ABSTRACT
A Scintec MFAS sodar is in operation since summer 2008 at Ahtopol meteorological observatory (Bulgarian Black Sea coast) allowing climatological records of the wind profile up to 400 – 600 m height. The simultaneous turbulence observations with ultrasonic anemometers form unique for Bulgaria basis for studies of the structure of the coastal boundary layer. The monitoring will develop further to cover temperature and humidity profiles, ozone and aerosol concentrations, as the site is suitable for atmospheric composition background observations.

1. INTRODUCTION
The wind profile in coastal areas has been studied in the 1980-ies and 1990-ies through a number of experimental campaigns worldwide using Doppler wind radars, lidars, sodars, instrumented tall masts, mesoscale networks of ground and aerological stations as described in papers [1 – 6]. The aim of such studies was to provide data for evaluation of mesoscale models performance in coastal areas and to develop further the parameterisations used in these models. As discussed in [7], the variety of physical, geographical and climate conditions related to sea breeze circulations, as well as weather patterns in coastal regions is huge, so mesoscale models need to be constantly and vastly evaluated.

For this reason, conducting detailed meteorological observations in coastal areas is very important issue both from scientific and practical point of view. Moreover, the present day remote sensing technologies allow continuous monitoring and high special resolution, thus new quality data for model evaluation and applications [8 -10]. Among the contemporary most important applications needing wind profile is the wind energy production. For these needs both direct wind profile and turbulence measurements and validated models are required.

2. DESCRIPTION OF SITE AND MEASUREMENTS
In Bulgaria, one sodar is operation since 2008 at a remote site on the Black Sea coast under a Bulgarian – Russian collaborative project [11, 12] between the National Institute of Meteorology and Hydrology - Bulgarian Academy of Sciences (NIMH-BAS) and the Research and Production Association (RPA) “Typhoon” in Obninsk, which is part of the Russian Federal Service on Hydrometeorology and Environmental Monitoring (Roshydromet).

The site is located in flat grassland, 30 m above sea level, about 500 m inland from a steep about 10 m high coast. The coast line is stretching out from north-north-east to south-south-west direction, therefore the winds from the sector 0 – 150 degrees are representing marine conditions, Figure 1.

As shown in Figure 2, in addition to standard synoptic station equipment, an ultra sonic anemometer and a solar radiation sensor are mounted on a meteorological mast at height of 4.5 m; air temperature and humidity sensors are installed at 2 m height within a thermometer screen. These sensors form an automatic meteorological station named MK-15 assembled by “Typhoon”. The frequency of measurements of MK-15 is 0.5 Hz and records are made every 10 seconds.

The sodar is located on the roof of the administrative building at about 4.5 m high, Figure 3. It is a SCINTEC
Flat Array middle range instrument (MFAS) with frequency range 1650 – 2750 Hz; 9 emission/reception angles (0°, ±22°, ± 29°); maximum 100 vertical layers; range between 500 – 1000 m; accuracy of horizontal wind speed 0.1 – 0.3 ms⁻¹; range of horizontal wind speed ± 50 ms⁻¹; accuracy of vertical wind speed 0.03 – 0.1 m/s; range of vertical wind speed ± 10 ms⁻¹; accuracy of wind direction 2 - 3 degrees.

The sodar was set to measure in regime “optimized pulses for resolution” at 47 levels from 30 to 500 m with resolution of 10 m. The averaging time is 20 minutes and the records are made every 10 minutes, thus presenting running 20-minute averages.

3. SEA BREEZE DAY ANALYSIS

The wind profile in the region is dominated by the features of breeze circulation which occurs already in March and may be observed also in days in November. Typically, during all days in July and 60% of the days in June and August breeze circulation develops at the Ahtopol site [12]. In May and September, the scale of the breeze cell is smaller and the phenomenon can fall entirely within the range of the sodar [13].

For illustration here we give the measurements on 5th September 2008, when a strong breeze circulation was observed and almost the entire breeze cell was falling within the range of the sodar. The effect of reduced wind speed above the flow from the sea, as well as the indication of reverse flow aloft is clearly seen in Figure 3 suggesting a closed breeze cell of 700 m size.

The turbulence characteristics, vertical wind speed and standard deviation of it, show maximum values in the area of maximal wind speed of the breeze cell, between 200 and 400 m, Figure 4. This zone is also pronounced in the instantaneous profiles of horizontal and vertical wind speed and the standard deviation of the vertical wind speed, Figures 5 and 6.

Figure 3. Wind direction (upper panel) and wind speed (lower panel) on 5 September 2008.

Figure 4. Vertical wind speed (upper panel) and standard deviation of the vertical wind speed (lower panel) on 5 September 2008.

Figure 5. Vertical profile of the horizontal (upper panel) and vertical (lower panel) wind speed (upper panel) on 5 September 2008.
The sonic anemometer data give insight of the sea breeze features near the surface, Figure 7.

The onset of the sea breeze is clearly seen in the wind direction rapid shift from SW to NE and in the sharp wind speed increase. The moment of the sea breeze onset is marked with a slight decrease in temperature and no further significant increase of it. Rapid changes are also observed in the records of the turbulence parameters – standard deviation of the vertical wind speed, friction velocity and kinematic sensible heat flux.

4. LONG TERM WIND PROFILE

Looking into a longer data range (June 2009 – June 2011), the maximal wind speed appears at about 150 m. Still, the size of the breeze cells, hence the height of maximal wind speed, is much larger in June, July and August.

Further analysis will reveal the wind profile features at different flow situations.

CONCLUSIONS

The described data set gives opportunities to study the wind and turbulence regimes at the Bulgarian Southern Black Sea Coast for different applications: air quality, wind power assessments, mesoscale models evaluation.

The site is suitable and will be developed to an atmospheric composition observatory. For this purpose, the studies of the dynamics of the atmosphere provided

ACKNOWLEDGMENTS

This work is part of scientific cooperation between the meteorological services of Bulgaria and Russia. The work is part of the activities within COST Action ES0702 (EG-CLIMET) and COST ES1002 (WIRE). It is also related to the work of E. Batchvarova in the Danish Research Agency Strategic Research Council (Sagsnr. 2104-08-0025) “Tall wind project”.

REFERENCES


Environ., 32, 2055-2069.


