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PLANETARY BOUNDARY LAYER: A MODEL VALIDATION

Eliana Pecorari[1], Martina Busato[1] and Giancarlo Rampazzo[1]

[1]Department of Environmental Science, Informatics and Statistics, University Ca' Foscari Venice, Calle Larga Santa Marta 2137, Dorsoduro 30121 Venice, Italy.

The diurnal variation of various meteorological parameters in the Planetary Boundary Layer at different altitudes has been studied through a remote sensing instrumentation and a sonic anemometer. RASS-SODAR integrated system allowed the definition of the vertical temperature profiles and the determination of the vertical wind speed and direction profiles. The Sonic Anemometer provided the dataset used to obtain the time trend of other meteorological and dispersive parameters, and to evaluate the PBL turbulence and heat exchange.

Key words: *Planetary Boundary Layer, Rass/Sodar measurements, meteorological modeling.*

INTRODUCTION

Meteorological conditions strongly affect secondary pollutants formation. Complex and non linear processes, in fact, are involved in pollutants production and accumulation. Understanding meteorological parameters behavior is important especially for wind and temperature profiles in the *Planetary Boundary Layer* (PBL) where air pollutants dispersion is more dangerous for human health. Unfortunately upper data are not easily available and measurements entail high costs. Meteorological models, usually used as dispersion pre-processor, can help to overcome this problem.

A new project has been conducted in Venice area to better understand PBL conditions. Particular attention has been given to lagoon affection on PBL dynamics.

METHODOLOGY

The diurnal variation of various meteorological parameters in the Planetary Boundary Layer has been studied through a remote sensing instrumentation and a sonic anemometer. RASS-SODAR integrated system allowed the determination of the vertical temperature profiles and of the vertical wind speed and direction profiles. The Sonic Anemometer provided the dataset used to obtain the time trend of other meteorological and dispersive parameters, and to evaluate the PBL turbulence variables and the energetic fluxes.

The mobile RASS- Airone provided by ISMES-CESI was installed on board a 13 m semi-trailer carrying a container containing acquisition electronics, Doppler radar and an acoustic generator.Remote measurement takes place when the acoustic generator emits a brief impulse upward and the corresponding radio echo captured by the Doppler radio receiver antenna is analyzed. The SODAR LP-120 was provided by ISMES-CESI and is composed by three individual antennas aimed in specific directions to steer the acoustic beam. The Sonic Anemometer METEK-USA 1, provided by ISMES-CESIusesultrasonic sound wavesto measure wind velocity. They measure wind speed based on the time of flight of sonic pulses between 3 pairs oftransducers. The instrumentation is connected with a data capture system Meteoflux®, that allow to collect real time data of the three wind component and of the *eddy covariance* requested for the calculation of turbulence parameter and of radiation fluxes. The anemometer was coupled with a meteorological station to measure local temperature, pressure, humidity and precipitation. Severalsensors have been located to collect radiation and heat flux data. The instrumentation is showed in Figure 28.

Figure 28. Rass/Sodar station with the Sonic Anemometer.

The monitoring stations have been located in strategic areas of the Venice Lagoon (Porto, the lagoon site, and Malamocco, the sea site) and for two different periods (autumn-winter and spring-summer, respectively). Other data has been obtained by a RASS-SODAR integrated system located in Fusina, which works in continuous for the entire year (

Figure 29). Unfortunately only one instrumentation was available and the two campaigns were conducted in different periods. Data was collected from the September 2009 to the Dicember 2009 in the lagoon site and from march 2010 to July 2010 in the sea site. Data from the fixed instrument in land site were always available so comparison between land and lagoon site were made for the first period, and comparison between land and sea site were made for the second one. Logistic problems didn't allow to collect nocturnal data in lagoon site and to have always coherent data among the three stations.

Measurements have been used to validate a diagnostic meteorological model (*MINERVE*) (Desiato et al., 1998, Aria Technologies, 2001) and a turbulence model (*SURFPRO*) (D'Allura et al., 2004). Minerve is a 3D wind field model for complex terrains; it produces a mass-consistent wind field with data from a dispersed meteorological network. Temperature and humidity fields can also be interpolated. SURFPRO produces the fields of dry deposition velocities and turbulent diffusivities.

Figure 29. Sample sites location in Venice area.

