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Estimating Net Community Production Using Dissolved Inorganic Carbon Content in the Amundsen Sea Polynya, Antarctica

Mi Seon Kim[1,2]♣ (mskim@kopri.re.kr) and Tae Siek Rhee[1]

[1]Korea Polar Research Institute, Incheon, Korea
[2]Department of Ocean Environmental Sciences, Chungnam National University.

Introduction

The net community production (NCP) can be estimated using various technique. Here we used the difference of dissolved inorganic carbon (DIC) concentrations in the water column between the surface and deep waters to determine NCP assuming that the deep water preserves the winter characteristics of dissolved inorganic content. This is true in the Amundsen Sea polynya (ASP) as the winter water is detected below the mixed layer. Various literature shows ambiguous definition of the reference depth between the surface and deep waters. We estimated NCP in the Amundsen Sea polynya applying various reference depths relevant to the biological production and vertical mixing.

Sampling and Methods

1. Sampling

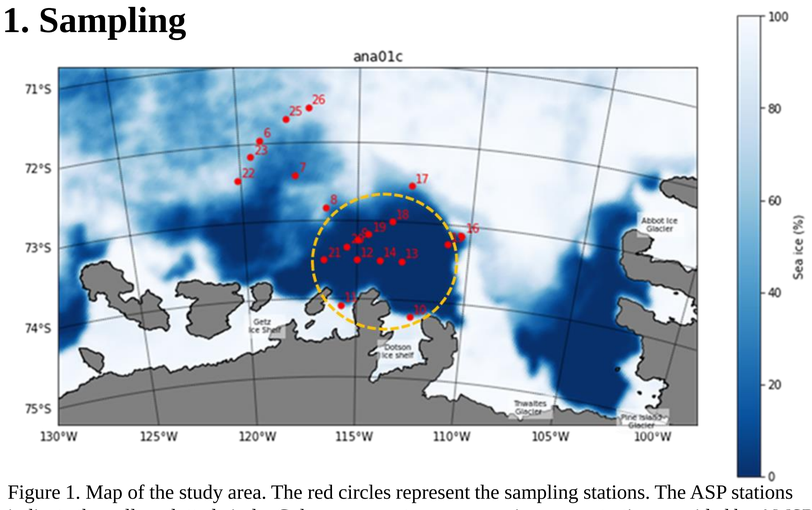


Figure 1. Map of the study area. The red circles represent the sampling stations. The ASP stations indicate the yellow dotted circle. Colors represent average sea-ice concentration provided by AMSR-E during the ANA01C cruise (Dec. 2010 ~ Jan. 2011) of the Korean research ice-breaker R/V *Araon*.

2. Analytical Method

2.1 Analyses

- Dissolved Inorganic Carbon (DIC) and Total Alkalinity (TA)
  : a Versatile Instrument for Determination of Titration Alkalinity (VINDTA 3C)
- Nutrients
  : a 4-channel continuous Auto-Analyzer (QuAAtro, Seal Analytical).

2.2 NCP calculation from DIC

- $seasonal\ NCP (mmol\ C\ m^{-2})$

$$= \int_0^x (DIC_x - DIC_{observed})dz + Gas\ exchange$$

- $NCP\ (mmol\ C\ m^{-2}\ d^{-1})$

$$= seasonal\ NCP \div Number\ of\ open\ water\ days$$

- **Gas exchange** did not include here, but will be considered later.
- **The number of open water days (54 days)** were estimated from the date of ≤ 50 % average ice concentration in the polynya area to the date of sampling.

3 Depth Definition

3.1 Mixed Layer Depth (MLD)

Table 1. Criteria used to define MLD in Ocean.

