Airborne Black Carbon and Traffic Patterns during the First Year of 'Area C' LEZ in Milan

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Background

Air quality is the most serious environmental and health problem for Milan, a city located in the Po Valley in Italy, one of the main polluted EU areas. Although main pollutant concentrations have decreased during the last decade, every year a great number of EU Directive threshold exceedance episodes for PM10, NO_2 and O_3 still occur, implying important health diseases for population (WHO, 2013).

Road traffic within the city is the main contributor to the emission of several airborne health hazardous compounds. As a result different traffic limitation interventions have been implemented in the recent years to improve air quality in the city center. However, the evidence of PM and other pollutants reduction has been as yet scanty.

By January 16th 2012 Milan Municipality implemented a new private traffic restriction scheme called 'Area C', which prohibits the circulation in the city center of diesel cars Euro 0, 1, 2, and 3, while a ticket is required for Euro 4-6, and for gasoline powered cars Euro 1-6. Only electric, hybrid, LPG and methane powered vehicles are allowed to enter Area C without charge. Area C ('*C*' is for *Congestion Charge*) is operating on workdays from 07:30 am to 07:30 pm. This Low Emission Zone (LEZ) was introduced in observance to the results of a public referendum indicating that the vast majority (79%) of Milan citizens wanted to potentiate public transports and to limit traffic-related pollution. Furthermore inside Area C LEZ the access is also forbidden to heavy duty vehicles longer than 7.5 meters.

During the experimental phase of the Area C LEZ implementation (2012) Milan Municipality has carried out an air quality monitoring project based on Black Carbon (BC) measurements. BC is considered a valuable additional air quality metric to evaluate the health risks of primary combustion particles from traffic, including organics, not fully taken into account with PM2.5 mass (WHO, 2012; UNECE-CLRTAP, 2012; US-EPA, 2011; HEI, 2010).

Aims

To evaluate BC, PM10 and PM2.5 concentration inside and outside Area C LEZ in different traffic-proximity exposure conditions and to assess effectiveness of Black Carbon as a new indicator for environmental and health effects of traffic generated nanoparticles in local circulation restriction interventions.

Material and methods

Monitoring sites

Black carbon, PM10 and PM2.5 real-time measurements were performed contemporaneously inside and outside Area C LEZ, in different seasons for several weeks, both at residential and kerbside couples of fixed sites, in order to represent different kind of traffic-proximity exposure for living population and 'city users':

1. The first couple of sites, at kerbside, represents a 'direct proximity ground level residential exposure' in the city. Both sites (Figure 1) were situated on the main ring road of each zone considered: one in the city center inside Area C LEZ (Sforza Street, along 'Navigli Ring road'), the other outside the traffic restriction zone (Maciachini Square, along 'External Ring road'), 5 km away. The monitors were placed at the street level, at a distance of less than 10 m from the center of the roadway. Sforza site, located on the only Area C inner ring road, represents exposure on the busiest street inside the Area C LEZ.
2. The second couple of sites represents a 'roadside third floor level residential exposure' in the city. Two urban residential sites were chosen (Figure 2), one in the city center inside Area C LEZ (Beccaria Street), the other, outside the traffic restriction zone (Porpora Street), 3 km away. The monitors were placed on the terrace of two third floor offices. Both the sites are situated in a large square on which different important streets meet and are open to pollutants dispersion by wind.

In the n. 1 kind of sites two different sampling campaigns were scheduled, in Spring (from May 20th to May 29th, 2012) and at the end of Summer (from Sept 15th to Sept 25th, 2012), both with residential heating 'shut down'. In the n. 2 kind of sites the sampling campaigns were scheduled in Winter (from Febr 1st to Febr 26th, 2012), with residential heating in use and in Autumn (from Oct 1st to Oct 28th, 2012), before and during the start of residential heating (Oct 15th is the data admitted by law), with merely the traffic source as anthropic contribute to PM an BC concentrations in the first two weeks of this last sampling period.

In the framework of this study several mobile sampling campaigns, using portable samplers, have been realized in order to evaluate Black Carbon 'pedestrian personal exposure' along one of the main access axis to the city center; the results are under elaboration and will be discussed in a future paper.

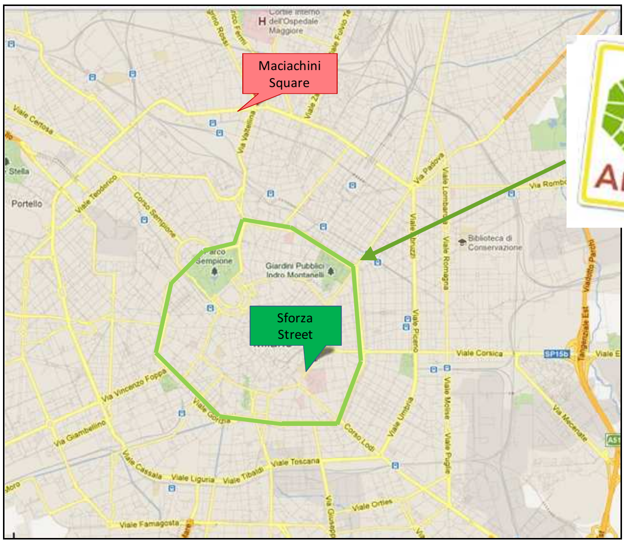

Figure 1 - Location of the two 'kerbside' sites

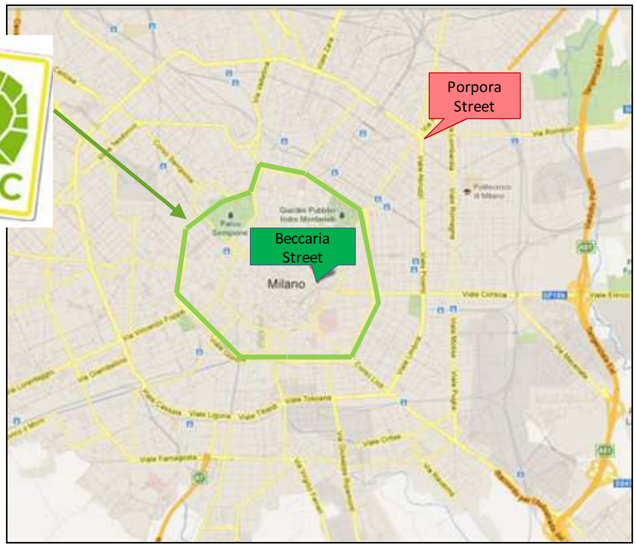

Figure 2 - Location of the two 'residential' sites

Instruments

BC concentrations were measured at 5-minute time resolution with Aethalometers (Magee, USA) while PM with Aerocets (MetOne, USA) with a 15-minute scheduled sampling time. In the two sites, pairs of identical instruments have been used, each aligned and calibrated with a reference instrument (AE31 in the case of Black Carbon, BAM-1020 in the case of PM). At the end of the measurements a data processing system was adopted for the compensation and validation of the measured data.

Traffic flow volumes, hourly patterns and composition were obtained by mean of inductive loop detectors at 5-minute time resolution and real-time video camera techniques, on-site located or referred to the LEZ access control system.

Meteorological data and traffic related pollutants concentrations (e.g. NO_2, NO, CO) used in this study have been processed basing on the Regional Air quality and Meteorological network dataset, selecting the nearest monitor station for any sampling site of this study.

Boundary layer mixing height values have been estimated using: a) measured data by Sodar wind profiler, in the historical center of the city, as for nocturnal mixing height values; b) Batchvarova-Gryning model (Batchvarova and Gryning, 1994) applied to conventional meteorological ground parameters measured near the Sodar wind profiler, as for diurnal mixing height values.

Results and discussion

Airborne Black carbon and PM

At kerbside sites in May, during working days with Area C LEZ in force, the 24h mean (SD) BC concentrations were 2.4 (0.5) µg/m^3 and 4.0 (2.3) µg/m^3 inside and outside Area C respectively ($p<0.0001$), indicating an absolute difference of 1.6 (2.0) µg/m^3 or -40% inside LEZ as compared to the outside area. BC/PM10 and BC/PM2.5 ratios were 50% and 59% lower inside LEZ.

In September (Figure 3), at the same sites, during working days with LEZ in force, the 24h mean (SD) BC concentrations were 3.2 (0.8) µg/m^3 and 6.7 (1.0) µg/m^3 inside and outside Area C respectively ($p<0.0001$), indicating an absolute difference of 3.5 (1.4) µg/m^3 or -52% inside LEZ as compared to the outside area. BC/PM10 and BC/PM2.5 ratios were 50% and 60% lower inside LEZ.

At third floor residential sites, in February, the 24h mean BC concentrations reached a value of 5.6 (1.9) µg/m^3 inside and 7.8 (2.5) µg/m^3 outside Area C ($p<0.0001$), with an absolute difference of 2.2 (1.3) µg/m^3 or -28% in the LEZ. BC/PM10 and BC/PM2.5 ratios were 32% and 25% lower inside LEZ.

At the same sites, in October, one-month sampling campaign has been realized crossing the turning on of the residential heating power plants (Figure 4). Referring to the first week, characterized by more stable meteorological conditions and the heating plants turned off the 24h mean BC concentrations reached a value of 2.8 (1.4) µg/m^3 inside and 4.1 (1.6) µg/m^3 outside Area C ($p<0.0001$), with an absolute difference of 1.3 (1.1) µg/m^3 or -32% in the LEZ. The BC percentage difference between in and outside LEZ decreased by about 50% with domestic heating turned on (-12% *vs*. -33% on average or -24% *vs*. -52% on single days).

No statistically significant changes were found in PM10 and PM2.5 concentrations between the inside and the outside site for any sampling campaign performed.

The results obtained in this study are in agreement with literature for similar sites (Reche *et al.*, 2011; Boogaard *et al.*, 2011) and a previous kerbside summer study on the same area (Invernizzi *et al.*, 2011).

