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Micro-particle in surface snow at Princess Elizabeth Land, East Antarctica

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Abstract During the Austral summer of 1996/1997, the First Chinese Antarctic Inland Expedition reached the inland area about 330 km along the direction around 76°E from Zhongshan Station, and collected 84 surface snow samples at an interval of 4 km. Micro-particle analysis of the samples indicates that the micro-particle concentration apparently decreases with the increasing of altitude, and the amplitudes of micro-particle concentration is much larger in the lower altitude than in the higher altitude. Further analysis of grain-size distributions of micro-particle, percentage of micro-particles from different sources and variations with altitude suggest that micro-particles in this area are from a considerably dominant source. Although this area is controlled by polar easterly wind and katabatic wind, transportation and deposition of the micro-particles are mainly influenced by marine transportation in coastal area.

Key words surface snow, concentration and distribution of micro-particle, Antarctic ice sheet.

1 Introduction

Many research achievements in ice core studies have shown that the micro-particle in snow-ice may be regarded as a climate and environmental proxy (Yao *et al*. 1989; Xie and Yao 1997; Thompson 1984). Investigation of time series focuses on micro-particle concentration and size distribution along with the change of time. The seasonal or longer-time environmental fluctuations as well as the rough time series can be deduced according to the micro-particle concentration and size distribution in the deposition of snow and ice (Thompson 1984; Fiacco 1991; Steffensen 1995). However, investigating spatial change of micro-particles is helpful to understand sources of micro-particles, to discuss the role of local climatic and geographical condition on deposition of micro-particles into snow and ice, and to reveal the regularity of spatial change of micro-particles (Thompson and Thompson 1982). In this paper, we have cooperated the micro-particle concentration, the size distribution and the geographical factors (such as altitude, distance from the sea etc.) to expound the spatial change and possible sources of micro-particles on surface snow along a distance of 330 km from Zhongshan Station at Princess Elizabeth Land, East Antarctica.

2 Sampling and analysis

2.1 *Collection of surface snow sample*

During the Austral summer of 1996/1997, the First Chinese Inland Expedition reached the inland area about 330 km from Chinese Zhongshan Station, and at an altitude of 2320 m (Fig. 1). The surface snow samples in this paper are collected from the upper 3 cm surface snow of ice sheet, which along the profile around 76°E from Chinese Zhongshan Station (69°25′S, 76°21′E, 100 m) to the point near LGB65 (71°53′S, 77°57′E, 2325 m). The sampling altitude is ranging from 386.0 m to 2307.9 m. A total of 84 surface snow samples were collected at an interval of 4 km in the period of 10 days from January 19 to January 28 in 1997, and 8 ~ 9 samples were collected every day. Because parts of expedition route were coincided with the route of Australian Lambert Glacial Expedition, samples were collected at the sites as nearly as the Australian surveyor′s poles for the data comparison.

The sampling process should avoid the man-made contamination. At every sampling site, three surface snow samples were collected by use of cleaned sampling bottles at the points of a equilateral triangle, and each sample was collected at the top of microrelief to decrease the influence of topography as less as possible. During sample collection, the longitude, latitude, altitude of sampling site, and the number of Australian surveyor′s pole were recorded. The samples were preserved at low temperature to prevent the ex-

