The contribution ratio of river water discharged into the red tide areas in the upper Gulf of Thailand based on numerical simulation

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Introduction

Red tide and hypoxia resulting from eutrophication in the upper Gulf of Thailand have been reported. Nowadays, they are of interest and widely known in the Thai community. Morimoto et al. (2021) reported the development of hypoxia in the upper Gulf of Thailand (UGoT) from August to November 2014, with the most severe event occurring from September to November 2014. Hypoxia in the upper Gulf of Thailand can always occur with favorable environmental conditions during the wet season when water is stratified from low-salinity waters containing inorganic nutrients and organic matter in the water mass in large quantities. Although we do not understand their mechanism well, we do understand their seasonal variations with the intensity of the problem in the wet than in the dry season. The increase in freshwater and nutrient supply during the same period of the southwesterly wind makes the northeastern part of UGoT the most affected area. Discharge water from four main rivers, one of which is The Chao Phraya River, the largest river in Thailand, plays a vital role in enhancing water stratification and transporting materials from the land into the sea. In this research, we are interested in the contribution ratio of water and material from each river in the red tide area in the northeast of UGoT from June to August between 2022 and 2023. Both periods are selected because strong bloom occurred in 2023 not in 2022. The ratio is expected to change between years and may influence nutrient conditions and the red tide of green Noctiluca, a dominant plankton, mostly blooms.

Procedure

The Princeton Ocean Model (POM) (Mellor, 1998) is used for current simulation in UGoT (Figure 1). It is coupled with passive tracer subroutines to simulate the distribution of a conservative dissolved material released from 4 river mouths including the Thachin River, The Maeklong River, The Chaopraya Ricer and the Bangpakong River. POM is forced by monthly winds (ASCAT) (http://remss.com), water elevation at the open boundary (Harmonic Analysis) and monthly river discharge (Royal Irrigation Department). It is operated in diagnostic mode

with climatology temperature and salinity data from World Ocean Atlas 2001. The tracers are continuously released at the sea surface at 4 river mouths with an initial concentration of 100 units and operation time of 30 days. The contribution of the tracer, referred to as the influence of river water, from each river in the focused plankton-bloom area (red rectangular in Figure 1) is investigated.

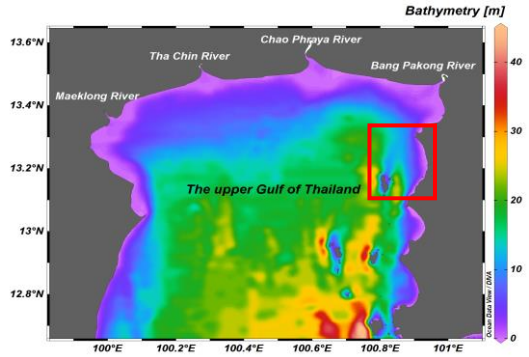

Figure 1 The upper Gulf of Thailand showing water depth in meters, and the focused eutrophic area in red rectangular.

Results and discussion

The river discharge in both years was clearly different (Figure 2). It is noted that there was a high volume of water in 2022 and a low volume in 2023. The peak water levels occurred between September and November. In October, the water levels were highest for the Bang Pakong River, Tha Chin River, and Mae Klong River. However, for the Chao Phraya River, the highest water levels were observed in November, approximately one month later than the other rivers.

Wind patterns also varied each year. In 2022, the winds were lighter compared to 2023 (Table 1). The wind directions showed no significant difference between June and July, but there was a noticeable difference in August. In 2023, the southwest winds were oriented more towards the east compared to 2022 (Figure 3).

