Atmospheric Boundary-Layer Height at Marine and Land Air Masses Based on Sodar Data

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Abstract. The evolution of the Atmospheric Boundary Layer (ABL) or the layer adjacent to the surface is a subject of research worldwide due to its importance for all human activities. During the last two decades, its monitoring has been increasingly carried out with the use of modern ground-based remote sensing instruments for atmospheric profiling, such as sodars, lidars, and microwave radiometers. The acoustic sounding of the atmosphere with sodars is now established as a reliable and highly effective method for profiling wind and turbulence in different ranges. Such a method of observation was used in the Southern Bulgarian Black Sea coastal zone during the period August 2008 to October 2016. The accumulated long-term data are of high spatial (10 m) and temporal (10 min) resolution and provide climatological information on the ABL vertical structure up to 600 m above the ground. In this study, the performed acoustic profiling is used to derive the ABL height in two of its main thermodynamic states: stable and convective. For this purpose, monthly analyzes of data covering the entire study period were performed. Two main types of coastal air masses were analyzed: those from land and marine. The appropriate selection of the monthly periods of analysis in combination with selected time intervals corresponding to night time and day time air masses, gives the opportunity to derive monthly average profiles characterizing the states of the atmosphere with stable and unstable stratification. The heights of the different types of stratified boundary layer are obtained by tracking the gradient changes in the monthly average profiles of turbulent characteristics, such as variance of vertical wind speed, eddy dissipation rate, turbulent kinetic energy, and buoyancy production. The results reveal monthly changes in the nocturnal marine (330 - 400 m in May and 290 m in November) and land (440 - 490 m in April, 470 - 490 m in May and about 360 m in June) ABL heights derived taking into account the vertical range of the sodar. This study has a wide practical potential and it provides important for the coastal ABL information which could be used in various prognostic, climate, and dispersion models.

Keywords: Sodar · Atmospheric Boundary Layer · Turbulent characteristics · Climatological analysis · Black Sea

1 Introduction

The study of the ABL structure has important theoretical and practical significance, and the determination of its characteristics makes it possible to obtain information about the

state of the atmosphere close to the surface. According to its stratification, the ABL is divided into three main thermodynamic states: stable, neutral, and convective (unstable). In dispersion models describing air pollution, ABL is called the mixing layer (ML) and its height can be associated with the height of the convective boundary layer (CBL), the base of the elevated inversion which caps the CBL, the height of internal boundary layer (IBL) or the height of the accumulation of aerosols recorded in remote measurements [1]. Determining the height of the ML, using ground-based remote sensing methods, is a topic described and discussed over the years in various scientific papers [2–5]. Several main methods used to determine diurnal variations in ML are outlined in a review by Emeis et al. [4]. Among the mentioned methods using acoustic sounding of the atmosphere are the analyzes of vertical wind variance method (VWV method), as well as analyzes of enhanced acoustic received echo method (EARE method) together with VWV method. Algorithms using more than one ground-based remote sensing instrument for measuring meteorological characteristics in ABL are being developed at advanced observation stations, as combinations of acoustic (sodars), optical (ceilometers and lidars), and electromagnetic (wind radars and RASS extensions) soundings of the atmosphere, including surface measurements of turbulent heat fluxes. The ability of all these instruments to monitor the diurnal variations of ML is limited by their vertical range. A disadvantage of the acoustic sounding systems of the atmosphere is the fact that ambient noise (including the noise of falling drops during heavy rain) disturbs the measurements. The use of sodars in urban areas is limited due to the persistent signal they produce. The advantages are the low height from which the measurement with acoustic waves can start, the ability of the instrument to determine the height of the ML based on turbulence parameters, as well as the high vertical resolution of the measurements allowing to determine the height of shallow ML (especially at night). Estimating the ABL height through the turbulent profiles' characteristics (sigW, TKE, BP, etc.) has been suggested during recent years in studies based on data from remote sensing measurements [3, 6, 7].

In the absence of temperature and humidity profiles in the atmosphere, it is possible to retrieve more information for the ABL from the sodar wind and turbulence data and this advantage is used in the present paper. While with the lidars the calculations of sigW are based on a backscatter signal from aerosols (only when scanning vertically), the measurements of turbulent characteristics with sodars are direct. In this paper, all profiles of the turbulent parameters are presented and explored first as information from all long-term measurements with given characteristics and then divided to cold and warm part of the year. The vertical extent of the nocturnal ABL falls better in the range of the sodar which allows to assess its characteristics, including its height. The paper consists of a description of the observation site, available data, methods or types of analyses used, results and conclusion.

