Author’s Responses to Referees and Editors

23 November 2021

Dear Referees and Editors,

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.

Best Regards,
Tingfeng Wu and co-authors

Geosc. Mod. Dev. Executive Editor: Juan A. Añel

1. After checking your manuscript, it has come to our attention that it does not comply with our Code and Data Policy.

https://www.geoscientific-model-development.net/policies/code_and_data_policy.html

[Responses] We have read the Code and Data Policy and agree the Code and Data Policy.

2. Part of your code is archived in GitHub. However, GitHub is not a suitable repository. GitHub itself instructs authors to use other alternatives for long-term archival and publishing, such as Zenodo. Therefore, please, publish the code in one of the appropriate repositories.

[Responses] We have uploaded the source code of the EFDC model to the Zenodo. It can be freely archived from https://doi.org/10.5281/zenodo.5602801 (Wu, 2021).

3. In this way, please, be aware that you must include in a potential reviewed version of your manuscript the modified 'Code and Data Availability' section, the DOI of the code.

[Responses] We have modified corresponding content of 'Code and Data Availability' section.

4. Also, some of the Zenodo repositories that you have linked are restricted. We can not accept this. To limit access to the repositories has the same result that not sharing the information. Therefore, you must establish open repositories that you can not delete later.

[Responses] All restrictions have been cancelled.

The source code of the WCCM model is freely available from https://doi.org/10.5281/zenodo.5709811 (Wu and Qin, 2021). The dataset of measured water level and current is freely available from https://doi.org/10.5281/zenodo.5184459 (Hu and Wu, 2021).

Anonymous Referee #1

General comments

The manuscript considers the effect of parameterization of wind forcing to wind generated waves in a shallow lake in China. The authors have developed a new method for estimating and modelling wind-driven current that is specifically suited for shallow lakes. A measurement campaign of wind and flow conditions was conducted to support the development of a wave-current coupled model.

Overall, the science in the manuscript is described well and the subject fits within the journal's scope. The theory and implementation into the model are clearly written for the most part and relevant material is included in the article and appendices. The readability and structure of the paper are satisfactory. This paper gives interesting insight to 2-D and 3-D modelling of shallow inland lakes where the atmosphere-water interface parameterizations can behave differently to the ones used in general hydrodynamic ocean or coastal models. Especially the significance of turbulence parameterization, wind drag coefficient and the wave-flow model coupling are of benefit to shallow lake modelling development.

After minor to medium improvements to clarify some points and make the paper more readable, I can recommend the paper to be accepted for publication. I also suggest making the source code fully open (without the need to ask for access) as is the standard these days.

[Responses] We appreciate the reviewer's careful and constructive general comments. The restriction of the code has been cleared. The section of code sharing and data availability in the text has been revised accordingly.

Specific comments

1 In the abstract at row 19 you say "Comparing with other model…". This should be rephrased to include minimum relevant information about what you are comparing to. E.g. "Compared with a reference model…"

[Responses] Changed as suggested.

2 In row 33 you refer to Sterner et al. 2017 when discussing 3-D ocean model applicability to shallow lakes. I don't think this reference fits here. Please remove this or explain the relevance. On the other hand, the second reference (L ükÅ et al. 2020) is spot-on.

[Responses] Comments taken. The citation of Sterner et al 2017 has been removed.

3 At chapter 2.1, provide references for the weather conditions at Lake Taihu.

[Responses] Comments taken. Wu, et al. (2018) has been added to describe the weather conditions.

4 At chapter 2.2, provide the height at which the wind measurements were taken.

[Responses] The height info has been added.

5 At the introduction to Chapter 3, provide some references and examples of 3-D model –SWAN couplings that have already been done and why they are not sufficient for this work. In Chapter 3.1 provide an justification why an LCM is developed from the ground up instead of modifying one of the existing, well tested and freely available open source 3-D ocean coastal/ocean models.

[Responses] Thank you very much for this very constructive comment. We have added the following text to Chapter 3.

