**An Organic Carbon Budget for Coastal Southern California Determined By
Estimates of Vertical Nutrient Flux, Net Community Production and Export**

William Z. Haskell II^{1*^}, Maria G. Prokopenko², Douglas E. Hammond¹,
Rachel H. R. Stanley³, William M. Berelson¹, J. Jotautas Baronas¹,
John C. Fleming¹, Lihini Aluwihare⁴

¹Dept. of Earth Sciences, University of Southern California, 3651 Trousdale Pkwy, Los Angeles, CA, 90089, U.S.A.

²Dept. of Geology, Pomona College, 185 E. 6th Street, Claremont, CA 91711, U.S.A.

³Dept. of Chemistry, Wellesley College, 106 Central Street, Wellesley, MA, 02481, U.S.A.

⁴Scripps Institute of Oceanography, UC San Diego, 9500 Gilman Drive, La Jolla, CA, 92093 U.S.A.

*Corresponding author. Tel.: 240-687-0772; Fax: 213-740-8801; E-mail address: whaskell@umces.edu

^Present Address: Horn Point Laboratory, University of Maryland Center for Environmental Science,
2020 Horns Point Rd., Cambridge, MD, 21613, U.S.A.

Abstract:

Organic carbon export and burial in coastal upwelling regions is an important mechanism for oceanic uptake of atmospheric CO₂. In order to understand how these complex systems will respond to future climate forcing, further studies of nutrient input, biological production and export are needed. Using a ⁷Be-based approach, we produced an 18-month record of upwelling velocity estimates at the San Pedro Ocean Time-series (SPOT), Southern California Bight. These upwelling rates and vertical nutrient distributions have been combined to make estimates of potential new production (PNP), which are compared to estimates of net community oxygen production (NOP) made using a one-dimensional, two-box non-steady state model of euphotic zone biological oxygen supersaturation. NOP agrees within uncertainty with PNP, suggesting that upwelling is the dominant mechanism for supplying the ecosystem with new nutrients in the spring season, but negligible in the fall and winter. Combining this data set with estimates of sinking particulate organic carbon (POC) flux from water column ²³⁴Th:²³⁸U disequilibrium and sediment trap deployments, and an estimate of the ratio of dissolved organic carbon (DOC):POC consumption rates, we construct a simple box model of organic carbon in the upper 200m of our study site. This box model (with uncertainties of ± 50%) suggests that in spring, ~28% of net production leaves the euphotic zone as DOC, of this, ~12% as horizontal export and ~16% via downward mixing. The remaining ~72% of net organic carbon export exits as sinking POC, with only ~10% of euphotic zone export reaching 200m. We find the metabolic requirement for the local heterotrophic community below the euphotic zone, but above 200m, is ~105 ± 50 mmol C m⁻² d⁻¹, or ~80% of net euphotic zone production in spring.

1. Introduction

The marine biological carbon pump, defined as the photosynthetic fixation of CO₂ into organic material (C_{org}) and subsequent transport from the surface ocean into the ocean's interior, is a critical atmospheric CO₂ removal process (Sarmiento and Siegenthaler, 1992). Marine ecosystems over the continental margins account for ~10-15% of global net primary production, but contribute ~40% of export which settles to beneath the permanent thermocline and ~2/3 of export reaching the sea floor sediments (Muller-Karger et al., 2005). Because continental shelf productivity, export efficiency, and sedimentation rates are all elevated relative to the open ocean, it is estimated that up to ~90% of global C_{org} burial may occur in ocean margin sediments (Sarmiento and Gruber, 2006), the majority of which is in coastal upwelling regions. Thus, ocean margins, and particularly upwelling zones, are critical for carbon burial on geologically relevant time scales (10⁴-10⁸ yrs; Sigman and Haug, 2003) and even small fluctuations in export production in these regions can have a large impact on global carbon budgets.

The biological pump is a critical link between marine ecosystems in the sunlit surface ocean and regions of high nutrient content beneath the thermocline, the physical boundary that impedes mixing between the surface and deep. The effect that future climate change may have on this connection between the surface and deep is still unknown (Emerson, 2014), in part because more information on how this linkage functions is needed. For example, one of the least constrained aspects of the biological pump is the contribution of dissolved organic matter (DOC; Hansell et al., 2009; del Giorgio and Williams, 2001) export, which is believed to support a large portion of prokaryote heterotrophic production in the oceans (del Giorgio and Duarte, 2002). In

order to understand the role of DOC, a full understanding of particulate organic carbon (POC) production and consumption must be obtained.

New production is defined as primary production fueled by ‘new’ nutrients introduced from outside of the euphotic zone, mostly from beneath the thermocline boundary (Dugdale and Goering, 1967). At steady state, new production is equal to the fraction of primary production that is exported out of the system (Eppley and Peterson, 1979). However, marine ecosystems often exhibit strongly non-steady state dynamics and it is uncertain over what timescales they resemble the steady state view often used to describe them. During most oceanographic studies, only one component of export production is typically measured and the steady state assumption is used to estimate new production. Time-series studies of net production or those that employ more than one method are rare, but give a more complete view of the strength of the biological pump. Our approach is to estimate not only the transport of nutrients into the surface ocean, but to also monitor changes through time in the dissolved oxygen pool, the DOC pool, as well as rates of sinking particulate C_{org} , which gives a more complete view of both the particulate and dissolved fractions of export production out of the surface ocean. Furthermore, with estimates of vertical transport, we are able to use dissolved oxygen as a tracer of biological production, an approach that is limited in upwelling regions without adequate constraints on the vertical transport of oxygen-deficient waters from below.

In this study, upwelling velocities determined using the ^7Be -based approach described in Haskell et al. (2015b), eddy diffusivity estimates and nutrient profiles are used to estimate the vertical flux of nutrients at the San Pedro Ocean Time-series (SPOT) station (33°33'N, 118°24'W; Figure 1), in a region characterized by seasonally variable

upwelling velocity. These nutrient input fluxes are then compared with three estimates of new production rates: 1) the net biological oxygen production rate estimated from O_2/Ar supersaturation in surface waters and quantifying physical transport, including air-sea gas exchange and vertical fluxes within the thermocline, 2) the vertical export rate of sinking particulate C_{org} caught in sediment traps, and 3) the vertical C_{org} flux estimated using a ^{234}Th balance in the water column and a $C_{org} \cdot ^{234}Th$ ratio in sinking particles. This study is part of an effort aimed at characterizing the biological response to upwelling at SPOT on 21 cruises between January 2013 and June 2014; the Upwelling Regime In-Situ Ecosystem Efficiency (Up.R.I.S.E.E.) study.

2. Methods

2.1 Beryllium-7

All methods used in measuring the activity of 7Be and calculating the upwelling velocities presented here are described in Haskell et al. (2015b), with three notable exceptions: 1) Due to the continued drought in Southern California, the wet depositional flux of 7Be approached zero toward the end of the 2014 sampling season. Following the logic that the reloading of 7Be associated with aerosols in the atmosphere following each rain event is a function of time between rainfall events (eq. 3c in Haskell et al., 2015b), we increased the maximum reloading rate (r_{max}) in this equation from 120 to 140 $dpm\ m^{-2}\ d^{-1}$ for the late May and June 2014 sampling intervals (The wet input flux during this period was ~4% of wet input during this same period in 2013). 2) For October 2013, the upper limit on the measured concentration of 7Be is used in the calculation of upwelling velocity since the measured concentration was $0 \pm 12\ dpm\ m^{-3}$ (Table B1). 3) All rainfall

rates used in the wet input flux calculation are mean regional rates using the same stations as described in Haskell et al. (2015b) with the exception of December 2013, when only one station (Oceanside, CA) was used. The surface currents were dominated by flow from the south prior to the sampling date, according to the JPL Regional Ocean Model (ROMS) output (NASA, 2013). Just as in Haskell et al. (2015b), the wet input flux was calculated using the activity measured closest to each rainfall event, until the second half of the spring season (Up18-21) when the seasonal mean was used since there were no measurements of ^7Be activity in rain during this period. Tables B1 and B2 list all data used in calculating the upwelling velocities presented here, following the approach outlined in Haskell et al. (2015b).

2.2 Nutrients

Samples for dissolved nutrient and pH analysis were collected via Niskin at 12 depths from the surface to 400m and filtered through 0.8/0.2 μm Acrodisc syringe filters. One Nalgene bottle was filled completely leaving no headspace and kept at ambient temperature for 6-8 hours until return to the lab where pH was measured using a combination electrode calibrated with buffers of pH 4 and 7, referenced to NBS standards. About 20 of these samples were analyzed for alkalinity and total dissolved inorganic carbon (DIC). To make the measured pH internally consistent with the DIC and alkalinity, all pH values were increased by 0.02, the estimated uncertainty in electrode calibration. After the pH aliquot was taken, samples were refrigerated until silicic acid and phosphate analyses were done colorimetrically at USC with a Hitachi UV/vis-spectrophotometer (Parsons et al., 1984; Strickland and Parsons, 1968). Nitrate samples were collected in acid-washed 60 mL HDPE Nalgene bottles and frozen at -20°C until

analysis. Nitrate concentrations in samples collected from January to June 2013 were determined by converting nitrate to N_2O (Sigman et al., 2001) and quantifying the amount of N_2O as integrated sample areas on an Isotope Ratio Mass Spectrometer (IRMS) in the D. Sigman lab at Princeton University. Prior to analyses, nitrite was chemically removed from samples (Granger and Sigman, 2009). The remainder of the samples (October 2013 to June 2014) were analyzed for nitrate + nitrite and nitrite only by chemoluminescence, modified from Braman (1989) and Cox (1980). The analytical uncertainty for nitrate and silica concentrations is $\sim 0.5 \mu\text{M}$. Samples for DIC were collected at each depth by using a syringe to inject 5-7 ml of filtered water into evacuated vials through a needle-pierced septum. Following measurement of the mass of water, measurements of TCO_2 and $\delta^{13}\text{C}$ were made on a Picarro Cavity Ring-Down Spectrometer at USC. Alkalinity was calculated from DIC and pH using Mehrbach constants. On samples titrated for alkalinity, DIC calculated from the adjusted pH was within $\pm 10 \mu\text{mol kg}^{-1}$ (± 1 ssd) of the measured values. Measurements were standardized with Dickson standards from SIO, and alkalinity precision was typically $\pm 5 \mu\text{eq kg}^{-1}$. As an indication of precision for the time series, the calculated/measured alkalinity at 400m for 21 samples had a sample standard deviation of $\pm 14 \mu\text{eq kg}^{-1}$. DOC samples were syringe-filtered into acid-washed and combusted 40 mL borosilicate vials with silicone/PTFE septa caps (Thermo Fisher Scientific). After sampling, samples were acidified with distilled HCl to pH ~ 2 and refrigerated until analysis on a Shimadzu TOC- V_{CSN} analyzer at Scripps Institute of Oceanography (L. Aluwihare lab). The analytical uncertainty on DOC concentrations based on replicates is $\sim 5 \mu\text{M}$. Each day's run included the analysis of a deep seawater community standard, and if the concentration of

this standard was not between 41-42 μM C then all samples were re-analyzed. Many of the DOC concentrations we measured were higher than expected based on previous regional measurements (CalCOFI). Although we have no explanation for this observation, it appears to be a rather uniform feature throughout the data set. No calculations in this study rely on absolute DOC concentrations. Therefore, the calculations presented here are unaffected by this feature. All nutrient, DIC, Alk, pH and DOC measurements are presented in Table C1.

2.3 Thorium-234

Vertical profiles from the surface to 200 meters were collected for thorium via Niskin/CTD on every cruise. Ten liters were collected at eight depths, chosen based on the fluorescence profile observed during the CTD's descent. A ^{229}Th spike of known activity was added to the samples as they were being transferred from Niskins into 10L or 20L polycarbonate carboys (to an activity ~ 0.9 dpm/L) and allowed to equilibrate for at least 24 hours. The recovery yield of ^{229}Th in each sample was used in all calculations of ^{234}Th to correct for methodological efficiency, including any possible loss to adsorption onto the sides of the carboys. The samples were co-precipitated with MnO_2 using the technique originally developed by Rutgers van der Loeff and Moore (1999) and detailed in Haskell et al. (2013). Samples were filtered onto a 0.45 μm Pall Supor Membrane filter (142mm).

The filters were dried at room temperature, placed in a plastic test tube, and placed in an Ortec low background gamma detector (intrinsic germanium, well-type, 150cc active volume). ^{234}Th has readily identifiable gamma peaks at 63.2 keV (branching ratio $\sim 4\%$) and 92.4 + 92.8 keV (branching ratio $\sim 5.5\%$). All reported activities of ^{234}Th

have been calculated using the sum of these two peaks. The activity ratio of the two peaks was monitored to confirm that there is no interference with other gamma sources. Background for a blank filter and filter self-absorption were determined to be negligible, by co-precipitating, filtering and counting a standard in the same manner as the samples. The counting efficiencies were also adjusted for sample geometries by counting standards and spike solutions of differing volumes. Each sample was counted until counting uncertainty was below 8%. Counts were corrected for ^{234}Th decay, ingrowth from ^{238}U between collection and filtration, and production from co-precipitated ^{238}U , which was measured by re-counting multiple samples from each profile six months after collection (>5 half-lives). Standardization was done using a solution of known ^{238}U activity. Each measurement of ^{234}Th is presented in Table A1.

2.4 Sediment Traps

During 13 of the 22 cruises, one string of surface-tethered drifting sediment traps containing two Particle-Interceptor-Traps (PITs) was deployed at 100m and 200m. A 50m section of 1-inch thick bungee cord was inserted to dampen the movement caused by waves. A series of five surface buoys were attached to the line and to a mast buoy, which held a strobe light, radio transmitter, radar reflector and Pacific Gyre GPS satellite transmitter. Each trap had a total surface area of 0.0851 m^2 (Knauer et al., 1979; Haskell et al., 2013). All traps had 12 collection tubes with an aspect ratio of 6.4 and had 1 cm x 1 cm baffles fitted into the top opening of the tubes. Funnels with centrifuge tubes were attached into the base of each trap tube. The centrifuge tube (50 mL) contained a brine solution of NaCl (in excess of sea water by 5 ppt) prepared from filtered seawater that was poisoned with 3% formaldehyde and buffered with disodium tetraborate.

211 Deployments averaged 25 hours, and were typically deployed near noon. After recovery,
212 each trap was covered and allowed to settle for at least 1 hour before the water overlying
213 the centrifuge tubes was siphoned off and the tubes removed from the bottom of each trap
214 tube and capped. Trap material from each tube was stored overnight in a refrigerator, then
215 the overlying water was decanted, and the material was picked under a microscope to
216 remove all zooplankton, referred to as 'swimmers' (defined as those which appeared to be
217 intact, thus able to actively swim into the trap to feed on the trap material). Any
218 zooplankton which had not been whole or which had appeared mutilated or 'worn,' was
219 assumed to have been deceased before entering the trap and thus was left included in the
220 trap material. After picking, all twelve centrifuge tubes were combined in a series of three
221 DIW diluting/centrifuging/decanting cycles (12 to 6, 6 to 2, then 2 to 1) to remove all
222 salts from each sample. For all trap deployments, material from each trap (and swimmers
223 separately) were then filtered onto Whatman Nuclepore polycarbonate membrane (0.4
224 μm) filters and left to dry at room temperature for 2 days. Each filter was folded and put
225 in a counting tube, and placed in a gamma detector (same as Th analysis) to measure
226 thorium and beryllium activities. After counting, the filters were removed from the tubes,
227 the trap material scraped off and homogenized into powder with a mortar and pestle, then
228 divided into three splits. One split was placed in silver foil, acidified with HCl fumes to
229 drive off the inorganic C, and then pelletized. One split was placed in tin foil without
230 acidification. Both splits were sent to the UC Davis Stable Isotope Facility (SIF) for C
231 and N elemental analysis via an isotope ratio mass spectrometer (IRMS;
232 <http://stableisotopefacility.ucdavis.edu>). The two splits varied in N content on average by
233 7% of the measured value, suggesting the material was rather homogeneous. A third split

was transferred to a centrifuge tube for digestion in Na_2CO_3 to measure biogenic silica (SiO_2) using colorimetric analysis at USC (DeMaster, 1979; 1991). The results of each analysis were then scaled up by weight percent to the initial mass weight of the entire trap catch. Uncertainty in surface-tethered sediment trap fluxes are reported here as $\pm 50\%$. This was estimated by propagating estimated uncertainty associated with trap efficiency ($\sim 35\%$; Haskell, 2015), handling during picking ‘swimmers,’ filtering and crushing ($\sim 25\%$), and average difference in organic content between sample splits ($\sim 7\%$), which is consistent with previous surface-tethered sediment trap studies (Haskell et al., 2013).

2.5 Dissolved Oxygen/Argon Ratios

Samples for O_2/Ar analysis were collected from Niskin bottles in 300 and 500 mL glass flasks equipped with airtight Louwers-Hapert valves (with 3 high-vacuum greased Viton O-rings in valve stem) and side arms (Emerson et al., 1995, 1999; Hendricks et al. 2004). Prior to sampling, each bottle was poisoned with 150 μL saturated HgCl_2 , dried in an oven at 50°C , then evacuated to < 1 mtorr and weighed. Reuer et al. (2007) has shown that samples collected in this manner can be stored for up to 6 months without significant leakage. Each bottle was first evacuated on a rotary vane vacuum pump (Pfeiffer Duo 2.5) for at least 5 minutes before evacuation using a turbo drag dry high vacuum pump (Alcatel Drytel 31) down to, and held at, < 1 mtorr for at least 5 minutes. After sampling, the samples ($\sim 150\text{--}350$ mL) were equilibrated with the headspace at room temperature for $\sim 12\text{--}24$ hours on a shaking table (Emerson et al. 1991; 1995), weighed, and drained. They were then sent to the laboratory of Rachel Stanley (WHOI) where they were analyzed for O_2 ($m/z = 32$) and Ar ($m/z = 40$) by peak jumping using a Finnigan MAT 253 IRMS. Prior to analysis, H_2O was removed cryogenically on a vacuum line with an ethanol cold

trap at -68°C . O_2 and N_2 were then separated on a GC column of mol sieve 13X at $T = -5^{\circ}\text{C}$, ensuring that N_2 did not interfere with the measurements. The O_2 and Ar were trapped first on a mol sieve trap at liquid nitrogen temperatures and then onto a cryogenic trap at 12 K before being released into the mass spectrometer by heating the cryogenic trap to 290°C for ~ 30 minutes (Barkan and Luz, 2003). The long-term standard deviation of the O_2/Ar ratio in a laboratory standard is 0.2% (Stanley et al., 2010). O_2 and Ar have slightly different solubilities, thus a correction is applied to the measured ratio to account for this difference during the sample/headspace equilibration step.

2.6 CTD Oxygen Sensor Calibration

The CTD oxygen sensor (Seabird SBE 43) was calibrated using Winkler titrations (Carpenter, 1965) on samples collected in duplicate at 5 depths on every CTD cast. Winkler titrations were performed the day after each cruise for most of the one day cruises, and typically two days following each two-day cruise, with equipment and procedure outlined by Langdon (2010). In one case (Up-1), Winkler analyses were performed 4 days after the cruise.

