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Nutrients, Chlorophyll, Primary Production and Related Biogeochemical Properties in the Ocean Mixed Layer

A Compilation of Data Collected at Nine JGOFS Sites

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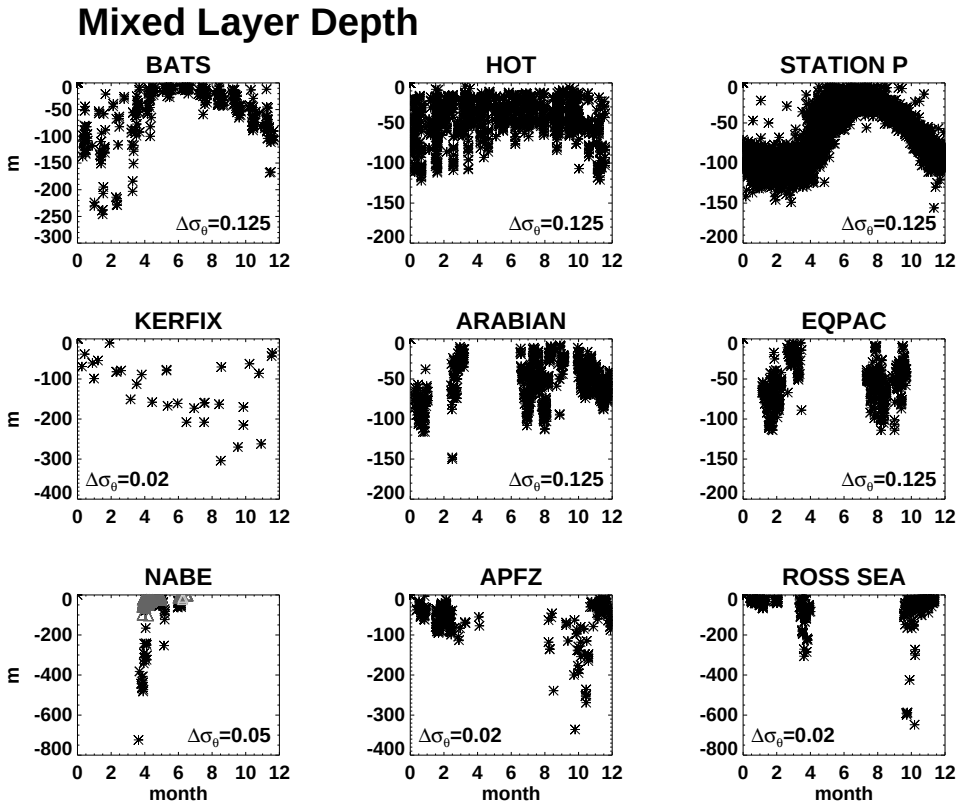

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Preface

Field measurements of nutrients, chlorophyll, primary production and other biogeochemical parameters are compiled for nine JGOFS time-series and process study sites. Daily mixed layer depths are determined for each site and then used to calculate average mixed layer concentrations for each available parameter. The data span a range of biogeochemical regimes from oligotrophic zones, classic spring bloom and high-nitrate low-chlorophyll (HNLC) environments. The resulting data sets should facilitate regional and global ecosystem model development by providing a consistent, quality controlled set of observations for key JGOFS sites. Data are presented for four Time-Series locations: BATS, HOT, KERFIX, and Station P, and four U.S. JGOFS Process Study sites: Arabian Sea, Equatorial Pacific (EqPac), North Atlantic Bloom Experiment (NABE), and the U.S. Southern Ocean Survey (which includes two distinct regions: the Ross Sea and Antarctic Polar Front Zone). These data are described in this report, including a description of data sources, methodologies, and results with a focus on the seasonal cycle composites. The data and documentation are available electronically through the Data Support Section at the National Center for Atmospheric Research (*http://dss.ucar.edu/datasets/ds259.0)*.

1. INTRODUCTION

Global carbon cycle models are becoming more prevalent and sophisticated as the scientific community seeks to understand how various earth systems will respond to increasing CO_2 in the atmosphere. The role of the biosphere, particularly in the marine environment, is gaining more attention as physical and biological modelers alike realize that the ocean's role in the carbon cycle may be largely influenced by biogeochemical reactions in the upper ocean. The fixing of inorganic carbon by phytoplankton in the euphotic zone (production), largely depends on physical processes to deliver limiting macronutrients from deeper oceanic zones. The ultimate fate of that production is in turn controlled by physics (advection, mixing), and by biological processes such as how various food webs package the carbon into sinking particles or dissolved organic matter (DOM), how much is recycled in the euphotic zone, and how much is exported as sinking material or DOM. Net community export production is a measure of how much fixed carbon is removed from the surface ocean. These values are difficult to obtain on a global or even regional basis, and vary widely from studies based on satellite data (e.g. Field *et al.* 1998), empirical and theoretical temperature relationships (e.g. Laws et al. 2000) and ecosystem models (e.g. Moore et al. in press(a), in press(b)).

Bringing these various approaches toward a more complete understanding of upper ocean carbon cycle science has been a standing goal of the U.S. JGOFS Synthesis and Modeling Project (U.S. JGOFS 1997). This technical report is an effort to provide investigators with physical, biological and chemical data in a common format for various sites around the globe (Fig. 1). The ideal locations for reporting such data are the time-series stations. These provide regular observations over long time periods and capture both the natural variability and long-term trends at specific locations. In addition, detailed process study investigations have been conducted in most major oceans. These studies were typically confined to a few years of sampling at most, but each provides a wealth of contemporaneous data at the regional scale.

This technical report provides summary data for nine distinct US JGOFS and international JGOFS sites. Four of these are point-locations where long-term time-series data have been collected: the Bermuda Atlantic Time-series Study (BATS); the Hawaiian Ocean Time-series (HOT); KERFIX, the French JGOFS site; and Station P, the Canadian JGOFS time-series station. The remaining sites are U.S. JGOFS Process Study sites: Arabian Sea; Equatorial Pacific (EqPac); North Atlantic Bloom Experiment (NABE); and the Antarctic Environment and Southern Ocean Survey (AESOPS) (which includes two distinct regions:

the Ross Sea and Antarctic Polar Front Zone). To provide an easy to use, practical presentation of data from each of these sites, both depth-profile data and the mixed layer average for each variable are determined on a cast-by-cast basis. Where possible, data are also standardized to common units. These data are available through the Data Support Section of the National Center for Atmospheric Research (*http://dss.ucar.edu/datasets/*) as dataset 259.0.

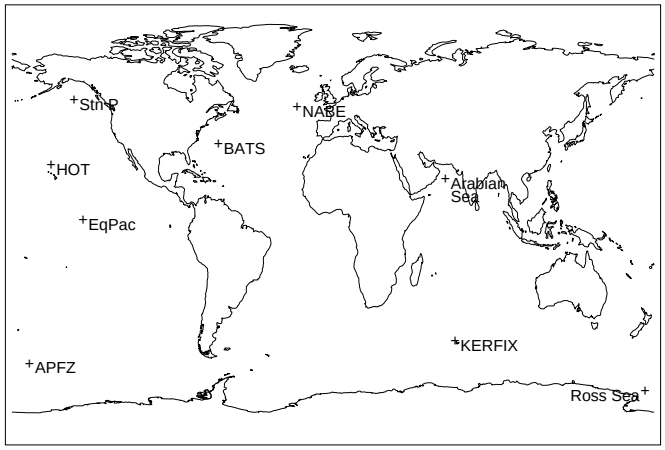

Fig. 1. Location of time-series stations and process study sites included in this report.

2. BASIC METHODOLOGY

2.1 DETERMINATION OF MIXED LAYER DEPTH

The mixed layer is that part of the surface ocean that is turbulently mixed by atmospheric processes (predominantly wind). A number of criteria are used as a measure of the mixed layer depth (MLD), based on temperature, density, or salinity. The reader is referred to You (1995, Appendix) for a concise summary of these criteria.

The criterion used in a particular oceanographic region depends on (1) which variables were measured (i.e., temperature, salinity, or both); (2) whether regional winds homogenize water properties to sufficient depths; and (3) the application (e.g. high frequency variability versus seasonal cycle). For example, the single most commonly used criterion is the depth where potential density (σ_θ) is 0.125 kg m^{-3} greater than the surface value. In most regions other than cold, polar environments, this corresponds closely with depth where temperature is 0.05°C cooler than at the surface (for example, Monterey and Levitus 1997, provide two values of MLDs for the world oceans using each of these criteria).

These two criteria work well in mid-latitudes, where strong winds result in deep, well-mixed surface layers, so that the MLD coincides with both the thermocline and pycnocline.

However, detecting MLD in both low latitude and high latitude oceans is more problematic. At high latitudes, the MLD is often difficult to detect, primarily because the vertical temperature gradient is extremely weak. At low latitudes, light winds result in insufficient mixing, so that the thermocline and pycnocline occur at significantly different depths. This is clearly the case in the EqPac study, where Wilf Gardner noted:

> *"A year ago we submitted to the JGOFS EqPac data base the mixed-layer depths based on a density increase of 0.03 density units from surface values. This was the best fit for MLD compared to looking at the density profiles and noting the depth of the first minor break in slope of σ_θ. This procedure was very sensitive to identifying the slight stratification that resulted from daytime solar heating, especially in regions of colder upwelled water. This also lead to maximizing the diel variation in MLD. We still believe this is the best criterion for investigating short time-scale processes in surface waters. For investigating longer-term processes, however, one might want to consider the MLD based on the commonly used Levitus standard of an increase of 0.125 density units from the surface value."* (Note to EqPac Users: June 22, 1995, *http://usjgofs.whoi.edu/PI-NOTES/Gardner_mixed.html)*

Based on the above observations, we have chosen one or several site-specific criteria to determine MLDs for the JGOFS sites:

Location	**Latitude**	**Longitude**	**Reported Criteria**	**Used in Calculations**
Station P	50°N	145°W	σ_θ=0.03 & 0.125 kg m^{-3}	σ_θ=0.125 kg m^{-3}
BATS	31°40′N	64°10′W	σ_θ=0.03 & 0.125 kg m^{-3}	σ_θ=0.125 kg m^{-3}
			pot. temp=0.1 & 0.5°C †	pot. temp=0.5°C
			temp=0.1 & 0.5°C †	temp=0.5°C
HOT	22°45′N	138°W	σ_θ=0.03 & 0.125 kg m^{-3}	σ_θ=0.125 kg m^{-3}
KERFIX	50°40′S	68°25′E	σ_θ=0.01 & 0.02 kg m^{-3}	σ_θ=0.02 kg m^{-3}
Arabian Sea	10-23°N	57-69°E	σ_θ=0.03 & 0.125 kg m^{-3}	σ_θ=0.125 kg m^{-3}
EqPac	12°N-12°S	140°W	σ_θ=0.03 & 0.125 kg m^{-3}	σ_θ=0.125 kg m^{-3}
APFZ	55-65°S	170°E-170°W	σ_θ=0.01 & 0.02 kg m^{-3}	σ_θ=0.02 kg m^{-3}
Ross Sea	70-73°S	170°E-170°W	σ_θ=0.01 & 0.02 kg m^{-3}	σ_θ=0.02 kg m^{-3}
NABE	47°N	20°W	σ_θ=0.05 & 0.125 kg m^{-3}	σ_θ=0.05 kg m^{-3}

† 0.1°C is usually equivalent to σ_θ =0.03 kg m^{-3}; and 0.5°C is usually equivalent to σ_θ =0.125 kg m^{-3}.

The calculated MLDs for each site are illustrated in Figure 2. When possible, bottle data are used to calculate MLD. However, where bottle data are sparse, CTD data are used.

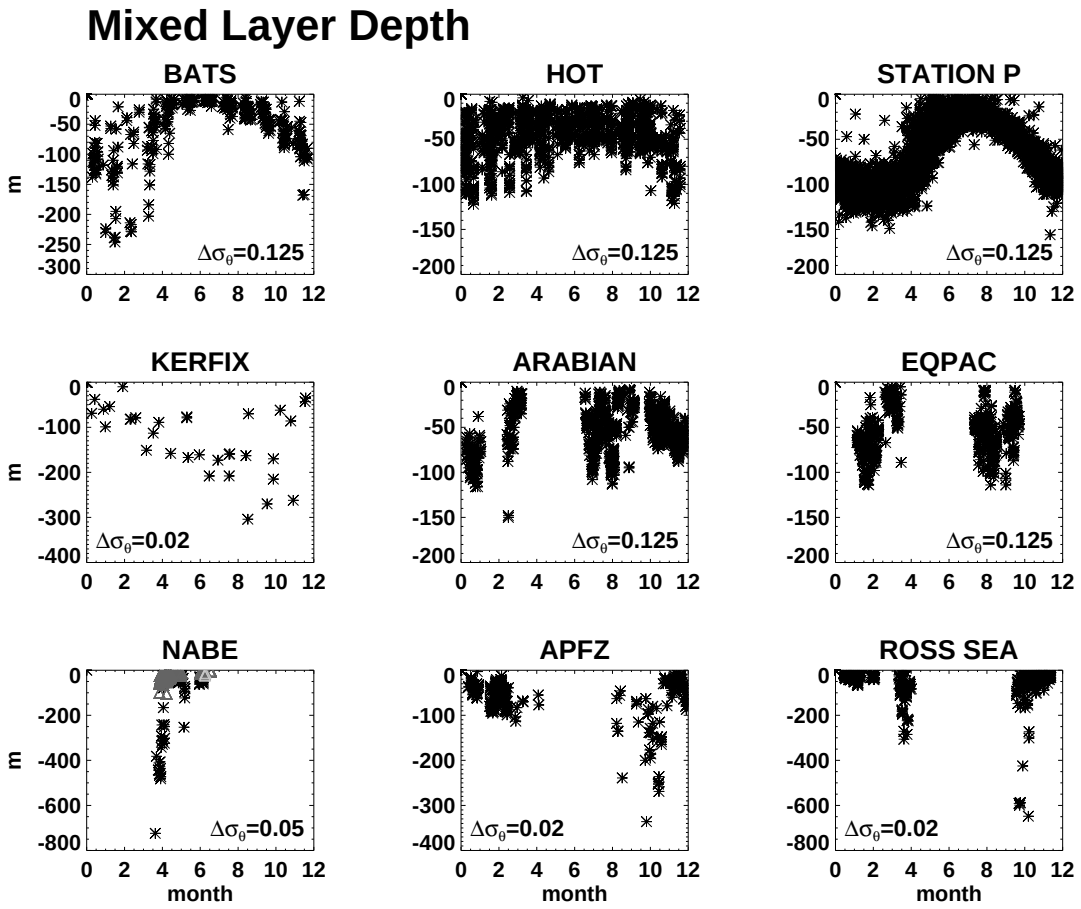

Fig. 2. Composite seasonal cycle of MLDs for each site. Criterion used for determining MLD is also shown. Data from BOFS (triangles) and PRIME (diamonds) taken within the NABE region are also shown. Note change in scale across sites.

MLDs for all stations are reported uniformly according to the following format:

Field	Description	Units
event	event number for cast (for ID purposes; often derived from date and cast no.)	number
date	date	YYMMDD
yday	year day	decimal days
lat	latitude	decimal degrees
lon	longitude	decimal degrees
mld#1	MLD according to criterion #1 (usually: 0.03 σ_θ for low-mid latitudes, 0.02 σ_θ for high latitudes)	m
mld#2	MLD according to criterion #2 (usually: 0.125 σ_θ for low-mid latitudes, 0.05 σ_θ for high latitudes)	m
st_depth	shallowest depth of profile	m

2.2 AVERAGING METHOD

Using the MLDs, we determined mixed layer averages of physical, chemical, and biological variables for each cast. Most physical water properties are fairly uniform or exhibit only weak gradients within the mixed layer (by definition). But this is not true for all biogeochemical properties, in particular primary production, which varies strongly with depth (light). The average mixed layer concentrations of variables are determined using the trapezoidal technique (Figure 3). Mixed layer averages for most of the measured bottle parameters are provided for each study site, along with mixed layer averages of primary production, and pigments. Also provided are the number of samples used to calculate the average.

2.3 PRIMARY PRODUCTION

Nearly every site reported primary production differently, though most sites used similar methodologies (note that no primary production data are available from Station P or KERFIX). We report primary production averaged over the mixed layer, in units standardized as $\mathrm{mmolC\,m^{-3}\,d^{-1}}$. To obtain the integrated production for the mixed layer, one must multiply the average mixed layer production by the mixed layer depth, which yields production in $\mathrm{mmolC\,m^{-2}\,d^{-1}}$.

All primary production measurements at the sites included in this report were performed using ^{14}C incubations. However, primary production estimates are somewhat problematic.

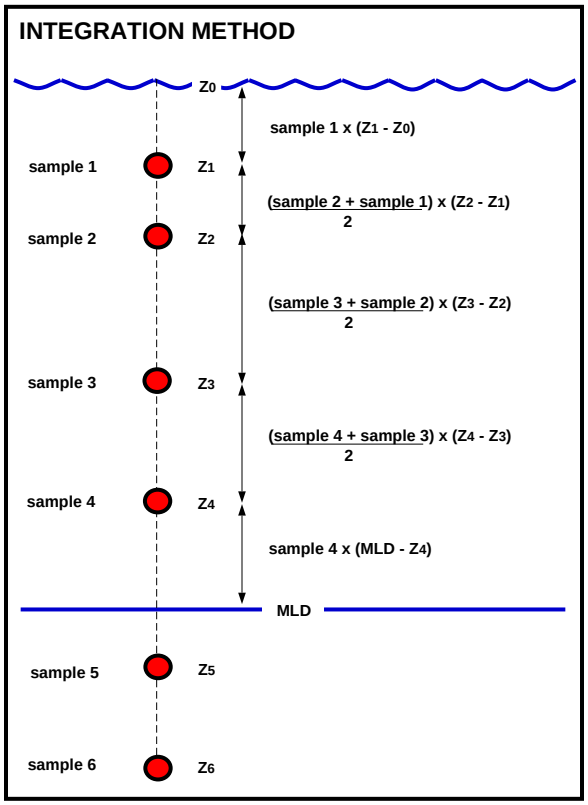

Fig. 3. Trapezoidal method for integrating variables within the mixed layer.

