Year-to-year variations of the atmospheric Ar/N_2 and O_2/N_2 ratios observed in the northern mid-to-high latitudinal region for the period 2012-2016

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Atmospheric Ar/N_2 varies basically due only to a difference in the solubility between Ar and N_2 and its subsequent effect on the air-sea Ar and N_2 fluxes. Since the solubility varies in response to ocean warming/cooling, variation in the atmospheric Ar/N_2 ratio is a unique tracer for air-sea heat fluxes or ocean heat content (OHC) (Keeling et al., 2004). Therefore, a simultaneous observations of Ar/N_2 and O_2/N_2 enable us to estimate the contribution of the air-sea heat fluxes to atmospheric potential oxygen ($APO = O_2 + 1.1xCO_2$), which is an indicator of air-sea O_2 fluxes (Stephens et al., 1998). Recently, we developed a high-precision measurement system of the atmospheric Ar/N_2, O_2/N_2, CO_2/N_2, stable isotopic ratios of N_2, O_2 and Ar (Ishidoya and Murayama, 2014) and started its application to the analyses of the air samples collected at several ground-based stations, on an oceanographic research vessel (Ishidoya et al., 2016), in the free troposphere on an aircraft (Ishidoya et al., 2014) and in the stratosphere using a balloon-borne cryogenic air sampler (Ishidoya et al., 2013). In this study, we present the Ar/N_2 and APO observed onboard the research vessel MIRAI in the northern North Pacific and the Arctic Ocean in the every autumn since 2012, and those observed at ground-based station at Tsukuba (36°N, 140°E) and Hateruma (24°N, 124°E) since 2012. Both the Ar/N_2 observed at Tsukuba (updated from Ishidoya and Murayama, 2014) and Hateruma showed clear seasonal cycles with summertime maxima, reflecting seasonal changes in the air-sea Ar and N_2 fluxes due to the seasonal changes in the sea surface temperature around the stations. Moreover, the Ar/N_2 at both sites showed clear interannual variations; gradually increased from 2012 to the begenning of 2015 and decreased subsequently. Similar characteristic was also found from the year-to-year variations in Ar/N_2 observed onboard MIRAI. In addition, the secular decreasing rates of APO observed at Tsukuba, Hateruma and onboard MIRAI from 2012 to the begenning of 2015 were smaller than those from 2015. These facts suggest not only the interannual variation of Ar/N_2 found in this study is universal from the northern subtropical to polar region, in other words, global or hemispheric OHC during the period is expected to show similar interannual variation to Ar/N_2, but also the observed interannual variation of APO is at least partly driven by air-sea O_2 and N_2 fluxes due to solubility changes. This suggestion may be supported by the global OHC reported by NOAA/NODC (updated from Levitus et al., 2012), which increased from 2012 to the middle of 2015 and decreased slightly thereafter.

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