3. Calculation

3.1 $^{234}\text{Th}/^{238}\text{U}$ Disequilibrium

In order to constrain particle export, we calculated ^{234}Th export from the upper 100m, by integrating the $^{234}\text{Th}/^{238}\text{U}$ disequilibrium (Coale and Bruland, 1985; Buesseler et al., 1992; Buesseler, 1998). Previous studies at this location have found that ^{234}Th is removed from the water column primarily by organic carbon flux (Bruland et al., 1981; Thunell et al., 1994). The disequilibrium at each station was calculated using trapezoidal

integration of the difference between ^{238}U activity and ^{234}Th activity from the surface to the depth at which the sediment traps were deployed, and will be referred to as the depth-integrated thorium deficiency (D_{Th}). If ^{234}Th activity was in excess of ^{238}U activity within this depth range, then the integrated excess was subtracted from the integrated deficiency. The uncertainty in D_{Th} was calculated by averaging the propagated uncertainty for each sample used in the integration, multiplying by the depth interval integrated, and dividing by the square root of the number of samples in that depth interval. We use the approach outlined in Haskell et al. (2015b) when calculating the particle export of ^{234}Th (P_{Th}), assuming steady-state:

$$P_{\text{Th}} = \int_{\text{Th}} \lambda_{\text{Th}} (U - Th) dz + w_H (Th_{\text{deep}} - Th_{\text{surf}}) = D_{\text{Th}} + w_H (Th_{\text{deep}} - Th_{\text{surf}}) \quad (1)$$

where λ_{Th} = the decay constant of ^{234}Th (0.0288 day^{-1}), z_T is the trap depth (either 100m or 200m), U is the activity of ^{238}U (dpm m^{-3}); the soluble parent nuclide of ^{234}Th , Th is the activity of ^{234}Th (where subscript 'deep' signifies below the zone of deficiency, and 'surf' signifies within the zone of deficiency), and w_H equals the upwelling velocity. The export flux of particulate organic carbon (POC) out of the zone of ^{234}Th deficiency can be estimated from P_{Th} if the ratio of POC: ^{234}Th in sinking particles is established. In this study, POC and ^{234}Th were measured on material caught in sediment traps set at 100m and 200m. This ratio is then used in the following equation to estimate POC export:

$$\text{POC flux} = P_{\text{Th}} * (\text{POC} : ^{234}\text{Th}) \quad (2)$$

For 7 of the 20 sampling periods, there were not any accompanying sediment traps to measure the ratio. For these, we used the most recent ratio measured in the calculation of POC flux, except for the first cruise (SP42) where we used the seasonal average since it

occurred a month prior to the most recent trap deployment (100m = 7.4 (1σ = 2.6) μmol dpm⁻¹; 200m = 6.6 (1σ = 4.3) μmol dpm⁻¹).

3.2 Net Oxygen Production from O₂/Ar Ratios

Oxygen, a counterpart of carbon in photosynthesis and respiration, is also used as a tracer for net biological carbon production in this study (Bender et al., 1987; Emerson, 1987; Emerson et al., 1991, 1995, 1997; Spitzer and Jenkins, 1989). O₂ concentration in the mixed layer depends on its sources and sinks; the rates of gross photosynthetic production, respiration, air-sea gas exchange, bubble injection (Bender et al., 1987; Emerson, 1987), and vertical transport. Including terms for vertical transport (upwelling and eddy diffusivity; J_{O₂}), the O₂ flux balance can be written as:

$$H_{ML} * \frac{\partial O_2}{\partial t} = NOP + k \left([O_2]_{eq} - [O_2]_{dis} \right) + BI + J_{O_2} \quad (3a)$$

$$\text{where, } NOP = GOP - R \quad (3b)$$

where O_{2dis} is the concentration of dissolved O₂, H_{ML} is mixed layer depth, GOP is gross O₂ photosynthetic production, R is total community respiration, NOP is net community oxygen production, *k* is the rate of gas exchange (piston velocity; in m/d), O_{2eq} is concentration of O₂ in equilibrium with the atmosphere at a given temperature and salinity, and *BI* is oxygen flux due to bubble injection. To account for deviation in O₂ concentration from equilibrium caused by physical processes (bubble injection, changes in O₂ solubility due to temperature and/or salinity variations), the O₂/Ar gas ratio is used as a tracer for the biological processes (photosynthesis and respiration), taking advantage of similarities in the solubilities of the two gases (Craig and Hayward, 1987). Thus, deviation from the equilibrium O₂/Ar, defined as:

$$D \left(\frac{O_2}{Ar} \right) = \frac{\left(\frac{O_2}{Ar} \right)_{dis}}{\left(\frac{O_2}{Ar} \right)_{eq}} - 1 \quad (4)$$

reflects *biologically driven* deviation of dissolved O_2 from atmospheric equilibrium (O_2/Ar_{dis} and O_2/Ar_{eq} are measured and equilibrium ratios, respectively). In this study, we model the euphotic zone as a 1-dimensional, two-box system with one box defined from the surface to the base of the mixed layer (ML box) and one box from the mixed layer depth (MLD) to the base of the euphotic zone (BML box; Figure 2). Oxygen mixed layer depths were determined as the depth at which the oxygen concentration was 0.5% different from the surface concentration (Castro-Morales and Kaiser, 2012) and ranged between 10m and 35m. Euphotic depths were typically between 35m and 65m, with the exception of Up-8 and Up-15 (30m and 70m). For 9 cruises (Up-13 to Up-21), the base of the euphotic zone was determined with the CTD as the depth at which 1% of the surface photosynthetically available radiation (PAR) is measured. Prior to Up-13, there was no PAR sensor on the CTD unit. Since the deep Chlorophyll-a maximum (DCM; determined from CTD fluorescence profiles) is almost always above the euphotic depth in Southern California Bight (Cullen and Eppley, 1981), for the remainder of the cruises, the euphotic depth was defined as 10m below the DCM. However, during Up-2, -3, and -4, the DCM was within the mixed layer. For these three cruises, the euphotic depth was defined as 15m below the MLD.

By using $\Delta O_2/Ar$ in eq. 3, adding terms for vertical transport (an advection term introducing O_2 from below and balancing it with horizontal export at the surface, and an eddy diffusivity term following Wurgaft et al., 2013; middle two terms in eqs. 5a and 5b) and non-steady state change in the inventory of biologically produced oxygen (last term

in eqs. 5a and 5b), we define the mass balance of net biologically produced O_2 in each of these two boxes:

$$\begin{aligned}
 NOP_{ML} = & k[O_2]_{eq} * D\left(\frac{O_2}{Ar}\right)_{ML} - w_H \left[\left([O_2]_{satBML} * D\left(\frac{O_2}{Ar}\right)_{BML} \right) - \left([O_2]_{satML} * D\left(\frac{O_2}{Ar}\right)_{ML} \right) \right] \\
 & - \frac{K_z}{Z_{BML-ML}} * \left[\left([O_2]_{satBML} * D\left(\frac{O_2}{Ar}\right)_{BML} \right) - \left([O_2]_{satML} * D\left(\frac{O_2}{Ar}\right)_{ML} \right) \right] \\
 & + \frac{\partial \left(H_{ML} * [O_2]_{satML} * D\left(\frac{O_2}{Ar}\right)_{ML} \right)}{\partial t}
 \end{aligned} \tag{5a}$$

$$\begin{aligned}
 NOP_{BML} = & -w_H \left[\left([O_2]_{satDeep} * D\left(\frac{O_2}{Ar}\right)_{Deep} \right) - \left([O_2]_{satBML} * D\left(\frac{O_2}{Ar}\right)_{BML} \right) \right] \\
 & - \frac{K_z}{Z_{Deep-BML}} * \left[\left([O_2]_{satDeep} * D\left(\frac{O_2}{Ar}\right)_{Deep} \right) - \left([O_2]_{satBML} * D\left(\frac{O_2}{Ar}\right)_{BML} \right) \right] + \frac{K_z}{Z_{BML-ML}} * \left[\left([O_2]_{satBML} * D\left(\frac{O_2}{Ar}\right)_{BML} \right) - \left([O_2]_{satML} * D\left(\frac{O_2}{Ar}\right)_{ML} \right) \right] \\
 & + \frac{\partial \left(H_{BML} * [O_2]_{satBML} * D\left(\frac{O_2}{Ar}\right)_{BML} \right)}{\partial t}
 \end{aligned} \tag{5b}$$

where w_H is upwelling velocity, K_z is the eddy diffusivity coefficient, Z is the difference in depth between the ML and the sample defining the BML value (and between BML and the Deep value in 5b), ‘Deep’ refers to values crossing the euphotic depth from below, and H_{BML} is the height of the BML box. Eqs. 5a and 5b have assumed that deviation of Ar from equilibrium is negligible ($\leq 3\%$ in BML box; typically $\leq 1\%$ in other studies: Emerson et al., 1991; Spitzer and Jenkins, 1989; Hamme and Severinghaus, 2007). Here, we define ‘Deep’ values as those measured at the euphotic depth. Where there was no sample measured at this depth, they were determined using linear interpolation between available data above and below. When the euphotic depth was equal to the depth of the sample defining the BML box value, the BML production rate is reported as zero because

there is no change in values entering and leaving the BML box. Often there was a gradient within either the ML or BML boxes. Therefore, as is the case for most ML values, when two measurements were taken within either the ML or BML boxes, the mean of the two was used in the calculations. When sampling, we used the downcast CTD profile of dissolved oxygen to choose sampling depths that best represented each depth zone in the box model. The NSS term accounts for the change in box sizes through time, which may entrain waters through the bottom of each box. The NSS term was ignored for the first cruise (SP42) because NSS change could not be assessed, and it was ignored if the time between samplings was greater than 2 months (Up-9 and Up-10). The total NOP in the euphotic zone is then reported as the sum of the NOP in each box:

$$NOP_{Euph} = NOP_{ML} + NOP_{BML} \quad (5c)$$

Uncertainty in NOP estimates using this method was determined using a Monte Carlo approach, which found the standard deviation of the distribution of NOP calculated 10,000 times using randomly selected values for upwelling velocity (w_H), piston velocity (k), and eddy diffusivity (K_z) within the range of uncertainty in each of these variables. We ran this simulation for each NOP calculation until three consecutive runs (10,000 simulations each) found standard deviations that varied by less than 2% and we report the average of these three runs as the uncertainty in NOP.

Under the assumption that all NCP is supported by growth on nitrate (and the relative carbohydrate/lipid composition of organic carbon is constant), NCP is stoichiometrically related to NOP through a photosynthetic quotient of 1.4 ± 0.1 (Laws, 1991):

$$NCP = NOP / 1.4 \quad (6)$$

All NCP values reported in this study were calculated in this manner. As evidence that this stoichiometry is appropriate to use at SPOT, we calculated total oxidized carbon (TC_{ox}), defined as total DIC minus an estimate of DIC sourced from carbonate dissolution (accounting for the oxidation of organic nitrogen species):

$$TC_{ox} = DIC - \frac{Alk + [NO_3^-]}{2} \quad (7)$$

where Alk is total alkalinity and $[NO_3^-]$ is nitrate concentration. This approach assumes that all alkalinity is sourced from carbonate locally and all local nitrate is sourced from organic nitrogen oxidation to nitrate. By plotting TC_{ox} concentration versus apparent oxygen utilization (AOU; defined as the oxygen solubility concentration minus the measured concentration) below the euphotic zone (~55-400m), we determined a stoichiometry of 1.44 ± 0.03 (C:O₂) in remineralized organic material (Figure 7c).

3.3 Gas Exchange Coefficient (Piston Velocity)

Piston velocities (k ; m d⁻¹) were determined using the wind speed-based parameterization presented by Nightingale et al. (2000). We used daily averaged 0.25° x 0.25° wind speed measurements 10m above the sea surface by ASCAT satellite (W_{10} ; m d⁻¹; NASA, 2014) and sea-surface temperature measured at NOAA buoy #46222 (NOAA, 2013b). The k values presented in this manuscript are 15-day weighted means of the contribution of winds each day to the ventilation of the surface layer on the day of sampling by considering both the time interval between each day and the sampling date, as well as the magnitude of the wind speed, following Reuer et al. (2007). We did not test the more recent parameterizations of Ho et al. (2006) or Sweeney et al. (2007), but a recent comparison by Yeung et al. (2015) in the south Pacific found that these were not statistically different than that of Nightingale et al. (2000), similar to the results of Bender

et al. (2011). Here, uncertainty in k is reported as 15% (Stanley et al., 2009; Ho et al., 2006).

3.4 Vertical Eddy Diffusivity and Entrainment

Vertical eddy diffusivity at the base of the ML and BML boxes was estimated using the formulation of Haskell et al. (2016), which calculates the rate of turbulent kinetic energy dissipation due to horizontal shear at each depth using the same weighting procedure as we used to calculate piston velocity (k); we calculate eddy diffusivity (K_z) for each daily mean wind speed, then use the weighting procedure of Reuer et al. (2007) to calculate a 15-day weighted K_z . The only difference to the k calculation is that in order to calculate K_z , we must make the assumption that the density, vertical density gradient, and depths of mixed layer and euphotic zone change linearly between sampling dates. These estimates are for the contribution to eddy diffusivity due to horizontal shear only, and neglect any other sources of turbulence, such as convection, internal waves, etc. Therefore, they represent a lower limit to the rate of total eddy diffusivity. These estimates for eddy diffusivity have high uncertainty ($\pm 34\%$ by error propagation of the drag coefficient (C_D) ($\pm 30\%$) and k). This approach is derived under the assumption of negligible vertical advection, which appears to be appropriate during autumn and winter. However, this assumption is certainly violated during the spring months. We are unable to estimate the additional uncertainty introduced by assuming advection does not affect this estimate, but as we will discuss below, eddy diffusivity is the smallest term in the estimates of NOP, always much smaller than the total uncertainty in NOP. Furthermore, eddy diffusive nutrient fluxes are approximately an order of magnitude smaller than upwelling fluxes on average in the spring months. Therefore, the uncertainty introduced

by this assumption is likely much smaller than the total uncertainty reported for both NOP and vertical nutrient fluxes. Because of this, we chose to use these diffusivity estimates in the nutrient and oxygen budgets presented here because they are instructive in determining the relative contribution of eddy diffusivity and advection to vertical transport, which will be discussed in more detail in Section 4.3. The effect of entrainment into each box from below is included in the NOP NSS term, as it accounts for the change in the size of each box through time. The change in ^7Be inventory through time is also included in estimates of vertical advection, which would also reflect any entrainment due to changes in mixed layer depth.

3.5 Vertical Nutrient Flux

To estimate the flux of nutrients into the euphotic zone, we use a similar approach as Haskell et al. (2015a). The nutrient concentration measured closest to this boundary (N_{deep}) multiplied by the upwelling velocity (w_H) gives an estimate of the vertical flux of nitrate into the euphotic zone due to advection. To satisfy water mass balance, upwelled waters into the euphotic zone must be balanced by water leaving horizontally with the concentration of the surface waters (N_{ML}), thus the net flux of any nutrient into the euphotic zone (J_{adv}) can be estimated using the following equation:

$$J_{\text{adv}} = w_H (N_{\text{deep}} - N_{\text{ML}}) \quad (9)$$

Here, we define N_{deep} as the first measured nutrient concentration below the euphotic zone. During each cruise, the depths at which nutrients were measured were chosen using the downcast measurements of temperature, oxygen, Chl-a fluorescence, and photosynthetically active radiation (PAR) sensors mounted on a Seabird CTD, with particular focus on sampling the region just above and below the estimated depth of 1%

surface PAR value in an attempt to estimate the nutrient concentration and nutrient gradient in the 20m immediately below the euphotic depth ($\delta N / \delta z_{\text{deep}}$). For 14 of the 21 cruises, N_{deep} was within 5m of the euphotic depth determined by either PAR or fluorescence. A water column Si budget is used as evidence to support the choice in euphotic depth used in the nutrient model in Section 4.6. With an estimate of the rate of eddy diffusivity (K_z), the vertical flux of nutrients to the euphotic zone due to eddy diffusivity (J_{diff}) can also be estimated as follows:

$$J_{\text{diff}} = -K_z \left(\frac{\partial N}{\partial z} \right)_{\text{deep}} \quad (10)$$

4. Results

4.1 Upwelling Cycle and Upwelled Nutrients

Using the Non-Steady State (NSS) approach described in detail in Haskell et al. (2015b) for the 2013 sampling period, we extended the estimates of upwelling velocity (w_H) at SPOT for each sampling period in 2014 (Table 1 and Figure 3). All the data used in these calculations are presented in Tables B1 and B2. The overall magnitude and temporal pattern of upwelling velocity was very similar for both years: 1) upwelling velocity increases throughout the spring months from low values in the winter, 2) the maximum upwelling velocity was reached in late April/early May each year at 2.5 ± 1.3 and $2.8 \pm 1.6 \text{ m d}^{-1}$, and 3) there was a destabilizing event in the euphotic zone in February, which appears to be the initial upwelling ‘pulse’ each year. Although within the uncertainty, the pressure field-based Bakun Index-derived upwelling velocities were typically smaller than the ^7Be -based estimates, except during the month of June. Estimates from three cruises (October, December and January) were used to characterize

upwelling during autumn and winter. The uncertainty for these three values are reported as 0.5 m d^{-1} since their small magnitude resulted in an underestimate of true uncertainty using error propagation. A velocity of 0.5 m d^{-1} was determined as the long-term mean uncertainty for this method using the numerical model approach described in Haskell et al. (2015b). The calculated upwelling velocity was low and even slightly negative during this period (averaging to approximately zero), suggesting eddy diffusivity is likely the main mechanism of vertical nutrient flux during fall and winter in the region. The velocity determined during January of 2013 is higher than that determined for January 2014, but there is reason to believe that the lack of a non-steady state term for this period may be responsible for this observation (Haskell et al., 2015b). The general agreement with the Bakun Index suggests that this pressure field-based approach is overall a good indicator of monthly upwelling velocity at SPOT, with the exception of the initiation of the annual decrease in upwelling velocity in June. This disagreement, if indicative of the spatial scales over which each approach applies as discussed in Haskell et al. (2015b), suggests that upwelling in the inner portion of the Southern California Bight may relax slightly earlier each year than in the regions further offshore.

The concentration profiles of major nutrients (nitrate, phosphate, silicic acid and inorganic carbon) were measured during each cruise. All nutrient concentrations are presented in Table C1. Plots of nitrate, phosphate and silicic acid profiles through time in the upper 100m are shown in Fig. 4 aligned in time with upwelling velocity calculated using the ^7Be -based approach. Mixed layer nitrate concentrations were near-zero for all cruises except two (Up-2 and Up-19). The depth of the nutricline and near-surface nutrient gradients beneath the euphotic zone generally follow upwelling velocity through

time in both 2013 and 2014 by shoaling and strengthening, respectively, during increases in upwelling velocity, and by deepening and weakening, respectively, during periods of decreasing upwelling velocity. Assuming a one-dimensional system, and that upwelling and eddy diffusivity are the only two processes acting on the nutrient gradients just below the euphotic zone, this observation suggests that upwelling is the dominant vertical nutrient transport mechanism and that eddy diffusivity likely remains relatively constant compared to changes in upwelling velocity throughout the upwelling season. This observation is supported by the eddy diffusivity estimates presented in Table 1 and Fig. 4 and discussed in detail below.

