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Spectral Characteristics of Wind Variability in the Coastal Zone of the South Coast of Crimea 1997–2006

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Abstract
The paper studies the spectral characteristics of the coastal wind field variability near the South coast of Crimea in the zone of horizontal inhomogeneities of the land surface underlying the atmosphere and sea to specify the role of the coastal wind variability in the formation of coastal water circulation features. Reliable knowledge of these features is necessary for ecological standardization of the anthropogenic impact on marine ecosystems as part of ecological and economic processes management in the coastal sea zone. Archived data were used from standard meteorological observations of wind variability over a 10-year period of instrumental monitoring (1997–2006) at the Black Sea hydrophysical sub-satellite testing area of Marine Hydrophysical Institute near Cape Kikineiz onshore and offshore and at the hydrometeorological station near Cape Nikita (Yalta). The advanced information technology of processing and quality control of vector data was used to ensure the unity of multi-year measurements, which allowed increasing the accuracy of measured wind characteristics. The peculiarities of spectral characteristics of the coastal wind field variability in daily, mesoscale and seasonal ranges were found out. The obtained *in situ* results were compared with the known results of numerical modelling using modern models of regional atmospheric circulation with high spatial and temporal resolution. The scientific novelty of the work is in obtaining representative empirical knowledge during the analysis of materials on the peculiarities of wind condition variability near the coast in zones with horizontal heterogeneities of the properties of the land surface underlying the atmosphere and comparing these results with the existing model developments. Such integrated studies provide reliable knowledge of the circulation patterns of coastal waters off the South coast of Crimea given the effects of local winds.

Keywords: South coast of Crimea, coastal zone, marine ecosystem, monitoring, meteorological parameters, wind conditions, distribution histogram, spectral density

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Спектральные характеристики изменчивости ветра в прибрежной зоне Южного берега Крыма в 1997–2006 годах

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Аннотация

Целью работы является исследование спектральных характеристик изменчивости поля прибрежного ветра у Южного берега Крыма в зоне горизонтальных неоднородностей подстилающей атмосферу поверхности суши и моря для уточнения роли изменчивости прибрежного ветра в формировании особенностей циркуляции прибрежных вод. Достоверные знания об этих особенностях необходимы для экологического нормирования антропогенного воздействия на морские экосистемы в рамках управления эколого-экономическими процессами в прибрежной зоне моря. Использованы архивные данные стандартных метеорологических наблюдений изменчивости ветра за 10-летний период инструментального мониторинга (1997–2006 гг.) на Черноморском гидрофизическом подспутниковом полигоне Морского гидрофизического института у м. Кикинеиз на суше и в море, а также на гидрометеорологической станции у м. Никита (г. Ялта). Для обеспечения единства многолетних измерений использована перспективная информационная технология обработки и контроля качества векторных данных, которая позволила повысить точность измеряемых характеристик ветра. Выявлены особенности спектральных характеристик изменчивости поля прибрежного ветра в суточном, мезомасштабном и сезонном диапазонах. Полученные натурные результаты сопоставлены с известными результатами численного моделирования с использованием современных моделей региональной атмосферной циркуляции с высоким пространственным и временным разрешением. Научная новизна работы заключается в получении репрезентативных эмпирических знаний при анализе материалов об особенностях изменчивости ветровых условий у побережья в зонах с горизонтальными неоднородностями свойств подстилающей атмосферу земной поверхности и сопоставлений этих результатов с существующими модельными разработками. Такие комплексные исследования позволяют получить достоверные знания о закономерностях циркуляции прибрежных вод у Южного берега Крыма с учетом воздействия местных ветров.

Ключевые слова: Южный берег Крыма, прибрежная зона, морская экосистема, мониторинг, метеопараметры, ветровые условия, гистограмма распределения, спектральная плотность

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Introduction

Currently, the development of natural, economic and recreational complexes near the South coast of Crimea is due to the intensive development of its land area and the coastal zone of the Black Sea. Based on estimates of the level of anthropogenic pressure on the coastal zones and ecotones of the Black Sea coast of Crimea, it was noted in [1] that the coastal ecosystems of the Black Sea tend to degrade under the influence of anthropogenic pollution entering the marine environment, which requires adoption of legal restrictive measures. According to [1, 2], an ecotone is a zone at the interface between two media, where boundary effects are manifested in a special mode of geochemical processes that create the possibility of the existence of specific biocenoses and ecosystems in the boundary zones. Near the Southern coast of Crimea (SCC), such zones are the coastal ecotone of the land and the coastal marine ecotone, which exist at the boundary of land and sea.

