Stima dei fattori di emissione di particolato atmosferico, in numero ed in massa, nell'area urbana di Lecce per diversi intervalli dimensionali

M. Conte, A. Donateo, F.M. Grasso, D. Contini

Istituto di Scienze dell'Atmosfera e del Clima
ISAC-CNR

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Intro e obiettivi

Traffico veicolare …

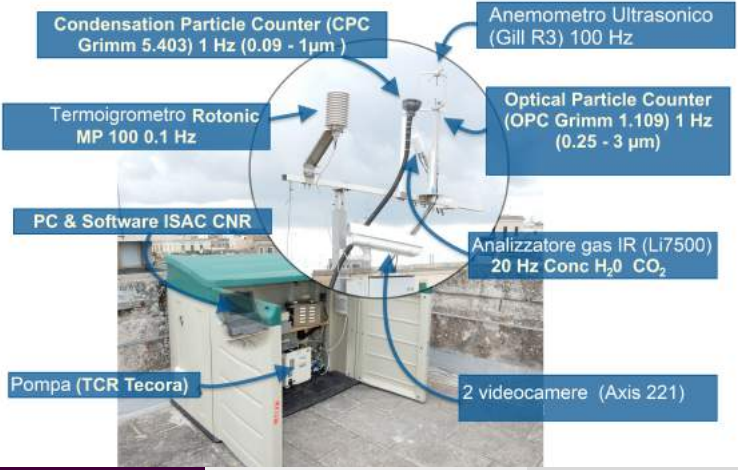
- principale fonte d'inquinamento nelle aree urbane
- complessa sorgente da stimare in termini di emissione

Stima dei fattori di emissione (EFs) size-segregated di particelle da misure di flussi turbolenti ottenuti mediante eddy-covariance (EC)

Sito di misura

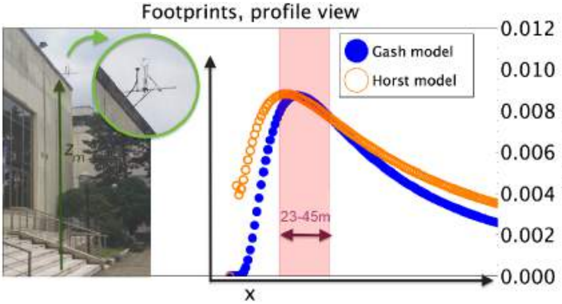
$d_0 = 7 \pm 0.5$ m
$z_0 = 1.3 \pm 0.1$ m
$z_w = 14$ m

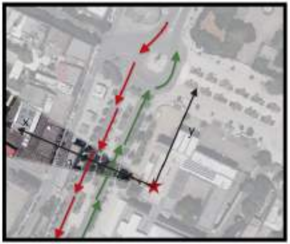
AFIRE (Aerosol Fluxes In uRban Environment)
10 Marzo-24 Aprile 2015
[Conte et al., 2018. Stoten, 622; 1067-78]



Footprints: Horst & Gash

Footprint f: rappresenta il contributo, per unità di area, di tutti gli elementi di superficie sopravento, al flusso scalare misurato $\mathrm{F}_m \rightarrow F_m = \int_{-\infty}^{+\infty} \int_{-\infty}^{x} S(x)\, f(x, y, z_m)$





$$\bar{f}^y(x, z_m) \simeq \frac{d\bar{z}}{dx}\frac{z_m}{\bar{z}^2}\left[\frac{\bar{u}(z_m)}{U(\bar{z})} A \exp\left(-z_m/(\bar{z}B)\right)^r\right]$$

Horst Model (1994)

$$\bar{f}^y(x, z_m) \simeq \frac{u z_m}{k u^* x_0^2} \exp\left(-\frac{u z_m}{k u^* x_0}\right)$$

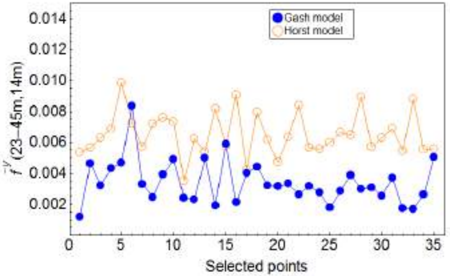
Gash Model (1986)

Footprints: selezione dei dati

- **direzione del vento:** 292.5±10°
- **condizioni atmosferiche neutrali:** $|(z_0 - d_0)|/L < 0.1$

35 casi selezionati!