The net fluxes of nitrate and silica due to upwelling across the euphotic zone boundary are shown in Table 2, calculated as described in Section 3.5. In general, there is higher upwelled nitrate flux during periods of higher upwelling velocity. In addition, the effect of higher upwelling velocity is compounded by typically higher nutrient concentrations during these periods as a result of the shoaling nutricline. Nitrate flux due to upwelling ranged from 1.7 ± 1.3 to 19.2 ± 10.3 $\text{mmol m}^{-2} \text{d}^{-1}$ during the spring months and averaged $\sim 0.1 \pm 0.3$ $\text{mmol m}^{-2} \text{d}^{-1}$ during the fall and winter. Si fluxes ranged from 1.5 ± 1.2 to 16.4 ± 7.5 $\text{mmol m}^{-2} \text{d}^{-1}$ in spring and averaged $\sim -0.1 \pm 0.3$ $\text{mmol m}^{-2} \text{d}^{-1}$ in fall/winter.

4.2 Eddy Diffusive Nutrient Flux

Table 1 also presents all estimates of wind speed and wind speed-derived rates of gas exchange and eddy diffusivity. Overall, wind speeds were on average higher during the second year, but with a standard deviation of only 1.3 m s^{-1} through both years. Higher wind speeds in 2014 are consistent with the general conditions experienced at sea

during the second year. The same overall pattern is reflected in piston velocity. The mean for all sample dates and standard deviation of the best estimates of wind speed was 4.8 (S.D. = 1.3) m s⁻¹, piston velocity was 1.9 (S.D. = 0.6) m d⁻¹, eddy diffusivity at the base of the mixed layer was 1.7 (S.D. = 1.1) m² d⁻¹, and eddy diffusivity at the base of the BML box was 1.5 (S.D. = 0.9) m² d⁻¹. Six of the estimates at the MLD and at the base of the BML box were under 0.9 m² d⁻¹, a commonly accepted value for ‘background’ turbulent diffusivity (Ledwell et al., 1993). Since these are likely underestimates, we assumed these values to be 0.9 m² d⁻¹. All estimates are within the range of previously published diffusivity estimates in the Southern California Bight based on nitrate uptake rates in the upper thermocline (0.4 – 5.3 m² d⁻¹, mean: 2.7 m² d⁻¹) and below the thermocline (0.1 – 2.6 m² d⁻¹; Eppley et al., 1979). They are also within uncertainty of other estimates in a similar oceanic regime (King and Devol, 1979; 0.4 - 4.0 m² d⁻¹, mean: 1.9 m² d⁻¹).

The wind-based estimates of eddy diffusivity at the base of the BML box (K_{z-BML}) were used to estimate the diffusive flux of nitrate into the euphotic zone. For the three fall/winter cruises, the estimated vertical eddy diffusivity equaled 2.1 ± 0.8 m² d⁻¹ for Up-9, 0.9 ± 0.3 m² d⁻¹ for Up-10, and 0.9 ± 0.3 m² d⁻¹ for Up-11 (average = 1.3 ± 0.5 m² d⁻¹). Although the advective nitrate flux was only $\sim 0.1 \pm 0.3$ mmol m⁻² d⁻¹ during the fall and winter months, the net diffusive nitrate flux for these three cruises equaled 0.9 ± 0.5 , 0.1 ± 0.1 , and 0.3 ± 0.2 mmol m⁻² d⁻¹, respectively (average = 0.4 ± 0.2 mmol m⁻² d⁻¹; Table 2). Eddy diffusive nitrate flux in the spring months ranged from 0.3 ± 0.1 to 1.7 ± 0.9 mmol m⁻² d⁻¹, always much less (approximately an order of magnitude) than the nitrate flux attributed to advection, and thus not a very significant term during the spring.

4.3 Net Community Oxygen Production

Here we consider the contribution of each term in eq. 5 towards the total NOP in the ML box (NOP_{ML} ; eq. 5a), the BML box (NOP_{BML} ; eq. 5b), and the total euphotic zone (NOP_{Euph} ; eq. 5c; Table 3). Note that the contribution to the ML box is shown above that in the BML box in the column, $\text{NOP}_{\text{ML/BML}}$. NOP_{ML} and NOP_{BML} equal the sum of contributions from each term in each of the boxes and NOP_{Euph} is the sum of NOP_{ML} and NOP_{BML} . Total NOP rates in the euphotic zone ranged from $14 \pm 21 \text{ mmol m}^{-2} \text{ d}^{-1}$ in the fall/winter to $214 \pm 55 \text{ mmol m}^{-2} \text{ d}^{-1}$, peaking in April of each year. Half of the time, more NOP occurred within the mixed layer. However, during the periods of highest net production, more NOP occurred in the BML box. This is, in part, due to the shoaling of the mixed layer from thermal stratification in the late spring, which is concurrent with the highest upwelling rates. Nevertheless, an oxygen budget of the entire euphotic zone is necessary to capture the majority of the NOP. The upwelling term (T_{WH}) is the most influential term on total NOP, followed by the non-steady state term (T_{NSS}), the gas exchange term (T_{k}), and the eddy diffusivity term (T_{Kz}). This emphasizes the significance of upwelling on the physical and chemical dynamics in the upper ocean of the inner Southern California Bight and specifically the importance of upwelled waters from the strong oxycline in a surface ocean oxygen budget. Notably, the term used to estimate the flux of oxygen across the sea surface (T_{k}) does not represent total NOP well. Despite the rates of upwelling and gas exchange being approximately equal, upwelling has a more significant influence on NOP_{Euph} . This observation is likely because the difference in oxygen concentration between the boxes is generally greater than the difference in oxygen between the ML and the atmosphere, as a result of vigorous biological production

of oxygen below the mixed layer. The non-steady state term (T_{NSS}) was also significant for many of the cruises, but was only larger than the sum of the transport terms during two of the sampling dates. This implies that non-steady state dynamics are not as important as upwelling in the biological oxygen supersaturation signal over the timescale of the residence time of oxygen in the surface ocean throughout this study (~2 weeks).

NOP_{Euph} is well correlated ($p < 0.001$; $r = 0.77$) with particulate organic carbon (POC) export at 100m, upwelling velocity ($p = 0.003$; $r = 0.62$), and to a much lesser extent, integrated chlorophyll concentration measured by fluorescence in the euphotic zone (calibrated with bottle Chl-a measurements, D. Kim, *pers. comm.*; $p < 0.07$; $r = 0.41$; Figure 5). The Pearson correlation coefficient (r) is largest for POC export at 100m. The linear relationship between POC export and NOP indicates that POC export from the euphotic zone is a relatively constant fraction of total net production through time and hence the fraction remineralized in the region below the euphotic zone likely does not change significantly through time. The linear relationship between NOP and upwelling velocity may also be evidence that upwelled nutrients are balanced by a stoichiometric equivalent of export production (steady state) over relatively short timescales (Eppley and Peterson, 1979). However, because the upwelling term is the most influential on NOP rates, it is impossible to decipher the true nature of this correlation. As to the weaker correlation between integrated chlorophyll concentration and NOP, there are many possible explanations: 1) there may be a non-linear relationship between biomass and biological production (Eppley et al., 1985), 2) biomass accumulation may not correlate well with chlorophyll accumulation, since cell chlorophyll content is organism-

specific (Caron et al., 1995), and 3) the rate of production per chlorophyll is a photoadaptive variable, not a constant (Cote and Platt, 1983).

4.4 Sediment Trap-based Export Production

Rates of carbon and nitrogen export in sinking particles from the surface ocean, calculated during 13 surface-tethered sediment trap deployments, are shown in Table 4 and Fig. 6a (red squares). The range of sediment trap export fluxes of POC at 100m was 2.1 to 20.4 mmol C m⁻² d⁻¹ and 1.8 to 13.4 mmol C m⁻² d⁻¹ at 200m, consistent with the results of a recent 4-year trap study in the same location by Collins et al. (2011). At both depths, the peak export rate occurred in April of each year. The smallest POC export rates were measured in the fall and winter and were all < 5 mmol C m⁻² d⁻¹. Export increased from January to April during each of the two spring seasons and decreased in May and June toward the summer and fall. During 5 of the 13 deployments, the 200m trap caught a larger amount of POC than the 100m trap. This is contrary to the canonical view that POC flux attenuates with depth (Martin et al., 1987). However, in 2 of the 5 cases, the difference in flux between the two depths is less than 15% of their value, which is much smaller than the estimated ~50% uncertainty in trap flux values. Of the remaining 3 deployments, the flux into the two traps are within 50% of each other and in one case, both trap fluxes are under 5 mmol C m⁻² d⁻¹. One major assumption made when interpreting sediment trap export fluxes is that the system is 1-dimensional, but these three trap deployments may be evidence that horizontal processes affected the system during these deployments. Another possible explanation could be the short duration of the trap deployments. Assuming that the mean particle sinking speed is somewhat constant down to 200m and less than 200 m d⁻¹, each trap was likely sampling a different

time period of export flux from the euphotic zone. Given the patchiness often attributed to surface phytoplankton blooms (Buesseler et al., 2007; Eppley et al., 1985), it is not unexpected to estimate a higher rate of export in a deeper trap during a 1-day deployment.

Nitrogen export generally followed the same temporal pattern as POC (Table 4). On average, the $C_{org}:N$ ratio was 8.0 and 8.1 at 100m and 200m, respectively. During 6 deployments this value increased with depth, while during 6 deployments it decreased with depth, and for one deployment remained the same. This data set suggests that C_{org} and N were remineralized at comparable rates between 100m and 200m at our study site. Collins et al. (2011) reported the annual mean $C_{org}:N$ ratio on organic material caught at 550m and 800m as 8.9 and 9.9, suggesting an increase in this ratio with depth. Given that the distance between the traps in this study was only 100m, and the highly dynamic environment of the study site, we consider the difference in $C_{org}:N$ with depth on sinking particles insignificant.

Biogenic Si (bSi) was measured in trap material during 9 of the 13 trap deployments (Figure 6b; black circles). For only 5 deployments, we were able to measure bSi in both the 100m and 200m traps. During each of these 5 deployments, weight % bSi in both the 100m and 200m traps agreed within 20% (4 of which agreed to within 10%). Therefore, we assume that for the 4 deployments that we do not have analyses in both traps (Up-1, 9, 11, and 13; marked with a '*' in Table 4), the % bSi is equivalent in both traps. bSi flux into the traps was typically greater than both POC and PON flux due to preferential remineralization of C_{org} and N above the trap depth and followed a similar temporal trend, peaking in March, April and May. This observation suggests that diatoms

significantly contribute to export during the spring months, which is an expected result at this location (Thunell et al., 1994).

Furthermore, we can use bSi flux as a test of the whether the depth horizon we chose for our nutrient model accurately represents the euphotic depth by constructing a simple budget for upwelled silicic acid and bSi export, similar to the approach of Haskell et al. (2015a). Since silicon does not have an organic form in marine systems, all biological uptake contributes to the formation of dense siliceous frustules, which sink out of the euphotic zone upon the death of frustule-bearing organisms. Under the assumption of steady state in a one-dimensional system, a budget of upwelled silicic acid into the euphotic zone should be balanced by export of bSi frustules sinking out of the euphotic zone. In Figure 6b, we present the results of the calculations of upwelled and vertical eddy diffusive Si fluxes shown in Table 2 for purposes of comparison to the export of bSi caught in sediment traps reported in Table 4. Our estimates of upwelled silicon flux are sensitive to the choice of euphotic depth, so if our estimated euphotic depth based on the nitrate gradient overestimates the true depth of the euphotic zone, then the estimates of upwelled silicon will also be larger than silicon export and visa versa. Of the nine dates that both vertical Si transport into the euphotic zone and bSi in trap material were measured, the input flux of Si was equal to the export flux within uncertainty for seven. On the remaining two sampling dates (Up-1 and Up-13), the sediment trap export underestimated the input flux, which could occur if either the traps were not perfectly efficient at catching sinking particles or some Si was remineralized above the trap depth. However, although within uncertainty, bSi export values determined for two sediment trap deployments in the first year were much larger than the estimated input flux (Up-3

and Up-5). This may be due to differences in the timescales over which these upwelling fluxes and export fluxes apply, since sediment traps were only deployed for 1 day (similar to the observed difference in Th and sediment trap export discussed in the following section). Regardless, the input and output fluxes of Si for all other sampling periods agree to within uncertainty.

4.5 Thorium-based Export

The ^{234}Th : ^{238}U disequilibrium approach for estimating POC export was used for every cruise except Up-14 and Up-16, providing insight into particle export fluxes between sediment trap deployments (Figure 6a; black circles). Generally, export estimates calculated using this approach agreed well with those calculated using the sediment trap approach, although in most cases, they were larger in magnitude. Fig. 6c shows estimates of POC export made using each of the two methods plotted against one another. The least squares fit of this plot has a fairly low Pearson correlation coefficient ($r^2 = 0.36$; not shown) and shows that the sediment traps typically collected less POC than the water column Th inventory calculation would predict (slope of 0.48; not shown). However, for 8 of the 26 trap deployments (2 traps deployed 13 times), the traps collected more Th than predicted by the Th deficiency (Table 4). Part of the reason the slope and r^2 values are so low is that the deployments appear to roughly fall into two groups: Either the traps slightly overcollect relative to the Th deficiency (~120%), or they strongly undercollect (~20%). One possible explanation for this disagreement may be that these two approaches are estimating particle export over different periods of time. The majority of particles collected in the sediment traps likely left the surface ocean prior to our arrival at the sampling site, depending on the sinking velocity of each particle, and

the traps can only capture a small window in time since they are set at 100m and 200m for only one day. The memory of the Th deficiency likely extends from the moment of sampling to ~2-3 weeks back in time depending on the mean sinking velocity of particles over that time, but the most recent particle sinking events will preferentially affect the deficiency more than older events due to ingrowth of Th over time. Another possible explanation is the spatial scale over which each method likely applies. The ‘statistical funnel’ (Siegel et al., 1990) for sediment traps set at 100m and 200m is likely not as large as the area captured by the Th signal. This is because the memory of the Th deficit due to particle removal extends for weeks in a region with a surface layer residence time of ~2-3 weeks (San Pedro Basin; Hickey, 1992). Thus the Th signal will likely reflect a mean particle export rate over a larger area than the traps on average.

Given that this study takes place in a highly productive and dynamic coastal region, changes in particle fluxes over weeks-long periods of time are not unexpected, which would explain the differences in export during the time and space windows that traps and Th capture, respectively. Furthermore, marine biological blooms are typically patchy in nature, thus it is likely that the method that captures a shorter time/space window will most often underestimate the regional export flux, except for when this small window captures a relatively rare bloom period (Buesseler, 1998). This may explain why the traps overcollect relative to Th during only 8 of the 26 trap deployments. Since each of these approaches may be more appropriate to estimate the true particle export flux at SPOT at different times, we will use the mean of the two when discussing particle export in this manuscript henceforth (last column in Table 4).

5. Discussion

5.1 Balance of Nutrient Input, Production and Export from the Euphotic Zone

Table 5 summarizes the different estimates of net productivity: 1) amount of organic material that could be produced from nitrate transported via upwelling and eddy diffusion into the euphotic zone (Potential New Production, or PNP), 2) the net community production (NCP) calculated as NOP divided by the photosynthetic quotient of marine phytoplankton in culture (1.4; Laws, 1991; supported at our study location by Fig. 7c), and 3) the POC export at 100m for all cruises in this study (all in units of $\text{mmol C m}^{-2} \text{ d}^{-1}$). The last column shows the ratio of POC export to NCP. PNP and NCP are also plotted through time in Figure 7a for comparison. PNP and NCP follow the same general temporal pattern and agree within uncertainty for all cruises, although the uncertainties are large. Table 5 also presents the mean values for each season during the study. The mean PNP and NCP agree rather well for the spring seasons each year, but there are significant differences between the best estimates on individual sampling dates. From this data set, we cannot distinguish a difference in nutrients upwelled/mixed upward and the net community production on average, suggesting that the surface ocean ecosystem is in approximate steady state over seasonal timescales. However, the disagreements on shorter timescales suggest that vertical transport and net community production are likely decoupled over daily to weekly timescales. The spring seasonal means of both PNP and NCP between years are also about equal, meaning that the amount of upwelled nutrients and net community production is approximately the same in 2013 and 2014, despite the apparent decrease in nutrient content of the upwelled water from 2013 to 2014 (Figure 4). The mean fall/winter values of PNP and NCP agree within uncertainty, although the best

estimates do not appear to agree well (4 ± 17 and 19 ± 15 mmol m⁻² d⁻¹, respectively). PNP is low due to the virtual absence of upwelling, but we know there must be more net production within the euphotic zone than the PNP best estimate predicts, since there is a mean POC export at 100m of 5 ± 3 mmol C m⁻² d⁻¹. Therefore, it is likely that the NCP best estimate is a better indicator of net euphotic zone production during this time of the year.

We can use the mean input/export flux of carbon during the peak spring months (~130 mmol C m⁻² d⁻¹) and during the low-flux fall/winter months (~20 mmol C m⁻² d⁻¹) to estimate the residence time of particulate organic carbon (POC) in the euphotic zone. In a steady state system, the residence time of a particular substance can be estimated by dividing the total inventory, defined as the depth of the euphotic zone (~50m year-round) times the concentration of POC in the euphotic zone (~5 mmol C m⁻³ consistent year-round; determined by filtering > 0.7 µm suspended particulate and analyzing for organic carbon content; Haskell et al., *unpublished*), by the flux in or out of the system (in this case, a range of 20-130 mmol C m⁻² d⁻¹). The result is a residence time that ranges from 2 days during the period of peak upwelling to 12.5 days in the low flux periods in the fall and winter.

The mean spring POC export at 100m is also approximately the same in both years and was consistently ~15% of the estimated NCP in the euphotic zone. The mean POC export in the fall/winter is a higher proportion of the euphotic zone NCP (~24% on average). However, this may be due to an overestimation of the export flux using the Th-based approach. Using the sediment trap-based estimates only, the Export/NCP ratio is the same as the ratio in the spring seasons (~15%). The implication of the overall

consistency between years is that over seasonal timescales, the heterotrophic community in the 50m beneath the euphotic zone may consume approximately the same proportion of export that leaves the euphotic zone. In the next section, we will explore this in more detail as we calculate the metabolic requirement of the heterotrophic community beneath the euphotic zone.

5.2 Metabolic Balance in the Aphotic Zone at SPOT and Quantifying the DOC 'Leak'

The fate of dissolved organic carbon (DOC), while likely an important contributor to export production (Hansell et al., 2009), has long been difficult to quantify. The approach of estimating net production with O_2/Ar relies on the balance of community rates of photosynthesis and respiration, regardless of whether the exported organic material is in the dissolved or particulate phase. Thus, under our assumption that NOP is representative of net production over a sufficiently long/large temporal/spatial scale to approach a steady state with export production (Estapa et al., 2015), NCP represents the sum of both particulate and dissolved carbon export from the euphotic zone. This makes dissolved oxygen, in combination with estimates of particulate export from traps and Th , a useful tracer for estimating the contribution of DOC to total organic carbon export.

