Title

The influence of Kuroshio intrusion on the low-trophic ecosystem in the Yellow Sea

Members' names and affiliations

Name	Age	M/F	Affiliation	Position	Contribution part
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Aim

As an important marginal sea in the northwest Pacific Ocean (Chen et al.,2009), the Yellow Sea is influenced by nutrient inputs from different sources. In addition to inputs from terrestrial sources such as rivers and atmospheric deposition (Guo et al.,2020), water exchange with neighboring oceans is also an important external source of nutrients to the Yellow Sea (Zhao et al.,2019). This paper plans to quantify the effects of nutrient input from the outer sea on the lower trophic level ecosystem of the Yellow Sea through sensitivity experiments, which will help to deepen the understanding of the connection between the Yellow Sea and the Pacific Ocean and provide a reference basis in the rational exploitation of aquatic resources and environmental protection in the Yellow Sea area.

Procedure

The coupled physical-biogeochemical model (ECSECOM) of the East China Sea established by Zhao et al (2011) is used, and the model mainly consists of two modules, the hydrodynamic module and the biogeochemical module. The above model was adapted by Wang et al(2019) and Jiang et al(2020). 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).

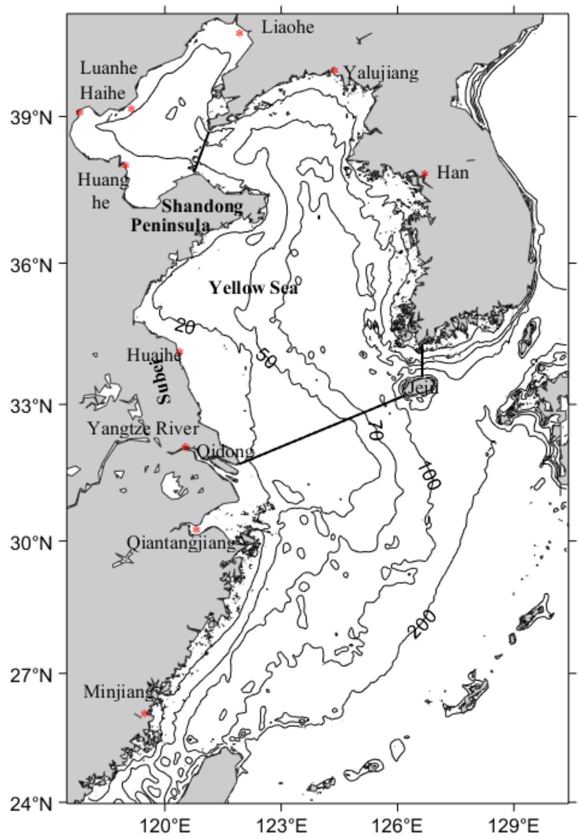

Fig. 1. The model domain and bathymetry. From the north to the south, we take the section from Old Tiesan to Pungrae, the section through the Jeju Strait at 126.64°E and the section from the mouth of Qidong to the southwest of Jeju Island as the exchange interface between the Yellow Sea and the neighboring sea (shown by the thick black line in the figure).

In order to study the effects of nutrient input from the outer sea on inorganic nutrients and the processes affecting their contents in the Yellow Sea, a simultaneous 10% increase in the nutrient concentration of Kuroshio input was used as a set of sensitivity experiments to compare with the normally set control experiments to quantify the contribution of the invasion of the outer Kuroshio current system into the continental shelf to the inorganic nutrients of the lower trophic level ecosystem of the Yellow Sea and its related impact processes.

Results

The seasonal changes of nutrients and chlorophyll variation amounts in the surface layer of the Yellow Sea after a 10% increase of Kuroshio nutrient concentration are shown in **Fig. 2**. In this paper, February, May, August and November represent the four seasons of winter, spring, summer and autumn, respectively.

