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A PARALLEL WIND ANALYSIS AT TWO COASTAL SITES (TYRRHENIAN AND BLACK SEA) USING REMOTE SENSING SENSORS AND GROUND BASED STATIONS

T. Lo Feudo[1], *D. Barantiev* [2], *R. Calaudi* [1], *E. Avolio*[1], *D. Gullì*[1], *H. Kirova*[2], *A.M. Sempreviva*[3], *C. R. Calidonna*[1] *and E. Batchvarova*[2]

[1] CNR–ISAC (Institute for Atmospheric Sciences and Climate), UOS of Lamezia Terme, Italy, t.lofeudo@isac.cnr.it
[2] National Institute of Meteorology and Hydrology -Bulgarian Academy of Sciences, Bulgaria
[3] Wind Energy Department, Technical University of Denmark, Roskilde, Denmark

Abstract: A parallel study, between wind profiles until 300m measured in experimental sites at Tyrrhenian Sea and at Black Sea we realize in order to investigate how the variation of wind flow influences meteorological parameter on coastal sites. The data set available made possible a key study of the influence of different wind regimes in the two sites. In particular it was possible to select days with different wind regime: one with well-developed breeze regime, one with not well developed breeze regime and the last one with uncompleted sea breeze. The stability classification in the three days was studied using two sonic anemometer at frequency of 10Hz placed at 10m and in operation simultaneously in both coastal sites. Finally this last data were compared with SAR (Synthetic Aperture Radar) wind obtaining a good correlation and demonstrating that it is possible use the satellite data for wind resource estimation.

Keywords: remote sensing, breeze circulation, Mediterranean basin, Black Sea, costal site.

1. INTRODUCTION

In this study we report analyses of wind data from different remote sensing and ground bases instruments, at two coastal sites: Ahtopol, at the Bulgarian southern black sea coast and Lamezia Terme, at the Italian Tyrrhenian Sea coast of Calabrian peninsula. The availability of Leosphere Wind Cube profiles until 250m at Lamezia Terme (Italian coast) and SCINTEC MFAS SODAR data until 720m (Bulgarian coast) made possible a key study of the influence of different wind regimes in the two sites.
The lidar and sodar were in operation simultaneously during an intensive experimental campaign in summer 2009. We performed a stability classification of days of the campaign using two sonic anemometer at frequency of 10Hz placed at 10 m and in operation simultaneously in both coastal sites. The data set of winds were compared with SAR (synthetic aperture radar) in order to proving that it is possible use the satellite data for wind resource estimation**.**

2. EXPERIMENTAL SITES AND DATA SET AVAILABLE

2.1 EXPERIMENTAL SITES

The experimental site of Lamezia Terme is located about 500m inland from the coastline at the west end of the only sea-to-sea valley around 30km wide (the narrowest part of the Calabrian region along west-east direction). The area is flat but influenced by valley/mountain and land/sea breeze. At Lamezia Terme, the flow regime is characterized by a daily stable/unstable atmospheric stability cycle [1], an east-west sea/land breeze system and large scale conditions mostly from west.
The meteorological observatory of Ahtopol is located in south-eastern part of the Bulgarian black sea coast region. (60 km south-east of Burgas). the site is about 400 m inland and 30 m height above the sea level located primarily in flat grassland; the coast line is stretching out from NNW to SSE with a steep about 10m high cost. At Athopol the flow regime is characterized by several types of breeze circulation, days with strong synoptic flow and no breeze circulation and combined regional and local forcing situations. For the breeze circulation it can be noted that closed breeze cells occur with different frequency from year to year and a characteristic turning of the wind from west (night) through north (morning) to east (day) and through south (evening) to west (night) is frequent.

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Figure 1. Lamezia Terme and Athopol observatories.

2.2 DATA SET

The following sensors were installed during the summer campaign of 2009 at Lamezia Terme: a LIDAR (WLS7-Windcube), a SODAR (DSDPA.90-24-METEK) and a ceilometer (CL31, Vaisala). At the surface, mean and turbulent meteorological parameters where sampled by standard meteorological instruments and by a METEK Ultrasonic anemometer respectively at the height of 10m. In the previous study [2], [3] we chose the stability classes using the mast data, how to shows in the Figure 2, also, we compared the wind measured with the sodar and lidar at Lamezia Terme site obtaining a good performance.