To estimate the relative proportion of DOC consumption between from 55-100m (base of the euphotic zone to 100m trap) and 100-200m (between traps), we investigated the in-situ relationship between the dissolved organic carbon pool and our estimate of total oxidized carbon (TC_{ox}) during Spring 2014 in these two depth zones (Figures 8a and 8b). Assuming a one-dimensional system and that the same transport processes affect both DOC and TC_{ox} equally, the slope of these plots should represent the ratio of DOC consumption to total organic carbon consumption (or TC_{ox} production) in each of these

regions. These results suggest that ~30% of the organic carbon remineralization in these two depth zones is fueled by DOC. However, a plot of DOC vs. TC_{ox} from 55-200m has a much smaller slope (0.10; Fig. 8c), suggesting that only ~10% of total carbon remineralization from the euphotic zone to 200m is fueled by DOC. Considering the limited number of data points in this fit and the analytical uncertainty on DOC concentration measurements ($\sim \pm 5 \mu M$), the uncertainty in the DOC vs. TC_{ox} relationship at our study site is likely greater than the uncertainty in the fit shown in Fig. 8 (indicated by the variance from the linear regression). In light of this, we chose to take the mean of 10% and 30% to represent the mean DOC: TC_{ox} ratio in spring (~20%), which is likely within the uncertainty of both fits. Using the same approach for the fall profile, we found that ~15% and ~7% of the carbon remineralization is from DOC in the shallow and deep zones, respectively, whereas the fit of the entire depth range was also ~10%. We chose to use the ~10% as the fall DOC consumption ratio since the difference between 15% and 7% is likely indistinguishable within uncertainty. In the following paragraph, we build an organic carbon budget for both the spring and fall seasons separately using all of this information in a step-wise fashion, as illustrated in Figure 9. Admittedly, these estimates have large associated uncertainties ($\sim \pm 50\%$), but they do justify the magnitude of export fluxes presented in this work.

Horizontal export of net DOC production in the surface layer must be added to this budget to balance the upwelling mass flux. We estimate this by taking the difference between the DOC concentration of waters entering the euphotic zone and those at the surface ($\sim 10 \mu M$) and multiplying this by the mean upwelling velocity ($1.5 m d^{-1}$). The result is that $\sim 15 mmol C m^{-2} d^{-1}$ would be lost to horizontal export in spring. In fall, the

upwelling velocity is approximately $\sim 0 \text{ m d}^{-1}$, so the horizontal export is also $\sim 0 \text{ mmol C m}^{-2} \text{ d}^{-1}$. Therefore, $\sim 115 \text{ mmol C m}^{-2} \text{ d}^{-1}$ enters the aphotic zone above 100m as it is exported from the euphotic zone as either POC or DOC in spring.

In the spring, under the assumption of a one-dimensional system, if $\sim 18 \pm 8 \text{ mmol C m}^{-2} \text{ d}^{-1}$ reaches the sediment traps set at 100m and $\sim 10 \text{ mmol C m}^{-2} \text{ d}^{-1}$ reaches 200m, then the POC loss in the deep zone is $\sim 8 \text{ mmol C m}^{-2} \text{ d}^{-1}$. If $\sim 20\%$ of the organic carbon loss is to DOC, then $\sim 2 \text{ mmol C m}^{-2} \text{ d}^{-1}$ of DOC is also lost in this zone. With the loss of POC across the 200m boundary of $\sim 10 \text{ mmol C m}^{-2} \text{ d}^{-1}$, this means $\sim 95 \text{ mmol C m}^{-2} \text{ d}^{-1}$ must be consumed between 55 and 100m. Using our $\text{TC}_{\text{ox}}/\text{DOC}$ -based estimate that $\sim 20\%$ of total C loss is from DOC, $\sim 19 \text{ mmol C m}^{-2} \text{ d}^{-1}$ of DOC must be lost in this zone. This means that a total of $\sim 28\%$ of total euphotic zone NCP is exported as DOC either horizontally or vertically in the spring months and the remaining 72% ($\sim 94 \text{ mmol C m}^{-2} \text{ d}^{-1}$) leaves the euphotic zone as sinking POC. $\sim 80\%$ ($\sim 76 \text{ mmol C m}^{-2} \text{ d}^{-1}$) of this POC export is consumed by heterotrophs between $\sim 55\text{m}$ and 100m.

In the fall, only $\sim 20 \pm 15 \text{ mmol C m}^{-2} \text{ d}^{-1}$ (DOC + POC) is exported from the euphotic zone and $\sim 5 \pm 3 \text{ mmol C m}^{-2} \text{ d}^{-1}$ reaches the sediment traps at 100m (POC). Our estimate of DOC consumption is that only $\sim 1.5 \text{ mmol C m}^{-2} \text{ d}^{-1}$ total is consumed from 55m to 200m. Therefore, we estimate that $\sim 18.5 \text{ mmol C m}^{-2} \text{ d}^{-1}$ ($\sim 92\%$) leaves the euphotic zone as POC export and about 73% of this POC is consumed before reaching 100m ($\sim 13.5 \text{ mmol C m}^{-2} \text{ d}^{-1}$). The POC loss between the 100m and 200m sediment traps is only $\sim 1 \text{ mmol C m}^{-2} \text{ d}^{-1}$, meaning our DOC consumption estimate in the deep zone is $\sim 0.1 \text{ mmol C m}^{-2} \text{ d}^{-1}$. Given the uncertainty in our estimates and the small magnitude of the

DOC loss component, we believe this number likely has an uncertainty of at least $\pm \sim 0.5$ mmol C m⁻² d⁻¹.

6. Conclusions

In this study, we used estimates of upwelling velocity determined from a ⁷Be mass balance in the upper thermocline and estimates of vertical eddy diffusivity to calculate the potential new production (PNP) from the vertical flux of nitrate into the euphotic zone at SPOT in 2013 and 2014. Net community production (NCP) was calculated by combining the vertical transport rates and measurements of O₂/Ar in a one-dimensional two-box model of the euphotic zone. Although NCP and PNP did not agree on every sampling date, they did agree within uncertainty over monthly timescales, suggesting that the euphotic zone at SPOT is at steady state over months, but not over weeks. Using these NCP values, export rates from a water column Th budget and sediment trap deployments, and an estimate of relative DOC:POC consumption, we constructed an organic carbon budget for the upper 200m at SPOT. This exercise showed that in spring, of the ~ 130 mmol C m⁻² d⁻¹ that is exported from the euphotic zone, $\sim 28\%$ leaves as DOC, including ~ 15 mmol C m⁻² d⁻¹ that is lost as horizontal DOC export. The remaining 72% leaves the euphotic zone as sinking POC. Within ~ 50 m of the base of the euphotic zone, $\sim 80\%$ of the vertically exported organic carbon is remineralized, but ~ 18 mmol C m⁻² d⁻¹ gets to 100m and ~ 10 mmol C m⁻² d⁻¹ gets to 200m as sinking POC. In fall, there is only a total of ~ 20 mmol C m⁻² d⁻¹ that is exported from the euphotic zone, $\sim 10\%$ as DOC and $\sim 90\%$ as sinking POC. $\sim 75\%$ of this export is remineralized within the first ~ 50 m below the euphotic zone and $\sim 20\%$ reaches 200m, but the fall estimates

are highly uncertain due to their small magnitude. Although there are some methodological biases associated with combining multiple approaches, this study provides a unique perspective on non-steady state organic carbon export and remineralization in an upwelling region. The dynamics of this process are often neglected in studies of organic carbon export, but are critical to furthering our understanding of the sources and fate of both particulate and dissolved organic material in marine systems.

Acknowledgments:

We would like to thank Troy Gunderson for SPOT management, Zoe Sandwith for assistance with O₂/Ar analysis, Vicky Espinoza for sample collection and analysis, Nick Rollins for DIC analysis and satellite data compiling, Baron Barrera for ⁷Be sample processing, Corinne Calhoun for 2013 nitrate analysis, and Paulina Pinedo-Gonzalez, Danielle Monteverde, and Chris Suffridge for help with sample collection. None of this work could have been possible without the helpful assistance of the captain and crew of the R/V Yellowfin. We would also like to thank the USC Wrigley Institute of Environmental Science for the use of their CTD. We are grateful to an anonymous reviewer for many helpful comments on the manuscript. Financial support for this project came from a graduate research grant from the International Association for Geochemistry to William Haskell, and grants 1260296 to Maria Prokopenko and 1260692 to Douglas Hammond from the Chemical Oceanography program of the National Science Foundation. All data used in this study is presented in this manuscript and in the Appendices.

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1 **Figures:**

2 **Figure 1:** Map of the study location. The San Pedro Ocean Time series (SPOT) is
3 indicated by an 'X' offshore of Los Angeles (NGDC, 2011).
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Figure 2: Illustration of the one-dimensional two-box NOP model used in this study. The blue and yellow boxes represent the ML and BML boxes, respectively, which are divided by the mixed layer depth (MLD; dashed line). The purple region represents the ‘deep’ portion of the water column below the euphotic depth (Euph; dashed line). Black and red dots represent the depths where samples were typically taken. The black line represents a profile when the biologically produced portion of the oxygen pool decreases with depth and the red dashed line represents a profile with a subsurface maximum, which is a common feature in our study region.

Figure 3: Upwelling velocity calculated using the NSS ^7Be -based method described in Haskell et al. (2015b; black bars) and the monthly Bakun Upwelling Index (green bars). Uncertainty in the ^7Be velocities are shown as black error bars aligned with the sampling date.

Figure 4: Time series of nutrient concentration (all in μM), ^7Be -based upwelling velocity, and eddy diffusivity at the euphotic depth calculated using wind speed and vertical density gradient.

The thin black lines and dashed line in the upwelling velocity panel indicate the uncertainty of the estimates and the boundary between positive (upwelling) and negative (downwelling) values, respectively. The white lines in the nutrient panels indicate the mixed layer depth.

Figure 5: Net oxygen production rate plotted versus a.) POC flux at 100m estimated using traps and Th, b.) integrated chlorophyll in the euphotic zone, and c.) upwelling velocity calculated using the Be-based approach. All parameters have ~50% uncertainty. Pearson correlation coefficients (r) and significance levels (p) are shown for the linear regression on each plot.

Figure 6: Time series plots of export fluxes and a comparison of sediment trap-based and Th-based export estimates.

a.) Particulate organic carbon (POC) flux across the 100m and 200m horizons estimated using surface-tethered sediment traps (red squares) and a water column Th budget (black circles) from January 2013 to June 2014. b.) Plot of the input flux of Si into the euphotic zone (red) via upwelling and eddy diffusivity and the export flux of biogenic silica (bSi) into sediment traps set at 100m (black) deployed periodically throughout the study period. c.) POC flux estimated using sediment trap deployments and a water column Th budget. The 1:1 line is shown in black. Panels a and b are aligned in time on the x-axis.

Figure 7: a.) Potential new production (PNP; red) and net community production (NCP; black) plotted versus time. Uncertainty reported as 1σ determined by Monte Carlo simulation described in the text, b.) PNP plotted versus NCP. The black line is the total least squares linear regression with the slope and statistical values shown, and c.) Total oxidized carbon (TC_{ox} ; eq. 7) concentration plotted versus apparent oxygen utilization (AOU) beneath the euphotic depth (55-400m). AOU is defined as the saturation concentration of oxygen at the sampling temperature and salinity minus the measured concentration. The slope of 1.44 ± 0.03 represents the stoichiometry of $\text{C}:\text{O}_2$ in remineralized organic material, which is used to calculate NCP from NOP.

Figure 8: Plots of TC_{ox} versus DOC concentration in the depth ranges: a.) 55m to 100m, b.) 100m to 200m, and c.) 55m to 200m in Spring 2014. Black lines are the linear regressions with statistics shown in the top right corner of each plot.

Figure 9: Illustration of the organic carbon budgets during spring and fall at SPOT calculated using O₂/Ar-based estimates of euphotic zone net community production, sediment trap deployment/Th-based estimates of POC export, and a water column DOC budget. The arrows and bold numbers represent fluxes across the boundary shown, whereas the numbers in parentheses represent losses within the box shown (all in mmol C m⁻² d⁻¹). Uncertainties are ~ ± 50 % for all values.

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53 **Tables:**

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Table 1: All vertical transport terms used in this study.

Cruise I.D.	Date	MLD (m)	Euph (m)	w_H^a (m d ⁻¹)	W_{10}^b (m s ⁻¹)	k^c (m d ⁻¹)	K_{z-ML}^d (m ² d ⁻¹)	K_{z-BML}^e (m ² d ⁻¹)
SP42	1/16/13	30	45	0.9 ± 0.6	4.6 ± 0.3	1.5 ± 0.2	3.6 ± 1.3	-
Up-1	2/13/13	35	45	0.6 ± 0.3	4.3 ± 0.5	1.4 ± 0.2	0.9 ± 0.3	1.0 ± 0.3
Up-2	2/28/13	35	37	1.9 ± 0.9	4.5 ± 0.6	2.8 ± 0.4	1.8 ± 0.6	2.2 ± 0.9
Up-3	3/14/13	35	44	1.5 ± 1.0	5.2 ± 0.6	2.0 ± 0.3	2.0 ± 1.1	1.9 ± 0.7
Up-4	4/3/13	30	45	1.3 ± 0.8	5.2 ± 0.4	2.0 ± 0.3	<i>0.9 ± 0.3</i>	1.8 ± 0.4
Up-5	4/25/13	13	30	1.8 ± 1.0	4.1 ± 0.4	1.3 ± 0.2	<i>0.9 ± 0.3</i>	<i>0.9 ± 0.3</i>
Up-6	5/10/13	10	26	2.5 ± 1.3	4.7 ± 0.4	2.1 ± 0.3	1.8 ± 0.7	2.1 ± 0.8
Up-7	5/22/13	10	34	2.4 ± 1.3	4.4 ± 0.3	1.5 ± 0.2	1.1 ± 0.4	1.5 ± 0.6
Up-8	6/20/13	12	30	1.2 ± 0.5	3.3 ± 0.3	1.1 ± 0.2	<i>0.9 ± 0.3</i>	2.7 ± 1.0
Up-9	10/3/13	12	50	-0.2 ± 0.5	5.0 ± 0.5	2.2 ± 0.3	2.1 ± 0.8	2.1 ± 0.8
Up-10	12/9/13	32	50	0.3 ± 0.5	4.8 ± 0.8	2.1 ± 0.3	<i>0.9 ± 0.3</i>	<i>0.9 ± 0.3</i>
Up-11	1/15/14	30	45	-0.1 ± 0.5	3.2 ± 0.2	1.2 ± 0.2	1.0 ± 0.4	<i>0.9 ± 0.3</i>
Up-12	1/29/14	30	45	0.8 ± 0.7	2.9 ± 0.4	0.7 ± 0.1	<i>0.9 ± 0.3</i>	<i>0.9 ± 0.3</i>
Up-13	2/12/14	20	30	2.2 ± 1.1	6.6 ± 0.5	2.6 ± 0.4	2.7 ± 1.1	3.1 ± 1.2
Up-14*	3/5/14	15	50	1.7 ± 0.8	7.9 ± 0.5	3.2 ± 0.5	2.3 ± 0.8	3.2 ± 1.2
Up-15	3/12/14	25	45	1.1 ± 0.5	3.2 ± 0.6	0.9 ± 0.2	<i>0.9 ± 0.3</i>	<i>0.9 ± 0.3</i>
Up-16*	4/4/14	25	33	1.5 ± 0.7	5.9 ± 0.6	2.9 ± 0.5	4.7 ± 1.7	1.4 ± 0.5
Up-17	4/11/14	15	40	1.8 ± 0.8	4.0 ± 0.6	1.4 ± 0.2	1.3 ± 0.4	<i>0.9 ± 0.3</i>
Up-18	4/24/14	18	55	1.4 ± 0.7	5.6 ± 0.3	2.0 ± 0.2	1.7 ± 0.6	<i>0.9 ± 0.3</i>
Up-19	5/7/14	25	31	2.8 ± 1.4	7.3 ± 0.8	2.4 ± 0.4	3.1 ± 1.1	2.1 ± 0.6
Up-20	5/22/14	20	30	2.1 ± 1.3	5.1 ± 0.6	2.1 ± 0.2	1.5 ± 0.6	1.4 ± 0.6
Up-21	6/19/14	13	41	0.6 ± 0.5	4.7 ± 0.4	1.8 ± 0.3	1.4 ± 0.6	0.9 ± 0.3

^aUpwelling velocity. Uncertainty calculated by propagating the uncertainty in the ⁷Be inventory, input and D_{Th}. Uncertainty in w_H for Up-9, 10 and 11 is reported as 0.5 m d⁻¹.

^b15-day weighted wind speed estimate 10m above the sea surface. Uncertainty reported as the standard deviation of the mean of 15 daily means.

^c15-day weighted piston velocity. Uncertainty is reported as 15% (Stanley et al., 2009; Ho et al., 2006).

^dEstimated eddy diffusivity due to shear at the base of the mixed layer using W_{10} , O_2 and density. Uncertainty reported as 34% (Haskell et al., *in press*).

^eEstimated eddy diffusivity due to shear at the base of the 'below mixed layer' box. Values under 0.9 m² d⁻¹ were set to 0.9 m² d⁻¹ (in italics).

*No upwelling velocity was calculated for Up-14 and Up-16. The reported values were determined by linear interpolation of calculated values immediately before and after each cruise and uncertainty is assumed to be 50%.

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Table 2: Nutrients at the base of the euphotic zone and vertical nutrient fluxes across the base of the euphotic zone due to upwelling and eddy diffusivity.

