inter.noise
21-24 AUGUST
SCOTTISH EVENT CAMPUS
GLASGOW 2022

Study of vertical noise profile through Helium filled-balloon measurements in the city of Milan

Roberto Benocci[1], Fabio Angelini[2], Andrea Potenza[3], Giovanni Zambon [4]
Department of Earth and Environmental Sciences (DISAT), University of Milano-Bicocca
Piazza della Scienza 1, 20126 Milano, Italy.

ABSTRACT

Considering the actual "vertical" housing development in the last few decades, the number of people living in high-rise building is continuously increasing. At present in the city of Milanmore than 500 (0.4% of total) buildings exceed the height of 50 m, with a number of residents of about 14000 (1% of total). For this reason, we planned an experimental campaign to study the vertical noise profile through air-balloon measurements in the city of Milan. Results show that the noise levels increase with the height with respect to ground-reference measurements, as a result of the contribution from an extended area. The highest levels are reached at about 90 m. Critical issues regarding this measurement technique are also outlined.

1. INTRODUCTION

Traffic noise represents the major annoyance source in large cities as it has been well documented in a number of studies [1–6]. Prompted by EU directives, local administrations adopted strategic noise maps to determine the population exposure to environmental noise. A more realistic picture of the population exposure due to real traffic dynamics came from the introduction of dynamic noise mapping [7-9] and indication of speed-dependent vehicle spectra [10, 11]. Considering the actual "vertical" housing development in the last decade, the number of people living in high-rise building is increasing. At present in the city of Milan about 500 (0.4% of total) buildings exceed the height of 50 m, with a number of residents of about 14000 (1% of total). Therefore, the evaluation of the population exposure to noise at different heights becomes crucial, as residents might undergo noise annoyance despite the distance from the source as highlighted in [12]. The aim of this study is to observe the acoustic propagation at heights greater than what it has been done till now and define a proper noise acquisition methodology. In this paper, we present the results of a traffic noise measuring campaign in the northern side of the metropolitan area of Milan performed with the aid of a Helium-filled balloon, finalized to study the noise contribution at different heights from the surrounding area.

2. AIR BALLOON MEASUREMENTS

In this section, we will describe the measurements of the vertical noise profile obtained with the aid of a Helium-filled tethered balloon (14 m long and diameter of 3 m) illustrated in Figure 1. The aim

[1] roberto.benocci@unimib.it
[2] fabio.angelini@unimib.it
[3] a.potenza@campus.unimib.it
[4] giovanni.zambon@unimib.it

is to observe how noise propagates vertically at heights greater than observed till now and define a proper sampling methodology. The balloon was equipped by a Class A phono meter and a meteorological station placed on a Plexiglas platform (see Figure 2), positioned at a distance of 7 m below the balloon. The meteorological station measured the main meteorological parameters (pressure, temperature, wind speed and relative humidity) every 6 s. Ascent and descent rates were controlled by an electric winch and could be varied from near zero to 50.0 ± 0.1 m/min. As a , of the drag force exerted by the wind on the tethered balloon, of the technical characteristics of the balloon/winch and the weight of the carried instrumentation, vertical profiles could be successfully and safely measured, in urban environment, when the wind speed was lower than about 5 m/s. To be noted that a wind speed < 5 m/s represents the threshold for validating the noise measurements in environmental contexts as reported in [13].

Figure 1: Helium-filled tethered balloon (14 m long and diameter of 3 m) with the equipped Plexiglas platform.

Figure 2: Plexiglas box containing a meteorological station and a Class A phono meter.

The measurements were carried out at U9 building roofing (see Figure 3) of the University of Milano-Bicocca located in the northern side of Milan metropolitan area. To be noted that the near-by noise sources are represented by local roads and a railway facing U9 building. On the roof of U9 building we also placed two noise monitoring stations as a reference, as illustrated in Figures 3 - 4. The phono meter on the balloon and the monitoring stations were synchronized and the acquisition set at 1 s resolution. We performed three vertical noise profiles. In Table 1 the characteristics of each measurement are summarized.

Table 1: Summary of performed measurement conditions.

