Time-series methods overview: why results must be comparable from site to site

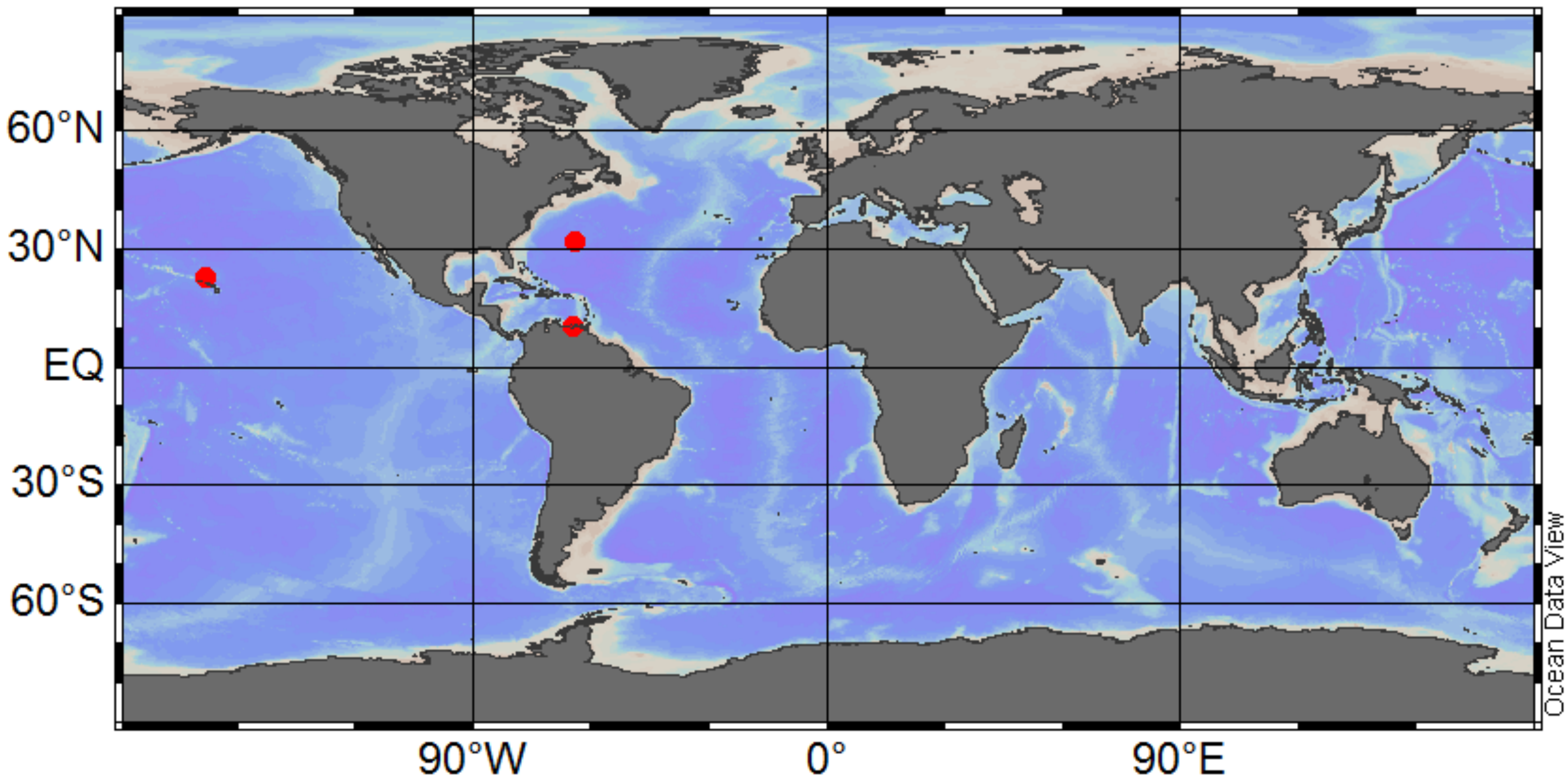
Ken Johnson
Monterey Bay Aquarium Research Institute

Ocean Time-Series Advisory Committee

OCB SSC member Ken Johnson is the chair of the Ocean Time-Series Advisory Committee (OTSAC), which is charged with reviewing existing ocean biogeochemical time-series (e.g., HOT, BATS, CARIACO - see 2007 summary of parameters being measured at these sites), developing recommendations to improve the effectiveness and inter-comparability of these time-series, and interfacing with the OCB research community to identify and communicate the needs for existing and future time-series sites.

NAME	AFFILIATION
Ken Johnson (Chair)	MBARI
Craig Carlson	UCSB
John Dunne	NOAA/GFDL
Ricardo Letelier	OSU
Susanne Neuer	Arizona State Univ.
Mary Jane Perry	Univ. of Maine
Paul Quay	Univ. of Washington
Chris Sabine (*ex officio*)	NOAA/PMEL

US-OCB Time Series – HOT/BATS/CARIACO

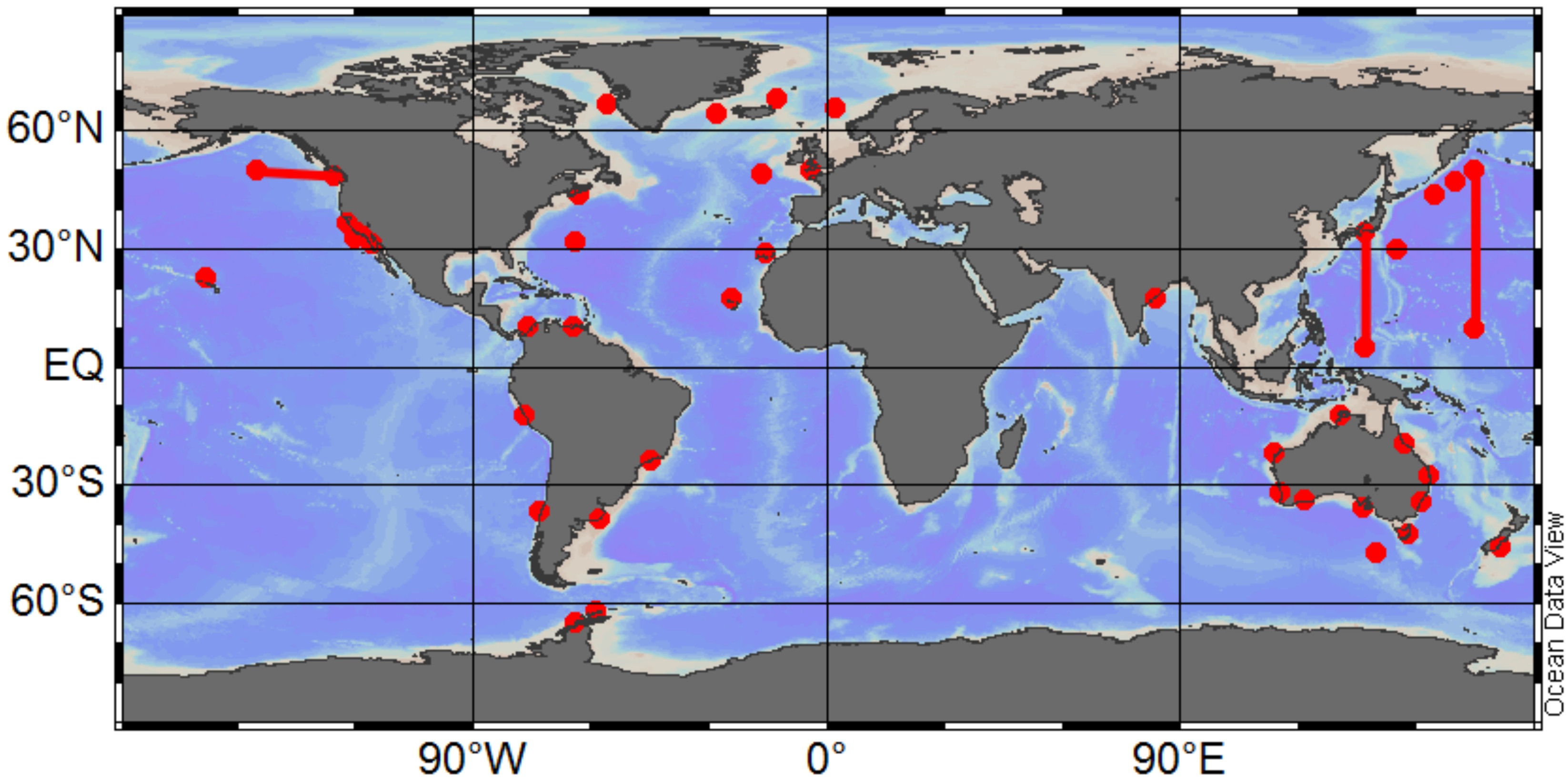


OCB time series success is a reflection of open data access policy

Time Series	Publ. Interval	Number
HOT	1990-2012	549
BATS	1988-2012	480
CARIACO	1996-2012	89*
Total		1118

*Publications by CARIACO PI's only.

Time Series Represented at this Workshop



Why time series?

