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# Latitudinal distribution of $CO_2$ and $CH_4$ on the route of the Chinese Arctic Research Expedition 2003

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**Abstract** During the 2nd Chinese Arctic Research Expedition, 20 pair of atmospheric samples were collected on the cruising route from Shanghai to Arctic Ocean using NOAA /ESRL flask sampling unit. Mean concentration of $CO_2$ and $CH_4$ were analyzed in different latitude zone from 30°N to 80°N and the distribution characteristics were studied. Mean concentration of $CO_2$ decrease toward high latitude which indicates the uptake effect of $CO_2$ by ocean. Coinciding with the $CH_4$ global distribution character, mean $CH_4$ concentration increase from 45°N to the North Pole region. Regional or local airmass may influence the greenhouse gas concentrations near seashore in the middle latitude (30°N-45°N).

**Key words** the 2nd Chinese Arctic Research Expedition, $CO_2$ and $CH_4$, concentration, latitudinal distribution

## 1 Introduction

From July 10th to September 26, 2003, "*Xuelong*" scientific expedition icebreaker executed the 2nd Chinese Arctic Research Expedition (CHINARE 2003). The voyage started from Shanghai to Dalian via Yellow Sea and Bo Hai and the cruising route, which is more than 14000 seamiles, from Dalian to Arctic ocean via Yellow Sea, Sea of Japan, Okhotsk Sea, Bering sea, Chukchi Sea and Canada basin, highest latitude of the site which the icebreaker arrived at about 81°13. 57′N (Zhang 2004).

It is a cooperative project between Chinese Academy of Meteorological Sciences (CAMS) and Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences (CAREERI, CAS). The atmospheric samples were collected along the route of CHINARE 2003 and the concentrations of $CO_2$ and $CH_4$ were measured using gas chromatograph (GC) and non-dispersive infrared absorbance (NDIR) system. The distribution of mean concentration of $CO_2$ and $CH_4$ in different latitudinal zones were studied in this paper.

## 2 sampling, analyzing and data processing

The air sampling unit (MAKS) is of the Earth System Research Laboratory/National Oceanic and Atmospheric Administration (ESRL/NOAA), U.S.A. The system consists of a pump, a press gauge, control valves and batteries. A pair of 2.5 L glass flasks was flushed for about 15 minutes with the ambient air to replace the air inside the containers fully before the collection of air samples. The air pressure inside the glass flask is about 0.3 atm. The sampling unit was mounted on the platform above the cab of "*Xuelong*" icebreaker which was about 30 m above sea level and the sampling inlet was 5 m above the platform. The wind speed should be more than 2 m/s when collecting and the operator should be 15 m away downwind the sampling site and try to hold his breath when he operated the switches and valves to eliminate jamming. The sampling times were usually in the morning (8:00 to 11:20 local time) in order to collect fully mixed air. The latitude, longitude, sampling time, air pressure, temperature, wind speed and direction were recorded with each sample.

20 pairs of samples were collected from July 11th to September 23rd and the latitudinal range is from 31°08.850N to 77°33.305N while the longitudinal range from 121°44.997E to 160°33.536W. Usually the latitudinal range between two adjacent sampling sites was greater than 2 degrees except one case. There were 12 pairs of samples collected on the route from Shanghai to Arctic Ocean and 8 pairs on the way back. The sampling sites are shown in Figure 1.

