スバールバル諸島ニーオルスンにおける大気中酸素/窒素比の高精度連続観測

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High-precision continuous measurement of the atmospheric O_2/N_2 ratio at Ny-Ålesund, Svalbard

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Introduction

Simultaneous observations of atmospheric O_2 (defined as O_2/N_2 ratio) and CO_2 concentrations provide valuable information about the global carbon cycle. For example, data from long-term observations allows us to estimate land biotic and oceanic CO_2 sinks sepatrately. For a better understanding of the global carbon cycle in terms of atmospheric O_2, several laboratories have developed precise measuremet system for the atmospheric O_2/N_2 ratio and have conducted simultaneous observations of the atmospheric O_2/N_2 ratio and CO_2 concentration mainly using descrete flask samping with subsequent laboratory analysis (e.g. Maning and Keeling, 2006). To elucidate the variations of the atmospheric O_2/N_2 ratio in more detail, continuous measurements have been made recently (e.g. Stephens et al., 2007, van der Laan-Luijkx et al., 2010). We have also developed a high-precision continuous measurement system for the atmospheric O_2/N_2 ratio, and initiated systematic observation at Ny-Ålesund (78˚55'N, 11˚56'E), Svalbard since November 2012 (Goto et al., 2013a), which is the first continuous observation in the Arctic region. Here, we present our measurement system and the results obtained so far.

Method

A differential fuel-cell oxygen analyzer (Oxizilla II, Sable Systems) is employed for our measurement system. In this analyzer, sample air or standard air pass through one fuel cell, flowing a reference air through another cell. To obtain highly precise values of the atmospheric O_2/N_2 ratio, pressure fluctuations of the sample air, standard air and reference air were controlled to within an order of 10^{-3} Pa by using flow regulation valves and differential pressure sensors, with the temperature inside of the analyzer stabilized to 32.0 ± 0.1 ℃ (Goto et al., 2013b). This system is also equipped with a NDIR analyzer to measure CO_2 concentration simultaneously. To calibrate the analyzer, we use two working standard air prepared by adjusting the O_2/N_2 ratio of dried and compressed natural air. Their O_2/N_2 ratios are determined against our primary standard air system (Ishidoya et al., 2003). Considering the remoteness of the observation site, special attention was paid to the measurement system, in that: (1) the system can be controlled remotely from Japan via the Internet; (2) all of the output data from the system can be monitored and collected in Japan via the Internet; and (3) a specially designed water trap based on a Stirling cooler is employed to automate the removal of the water vapor contains in the sample air. The analytical precision of the system was estimated to be within 4.0 per meg (1σ) of replicate analyses of the same sample air.

Results and discussion

Caracteristic events of the atmospheric O_2/N_2 ratio were sometimes observed at Ny-Ålesund. For example, on November 14–21, 2012, the O_2/N_2 ratio decreased by about 22 per meg (≒4.6 ppm) and then returned to its original level, while the CO_2 concentration increased by about 3 ppm and then decreased by about almost the same amount. A similar event was observed on February 5–9, 2013. In this event, O_2/N_2 ratio decreased by about 45 per meg (≒9.4 ppm) and CO_2 concentration increased by about 6 ppm. The O_2:CO_2 exchange ratio defined as the slope of a liner regression line between the measured values of O_2/N_2 ratio and CO_2 concentration were calcurated to be –1.53 ± 0.12 ppm/ppm for the former event and –1.59 ± 0.46 ppm/ppm for the later event. It is known that the O_2:CO_2 exchange ratio depends on the process that controls their variation. For example, the O_2:CO_2 exchange ratio associated with fossil fuel burning is estimated to be 1.83–2.00 ppm/ppm for natural gas, 1.52–1.56 ppm/ppm for gasline, 1.39–1.44 ppm/ppm for oil, and 1.17 for coal (Keeling, 1988). The values of O_2:CO_2 exchange ratio calculaed for the observed two events at Ny-Ålesund are close to that for gasoline. Therefore, the cause of those variations of O_2/N_2 ratio and CO_2 concentration would be attributable to the transport of polluted air affected by fossil fuel combustion in urban areas. In fact, the results of the backward trajectory analysis indicated that the air masses arrived at Ny-Ålesund on November 14–21, 2012 and February 5–9, 2013 passed near or over Oslo, Norway and Moscow, Russia,

respectively. Because CO_2 emission data for indivisual fossil fuel type in each countory are available from the Carbon Dioxide Information Analysis Center (CDIAC), we can estimate an average O_2:CO_2 exchange ratio for each country. We actually calculated the average O_2:CO_2 exchange ratio in Norway and Russia to be –1.54 ppm/ppm and –1.62 ppm/ppm, respectively, and these ratios are in good agreement with –1.53 ± 0.12 ppm/ppm and –1.59 ± 0.46 ppm/ppm observed at Ny-Ålesund on Nobember 14–21, 2012 and February 5–9, 2013.

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