Taking DIN as an example,in the results of sensitivity experiments, DIN showed a general increase in winter, and the sea area of northern Jiangsu-Yangtze River estuary became a high value area with an increment of more than 0.3 mmol/m^3. There is a tongue-shaped high value area of increasing concentration showing gradient changes extending northward from the Kuroshio Current axis to Jeju Island, along the Yellow Sea Trough into the North Yellow Sea, and as far as the Bohai Strait. In spring, DIN showed a decrease in the surface layer of the central South Yellow Sea and the southern Shandong Peninsula, and the increasing trend of DIN concentration in the sea area of northern Jiangsu and the Yangtze River estuary was weaker than that in winter, but there were still high value areas along the 50m isobath west of the outer side of the area where the concentration increased more than 0.2 mmol/m^3.

In summer, the area where DIN concentration increased was further reduced and its intensity weakened, only in the shallow shore of northern Jiangsu Province, near the mouth of the Yangtze River and the coast of the Korean Peninsula, while the rest of the sea area showed a decreasing trend.

In autumn, the surface DIN concentration in the central part of the South Yellow Sea to the southern part of Shandong Peninsula and the northern part of the Yangtze River mouth showed a decrease, while the coastal sea area showed an increase, especially in the southwestern part of the South Yellow Sea where the 50m isobath is shallow, with the most significant increase of more than 0.3 mmol/m^3; the increase of surface DIN in the North Yellow Sea area did not change significantly.

In winter, there was no significant change in surface chlorophyll in most of the Yellow Sea; in spring, there was a significant increase along the 50 m depth contour in the outer part of the shallows of northern Jiangsu to the northeastern part of the Yangtze River mouth; in summer, the high value area of chlorophyll increase was distributed along the 50 m depth contour in the outer part of northern Jiangsu - Yangtze River mouth closer to the shore, and the high value area of increase also appeared off Haeju Bay, which may be influenced by the presence of a northward current transporting nutrients off Jiangsu in summer (Qiao et al.,2008;Xia et al.,2006); in autumn, the high value area of increase in concentration extended from Jeju Island to the central part of the South Yellow Sea.

