THE ROLE OF ATMOSPHERIC MODELLING IN THE IMPLEMENTATION OF NEW NATIONAL ENVIRONMENTAL STANDARDS FOR AIR QUALITY IN NEW ZEALAND

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INTRODUCTION

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, R.A. et al.*, 2001; *McGowan, J.A. 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 examines ways in which air pollution modelling is currently being applied to ensuring that the new National Environmental Standards are achieved in New Zealand by 2013.

NATIONAL ENVIRONMENTAL STANDARDS

The new National Environmental Standards 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 New Zealand, 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 μg 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 to 30 days each winter on which a 24-hour average of 50 μg 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 (Figure 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.

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-hour mean	One 8-hour period in a 12-month period
Nitrogen dioxide	200 µg m^{-3} as a 1-hour mean	9 hours in a 12-month period
Ozone	150 µg m^{-3} as a 1-hour mean	Not to be exceeded at any time
PM_{10}	50 µg m^{-3} as a 24-hour mean	One 24-hour period in a 12-month period
Sulphur dioxide	350 µg m^{-3} as a 1-hour mean	9 hours in a 12-month period
	570 µg m^{-3} as a 1-hour mean	Not to be exceeded at any time

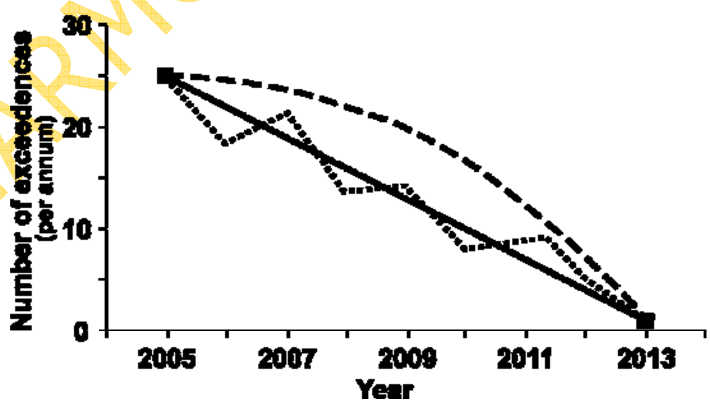

Fig. 1; The straight/curved line path concept applied to an airshed currently recording 25 exceedences per annum. The solid, dashed and dotted lines represent the straight line path, curved line path and hypothetical number of exceedences recorded each year up to 2013.

There are three key aspects of this new approach to air quality management of interest from an air pollution modelling point of view. First, the concept of an airshed is used as the basis for air quality management, but is not clearly defined. Second, monitoring of air pollutants must take place in the most affected areas within these airsheds, but no advice is given on identifying the location of these areas. Third, a linear (or curvi-linear) model should be used to predict future projections of the decline in pollution levels required to achieve the new standards.

APPLICATIONS OF ATMOSPHERIC MODELLING

Atmospheric 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, P. et al.,* 2005). 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, A.P. and P. Zawar-Reza*, 2002). They may also have applications in long-term epidemiological studies of human exposure to air pollution (*Wilson, J.G. and P. Zawar-Reza*, 2005). In addition, these models can be used to predict future ambient air pollution concentrations in response to a range of different air quality management strategies, essentially evaluating scenarios of possible emission reductions.

AIRSHED MODELLING AS A MANAGEMENT TOOL

An idealised airshed is essentially a region within which an air pollution problem is largely 'contained' because of the combined effect of the topography and local meteorological conditions. That is, any emissions emitted within the boundary of that region tend to contribute to the air quality of only that region, and the air pollution experienced is emitted only by sources within that region. There is therefore no point going outside the region to solve the air pollution problem, and any amelioration strategies must apply to emissions that originate inside it. In reality, there will generally be some downstream leakage of pollution in and out of airsheds, out to sea in the case of most of New Zealand's coastal cities, such as Christchurch or Auckland, and into inland mountain basins due to plain-to-basin airflow (*Kurita, H. et al.*, 1990). In more densely populated or industrialised countries, leakage of pollutants can obviously take place from one airshed to another. Technically, an airshed may vary in size from a few square kilometres in a valley or small basin (Figure 2) to a large flat uniform area covering hundreds of square kilometres. However, the time frame for air pollution transport and dispersion is such that there is generally an upper limit to the size of area involved.

