WINTER AND SUMMER BREEZES IN A COASTAL REGION

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INTRODUCTION

Given the large number of urban complexes located in the vicinity of shorelines, in the last decades the knowledge of the wind circulation in correspondence of coastal areas has gained the interest of the scientific community. This attention has been greatly stimulated by the interest in modeling pollutant dispersion in coastal areas, where the presence of the sea surface induces local winds such as sea and land breezes, which, in turn, regulate transport and dispersion of airborne materials emitted within coastal urban complexes (*Simpson, J.E.*, 1994). The wind circulation is nearly often complicated by other local winds systems associated with mountains chains (e.g., terrain-forced flows and diurnal mountain winds, *Whiteman, C.D.,* 2000) as well as by flow convergence and divergence caused by the heat island circulation associated to urban complexes (*Oke, T.R.*, 1982). Although events of high pollution in large cities occur mostly during the cold season, in the past not many studies have been devoted to investigate wintry local circulations. This partial lack of knowledge is the principal motivation of this work, which deals with the use of the three dimensional meteorological model CSUMM (Colorado State University Mesoscale Model) to calculate the wind field in the nocturnal and morning planetary boundary layer in Rome and the surrounding area. Previous numerical investigations based on a single day analysis illustrated that this area is subject to local winds circulations such as sea and land breezes and slope flows both during the summer (e.g., *Monti, P. and G. Leuzzi*, 2005) and the winter (e.g., *Ferretti, R. et al.,* 2003). To extend the previous analysis to longer periods, in this work a series of numerical simulations were conducted considering the months of March and August 1996. The results, in reasonable good agreement with the data collected during a field campaign conducted in the roman area during the year 1996, showed that the establishment of the wintry sea breeze was not an unusual event, even though the onset time, duration and intensity of the wind differ significantly from those observed in summer.

STUDIED AREA, MODEL DESCRIPTION AND METEOROLOGICAL STATIONS

The study domain is nearly centred on the city of Rome, which is located in a relatively flat area, about 25 km inland from the shoreline (Figure 1). With the exception of the west side, the city is surrounded by hills and high mountains. The eastern side of the city is the southwestern border of the north-oriented Tiber Valley. CSUMM (developed originally by *Pielke, R.A.*, 1974) was used for the evaluation of the wind velocity, temperature and specific humidity in a gridded domain. CSUMM is a hydrostatic, incompressible, prognostic model able to predict the evolution of the atmosphere by the space-time integration of the budget equations of mass, momentum, heat, moisture and turbulent kinetic energy. The modelling domain consists of a 51×51 horizontal grid points with a constant grid size of $4 \times 4\ \mathrm{km}^2$. In order to take account the strong surface layer gradients, the vertical grid levels are unevenly spaced, i.e., the lower 11 levels are z=10, 20, 44, 100, 300, 500, 700, 900, 1200, 1500 and 2000 m, while the other 7 levels are equally spaced up to 9000 m with a grid size of 1000 m. CSUMM requires as input data several soil parameters as density, specific heat, thermal diffusivity, moisture availability, roughness and albedo. It also requires the knowledge of the geostrophic wind and the initial profiles of temperature and specific humidity. These have been taken from radio-soundings performed at the military airport of Pratica di Mare (PDM in

Figure 1), located nearly 6 km from the coast at 20 m above the sea level (ASL). Since in the lower layers the winds recorded by the radiosonde are generally representative of local circulation rather than by large scale flow as requested to initialise the numerical model, in the height range $0 < z < 500\,\mathrm{m}$ the wind data were taken from data reanalysis of ECMWF (European Centre for Medium-Range Weather Forecast). The temperature of the sea-surface was based on CDC (Climate Data Center) data. Each simulation starts at 6 LST (Local Standard Time) and lasts 48 hours later. The numerical results were compared with data collected using sodars located at PDM and at IFU (Figure 1). The latter was placed on the roof of the building of the Department of Physics of the University of Rome “La Sapienza”, nearly 60 m ASL. Both the sodars are continuously operating and enable measurements of the wind speed and direction in the height range ~40-900 m above the ground level (AGL), providing statistics over 10-min of the mentioned quantities with a vertical resolution of 27 m.

