

PROPOSED EXXON RESEARCH PROGRAM TO  
HELP ASSESS THE GREENHOUSE EFFECT

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PROGRAM GOAL

- USE EXXON EXPERTISE AND FACILITIES TO HELP DETERMINE THE LIKELIHOOD OF A GLOBAL GREEN-HOUSE EFFECT

## RATIONALE FOR EXXON INVOLVEMENT

- DEVELOP EXPERTISE TO ASSESS THE POSSIBLE IMPACT OF THE GREENHOUSE EFFECT ON EXXON BUSINESS
- FORM RESPONSIBLE TEAM THAT CAN CREDIBLY CARRY BAD NEWS, IF ANY, TO THE CORPORATION
- PROVIDE THE GOVERNMENT WITH HIGH QUALITY INFORMATION TO REDUCE THE BUSINESS RISK OF INADEQUATE GOVERNMENT POLICY
- GENERATE IMPORTANT SCIENTIFIC INFORMATION THAT WILL ENHANCE THE EXXON IMAGE AND PROVIDE PUBLIC RELATIONS VALUE

## DOE INTEREST

- ACCELERATE CONTEMPLATED RESEARCH PROGRAM IN OCEANIC CO<sub>2</sub> MEASUREMENTS
- COST EFFECTIVE METHOD TO ACQUIRE ESSENTIAL OCEANOGRAPHIC DATA
- OBTAIN INDUSTRIAL PARTICIPATION TO COMPLEMENT CURRENT ACADEMIC EFFORT
- CONTRIBUTION OF DATA FROM EXXON FUNDED PROGRAMS TO DETERMINE SOURCE OF CO<sub>2</sub> IN ATMOSPHERE AND AIR-OCEAN CO<sub>2</sub> MASS TRANSFER COEFFICIENTS

## DEFINITION

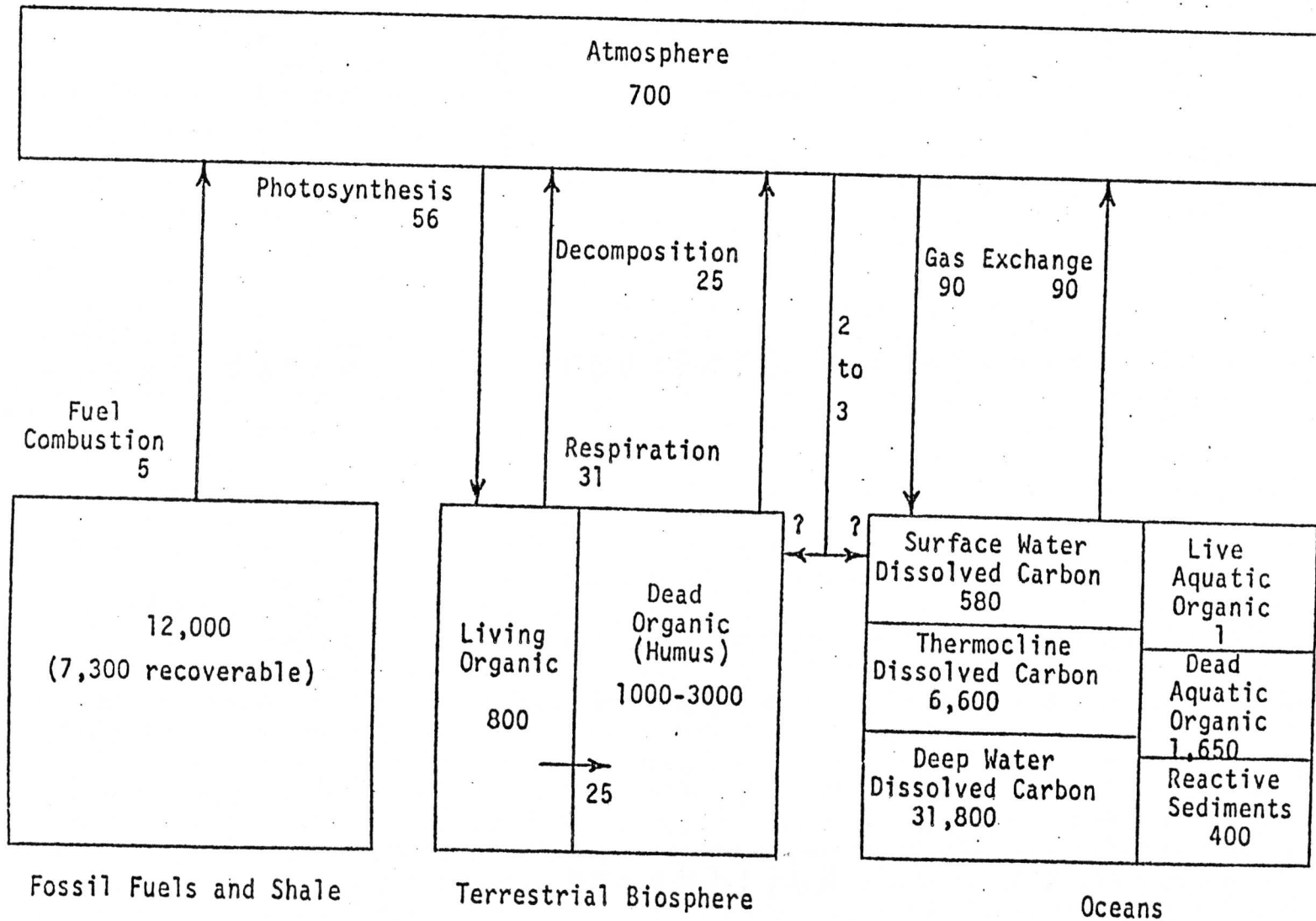
GREENHOUSE EFFECT - AN UPSET IN THE EARTH'S THERMAL BALANCE CAUSED BY THE REABSORPTION OF INFRARED RADIATION FROM THE EARTH BY THE INCREASING LEVELS OF CO<sub>2</sub> AND OTHER ATMOSPHERIC COMPONENTS

