

Application of a Lagrangian Model to Investigate Patterns of Radionuclides Dispersion Over Complex Terrain – Part 2: The Impact of Low-Level Jet in the Concentration Field

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1 Introduction

Comparing to eulerian models, lagrangian particles models present several advantages: (1) same capacity to estimate near-field and far-field dispersion; (2) turbulent transport against gradient of mean properties; (3) deals with pollutants emitted by continuous and variable intensity; (4) handle pollutants emitted by point, area and volume sources; (4) has computational simplicity; (5) describe dispersion for non-isotropic, non-homogeneous and non-stationary conditions. Major problem facing this kind of model is related to its inability to handle chemical reactions in the atmosphere (Pereira et al., 2000; Wilson and Sawford, 1996).

The objective of this work is to show how the topographic induced low-level jet (LLJ) modulates the behavior of the concentration field generated by a point source located at the surface, emitting continuously. A description of the LLJ and its relation with mesoscale features of the topography in this area is carried out in a companion paper Karam et al. (2001).

The area of study corresponds to $10,000 \text{ km}^2$ distributed over a region of complex terrain and land used (Figure 1). An industrial installation called Centro Experimental of Aramar (CEA) is located at the center of this region. Despite of rigor in the application of safety procedures (CTMSP, 1997), the process of enrichment of uranium by ultra-centrifugation of gas UF_6 can always represent a potential for air contamination that cannot be discarded.

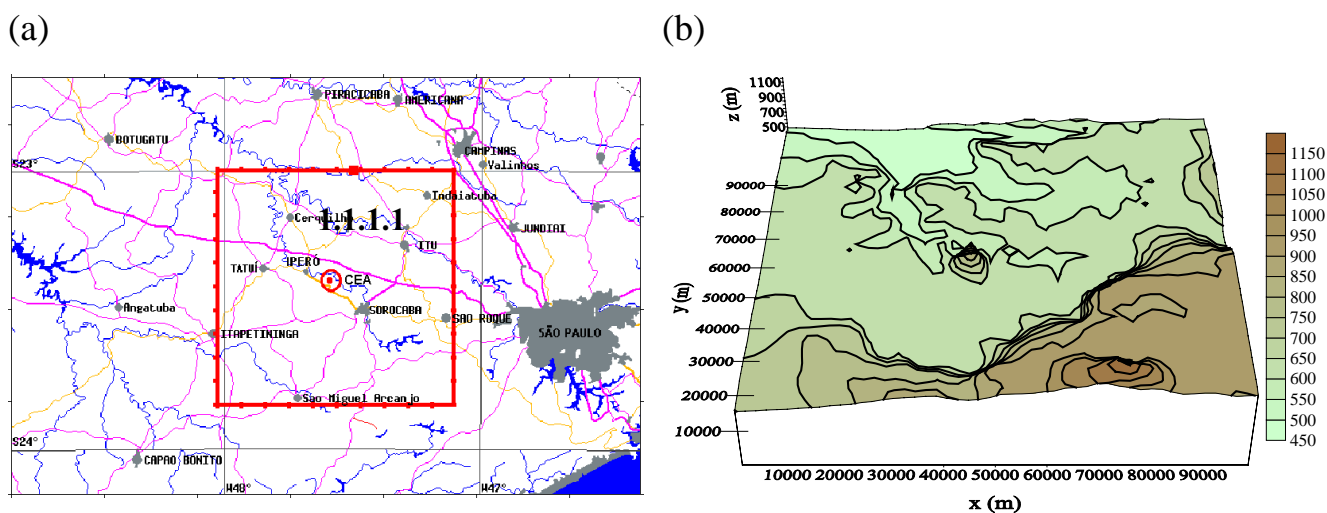


Figure 1 (a) Geographic map of the State of São Paulo. Area of study is indicated by square in the center representing 100 by 100 km. (b) Topography of the area of study. The emission is located in the center both figures, in the Centro Experimental of Aramar (CEA).

2 Methodology

Space and time evolution of PBL is simulated numerically using mesoscale model TVMnh (Karam et al. 2001). In this model the time and space evolution of PBL is evaluated using a 1.5 order turbulence closure and surface similarity theory. The height of PBL is estimated as the height where the TKE (e_T) drops to 10% of the surface value. Variances of wind speed components are estimated from $\sigma_{u,E}^2 = 2e_T/3$. The boundary conditions and external forcing used in this simulation was set up considering an undisturbed atmosphere, with clear sky and weak NE geostrophic wind of 1 m/s.