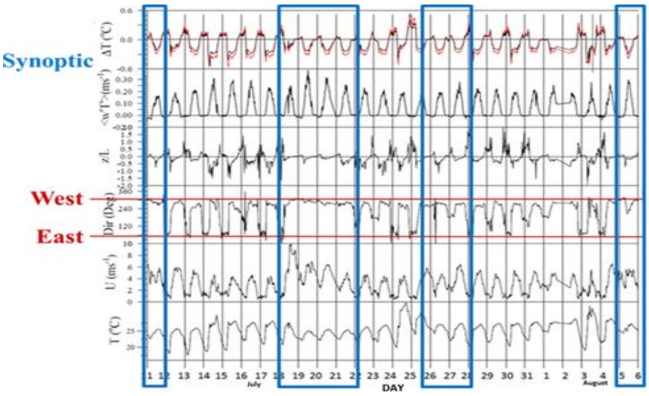


Figure 2. From top to bottom, time series of Temperature differences (DT), turbulent heat flux w'T'(note that positive values indicate downward fluxes), the Monin-Obukov z=L, wind direction DIR, wind speed U, air temperature T, the area in the blue box corresponds to synoptic flows; red line delimits the cycle of the complete sea/land breeze in West-East directions.

At Athopol, the following sensors were installed in the site: a SCINTEC MFAS Sodar (data until 720m) and at the surface a 3D sonic anemometer at frequency of 10 Hz placed at 4.5m. Figure 3 shows the choose of the breeze days and stability classes using the mast data [4], [5].

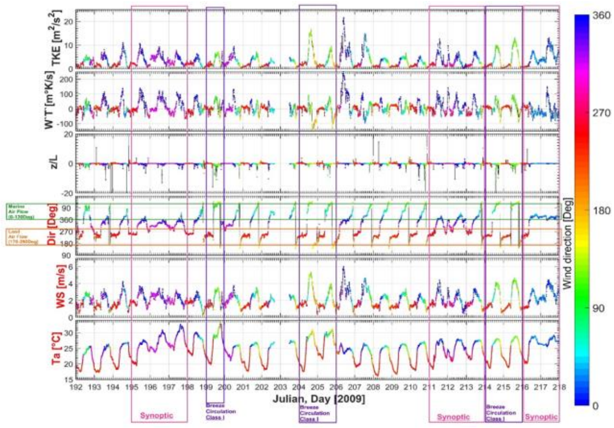
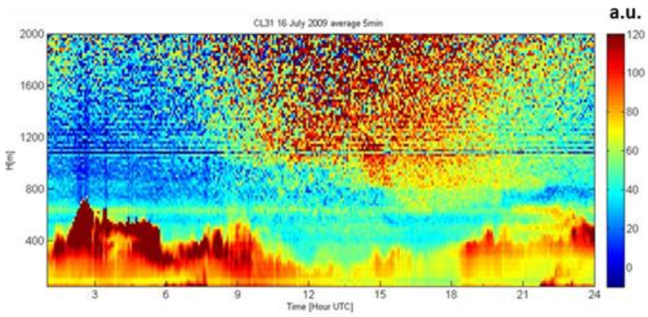


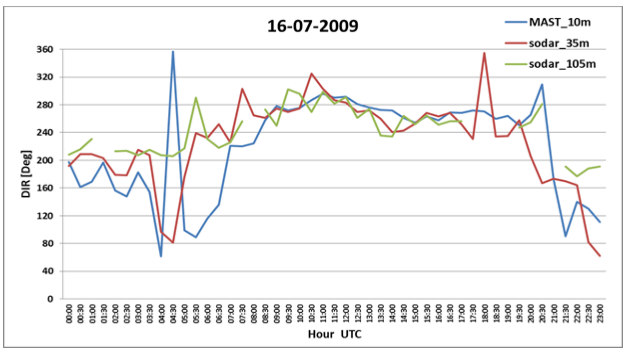
Figure 3. Sonic anemometer time series (from top to bottom) of turbulent kinetic energy, turbulent heat flux, z/L (dimensionless ratio of Monin-Obukov), wind direction, wind speed, acoustic temperature. Synoptic flows (pink), breeze circulation (purple), land and sea flows (orange and green) periods in the boxes.

3 CASE STUDY: LAMEZIA TERME AND ATHOPOL

3.1 WELL DVELOPED BREEZE: LAMEZIA TERME

During a sea breeze well developed at Lamezia Terme, figure 4 shows the daily evolution of the vertical structure of the ABL, measured with Ceilometer. Also, the daily evolution of wind direction measured by SODAR and mast datasets, at different heights, and finally the daily evolution of wind profiles of wind speed and direction using a lidar windcube.