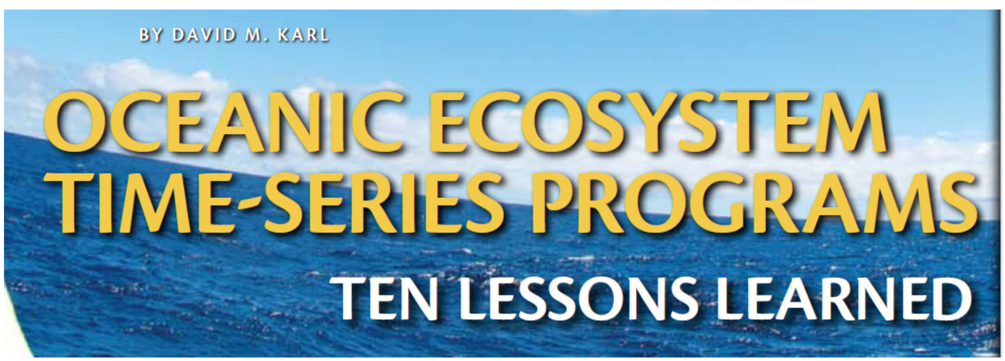
Abstract

Time-series observations form a critical element of oceanography. New interdisciplinary efforts launched in the past two decades complement the few earlier, longer-running time series to build a better, though still poorly resolved, picture of lower-frequency ocean variability, the climate processes that drive variability, and the implications for food web dynamics, carbon storage, and climate feedbacks. Time series also enlarge our understanding of ecological processes and are integral for improving models of physical-biogeochemical-ecological ocean dynamics. The major time-series observa-

Contributions of Long-Term Research and Time-Series Observations to Marine Ecology and Biogeochemistry

Hugh W. Ducklow,[1] Scott C. Doney,[2]
and Deborah K. Steinberg[3]

The use of time-series data to generate testable hypotheses demands that the measurement program be properly designed and that the observations are analytically consistent, accurate, and relevant. A hallmark of most oceanic



Detecting the time varying component in an unambiguous manner requires comparisons across time series! Rare for more than 2 time series (e.g., HOT vs. BATS).

- Temporal Trends
- Temporal Patterns
- Absolute values

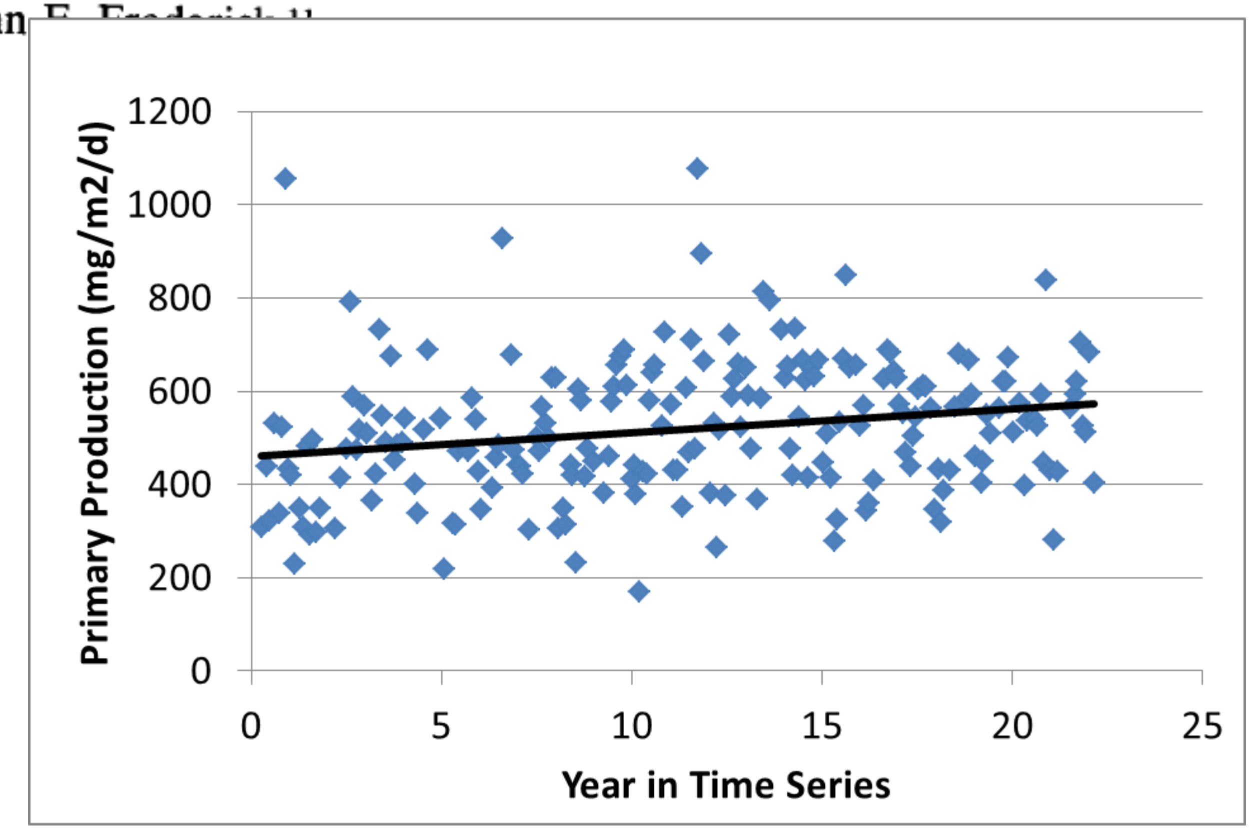
JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 103, NO. D14, PAGES 17,149–17,161, JULY 27, 1998

Factors affecting the detection of trends: Statistical considerations and applications to environmental data

Elizabeth C. Weatherhead,[1] Gregory C. Reinsel,[2] George C. Tiao,[3] Xiao-Li Meng,[4] Dongseok Choi,[4] Wai-Kwong Cheang,[2] Teddie Keller,[5] John DeLuisi,[6] Donald J. Wuebbles,[7] James B. Kerr,[8] Alvin J. Miller,[9] Samuel J. Oltmans,[10] and John

Ordinary statistics $P<0.005$

Correct for autocorrelation, will only become significant after ~28 years of data



Biogeosciences, 7, 621–640, 2010
www.biogeosciences.net/7/621/2010/

Biogeosciences

Detection of anthropogenic climate change in satellite records of ocean chlorophyll and productivity

S. A. Henson[1,*], J. L. Sarmiento[1], J. P. Dunne[2], L. Bopp[3], I. Lima[4], S. C. Doney[4], J. John[2], and C. Beaulieu[1]

Table 1. Length of time series in years needed to detect a global warming trend in chlorophyll concentration and primary production (bold) above the natural variability, reported for each model as the average within the biomes (see Fig. 1 for biome locations). One standard deviation of the spatial average is shown in brackets.

Biome	GFDL	IPSL	NCAR	Biome mean
1. High latitude North Pacific	41 (15)	41 (11)	41 (10)	41
	40 (12)	**43 (11)**	**41 (12)**	**41**
2. Oligotrophic North Pacific	36 (10)	37 (11)	44 (12)	39
	38 (11)	**30 (13)**	**36 (11)**	**35**
3. Equatorial Pacific	34 (8)	32 (11)	49 (8)	35
	31 (10)	**29 (8)**	**38 (12)**	**33**
4. Oligotrophic South Pacific	41 (13)	36 (10)	48 (12)	42
	43 (14)	**35 (14)**	**50 (14)**	**43**
5. Southern Ocean – Pacific	37 (13)	48 (17)	45 (12)	43
	42 (15)	**49 (18)**	**40 (13)**	**44**
6. High latitude North Atlantic	40 (12)	31 (9)	37 (10)	36
	41 (11)	**33 (8)**	**43 (11)**	**39**
7. Oligotrophic North Atlantic	42 (13)	34 (11)	35 (16)	37
	44 (14)	**31 (12)**	**38 (13)**	**38**
8. Equatorial Atlantic	45 (9)	26 (7)	24 (8)	32
	45 (10)	**15 (2)**	**32 (6)**	**31**
9. Oligotrophic South Atlantic	40 (12)	35 (12)	33 (13)	36
	40 (13)	**23 (13)**	**38 (14)**	**34**
10. Southern Ocean – Atlantic	37 (11)	43 (10)	36 (11)	39
	39 (18)	**43 (13)**	**35 (12)**	**39**
11. Arabian Sea	37 (6)	33 (6)	29 (8)	33
	37 (7)	**20 (5)**	**35 (9)**	**31**

Trend detection requires comparison across multiple time series.