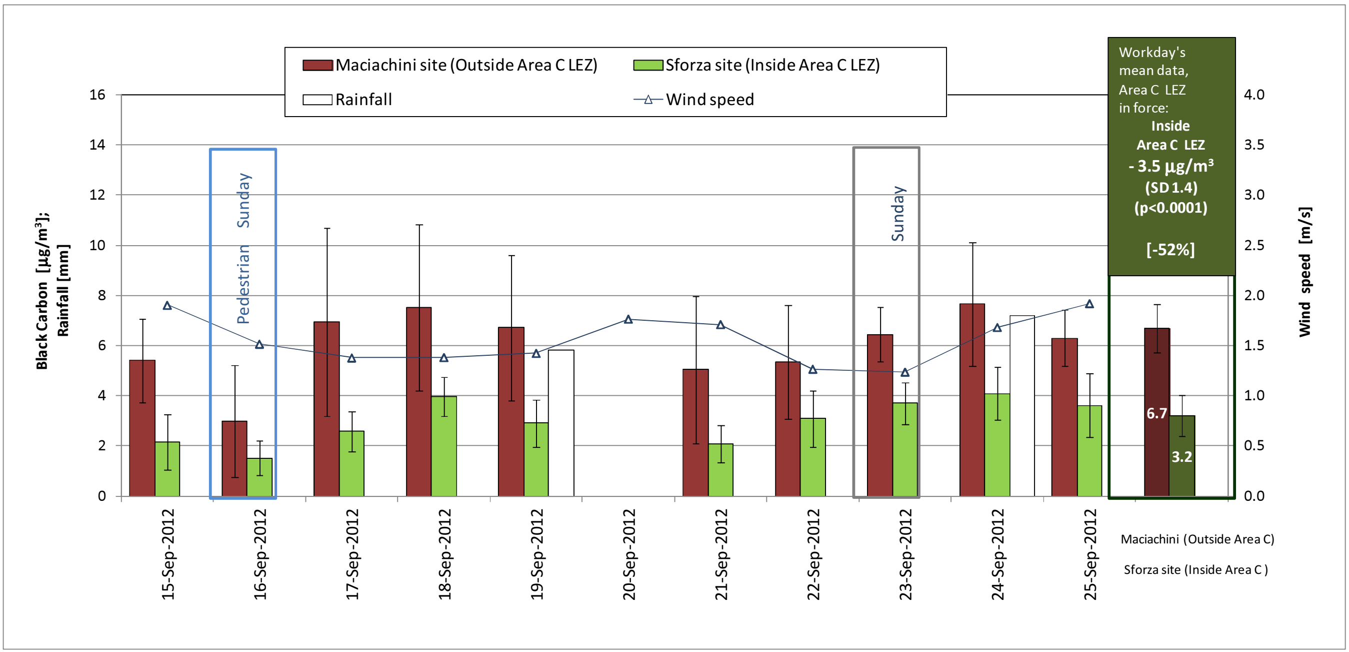

Figure 3 - BC concentrations inside and outside Area C LEZ during September monitoring campaign at kerbside sites

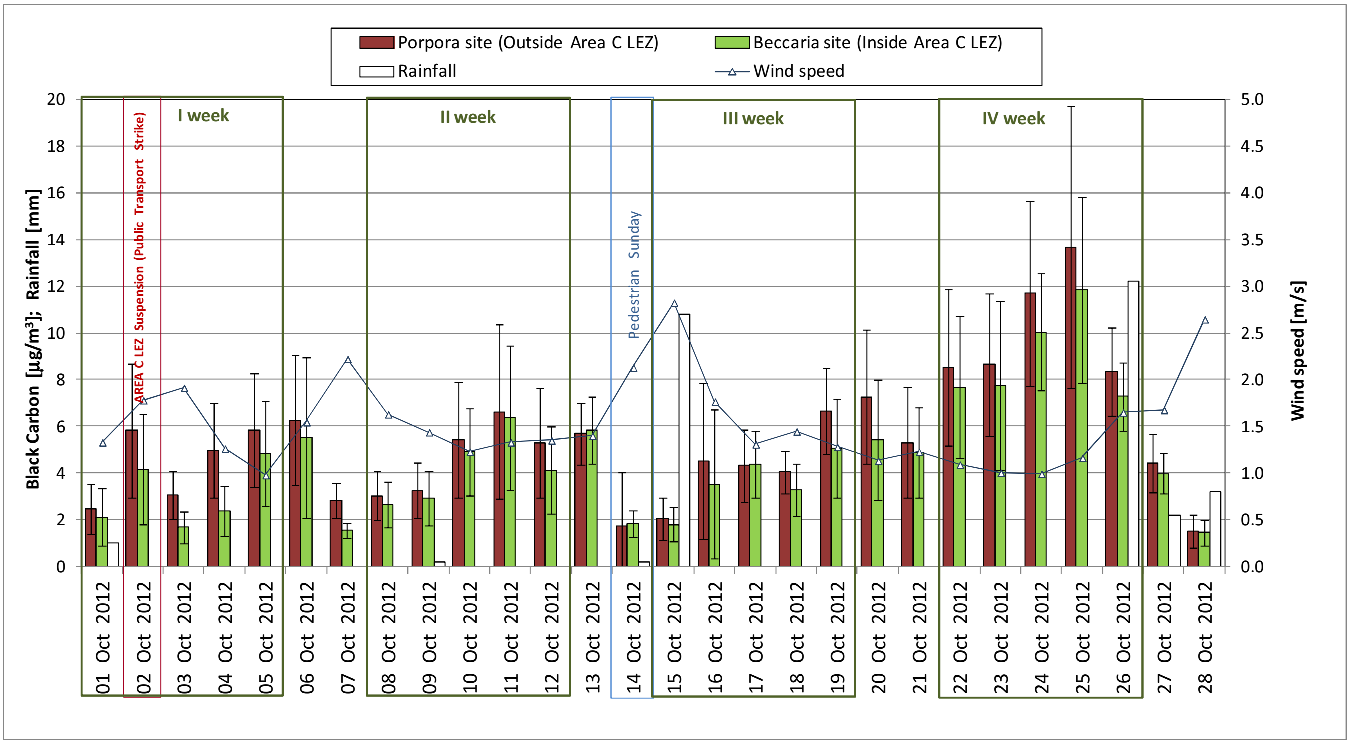

Figure 4 - BC concentrations inside and outside Area C LEZ during October monitoring campaign at residential sites

At kerbside, during the 'Pedestrian Sunday' initiative Black Carbon mean concentrations of the two sites were measured 78% lower (May 27th, 2012) or 75% lower (September 16th, 2012) compared to the nearest Sundays without traffic restrictions, also despite less dispersive meteorological conditions. These results are in a perfect agreement with traffic measurements which reports a 72% reduction in relation to a typical Sunday circulation. In October these results couldn't be confirmed due to perturbed meteorological conditions during most of the Sundays.

At residential sites during the autumn campaign, in correspondence to a temporary suspension of the Area C LEZ measure due to a public transport strike (October 2nd, 2012), an increase in Black Carbon concentrations has been registered, ranging from 1.9 to 2.4 times in Porpora site (outside Area C LEZ) and from 2 to 2.5 times in Beccaria site (inside Area C LEZ), compared to measurements on the previous and following days. Considering the toxicity associated with this indicator (Janssen *et al.*, 2011) it can be supposed that a similar increase in health risk has happened during that day. These data demonstrate the extreme sensitivity of the Black Carbon indicator to urban traffic volume and congestion changes, not observed in any other pollutant currently measured by the institutional Regional Environmental Agency monitoring network (PM10, PM2.5, NO_2, CO).

Traffic pattern vs. Black Carbon and others pollutants

At the kerbside sites during May campaign (Figure 5) downwind BC concentrations showed high Pearson's correlation coefficient (R) with local traffic volumes (R= 0.66 for 7-19 h; 0.85 for 4-17 h) revealed by mean of on-site inductive loop detectors, while PM10 (R= -0.32 for 7-19 h; -0.47 for 4-17 h) and PM2.5 (R=0.16 for 7-19 h; -0.77 for 4-17 h) showed negative or poor correlations; the highest correlation (R=0.83 for 7-24 h) was found between BC and commercial vehicles patterns, monitored by video cameras techniques.

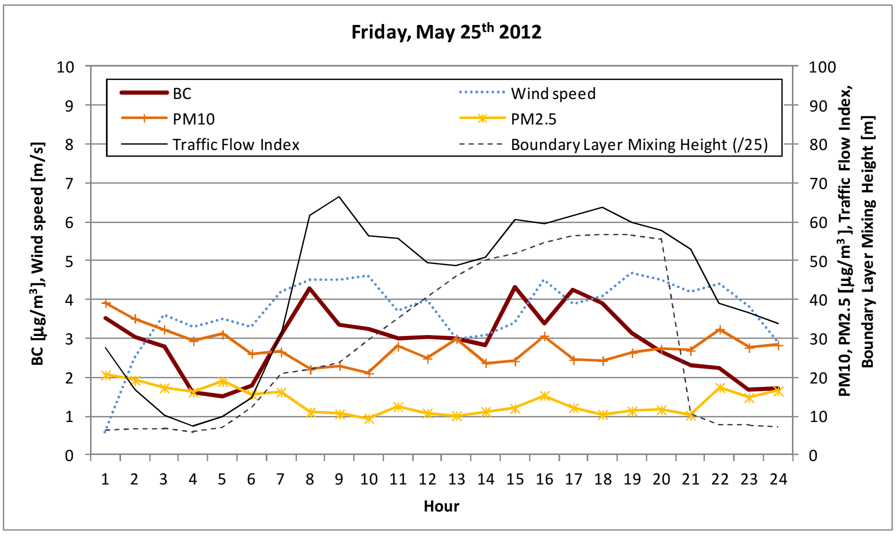

Figure 5 - Working day hourly data of BC, PM10 and PM2.5 concentrations versus traffic flow index, wind speed and boundary layer mixing height at Maciachini kerbside site (outside Area C LEZ) during Spring monitoring campaign (May, 25th 2012)

Typical working day patterns analysis and the Pearson's correlation coefficients calculation have been also performed between Black carbon concentrations, with Area C LEZ in force, and the number of vehicles entering the LEZ monitored in real-time at 43 entry gates.

The number of total vehicles entering Area C LEZ is affected by a very important seasonal two wheelers commuting traffic flux leaving the LEZ at evening rush hours, which cannot be registered by mean of the Access control system, that monitors only entering vehicles. This has a strong influence on the 'Total vehicle entering Area C' fluxes, originally considered to verify Pearson's correlation coefficients between traffic pattern and Black Carbon or other pollutants concentration. Thus, in order to obtain a more realistic daily traffic pattern and coherently compare it to BC and other air quality indicators, in the following analysis the number of vehicles entering Area C 'without motorcycle contribute' is considered as total. This is also justified by the fact that emission factors of elemental carbon (EC) for motorcycles are very low in comparison to those of other vehicles categories (Katsis *et al.*, 2012).