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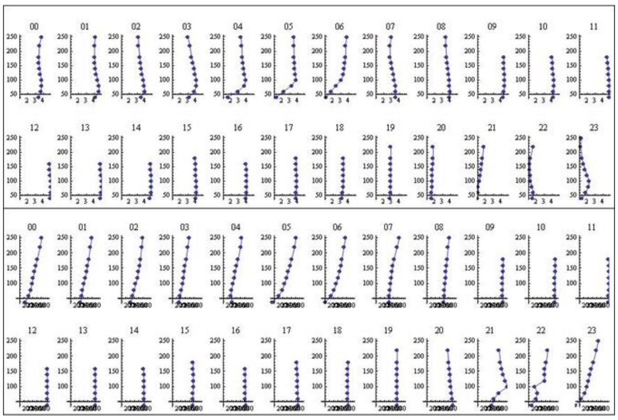
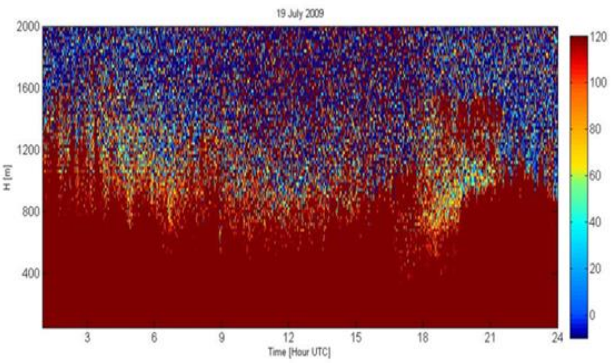
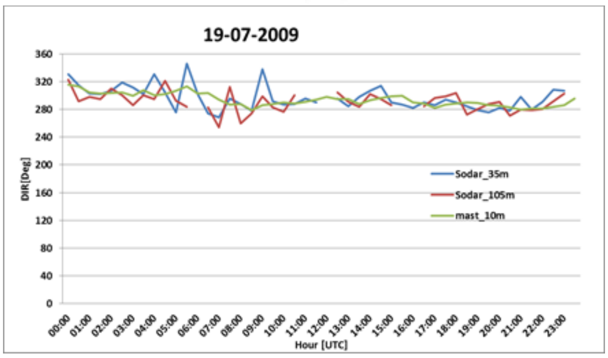


Figure 4. Daily evolution of: (top) of the backscatter coefficient in arbitrary units measured with ceilometer; (center) of wind direction measured by Sodar and mast datasets; (bottom) of wind profiles of wind speed and direction using a lidar windcube.

3.2 NOT DEVELOPED BREEZE: LAMEZIA TERME

Here we report the same analysis during a background flow, in synoptic weather conditions. In figure 5 we report the daily evolution of the vertical structure of the ABL, measured with Ceilometer, the daily evolution of wind direction measured by SODAR and mast datasets and finally the daily evolution of wind profiles of wind speed and direction using a LIDAR WINDCUBE.





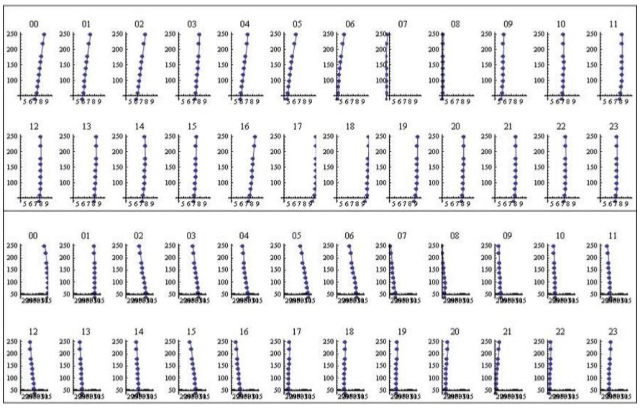


Figure 5. Daily evolution of (top) the vertical structure of the ABL measured with Ceilometer at the site; (center) daily evolution of wind direction measured by Sodar and mast datasets; (bottom) daily evolution of wind profiles of wind speed and direction using a lidar windcube.