- ATMOSPHERIC CO<sub>2</sub> HAS INCREASED 15% SINCE THE INDUSTRIAL REVOLUTION
- THE ANNUAL ANTHROPOGENIC ADDITION OF CO<sub>2</sub> TO THE ATMOSPHERE HAS BEEN INCREASING AT 4% PER YEAR SINCE THE INDUSTRIAL REVOLUTION
- THIS INCREASE HAS BEEN ATTRIBUTED TO FOSSIL FUEL UTILIZATION
- APPROXIMATELY 10-15% OF THE CO<sub>2</sub> FROM FOSSIL FUELS CANNOT BE ACCOUNTED FOR
- ATMOSPHERIC CO<sub>2</sub> CONTRIBUTION FROM FOREST CLEARING IS NOT KNOWN

# The Carbon Cycle

1978

Fluxes in Gt/a  
Pool sizes in Gt



## MAJOR RESEARCH NEEDS

<u>PROBLEM AREA</u>	<u>RESEARCH NEEDS</u>	<u>EXXON CAPA- BILITY</u>
ATMOSPHERE	- WEATHER MODELING	NO
	- DISPERSION OF CO <sub>2</sub>	YES
OCEAN	- INTERLAYER EXCHANGE OF CO <sub>2</sub>	YES
	- CIRCULATION OF SEAWATER	YES
TERRESTRIAL BIOSPHERE	- STORAGE AND EXCHANGE OF CARBON	YES
INTER-AREA EXCHANGE	- CO <sub>2</sub> EXCHANGE ACROSS OCEAN-ATMOSPHERIC INTERFACE	YES
	- CO <sub>2</sub> EXCHANGE BETWEEN BIO- SPHERE AND ATMOSPHERE	

PROPOSED PROGRAMS

PROGRAMS

FUNDING

OCEAN SAMPLING PROGRAM

- TANKER SAMPLING SYSTEM
- DRILLING SHIP STATION

DOE/EXXON

EXXON

LAND BIOTA SAMPLING PROGRAM

- C-13 AND C-14 SAMPLING

EXXON



## OBJECTIVES OF OCEAN SAMPLING

- DETERMINE CO<sub>2</sub> FLUX BETWEEN AIR AND OCEAN

$$\underline{\text{FLUX}} = (\text{TRANSFER COEFFICIENT}) \times (\text{DRIVING FORCE})$$

DRIVING FORCE DETERMINED FROM TANKERS AS A FUNCTION OF CO<sub>2</sub><sub>ATM</sub>, CO<sub>2</sub><sub>SW</sub>, TEMPERATURE, LOCATION, ETC.

TRANSFER COEFFICIENT DETERMINED FROM DRILLING SHIPS BY TRACER STUDY AS A FUNCTION OF WEATHER, SEA-STATE, ETC.

- CROSSCHECK RATE OF CO<sub>2</sub> EXCHANGE ACROSS THE AIR-SEA INTERFACE USING C-14 RELEASED DURING ATOMIC BOMB TESTS AS TRACER

