Wet Deposition of Excess Sulfate at Macquarie Island, 54° S

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Abstract. Annual wet deposition of excess sulfate at Macquarie Island has been estimated from 5 months of rainwater composition data covering the Austral summer of 1985/86. The resulting figure of 2.1 ± 0.6 mmol/m²/yr is at the low end of previous estimates of maritime excess sulfate deposition by precipitation. Within estimated uncertainty limits this figure is consistent with the DMS emission flux which would be predicted for latitude 50°–60° S, based solely on available Northern Hemispheric DMS measurements.

Key words. Excess sulfate, marine rain, wet deposition.

1. Introduction

The balance, or lack of balance, calculated for the atmospheric inputs and outputs of sulfur species has provided one means of testing our understanding of the maritime, atmospheric sulfur cycle. This cycle has become of considerable interest with the recognition that the ocean is a significant source of atmospheric sulfur (Andreae and Raemdonck, 1983; Cline and Bates, 1983), and that changes in this cycle and changes in global climate may be interdependent (Charlson et al., 1987). Calculations of this sort were used specifically by Andreae and Raemdonck (1983) and more recently by Bates et al. (1987) to assess the consistency between estimated emissions of dimethyl sulfide from the world’s oceans, and the idea that this gas is the predominant source of excess sulfate found in maritime aerosols and rain.

Attempts to balance the maritime atmospheric sulfur budget hinge very much on the availability of data adequate for the task of estimating both oceanic emissions and deposition to the oceans. The availability of data on the emissions side has increased dramatically in recent years, especially for the northern oceans (see Bates et al., 1987, and references therein), however data on deposition of excess sulfate has remained limited.

In the case of wet deposition of excess sulfate, almost all of the vast reaches of the southern oceans are devoid of relevant data derived directly from rainwater sulfate concentration. The major reviews by Varhelyi and Gravenhorst (1983)
and Galloway (1985) summarise precipitation data from only three sites and one cruise in the southern tropics, and only three sites in the southern mid-latitudes, with no data between about 40°S (Amsterdam Island) and the Antarctic continent. This lack of representative data makes problematic any attempt to interpret the emission/deposition imbalance perceived by Bates et al. (1987), who suggested that their extrapolated, global oceanic emission rate for DMS, of 1.4 mmol/m²/yr appeared to be lower than the 4.4 mmol/m²/yr estimate of average, global, non-sea-salt sulfur deposition arrived at from the figures of Galloway (1985). Wet deposition contributed 3.1 mmol/m²/yr, or almost 75% of the latter estimate.

This brief paper presents a preliminary estimate of excess sulfate wet deposition at Macquarie Island, 54°29' S, 159°58' E, based on concentrations of chloride and sulfate ions in 47 rainwater samples collected between December 1985 and April 1986. This small data set is by itself of limited use for extrapolations to global scale. However, it has three points of significance. It contributes data on excess sulfate deposition in the hitherto uninvestigated region between 40°S and the Antarctic; the estimated annual rate of wet deposition is at the low end of the range tabulated by Galloway (1985) for remote maritime areas, despite the fact that it is probably an overestimate since it is based on summertime measurements when DMS emissions are assumed to be maximum; however the magnitude of the wet deposition estimate is consistent with an estimate of DMS emissions for this latitude extrapolated from northern hemispheric DMS data.

2. Sample Collection and Analysis

Macquarie Island is located in longitude about halfway between Australia and New Zealand but at a latitude that puts the island halfway to the Antarctic continent (Figure 1). As such, long-range transport of continental sulfates to the island is unlikely, making this a favourable site for sampling rainwater free from anthropogenic and continental influence.

The island is uninhabited except for the small, permanent ANARE (Australian National Antarctic Research Expeditions) scientific base. Exhaust emissions from small internal combustion engines associated with the ANARE activities are the only possible source of contamination that we can identify. Location of the samplers was chosen so as to avoid any such contamination. In addition, our expectation is that the persistent, strong winds encountered at this site would serve to rapidly disperse any small sulfur emissions from the ANARE activities to insignificant levels.

Rainwater collections were made primarily at the isthmus and Lambing Gully sites, although a few collections were made at Ski-Hut and Mt Elder (see Figure 1). No site-related effects on excess sulfate concentration were found, so for the purposes of the following analyses the data have been pooled.