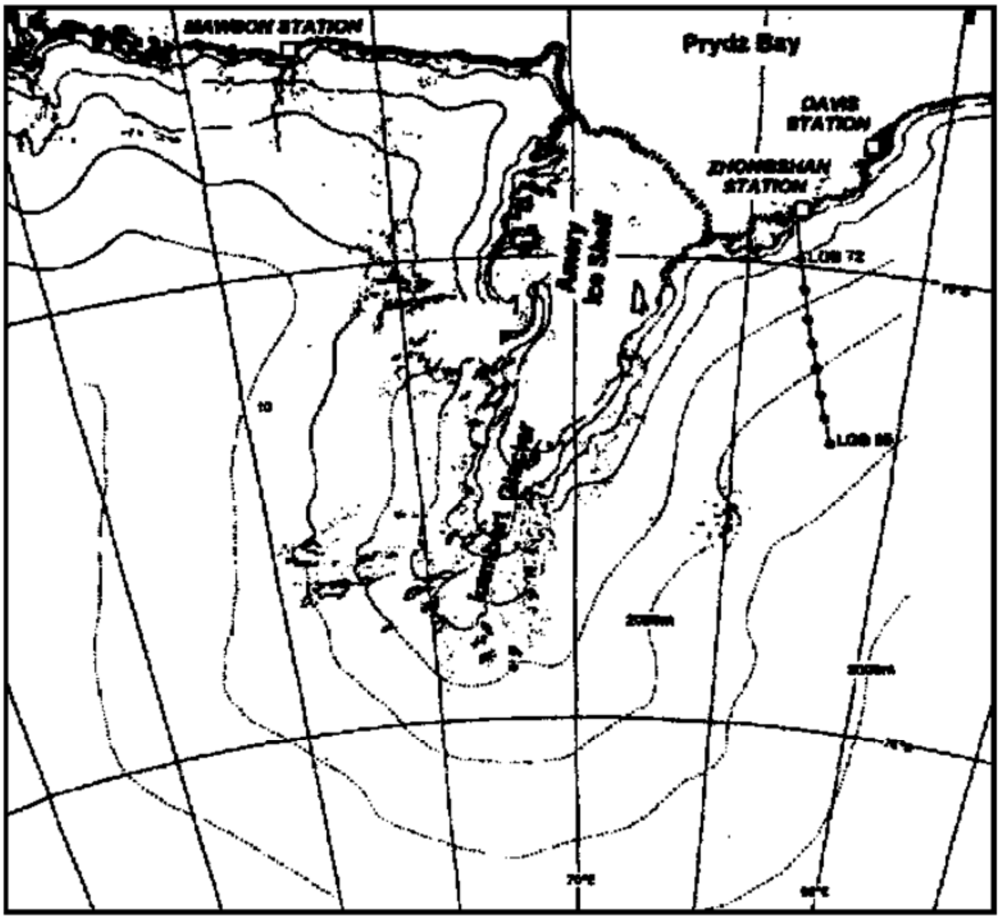

Fig. 1. The route of the Chinese First Antarctic Inland Expedition.

change between water and air or the dissolution of micro-particles caused by sublimation and coagulation.

2.2 *Laboratory analysis*

2.2.1 *Sample divided*

Surface snow samples were divided in the low temperature laboratory, and the whole process of sample divided was in the class-100 clearing room. The Coulter Accuvette container (Polycarbonate) are used for sample divided and measurement. These containers have been cleaned before delivery, and according to the blank measurement, the values of blank are accepted, so it is no necessary for rinsing before measurement. The capacity of Accuvette container is about 35 ml. After melting a full bottle of surface snow sample, we can obtain 10 ~ 15 ml water sample, it is enough for the micro-particle analysis. The samples were preserved at low temperature laboratory until they were analyzed.

2.2.2 *Instrument and parameter*

The Coulter Multisizer II Counter was used in measurements of the particle concentration and size distribution of surface snow sample in this study. As non-conductive particles pass through the orifice, they displaces amounts of electrolyte proportional to their volume and acts as resistance to the normal unobstructed electrical current that flows between the two electrodes located on either side of the orifice. This instrument tests the changes of current between the two electrodes to measure the particle concentration and distribution in the samples. For the analysis of surface snow sample, parameters of instrument are set as followed: aperture for measurement is 20 μm (measure particles ranging from as low as 2% up to 60% of the orifice diameter); orifice current setting is 800 μA; gain setting is 4; Kd value is about 266.06; channel setting is 128; control mode is siphon; sampling volume is 100 μl, particle diameters which to be measured are ranging from 0.5 μm to 12 μm.

2.2.3 *Sample preparation and analysis*

The method of sample preparation is depended on the analytic principle of instrument. To obtain electrical field between the two electrodes located on either side of orifice, electrolyte is added into melted samples to enhance conductivity of the samples. In samples of snow and ice from Antarctica the micro-particles are relatively low in content and are generally small in size, so the higher electrolyte concentration is demanded to enhance the sensitivity of instrument. But when the electrolyte concentration is too high, it may lead to the sharp rise in blank noise. In view of the above-mentioned facts, we choose 2% NaCl (by weight) solution as the electrolyte to get the higher sensitivity of instrument and the lower blank noise.

The snow samples are prepared in a class-100 clean room by melting in a warm water bath of 30℃. 10 ml samples are poured into Accuvette containers, adding 1.25 ml of a pre-filtered (0.22 μm Millipore filters in series for 5 ~ 7 times) 18% (by weight) NaCl solution. Then electrolyte solution is got with a concentration similar to the 2% NaCl solution. Before measurement, one should gently stir the sample and put the sample into ultrasonic bath to remove micro-bubbles in the sample. Three times of measurement were performed on each sample to ensure the reproducibility of the data. When deviations were less than 10%, the average values of the three times were considered as the last result.