Flight number	Direction	Acquisition Mode
1	Ascent ↑	Continuous up to 500 m
	Descent ↓	Continuous down to 150 m 5 min. stop at 150, 120, 90, 60, 40, 20 m Continuous down to roof height
2	Ascent ↑	Continuous up to 330 m
	Descent ↓	Continuous down to roof height
3	Ascent ↑	Continuous up to 355 m
	Descent ↓	Continuous down to 300 m 10 min. stop at 300 and 100 m Continuous down to roof height

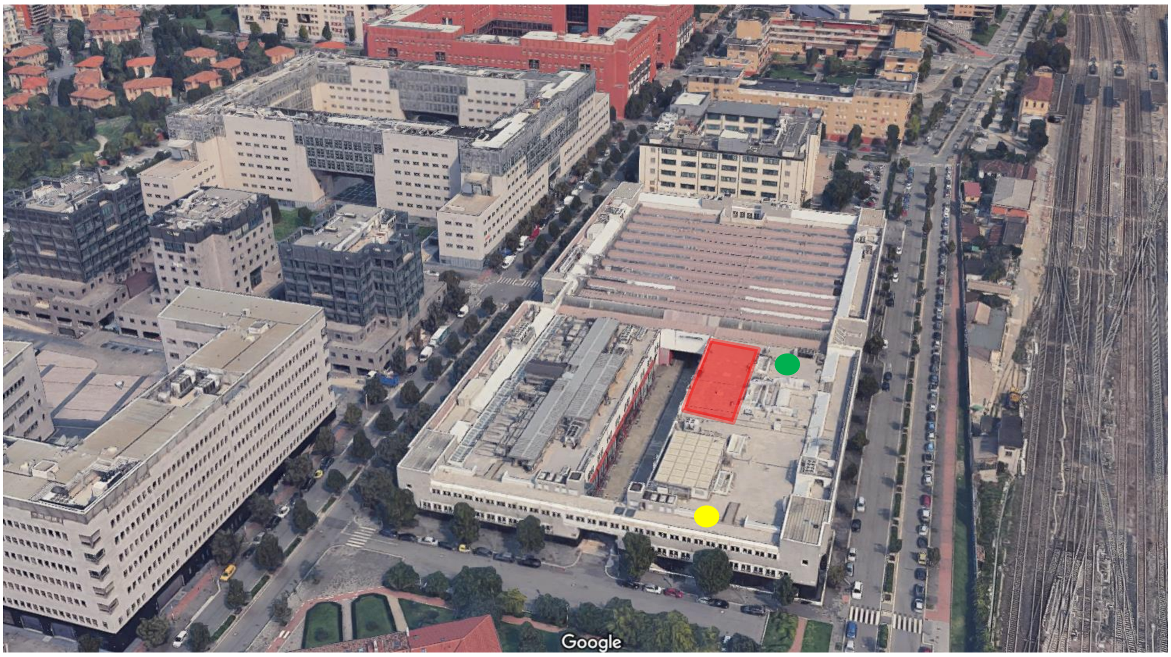

Figure 3: Top view of the measurement location on the roof of U9 building of the University of Milano-Bicocca, showing the balloon take-off position (in "red") and the two ground-reference points (yellow spot named *street side*, and the green spot named *roof center*).

Figure 4: Noise monitoring station for ground-reference measurements (*roof center*).

From the recorded time history, the non-traffic anomalous events (trains, airplanes fly-over, sirens construction yard noise, etc.) have been removed as described in [14,15]. As for the stops at different heights, the corresponding equivalent level has been extracted.

Pressure data from on-board monitoring instruments were used to calculate the sampling height. In fact, although the balloon profiles were carried out at low wind speed (v < 5 m/s), the tether-line was not perfectly perpendicular to the ground. Thus, the geometric height of the balloon position was calculated (by means of pressure data) and considered as the real balloon height, AGL (Z). The ipsometric relation has been applied to derive the effective height:

$$Z = Rd * Tv * \frac{1}{g} * Ln(\frac{Pbase}{Ptop}) \quad (1)$$

where *Z* is the height variation (geopotential meters), *Rd* is the gas constant, *Tv* the mean temperature in Kelvin between the two levels of pressure, g the gravity acceleration, $\frac{Pbase}{Ptop}$ the ratio between the atmospheric pressure at the ground level and at the considered height.

3. RESULTS AND DISCUSSION

The results shown in Figure 5 refer to the noise levels recorded during the flight number 1 at different heights and compared with levels from the reference-ground monitoring stations placed on U9 building roof.

