

# A PRACTICAL AND LOW-COST METHOD TO ASSESS THE AIR QUALITY IN LARGE CITIES: BUENOS AIRES EXPERIENCE

Arkouli Marcelina<sup>2</sup>, Baumbach Günter<sup>2</sup>, Vogt Ulrich<sup>2</sup>, Ulke Ana<sup>4</sup>, Endlicher Winfried<sup>1</sup>, Schultz Eckart<sup>3</sup>, Müller Marlén<sup>1</sup>, Wolf-Benning Uta<sup>1</sup>, Dawidowski Laura<sup>5</sup>, Faggi Ana<sup>6</sup>

<sup>1</sup>Institute of Geography, Department of Climatology, Humboldt-Universität zu Berlin, Germany  
([wilfried.endlicher@geo.hu-berlin.de](mailto:wilfried.endlicher@geo.hu-berlin.de))

<sup>1</sup>Institute of Geography, Department of Climatology, Humboldt-Universität zu Berlin, Germany  
([marlen.mueller@geo.hu-berlin.de](mailto:marlen.mueller@geo.hu-berlin.de))

<sup>2</sup>Institute of Process Engineering and Power Plant Technology, Department of Air Quality Control, Universität Stuttgart, Germany ([arkouli@ivd.uni-stuttgart.de](mailto:arkouli@ivd.uni-stuttgart.de))

<sup>2</sup>Institute of Process Engineering and Power Plant Technology, Department of Air Quality Control, Universität Stuttgart, Germany ([baumbach@ivd.uni-stuttgart.de](mailto:baumbach@ivd.uni-stuttgart.de))

<sup>2</sup>Institute of Process Engineering and Power Plant Technology, Department of Air Quality Control, Universität Stuttgart, Germany ([vogt@ivd.uni-stuttgart.de](mailto:vogt@ivd.uni-stuttgart.de))

<sup>3</sup>Department of Human-Biometeorology, Deutscher Wetterdienst, Germany ([eckart.schultz@dwd.de](mailto:eckart.schultz@dwd.de))

<sup>4</sup>Faculty of Sciences, Department of Atmospheric Sciences, University of Buenos Aires, Argentina  
([ulke@at.fcen.uba.ar](mailto:ulke@at.fcen.uba.ar))

<sup>5</sup>National Commission of Atomic Energy, Department of Environmental Monitoring, Argentina  
([dawidows@cnea.gov.ar](mailto:dawidows@cnea.gov.ar))

<sup>6</sup>Faculty of Ecological Engineering, University of Flores, Argentina ([afaggi@macn.gov.ar](mailto:afaggi@macn.gov.ar))

## Abstract

Results of the Buenos Aires Research on Urban Climate and Air Pollution project (BARUCA) are presented. A combination of continuous measurements at seven sites and grid random measurements on ground at 60 sites and vertical soundings with tethered balloons were performed in Buenos Aires city from May 2006 to May 2007. The observational campaign provided for the first time intensive measurements in both space and time resolution for a one year period to advance in this field. During an intensive observation period, the vertical structure and evolution of the atmospheric layer and meteorological parameters was found to agree with the particulate matter distribution. Results obtained from the ground measurements and vertical balloon soundings showed that PM<sub>2.5</sub> is horizontally and vertically more evenly distributed in the atmosphere than PM<sub>10</sub>. PM<sub>2.5</sub> diurnal courses showed as well a more clearly seasonal variation than that of PM<sub>10</sub>. The horizontal distribution of PM<sub>10</sub> concentrations in an area covering 48% of the total area Buenos Aires city was determined.

**Keywords:** PM<sub>10</sub>, PM<sub>2.5</sub>, air quality, local flow, Buenos Aires.

## 1. Introduction

The project BARUCA (Buenos Aires Research on Urban Climate and Air Pollution) was established to determine the air pollution situation in Buenos Aires city as well as the existence of specific local flow systems in the urban atmosphere and their influence on the dispersion of air pollutants. Buenos Aires city, the capital of Argentina, is located at the right margin of the Río de la Plata. The city is a part of the Buenos Aires Metropolitan Area (BAMA), the third biggest metropolis in Latin America. Buenos Aires city has a population of approximately 3 million

inhabitants and an area of 203 km<sup>2</sup>. To investigate the horizontal, vertical and temporal distribution of air pollutants, discontinuous samplings at many points within a grid, continuous measurements at selected points and balloon soundings at two sites had been carried out in Buenos Aires city. Special emphasis should be given to PM<sub>10</sub> and PM<sub>2.5</sub> behavior.

