

# Three-dimensional modeling of suspended sediment transport in a subalpine lake

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**Abstract** Suspended sediment in the lakes can impact the aquatic ecosystem and water resource management. A three-dimensional hydrodynamic and suspended sediment transport model was performed to simulate temporal and spatial variations of suspended sediment and applied to the subtropical subalpine Yuan-Yang lake of Taiwan. The model was validated with measured water level and suspended sediment concentration in 2009 and 2010. The overall model simulation results are in quantitative agreement with the available field data. The validated model was then used to find out the important parameter which affected the suspended sediment concentration and to investigate the effect of wind stress on mean current and suspended sediment distribution in the lake. Modeling results of sensitivity analysis indicate that the settling velocity plays a crucial parameter in the suspended sediment transport. The simulated results also show that the bottom currents are in opposite direction as surface currents due to return flows. Remarkable lake circulation was found and affected by the wind speed and direction. Mean suspended sediment concentration at the bottom layer is less than that at the top layer. Strong wind would result in higher mean current and mean suspended sediment distribution at the top layer. The wind stress plays a significant influence on mean circulation and suspended sediment transport in a shallow lake.

**Keywords** Suspended sediment · Numerical model · Sensitivity analysis · EFDC · Wind-driven current · Yuan-Yang lake

## Introduction

Sediment in shallow lakes can affect the physical and chemical environment of the water column through resuspension and transportation. Suspension sediments in water column can reduce the light intensity and influence the growth of phytoplankton. Furthermore, nutrients, heavy metals, and pesticides can be absorbed onto sediment particles and also desorbed from sediment to the water column. In addition, nutrients absorbed to the deposited sediment and organisms in the mud may be released from lake bed (Ji et al. 2002; Chao et al. 2007; Chalov et al. 2015). These sediment transport processes are quite important and have been considered in some three-dimensional models.

Wind-induced circulation is one of critical issues to sediment resuspension processes which have been reported by Aalderink et al. (1984), Kumagai (1988), Podsetchine and Huttula (1994), Hutter et al. (1998) and Kjaran et al. (2004), etc. In recent, Chao et al. (2008) developed and applied a three-dimensional numerical model for simulating cohesive sediment transport in water bodies where wind-induced currents and waves are important in a shallow oxbow lake. Chung et al. (2009) used a one-dimensional model to demonstrate the sediment resuspension as a main source of nutrients in a large lake.

The basic processes involved in sediment transport such as flocculation, deposition, and erosion have been studied by many researchers. Partheniades (1965) proposed a formula to calculate the erosion rate of cohesive sediment. Krone (1962) and Mehta and Partheniades (1975)

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investigated deposition of cohesive sediment and proposed formulas to estimate deposition rates. Thorn (1981), Ziegler and Nisbet (1995) and Li and Mehta (1998) established several empirical formulas for settling velocity of flocs by taking into account the effects of sediment size, sediment concentration, salinity, turbulent intensity, and bed shear stress. A number of laboratory studies have improved our knowledge of the resuspension behavior of fine-grained material. However, transferring the results of laboratory experiments to field studies has been problematic because of the complexity of real sediments and of natural flows.

Due to the difficulty in measuring the sediment dynamics in laboratory and in situ, one way to study the sediment dynamics in lakes is with a numerical model. The simulation of the movement of particulates in lakes and representation of the processes involved in sediment transport is a challenging objective. Sediment transport models have been broadly developed and applied to investigate sediment dynamics in lakes including one-dimensional model (Chung et al. 2009), vertical two-dimensional model (Hawley et al. 2009; Zouabi-Aloui and Gueddari 2014), horizontal two-dimensional model (Kjaraan et al. 2004; Lee et al. 2007; Stroud et al. 2009), and three-dimensional model (Jin and Ji 2004; Cardenas et al. 2005; Wang et al. 2013; Lv et al. 2013).