The water area of the marine ecotone is the coastal extremity of the shelf zone and includes an adjacent shallow strip of the open part of the sea, bays and gulfs. The existence zone of the coastal ecotone of the sea near Cape Kikineiz of the SCC occupies a coastal strip limited by depths of 50–70 m at a distance of up to 1 km from the coast. To establish the degree of damage caused to the coastal ecosystem by pollution of this water area, reliable data on the intensity of processes in the coastal frontal zones and sections are required [1, 2]. The circulation of waters in the shallow coastal area of the shelf near the SCC has its own regularities [3, 4] and differs from the dynamics of waters in the adjacent shelf-slope part of the sea, as well as from the Rim Current [5]. The specific features of coastal water circulation are determined by the geographic location and structure of the unique natural landscape of the SCC, the shape of the coastline and bottom relief, and the intensification and stability of water circulation are associated with oceanological and meteorological disturbances.

At the current level of the Black Sea pollution flux [6] entering the marine environment, it is necessary to apply ecological regulation of anthropogenic impacts on marine ecosystems in the framework of managing ecological and economic processes in the coastal zone of the sea [7]. In order to determine scientifically based limiting norms of the pollution fluxes entering marine environment, along with the estimates of their level and the capabilities of the ecosystem assimilation capacity, reliable knowledge about the features of coastal water circulation is required. Based on the results of long-term field studies of the coastal currents near the SCC, presented in [3, 4], the regularities of the cyclonic circulation of the stationary alongshore current and the features of its variability in the gravitational-inertial, subinertial and seasonal ranges were revealed. Experimental identification of the factors causing such an intensification of currents is an urgent task.

It is known that the intensity of the wind circulation in the sea depends on the wind conditions of the atmospheric surface layer. Near the coast in the zone of the surface underlying the atmosphere (land and sea), the characteristics of the air flow (wind) are variable over a wide range. From the analysis of the published results of research on wind characteristics near the SCC, the following should be noted. According to the instrumental measurements, the wind variability near the coast is formed as a result of contribution of a large-scale wind field, which is transformed when the wind flows around the Main Range of the Crimean Mountains, and a superposition of local formations of thermal and orographic origin [1), 2), 3), 4)] [8]. At the same time, the practical value of the results of modelling studies obtained at Marine Hydrophysical Institute (MHI) according to the data of a regional retrospective analysis (reanalysis) based on various numerical models of atmospheric circulation, presented in a series of works [9–15], should be especially noted.

The main elements of the large-scale cyclonic circulation of the Black Sea waters are the Rim Current jet and two macrocyclonic gyres in the eastern and western parts of the sea [5, 16]. The seasonal variability of the large-scale circulation of the Black Sea waters is largely determined by the action of the driving stress of the wind, and the wind field vorticity is the main characteristic that determines the generation of wind circulation in the sea [9]. On seasonal time scales of variability, vorticity of the field of the driving wind velocity modulus on the Black Sea surface includes background vorticity associated with the general large-scale atmospheric circulation and a regional component. Regional vorticity associated with orography and contrast between the characteristics of the underlying surface of the sea and land dramatically affects the formation of the total wind field of the surface layer of the atmosphere [13], which, as a result, is the dominant factor in the formation of variability of hydrophysical fields of the Black Sea [11]. Based on the results of a review of materials from early *in situ* [1)–4)] [8] and theoretical studies [9–15], brief information is given below, which is necessary for further discussion of the results of studies of spectral characteristics of the surface wind field variability in the zone of the land and sea surface underlying the atmosphere.

The hydrometeorological regime of the SCC and adjacent water areas is mainly determined by macrocirculation processes of the Mediterranean climatic region, features of coastline configuration, and geomorphological structure of the Crimean Peninsula [8, 9]. Atmospheric processes occurring over the Black Sea are distinguished by a wide variety of forms, which are largely due to the features of baric conditions and orographic features of the SCC.

[1)] Lapin, M.N., 1954. [*The Black Sea Pilot*]. Leningrad: Izd-vo Gidrograficheskogo Upravleniya Voenno-Morskih Sil, 506 p. (in Russian).

