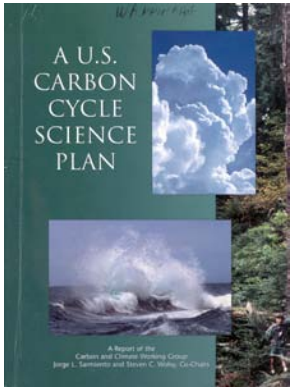
The AOML Ocean Carbon Program

Overall justification: Quantify the response of the ocean-biosphere-atmosphere system to [increasing] release of anthropogenic carbon

The Global Earth Observation System of Systems

"The Integrated Global Carbon Observation project is developing a global carbon-observing system. "

Science and Implementation Plans:



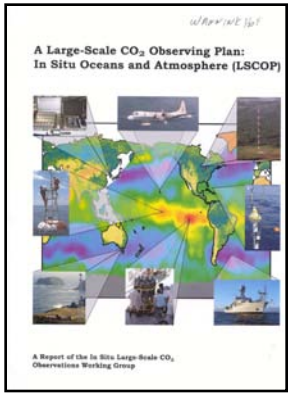
1999

Three key questions regarding ocean carbon

- Where is CO_2 invading into ocean?
- Where is it stored in the ocean?
- Will ocean uptake and storage change in the future?

And an additional one:

- What are the environmental and ecological impacts of the oceanic CO_2 sequestration?

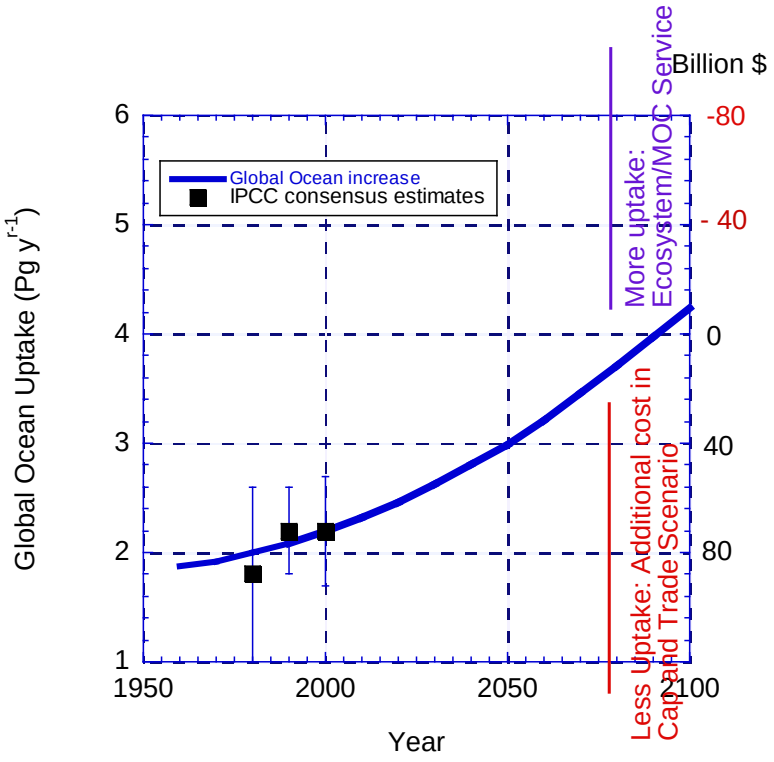


2002

QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.

The Default Assumption (IPCC models)

- The sequestration of CO_2 by the ocean is proportional to the increase of atmospheric CO_2
- The uptake of anthropogenic CO_2 is controlled by the large-scale overturning (MOC), a buffer factor and a biological "pump" *that is in steady state*



QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.

The $ benefit of carbon offsets

Ecobusinesslinks.com Carbon Offset Survey

(Prices are for individuals, businesses may be able to get volume discounts)

Carbon Offset Provider	Price (US$/Metric ton CO2)	Non-profit	Projects Types	Project Choice	Offset Types	Product Certification/ Verification*
AtmosClear Climate Club USA	$3.96[a] - $25.00	No	Methane	No	Car, Home	Environmental Resources Trust
Carbonfund.org USA	$4.30[b] - 5.50	Yes	Renewables, Efficiency, Reforestation	Yes	Home, Car, Air, Events, Business	Environmental Resources Trust, Climate Community and Biodiversity Standards, Chicago Climate Exchange, UNFCCC JI
e-BlueHorizons USA	$5.00	No	Renewables, Reforestation	No	Home, Car, Air	Chicago Climate Exchange, Environmental Resources Trust
Eco2Pass USA	$5.62-6.25	No	Projects from Chicago Climate Exchange	No	Car, Home, Personal, Family	Chicago Climate Exchange
DriveNeutral.org USA	$6.93 & up	Yes	Efficiency	No	Car	Chicago Climate Exchange
DrivingGreen Ireland	$8.00	No	Renewables	No	Car, Air, Events	SES
Terrapass USA	$10.91	No	Renewables, Efficiency	No	Car, Air, Events, Business	Chicago Climate Exchange, Center for Resource Solutions
The CarbonNeutral Company UK	$12.64 (USA) £7.50 (UK VAT incl.)	No	Renewables, Efficiency, Reforestation, Methane	Yes	Car, Air, Events, Business, Deliveries, + many others	CDM Gold Standard, Edinburgh Centre for Carbon Management, Independent Advisory Committee, UNFCCC JI, PricewaterhouseCoopers
Native Energy USA	$13.20	No	Renewables, Methane	Yes	Home, Car, Air, Events, Business	Their "Vintage Offsets" are CDM verified products.
Standard Carbon USA	$15.00	No	Methane, Efficiency, Renewables, Carbon Sequestration	No	Car, Air, Sea, Events, Political Campaigns	Chicago Climate Exchange
Cleaner Climate UK & Australia	$15.00-18.00	No	Renewables, Efficiency	No	Air, Car, Home, Business	CDM Gold Standard
Sustainable travel International US, Switzerland	$5.25	Yes	Renewables	No	Air, Car, Home, Hotel	See Myclimate