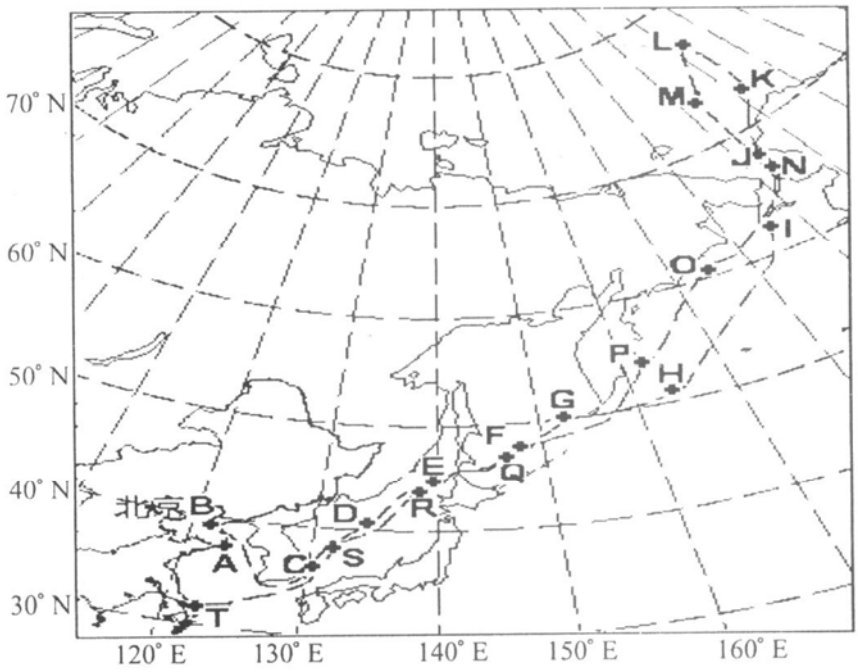


Fig. 1 Sketch map of sampling sites on the route of the 2nd Chinese Arctic Research Expedition 2003.

Samples were sent back to CAMS and the concentrations of $CH_4$ and $CO_2$ were measured with GC and NDIR system. The analyzing condition and parameters of the GC system are described in Table 1.

Non-dispersive infra-red (NDIR) gas analyzer (Li-cor 6251, LI-COR INC. USA) was used to measure the $CO_2$ concentrations with a precise of 0.1 $\mu mol \cdot mol^{-1}$. To eliminate the influence of vapor upon the measure results, the air samples were passed through a vapor trap with low temperature (−50℃) before pumped into the NDIR system. All standard gases traceable to the WMO scale come from the ESRL/NOAA which insures the results comparable to WMO scale standard.

Table 1 Basic parameters of the gas chromatographic system

| Parameters | Unit | |
|---|---|---|
| Detector | | FID |
| Main column | | 2 m, Molecular Sieve 5 A (60/80), 1/8 inch O. D. |
| Pre-cutting column | | 2m, Porapak Q (50/80), 1/8 inch O. D. |
| Oven temperature | ℃ | 80 |
| Detector temperature | ℃ | 250 |
| Carrier gas flow rate | $cm^3 min^{-1}$ | 40 |
| Hydrogen flow rate | $cm^3 min^{-1}$ | 40 |
| Synthetic air flow rate | $cm^3 min^{-1}$ | 450 |
| Sample flow rate | $cm^3 min^{-1}$ | 150 |
| Time of analysis | min | 5 |

Every sample was analyzed once and the averaged results of one pair of flasks were used as the $CH_4$ concentration of the sampling site. The differences between flasks of one pair vary from 0.5 nmol·mol$^{-1}$ to 8.0 nmol·mol$^{-1}$ and the mean value is 3.2 nmol·mol$^{-1}$ which are close to the precision of the GC system so that all measurement results were kept. For $CO_2$ measurement, every sample was analyzed twice and the average result was considered as the concentration of the sample. The differences of each samples vary from 0.01 μmol·mol$^{-1}$ to 2.3 μmol·mol$^{-1}$ and mean difference is 0.06 μmol·mol$^{-1}$. The differences between one pair of flasks vary from 0.01 μmol·mol$^{-1}$ to 17.5 μmol·mol$^{-1}$. According to the data select criterion of ESRL/NOAA (Komhyr *et al* 1985; Conway *et al* 1988; 1994; Thoning *et al* 1995), samples with a pair difference greater than 0.5 μmol·mol$^{-1}$ were rejected. In this study, pair difference at sampling site B and P are 1.1 μmol·mol$^{-1}$ and 17.5 μmol·mol$^{-1}$, respectively, which may not reflect the background condition and were deleted in the final result. The $CO_2$ concentration at each sampling site was calculated by averaging a pair of two samples at this site.

The sampling sites are all on the ocean surface and the data selecting process had avoided the samples polluted by artificial activities. So the results generally represent the background conditions of the natural distribution of $CO_2$ and $CH_4$ on the cruise route.

## 3 Results and discussions

Figure 2 shows the $CO_2$ and $CH_4$ latitudinal distribution of all sampling sites on the cruise route. To eliminate the errors owing to the uneven distribution of sampling sites, all samples were ranged to five latitudinal zones from 30°N to 80°N according to their latitude and each zone consisted of 2 to 6 samples. All samples in one latitudinal zone were averaged to get a mean $CO_2$ and $CH_4$ concentration of this zone (Figure 3). In general, from 40°N to the north polar region, the $CO_2$ concentrations show a decrease trend with the increase of latitude which is converse with the global distribution of atmospheric $CO_2$ (http://www.cmdl.noaa.gov/ccgg) while it's coincide with the global $CO_2$ distribution of marine sampling site (Tans *et al* 1989, 1998). The $CH_4$ concentration distribution from 40°N to the north is coincide with the global distribution of atmospheric $CH_4$ (http://www.cmdl.noaa.gov/ccgg Tans *et al* 1998) which increase with the latitude. The $CO_2$ concentration