The atmospheric dispersion is simulated using a modified version of Langevin stochastic differential equation, where non-homogenous turbulence conditions are considered explicitly (Legg and Raupach, 1982). All particles trajectories are evaluated by coupling Langevin equation to the mesoscale model TVMnh. The Langevin equation is solved numerically using the method of finite difference forward in time:

$$u_i(t + \Delta t) = au_i(t) + b\sigma_{u,E}\zeta + (1-a)T_L \frac{\partial}{\partial x_i}(\sigma_{u,E}^2)\delta_{i3}, \quad (1)$$

where u_i ($i = 1,2,3$) is the velocity in the direction x , y and z at time t ; ζ is a random number from distribution with zero mean and unit variance; T_L is the lagrangian integral time scale and set equal to 200 s for u , v direction and 20 s for w direction (Zannetti, 1990); Δt is the time step 9 s of Langevin equation; $a = \exp(-\Delta t/T_L)$; $b = (1-a^2)^{1/2}$; and δ_{i3} is the Kronecker delta.

The emission of particles was set at 10 m above the surface (550 m amsl). During the simulation (24 hours) it was released 20,000 particles continuously, corresponding to ~ 2 particle at each time step. In this simulations particles represent an inert gas. Deposition and removal process were not considered here.

The mean concentration, $C(x, y, z, t)$, is calculated totalizing the number of particles (N) in each grid cell every hour as follows (Nguyen et al., 1997):

$$C(x, y, z, t) = \sum_{i=1}^N \frac{m_i}{\Delta x \Delta y \Delta z}, \quad (2)$$

where m_i is the mass of each particle; Δx , Δy and Δz are grid-spacing intervals in the x , y and z direction, respectively.

3 Results and conclusions

Figure 2 shows of the ground-level average concentration of the radionuclides (kg/m^3) in a 30 m layer adjacent to the surface. The concentration is averaged over 12 hours during daytime (06:00-18:00 LT) and nighttime (18:00-06:00 LT), and displayed in terms of the \log_{10} .

During daytime the concentration field exhibits a conical shape that is typically found under homogenous and stationary conditions (Figure 2a). This high concentration area is elongated in the NE-SW direction. This pattern is due to the fact the wind blows from NE during most of the daytime (Figure 3). Higher concentrations are found close to the source, as expected for convective conditions.

During nighttime concentration field at the surface is more complex (Figure 2b) because the flow close to surface shifts progressively from SSE to ESE between 20:00 LT and 06:00 LT. There is also a minimum value upwind of Araçoiaba hill caused by blocking effects. The LLJ (Karam et al. 2001) occurs at 200 m and from SE between 24:00 and 06:00 LT and it is responsible for the second maximum in the surface concentration field observed in the SE sector of Figure 2b.

