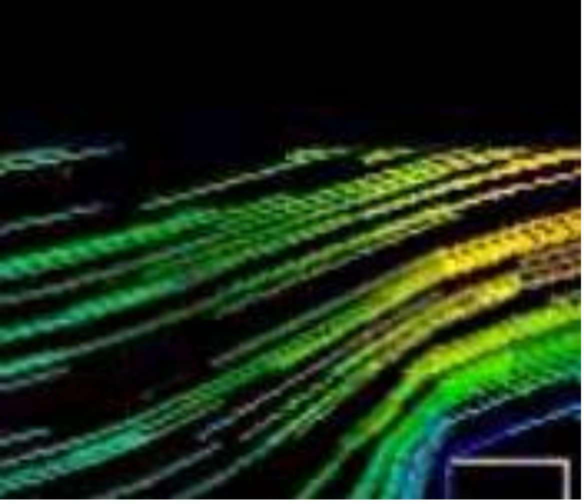
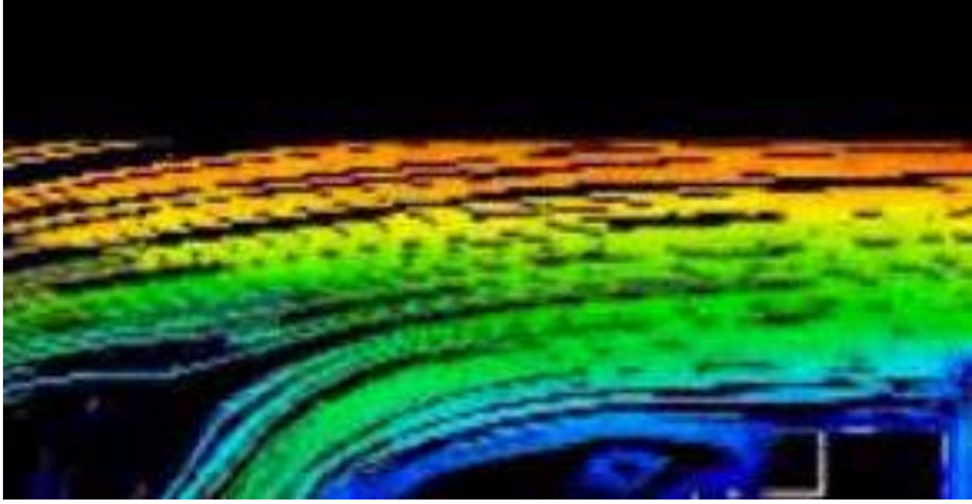
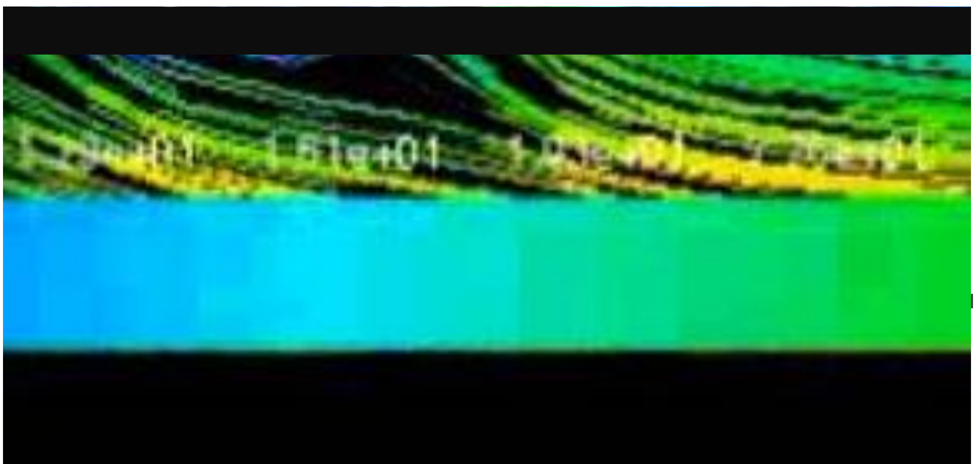



Urban parks and air pollution reduction: does location matter?

Thesis Report LUP- 80436
Fisqa Tasyara

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Urban Parks and Air Pollution Reduction: Does location matters?

an example of spatial modelling for park allocation analysis

Thesis Report LUP-80436 - Fisqa Tasyara

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Fisqa Tasyara

List of Content

Summary

Air pollution has been a recurring nightmare for urban citizen and government because of the health hazard it has. Urban parks are considered to have a high potential to reduce air pollution because of their proximity to people (by which they can benefit the public directly) and can be provided locally in urban ecosystems.

However, different parks affect air quality differently because they have different green coverage (i.e. leaf area density), different shape, and or different size. One other factor that is less researched is different locations in relation to the pollution source and concentration of people, and to the wind directions. When planners and decision-makers work under the assumption that people can and will always go to parks, then there is no pressing problem about parks allocation other than users' accessibility. However, most people spend up to 50% of their life in and around their home. This leads to a challenge for planners and urban designers of where to locate a park to ensure clean air for the people and to the questions of this research.

The main research question answered by this research is:

What is the effect of a park's location on the spatial pattern of air pollution dispersion from its source to place of habitation?

The question was answered by analysing the NO_2 dispersion in two existing areas in Rotterdam with parks at varying locations. Real case was selected to be used in this research to provide an example of spatial modelling in the analysis as could be done in real spatial planning practice.

The air pollution dispersion was generated through computer simulations that provide the spatial pattern of NO_2 concentrations, which indicate the dispersion of the pollutant. What meant by air pollution dispersion here is the NO_2 dispersion as indicated by the pattern of the concentrations in two case areas in Rotterdam. NO_2 was selected as the indicator as it is the most common pollutant found in the air, and it also acts as an indicator of other pollutants (i.e. when there is a high amount of NO_2 in an area, there is also a high possibility of tropospheric ozone, nitrate aerosols, and $PM_{2.5}$.

The research was done with a scenario approach, which in this case is referred as 'configurations'. The first scenario (or in this case configurations) the parks were at the existing locations, the second was with the park in the relatively favourable locations, and the last was when the parks are in the relatively unfavourable locations. The dependent variable was the spatial pattern of the NO_2 dispersion. The parameters in this experiment were the meteorological conditions and the pollution sources as seen in the table on the screen.

The program used to generate the NO_2 dispersion was the ENVI-Met. The program set was developed as computer simulation for urban heat, but in its development it also included dispersion and deposition model to simulate the dynamic behaviour of particles and inert gases.

The research was done using the urban configuration of Rotterdam, which was selected because it had the highest pollution level in the Netherlands (in 2012, based on the Numbeo Pollution index). Two sample areas from two regions in Rotterdam were used in the simulation. The first was from Rotterdam Centrum and the second was from Charlois. The areas were selected because there are pollution measuring units in the area and because of their vulnerability to air pollution. The simulation was ran using a 750x750m, or a 150x150grid map. The simulations were planned to be done for larger areas, but this turned out to be overcomplicated for the ENVIMet software and the hardware used in this research.

Nevertheless, the case areas still included major roads and smaller roads (as pollution sources), habitation areas, and parks. The maps obtained from the Municipality of Rotterdam were converted to ENVI-Met maps. The parks were located in these locations, and the habitation areas are located in these locations. The roads were used as the line source of NO2 with the configuration.

The locations for the favourable and unfavourable were selected based on the simulation outcomes of the current situation. In general, it applies that the more favourable location is at the downwind from a pollution source and at the upwind of habitation area while the unfavourable is the opposite. The size of the location was also taken into consideration to avoid large physical change in the relocated parks. This measure was taken to ensure that the park's locations were the only variable changed.

Each configuration was run for two different meteorological and emission condition in March 15 2012 (spring) and at September 15 2012 (autumn) so that in total, 12 simulations were done. The results of the simulations for each season were compared to see the effect of the parks at different locations. Next, I will explain the results of the simulations. Because of the time constraint of this presentation, I will only show and explain the horizontal dispersion at 2m and I will explain the spatial pattern of the NO_2 with the three configuration while explaining the differences between them. First are the spatial patterns of the NO_2 dispersion in Rotterdam Centrum, after that I will explain about the spatial patterns in Charlois.

Effect of parks' locations to air pollution dispersion

There were obvious differences between the spatial patterns of NO_2 dispersion in the three configurations. Most of the differences in can be explained by the reduction in wind speed and the different local wind direction caused by the different locations of parks. The effect of a park's location on the spatial pattern of air pollution dispersion from its source into place of habitation in this research can be summarized into three main effects;

1. to the direction of dispersion,
2. to the NO_2 concentration at the parks' vicinity, and
3. to the NO_2 concentration at the downwind (at a distance) from the parks.

The parks in this research altered the spatial pattern of NO_2 dispersion in the case areas when they were located in different locations because they received the NO_2 at different angles, and because they changed the wind flow (speed and direction) in the case areas. There was different emission level in spring and autumn in both case areas. However, the differences in maximum concentration level observed in the simulation result were larger than the emission difference. This suggested that the configurations had stronger effect to NO_2 concentration increase/decrease than the emission level.

Conclusion

The results showed that park's location does affect the spatial pattern of air pollution even though the difference was only between 5 and 30µg/m^3. The effect was more obvious in dense area such as Charlois where the different park locations showed more diverse effect to NO_2 dispersion pattern. The favourable locations selected in this research didn't always provide positive result. In Rotterdam Centrum, the result was supporting to the more favourable locations with the hospital getting less exposure to NO_2 when the parks were located in the more favourable location. When the parks were located in the less favourable locations, most of the habitation areas were exposed to NO_2. On the other hand, the lowest NO_2 concentration in Charlois was achieved when the parks were located in the less favourable locations.

The results of this research support the notion about the importance of analytical simulations in spatial planning, especially for park and green city development. It is difficult to predict accurately the interaction between the wind flow and urban configurations. This was shown by the different effects of Karel de Stouteplein and Lapelarsingel to the NO_2 concentration in Charlois when they were both located in parallel to the NO_2 source; and the differences between the spatial pattern of NO2 dispersion in Rotterdam Centrum and Charlois. The results for Rotterdam Centrum and Charlois were different not only in value of NO_2 concentration but also the size and locations of the hotspots. The fact that the less favorable location provided the lowest NO_2 concentration in Charlois affirmed the importance of spatial simulation even more.

Nevertheless, it has to be noted that the presence of a park does help reduce NO_2 concentration at its leeward, and there are three criteria that have to be fulfilled for this effect to be achieved. The criteria are;

1) the park has to be at the downwind of pollution source,
2) there has to be no other NO2 source between the park and the habitation area at its leeward,
3) the wind direction has to come at a wide angle (as close as possible to 90o) to the park.

Even after the criteria are fulfilled, the amount of the decrease and where the decrease start to happen still depend on the physical configuration of the park's vicinity. In this research the decrease was relative constant (between 5-15µg/m^3).

Chapter 1 Introduction

Air pollution is a prominent problem in urban areas; it creates inconvenience and hazard to human health. Bolund & Hunhammar (1999) and Gómez-Baggethuna & Barton (2013) identified air filtering (air pollution reduction) as one of the most important ecosystem services (ESs) in urban areas, along with noise reduction, micro-climate regulation, and rainwater drainage (surface runoff reduction). Air pollution regulation is considered important for urban communities because it benefits the public directly, and can be provided locally in urban ecosystems by developing urban green spaces. The benefit of such a service increases significantly in vulnerable areas such as areas with higher population densities. Annually, approximately 1.3 million people worldwide die prematurely due to outdoor air pollution (WHO, 2011). The Multicenter European Study of Cohorts for Air Pollution Effects (ESCAPE) found a correlation between long exposures of air pollution (such as NO_2) and mortality rates in their 22 European cohort studies (Beelen, et al., 2014; Raaschou-Nielsen, et al., 2013). Reduced lung function growth is linked to NO_2 concentrations currently measured in cities of Europe and North America (WHO, 2014). Long exposure to air pollution from vehicular fume in traffic is also reported to correlate with high blood pressure in children in the Netherlands (Bilenko, et al., 2015).

Urban parks are considered to have a high potential to reduce air pollution because of their availability in urban areas and their proximity to people. Vegetation in parks can improve air quality by absorbing pollutants from the atmosphere (Escobedo, et al., 2011; Gómez-Baggethun, et al., 2013). They also disrupt the wind flow that carries the pollutants, creating a “shadow” area behind them that is relatively cleaner (van Hove, 2014). Because of that, parks can provide both a global and a local scale benefit.

There are two widely believed ideas about parks and urban air quality. First; that addition of parks will always improve the air quality of a city. Numerous researches have shown that different parks have different effect on air quality (Cohen, et al., 2014; Mensink, et al., 2012; Nowak, et al., 2006), which falsified those claims. Second; most decision makers believe that the services provided by parks will always benefit the population equally. A number of researches have shown that parks are not equally accessible to inhabitant in a city due to social and physical reasons (e.g. Ho, et al., 2005; Barbosa, et al., 2007; Lin, et al., 2014). Other than that, the location of the parks, in reference to air pollution source and to the concentration of people, also affects how much air pollution they receive and absorb, and how many people can benefit from the existence of the park (Burkhard, et al., 2012; Tasyara, 2015). People who reside at the windward of the park commonly get more benefit.

There have been a number of studies that focus on benefit delivery from parks (e.g. Fisher et al., 2009; Syrbe & Walz, 2012; and Serna-Chaveza, et al., 2014) and spatial dynamic (e.g. Bagstad, et al., 2013; Bagstad, et al., 2014). Those studies addressed the importance of the locations of the green spaces (including parks) and direction to the people. Unfortunately, those studies only mentioned about air quality improvement service sparingly because air quality improvement does not have obvious product. Researches on air pollution have been done often by measuring the reduction of pollutant concentration within green spaces, but the spatial range and pattern of this effect is less known. Investigating the effect of a park to the spatial pattern of air pollution is a good way to combine the approaches in air pollution research, air quality improvement service delivery, and park planning.

Various researches have shown that air pollution within a park is lower than the surrounding roads (e.g. Jim and Chen, 2008; Makhelouf, 2009; Paoletti et al., 2011; Yin et al., 2011). However, there are also researches that show tree clusters increase the concentration of NO_2 at its windward (Hofschreuder et al. 2010; De Maerschalck et al., 2009). This implies that people have to physically access a park to be able to have fresh air. However, most people spend 30% of their daily life sleeping, 10-20% doing domestic works, 10% travelling/commuting, and 20% working (European Commission, 2004). That means, up to 50% of a person's life is spent in and around their home. In the Netherlands, especially in Rotterdam, a large number of people are living near busy roads. Pollutants from traffic (such as NO_2) may enter through open windows to contaminate the indoor air, especially during traffic rush hours (Chang, 2002). This leads to a challenge for planners and urban designers of where to locate a park to ensure clean air for the people. A number of researchers have found a decrease of pollutant concentration at the leeward side of road-side tree line (De Maerschalck et al., 2009, 2010; Maiheu et al., 2010). However, no agreement has been reached whether it's more effective to locate a park at the leeward of a source, or any other places. A study about the spatial range and pattern of park's benefit on air quality is still need to be done.

This research contributes to the debate on air pollution management, park planning, and ecosystem service delivery by urban parks. It is intended to provide some of the knowledge about the effect of parks to the air quality of its surroundings when they are located at different locations. The main research question answered by this research is:

What is the effect of a park's location on the spatial pattern of air pollution dispersion from its source to place of habitation?

The evaluation was done by comparing the NO_2 dispersion in two areas in Rotterdam (explained further in the chapter 4) with parks at varying locations. Real case was selected to be used in this research to provide an example of spatial modelling in the analysis as could be done in real spatial planning practice. The air pollution dispersion is generated through computer simulation that provides the spatial pattern of NO_2 concentrations, which indicate the dispersion of the pollutant. Spatial analysis was done to answer the following research questions:

- What is the existing spatial pattern of air pollution dispersion in the study area?
- What is the spatial pattern of air pollution dispersion in the study area when the parks are located in more favourable locations?
- What is the spatial pattern of air pollution dispersion in the study area when the parks are located in less favourable locations?
- What is the difference in the spatial pattern of air pollution dispersion at the case studies between the existing park locations, most ideal locations, and less ideal locations?

NO_2 was selected as the indicator of air pollution in this research because aside from being the most common pollutant found in the air, NO_2 also acts as an indicator of other pollutants (explained further in background theory). ENVI-Met was used to simulate the effect of parks to the NO_2 when they are located in different places. The research methodology is explained further in chapter three of this report. The simulation was done using the setting of an existing city to provide a knowledge that is as close as possible to the actual condition landscape planners and architects have to face.

Chapter 2 Theoretical background

2.1 NO_2 IN URBAN AREAS

Nitrogen dioxide (NO_2) is one of a group of highly reactive gasses known as “oxides of nitrogen,” or “nitrogen oxides (NO_x).” It is commonly used as the indicator for the larger group of nitrogen oxides. NO_2 also has a strong link to other air pollutants. For example, in the presence of hydrocarbons and ultraviolet light, NO_2 is the main source of tropospheric ozone and nitrate aerosols, which form an important fraction of the ambient air $PM_{2.5}$ mass. Current scientific evidence links short-term NO_2 exposures, with adverse respiratory effects including airway inflammation in healthy people and increased respiratory symptoms in people with asthma (US EPA, 2015). Barck et al. (referred in Hesterberg, et al., 2009) even observed an enhanced proinflamatory processes (e.g. allergic reaction to pollen) on a group of asthmatics, children, and elderly people (susceptible group) after being exposed to 500µg of NO_2 for only 15 minutes. Those conditions are the reason why I decided to use the NO_2 emission level in this research.

In urban areas, combustion (i.e. burning of gasoline, diesel, and coal) are the main causes of NO_2 pollution (Oke, 1987; Seinfeld and Pandis, 2006). Traffic holds a relatively high proportion in the emission of NO_2 (Stanners and Bourdeau, 1995; Fenger, 1999). Currently, WHO set a guideline value of 40µg/m^3 (annual mean) or 200µg/m^3 as the safe limits to protect the public from the health effects of gaseous NO_2. The NO_2 levels of in the Netherlands have shown a steady decrease between 1993 and 2012. However, the final limit value was exceeded in approximately half the traffic-related monitoring sites in 2012, particularly in Amsterdam and Rotterdam (Mooibroek, et al., 2013).

NO_2 emitted from its source(s) are subjected to atmospheric processes (by which the pollutant is dispersed vertically and horizontally), and sink processes (i.e. Photochemical transformation and deposition by vegetation). Both processes determine NO_2 concentration levels at a distance from its source. The processes are determined by the (1) emission level, (2) meteorological factors such as wind speed and atmospheric stability, (3) location of the source relative to physical obstructions/windbreaks, and (4) topographical factors that affect air movement. The following sections explain about the atmospheric (further referred to as dispersion) and sink processes that happened to NO_2 in urban areas.

2.1.1 ATMOSPHERIC PROCESSES - NO_2 DISPERSION

NO_2 dispersion is when the air motion (wind) distributed NO_2 from one region of atmosphere to another. Dispersion enhances dilution and provides an opportunity for the NO_2 to interact with NO_2 from different sources. Dispersion and NO_2 concentration are highly related to each other. According to Oke (1981), dispersion affects the NO_2 concentration in an area as much as the emission level and the natural or chemical process it underwent (e.g. Deposition by vegetation and photochemical transformation). Dispersion also determines and characterizes the nature of the pollution problem. The knowledge about dispersion forms the basis for understanding the controls that are to be put into effect and for evaluating their effectiveness of the reduction effort (Wichman-Fiebig, 2011). The focus of this research was not only on the where and how much, but also how the NO_2 flow, to where, and how much it is affected by the relocation of parks. This is the reason why the research question was focused on the spatial pattern of NO_2 dispersion and not only on the NO_2 concentration.

Near its release height, NO_2 dispersion is affected by the motion of air (wind speed, direction, flow, and distance) (Ojha, et al., 2010), which is affected by the temperature and physical configuration of the urban landscape. Dispersion begins at the point of release and is inversely proportional to wind speed. For continuously emitting sources like fumes from traffic (as used in this research), more pollution concentration is decreased when the wind speed is higher (Godhis, et al., 2014). The higher from the release height, and further from the source, NO_2 dispersion is affected by larger atmospheric system (case in point, coastal and river valleys airflows, up to global climate). For this research, even though the computer simulations take into account the NO_2 dispersion from 0 to more than 50m from the ground, the focus was placed on the NO_2 dispersion that happened in the near vicinity of its source (explained further in chapter 5).

2.1.1.1 Windflow

Wind is characterized by its velocity (wind speed) and direction, which are affected the condition of the atmosphere (Godish, et al., 2014). The wind speed is affected by the horizontal pressure and temperature gradients, and also friction. Horizontal pressure and temperature gradient are affected by the weather condition. The variability of temperature influences the wind flow characteristics (Ojha, et al., 2010). The higher the pressure and temperature gradients, the higher the wind speed (strong wind). Frictions reduce wind speed (or weaken) and can change wind direction. Urban landscape commonly creates more friction than suburbs and rural landscape because of the high building and vegetation density. Friction occurs at building walls and vegetation clusters, leading to wind speed reduction, deflection (change of direction) and formation of recirculation regions (also termed as vortex) that reduce the NO_2 dispersal (Oke, 1981, Godhis, 2014; Lenzholzer, 2015).

Direction of the windflow is important in the dispersion of NO_2. Areas at the downwind of point sources where winds are relatively persistent may experience relatively high ground-level concentrations compared to other areas at similar distances (Gilbert et al., 2012; Godhis et al., 2014). Depending on the wind direction, a vortex can be developed in the canyon and can increase or decrease air pollution concentration at the windward side of an urban canyon (Nikolova, et al., 2011). Flow direction and velocity are the result of interactions between the outer or main airflow and the spatial distribution and characteristics of buildings (and other large obstacles) in the area of investigation (Ahmad, et al., 2005).

If the wind is more variable (e.g. more turbulent), pollutants will be diluted in a larger volume of air and be more equally dispersed around the source; ground-level concentrations are therefore likely to be lower (Godhis et al., 2014). In their research, Wania et al. (2012) found that increase in particle concentration can be explained by the reduction in wind speed and air mixing, alongside the consequent inhibition of ventilation. Wind speed reductions lead to a reduced mixing inside an urban canyon and a reduced inflow of fresh air. Their research confirmed the previous researches done by confirmed in Czáder et al. (2009), De Maerschalck et al. (2008), Gromke et al. (2008) and Ries and Eichhorn (2001).

Other than the horizontal flow as explained in the previous paragraph, vertical wind flow also affect the direction of NO_2 dispersion in an area. Vertical wind flow is affected by temperature gradient (change of temperature following increase of height). When the ground temperature is high, air moves upward to the cooler layer of atmosphere. Inversion can happen when the ground is cooler than the atmosphere, which prevents NO_2's vertical dispersion. However, this inversion generally does not form in urban areas located on flat terrain (the condition of the study areas in this research). This is due to the fact that urban surfaces emit considerable quantities of heat that produce a well-mixed layer of air above them. The vertical wind flow in this research is mostly upwind, while the downwind flow happened because of the shape of the urban landscape (Godhis et al., 2014).

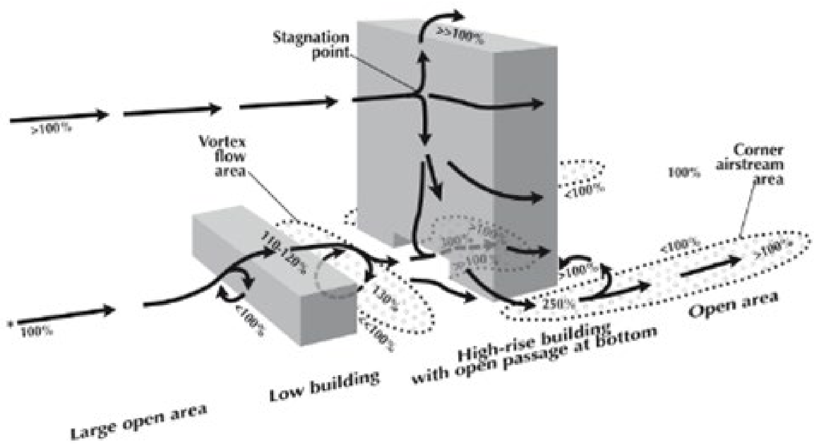


Figure 1.
Windbreaks by low and tall buildings (source: Forman, 2014)

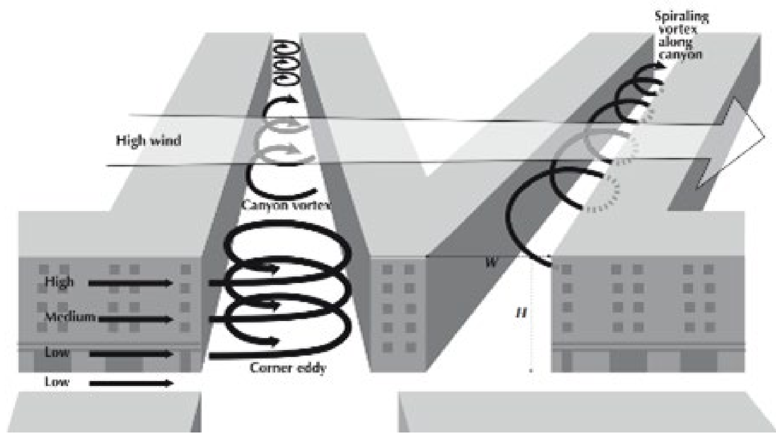


Figure 2.
Winflow in street canyons (source: Forman, 2014)

2.1.1.2 Effect of windbreaks to NO_2 dispersion

Windbreaks are any structures (natural or man-made) that disturb windflow in an area. If wind encounters a windbreak (buildings and vegetation), the flow separates from the ground surface, creating a zone of turbulence composed of chaotic “eddies”. NO_2 dispersed by the wind are deposited at various location around the windbreak, depending on the size, porosity and orientation. In urban areas, windbreaks can take the form of street canyons, cluster of or isolated buildings and/or trees (see figure 1 and 2). The effect of turbulence is to enhance atmospheric mixing and pollutant dilution that reduce NO_2 concentration. An exception is the downwash phenomena that cause plumes to be brought to the ground because of the windbreaks.

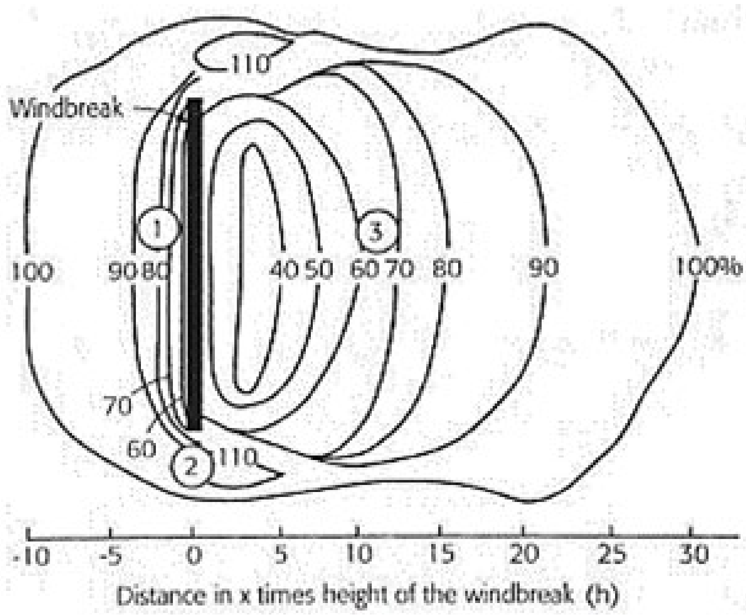


Figure 3
Wind flows around a shelterbelt
(Source: Lenzholer, 2015)

According to (Lenzholzer, 2015) the flow field around a single freestanding building of medium height is characterised by four zones of disturbance: 1) the windward[i] side a little above the middle of the building where the eddies are created due to the bouncing of the wind; 2) sheltered area (reduced wind speed) at the foot of the building at the windward side; 3) the corner streams with higher wind speeds at the sides of the building due to the compression of the air flowing around the building; 4) the sheltered area at the leeward[ii] side behind the building where the wind pressure is lower. The sheltered area, also commonly referred as the shadow area, is generally about three to eight times the height of the buildings (Forman, 2014; Lenzholzer, 2015).

[i & ii] Windward is the side of something that is toward the wind (Oxford dictionary) , also often termed as ‘upwind’. The term ‘upwind’ and ‘downwind’ are interchangeable with ‘windward’ and ‘leeward’ (the side of something that is sheltered from the wind) respectively. To avoid confusion, this research use the term ‘windward’ when referring to parts of buildings or vegetation clusters that are exposed to the wind, and ‘leeward’ for the sheltered side. The term ‘upwind’ is used when referring to the direction from which wind flowed in, and ‘downwind’ refers to the direction where the wind is flowing to.

In the sheltered area of a building or vegetation cluster, the wind is relatively slower. Although this condition is desired by human because of the calm wind, the NO_2 concentration is commonly higher than the areas with higher wind speed, but still lower than the area on the windward of the vegetation cluster. A wind tunnel studies performed by Gromke and Ruck (2010) showed that for the street canyons with trees of high crown porosity there was an increased concentration at the leeward wall/ at the sheltered area (+58%) and a decrease at the windward wall (-30%) in comparison to the tree-free reference case. Similar condition was also found by De Maerschalck, et al. (2009) and Hofschreuder, et al. (2010) in their Computational Fluid Dynamics (CFD) simulation, which was confirmed after by field measurement.

Windbreak's porosity has a major effect to the wind flow. Strong turbulence happens at the windward of an impermeable windbreak (e.g. building or impermeable woods). In contrary, a porous tree line permits the wind to flow through the gaps between the trees, creating a bleed flow that is sufficient to prevent or reduce turbulence at the windward or leeward side of the wind. When the canopy of vegetation is not very dense and the trees have high tops, the wind can flow through the top and the trunk part of the tree cluster, but the sheltered area with low wind speed behind the cluster will be much larger (Lenzholzer, 2015).

The configuration and location of the windbreak are also very important. Windbreaks that are perpendicular to wind direction is more effective than those at an angle (Erell et al., 2011; as referred in Forman, 2014). Urban canyons can create a ventilation path, create turbulences, or triggered very strong vortices depending on the angle to the inflowing wind (figure 2). In general, urban canyons that have low height-to-width ratio usually create more streamline flow. However, the amount of vortices created at the windward side of the canyon is still dependent to the angle of the wind flow and canyon wall.

Vortices created by the diagonal wind both rotate and flow along the street (figure 2). The wind that flows in the same direction as the street can flow in the canyon without creating any turbulence or vortices. On the other hand, above-roof airflow crossing over the street perpendicularly creates a secondary flow in the form of a horizontal rotating vortex within the canyon (see figure 2b), and so does near ground wind that flow diagonally over the street in the canyon. The vortex created by the perpendicular wind rotates in place, preventing NO_2 dispersion (Forman, 2014).

Wind that flows perpendicularly over a deep street canyon (e.g. Height/Weight ≥ 2) creates complex secondary airflow patterns that confine windflow, reduce dispersion of pollutants and increase the pollution concentrations inside the street canyon (Erell et al., 2011; as referred in Forman, 2014). The vortex formed beneath the roof level rotates in a cylinder and this rotation may cause another vortex to form below it that rotates in the opposite direction. Said counter-rotating vortices can also be produced in wider canyons (H/W < 1[iii]).

At city street intersections, wind moving along one street reaches the corner of a building and forms a vertical vortex in the end portion of the intersecting street canyon (Figure 2). However, wind speed is low at street level and higher above, so the complex vortex and turbulent airflows present may be simply viewed as a "street-corner eddy." This street-corner eddy commonly also prevent the dispersion of NO_2.

[iii] Height/weight ration. The higher the ration (>1) or the higher the building height, the deeper the canyon. Speed of wind that flow parallel to the street in deep canyon is commonly higher than in shallow canyon, and even more than in open space.

2.1.2. SINK PROCESS

The sink processes of NO_2 can happen on leaf surface or in the atmosphere. Such process happened because of the dry deposition process called gas diffusion through stomata in the leaves of vegetation. Because of that, vegetation can intercept NO_2 and filter out airborne particulates (Nowak, et al., 2006; Escobedo, et al., 2011; Gómez-Baggethun, et al., 2013), which reduced the concentration level and prevented further dispersion. Dry deposition is characterized by deposition velocity. It is a proportionality constant that relates the flux of a chemical species or particle to a surface and its concentration at some reference height. The dry deposition velocities of NO_2 ranged from 0.1-0.5cm/Sec (Godish, et al., 2014). Because most of the sink processes on trees happened at the surface of the leaves, stomatal resistance - which expresses the extent of the inhibition of gas diffusion through stomata - is the key parameter in air pollution modelling (Mensink, et al., 2012). Trees that have large leaf surface areas (usually shown by the number of leaf area densities/LAD) commonly have the most significant effects on air quality.

In the atmosphere, the sink processes (removal) for NO_2 involve two distinct processes: (1) oxidation to gas phase HNO_3 followed by incorporation into cloud or rain water or dry deposition, and/or (2) difusion by the wind turbulence to dilute it (Lee & Schwartz, 1981). The dilution by the advection of the wind is affected by the wind velocity and the diffusion coefficient of NO_2. The higher the velocity of the wind, the higher the diution or the lower the NO_2 concentration. In a similar manner, the higher the diffusion coefficient of NO_2 to the component in the atmosphere, the faster they diffuse with each other/diluted. It has to be noted that this research was focused on the spatial dispersion of NO_2 that incorporate the biological removal by vegetation. The chemical removal process of NO_2 in the atmosphere was not taken into consideration in the simulation, even though some scholars have argued that the dilution of pollutants in the atmosphere is one of the best solution to reducing air pollution, disregarding the resulting element.

2.2 URBAN PARKS AND NO_2 DISPERSION

Among urban green areas, urban park is a specific category. This type of landscape is especially created for urban dwellers and is the typical public urban vegetation site with specific public maintenance and utilization (Breuste et al., 2013). According to Konijnendijk, et al. (2013), parks are defined as delineated open space areas, mostly dominated by vegetation and water, and generally reserved for public use. Various studies have proven the benefit of parks to urban dwellers outside of the parks' boundaries (off-site benefit), especially those who are living at the leeward of the parks. According to Amorin et al. (2010), the effect of parks on air quality is affected by meteorological conditions (e.g. wind direction), the aspect ratio of the street-canyons, and the presence of vegetation. The effect is a complex process that happens at the micro and local scale (Mensink, et al., 2012).

On the micro scale, the vegetation inside of a park intercept and filter out particulate through their leaves as explained in Sink Processes. The larger the leaf surface areas in a park, the larger amount of NO_2 that can be intercepted. However, at the local scale, park's effect on NO_2 distribution is mainly due to its structural aspect. Maiheu et al., (2010) found from his computational fluid dynamics (CFD) study that the aerodynamic effect of urban vegetation is more significant than its deposition process. Tree line along a road obstructs the wind flow, leading to less pollutant dispersion and higher concentrations of NO_2 at short distances from the road (Mensink, et al., 2012).

For urban parks with large amount of grass coverage, the effect is more similar to open field. The wind speed is close to, if not the same as, the original wind speed. Commonly there are only slight turbulences near the ground due to friction with rough (grass) surface, but not very significant to increase the dilution of NO_2. In other words, the larger the size of a park's grassed surface, the further NO_2 is dispersed. However, it has to be noted that even though I acknowledge the effect of the park's size and physical structures inside of a park to NO_2 dispersion, this research only use it as a considereation in selecting parks to be simulated but not as a manipulated variable. The analysis were done on the effect of the park's location to the spatial pattern of NO_2 dispersion in the case areas and not on the different effects of the park's physical condition.

2.3 PLANNING PARKS TO MANAGE NO_2 DISPERSION

Despite the vast literature on urban parks and their benefit to air quality improvement efforts, only a small number of scientific literature was found on park location planning (e.g. (Myers, 1975; ; Turner, 1992; Turner, 1995; Yeh & Chow, 1996; Maruani & Amit-Cohen, 2007; Neema & Ohgai, 2010; Chandio, et al., 2011) and even less on park allocation planning specifically to reduce air pollution. The limited information that was available and useful to filter the precise planning strategy made the study of reference areas quite general.

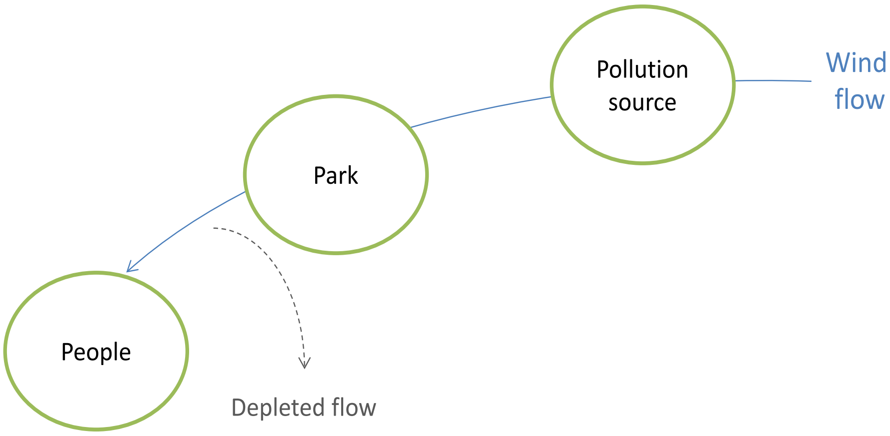


Figure 4
Ideal location of parks to reduce air pollution

According to van Hove (2014), the distance between parks to a pollution source and their location in relation to the source affects the parks' filtering effect and the process of dispersion and dilution. When a park is located between the source and the people, at a relatively close distance from the source, the processes that happen are disturbances of dispersion and air filtering. On the other hand, when the park is located far from the pollution source, the atmospheric processes would already have happened and the pollutant will already be mixed with the air when it reached the vegetation in the park. In that condition, the process that happens is only the air filtering. However, as mentioned in the previous section, physical effects of vegetation dominate over pollutant deposition/air filtering. Because of that, It would be better to locate parks where the physical effect can still happen. In other words, it would be better to locate parks close to the source of NO_2.

The ideal arrangement of source, parks, and people should follow the spatial pattern of dispersion of NO_2. Because NO_2 dispersion is affected mostly by wind flow, then the schematic of the location can be summarized as figure

4. The implementation of this idea can be done by executing geographical analysis methods and modelling that simulate the dispersal flow clearly. There is a wide range of analysis techniques that make use of this concept. This research used the NO_2 dispersion pattern and wind direction simulation as a base to select park locations.

2.3.1 NO_2 DISPERSION MODELLING IN PARK PLANNING

To be able to plan sustainably, planners have to consider the environmental consequences (including air pollution dispersion). Air dispersion modelling is the process of estimating air pollutant concentrations that result from an emissions source, taking into account source parameters, meteorological conditions, and the physical structure of the urban configurations. Air pollution dispersion modelling provides a useful support to decision making processes incorporating environmental policies and management process. They generate information that can be used in the decision making process. The main objectives of models are: to integrate observations, to predict the response of the system to the future changes, to make provision for future development without compromising with quality (Srivastava & Rao, 2011).

The main objective of dispersion modelling is to predict the rate of spread of the pollutant cloud, and the consequent decrease in mean concentration. The model has to be able to predict rates of diffusion based on measurable meteorological variables such as wind speed, atmospheric turbulence, and thermodynamic effects. The algorithms at the core of air pollution models are based upon mathematical equations describing these various phenomena which, when combined with empirical (field) data, can be used to predict concentration distributions downwind of a source (Macdonbald, 2003). The use of air pollution dispersion modelling (or in the specific case of this research, the NO_2 dispersion modelling) provide planners with the knowledge about the effect of the arrangement of the urban elements (in this case, parks) to air pollution.

2.3.2 ENVI-MET FOR NO_2 DISPERSION MODELLING

The simulations in this research were done using ENVI-Met program. It is designed for micro-climate and local air quality numerical modelling and analyses. It is capable of solving complex three-dimensional flows,

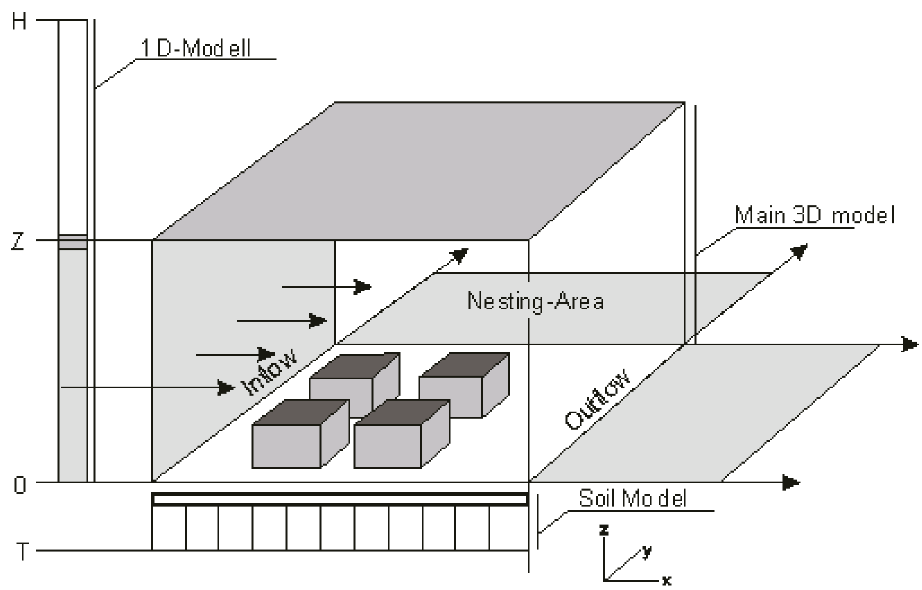


Figure 5
Schematic overview over the ENVI-met model layout (source: ENVI-MET, 2015)

temperature and turbulence fields, relative humidity and long/short - wave radiation and the dispersion of different gases and particulate matter typically traffic related. A special focus is on the simulation of surface-plant-air interaction with the urban environment. This program has the capability to run a mathematical algorithm to simulate temperature gradients, wind speed and direction, and dry deposition by vegetation. Even though the main objective of the program's development was to simulate urban air temperature and wind, this program is also very reliable to simulate air pollution dispersion. A number of researches has been done to test the compatibility of ENVI-Met for air pollution simulation (e.g. Ozkeresteci, et al., 2003; Wania, et al., 2012) and to execute simulations for specific real-case studies (De Maerschalck, et al., 2009; Nikolova, et al., 2011).

ENVI-met's simulation is called the Computational Fluid Dynamics (CFD). CFD-based models can be used to describe the complex dispersion phenomena in urban micro environments. The schematic in figure 5 provides the impression over the very basic structure of a microclimate model like ENVI-met. The general design is not only specific to ENVI-met, but is used by almost all 3D numerical models. The main model in ENVI-met is designed in 3D with 2 horizontal dimensions (x and y) and one vertical dimension (z). Inside this main model, the typical elements that represent the area of interest are placed: buildings, vegetation, different types of surfaces. In this main 3D model, ENVI-met simulates atmospheric parameters (wind field, concentrations) with a typical resolution between 0.5 and 10 m and a typical time frame of 24 to 48 hours with a time step of 10 Sec at maximum. This resolution allows analysing small-scale interactions between individual buildings, surfaces and vegetation (ENVI-Met, 2009).

In running the simulation, the area of interest is reduced into grid cells (x, y, and z). The size of each dimension defines the resolution of the model. The smaller one single grid cell is, the finer the resolution of the model is (ENVI-met, 2015). For example, a 100 x 100 m (x * y) area can be organised in 100 x 100 grid cells of 1 x1 m each or it can be organised in 20 x 20 grid cells with 5 x5 m each. Z indicates the vertical dimension of the model. The vertical extensions of z (Δz) are identical except the lowest five cells, which have a vertical extension of $\Delta z = 0.2\ \Delta z$. This is intended to help increase the accuracy when calculating surface processes and related surface simulations. The vertical extensions can use the same scale as x and y, or different depending on what the simulation is intended to show. For each simulation, a compromise has to be found between the accuracy and resolution of the model and the number of treatable grid cells.

The model layout in ENVI-Met is depicted in figure 5. The 1D model above the main 3D model is needed to reduce the needed computing power and time by taking over the calculation of the atmospheric process at the top of the 3D model. The nesting area around the main 3D is a band of grid cells surrounding the core of the 3D model. The function is to provide space for the flow field to re-establish its simpler structure as it hits the model border. It is needed because every numerical model, especially 3D models such as ENVI-met, are not working reliably at their model borders and on the grids very close to them. So the best thing to do is to move these borders as far as possible away from the area of interest in the core area. The more nesting grids used, the lower is the chance that there will be a numerical problems because one or more of the model borders are interfering with internal model dynamics (ENVI-met, 2015).

ENVI-met implement a detailed meteorological and vegetation module. This module includes the atmospheric model, turbulence, air temperature and humidity, radiative fluxes, and pollutant dispersion. The atmospheric module is used to calculate the main atmospheric processes are based on equations that describe the evolution of the main forecasting variables: temperature, humidity, and wind flow (speed and direction) as inputs. Turbulence is described using a model that is linked to soil and vegetation models. The vegetation module describes the interaction of local vegetation with the atmosphere, not only on the wind and turbulence fields, but also on the thermodynamic processes and the deposition of gases and particulate matter. The model can also calculate dispersion of different gases and particles, including leaves absorption (ENVI-met, 2015).

In the model, each plant is treated as a one-dimensional, permeable column that is subdivided into layers following the vertical extension of the model. Above ground, each plant is described by a Leaf Area Density (LAD) profile and under the soil surface by a root area density (RAD) profile (Wania, et al., 2012). An integrated vegetation model helps to resolve source/sink terms, which are calculated using the LAD and wind, temperature and humidity gradients. This vegetation model addresses interactions between the leaves and the surrounding air and is expressed in terms of sensible heat flux, evaporation flux of liquid water on leaves and transpiration flux.

ENVI-Met includes a dispersion and deposition model to simulate the dynamic behaviour of particles and inert gases. The concentration of a component (gas or particle) is calculated with the standard atmospheric dispersion equations (Eulerian approach). Processes that induce a local increase or decrease in the concentration of a component are included by adding source and sink terms in the atmospheric dispersion equation. The main forcing factors of sedimentation and deposition (sink terms) in the model are gravitational settling and any dry deposition on surfaces such as soil, buildings and/or plants. The loss of wind speed due to vegetation friction is parameterised in airflow equations by introducing the LAD, leaf diameter (different values for deciduous and coniferous trees) and a plant type specific parameter to calculate deposition velocity; where the LAD is an important parameter in the calculation of the mass of particles deposited. An additional measure of surface resistance for gases is added, as plants actively regulate gas exchange with the ambient air, mainly parameterised through resistance of stomata and the wet leaf fraction via the plant model (Wania, et al., 2012).

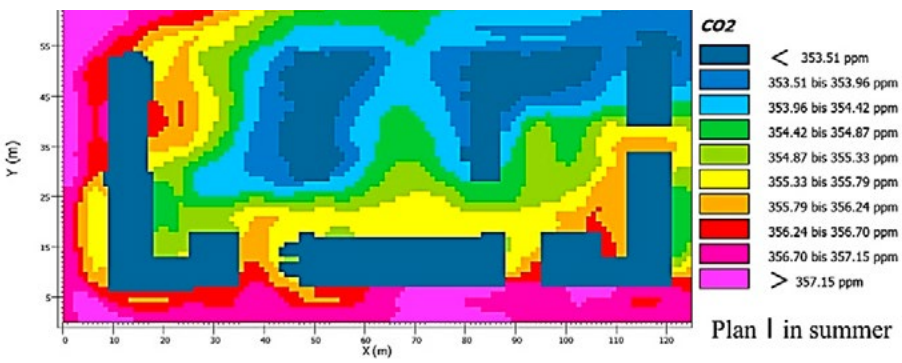


Figure 6
Example of ENVI-met simulation output for CO_2 dispersion (Source: Yang, et al., 2014)

Chapter 3 Study Area

Rotterdam is a city in the western part of the Netherlands. This city was selected as a case study because it had the highest pollution level in the Netherlands (based on the Numbeo Pollution index). Two sample areas from two regions in the Rotterdam were used in the simulation. The first is from Rotterdam Centrum and the second is from Charlois (figure 7). The regions were selected because there are pollution measuring units in the area[iv] and because of their vulnerability to air pollution as indicated in table 1.

Table 1
Vulnerability Indicators of the Selected Areas

** compared to other regions in Rotterdam. Data from Geemente Rotterdam (demographic data); TNO, RIVM and DCMR (air pollution in Rotterdam during 2012)*

Indicators*	Rotterdam Centrum	Charlois
Number of people living along busy roads	Very High	Very High
Number of people died from lung disease	Medium	Very High
Number of infants	Very High	Medium
Number of people age 65+	High	Medium
Infants with asthma or bronchitis	High	Medium
Children with asthma or bronchitis	Medium	Very high
65+ with asthma or bronchitis	Low	High
Number of immigrants	Medium	High
Number of people with low-income	Medium	Very High
Unemployment	Very High	Very High
Social exclusion	Medium	Very High
Pollution level (NO2)	Moderate-high	Moderate-high

There were 30,405 people living in Rotterdam Centrum and 34.9% lived along busy roads. There were 16,709 non-western immigrants living in the district who commonly have low paying jobs that demand them to be in close proximity to air pollution source. There were 4,574 children of 0-4 years and 8,304 elderly people (age 65 up) who are prone to air pollution. From those numbers, 7.8% infants and 11.6% elderly people suffered from asthma or bronchitis. In this district, 7 out of 10,000 people were expected to die from respiratory diseases. The pollution level (NO_2) in Rotterdam Centrum can be categorized as moderate-high with the average of 34.65µg/m^3 per hour and maximum of 110.94µg/m^3.

There were 64,569 people living in Charlois and 13.5% lived along busy roads. There were 39,604 non-western immigrants who commonly have low paying jobs that make them prone to the air pollution problem. There were 1,035 children of 0-4 years and 2,768 elderly people (age 65 up) who are prone to air pollution. From those numbers, 6.8% infants and 21.9% elderly people suffered from asthma or bronchitis. In this district, 9 out of 10,000 inhabitants were expected to die from respiratory diseases. The NO_2 level in Charlois was higher than Rotterdam Centrum with the average of 42.51µg/m^3 per hour and maximum of 132.30µg/m^3.

[iv] Schiedamsevest in Rotterdam Centrum and Pleinweg in Charlois. See chapter 4 for further information

Case areas for the simulations were selected in Rotterdam Centrum and Charlois which include major roads, settlements and/or clusters of buildings, and a park or green structure. The case areas have high building occupation and also large areas of open green spaces. Further explanation about the condition of the buildings, roads, and parks in the case areas are available in the Raw Input section of Research Method and Data Processing chapter of this report.

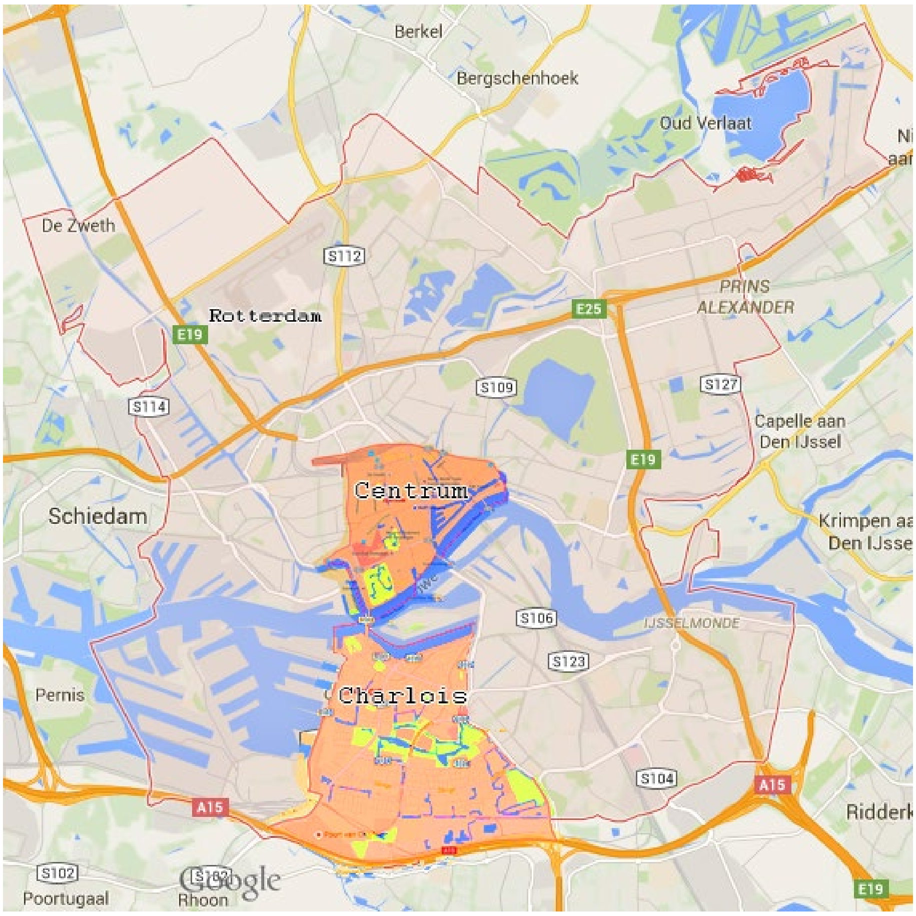


Figure 7
Reference map of the study area (Rotterdam Centrum and Charlois)

Figure 8
Typical condition of the urban configuration in Rotterdam Centrum and Charlois

Chapter 4 Research Method and Limitation

This research was done in consecutive phases as illustrated in figure 9. The first phase was data collection and data processing to initiate the simulations. The data collected includes the NO_2 concentration in Rotterdam, meteorological condition, demographic, and land uses. The data were then adjusted to be in accordance to the specification demanded by ENVI-Met. The second phase was simulation to find out the effect of parks to NO_2 concentration in the case areas. The third phase was an analysis of simulation result to know the NO_2 concentration level, the NO_2 hotspots in the case areas, and the amount of people who were exposed to NO_2. In the fourth phase, I selected new locations based on the NO2 dispersion pattern from the simulation and the location of the source and people. After that, I ran more simulations based on the new locations (ideal and least ideal). The following sections provide more explanations about simulations done in this research, including the assumptions, parameters and dependent variables used in the simulations. The result and analysis of the simulations are available in the next chapter.