Ocean Deoxygenation in a Warming World

Ralph F. Keeling,[1] Arne Körtzinger,[2] and Nicolas Gruber[3]

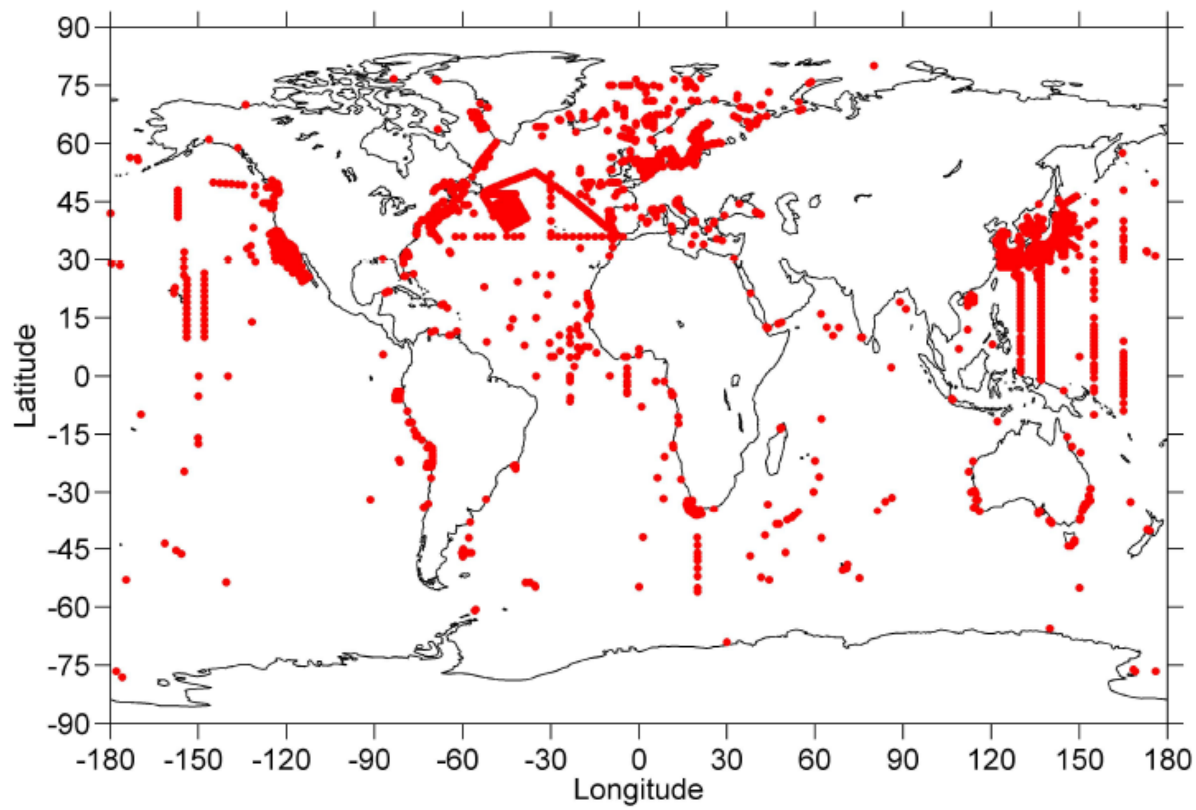
Biogeosciences, 7, 2283–2296, 2010
www.biogeosciences.net/7/2283/2010/
doi:10.5194/bg-7-2283-2010

Biogeosciences

Evidence for greater oxygen decline rates in the coastal ocean than in the open ocean

D. Gilbert[1], N. N. Rabalais[2], R. J. Diaz[3], and J. Zhang[4]

Fig. 2 Red dots are regions with sufficient oxygen data to compute temporal trends according to a minimal set of criteria for data availability (from Gilbert et al., 2010).



Distance from Coast (km)	Number of Papers	% Negative O_2 Trend
0-30	41	70.7
30-100	19	68.4
100+	40	77.5

es, 7, 2283–2296, 2010

es from the coast, using data
number of time series; Perc

1997)

(Laine et al., 1997)

100+ −0.5

Analyze entire data set (all time series)

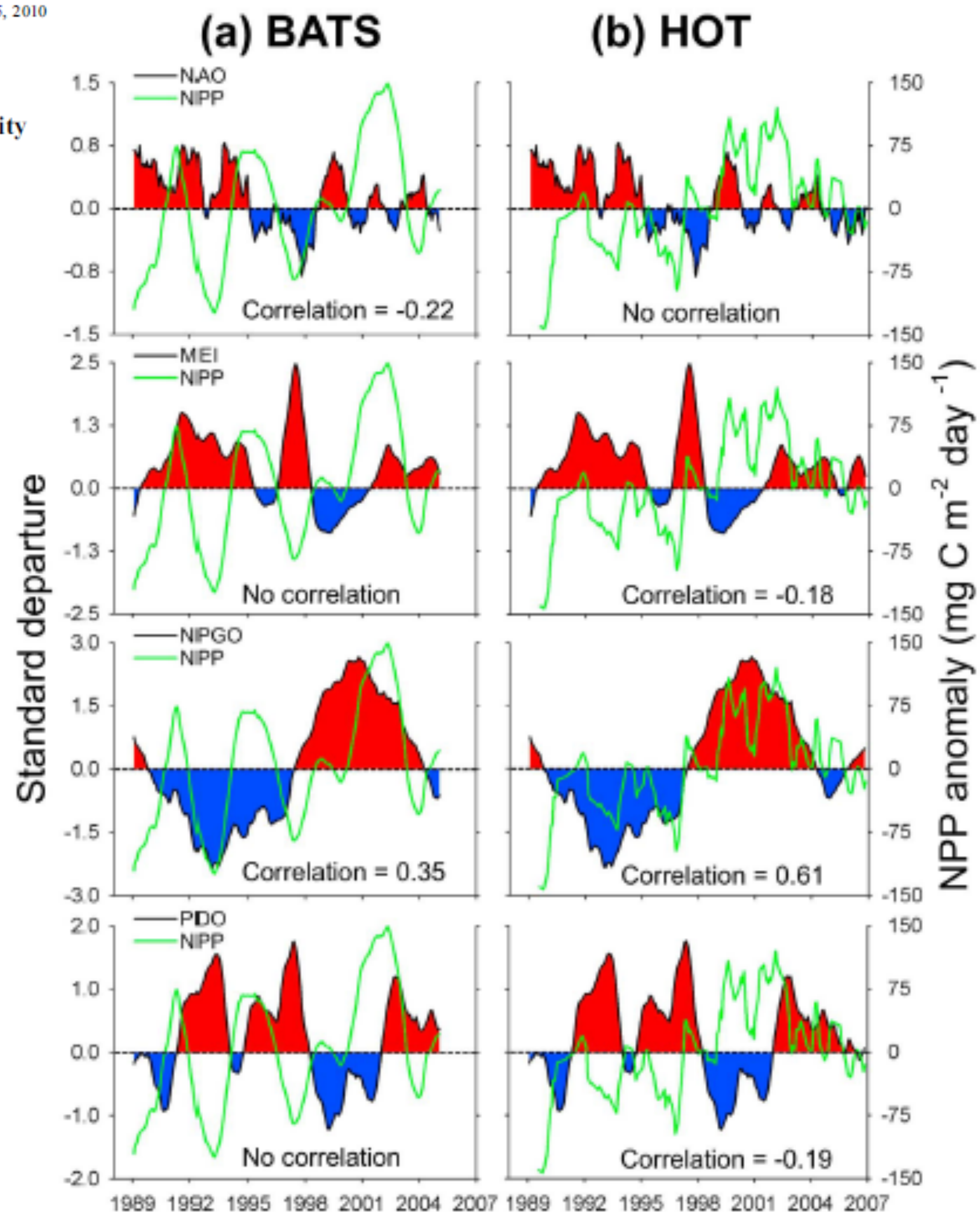
Distance from Coast (km)	Number of Sites	% Negative O_2 Trend
0-30	424	64.2
30-100	632	57.6
100+	2330	49.1

30–100	−0.15	−0.19	1.09	632	57.6	[53.6, 61.5]
100+	0.02	−0.09	1.40	2330	49.1	[47.0, 51.1]

GLOBAL BIOGEOCHEMICAL CYCLES, VOL. 24, GB3020, doi:10.1029/2009GB003655, 2010

Challenges of modeling depth-integrated marine primary productivity over multiple decades: A case study at BATS and HOT

Vincent S. Saba,[1,2] Marjorie A. M. Friedrichs,[1] Mary-Elena Carr,[3] David Antoine,[4] Robert A. Armstrong,[5] Ichio Asanuma,[6] Olivier Aumont,[7] Nicholas R. Bates,[8]