Cruise ID	Date	NO_3^- euph ^a (all in mM)	Si(OH)_4 euph (all in mM)	$\delta\text{NO}_3^-/\delta z^b$ (all in mmol m ⁻⁴)	$\delta\text{Si}/\delta z$ (all in mmol m ⁻⁴)	Upwelled ^c		Eddy Diffusive ^d		Total ^e	
						NO_3^- Flux (all in mmol m ⁻² d ⁻¹)	Si Flux (all in mmol m ⁻² d ⁻¹)	NO_3^- Flux (all in mmol m ⁻² d ⁻¹)	Si Flux (all in mmol m ⁻² d ⁻¹)	NO_3^- Flux (all in mmol m ⁻² d ⁻¹)	Si Flux (all in mmol m ⁻² d ⁻¹)
SP42	1/16/13	-	-	-	-	-	-	-	-	-	-
Up-1	2/14/13	8.5	5.3	0.83	0.79	5.3 ± 2.6	3.3 ± 1.6	0.8 ± 0.4	0.8 ± 0.4	6.1 ± 3.0	4.1 ± 2.0
Up-2	2/28/13	6.9	4.8	0.36	0.32	13.3 ± 6.3	9.3 ± 4.4	0.8 ± 0.4	0.7 ± 0.4	14.1 ± 6.7	10.0 ± 4.8
Up-3	3/14/13	4.9	5.8	0.83	0.54	7.5 ± 4.9	9.0 ± 5.8	1.5 ± 0.9	1.0 ± 0.6	9.0 ± 5.8	10.0 ± 6.4
Up-4	4/3/13	10.2	9.4	0.82	0.77	13.0 ± 8.1	12.0 ± 7.4	1.5 ± 0.8	1.4 ± 0.8	14.5 ± 8.9	13.4 ± 8.2
Up-5	4/25/13	6.2	4.4	0.86	0.83	11.3 ± 6.1	8.0 ± 4.3	0.8 ± 0.5	0.7 ± 0.5	12.1 ± 6.6	8.7 ± 4.8
Up-6	5/10/13	5.8	2.1	0.82	0.94	14.6 ± 7.7	5.3 ± 2.8	1.7 ± 0.9	2.0 ± 1.0	16.3 ± 8.6	7.3 ± 3.8
Up-7	5/23/13	7.9	5.8	0.39	0.38	19.2 ± 10.3	14.2 ± 7.6	0.6 ± 0.3	0.6 ± 0.3	19.8 ± 10.6	14.8 ± 7.9
Up-8	6/20/13	9.5	7.5	0.29	0.25	11.1 ± 4.8	8.8 ± 3.8	0.8 ± 0.4	0.7 ± 0.4	11.9 ± 5.2	9.5 ± 4.2
Up-9	10/4/13	8.0	6.9	0.45	0.33	-1.9 ± 4.0	-1.6 ± 3.5	0.9 ± 0.5	0.7 ± 0.4	-1.0 ± 2.0	-0.9 ± 1.8
Up-10	12/10/13	7.7	5.7	0.16	0.11	2.3 ± 3.8	1.7 ± 2.9	0.1 ± 0.1	0.1 ± 0.1	2.4 ± 3.9	1.8 ± 2.8
Up-11	1/16/14	2.6	2.7	0.28	0.16	-0.2 ± 1.3	-0.2 ± 1.4	0.3 ± 0.2	0.1 ± 0.1	0.1 ± 1.4	-0.1 ± 1.5
Up-12	1/29/14	3.0	2.0	0.37	0.28	2.5 ± 2.1	1.7 ± 1.4	0.3 ± 0.2	0.2 ± 0.1	2.8 ± 2.3	1.9 ± 1.5
Up-13	2/13/14	3.3	2.2	0.29	0.26	7.4 ± 3.7	4.9 ± 2.4	0.9 ± 0.4	0.8 ± 0.4	8.3 ± 4.1	5.7 ± 2.8
Up-14	3/5/14	7.6	6.0	0.23	0.26	12.6 ± 6.3	10.0 ± 5.0	0.7 ± 0.4	0.8 ± 0.5	13.3 ± 6.7	10.8 ± 5.5
Up-15	3/13/14	4.7	3.7	0.34	0.27	5.1 ± 2.4	4.0 ± 1.9	0.3 ± 0.1	0.2 ± 0.1	5.4 ± 2.5	4.2 ± 2.0
Up-16	4/4/14	6.0	5.0	0.52	0.65	8.8 ± 4.4	7.3 ± 3.7	0.7 ± 0.4	0.9 ± 0.5	9.5 ± 4.8	8.2 ± 4.2
Up-17	4/11/14	8.0	9.0	0.45	0.43	14.6 ± 6.7	16.4 ± 7.5	0.4 ± 0.2	0.4 ± 0.2	15.0 ± 6.8	16.8 ± 7.6
Up-18	4/24/14	10.3	9.3	0.40	0.34	14.7 ± 6.9	13.3 ± 6.3	0.4 ± 0.2	0.3 ± 0.2	15.1 ± 7.0	13.6 ± 6.5
Up-19	5/8/14	4.6	2.6	0.14	0.51	12.9 ± 6.3	7.2 ± 3.5	0.3 ± 0.1	1.1 ± 0.5	13.2 ± 6.4	8.3 ± 4.0
Up-20	5/22/14	5.1	6.4	0.67	0.43	10.6 ± 6.7	13.4 ± 8.4	1.0 ± 0.5	0.6 ± 0.3	11.6 ± 7.2	14.0 ± 8.7
Up-21	6/19/14	2.7	2.4	0.35	0.24	1.7 ± 1.3	1.5 ± 1.2	0.3 ± 0.2	0.2 ± 0.1	2.0 ± 1.5	1.7 ± 1.3

^aThe difference between the first nutrient measurement made below the euphotic zone and the concentration at the surface (Table C1).^bAnalytical precision on nitrate and silicic acid concentration is ~0.5 mM.^cNitrate and silicon gradients in the 20m below the euphotic depth.^dFlux of nitrate and silicon due to upwelling defined as upwelling velocity multiplied by NO_3^- euph and Si(OH)_4 euph. Uncertainty in upwelled nutrients reported here is equivalent to uncertainty in w_H .^eFlux of nitrate and silicon due to eddy diffusivity defined as the eddy diffusivity coefficient multiplied by the nutrient gradients below the euphotic zone.^fDefined as the sum of upwelled and eddy diffusive fluxes.

Table 3: All measurements used in the net oxygen production estimates.

Cruise ID	Date	MLD/EuphD (m)	Depth (m)	[O ₂] _{sat} ^a (mM)	DO ₂ /Ar ^b	T _k ^c	T _{wh} ^d	T _{Kz} ^e	T _{NSS} ^f	NOP _{ML/BML} ^g	NOP _{Euph} ^h
SP42*	1/16/13	30	10	265.5	-0.0105	-9	45	-12	-	25	25 ± 29
		45	20	267.2	-0.0286	-	-	-	-	-	
			45	271.5	-0.1900						
Up-1	2/14/13	35	10	262.6	0.0257	5	38	6	10	58	62 ± 17
		45	32	263.5	-0.0010	-	0	-6	9	4	
			45	271.5	-0.1900						
			70	280.1	-0.4608						
Up-2	2/28/13	35	5	265.4	-0.0136	-19	128	17	-26	100	110 ± 69
		50	17	265.9	-0.0328	-	22	-16	3	10	
			37	269.5	-0.2453						
			100	285.3	-0.5808						
Up-3	3/14/13	35	5	261.8	0.0815	27	64	12	51	153	168 ± 59
		50	20	264.6	0.0130	-	23	-12	3	14	
			45	267.5	-0.0931						
			70	280.1	-0.4353						
Up-4	4/3/13	30	5	256.4	0.0633	35	19	7	3	63	186 ± 69
		45	29	260.6	0.0110	-	97	2	23	123	
			45	276.0	-0.2394						
			70	281.4	-0.4928						
Up-5^	4/25/13	13	4	252.9	0.0704	25	57	3	-3	82	184 ± 67
		35	18	262.0	0.0711	-	92	2	7	101	
			30	268.3	-0.1533						
			60	281.3	-0.5161						
Up-6^	5/10/13	10	5	245.6	0.0318	18	-17	2	-10	-7	182 ± 81
		45	17	255.2	0.0549	-	172	5	12	189	
			28	269.0	-0.0707						
			61	282.0	-0.4501						
Up-7^	5/23/13	10	5	242.3	0.0287	11	74	0	-1	85	104 ± 71
		45	22	265.5	0.0139	-	102	5	-88	19	
			34	273.4	-0.1654						
			100	284.6	-0.5855						
Up-8	6/20/13	12	5	238.6	0.0365	12	-20	-2	2	-8	44 ± 11
		30	10	239.7	0.0452	-	25	19	7	52	
			18	260.7	0.0975						
			30	274.0	-0.1411						
Up-9	10/4/13	12	8	233.5	0.0335	19	4	-2	-	19	14 ± 21
		48	28	258.2	0.0766	-	-12	8	-	-5	
			35	264.9	0.0580						
			60	276.7	-0.2970						
Up-10	12/10/13	32	10	251.3	0.0115	6	19	4	-	28	20 ± 27
		52	25	251.4	0.0104	-	-2	-6	-	-8	
			50	268.6	-0.1974						
			65	274.7	-0.2212						
Up-11	1/16/14	30	8	254.4	0.0344	12	-1	2	5	18	48 ± 16
		45	22	255.7	0.0344	-	-3	1	32	30	
			32	256.3	0.0023						
			45	260.6	-0.0937						

Table 3 (continued): All measurements used in the net oxygen production estimates.

Cruise ID	Date	MLD/EuphD (m)	Depth (m)	[O ₂] _{sat} ^a (mM)	DO ₂ /Ar ^b	T _k ^c	T _{wh} ^d	T _{Kz} ^e	T _{NSS} ^f	NOP _{ML/BML} ^g	NOP _{Euph} ^h
(all in mmol m ⁻² d ⁻¹)											
Up-13	2/13/14	20	5	256.0	0.0709	51	108	13	18	191	156 ± 55
		35	15	256.7	0.0708	-	13	-10	-38	-35	
			30	263.4	-0.0981						
			45	270.2	-0.1995						
Up-14 [^]	3/5/14	15	5	251.2	0.0332	29	12	1	-13	28	108 ± 28
		45	12	251.9	0.0318	-	44	5	31	80	
			22	258.6	0.0408						
			35	264.7	-0.0275						
			100	281.8	-0.4574						
Up-15 [^]	3/13/14	25	10	251.9	0.0288	7	31	3	9	50	131 ± 48
		70	20	253.6	0.0310	-	76	4	1	81	
			35	261.0	-0.0163						
			45	266.9	-0.1203						
			80	277.8	-0.3701						
Up-16 [^]	4/4/14	25	10	261.1	0.1076	52	96	31	11	190	205 ± 59
		40	23	262.2	0.0188	-	28	-34	21	15	
			33	265.9	-0.1630						
			44	275.6	-0.3017						
Up-17	4/11/14	15	5	257.2	0.0458	24	-17	-1	-26	-19	214 ± 55
		40	12	257.9	0.0821	-	79	9	145	233	
			26	263.5	0.0949						
			40	272.4	-0.1949						
Up-18 [^]	4/24/14	18	6	247.0	0.0270	15	59	2	-10	66	156 ± 69
		60	14	247.1	0.0292	-	87	0	2	90	
			39	261.2	0.0324						
			55	273.7	-0.2604						
			100	282.4	-0.5036						
Up-19	5/8/14	25	5	255.6	0.0686	47	152	34	25	259	170 ± 81
		33	12	256.6	0.0709	-	19	-31	-77	-89	
			31	266.2	-0.1199						
			45	276.2	-0.4115						
Up-20 [^]	5/22/14	20	7	243.0	0.0655	37	46	3	-9	78	117 ± 65
		40	17	243.8	0.0665	-	64	1	-26	39	
			30	259.9	0.0934						
			39	271.8	-0.1204						
			70	280.3	-0.3985						
Up-21 [^]	6/19/14	13	5	236.9	0.0136	7	-3	0	-11	-7	41 ± 19
		60	10	237.7	0.0164	-	28	2	18	48	
			28	260.5	0.0676						
			41	266.5	-0.0061						
			85	283.0	-0.3043						

*Only mixed layer biological supersaturation of oxygen was measured during SP42. The sample reported here for 45m is the value measured on the following cruise, which was used to complete the calculation of ML NOP. Without this, the NOP estimate is -8 mmol m⁻² d⁻¹.

[^]The BML box values are defined as the mean of the two samples within that box.

^aOxygen saturation concentration calculated in mmol kg⁻¹ using temperature and salinity measured by Seabird CTD (Garcia and Gordon, 1992), then converted to mM assuming a density of 1.0255 kg L⁻¹.

^bBiological supersaturation of oxygen calculated from measurements of O₂/Ar by IRMS.

^cValue of the gas exchange term in NOP Eqs. 3.5a and 3.5b.

^dValue of the upwelling term in NOP Eqs. 3.5a and 3.5b.

^eValue of the eddy diffusivity term in NOP Eqs. 3.5a and 3.5b.

^fNon-steady state term determined by the change in the biological supersaturation of oxygen in, and size of, each box.

^gTotal 'Mixed Layer' (top) and 'Below Mixed Layer' (bottom) NOP, including the transported signal between boxes and NSS changes.

^hNOP in the entire euphotic zone determined as the sum of the total NOP in the ML and BML boxes. Uncertainty on NOP is estimated by Monte Carlo simulation and described in the text.

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Table 4: Export fluxes of Th, POC and PON calculated using sediment traps and thorium budget.

Cruise ID	Depth (m)	Date	Sediment trap-based: ^a						Th based: ^b						Mean C _{org} Flux σ^c (mmol m ⁻² d ⁻¹)																
			Mass Flux (mg m ⁻² d ⁻¹)	C _{org} :Th (mmol dpm ⁻¹)	Be:Th (mmol dpm ⁻¹)	C _{org} :N (mmol dpm ⁻¹)	bSi:Th (mmol dpm ⁻¹)	Th Flux (dpm m ⁻² d ⁻¹)	σ (mmol m ⁻² d ⁻¹)	C _{org} Flux (mmol m ⁻² d ⁻¹)	σ (mmol m ⁻² d ⁻¹)	N Flux (mmol m ⁻² d ⁻¹)	σ (mmol m ⁻² d ⁻¹)	bSi Flux (mmol m ⁻² d ⁻¹)		σ (mmol m ⁻² d ⁻¹)															
SP-41	100	1/16/13	-	-	-	-	-	-	-	-	-	-	-	-	-	8.1	5.1														
	200		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-														
Up-1	100	2/14/13	334	11.71	0	5.4	1.52	394	4.6	2.3	0.85	983	492	11.5	5.8	2.12	1.06	1.5	0.7	8.1	4.0										
	200		503	8.28	0.007	6.9	1.05	858	429	7.1	3.6	1.02	683	342	5.7	2.9	0.81	0.41	0.7	0.4	6.4	3.1									
Up-2	100	2/28/13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12.3	5.8								
	200		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12.8	6.0							
Up-3	100	3/14/13	1904	3.76	0.036	8.0	7.69	3759	1880	14.1	7.1	1.77	0.88	28.9	14.5	17.4	8.7	1778	1745	10.1	6.5	1.27	0.82	20.7	13.4	12.1	7.8				
	200		1158	4.52	0.019	7.2	7.44	2339	1170	10.6	5.3	1.46	0.73	17.4	8.7	1778	1150	8.0	5.2	1.11	0.72	13.2	8.6	9.3	6.0						
Up-4	100	4/3/13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18.5	11.4			
	200		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16.3	10.1			
Up-5	100	4/25/13	1618	6.32	0.009	7.8	7.62	3033	1516	19.2	9.6	2.45	1.23	23.1	11.6	16.3	8.1	2560	1374	16.2	8.7	2.07	1.11	19.5	10.5	17.7	9.5				
	200		1253	4.69	0.005	7.8	5.72	2851	1426	13.4	6.7	1.71	0.85	16.3	8.1	2072	1112	9.7	5.2	1.24	0.67	11.9	6.4	11.5	6.2						
Up-6	100	5/10/13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14.3	7.5	
	200		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.8	3.1	
Up-7	100	5/23/13	366	5.16	0.002	9.1	-	1036	518	5.3	2.7	0.59	0.29	-	-	-	-	4216	2265	21.8	11.7	2.39	1.28	-	-	-	-	-	-	13.6	7.3
	200		253	3.05	0.001	5.1	-	897	449	2.7	1.4	0.54	0.27	-	-	-	-	3478	1868	10.6	5.7	2.07	1.11	-	-	-	-	-	-	6.7	3.6
Up-8	100	6/20/13	212	8.02	0.064	7.5	-	409	205	3.3	1.6	0.44	0.22	-	-	-	-	858	373	6.9	3.0	0.91	0.40	-	-	-	-	-	-	5.1	2.2
	200		165	12.34	0.064	6.8	-	235	118	2.9	1.4	0.43	0.21	-	-	-	-	537	233	1.6	0.7	0.32	0.14	-	-	-	-	-	-	2.2	1.0
Up-9	100	10/4/13	433	10.17	0.006	7.1	1.77	339	170	3.4	1.7	0.49	0.24	0.6	0.3	0.2*	-	710	426	7.2	4.3	1.02	0.61	1.3	0.8	5.3	3.2	5.4	3.2		
	200		195	10.41	0	10.0	0.80	374	187	3.9	1.9	0.39	0.19	0.3*	0.2*	-	-	656	393	6.8	4.1	0.68	0.41	0.5	0.3	5.4	3.2				
Up-10	100	12/10/13	158	8.24	0.037	7.6	-	325	163	2.7	1.3	0.35	0.18	-	-	-	-	1127	445	9.3	3.7	1.22	0.48	-	-	-	-	-	-	6.0	2.4
	200		131	6.85	0.00	10.2	-	268	134	1.8	0.9	0.18	0.09	-	-	-	-	1816	717	12.4	4.9	1.22	0.48	-	-	-	-	-	-	7.1	2.8

Table 4 (continued): Export fluxes of Th, POC and PON calculated using sediment traps and thorium budget.

Cruise ID	Depth (m)	Date	Sediment trap-based: ^a					Th-based: ^b					C _{org} Flux					N Flux					Mean C _{org} Flux ^c				
			Mass Flux (mg m ⁻² d ⁻¹)	C _{org} :Th (mmol dpm ⁻¹)	Ba:Th (mmol dpm ⁻¹)	C _{org} :N (mmol dpm ⁻¹)	bsi:Th (mmol dpm ⁻¹)	Th Flux (dpm m ⁻² d ⁻¹)	σ	C _{org} Flux (mmol m ⁻² d ⁻¹)	σ	N Flux (mmol m ⁻² d ⁻¹)	σ	bsi Flux (mmol m ⁻² d ⁻¹)	σ	Th Flux (dpm m ⁻² d ⁻¹)	σ	C _{org} Flux (mmol m ⁻² d ⁻¹)	σ	N Flux (mmol m ⁻² d ⁻¹)	σ	bsi Flux (mmol m ⁻² d ⁻¹)	σ	Mean C _{org} Flux (mmol m ⁻² d ⁻¹)	σ	Mean C _{org} Flux (mmol m ⁻² d ⁻¹)	σ
Up-11	100	1/16/14	150	6.23	0.223	7.0	0.30	332	166	2.1	1.0	0.30	0.15	0.2*	0.1*	504	228	3.1	1.4	0.45	0.20	0.2	0.1	2.6	1.2		
	200		645	16.69	0.055	11.4	3.14	255	128	4.3	2.1	0.37	0.19	0.8	0.4	720	325	4.5	2.0	0.64	0.29	2.3	1.0	4.4	2.0		
Up-12	100	1/29/14	-	-	-	-	-	-	-	-	-	-	-	-	-	846	668	5.3	4.2	0.76	0.60	-	-	5.3	4.2		
	200		-	-	-	-	-	-	-	-	-	-	-	-	-	154	122	2.6	2.1	0.23	0.18	-	-	2.6	2.1		
Up-13	100	2/13/14	191	4.32	0.099	8.4	0.73	547	274	2.4	1.2	0.28	0.14	0.8*	0.4*	2311	892	10.0	3.9	1.19	0.46	1.7	0.7	6.2	2.4		
	200		377	3.22	0.025	7.0	2.09	812	406	2.6	1.3	0.37	0.19	1.7	0.8	2863	1105	9.2	3.6	1.32	0.51	6.0	2.3	5.9	2.3		
Up-15	100	3/13/14	621	5.22	0.022	7.1	1.78	1517	759	7.9	4.0	0.74	0.37	2.7	1.3	2187	813	11.4	4.2	1.07	0.40	3.9	1.4	9.7	3.6		
	200		1078	4.02	0.019	8.0	1.40	2647	1324	10.6	5.3	1.12	0.56	3.7	1.9	2112	785	8.5	3.2	0.89	0.33	3.0	1.1	9.5	3.5		
Up-17	100	4/11/14	1247	8.78	0.013	8.1	5.80	2327	1164	20.4	10.2	2.51	1.25	13.5	6.8	3434	1684	30.2	14.8	3.70	1.81	19.9	9.8	25.3	12.4		
	200		922	3.62	0.010	7.6	3.73	2896	1448	10.5	5.2	1.38	0.69	10.8	5.4	4347	2132	15.7	7.7	2.06	1.01	16.2	8.0	13.1	6.4		
Up-18	100	4/24/14	-	-	-	-	-	-	-	-	-	-	-	-	-	2364	1358	20.8	11.9	2.55	1.46	-	-	20.8	11.9		
	200		-	-	-	-	-	-	-	-	-	-	-	-	-	2284	1312	8.3	4.7	1.09	0.63	-	-	8.3	4.7		
Up-19	100	5/8/14	1036	6.81	0.019	8.7	4.08	1644	822	11.2	5.6	1.28	0.64	6.7	3.3	1764	1013	12.0	6.9	1.37	0.79	7.2	4.1	11.6	6.7		
	200		722	5.57	0.010	9.5	3.25	1446	723	8.1	4.0	0.84	0.42	4.7	2.3	834	479	4.6	2.7	0.49	0.28	2.7	1.6	6.3	3.6		
Up-20	100	5/22/14	-	-	-	-	-	-	-	-	-	-	-	-	-	2702	1981	18.4	13.5	2.10	1.54	-	-	18.4	13.5		
	200		-	-	-	-	-	-	-	-	-	-	-	-	-	2176	1595	12.1	8.9	1.27	0.93	-	-	12.1	8.9		
Up-21	100	6/19/14	392	11.38	0.041	11.9	-	369	185	4.2	2.1	0.35	0.18	-	-	935	676	10.6	7.7	0.89	0.64	-	-	7.4	5.4		
	200		169	2.12	0.003	7.8	-	1146	573	2.4	1.2	0.31	0.16	-	-	602	435	1.3	0.9	0.16	0.12	-	-	1.9	1.3		

^aUncertainty is reported as 50% for all sediment trap deployments.^bUncertainty in Th-based approach calculated by propagating uncertainty in upwelling velocity and Th deficiency.^cUncertainty is reported as the same as in Th-based approach.