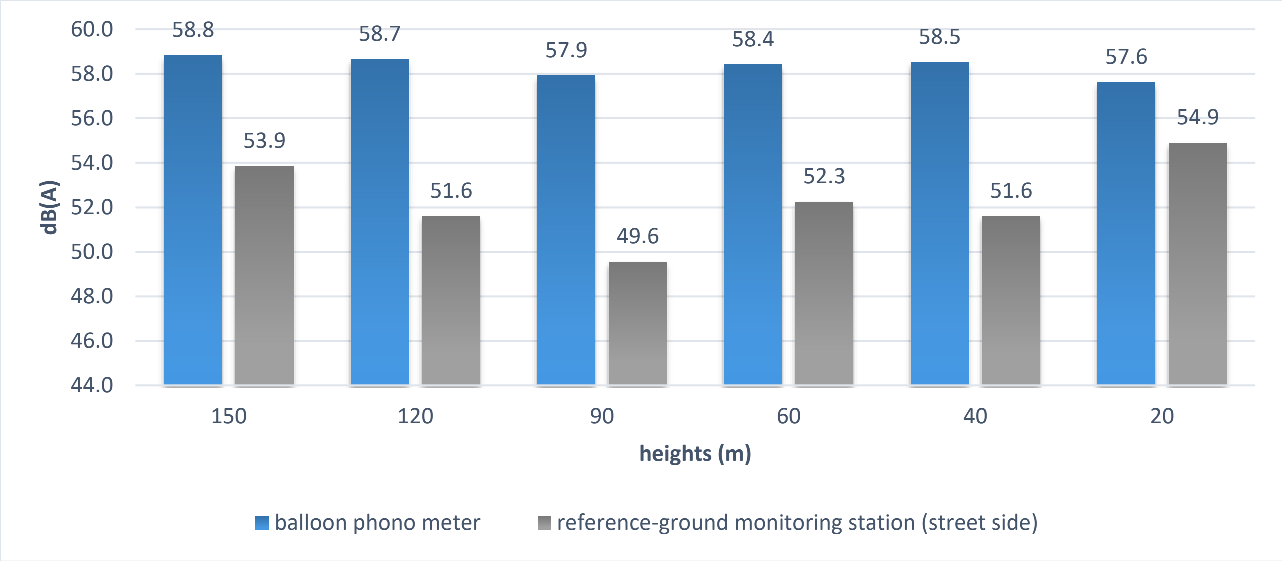

Figure 5: Noise levels measured during flight number 1 at different heights and compared with the reference-ground monitoring station (*street-side*) on U9 building roof.

We can observe how the levels measured on the balloon are always higher than the ground reference. In particular, the monitoring station facing the road (*street side*) presents high variability, coherently with vehicle transits during the recording. This result can be explained by both the presence of wind and the possibility that sources coming from the surrounding areas contribute to the level increase. However, the wind speed is usually below the threshold value (< 5 m/s).

In Figure 6 the variation of the noise levels, ΔL, recorded from the balloon phono meter at different height and corresponding values taken from the ground-reference monitoring station. We can observe a progressively increase of ΔL with the height. ΔL reaches a maximum at about 90 m followed by a decrease. The decrease is the consequence of both the noise attenuation due to the source-receptor distance and exhaustion of new intercepted sources. However, the wind speed during all the measurements remained within acceptable values, as it can be observed in Figure 7. Gusts of wind of about 5 m/s are recognized at the height of 60 and 120 m. The mean wind speed remained well below such value in agreement with D.M. 16/03/1998 [13]. The fluctuations of ΔL might be attributed to the variability induced by the presence of vehicle transits recorded by the ground-reference monitoring station.