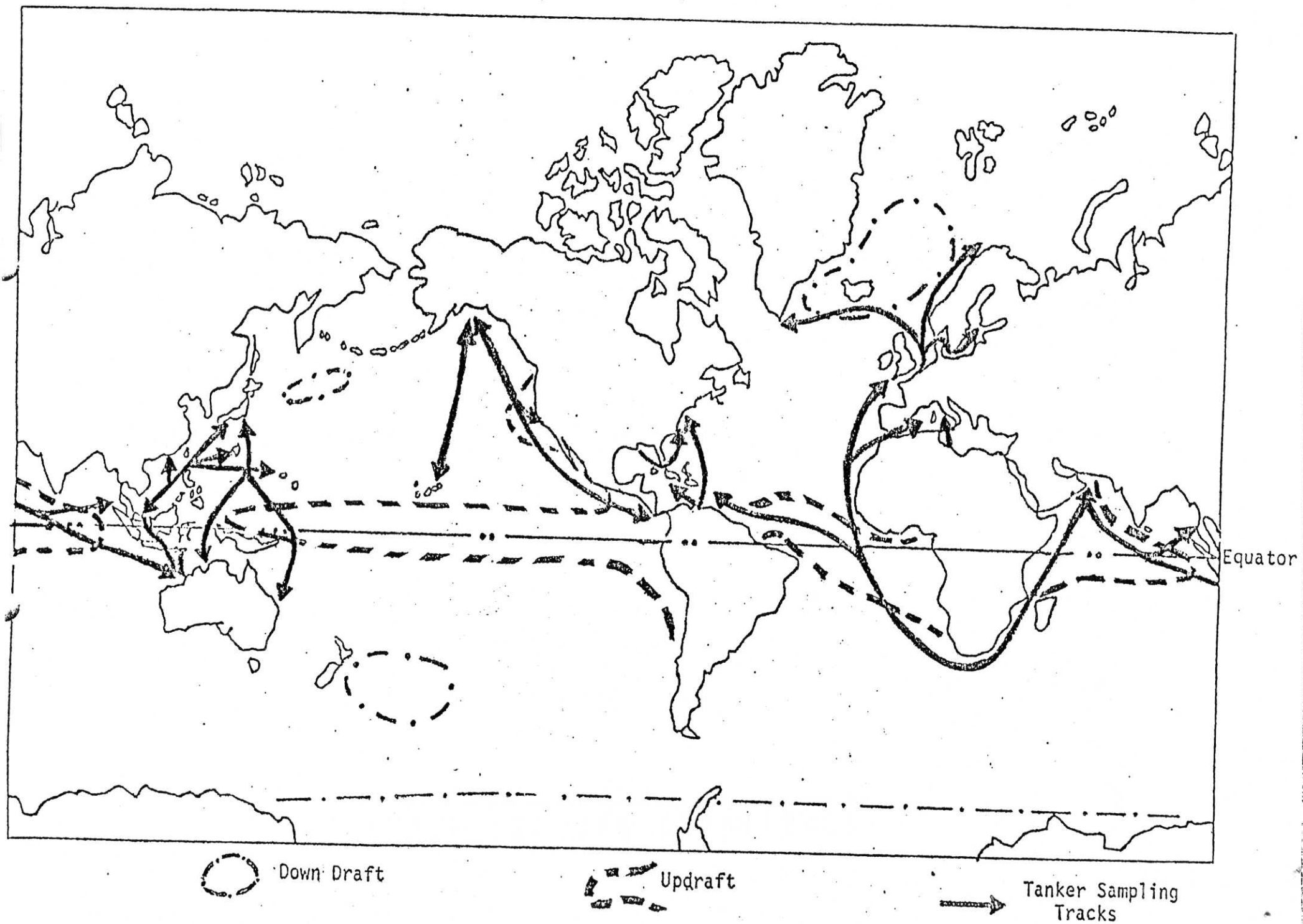
## TANKER PROGRAM

- TANKERS WILL SAMPLE CONTINUOUSLY
  - ATMOSPHERIC CO<sub>2</sub> TO  $\pm 0.5$  PPMV
  - OCEAN CO<sub>2</sub> TO  $\pm 0.5$  PPMV
  - SEA AND AIR TEMPERATURE TO  $\pm 0.1^{\circ}\text{C}$
  - RELATIVE HUMIDITY
  - BAROMETRIC PRESSURE
  - SALINITY
  - SEAWATER PH
  
- TANKER WILL ALSO SAMPLE SURFACE SEAWATER FOR C-14 ON A PERIODIC BASIS
  
- DEPTH THERMOMETERS WILL BE USED PERIODICALLY TO DETERMINE THE TEMPERATURE PROFILE OF THE OCEAN ALONG THE TANKER ROUTE

## TANKER PROGRAM (CONTINUED)

- TANKER WILL BE ABLE TO REPEAT MEASUREMENTS ALONG A PARTICULAR ROUTE ANYWHERE FROM 10 TO 40 TIMES PER YEAR DEPENDING ON ROUTE LENGTH AND PETROLEUM DEMAND
- TANKER PROGRAM WILL BE EXPANDED FROM ONE ROUTE DURING THE FIRST YEAR TO FIVE BY THE THIRD YEAR
- SOME TANKER ROUTES PROPOSED IN THIS PROGRAM CROSS AREAS WHERE RELATIVELY LITTLE OCEANOGRAPHIC WORK HAS BEEN DONE
- THE DATA COLLECTED WILL BE USED TO DETERMINE  $\text{PCO}_2$  LEVELS ON A REGIONAL AND SEASONAL BASIS IN BOTH THE ATMOSPHERE AND THE OCEANS

