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FLOW AND DISPERSION MODELLING STUDY AT ONE OF DENMARKS TRAFFIC HOT-SPOTS

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Abstract: This study aims to investigate in details the pollution situation near one of Denmark's NO_2 hot-spots, the monitoring station at H.C. Andersens Boulevard (HCAB) in Copenhagen. The investigations cover various elements as detailed traffic counts in each of the 7 traffic lanes; wind speed measurements both at a nearby roof station and inside the street canyon and measurements at different locations in the street additional to the main monitoring station. Moreover the study contributes to a further development of the Operational Street Pollution Model (OSPM) that allows handling the inhomogeneous distribution of the emissions over the various lanes and the positioning of the receptor location further away from the buildings. The presentation will give an overview of the study and show the main results and conclusions derived from this comprehensive project.

Key words: *Street scale air pollution, OSPM*

INTRODUCTION

HCAB is a street station in the Danish National Monitoring Programme and presently the only monitoring station where the EU limit value for NO_2 is exceeded. This exceedance triggered a lot of interest and research connected with this station. Previously the Danish EPA funded a measuring campaign over several month with a parallel station moved about 3 m further away from the traffic compared to the permanent station (Ellermann et al. 2014). These parallel measurements indicated a relatively large difference of 10 µg/m^3 (18%) between these two locations just 3 m apart.

In order to investigate these small scale air pollution gradients in more details and develop methods to describe these gradients better with OSPM, a new project has been initiated.

The project results help gain a deeper understanding of the complex dispersion situation near HCAB and key findings of the various project elements will be presented. The newly implemented features in OSPM give a much better possibility to describe the measured pollution levels and gradients.

METHODOLOGY

The location of the permanent monitoring station at HCAB close to the 7 traffic lanes is shown in Figure 1. The here-described investigation includes the following experimental elements:

- Concentration measurements using passive samplers and small mobile sensors arranged in horizontal profiles along and perpendicular to street orientation to investigate the gradients in NO_2 concentrations (not reported here)
- Detailed traffic counts and emission modelling in all 7 driving lanes
- Meteorological measurements using sonic anemometers both in the street canon and at the roof top.

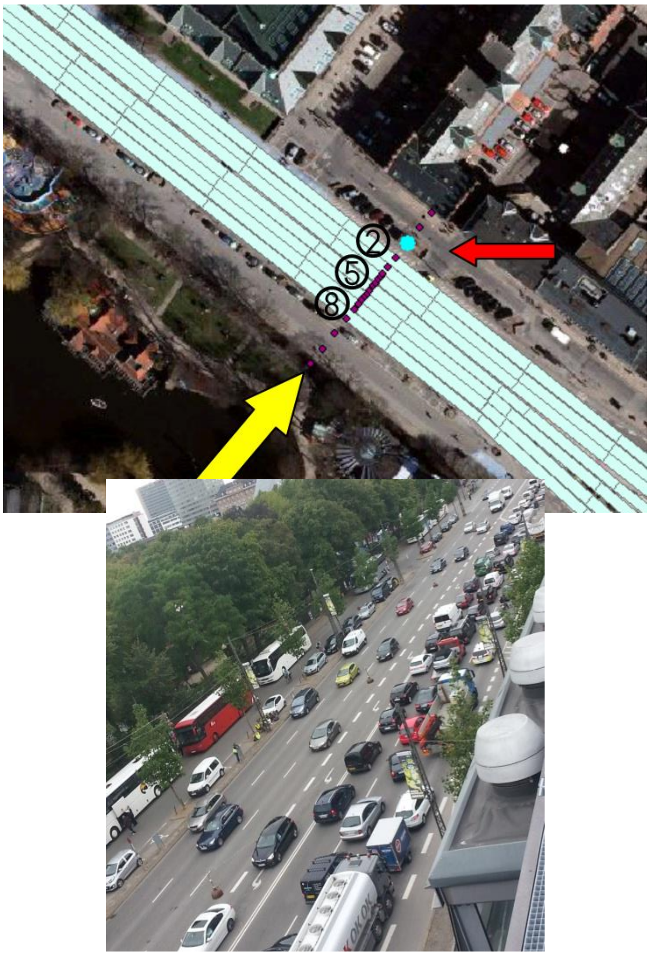

Figure 1. Map of the location of the measuring station H.C. Andersens Boulevard (read arrow) and the 7 traffic lanes close to it. The cross section for traffic counts and the lane numbering are marked. Lane No.5 is a left exit only lane. The photo on the right side is taken from the roof, close to the red arrow, and shows the traffic lanes but the monitoring station on the right side is hidden.