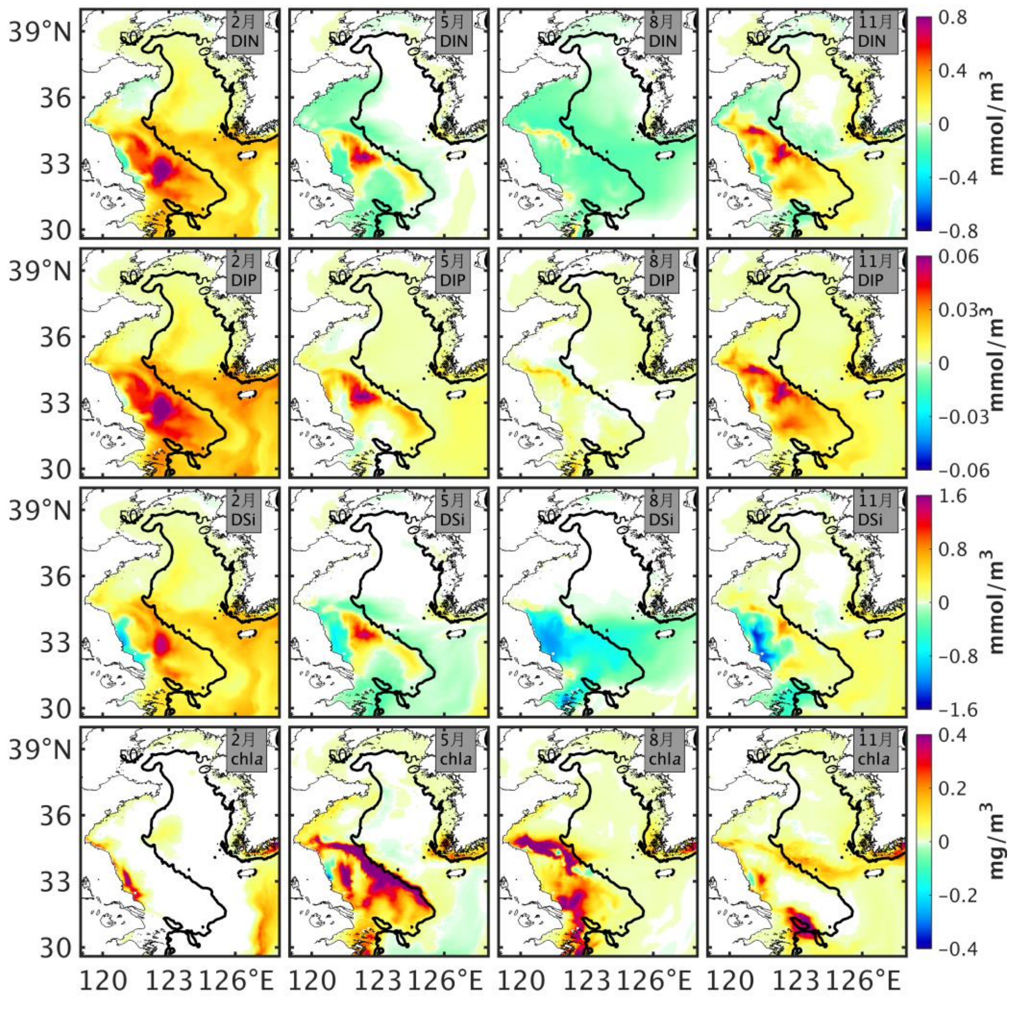

Fig. 2 Distribution of nutrient and chlorophyll contributions to the surface layer of the Yellow Sea by increasing Kuroshio nutrients(Black contours are 50m isobaths).

The distribution of nutrient fluxes from the southwest of Jeju Island is shown in Fig. 3, with positive values indicating inflow into the Yellow Sea and negative values indicating outflow from the Yellow Sea. In terms of the year-round distribution of the change amount, the annual average fluxes of nutrients show the loss of the existing amount. The seasonal distribution shows that in winter and spring, the nutrients fluxes variation is only replenished in the northern part of the strait, while other locations show loss and are more evenly distributed. In summer and autumn, the high value area of loss appears in the central 30m of the strait, and the high value area expands to the surface layer continuously, and is only replenished in the shallow surface layer at 10m and the deep bottom layer at 70m, and the value is small.