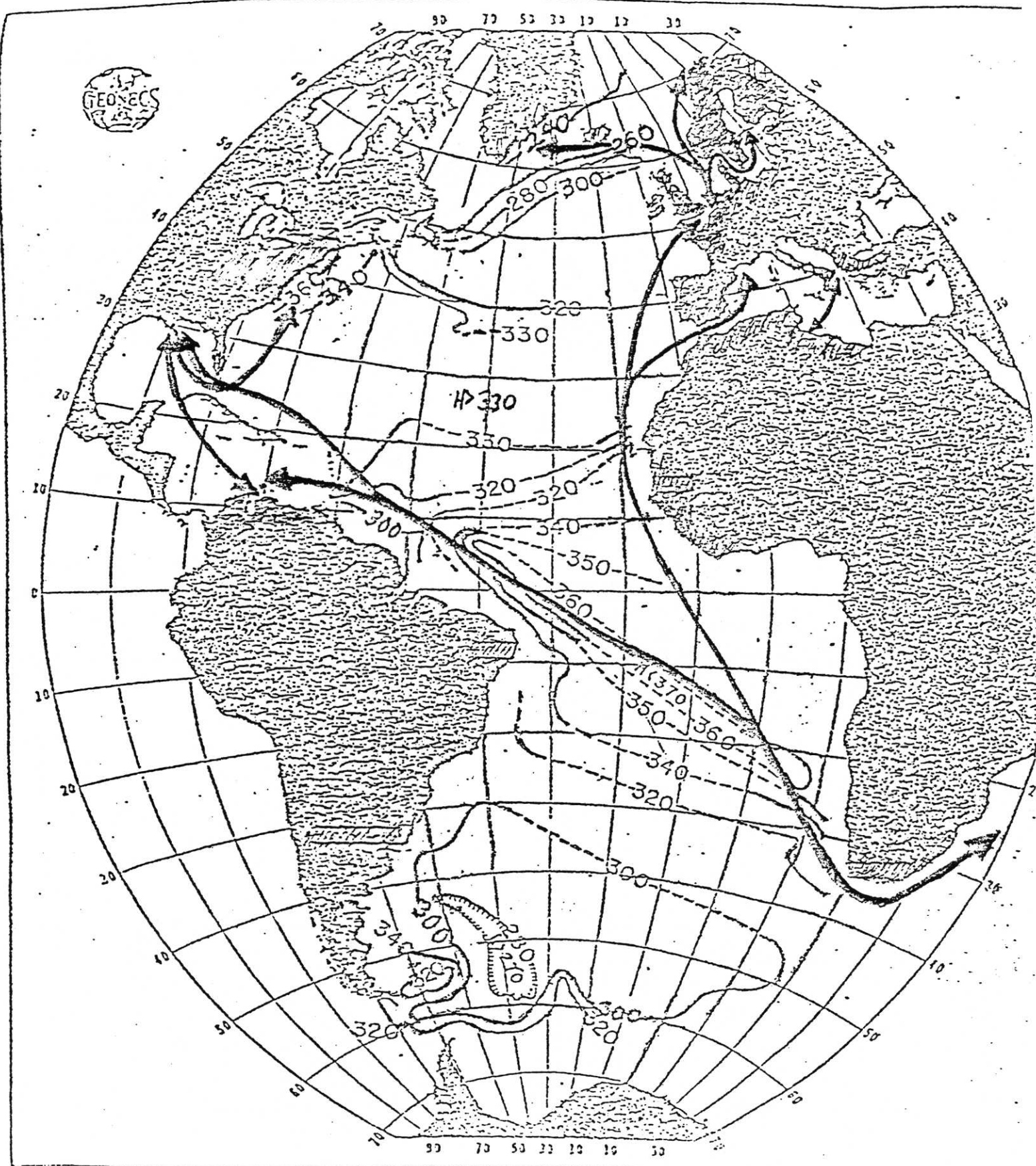
DEEP WATER WELLINGS AND TANKER ROUTES



$pCO_2 \cdot 10^{-6} \text{ atm.}$

IN THE SURFACE WATER OF THE ATLANTIC OCEAN

JULY 1972 - MARCH 1973

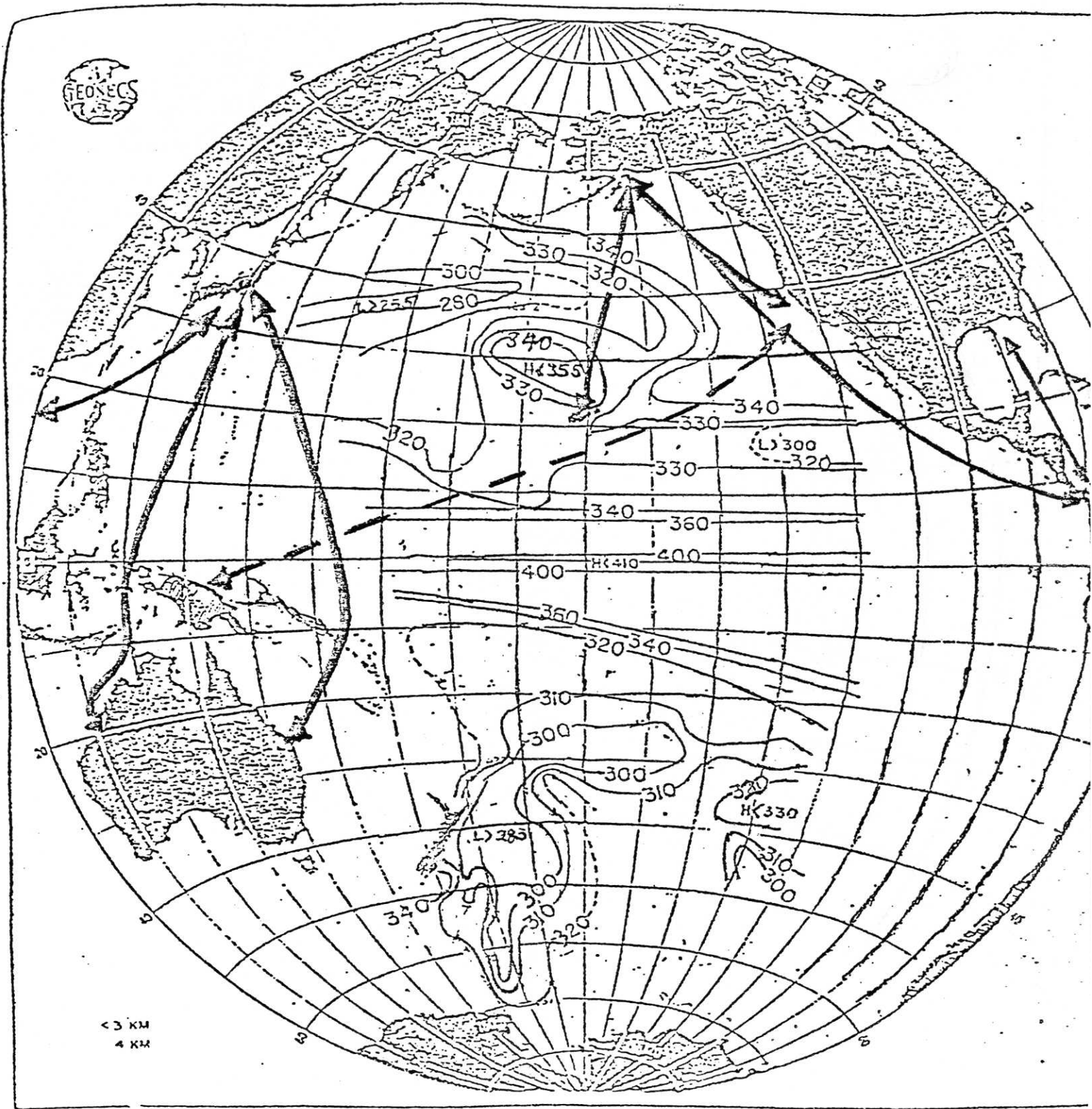


All Exxon Atlantic tanker routes.

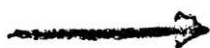
$pCO_2 \cdot 10^{-6}$  atm.

IN THE SURFACE WATERS OF THE PACIFIC OCEAN

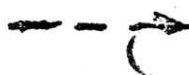
AUGUST 1973 - JUNE 1974



Pacific tanker routes.



Exxon routes



Other tanker routes

## DRILLING SHIP PROGRAM

- EXXON CONTRACTED DRILLING SHIPS ARE PRESENTLY EXPLORING MANY DEEP WATER AREAS AROUND THE WORLD
  - DRILL IN OCEAN DEPTHS WELL OVER 1000 FEET, SOMETIMES AS MUCH AS 5000 FEET
  - REMAIN IN ONE LOCATION FOR TWO TO THREE MONTHS
- AT THESE DEPTHS, THE OCEAN IS USUALLY WELL STRATIFIED, AND IS SUITABLE FOR TRACER GAS STUDY

DRILLING SHIP PROGRAM (CONTINUED)

- MEASUREMENT OF SURFACE WATER RADON-222 PROFILES AND WEATHER DATA CAN BE USED TO DETERMINE THE RATE OF GAS EXCHANGE AS A FUNCTION OF WIND SPEED AND SEA STATE
