Title

Contributions of external sources of nutrients to export production in the East China Sea

Members' names and affiliations

Name	Age	M/F	Affiliation	Position	Contribution part
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LaMer Faculty member in charge	Xinyu Guo			Professor	Beneficial discussion

Aim

The research aims to apply the tracking technique to the external nutrients in the East China Sea (ECS), evaluate their roles in the export productions over the continental shelf of the ECS and explore the corresponding dynamic mechanism. Large rivers are vital pathways in the terrestrial–marine nitrogen linkage. Riverine loading is a direct nitrogen source for the shelf seas and contributes to the export production there. We focus on the riverine nitrogen budget and evaluate the role of riverine nitrogen in export production and carbon sequestration.

Procedure

A physical-biological coupled model with a tracking technique was used to investigate transport and budget of riverine dissolved nitrogen and its produced particulate nitrogen in the ECS. The model covers the region from 24.0 to 41.0° N and from 117.5 to 131.5° E with a resolution of 1/18° (5–6 km) and 21 σ layers (Fig. 1). The 50-m, 100-m, and 200-m isobaths along with the Taiwan Strait section (TAS), 34.7° N section (34N), and the Tsushima Strait section (TUS) separate the ECS into three subregions: the inner (0–50 m), middle (50–100 m), and outer shelves (100–200 m), which are used in the nitrogen budget evaluation.

The model consists of two parts. The first part is a physical–biological coupled model based on Zhao and Guo (2011) and Wang et al., (2019), which is used for calculating the cycles of all nitrogen sources. Wang et al. (2019) analyzed the nitrogen budget from all ECS sources based on the results from the same physical–biological coupled model. The second part is the tracking model following the method in Ménesguen et al., (2006), which separately calculates the state variables from different nitrogen sources. We applied it here to calculate the nitrogen budget from riverine source. The method in this study is the same as that used in J. Zhang et al. (2019), but only the DIN tracking case was applied here and the target sources were changed to many rivers.

There are ten main rivers loading nutrients into the ECS in our study area. The model results for the DIN from the Changjiang River are mainly presented in the following because of its leading role among all the riverine DIN sources. The DIN from the Changjiang River and its supported PON are denoted by DIN_C and PON_C.

At the beginning of the tracking module, the riverine DIN was pumped into the ECS through the estuaries where its related state variables have a value of zero. Then phytoplankton and detritus supported by the riverine DIN are generated over the continental shelf. Their sum is defined as particulate organic nitrogen (PON) here. Under the circumstances, the riverine DIN-tracking case was run for over 5 years when the state variables reached a stationary state and the results in the final calculation year are used for our analysis.

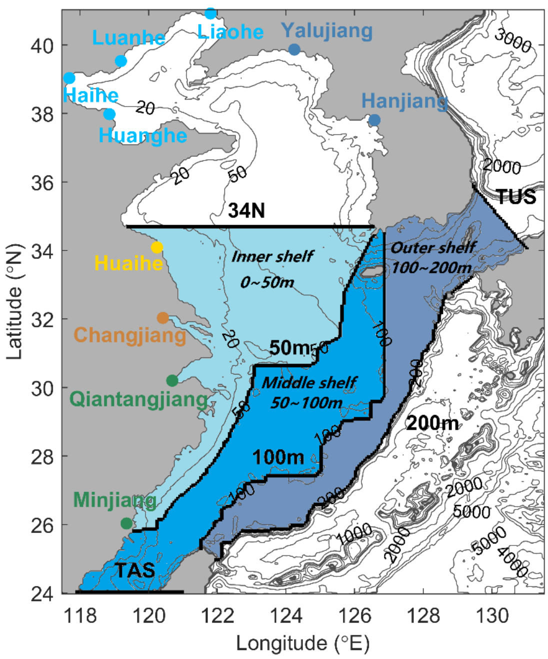

Fig. 1. The model domain and bathymetry. The grey contour lines represent the isobaths. The dots along the coast denote the positions of inflow from rivers and the same group of rivers has the same color. The black thick line shows the positions of the Taiwan Strait (TAS), Tsushima Strait (TUS), 34.7° N section (34N), and three designated isobaths sections: 50-m, 100-m, and 200-m isobaths. Note that the Cheju Strait section is appended to the 100-m isobath for convenience. With these sections, the ECS is divided into the inner shelf (0–50 m), middle shelf (50–100 m), and outer shelf (100–200 m) subregions.

Results

Export production is the amount of carbon fixed by photic zone autotrophs, and either sinks to deeper water and sediments or is transported to open oceans. In a steady state, export production balances new production. In the continental shelf, the carbon and nutrients regenerated below the euphotic layer can easily return to the euphotic layer and are reused by phytoplankton (Chen, 2003). Thus, the carbon export to sediment and open ocean rather than below the euphotic layer in the continental shelf plays an important role in long-term carbon sequestration (Simpson and Sharples, 2012).