Many efforts have been made on coupled current-wave model development, especially on the coupling of the Simulating WAves Nearshore model (SWAN; Booij and Holthuijsen, 1999) to existing three-dimensional current models (Chen et al., 2018; Liu et al., 2011; Warner et al., 2008; Wu et al., 2011). However, due to the difficulty in modifying the existing model codes (Chen et al., 2018), most of these coupled models were developed using a third party software (e.g. Model Coupling Toolkit), rather than directly merging the original codes. However, this is not yet an efficient way to modify some key processes or parameters in these models. Herein, a two-way wave-current coupled model (WCCM) is developed by merging the codes of a three-dimensional lake current model (LCM) and SWAN.

Although most current models largely use same governing equations and solution methods, the differences of the selected programming languages, operating environment, mesh, and description of key processes or parameters impede the developers to fully understand these models and further modify their codes. It is preferable to develop a new model to analyse the suitable descriptions of winds, wind waves, and turbulence in the model. Therefore, based on the classic method (Blumberg and Mellor, 1987), LCM with concise and efficient programming is developed to simulate the water temperature, water level, and lake currents.

References:

Chen, T., Zhang, Q., Wu, Y., Ji, C., Yang, J., and Liu, G.: Development of a wave-current model through coupling of FVCOM and SWAN, Ocean Eng., 164, 443-454, 2018.

Blumberg, A. F., and Mellor, G. L.: A description of a three-dimensional coastal ocean circulation model, In: Heaps, N. (eds.): Three-dimensional Coastal Ocean Models, pp. 1-16, 1987.

Booij, N., Ris, R. C., and Holthuijsen, L. H.: A third-generation wave model for coastal regions, Part I, Model description and validation, J. Geophys. Res. -Oceans, 104(C4), 7649-7666, 1999.

Liu, B., Liu, H., Xie, L., Guan, C., and Zhao, D.: A coupled atmosphere-wave-ocean modeling system: simulation of the intensity of an idealized tropical cyclone, Mon. Weather Rev., 139(1), 132-152, 2011.

Warner, J. C., Sherwood, C. R., Signell, R. P., Harris, C. K., and Arango, H. G.: Development of a three-dimensional, regional, coupled wave, current, and sediment-transport model, Comput. Geosci., 34(10): 1284-1306, 2008.

Wu, L., Chen, C, Guo, P, Shi, M, Qi, J., and Ge, J.: A FVCOM-based unstructured grid wave, current, sediment transport model, I. model description and validation, J. Ocean U. China, 10 (1), 1-8, 2011.

6 At row 199 the reference to Koue 2018 is odd at this point. How is this relevant to measuring the performance of WCCM?

[Responses] Eqs. (24) and (25) from Koue et al. (2018) are used to compute correlation coefficient and mean absolute error. However, they are common statistics. Therefore, we deleted this citation as suggested.

References:

Koue, J., Shimadera, H., Matsuo, T., and Kondo, A.: Evaluation of thermal stratification and flow field reproduced by a three-dimensional hydrodynamic model in Lake Biwa, Japan, Water, 10, 47, doi: http://dx.doi.org/10.3390/w10010047, 2018.

7 Also at row 200 the reference to Carvalho et al. 2012 seems out of place. Carvalho's paper doesn't mention MAEUVD.

[Responses] Comments taken. We have deleted this citation.

8 Chapter 4.1. You refer to this chapter (rows 124 and 181) for more information about the calibration of the model and deriving the wind drag coefficient. However, an explanation about the calibration process is missing. Please add a section describing clearly how the observation data was used to calibrate the model and how the wind drag coefficients were derived based on calibration and the observations.