*Calculated assuming %bsi was equal to that measured in the other trap on the same deployment.

Table 5: Net production calculated with upwelling and diffusive nitrate flux, NOP and particle export

Cruise I.D.	Date	Pot. New Prod. ^a	NCP ^b	POC Export ^c at 100m	Export/NCP ^d %	
		(all in mmol C m ⁻² d ⁻¹)				
Up-1	2/13/13	49 ± 24	44 ± 12	8 ± 4	18 ± 9	
Up-2	2/28/13	113 ± 54	79 ± 49	12 ± 6	16 ± 8	
Up-3	3/14/13	72 ± 46	120 ± 42	12 ± 6	10 ± 5	
Up-4	4/3/13	116 ± 71	133 ± 42	19 ± 10	14 ± 7	
Up-5	4/25/13	97 ± 53	131 ± 51	18 ± 9	12 ± 6	
Up-6	5/10/13	131 ± 69	130 ± 58	14 ± 7	11 ± 6	
Up-7	5/22/13	158 ± 85	74 ± 51	14 ± 7	18 ± 9	
Up-8	6/20/13	95 ± 42	32 ± 8	5 ± 3	15 ± 8	
Spring '13 Mean		103 ± 55	94 ± 39	13 ± 7	15 ± 8	
						Traps Only ^e
Up-9	10/3/13	-8 ± 20	10 ± 15	5 ± 3	57 ± 29	37 ± 19
Up-10	12/9/13	20 ± 31	14 ± 19	6 ± 3	42 ± 19	17 ± 9
Up-11	1/15/14	0 ± 10	34 ± 11	3 ± 2	8 ± 4	6 ± 3
Fall/Winter '13 Mean		4 ± 17	19 ± 15	5 ± 3	24 ± 12	14 ± 7
Up-13	2/12/14	66 ± 33	111 ± 39	6 ± 3	6 ± 3	
Up-14	3/5/14	107 ± 54	77 ± 20	-	-	
Up-15	3/12/14	43 ± 20	94 ± 34	10 ± 5	10 ± 5	
Up-16	4/4/14	76 ± 39	146 ± 42	-	-	
Up-17	4/11/14	120 ± 55	153 ± 39	27 ± 14	18 ± 9	
Up-18	4/24/14	120 ± 57	111 ± 49	21 ± 11	19 ± 10	
Up-19	5/7/14	106 ± 52	121 ± 58	12 ± 6	10 ± 5	
Up-20	5/22/14	92 ± 52	84 ± 46	18 ± 9	22 ± 11	
Up-21	6/19/14	16 ± 13	29 ± 14	7 ± 4	25 ± 13	
Spring '14 Mean		83 ± 42	103 ± 38	14 ± 7	16 ± 8	

^aCalculated as the total vertical nitrate flux from Table 2 multiplied by the mean POC:PON ratio in trap material (8.0).

^bNet Community Production calculated as the NOP divided by the photosynthetic quotient of 1.4 (Laws, 1991).

^cReported here as the mean of sediment trap and Th-based POC export across the 100m horizon.

^dFall ratios in parentheses use sediment trap export only.

^eExport/NCP using the sediment trap export flux only.

*All uncertainties reported as 1 standard deviation from the best estimate.

65 **Appendix A: All ^{234}Th measurements made during this study.**

Table A1: UpRISEE ^{234}Th Measurements

Sample I.D.	Date	Depth (m)	Total ^{234}Th (dpm L ⁻¹)	+/-	^{238}U (dpm L ⁻¹)	^{229}Th Yield	Def. Depth*
*SP42-A	1/16/13	0	2.02	0.12	2.38	0.52	40
*SP42-B		0	1.56	0.11	2.38	0.80	
SP42-7		5	1.71	0.07	2.38	0.80	
SP42-6		15	1.45	0.08	2.38	0.95	
SP42-5		25	1.77	0.08	2.38	0.94	
SP42-4		30	1.74	0.14	2.38	0.80	
SP42-3		35	2.22	0.11	2.38	0.90	
SP42-2		55	2.44	0.10	2.38	0.95	
SP42-1		180	2.48	0.11	2.42	1.00	
*Up1-A	2/13/13	0	0.73	0.06	2.38	0.88	55
*Up1-B		0	1.54	0.07	2.38	0.82	
Up1-9		7	1.50	0.13	2.38	0.51	
Up1-8		25	1.50	0.17	2.38	0.80	
Up1-7		35	1.70	0.15	2.38	0.91	
Up1-6		45	2.21	0.11	2.38	0.71	
Up1-5		55	2.24	0.31	2.37	0.85	
Up1-4		75	2.65	0.16	2.39	0.74	
Up1-3		100	2.33	0.20	2.40	0.86	
Up1-2		150	2.58	0.15	2.41	0.78	
Up1-1		200	2.62	0.25	2.42	0.79	
Up2-8	2/28/13	5	1.53	0.16	2.38	0.80	75
Up2-7		10	1.34	0.15	2.38	0.97	
Up2-6		18	1.29	0.10	2.38	1.09	
Up2-5		30	1.37	0.15	2.38	0.95	
Up2-4		50	1.47	0.11	2.38	1.12	
Up2-3		75	2.04	0.18	2.39	1.05	
Up2-2		100	1.96	0.23	2.40	1.00	
Up2-1		200	2.05	0.18	2.42	0.99	
Up3-8	3/14/13	5	1.37	0.12	2.38	0.86	70
Up3-7		12	1.92	0.16	2.38	0.66	
Up3-6		24	1.89	0.21	2.38	0.75	
Up3-5		40	2.04	0.19	2.38	0.75	
Up3-4		60	2.00	0.15	2.38	0.78	
Up3-3		100	2.45	0.23	2.40	0.74	
Up3-2		150	2.72	0.47	2.42	0.67	
Up3-1		200	2.58	0.37	2.42	0.39	
*Up4-A	4/3/13	0	0.85	0.07	2.38	0.77	100
*Up4-B		0	2.16	0.20	2.38	0.49	
Up4-8		2	1.28	0.15	2.38	0.92	
Up4-7		10	1.14	0.12	2.38	1.14	
Up4-6		22	1.52	0.14	2.38	0.94	
Up4-5		40	1.57	0.20	2.38	1.05	
Up4-4		60	1.63	0.13	2.38	1.01	
Up4-3		101	2.11	0.16	2.40	0.81	
Up4-2		150	2.44	0.20	2.41	0.83	
Up4-1		201	2.28	0.27	2.42	0.80	
*Up5-A	4/25/13	0	0.90	0.06	2.38	1.01	35
*Up5-B		0	0.96	0.08	2.38	0.83	
Up5-8		8	1.31	0.10	2.38	0.93	
Up5-7		20	0.93	0.09	2.38	0.96	
Up5-6		35	2.19	0.18	2.38	0.77	
Up5-5		71	2.39	0.20	2.40	0.82	
Up5-4		100	2.54	0.16	2.41	0.82	
Up5-3		120	2.43	0.20	2.41	0.77	
Up5-2		150	2.48	0.20	2.42	0.84	
Up5-1		200	2.27	0.31	2.43	0.79	
*Up6-A	5/10/13	0	1.41	0.14	2.38	0.77	35
*Up6-B		0	1.58	0.16	2.38	0.85	
Up6-8		10	1.38	0.13	2.38	0.84	
Up6-7		25	1.12	0.09	2.38	0.67	
Up6-5		45	3.27	0.25	2.38	1.05	
Up6-4		70	2.51	0.29	2.40	0.70	
Up6-3		100	2.40	0.21	2.41	0.95	
Up6-2		150	2.21	0.21	2.42	1.10	
Up6-1		200	2.63	0.25	2.43	0.86	

Table A1 (continued): UpRISEE ^{234}Th Measurements

Sample I.D.	Date	Depth (m)	Total ^{234}Th (dpm L ⁻¹)	+/-	^{238}U (dpm L ⁻¹)	^{229}Th Yield	Def. Depth*
Up7-8	5/22/13	5	1.57	0.11	2.38	0.84	40
Up7-7		18	1.44	0.11	2.38	0.89	
Up7-6		28	1.44	0.11	2.37	0.87	
Up7-5		40	2.05	0.16	2.37	0.97	
Up7-4		70	2.46	0.15	2.40	0.84	
Up7-3		100	2.03	0.15	2.41	0.89	
Up7-2		150	2.92	0.17	2.42	0.66	
Up7-1		200	2.99	0.24	2.42	0.56	
Up8-8	6/20/13	5	2.23	0.16	2.39	0.50	30
Up8-7		13	1.24	0.08	2.38	0.81	
Up8-6		23	2.07	0.11	2.38	0.77	
Up8-5		38	2.87	0.16	2.38	0.70	
Up8-4		49	2.53	0.13	2.38	0.81	
Up8-3		75	2.40	0.15	2.39	0.77	
Up8-2		150	2.62	0.17	2.41	0.86	
Up8-1		200	2.85	0.14	2.42	0.81	
Up9-8	10/3/13	15	1.55	0.07	2.39	0.98	60
Up9-7		35	2.06	0.12	2.37	0.69	
Up9-6		51	1.54	0.09	2.37	0.92	
Up9-5		65	2.39	0.22	2.38	0.89	
Up9-4		80	2.55	0.11	2.38	0.78	
Up9-3		100	2.63	0.13	2.39	0.86	
Up9-2		150	2.36	0.14	2.41	0.83	
Up9-1		200	2.42	0.27	2.42	0.49	
*Up10-A	12/9/13	0	0.73	0.06	2.38	1.08	65
*Up10-B		0	1.53	0.09	2.38	0.97	
Up10-8		10	1.47	0.06	2.38	1.01	
Up10-7		20	1.55	0.06	2.38	1.02	
Up10-6		30	1.72	0.07	2.38	0.92	
Up10-5		44	1.95	0.09	2.36	0.97	
Up10-4		66	2.12	0.10	2.37	0.81	
Up10-3		100	2.30	0.09	2.38	0.86	
Up10-2		148	2.14	0.12	2.41	0.90	
Up10-1		197	2.42	0.13	2.42	0.72	
Up11-8	1/15/14	15	1.29	0.08	2.38	0.91	45
Up11-7		31	1.74	0.07	2.38	0.89	
Up11-6		45	2.26	0.11	2.37	0.80	
Up11-5		55	3.05	0.18	2.36	0.65	
Up11-4		70	2.90	0.15	2.37	0.78	
Up11-3		100	2.22	0.12	2.38	1.07	
Up11-2		150	2.46	0.18	2.41	0.88	
Up11-1		200	2.18	0.15	2.42	0.95	
Up12-8	1/29/14	10	2.23	0.08	2.38	1.02	50
Up12-7		25	2.00	0.09	2.38	0.94	
Up12-6		40	1.90	0.08	2.37	1.02	
Up12-5		55	2.57	0.27	2.37	0.86	
Up12-4		75	2.24	0.14	2.37	0.91	
Up12-3		100	2.80	0.19	2.39	0.90	
Up12-2		150	2.38	0.17	2.41	1.01	
Up12-1		201	3.01	0.40	2.42	0.85	
Up13-7	2/12/14	5	1.59	0.13	2.37	0.90	40
Up13-6		15	1.66	0.11	2.37	0.79	
Up13-5		25	2.43	0.18	2.37	0.77	
Up13-4		40	2.20	0.24	2.37	0.84	
Up13-3		70	2.06	0.14	2.39	0.81	
Up13-2		100	2.12	0.15	2.40	0.85	
Up13-1		200	2.32	0.25	2.43	0.77	

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Table A1 (continued): UpRISEE ²³⁴Th Measurements

Sample I.D.	Date	Depth (m)	Total ²³⁴ Th (dpm L ⁻¹)	+/-	²³⁸ U (dpm L ⁻¹)	²²⁹ Th Yield	Def. Depth*
*Up15-A	3/12/14	0	1.53	0.12	2.37	0.68	70
*Up15-B		0	2.07	0.17	2.37	0.55	
Up15-8		10	1.45	0.08	2.37	1.32	
Up15-7		20	2.11	0.14	2.37	1.02	
Up15-6		35	2.03	0.14	2.37	1.06	
Up15-5		50	2.03	0.24	2.37	1.00	
Up15-4		70	2.03	0.15	2.38	1.15	
Up15-3		100	2.59	0.15	2.39	0.83	
Up15-2		150	2.25	0.18	2.41	0.99	
Up15-1		200	2.49	0.20	2.42	1.11	
Up17-8	4/11/14	10	1.14	0.09	2.37	0.95	100
Up17-7		24	1.36	0.14	2.38	0.81	
Up17-6		35	1.65	0.18	2.38	0.84	
Up17-5		50	1.78	0.26	2.38	0.97	
Up17-4		70	1.95	0.15	2.39	0.96	
Up17-3		100	2.25	0.19	2.41	0.92	
Up17-2		150	1.81	0.15	2.42	1.09	
Up17-1		201	2.53	0.17	2.43	0.92	
Up18-8	4/24/14	15	1.69	0.13	2.38	0.94	75
Up18-7		35	1.53	0.10	2.38	1.10	
Up18-6		50	1.64	0.13	2.38	1.06	
Up18-5		60	1.87	0.27	2.38	0.98	
Up18-4		75	2.28	0.24	2.38	0.84	
Up18-3		100	2.33	0.23	2.40	0.86	
Up18-2		150	2.85	0.25	2.41	0.82	
Up18-1		201	2.97	0.24	2.42	0.79	
Up19-7	5/7/14	5	2.08	0.10	2.38	1.20	20
Up19-6		12	2.22	0.10	2.38	1.03	
Up19-5		22	2.64	0.15	2.38	0.96	
Up19-4		40	2.88	0.21	2.38	0.88	
Up19-3		65	2.77	0.18	2.39	0.88	
Up19-2		100	3.06	0.19	2.40	0.89	
Up19-1		201	3.04	0.20	2.41	1.05	
Up20-7	5/22/14	10	1.40	0.13	2.38	0.94	50
Up20-6		25	1.38	0.14	2.37	1.08	
Up20-5		40	2.04	0.22	2.37	0.81	
Up20-4		55	2.47	0.38	2.38	0.93	
Up20-3		75	2.24	0.28	2.39	0.92	
Up20-2		100	2.37	0.26	2.39	0.97	
Up20-1		200	2.78	0.31	2.42	0.92	
Up21-7	6/19/14	10	1.69	0.13	2.38	1.07	50
Up21-6		30	1.84	0.15	2.37	1.06	
Up21-5		43	2.00	0.14	2.37	1.18	
Up21-4		61	2.52	0.26	2.37	1.20	
Up21-3		81	2.91	0.21	2.37	1.01	
Up21-2		101	2.64	0.14	2.38	1.06	
Up21-1		200	2.49	0.16	2.42	1.07	

*Depth where Th and U are in equilibrium, above which there exists a Th deficiency due to particle export.

Appendix B: All data pertaining to upwelling velocity calculations.

Table B1: All ⁷Be data pertaining to the upwelling velocity calculations.

Cruise I.D.	Date	MLD (m)	[Be] (ML) (dpm L ⁻¹)	σ	Yield ^a [Be] (BLM) (dpm L ⁻¹)	σ	Yield	α ^b (m ⁻¹)	C _{inv} ^c (dpm m ⁻²)	σ ^d	Input F: all in (dpm m ⁻² d ⁻¹)				Output: all in (dpm m ⁻² d ⁻¹)						
											WET	DRY	Total	σ	P _{Be} ^e	σ	NSS	Decay	Total	σ	
SP42	1/16/13	15	0.043	0.028	0.80	0.036	0.013	0.90	0.01777	3065	1374	97	32	129	53	51	32	0	40	91	57
1	2/13/13	35	0.125	0.024	0.79	0.018	0.009	0.90	0.19379	5020	894	246	20	266	109	54	27	69	65	188	95
2	2/28/13	28	0.067	0.017	0.99	0.015	0.006	0.57	0.14966	2324	486	162	59	222	91	92	43	-116	30	6	3
3	3/14/13	35	0.071	0.016	0.90	0.064	0.012	1.0	0.01038	9325	4318	373	50	373	153	131	85	10	121	263	170
4	4/3/13	10	0.089	0.016	0.90	0.074	0.015	0.87	0.01846	5712	2608	268	33	301	123	104	64	9	74	187	116
5	4/25/13	13	0.075	0.033	0.97	0.054	0.018	0.93	0.03285	3258	963	185	67	252	103	82	44	-9	42	115	62
6	5/10/13	12	0.096	0.036	0.63	0.045	0.023	0.79	0.07577	2420	601	375	39	375	154	87	46	16	21	124	65
7	5/22/13	10	0.052	0.028	1.0	0.007	0.005	1.0	0.20053	779	254	110	98	209	85	102	55	-31	10	81	44
8	6/20/13	12	0.054	0.018	1.0*	0.009	0.004	1.0	0.09445	950	136	34	71	105	43	29	12	1	12	42	18
9	10/3/13	15	0.012 ^h	0.012	1.0	0.008	0.017	1.0	0.04055	477	207	4	35	39	16	36	22	0	6	42	26
10	12/9/13	32	0.062	0.027	0.90	0.010	0.008	1.0	0.18245	2306	748	116	9	125	51	54	28	24	30	107	55
11	1/15/14	25	0.076	0.029	0.90	0.040	0.012	0.85	0.06419	3082	368	27	47	74	30	30	15	10	40	80	40
12	1/29/14	30	0.051	0.018	1.0	0.026	0.010	0.66	0.06737	2306	344	24	13	37	15	16	13	-53	30	-6	5
13	2/12/14	20	0.068	0.013	1.0*	0.009	0.011	0.65	0.20223	1706	301	259	13	272	112	72	34	24	22	119	56
15	3/12/14	22	0.207	0.017	1.0*	0.027	0.006	0.96	0.20369	5565	429	624	63	624	256	109	49	218	72	399	180
17	4/11/14	18	0.057	0.012	1.0*	0.030	0.010	1.0	0.06419	1930	338	61	59	120	49	80	35	-90	25	16	7
18	4/24/14	20	0.047	0.015	1.0*	0.027	0.009	1.0	0.05543	1784	302	40	124	164	67	77	35	-16	23	84	39
19	5/7/14	20	0.026	0.009	1.0	0.012	0.005	1.0	0.07732	872	153	32	98	129	53	62	29	-31	11	42	20
20	5/22/14	20	0.021	0.020	1.0	0.008	0.009	1.0	0.09651	651	97	0	131 ⁱ	131	54	85	51	-7	8	86	52
21	6/19/14	18	0.034	0.012	1.0	0.004	0.009	1.0*	0.21401	781	223	6	77 ^j	83	34	43	33	8	10	62	48

^hFor this point, the upper limit was used in the calculations as the measured value was 0.0 +/- 0.012.

