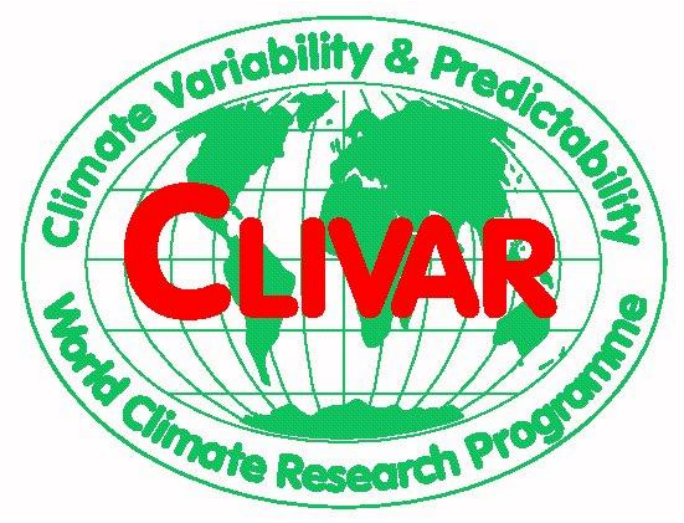
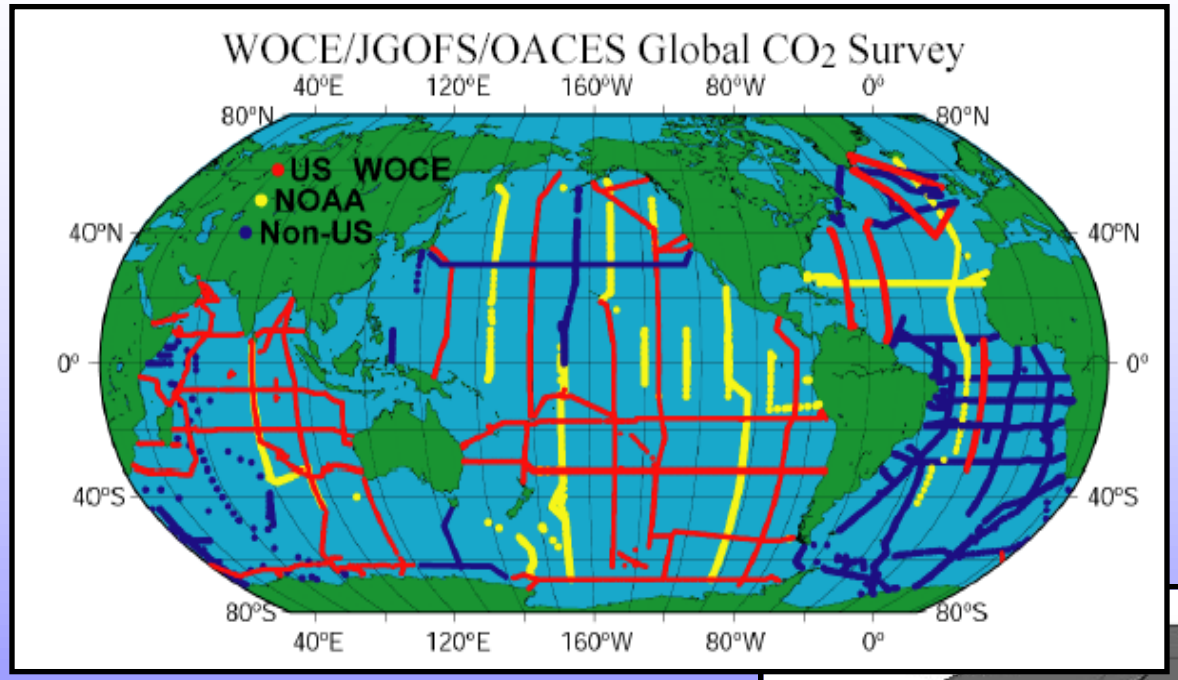


CLIVAR Repeat Hydrography Program: A global Ocean Carbon Observing Network

Richard A. Feely

NOAA/PMEL

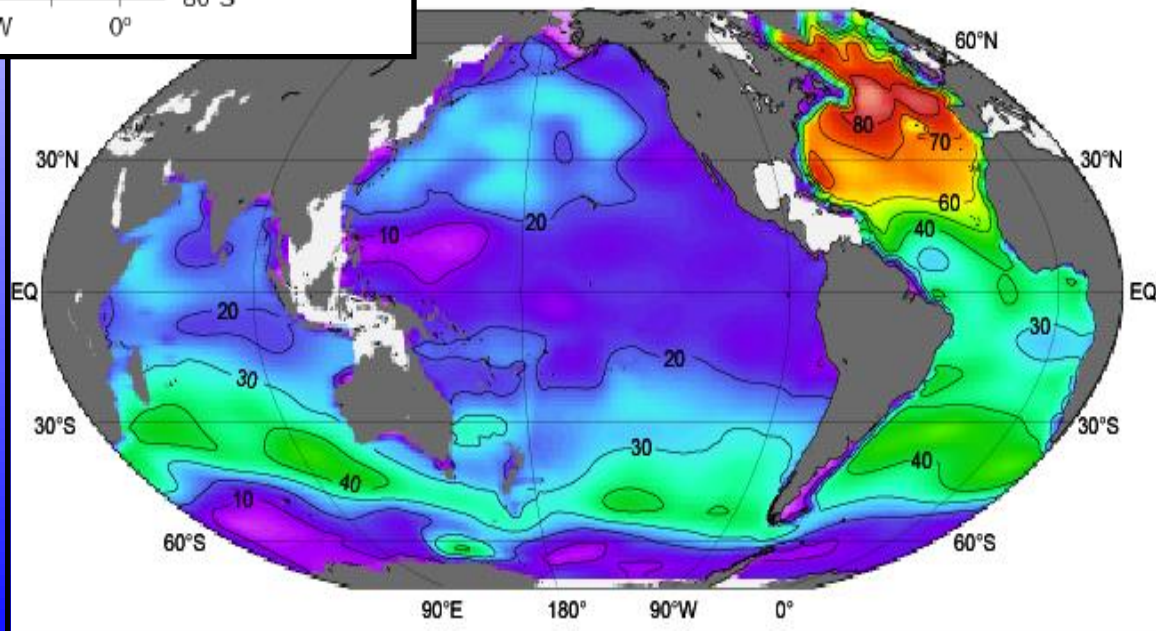
Inventories



A first look at the distribution of anthropogenic CO_2 in the ocean was based on the WOCE/JGOFS/OACES global survey of carbon conducted in the 1990s.

Global Inventory:
118±19 PgC thru 1994

North Atlantic has the largest column inventories of anthropogenic CO_2 (mol m^{-2}).