1 ton CO_2 ≈ $11

www.ecobusinesslinks.com

Where is CO_2 Stored in the Ocean ?

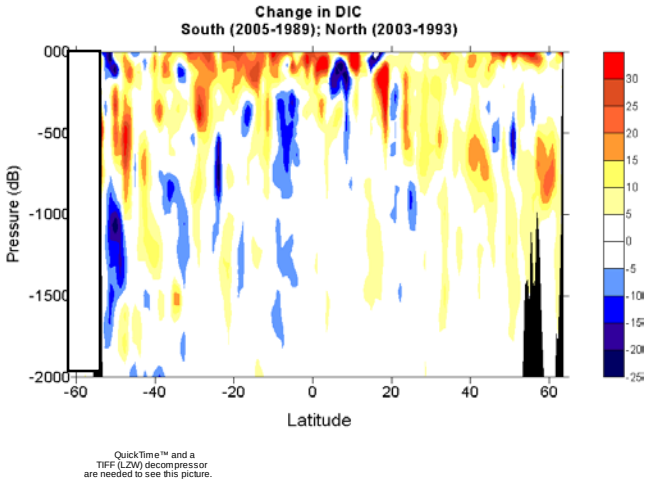
CLIVAR/CO_2 Repeat Hydrography Program: Determine the decadal changes in anthropogenic carbon in the ocean

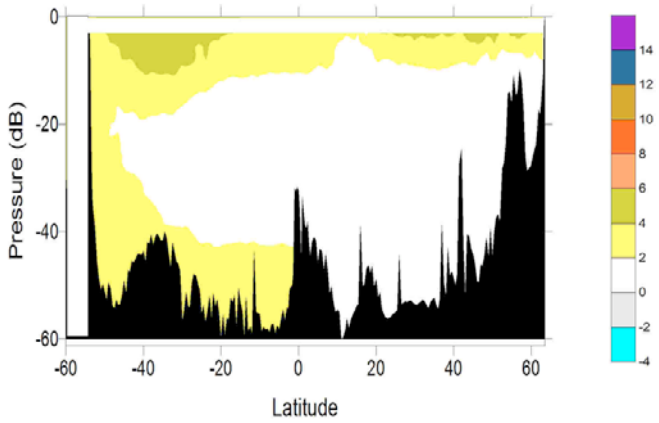
Estimates of ocean inventory changes in anthropogenic carbon (mol C $m^{-2}yr^{-1}$) over the last decade. (0.5 mol C $m^{-2}yr^{-1} \approx 2$ Pg C)

	Atlantic (25°W)	Pacific (152°W)	Indian (80°E)
Northern Hemisphere	0.63	0.25	0.3
Southern Hemisphere	0.75	0.41	0.5

*Indian Ocean changes are preliminary and based on work in the 1990s.

1. Highly accurate measurements to detect small changes (0.5 % $decade^{-1}$)
2. Large differences between regions
3. The changes in total dissolved inorganic carbon (DIC) are patchy- why?

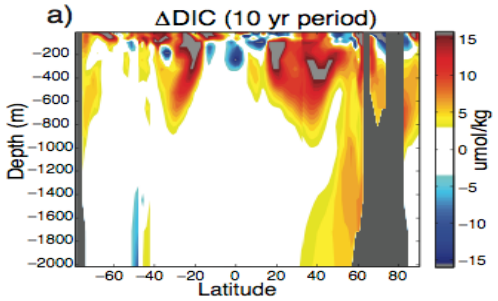


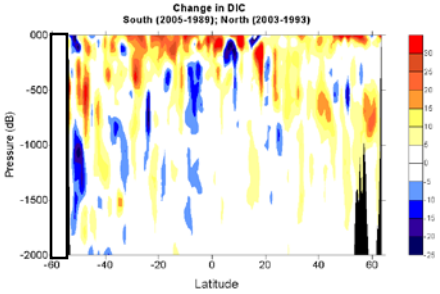


Wanninkhof et al. in prep. 2008. Decadal Changes in Inorganic Carbon along Meridional Section A16 in the Atlantic Ocean from 1989-2005: Separating Natural Variability from Anthropogenic Input

Verification and Attribution of Patchy Changes in DIC with Ocean Biogeochemistry Models

