Climatologia delle concentrazioni atmosferiche di PM_{10} in pianura Padana

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PM 2014

ID	Station name	Station type	Activation date
	Long term trend dataset		
1	Arese	UB	Jan 2002
2	Bergamo Meucci	UB	Jul 2000
3	Brescia Broletto	UT	Oct 2000
4	Castelnovo Bariano	SuB	Jan 2002
5	Forlì	UB	Jan 2001
6	Limito	UB	Mar 1998
7	Magenta	UB	Mar 1998
8	Meda	UT	Feb 1998
9	Modena	UB	Feb 1998
10	Parma	UB	Apr 2002
11	Pizzighettone	UB	Feb 2000
12	Ravenna Zalamella	UT	Oct 1999
13	Reggio Emilia	UB	Jun 2001
14	Rimini	UB	Jan 2001
15	Torino Caduti	SuB	Jan 2002
16	Torino Consolata	UT	Jul 1999
17	Treviglio	UT	Feb 2000
18	Vimercate	UB	Feb 1998
	Extended analysis dataset		
19	Alessandria Lanza	UB	Feb 2007
20	Asti D'Acquisto	UB	Dec 2002
21	Biella Sturzo	UB	Feb 2003
22	Bologna	UB	Nov 2007
23	Borsea	UB	Jan 2003
24	Carmagnola	SuT	Jan 2006
25	Cerano	SuB	Jan 2005
26	Cremona	UB	Apr 2006
27	Druento	RB	Nov 2002
28	Febbio*	RR	Nov 2004
29	Imola	UT	Nov 2003
30	Mantova Ariosto	UB	Jan 2003
31	Mantova Gramsci	UT	Aug 2005
32	Mantova S.Agnese	UB	Jan 2005
33	Milano	UB	May 2007
34	Padova Mandria	UB	Jan 2004
35	Piacenza	UB	Jan 2005
36	Rovigo	UT	Jan 2004
37	Sannazzaro De' Burgondi	UB	Jan 2007
38	Verona Cason	RB	Jan 2004
39	Verona C.so Milano	UT	Jan 2003
40	Vigevano Petrarca	UT	Sep 2004
41	Voghera Pozzoni	UB	Nov 2005

Dataset:

- gravimentric equivalent PM_{10} downloaded from respective ARPA websites (or provided by ARPA)
- PM_{10} data manually inspected: annual, monthly, weekly and daily patterns examined and spurious values removed
- Provincial emissions estimates (inventory version 13 05 2013) for PM_{10}, $PM_{2.5}$, SO_2, NO_x, NM-VOC, CH_4, NH_3, CO by ISPRA

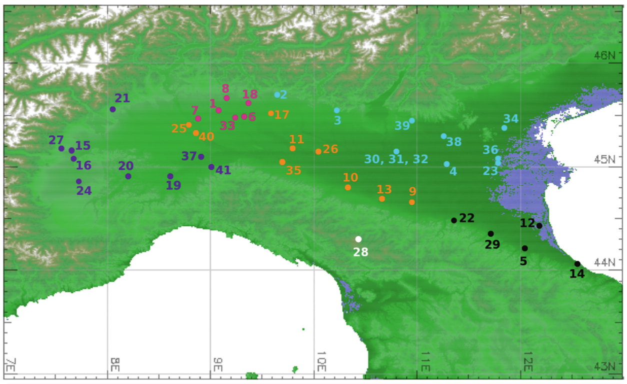


Figure: Location of PM_{10} monitoring stations included in the analysis. Key for ID number is found in Table, colour code refers to result of cluster analysis using Euclidean distance.

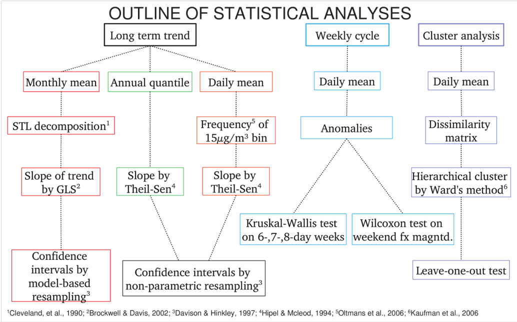
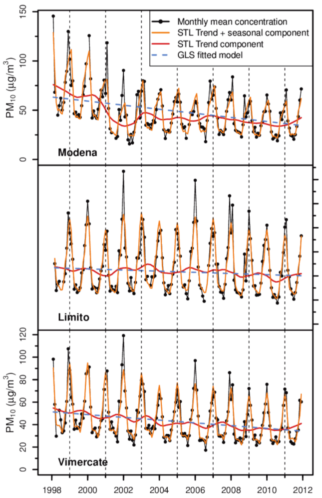


Table: Analysed PM_{10} sampling sites for long term trend and for extended statistical analysis.

