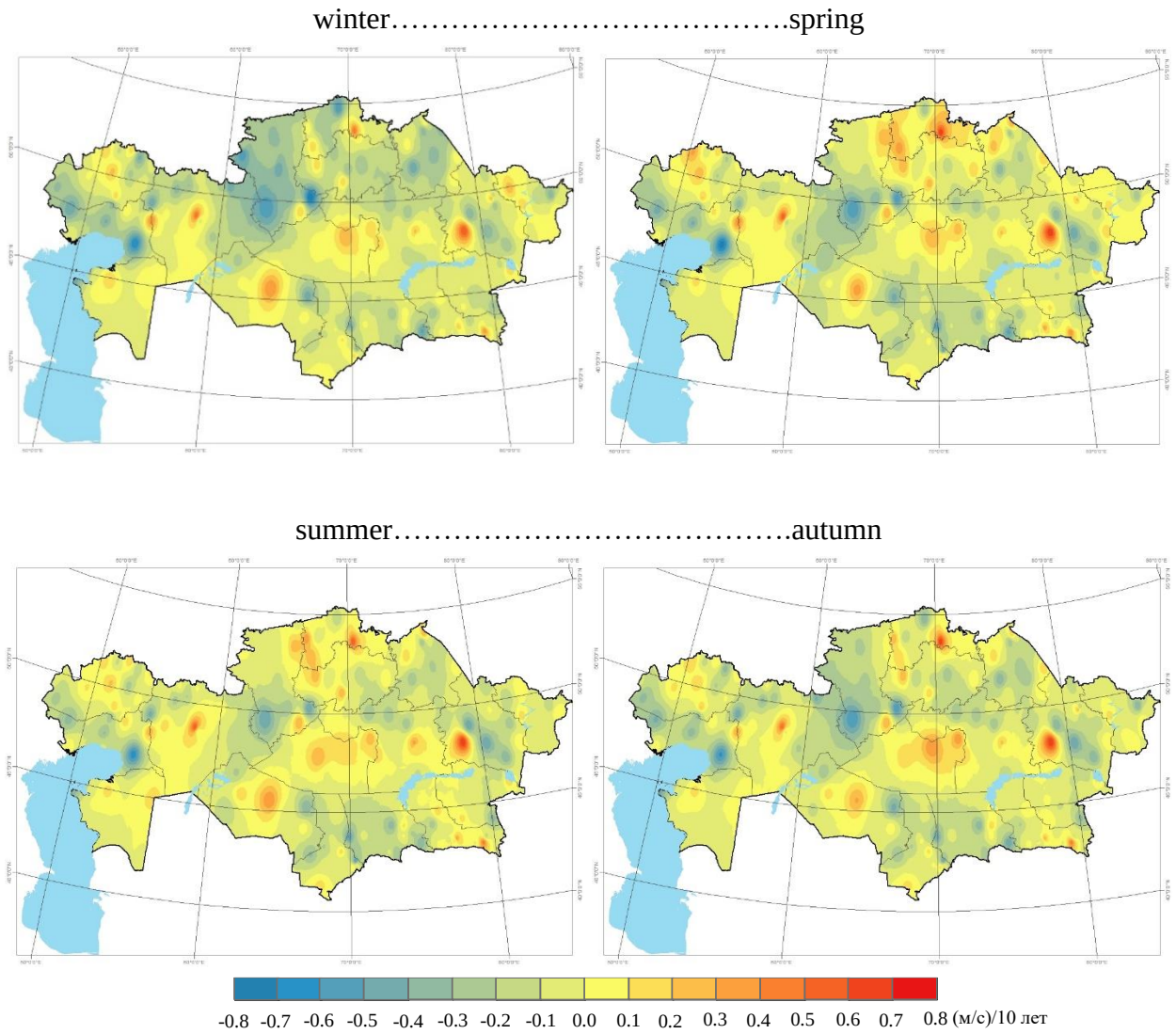


Figure 4.1 -Spatial distribution of the values of the linear trend coefficient of seasonal average wind speed (m/s)/10 years calculated based on observation data for the period 1979-2024.

Overall, a spatial analysis of linear trends in average wind speed revealed significant heterogeneity across Kazakhstan and across seasons. The largest and most consistent increase in average wind speed was observed at the Barshatas meteorological station in Abay region, where positive values were recorded in all seasons. Meanwhile, a decrease in average wind speed was observed at the Kulsary meteorological station in Atyrau region, Arkalyk and Torgai in Kostanay region, and Zhalanashkol in Zhetisu region.