The conceptual and methodological problems of ^{14}C incubations (e.g. assumption that ^{14}C-DOC is negligible; problems of adsorption of ^{14}C-DOC on filters) have been addressed by Karl et al. (1998), and the reader is referred to this paper for further information. Users of these data are also urged to consider the different field methodologies between sites, and how the incubations were originally reported.

Most study sites followed the primary production methodology outlined in the U.S. JGOFS Sampling and Analytical Protocols (see Barber 1993). This procedure uses in situ incubations of companion light and dark bottles at an array of depths within the euphotic zone, (surface to 0.1% I_0 light depth); and primary production is usually determined as the light bottle less the dark bottle production (to account for non-photoautotrophic carbon fixation and adsorption). There are subtle differences between sites, however. Some studies conducted incubations from dawn to dusk, while others from dawn to dawn. Also, some experiments were conducted "on deck" in the ship laboratory, using water baths and arti-

ficial lighting to simulate those of the in situ array. And finally, some sites report primary production as daily rate while others report rate per incubation period. The following table outlines these differences between sites.

Site	**Type**	**Duration**	**Original Units**
BATS	in-situ	dawn-dusk	$\mathrm{mgC\,m^{-3}\,d^{-1}}$
HOT	in-situ and/or on-deck	dawn-dusk	$\mathrm{mgC\,m^{-3}}$
NABE	in-situ	dawn-dusk	$\mu\mathrm{mol\,C\,L^{-1}\,time\_inc^{-1}}$
		dawn-dawn†	
EqPac	in-situ	dawn-dawn	$\mathrm{mgC\,m^{-3}\,d^{-1}}$
Arabian Sea	in-situ	dawn-dusk	$\mathrm{mgC\,m^{-3}}$
		dawn-dawn†	
Southern Ocean	in-situ and/or on-deck	dawn-dawn	$\mathrm{mmolC\,m^{-3}\,d^{-1}}$

† Dusk-dawn portion of incubation was performed by placing bottles retrieved at dusk into an on-deck incubator for the dusk-dawn period.

The daily ^{14}C primary production rates are usually based on 24 hour incubations, but at both HOT and BATS, incubations were conducted dawn-dusk. The BATS primary production data are reported as $\mathrm{mgC\,m^{-3}\,d^{-1}}$, but at HOT, it is reported as $\mathrm{mgC\,m^{-3}}\mathit{incubation\_period}^{-1}$. According to D. Karl (pers. comm.), "Since primary production does not occur at night (at least not the light dependent kind) ... per light day production estimates are effectively per day, once one deals with what to do about the dark bottles..." When using dawn-dusk incubations, a logical step might be to double the dark respiration values (to account for respiration both at day and night), but this is not always done. For this report HOT primary production rates are standardized to daily rates by merely subtracting the dark bottle value from the light bottle value.

Two sites, NABE and the Arabian Sea, provided concurrent data for both dawn-dusk and dawn-dawn incubations. At NABE, the difference in these estimates was reported as less than 15% (Knudson et al. 1998; Fig. 4). Similarly, a comparison of Arabian Sea 12 hour and 24 hour incubations shows that the 24 hour estimates are consistently lower by about 15–20%, which reflects the additional night-time respiratory loss.

Another difference between the primary production estimates is whether they were performed in situ or on-deck. Both in situ and on-deck incubations were performed in the Ross Sea. The on-deck incubations used the Morel optical model (Morel 1988; Barber et. al. 1997) to estimate light intensity for the simulated incubation depths. A comparison of the two (Fig. 5) reveals that the methods produce results with considerable differences ($r^2 = 0.73$), with on-deck incubations generally resulting in higher estimates.

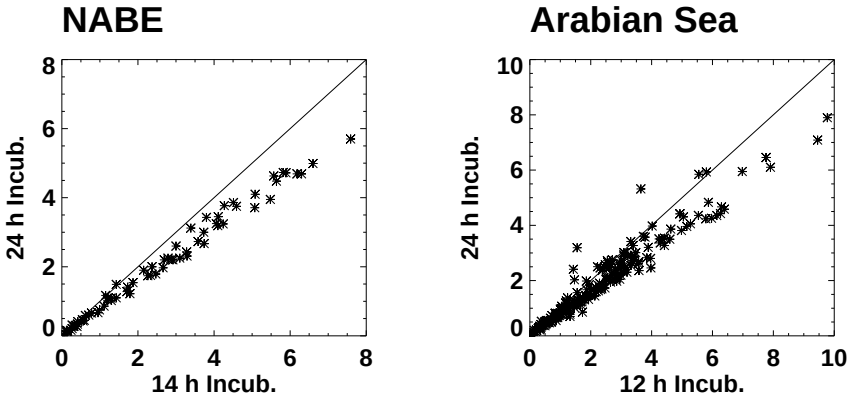

Fig. 4. Comparison of dawn-dawn (24 h) versus dawn-dusk (12 and 14 h) incubations at two sites, NABE and the Arabian Sea. All data are reported as mmolC m^{-3} *incubation_period*$^{-1}$.

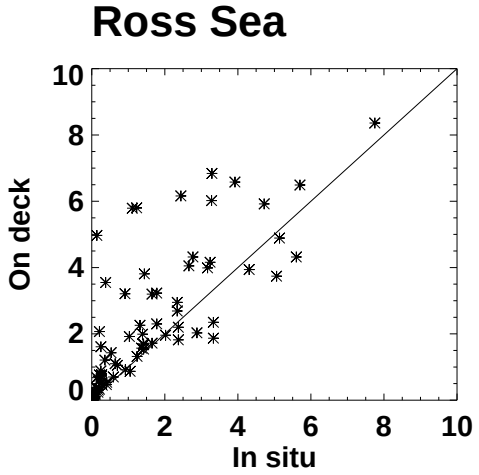

Fig. 5. Comparison of in situ versus on deck incubations at the Ross Sea site. All data are reported as mmolC m^{-3} d^{-1}.

2.4 UNIT CONVERSIONS

The tables in this report list for each variable both the original reported units, and the converted standardized units. For example, most of the time-series sites reported concentrations in mg kg^{-1} or μmol kg^{-1}, while the process study sites reported concentrations in mg L^{-1} or μmol L^{-1}. We adapted a standard of reporting concentrations in reference to water mass, and therefore report most parameters as concentration per kg (usually μmol kg^{-1}). When converting from L^{-1} to kg^{-1}, the measured density of the same water sample is used; when not available, a representative density value for a particular site (e.g. 1026 kg m^{-3}, 1027 kg m^{-3}) is used. Pigment concentrations (e.g., μg L^{-1} or mg m^{-3}) are reported as weight per unit volume (usually mg m^{-3}), primary production as moles per unit volume (mmolC m^{-3} d^{-1}), and bacteria counts as cells$\times 10^8$ L^{-1}, in agreement with the

most commonly used convention for these parameters.

3. RESULTS

The results of the data compilation for each site are reported using the following format:

A. Site description

B. Site-specific methodology

C. Description of reported variables

Each variable at a site is presented as two files: the mixed layer averages (**.dat*), and the discrete profile data (**.pfl*). The file naming convention generally follows the format of *site_type_VAR_crit*.dat and *site_type_VAR*.pfl where:

site	study site (bats=BATS, arab=ARABIAN SEA, etc)
type	type of data (b=bottle, pp=primary production, etc)
VAR	variable analyzed (in caps unless derived from data)
crit	criterion used for mixed layer calculation (Pot_T=potential temperature, Sig_th=σ_θ, Temp=temperature) *Note that only the BATS and KERFIX sites report data using different MLD criteria, so this only exists in files for those sites*

The format for all mixed layer average files is as follows:

event	event number for the cast
date	date as YYMMDD
yday	year day as DDD.dd
lat	latitude
lon	longitude
mld	mixed layer depth
var_surf	surface value
var_avg	average mixed layer value as integrated total/mld
cnt	no. of samples in the mixed layer

3.1 TIME SERIES STATIONS

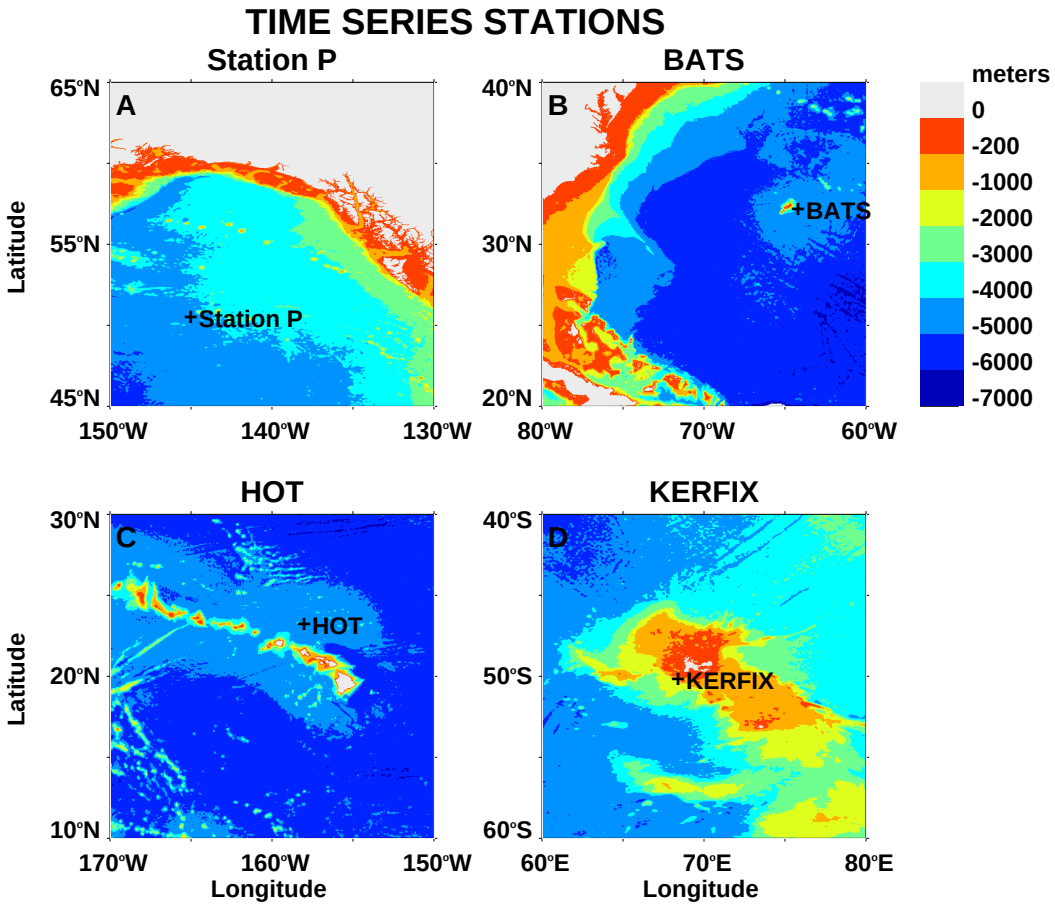

Fig. 6. Time-series stations shown in relation to the surrounding topography (topography extracted from 2-minute topography of Smith and Sandwell 1997).

3.1.1 Station P (Station PAPA) (Fig. 6a)

Nominal Location:	50°N 145°W
Dates of Analysis:	1959 through 1995
Data Source:	Robin Brown Institute of Ocean Sciences P.O. Box 6000 Sidney, B.C. V8L 6B2 CANADA

Station P is essentially subarctic, and is characterized by high nitrate low chlorophyll (HNLC) waters and iron deficiency. The following excerpt, derived from the 1998 Coastal Salinity Workshop report (Woody et al. 1999) held in Hampton, Virginia, il-

lustrates the importance of this time-series station in detecting long-term trends in ocean physics/chemistry.

> *"In the past decade many regions in the world's oceans have experienced a decline in salinity and accompanying changes in the mixed layer depth. This is particularly true for the North Pacific where the mixed layer depth at Ocean Station P (50°N, 145°W) has decreased at a rate of about 63 m/century. Elsewhere in the coastal North Pacific, the mixed layer depth has been decreasing at a rate of about 32 m/century."*

Site-specific Methodology

None.

Description of reported variables

Station P bottle data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
stnp_b_TEMP	temperature	°C	°C
stnp_b_SAL	salinity	PSS	PSS
stnp_b_NIT	nitrate	μmol kg^{-1}	μmol kg^{-1}
stnp_b_PHO	phosphate	μmol kg^{-1}	μmol kg^{-1}
stnp_b_SIL	silicate	μmol kg^{-1}	μmol kg^{-1}
stnp_b_OXY	diss. oxygen	μmol kg^{-1}	μmol kg^{-1}

Station P chlorophyll and zooplankton biomass data

Surface chlorophyll *a* data from Station P were originally compiled by Bruce Frost, who reported all chlorophyll measurements for a given year and day. We matched these data with average MLD for a given day.

Net zooplankton biomass data, also compiled by Bruce Frost, are mean monthly estimates of zooplankton biomass based on the data in Fulton (1980). Frost noted that prior to July 1966 samples were collected with a Norpac net; and after July 1966, with an S4 net. Based on comparisons of coincident data using both nets, Frost increased the original Norpac biomass values by a factor of 1.7705. This data set also included interpolated values for months where no data were available. We eliminated the interpolated values

from the data provided in this report.

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
stnp_chl_SURFCHLA	surf. chlorophyll a	mg m^{-3}	mg m^{-3}
stnp_zoo_ZOO	net zooplankton biomass	mg wet wt m^{-3}	mg wet wt m^{-3}

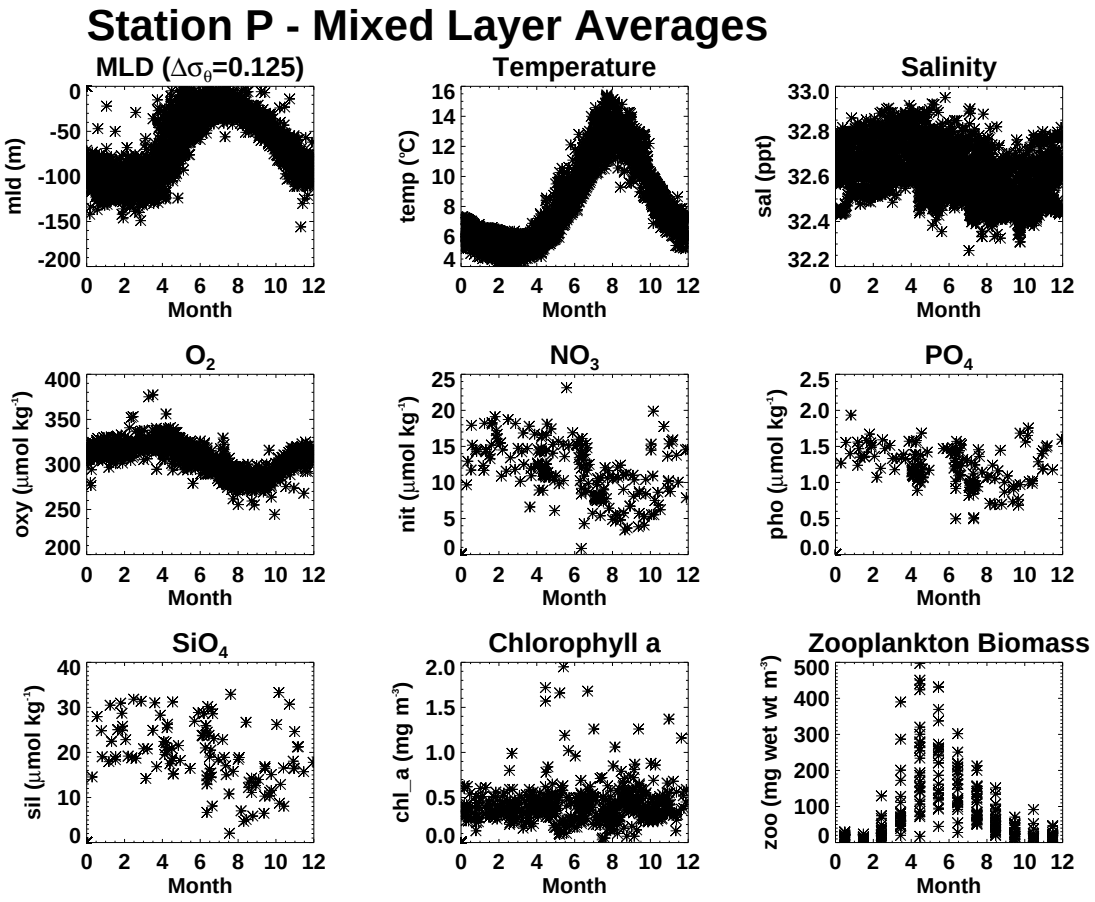

Fig. 7. Mixed layer averages for selected variables from the Station P site.

3.1.2 Bermuda Atlantic Time-series Study - BATS (Fig. 6b)

Site Description	
Nominal Location:	31°40′N, 64°10′W
Dates of Coverage:	BATS CORE data are available beginning in Oct 1988
Dates of Analysis:	Oct 1988 – Dec 31 1999
Data Source:	*http://www.bbsr.edu/users/ctd/*

Site-specific Methodology

For the BATS site, three different methods are used to calculate MLD:

(1) depth where temperature was 0.5°C cooler than at the surface (*Temp*);

(2) depth where potential temperature was 0.5°C cooler than at the surface (*Pot_T*);

(3) depth where σ_θ was 0.125 greater than at the surface (*Sig_th*).

Method in filenames reflect the method used. Each of these produced nearly identical results, but temperature measurements were available for all casts, and using this criterion produces more data points than using either potential temperature or σ_θ.

