INTERANNUAL VARIATIONS OF WINTER OCEANIC pCO_2 AND AIR-SEA CO_2 FLUX IN THE WESTERN NORTH PACIFIC

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ABSTRACT

We report the interannual variations of winter CO_2 partial pressure in surface waters (pCO_2^{sea}) and overlying air (pCO_2^{air}) and air-sea CO_2 flux in the extensive area (3-34°N) from subtropical to equatorial along 137°E during the period of 1983-2003. The pCO_2^{sea} varied largely in the equatorial region of 3-6°N, depending on the variations of the oceanographic conditions related to the El Niño-Southern Oscillation (ENSO) events. The pCO_2^{sea} variations in the subtropical gyre north of 23°N were small due to highly counteracting effects between anti-correlated sea surface temperature (SST) and dissolved inorganic carbon (DIC) anomalies through the entrainment process, irrespective of large variations of SST. By contrast, it was found that there occurred a low negative correlation between SST and DIC in the region restricted around 15-18°N in the North Equatorial Current, which resulted in a large amplitude of variations of pCO_2^{sea} and hence CO_2 influx. The interannual variations of CO_2 flux depended predominantly on those of the difference between pCO_2^{sea} and pCO_2^{air} (ΔpCO_2) south of 18°N but on those of wind speed in the northern region.

INTRODUCTION

The oceans are understood to be a major sink for increasing atmospheric CO_2 resulted from industrial CO_2 emissions. Although a number of observational and modeling studies have aimed for evaluating the long-term changes and variability on variable scales in the oceanic sink, its temporal variability is poorly established. The interannual variability of the upper ocean carbon cycle and its controlling factors have been investigated on the basis of the time-series data of the carbonate system at a fixed station in the eastern subtropical North Pacific [*Gruber et al*., 2002] and the North Atlantic [*Brix et al*., 2004]. In the western North Pacific, we have previously described the latitudinal and seasonal variations and increasing long-term trend of pCO_2^{sea} from the subtropical to equatorial region along 137°E [*Inoue et al*., 1995; *Ishii et al*., 2001; *Midorikawa et al*., 2005]. In the present study, we report the characteristics of the interannual variations of winter pCO_2^{sea} and air-sea CO_2 flux in the western North Pacific for two decades and discuss their controlling factors.

OBSERVATIONS AND METHODS

The observations of pCO_2^{sea}, pCO_2^{air}, and related hydrographic parameters, such as SST and sea surface salinity, were conducted aboard the R/V *Ryofu Maru* of the Japan Meteorological Agency from 3°N to 34°N along 137°E in the western North Pacific during nearly the same periods from late January to early February every winter, and details of the methods have been described in *Inoue et al.* [1995]. The air-sea CO_2 flux was estimated from the combination of the observed ΔpCO_2 and the empirical equation for the gas transfer coefficient for the long term proposed by *Wanninkhof* [1992]. The wind speed data were taken from the re-analysis by National Center for Environmental Prediction.

RESULTS AND DISCUSSION

The time series of pCO_2^{sea} revealed significant increasing trend (1.3 ± 0.2 to 2.1 ± 0.2 µatm yr^{-1}, r^2 = 0.67-0.91) for two decades over the whole area. The detrended pCO_2^{sea} showed significant interannual variations that were different in different regions: the standard deviation of yearly anomalies (blue circles in Fig. 1) from the average of detrended pCO_2^{sea} for 1983-2003 was large (7.2-7.3 µatm) in 3-6°N and 15-18°N, and was small (3.2-4.2 µatm) in 23-32°N.

The amplitude of interannual variations of $p\mathrm{CO}_2^{sea}$ was closely related to the extent of compensation between SST and DIC anomalies, contributing to $p\mathrm{CO}_2^{sea}$ anomalies often in the opposite direction, in the respective latitudes. The $p\mathrm{CO}_2^{sea}$ variations in the northern subtropical region (25-32°N) was depressed by the counteraction between highly anti-correlated SST and DIC variations through the entrainment process resulted from the strong winter northwest monsoon. On the other hand, the variations were relatively large in the equatorial (3-6°N) and northern NEC regions (15-18°N), because the effects of SST and DIC variations were not counteracted each other and, consequently, contributed significantly to $p\mathrm{CO}_2^{sea}$ anomalies due to the variations of the oceanographic conditions related to the ENSO events in 3-6°N and probably due to the influence of different source water transported laterally in 15-18°N.