The identified trends are of practical importance, as an increase in average wind speed can exacerbate the impacts of extreme wind events, affecting infrastructure, energy, agriculture, and ecosystems, while a decrease in wind speed in certain regions may reflect a weakening of wind activity. Thus, an analysis of seasonal, multi-year changes in average wind speed allows us to identify zones with increased or decreased wind loads and serves as a basis for assessing the risks of natural and man-made impacts.

a. Long-term trend in the number of days with strong winds by season

The spatial distribution of the linear trend coefficient (day/10 years) in the series of the number of days with a speed greater than 15 m/s by season is presented in Figure 4.2.

The highest values of the linear trend coefficients in the series of the number of days with a speed greater than 15 m/s are noticeable in the spring period, and the lowest in the winter.

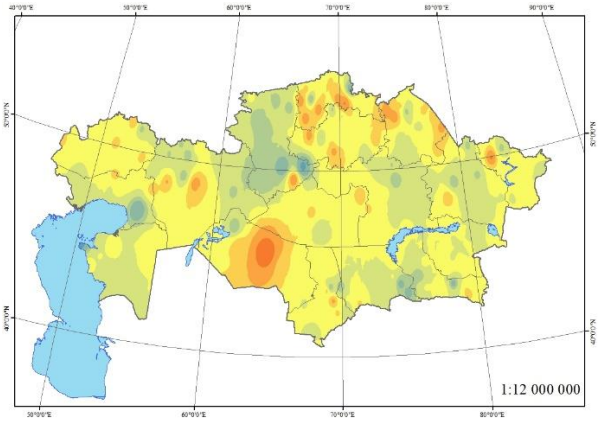
In winter, the spatial distribution of the linear trend coefficient for the number of days with wind speeds greater than 15 m/s (days per 10 years) showed that the largest increase was observed at the Zhosaly weather stations in Kyzylorda region (+6.9 days/10 years) and Ust-Kamenogorsk in East Kazakhstan region (+4.3 days/10 years). The largest decrease was recorded at the Fort-Shevchenko weather stations in Mangystau region (-5.6 days/10 years) and Arkalyk weather stations in Kostanay region (-4.9 days/10 years).

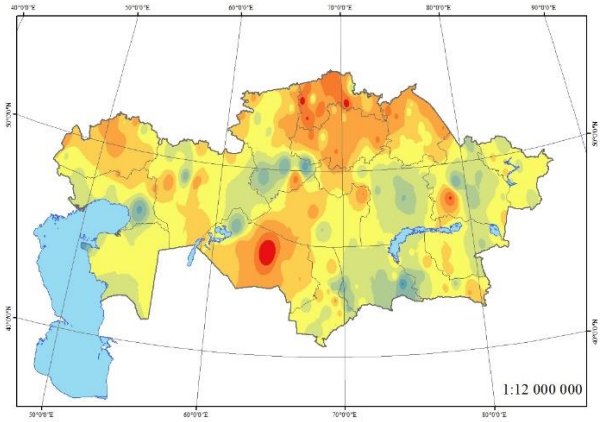
In spring, the maximum increase in the number of days with strong winds was noted at the weather stations of Zhosaly in the Kyzylorda region (+9.2 days/10 years) and Chkalovo in the North Kazakhstan region (+7.4 days/10 years), and a decrease was noted at the weather stations of Shokpar in the Zhambyl region (-6.3 days/10 years) and Arkalyk in the Kostanay region (-5.1 days/10 years).

In summer, the largest positive trends were recorded at the Zhosaly weather stations in Kyzylorda region (+11.4 days/10 years) and Barshatas in Abay region (+8.2 days/10 years). Negative values were observed at the Shokpar weather stations in Zhambyl region (-6.9 days/10 years) and Arkalyk in Kostanay region (-5.1 days/10 years).

