

THE RECORD OF AEROSOL DEPOSITED SPECIES IN ICE CORES, AND PROBLEMS OF INTERPRETATION

Eric W. Wolff
British Antarctic Survey
Natural Environment Research Council
High Cross
Madingley Road
Cambridge CB3 0ET
UK

1. Introduction

Ice cores have now become established as one of the primary archives of paleoclimatic information, covering timescales from seasonal up to 100,000 years or more. In the polar ice sheets, where there is little or no melting, snow layers build up year by year. Included in them are samples of the atmosphere: trace gases in air bubbles, particles and adsorbed gases, and the water molecules themselves. By drilling into the ice at suitable places, we can collect cores that give profiles of chemical content and physical properties of the ice. These are then used to infer the state of the atmosphere in the past.

For some species, this inversion to a relevant atmospheric variable is either fairly simple, or has been well-calibrated. For instance, for a non-reactive trace gas such as methane, the concentration in the air extracted from gas bubbles is assumed to be identical to the concentration in the atmosphere at the time the bubble was sealed (Raynaud et al. 1993). The oxygen isotopic content of water molecules in ice has long been assumed to represent the temperature at the time of snowfall; recent studies (Cuffey et al. 1995; Johnsen et al. 1995) have used borehole temperatures to calibrate this signal.

For particulate and reactive gas species, it has also until recently been assumed that there was a linear relationship between changes seen in the ice and changes in the atmosphere at the time of snowfall. This has offered the attractive proposition of learning about atmospheric changes representing some of the forcing factors for climate. For instance, there are papers that use ice core data to try to derive past volcanism (using sulphate or acidity measurements), sea ice position (marine ions), atmospheric circulation patterns (dust), marine biological productivity (methanesulphonic acid), stratospheric temperatures (nitrate), pollution (e.g. lead), oxidative

capacity of the atmosphere (hydrogen peroxide), and many other parameters. However, there has been a growing realisation that depositional and post-depositional processes confuse the interpretation for many species, and this workshop is the culmination of that awareness.

This chapter, along with two others, aims to show the potential of ice cores to deliver information on paleoatmospheric chemistry. In each case, the chapters will give a flavour of the data that exist, and will explain some of the difficulties involved in interpreting the ice core profiles in terms of atmospheric changes. The processes causing the difficulties will be explored in later chapters. The present chapter concentrates on the chemical species that are delivered to the snow as aerosol (that is, as solid or liquid particles). The following chapters look at acidic gases, including nitric and organic acids (Legrand et al. 1996) and at other gases such as hydrogen peroxide and formaldehyde (Neftel 1996).

2. Aerosol sources, transport and deposition

We can distinguish a number of types of aerosol reaching the polar regions, derived from various sources.

a) Terrestrial material, derived from soil and desert dusts. In ice cores, this is investigated by looking at particle numbers or volume, or by using marker elements such as Al, Si, or Ca.

b) Marine aerosol, from sea spray. The two marker species are sodium and chloride. Both present some problems: sodium can have a significant terrestrial source in some cores, while chloride can be fractionated by reaction with acids, producing HCl which can be volatilised from the particle, so that chloride can be in excess or deficit compared to other marine ions.

c) Sulphur species. Methanesulphonic acid (MSA) comes from oxidation of dimethyl sulphide (DMS), produced by marine algae. Sulphate is also produced from this source, though it has additional sources from volcanism (particularly sporadic spikes after major eruptive volcanoes), sea salt aerosol, and in recent times pollution.

d) Pollution. Apart from sulphate, there have been major studies involving a range of heavy metals, such as lead (Pb). Work has also been carried out on organochlorine compounds, though these may not be deposited exclusively in the aerosol phase.

e) Exotic material. The possibility must exist to study sources such as pollen, diatoms, and various biological molecules. Most of these species are in relatively small concentrations,