Based on these experimental inputs as well as previous work conducted by Ottosen at al. (2015) and the suggestions for improvement listed in Kakosimos et al. (2010), this project also includes a further development of OSPM as: the operational implementation of the inhomogeneous distribution of the emissions in-between different driving lanes and enable a variable horizontal positioning of the modelled receptor point between building wall and driving lanes in case of very wide sidewalks or bike lanes as shown in Figure1.

RESULTS

Some first results from this comprehensive project are given below. Figure1 shows the results from the detailed traffic counts and the estimated NOx emissions. The also counted bike/parking lanes are also counted but omitted here due to the negligible NOx emissions. The left-turn lane in the middle has as expected lowest emissions traffic and emissions. The outer driving lanes most to the right (No. 2 and 8) are less frequently used by passenger cars and more frequently used by buses and trucks compared to the rest of the lanes. Due to the higher heavy duty share those outer lanes have highest NOx emissions.

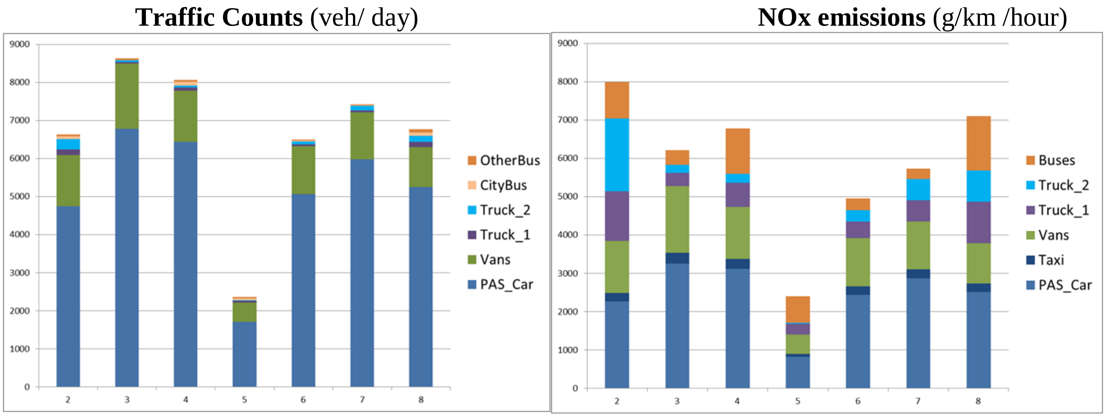

Figure 2 Left panel: Detailed traffic counts at the 7 driving lanes at HCAB. Lane 2 is closest to the monitoring station; lane 5 is the left-turn lane, see Figure1. Right panel: Average emissions of NOx per lane and vehicle class.

The above mentioned parallel measurements at HCAB in 2014 (Ellermann et al., 2014) have been reanalysed with respect to wind direction. Figure 3 shows the NOx concentration at the two stations with respect to wind direction. This kind of plot has been shown as an important indicator for model evaluation (Ketzel et al. 2012). The relative difference between the concentrations measured at the two stations is larger for the wind directions around 30 compared to 210. For wind direction 30 the stations are located at the so-called leeward side of the buildings along the street and affected by the well-known recirculation vortex. In Figure 2 modelled concentration are plotted as well using the standard OSPM (not taking into account the positioning of the driving lanes and assuming homogenous distribution of the emissions). The results seem to follow much better the measurements from the station2 that was moved 3 m further away from the traffic indicating that especially the elevated concentrations around wind directions 0…90 are underestimated for station1.

