Spatial variation of particulate air pollution in Christchurch and Nelson/Richmond during winter 2008

Photo by Jeff Smith

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Spatial variation of particulate air pollution in Christchurch and Nelson/Richmond during winter 2008

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Executive Summary

The objectives of this study were to:

- Provide a preliminary assessment of the spatial variation of PM_{10} concentrations across airsheds in Christchurch and Nelson/Richmond.

- Illustrate how Councils may potentially use the mobile monitoring technique as an input to any review they may undertake on their air quality monitoring networks in terms of meeting AQNES Regulation 15.

- Present a case study (Nelson/Tasman) to show how the data collected by the mobile monitoring platform can be used to help identify the sources of pollution within an airshed and understand the transport of pollutants between airsheds.

A vehicle-based mobile monitoring system was used to assess spatial variation of particulate pollution. The monitoring campaigns were performed on winter nights between June and August 2008 in the Nelson-Richmond and Christchurch areas. Monitoring was undertaken for a total of seven and eight nights in Nelson-Richmond and Christchurch respectively. The results from two monitoring campaigns are presented focusing on describing the spatial variability of particulate matter concentrations within these three urban areas.

In the monitored urban areas the observed spatial distribution of particulate matter (PM_1, $PM_{2.5}$, PM_{10} and BC) is consistent with residential combustion being the major contributor to air pollution on winter nights. Large gradients were observed between residential and non-residential areas with lower concentrations observed in commercial areas that are not active at night time.

In general, most of the monitoring sites currently operating in the airsheds of Nelson, Richmond and Christchurch appear to be located within high concentration areas. Therefore these sites are useful in meeting the monitoring requirements as defined by the NES. However, from a scientific point of view of trying to understand the distribution and behaviour of pollutants in the airsheds, pollution gradients are generally not captured by the NES sites. The whole coverage of the stations is biased towards highly populated areas leaving a relatively big gap in understanding regarding the variation of PM_{10} concentrations across these urban areas.

The preliminary results presented in this report indicate that the concentrations observed in the shallow valley extending south-west of Richmond are more strongly controlled by local emissions rather than pollutant transport within the valley.

Black carbon measurements were used to identify the sources that control the particulate matter concentration in Nelson-Richmond. The use of δC as a tracer for wood combustion showed results consistent with other source identification techniques.

This report shows that the mobile sampling can be a valuable tool in gathering information about the spatial distribution of pollution in urban areas. The report offers some preliminary analysis from the field campaign held last winter and shows a number of the potentially useful ways analysis can be performed.

1. Introduction

1.1. Regulation and sources of particulate matter in New Zealand

The Air Quality National Environmental Standards (AQNES) of New Zealand took effect in October 2004 and include a threshold of 50 $\mu g/m^3$ for 24-hour average concentrations of respirable particulate matter (PM_{10}). Exceedances of the AQNES for PM_{10} have been observed at around 30 urban areas within New Zealand and home heating has been widely identified as the main cause of air pollution when PM_{10} exceedances occur (MfE 2008). Road traffic emissions are also a notable source of airborne particulate matter in large urban centres such as Auckland (Davy et al. 2008).

The AQNES imposes a requirement for Regional Councils to monitor PM_{10} in airsheds where the ambient standard for PM_{10} is likely to be exceeded. Specifically, Regulation 15 of the AQNES states that monitoring must be conducted at a location where PM_{10} concentrations are likely to be greatest, or exceeded the greatest number of times, within the airshed. Due to the monitoring requirements defined within the AQNES, it is important to understand the spatial variability of PM_{10} concentrations within a particular airshed.

Throughout New Zealand, PM_{10} is generally monitored continuously at only one or two locations within each gazetted airshed, with the exception of the larger urban areas such as Auckland (nine sites) and Christchurch (four). This limited number of monitoring sites may be insufficient to provide a comprehensive spatial assessment of PM_{10} concentrations throughout the airsheds. Permanent PM_{10} monitoring stations are expensive to install and operate so that invariably, a comprehensive spatial coverage of permanent stations is neither practical nor realistic. The most common approach is to use other means to identify the area where PM_{10} concentrations are likely to be greatest, before installing a permanent monitoring station.

1.2. Spatial variation of particulate matter within airsheds

PM_{10} concentrations may vary within airsheds due to spatial variability of emissions (e.g. Wilton 2005, Iremonger & Graham 2007), along with topographical or meteorological influences (Aberkane 2000, Iremonger & Graham 2007). Techniques for assessing spatial variation of PM_{10} concentrations within airsheds include airshed dispersion modelling and survey monitoring. The latter approach was used by Hamilton et al. (2004) to evaluate particulate concentrations at two urban areas near Christchurch. Hamilton et al. (2004) used a handheld Dustrak® portable laser photometer to record data related to PM_{10} concentrations at 20 sites in Rangiora and Kaiapoi. In addition, a Kestrel® handheld instrument was used to obtain manual

observations of wind speed, air temperature and humidity. Due to the "stop and go" nature of the sampling, two hours were required to traverse the 20 sites at both towns.

From sampling over five nights, Hamilton et al. (2004) constructed contour plots based on the 10 measurements taken in each town. The survey identified that highest concentrations were recorded in residential neighbourhoods, which was attributed to burning of solid fuel on domestic heating appliances in those areas.

In another published study of spatial variability in New Zealand, Conway et al. (2007) used the same instruments and technique at ten sites in Invercargill. While highest concentrations were observed in the southern residential suburbs, a complex meteorological environment was reported. Only a limited number of observations are possible when using this technique and this may have been inadequate to identify the spatial pattern at a sufficiently high resolution.

For both of these studies, numerical modelling of air pollution concentrations and meteorology was undertaken using The Air Pollution Model (TAPM), which provided useful information about the distribution of pollution under various topographical locations and meteorological scenarios. However, the model performance was compromised due to the coarse spatial resolution of the emission data.

Airshed particulate modelling has been conducted for some New Zealand urban areas, including Christchurch (Zawar-Reza et al. 2005), Hastings (Gimson 2006) and Rotorua (Fisher et al. 2007). These models demonstrate the variable nature of particulate concentrations throughout airsheds in New Zealand, depending on factors including the spatial distribution of emissions, topography and meteorological characteristics.

Mobile measurements, using instruments mounted in a vehicle, offer a complimentary means of validating or reinforcing conclusions drawn from modelling, or may be used as an alternative means of assessing spatial variation in airsheds where no modelling has been undertaken. Advances in miniaturisation have made it possible for air quality instrumentation to be deployed on mobile platforms and to be operated whilst on the move. Although relatively labour intensive, this method maximises the utility of single instruments and provides information about the spatial variability of pollutant concentrations.

While the temporal variability at greater than weekly timescales is difficult to capture with these kinds of measurements, there are several advantages of mobile monitoring. Recent developments in air quality monitoring technology mean that it is now possible to build a relatively low cost mobile monitoring system that provides good quality, real time data at high spatial resolution. Such a mobile measurement system could

provide data to allow the assessment of the variation of contaminant concentrations across an airshed for the purposes of identifying hot spots for monitoring sites, validating airshed dispersion models, or for input to the development or improvement of air quality management strategies.

Olivares et al. (2008) developed a system for measuring spatial patterns of particulate matter, including PM_{10}, and other associated variables from a moving vehicle. This system was successfully trialled during winter 2007 at Alexandra, Christchurch and Auckland (Olivares et al., 2008). The next stage of this project was to conduct airshed monitoring using the mobile system, followed by data analysis and assessment of spatial variation of pollution within airsheds.

1.3. Project Objectives

The objectives of this project are to:

- Provide a preliminary assessment of the spatial variation of PM_{10} concentrations across airsheds in Christchurch and Nelson/Richmond.
- Illustrate how Councils may potentially use the mobile monitoring technique as an input to any review they may undertake on their air quality monitoring networks in terms of meeting AQNES Regulation 15
- Present a case study (Nelson/Tasman) to show how the data collected by the mobile monitoring platform can be used to help identify the sources of pollution within an airshed and understand the transport of pollutants between airsheds.

2. Method

2.1. Instrumentation configuration on vehicle

Instruments were located both inside the vehicle and in a rooftop enclosure (Figure 2-1). A purpose-built conduit was used to bring cables and sample tubes through the vehicle rear passenger window, to and from the rooftop enclosure.

2.2. Measurement of Particulate Matter

A GRIMM Model 107 Dust Monitor (Grimm Aerosol Technik GmbH & Co. KG, Germany) was housed in the rooftop enclosure, with power and data cabling via the window conduit. The GRIMM monitor is a low-volume sampler that uses a light scattering technique to continuously measure particle number concentration and size

distribution in an air stream. Particulate mass concentrations (µg m^{-3}) are calculated internally by the instrument, making some assumptions about particle density and optical properties. Because particle density information is generally unavailable, it is recommended to calibrate the GRIMM by comparing results with those obtained by another measurement technique (Maletto et al. 2003).

Figure 2-1: Mobile monitoring vehicle and (inset) rooftop enclosure. Rooftop instrumentation (including Airmar and temperature + relative humidity sensor) and air intake is shown.

An equivalent GRIMM Model 107 Dust Monitor was collocated at the Environment Canterbury permanent monitoring station, to identify measurement differences between the GRIMM PM_{10} sampler and the official monitors. To assess the relative performance of the GRIMM used for mobile monitoring during the Christchurch campaign, the monitoring vehicle was also parked for one hour at the same location. Because the main objective of this system is to investigate relative concentrations throughout airsheds, a full calibration of the GRIMM is unnecessary.

The GRIMM is well suited to this mobile application due to the fast response time with near-continuous (six second time resolution), simultaneous measurements of PM_{10}, $PM_{2.5}$ and PM_1 mass values. Because the instrument provides this information on particle size distributions, concentrations of fine particles are identified, which are of particular interest because of the associated health effects.

2.3. Air intake

The intake was designed and built by NIWA with a convex top-piece (Figure 2-2) intended to direct air and particulate matter into the intake tube. Air was drawn through the system intake using a pump (Charles Austen Pumps – model CAPEX V2-SE) capable of 17L/min maximum flow. Sample air was then isokinetically drawn from the main intake into the GRIMM and aethelometer using the dedicated pumps of these instruments.

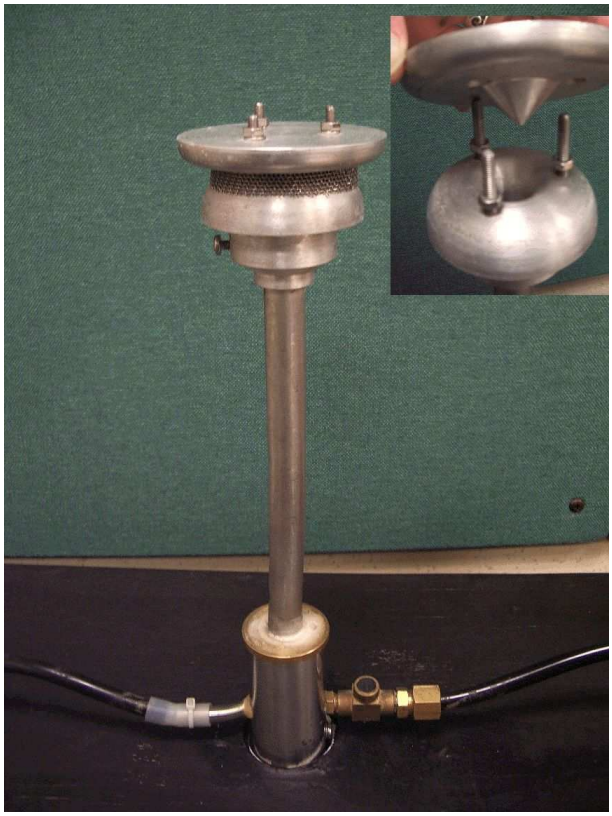


Figure 2-2: Sample tube intake, showing (inset) convex top-piece designed to direct flow into the tube.

This arrangement was developed in an effort to overcome sampling losses that were previously observed when the system was operated at moderate vehicle speeds with the regular GRIMM intake (Olivares et al. 2008). The purpose-built intake and installation of the separate pump successfully overcame this issue, as demonstrated by Figure 2-3. Figure 2-3 shows the comparison between the data obtained during the

2007 and 2008 campaigns in terms of the ratio PM_1:PM_{10} against total wind speed (wind at the tip of the inlet, i.e., wind speed + vehicle speed). For a combustion dominated aerosol this ratio is expected to be between 0.5 and 0.9 and it is expected to be insensitive to meteorological conditions at timescales of less than 1 day. As Figure 2-3 shows, during the 2007 campaign the observed PM_1:PM_{10} ratio did show a marked inclrease when the total wind speed reached 5m/s (~18km/hr). During the 2008 campaigns the data shows no significant increase in the PM_1:PM_{10} ratio even at total wind speeds of more than 20m/s (~75km/hr).

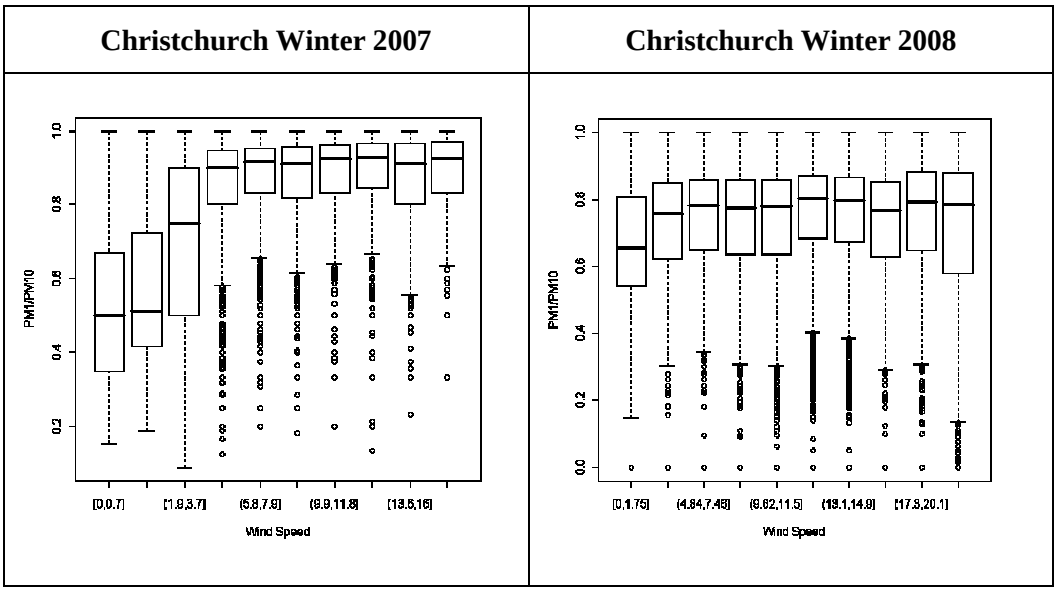


Figure 2-3: Ratio of PM_1:PM_{10} versus absolute wind speed. Data are those obtained over the entire Christchurch campaigns.

The behaviour of the PM_1:PM_{10} ratio during the 2007 campaign is suspected to be a consequence of a design or construction failiure in the original GRIMM inlet because it was not performing as specified by the manufacturer.

2.4. Measurement of Black Carbon

A Magee Scientific (Berkeley, California) AE22 aethalometer was housed in the vehicle with a sample tube passing through the window conduit into the rooftop enclosure. The aethalometer measures the optical absorption of particles on a filter through which an air stream is drawn. The optical absorption provides an index of mass concentration of 'Black' or Elemental Carbon (BC) particles that in urban environments are generally associated with coal or diesel combustion. The aethalometer used in this study uses two wavelengths: 880 nm (near-IR) to quantify BC and 370 nm (UV) that provides a qualitative measure of aromatic organic compounds. The dual wavelength measurement may be used for identification of different sources; for example, vehicle emissions vs. wood smoke from home heating

or biomass combustion. Near real time measurements are possible with a time resolution from five seconds to one hour.

2.5. Meteorology

A PB100 (AIRMAR Technology Corporation, MILFORD, New Hampshire) ultrasonic weather station was mounted on the system's rooftop enclosure (Figure 2-1). The weather station provides measurements of wind speed and wind direction (both absolute and relative to the vehicle movement), air temperature, relative humidity and barometric pressure.

2.6. Position of vehicle

A handheld GPSmap 76CSx (Garmin International Inc., Olathe, Kansas, USA) was used to obtain location and movement information. The instrument was fitted inside the in-car enclosure and an active antenna was put on the exterior of the vehicle to use the full capacity of the sensor. This instrument was capable to give accurate horizontal and vertical position (within 10m) even in very covered locations. Furthermore, the internal barometer offers a better vertical accuracy, necessary when analysing topographic effects on the measurements.

2.7. Data acquisition and accessory equipment

All the RS232 based instruments were interfaced to a PC (IBase – IB881) via an eight serial ports to USB adapter (Qualtech ESU2-100). A NIWA developed application was deployed for system control and data acquisition such that data were stored at 1 second intervals.

The PC also provided an on-screen display of instantaneous data and diagnostic information in real time. All instruments and equipment were ultimately powered from a dedicated 12VDC lead-acid battery power supply, with a 12VDC-240VAC inverter used to power the aethalometer and DC-DC converters as required for other applications.

2.8. System configuration and operation

The GRIMM and Airmar instruments were installed in the rooftop box. Inside the vehicle, the Aethalometer enclosure along with the GPS, serial-USB interface and power converters, were positioned on the rear seat, directly behind the driver. The system was operated by two people. One person was driving while the second

assessed the performance of the instruments, assisted with navigation and notified the driver when it was necessary to stop for maintenance.