[Responses] We have revised the manuscript as following:

Firstly, in Section 3.1.3, a paragraph has been added to describe 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 of C_s under light winds is different from that under high winds, and piecewise function is recommended to fit the changes of C_s with wind speed (Large and Pond, 1981). A constant (C_c) is used to represent C_s when wind speed is below the critical wind speed (W_{cr}), while a proportional function is adopted for C_s increase with wind speed when wind speed is greater than 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.

x-direction: $$C_s = \begin{cases} f(|u_w|) + a & |u_w| \geq W_{cr} \\ C_c & |u_w| < W_{cr} \end{cases}, \tag{R1}$$

$$\text{y-direction:}\quad C_s = \begin{cases} f(|v_w|) + a & |v_w| \geq W_{cr} \\ C_c & |v_w| < W_{cr} \end{cases}, \qquad \text{(R2)}$$

Where $f(|u_w|)$ and $f(|v_w|)$ are the logistic functions.

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 (0.003) when wind speed is above 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.

$$\text{x-direction:}\quad C_s = \begin{cases} \frac{0.0046}{1.8+e^{4-0.2|u_w|}} + 0.00041 & |u_w| \geq 7.5 \\ 0.00074 & |u_w| < 7.5 \end{cases}, \qquad \text{(R3)}$$

$$\text{y-direction:}\quad C_s = \begin{cases} \frac{0.0046}{1.8+e^{4-0.2|v_w|}} + 0.00041 & |v_w| \geq 7.5 \\ 0.00074 & |v_w| < 7.5 \end{cases}, \qquad \text{(R4)}$$

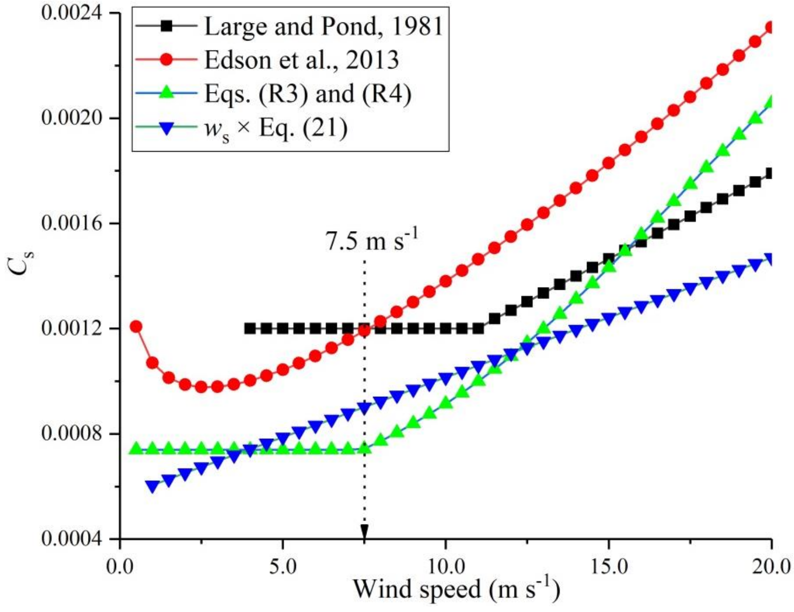

Fig. R1-1 Changes of wind drag coefficient with wind speed calculated by the equations proposed by Large and Pond (1981), Edson et al. (2013), Eqs. (R3) and (R4), w_s × Eq. (19)

It should be noted that the upper limit of C_s in the original manuscript has been toned down according to measured C_s reported by Geernaert et al. (1987). The reason of this modification is that: the maximum wind speed during the 2015 or 2018 field observation was less than 16 m s^{-1}, so that the change of C_s in the original manuscript had not been validated under wind speed > 16 m s^{-1}. Actually, C_s in the revised manuscript is the same as those in original manuscript under wind speed < 16 m s^{-1} (Fig. R1-2). This implies that more field researches are required to determine the change of C_s under higher wind speed, despite this wind event is seldom happen for inland lakes.