2.2.4 *Blank control*

Blank is Milli-Q water which is pre-filtered by using 0.22 μm millipore filters for 5 – 7 times. The preparing method and the instrument parameter for measuring the blank is identical with the samples. In the sample analysis, we performed a blank test each by analyses of 10 – 15 samples so as to ensure the reliability of the data (Fig. 2).

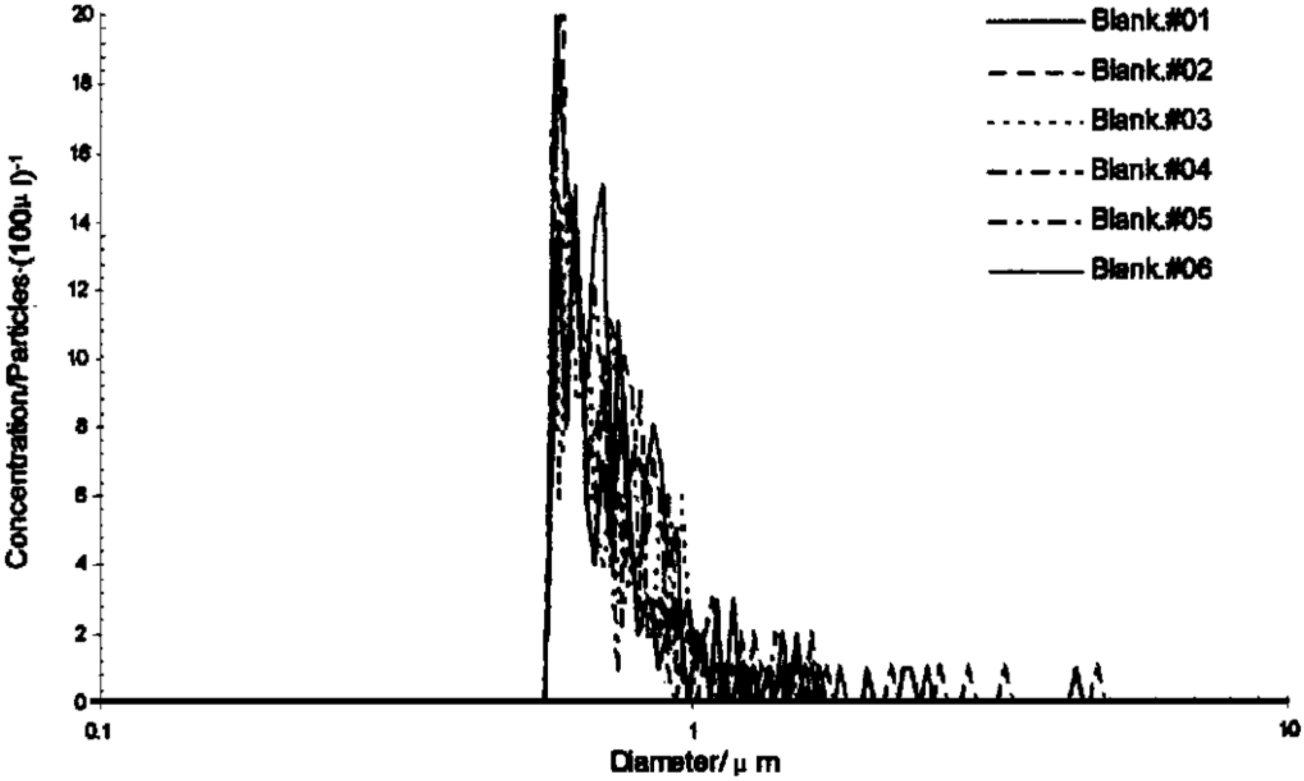

Fig. 2. Blank control in micro-particle analysis of surface snow sample.

3 Results and discussion

3.1 *Changes of micro-particle concentration*

Changes of micro-particle concentration in the surface snow samples along with the altitude (386 – 2320 m) are shown in Fig. 3. The average micro-particle concentration is 97261 particles/ml, the maximum is 354253 particles/ml, and the minimum is 16480 particles/ml, the maximum is 20 times lager than minimum. These results are comparable with the region of King George Island, Antarctica (Wang *et al*. 1996).