2.9. Experimental trials – winter 2007

The mobile system was successfully trialled during winter 2007 in Alexandra, Christchurch and Auckland (Olivares et al. 2008). Results of the trial showed that the mobile monitoring system may be applied to: evaluation of variability of PM concentrations both within and between airsheds; identification of potential locations for new monitoring sites within airsheds to ensure compliance with AQNES Regulation 15; and assessment of the representativeness of data collected by existing monitoring sites.

2.10. Locations of monitoring campaigns – winter 2008

During winter 2008, mobile monitoring of airborne particulate was undertaken in Nelson, Richmond and Christchurch (Figure 2-4). Table 2-1 shows the campaign dates and the number of nights when measurements were obtained. Monitoring was usually undertaken for a 5-7 hour period between 1900hr and 0100hr, with the exception of the Christchurch campaign that included two nights (5th and 6th August) when monitoring was undertaken continuously between 1900hr and 0700hr.

2.11. Measurement routes

For the mobile campaign in Christchurch, different routes were monitored each night. Weather conditions on the first night (4 August) were characterised by windy and showery conditions, with the result that PM_{10} concentrations were largely homogeneous throughout the area that was monitored. Therefore, data from the first night were ignored from analysis.

Following this, an east-west transect from Sumner to Yaldhurst was monitored for two complete nights. Further monitoring included nights when the vehicle was driven on a largely north-south transect from the Port Hills to the northern suburbs of Christchurch. Two nights were also spent undertaking concentrated monitoring, with intensive coverage of the Southern area from Woolston to Wigram (12 August) and in the suburbs around St Albans (13 August).

For the Nelson-Richmond area, measurements followed a circuit across the two cities for six of the seven monitoring nights. The circuit covered central Richmond in an almost grid-like pattern, then travelled towards Nelson through the inland valleys and crossed central Nelson. Finally, the circuit covered the coastal areas of Nelson towards

Richmond passing by Tahunanui. The last night (27th of July), a different route was selected that crossed the original circuit in order to provide information about the gradients between the inland and coastal "legs" of the original circuit. Also, during the last night of monitoring in Nelson-Richmond, the circuit was extended southward towards Brightwater and Wakefield in an attempt to make a preliminary assessment of the extent of the urban plume from Richmond.

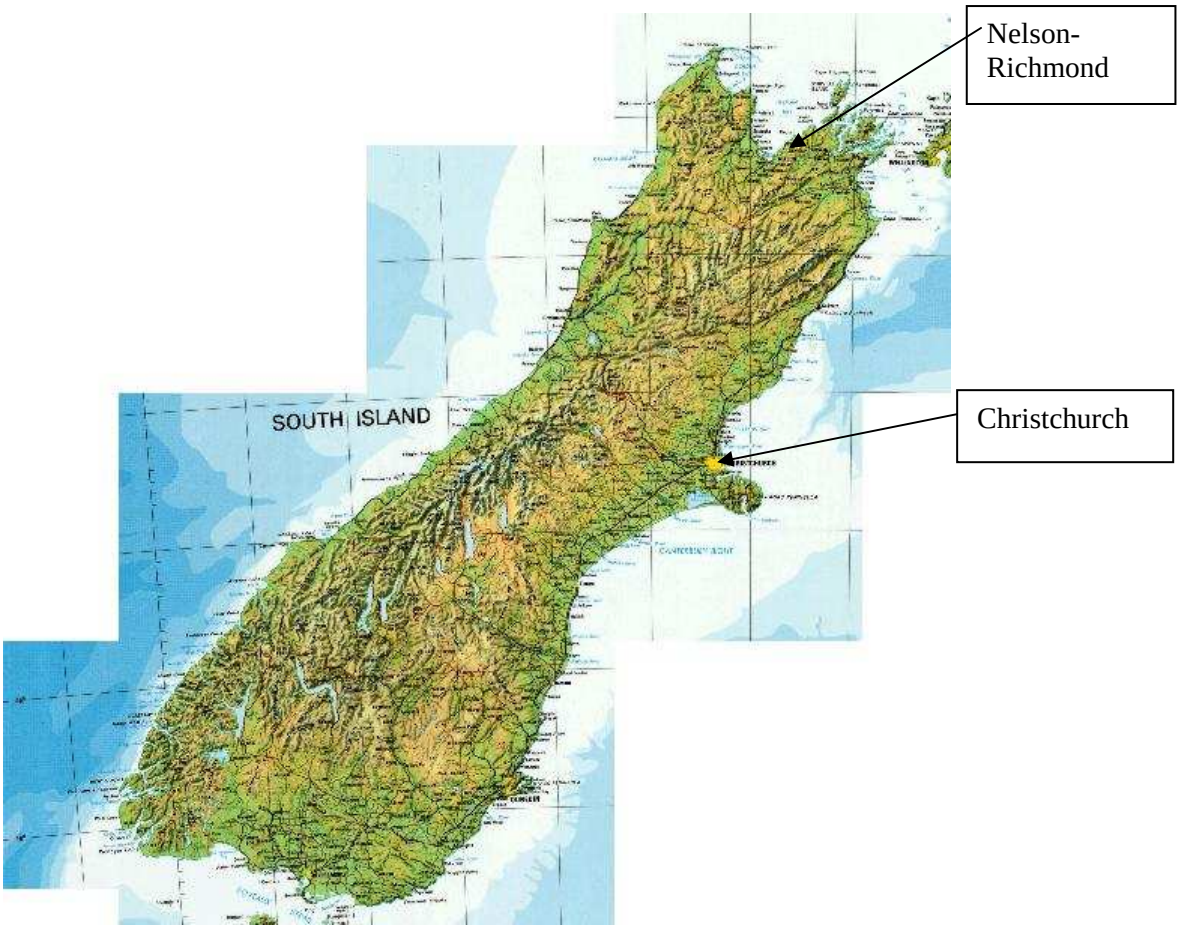


Figure 2-4: Map of the South Island of New Zealand, showing locations of the two monitoring campaigns.

Table 2-1: Measurement dates of the mobile monitoring undertaken at Nelson and Christchurch during winter 2008.

	Measurement dates	Number of nights
Nelson - Richmond	19 July – 27 July	7
Christchurch	4 August – 20 August	8

2.12. Comparison of PM_{10} monitoring instruments

To compare results from the GRIMM particulate monitor with data obtained using an NES compliant instrument, the mobile system was parked next to Environment Canterbury's monitoring site in Woolston (Christchurch) for one hour at 2200hr on 6 August. The mean of 10 minute average PM_{10} concentrations measured by the NES compliant Filter Dynamics Measurement System (FDMS) between 2200hr and 2300hr was 44 $\mu g/m^3$. The mean PM_{10} concentration recorded by the mobile system GRIMM during the same period on 6 August was 53 $\mu g/m^3$.

While the GRIMM measurement was somewhat higher than the FDMS record, the disparity is not substantial and is not a great concern *per se*, because it is unrealistic to expect a robust evaluation of instrument performance by comparing only one hour of data. For a longer term investigation of GRIMM performance, another Model 107 Dust Monitor was operated next to the FDMS sample intake at Woolston between 6 August and 20 August 2008.

Hourly average concentrations from the FDMS versus GRIMM are plotted in Figure 2-5. The scatter of hourly average data in Figure 2-5 demonstrates that a robust comparison cannot be expected from comparison of data from only one hour. The linear regression line (r^2=0.89) in Figure 2-5 suggests that the GRIMM underreport concentrations by about 15%, compared to the FDMS results, at PM_{10} concentrations of 150 $\mu g/m^3$.

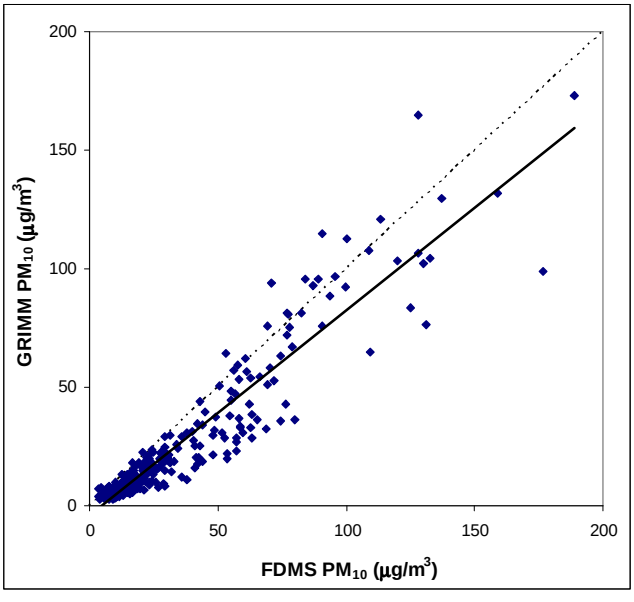


Figure 2-5 **Scatterplot of hourly average PM_{10} data obtained from an FDMS permanently installed at Woolston and a GRIMM instrument, collocated between 6 August and 20 August 2008. Linear regression line (solid line) has equation *y=0.9x–4* (r^2=0.89) and 1-1 line is plotted for comparison (dotted line). FDMS data were provided by Environment Canterbury.**

Because the analyses in this report are concerned with the spatial distribution, more important than to obtain robust measures of PM_{10} is to assess the relative PM_{10} concentrations. Furthermore, the differences between GRIMM data and FDMS results are shown to be systematic (Figure 2-5) and therefore the GRIMM Model 107 Dust Monitor is well suited for mobile monitoring to evaluate PM_{10} monitoring sites for NES compliance.

3. Christchurch – Results and Discussion

3.1. PM_{10} monitoring network within the Christchurch airshed

Of the four sites indicated in Figure 3-1, where Environment Canterbury continuously monitors PM_{10}, concentrations are invariably highest at the Coles Place and Woolston sites. Two of the monitoring nights in particular (12 and 13 August) were specifically dedicated to focussed investigations to assess the representativeness of the data collected at the Woolston and St Albans monitoring locations for the Christchurch airshed as a whole.

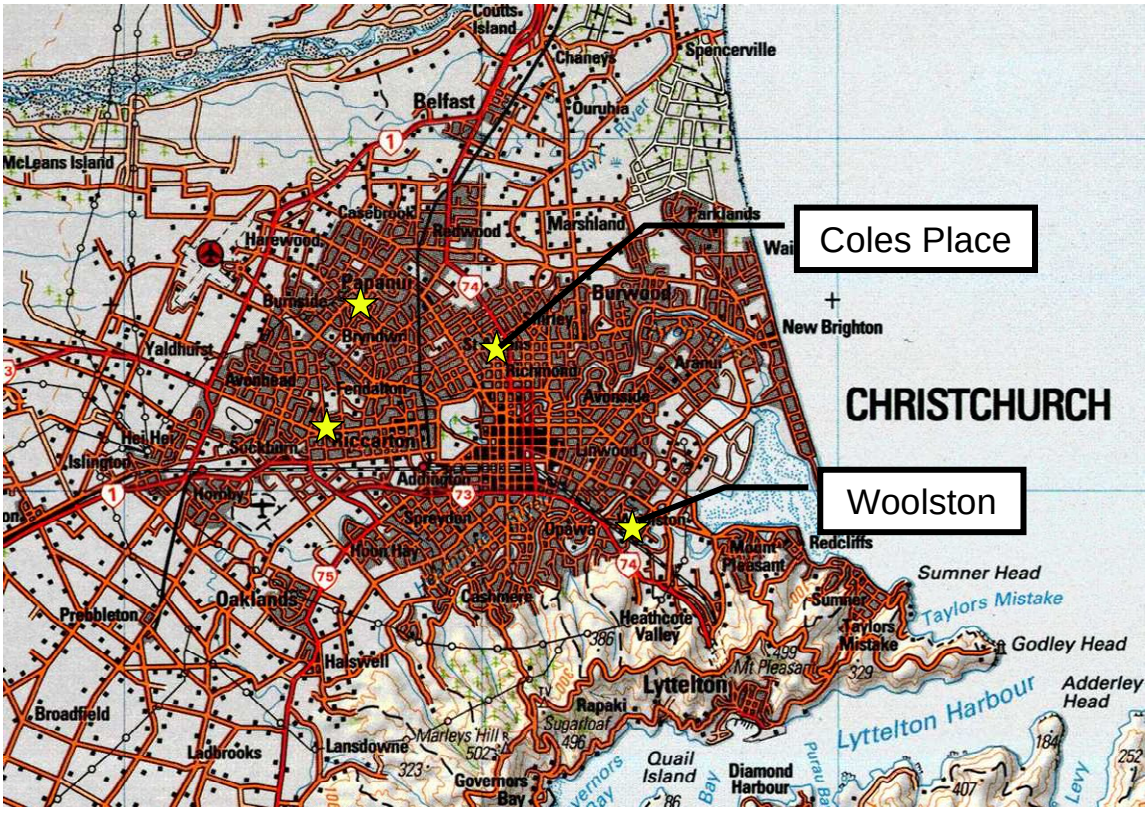


Figure 3-1: Location of sites in Christchurch where Environment Canterbury monitors PM_{10} concentrations on a permanent basis (shown by yellow stars). Coles Place (St Albans) and Woolston monitoring stations are labelled.

3.2. Variation of PM_{10} concentrations across the Christchurch airshed

Data from the entire Christchurch campaign (eight nights over the period 5 to 20 August) were combined and plotted in Figure 3-2. The combined plot provides a general description of where highest concentrations were observed during the entire Christchurch campaign, although some caution is required when interpreting these results.

The first reason for caution is that runs were undertaken over different nights when meteorological conditions may have differed. The spatial variation of concentrations plotted in Figure 3-2 will therefore be confounded to some extent by temporal variability.

Another reason for caution is that some locations were visited more often than others, which would bias results toward the locations that were monitored for a longer period. To help with the interpretation of these results, the transparency in the lower panel of Figure 3-2 corresponds to the amount of time spent on each location. Thus, areas that were visited very often are opaque while areas visited very little are transparent. An analysis and comparison of the amount of time spent in each monitoring grid is provided in Appendix B. Grid Monitoring Time.

Despite these cautionary remarks, the run combined results do provide a useful indication of the relative spatial variability of PM_{10} concentrations.

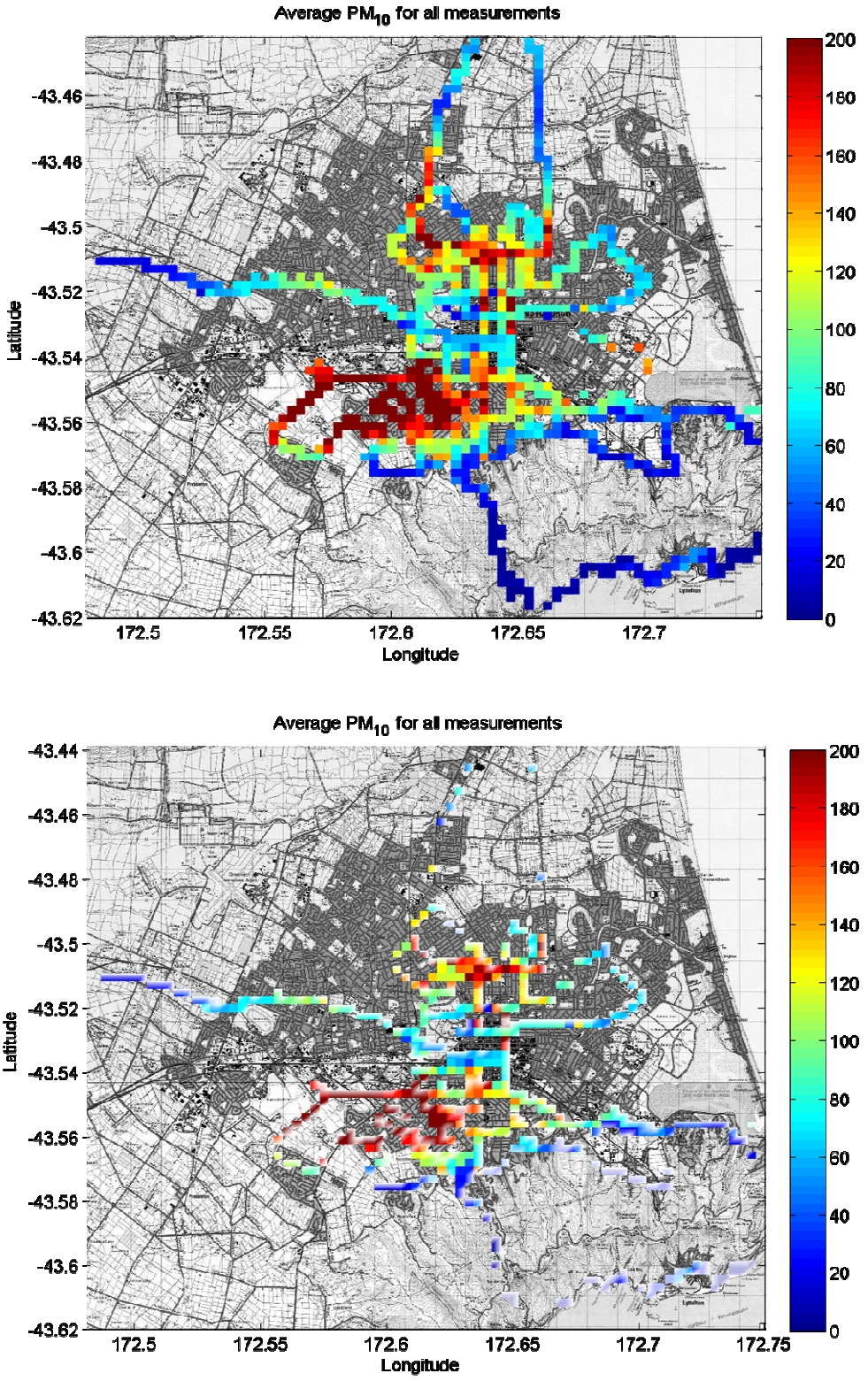


Figure 3-2: **PM_{10} concentrations averaged over ~120m^2 grids, for all nights when the mobile system was active within the Christchurch airshed during the monitoring campaign from 05 August 2008 – 20 August, 2008. Colour scale is PM_{10} concentration (µg/m3). The lower panel incorporates a visibility mask that highlights areas where the system travelled more often (see text for details).**

A plot of isopleths showing areas of equal PM_{10} concentrations is shown in Figure 3-3 and was constructed by interpolation of data points from Figure 3-2. The isopleths are valuable for showing the general pattern of PM_{10} concentrations during the Christchurch campaign. However, some further caution is advised with Figure 3-3 because, due to limitations of time and resources, the entire city area was not monitored during the campaign. It can be seen in Figure 3-2 that data were not collected in some of the western suburbs in particular. Therefore the interpolation and isopleths will not be representative in those suburbs and is indicated as such in Figure 3-2 by the transparency mask.

