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OB14E-0415

Comparison of POC flux vertical attenuation between the subarctic and subtropical regions in the western North Pacific

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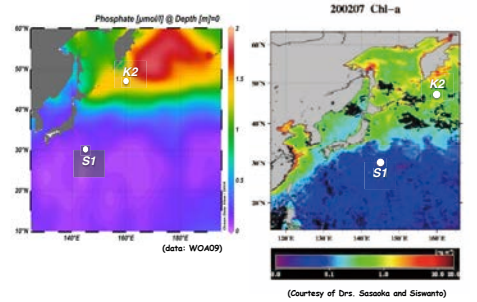
Abstract

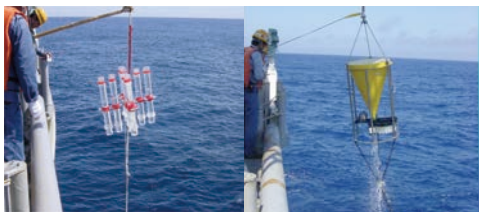
In order to verify the biological carbon pump and its future change by multiple stressors such as warming, acidification and hypoxia in the western North Pacific, comparative study of biogeochemistry between the subarctic-eutrophic and subtropical-oligotrophic regions (K2S1 project: Honda et al. 2017) was conducted between 2010 and 2014. Seasonal or time-series observation by using research vessels and sediment trap mooring system, satellite data analysis and numerical simulation revealed that primary productivity and particulate organic carbon (POC) flux upper 200 m at subtropical station S1 were comparable to or slightly higher than those at subarctic station K2. However, POC flux at deep sea (~ 5000 m) of K2 was ~ 2 times higher than that at S1. These observations resulted in that POC flux vertical attenuation at K2 was smaller than that at S1. In other words, POC in the subarctic Pacific was transported to deep more efficiently than the subtropical Pacific. Major chemical component of sinking particle was biogenic opal at K2 while $CaCO_3$ was major component at S1. Multiple linear regression analysis indicated that correlation coefficient between biogenic opal and POC at K2 was the highest among other ballasts ($CaCO_3$ and lithogenic materials). Thus, biogenic opal might play an important role in effective POC vertical transport in the western North Pacific. In addition, from the view point of metabolism, lower water temperature and dissolved oxygen concentration in the twilight zone at K2 might also support smaller POC flux vertical attenuation. On the other hand, based on seasonal onboard observation, zooplankton / prokaryote carbon demand (CD) in the water column at K2 was ~ 2.5 / 1.5 times higher than those at S1. This observation is contradictory to smaller POC attenuation. Moreover, these CD was higher than carbon supply suspected from POC flux and "active" carbon flux by zooplankton, especially at K2. In order to explain this "mismatch", beside gravitational POC flux, other carbon supply mechanism such as Particulate Injection Pumps (PIPs: Boyd et al. 2019) should be taken into accounts and mechanism of aggregation (turbulence, microbes) should be revisited.

1 Comparative study for biogeochemistry between the western North Pacific Eutrophic SubArctic (SA) and Oligotrophic SubTropical (ST) region (K2S1project 2010-2014)



(Courtesy of Drs. Sasaoka and Siswanto)

2 Sediment Trap experiment



Drifting Sediment Trap Moored Sediment Trap

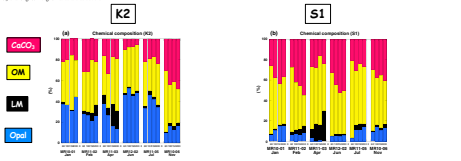
3 Comparable PP and POC flux upper 200 m

(Honda et al. JO 2015)

Table 2 Averages of the fluxes of major components and the chemical composition of the sinking particles for each depth and both stations

