Application of an Urban Street Canyon Model for Predicting Vehicular Pollution in an Urban Area in Dublin

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Overview

- Objectives
- Urban Street canyon model - STREET
- Urban Street canyon model - OSPM
- Comparison of STREET and OSPM with monitored data.
- Conclusions

Overall Research Objectives

- To identify suitable modelling techniques for motorway and urban street canyon.
- To develop models suitable for implementation in integrated transport environmental modelling.

Overall Research Objectives

- To determine the accuracy of the models through comparison of predicted and ambient air quality data .
- To investigate the sensitivity of model outputs to meteorological, traffic and background concentration inputs.
- To recommend best practice for air quality modelling of traffic emissions in Ireland.

$C = C_s + C_b$

Urban Street Canyon Model- STREET

- Proposed by Johnston et al., 1973
- Semi empirical model
- Calculates series of hourly concentrations at different receptor locations within the street canyon

$C = C_s + C_b$

Urban Street Canyon Model- STREET

- C=Cs+Cb.
- Cs is the concentration component due to vehicle emission and Cb is the background concentration.
- Cs is calculated using a simple box model.
- It measures concentration on the leeward and windward side of the street.

Urban Street Canyon Model- STREET

- Leeward side concentration:

$$C_s^L = \frac{KQ}{(U + U_s)\left(\sqrt{x^2 + z^2} + h_o\right)}$$

- Windward side concentration:

$$C_s^w = \frac{KQ}{W(U + U_s)}\left(\frac{H - z}{H}\right)$$

Urban Street Canyon Model- STREET

In the above expressions :

- K is an empirical constant (assumed 7).
- Q is rate of release of emissions in the street
- *x* is the horizontal distance between receptor and nearest traffic lane.
- *z* is the height of the receptor.
- U is the roof level wind speed
- U_s is a constant that accounts for additional air movement due vehicle traffic (empirical value of 0.5m/s)
- h_0 accounts for initial height of pollution dispersion (empirical value of 2m).
- H and W are the height and width of canyon.

Urban Street Canyon Model- OSPM

- It is also a semi empirical model based on similar mathematical formulation. It combines Gaussian technique along with empirical box model technique to calculate concentrations of exhausts in street canyons.
- It assumes three contributions- direct contribution of pollutants from source to receptor (Cd), a recirculation component (Cr) and background concentration (Cb). C=Cs+ Cr+Cb.

Urban Street Canyon Model- OSPM

- Commercial software available in the market.
- The equations used in the model have been described by Buckland (1998).
- In this study the equations presented by Buckland have been implemented.

Urban Street Canyon Model- OSPM

Steps followed

1. Calculate the length of the street vortex (Lv):

$$L_v = 2\, r\, H_b$$

r indicates the strength of the vortex:

r = 1 for wind speed U ≥ 2m/s and

r = 0.5U for U < 2m/s.

Hb is the height of street building.

Urban Street Canyon Model- OSPM

Steps followed

2. Calculate the length of the recirculation zone (Lr):

$$L_r = Min(L, L_v \sin\phi)$$

Φ represents the wind angle.

Urban Street Canyon Model- OSPM

3. Calculate traffic turbulence and combined turbulence using the following expressions:

$$\sigma_{wo} = b\left(\frac{V_c N_c S_c^2 + V_h N_h S_h^2}{l}\right)^{0.5}$$

$$\sigma_w = \sqrt{(0.1 U_b)^2 + \sigma_{wo}^2}$$

Urban Street Canyon Model- OSPM

Where b is aerodynamic drag coefficient , Vc and Vh are avg driving speeds for cars and heavy vehicles, Nc and Nh are the traffic intensities for cars and heavy vehicles and Sc2 and Sh2 are avg horizontal areas.