Figure 6 shows that in all campaigns the BC concentrations have quite similar patterns, determined by daily traffic volume changes and boundary layer mixing height diurnal evolution.

BC concentrations daily patterns, as those of the other pollutants, are however strongly affected by the boundary layer mixing height, which disperses pollutant during the central hours of the day and traps BC emissions produced during the evening traffic rush hours (8:00-9:00 pm), especially in autumn and winter seasons characterized by nocturnal temperature inversion linked, in the Po Valley, to persistent fog episodes too.

During traffic restriction hours BC concentration pattern appears mainly correlated to passenger cars (with R ranging from 0.51 to 0.87 at kerbside and from 0.38 to 0.86 at third floor level residential sites) and to trucks daily fluxes (with R ranging from 0.64 to 0.91 at kerbside and from 0.47 to 0.82 at third floor level residential sites). In Figure 7 BC data for the kerbside sites campaign are represented in comparison to PM10 and PM2.5 Pearson's correlation coefficient, calculated *vs.* other traffic related pollutants concentration too.

Probably due to the high percentage of diesel engines in passenger car fleet (above 48% in Milan), the Pearson's correlation coefficient between hourly mean BC concentrations (both inside and outside sites) *vs.* passenger cars entering Area C LEZ is significant. This data seems to confirm the role of main attractor of the historical city center and the fact that a measure adopted for the central area can affect also traffic volumes and related pollution outside the same area.

Pearson's correlation coefficient of BC concentrations *vs.* passenger cars entering the Area C LEZ has been observed mainly higher in external sites than in the internal ones during the daytime traffic restriction hours. This result is consistent with the statistics obtained using the number plate identification system which reports that inside Area C LEZ the passenger cars fleet is mainly constituted by more technological advanced and less polluting vehicles. For passenger cars the Elemental Carbon (EC) mean emission factor of the Area C LEZ is in fact about 32% lower than in the outside areas (City of Milan and AMAT, 2012).

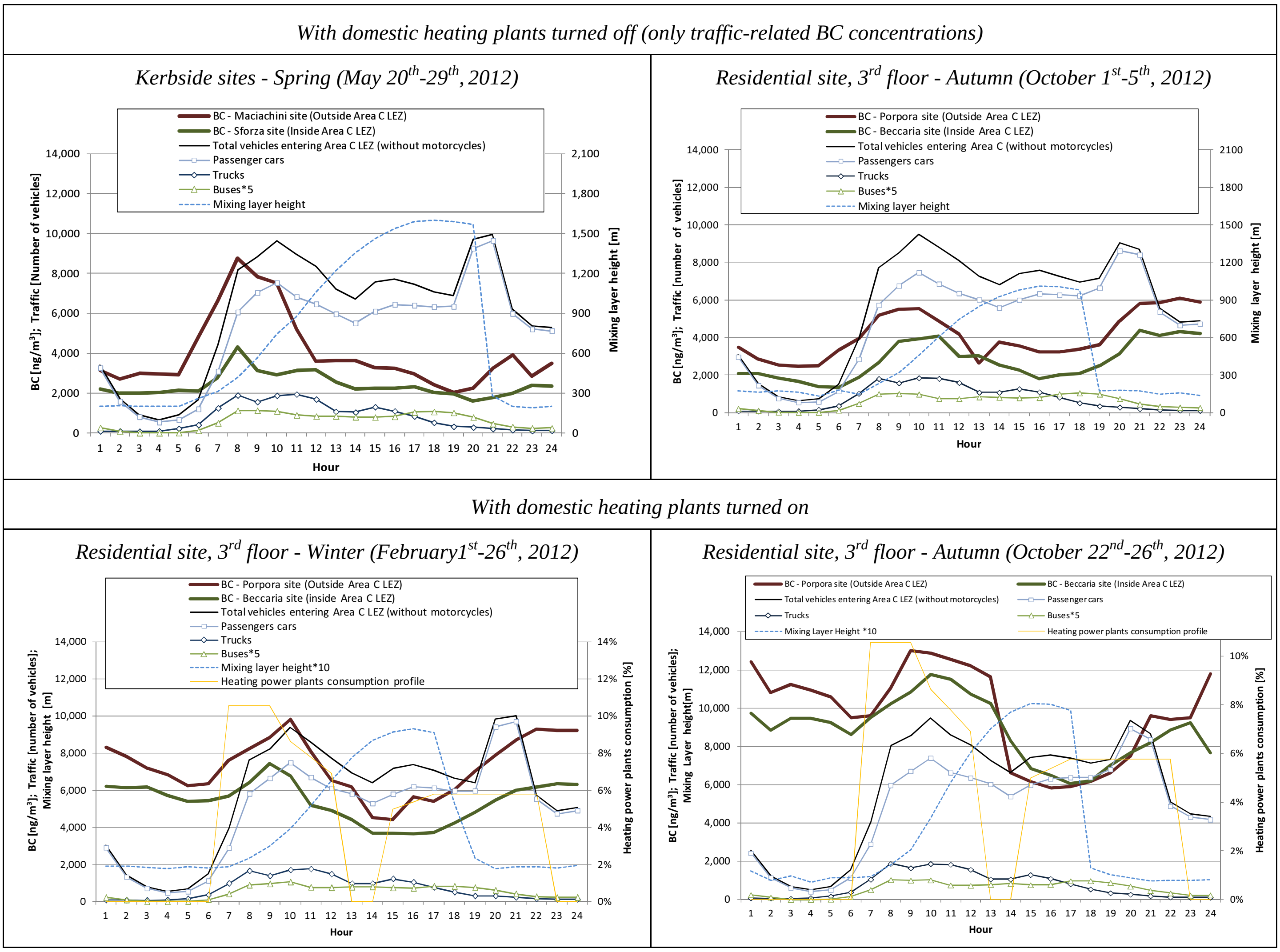

Figure 6 - Typical working day hourly data of BC, concentrations versus vehicles entering Area C LEZ (motorcycles excluded) and boundary layer mixing height at kerbside sites and residential sites (inside and outside Area C LEZ) during several campaigns.

Regarding trucks vehicles entering the Area C LEZ, the Pearson's correlation coefficient *vs.* BC concentration is higher in the inside sites probably due to the fact that the variable considered is the number of trucks vehicles entering Area C LEZ. However, unlike passenger cars (more linked to commuting fluxes) daily pattern of commercial traffic can be very different inside and outside the historical centre, as evidenced by video cameras data.

The high correlation values obtained *vs.* motorcycle fluxes (up to R=0.86) do not justify taking into account the low emission factor of these vehicles (Katsis *et al*., 2012), but probably derive from the combined effect of the decrease of BC concentration and the increase of mixing layer height and the lack of registration of commuting motorcycles leaving the Area C LEZ in the evening.

PM10 and PM2.5 concentrations do not appear to be so sensitive as Black Carbon to traffic fluxes; in particular at the internal kerbside site also a non positive correlation versus passenger cars entering the traffic restriction zone has been registered. The significant correlation obtained between PM10 concentration *vs.* passenger cars and trucks at the external kerbside site (Figure 7) could be linked to re-suspended dust, road abrasion and non-exhaust emissions (tires and brakes) contributions, deriving by higher traffic fluxes and heavy duty vehicles admitted outside the Area C LEZ.

At third floor level residential sites daily BC patterns seem to be very sensitive to traffic fluxes, similarly to what occurs at kerbside sites: Pearson's correlation coefficient (R) ranges from 0.83 to 0.87 at residential sites in autumn campaign before the turning on of the residential heating and reaches the lower values of 0.73-0.77 during the coldest season in February compared to a Pearson's correlation coefficient ranging from 0.79 to 0.88 at kerbside sites in summer seasons.

Even though the correlation of airborne BC concentrations appears more robust *vs.* traffic pattern, monitoring performed during cold season at residential sites shows a correlation between BC concentration daily pattern and the diurnal profile of residential heating, in particular at the turning on of the plants (6:00 am) or during the central hours of the day (1:00-3:00 pm, heating suspension for energy saving).

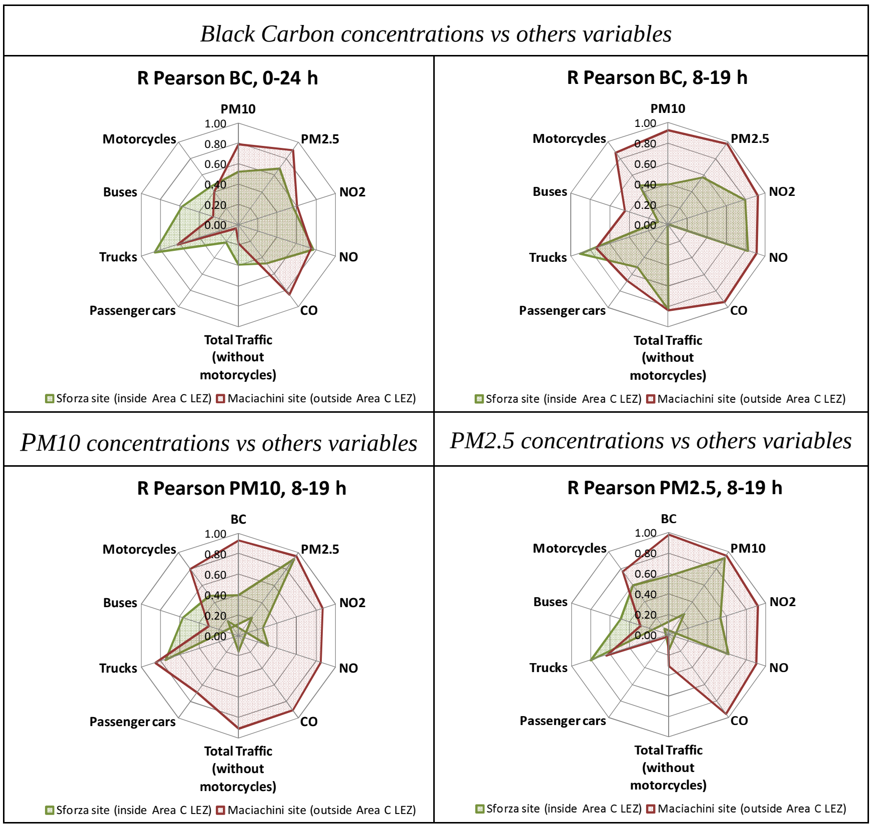

Figure 7 - Pearson's correlation coefficient (R) for BC (0-24 h and 8-19 h), PM10 and PM2.5 (8-19 h) concentrations vs. others traffic related pollutants (right side) or vehicles entering Area C LEZ (left side) at kerbside sites, inside (green) and outside (red) Area C LEZ, during Spring monitoring campaign (May 20th-26th, 2012)

Conclusions

A statistically significant difference was found in BC concentrations inside Area C LEZ, both at kerbside and residential roadside sites, with an improvement of one to three BC epidemiological 'change units' (Janssen *et al.*, 2011); this means a remarkable difference in terms of personal exposure to traffic particulate toxic emissions and related expected mortality and morbidity, with health benefits for resident population and city users.