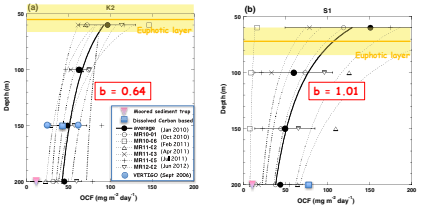
Stn.	Depth (m)	Flux (mg m^{-2} day^{-1})					Contribution (%)				PP (mg m^{-2} day^{-1})	E-ratio (%)	Opal/$CaCO_3$	Org-C/Inorg-C
		Total	Org-C	Opal	$CaCO_3$	LM	OM	Opal	$CaCO_3$	LM				
K2	60	651.2	96.7	202.3	135.9	16.6	43.8	32.1	21.5	2.6	313	30.9	1.5	5.9
	100	482.9	62.7	167.2	121.6	15.0	37.1	34.6	25.2	3.1		20.0	1.4	4.3
	150	317.1	44.9	105.3	61.0	13.2	44.0	32.6	19.2	4.2		15.6	1.7	6.7
	200	326.7	43.2	105.1	77.8	14.5	39.6	32.2	23.8	4.4		14.5	1.4	4.8
(MST)	200	149.3	13.0	65.8	24.4	1.3	28.7	44.1	16.4	0.8		4.8	2.7	5.1
S1	60	670.4	150.1	34.4	193.1	13.9	64.0	5.1	28.8	2.1	353	42.5	0.2	6.5
	100	323.5	56.1	21.9	128.4	12.8	49.6	6.8	39.7	4.0		15.9	0.2	3.6
	150	286.6	48.3	16.1	115.4	17.2	48.1	5.6	40.3	6.0		13.7	0.1	3.5
	200	301.3	42.1	24.8	136.4	20.0	39.9	8.2	45.3	6.6		11.9	0.2	2.6
(MST)	200	118.5	12.5	6.2	60.6	3.5	30.1	5.3	51.1	2.9		4.0	0.1	1.7

PP is the integrated primary productivity measured during the drifting sediment trap deployment. The E-ratio is the export ratio, which is the ratio of organic carbon flux to PP. Opal/$CaCO_3$ and Org-C/Inorg-C are the molar ratios of the Opal and $CaCO_3$ fluxes and of the organic carbon and inorganic carbon fluxes, respectively. Data in line "MST" are the average of 200-m moored time-series sediment traps data obtained near the time of DST deployment (detail data are shown in the caption of Fig. 3). Measurement errors of concentrations are about 5 % and that of Opal/$CaCO_3$ and Org-C/Inorg-C ratios are about 7 %



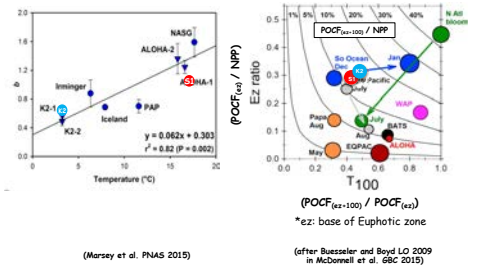
4 POCF Vertical attenuation upper 200 m

$$POC_{(Z)} = POC_{(60)} \times (Z/60)^{-b}$$



(Honda et al. JO 2015)

5 Exponent "b" vs Temperature (left) Export ratio vs Transfer efficiency (right)

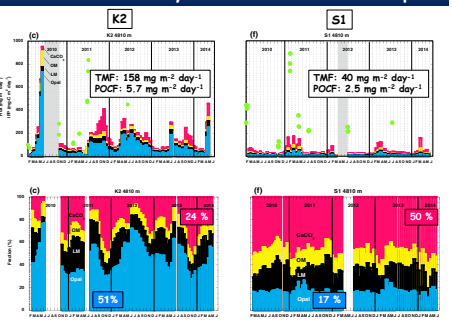


*ez: base of Euphotic zone

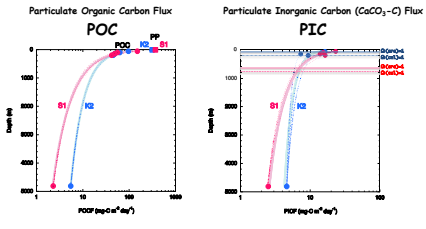
(Marsey et al. PNAS 2015)

(after Buesseler and Boyd LO 2009 in McDonnell et al. GBC 2015)

6 Seasonal variability in "marine snow" in Deep



7 POCF / PICF Vertical attenuation

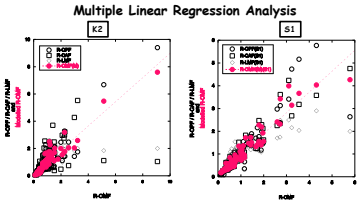


$POC_{(Z)} = POC_{(60)} \times (Z/60)^{-b}$	K2	S1
z0 (m)	b	b
60	0.654	0.953
100	0.628	0.825
150	0.630	0.878
200	0.662	0.914

