MECHANISM ANALYSIS TO PREDICT "AOSHIO" UPWELLING OF ANOXIC BOTTOM WATER BY THE 4-m CHANNEL EXPERIMENT AND TWO-DIMENSIONAL HYDRODYNAMIC-MODEL CALCULATION

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Tokyo bay is surrounded by many large cities and has accepted high levels of nutrient and organic pollutant load through rivers and urban waste sewage yet, in spite of many kinds of governmental regulations for water quality. Bottom water mass becomes anoxic during the stratified summer season in eutrophicated Tokyo Bay, resulting in some ecological problems. One such problem is the "Aoshio" or "blue tide" phenomenon observed along the northeastern coast of Tokyo Bay during summer seasons since the 1960's, attracting public concern because of both the unpleasant smell (mainly due to H_2S) and die-offs of fish and shellfish. Aoshio events had been believed to result from upwelling of anoxic water from the bottom of the bay to the surface by the constant wind blowing from the north.

The periodic observations we have conducted in the northeast sector of Tokyo Bay since 1989, suggest that vertical mixing of the coastal water column is an additional causative factor (Fig. 1). Such mixing was enhanced by reduced temperature stratification of the water column due to surface cooling. A heat valance calculation at the air-sea interface showed net heat loss of water during an Aoshio period, due to changes in climate conditions such as low air temperature and low level of solar radiation (Fig. 2).

Physical processes of Aoshio occurrence have been investigated to make the prediction method, which we proposed at the past Baltimore conference, more accurate on

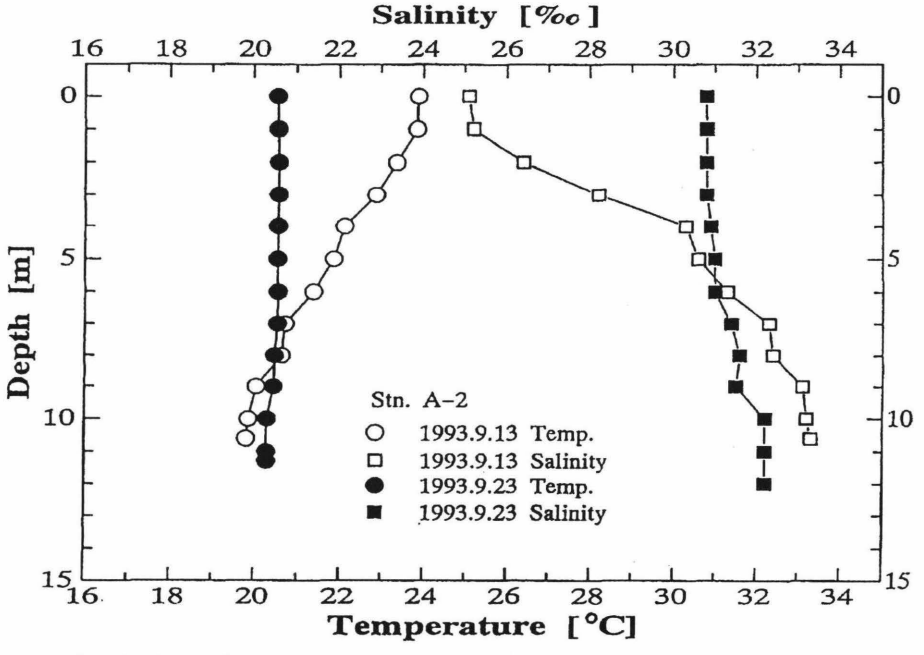
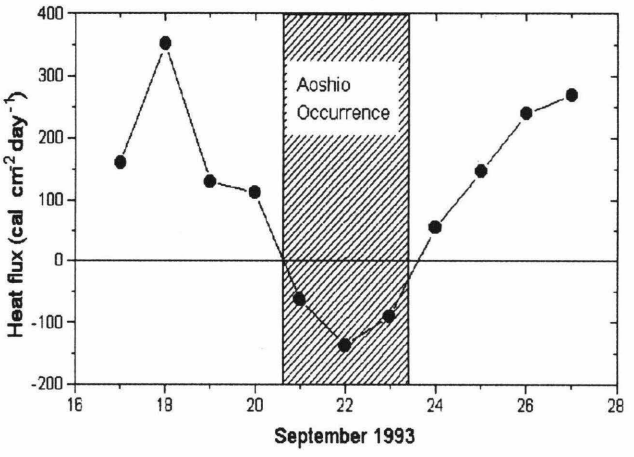