Description of reported variables

BATS bottle data

FILENAME†	VARIABLE	ORIG UNITS	FINAL UNITS
bats_b_MLD_*method*	mixed layer depth	m	m
bats_b_T_*method*	temperature (bottle)	°C	°C
bats_b_SAL_*method*	salinity	PSS	PSS
bats_b_ANOM1_*method*	O_2 anomaly #1	μmol kg^{-1}	μmol kg^{-1}
bats_b_ANOM2_*method*	O_2 anomaly #2	μmol kg^{-1}	μmol kg^{-1}
bats_b_NO2_1_*method*	nitrite	μmol kg^{-1}	μmol kg^{-1}
bats_b_NO3_1_*method*	nitrate	μmol kg^{-1}	μmol kg^{-1}
bats_b_PO4_1_*method*	phosphate	μmol kg^{-1}	μmol kg^{-1}
bats_b_O2_1_*method*	oxygen	μmol kg^{-1}	μmol kg^{-1}
bats_b_O2_2_*method*	oxygen	μmol kg^{-1}	μmol kg^{-1}
bats_b_SI_1_*method*	silicate	μmol kg^{-1}	μmol kg^{-1}
bats_b_POC_*method*	particulate organic carbon	μg kg^{-1}	μmol kg^{-1}
bats_b_TOC_*method*	total organic carbon	μmol kg^{-1}	μmol kg^{-1}
bats_b_doc_*method*‡	dissolved organic carbon	n/a	μmol kg^{-1}
bats_b_PON_*method*	particulate organic nitrogen	μg kg^{-1}	μmol kg^{-1}
bats_b_TON_*method*	total organic nitrogen	μmol kg^{-1}	μmol kg^{-1}
bats_b_don_*method*§	dissolved organic nitrogen	n/a	μmol kg^{-1}
bats_b_cton_*method*¶	C to N ratio of particulate organic matter	n/a	ratio
bats_b_TCO2_*method*	total carbon dioxide	μmol kg^{-1}	μmol kg^{-1}
bats_b_CHL_*method*	Turner chlorophyll *a*	μg kg^{-1}	mg m^{-3}
bats_b_PHAEO_*method*	Turner phaeopigments	μg kg^{-1}	mg m^{-3}
bats_b_BACT_*method*	bacteria	cells$\times 10^8$ kg^{-1}	cells$\times 10^8$ L^{-1}

† *method* in filenames reflect which mixed layer criterion is used: *Temp* = temperature difference of 0.5°C ; *Pot_T* = potential temperature difference of 0.5°C ; *Sig_th* = density difference of 0.125σ_θ

‡ Calculated as TOC–POC (sample TOC – sample POC; then those values averaged).

§ Calculated as TON–PON (sample TON – sample PON; then those values averaged).

¶ Calculated as ratio of molar concentration of POC to molar concentration of PON.

BATS HPLC pigment data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
bats_hplc_P1_*method*	chlorophyll c_3	ng kg^{-1}	mg m^{-3}
bats_hplc_P2_*method*	chlorophyllide a	ng kg^{-1}	mg m^{-3}
bats_hplc_P3_*method*	chlorophyll $c_1 + c_2$ & chlorophyll Mg 3,8DVPa_5	ng kg^{-1}	mg m^{-3}
bats_hplc_P4_*method*	peridinin	ng kg^{-1}	mg m^{-3}
bats_hplc_P5_*method*	19′-butanoyloxyfucoxanthin	ng kg^{-1}	mg m^{-3}
bats_hplc_P6_*method*	fucoxanthin	ng kg^{-1}	mg m^{-3}
bats_hplc_P7_*method*	19′-hexanoyloxyfucoxanthin	ng kg^{-1}	mg m^{-3}
bats_hplc_P8_*method*	prasinoxanthin	ng kg^{-1}	mg m^{-3}
bats_hplc_P9_*method*	diadinoxanthin	ng kg^{-1}	mg m^{-3}
bats_hplc_P10_*method*	alloxanthin	ng kg^{-1}	mg m^{-3}
bats_hplc_P11_*method*	diatoxanthin	ng kg^{-1}	mg m^{-3}
bats_hplc_P12_*method*	zeaxanthin+lutein	ng kg^{-1}	mg m^{-3}
bats_hplc_P13_*method*	chlorophyll b	ng kg^{-1}	mg m^{-3}
bats_hplc_P14_*method*	chlorophyll a	ng kg^{-1}	mg m^{-3}
bats_hplc_P15_*method*	$\alpha + \beta$-carotene	ng kg^{-1}	mg m^{-3}
bats_hplc_P18_*method*	lutein	ng kg^{-1}	mg m^{-3}
bats_hplc_P19_*method*	zeaxanthin	ng kg^{-1}	mg m^{-3}
bats_hplc_P20_*method*	α-carotene	ng kg^{-1}	mg m^{-3}
bats_hplc_P21_*method*	β-carotene	ng kg^{-1}	mg m^{-3}

BATS primary production data

FILENAME hplc	VARIABLE	ORIG UNITS	FINAL UNITS
bats_pp_LT1_*method*	^{14}C prim prod light btl #1	mgC m^{-3} d^{-1}	mmolC m^{-3} d^{-1}
bats_pp_LT2_*method*	^{14}C prim prod light btl #2	mgC m^{-3} d^{-1}	mmolC m^{-3} d^{-1}
bats_pp_LT3_*method*	^{14}C prim prod light btl #3	mgC m^{-3} d^{-1}	mmolC m^{-3} d^{-1}
bats_pp_DARK_*method*	^{14}C prim prod dark btl	mgC m^{-3} d^{-1}	mmolC m^{-3} d^{-1}
bats_pp_T0_*method*	^{14}C prim prod time 0	mgC m^{-3} d^{-1}	mmolC m^{-3} d^{-1}
bats_pp_PP_*method*	^{14}C prim prod light – dark	mgC m^{-3} d^{-1}	mmolC m^{-3} d^{-1}
bats_pp_THY1_*method*	Bact gr rate, ^{3}H-thym. #1	pmol L^{-1} h $^{-1}$	pmol L^{-1} h $^{-1}$
bats_pp_THY2_*method*	Bact gr rate, ^{3}H-thym. #2	pmol L^{-1} h $^{-1}$	pmol L^{-1} h $^{-1}$
bats_pp_THY3_*method*	Bact gr rate, ^{3}H-thym. #3	pmol L^{-1} h $^{-1}$	pmol L^{-1} h $^{-1}$
bats_pp_THY_*method*	Mean bacterial growth rate	pmol L^{-1} h $^{-1}$	pmol L^{-1} h $^{-1}$

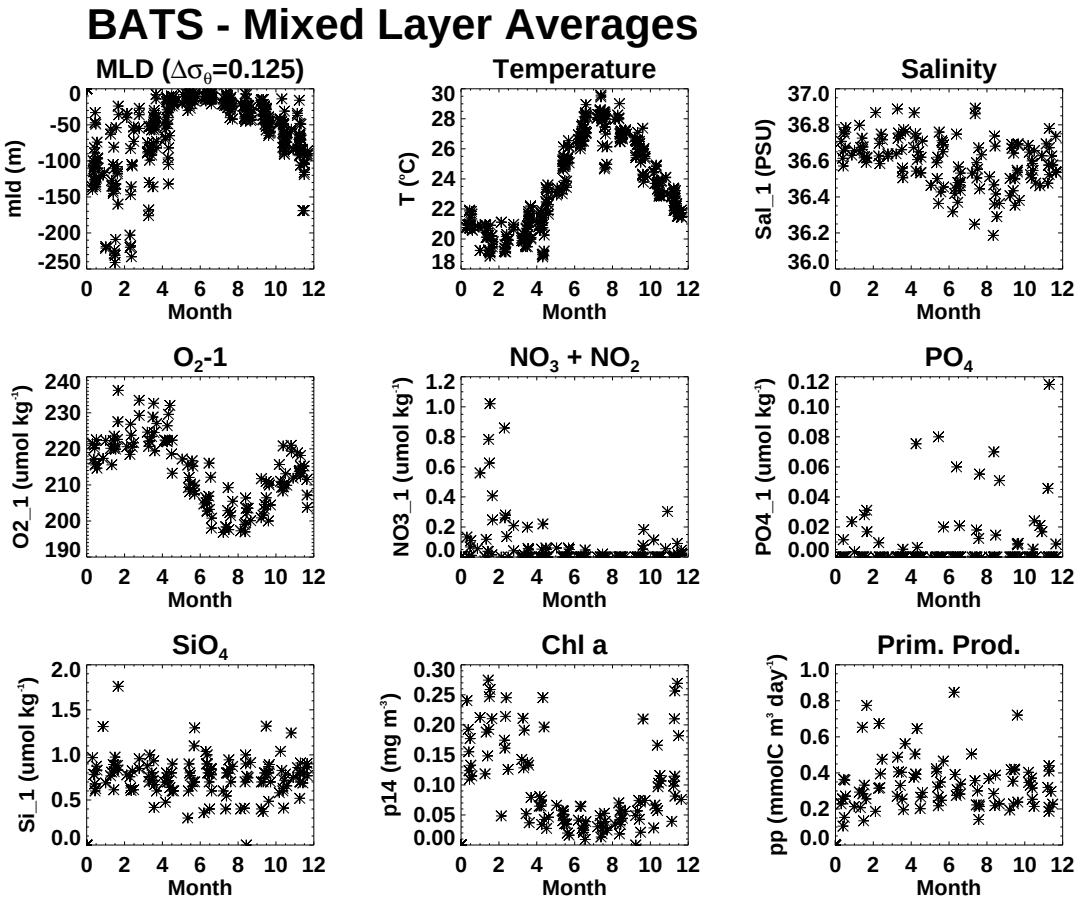

Fig. 8. Mixed layer averages for selected variables from the BATS site.

3.1.3 Hawaiian Ocean Times-series - HOT (Fig. 6c)

Nominal Location:	22°45′N, 158°W (Station ALOHA)
Dates of Coverage:	HOT ALOHA data are available beginning in Oct 1988
Dates of Analysis:	Oct 1988 – Dec 1998
Data Source:	*http://hahana.soest.hawaii.edu/hot/hot-dogs/interface.html*

Site-specific Methodology

None.

Description of reported variables

HOT bottle data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
aloha_b_TEMP	temperature	°C	°C
aloha_b_SAL_CTD	CTD salinity	PSS-78	PSS-78
aloha_b_SAL_BOT	bottle salinity (Autosal)	PSS-78	PSS-78
aloha_b_OXY_BOT	bottle oxygen	μmol kg^{-1}	μmol kg^{-1}
aloha_b_DIC	dissolved inorganic carbon	μmol kg^{-1}	μmol kg^{-1}
aloha_b_PH	pH	pH units	pH units
aloha_b_ALK	alkalinity	μeq kg^{-1}	μeq kg^{-1}
aloha_b_PHOS	phosphate, PO_4	μmol kg^{-1}	μmol kg^{-1}
aloha_b_NIT	NO_3 + NO_2	μmol kg^{-1}	μmol kg^{-1}
aloha_b_SIL	silicate, SiO_4	μmol kg^{-1}	μmol kg^{-1}
aloha_b_DOP	dissolved organic phosphorus	μmol kg^{-1}	μmol kg^{-1}
aloha_b_DON	dissolved organic nitrogen	μmol kg^{-1}	μmol kg^{-1}
aloha_b_DOC	dissolved organic carbon	μmol kg^{-1}	μmol kg^{-1}
aloha_b_TDP	total dissolved phosphorus	μmol kg^{-1}	μmol kg^{-1}
aloha_b_TDN	total dissolved nitrogen	μmol kg^{-1}	μmol kg^{-1}
aloha_b_PC†	particulate carbon	μmol kg^{-1}	μmol kg^{-1}
aloha_b_PN	particulate nitrogen	μmol kg^{-1}	μmol kg^{-1}
aloha_b_cton‡	C to N ratio of particulate matter	n/a	ratio
aloha_b_PPH	particulate phosphorus	nmol kg^{-1}	nmol kg^{-1}
aloha_b_CHL	fluorometric chlorophyll	μg L^{-1}	mg m^{-3}

† Note that particulate carbon includes both particulate organic carbon and particulate inorganic carbon.

‡ Calculated as ratio of molar concentration of PC to molar concentration of PN. Note that this differs from the normal calculation of C:N, which is determined as the molar ratio of POC to PON.

HOT HPLC pigment data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
aloha_hplc_CHL3	chlorophyll c_3	ng L^{-1}	mg m^{-3}
aloha_hplc_CHL12	chlorophyll $[c_1 + c_2]$ & Mg 3,8 DVP4a_5	ng L^{-1}	mg m^{-3}
aloha_hplc_CHLPLUS	chlorophyll c_1, c_2, c_3	ng L^{-1}	mg m^{-3}
aloha_hplc_PERID	peridinin	ng L^{-1}	mg m^{-3}
aloha_hplc_BUT19	19′-butanoyloxyfucoxanthin	ng L^{-1}	mg m^{-3}
aloha_hplc_FUCO	fucoxanthin	ng L^{-1}	mg m^{-3}
aloha_hplc_HEX19	19′-hexanoyloxyfucoxanthin	ng L^{-1}	mg m^{-3}
aloha_hplc_PRASINO	prasinoxanthin	ng L^{-1}	mg m^{-3}
aloha_hplc_DIADINO	diadinoxanthin	ng L^{-1}	mg m^{-3}
aloha_hplc_ZEAXAN	zeaxanthin	ng L^{-1}	mg m^{-3}
aloha_hplc_CHLB	chloropyll b	ng L^{-1}	mg m^{-3}
aloha_hplc_CHLA	chlorophyll a	ng L^{-1}	mg m^{-3}
aloha_hplc_CHLC4	chlorophyll c_4	ng L^{-1}	mg m^{-3}
aloha_hplc_ACAR	α-carotene	ng L^{-1}	mg m^{-3}
aloha_hplc_BCAR	β-carotene	ng L^{-1}	mg m^{-3}
aloha_hplc_CAROTEN	carotene	ng L^{-1}	mg m^{-3}
aloha_hplc_CHLDA	chlorophyllide a	ng L^{-1}	mg m^{-3}
aloha_hplc_VIOL	violaxanthin	ng L^{-1}	mg m^{-3}
aloha_hplc_LUTEIN	lutein	ng L^{-1}	mg m^{-3}
aloha_hplc_MVCHLA	monovinyl chlorophyll a	ng L^{-1}	mg m^{-3}
aloha_hplc_DVCHLA	divinyl chlorophyll a	ng L^{-1}	mg m^{-3}

HOT primary production data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
aloha_pp_CHLA	chlorophyll a	mg m^{-3}	mg m^{-3}
aloha_pp_LT12	light 12	mg C m^{-3} incub-per^{-1}	mmolC m^{-3} d^{-1}
aloha_pp_DK12	dark 12	mg C m^{-3} incub-per^{-1}	mmolC m^{-3} d^{-1}
aloha_pp_pp†	prim. prod, (lt12–dk12)	mg C m^{-3} incub-per^{-1}	mmolC m^{-3} d^{-1}

Calculated as the LT12 value minus the DK12 value.

HOT bacteria data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
aloha_bact_HBACT	heterotrophic bacteria	cells$\times 10^5$ ml^{-1}	cells$\times 10^8$ L^{-1}
aloha_bact_PBACT	Prochlorococcus	cells$\times 10^5$ ml^{-1}	cells$\times 10^8$ L^{-1}
aloha_bact_SBACT	Synechococcus	cells$\times 10^5$ ml^{-1}	cells$\times 10^8$ L^{-1}
aloha_bact_EBACT	eukaryotes	cells$\times 10^5$ ml^{-1}	cells$\times 10^8$ L^{-1}

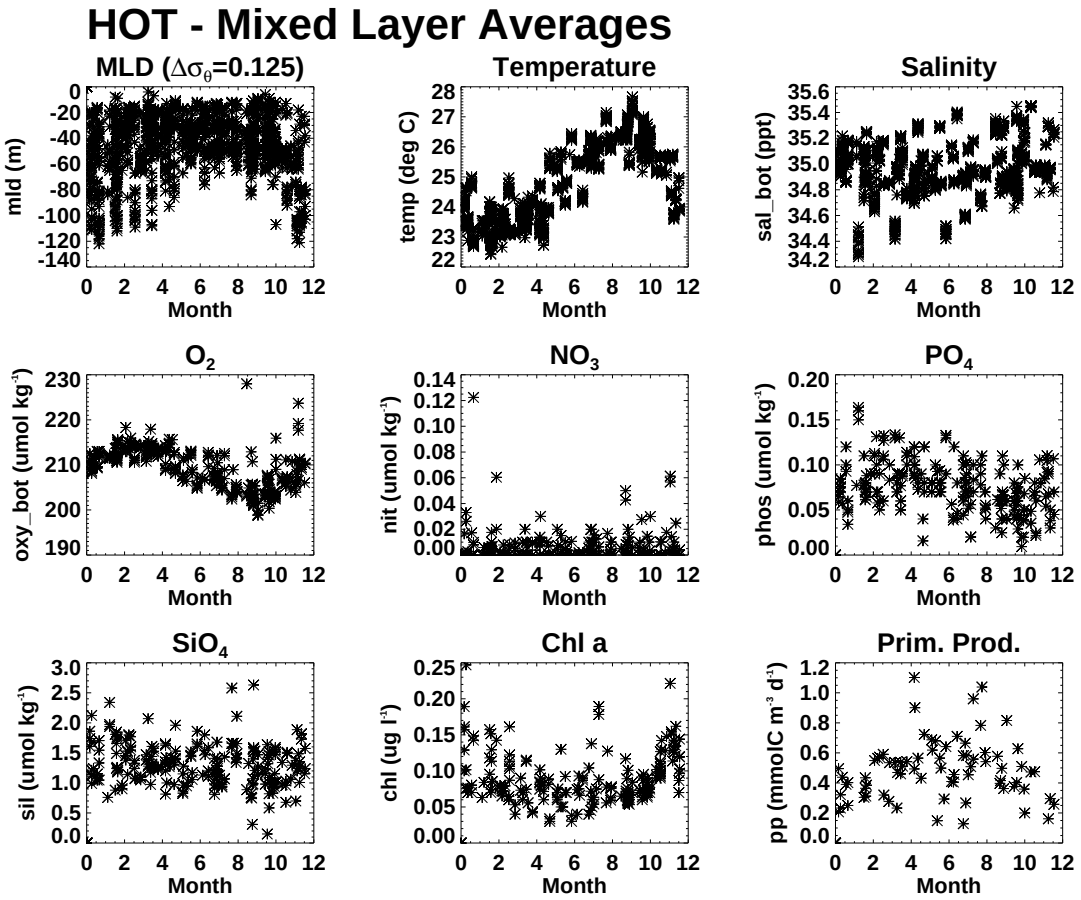

Fig. 9. Mixed layer averages for selected variables from the HOT ALOHA site.