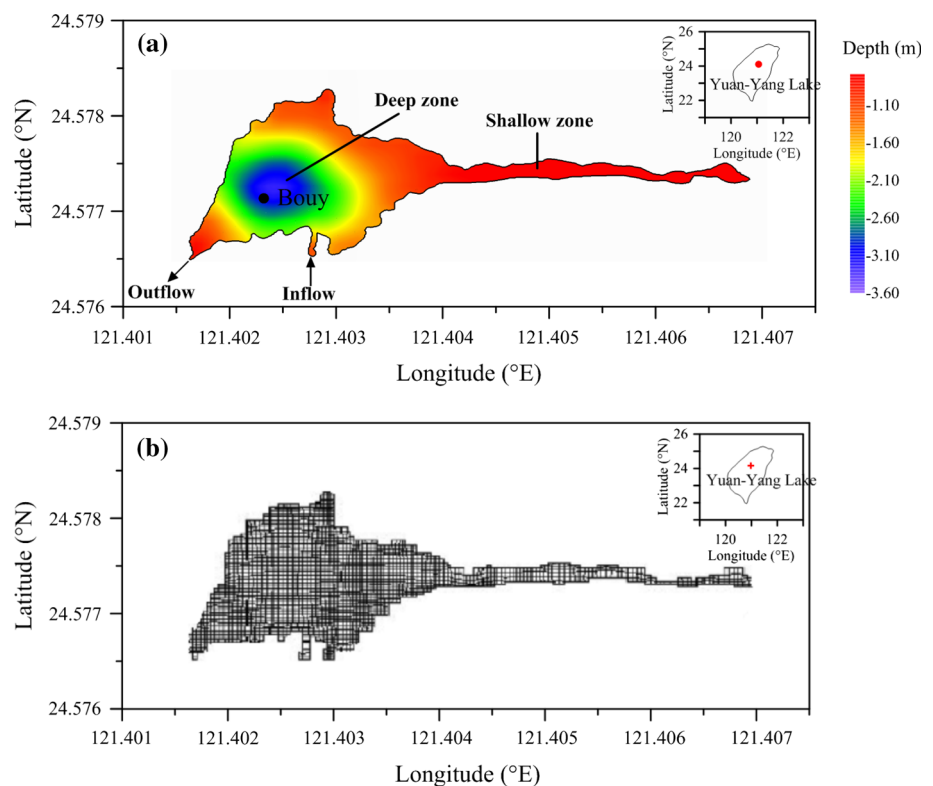
Three-dimensional models seem particularly appropriate, owing to the complex bathymetries in lakes, the

vertical gradients in water temperature, suspended sediment concentration, and density currents. In the present study, a three-dimensional real-time hydrodynamic and suspended sediment transport models were performed and applied to simulate the hydrodynamics and sediment dynamics in the Yuan-Yang lake. Model simulation was validated against profiles of water level and time-variation suspended solids in 2009. The validated model then was applied to find out the most sensitive parameter and the influence of wind-induced current on sediment dynamics.

### Characteristics of study site

Yuan-Yang lake (YYL) is in the north-central region of Taiwan (24°35'N, 121°24'E) (Fig. 1a). YYL is a small (3.6 ha), shallow (4.5 m maximum depth) lake in a mountainous catchment 1730 m above sea level. Figure 1a shows the bathymetry of YYL. The lake and surrounding catchment (374 ha) were designated as a long-term ecological study site by the Taiwan National Science Council in 1992, and it became part of the global lake ecological observatory network (GLEON) in 2004. The steep watersheds are dominated by pristine Taiwan false cypress [*Chamaecyparis obtusa* Sieb. and Zucc. var. *formosana* (Hayata) Rehder] forests. The average annual temperature is approximately 13 °C (the monthly average ranges from −5 to 15 °C), and the annual precipitation is more than

**Fig. 1** **a** Map of the Yuan-Yang lake (YYL) in the north-central region of Taiwan and **b** horizontal grid of YYL for three-dimensional hydrodynamic and suspended sediment transport model



4000 mm. YYL is subject to 3–7 typhoons in the summer and autumn each year, during which more than 1700 mm of precipitation may fall on the lake. The water column is stratified from early April to October. Stratification begins when the surface water temperature exceeded 11 °C, and it persists until the temperature falls below approximately 13 °C. The water column is usually completely mixed in the winter and is associated with intensive rainfall during the typhoon season (Kimura et al. 2012, 2014). The mean discharge and suspended sediment concentration are 0.80 m<sup>3</sup>/s and 7.0 mg/L at the inflow location, respectively, while they are 0.72 m<sup>3</sup>/s and 6.98 mg/L at the outflow location. Figure 2 shows the spatial distributions of suspended sediment concentration on June 13 and November 14, 2009. It can be seen that the suspended sediment concentration is low during autumn season and is slightly high during summer season. According to the sieve analysis of bottom sediment, the bottom sediment type can be attributed between fine sand and silt (Tsai et al. 2008).

transport, and biogeochemical processes in surface water system (Hamrick 1992; Hamrick and Wu 1997). The EFDC model solves the three-dimensional, vertical hydrostatic, free surface, turbulent averaged equations of motions for a variable density fluid. Dynamically coupled transport equations for turbulent kinetic energy, turbulent length scale, salinity, and temperature are also solved. The two turbulence parameter transport equations implement the Mellor–Yamada level 2.5 turbulence closure scheme (Mellor and Yamada 1982; Galperin et al. 1988). The EFDC model used a sigma vertical coordinate and curvilinear and orthogonal horizontal coordinates.

