Application of a Lagrangian Model to Investigate Patterns of Radionuclides DispersionOver Complex Terrain - Part 1: Local Circulation and Low-Level Jet

H.A. Karam[1], A.P. Oliveira and M.M.R. Pereira
Group of Micrometeorology, Department of Atmospheric Sciences, Institute of Astronomy and Geophysics, University of São Paulo, Rua do Matão, 1226, São Paulo, SP, 05508.900, Brazil (hakaram@model.iag.usp.br)

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1 Introduction

The topography in the São Paulo State (SPS) is very complex (Figure 1). The high elevation areas (1000-1800 m) follow the coastline, which is oriented in the NE-SW direction. In the countryside the terrain slopes towards west, reaching about 300 meters in the Paraná River Valley, around 700 km westward in the SW sector of SPS.

There are evidences that the circulation in the countryside of SPS is effected by: sea breeze (Oliveira and Silva Dias, 1982; Silva Dias and Machado, 1997) and by other local circulations induced by topography effects such as anabatic and catabatic winds, channeling and blocking (Karam, 1995).

Tethered balloon observations carried out in area located in SPS (Iperó) have indicated also the presence of low-level jet (Oliveira et al., 1998). Karam and Oliveira (2001) have shown that the slope of the countryside of SPS is steep enough to support a mesoscale circulation with an embedded LLJ with characteristic similar to the one observed in Iperó.

The objective of this research is to describe the patterns of circulation that are thermally driven and modified by topography and land cover in the countryside and their impact on the air pollution conditions in Iperó.

In this work we will focus on the role played by of these circulations in the formation of the Low-level Jet (LLJ) observed there in the region of Iperó. Special emphasis will be given to the sea breeze circulation induced by the Atlantic Ocean, located at 120 km East of Iperó. In this investigation, the atmospheric circulation is simulated numerically using a non-hydrostatic mesoscale model TVMnh30c (Thunis, 1995).

2 Numerical Simulations

The mesoscale model TVM was run for 24 hours starting at 6h00 LT (Local Time). This simulation was set up in an area of 1500 by 1500 km centered in Iperó (23°23’36’’S, 47°35’58’’W). This area contains part of the Atlantic Ocean at east and the countryside of SPS. The input parameters correspond to a Julian Day 68 (March 9) or summer conditions. In this simulation the model was set with the following characteristics:

- The domain in the horizontal direction corresponds to an area of 1500km by 1500km distributed over a grid of 51 by 51 points, resulting in a resolution of 35 km;
- The domain in the vertical direction corresponds to a column of 13 km distributed logarithmically in 25 levels, resulting in vertical resolution of 30 m at surface and near 1200 m at the top;

- Topography and land use in this domain was obtained from GTOPO30 and IGBP respectively.
- The maximum time step was 90s and the simulation time was 24h;
- Large-scale flow was equal to a NE geostrophic wind of $1ms^{-1}$ kept constant during the simulation.

3 Results and Discussion

The sea breeze circulation penetrates inland about 100 km in most of the domain of simulation. In Iperó the sea breeze did not penetrate. The circulation in this area seems to respond to the anabatic flows induced by the topography. Figure 1 display the numerical simulation results at 18h00 LT, corresponding to 12 hours of numerical simulation.

