B-5 Evaluation of Exchange of Carbon Dioxide between the Atmosphere and the Ocean
(FY 1987-1991)

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Recent increase of atmospheric CO_2 has been attracting great public concerns as one of the triggers for the global climate change in near future. Since it has been considered that the ocean plays an important role for stabilizing the concentration of the atmospheric CO_2, the studies on the exchange of CO_2 between the atmosphere and the ocean has been conducted in this project.

We developed an automatic air/sea CO_2 analyzer operated on shipboard in order to perform simultaneous accurate measurements of pCO_2 in the air and the surface sea water. The air/sea CO_2 analyzer consists of a NDIR analyzer, an air/sea equilibrator, an air sampling system including solenoid valves, air pumps and air dryers, and a data acquisition-storage system. Air samples are also collected in 5 liter pyrex-glass flasks. CO_2 gases were isolated from the air samples using vacuum line after measuring the concentration of CO_2 and methane, and stable carbon isotopic ratios were determined by a mass spectrometer. A circular wind water tunnel was also constructed to assess the exchange process of CO_2 between the air and the sea in laboratory.

Using the air/sea CO_2 analyzer, measurements of pCO_2 in the air and the surface sea water were performed in the wide area of the Pacific Ocean from 1987 to 1991. The concentration of the atmospheric CO_2 increased by 4 to 5 ppm from 1987 to 1989, which is characteristic of the pCO_2 increase during El Niño period. $I(^{13}C)$ values, calculated from $\delta^{13}C$ of atmospheric CO_2, are about -25 ‰ in the mid-latitude in the Northern Hemisphere, while that near the equatorial region is larger than that in the mid-latitude. These results suggest that the seasonal variation of the atmospheric pCO2 in the mid-latitude is attributed to the CO_2 exchange between the atmosphere and the biosphere, while the CO_2 exchange between the atmosphere and the ocean has a pronounced effect in the equatorial region.

The temporal and spatial variations of pCO_2 in the surface sea waters

were also observed. The pCO2 in the surface sea water in the western North Pacific varied seasonally between 290 ppm and 360 ppm, and the phase of the variation differed from that in atmosphere. Distribution of pCO_2 in the surface sea waters in the equatorial Pacific showed a significant change between 1987 (El Niño period) and 1989 (La Niña period)(Figure 1).

CO_2 fluxes ($F(CO_2)$) between the air and the sea over the equatorial Pacific for 1987 and 1989 were calculated according to the following equation; $F(CO_2) = 0.016(U-3)\ pCO_2$ (U : wind speed ($m\ s^{-1}$); pCO_2 : pCO_2(sea) - pCO_2(air)) The distribution of ΔpCO_2 in the eastern Pacific is estimated using two methods concerning the relationship between ΔpCO_2 and temperature. The total flux of CO_2 in the equatorial Pacific was about 0.41 Gt-C/yr during the El Niño period (1987), while that during the La Niña period (1989) was about 1 Gt-C/yr (Table 1). This result indicates that a large amount of CO_2 equivalent to 20% of the annual CO_2 emission through fossil fuel combustion would be evolved from this area if La Niña event could continue for one year.

In the laboratory on land, experiments of CO_2 exchange between the air and the sea water were carried out using the circular wind water tunnel. The exchange coefficient depends clearly on the wind speed.