- DEEP WATER SAMPLING CAN ALSO BE PERFORMED TO ENHANCE OUR UNDERSTANDING OF DEEP OCEAN EXCHANGE OF CO<sub>2</sub>, RADON-222, AND OTHER CHEMICAL TRACERS



## INFORMATION YIELDS

### TANKER PROGRAM

- THE FOLLOWING DATA WILL BE COLLECTED ALONG THE TANKER ROUTES:
  - ATMOSPHERIC  $PCO_2$
  - OCEANIC  $PCO_2$
  - SEA TEMPERATURE PROFILES
  - SALINITY
  - PH
  - SURFACE WATER CARBON-14 LEVELS
  
- USING THE ABOVE DATA TO MAP SEASONAL AND REGIONAL VARIATIONS WILL ENHANCE OUR UNDERSTANDING OF:

## INFORMATION YIELDS (CONTINUED)

- ATMOSPHERIC CIRCULATION
  - + THE VARIATIONS WILL HELP DETERMINE GLOBAL AIR CIRCULATION PATTERNS AND COULD BE A USEFUL CONTRIBUTION TO THE TRANSIENT TRACES PROGRAM NOW BEGINNING UNDER DOE FUNDING
- OCEANIC  $pCO_2$ 
  - + WILL BE USED TO ESTABLISH GLOBAL SEAWATER CIRCULATION PATTERNS
  - + BY CROSSING UPWARD AND DOWNWARD ADVECTION ZONES THE SEASONAL AND YEARLY EXCHANGE OF SURFACE AND DEEP WATER WILL BE MONITORED
- OCEANIC AND ATMOSPHERIC  $pCO_2$ 
  - + WILL BE USED TO ESTABLISH THE CONCENTRATION GRADIENT ACROSS THE INTERFACE

INFORMATION YIELDS (CONTINUED)