- **velocità del vento:** > 0.5 m/s
- **Traffico:** > 248 Veh/h
- **Eliminazione flussi negativi:** 38% OPC



$\bar{f}^y_{Gash}$ - - → mediamente più bassa rispetto a $\bar{f}^y_{Horst}$

$$EF = \frac{F_m}{\bar{f}^y \, T_R}$$

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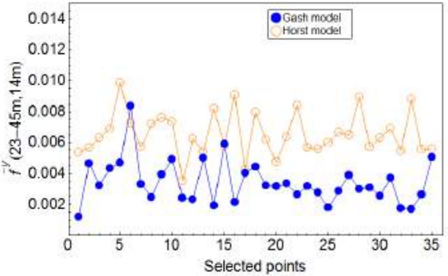

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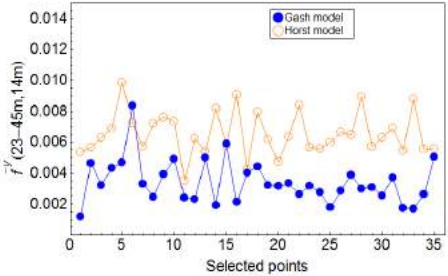

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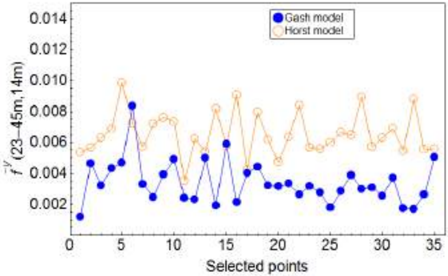

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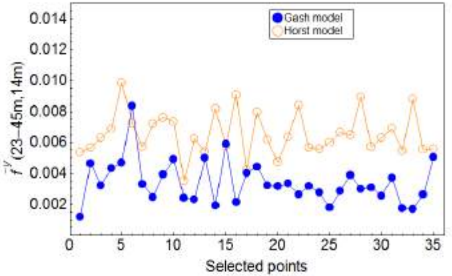

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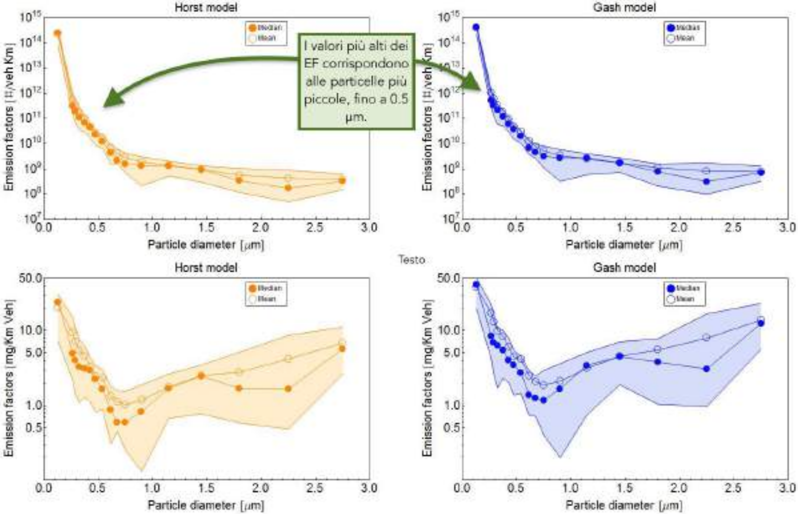
Fattori di emissione size-segregated



