Air quality measurements by two airboxes in the city of Amsterdam

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Introduction

During the measurement campaign, two airboxes were measuring in Amsterdam. These airboxes measure NO_2 and particulate matter (in three different classes PM_{10}, particles smaller than 10 µm, $PM_{2.5}$ and PM_1). One of the airboxes was placed on a relatively busy connecting road in Amsterdam: Valkenburgerstraat. The other one was placed in a much quieter side street of the Valkenburgerstraat: Rapenburg. Both airboxes were mounted on lampposts on the side of the street. The airboxes were measuring from the 6th of July 2016 until the 7th of September 2016. The data are collected at 10 minute intervals.

The main source of NO_2 in urban areas comes from mobile combustion (traffic on road and water). During this combustion NO is formed, which is rapidly oxidized to NO_2 by reaction with ozone (O_3). When there is sunlight a photochemical reaction takes place and NO_2 is decomposed back to NO and O_3. During the day, therefore a balance is formed between these two reactions. However, during the night with the lack of sunlight all NO reacts with available O_3 to form NO_2.

Traffic is also an important source for particulate matter. Also resuspension of road dust and soils is an important source of particulate matter, especially in summer months (Harrison et al., 1997).

Setup

Location

Figure 1 shows the location of the two airboxes. Airbox (a) was located on the Valkenburgerstraat near housenumber 66. On this location the GGD Amsterdam also had a passive sampler to measure the concentration of NO_2 every month. The other airbox (b) is located on the Rapenburg near housenumber 99.

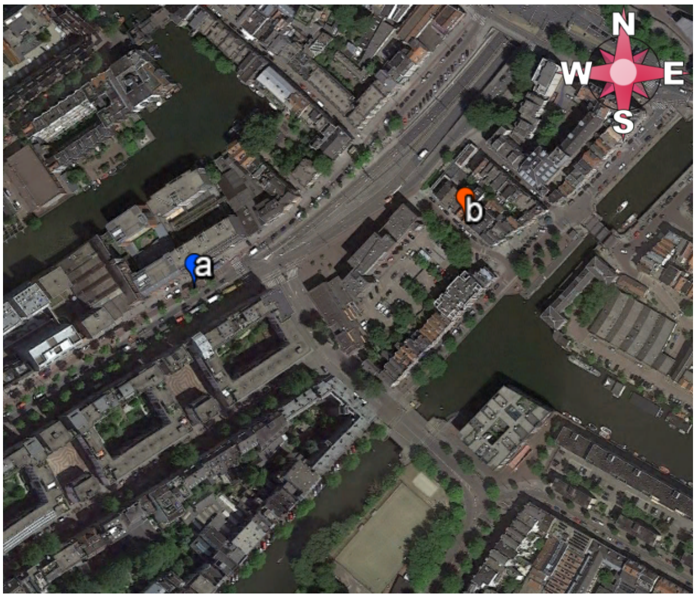

Figure 1: Measurement location of the two airboxes in Amsterdam, where a is the airbox on the Valkenburgerstraat and b the one on the Rapenburg.

Figure 2 shows the location of the two airboxes in more detail. From this figure you can immediately tell that in the Valkenburgerstraat there is much more traffic than in the Rapenburg. The location Valkenburgerstraat also has apartment blocks of 6 stories high on both sides. The lamppost on which the airbox was mounted was relatively close to road. The Rapenburg has houses on one side of the street only, which are about 4 stories high.

Figure 2: Location of the two airboxes with in red the lamppost on which they were mounted for Valkenburgerstraat (a) and Rapenburg (b).

Calibration

The NO_2 sensors of the airboxes were calibrated by comparing one month of measurements on the Valkenburgerstraat with that of the passive sampler measurements for that month. Unfortunately, no passive sampler was present on the Rapenburg. Thus we used the factor found on the Valkenburgerstraat also on the Rapenburg. From experience we know that the NO_2 sensors are comparable to one another, therefore we do not expect a very different calibration factor on the Rapenburg.

