Estimation of transfer velocity using triple oxygen isotopes

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The accurate estimation of transfer of trace gases across air-water interface is required to understand ocean-atmosphere coupling in biogeochemical cycling of material on the earth system. A variety of different parameterizations were proposed to calculate transfer velocity (k). Several empirical equations were developed for k as a function of wind speed using linear, quadratic and cubic relationships. The use of these parameterizations led to k values that may differ by more than a factor of 2. Nevertheless, these estimates have large uncertainties (~30%) resulting in large errors in the flux estimates. We estimated k by a novel method using triple oxygen isotopes. Due to different fractionation mechanisms in the stratosphere (mass-independent) and mass dependent by all processes on the earth surface, such as photosynthesis, respiration, air-sea exchange etc., \( \delta^{17}\text{O}-\delta^{18}\text{O} \) relationship of atmospheric O\(_2\) is different from that of mass dependent relationship. This difference is called as \( ^{17}\Delta \) anomaly. The \( ^{17}\Delta \) anomaly of dissolved oxygen in the mixed layer is controlled by gross oxygen production (GOP) and influx of O\(_2\) from atmosphere. The former increases the anomaly whereas the latter decreases. Thus, if GOP is known, it is possible to estimate transfer velocity of oxygen using average mixed layer \( ^{17}\Delta \) anomaly of dissolved oxygen.

We estimated transfer velocity of oxygen in the Sagami Bay, central Japan, using \( ^{17}\Delta \) anomaly measured in the upper 40m during spring and summer seasons, at 2 hour interval for two days during each season, and GOP was measured using a Fast Repetition Rate Fluorometer (FRRF). The mixed layer \( ^{17}\Delta \) anomaly was corrected to remove influence of vertical and horizontal advections. The transfer velocity derived by \( \Delta^{15}\text{O} \) anomaly is grossly consistent with Wanninkhof [1992] model. However, anomaly based transfer velocity is higher at lower wind speeds and vice versa that could possibly due to the mixed layer anomaly is an averaged signal over the residence time of oxygen (~one week in case of Sagami Bay); therefore transfer velocity is also a weekly average whereas Wanninkhof model derives instantaneous transfer velocity. This study suggests that weekly to monthly (based on the residence time of dissolved oxygen in the mixed layer) averaged transfer velocity, with reduced errors, can be derived using \( \Delta^{15}\text{O} \) anomaly and GOP obtained by FRRF in the mixed layer of the oceans.

REFERENCE