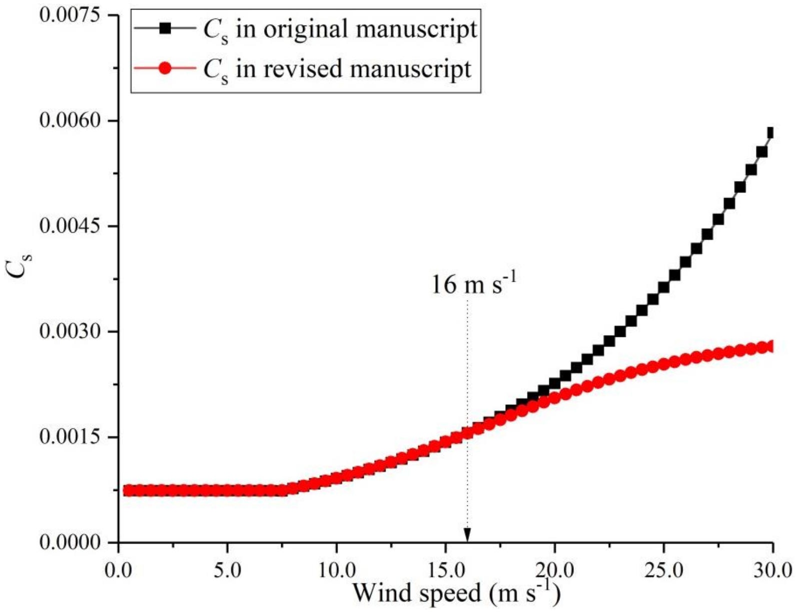

Fig. R1-2 Wind drag coefficients calculated by Eqs. (16) or (17) in original manuscript and revised manuscript

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.

9 Move the EFDC mentions at rows 179-180 to the chapter 3.5.2 to avoid forward references.

[Responses] Changed as suggested.

10 At row 241 you say that the measured flow speeds were lowest at the surface and highest at the bottom and it seems so also from Fig.7. Also in 2018 (row 262) the measured speed at bottom is highest. In simulations (Figs 6,7) the simulated surface speeds are generally higher than bottom speeds. Discuss why this is so.

[Responses] We have added a section entitled "5.4 Challenges of the hydrodynamic model development for shallow lakes" in the revised manuscript to address this point. The detailed response to this comment is indicted as following:

The mean measured flow speed in the middle water layer is the highest during the 2015 field observation (Row 241), while it is the lowest during the 2018 field observation (Row 262). However, the mean of simulated flow speed decrease with the increase of water depth.

In this study, the energy of lake hydrodynamics mainly transferred from winds because the influences of inflow and outflow were neglected. According to Ekman theory (Hutter et al., 2011), the magnitude of wind-driven currents decreases with the increase of the water depth in a water body. This is the cause of the decrease in the mean WCCM- or EFDC-simulated flow speed along water depth. The simulation of wind-driven currents in Lake Okeechobe in America also indicated similar result (Jin et al., 2000). However, at some periods, the simulated flow speed in the middle or bottom water layer can exceed that in the surface water layer under the condition of the synergism of pressure gradient stress caused by the tilt of lake surface and low or reverse winds (Fig. R1-3).

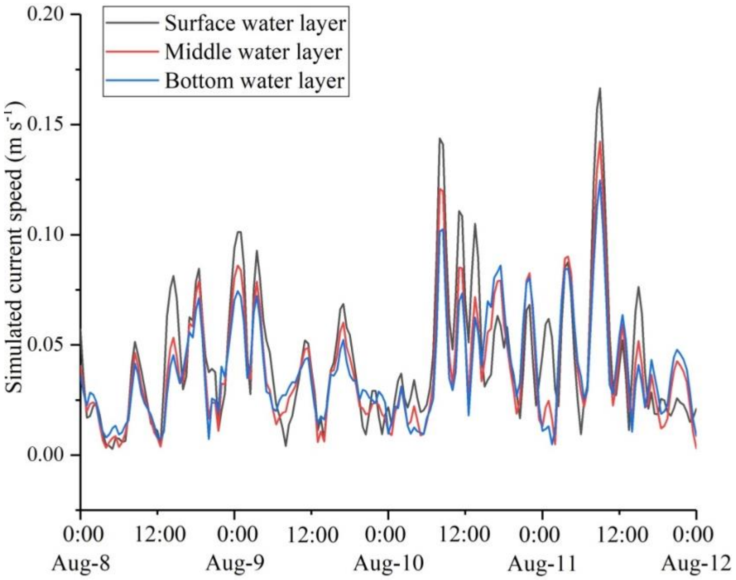

Fig. R1-3 WCCM-simulated current speed of surface, middle, and bottom water layer during the 2015 field observation