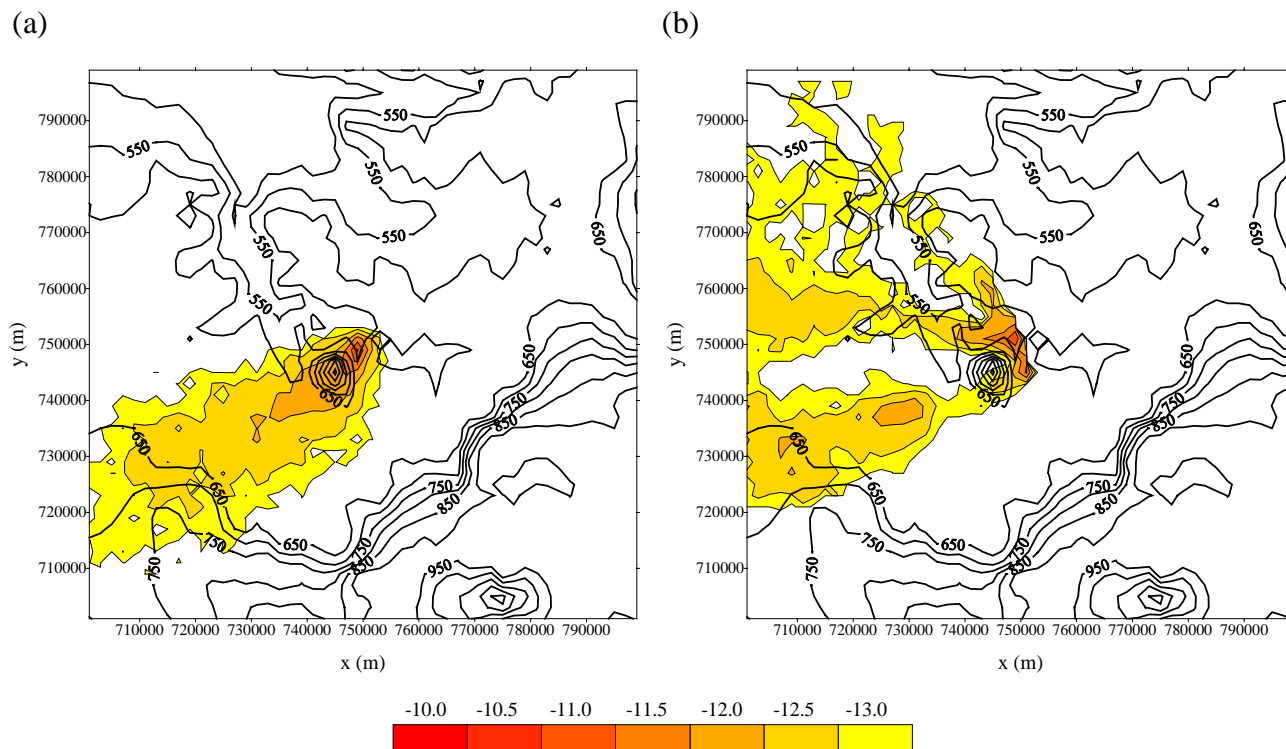


Figure 2 Average of 24:00 LT of the logarithm of the atmospheric concentration of radionuclides (kg/m^3) in the put upon level of 0-30 m the topography of the study area. (a) instable conditions and (b) stable condition. The continuous punctual source is located in the center of the domain.

Figure 4 shows the lateral view of radionuclides cloud simulated at 06:00 LT and emitted point source located at surface in Iperó. The cloud of pollutant is strongly distorted by the wind shear above and below the jet core. The jet has an important role in the regional transport of pollutant on a scale of 250 km. This dispersion in the horizontal direction is associated with a jet core intensity of $8.5 ms^{-1}$ and SE wind direction and occurs during nighttime.

During the nighttime, the low-level jet is responsible also by an increase in the intensity of turbulence. There is an increase in the transport of radionuclides downward from the residual layer, increasing the ground-level concentration at nighttime downwind the source. Similar results were found in Corsmeier et al. (1997).

During daytime, as the convective PBL increases, the dispersion of radionuclides is dominated by vertical mixing. As consequence, the radionuclides at higher levels (2000-2500 m), brought there by diurnal evolution of the PBL, were confined to the regions near to the source.

The next steps of this research is to implement some interactions of the pollutant with the environment in our dispersion model: (a) buoyancy of the heavy gas, (b) the UF_6 radioactive depletion, (c) the surface deposition, (d) the asymmetry in w fluctuations and (e) variations in the lagrangian time scales.

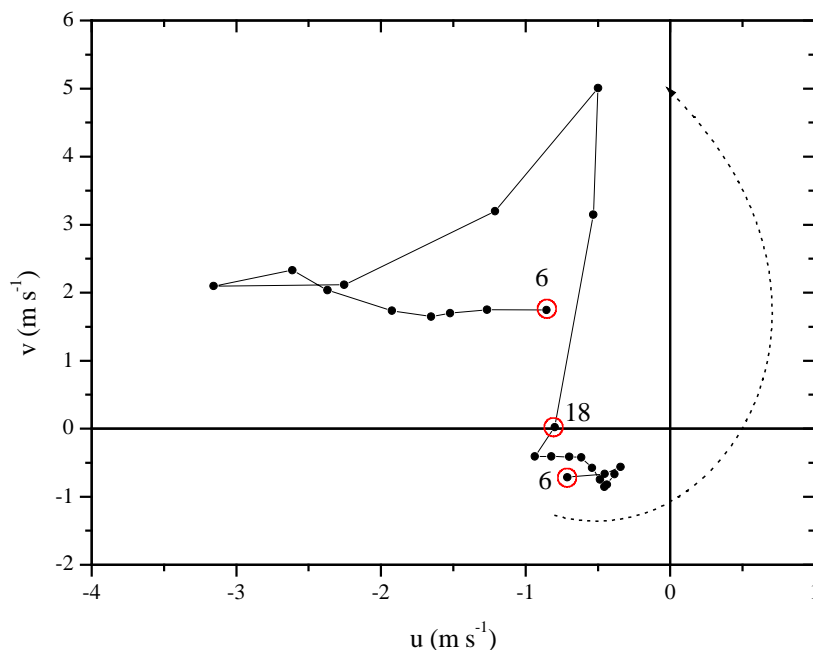


Figure 3 Hodograph simulated for the period of 24:00 LT in the level of 0-30 m.

