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Trace elements and metal pollution in aerosols at an alpine site, New Zealand: Sources, concentrations and implications

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HIGHLIGHTS

- Dust samples collected in New Zealand of both Australian and local origin.
- High concentrations of metal pollutants in dusts.
- Australian dust concentrations in NZ air correlates with dust storms in Australia.
- Geochemical fingerprinting effective at determining dust source.

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ABSTRACT

Atmospheric aerosol samples were collected at a remote site in New Zealand's Southern Alps. Collected samples were found to be a mixture of New Zealand and Australian sourced sediment, using their trace element signatures. Aerosol concentrations and the relative contribution of different sources was found to be a function of specific air-mass trajectories influencing the study site, dust entrainment rates in source areas and rainfall. Results show that Australian dust is a major source of particulate matter in New Zealand, particularly in remote alpine locations; however, locally derived dust is also important. Metal pollutants, including Pb, Cu and Sn, were enriched in the samples by approximately 15 times and up to >100 times expected natural concentrations, confirming that metal pollution is a ubiquitous component of the atmosphere, even in relatively remote locations. Moreover, pollutants were highly enriched in otherwise clean air, i.e. during and following rainfall. Additionally, high concentrations of elements naturally enriched in sea water, e.g. Sr, Ba and Rb, were deposited alongside mineral dust, reflecting the oceanic origin of air influencing the site and the role of sea spray in contributing aerosol to the atmosphere. These elements experienced the greatest enrichment during rainfall, implying sea spray and pollution become relatively important during otherwise clean air conditions.

1. Introduction

Long-range dust transport is an important component of sedimentary and biogeochemical systems. Dust has, for example, been demonstrated to be a driver of ocean productivity through additions of principally Fe and Si (though other elements are also important) in settings, such as the Southern Ocean, that are otherwise very depleted in these elements (Boyd et al., 2004; Duce and Tindale, 1991; Martin et al., 1994). The role of dust in sedimentary systems is apparent in oceanic settings remote from continents where significant dust mantles the ocean floor (Hesse, 1994; McGee et al., 2007; Rea, 1994). Copious dust transport and deposition marked the glacial cycles of the Quaternary Period, resulting in accumulation of loess downwind of cold climate regions, most notably in China where loess deposits of up to 100 m date from this time, but also in Eurasia, North America, Northern Europe, southern South America and New Zealand (Maher et al., 2010). Dust therefore played a major role in biogeochemical

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processes during cold climate phases. In arid and semi-arid environments, such as in Australia, loess has been harder to recognize, but here also it appears that during cold climate phases dust inputs were significant (Hesse and McTainsh, 2003). Further from source, dust inputs have been shown to contribute to soil formation. For example Saharan dust has been found to contribute to soil formation in the Caribbean Islands and Florida (Muhs et al., 2007). Similarly, Asian dust contributes to Hawaiian soils (Kurtz et al., 2001; Rex et al., 1969), while Australian dust has been shown to contribute to soil formation in New Zealand (Marx et al., 2009).

There are few studies of contemporary dust deposition rates in the Australian region (Hesse and McTainsh, 2003) because with the exception of large events, deposits are difficult to identify and quantify (McTainsh, 1989). Despite this, dust deposition is still an important component of current biogeochemical cycles (Shao et al., 2011). Satellite monitoring can provide useful information on spatial and temporal characteristics of dust transport, in addition to atmospheric concentrations for both longer term, e.g., over multiple years (Prospero et al., 2002), and event-based studies (Bullard et al., 2008). Atmospheric and deposition monitoring also provide important data on dust and aerosol concentrations and chemistry (Prospero, 1999), often at a fine scale, which may not otherwise be determined, e.g. by modelling or remote sensing.

In addition to 'natural' dust transport, dust transport and deposition rates have increased in many settings as a result of anthropogenic activities (e.g. Marx et al., 2011; Neff et al., 2008). The composition of the dust aerosol itself has also changed as a result of enrichment of metals (e.g. Marx et al., 2008) and other contaminants within the environment (e.g. Lavin et al., 2012). Serving as evidence of the biogeochemical significance of dust additions, these anthropogenic constituents are now found accumulating in environments where dust is a major sedimentary input (e.g. Brännvall et al., 1999; Le Roux et al., 2004; Marx et al., 2010).

In this study, we examine contemporary concentrations, chemistry and sources of dust and other aerosols within the atmosphere in a remote alpine setting in the Southern Alps, South Island, New Zealand. We build on results presented in Lavin et al. (2012) using some of the same data; however, whereas that study focused on identifying sources of semi-volatile organic pollutants in the atmosphere, this study examines the concentrations, composition and sources of aerosol collected alongside the organic pollutants.