Ub represents the wind speed at street level and is a logarithmic function of the roof level wind speed given by the expression

$$U_b = U \left(\frac{\ln\left(\frac{h_0}{z_0}\right)}{\ln\left(\frac{H}{z_0}\right)} \right) (1 - 0.2 \sin \phi)$$

Urban Street Canyon Model- OSPM

4. Calculate length of slant edge (Ls) and vent velocity (Ud) using the following expressions:

$$L_s = \left((0.5 L_r)^2 + H_b \right)^2$$

$$U_d = \sqrt{(U_b)^2 + \sigma_{wo}^2}$$

Urban Street Canyon Model- OSPM

4. Calculate Cd and Cr using the following expressions:

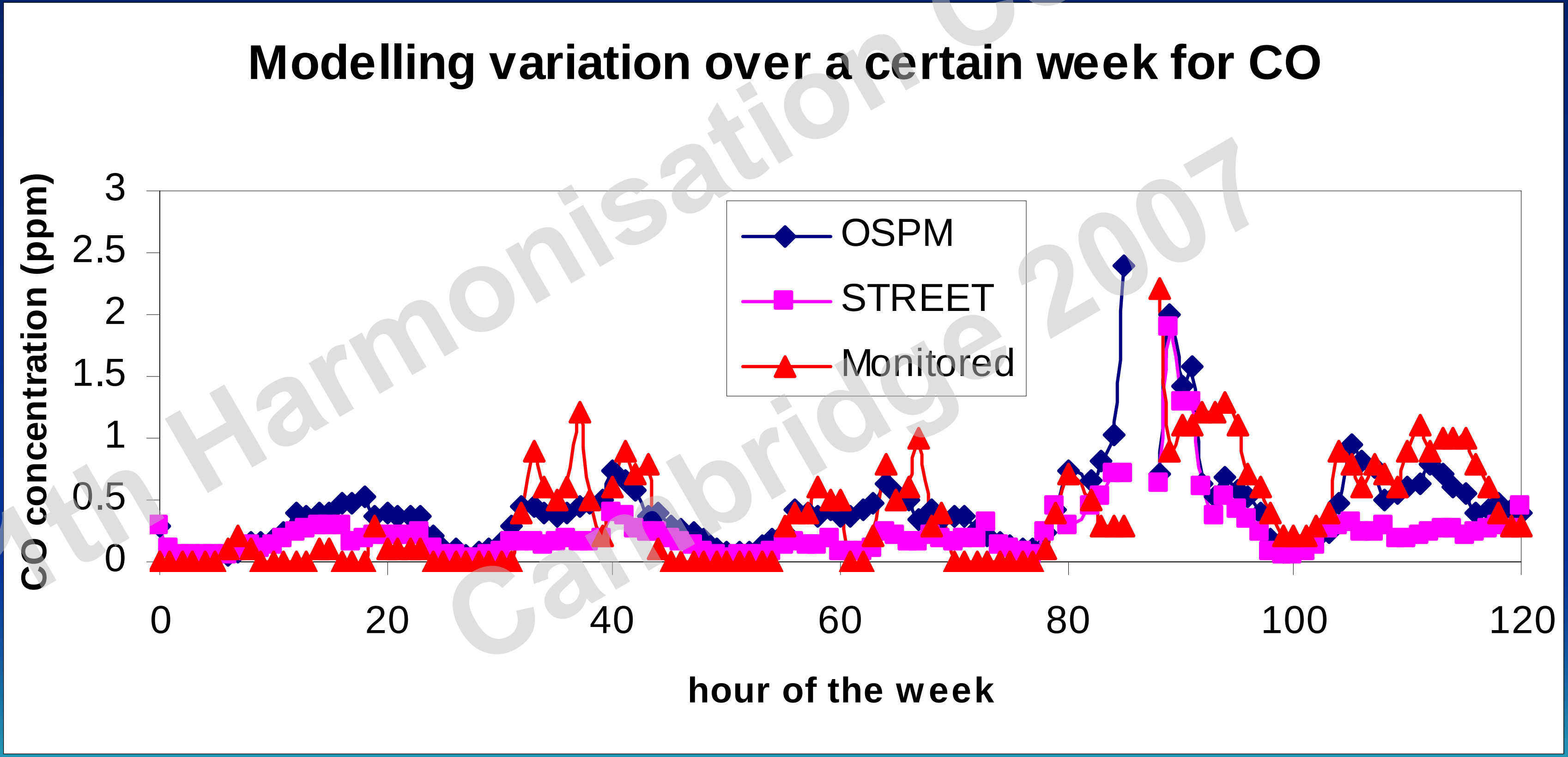
$$C_d = \sqrt{\frac{2}{\pi}}\frac{1}{U_b}\sum_i \frac{Q}{\left[h_0 + \left(\sigma_w / u_b\right) x_i\right]}$$