Author	MLD Threshold Criterion
Kara et al. (2000)	$\Delta\sigma_\theta = \sigma_\theta (T + \Delta T, S) - \sigma_\theta (T, S)$ with $\Delta T = 0.8℃$
Suga et al. (2004)	$\Delta\sigma_\theta = 0.125$ kg m^{-3}
Thomson and Fine (2003)	$\Delta\sigma_\theta = 0.01$ to 0.03 kg m^{-3}
Weller and Plueddeman (1996)	$\Delta\sigma_\theta = 0.03$ kg m^{-3}
Rintoul and Trull (2001)	$\Delta\sigma_\theta = 0.05$ kg m^{-3}
Schofield et al. (2015)	Max(N^2)

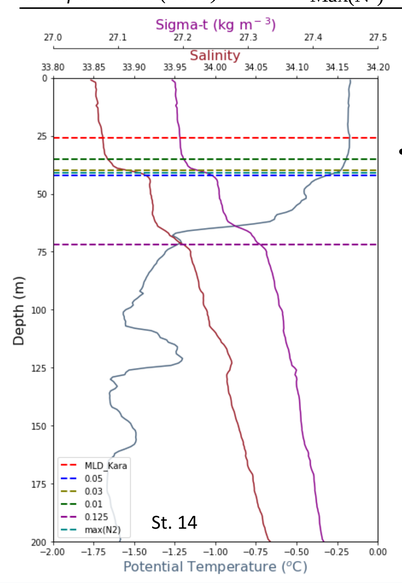


Figure 2. Plot of vertical profile of potential temperature, salinity and sigma-t and MLD calculated by threshold criterion in each station

- The T, S, and Sigma-t vertical profiles of each station were compared with the MLD calculated by reference methods (Table1, Figure 2), and MLDs calculated at sigma-t 0.05 kg m^{-3} were used.

3.2 Potential Temperature Minimum depth (pTmin)

- Used the Gaussian filter function (sigma = 3) provided by the Python library pandas.
- The pTmin depths were chosen as the pole of the first curve while the water temperature was less than -1℃ (Figure 3).

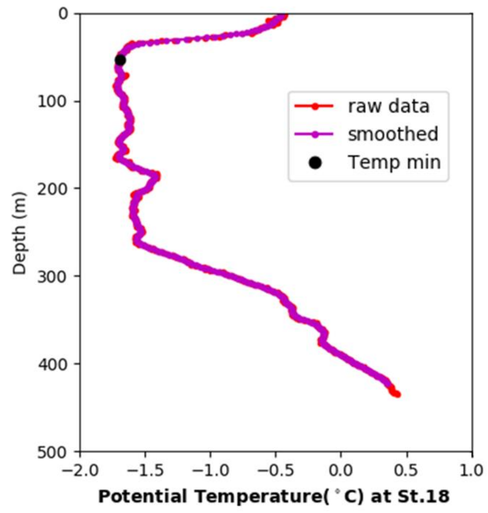


Figure 3. Determination of potential temperature minimum depth (pTmin) using Gaussian filter function.

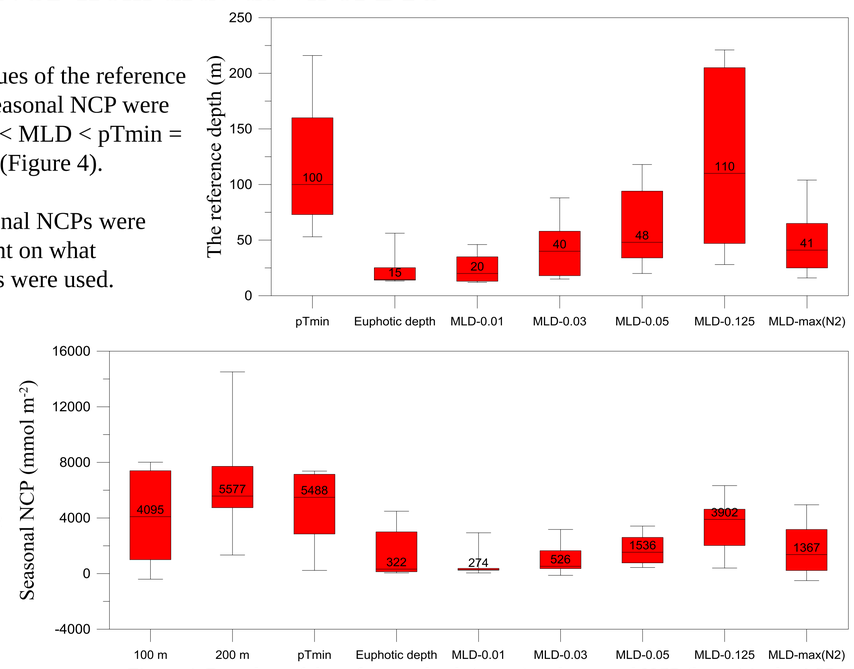
3.3 The others

- **100 m and 200 m**; the nearest two water depths were interpolated at the stations where the water depth samples were not collected.
- **Euphotic depths** (1% of the surface irradiance) were calculated at the stations where vertical CTD casts were made.

