Application of indicators of CO_2-related concentration in seawater to various seas

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Carbon dioxide capture and storage (CCS) is an efficient technology to reduce CO_2 emission from large sources into the atmosphere. However, there is a risk of CO_2 leakage due to changes in the underground environment even if its possibility is thought to be low. If CO_2 leaks through the seafloor into seawater, it will decrease seawater pH and may affect the marine ecosystem (e.g. Blackford et al., 2014). Therefore, it is important to examine whether an increase in CO_2-related concentration in seawater, such as pCO_2 and DIC, takes place.

It is well known that CO_2-related concentrations in seawater have large spatial and seasonal fluctuations due to the biological and organic ecosystem activities. Therefore, an appropriate indicator is required for distinguishing the abnormal increase in seawater CO_2 concentration from natural fluctuations. DeGrandpre et al. (1997) showed a strong correlation between partial pressure of CO_2 (pCO_2) and dissolved oxygen (DO) saturation in seawater off Cape Hatteras, North Carolina. However, when this correlation was applied to data observed off Tomakomai, there was a large variation (Nishimura et al., 2020). This is because the sea off Tomakomai is a mixing area of a warm current, a cold current, and land water.

Nishimura et al. (2020) derived an effective indicator to distinguish changes in concentration associated with CO_2 originating from natural fluctuations. To avoid misidentification of natural fluctuation with abnormally high concentration, such as CO_2 leakage from seafloor, they proposed a procedure: namely, the abnormality is judged only when multiple correlations of different types indicate exceeding all the upper ends of their statistical intervals: e.g. 3-sigma. The objectives of this study is to examine the applicability of this procedure using various seawater data obtained in oceans around the world to show its universality.

We applied the three indicators to data disclosed online by Ocean Carbon Data System (OCADS), NOAA National Centers for Environmental Information (NCEI), and examine the universality of the procedure proposed by Nishimura et al. (2020) to avoid the false positive. First, we picked up the data with a water depth of 100 m or less off the west coast of America. Pre-treatment was performed to exclude data that seems to be brackish water with a salt content of 31 ‰or less.

Next, we applied the indicators to the seawaters east of Dominica and Giana. The pCO2-[DO saturation] correlation shown in (b), the [nDIC + 0.768DO]-T correlation in (c), and the [DIC −0.5TA + 0.83DO]-T correlation in (d) were very good around single regression curves. Any data point did not exceed the upper end of 95% prediction interval of all the indicators, meaning that there was no abnormally large CO_2-reated concentration in this sea area.

Therefore, it is reasonable to use multiple indicators to judge CO_2 leaks from the seafloor and, in fact, by using multiple indicators, it is possible to reduce the probability of misidentifying natural fluctuation as an abnormally high concentration value (false positive).

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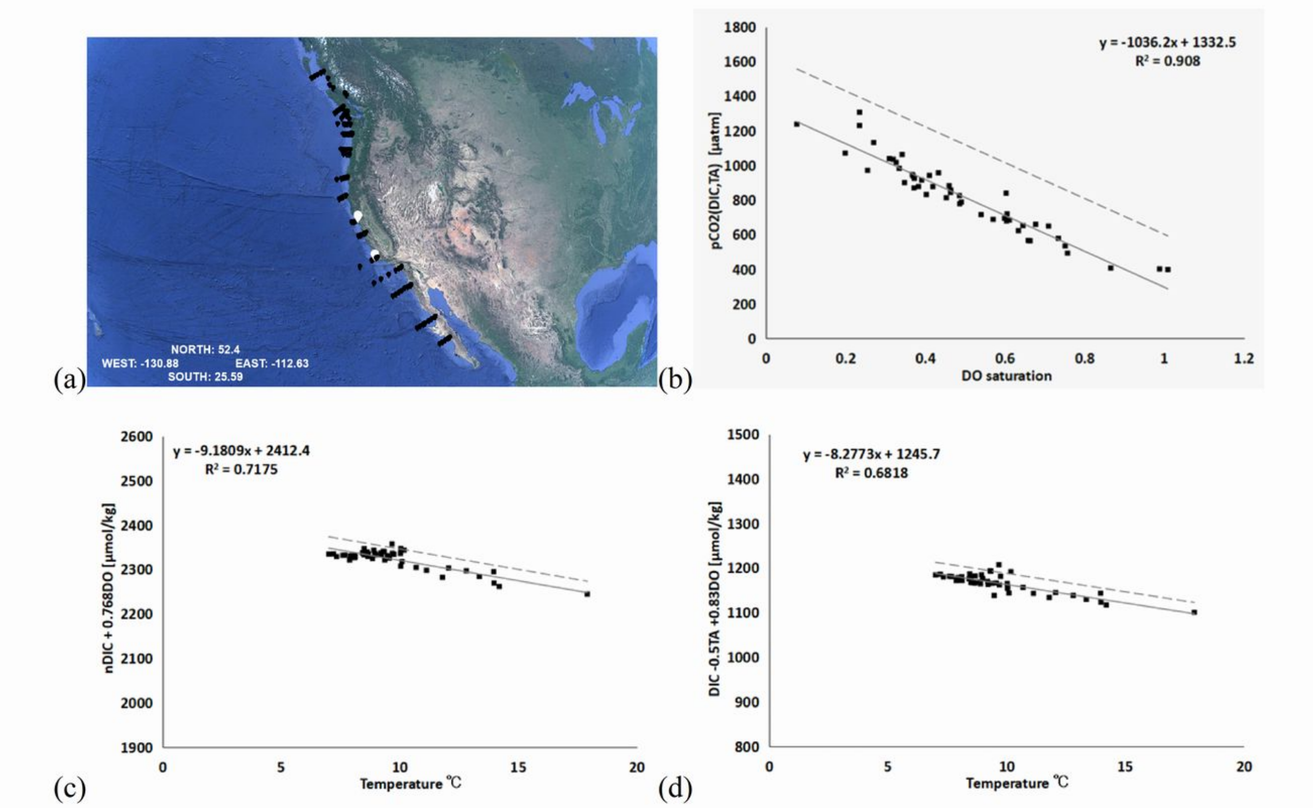

Fig. 1 (a) Horizontal locations of the observation points, (b) pCO_2-[DO saturation] correlation, (b) [nDIC + 0.768DO]-T correlation, and (c) [DIC − 0.5TA + 0.83DO]-T correlation of the seawaters near the seafloor, the depth of which is 100 m or less, off the west coast of America.