In autumn, positive trends were observed at the weather stations of Zhosaly in Kyzylorda region (+7.7 days/10 years) and Timiryazevo in North Kazakhstan region (+4.8 days/10 years), negative trends were observed at Fort-Shevchenko in Mangystau region (-6.61 days/10 years), Shokpar in Zhambyl region (-5.8 days/10 years).

winter spring





summer autumn

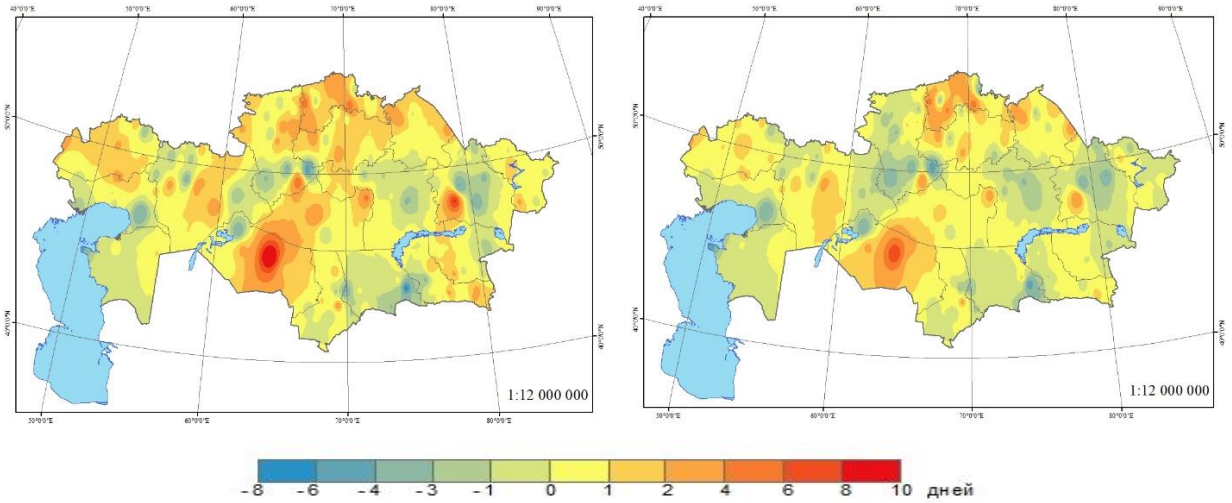


Figure 4.2– Linear trend coefficients (day/10 years) in the series of the number of days with a speed greater than 15 m/s 1979-2024

Overall, an analysis of long-term linear trends in the number of days with strong winds revealed that the increase in the frequency of strong winds is most characteristic of the Zhosaly weather station in Kyzylorda region, where positive trend values are observed in all seasons. At the same time, a steady decline in the number of days with winds over 15 m/s is observed at the Arkalyk weather station in Kostanay region, Shokpar in Zhambyl region, and Fort-Shevchenko in Mangystau region.

The identified trends in the number of days with winds ≥15 m/s enable us to assess the risks of extreme wind events and plan energy systems, agriculture, construction, and ecosystem protection measures. An increase in the number of such days increases the likelihood of negative impacts on populations and infrastructure.

To assess spatial differences and long-term changes in the wind regime, the linear trend coefficients of regionally averaged wind characteristics were calculated for the regions of Kazakhstan for the period 1979–2024, the values of which are presented in Table 4.1. The indicators are presented by seasons: winter, spring, summer, autumn.

An analysis of linear trends in seasonal values of average wind speed and the number of days with wind speed greater than 15 m/s for the period 1979–2024 revealed significant spatial and seasonal heterogeneity in changes in the wind regime in Kazakhstan.

The most significant increase in wind activity is observed in the North Kazakhstan region, where statistically significant increases in average wind speed were recorded in spring (+0.18 m/s/10 years) and summer (+0.11 m/s/10 years). The number of days with strong winds also increased significantly: by +4.37 days/10 years in winter and by +2.45 days/10 years in autumn. Similar trends are partially observed in the Zhambyl region, where positive wind speed trends were noted in spring (+0.24 m/s/10 years) and summer (+0.21 m/s/10 years), while the number of strong windy days decreased in winter and autumn.

The East Kazakhstan Region, Abay Region, and Karaganda Region are characterized by generally weak and mostly statistically insignificant trends. For example, in the East Kazakhstan Region, seasonal wind speed trends fluctuate within ±0.1 m/s/10 years, showing no consistent

pattern of change. In the Abay Region, no clear trends were detected, with the exception of a slight increase in summer (+0.07 m/s/10 years). In the Karaganda Region, positive wind speed trends are observed in spring and summer, but their values are close to the significance threshold.