ⁱMPOES measurements of ⁹Be yield that were greater than 115%. Uncertainty in yields estimated as 15%, so all yields between 100-115% reported as 1.0.

The cause for the yields greater than 100% is unknown, but likely occurred during the resin-mediated cation exchange.

^jThe r_{max} in the dry deposition equation is set at 140 dpm m⁻² d⁻¹ for these two sampling periods.

^kRecovery yield for the ⁷Be measurement.

^lDepth attenuation coefficient fit to the ⁷Be profile.

^mInventory of ⁷Be in the water column.

ⁿReported here as one standard deviation lower than the best estimate. Some values have asymmetric uncertainty with one standard deviation being larger on the upper end.

^oVertical export of ⁷Be on sinking particles.

^pNon-steady state change in the ⁷Be inventory.

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Table B2: All ^{234}Th data pertaining to the upwelling velocity calculations.

Cruise I.D.	Date	Th (surf) (dpm L ⁻¹)	σ	Th (deep) (dpm L ⁻¹)	σ	D_{Th}^a (dpm m ⁻² d ⁻¹)	σ	P_{Th}^b (dpm m ⁻² d ⁻¹)	σ
SP42	1/16/13	1.71	0.07	2.44	0.10	517	83	1834	1152
1	2/13/13	1.50	0.13	2.34	0.20	524	118	1945	973
2	2/28/13	1.35	0.15	2.05	0.18	1930	187	3285	1545
3	3/14/13	1.37	0.09	2.45	0.23	1023	194	4695	3038
4	4/3/13	1.28	0.13	2.11	0.16	1870	150	3708	2295
5	4/25/13	1.50	0.09	2.50	0.20	671	121	2932	1573
6	5/10/13	1.41	0.12	2.21	0.21	726	160	3122	1647
7	5/22/13	1.57	0.10	2.92	0.17	957	114	3659	1965
8	6/20/13	1.73	0.16	2.40	0.15	74	120	1020	443
9	10/3/13	1.55	0.07	2.63	0.13	970	155	1271	786
10	12/9/13	1.47	0.06	2.30	0.09	853	97	1847	988
11	1/15/14	1.29	0.08	2.20	0.12	504	150	1038	540
12	1/29/14	2.11	0.09	2.80	0.19	273	193	558	463
13	2/12/14	1.59	0.13	2.12	0.15	920	191	2488	1225
15	3/12/14	1.45	0.08	2.59	0.15	888	189	3750	1756
17	4/11/14	1.14	0.09	2.25	0.19	1935	205	2759	1264
18	4/24/14	1.69	0.13	2.33	0.23	1449	238	2669	1262
19	5/7/14	2.13	0.11	3.13	0.19	-960	188	2139	1042
20	5/22/14	1.40	0.13	2.37	0.26	665	300	2917	1830
21	6/19/14	1.69	0.13	2.64	0.14	355	222	1486	1190

^a Depth-integrated thorium deficiency to 100m.^b Thorium export on sinking particles across the 100m horizon.

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83 Appendix C: CTD sensor and nutrient measurements.

Table C1: CTD sensor and nutrient measurements

Cruise	Depth (m)	Temp. (°C)	Salinity (ppt)	Oxygen ^a (mmol kg ⁻¹)	AOU ^b (mmol kg ⁻¹)	Chl Fluor. (mg m ⁻³)	Density (kg m ⁻³)	pH (NBS)	DIC (mmol kg ⁻¹)	Alk. (mmol kg ⁻¹)	DOC (mM)	NO ₃ ⁻ (mM)	PO ₄ ³⁻ (mM)	H ₄ SiO ₄ (mM)
Up-1 (2/14/13)	9	13.87	33.50	267.2	-11.1	0.43	25.06	8.04	2052	2246	-	0.04	0.33	2.48
	33	13.70	33.49	259.9	-2.9	1.59	25.08	8.00	2000	2172	-	0.96	0.39	3.38
	45	12.24	33.47	208.1	56.7	0.22	25.34	7.93	2093	2239	-	8.51	0.75	7.74
	54	11.08	33.53	163.8	107.4	0.01	25.61	7.81	2077	2179	-	15.94	1.25	14.85
	71	10.62	33.62	151.3	122.4	-0.01	25.77	7.71	2190	2260	-	-	1.38	18.59
	85	10.33	33.69	141.5	133.7	-0.03	25.87	7.74	2161	2239	-	20.23	1.46	20.62
	100	10.19	33.81	121.2	154.6	-0.04	25.99	7.69	2174	2241	-	23.19	1.68	25.86
	120	9.86	33.93	104.8	172.7	-0.05	26.14	7.67	2196	2255	-	25.04	1.81	29.16
	151	9.31	34.01	99.1	181.7	-0.04	26.29	7.67	2198	2256	-	26.84	1.86	32.01
	201	8.86	34.12	76.8	206.5	-0.04	26.45	7.62	2265	2305	-	28.86	2.08	28.42
	301	7.79	34.20	43.2	246.7	-0.01	26.68	7.57	2239	2264	-	33.79	2.41	51.13
	401	6.97	34.26	21.4	273.9	-0.02	26.84	7.54	2296	2305	-	35.81	2.69	64.12
Up-2 (2/28/13)	5	13.34	33.52	259.8	-1.0	0.60	25.18	7.98	2054	2230	-	4.28	0.46	6.43
	17	13.24	33.52	255.7	3.6	1.63	25.20	7.97	2052	2223	-	5.32	0.50	6.71
	37	12.59	33.52	223.3	39.5	0.91	25.32	7.87	2092	2224	-	11.18	0.97	11.19
	55	11.16	33.59	155.6	115.0	0.20	25.65	7.76	2140	2230	-	17.62	1.32	16.94
	70	10.74	33.67	140.7	132.1	0.02	25.78	7.72	2160	2236	-	20.32	1.50	20.50
	85	10.17	33.76	129.1	147.0	-0.03	25.95	7.68	2172	2239	-	22.75	1.66	23.90
	100	9.84	33.81	121.5	156.4	-0.04	26.05	7.67	2145	2205	-	23.91	1.73	25.99
	119	9.70	33.92	106.1	172.4	-0.05	26.16	7.63	2153	2203	-	25.81	1.91	29.50
	150	9.20	34.03	91.6	189.8	-0.05	26.33	7.63	2166	2214	-	27.14	2.01	33.35
	200	8.74	34.12	75.3	208.8	-0.04	26.47	7.59	2225	2262	-	29.60	2.15	39.53
	250	8.40	34.20	54.0	232.0	-0.04	26.59	7.57	2219	2249	-	31.31	2.34	45.35
	401	6.93	34.27	18.8	276.7	-0.03	26.86	7.49	2313	2322	-	36.51	2.74	65.12
Up-3 (3/14/13)	5	14.02	33.52	281.1	-25.9	1.20	25.04	8.05	2024	2231	-	0.41	0.25	1.84
	20	13.50	33.51	265.2	-7.2	1.58	25.14	8.02	2045	2236	-	1.93	0.40	3.84
	44	12.95	33.52	240.2	20.7	0.43	25.25	7.95	2075	2239	-	5.26	0.70	7.65
	55	11.88	33.56	178.6	88.0	0.30	25.48	7.82	2121	2234	-	14.34	1.21	13.58
	71	10.71	33.65	146.7	126.4	0.08	25.77	7.75	2150	2236	-	19.87	1.60	19.34
	86	10.30	33.76	127.3	148.0	0.01	25.93	7.70	2168	2241	-	21.77	1.80	22.72
	100	10.20	33.88	107.2	168.4	-0.02	26.05	7.68	2188	2254	-	23.39	1.94	26.56
	121	9.90	33.95	102.5	174.7	-0.01	26.15	7.65	2197	2255	-	24.95	1.98	28.33
	150	9.31	34.07	86.1	194.5	-0.02	26.34	7.63	2212	2263	-	27.36	2.13	33.33
	180	8.96	34.12	76.4	206.2	-0.03	26.43	7.61	2227	2272	-	28.76	2.27	37.18
	300	8.11	34.22	45.3	242.5	-0.03	26.65	7.56	2291	2319	-	32.27	2.57	48.97
	399	6.97	34.26	21.5	273.8	-0.01	26.85	7.52	2289	2304	-	36.25	2.85	63.72
Up-4 (4/3/13)	5	15.06	33.52	274.8	-24.7	0.32	24.82	8.06	2006	2212	-	0.02	0.26	1.41
	29	14.25	33.52	262.2	-8.1	2.62	24.99	8.04	2030	2226	-	0.86	0.35	3.93
	45	11.42	33.59	167.4	101.8	0.70	25.58	7.90	2090	2227	-	10.20	0.97	10.83
	55	10.84	33.65	147.3	125.1	0.14	25.75	7.76	2150	2237	-	18.37	1.57	18.56
	70	10.47	33.72	132.4	142.0	0.00	25.87	7.72	2167	2241	-	21.42	1.72	21.80
	85	10.18	33.81	120.2	155.7	-0.04	25.99	7.69	2177	2241	-	22.91	1.91	24.87
	100	10.07	33.85	112.7	163.8	-0.04	26.05	7.68	2180	2241	-	23.84	1.96	26.86
	120	9.86	33.91	105.8	171.8	-0.03	26.13	7.67	2201	2261	-	24.88	2.00	27.89
	150	9.39	34.04	88.3	191.9	-0.04	26.30	7.64	2209	2259	-	27.07	2.19	32.60
	200	8.96	34.14	69.7	212.9	-0.04	26.45	7.62	2233	2276	-	28.73	2.38	37.71
	240	8.58	34.18	57.3	227.6	-0.03	26.54	7.58	2242	2274	-	30.69	2.47	42.64
	400	7.00	34.26	20.8	274.3	-0.02	26.84	7.52	2279	2291	-	35.95	2.93	62.82
Up-5 (4/25/13)	4	15.74	33.58	273.2	-26.5	0.13	24.71	8.06	2025	2240	-	0.00	0.24	1.44
	18	13.97	33.57	287.2	-31.7	0.70	25.07	8.04	2040	2241	-	0.27	0.31	1.32
	30	12.81	33.56	210.2	51.4	1.34	25.31	7.92	2080	2233	-	6.20	0.86	5.80
	45	11.03	33.66	141.5	129.7	0.43	25.72	7.73	2154	2238	-	19.04	1.67	18.30
	60	10.46	33.74	122.2	152.2	0.16	25.89	7.69	2172	2242	-	22.11	1.97	22.53
	80	10.23	33.86	105.2	170.3	0.01	26.02	7.66	2189	2250	-	23.73	2.04	25.79
	100	9.85	33.97	96.3	181.2	0.02	26.17	7.65	2201	2259	-	25.23	2.17	28.88
	130	9.57	34.06	83.0	196.1	-0.03	26.29	7.64	2211	2265	-	26.75	2.26	32.07
	160	9.40	34.13	70.4	209.6	0.00	26.38	7.63	2222	2273	-	28.36	2.41	35.21
	180	9.24	34.18	60.2	220.7	-0.03	26.44	7.58	2240	2275	-	29.51	2.50	38.16
	300	7.88	34.22	40.8	248.5	-0.04	26.68	7.54	2262	2285	-	33.83	2.80	50.82
	400	7.00	34.26	21.2	273.8	-0.01	26.84	7.52	2292	2308	-	36.20	3.02	62.76

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Table C1 (continued): CTD sensor and nutrient measurements

Cruise	Depth (m)	Temp. (°C)	Salinity (ppt)	Oxygen ^a (mmol kg ⁻¹)	AOU ^b (mmol kg ⁻¹)	Chl Fluor. (mg m ⁻³)	Density (kg m ⁻³)	pH (NBS)	DIC (mmol kg ⁻¹)	Alk. (mmol kg ⁻¹)	DOC (mM)	NO ₃ ⁻ (mM)	PO ₄ ³⁻ (mM)	H ₄ SiO ₄ (mM)
Up-6 (5/10/13)	5	17.26	33.62	253.3	-13.9	0.10	24.39	8.05	2019	2230	-	0.00	0.16	0.89
	16	15.28	33.59	276.2	-27.3	0.54	24.80	8.02	2027	2225	-	-	0.21	0.70
	26	12.77	33.59	278.7	-17.0	1.38	25.34	7.92	2072	2225	-	5.82	0.86	2.99
	38	11.59	33.53	184.7	83.6	15.14	25.52	7.71	2159	2236	-	15.63	1.53	14.30
	60	10.39	33.66	137.8	137.1	0.22	25.84	7.68	2159	2226	-	19.97	1.87	20.18
	80	9.95	33.81	113.6	163.6	0.05	26.03	7.64	2185	2240	-	23.87	2.02	25.70
	100	9.80	33.88	103.0	175.0	-0.03	26.11	7.62	2197	2246	-	25.16	2.07	27.94
	120	9.48	33.97	103.5	176.3	-0.04	26.24	7.61	2203	2249	-	26.11	2.17	29.62
	150	9.35	34.04	88.9	191.5	-0.07	26.31	7.60	2207	2251	-	26.46	2.16	31.15
	180	8.94	34.12	80.5	202.3	-0.04	26.44	7.58	2229	2265	-	28.48	2.50	36.72
	300	8.02	34.23	39.7	248.7	-0.02	26.67	7.53	2276	2295	-	32.92	2.70	48.90
	399	7.18	34.26	22.9	270.9	-0.02	26.82	7.51	2286	2300	-	35.92	2.95	60.99
Up-7 (5/23/13)	5	17.98	33.58	249.6	-13.3	-0.01	24.19	8.08	2013	2235	-	0.00	0.30	2.74
	22	13.33	33.46	274.5	-15.6	1.25	25.10	8.01	2032	2221	-	1.73	0.43	5.27
	34	11.93	33.44	222.8	43.7	1.67	25.38	7.90	2073	2217	-	7.87	1.15	8.57
	70	10.22	33.73	131.7	144.1	0.19	25.92	7.71	2179	2254	-	21.91	1.81	22.26
	100	9.88	33.91	99.6	177.9	-0.03	26.12	7.66	2205	2263	-	25.03	2.11	28.17
	120	9.63	33.99	93.3	185.5	-0.03	26.23	7.64	2206	2260	-	26.31	2.20	31.00
	150	9.12	34.04	95.0	186.9	-0.04	26.35	7.64	2219	2273	-	26.32	2.20	33.83
	180	8.81	34.10	81.9	201.7	-0.02	26.45	7.65	2229	2284	-	29.10	2.30	37.35
	201	8.69	34.13	73.6	210.8	-0.05	26.49	7.61	2236	2280	-	29.76	2.43	39.47
	302	7.93	34.22	40.9	248.0	-0.03	26.68	7.55	2272	2296	-	33.63	2.60	50.81
	400	7.13	34.26	22.7	271.5	-0.03	26.83	7.53	2292	2308	-	36.14	2.94	61.45
	502	6.46	34.30	12.4	286.2	-0.02	26.94	7.51	2306	2315	-	37.93	3.17	72.48
Up-8 (6/20/13)	5	18.79	33.63	251.2	-18.5	0.07	24.02	8.03	2013	2232	-	0.00	0.10	1.54
	10	18.56	33.62	256.0	-22.3	0.18	24.07	8.03	2017	2237	-	0.03	0.08	1.82
	18	14.20	33.58	288.2	-34.0	1.91	25.01	8.01	2018	2224	-	0.03	0.18	1.49
	30	11.79	33.54	218.0	49.2	2.08	25.48	7.86	2086	2224	-	9.51	0.82	9.00
	51	10.62	33.57	175.6	98.2	0.46	25.72	7.76	2124	2226	-	15.54	1.20	14.18
	75	9.90	33.71	139.0	138.8	0.01	25.96	7.68	2160	2234	-	21.00	1.58	21.13
	100	9.52	33.88	114.1	165.6	-0.03	26.16	7.64	2186	2246	-	24.42	1.88	26.82
	125	9.13	33.97	110.2	171.7	-0.03	26.29	7.62	2207	2260	-	26.16	2.03	30.54
	151	8.85	34.05	96.4	187.1	-0.06	26.40	7.61	2212	2262	-	27.04	2.12	33.45
	190	8.53	34.10	81.6	203.8	-0.05	26.49	7.57	2234	2272	-	28.79	2.27	38.32
	301	8.22	34.26	35.6	251.5	-0.03	26.67	7.52	2301	2325	-	31.71	2.70	49.68
	401	7.45	34.27	24.8	267.2	-0.02	26.79	7.49	2300	2314	-	34.84	2.94	57.99
Up-9 (10/4/13)	8	19.97	33.63	237.4	-9.6	0.04	23.73	8.14	2013	2249	67	0.34	0.16	0.84
	28	14.73	33.47	282.8	-31.1	0.34	24.82	8.09	2028	2240	66	0.12	0.27	2.44
	35	13.45	33.45	276.1	-17.8	0.94	25.08	8.07	2041	2244	67	0.37	0.37	3.75
	50	12.05	33.47	205.8	60.0	1.13	25.38	7.93	2100	2239	60	8.37	0.93	7.72
	60	11.33	33.49	185.7	84.1	0.51	25.53	7.86	2120	2235	56	12.84	1.29	11.03
	80	10.78	33.56	162.9	109.9	0.16	25.69	7.81	2148	2243	53	17.08	1.58	15.89
	100	10.29	33.67	137.8	137.7	0.02	25.86	7.75	2171	2247	51	20.90	1.79	21.46
	120	9.96	33.81	115.9	161.3	-0.05	26.03	7.72	2196	2263	50	23.48	1.94	25.26
	149	9.57	33.95	100.5	178.8	-0.05	26.21	7.69	2207	2265	49	25.26	2.09	29.48
	200	9.35	34.15	69.7	210.5	-0.04	26.39	7.67	2234	2285	50	27.89	2.37	35.01
	300	8.55	34.25	39.0	246.0	-0.03	26.61	7.58	2274	2299	-	31.47	2.73	46.34
	401	7.54	34.27	24.4	267.0	-0.02	26.77	7.55	2293	2309	-	34.24	2.93	56.59
Up-10 (12/10/13)	10	16.06	33.60	248.5	-3.4	0.37	24.66	8.07	2022	2228	-	0.21	0.23	1.54
	25	16.04	33.60	248.5	-3.3	0.65	24.67	8.07	2021	2226	-	0.14	0.28	1.53
	50	12.80	33.39	211.5	50.4	0.65	25.18	7.89	2083	2212	-	7.89	0.84	7.26
	65	11.71	33.38	209.2	58.7	0.27	25.38	7.86	2091	2208	-	10.23	0.99	8.93
	85	11.29	33.51	172.0	98.0	0.09	25.56	7.80	2125	2224	-	15.79	1.29	12.92
	100	10.57	33.55	170.4	103.7	0.00	25.72	7.77	2138	2227	-	16.93	1.43	15.35
	120	10.01	33.70	137.8	139.3	-0.03	25.94	7.71	2175	2242	-	22.15	1.75	21.91
	150	9.45	33.91	114.4	165.6	-0.04	26.19	7.67	2201	2257	-	25.31	1.90	26.56
	200	9.22	34.07	84.9	196.3	-0.05	26.36	7.63	2216	2258	-	30.79	2.22	33.69
	241	8.53	34.12	70.7	214.6	-0.05	26.50	7.60	2245	2280	-	30.67	2.33	38.66
	300	8.34	34.22	41.5	244.8	-0.04	26.62	7.54	2275	2290	-	33.51	2.65	46.38
	400	7.23	34.27	19.7	273.8	-0.01	26.82	7.52	2305	2312	-	37.87	2.93	60.34