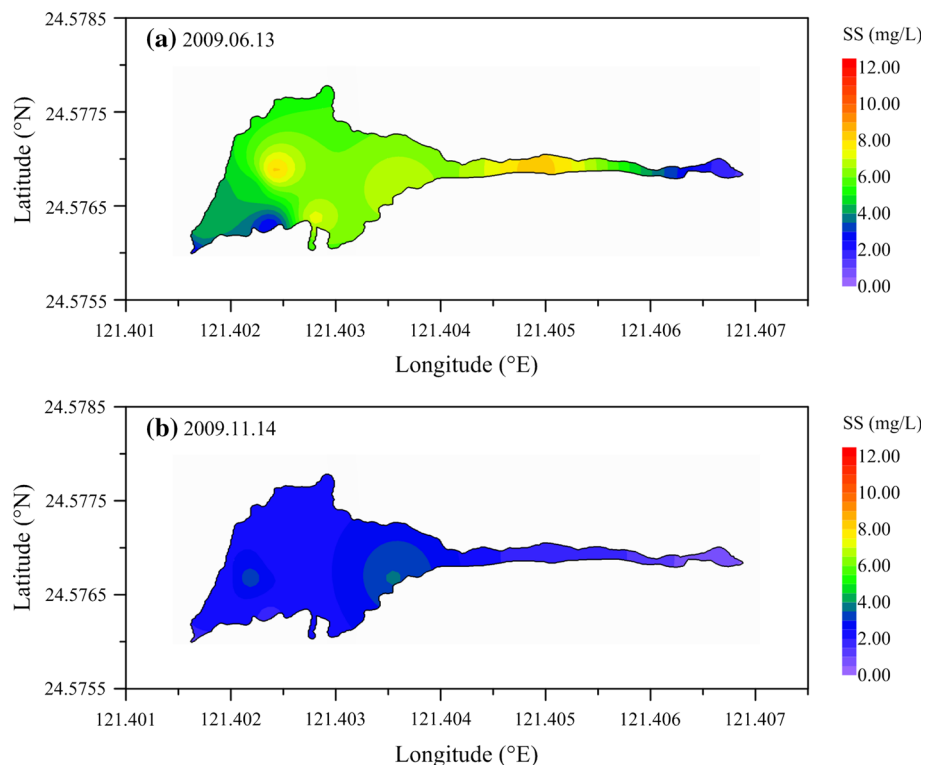
The numerical scheme adopted in EFDC model to solve the equation of motion uses second-order accurate spatial finite difference on a staggered or C grid. The model’s time integration uses a second-order accurate three-time level finite difference scheme with an internal–external mode splitting procedure to separate the internal shear or baroclinic mode from the external or barotropic model. The external mode solution is semi-implicit and simultaneously computes the two-dimensional surface elevation field by a preconditioned conjugate gradient procedure. The external solution is completed by the calculation of the depth average barotropic velocities using the new surface elevation field. The semi-implicit external solution allows large time steps that are constrained by the stability criteria of the explicit central difference or high-order upwind advective scheme used for the nonlinear accelerations

## Model description

### Hydrodynamic model

The model developed in this study is based on the environmental fluid dynamics code (EFDC), a public domain modeling package for simulating three-dimensional flow,

**Fig. 2** The spatial distribution of suspended sediment concentration on **a** June 13, 2009 and **b** November 14, 2009