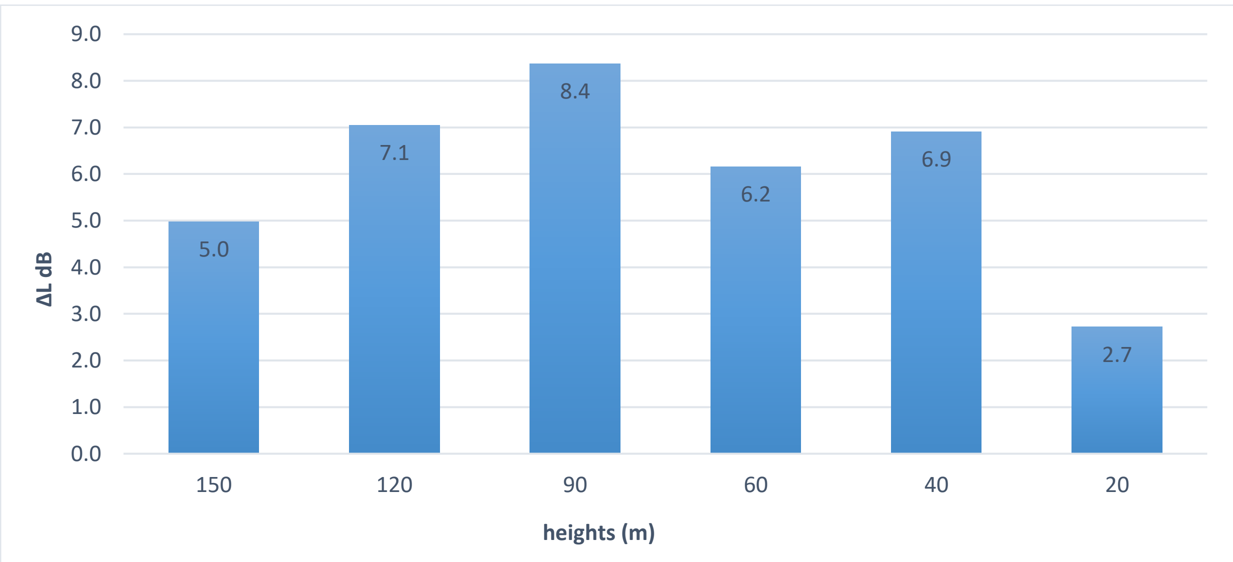

Figure 6: Variation of noise levels, ΔL, recorded from the balloon phono meter at different height with respect to the ground-reference monitoring station (*street side*).