The fluctuation, i e. peaks and valleys of micro-particle concentration along with the altitude, are striking in the lower altitude (386.0 – 814.0 m) area, and the maximum of micro-particle concentration on the whole profile occurs at the lowest sampling site (386 m) in this region. In the altitude range from 875.0 m to 1992.9 m, though the fluctuations of micro-particle concentration are still very rough, the amplitudes is not as large as in the lower altitude area, and the minimum of micro-particle concentration on the whole profile appeared at the highest sampling site (1992.9 m) in this section. In the higher altitude (1996.2 – 2307.9 m) area, changes of micro-particle content are still apparent, but the amplitudes of these changes are far less than the two regions. Though the amplitude varies in the different area, the valley values of micro-particle concentration are similar on the whole. So it indicates that the backgrounds of micro-particle concentration are roughly identical.

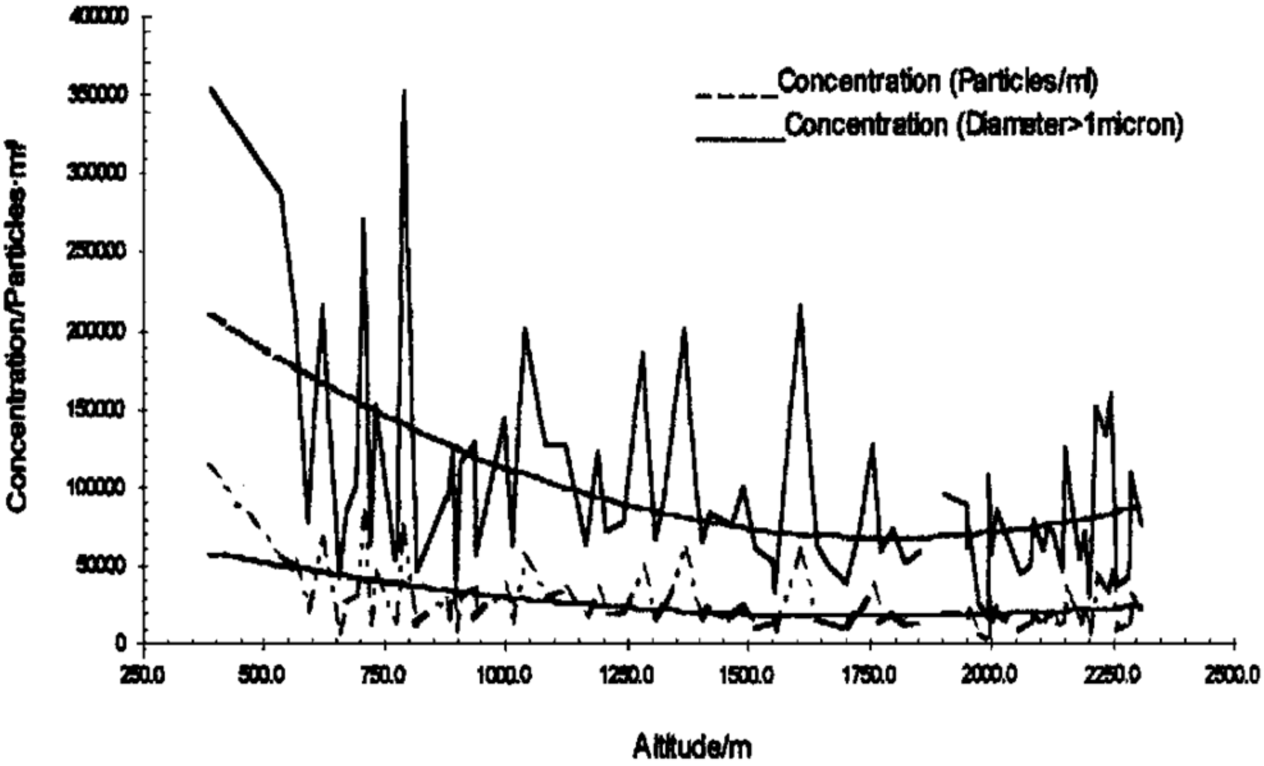

Fig. 3. Change of total micro-particle content including the micro-particles > 1 μm in different altitudes.

There is an apparent tendency that the micro-particle concentrations decrease with the elevation in the lower altitude area. As the ascending of the altitude, this tendency gradually tends to plain. On the whole profile, the micro-particle concentration is decreasing with the tendency from sharp to plain. So we could imagine that in this profile, micro-particles in surface snow are mainly from acoastal dominant source. The deposition of micro-particle on ice sheet surface is influenced by local transportation in coastal area, and this influence is progressively decreasing with the rising of altitude and the increasing of distance from the sea.

But in the altitude interval from 2000 m to 2300 m, the micro-particle concentration appears a very slowly rising tendency along with altitude. We suggested that this tendency is attributed to the rising of micro-particle concentration in higher altitude area, in which more micro-particles were deposited through the dry deposition because of the lower accumulation rate on inland of ice sheet area.

