PROGRESS REPORT
for
CO₂ MEASUREMENTS ALONG WOCE P-16 and 19 SECTIONS
IN THE SOUTH PACIFIC OCEAN: A JOINT LDGO/WHOI PROGRAM

OCT 15 1990

(Grant No. DE-FG02-90ER60983)

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DE91 000878

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(July 30, 1990)

This report covers the progress made since June 1, 1990, the beginning of this grant. The objective of the six-month period covered by this grant is to prepare for the field operations in the South Pacific Ocean. The coulometer and gas chromatograph systems, which will be used for the measurements of the total CO₂ concentration and pCO₂ aboard research ships, are being calibrated presently. Various spare parts needed for the expedition are being ordered, and the Pure-Air generators and hydrogen generators are being serviced. Our preparation is on schedule. We have participated in two meetings where the problems associated with instrumentation and calibration were actively discussed among the participants of the DOE CO₂ program.

The exact dates of the oceanographic expedition are currently uncertain, although it was originally scheduled to begin in November, 1990. We have been informed by the WOCE Committee that the expedition may be postponed to January, 1991. The postponement has been caused by the delay in the completion of refitting the research ship scheduled for the expedition.

DISCLAIMER

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PROPOSED INVESTIGATION
for
Continuation of DE-FCO2-90ER60983

Introduction:

One of the stated objectives of the DOE Global Change Program is to determine the fate of fossil fuel CO₂ released into the atmosphere. It has been observed that the atmospheric CO₂ concentration has been increasing at a rate corresponding to about 55% of the annual industrial CO₂ emission. This suggests that the remaining 45% is being taken up by active CO₂ reservoirs such as the terrestrial biosphere and the oceans. In order to reliably predict the future course of atmospheric CO₂ increase, it is important to know (a) whether the airborne fraction might change and (b) what is the CO₂ up-take rate of the oceanic and land biosphere respectively. On the basis of various ocean-atmosphere models calibrated using the distribution of carbon-14 in air and sea, the oceanic up-take has been estimated to be in the range of 26 to 44%. On the other hand, on the basis of the GISS/NASA 3-D general circulation model of the atmosphere, the meridional gradient of atmospheric CO₂ concentration and the air-sea CO₂ flux over the northern hemisphere oceans, Tans, Fung and Takahashi (1990) have estimated that the oceanic up-take might be as small as 10% the industrial emission. Hence, the partition of the CO₂ being taken up by the biosphere and oceans is poorly known. The major objective of this proposed investigation is to accurately determine the distribution of pCO₂ and total CO₂ concentration in the South Pacific Ocean along the WOCE Sections P-16 and P-19. These data will not only serve as the baseline for the future measurements, but also will be used in improved ocean CO₂ models, which would give more reliable estimates for the oceanic up-take of CO₂.

Proposed Program:

The objective of the first project year, June 1, 1990 through October 14, 1990, has been to improve, test, calibrate and prepare the existing sea-going equipment for the measurement of pCO₂ and total CO₂ concentration. The progress on the equilibrator/gas chromatograph and coulometer systems is on schedule.

During the second year, October 15, 1990 through October 14, 1991, the field program will begin. Although the WOCE oceanographic expedition was originally scheduled to begin in November, 1990, it is likely that this will be postponed to January, 1991, due to the unexpected delay in refitting the research vessel scheduled for the expedition. The field work described below is based on the original schedule for the first field

season. If the plan currently being considered is put into effect, we would plan to take part in Leg P-17C (Tahiti to San Diego), which would replace Leg 16 (Punta Arenas, Chile to Tahiti) during this year. In that, the number of days at sea is approximately the same. Furthermore, since one of the two ports of calls (Tahiti) is the same under the original and the revised plan, the effect on the budget would be slight. The budget included in this proposal is based on the original plan, but should be able to accommodate the revised plan as well. Our work schedule will be adjusted according to any future changes in the WOCE expedition schedule.