[2)] Potapov, N.S., 1956. [Breeze Circulation on the South coast of Crimea]. In: Shuleykin, V.V., ed., 1956. *Trudy Morskogo Gidrofizicheskogo Instituta*. Moscow: Izd-vo AN SSSR. Vol. 8, pp. 98–108 (in Russian).

[3)] Chernyakova, A.P., 1965. Typical Wind Fields of the Black Sea. In: MGMO ChAM, 1965. [*Collection of Works of the Basin Hydrometeorological Observatory of the Black and Azov Seas*]. Leningrad: Gidrometeoizdat. Iss. 3, pp. 78–121 (in Russian).

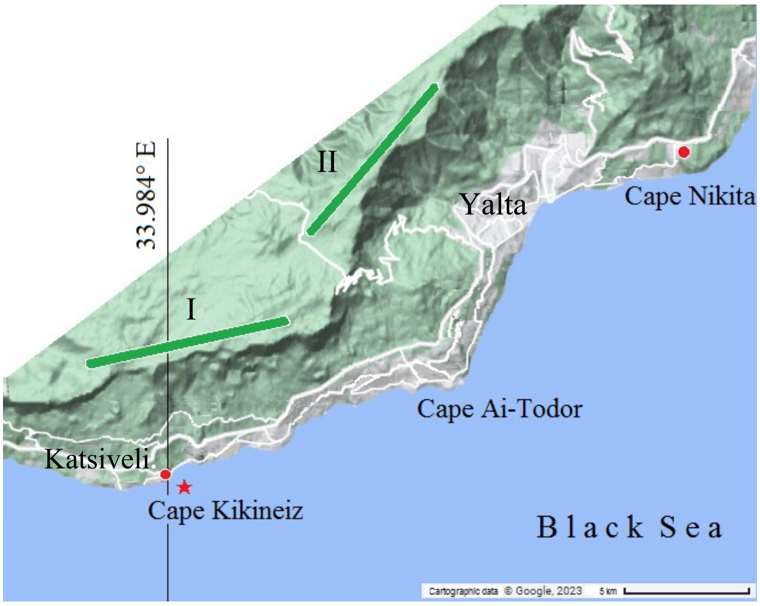
[4)] Zats, V.I., Lukyanenko, O.Ya. and Yatsevich, G.V., 1966. [*Hydrometeorological Regime of the Southern Coast of Crimea*]. Leningrad: Gidrometeoizdat, 120 p. (in Russian).

During the year, barico-circulation features of atmospheric processes over the Black Sea have well-defined seasonal differences. In this case, the regional vorticity of the wind field is the main factor in the formation of the seasonal course of the vorticity of the wind velocity field, which varies from cyclonic in winter to anticyclonic in summer [8, 9]. As it is known, wind conditions on land and near the coast are significantly different from wind conditions in open areas of the sea [8]. Geomorphological and orographic subregional features of the SCC region change the nature of regional atmospheric circulation and contribute to the emergence of its local manifestations [1)–4)] [8–10, 12–15].

The purpose of this work is to study spectral characteristics of multiscale variability of the coastal wind on the basis of the archival data obtained over a 10-year period of instrumental monitoring from 1997 to 2006 near Cape Kikineiz at the Black Sea hydrophysical sub-satellite testing area (BSHSTA) of MHI, as well as the data from the meteorological station at Cape Nikita. The scientific novelty of the work lies in obtaining reliable empirical knowledge based on the analysis of archival materials on variability of characteristics of the coastal wind in zones with horizontal inhomogeneities of the properties of the earth's surface underlying the atmosphere and comparison of these characteristics with existing theoretical developments. These materials are necessary for further studies of variability of the spectral characteristics of the coastal wind field near the SCC and revealing their relationship with the features of coastal water circulation [4].

Materials and methods

This paper presents the results of processing and analysis of the archival data of standard meteorological observations of wind variability performed on a contractual basis in 1997–2006 near Cape Kikineiz and at Cape Nikita (Fig. 1). The means for monitoring the hydrometeorological situation at BSHSTA of MHI provided contact monitoring of the wind field characteristics at the polygon near Cape Kikineiz in the zone of the land's surface underlying the atmosphere and the coastal zone of the sea. The wind characteristics were measured at the coastal hydrometeorological station of Katsiveli village (Fig. 1) with coordinates 44.38° N and 33.98° E, at a height of ~ 40 m and at a distance of ~ 150 m from the water's edge. The measurements of the wind characteristics near Cape Nikita (Fig. 1) were carried out at the Nikitsky Sad meteorological station, located at a distance of ~ 25 km to the northeast of Cape Kikineiz, with coordinates of 44.51° N and 34.24° E, at a height of ~ 200 m and at a distance of ~ 550 m from the water's edge. The wind characteristics of the atmospheric surface layer were measured in the Goluboy Gulf (Fig. 1) at the marine hydrometeorological station of the stationary oceanographic platform [3] with coordinates 44.39° N and 33.98° E, at an altitude of 18 m above sea level and at a distance of ~ 450 m from the coast. The measurements on the platform at sea are presented for the 7-year observation period 1997–2003 during the seasons of the greatest development of the breeze from May to October.