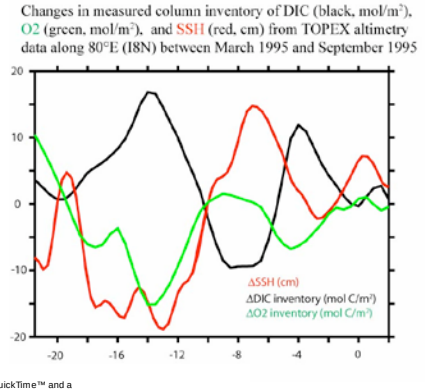
1. Incorporating a multi-species biogeochemistry/functional group model into a high resolution GCM with synoptic forcing, changes of similar magnitude are observed (NCAR community model): we can model the anomalies





The Impact of Ocean Carbon System Variability on the Detection of Temporal Increases in Anthropogenic CO_2
Levine et al., (WHOI), 2008 in press

2. Using remotely sensed SSH a clear pattern between DIC and SSHA are observed that are validated with the OCMIP models: we have means of detecting the anomalies



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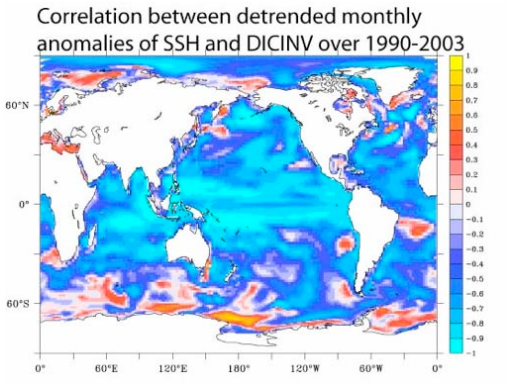
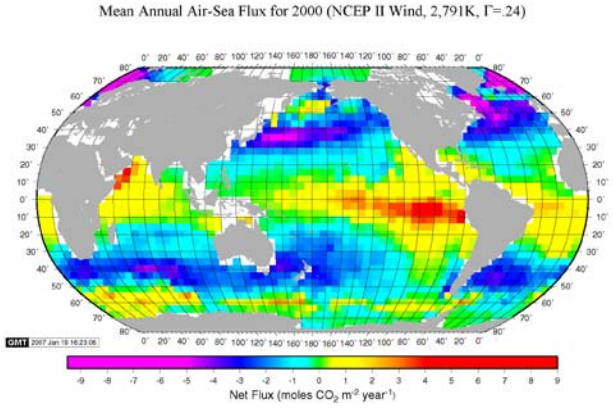
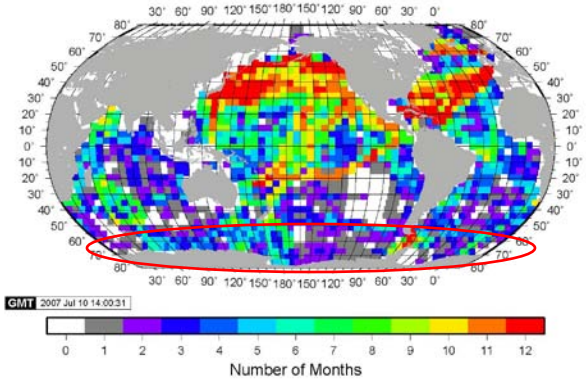


Altimetry helps to explain patchy changes in hydrographic carbon measurements
Rodgers et al. 2008 (Princeton/GFDL) submitted

Where is CO_2 Invading into the Ocean?

Global climatology

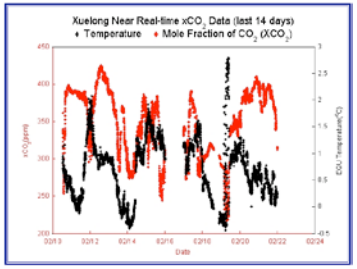


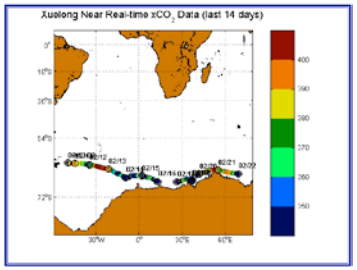


Takahashi et al. 2008
LDEO /Columbia U.
26 co-authors
Climatological Mean and Decadal Change in Surface Ocean pCO_2, and Net Sea-air CO_2 Flux over the Global Oceans
accepted

High latitude work (IPY):

Xue Long (funded in part by NOAA/ADR)
Gould
Polar Stern
Palmer (NOAA)
Nuka Artica
Healy (NOAA)