The PM sensors of the two airboxes were normalized with one another at the ECN terrain. For a period the airboxes were mounted next to one another. The normalization ensure that the PM concentrations measured by the two airboxes can be compared to one another. However, it is not a direct calibration of the sensors, thus it is possible that there is an offset between the measurements of the airboxes and the actual PM concentrations (as measured by a reference instrument).

Results

Figure 3 shows the time series of NO_2. From this figure it is clear that the NO_2 concentrations are in general higher on the Valkenburgerstraat than on the Rapenburg. With the much busier traffic on the Valkenburgerstraat this is to be expected.

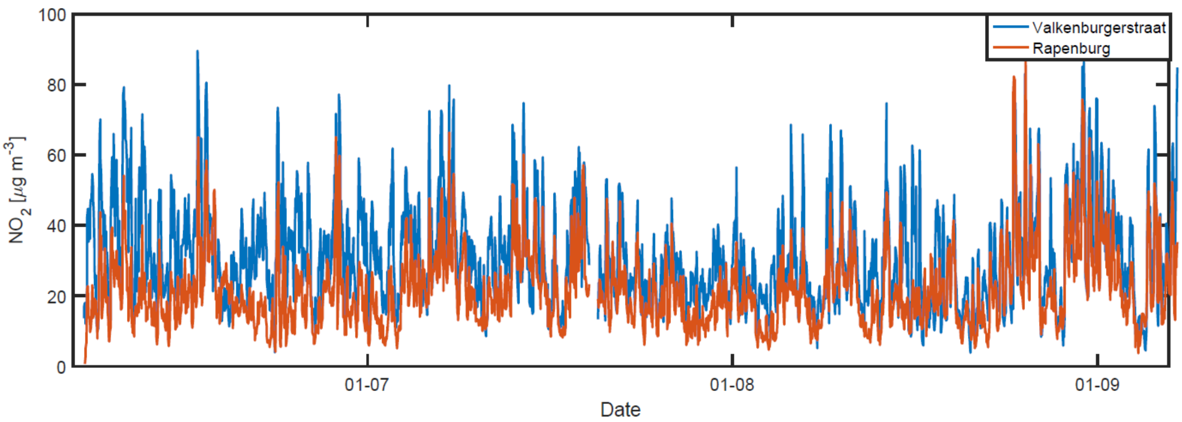

Figure 3: Time series of NO_2 for the complete measurement period.

Figure 4 shows the complete time series of PM_{10}. Also for PM_{10} the concentration are higher on the Valkenburgerstraat than on the Rapenburg. The pattern of PM_{10} concentrations is very similar for the two measurement locations. The very extreme value in mid-August, lasting several hours, is not well understood. It may be due to reconstruction work nearby but we do not have information about this.

The time series of $PM_{2.5}$ and PM_1 are not shown here, but the general picture of these quantities are the same as that of PM_{10}. With slightly higher concentrations for the Valkenburgerstraat than those on the Rapenburg. And a very similar pattern for the two measurement locations.