- + THE CONCENTRATION VARIATIONS ACCORDING TO SEASON AND REGION WILL BE USED TO GENERATE MORE ACCURATE CO<sub>2</sub> EXCHANGE MODELS
- OCEAN TEMPERATURE PROFILES
  - + WILL BE USED TO DETERMINE THE THICKNESS OF THE SURFACE WATER LAYER AND ITS VARIATION ACCORDING TO SEASON AND REGION
  - + THIS WILL PROVIDE ADDITIONAL INFORMATION ON OCEAN CIRCULATION PATTERNS AND WIND EFFECTS ON OCEAN MIXING
- SALINITY
  - + WILL BE USED TO DEFINE OCEAN WATER MASSES
  - + IT IS ALSO USED TO CORRECT THE RAW pCO<sub>2</sub> MEASUREMENTS

INFORMATION YIELDS (CONTINUED)

- PH WILL BE USED TO DETERMINE TOTAL INORGANIC CARBON
- SURFACE WATER C-14 LEVELS
  - + WILL BE USED AS AN ALTERNATIVE METHOD OF CHECKING THE OCEAN-AIR CO<sub>2</sub> EXCHANGE
  - + SEASONAL AND YEARLY TIME TRENDS OF C-14 LEVELS IN THE UPWARD ADVECTION ZONES WILL BE USED TO MEASURE CARBON PENETRATION AND COMPLEMENT THE TRANSIENT TRACER PROGRAM IN THIS AREA

INFORMATION YIELDS (CONTINUED)

DRILLING SHIP PROGRAM WILL BE USED TO:

- OBTAIN A RELATION FOR THE GAS EXCHANGE COEFFICIENT OF A NON-REACTIVE GAS WITH WIND SPEED AND SEA STATE
- DETERMINE NEEDED CORRECTIONS FOR CO<sub>2</sub> REACTIVITY
- THE GAS TRANSFER COEFFICIENT FUNCTION WILL BE USED WITH THE REGIONAL AND SEASONAL pCO<sub>2</sub> MEASUREMENTS AND PREVAILING LOCAL WEATHER CONDITIONS TO CALCULATE MORE ACCURATELY THE NET FLUX OF CARBON INTO THE OCEAN