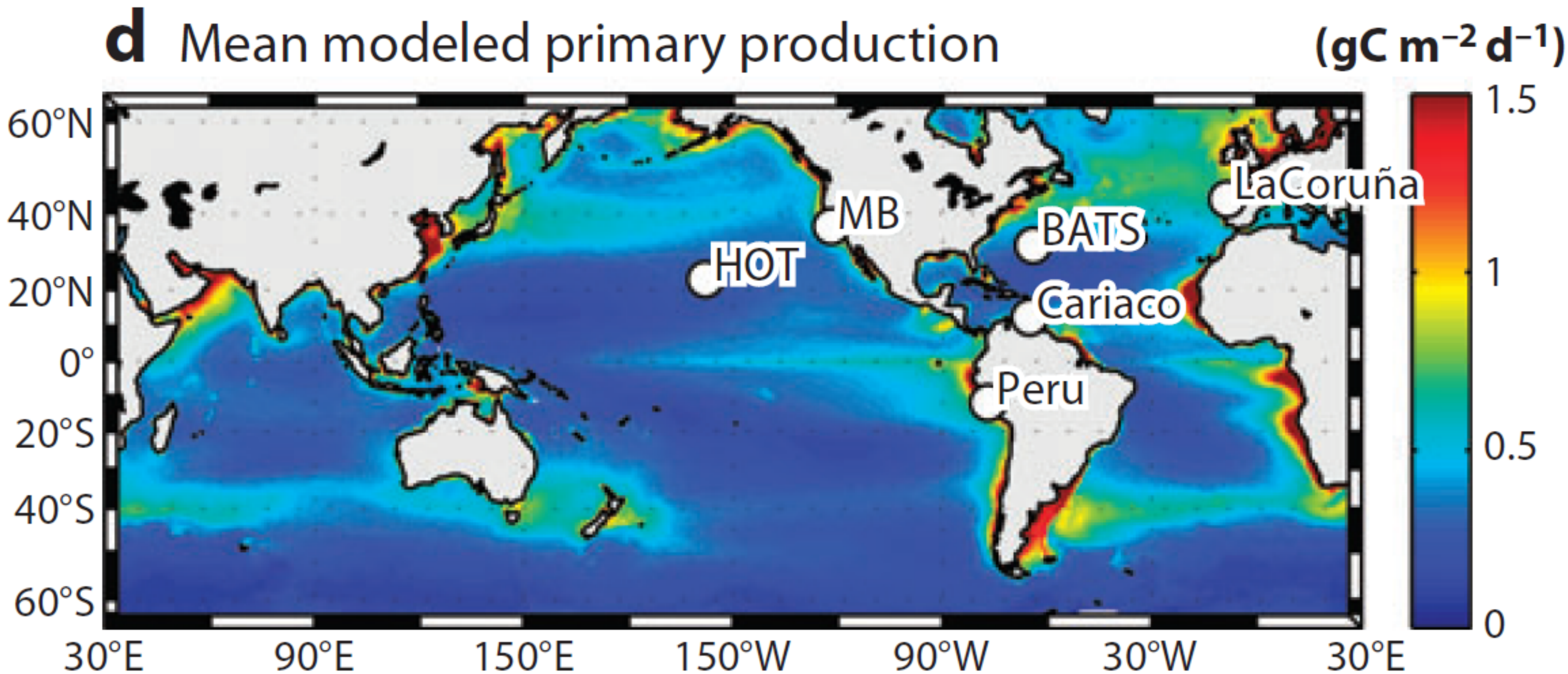


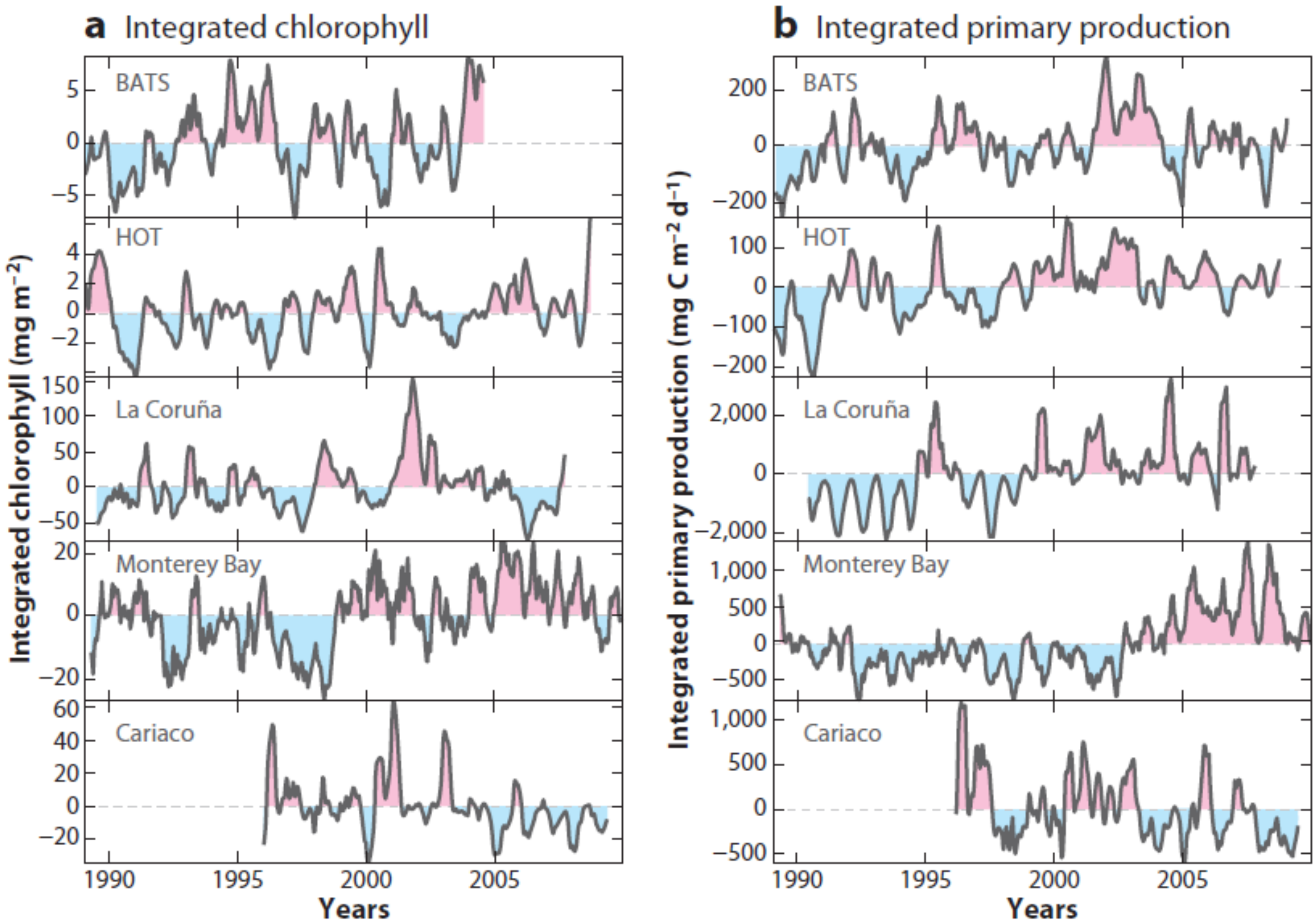
Marine Primary Production in Relation to Climate Variability and Change

Annu. Rev. Mar. Sci. 2011. 3:227–60

Francisco P. Chavez, Monique Messié, and J. Timothy Pennington

Monterey Bay Aquarium Research Institute, Moss Landing, California 95039; email: chfr@mbari.org

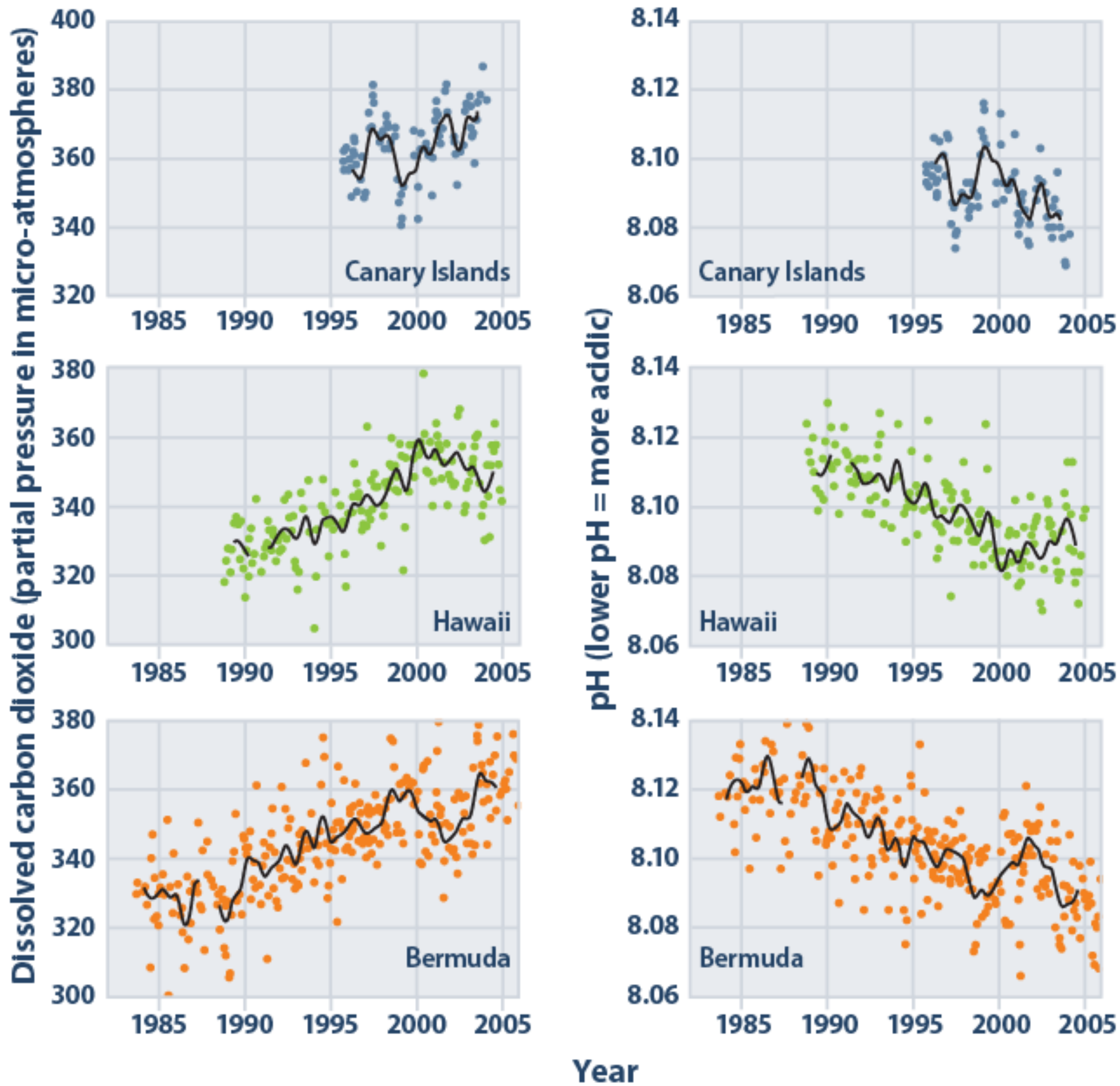




a Integrated chlorophyll
b Integrated primary production
BATS
HOT
La Coruña
Monterey Bay
Cariaco
Integrated chlorophyll (mg m⁻²)
Integrated primary production (mg C m⁻² d⁻¹)
1990
1995
2000
2005
Years