According to the mass balance data (Higham and Craven 1997) in this region, accumulation rate varies in different altitudes, in the lower altitude area is about 30 – 50 cm/a in snow layer depth, in the area above 2000 m, the value decreases apparently (10 – 20 cm/a in snow). If we considered the micro-particle concentration in 3 cm surface snow samples as the average annual concentration of every sampling site, we could calculated the average annual micro-particle flux on sampling site in altitude interval from 1000 m to 2300 m through cooperation with the mass balance data. Figure 4 shows the changes of average annual flux along with the altitude. It can be seen that the tendency of average annual flux is similar with the tendency of micro-particle concentration of 3 cm surface snow sample in the higher accumulation rate area. But in the area of 2000 – 2300 m, where the accumulation rate is much lower than the lower altitude area, the tendency of average annual flux apparently decreases with the rising of altitude, while the tendency of micro-particle concentration becoming very gentle. Therefore, as a whole tendency of average annual flux, it can be got that it decreases obviously with the rising of the altitude. This result coincides with the transportation way of micro-particles from coastal area to inland.

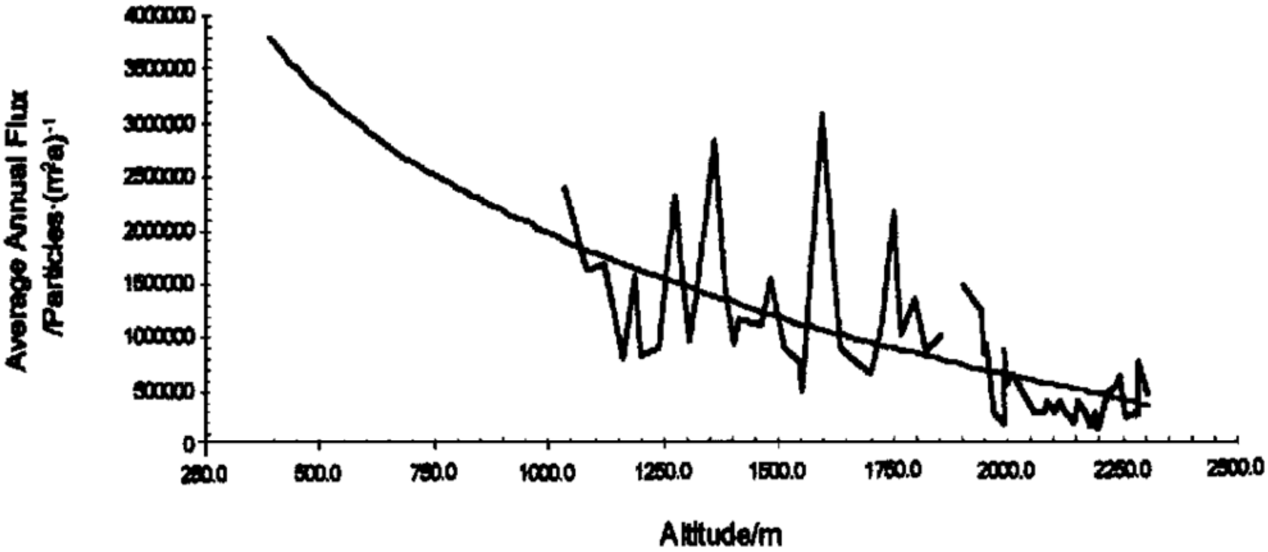

Fig. 4. Change of average annual flux in different altitudes.

3.2 *Size distribution and source area*

Previous researches indicated (Ram and Gayley 1994) that it could reveal the background condition in somewhere from the micro-particle size distribution in samples, because the tendencies of size distribution in different range vary in different region and time. We have combined the results of micro-particles analysis to compare the size distributions in five samples randomly chosen from 84 surface snow samples (Figure 5). From figure 5, the micro-particle content in every sample is different, but for individual sample, in the 128 channels divided by instrument, the number of micro-particle accumulation is higher in the channels of the finer diameters than in the channels of coarser diameters. There is almost no any accumulation number in the channels of the diameter greater than 10 μm. The size distributions in these five samples are similar despite the difference of micro-particle concentration. In view of the whole samples in this profile, the size distributions are at same shape in 128 channels divided by instrument. So it suggests that micro-particles in these 84 surface snow samples mainly come from a considerably dominant source, the difference of micro-particle content caused by the different sampling site has not influenced the size distributions in the samples.