Monthly means



Station	Slope 2002–2011 $\mu g\,m^{-3}\,yr^{-1}$	Change 2002–2011 $\%\,yr^{-1}$	Slope since time series start $\mu g\,m^{-3}\,yr^{-1}$	Change since time series start $\%\,yr^{-1}$
Arese	**−1.395 ± 0.378**	**−2.9 ± 0.8**		
Bergamo M.	**−1.381 ± 0.339**	**−3.2 ± 0.8**	**−1.120 ± 0.319**	**−2.6 ± 0.7**
Brescia B.	**−1.188 ± 0.331**	**−2.7 ± 0.7**	**−0.690 ± 0.375**	**−1.5 ± 0.8**
Castelnovo Bariano	**−1.099 ± 0.316**	**−2.7 ± 0.8**		
Forlì	**−1.504 ± 0.401**	**−4.7 ± 1.3**	**−1.204 ± 0.324**	**−3.6 ± 1.0**
Limito	**−0.892 ± 0.158**	**−1.9 ± 0.3**	**−0.508 ± 0.127**	**−1.1 ± 0.3**
Magenta	**−1.273 ± 0.363**	**−2.7 ± 0.8**	**−0.648 ± 0.247**	**−1.4 ± 0.5**
Meda	**−1.450 ± 0.431**	**−2.9 ± 0.9**	**−1.182 ± 0.315**	**−2.3 ± 0.6**
Modena	0.190 ± 0.523	0.4 ± 1.2	**−2.087 ± 0.626**	**−4.3 ± 1.3**
Parma	**−0.629 ± 0.395**	**−1.7 ± 1.0**		
Pizzighettone	**−1.086 ± 0.179**	**−2.5 ± 0.4**	**−0.581 ± 0.208**	**−1.4 ± 0.5**
Ravenna Zalamella	−0.555 ± 0.833	−1.6 ± 2.4	**−1.310 ± 0.548**	**−3.5 ± 1.5**
Reggio E.	−0.114 ± 0.800	−0.3 ± 2.3	−0.169 ± 0.700	−0.5 ± 2.0
Rimini	**−0.987 ± 0.227**	**−2.7 ± 0.6**	**−0.745 ± 0.222**	**−2.0 ± 0.6**
Torino Caduti	**−1.173 ± 0.503**	**−2.6 ± 1.1**		
Torino Consolata	**−2.293 ± 0.390**	**−4.0 ± 0.7**	**−2.094 ± 0.237**	**−3.6 ± 0.4**
Treviglio	−0.514 ± 0.641	−1.2 ± 1.5	0.240 ± 0.721	0.6 ± 1.7
Vimercate	**−0.941 ± 0.174**	**−2.2 ± 0.4**	**−1.257 ± 0.114**	**−2.8 ± 0.3**

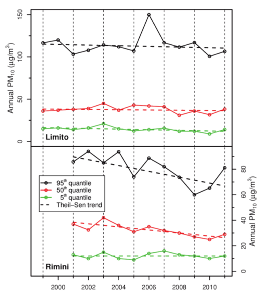
Table: Generalised Least Squares (GLS) trend (± standard error) for deseasonalised monthly mean time series of daily PM_{10} concentration. Boldfaced values indicate slope significantly different from zero at a 95% confidence level.

Figure: STL decomposition for monthly mean PM_{10} along with GLS fitted slope for three selected sites.

The trend for monthly means is significantly decreasing for almost all sites; the slope is generally steeper over the period 2002 – 2011 for almost all observations.
Annual trends are partially consistent with GLS estimates. As expected, significant slopes occur more frequently for 50th and 95th quantiles than for lower concentration indicating a more widespread decrease in peak concentration.
PM_{10} in the Po valley exhibits a distinctive seasonality, and the steeper drop in annual higher concentrations (occurring in winter) is coupled with a significant drop in daily concentration also for summer months.

Annual quantiles and binned daily means

Figure left: Annual quantiles along with Sen slope for daily PM_{10} at Limito and Rimini.
Figure bottom: Significant changes in monthly frequency distribution of PM_{10} at Castelnovo Bariano (a) and Parma (b).