A series of measurements using different measurement techniques were performed at different sites of the city from May 2006 till June 2007. To get knowledge of the temporal variation of particulate matter (PM<sub>10</sub> and PM<sub>2.5</sub>), continuous ground measurements were performed at seven selected sites distributed within the city. The horizontal distribution of particulate matter (PM) over the city in many different areas was investigated by random grid measurements performed at 60 sites distributed to cover 48% of the total area of Buenos Aires city. The vertical structure of meteorological parameters and particulate matter as well were investigated by vertical soundings using tethered balloons. Furthermore, a neural network modelling approach is used to define a correlation between site characteristics and air pollution concentrations. Input parameters such as traffic intensity, land use (residential, commercial, green areas and population), meteorological parameters which characterize the dispersion conditions, as well as ambient air quality data will be used to train the model. The procedure will allow obtaining the concentrations' distribution with a low cost method that could be applied to predict air quality. In this paper results of the measurements are subject of consideration. Results of neural network modelling will be presented in another paper.

## 2. Description of measurements

### 2.1 Random grid measurements

For the random grid measurements of particulate matter the investigation area was divided into assessment squares of approximately 1.5 x 1.5 km<sup>2</sup> making a total of 43 squares and 60 measurement points. The extension of this grid is shown in Figure 1. All measurement points were located at the intersection of two streets. A Grimm light scattering photometer (GRIMM 1.108, 2006) was fixed on the roof of a car with which the grid points of each square were visited randomly and the PM recording was taken. Within the measurement period, June 2006 until March 2007, 26 individual measurements of 30 minutes were performed at each grid point of each square. For the square area between four corners/points the average concentration was calculated using the results of all the measurements at these four points. Thus the average concentration in each square is based on 104 measurements for each square and are depicted in Figure 1 in different colours respectively in different grey intensities. The total measurement area of the random PM measurements covered approximately 48% of the city's total area. The advantage of the method is that one measurement team can visit a large number of sites with one instrument and gain a high temporal resolution.

### 2.2 Neural network modelling

### 2.3 Permanent and periodic ground measurements of PM<sub>10</sub> and PM<sub>2.5</sub>

Continuous ground measurements of PM (0.23 to > 20 µm) were performed using two Grimm light scattering photometers (GRIMM 1.108, 2006). The instruments were protected with outdoor housings (Grimm No. 165) equipped with temperature and humidity sensors. The time resolution was in one minute basis. The data of both instruments were downloaded weekly and maintenance was given when necessary. One Grimm device was permanently installed at site P1, the reference measurement station, from May 2006 until May 2007. The second device was changed every four to six weeks in order to measure continuously at each of the six sites (P2 to P7) over these shorter periods. These sites are also shown in Figure 1.

### 2.3 Vertical profiles of meteorological parameters and particulate matter using tethered balloon systems

Two tethered balloon systems were employed for the determination of the vertical structure of meteorological parameters and particulate matter. Meteorological parameters such as wind direction, wind speed, dry and wet temperature, humidity and atmospheric pressure were measured with a meteorological sonde which was fixed on the rigging of each balloon. For the determination of vertical and temporal variation of particulate matter, a light scattering photometer (GRIMM 1.108, 2006 Grimm Aerosol Technik GmbH) was fixed together with the meteorological sonde at the balloon line, approximately 1m below the balloon. During the one year measurement period, a total of eight measuring campaigns distributed in all seasons of the year were carried out. Each campaign lasted for two to five days. The results of a winter campaign performed at site P7 (Fig. 1) are discussed in Section 3.3.

## 3. Results and discussions

### 3.1 Random grid measurements

The results of the random grid measurements are shown in Figure 1. The average annual concentrations of  $PM_{10}$  for a total of 43 squares and seven sites are shown in the map. The concentrations range from 50-60  $\mu g m^{-3}$  (squares in dark grey colour) and from 40-50  $\mu g m^{-3}$  (squares in light grey colour). Most of the measurement sites are located within areas showing commercial and residential activities. No industrial activities are located within the measurement sites. The highest concentrations were measured at sites with high to medium traffic incidence with commercial and residential activities. Furthermore, the sites are located within street canyons, with high buildings which hinder the ventilation coming from the coast. The lowest concentrations were measured sites with low traffic incidence.