This study showed how local interventions on traffic circulation can produce important effects on airborne toxic traffic-related pollutants, such as Black Carbon, reducing direct proximity and residential exposure.

Also an high sensitivity of BC to changes in traffic flows, net of weather events, has been demonstrated thus Black Carbon can be considered a very effective indicator of health effects deriving by traffic circulation for cities, such as Milan, characterized by an high fraction of diesel engines in the vehicles fleet.

Acknowledgments

This work was funded by the City of Milan. The authors want to dedicate this work to the memory of Dr. Giovanni Invernizzi (SIMG), who promoted the first traffic-proximity exposure research projects in Italy and thanks to whom this study was possible.

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Milano

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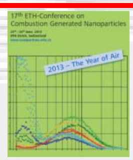
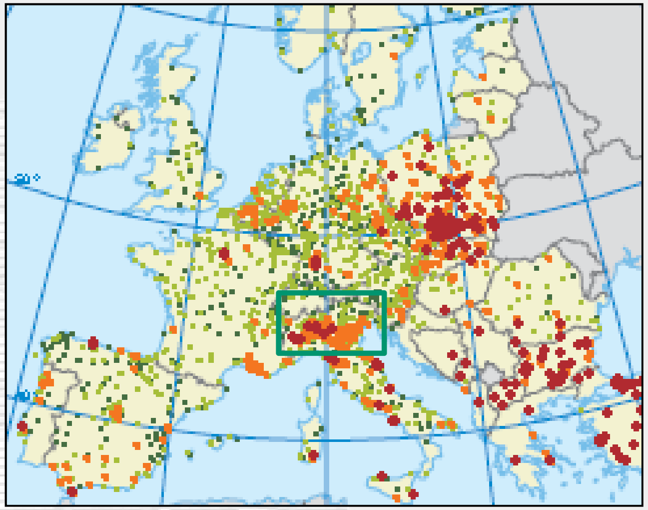
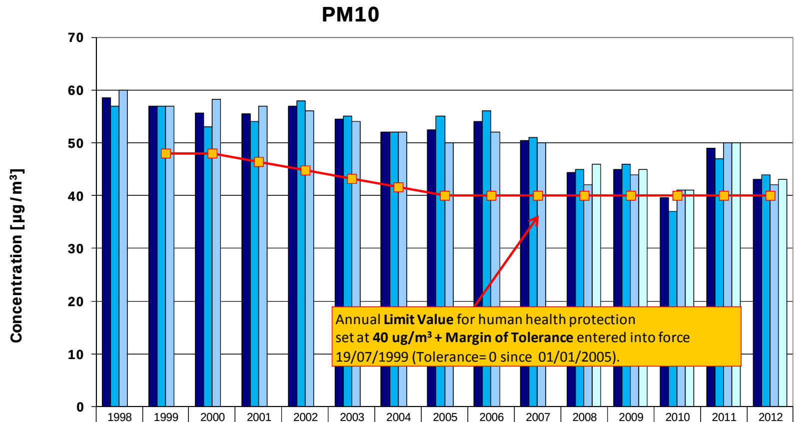


17th ETH Conference on Combustion Generated Nanoparticles, June 23rd-26th 2013, Zurich, Switzerland

AGENZIA MOBILITÀ AMBIENTE TERRITORIO

Background





	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Annual mean	59	57	56	56	57	55	52	53	54	51	44	45	40	49	43
MI-Juvara / Pascal (Urban Background)	57	57	53	54	58	55	52	55	56	51	45	46	37	47	44
MI-Zavattari / MI-Verziere (Traffic/Traffic LEZ)	60	57	58	57	56	54	52	50	52	50	42	44	41	50	42
MI-Senato (Traffic LEZ)											46	45	41	50	43
Limit Value + Margin of Tolerance [Dir.1999/30/CE; Dir.2008/50/CE]		48	48	46	45	43	42	40	40	40	40	40	40	40	40

Year

Air quality is the most important environmental and health problem for the city of Milan

Source: ARPA Lombardia and AMAT processing ARPA Lombardia hourly data

Background and Motivation

✓ In Milan **road traffic** is the main source of air pollutants and toxics compounds

✓ The effect of the adopted **local traffic measures** evaluated by mean of PM or other conventional pollutant monitoring (NO_x, CO) has been scant or unsuccessfull

Black Carbon as a new metric?

"*Black carbon particles are a* ***valuable additional air quality metric*** *to evaluate the* ***health risks of primary combustion particles from traffic including organics****, not fully taken into account with PM2.5 mass*"

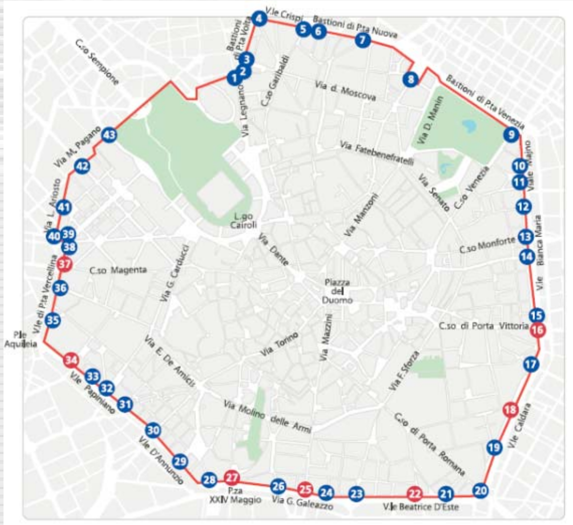
'REVIHAAP. First results' (WHO, 2013)

Aims of this study

1) To evaluate **Black Carbon** (BC), **PM10** and **PM2.5** concentrations **inside and outside 'Area C' LEZ** in **different traffic-proximity exposure conditions**

2) To assess **effectiveness of Black Carbon** as a **new indicator** for **environmental** and **health effects** of traffic generated nanoparticles in **local traffic restriction interventions for Milan** (48% diesel cars)

‘Area C’: the Milan Low Emission Zone



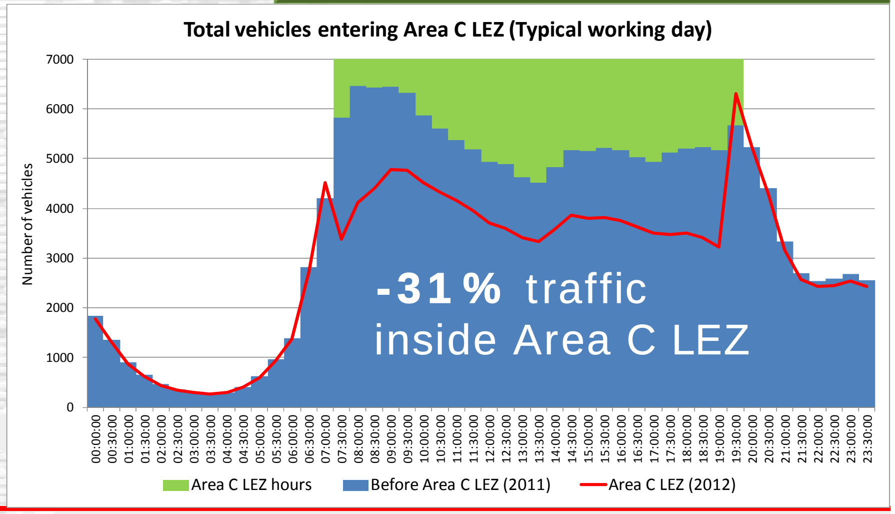
Cameras at each entry gate

Video license linked to records

Access forbidden
- Euro 0-3 Diesel vehicles
- Euro 0 Gasoline vehicles
- Trucks over 7.5 mts

Access with payment
- Euro 4&on Diesel vehicles
- Euro 1&on Gasoline vehicles

Free Access
- electric, hybrid,
- LPG and methane vehicles
- mopeds & motorcycles



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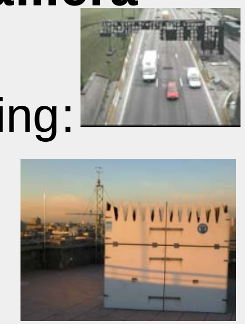
Method and Instruments

Two couple of fixed monitoring sites (kerbside, 3rd floor level residential) in/out Area C LEZ for **four different seasons campaigns**

- **Black Carbon** measured with MicroAethalometer™ (AE51, Magee Scientific).

- **PM10 and PM2.5** measured with Optical Particle Counters (Aerocet 531 - MetOne Instruments Inc.; DustMonitor - Contec Eng.)