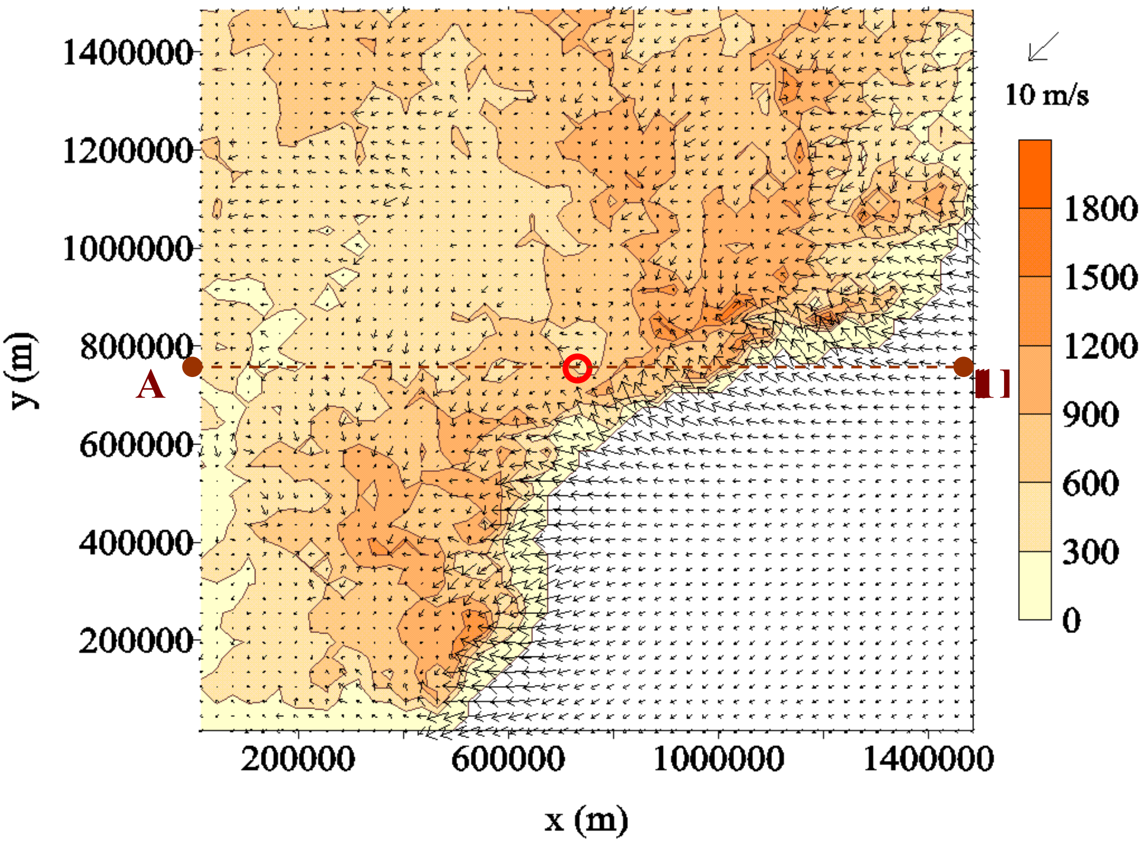


Figure 1 Horizontal wind field at 15 m above the surface at 18:00 LT. Topography is indicated by orange scale. The red open circle in the center indicates position of Iperó. Letters A and B define the position of the cross section displayed in Figure 3.

Figure 2 displays the wind field at 15 m above the surface at 3h00 LT, corresponding to 21 hours of numerical simulation. Areas where wind speed is greater than 4 m/s are located over the high elevations. In the region of Iperó the wind speed at 337 m reaches near 10 m/s. The flow over the Atlantic Ocean, in SE sector of domain, is from East. In the NW sector, over the countryside of SPS, the flow follows the topography, diverging in the higher elevations and converging in the lower elevations. The area of low wind speed following the coastline is an indication of catabatic flow down to the high mountains line near the ocean.