F i g . 2 . Schematic map of the studied area near the South coast of Crimea. The circles are for onshore weather stations, the star is for those in the Goluboy Gulf. Line I denotes the ridge orientation near Cape Kikineiz, line II – near Cape Nikita

The south coast of the Crimean Peninsula from Cape Sarych to Cape Ai-Todor is protected by the Main Range of the Crimean Mountains, blocking direct access to northern winds [2)]. The southern cliffs of the mountain range, as well as the adjacent coastline near the village of Katsiveli, are oriented from the west-southwest to the east-northeast (straight line I in Fig. 1). The land area between the cliffs and the coast reaches a width of 4 km, and the heights of the mountains are in the range of 1000–1200 m. From Cape Ai-Todor to Cape Nikita, the coastal strip of the SCC is protected by a mountain range from the northeast [2)], where the slopes of the mountains towards the sea are oriented from the southwest to the northeast (straight line II in Fig. 1). At Cape Nikita, the land strip between the mountain range and the coastline reaches a width of 8 km, with the height of the adjacent mountain range ~ 1200 m.

The instrumental measurements of the wind field characteristics were made by M-63M anemorumbographs. The wind meters operated in the standard averaging mode with 8-term registration of measurements in one day. Every 3 hours, the instantaneous successive values of the modulus of the velocity and direction of the wind vector averaged over a 10-minute time interval were recorded. The totality of the initial chronological sequences for the 10-year period of research amounted to 29,216 pairs of components of 3-hour readings of the coastal wind vector characteristics.

According to the passport data, the primary measuring transducers of the anemorumbograph have typical metrological characteristics with a sensitivity (the least significant digit of the meter) for the wind velocity channel no more than 0.1 m/s and the wind direction channel no more than 3°. The measurement technology made it possible to exclude the contribution of faulty values and significant methodological measurement errors, and further application of the procedure for analyzing the results of statistical processing of the set of vector data for monitoring wind characteristics made it possible to increase the averaged data accuracy. To ensure the uniformity of long-term measurements, the materials underwent data quality control in the prescribed manner and, on their basis, vector-averaged 9-hour and average daily values of the wind velocity and direction modulus were calculated. The results of statistical processing of vector-averaged data, taking into account the analysis of the actual values of the current histograms of distribution of the modulus of the wind velocity vector and direction, ensured an increase in the accuracy of measurements of wind components to the limiting levels of random errors [17]. At certain averaging intervals, the limiting random mean-square errors in measuring the modulus of the wind vector velocity and direction are reduced to 0.1–0.2 m/s and to 5°, respectively.

On the basis of a set of initial data of instrumental measurements, 3652 pairs of mean hourly values of the wind vector components were formed. The *in situ* data are further used in full in statistical and spectral analysis. It should be noted that in the course of modelling studies in [10, 13, 15], to identify the contribution of the breeze against the background of synoptic disturbances, a special method of digital filtering of the processed data, the "method of difference composites", was used under the assumption that the fields of breeze and synoptic circulation are additive. The spectral analysis of the vector characteristics of the air flow (wind) in this work was carried out within the framework of a linear (filter) estimation of the energy spectrum of oscillations, similar to the method of analyzing a set of vector data in [3, 4] through periodogram smoothing using a fast Fourier transform procedure. The features of the method of spectral analysis of vector characteristics are presented in the works [5), 6)]. On the basis of these materials, a software information product used in this work was developed. The choice of vector data filtering parameters made it possible to reliably investigate the energy contribution and spectral features of the distribution of the total energy density of oscillations with multiscale variability of the coastal wind field. Estimations of breeze characteristics were also obtained under the assumption that the fields of the breeze and synoptic circulation are additive.

