Seasonal variations in the atmospheric Ar/N_2 ratio observed at ground-based stations in Japan and Antarctica and its application to an evaluation of the air-sea heat flux

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Variations of the atmospheric Ar/N_2 ratio at the ground surface are driven principally by air-sea Ar and N_2 fluxes due to changes in solubility in seawater (e.g. Keeling et al., 2004). Recently, we expanded our model study for the gravitational separation to Ar/N_2 ratio, and found that temporal variations of gravitational separation in the middle atmosphere could also modify the long-term trend of the surface Ar/N_2 ratio (Ishidoya et al., in preparation). Therefore, the surface Ar/N_2 ratio is a unique tracer of the spatiotemporally-integrated air-sea heat flux and the circulation in the middle atmosphere. We have continued systematic observations of the Ar/N_2 ratio by using a mass spectrometer at Cape Ochiishi (43°N, 146°E), Tsukuba (36°N, 140°E), Takayama (36°N, 137°E), Hateruma Island (24°N, 124°E) and Minamitorishima (24°N, 154°E), Japan and Syowa station (69°S, 40°E), Antarctica since 2012. Clear seasonal Ar/N_2 ratio cycles with summertime maxima have been observed at the middle to high latitudinal stations, and the peak-to-peak amplitudes of the average seasonal cycles at Ochiishi, Tsukuba, Hateruma and Syowa were found to be 21, 11, 5 and 32 per meg, respectively. To evaluate the seasonal air-sea heat flux based on seasonal cycles of Ar/N_2 ratio in the atmosphere, we carried out simulations of the Ar/N_2 ratio using an atmospheric transport model (GSAM-TM) that incorporated the Ar (N_2) flux derived from an equation of the relationship between the air-sea Ar (N_2) flux and the air-sea heat flux (Keeling et al., 1993; Weiss, 1970). We use the air-sea heat flux components, which mainly drive spatiotemporal variations of the air-sea Ar (N_2) fluxes, and sea surface temperature (SST) from the ERA5 (Hersbach et al., 2019). Thus simulated seasonal cycles of Ar/N_2 ratio agreed well with those observed. On the other hand, the amplitudes of the seasonal cycles of Ar/N_2 ratio simulated by using the TransCom seasonal air-sea N_2 flux (Garcia and Keeling, 2001), widely used in the simulation of the atmospheric O_2/N_2 ratio and based on the past ECMWF seasonal air-sea heat flux, underestimate the observed seasonal cycles significantly. These facts suggest that the air-sea heat fluxes and SST from the ERA5 is reasonable to reproduce the atmospheric Ar/N_2 variations on the seasonal time scale.

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