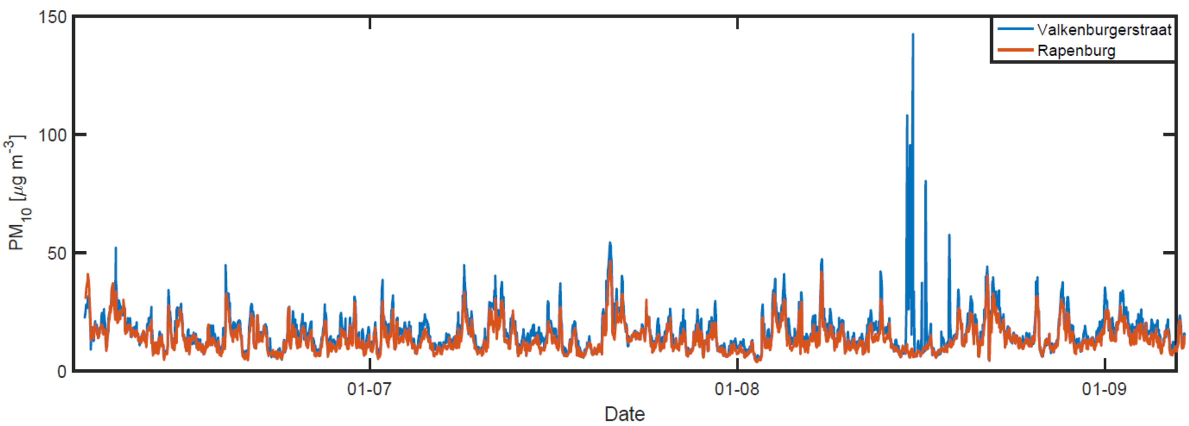

Figure 4: Time series of PM_{10} for the complete measurement period.

Another way to get a good overview of the variability of the data is by looking at box plots. The box plot for NO_2 is plotted in Figure 5. The difference between the two data set is clearly visible with higher NO_2 concentrations at the Valkenburgerstraat. Also the whiskers are bigger for the Valkenburgestraat than the Rapenburg, indicating more variation in the NO_2 concentrations.

A box plot is a graphical way to display the distribution of data. It is useful to quickly get insight in the distribution of different datasets. The red line in the box plot represents de median of the data (i.e., the middle value of a dataset). The blue box around the red line represent the points that cover 50% of the data (i.e. 25% quartiles). The dotted lines (also known as whiskers) indicate 99.3% coverage of the data. Lastly, the red crosses indicate the outliers.

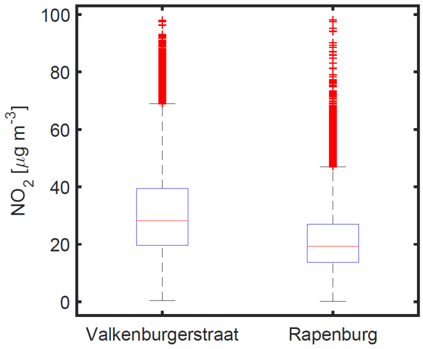

Figure 5: Box plot of the NO_2 data set for the Valkenburgerstraat and Rapenburg.

Figure 6 shows the box plots for particulate matter. From this figure it is clear that for all particulate matter classifications the concentrations at the Valkenburgerstraat are slightly higher. This is the case for the median, but also for the quartiles, whiskers and outliers.

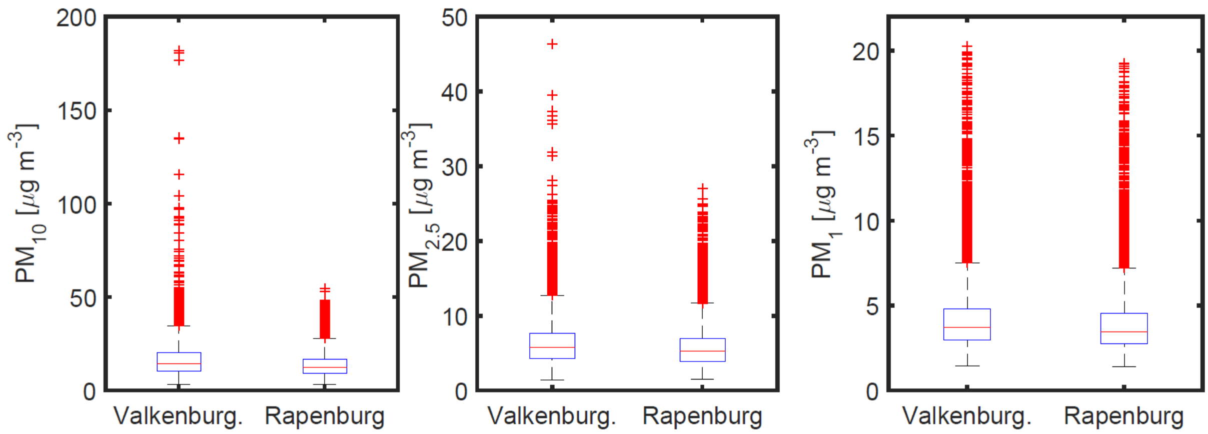

Figure 6: Box plot of the PM_{10} , $PM_{2.5}$ and PM_1 data set for the Valkenburgerstraat and Rapenburg.