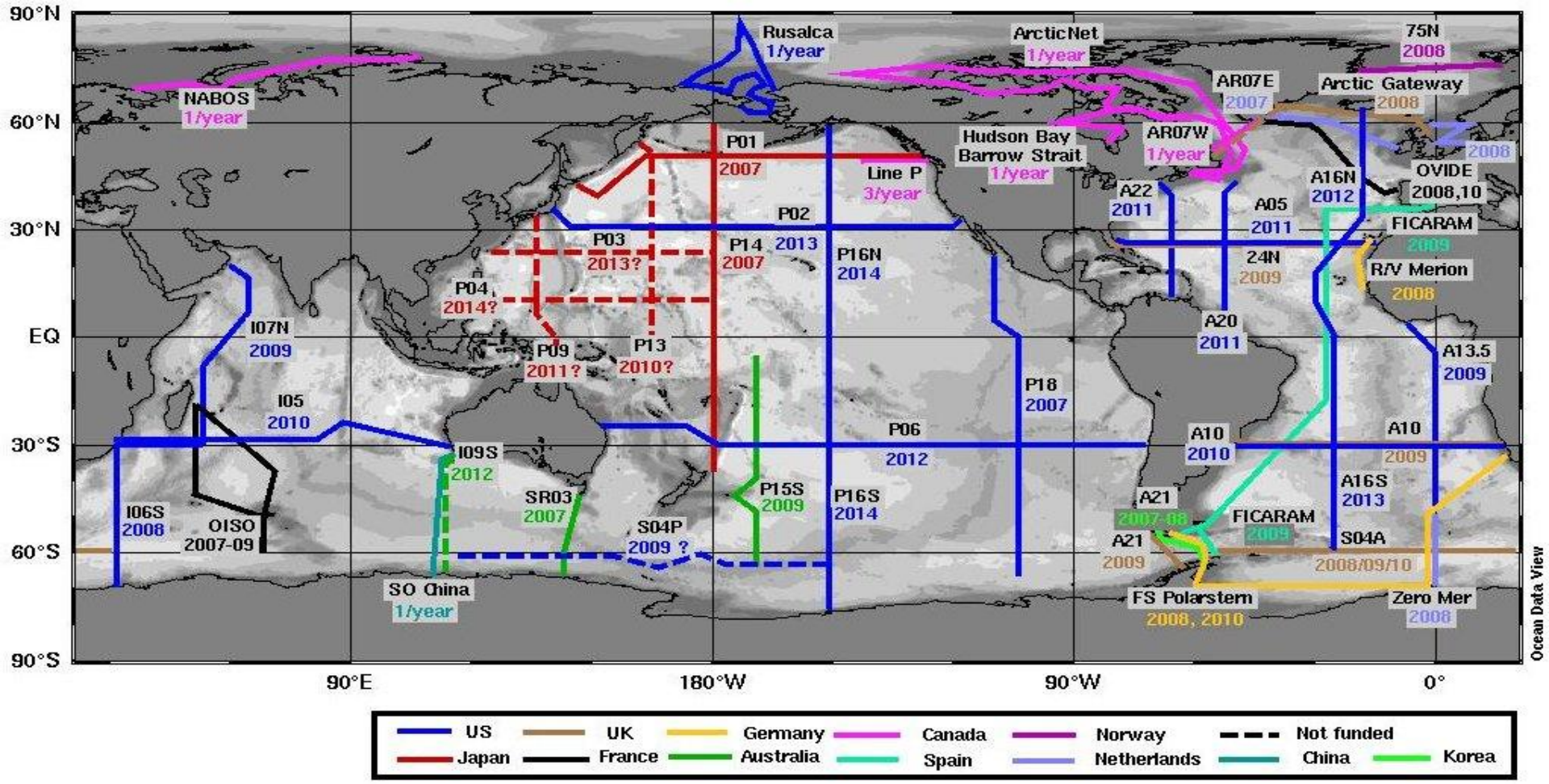
Objectives of the CLIVAR/CO_2 Repeat Hydrography Program

- Data for Model Calibration and Validation
- Carbon system studies
- Heat and freshwater storage and flux studies
- Deep and shallow water mass and ventilation studies
- Calibration of autonomous sensors

CLIVAR/CO_2 Repeat Hydrography

Goal: To quantify decadal changes in the inventory and transport of heat, fresh water, carbon dioxide (CO_2), chlorofluorocarbon tracers and related parameters in the oceans.

Approach: The sequence and timing of the CLIVAR/CO_2 Repeat Hydrography cruises have been selected so that there is roughly a decade between them and the WOCE/JGOFS global survey.



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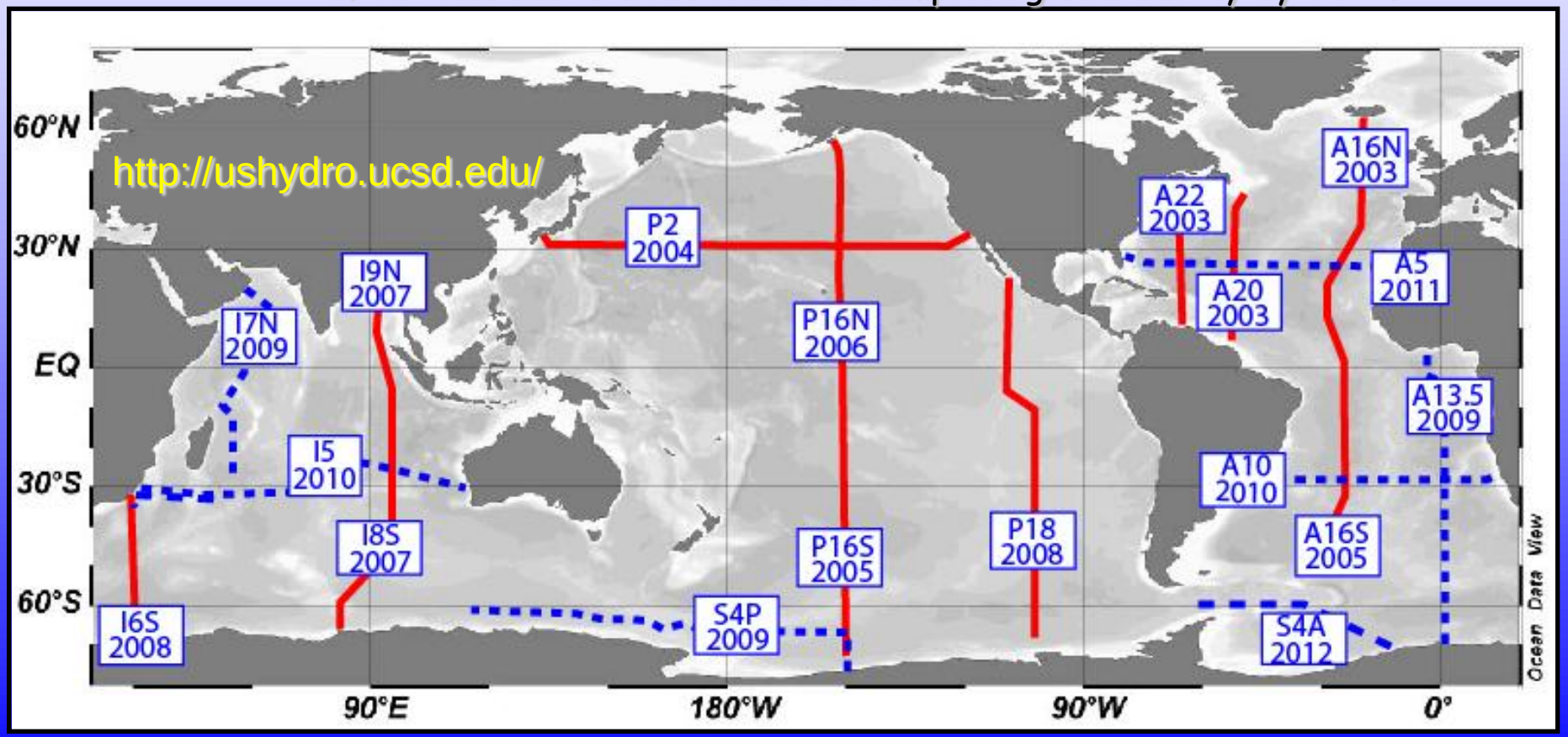
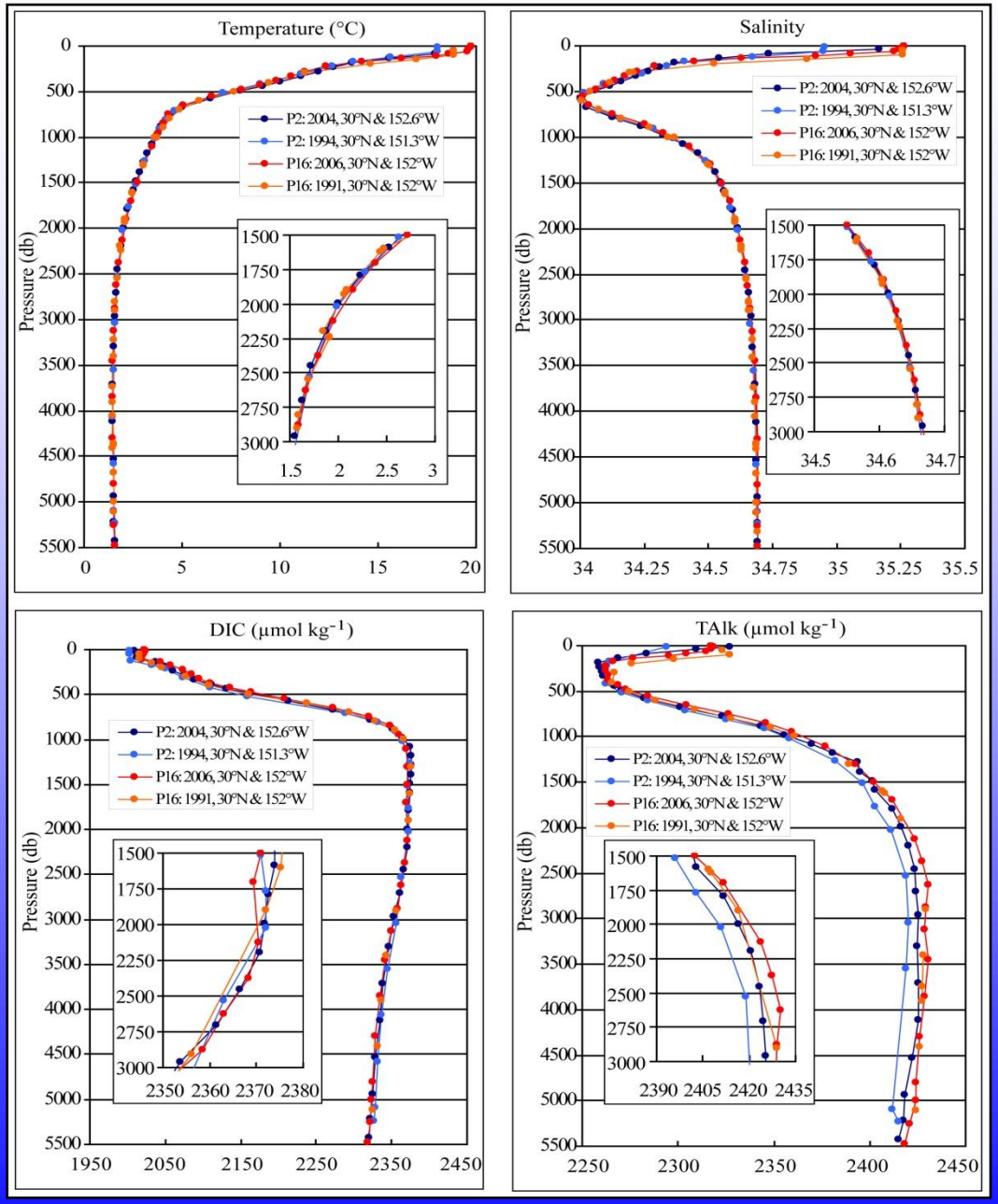
Approach: The sequence and timing of the U.S. CLIVAR/CO_2 Repeat Hydrography cruises have been selected so that there is roughly a decade between them and the WOCE/JGOFS global survey.