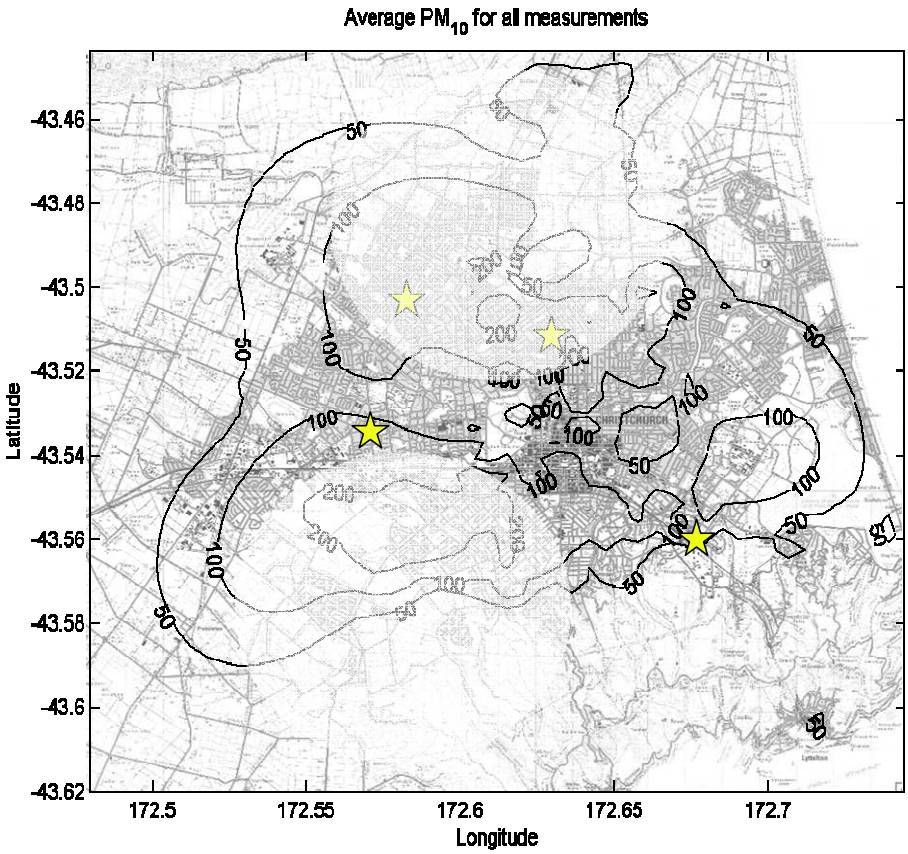


Figure 3-3: Isopleths of PM_{10} concentrations (µg/m^3) averaged for all nights during the Christchurch monitoring campaign from 05 August 2008 – 20 August, 2008. Yellow stars indicate Environment Canterbury PM_{10} monitoring sites. Transparency masks correspond to areas where the contours are most uncertain.

Notwithstanding these cautionary remarks, Figure 3-2 and Figure 3-3 show that PM_{10} concentrations were relatively low in the CBD area of Christchurch during the nights when monitoring was undertaken. Highest PM_{10} concentrations were observed in two general locations: 1) the St. Albans area and adjacent suburbs; and 2) the southern suburbs between Beckenham and Hoon Hay, a short distance from the base of the port hills. These areas were investigated in detail during two nights of intensive monitoring that provide data at a relatively high spatial resolution. Monitoring was focussed on

the southern suburbs during 12 August, while a concentrated investigation of St. Albans and adjacent suburbs was completed the following night (13 August).

In addition, monitoring on the night of 20 August is also investigated more closely, because NES exceedances recorded at St. Albans and Woolston indicate that 20 August was a relatively high pollution night. The detailed results from these objective specific monitoring investigations are presented in the following Sections.

3.3. Representativeness of Woolston and St Albans PM_{10} monitoring sites

The aim of this section is to assess whether highest concentrations in Christchurch occurred in the vicinity of monitoring stations at Woolston and Coles Place during the nights of 12 and 13 August 2008, when mobile monitoring was focussed around these locations. Because the data were only collected over one night at each location, they represent a very preliminary, rather than a definitive assessment of the location of highest 24 hour average PM_{10} concentrations within Christchurch.

Nonetheless, hourly average PM_{10} concentrations were relatively high during the two nights, with peak hourly average concentrations of 128 $\mu g/m^3$ at Woolston (Figure 3-4a) and 194 $\mu g/m^3$ at St Albans (Figure 3-4b) on 12 August 2008. During the following night, 13 August, monitoring was focussed on the suburbs surrounding St Albans and hourly average PM_{10} concentrations at Coles Place peaked at 83 $\mu g/m^3$ (Figure 3-4b). Therefore, the nights of 12 August and 13 August 2008 may be regarded as representative of high pollution nights and this analysis provides a valuable assessment of the location of PM_{10} monitoring sites in Christchurch.

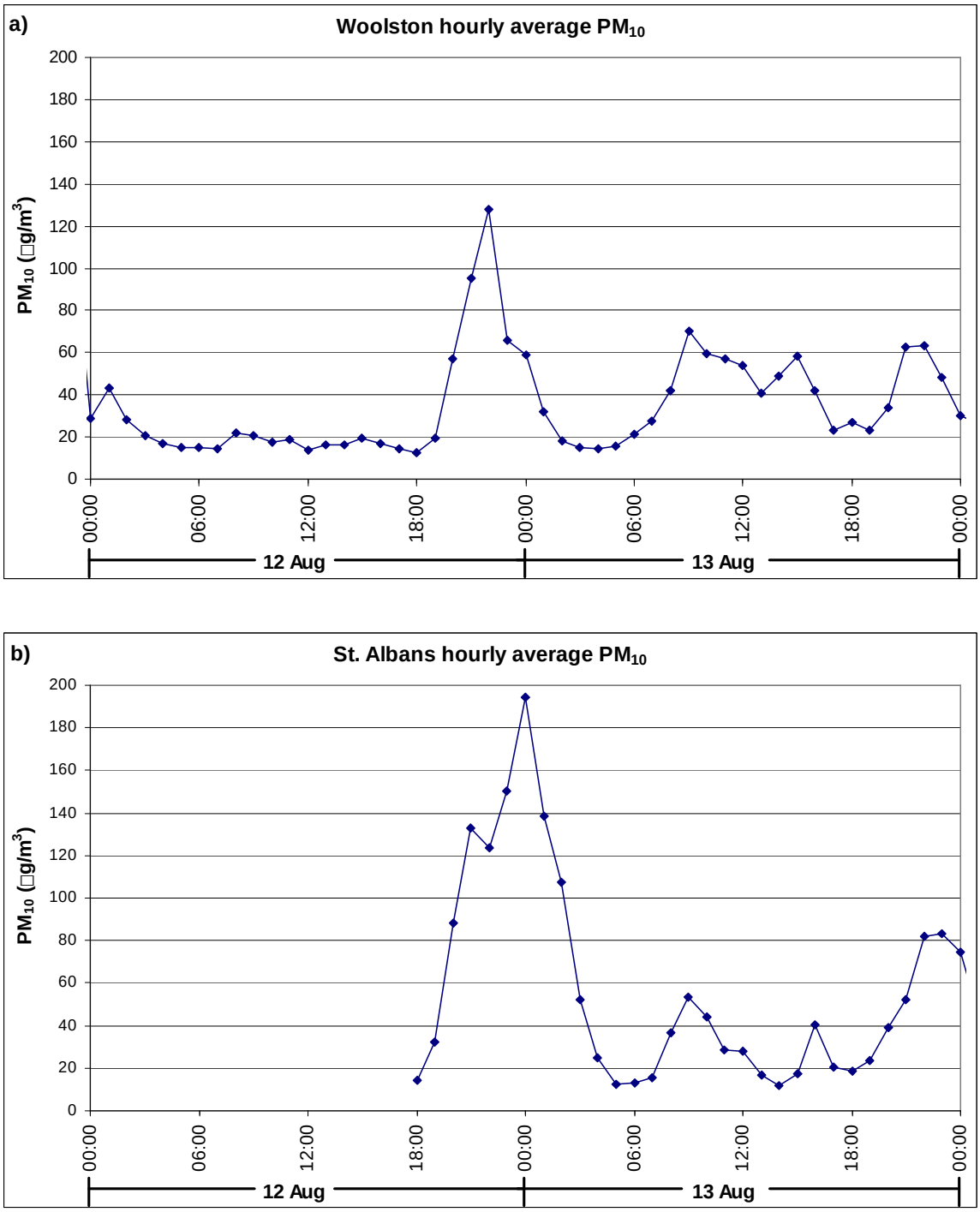


Figure 3-4: **Hourly average PM_{10} concentrations observed at Environment Canterbury monitoring sites at a) Woolston and b) St. Albans, 12-13 August, 2008. Data provided by Environment Canterbury.**

3.3.1. Woolston monitoring site - 12 August 2008

Monitoring was focussed on the suburbs near the Woolston monitoring site between 2000hr on 12 August and 0040hr on 13 August. Two identical routes were completed,

which passed the Woolston monitoring station before meandering through the suburbs to the west and then returning directly to Woolston via Brougham Street. At the end of the monitoring period around midnight, a detour was also taken to the Environment Canterbury Coles Place, St Albans monitoring site. PM_{10} concentrations were averaged over 400m × 400m grids for the entire monitoring period and are plotted in Figure 3-5.

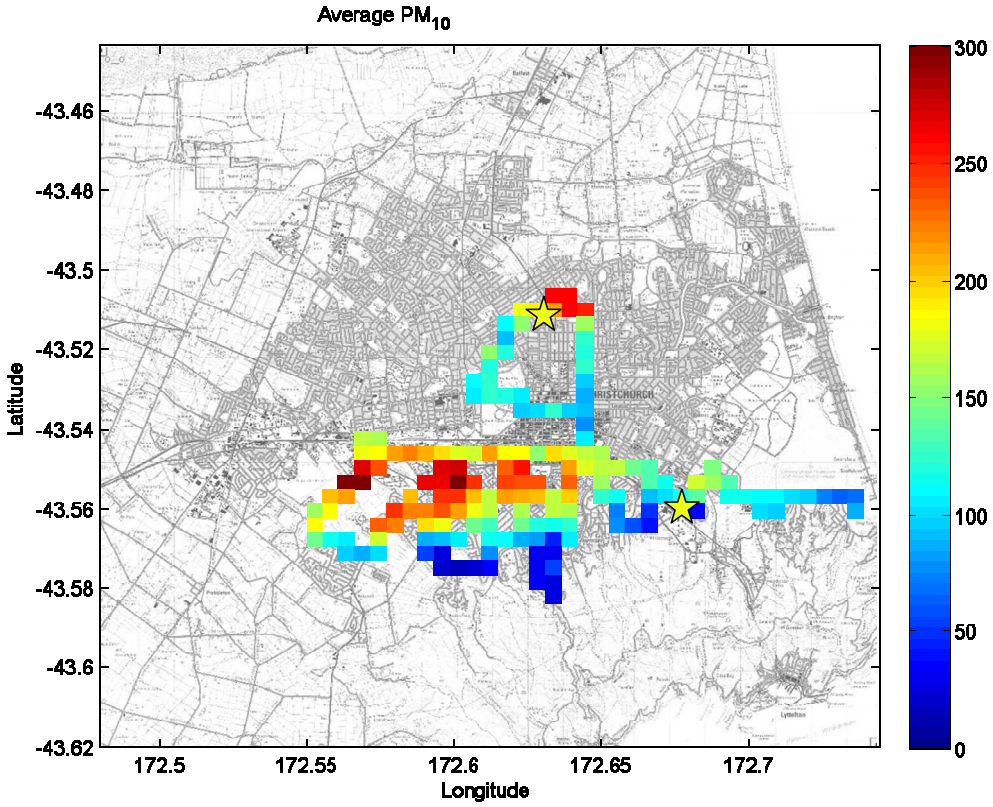


Figure 3-5: PM_{10} concentrations averaged over 400x400m^2 grids, in the vicinity of Woolston monitoring station during the night of 12 August, 2008. Colour scale is PM_{10} concentration (µg/m^3). Yellow stars indicate Environment Canterbury PM_{10} monitoring sites at Woolston and St Albans.

PM_{10} concentrations of around 150 µg/m^3 were recorded by the mobile monitoring system in the vicinity of the Woolston monitoring site (Figure 3-5) and this is consistent with the peak hourly average PM_{10} concentration of 128 µg/m^3 observed at 2200hr at the Environment Canterbury monitoring site at Woolston (Figure 3-4a). PM_{10} concentrations of around 200 µg/m^3 were also measured by the mobile monitoring system in St Albans (Figure 3-5) and this is consistent with the peak hourly PM_{10} concentration of 194 µg/m^3 recorded at midnight at the Environment Canterbury Coles Place monitoring site (Figure 3-4b).

During the mobile monitoring period on 12 August, wind was light and variable at Woolston although a light easterly of around 1m/s was observed during the second trip

around the monitoring route before midnight (Figure 3-6a). At St Albans, windspeeds were lower than the operating threshold of the wind monitoring instruments (<1m/s) for almost the entire period of mobile monitoring on 12 August (Figure 3-6b).

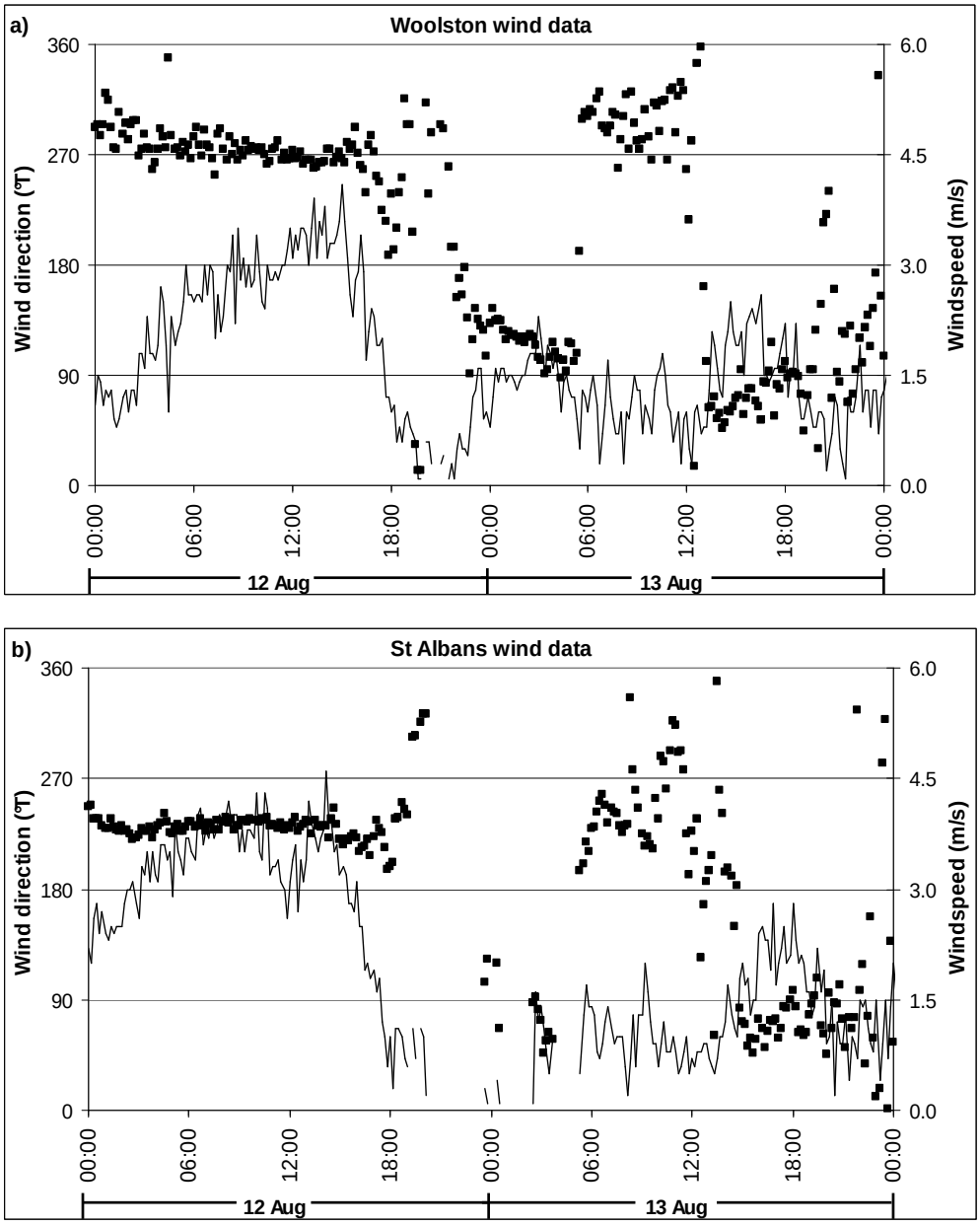


Figure 3-6: 10 minute averages of windspeed (solid line) and wind direction (black squares) recorded at Environment Canterbury air quality monitoring stations at a) Woolston and b) St Albans, 12-13 August, 2008. Missing data are a consequence of windspeed being lower than the operating threshold of the instruments. Data provided by Environment Canterbury.