Figure 7a shows a one week time series of NO_2 measured with the airboxes as well as the measurements done at the GGD station at the Vondelpark in Amsterdam. It is clear that the pattern of the airbox NO_2 measurements are rather similar to the GGD station. The values of the LML stations are in general comparable to those on the Rapenburg, which is to be expected since the Vondelpark station is like the Rapenburg a reasonably quiet (background) location.

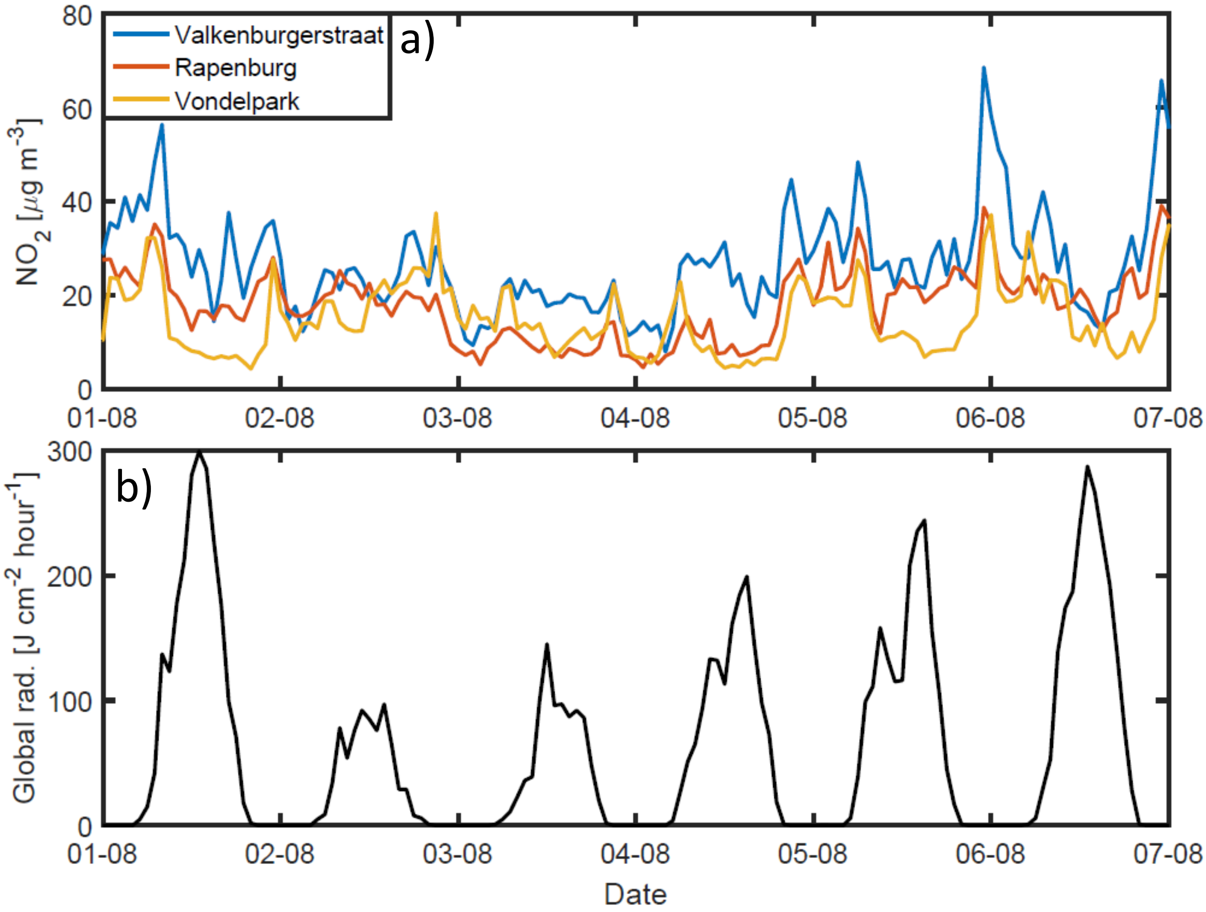

Figure 7: Time series of the NO_2 concentrations of the airboxes at Valkenburgerstraat and Rapenburg as well as measurements at the Vondelpark station (a). Time series of the global radiation measured at Schiphol by the KNMI (b).