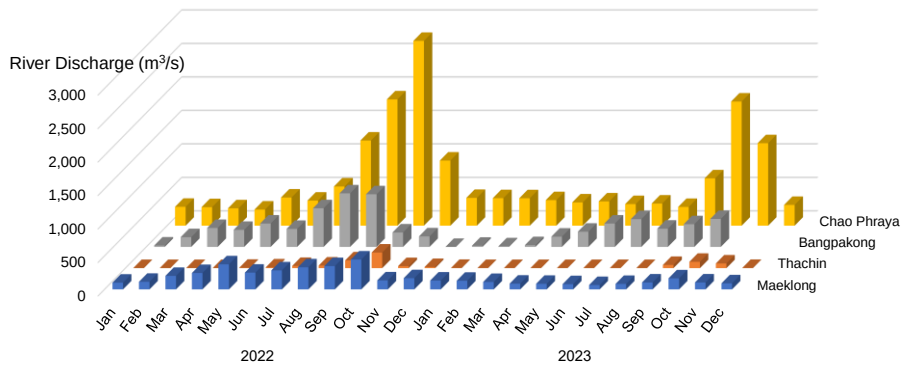

Figure 2 Monthly average river discharge from the four main rivers flowing into the upper Gulf of Thailand in 2022 and 2023.

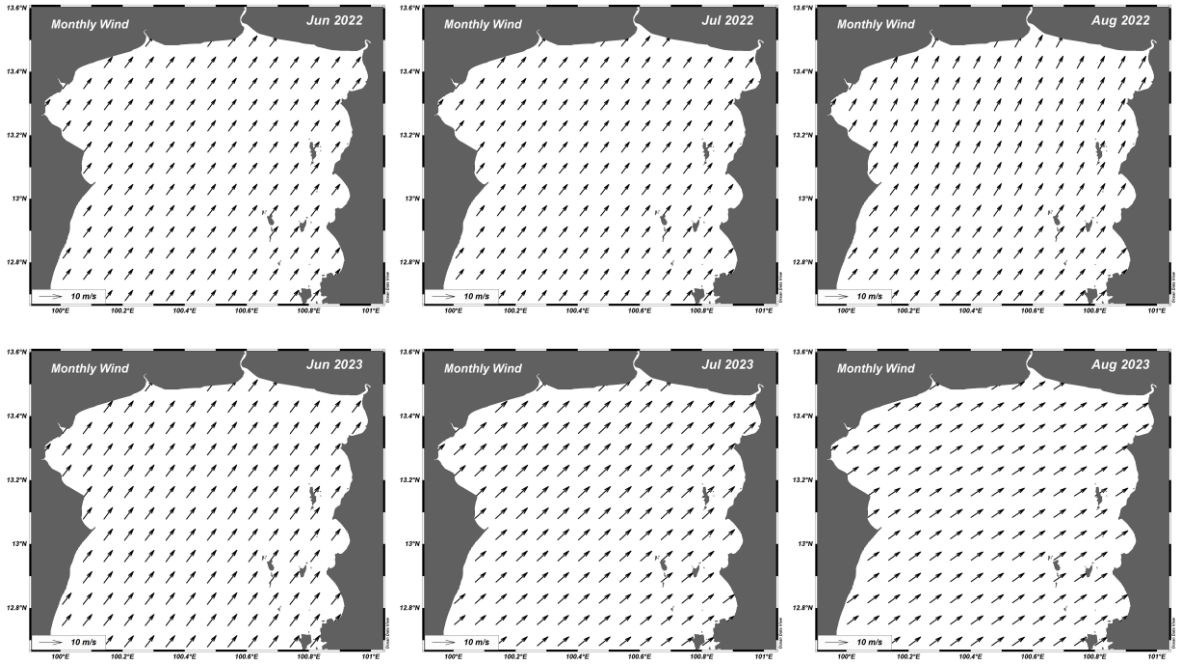

Figure 3 Monthly average winds over the upper Gulf of Thailand in June, July, and August of 2022 and 2023.

Table 1 Average wind speed and standard deviation over the upper Gulf of Thailand's northern region in June, July, and August of 2022 and 2023.

