Although we did not calculate the change in dissolved oxygen, the good agreement between observed and calculated values of temperature and salinity at the surface along the northern shore indicates that our model accurately simulated the flow pattern and mixing process that occurred during the Awoshiwo event.

Daily-averaged simulation results showed a two-layer flow on 3 October, with shoreward flow at the bottom and offshore flow at the surface in the B-B section in Fig. 3.2 (Fig. 3.17). This flow pattern induced strong upwelling at the northern shore and vertical circulation within the cross-section of B-B (Fig. 3.18). The simulated, daily-averaged, horizontal flow profile at the surface (1st layer) showed clockwise circulation in the upper basin and southward flow along the eastern shore (Figure 3.19 (a)). However, the horizontal flow profile at the bottom (7th layer) showed a northward flow along the eastern shore (Fig. 3.19 (b)).

The calculated vertical eddy-diffusivity coefficient at St. C (Fig. 3.2) increased in response to wind blowing in a north-south direction (Fig. 3.20). This coefficient was 10 to 100 times more intense on 24 September and 2 to 4 October, when northerly winds blew and the Awoshiwo occurred, than on other days. Also, the coefficient was 100 to 10 000 times more intense on 28 September than on other days; on that day a southerly wind blew, indicating that vertical mixing was being enhanced along the northern shore.

The mechanism leading to the occurrence of Awoshiwo events, based on the above model calculations, can be summarized as follows: When the northerly wind blows, it generates an offshore flow at the surface and shoreward flow at the bottom along the northern shore of Tokyo Bay. These flows move anoxic bottom water shoreward and the water column along the northern shore is replaced rapidly as a result of strong upwelling and enhanced vertical mixing.

3.4 Discussion

Model calculations showed that strong upwelling and vertical mixing were generated along the northern shore of Tokyo Bay when Awoshiwo events occurred in 1989. When northerly winds continue to blow, they cause an offshore current at the surface and a shoreward current at the bottom, which increase the vertical velocity gradient, leading to enhanced vertical mixing along the northern shore (Figs. 3.6, 3.19, and 3.20). Although southerly winds also enhance vertical mixing, the effects of the two wind directions on the characteristics of the water column along the northern shore are opposite. When the northerly wind was dominant (i.e. 24 September, 2 to 4 October, 8 October and 12 October in Fig. 3.6), surface water quality underwent rapid change (temperature decrease and salinity increase) whereas bottom water quality changed very little (Figs. 3.10 (a) and 3.11 (a)). In contrast, when the southerly wind was dominant (i.e. 15, 19, 20, 28 and 29 September and 17 October), surface water quality showed little change but bottom water quality changed dramatically (temperature increase and salinity decrease) (Figs. 3.10 (a) and 3.11 (a)).

These opposing responses of the water column can be explained explicitly by considering the northern shore area as a control volume. When the northerly wind blows, surface water flows out of the control volume and bottom water flows into it. Since vertical mixing is enhanced while the wind is blowing in a north-south direction (Fig. 3.20), the convective effects, characterized by the outflow of surface water and inflow of bottom water together with enhanced vertical mixing, make the water column quality dependent on bottom water quality before mixing. Thus, oxygen can be depleted at the surface if the bottom anoxic condition was established before the mixing. This is the necessary condition and physical process that lead to the occurrence of Awoshiwo events, as induced from our model.

When the southerly wind blows, surface water flows into the northern shore area and bottom water flows out of it (Fig. 3.21). Since vertical mixing is also accelerated (Fig. 3.20, September 28), the entire water column quality is depend on surface water quality before