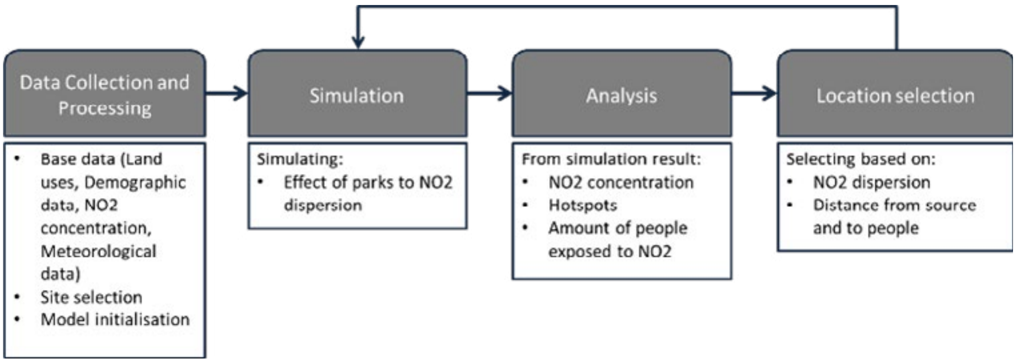


Figure 9
Research Procedure

The influence of park's locations to NO_2 dispersion pattern was analysed with ENVI-met by comparing different scenarios in two case areas. The choice of parameters to be tested and the general layout of the model area were influenced by the following assumptions:

- The local concentration of NO_2 is determined by the quantity of pollutants emitted in a certain area and dispersion mechanisms (Wania, et al., 2012);
- Dispersion depends on the local flow of air between buildings and other obstacles, such as trees (Hunter et al., 1992) and affected by the local temperature flux and humidity;
- Flows are determined by the local wind field, which is influenced by canyon geometry and the (approaching) wind direction (Hunter et al., 1992);

- Flow direction and velocity are the result of interactions between the main airflow, the spatial distribution and characteristics of buildings, and large obstacles such as parks in the area of investigation (Ahmad et al., 2005; Oke, 1988); and
- Parks reduce NO_2 most effectively when located between the pollution source and the people, under the condition that they are located before the atmospheric mixing distance of NO2 (van Hove, 2014).

The scenarios for the simulations were defined with varying park locations, different NO_2 emission, and different inflow condition. The parameters required for each model run and the defined test parameters are summarised in Table 2. The parameters were selected from spring and autumn 2012 because the parks' physical structures and the meteorological condition of the area were in most similar condition. The defined meteorological parameters (temperature, wind, humidity) correspond to an average day in Rotterdam in spring and autumn 2012.

Table 2
Overview of the main parameters and variable required to the configuration of the model

Parameter	Definition	Input condition	
		Spring 2012	Autumn 2012
Meteorological conditions	temperature	294 K	292K
	Relative humidity at 2m	79.14%	85.99%
	Specific humidity in	12 g Water/kg air	11.48 g Water/kg
	2500m	301	air
	Inflow direction	4 m/s	205
	Wind speed at 10m		4m/s
Pollution source	Species	NO_2	NO_2
	Source geometry	Linear source at 1m height	Linear source at 1m height
	Emission rate (µg/m^3)		
	Rotterdam Centrum	105.91	80.48
	Charlois	131.50	121.00
Variable			
Park locations	Location of the parks within the case-areas	Existing locations	
		Favourable locations	
		Less favourable locations	

4.1 PRE-SIMULATIONS

Maps of street, buildings, and land uses (parks and street vegetation) were overlaid in ArcMap and then clipped with the administrative boundaries for Rotterdam Centrum and Charlois. A grid of 1200 x 1200m (using fishnet tools in ArcMap) was set on the map to create a sampling grid. The case areas were selected in grids that included major roads, buildings, and park/green structures (figure 10). The 1200 x 1200m size was selected to accommodate the 250x250 grid limitation by ENVI-Met with a border of empty 5 pixels (minimum) on each border of the input map. The scale used was 1:500.

The maps for the case areas were digitized manually into a 250x250 grid map in ENVI-Met editor. The locations and size of the green structures (parks and street vegetation) were manually digitized based on the GIS file provided by the Municipality of Rotterdam, and cross-checked with Google satellite view. The cross check was needed because the GIS file only included the green land uses (e.g. Orchard and grassland) and not the exact location of the trees/shrubs. Some vegetation was added based on the crosscheck . The complexity of the urban landscape in both areas had

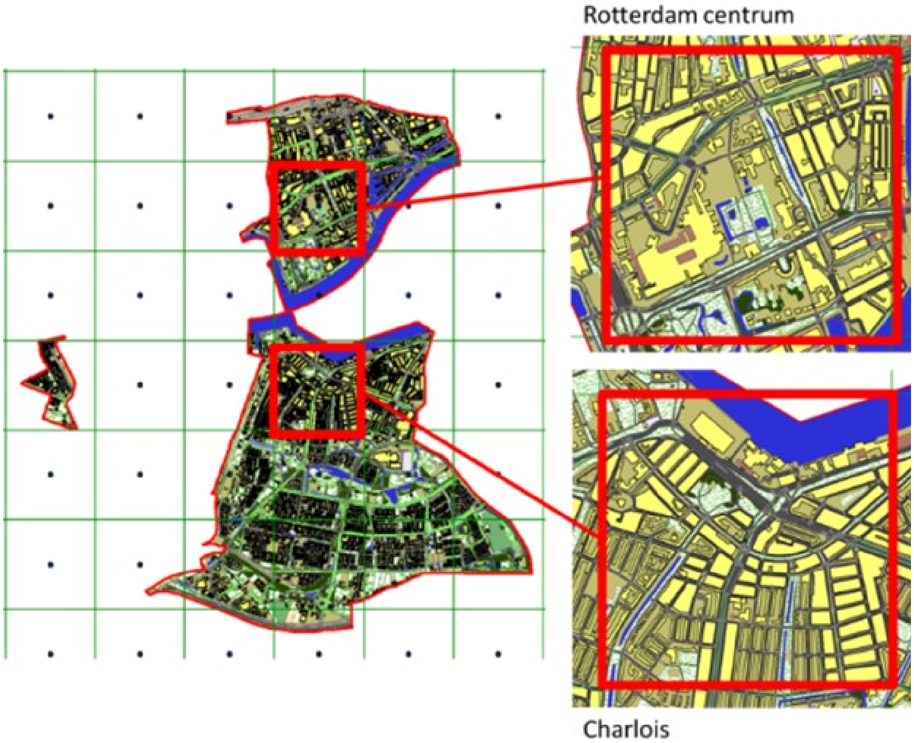


Figure 10
Case Areas

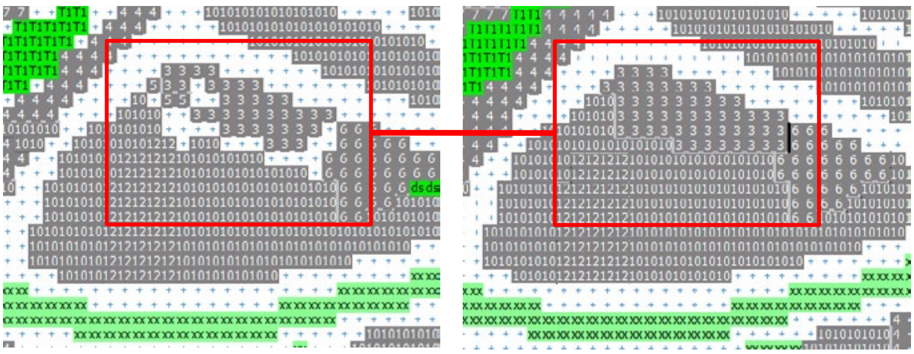


Figure 11
Examples of the map simplification

to be simplified to avoid errors in the mathematical equation of the wind turbulence. The simplification includes:

1. All roofs were considered as flat beds (see program limitation);
2. A row of buildings got assigned one height value (i.e. The height of the majority) to reduce complicated turbulence over the roofs);
3. When there was narrow, irregularly shaped courtyard, the open space was filled with solid building of the same height as the surrounding buildings (see figure 11).

Two trial simulations were done to test the program. The first was to test the running time of 50x50, 180x180, and 250x250 models with dummy maps. In this test, a 3 hour simulation of 250x250 models can finish in 4 hours. The second was done to check the model configuration. The trial simulation was run for a 250x250 map; however the air turbulence simulated for both case areas was too complicated. This error usually happens because the model is too complicated (e.g. Irregular shapes and narrow space between buildings). Because the map for Rotterdam Centrum was less complex than Charlois and both simulations showed the same error message, I concluded that the complexity was also caused by the map size and not only the building arrangement. The maps were then cropped into a 150x150 grid (scale 1:500), reducing the size of the case area into only 750x750m. I made sure that the maps still include major roads, buildings, and parks (figure 14 and 15). The program could be executed without any glitches using the cropped maps. Because of that, the remaining simulations were done with the 150x150 maps.

4.2. MODEL PARAMETERS

4.2.1 METEOROLOGICAL CONDITIONS

A simulation with ENVI-met requires the definition of a set of meteorological parameters:

- Wind speed and wind direction at 10m above ground level.
- Roughness length: this parameter describes the roughness of the location where wind speed is measured and is used to calculate the vertical wind profile above the urban canopy layer. It was set to 0.1, which is a typical value for urban areas (ENVI-Met, 2009).
- Temperature: includes the definition of the temperature for all layers of air in the three-dimensional model, alongside a constant reference temperature at a height of 2500 m, which is used by the one-dimensional model to simulate boundary conditions. In addition, the temperature of the soil is also defined. ENVI-met starts with a zero-gradient and lets the thermal stratification develop during the model's initialisation phase based on the initial surface temperature.
- Humidity: the vertical humidity profile is calculated through both specific humidity (at 2500 m) and relative humidity (in 2m height).

The meteorological condition used in the simulations was based on data measured at Rotterdam The Hague Airport from December 2011 to November 2012 (source: KNMI). The data used were as written in table 2. The temperature, humidity, and wind speed in both seasons are similar, which mean that the NO_2 was dispersed in a similar manner. The most significant difference was the wind directions. The reason why the simulations were done in different seasons was because in real condition, different wind direction dominates different season. North-west wind happens most often in spring while southwest wind happens most often in autumn.

4.2.2 NO_2 EMISSION SOURCE

The NO_2 concentration was collected from TNO (done in 2009 for Rijnmond region) and two measuring stations, Schiedamsevest in Rotterdam Centrum and Pleinweg in Charlois from December 2011 to November 2012. The measurement from TNO was done to select the case areas while the measurement from Schiedamsevest and Pleinweg was used as the emission level input in the simulations.

The maximum NO_2 concentration in the study areas was still below the European Comission and WHO's hourly standard of 200μg/m^3. However, when compared to their neighbouring areas, Rotterdam Centrum and Charlois had the highest NO_2 concentration. In average, the NO_2 concentration in Charlois was higher than in Rotterdam Centrum. In Charlois, the highest concentration of NO_2 was recorded during the rush hour at 08.00 (131.50μg/m^3) in Spring and in Autumn (121μg/m^3). The highest concentration in Rotterdam Centrum was measured at 14.00 in Spring (109.16μg/m^3) and at 10.00 in Autumn (110.94μg/m^3). The different

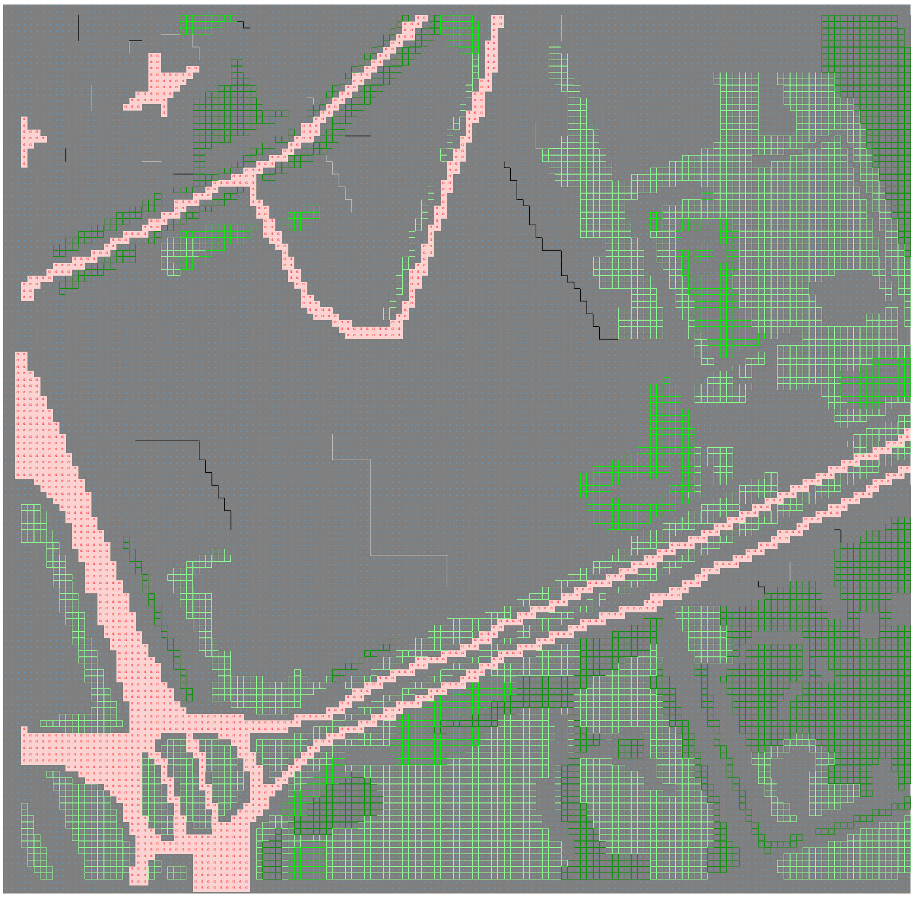


Figure 12
Configuration of emission source in Rotterdam Centrum

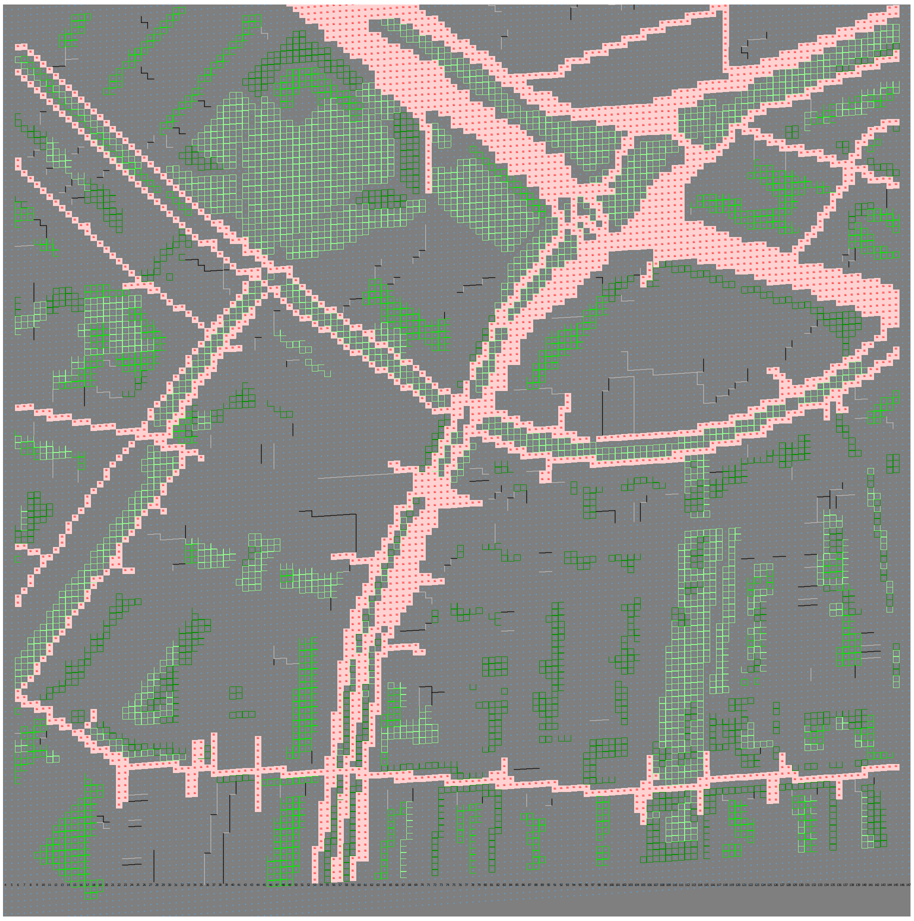


Figure 13
Configuration of emission source in Charlois

peak time can be explained by the fact that there were more industry area and settlement in Charlois, which caused more traffic volume at rush hours in Charlois than in Rotterdam Centrum.

The hourly emission data were assumed as the level of emission sourced from traffic, which includes heavy-duty vehicles and personal vehicles that move along freeway, arterial streets, and local roads; or idling in the intersection. The location of the source was mapped as the red lines as shown in figure 12 and 13. The location was selected based on the width of the road and the traffic reports from the Municipality of Rotterdam. The release height was assumed as 1m above ground to generalize between the regular vehicles and the heavy-duty vehicle. The emission at 08.00 in Rotterdam Centrum was 105.91µg/m^3 in spring and 80.48µg/m^3 in autumn, while in Charlois it was 131.50µg/m^3 in spring and 121.00µg/m^3 in autumn (complete list available in appendix 1).

The simulations were run to show the NO_2 dispersion at 08.00 in spring and autumn 2012. The maximum hourly NO_2 concentration level was used as the input parameter to show the worst case scenario of the rush hours as it happened in 2012. Even though the highest NO_2 concentration in Rotterdam Centrum was at 14.00, the simulations were run for 08.00 to maintain the uniformity of the other parameters (namely the meteorological condition). The selection of simulation time was also because wind turbulence is daytime phenomena and are dampened by night-time radiative cooling of the ground and air adjacent to it (Godish, et al., 2014). The fluid dynamics of NO_2 (which determine the gas' movement in the simulations) and also transfer resistance of the soil and leaves were set based on the ENVI-Met's standard. The diffusion coefficient was set to 0.2558cm^2/second.

4.2.3 PARK, ROADS, AND BUILDING CONFIGURATIONS

The model area covers 750x750 m and a vertical height of 170m to provide enough space for air turbulence above the model. The size of the grid cells was set to 5mx5mx5m (scale for xyz, respectively 5mx5mx1m for the lowest five grid cells). The configuration is as provided in figure 14 and 15, in which buildings are indicated by the grey geometric shapes and parks are indicated by the different shades of green. This section explains the existing configuration of the case areas and the selection process for the ideal and least ideal. The favourable and less favourable locations are explained in chapter 5.

The case area in Rotterdam Centrum included two large parks (Het Park in the southwest of a major road and the Rotterdam Museumpark, at the east of the area). The place of habitation in this case area includes a hospital complex at the centre of the map (Erasmus MC Hospital) and a small cluster of small apartment buildings and row houses in the north-west part of the map (top left). Only a part (1/3 or the northern part) of Het Park was included in the case study because the size of the park was too large (it would dominate the map if included fully). The shortest building in Rotterdam Centrum areas was 1m (the half constructed part of Erasmus MC Hospital), the tallest was 45m (an apartment building). The roads around the Erasmus MC were large arterial roads ('S-Gravendijkwal) with 8 lanes each way (4 lanes each direction) and smaller 4 lane-roads (Westeerzedijk). The roads around the building cluster were narrow two way street.

The case area in Charlois included two medium sized parks (Karel de

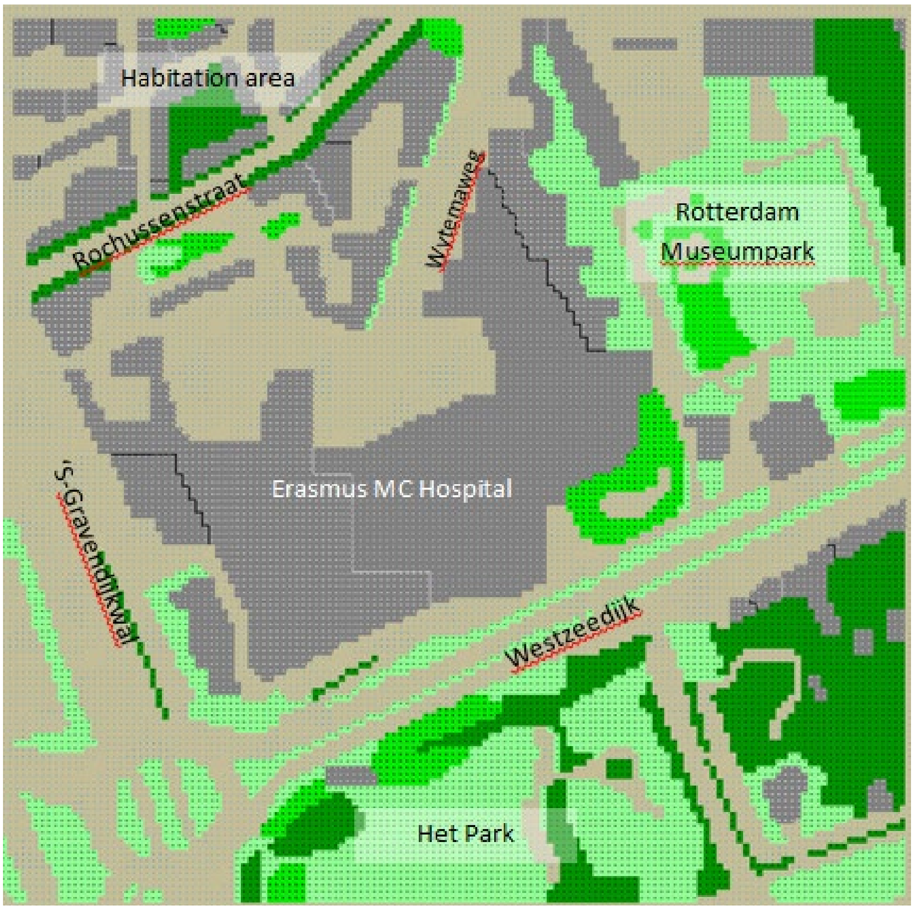


Figure 14
The configuration of the case area in Rotterdam Centrum

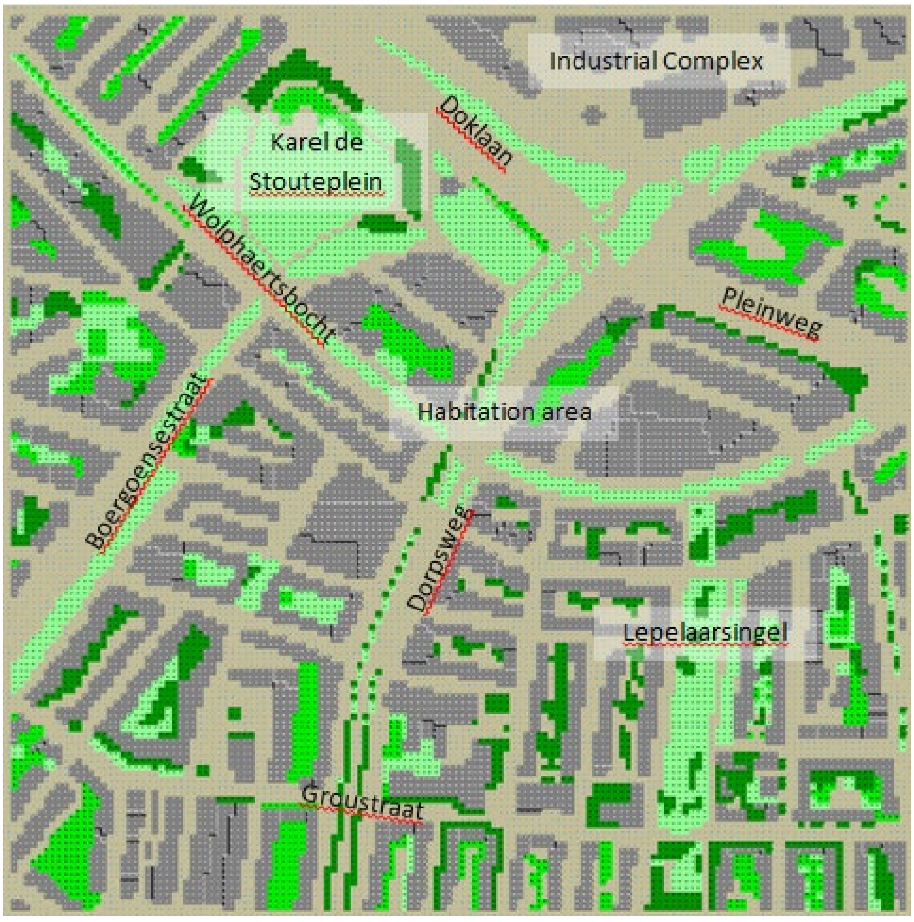


Figure 15
The configuration of the case area in Charlois

Stouteplein Park in the SouthWest of a major road and a neighbourhood park in Lapelaarsingel street at the southeast of the area). The place of habitation in this area includes a dense cluster of apartment buildings that are spread in most part of the area. The shortest building in Charlois was 3m high (garages) and the tallest was 55m (mixed use building with store on the bottom and settlements at the higher floor). The average building height in Rotterdam Centrum and Charlois was 15m (four-leveled settlement building with an attic/roof). The road at the south of the industrial area was large arterial road with 4 lanes in each direction (Dorpsweg). The roads around the settlement area were 4 lanes arterial roads (2 lanes each direction), and smaller 2 lane roads. In both case areas, the actual bicycle paths were separated from pedestrian and car lanes, but were considered to be the same as pedestrian paths in the input map.

All of the parks in the two case areas were dominated by grassland with a small percentage of tree clusters. The types of vegetation were assigned according to the ENVI-met global database (classified according to the type, height, leaf area density, and shape of crown layer). The types of vegetation

Table 3
Vegetation characteristics used in the simulations

Type	Code	Colour	Characteristic
Grass	xx		Grass, average density
Deciduous	h		Hedge dense, 2m
Deciduous	ds		Tree 10 m dense, distinct crown layer
Deciduous	T1		Tree 10 m very dense, leafless base
Deciduous	T2		Tree 15 m very dense, leafless base
Deciduous	Sk		Tree 15 m very dense, distinct crown layer
Deciduous	L1		Tree, light density 15 m

Table 4
Simulations schematic
* the meteorological condition in each season

Case Area	Variables	Parameters	
		Season*	NO_2 concentrations at
Rotterdam Centrum	Existing Location	Spring	08.00
		Autumn	08.00
	Ideal Location	Spring	08.00
		Autumn	08.00
	Less ideal location	Spring	08.00
		Autumn	08.00
Charlois	Existing Location	Spring	08.00
		Autumn	08.00
	Ideal Location	Spring	08.00
		Autumn	08.00
	Less ideal location	Spring	08.00
		Autumn	08.00

used in the simulations are from the global database of ENVI-Met as listed in table 3. The database provides information about the plant type, leaf area density, and stomatal resistance to be used in the NO_2 diffusion calculation. The same vegetation and physical arrangement were used in all of the simulation. Slight variations in angles had to be done to accommodate the shape of the space.

4.2.4 SUMMARY OF THE PERFORMED SIMULATION RUNS

Table 4 shows the outline of the test series that was performed for each case area. Each case area was run for three different locations with two different meteorological and emission condition in March 15 2012 (spring) and at September 15 2012 (autumn). The simulation was run 12 times. The results of the simulations for each season was compared to see the effect of the parks at different locations.

The simulations of the existing locations for spring and autumn resulted in two maps of NO_2 concentrations that show the hotspots and spatial pattern of the NO_2 dispersion. After I overlaid the result, I implemented a buffer of 50m from the hotspot only to the same direction with the wind (northwest to southeast and southwest to northeast). By doing this, I could pinpoint the locations that are exposed to NO_2 in both seasons. Based on that, I selected more favourable and less favourable location for the parks. The term “favourable” here pragmatically defined as the location where the park is expected to provide more benefit than the existing location, and the oposite for the “less favourable”. The use of more favourable and less favourable locations was basically the same as purposeful sampling. This sampling method was used as a pragmatic solution to the constrictive configuration of an existing city used in this research. However, it has to be noted that theoretical reasoning was implemented in the location selection as mentioned in chapter 2 and later in chapter 5. Based on the hipothesis mentioned in section 2.3, the more favourable location for a park to reduce air pollution is at the downwind from an air pollution source and at the upwind of habitation area. The less favourable locations are then at the upwind of a pollution source and/or at the downwind of a habitation area.

Some compromises had to be done in the location selection process and park relocation because the simulations were done with the physical configuration of an existing city. The compromises included small changes in the park design to fit the location (e.g. removal of small vegetation), and selection of locations that did not fullfill the citeria in the hipothesis in one of the season (e.g. located at the downdwind of a pollution source in spring but was the upwind of another pollution source in autumn; explained further in section 5.1).

4.3 LIMITATION

This research was focused on the effect of park’s location to the spatial pattern of NO_2 dispersion. This was done due to the limited research time and resources (hardware). Other than that, there were also some limitations in this research due to the limitation of the computer simulation program, and the availability of data as explained bellow.

4.3.1 LIMITATION OF ENVI-MET

The processing time needed to analyse one area is highly dependent to its size. The larger the size of the area, the longer it takes to complete the analysis. ENVI-Met also need to have two hours of simulations for wind field adjustment time. The simulation time had to be set to start at 06.00 (at least) to get a reliable simulation result of NO_2 concentration that happened at 08.00. Three hours long simulation usually takes 6-8 actual hours to finish. To overcome the time constraint, this research utilized three computers in parallel to run simulations on 150x150 grid cells maps (further explanation available in the research method chapter). A crosscheck of the simulation was done on different computers to ensure no discrepancy in the results.

The physical elements (buildings and vegetation) were limited to multiplication of the scale. Because of this, the elements cannot be exactly in the same size as the real condition. There was some size reduction or increase. In this research, the scale of 1:500 was used because it is the closest to the smallest building and road width.

4.3.2 LIMITATION DUE TO DATA AVAILABILITY

The demographic data were available only at the district level on the smallest scale. Because of the time constraint, which stated that this research has to be finished in a 6 month period, field survey to gather data at the ward scale cannot be done. Because of this, it is assumed that all blocks in the case study have the same vulnerability to NO_2 exposure. In this case, the park's alternative locations were determined based only on the location of the NO_2 hotspots and the dispersion direction.

The latest demographic data available were for the year 2012. To be able to calculate the number of people who benefit from the existence of a park closer to the condition at that time, the pollution and meteorological condition were also selected from the same period. Other than that, this condition did not cause a bias in the research because the main purpose was to provide a simulation of the effect of park location to pollution dispersion, not to show the actual condition.

Due to the limited amount of undeveloped or underdeveloped land in the Rotterdam area, it is assumed that all land parcels are available to be transformed into a park. In the input maps for the relocated parks, the original land uses were moved to the park's pervious location so that the building and land cover percentage did not change. The new park had the same shape and design as the existing park. By doing this, the only variable that change was the location of the park. Some adjustments had to be done to accomodate the parks in the new locations (e.g. small croppings of the grasslands), however the changes were minute and did not cause a bias simulation result.

Chapter 5 Results

This chapter provides the answers to the research questions, as stated in the introduction;

1. What is the existing spatial pattern of air pollution dispersion in the study area?
2. What is the spatial pattern of air pollution dispersion in the study area when the parks are located in more favourable locations?
3. What is the spatial pattern of air pollution dispersion in the study area when the parks are located in less favourable locations?
4. What is the difference in the spatial pattern of air pollution dispersion at the case studies between the existing park locations, most ideal locations, and less ideal locations?

The chapter is divided into 5 sections. The first section explains the condition of the air pollution with the existing parks to answer question 1. This section also explains the park location selection process to answer questions 2 and 3. The second section explains the condition of the air pollution after the parks are relocated to the more favourable locations, while the third section explains the condition after the parks are relocated to the less favourable locations. The fourth section explains the difference between the conditions of the air pollution when the parks are located in their existing locations, at the favourable location, and at the least favourable location to answer question 4. The answer to the main research question is provided in the last section of this chapter.

The result of the simulations are shown through the the top view map/XY section of the NO_2 concentration at 2m from the ground[v], and exemplary vertical (XZ or YZ) sections to show the vertical pattern of wind movement and NO_2 dispersion. The spatial pattern is shown in 20 classes of NO_2 concentrations with 5µg/m^3 intervals. The horizontal concentration is shown at 2m because it is close to the release height, it is the closest to the average human height, and it is the height in which the bottom crown of trees overlaps with tall shrubs in the park (maximum leaf coverage). The maps in this section show the wind direction (indicated by the series of small arrows), building arrangement (grey blocks), leaf area density/LAD of the parks and street vegetation (shades of green), and NO_2 concentration (indicated in the map legend). The figures shown in section four of this chapter only show the NO_2 concentration, wind direction and wind speed to show the the spatial patterns more clearly.

[v] Larger maps are available in appendix 2

5.1 EXISTING SPATIAL PATTERN OF AIR POLLUTION DISPERSION IN THE STUDY AREAS

This section is divided into two parts; the first part provides the explanations about the existing spatial pattern of NO_2 dispersion in Rotterdam Centrum in spring and autumn, while the second part is for Charlois.

5.1.1 ROTTERDAM CENTRUM

In spring, the wind flowed at 301°-306° on the open area in the west side of the area. The wind speed was between 2.50 and 1m/s, which were as expected because commonly wind speed at layer is 60% of the speed at 10m. The wind dispersed NO_2 to the southeast. The wind direction between the buildings was more diverse (from 301° to 359°) depending on the angle of the configuration of the buildings. The hotspots (figure 16a) formed around the large roundabout at the southwest or the case area, which is the intersection of 'S-Gravendijkwal and Westzeedijk. A small hotspot also formed at Rochussenstraat. The highest NO_2 concentration according to the simulation was 85-90µg/m^3 at the border between the roundabout and Het Park. This condition is in accordance with the research done by Maerschalck, et al. (2008) and Wania, et al. (2012) that showed an increase of air pollution at the windward of roadside tree line. The NO_2 level in Het Park in spring decreased from as high as 65µg/m^3 at the west border to between 10-5µg/m^3 285m into the park. In Museumpark, the NO_2 concentration was only 5-0µg/m^3.

The wind in autumn was flowing at 205° and the wind speed was between 3 and 0.50m/s. The hotspot was formed at the windward of tree line in S-Gravendijkwal and at the windward of the border between the roundabout and Het Park. Different from the condition in spring, the highest concentration in the hotspot in autumn was only 60µg/m^3 (30 µg/m^3 lower). The concentration at Rochussenstraat was also lower, although only 5-10µg/m^3. The emission level in autumn was lower than in spring, however the difference was only 25µg/m^3 while the maximum concentration in autumn was 30µg/m^3 lower. On the other hand, the concentration in the north and northeast of the hospital was in average 5µg/m^3 higher than in spring.

The difference between the hotspot location, maximum concentration, and spatial pattern of NO_2 dispersion in spring and autumn can be explained by the different wind direction (both the inflow and the local wind in the area). The wind in spring dispersed NO_2 toward the southeast where the roundabout (which was also a major source) was located. Vortices were formed at the windward side of the park that followed by an NO_2 build up. On the other hand, the wind in autumn dispersed NO_2 toward the north and northeast that was more ventilated and had less NO_2 sources. Unfortunately the autumn wind also dispersed NO_2 from the roundabout over the hospital, which increased the concentration at the hospital's north when the downwash pushed NO_2 toward the ground.

The difference of dispersion directionin spring and autumn is shown more clearly in the vertical sections as shown in figure 17-19. Figure 17 a-b show the different NO_2 dispersion at the roundabout and in Het Park, figure 18 and 19 a-b show that NO_2 was dispersed to the south (towards Y 0) in spring and to the north (towards Y 150) in autumn.

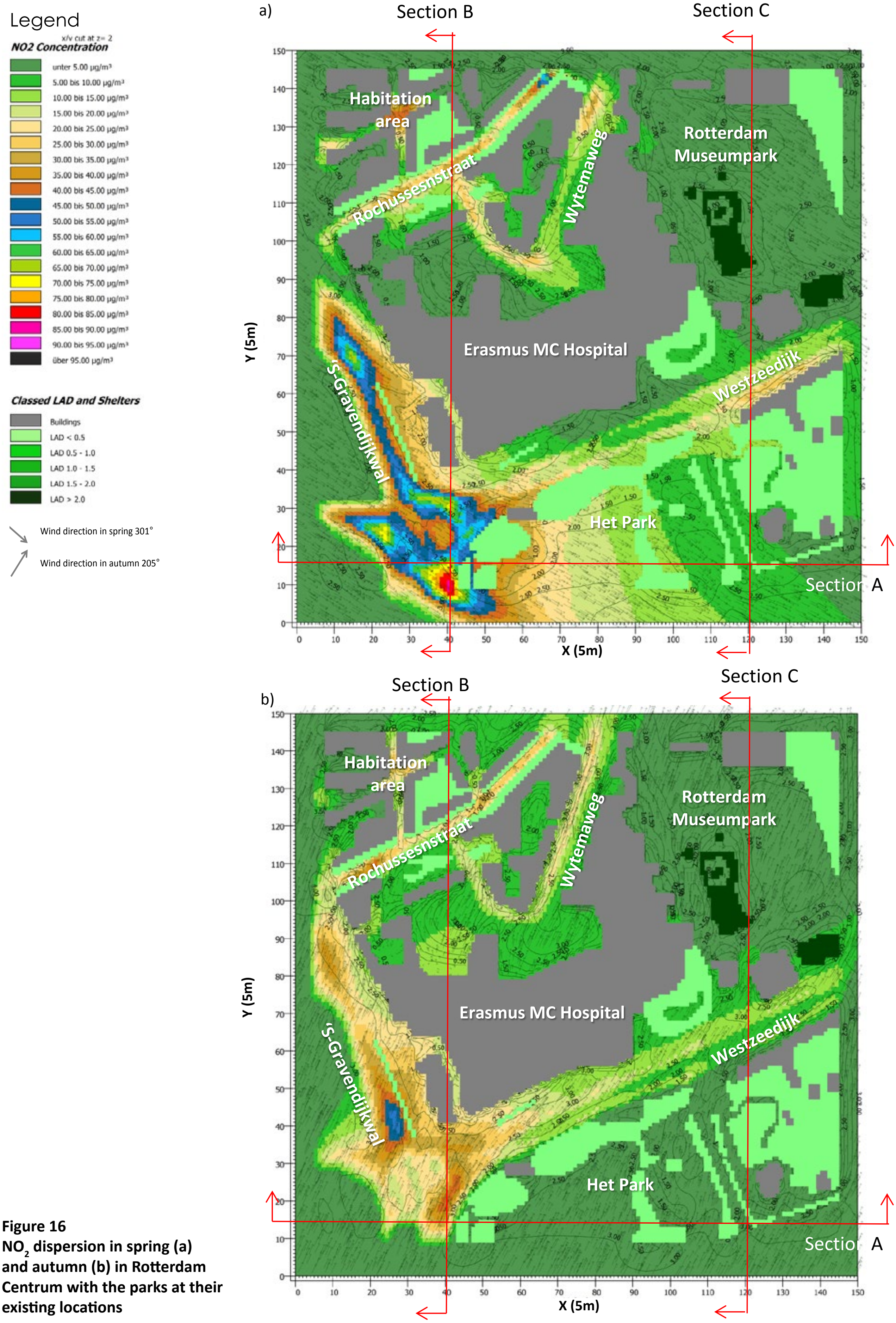
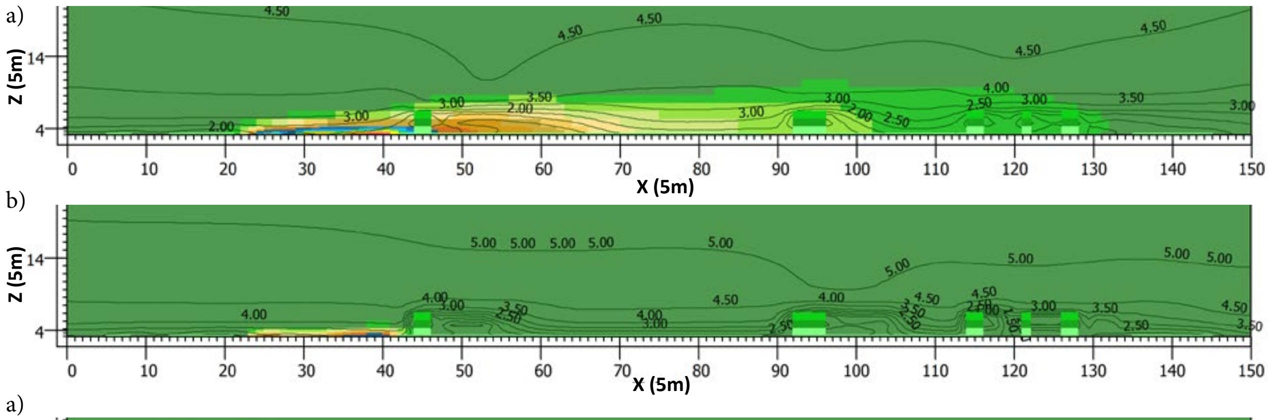
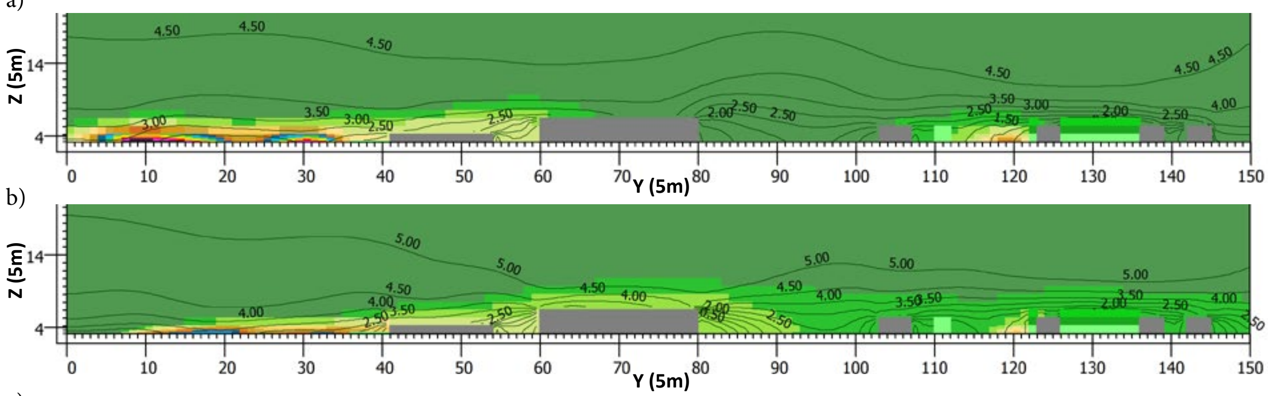


Figure 16
NO_2 dispersion in spring (a) and autumn (b) in Rotterdam Centrum with the parks at their existing locations

a)
b)



a)
b)



a)
b)

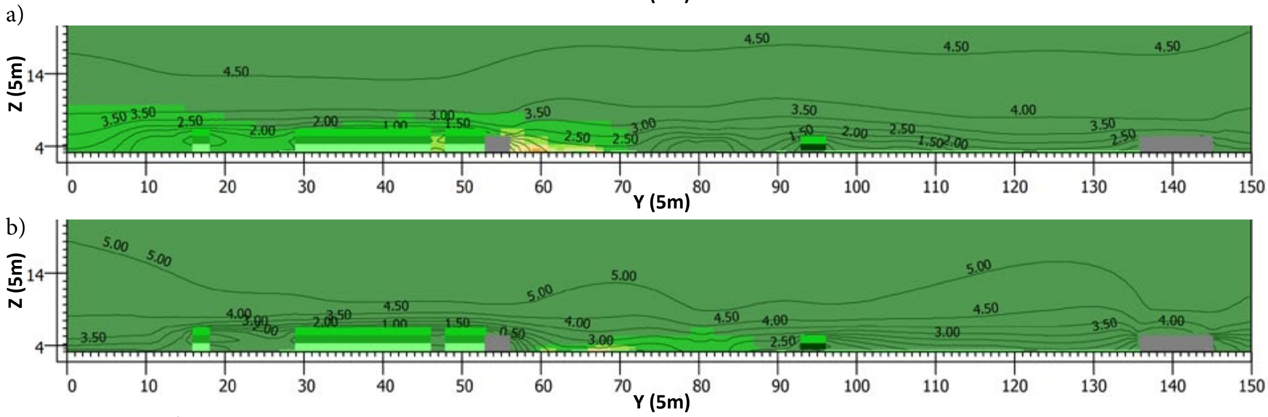


Figure 17 (top) a-b
Vertical spatial pattern of NO_2 dispersion at section A of Rotterdam Centrum in spring (a) and in autumn (b)

Figure 18 (middle) a-b
Vertical spatial pattern of NO_2 dispersion at section B of Rotterdam Centrum in spring (a) and in autumn (b)

Figure 19 (bottom) a-b
Vertical spatial pattern of NO_2 dispersion at section C of Rotterdam Centrum in spring (a) and in autumn (b)

The spatial pattern of the dispersion in Rotterdam Centrum in spring and autumn was as shown in figure 20. The Erasmus Hospital was always directly exposed to NO_2 from the traffic fumes. Based on the existing spatial pattern and the urban configuration of the area, the favourable location is as shown in figure 21a. In this configuration, the parks are located at the upwind of the habitation areas in autumn and spring. Theoretically the parks can disturb the dispersion and prevent NO_2 from reaching the habitation areas. Figure 21b shows the less favourable configuration. In that configuration, Rotterdam Museumpark was on the windward of the pollution source in the spring and at the leeward of the hospital in the autumn. Het Park was on the windward of NO_2 source in the spring and at the leeward of the source (but not at the windward of any habitation area) in autumn.

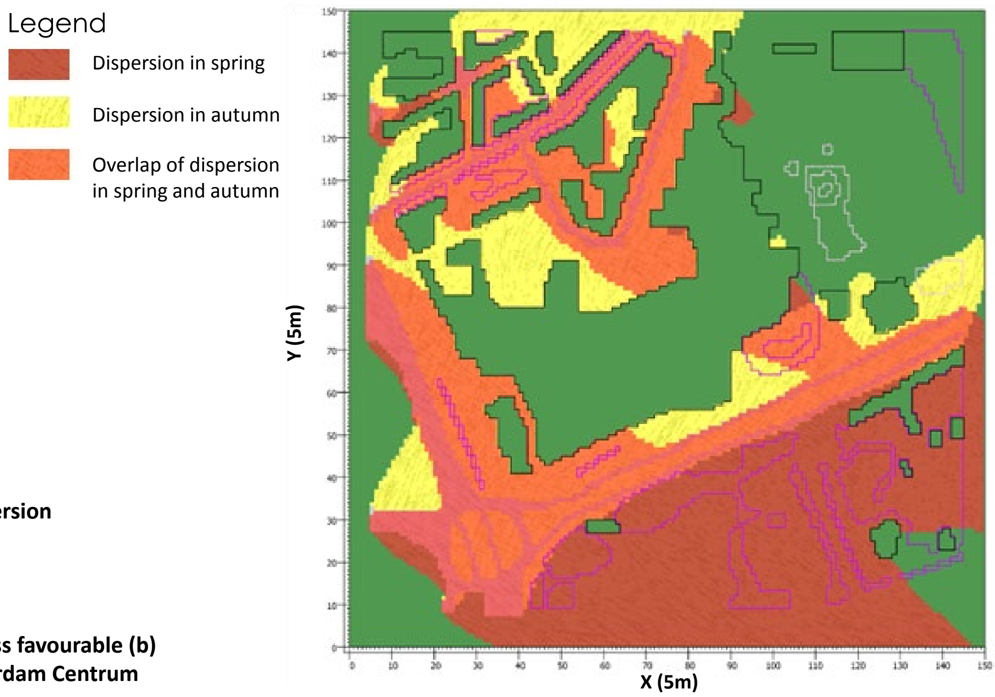
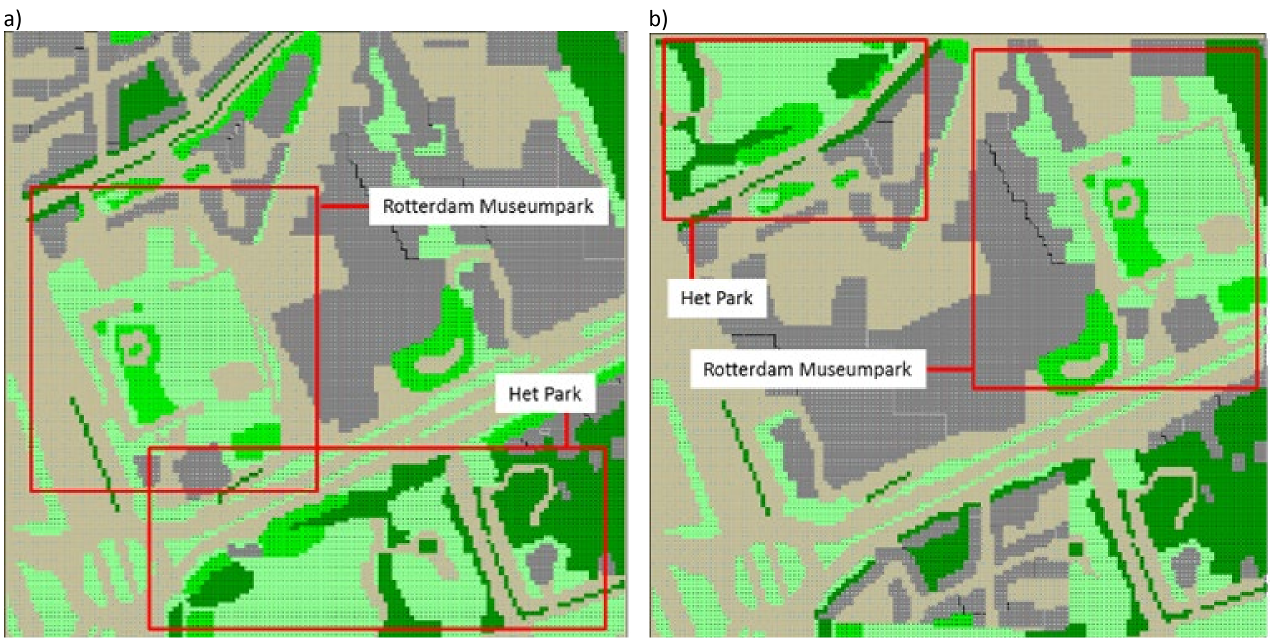


Figure 20
Spatial pattern of NO_2 dispersion in Rotterdam Centrum

Figure 21
More favourable (a) and less favourable (b) locations for parks in Rotterdam Centrum



5.1.2 CHARLOIS

As shown in figure **22**a, the hotspots in spring formed at the north of the case area (in Doklan and Pleinweg). The hotspot was formed at that particular locations because of three conditions: 1) the traffic volume; 2) the wind that flowed at 3-2m/s into the area at 301° angle dispersed NO_2 to the west (the same direction with the urban canyon); and 3) the configuration of the buildings. The traffic volume in Doklan and Pleinweg was relative high (see figure 13). A canyon effect happened in that location because the wind was the same direction with the shape of the buildings. The vortices created by the canyon effect trapped NO_2 and created a hotspot in the canyon. The highest NO_2 concentration at the hotspot was more than 95µg/m^3; and was 55-50µg/m^3 at the north and south side. On the other hand, the ventilation at the side of Dorpsweg helped dispersed NO_2 from the canyon out of the area, making the highest concentration in Dorpsweg to only reached 35-20µg/m^3, and the concentration in habitation area only between 20 and 5µg/m^3. In this configuration, the parks (Karel de Stouteplein and Laperlaarsingel Park) were parallel to the wind (and NO_2) flow. The same low concentration (only 0-15µg/m^3) at both the windward and leeward side of the park suggests that the parks didn't affect NO_2 dispersion in the area.

The wind in autumn flowed into the area at 205° (from southwest to northeast), in 2.5-1m/s, which dispersed NO_2 from the sources toward the northeast (figure 22b). The hotspot was then formed in Dorpsweg (the main road that stretched from south to north) at which the maximum concentration reached up to 85µg/m^3. The formation of the hotspot can also be expained by the canyon effect that happened in that location because the wind was flowing at the same direction with the canyon. On the other hand, the NO_2 concentration was only 55-25µg/m^3 at Doklan and Pleinweg. The NO_2 concentration in the habitation area was mostly only 10-0µg/m^3 (10-5µg/m^3 lower than in spring) and only increased to 40-50µg/m^3 at the border with the roads.