Fig. 1 Vertical profiles of temperature and salinity observed during an Aoshio period (1993.9.23) and before it (1993.9.13) at the our coastal station (Stn.A-2) in Tokyo Bay.

Fig. 2
Heat flux (Q_n) was calculated with the following equation:
$Q_n = Q_g - Q_f - Q_l - Q_s$,
where Q_g, Q_r, Q_l, and Q_s are global solar radiation, thermal radiation, latent heat, and sensible heat transfer rate, respectively; these were calculated from observed values.



the basis of mechanism analyses. Experiments using a 4-m channel with a wind tunnel showed that constant direction wind caused upwelling of the bottom water mass along the coastal head of the channel, and that cool wind mixed the water column even under the condition stratified by 1 ‰ halocline. These phenomena were verified by a flow visualization method. A two-dimensional hydrodynamic model has been developed using MAC algorithm in order to simulate water currents in the channel and to reveal Aoshio mechanisms (Fig. 3).

Our studies, which include the field survey, channel experiments and model calculations, suggest that three conditions predict Aoshio formation in Tokyo Bay:

1) the existence of anoxic bottom water,
2) a continuous north wind for more than two days,
3) a mean air-temperature decrease of 4 ºC or more in a day.

Days with all three of these conditions coincided with 50 of the 54 days of Aoshio occurrence reported over the past 5 years.

This simple method to predict Aoshio can potentially be used to avoid serious damages of fisheries and to manage the water environment in enclosed coastal seas.

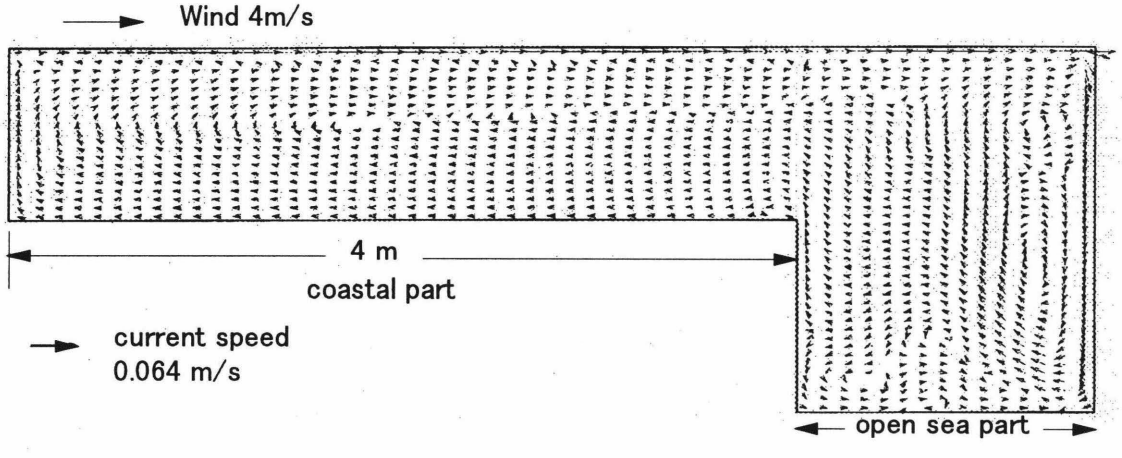


Fig. 3. A two-dimensional model calculation. The calculation shows upwelling along the coast (left side in this Fig.) of the 4m-channel under the stratified condition at 1.5 h after the start of cool-wind blowing, which was consistent with experimental results.