Horst model

Gash model

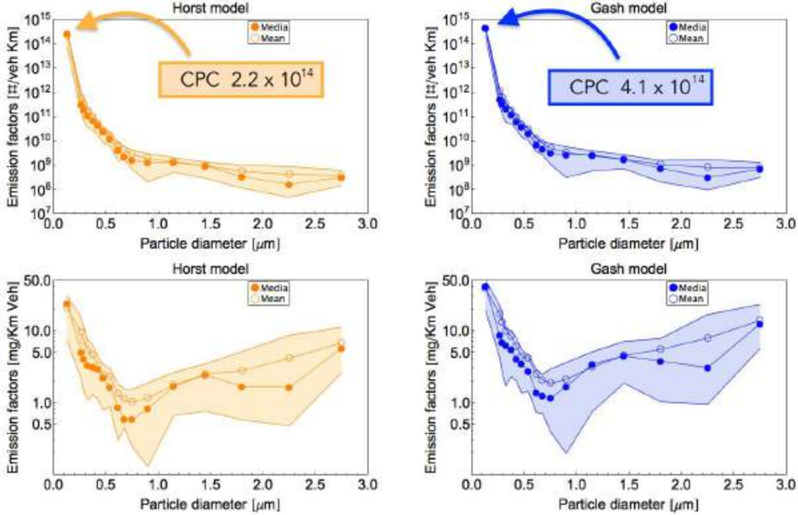
Horst model

Gash model

I valori più alti dei EF corrispondono alle particelle più piccole, fino a 0.5 µm.

Testo

Fattori di emissione size-segregated

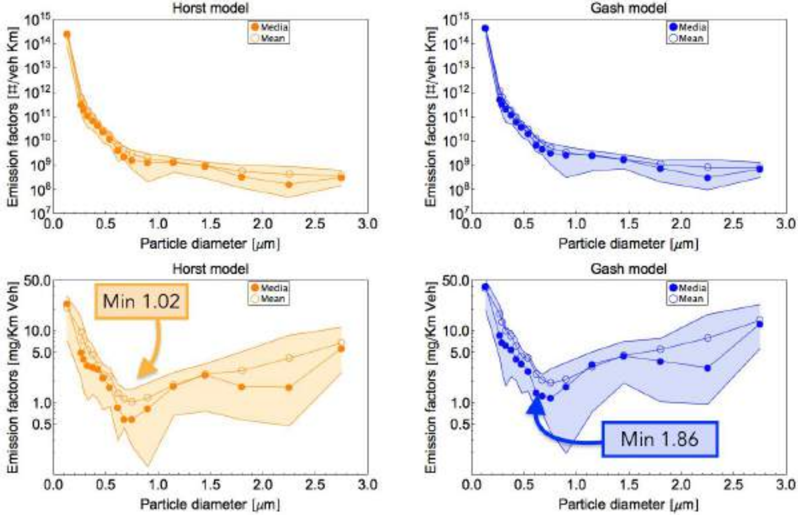

Horst model

Gash model

CPC 2.2 x 10^{14}

CPC 4.1 x 10^{14}

Fattori di emissione size-segregated

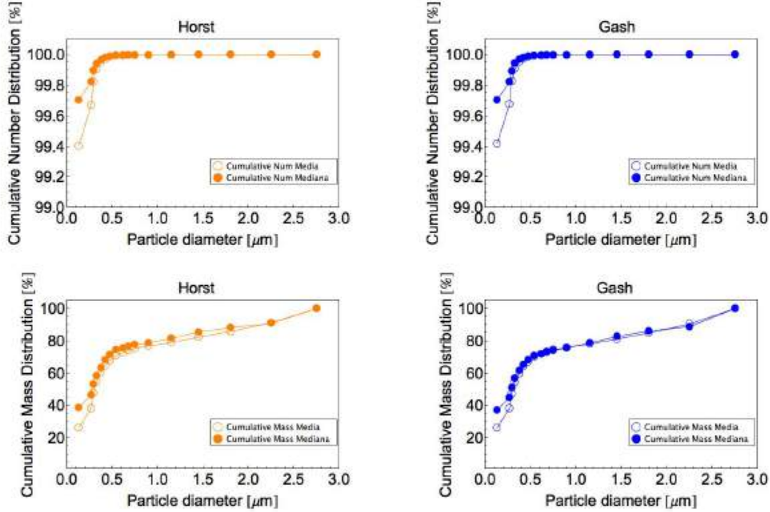


Min 1.02

Min 1.86

Risultati: distribuzione cumulativa

Crescita rapida moda di accumulazione



Crescita meno rapida: il 50% delle emissioni in massa si trovano entro 0.5 μm

Comparazione dei EFs

Fattori di emissione size-segregated di particelle (in numero ed in massa)