A decrease in wind activity is predominantly recorded in the western regions of the country, especially in winter. For example, in the Atyrau and Mangystau regions, a decrease in average wind speed to -0.21 m/s/10 years was recorded, accompanied by a decrease in the number of days exceeding 15 m/s. Negative seasonal trends are also observed in several northwestern and central regions (Akmola and Aktobe).

The southern and southeastern regions (Almaty, Turkestan, and Zhetisu regions) are characterized by weak, mostly insignificant trends. However, in Kyzylorda region, an increase in the number of days with wind speeds over 15 m/s is observed in the spring and summer, which may indicate a localized increase in wind activity.

Thus, the obtained results indicate a strengthening of the wind regime in the northern and some southern regions, primarily during the warm season, with relative stability in the east and weakening winds in the west of the country. The identified trends are important for consideration in wind energy projects, agrometeorology, dust storm monitoring, and climate risk assessment.

Table 4.1– Estimates of the linear trend (bold font - statistically significant at an increase of 5% significance level) of regionally averaged wind characteristics for the regions of Kazakhstan for 1979-2024: average seasonal wind speed and the number of days with wind speed greater than 15 m/s.

No.	Region	Average seasonal wind speed ((m/s) / 10 years))				Number of days with wind speed greater than 15 m/s (days/10 years)			
		winter	spring	summer	autumn	winter	spring	summer	autumn
1	North Kazakhstan	-0.06	**0.18**	**0.11**	0.09	1.1	**4.37**	**2.48**	**2.45**
2	Akmola	-0.52	-0.41	-0.35	-0.42	-0.34	**1.75**	**0.83**	0.21
3	Kostanay	-0.31	-0.12	-0.08	-0.2	-1.26	0.69	**0.7**	-0.57
4	Pavlodar	-0.19	-0.04	-0.07	-0.09	0.54	**2.19**	**1.25**	**0.98**
5	East Kazakhstan	-0.06	-0.06	-0.08	-0.08	-0.13	0.07	0.39	-0.17
6	Abai	-0.08	-0.04	-0.07	-0.07	-0.52	0.03	-0.19	-0.27
7	Karaganda	-0.12	-0.11	-0.08	-0.1	-0.16	-0.13	0.07	-0.28
8	Ulytau	**0.12**	0.04	**0.13**	0.13	**0.93**	**1.63**	**1.75**	**1.08**
9	West Kazakhstan	-0.04	**0.1**	**0.08**	0.05	0.14	**1.51**	**0.85**	0.58
10	Atyrau	-0.21	-0.19	-0.14	-0.17	-0.37	0.08	0.14	-0.19
11	Mangystau	0.0	-0.02	0.02	0.0	-0.91	-0.71	-0.76	-1.23
12	Aktobe	-0.17	-0.11	-0.07	-0.13	-0.32	0.68	**0.58**	0.33
13	Kyzylorda	-0.13	-0.18	-0.14	-0.12	**0.81**	**1.41**	**1.44**	**1.12**
14	Turkestan	-0.03	-0.05	-0.07	-0.06	0.2	0.43	0.26	0.01
15	Zhambyl	-0.17	-0.24	-0.21	-0.2	-0.41	-1.12	-1.03	-0.82
16	Almaty	-0.04	-0.01	0.01	-0.02	-0.09	0.4	**0.64**	0.08
17	Jetisu	-0.13	-0.08	-0.03	-0.09	0.11	0.43	**0.4**	0.0