The proposed WOCE field program for the P-16 and P-19 sections (see Fig. 1) is divided into three legs: Leg 1 from Puerto Quetzal (14°N), Guatemala, to Punta Arenas (54°S), Chile, along the 88°W meridian (51 days at sea); Leg 2 from Punta Arenas, Chile, to Tahiti (19°S) along the 150°W meridian via the 55°S - 60°S latitude (59 days at sea); and Leg 3 from Tahiti to Hawaii (21°N) along the 150°W meridian (30 days). During these three legs, a total of about 400 hydrographic (i.e. small volume) stations and 40 large volume stations have been planned. On the average, a small volume station will be occupied at every 1° in longitude or latitude. At each small volume station, water samples will be collected at 36 depths, ranging from the surface to the bottom of the ocean. The total CO_2 concentration in seawater will be measured at sea, and will also be determined in the land-based laboratories of L-DGO for a limited number of stored samples. The CO_2 partial pressure in discrete water samples will be determined at sea using the equilibrator-gas chromatograph system of L-DGO (Takahashi et al., 1982). The total alkalinity in stored water samples will be measured by the WHOI investigator using a titrator (Bradshaw et al., 1981), and the measured values will be compared with those computed using the total CO_2 concentration, pCO_2 and the concentrations of dissolved phosphate and silicate in seawater. The computational method has been described by Takahashi et al. (1982) and Peng et al. (1987). In addition to these CO_2 measurements, the following properties will be determined in these samples by other WOCE participating investigators; salinity and the concentrations of dissolved oxygen, CFC's, nitrate, nitrite, phosphate and silica. Some of these samples will be stored for accelerator ^{14}C measurements. Large volume samples (270 liters) will be collected at 18 levels for the determination of ^{14}C (by the radioactive counting method), ^{85}Kr , ^{39}Ar , ^{226}Ra and other tracers.

According to the WOCE plan, the following number of stations are scheduled; 175 stations for Leg 1 (51 days at sea), 136 stations for Leg 2 (59 days at sea), and 89 stations for Leg 3 (30 days at sea). This corresponds to about 3 stations per day at sea (i. e. 400 stations during

130 days at sea). The present capacity for the shipboard measurement of total CO_2 and pCO_2 is one station (36 water samples) per day with two marine analysts aboard. This plan will allow us to determine a complete depth profile from the surface to the sea floor at every third station or at every 3° interval in latitude or longitude. In the areas where major oceanographic features such as equatorial upwelling and boundary currents exist, measurements will be made at closer intervals. In addition, 2 to 3 samples of surface mixed layer will be taken and analyzed at every station.

For field work on WOCE ships, we are limited to two berths. The Lamont group will be responsible for the shipboard measurement of the total CO_2 concentration and the CO_2 partial pressure in discrete water samples during Legs 1 and 2. Two marine analysts will operate a coulometer for total CO_2 concentration measurements and a gas chromatograph for pCO_2 measurements. We plan to have two L-DGO analysts at sea during Leg 1, and one Lamont analyst and one Woods Hole analyst during Leg 2. The water samples for total CO_2 and alkalinity measurements at the land-based laboratories of Woods Hole will be also collected during the first two legs and stored aboard ship for subsequent shipment to Woods Hole. It is our understanding that the SIO group (C. D. Keeling) has proposed to have a technician aboard for the collection of water samples during Leg 3 (from Tahiti to Hawaii), and that these samples will be stored and analyzed for the total CO_2 concentration and alkalinity at Scripps. This will leave one berth available for the L-DGO/WHOI program. We plan to have a WHOI analyst aboard during Leg 3 to operate the coulometer and/or chromatograph for a limited number of water samples in order to allow a direct comparison between the coulometric and manometric measurements.

The data processing and the determination of CO_2 in stored water samples will begin as soon as the field expeditions are completed.

U. S. DEPARTMENT OF ENERGY
NOTICE OF ENERGY RD&D PROJECT

1. Descriptive TITLE of work
(150 characters including spaces)

CO₂ MEASUREMENTS ALONG THE WOCE P-16 AND 19 SECTIONS IN THE SOUTH PACIFIC OCEAN;
A JOINT LDGO/WHOI PROGRAM.

2. CONTRACT or
grant number DE-FG02-90ER60983

- 2A. MASTER contract number
(GOCO's) _____

- 2B. Responsible PATENT office _____

3. Performing organization CONTROL
number (internal)

- 3A. Budget and Reporting code
KP05

- 3B. Funding YEAR for this award
Oct. 15, 1990 - Oct. 14, 1991

4. Original contract start date 6/1/90

- 4A. Current contract start date 10/15/90

- 4B. Current contract close date 10/14/91

- 4C. Anticipated project termination
date 10/14/92

5. Work STATUS

☐ Proposed ☒ Renewal
☐ New ☐ Terminated

- 5A. Manpower (FTE) _____

- 5B. CONGRESSIONAL district 16 & 17

- 5C. STATE or Country where work is being
performed United States

- 5D. COUNTRY sponsoring research United States

6. Name of PERFORMING organization Trustees of Columbia University in the City of New York
Box 20, Low Memorial Library
New York, New York 10027

- 6A. DEPARTMENT or DIVISION
Lamont-Doherty Geological
Observatory

- 6B. Street Address
Route 9W

- 6C. City, State, Zip Code
Palisades, New York 10964

7. Circle only one code for TYPE of Organization Performing R&D:

☒ CU - College, university, or trade school
FF - Federally funded RD&D centers or laboratory operated for an agency of the U. S.
Government
IN - Private industry
NP - Foundation or laboratory not operated for profit
ST - Regional, state or local government facility
TA - Trade or professional organization
US - Federal agency
XX - Other
EG - Electric or gas utility

- 8A. Contractor's PRINCIPAL INVESTIGATOR/s or project manager
Name/s (Last, First, MI) Takahashi, Taro

- 8B. PHONE/s (in order of PI names with commercial followed by FTS)

Comm. (914)359-2900; FTS _____; Comm. _____; FTS _____

- 8C. PI's address (if different from that of Performing Organization)
Route 9W, Palisades, New York 10964

9. DOE SUPPORTING Organization (DOE Assistant Secretary and office sponsoring the work; technical monitor; and administrative monitor).