$$C_r = \left(\frac{Q L_r}{L \sigma_{wt} (0.5L + U_d L_s)}\right)$$

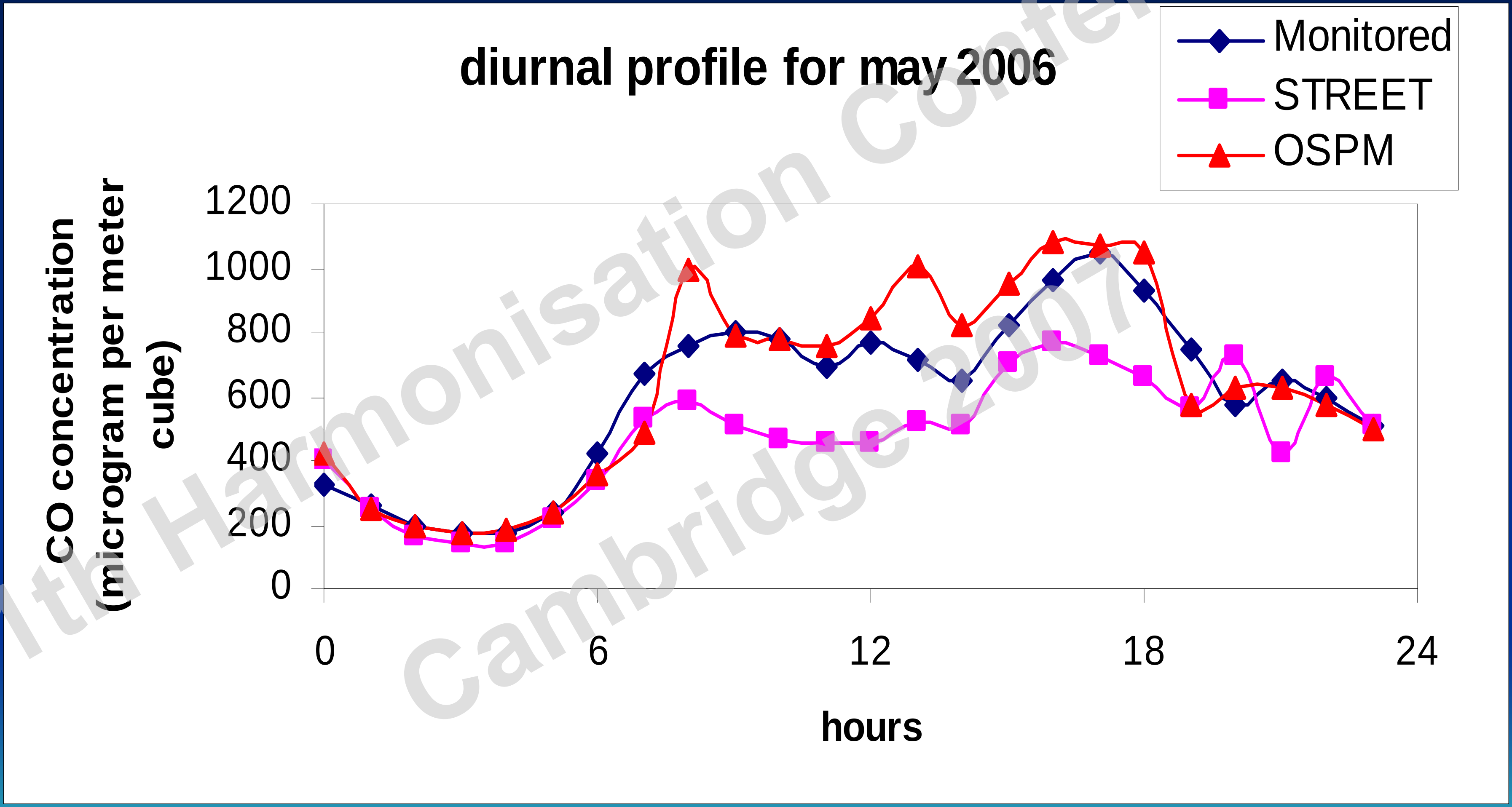
Input data for the street canyon models.

