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# Temporal variations in marine chemical concentrations in coastal areas of eastern Antarctica and associated climatic causes

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ABSTRACT

Snow pit (and a firn core) samples obtained from coastal areas in the eastern Lambert basin of eastern Antarctica enabled us to investigate the temporal variations in soluble marine ion concentrations and the possible mechanisms influencing their variations. The concentrations of seasonal sea salt ions ($Na^+$, $Cl^-$ and $Mg^{2+}$) at the coastal site (LH406) were maximal in the spring and minimal in the summer; broad maximal values also occurred in the winter and minimal values occurred in the summer in the interior site (ZG050). The sea ice extent (SIE) in the Indian Ocean sector of eastern Antarctica followed similar temporal distribution patterns. Two sulfur compounds ($SO_4^{2-}$ and MSA) experienced seasonal variations similar to those observed for sea salt ions at the LH406 site. However, distinct variations were reported at the ZG050 site. The variations in $nssSO_4^{2-}$ levels in the ZG050 snow pit that occurred over a 14-year period were positively correlated with variations in SIE. However, this relationship was different from that at the western Lambert basin. The change in direction of the supplementary prevailing wind during 1994–1995 produced a significant change in the concentrations of marine ions. A change in the source region may be the primary cause of this difference.

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## 1. Introduction

Atmospheric matter is constantly deposited on the polar ice caps, and thus, these ice caps represent a powerful and unique archive of past climatic and environmental changes that offers the possibility of understanding the forcing factors and positive and negative feedback mechanisms of the climatic system (Kreutz and Mayewski, 1999; Traversi et al., 2004). In previous studies, continuous ice core sampling from the surface and deep layers has lengthened the available paleo-climatic and paleo-environmental information to hundreds of thousands of years (Augustin et al., 2004). For example, the EPICA Dome C (European Project for Ice Coring in Antarctica, in the Pacific/Indian Ocean sector, East Antarctica) ice core project yielded a climatic history of the last 800,000 years that included at least eight glacial–interglacial transition events (Augustin et al., 2004). The deep ice core drilling project at Dome Argus, an important project of the International Trans-Antarctica Scientific Expedition (ITASE), aims to obtain a climatic record of Antarctica spanning one million years, the longest period yet attempted (Xiao et al., 2008). However, a reliable relationship between glaciological data and paleo-atmospheric composition depends on our understanding of how changes in source intensity and transport efficiency are reflected in the snow for different climatic conditions and how changes in the chemical and physical features of snow deposition, which can affect depositional and post-depositional processes, affect the ice layer composition (Mayewski and Legrand, 1990; Hansson, 1995; Wagnon et al., 1999). Many previous studies have discussed the spatial distribution of different climatic indicators (e.g., sea spray elements, sulfur compounds and nitrogen ions) (Qin et al., 1992, 2000; Suzuki et al., 2002; Bertler et al., 2005). However, given the large area of the Antarctic ice sheet and the complexities of the climatic systems in different regions, it is necessary to perform studies on spatial distribution in different areas. Such studies

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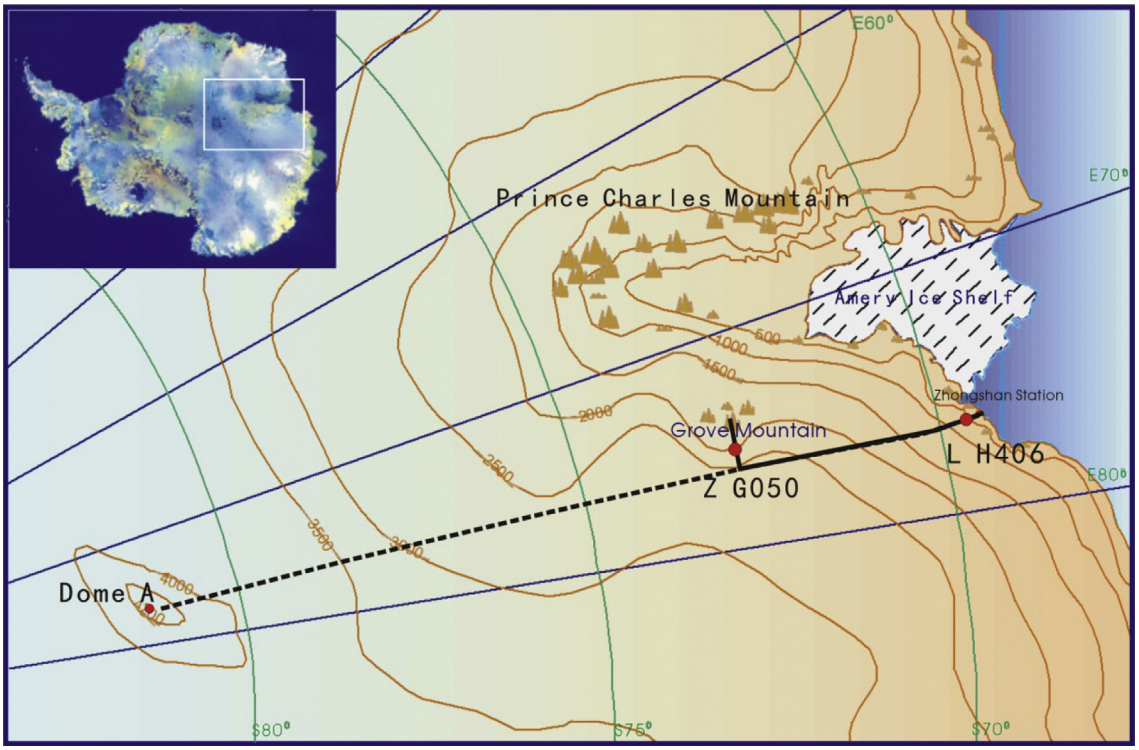