It should be noted for completeness that while the mobile observations are reasonably consistent with Environment Canterbury monitoring records, the averaging periods for these measurements are different. The Environment Canterbury data are hourly averages, whereas the mobile data are averages from total time spent monitoring

within each 400m^2 grid, which has a maximum period of around two minutes (e.g. Figure 3-7) although longer periods occasionally occurred when the mobile system was parked up. The most common reasons for parking the vehicle were to allow the aethalometer tape to advance (~5min), when collocated next to Environment Canterbury monitoring sites (usually ~10min), or for refreshment stops (up to 20min).

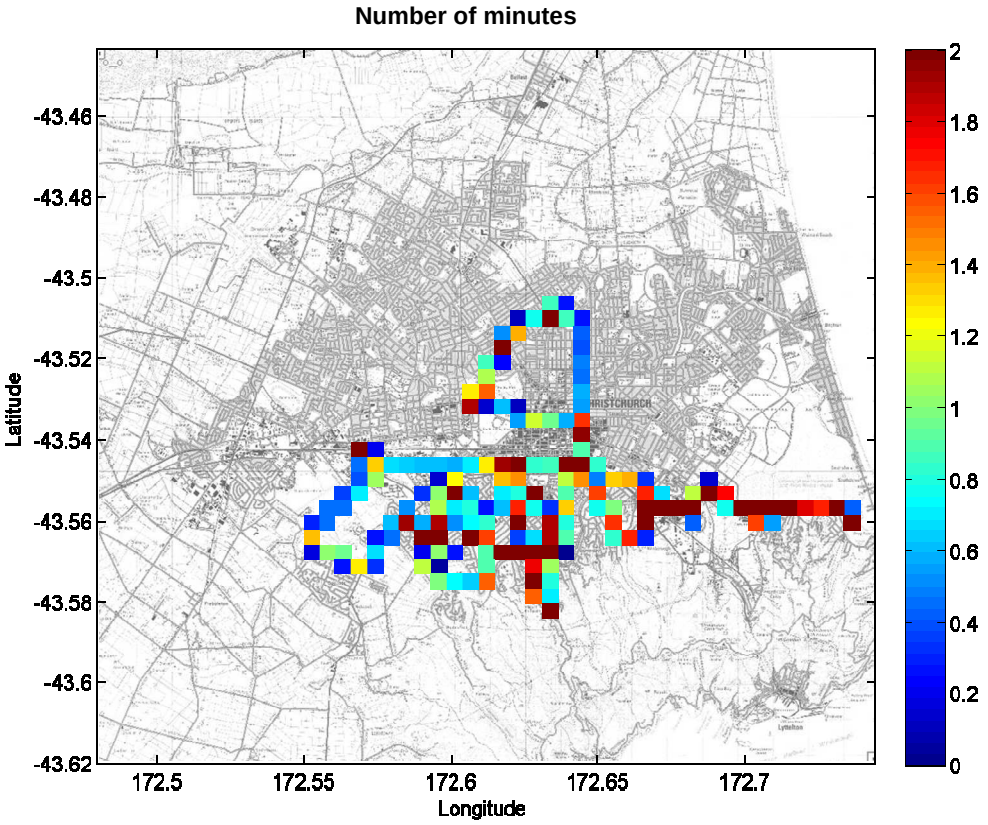


Figure 3-7: Averaging times for monitoring undertaken within 400m^2 grids during the night of 12 August, 2008. Colour scale represents the total number of minutes spent monitoring within a 400m^2 grid. The colour brown represents times greater than 2 minutes and may include longer periods when the vehicle was parked.

Notwithstanding the cautionary remarks, the highest PM_{10} concentrations (up to around 300 µg/m^3) were consistently observed by mobile monitoring over a wide area in suburbs to the west of Woolston (Figure 3-5). This suggests that, along with the monitoring sites at Woolston and St Albans, other pollution hotspots may exist in Beckenham and/or Hoon Hay. Fixed site survey monitoring campaigns undertaken for at least one winter in Beckenham and/or Hoon Hay would provide data which could be used to confirm the location of these additional hotspots.

3.3.2. Coles Place monitoring site - 13 August 2008

To investigate the representativeness of PM_{10} concentrations measured at the Environment Canterbury monitoring station in Coles Place, mobile monitoring was

undertaken in St Albans and nearby suburbs on the night of 13 August. Two identical routes were completed, between 2000hr on 13 August and 0120hr on 14 August, which passed the Coles Place monitoring station before meandering through the suburbs to the east. PM_{10} concentrations were averaged over 400m × 400m grids for the entire monitoring period and are plotted in Figure 3-8.

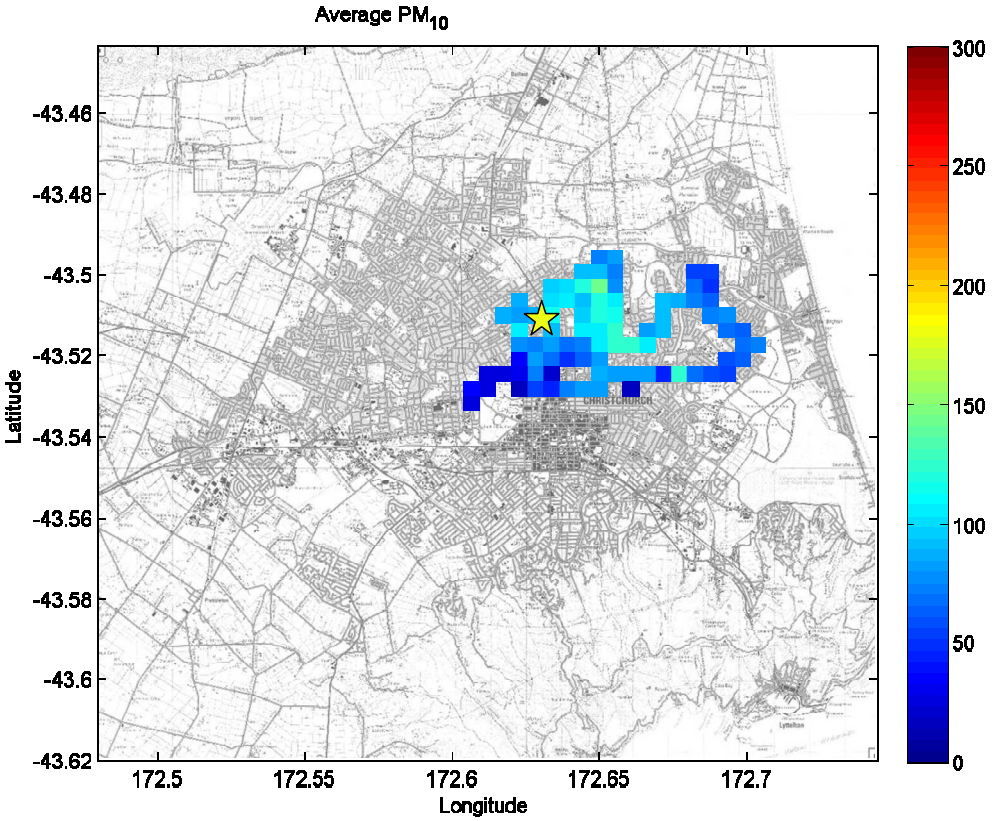


Figure 3-8: **PM_{10} concentrations averaged over 400m^2 grids, in the vicinity of the Coles Place, St Albans monitoring station during the night of 13 August, 2008. Colour scale is PM_{10} concentration (µg/m^3). Yellow star indicates the Environment Canterbury monitoring site at St Albans.**

While the PM_{10} concentrations observed during the monitoring on 13 August (Figure 3-8) did not reach the same magnitude as those on 12 August (Figure 3-7), concentrations of around 150 µg/m^3 were recorded in grids adjacent to the Coles Place monitoring site and at adjacent suburbs of Mairehau and Shirley. PM_{10} concentrations were much lower in the suburbs further east, along with southern locations closer to the CBD area (Figure 3-8). This suggests that the permanent monitoring site at Coles Place is well located to collect PM_{10} data which is representative of the higher concentrations experienced in the northern suburbs of Christchurch.

A light easterly wind of around 1m/s was present at both Woolston and St Albans throughout the period of mobile monitoring on 13 August (Figure 3-8). Because the mobile monitoring was largely undertaken to the east of the St Albans permanent

monitoring site, it might be considered that this is not a representative evaluation of the St Albans monitoring site because it was conducted upwind. However, mobile monitoring was also undertaken immediately west (i.e. downwind) of the Coles Place site and higher PM_{10} concentrations were not observed in those locations either (Figure 3-8). Therefore, there was no evidence on 13 August that indicates the need for another permanent monitoring site in the northern suburbs of Christchurch.

3.4. High pollution night - 20 August 2008

On 20 August 2008 another circuit was navigated, that passed the Woolston monitoring site, then went over the Port Hills to Lyttleton and back through Dyers Pass, looped through Beckenham and Spreydon, through the CBD and on to the northern suburbs via Papanui, before coming back down through Marshland and Shirley to the permanent monitoring site at St Albans. This monitoring was undertaken between 1940hr on 20 August and 0030hr on 21 August 2008. While the spatial coverage around the Environment Canterbury monitoring sites was not as comprehensive as during the monitoring on 12 August and 13 August, data from the night of 20 August are an extremely valuable addition to the monitoring data because PM_{10} concentrations were relatively high.

Exceedances of the NES for PM_{10} were observed at both Woolston and St Albans on 20 August and 21 August (Table 3-1).

Table 3-1 24 hour average PM_{10} concentrations observed at Environment Canterbury monitoring sites in Woolston and St Albans during 20 August and 21 August 2008[1]. Averaging period is from midnight to midnight.

	PM_{10} concentration ($\mu g/m_3$)	
	Woolston	**St Albans**
20 August 2008	55	58
21 August 2008	77	83

On both nights, the single high pollution event that prevailed through the night of 20 August and early morning 21 August was responsible for causing the occurrence of PM_{10} exceedances on both 20 August and 21 August (Figure **3-9**). The reason for this phenomenon is because the midnight-midnight reporting framework of the NES means that the high pollution event was split between the two 24 hour reporting periods. This demonstrates that the night of 20 August was a very strong pollution event and it was fortuitous that mobile monitoring was undertaken on that night.

[1] Data obtained from Tables at Environment Canterbury website: http://www.ecan.govt.nz/Our+Environment/Air/Monitoring/, last accessed 12 November 2008.

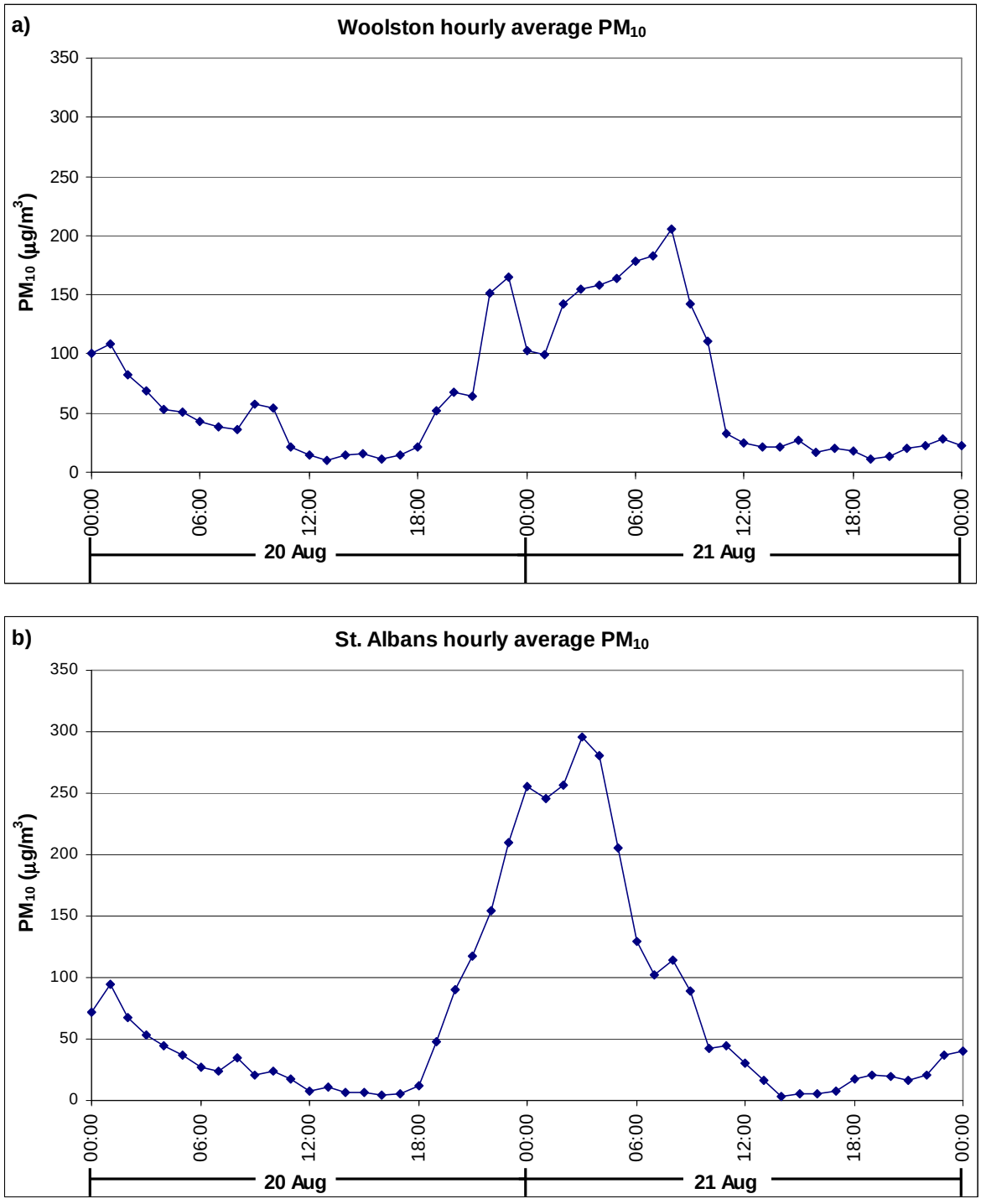


Figure 3-9 : Hourly average PM10 concentrations observed at Environment Canterbury monitoring sites at a) Woolston and b) St. Albans, 20-21 August, 2008. Data provided by Environment Canterbury.

Wind at both St Albans and Woolston was very light (<1m/s) and variable for the entire period of monitoring on 20 August (Figure 3-10), which indicates that dispersion of ambient PM_{10} would have been limited.

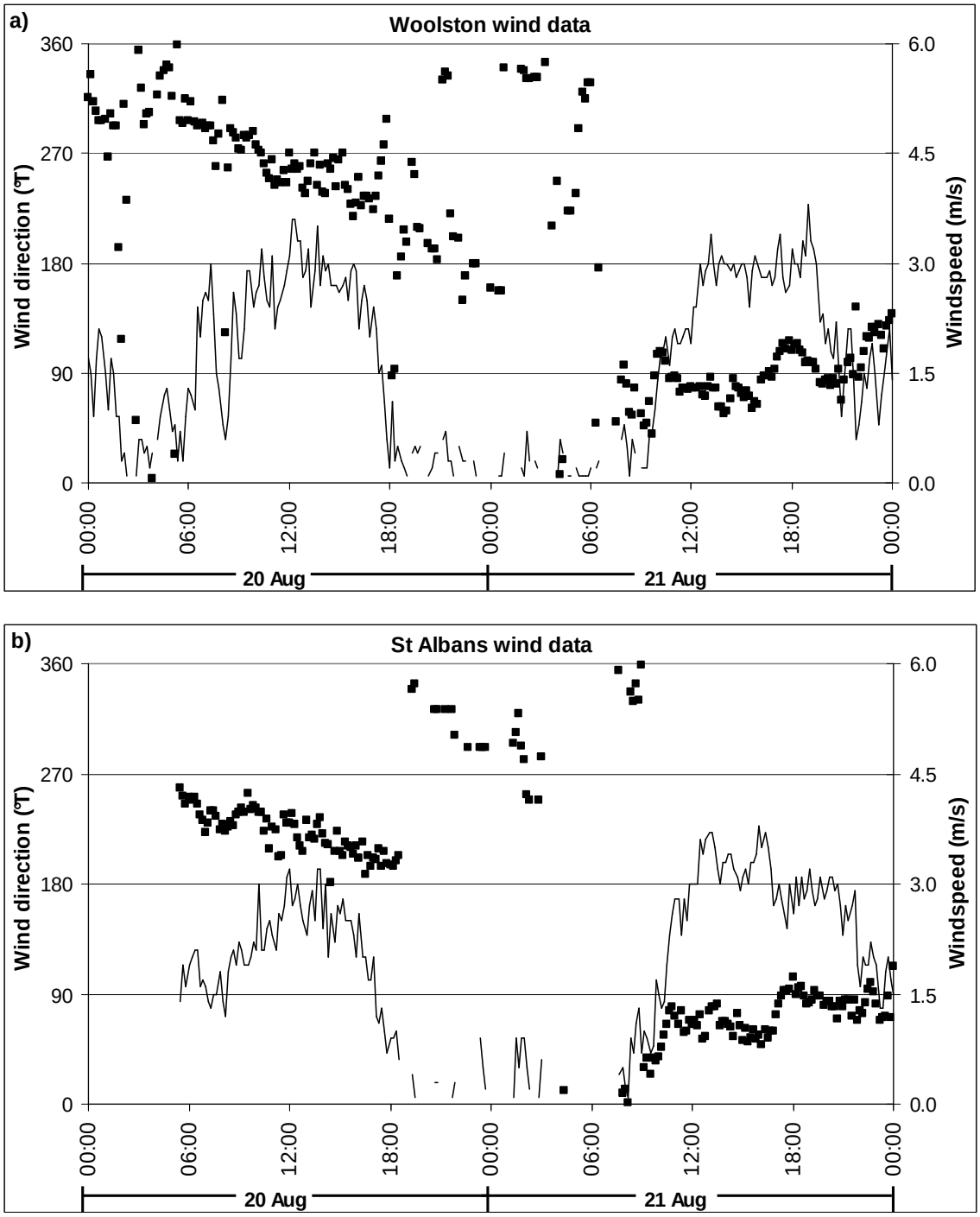


Figure 3-10: 10 minute averages of windspeed (solid line) and wind direction (black squares) recorded at Environment Canterbury air quality monitoring stations at a) Woolston and b) St Albans, 20-21 August, 2008. Missing data are a consequence of windspeed being lower than the operating threshold of the instruments. Data provided by Environment Canterbury.