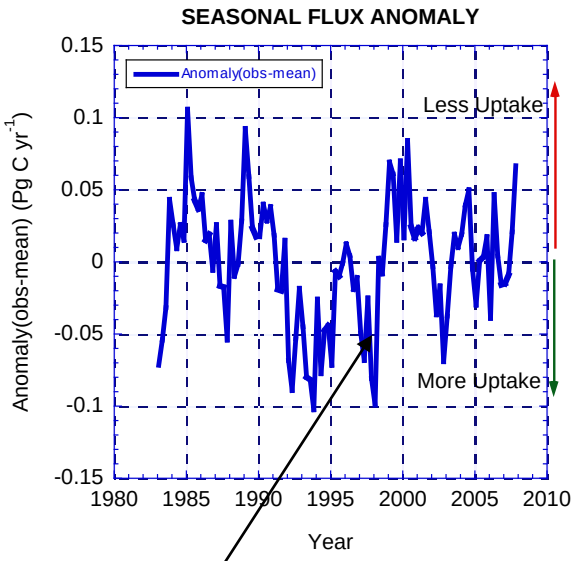
Near real-time display from Xue Long

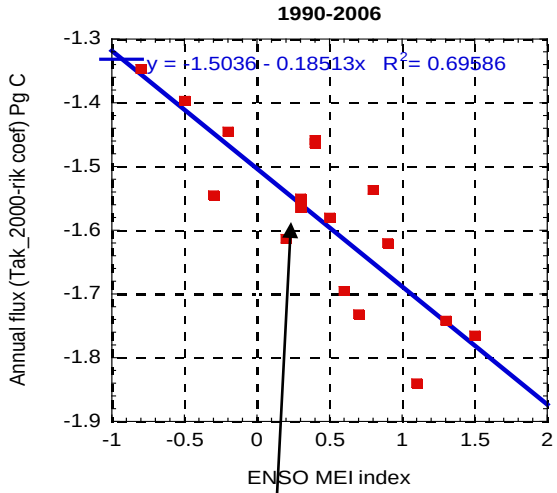
QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.

http://www.aoml.noaa.gov/ocd/gcc/

Is the Ocean Uptake and Storage Changing?

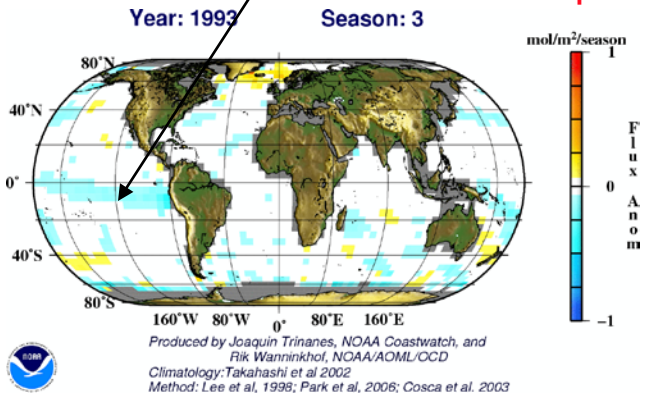
Using empirical relationships with SST- determine inter-annual variability





Product: Seasonal air-sea CO_2 flux maps

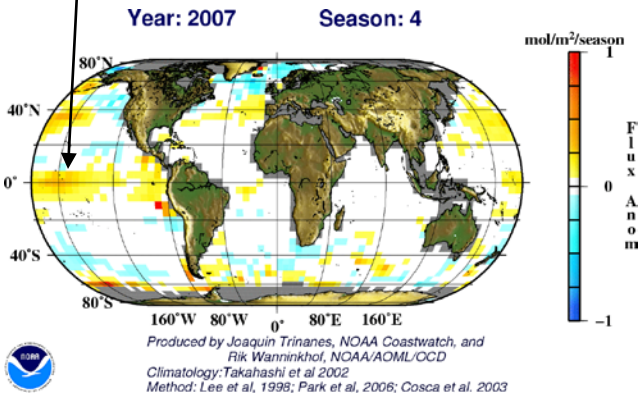
El Niño: More uptake



QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Remotely sensed products:
Reynold's SST
NCEP-2 winds

La Nina: Less uptake



Courtesy J.Trinanes

What are the environmental and ecological impacts of the oceanic CO_2 sequestration?

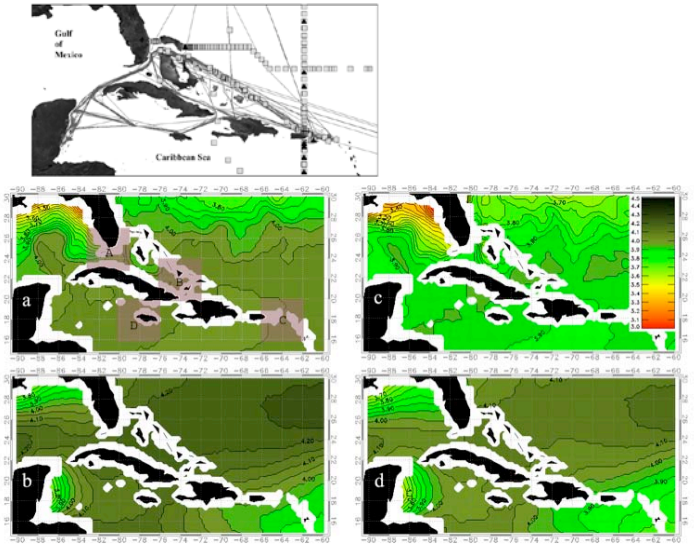
Ocean acidification:

The major concern is decreased production of calcium carbonate (tests, shells, corals):

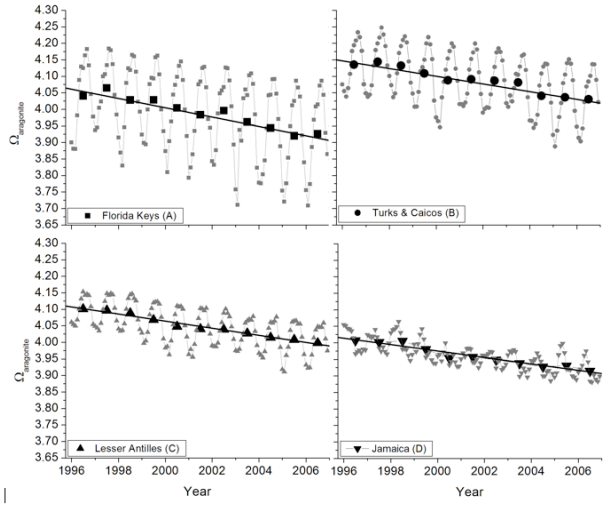
$$CaCO_3 + CO_2 + H_2O = 2\ HCO_3^- + Ca^{2+}$$ Note- Where is the acid?