Achievements: The U.S. CLIVAR/CO_2 Repeat Hydrography Program has completed 12 of 18 lines and is on schedule to complete global survey by 2012.

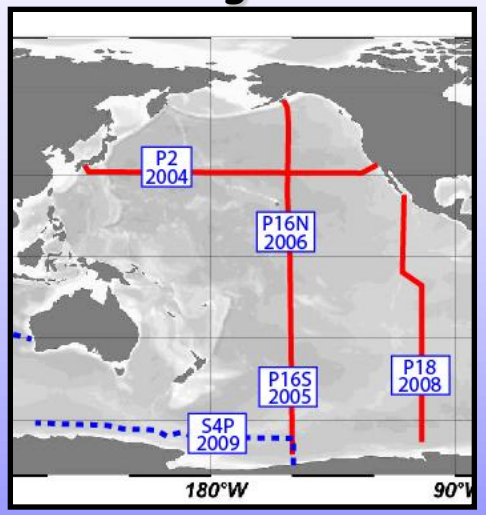


Comparison of profiles from stations near the intersection of P2 and P16N.



Repeat Hydrography Data Are Very High Quality

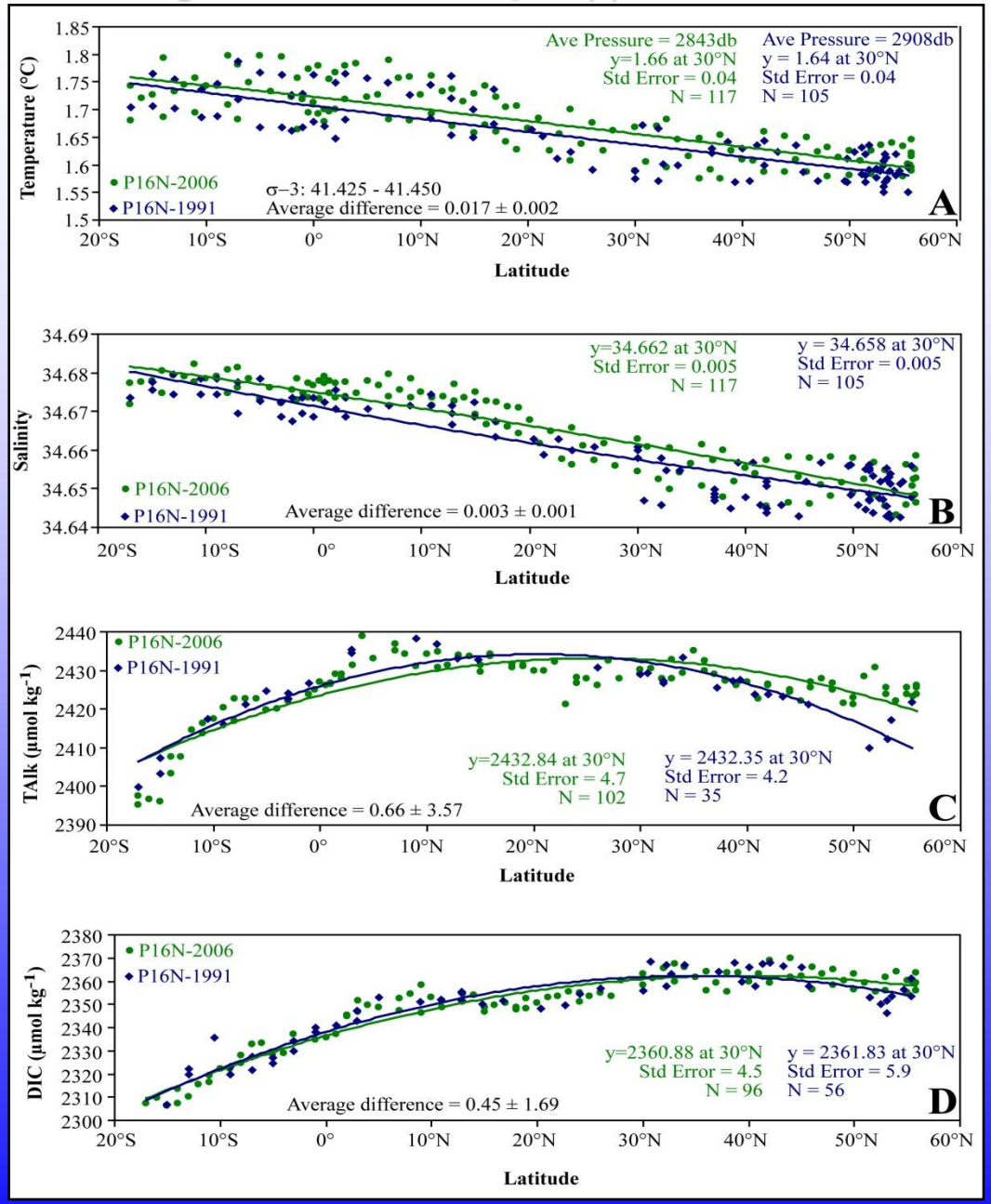
P02 along 30° N
Japan to San Diego, CA
June-August 2004



P16N along 152° W
Tahiti to Kodiak, AK
Feb.-March 2006

Comparison of crossover and overlap stations indicate the DIC data are good to +/- 1 µmol kg^{-1} and alkalinity data are good to +/- 2 µmol kg^{-1}

Comparison of 1991 P16N data with 2006 P16N data along 41.425-41.450 σ_3 isopycnal surface.