- Hourly vehicle flow.(2000-2500vehicles/day, 10% HDV)
- Vehicle speed. (35km/hr at night time and 15 km/hr at day time)
- Emission factors (CO: 2.59 at daytime and 1.30 at nighttimes, NOx:0.75 at daytime and 0.52 night time)
- Meteorological data- wind speed and wind direction.
- Road characteristics- (x=6m, z=1, H=16m, W=21m, L=21m)
- Background concentrations obtained from a Dublin City Council for a similar site as the study site.

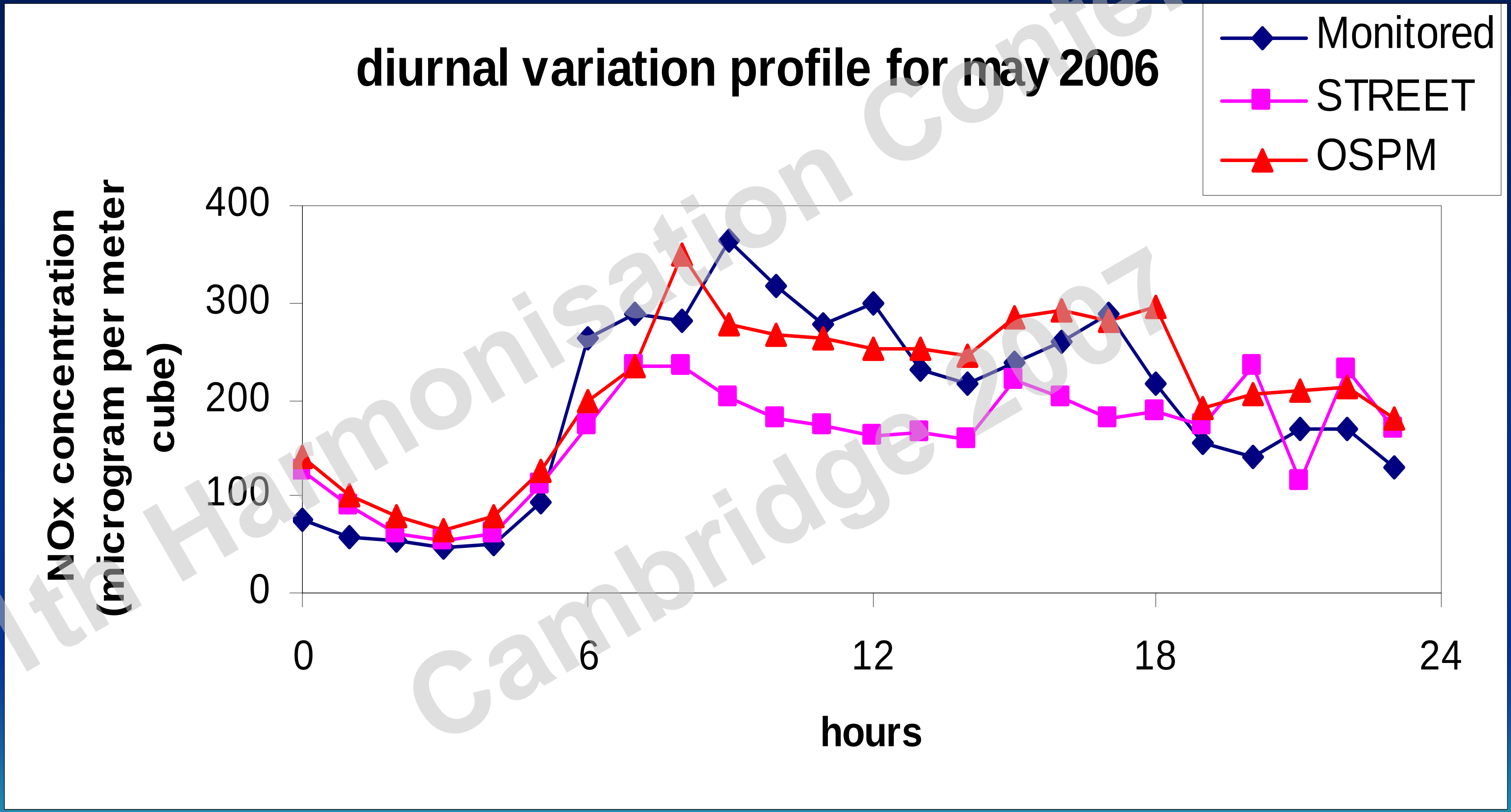
Variation profile for a certain week for CO