It is a saturation state issue: $\Omega = [Ca^{2+}]\,[CO_3^{2-}] / K_{sp}$

Changing saturation states in the Caribbean Sea



QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.



Gledhill et al. 2008 NESDIS, in review
Ocean acidification of the greater Caribbean Region 1996 – 2006

Conclusions

- The decadal CLIVAR CO_2 survey ("ocean observations yesterday-results today") are providing a snapshot of changing ocean CO_2 inventories, and biogeochemical changes that were unexpected. The observations have provided impetus to improve models.

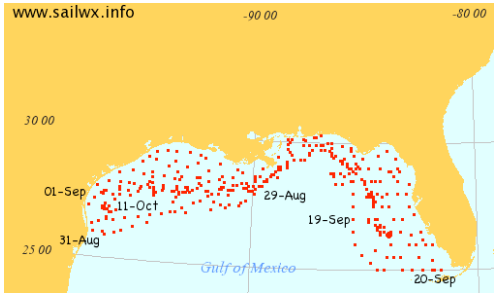
- The surface water observations along with empirical methods and remote sensing provide seasonal estimates of CO_2 flux that serve as a first-order estimate of changing fluxes.

- Increasing observations at high latitude will provide validation climate change induced decreases in oceanic uptake (Southern Ocean-winds; Arctic Ocean-ice melt).

- The surface water CO_2 observing system should be used as the backbone for ocean acidification monitoring with emphasis and coastal observations.

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Installation of pCO_2 system on NOAA fisheries ship *Gunther*, March 2008
In support of NGI CI



Posters:

1,2: Methods of determining decadal changes in anthropogenic CO_2 in the ocean (Peng et al.; Wanninkhof et al.)

3: Recommendations on UW pCO2 data reduction (Pierrot et al.)

Questions?

Supplementary material: AOML Ocean Carbon group Facts and Figures

AOML CO_2 group

PI's

Dr. T-H. Peng (lead)
Dr. D. Pierrot
Dr. R. Wanninkhof

Associates

R. Castle
B. Huss
E. Peltola
K. Sullivan
Dr. H. Lueger (part-time)
J. Trinanes (part-time)

Participating PI's AOML/CIMAS

Dr. M. Baringer (PhOD) - CLIVAR/CO2
Dr. G. Goni (PhOD)- VOS-pCO2
Dr. C. Langdon (RSMAS/CIMAS)- CLIVAR/CO2
Dr. J.-Z. Zhang (OCD)- CLIVAR/CO2