2 Measuring Site and Equipment

Meteorological observatory (MO) Ahtopol (Fig. 1) is the southernmost synoptic station in the operational meteorological network of the Bulgarian National Weather Service. It is located in the southern parts of the Bulgarian Black Sea coast, which according to the classification of Sabev, Stanev [8] falls into the Black Sea coastal Strandzha

climate area, which is part of the Black Sea climatic sub-region of the Continental-Mediterranean climatic zone in Bulgaria. Due to the temperature influence of the Black Sea basin in this climatic region, there are mild winters compared to the inland of the country, delays in the transition seasons and warm but fresh summers [9]. The pronounced breeze circulations are typical for the warm half of the year, but also during the cold one when a lower frequency and smaller spatial scales of the local coastal circulations are observed [10]. The terrain close to the MO Ahtopol is primarily flat grassland and the coastline is stretching out from NNW to SSE with a steep about 10 m high coast (Fig. 1). A monostatic Doppler Flat Array Sodar Scintec MFAS is installed on the roof of the administrative building at 4.5 m above the ground level (AGL). The building is located about 400 m inland at 30 m height above sea level (Fig. 1). The acoustic remote sensing system is a multi-frequency instrument with a working range of 1650–2750 Hz and multi-beam operation of 9 emission/reception angles ($0°, \pm 9.3°$, $\pm 15.6°, \pm 22.1°, \pm 29°$). According the technical specification of the instrument the accuracy of wind speed measurements are 0.1–0.3 ms^{-1} and for wind direction are 2–3° [11]. The maximum vertical range of the sodar is from 150 m to 1000 m with a vertical resolution of 10 m and the first measurement level is 30 m AGL. The output of the acoustic sounding of the atmosphere is saved every 10 min with a 20-min averaging period (running averages).
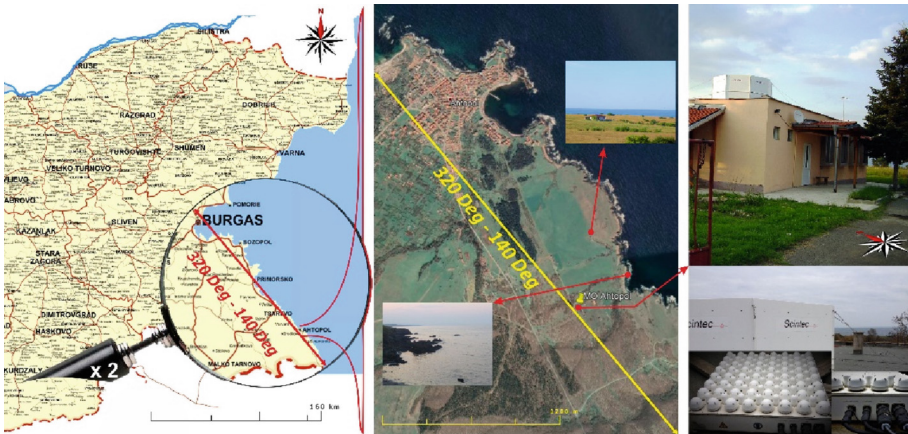

Fig. 1. Location of MO Ahtopol in southeastern Bulgaria (left) with close views of the terrain (middle - Google Earth) and administrative building with sodar system on the roof (right). Geographical coordinates: 42° 5′ 3.37″ N, 27° 57′ 4.49″ E

3   Data and Analysis Overview

3.1   Data Availability

The high spatial and temporal resolution of acoustic soundings of the coastal ABL participating in this study covers a period of 3014 days from 1 August 2008 to 31

October 2016. The sodar measurements cover about 79% of the total period which is equal to about 340 000 time series. The missing data is caused by two main reasons. The first one was due to a night time restriction of the sodar measurements during the months from August to October of 2008 (between 18 and 07 local time) and from the end of July to December 2009 (between 21:40 and 07:30 local time). After December 2009 the operational regime was set to continuous mode. The second reason for the lower availability of acoustic data was a frequent interruption in the main power supply in the MO Ahtopol which in combination with the lack of internet until 2011 made the remote maintenance of the sodar impossible. Until 26 September 2014 the sodar output was recorded at local time (Eastern European Time (EET) in the cold half of the year and EET + 1 in the warm one, respectively). After this date, the recordings were made by EET. For the purposes of this study, the time series are unified to EET.

The effective vertical range (actual height of measurements) of the sodar depends on both the presence of turbulent inhomogeneities above the sodar antenna and the set time resolution of the output data. In addition, the updates of the operational software could lead to improvements in the operational mode of the sodar and data quality control management which in the end could reflect to better effective vertical range. A more detailed description of the monthly data availability and the maximum effective range of the sodar for the study period is presented in Barantiev et al. [12], Barantiev, Batchvarova [13].

3.2   Analysis

For the purposes of this study, data from the acoustic sounding system of the atmosphere in the Ahtopol (Scintec MFAS) are analyzed by months for the period from August 2008 to October 2016. Two main types of coastal air masses were analyzed: air masses from land and marine air masses. The selection of the monthly periods of analysis in combination with selected time intervals, corresponding to nocturnal and daytime air masses, make it possible to involve profiles related to two main states of the atmosphere - stable and unstable stratification. The monthly analyzes performed are shown in Table 1 in three main periods determining:

- nocturnal (from 22:00 to 05:00 EET) stable boundary layer (SBL) of land air masses (wind direction from 170° to 290°) during the months from March to November;
- nocturnal (from 22:00 to 05:00) CBL of marine air masses (wind direction from 0° to 120°) during the months from May to November;
- daily (from 10:00 am to 3:00 pm) CBL of land air masses (wind direction from 170° to 290°) during the months of March, April, May, October, and November;

The monthly maximum of the effective vertical range reached is presented in Table 1 in the second column of each of the three main periods considered. During some of the months presented in Table 1, it can be seen that the maximum monthly effective height of the measurements has reached the maximum vertical range of sodar, but due to low data availability in height, the analyzes in this study are limited up to 600 m.