The measured current speed also decreased along water depth at some periods, while the mean of the current speed measured by Acoustic Doppler Current Profiler (ADCP) does not show such vertical distribution patterns (Huang et al., 2010; Ishikawa et al., 2021; Jin et al., 2000; Scheu et al., 2015; Soulignac, et al., 2017; Valipour et al., 2017; Zheng et al., 2015). According to the field observation of lake current near lakeshore in Lake Taihu, Zheng et al. (2015) found that the measured current speed increased from the water surface to about one third of the depth, and then decreased towards the lakebed during most of the field observation. However, there is no dominant vertical current profile can be found in Lake Créteil, France (Soulignac et al., 2017), which is a shallow lake with mean water depth of 4.5 m. Moreover, other comparisons between ADCP-measured and model-simulated current speeds also indicated that the magnitude of the model-simulated current speed is lower than that of the ADCP-measured current speed (Huang et al., 2010; Ishikawa et al., 2021; Jin et al., 2000; Soulignac et al., 2017).

We inferred that there are three possible explanations. Firstly, based on Doppler effect of sound waves, ADCP measured the 3-D lake currents via detecting the movement speed of suspended particle matter (SPM) in water bodies. However, the spatiotemporal distributions of the concentration and physicochemical properties of SPM are dynamic. For example, the grain size and concentration of SPM increased from lake-surface to lakebed under high winds in Lake Taihu (Zheng et al., 2017). This will undoubtedly influence the measurements of real currents in lakes. Secondly, the spatiotemporal resolution of the input data of the numerical models could cause errors of the simulated lake currents, including mesh, underwater topography, boundary conditions, and wind field. Thirdly, the influence of wind waves on lake currents is still not fully understood. The contributions of wind waves to the development of lake currents are likely underestimated in shallow lakes. Therefore, besides wave-induced radiation stress, more investigations are needed to fully understand the interaction between wind waves and lake currents in shallow lakes.

References:

Huang, A., Rao, Y. R., Lu, Y., and Zhao, J.: Hydrodynamic modeling of Lake Ontario: An intercomparison of three models, J. Geophys. Res.-Oceans, 115, C12076, https://doi.org/10.1029/2010JC006269, 2010.

Hutter, K., Wang, Y., Chubarenko, I. P.: Physics of lakes. Volume 1: Foundation of the mathematical and physical background. Berlin: Springer, 2011.

Ishikawa, M., Gonzalez, W., Golyjeswski, O., Sales, G., J. Rigotti, A., Bleninger, T., Mannich, M., Lorke, A.: Effects of dimensionality on the performance of hydrodynamic models, Geosci. Model Dev., https://doi.org/10.5194/gmd-2021-250, 2021.

Jin, K. R., Hamrick, J. H., and Tisdale T.: Application of three-dimensional model for Lake Okeechobee, J. Hydraul. Eng., 126, 758-771, 2000.

Soulignac, F., Vinçon-Leite, B., Lemaire, B. J., Martins, J. R., Scarati, Bonhomme, C., Dubois, P., Mezemate, Y., Tchiguirinskaia, I., Schertzer, D., Tassin, B.: Performance assessment of a 3D hydrodynamic model using high temporal resolution measurements in a shallow urban lake, Environ. Model. Assess., 22, 309-322, 2017.

Valipour, R., Boegman, L., Bouffard, D., Rao, Y. R.: Sediment resuspension mechanisms and their contributions to high-turbidity events in a large lake, Limnol. Oceanogr., 62(3), 1045-1065, 2017.