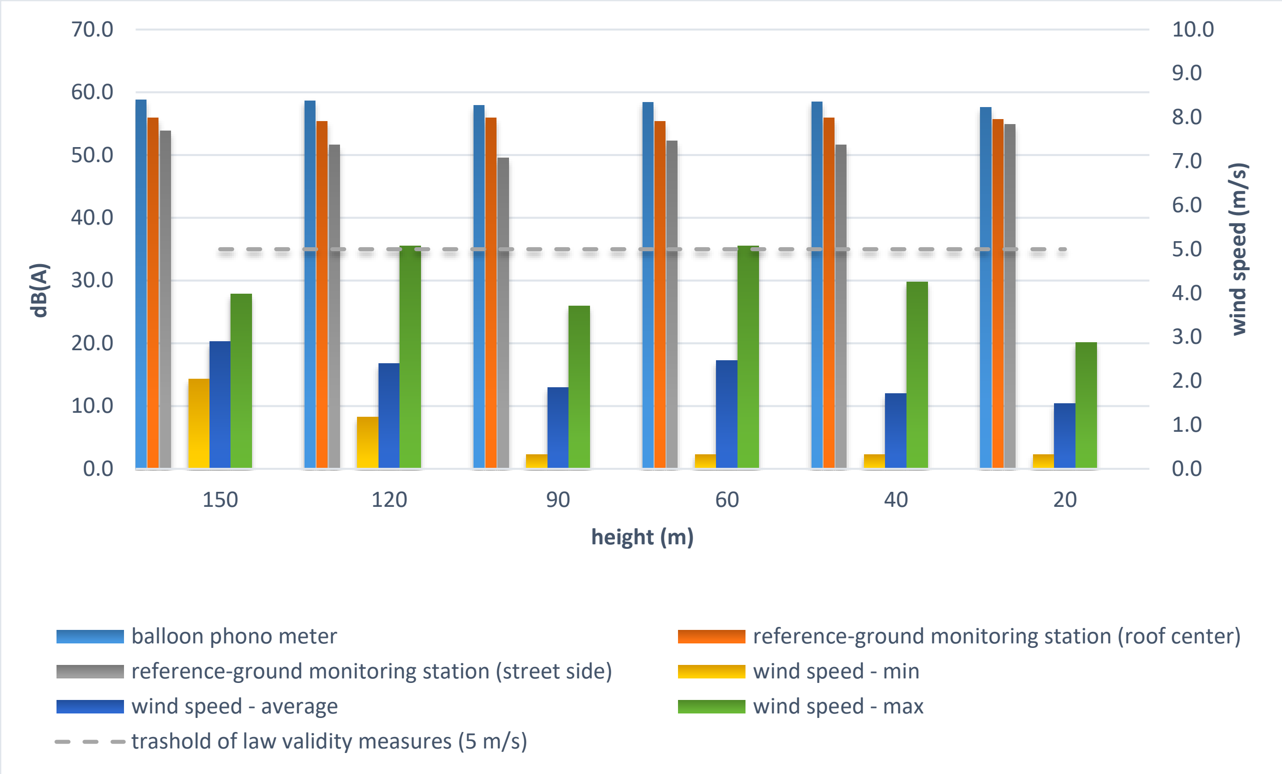

Figure 7: Wind speed and noise levels as a function of height. The dashed line refers to the wind acceptable limit of 5 m/s.

At a balloon height of 60 m, the transit of a train convoy was recorded. The event lasted about 30 s and its level together with the wind speed are illustrated in Figure 8.

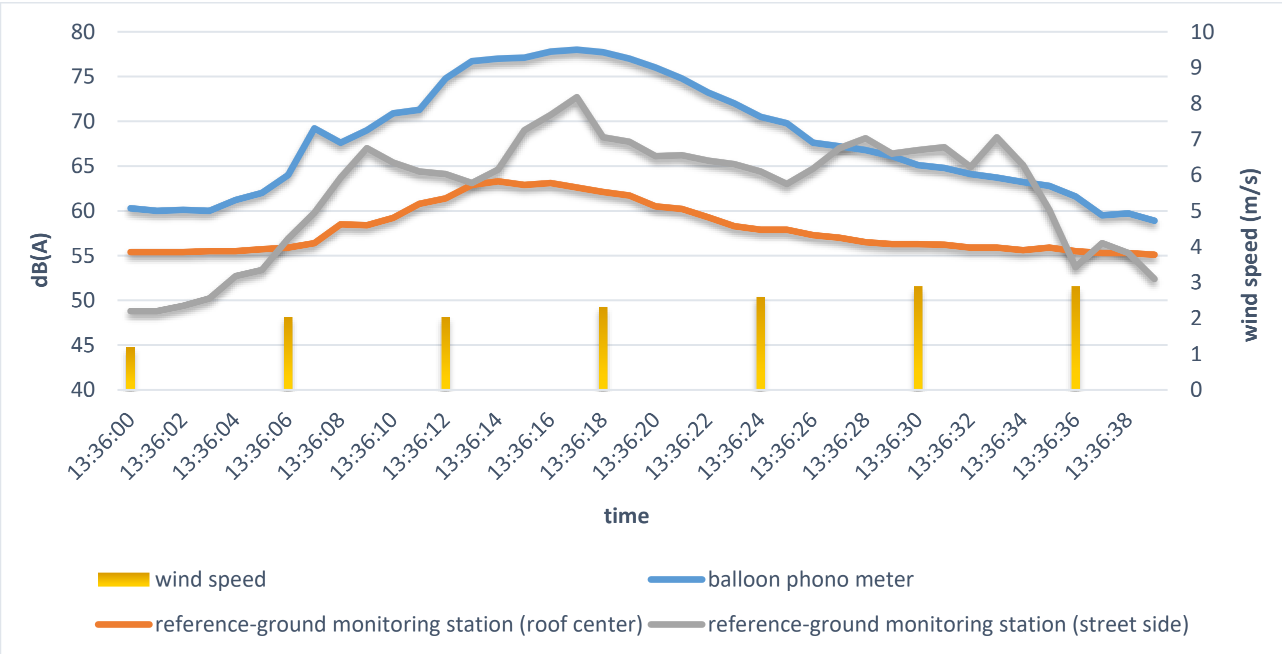

Figure 8: Recording of the transit of a train convoy from the ground-reference phono meter and at the height of 60 m. The wind speed is also displayed.