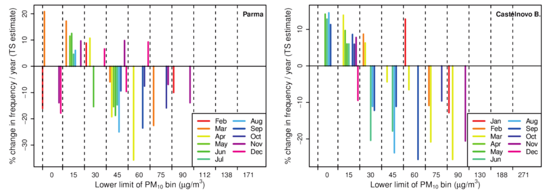
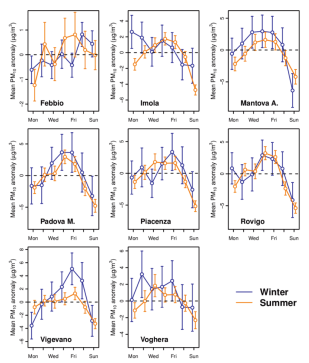


Table 3: Analysis of trend for annual quantiles and for monthly frequency of PM_{10}. Slope for annual quantiles is computed by Theil-Sen method (TS): boldfaced values indicate slope significantly different from zero at a 95% confidence level.

Station	5th annual quantile Slope $\mu g\,m^{-3}\,yr^{-1}$	5th Change $\%\,yr^{-1}$	50th annual quantile Slope $\mu g\,m^{-3}\,yr^{-1}$	50th Change $\%\,yr^{-1}$	95th annual quantile Slope $\mu g\,m^{-3}\,yr^{-1}$	95th Change $\%\,yr^{-1}$	Months with significant trend
Arese	**−0.500**	**−3.5**	**−1.400**	**−3.7**	−3.125	−2.8	2–4 (–), 6–7 (–), 9–11 (–)
Bergamo M.	**−0.750**	**−5.5**	**−1.714**	**−4.8**	**−2.730**	**−2.8**	1 (–), 3 (–), 5 (–), 7–8 (–), 10–11 (–)
Brescia B.	**−0.714**	**−5.2**	**−1.071**	**−2.9**	−0.030	0.0	3 (–), 6 (–), 8 (–), 10–12 (–)
Castelnovo B.	**−0.236**	**−1.9**	**−1.500**	**−4.6**	**−4.600**	**−5.0**	1 (–), 3 (–), 6 (–), 8–11 (–)
Forlì	**−0.606**	**−5.5**	**−1.250**	**−4.6**	**−3.643**	**−5.1**	1 (–), 3 (–), 6–8 (–), 10–12 (–)
Limito	**−0.342**	**−2.4**	−0.156	−0.4	−0.616	−0.5	5 (–), 7–9 (–)
Magenta	**−0.121**	**−0.7**	**−0.625**	**−1.6**	**−2.112**	**−2.0**	4 (+), 7–9 (–)
Meda	**−0.219**	**−1.4**	−0.542	−1.4	**−3.011**	**−2.5**	1 (–), 3 (–), 5–8 (–), 10 (–), 12 (–)
Modena	**−0.138**	**−0.9**	**−1.657**	**−4.3**	**−4.046**	**−3.8**	1–12 (–)
Parma	**0.462**	**4.1**	**−1.000**	**−3.0**	**−2.550**	**−3.2**	2 (±), 3–8 (–), 11 (±), 12 (+)
Pizzighettone	**−0.329**	**−2.1**	**−0.621**	**−1.6**	−1.429	−1.7	2–3 (–), 9 (–), 11 (–)
Ravenna Z.	**−0.775**	**−5.7**	**−1.889**	**−6.0**	**−5.173**	**−6.4**	1–8 (–), 10–12 (–)
Reggio E.	**−0.013**	**−0.1**	−0.857	−2.9	−1.575	−2.1	1–3 (–), 6–8 (–), 10–11 (–)
Rimini	0.000	0.0	**−1.200**	**−3.7**	**−2.283**	**−2.8**	3 (–), 6–10 (–)
Torino Ca.	**−0.429**	**−3.5**	**−1.500**	**−4.0**	−0.161	−0.2	1–7 (–), 9 (–), 10 (+), 12 (+)
Torino Co.	**−1.130**	**−5.8**	**−2.056**	**−4.3**	**−3.078**	**−2.4**	1 (–), 3–9 (–)
Treviglio	**−0.250**	**−1.7**	−0.333	−1.0	−1.950	−1.9	2–3 (–)
Vimercate	**−0.418**	**−2.7**	**−1.000**	**−2.7**	**−3.439**	**−3.4**	1–3 (–), 5–10 (–), 12 (–)

In the results from the analysis of monthly frequency distribution of daily PM_{10} a – sign next to a specific month indicates a decrease in frequency of higher concentration bins towards lower bins.
A + sign in Table 3 next to a specific month indicates a shift from lower to higher concentration bins and a ± sign indicates a shift in lower and higher concentration bins towards median concentrations.
Results of monthly trend show a general decrease at all sites for most months. It is worth-noting that all summer months having a significant slope exhibit a concentration decrease, while eventually some winter months show an increase or a shift to median bins.