Repeat Hydrography Data Agree Well With Historical Data

Comparison of deep waters on isopycnal surfaces show no significant offsets between Repeat Hydrography and WOCE cruises.

CLIVAR/CO_2 Repeat Hydrography

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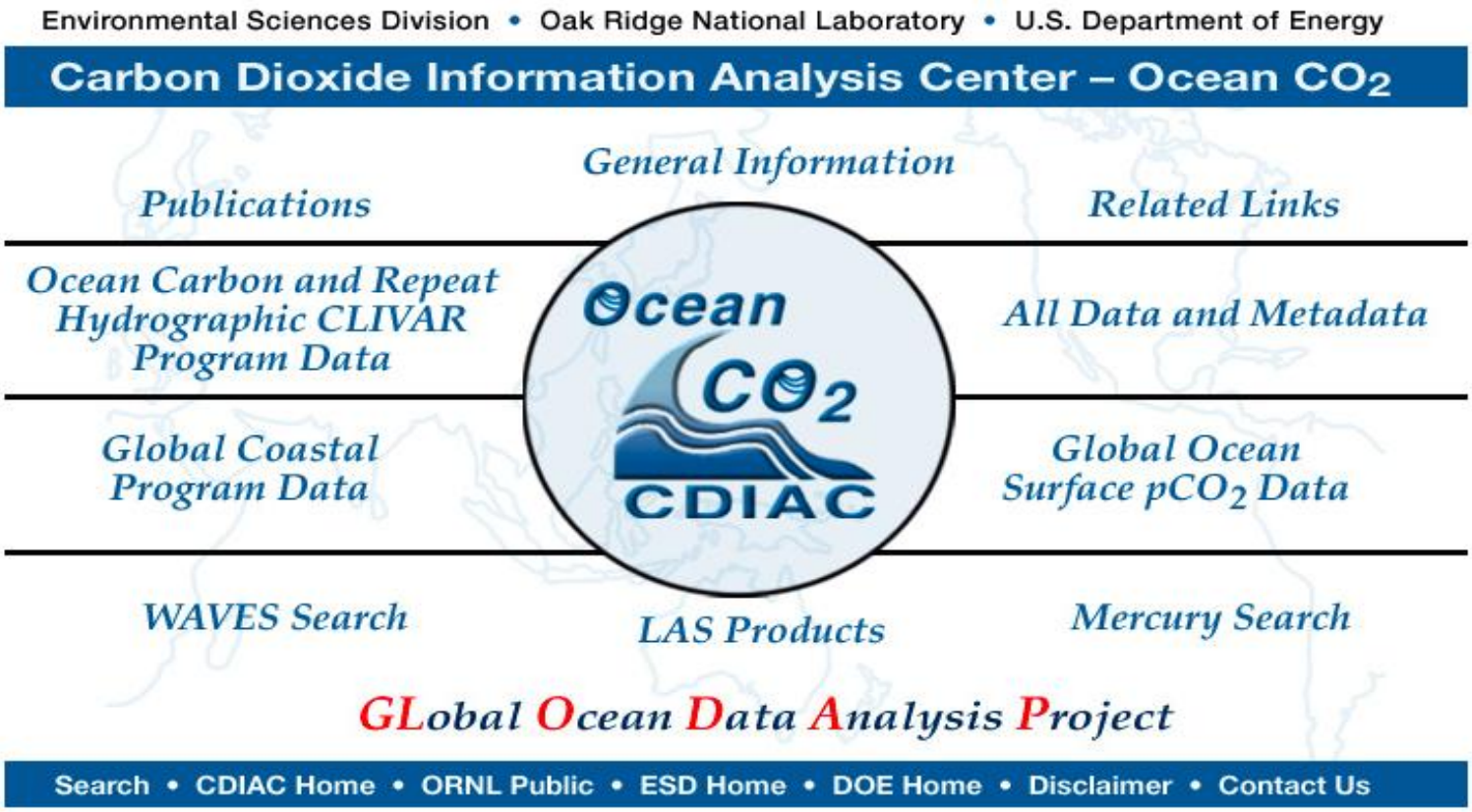

CLIVAR/CO_2 Repeat Hydrography

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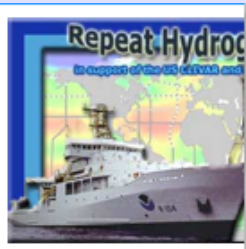
Ocean CO_2 CDIAC

Carbon Dioxide Information Analysis Center
Environmental Sciences Division
Oak Ridge National Laboratory
U.S. Department of Energy



- Repeat Hydrography Global Map
- Introduction
- CDIAC/WHPO(CCHDO) Data Management Plan (PDF)
- Repeat Carbon Measurements Science Team
- U.S. Repeat Hydrography Program Office
- Program Links
- CDIAC Ocean Home
- GLODAP Data
- *Mercury* Search
- WAVES Search