9A. PROGRAM division or office

(full name) Carbon Dioxide Research Division

Program Office Code _____

9B. TECHNICAL monitor (Last, First, MI) Riches, Michael

9C. Address U.S. Dept. of Energy, ER-76

9D. Phone _____

Comm. (301) 353-3264

Germantown, MD 20545

FTS _____

9E. ADMINISTRATIVE monitor (Last, First, MI) Adkins, Keith

10. FUNDING in thousands of dollars (KS). Funds represent budget obligations for operating and capital equipment (FY runs October 1 - September 30).

Funding organization(s)	Current FY <u>90</u>	Next FY <u>91</u>
A. DOE	\$70,000	\$314,536
B.		
C.		

10D. Does the current FUNDING cover more than one year's work?

Yes _____

No X

E. If yes, provide dates (from when to when). _____

11. Descriptive SUMMARY of work. Enter a Project Summary using complete sentences limited to 200 words covering the following: Objective(s), state project objectives quantifying where possible (e.g., "The project objective is to demonstrate 95% recovery of sulfur from raw gas with molten salt recycling at a rate of one gallon per minute."); approach, describe the technical approach used (how the work is to be done); expected product/results, describe the final products or results expected from the project and their importance and relevance.

The objective of the first project year, June 1, 1990 through October 14, 1990, has been to improve, test, calibrate and prepare the existing sea-going equipment for the measurement of pCO₂ and total CO₂ concentration. The progress on the equilibrators/gas chromatograph and coulometer systems is on schedule.

During the second project year, October 15 through October 14, 1991, the field program for measurements of pCO₂ and total CO₂ concentration in the South Pacific Ocean will begin. The anticipated data will greatly improve the available oceanic CO₂ data base and will allow an improved estimate and prediction for the future course of the oceanic uptake and storage of the fossil fuel CO₂. Although the WOCE (World Ocean Circulation Experiment) expedition was originally scheduled to begin in November, 1990, it has been postponed to January, 1991, or thereafter due to the unexpected delay in refitting the research vessel scheduled for the expedition. The Lamont Group will be responsible for the shipboard measurement of the total CO₂ concentration and the CO₂ partial pressure in discrete water samples during Leg 1 (Puerto Quetzal, Guatemala, to Punta Arenas, Chile) along the 88°W meridian (51 days at sea) and leg 2 (Punta Arenas, Chile to Tahiti) along the 150°W meridian (59 days at sea). During the expedition, we plan to determine the distribution of the CO₂ properties at about 100 locations from sea surface to the ocean bottom at 36 levels.

After the completion of the field program, the data will be processed and distributed to the scientific community for various model studies being developed for prediction of the future course of the atmospheric CO₂ level.

12. PUBLICATIONS available to the public. List the five most descriptive publications that have resulted from this project in the last year that are available to the public. (Include author, title, where published, year of publication, and any other information you have to complete full bibliographic citation.) Use the back of this form or additional sheets if necessary.

no publications as of yet.

13. KEYWORDS (Listed five terms describing the technical aspects of the project. List specific chemicals and CAS number, if applicable.)

CARBON DIOXIDE CONCENTRATION
CARBON DIOXIDE PARTIAL PRESSURE
SOUTH PACIFIC OCEAN
WORLD OCEAN CIRCULATION EXPERIMENT (WOCE)

14. RESPONDENT. Name and address of person filling out the Form 538. Give telephone number, including extension (if you have FTS number, please include it) at which person can be reached. Record the date this form was completed or updated. The information in Item 14 will not be published.

Respondent's Name: Taro Takahashi Phone No.: (914) 359-2900 Date: _____
Lamont-Doherty Geological Observatory
Street: Route 9W
City: Palisades State: New York Zip: 10964

15. Additional space for furnishing information in items 1 to 14. (Indicate item numbers to which answers apply.)

Item No.

NOTICE: Return this form to the office indicated in the reporting requirements for your award agreement covering this project. If you have completed a similar programmatic office project description during the current Fiscal Year, complete only the new data elements on this form and send it and a copy of the description completed earlier to Department of Energy, Office of Scientific and Technical Information, P. O. Box 62, Oak Ridge, TN 37831.

- END -

DATE FILMED

11 / 06 / 90