All of the differences between the NO_2 dispersion in spring and autumn can be explained by the different emission rate, wind speed, and wind directions in both seasons. The emission in autumn was 10µg lower than in spring (see table 2 in chapter 4), and the maximum concentration in autumn was also 10µg/m^3 lower than in spring. The wind in spring was stronger than in autumn which helped disperse NO_2 out of the area. The wind in spring was flowing at 301° while in autumn it was 205°. The different direction caused the canyon effect to happen at different locations. In spring the wind was the same direction as the Doklan and Pleinweg canyon while in autumn the wind was the same direction as the Dorpsweg.

The difference of dispersion directionin spring and autumn is shown more clearly in the vertical sections as shown in figure 23-25. Figure 23 a-b show that the dispersion happened from west to east, but we can see that the concentration in the east was lower in spring because of the north/south dispersion as shown in figure 24-25 a and b. Figure 24-25 show that NO_2 was dispersed to the south in spring and to the north in autumn.

The spatial pattern of the NO_2 dispersion in spring and autumn is as shown in figure 26. Most roadside buildings were exposed during spring and autumn. Based on that, and on the urban configuration, the more and the less favourable locations are shown in figure 27a and 27b. In the more favourable locations (for the second simulation), Karel de Stouteplein

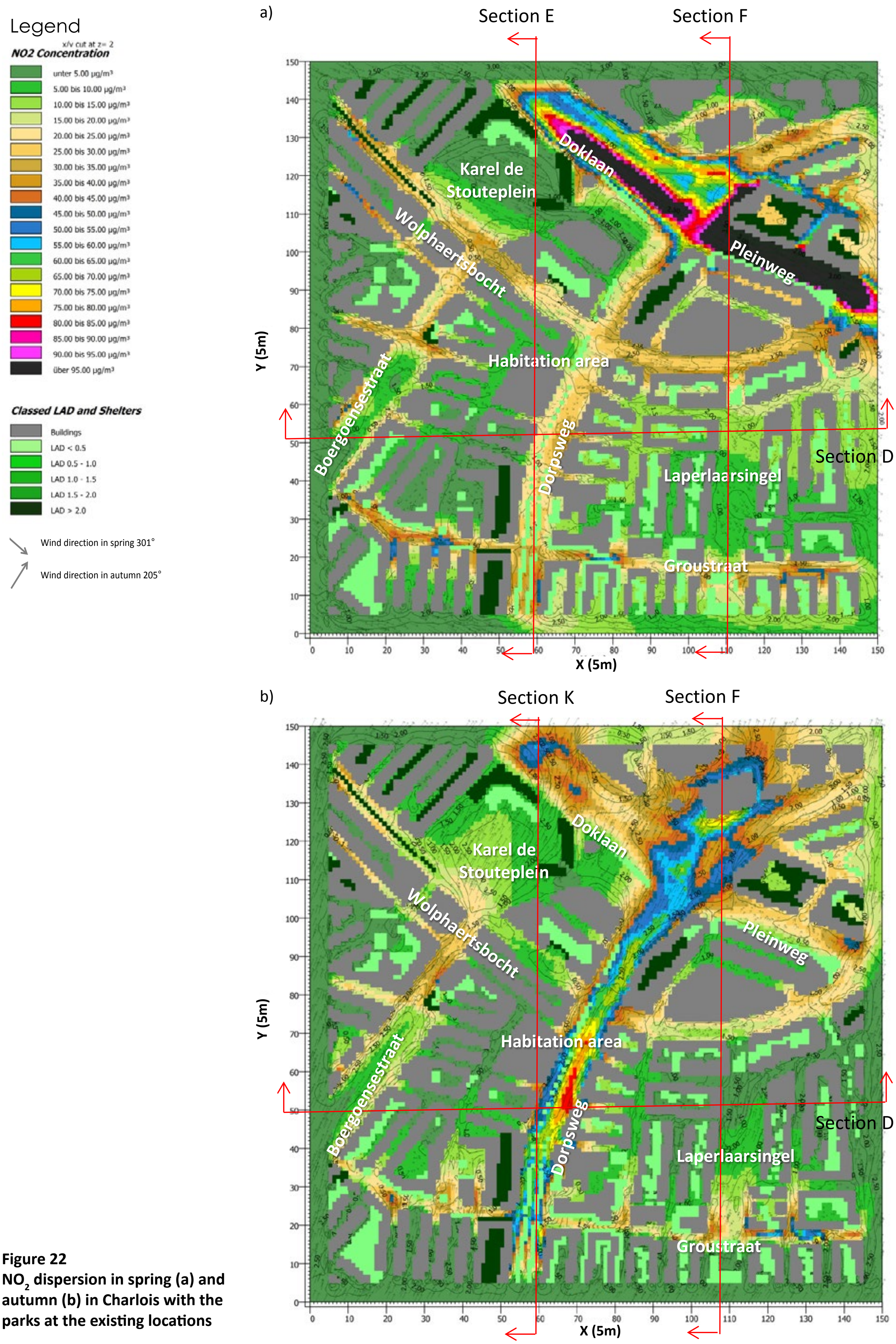


Figure 22
NO_2 dispersion in spring (a) and autumn (b) in Charlois with the parks at the existing locations

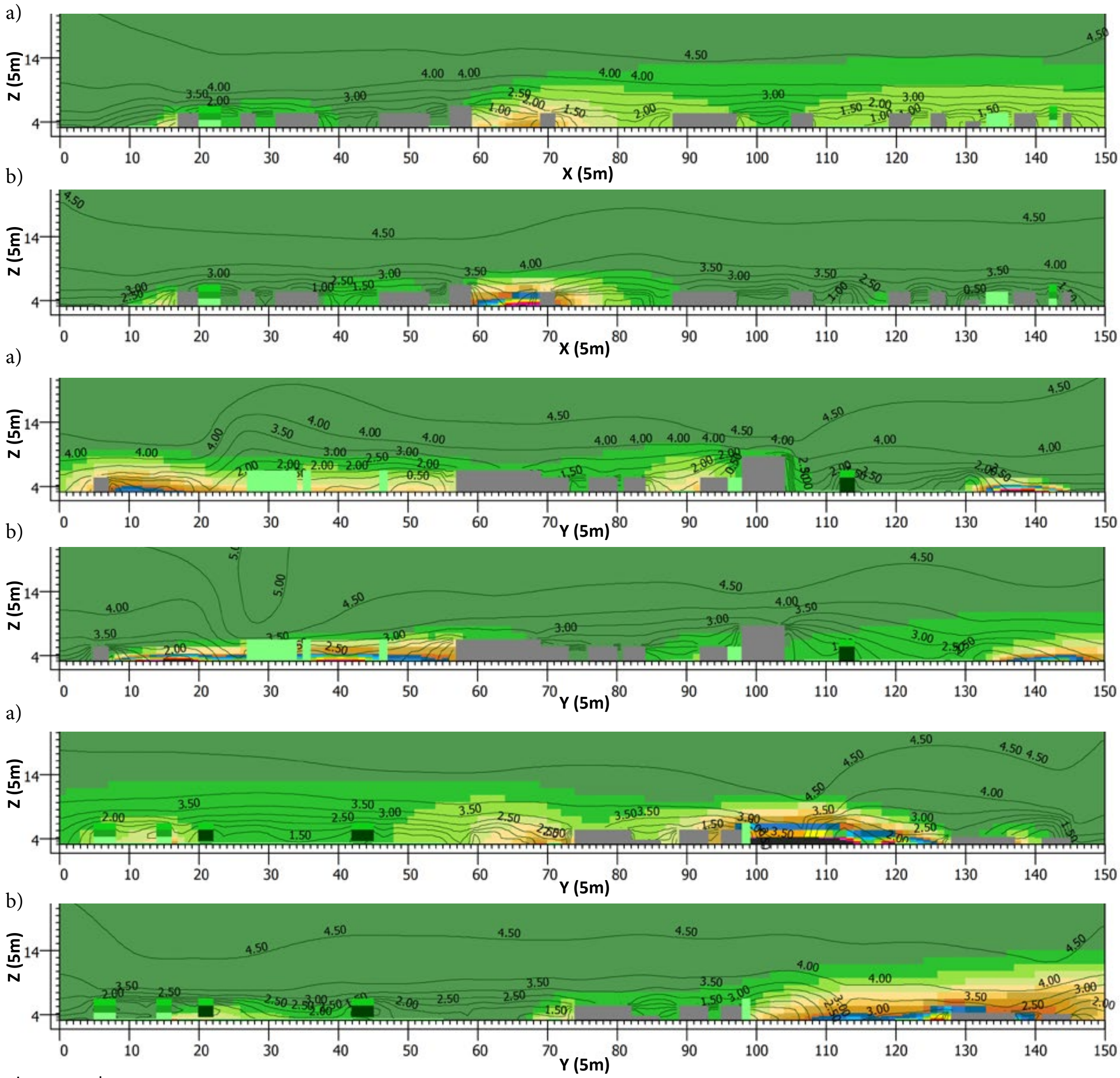


Figure 23 (top) a-b
Vertical spatial pattern of NO_2 dispersion at section D of Charlois in spring (a) and in autumn (b)

Figure 24 (middle) a-b
Vertical spatial pattern of NO_2 dispersion at section E of Charlois in spring (a) and in autumn (b)

Figure 25 (bottom) a-b
Vertical spatial pattern of NO_2 dispersion at section F of Charlois in spring (a) and in autumn (b)

and Lapelaarsingel parks were located close to the hotspots and at the windward of a habituated area in spring and autumn. In the less favourable locations (the third simulation), the Karel de Stouteplein Park was relocated to a location that in spring was the leeward of the habitation area while in autumn it was on the windward of a settlement, at the leeward of low polluted road (Gruttostraat). The Lapelaarsingel Park was relocated to a location that was at the parallel of the pollution dispersion in spring and at the windward of the pollution source in autumn. The location for Karel de Stouteplein Park in the second simulation was at the windward of Wolphaertsbocht. Even though Wolphaertsbocht is one of the sources of NO_2 in this simulation, the concentration at the road was low. Pleinweg was a larger source of NO_2 than in this research. Because of that, based on the hipothesis, location for Karel de Stouteplein in the second simulation was still more favourable than the existing location that was parallel to the major NO_2 source (Doklaan) or to the third simulation in which the location was on the downwind of a road with only low pollution level.

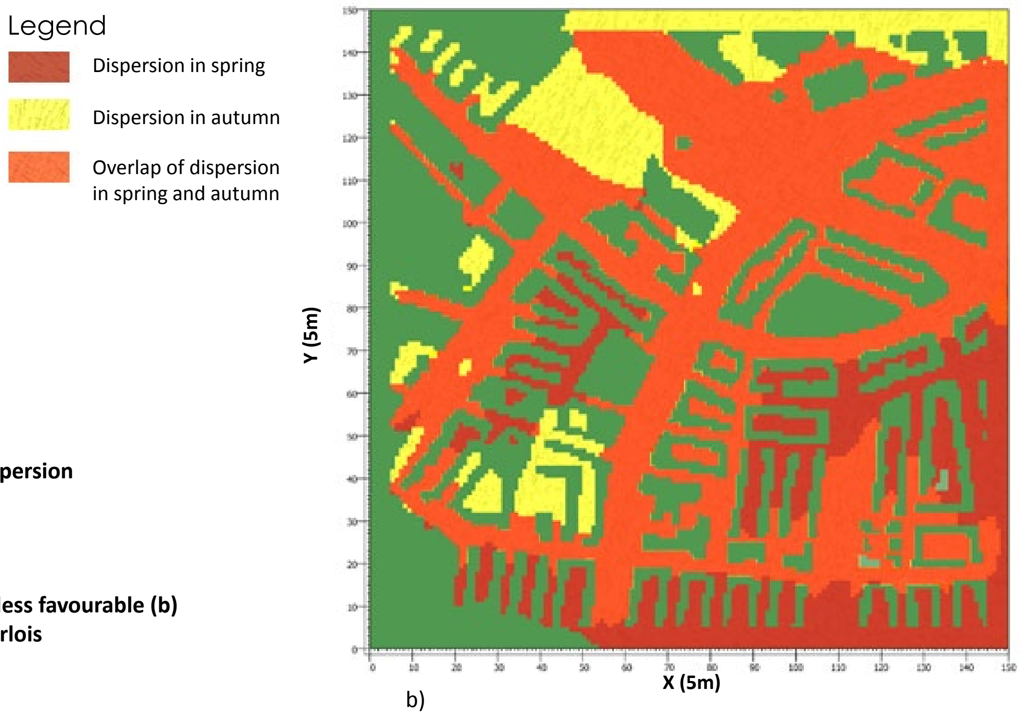


Figure 26
Spatial pattern of NO_2 dispersion in Charlois

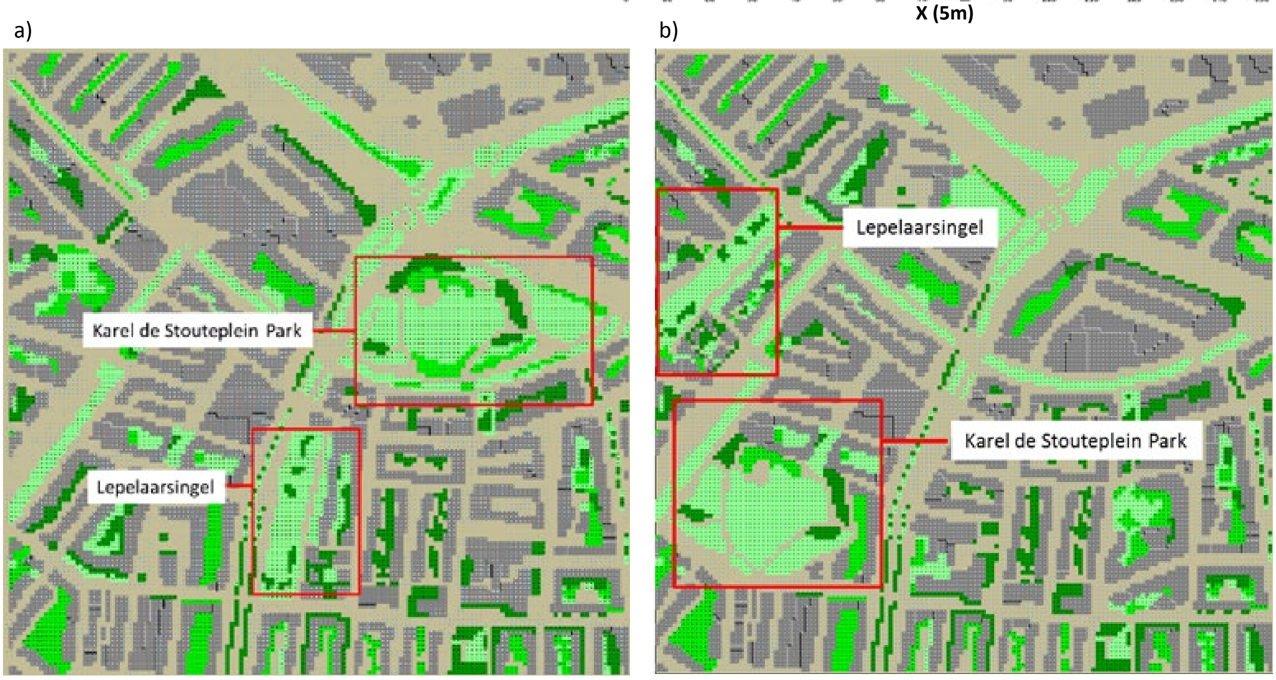


Figure 27
More favourable (a) and less favourable (b) locations for parks in Charlois

5.2 THE SPATIAL PATTERN OF AIR POLLUTION DISPERSION IN THE STUDY AREA WHEN THE PARKS ARE LOCATED IN MORE FAVOURABLE LOCATIONS

This section is divided into two parts; the first part provides the explanations about the NO_2 dispersion in Rotterdam Centrum in spring and autumn, the second part provides the explanations about the spatial pattern of NO_2 dispersion in Charlois in spring and autumn. The result is shown in a similar manner with the first section of this chapter.

5.2.1 ROTTERDAM CENTRUM

The dominant wind direction in the spring was 311° (especially in the west, open part of the area) even though the inputted wind direction was 301°. This deflection of wind direction can be explained by the open space provided by the relocated Museumpark on the west side of the case area. The wind speed was between 2.50 and 1m/s, which were as expected because commonly wind speed at layer is 60% of the speed at 10m. The hotspots in spring (figure 28a) formed around the large roundabout at the southwest or the case area, which is the intersection of 'S-Gravendijkwal and Westzeedijk. A small hotspot also formed at Rochussenstraat. The highest NO_2 concentration according to the simulation was higher than 95µg/m^3 at the border between the roundabout and Het Park. The NO_2 level in Het Park decreased from as high as 65µg/m^3 at the west border to 10-5µg/m^3 after 250m into the park. In the relocated Museumpark, the NO_2 concentration was only from 15µg/m^3 to lower than 5µg/m^3 after 60m into the park.

The wind direction in autumn was only deflected 1-3° from the windward surfaces of tree clusters and buildings. The wind speed was between 3 and 0.50m/s. The hotspots in autumn also formed around the large roundabout. The concentration at the roundabout was 40-35µg/m^3 lower than in spring. The highest concentration in the hotspot was only 60 to 55µg/m^3 and was formed at the windward of the tree line at 'S-Gravendijkwal. On the other hand, the concentration in the north and northeast of the case area was in average 10-5µg/m^3 higher than in spring because of the direction of the NO_2 dispersion.

As explained in the first section of this chapter, the differences between the NO_2 dispersion in spring and autumn in Rotterdam Centrum were caused by the difference in spring and autumn's windflow. The low wind speed in autumn and the presence of the building at the southeast of Museumpark caused NO_2 build up in the roundabout and caused the difference in maximum concentration between spring and autumn to be 10µg higher than the difference in emission levels.

The difference of dispersion directionin spring and autumn is shown more clearly in the vertical sections as shown in figure 29-31. Figure 29 a-b show that the dispersion happened from west to east (towards X 150), but the concentration in the east was lower in spring because of the north/south dispersion as shown in figure 30-31 a and b. Figure 30-31 show that NO_2 was dispersed to the south (towards Y 0) in spring and to the north (towards Y 150) in autumn.

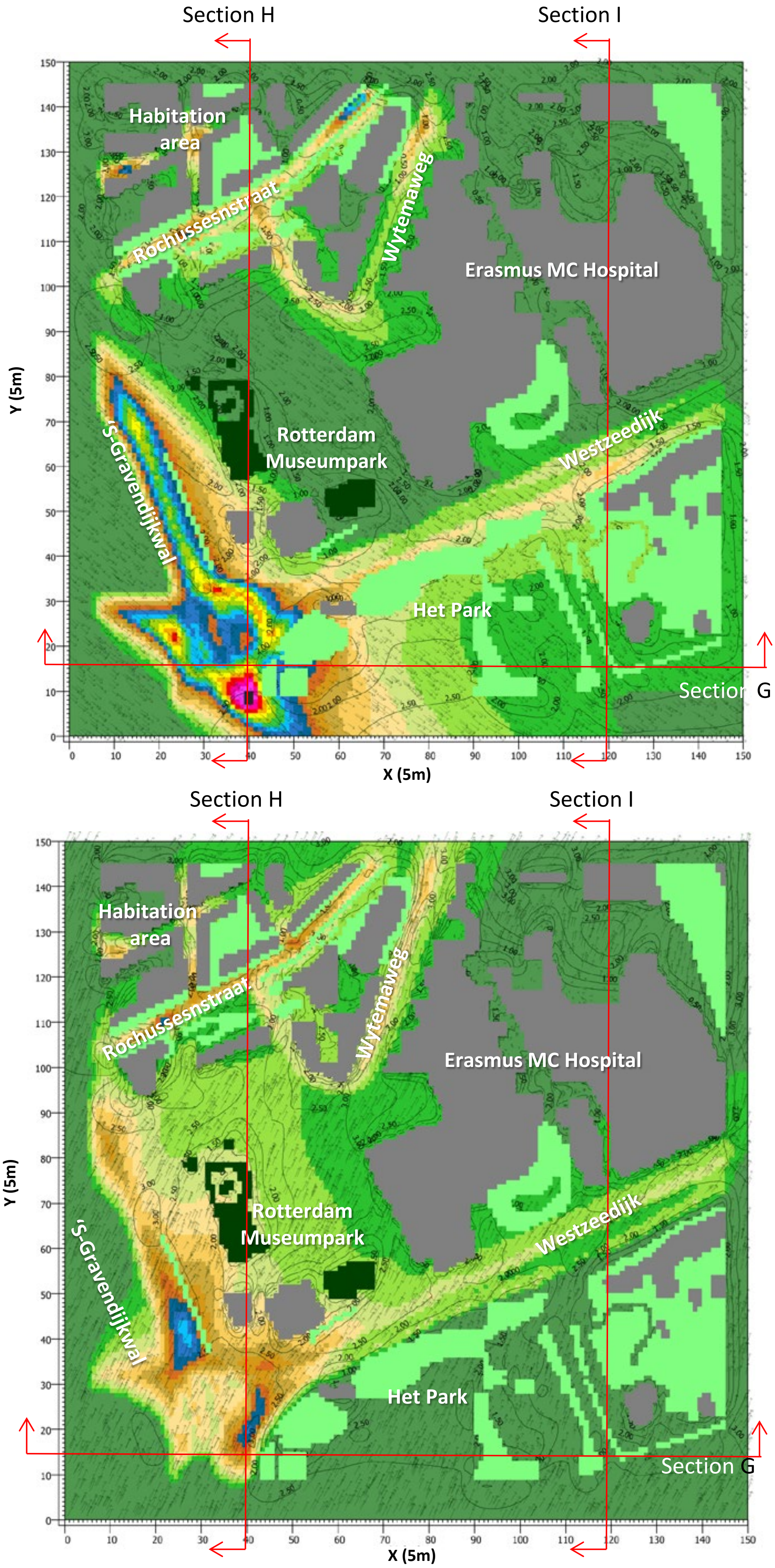
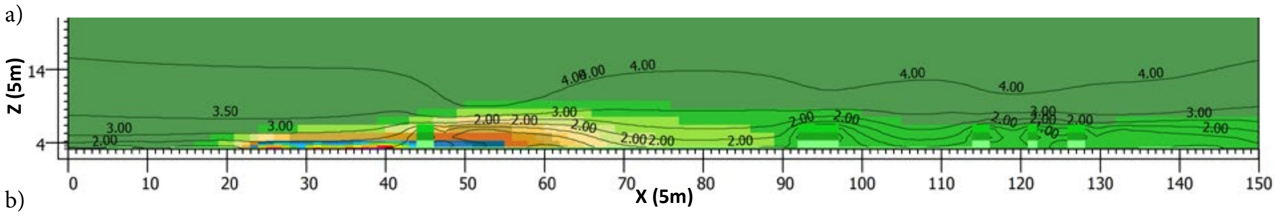
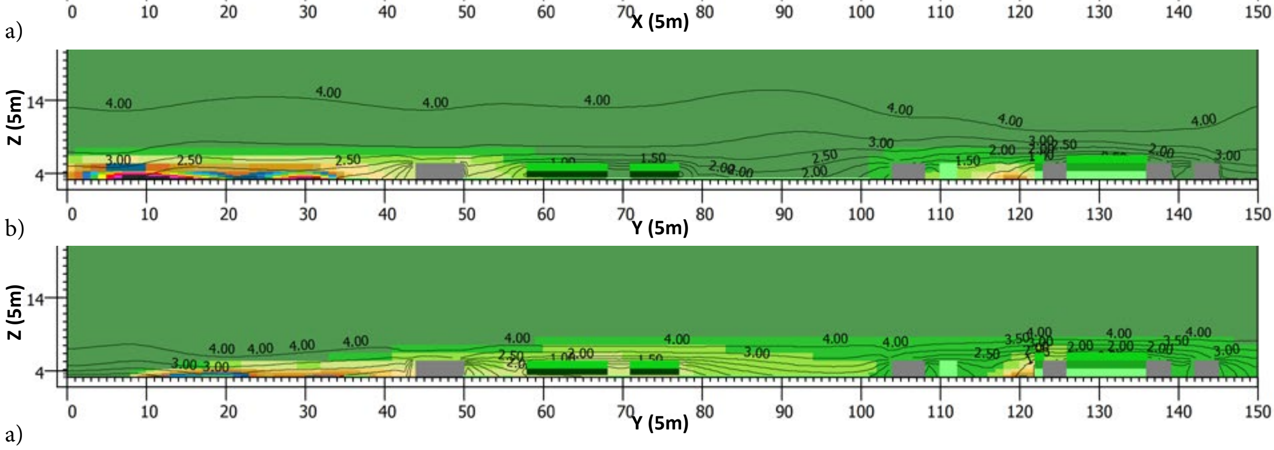


Figure 28
NO_2 dispersion in spring (a) and autumn (b) in Rotterdam Centrum with the parks at their more favourable locations





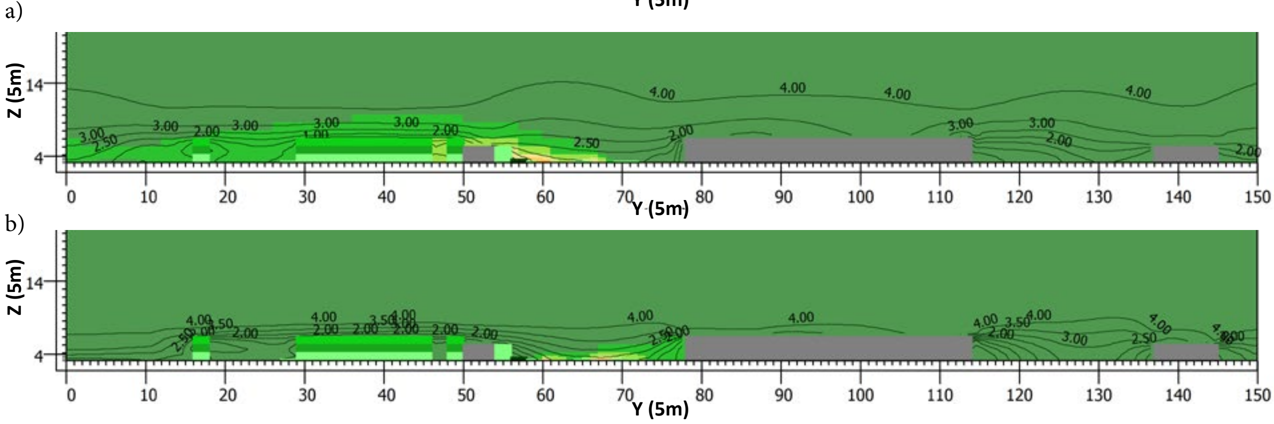


Figure 29 (top)
Vertical spatial pattern of NO_2 dispersion at section G of Rotterdam Centrum in spring (a) and in autumn (b)

Figure 30 (middle)
Vertical spatial pattern of NO_2 dispersion at section H of Rotterdam Centrum in spring (a) and in autumn (b)

Figure 31 (bottom)
Vertical spatial pattern of NO_2 dispersion at section I of Rotterdam Centrum in spring (a) and in autumn (b)

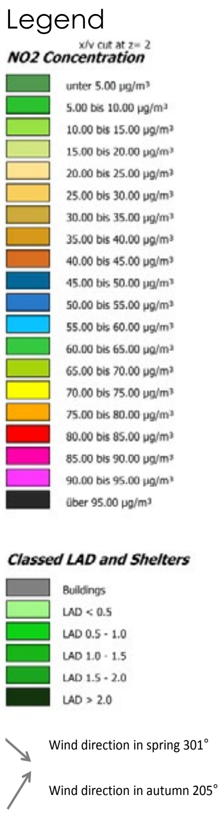
5.2.2 CHARLOIS

As shown in figure 32a, the hotspots in spring formed at the north of the case area (in Doklan and Pleinweg) because the traffic volume in Doklan and Pleinweg was relative high and because the wind that flowed into the area at 301° in 3-2m/s trapped NO_2 in the Doklan-leinweg canyon. The highest NO_2 concentration at the hotspot was more than 95µg/m^3; and was only 55-50µg/m^3 at the south and north side of the canyon. The NO_2 concentration in the urban canyon at Dorpsweg was only 35-20µg/m^3 and the NO_2 concentration at the habitation area was only from 15µg/m^3 to less than 10µg/m^3. In this configuration, Karel de Stouteplein Park was parallel to the wind that flowed in Pleinweg, but it was also almost perpendicular to the wind that flowed from Doklan. The concentration at the windward and leeward of the park (at Dorpsweg) was both 20-25µg/m^3. This suggest that the park didn't affect the NO_2 dispersion, however when we see the pattern inside the park, it is evident that the concentration at the west side was 5µg/m^3 higher than at the east. Laperlaarsingel Park was located at an angle to the wind direction. The concentration at the windward was 10-15µg/m^3 higher than its leeward.

The wind in autumn flowed into the area at 205^o (from southwest to northeast) in 3-1.5m/s, which dispersed NO_2 from the sources toward the northeast. The hotspot was then formed in Dorpsweg (the main road that stretched from south to north) at which the maximum concentration reached up to 90µg/m^3 (figure 42b). On the other hand, the NO_2 concentration in the habitation area was mostly only 10µg/m^3 to lower than 5µg/m^3 (10-5µg/m^3 lower than in spring) and only increased to 40-50µg/m^3 at the border with the roads. The wind flowed into Karel de Stouteplein Park at 205^o from southwest to north and northeast (at an angle/oblique to the park). The concentration at the north border of the park was the same as the south because there were NO_2 sources at either side. The concentration at 20m leeward of Karel de Stouteplein was higher than its windward. This conditioned happened because the wind that flowed through the park and dispersed NO_2 to the north was blocked by the building at the north of Pleinweg. The wind then formed vortices at the windward of the building that led to high NO_2 concentration being trapped in that location. On the other hand, the concentration at the leeward of Laperlaarsingel Park was 35µg/m^3 than its windward. This happened because the park was parallel with the wind direction in Dorpsweg. The dispersion flow only 'bled[vi]' 15m into the park.

The spatial pattern of the NO_2 dispersion in autumn was different from the pattern in spring mainly due to the different wind direction. The difference of dispersion directionin spring and autumn is shown more clearly in the vertical sections as shown in figure 33-35. Figure 33 a-b show that the dispersion happened from west to east, but we can see that the concentration in the east was lower in spring because of the north/south dispersion as shown in figure 34-35 a and b. Figure 34-35 show that NO_2 was dispersed to the south (toward Y 0) in spring and to the north in autumn.

[vi] See section 2.2



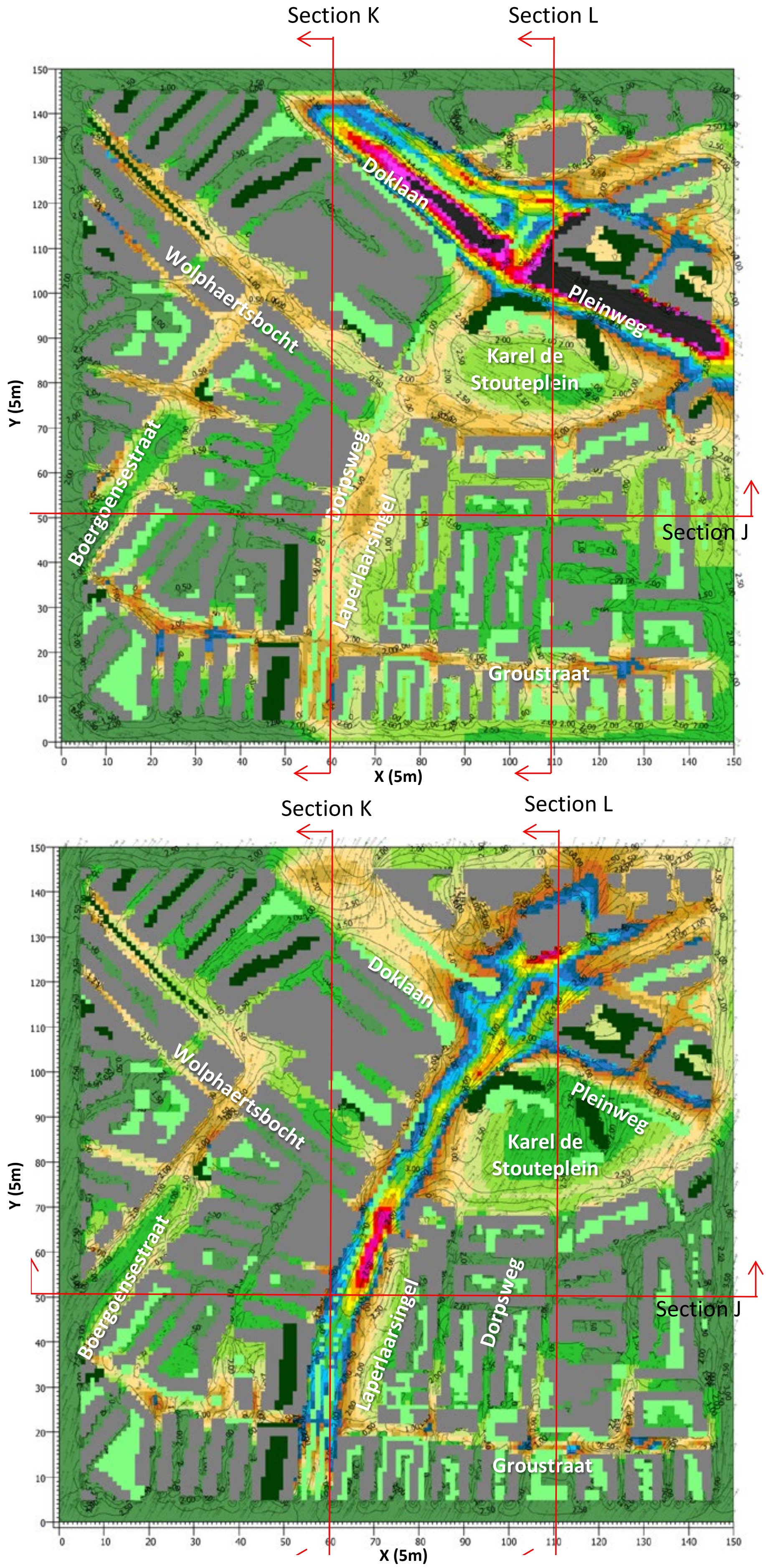


Figure 32
NO_2 dispersion in spring (a) and autumn (b) in Charlois with the parks at the more favourable locations

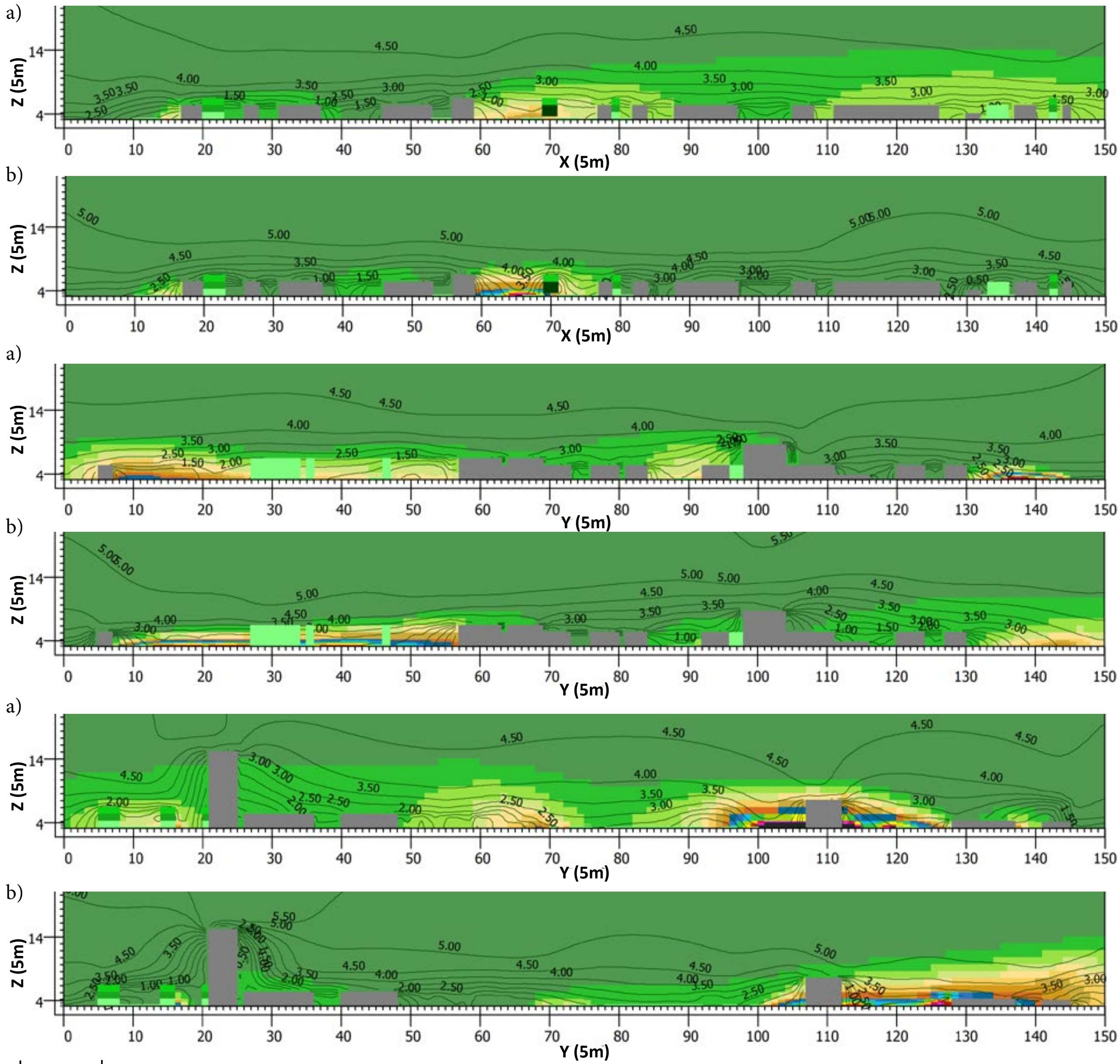


Figure 33 (top)
Vertical spatial pattern of NO_2 dispersion at section J of Charlois in spring (a) and in autumn (b)

Figure 34 (middle)
Vertical spatial pattern of NO_2 dispersion at section K of Charlois in spring (a) and in autumn (b)

Figure 35 (bottom)
Vertical spatial pattern of NO_2 dispersion at section L of Charlois in spring (a) and in autumn (b)

5.3 THE SPATIAL PATTERN OF AIR POLLUTION DISPERSION IN THE STUDY AREA WHEN THE PARKS ARE LOCATED IN LESS FAVOURABLE LOCATIONS

This section is divided into two parts; the first part provides the explanations about the NO_2 dispersion in Rotterdam Centrum in spring and autumn, the second part provides the explanations about the spatial pattern of NO_2 dispersion in Charlois in spring and autumn. The result is shown in a similar manner with the first and second section of this chapter.

5.3.1 ROTTERDAM CENTRUM

In this scenario, a part of Het Park was relocated to the north of the area. Het Park was not relocated completely because of the size of the space at the new location. Museumpark was not relocated because it was already located at a (theoretically) not favourable location. In spring, the wind flowed at 301°-306°, in 2.50 and 1m/s, at the open area at the west side of the area and dispersed NO_2 to southeast. The hotspots in spring (figure 36a) formed around the large roundabout at the southwest or the case area, which is the intersection of 'S-Gravendijkwal and Westzeedijk. A small hotspot also formed at the intersection in the habitation area in the south. The highest NO_2 concentration according to the simulation was 95µg/m^3 (indicated by the area in magenta in figure 36a). The highest NO_2 concentration in relocated Het Park at the north of the area was only 20µg/m^3, but in most of the park the concentration was less than 5µg/m^3. On the other hand, the NO_2 concentration at the roundabout was between 90µg/m^3 (at the border with the habitation area). The highest concentration at the habitation area was 45µg/m^3. The concentration decreased to 10-5µg/m^3 400m east of the border between the roundabout and the habitation area. In the Museumpark, the NO_2 concentration was under 5µg/m^3.

In autumn, the wind was flowing at 205°, from 3.5 to 1m/s. The wind condition also caused the hotspot to form around the large roundabout. The concentration at the roundabout was 40-35µg/m^3 lower than in spring. The highest concentration athe windward of the tree line in 'S-Gravendijkwal was only 60 to 55µg/m^3. On the other hand, the concentration in the north and northeast of the case area was in average 10-5µg/m^3 higher than in spring because of the direction of the NO_2 dispersion.

As explained in the first section of this chapter, the differences between the NO_2 dispersion in spring and autumn in Rotterdam Centrum were caused by the difference in spring and autumn windflow. However, it should be noted that the difference between the maximum NO_2 concentration in spring and autumn was larger than the difference between the NO_2 emissions. The difference of the maximum concentration was 35µg/m^3 while the difference in emission levels in spring and autumn was only 25µg/m^3.

The difference of dispersion directionin spring and autumn is shown more clearly in the vertical sections as shown in figure 37-39. Figure 37 a-b show that the dispersion happened from west to east (towards X 150), but the concentration in the east was lower in spring because of the north/south dispersion as shown in figure 38-39 a and b. Figure 38-39 show that NO_2 was dispersed to the south (towards Y 0) in spring and to the north (towards Y 150) in autumn.

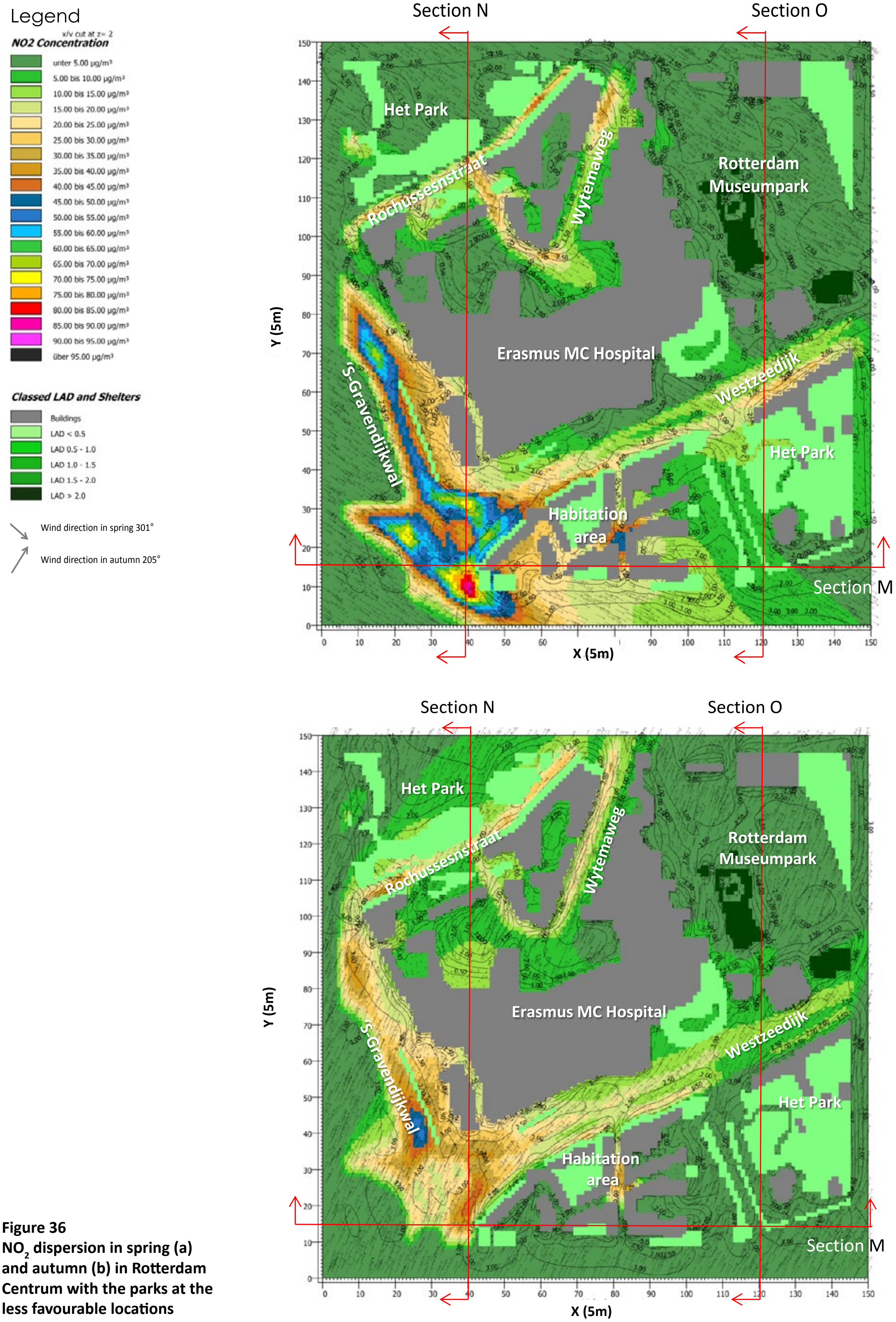
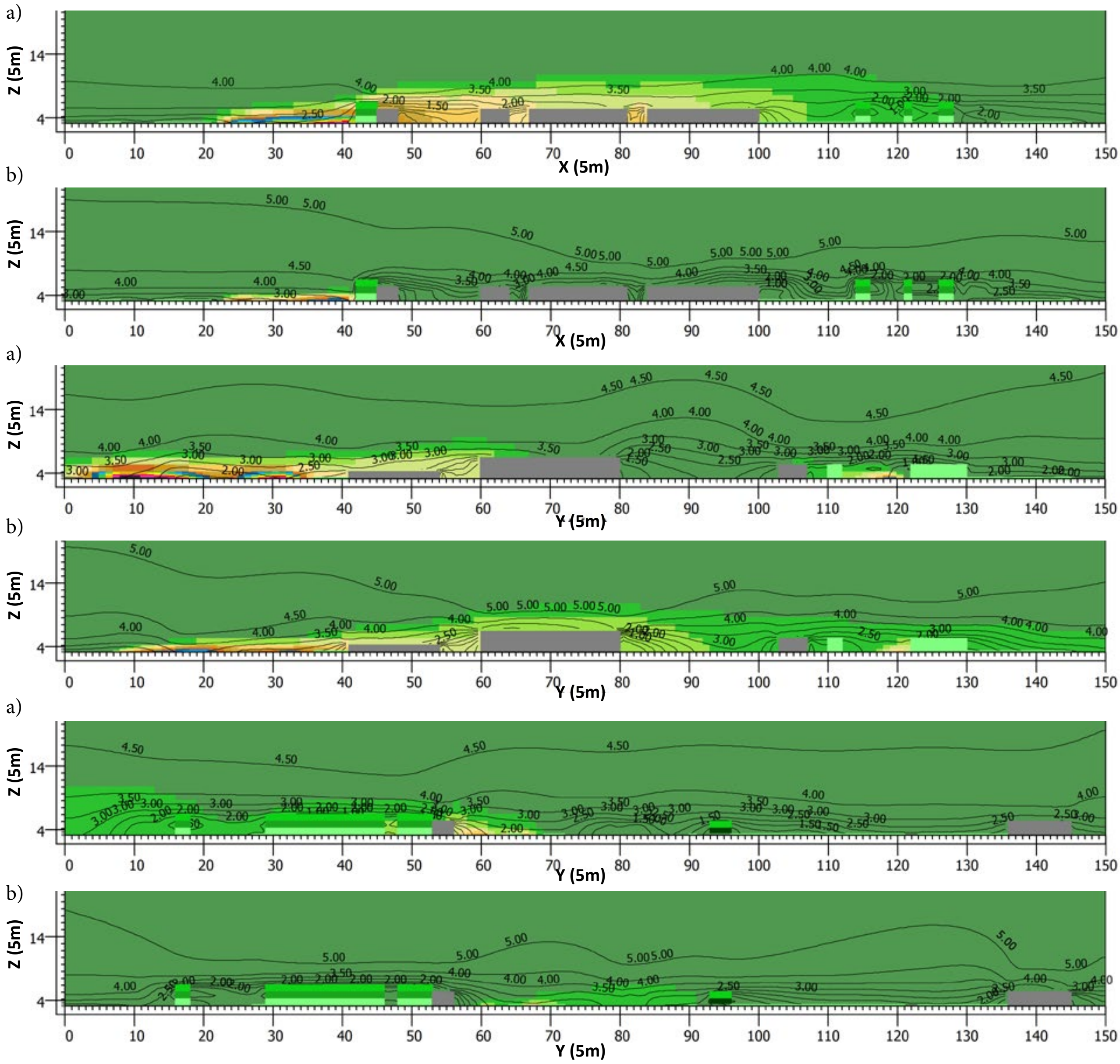


Figure 36
NO_2 dispersion in spring (a) and autumn (b) in Rotterdam Centrum with the parks at the less favourable locations



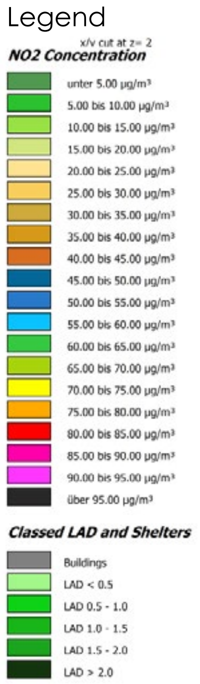


Figure 37 (top)
Vertical spatial pattern of NO_2 dispersion at section M of Rotterdam Centrum in spring (a) and in autumn (b)

Figure 38 (middle)
Vertical spatial pattern of NO_2 dispersion at section N of Rotterdam Centrum in spring (a) and in autumn (b)

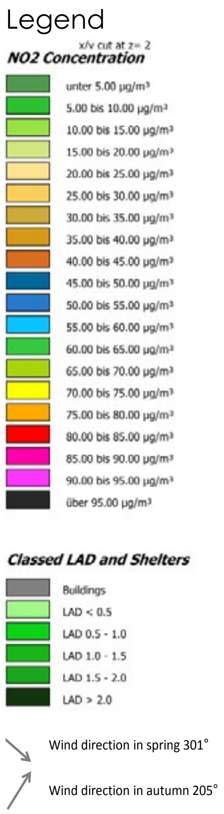
Figure 39 (bottom)
Vertical spatial pattern of NO_2 dispersion at section O of Rotterdam Centrum in spring (a) and in autumn (b)

5.3.2 CHARLOIS

As shown in figure 40a, the hotspots in spring formed at the north of the case area (in Doklan and Pleinweg) because the traffic volume in Doklan and Pleinweg was relative high and because the wind that flowed into the area at 301°, in 3 to 1m/s, trapped NO_2 in the Pleinweg canyon. The highest NO_2 concentration at the hotspot was more than 95µg/m^3 in Pleinweg while in Doklan the highest concentration was only 85µg/m^3. The NO_2 concentration in the habitation area was only from 15µg/m^3 to less than 10µg/m^3. The NO_2 concentration in the urban canyon at Dorpsweg was only 35-20µg/m^3. However, there was also a small hotspot (with NO^2 concentration from 20-60µg/m^3) at the south section of Dorpsweg. In this configuration, the Karel de Stouteplein was located at the leeward of an NO_2 source with low concentration (Boergoensestraat), and at the windward of the major source in Dorpsweg. The concentration at the windward was 5µg/m^3 higher than at the leeward. Laperlaarsingel Park (the short side of the park) was located parallel to a source with low emision. The concentration at the windward and the leeward of the park was both only 0-5µg/m^3. The same low concentration (only 0-5µg/m^3) at both the windward and leeward side of the park suggests that the parks didn't affect NO_2 dispersion in the area.

The wind in autumn flowed into the area at 205^o (from southwest to northeast) in 3-1.5m/s, which dispersed NO_2 from the sources toward the northeast. The hotspot was then formed in Dorpsweg (the main road that stretched from south to north) at which the maximum concentration reached up to 70µg/m^3. On the other hand, the NO_2 concentration in the habitation area was mostly only 10µg/m^3 to lower than 5µg/m^3 (10-5µg/m^3 lower than in spring) and only increased to 40-50µg/m^3 at the border with the roads. The concentration at the leeward of Karel de Stouteplein was 15-10µg/m^3 lower from the windward. One thing to be noted is the wave-like pattern that formed in front and in the park. This pattern was formed because of the configuration if the buildings at the south of the park that created channel and 'shadow' area in Groustraat. The NO_2 concentration in and around the Laperlaarsingel Park was similar to the condition in spring.