Results and discussion

1. Seasonal NCP from drawdown of DIC

- The median values of the reference depth and the seasonal NCP were Euphotic depth < MLD < pTmin = 100 m < 200 m (Figure 4).
- Estimated seasonal NCPs were highly dependent on what reference depths were used.



→ It was important to determine the most appropriate criteria.

Figure 4. Box plots of the reference depth (upper) and seasonal NCP (lower) in the ASP.

2. The C:N:P ratio

- The C: N: P ratios for each criterion were compared to determine reference depths were affected by biological activity (Figure 5). **→ All reference depths were affected by biological activity.**

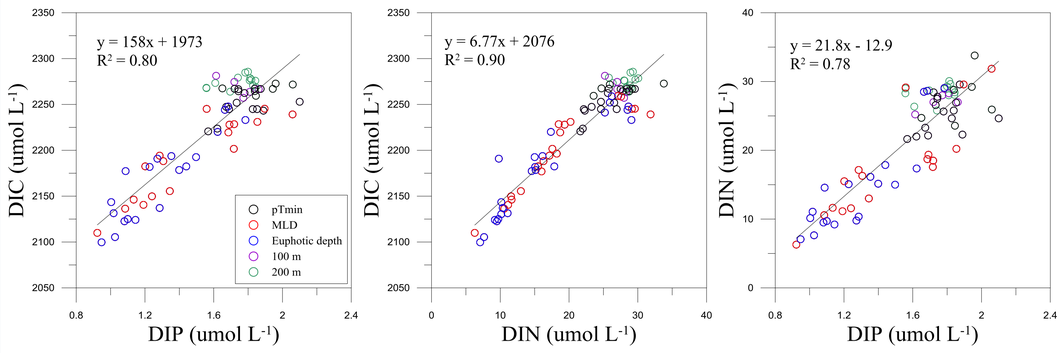
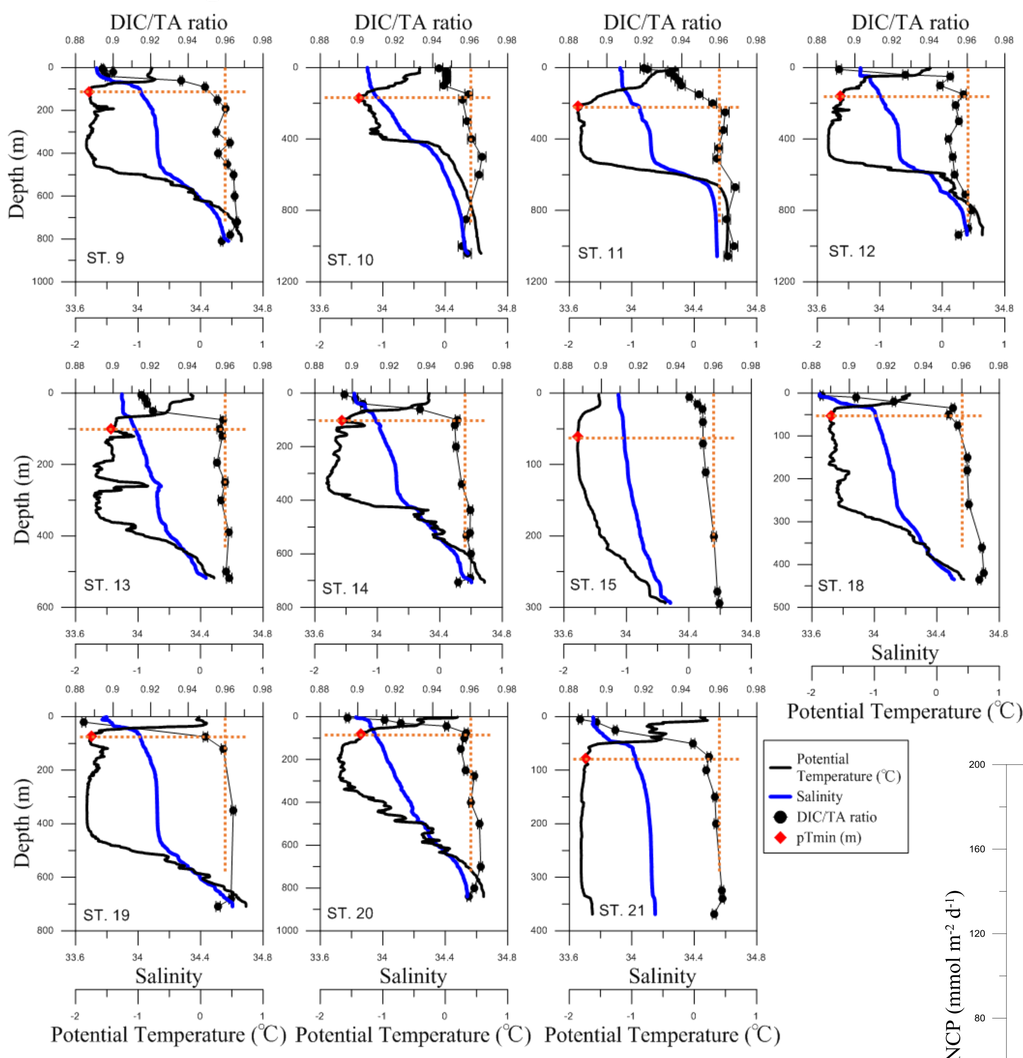