The highest PM_{10} concentrations measured by the mobile monitoring system on 20 August were observed in the northern suburbs of Papanui, St Albans and Shirley, along with southern neighbourhoods between Hoon Hay and Beckenham. At these locations, concentrations in excess of 300 $\mu g/m^3$ were observed (Figure 3-11). The

monitoring on 20 August provides further evidence that the Environment Canterbury monitoring site is ideally located to capture worst-case PM_{10} concentrations in the northern suburbs of Christchurch.

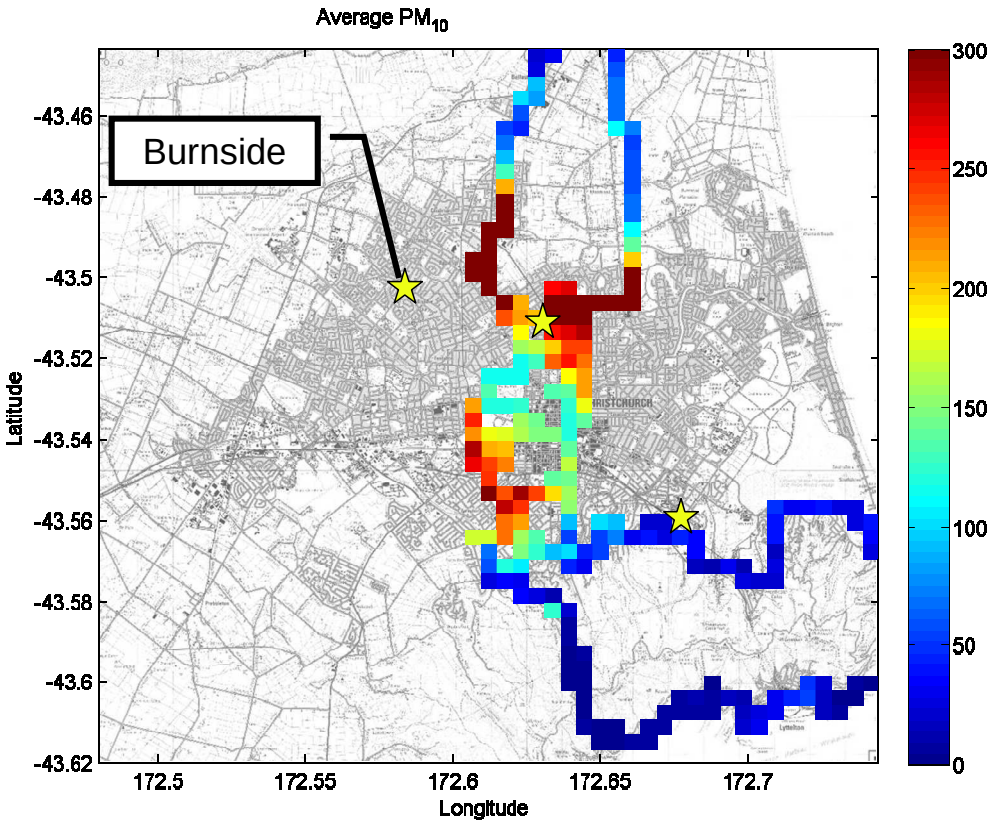


Figure 3-11: PM_{10} concentrations averaged over 400m^2 grids during the night of 20 August, 2008. Colour scale is PM_{10} concentration (µg/m^3). Yellow stars indicate Environment Canterbury PM_{10} monitoring sites at Woolston, St Albans and Burnside (labelled).

While there were also high PM_{10} concentrations in the northern suburb of Papanui, the magnitudes are identical to maximum observations at St Albans (Figure 3-11). Papanui is located between Environment Canterbury monitoring sites in St Albans and Burnside (Figure 3-11). On 20 August, a 24 hour average PM10 concentration of 65 µg/m^3 was observed at the Burnside monitoring site and this is slightly greater than the 58 µg/m^3 observed at Coles Place (Table 3-1). However, on 21 August the 24 hour average at Burnside was only 48 µg/m^3 and this is substantially lower than the 83 µg/m^3 average concentration observed at Coles Place. This demonstrates that air quality in Papanui is more conservatively represented by monitoring at Coles Place than by observations from Burnside. Based on the analysis of monitoring data from the night of 20th August, it appears that establishing an additional permanent monitoring station at Papanui would add little value to Ecan's monitoring network because it would be in close proximity to the Coles Place site.

Figure 3-11 provides further evidence that pollution hotspots may exist in Beckenham and/or Hoon Hay because concentrations of at least 300 µg/m^3 were observed in this location on 20 August. This is considerably greater than the PM_{10} concentrations observed by mobile monitoring on 12 August, although this is likely at least partially a consequence of spatial variability being confounded by temporal variation. The mobile monitoring system passed through Woolston early during the monitoring period on 20 August and the data represent concentrations at a time between 2000hr and 2100hr. Figure **3-9** shows that the hourly average PM_{10} concentration at the Environment Canterbury monitoring station in Woolston was less than 100 µg/m^3 during this time and increased substantially after 2100hr. However, the PM_{10} concentrations observed between Beckenham and Hoon Hay are exceptionally high and this alone demonstrates the potential value to be gained by undertaking survey monitoring campaigns for at least one winter. The data which could be used to confirm the location of a pollution hotspot in Beckenham and/or Hoon Hay.

4. Results and Discussion – Nelson-Richmond

4.1. PM_{10} monitoring network within the Nelson and Richmond airsheds

Figure 4-1 shows the location of the three permanent PM_{10} monitoring sites within the Nelson and Richmond airsheds.

4.2. Variation of PM_{10} concentrations across the Nelson and Richmond airsheds

Data from the entire mobile air quality monitoring campaign that was collected within the Nelson airsheds were combined and plotted in Figure 4-2 (a). The combined plot provides a general description of where highest concentrations were observed during the campaign, although some caution is required when interpreting these results. The runs were undertaken on different nights and meteorological conditions varied during the campaign. Therefore, the spatial variation of concentrations plotted in Figure 4-2 (a) will include the impact of temporal variability. This issue will be addressed in further detail in the following sections.

The second issue worth noting is that not all areas were equally covered by the measurements; some were monitored more frequently or for a longer period of time. Plots showing the amount of time spent within each monitoring grid cell are displayed in Appendix B. Figure 4-2 (b) shows the same data as Figure 4-2 (a) but with a transparency mask applied that differentiates the areas by the amount of time spent monitoring within them. Grids cells that were monitored for a longer period of time are plotted with increased colour intensity. The grid cells with more intense colour indicate areas where the concentrations are more representative and robust.

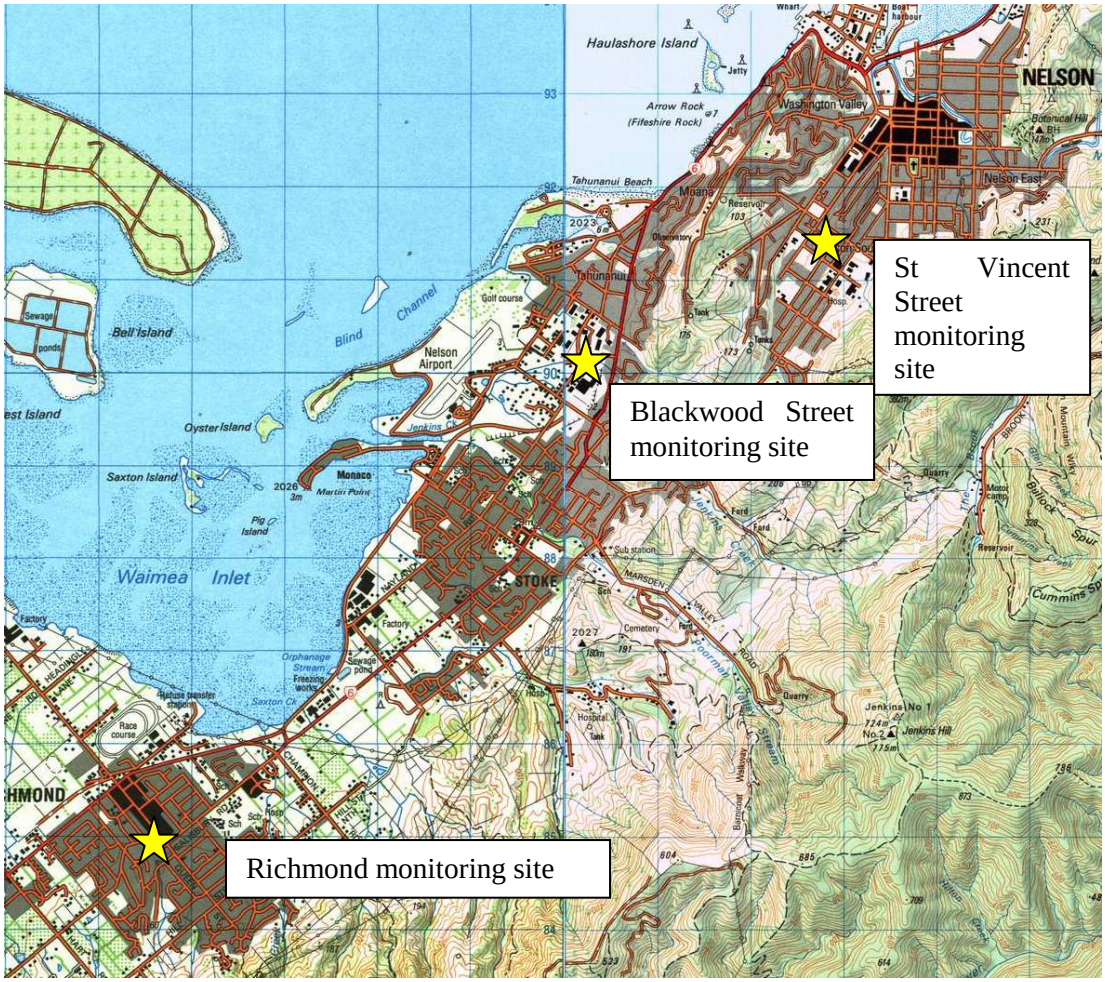


Figure 4-1: Location of the permanent PM_{10} monitoring sites within the Nelson and Richmond airsheds - St Vincent St. (NCC), Blackwood St (NCC) and Richmond (TDC).

Data from the complete Richmond mobile air quality monitoring campaign were combined and plotted in Figure 4-3 (a). Figure 4-3 (b) shows the Richmond data with a transparency mask applied. The cautionary remarks made regarding the Nelson data and its interpretation also apply to the Richmond data set and Figures 4-3 (a) and (b).

Despite these cautionary notes, the combined results do provide a general and useful indication of spatial variability of PM_{10} concentrations throughout both the urban areas within the Nelson and Richmond airsheds.

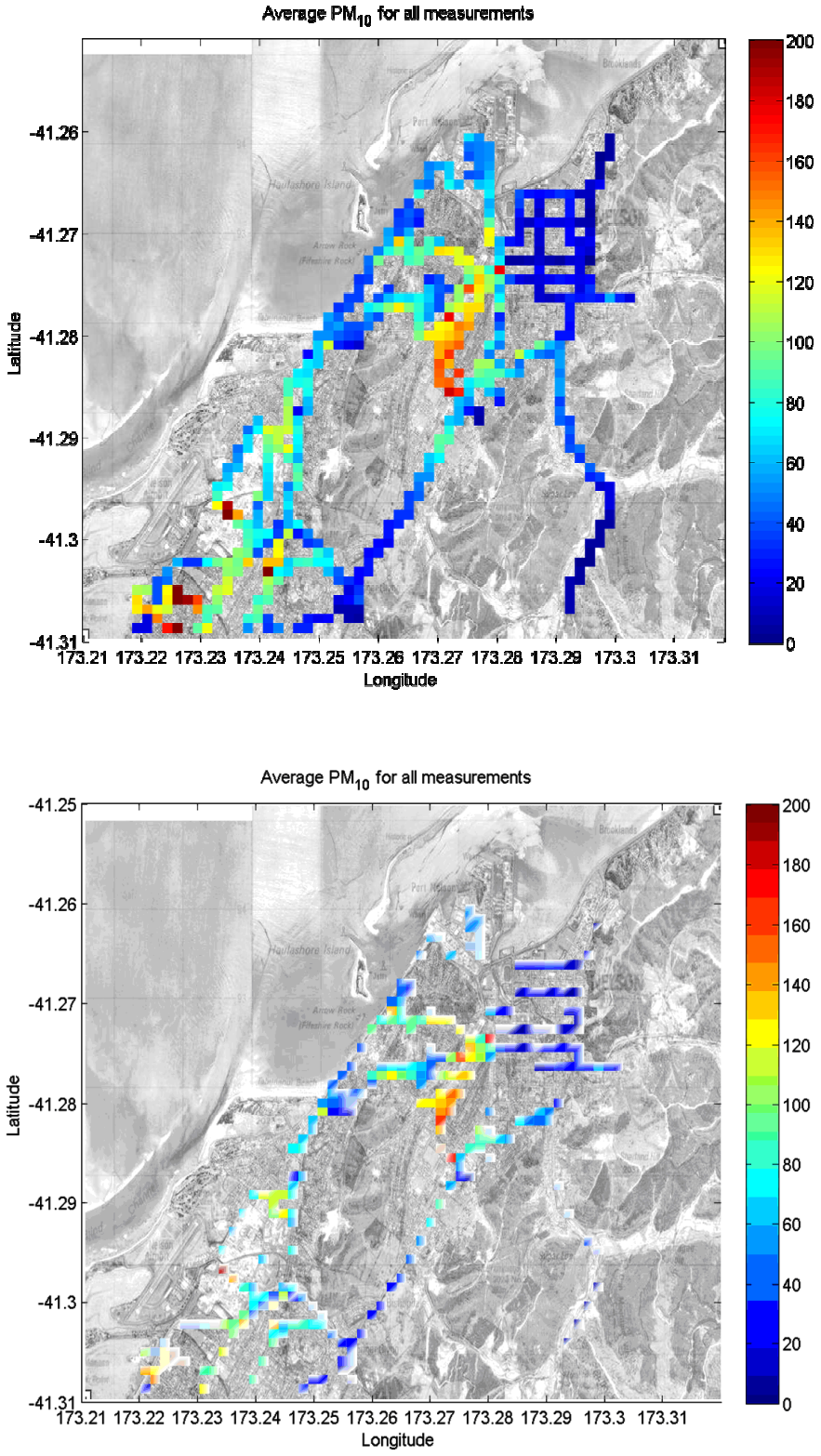


Figure 4-2 **(a) Nelson urban area - PM_{10} concentrations averaged over ~120m^2 grids, for all nights when the mobile system was active. Colour scale is PM_{10} concentration (µg/m^3). (b) PM_{10} concentrations with transparency mask applied to highlight areas that were measured more often.**