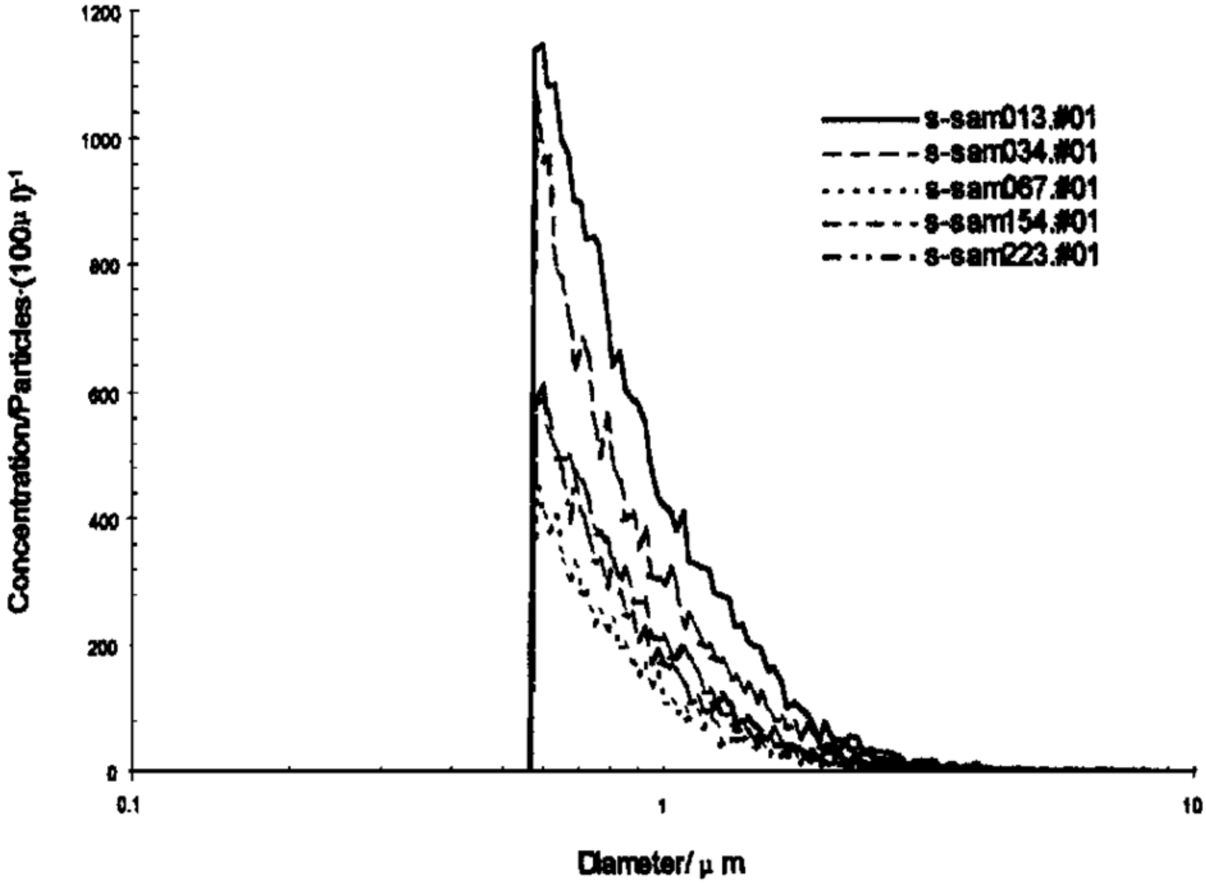

Fig. 5. Size distribution of micro-particles in surface snow sample.

The research of atmospheric aerosol background has revealed that the ratio of coarse and fine particles can be used in the recognizing of micro-particle sources (territorial and global insoluble particles), and then to understand the background condition of atmospheric aerosol (Thompson *et al*. 1975). A study on micro-particles in ice cores from King George Island in West Antarctica has proved that in the coastal area of Antarctica, concentrations of micro-particle decreased considerably with the time when samples were being melted (Kang *et al*. 1998). The reason is that a part of small sea-salt grains have dissolved. The dissolution happened among micro-particles with size less than 3 μm, especially in size less than 1 μm. So we could assume that the terrestrial source micro-particles from coastal area are mainly concentrated in size larger than 1 μm, and the micro-particles greater than 1 μm could represent the source of micro-particles better. On the other hand, due to the existence of instrument noise, the accumulative number of micro-particles less than 1 μm is not so accurate as the number of large micro-particles because it has involved many noises. So we consider the diameter of 1 μm as a rough limit to divide the sea-salt and insoluble particle, and discuss the percentage variation of micro-particles larger than 1 μm along with the altitude (Fig. 6).

