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Effect of seasonal change in gas transfer coefficient on air-sea CO2 flux in the western North Pacific

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Introduction

In the subtropical North Pacific, seasonal change in the partial pressure of CO2 at the sea surface (hereafter, pCO2) is primarily controlled by temperature, where maximum (minimum) pCO2 is found in summer (in winter). Whereas in the subarctic North Pacific, seasonal change in pCO2 is dominated by biological as well as physical mixing processes and temperature. The pCO2 is high in winter and low in summer due to mixing with deep waters and biological uptake. As the winter monsoon occurs in the western North Pacific (WNP). We developed a three-dimensional ocean ecosystem model including the carbon cycle, and apply it to WNP to understand seasonal variations and horizontal distributions of the net air-sea CO2 flux and the dpCO2, especially the effect of the winter monsoon on the net air-sea CO2 flux.

Model and experiment design

We applied our 3-D ecosystem model, COCO-NEMURO (the CCSR Ocean Component Model coupled with the North Pacific Ecosystem Model Used for Regional Oceanography to the first 1500 m in WNP (about 110-180E, 10-60N) with an offline calculation method. The horizontal resolution is 0.28 degree (longitude) and 0.19 degree (latitude). We used daily-mean data during 10 years, which is calculated in the pre-industrial simulation in the climate model, Model for Interdisciplinary Research on Climate (MIROC). The initial conditions and boundary conditions of ocean total carbon dioxide, total alkalinity and nutrients are taken from the annual mean of the Global Ocean Data Analysis Project (GLODAP) 3-D data set and monthly mean of World Ocean Atlas 2005, respectively. At the sea surface, the daily absolute wind speeds is taken from MIROC. The air-sea CO2 flux is estimated by multiplying the dpCO2 (pCO2sea - pCO2air) by the CO2 gas transfer coefficient (Takahashi et al., 2009). The gas transfer piston velocity is based on Wanninkhof et al. (1992). The experiment was conducted for 10 years after a 10 year spin-up, where the MIROC data during 10 years were used. We analyzed the annual and monthly mean during the 10 years.

Result and Discussion

Positive (negative) values of the annually averaged dpCO2 are found in the subtropical region and in small areas of the subarctic region (in areas near Japan). Approximately the distribution of the annually averaged net CO2 flux is the same as the annually averaged dpCO2. However, larger (less) intensity of the net CO2 flux appears in the subarctic region (in the subtropical region) against the intensity of dpCO2 in those areas due to large (small) coefficient of CO2 gas transfer in the subarctic region (in the subtropical region). Interestingly, the negative dpCO2 areas are not enhanced by larger coefficients of CO2 gas transfer around 40N, and the area of positive net CO2 flux is enlarged compared with that of dpCO2 in the subarctic region. Moreover the areas with different signs between the net CO2 flux and the dpCO2 are found both in the subtropical region and in the subarctic region. This is because that seasonal change in coefficients of CO2 gas transfer is correlated with that in dpCO2. Strong winter monsoon caused the coefficient of gas transfer is high (low) in winter (in summer). Therefore, even if the annual average dpCO2 is zero in an area, but the area is still a sink for atmospheric CO2. We showed the distribution of the correlated effect term in WNP, which have negative (positive) values in the subtropical region (in the subarctic region). In the subtropical (subarctic) region, the seasonal variations of coefficients of CO2 gas transfer and dpCO2 lead to a weakened emission (absorption) of CO2 gas to (from) the atmosphere.

References

Takahashi T. et al. 2009: Climatological mean and decadal change in surface ocean pCO2, and net sea-air CO2 flux over the global oceans. Deep Sea Res. II, 56, 554-577.

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