EFs	**Horst**	**Gash**	**Horst**	**Gash**
	Numero [#/Veh km]		**Massa [mg/Veh km]**	
CPC $D_p < 0.25\mu m$	$\mathbf{2.6\,10^{14}}$ $(9.2\,10^{13} - 3.2\,10^{14})_{IQR}$	$\mathbf{4.5\,10^{14}}$ $(2.3\,10^{14} - 5.5\,10^{14})_{IQR}$	**24.3** $(8.5 - 29.9)_{IQR}$	**41.9** $(21.3 - 50.5)_{IQR}$
OPC′ $0.25 < D_p < 0.6\mu m$	$\mathbf{7.6\,10^{11}}$ $(3.2\,10^{11} - 1.9\,10^{12})_{IQR}$	$\mathbf{1.4\,10^{12}}$ $(6.2\,10^{11} - 2.6\,10^{12})_{IQR}$	**24.0** $(11.9 - 51.8)_{IQR}$	**42.5** $(22.1 - 73.1)_{IQR}$
OPC″ $0.6 < D_p < 3\mu m$	$\mathbf{1.03\,10^{10}}$ $(3.3\,10^{9} - 1.5\,10^{10})_{IQR}$	$\mathbf{2.2\,10^{10}}$ $(4.8\,10^{9} - 3.0\,10^{10})_{IQR}$	**13.7** $(6.0 - 29.0)_{IQR}$	**23.0** $(15.7 - 48.6)_{IQR}$
$\mathbf{PM_1}$	$\mathbf{2.2\,10^{14}}$ $(6.1\,10^{13} - 3.2\,10^{14})_{IQR}$	$\mathbf{4.2\,10^{14}}$ $(1.7\,10^{14} - 5.5\,10^{14})_{IQR}$	**36.6** $(15.6 - 79.9)_{IQR}$	**62.4** $(40.0 - 110.6)_{IQR}$
$\mathbf{PM_{2.5}}$	$\mathbf{2.2\,10^{14}}$ $(6.1\,10^{13} - 3.2\,10^{14})_{IQR}$	$\mathbf{4.2\,10^{14}}$ $(1.7\,10^{14} - 5.5\,10^{14})_{IQR}$	**42.7** $(21.0 - 91.9)_{IQR}$	**74.0** $(44.1 - 128.0)_{IQR}$

Comparazione dei EFs con letteratura

EFs	**Numero [#/Veh km]**	**Note**
AFIRE (2015)	$\mathbf{2.2\,10^{14}}$ **Horst** $(9.2\,10^{13} - 3.2\,10^{14})_{IQR}$ $\mathbf{4.2\,10^{14}}$ **Gash** $(2.3\,10^{14} - 5.5\,10^{14})_{IQR}$	EC
Nickel et al. (2013)	$\mathbf{3.5\,10^{14}}$	tracciante NO_x
Contini et al. (2012)	$\mathbf{2.9\,10^{14}}$ $(2.2\,10^{14} - 5.0\,10^{14})_{IQR}$	EC
Wang et al. (2010)	$\mathbf{(1.9 \pm 0.03)\,10^{14}}$	EC
Jarvi et al. (2009)	$\mathbf{(3.0 \pm 1.1)\,10^{14}}$	EC
Martensson et al. (2006)	$\mathbf{(1.4 \pm 0.1)\,10^{14}}$	EC
Kristensson et al. (2004)	$\mathbf{(4.6 \pm 1.9)\,10^{14}}$	Tunnel
Ketzel et al. (2003)	$\mathbf{(2.8 \pm 0.5)\,10^{14}}$	Street canyon