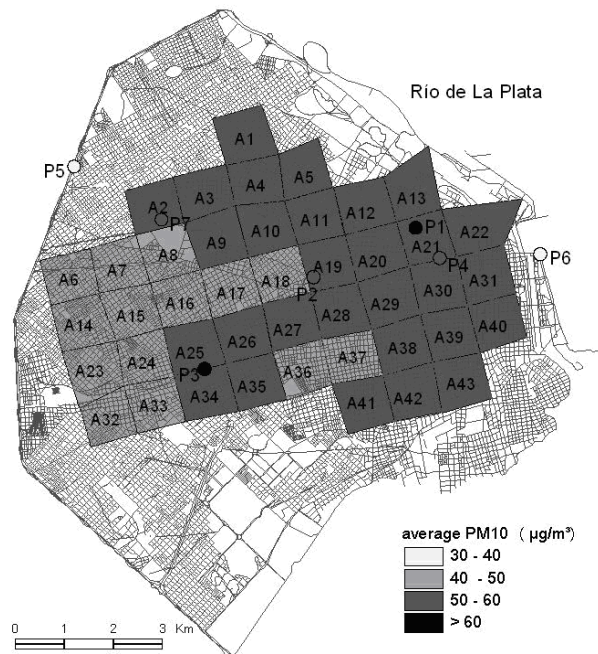


Figure 1. Map of Buenos Aires city with the results of random grid measurements for  $PM_{10}$  ( $\mu g m^{-3}$ ) and of permanent measurement sites (P1 to P7).

### 3.2 Permanent and periodic continuous ground measurements of $PM_{10}$ and $PM_{2.5}$

Figure 2 shows the average diurnal cycle of  $PM_{10}$  and  $PM_{2.5}$  for the four seasons. The average diurnal course of  $PM_{2.5}$  shows higher concentrations during winter and lower concentrations during summer. This is due on the one hand to the more frequent occurrences of stable and

neutral meteorological conditions coupled with lower mixing heights during winter, whereas during summer the occurrence of unstable conditions and higher mixing heights are more frequent (Ulke and Mazzeo, 1998). On the other hand, the traffic incidence in the city during summer is much lower than the one observed in winter. Similar concentrations were found in autumn and spring, when unstable and neutral conditions have almost the same frequency and the mixing heights are almost similar (Ulke and Mazzeo, 1998). Results of daily averaged values of  $PM_{10}$  (in  $\mu g m^{-3}$ ) measured at seven sites in Buenos Aires city show only one exceedance at site P1 of the Buenos Aires daily limit value of  $150 \mu g m^{-3}$ . However, the EU daily limit value of  $50 \mu g m^{-3}$  was exceeded at all sites.

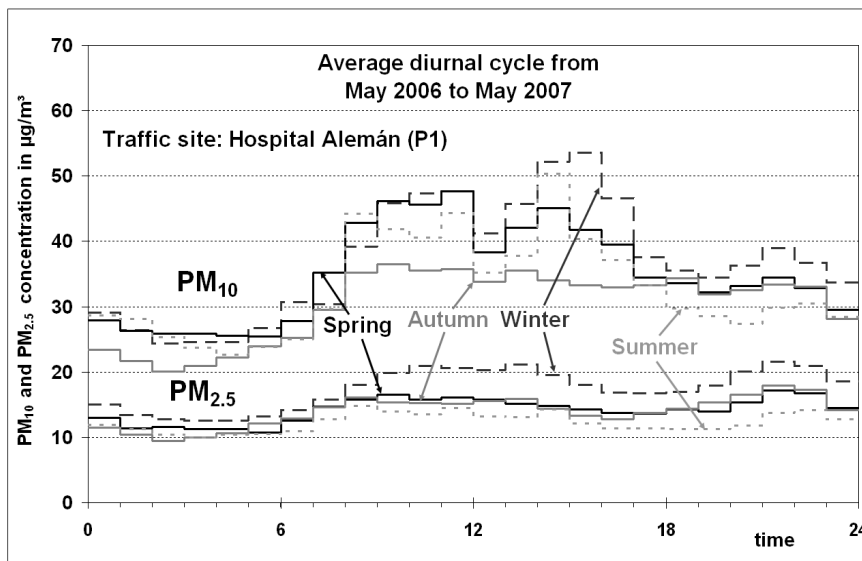


Figure 2. Average diurnal cycles of  $PM_{10}$  and  $PM_{2.5}$  ( $\mu g m^{-3}$ ) in summer, autumn, winter and spring at site P1 from May 2006 to May 2007.

