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Application of airshed modelling to the implementation of the New Zealand National Environmental Standards for air quality

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A R T I C L E I N F O

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A B S T R A C T

Christchurch is one of New Zealand's cities that suffers from high levels of particulate pollution due to the use of wood-burning heaters in the winter months. Frequent exceedences of the National Environmental Standards (NES) for ambient air quality of 50 $\mu g\,m^{-3}$ occur for daily PM_{10} (particulate matter with an aerodynamic diameter of 10 μm or less). The main objective of this study is to assess the efficacy of the emission reduction strategy implemented by Environment Canterbury (the local air quality management authority) for the city of Christchurch using an air pollution model called TAPM. This model is used with and without data assimilation to simulate the meteorology and particulate matter dispersion for 1–9 July, 2001, when a stagnant anticyclone dominated the region and led to a prolonged period of poor air quality (the NES was exceeded on every day). This period is again tested with the projected 2013 emission inventory to investigate the reduction in PM_{10} concentrations due to predicted emission reductions. The last surveyed emission inventory for Christchurch was conducted in 2001, when particulate emissions for a 'typical winter day' were estimated to be 7145, 974, and 1001 tonnes per day from domestic, industrial, and transport sources, respectively. Emission inventories for 2013 – also for a 'typical winter day' – are based on policy implementation resulting in predicted 2013 particulate emission strengths of 998 (domestic), 1164 (industry), and 421 (transport) tonnes per day. Results show that the 2013 emission inventory will cause no exceedences at the location of the monitoring station in Christchurch. However, due to the complex wind regime and topography of the area, it is highly likely that the NES will be exceeded at locations away from the monitoring site, making Christchurch non-compliant with its objectives. This is particularly significant as the NES apply to the maximum concentration occurring anywhere in the polluted airshed.

1. Introduction

Mesoscale atmospheric numerical models are increasingly being used to address air quality management problems that require an understanding of the spatial and temporal variation in air pollution (Zawar-Reza et al., 2005a,b). They can predict spatial and temporal variation of the wind field and atmospheric structure over complex terrain, factors that determine air pollution dispersion. They can be used to define airsheds by applying back-trajectories to identify the pathways followed by air during periods of build up of pollution (Sturman and Zawar-Reza, 2002). They may also have applications in long-term epidemiological studies of human exposure to air pollution (Wilson and Zawar-Reza, 2006). These models are frequently meshed with atmospheric chemistry models/modules that predict spatial and temporal variations in chemical composition. However, they need good quality information about pollutant emissions to provide useful predictions. These air

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pollution dispersion models can be used to identify parts of airsheds likely to experience highest concentrations of pollution, and therefore assist in location of monitoring sites. They can also be used to predict future spatial patterns of ambient air pollution concentrations in response to different air quality management strategies, essentially evaluating scenarios of possible emission reductions. In this way, they can also be used to evaluate the effectiveness of existing and proposed air quality management strategies, and assess whether deadlines for implementation of new environmental standards are likely to be met.

In spite of its 'clean-and-green' image, New Zealand suffers from air pollution levels that are considered to present a risk to human health, particularly with respect to PM_{10} (Ministry for the Environment, 2002; Spronken-Smith et al., 2001; McGowan et al., 2002). Air pollution regulation in New Zealand is covered by the Resource Management Act 1991, which requires regional authorities to establish environmental management strategies to address problems of air, land and water quality. Under the powers of this act, on 6 September 2004, the New Zealand Ministry for the Environment issued new and more stringent National Environmental Standards for air pollution to be fully implemented by 2013. The regulations that have been established to ensure that regional authorities meet the new standards involve implicit recognition of the role of atmospheric processes in the transport and dispersion of air pollution within 'airsheds'. As a result, atmospheric dispersion models are becoming increasingly significant tools to assist in achieving the prescribed air quality targets. This paper therefore describes an application of The Air Pollution Model (TAPM; Hurley, 2005) to ensuring that the new National Environmental Standards are achieved in New Zealand by 2013, providing a case study illustrating the application of advanced atmospheric modelling techniques to assessment of the effectiveness of current and proposed emissions reductions.

2. National Environmental Standards

The new National Environmental Standards in New Zealand relate to a range of different air pollutants, including particulate material, carbon monoxide, nitrogen dioxide, ozone and sulphur dioxide. Particulate material is a major pollutant in this country, largely because of the traditional use of wood and coal for home heating. It is therefore a major focus of the new standards. Key elements of the new National Environmental Standards that relate to PM_{10} (particulate material less than 10 μm in diameter) pollution are:

1. Regional authorities are required to define air quality management regions based on the concept of airsheds. The regulations state that 'The ambient air quality standard for a contaminant applies at any place: (a) that is in an airshed; and (b) that is in the open air; and (c) where people are likely to be exposed to the contaminant' (Regulation 14, in Ministry for the Environment, 2005).
2. Much more stringent ambient air quality standards were prescribed (Table 1). In particular, the ambient air quality standard for PM_{10} is not to be exceeded more than once per year by 2013. Several New Zealand cities regularly exceed this standard, with Christchurch experiencing 25–30 days each winter on which a 24-h average of 50 $\mu g\,m^{-3}$ is exceeded.
3. The regional authority must establish monitoring for air pollutants in an airshed if there is any likelihood of standards being exceeded. They must also conduct the monitoring in that part of the airshed where there is likely to be the greatest exceedences, or the greatest number of exceedences, using standard measurement procedures (e.g. a high volume sampler for PM_{10}).
4. Between 1 September 2005 and 2013, the regional authority must decline all applications for 'discharge-to-air' permits if the discharge is likely to cause the concentration of PM_{10} in the airshed to rise above the 'straight line path'. The straight line path is defined by a straight line starting on the *y* axis of a graph at a point representing the number of exceedences of the ambient concentration of PM_{10} in the airshed at 1 September 2005, and ending on the *x* axis of the graph at a point representing the new environmental standard for PM_{10} at 1 September 2013 (Fig. 1). Amendments to the regulations in August 2005 allowed the fitting of a curved line path in place of a straight line path, as long as the air quality target would be reached by 2013, as well as allowing approval of new emissions consents if it can be demonstrated that emissions would be reduced elsewhere to offset the effect of a new pollution source. After 2013, regional authorities must decline all applications for 'discharge-to-air' permits if the concentration of PM_{10} in the airshed breaches its ambient air quality standard, or if the discharge is likely to cause the concentration of PM_{10} in the airshed to rise above the new air quality standard.

3. The Christchurch air pollution problem

High levels of PM_{10} in Christchurch are associated with domestic heating sources operating in the evening

Table 1
New Zealand's new ambient air quality standards for air pollutants effective from 2013 (Ministry for the Environment, 2005)

Contaminant	Threshold concentration	Permissible excess
Carbon monoxide	10 $mg\,m^{-3}$ as a running 8-h mean	One 8-h period in a 12-month period
Nitrogen dioxide	200 $\mu g\,m^{-3}$ as a 1-h mean	9 h in a 12-month period
Ozone	150 $\mu g\,m^{-3}$ as a 1-h mean	Not to be exceeded at any time
PM_{10}	50 $\mu g\,m^{-3}$ as a 24-h mean	One 24-h period in a 12-month period
Sulphur dioxide	350 $\mu g\,m^{-3}$ as a 1-h mean	9 h in a 12-month period
	570 $\mu g\,m^{-3}$ as a 1-h mean	Not to be exceeded at any time