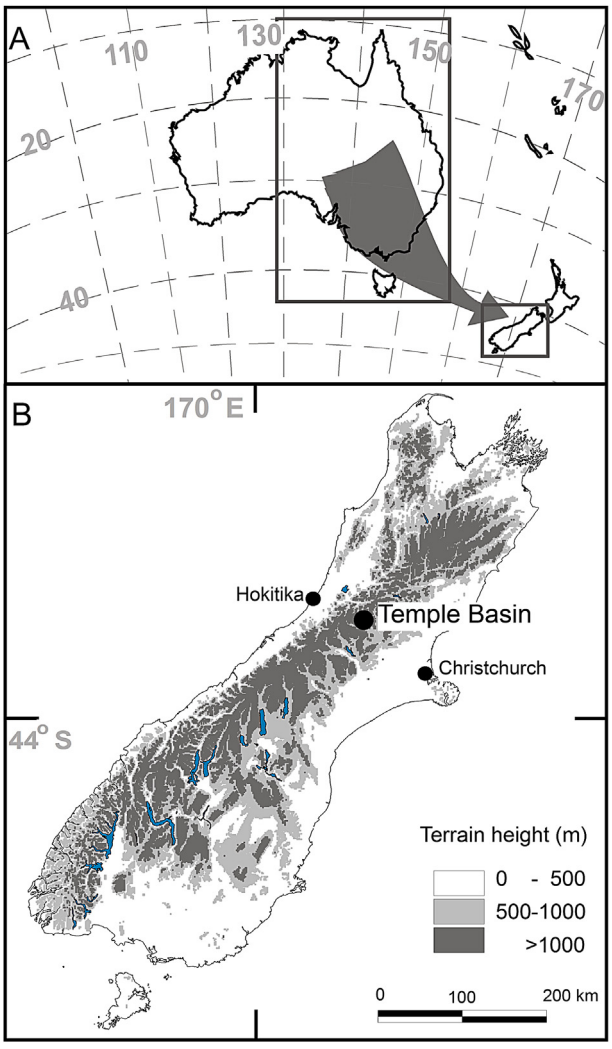

Fig. 1. (A) The relative position of New Zealand and Australia. The arrow indicates the main dust transport pathway from eastern Australia. (B) Location of Temple Basin at Arthur's Pass in the central South Island, New Zealand.

2. Methods

2.1. Aerosol collection

Aerosol samples were collected at Temple Basin Ski Club (42.91°S, 171.57°E, 1320 m asl), in Arthur's Pass National Park, Southern Alps, New Zealand (Fig. 1) using a total suspended particulate sampler (Flow-Set high-volume sampler TSP, Lear Siegler, Australia) on 20 cm × 25 cm, 2-μm pore size polycarbonate membrane filters (Sterlitech Corporation, Kent WA, USA) between 16-Jan and 16-Feb 2009 as described in Lavin et al. (2012). No sampling occurred on 4-Feb due to a power failure. The sampler was run for 23.5 h day^{-1} with ~353 m^3 of air sampled daily. Filters were changed daily and stored in chemically inert plastic bags prior to and following collection. Temple Basin is a westward draining basin in the central Southern Alps surrounded by peaks of >1700 m asl. The air sampler was positioned within an alpine tussock grassland and herb field on the southern side of the basin facing a north-westerly aspect.

2.2. Climate data

Rainfall data were obtained from the weather station at Arthur's Pass Village AWS (42.94°S, 171.56°E, 738 m asl) (National Institute of Water and Atmospheric Research), 4 km south and 560 m lower than Temple Basin. Four-day air-mass back-trajectories were generated using the HYSPLIT model (NOAA Air Resources Laboratory, Silver Spring, MD, USA). Back-trajectories were generated for each 24-h sampling period at 1200, 1600, 2000, 2400, 0400 and 0800 h at 2500, 2700, 2900 m asl, yielding a catalogue of 18 trajectories/sampling day.

2.3. Australian dust activity data

Dust activity in Australia was measured using observational data from the Bureau of Meteorology held in the Dust Event Database at Griffith University (McTainsh et al., 2011). Daily dust activity was quantified as dust event frequency (DEF), representing the total number of dust storms (severe and moderate), local dust events and dust haze events (definitions in O'Loingsigh et al., 2010) occurring in the southeastern sector of the continent (bordered by Lat. 26°S and Long. 129°E).

2.4. Dust recovery and trace element analysis

To recover the collected aerosol, the filters were soaked for 72 h at 100 °C in 30 ml Teflon beakers filled with triple sub-