The development of ecosystem model coupled with sediment processes for the upper Gulf of Thailand

Anukul Buranapratheprat[1], Siraporn Tong-u-dom[2] and Akihiko Morimoto[2]
[1]Department of Aquatic Science, Faculty of Science, Burapha University, Thailand
[2]Center for Marine Environmental Studies (CMES), Ehime University, Japan

Introduction

The upper Gulf of Thailand has long been deteriorating by eutrophication. The resulting environmental problems are the development of red tide and hypoxia in water columns causing problems to tourism and coastal aquaculture in the surrounding area. Red tide is usually intense during the southwest monsoon when river discharge is very large, and wind directs landward, and better situation occurs during the northeast monsoon when the discharge is low, and wind blows seaward. The river-borne nutrient sources and flooding time of water mass controlled by seasonal river discharge and circulation are important to control the bloom intensity. Sub-surface hypoxia develops in the north of the gulf from mid-southwest monsoon period to the onset of the northeast monsoon season (Buranapratheprat et al., 2021). A lower trophic level ecosystem model was used to simulate red tide and hypoxia in the gulf. The model can reproduce sub-surface hypoxia compared with the results from field observations (Morimoto et al., 2021). However, discrepancy between both results was also found such as the expansion of sub-surface hypoxia in some seasons. This may be due to the limitation of this model that includes just nutrient sources from river discharge for the simulation.

In this study, we modify a lower trophic ecosystem model to be coupled with bottom sediment processes. Since we still do not know the contribution of sediment to support primary productivity in this coastal sea, a sensitivity analysis is conducted to comprehend the responses of the ecosystem on sediment interaction in different scales. This research will help us understand clearer in eutrophication process in this tropical coastal region.

Procedure

We applied a lower trophic ecosystem model coupled with circulation model (The Princeton Ocean Model) for the upper Gulf of Thailand (Figure 1) based on the study of Morimoto et al. (2021). The model is modified to include the release of nutrients from the sea bottom as an alternative nutrient source in this study. Three case studies are shown in Table 1.

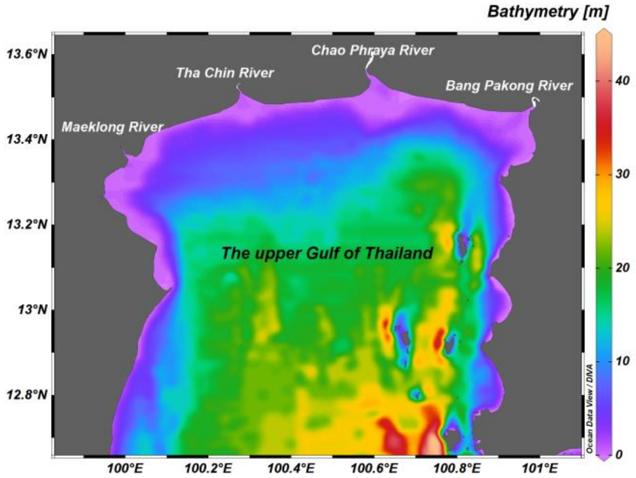

Figure 1 The upper Gulf of Thailand showing water depth in meter.

Table 1 Three case studies for the numerical experiments.

Case study	**Nutrient fluxes from sea bottom**			**Note**
	DIN	**DIP**	**PON**	
Control	No	No	No	
Case_01	0.6 mg N/m^2/day	0.03 mg N/m^2/day	No	Morimoto et al. (2021)
Case_02	0.6 mg N/m^2/day	0.03 mg N/m^2/day	2.0 mg N/m^2/day (assumes)	

Remarks: DIN, DIP, and PON stand for dissolved inorganic nitrogen, dissolved inorganic phosphorus, and particulate organic nitrogen, respectively.

The study area is influenced by the northeast and the southwest monsoon, but red tide and near-bottom water hypoxia usually develop during the southwest and the onset of the northeast. We will present the results as monthly data in those periods including May, July, September, and December which are represented as the early southwest, the southwest, the transition between seasons, and the early northeast monsoon, respectively.

Results and discussion

Surface current changes seasonally following the monsoon influences (Figure 2). Surface currents tend to move northeastward into the gulf in May, July, and September following the influence of monsoonal winds. Relatively strong currents flowing southward along the west coast develop in December due to the influence of the northeast monsoon. The distributions of surface chlorophyll-a for Control case are shown in Figure 3. Their temporal variations are also observed. High concentration mostly appears near the north coast in all resulting months except December, the northeast monsoon period.