3.1.4 KERFIX (Fig. 6d)

Nominal Location:	50°40′S, 68°25′E, 100km SW of Kderguelen Island
Dates of Coverage:	near-monthly observations between 1990 and 1995.
Dates of Analysis:	Apr 1990 – Mar 1995
Data Source:	*http://www.obs-vlfr.fr/jgofs/html/html/acces_base.html*

Site-specific Methodology

Two sets of data are provided for the KERFIX site. The first is based on MLDs calculated for each cast. These data are consistent with other sites in this report; however, there are numerous casts for which the MLD could not be calculated.

The second dataset is based on MLDs determined by Park et al. (1998). Park et al. provided MLD determinations for most months between Dec 1990 – Dec 1994, in three separate files: for year/month (kerfixmld_ymavg), averaged monthly (kerfixmld_mavg), and the root-mean-squared variability of monthly mld (kerfixmld_rms). His year/month MLDs are used to calculate mixed layer averages of this alternative KERFIX data set. Park's MLDs were determined using a sequence of interpolations: (1) linear interpolation of missing pressure values; (2) linear interpolation to regular depth intervals of 10 m; and finally, (3) linear interpolation to 15th of each month.

Description of reported variables

KERFIX bottle data

FILENAME†	VARIABLE	ORIG UNITS	FINAL UNITS
kerfix_b_TEMP_*method*	temperature	°C	°C
kerfix_b_SAL_*method*	salinity	PSS	PSS
kerfix_b_OXY_*method*	oxygen	μmol L^{-1}	μmol kg^{-1}
kerfix_b_NO3_*method*	nitrate, NO_3	μmol L^{-1}	μmol kg^{-1}
kerfix_b_PO4_*method*	phosphate, PO_4	μmol L^{-1}	μmol kg^{-1}
kerfix_b_SIO2_*method*	silicate, SiO_2	μmol L^{-1}	μmol kg^{-1}
kerfix_b_NH4_*method*	ammonium, NH_4	μmol L^{-1}	μmol kg^{-1}
kerfix_b_CHLA_*method*	chlorophyll *a*	mg m^{-3}	mg m^{-3}
kerfix_b_TCO2_*method*	total CO_2	μmol kg^{-1}	μmol kg^{-1}
kerfix_b_PCO2_*method*	partial pressure of CO_2	μatm	μatm
kerfix_b_ALK_*method*	alkalinity	μeq kg^{-1}	μeq kg^{-1}

† *method* in filenames reflect which MLD determination is used: *botmld* = MLD determined from bottle data; *park* = MLD interpolated from Park et al. (1998) monthly values.

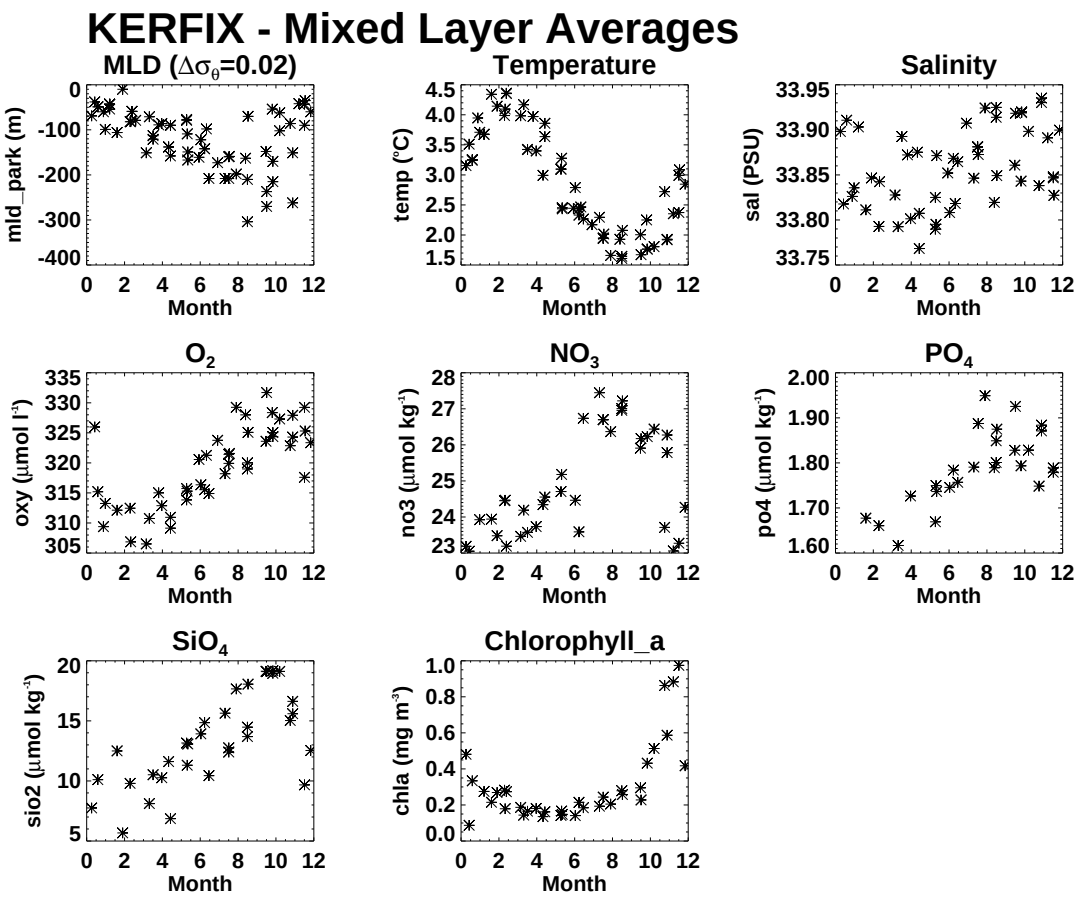

Fig. 10. Mixed layer averages for selected variables from the KERFIX site.

3.2 PROCESS STUDY SITES

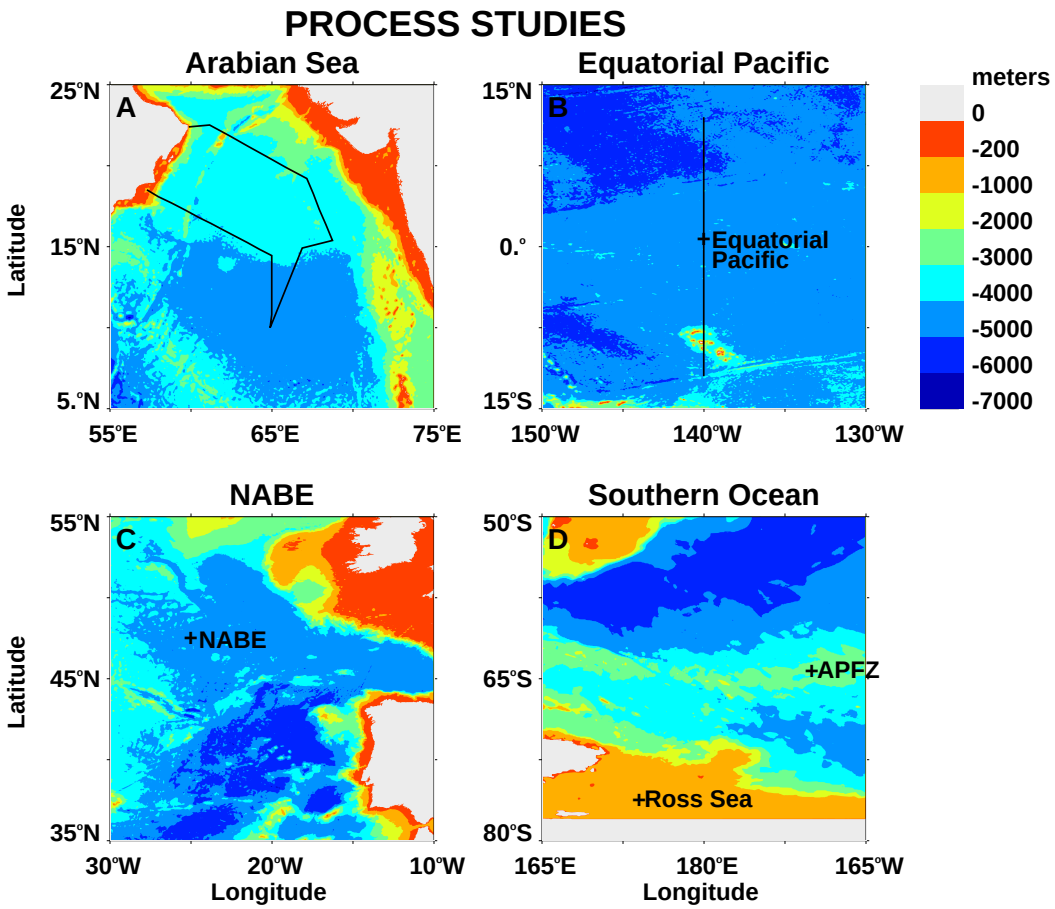

Fig. 11. Process study sites shown in relation to the surrounding topography (topography extracted from 2-minute topography of Smith and Sandwell 1997; except for Southern Ocean (11D) which was extracted from TerrainBase (Row et al. 1994, Row et al. 1995).

3.2.1 Arabian Sea (Fig. 11a)

Regional Coverage:	Arabian Sea from 10–23°N and 57–69°E
Dates of Coverage:	Sep 1994 – Dec 1995
Data Source:	*http://usjgofs.whoi.edu/jg/dir/jgofs/arabian/*

Site-specific Methodology

MLDs, determined for each CTD cast, were already available for most cruises, as provided by Wilford Gardner via the US JGOFS data system. Gardner provided four separate values based on: (a) 0.03 density increase relative to surface; (b) 0.1°C decrease relative to the surface, a nearly equivalent measure to (a); (c) 0.125 density increase relative to surface; and (d) 0.1°C decrease relative to the surface, a nearly equivalent measure to (c).

However, since MLDs were not available for all cruises, these are recalculated according to Gardner's criteria (a) and (c) and using the CTD data from the US JGOFS data server. These "new" MLD files are provided as: ttn-*crno*_mld.dat where *crno* is the Arabian Sea cruise number. The 0.125 density criterion is used to calculate mixed layer averages for Arabian Sea data.

Description of reported variables

Arabian Sea bottle data:

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
arab_b_TEMP	from CTD	°C	°C
arab_b_SAL_CTD	CTD salinity	PSU	PSU
arab_b_SAL_BOT	bottle salinity (Autosal)	PSU	PSU
arab_b_O2_1	oxygen (Winkler)	$\mathrm{ml\,L^{-1}}$	$\mathrm{ml\,L^{-1}}$
arab_b_O2_2	oxygen (Winkler)	$\mu\mathrm{mol\,kg^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
arab_b_O2_3	oxygen (Winkler)	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,L^{-1}}$
arab_b_NO3	nitrate	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
arab_b_PO4	reactive phosphorus	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
arab_b_SiO4	silicic acid/reactive silica	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
arab_b_NO2	nitrite	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
arab_b_NH4	ammonium	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$

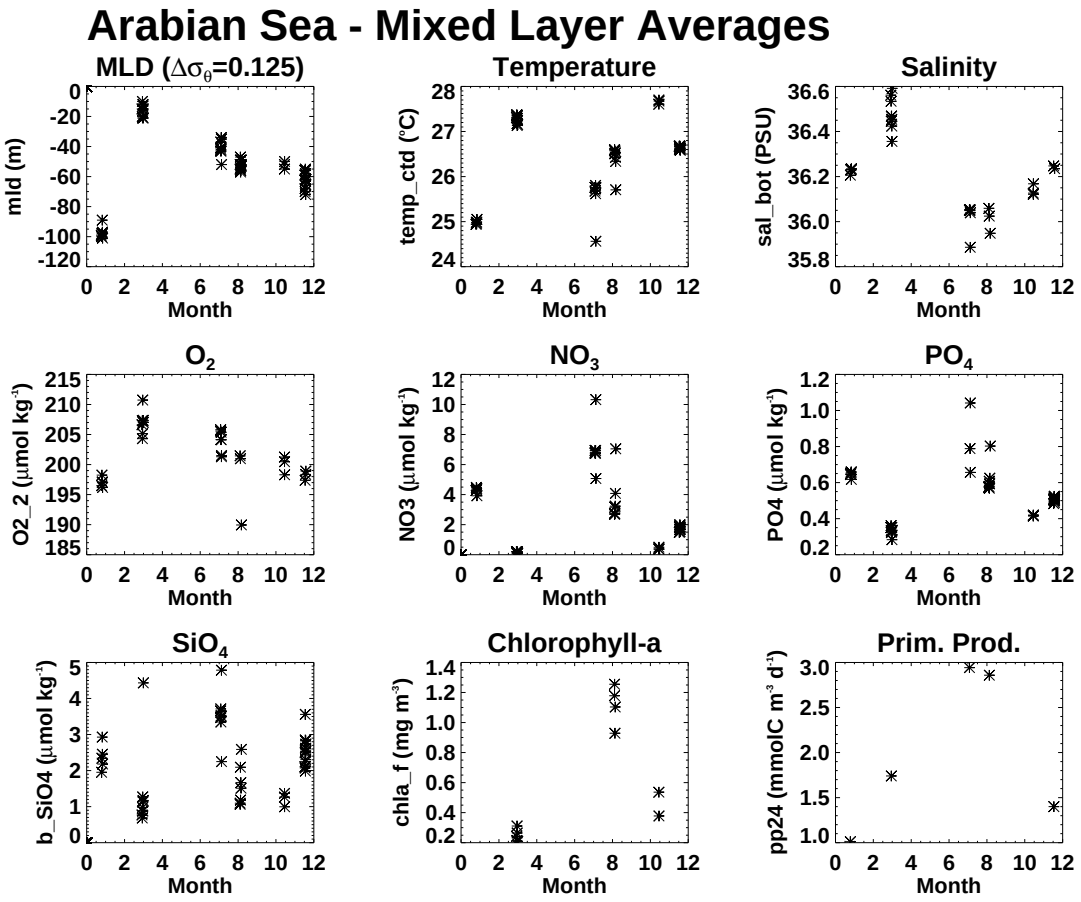

Fig. 12. Mixed layer averages for selected variables from the Arabian Sea Process Study. Because data cover a wide spatial area, shown here is a subset of data from the main data set, extracted for a 1°grid cell centered at 16°N and 62°E.

Arabian Sea primary production

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
arab_pp_CHL_A	chl *a* fluoro. method	mg m^{-3}	mg m^{-3}
arab_pp_PP12	prim. prod., C assim dawn-dusk (12hr)	mgC m^{-3} †	mmolC m^{-3} 12h^{-1}
arab_pp_PB12	C assim. per unit chl *a* dawn-dusk (12hr)	mgC m^{-3} †	mmolC mgChl^{-1} 12h^{-1}
arab_pp_PP24	prim. prod., C assim dawn-dawn (24hr)	mgC m^{-3} †	mmolC m^{-3} d^{-1}
arab_pp_PB24	C assim. per unit chl *a* dawn-dawn (24hr)	mgC m^{-3} †	mmolC mgChl^{-1} d^{-1}

† Stated units are in mgC m^{-3}; the units for both of these values are actually mgC mgChl^{-1} d^{-1}, with one day equivalent to either the 12 h or 24 h incubation.