Figure 10

Ocean Carbon Dioxide Levels and Acidity, 1983–2005



Data source: Bindoff, N.L., J. Willebrand, V. Artale, A. Cazenave, J. Gregory, S. Gulev, K. Hanawa, C. Le Quéré, S. Levitus, Y. Nojiri, C.K. Shum, L.D. Talley, and A. Unnikrishnan. 2007. Observations: Oceanic climate change and sea level. In: Climate change 2007: The physical science basis (Fourth Assessment Report). Cambridge, United Kingdom: Cambridge University Press.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climatechange/science/indicators.

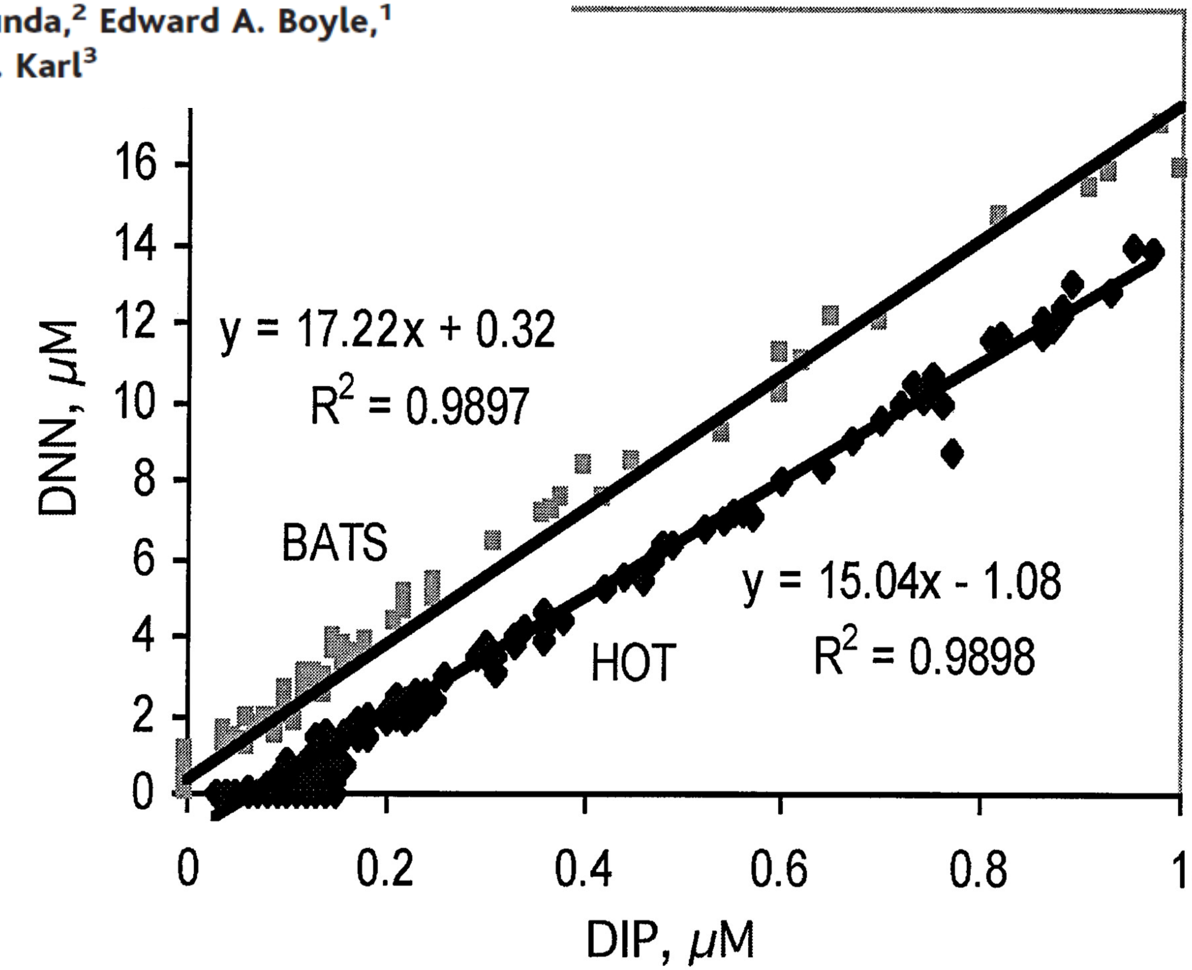
Detecting the time varying component in an unambiguous manner requires comparisons across time series! Rare for more than 2 time series (e.g., HOT vs. BATS).

- Temporal Trends
- Temporal Patterns
- Absolute values

Comparison of absolute values between sites.

Phosphate Depletion in the Western North Atlantic Ocean

Jingfeng Wu,[1*] William Sunda,[2] Edward A. Boyle,[1]
David M. Karl[3]



J Wu et al. Science 2000;289:759-762

Published by AAAS

HOT Methods Manual

Samples for the determination of dissolved inorganic nutrient concentrations (soluble reactive phosphorus, [nitrate+nitrite], and silicate) were collected as described in Tupas et al. (1993). Up until February 2000, analyses were conducted at room temperature on a four-channel Technicon Autoanalyzer II continuous flow system at the University of Hawaii Analytical Facility. Starting March 2000, samples have been run using a six-channel Bran Luebbe Autoanalyzer III. The average precisions during 2010 from duplicate analyses are given in the Table below. Figure 20, Figure 21, & Figure 22 show the mean and 95% confidence limits of nutrient concentrations measured at three potential density horizons for the past 22 years of the program. In addition to standard automated nutrient analyses, specialized methods are used to determine concentration of nutrients that are normally below the detection limits of autoanalyzer methods.

DETERMINATION OF DISSOLVED NUTRIENTS (N, P, SI) IN SEAWATER WITH HIGH PRECISION AND INTER-COMPARABILITY USING GAS-SEGMENTED CONTINUOUS FLOW ANALYSERS

D. J. Hydes[1], M. Aoyama[2], A. Aminot[3], K. Bakker[4], S. Becker[5], S. Coverly[6], A. Daniel[3], A. G. Dickson[5], O. Grosso[7], R. Kerouel[3], J. van Ooijen[4], K. Sato[8], T. Tanhua[9], E. M. S. Woodward[10], J. Z. Zhang[11]