Month	Average wind speed over UGoT (m/s)	
	2022	2023
June	5.68 ± 0.07	6.23 ± 0.04
July	5.60 ± 0.03	6.62 ± 0.37
August	5.94 ± 0.07	6.20 ± 0.08

Regarding water currents, there was a reasonable difference between the years (Figure 4). It was observed that the water flow velocity in 2023 was higher than in 2022. Particularly, the flow downstream towards the eastern side of UGoT, near Sichang Island, was stronger in 2023. This led to a greater dispersion of tracers towards the south along the eastern coastline of UGoT compared to 2022 (Figure 5). When considering the proportion of water volume flowing into the area prone to plankton blooms, it was found that the Bang Pakong River had the highest proportion consistently across both years. Following it were the Chao Phraya River, Mae Klong River, and Tha Chin River, respectively. However, during the dry year of 2023, the proportions from the Bang Pakong and Chao Phraya Rivers decreased, while those from the Mae Klong River and Tha Chin River increased (Figure 6). This difference may have contributed to the varying occurrences of plankton blooms between the two years, which will require further investigation in the future.

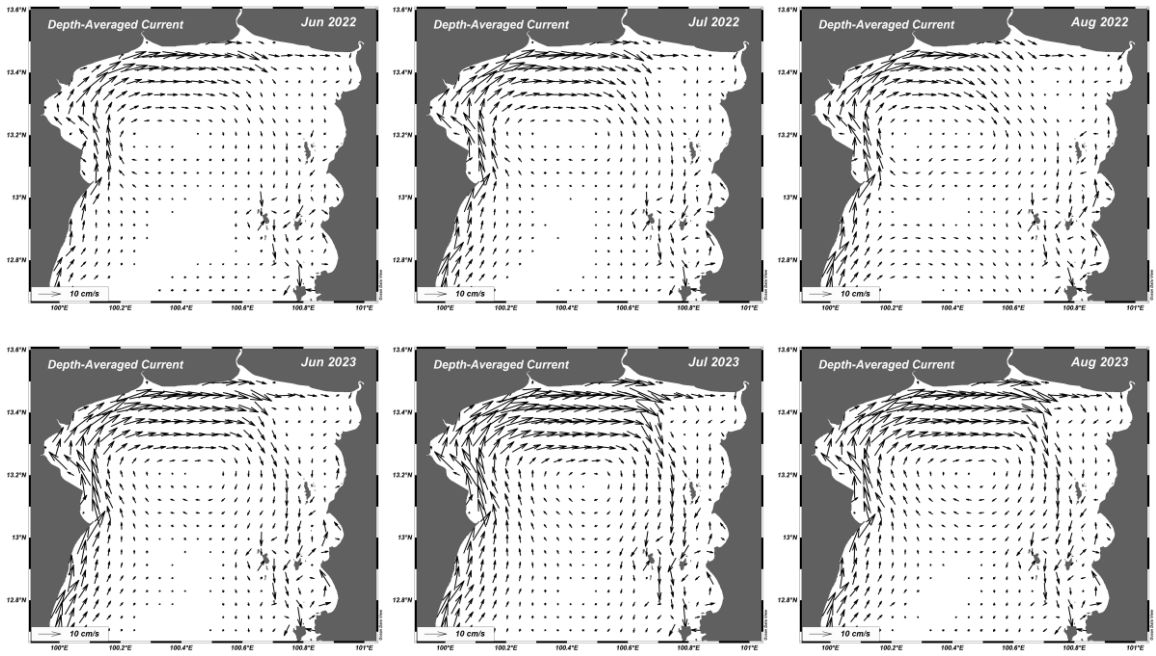

Figure 4 Depth-averaged currents based on monthly average in the upper Gulf of Thailand in June, July, and August of 2022 and 2023.