Arabian Sea chlorophyll-fluorometric data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
arab_df_CHLA_F	chlorophyll a fluorometric	$\mathrm{mg\,m^{-3}}$	$\mathrm{mg\,m^{-3}}$
arab_cf_PHAEO	phaeopigments	$\mathrm{mg\,m^{-3}}$	$\mathrm{mg\,m^{-3}}$

Arabian Sea HPLC pigment data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
arab_hplc_CHL_A1	chlorophyll a	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
arab_hplc_CHL_A1p	chlorophyll a'	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
arab_hplc_CHL_A2	divinyl-chl a	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
arab_hplc_CHL_A_TOT	chl a_1, chl a_2, chl dea, chl a_1', & allomerized chl a	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
arab_hplc_CHL_B1	chlorophyll b	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
arab_hplc_CHL_B2	divinyl-chl b	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
arab_hplc_CHL_B_TOT	sum of chl b_1 and chl b_2	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
arab_hplc_CHL_C	sum of chl c_1, chl c_2, & Mg 3,8 divinyl-pheoporphyrin a_5	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
arab_hplc_CHL_C3	chlorophyll c_3	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
arab_hplc_CHL_C4_1	phytolated chl c	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
arab_hplc_CHL_C4_2	phytolated chl c	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
arab_hplc_CHLIDE_A	chlorophyllide a	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
arab_hplc_CHLIDE_B	chlorophyllide b	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
arab_hplc_PERIDININ	peridinin	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
arab_hplc_FUCOX	fucoxanthin	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
arab_hplc_FUCOX_BUT	19′-butanoyloxyfucoxanthin	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
arab_hplc_FUCOX_HEX	19′-hexanoyloxyfucoxanthin	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
arab_hplc_CIS_FUCOX	cis-fucoxanthin	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
arab_hplc_CIS_HEX	cis-19′-hexanoyloxy-fucoxanthin	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
arab_hplc_CAROTENE_A	α-carotene	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
arab_hplc_CAROTENE_B	β-carotene	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
arab_hplc_CAROTENE	α & β-carotene	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
arab_hplc_ALLOX	alloxanthin	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
arab_hplc_DIADINOX	diadinoxanthin	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
arab_hplc_DIATOX	diatoxanthin	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
arab_hplc_LUTEIN	lutein	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
arab_hplc_NEOX	neoxanthin	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
arab_hplc_PRASINOX	prasinoxanthin	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
arab_hplc_VIOLAX	violaxanthin	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
arab_hplc_ZEAX	zeaxanthin	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$

Arabian Sea bacteria data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
arab_bact_BACT	count of bacteria cells	cells$\times 10^9$ L^{-1}	cells$\times 10^8$ L^{-1}

Arabian Sea particulate organic matter and dissolved carbon data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
arab_poc_POC	particulate organic carbon	μmol L^{-1}	μmol kg^{-1}
arab_poc_PON	particulate organic nitrogen	μmol L^{-1}	μmol kg^{-1}
arab_poc_CTON	C to N ratio of particulate organic matter	ratio	ratio
arab_toc_TOC	total organic carbon	μmol L^{-1}, and μmol kg^{-1}	μmol kg^{-1}
arab_doc †	dissolved organic carbon	n/a	μmol kg^{-1}

† Calculated as difference between particulate organic carbon and total organic carbon

3.2.2 Equatorial Pacific - EqPac (Fig. 11b)

Nominal Track:	N-S line, 12°S – 12°N, along 140°W
Dates of Coverage:	All cruises were conducted within the calendar year 1992.
Data Source:	*http://usjgofs.whoi.edu/jg/dir/jgofs/eqpac/*

Site-specific Methodology

MLDs were provided by Wilf Gardner as two depths: where potential density was 0.03 kg m^{-3} and 0.125 kg m^{-3} greater than the surface. Dr. Gardner recommended using 0.03 kg m^{-3} for short term determinations of MLD (e.g. diel variation) but that for longer-term processes, MLD based on the Levitus standard (0.125 kg m^{-3} difference) may be more appropriate. For our calculations, we used the 0.125 kg m^{-3} criterion.

Description of reported variables

Equatorial Pacific bottle data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
eqpac_b_TEMP_CTD	CTD temperature	°C	°C
eqpac_b_SAL_CTD	CTD salinity	PSS	PSS
eqpac_b_SIGMA_T_CTD	CTD sigma-theta	$\mathrm{kg\,m^{-3}}$	$\mathrm{kg\,m^{-3}}$
eqpac_b_POTEMP_CTD	CTD potential temperature	°C	°C
eqpac_b_SIGMA_0_CTD	CTD potential density	$\mathrm{kg\,m^{-3}}$	$\mathrm{kg\,m^{-3}}$
eqpac_b_O2_BOT	dissolved oxygen (Winkler)	$\mathrm{ml\,L^{-1}}$	$\mathrm{ml\,L^{-1}}$
eqpac_b_O2	dissolved O_2 conc	$\mu\mathrm{mol\,O_2\ kg^{-1}}$	$\mu\mathrm{mol\,O_2\ kg^{-1}}$
eqpac_b_SAL_BOT	bottle salinity	PSS	PSS
eqpac_b_NH4	ammonium	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
eqpac_b_NO3	nitrate	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
eqpac_b_NO2	nitrite	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
eqpac_b_PO4	phosphate	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
eqpac_b_SIO4	silicate	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
eqpac_b_UREA	urea	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
eqpac_b_CHL_A	chlorophyll *a*	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
eqpac_b_PHAEO	total phaeopigments	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
eqpac_b_FO_TO_FA	ratio of fluorometric reading before (Fo) and after (Fa) acidification	ratio	ratio

Equatorial Pacific primary production data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
eqpac_pp_CHL_A	chlorophyll *a*	$\mathrm{mg\,m^{-3}}$	$\mathrm{mg\,m^{-3}}$
eqpac_pp_PP24	primary production, C assimilation	$\mathrm{mgC\,m^{-3}\,d^{-1}}$	$\mathrm{mmolC\,m^{-3}\,d^{-1}}$
eqpac_pp_PB24	chl *a* specific production	$\mathrm{mgC\,mgChl^{-1}\,d^{-1}}$	$\mathrm{mmolC\,mgChl^{-1}\,d^{-1}}$

Equatorial Pacific HPLC pigment data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
eqpac_hplc_CHL_C3	chlorophyll c_3	ng L^{-1}	mg m^{-3}
eqpac_hplc_CLID	chlorophyllide a	ng L^{-1}	mg m^{-3}
eqpac_hplc_CHL_C1_C2	chlorophylls c_1 and c_2	ng L^{-1}	mg m^{-3}
eqpac_hplc_PER	peridinin	ng L^{-1}	mg m^{-3}
eqpac_hplc_FUCOX_BUT	19′-butanoyloxyfucoxanthin	ng L^{-1}	mg m^{-3}
eqpac_hplc_FUCOX	fucoxanthin	ng L^{-1}	mg m^{-3}
eqpac_hplc_FUCOX_HEX	19′-hexanoyloxyfucoxanthin	ng L^{-1}	mg m^{-3}
eqpac_hplc_PRAS	prasinoxanthin	ng L^{-1}	mg m^{-3}
eqpac_hplc_VIOL	violaxanthin	ng L^{-1}	mg m^{-3}
eqpac_hplc_DIAD	diadinoxanthin	ng L^{-1}	mg m^{-3}
eqpac_hplc_ALLOX	alloxanthin	ng L^{-1}	mg m^{-3}
eqpac_hplc_DIATOX	diatoxanthin	ng L^{-1}	mg m^{-3}
eqpac_hplc_ZEA	zeaxanthin	ng L^{-1}	mg m^{-3}
eqpac_hplc_CHL_B	chlorophyll b	ng L^{-1}	mg m^{-3}
eqpac_hplc_ALLOA	allomerized chlorophyll a	ng L^{-1}	mg m^{-3}
eqpac_hplc_CHL_A	chlorophyll a	ng L^{-1}	mg m^{-3}
eqpac_hplc_C4	phytolated chl c-like pigment	ng L^{-1}	mg m^{-3}
eqpac_hplc_CHL_Ap	chlorophyll a'	ng L^{-1}	mg m^{-3}
eqpac_hplc_CAROTENE_A	α-carotene	ng L^{-1}	mg m^{-3}
eqpac_hplc_CAROTENE_B	β-carotene	ng L^{-1}	mg m^{-3}

Equatorial Pacific bacteria data†

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
eqpac_bact_THY_INCORP	thymidine incorporation	pmol $L^{-1}hr^{-1}$	pmol $L^{-1}hr^{-1}$
eqpac_bact_LEU_INCORP	leucine incorporation	pmol $L^{-1}hr^{-1}$	pmol $L^{-1}hr^{-1}$
eqpac_bact_BACT	bacteria abundance	cells$\times 10^6$ ml^{-1}, cells$\times 10^8$ L^{-1}	cells$\times 10^8$ L^{-1}

† For samples from EqPac cruise tt007, Dave Kirchman noted: "... some samples that were clearly anomalous, but again we did not delete or change these. Some of these anomalous values may be due to problems with the CTD bottles, but others are clearly not. (see http://usjgofs.whoi.edu/PI-NOTES/Kirchman_bact.html for details).

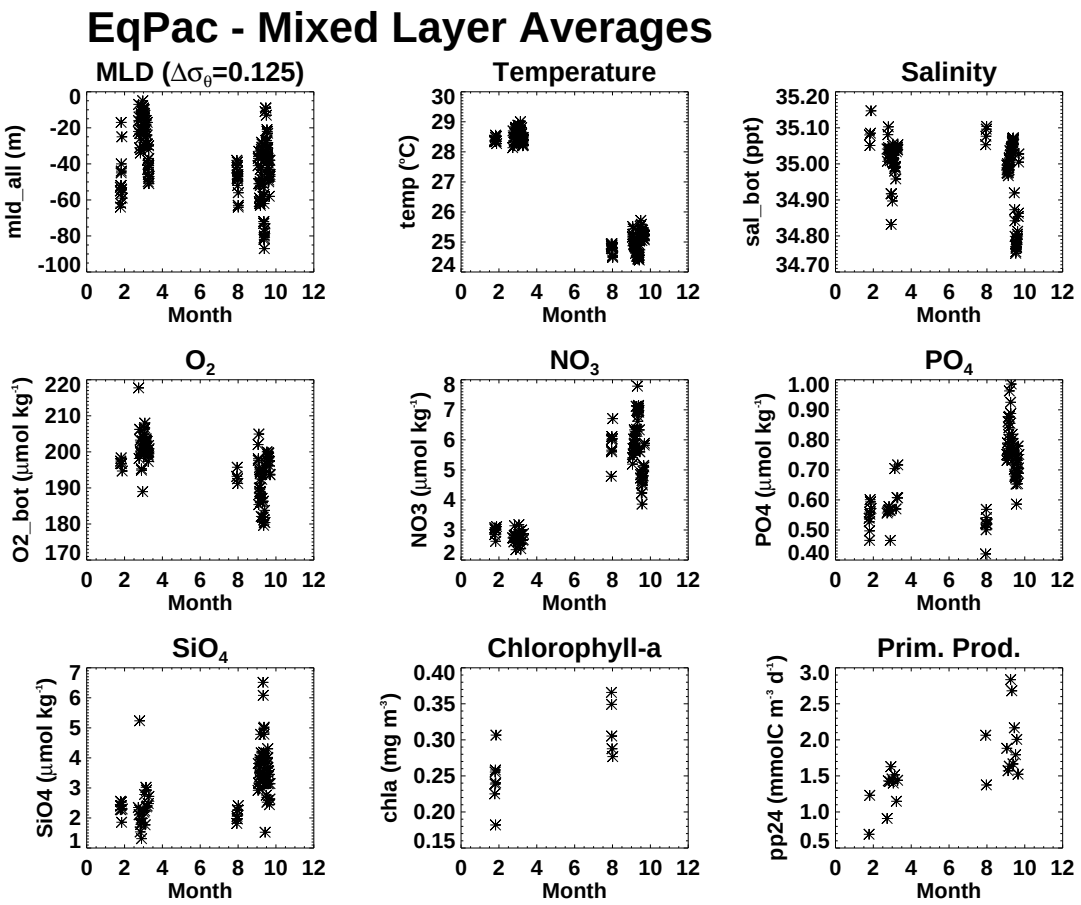

Fig. 13. Mixed layer averages for selected variables from Equatorial Pacific Process Study. Because data cover a wide spatial area, shown here is a subset of data from the main data set, extracted for a 1°grid cell centered at 0°and 140°W.

Equatorial Pacific particulate and dissolved organic matter†

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
eqpac_poc_TPC	total particulate carbon	$\mu g\,L^{-1}$,$\mu mol\,L^{-1}$	$\mu mol\,kg^{-1}$
eqpac_poc_POC	particulate organic carbon	$\mu g\,L^{-1}$,$\mu mol\,L^{-1}$	$\mu mol\,kg^{-1}$
eqpac_poc_DOC	dissolved organic carbon	$\mu g\,L^{-1}$,$\mu mol\,L^{-1}$	$\mu mol\,kg^{-1}$
eqpac_poc_DON	dissolved organic nitrogen	$\mu g\,L^{-1}$,$\mu mol\,L^{-1}$	$\mu mol\,kg^{-1}$
eqpac_poc_CTON	C to N ratio of particulate organic matter	ratio	ratio

† Note that not all cruises report all variables. Also, cruises 7,11 reported values in $\mu g\,L^{-1}$, while cruises 8,12 reported values in micromolar.

3.2.3 North Atlantic Bloom Experiment - NABE (Fig. 11c)

Nominal location:	47°N 20°W
Dates of Coverage:	NABE: intervals between April and August of 1989
	BOFS: intervals between April and August of 1989
	PRIME: Jun–Jul 1995; 6 week campaign in 1996
Data Sources:	(1) *http://usjgofs.whoi.edu/jg/dir/jgofs/nabe/* (2) BOFS Data Set on CD-ROM; (3) PRIME Data Set on CD-ROM; and also (4) Geoff Evans (from Fasham and Evans 1995.)

Site-specific Methodology

NABE cruise data are available from the US JGOFS site for: *Atlantis II* leg 4 (1989 Apr 20 – May 10); *Atlantis II* leg 5 (1989 May 15 – Jun 08); and *Endeavor* (1989 Jun 29 – July 6). Also used in this analysis are data obtained from the Plankton Reactivity in the Marine Environment (PRIME) Project Data Set (Hadziabdic and Cramer 1999), and from the Plankton Biogeochemical Ocean Flux Study (BOFS) (Lowry et al. 1994). Both of these data sets are available on CD-ROMS from the British Oceanographic Data Center (*http://www.bodc.ac.uk/*).

The method of calculating MLD at the NABE location is determined using a criterion of 0.05 σ_θ difference from the surface. This value is used because it produces similar MLDs to those determined by the BOFS method (Lowry et al. 1994) (Fig. 14). Lowry et al. (1994) determined MLD as the depth where a gradient of 0.05°C m^{-1} was sustained for at least 4 m. We calculate MLDs using the criteria of 0.02, 0.05, and 0.125 σ_θ (similarly to that used at other JGOFS sites). The 0.05 σ_θ criterion most closely matches that used for the BOFS calculations.

Bottle, primary production, and pigment data are provided for not only the US JGOFS cruises (NABE), but also for the U.K. cruises (BOFS, and PRIME). In addition, Geoff Evans' original data are provided, which are 0–30 m averages of NO_3, NH_4, PON, zooplankton, and bacteria reported in terms of nitrogen (mmol N m^{-3}); and chlorophyll in mg m^{-3}.

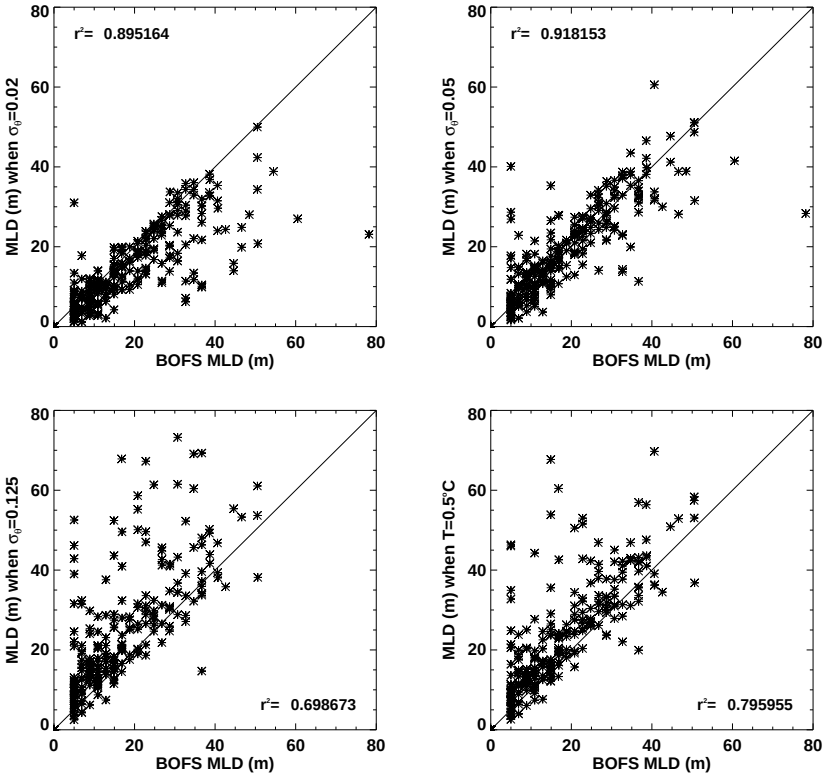

Fig. 14. Comparison of MLDs determined with the criteria: σ_θ = 0.02, 0.05, 0.125; and Temp = 0.5°C , with those determined by BOFS.