### 3.3 Vertical profiles of particulate matter determined with tethered balloon systems

The here presented balloon sounding campaign was carried out in winter from August, 03 to 06, 2006 at a site located northwest from the city centre, close to a city highway (site P5 in Fig. 1). In this paper only selected soundings performed on the 03 of August are subject of interpretation. During the hours 0704 till 0744 local time a neutral layer was developed on the surface up to a height of 60m. Above this layer a stable one followed from 60m to 200m.  $PM_{10}$  and  $PM_{2.5}$  profiles showed a gradual decrease of the concentrations which remained constant with height above the stable layer, see Figure 4. The ratio of  $PM_{2.5}:PM_{10}$  was less than 0,5 below this stable layer. Above this layer the ratio increased (0,8-0,9) showing the presence of more fine material. The lower wind intensities allowed the balloon to reach higher altitudes and a thick elevated neutrally stratified layer was present.

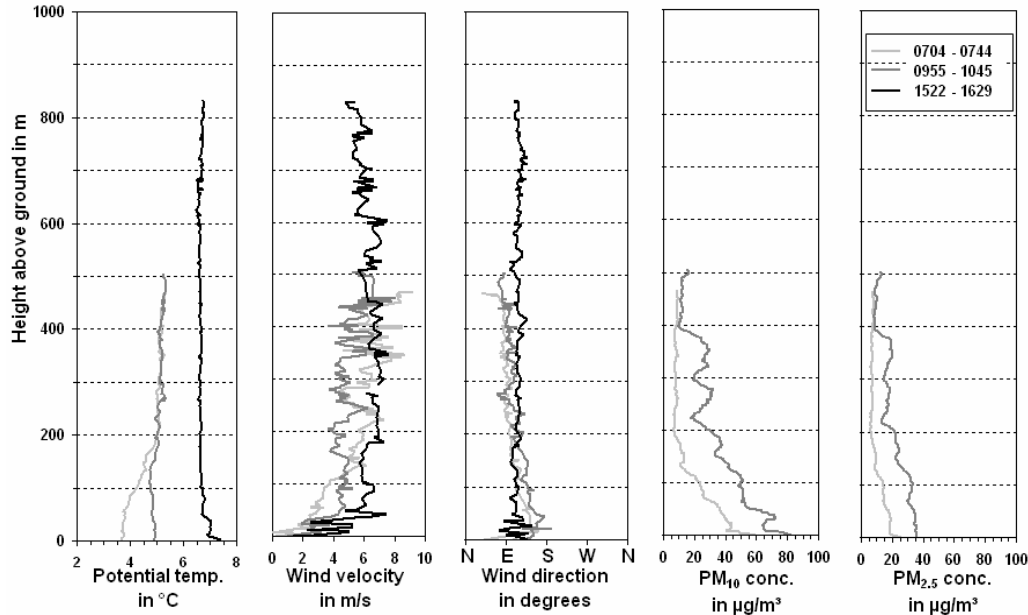


Figure 4. Vertical profiles of potential temperature, wind velocity and wind direction at 0704-0744 (light grey), 0955-1045 (dark grey) local time on 03 August 2006. The sounding performed at 1522-1629 (black) shows only meteorological parameters.