From Fig. 6, the ratio of micro-particles larger than 1 μm in the samples are commonly ranging from 20% – 30%. The maximum of 31.75% and the minimum of 18.17%, both appeared in the lower altitude area (below 1000 m). The variation of these ratios with the altitude are much larger in the lower altitude than in the higher altitude,

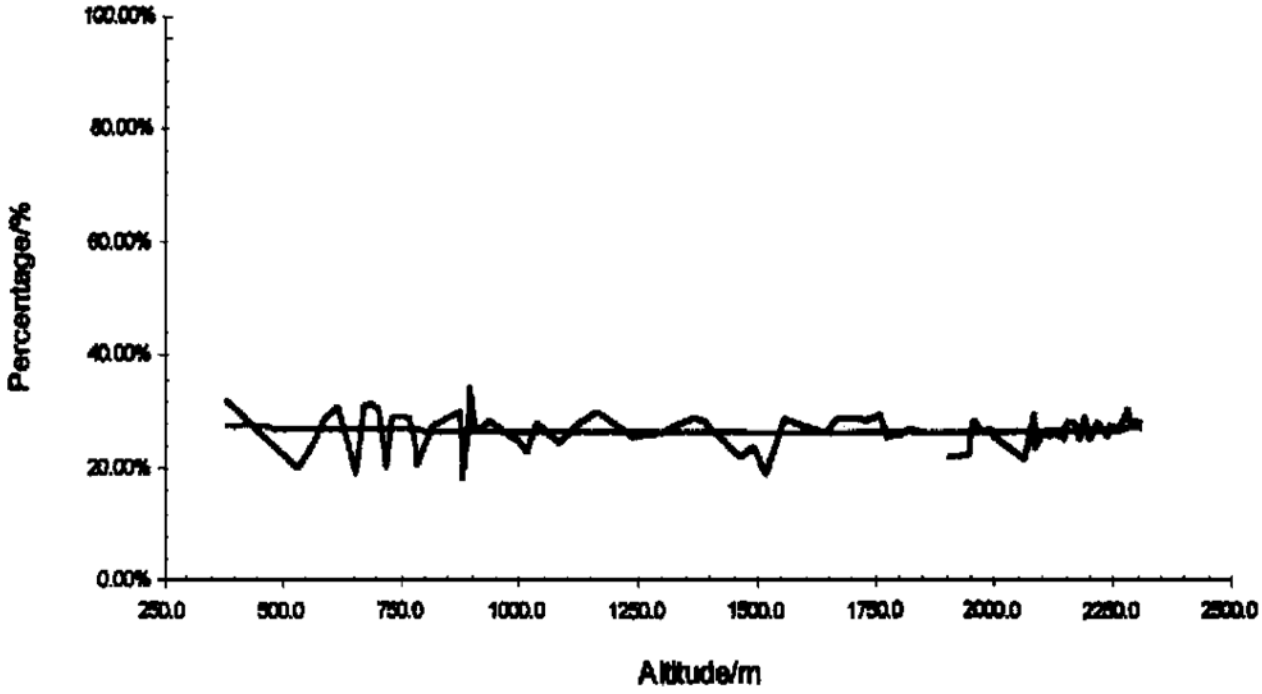

Fig. 6. Ratio curve of micro-particles larger than 1 μm in different altitudes.

reflecting the micro-particle deposition is influenced by marine air transportation in the lower altitude more than that in the higher altitude. From the whole profile, the tendency of the ratio variation is almost around a horizontal line, which indicates that components of micro-particles from different sources are normally alike and does not change due to the difference of sampling altitude.

The changes of total content of micro-particles and micro-particles larger than 1 μm are shown in figure 3. The changes are similar in peak and valley. The content of micro-particles larger than 1 μm also decreases with the rising of altitude, which indicates that the process of transportation and deposition of micro-particles larger than 1 μm are synchronous with the process of micro-particles from other sources. But from the differences of absolute value, the value of total content of micro-particles in different samples is much higher than the value of micro-particles lager than 1 μm. The decreasing tendency of micro-particles lager than 1 μm is not as apparent as the total micro-particle content, because the ratios of micro-particles larger than 1 μm are much higher in the lower altitude area than in the higher altitude area (as in figure 6, the maximum and the minimum ratios both appear in the lower altitude area). It has proved, in the other side, that micro-particles in the sample are more influenced by marine air transportation in lower altitude area than in higher altitude area.