Supplementary material: AOML Ocean Carbon group Facts and Figures

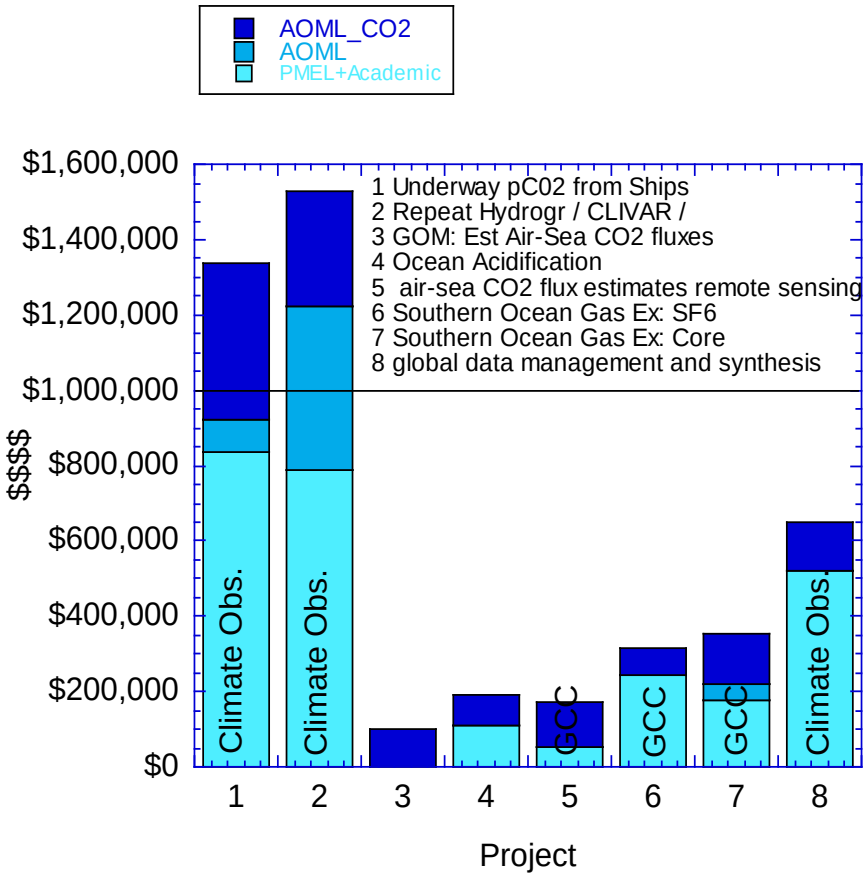
Collaborators

Investigator	first	institution	Capacity
Asher	Bill	APL/U.Wash	academic
Jessup	Andy	APL/U.Wash	academic
McNeill	Craig	APL/U.Wash	academic
Bates	Nick	BIOS Bermuda	academic
Speer	Kevin	Florida State	academic
Broecker	Wallace	LDEO/Columbia	academic
Ho	David	LDEO/Columbia	academic
McGillis	Wade	LDEO/Columbia	academic
Schlosser	Peter	LDEO/Columbia	academic
Takahashi	taro	LDEO/Columbia	academic
Zappa	Chris	LDEO/Columbia	academic
Hales	Burke	OSU	academic
Strutton	Pete	OSU	academic
Key	Robert	Princeton U.	academic
Rodgers	Keith	Princeton U.	academic
Sarmiento	Jorge	Princeton U.	academic
Donelan	Mark	RSMAS/U. Miami	academic
Hansell	Denis	RSMAS/U. Miami	academic
Langdon	Chris	RSMAS/U. Miami	academic
Millero	Frank	RSMAS/U. Miami	academic
Minnet	Peter	RSMAS/U. Miami	academic
Ortner	Peter	RSMAS/U. Miami	academic
Zika	Rod	RSMAS/U. Miami	academic
Dickson	Andrew	Scripps/UCSD	academic
Swift	Jim	Scripps/UCSD	academic
Talley	Lynne	Scripps/UCSD	academic
Weiss	Ray	Scripps/UCSD	academic
Morse	John	Texas A&M	academic
Yvon-Lewis	Shari	Texas A&M	academic
Huebert	Barry	U. Hawaii	academic
Li	Telu	U. Hawaii	academic
Lohrenz	Stephen	U. South Miss	academic
Cai	Wei-Jun	U.Georgia	academic
Miller	Bill	U.Georgia	academic
Wong	Yonchen	U.Georgia	academic
Yager	Patricia	U.Georgia	academic
Rao	Govind	U.Maryland/BC	academic
Kubat	Miroslav	U.Miami	academic
Salisbury	Joe	U.NewHampshire	academic
VanderMark	Doug	U.NewHampshire	academic
Byrne	Robert	USF	academic
Liu	Sherwood	USF	academic
Wang	Aleck	USF	academic
Buesseler	Ken	WHOI	academic
Doney	Scott	WHOI	academic
Glover	David	WHOI	academic
Lewis	Ernie	Brookhaven	federal
Kozyr	Alex	ORNL/DOE	federal

Investigator	first	institution	Capacity
Hoppema	Mario	Bremerhafen	International
Gruber	Nicolas	ETH, Zurich	International
Garbe	Christoph	Heidelberg	International
Alverez	Marta	Majorca	International
Nightingale	Philip	Plymouth	International
Lee	Kitack	Pohang U.	International
Johannessen	Truls	U. Bergen	International
Olsen	Are	U. Bergen	International
Pfeill	Benjamin	U. Bergen	International
Bakker	Dorothee	U. East Anglia	International
Kaiser	Jan	U. East Anglia	International
LeQuere	Corinne	U. East Anglia	International
Schuster	Ute	U. East Anglia	International
Watson	Andy	U. East Anglia	International
Ward	Brian	U. Galway	International
Koertzinger	Arne	U. Kiel	International
Steinhoff	Tobias	U. Kiel	International
Tanhua	Toste	U. Kiel	International
Wallace	Doug	U. Kiel	International
Boutin	Jacqueline	U. Paris	International
Merlivat	Liliane	U. Paris	International
Metzl	Nicolas	U. Paris	International
Hamme	Roberta	U. victoria	International
Rios	Aida	Vigo	International
Chen	Li-qi	Xiamen	International
Gledhill	Dwight	NESDIS	NOAA
Hughes	Ken	NESDIS	NOAA
Stathoplos	Linda	NESDIS	NOAA
Fairall	Chris	ESRL	NOAA/OAR
Sweeney	Colm	ESRL	NOAA/OAR
Gnanadesikan	Anand	GFDL	NOAA/OAR
Bullister	John	PMEL	NOAA/OAR
Feely	Richard	PMEL	NOAA/OAR
Johnson	Craig	PMEL	NOAA/OAR
Sabine	Chris	PMEL	NOAA/OAR
Heinze	Chirstoph	CARBOOCEAN	programs
Hood	Maria	IOCCP	programs
González	Melchor	Las Palmas	programs
Hare	Jeffrey	SOLAS	programs
Turk	Daniela	SOLAS	programs
Students			
Levine	Naomi	WHOI	academic
Chanson	Marava	RSMAS/U. Miami	academic
Park	Guen-Ha	Pohang U.	International
Jiang	Li-Qing	U.Georgia	academic

Funding Profile AOML CO_2 group- FY-2008 "Extramural"

(note, expected- no funds for FY-08 have been allocated to date)



Projects:
1,2,8- Climate Obs.
5,6,7- Global Carbon Cycle Program
3- NGI cooperative institute
4- NASA biogeochemistry