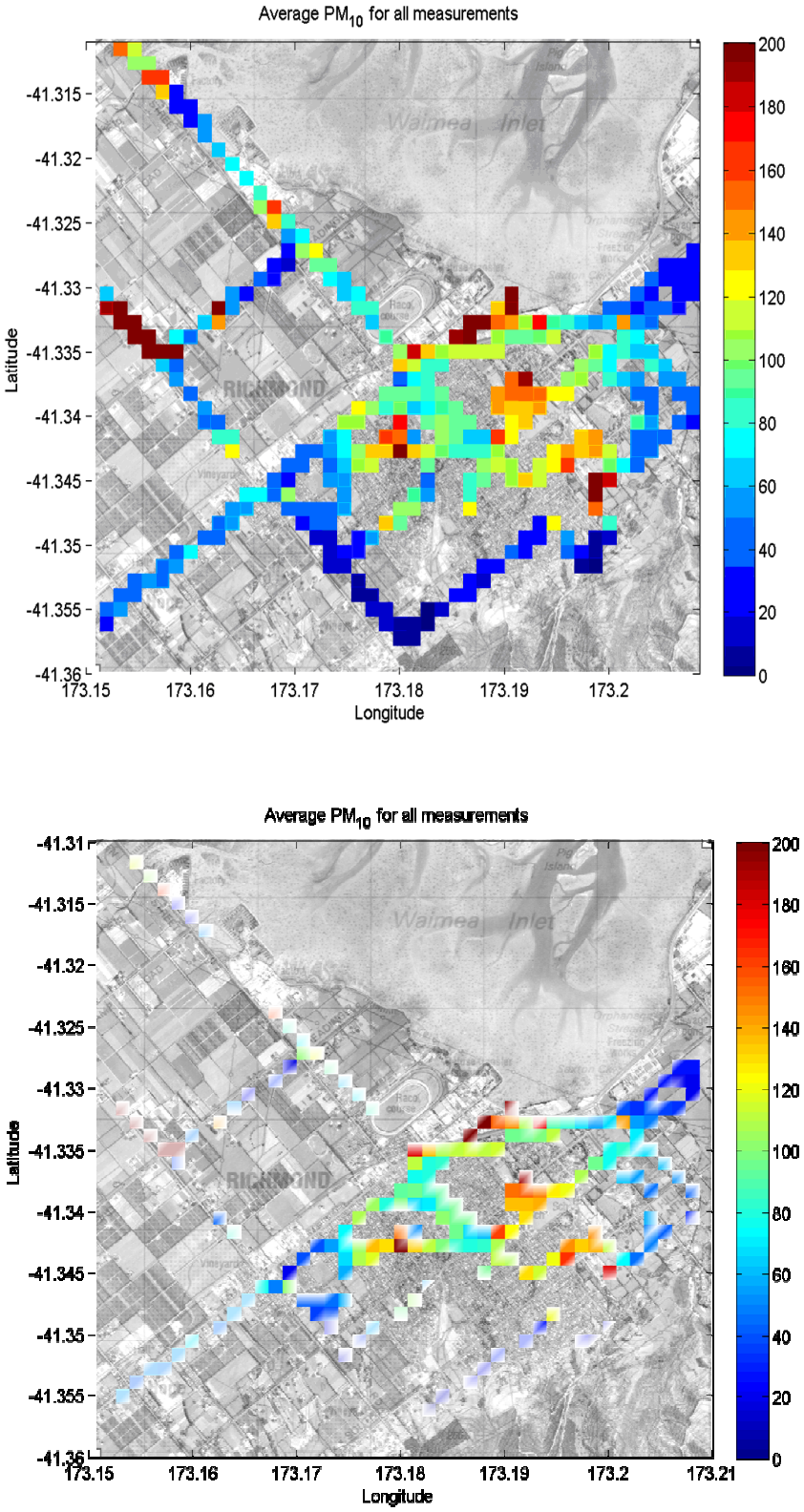


Figure 4-3 : **(a) Richmond urban area - PM_{10} concentrations averaged over ~120m^2 grids, for all nights when the mobile system was active. Colour scale is PM_{10} concentration (µg/m^3). (b) PM_{10} concentrations with transparency mask applied to highlight areas that were measured more often.**

Interpolating the monitoring data that sits behind Figure 4-2 (a), an isopleth plot showing PM_{10} concentrations for the Nelson airshed was generated (Figure 4-4). An equivalent isopleth concentration plot for the Richmond airshed is shown in Figure 4-5. It must be noted that extra caution is needed when interpreting Figure 4-4 and Figure 4-5 This is because the interpolation process gives the sense that we have robust information in some areas where little or no monitoring was undertaken. However, for the central parts of Nelson and Richmond, this interpolation is robust and Figure 4-4 and Figure 4-5 do give useful information about the likely location of PM_{10} hot spots within the urban areas of Nelson and Tasman airsheds.

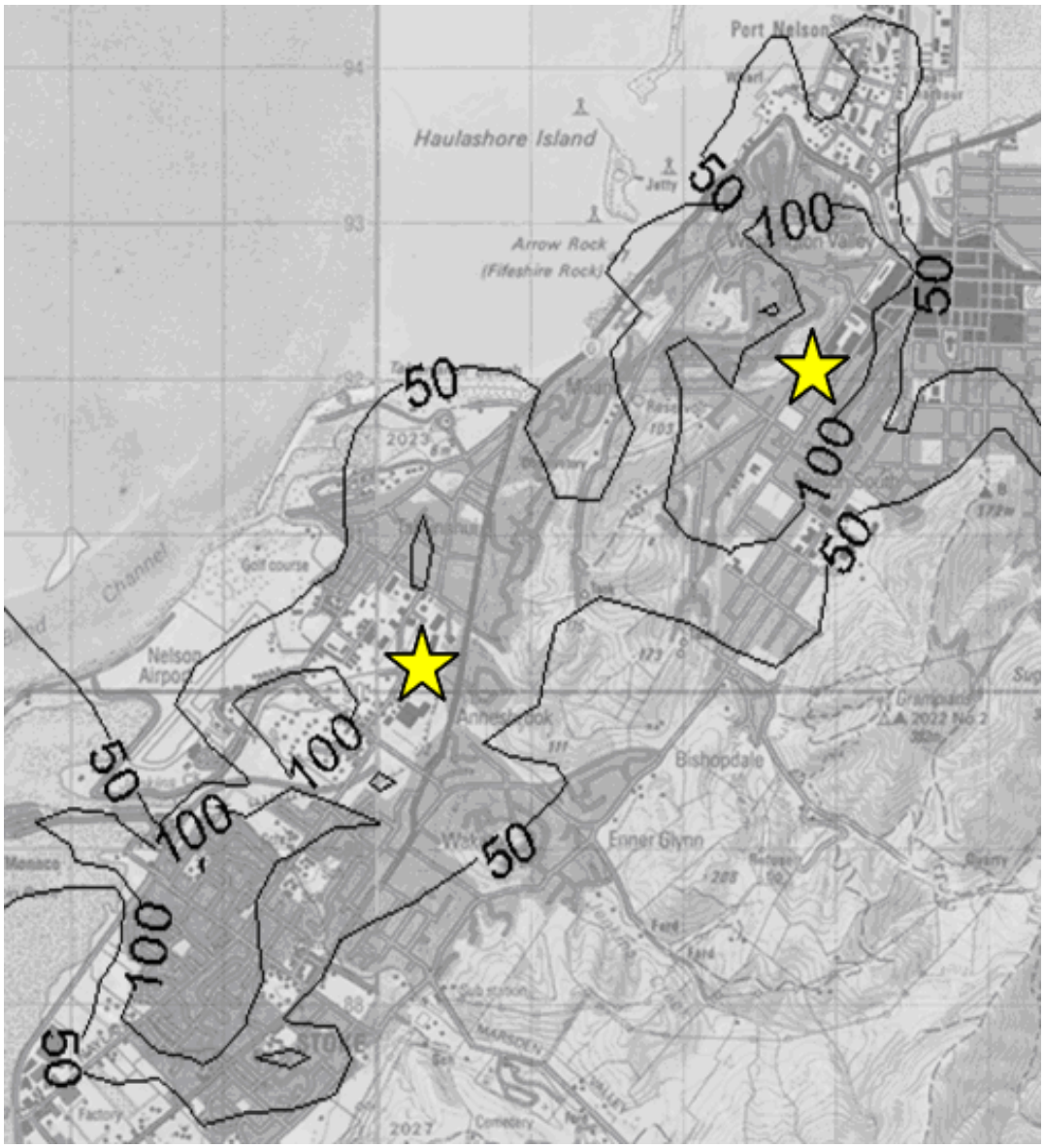


Figure 4-4 : Isopleths of PM_{10} concentrations ($\mu g/m^3$) averaged for all nights during the Nelson monitoring campaign. Yellow stars indicate Nelson City Council PM_{10} monitoring sites.

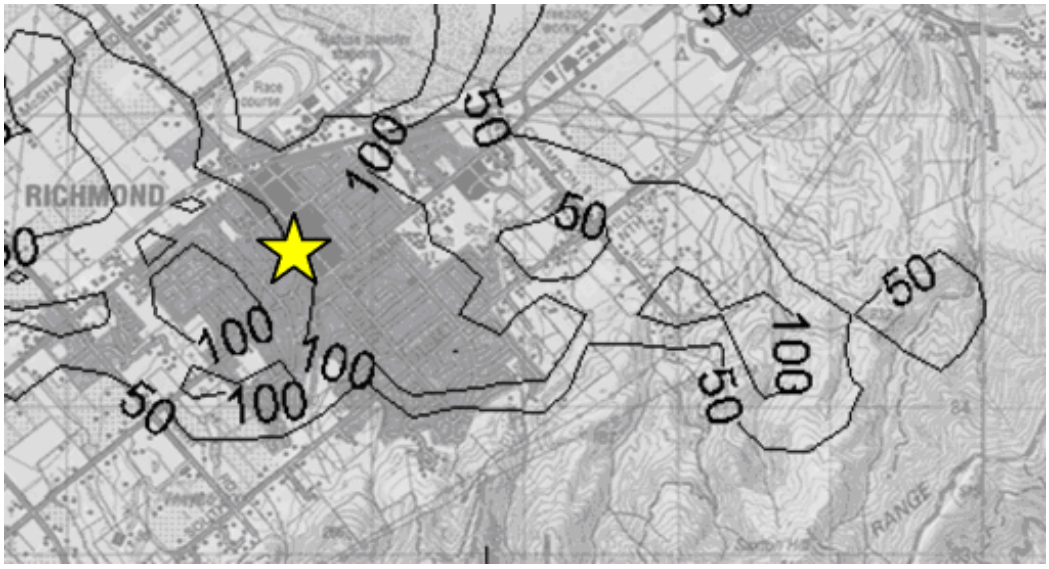


Figure 4-5 : Isopleths of PM_{10} concentrations ($\mu g/m^3$) averaged for all nights during the Richmond monitoring campaign. Yellow star indicates the Tasman District Council PM_{10} monitoring site.

Despite the cautionary remarks regarding the interpretation of the data, Figure 4-2, Figure 4-3, Figure 4-4 and Figure 4-5 indicate that there are three areas that had higher PM_{10} concentrations during the nights when monitoring was undertaken. The hotspots identified are: central Richmond, Stoke and central Nelson. These hot spots coincide with the larger residential areas where relatively large number of houses use solid fuel burners for heating.

When analysed in more detail the Nelson data revealed high concentration were observed in the Washington Valley and Toi Toi areas while the eastern parts of the city showed very low concentrations. This may be related to the topography of the area or differences in the emission characteristics of the areas.

Considering the topography of Nelson City, high concentrations were expected in the central neighbourhoods while lower concentrations were expected in the coastal areas. However, as shown in Figure 4-2, central-east Nelson showed very low concentrations while the central-west neighbourhoods showed consistently higher concentrations indicating that emission intensity (residential combustion) plays a more significant role than topography in this area.

Continuing south, the next high concentration area can be observed between Annesbrook and Nayland. Annesbrook/Tahunanui corresponds to an area that is more industrial and at sea level. This indicates that the industrial activities in the area may also play a significant role in the air quality in Annesbrook and Tahunanui. This also indicates that in the south western part of Nelson, air quality seems to be quite a localised issue.

In the Richmond area the, pattern matches the residential density with high concentrations in central Richmond. This indicates that residential combustion plays a major role in determining the air quality in the Richmond area. It is also worth noticing the small pocket of high concentrations to the east of Richmond (along Hill Street). This seems to be the combined effect of residential emissions within "micro valleys" in this part of the city, which could mean that the air quality in the eastern part of Richmond has potentially little or no relation to the levels observed downtown. Another hotspot was identified in Richmond that showed up consistently in the data collected over the higher air pollution nights. This pocket of relatively high pollution was found in the area of Hunt Street (between 100m and 700m south-east of Jubillee Park). This hotspot is most likely due to the presence of a low ridge damming the flow of polluted air from the south-west which results in an accumulation of contaminants.

4.3. Representativeness of permanent PM_{10} monitoring stations in Nelson-Richmond

Figure 4-4 shows the horizontal distribution of PM_{10} concentration in the Nelson area with the monitoring stations highlighted. Figure 4-5 shows the horizontal distribution of PM_{10} concentration in the Richsmond area with the monitoring stations highlighted. From these figures it is clear that the Richmond (Richmond) and St Vincent Street (Nelson) sites are located well within high concentration pockets. However, the Blackwood Street monitoring station in Nelson (Tahunanui) is located outside the high concentration area near Stoke. Considering that high PM_{10} concentrations seem to be a very local issue, the evolution of ambient concentrations in Stoke may not follow the same trends observed by the monitoring site intended to represent the area.

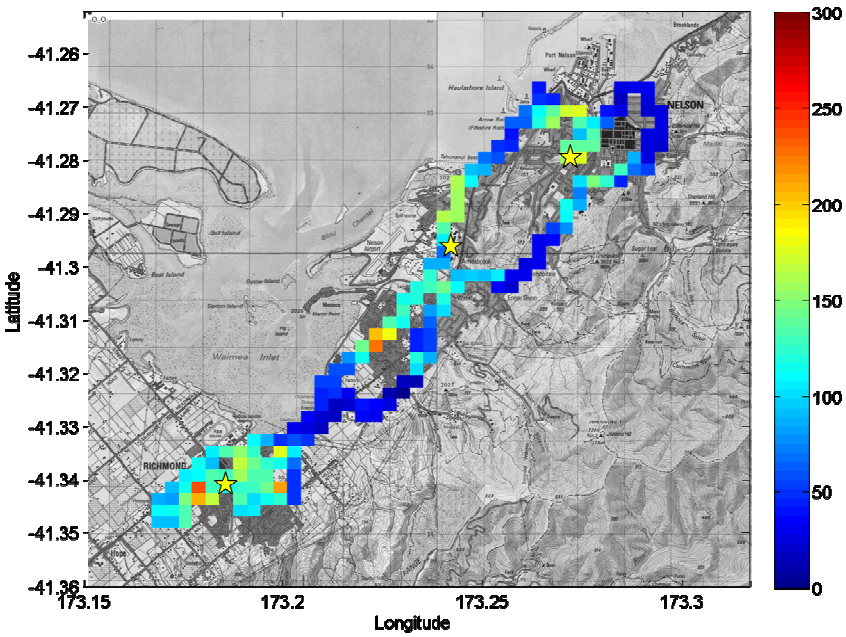
However, given the limited number of nights when mobile measurements were made, it cannot be definitively established if the high concentration areas identified are persistent, frequent or representative of the normal situation in the area.

Figure 4-6 shows the horizontal distribution of PM_{10} concentrations during two monitoring nights (21st and 25th of July) when relatively high concentrations were observed by the mobile monitoring system. The general patterns of PM_{10} concentrations identified in previous sections are also present in the individual night runs displayed in Figure 4-6. This suggests that they are likely to be a persistent feature in the area. Particularly relevant is the fact that three clearly defined areas of high concentrations are identified, regardless of the level of concentrations. Central Richmond, Stokes and central Nelson are clearly and consistently showing higher concentrations than the rest of the urban areas monitored in the study.

In summary, even though a complete evaluation of the current permanent monitoring sites cannot be carried out because of the limited temporal coverage of these mobile measurements, there are clear indications that the St Vincent Street and Richmond monitoring sites are located in areas where relatively high PM_{10} concentrations are likely to occur. The Blackwood street site may not be able to represent the highest

concentrations experienced in the Stoke area. However, this finding is not surprising as the main purpose of the Blackwood St site is to monitor the effects of the discharges from the surrounding industrial plants. Figure 4-6 provides evidence that a residential pollution hotspot may exist in Stoke. This demonstrates that there may be potential value of NCC to undertake a survey monitoring campaign for at least one winter in that area of Stoke.

21st July



25st July

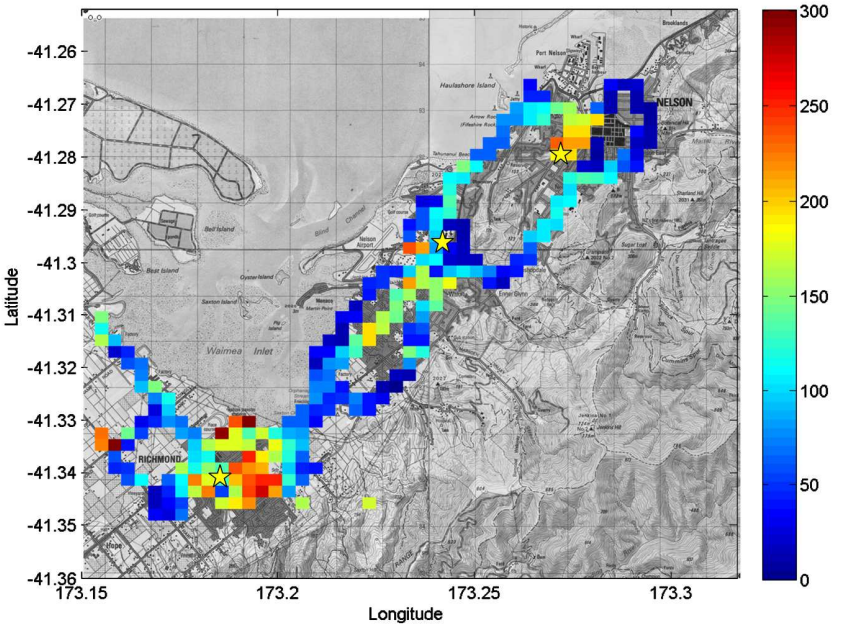


Figure 4-6 : **PM_{10} concentrations averaged over 200m^2 grids, for two nights when the mobile system was active within the Nelson-Richmond urban areas (21st and 25th of July). Colour scale is PM_{10} concentration (µg/m^3). The yellow stars mark the location of the monitoring stations in the area.**

4.4. Measurements outside the Richmond urban area

One night's monitoring was invested in a preliminary investigation of the extent of spread of the urban plume from Richmond. Figure 4-7 shows the route followed on July 27th that included the towns of Brightwater and Wakefield. There was only one night of measurements made on this route and therefore the conclusions of this analysis must be taken as preliminary and not necessarily representative of the normal conditions in the area. Furthermore, air pollution transport is a three-dimensional process and while valuable information can be gathered from surface concentrations, a complete understanding of the phenomena would include gathering information at different heights.