The measurements made at 0955-1045 local time showed a developing unstable layer near the surface, with a capping stable layer from 150m to 200m present only during the ascent sounding. The  $PM_{10}$  and  $PM_{2.5}$  profiles during this sounding, showed higher concentrations than the previous sounding even though the mechanical turbulence seems to be stronger near the surface and the stratification was less stable. Up to this height the  $PM_{10}$  concentrations varied from 70 to 30  $\mu\text{g m}^{-3}$ . Above this height the concentrations gradually decreased up to 10  $\mu\text{g m}^{-3}$ . This feature probably reflects the presence of traffic emissions. The prevailing wind direction during the sounding was SE. The wind velocities increased sharply from the surface up to the height of 100m. Above this height the average wind velocity remained constant from 4 to 6  $\text{m s}^{-1}$ . Figure 5 depicts the average mass distribution of PM at different heights obtained from several soundings performed during the day. The large particles show always a higher concentration than the others since their mass is higher. But, below 100m the dominating coarse mode are particles with a diameter greater than 5  $\mu\text{m}$  and above this height the concentrations of this mode decrease sharply. This shows that particle of this size range can not be suspended till higher altitudes and tend to sink. However, particles in the size range from 0,3 - 3  $\mu\text{m}$  are more evenly distributed and the concentrations gradually decrease with height. Similar profiles of mass distribution PM were observed by Maletto et al. (2003).

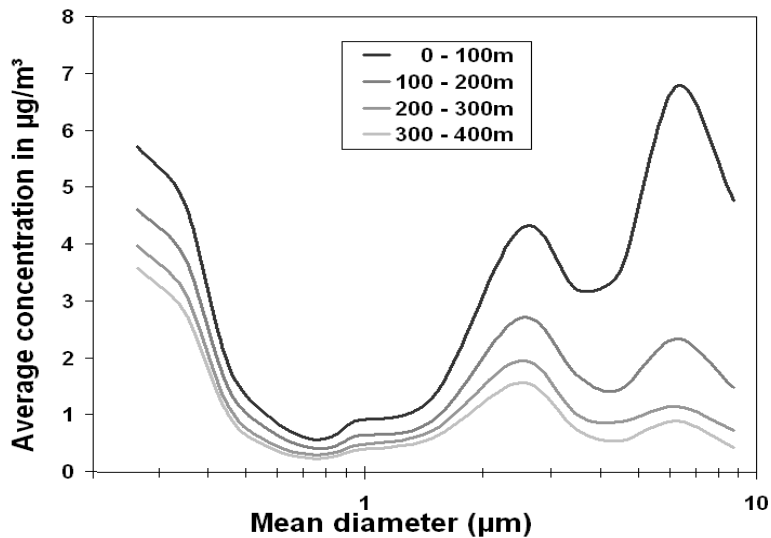


Figure 5. Average mass distribution of PM at different heights, obtained from vertical soundings performed from 0700 1700 on 03 August 2006.

#### 4. Summary and conclusions

PM<sub>10</sub> concentrations in areas with high traffic incidence ranged from 50 to 60 µg m<sup>-3</sup>. In areas with low to medium trafficked streets the concentrations ranged from 40 to 50 µg m<sup>-3</sup>. The seasonal pattern showed a relationship with the climatology of air pollution dispersion. Average diurnal courses of PM<sub>2.5</sub> show a clear seasonal variation with higher concentrations during winter and lower during summer. However, for PM<sub>10</sub> the seasonal variation can not be clearly distinguished. PM<sub>10</sub> concentrations show a stronger variation than PM<sub>2.5</sub> concentrations, due to the shorter residence times of PM<sub>10</sub> in the air than that of PM<sub>2.5</sub>. Results from balloon soundings show that fine particles with a diameter of 0,3 – 3µm are vertically more evenly distributed in the atmosphere than coarse particles (> 5µm) which tend to sink.

#### Acknowledgments

The project is funded by the German Research Association (DFG). We thank Servicio Meteorologico Nacional (National Weather Service of Argentina) for providing the meteorological data and NCEP for the gridded meteorological information.

## References

BARUCA, Buenos Aires Research on Urban Climate and Air Pollution. Link: <http://www.ivd.uni-stuttgart.de/baruca>

Grimm Aerosol Technik GmbH & Co. KG. Manual for Aerosol Dust Monitor Model 1.104 – 1.109 and Software 1.177.

Maletto, A., McKendry, I.G., Strawbridge, K.B., 2003. Profiles of particulate matter size distribution using a balloon borne lightweight aerosol spectrometer in the planetary boundary layer. *Atmospheric Environment*, 37, 661-670.

Ulke, A.G., Mazzeo, N.A., 1998. Climatological Aspects of the Daytime Mixing Height in Buenos Aires city, Argentina, *Atmospheric Environment*, 32, 9, 1615-1622.