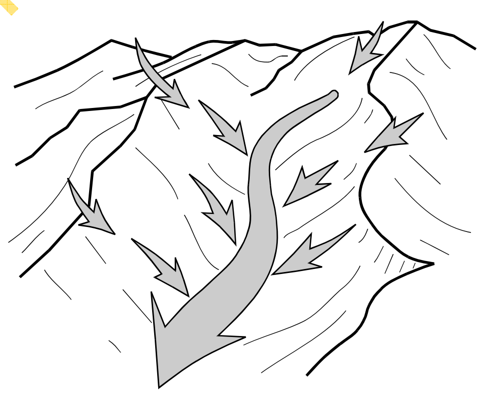

Fig. 2; Idealised representation of an airshed dominated by nocturnal cold air drainage.

Key issues in trying to delimit airsheds over areas of complex terrain include the nature of the air pollution problem, particularly the types of pollutant being emitted and the temporal and spatial patterns of their emission. The meteorological conditions associated with high levels of pollution are also important. For example, high levels of PM_{10} in Christchurch are associated with domestic heating sources operating in the evening between 1800 and 2200 NZST, when the weather conditions are dominated by anticyclonic, cool, calm and clear conditions. In these circumstances, strong surface-based temperature inversions develop and airflow is dominated by localised nocturnal cold air drainage and stagnation. *Sturman, A.P. and P. Zawar-Reza,* (2002) provided an example of how atmospheric mesoscale models can be combined with back-trajectory techniques to help delimit the airshed associated with such night-time PM_{10} air pollution problems (Figure 3).

In contrast, air pollution in Auckland in the North Island of New Zealand is more strongly affected by motor vehicle sources during daytime hours. It is obvious that defining an airshed for a nocturnal pollution problem, when the atmosphere is very stable, is easier than for a daytime situation when convective turbulence is dominant and pollution transport occurs over longer distances and involves greater diffusion. The concept of an airshed is clearly a dynamic one, as the extent of an airshed will vary depending on the time of day and year, so that wintertime nocturnal emissions of PM_{10} will be confined in a smaller area than daytime summer emissions of NOx, and the subsequent production of ozone.

(a) (b)

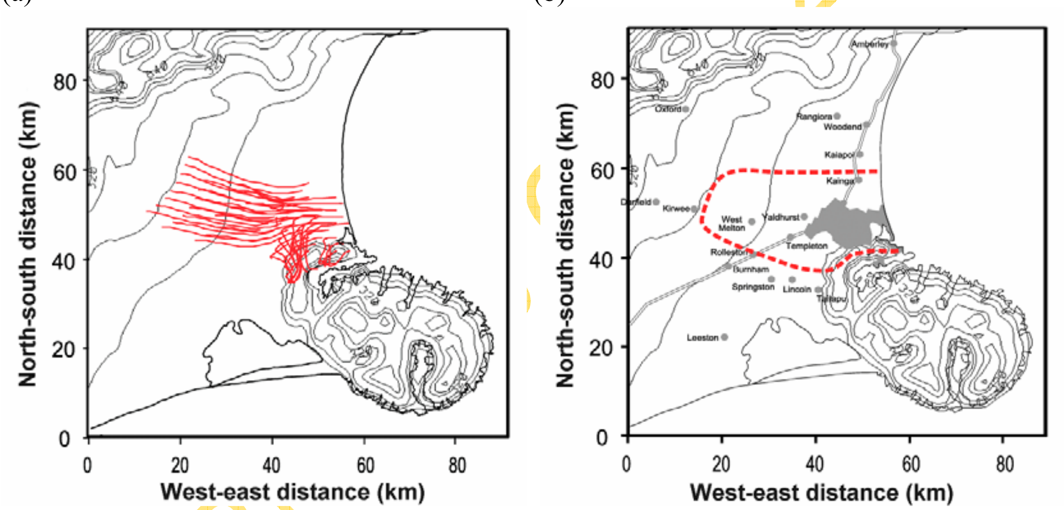

Fig. 3; Application of (a) an atmospheric mesoscale model and back-trajectory techniques to (b) the delimitation of the clean zone for Christchurch, New Zealand (after Sturman, A.P. and P. Zawar-Reza, 2002).

The integration of mesoscale meteorological models with air pollution modules can assist in locating air pollution monitoring sites, a key requirement of New Zealand's new National Environmental Standards. Figure 4 provides an example of the application of TAPM (The Air Pollution Model — developed by the Commonwealth Scientific and Industrial Organisation, Australia) to mapping average 24-hour ambient concentrations of PM_{10} over Christchurch during winter, based on an emissions inventory developed by the regional authority (Environment Canterbury). It is clear that the main monitoring site at Coles Place appears to be located close to the area of highest concentrations, and therefore conforms to the requirements of the new National Environmental Standards. These integrated models can also be used to identify what reductions in emissions are required to meet the new standards by 2013. That is, pollution reduction scenarios associated with the straight line path concept can be evaluated and major emissions sources can be targeted in a strategic way.