APPLICATION

MAXIMUM WIND SPEED,ANOMALY IN AVERAGE WIND SPEEDFOR 2024

No.	Weather stations	Maximum wind speed, m/s	Anomaly of average wind speed, m/s
1 North Kazakhstan region			
1	Petropavlovsk	28	0.2
2	Vozvyshenka	20	0.2
4	Blagoveshchenka	27	0.9
5	Sergeevka	21	1.6
6	Taiynsha	33	0.8
7	Timiryazevo	26	1.1
8	Kishkenekol	25	1.1
9	Chkalov	34	2.0
10	Saumalkol	24	-1.1
11	Ruzaevka	27	-0.9
2 Akmola region			
12	Nur-Sultan	22	1.5
13	Kokshetau	25	0.0
14	Shchuchinsk	26	-0.3
15	Balkashino	24	-0.3
16	Akkol	24	-0.4
17	Zhaksy	26	-0.1
18	Yesil	30	1.0
19	Atbasar	24	-0.5
20	Ereimentau	33	0.0
21	Zhaltyr	30	0.1
22	Egindykol	29	0.7
23	Arshaly	29	0.4
24	Korgalzhyn	29	0.4
3 Kostanay region			
25	Presnogorkovka	22	0.1
26	Karabalyk	21	-0.1
27	Mikhailovka	20	0.0
28	Sarykol	20	0.2
29	Kostanay	20	-0.6
30	Rudnyi	22	0.0
31	Karasu	28	0.3
32	Tobol	20	-0.2
33	Arshalinsky agricultural holding	19	-0.1
34	Kushmurun	23	0.2

No.	Weather stations	Maximum wind speed, m/s	Anomaly of average wind speed, m/s
35	Jetygara	24	-0.1
36	Zheleznodorozhnyi temporary storage warehouse	28	-0.6
37	Dievskaya	20	0.0
38	Karamendy	26	-0.4
39	Arkalyk	23	-0.7
40	Amangeldy	18	0.2
41	Torgai	20	0.1
42	Ekidin	28	0.8
4 Pavlodar region			
43	Mikhailovka	23	0.3
44	Fedorovka	26	-0.4
45	Ertis	30	0.8
46	Lozovaya	28	0.3
47	Golubovka	26	-0.3
48	Aktogay	30	-0.5
49	Uspenka	25	-0.2
50	Zholboldy	29	1.1
51	Sharbakty	34	0.7
52	Krasnoarmeika	24	-0.2
53	Pavlodar	25	-0.2
54	Shaldai	27	0.6
55	Ekibastuz	28	-1.1
56	Koktobe	27	-0.3
57	Bayanaul	31	-0.3
5 Abay region			
58	Semiyarka	28	-0.4
59	Dmitrievka	20	0.7
60	Semipalatinsk	20	-0.3
61	Shalabai	20	-0.1
62	Shar	20	0.7
63	Zhalgyztobe	29	0.1
64	Kainar	14	-0.4
65	Karaul	28	-0.4
66	Kokpekti	20	-0.6
67	Barshatas	25	1.6
68	Ayagoz	28	-0.7
69	Aksuat	24	0.2
70	Urzhar	18	-0.5
71	Aktogay	20	0.0
72	Bakty	23	0.3

No.	Weather stations	Maximum wind speed, m/s	Anomaly of average wind speed, m/s
6 East Kazakhstan region			
73	Shemonaikha	24	-0.1
74	Leninogorsk	24	0.5
75	Ust-Kamenogorsk	26	0.6
76	Seleznevka	28	-0.1
77	Katon-Karagay	25	-0.1
78	Ulken Naryn	29	0.2
79	Samara	24	0.4
80	Markakol Nature Reserve	20	-0.4
81	Kurshim	28	-0.7
82	Terekty	18	-0.1
83	Tugyl	23	-0.3
84	Akzhar	25	-0.6
85	Zaisan	23	-1.0
7 Karaganda region			
86	Rodnikovskoye	34	0.6
87	Korneevka	34	0.1
88	Kertindi	23	-1.0
89	Karaganda	25	0.1
90	Bes-oba	27	0.2
91	Zharyk	28	0.4
92	Aksu-Ayuly	24	0.2
93	Akadir	23	0.2
94	Aktogay	17	0.2
95	Kyzyltau	26	0.5
96	Bektauata	18	-0.1
97	Balkhash	23	-0.4
98	Sary Shagan	26	0.1
8 Region of Ulytau			
99	Zhana-Arka	28	1.2
100	Zhetykonur	18	-0.1
101	Zhezkazgan	22	-0.2
102	Kzylzhar	27	1.0
9 West Kazakhstan region			
103	Yanvartsevo	22	0.7
104	Aksai	21	-1.3
105	Uralsk	20	-0.5
106	Kamenka	21	0.4
107	Chingirlau	26	0.6
108	Jambeity	22	-0.1
109	Chapaevo	25	1.2