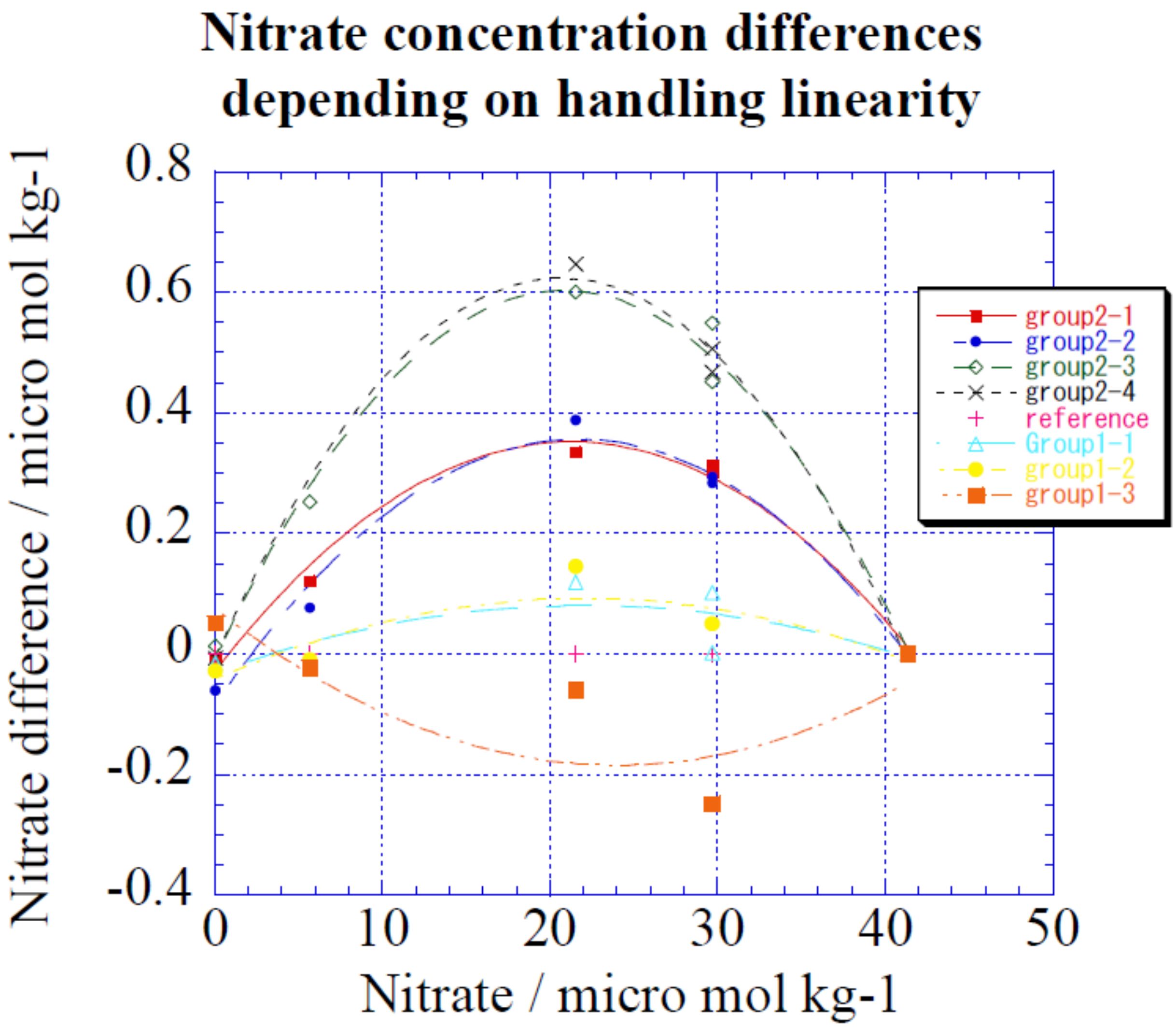


Figure 4. Plot of difference between nitrate concentration values reported by individual laboratories and the reference laboratory. The reference laboratory measured five standards and applied a quadratic fit. Group 1, laboratories measured 5 standards and applied a linear fit, Group 2 laboratories measured two standards and applied linear fit.

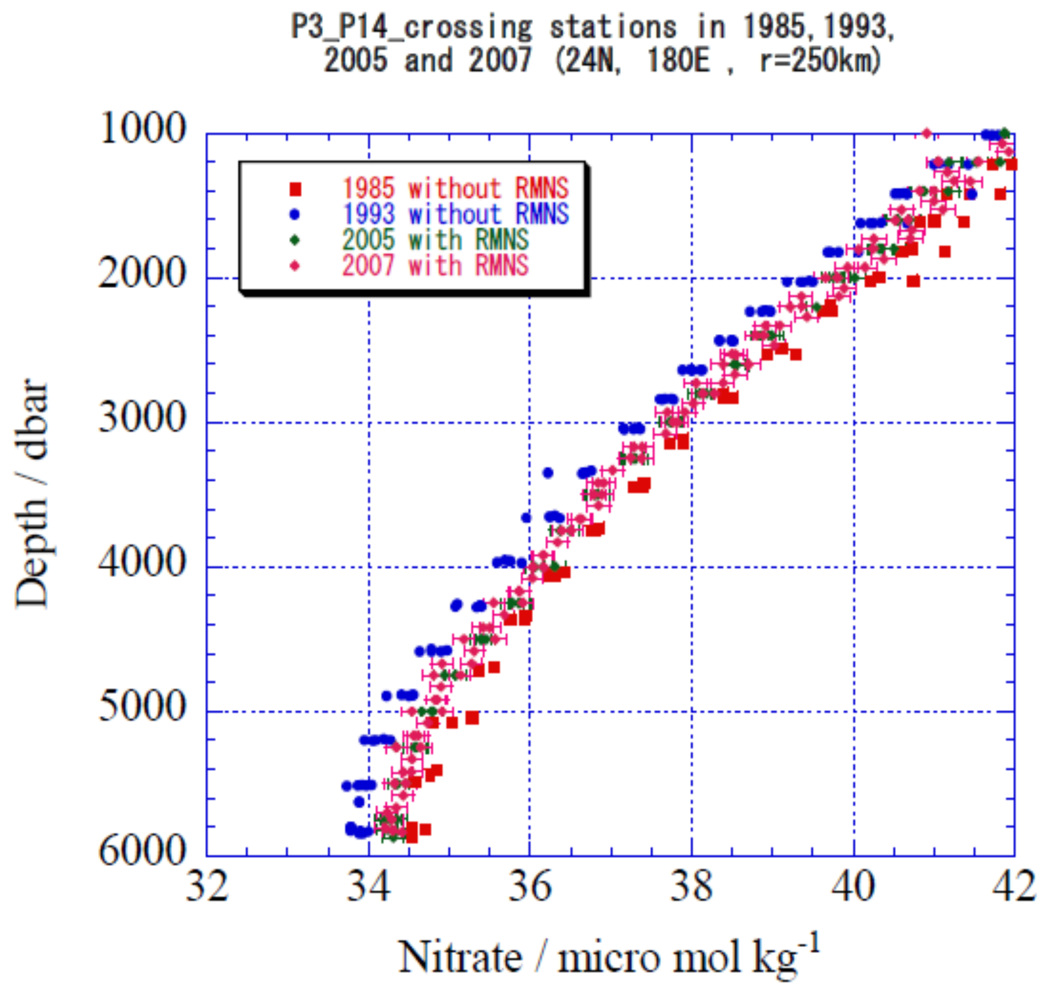


Figure 5. Profiles of nitrate concentration in the North Pacific Ocean at the crossing of P3 line and P14 line carried out in 1985 (P3), 1993 (P14), 2005 (P3) and P14(2007).

Earth Syst. Sci. Data, 2, 99–104, 2010
www.earth-syst-sci-data.net/2/99/2010/

Open Access Earth System Science Data

The Irminger Sea and the Iceland Sea time series measurements of sea water carbon and nutrient chemistry 1983–2008

J. Olafsson[1,2], S. R. Olafsdottir[1], A. Benoit-Cattin[1], and T. Takahashi[3]

Samples from all collection depths have been taken for salinity, dissolved oxygen and inorganic nutrients. From 1983 to 1991 only surface samples for pCO_2 and TCO_2 were collected. Water column sampling for TCO_2 started in 1991 and for pCO_2 in 1993.

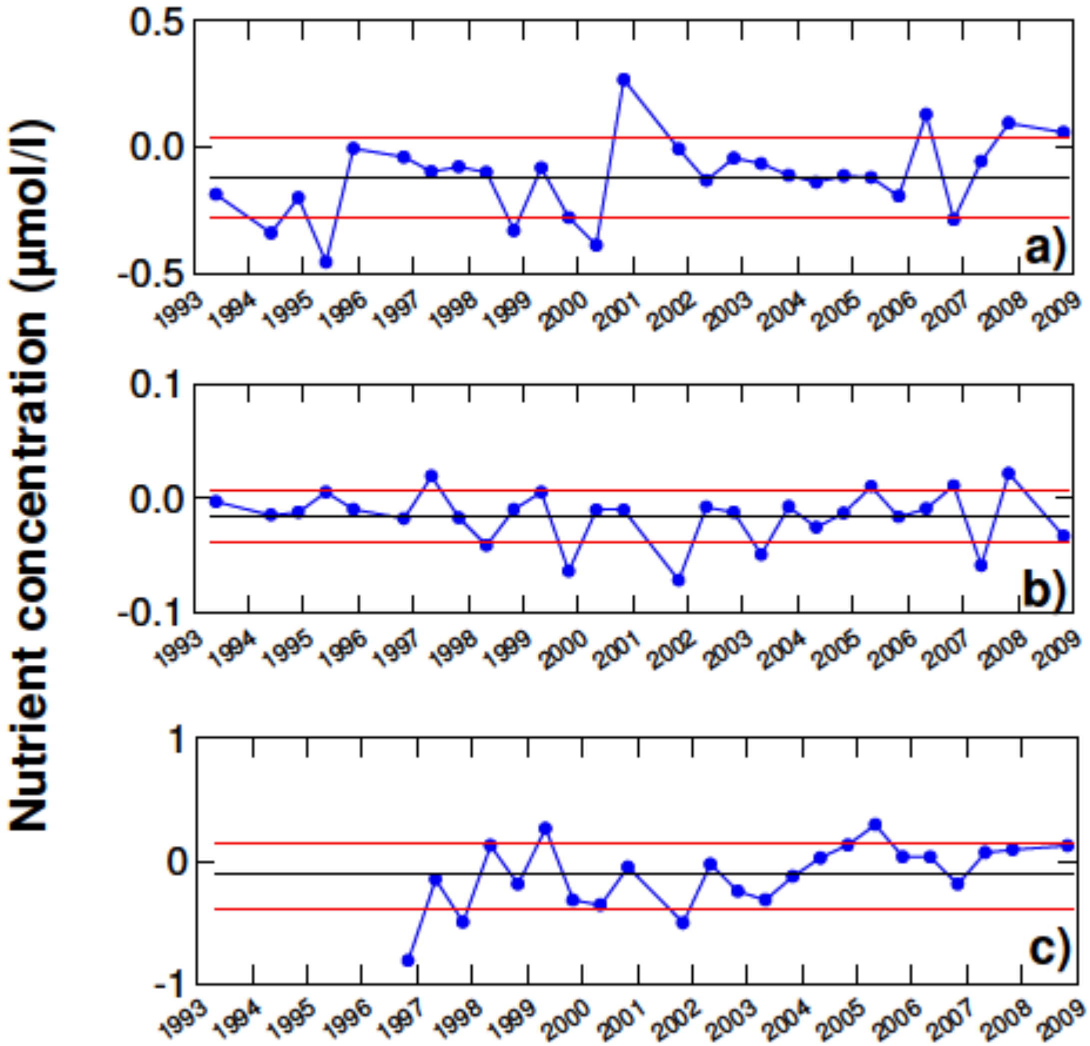
3 Methods and quality control procedures

3.1 Hydrography

From 1983 to the end of 1989 the station water sampling was conducted with TPN-Nansen water bottles, from HYDROBIOS GmbH, on a hydrowire. They were fitted with reversing mercury thermometers. From the beginning of 1990 the station work has been conducted using SEA-BIRD Conductivity-Temperature-Depth (CTD) profiling instruments and water bottles on a rosette. Sample salinity measurements were carried out using Guildline Autosal Model 8400 salinometers.