EFs $\mathbf{PM_{2.5}}$	**Massa [mg/Veh km]**	**Note**
AFIRE (2015)	**42.7 Horst** $(21.0 - 91.9)_{IQR}$ **74.0 Gash** $(44.1 - 128.0)_{IQR}$	*EC*
Huang et al. (2017)	$\mathbf{(34 \pm 23.5)}$	Tunnel
Ferm et al. (2015)	$\mathbf{(20 \pm 8)}$	NO_X tracciante
Wang et al. (2010)	$\mathbf{(46 \pm 1)}$	NO_X tracciante
Ketzel et al. (2007)	$\mathbf{(30 - 60 \pm 1)}$	NO_X tracciante

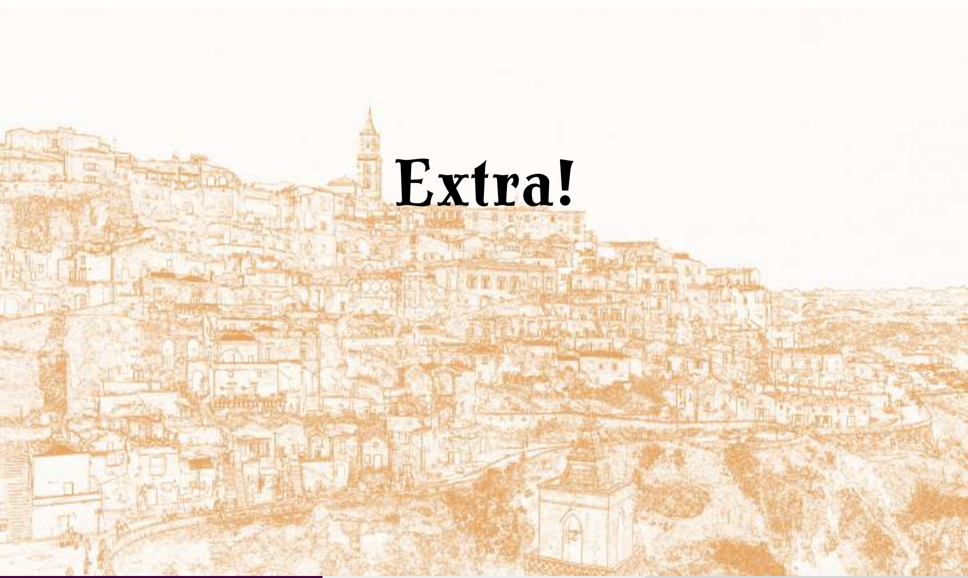
Conclusioni

Utilizzando le correlazioni dei flussi con il traffico e con i parametri meteorologici locali è stato possibile ottenere delle **parametrizzazioni delle emissioni di particelle in condizioni operative reali** utilizzabili nei modelli di dispersione.

- Le footprints sono state valutate mediante due formule analitiche: **Horst & Gash** --→ **Gash è mediamente più basso del 30% rispetto ad Horst**
- I EFs in numero più alti si trovano in corrispondenza delle particelle ultrafini --→ **contributo exhaust**
- I EFs in massa si osserva un importante contributo delle particelle grandi (moda coarse)--→ **contributo non-exhaust**
- I EFs per numero totale, **PM_1 e $PM_{2.5}$** sono **comparabili con quanto riportato in letteratura**

Grazie per la vostra attenzione!

Per ulteriori informazioni: m.conte@isac.cnr.it

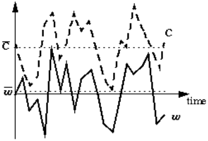


Extra!

