THE NUMERICAL ANALYSIS OF MIXING DEPTH AND THE THICKNESS OF BBL CONSIDERING THE SUBMERGED AQUATIC VEGETATION AND WIND STRESS

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1. Introduction

Mangrove forests, salt marshes, and seagrass meadows have a vital role in mitigating global warming (Duarte et al.,2013). They contribute about 50% of carbon burial in ocean sediments (Duarte et al., 2013). On the other hand, submerged aquatic vegetations (SAVs) significantly affect the mixing depth (the thickness of the upper layer), resulting in a change in carbon flux with the atmosphere. According to the numerical simulations in the previous studies, mixing depth becomes larger with increasing SAV's density and decreasing SAV's height (Herb et al., 2005, Vilas et al., 2017). On the other hand, Coates et al. (2009) indicated that wind stress was not crucial for mixing depth in SAV's meadow since it did not change the vertical turbulent kinetic energy (TKE) profile, except in the thin surface layer, thus mixing depth became similar even though wind speed varied under the effect of SAVs (Coates et al., 2009). In addition, it is crucial to estimate the thickness of the benthic boundary layer (BBL) because dissolved inorganic carbon elucidates from bottom sediments, affecting carbon flux. Therefore, we aim to clarify how wind stress impacts the mixing depth and thickness of BBL with SAVs.

2. Methods

To study the impact of wind stress on the mixing depth and BBL thickness with SAVs, we used the Grid integrated SAV (GiSAV) model, which reproduces the flow fields interacted with SAVs with high accuracy. Wind speed was given 2.5 $\mathrm{m\ s^{-1}}$, 5.0 $\mathrm{m\ s^{-1}}$ and 7.5 $\mathrm{m\ s^{-1}}$. The drag coefficient of SAV was 1.0, and SAV's spacing was given 0.1m in all cases. The water depth is 1.0m. The horizontal and vertical grids are 6.0m and 0.01m, respectively. The thermocline location was defined with a vertical eddy diffusivity of $1.0 \times 10^{-6}\ \mathrm{m^2\ s^{-1}}$. Several different SAV heights were used to investigate the effect of SAV's height on the mixing depth until the mixing depth reached the bottom. We investigated the mixing depth and thickness of BBL at the center of the SAVs meadow.

3. Results

Mixing depth increased with increasing wind speed as opposed to the previous study (Coates et al., 2009) (Fig.1). It resulted from the fact that TKE became larger as the wind speed increased and TKE was transported farther from the water surface. The mixing depth decreased with the increase in the SAV's height (Fig.1).

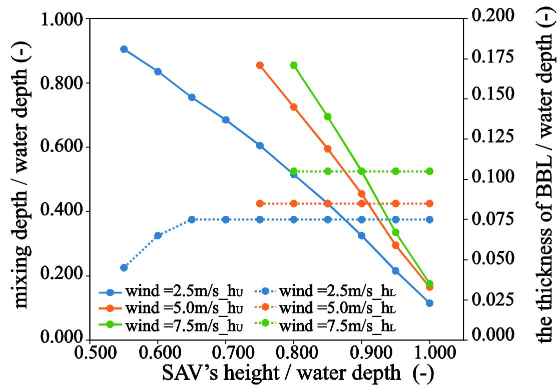

Figure 1 SAV's height (h_a) nondimensionalized by water depth (H) VS mixing depth nondimensionalized by water depth (h_U/H) and the thickness of BBL nondimensionalized by water depth (h_L/H). The solid and dashed lines show h_U/H and h_L/H. The horizontal axis shows h_a/H. The left vertical axis is h_U/H, The right vertical axis is h_L/H. The blue line, orange line, and green line are the results with wind speed of 2.5$\mathrm{m\ s^{-1}}$, 5.0 $\mathrm{m\ s^{-1}}$,and 7.5 $\mathrm{m\ s^{-1}}$, respectively.