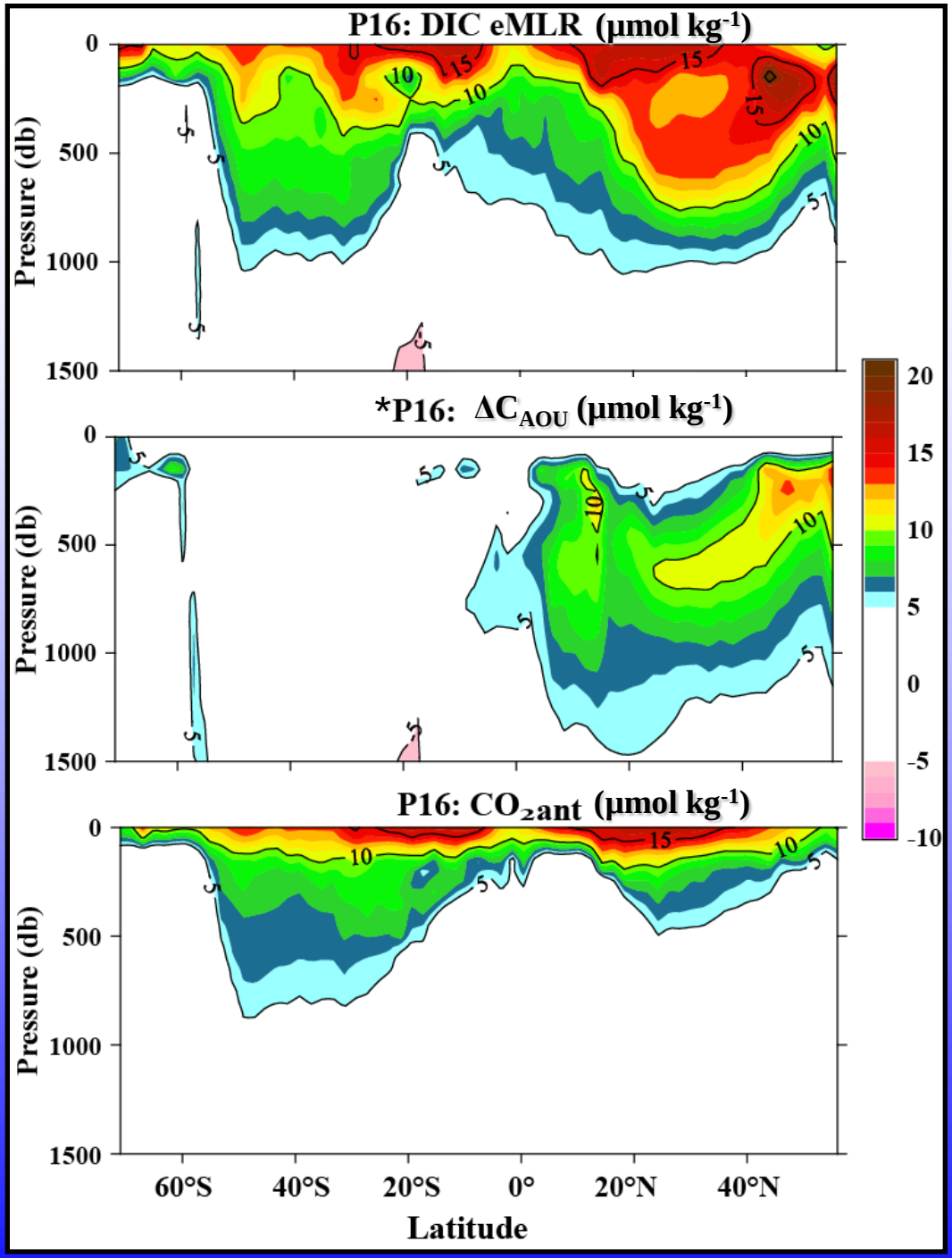
The CLIVAR Repeat Section Data Status

Last updated: 07-May-2008

No.	Section Country	Carbon PI	Hydrographic Data Status at CCHDO	CO_2 Data Status at CDIAC	CDIAC QC?	Are the CO_2 Data Submitted to CCHDO?	Are the CO_2 Data merged at CCHDO?	Are the Data Available Through CDIAC Web Site?	Are the Data Available Through *Mercury* Search?
	Atlantic Ocean								
1	A20_2003a USA	TCO_2 - Feely, Sabine TALK - Dickson	final	TCO_2 - final TALK - not submitted	TCO_2 - yes TALK - no	TCO_2 - yes TALK - no	TCO_2 - yes TALK - no	TCO_2 - yes TALK - no	TCO_2 - yes TALK - no
2	A22_2003a USA	TCO_2 - Feely, Sabine	final	TCO_2 - final TALK -	TCO_2 - yes TALK -	TCO_2 - yes (01/12/2005) TALK - yes	TCO_2 - yes TALK - yes	TCO_2 - yes (01/17/2005) TALK - yes	yes

Repeat Hydrography Program Accomplishments and Challenges for the Future

- To date we have completed about 67% of the decadal survey.
- The completed cruises have met 100% of their objectives, the data have been submitted to the data centers, and we are getting some very exciting results.
- Continued support for funding and ship-time is needed to complete the first global decadal survey by 2014 as planned.
- We need to continue to foster collaborations with national and international partners to coordinate the modeling and synthesize of these results with the growing international data set.



Pacific eMLR Sections Show Much More Coherent Patterns of Change

eMLR function without AOU shows a very large DIC change in the North Pacific

The AOU eMLR function isolates the change in apparent oxygen remineralization rate

Subtracting the AOU eMLR from the DIC eMLR gives the atmospheric CO_2 uptake

* AOU converted to C units using Redfield Ratio

Synthesis Activities

Atlantic Ocean Synthesis:

Initiated in June 2006 with meeting in Laugarvatn, Iceland and Delmenhorst, Germany in 2007 (CarboOcean and IOCCP)

Workshop participants developed three coordinated synthesis groups and a common data module: North Atlantic working group (lead: Are Olsen, Bjerknes Center for Climate Research, Bergen, Norway)Atlantic working group (lead: Toste Tanhua, IFM-GEOMAR, Kiel, Germany)South Atlantic / Southern Ocean (lead: Mario Hoppema, AWI, Bremerhaven, Germany)Data: Robert Key, Princeton University, USA

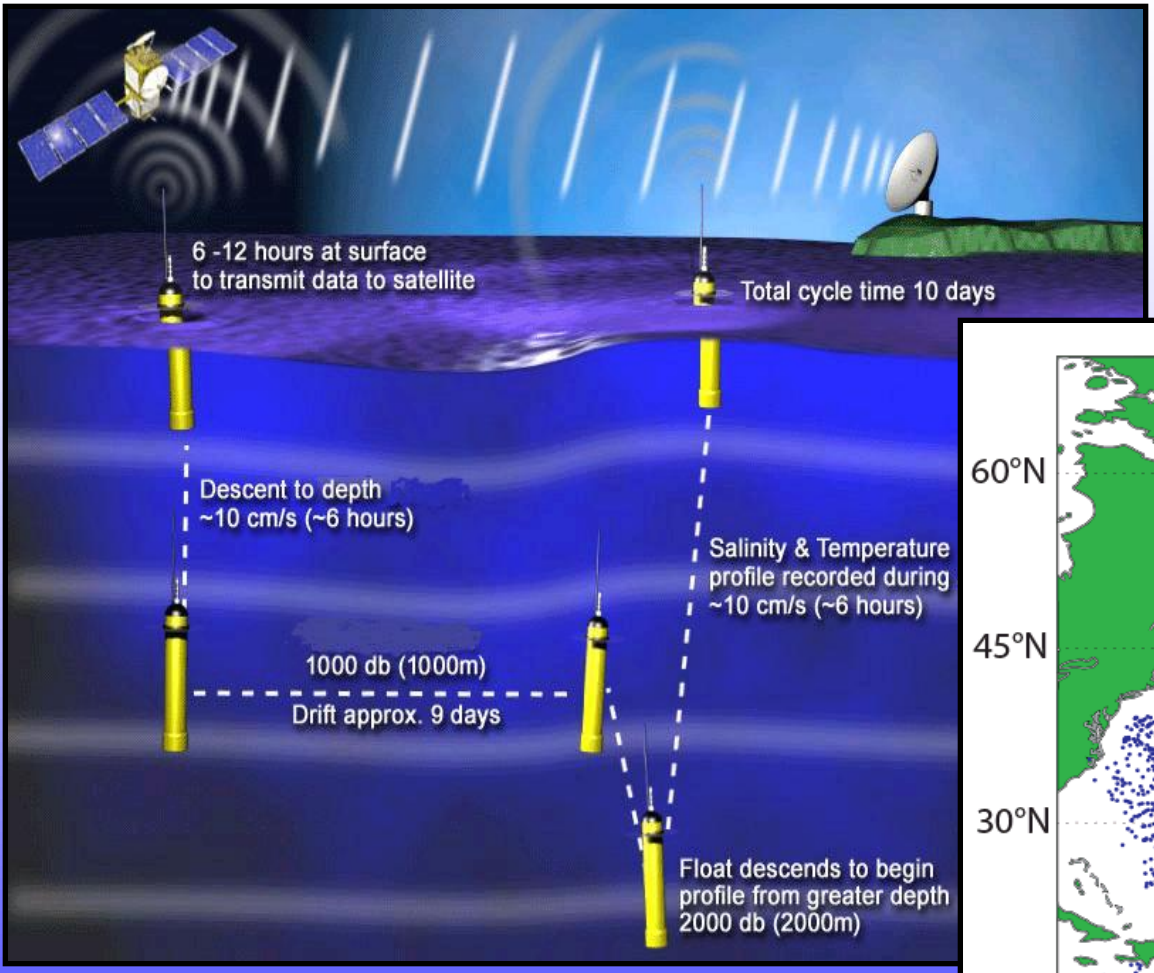
Pacific Ocean Synthesis: Three synthesis groups formed.