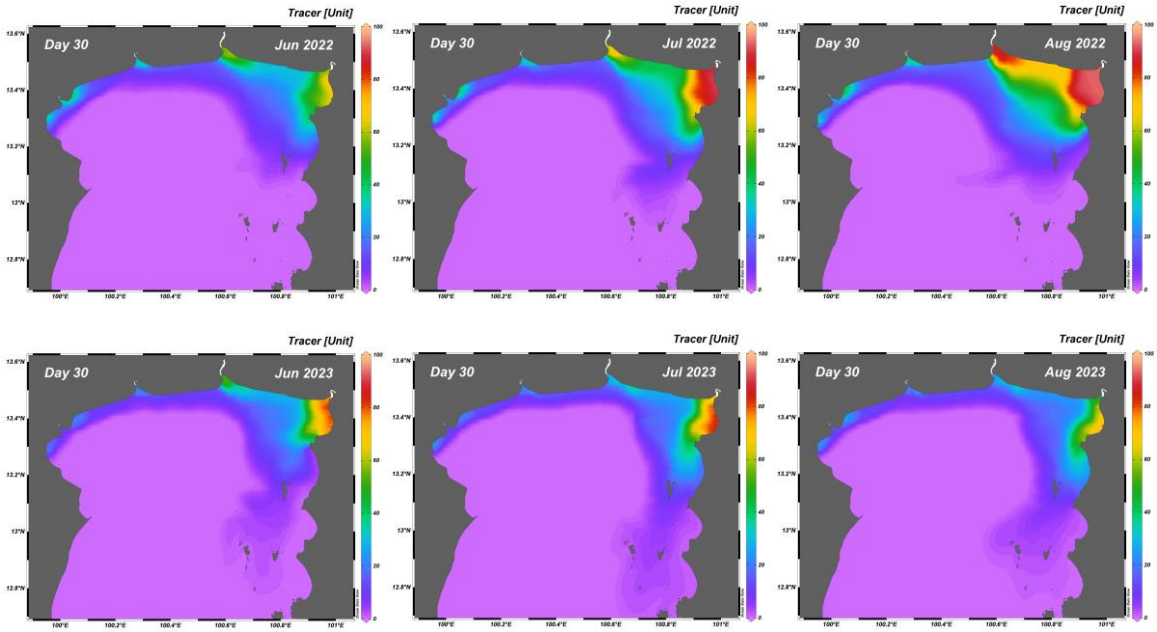

Figure 5 Dispersion of tracer from the four main rivers in the upper Gulf of Thailand on the 30th day after release at the river mouths in June, July, and August of 2022 and 2023.

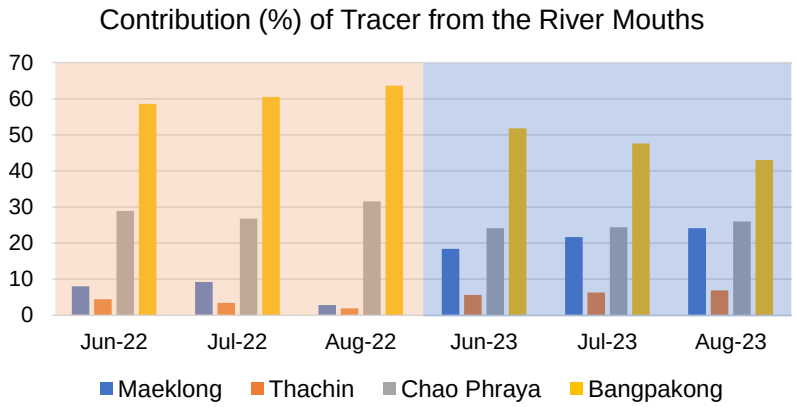

Figure 6 Proportions of tracer from the four main rivers entering the area where frequent occurrences of red tide, particularly in the eastern region of the upper Gulf of Thailand (Figure1), in June, July, and August of 2022 and 2023.

Perspectives in the future

We will improve the simulation results by focusing on the sensitivity analysis of wind and river discharge on the contribution of discharged water from the main rivers into the focusing area.

References

Mellor, G.L. (1998). *User's Guide for a Three-Dimensional, Primitive Equation, Numerical Ocean Model*. Program in Atmospheric and Oceanographic Sciences Report, Princeton University, Princeton, N.J.

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