Weekly patterns and cluster analysis



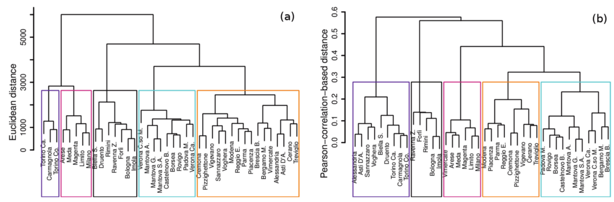


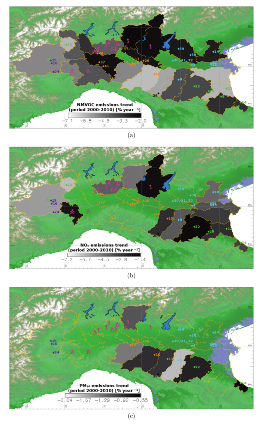
Figure left: 7-day week mean PM_{10} anomaly for winter and summer seasons for few sites

Figure right: Results of cluster analysis on daily PM_{10} data using Euclidean distance (a) and Pearson-correlation-based distance (b). Coloured boxes indicate clusters.

All sites besides Febbio showed the same pattern for mean anomaly, although with different intensity, with a minimum from Saturday through Monday and a maximum on Wednesday or Thursday. Febbio showed a significant increase from Monday through Sunday, and it is believed to be generated by an increase in emissions (e.g. wood-burning for domestic heating or traffic) during weekends.

Considering the whole year, a significant weekly periodicity is present during 7 day week at all sites besides Febbio, Forlì and Sannazzaro. Most of shorter time series show a weekly periodicity in summer and not in winter, whereas many of longer ones still exhibits a weekly periodicity in both seasons. The lack of weekly periodicity in winter might be due to the large fraction of SIA in PM_{10} in this season, uncoupling the weekly fluctuations of primary anthropogenic emissions (non-exhaust included) and PM_{10} concentration. Possibly this buffering effect by SIA is dimmed in longer time series by a higher primary/SIA ratio in the late 90s early 2000. $PM_{2.5}$ in the Po Valley has been shown to have a larger relative fraction of secondary aerosol than PM_{10}, and a lower contribution from re-suspension. Consistently a significant weekly cycle in $PM_{2.5}$ is observed only at very few sites.
Cluster analysis identifies five main clusters, confirmed by sensitivity analyses: a group based SE having similar patterns and lower concentration including also two NW background sites (Biella and Druento) having relatively low concentration. Two clusters identify the two main metropolitan areas of the valley, Turin and Milan. Finally, both NE and centre of the Po valley are grouped according to their PM_{10} levels and patterns leading to two different clusters. Sensitivity analysis and divisive hierarchical clustering showed a persistent structure featured by 4 main clusters representative of the metropolitan area of Turin and Milan and the ones of the south-east and north-east of the valley, with the sites in the central Po valley, and generally sites at cluster boundaries, occasionally assigned to the geographically adjacent cluster.

Analysis of provincial emissions



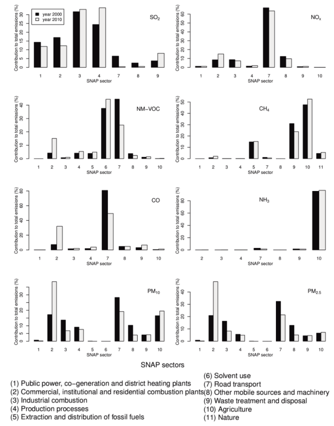


Figure left: Significant annual trend in total emissions of NM-VOC (a), NO_x (b) and PM_{10} (c)

Figure right: Change in percent contribution by each SNAP sector to the emission of 8 atmospheric pollutants in the Po valley (period 2000-2010).

No significant statistical correlation arose from the comparison of trends in background PM_{10} and emissions in each province, although the results from analyses above strongly suggest that the drop observed in PM_{10} concentration derives primarily from a decrease in local emissions.
Simulation studies by De Meij et al. (2009) and Deserti et al. (2006) showed that, in order to have a decrease in PM_{10} similar to the one observed in this study, a large reduction in both primary and secondary PM_{10} sources is required. On the contrary, a minor and restricted decrease in PM_{10} emissions is observed from inventory data.

Conclusions

- Significant downward trend at most sites for different time scales (monthly, annual, seasonal) and for different pollution regimes (5th, 50th and 95th quantile)
- Weekly cycle (i.e. anthropogenic) for PM_{10} at most sites, particularly in summer (increase in the percentage of secondary fraction through years)
- Spatial-based differences in PM_{10} with impact of large urban areas on the surroundings
- Large decrease in emissions for some species (mostly SO_2, NO_X, NMVOC) and small decrease in PM_{10} and $PM_{2.5}$ emissions (uncertainties both in chemical-transport models and inventories)

More details on Bigi and Ghermandi, ACP 2014