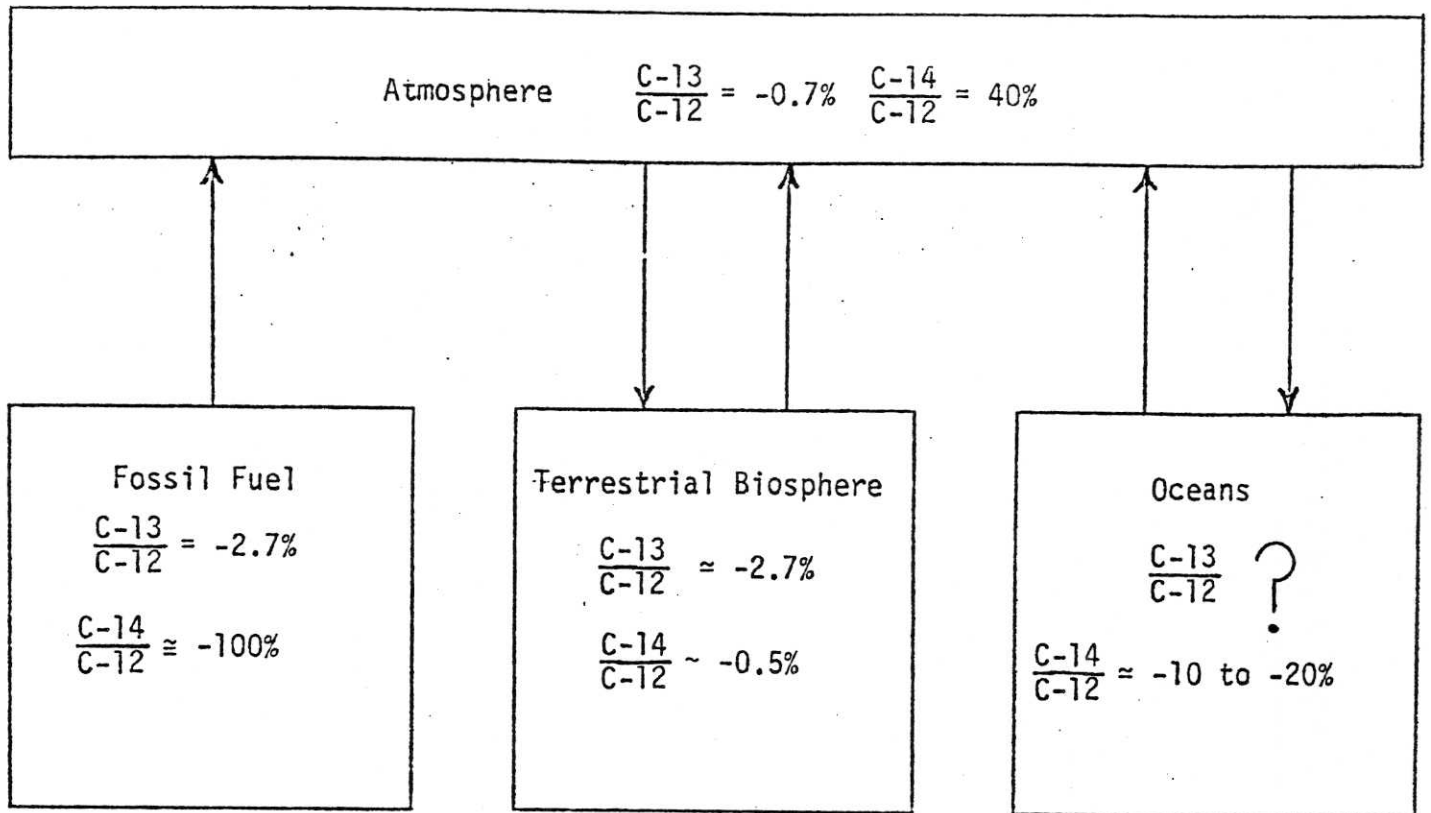
## PROGRAM RESULTS AND BENEFITS

- A RELATIVELY INEXPENSIVE MEANS OF PROVIDING HIGHLY USEFUL INFORMATION ON YEARLY, SEASONAL AND REGIONAL ATMOSPHERIC AND OCEANIC PROCESSES
- IMPROVED AIR-OCEAN CARBON EXCHANGE MODEL
- ADDITIONAL INFORMATION ON BOTH ATMOSPHERIC AND OCEANIC CIRCULATION PATTERNS
- REPORTS FROM EXXON ON THE FINDINGS ISSUED JOINTLY WITH LAMONT-DOHERTY AND OTHER PARTICIPATING INSTITUTIONS
- SAMPLING VESSELS WILL BE AVAILABLE FOR ADDITIONAL SCIENTIFIC MEASUREMENTS TO ENHANCE OUR UNDERSTANDING OF THE CARBON BUDGET OR RELATED AREAS

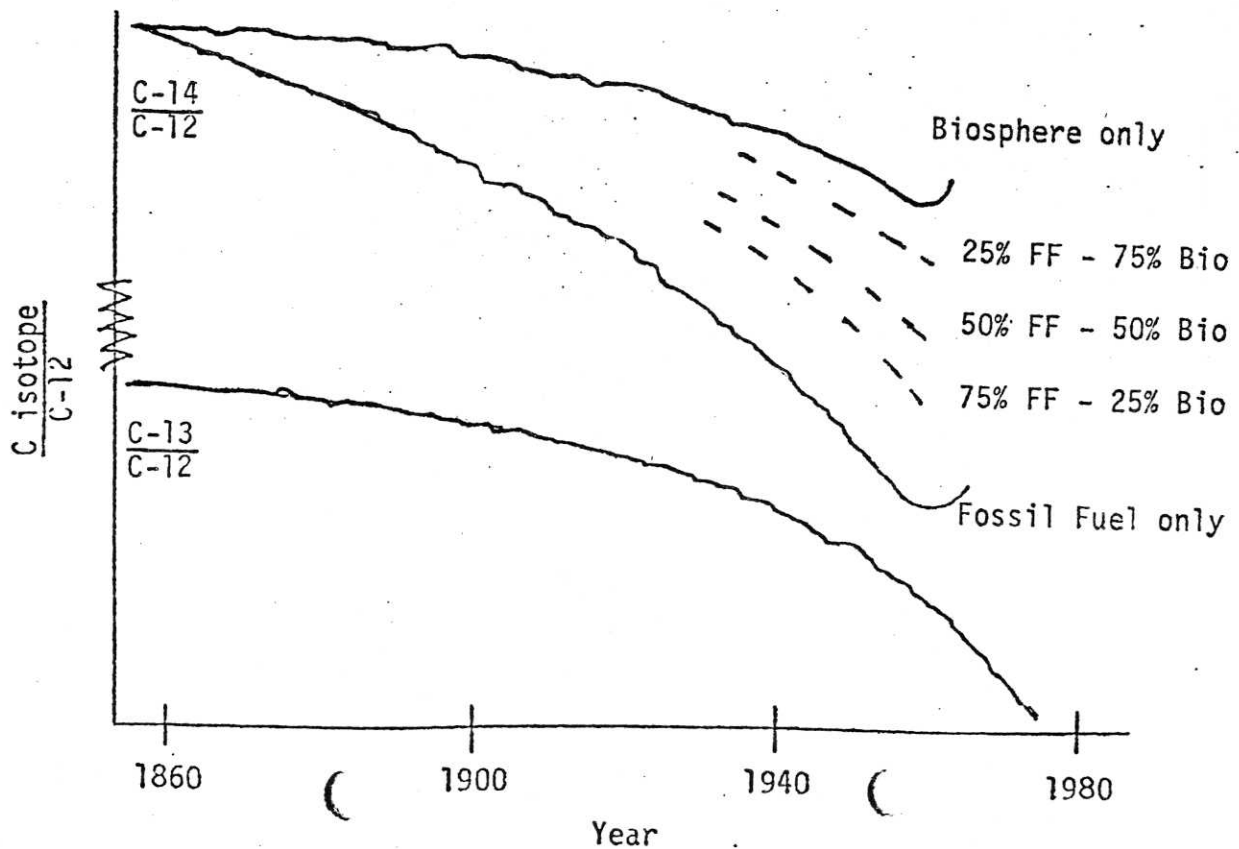
## THEORY OF LAND BIOTA SAMPLING

- INCREASE IN ATMOSPHERIC CO<sub>2</sub> MAY BE DUE TO FOSSIL FUEL COMBUSTION OR FOREST CLEARING
- SOURCE OF CO<sub>2</sub> MAY BE IDENTIFIED BY CARBON ISOTOPES IN THE ATMOSPHERE
  - C-13 IS PRESENT IN FOSSIL FUELS AND PLANTS
  - C-14 IS PRESENT ONLY IN PLANTS
- MEASURING RELATIVE CHANGE OF C-13 AND C-14 IN STORED BIOMASS CAN YIELD INFORMATION ON THE SOURCE OF THE CO<sub>2</sub> THAT WAS PRESENT DURING PLANT GROWTH