Scheu, K. R., Fong, D. A., Monismith, S. G., Fringer, O. B.: Sediment transport dynamics near a river inflow in a large alpine lake, Limnol. Oceanogr. 60, 1195-1211, 2015.

Zheng, S., Wang, P., Wang, C., Hou, J.: Sediment resuspension under action of wind in Taihu Lake, China. Int. J. Sediment Res., 30, 48-62, 2015.

11 At row 293 (and 345), you say that "WCCM can accurately simulate the wind-driven currents…" and later at row 352 "…correlation between simulated and measured current speed remains low…". Which one is it? I agree that a) according to the data there is a clear improvement over a reference model and b) correlation with flow speeds can be low. Please be more elaborate about which part of WCCM results is accurate and which parts still need work.

[Responses] Comments taken. We have revised the sentence accordingly, and add more discussions in Chapter 5.4.

12 Chapter 5.1, row 299: "…, considering the discontinuity of changing trend and directionality of wind momentum transmission, …" is hard to understand in the middle of the sentence. Please rephrase for more clarity. Almost same sentence appears at row 302. The whole chapter would benefit from rewriting with more clear language.

[Responses] We have rewritten the whole Chapter.

13 At rows 325 to 333, you compare the current fields of WCCM and EFDC. Which one (or neither) produces similar vortices as is observed (if there is observations)? Explain which model fits the reality better qualitatively (not just with current speeds etc).

[Responses] This is a great suggestion, however it is difficult to measure current fields in the broad Lake Taihu. The reasons are multifold. (1) In order to measure the basin-scale current field of Lake Taihu, we should complete the measurement of current fields of the whole lake within a very short period because the wind-driven currents in Lake Taihu change rapidly (Figs 6 and 10). This is almost an impossible task because the water area of Lake Taihu is 2339 km^2. (2) The magnitude of current speed is very small (mean of ~5 $cm\ s^{-1}$ in this study) so that any small disturbance will result in the measurement error. However, boat-based ADP measurement will unavoidably generate disturbances, including propeller-induced disturbance, wind- or wind wave-induced boat sway or movement, change of boat’s speed, instrument failures, and etc. (3) We also cannot measure the current field via the fixed mooring observation, because we do not have enough ADPs to cover whole lake. (4) It is very dangerous to measure lake currents during strong wind events when is the best time to measure lake hydrodynamics in Lake Taihu. Therefore, we do not have completely observed current fields, which can be used to perform the qualitative evaluation of the modeled current fields between different models. Actually, according to the available literatures, there is no report about the observed basin-scale current fields of large lakes worldwide.

14 Discuss is the model resolution sufficient for this kind of simulation. 1 km x 1 km seems a bit coarse for this.

[Responses] Comments taken. We have revised the first paragraph in Chapter 3.4.

I agree with you that finer grid will provide us more details about the lake current field, especially for rectangular grid. We will improve grid resolution in subsequent modeling studies. Here, the reasons for selecting 1 km grid include: 1) To calibrate parameters in numerical experiments, massive model simulation tasks should be completed. It is necessary to use coarser grid to improve computing efficiency. 2) Several numerical models at 1 km resolution have been successfully applied to Lake Taihu (Hu et al., 2006; Mao et al., 2008; Liu et al., 2018). Therefore, we use the mesh with size of 1 km in this study.

References:

Hu, W., JØrgensen, S. E., Zhang, F.: A vertical-compressed three-dimensional ecological model in Lake Taihu, China. Ecol. Model., 190(3-4), 367-398, 2006.

Mao, J., Chen, Q., Chen, Y.: Three-dimensional eutrophication model and application to Lake Taihu, China, J. Environ. Sci., 20, 278-284, 2008.

Liu, S., Ye, Q., Wu, S., Stive, M.J.F.: Horizontal Circulation Patterns in a Large Shallow Lake: Taihu Lake, China. Water, 10, 792. https://doi.org/10.3390/w10060792, 2018

15 What were the blanking distances/dead areas of the ADP measurements? If they are significant, please discuss if it affects the reported flow speeds and therefore the comparisons to simulations. Do you compare the same height layers from model and ADP?