[5)] Konyaev, K.V., 1981. [*Spectral Analysis of Random Oceanological Fields*]. Leningrad: Gidrometeoizdat, 207 p. (in Russian).

[6)] Blatov, A.S., Bulgakov, N.P., Ivanov, V.A., Kosarev, V.N. and Tuzhilkin, V.S., 1984. *Variability of Hydrophysical Fields of the Black Sea*. Leningrad: Gidrometeoizdat, 240 p. (in Russian).

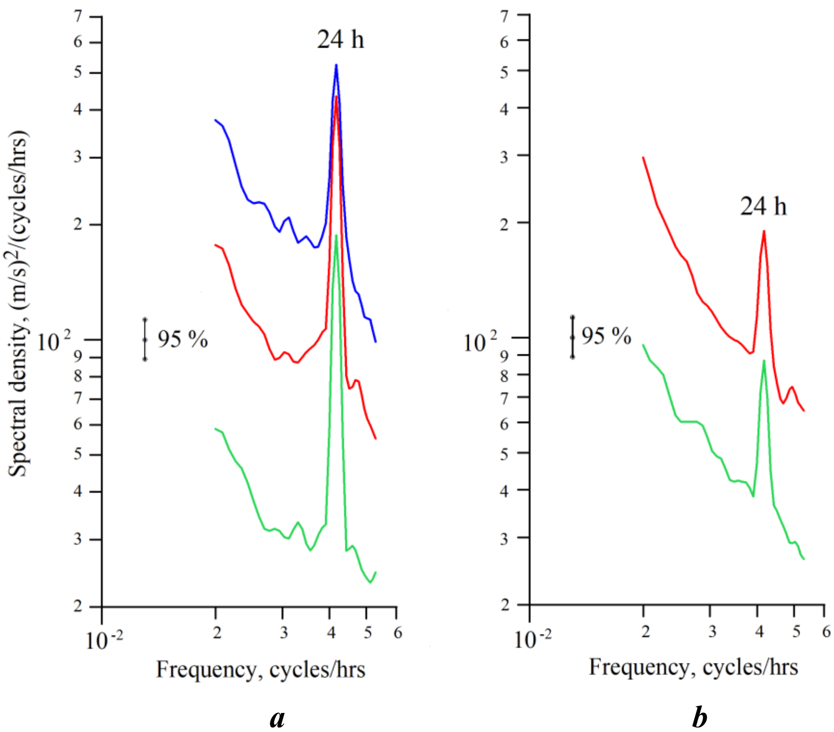
Discussion and results

In the zone of narrowing of the continental slope between the southern tip of the Crimean Peninsula and the Anatolian coast, the water area of the Black Sea is divided along the meridian 34° E passing through the territory of BSHSTA of MHI (33.984° E) to the eastern and western parts [12], where macrocyclonic circulations of currents ("Knipovich spectacles") are formed [16]. The transitional zone between the gyres, adjacent to the territory of BSHSTA of MHI, is both functionally and territorially associated with the connecting "bridge of Knipovich spectacles".

The Crimean Mountains, horizontal inhomogeneities of the underlying surface, and thermal land-sea contrasts cause disturbances in the lower part of the atmospheric boundary layer, contributing to the generation and development of a wide range of mesoscale processes near the SCC. One of the empirical problems considered in this paper is the study of the variability features of such mesoscale disturbances based on the spectral analysis of *in situ* data. Taking into account the previously accumulated knowledge obtained on the basis of numerical modelling of the atmospheric circulation over the Black Sea, it is possible to reasonably identify the variability features of the coastal wind characteristics.

The structure of atmospheric fields in the zone of the coastal ecotone of land and sea near the SCC is most variable in the spring-summer and summer-autumn seasons (May–October) [10, 14, 15]. At this time of the year, the daily variability of atmospheric fields is clearly expressed due to the maximum intensification of breeze circulation, which is the result of temperature contrasts between the sea and land associated with daily and seasonal cycles. The daytime breeze (sea breeze) is a gravitational flow of air propagating towards the land, and the night breeze (continental breeze) has the opposite direction. Instrumental studies of breeze circulation near the village of Katsiveli have been carried out since 1949 [2)] by a complex of upper-air observations, including drifter balloon-pilot studies. Subsequently, a representative method for studying breeze circulation was numerical simulation using regional atmospheric circulation models with high spatial and temporal resolution [9, 13–15]. The set of *in situ* data on the variability of coastal wind characteristics analyzed in this paper makes it possible to resume contact field studies of the breeze circulation features near the SCC at a new technological level in order to subsequently assess the role of local winds in the formation of coastal water circulation features.