The balloon phono meter and the ground-reference monitoring stations present a similar trend but differ significantly in terms of noise levels (the difference with *roof center* sensor is about 15 dB at the transit peak; the *street side* sensor shows also the superposition of vehicles transits). The exposition of the balloon instrument in open field to the surrounding area sources makes the recorded

noise levels always higher than at "ground level", though the vicinity of this latter to local sources. Separating walls delimiting the railways path also contributes to the attenuation.
In Figure 9 the equivalent noise levels time profile taken during the continuous ascent of flight n. 2 are compared to the on-roof monitoring stations. The non-traffic noise anomalous events have been removed from the original recorded data. In the graph, it is also shown the balloon height with the dashed line indicating the wind threshold speed of 5 m/s. This limit is reached at a balloon height of about 100 m.

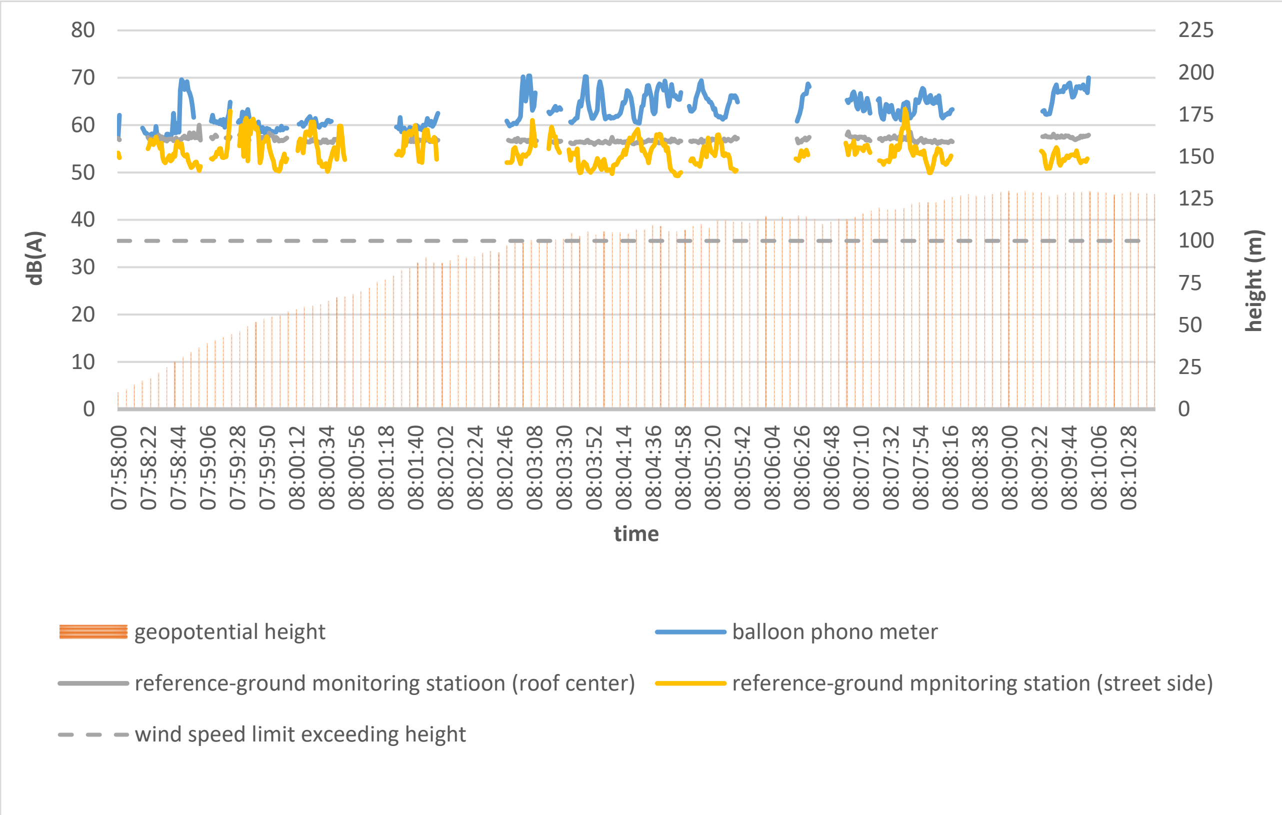

Figure 9: Equivalent noise levels time profile taken during the continuous ascent of flight n. 2 compared to the on-roof monitoring stations. The dashed line indicates the wind threshold speed of 5 m/s.