decrease about 1.1 μmol·mol$^{-1}$ with 10 degrees increase in latitude except in the 50°N-60°N zone which the sole two samples in this latitudinal zone maybe confused the real background value. In general, the $CH_4$ concentration increase about 7.2 nmol·mol$^{-1}$ with 10 degrees increase in latitude from 40°N-80°N zone. It's notable that the increase grads are not uniformly, from 40°N-50°N to 50°N-60°N the $CH_4$ zonal averaged concentration increase 13.7 nmol·mol$^{-1}$ while the increase grads are about 3.6-7.2 nmol·mol$^{-1}$ between other adjacent latitudinal zones.

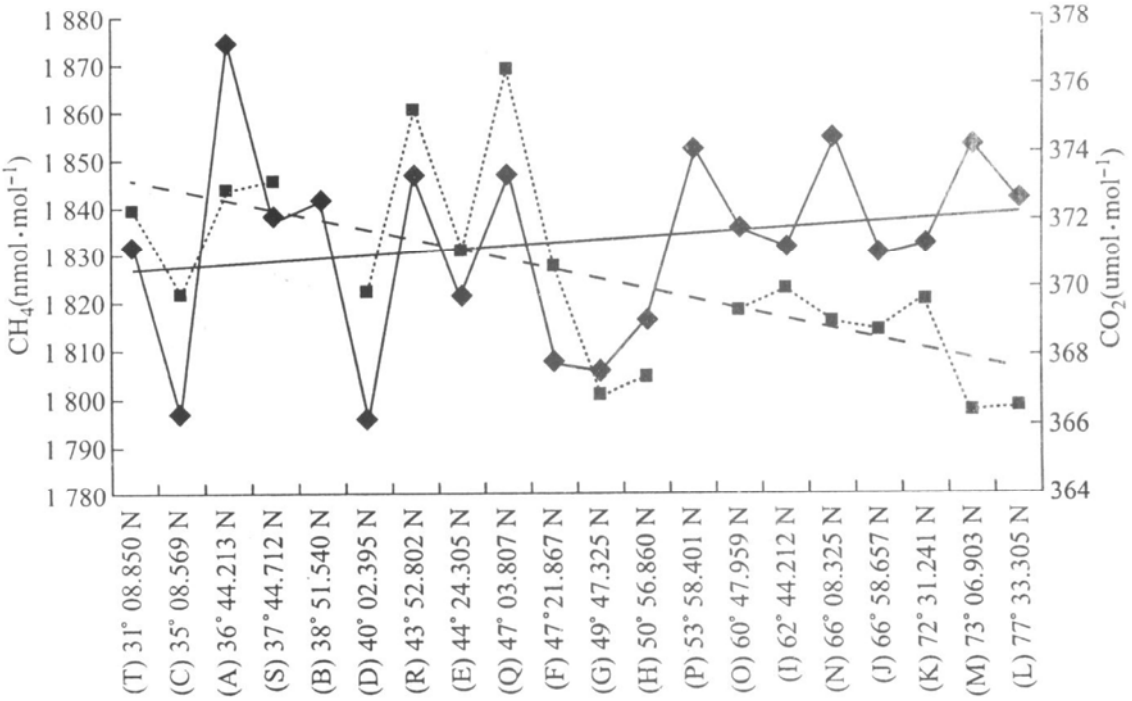


Fig 2 Variations of $CO_2$ and $CH_4$ in different sampling sites

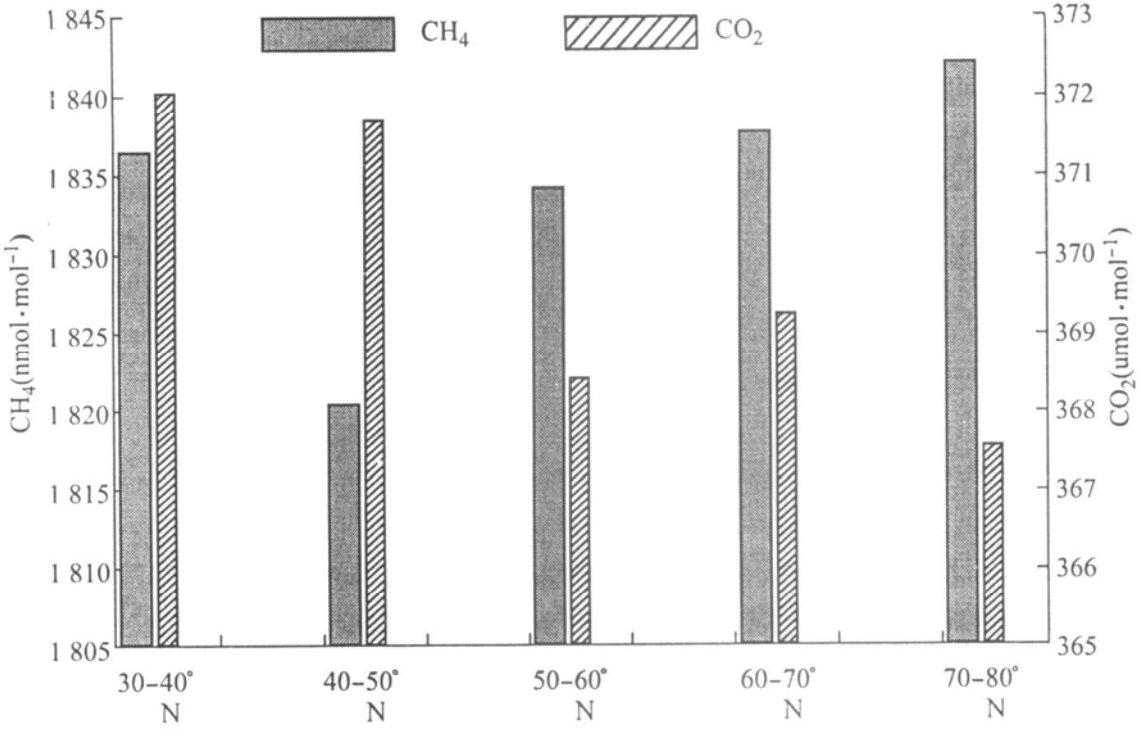


Fig 3 Variations of $CO_2$ and $CH_4$ in different latitude zone

The decrease trend of $CO_2$ concentration could be explained by the uptake effect of $CO_2$ in the ocean. The sea surface temperature at high latitude are cooler and the north pacific and Arctic Ocean are $CO_2$ sink in summer (Takahashi *et al* 1997; Sabine *et al* 2004; Wang *et al* 2003; Wang 1999), while at low latitude zone, the sea surface temperature are higher and the seawater is usually act as $CO_2$ source (Bates 2006; Ji *et al* 2003; Chen *et al* 2004; McKinley *et al* 2006; Takahashi *et al* 2006). The air temperature and seawater temperature measured on the cruise route both decrease from low latitude to higher latitude also prove this conclusion.

It's notable that the $CO_2$ and $CH_4$ concentration at air sampling sites in the latitudinal zone between 30°N and 45°N, which are in the continental shelf and marginal sea area (e.g. sampling site A-E and R-T), show no obvious trend as those sites north of 45°N. For example, from site A