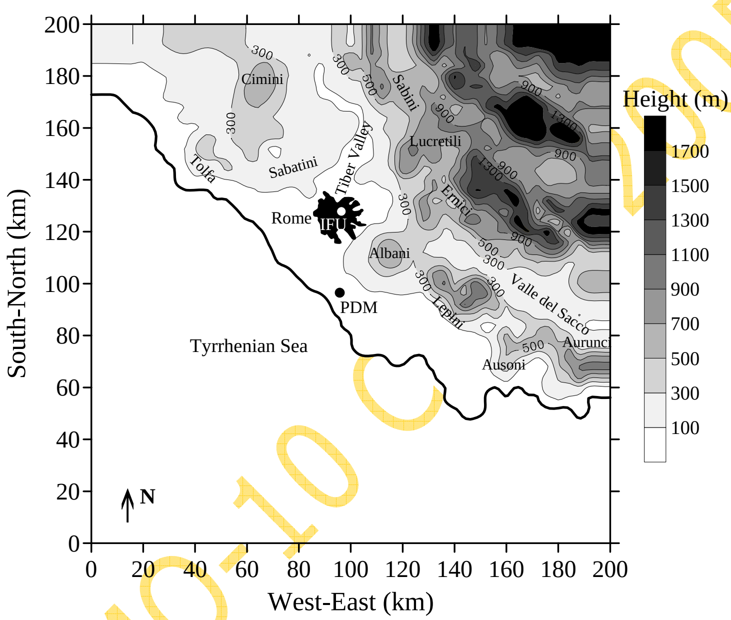

Fig. 1; The model domain. The location marked with IFU represents the “University” station, while PDM indicates “Pratica di Mare” station.

RESULTS

As mentioned in the introduction, the main point of this study is the analysis of the local circulations occurring during March and August 1996. Inspection of the data showed that among the summery and wintry months March and August were the more conducive for the development of thermally-driven flows. Before discussing them, however, we will first describe the main characteristics of a typical summer day with low wind speed and strong solar insolation. Figure 2 shows the time series of the modelled (full circles) and observed (open circles) wind speed (Figure 2a) and wind direction (Figure 2b) at ~40 m AGL on 4 August 1996 at PDM. The geostrophic wind speed was westerly ($\alpha \cong 260°$) and well-below $3\,\mathrm{m\,s^{-1}}$ within the first 1000 m AGL. The agreement between simulation and observation was reasonable. The figure reveals both the presence of the easterly nocturnal regime (this aspect will be discussed later) and the occurrence of a westerly diurnal regime, mainly associated to the sea breeze current. These periods are separated by a transition regime in the time interval ~7-10 LST. Figure 2 also shows the occurring of the evening transition in the period ~20-00 LST, when the wind exhibited a clockwise rotation toward east.

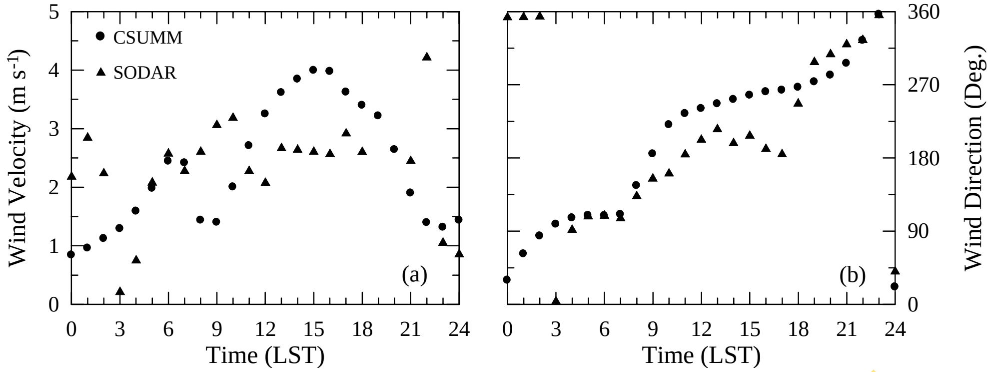

Fig. 2; Observed (circles) and simulated (triangles) (a) wind speed and (b) wind direction at ~40 m AGL on 4 August at PDM as a function of the time of the day.