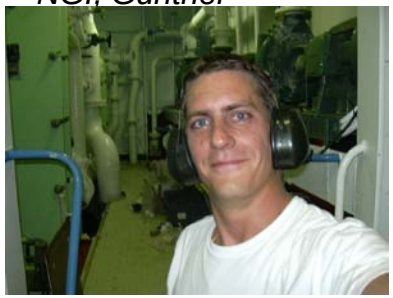
Legend- *dark blue*: funds for AOML CO_2 group; *light blue*: other AOML investigators; *light green*: other partners (academic & PMEL)

Most efforts are collaborative

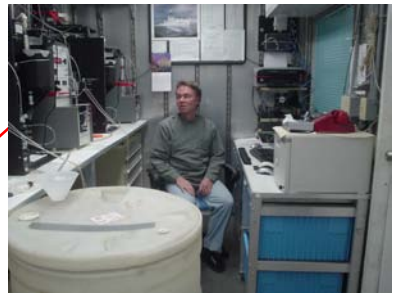
CO_2 group members- Focus on observations

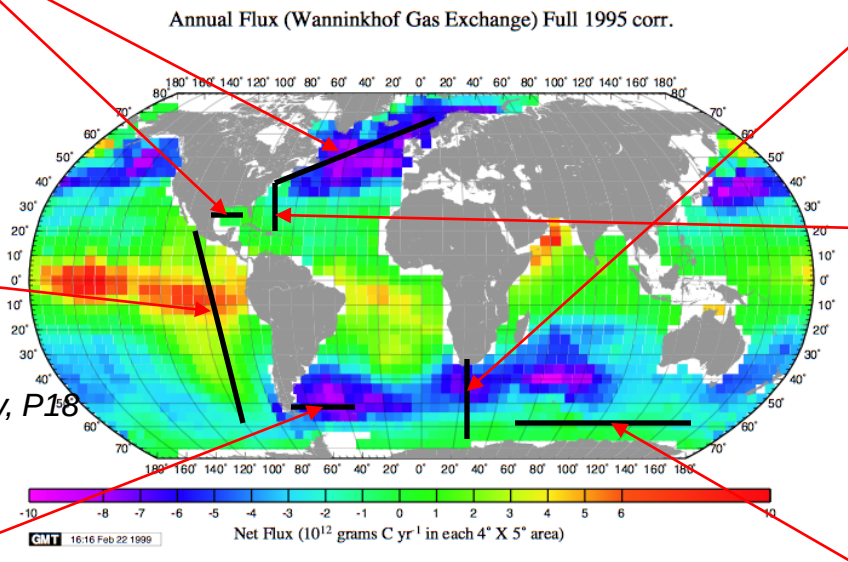
February-April, 2008 is a particularly busy field season:

Denis,
Icealot, KNORR
NGI, Gunther



Esa, Juliana, (Fl State):
CLIVAR/CO2 Repeat Hydrography, I6





Liz (RSMAS)
Explorer of the Seas

Bob, Chris K.(U.Miami),

Simone (PMEL)

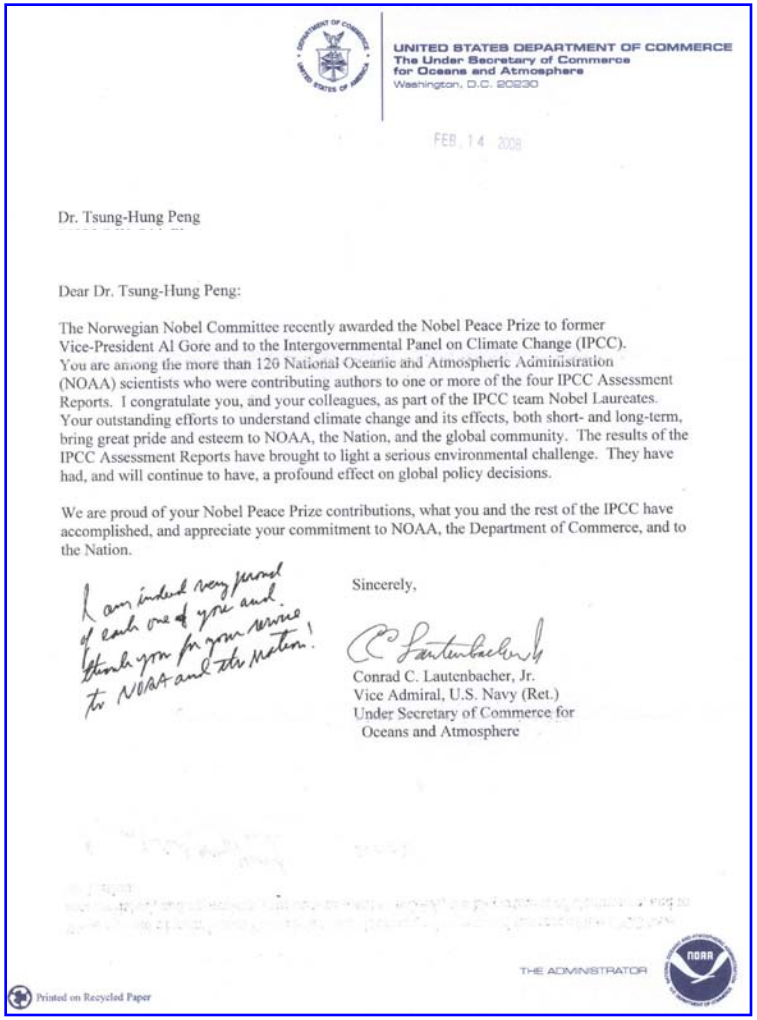
CLIVAR/CO2 Repeat Hydrogaphy, P18

Kevin, Bob:
Southern Ocean Gas Ex Experiment

Yuanhui (3rd Institute)
Xue Long (Snow Dragon)

QuickTime™ and a
Photo - JPEG decompressor
are needed to see this picture.