Description of reported variables

NABE bottle data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
nabe_b_TEMP	temperature	°C	°C
nabe_b_POTEMP	potential temperature	°C	°C
nabe_b_SAL	salinity	PSU	PSU
nabe_b_SIGMA_T	sigma-t		
nabe_b_O2	oxygen	$\mathrm{ml\,L^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
nabe_b_NO3	nitrate	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
nabe_b_NO2	nitrite	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
nabe_b_PO4	phosphate	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
nabe_b_SIO3	silicate	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
nabe_b_NH4	ammonium	$\mathrm{nmol\,L^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
nabe_b_POC	particulate organic carbon	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
nabe_b_PON	particulate organic nitrogen	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
nabe_b_TALK_b	total alkalinity (Brewer)	$\mu\mathrm{eq\,kg^{-1}}$	$\mu\mathrm{eq\,kg^{-1}}$
nabe_b_TALK_t	total alkalinity (Takahashi)	$\mu\mathrm{eq\,kg^{-1}}$	$\mu\mathrm{eq\,kg^{-1}}$
nabe_b_TCO2_b	total CO_2 (Brewer)	$\mu\mathrm{mol\,kg^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
nabe_b_TCO2_t	total CO_2 (Takahashi)	$\mu\mathrm{mol\,kg^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
nabe_b_PCO2_20	pCO_2 at 20°C (Takahashi)	μatm	μatm

NABE primary production data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
nabe_pp_PP	prim prod *Atlantis* 119,4	μmolC L^{-1} inc_time^{-1}	mmolC m^{-3} d^{-1}
	prim prod *Atlantis* 119,5	mgC m^{-3} d^{-1}	mmolC m^{-3} d^{-1}
	prim prod *Endeavor*	mgC m^{-3} d^{-1}	mmolC m^{-3} d^{-1}

NABE bacteria data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
nabe_biol_BACT	bacterial abundance	cells$\times 10^9$ L^{-1}	cells$\times 10^8$ L^{-1}

NABE pigment data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
nabe_pig_CHL_A	chlorophyll *a*	ng L^{-1}	mg m^{-3}
nabe_pig_PERIDININ	peridinin	ng L^{-1}	mg m^{-3}
nabe_pig_FUCOX_BUT	butanoyloxyfucoxanthin	ng L^{-1}	mg m^{-3}
nabe_pig_FUCOX	fucoxanthin	ng L^{-1}	mg m^{-3}
nabe_pig_FUCOX_HEX	hexanoyloxyfucoxanthin	ng L^{-1}	mg m^{-3}
nabe_pig_DIADINOX	diadinoxanthin	ng L^{-1}	mg m^{-3}
nabe_pig_DIATOX	diatoxanthin	ng L^{-1}	mg m^{-3}
nabe_pig_ZEAX	zeaxanthin	ng L^{-1}	mg m^{-3}
nabe_pig_CAROTENE	carotene	ng L^{-1}	mg m^{-3}

Geoff Evans' Data †

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
nabe_e_NO3	NO_3	mmol N m^{-3}	mmol N m^{-3}
nabe_e_NH4	NH_4	mmol N m^{-3}	mmol N m^{-3}
nabe_e_PON	part. organic nitrogen	mmol N m^{-3}	mmol N m^{-3}
nabe_e_CHL	chlorophyll	mg m^{-3}	mg m^{-3}
nabe_e_BACT	bacteria	mmol N m^{-3}	mmol N m^{-3}
nabe_e_ZOO	zooplankton	mmol N m^{-3}	mmol N m^{-3}

† Data provided by Geoff Evans, are averages for the top 30 m

BOFS bottle data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
bofs_b_TEMP	temperature	°C	degc
bofs_b_SAL	salinity	PSU	PSU
bofs_b_O2	dissolved O_2	μmol L^{-1}	μmol kg^{-1}
bofs_b_NO3	NO_3	μmol L^{-1}	μmol kg^{-1}
bofs_b_NO2	NO_2	μmol L^{-1}	μmol kg^{-1}
bofs_b_PO4	PO_4	μmol L^{-1}	μmol kg^{-1}
bofs_b_SI	SiO_4	μmol L^{-1}	μmol kg^{-1}
bofs_b_NH4	NH_4	μmol L^{-1}	μmol kg^{-1}
bofs_b_CPHYL	chlorophyll	mg m^{-3}	mg m^{-3}

BOFS primary production data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
bofs_c14_PTOT	^{14}C uptake primary production	mgC m^{-2} day^{-1}†	mgC m^{-2} day^{-1}†
bofs_c14_CHLTOT	total chlorophyll (sum: >5μm fraction >1–5μm fraction >0.2–1μm fraction in original BOFS C14DAT file)	mg m^{-3}	mg m^{-3}

† Note that BOFS provided primary production as the integrated value over the euphotic depth. Original units are retained here.

BOFS pigment data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
bofs_pig_CHFL	fluorometric chl	$\mathrm{mg\,m^{-3}}$	$\mathrm{mg\,m^{-3}}$
bofs_pig_PHFL	fluorometric phaeopigments	$\mathrm{mg\,m^{-3}}$	$\mathrm{mg\,m^{-3}}$
bofs_pig_CHLSP	spectrophoto. chl	$\mathrm{mg\,m^{-3}}$	$\mathrm{mg\,m^{-3}}$
bofs_pig_PHSP	spectrophoto. phaeopigments	$\mathrm{mg\,m^{-3}}$	$\mathrm{mg\,m^{-3}}$
bofs_pig_CHLHPLC	HPLC chl a	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
bofs_pig_CHLC3	chlorophyll c_3	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
bofs_pig_CHLC1C2	chlorophyll $c_1 c_2$	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
bofs_pig_CHLB	chlorophyll b	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
bofs_pig_PERID	peridinin	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
bofs_pig_BUTAN	butanoyloxyfucoxanthin	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
bofs_pig_FUCOX	fucoxanthin	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
bofs_pig_HEXOXY	hexanoyloxyfucoxanthin	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
bofs_pig_DIADIN	diadinoxanthin	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
bofs_pig_LUTEIN	lutein	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
bofs_pig_BCAROT	β-carotene	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
bofs_pig_CHLIDEA	chlorophyllide a	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
bofs_pig_PHORBA	phaeophorbide a	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
bofs_pig_PHORBL	phaeophorbide like	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
bofs_pig_PHPHYTA	phaeophytin a	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
bofs_pig_PHPHYTL	phaeophytin like	$\mathrm{ng\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$

PRIME bottle data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
prime_b_TEMP	temperature (unspec. method)	°C	°C
prime_b_TEMP_CTD	temperature (CTD)	°C	°C
prime_b_TEMP_RT	temperature (rev. therm.)	°C	°C
prime_b_POT_TEMP	potential temperature	°C	°C
prime_b_SAL	salinity (unspec.)	PSU	PSU
prime_b_SAL_CTD	salinity (CTD)	PSU	PSU
prime_b_SAL_BENCH	salinity (bench salin.)	PSU	PSU
prime_b_O2_WINK	O_2 (Winkler)	μmol L^{-1}	μmol kg^{-1}
prime_b_O2_BECK	O_2 (Beckmann)	μmol L^{-1}	μmol kg^{-1}
prime_b_O2_SAT	O_2 saturation	%	%
prime_b_NO3_1	nitrate	μmol L^{-1}	μmol kg^{-1}
prime_b_NO2_1	nitrite	μmol L^{-1}	μmol kg^{-1}
prime_b_SIO3_1	silicate	μmol L^{-1}	μmol kg^{-1}
prime_b_CHLA	chl *a* (unspec. method)	μg L^{-1}	mg m^{-3}
prime_b_CHLA_F0	chl *a* (in-situ fluorometry)	μg L^{-1}	mg m^{-3}
prime_b_CHLA_F1	chl *a* (GF/F filtered)	μg L^{-1}	mg m^{-3}
prime_b_CHLA_F2	chl *a* (0.4 μm filtered)	μg L^{-1}	mg m^{-3}
prime_b_CHLA_F5	chl *a* (0.4 μm filtered)	μg L^{-1}	mg m^{-3}
prime_b_PHAEO_F1	phaeopigments (GF/F filtered)	μg L^{-1}	mg m^{-3}
prime_b_DOC	dissolved organic C	μmol L^{-1}	μmol kg^{-1}
prime_b_POC	particulate organic C	μmol L^{-1}	μmol kg^{-1}
prime_b_PON	particulate total N	μmol L^{-1}	μmol kg^{-1}
prime_b_FE_TOTDISS	dissolved total iron	nmol L^{-1}	nmol kg^{-1}
prime_b_FE_LIG_TOTDISS	total dissolved iron complexed by ligands	nmol L^{-1}	nmol kg^{-1}
prime_b_FE_INORG_DISS	total dissolved inorganic iron	nmol L^{-1}	nmol kg^{-1}
prime_b_MESOZOO_BIO	total mesozoopl. biomass computed from cell cnt	mg m^{-3}	mg m^{-3}
prime_b_MICROZOO_BIO	microzoopl. biomass	mgC m^{-3}	mgC m^{-3}
prime_b_MICROZOO_CNT	microzoopl. abundance	cells ml^{-1}	cells ml^{-1}
prime_b_BACT_CNT	total bacteria	cells ml^{-1}	cells ml^{-1}

PRIME primary production data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
prime_b_C_UPTAKE_INSITU	carbon uptake (in situ incubation)	mg m^{-3} d^{-1}	mmolC m^{-3} d^{-1}
prime_b_C_UPTAKE_INCUB	carbon uptake (nat. light incubation)	mg m^{-3} d^{-1}	mmolC m^{-3} d^{-1}
prime_b_CALC_MAX	calcification maximum	see note †	see note †
prime_b_PHOTO_MAX	photosynth. maximum	mgC mgChl^{-1} h^{-1}	mgC mgChl^{-1} h^{-1}

† both original and final units of maximum calcification are mgC (μE m^{-2} s^{-1})$^{-1}$ mgChl^{-1} h^{-1}.

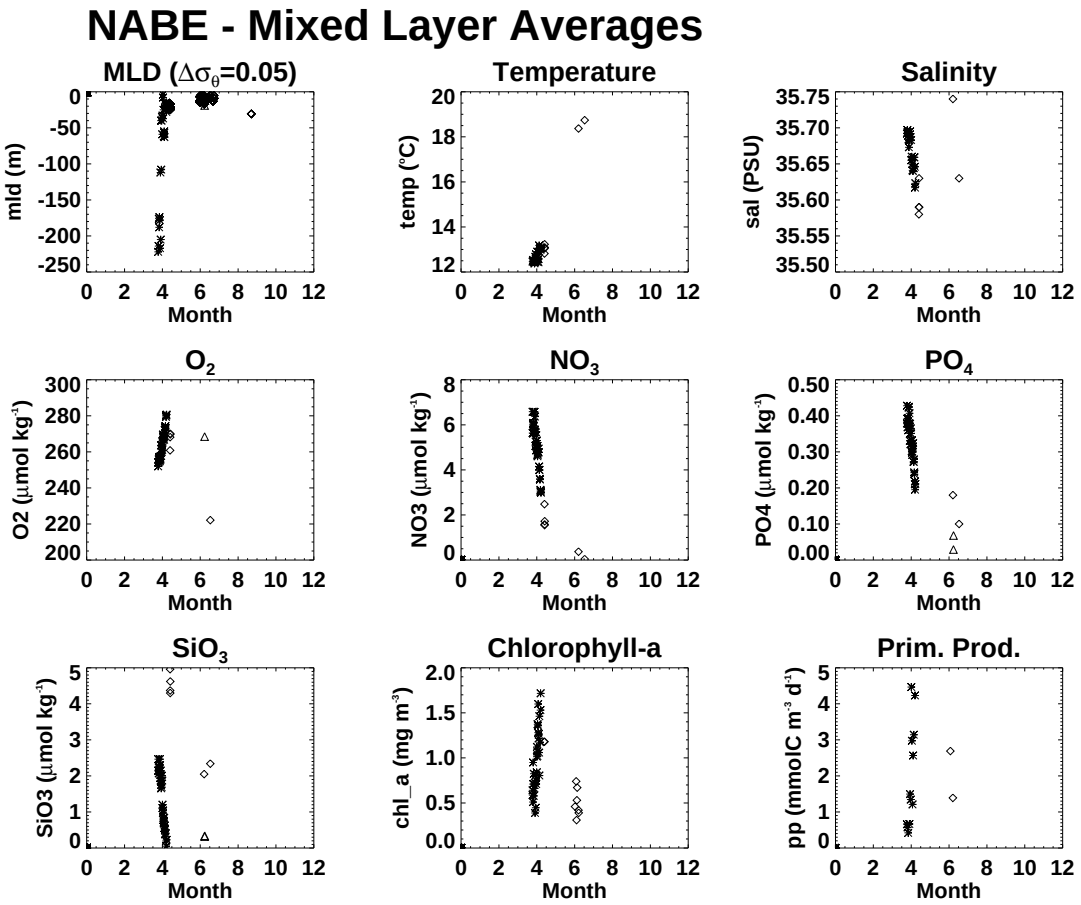

Fig. 15. Mixed layer averages for selected variables from North Atlantic Bloom Experiment, within a 3°grid cell centered at 47°N, 20°W. Asterisk represents US JGOFS NABE samples; diamonds represent BOFS data; and triangles represent PRIME data.

3.2.4 and 3.2.5 SOUTHERN OCEAN REGIONS

US JGOFS sampled two major regions during the Antarctic Environment and Southern Ocean Process Study (AESOPS) cruises, the Antarctic Polar Front Zone (APFZ) and the Ross Sea. Cruises aboard the R/V *Roger A. Revelle*, which included two survey cruises and two process study cruises, were conducted almost entirely in the APFZ. Cruises aboard the R/V *Nathaniel B. Palmer* were conducted primarily in the Ross Sea area, although the site survey cruise (NBP-96-4) and the Benthic Process and Mooring Recovery cruise (NBP-98-2) were centered mainly in the APFZ.

Using data from all of the Palmer and Revelle cruises, we create separate data sets for the Ross Sea and the APFZ. Data are segregated according to geographic location: Those obtained from north of 70°S are included in the APFZ files, while those obtained from

south of 70°S are included in the Ross Sea files.

3.2.4 Antarctic Polar Front Zone (APFZ) (Fig. 11d)

Nominal Region:	60–70°S 165–175°W
Dates of Coverage:	Oct 1997 – Apr 1998
Data Source:	*http://usjgofs.whoi.edu/jg/dir/jgofs/southern/* Directory KIWI includes AESOPS (KIWI) cruises near the APFZ (aboard the *Roger A. Revelle*); for chart cruise tracks see: *http://usjgofs.whoi.edu/images/aesops/revelle.gif*
Added Note:	a significant number of APFZ samples were also obtained on the *Revelle* cruises, see Ross Sea section for more information

Site-specific Methodology

None.

Description of reported variables

APFZ bottle data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
apfz_b_TEMP	ctd temp	°C	°C
apfz_b_SAL_CTD	ctd salinity	PSS	PSS
apfz_b_SAL_BOT	bottle salinity (Autosal)	PSS	PSS
apfz_b_O2_1	oxygen (Winkler)	$\mathrm{ml\,L^{-1}}$	$\mathrm{ml\,L^{-1}}$
apfz_b_O2_2	oxygen (Winkler)	$\mu\mathrm{mol\,kg^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
apfz_b_O2_3	oxygen (Winkler)	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,L^{-1}}$
apfz_b_NO3	nitrate	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
apfz_b_PO4	phosphate	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
apfz_b_SiO4	silicate	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
apfz_b_NO2	nitrite	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
apfz_b_NH4	ammonium	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$

APFZ primary production data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
apfz_pp_CHL_A	chl a, fluorometric	$\mathrm{mg\,m^{-3}}$	$\mathrm{mg\,m^{-3}}$
apfz_pp_PP24	prim. prod., C assim.	$\mathrm{mmolC\,m^{-3}\,d^{-1}}$	$\mathrm{mmolC\,m^{-3}\,d^{-1}}$
apfz_pp_PB24	C assim. per unit chla	$\mathrm{mmolC\,mgChl^{-1}\,d^{-1}}$	$\mathrm{mmolC\,mgChl^{-1}\,d^{-1}}$

APFZ chlorophyll data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
apfz_pig_CHL_A	chl a – fluorometric	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$

APFZ HPLC pigment data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
apfz_hplc_ALLOX	alloxanthin	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
apfz_hplc_CAROTENE_A	α-carotene	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
apfz_hplc_CAROTENE_B	β-carotene	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
apfz_hplc_CAROTENE_G	γ-carotene	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
apfz_hplc_CHL_A1	chlorophyll a_1; [monovinyl chl a]	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
apfz_hplc_CHL_A1p	chlorophyll a_1'	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
apfz_hplc_CHL_A_TOT†	chl a_1, chl a_1', chlide a & allomerized chl a'; [monovinyl chl a & chlide a]	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
apfz_hplc_CHL_B1	chlorophyll b_1; [monovinyl chl b]	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
apfz_hplc_CHL_C12	chlorophyll c_{12}	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
apfz_hplc_CHL_C3	chlorophyll c_3	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
apfz_hplc_P_CHLC3	phytolated chl c_3	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
apfz_hplc_CHLIDE_A	chlorophyllide a	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
apfz_hplc_DIADINOX	diadinoxanthin	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
apfz_hplc_DIATOX	diatoxanthin	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
apfz_hplc_FUCOX	fucoxanthin	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
apfz_hplc_FUCOXANTHIOL	fucoxanthiol	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
apfz_hplc_FUCOX_BUT	19′-butanoyloxyfucoxanthin	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
apfz_hplc_FUCOX_HEX	19′-hexanoyloxyfucoxanthin	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
apfz_hplc_FUCOX_ISO1	fucoxanthin isomer 1	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
apfz_hplc_FUCOX_ISO2	fucoxanthin isomer 2	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
apfz_hplc_LUTEIN	lutein	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
apfz_hplc_PERIDININ	peridinin	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
apfz_hplc_VIOLAX	violaxanthin	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
apfz_hplc_ZEAX	zeaxanthin	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$

† Note different reporting: Palmer cruises describe CHL_A_TOT as "Monovinyl chlorophyll a plus chlorophyllide a"; Revelle cruises describe it as "sum of chl_a1, chlide_a, chl_a1′ and allomerized chl a′s".

APFZ bacteria data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
apfz_bact_BACT_HET	heterotrophic bacteria abund.	cells$\times 10^9$ L^{-1}	cells$\times 10^8$ L^{-1}

APFZ organic carbon and nitrogen data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
apfz_toc_TOC	total organic carbon	μmol L^{-1},μmol kg^{-1}	μmolC kg^{-1}
apfz_doc_DOC	dissolved organic carbon	μmol L^{-1}	μmolC kg^{-1}
apfz_poc_POC	particulate organic carbon	μg L^{-1}	μmolC kg^{-1}
apfz_poc_PON	particulate organic nitrogen	μg L^{-1}	μmolN kg^{-1}
apfz_poc_cton†	carbon to nitrogen ratio of particulate organic matter	n/a	ratio

† C:N ratio is determined as the ratio of POC to PON.

