CLIVAR/CO_2 REPEAT HYDROGRAPHY PROGRAM: INITIAL CARBON RESULTS FROM THE NORTH PACIFIC

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ABSTRACT

We have employed a Multi-parameter Linear Regression (MLR) analysis procedure to determine the uptake of anthropogenic CO_2 between two east-west hydrographic surveys of the North Pacific that occurred in 1994 and 2004. The results revealed water column integrated uptake rates of anthropogenic CO_2 that ranged from 1.1 to 1.3 mol m^{-2} yr^{-1} depending on location. The combined effect of the tilted density surfaces and the younger waters with higher anthropogenic CO_2 concentrations leads to higher total column inventories in the western North Pacific.

INTRODUCTION

The primary goal of the CLIVAR/CO_2 Repeat Hydrography Program is to quantify the role of the ocean in sequestering anthropogenic CO_2. Information on decadal or shorter timescales is essential to determine any feedbacks of oceanic carbon system due to climate change, and to determine the changes due to natural variability. Discrete high-quality dissolved inorganic carbon and total alkalinity data were acquired as part of the WOCE/JGOFS Global CO_2 survey in the Pacific Ocean between 1989 and 1998. This was followed by repeat surveys in 2001 and 2004 as part of the Sub-arctic Gyre Experiment (SAGE) along the P17N line in the eastern North Pacific and the CLIVAR/CO_2 Repeat Hydrography Program east-west P2 cruise along 30°N. The difference between the measured DIC in the upper water column (100 - 1000 db) for the P2 2004 occupation and the 1994 occupation is shown in Fig. 1A. We then utilized a Multi-parameter Linear Regression (MLR) analysis procedure to further evaluate the difference between the two cruises (Fig. 1B). Using the 1994 data set, commonly measured hydrographic quantities were inputted into the MLR analysis as the independent parameters. Based on the relationship of DIC to those hydrographic properties, equation (1) was used to predict DIC from the 2004 hydrographic data:

$$DIC = a + b(t) + c(S) + d(AOU) + e(Si) + f(P) \quad (1)$$

where a, b, c, d, e, and f are coefficients determined from the 1994 data, t is theta, S is salinity, AOU is apparent oxygen utilization, Si is inorganic silicate, and P is phosphate. The data were interpolated and gridded to common reference pressures, and the total change in DIC between 2004 and 1994 is determined as the difference between the measured DIC gridded values and those predicted from the 2004 hydrographic measurements utilizing the 1994 coefficients (Fig. 1B).

Similar procedures determined the change in anthropogenic DIC from Equation (2) where

$$\Delta C_{ANTHRO} = \Delta C_{MEAS} - \Delta C_{ORG} - \Delta C_{TALK} \quad (2); \text{ and}$$

$$\Delta C_{MEAS} = C_{MEAS2004} - C_{CALC(MLR1994)} \quad (3); \text{ and}$$

$$\Delta C_{ORG} = (117/170) * (AOU_{MEAS} - AOU_{CALC(MLR1994)}) \quad (4); \text{ and}$$

$$\Delta C_{TALK} = 0.5 * (TALK_{MEAS} - TALK_{CALC(MLR1994)}) \quad (5)$$

RESULTS

Fig. 1C is the calculated anthropogenic uptake over the last decade. The values range between 0 - 35 µmol kg^{-1} with the largest values occurring on the eastern edge of the basin at intermediate depths from about 100-800m depth along the 30°N. The results of this research suggest an annual CO_2 uptake of 1.0-1.4 µmol kg^{-1} yr^{-1} in the mixed layer, based on direct observations and multiple linear regression approaches. Water column integrated uptake rates ranged from 1.1 to 1.3 mol m^{-2} yr^{-1}, depending on location. Deep ventilation within the Kuroshio Extension and the subsequent circulation in the subtropical gyre generates a strong east-west gradient in the anthropogenic CO_2 penetration depth. The combined effect of the tilted density surfaces and the younger waters with higher anthropogenic CO_2 concentrations leads to higher total column inventories in the western North Pacific. The integrated amount of anthropogenic CO_2 in the North Pacific is estimated to be 16.5 Pg C through 1994 north of the equator but not including the marginal seas. This estimate is approximately 16% of the amount of anthropogenic CO_2 taken by the global oceans.

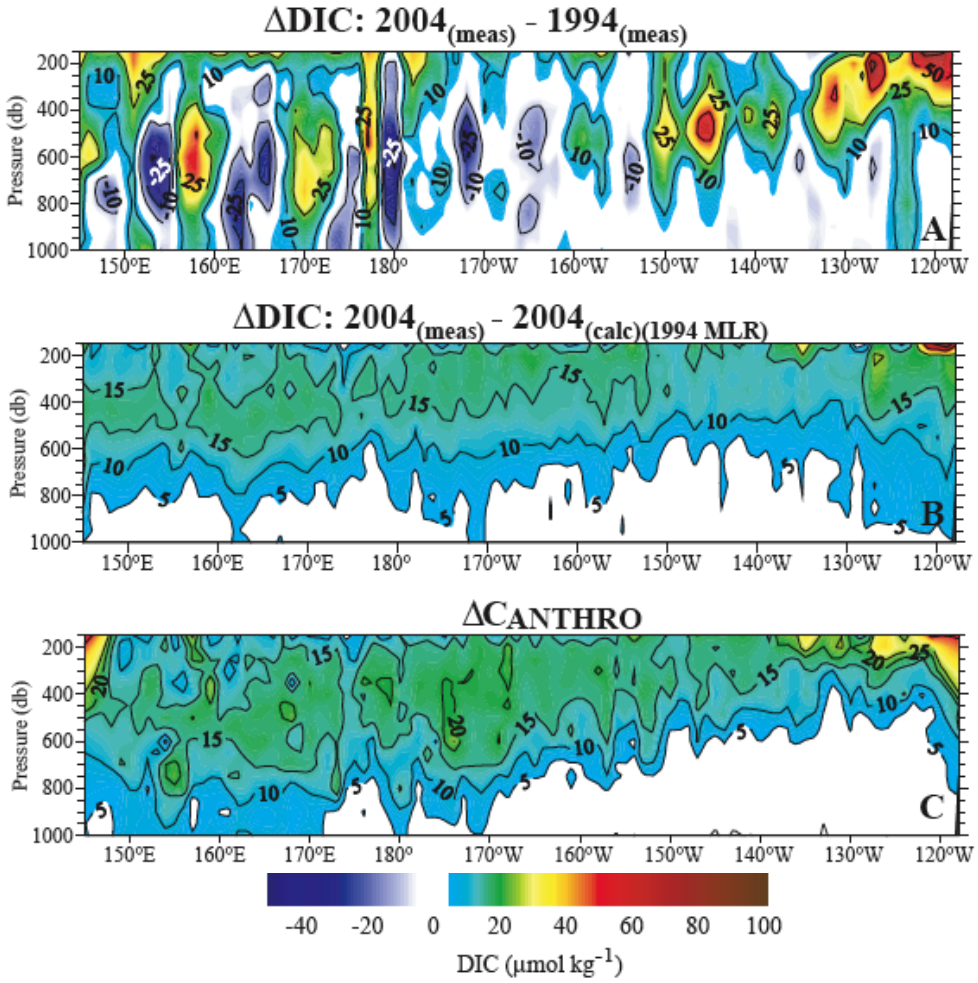

Fig. 1. Distribution of: (A) measured DIC difference; (B) measured – calculated DIC; and (C) anthropogenic DIC along the P2 30°N section in the North Pacific.