Figure 5. Interrelationships between dissolved inorganic carbon and dissolved inorganic nutrients (N, P) of the reference depths.

3. Estimating NCP



- The pTmin meant Winter Water because it was a value determined by avoiding other incoming water mass. Thus, it could be used to calculate all biological production from the prebloom to the date of sampling.
- The ratios of DIC/TA (0 m ~ 100 m; 0.930 ± 0.024, n = 59) were low by biological production in the surface layer. Below 100 m depth, the DIC/TA ratios (< 100 m; 0.960 ± 0.004, n = 83) were almost constant (Figure 6).
- The pTmin depths could be estimated to be seasonal NCP because those existed at the depth of 0.955 ± 0.003 which were close to the DIC/TA ratio of deep water at each station (the orange dotted line).

Figure 6. The vertical distributions of potential temperature, salinity, DIC/TA ratio and potential temperature minimum depth of each stations in the ASP.

- The estimated NCPs in the ASP were compared with those reported in the same region and time (Figure 7). The literature were estimated NCP using DIC and O_2/Ar. Their average values were similar.
- The NCPs in February 2012 were about 20% of that in January 2011. We will investigate the temporal variation of the NCP using the proposed method.

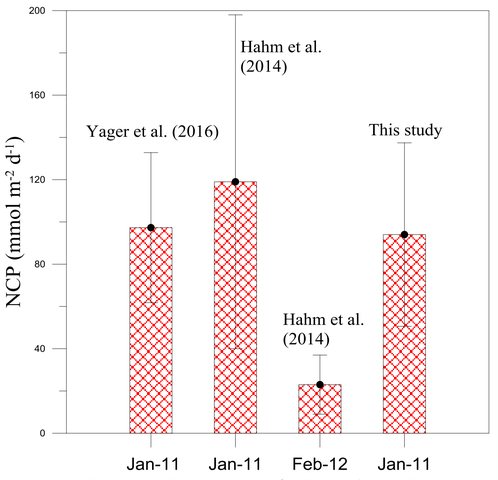


Figure 7. Comparison of NCP in the ASP in January 2011 and February 2012.

✓ **References**

[1] Hahm, D., et al. (2014) J. Geophys. Res. Oceans, 119, 2815–2826, doi:10.1002/2013JC009762.

[2] Yager, P. L., et al. (2016) Elementa, 4, 1–36, doi:10.12952/journal.Elementa.000140.

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