Interannual variations in delta(APO) and delta(Ar/N_2) observed at four Japanese stations for the period 2012-2022

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Atmospheric Potential Oxygen (APO=O_2+1.1xCO_2) (delta(APO)) varies due to air-sea O_2, N_2 and CO_2 fluxes and fossil fuel O_2 and CO_2 fluxes, while atmospheric Ar/N_2 ratio (delta(Ar/N_2)) varies due only to air-sea Ar and N_2 fluxes. It has been reported by past studies that seasonal and interannual variations in delta(APO) are driven mainly by the air-sea O_2 and N_2fluxes, although the air-sea CO_2 and fossil fuel fluxes cause a secular delta(APO) trend (e.g. Tohjima et al., 2019; Ishidoya et al., 2021). As to the air-sea exchange, Ar and N_2 fluxes are driven by solubility change, and O_2 flux is driven by both solubility and biospheric changes. Therefore, it is expected that we can separate an interannual variation in delta(APO) due to the solubility change (delta(APO)$_{therm}$) from that to the net marine biological activities (delta(APO)$_{netbio}$) by a combined analysis of delta(APO) and delta(Ar/N_2). We have conducted simultaneous observations of delta(APO) and delta(Ar/N_2) at various observational sites, and the data longer periods than 10 years have been obtained at Tsukuba (36°N, 140°E), Hateruma Island (24°N, 124°E), Cape Ochiishi (43°N, 146°E), and Takayama (36°N, 137°E), Japan (updated from Ishidoya et al., 2021). The annual change rate of the average delta(APO)$_{therm}$ at the four sites, obtained by multiplying a coefficient of 0.9 derived from differences in the solubility in O_2 and Ar (Weiss, 1970), was found to vary in phase with the Southern Oscillation Index (SOI) and the annual change rate of the global ocean heat content. On the other hand, the corresponding annual change rate of the average delta(APO)$_{netbio}$, obtained by subtracting the rate of delta(APO)$_{therm}$ from delta(APO) (small contributions of the air-sea CO_2 and fossil fuel fluxes are also subtracted based on a simulation using an atmospheric transport model), varied in opposite phase with SOI. These responses of delta(APO)$_{therm}$ and delta(APO)$_{netbio}$ to El Niño / La Niña events are qualitatively consistent with those expected from the simulations based on a community earth system model by Eddebbar et al. (2017).

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References

Eddebbar, Y. A., et al., Impacts of ENSO on air-sea oxygen exchange: Observations and mechanisms, Global Biogeochem. Cy., 31, 901–921, 2017.
Ishidoya, S., et al., Secular change in atmospheric Ar/N_2 and its implications for ocean heat uptake and Brewer-Dobson circulation, Atmos. Chem. Phys., 21, 1357-1373, 2021.
Ishidoya, S., et al., Spatiotemporal variations of the delta(O_2/N_2), CO_2 and delta(APO) in the troposphere over the Western North Pacific, Atmos. Chem. Phys., 22, 6953–6970, 2022.
Tohjima, Y., et al., Global carbon budgets estimated from atmospheric O_2/N_2 and CO_2 observations in the western Pacific region over a 15-year period, Atmos. Chem. Phys., 19, 9269–9285, 2019.
Weiss, R. F., The solubility of nitrogen, oxygen and argon in water and seawater, Deep-Sea Res., 17,

721–735, 1970.

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