All profiles involved in the respective monthly analyzes in Table 1 (the third column in each of the three main periods considered) meet the general condition of consisting

Table 1. Selected periods of monthly analyzes, maximum heights reached and the maximum number of involved profiles characterizing SBL and CBL.

SBL characteristics of nocturnal land air masses			CBL characteristics of nocturnal marine air masses			CBL characteristics of daytime land air masses		
(22 ÷ 05 EET; 170 ÷ 290°)			(22 ÷ 05 EET; 0 ÷ 120°)			(10 ÷ 15 EET; 170 ÷ 290°)		
Month	Height [m]	Profiles	Month	Height [m]	Profiles	Month	Height [m]	Profiles
MAR	730	2037	–	–	–	MAR	670	384
APR	730	2372	–	–	–	APR	680	387
MAY	700	1855	MAY	700	137	MAY	610	221
JUN	1000	1646	JUN	600	222	–	–	–
JUL	1000	1017	JUL	580	391	–	–	–
AUG	590	357	AUG	400	653	–	–	–
SEP	940	1058	SEP	700	1026	–	–	–
OCT	660	1177	OCT	730	1033	OCT	690	305
NOV	700	1251	NOV	600	652	NOV	630	488

of a minimum of 10 points in height, satisfying the corresponding periods' conditions for time intervals (day and night), wind direction (land and marine air masses) and permitting an interruption only for lack of data. The evolution of the vertical structure of the coastal boundary layer during the different periods is studied by tracking the changes in the monthly average profiles meeting the criteria specified in Table 1. Twelve basic output parameters from the sodar measurements were analyzed ~~in this study~~ - wind direction (WD), wind speed and its variance (WS, sigWS), vertical wind speed and its variance (W, sigW), horizontal wind speed components and their variance (U, sigU, V, sigV), eddy dissipation rate (EDR), turbulent intensity (TI) and turbulent kinetic energy (TKE). In addition, Buoyancy Production (BP) profiles are derived using the vertical wind speed variance sigW (σ_w) measured from the sodar at different altitudes (z) from Eq. (1) [14]:

$$\beta = \frac{\sigma_w{}^3}{z} \tag{1}$$

4   Results

4.1   Nocturnal Stable Boundary Layer (SBL) of Air Masses from the Land

The nocturnal land air masses are expected to have the characteristic of stable ABL (SBL). Situations with a stable ABL during the day for land air masses are expected to occur during the day in some winter days, but these cases are not considered in this study. The attention in this analysis is focused on a typical case of night breeze (land breeze) during the warm half of the year. For that purpose, the nocturnal acoustic sounding data

(from 22 to 05 EET) with registered WD from the land (from 170° to 290°) for the months from March to November are analyzed (Table 1 – first main period on the left). For each of the considered months, monthly average profiles and their dispersions of 12 output parameters from the acoustic sounding of the coastal ABL were calculated, as in Fig. 2 are shown to present the characteristics of nocturnal land air masses for the months of May. The color dots are related to the color bar on the right side of the graphics in Fig. 2 and have indicated the number of individual profiles involved in the derivation of the average monthly value at given height AGL. For this particular case, the maximum number of profiles is 1855 (Table 1 - the third column in the first main period for May) and their number decreases rapidly in height. Lower availability of data for monthly averages is observed for sigWS, sigU, sigV, and TI profiles, as these parameters are expressed with a second statistical moments of the respective sodar parameters, which requires higher quality control of the raw data involved compared to the first statistical moments, such as wind components.
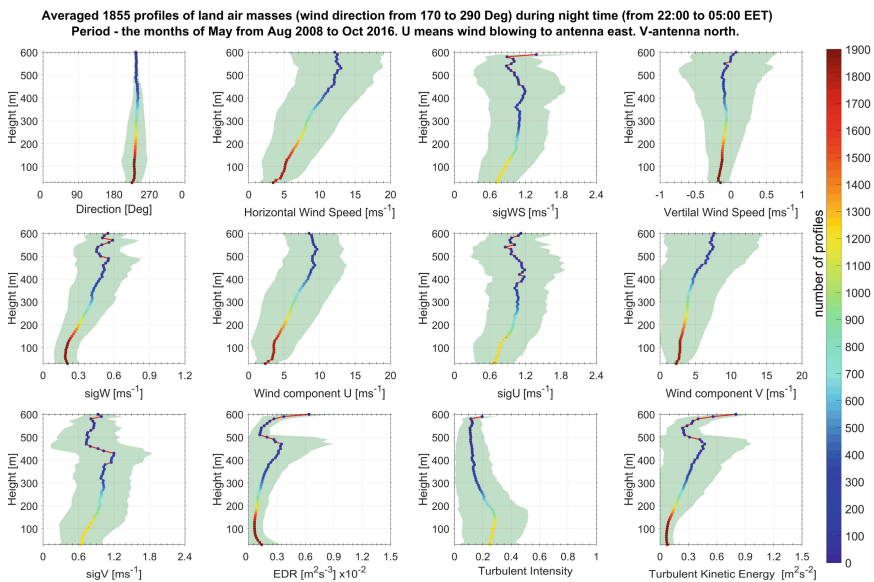

Fig. 2. Averaged nocturnal land air masses characteristics registered at MO Ahtopol during the months of May in the period Aug 2008 to Oct 2016. Monthly average profiles (color dots on red line) and their dispersions (green area) from left to right and from top to bottom: WD, WS, sigWS, W, sigW, U, sigU, V, sigV, EDR, TI, TKE. The color legend denotes the number of profiles reaching the specific height.