The spatial pattern of the NO_2 dispersion in autumn was different from the pattern in spring mainly due to the different wind direction. The difference of dispersion directionin spring and autumn is shown more clearly in the vertical sections as shown in figure 41-43. Figure 41 a-b show that the dispersion happened from west to east (towards X 150), but we can see that the concentration in the east was lower in spring because of the north/south dispersion as shown in figure 42-43 a and b. Figure 42-43 show that NO_2 was dispersed to the south (towards Y 0) in spring and to the north (towards Y 150) in autumn



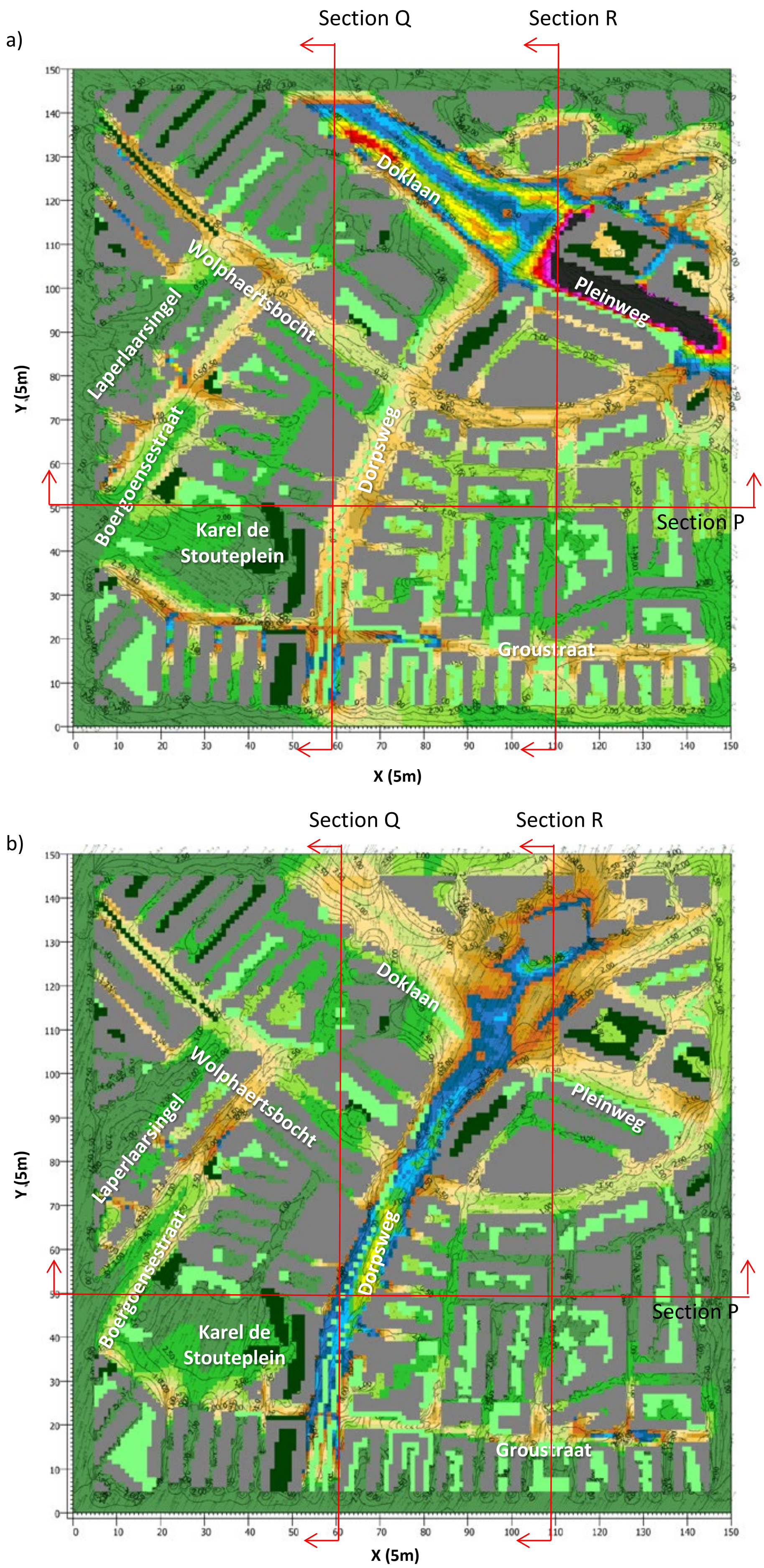


Figure 40
NO_2 dispersion in spring (a) and autumn (b) in Charlois with the parks at the less favourable locations

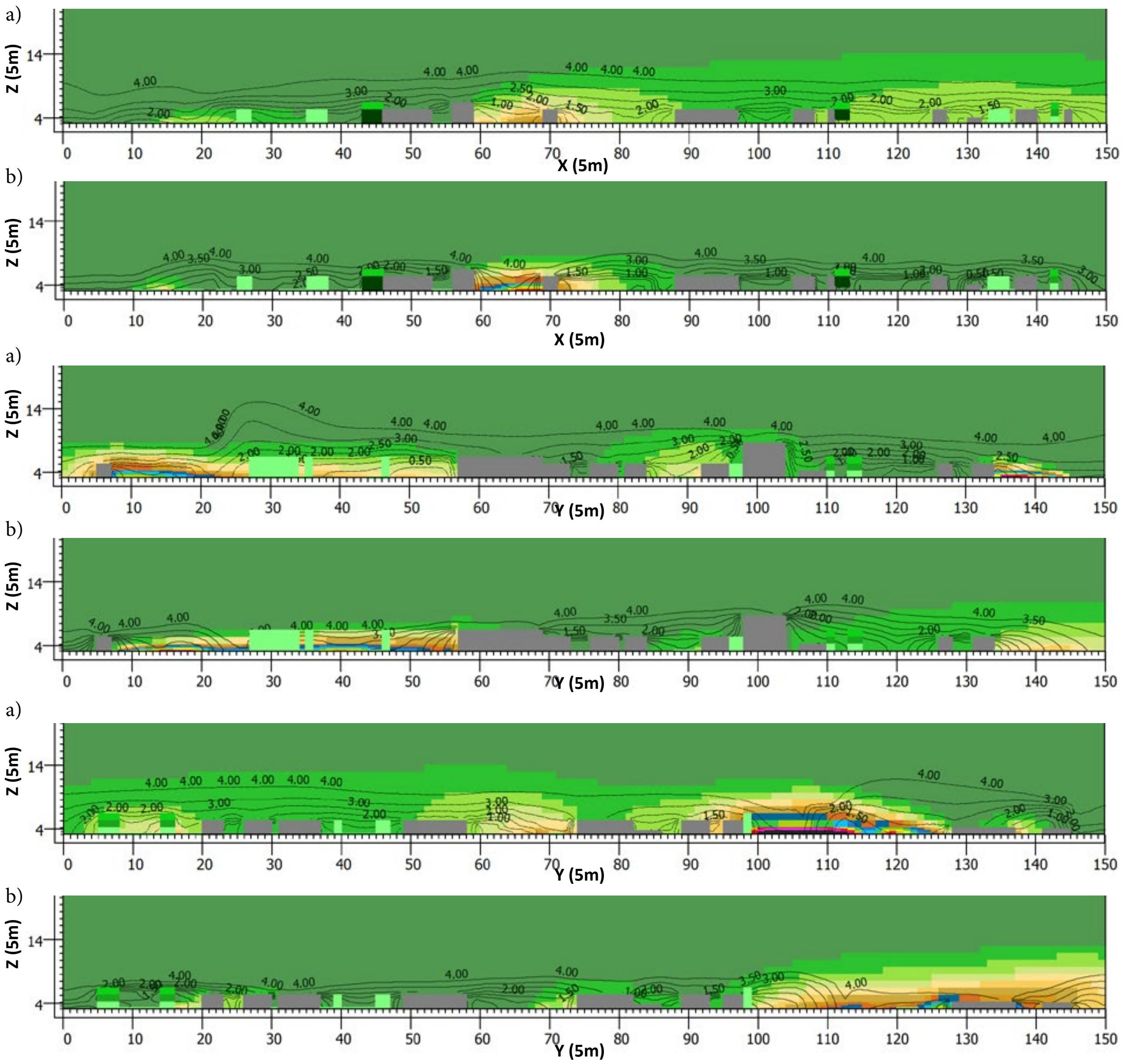


Figure 41 (top)
Vertical spatial pattern of NO_2 dispersion at section P of Charlois in spring (a) and in autumn (b)

Figure 42 (middle)
Vertical spatial pattern of NO_2 dispersion at section Q of Charlois in spring (a) and in autumn (b)

Figure 43 (bottom)
Vertical spatial pattern of NO_2 dispersion at section R of Charlois in spring (a) and in autumn (b)

5.4 THE DIFFERENCES IN THE SPATIAL PATTERN OF AIR POLLUTION DISPERSION AT THE CASE AREAS BETWEEN THE EXISTING PARK LOCATIONS, MOST IDEAL LOCATIONS, AND LEAST IDEAL LOCATIONS

This section is then divided into two parts. The first parts explain the differences in the spatial patterns of NO_2 dispersion in Rotterdam Centrum in spring and in autumn. The second part explains the differences in the spatial patterns of NO_2 in Charlois in spring and autumn. The differences are explained by comparing the NO_2 concentration at certain distances from reference points in the case areas. I selected one reference point in Rotterdam Centrum and two reference points in Charlois (explained further in the Charlois section). From the reference points, I charted the NO_2 concentration at 20m intervals toward the east and the northeast until the point with the lowest NO_2 concentration. The reference points and direction of the chart were selected so that the chart can be present the dispersion pattern in the clearest way. The patterns are shown in two charts for each season to avoid rehashing.

Because the NO_2 concentration was displayed by Envi-Met in classes of 5µg/m^3 intervals, the concentration at the 20m intervals from the reference point in this analysis was rounded down. Case in point, when NO_2 concentration at 20m from the reference point is in between 55-60µg/m^3, the concentration is considered as 55µg/m^3. However, if the measured concentration in that particular distance is the border between 55-60µg/m^3 and 60-65µg/m^3, and then the concentration is considered to be 60µg/m^3. When the reference line passed over a building, the concentration is inputted as unknown instead of 0 to avoid discrepancy in the chart.

5.4.1 ROTTERDAM CENTRUM

5.4.1.1 Spring

Figure **44**a-c show the NO_2 dispersion in spring, reference point and direction of measurement (black dot and lines) for this analysis. As shown in the pictures, the hotspots were located in the same area in each of the three configurations. I measured the NO_2 concentration from the centre of the roundabout because the largest hotspot was located there and NO_2 was dispersed toward the east.

As seen in the chart in figure 45, there was a high NO_2 build up at the roundabout (0 to 100m from the reference point/the border between the roundabout and the park). The highest build up happened in configuration 2 where the NO_2 concentration from 40µg/m^3 at the reference point increased to 70µg/m^3 in 60m. The lowest concentration happened in configuration 1 where the concentration only increased to 55µg/m^3. It should also be noted that the highest concentration in configuration 2 was more than 95µg/m^3 (at the southeast of the reference point) while in configuration 1 and 3 the concentration only reached 85µg/m^3. However, even though there was a relatively high build up at the roundabout in configuration 2, a sharp decline of NO_2 concentration happened at 40m windward of the park (60m from the reference point). The NO_2 concentration decreased from 70µg/m^3 to 45µg/m^3 in just 40m. In configuration 1, the concentration only decreased 5µg/m^3 in 40m. The NO_2 concentration in configuration 1 and 2 decreased in similar manner after

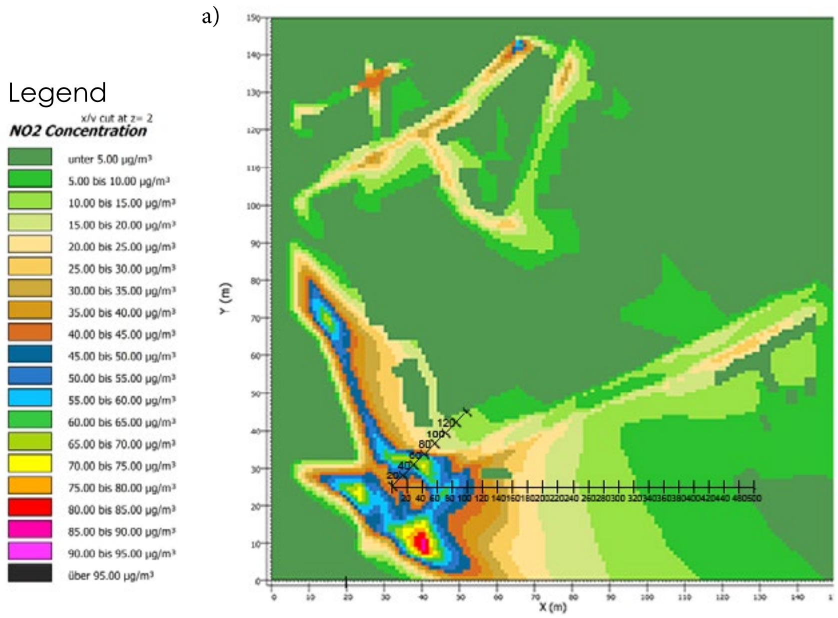
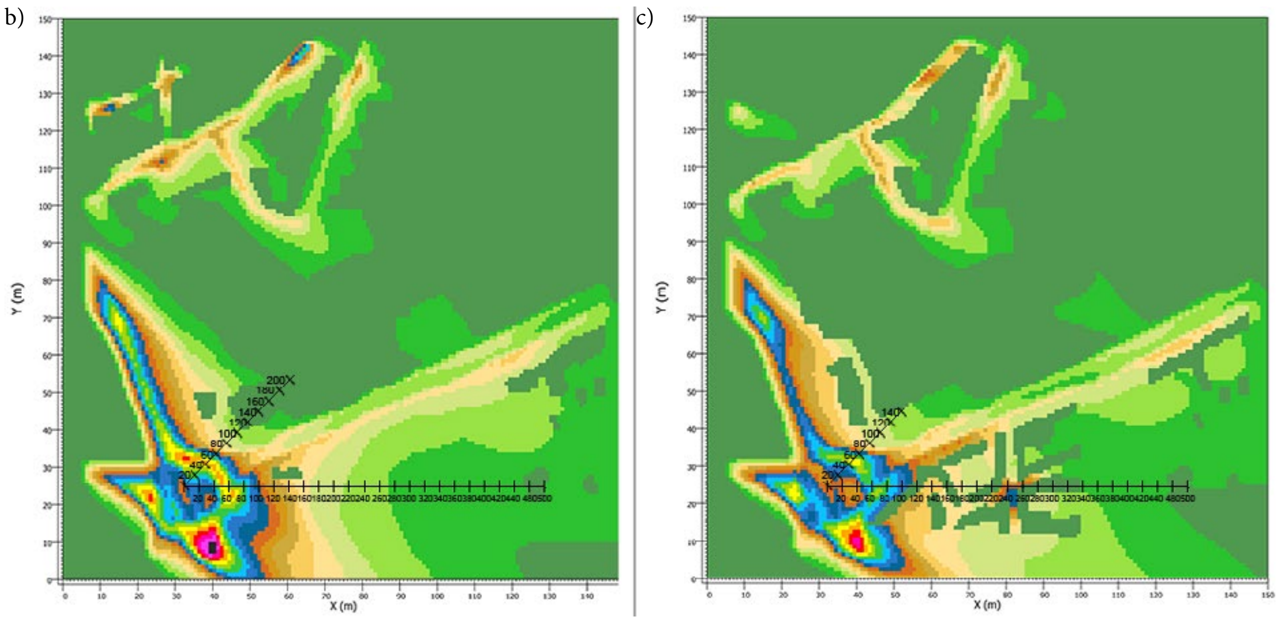


Figure 44
Spring NO_2 dispersion in Rotterdam Centrum in configuration 1 (a), configuration 2 (b), and configuration 3 (c)



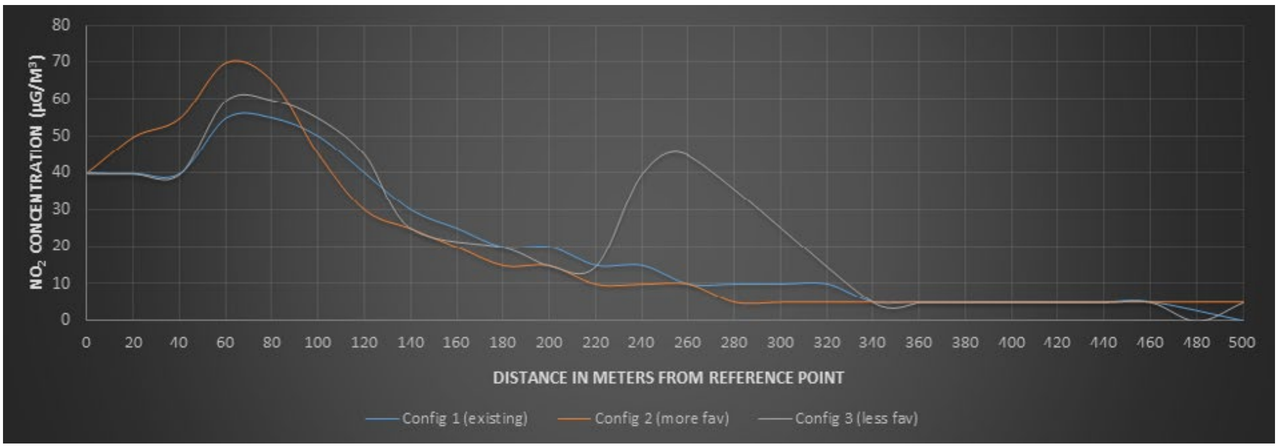


Figure 45
Differences in spring NO_2 concentration in Rotterdam Centrum from West to East

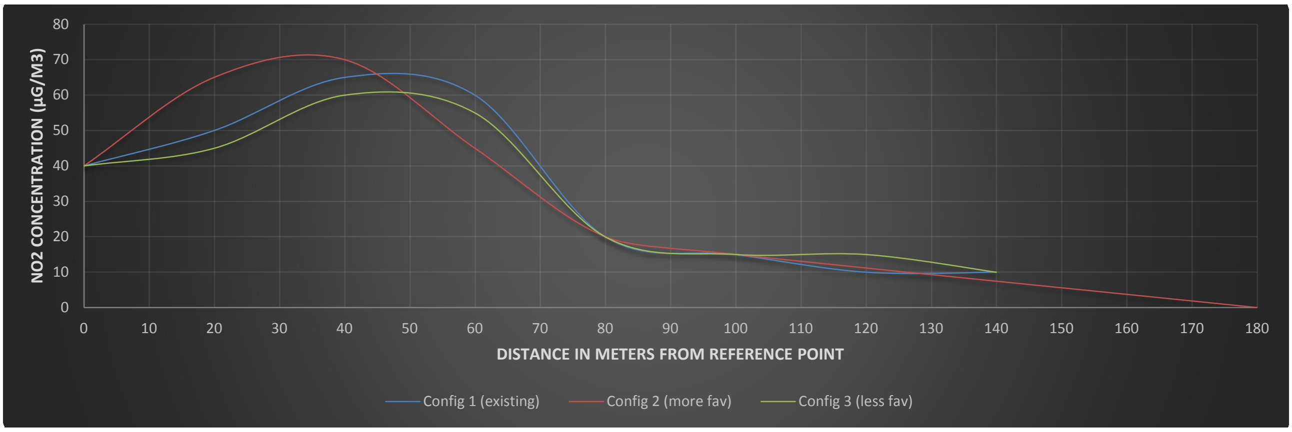


Figure 46
Differences in spring NO_2 concentration in Rotterdam Centrum from southwest to northeast

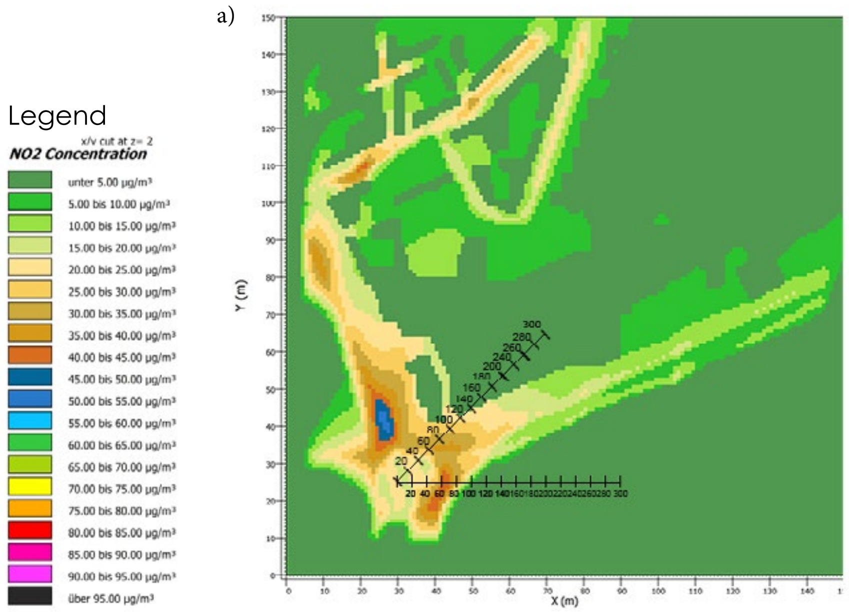
100m from the reference point. The chart also shows that there was higher concentration decreased in configuration 2 than configuration 1 and 3. In all three configurations, the concentration started to decrease between 80 and 100m from the reference point. The NO_2 concentration decreased 20µg/m^3 in only 20m in configuration 2. Meanwhile it only decreased 5µg/m^3 in configuration 1 and 3. Inside the park, the concentration decreased from 40µg/m^3 to 5µg/m^3 in 180m in configuration 2. In configuration 1, the same amount of decrease happened in 240m.

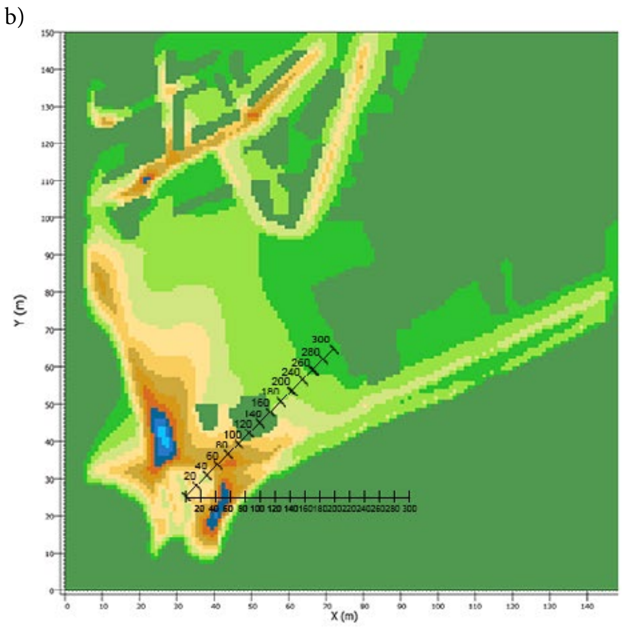
The NO_2 concentrations in configuration 3 shown in figure 45 varied the most because of the buildings in the habitation area. Between 40 and 130m, the concentration was higher than configuration 1, but still lower than configuration 2. This condition led to the highest concentration at 90-120m from the reference point between the three configurations. After 120m from the reference point, the concentration decreased from 45µg/m^3 to 25µg/m^3 at 140m. However, the decrease was just as declivous as configuration 1. There was a high spike of concentration between 200 – 300m from the reference point in configuration 3 because of the source in the relocated habitation area.

The differences in NO_2 dispersion toward the northeast of the case area is shown in figure 46. The lowest concentration happened in configuration 3 (5µg/m^3 lower than in configuration 1 and up to 20 than configuration 2) for the first 50m. However, the NO_2 concentration 2 dipped after 40m. The NO_2 concentration from 140m toward the northeast cannot be shown because of the building in the location. NO_2 was dispersed to the southeast and west over the building (more than 500m from the reference point). In configuration 2, the NO_2 was dispersed further to northeast until it reached 0-5µg/m^3 at 180m.

5.4.1.2 Autumn

As shown in figure 47 a, b, and c, the condition at and around the roundabout varied slightly in each configuration. In configuration 2, the NO_2 concentration was 5µg/m^3 higher between 40 and 60m to the east of the reference point than in configuration 1 and 3 (see figure 48). This increase happened because the relocated park decreased the wind speed, and prevented the formation of strong wind that dispersed NO_2 to the





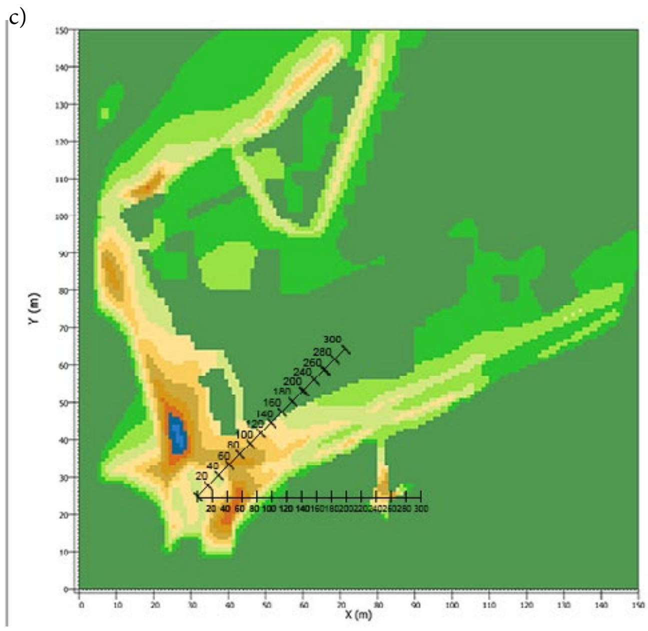


Figure 47
Autumn NO_2 dispersion in Rotterdam Centrum in configuration 1 (a), configuration 2 (b), and configuration 3 (c)

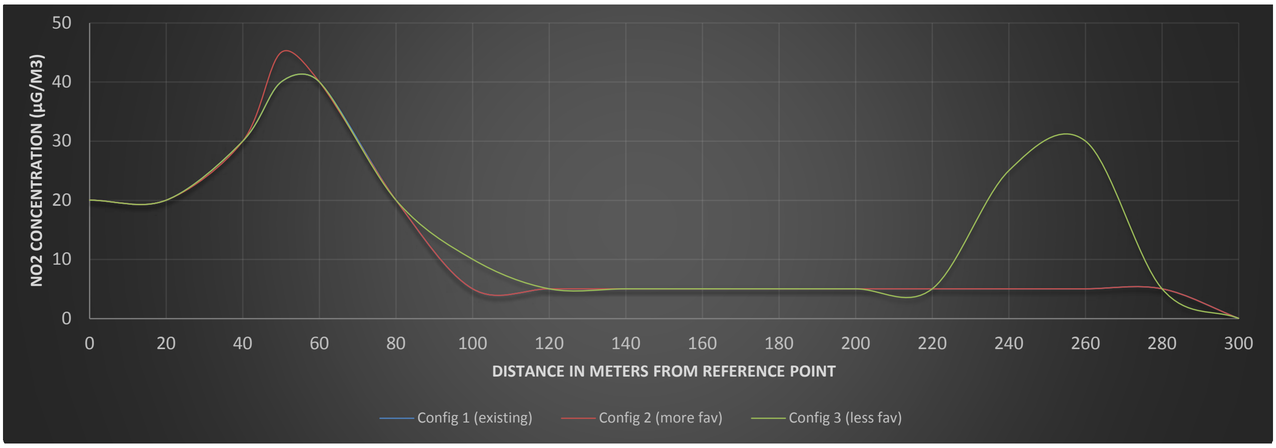


Figure 48
Differences in autumn NO_2 concentration in Rotterdam Centrum from west to east

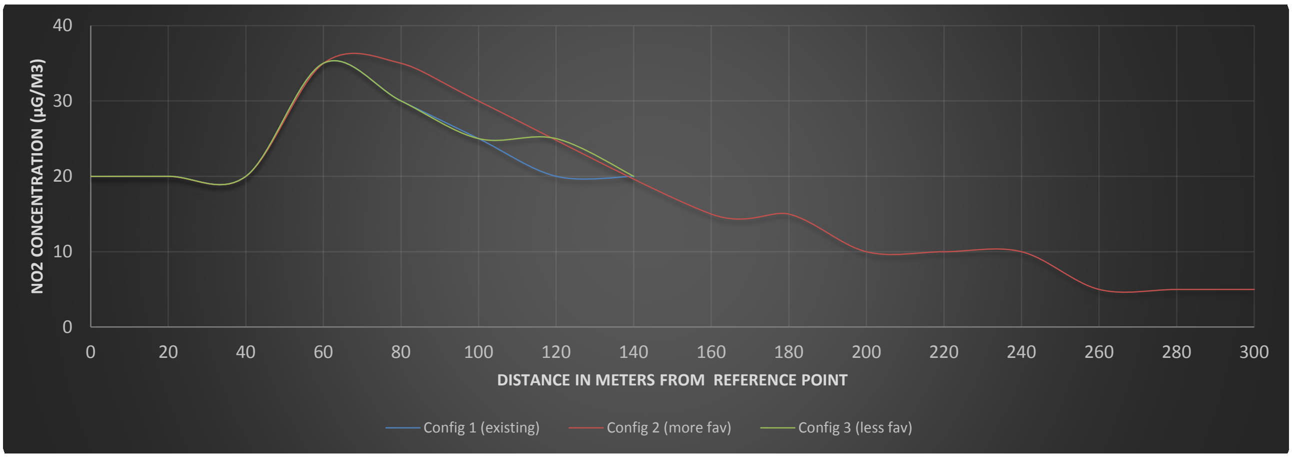


Figure 49
Differences in autumn NO_2 concentration in Rotterdam Centrum from southwest to northeast

two main roads at the side of the park (see section 2 of this chapter). From 60m toward the east, the NO_2 concentration was exactly the same in configuration 1 and 2 which was expected because the configurations there were exactly the same. There was a 5µg/m^3 increase between 80 and 120m, and up to 25µg/m^3 between 220 and 280m from the reference point in configuration 3. The second increase can be attributed to the presence of an extra source following the relocated habitation area. However, the first increase was more interesting to this research because it showed the different effect between a park and tree-lined building to NO_2 dispersion. The increase in configuration 3 suggests that there is higher NO_2 build up at the windward side of a tree-lined building than at the windward of a tree cluster in a park. The NO_2 concentration increase in configuration 2 happened 20m at the windward of the tree cluster. On the other hand the increase in configuration 3 happened right at the building's border. This condition is similar to the result from the spring simulation even though the wind flowed to different direction.

From the reference point to the northeast, the NO_2 concentration was the same in all three configurations until 60m from the reference point (see figure 49). Between 60 and 120m from the reference point, the NO_2 concentration in configuration 2 was 5µg/m3 higher than in configuration 1 and 3. At 120 to 140m, the concentration in configuration 2 and 3 was the same. The NO_2 concentration at configuration 1 was 5µg/m3 lower until the dispersion of NO_2 was stopped at 140. The dispersion in configuration 1 and 3 was stopped at 140m because of the hospital building, meanwhile the dispersion continued in configuration 2 until it reached the 310m from the reference point where the park bordered with the hospital. More steep decrease of NO_2 concentration in configuration 1 and 3 was also caused by the presence of the hospital building. The building acted as a solid windbreak that split the wind (and NO_2 dispersion) to either side of the building and upward.

5.4.2 CHARLOIS

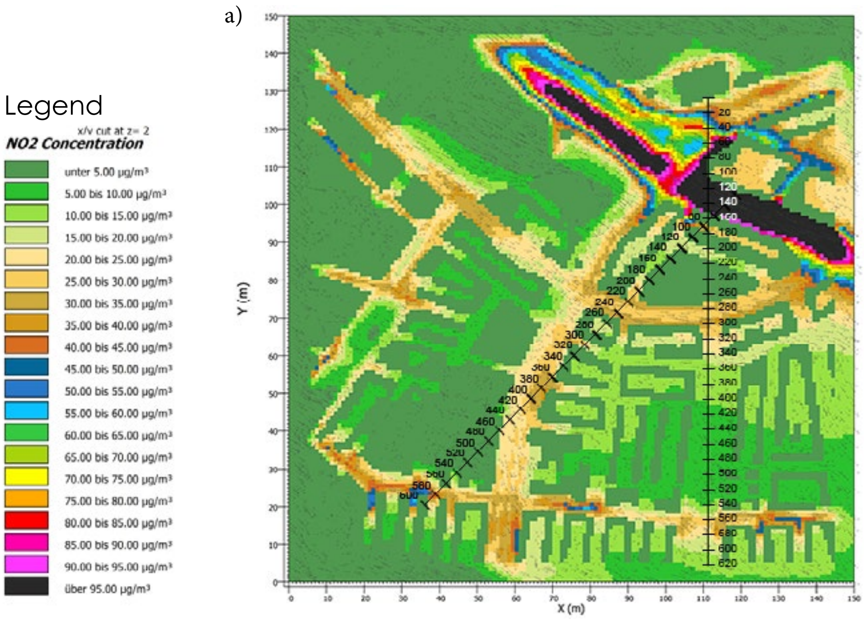
5.4.2.1 Spring

Figure 50a-c show the NO_2 dispersion in spring, reference point and direction of measurement for this analysis. The hotspot was formed mainly in the north of the case area in all three configurations, albeit with different pattern. In general NO_2 was dispersed from northwest to the east and south. The first point was at the north of the main largest hotspot to the south, and the second point was at the highest concentration in the area (140m from the first point) to the southwest.

As seen in the chart in figure 51, there was a high NO_2 build up at the north of the area until 180m from the reference point. The concentration was very similar, except between 40 and 80m in configuration where the concentration was 5µg/m^3 higher than configuration 1 and 3. However, the concentration in configuration 2 was lowest between 140 and 300m from the reference point. It has to be noted that the decrease started from 140m, which was 20m from the park's border. In configuration 1 and 3, the decrease of NO_2 concentration started further south between 140 and 160. The NO_2 concentration between in the park in configuration 2 of course was significantly lower than in configuration 1 and 2. What need to be noted is the difference in concentration between 260 and 400m.

The NO_2 configuration at the leeward of the park (especially between 260 and 300m fromt the refernce point) was 10-5µg/m^3 lower in configuration 2 than in configuration 1 and 3. This condition caused by the wind that flowed through the park and dispersed NO_2 more to the southeast direction, while configuration 1 and 3 created a canyon effect that trapped the NO_2 on the road. Unfortunately that condition caused a slower decreased in configuration 2. In configuration 1 and 3, the NO_2 concentration already dipped to 20µg/m^3 at 320m while the concentration in configuration 2 was still 25µg/m^3. This happened because wind from the park dispersed NO_2 from the south of the park further south in configuration 2. This suggests that the presence of a park at the windward of an NO_2 source disperse the pollutant further away than when there is no park. On the other hand, the presence of a park in configuration 1 between 400 and 540m from the reference point didn't change the dispersion pattern of NO_2 inside the park or at its south significantly. The NO_2 concentration between 400 and 620m from the reference point was exactly the same in configuration 1 and 2, and only 5µg/m^3 lower in configuration 3.

There were some notable differences in the NO_2 concentration in the three configurations in the northeast-southwest chart (figure 52). The first was between 20 and 200m from the reference point. As was also shown in the previous figure, the NO_2 concentration in configuration 2 was 5-10µg/m^3 lower than configuration 1 and configuration 2 mostly because of the park. However, it has to be noted that there was less difference between the three configurations at 200 to 240m from the reference point. This condition happened because the curvature of the road led to more similar canyon effect in that location in all three configurations. The second difference was between 320 and 460 meters from the reference point. In average, the NO_2 concentration there was the lowest in configuration 2 (between 15 and 30µg/m^3) when the park was located at the east of the road. In configuration 2, the park provided space for NO_2 to be dispersed to the east and then out of the area. On the other hand, the park in



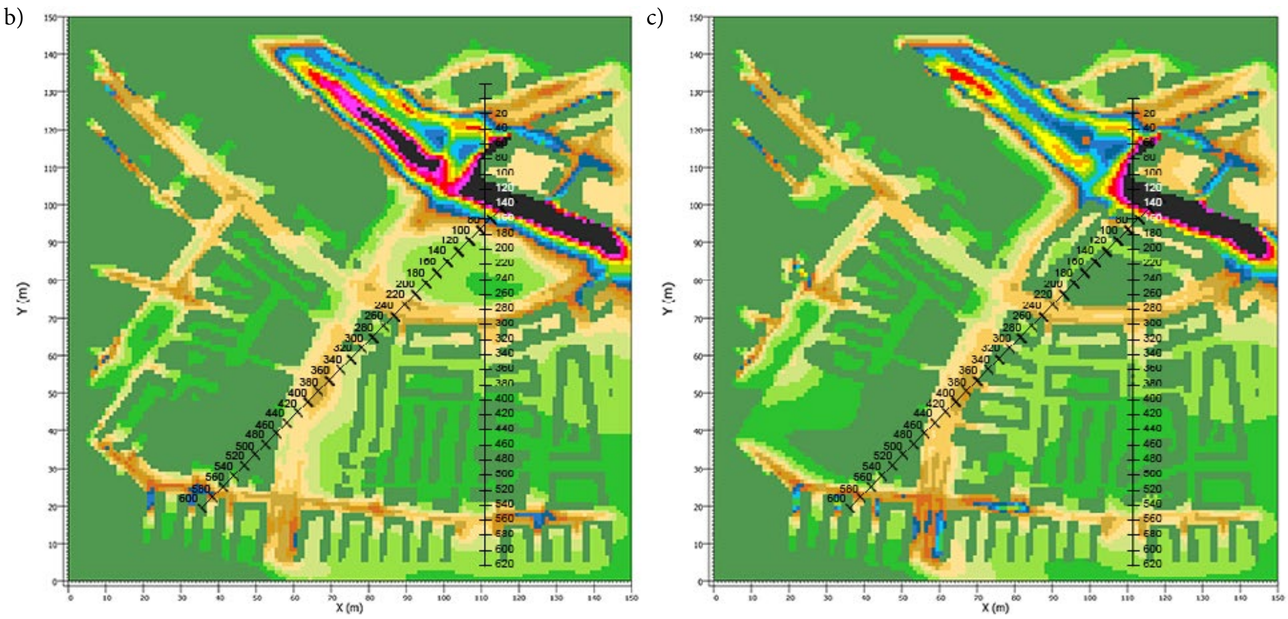


Figure 50
Spring NO_2 dispersion in Charlois in configuration 1 (a), configuration 2 (b), and configuration 3 (c

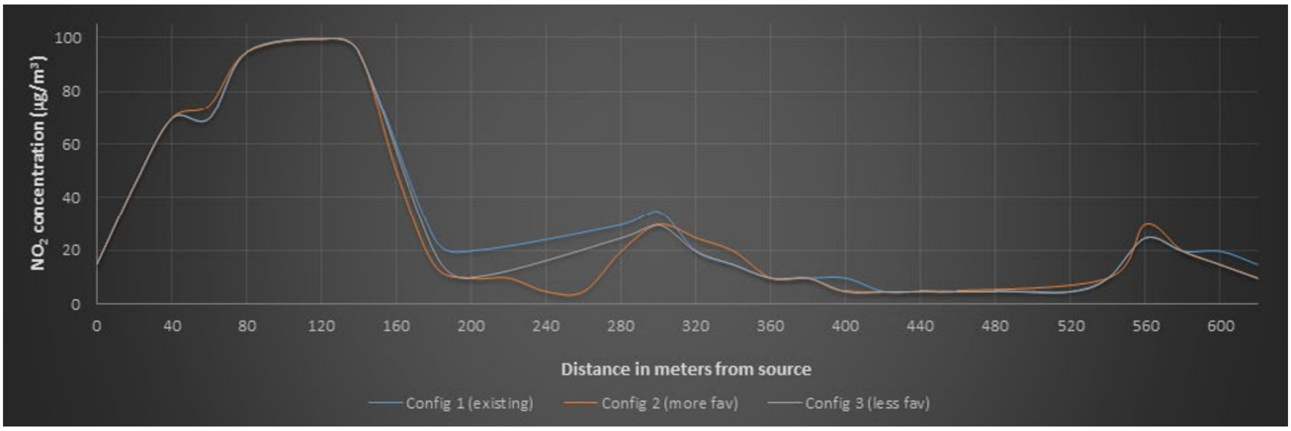


Figure 51
Differences in spring NO_2 concentration in Charlois from north to south

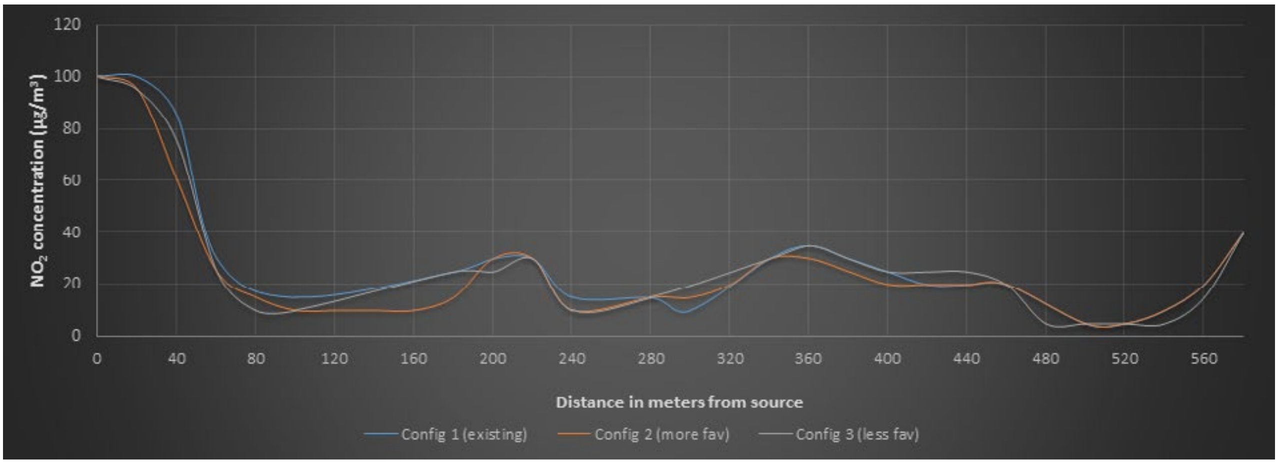


Figure 52
Differences in spring NO_2 concentration in Charlois from northeast to southwest

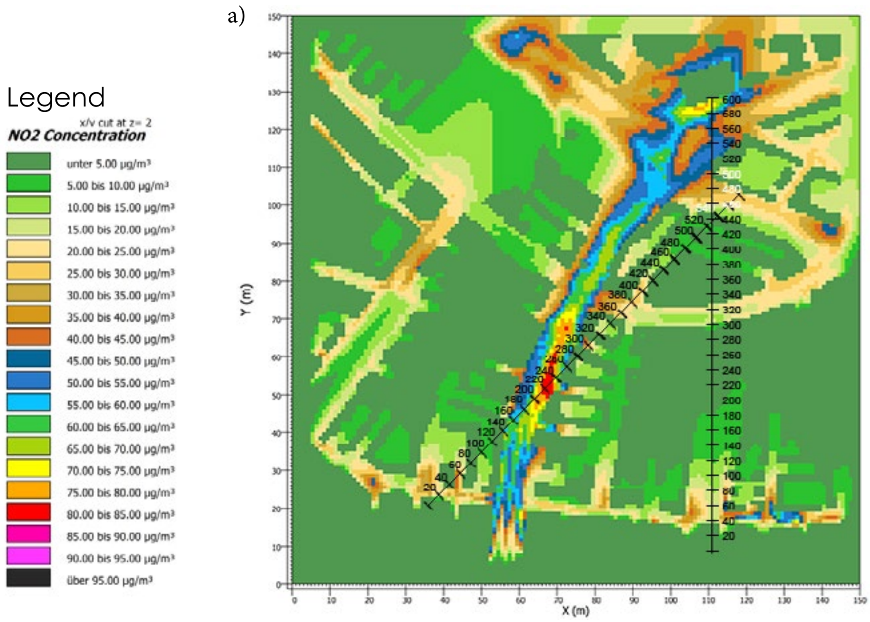
configuration 3 increased vortices at the south of the area that prevented the wind to flush out the NO_2 from the urban canyon, which make the concentration 5µg/m^3 higher than configuration 2 and 1.

5.4.2.2 AUTUMN

Figure 53a-c show the NO_2 dispersion in autumn, reference point and direction of measurement for this analysis. The hotspot was formed mainly on the main road that stretches from the south to north in all three configurations, albeit with different pattern. In general NO_2 was dispersed from the south to the north and slightly to the east. The NO_2 concentration was charted from the south/southwest toward north/northeast following the general direction of the dispersion.

There were some notable differences in the dispersion pattern shown in the south-north chart in figure 54. The first was between 20 and 60m from the reference point. The concentration in configuration 1 was only 5-15µg/m^3 because of the presence of a park there. The concentration was higher when the park was changed into habitation area (5µg/m^3 higher in configuration 3, and up to 25µg/m^3 higher in configuration 2). The concentration in configuration 2 was higher than in configuration 3 because of the different building configuration (explained in section 2 and 3 on this chapter). It has to be noted that even though there was a high build-up of NO_2 on the road, the concentration at its north (between 60-200m from reference point) was lower when the location was used as habitation area rather than a park (5µg/m^3 lower in configuration 3, and 15µg/m^3 lower in configuration 2). This happened because the buildings at the habitation area prevented NO_2 dispersion to the north.

The second difference happened between 280 and 600. In configuration 2, the concentration between 280 and 460m from the reference point was only 5-10µg/m^3 but then it increased to 70-80µg/m^3 after 460m from the reference point. This condition happened because of two conditions; 1) the presence of the park between 340 and 460m decreased the NO_2 concentration by dispersing it to the north, 2) the building at the north of the park stopped the flow of dispersion and trapped the NO_2 at its windward side. Configuration 3 had the lowest concentration (25-60µg/m^3)



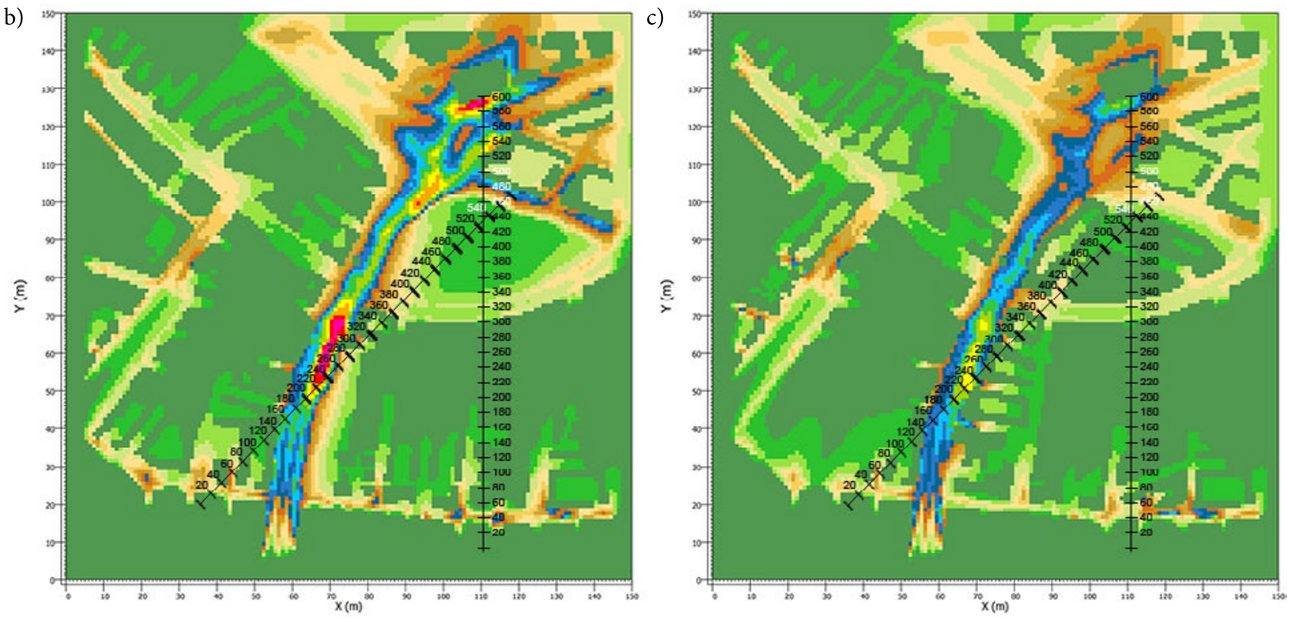


Figure 53
Autumn NO_2 dispersion in Charlois in configuration 1 (a), configuration 2 (b), and configuration 3 (c

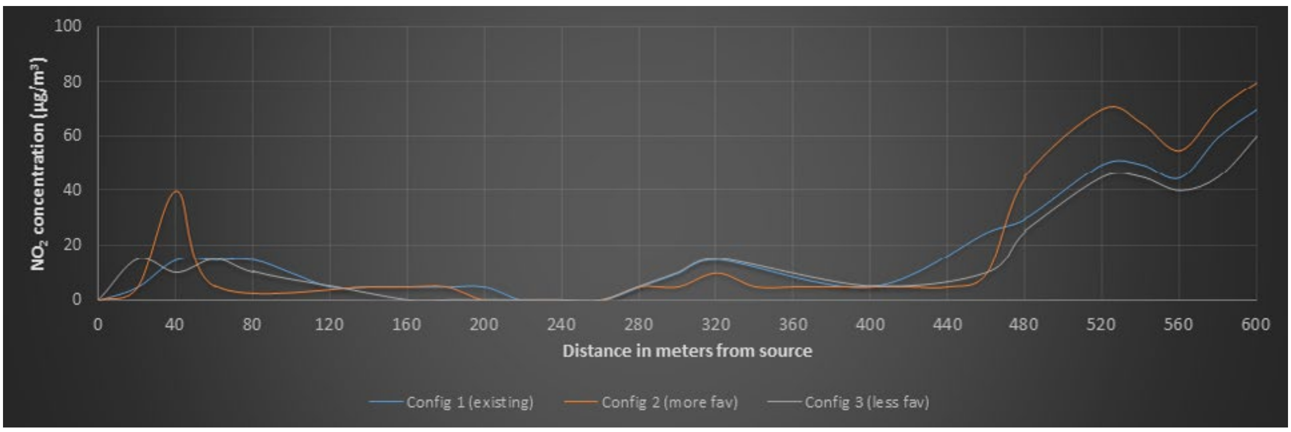


Figure 51
Differences in autumn NO_2 concentration in Charlois from south to north

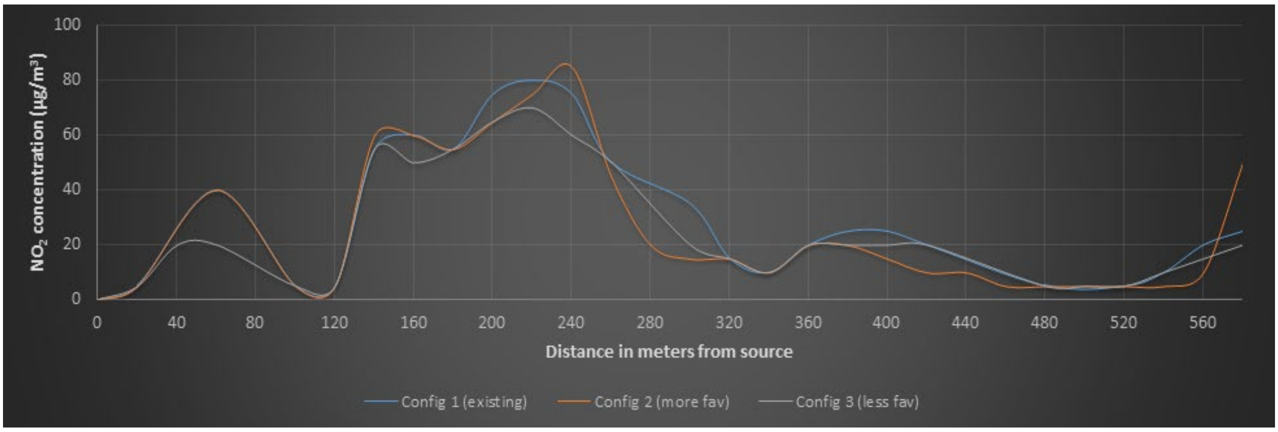


Figure 52
Differences in spring NO_2 concentration in Charlois from southwest to northeast

between 460 and 600m from the reference point because of the building configuration there (explained in section 3 of this chapter) and because of the flushing effect that happened in the main road at its west.

There were also some notable differences in the southwest-northeast chart as shown in figure 52. In the first 100m, the maximum concentration in configuration 1 and 2 was 40µg/m^3 at 60m while the concentration in configuration 3 only reached 20µg/m^3 at 40m from the reference point. Further to the southeast, the concentration increased to as high as 80µg/m^3 at 220m, 85µg/m^3 at 240m in configuration 2, and only 70µg/m^3 at 220m in configuration 3. The concentration was the highest in configuration 2 because the park that was relocated to that location dispersed NO_2 to the north further than in configuration 1 and 3. NO_2 build up happened sooner in configuration 1 (from 140m). However, NO_2 build-up happened further north (from 160m) and the increase was steeper than in configuration 1. The concentration in configuration 3 was the lowest because the configuration of the park and building there dispersed the NO_2 faster and further to the north (i.e. the build-up in configuration only happened after 220m, and only reached 70µg/m^3). The NO_2 concentration in configuration 1 and 3 between 380 and 460m was only 5µg/m^3 higher than in configuration 2. The more notable difference happened between 520 and 580m from the reference point where there was a high spike in configuration 2. It was at the road with a major source of NO_2 at the leeward of a park. Instead of helping NO_2 dispersion from the source, the park provided space for the wind to retain its original speed to southwest and dispersed NO_2 toward the buildings. The almost perpendicular wind created vortices at the windward of the buildings that trapped and increased the NO_2 concentration to 50µg/m^3 (25µg/m^3 higher than in configuration 1 and 30µg/m^3 higher than in configuration 3).