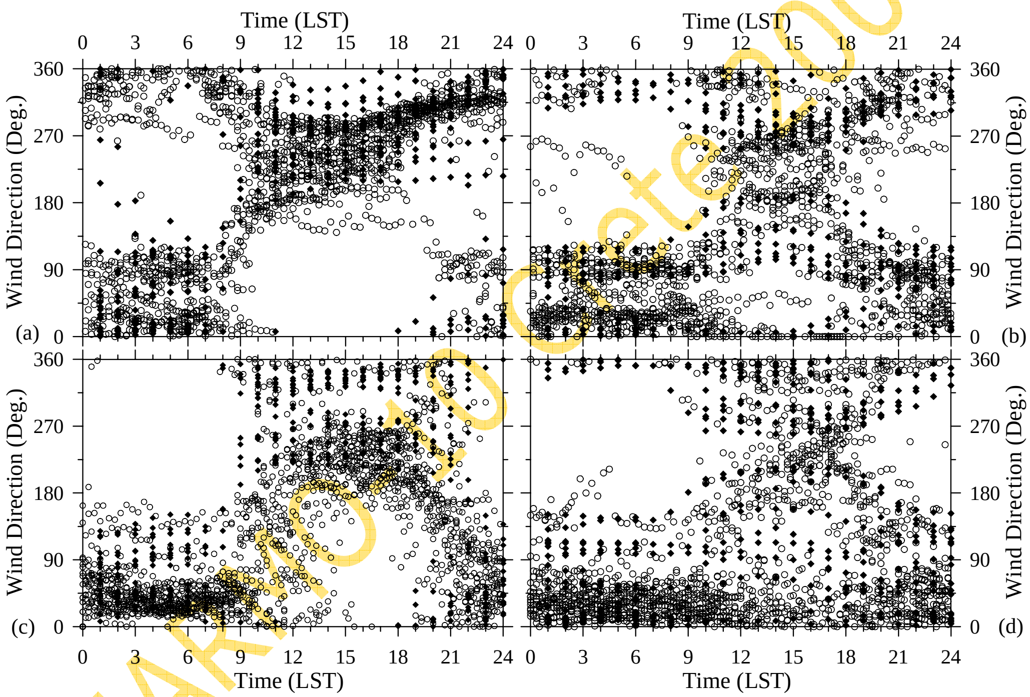

Fig. 3; Predicted (full diamonds) and observed (open circles) wind direction as a function of the time of the day at:(a) PDM at 66 m AGL in August; (b) PDM at 66 m AGL in March; (c) IFU at 98 m AGL in August and (d) IFU at 98 m AGL in March.

We look now at the characteristics of the winds occurring in March and August 1996. The first step deals with the identification of the days in which the weather conditions were conducive for the development of local thermally-driven circulations. Therefore, only the days characterized by clear skies and wind speed below a certain threshold value were considered for the analysis. Based on the same sodar data set used in the present study, *Coniglio, L.* (2004) proposed a threshold value of $8\,\mathrm{m\,s^{-1}}$ measured at 66 m AGL at PDM. Using this procedure, 22 days both in March and in August suitable for the onset of thermally-driven circulation were identified. Thus, a series of 22 simulations, 11 in March and 11 in August, with a time duration of 48 hours each, were performed by CSUMM. Figure 3a shows the scatter plot of the observed (open circles) and simulated (full diamonds) wind direction during August at 66 m AGL at PDM as a function of the time of the day. A general good agreement between simulations and measurements was obtained. We note that both the diurnal and the nocturnal circulations were well predicted by the model. During the night two distinct regimes occurred: the first one was easterly while the second one was north-northeasterly. This nocturnal configuration was also present in March (Figure 3b).

