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Cochlodinium polykrikoides blooms and eco-physical conditions in the South Sea of Korea

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Abstract

Eco-physical conditions for the initiation and termination of *Cochlodinium polykrikoides* blooms in the South Sea of Korea are examined in this paper. The *C. polykrikoides* blooms generally occur in the sea near Naro-Do in late August every year. The submarine canyon near Naro-Do plays an important role in surface water intrusion from the open ocean driven by northeasterly winds. In late August, the monsoonal wind system in Korea changes from southwesterly to northeasterly winds, causing Ekman transport of warm, fresh Changjiang Diluted Water (CDW) into the sea near Naro-Do and creating a front between inland sea water and CDW. Along the front, aggregation of single *C. polykrikoides* cells in the CDW and downwelling yield favorable eco-physical conditions for development of *C. polykrikoides* blooms. When typhoons and strong northeasterly winds bring vertically well-mixed East China Sea water into the sea near Naro-Do again in September, the eco-physical conditions favor diatom growth and lead to the termination of *C. polykrikoides* blooms.

Keywords: *Cochlodinium polykrikoides*; Eco-physical conditions; Harmful algae; Changjiang diluted water

1. Introduction

Cochlodinium polykrikoides blooms in the South Sea of Korea have occurred yearly near Naro-Do in late August since 1995. However, eco-physical conditions supporting the initiation of these harmful algal blooms (HABs) have not been well studied. The physical conditions favorable for HAB formation studied previously include wind stress (Franks and Anderson, 1992a,b) and shoreward currents (Steidinger et al., 1998). This paper presents and analyzes the eco-physical environment preceding the initiation and termination of *C. polykrikoides* blooms in the South Sea of Korea.

2. Materials and methods

The study area was located in the middle of the southern coast of the Korean Peninsula and is shown with bottom topography and locations of various measurements used for this investigation in Fig. 1. Among many eco-physical characteristics in the study area, the front formation between near-shore water and offshore water was analyzed using time variation of wind and hydrodynamic characteristics of water mass. A real-time data buoy equipped with CTD and a thermister chain was moored during 2003 to measure temperatures at 2 m depth interval and bottom salinity. The salinity data at Station 204-01 were from bi-monthly hydrographic surveys by the National Fisheries Research & Development Institute (NFRDI). Daily winds measured at Sori-Do and remotely measured by QuikSCAT satellite (http://manati.orbit.nesdis.noaa.gov/quikscat/) were used for interpreting wind-driven transport in the study area. Historical mean daily winds in the offshore sea were from the Special Sensor Microwave Imager (SSM/I) archives (http://podaac.jpl.nasa.gov).

3. Results

3.1. Location and timing of C. polykrikoides bloom initiation in Korea

As a channel for inflow or outflow of bottom water in the sea near Naro-Do (Fig. 1), the submarine canyon connected to the adjacent open ocean often facilitates the setup of a front between the surface water from the open ocean and the inland sea surface water. When northeasterly winds blow, the open

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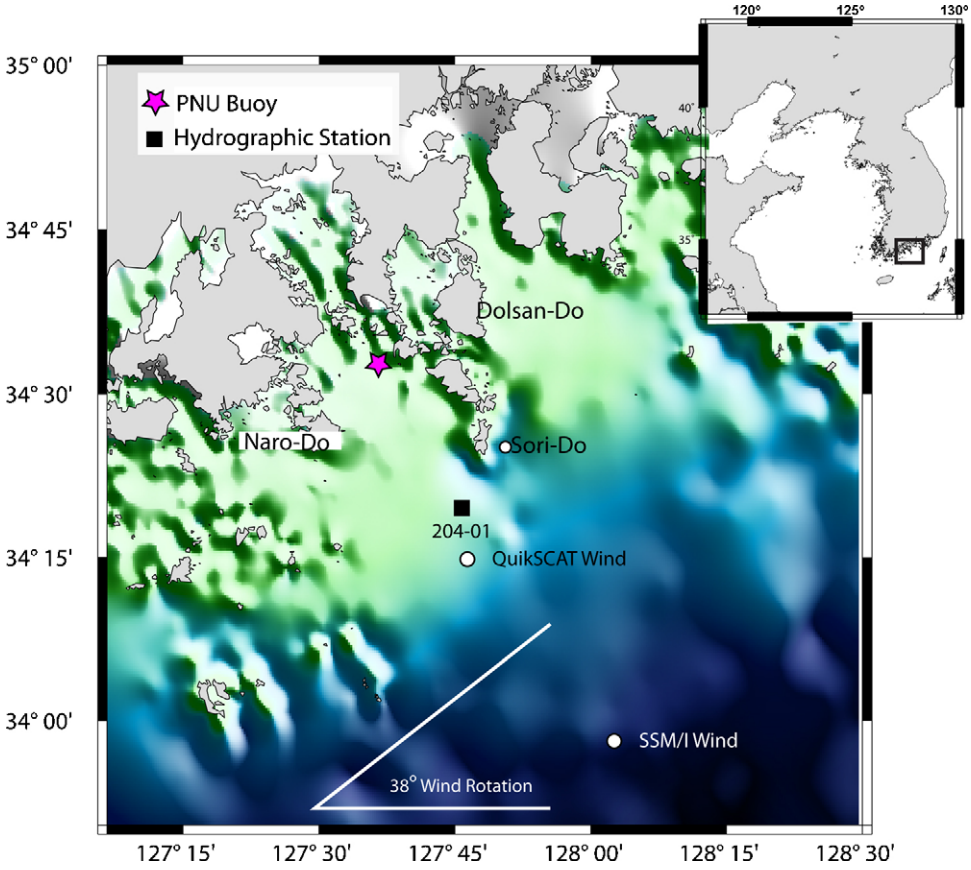