This dispersion patterns as shown in figure 51 and 52 suggest that parks that are located at the upwind of NO_2 source can have different effects. The park increased NO_2 dispersion when there was no or minimum disturbance at the downwind of the source. On the other hand, there was a 30µg/m^3 NO_2 concentration increase compared to the configuration where there was a solid windbreak at the downwind of the source instead of a park.

5.5 THE EFFECT OF A PARK'S LOCATION ON THE SPATIAL PATTERN OF AIR POLLUTION DISPERSION FROM ITS SOURCE INTO PLACE OF HABITATION

The effect of the park's location on the spatial pattern of air pollution dispersion from its source into place of habitation can be understood by analysing the different spatial patterns as shown in section 5.1, 5.2, 5.3,and especially 5.4. The observed differences in spatial pattern of NO_2 dispersion in can be explained by the reduction in wind speed and the different local wind direction (including formation of fortices at the windward of the windbreaks), alongside the consequent inhibition of ventilation shaped by the urban configurations.

The effect of a park's location on the spatial pattern of air pollution dispersion from its source into place of habitation in this research can be summarized into three main effects; to the direction of dispersion, to the NO_2 concentration at the parks' vicinity, and to the NO_2 concentration at the downwind (at a distance) from the parks. The parks in this research altered the spatial pattern of NO_2 dispersion in the case areas when they were located in different locations because they received the NO_2 at different angles, and because they changed the wind flow (speed and direction) in the case areas. There was different emission level in spring and autumn in both case areas. However, the differences in maximum concentration level observed in the simulation result was larger than the emission difference. This suggest that the configurations have stronger effect to NO_2 concentration increase/decrease than the emission level. The following sections explain and provide the examples of the effects in Rotterdam Centrum and Charlois.

5.5.1 EFFECT TO DIRECTION OF DISPERSION

The presence of a park can either deflect wind direction, or provide space for the wind to retain its original direction. The clearest example of this effect was when the parks were located in the more favourable locations in Rotterdam Centrum (configuration 2). The presence of Museumpark in configuration 2 in Rotterdam Centrum deflected the dominant wind direction, changing it from 301° to 311°. That change caused an expansion of hotspot at the south of the case area to more than 50m to the south and increased the NO_2 concentration 15µg/m^3.

The effect of parks to NO_2's dispersion direction was less clear in Charlois because of the building density of the area. The effect of the different configurations to the local wind direction there only happened inside the park and up to 50m around them. The main dispersion direction didn't change significantly, but the NO_2 concentration can still increase or decrease in some locations. Case in point is the concentration at the windward of Karel de Stouteplein Park in configuration 2 that increased 30µg/m^3 because the wind was flowing to the north instead of flowing to the east like in configuration 1 and 3. In general, the wind direction around the tree clusters in the parks was deflected 5-10° away from the windward side when the wind was oblique to the park's border. It is important to note that wind direction changed around a park because of the tree cluster in it. Case in point, when Laperlaarsingel was located at the more favourable location, the park did not deflect wind direction. Instead, it provided space for the wind to retain its original direction (301° in spring, and 205° in autumn). Because of that, the NO_2 concentration in the urban canyon was 5-10µg/m^3 lower than in configuration 1 and 3 in spring. In autumn, the NO_2 concentration build up in the urban canyon started 50m further north than in configuration 1.

5. 5.2 EFFECT TO NO_2 CONCENTRATION IN THE PARK'S VICINITY

In spring and autumn, the parks in Rotterdam Centrum created an increase of NO_2 concentration up to 15µg/m^3 at their windward when they were located at the more favourable locations than the existing or less favourable locations. That condition was caused by the amount of NO_2 that dispersed to the parks, the wind speed, and the angle in which the wind hit the tree cluster at the border of the parks. The relocated Museumpark reduced the wind speed by 1m/s and caused changed the wind direction (explained above). It has to be noted that the NO_2 concentration increase was also followed by a 5-10µg/m^3 decrease closer to the border of the park. The rapid decrease also continued inside the park, at which the concentration became less than 5µg/m^3 40m sooner than in the existing configuration. On the contrary, the NO_2 concentration at the windward of a tree-lined or non tree-lined building was consistently 5-10µg/m^3 higher than the windward surface of tree clusters . This condition happened both when the wind was oblique and when the wind was parallel to the park.

When the parks were located at the downwind of an NO_2 source, the park lowered the NO_2 concentration in their windward by 10µg/m^3 compared to when there was no park. The parks' leeward was also 10µg/m^3 lower than the windward. Parks that were located at the downwind of an NO_2 source intercepted the pollution and provide relatively open space for NO_2 to disperse horizontally and vertically, which decreased the NO_2 concentration naturally, as long as the park was in a large angle (as close as possible to be perpendicular) to the wind direction.

Karel de Stouteplein always increased the NO_2 concentration in the road that was parallel to it by 5-10µg/m^3 (compared to when there was no park), except in the third configuration where the concentration did not change. For Laperlaarsingel Park, the NO_2 concentration in the road that was parallel to the park was always lower than when there was no park except when the park was located in an area that already has a low NO_2 concentration and not passed by the dispersions path. This condition can be explained by the angle in which the wind was flowing to the park. Karel de Stouteplein was parallel to the wind direction so there was almost no NO_2 dispersion into the park. On the other hand, Laperlaarsingel was arranged in a slight angle so there was still NO_2 dispersion into the park.

5.5.3 EFFECT TO NO_2 CONCENTRATION AT THE DOWNWIND OF THE SOURCE

When the parks were located at the upwind of an NO_2 source, the NO_2 concentration at the downwind of the source was 5-35µg/m^3 higher compared to the other two configurations. The increase happened from 100 to more than 500m away (see the condition of Charlois in section 2 and 3). The amount of increase was affected by the building configuration at the downwind of the park. The closer the buildings to the source, the higher the NO_2 concentration increase. Wide canyon at the downwind of the parks led to 5-30µg/m^3 increase at closer distance from the source while the effect of narrow canyon usually happened at further distance. That condition happened because narrow canyons usually have strong wind that can flush NO_2 out. This suggests that the shape of the park and the surrounding building configuration also affect the NO_2 dispersion.

Chapter 6 General Conclusion and Discussion

In this chapter, the use of ENVI-Met for dispersion modelling, main findings with regard to the research questions, and the connection between the results in this thesis with the background theories as presented in chapter 2 are summarised. This chapter also provide the general conclusions based on the findings of the studies presented in this thesis. Furthermore, the strengths and limitations of this thesis are considered and suggestions for further research are presented. This chapter concludes with recommendations for park allocation planning.

6.1. ENVI-MET FOR DISPERSION MODELLING

In this research the effect of park's location on NO_2 dispersion was modelled and analysed with the configuration of an existing city using the ENVI-Met model. I used the result of the simulation using the existing configuration as a base to select more favourable and less favourable locations for parks. I compared the different spatial pattern of NO_2 dispersion from line source that was created by the presence of the park in their existing locations, in the more favourable locations, and the less favourable locations. The results revealed that the effects of the parks were different when they are located in different locations. The results of one area also cannot be replicated in another area. Case in point, the effect of the parks in Rotterdam Centrum differed from the result in Charlois (see section 5.1-5.3).

ENVI-Met provided various information in the simulation results; NO_2 concentration, the wind direction (in degree), wind speed. The graphical result (in horizontal or vertical cut) was convenient and easy to interpret. However, the program is not user friendly. A long duration had to be set aside to familiar oneself to the four main program needed to finish any simulations (the map editor, the data configuration editor, the ENVI-Met simulator, and the graphic generator program). Because ENVI-Met is an evolving open source program (i.e. not profit based and developed communaly by a group of programmer), there is limited resource to find the manual and guidebook that can explain the data limitation (e.g. wind speed that was limited to maximum 8m/s). Nevertheless, the use of clearly interpreted outputs generated by ENVI-met is of great use for decision makers, which make it a valuable resource in urban planning.

6.2 MAIN FINDINGS IN REGARDS TO THE RESEARCH QUESTIONS 1-4

6.2.1 What is the existing spatial pattern of air pollution dispersion in the study area?

In spring, NO_2 in Rotterdam Centrum was dispersed to the southeast. Large amount of NO2 was concentrated on the roads in the west side of the area, at the windward of the hospital, and at the west part of Het Park. Almost no NO_2 was dispersed to Rotterdam Museum Park. In autumn, NO_2 was dispersed to the northwest and northeast following the direction of the urban canyons shaped by the roads, buildings, and parks in the area. Small hotspots were formed on the road at the west side of the area.

NO_2 in Charlois was dispersed to southeast in spring with a large concentration build up in the urban canyon that stretched from northwest to southeast at the north side of the area. The NO_2 from the sources that stretched from south to north was easily dispersed to the east because of the configuration of the parks and buildings that ventilted the area. In autumn the concentration build up happened in the urban canyon that stretches from south to north while there was only low concentration in the northwest-southeast canyon.

6.2.2 What is the spatial pattern of air pollution dispersion in the study area when the parks are located in the more favourable locations?

In spring, NO_2 in Rotterdam Centrum was dispersed to the southeast. Large amount of NO_2 was concentrated on the roads in the west side of the area and at the west part of Het Park. Some NO_2 also bled into the relocated Museumpark. In autumn, NO_2 was dispersed to the northeast through the relocated Museumpark. Small hotspots were formed on the road at the west side of the area and at the west side of Het Park.

NO_2 in Charlois was dispersed to southeast in spring with a large concentration build up in the urban canyon that stretched from northwest to southeast at the north side of the area. The NO_2 from the sources that stretched from south to northwas easily dispersed to the east because of the configuration of the parks and buildings that ventilted the area. In autumn the concentration build up happened in the urban canyon that stretches from south to north. Small concentration build up happened at the northeast of the area.

6.2.3 What is the spatial pattern of air pollution dispersion in the study area when the parks are located in less favourable locations?

In spring, NO_2 in Rotterdam Centrum was dispersed to the southeast. Large amount of NO_2 was concentrated on the roads in the west side of the area and at the west side of the relocated habitation area. n autumn, NO_2 was dispersed to the northwest and northeast following the direction of the urban canyons shaped by the roads, buildings, and parks in the area. Small hotspots were formed on the road at the west side of the area.

NO_2 in Charlois was dispersed to southeast in spring with a large concentration build up in the urban canyon at the northeast of the area. The NO_2 from the sources that stretched from south to north was easily dispersed to the east because of the configuration of the parks and buildings that ventilted the area. However, a small hotspot was formed at the south of the north-south canyon. In autumn the concentration build up happened in the urban canyon that stretches from south to north.

6.2.4 What is the difference in the spatial pattern of air pollution dispersion at the case studies between the existing park locations, most ideal locations, and less ideal locations?

In Rotterdam Centrum, the dispersion pattern in configuration 1 (existing locations) and 3 (less favourable locations) in spring and autumn was very similar with the exception of the small hotspot that moved from the north in configuration 1 to the south in configuration 3. In configuration 2 (more favourable locations), the NO_2 in Rotterdam Centrum was dispersed further south in spring when the parks were located in the more favourable locations. This suggest that NO_2 was dispersed the furthest in configuration 2.

In Charlois, the NO_2 hotspot in spring was formed further east in each configuration (the furthest was in configuration 3). Similarly, the hotspot in autumn was formed furthest north in configuration 3. This suggest that NO_2 was dispersed the furthest in configuration 3.

6.3 GENERAL CONCLUSION - THE EFFECT OF A PARK'S LOCATION ON THE SPATIAL PATTERN OF AIR POLLUTION DISPERSION FROM ITS SOURCE INTO THE PLACE OF HABITATION

The results showed that park's location does affect the spatial pattern of air pollution. The effect is more obvious in dense area such as Charlois where the different park locations showed more diverse effect to NO_2 dispersion pattern. The favourable locations selected in this research didn't always provide positive result. In Rotterdam Centrum, the result was supporting to the more favourable locations with the hospital getting less exposure to NO_2 when the parks were located in the more favourable location. When the parks were located in the less favourable locations, most of the habitation areas were exposed to NO_2. On the other hand, the lowest NO_2 concentration in Charlois was achieved when the parks were located in the less favourable locations. The NO_2 concentration of Pleinweg in autumn increased when Karel de Stouteplein was located in the favourable locations. The NO_2 concentration in Dorpsweg also increased when Laperlaarsingel Park was located in the more favourable locations. Those results can be contributed to the wind pattern and bottle neck effects that were caused by the parks. Nevertheless, both the increase and decrease of NO2 concentration that happened in the area after the relocations of parks were only 5-15µg/m^3 at the most. For the case of NO_2 exposure, various health studies (including WHO) only highlighted the effect of exposure to more than 200µg/m^3.

The results of this research support the notion about the importance of analytical simulations in spatial planning, especially for park and green city development. It is difficult to predict accurately the interaction between the wind flow and urban configurations. This was shown by the different effects of Karel de Stouteplein and Lapelarsingel to the NO_2 concentration in Charlois when they were located in parallel to the NO_2 source; and the difference between the spatial pattern of NO_2 dispersion in Rotterdam Centrum and Charlois. The results for Rotterdam Centrum and Charlois were different not only in value of NO_2 concentration but also the size and locations of the hotspots. The fact that the less favorable location provided the lowest NO_2 concentration in Charlois affirmed the importance of spatial simulation even more.

Nevertheless, it has to be noted that the presence of a park does help reduce NO_2 concentration at its leeward even though there are three criteria that have to be fulfilled for this effect to be achieved. The criteria are; 1) the park has to be at the downwind of pollution source, 2) there has to be no other NO_2 source between the park and the habitation area at its leeward, 3) the wind direction has to come at a wide angle (as close as possible to 90^o) to the park. Even after the criteria are fulfilled, the amount of the decrease and where the decrease start to happen still depend on the physical configuration of the park's vicinity. In this research the decrease was relative constant (between 5-15μg/m^3).

Results of this study are in general agreement with the experiments done by Wania et al, 2012), Hofschreuder, et al. (2010), Czáder et al. (2009), De Maerschalck et al. (2008), Gromke et al. (2008) and Ries and Eichhorn (2001). However, due to different underlying street canyon and vegetation configurations, a comparison must be limited to more general characteristics.

The effect of wind speed reduction that lead to concentration increase as shown especially in configuration 2 of Rotterdam Centrum was confirmed in Wania et al, 2012), Czáder et al. (2009), De Maerschalck et al. (2008), Gromke et al. (2008) and Ries and Eichhorn (2001).

The formation of hotspot in urban canyons (especially around the street vegetation) in the Dorpsweg in Charlois corroborated the findings in the research done by Wania et al., (2012) and Gromke and Ruck (2010). However, it has to be noted the simulations done in this research found another phenomena that hasn't been observed in Gromke and Ruck's wind tunnel experiment or Wania's simulation. The simulations done in Charlois showed that the hotspot shifted more than 10m downwind when there was an open space (in this case, parks) at the inlet (configuration 2) or near the inlet of the canyon (configuration 3).

Hotspots also formed at the windward and corner of buildings as predicted based on the theory by Lenzholzer (2015) and Forman (2014), and the researches done by Wania et al. (2012), Hofschreuder, et al. (2010) and De Maerschalck et al. (2008). The 5-10μg increase of NO_2 concentration at the leeward of buildings in Rotterdam Centrum and Charlois also corroborate the theories by Lenzholzer and Forman about the downwash wind on the leeward of buildings. However, it has to be noted that there are a number of differences observed in the simulation results in this research compared to the previously established theories and researches. First, the increase only happen when the wind direction was perpendicular or oblique to the windbreaks. Second, there was a 20m deep shadow area in front of tree cluster where the NO_2 concentration decrease in average 1μg/m while there was no shadow area that formed at the windward of any buildings in the case areas. Third, Wania et al. (2012) found that pollutant concentrations was higher for oblique compared to perpendicular inflows meanwhile the increase in this research was consistent (always 5-10μg/m^3) for oblique, perpendicular, and parallel wind. That difference can be explained by the different configuration of sources used in this research. Different from the previous research by Wania et al., the line sources in this research was arranged in an oblique configuration following the curvature of the roads in the case areas which affected the location of NO_2 build up in the simulation.

The simulation results also corroborate the theory by Errel et al. (2011, as referred in Forman, 2014) that windbreaks that are perpendicular to wind direction is more effective than those at an angle. Errel et al. (2011) found in their research that windbreaks are more effective to reduce wind disturbance when they are perpendicular to the wind direction. The same theory also applies to park's effectiveness in reducing NO_2 concentration and in helping NO_2 dispersion. The concentration at the leeward of the park that was perpendicular to the wind direction was 10-15µg lower than at the windward. Other than that, the concentration at the windward of the park was also 10-15µg lower than when the park was replaced by buildings. This finding also corroborate with the findings by Maerschalck et al. (2009, 2010) and Maiheu et al. (2010). The bleed flow mentioned by Lenzholzer (2015) was evident in the simulations (especially in Het Park, Rotterdam Centrum, and Karel de Stouteplein, Charlois). Unlike buildings that blocked the NO_2 flow, the bleed flow that happened through the tree cluster in Het Park and Karel de Stouteplein allowed NO_2 to disperse into the park while reducing the concentration by 3µg in every 10m.

6.4 RECOMMENDATIONS

6.4.1 For future research

Simulating the transport of pollutants within a street canyon cannot and shouldn't be extrapolated to other sites because the characteristics are different for each canyon. The airflow in street canyons is not steady and not homogeneous. This research has shown that a change of configuration in a canyon can change the NO_2 dispersion pattern in the area. The effect can be seen in a location as far as 500m downwind from where the change was done. The result of this research can be used as an example and as a base for general prediction. However, simulations should still be done for each researched area.

Roof shape also determines the turbulence and vortices in urban areas. When combined with park allocation, the resulting spatial pattern of NO_2 dispersion might be significantly different. Other than that, this research used line source as the emission input. However, the program ignored the turbulence generated by the moving vehicles themselves, which according to several scholars (i.e. Minor and Mehta, 1979; Godhis, 2014) also affects the spatial pattern of NO_2 dispersion. Unfortunately the program used in this research cannot implement those factors in its simulation. Further research should also be done to explore all the determining factors (such as the roof shape) along with the effect of the park's location, to provide a simulation that is as close to the real condition as possible.

6.4.2 Recommendation for park allocation planning

The results of this research provide the base for a further recommendation for park allocation planning. When the objective of park development is to reduce the concentration of NO_2 (or other air pollutants) at local scale, it is better to:

- locate the park at the downwind of the pollution source with the note that there is no other source of air pollution on the leeward side of the park;
- locate the park at a location that is perpendicular to the direction of the wind inflow or at an angle that is as close as possible to 90^o to the wind direction of wind;
- do dispersion simulation in the early phase of the planning and after the park design are available. The dispersion modelling at the early phase will provide the knowledge about the existing spatial pattern of air pollution dispersion, while the dispersion modelling by using the design will provide the information about the effect of the design in the planned location to the air pollution dispersion. Proper dispersion simulation can avoid the need for time consuming and expensive major revisions

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Appendix

Appendix 1 - Hourly Emission Measurement
Appendix 2 - Dispersion Maps

NO_2 Emission Measurement - Rotterdam Centrum

months	Dates	Hour																							
		0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00
Dec-11	1		38	29	22	15	18	27	38	44	46	44	46	54	43	45	56	55	80	91	99	105	86	63	51
	2	50	23	22	12	15	22	56	82	124	120	95	105	62	60	60	58	59	67	80	74	63	72	64	69
	3	68	56	37	26	22	20	22	20	20	21	27	31	41	35	41	37	30	41	45	46	34	25	21	38
	4	21	30	42	13	13	17	23	18	20	25	29	20	23	28	29	24	36	48	60	64	56	65	36	22
	5	21	10	9	7	9	10	24	35	55	54	48	45	33	36	39	43	50	43	37	33	29	27	30	23
	6	25	21	19	17	16	19	27	42	46	54	49	43	44	42	36	46	46	59	47	52	65	48	41	39
	7	35	40	40	36	35	33	34	40	37	42	39	39	29	33	29	34	32	29	32	24	19	17	14	15
	8	15	14	11	13	12	16	30	63	86	94	70	77	71	58	54	53	55	47	41	37	31	28	26	18
	9	10	17	15	13	11	9	19	32	36	41	45	42	39	42	36	39	42	50	52	47	40	33	35	46
	10	34	27	19	30	28	22	35	41	32	41	46	43	35	30	34	43	53	55	59	56	62	79	80	69
	11	69	61	59	51	46	49	66	52	53	54	56	46	51	48	44	52	45	53	55	48	52	44	41	40
	12	29	29	28	24	20	30	41	58	76	74	89	63	36	30	38	36	38	59	71	69	58	43	41	35
	13	26	23	17	11	10	13	12	20	27	34	36	46	37	30	38	46	60	61	61	49	36	25	29	23
	14	32	23	20	28	22	20	35	62	62	103	97	77	74	64	65	67	51	40	51	51	51	37	35	32
	15	28	21	20	18	17	27	30	40	47	41	56	50	54	44	50	50	36	40	39	58	63	51	59	59
	16	54	36	33	25	16	12	15	25	29	39	40	56	58	50	39	56	74	72	79	92	66	93	98	89
	17	98	91	46	25	26	23	37	47	35	40	48	42	39	30	36	48	48	46	52	56	38	47	44	31
	18	77	74	45	28	24	40	36	28	38	31	33	31	32	47	40	39	38	61	71	63	60	52	97	89
	19	66	89	47	33	33	78	79	74	125	112	93	83	91	78	73	77	79	71	71	65	48	44	54	49
	20	33	27	29	35	38	44	38	53	57	70	63	50	50	41	37	36	52	51	47	56	40	51	51	42
	21	43	31	38	40	51	60	78	87	83	82	79	78	84	70	80	95	91	96	88	86	69	72	64	58
	22	53	51	49	48	51	43	45	57	70	54	61	60	63	72	68	61	66	51	62	65	63	60	59	62
	23	63	57	56	54	53	47	42	51	62	67	63	60	56	47	52	53	53	56	49	41	39	36	32	24
	24	23	10	12	10	10	10	9	15	17	15	22	28	30	30	29	50	41	38	55	45	45	39	37	31
	25	27	29	25	23	21	23	25	29	29	31	29	33	30	26	31	26	30	39	42	41	39	41	41	37
	26	36	31	30	35	46	39	32	28	30	32	36	43	43	47	42	39	54	39	54	39	35	39	34	35
	27	27	23	23	25	30	32	28	33	55	62	70	68	74	66	62	83	74	75	79	76	72	64	59	55
	28	37	35	24	15	15	17	23	26	25	31	30	37	35	34	43	46	47	47	41	43	49	44	19	15
	29	17	13	11	8	12	13	15	24	31	31	34	39	33	50	32	37	29	38	37	37	21	19	25	20
	30	14	11	9	9	6	6	10	15	24	26	30	34	32	35	45	42	56	53	72	79	78	89	76	48
	31	41	44	29	28	22	20	25	42	50	48	41	41	43	42	37	32	35	55	54	54	54	51	51	38
01-Jan	1	37	47	37	32	32	31	31	26	24	22	26	38	41	30	26	26	31	41	30	24	20	15	23	16

months	Dates	Hour																							
		0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00
	2	16	27	30	29	28	24	22	30	44	50	59	63	62	44	43	23	31	31	51	56	58	57	46	42
	3	35	28	25	26	17	14	22	23	29	30	27	30	27	27	27	28	31	43	41	37	27	12	16	13
	4	26	31	29	25	9	11	11	17	31	37	35	39	29	35	23	23	44	47	54	47	42	35	30	27
	5	26	23	23	19	18	16	19	18	31	35	28	21	21	20	21	23	23	22	22	23	15	11	11	12
	6	7	6	6	4	5	5	9	14	27	24	33	36	33	36	31	31	38	46	61	67	51	69	59	60
	7	60	48	39	37	38	32	21	19	26	26	26	29	22	20	21	25	23	26	26	29	29	38	42	37
	8	33	26	25	20	16	13	16	14	20	21	25	25	21	17	18	22	28	36	41	56	67	76	79	68
	9	57	59	38	50	50	36	49	69	70	69	63	53	52	54	53	68	68	75	72	67	47	44	43	40
	10	38	43	47	39	52	65	60	70	90	77	88	87	93	82	79	76	69	65	78	77	69	46	31	36
	11	43	55	37	32	36	39	43	50	52	56	60	43	53	51	45	63	61	69	70	64	65	63	55	50
	12	53	48	44	42	35	31	31	45	40	52	52	41	40	37	30	39	44	48	41	36	33	48	40	35
	13	38	27	35	27	15	10	22	52	64	75	68	52	52	48	45	45	52	51	80	62	67	46	47	50
	14	54	45	34	28	24	24	32	48	45	71	86	64	45	43	42	43	50	69	94	105	104	115	116	123
	15	112	119	111	101	90	92	88	78	72	71	69	62	39	25	25	31	55	60	72	70	69	61	58	48
	16	38	37	33	29	30	31	42	52	62	70	74	73	73	83	61	61	57	78	92	91	92	90	81	88
	17	83	82	73	74	73	75	94	134	140	116	122	123	103	93	82		74	99	99	113	87	85	72	77
	18	64	59	55	52	50	49	52	73		82	80	61	65	56	57	58	70	64	55	59	52	48	48	44
	19	42	36	36	36	35	37	50	49	50	62	79	82	96	85	59	59	56	59	61	62	52	48	39	23
	20	16	23	17	13	11	11	18	30	37	48	37	44	42	50	36	52	53	64	74	88	98	86	86	80
	21	74	62	57	33	43	51	47	40	38	36	39	21	23	23	26	31	36	28	36	32	29	28	22	21
	22	16	19	13	14	16	17	18	18	21	16	23	30	23	17	17	20	20	24	20	17	22	35	49	32
	23	26	32	24	27	26	25	41	58	77	97	74	63	41		40	38	44	58	72	72	60	45	39	38
	24	27	34	21	24	24	31	61	134	132	144	117	75	68	83	80	68	86	78	84	90	68	71	53	60
	25	49	46	34	30	30	30	33	52	57	59	57	64	51	62		53	60	77	62	66	60	59	49	51
	26	45	43	39	30	27	28	35	43	48	46	53	49	55	57	43	54	57	69	101	90	83	80	80	74
	27	78	70	59	50	52	46	52	86	80	72	75	73	80	76	65	61	64	66	86	80	96	93	78	65
	28	69	67	59	58	55	53	56	55	51	48	48	54	60	65	46	49	46	48	57	57	56	60	68	58
	29	59	60	50	38	30	20	19	14	14	15	20	18	22	25	25	25	36	27	36	30	30	34	28	26
	30	25	17	17	16	21	23	28	33	56	77	64	66		59	60	72	77	65	62	64	53	53	53	54
	31	47	48	36	34	39	42	42	46	51	54	48	46	45	41	37	38	41	45	55	64	58	46	45	40
Feb-12	1	36	30	27	25	24	19	24	37	47	50	43	38	35	38	30	30	31	34	35	35	28	27	26	22
	2	19	15	13	12	14	16	19	26	34	46	42	50	36	31	29	30	36	38	38	45	42	41	39	47
	3	43	31	28	32	47	62	79	78	84	103	102	88	69	79	59	64	59	71	86	81	81	73	76	72
	4	70	59	58	63	63	59	68	82	103	106	118	72	56	52	42	48	58	73	75	68	80	79	65	65

months	Dates	Hour																							
		0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00
	5	66	57	56	60	60	64	60	55	46	37	32	31	34	39	46	43	50	54	55	46	48	51	51	46
	6	44	53	40	41	48	57	78	89	103		97	85	77	76	79	89	82	92	88	83	89	88	84	78
	7	75	73	65	61	57	61	59	58	61	63	63	60	46	60	46	30	32	37	46	54	47	39	34	38
	8	30	17	13	12	11	14	18	29	38	42	50	46	34	31	29	26	27	32	39	47	52	54	53	54
	9	54	47	68	61	66	72	70	71	70	79	81	74	78	86	82	71	60	57	61	50	62	64	63	62
	10	63	67	60	46	39			58	68	76	59	49	39	39	38	35	45	57	68	83	82	88		
	11		43	36			52	51	48	40	48	51	38	49	49	37	37	43	62	49	54	64	80	76	89
	12	107	113	103	98				85	68	67	68	56	58	49	58	56	69	71	70	73	72	67	72	70
	13	60	60	67				87	98	108	108		121	81	67	69	73	69	66	80	86	73	75	62	23
	14	17	12	8	10	10	11	26	38	62	66	70	62	55	43	38	46	54	64	72	75	57	43	30	23
	15	21	10	8	6	5	6	11	28	40	52	37	30	33	32	30	35	40	41	32	31	30	20	17	21
	16	23	21	14	13	16	16	41	66	76	81	102	77	74	48	74	69	74	81	80	76	76	71	69	72
	17	65	68	60	49	33	38	45	62	73		78	64	59	57	46	46	67	80	71	59	69	67	66	60
	18	56	47	34			29	28	41	45	43	50	44	40	39	48	48	45	39	40	42	38	33	40	
	19	46	36	28		15	12	26	26	21	20	21	26	17	28	28	40	33	39	41	44	51	49	75	64
	20	71	79	50	24			85	99	113	140	99	84	54	49	47	44	56	52	69	79	81	74	64	72
	21	60	55	42	38	39		40		62	71	69	58	59	57	57	68	49	58	61	59	54	53	43	59
	22	58	46	41	35	32	32	48	56	72	70	66	62	54	41	50	39	45	51	61	58	42	35	28	33
	23	25	37	39	35	38	28	23	37	57	57	60	67	56	53	56	51	58	58	67	62	63	54	45	43
	24	40	47	43	47	47	48	50	52	57	58	51	55	51	49	46	55	54	48	71	66	68	78	81	82
	25	86	91	79	80	78	74	73	66	70	64	65	47	30	29	23	26	32	31	41	46	52	63	72	69
	26	56	38	49	53	40	41	40	24	30	30	23	22	29	33	32	40	32	38	40	48	68	80	71	62
	27	52	66	63	62	55	56	60	73	79	76	65	61	58	55	57	58	64	65	72	71	60	62	52	59
	28	55	54	45	37	42	47	53	56	61	55	69	69	61	75	61	63	74	70	76	67	64	59	63	60
	29	57	53	52	50	50	49	55	62	61	69	60	55	64	60	65	62	62	70	74	77	86	73	66	65
Winter	Avrg	45.11	42.63	36.96	33.12	31.40	32.64	39.32	48.51	55.03	57.87	57.14	53.54	49.37	47.44	44.95	47.00	50.33	54.59	59.48	59.39	56.28	54.49	51.41	48.26
	Max	112.34	118.66	111.44	100.69	90.27	92.26	94.04	134.18	139.74	144.44	121.66	123.41	102.54	93.29	82.38	94.58	90.96	98.69	100.51	112.69	104.67	114.80	116.00	123.19
	Min	7.15	5.58	6.44	4.18	4.50	5.19	9.16	13.84	14.07	14.56	19.65	17.85	16.88	16.56	17.34	19.51	20.45	21.96	19.93	17.32	14.77	10.87	11.41	12.41
Mar-12	1	67	67	60	57	53	48	48	56	77	61	57	65	61	69	73	72	91		93	100	82	81	73	65
	2	62	44	45	48	49	50	56	59	52	59	47	47	40	39	46	63	55	56	62	62	63	66	65	58
	3	54	55	53	45	43	43	42	49	47	47	54	55	40	39	35	36	51	51	51	44	47	48	43	51
	4	53	48	51	50	49	44	49	54	41	39	33	31	39	38	43	60	46	56	38	45	37	47	38	31
	5	40	28	23	17	15	17	36	31	44	71	68	54	60	73	56	53	55	59	79	59	57	42	39	36
	6	34	27	20	18	19	21	28	63	82	71	74	57	50	36	51	49	53	54	69	76	81	77	61	70

months	Dates	Hour																							
		0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00
	7	62	58	52	50	50	49	51	51	57	56	55	48	51	48	57	61	54	63	57	61	62	39	29	22
	8	32	18	11	13	14	17	34	75	99	85	54	46	41	34	35	41	51	50	66	75	92	98	89	90
	9	76	68	66	65	61	68	74	80	80	76	78	65	63	58	51	48	60	68	61	59	60	52	60	65
	10	47	44	62	43	55	62	62	63	58	57	59	61	58	59	56	47	42	41	51	85	79	72	72	71
	11	67	47	58	49	37	32	40	65	61	50	37	32	29	26	30	25	28	28	43	55	66	87	91	80
	12	78	71	66	56	61	60	72	101	107	125	102	78	53	50	42	36	51	42	37	64	53	44	37	40
	13	50	33	13	8	9	12	18	31	54	63	72	77	45	55	46	65	74	52	62	63	53	54	57	59
	14	36	29	25	20	25	22	33	40	39	66	62	44	66	67	50	58	65	70	57	81	76	66	64	70
	15	58	61	57	61	57	62	74	74	98	94	103	103	95	76	70	73	88	90	94	102	91	112	108	90
	16	87	91	88	84	71	49	31	49	68	47	59	57	52	48	49	58	83	71	71	93	88	84	93	46
	17	41	53	46	51	59	45	46	52	57	61	47	38	40	38	38	32	47	45	41	43	56	43	46	41
	18	42	35	31	26	34	19	31	37	24	32	23	24	31	28	26	34	37	28	47	44	43	43	34	28
	19	37	45	54	53	60	71	102	144	160	136	94	55	46	45	38	55	48	53	42	77	98	90	90	83
	20	79	75	69	66	63	59	64	100	87	100	70	51	32	49	44	42	57	52	69	99	93	80	101	119
	21	106	104	82	76	71	73	78	138	121	100	87	62	59	74	76		82	60	52	71	63	87	86	64
	22	51	43	47	51	43	27	31	46	54	50	59	60	29	44	42	40	26	20	41	46	44	44	39	46
	23	32	23	28	26	21	21	30	41	63	58	42	38	39	33	49	43	54	62	50	43	54	65	90	87
	24	77	64	57	49	41	38	35	36	32	34	40	44	36	25	18	18	23	20	23	33	33	37	53	55
	25	41	30	28	21	23	22	19	20	20	14	15	11	15	20	15	14	16	17	16	19	24	27	26	26
	26	23	16	13	13	17	26	67	76	95	74	63	36	24	21	25	19	21	23	24	34	60	86	60	51
	27	47	49	50	52	54	89	117	121	126	116	102	70	60	51	48	52	69	65	66	70	72	66	77	90
	28	87	78	65	61	56	74	106	128	135	151	120	83	54	53	48	65	58	59	54	65	89	105	103	80
	29	49	45	53	49	59	75	89	124	121	108	83	43	38	39	50	58	47	43	39	38	34	53	58	54
	30	46	42	46	17	13	21	48	52	54	46	41	48	47	41	42	45	47	45	47	43	34	33	55	54
	31	88	52	36	23	27	49	42	35	26	25	22	23	21	20	21	23	25	23	29	27	33	31	44	70
Apr-12	1	63	73	80	85	83	82	79	80	75	35	21	20	24	23	18	22	21	20	26	29	45	59	58	29
	2	25	19	21	32	61	64	101	119	116	113	121	113	73	56	63	50	52	52	59	72	104	123	111	117
	3	104	99	90	98	97	115	133	133	122	99	73	69	52	47	64	56	73	78	92	92	81	59	66	57
	4	56			57	58	72	56	57	44	43	50	34	32	34	34	38	31	32	36	40	50	44	43	30
	5	22	18	16	14	12	14	26	36	35	31	28	22	23	23	23	26	25	28	32	32	42	47	41	30
	6	29	64	69	68	66	63	86	101	103	76	43	35	38	32	34	43	54	55	59	72	69	61	63	53
	7	35			18	14	27	40	58	50	24	19	31	26	23	24	27	28	24	24	22	33	36	53	46
	8	25		52	57	42	56	74	59	23	24	24	46	31	22	20	26	31	35	33	26	21	24	23	20
	9	23	24	25	25	23	35	38	31	37	36	41	36	29	33	30	29	34	27	30	24	26	27	19	15

months	Dates	Hour																							
		0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00
	10	13	10	10	9	10	18	32	54	55	52	52	58	32	44	39	51	51	50	58	60	62	83	64	73
	11	69			25	27	45	70	62	61	48	45	33	40	48	48	42	60	81	73	52	62	50	56	65
	12	64			64	68	82	134	166	114	94	84	79	72	91	95	68	43	47	40	43	55	67	57	52
	13	46	51	56	56	57	87	130	125	110	54	64	75	90	91	100	79	74	61	41	36	57	69	67	82
	14	94	77	68	77	64	55	85	87	60	29	23	37	23	23	21	22	27	24	25	26	35	33	41	34
	15	36	27	22	26	32	23	19	27	18	22	17	17	20	25	25	23	19	22	14	16	21	25	33	35
	16	33			23	22	58	104	105	72	65	39	30	38	32	33	38	38	44	40	34	43	69	89	106
	17	97	95	87	63	54	62	95	107	92	72	79	49	40	35	32	56	48	35	40	36	32	29	35	28
	18	26		24	25	25	37	59	75	58	51	44	34	38	40	32	42	35	37	37	30	38	36	27	23
	19	16	0	11	10																				
	20		0	37	32											54	50	50	40	39	34	30	32	39	41
	21	30			45	43	35	27	35	33	31	30	39	36	42	30	27	37	46	50	54	63	47	48	51
	22	44			26	27	27	48	36	33	25	21	22	28	24	23	23	28	28	39	29	35	35	50	46
	23	37			19	20	33	51	64	75	54	47	42	36	33	32	31	36	36	55	27	54	47	41	26
	24	26			20	25	26	62	71	62	64	64	74	74	85	87	93	104	105	89	64	52	39	34	38
	25	22			27	32	46	50	58	82	55	48	37	31	36	35	38	42	40	54	29	27	24	23	22
	26	22	16	13	18	20	24	34	43	44	31	24	20	20	31	52	41	45	37	46	47	52	54	48	40
	27	34											30	34	30	31	44	59	53	51	72	89	104	78	73
	28	54	47	51	48	26	27	21	21	20	18	21	27	24	25	22	23	24	25	32	19	16	14	13	14
	29	12	12	12	10	8	14	11	14	21	19	23	36	41	49	47	65	53	32	36	35	48	57	85	110
	30	99	84	82	74	88	86	79	70	46	33	29	21	24	29	28	26	18	16	18	17	18	15	13	12
May-12	1	10	10	9	10	12	16	33	47	50	53	64	59	48	45	51	60	68	65	51	65	61	81	65	86
	2	96	90	79	69	69	66	76	64	55	64	39	45	44	42	50	73	81	68	65	73	66	53	74	66
	3	64	71	48	25	35	37	54		62	64	71	63	62	62	67	55	51	54	69	71	60	62	50	37
	4	38	18	15	22	17	26	43	44	57	49	41	52	51	55	58	59	53	38	33	47	37	35	40	28
	5	29	22	16	16	20	21	24	22	20	7	18	21	17	15	14	18	17	18	16	19	15	16	11	14
	6	11	10	8	8	7	8	10	7	7	9	9	7	8	10	11	10	10	14	12	15	21	28	31	25
	7	20	13	16	13	16	30	45	66	70	72	61	58	44	43	26	29	36	38	42	37	44	38	41	37
	8	30	27	28	26	24	35	46	69	75	60	72	59	75	44	54	52	81	81	97	66	54	52	63	77
	9	66	43	24	26	42	49	66	81	82	100	67	58	57	42	52	40	42	32	37	53	52	48	45	59
	10	43	31	29	27	25	27	34	43	47	59	47	38	45	42	47	75	58	51	53	57	56	44	36	30
	11	28	33	33	30	24	28	34	48	41	40	39	38	39	30	31	30	30	32	51	44	36	37	37	36
	12	37	41	33	17	17	42	62	35	37	37	27	21	27	21	23	19	21	26	34	26	33	36	56	65
	13	92	78	74	65	64	59	69	56	26	34	21	37	50	42	46	43	36	42	36	24	33	57	55	68

months	Dates	Hour																							
		0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00
	14	65	28	23	27	48	81	75	66	56	48	39	36	41	36	45	35	47	42	37	35	31	33	30	24
	15	37	41	25	14	21	44	75	95	92	52	51	50	39	63	44	42	42	31	31	28	24	29	26	18
	16	16	8	6	10	7	21	44	49	41	35	37	26	34	30	27	29	30	31	44	41	39	55	85	93
	17	92	68	42	44	55	58	56	54	48	39	25	23	29	35	29	28	30	33	36	28	44	48	43	28
	18	27	19	17	21	23	34	43	49	61	69	46	52		40	43	42	37	36	57	51	48	42	57	53
	19	50	54	51	50	53	52	53	36	38	36	29	30	27	29	34	41	39	38	33	36	44	45	48	48
	20	48	30	41	31	29	28	30	24	18	17	18	20	18	18	18	18	27	27	35	46	53	51	51	49
	21	59	49	48	40	37	46	69	70	60	47	47	56	62	50	53	53	60	65	68	56	56	55	62	42
	22	33	31	21	21	26	46	72	75	65	63	56	45	56	51	58	60	71	61	72	64	53	67	47	49
	23	42	34	32	33	40	89	109	108	117	88	90	105	113	124	134	112	99	88	88	98	95	107	110	104
	24	88	78	78	75	68	67	79	83	74	79	80	45	37	48	30	34	38	53	75	46	42	35	31	29
	25	27	22	12	11	13	24	43	38	48	54	51	41	36	47	37	36	33	29	35	26	34	32	24	21
	26	21	18	17	15	17	22	29	31	25	26	32	26	28	39	27	28	27	36	42	32	38	51	43	43
	27	44	34	26	22	18	18	17	17	15	16	20	21	14	16	25	12	9	12	10	16	32	36	55	44
	28	47	57	44	25	29	39	28	26	19	17	18	27	30	26	31	23	30	32	38	35	34	42	42	34
	29	26	22	21	32	43	66	68	60	64	54	68	81	70	67	65	49	40	39	41	44	42	48	35	43
	30	46	39	29	28	36	58	88	74	87	92	96	88	93	82	81	82	55	62	50	46	51	64	66	84
	31	76	49	50	64	79	59	91	79	79	64	61	61	51	40	37	41	43	48	48	64	44	40	33	35
Spring	Avrg	48.47	43.37	40.49	37.24	38.55	44.66	56.86	63.63	62.21	56.36	51.01	46.27	42.99	42.65	42.76	43.50	46.00	44.39	47.58	48.68	51.03	53.14	53.76	51.89
	Max	106.40	104.45	90.21	98.48	97.22	114.56	133.81	166.18	160.38	151.33	120.63	112.88	112.92	124.31	133.59	112.17	103.51	105.04	97.10	102.21	103.72	123.42	111.48	118.99
	Min	10.28	0.00	6.49	7.71	7.24	8.06	9.58	6.82	7.09	7.03	8.92	6.82	8.23	10.01	10.73	10.33	9.39	11.57	10.04	14.70	15.40	14.34	11.22	12.26
Jun-12	1	36	21	7	12	15	37	75	60	63	63	43	59	58	46	45	59	50	30	35	39	31	38	31	34
	2	28	36	46	56	59	71	57	40	24	23	30	26	29	17	21	28	23	27	28	27	16	12	16	21
	3	13	15	14	14	10	13	18	10	14	12	24	17	20	18	20	17	20	19	20	29	38	26	25	25
	4	33	28	21	16	12	28	35	31	35	30	46	35	30	42	42	53	42	42	28	28	29	32	34	45
	5	63	32	30	33	41	81	121	108	62	52	54	55	44	40	53	38	36	37	51	39	46	48	51	39
	6	37	28	21	23	26	31	47	52	51	55	54	65	57	40	27	38	36	26	32	30	43	35	44	49
	7	28	15	17	20	31	57	65	76	60	66	48	44	48	35	63	64	74	92	75	73	43	47	40	35
	8	46	49	36	25	28	32	46	46	41	28	32	30	30	26	28	18	23	18	19	20	17	15	14	12
	9	12	11	12	10	10	12	13	16	19	21	24	18	22	28	21	23	28	32	25	24	35	38	36	34
	10	30	35	47	43	35	41	31	29	35	29	21	20	25	37	24	30	33	47	26	26	25	27	31	22
	11	15	12	13	13	12	27	51	72	75	64	57	60	55	42	47	47	72	58	78	78	59	72	54	41
	12	31	26	27	20	22	36	30	42	40	31	29	54	40	31	38	41	43	47	45	27	29	23	23	21
	13	25			18	18	44	72	70	62	42	29	38	42	28	32	27	33	38	28	29	28	26	35	65

months	Dates	Hour																							
		0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00
	14	60	68	58	60	57	58	98	73	36	32	27	24	36	38	29	21	21	32	37	30	30	39	26	26
	15	25	21	25	34	34	52	67	88	75	73	65	59	74	50	45	51	43	54	41	38	37	32	33	29
	16	28	24	22	21	22	28	27	29	30	18	19	17	22	24	22	28	25	17	21	28	31	35	36	32
	17	23			11	15	14	15	14	11	11	15	19	18	19	19	22	28	22	20	42	45	35	62	56
	18	61	28	25	19	24	32	55	78	83	50	50	52	44	57	57	48	38	45	30	29	30	33	50	52
	19	61		54	57	73	91	94	103	98	71	55	53	55	59	52	63	64	61	53	40	39	43	53	51
	20	60	43	40	41	42	65	63	61	40	43	26	17	21	19	18	21	19	24	20	20	22	18	19	17
	21	16	14	16	16	16	33	55	52	66	64	58	53	35	34	44	49	51	44	70	59	45	57	57	37
	22	17	22	11	13	16	25	36	32	33	33	28	28	22	29	20	33	25	30	25	24	18	21	20	15
	23	14		14	14	19	15	23	21	18	19	17	19	16	18	17	15	15	16	22	29	37	33	35	41
	24	26		26	28	25	24	27	28	26	15	17	19	20	20	18	18	19	21	16	13	24	41	43	30
	25	40	22	22	23	24	41	77	52	45	48	38	32	34	33	36	38	37	29	33	29	26	29	57	55
	26	45	38	18	16	41	72	105	108	91	75	58	63	65	65	49	63	48	45	65	65	68	51	51	53
	27	59	59	42	30	39	37	45	45	37	45	36	33	26	37	42	50	38	36	52	50	62	62	47	46
	28	43	41	39	35	34	43	55	75	58	57	47	60	45	52	66	62	55	48	58	70	58	57	58	66
	29	55	37	41	38	33	40	56	54	66	53	48	42	39	36	44	30	38	37	44	46	37	42	70	47
	30	42	48	41	40	28	37	39	34	22	22	18	18	18	22	29	29	34	46	40	32	49	29	30	38
Jul-12	1	27	26	14	15	16	21	23	16	10	9	15	18	19	24	29	26	26	32	22	22	31	28	24	37
	2	27		15	15	16	34	66	64	62	45	32	34	46	54	39	40	41	43	50	45	48	56	64	49
	3	70		41	34	36	44	58	68	79	69	70				43	36	47	48	44	50	56	46	47	52
	4	48	33	39	38	43	70	98	95	83	84	62	53	44	43	58	55	61	56	61	53	54	40	50	64
	5	73	47	30	34	27	36	76	94	99	118	96	106	96	64	46	44	38	31	49	44	52	64	98	63
	6	68	55	27	17	23	57	100	83	66	58	49	46	51	42	35	48	33	52	52	43	36	49	63	101
	7	86	76	65	55	33	31	34	32	25	25	21	19	22	22	23	25	22	33	28	33	49	65	63	43
	8	44	37	28	35	23	18	28	25	18	24	28	30	34	27	21	31	24	30	34	25	25	29	22	18
	9	21	22	11	21	33	23	40	36	50	46	46	50	43	54	36	38	32	29	33	36	36	51	49	37
	10	42	36	36	30	32	42	53	57	50	37	33	37	26	43	43	45	45	46	43	27	37	30	31	34
	11	27	19	19	22	25	25	36	37	35	40	39	26	29	32	23	25	18	31	22	22	26	29	29	34
	12	32			29	20	28	50	74	71	59	29	31	31	27	32	35	29	37	32	27	41	55	56	43
	13	42	27	18	19	14	34	41	44	35	30	45	22	41	39	38	45	30	26	32	27	25	37	40	28
	14	26	20	17	35	22	21	21	22	28	28	27	26	22	23	21	27	36	35	42	35	34	37	42	52
	15	56	53	40	34	40	36	50	36	25	21	22	31	35	37	39	26	25	21	20	25	27	26	30	50
	16	39	24	44	42	25	32	38	45	45	37	40	36	43	40	33	33	27	40	34	24	19	22	34	28
	17	21	9	17	18	25	28	38	44	46	39	45	34	28	17	32	33	34	42	32	39	46	52	44	28

months	Dates	Hour																							
		0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00
	18	17			33	34	36	35	34	29	26	27	29	34	28	25	37	23	31	29	34	33	23	23	19
	19	25			27	24	22	35	36	33	28	17	17	21	27	43	37	32	36	31	33	33	38	35	36
	20	54	43	32	32	35	67	88	80	70	41	34	37	36	30	32	37	29	36	32	24	34	27	48	54
	21	44	58	57	55	48	44	65	63	36	26	17	24	25	28	20	17	24	25	20	22	30	38	48	62
	22	68			52	49	50	53	47	23	18	20	25	22	20	25	25	21	31	24	23	33	59	75	99
	23	83	51	36	24	20	34	56	72	85	69	47	33	34	32	33	43	53	50	53	50	46	72	101	62
	24	52	79	48	39	62	89	113	122	119	101	77	64	52	49	47	59	56	52	52	58	58	77	54	89
	25	98	93	70	55	71	75	100	101	108	92	84	63	47	57	50	50	48	52	45	45	60	62	70	34
	26	30	26	21	21	18	19	26	29	26	21	19	20	19	22	20	27	20	19	20	20	18	22	20	22
	27	26	21	14	12	15	29	40	48	61	65	66					75	73	92	91	81	71	64	47	52
	28	36	25	22	20	18	21	34	29	43	27	22	26	32	25	43	55	43	33	38	51	39	40	47	71
	29	55	56	30	31	51	30	25	25	25	22	19	14	18	23	17	18	20	24	34	37	29	38	43	38
	30	44	22	17	32	20	41	43	46	41	36	21	24	27	21	21	21	24	25	22	21	27	33	27	31
	31	30	34	44	64	28	33	45	48	53	47	41	40	32	37	30	40	36	48	53	45	36	33	35	39
Aug-12	1	34	32	35	28	41	44	54	57	71	51	45	30	32	32	29	43	52	62	75	91	73	87	57	40
	2	56	90	75	31	71	76	73	64	62	50	44	34	41	41	51	28	22	31	27	36	38	46	48	71
	3	60	40	36	33	45	59	68	61	41	33	24	34	33	32	41	44	31	36	50	39	67	69	57	43
	4	35	51	45	38	37	43	37	33	26	33	34	25	19	20	17	19	20	25	39	38	48	64	62	74
	5	57	44	46	46	35	33	42	40	34	39	39	41	21	21	20	32	32	37	25	38	39	42	50	42
	6	35	24	20	22	21	35	40	39	43	19	24	25	28	34	20	28	30	34	36	29	28	33	29	29
	7	31			15	18	36	39	39	48	50	45	40	34	25	27	24	23	34	47	48	33	42	47	35
	8	45	36	40	42	52	56	67	64	57	52	44	52	48	49	53	50	49	53	42	40	51	52	52	59
	9	61	42	44	43	47	57	96	94	77	45	25	25	25	27	49	31	30	35	30	29	30	16	18	19
	10	16	21	21	27	29	44	58	81	64	55	39	31	34	26	25	23	27	29	23	25	40	46	37	45
	11	43	41	41	32	26	30	39	62	45	40	16	22	24	29	21	23	33	24	25	29	37	38	39	29
	12	27	20	21	21	20	22	24	24	20	20	22	22	19	26	24	21	26	24	29	23	41	39	42	37
	13	34	30	32	32	38	47	66	69	83	80	68	56	44	50	50	56	51	48	55	42	55	57	58	52
	14	64	35	44	54	51	52	68	84	106	76	73	63	50	57	55	56	75	61	47	34	45	42	55	56
	15	56	37	32	28	22	33	48	55	64	57	52	57	51	52	50	64	71	82	96	41	21	21	21	19
	16	19	22	49	56	40	48	68	69	67	48	57	42	34	33	41	43	40	44	47	41	56	62	46	54
	17	39	43	42	51	51	53	74	70	86	63	51	43	44	39	50	53	60	53	48	52	80	124	122	122
	18	101	67	51	43	40	39	40	40	45	51	42	43	41	33	39	37	41	42	51	83	84	82	79	105
	19	136	100	60	38	35	41	46	38	35	36	28	37	37	34	34	30	59	64	73	113	90	74	73	99
	20	106	31	27	34	41	47	73	89	92	87	94	81	54	56	55	51	59	43	40	55	59	74	79	79

