REMOTE ESTIMATES OF MARINE PRIMARY PRODUCTIVITY IN THE SOUTHERN OCEAN FROM CARIOCA DRIFTERS AND SATELLITE BASED OBSERVATIONS

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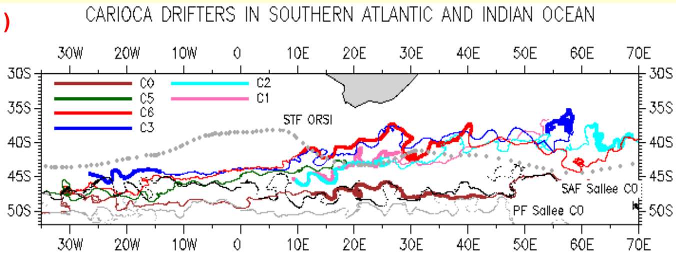
Six CARIOCA buoys drifted from 2006 to 2009 in the Atlantic and Indian sector of the Southern Ocean. During selected periods over the spring-summer season, November 15 - March 15, derived values of the surface dissolved inorganic carbon (DIC) displayed conspicuous daily variations with a close to sunrise maximum and a close to sunset minimum. Net Community Production (NCP) integrated over the mixed layer is computed from the daily change of the maxima of DIC combined with mixed layer depths estimated from Argo floats. The values of NCP are compared to the marine Net Pimary Productivity (NPP) values as derived from Seawifs observations and the ocean color model of Antoine and Morel(1996) during the same time intervals.

(1)



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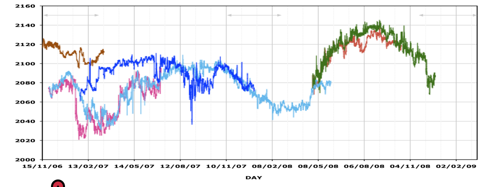


Figure1): Trajectories followed by the 6 buoys. The heavy segments on the lines correspond to the November 15-March 15 periods. The subantarctic front, SAF, is detected by altimetry (Sallee et al, 2008). The climatological subtropical front of Orsi, STF, is indicated. The buoy C0 deployed in 2006 drifted eastward close to the SAF. The 5 other buoys respectively deployed in 2006 (C1, C2), 2007 (C3), and 2008 (C5, C6), all deployed in the subantarctic zone, SAZ, move towards the north east and cross the STF ending their course in the subtropical zone.

Figures 2) and 3): Variation of SST and DIC between November 15, 2006 and March 15, 2009. The arrows indicate the spring-summer periods (15/11-15/03) during which an SST increase and a DIC decrease are observed.

Calculation of NCP from diel cycles of DIC

METHOD

Biological processes, photosynthesis and respiration, and air-sea exchange are the mechanisms responsible for the change in DIC during one day, $(C_M-C_m)_{d-1}$. No mixing due to lateral advection as the buoy drifts in the same water mass; no vertical contribution during the daylight part of the day while the mixed layer is shoaling. Net community production between sunrise and sunset, and the air-sea flux, F, are the processes responsible for the change of DIC during the daylight period at 2m. During the second part of the day, nocturnal convection mixes the warm layer established during daylight down into the lower levels. $\Delta C/\Delta t$ is the change of DIC computed across 2 consecutive mornings at the end of the nocturnal convection within the mixed layer, h. In (1), ρ is the density of seawater. h is estimated from Argo profiles colocated with the buoys. F is computed from buoys data. The biological decrease of DIC takes place without significant change of alkalinity. NCP integrated over the mixed layer is calculated with equation (1)(Boutin and Merlivat, 2009).

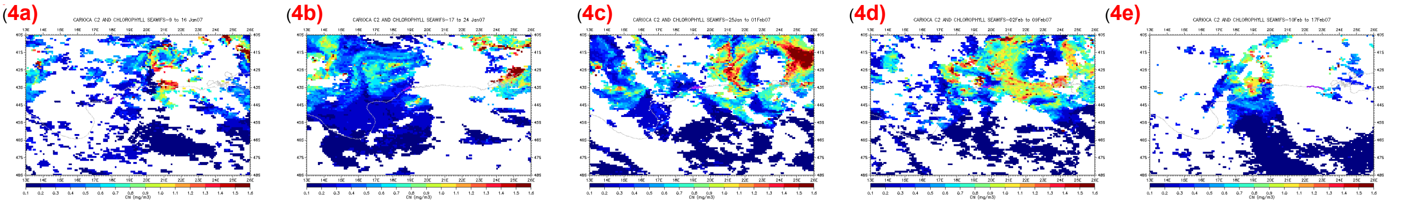
$$\text{NCP} = h\frac{\Delta C}{\Delta t} + \frac{F}{\rho} \quad (1)$$