Comparison of time series of air-sea CO_2 flux anomaly with those of $\Delta p\mathrm{CO}_2$ or wind speed showed distinctly different controlling factors for the interannual variations of CO_2 flux in different latitudes. The CO_2 flux was dominated by the magnitude of $\Delta p\mathrm{CO}_2$ (r^2 = 0.75-0.91) south of 18°N, whereas the influx in 23-32°N was dependent on wind speed (r^2 = 0.60-0.85) rather than small variations of $\Delta p\mathrm{CO}_2$ ($r^2 < 0.43$).

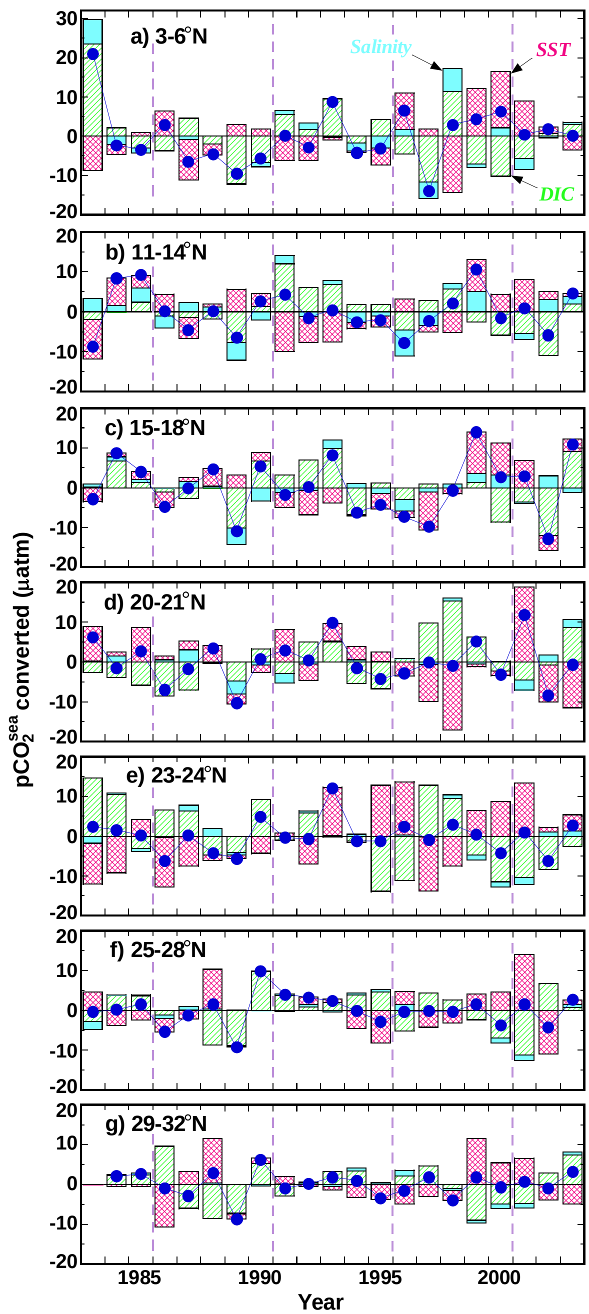

Fig. 1. Time series of contributions of SST, salinity and DIC concentration to anomaly of detrended $p\mathrm{CO}_2^{sea}$ (blue circles). Anomalies of respective properties were converted to $p\mathrm{CO}_2^{sea}$ values.

REFERENCES

Brix, H., N. Gruber, and C.D. Keeling (2004), Interannual variability of the upper ocean carbon cycle at station ALOHA near Hawaii, *Global Biogeochem. Cycles, 18*, GB4019, doi:10.1029/ 2004GB002245.

Gruber, N., C. D. Keeling, and N. R. Bates (2002), Interannual variability in the North Atlantic Ocean carbon sink, *Science, 298*, 2374-2378.

Inoue, H. Y., H. Matsueda, M. Ishii, K. Fushimi, M. Hirota, I. Asanuma, and Y. Takasugi (1995), Long-term trend of the partial pressure of carbon dioxide ($p\mathrm{CO}_2$) in surface waters of the western North Pacific, 1984-1993, *Tellus, 47B*, 391-413.

Ishii, M., H. Y. Inoue, H. Matsueda, S. Saito, K. Fushimi, K. Nemoto, T. Yano, H. Nagai, and T. Midorikawa (2001), Seasonal variation in total inorganic carbon and its controlling processes in surface waters of the western North Pacific subtropical gyre, *Mar. Chem., 75*, 17-32.

Midorikawa, T., K. Nemoto, H. Kamiya, M. Ishii, and H. Y. Inoue (2005), Persistently strong oceanic CO_2 sink in the western subtropical North Pacific, *Geophys. Res. Lett., 32*(5), L05612, doi:10.1029/2004GL021952.

Wanninkhof, R. (1992), Relationship between wind speed and gas exchange over the ocean, *J. Geophys. Res., 97*, 7373-738.