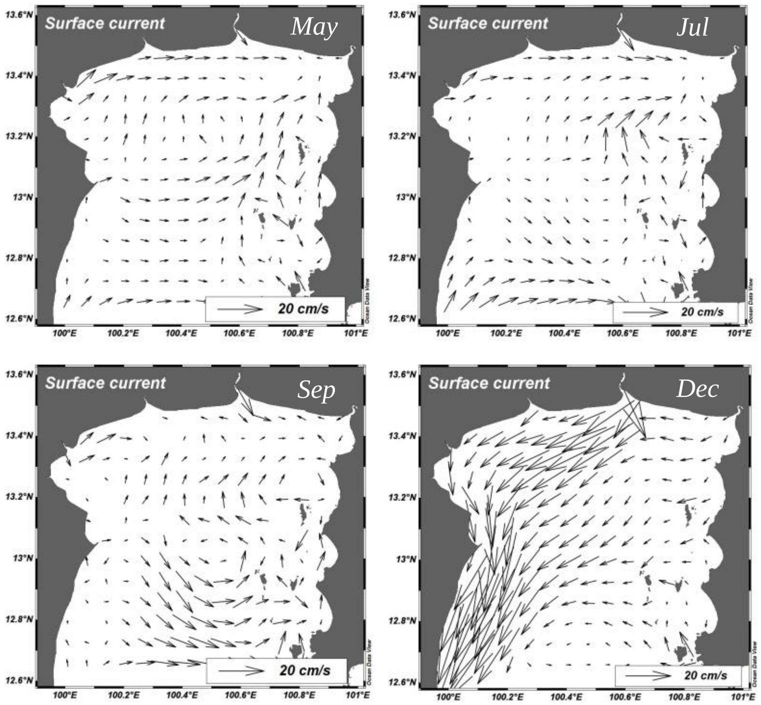

Figure 2 Monthly simulated surface current in the upper Gulf of Thailand in May, July, September, and December.

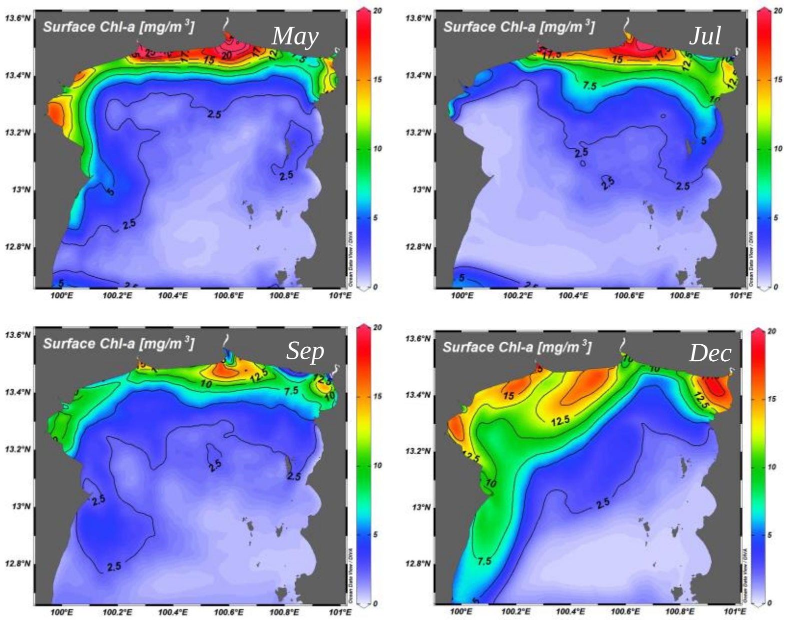

Figure 3 Monthly simulated surface Chlorophyll-a in the upper Gulf of Thailand in May, July, September, and December.