Fig. 1. Topographic map showing location of islands, wind observations, hydrographic station and moored instrument. The winds are rotated 38° counterclockwise to align with the coast.

ocean surface water is easily transported into the inland sea, since the bottom water can flow out to the open ocean through the submarine canyon. Lim et al. (2002) showed previously the formation of fronts between clear offshore water and turbid near-shore water in the area near Naro-Do. A true color satellite image shows the intrusion of clear open ocean surface water into the turbid coastal sea south of Naro-Do (Fig. 2). The frequent outbreak of red tides in Monterey Bay, California, USA (Kudela et al., 2008) may also be related to the existence of the Monterey Submarine Canyon bisecting Monterey Bay and having a similar topographical influence on this inland bay.

Daily mean wind measurements obtained from the SSM/I reveal a change from weak southwesterly winds to strong northeasterly winds in late August (Fig. 3). The strong northeasterly wind causes the Ekman transport of open ocean surface water into the area near Naro-Do. The possible mechanisms of *C. polykrikoides* bloom outbreaks caused by this wind-driven onshore transport of open ocean water are presented in the following section.

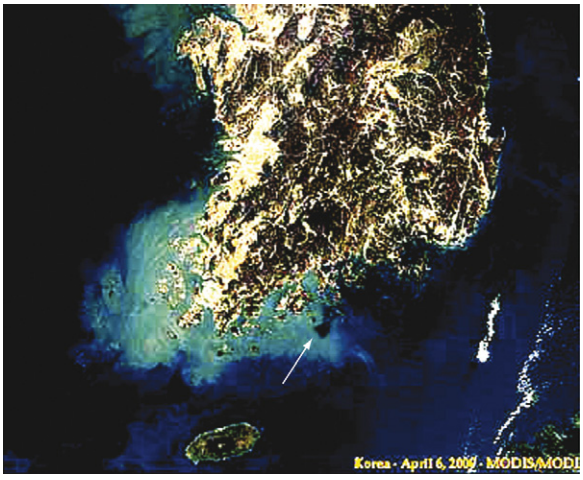

Fig. 2. True color image of seas around Korea on April 6, 2000 taken by the NASA MODIS Terra satellite. The intrusion of dark offshore water into the bright inshore water is clearly visible and marked by the white arrow.

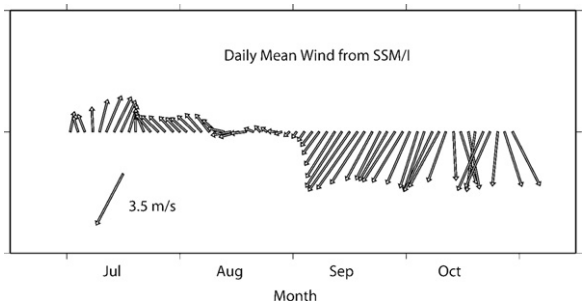

Fig. 3. Daily mean Special Sensor Microwave Imager (SSM/I) wind off Naro-Do (see Fig. 1). Mean winds are computed from year 1988 to year 2000.