Eddy-covariance method

The vertical turbulent fluxes are evaluated by the “**eddy-correlation**” (EC) **method.**

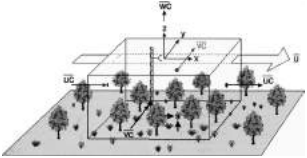
$$F_c = \overline{w\,c} = \overline{\left(\overline{w} + w'\right)\left(\overline{c} + c'\right)} = \overline{w}\,\overline{c} + \overline{w'\,c'}$$



The starting point is the **conservation equation**:

$$\frac{\partial\bar{c}}{\partial t} + \left(\bar{u}\frac{\partial\bar{c}}{\partial x} + \bar{v}\frac{\partial\bar{c}}{\partial y} + \bar{w}\frac{\partial\bar{c}}{\partial z}\right) = -\left(\frac{\partial\overline{u'c'}}{\partial x} + \frac{\partial\overline{v'c'}}{\partial y} + \frac{\partial\overline{w'c'}}{\partial z}\right) + \mathcal{D} + \mathcal{S}_c$$

Assuming the molecular diffusion (D) negligible together with horizontal uniformity, homogeneity and stationarity hypothesis:



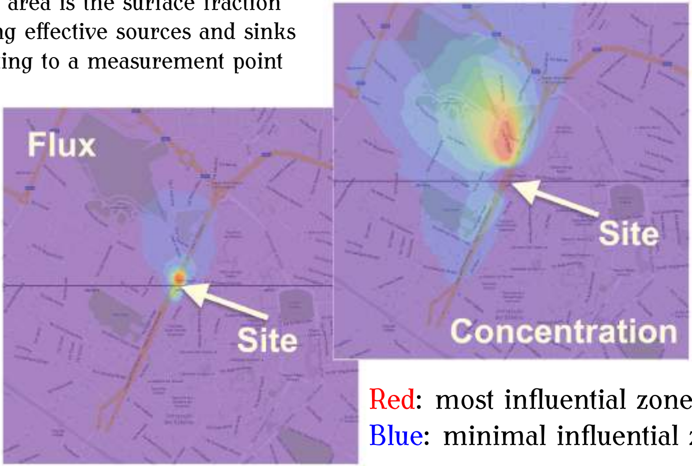
$$0 = -\overline{w'c'} + \int_0^z \mathcal{S}_c dz$$

The turbulent flux at height z is

$$\overline{w'c'} = \int_0^z \mathcal{S}_c dz$$

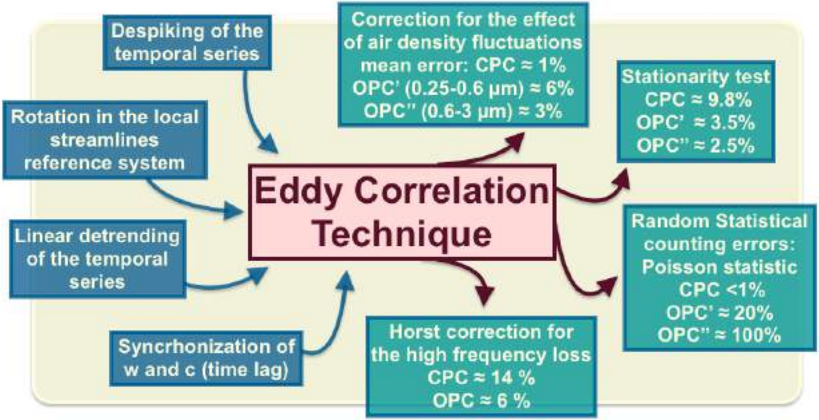
Site characteristic…Source areas

A source area is the surface fraction containing effective sources and sinks contributing to a measurement point



Red: most influential zones
Blue: minimal influential zones

Post-Processing and Data Selection



Despiking of the temporal series

Rotation in the local streamlines reference system

Linear detrending of the temporal series

Synchronization of w and c (time lag)

Eddy Correlation Technique

Correction for the effect of air density fluctuations mean error: CPC ≈ 1% OPC' (0.25-0.6 μm) ≈ 6% OPC'' (0.6-3 μm) ≈ 3%

Stationarity test CPC ≈ 9.8% OPC' ≈ 3.5% OPC'' ≈ 2.5%

Random Statistical counting errors: Poisson statistic CPC <1% OPC' ≈ 20% OPC'' ≈ 100%