The fact that there are two low concentration areas (between Wakefield and Brightwater and between Brightwater and Richmond) shown in Figure 4-7 indicates that the extent of the "urban plume" from Richmond at ground level is very limited towards the south indicating that during this night, the concentrations observed in Brightwater and Wakefield were the result of local emissions rather than the effect of transport of pollution from other areas. Similarly, the measurements indicate that the air pollution problem in Richmond is mainly the result of local emissions and that the impact from other urban centres is limited.

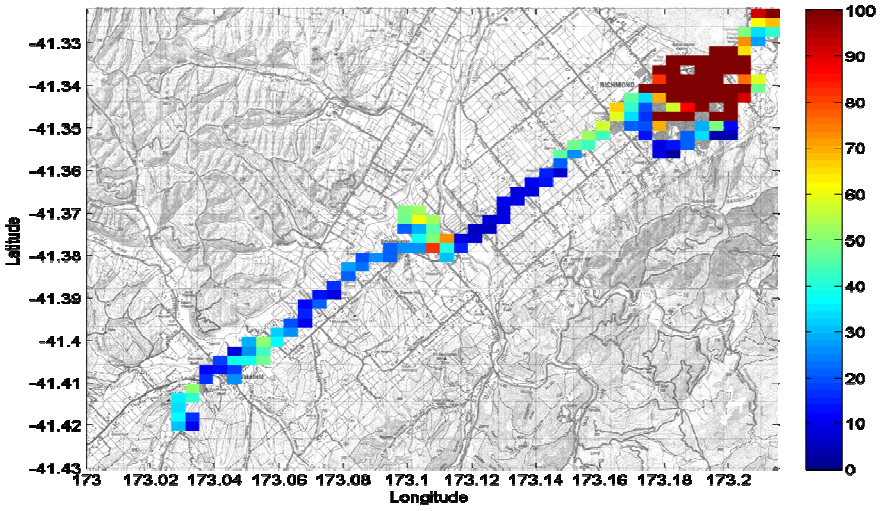


Figure 4-7 **PM_{10} concentrations averaged over 200m^2 grids, for the night of 27th of July including Brightwater and Wakefield urban areas. Colour scale is PM_{10} concentration (mg/m^3). Note the different colour scale from previous PM_{10} plots.**

A more detailed analysis of the Brightwater data showed levels comparable to those observed in central Richmond even though it is a much smaller settlement. Within Brigthwater a small area of relatively high concentrations was identified to the southwest of the township that may be related to higher residential density.

On the other hand, concentrations in Wakefield were lower than in Nelson and Brightwater. This may be related to a lower population density and therefore lower emissions. However, a relative increase of PM_{10} concentrations inside Wakefield was observed, indicating that local emissions play a significant role in the horizontal distribution of PM_{10} in this town.

In summary, even though a full assessment of the transport patterns in this complex topography requires the use of other techniques (modelling and monitoring) in addition to mobile measurements, the preliminary results presented in this report indicate that the concentrations observed in the area are more strongly controlled by local emissions rather than pollutant transport within the valley.

4.5. Black carbon measurements and source identification

Figure 4-8 shows the average pattern of BC concentrations as measured by the mobile monitoring system. As an overview, the spatial distribution of BC in the area is similar to that of PM_{10} which points to a common source. However, when expressing BC as a fraction of PM_{10} the picture becomes more interesting (Figure 4-9). In fact, BC normally represents ~10% of the total PM_{10} but in some areas this fraction increases to more than 25% meaning that in those areas ~1/4 of PM_{10} is soot and therefore generated by not just wood burning but also from fossil fuel (most likely diesel and coal) combustion.

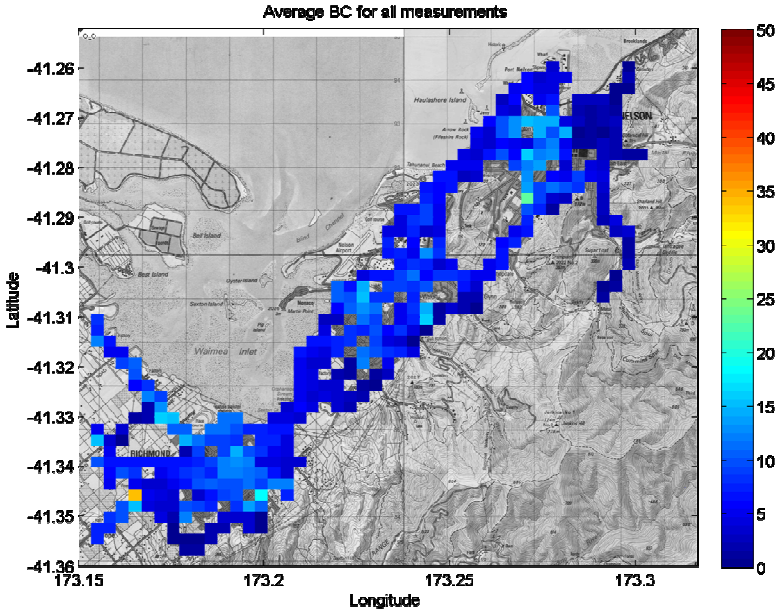


Figure 4-8: BC concentrations averaged over 200m^2 grids, for all nights when the mobile system was active within the Nelson-Richmond urban areas. Colour scale is BC concentration (µg/m^3).

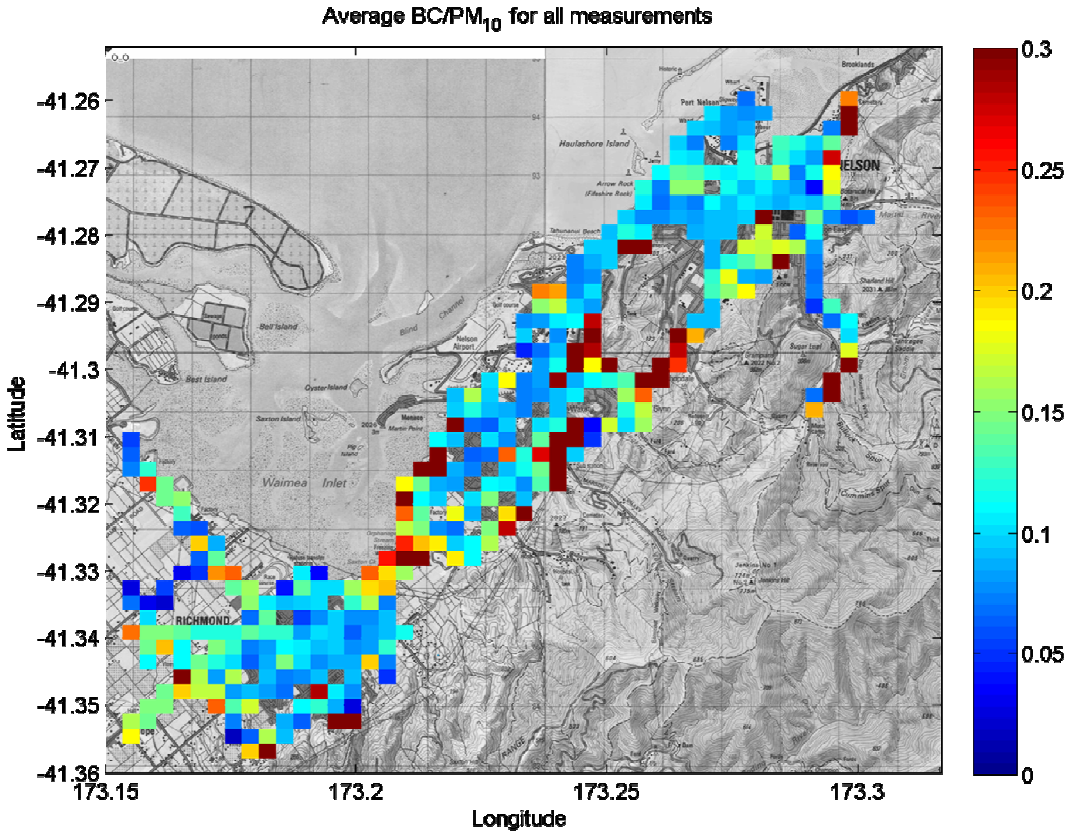


Figure 4-9: **BC/PM_{10} ratio averaged over 200m^2 grids, for all nights when the mobile system was active within the Nelson-Richmond urban areas. Colour scale is BC/PM_{10} (dimensionless).**

PM_{10}, however, is not the best indicator of combustion related pollution because it will also include PM from other sources such as wind blown dust and marine (sea salt) aerosols. To overcome this problem we also measure PM_1 concentration that is more directly related to combustion processes (Seinfeld and Pandis, 1998). Figure 4-10 shows the average distribution of PM_1 in the Nelson-Richmond area. This figure shows more clearly the extent of the three high concentration areas, which correspond to residential areas.

In most areas monitored, PM_1 represented more than 70% of the observed PM_{10} concentrations (Figure 4-11). However there were some small areas where PM_1 represented less than 50% of the PM_{10} concentrations. This variation in the PM_1/ PM_{10} ratio is again related to the sources of particulate matter monitored within those particular areas. A PM_1/ PM_{10} ratio of less than 50% means that most of the particulate matter is in the coarse mode (larger than 1μm) and is therefore more likely to be generated by mechanical processes (i.e., wind blown dust, sea spray) rather than combustion processes which tend to produce much smaller particles.

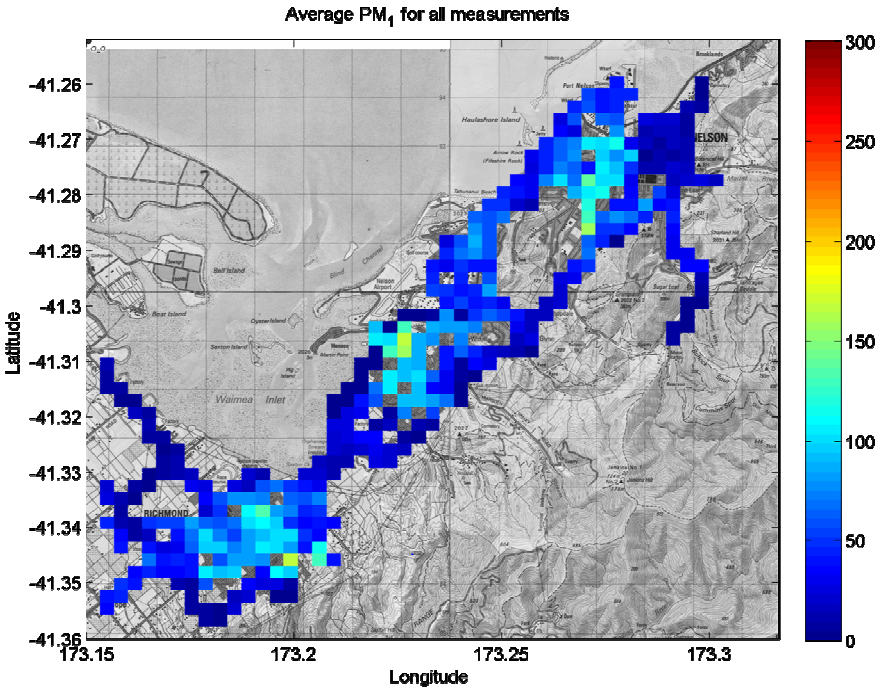


Figure 4-10: **PM_1 concentrations averaged over 200m^2 grids, for all nights when the mobile system was active within the Nelson-Richmond urban areas. Colour scale is PM_1 concentration (µg/m^3).**

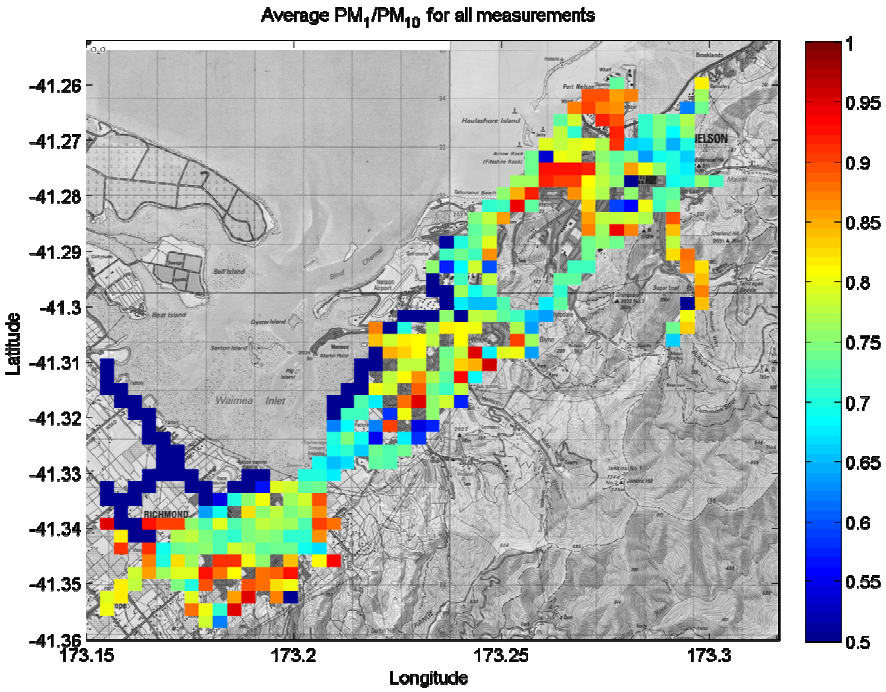


Figure 4-11: **PM_1/PM_{10} ratio averaged over 200m^2 grids, for all nights when the mobile system was active within the Nelson-Richmond urban areas. Colour scale is PM_1/PM_{10} (dimensionless).**

To identify the contribution of residential wood burning in the area, the signals from the two wavelength channels from the Aethalometer were used to generate a δC signal. According to Allen et al. (2004), this δC parameter is related specifically to wood combustion and is therefore useful for source identification. Figure 4-12 shows the horizontal distribution of δC with values in residential areas that are more than a factor of two those observed in non non-residential areas. This indicates that residential wood burning dominates the particle concentration throughout the urban areas. Furthermore, δC is shown to be useful to identify the spatial extent of the impact of residential combustion in the Nelson-Richmond area.

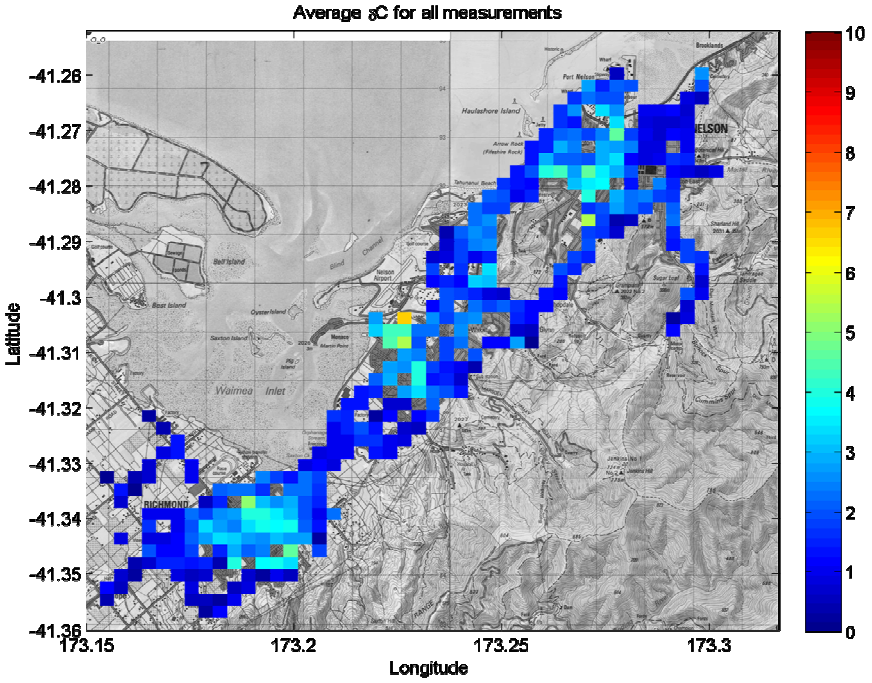


Figure 4-12: δC signal (*uv*BC-BC) according to Allen et al. (2004). Average over 200m^2 grids, for all nights when the mobile system was active within the Nelson-Richmond urban areas. Colour scale is δC (μg/m^3).

5. Summary and conclusions

The objectives of this study were to:

- Provide a preliminary assessment of the spatial variation of PM_{10} concentrations across airsheds in Christchurch, Nelson and Richmond.

- Illustrate how Councils may potentially use the mobile monitoring technique as an input to any review they may undertake on their air quality monitoring networks in terms of meeting AQNES Regulation 15.