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Table C1 (continued): CTD sensor and nutrient measurements

Cruise	Depth (m)	Temp. (°C)	Salinity (ppt)	Oxygen ^a (mmol kg ⁻¹)	AOU ^b (mmol kg ⁻¹)	Chl Fluor. (mg m ⁻³)	Density (kg m ⁻³)	pH (NBS)	DIC (mmol kg ⁻¹)	Alk. (mmol kg ⁻¹)	DOC (mM)	NO ₃ ⁻ (mM)	PO ₄ ³⁻ (mM)	H ₄ SiO ₄ (mM)
Up-11 (1/16/14)	7.5	15.46	33.51	257.8	-9.7	0.10	24.72	8.03	2050	2250	-	0.00	0.21	1.90
	22	15.21	33.51	262.3	-12.9	0.94	24.77	8.04	2038	2243	-	0.03	0.21	1.90
	32	15.10	33.50	259.3	-9.4	1.46	24.79	8.02	2050	2241	-	0.59	0.31	2.64
	45	14.28	33.43	239.8	14.3	0.90	24.91	7.95	2076	2239	-	2.56	0.52	4.57
	65	12.31	33.39	209.9	54.7	0.27	25.27	7.86	2110	2236	-	8.12	0.92	7.81
	85	11.28	33.51	173.4	96.7	0.04	25.57	7.77	2143	2236	-	13.49	1.27	13.39
	100	10.93	33.57	162.6	109.4	-0.01	25.68	7.74	2155	2237	-	14.80	1.42	16.14
	120	10.58	33.68	143.5	130.3	-0.04	25.82	7.71	2177	2250	-	17.79	1.56	19.14
	150	10.12	33.87	111.4	164.8	-0.05	26.05	7.64	2201	2255	-	21.78	1.91	25.47
	230	9.06	34.14	67.5	214.5	-0.05	26.44	7.59	2241	2277	-	28.39	2.35	37.26
	300	8.30	34.19	51.5	235.2	-0.04	26.60	7.53	2276	2292	-	31.48	2.53	44.59
	400	7.45	34.26	24.2	267.9	-0.02	26.78	7.48	2300	2302	-	36.18	2.87	56.53
Up-12 (1/29/14)	10	15.92	33.53	252.9	-7.0	-0.02	24.64	8.02	2009	2190	-	0.18	0.21	1.54
	24	15.81	33.53	252.9	-6.5	0.08	24.66	8.03	1992	2174	-	0.72	0.30	1.72
	32	15.17	33.48	254.0	-4.4	0.27	24.75	8.03	2029	2215	-	0.34	0.30	2.18
	45	13.73	33.40	236.3	20.7	1.57	25.00	7.98	2060	2225	-	3.14	0.51	3.56
	60	12.30	33.33	219.2	45.5	0.47	25.23	7.88	2104	2231	-	8.68	0.92	7.72
	80	11.47	33.51	172.0	97.0	0.22	25.53	7.78	2142	2235	-	14.19	1.32	12.69
	100	10.81	33.64	147.3	125.2	-0.03	25.75	7.73	-	-	-	17.66	1.57	13.85
	120	10.51	33.79	120.0	154.0	-0.04	25.92	7.67	2178	2235	-	20.85	1.87	23.02
	150	10.02	33.97	96.4	180.1	-0.06	26.14	7.63	2195	2240	-	24.99	2.12	27.89
	220	8.93	34.08	87.9	195.0	-0.06	26.41	7.61	2250	2288	-	28.75	2.26	34.81
	300	8.33	34.20	51.1	235.3	-0.03	26.60	7.56	2274	2296	-	32.23	2.60	44.40
	400	7.44	34.25	26.6	265.5	-0.02	26.77	7.51	2290	2298	-	34.81	2.94	56.53
Up-13 (2/13/14)	5	15.17	33.47	272.5	-22.9	0.32	24.75	8.06	1990	2187	121	0.44	0.20	1.26
	15	15.02	33.46	273.3	-22.9	0.57	24.78	8.07	1991	2193	107	0.51	0.19	1.45
	30	13.75	33.40	230.9	26.0	1.30	25.00	7.97	2020	2181	86	3.76	0.56	3.42
	45	12.51	33.38	209.2	54.3	0.41	25.23	7.90	2044	2173	-	8.09	0.91	7.34
	60	11.85	33.54	162.6	104.2	0.22	25.48	7.82	2118	2223	75	12.09	1.22	12.25
	80	11.12	33.70	136.0	134.6	0.00	25.74	7.73	2103	2178	-	17.97	1.67	18.95
	100	10.71	33.87	105.1	167.6	-0.04	25.95	7.67	2153	2210	76	21.01	1.86	24.63
	120	10.08	33.92	108.0	168.3	-0.06	26.09	7.67	2187	2243	-	21.85	1.96	25.89
	150	9.54	34.07	82.2	197.1	-0.04	26.31	7.63	2204	2247	69	25.34	2.26	33.16
	180	9.31	34.15	66.9	213.6	-0.04	26.41	7.61	2195	2231	-	27.47	2.40	35.70
	301	8.18	34.24	37.6	249.7	-0.01	26.65	7.55	2276	2294	-	31.67	2.80	48.58
	400	7.20	34.24	26.4	267.4	-0.02	26.80	7.52	2296	2304	-	34.50	2.99	59.32
Up-14 (3/5/14)	5	16.16	33.41	254.8	-9.9	0.19	24.49	8.03	2011	2203	85	0.62	0.24	1.67
	12	15.99	33.44	256.5	-10.8	0.22	24.55	8.03	2006	2196	95	0.09	0.14	1.25
	22	14.65	33.45	265.8	-13.6	0.34	24.85	8.02	2016	2200	105	0.23	0.14	1.20
	35	13.51	33.41	237.2	20.9	1.53	25.05	7.97	2047	2211	93	0.99	0.29	3.55
	50	12.18	33.42	198.2	67.0	0.46	25.32	7.85	2089	2207	73	8.19	0.81	7.67
	70	11.47	33.47	181.3	87.8	0.23	25.50	7.79	2121	2217	-	10.03	1.16	12.56
	100	10.38	33.75	128.1	146.7	-0.01	25.91	7.69	2165	2229	66	19.52	1.76	20.77
	120	9.91	33.87	114.3	163.1	-0.06	26.09	7.64	2187	2237	-	22.46	1.81	25.12
	150	9.60	34.05	86.1	192.8	-0.05	26.28	7.61	2226	2265	61	25.83	2.06	30.21
	200	9.18	34.16	65.1	216.1	-0.04	26.44	7.57	2243	2271	-	29.60	2.23	36.44
	300	8.20	34.20	50.0	237.3	-0.03	26.62	7.53	2264	2278	-	32.56	2.45	45.52
	400	7.59	34.24	29.9	261.3	-0.02	26.74	7.49	2293	2296	-	33.02	2.74	54.35
Up-15 (3/13/14)	10	15.99	33.45	256.2	-10.6	-0.01	24.56	8.04	2020	2215	102	0.12	0.13	2.03
	20	15.64	33.45	259.5	-12.2	0.04	24.63	8.04	2014	2209	104	0.11	0.13	2.07
	36	14.07	33.42	264.5	-9.3	0.76	24.94	7.98	2045	2214	99	1.40	0.39	3.58
	45	13.10	33.39	234.3	26.0	1.42	25.12	7.92	2066	2209	86	4.78	0.60	5.73
	60	11.57	33.39	201.3	67.4	0.70	25.41	7.84	2106	2220	79	9.94	1.01	9.77
	80	11.13	33.54	165.7	105.2	0.16	25.61	7.75	2145	2229	70	15.29	1.36	15.14
	100	10.45	33.62	153.8	120.8	0.01	25.80	7.72	2161	2236	67	17.60	1.56	19.51
	120	10.11	33.80	121.8	154.6	-0.02	26.00	7.65	2188	2240	85	21.51	1.86	25.38
	150	9.63	34.00	96.2	182.6	-0.06	26.24	7.61	2214	2253	81	23.69	2.15	30.27
	200	9.11	34.11	78.1	203.7	-0.04	26.41	7.57	2237	2266	83	26.08	2.25	35.94
	300	8.29	34.20	48.5	238.2	-0.03	26.61	7.53	2264	2277	-	29.59	2.52	45.96
	400	7.40	34.25	25.8	266.6	-0.01	26.78	7.51	2288	2298	-	32.79	2.84	57.93

Table C1 (continued): CTD sensor and nutrient measurements

Cruise	Depth (m)	Temp. (°C)	Salinity (ppt)	Oxygen ^a (mmol kg ⁻¹)	AOU ^b (mmol kg ⁻¹)	Chl Fluor. (mg m ⁻³)	Density (kg m ⁻³)	pH (NBS)	DIC (mmol kg ⁻¹)	Alk. (mmol kg ⁻¹)	DOC (mM)	NO ₃ ⁻ (mM)	PO ₄ ³⁻ (mM)	H ₄ SiO ₄ (mM)
Up-16 (4/4/14)	10	14.17	33.47	285.9	-31.3	3.17	24.97	8.10	2018	2247	93	0.04	0.11	0.44
	23	13.96	33.47	266.0	-10.3	3.29	25.01	8.02	2039	2230	94	0.61	0.85	1.95
	33	13.27	33.44	238.8	20.6	2.45	25.12	7.92	2085	2229	89	6.08	0.85	5.48
	44	11.53	33.47	188.5	80.3	0.34	25.47	7.82	2123	2230	87	11.75	1.26	12.63
	60	10.68	33.59	159.3	114.0	0.07	25.73	7.74	2159	2240	79	15.09	1.52	17.07
	80	10.20	33.80	121.8	154.0	-0.03	25.98	7.66	2176	2232	72	20.25	1.87	23.71
	101	9.91	33.87	113.0	164.4	-0.03	26.08	7.65	2208	2260	-	20.40	1.97	25.76
	120	9.55	33.94	105.1	174.3	-0.04	26.20	7.62	2212	2257	76	27.36	2.12	28.95
	142	9.34	34.01	93.0	187.6	-0.05	26.29	7.61	2246	2285	73	29.44	2.17	31.83
	200	8.96	34.19	55.8	226.8	-0.03	26.49	7.54	2272	2292	-	33.11	2.51	38.17
	304	7.92	34.23	36.2	252.9	-0.02	26.68	7.52	2293	2306	-	37.38	2.81	51.26
	400	7.11	34.26	20.5	273.8	-0.02	26.83	7.48	2295	2293	-	36.28	3.05	63.15
Up-17 (4/11/14)	5	14.94	33.45	268.4	-17.6	0.06	24.79	8.03	2025	2222	82	0.23	0.22	0.49
	12	14.79	33.46	280.1	-28.6	0.23	24.83	8.05	2017	2222	83	0.19	0.21	0.49
	26	13.71	33.49	289.7	-32.8	0.71	25.08	8.03	2016	2217	90	0.57	0.32	1.05
	40	12.08	33.53	203.3	62.3	3.03	25.42	7.86	2096	2226	83	8.23	0.95	9.46
	60	10.55	33.63	149.5	124.6	0.60	25.78	7.71	2161	2236	78	17.26	1.59	17.98
	80	9.99	33.78	122.0	155.1	0.17	26.00	7.66	2179	2238	67	23.18	1.87	23.76
	101	9.86	33.89	108.0	169.6	-0.01	26.11	7.64	2194	2246	64	22.90	1.97	26.78
	120	9.55	33.96	98.8	180.6	-0.04	26.21	7.61	2215	2259	66	27.02	2.11	29.66
	150	9.43	34.06	82.9	197.0	-0.02	26.31	7.59	2234	2269	75	28.76	2.29	33.07
	200	9.00	34.18	61.2	221.1	0.01	26.48	7.55	2237	2263	61	32.22	2.51	39.13
	300	8.02	34.23	38.1	250.3	-0.02	26.67	7.51	2275	2287	-	32.80	2.79	50.70
	401	7.13	34.26	21.6	272.5	0.00	26.82	7.48	2289	2290	-	38.75	2.80	62.69
Up-18 (4/24/14)	6	17.05	33.53	250.0	-9.4	0.00	24.37	8.02	2017	2210	131	0.06	0.21	1.40
	14	16.98	33.52	251.5	-10.6	0.03	24.38	8.02	2020	2213	98	0.07	0.16	1.39
	39	14.14	33.49	268.0	-13.3	0.62	24.98	8.01	2035	2220	-	0.73	0.32	2.33
	55	11.83	33.54	180.9	86.0	0.74	25.47	7.82	2111	2221	-	10.31	1.05	10.66
	65	11.15	33.53	171.4	99.4	0.42	25.60	7.76	2128	2218	86	14.34	1.25	14.05
	80	10.55	33.60	156.0	118.1	0.15	25.76	7.72	2143	2221	-	18.35	1.43	17.17
	100	10.29	33.79	124.1	151.2	-0.02	25.96	7.65	2179	2235	79	21.81	1.86	23.51
	120	9.93	33.87	114.3	162.9	-0.04	26.08	7.63	2198	2249	-	24.41	1.89	26.37
	150	9.50	33.99	99.4	180.2	-0.05	26.25	7.61	2207	2249	74	26.32	2.06	30.16
	200	9.06	34.12	75.6	206.4	-0.05	26.42	7.56	2248	2276	73	29.07	2.31	37.36
	300	8.25	34.23	41.3	245.6	-0.03	26.63	7.50	2273	2281	-	33.94	2.60	47.78
	401	7.36	34.25	25.4	267.2	-0.03	26.79	7.49	2287	2291	-	35.29	2.85	58.62
Up-19 (5/8/14)	5	15.23	33.52	272.0	-22.8	0.79	24.78	7.99	2029	2202	-	1.86	0.26	6.12
	12	15.02	33.53	279.0	-28.8	2.57	24.83	7.98	2027	2195	-	5.32	0.37	6.77
	31	13.21	33.53	225.6	33.9	1.35	25.20	7.88	2094	2223	-	6.49	0.73	8.67
	45	11.40	33.57	163.7	105.6	0.77	25.58	7.69	2174	2236	-	8.50	1.46	15.79
	60	10.47	33.69	133.0	141.4	0.20	25.84	7.66	2180	2234	-	20.80	1.71	21.01
	80	10.19	33.79	117.0	158.9	0.00	25.97	7.61	2212	2251	-	20.41	1.81	24.16
	100	9.58	33.82	130.5	148.9	-0.03	26.10	7.64	2196	2242	-	23.07	1.81	25.28
	120	9.38	33.87	124.9	155.7	-0.03	26.17	7.62	2176	2217	-	23.36	1.86	26.85
	150	9.39	34.04	94.3	185.9	-0.06	26.31	7.59	2209	2241	-	24.18	2.11	32.16
	220	8.63	34.13	74.6	210.1	-0.04	26.49	7.53	2238	2252	-	28.85	2.31	39.36
	300	8.18	34.27	32.0	255.3	-0.04	26.68	7.48	2275	2273	-	32.75	2.72	50.04
	401	7.40	34.27	23.9	268.4	-0.03	26.79	7.45	2285	2272	-	34.14	2.89	58.91
Up-20 (5/22/14)	7	17.86	33.53	262.3	-25.4	0.03	24.17	8.05	2048	2241	126	0.07	0.28	2.07
	17	17.69	33.52	263.5	-25.8	0.13	24.21	8.05	2035	2227	99	0.22	0.28	2.07
	30	14.40	33.46	279.6	-26.2	0.52	24.88	8.02	2045	2225	-	0.15	0.38	2.27
	40	12.07	33.46	217.6	48.2	1.71	25.36	7.89	2110	2235	87	5.13	0.79	8.51
	50	11.21	33.48	186.4	84.2	1.36	25.54	7.78	2133	2220	84	11.80	1.24	12.76
	70	10.69	33.61	155.1	118.2	0.32	25.75	7.70	2162	2225	-	17.60	1.54	17.78
	90	10.00	33.67	152.1	125.2	0.06	25.91	7.68	2170	2227	-	19.66	1.58	21.73
	120	9.57	33.81	135.7	143.9	-0.03	26.09	7.65	2191	2237	82	23.02	1.83	25.74
	150	9.55	34.02	89.7	189.6	-0.04	26.26	7.59	2218	2248	77	25.89	2.12	31.33
	200	9.41	34.14	68.9	210.9	-0.06	26.39	7.55	2239	2256	-	27.63	2.37	36.16
	300	8.57	34.27	37.8	247.0	-0.02	26.62	7.51	2260	2264	-	30.81	2.70	46.59
	400	7.83	34.27	27.4	262.2	-0.03	26.73	7.48	2272	2267	-	33.43	2.84	54.75
Up-21 (6/19/14)	5	19.22	33.56	238.7	-7.8	-0.02	23.86	8.01	2063	2245	93	0.00	0.24	2.16
	10	19.03	33.55	238.6	-6.8	-0.01	23.91	8.02	2050	2232	116	0.00	0.29	2.16
	28	14.32	33.37	278.9	-24.9	0.39	24.83	8.00	2053	2225	126	0.00	0.39	2.83
	41	13.17	33.40	248.5	11.5	1.83	25.11	7.95	2071	2223	87	2.74	0.54	4.53
	65	11.78	33.39	210.5	56.9	0.73	25.38	7.82	2110	2215	78	11.14	1.05	10.40
	85	10.28	33.47	189.7	86.2	0.10	25.71	7.75	2141	2220	74	15.63	1.34	15.40
	100	10.06	33.62	156.7	120.3	0.01	25.87	7.68	2171	2230	-	19.97	1.59	21.34
	121	9.51	33.81	132.3	147.6	-0.05	26.10	7.64	2193	2237	76	23.69	1.89	26.66
	151	9.14	33.91	115.9	166.0	-0.05	26.25	7.61	2214	2250	71	25.47	1.98	30.07
	197	9.31	34.18	65.3	215.1	-0.04	26.43	7.57	2239	2263	-	27.46	2.32	37.28
	298	8.43	34.25	39.5	246.3	-0.03	26.62	7.49	2287	2287	-	31.75	2.76	47.41
	401	7.48	34.25	28.2	263.6	-0.02	26.77	7.47	2330	2323	-	34.11	3.04	57.76

^a Oxygen concentration calibrated by Winkler titration (See Figure A3 for calibration curve).^b Apparent oxygen utilization defined as the saturation concentration of oxygen at the given temperature and salinity minus the measured oxygen concentration.