Besides the NO_2 also the global radiation measured at Schiphol airport by the KNMI (Royal Netherlands Meteorological Institute) is shown in Figure 7. The global radiation is an indication for the amount of sunlight, the higher the concentration the more sunlight is received. On the 5th and the 6th of Augusts the global radiation is relatively high, on these day the sun was shining. For both of these days the concentrations of NO_2 increases rapidly at the end of the evening beginning of the night. This is probably caused by the photochemical reactions that occur during the day that suppresses the formation of NO_2. During the night with the lack of sunlight and no longer photochemical reactions the NO_2 is formed from NO and O_3.

To investigate the daily development the average daily cycle of NO_2 and PM_{10} are plotted in Figure 8 and 9. For NO_2 a clear daily cycle is visible with a clear peak around 9 o'clock, which is caused by the traffic rush hour. There is no clear peak visible for the rush hour in the evening. This is probably caused by the photochemical reaction that transforms NO_2 in NO and O_3. For these summer months the sun is still shining during the evening rush hour. The increase of the NO_2 concentration later in the evening also supports this hypothesis. The NO and O_3 that was formed under the influence of sunlight is again transformed into NO_2 in the late evening.

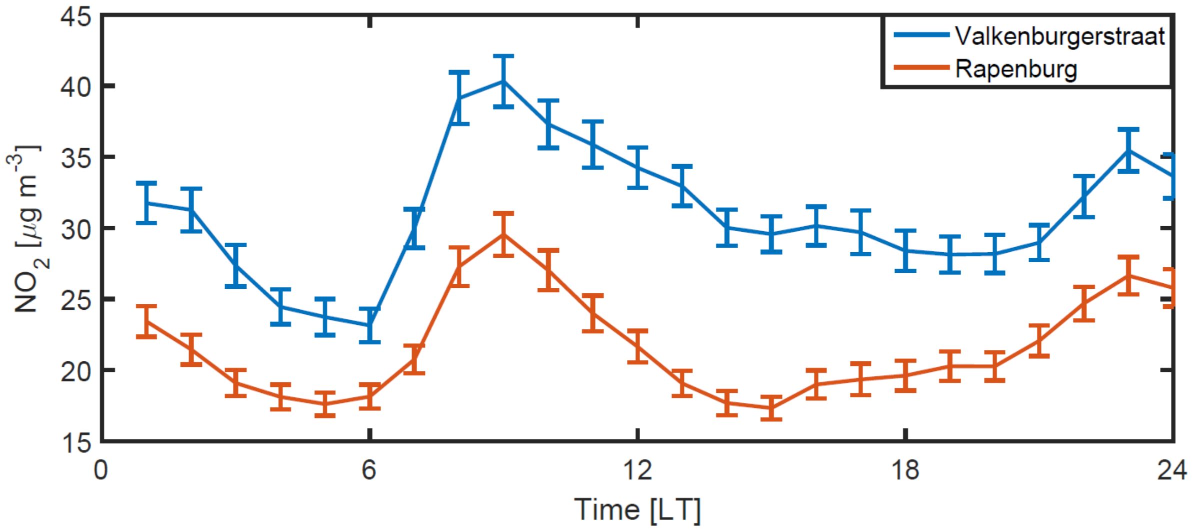

Figure 8: Average daily cycle of NO_2 concentration including the error bar.