months	Dates	Hour																							
		0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00
	21	69	62	61	62	49	61	74	72	84	81	69	65	50	48	53	68	55	47	43	51	63	66	59	53
	22	63	28	27	18	22	32	46	50	38	33	25	32	34	33	28	36	30	35	29	30	34	40	46	36
	23	25	33	48	47	47	55	61	80	65	57	48	57	69	51	57	44	51	54	62	60	39	38	29	37
	24	35	20	20	15	20	52	67	78	81	79	84	70	89	72	51	47		70	63	47	61	68	41	44
	25	35	29	23	27	23	19	26	26	29	19	24	26	19	21	18	22	26	19	19	21	15	17	18	18
	26	20			25	20	27	22	20	17	24	16	28	25	23	17	24	19	32	30	29	40	50	57	68
	27	69	67	56	38	32	41	67	60	62	59	49	43	43	48	50	38	48	53	53	47	56	66	55	41
	28	29			29	27	42	58	72	74	67	70	71	47	50	32	31	47	48	38	33	43	45	71	50
	29	40	43	27	33	35	62		83	80	84	49	46	61	40	41	43	44	46	50	39	50	29	28	26
	30	33	19	18	29	21	27	53	56	65	50	36	35	35	43	46	57	49	88	66	70	48	61	57	31
	31	31	14	11	11	12	17	24	29	35	34	30	30	25	34	27	27	36	31	29	28	38	46	64	73
Summer	Avrg	43.30	36.98	32.42	30.82	31.20	40.37	53.01	54.89	52.05	45.68	40.06	38.30	36.77	35.60	35.60	37.74	37.62	40.12	40.24	39.28	41.17	44.21	46.04	45.52
	Max	135.82	100.43	75.26	64.03	73.16	90.95	120.70	122.30	118.87	118.29	96.19	106.04	96.32	71.66	66.47	75.45	75.15	91.84	96.18	112.92	90.00	123.93	121.86	122.09
	Min	12.44	8.83	7.34	10.06	9.57	11.65	13.46	10.46	9.81	9.17	14.76	14.14	16.03	16.79	16.63	15.19	15.43	16.13	16.23	13.44	14.97	12.24	13.79	11.82
Sep-12	1	79	33	26	31	47	61	62	69	83	44	42	40	34	43	35	42	34	34	37	47	54	66	73	68
	2	53	42	46	40	36	38	35	37	34	26	20	25	23	35	30	35	32	34	36	37	42	40	41	38
	3	43	41	41	41	44	59	94	82	75	51	43	55	44	30	34	46	40	38	40	37	55	55	68	67
	4	63	51	42	36	36	51	90	105	114	76	80	68	75	66	58	57	69	69	72	62	60	54	37	40
	5	30	18	16	21	24	44	50	59	63	57	43	43	42	38	42	53	36	38	30	40	42	55	60	41
	6	31			33	34	44	87	111	113	74	44	46	49	57	55	48	49	46	55	41	53	56	55	53
	7	45			35	42	59	75	79	85	65	42	49	49	50	31	36	45	41	48	53	57	64	82	83
	8	92	89	76	68	60	60	59	61	61	57	72	68	75	62	61	57	67	65	67	64	59	77	70	61
	9	69	64	70	70	70	72	71	77	71	77	69	60	55	57	47	37	65	51	46	81	107	95	93	91
	10	58	18	10	10	5	7	38	30	43	36	22	9	11	7	10	16		16	24	22	19	18	18	23
	11	7			26	28	35	50	69	60	48	43	47	45	51	36	34	40	46	47	53	58	75	90	91
	12	70	28	21	16	17	49	88	93	79	49	36	45	48	40	55	49	38	41	52	48	44	33	38	33
	13	31	18	24	21	21	33	34	40	46	40	22	26	28	51	41	54	46	44	51	48	44	42	51	47
	14	51	32	30	25	18	28	39	49	42	38	47	48	41	46	32	27	50	41	36	41	40	39	36	35
	15	28	24	30	21	23	24	38	47	49	43	41	26	24	36	22	33	39	37	39	58	78	73	75	68
	16	60	52	55	48	37	31	28	30	31	32	30	22	24	25	38	25	34	37	40	43	53	55	33	38
	17	32	26	33	40	37	33	58	63	72	70	61	69	54	36	52	49	39	45	48	49	35	40	32	31
	18	36	18	26	20	28	40	71	55	61	65	58	29	37	37	44	45	33	43	72	60	43	81	86	47
	19	58	21	15	14	17	36	77		70	46	34	20	35	44	38	32	48	45	68	57	73	79	80	76
	20	71	43	42	43	37	49	74	76	74	91	74	54	57	59	57	65	55	43	57	50	78	75	69	60

months	Dates	Hour																							
		0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00
	21	55	59	48	42	57	61	80	85	88	86	88	76	65	68	84	67	84	89	96	98	84	84	89	65
	22	32	29	18	31	33	40	40	71	66	45	36	34	28	30	29	31	27	28	40	67	88	88	97	89
	23	67			71	49	37	30	30	29	30	31	20	29	30	35	31	35	25	28	30	25	22	17	16
	24	10	11	11	14	18	32	66	74	67	73	61	52	31	39	36	25	25	25	34	27	22	20	20	22
	25	20	17	14	17	15	25	37	48	57	50	34	36	32	33	27	38	44	42	48	50	44	43	30	19
	26	26	16	13	9	9	18	33	39	56	53	46	34	32	31	32	48	42	42	55	54	56	48	48	37
	27	32	24	25	36	35	36	47	59	59	61	64	51	56	52	42	49	54	70	69	84	86	82	74	62
	28	56	51	46	43	44	49	50	60	63	57	47	42	41	55	47	47	59	63	70	74	60	52	52	37
	29	21	29	32	41	26	32	33	50	33	47	37	24	27	21	26	26	34	34	35	39	55	55	66	61
	30	41	49	38	36	33	57	49	47	41	41	34	24	19	19	19	22	27	42	30	58	39	50	46	30
Oct-12	1	25	29	21	26	28	30	52	61	74	58	58	39	51	46	53	57	74	85	75	68	47	41	35	28
	2	35	37	24	23	23	33	65	67	66	60	57	58	43	58	47	53	53	54	55	76	59	56	51	44
	3	36	27	24	21	18	16	37	35	43	48	49	61	46	46	45	80	60	58	58	53	45	37	42	39
	4	33	44	34	39	39	46	67	85	92	86	88	72	48	36	40	34	41	33	55	72	68	68	59	52
	5	53	41	30	33	31	33	50	39	43	35	35	30	29	39	38	44	35	50	52	55	51	67	60	46
	6	74	53	34	37	25	31	43	30	40	47	54	57	55	36	38	33	37	51	77	89	106	93	87	83
	7	99	84	64	57	61	68	68	48	71	79	40	24	26	31	34	27	33	39	72	94	96	93	98	76
	8	71	63	57	54	55	77	90	106		88	66	65	52	53	63	68	69	67	73	76	78	77	63	62
	9	60	53	50	49	41	55	84	118	121	110	90	77	47	47	46	52	51	69	97	113	126	120	111	96
	10	88	72	61	57	50	74	121	113	121	124	110	91	90	64	52	74	58	79	93	73	90	64	62	66
	11	74	61	59	55	53	58	75	88	86	85	72	75	74	74	67	64	71	68	75	67	73	64	62	57
	12	45	37	32	29	28	35	51	61	51	45	57	39	41	44	59	43	42	40	43	45	64	44	38	54
	13	42	42	49	33	35	35	28	38	47	55	39	48	49	44	51	56	51	55	58	64	68	54	61	58
	14	37	45	38	28	24	23	20	27	29	28	30	45	55	51	46	47	44	37	46	54	40	35	33	29
	15	46	51	47	40	27	30	88	123	118	106	74	55	41	41	39		56	52	60	44	46	43	37	32
	16	28	20	25	23	21	28	38	44	54	52	47	48	38	35	37	41	29	37	49	44	45	47	47	47
	17	43	44	33	35	36	35	40	53	53	50	43	56	43	49	33	52	43	54	63	55	41	33	40	32
	18	34	31	28	16	10	26	53	65	60	63	71	78	79	87	81	77	90	80	98	82	78	92	89	75
	19	77	72	62	63	59	62	78	91	90	103	77	73	77	83	91		103	100	95	94	73	53	62	58
	20	54	50	51	46	46	47	43	49	37	47	47	40	35	57	62	51	57	55	53	46	46	45	49	35
	21	29	20	19	19	15	13	10	12	14	17	11	13	16	22	20	20	24	28	31	30	31	31	29	30
	22	27	24	22	21	24	27	40	38	39	34	47	30	39	49	68	56	70	68	84	62	56	48	55	58
	23	54	50	47	41	39	40	48	54	42	43	53	47	30	49	63	41	50	61	57	47	47	38	36	36
	24	31			27	33	38	46	35	32	34	31	29	46	48	46	65	43	58	49	38	34	32	31	29

months	Dates	Hour																							
		0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00
	25	27			22	18	19	24	34	32	38	33	42	35	32	45	42	51	40	30	36	36	22	20	24
	26	24	17	16	5	7	11	22	39	50	52	41	40	34	36	29	26	27	34	47	44	49	50	63	66
	27	68	76	59	45	31	15	16	24	50	59	36	44	27	17	17	23	25	28	50	84	83	82	81	71
	28	76	81	72	79	73	72	65	69	74	87	72	42	48	29	29	28	35	44	52	40	23	32	32	28
	29	26	25	23	18	19	15	22	42	59	61	55	54	51	52	54	46	59	58	55	58	51	41	39	43
	30	43	49	32	20	32	43	59	89		103	90	107		115	90	80	88	71	81	95	83	70	74	72
	31	54	57	54	57	56	53	59	63	59	65	63	53	49	48	52	54	59	74	72	73	65	49	54	48
Nov-12	1	49	35	31	28	24	21	30	43	52	40	43	48	59	44	51	59	47	46	51	57	43	37	40	
	2	43	35	19	17	17	12	14	19	35	41	49	36	45	33	38	46	57	54	70	58	61	59	47	50
	3	44	35	24	22	25	30	27	33	38	39	45	51	50	45	56	44	32	42	46	49	38	41	54	45
	4	31	42	47	45	36	35	44	40	54	38	35	31	40	43	51	69	74	65	39	36	37	32	31	27
	5	26	19	19	17	22	25	48	87	117	112	92	71				56	65	78	79	122	121	115	91	89
	6	79	52	51	47	45	40	74	102	134	169	149	90	52	36	32	33	38	56	64	53	61	55	42	36
	7	30	24	19	16	19	23	36	65	78	83	79	59	59		49	47	53	54	58	55	50	43	40	39
	8	39	39	33	33	33	30	37	49	57	72	59	66	68	46	46	43	51	65	56	78	57	49	49	56
	9	43	66	42	50	48	47	61	97	79	67	79	61	67	71	78	80	72	83	73	78	69	63	59	59
	10	56	43	39	32	28	27	27	32	33	34	40	45	42	48	43	46	51	50	48	53	49	48	46	38
	11	35	37	51	48	44	41	40	41	40	43	41	41	45	39	44	54	57	67	68	80	50	42	41	45
	12	44	42	42	40	35	38	51	57		66	59	60	50	57	64	58	59	63	58	61	57	49	48	36
	13	29	26	21	21	19	20	31	48	54	49	53	56	54		51	68	59	52	66	58	61	58	56	57
	14	55	51	45	42	37	39	51	68	67	67	86	77	77	76	75	75	71	77	87	88	82	79	78	78
	15	76	75	64	57	57	52	44	60	67	64	72		69	64	73	73	68	70	61		58	58	62	57
	16	57	49	44	43	41	46	46	59	57	57	55	54	55	56	49	60	54	54	63	59	60	49	47	46
	17	46	48	41	40	44	38	40	44	42	44	39	37	36	36	37	41	41	37	50	52	41	43	36	38
	18	40	47	46	60	51	39	50	64	79	67	66	82	87	66	49	57	69	116	115	109	134	112	108	108
	19	95	86	64	55	48	55	64	94	76	76	63	64		46	51	51	48	46	60	59	54	49	46	39
	20	37	35	42	41	33	30	30	53	51	56	61	54	56	66	51	58	65	79	69	68	53	52	56	52
	21	46	46	43	42	37	35	39	59	52	64	69	67	48	55	54	54	66	60	56	49	38	41	42	34
	22	31	21	51	57	41	37	45	62	60	69	59	63	62	49	43	51	48	64	62	60	45	46	42	35
	23	30	20	17	14	13	13	18	39	51	59	67	66	98	75	84	104	115	84	108	96	92	84	83	89
	24	99	82	72	74	69	68	72	77	80	70	55	59	57	61	60	46	53	58	54	58	47	51	45	43
	25	48	55	40	23	19	12	10	13	11	15	18	18	23	22	24	26	28	26	26	24	25	29	25	26
	26	29	17	22	24	18	22	23	49	65	67	64	68	57	58	61	51	65	68	87	88	89	73	60	58
	27	42	28	27	23	21	19	25	49	66	66	66	59	62	58	67	74	67	85	98	101	95	90	84	98

months	Dates	Hour																							
		0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00
	28	99	87	80	79	69	71	69	75	66	75	85	65	57	38	47	53	76	57	56	45	45	52	37	35
	29	29	22	17	26	25	30	43	61	66	79	70	48	29	28	44	56	51	67	71	94	92	87	98	90
	30	85	73	80	67	74	73	84	132	150	182	175	124	89	70	59	60	71	78	71	91	85	48	64	70
Fall	Avrg	47.65	41.91	37.89	35.98	34.18	38.10	49.69	59.53	62.01	61.21	55.88	50.69	47.32	46.83	47.00	48.50	51.70	53.93	58.84	60.79	59.30	56.38	55.36	51.53
	Max	99.33	88.62	80.47	79.38	74.09	76.72	121.28	132.25	149.81	181.80	175.23	124.27	97.51	114.50	91.04	103.81	114.94	116.40	115.34	121.53	133.76	120.24	111.35	108.14
	Min	6.66	8.83	7.34	4.56	4.96	6.95	10.43	10.46	9.81	9.17	11.04	8.97	10.52	6.84	10.24	15.19	15.43	16.13	16.23	13.44	14.97	12.24	13.79	11.82

* data in μg/m^3
Measurement done by the National Institute of Public Health and the Environment/RIVM at the Schiedamsevest measurement station

NO_2 Emission Measurement - Charlois

months	Dates	Hour																							
		0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00
Dec-11	1	45.7	52.7	18.8	30.8	13.7	17.8	23.9	30.0	28.2	42.0	39.9	38.1	50.9	54.0	55.4	57.2	59.6	53.7	56.0	66.9	75.1	65.3	52.8	31.3
	2	58.1	15.6	24.3	15.5	8.6	13.1	15.0	20.9	50.6	17.8	56.2	40.8	66.2	66.0	37.6	86.0	97.7	67.9	88.2	103.9	66.5	50.7	53.3	45.6
	3	39.6	23.0	23.4	30.3	32.6	48.2	68.8	69.3	79.8	74.6	70.4	66.2	67.4	56.8	53.8	62.4	63.5	85.9	76.3	66.7	55.7	71.1	61.7	51.7
	4	53.9	61.9	24.8	23.1	36.8	62.1	65.2	77.2	78.6	73.7	69.1	58.5	66.4	66.3	78.9	85.2	94.6	108.0	96.1	56.2	57.8	68.1	79.6	83.2
	5	77.9	75.5	68.6	66.5	72.8	41.2	39.3	69.0	91.6	109.8	107.8	125.0	95.6	77.3	68.2	89.6	116.3	95.7	86.4	81.0	37.1	21.1	23.0	16.4
	6	11.1	11.4	5.3	11.2	20.4	37.1	77.1	96.5	109.4	120.8	108.7	104.8	102.5	86.9	66.1	71.8	97.8	86.7	73.3	58.6	64.9	43.7	43.0	39.5
	7	43.3	35.5	21.2	18.0	16.2	25.3	42.5	55.0	51.2	62.7	67.8	83.8	73.4	82.7	87.4	91.8	89.2	69.6	64.4	54.7	56.3	51.0	48.4	40.6
	8	33.3	31.0	31.7	33.9	40.3	43.0	47.8	48.7	63.0	67.5	58.1	59.3	75.3	77.1	66.3	53.0	62.3	62.0	60.8	58.0	50.5	41.2	39.6	41.3
	9	39.3	35.5	36.8	31.1	25.8	21.7	22.5	28.3	45.7	36.5	45.7	40.6	45.9	43.3	46.0	44.4	48.6	60.2	50.9	40.2	38.7	28.0	34.5	23.8
	10	16.8	8.3	8.6	12.4	14.5	13.0	30.7	32.6	34.9	37.8						26.1	39.0	42.3	39.5	50.7	32.6	28.7	39.0	36.5
	11	17.9	21.3	18.0	23.7	23.6	27.3	29.7	47.8	61.2	76.7						83.8	99.1	85.6	84.1	67.3	44.9	37.0	35.5	35.0
	12	31.9	30.1	22.7	30.3	35.8	55.3	61.2	72.2	66.9	68.4	60.6	48.8	45.6	48.4	50.7	59.5	69.9	70.7	74.9	70.7	64.0	66.0	61.8	59.8
	13	58.5	51.8	52.0	54.6	59.1	61.1	76.9	91.7	96.2	88.5	80.8	91.2	87.1	71.3	73.1	77.8	86.1	90.8	82.6	77.4	70.0	67.6	66.1	61.3
	14	54.1	46.9	43.4	40.6	37.5	40.7	48.3	57.4	58.6	55.2	51.0	61.0	59.6	60.8	60.2	67.3	66.5	61.6	57.4	51.0	36.3	35.1	28.1	21.5
	15	13.0	12.3	9.2	9.6	9.2	11.3	16.9	16.7	22.2	25.4	30.8	28.2	27.6	43.9	34.0	48.1	53.3	54.2	47.9	47.6	39.8	43.9	42.8	39.4
	16	33.4	14.9	13.2	9.3	11.2	9.1	8.0	10.2	15.4	19.8	22.6	24.6	23.5	32.4	28.1	36.3	42.9	42.4	40.8	37.7	37.6	54.2	54.1	52.9
	17	50.3	33.9	35.0	37.9	44.0	57.8	66.6	67.3	77.5	62.4	64.0	74.4	57.9	46.7	60.6	66.3	72.4	62.2	77.0	73.4	71.5	60.1	54.3	56.3
	18	47.3	46.4	33.1	30.7	28.3	37.1	70.0	75.8	69.2	66.5	72.1	59.7	68.3	61.9	78.0	94.1	96.8	92.3	93.8	76.1	76.1	79.8	84.0	88.3
	19	82.9	84.2	83.4	82.7	78.0	76.3	82.1	84.7	75.5	72.6	72.8	76.2	69.7	74.4	69.8	67.2	70.5	67.2	60.2	55.3	48.4	49.4	44.8	45.4
	20	42.6	41.6	41.8	42.4	42.0	42.4	52.5	53.0	52.1	53.4	51.0	51.0	53.8	56.5	61.4	66.1	73.7	61.8	64.2	62.1	55.9	56.1	51.3	47.7
	21	41.1	38.2	36.7	35.6	39.3	41.2	51.3	74.5	98.3	77.8	78.3	65.8	66.5	60.9	63.7	70.3	79.8	68.1	66.1	59.0	57.2	50.6	51.7	47.6
	22	40.3	40.4	41.6	41.6	29.5	31.5	30.2	31.8	39.6	44.0	50.6	54.1	63.1	60.7	64.4	59.1	55.9	50.6	64.3	60.1	45.8	43.3	26.6	17.1
	23	16.1	13.9	11.7	10.5	9.6	8.8	6.9	7.3	5.3	6.1	9.0	9.3	13.1	23.2	26.1	31.4	35.1	35.3	33.4	21.7	24.4	21.4	17.4	14.4
	24	13.7	10.3	10.3	10.6	18.7	21.8	42.3	63.1	73.6	76.3	71.8	61.4	40.7	48.1	61.9	58.0	54.8	45.7	25.6	23.0	12.2	15.1	13.4	18.3
	25	21.6	17.5	17.1	36.4	14.7	27.9	40.4	35.9	18.6	17.3	23.9	27.6	23.5	23.0	21.6	17.9	21.9	9.4	11.5	9.3	12.8	12.8	16.3	25.2
	26	16.0	11.2	12.2	12.1	14.4	13.2	14.0	22.0	17.7	17.7	18.3	19.1	13.3	16.3	19.6	26.5	31.9	23.5	26.8	19.1	20.8	15.8	11.0	11.5
	27	8.6	18.6	14.3	8.8	11.2	14.7	20.3	25.8	29.6		32.0	35.2	40.0	57.5	77.4	101.8	71.6	90.6	93.0	61.1	51.7	47.2	57.4	44.0
	28	27.1	33.1	26.1	24.9	31.8	46.6	57.3	61.0	56.5	58.1	58.1	60.2	71.2	69.7	65.1	63.6	57.4	43.4	36.9	31.4	32.4	27.6	25.5	24.1
	29	20.4	14.4	11.9	12.0	13.8	15.9	13.3	14.0	14.8	22.4	34.9	38.0	31.2	39.7	44.7	44.7	48.6	37.8	31.4	24.7	16.1	11.5	10.8	10.0
	30	8.5	7.4	7.7	5.8	5.4	4.6	5.7	6.6	9.4	9.9	10.6	10.8	13.1	14.9	14.2	17.7	18.3	19.4	18.1	14.9	13.4	12.9	11.5	9.4

months	Dates	Hour																							
		0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00
	31	6.5	5.3	5.2	5.2	7.0	9.6	10.8	13.5	15.3	17.4	19.9	24.7	29.4	31.8	34.2	33.3	40.8	30.8	26.5	21.1	17.2	10.1	12.3	13.4
01-Jan	1	24.5	15.9	9.5	8.1	7.5	7.6	6.9	8.9	11.4	11.1	8.4	9.1	14.4	11.5	18.9	26.2	34.9	22.6	20.0	17.1	11.2	9.6	32.6	33.7
	2	15.9	10.2	8.8	18.5	34.8	41.2	58.7	64.3	62.3	52.7	34.4	35.0	31.3	23.5	33.4	32.2	46.2	45.2	35.9	32.6	29.5	23.2	22.2	18.9
	3	14.8	12.6	14.0	12.6	9.8	14.8	21.9	21.7	28.8	15.4	15.0	15.0	16.5	18.6	17.1	35.5	39.9	30.7	27.1	34.0	38.6	36.5	38.0	20.0
	4	11.4	9.6	9.0	21.3	22.7	23.3	24.7	37.3	41.9	54.0		51.4	54.7	54.5	47.4	46.9	44.2	45.2	28.6	20.1	14.2	12.6	9.1	8.1
	5	5.7	4.7	8.4	9.2	10.6	14.2	33.6	46.8	49.0	37.7	34.7	41.7	32.0	34.9	39.4	43.9	45.2	20.3	20.0	14.5	9.8	11.5	10.1	8.5
	6	8.0	5.3	4.9	4.4	5.3	8.6	18.2	21.8	22.6	24.3	30.5	32.1	29.7	27.1	42.4	49.8	74.0	78.2	70.5	53.5	34.0	36.9	47.6	45.0
	7	32.9	25.1	18.9		15.5	21.0	45.2	45.8	33.6	38.5	48.7	44.3	40.9	41.4	43.5	42.4	50.6	49.0	51.8	49.7	55.1	50.8		44.2
	8	39.2	39.3	26.2		23.6	23.9	16.7	20.0	27.5	27.5	28.7	27.0	25.0	22.3	28.2	36.4	40.8	58.7	62.5	79.3	84.9	90.1	68.7	46.9
	9	43.3	35.1	21.6	17.9	40.5	58.5	66.1	70.6	65.9	66.5	57.4	54.2	72.1	75.3	75.8	78.4	102.6	77.9	75.2	68.4	54.9	41.2	43.8	41.8
	10	45.5	46.5	62.7	68.0	68.7	52.9	79.2	75.2	86.4	73.1	59.7	60.2	54.3	56.4	56.5	55.0	63.5	63.9	62.6	54.1	51.2	54.4	56.5	42.7
	11	41.3	37.9	42.7	42.7	50.4	53.0	69.1	76.7	68.4	53.9	70.0		67.8	73.9	81.5	75.4	70.0	58.1	57.4		49.9	34.4	35.1	36.2
	12	34.2	30.1	28.8	16.3	12.3	24.8	31.0	31.6	32.6	32.3	37.3	38.3	40.0	52.8	60.4	54.6	41.6	41.7	32.4	35.7	52.9	35.8	37.1	32.0
	13	28.2	47.0	52.4	21.3	14.1	20.8	41.8	47.4	62.3	65.0	47.3	37.5	39.4		35.7	40.3	57.6	72.4	63.4	55.2	43.1	41.3	35.0	39.8
	14	42.0	29.6	20.4	18.6	16.0	22.0	36.4	28.2	55.3	73.9	50.3	46.1	31.9	33.1	46.4	45.9	58.7	59.7	100.6	96.9	95.8	107.2	117.9	109.1
	15	126.3	101.7	108.1	98.1	86.9	81.1	70.4	66.4	61.7	60.6	51.3	39.2	28.5	22.9	18.9	23.9	49.6	70.2	71.0	66.1	66.6	54.9	51.4	45.3
	16	43.3	47.3	37.8	32.5	33.1	44.2	63.8	62.1	60.6	59.4	52.7	59.5	57.4	62.0	58.8	67.4	91.3	72.3	72.1	71.9	76.0	85.3	90.0	83.3
	17	79.9	73.9	76.2	72.7	74.2	95.1	104.2	116.0	123.1	109.3	121.6	90.2	78.1	71.8	69.7	85.1	92.2	101.6	107.5	92.8	80.3	79.7	72.1	62.8
	18	59.2	57.4	51.0	48.7	48.8	55.7	67.0	63.4	74.3	68.2	65.7	54.7				56.0		51.7	44.8	43.3		39.2	39.1	36.1
	19	32.7	28.4	26.2	25.0	24.6	32.4	41.4	49.9		65.3	65.9	90.0	88.8	85.9	86.4	83.1	86.8	80.8	81.8	82.3	74.8	65.9	62.7	41.0
	20	44.0	34.8	25.6	20.4	19.8	29.5	43.4	54.9	51.5	54.8	65.1	53.5	66.1	67.0	69.6	75.2	69.1	81.8	82.4	102.8	110.8	96.1	80.5	68.9
	21	39.4	30.1	18.8	28.0	31.9	22.0	20.4	25.5	30.4	30.3	47.6	47.2	46.3	50.0	59.3	62.5	51.8	49.5	57.5	46.7	44.2	35.9	29.6	28.4
	22	29.0	20.1	23.3	25.6	31.0	33.7	37.9	41.4	37.1	24.0	18.6	23.4	37.6	34.1	35.7	33.1	35.2		27.3	33.1	41.6	67.7	61.5	47.5
	23	51.2	33.6	59.5	43.7	39.7	58.6	72.0	89.9	92.4	74.3	80.2	74.8	63.1	67.9	72.0	74.4	87.7	98.4	86.9	80.8	68.9	53.2	37.6	20.8
	24	31.2	24.0	22.2	26.5	39.5	82.8	115.8	120.2	119.6	126.0	80.8	66.8	63.2	66.6	61.6	73.9	88.9	104.6	79.7	73.1	71.5	57.9	59.8	48.1
	25	43.8	32.6	29.7	27.3	31.5	35.7	58.9	72.4	73.8	70.3	59.9	61.3	69.2	62.9	69.9	73.8	71.4	83.5	77.4	66.4	62.3	60.6	51.5	46.5
	26	46.5	36.4	28.2	27.2	29.7	34.0	48.3	56.1	57.3	69.3	55.5	63.4	59.6	59.7	63.0	75.9	102.2	130.1	132.3		88.4	66.2	53.4	56.4
	27	58.9	50.9	47.8	40.6	30.8	32.2	60.8	62.9	67.9	72.3	64.3	58.7	54.2	49.6	46.4	47.0	65.4	71.7	98.1		90.8	76.5	71.6	69.0
	28	63.9	66.0	56.8	52.2	50.4	46.0	44.9	45.8	47.2	53.1	51.9	49.0	48.1	40.8	46.2	45.1	46.4	56.4	56.1	58.4	61.7	56.7	56.0	55.0
	29	50.0	43.7	34.9	25.5	20.6	15.4	12.9	11.3	11.3	13.7	14.6	17.4	17.8	18.4	23.1	25.2	24.7	31.1	25.4	35.1	27.0	22.2	23.9	20.5
	30	18.1	16.7	17.6	20.7	23.7	28.4	34.2	41.5	47.3	45.5	42.8	44.9	42.6								55.0	46.9	49.1	48.5
	31	44.6	39.3	34.0	31.3	34.4	41.1	44.2	45.3	47.2	45.0	37.3	38.2	35.9	35.1	37.7	42.1	49.6	52.6	46.3	44.7	41.7	34.1	29.6	28.1

months	Dates	Hour																							
		0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00
Feb-12	1	26.4	22.4	20.8	19.8	18.8	21.2	29.5	39.2	41.0	40.0	34.9	30.8	30.9	29.6	30.7	40.4	43.4	41.5	36.0	33.0	28.4	25.9	22.4	19.8
	2	15.5	13.8	12.0	13.0	14.7	17.7	28.3	33.0	37.0	37.9	31.1	29.4	28.1	29.7	28.7	34.4	42.2	44.1	43.1	43.2	40.0	37.0	34.5	31.0
	3	31.8	28.3	27.2	30.3	36.4	45.8	49.2	60.4	85.7	97.1	83.4	60.7	55.0	41.1	85.5	89.1	106.4	82.4	92.4	102.1	76.1	73.9	68.5	65.4
	4	61.5	58.1	55.5	57.9	60.7	60.0	60.5	60.4	63.8	61.6	58.5	48.4	44.1	51.0	61.9	66.9	76.4	76.9	87.8	80.3	87.1	83.7	73.4	85.1
	5	61.2	58.8	61.4	65.9	65.2	62.3	57.9	42.8	35.9	38.5	35.9	37.8	48.2	53.6	50.5	58.0	62.9	69.1	67.2	67.0	66.2	57.2	56.4	52.2
	6	47.7	43.9	44.7	57.2	60.8	70.5	82.3	87.4	99.3	80.2	79.7	77.4	81.5	79.9	76.3	83.7	81.9	81.3	79.7	80.5	78.4	77.7	77.0	73.0
	7	70.5	64.7	60.0	55.8	53.5	55.0	53.6	55.5	56.1	55.6	47.4	48.1	36.4	37.5	31.4	33.0	48.4	55.2	45.3	45.3	39.5	34.4	35.2	31.9
	8	22.9	15.2	13.7	13.0	14.7	16.8	24.0	32.2	38.9	47.1	33.7	31.6	35.5	30.6	28.2	33.9	41.5	45.0	42.4	52.2	49.2	53.4	54.5	52.7
	9	49.5	47.2	56.7	54.2	48.0	52.9	56.1	63.7	73.1	72.0	73.9	69.5	79.3	86.1	86.9	75.9	47.7	54.6	50.2	63.2	52.5	48.4	51.1	48.7
	10	47.5	44.8	37.5	35.2	37.1	40.4	43.6	59.3	61.6	49.3	49.2	42.8	34.9	34.2	40.4	43.6	49.5	57.3	71.7	72.3	72.8	65.5	57.6	50.2
	11	44.5	37.8	34.0	30.5	31.9	33.2	35.6	39.1	44.5	41.6	40.4	39.7	29.7	28.0	29.6	32.3	34.3	46.3	53.3	71.3	58.4	64.6	69.8	64.3
	12	73.8	98.4	83.2	78.4	83.4	90.1	83.0	80.2	73.2	65.4	56.7	48.5	50.4	42.9	47.7	62.5	69.0	65.3	65.3	65.6	62.3	64.5	60.9	57.1
	13	58.3	53.2	49.4	50.7	57.5	79.5	77.0	83.3	98.7	97.3	98.4	100.7	92.3	95.7	93.0	96.2	102.8	97.0	98.3	82.0	67.6	73.8	30.2	16.7
	14	11.1	9.4	10.9	10.8	11.2	17.8	25.7	36.5	57.2	71.7	48.5	42.9	39.1	37.2	48.9	54.6	81.1	86.9	106.0	87.0	71.9	45.1	31.2	29.2
	15	16.8	13.7	10.8	7.2	7.0	11.2	28.0	34.8	39.1	35.2	25.8	31.3	22.3	29.6	29.7	34.8	39.3	39.4	31.4	26.6	21.9	18.7	19.4	22.8
	16	21.0	14.3	10.4	15.0	14.1	28.0	49.1	62.0	73.0	97.5	95.6	107.3	92.2	90.2	92.6	85.1	85.1	91.1	86.0	60.1	54.5	60.2	51.4	57.6
	17	62.0	49.8	51.9	61.2	63.9	69.2	71.6	70.8	79.0	88.8	72.8	84.6	65.5	63.5	63.1	89.3	84.9	95.4	70.1	52.4	49.8	40.3	36.2	27.6
	18	24.8	24.0	19.0	17.4	18.1	23.4	21.3	16.8	22.2	21.5	19.2	30.6	21.2	17.4	16.9	19.9	20.2	15.5	19.0	14.9	15.9	37.0	69.6	69.7
	19	61.1	52.4	47.2	32.8	18.1	35.8	35.3	33.2	43.6	24.8	51.8	33.9	42.6	40.4	65.1	55.3	55.8	48.3	52.2	53.6	54.0	54.2	45.5	74.3
	20	96.7	68.2	50.7	78.6	43.9	56.8	61.5	80.9	87.6	65.7	51.1	33.6	30.3	28.5	29.1	39.4	40.2	59.3	66.3	54.7	49.9	49.8	46.9	46.9
	21	37.2	30.1	27.2	22.8	19.0	22.2	32.0	44.5	51.5		46.2	47.2	44.3	43.6	50.5	48.5	61.7	40.8	38.5	40.4	37.1	37.9	56.0	51.0
	22	40.3	33.2	29.7	22.4	18.2	23.4	35.5	38.0	40.4	37.8	40.6	32.7	31.3	35.7	27.9	34.0	41.6	47.5	34.0	31.5	24.4	18.8	17.8	14.5
	23	12.7	11.0	12.0	23.3	39.4	56.7	81.1	87.1	76.6	84.0	75.9	55.1	46.5	47.2	47.2	52.7	60.5	52.6	46.4	55.2	42.5	38.8	24.4	20.3
	24	16.2	27.1	27.8	31.4	40.0	39.6	43.9	45.1	46.6	43.2	36.6	38.8	48.2	55.6	57.7	70.6	85.0	70.2	58.0	66.6	74.4	80.5	81.7	83.0
	25	81.7	73.3	75.8	77.5	79.0	77.1	73.4	60.7	68.5	73.7	63.2	44.3	39.5	26.6	30.0	30.7	39.1	48.6	59.3	55.4	63.5	62.3	71.0	58.3
	26	39.8	43.0	60.5	44.8	42.5	39.7	22.8	21.2	25.9	19.2	16.7	23.6	29.7	49.3	57.7	56.8	37.2	51.1	60.5	82.5	102.7	90.2	86.5	55.1
	27	36.6	22.6	30.7	44.4	52.4	47.9	52.5	61.7	53.4	52.2	47.2	44.4	50.0	57.4	49.2	49.0	62.1	49.6	48.0	40.0	35.5	42.1	44.0	37.4
	28	37.9	29.9	27.8	28.1	43.9	43.0	50.7	56.8	50.1	46.1	51.5	52.7	49.5	49.0	66.3	67.0	59.8	62.6	56.0	59.3	49.8	47.8	49.7	44.7
	29	47.9	36.3	37.2	37.0	41.3	46.4	53.6	48.7	50.9	50.2	53.0	50.4	49.9	53.7	46.8	56.2	59.9	59.3	57.4	52.3	55.5	56.7	55.8	54.3
Winter	Avrg	39.28	34.67	32.11	32.13	32.56	37.53	45.56	50.73	54.80	54.40	51.75	49.79	48.83	49.27	51.53	56.21	62.00	61.46	59.83	55.17	51.69	48.48	46.70	42.64
	Max	126.30	101.70	108.10	98.10	86.90	95.10	115.80	120.20	123.10	126.00	121.60	125.00	102.50	95.70	93.00	101.80	116.30	130.10	132.30	103.90	110.80	107.20	117.90	109.10
	Min	5.70	4.70	4.90	4.40	5.30	4.60	5.70	6.60	5.30	6.10	8.40	9.10	13.10	11.50	14.20	17.70	18.30	9.40	11.50	9.30	9.80	9.60	9.10	8.10

months	Dates	Hour																							
		0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00
Mar-12	1	51.8	43.4	38.2	32.4	30.7	48.4	64.4	73.6	65.3	62.8	53.1	55.1	75.0	65.7	69.7	66.5	85.1	87.2	104.1	86.2	79.7	70.8	64.9	61.6
	2	46.7	41.4	46.7	49.0	49.9	52.8	55.0	44.7	45.5	45.1	31.4	43.0	42.0	42.5	41.4	45.3	52.0	55.2	65.9	68.8	62.1	54.8	51.5	49.6
	3	47.5	44.7	41.3	42.4	37.6	41.3	45.5	43.8	47.8	49.3	44.8	40.8	31.1	27.2	33.8	42.4	39.5	44.3	28.9	37.2	27.8	36.0	40.6	32.1
	4	34.2	36.4	28.3	25.3	34.0	39.4	42.4	35.7	37.3	35.3	34.0	41.0	50.0	51.9	54.5	56.8	66.6	69.6	72.4	62.8	55.3	50.0	40.8	37.2
	5	37.8	21.2	14.5	16.2	18.2	35.6	51.0	65.6	70.8	60.8	55.7	51.1	48.0	42.1	45.3	50.6	65.5	51.7	50.6	44.1	33.9	31.3	27.5	24.1
	6	23.6	20.6	20.8	15.0	19.8	32.2	61.5	65.3	57.4	52.1	56.5	50.4	46.0	52.0	53.2	66.3	59.7	47.0	69.3	65.1	54.1	47.7	51.6	50.8
	7	53.4	49.0	42.6	45.2	45.3	51.3	52.6	54.1	59.1	47.2	48.3	48.9	46.8	52.2	60.8	62.1	59.4	55.9	47.7	68.7	43.3	32.4	25.5	31.9
	8	19.4	16.7	18.4	15.6	20.8	30.1	51.4	75.1	76.6	56.1	44.7	50.0	52.2	33.5	40.5	49.4	66.5	71.4	87.3	85.9	88.7	72.9	63.0	51.4
	9	55.2	50.4	33.7	42.6	52.0	68.3	83.7	75.9	66.3	49.1	45.2	40.8	40.0	32.9	31.8	42.8	43.1	46.6	33.0	33.4	27.7	29.2	26.4	21.0
	10	22.7	21.9	21.3	21.9	24.8	35.9	29.2	37.8	44.8	52.5	65.9	70.2	67.1	68.6	69.0	58.5	61.3	58.5	75.2	67.1	54.5	50.7	61.8	63.8
	11	40.6	49.7	40.2	29.7	27.6	28.3	34.6	33.7	36.3	40.5	30.3	24.9	29.3	28.4	24.0	25.2	29.5	31.6	48.6	64.4	80.9	92.7	72.5	71.3
	12	77.5	74.1	67.2	61.2	66.7	74.1	86.4	102.1	131.5	112.3	83.5	65.8	56.4	47.3	30.8	40.6	40.9	45.2	39.0	52.0	43.7	33.5	36.8	45.0
	13	39.2	15.7	9.1	9.1	11.8	15.0	31.4	41.8	54.4	45.2	35.2	38.6	42.7	38.6	45.8	43.4	47.0	52.3	51.0	50.3	57.3	57.9	35.3	29.6
	14	26.4	24.2	21.1	18.2	17.5	21.0	31.1	46.3	47.0	55.6	37.4	40.6	40.4	42.1	45.1	48.6	47.2	59.4	49.9	57.4	62.6	60.6	65.4	54.9
	15	63.8	60.4	60.5	60.1	57.5	64.8	82.3	100.7	107.6	83.2	84.7	76.7	76.1	72.8	75.2	90.4	104.9	127.9	107.7	110.4	114.0	100.3	96.6	85.3
	16	77.4	77.5	68.6	60.1	30.6	25.6	29.2	42.0	43.0	35.2	33.5	33.3	29.9	33.2	42.3	51.9	52.0	63.1	88.7	98.4	96.3	96.7	89.6	66.4
	17	14.4	22.1	18.8	22.3	17.6	25.4	24.0	30.5	38.4	38.1	30.7	32.5	33.6	35.9	34.1	49.6	58.7	69.0	63.5	65.8	49.5	47.9	45.2	47.1
	18	41.3	40.1	27.0	20.5	46.8	15.3	15.3	11.3	11.6	24.0	18.7	19.0	50.1	55.2	46.9	47.0	52.2	53.3	40.6	39.8	38.0	23.2	21.7	23.7
	19	19.1	28.8	33.4	44.5	59.5	85.6	107.6	123.9	102.3	96.4	65.4	63.9	72.6	69.8	59.6	62.3	73.3	74.6	97.7	87.3	67.6	60.6	68.4	60.3
	20	53.1	60.4	56.2	45.2	46.3	51.3	63.9	60.2	55.7	46.6	51.7	42.8	32.8	30.9	44.8	47.4	45.6	42.4	48.3	80.9	99.8	83.4	81.0	78.0
	21	76.3	57.1	58.9	61.8	60.6	69.9	86.4	97.1	98.7	75.7	75.2			62.7	56.3	54.7	47.3	50.8	61.3	63.2	78.4	58.6	51.0	41.9
	22	33.8	33.9	31.5	29.1	29.3	38.9	50.7	48.8	44.2	40.9	38.4	34.9	31.7	35.1	27.9	54.9	25.4	36.0	51.0	55.6	38.7	30.4	31.4	29.0
	23	25.3	19.6	19.6	19.8	22.2	30.7	44.1	47.7	43.0	41.4	37.9	39.2	33.3	34.8	30.2	37.9	39.0	46.5	54.9	73.9	63.8	50.4	56.3	64.0
	24	53.3	45.6	45.1	40.0	40.6	37.0	36.3	30.6	36.1	38.7	48.0	29.1	27.8	23.6	22.1	19.6	24.0	31.5	41.7	33.6	27.6	30.7	47.1	45.5
	25	34.0	24.9	18.1	15.6	20.5	14.6	14.3	14.9	15.9	19.1	19.3	22.1	19.1	17.2	16.8	21.4	20.0	20.2	34.7	26.9	27.8	28.4	24.4	16.0
	26	12.4	11.7	13.4	21.9	48.3	71.8	76.7	62.0	58.3	32.6	25.9	25.1	21.7	23.3	26.2	26.4	30.7	27.0	32.9	36.3	41.8	38.5	36.7	49.0
	27	34.9	24.2	26.8	45.8	89.3	113.8	113.1	106.8	101.6	90.1	64.0	43.0	37.9	47.2	64.7	61.7	75.1	82.9	66.9	77.4	78.3	67.6	80.6	64.9
	28	71.1	70.9	60.3	69.5	90.0	108.7	124.5	117.6	113.3	92.3	67.0	61.5	56.2	55.1	57.0	50.0	60.9	65.2	88.3	97.3	93.8	66.4	46.7	44.6
	29	43.3	41.5	61.4	66.6	73.8	102.7	106.3	92.2	65.3	40.5	32.9	30.1	36.2	38.9	45.2	44.4	37.2	39.3	29.6	47.6	42.2	69.2	66.2	53.3
	30	38.7	19.6	11.1	22.9	39.9	38.3	47.1	33.9	29.6	31.9	38.2	31.3	39.8	41.1	47.2	37.3	40.9	37.0	41.8	26.6	34.7	60.2	32.1	28.4
	31	33.1	62.0	57.3	61.8	45.2	30.8	20.9	21.5	22.6	20.2	20.1	17.2	17.5	16.3	18.5	15.8	22.0	22.4	18.2	22.7	33.8	37.6	43.6	
Apr-12	1	36.3	39.0	47.4	54.7	51.7	43.3	53.3	56.8	29.4	16.7	18.0	20.6	25.6	30.9	31.1	33.3	34.9	30.4	35.8	54.8	73.2	76.1	56.5	44.0

months	Dates	Hour																							
		0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00
	2	57.7	40.1	41.3	32.0	71.8	81.7	95.7	90.8	98.4	106.6	83.6	64.0	50.9	36.7	38.8	55.6	96.4	91.8	92.7	107.3	112.9	113.3	102.8	102.6
	3	98.7	96.4	94.6	95.3	97.6	109.7	117.3	127.3	104.6	79.2	62.6	29.1	43.9	58.1	58.9	108.5	99.1	97.5	106.4	69.3	64.2	54.4	49.7	43.4
	4	47.5	39.3	47.1	52.8	63.5	55.7	50.1	38.8	32.4	31.0	34.1	31.8	34.5	35.3	34.5	35.7	36.5	40.2	39.9	39.6	41.1	36.6	31.8	23.1
	5	20.1	16.2	14.5	13.3	10.1	16.8	22.3	27.1	26.8	25.4	23.8	24.7	25.3	19.1	26.8	29.1	31.1	28.5	28.6	31.4	34.4	30.4	24.8	27.3
	6	26.2	23.4	35.1	42.5	45.5	62.3	77.9	58.7	38.0	29.9	28.8	38.2	49.9	49.9	62.9	78.1	87.3	81.3	81.7	95.5	75.4	76.5	59.7	46.7
	7	18.6	14.0	12.4	11.1	13.8	24.1	36.5	48.2	18.8	19.7	24.5	15.5	24.2	14.9	22.7	21.7	20.7	15.9	19.8	21.5	23.6	32.9	32.5	18.5
	8	19.4	31.5	36.3	21.9	18.3	25.2	26.1	16.0	21.0	31.0	34.7	35.1	32.8	28.2	21.9	22.8	27.1	22.9	23.5	19.6	26.1	28.8	20.9	14.3
	9	14.7	12.5	12.6	10.8	13.6	20.0	29.3	24.6	16.6	14.8	13.3	19.1	19.0	16.6	16.6	19.4	17.6	16.9	21.9	25.5	24.6	16.7	13.0	9.8
	10	8.3	5.6	5.9	6.9	15.5	26.3	31.4	29.2	33.2	29.8	30.8		29.7	48.5	36.5	57.1	62.5	69.8	36.4	47.6	65.2	62.8	68.6	64.1
	11	46.4	20.1	16.1	19.2	28.2	46.3	38.2	37.7	37.2	25.4	30.5	31.9	42.7	68.8	74.1	64.4	91.3	89.1	69.4	78.2	62.3	56.2	66.5	62.5
	12	57.6	56.4	53.3	52.9	62.5	74.2	78.0	114.4	88.3	75.9	60.4	47.3	56.0	75.7	103.6	108.5	84.0	62.2	54.6	65.6	78.6	49.3	41.6	47.7
	13	37.2	36.7	39.5	59.0	79.7	93.7	95.5	71.5	80.0	80.9	83.3	72.9	84.6	98.9	75.9	60.0	61.4	48.9	56.9	43.3	53.2	51.7	56.2	69.0
	14	56.8	46.9	44.9	47.6	44.3	44.3	53.5	50.5	23.2	23.3	24.6	21.7	23.8	18.9	25.1	26.0	19.6	16.9	22.2	19.9	20.8	27.4	23.2	19.3
	15	18.2	12.8	14.9	16.3	14.7	12.1	13.5	10.5	16.7	15.5	9.3	13.8	14.1	18.4	12.5	11.4	14.0	12.0	11.7	11.8	14.5	22.1	27.0	21.1
	16	12.7	8.4	11.5	13.2	37.8	56.9	78.9	57.6	35.8	23.2	30.3	28.2	29.6	28.8	27.6	31.5	29.3	24.0	20.9	29.7	44.8	43.3	57.5	78.2
	17	74.3	66.1	62.9	66.2	74.3	99.3	93.6	105.9	87.8	84.5	54.4	34.6	41.1	38.3	61.7	64.8	70.1	66.6	44.1	38.6	31.1	25.2	27.7	19.4
	18	18.1	15.0	16.3	21.8	46.1	67.8	65.4	63.3	54.8	50.3	49.2	45.6	47.4	47.6	60.9	57.8	64.4	60.0	50.7	49.3	47.2	33.2	26.9	18.5
	19	17.8	14.1	11.2	16.1	32.0	60.0	64.5	81.1	71.2	58.0	50.4	56.1		61.2	59.4	57.9	79.1	62.2	46.5	34.0	78.3	74.8	56.4	42.0
	20	26.1	28.2	29.2	28.7	61.7	74.1	72.8	73.4	61.2	50.1	42.0	45.5	61.0	74.8	51.6	59.5	57.8	66.1	37.9	52.4	63.2	40.6	61.0	56.1
	21	47.6	46.9	47.0	46.3	30.2	32.3	35.5	23.5	26.1	24.4	25.4	34.4	29.2	29.8	27.7	31.0	27.4	63.9	52.3	45.2	31.2	56.0	62.9	42.1
	22	23.0	16.1	14.0	15.2	19.4	22.1	20.0	17.5	16.6	15.5	13.3	17.2	20.9	26.7	34.1	32.2	33.8	31.7	27.1	28.9	26.2	71.3	59.7	34.2
	23	16.8	10.3	11.6	12.5	19.4	29.3	47.0	43.5	35.1	37.6	36.2	31.6	31.2	40.6	54.8	62.0	56.6	59.1	45.2	53.2	47.1	40.5	28.4	20.8
	24	21.1	21.7	19.8	27.1	45.5	77.2	91.0	91.6	58.8	43.2	53.7	84.3	96.5	89.0	99.3	75.4	93.8	76.0	91.5	78.1	76.7	52.0	64.3	51.5
	25	38.7	11.9	12.8	22.6	49.5	66.3	71.3	79.2	62.7	53.1	48.1	46.4	49.2	56.3	65.7	68.2	60.0	54.5	48.5	39.5	37.0	31.9	29.8	28.4
	26	20.6	13.5	11.6	13.7	25.6	46.7	55.3	60.0	46.3	31.5	32.8	31.3	36.3	43.8	34.6	50.9	69.1	62.1	63.7	58.2	59.4	53.4	53.4	31.3
	27	27.6	19.6	13.7	12.8	30.4	53.0	35.9	36.5	25.7	20.3	27.5	23.0	23.7	25.8	33.9	39.5	40.4	75.8	82.8	84.0	96.8	76.6	69.2	62.6
	28	46.5	36.8	36.8	25.9	21.4	24.1	24.2	15.9	16.5	21.2	23.4	23.1	28.9	29.7	24.5	29.7	24.9	22.1	22.3	18.0	13.8	14.4	13.4	14.1
	29	17.0	11.6	10.1	9.9	13.8	9.4	9.1	10.3	18.7	18.2	27.2	33.8	46.3	45.7	59.7	51.9	38.3	34.2	24.8	35.9	47.9	89.3	92.3	101.6
	30	92.9	76.3	73.6	77.4	80.4	83.1	71.9	49.1	38.8	32.7	20.1	33.7	29.2	34.4	27.5	17.9	17.0	17.0	18.6	18.5	13.4	13.6	10.3	8.7
May-12	1	8.2	10.9	10.7	14.2	23.9	33.2	36.9	47.6	46.9	60.3	56.9	53.3	37.7	30.5	56.7	96.5	85.8	75.2	65.7	77.1	76.2	68.6	81.2	74.7
	2	81.4	60.4	78.6	59.5	63.1	57.6	57.3	51.7	46.2	38.8	41.3	49.4	47.2	53.8	73.8	91.7	89.5	74.1	98.4	93.2	83.2	87.0	83.3	81.3
	3	48.4	32.0	19.5	28.9	33.8	51.0	49.1	47.5	46.9	44.0	45.5	42.9	42.9	63.4	62.6	68.2	66.2	66.0	61.2	42.5	42.4	46.5	28.3	20.8