DATA ANALYSIS

Daily variability of Planetary Boundary Layer don't permit an homogeneous analysis only based on average values. Besides this a general and typical behavior has been checked for the sites investigated.From RASS data temperature profiles were plotted while wind ones was get by SODAR measurements. The anemometer allowed to measure other parameters that are significant in heat exchange and in dispersion phenomena such as: global and net radiation, stability class and mixing height and wind component standard deviation. All these parameters have a cyclical behavior and are influenced by solar radiation and by meteorological phenomena like clouds or precipitation. Unfortunately land site wasn't supplied with an anemometer and data couldn't have been compared.

In the first period PBL profiles show significant correlations between land and lagoon sites at different heights for both wind ($0.6 \div 0.8$, with $p < 0.5$) and temperature (0.9, with $p < 0.5$) data. During the second period correlations show significant values for temperature profiles ($0.7 \div 0.9$, with $p < 0.5$) while wind values are not well correlated ($0.3\div 0.5$, with $p < 0.5$) at different heights.

Temperature profiles show a typical daily behavior in all the sites investigated but land site is generally warmer than the other two sample stations. unfortunately lagoon and sea data don't reach more than 600 m of heights because the mobile instrumentation was less powerful than the fixed one in land site. Some peculiarities can be observed in the afternoon temperature profiles. As regard the first period generally an early inversion occurs in the lagoon site from 3 pm probably connected with the formation of the stable nocturnal layer. That doesn't happen for land site where it arises from 6 to 8 pm. Unfortunately lack of nocturnal data doesn't allow to observe the profile for the 24 hours. The differences between the two sample sites can depend on PBL behavior for different geographic positions. An example of absolute temperature profile during the day for the first period is showed inFigure 30.

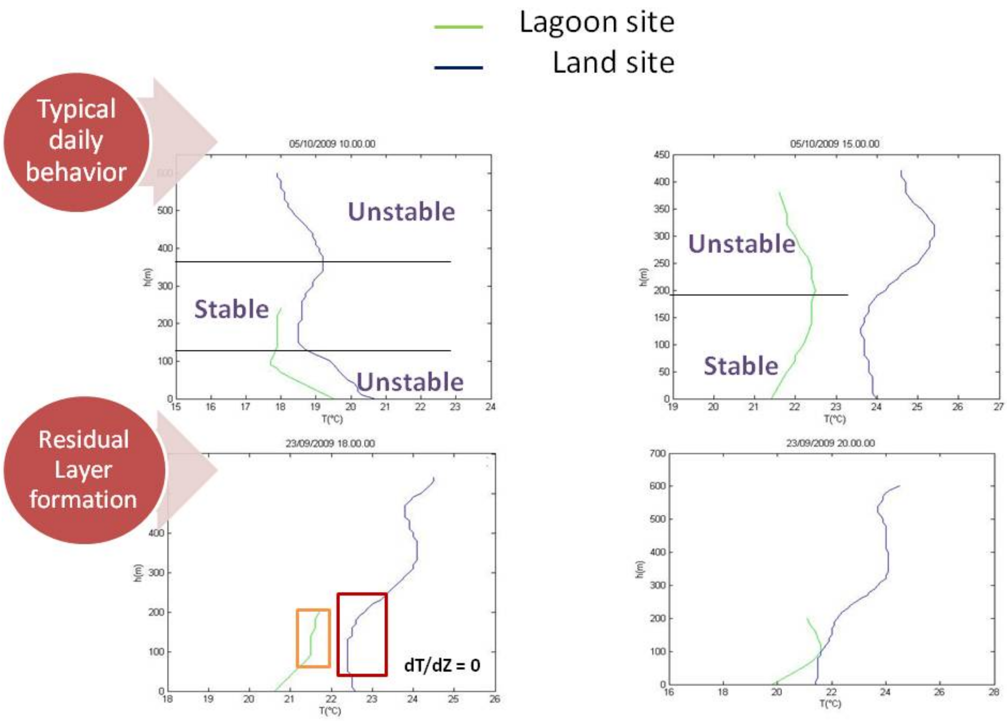

Figure 30. Land and lagoon comparison of temperature profiles.

Wind profiles confirm the typical Venice climatology with calm wind and breeze. Wind speed increases with height reaching high values over 150 m or over the elevated inversion height defined by temperature profiles. Land site wind is generally lower respect to the sea sites while lagoon present more comparable values at the different heights The first period is characterized by highest wind values in the morning while the second one shows nocturnal more windy situations.