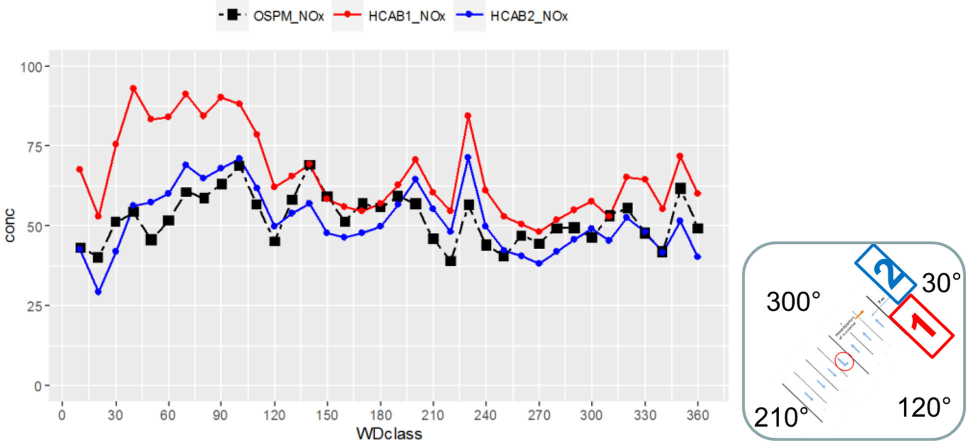

Figure 3 Mean concentrations of NOx and OSPM model results as a function of wind direction (measured at urban background station) in observation period (8/2 – 23/6 2014) with the two parallel stations at HCAB. The sketch on the right indicates the parallel / perpendicular wind directions with respect to the street orientation of HCAB and the position of the station2 3 meter further away from traffic.

In order to test the new developed OSPM version (Ottosen, 2016) that is able to account for inhomogeneous distribution of the emissions a sensitivity study was performed. The test aims at validating the wind direction dependence of the concentrations under the conditions at HCAB and for the sake of simplicity constant emissions and wind speed is assumed and only wind direction is changed. Results are given in Figure 4 and confirm qualitatively that the model is able to reproduce the increase in concentrations due to a 3 m shift in emissions. The increase in concentrations due to the shift is especially pronounces for wind directions 30…90 replicating a similar behavior as observed in the measurements in Figure 3.

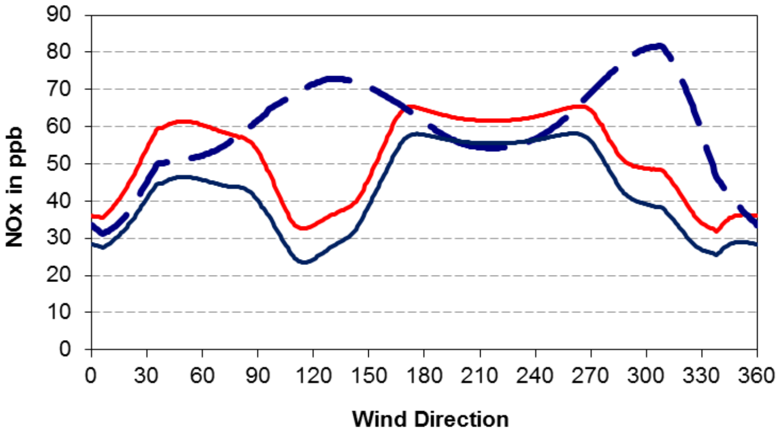

Figure 4 Sensitivity study using new developed version of OSPM. Dashed line: Standard OSPM with homogeneous emissions. Solid blue line: limit emissions to the seven traffic lanes using correct geometry. Solid red line: Assuming non-homogeneous emissions and moving traffic/emissions 3 m closer to the receptor.

CONCLUSION

Measurements at HCAB have shown high spatial gradients both in earlier campaigns in 2014.
We have gained new insights in the difference measured at two stations by reanalysing the results and plotting against roof wind direction.

For the first time detailed traffic counts and emission estimated per driving lane were obtained. The new OSPM version accounting for in-homogeneous distribution of the emissions is giving a promising first qualitative agreement with the observations.

Future work has to be done implementing a shift of the receptor point (instead emissions) into OSPM.

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