$PICF_{(Z)} = PICF_{(60)} \times (Z/60)^{-b}$	K2	S1
z0 (m)	b	b
60	0.248	0.527
100	0.252	0.491
150	0.082	0.518
200	0.166	0.617

8 Transfer coefficient for respective ballasts

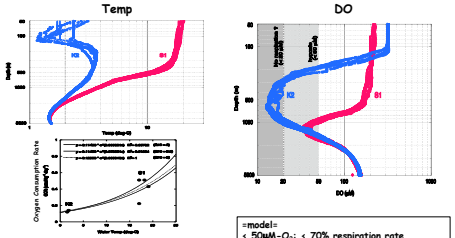
Multiple Linear Regression Analysis



R-OCF = a x R-Opal + b x R-$CaCO_3$ + c x R-LM + residual

	n	a: Opal	b: $CaCO_3$	c: LM	residual	R^2
K2	89	0.79	0.23	-0.04	0.01	0.89
S1	94	0.26	0.79	-0.12	0.06	0.92

9 Lower Temp and DO in the twilight zone at K2



Q_{10}= ~ 2
(Sukigara et al. DSR I 2019)

(100-1000m)
Remineralization (or Respiration) rate (RR)
$RR_{(S1)} = 2.7_{(200m)} \sim 1.1_{(1000m)}$ * $RR_{(K2)}$

=model=
< 50μM-O_2: < 70% respiration rate
< 5μM-O_2: < 20% respiration rate
(Devries and Weber GBC 2016)

=shipboard incubation=
20μM-O_2: inhibition of (0%) respiration rate
(Keil et al. BGS 2016)

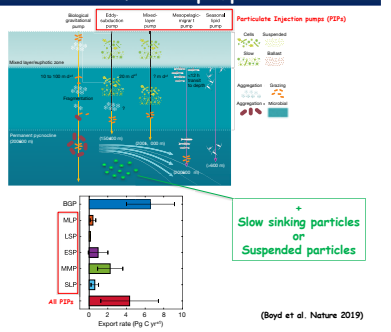
10 "Inconvenient truth"

* Sinking velocity
* Higher Carbon demand and "Mismatch" of Carbon supply / demand

		K2	S1	reference
Sinking Velocity (m day^{-1})	at 100 - 200 m	31 ± 17	63 ± 26	Sukigara et al. (2018)
Oxygen Consumption Rate (mmol kg^{-1} day^{-1})	at 100m	0.12 - 0.14	0.43 - 0.51	Sukigara et al. (2018)
	at 200m	0.01	0.27 - 0.51	
Δ POC (mg-C m^{-2} day^{-1})	200 - 4810 m	~ 40	~ 40	
	(200 - 1000m)	(~ 30)	(~ 33)	Honda et al. (2017)
ZP (Metazoan) Carbon Demand (mg-C m^{-2} day^{-1})	150 (or 200) - 1000 m	100 ± 4	40 ± 11	Kobari et al. (2016)
				* K2: 2,250, S1: 300
Prokaryote Carbon Demand (mg-C m^{-2} day^{-1})	150 (or 200) - 1000 m	13.9 ± 1.8	9.6 ± 1.2	Honda et al. (2017)
	200 - 4810 m	13.9 ± 0.9	10.6 ± 0.7	Uchimiya et al. (2018)
				* K2: 1,440, S1: 940
				* Biomass (200-1000m) (mg m^{-3})

(+ DOC) K2: 0.95 , S1: 8.23
(+ ZP excretion) K2: 0.9 , S1: 1.1

11 Evaluation of other pumps ?!



(Boyd et al. Nature 2019)

12 Summary

Based on K2S1project in the western North pacific

* Vertical attenuation in POC at subarctic K2 is significantly smaller than at subtropical S1.
(higher efficiency in POC vertical transport at K2).

* Biogenic Opal might be a key component for the effective POC vertical transport ("Protective suit" rather than ballast?!).

* Lower temperature and DO at K2 might associate with smaller remineralization.

Take home message:
Lower Sinking velocity, Higher CD and Mismatch at K2
(Other Biological pump: PIPs? Suspended particles?
and Revisit of aggregation mechanism?)