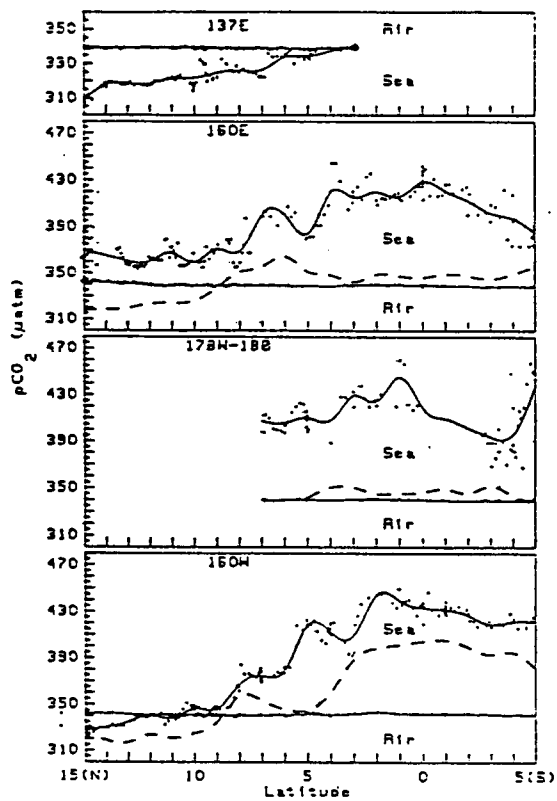

Figure 1. Distribution of pCO_2 in the equatorial Pacific;
solid line: 1989,1-2 ;broken line: 1987, 1-2

Table 1. CO_2 flux in the equatorial Pacific

1987 January~February	135.5°E ~159.5°E	159.5°E ~160.5°W	160.5°W ~80.5°W	Total
E (mol/m²yr)	0.028	0.063	0.049	0.049
ΔpCO2 (μatm)	8.0	14.6	46.4	31.0
Flux (Gt-C)	0.01	0.05	0.34	0.41
E (mol/m²yr)	0.028	0.063	0.049	0.049
ΔpCO2 (μatm)	8.0	14.6	46.2	30.9
Flux (Gt-C)	0.01	0.05	0.34	0.41
1989 January~February	**135.5°E ~159.5°E**	**159.5°E ~160.5°W**	**160.5°W ~80.5°W**	**Total**
E (mol/m²yr)	0.028	0.063	0.049	0.049
ΔpCO2 (μatm)	36.7	81.5	93.1	80.2
Flux (Gt-C)	0.04	0.35	0.59	0.98
E (mol/m²yr)	0.028	0.063	0.049	0.049
ΔpCO2 (μatm)	36.7	81.5	90.9	78.9
Flux (Gt-C)	0.04	0.35	0.57	0.97

B-6. Study on the Carbon Cycle in the Ocean

(1) Potential of Carbon Fixation by Marine Phytoplankton

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(2) Study on Sedimentation Flux of Particulate Carbon in the Ocean

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(3) Study on the Diagenetic Process from Marine Particulate Matter to Sedimentary Particles and the Related Carbon Cycle

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The ocean exchanges a huge amount of CO_2 with the atmosphere, that is the greatest of the fluxes between global carbon reservoirs. The exchange flux of CO_2 between the atmosphere and the ocean is estimated as 100×10^{15}gC/y, that is much larger than the anthropogenic emission

rate of CO_2 ($6x10^{15}$gC/y). Therefore, the gas exchange effectively controls the atmospheric concentration of CO_2 over the long time scale. Since the atmosphere retains only one half of CO_2 emitted from burning fossil fuel, it is believed that the ocean absorbs a large portion of the other half. However, the CO_2 absorption flux of the ocean has not been confirmed. In this program, investigations of the carbon cycling in the ocean, related especially to bio-geochemical aspect, will be studied.

(1) Potential of carbon fixation by marine phytoplankton

Laboratory experiments on CO_2 fixation and gas exchange are performed by use of a clonal culture of marine phytoplankton. A preliminary tank experiment has already be done, in which cell growth related to atmospheric CO_2 concentration was observed. A mathematical model of carbon cycle has been developed and applied.

(2) Study on sedimentation flux of particulate carbon in the ocean

Sediment trap experiments to measure the net carbon flux in the pelagic zone in the ocean have been started in tropical and subtropical regions in the Northwest Pacific. Time series sampling may determine the seasonally averaged flux of particulate carbon. The degradation process of the settling particle in the deep sea is also studied.

(3) Study on the diagenetic process from marine particulate matter to sedimentary particles and the related carbon cycle

Decomposition and transformation of organic carbon during early diagenesis are the key processes of the fixation of carbon to oceanic sediment. Concentrations of dissolved amino acids in interstitial waters are used as sensitive tracers for early diagenesis of organic carbon on the sea floor. Carbon flux between deep sea water and ocean sediment is determined from the results.