Recognition for input to fourth IPCC assessment



UNITED STATES DEPARTMENT OF COMMERCE
The Under Secretary of Commerce
for Oceans and Atmosphere
Washington, D.C. 20230

FEB 14 2008

Dr. Tsung-Hung Peng

Dear Dr. Tsung-Hung Peng:

The Norwegian Nobel Committee recently awarded the Nobel Peace Prize to former Vice-President Al Gore and to the Intergovernmental Panel on Climate Change (IPCC). You are among the more than 120 National Oceanic and Atmospheric Administration (NOAA) scientists who were contributing authors to one or more of the four IPCC Assessment Reports. I congratulate you, and your colleagues, as part of the IPCC team Nobel Laureates. Your outstanding efforts to understand climate change and its effects, both short- and long-term, bring great pride and esteem to NOAA, the Nation, and the global community. The results of the IPCC Assessment Reports have brought to light a serious environmental challenge. They have had, and will continue to have, a profound effect on global policy decisions.

We are proud of your Nobel Peace Prize contributions, what you and the rest of the IPCC have accomplished, and appreciate your commitment to NOAA, the Department of Commerce, and to the Nation.

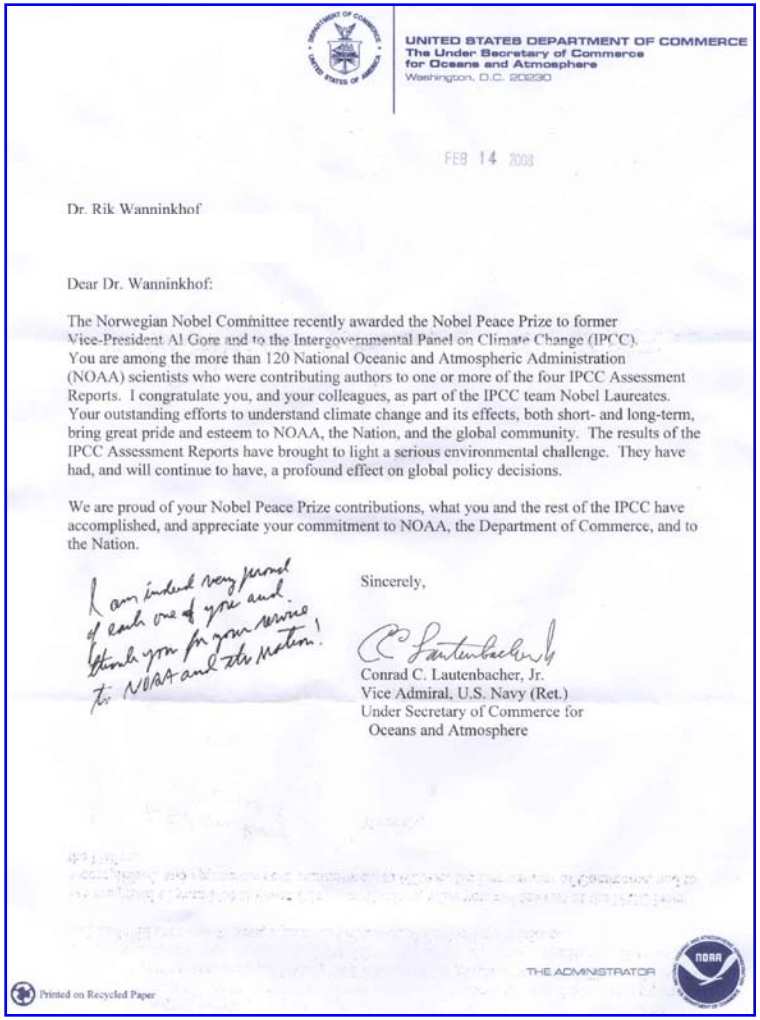
I am indeed very proud of each one of you and thank you for your service to NOAA and the nation!

Sincerely,

Conrad C. Lautenbacher, Jr.
Vice Admiral, U.S. Navy (Ret.)
Under Secretary of Commerce for
Oceans and Atmosphere

THE ADMINISTRATOR

Printed on Recycled Paper



UNITED STATES DEPARTMENT OF COMMERCE
The Under Secretary of Commerce
for Oceans and Atmosphere
Washington, D.C. 20230

FEB 14 2008

Dr. Rik Wanninkhof

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I am indeed very proud of each one of you and thank you for your service to NOAA and the nation!

Sincerely,

Conrad C. Lautenbacher, Jr.
Vice Admiral, U.S. Navy (Ret.)
Under Secretary of Commerce for
Oceans and Atmosphere

THE ADMINISTRATOR

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