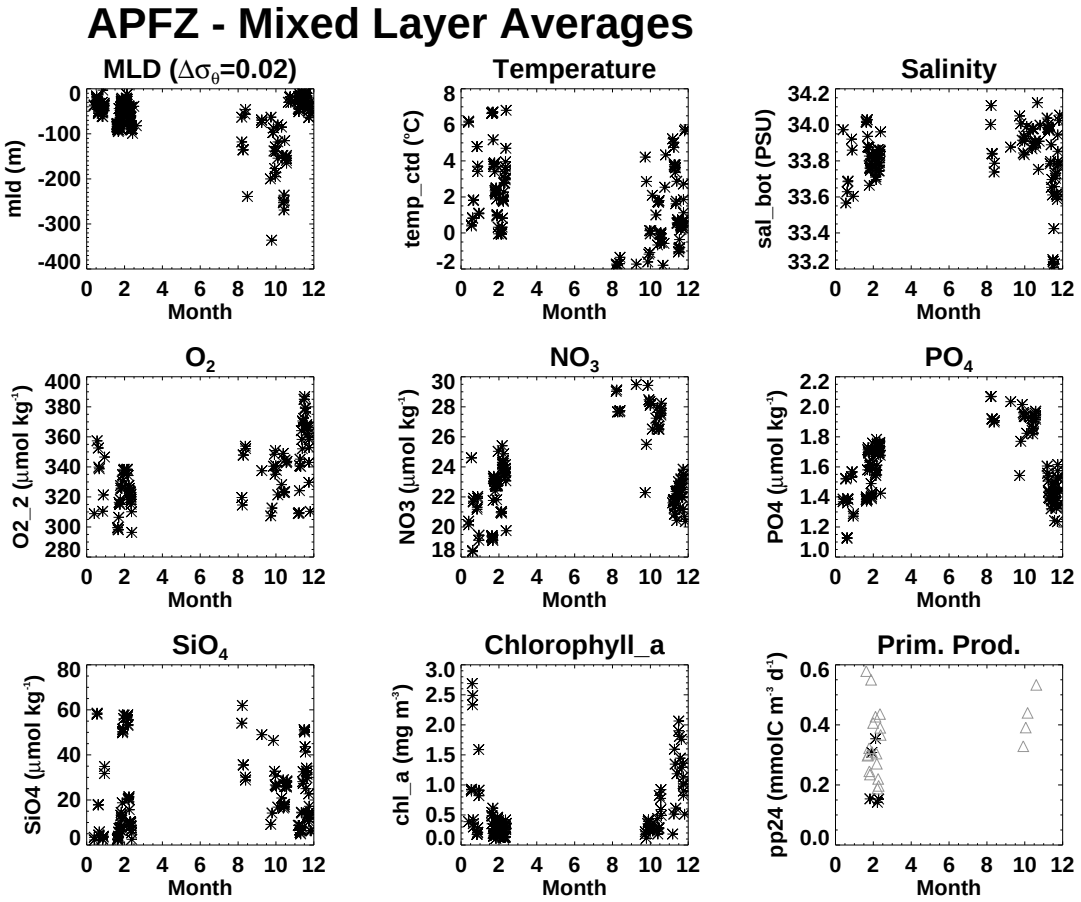

Fig. 16. Mixed layer averages for selected variables from Antarctic Polar Front Zone. For primary production, both in situ (asterisk) and on deck (triangle) incubations are shown.

3.2.5 Ross Sea (Fig. 11e)

Nominal Region:	70–76°S 168°E–175°W
Dates of Coverage:	Sep 1996 – Mar 1998
Data Source:	*http://usjgofs.whoi.edu/jg/dir/jgofs/southern/* Directory ROSS includes data from the *Nathaniel B. Palmer*); cruises; for chart of cruise tracks, see *http://usjgofs.whoi.edu/images/aesops/palmer.gif*
Added Note:	Quite a few locations outside the Ross Sea were also sampled on the *Palmer* cruises (e.g., cruise nbp96_4, a site survey cruise, was primarily in the APFZ).

Site-specific Methodology

None.

Description of reported variables

Ross Sea bottle data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
ross_b_TEMP	ctd temp	°C	°C
ross_b_SAL_CTD	ctd salinity	PSS	PSS
ross_b_SAL_BOT	bottle salinity (Autosal)	PSS	PSS
ross_b_O2_1	oxygen (Winkler)	$\mathrm{ml\,L^{-1}}$	$\mathrm{ml\,L^{-1}}$
ross_b_O2_2	oxygen (Winkler)	$\mu\mathrm{mol\,kg^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
ross_b_O2_3	oxygen (Winkler)	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,L^{-1}}$
ross_b_NO3	nitrate	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
ross_b_PO4	phosphate	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
ross_b_SiO4	silicate	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
ross_b_NO2	nitrite	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$
ross_b_NH4	ammonium	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{mol\,kg^{-1}}$

Ross Sea primary production data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
ross_pp_CHL_A	chl *a*, fluorometric	$\mathrm{mgChl\,m^{-3}}$	$\mathrm{mgChl\,m^{-3}}$
ross_pp_PP24	prim. prod., C assim	$\mathrm{mmolC\,m^{-3}d^{-1}}$	$\mathrm{mmolC\,m^{-3}d^{-1}}$
ross_pp_PB24	C assim per unit chl *a* on-deck incubation	$\mathrm{mmolC\,mgChl^{-1}\,d^{-1}}$	$\mathrm{mmolC\,mgChl^{-1}\,d^{-1}}$
ross_pp_od_CHL_A	chl *a*, fluorometric on-deck incubation	$\mathrm{mgChl\,m^{-3}}$	$\mathrm{mgChl\,m^{-3}}$
ross_pp_od_PP24	prim. prod., C assim on-deck incubation	$\mathrm{mmolC\,m^{-3}d^{-1}}$	$\mathrm{mmolC\,m^{-3}d^{-1}}$
ross_pp_od_PB24	C assim per unit chl *a* on-deck incubation	$\mathrm{mmolC\,mgChl^{-1}\,d^{-1}}$	$\mathrm{mmolC\,mgChl^{-1}\,d^{-1}}$

Ross Sea bacteria data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
ross_bact_BACT_HET	heterotrophic bacteria abund.	$\mathrm{cells{\times}10^{9}\ L^{-1}}$	$\mathrm{cells{\times}10^{8}\ L^{-1}}$

Ross Sea organic carbon and nitrogen data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
ross_toc_TOC	total organic carbon	$\mu\mathrm{mol\,L^{-1}}$,$\mu\mathrm{mol\,kg^{-1}}$	$\mu\mathrm{molC\,kg^{-1}}$
ross_doc_DOC	dissolved organic carbon	$\mu\mathrm{mol\,L^{-1}}$	$\mu\mathrm{molC\,kg^{-1}}$
ross_poc_POC	particulate organic carbon	$\mu\mathrm{g\,L^{-1}}$	$\mu\mathrm{molC\,kg^{-1}}$
ross_poc_PON	particulate organic nitrogen	$\mu\mathrm{g\,L^{-1}}$	$\mu\mathrm{molN\,kg^{-1}}$
ross_poc_cton†	carbon to nitrogen ratio of particulate organic matter	n/a	ratio

† C:N ratio is determined as the ratio of POC to PON.

Ross Sea phaeopigment data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
ross_pig_CHL_A	chlorophyll *a*	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
ross_pig_PHAEO	phaeopigments	$\mu\mathrm{g\,L^{-1}}$	$\mathrm{mg\,m^{-3}}$
ross_pig_FO_TO_FA	ratio of fluoro. readings before (Fo) and after (Fa) acidification	ratio	ratio

Ross Sea HPLC pigment data

FILENAME	VARIABLE	ORIG UNITS	FINAL UNITS
ross_hplc_ALLOX	alloxanthin	$\mu g\,L^{-1}$	$mg\,m^{-3}$
ross_hplc_CAROTENE_A	α-carotene	$\mu g\,L^{-1}$	$mg\,m^{-3}$
ross_hplc_CAROTENE_B	β-carotene	$\mu g\,L^{-1}$	$mg\,m^{-3}$
ross_hplc_CAROTENE_G	γ-carotene	$\mu g\,L^{-1}$	$mg\,m^{-3}$
ross_hplc_CHL_A1	chlorophyll a_1;	$\mu g\,L^{-1}$	$mg\,m^{-3}$
	[monovinyl chl a]	$\mu g\,L^{-1}$	$mg\,m^{-3}$
ross_hplc_CHL_A1p	chlorophyll a_1'	$\mu g\,L^{-1}$	$mg\,m^{-3}$
ross_hplc_CHL_A_TOT†	chl a_1, chl a_1', chlide a & allomerized chl a'; [monovinyl chl a & chlide a]	$\mu g\,L^{-1}$	$mg\,m^{-3}$
ross_hplc_CHL_B1	chlorophyll b_1;		
	[monovinyl chl b]	$\mu g\,L^{-1}$	$mg\,m^{-3}$
ross_hplc_CHL_C	chl c_1, chl c_2 & Mg 3,8 divinyl pheoporphyrin	$\mu g\,L^{-1}$	$mg\,m^{-3}$
ross_hplc_CHL_C12	chlorophyll c_{12}	$\mu g\,L^{-1}$	$mg\,m^{-3}$
ross_hplc_CHL_C3	chlorophyll c_3	$\mu g\,L^{-1}$	$mg\,m^{-3}$
ross_hplc_P_CHLC3	phytolated chl c_3	$\mu g\,L^{-1}$	$mg\,m^{-3}$
ross_hplc_CHLIDE_A	chlorophyllide a	$\mu g\,L^{-1}$	$mg\,m^{-3}$
ross_hplc_DIADINOX	diadinoxanthin	$\mu g\,L^{-1}$	$mg\,m^{-3}$
ross_hplc_DIATOX	diatoxanthin	$\mu g\,L^{-1}$	$mg\,m^{-3}$
ross_hplc_FUCOX	fucoxanthin	$\mu g\,L^{-1}$	$mg\,m^{-3}$
ross_hplc_FUCOXANTHIOL	fucoxanthiol	$\mu g\,L^{-1}$	$mg\,m^{-3}$
ross_hplc_FUCOX_BUT	19′-butanoyloxyfucoxanthin	$\mu g\,L^{-1}$	$mg\,m^{-3}$
ross_hplc_FUCOX_HEX	19′-hexanoyloxyfucoxanthin	$\mu g\,L^{-1}$	$mg\,m^{-3}$
ross_hplc_FUCOX_ISO1	fucoxanthin isomer 1	$\mu g\,L^{-1}$	$mg\,m^{-3}$
ross_hplc_FUCOX_ISO2	fucoxanthin isomer 2	$\mu g\,L^{-1}$	$mg\,m^{-3}$
ross_hplc_LUTEIN	lutein	$\mu g\,L^{-1}$	$mg\,m^{-3}$
ross_hplc_PERIDININ	peridinin	$\mu g\,L^{-1}$	$mg\,m^{-3}$
ross_hplc_PRASINOX	prasinoxanthin	$\mu g\,L^{-1}$	$mg\,m^{-3}$
ross_hplc_VIOLAX	violaxanthin	$\mu g\,L^{-1}$	$mg\,m^{-3}$
ross_hplc_ZEAX	zeaxanthin	$\mu g\,L^{-1}$	$mg\,m^{-3}$

† Palmer and Kiwi cruises report CHL_A_TOT slightly differently: Palmer cruises describe it as "Monovinyl chlorophyll a plus chlorophyllide a"; Revelle cruises describe it as "sum of chl_a1, chlide_a, chl_a1′ and allomerized chl a′s".

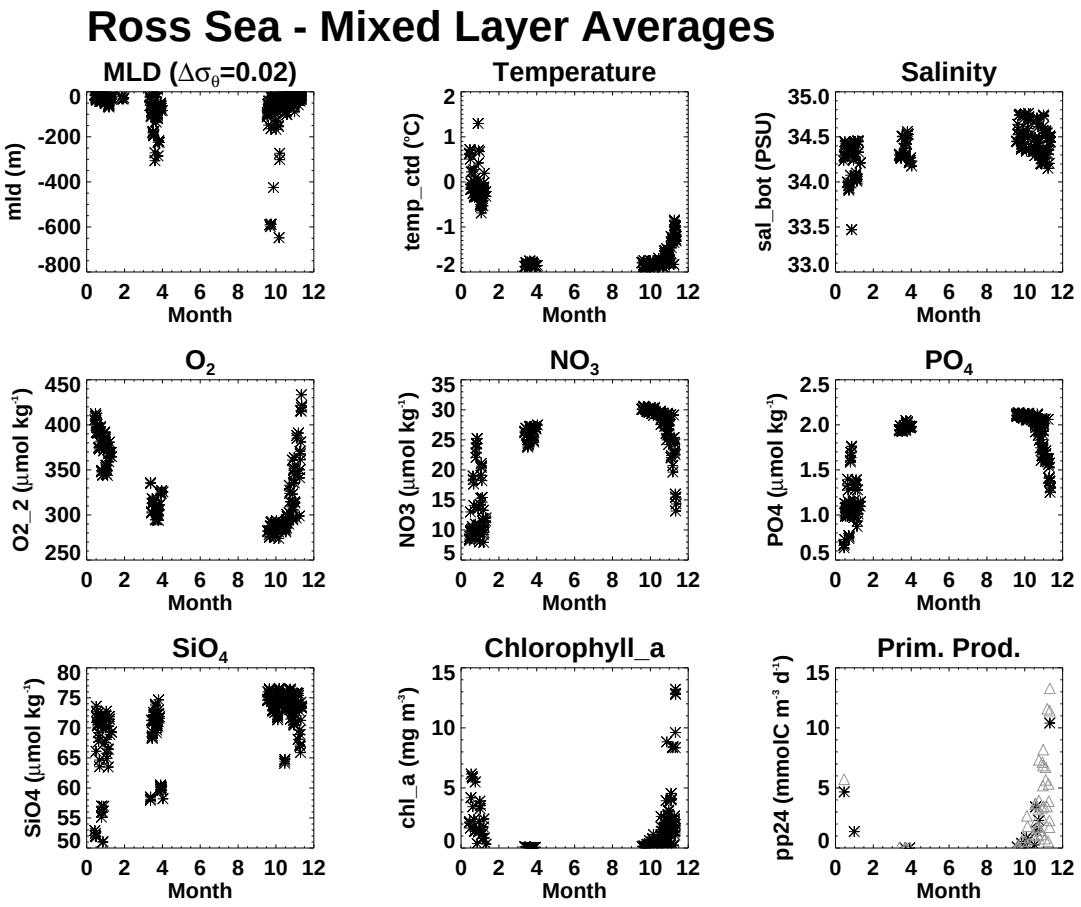

Fig. 17. Mixed layer averages for selected variables from the Ross Sea. For primary production, both in situ (asterisk) and on deck (triangle) incubations are shown.

4. GENERAL NOTES AND OBSERVATIONS

Probably the most important factor to take into account when using these data are the different methodologies applied at the various sites, as well as differences in how data are reported. This is addressed in detail earlier in this report for primary production measurements, but similar caution is recommended with other parameters as well.

For example, surface chlorophyll only is reported at Station P, while all other sites report chlorophyll concentrations for several depths. A comparison of the two measures illustrates that surface chlorophyll and mixed layer chlorophyll are highly correlated at all sites (Fig. 18); but this is certainly not true of all variables.

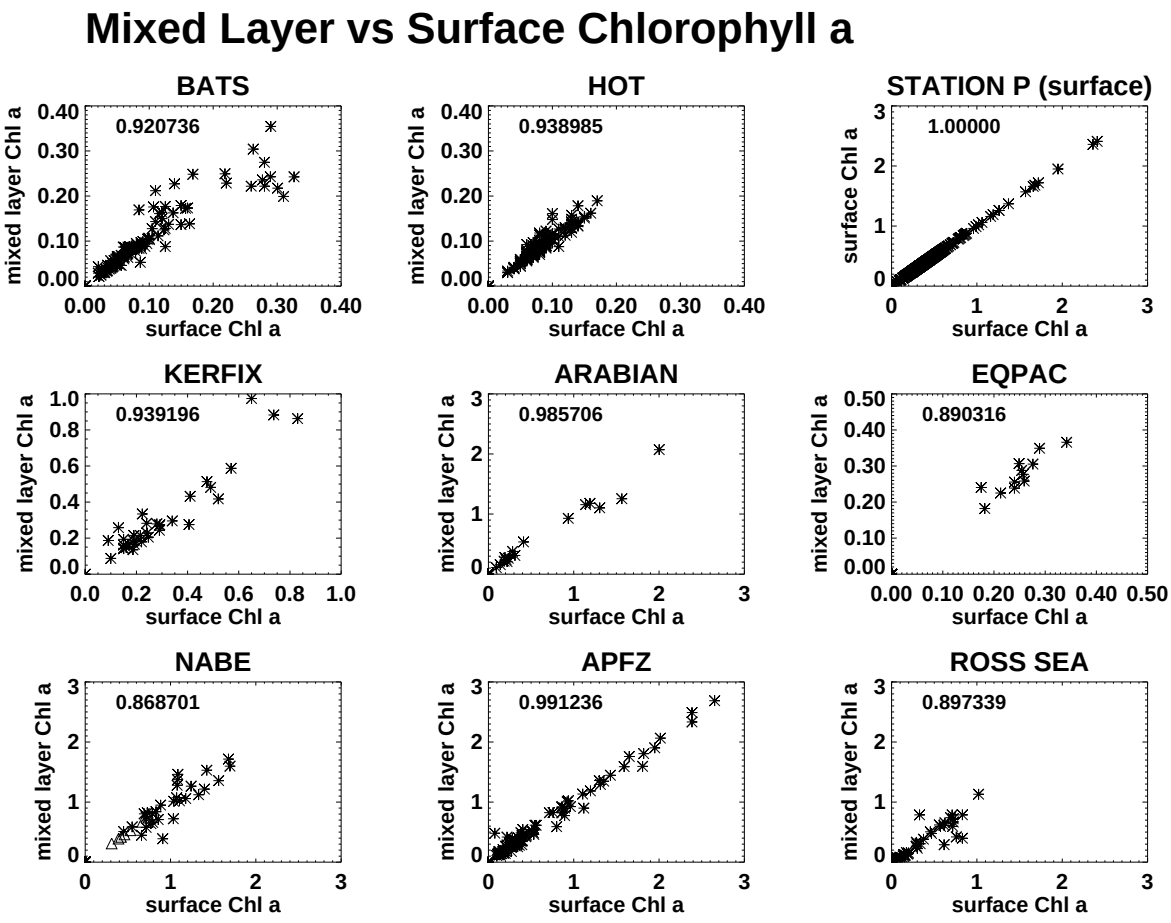

Fig. 18. Mixed layer chlorophyll concentration versus surface chlorophyll concentration ($\mathrm{mg\,m^{-3}}$). Regression coefficients are indicated for each site. Station P has surface values only, but is included for comparison with the other sites.