3.3.1 Nutrient analysis quality control

To assess the accuracy of the nutrient methods and procedures we have participated in, and subscribed to, the QUASIMEME laboratory QC programme and received since 1993 test materials for analysis twice a year (Wells et al., 1997). In QUASIMEME the laboratory performance is expressed with a z-score where $|z| < 2$ is considered as acceptable results and where z is the difference between the laboratory result and the assigned value divided by the total error (Cofino and Wells, 1994). The test material concentrations have been variable over the years, sometimes been well above the range observed at the time series locations. We therefore prefer to express the MRI long term nutrient analyses performance on the basis of the differences between reported and assigned concentrations rather than z-scores as these differences are directly comparable to the analytical uncertainty (Fig. 2). The average difference of MRI reported values for nitrate (Fig. 2a) from 1993–2008 is -0.12 µmol/l (standard deviation = 0.16 µmol/l, $n = 28$), for phosphate (Fig. 2b) it is -0.02 µmol/l (standard deviation = 0.02 µmol/l, $n = 28$). From 1996 silicate has been



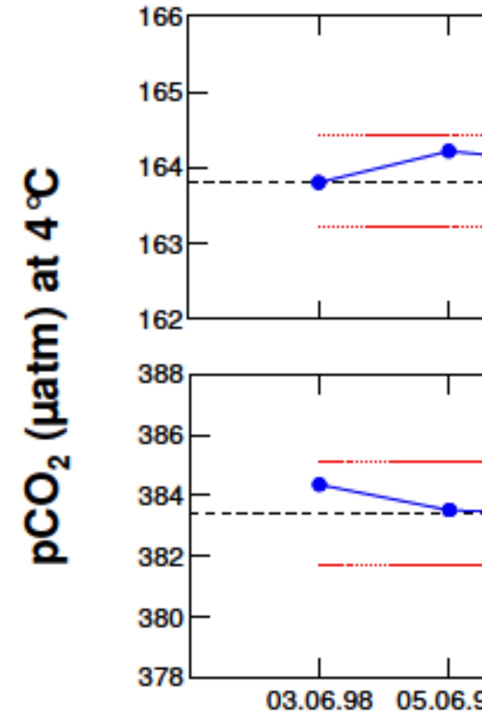


Figure 3. Results of $p\mathrm{CO}_2$
$p\mathrm{CO}_2$ (µatm at 4 °C) in **(a)** sa
from 200 m depth. The av
experiment are shown with a
deviations are shown with re

Firefox | ESSD - Special Issue - CARINA: a consist... | +

www.earth-syst-sci-data.net/special_issue2.html

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Special Issues

ESSD - Special Issue

CARINA: a consistent carbon-relevant data base for the Arctic, Atlantic and Southern Oceans
Editor(s): T. Tanhua, A. Olsen, M. Hoppema, and V. Gouretski

CARINA: nutrient data in the Atlantic Ocean — 06 Nov 2009
T. Tanhua, P. J. Brown, and R. M. Key
Earth Syst. Sci. Data, 1, 7-24, 2009
Abstract | Final Revised Paper (PDF, 1527 KB) | Discussion Paper (ESSDD)

Overview of the Nordic Seas CARINA data and salinity measurements — 19 Nov 2009
A. Olsen, R. M. Key, E. Jeansson, E. Falck, J. Olafsson, S. van Heuven, I. Skjelvan, A. M. Omar, K. A. Olsson, L. G. Anderson, S. Jutterström, F. Rey, T. Johannessen, R. G. J. Bellerby, J. Blindheim, J. L. Bullister, B. Pfeil, X. Lin, A. Kozyr, C. Schirnick, T. Tanhua, and D. W. R. Wallace
Earth Syst. Sci. Data, 1, 25-34, 2009
Abstract | Final Revised Paper (PDF, 5764 KB) | Discussion Paper (ESSDD)

Nordic Seas total dissolved inorganic carbon data in CARINA — 25 Nov 2009
A. Olsen
Earth Syst. Sci. Data, 1, 35-43, 2009
Abstract | Final Revised Paper (PDF, 2960 KB) | Discussion Paper (ESSDD)

CARINA alkalinity data in the Atlantic Ocean — 27 Nov 2009
A. Velo, F. F. Perez, P. Brown, T. Tanhua, U. Schuster, and R. M. Key
Earth Syst. Sci. Data, 1, 45-61, 2009
Abstract | Final Revised Paper (PDF, 3111 KB) | Discussion Paper (ESSDD)

Consistency of cruise data of the CARINA database in the Atlantic sector of the Southern Ocean — 08 Dec 2009
M. Hoppema, A. Velo, S. van Heuven, T. Tanhua, R. M. Key, X. Lin, D. C. E. Bakker, F. F. Perez, A. F. Ríos,

SAMPLING AND ANALYSIS OF Fe: THE SAFE IRON INTERCOMPARISON CRUISE

Ken Johnson; Ed Boyle; Ken Bruland, Kenneth Coale; Chris Measures; Jim Moffett and the SAFE Participants

Vol. 88, No. 11, 13 March 2007

Developing Standards for Dissolved Iron in Seawater

PAGES 131–132

tories from nine nations on subsamples of a single surface water sample from the Atlantic

dations of an international study group, *Accred. Qual. Assur., 6*, 274–277.
Johnson, K. S., J. K. Moore, and W. O. Smith (2002), Workshop highlights iron dynamics in ocean carbon cycle, *Eos Trans. AGU, 83*(43), 482, 484.
Martin, J. H. (1990), Glacial-interglacial CO_2 change: The iron hypothesis, *Paleoceanography, 5*, 1–13.
Martin, J. H., and R. M. Gordon (1988), Northeast Pacific iron distributions in relation to phytoplankton productivity, *Deep Sea Res., 35*, 177–196.
National Research Council (2002), *Chemical Reference Materials: Setting the Standards for Ocean Science*, Natl. Acad. Press, Washington, D. C.