The values of the monthly average WS profile increase almost linearly to a height of 530 m AGL (96 individual profiles available at this height) reaching a maximum value of 13 ms^{-1}, while downward motions are observed in almost the entire range of the measurements expressed by low negative values of the vertical wind speed up to 580 m AGL (68 individual profiles available at this height). Well expressed peaks are observed tracking the shape of the monthly average turbulent profiles of sigW, EDR and TKE

and the maximum of their dispersions presented in Fig. 2 at height between 470–490 m (respectively 56, 51 and 53 profiles involved in the averaged outputs). At 490 m, the values of the vertical wind variance (sigW) stop rising and sharply decrease in the next few tens of meters, forming a well-defined peak in the shape of the monthly averaged profile, which is a criterion for determining the height of this coastal nocturnal SBL of land air masses during May. The surface layer (SL) height is defined between 50 and 100 m by the observed changes in the sign of the monthly average profile gradients of sigW, EDR, and TKE close to the ground. The values of SL height are also supported by changes of the other monthly average profiles close to the ground shown in Fig. 2.

The monthly averaged profiles of the vertical wind variance and its dispersions for the months from March to November are derived and compared in Fig. 3 to illustrate the VWV method for determining the height of ABL from sodar data.
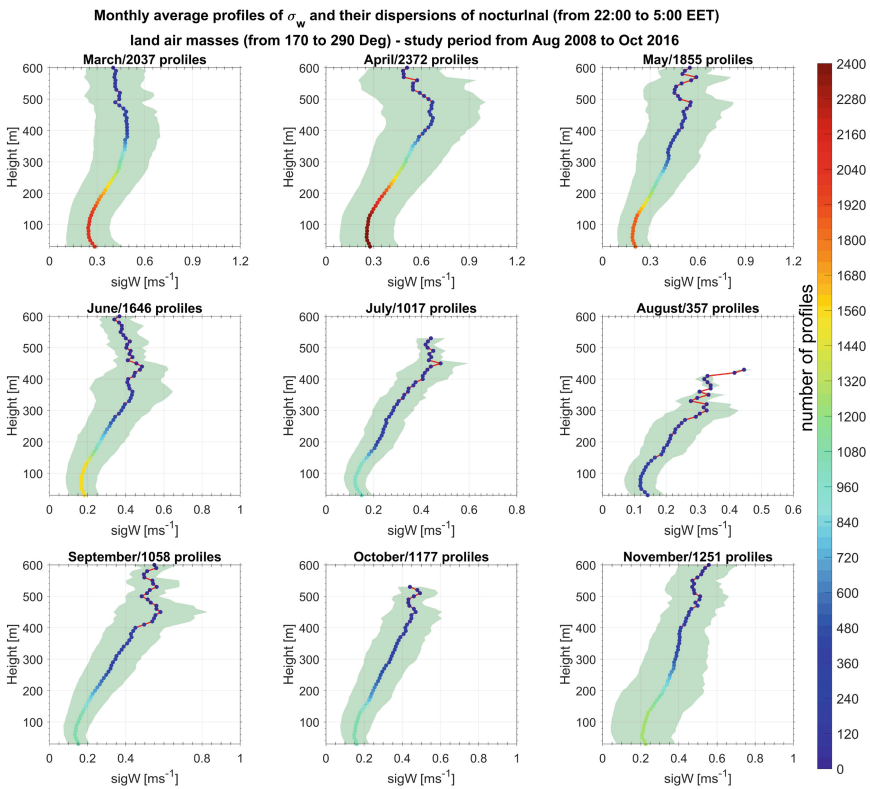

Fig. 3. Nocturnal monthly average profiles of the vertical wind variance and its dispersion during the months from March to November in the period from Aug 2008 to Oct 2016. Color legend as in Fig. 2.

In addition to the height of SBL in the respective months, Fig. 3 shows a higher availability of the profiles involved in the calculation of the derived monthly average profiles during the months from March to June, with a minimum in August when the

breeze circulation is well developed, and a gradual increase towards to the last presented month of the analysis of nocturnal land air masses. The small vertical dimensions of the nocturnal breeze cell in some of the months [10, 15] leads to failure in the fulfillment of the wind direction condition from 170° to 290°, which should consist of a minimum of 10 points along the entire length of the measured profile (due to the presence of reverse flow from the sea to the land). A defined height (360–500 m) of SBL by the VWV method falling within the sodar vertical range in MO Ahtopol is observed in the months from April to June and from September to November.

