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Measurement of air-water carbon dioxide transfer velocity and analysis of its regulating factors

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Introduction

The world ocean takes up 1/2-1/3 of CO_2 emitted by anthropogenic combustion of fossil fuels, and this CO_2 transfer from the air to the ocean is expected to counteract the global warming. On the other hand, CO_2 flux in coastal sites have not been estimated accurately due to its small area and unidentified regulating factor of the gas flux. However, because concentration of dissolved CO_2 at coral reefs varies largely in result of biological activities such as photosynthesis and calcification, the CO_2 flux per unit should be large.

Air-water flux of slightly soluble gas such as CO_2 is regulated by difference of air-water partial gas-pressure and gas-transfer velocity (hereafter, k) which is determined mainly by turbulence condition near water surface. The difference of partial pressure have been measured at various coral reefs in the long term, and noted to be affected by photosynthesis and calcification. On the contrary, k has not been analyzed enough because of few measurements in coastal sites. In this study, k and its regulating factor at coral reefs was analyzed in order to evaluate CO_2 flux at coral reefs quantitatively.

Measurement of k using a floating chamber method

Because water condition in coastal sites varies largely more than that in the open ocean, measurement method with high temporal and spatial resolution is required for analysis of regulating factor of k. In this study, a floating chamber method, which has higher resolution and precision than other existence methods, was used to measure k at coral reefs. For the measurement, biases indicated in previous critics (temperature and pressure change inside the chamber and disturbance of water surface by the chamber) were lowered and confirmed to be nonsignificant.

Furthermore, 3-D current velocity measurement was performed with ADV for quantification of turbulence condition near water surface and analysis of regulating factor of k.

Measurements were performed at Shiraho reef and Fukido reef on Ishigaki Island, Okinawa prefecture, Japan during 2003-2006 discontinuously. At the reefs, various topographies and biological coverage (seagrass, coral) existed in relative narrow area. From comparison of results from these sites, general regulating factors at coral reefs were evaluated.

Results and discussion

Measured k did not show any correlation relationship with empirical parameters (wind speed, current speed, and water-depth), and were larger than results from empirical relationships. This indicates that k at coral reefs is regulated by factors other than those empirical parameters. On the other hand, high correlation between measured k and energy dissipation rate, which is one of turbulent parameters, was confirmed. This result agrees with a previous study (Zappa et al., 2003) and indicates that energy dissipation rate is direct regulating factor of k in coastal sites, including rivers and coral reefs.

Energy dissipation rate at coral reefs was significantly higher than those in rivers, and seemed to differ between measurement sites. Moog and Jirka (1999) and Colbo (2006) suggested that macro-scale elements and interaction of tidal effect and topography enhance turbulence in coastal sites. Therefore those coastal conditions are though to enhance energy dissipation rate and k at measurement sites. Analysis with Reynolds stress indicated that vertical strong momentum flux occurred just above corals and seagrass, and horizontal momentum flux was notable at a site where measured energy dissipation rate was the highest among the sites.

Summary

In this study, k at coral reefs is confirmed to be larger than results from empirical relationships, and be affected by macro-scale elements and interaction between tide and topography. These results indicate that air-water CO_2 flux at coral reefs is larger than previous estimations and contributes to global warming more significantly.