

Influence of Kiso rivers discharge on surface residual currents and distribution of Chlorophyll a in Ise Bay

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Ise Bay is a semi-enclosed bay located in the center of Honshu island of Japan, and it is coastal area where the rate of fresh water flows is greater than that in Tokyo Bay and Osaka Bay of the similar size. In such a bay, estuary circulation induced by the inflows of fresh water would be prominent. However, it has not been known how fresh water inflows influence the variability of horizontal circulations in the bay. This study is, thus, aimed at understanding the surface residual currents by using High Frequency radar (HF radar) in Ise Bay, which allows us to investigate the influence of Kiso rivers to the surface residual currents. In summer in Ise Bay, red tides occur frequently owing to the excessive increase of phytoplankton. However, as there have been no study on the relationship between flow fields and phytoplankton of Ise Bay, we also studied the influence of the surface residual currents to the distribution of chlorophyll a.

Surface residual currents were calculated by the harmonic analysis of hourly data of HF radar from January 1, 2010 to December 31, 2013. We used the data of the daily mean discharge rate of the Kiso rivers (Kiso River, Nagara River and Ibi River). For wind directions and speeds, we used hourly data of the vane anemometers installed at Ise-Wan Sea Berth (Bay head), Chubu International Airport, and No.4 lighted buoy (Mid-bay). The distribution of chlorophyll a was calculated from the data of MODIS –the ocean color sensor mounted on the satellite Aqua. In this study, we focused on the variability in summer (June –August) when red tides frequently occur, after having understood the seasonal variability. The monthly mean discharge of Kiso rivers was low in winter, and high in summer with the highest discharge of $1015.6 \text{ m}^3 \text{ s}^{-1}$ in July. As river discharge reflected the seasonal variability of precipitation, the increase of the discharge in summer suggested the influences of the rainy season and typhoons. The monthly mean surface residual currents in Ise Bay generally flowed from the north to the south during January to May, and during September to December, and the current was stronger at the eastern part than at the western part. On the other hand, in July, the current speed was faster at the western part than at the eastern part, and in August, a cyclonic circulation appeared at mid-bay. The monthly mean concentration of chlorophyll a was low in winter when the river discharge was low, but it became high when the discharge rate increased in summer. In July, when the highest concentration of 10 mg m^{-3} was observed, chlorophyll a was distributed from bay head to the coast of Mie prefecture. From these seasonal variability, the change of characteristic in the surface residual currents and in the chlorophyll a distributions in summer were identified, and it was thought that they were largely influenced by Kiso rivers discharge.

Then, in order to identify the factors that influences the directions of the surface residual currents in summer, we compared the daily mean direction of the surface residual currents in bay head at 34.823° N , 136.724° E with the daily mean of the river discharge. As a result, when the river discharge became three times as much of the annual mean ($1500 \text{ m}^3 \text{ s}^{-1}$) or more, the surface residual currents flowed to west. On the other hand, when the discharge was less than $1500 \text{ m}^3 \text{ s}^{-1}$, direction of the residual currents was varied. It is thought that, when the river discharge was high, they were turned to west due to the Coriolis force. Furthermore, as we compared the flow and the wind direction and speed, it was revealed that the residual currents were greatly affected by the wind of mean speed 5.7 m s^{-1} and higher.

Then, in order to study the changes in chlorophyll a distributions and advection, we compared the daily

distribution of chlorophyll a, the daily mean of the residual currents and that of the river discharge. After the discharge of $1500 \text{ m}^3 \text{ s}^{-1}$ or more, water with high chlorophyll a of 10 mg m^{-3} or higher was distributed from bay head to the coast of Mie prefecture, and after the discharge of less than $1500 \text{ m}^3 \text{ s}^{-1}$, high chlorophyll a water was distributed in bay head, or from bay head to the coast of Chita Peninsula. It was suggested that the high chlorophyll a water was probably drifted from the bay head to the coast of Mie prefecture when the river discharge rate was high, and it stayed in the bay head or drifted to the coast of Chita Peninsula when the river discharge was low.

Keywords: Ise Bay, surface residual current, HF radar, river discharge, Chlorophyll a