Author Reply to Referee #2

18 November 2021

Dear Referee,

We have revised the manuscript in light of all the reviewer's comments. As a result, the manuscript has been substantially improved. Please find down below our pointwise responses to reviewer's comments and attached a marked-up version of the revised manuscript. We deeply appreciate the reviewer's careful and constructive comments.

Regards,

Tingfeng Wu and co-authors.

Anonymous Referee #2

General comments

This manuscript developed a three-dimensional wave-current coupled model (WCCM) for a large shallow lake, and optimized the descriptions of wind input, wave influence, and turbulence scheme basing on the field hydrodynamic data measured during wind-induced upwelling process in Lake Taihu. In this manuscript, the equations of the WCCM were correctly described, and the simulations seem fairly successful comparing with the high quality field hydrodynamic data. This original work can give us new insight of wind induced hydrodynamics and promote model development for large shallow lakes. Moreover, this manuscript is well organized and ideally situated for the journal. Therefore, I encourage this MS to be publish in GMD after minor revision.

[Responses] Many thanks for these positive general comments.

My specific comments are as follows.

1 Lines 71, 73, 83, the units should be superscript. Line 71, it covers a water area....

[Responses] Changed as suggested.

2 The variable of water density (ρ) hasn't been clearly described in the manuscript. Is it determined by water temperature?

[Responses] We have revised the manuscript as follows. (1) Two equations are added to Section 3.1.1 to explain the calculation of water density. (2) The measurement of water temperature is added in Chapter 2.2. (3) Fig. B4 is used to demonstrate the accuracy of simulation of water temperature and water density.

Yes, water density is calculated from water temperature. Actually, water temperature and density are state variables in the WCCM model and can be calculated by the equations of water temperature and density. During the 2015 and 2018 field observations, water temperature at LHWS station was recorded at the depth of 1 m below lake surface. We used these data to validate the temperature simulations. The results indicated that the correlation coefficient (r) between measured- and WCCM-simulated water temperature at the LHWS station during the 2015 and 2018 field observations are 0.98 and 0.99 respectively, while the mean absolute error (*RMSE*) are 0.22 ^{o}C and 0.25 ^{o}C (Fig R2-1). The WCCM can accurately simulate the changes of water temperature in Lake Taihu. The calibration and verification will be depicted in detail in another paper.

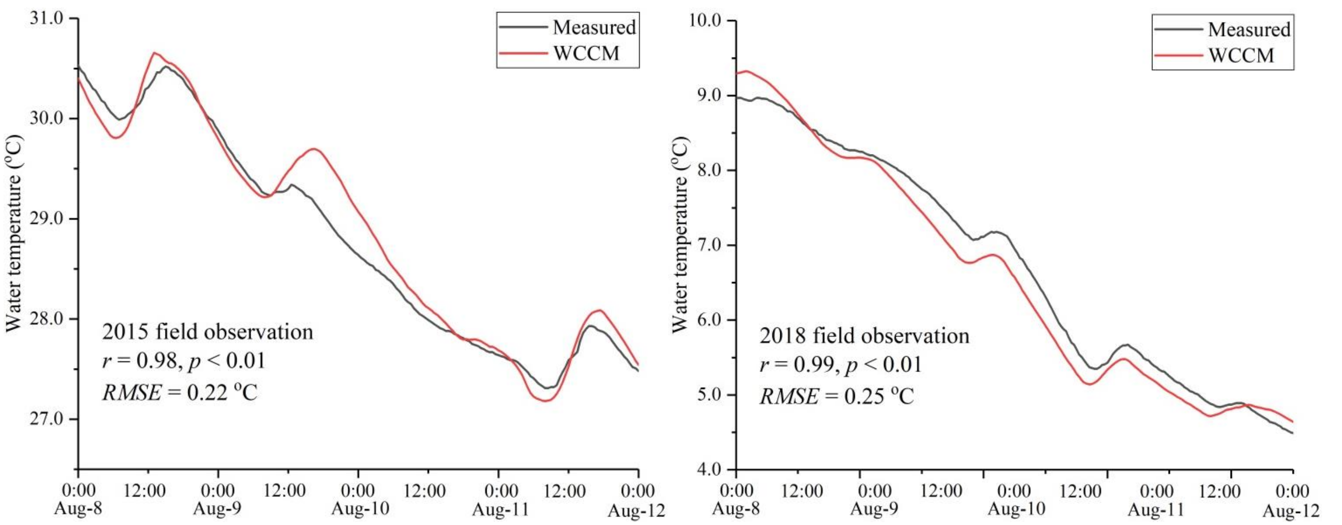

Fig. R2-1 Correlation coefficient (r) and mean absolute error (*RMSE*) between measured- and WCCM-simulated water temperature at the LHWS station during the 2015 and 2018 field observations

3 The proposed wind drag coefficient equations are very interesting (Fig. R1). It seemed similar with the COARE 3.5 (Edson et al., 2013) and Large and Pond (1981) equations (Fig. 1). Is there any relationship between your equation and those equations?