Numerical experiments on sensitivity analysis are conducted to test the response of the simulated ecosystem on the releases of dissolved inorganic nutrients (DIN and DIP), and particulate organic nitrogen (PON) from the sea bottom for case studies Case_01 and

Case_02, respectively. The responses of simulated sea surface chlorophyll-a and near-bottom water dissolved oxygen (DO) are presented in Table 2 and Table 3 as monthly averaged values. The results show increasing trends on surface chlorophyll-a and decreasing trends on near-bottom DO when nutrients from the sea bottom are released. The nutrients released in both dissolved and particulate forms (Case_02) generate larger changes than those released in just dissolved form (Case_01). The extreme values (highest surface chlorophyll-a, and lowest near-bottom DO) occur in September because of large river discharge and long residence time of fresh water in the area (Buranapratheprat et al., 2021). Compared with the Control case, near-bottom hypoxia expands much larger in Case_01 and Case_02, respectively (Figure 4). Near-bottom hypoxia covers almost the entire area if both dissolved and particulate nutrients from the sea bottom are released uniformly over the area. This is not realistic but informs us of the importance of alternative nutrient sources that may be significantly contributed to the development of near-bottom hypoxia in the area. We should do numerical or field experiments to investigate nutrient fluxes from the sea bottom in the future.

Table 2 Simulated sea surface chlorophyll-a (mg/m^3) monthly averaged over the study area for each case study.

Case study	May	Jul	Sep	Dec
Control	3.69 ± 4.10	3.20 ± 3.65	3.28 ± 2.93	5.20 ± 4.70
Case_01	4.75 ± 4.44	4.52 ± 3.40	5.03 ± 3.31	6.33 ± 5.19
Case_02	8.68 ± 4.29	8.41 ± 4.60	9.41 ± 3.61	8.41 ± 6.00

Table 3 Simulated near-bottom DO (mg/l) monthly averaged over the study area for each case study.

Case study	May	Jul	Sep	Dec
Control	3.88 ± 2.09	5.11 ± 1.61	3.68 ± 1.84	4.90 ± 1.68
Case_01	3.40 ± 2.13	4.63 ± 1.84	2.71 ± 1.93	4.69 ± 1.81
Case_02	2.10 ± 2.00	3.27 ± 2.25	1.45 ± 1.84	4.16 ± 1.98

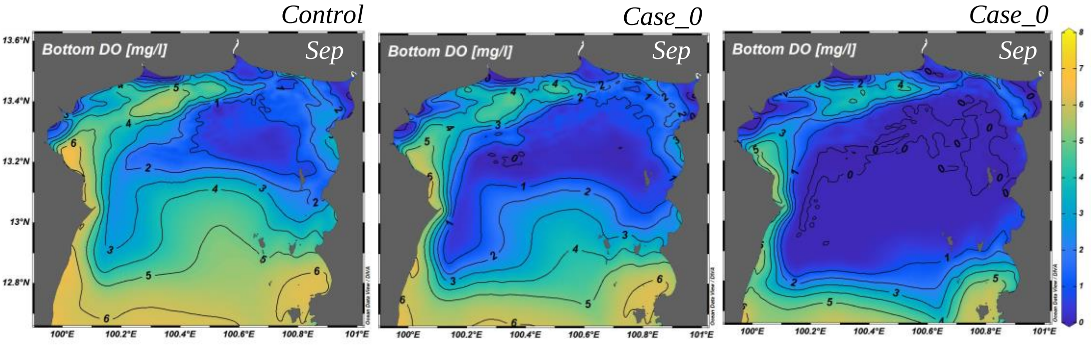

Figure 4 Monthly simulated near-bottom DO in the upper Gulf of Thailand in September for tree case studies: Control, Case_01, and Case_02, respectively.

Conclusion

Numerical experiments were conducted to investigate the response of chlorophyll-a and hypoxia development on the release of nutrients from the sea bottom in the upper Gulf of Thailand. The release of nutrients from the sea bottom increases sea surface chlorophyll-a and decreases near-bottom water DO. This research addresses the importance of alternative nutrient sources that may be significantly contributed to the development of near-bottom hypoxia in the area.

References

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Morimoto, A., Mino, Y., Buranapratheprat, A., Kaneda, A., Tong-U-Dom, S., Sunthawanic, K., Yu, X., Guo, X. 2021. Hypoxia in the Upper Gulf of Thailand: Hydrographic observations and modeling. *Journal of Oceanography* 77, 859 -811. https://doi.org/10.1007/s10872-021-00616-3

Publication/conference presentation

It was planned to publish the complete results in a scientific journal in the future on the title of “The development of ecosystem model coupled with sediment processes for the upper Gulf of Thailand”

Perspectives in the future

We will do numerical or field experiments to investigate nutrient fluxes from the sea bottom in the upper Gulf of Thailand in the future.