Monthly average profiles of four turbulent parameters (three derived from Sodar - sigW, EDR, TKE, and one calculated BP) are presented in Fig. 4 for three different months with a well-defined height of nocturnal coastal SBL in MO Ahtopol. The observed changes in the shape of the monthly average profiles confirm the above results. It could be concluded that with the onset of the summer season, the average SBL height and the availability of data with air masses coming from the land in height decrease.
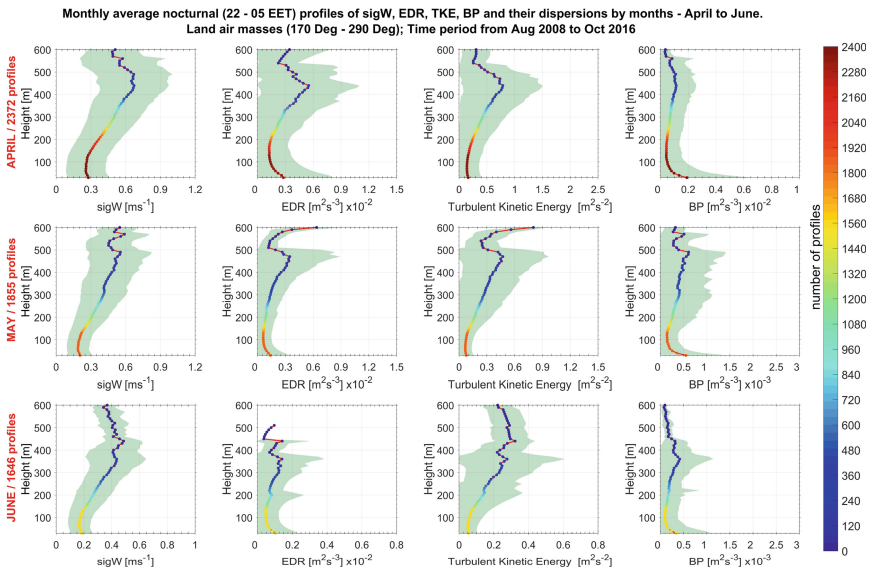

Fig. 4. Heights of nocturnal SBL of coastal air masses coming from the land at MO Ahtopol. April - 490 m (110 involved profiles for sigW); May - 490 m (56 involved profiles for sigW); June - 360 m (120 involved profiles for sigW). Color legend as in Fig. 2.

Specific information about the thermodynamic state of the atmosphere in this study was obtained by deriving monthly diagrams of stability classes probabilities at different heights according to the Pasquill-Gifford classification using the σ_ϕ method [16]. The vertical profiles of the atmospheric stability classes are one of the sodar output parameters and the probability distributions at different heights of the Pasquill-Gifford classes for the months of April, May, and June are shown in Fig. 5. The sum of all probabilities at a given altitude is considered 100% based on all available time series with disposable data for the respective altitude.
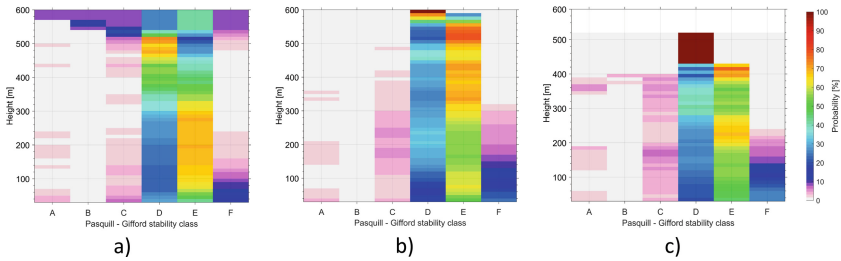
Fig. 5. Monthly diagrams of stability classes probabilities at different heights of nocturnal coastal SBL (land air masses). April – a); May – b); June – c). The color legend denotes the respective probability distribution of the observed stability classes at given altitude.

According to the classification used, the probabilities range from 15% to 69% with a mean value of 52% for the slightly stable stratification (E) of the nocturnal land air masses are observed for the months of April (Fig. 5 – a). The neutral stratification (D) can be indicated as the second dominant thermodynamical state of the atmosphere for this type of air masses with probability distribution values in the range of 22% to 73% with a maximum at 500 m and 37% mean value. The dominant class of atmospheric stratification for the months of May for nocturnal land air masses (Fig. 5 – b) can be indicated as the slightly stable (E) with more than 50% probability up to 580 m AGL with 60% mean value throughout the acoustic sounding layer. In this type of air masses, the results of stability classes probabilities with height have determined the neutral stratification again as the second dominant class with an average value of 32%. The probability distribution values in height of the atmospheric stratification for the months of June (Fig. 5 – c) have shown similar results but the dominant class of slightly stable stratification (E) is completely replaced by a 100% probability of neutral stratification (D) after 420 m AGL. The stable stratification (F) is presented in all three monthly diagrams of stability classes as the third dominant class of atmospheric stratification up to 300 m AGL with a mean probability of about 4% for the months of April, 5% for the months of May, and 6% for the months of June with a maximum of 17%, 24%, and 27% respectively. The mean probability values of extremely unstable (A) and unstable (B) classes have been below 2% for April (Fig. 5 – a) and below 1% for May and June (Fig. 5 – b, c).