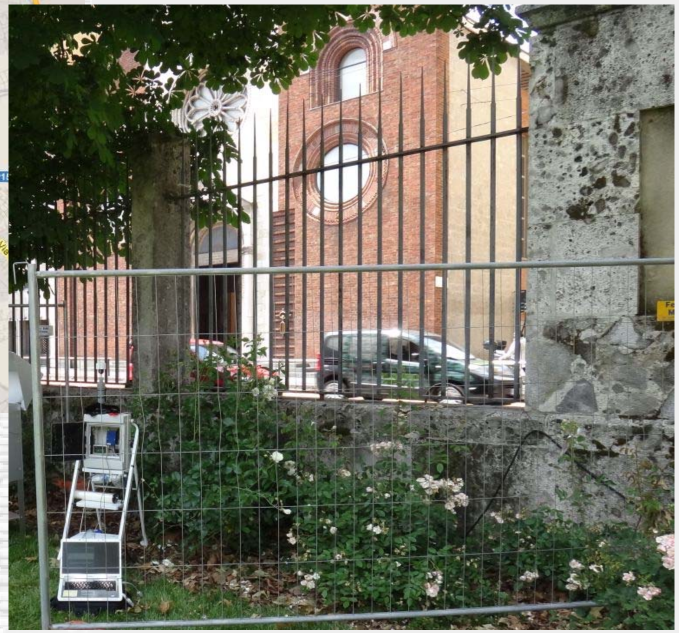
- **Traffic data**: **inductive loop detectors** and real-time **video camera techniques**,



- **Boundary layer mixing height** values have been estimated using:
    - a) measured data by Sodar wind profiler
    - b) Batchvarova-Gryning model

- **Meteorological data, NO_2, NO, CO** from regional Air quality and Meteorological networks

Kerbside sites, in / out 'Area C' LEZ



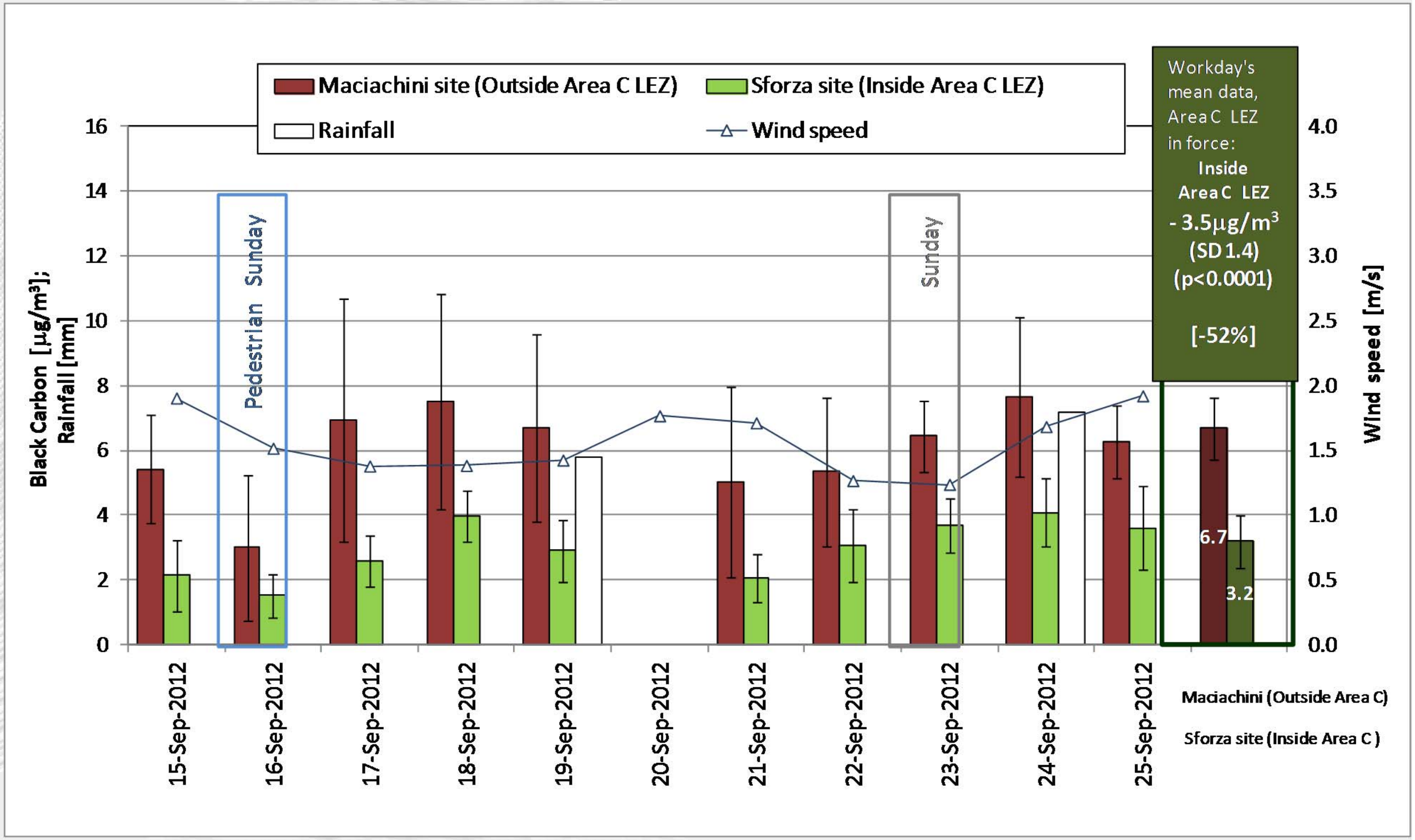
Spring campaign
(May 20th-29th 2012)

Summer campaign
(Sept 15th-25th 2012)

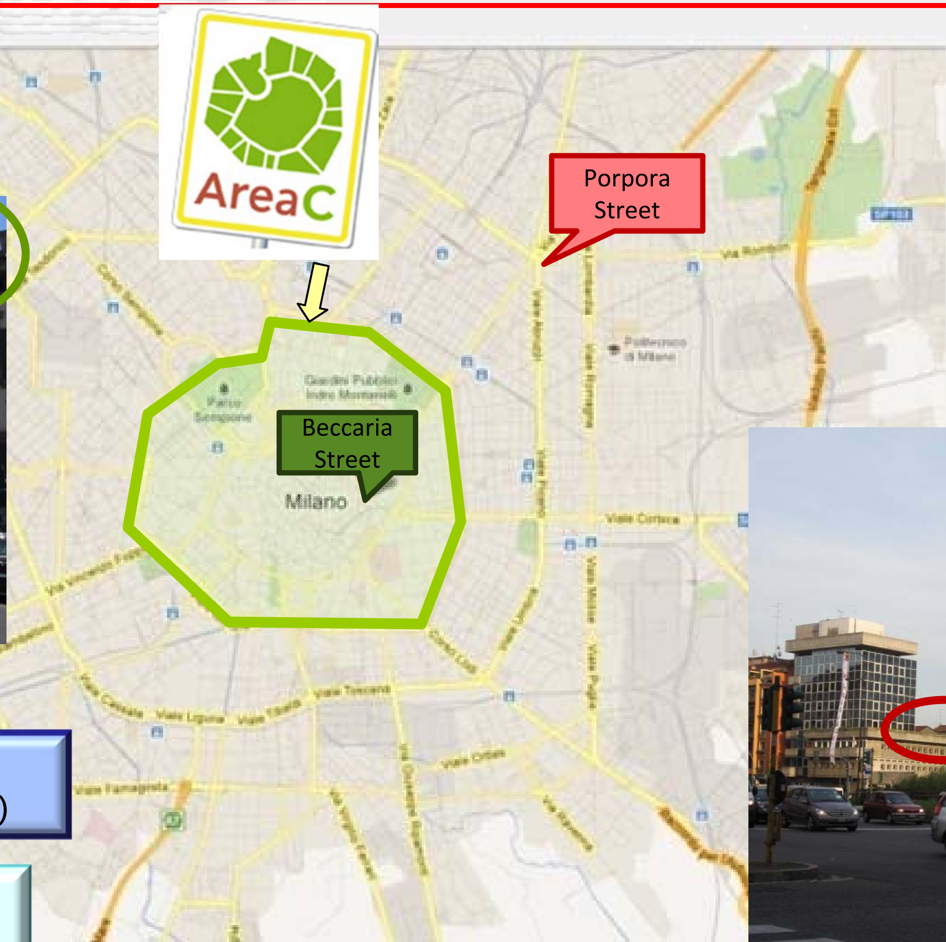
- ✓ Less than 10 m from the center of the roadway
- ✓ Near crossroad with traffic light

Summer campaign, Kerbside sites, in / out 'Area C' LEZ

24 h average BLACK CARBON concentrations (*September 15th-25th 2012*)



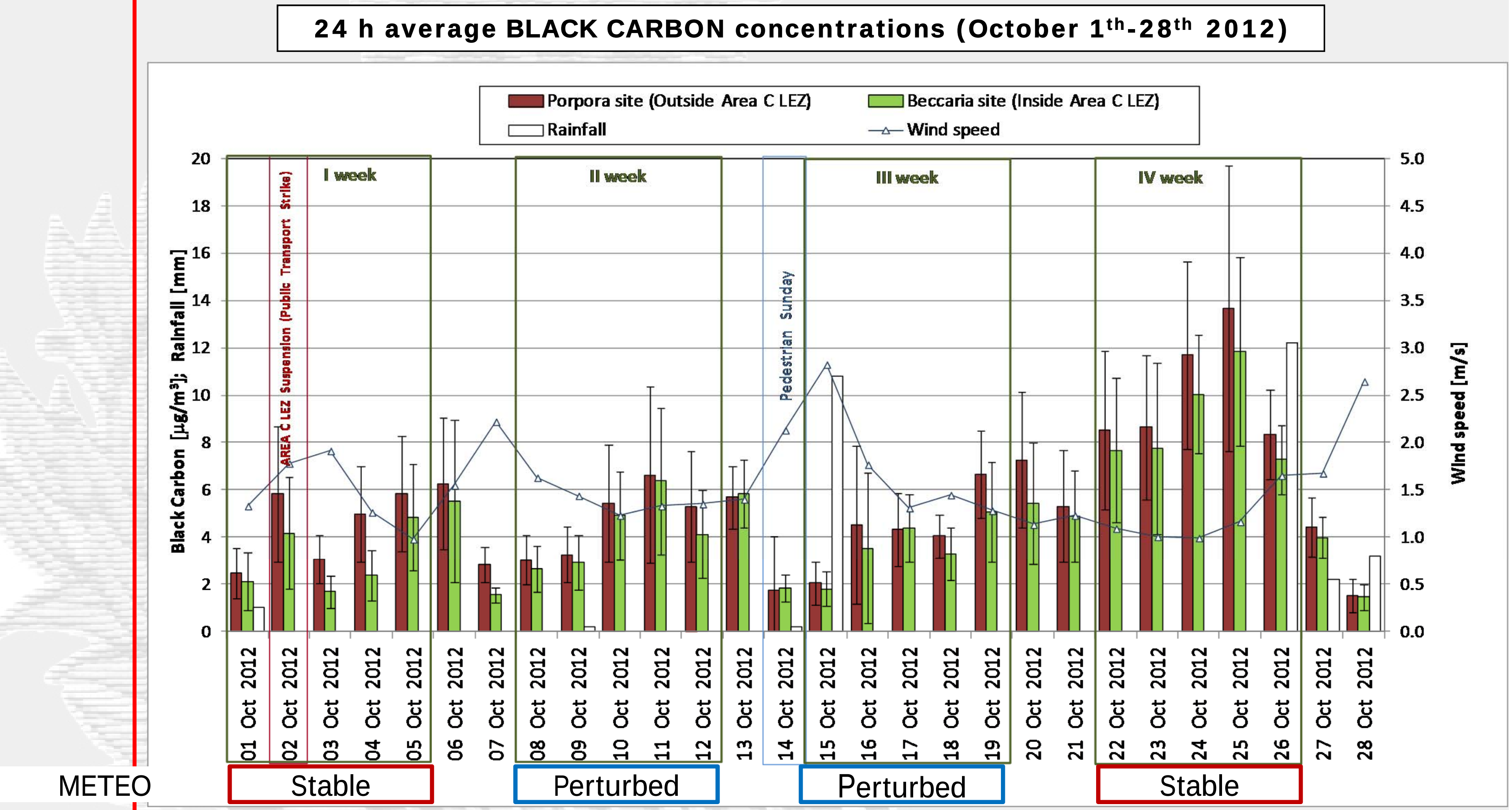
3rd floor level residential roadside sites, in / out 'Area C' LEZ



