Influence of upwelling on harmful algal blooms

Jang-Geun Choi[1], Thomas C. Lippmann[1]
jc1404@wildcats.unh.edu

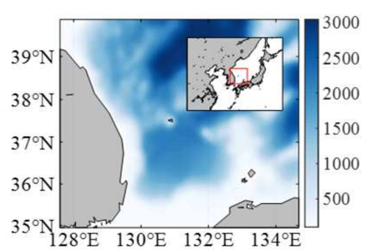
[1]Department of Earth Science, University of New Hampshire, Durham, NH 03824
[2]Department of Oceanography, Pusan National University, Busan, 609-735, Republic of Korea

Introduction

Harmful Algal blooms (HAB) are excessive blooms of monospecific phytoplankton species. Because HABs significantly increase fish mortality, they hamper fishery industries. Kim et al. (2016) pointed out that horizontal advection off the south coast of Korea and coastal upwelling provided nutrients to the surface waters that subsequently led to an anomalous HAB event off the east coast of Korea. Unfortunately, even qualitative assessment of the relative contributions by horizontal advection or vertical upwelling is poorly understood. In this study, numerical sensitivity experiments for the two mechanisms are conducted using a coupled eco-physical model.

Model configuration

Regional Ocean Modeling System (ROMS)



Atmospheric forcing: COADS2005
Lateral boundary condition: HYCOM
Spatial resolution: 1/8°
Time step: 200 sec

Figure 1. Bathymetry and the model configuration.

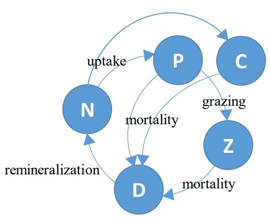


Figure 2. Schematics for ecosystem model which couple traditional NPZD (Nutrient-Phytoplankton-Zooplankton-Detritus) proposed by Powell et al. (2006) with red-tide species C. polykrikoides model from Cho and Cho (2014).

Sensitivity experiment for upwelling-favorable wind and biomass transport from boundary

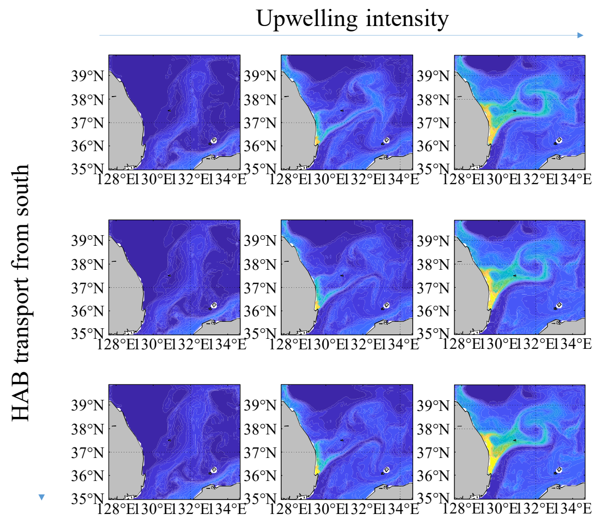


Figure 3. Simulated diatom distribution in different upwelling-favorable wind and harmful algae transport from southern boundary. Diatom group sensitively responds to upwelling-favorable wind.

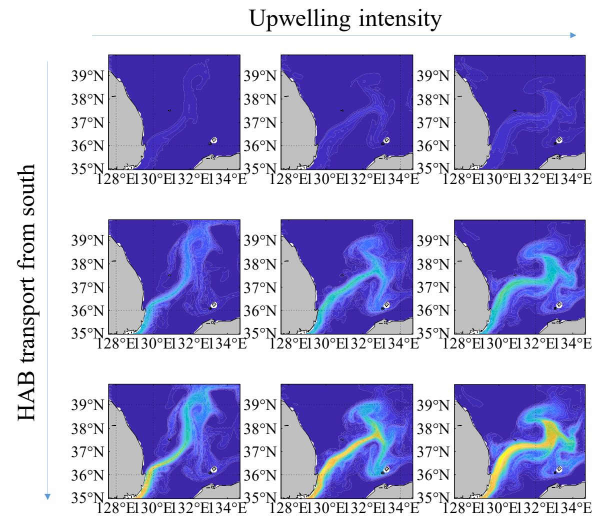


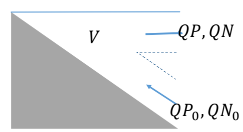
Figure 4. Simulated harmful algae distribution in upwelling-favorable wind and harmful algae transport from southern boundary. Harmful algae do not respond to upwelling-favorable wind.

Why harmful algal bloom is not enhanced by upwelling?

Mechanism 1: vulnerability for ventilation

$$\frac{\partial P}{\partial t} = U_{max}\frac{N}{N+K}P - \sigma P + \frac{Q(\tau)}{V}P_0 - \frac{Q(\tau)}{V}P$$

$$\frac{\partial N}{\partial t} = -U_{max}\frac{N}{N+K}P + \frac{Q(\tau)}{V}N_0 - \frac{Q(\tau)}{V}N$$



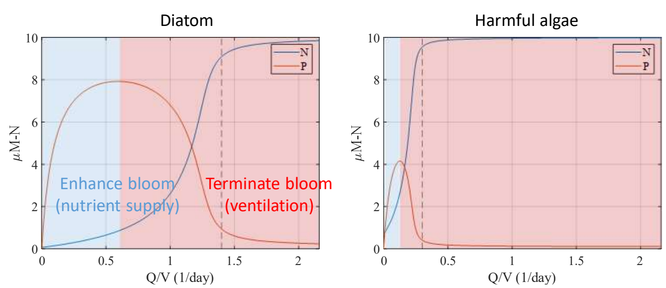


Figure 5. Steady-state solution of simplified ecosystem model describing upwelling event. Once upwelling is too intense, transport toward offshore become dominant than growth of phytoplankton, so biomass in the control volume decrease. Harmful algae, which has low maximum growth, is vulnerable to intense upwelling event.

Mechanism 2: resource competition

$$\frac{\partial P_1}{\partial t} = U_1\frac{N}{N+K}P_1 - \sigma P_1$$

$$\frac{\partial P_2}{\partial t} = U_2\frac{N}{N+K}P_2 - \sigma P_2$$

$$\frac{\partial N}{\partial t} = -U_1\frac{N}{N+K}P_1 - U_2\frac{N}{N+K}P_2 + \frac{Q(\tau)}{V}N_0$$

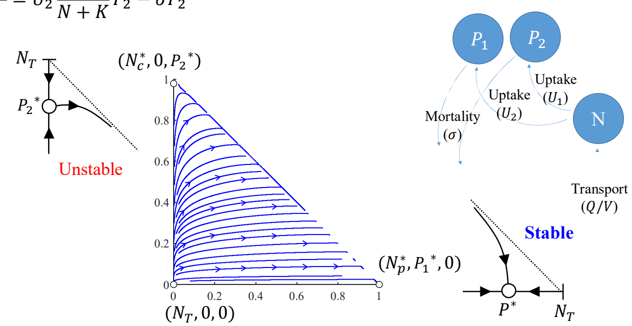


Figure 6. Phase-portraits plot of simplified ecosystem model which focus on resource competition for upwelled nutrients. There is no coexistence solution and the only non-trivial stable steady state solution is the diatom bloom solution. This implies that harmful algae are defeated by diatoms in the resource competition.