months	Dates	Hour																							
		0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00
	4	18.0	15.9	14.3	16.2	22.7	35.4	29.9	31.3	45.3	62.1	80.5	79.1	81.4	101.9	83.2	87.8	59.7	45.7	35.3	29.8	31.5	28.6	19.5	18.4
	5	13.8	14.6	9.3	10.6	17.1	15.9	18.6	17.0	21.5	18.1	18.1		22.3	18.5	22.7	22.4	23.3	25.6	25.2	21.5	18.4	13.6	16.9	15.1
	6	10.5	11.7	8.2	8.5	7.5	8.1	8.5	9.9	8.1	9.9	8.8	10.1	11.3	10.9	14.9	12.0	14.4	15.7	15.6	17.8	21.6	22.2	22.9	16.7
	7	12.6	12.7	13.0	16.7	32.1	45.6	63.6	71.1	71.3	44.9	41.7	43.8	46.3	49.3	53.0	62.3	56.9	60.3	55.4	65.6	59.8	57.5	48.6	41.6
	8	31.7	26.2	29.9	28.2	45.8	71.9	78.8	81.9	73.7	76.4	80.5	79.1	55.8	56.2	65.1	83.7	95.3	75.8	56.0	46.7	57.8	75.1	69.6	68.7
	9	46.2	22.4	27.5	31.2	36.9	50.7	91.3	81.4	46.4	34.9	38.5	34.5	34.0	30.8	51.5	55.2	37.6	44.0	31.3	57.0	63.2	57.2	45.0	44.7
	10	30.0	30.4	26.4	22.4	34.3	45.3	47.7	57.5	59.4	58.5	36.1	31.6	22.5	36.6	43.7	42.7	83.3	70.6	42.5	31.9	28.4	15.3	11.2	10.7
	11	7.2	6.2	5.1	5.2	8.4	15.0	26.6	17.7	19.1	21.9	25.3	33.9	32.5	42.0	64.7	69.0	65.4	69.6	46.9	35.6	40.2	28.4	22.5	22.2
	12	25.6	17.5	15.1	13.3	24.3	29.8	23.2	22.4	32.7	19.4	19.0	16.2	16.6	26.2	28.0	23.4	26.5	18.8	28.7	21.3	23.6	31.9	37.7	43.5
	13	43.2	42.0	26.2	38.7	42.3	51.8	41.5	39.4	54.3	45.0	40.8	36.3	35.8	43.5	40.3	29.8	24.4	24.0	24.0	22.2	51.3	83.2	78.3	51.8
	14	23.1	17.2	15.2	24.1	56.4	59.1	48.1	37.4	26.1	26.4	28.6	26.9	24.4	18.5	32.4	70.8	72.9	73.8	73.4	60.7	44.4	41.7	26.4	20.6
	15	18.5	7.9	5.7	6.8	23.1	82.4	89.0	89.8	52.8	52.1	43.1	36.1		71.6	47.0	40.9	32.4	27.5	31.9	25.2	20.2	21.4	12.9	9.9
	16	7.7	8.1	7.9	6.9	15.7	34.1	30.7	27.4	27.6	29.3	27.3	26.9	27.0	37.1	41.7	44.2		34.8	41.3	63.8	63.5	52.4	58.0	63.3
	17	52.5	37.5	31.0	39.6	49.4	54.6	50.2	46.1	29.0	19.6	34.1	34.3	32.5	37.3	42.6	50.3	40.2	41.4	38.9	46.1	41.0	42.3	29.4	21.6
	18	20.8	18.7	20.3	24.3	37.9	41.6	55.1	67.6	61.8	53.1	48.6	47.9	47.6	51.5	42.3	31.3	40.1	33.2	48.9	43.1	45.2	51.4	52.9	53.4
	19	55.1	46.7	37.2	39.9	42.1	46.7	39.8	40.8	37.6	38.3	29.0	18.8	18.1	42.1	38.9	53.3	49.6	35.3	32.1	20.7	24.3	23.8	35.3	26.8
	20	19.3	18.0	14.5	16.4	24.6	16.3	17.2	16.0	16.5	16.5	17.8	15.0	23.4	21.8	24.0	24.0	25.9	32.3	39.7	59.3	59.4	61.6	64.3	54.3
	21		53.6	43.7	37.5	43.5	56.9	56.2	57.0	51.8	54.8	44.4	50.1	48.5	48.5	56.4	54.5	59.1	63.0	65.1	52.9	48.3	54.4	36.2	28.1
	22	24.1	21.5	18.1	21.3	40.3	51.4	67.0	68.6	63.5	56.1	54.2	52.7	49.3	54.8	72.2	70.0	75.6	65.9	70.3	63.9	89.0	97.5	81.1	89.1
	23	68.5	64.9	83.0	73.4	69.7	71.5	61.6	62.9	55.1	49.3	61.9	63.2	91.9	113.7	69.6	100.4	114.5	106.2	116.8	130.4	85.9	96.4	96.9	93.8
	24	84.4	77.1	72.2	79.2	70.0	76.7	76.1	84.3	84.7	57.7	42.3	39.7	37.3	40.2	40.8		46.8	39.5	35.1	41.5	39.7	29.1	30.7	21.7
	25	20.7	18.9	12.3	14.2	22.4	29.2	30.8	31.3	35.4	30.7	28.6	25.9	25.8	27.9	34.0	28.4	25.0	20.5	27.5	25.2	32.7	27.6	21.9	16.0
	26	13.4	13.4	13.3	13.9	18.4	23.7	28.1	26.2	25.8	22.9	25.4	25.0	38.5	32.1	24.7	28.3	33.8	28.9	26.7	39.2	33.5	33.3	34.5	37.1
	27	31.6	21.7	17.9	16.4	18.0	18.6	18.3	19.4	24.4	19.0	15.6	17.9	19.1	20.1	16.9	18.4	17.1	18.8	16.3	19.9	28.4	57.2	53.9	45.2
	28	33.0	43.6	40.0	27.3	45.5	39.0	28.0	25.3	14.1	16.0	22.7	43.4	31.5	34.7	34.2	35.5	40.0	34.2	32.0	38.9	59.1	48.7	55.5	27.4
	29	23.6	63.2	53.8	46.9	64.9	57.2	49.7	58.8	56.6	57.5	70.3	59.5	69.3	61.2	40.9	37.9	41.6	40.7	37.1	38.6	43.9	33.3	31.3	26.0
	30	24.3	32.7	27.0	20.0	48.1	65.8	60.4	79.7	64.6	65.9	51.8	65.7	50.2	65.4	92.4	103.8	92.1	81.5	98.9	100.1	112.4	99.3	91.4	81.6
	31	79.9	81.0	34.3	27.8	35.3	56.3	50.6	43.7	34.7	38.0	34.7	30.9	36.6	46.4	62.2	64.3	61.3	71.6	63.8	37.6	33.6	29.1	37.3	49.7
Spring	Avrg	36.74	33.11	30.88	31.59	39.24	48.14	52.69	53.33	48.72	43.66	40.51	39.19	40.09	43.46	45.64	49.82	51.81	50.86	50.56	51.64	52.00	50.41	47.66	43.08
	Max	98.70	96.40	94.60	95.30	97.60	113.80	124.50	127.30	131.50	112.30	84.70	84.30	96.50	113.70	103.60	108.50	114.50	127.90	116.80	130.40	114.00	113.30	102.80	102.60
	Min	7.20	5.60	5.10	5.20	7.50	8.10	8.50	9.90	8.10	9.90	8.80	10.10	11.30	10.90	12.50	11.40	14.00	12.00	11.70	11.80	13.40	13.60	10.30	8.70
Jun-12	1	25.5	8.7	14.4	15.9	24.6	40.0	34.6	34.6	33.5	32.8	31.7	32.0	34.1	36.3	35.4	27.3	33.0	24.3	29.1	19.5	19.5	16.8	17.0	13.0

months	Dates	Hour																							
		0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00
	2	10.8	16.5	14.9	19.2	24.3	20.1	13.4	14.8	14.8	20.1	17.9	26.4	21.3	19.0	17.5	19.8	18.9	16.5	20.6	15.1	14.3	15.5	16.7	11.0
	3	11.5	8.1	7.5	8.9	8.8	8.9	10.7	8.5	7.4	10.8	12.5	14.5	15.1	18.4	17.4	32.3	21.5	28.7	21.0	24.5	27.1	31.4	21.6	25.5
	4	15.9	12.3	10.2	11.7	22.6	29.3	29.4	36.0	29.4	27.8	31.8	29.7	29.7	24.5	34.7	35.8	28.9	24.4	20.4	22.7	21.5	23.7	28.4	25.3
	5	23.3	35.2	36.8	36.9	53.0	75.7	70.0	61.5	47.6	49.0	45.2	32.5	45.3	36.2	36.8	35.0	43.9	44.0	44.6	45.5	50.5	57.4	54.4	39.7
	6	32.1	23.2	26.5	27.1	34.9	44.0	55.3	60.1	51.5	41.7	43.2	30.8	24.1	28.4	22.4	25.5	24.6	17.8	24.5	31.7	36.2	40.1	42.9	21.7
	7	7.0	5.2	9.4	8.2	15.6	33.9	44.5	52.7	48.1	42.1	43.7	41.4	37.5	44.8	41.9	52.3	82.4	75.8	59.4	52.5	52.2	36.6	17.1	24.7
	8	27.0	25.8	22.6	17.3	25.9	38.2	28.8	25.4	12.6	10.9	13.1	12.6	16.3	14.2	13.8	31.8	11.5	9.1	10.4	9.6	8.1	7.5	5.6	4.5
	9	2.5	4.3	3.3	3.9	4.9	5.7	6.3	7.6	11.6	13.1	11.6	12.1	15.1	14.7	20.7	23.3	20.9	10.8	9.9	11.7	11.0	9.1	11.0	13.0
	10	11.8	14.0	14.7	11.6	11.5	16.3	12.7	14.7	12.4	14.9	13.7	21.3	24.8	19.6	31.8	20.3	42.3	28.1	18.3	19.7	24.3	27.7	21.3	12.4
	11	10.4	9.8	11.2	11.1	26.6	49.6	50.8	56.0	54.4	49.0		37.9	38.1	39.6		44.9	40.2	63.2	71.7	53.4	48.5	39.1	34.5	28.0
	12	26.1	21.3	15.8	16.4	18.8	25.9	32.9	35.7	34.5	30.9	38.2	30.1	28.7	23.1	25.0	24.3	27.6	27.2	14.7	18.9	16.3	15.2	15.5	14.2
	13	11.5	10.4	7.5	9.1	18.4	37.2	40.1	36.6	25.5	31.4	26.3	25.9	24.8	28.6	22.2	28.6	23.3	19.7	21.7	21.2	12.0	19.1	40.1	28.2
	14	21.4	22.2	28.2	37.1	46.4	61.0	40.4	22.5	26.0	28.8	22.3	18.8	14.4	21.9	21.8	26.5	29.7	25.2	26.0	26.7	23.4	21.8	22.4	21.1
	15	21.9	26.8	29.5	32.0	49.6	56.3	69.9	74.7	62.6	63.0	61.4	56.2	38.9	33.6	29.6	38.0	51.6	42.0	38.6	41.5	32.5	34.6	32.7	
	16	22.3	19.0	18.2	20.1	24.1	26.7	16.4	11.2	10.2	13.7	17.2	13.9	18.7	13.1	13.8	23.4	23.3	15.7	17.6	14.8	10.3	13.3	20.3	8.5
	17	7.5	5.8	5.5	4.2	4.0	4.8	5.6	7.3	7.2	7.8	6.6	7.6	10.7	11.0	12.7	15.4	17.1	19.5	35.5	42.3	34.0	32.2	40.3	29.9
	18	24.6	22.6	21.8	21.6	32.3	39.9	63.7		46.6	43.9	38.5	42.7	61.4	68.6	70.8	61.8	55.3	53.0	50.8	53.0	48.5	44.0	56.9	48.5
	19	33.1	25.6	49.0	42.4	63.5	69.4	77.4	65.6	45.1	37.1	30.1	29.6	42.3	41.7	34.0	49.9	42.4	49.3	33.7	24.8	30.9	37.3	34.6	30.5
	20	26.3	18.5	19.2	19.8	22.4	33.0	38.2	42.1	39.2	35.2	22.9	15.8	16.5	17.4	27.6	20.1	23.7	19.7	19.2	17.3	18.9	21.8	21.9	18.8
	21	16.1	14.1	13.2	17.1	28.0	53.0	59.0	51.4	41.7	51.1	47.4	36.9	39.6	42.3	52.8	51.3	47.3	66.1	69.4	66.4	65.9	31.7	18.6	7.3
	22	6.7	2.6	2.8	4.0	15.3	35.8	26.3	21.2	16.0	13.5	16.2	13.8	22.8	11.6	13.0	16.1	17.6	12.0	12.6	12.8	11.6	7.3	7.4	7.1
	23	6.5	6.2	7.5	6.7	7.5	9.5	9.3	8.9	11.1	12.0	14.3	11.6	13.2	18.9	18.7	17.8	20.6	18.5	24.2	22.0	13.3	15.8	15.4	18.6
	24	14.1	12.7	10.8	10.0	14.5	21.8	24.9	17.1	11.9	8.2	8.8	13.3	16.1	8.9	10.9	19.4	32.7	29.1	25.0	33.9	42.1	23.4	20.9	19.8
	25	15.9	29.0	37.3	51.7	63.1	69.0	57.3	65.0	49.9	49.3	39.6	39.2	29.0	30.0	27.1	33.0	32.1	32.0	22.9	26.0	28.5	38.3	43.2	63.8
	26	35.0	29.4	34.2	40.7	49.4	63.0	63.8	52.9	39.6	38.0	50.3	39.7	48.9	58.4	56.2	62.2	68.3	72.8	62.1	61.3	60.3	39.3	34.1	43.7
	27	48.8	42.0	18.1	17.8	22.1	24.0	25.5	29.6	29.8	30.8	38.6	34.7	32.4	38.9	53.4	51.9	37.9	27.9	29.4	31.4	31.6	24.5	32.9	29.3
	28	26.1	24.9	28.9	31.8	34.9	42.7	40.9	50.5	44.3	42.9	39.3	40.2	52.9	55.7	61.8	63.3	62.3	68.8	62.0	64.6	34.4	44.2	26.0	16.3
	29	30.4	23.2	18.9	17.6	18.7	27.3	38.1	38.6	29.3	28.6	27.8	35.0	35.3	18.4	22.4	23.4	26.1	37.5	26.0	21.1	39.4	66.7	39.5	34.4
	30	26.8	16.2	21.1	19.4	24.3	32.8	25.2	13.6	15.1	14.1	19.4	20.1	15.0	17.1	21.2	21.5	37.7	44.9	50.5	35.1	35.5	26.8	17.2	16.2
Jul-12	1	10.8	7.5	12.6	9.2	10.8	7.8	6.7	3.5	2.8	4.4	8.8	10.1	15.8	14.7	16.6	28.5	21.1	14.7	12.0	13.0	10.6	15.8	17.1	17.8
	2	13.3	7.9	11.8	13.9	34.4	40.7	27.8	39.3	30.5	38.4	37.1	43.1	36.7	34.5	33.0	47.2	45.8	47.0	51.7	57.6	62.5	65.0	64.4	54.2
	3	49.2	40.9	28.0	30.5	45.8	64.1	62.7	64.5	52.1	39.5	27.0	26.9	20.8	21.9	27.6	31.1	34.3	28.1	31.9	39.9	38.6	55.8	59.2	48.6

months	Dates	Hour																							
		0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00
	4	35.8	40.2	46.6	48.9	56.8	74.7	75.5	69.1	63.0	58.6	50.6	40.9	34.3	41.5	43.7	52.9	44.1	56.2	56.5	62.1	80.8	66.5	70.6	48.9
	5	78.1	50.0	30.3	28.6	37.6	64.7	72.8	74.9	89.6	70.5	91.7	73.6	72.9	59.1	54.5	36.3	28.6	33.2	34.4	37.8	49.5	47.5	78.8	73.2
	6	88.1	56.0	14.6	33.3	68.9	69.1	51.1	42.6	26.8	25.3	24.9		20.9	18.1	32.2	43.0	35.2	32.7	46.9	36.7	33.0	49.4	66.8	64.2
	7	56.4	54.2	47.5	30.3	25.8	32.2	24.0	21.8	24.9	27.9	21.6	21.8	24.6	19.5	27.3	21.0	28.0	31.2	36.9	47.5	56.3	44.2	47.0	35.6
	8	26.5	21.7	20.8	17.0	16.6	21.3	16.5	14.9	23.4	24.5	21.7	32.9	32.2	12.5	20.3	24.8	24.5	15.0	11.4	16.4	20.4	19.0	20.5	18.8
	9	24.6	29.4	12.9	11.8	13.4	19.2	23.1	22.5	30.9	22.4	24.0	17.5	15.3	23.4	55.9	60.0	60.1	28.3	31.2	30.0	32.4	24.2	18.3	8.6
	10	7.7	21.2	20.6	14.8	20.4	27.9	26.4	21.9	17.4	13.4	14.9	10.9	18.4	20.8	25.0	26.5	40.9	30.6	26.6	21.8	15.5	18.0	19.5	8.1
	11	5.1	4.9	3.8	5.8	11.0	13.2	16.2	34.1	27.5		21.4	28.3	32.2			30.7	24.7	24.2	29.1	19.6	14.3	13.1	12.2	10.3
	12	14.5	14.2	13.6	10.0	13.9	40.0	78.7	83.9	54.6	35.8	39.9	36.3	41.5	38.6	33.3	31.3	29.4	25.1	27.4	29.1	24.8	49.0	39.1	31.0
	13	16.2	13.7	14.8	13.2	17.2	25.0	22.1	19.7	19.6	24.8	20.8	24.2	17.4	23.1	27.6	35.8	29.9	35.0	31.5	27.7	22.4	17.5	23.9	15.1
	14	19.7	12.3	16.4	11.1	12.3	14.8	10.6	19.4	14.9	18.2	11.6	12.9	38.9	54.2	49.1	36.8	31.4		24.7	26.3	31.5	30.4	29.0	41.2
	15	35.3	20.9	30.8	25.2	23.0	28.3	19.5	22.0	30.4	36.1	25.4	29.0	15.3	27.2	36.2	23.6	29.0	32.6	37.1	38.0	42.5	33.1	15.3	17.1
	16	10.6	11.7	13.0	18.0	20.9	45.1	49.2	21.3	23.0	18.5	20.4	27.6	28.2	27.6	22.2	21.0	23.6	17.7	12.4	9.2	11.2	9.8	8.5	14.7
	17	25.8	23.5	26.0	31.7	37.4	43.0	40.2	39.2	47.0	43.7	52.2	41.4	48.1	59.3	48.6	49.1	36.1	35.7	24.8	23.3	19.9	21.8	17.5	12.1
	18	13.9	11.4	11.6	11.8	18.7	22.1	21.4	16.8	12.2	13.2	15.2	14.0	16.7	19.9	21.9	17.3	19.2	20.2	14.2	14.2	9.9	9.7	7.0	9.7
	19	5.9	7.2	8.4	10.6	17.6	41.9	55.2	48.8	36.2	33.2	39.4	37.1	36.3	38.6	41.9	36.3	35.8	28.8	21.8	24.3	34.0	57.0	49.4	30.3
	20	47.0	60.1		39.6	43.1	43.3	53.3	41.8	39.6	44.3	54.8	42.4	33.1	38.4	22.1	20.1	17.2	26.0	19.6	15.1	28.5	21.3	29.3	23.4
	21	13.8	12.4	13.0	19.1	38.2	40.4	33.4	49.0	32.6	20.6	17.1	20.9	20.0	15.6	20.3	17.8	20.9	20.6	15.2	13.6	19.3	20.5	22.0	17.3
	22	25.7	27.2	35.6	37.5	34.8	31.9	30.8	15.5	17.5	17.9	13.0	17.5	23.7	17.9	23.1	19.4	19.6	17.8	18.6	36.2	26.4	57.0	70.2	66.8
	23	67.1	50.6	32.4	27.2	43.7	64.3	63.2	57.6	39.1	30.3	22.6	25.1		32.3	46.5	41.0	44.8	50.2	58.6	62.8	75.5	75.2	77.1	73.2
	24	56.1	46.5	36.1	34.6	54.4	64.9	77.9	94.6	78.1		45.9	32.4	42.6	32.8	34.8	40.4	27.3	31.2	44.1	32.5	45.3	43.5	49.5	42.2
	25	36.7	26.6	27.9	57.8	77.5	91.4	101.7	99.8	93.2	81.3	72.3	58.3	63.7	57.3	49.5	51.8	79.2	48.7		46.0	54.0		30.1	27.0
	26	18.8	14.1	14.5	12.6	16.8	20.4	25.6	26.2	29.0	18.9	21.1	20.0	23.5	17.4	19.3	19.5	28.5	25.1	20.2	22.4	23.9	25.5	22.5	19.3
	27	18.7	16.6	14.5	15.3	18.5	23.7	34.6	37.8	47.6	56.2	102.4	88.7	84.1	99.8	99.7	93.7	93.6	87.0	78.3	54.9	45.8	43.8	41.5	29.2
	28	15.4	14.4	13.6	13.9	11.4	24.8	22.9	27.6	26.9	20.8	19.9	26.1	20.7	23.3	25.9	28.0	27.7	26.0	34.2	33.2	23.8	24.4	32.5	53.8
	29	60.1	29.3	19.9	15.1	10.5	13.6	12.5	17.8	25.6	23.7	23.5	27.3		16.1	20.0	16.0	19.9	21.3	17.8	34.8	31.1	38.7	39.8	22.2
	30	15.6	7.8	19.1	19.8	37.3	31.7	19.3	21.0	18.2	27.1		25.7	29.0	21.5	26.5	23.2	28.5	28.4	29.4	18.7	20.0	17.2	15.0	19.6
	31	25.5	16.4	19.4	19.3	37.2	37.0	41.7	34.0	37.6	30.4	31.1	22.1	26.6	26.5	44.7	30.3	42.1	52.0	37.7	25.9	17.1	29.3	26.8	17.0
Aug-12	1	22.2	21.8	22.0	29.1	39.4	46.6	54.5	50.3	45.8	47.0	35.7	33.0	34.6	40.9	44.2	55.9	65.9	83.1	77.8	68.1	64.6	40.2	26.7	39.5
	2	39.2	30.0	41.6	27.2	33.4	45.4	44.0	38.1	25.8	22.0	17.8	43.2	31.9	24.9	21.4	30.3	32.6	29.6	23.3	18.5	20.8	29.1	47.9	44.2
	3	36.6	34.0	38.6	34.8	41.8	48.5	39.5	30.8	21.2	20.2	21.8	21.6	26.1	29.2	24.7	24.8	26.2	32.2	26.4	57.2	53.6	53.7	46.5	30.4
	4	24.7	25.0	15.7	21.4	27.3	31.0	23.8	25.1	29.1	26.3	24.3	13.2	12.8	17.2	12.0	22.0	21.3	32.5	49.5	60.3	50.4	60.2	65.2	56.9

months	Dates	Hour																							
		0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00
	5	39.4	27.6	33.1	31.5	27.2	25.4	25.4	32.8	25.3	27.3	16.1	12.5	20.0	23.4	28.2	29.8	40.0	31.4	32.1	39.5	29.1	46.0	53.1	35.5
	6	18.9	12.6	12.8	15.0	19.9	21.6	19.9	21.4	19.0	11.6	19.1	16.6	16.7	13.6	23.5	23.0	27.7	24.5	20.3	26.4	11.8	15.0	12.3	11.2
	7	9.8	8.9	7.9	10.5	11.1	19.0	23.0	24.3	23.8	27.2		41.4	39.8	32.7	31.5	27.1	32.9	44.4		40.9	28.9	21.8	14.1	16.6
	8	17.4	14.8	15.6	18.8	33.5	33.2	37.6	30.0	25.6	19.8	26.3	18.9	27.0	28.3	31.7	39.8	46.1	51.7	48.0	49.7	35.6	39.0	36.1	32.6
	9	28.9	22.4	25.9	39.5	50.8	64.0	67.7	54.3	31.4	35.4	22.5	18.7	18.2	20.7	20.6	28.2	23.8	26.6	18.6	18.3	17.6	19.9	17.1	17.4
	10	16.4	16.0	19.7	18.8	31.9	45.5	45.3	38.7	33.9	24.4	17.2	18.4	22.2	14.7	15.6	16.2	20.4	21.5	24.9	26.1	25.0	31.3	28.0	36.2
	11	31.7	25.3	21.2	19.3	20.8	32.5	30.9	23.5	30.3	19.9	18.1	22.8	16.5	23.7	18.2	16.4	14.2	12.8	17.7	24.3	23.5	26.1	26.0	22.1
	12	17.6	17.1	18.3	17.1	18.9	22.1	19.7	18.5	17.4	16.1	18.3	16.9	22.5	27.5	25.5	22.0	25.1	36.0	39.0	26.5	32.3		31.9	34.8
	13	29.8	24.4	23.7	28.6	46.4	66.1	67.2	63.2	55.7	50.1	37.8	21.7	32.1	32.2	35.9	44.9	44.9	43.0	49.0	50.1	49.8	48.4	52.0	55.0
	14	53.6	43.3	53.0	52.7	48.2	57.7	66.5	73.6	67.7	50.7	39.6	36.3	34.0	38.2	31.0	48.5	57.1	59.4	40.8	51.2	43.8	42.3	41.4	36.5
	15	32.7	39.6	41.6	26.9	34.0	42.6	44.8	43.3	41.9	48.4	46.8	44.9	47.6	43.2	57.4	67.3	84.0	99.3	50.8	47.8	38.5	52.4	52.9	48.4
	16	45.1	19.8	25.4	27.8	41.7	53.3	53.0	34.2	26.1	28.1	28.5	25.7	19.5	26.4	20.0	21.7	21.5	30.7	33.8	56.9	60.5	46.2	40.9	40.0
	17	47.9	43.4	48.7	44.1	51.6	63.6	61.6	62.0	57.5	44.0	43.8	48.8	49.5	47.6	57.1	53.7	60.5	59.2	75.8	109.9	107.0	91.5	99.7	105.9
	18	89.3	71.0	65.4	60.7	44.0	46.2	49.9	53.2	47.1	49.0	53.6	55.9	61.2	64.1	62.7	51.6	73.6	64.3	95.4	73.3	83.9	66.9	58.2	60.2
	19	62.2	42.7	31.5	29.1	32.7	39.6	44.0	46.1	34.8	29.0	22.4	25.2	32.7	24.1	21.7	33.1	90.0	95.1	69.4	70.8	63.8	58.6	97.3	83.5
	20	37.4	42.0	56.7	49.4	46.5	49.7	51.6	76.8	112.9	111.5	88.9	70.2	68.3	69.9	58.6	29.9	56.8	61.6	45.2	31.3	41.4	65.4	46.6	52.9
	21	28.9	24.3	22.6	30.7	35.1	54.3	53.3	62.6	50.6	40.7	46.2	42.2	29.1	31.7	59.4	61.1	56.6	54.3	67.4	47.4	42.0	24.8	21.1	19.9
	22	31.1	36.1	32.5	28.4	46.7	52.7	61.1	59.5	53.3	47.7	27.8	53.1	38.4	33.2	24.0	34.2	42.4	40.9	35.0	24.8	22.3	15.9	15.3	15.0
	23	15.6	10.6	11.6	13.7	24.1	33.0	46.3	35.8	33.0	31.3	25.9	24.8	30.9	43.7	47.6	60.4	65.1	58.9	50.8	46.2	28.3	26.4	30.4	25.7
	24	18.8	13.7	12.6	14.9	43.9	68.6	79.4	78.7	60.5	59.3	62.1	69.5	50.6	44.1	58.2	55.4	67.3	97.8	56.2	65.6	76.9	43.1	38.5	27.6
	25	16.9	24.5	28.8	21.4	20.7	23.7	20.2	16.6	10.2	15.5	13.9	20.7	13.6	16.2	14.0	19.2	15.3	11.9	14.9	15.6	8.4	8.2	9.1	10.2
	26	6.3	6.7	9.1	6.2	20.0	32.3	31.6	43.6	40.9	20.5	19.5	25.2	31.9	26.4	26.5	22.0	31.1	32.7	36.0	45.6	46.9	56.5	49.2	49.0
	27	42.0	27.8	30.0	29.9	44.5	65.5	62.7	60.5	50.9	47.5	48.3	46.5	48.4	59.0	53.7	72.1	56.7	67.5	65.2	74.9	72.9	66.1	48.9	36.0
	28	31.6	23.4	25.6	30.4	49.4	64.1	76.8	71.4	58.2	46.6	65.0	36.3	39.1	54.4	53.9	59.7	57.1	53.5	50.1	75.5	48.1	55.5	49.8	45.7
	29	37.0	26.5	24.8	33.9	49.2	64.1	72.7	88.1	72.8	68.4	55.2	48.4	42.9	22.1	28.1	32.5	43.9	47.8	62.7	57.4	48.0	52.1	29.5	9.9
	30	10.5	11.5	17.0	14.9	30.2	41.7	56.9	61.6	36.1	36.8	32.2	25.1	28.4	38.9	53.7	52.4	49.0	69.5	70.0	41.5	66.7	40.7	29.3	34.5
	31	47.0	17.6	13.5	8.2	10.7	18.0	22.7	57.6	26.9	21.6	28.4	17.0	22.0	15.0	21.9	24.5	27.9	21.4	21.0	39.8	34.3	46.3	43.5	56.2
Summer	Avrg	27.43	22.94	22.37	22.98	30.56	39.66	41.10	40.61	35.72	32.85	31.97	30.40	31.17	31.16	33.32	35.11	37.96	38.34	36.39	36.88	35.87	35.50	34.67	31.15
	Max	89.30	71.00	65.40	60.70	77.50	91.40	101.70	99.80	112.90	111.50	102.40	88.70	84.10	99.80	99.70	93.70	93.60	99.30	95.40	109.90	107.00	91.50	99.70	105.90
	Min	2.50	2.60	2.80	3.90	4.00	4.80	5.60	3.50	2.80	4.40	6.60	7.60	10.70	8.90	10.90	15.40	11.50	9.10	9.90	9.20	8.10	7.30	5.60	4.50
Sep-12	1	23.2	32.6	21.0	31.9	39.7	48.0	50.5	56.4	42.6	54.0	53.9	46.8	45.8	32.6	36.6	31.5	32.6	35.3	44.7	64.4	59.9	68.5	48.7	55.2
	2	50.2	45.6	47.4	34.8	34.6	31.8	34.6	29.2	20.5	27.1	19.3	19.4	24.2	28.4	23.5	20.7	40.2	51.8	60.3	63.5	49.5	57.9	56.3	54.5

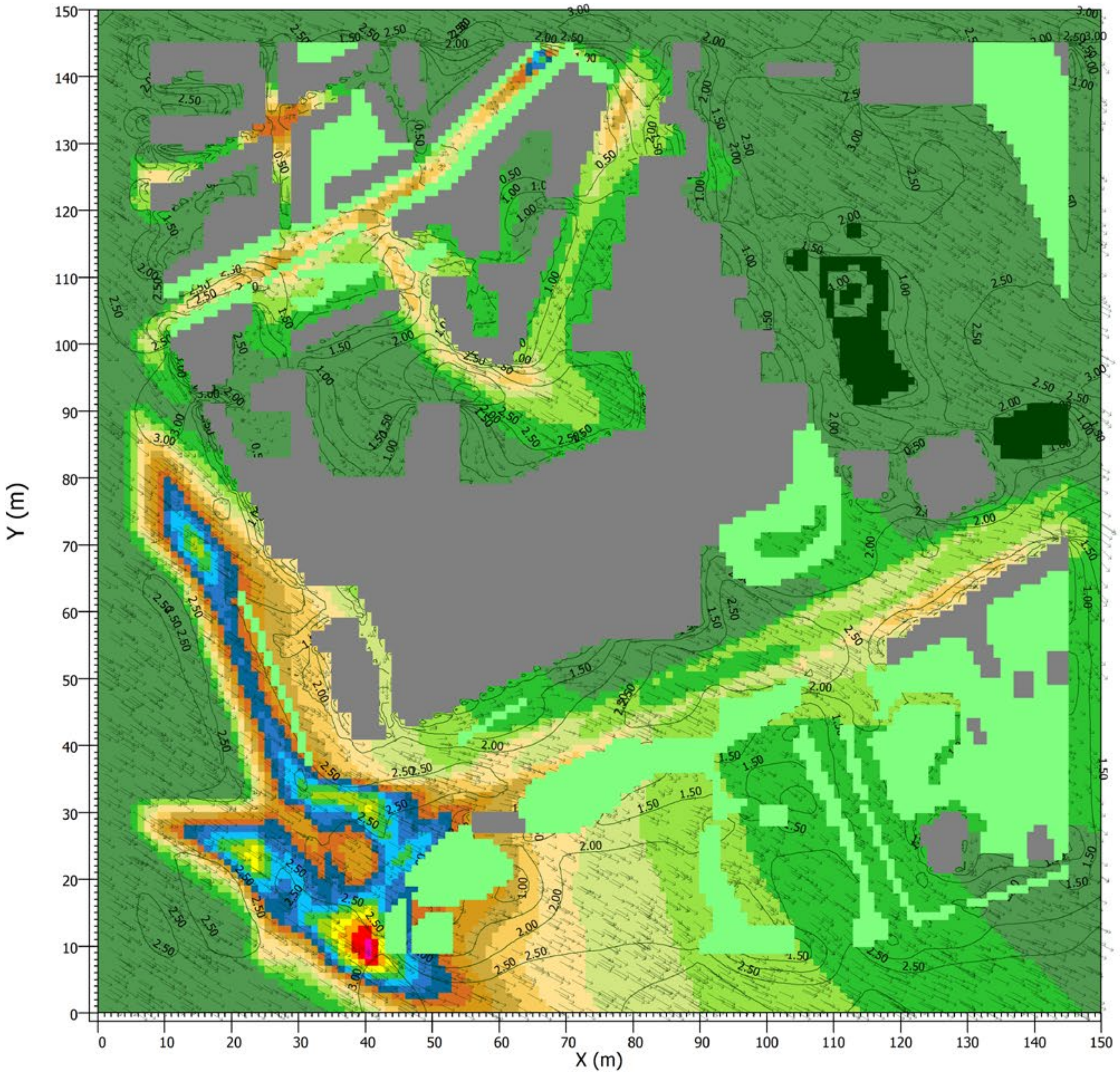
months	Dates	Hour																							
		0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00
	3	40.3	42.4	28.5	29.6	52.2	57.7	50.8	56.1	44.1	36.8	39.4	42.3	31.3	35.1	30.5	28.2	27.5	32.2	32.3	38.8	37.4	44.9	50.8	63.8
	4	48.4	44.5	38.5	33.1	42.7	55.5	56.0	59.2	48.0	47.4	50.0	49.3	58.4	71.2	94.2	92.7	87.2	66.7	73.9	51.8	47.2	35.1	25.1	19.5
	5	16.0	16.7	12.1	13.4	31.4	29.0	37.5	37.5	34.3	31.0	32.5	30.1	38.6	38.6	34.7	36.3	28.3	27.0	29.3	31.4	21.8	25.8	24.1	18.3
	6	15.5	11.4	8.8	13.6	20.2	47.0	61.9	56.2	58.7	58.5	75.8	53.9	77.3	74.3	78.5	65.1	49.5	51.0	37.6	27.8	43.8	35.0	26.8	28.0
	7	23.7	22.9	21.3	30.2	35.3	48.8	50.1	48.7	40.9	45.4	54.5	67.0	63.9	53.7	60.0	69.1	79.6	73.9	69.7	95.4	90.3	84.8	76.8	71.0
	8	56.8	51.4	43.0	33.8	40.6	47.6	50.4	43.6	40.1	45.8	52.1	50.3	58.2	66.4	60.9	48.3	60.8	68.9	69.2	73.1	52.7	65.7	55.5	72.7
	9	55.7	57.6	58.2	64.3	63.7	59.7	58.3	52.9	49.7	52.7	50.2	75.3	71.6	63.9	47.2	69.5	40.0	29.2	93.2	120.1	96.8	98.3	80.8	39.2
	10	14.2	15.2	8.8	16.5	23.0	27.9	36.9	46.0		31.5	19.7	18.9	26.5	22.2	25.1	30.1	34.2	41.5	68.0	79.7	34.2	36.9	31.9	21.1
	11	18.0	16.3	14.9	11.2	17.6	34.2	38.9	33.6	30.6	26.5	34.4	74.2	74.3	51.9	54.5	66.1	68.3	56.9	65.8	44.5	50.7	60.9	67.6	56.6
	12	39.7	14.3	24.1	27.6	46.6	69.1	80.4	77.7	68.2	64.1	53.4	50.6	49.1	51.9	63.1	79.2	47.7	41.6	35.0	24.3	17.0	15.3	21.0	25.3
	13	21.7	23.3	20.5	17.1	21.0	26.6	27.3	32.9	32.0	23.2	20.1	20.4	32.5	30.5	47.2	56.1	46.2	51.9	61.7	40.3	29.2	26.8	19.6	14.5
	14	10.8	11.4	10.1	10.2	12.9	21.9	26.1	41.4	35.2	27.4	27.9	22.4	31.1	58.4	53.9	79.7	65.2	57.2	37.1	54.0	48.8	38.6	36.3	29.0
	15	27.6	33.6	48.0	41.8	45.0	41.9	58.8				57.2	44.5	30.4	31.0	32.3	40.2	40.4	41.8	43.1	53.3	72.9	59.1	62.0	63.2
	16	46.0	41.0	35.1	26.5	27.6	28.4	26.6	22.3	20.6	16.7	13.9	15.7	16.1	19.0	18.5	20.9	30.4	20.6	31.9	28.7	34.7	23.1	16.1	21.3
	17	11.9	10.8	10.8	13.8	25.0	46.7	38.1	38.2	34.8	27.9	26.6	32.0	36.0	23.6	29.0	26.4	46.8	34.4	31.4	21.3	20.3	23.0	16.3	9.6
	18	8.5	8.9	10.6	15.7	25.7	46.8	29.4	43.5	43.6	37.2	55.8		54.5	56.7	58.8	68.2	60.7	81.0	57.1	60.2	53.2	58.7	33.8	35.6
	19	30.1	34.9	33.6	48.2	64.3	61.8	68.4	66.1	48.3	46.6	48.5	50.0	51.9	47.9	47.2	61.4	47.3	61.2	74.4	72.2	79.1	67.6	53.0	35.6
	20	32.7	31.0	26.3	29.8	39.7	45.1	66.9	65.3	65.9	61.3	55.2	37.7	35.3	44.9	49.7	39.7	42.1	40.7	51.5	57.4	64.6	59.0	49.3	40.5
	21	38.1	39.0	37.0	42.8	54.9	64.7	74.3	74.2	69.5	68.5	48.3	52.1			60.6	57.7	54.9	72.4	81.0	74.4	70.3	55.6	51.6	27.4
	22	24.8	7.0	15.2	22.7	35.4	24.0	36.1	43.7	32.2	40.2	25.3	25.8	27.3	25.8	22.6	23.8	31.5	26.9	51.9	45.0	34.2	62.1	71.7	62.9
	23	55.2	60.2	63.3	50.3	34.3	38.4	32.3	29.5	26.7	18.9	20.5	24.8	21.7	23.5	23.6	28.4	25.1	24.6	19.7	20.0	15.3	12.7	11.5	11.9
	24	11.0	10.8	12.7	17.5	35.1	58.4	61.9	63.0	65.1	59.6	50.2	37.9	41.3	35.9	22.7	16.7	26.0	17.6	17.1	11.0	9.3	13.4	17.0	14.5
	25	7.2	8.8	9.6	6.5	15.6	36.7	46.3	66.7	44.6	38.0	22.0	22.3	30.3	35.9	30.2	49.4	61.6	58.5	55.5	46.2	39.4	31.0	25.2	23.6
	26	16.9	12.7	9.7	11.6	26.4	45.6	47.7	55.6	55.6	49.0	42.4	36.0	30.3	34.3	39.5	50.6	60.3	55.9	55.8	53.6	50.3	42.7	37.6	28.8
	27	23.3	21.0	19.6	14.3	20.8	35.7	31.6	41.1	35.1	48.3	34.1	35.8	40.5	50.5	69.7	60.1	58.1	68.7	73.6	73.6	82.6	76.5	62.9	46.7
	28	29.2	29.6	31.9	30.7	24.3	27.1	32.5	29.7	29.4	24.4	27.0	37.8	33.3	25.0	26.9	35.6	40.1	40.3	50.7	39.9	33.1	26.7	17.5	14.7
	29	19.5	11.8	10.0	15.5	33.8	19.5	34.8	47.5	54.8	47.4	46.4	48.1	46.8	53.6	67.0	56.0	68.7	63.7	54.3	36.8	31.5	39.3	45.5	55.0
	30	56.7	33.9	31.6	35.9	27.2	27.1	26.7	29.4	24.6	21.4	16.8	18.0	18.1	17.0	16.5	17.5	19.5	24.2	44.4	49.1	35.7	39.8	26.3	12.4
Oct-12	1	13.8	13.6	16.7	20.9	34.0	39.0	36.6	53.0	52.5	52.4	30.1	27.5	33.8	34.1	34.4	49.6	58.3	50.9	47.3	31.4	29.4	22.3	20.6	23.3
	2	19.3	14.2	12.3	10.2	20.7	28.4	43.4	41.0	35.6	28.1	33.9	32.7	28.0	24.6	36.5	55.5	51.3	36.3	59.5	58.1	54.5	53.4	44.0	33.4
	3	15.8	12.6	11.0	11.4	23.7	31.8	29.0	30.5	32.1	24.5	38.5	31.2	27.0	41.7	36.3	41.6	69.5	54.3	33.5	24.9	25.3	20.1	20.1	21.6
	4	18.8	14.8	16.0	16.9	24.3	32.1	41.3	56.0	53.7	43.4	43.8	61.3	62.6	62.1	59.8	67.0	64.0	50.7	52.3	41.4	30.1	29.0	32.9	32.8

months	Dates	Hour																							
		0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00
	5	28.0	27.0	31.0	30.3	31.7	50.7	47.2	33.7	19.5	17.0	46.0	65.9	61.3	81.4	65.3	63.1	70.6	74.3	81.0	86.5	72.3	70.2	55.5	26.5
	6	36.2	83.2	23.1	21.3	20.5	35.0	23.9	26.6	28.0	38.9	40.9	54.1	41.3	34.5	48.9	51.4	56.8	51.4	74.3	94.2	77.0	82.4	87.3	84.1
	7	68.5	51.7	52.3	52.5	53.7	55.8	56.4	34.8	38.2	34.5	17.8	17.5	18.0	28.8	29.3	34.0	40.1	44.2	77.3	81.0	73.9	71.1	66.2	63.4
	8	55.4	56.3	48.5	47.7	56.2	73.9	79.7	87.0	82.9	63.8	67.4	61.0	62.3	74.3	76.6	80.4	77.8	73.3	69.3	65.1	66.8	60.6	53.3	55.2
	9	53.8	50.8	51.3	53.3	60.7	69.2	63.7	66.4	67.9	72.2	42.8	36.1	38.8	37.0	44.6	47.2	67.8	63.6	65.3	85.5	85.8	79.0	70.7	71.5
	10	65.7	60.0	59.4	61.4	68.3	77.8	80.8	96.3	90.7	82.6	69.9	68.0	51.3	51.2	57.8	56.9	54.3	68.8	71.2	69.8	58.2	52.8	63.4	59.1
	11	56.0	53.2	52.6	52.0	53.4	62.5	77.1	73.9	71.3	69.8	65.3	58.0	63.9	59.9	63.7	73.9	75.2	80.0	70.7	68.4	58.6	57.5	50.3	42.4
	12	36.6	29.7	28.9	27.5	33.2	42.4	38.9	38.3	26.6	31.5	29.6	23.4	24.8	45.7	67.5	81.3	64.6	52.0	57.9	50.8	24.9	32.9	32.5	22.5
	13	18.4	17.3	20.3	19.1	33.0	30.6	35.3	38.6	38.5	39.6	45.5	44.0	47.9	26.2	45.1	55.0	65.2	48.9	34.6	30.5	66.4	53.9	39.4	16.5
	14	14.1	11.8	8.8	9.4	8.8	9.1	10.5	15.7	15.1	15.7	40.7	66.5	73.9	62.6	58.9	43.3	38.5	32.2	37.6	27.7	20.2	21.5	18.7	17.9
	15	16.1	25.9	38.1	19.6	23.2	69.9	85.6	86.3	100.2	85.9	52.9	48.4	24.7	26.3	28.8	51.3	73.5	57.8	42.3	28.7	27.1	22.5	19.8	17.8
	16	14.8	16.0	20.1	19.7	27.3	41.1	51.0	54.1	56.7	45.5	30.1	22.8	25.4	19.5	24.1	23.8	34.4	29.7	25.4	27.5	23.0	25.2	32.3	38.1
	17	33.3	29.2	32.2	35.3	31.2	41.4	55.0	67.2	52.3	41.1	46.9	44.5	45.0	39.7	38.9	42.5	60.8	54.7	53.0	41.2	36.8	40.9	31.0	27.9
	18	33.9	28.4	14.1	14.9	36.2	61.6	83.0	69.3	73.7	66.2	73.6	73.8	76.3	75.0	85.0	88.1	102.1	86.5	92.5	75.1	96.9	86.9	86.5	79.9
	19	64.8	58.4	55.4	60.8	50.7	67.4	66.7	69.6	77.2	68.1	67.2	68.1	65.5	72.3	78.5	85.7	98.1	85.7	75.8	70.4	56.0	56.1	64.3	59.2
	20	52.1	46.3	42.3	36.0	38.2	27.4	26.4	24.3	29.5	33.9	32.2	53.9	51.9	63.6	56.7	72.0	63.4	58.4	51.8	44.3	30.2	36.3	23.4	21.0
	21	20.0	16.0	12.2	9.7	5.9	7.6	8.4	10.8	8.4	8.3	9.4	14.8	14.6	20.1	18.3	25.6	23.6	27.5	25.5	25.6	25.6	24.2	24.5	25.2
	22	23.4	19.9	19.5	21.3	25.3	28.4	34.9	33.1	59.2	34.7	34.0	41.3	52.0	50.4	49.0	50.4	59.6	68.0	73.9	71.9	57.8	57.1	53.9	50.6
	23	48.5	43.2	38.4	36.9	37.6	36.2	37.4	36.4			22.1	40.8	41.5	42.2	43.1	43.3	47.9	50.1	46.6	38.5	33.2	28.2	30.5	27.7
	24	27.3	26.9	27.3	28.8	32.4	32.3	40.2	31.9	27.8	28.4	29.8	36.3	38.3	34.0	40.3	39.6	49.0	43.2	39.3	33.4	31.6	29.4	25.4	25.5
	25	25.2	23.9	23.0	18.6	16.6	22.4	27.4	31.3	32.4	36.1	35.1	34.9	31.7	38.9	42.6	43.5	33.6	27.7	30.7	41.3	26.5	21.3	20.3	20.1
	26	19.7	16.2	4.7	5.8	10.2	17.3	25.7	29.5	36.9	37.2	36.1	25.0	19.0	26.5	24.0	31.5	38.6	41.0	49.0	36.4	32.7	35.1	56.0	54.6
	27	39.9	39.7	36.0	20.4	13.1	14.3	14.8	31.0	37.8	29.7	33.5	33.9	16.0	16.3	23.4	25.6	21.2	31.4	39.3	50.6	48.9	60.4	42.6	47.4
	28	36.2	55.1		52.4	58.3	63.4	62.0	59.0	60.8	61.2	38.8	51.2	32.7	23.0	19.6	22.0	25.9	27.7	37.9	52.0	30.5	27.2	35.4	33.3
	29	27.7	23.4	20.3	15.1	15.7	15.6	23.4	33.6	49.9	36.9	42.6	33.8	37.4	38.0	32.7	37.5	35.4	41.3	55.5	49.9	52.3	36.1	28.1	35.5
	30	25.9	22.5	33.8	24.5	20.1	32.1	45.2	74.9	93.0	96.5	101.8	90.9	92.8	73.2	67.3	67.8	69.7	76.2	92.2	71.1	55.3	48.5	45.7	53.8
	31	50.8	49.1	44.0	47.4	49.3	46.9	57.0	58.0	52.2	61.5	51.1	50.1	44.9	53.9	50.9	49.4	70.3	78.7	81.7	81.4	60.7	52.8	51.5	53.2
Nov-12	1	45.0	33.1	22.9	25.0	32.1	30.9	47.6	52.8	65.1	82.8	46.5	54.2	34.4	29.3	30.8	38.9	33.9	31.1	39.4	30.1	18.5	26.6	28.3	17.4
	2	9.8	7.0	8.8	7.6	6.3	12.8	15.8	23.5	29.9	22.7	23.9	19.9	20.6	23.8	36.5	48.3	66.2	69.6	56.2	39.8	37.4	26.2	23.2	18.3
	3	16.4	12.0	15.7	17.5	27.3	26.0	29.7	33.2	47.9	47.3	46.4	45.8	56.5	44.6	29.8	30.1	26.4	29.4	46.5	62.8	59.2	41.9	24.5	17.2
	4	21.5	20.6	23.2	16.6	32.7	40.8	38.0	42.6	34.5	30.4	30.7	35.2	42.9	60.3	69.4	69.7	80.0	32.6	23.3	21.8	23.7	16.4	14.1	10.8
	5	11.6	10.6	11.3	12.4	13.3	22.3	56.5	79.6	92.9	70.1	75.4	69.3	65.6	70.5	50.9	60.5	71.2	85.6	109.9	109.0	100.5	88.3	82.4	72.8

months	Dates	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00
		Hour																							
	6	67.8	51.5	57.0	49.2	53.9	67.3	83.4	80.1	100.8	107.3	93.8	61.3	58.7	58.8	60.7	57.6	72.4	56.2	49.9	47.3	35.9	49.5	52.4	44.2
	7	45.1	35.5	28.4	30.8	42.9	50.0	73.0	74.4	86.8	75.4	63.9	41.1	39.7	49.7	55.5	47.3	48.1	45.7	39.6	36.8	31.4	22.6	13.9	13.8
	8	12.8	9.5	9.2	7.8	12.3	19.3	28.5	35.0	38.3	43.0	46.1	48.6	50.3	68.8	80.2	77.9	78.1	76.5	67.7	58.8	61.1	55.4	34.9	27.6
	9	29.0	27.8	33.7	33.5	29.5	35.4	45.6	49.0	57.5	60.6	60.8	59.0	66.1	65.4	71.9	58.9	75.9	87.8	81.4	81.2	77.8	56.4	49.8	50.5
	10	37.1	32.4	26.5	20.3	18.3	24.7	32.9	30.6	32.7	42.8	47.0	45.4	44.6	40.5	42.5	51.1	56.8	54.4	50.3	44.9	43.8	42.0	41.0	50.6
	11	51.8	16.2	11.9	12.5	18.2	14.9	22.4	22.9	28.1	29.4	28.3	30.6	36.6	41.0	38.9	38.8	39.4	51.3	47.3	33.8	28.4	24.3	26.7	30.1
	12	22.7	21.9	22.1	20.2	24.0	39.2	45.3	48.1	58.6	49.7	40.1			36.5	46.5	67.2	70.3	67.4	58.8	55.5	49.1	43.0	36.7	25.4
	13	20.1	17.1	18.6	13.6	14.1	21.1	37.4	44.5	40.1	36.7	30.5	34.3	31.2	40.1	44.2	54.5	55.7	62.4	57.8	55.6	47.6	48.3	51.4	45.2
	14	43.2	40.4	34.1	34.0	33.5	43.9	52.9	61.5	58.6	65.2	58.6	50.2	56.3	52.3	53.4	56.9	64.1	73.9	70.6	70.8	74.3	75.5	69.6	65.0
	15	61.1	54.9	44.4	41.7	40.4	39.9	42.4	46.3	65.2	67.0	53.7	60.8	59.2	55.2		83.4	87.0	88.7	74.0	64.0	59.3	55.9	51.0	48.0
	16	44.3	40.4	37.9	38.9	43.2	46.8	54.4	56.2	63.6	53.8	54.7	57.3	56.0	61.6	64.5	56.7	59.2	73.0	64.2	64.7	53.1	54.7	51.2	47.7
	17	47.2	44.2	39.5	36.8	36.9	39.1	41.2	46.0	45.8	43.2	36.4	27.1	34.1	35.0	37.7	41.1	45.0	43.8	44.8	45.8	37.8	32.9	32.1	32.9
	18	40.3	47.8	61.2	59.3	35.2	32.7	39.6	62.2	66.0	68.3	66.3	67.5	56.9	33.6	47.0	53.5	89.7	104.0	104.8	101.5	100.7	104.4	101.6	87.3
	19	80.3	68.2	53.6	53.0	45.9	53.6	71.6	77.1	65.6	71.8	60.5	54.7	50.7	62.4	62.9	58.8	74.5	88.8	62.7	56.4	51.8	44.8	36.3	33.8
	20	33.1	39.3	38.0	29.1	24.8	32.3	51.6	45.4	56.1	48.3	52.9	53.8	62.4	57.3	57.7	68.0	80.1	82.0	60.8	56.4	48.1	48.2	53.4	49.4
	21	44.0	41.8	37.0	34.1	32.4	36.7	52.3	54.5	60.7	57.5	51.7	51.2	61.0	55.4	66.3	62.3	67.7	67.5	45.3	25.5	25.0	26.3	32.4	32.7
	22	42.5	23.8	23.6	21.5	20.1	29.7	53.3	73.5	69.1	71.7	63.2	53.2	44.4	58.1	55.6	69.8	76.6	82.2	78.0	52.7	47.2	44.2	34.3	27.1
	23	21.9	16.3	13.9	13.0	13.4	23.5	43.5	53.5	67.7	50.1	39.7	62.3	54.3	60.4	62.8	71.7	76.5	91.6	97.7	89.7	94.4	81.9	82.0	91.0
	24	75.9	67.3	64.2	62.0	58.4	57.5	60.6	63.5	53.1	56.7	49.4	46.5	44.9	53.5	48.8	54.8	53.6	52.2	48.0	50.1	42.4	42.1	45.1	48.1
	25	46.0	35.7	24.6	18.9	8.4	5.9	6.8	5.9	6.6	7.7	6.5	7.2	10.4	9.6	11.2	16.1	14.8	20.7	19.3	19.2	19.3	15.3	18.1	17.9
	26	16.5	16.1	17.2	20.8	25.1	38.4	74.7	74.5	84.3	78.6	66.0	60.2	65.4	67.5	63.7	80.9	81.8	102.5	97.0	70.5	42.3	46.5	51.3	45.1
	27	30.0	25.3	27.7	18.2	20.1	36.1	52.6	66.5	79.3	78.7	66.6	68.1	61.8	86.9	82.0	85.5	99.3	103.6	94.8	99.5	86.8	84.6	82.8	79.9
	28	84.7	75.1	92.1	76.1	65.4	63.4	57.2	49.2	48.6	59.8	65.1	52.5	35.2	31.1	43.5	59.3	51.5	47.6	35.3	36.2	32.4	24.9	29.6	18.5
	29	12.9	11.7	18.5	15.3	17.2	23.4	31.0	39.6	51.3	48.8	42.9	28.5	25.8	34.2	40.0	46.4	53.7	73.1	85.8	64.5	68.1	79.4	77.3	76.7
	30	72.1	64.8	67.3	67.7	63.9	90.0	108.2	101.4	121.0	124.6	104.5	74.3	54.6	43.2	46.9	50.5	60.8	84.2	76.5	60.6	45.6	61.1	60.0	58.5
Fall	Avrg	33.94	30.95	29.04	28.30	31.99	39.33	46.04	49.19	50.28	47.96	44.58	44.21	43.69	44.79	47.09	51.71	55.48	55.68	56.66	53.49	48.10	46.20	42.80	39.15
	Max	84.70	83.20	92.10	76.10	68.30	90.00	108.20	101.40	121.00	124.60	104.50	90.90	92.80	86.90	94.20	92.70	102.10	104.00	109.90	120.10	100.70	104.40	101.60	91.00
	Min	2.50	2.60	2.80	3.90	4.00	4.80	5.60	3.50	2.80	4.40	6.50	7.20	10.40	8.90	10.90	15.40	11.50	9.10	9.90	9.20	8.10	7.30	5.60	4.50