Table 1

Buoy	Year	Period	Latitude	Longitude	CM-Cm μmol kg⁻¹d⁻¹	ΔC/Δt μmol kg⁻¹d⁻¹	F mmol m⁻²d⁻¹	MLD m	NCP mmol m⁻²d⁻¹	NPP mmol m⁻²d⁻¹
C0	2006	20-25 Apr	49.3°S	30.3°W	1.58±0.53	-1.36±0.08	4.25	60	86±5	16±1.5
	2006	28Nov-7Dec	47.8°S	16.4°E	4.35±0.63	-0.33±0.07	2.03	85	30±6	30
	2006	11-18 Dec	46.8°S	18.0°E	3.78±0.92	-0.59±0.21	0.45	85	50±18	41±1
	2006	20-25 Dec	47.3°S	20.3°E	1.85±0.79	-0.43±0.28	<0.01	85	37±24	39±3
	2006	26-30 Dec	47.7°S	21.2°E	2.60±0.20	-0.60±025	<0.01	85	51±21	36±1
C1	2007	27Feb-2 Mar	41.7°S	25.5°E	3.85±0.46	-1.20±020	7.63	65	85±13	109±11
C2	2007	14-17 Jan	43.7°S	17.9°E	3.77±1.28	-1.79±0.14	3.61	50	93±7	42±2
	2007	22-25 Jan	43.0°S	18.9°E	3.66±0.39	-1.85±0.10	3.2	50	96±5	50±3
	2007	1-5 Feb	42.9°S	20.0°E	4.61±2.00	-2.66±0.26	7.11	50	140±13	63±15
	2007	13-16 Feb	43.0°S	23.0°E	4.21±1.62	-1.96±0.06	10.1	60	127±4	66±1
	2007	22-24 Nov	37.5°S	62.4°E	4.70±2.10	-1.24±0.06	-1.18	49	60±3	56±3
C3	2007	31Jan-3Feb	44.8°S	25.0W	2.33+/-0.93	-0.65±0.11	4.58	55	40±6	42±3
		2-5 Dec	37.3°S	57.2°E	1.60±1.00	-0.80±0.16	-0.02	34	27±5	83±5
C5	2008	14-17 Dec	42.6°S	18.2°E	6.20±1.10	-3.03±0.18	-2.75	35	103±6	114±26
C6	2008	16-20 Nov	41.1°S	11.4°E	2.5±0.6	-1.68±0.13	-1.92	38	62±5	49±1
	2009	1-3 Jan	39.7°S	29.8°E	6.5±0.6	-4.43±0.09	-3.04	17	72±2	87±5

Comparison of NCP from diel cycles of DIC and NPP from a biooptical model

(4a) (4b) (4c) (4d) (4e)



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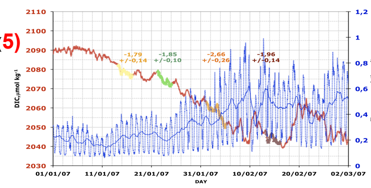

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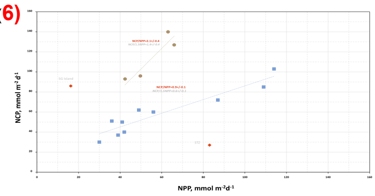

The biooptical model of Antoine and Morel (1996) has been used to estimate NPP based on weekly values of chlorophyll concentration measured by Seawifs, collocated with the buoy trajectories. The last two columns of table 1 indicate the values of NCP calculated with the buoys data and NPP computed with the model. Figures 4) (a, b, c, d,e) show 5 successive weekly chlorophyll Seawifs images from January 9 to February 16, 2007 (the spatial resolution of the data is 9 km). The trajectory of the buoy C2 is superimposed during the periods indicated in table 1 (highlighted in purple on the trajectory). Figure 5) shows the values of DIC derived from the measurements made by the buoy C2 during the time interval, January 1st- March 2, 2007. The gradients $\Delta C/\Delta t$ used in the calculation of NCP (penultimate column of table 1) are indicated in colors. Figure 6) shows the values of NCP as a function of NPP in the 16 studied situations. The blue points (10 values) show a good linear relationship observed between NCP and NPP in a large range of variations of the 2 quantities, from 20 to 140 mmolm^{-2}d^{-1}. The 4 brown data points show the results corresponding to the 4 successive measurements made by the buoy C2 between January 14 and February 16, 2007, illustrated on figures 4) and 5). During this time interval, the buoy was drifting along the subtropical front, in a region characterized by the presence of many Agulhas rings and eddies, south of South Africa (Dencausse et al, 2011). The ratios NCP/NPP must necessary be lower than 1. The NCP/NPP ratios estimated in the 2 above studies are respectively equal to 0.9+/-0.1 and 2.1+/-0.4. The algorithms used to compute chlorophyll from Seawifs measurements possibly underestimate their values by a factor 3 in the Southern Ocean (Kahru and Mitchell, 2010) and thus would lead to an underestimation of NPP of about a factor 1.5. The corrected values of NCP/NPP would then be equal respectively to 0.6 and 1.4. The first figure is in reasonable argument with values reported in the literature for the Southern Ocean. At the opposite, it is clear that the bioptical model does not capture the behavior of the structures followed by the buoy C2 in the Agulhas rings region. In addition, Figures 4) indicate that a fairly large cloud cover was present during the January-February period when the buoy was drifting in the area, which could have degraded the quality of the estimation of chlorophyll concentrations.

Conclusion

This study highlights the possibility of quantifying the high frequency features of the carbon biological pump at the ocean surface and the estimation of biological carbon net community production rates by an in situ non-intrusive method from unattended platforms. There is evidence that tight relationships between NCP and satellite based primary production may be derived This is of special interest to estimate the role of the ocean to sequester carbon in large remote areas like the Southern Ocean if geographical and temporal conditions to apply such relationships may be identified..

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