# Global Carbon Isotope Distribution



## Atmospheric Carbon Isotope Ratios





## PROPOSED PROGRAM - LAND BIOTA SAMPLING

- TREE RINGS HAVE PROVIDED INITIAL C-13/C-12 AND C-14/C-12 DATA
  - SAMPLE NOT ISOLATED IN YEARLY INCREMENTS
  - NO TEMPERATURE AND GROWTH HISTORY
  
- USE A LAND BIOTA SOURCE THAT HAS:
  - WEATHER AND GROWTH HISTORY
  - NOT UNDERGONE ISOTOPE EXCHANGE AFTER GROWING SEASON
  - AVAILABLE SAMPLES DATING BACK TO 1830
  - AFTER SOME INITIAL INVESTIGATION, WINE SEEMS TO BE CAPABLE OF PROVIDING THE BEST SAMPLES

## PROPOSED PROGRAM SCHEDULE

PHASE I (ONE-YEAR PROGRAM - K\$ 300 EXXON AND  
K\$ 200 DOE)

- ESTABLISH COOPERATIVE PROGRAM WITH  
LAMONT-DOHERTY
- INITIATE RESEARCH WITH A SINGLE TANKER  
AS A PILOT PROGRAM
- IMPLEMENT DRILLING SHIP SAMPLING PROGRAM
- CARRY OUT WINE MEASUREMENT PROGRAM FOR  
ONE LOCATION

PROPOSED PROGRAM SCHEDULE (CONTINUED)

PHASE II (FIVE-YEAR PROGRAM)

- IMPLEMENT FULL-SCALE TANKER PROGRAM USING UP TO FIVE DIFFERENT ROUTES (~ M\$/A 1.4 - GOVERNMENT)
- CONTINUE DRILLING SHIP PROGRAM AT SUITABLE LOCATIONS (K\$/A 50 - EXXON)
- CONTINUE LAND BIOTA MEASUREMENT WITH GEOGRAPHICALLY DIFFERENT SOURCES (K\$/A 80 - EXXON)

ESTIMATED COST OF FULL PROGRAM

(1979 K\$)

	<u>PHASE</u>	<u>1979</u>	<u>1980</u>	<u>1981</u>	<u>1982</u>	<u>1983</u>	<u>1984</u>
DRILLING SHIPS	I	50	--	--	--	--	--
LAND BIOTA MEASURE- MENTS }	II	--	50	50	50	50	50
	I	75	--	--	--	--	--
TANKER (PILOT PROGRAM)	II	--	80	80	--	--	--
	I	375	--	--	--	--	--
TANKERS (4 ADDI- TIONAL)	II	--	1040	1600	1400	1400	1400
TOTAL		<u>500</u>	<u>1170</u>	<u>1730</u>	<u>1450</u>	<u>1450</u>	<u>1450</u>
CUMULATIVE		500	1670	3400	4850	6300	7750
PROFESSIONALS		1.3	3.6	5.6	5.3	5.3	5.3
NON-PROFESSIONALS		2.5	7.1	11.8	11.8	11.8	11.8

GREENHOUSE EFFECT

	<u>Funding</u>		<u>Staffing</u>		'78	'79	'80	'81	'82	'83	'84
	\$	Source	GRL	Other Units							
1. Develop background	20 k	ER&E	1	P	—						
2. Develop research program	30 k	ER&E	1	P	—						
3. Obtain ER&E management approval	-		1	P	x						
4. Advise Exxon Corp. & affiliates	5 k	ER&E	1	P	—						
5. Advise DOE of program	-		1	P		x					
6. Plan program with affiliates (Exxon International, EUSA, etc.)	5 k	ER&E	1	P		—					
7. Arrange university partnership	50 k	ER&E	1	P		—					
8. Designate program manager	-	-	-	-		x					
9. Order and assemble instrumentation	125 k	ER&E	1	P		—					
0. Begin Phase I			1.3	P							
- Tanker No. 1	275 k	ER&E				—					
- Drilling Ship	25 k	ER&E				—					
- Land biota measurements	75 k	ER&E				—					
1. Prepare and submit proposals to DOE	30 k	ER&E	1	P		—					
2. Publish initial results	30 k	ER&E					x				
3. Order additional equipment	425 k	DOE					—				
4. Begin Phase II			6	P							
- 5 tankers	6.8 M	DOE					—				
- 9 drilling ships	225 k	ER&E					—				
- 2 different land biota sources	160 k	ER&E					—				
5. Awareness and corporate dissemination of information on overall problem	70 k	ER&E	0.1	P							