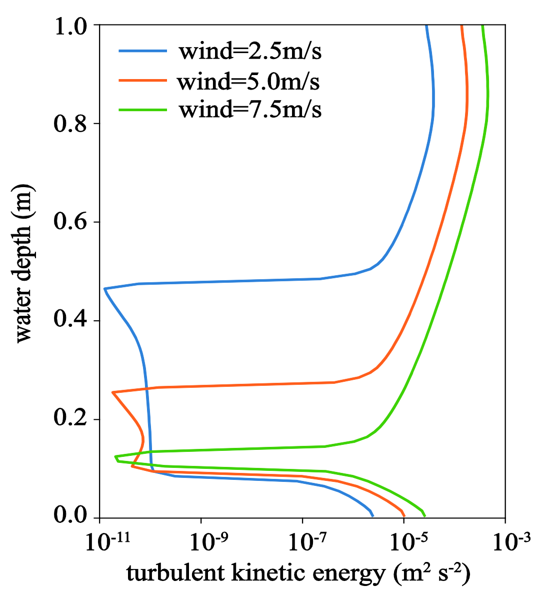

Figure 2 Vertical TKE profile for every wind speed (2.5 $\mathrm{m\ s^{-1}}$, 5.0 $\mathrm{m\ s^{-1}}$ and 7.5 $\mathrm{m\ s^{-1}}$. SAV's height=0.8m). Blue line, orange line, and green line show the TKE with wind speed =2.5 $\mathrm{m\ s^{-1}}$, 5.0 $\mathrm{m\ s^{-1}}$ and 7.5 $\mathrm{m\ s^{-1}}$, respectively. This figure indicates that vertical TKE profile is affected by the change in wind speed.

This result was similar to the previous study (Vilas et al., 2017). It is because the TKE dissipation occurs closer to the water surface as a longer SAV's height (Fig.3). Also, the thickness of BBL increased with increasing wind stress (Fig.1). Interestingly, the thickness of BBL was almost constant. However, SAV's height varied (Fig.1). In addition, we found that the TKE profile was similar within the BBL even though SAV's height varied where the thickness of BBL was constant (Fig.3). In the case of wind speed was 2.5 m s^{-1}, the thickness of BBL gradually decreased as far as SAV's height was less than 0.65m.

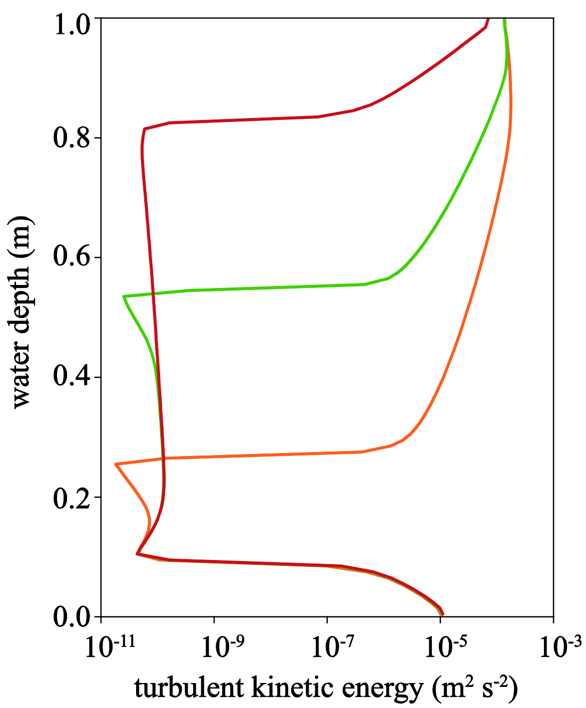

Figure 3 Vertical TKE profile for each SAV's height (SAV's height= 0.8m, 0.9m, and 1.0m. wind speed = 5.0 $m\ s^{-1}$). Orange line, green line and red line show the TKE with SAV's height = 0.8m, 0.9m, and 1.0m, respectively.

4. Conclusion

We found that wind stress is essential to estimating the mixing depth. Furthermore, the thickness of BBL was relevant to wind stress. Future studies need to formulate the mixing depth and thickness of BBL considering wind stress to estimate carbon flux accurately and efficiently.

5. Reference

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