4.2   Nocturnal CBL of Marine Air Masses

Conditions for the formation of convective ABL are observed in cases when the sea is warmer than the air above it. Such conditions are expected at night in summer and even during the day in winter. The different number of profiles corresponding to the respective conditions for nocturnal marine ABL and the maximum effective range reached in the different months are shown in Table 1 (second main period – CBL, 22 ÷ 05 EET; 0 ÷ 120°). The average monthly profiles of sigW and their dispersion, from May to November, describing the nocturnal coastal ABL are compared in Fig. 6. This type of marine air masses is generally characterized by a lower number of involved profiles meeting the relevant conditions for time interval and wind direction, mainly due to the

presence of local circulation, which determines the predominant flow from the land at night. Weak availability of the number of profiles is observed in August and May, as the maximum height to which the average profile reaches in May exceeds almost twice that in August. This is due to the greater instability of the atmosphere in May and the associated turbulent inhomogeneities in height, which fell within the range of sodar at the beginning of the pronounced breeze circulation season. As an additional reason for the low availability of the involved profiles in this analysis can be pointed out the night restrictions in the operating mode of the sodar in 2009 and 2010.
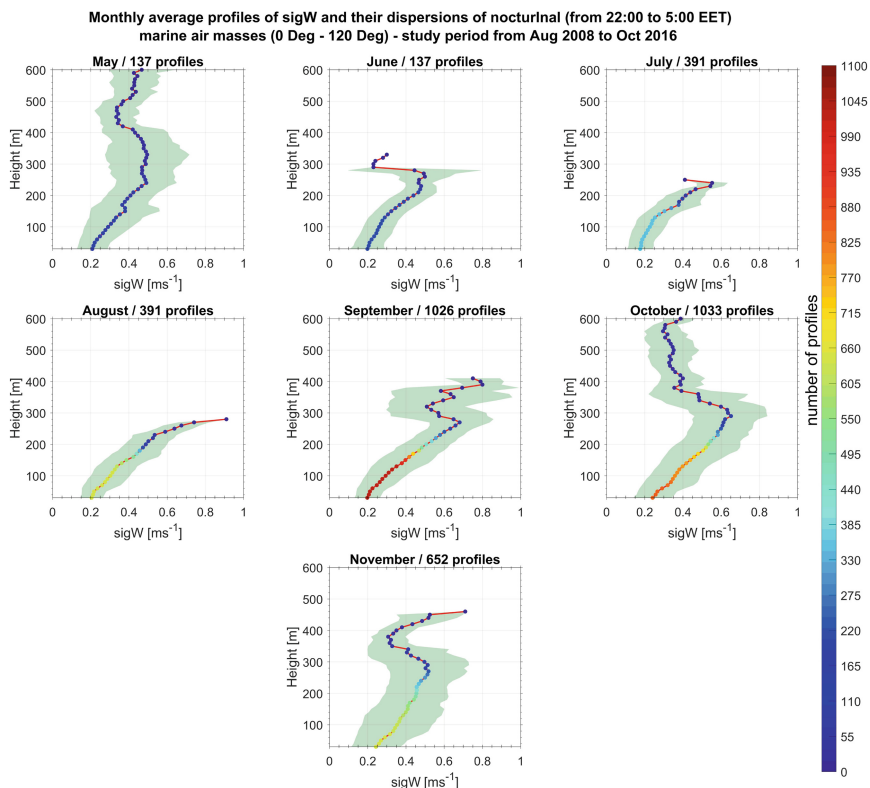
Fig. 6. Nocturnal monthly average profiles of the of the vertical wind variance and its dispersion during the months from May to November in the period from Aug 2008 to Oct 2016. Color legend as in Fig. 2.

The maximum number of profiles is observed in autumn, when the intensity of the breeze circulation along the coast begins to subside. A well-defined height of the nocturnal marine ABL, which fell within the sodar vertical range in Ahtopol, was observed in May, June, September, October and November and it is of the order of 260–330 m. The maximum height of the nocturnal marine ABL is observed in May (330 m), and in the summer months this height decreased and began to increase slightly after September to reach a height of 290 m in November.

The monthly average profiles of four turbulent parameters (sigW, EDR, TKE, and BP) in three different months (May, June, and November) with a defined nocturnal marine ABL height of 330 m in May, 270 m in June, and 290 m in November are shown in the graphs of Fig. 7. The changes in the sign of the vertical gradient of BP monthly average profiles are observed at almost the same height as those of the sigW profiles during the respective month. Close to the ground slightly decreasing values in height are observed in the averaged BP profiles, which are an indicator of IBL presence and slightly unstable or neutral non-disturbed marine air masses over it during the night. Height of 40–50 m AGL of IBL is confirmed by the changes of the lowest parts of the averaged profiles of BP, as the most prominent height can be indicated the one in November, where the highest values of the buoyancy parameter (buoyancy flow) are observed in combination with clearly expressed negative peak at 50 m AGL.
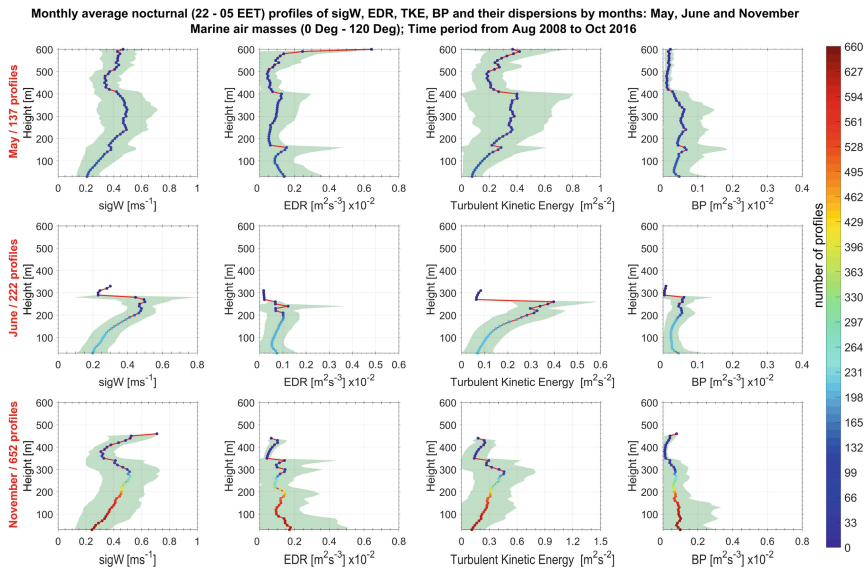

Fig. 7. Heights of nocturnal coastal CBL (marine air masses). May – 330 m (25 sigW profiles); June – 270 m (6 profiles); November – 290 m (146 profiles). Color legend as in Fig. 2.