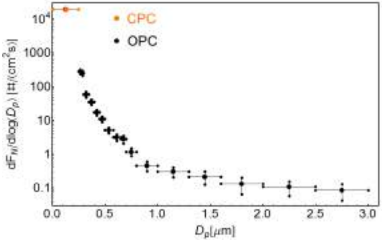
Horst correction for the high frequency loss CPC ≈ 14 % OPC ≈ 6 %

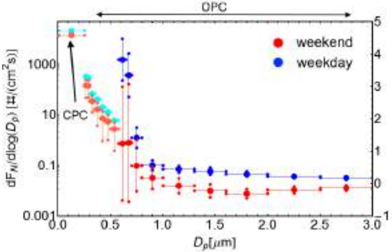
The corrections minimize errors and deviations from theoretical assumptions, experimental configuration problems and meteorological conditions [Donateo et al., 2014. Advances in Meteorology].

Number size distributions: fluxes

Number particle fluxes & Number particle concentrations: **similar behaviour!**

the maximum value was ~ 10^4 particles/cm$^2 s$ (D$_p$ <0.25 μm)
the minimum value was ~ 10 particles/cm$^2 s$ for D$_p$ > 0.5 μm.



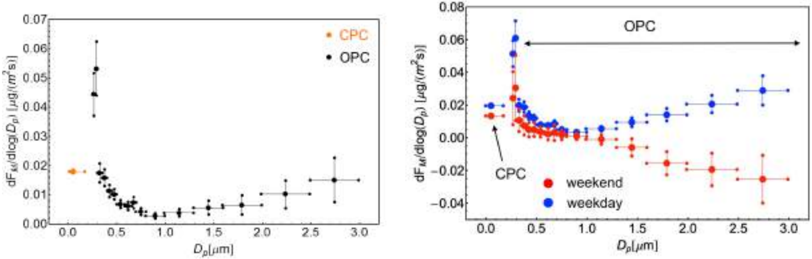


The deposition was smaller during weekdays and the particles larger than 1μm were mostly influenced by the daily activity:

The city is, on average, a continuous particle source.

Mass size distributions: fluxes

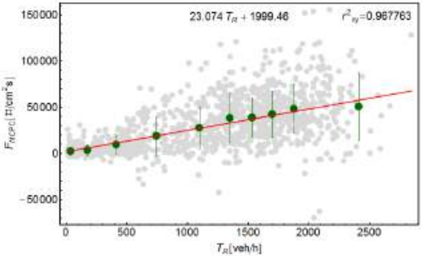
The accumulation mode gives the dominant contribution

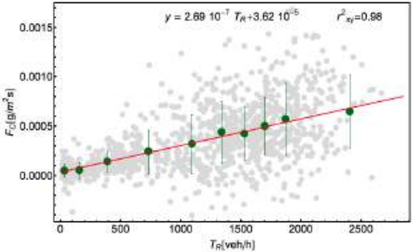


- The deposition fluxes are dominant for large particles and during weekends.
- It is evident the effect of resuspension of course particles due to the traffic.

Scatter plot

The correlation between $F_{N_{CPC}}$ and T_R (r_{xy}=0.62) and that between F_C and T_R (r_{xy}=0.61).

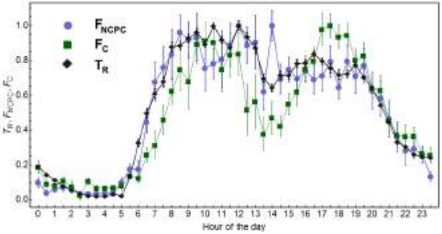




A linear fit of the average fluxes segregated in bins of T_R is a good first approximation!

... normalising the $F_{N_{CPC}}$, F_C and T_R

Daily cycle of these variables were correlated



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- Contini, D.; Donateo, A.; Elefante, C.; Grasso, F.M. Analysis of particles and carbon dioxide concentrations and fluxes in an urban area: correlation with traffic rate and local micrometeorology. *Atmos. Environ.* **2012**, 46, 25-35.
- Donateo A, Contini D (2014). Correlation of Dry Deposition Velocity and Friction Velocity over Different Surfaces for PM2.5 and Particle Number Concentrations. Advances in Meteorology 2014:12 pages.