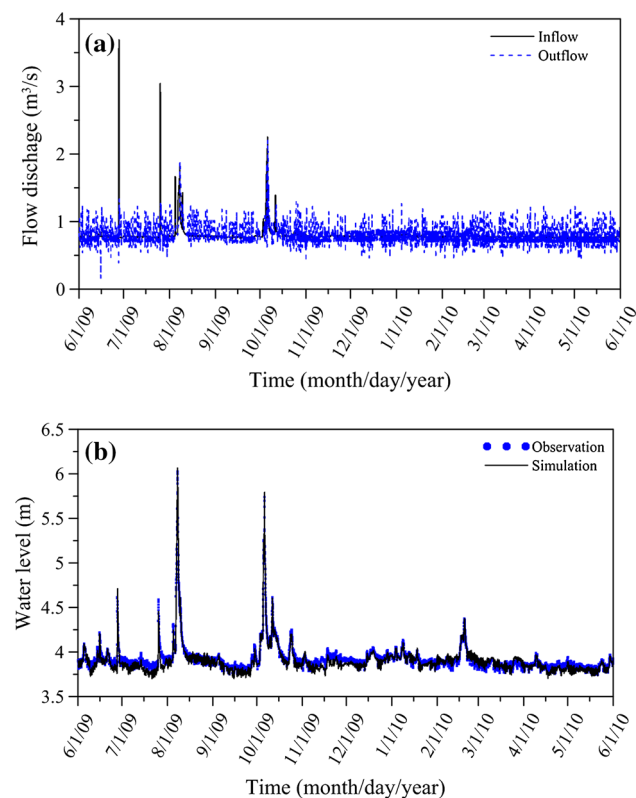
(Smolarkiewicz and Grabowski 1990; Smolarkiewicz and Margolin 1993). The EFDC model's internal momentum equation solution at the same time step as the external is implicit with respect to vertical diffusion. Time splitting inherent in the three-time level scheme is controlled by periodic insertion of a second-order accurate two-time trapezoidal step. Detailed description of the hydrodynamic equations and numerical scheme of the EFDC model can be found in Hamrick (1992) and Hamrick and Wu (1997).

### Suspended sediment transport model

The transport of suspended sediment in water column is described by the three-dimensional advective-diffusion equation:

$$\begin{aligned} \partial_t(\text{HC}) + \partial_x(\text{Hu}C) + \partial_y(\text{Hv}C) + \partial_z((w - w_s)C) \\ = \partial_x(\text{HK}_H\partial_x C) + \partial_y(\text{HK}_H\partial_y C) + \partial_z\left(\frac{K_v}{H}\partial_z C\right) + \text{HR}_s \end{aligned} \quad (1)$$

where  $H$  is the water depth;  $C$  is the sediment concentration;  $u$  and  $v$  are the horizontal velocity components in Cartesian horizontal coordinates  $x$  and  $y$ , respectively;  $w$  is the vertical velocity in the stretched vertical coordinate;  $w_s$  is the positive settling velocity of the sediment;  $z$  is the



**Fig. 3** **a** Time-series inflow and outflow discharges from June 1, 2009 to May 31, 2010 and **b** comparison of water level between model prediction and observation

sigma stretched vertical coordinate;  $K_H$  and  $K_v$  are the horizontal and vertical turbulent diffusivity coefficients; and  $R_s$  represents internal sources and sinks.

Vertical boundary conditions for Eq. (1) are:

$$-w_s C - K_v H^{-1} \partial_z C = 0; \quad z = 1 \quad (2)$$

at the free surface,  $z = 1$ , and

$$-w_s C - K_v H^{-1} \partial_z C = J_b; \quad z = 0 \quad (3)$$

or

$$C = C_b; \quad z = 0 \quad (4)$$

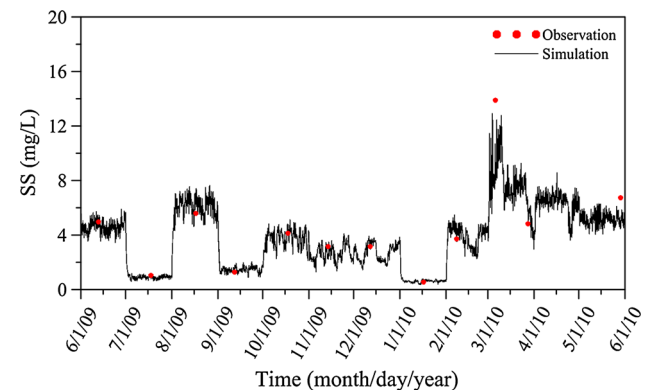
at the water column–sediment bed interface,  $z = 0$ , where  $J_b$  is the net flux of sediment ( $J_b = J_r - J_d$ ), either upward or downward, between the water column and the sediment bed; and  $C_b$  is the suspended sediment concentration at the bed in the column. The subscript b indicated evaluation at the bed in water column phase.