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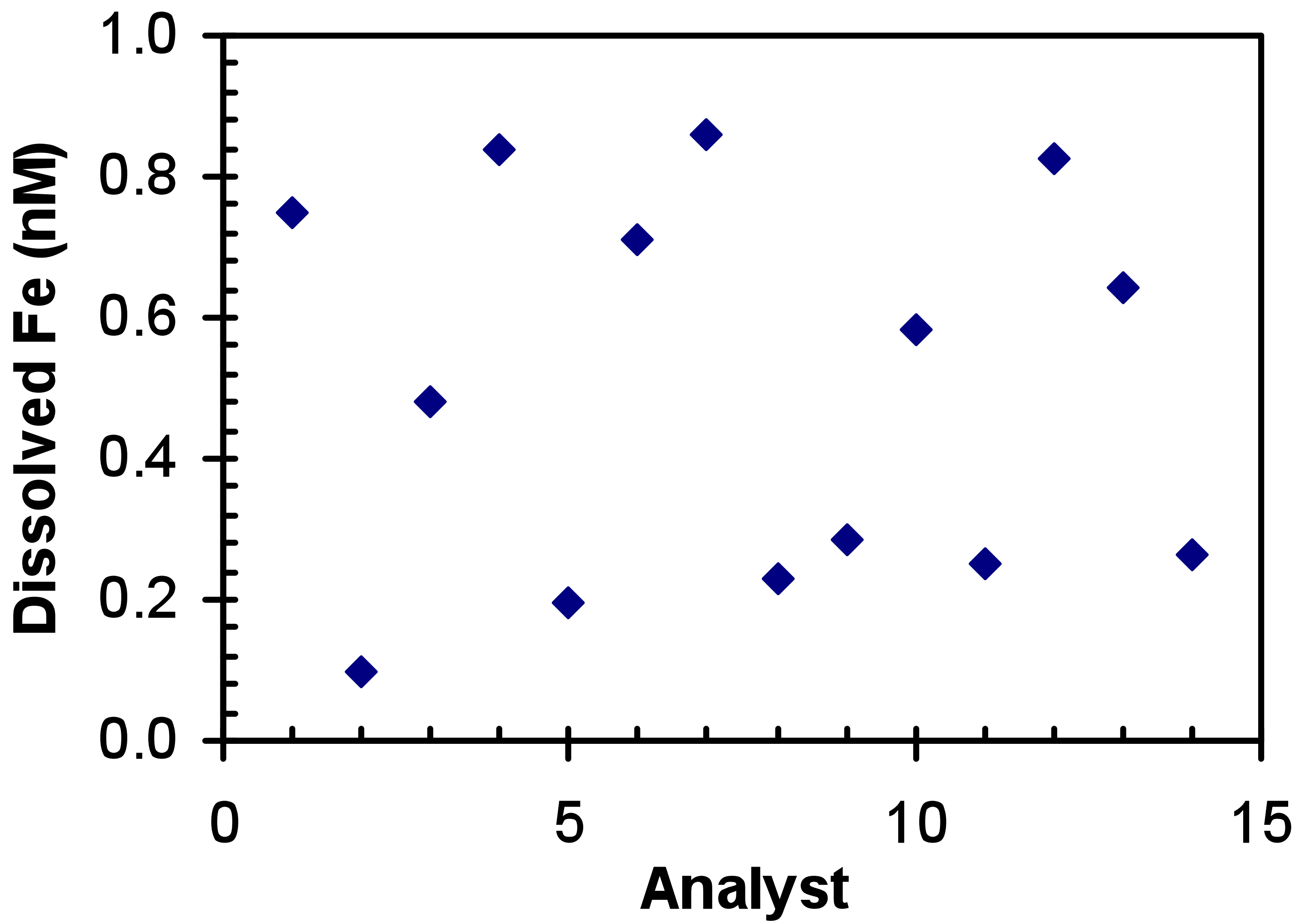
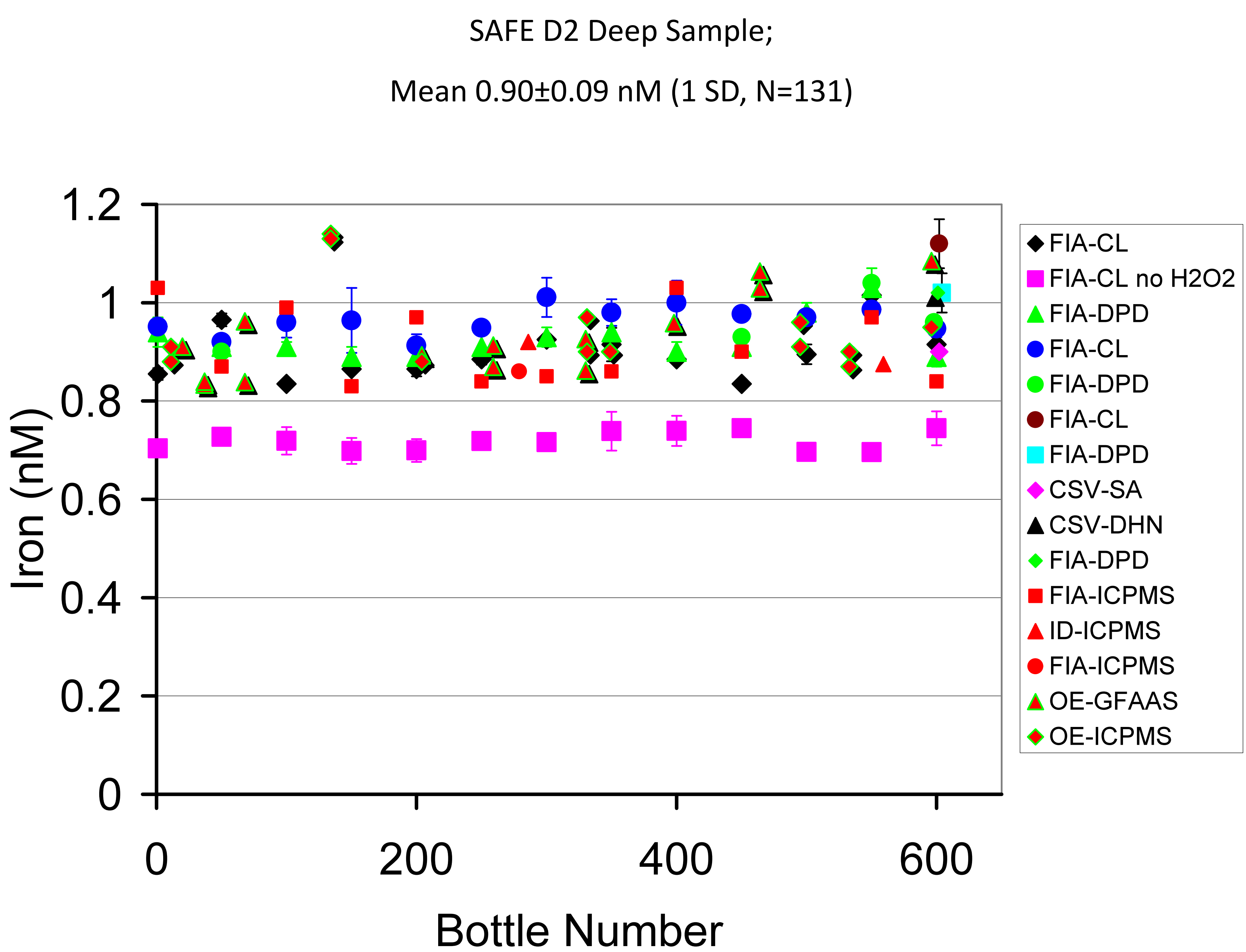
Vol. 88, No. 11, 13 March 2007

Developing Standards for Dissolved Iron in Seawater




SAFE D2 Deep Sample;
Mean 0.90±0.09 nM (1 SD, N=131)
Iron (nM)
1.2
1
0.8
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FIA-CL
FIA-CL no H2O2
FIA-DPD
FIA-CL
FIA-DPD
FIA-CL
FIA-DPD
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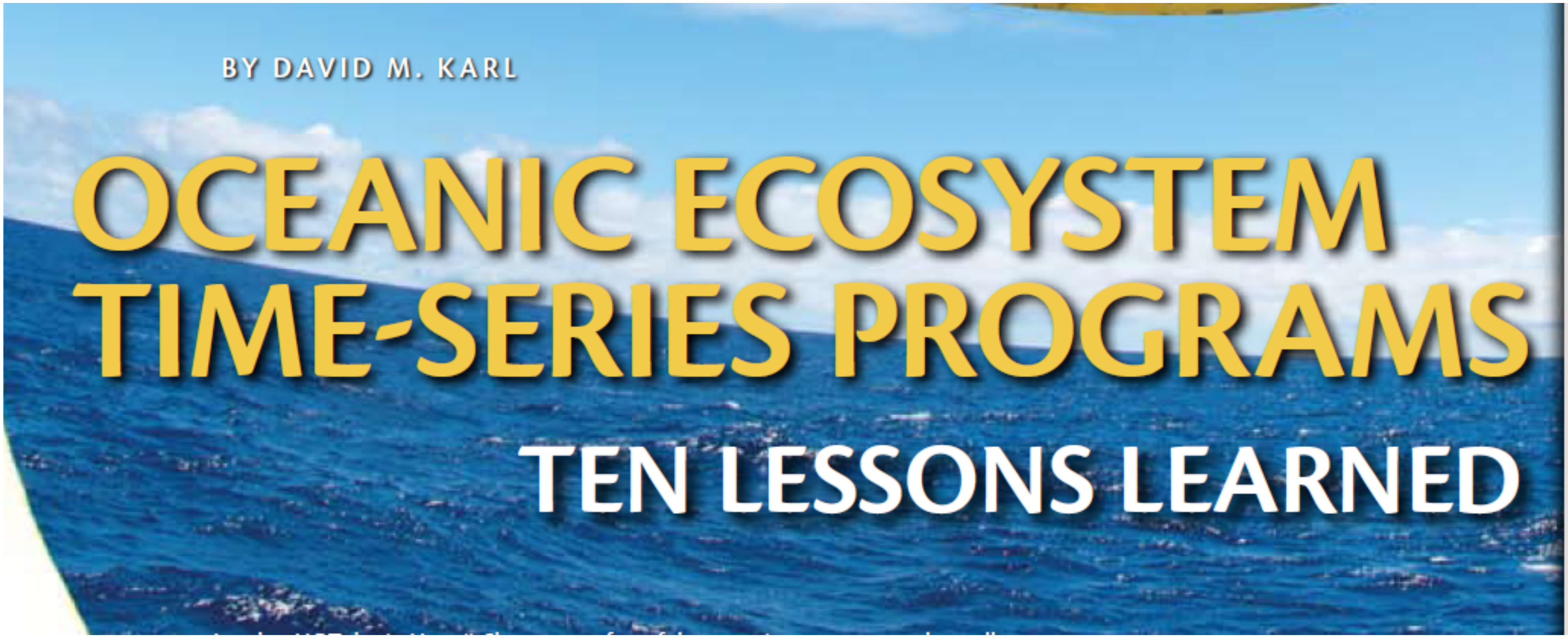
OE-ICPMS



We (you) need to implement these lessons across time series.