Winter campaign
(February 1st-26th 2012)

Autumn campaign
(October 1st-28th 2012)

Autumn campaign, 3rd floor residential roadside sites, in/out Area C LEZ



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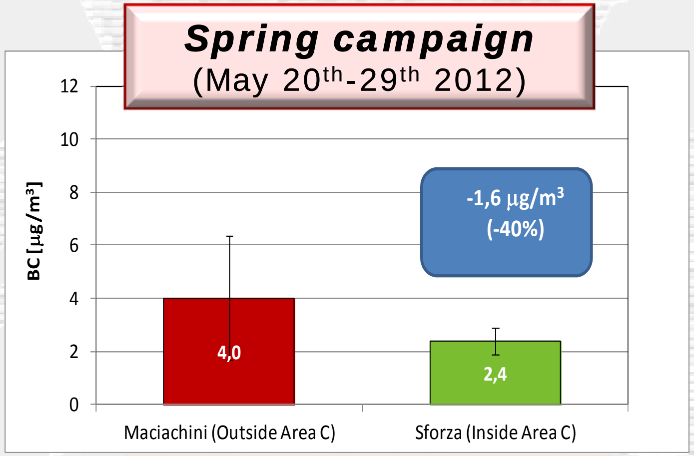
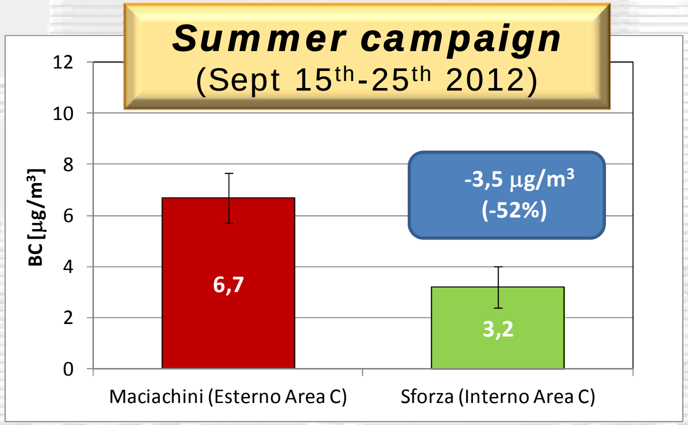
AGENZIA MOBILITÀ AMBIENTE TERRITORIO

Results of First Year Area C LEZ Monitoring Campaign Summary

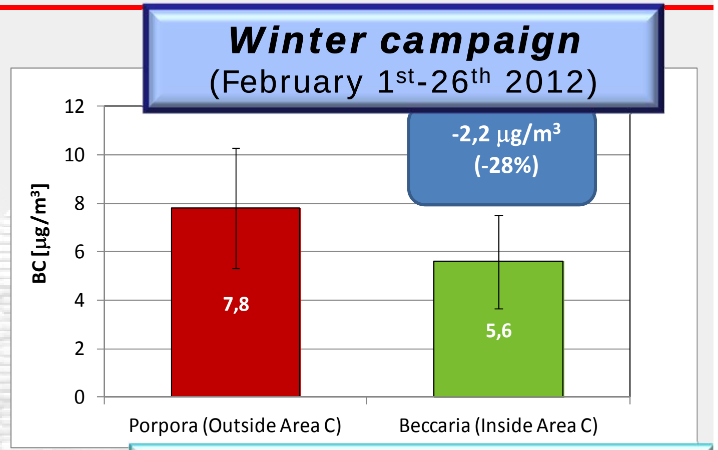
BLACK CARBON concentrations

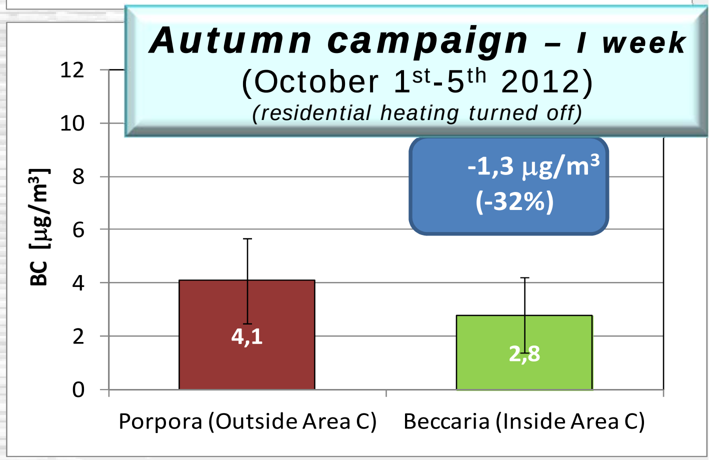
Kerbside sites





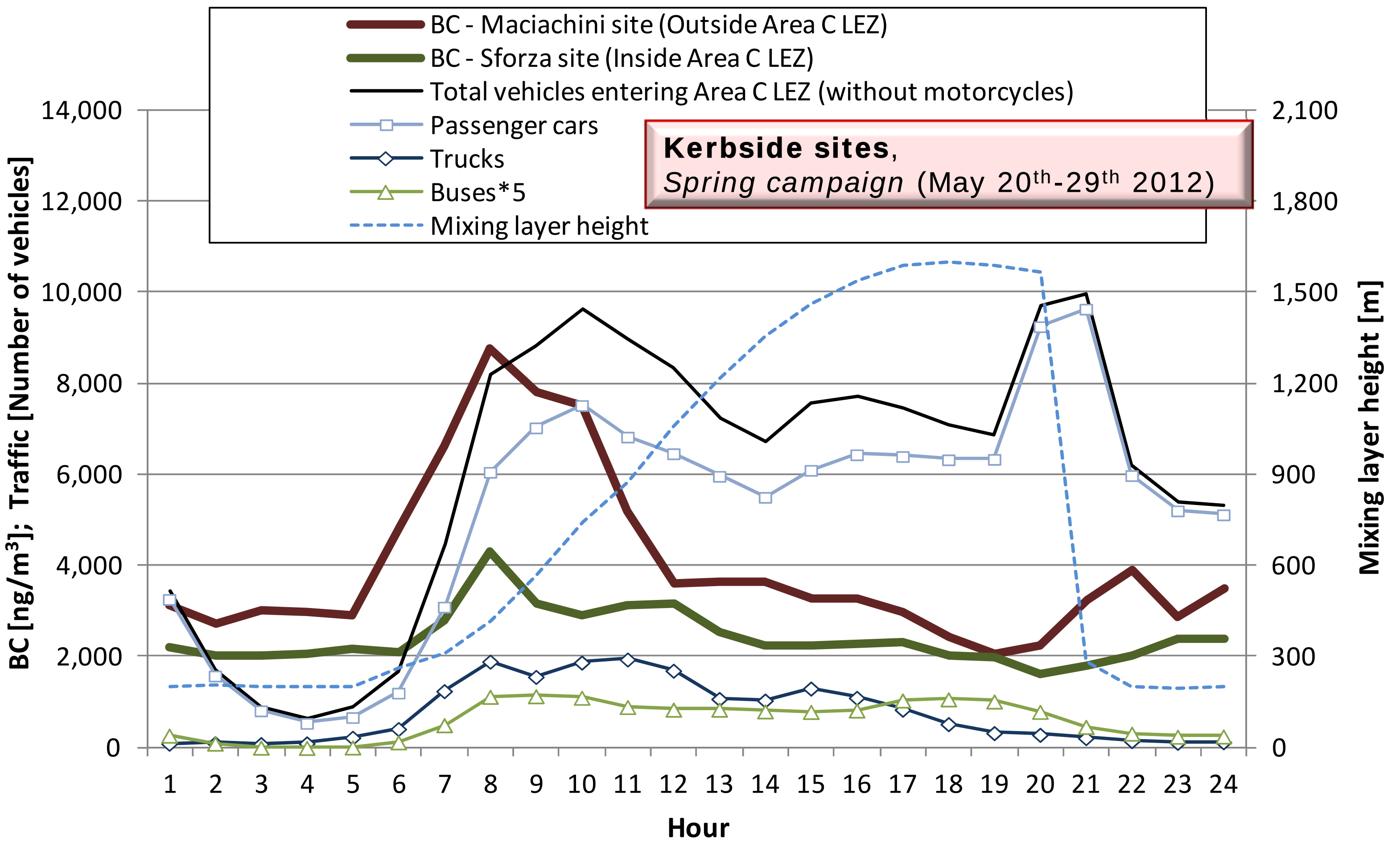
3rd floor level residential sites





- ✓Statistically significant changes in BC, despite no changes in PM10 and PM2.5 concentrations between the inside and the outside site
- ✓Results in agreement with literature for similar sites (Reche *et al.*, 2011; Boogaard *et al.*, 2011) and a previous kerbside summer study on the same area (Invernizzi *et al.*, 2011).