The ratio of nitrate and phosphate concentrations in the mixed layer varies considerably between sites (Fig. 19). However, caution should be exercised when interpreting NO_3:PO_4 ratios, because nutrient concentrations often drop to very low levels (and at times below detection limits) at these sites.

A better way to examine the relationship between NO_3 and PO_4 is to use the N* determination of Gruber and Sarmiento (1997):

$$N* = N - 16P + constant$$

where: constant = 2.90 $\mu\mathrm{mol\,kg^{-1}}$(Fig. 20). Among the time-series stations, BATS and HOT have a consistent surplus of NO_3 relative to PO_4. N* at KERFIX remains close to 0, but N* concentrations at Station P are low. Low N* concentrations generally indicate a net

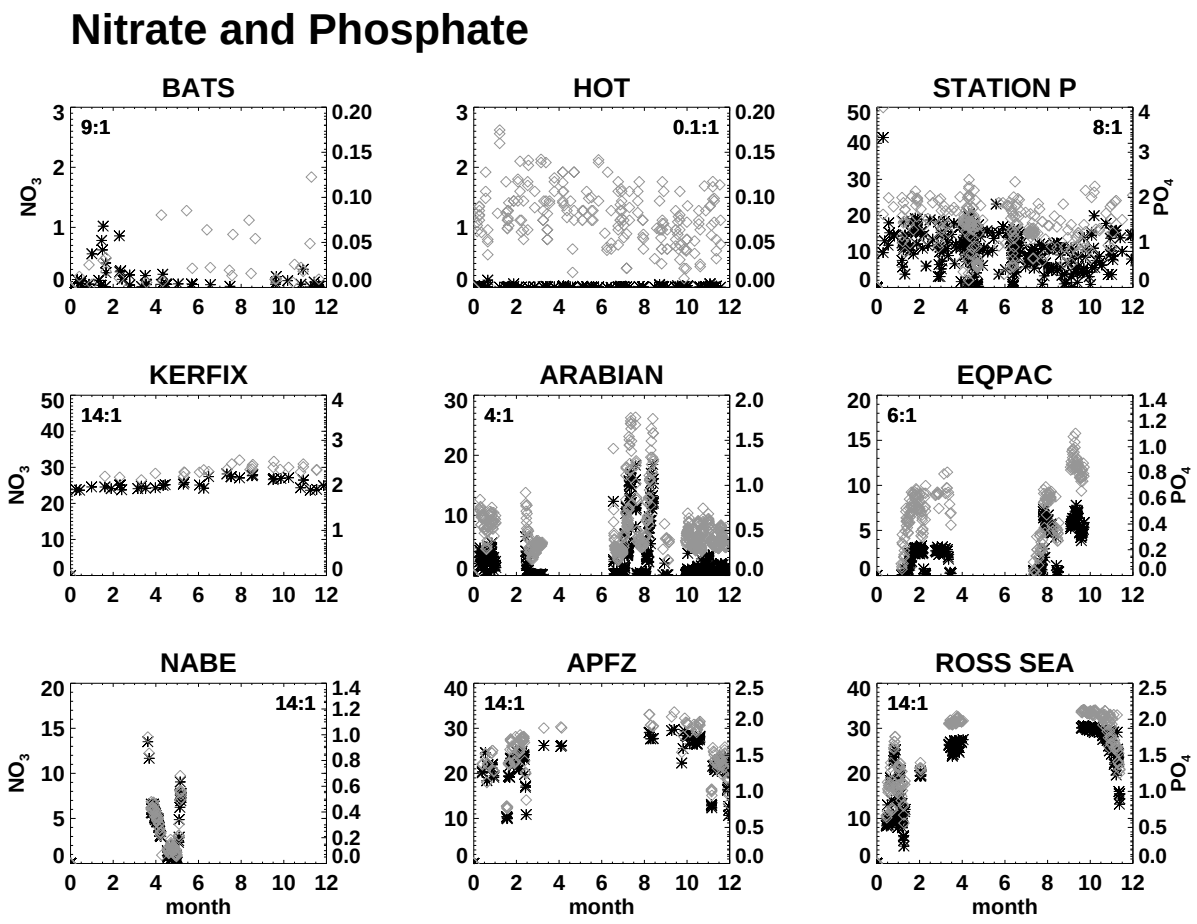

Fig. 19. Comparison of mixed layer averages of nitrate (asterisk) and phosphate (diamond) at the nine JGOFS sites. For ease of comparison, phosphate concentrations are plotted at the NO_3:PO_4 Redfield ratio of 16x. The average NO_3:PO_4 ratio is indicated for each site.

loss of N* (e.g. due to denitrification), and high N* is an indication of nitrogen fixation, or advection of fixed nitrogen from elsewhere. Whether denitrification is occurring at Station P, or whether the low N* values represent a sampling problem is unclear. Most of the Process Study sites show a wide range of N* values; this is partly due to the fact that the data shown were taken over a broader spatial area, and partly due to biological effects.

Also illustrated here is the between-site variation in (1) particulate organic carbon and dissolved organic carbon (Fig. 21); and (2) the C:N ratio of particulate organic matter (Fig. 22).

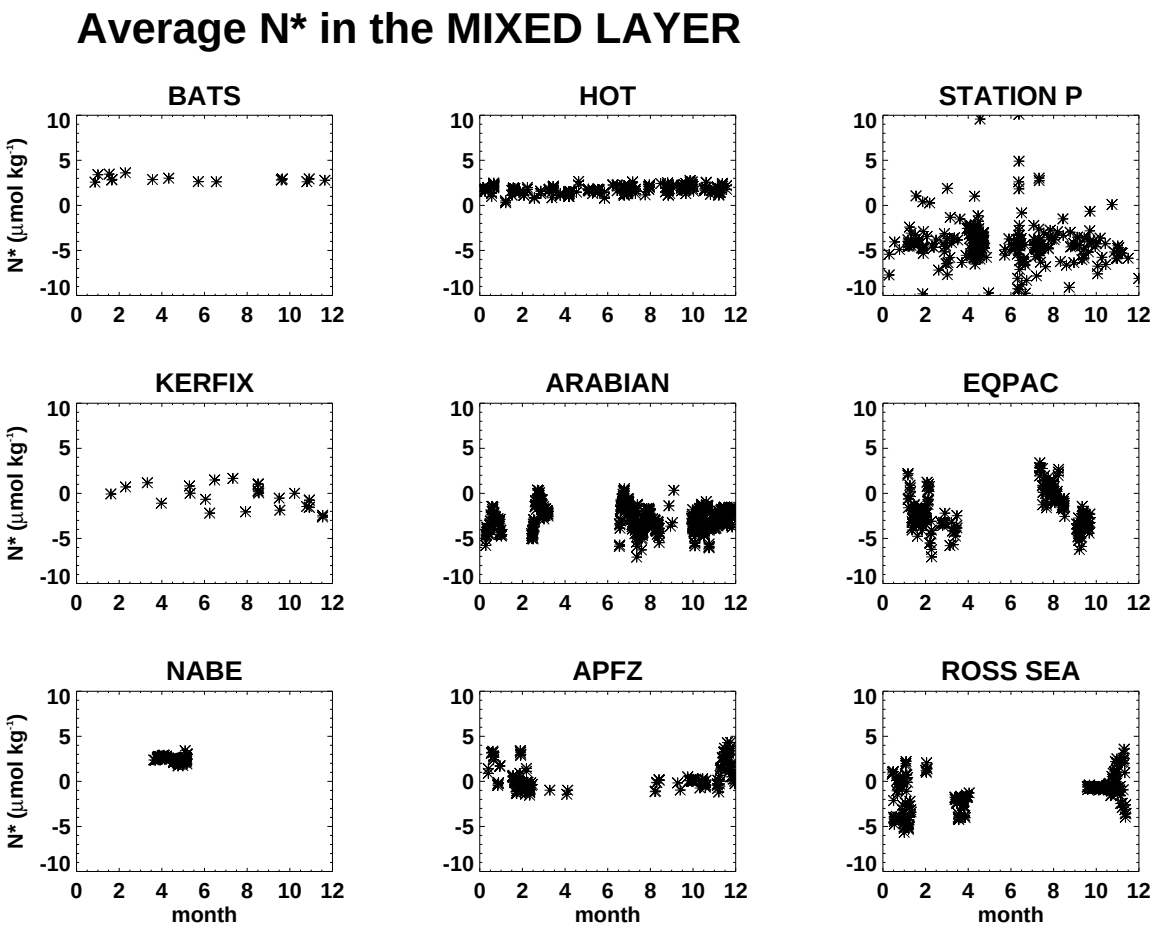

Fig. 20. N* at nine JGOFS sites. N* is calculated according to the equation of Gruber and Sarmiento (1997) N* = N – 16P + 2.90 μmol kg^{-1}. Note that all data for the process study sites are included, which introduces spatial variation in N* along cruise tracks.

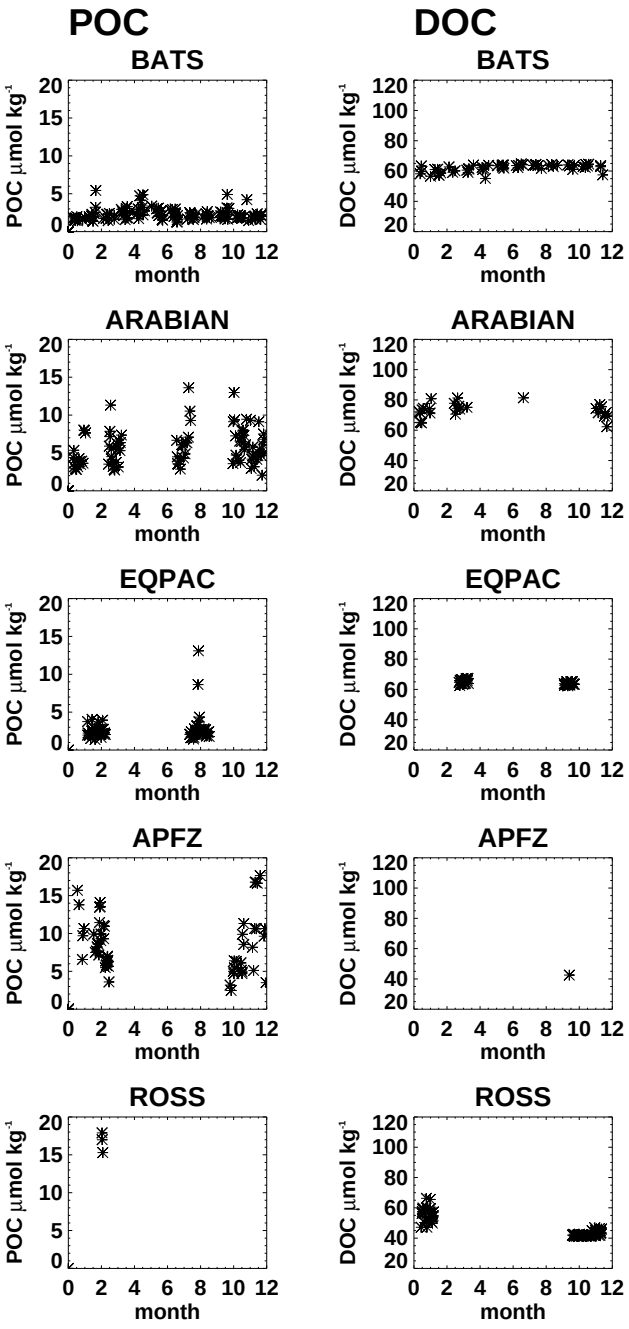

Fig. 21. Particulate organic carbon (POC) and dissolved organic carbon (DOC) at five sites. Note that DOC measurements for BATS and the Arabian Sea are not explicitly provided, and are calculated as difference between total organic carbon (TOC) and POC.

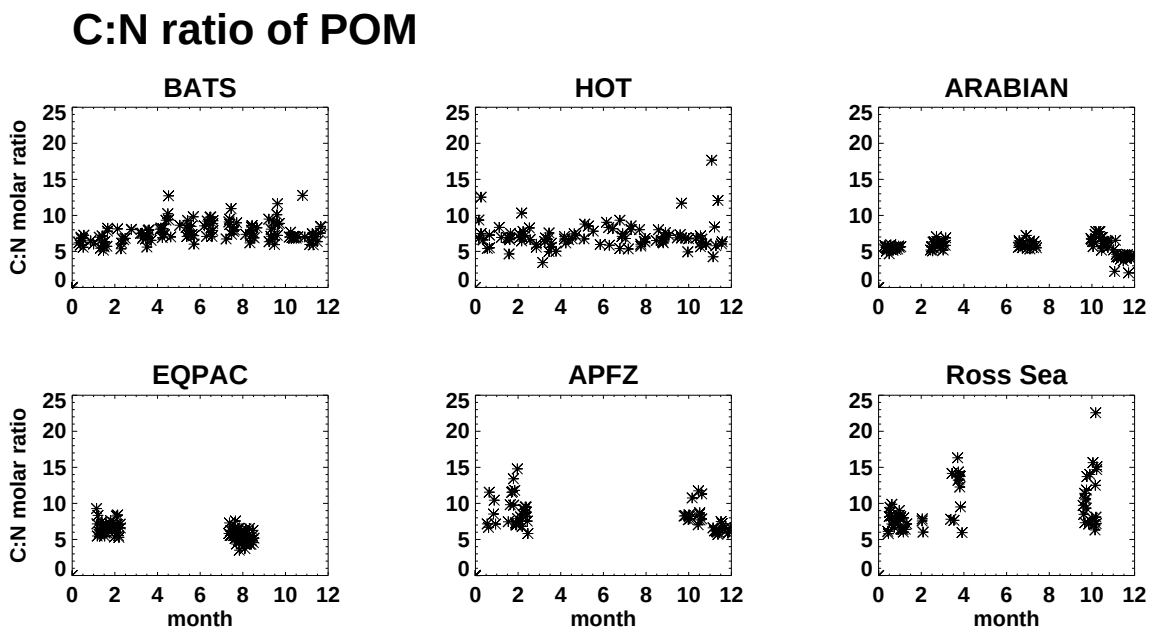

Fig. 22. C:N molar ratios of particulate organic matter at six sites. Note that the HOT ratio was determined for particulate matter (organic and inorganic components were not distinguished in the "particulate carbon" and "particulate nitrogen" data provided), while the ratio for other sites was determined for particulate organic matter.

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6. OTHER REFERENCES AND RESOURCES

The following is a non-exhaustive list of resources, special issues, and other references that provide information about the time-series and process study sites included in this report. These are organized by site.

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Knap, A., A. Michaels, A. Close, H. Ducklow, and A. Dickson (eds.), 1996. *Protocols for the Joint Global Ocean Flux Study (JGOFS) Core Measurements.* JGOFS Report No. 19, vi+170 pp. Reprint of the IOC Manuals and Guides No. 29, UNESCO 1994.

http://usjgofs.whoi.edu:81/mzweb/contrib.htm

Maintained by the U.S. JGOFS. Lists all U.S. JGOFS publications. Papers are listed alphabetically by first author.

http://ads.smr.uib.no/jgofs/publications/index.htm

Maintained by the International JGOFS. Various Publications and Reports.

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Siegel, D., A.F. Michaels, and D. Karl (eds.), 2001. Interpretations of Open Ocean Biogeochemical Processes at the US JGOFS Bermuda and Hawaii Time Series Sites. *Deep Sea Res.* II 48 (8–9).

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Maintained by the Bermuda Biological Research Station. Provides links to full text of BATS data reports and methods manuals.

http://hahana.soest.hawaii.edu/hot/hotpub.html

Maintained by School of Ocean and Earth Science and Technology, University of Hawaii. Lists (often with abstracts) HOT Publications, Data Reports and Manuals, Submitted Papers, Thesis and Dissertations, and Newsletters.

STATION P

Boyd, P.W. and P.J. Harrison (eds.), 1999. Canadian JGOFS in the NE Subarctic Pacific. *Deep Sea Res.* II 46 (11–12).

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KERFIX

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SOUTHERN OCEAN

Le Fèvre, J. and Tréguer, P. (eds.), 1998. Special Issue: Carbon Fluxes and Dynamic Processes in the Southern Ocean: Present and Past. *Journal of Marine Systems*, Volume 17 (1–4).

Smith, W.O. and R.F. Anderson (eds.), 2001. The US Southern Ocean Joint Global Ocean Flux Study (AESOPS). *Deep Sea Res.* II 47, (14–15).

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Contact:	For:
Richard T. Barber Duke University Marine Lab 135 Duke Marine Lab Road Beaufort NC 28516–9751 *rbarber@acpub.duke.edu*	guidance on primary production standards
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Hugh Ducklow School of Marine Sciences College of William & Mary Box 1346 Rte 1208 Greate Rd Gloucester Point, VA 23062–1346 *duck@vims.edu*	guidance on primary production standards
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Jefferson Keith Moore Nat. Center Atmos. Res. P.O. Box 3000 Boulder, CO 80302 *jkmoore@ucar.edu*	Quality control
Young-Hyang Park Laboratoire d'Océanographie Physique Muséum National d'Histoire Naturelle 43 rue Cuvier F–75231 Paris Cedex 05 FRANCE *yhpark@mnhn.fr*	KERFIX mixed layer depths
Diana Ruiz Pino LPCM, Universite Pierre et Marie Curie 4 Place Jussieu 75005 Paris Cedex FRANCE *ruiz@oceanar.mil.ar.*	KERFIX data
Frank Whitney Institute of Ocean Sciences Fisheries and Oceans Canada PO Box 6000 Sidney, B.C., V8L 4B2 CANADA *WhitneyF@pac.dfo-mpo.gc.ca*	Station P data

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