Initiated at meeting in Seattle June 2004 and Shonan Village, Japan 2005 (IOCCP and JAMSTEC)

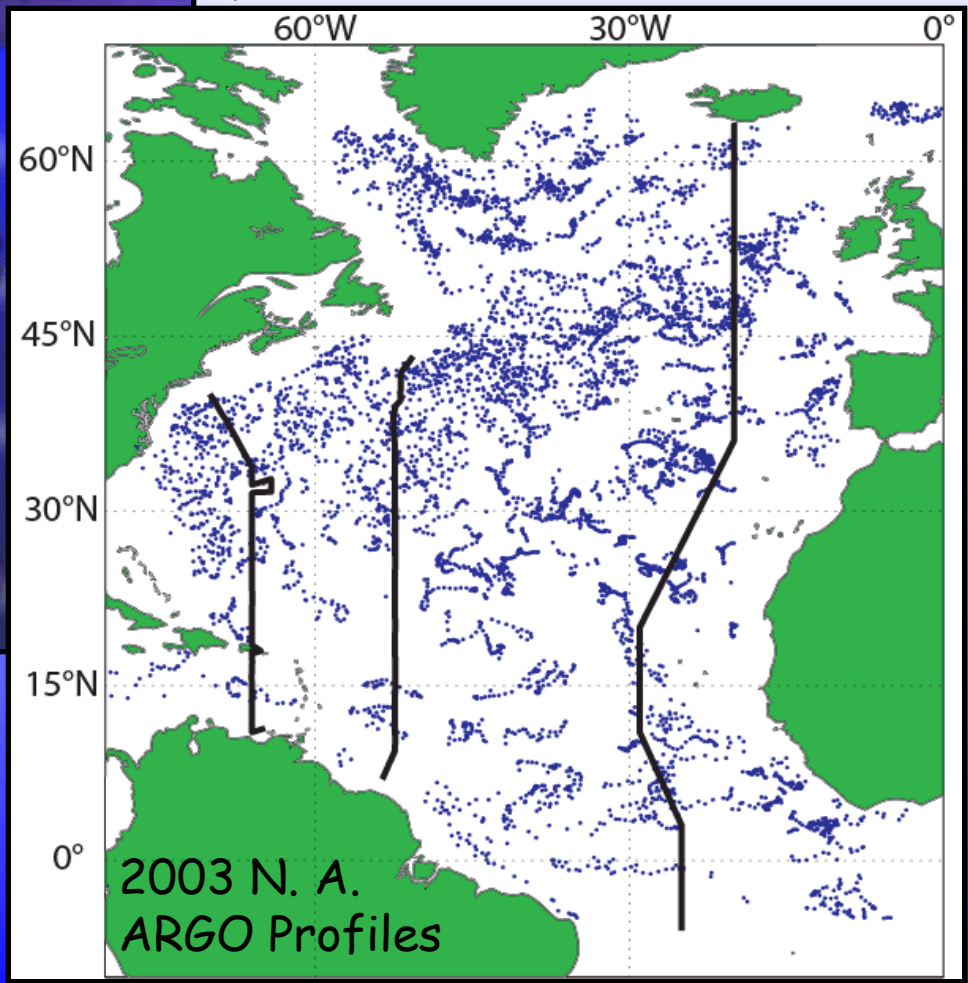
Indian Ocean Synthesis:

Discussed at Sustained Indian Ocean Biogeochemical and Ecological Research (SIBER) workshop October 2006

Future Directions: Is it possible to use ARGO to estimate carbon changes?



Approach: Use MLR fits of shipboard data (A16N, A22, A20) to derive functions to estimate carbon from ARGO profiles.

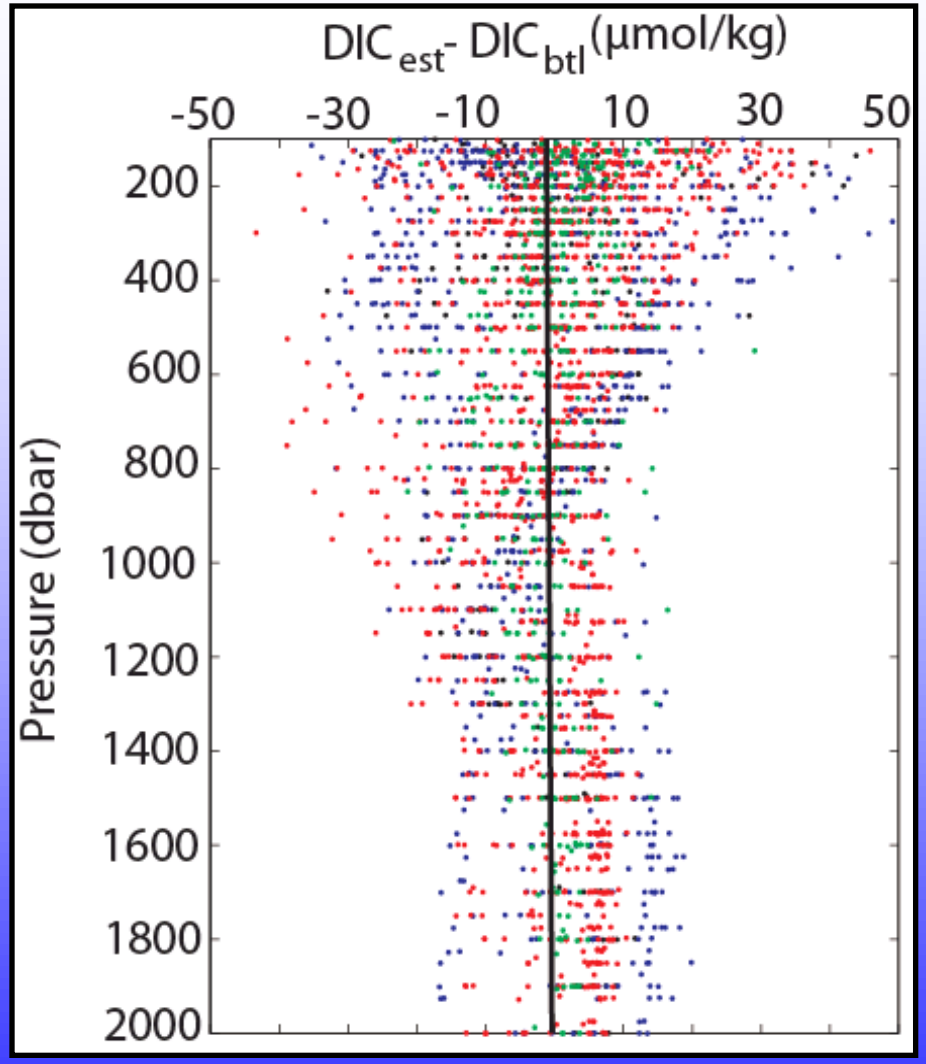


Measured Parameters:
T, S, P, Lat., Lon.