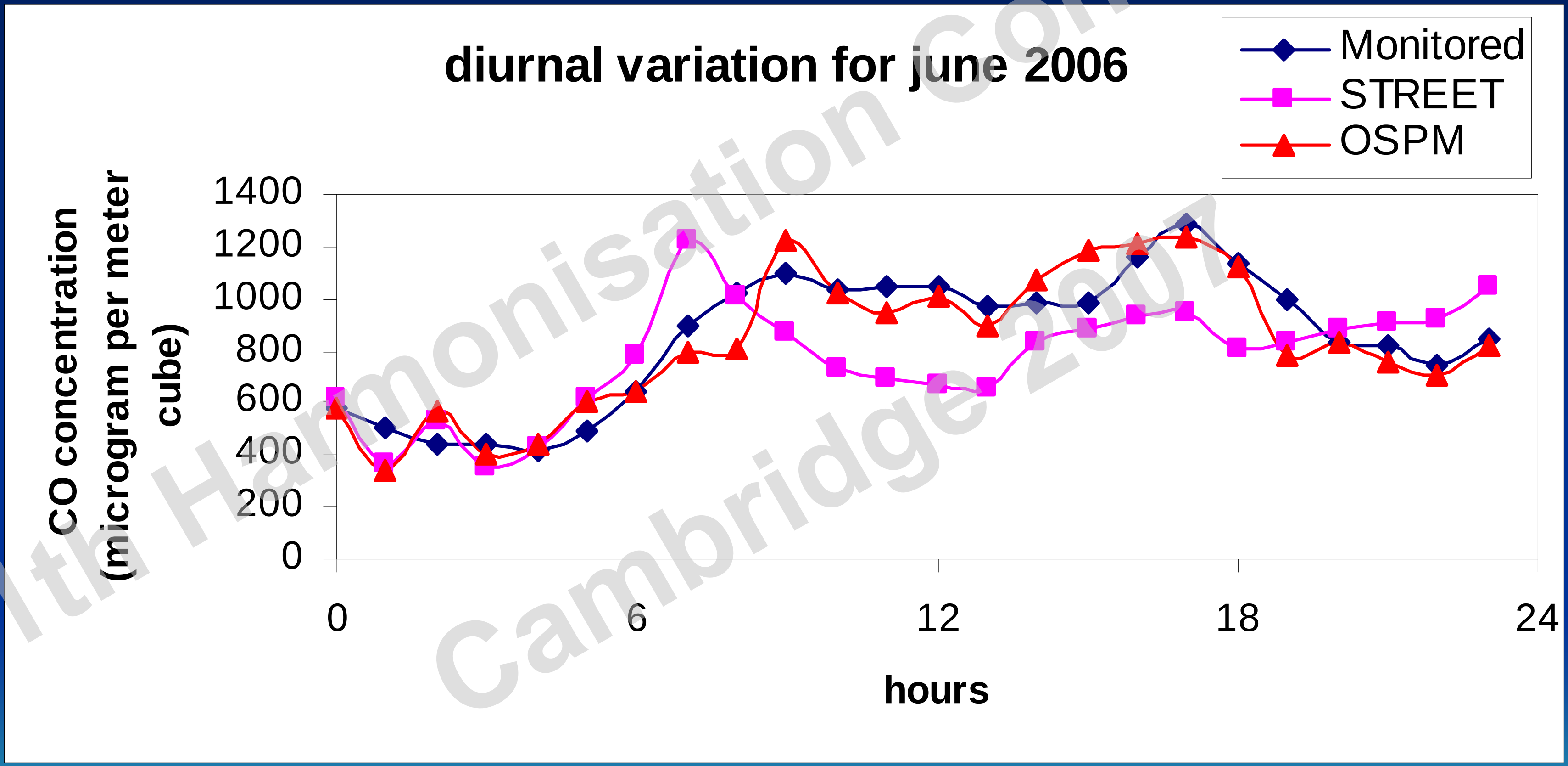
Diurnal profile on Pearse Street for CO (May-06)