A significant increase in wind velocities in the sea, compared to its velocities on land near Cape Kikineiz, has been instrumentally recorded since 1983. Fig. 2 shows the multi-year average full energy spectra of coastal wind oscillations near the SCC for 1997–2003, calculated from 9-hour vector-averaged data in the range of wind field variability periods from 18 hours to 2 days. The spectra in Fig. 2, *a* are calculated according to the data of the marine meteorological point in the Goluboy Gulf, the onshore meteorological point near Cape Kikineiz and the onshore meteorological station near Cape Nikita during the period of intensification of breeze circulation (May–October) and demonstrate a significant energy contribution of wind oscillations over a period of 24 h (1 day).



F i g . 2 . Full energy spectra of wind oscillations near the South coast of Crimea in the period range of 18 h – 2 days: *a* – at intensification of breeze circulation and daily variability of the coastal wind field (May – October) according to data from the marine meteorological point in the Goluboy Gulf, the onshore meteorological point near Cape Kikineiz and the onshore meteorological station near Cape Nikita (blue, red and green lines, respectively); *b* – at weaker daily variability of the coastal wind field (November – April) according to the data of the onshore meteorological point near Cape Kikineiz and the onshore meteorological station at Cape Nikita (red and green lines, respectively) at the 95 % confidence interval

The spectral maxima significantly exceed the limits of the 95% confidence interval and are credible. The long-term average spectra calculated from the data of the onshore meteorological point near Cape Kikineiz and the onshore meteorological station near Cape Nikita in November–April (Fig. 2, *b*) demonstrate a decrease in the energy contribution of wind oscillations over a period of 24 h compared with the spectra in Fig. 2, *a*. Wind characteristics were not measured in November–April at the meteorological point in the Goluboy Gulf near Cape Kikineiz.

As it is known, the daytime breeze carries the sea air in the atmospheric surface layer towards the coast, while the night breeze is directed from the coast towards the sea. As a result, a single quasi-cyclic process is formed with an oscillation period of 1 day, where the velocities of the daytime breeze near the Crimean Mountains can reach 8 m/s, and the night breeze near Crimea can reach 5 m/s [10] with a characteristic total breeze velocity of about 4–5 m/s [15]. Based on the presented complete energy spectra, the corresponding long-term average values of the daily coastal wind oscillation velocities were calculated for each of the observation points. In May–October, the average annual velocities of daily wind fluctuations in the sea near Cape Kikineiz were 9.7 m/s, on the shore near Cape Kikineiz – 10.4 m/s, and on the coast near Cape Nikita – 8.0 m/s. In November–April, the average multi-year velocities of daily wind fluctuations on the shore near Cape Kikineiz were 4.2 m/s, and on the shore near Cape Nikita – 3.1 m/s.

In the seasons of breeze circulation intensification (Fig. 2, *a*), the average multi-annual daily wind variability rates near Cape Kikineiz between the sea and land differed slightly, and on land between Cape Kikineiz and Cape Nikita had a difference of ~ 2 m/s. During the seasons of decreasing intensity of diurnal wind fluctuations (Fig. 2, *b*), the differences on land between Cape Kikineiz and Cape Nikita were ~1 m/s. The indicated average annual seasonal breeze velocities obtained from the *in situ* data near Cape Nikita almost coincide with the velocities calculated from the data of the regional reanalysis of atmospheric circulation for the Black Sea region based on the mesoscale model [10]. The daily wind variability velocities found on land near Cape Kikineiz during the period of weakening of the breeze circulation of the wind (November–April) also coincide with the model estimates.