to E, the $CH_4$ concentration increase firstly with the increase of latitude and then decrease northward while the $CO_2$ concentrations from site R to T decrease from north to south. From Figure 1 we can find that all the above sampling sites are not far away from the seashore influenced much by human activities and the backward trajectories analysis( figures are elliptical) also showed that the air mass arrived at those sites were all from the nearby continent and islands. It's reasonable to deduce that the air samples collected from those sites are affected by regional or local sources such as the Chinese mainland, the Korean Peninsula, the Japanese islands or some ships nearby which resulted in the variation trend of $CO_2$ and $CH_4$ concentration inconsistent with the corresponding trends north of 45°N.

## 4 Conclusions

The analyses results of $CO_2$ and $CH_4$ on the cruise route of Chinese Arctic Research Expedition, 2003 indicate that on the sea surface north of 45°N, the atmospheric $CH_4$ concentration increase northward that is coincide with the global latitudinal distribution of $CH_4$. The atmospheric $CO_2$ concentration decrease poleward which is reverse with the global $CO_2$ latitudinal distribution pattern and this phenomenon reflects the critical role the ocean playing in the global carbon cycle. In general, the higher latitude ocean acts as a sink of atmospheric $CO_2$ while at the low latitude the higher concentration of atmospheric $CO_2$ maybe a mixture of the weak source role of ocean and air mass from inhabited islands or continent. Much more observed data are needed to study the source or sink of different regions in ocean and the continental shelf.

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