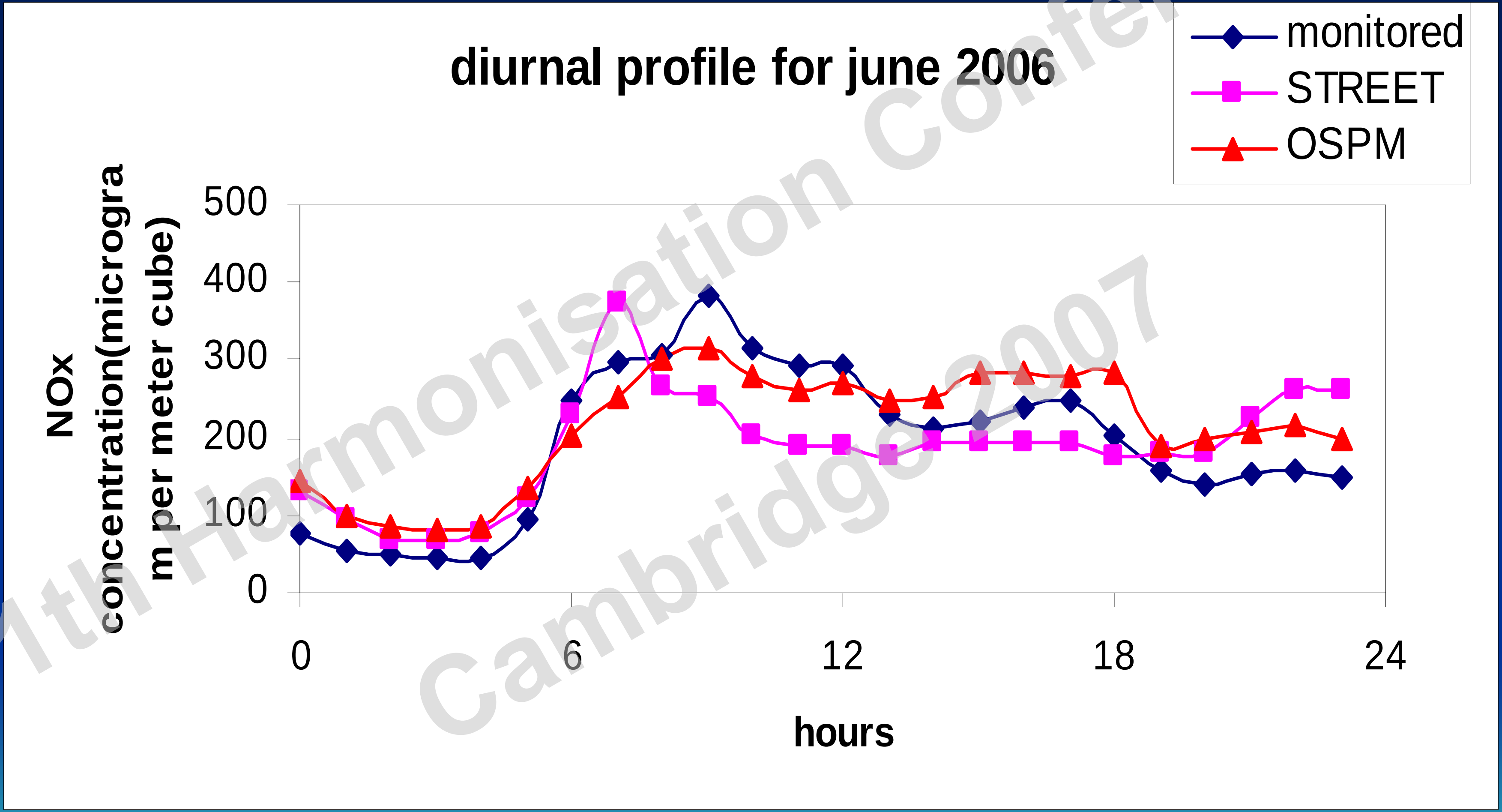
Diurnal profile on Pearse Street for NOx (May-06)