The changes in the atmospheric stratification probability distribution values in height of nocturnal marine air masses for the months of May, June and November are shown in the Fig. 8. Compared to the graphs of land profiles (Fig. 5), the marine air masses (Fig. 8) have revealed more unstable thermo-dynamical state of the atmosphere. Neutrally stratified atmosphere (D) is observed as dominant stratification in all nocturnal marine air masses with mean probability values in the range of 56% to 72% for the months of May, June and November (respectively Fig. 8 – a, b, c). The second dominant stability class for the months of May, June and November is slightly stable (E) and as the third one cloud be pointed the slightly unstable (C) with mean probability values in the range of 6% to 12%. The stable stratification (F) is observed only for the months November with mean value below 1% (Fig. 8 – c). The largest instability of the thermodynamical state

of all cases considered in Fig. 8 are observed in the averaged profiles of nocturnal marine air masses for the months of May (Fig. 8 – a).
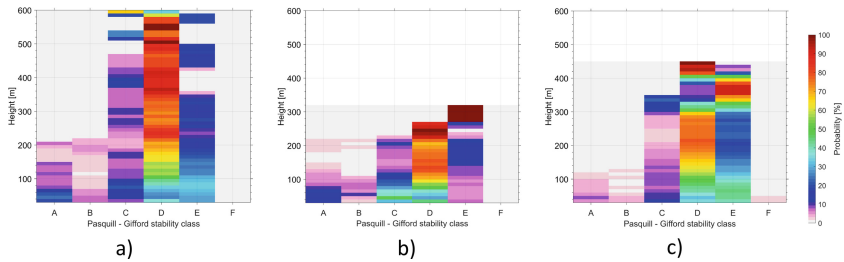

Fig. 8. Monthly diagrams of stability classes probabilities at different heights nocturnal coastal CBL (marine air masses). May – a); June – b); November – c. Color legend as in Fig. 5.

4.3   Daytime CBL of Land Air Masses

During the warm half of the year, and during the transition seasons in the southern Black Sea climatic sub-region in Bulgaria due to the mild climate, many sunny days, and warming of the ground surface, convective conditions in the ABL are expected. When a flow of land air masses passes over the sodar during the day, it is expected that the characteristics of convective ABL (CBL) will stand out in the observed profiles.

Different numbers of profiles are involved into the monthly analyses during the different months presented in Table 1 (third main period on the left), corresponding to the respective selected conditions for convective regime of the atmosphere during the day (10 ÷ 15 EET; 170 ÷ 290°). The warmest months (from June to September) are excluded from this study due to the low availability of this type of profiles determined by the presence of local coastal circulation (sea breeze) and the corresponding prevailing marine air masses during the day, as well as the inability of the sodar vertical range to cover such deep CBL of land air masses. Following the analysis scheme from the previous parts, Fig. 9 compares the average monthly profiles of vertical wind variances and their dispersions, but this time in March, April, May, November and October. Again, above each graph the maximum number of profiles involved in the derivation of the average values is shown. There is an increase in the height of CBL from 240 to 300 m with the onset of the warm season from March to May and a decrease from 410 to 300 m from October to November. Well-defined heights of 240 and 300 m AGL of daytime CBL of land air masses with the largest number of involved profiles in the calculation of the average monthly values are observed in March, April, and November in Fig. 10.

