Stable Oxygen Isotopes as a Tracer to Estimate Biogeochemical Processes in the Upper Ocean

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The estimation of marine primary production is important as it accounts about 50% of the total carbon fixation in the biosphere. About 60-90% of the primary production is respired by the heterotrophs in the upper few meters and the rest is exported to deeper layers. Therefore, accurate estimates of rates of gross primary production (GPP), community respiration (CR), and net community production (NCP) are fundamental in understanding global carbon cycling. The exchange of gases between ocean and atmosphere, which still has a major uncertainty, is an important part of the biogeochemical cycles of climatically important elements. These gases play very important roles in the atmospheric chemistry and climate regulations and their rate of sea-to-air flux is directly controlled by transfer velocity (k) itself. Therefore accurate estimation of gas transfer velocity is highly essential to understand how ocean reacts in the anthropocene.

Stable oxygen isotopes (triple isotopes of ^{16}O, ^{17}O and ^{18}O) are useful tracer for accurate estimation of phytoplankton metabolic rates and gas transfer velocity at the air-water interface. Unlike traditional methods, this method requires neither incubation of sample nor addition of artificial tracers to the system. The main principle of this method is that the ratio of triple oxygen isotopes in atmosphere depends primarily on the isotopic composition of photosynthetically produced O_2 from terrestrial and aquatic plants, and isotopic fractionation due to respiration. These processes fractionate isotopes in a mass-dependent way such that $\delta^{17}O$ enrichment is about half of $\delta^{18}O$ enrichment. On the contrary, photochemical processes in the stratosphere, such as ozone formation/ decomposition, cause both $\delta^{17}O$ and $\delta^{18}O$ of CO_2 and O_2 enriched and depleted respectively in mass-independent way. The stratosphere-troposphere mixing makes isotope ratio of tropospheric CO_2, and O_2 anomalous. The ^{17}O enrichment in CO_2 is lost at the earth's surface by isotope exchange with liquid water in leaves and in the ocean. On the contrary, O_2 does not exchange isotopes with water. During primary production, oxygen produces from H_2O with no fractionation. Since oxygen in H_2O is mass dependently fractionated, oxygen produced during primary production will hold mass dependent signature and shows anomaly with reference to atmospheric O_2. Therefore, the anomaly in the dissolved O_2 is governed by influx of O_2 from atmosphere that decreases anomaly, and GPP which increases. Hence, if influx of O_2 is known, the changes in anomaly are directly proportional to the GPP. Similarly if the anomaly changes are known in the absence of plankton production, the changes are solely due to air-sea exchange. We have done several experiments in the Sagami Bay, central eastern Japan and the subarctic North Pacific and the results obtained in these experiments will be presented.