Diurnal profile on Pearse Street for CO (June-06)



Diurnal profile on Pearse Street for NOx (June-06)



Results on Pearse Street.

- Statistical Analysis of Monitored and Predicted data (May)

	CO			NOx		
Parameter	Monitor	STREET	OSPM	Monitor	STREET	OSPM
Mean	596.7	479.7	643.5	195	163	212
IA	1	0.80	0.92	1	0.67	0.85
NMSE	0	0.12	0.03	0	0.18	0.06
R	1	0.86	0.94	1	0.72	0.88
FB	0	-0.23	0.06	0	-0.18	0.08
F2(%)	100	100	100	100	100	100

Results on Pearse Street.

- Statistical Analysis of Monitored and Predicted data (June)

	CO			NOx		
Parameter	Monitor	STREET	OSPM	Monitor	STREET	OSPM
Mean	854.1	772.2	830.7	192	187	214
IA	1	0.68	0.92	1	0.75	0.85
NMSE	0	0.07	0.01	0	0.12	0.05
R	1	0.64	0.92	1	0.72	0.92
FB	0	-0.09	-0.02	0	-0.02	0.11
F2(%)	100	100	100	100	100	100

Conclusions

- Two street canyon models, STREET and OSPM has been discussed and presented.
- Both models give sufficiently good results in predicting the CO and NOx concentrations on a busy, often congested street in Dublin.
- The performance of OSPM is better than STREET, as would have been expected

Conclusions

- The STREET model remains reasonably accurate in spite of its simplistic approach which allows it to be readily incorporated into transport network models of other areas.

- The modelling assessments were performed using two months data set. A detailed study set under one years study set is under progress.

Acknowledgement.

- This work has been completed under the Environment Transport Interface (ETI) project funded by the ERTDI Research Programme which is managed by the Irish EPA and forms part of the National Development Plan.

Thank You