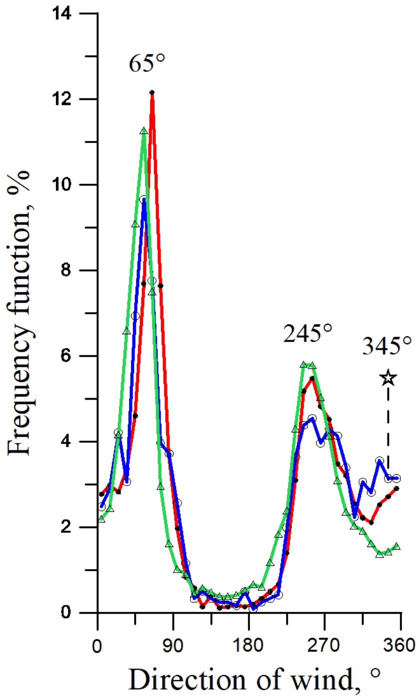
However, in the spring-summer and summer-autumn seasons (May–October), with the intensification of breeze circulation, the average multi-year velocities of wind oscillations with a daily period near Cape Kikineiz both on land and sea exceed the corresponding model estimates of the characteristic breeze velocity [15] almost twofold. In this regard, it should be noted that in work [2)], instrumental observations revealed a daily contribution of the local nighttime thermal wind of the slopes, when the released air periodically flows down from the Crimean Mountains. In [13], based on the results of modelling mesoscale features of atmospheric circulation in the coastal part of the SCC, it was shown that night breeze velocities can reach 10 m/s, which is associated with the appearance of a katabatic wind that occurs at night and propagates down the slope of the adjacent mountains near the village of Katsiveli [14]. The revealed mean annual wind velocities with a diurnal period significantly exceed the typical breeze velocities, which is due to the additional daily contribution of the local thermal wind and orography. The night katabatic wind makes a certain contribution to the daily fluctuations of the total wind in the village of Katsiveli. Occasionally, reaching hurricane force, it creates a situation of natural disaster, tearing off roofs from houses and buildings, breaking and uprooting perennial trees.

According to the rectilinear coastline scheme [15], the direction of the breeze is almost perpendicular to the coastline. The Crimean Mountains with heights near the SCC in the range of 1000–1200 m significantly change the structure of the breeze circulation. The sea breeze propagation height in Crimea is 500–1000 m [13], while it was noted in work [2)] that the upper limit of the sea breeze can reach 1600 m. In such cases, only the upper part of the flow penetrates onto land beyond the Main Range of the Crimean Mountains. In the case when high mountains block the propagation of breeze further on land [2)] [10, 15], an area of strong alongshore breeze air flows is formed near the SCC [15]. During the day, the breeze circulation periodically changes in terms of velocity and direction. With the development of both daytime and nighttime breezes, the action of the Coriolis force leads to the rotation of the velocity field vector during the day [10]. During the daily cycle, the development of the breeze is accompanied by a gradual change in its direction in a clockwise direction. Such diurnal dynamics of the local wind introduces additional distortions in *in situ* studies of the characteristics of the coastal wind field near the SCC in the range of mesoscale, synoptic and seasonal variability, which must be taken into account when processing and analyzing *in situ* data.

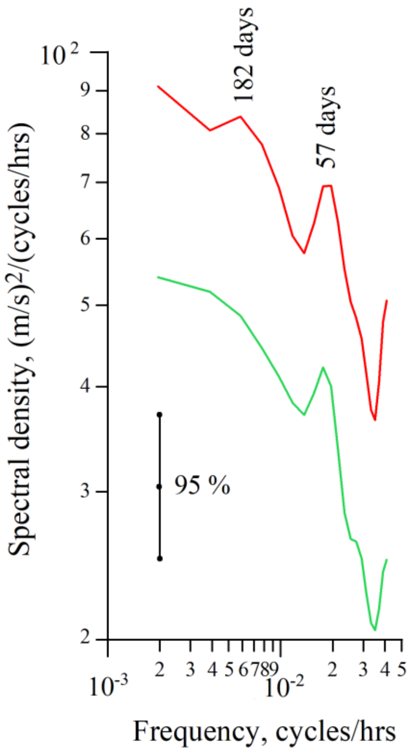
High Crimean Mountains significantly change the structure of the regional wind field near the coast [2)–4)] [8, 9, 13, 15] and form the alongshore structure of the coastal wind near the SCC, including the breeze component, both on land and in the near, relatively narrow coastal strip of the sea [14]. Fig. 3 shows the frequency distribution histograms of the alongshore wind directions near the SCC.

The mountains near the SCC significantly complicate the situation, creating a complex superposition of breeze and mountain-valley winds in the land-sea junction zone. In order to suppress the contribution of intense daily fluctuations caused by local winds (breezes, mountain-valley and katabatic winds) in the implementations, the procedure of daily vector averaging of the initial data was performed. The asterisk in Fig. 3 shows the maximum value of the probability density of the contribution of local winds from the mountains (from 345°), calculated from the initial data of the sea and coastal meteorological points near Cape Kikineiz before their daily averaging. At Cape Nikita, the intensive contribution of local winds from the mountains was not identified in the initial realizations. In Fig. 3, two main almost collinear directions are distinguished, along which the alongshore circulation of the coastal wind near the SCC is oriented.