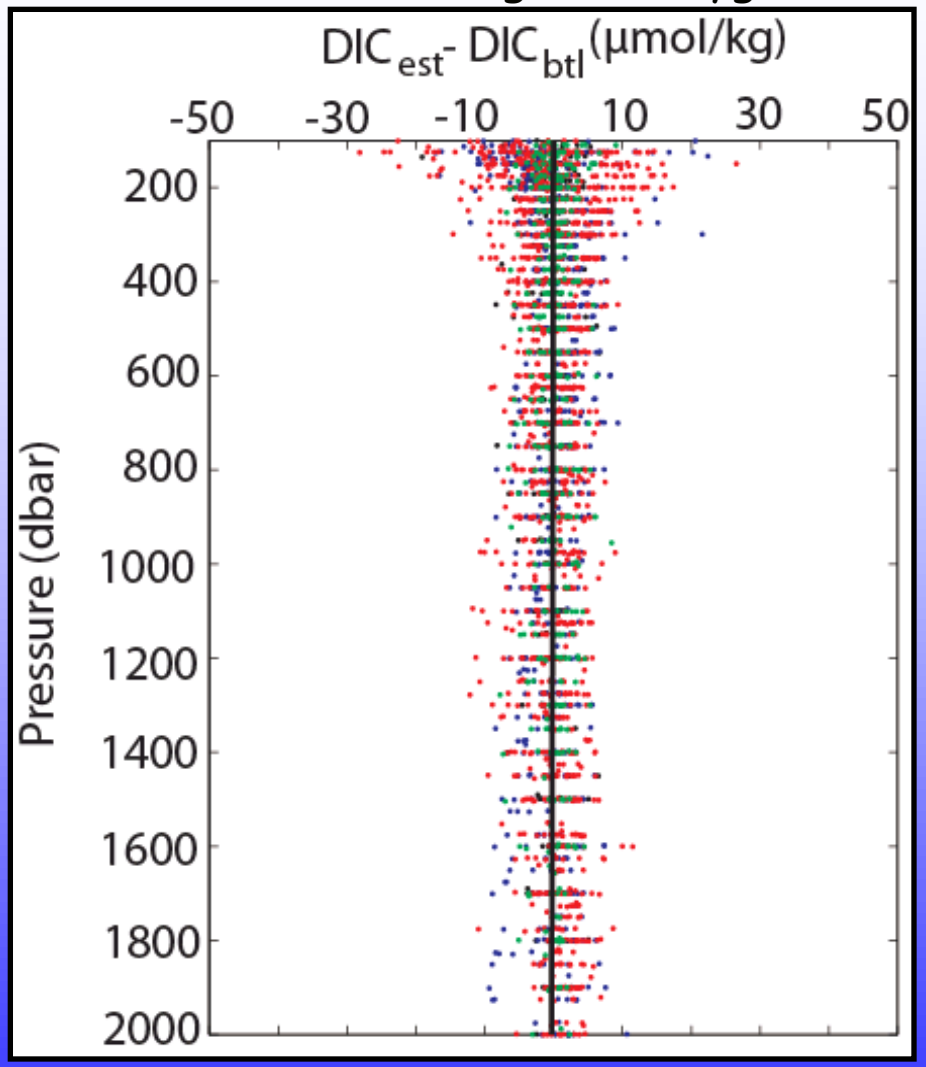
http://www.argo.ucsd.edu/

Oxygen Greatly Improves our Ability to Estimate Carbon Distributions

Rmse = 11.4 μmol/kg without oxygen



Rmse =3.7 μmol/kg with oxygen



Adding oxygen to the global ARGO data collection will make these data much more relevant for biogeochemical studies.

Recommendations

1. Increase Repeat Hydrography sample coverage in regions where active ventilation is occurring.

2. Test new methods for high-resolution O_2 and CO_2 profiling on Repeat Hydrography cruises. Provide support for profiling O_2 and CO_2 measurements.

3. Develop basin-scale carbon synthesis products and models that reproduce gas exchange, ventilation and biogeochemical processes.

4. Support international efforts for data synthesis and exchange.

CLIVAR has Many Mutual Interests With Carbon, so How Can We Work More Closely Together?

Current approaches:

1. Carbon representatives on CLIVAR basin panels
2. IOCCP involvement in various CLIVAR, JCOMM, OOPC meetings
3. Links between IOCCP and CLIVAR web pages
4. Jointly sponsored workshops (like repeat hydro workshop)

Synthesis is clearly starting to emerge as a dominant theme in the carbon community. How is synthesis being organized within CLIVAR and what opportunities are there for collaboration?

Do we still need carbon representatives on all of the basin panels or does it make more sense for us to coordinate through a broader group, like the Global Synthesis and Observations Panel (OceanObs'99)?

We have been talking about working closer together for years. What are some proactive steps we can take to actually move these interactions forward?

Cruises for the U.S. Global Carbon and Repeat Hydrography Program

2010 - A13.5
2011 - A10, S4P
2012 - A5, A20/A22
2013 - A16N, P02
2014 - A16S, P16S

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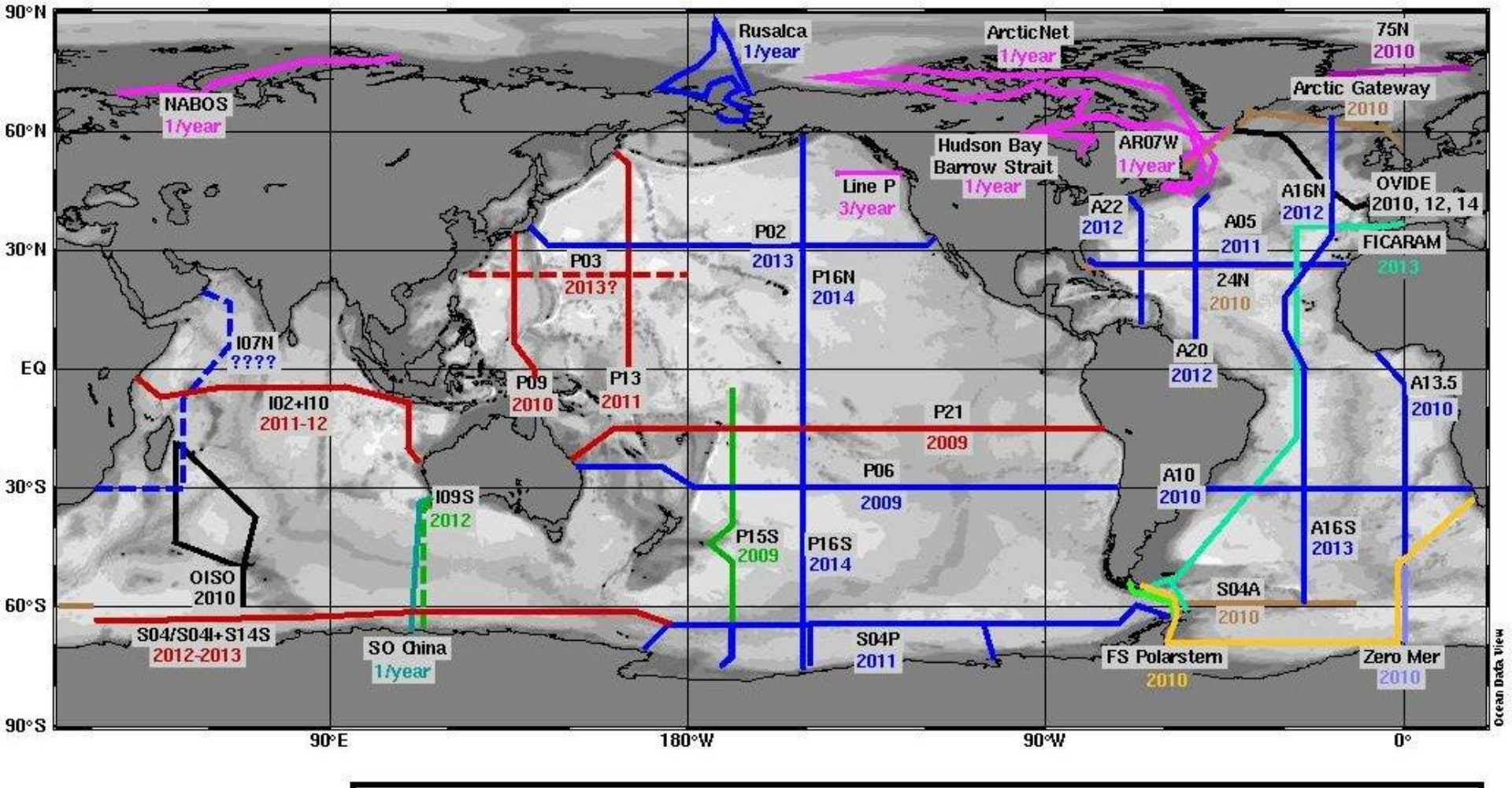
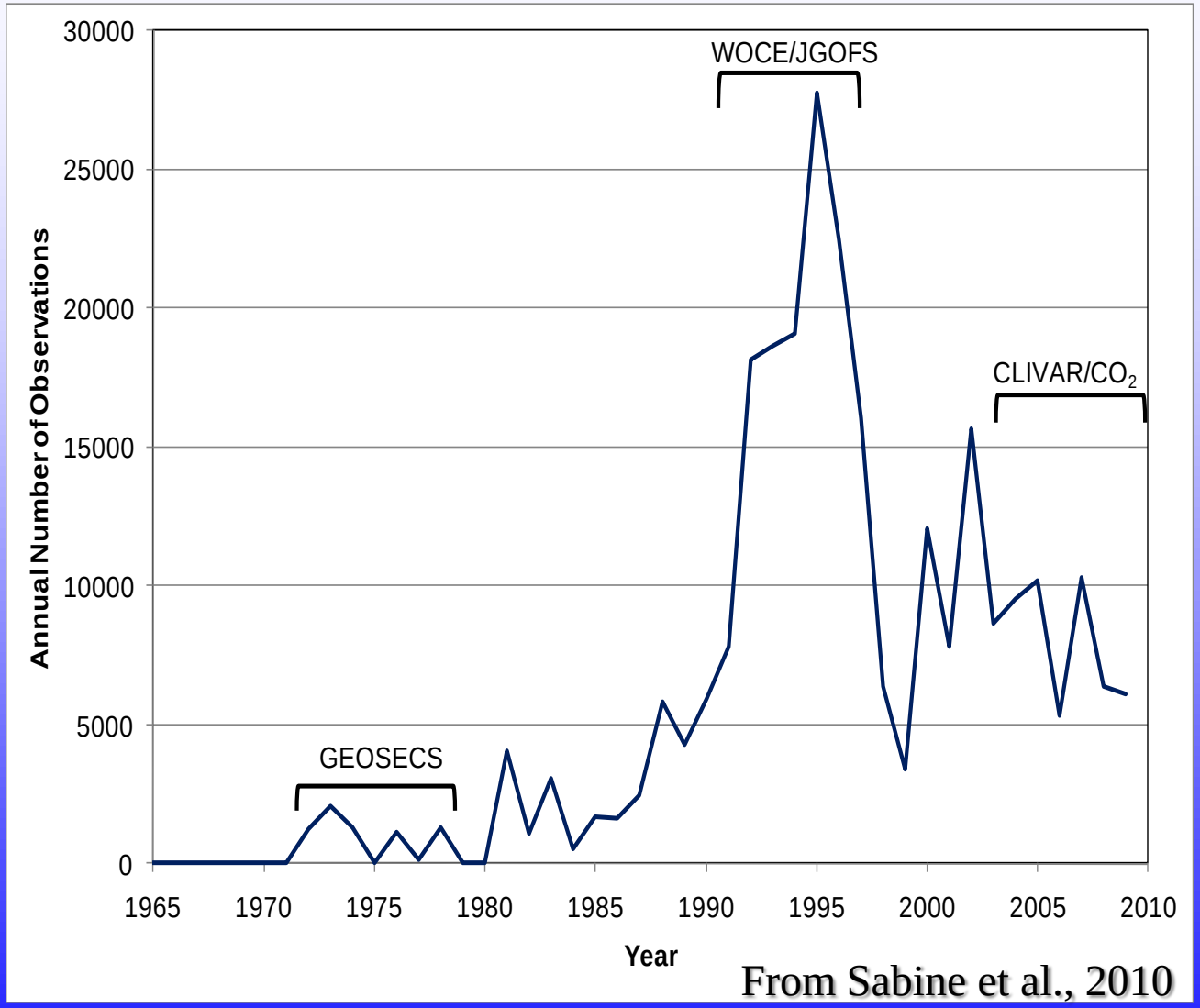