No.	Weather stations	Maximum wind speed, m/s	Anomaly of average wind speed, m/s
110	Karatobe	24	-0.3
111	Zhalpaktal	28	0.2
112	Dzhanybek	24	0.2
113	Taipak	25	0.7
114	Urda	22	-0.5
10 Atyrau region			
115	Inderborsky	25	0.2
116	Karabau	23	0.3
117	Sagiz	27	0.5
118	Zhana Ushtagan	14	-0.5
119	Makhambet	18	0.3
120	Atyrau	24	0.4
121	Kulsary	22	-0.5
122	Peshnoy	18	0.8
123	Ganyushkino	25	-0.3
11 Mangystau region			
124	Sam	21	0.8
125	Beineu	19	0.3
126	Kyzan	19	-0.1
127	Fort Shevchenko	20	-0.3
128	Tushibek	20	0.4
129	Aktau	24	0.2
12 Aktobe region			
130	Martuk	25	0.5
131	Kos-Istek	28	0.1
132	Rodnikovka	30	-0.1
133	Komsomolskoye	28	-0.7
134	Aktobe	29	0.1
135	Novoalekseevka	24	-0.2
136	Ilyinsky	27	-0.8
137	Karabutak	29	0.4
138	Temir	24	-0.04
139	Uil	28	-0.3
140	Emba	21	-0.3
141	Karaulkeldy	25	-0.1
142	Irgiz	25	-0.2
143	Mugodzharskaya	24	0.2
144	Shalkar	22	-0.2
145	Ayakkum	20	0.9
13 Kyzylorda region			
146	Aral Sea	25	-0.1

No.	Weather stations	Maximum wind speed, m/s	Anomaly of average wind speed, m/s
147	Kazalinsk	23	0.9
148	Zhosaly	28	0.6
149	Zlikha	23	-1
150	Karak	20	0.3
151	Kyzylorda	22	-0.4
152	Shieli	23	0.1
14 Turkestan region			
153	Tasty	24	-0.9
154	Sholakkorgan	20	-0.5
155	Ashysai	26	-0.02
156	Turkestan	23	-0.2
157	P.Zh.Kazhakhmetov (Shayan)	21	-0.2
158	Kyzylkum	20	-0.5
159	village of Turar Ryskulov	28	-0.7
160	Arys	15	-0.8
161	Shuyldak	14	0.2
162	Shymkent	22	-0.2
163	Tasaryk	18	0.6
164	Kazygurt	22	-0.5
165	Chardara	24	0.6
166	Zhetysay	12	-0.4
15 Zhambyl region			
167	Chiganak	25	0.0
168	Moyynkum	28	-1.1
169	Khantau	26	0.5
170	Shokpar	36	-0.1
171	Uyuk	28	0.2
172	Saudakent	26	-0.9
173	Tole bi	19	0.3
174	Kordai	22	0.1
175	Karatau	29	0.1
176	Merke	20	-0.3
177	Kulan	21	-0.1
178	Taraz	34	0.5
16 Region Zhetisu			
179	Ucharal	23	0.1
180	Alakol	25	0.3
181	Matai	23	1.0
182	Lepsi	9	0.0
183	Sarkand	20	0.2

No.	Weather stations	Maximum wind speed, m/s	Anomaly of average wind speed, m/s
184	Ushtobe	22	0.1
185	Taldykorgan	21	-0.6
186	Tekeli	16	0.1
187	Saryozek	25	0.4
188	Zharkent	25	-0.9
189	Zhalanashkol	40	-1.4
17 Almaty region			
190	Aul № 4	14	-0.3
191	Kuigan	23	-0.1
192	Bakanas	25	0.6
193	Kogaly	21	0.2
194	Aydarly	20	-0.4
195	Kapchagay	28	1.3
196	Shelek	24	0.6
197	Yesik	28	1.1
198	Aksengir	30	0.6
199	Kyrgyzsai	27	-0.7
200	Almaty (Stone plateau)	29	0.3
201	Almaty, OGMS	15	-0.1
202	Uzunagach	28	-0.4
203	Zhalanash	15	-0.7
204	Lake Ulken Almaty	15	-0.6
205	Kegen	20	1.0
206	Mynzhylky	17	-0.2
207	Narynkol	17	0.0

The bulletin was compiled by the Meteorological Research and Calculations Department
Scientific Research Center of the RSE "Kazhydromet"
Address: 010000, Astana, Mangilik El Ave. 11/1
Tel.: +7 (7172) 79-83-03
e-mail:info@meteo.kz