* data in $\mu g/m^3$
Measurement done by the environmental protection agency of local and regional authorities in the Rijnmond region/DCMR in Pleinweg

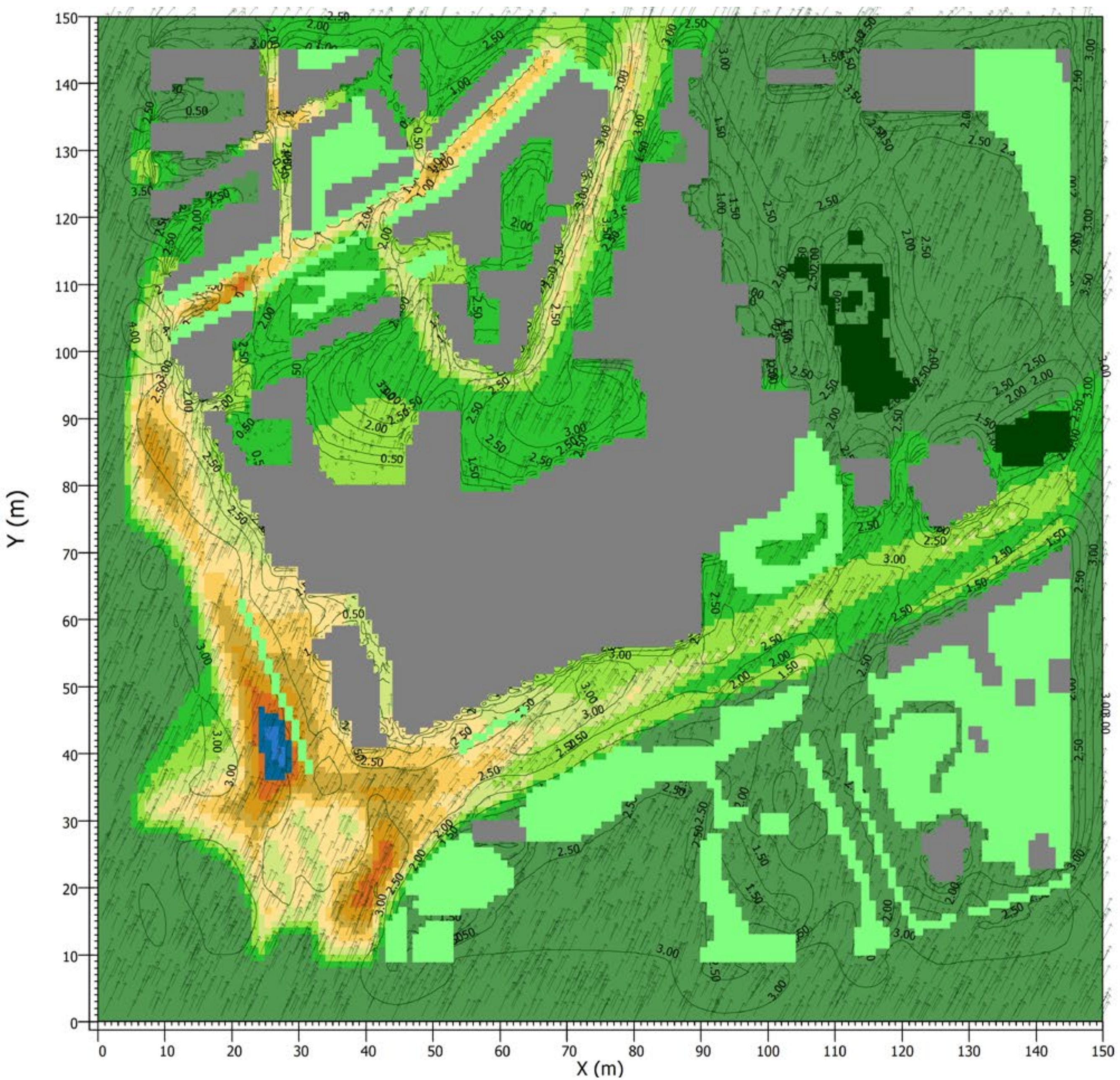
Centrum Configuration 1 Spring
15.04.2012
x/y cut at z= 2

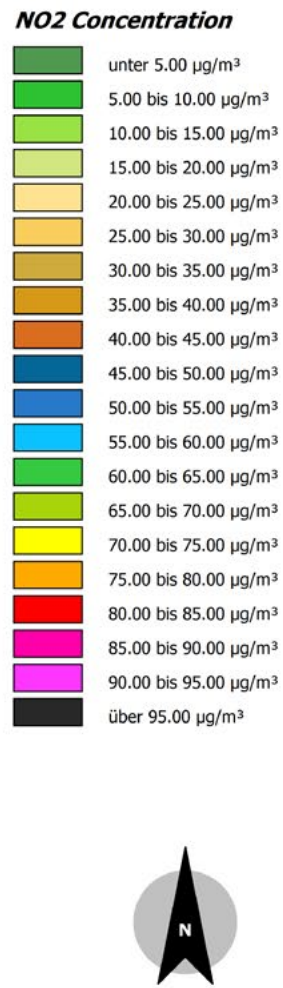


NO2 Concentration

- unter 5.00 µg/m³
- 5.00 bis 10.00 µg/m³
- 10.00 bis 15.00 µg/m³
- 15.00 bis 20.00 µg/m³
- 20.00 bis 25.00 µg/m³
- 25.00 bis 30.00 µg/m³
- 30.00 bis 35.00 µg/m³
- 35.00 bis 40.00 µg/m³
- 40.00 bis 45.00 µg/m³
- 45.00 bis 50.00 µg/m³
- 50.00 bis 55.00 µg/m³
- 55.00 bis 60.00 µg/m³
- 60.00 bis 65.00 µg/m³
- 65.00 bis 70.00 µg/m³
- 70.00 bis 75.00 µg/m³
- 75.00 bis 80.00 µg/m³
- 80.00 bis 85.00 µg/m³
- 85.00 bis 90.00 µg/m³
- 90.00 bis 95.00 µg/m³
- über 95.00 µg/m³

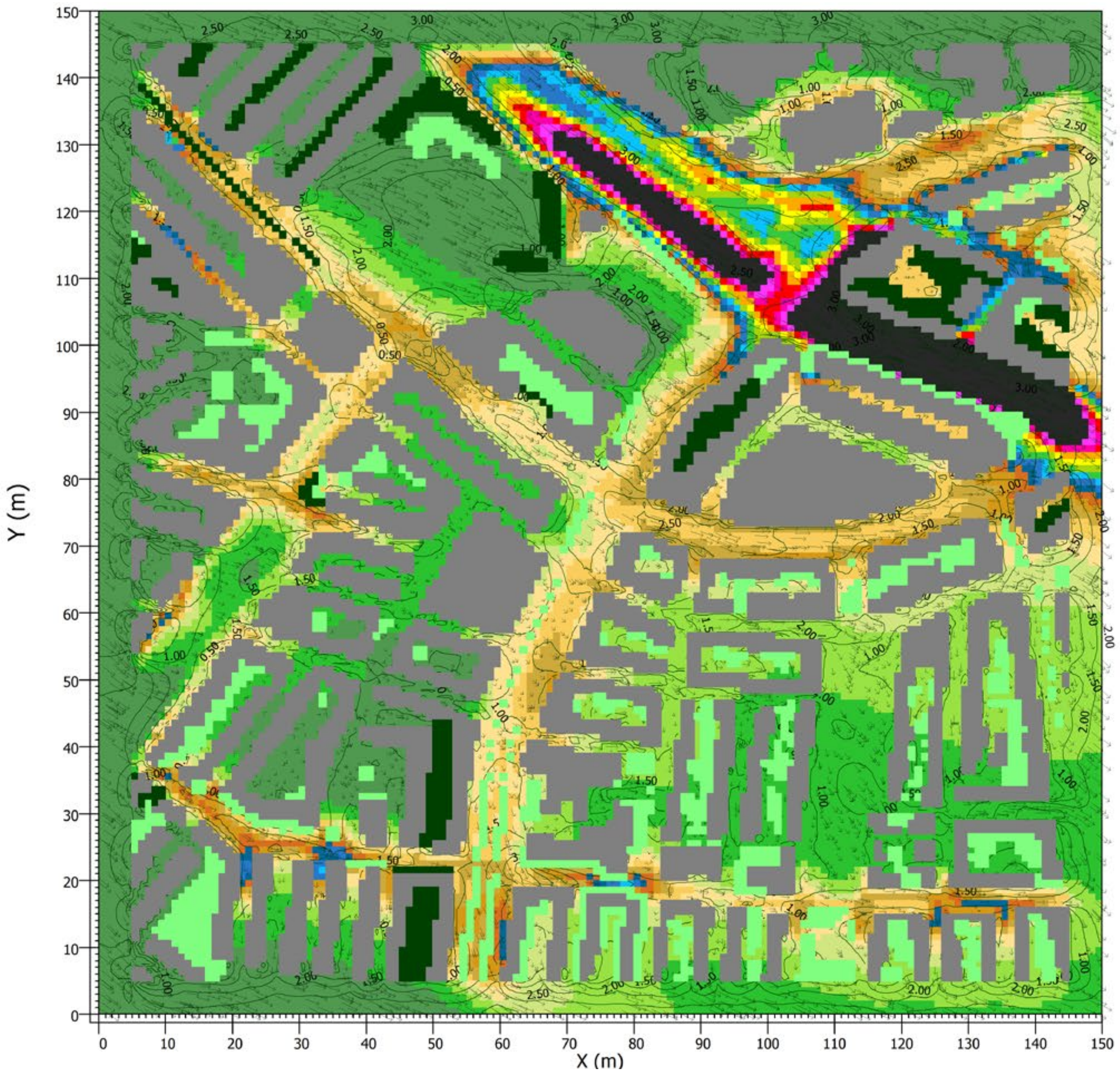
Centrum Configuration 1 Autumn
08:00:07 15.09.2012
x/y cut at z= 2





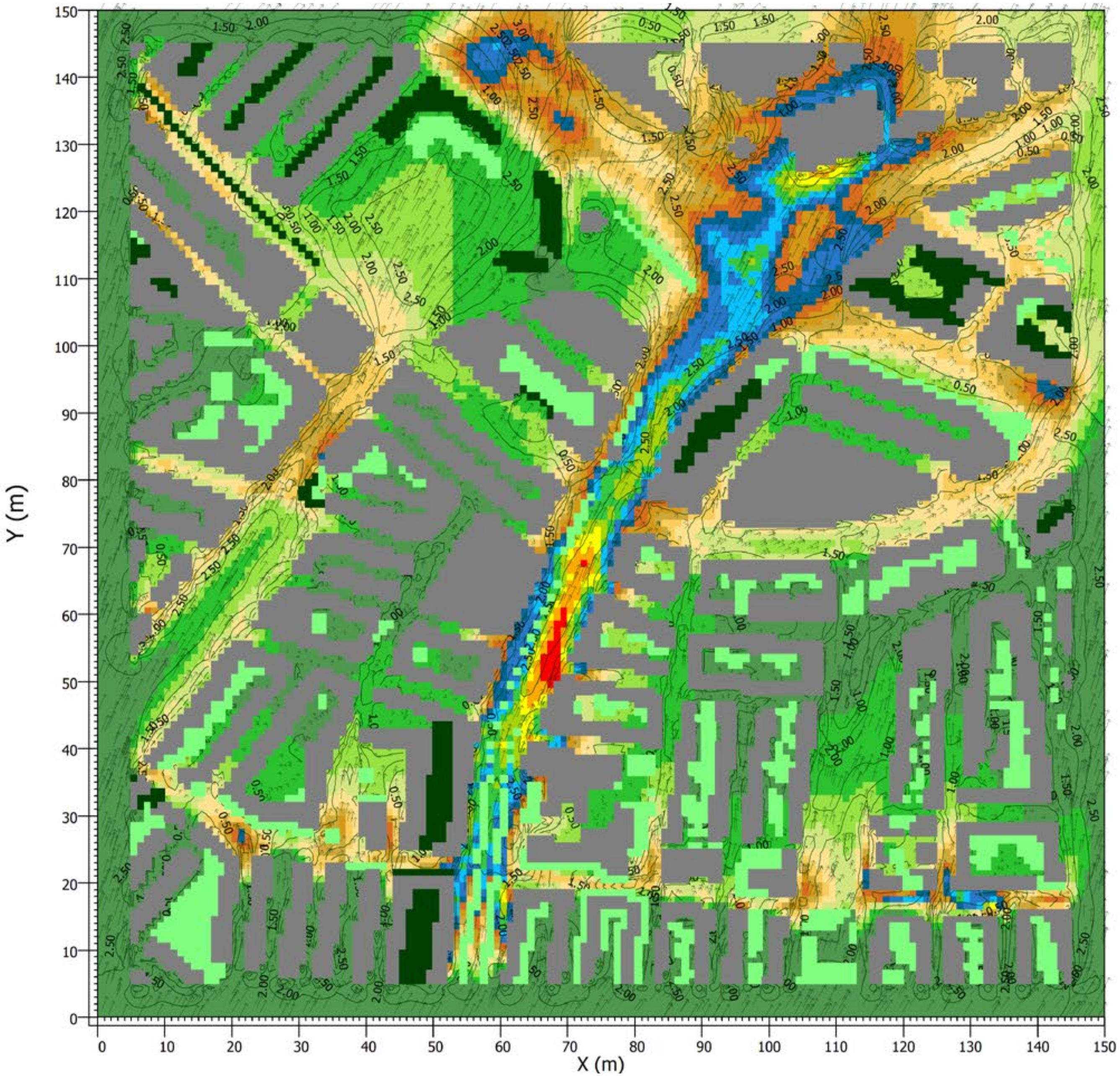
Charlois Configuration 1 Spring
08:00:07 15.04.2012

x/y cut at z= 2



NO2 Concentration

- unter 5.00 µg/m³
- 5.00 bis 10.00 µg/m³
- 10.00 bis 15.00 µg/m³
- 15.00 bis 20.00 µg/m³
- 20.00 bis 25.00 µg/m³
- 25.00 bis 30.00 µg/m³
- 30.00 bis 35.00 µg/m³
- 35.00 bis 40.00 µg/m³
- 40.00 bis 45.00 µg/m³
- 45.00 bis 50.00 µg/m³
- 50.00 bis 55.00 µg/m³
- 55.00 bis 60.00 µg/m³
- 60.00 bis 65.00 µg/m³
- 65.00 bis 70.00 µg/m³
- 70.00 bis 75.00 µg/m³
- 75.00 bis 80.00 µg/m³
- 80.00 bis 85.00 µg/m³
- 85.00 bis 90.00 µg/m³
- 90.00 bis 95.00 µg/m³
- über 95.00 µg/m³

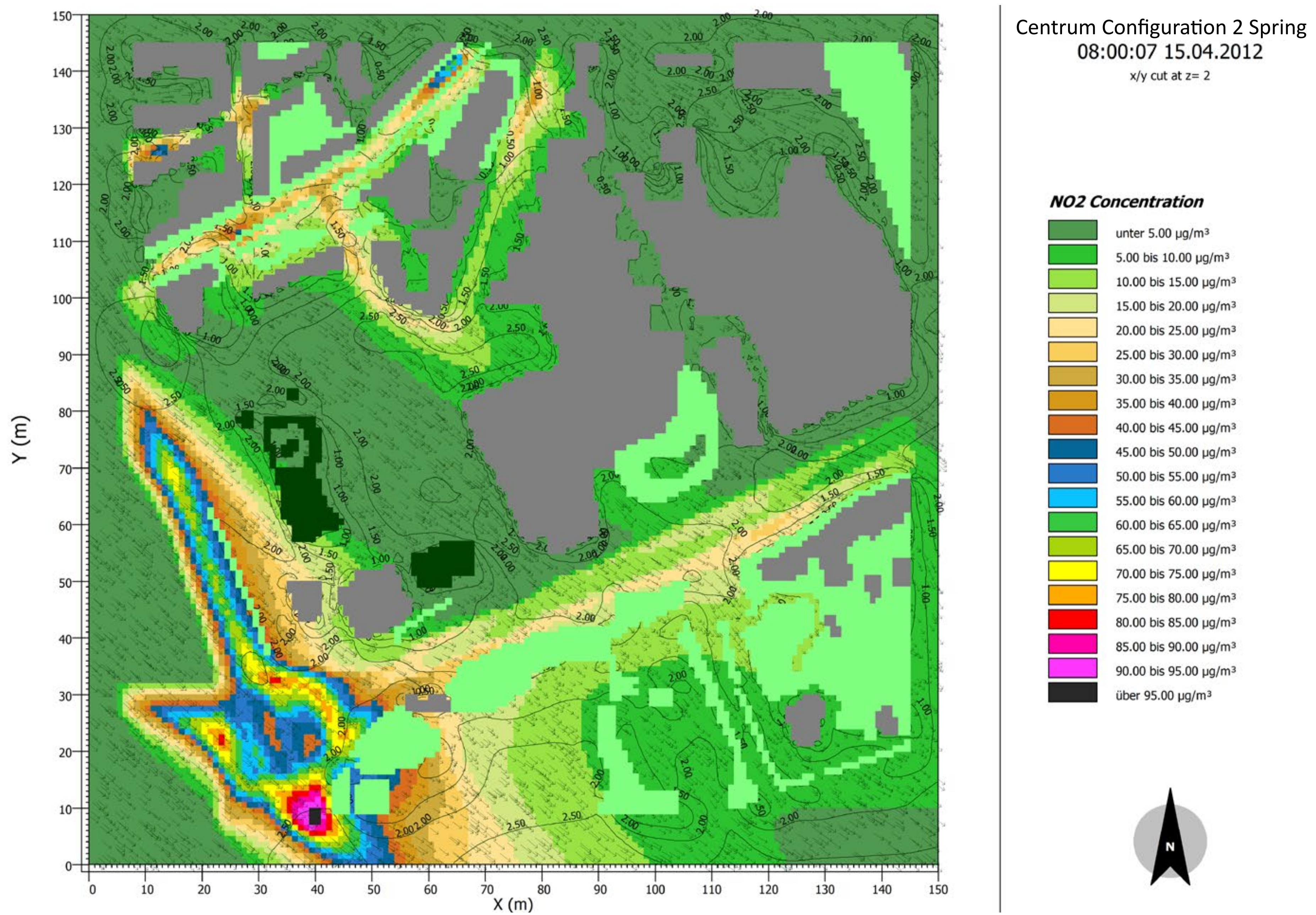


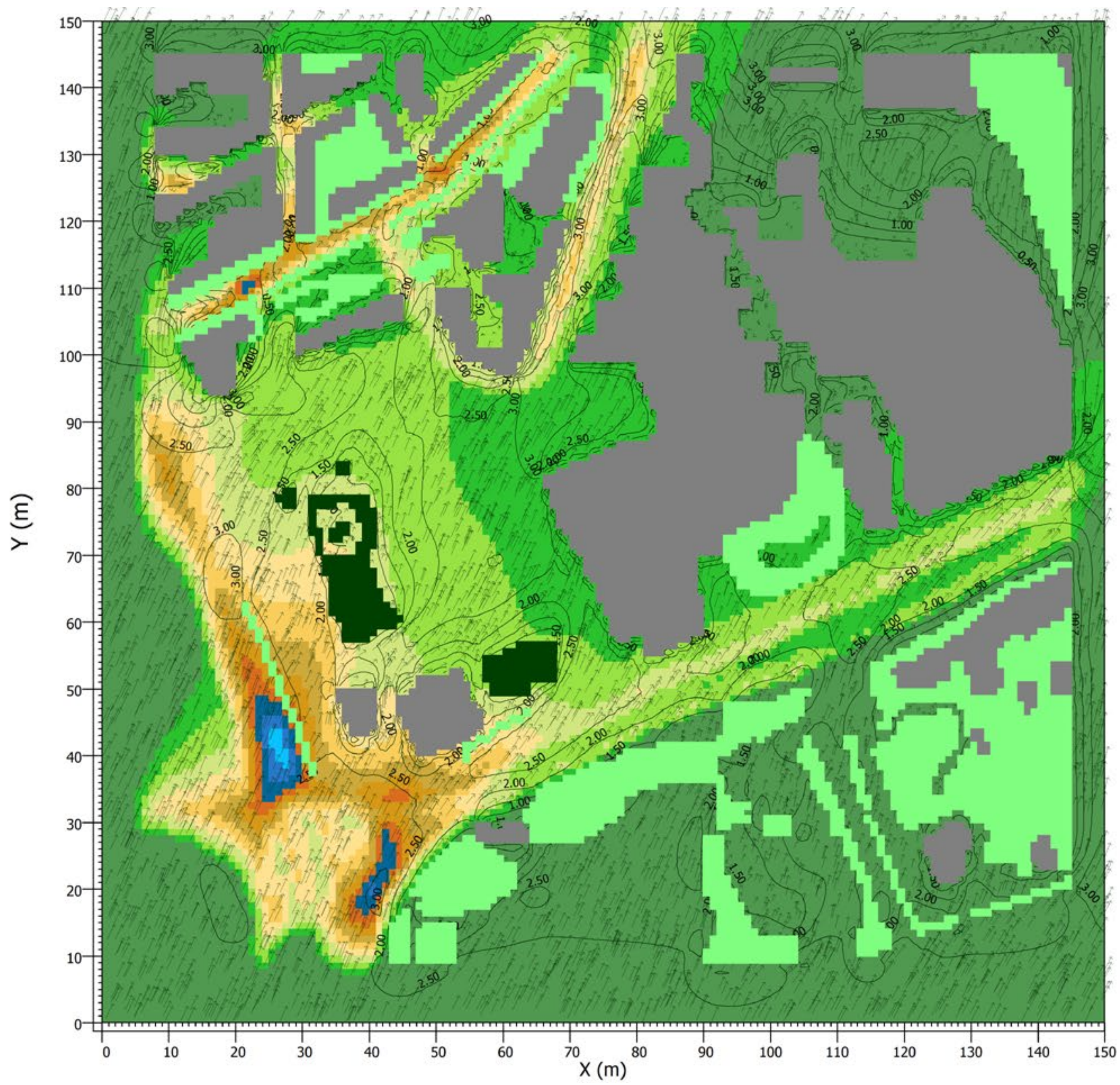
Charlois Configuration 1 Autumn
15.09.2012
x/y cut at z= 2

NO2 Concentration

unter 5.00 µg/m³
5.00 bis 10.00 µg/m³
10.00 bis 15.00 µg/m³
15.00 bis 20.00 µg/m³
20.00 bis 25.00 µg/m³
25.00 bis 30.00 µg/m³
30.00 bis 35.00 µg/m³
35.00 bis 40.00 µg/m³
40.00 bis 45.00 µg/m³
45.00 bis 50.00 µg/m³
50.00 bis 55.00 µg/m³
55.00 bis 60.00 µg/m³
60.00 bis 65.00 µg/m³
65.00 bis 70.00 µg/m³
70.00 bis 75.00 µg/m³
75.00 bis 80.00 µg/m³
80.00 bis 85.00 µg/m³
85.00 bis 90.00 µg/m³
90.00 bis 95.00 µg/m³
über 95.00 µg/m³

N


Centrum Configuration 2 Spring
08:00:07 15.04.2012
x/y cut at z= 2
NO2 Concentration
unter 5.00 µg/m³
5.00 bis 10.00 µg/m³
10.00 bis 15.00 µg/m³
15.00 bis 20.00 µg/m³
20.00 bis 25.00 µg/m³
25.00 bis 30.00 µg/m³
30.00 bis 35.00 µg/m³
35.00 bis 40.00 µg/m³
40.00 bis 45.00 µg/m³
45.00 bis 50.00 µg/m³
50.00 bis 55.00 µg/m³
55.00 bis 60.00 µg/m³
60.00 bis 65.00 µg/m³
65.00 bis 70.00 µg/m³
70.00 bis 75.00 µg/m³
75.00 bis 80.00 µg/m³
80.00 bis 85.00 µg/m³
85.00 bis 90.00 µg/m³
90.00 bis 95.00 µg/m³
über 95.00 µg/m³
N
X (m)
Y (m)

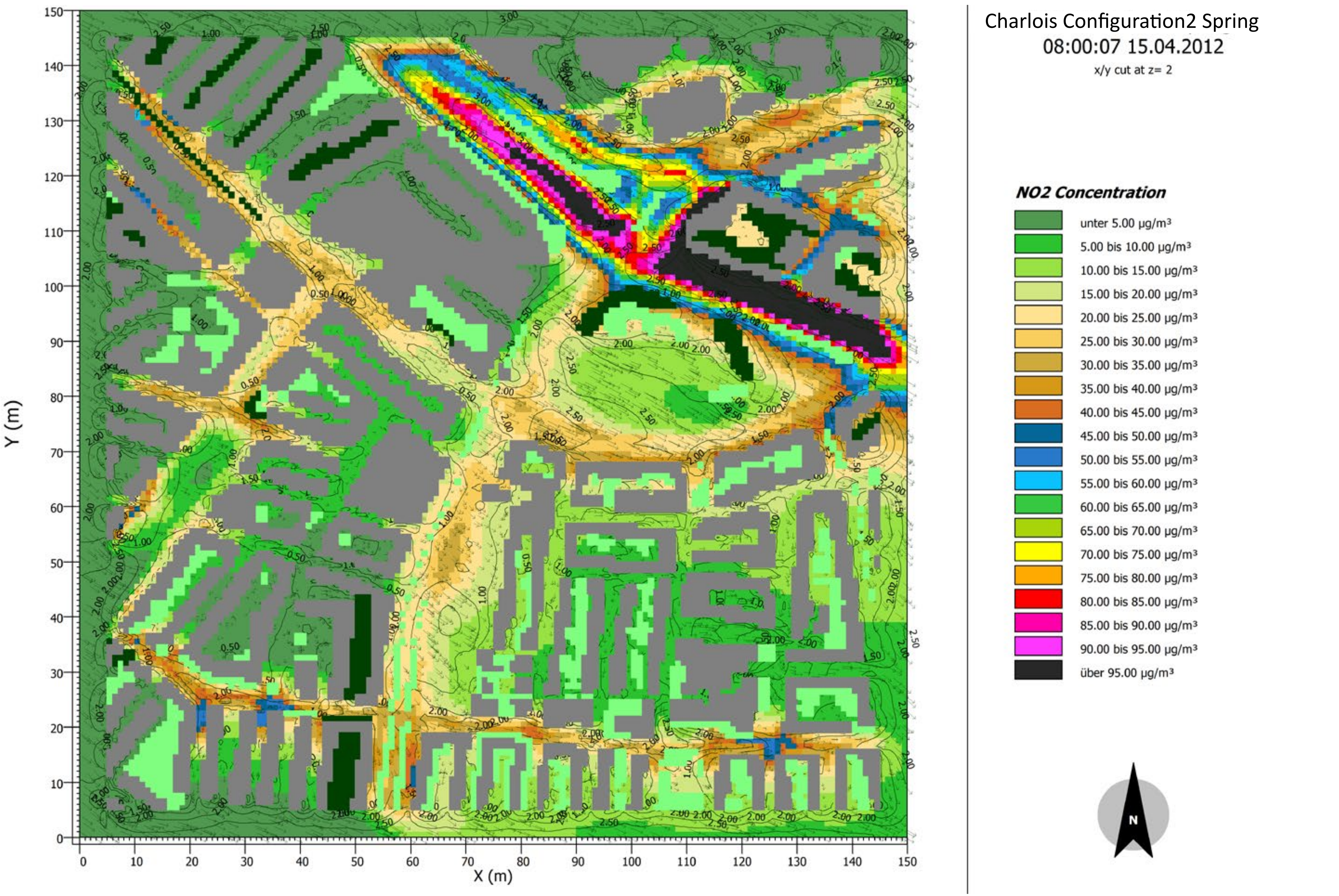


Centrum Configuration2 Autumn
08:00:07 15.09.2012

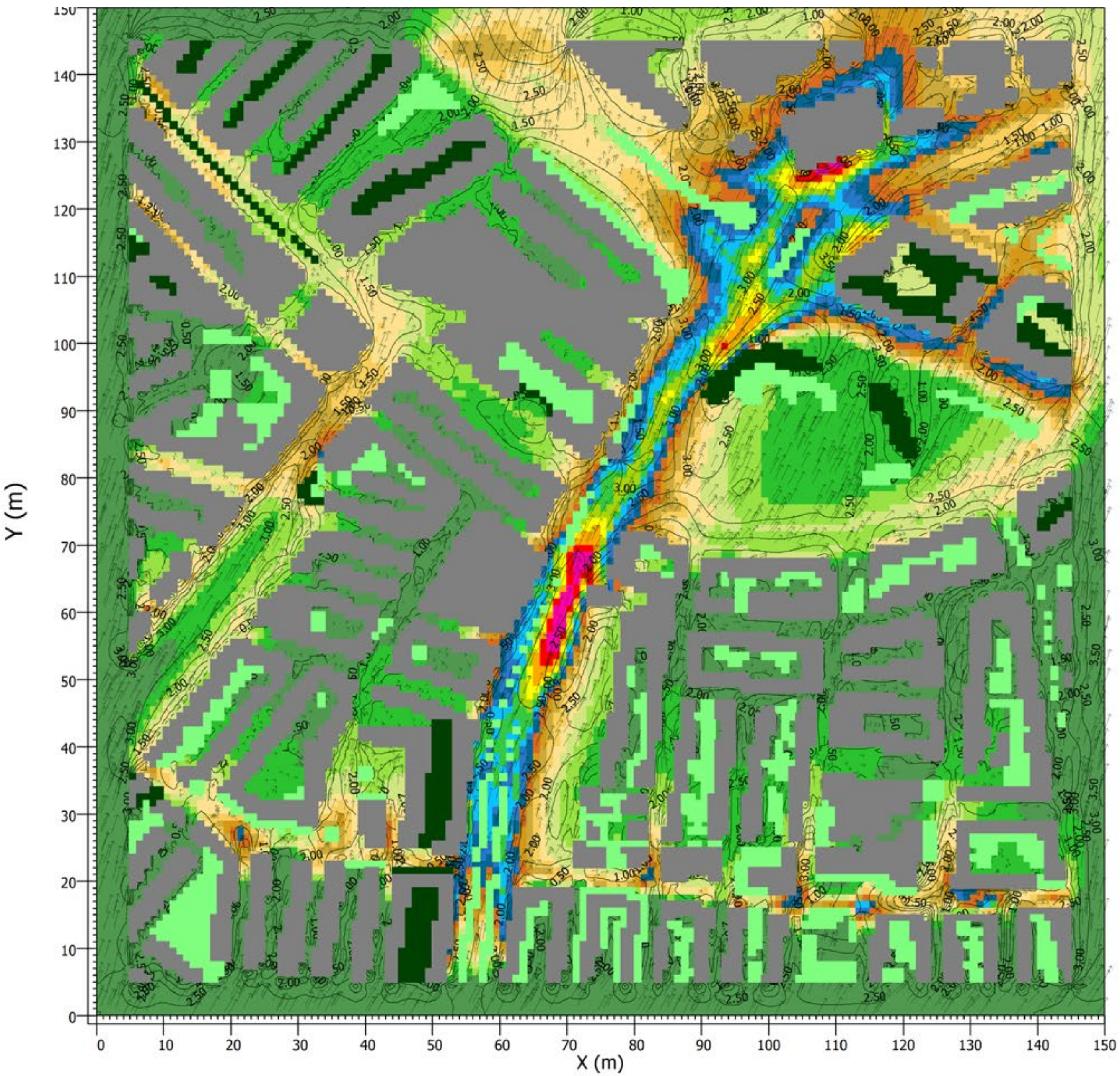
x/y cut at z= 2

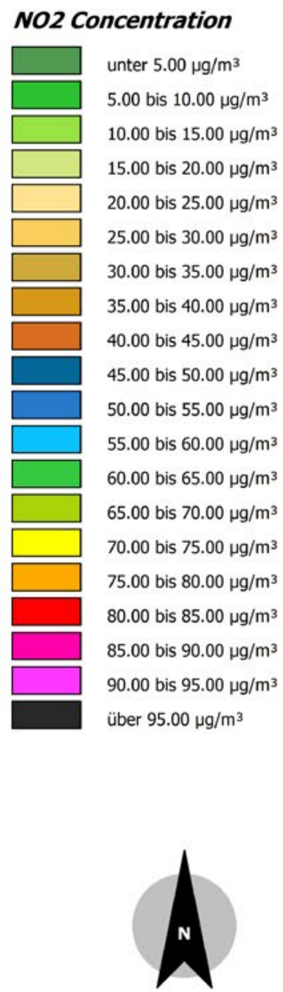
NO2 Concentration

- unter 5.00 µg/m³
- 5.00 bis 10.00 µg/m³
- 10.00 bis 15.00 µg/m³
- 15.00 bis 20.00 µg/m³
- 20.00 bis 25.00 µg/m³
- 25.00 bis 30.00 µg/m³
- 30.00 bis 35.00 µg/m³
- 35.00 bis 40.00 µg/m³
- 40.00 bis 45.00 µg/m³
- 45.00 bis 50.00 µg/m³
- 50.00 bis 55.00 µg/m³
- 55.00 bis 60.00 µg/m³
- 60.00 bis 65.00 µg/m³
- 65.00 bis 70.00 µg/m³
- 70.00 bis 75.00 µg/m³
- 75.00 bis 80.00 µg/m³
- 80.00 bis 85.00 µg/m³
- 85.00 bis 90.00 µg/m³
- 90.00 bis 95.00 µg/m³
- über 95.00 µg/m³

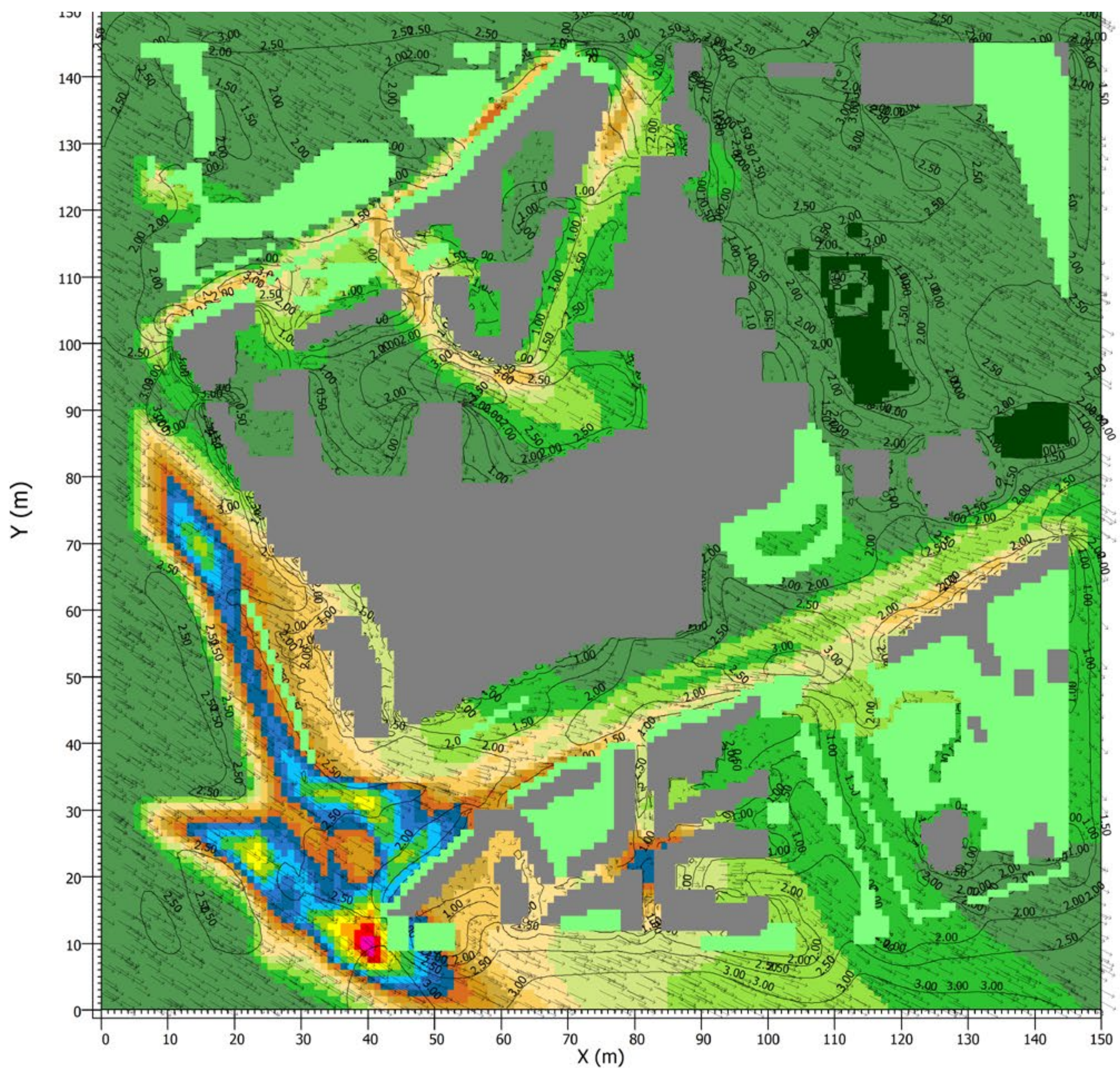

Charlois Configuration2 Spring
08:00:07 15.04.2012
x/y cut at z= 2
NO2 Concentration
unter 5.00 µg/m³
5.00 bis 10.00 µg/m³
10.00 bis 15.00 µg/m³
15.00 bis 20.00 µg/m³
20.00 bis 25.00 µg/m³
25.00 bis 30.00 µg/m³
30.00 bis 35.00 µg/m³
35.00 bis 40.00 µg/m³
40.00 bis 45.00 µg/m³
45.00 bis 50.00 µg/m³
50.00 bis 55.00 µg/m³
55.00 bis 60.00 µg/m³
60.00 bis 65.00 µg/m³
65.00 bis 70.00 µg/m³
70.00 bis 75.00 µg/m³
75.00 bis 80.00 µg/m³
80.00 bis 85.00 µg/m³
85.00 bis 90.00 µg/m³
90.00 bis 95.00 µg/m³
über 95.00 µg/m³
X (m)
Y (m)
N

Charlois Configuration 2 Autumn
08:00:07 15.09.2012
x/y cut at z= 2





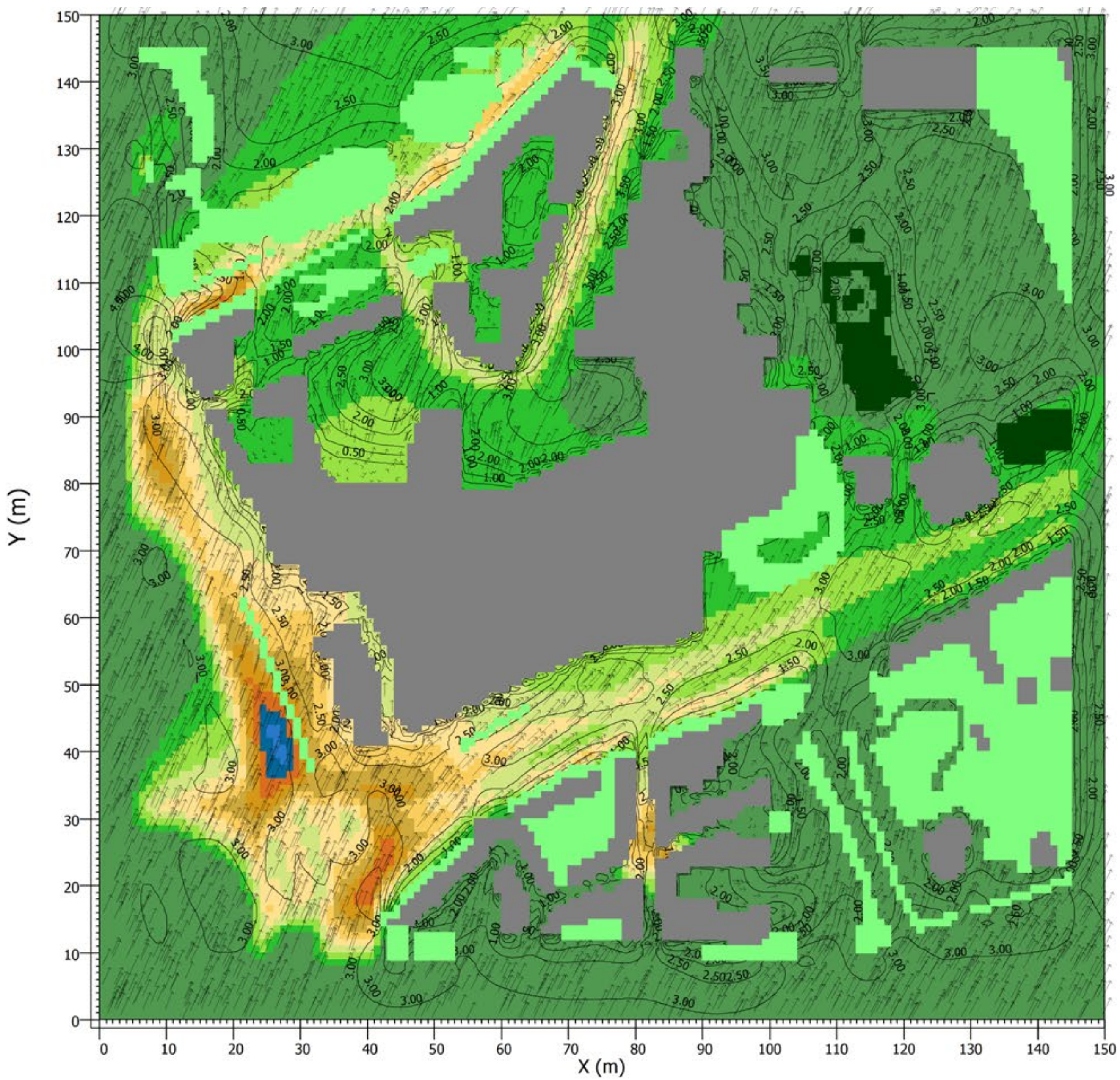
Centrum Configuration 3 Spring
08:00:07 15.04.2012
x/y cut at z= 2



NO2 Concentration

- unter 5.00 µg/m³
- 5.00 bis 10.00 µg/m³
- 10.00 bis 15.00 µg/m³
- 15.00 bis 20.00 µg/m³
- 20.00 bis 25.00 µg/m³
- 25.00 bis 30.00 µg/m³
- 30.00 bis 35.00 µg/m³
- 35.00 bis 40.00 µg/m³
- 40.00 bis 45.00 µg/m³
- 45.00 bis 50.00 µg/m³
- 50.00 bis 55.00 µg/m³
- 55.00 bis 60.00 µg/m³
- 60.00 bis 65.00 µg/m³
- 65.00 bis 70.00 µg/m³
- 70.00 bis 75.00 µg/m³
- 75.00 bis 80.00 µg/m³
- 80.00 bis 85.00 µg/m³
- 85.00 bis 90.00 µg/m³
- 90.00 bis 95.00 µg/m³
- über 95.00 µg/m³

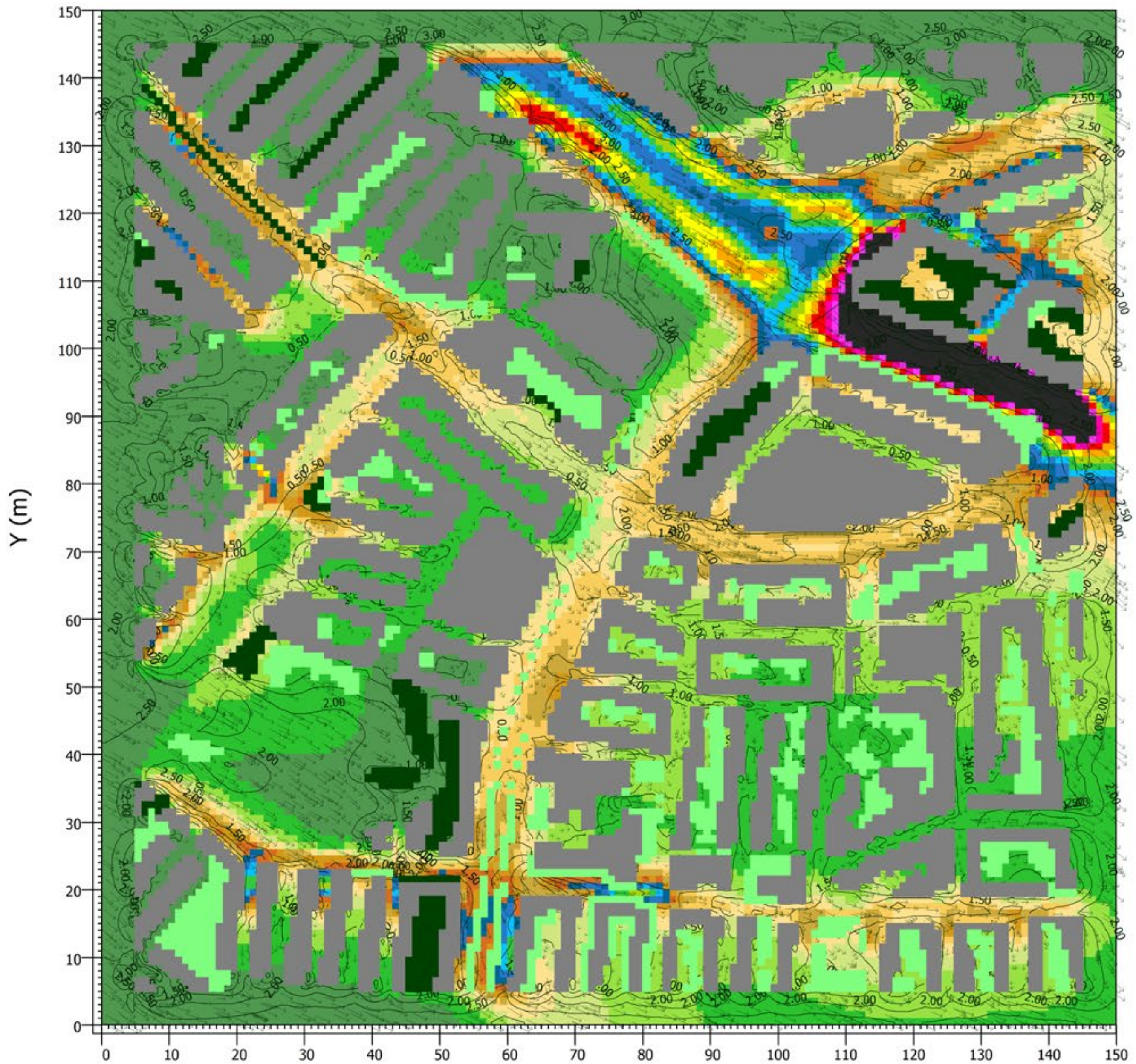
N



Centrum Configuration 3 Autumn

08:00:07 15.09.2012

x/y cut at z= 2

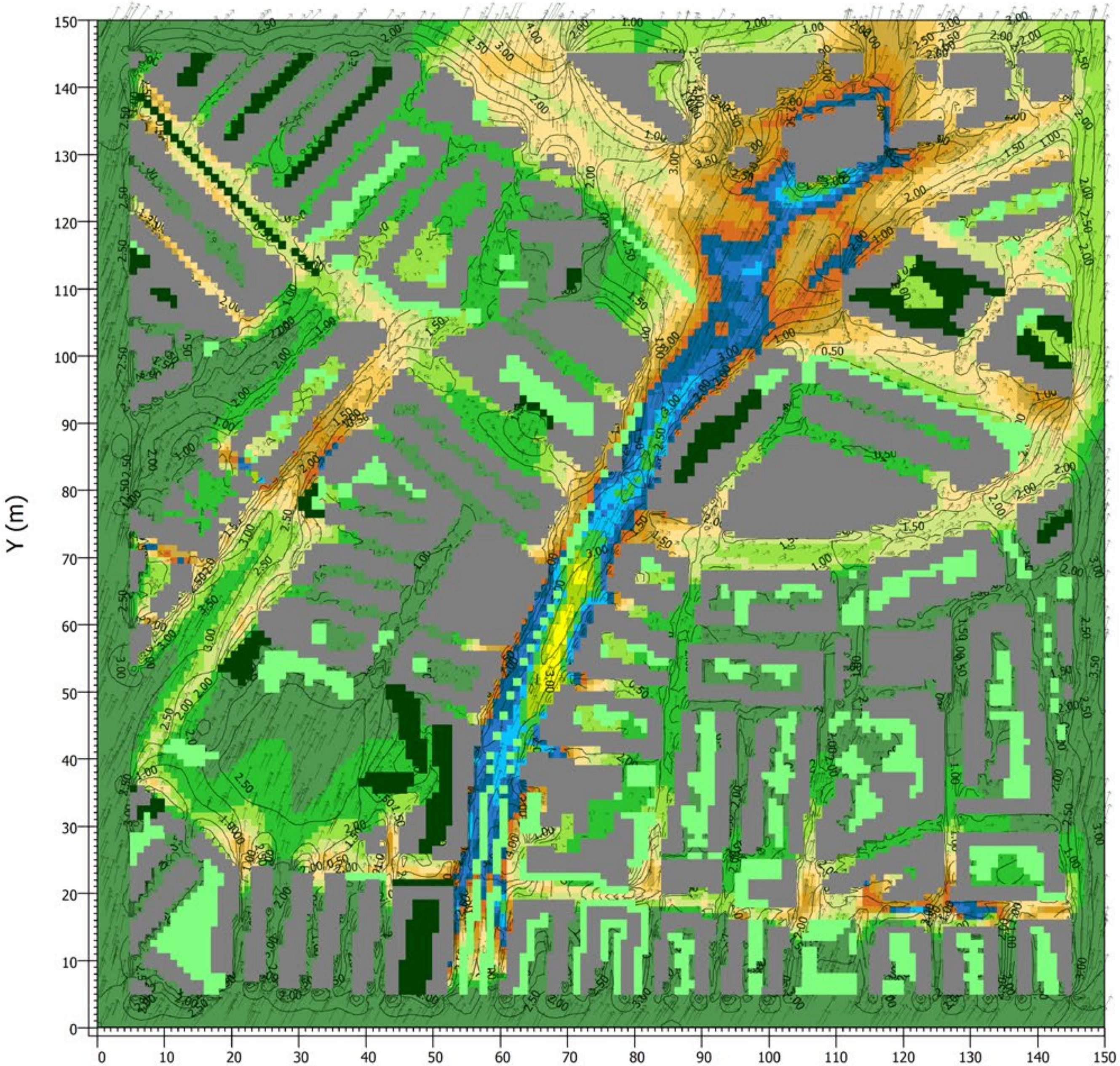


Charlois Configuration 3 Spring
15.04.2012

x/y cut at z= 2

NO2 Concentration

- unter 5.00 µg/m³
- 5.00 bis 10.00 µg/m³
- 10.00 bis 15.00 µg/m³
- 15.00 bis 20.00 µg/m³
- 20.00 bis 25.00 µg/m³
- 25.00 bis 30.00 µg/m³
- 30.00 bis 35.00 µg/m³
- 35.00 bis 40.00 µg/m³
- 40.00 bis 45.00 µg/m³
- 45.00 bis 50.00 µg/m³
- 50.00 bis 55.00 µg/m³
- 55.00 bis 60.00 µg/m³
- 60.00 bis 65.00 µg/m³
- 65.00 bis 70.00 µg/m³
- 70.00 bis 75.00 µg/m³
- 75.00 bis 80.00 µg/m³
- 80.00 bis 85.00 µg/m³
- 85.00 bis 90.00 µg/m³
- 90.00 bis 95.00 µg/m³
- über 95.00 µg/m³



Charlois Configuration 3 Autumn

15.09.2012

x/y cut at z= 2

NO2 Concentration

- unter 5.00 µg/m³
- 5.00 bis 10.00 µg/m³
- 10.00 bis 15.00 µg/m³
- 15.00 bis 20.00 µg/m³
- 20.00 bis 25.00 µg/m³
- 25.00 bis 30.00 µg/m³
- 30.00 bis 35.00 µg/m³
- 35.00 bis 40.00 µg/m³
- 40.00 bis 45.00 µg/m³
- 45.00 bis 50.00 µg/m³
- 50.00 bis 55.00 µg/m³
- 55.00 bis 60.00 µg/m³
- 60.00 bis 65.00 µg/m³
- 65.00 bis 70.00 µg/m³
- 70.00 bis 75.00 µg/m³
- 75.00 bis 80.00 µg/m³
- 80.00 bis 85.00 µg/m³
- 85.00 bis 90.00 µg/m³
- 90.00 bis 95.00 µg/m³
- über 95.00 µg/m³