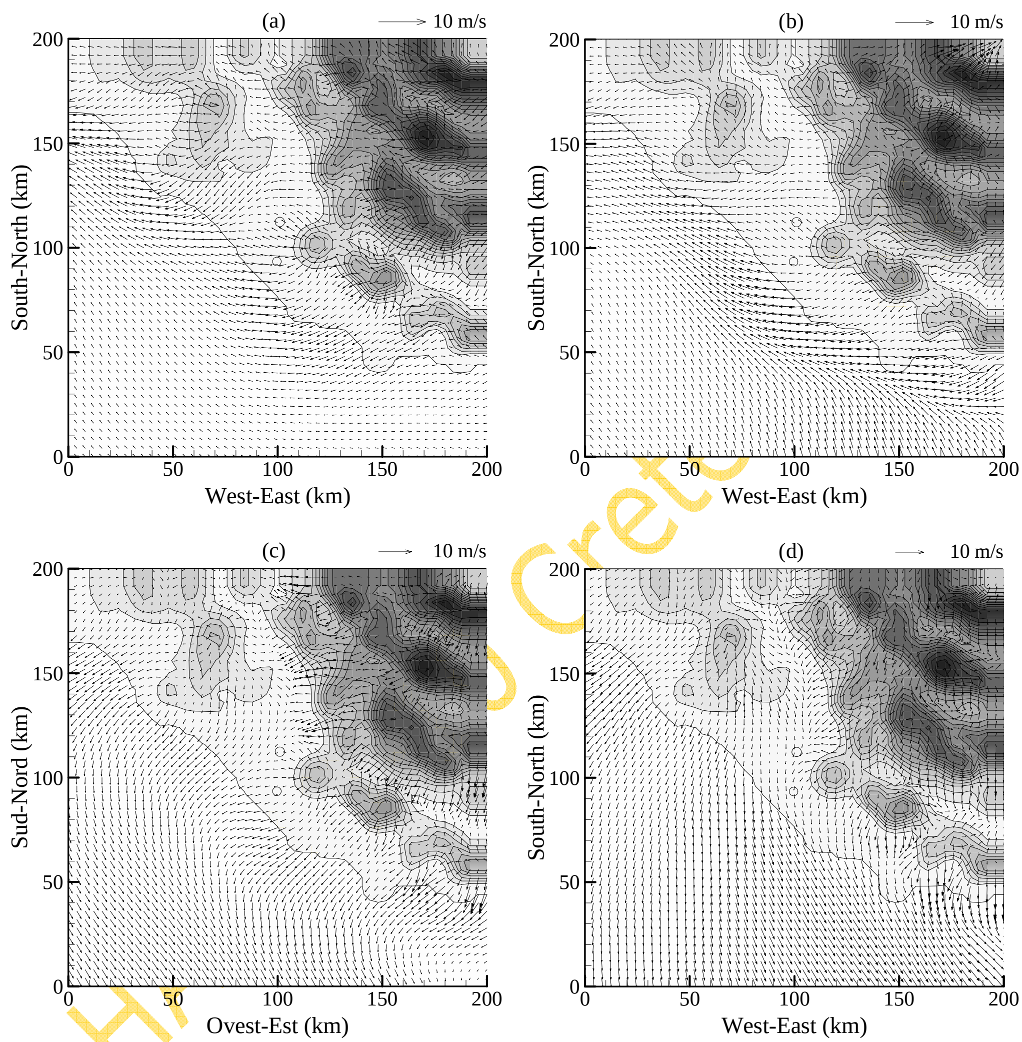

Fig. 4; Predicted near-surface wind vectors at 06 LST for different direction α of the geostrophic wind. (a) No geostrophic wind; (b) $\alpha \cong 160°$; (c) $\alpha \cong 350°$ and (d) $\alpha \cong 15°$.

To understand the reasons for the occurrence of the two circulations we analyzed carefully four runs, each of them corresponding to a different direction of the geostrophic wind (Figure 4). When the geostrophic wind was low or absent (Figure 4a, 27 August) nighttime winds at PDM were dominated by easterly katabatic flows originating at Colli Albani, located a few kilometres east of PDM. Similarly, an easterly wind was present nighttime at PDM both when the geostrophic wind was nearly southerly ($\alpha \cong 160°$, Figure 4b, 6 August) and nearly westerly ($\alpha \cong 260°$, 27 August), as already noted in the analysis of Figure 2. The flow configuration changed when the geostrophic wind was northerly, as apparent from Figure 4c ($\alpha \cong 350°$, 2 August) and 4d ($\alpha \cong 15°$, 10 August), when the wind at PDM was northeasterly and northerly, respectively. Note that in the cases described in Figures 4b-d the geostrophic wind had nearly the same speed ($\sim 1.5 \div 2\ \mathrm{m\,s^{-1}}$). It is also interesting to note the way in which the nocturnal winds at PDM were strongly influenced by the flow exiting the Tiber Valley when $\alpha \cong 15°$ (Figure 4d). During March (figure 3b), two well-distinct circulations took place at PDM: the first one northerly ($300° \div 45°$), with a diurnal wind rotation to ~250°, the second one easterly ($80° \div 130°$), with a diurnal wind rotation to ~200°. Both these circulations appeared to be strongly affected by the geostrophic wind, showing only a partial influence of the sea breeze during the daytime. Also, as expected, the time duration of the diurnal circulation in March was shorter than that occurring in August.

With regard to the urban site at IFU (Figure 3c and 3d in August and March, respectively), the agreement between simulations and observation is reasonably good. The regimes described above were still visible, even though they were not so evident as for PDM. Moreover, in both the months the number of events associated to the sea breeze was smaller than that observed at PDM. This seems reasonable in that IFU is located far from the shoreline and was certainly disturbed by the heat island circulation associated to Rome.

CONCLUSIONS

An analysis of the wind circulation in Rome and the surrounding area during March and August 1996 was carried out by means of a numerical mesoscale model. Particular attention was focussed to the local circulations occurring when large scale winds were weak. The results were in agreement with those collected during a field campaign conducted in different locations within the roman area in 1996. In August, during the daytime, the local circulation was strongly affected by the sea breeze. Nighttime winds were mainly influenced by katabatic flows originating at the slopes of the mountains chains encircling the roman area. Moreover, the wind fields resulting from the interaction of land breeze, katabatic, and down-valley winds exiting the Tiber Valley were analyzed as well as the way in which they were affected by the direction of the geostrophic wind. In March the sea breeze was still present, while the nocturnal circulation seemed to be mainly governed by the geostrophic wind.

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