In other applications including those with tidal forcing, either the elevation is prescribed as a function of time and space, or a radiation condition of the form

$$\frac{\partial \eta}{\partial t} + c\frac{\partial \eta}{\partial n} = F(s,t) \tag{37}$$

is prescribed. Here $c$ is the local shallow-water wave speed, $(gH)^{1/2}$, and $s$ is the tangential coordinate. The function $F(s, t)$ incorporates the necessary forcing due to tides and the mean calculation as described by Blumberg and Kantha (1985). The nonlinear terms in the momentum equations are neglected at the open boundaries.

Numerical experiments have been performed that involve the use of the circulation model in both prognostic and diagnostic modes (Blumberg and Mellor, 1983). In the prognostic mode, the momentum equations as well as equations governing the temperature and salinity distributions are integrated as an initial value problem. These predictive experiments do not always reach steady state because the oceanic response time for the density field can be considerable. As an alternative, diagnostic computations are considered.

In the diagnostic mode, the observed density distribution is specified at all points in the grid and held fixed in time. The velocity field consistent with this constraint is increase from zero. These experiments typically attain steady conditions after 10 days in even fairly large oceanic regions. The diagnostic approach not only provides a powerful tool for deducing circulation but also provides a consistent way of initializing a prognostic forecast model.

## 3. Upwelling of anoxic bottom water, induced by destratification and vertical circulation due to wind in Tokyo Bay

The mechanism which causes upwelling of anoxic bottom water (Aoshio), often occurs in the north-eastern coast of Tokyo bay during summer and early spring is analyzed by using a three dimensional circulation model (Watanabe et. al., 1998)

### 3.1 Description of Blue Tide (Awoshiwo)

The color of surface water along the coastline of northern Tokyo Bay (Fig. 3.1) often changes from blue to blue-white or blue-green as a consequence of strong northerly to northeasterly winds that continue for several days. This phenomenon is called blue tide (Awoshiwo).

Occurrences of blue tides have been observed since 1963. There were about 110 occurrences during 1980 to 1994, covering more than 160 days in that period. Although a huge blue tide covering a large area of Tokyo Bay (Fig. 3.1) is only observed once every few years, smaller blue tides occur several times every year during the period from May to September along the northern coast of the Bay.

Tokyo Bay is stratified from early summer to autumn, due to the temperature and salinity difference between surface and bottom water. During this period, at the surface of the water column higher solar radiation increases temperature while freshwater discharge from rivers decreases salinity, making the surface water less dense than the deeper water; density stratification of the water column is stabilized and vertical mixing is suppressed.

Phytoplankton blooms have occurred during this period; the plankton use nutrients in the surface water and gradually settle to the bottom. Biodegradation of organic matter in the bottom layer consumes oxygen. Since the oxygen supply from the surface is suppressed due to stable stratification, oxygen can be depleted and anoxic conditions formed at the bottom. Thereafter, organic compounds are oxidized by bacteria through processes such as sulfate reduction, which is likely in Tokyo Bay because sulfate is widely available. This process is