To analyze the large-scale variability of the wind field near the SCC, we used the average daily and average monthly vector-averaged values of the coastal wind velocity and direction modulus, formed over a 10-year period of *in situ* observations. Fig. 4 shows the long-term average full energy spectra of wind oscillations near the SCC for 1997–2006 in the variability range of 24–512 days.



F i g . 3 . Histograms of the frequency distribution of alongshore wind directions near the South coast of Crimea based on daily vector-averaged multi-year data from the Goluboy Gulf marine meteorological station, the onshore meteorological station at Cape Kikineiz and the onshore meteorological station at Cape Nikita (blue, red and green lines, respectively). Kikineiz and the onshore meteorological station near Nikita (blue, red and green lines, respectively). The star shows the maximum probability density value of diurnal slope wind contribution from land in the raw, not averaged data of the offshore and onshore meteorological points at Cape Kikineiz



F i g . 4 . The 1997–2006 long-term average full energy spectra of wind variability near the South coast of Crimea in the range of periods 24–512 days based on the data from the onshore meteorological point at Cape Kikineiz and onshore meteorological station Nikita (red and green lines, respectively) at 95 % confidence interval

The spectra in Fig. 4 demonstrate the reliable energy contribution of coastal wind fluctuations over a period of about two months (57 days) at the measurement points on land. The nature of the wind intense variability at the indicated points is almost identical, however, the values of the mean annual velocities of coastal wind oscillations near Cape Kikineiz are almost 1.5 times higher. Previously, the results of long-term studies of the coastal current variability near Cape Kikineiz [3] were published, where seasonal fluctuations of currents on the annual period, the second and third annual harmonics were reliably identified, as well as current fluctuations with a period of about two months, identified in the set of long-term average energy spectra of coastal current variability near the SCC (Fig. 2 in [3, p. 161]). Further spectral analysis of the *in situ* data presented in this paper made it possible to reliably separate the seasonal fluctuations of the coastal wind field on annual and semi-annual periods at a 90 % confidence interval.

This paper presents preliminary results of a study of the spectral characteristics of the coastal wind variability near the SCC, obtained from the analysis of archival *in situ* data. Further development of instrumental synchronous studies of the field of coastal wind and currents at BSHSTA of MHI near the SCC will allow to obtain new representative *in situ* data within the framework of the problem under study.

Conclusion

New scientific results were obtained on the basis of processing and analysis of archival data of standard meteorological observations of wind variability for a 10-year period of instrumental monitoring performed in 1997–2006 at the Black Sea hydrophysical sub-satellite testing area of the Marine Hydrophysical Institute near Cape Kikineiz on land and in the sea, as well as at the hydrometeorological station near Cape Nikita of the SCC. To ensure the uniformity of long-term measurements, a promising information technology for processing and quality control of vector data was used, which made it possible to improve the accuracy of measured wind characteristics.

On the basis of archival data of a full-scale experiment, the mean long-term full energy spectra of coastal wind field oscillations for the diurnal range of variability were studied. The seasonal variability of the intensity of diurnal wind fluctuations, associated with intra-annual changes in the contribution of breeze and local mountain-valley winds in the boundary zone of land and sea, was reliably revealed. Intense fluctuations of the coastal wind were revealed for periods of about 57 days, and the seasonal fluctuations of the coastal wind field near the SCC were reliably separated for annual and semi-annual periods.

The experience of working with the data from contact monitoring of wind characteristics allows us to continue instrumental *in situ* studies in this direction at the modern technological level. Representative estimates of the variability of coastal wind conditions and their contribution to the formation of the coastal water circulation structure are required to obtain new empirical knowledge in the framework of this problem that has not been sufficiently studied so far. A comprehensive analysis of current variability data and time-synchronous data of local wind characteristics makes it possible to obtain new scientific knowledge about cause-and-effect relationships and the contribution of wind variability of the near-water layer of the atmosphere to the formation of a quasi-stationary structure, regime and multi-scale variability of coastal water circulation off the coast, which remains one of the priority tasks of the Marine Hydrophysical Institute of the Russian Academy of Sciences.

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