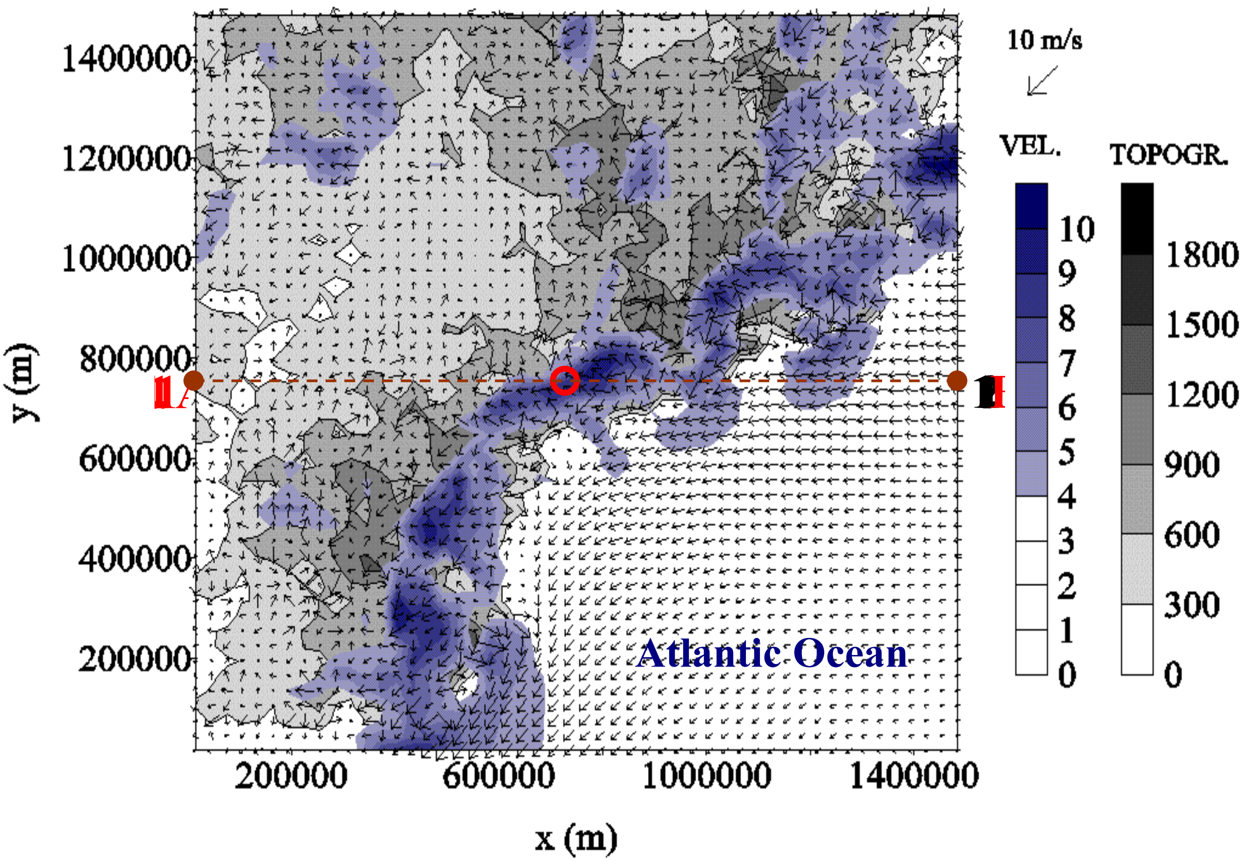


Figure 2 Horizontal wind field at 15 m above the surface at 03:00 LT. The wind velocity at 337 m above the surface is indicated by blue scale. Topography is indicated by gray scale. The red open circle in the center indicates position of Iperó. Letters A and B define the position of the cross section displayed in Figure 3.