- Present a case study (Nelson/Tasman) to show how the data collected by the mobile monitoring platform can be used to help identify the sources of pollution within an airshed and understand the transport of pollutants between airsheds.

A vehicle-based mobile monitoring system was used to assess spatial variation of particulate pollution. The monitoring campaigns were performed on winter nights between June and August 2008 in the Nelson-Richmond and Christchurch airsheds. Monitoring was undertaken for a total of seven and eight nights in Nelson-Richmond and Christchurch respectively. The results from two monitoring campaigns are presented focusing on the describing the spatial variability of particulate matter concentrations in these two urban areas.

In both urban areas the observed spatial distribution of particulate matter (PM_1, $PM_{2.5}$, PM_{10} and BC) is consistent with residential combustion being the major contributor to air pollution in winter nights. Large gradients were observed between residential and non-residential areas with lower concentrations observed in commercial areas that are not active at night time.

In general, most of the ambient air quality monitoring sites currently operating in the airsheds of Nelson, Richmond and Christchurch appear to be located within high concentration areas. Therefore these sites are useful in meeting the monitoring requirements as defined by the NES. However, from a scientific point of view of trying to understand the distribution and behaviour of pollutants within and between airsheds, pollution gradients are generally not captured by these NES sites. The whole coverage of these stations is biased towards highly populated areas leaving a relatively big gap in understanding regarding the variation of PM_{10} concentrations across these urban areas.

The preliminary results presented in this report indicate that the concentrations observed in the shallow valley extending south-west of Richmond are more strongly controlled by local emissions rather than pollutant transport within the valley.

Black carbon measurements were used to identify the sources that control the particulate matter concentration in Nelson-Richmond. The use of δC as a tracer for wood combustion showed results consistent with other source identification techniques.

This report shows that the mobile sampling can be a valuable tool in gathering information about the spatial distribution of pollution in urban areas. The report offers some preliminary analysis from the field campaign held last winter and shows a number of the potentially useful ways analysis can be performed.

6. Future work

Additional uses of these datasets could include attempting to answer the following research questions:

- Is there significant airshed leakage between Christchurch's urban and/or surrounding satellite settlements?
- Improving the understanding of sources of PM within Christchurch's urban areas
- How does the spatial and temporal nature of PM vary for each size fraction?

More work is needed to refine the analysis, in particular, the methods used to average data in both temporal and spatial senses could be reviewed and perhaps improved.

With refinements to the measuring strategy, a dataset could be obtained that would be suitable for the validation of airshed models. It would be particularly useful to attempt to address the following questions for very intensive case study days:

- Does the model capture the heterogeneity of the observed data?
    - In regards to meteorology
    - In regards to PM spatial and size and perhaps temporal distributions
- PM attenuation in the urban atmosphere is mostly ignored by models, is this a significant process?
- Do we need more comprehensive source emission profiles with improved temporal and spatial refinement?

7. Acknowledgements

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Appendix A: Horizontal transects in the Richmond area

The use of mobile platforms allows us to dig deeper and in different ways into the question of what is the spatial variability of ambient concentrations in specific areas. One of the ways that this can be done is by drawing "paths" that go through areas where it is expected to find spatial gradients in the ambient concentration.

This method was trialled with the Richmond dataset for two paths. The first from Bateup Rd to Hill St and the second one from Queen St to Champion/Salisbury Rds. Figure A-1 shows the transect paths and the data used to obtain the transect plots.

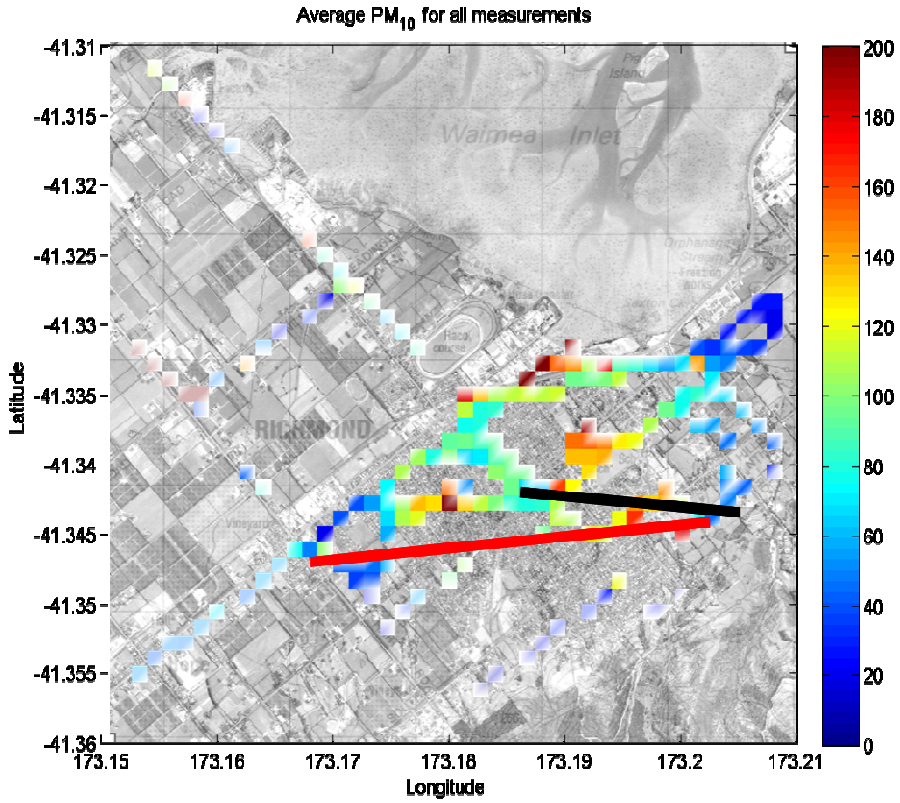
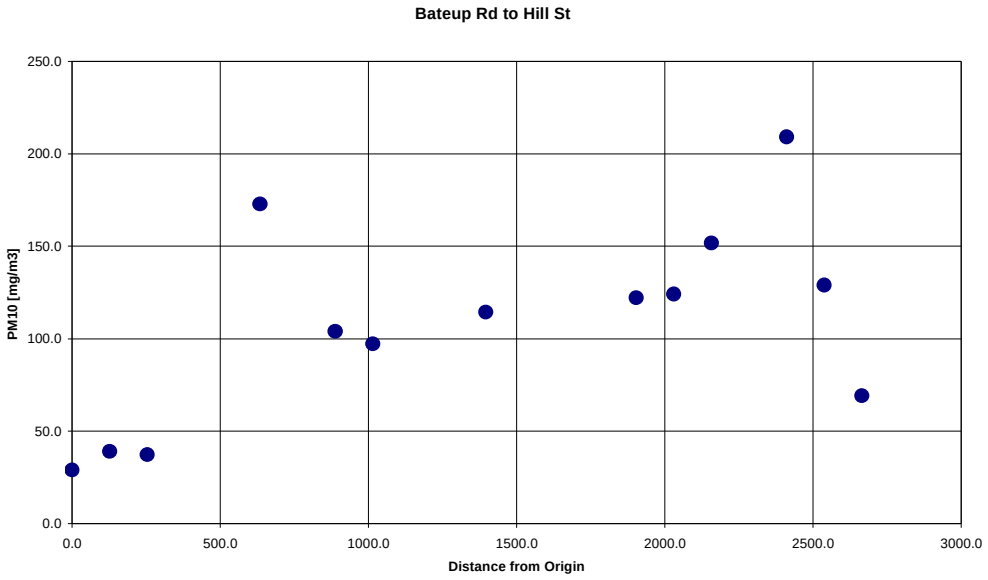


Figure A-1: Paths of the transects obtained for Richmond. Note that transects were calculated from the average of all the measurements for the paths. Colour scale is PM_{10} ($\mu g/m^3$). The red line goes from Bateup Rd to Hill St. The black line goes from Queen St to Champion/Salisbury Rds.

Figure A-2 shows the transect plots for the two paths identified in Figure A-1. The first path (Bateup Rd to Hill St) shows two high concentration areas. The first one is observed at about 600m from the start of the path and the second one at almost 2.5km from the start. The first of these two "peaks" corresponds to the residential area to the southwest corner of the urban area of Richmond while the second one corresponds to southeast of the city.

The second transect shows only one maximum at around 800m from the start that corresponds to where two narrow valleys come from Richmond Hill and where pollution seems to drain from residential areas above.



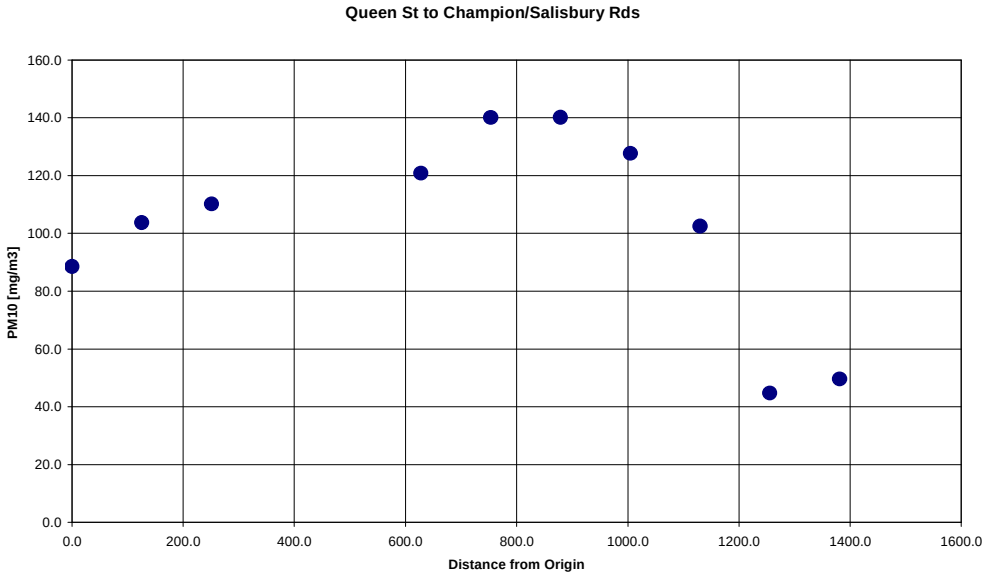


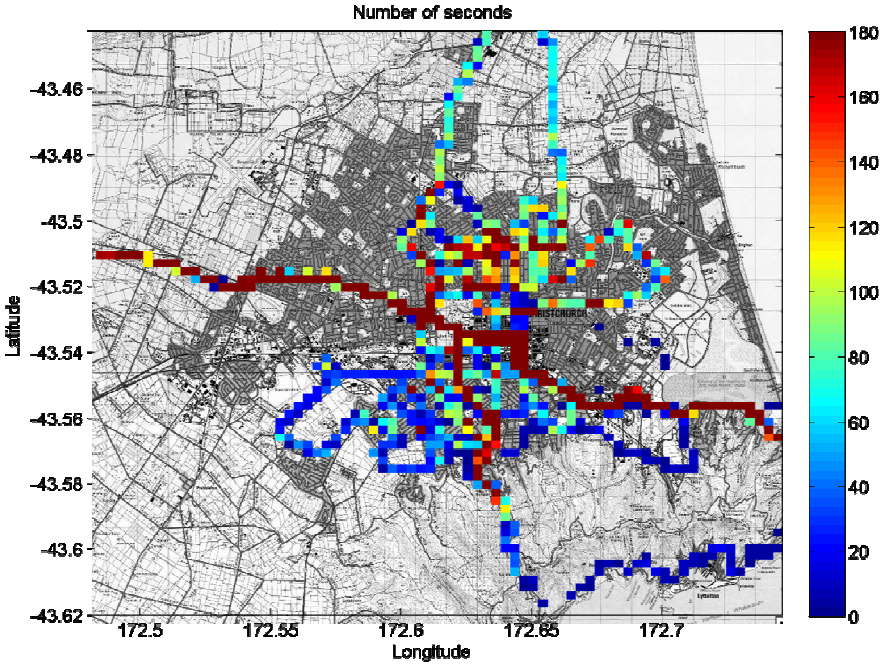
Figure A-2: Transect plots obtained for two paths in Richmond. See Figure A-1 for a description of the paths.

Appendix B: Grid Monitoring Time

One of the key issues related to mobile sampling is the amount of time spend at any location. The system used here allows for continuous measurements while in movement and therefore individual runs of the system will only pass a couple of seconds at any given point. This is the main reason why the minimum horizontal resolution presented here is 120m. Beyond that resolution, the number of datapoints behind each *square* would be too little to make the mean a representative metric.

However, the use of spatial averages does add robustness to the results in that more datapoints are used to construct the statistics making them less susceptible to random spikes in the data. Figure B-1 (a) and (b) and Figure B-2 shows the cumulative time spent in each of the grid squares that make the horizontal plots presented in the report.

(a) Christchurch



(b) Nelson

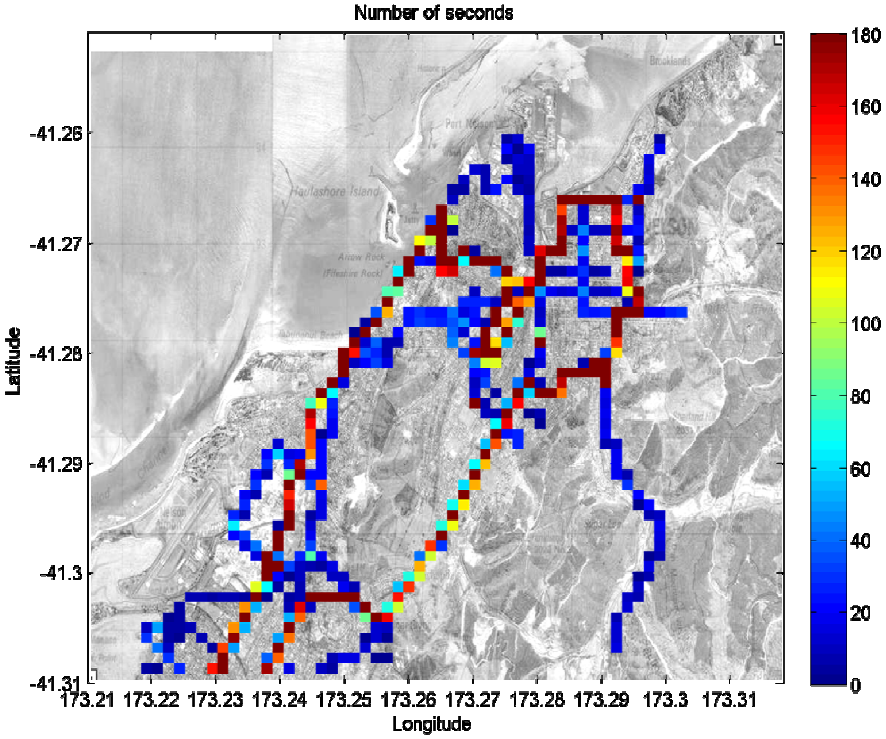


Figure B-1: **Grid monitoring time plots for two of the urban areas studied. (a) Christchurch and (b) Nelson. The colour scale corresponds to the number of seconds that the system spent within each of the squares and corresponds to the number of datapoints behind the statistics presented in the report.**

(c) Richmond

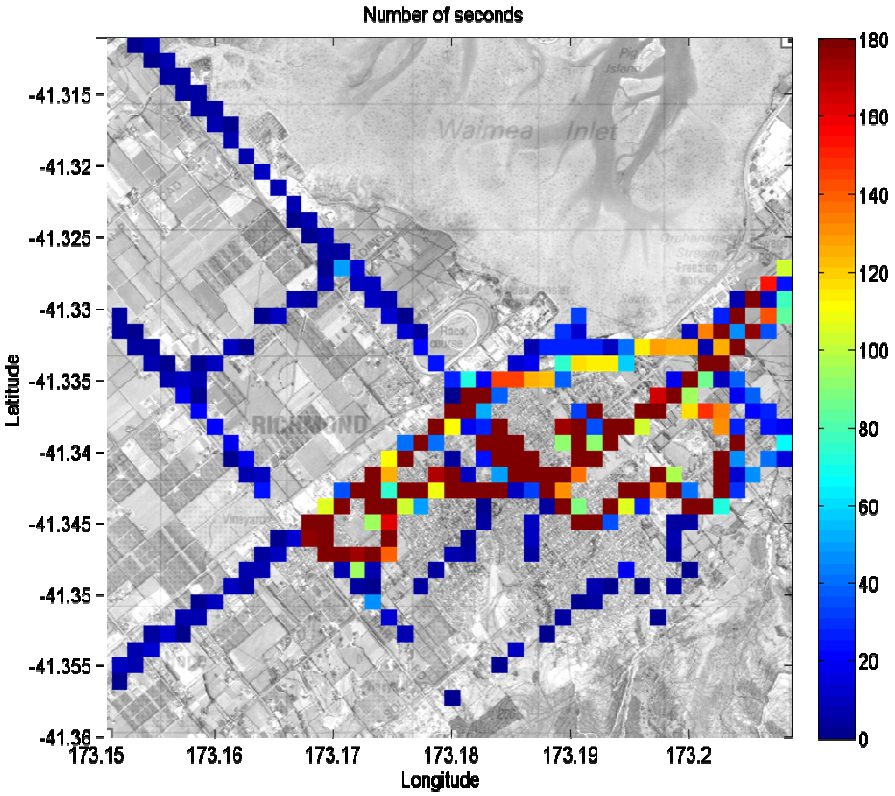


Figure B-2: **Grid monitoring time plots for the Richmond study area (c). The colour scale corresponds to the number of seconds that the system spent within each of the squares and corresponds to the number of datapoints behind the statistics presented in the report.**