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Decadal change and spatial variation of surface water pCO_2 over the North Pacific Ocean: A synthesis of 30 years of observations, 1970-2004

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Surface water pCO_2 data observed over three decades between 1970 and 2004 are analyzed for space and time (mean decadal) variability in thirty two 10˚ x 10˚ box areas over the North Pacific Ocean north of 10˚N. During this period, the pCO_2 values at SST increased at a mean rate of 1.2 $\pm$ 0.5 μatm yr^{-1} in all but four areas located in the vicinity of the Okhotsk and Bering Seas, where they decreased with time at a mean rate of -1.1 $\pm$ 0.6 μatm yr^{-1}. The mean rate of increase for the open ocean areas is somewhat slower than but consistent with the mean atmospheric CO_2 increase rate of 1.5 ppm yr^{-1} for the past three decades. This suggests that the increase is due to the atmospheric forcing with a delay of several years. The decrease observed in the four areas may be accounted for by the intensified biological production in these areas, which was reported by Gregg et al. (2003) on the basis of the CZCS and SeaWiFS satellite data. A decrease in mixed layer depths resulting from warming may also contribute to the increased drawdown of surface water pCO_2 by biological production. In the North Pacific outside the equatorial/tropical areas, the effects of PDO Phase Shift and El Nino events on seasonal pCO_2can not be clearly identified.

Seasonal amplitude of the pCO_2 values that are normalized to a constant temperature (the mean SST in each box area) reflects primarily the magnitude of seasonal changes in the total CO_2 concentration and hence approximates the net biological production. We have found that the natural logarithm of the seasonal pCO_2 amplitude correlates linearly with the seasonal maximum density of mixed layer (in winter) with R^2 of

0.84. This suggests that the magnitude of biological drawdown of surface water pCO_2 depends on the concentrations of CO_2 and nutrients in deep waters and hence the depth of winter convective mixing. We have also observed that the natural logarithm of winter-time pCO_2 normalized to a basin wide mean SST of 17.6 $^{\circ}$C correlates linearly with winter-time SST in the mixed layer with R^2 of 0.94. This relationship may be used to interpolate winter-time pCO_2 values in surface waters using winter SST values.