[Responses] Comments taken. We have rewritten Chapter 2.2. The deployment of ADP is described as follows.

A surface plate equipped an upward looking acoustic Doppler profiler (ADP; SonTek Inc., USA; accuracy ±1% of measured velocity) was fixed on the lakebed (Fig. R1-4). The upward looking 3000 kHz ADP burst sampled current profiles every 30 min at 1 Hz. Each current profile is divided into 30 0.15-m-thick current layers (Cell 1, Cell 2, ….., Cell 30; Fig. R1-4). Moreover, the height of the blanking region and mounting height of ADP is 0.7 m, which means that there is no measurement within the height of 0.7 m above the lakebed. After the field observations, the effectiveness of measured current velocity of each current layer (cell) is evaluated using the signal-to-noise ratio and water depth recorded by the ADP. Then the measured effective current velocity of surface, middle or bottom cell is used to validate the performance of hydrodynamic models at same or approximate height.

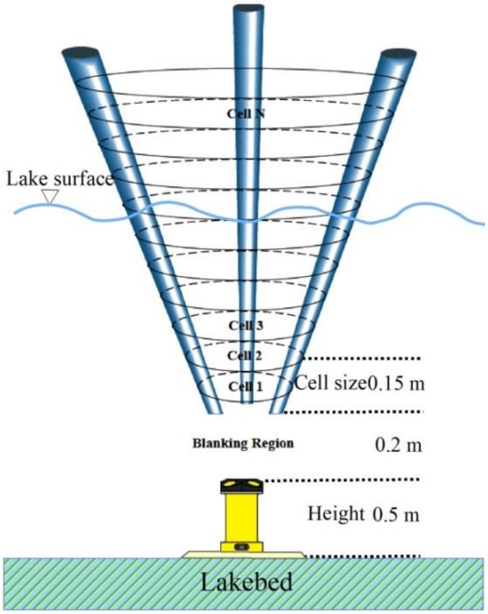

Fig. R1-4 Flow measurement of ADP during the field observations

Technical corrections: typo --> suggested correction

1 row 28: Naiver-Stokes --> Navier-Stokes

[Responses] Changed as suggested.

2 row 29: “…and solved the equations using…”

[Responses] Changed as suggested.

3 row 41: discontinuity --> discontinuous

[Responses] Changed as suggested.

4 rows 56-57. Sentence here is a bit repeating compared to the previous sentence and unclearly said, please rephrase.

[Responses] This sentence has been rephrased.

5 row 72: ‘…lakebed slope of 19.7”…’: should probably be in degrees °

Response: We cited this value from Qin et al. (2007), which have been added in the revised manuscript. The length (from the north to the south) of Lake Taihu is 68.5 km and width (from the east to the west) is 56 km. Mean depth is 1.9 m, and maximum depth is 2.6 m corresponding to an elevation of 3.0 m. The lake bottom features flat terrain with an average topographic gradient of 0 °0′19.66″ and elevation of 1.1 m (Qin et al., 2007).

References:

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

6 row 73: southeast should be capitalized at the start of a sentence

[Responses] Changed as suggested.

7 row 85: remove extraneous mention of (LCWS) after …USA)

[Responses] Comments taken.

8 row 135: firstly --> first

[Responses] Changed as suggested.

9 row 176: by 0 m s-1 --> to 0 m s-1

[Responses] Changed as suggested.

10 row 220: explain the parameter ws

[Responses] We have added a sentence to explain this parameter.

11 row 308: logistic curve: Should be logarithmic curve?

[Responses] The expression of logistic curve is reasonable.

12 Tables 2-5: Consistently use upper or lower case for all p in tables 2-5.

[Responses] Changed as suggested.

13 Please include LCWS location in the pictures in Figs. 7, 11.

[Responses] Changed as suggested.

