THE SPATIAL CHARACTERISTICS OF STRATIFICATION IN DEUKRYANG BAY, KOREA

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I. Introduction

The spatial mixing and stratification problem in coastal zone or estuaries is thought to be strongly related with surface heating, tidal and wind stirring and buoyancy effect by fresh water discharge or intrusion of high density water. In these, the vertical stirring associated with tidal current and wind stress has been easily touched in some areas to mixing and stratification made by the surface heating because of their barotropic characteristics. However, if we include density current effect for the stratification problem, that becomes so complex as it is hard to present the spatial distribution of stratification because the buoyancy input is localized at the lateral boundaries rather than being uniformly distributed over the surface and its strong baroclinic effects (Nunes et al. 1989; Simpson et al. 1991). Therefore, It can be only applied for the exceptional case.

Our study area, Deukryang Bay, Korea(Fig.1) is small, less than 1000 km^2 and the depth consists of mainly two parts, deeper than 20 m in mouth and eastern side of the bay while shallower than 10 m in the head and western side although the averaged depth is only 7.5 m. Due to its geographic shape it though to be an area of intense tidal mixing and seems that buoyancy induced by density current and tidal stirring effects can be divided into two part, shallow and deep region. However, generally it is very hard to expect that the mainfest front line can be sustained continuously in summer as English Channel in U.K. or other large continetal shelf area since the strong tidal current in spring tide affects the whole depth of the bay as almost the same strength and results in strong vertical mixing.

In this paper, we compared the spatial distribution of potential energy anomaly(PEA) based on observation data with that by the numerical computation during spring-neap tidal cycle. We estimated what fraction of tidal power must be expended in mixing to prevent the formation of stratification as considering the tidal current, the density current and wind stress factors in the bay. Finally, we draw some results from PEA spatial discrepancy between the contours of the observation and those of the compuation. From the result, we predict PEA distribution and its constribution for the stratification intensity.

2. Data and Method

We observed temperature, salinity and density twice in 1-2 July (spring) and 23 July (neap), 1992, respectively. The first observation points were 27 and the second were extended to 37 for more detail observation so that the station positions between the first and the second were different except transect C. The mooring station of current meter was R and the wind speed was W, and the solar radiation S was selected at Kwangju City located far from the study area about 100 km since there is no meteorological center including the solar radiation data near the study area.

We presents T-S diagrams, vertical density structure along line C and tidal current using the observation data of the surface and bottom during the spring and the neap tidal periods.

3. PEA distribution from the Observation Data and Analytical Model including Sea Surface Heating, Tide, Wind Stress and Density Current

From previous study, PEA distribution induced by surface heating, tidal and wind stirring and density current constitutes a key determination of stratification in the bay was found at two chosen area, less than 10 m and more than 10 m. However, to understand the formation process of stratification in the bay quantitatively it is necessary to implement diagnostic approach using numerical model including four factors and then from its results to redefine new tidal mixing efficiency value.

So that we derived new equation as following;

$$E_c = \int_{t_0}^{t_1} \left(-\frac{g\alpha}{2C_p} Q_T H - eC_{A}\rho_a W^3 - \varepsilon C_d \rho_w U^3 + \frac{(g\frac{\partial \rho}{\partial x})^2 h^5}{320 \langle \bar{N}_z \rangle \rho} \right) dt - (1)$$

Eq.(1) are complex form of heating, tide, wind and density current. Using Eq.(1), we compared the observation results to analytical model. Then, the averaged values of that the observation PEA mines the computation one were taken at two chosen area, shallow(less than 10 m) and deep(larger than 10 m). From the equation, we can select an optimal values of tidal mixing efficiency and estimate wind stress effect. The table suggests that the reasonable tidal mixing efficiency is about ε = 0.0020 that is much increased up to 0.006 than case of without density current effect since in the study of Lee. et al. (1996) they assumed that the stratification is formed only by surface heating which derives underestimated stratification value in calculation procedure. However, as we included denstiy current effect for the formation of stratifiction, value is increased. The discrepancy values in the table between the deep and the shallow region is smaller than that of table 1. It means that in this study density current can play an important role to define the formation of stratification and to select tidal mixing efficiency value while wind stress effect is not so dominant. Sign of ε value at shallow depth is faster changed than that of deep one. That is, vertical mixing induced by tidal stirring intensity is much effective at shallow than deep area. Therefore, the tidal stirring can destroy the stratification easily at shallow than at deep region.

Finally, we noticed that generally the pattern of stratification is much improved depending mainly on the balance between the stratifying influence by density current and the mixing influence of tidal current at deep region. At shallow the tidal mixing mainly affect the stratification phenomena.

6. Summary and Conclusion

Diagnostic approach using a modified model of Simpson and Hunter's equation (1974) was applied for the stratification phenomena during spring-neap tidal cycle in Deukryang bay. For reasonable estimation of contribution of surface heating, tidal and wind stirring and density current effects, we employed two dimensional model and Samaransinghe (1989)'s equation.

We ried to touch the diagnostic approach using numerical model including four factors , surface heating, density current, tidal and wind stirring for simulating the observation at all stations. The model successfully simulated the stratification characteristic comparing to observation one, particularly around upper part of Deukryang the bay and deep region. The model also allows that the deep part plays major role and the shallow minimal role. In procedure of the computation, the averaged discrepancy PEA between the calculation and the observation at shallow and deep, the PEA at shallow part is changed faster and smaller than that at deep one according to several values. It can be explained that the tidal current stirring intensity is more effective at the shallow than at the deep. Therefore, at shallow region tidal stirring effect is easily to overcome stratification formed in neap tide.

We also found that the reasonable ε value is about 0.020 which is about 0.006 increased ε values than without considering density current effects. It can be explained that the density current strongly contributed the formation of stratification, particularly at upper region of Deukryang bay and deep region.

From the study, the formation and intensity of stratification is mainly controlled and maintained by virtue of density current effect. Therefore, without considering density current effect, it is impossible to predict the stratification - destratification phenomena in the bay.