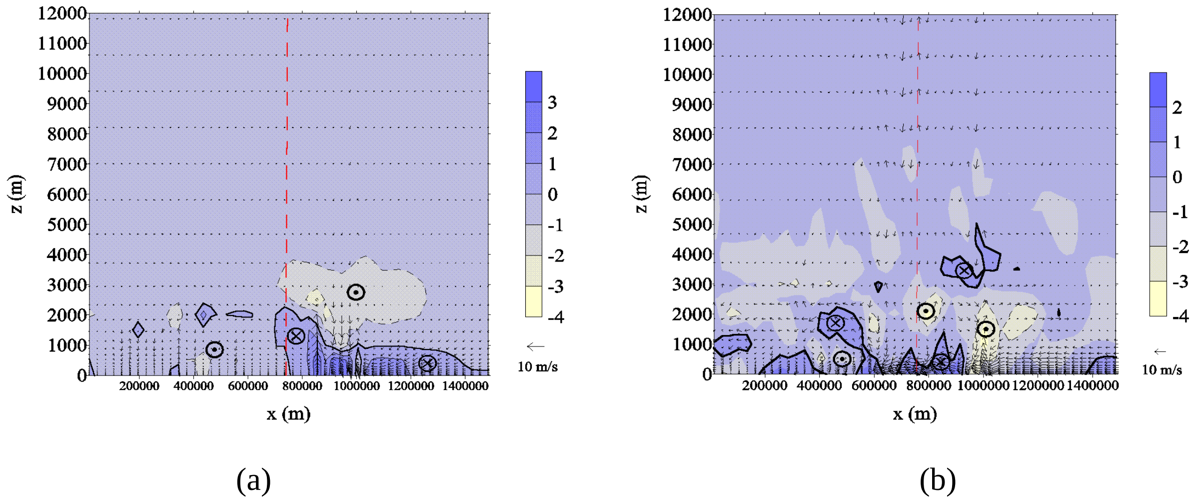
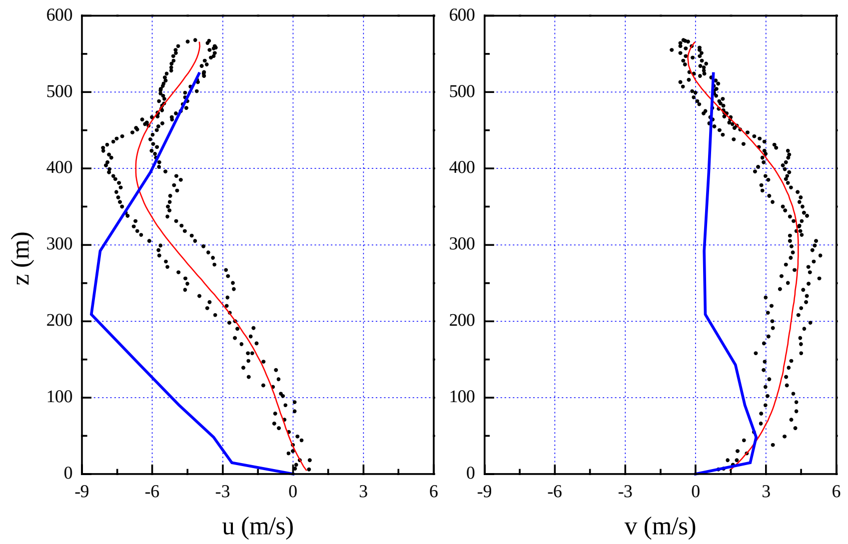


Figure 3 Meridional component of the wind vector (blue-yellow scale) simulated at (a) 18:00 LT and (b) 03:00 LT, along the line AB in Figure 1 and 2). The wind vector (u, 100*w) is present also. The vertical dashed red line indicates Iperó.

Figure 3 shows contours of meridional component of the wind speed in xz-plane crossing Iperó (as indicated in Figures 1 and 2) at (a) 18:00 LT and (b) 03:00 LT. The vectors correspond to u-component in the x-direction and 100w-component in the z-direction. In this Figures is presented the circulation cells associated sea breeze at the end of the day and the down-slope flow during the night.

Figure 4 presents the LLJ observed at Iperó. The intensity and direction of the simulated LLJ (blue line) agrees with the observed ones. The simulated core is about 200 m lower than the observed.



(a) (b)

Figure 4 (a) Zonal and (b) meridional wind speed components associated with a nocturnal low-level jet observed during winter at Iperó, Brazil at 03:00 LT. The bold lines indicate the simulation.

Figure 5a presents the hodograph of the wind simulated by the model. The diurnal oscillation of the wind, with NE during daytime and SE at nighttime, follows the observations in Iperó during winter and summer period (Figure 5b and 5c respectively).