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 $^{\circ}$C and 0.25 $^{\circ}$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.

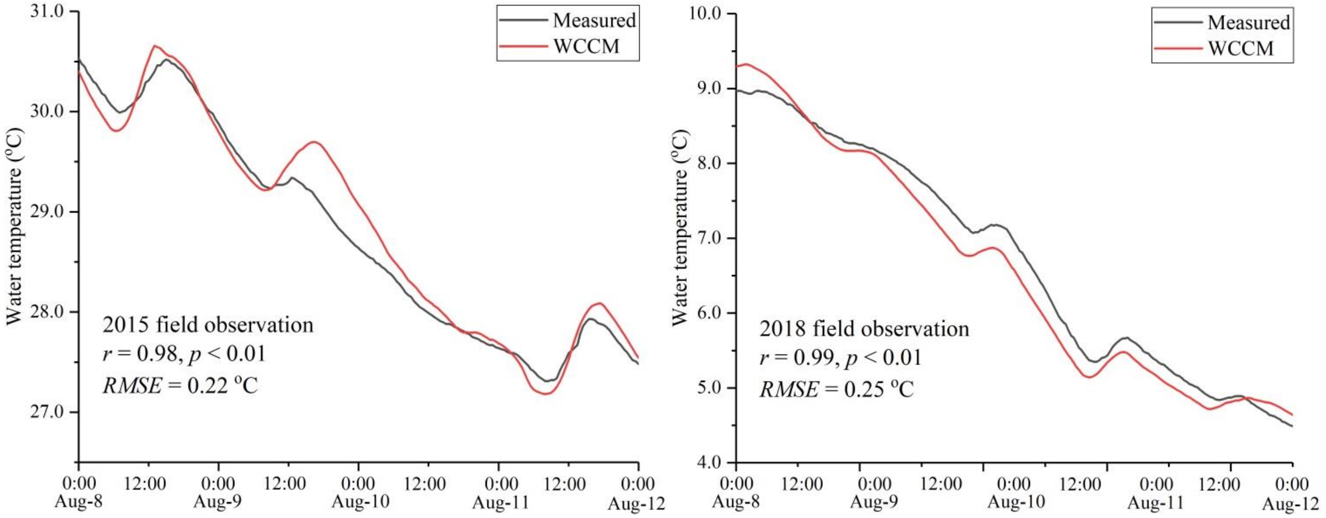

Fig. R2-1 Correlation coefficient (r) and mean absolute error ($RMSE$) between measured- and WCCM-simulated water temperature at the LHWS station during the 2015 and 2018 field observations

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.

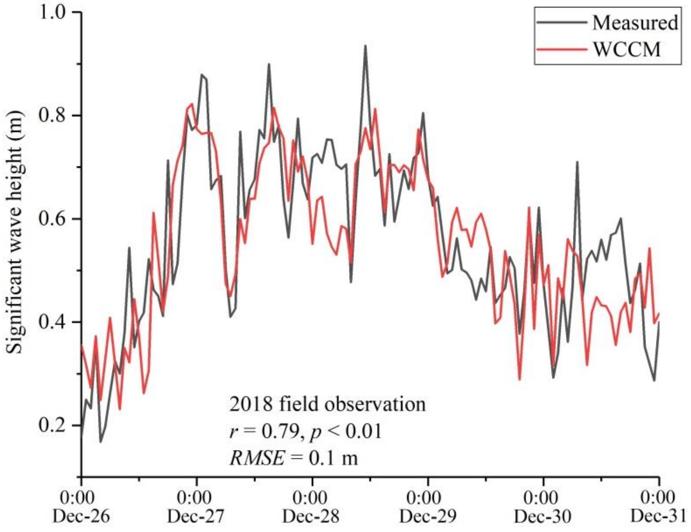

Fig. R2-2 Correlation coefficient (*r*) and mean absolute error (*RMSE*) between measured- and WCCM-simulated significant wave height at the LHWS station during the 2018 field observation

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.