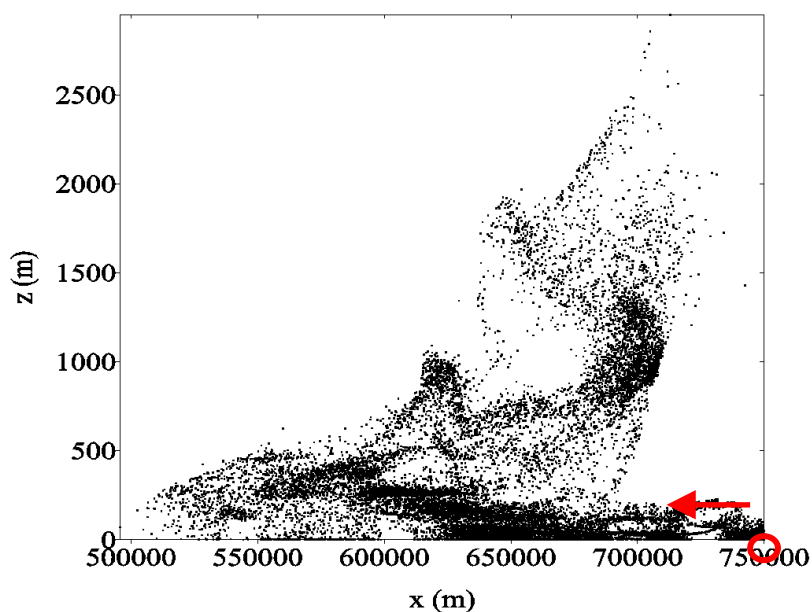


Figure 4 Lateral view of all particles in the volume of 250 km by 250 by 3 km at 06LT (after 24 hours of simulation). The circle indicates the source position and the arrow, the core jet height.

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Bibliography

1. Corsmeier, U., Kalthoff, N., Kolle, O., Kotzian, M and Fiedler, F., (1997), 'Ozone Concentration Jump in the Stable Nocturnal Boundary Layer During a LLJ-Event'. *Atmospheric Environment*, Vol. 31, pp. 1977-1989, 1997.

2. CTMSP – Centro Tecnológico da Marinha em São Paulo (1997), ‘Relatório de Impacto ambiental do Centro Experimental de Aramar’, 289 p., 1997.
3. Karam, H. A.; Oliveira, A. P; Pereira, M. M. R., (2001), ‘Dispersion of a Hypothetically Release Radionuclides Over Complex Terrain – Part I: The Impact of Low-Level Jet in the Trajectories’. *7th International Conference on Harmonization within Atmospheric Dispersion Modeling for Regulatory Purposes*. Belgirate, Italy, May 2001.
4. Legg, B. J. and Raupach, M. R. (1982), ‘Markov-Chain Simulation of Particle Dispersion in Inhomogeneous Flows: The Mean Drift Velocity induced by a Gradient in Eulerian Velocity Variance’, *Boundary Layer Meteorology*, Vol. 24, pp. 3-13, 1982.
5. Nguyen, K. C., Noonan, J. A., Galbally, I. E. and Physick, W. L, (1997), ‘Prediction of Plume dispersion in Complex Terrain: Eulerian Versus Lagrangian Models’. *Atmospheric Environment*, Vol. 31, pp. 947-958, 1997.
6. Pereira, M. R. P, Oliveira, A. P. and Karam, H. A., (2000), ‘Estudo Numérico da Dispersão de Poluentes Sobre uma Região de Topografia Complexa’ *XI Congresso Brasileiro de Meteorologia*, pp. 2270-2277, 2000.
7. Wilson, J. D. and Sawford, B. L., (1996), ‘Review of lagrangian stochastic models for trajectories in the turbulent atmosphere’, *Boundary-Layer Meteorology*, Vol. 78, pp. 191-210, 1996.
8. Zannetti, P., (1990), ‘Air Pollution Modeling – Theories, Computational Methods and Available Software’. Ed. Van Nostrand Reinhold, 444 p., 1990.