Edson, J. B., et al., 2013: On the exchange of momentum over the open ocean. J. Phys. Oceanogr., 43, 1589–1610.

Large, W. G., and S. Pond, 1981: Open ocean momentum flux measurements in moderate to strong winds. J. Phys. Ocean., 11, 324–336.

[Responses] Yes, we referred the wind drag coefficient equations proposed by Edson et al. (2013) and Large and Pond (1981). We have revised the manuscript as follows. Firstly, in Section 3.1.3, a paragraph has been added to describe the functions used in the equations of wind drag coefficient. Secondly, in Chapter 3.4, a paragraph has been added to determine the coefficients of these equations. Finally, in Chapter 5.1, a paragraph has been added to discuss the reasonability of the proposed equations.

The expression C_s of light winds is different from that of high winds, and piecewise function is recommended to fit the changes of C_s with wind speed in Large and Pond (1981). A constant is usually used to represent C_s below the critical wind speed (W_{cr}), while a proportional function is adopted for C_s for wind speed above W_{cr}. However, according to Geernaert et al. (1987), it can be concluded that C_s would approach to a constant (~0.003) for wind speed above 20 m s^{-1}. Therefore, we proposed that logistic function is more reasonable to derive the equations of C_s under high winds. Moreover, the components of winds in the *x*- and *y*-directions are used to calculate C_s in the *x*- and *y*-directions, respectively (Eqs. R1 and R2).

The parameters in Eqs. (R1) and (R2) are determined as follows. Firstly, equaling to the wind speed related to aerodynamically rough water surface (Wu, 1980), the critical wind speed of 7.5 m s^{-1} is used to distinguish between light and high winds. Secondly, referring to the curve of Edson et al. (2013) (Fig. R1-1) and the upper limit of C_s of ~0.003 (Wind speed > 20 m s^{-1}; Geernaert et al., 1987), the expression of the logistic function in Eq. (R1) or (R2) is preliminarily determined under high winds. Finally, the process-based observation data of 2015 are used to determine the logistic expression and the parameters of a, and C_c by trial-error method (Eqs. R3 and R4).

This comment is relevant to Reviewer #1's 8 comment, more explanations of the determination of the proposed wind drag coefficient are indicated in the response to that comment.

References:

Edson, J. B., Jampana, V., Weller, R. A., Bigorre, S. P., Plueddemann, A. J., and Fairall, C. W., Miller, S. D., Mahrt, L., Vickers, D., and Hersbach, H.: On the exchange of momentum over the open ocean, J. Phys. Oceanogr., 43(8), 1589-1610, 2013.

Geernaert, G. L., Larssen, S. E., and Hansen, F.: Measurements of the wind-stress, heat flux, and turbulence intensity during storm conditions over the North Sea, J. Geophys. Res. -Oceans, 98, 16571-16582, 1987.

Large, W. G, Pond, S.: Open ocean momentum flux measurements in moderate to strong winds, J. Phys. Oceanogr., 11, 324-336, 1981.

Wu, J.: Wind-stress coefficients over sea surface near neutral conditions-A revisit, J. Phys. Oceanogr., 10(5), 727-740, 1980.

4 Wind waves are very important for large shallow lakes. It is necessary to develop SWAN model to simulate wind waves in Lake Taihu. However, it is will be better to verify the performance of SWAN.

[Responses] Thank you very much for this very constructive comment! We have revised Chapter 2.2 and fourth paragraph in Chapter 3.4, and added a figure (i.e., Fig. R2-2) about the validation of the SWAN model in the revised manuscript.

Because SWAN model has been proven to be suitable for simulating the wind waves in Lake Taihu (Wang et al., 2016; Wu et al., 2019; Xu et al., 2013) and the SWAN model used in this study had also been validated (Wang et al., 2016; Xu et al., 2013), thus we did not indicate the validation of the SWAN model in the original manuscript.

