A study of two-dimensional phytoplankton pattern formation by an ocean physics-ecosystem modelling

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In the Toyama Bay, chlorophyll-a in the surface layer of a few meters activates in the rainy season of Jun to July, while forming the counterclockwise pattern (cf. Fig. 1). This characteristic distribution is found in the relationship between oceanic physical processes (advection and diffusion) and ecosystem in the Toyama Bay. However, the formation and development mechanisms are not revealed in detail. Then, we investigate to clarify the mechanisms of pattern formation using MODIS satellite image, ocean observation data, and physics-ecosystem modelling.
In this study, we used the NPZ model as an ecosystem model, introducing into the advection and diffusion terms as ocean physical processes in it. This horizontal two-dimensional system solved by finite differential method. The horizontal oceanic area is 100 km x 100 km referring to the width of the Toyama Bay and the horizontal resolution is 1 km x 1km. For the model calculation, we employed a horizontal diffusive coefficient of 10 m^2 s^{-1} and performed the cyclonic circulation as a back ground flow field. The experiments are carried out for macro and micro planktons, and several values of grazing rate coefficient showing a relationship between the predictor-pray of planktons as the ecosystem parameters. We compared results between obtained from the pure advection-diffusion system and obtained from the reaction-diffusion system.
For advection only, although the distribution of the eddy appeared in the model area, only the initial plankton patch extended. For diffusion only, the plankton patch spread in the radial direction with an initial total amount. For both of advection and diffusion case, although the amount of plankton was less, the pattern was similar to the satellite image. In the advection-diffusion system, however,we cannot reproduce rapid increase of chlorophyll-a like the satellite image. The development on the amount of plankton appeared in the adding reaction effect of ecosystem. Moreover, for large grazing rate and micro plankton case, we were able to obtain more similar pattern of the satellite observation in the Toyama Bay.
It is conclude that we can reproduce the similar pattern of chlorophyll-a observed from the MODIS satellite image (Fig, 1) by the numerical simulation of an physics-ecosystem modelling. Thus, it was found that in the Toyama Bay, the cyclonic chlorophyll-a pattern was due to the physical advective effect mainly. The pattern development from Fig. 1a to Fig. 1b for about one day is much faster than the physical scale and is owing to the ecosystem reaction-diffusion. Ring waves appeared also in many experiments in our study. These phenomena correspond to ring waves in the reaction-diffusion system and we need to investigate more in detail.

Keywords: Statellite imeage, Marine physical processes, chlorophyll-a, Ecosystem model, Toyama Bay, reaction-diffusion

Figure.1

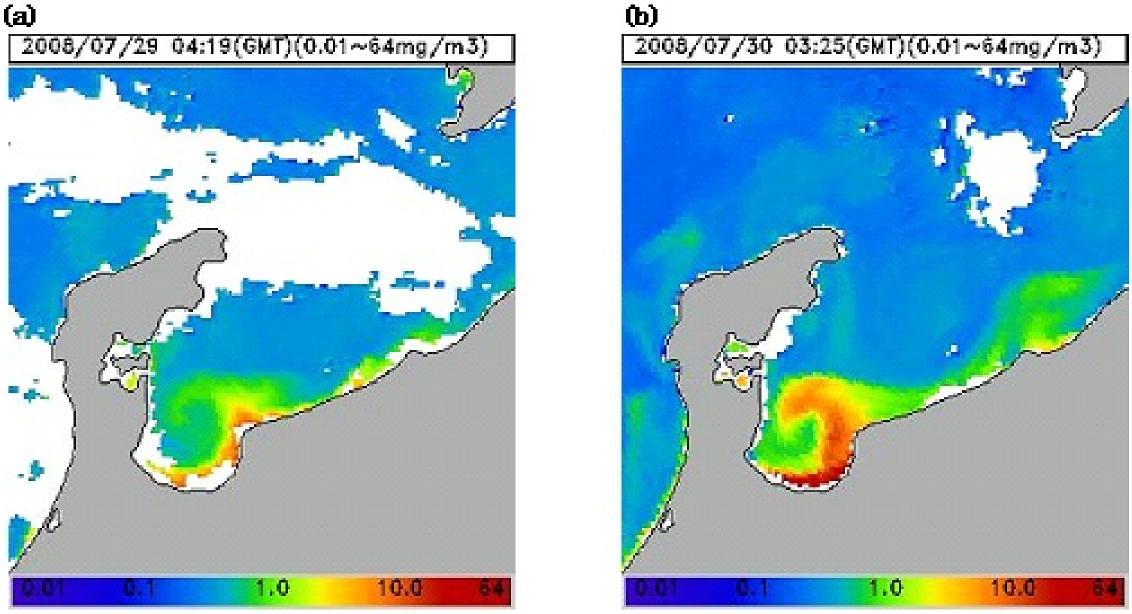

Figure.2