PM_{10} shows a less prominent daily cycle as NO_2. The concentration of PM_{10} is in general higher during the night than during the day. This is due to the daily change of the atmospheric boundary layer, the layer influenced by the earth's surface. During the day, the boundary-layer height grows due to the incoming sunlight. For pollutants the boundary-layer height represents the height till which they can mix in the atmosphere. Obviously, with the same amount of emissions concentrations will be higher when the boundary-layer height is lower, since the volume in which the pollutants reside is less.

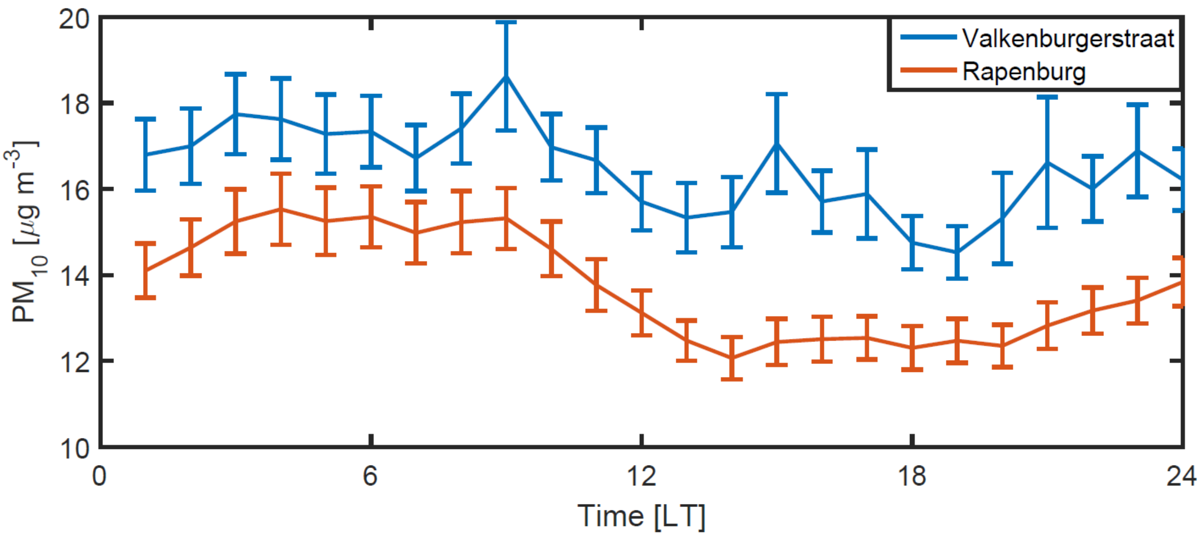

Figure 9: Average daily cycle of PM_{10} concentration including the error bar.