Actually, we have measured wind waves at LCWS station during the 2018 field observation. Therefore, this data is used to validate the SWAN model again. The results indicated that the correlation coefficient and mean absolute error between measured- and WCCM-simulated significant wave height at the

LHWS station are 0.79 and 0.1 m, respectively (Fig. R2-2). The SWAN model used in the WCCM can well simulate wind waves in Lake Taihu.

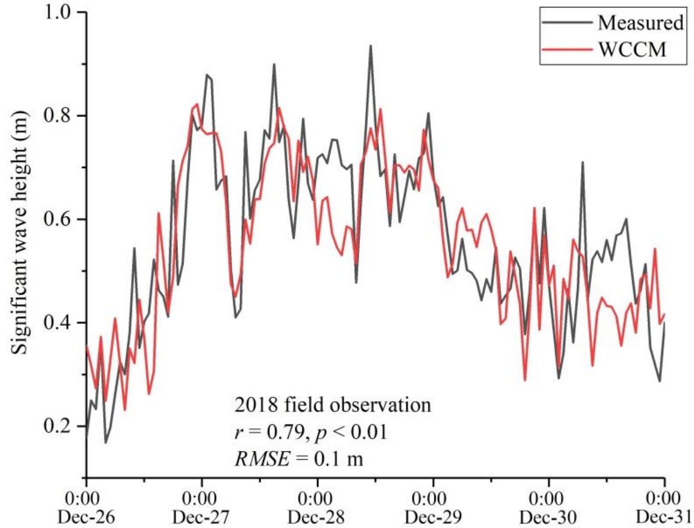

Fig. R2-2 Correlation coefficient (*r*) and mean absolute error (*RMSE*) between measured- and WCCM-simulated significant wave height at the LHWS station during the 2018 field observation

References:

Wang, Z., Wu, T., Zou, H., Jia, X., Huang, L., Liang, C., and Zhang, Z.: Changes in seasonal characteristics of wind and wave in different regions of Lake Taihu, J. Lake Sci., 28(1), 217-224, 2016. (in Chinese with English abstract)

Wu, T., Qin, B., Brookes, J. D., Yan, W., Ji, X., Feng, J., Ding, W., and Wang, H.: Spatial distribution of sediment nitrogen and phosphorus in Lake Taihu from a hydrodynamics-induced transport perspective, Sci. Total Environ., 650, 1554-1565, 2019.

Xu, X., Tao, R., Zhao, Q., and Wu, T.: Wave characteristics and sensitivity analysis of wind field in a large shallow lake-Lake Taihu, J. Lake Sci., 25(1), 55-64, 2013. (in Chinese with English abstract)

5 Lines 253-255, this demonstrates the importance of wind wave radiation stress. It will impact the simulation of the buoyancy cyanobacteria which is the most serious environment problem in Lake Taihu.

[Responses] Comments taken. We have revised the last paragraph in chapter 5.2 in the revised manuscript.

The impact of wave-induced radiation stress on the simulation of the lake current field would be helpful for us to simulate and understand of the movement of buoyant cyanobacteria which is the most serious problem in Lake Taihu (Qin et al., 2007; Stone, 2011; Wu et al., 2019). Because the absence of vortex in downwind area will reinforce the accumulation of cyanobacteria, and further promote cyanobacterial blooms within this water area.

Reference:

Qin, B., Xu, P., Wu, Q., Luo, L., Zhang, Y.: Environmental issues of Lake Taihu, China, Hydrobiologia, 581:3-14, 2007.

Stone, R.: China aims to turn tide against toxic lake pollution, Science, 333, 1210–1211, 2011.

Wu, T., Qin, B., Brookes, J. D., Yan, W., Ji, X., Feng, J., Ding, W., and Wang, H.: Spatial distribution of sediment nitrogen and phosphorus in Lake Taihu from a hydrodynamics-induced transport perspective, Sci. Total Environ., 650, 1554-1565, 2019.

6 Section 5.2: it is a very meaningful work for large shallow lake simulation. It firstly proved the important effects of wind waves on lake current simulation in large shallow lakes. I suggest that the authors or other limnologists can try to consider the influence of wave-driven bottom shear stress on lake current simulation in future work.

Response: We appreciate the recognition of our work. We have addressed this suggestion and added a brief discussion on this in Chapter 6.