The number of involved profiles in November is greater than in March and April. With the onset of the breeze circulation season along the coast, this type of daily profiles of land air masses decreases, and the height of the respective CBL increases. Indications for SL height of 40–60 m AGL are observed following the changes in the shapes and in the vertical gradients of averaged profiles of the vertical wind variations and the buoyancy parameter profiles presented in Fig. 9 and Fig. 10.
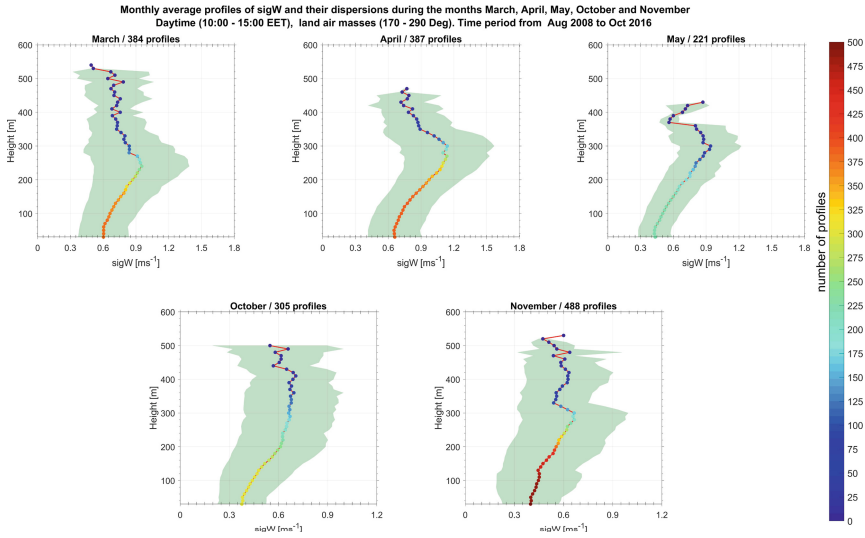
Fig. 9. Daytime monthly average profiles of the of the vertical wind variance and its dispersion during the months from March to May, October and November in the period from Aug 2008 to Oct 2016. Color legend as in Fig. 2.
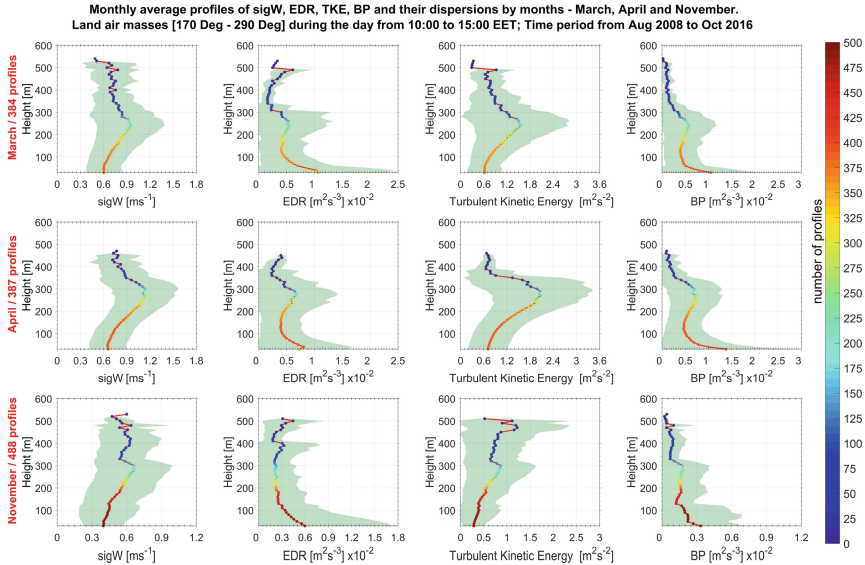

Fig. 10. Heights of daytime coastal CBL (land air masses). March – 240 m (229 sigW profiles); April – 300 m (169 profiles); November – 300 m (171 profiles). Color legend as in Fig. 2.

Mostly unstable condition from all presented cases in this study are observed in the diagrams of stability classes probabilities of daytime land air masses in the Fig. 11 for the months of March, April and November. Although the probability distribution of

the neutrally stratified atmosphere (D) dominates again, the results presented in Fig. 11 show as second and third dominant atmospheric stratification respectively classes slightly unstable (C) and extremely unstable (A) for the months of March and April (Fig. 11 – a, b). Highest average probabilistic values of 22% and 11% of respectively slightly unstable and extremely unstable atmospheric stratification are observed in March (Fig. 11 – a).
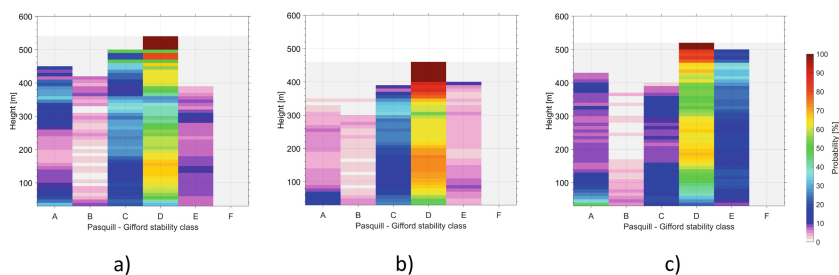

Fig. 11. Monthly diagrams of stability classes probabilities at different heights daytime coastal CBL (land air masses). March – a); April – b); November – c). Color legend as in Fig. 11.

5   Conclusions

A key point in the performed climatological analysis in this study is the specific selection of criteria determining a given state of ABL. The criteria are in accordance with the vertical range of the sodar and the expected results. The direct estimation of the ABL height in different thermodynamic states of the atmosphere in the coastal region, by means of monthly averaged profiles of sigW, is limited by the vertical range of the sodar and could be used for shallow boundary layers. Confirmation for the estimated from sigW height is given by two more directly derived parameters (EDR and TKE) and one calculated (BP). Thus, when covering a sufficiently large period of measurements, it is possible to derive climatic values of important meteorological quantities describing the vertical structure of the ABL, characterizing a certain type of local circulation in the coastal zones. This type of acoustic sounding data, with a high vertical resolution, has a wide practical potential and could be used in different types of dispersion, climate, and prognostic numerical models' assessments resulting in improved performance and greater reliability of the results. Our analysis reveals heights the nocturnal marine CBL of 330–400 m in May and 290 m in November. The retrieved heights of the nocturnal land ABL are 440–490 m in April, 470–490 m in May and about 360 m in June. This study has a wide practical potential and it provides important for the coastal ABL information which could be used in various prognostic, climate, and dispersion models.

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