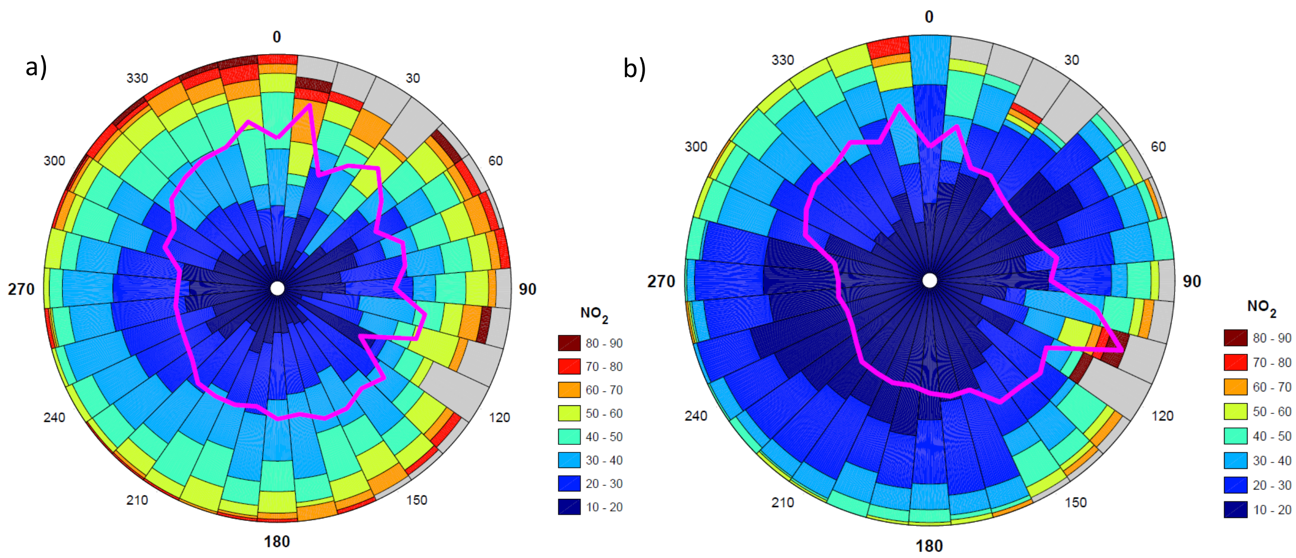

Figure 10: Wind roses of the NO_2 concentrations, with the wind direction taken from the Schiphol data gathered by the KNMI for the Valkenburgerstraat (a) and Rapenburg (b). The average NO_2 concentration per wind direction is plotted in magenta.

Another way to look at the data is by plotting wind roses, which indicate what the wind direction is when certain concentrations are measured. The wind roses for NO_2 are plotted in Figure 10. For the Valkenburgerstraat the wind rose has a relatively even distribution along the different wind directions, with slightly increased values from the North. The evenly distribution, is to be expected since in the Valkenburgerstraat the source of NO_2 of traffic is very close by.

For the Rapenburg there is a difference visible for the different wind directions. High NO_2 concentrations are mainly measured from north northeast (NNE) and east southeast (ESE). For NNE the source is probably the traffic on the Valkenburgerstraat. The peak from the ESE is probably caused by boats on the nearby canal.

Conclusions

The airboxes clearly measure the difference in concentration in NO_2 and PM_{10} between the Valkenburgerstraat and Rapenburg. For both components the concentrations on the Valkenburgerstraat are higher than those on the Rapenburg, which is expected since there is much more traffic on the Valkenburgerstraat. The difference between the two airboxes is more distinguishable for NO_2 than for particulate matter, since traffic is a direct source of NO_2. For PM traffic is barely a direct source, however indirectly it can cause resuspension of PM.

The measurements of the airboxes compare well with those of the Vondelparkstation (of GGD). For NO_2 the concentrations at Vondelpark agree rather well with the Rapenburg station, which is expected since both location are rather quite. Also for PM_{10} the Vondelpark station and Rapenburg airbox showed similar patterns and concentrations (not shown in this report). A direct comparison (one on one) between the LML station and the air boxes has no added value, since the measurements are too far apart from one another (around 3 km).

The daily cycle from NO_2 clearly shows a peak in the morning during the rush hour. In the evening a peak in NO_2 during rush hour is not visible, probably caused by the photochemical reaction which transforms NO_2 into NO and O_3. During the winter months such a peak in NO_2 during evening rush hour should be visible.

For PM_{10} there is no clear daily cycle present, both rush hours do not cause a peak. This is probably caused by the fact that traffic is not a direct source of PM. The influence of the boundary-layer height is visible for PM_{10}, with higher concentrations during the night than during the day.

The wind rose of the NO_2 measurements at the Rapenburg shows that both the traffic on the Valkenburgerstraat as well as the boat traffic on the canal acts as a source of NO_2. To investigate this in more detail wind measurement directly on the airbox location are necessary. The wind measured at Schiphol by the KNMI only gives a general idea of the wind direction, but in the urban area in Amsterdam local wind conditions can easily differ.

Literature

Harrison, R. M., A. R. Deacon, M. R. Jones, and R. S. Appleby, 1997: Sources and Processes affecting concentrations of PM10 and PM2.5 particulate matter in Birmingham (UK). *Atmos. Environ.*, **31**, 4103–4117.