3.3 SATELLITE CASE STUDY

Synthetic aperture radar (SAR) is an active remote sensing technique and it is a unique resource to measure wind over water surfaces at a spatial resolution of a few hundred meters. The higher resolution further allows monitoring of wind close to the coastlines, where most of the human offshore activities are confined. The drawback of SAR is the poorer temporal coverage due to more narrow swaths, but this has improved significantly over the last decade with more sensors with wider swaths of 400-500 kilometers, compared to typically 100 kilometers for the first generation sensors. One advantage of SAR, compared to optical remote sensing, is that the radar carries its own illumination source, and is thus independent of daylight. SAR operates in the microwave bands. Microwave radiation is able to penetrate clouds and precipitation [6]. Although no SAR sensor has been designed specifically for wind mapping, it has become clear that SAR data is very suitable for high resolution wind retrievals over the ocean including near-shore areas

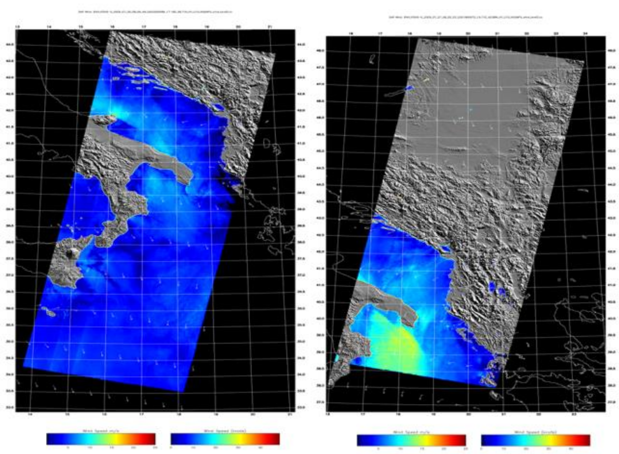


Figure 6. Synthetic aperture radar (SAR) -Imaging at 9:00 UTC respectively for well-developed breeze (left) and not developed breeze (right).

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3.4 WELL DVELOPED BREEZE: ATHOPOL

At black sea costal site, we show in figure 7 during a sea breeze day, the daily evolution of the vertical structure of the wind direction and wind speed using a SODAR [7], [8].
Figure 8 shows the daily evolution of the vertical structure of sigW, and backscatter raw signals of the SODAR. Here, we report also the turbulent kinetic energy (TKE) and Pasquill-Gifford Stability class using sonic measurements at height 4.5 m from the ground with 10 min output with 20 min running averages.

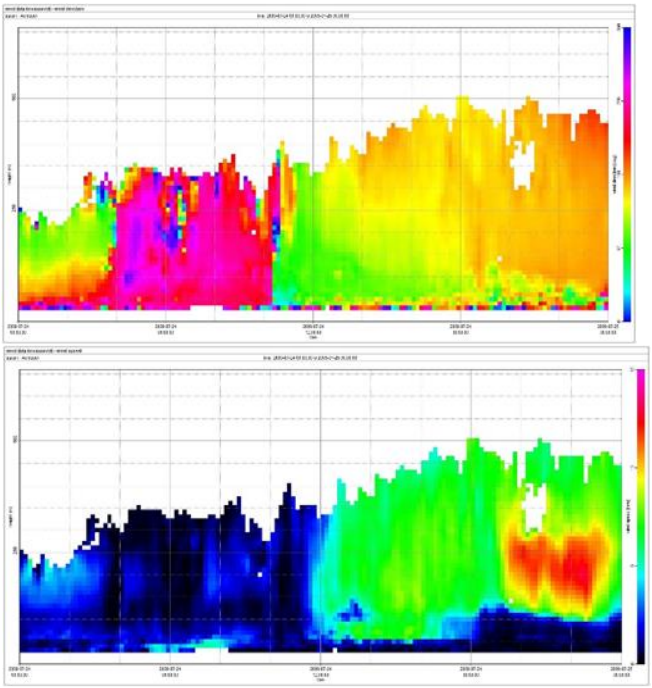

Figure 7. Daily evolution of the vertical structure of the wind direction (top), wind speed (down) using a SODAR.

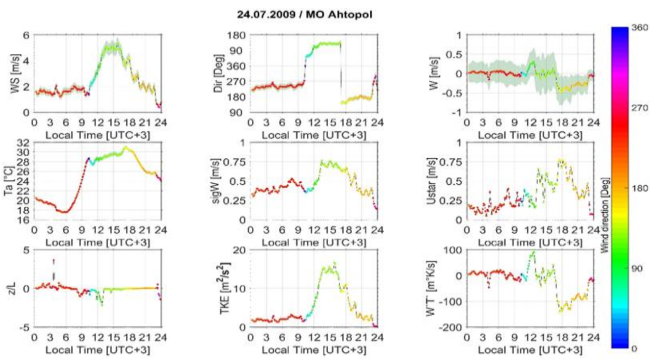

Figure 8. Daily evolution (left six cross-sections) of the vertical structure of the wind direction (left top), wind speed (left-down), sigW (center-top), backscatter raw (center - down), TKE (right – top) and Pasquill-Gifford Stability class (right – down).