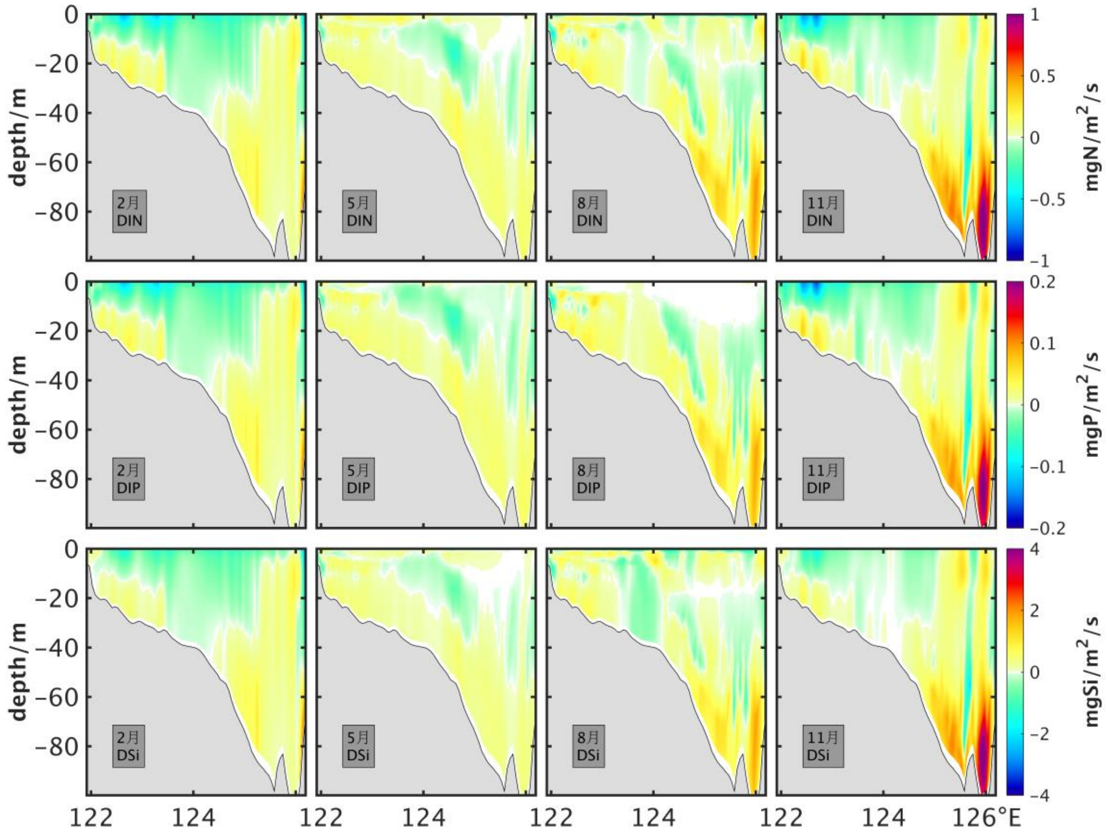

Fig. 3 Distribution of nutrient flux contribution from the Kuroshio tide to the southwest section of Qidong-mouth to Jeju Island

The change of nutrients exchange at the Yellow Sea interface after the increase of nutrient input from the model results is shown in **Fig. 4,** where positive values indicate an increase of the present stock and negative values indicate a decrease of the present stock.

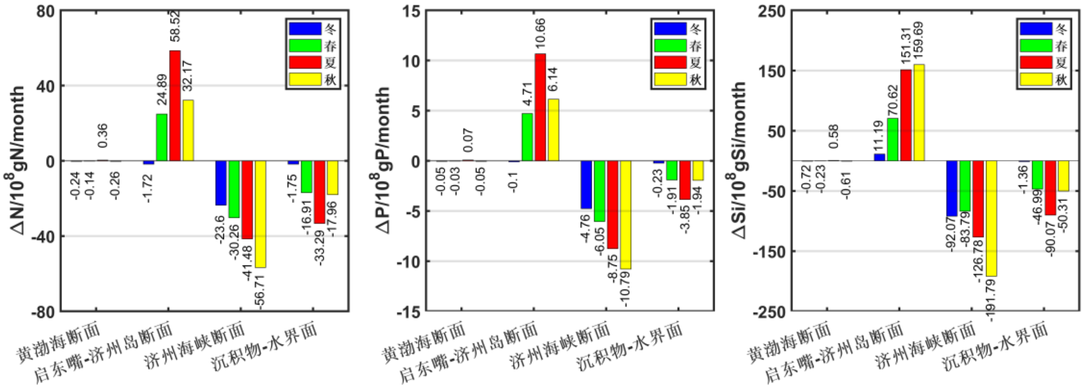

Fig. 4 Seasonal variations of nutrients fluxes exchanged at the Yellow Sea interface

(黄渤海断面：the Yellow and Bohai Sea Section;启东嘴-济州岛断面：the Qidongzui-Jeju Island Section;济州海峡断面：the Jeju Strait Section;沉积物-水界面: Sediment-water interface)

The nutrient input from the oceanic sea increased, and the nutrient exchange process at the Yellow Sea interface showed a loss of nutrient present in the Yellow Sea throughout the year, with N, P and Si losing 324.67×10^8gN/a, 52.07×10^8gP/a and 848.16×10^8gSi/a, respectively. the Jeju Strait section and the Qidongzui-Jeju Island section were the most important loss and replenishment processes. The exchange is also an important loss process, and the exchange process in the Yellow Sea and Bohai Sea sections has the least variation. In terms of seasonal variation, the variation of nutrient exchange process at the Yellow Sea interface is more fluctuating, and the variation is significantly larger in summer and autumn than in winter and spring.

Publication/conference presentation

There is an article under review.

Perspectives in future

The increase of Kuroshio nutrient concentration will have a non-negligible impact on the Yellow Sea. How the internal processes in the water column and interfacial exchange processes affecting the nutrient content of the Yellow Sea will change and the annual mean of regional-integrated increment of inorganic nutrients in the Yellow Sea need further quantitative analysis and discussion.