4 Conclusions

The main conclusions of this study are:

(a) The sloped terrain in countryside of SPS is the major cause of the LLJ observed in Iperó;

(b) Even though the sea breeze circulation does not penetrates in Iperó, it modulates this LLJ in the high elevation located East of Iperó;

(c) In our simulations, Iperó is always located in the transition zone between the Sea Breeze (at East) and anabatic flow (at West);

(d) The LLJ simulated occurs about 200 meters below the observed one.

(e) Diurnal evolution of the simulated wind agrees with the observation in Iperó.

Therefore, the simulations indicated that the mesoscale circulation and associated LLJ seems to be a typical feature of the countryside of São Paulo State. The dispersion of pollutants in this region has to take into consideration this circulations as indicated by the companion paper Pereira et al (2001).

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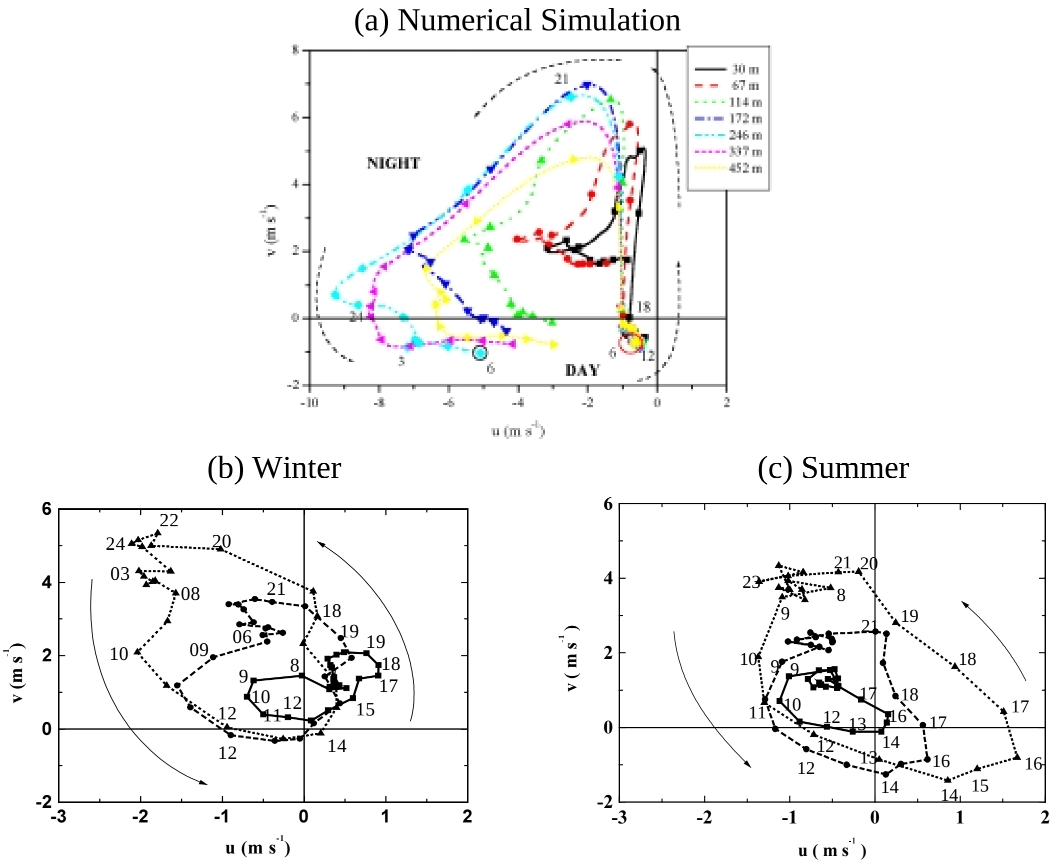

Figure 5 Wind hodograph (a) simulated numerically at 30, 67, 114, 172, 246, 337 and 452 m; (b) observed during winter (c) summer at 10, 60 and 80m (squares, circles and triangles) in Iperó. The numbers indicate local time.

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