BC *vs.* Traffic pattern (Typical working day)



- ✓ BC concentrations determined by daily traffic volume pattern and mixing height
- ✓ BC concentration outside well correlated with total vehicles entering Area C LEZ
- ✓ Motorcycles data not considered in the total traffic (particular commuting, seasonal)

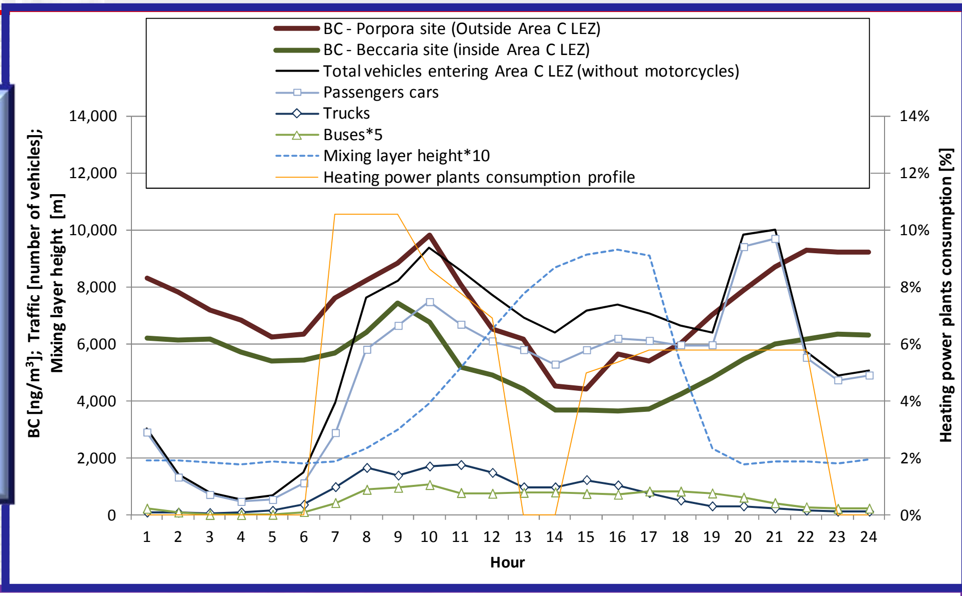
BC *vs.* Traffic and Domestic heating patterns (3rd floor sites)

Winter campaign
(February 1st-26th 2012)

T average= 1.4 °C; Tmin=-7.6 °C

R Pearson BC *vs.*
Total traffic; *Domestic Heating* :

Inside site = 0.73; *0.70*
Outside site = 0.77; *0.75*

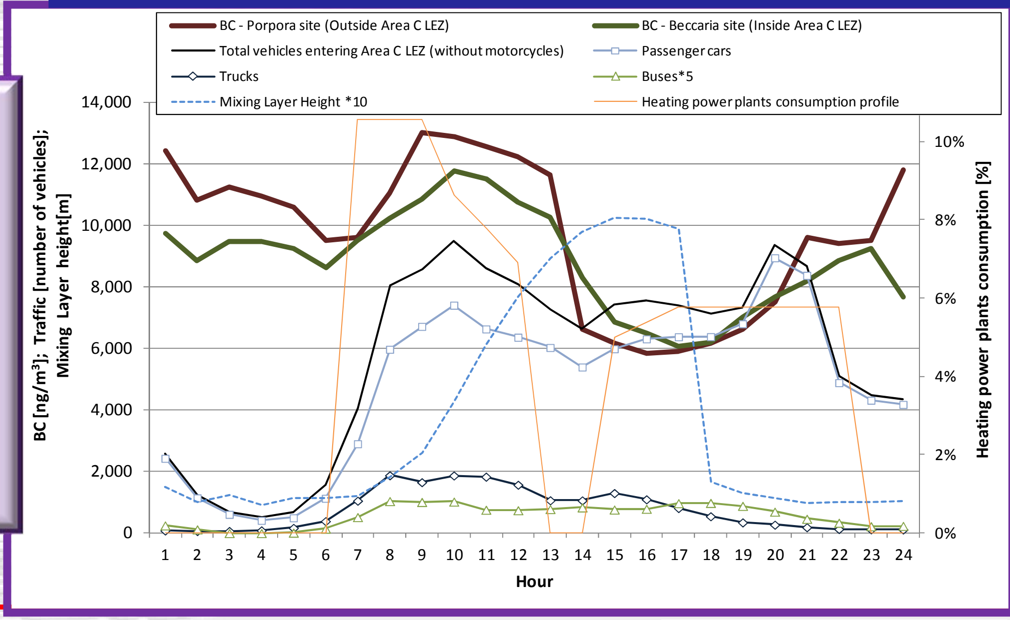


Autumn campaign - IV week
(October 22nd-26th 2012)

T average= 15.9 °C; Tmin=10.3 °C

R Pearson BC *vs.*
Total traffic; *Domestic Heating* :

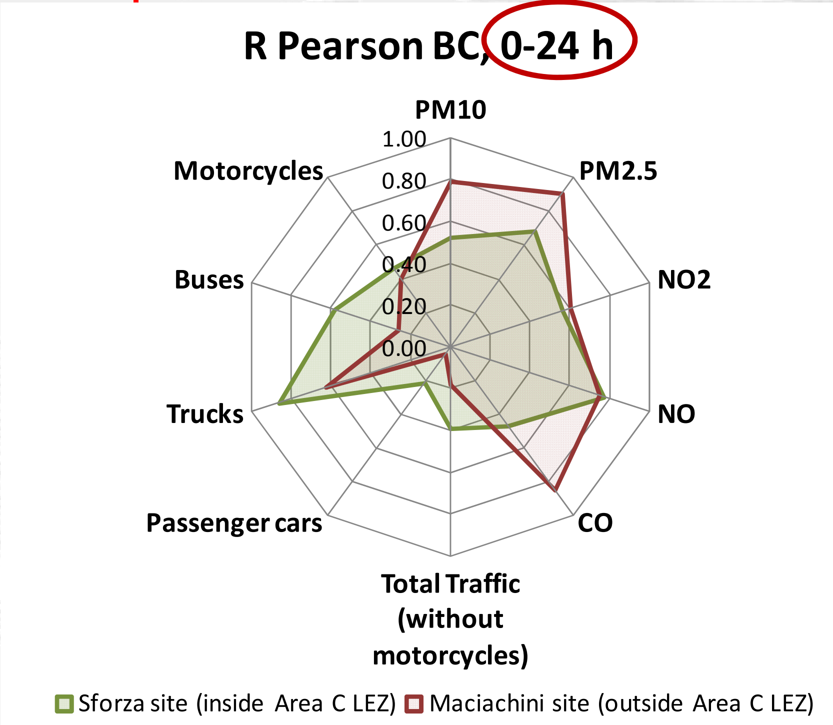
Inside site = 0.74; *0.31*
Outside site = 0.77; *0.41*

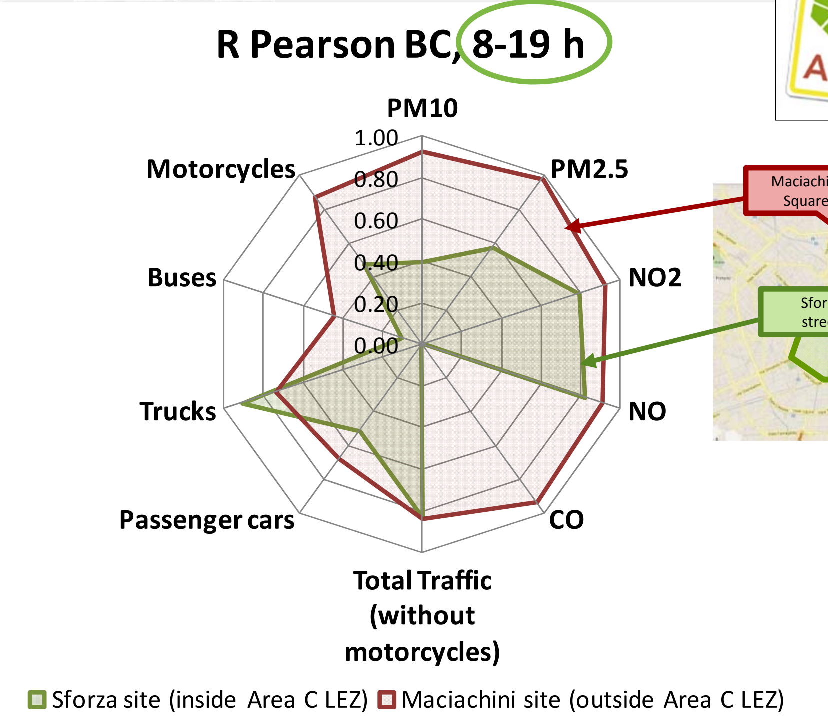


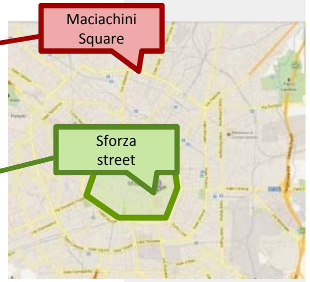
R Pearson correlation coefficient (typical working day)

Black Carbon *vs.* traffic and traffic-related pollutants

at Kerbside - Spring campaign (May 20th-29th 2012)