Indeed, we can observe a change of slope during the constant ascent rate, starting from the height of about 100 m when the wind threshold is reached. From such height the balloon starts deviating significantly from the perpendicular position, therefore, also intercepting different noise sources. To be noted also, how the noise levels of the balloon and the ground-reference phono meter present irregular patterns. In particular, the ground-reference phono meter records all the vehicular pass-bys coming from the adjacent roads. Flight n. 3 presents similar results.

4. CONCLUSIONS

In this paper, we presented the results of a noise measurements campaign performed by means of a Helium-filled tethered balloon. In particular, we were able to take three ascent-descent measurements. All results show that the noise levels increase with the height as a result of the contribution coming from an extended area. The highest levels are reached at about 90 m. Critical issues regard the possible presence of high speed wind which for values greater than 5 m/s introduces a bias, besides the possible deviation from the perpendicular take-off position.

5. ACKNOWLEDGEMENTS

We wish to thank Dr. L. Ferrero and Prof. E. Bolzacchini of the Department of Earth and Environmental Sciences of the University of Milano-Bicocca for sharing the air balloon for our open field noise measurements.

6. REFERENCES

1. S. Fidel, Nationwide urban noise survey. *J. Acoust. Soc. Am.*, **64(1)**, 198–206 (1978).
2. A. L. Brown, K.C. Lam, Urban noise surveys. *Appl. Acoust.*, **20(1)**, 23–39 (1987).
3. K. Kumar, V.K. Jain, A study of noise in various modes of transport in Delhi. *Appl. Acoust.*, **43(1)**, 57–65 (1994).
4. H. M. E. Miedema, H. Vos, Exposure response relationships for transportation noise. *J. Acoust. Soc. Am.*, **104(6)**, 3432–3445 (1998).
5. A. García, L. J. Faus, Statistical analysis of noise levels in urban areas. *Appl. Acoust*., **34(4)**, 227–247 (1991).
6. J. M. Fields, Effect of personal and situational variables on noise annoyance in residential areas. *J. Acoust. Soc. Am.*, **93(5)**, 2753–2763 (1993).
7. Benocci, R.; Bellucci, P.; Peruzzi, L.; Bisceglie, A.; Angelini, F.; Confalonieri, C.; Zambon, G. Dynamic noise mapping in the suburban area of Rome (Italy). *Environments*, 2019, **6.7**, 79.
8. Zambon, G.; Benocci, R.; Angelini, F.; Brambilla, G.; Gallo, V. Statistics-based functional classification of roads in the urban area of Milan. In Proceedings of the 7th Forum Acusticum, Krakow, Poland, 2014, 7-12.
9. Brambilla, G., Benocci, R., Confalonieri, C., Roman, H.E., Zambon, G. Classification of urban road traffic noise based on sound energy and eventfulness indicators. (2020) *Applied Sciences* (Switzerland), **10 (7)**, 2451.
10. G. Zambon, H.E. Roman, R. Benocci, Scaling model for a speed-dependent vehicle noise spectrum *Journal of Traffic and Transportation Engineering (English Edition),* **4 (3)**, pp. 230-239. (2017). doi: 10.1016/j.jtte.2017.05.001
11. G. Zambon, H.E. Roman, R. Benocci, Vehicle Speed Recognition from Noise Spectral Patterns, *International Journal of Environmental Research*, **11(4)**, 449-459 (2017).
12. R. Benocci, A. Bisceglie, F. Angelini, G. Zambon. Influence of traffic noise from local and surrounding areas on high-rise buildings. *Applied Acoustics*, **166**, 2020, 107362.
13. D.M. 16/03/1998; available at: http://www.gazzettaufficiale.it/eli/id/1998/04/01/098A2679/sg
14. R. Ma Alsina-Pagès, F. Alías, J. Claudi Socoró, F. Orga, R. Benocci, G. Zambon, Anomalous events removal for automated traffic noise maps generation, Applied Acoustics, 151, 2019, 183-192, https://doi.org/10.1016/j.apacoust.2019.03.007.
15. Orga, F., Socoró, J.C., Alías, F., Alsina-Pagès, R.M., Zambon, G., Benocci, R., Bisceglie, A. Anomalous noise events considerations for the computation of road traffic noise levels: The DYNAMAP's Milan case study. (2017) 24th International Congress on Sound and Vibration, ICSV 2017.