Considering the stable ratio of POC to PON (close to the Redfield ratio 6.63) in the ECS (Hung et al., 2000; Zhu et al., 2006), the export production due to DIN_C can be referred to as the sum of PON_C fluxes to open ocean and sediment. Treating the ECS shelf area as a whole (Fig. 3), the exports of PON_C are water–sediment flux (0.69 kmol s^{-1}), lateral flux to the Japan Sea through the TUS section (0.39 kmol s^{-1}), lateral flux to the South China Sea through the TAS section (0.06 kmol s^{-1}), lateral flux across the 200-m isobath (0.01 kmol s^{-1}), and lateral flux to the Yellow Sea through the 34N section (0.09 kmol s^{-1}). Except for the last flux, they are all export production induced by the DIN_C in the ECS, adding up to 1.15 kmol N s^{-1}, among which the water–sediment flux and the export to the Japan Sea account for 60% and 34%, respectively.

In our model calculation, the gross primary production supported by DIN_C over the whole shelf is 12.71 kmol s^{-1}. The respiration of phytoplankton and remineralization of detritus are 7.42 and 3.45 kmol s^{-1}, respectively. Their sum (10.87 kmol s^{-1}) is the recycling flux of DIN_C, accounting for 85% of the gross primary production. This percentage is similar to the estimation derived from the observation of the total nitrogen over the whole shelf (Zuo et al., 2016).

The ratio of export production to primary production (referred to as the e-ratio) related to the Changjiang River nitrogen is 0.09 (= 1.15/12.71), suggesting a handful of the primary production is exported. The e-ratio should be the same as the ratio of new production to primary production (referred to as the f-ratio). The f-ratio calculated from the relative concentration of nitrate is approximately 0.4 (Chen et al., 2001, 1999; Liu and Chai, 2009). Hung et al. (2016) gave an e-ratio of 0.16 based on trap-collected POC fluxes. Our e-ratio derived from DIN_C is lower than the above studies for two reasons: the calculation method is different, and the DIN from the Changjiang River is not assimilated effectively, indicating a lower e-ratio than other external nitrogen sources.

As a carbon sink, the ECS absorbs approximately 6.92–23.30 Tg C yr^{-1} of atmospheric carbon dioxide (Jiao et al., 2018). The export production estimated here, 1.15 kmol N s^{-1}, is converted to POC fluxes of 2.89 Tg C yr^{-1}, accounting for 12–42% of the carbon sequestration in the ECS. This percentage is comparable to an estimation of Chen (2000, 33%).

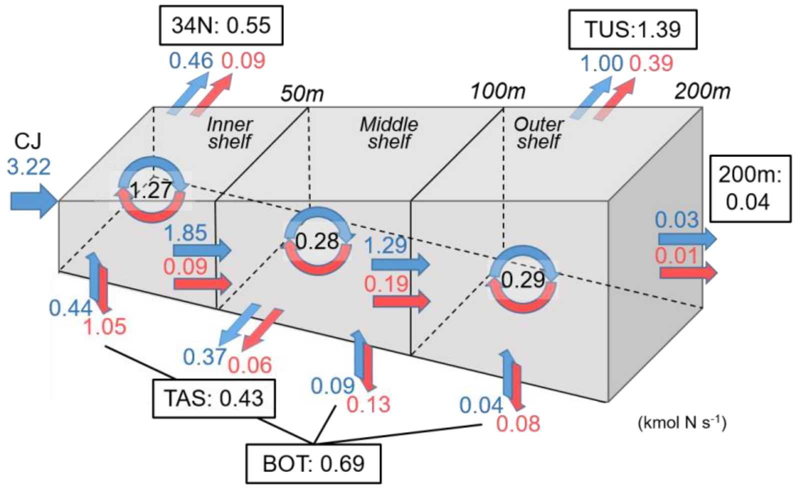

Fig. 3. Annual budgets of DIN_C and PON_C over the inner, middle, and outer shelves of the ECS. The straight blue (red) arrows with numbers denote the annual mean flux of DIN_C (PON_C). The value in each black box denotes the flux of total nitrogen (TN_C). The values inside the three circles denote the transformation flux between DIN_C and PON_C. All values are in kmol N s^{-1}.

Publication/conference presentation

1. Jing Zhang, Xinyu Guo, Liang Zhao, Budget of Riverine Nitrogen over the East China Sea Shelf. Environmental Pollution, under review.

Perspectives in future

Besides the terrestrial nutrients, oceanic nutrients (from the Kuroshio and the Taiwan Strait) also play an important role in the ecosystem of the ECS. We wonder which nutrient source contributes most to the export production of the ECS. The next step is to evaluate the oceanic nutrient budgets and the corresponding export production.

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