**Fig. 1.** Locations of the sampling sites. The dashed line shows the transect from the Zhongshan station to Dome A and the solid line represents the 2002/2003 CHINARE transect to the Grove Mountain area.

should also be conducted at sites that have already been studied, as studies using different time scales and temporal resolutions have not yet been performed.

Spatial research considers the sources of different ions such as $Na^+$, $Cl^-$ and $Mg^{2+}$ in sea salt (which have been shown to be closely related to the sea ice extent) (Becagli et al., 2004; Traversi et al., 2004), oxidized sulfur compounds such as $nssSO_4^{2-}$ and MSA (which are strongly influenced by the sea ice extent and sea surface temperature in the source area) (Traversi et al., 2004; Becagli et al., 2009) and nitrogen compounds in volcanic tephra depositions (Zhou et al., 2006; Ren et al., 2010) (which was significantly influenced by stratosphere/troposphere interchanges, lightning and other photo-induced atmospheric processes) (Traversi et al., 2004; Li et al., 2013). The deposition of chemical compounds is closely related to the intensity of atmospheric circulation (Ma et al., 2010). Many previous studies focused on rebuilding the history of atmospheric circulation and determining variations in signal intensities via variations in concentrations of chemical elements (Xiao et al., 2004; Zheng et al., 2010). After deposition, the original signals of the deposited compounds continue to change via drifting snow, sublimation and, for some unstable compounds (e.g., MSA, $NO_3^-$ and $NH_4^+$), re-emission from the snow layers and subsequent redeposition in the upper layers (Becagli et al., 2004; Traversi et al., 2004).

Here, we report on a study of the spatial and temporal distribution of primary (sea salt) and secondary (biogenic sulfur compounds and atmospheric nitrate) aerosol components from a snow pit and a firn core captured in coastal areas of the Princess Elizabeth Land and the inland areas near Grove Mountain. Both of the sampling sites lie on a transect from the Zhongshan station to Dome Argus (Ma et al., 2010; Ding et al., 2011).

## 2. Sampling and analysis

During the 2002–2003 Chinese National Antarctic Research Expedition (CHINARE), one snow pit and 25 firn core samples were taken at the beginning of an expedition route (approximately 450 km inland) that lies between Zhongshan Station and Dome A along the eastern side of the Lambert Glacier Basin. At the end of this transect, the expedition route turned right and moved into the Grove Mountain area, where another snow pit and eight firn core samples were obtained. We chose to study one firn core (LH406) near the coast and one snow pit (ZG050) from the interior plateau (Fig. 1). The LH406 firn core was chosen for its proximity to the sea, and because its high accumulation can provide detailed information on temporal variations in marine chemicals. The high sampling frequency (1 cm per sample) of the ZG050 snow pit in the inland area provides detailed information on variations in chemical concentrations, and its depth may yield a longer history of the influencing factors and mechanisms. Detailed geographic and sampling information from these two sites are presented in Table 1.

**Table 1**
Geographical and sampling information from the two sampling sites.

| Sampling site | LH406 | ZG050 |
|---|---|---|
| Locations | 69°35′36″S, 76°23′35″E | 73°15′01″S, 75°29′53″E |
| Altitude (m) | 679 | 2240 |
| Distance from the sea (km) | 24.6 | 434 |
| Depth (m) | 2.01 | 2.7 |
| Sample number | 67 | 270 |
| Accumulation (kg $m^{-2}$ $yr^{-1}$) | 260.6 | 80.1 |
| Sampling date (mm/dd/yy) | Feb 10, 2003 | Dec 21, 2002 |

After capturing the firn core from the LH406 sampling site, the outer 1 cm was removed using clean tools and the inner cores were separated and sealed in pre-cleaned sample bottles. The samples from the ZG050 site were obtained by pushing 120 ml pre-cleaned plastic bottles into the walls of the snow pits while the stratigraphic profile was observed taking all contamination-avoiding measures (Sun et al., 2002). All of the samples were transported frozen (−18 °C) to the State Key Laboratory of the Cryospheric Sciences

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