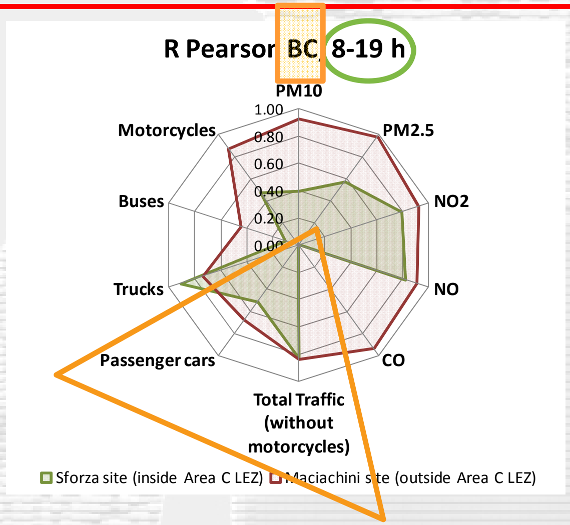


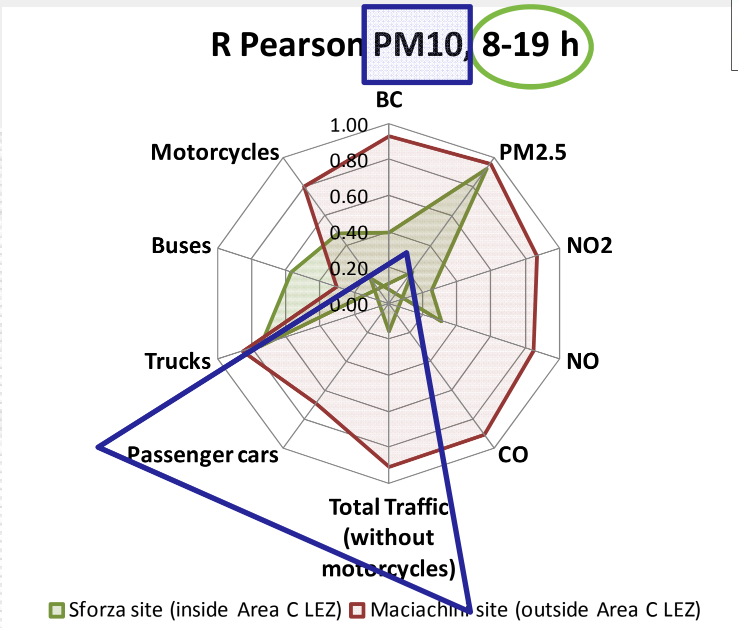


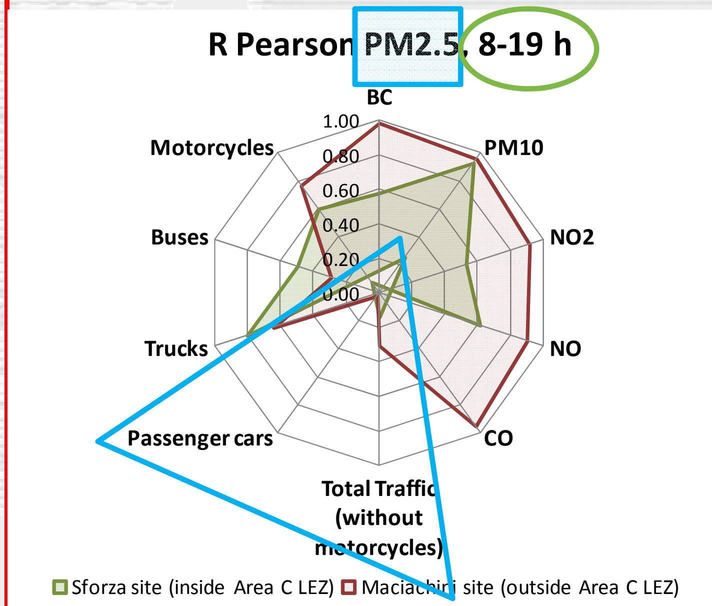
During Area C LEZ traffic restriction hours $R_{pearson}$ correlation coefficient is:

- ✓ lower inside Area C LEZ for passenger cars (lower-emission vehicles)
- ✓ higher inside Area C LEZ for trucks (different diurnal traffic pattern in/out)
- ✓ correlation with motorcycle due to confounding factors (but to better investigate)

R Pearson coefficient: BC *vs.* PM10 and PM2.5, 8-19 hours







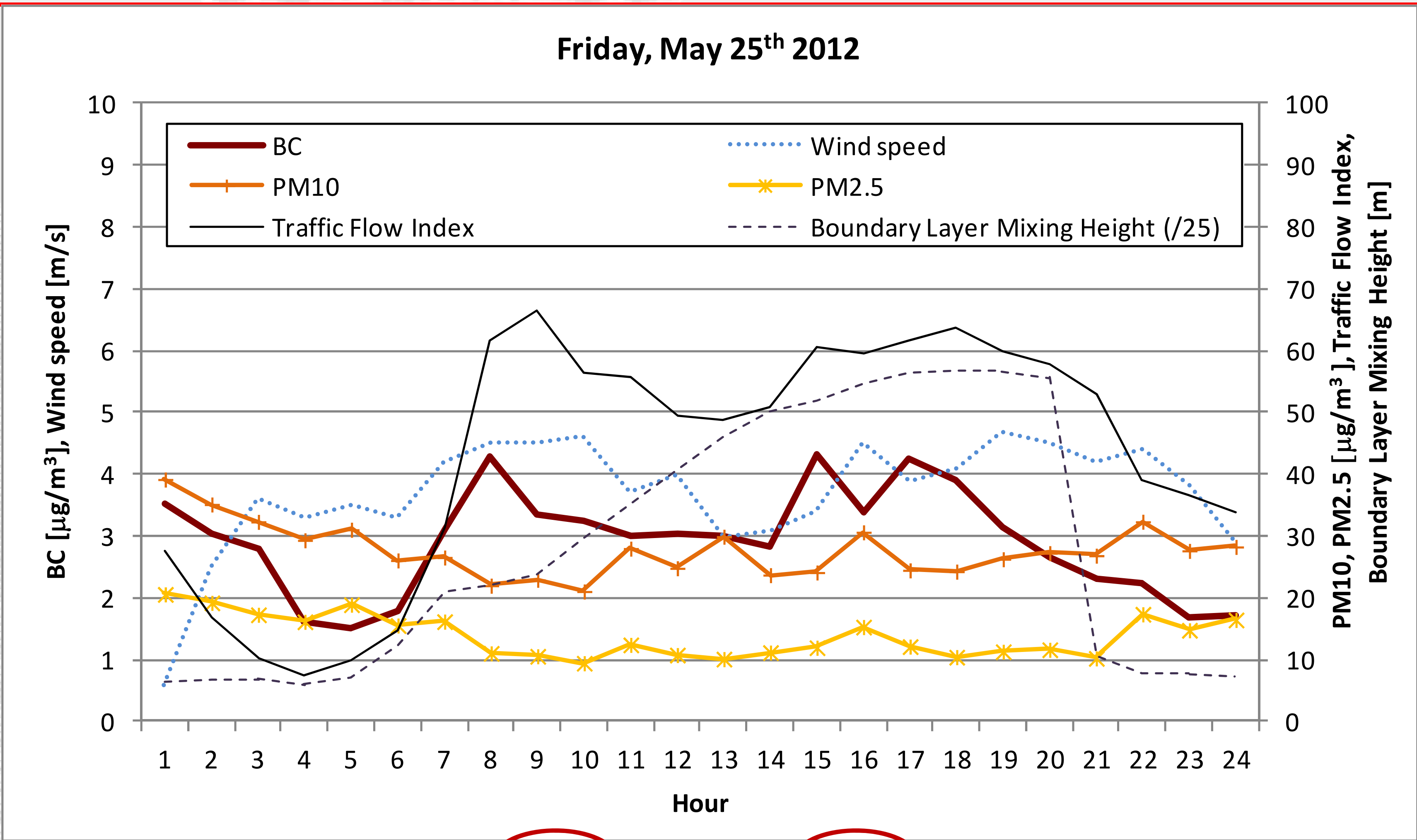
- ✓ PM10 and PM2.5 not so sensitive as Black Carbon to traffic fluxes (*see coloured triangles*):

Negative correlation with passenger cars (PC) and low with Total traffic inside Area C LEZ

- ✓ High PM10 *vs.* PC and Trucks R $_{Pearson}$ coeff. at the external kerbside site:

re-suspended dust, road abrasion and non-exhaust emissions due to higher traffic fluxes and HDV admitted outside the Area C LEZ

BC, PM10, PM2.5 *vs.* Traffic pattern (on-site data), at kerbsite



BC *vs.* local Traffic $R_{Pearson}$ = **0.66** for 7-19 h; **0.85** for 4-17 h

PM10 *vs.* local Traffic $R_{pearson}$ = **-0.32** for 7-19 h; **-0.47** for 4-17 h

PM2.5 *vs.* local Traffic $R_{pearson}$ = **0.16** for 7-19 h; **-0.77** for 4-17 h

Concluding remarks

- A statistically significant difference was found in BC concentrations **inside Area C LEZ**, both at **kerbside** and **residential** roadside sites

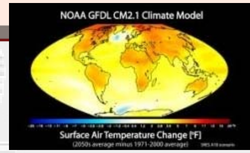
- **Local interventions on traffic circulation** (e.g. Low Emission Zones, Pedestrian Sundays o Car Free days) can **reduce health effects linked to toxic traffic-related pollutants exposure** for population and city users

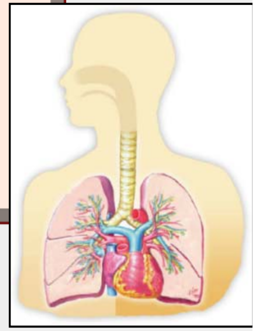
- **High sensitivity of BC** to changes in **traffic flows** net of weather events has been observed

- **Black Carbon** can be considered a **very effective indicator of environmental and health effects** deriving by **traffic circulation** for cities, such as **Milan**, characterized by an **high fraction of diesel engines** in the vehicles fleet

Future perspectives

- Which are the **Area C LEZ benefits** in term of **health diseases** (morbidity and mortality) **external costs ?**
- ...and taking into account also **BC climate change effects ??**





- Adoption of **BC monitoring** to verify environmental and health effects of:

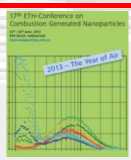
➢ the **Sustainable Mobility Urban Plan** under development:

- Freight delivery with zero emission vehicles on 'last mile'
- 30 km/h Zones,
- Pedestrian Areas,
- Bicycle Plan
- ...

➢ the **Heavy duty** and **Off-road vehicles** satellite control (GPS) Project

Milano

Comune di Milano



AGENZIA MOBILITÀ AMBIENTE TERRITORIO

In memoriam of Dr. Giovanni Invernizzi

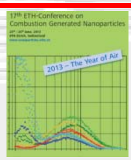
The authors want to dedicate this work to the memory of Dr. Giovanni Invernizzi (SIMG), who promoted the first traffic-proximity exposure research projects in Italy and thanks to whom 'Area C' LEZ Black Carbon study was possible

- ✓***MD, Scientific Director, Environmental Research Laboratory SIMG-Italian College GPs***
- ✓***Scientific Commitee Member of ISDE, International Society of Doctors for the Environment***
- ✓***Researcher at IRCCS, 'National Cancer Research Institute', Milan - Tobacco Control Unit***

...and a fine pianist!

Milano

Comune di Milano



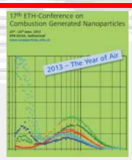
AGENZIA MOBILITÀ AMBIENTE TERRITORIO

Thank you for your attention!

silvia.moroni@amat-mi.it

Milano

Comune di Milano



AGENZIA MOBILITÀ AMBIENTE TERRITORIO

Mobility, Environment and Land Agency of Milan

http://www.amat-mi.it

http://www.amat-mi.it/it/ambiente/qualita-aria/il-progetto-di-monitoraggio-del-black-carbon/