Utilization of Satellite Imageries for Monitoring Harmful Algal Blooms at the Persian Gulf and Gulf of Oman

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Abstract. Harmful algal bloom (HAB), or “red tide”, at Gulf of Oman and Persian Gulf has occurred in fall 2008 until spring 2009, Cochlodinium polykrikoides was found starting to bloom in this area. By using MODIS Aqua satellite, we have started the monitoring of HAB at Northern Strait of Hormuz since early fall 2008. Results showed that the Inflow currents of Persian Gulf and upwelling in Northern Gulf of Oman with decreasing temperature have important role to developing HAB, and plume of sewages outflow industrial cities in northern and southern of Persian Gulf are the sources of nutrient for the Cochlodinium bloom in the offshore region.

The satellite information has proved to be very useful for the early detection and preparation for HAB mitigation in the region. The MODIS data showed that the red tide event during fall 2008 to spring 2009 was part of the winter soon bloom; however, it started soon and continued significantly longer than other years. Satellite ocean color data is useful to detect the red tide; however the algorithms require improvement to accurately estimate chlorophyll in highly turbid water and in red tide areas.

Keywords: Ocean Color, Persian Gulf, Harmful Algal Bloom, Upwelling, Inflow Current

1. Introduction

Hugest and longest time occurrence of harmful algal bloom (HAB) or red tide at the Persian Gulf and Gulf of Oman was recorded in 2008 -2009. The HAB event is caused by Cochlodinium polykrikoides, which could cause devastating effects on fisheries, aquaculture, tourism and environmental area that some effects have not gone away completely.

The effort of HAB monitoring using MODIS Aqua satellite sensor for Northern Strait of Hormuz started since early fall 2008. Daily MODIS Aqua images are processed and distributed to local authorities and researchers at Persian Gulf and Oman Sea. Besides, the product will also been uploaded to the “Ocean Color Satellite Observation of Persian Gulf Red Tide”.

2. Materials and Methods

Daily Level 2 MODIS Aqua chlorophyll a (chl-a), sea surface temperature (SST) and Remote sensing reflectance at 555 nm ($R_{555}$) images were downloaded from Ocean Color Web.

The imageries are processed by using SEADAS software due to the chl-a over-estimation problem by the MODIS algorithm in turbid waters, the $R_{555}$ image is used to identify the turbid water areas. RGB image is provided as the additional reference for the ocean color image.

3. Results and Discussions

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Our results showed that there was a seasonal upwelling phenomenon at the northern Gulf of Oman (figure 1), which could be possibly caused by the alongshore summer monsoon wind. Cooler upwelling water (about 26°C) from the northern tip that extended toward the west is associated with higher surface chl-a (figure 1). The nutrient supply from the upwelling water is expected to be the main source that supporting the bloom of phytoplankton. We speculate that this upwelling event is related to the offshore phytoplankton bloom and the continuing occurrence of HAB along northwestern Gulf of Oman after southeast monsoon.

![Fig. 1: Daily MODIS Aqua chl-a (right), and SST (left) on 31 October 2008.](image)

Based on the existing data and interpretation of MODIS Aqua satellite images, it seems that HAB started from Oman coasts in Arab Sea and after moving toward the south of Gulf of Oman via marine flow of water by mesoscale eddies to the northern Gulf of Oman and northern coasts of Strait of Hormuz are extended. Considering the fulfillment of bloom conditions by decreasing temperature and increasing the nutrients of municipal and industrial wastewater, this phenomenon could be developed and it was prevalent for 10 months to spring 2009.

Chlorophyll-a concentration on November 2008 showed that the Chlorophyll-a of water is increased and it is in the whole region of the north of Strait of Hormuz, based on climatic conditions and seasonal conditions of Strait of Hormuz, it seems that by reduction of temperature, phytoplankton of Cochlodinium polykrikoides is grown. Satellite images of this period shows the elongation of a concentrated algae band along northern coasts and central zone of Persian Gulf axis (The region between Nayband Gulf in Iran and Qatar peninsula moves toward southern coasts of Persian Gulf) show that more inclination of algae to coastline and more density to central regions of axis are the characteristics of this period. A mesoscale eddies in Gulf of Oman caused the movement of algae mass from the south to the north of Gulf of Oman and was seen on the coast line in the north of Gulf of Oman. Temperature decrease was 28 °C and average salinity was 37 psu in northern and central regions of axis and they are physical characteristics of the north of Strait of Hormuz.
Previously, the HAB event in Persian Gulf and Oman Sea was believed to be spread by the current from northern Gulf of Oman to northern Persian Gulf. Through the continuous satellite monitoring, we discovered that it could actually spread into Strait of Hormuz towards head of Persian Gulf in boundary of Iranian coast. In 31 October 2008, a large patch of high chl-a was observed off the upwelling area at the Gulf of Oman (figure 1). The patches moved northwestward towards the Persian Gulf a few weeks later. After 3 weeks (21 December 2008), the high chl-a patches reached northern Persian Gulf.

In 2008-2009, the *Cochlodinium* bloom has caused economic loss of aquaculture and tourism at this area. The dead fish cause by the HAB was washed up along the Iranian and Arabian tourist beach. MODIS Aqua satellite image at January 2009 shows that the dense bloom area covered about 140000 km$^2$ with 750 km in...
length Iranian coast (figure 4). The large bloom was observed remain 10 months at northern Strait of Hormuz. The mechanism on how *Cochlodinium* maintaining their bloom at this area remain unclear, but this strength has made this species a success in causing transboundary HAB.

4. Conclusion

The HAB monitoring using ocean color satellite at the Persian Gulf and Oman Sea showed some interesting findings that related to the HAB events. The transboundary HAB problem at Persian Gulf and Oman Sea will be a big threat for the marine ecosystem in the region. We strongly recommend for a regional joint monitoring effort. Present observation effort using MODIS Aqua satellite is very successful in observing large HAB at off shore water, however, it usage is very limited at the coastal water due to lower spatial resolution.

The most observable density and growth of the red tide by satellites is located across the northern Strait of Hormuz which has been survived there for more than 10 consecutive months. Growth and extension of the red tide has followed the current and ebb and flow pattern of the Persian Gulf and Sea of Oman, oceanic midscale ivies have played an important role in Sea of Oman to transfer algal patches from south to center and north of the region. Temperature condition (weather), nutrients and biological constraints of algae can explain the long term persistence and lack of persistence of the red tide in the region.

5. Acknowledgements

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6. References

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