3.5 NOT DEVELOPED BREEZE: ATHOPOL

When the day is characterized by synoptic flow, we note in figure 9 a change in wind direction and stability class respect to a breeze day. Figure 9 shows the daily evolution of the vertical structure of sigW, and backscatter raw signals of the SODAR. Here, we report also the TKE and Pasquill-Gifford Stability class using sonic measurements at height 4.5 m from the ground with 10 min output with 20 min running averages.

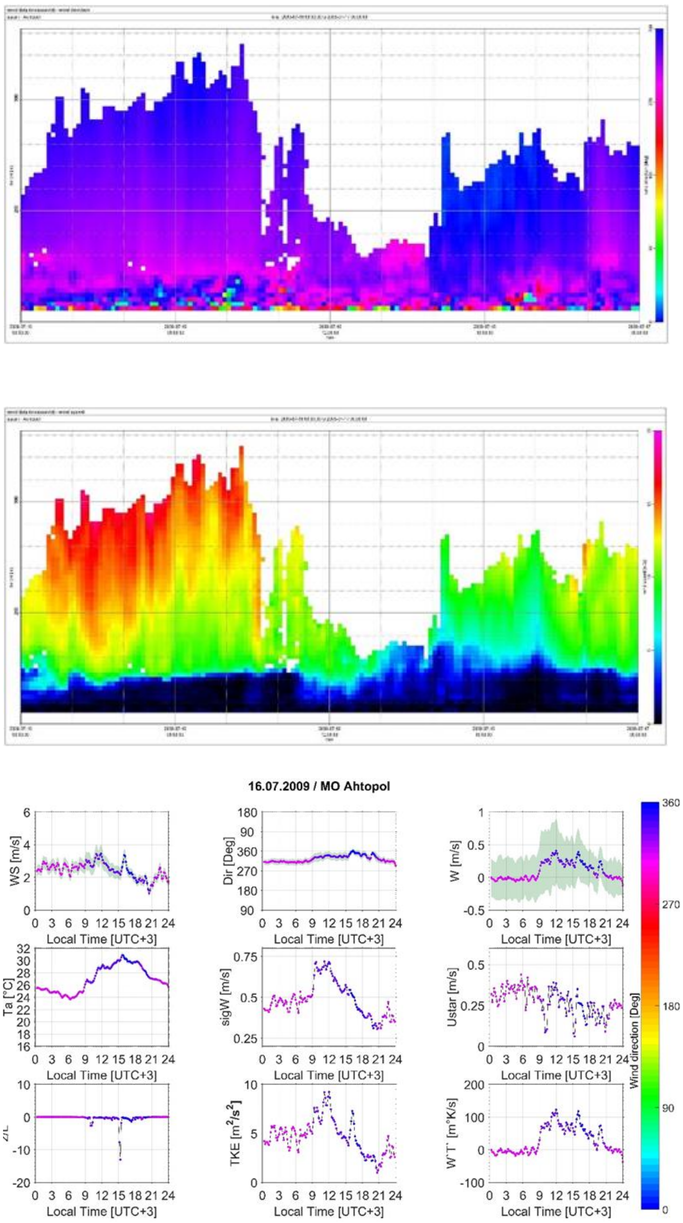

Figure 9. Daily evolution (left six cross-sections) of the vertical structure of the wind direction (left top), wind speed (left-down), sigW (center-top), backscatter raw (center - down), TKE (right – top) and Pasquill-Gifford Stability class (right – down).

4. RESULTS AND CONCLUSIONS

Lametia Terme: The ceilometer backscatter shows the cleaner air adverted from the sea, and the development of a thermal Internal Boundary Layer TIBL at a height range 200m-300m. The TIBL seems confirmed by the SODAR and LIDAR DOPPLER. In the afternoon, when the sea

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breeze is well developed the TIBL seems to merge into the convective BL, mixing aerosols. During sea-breeze regimes, stable–unstable daily cycle develops with well wind profiles varying accordingly. Low level jet form during the night-time. The SAR imaging shows a good agreement with other sensors used in this study

Athopol: In the surface layer the pronounced breeze circulations have high diurnal temperature and TKE amplitudes. The vertical turbulent structure of lower part of the costal ABL reveal the occurrences of maximum values at the fields of sigW and TKE and expressed extreme unstable conditions at the beginning and at the end of sea breeze circulation. The backscatter raw data show well developed CBL through the breeze days when more temperature inhomogeneous fall in the range of the SODAR. The synoptic case reveal an extreme stable condition and capping inversion.

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