The anemometer data were processed by Meteoflux® System and refer to weather parameters, wind components and energetic fluxes. Data were available only for lagoon and sea sites. These parameters are generally used for weather analysis or as modeling input. An inverse proportionality exist between solar radiation and stability classes that means very unstable situations during the day (value 1-2, class A-B of Beaufort scale) with high solar radiation and convective turbulence phenomena. Nocturnal period is characterized by stability (value 4, class D of Beaufort scale) that means mechanical turbulence phenomena. During the night or during in the early morning the value 6 (F of Beaufort scale) denotes foggy events.

MODELING

Data predicted were compared with measurements for the two periods. Generally the model tends to make homogeneous the data over the study area than reality and the vertical profiles are strongly influenced by upper air data used as input of the simulation. Differences appear more in the lower levels than over the 100 m height. An example for temperature data is showed in

Figure 31). Despite this, comparison shows a good correlation between predicted and measured except for data near the surface. That is probably due to the fact that surface meteorological data used by the model are interpolated among a big number of local stations, while measured data refers to a unique value.

CONCLUSION

Temperature and wind profiles are strongly correlated to heat exchange between earth and atmosphere as explained before. Data for heat exchange were necessary to better describe the PBL behavior. Data from lagoon and sea sites were available and some critical situations was stressed confirming the analysis described before. During the first period lagoon site shows a very stable situation in first hours of the night probably connected with the early inversion described before. This situation can be critical if emission sources are located in the area because pollution won't be dispersed easily. During summer period the sea site is characterized by daily strong instability at the lower heights and elevated inversion causing the typical capping inversion. Adding a calm wind situation to this typical PBL behavior will increase the risk of pollutant entrapment.

As regard modeling, some critical situation arise by data comparison. The temperature profile in the sea site seems to be discriminant respect to the other stations. That can depend on model but also on a real particular geographical position that is affected by the sea influence. Even though data demonstrate a good performance of the model, results can be improved with an increase of model data input with new measurements.

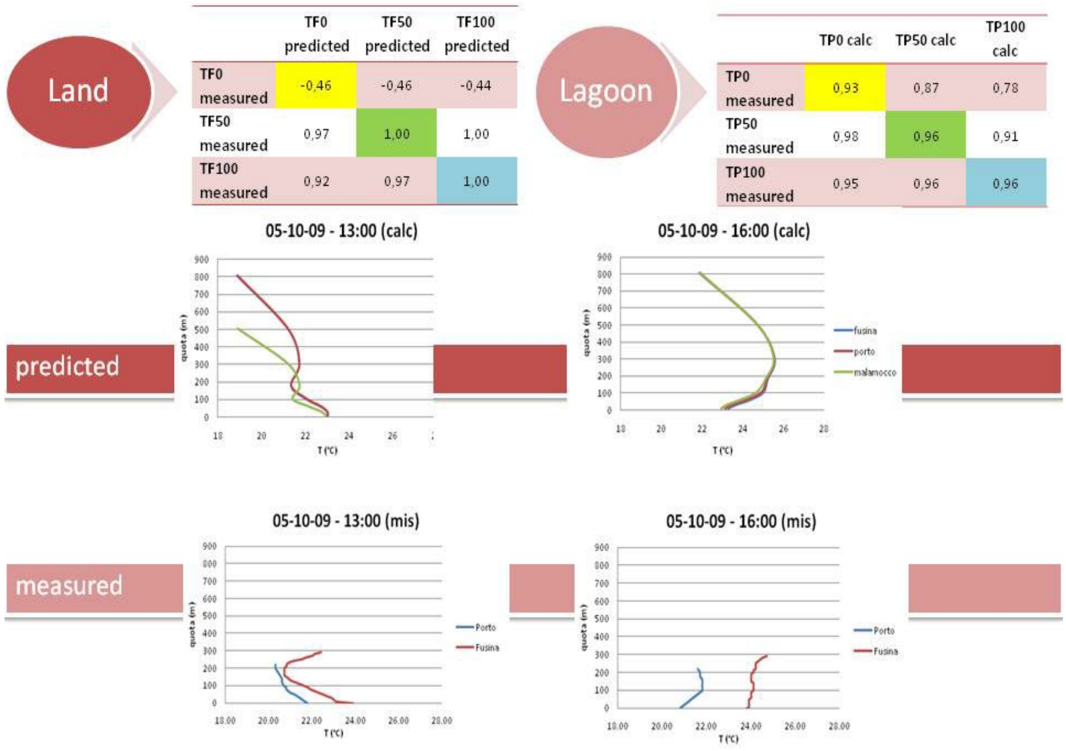

Figure 31. Comparison between predicted and measured data, land – lagoon case.

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