Global Interior Ocean Carbon Observations by Year

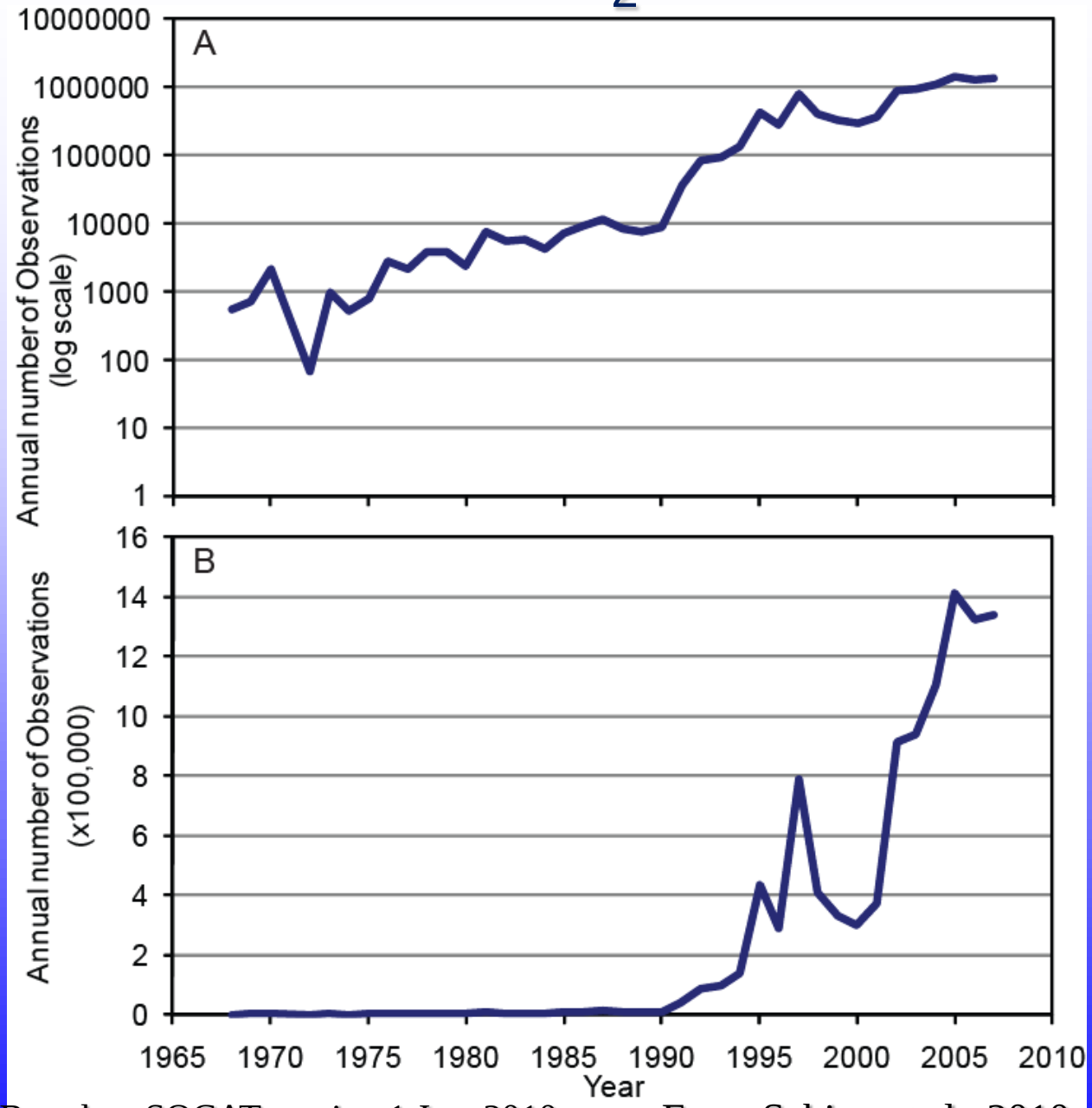


From Sabine et al., 2010

The WOCE/JGOFS period resulted in an unprecedented number of annual observations.

The CLIVAR/CO_2 program is making observations at 1/3 to 1/2 of the WOCE/JGOFS rate.

Global Surface CO_2 observations by year



Based on SOCAT version 1 Jan. 2010

From Sabine et al., 2010

The number of annual measurements has been increasing exponentially since for the last 50 years

A focus on studying ocean carbon in the 1990s led to the instrumenting of many more research ships

The dramatic increases in the 2000s can be attributed to the instrumenting of commercial ships

Thank You!

The R/V Thomas G. Thompson arriving in Papeete, Tahiti
for the beginning of P16N February 2006