4 Conclusions

From the investigation of micro-particle in surface snow samples, the conclusions can be obtained as follows:

(1) As to the results of micro-particle analysis, micro-particle concentration appears to be in the inverse ratio with sampling altitude (distance from the sea). Along with the increasing of sampling altitude, micro-particle concentration is decreasing with a tenden-

cy from sharp to plain. So it can be said that the route of micro-particle transportation is from coastal area to inland on the research profile.

(2) According to the farther investigation of size distribution, although micro-particle concentration varies in surface snow sample from different sampling altitude, the size distributions in samples are coincident on the whole, which indicates that the input of micro-particle are at the same way.

(3) From the result that the ratio of coarse (from earth) and fine (from the sea) particles are approximate, which suggests that the coarse and fine particles in surface snow samples from different altitude come from the same source. Moreover, as compared to the higher altitude area, the more striking variation of micro-particle concentration in lower altitude area suggests that the deposition process of micro-particles are more complicated in the lower altitude area than in the higher altitude area.

On 330 km glaciological profile from Zhongshan Station to inland of ice sheet, micro-particles in surface snow are mainly from sea-salt and unsolvable mineral material near the coastal area. Although this area is controlled by the polar easterly wind and the katabatic wind, the weak cyclone in this area plays an important role in transportation and deposition of micro-particles. The micro-particle deposition on ice sheet surface is mainly influenced by marine air transportation. This influence is weakened with the rising of altitude and the distance from the coast, and the tendency of the micro-particle deposition on ice sheet surface decreases sharply.

So, from the above statement, it suggests that on this research region, two zones can be divided. The zone from edge of ice sheet to altitude of 800 m is coastal area of Antarctica where the ice sheet is in salient relief with a lot of bare base rocks and a complex of marine transportation. The dusts in this area are mainly from coastal area and the surrounding base rocks, whose transportation and deposition are influenced by marine air transportation. Micro-particle contents in surface snow samples are higher, and the variations are more striking. The other zone is the area of the edge of ice sheet plateau. Supplying matters from sea and terrene are decreasing. The influence of marine transportation is weakening in this area. Micro-particle contents in samples assume a descending tendency, and the variations of micro-particle concentration are less than the coastal area. With progressively ascending of the altitude, the micro-particle contents are further decreasing, and the variations of content is tending to be gentle.

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References

Fiacco RJ(1991): Microparticles as Paleovolcanic Indicator in the 1989 GISP2 Firn and Ice Core. B. S. Earth Science, Norwich University, Thesis Submitted to the University of New Hampshire.

Higham M, Craven M(1997): Surface mass balance and snow surface properties from the Lambert Glacier Basin Traverses 1990 - 1994. Antarctica CRC and Australian Antarctic Division, Research Report, No 9.

Kang JC, Wen JH, Wang DL, Liu LB, Yan M, Li YS(1998): Microparticle content of ice core with time at melted state —— A study on microparticle of ice core from King George Island, Antarctica. Journal of Glaciology and Geocryology, 20(4): 376 - 380.

Ram M, Gayley RI(1994): Insoluble particles in polar ice: identification and measurement of the insoluble background aerosol. Geophysical Research Letters, 21(6): 437 - 440.

Steffensen JP(1995): Microparticles and Chemical Impurities in Ice Cores from Dye 3, South Greenland, and Their Interpretation in Paleoclimatic Reconstructions. Department of geophysics Niels Bohr Institute for Astronomy, Physics and Geophysics University of Copenhagen.

Thompson LG(1984): Microparticle analysis: An indicator of paloenvironment. Journal of Glaciology and Geocryology, 6(1): 25 - 31.

Thompson LG, Hamilton WL, Bull C(1975): Climatological implications of microparticle concentration in the ice core from "Byrd" Station, Western Antarctica. Journal of Glaciology, 14(72): 433 - 444.

Thompson LG, Thompson EM(1982): Spatial Distribution of Microparticles within Antarctic Snow-Fall. Annals of Glaciology, 3: 300 - 306.

Wang DL, Kang JC, Wen JH, Liu LB, Yan M, Li YS(1996): Microparticle size distribution in ice core from King George Island, Antarctica. The research of process and influence between Antarctica and globe environment. Meteorological Express, 229 - 233.

Xie ZC, Yao TD(1997): Insoluble microparticles in the cores and their climate and environmental implications. Journal of Glaciology and Geocryology, 19(4): 373 - 377.

Yao TD, Petit JR, Lorius C(1989): The edge of antarctica ice sheet —— microparticle analysis in ice core and its climatic implication. Chinese Science(B), 19(11): 1205 - 1211.