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Sources and transport of particulate matter on an hourly time-scale during the winter in a New Zealand urban valley

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ABSTRACT

In this study, sources of particulate matter less than 10 μm in aerodynamic diameter (PM_{10}) at four different monitoring sites in Nelson, New Zealand were investigated on an hourly time-scale. Three of the sites were located 2 m above ground on a horizontal transect in the southwest to northeast direction along an urban valley, while the fourth monitoring site was located centrally, but at a height of 26 m, using a knuckleboom, when wind conditions permitted. PM_{10} concentrations at each of the sites displayed distinct diurnal patterns, with PM_{10} concentration maxima in the evening (7–11 pm) and in the morning (9–10 am). New PM emissions were responsible for the morning peaks in PM_{10} concentrations. Using ion beam and light reflection analyses to identify elemental and black carbon concentrations, respectively, and positive matrix factorization to identify PM sources, five PM sources were identified for each site: biomass combustion, vehicles, marine aerosol, shipping sulfate and crustal matter. Biomass combustion was the most dominant source at each of the sites and was responsible for both the evening and morning peak PM_{10} concentrations, suggesting that Nelson residents are re-lighting their fires when they rise in the morning.

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1. Introduction

Particulate matter (PM) is well-known to have adverse effects on human health and a range of environmental effects, including local reductions in visibility and effects on the Earth's radiative balance (Dockery et al., 1993; Tsai and Cheng, 1999; Nel, 2005; Russell and Brunekreef, 2009; Pósfai and Buseck, 2010). As in many countries, PM concentrations in New Zealand are routinely monitored and the National Environmental Standard (NES) for PM sets a 24-h average limit for PM_{10} (PM with aerodynamic diameters less than 10 μm) concentrations at 50 μg m^{-3}. Many urban areas in New Zealand exceed the NES numerous times each year, particularly during the winter when wood combustion for home heating is common (http://www.mfe.govt.nz/environmental-reporting/report-cards/air/2009/index.html).

Particulate matter concentrations in New Zealand's urban environments have distinct diurnal cycles, independent of community size or population (Trompetter et al., 2010). During these cycles, PM_{10} concentrations peak between 22:00 and 0:00, with a less pronounced peak also occurring between 8:00 and 11:00. These peak concentrations can result in daily PM_{10} concentrations that exceed the NES. Currently very little is known about PM sources and their contributions on an hourly time-scale, information that is critical for effective air quality management (Ancelet et al., 2012). High-temporal resolution source apportionment studies can provide unique and highly relevant information for the implementation of PM mitigation strategies. To identify the sources and factors contributing to PM pollution episodes on an hourly time-scale, an intensive monitoring campaign was undertaken in Nelson, New Zealand (population 43,000; latitude −41.16°, longitude 173.17°) during the 2011 winter. Nelson is a small city located on the northern coast of New Zealand's South Island. Nelson is known to suffer from poor air quality during the winter, when domestic combustion for home heating is common, and exceeds the NES several times each year, primarily because of the formation of strong temperature inversions that limit the dispersion of pollutants.

We have recently reported the first PM source apportionment study using hourly data obtained from two sampling sites in the rural community of Masterton, New Zealand (Ancelet et al., 2012). In the current study, hourly coarse ($PM_{10-2.5}$) and fine ($PM_{2.5}$) samples were collected from four sites in Nelson using Streaker samplers and were analyzed for elemental and black carbon (BC) concentrations. Hourly PM_{10} concentrations were determined using continuous PM_{10} beta attenuation monitors (BAMs) and positive matrix factorization (PMF) was used to determine the PM sources and their contributions on an hourly time-scale at each site using the hourly elemental, BC and PM_{10} concentrations. The collection of samples and use of PMF are described in Section 2. Meteorological data was also collected at each of the sites and was used to provide insight into the transport and dispersion of PM.

Using hourly source contributions produced from the PMF analyses and meteorological data from each of the sites, potential PM transport mechanisms were identified based on the influence of wind speed and/or wind direction. Additionally, the role that urban topography plays in the development of elevated PM concentrations was evaluated.

2. Materials and methods

2.1. Sample collection

Ambient air monitoring was conducted at four locations in an urban valley in Nelson. Three of the sites were located along the general katabatic flow pathway (upwind, central and downwind) at heights of 2 m above ground level. The fourth site (Aloft) was located alongside the central site, but was raised to a height of 26 m above the ground level site using a knuckleboom when wind conditions permitted. When wind conditions did not permit, samples were still collected, just at ground level. This type of experimental setup has recently been reported (Ancelet et al., 2013), and Fig. 1 presents a schematic illustration of the sampling site locations. The sampling site locations were designed to provide an indication of PM transport horizontally and vertically within the Nelson airshed.