Water column–sediment bed exchange of suspended sediments and organic solids is controlled by the near-bed flow environment and the geomechanics of the deposited bed (Ziegler and Nisbet 1994, 1995; Liu et al. 2009). The deposition flux is

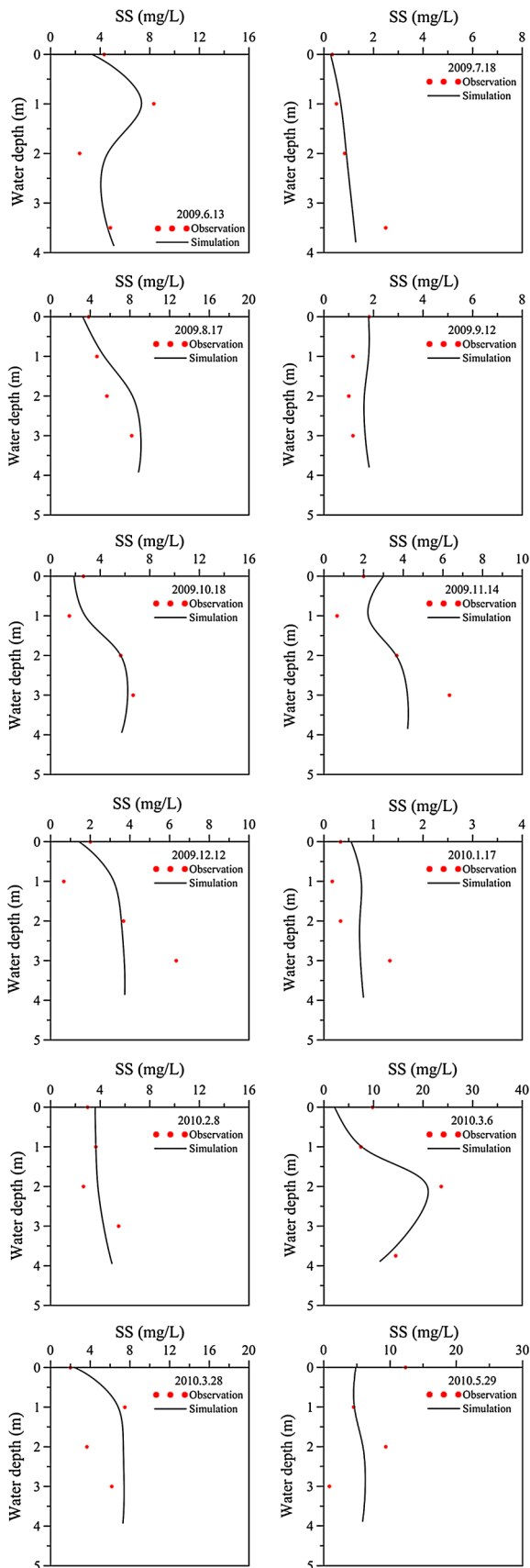
$$\begin{aligned} J_d = -w_s C_b \left( \frac{\tau_{dc} - \tau_b}{\tau_{dc}} \right) \quad \text{for } \tau_{dc} > \tau_b, \\ J_d = 0 \quad \text{for } \tau_{dc} \leq \tau_b \end{aligned} \quad (5)$$

where  $C_b$  is the sediment concentration near the bed;  $\tau_b$  is the bed stress or stress exerted by the flow on the bed ( $\tau_b = C_D |u_b| u_b$ ,  $C_D$  is the drag coefficient and  $u_b$  is the bottom velocity); and  $\tau_{dc}$  is the critical stress for deposition that depended on sediment material and floc physiochemical properties (Mehta et al. 1989). When the bed shear stress is larger than the critical deposition value, deposition ceases.

The bed erosion is the surface erosion, which is generally expressed as the following form:



**Fig. 4** The comparison of model-predicted and measured suspended sediment concentration at the buoy station from June 1, 2009 to May 31, 2010



◀**Fig. 5** Comparison of vertical suspended sediment profiles between model simulation and observation at the buoy station in 2009 and 2010

**Table 1** Statistical error between simulated and measured suspended sediment concentrations

Year/month/date	AME (mg/L)	RMSE (mg/L)
2009/6/13	1.13	1.34
2009/7/18	0.38	0.62
2009/8/17	1.16	1.42
2009/9/12	0.49	0.55
2009/10/18	0.75	0.88
2009/11/14	1.18	1.40
2009/12/12	1.45	1.83
2010/1/17	0.43	0.46
2010/2/8	0.58	0.70
2010/3/6	3.45	4.39
2010/3/28	1.47	1.96
2010/5/29	4.02	4.83

$$J_r = M \left( \frac{\tau_b - \tau_{ec}}{\tau_{ec}} \right)^\alpha \quad \text{for } \tau_b > \tau_{ec}, \tag{6}$$

$$J_r = 0 \quad \text{for } \tau_b \leq \tau_{ec}$$

where  $\tau_{ec}$  is the critical stress for surface erosion or resuspension;  $J_r$  is the erosion flux;  $M$  is the surface erosion rate per unit surface area of the bed; and  $\alpha$  is the site-specific parameter and is set to 1.0 for YYL.

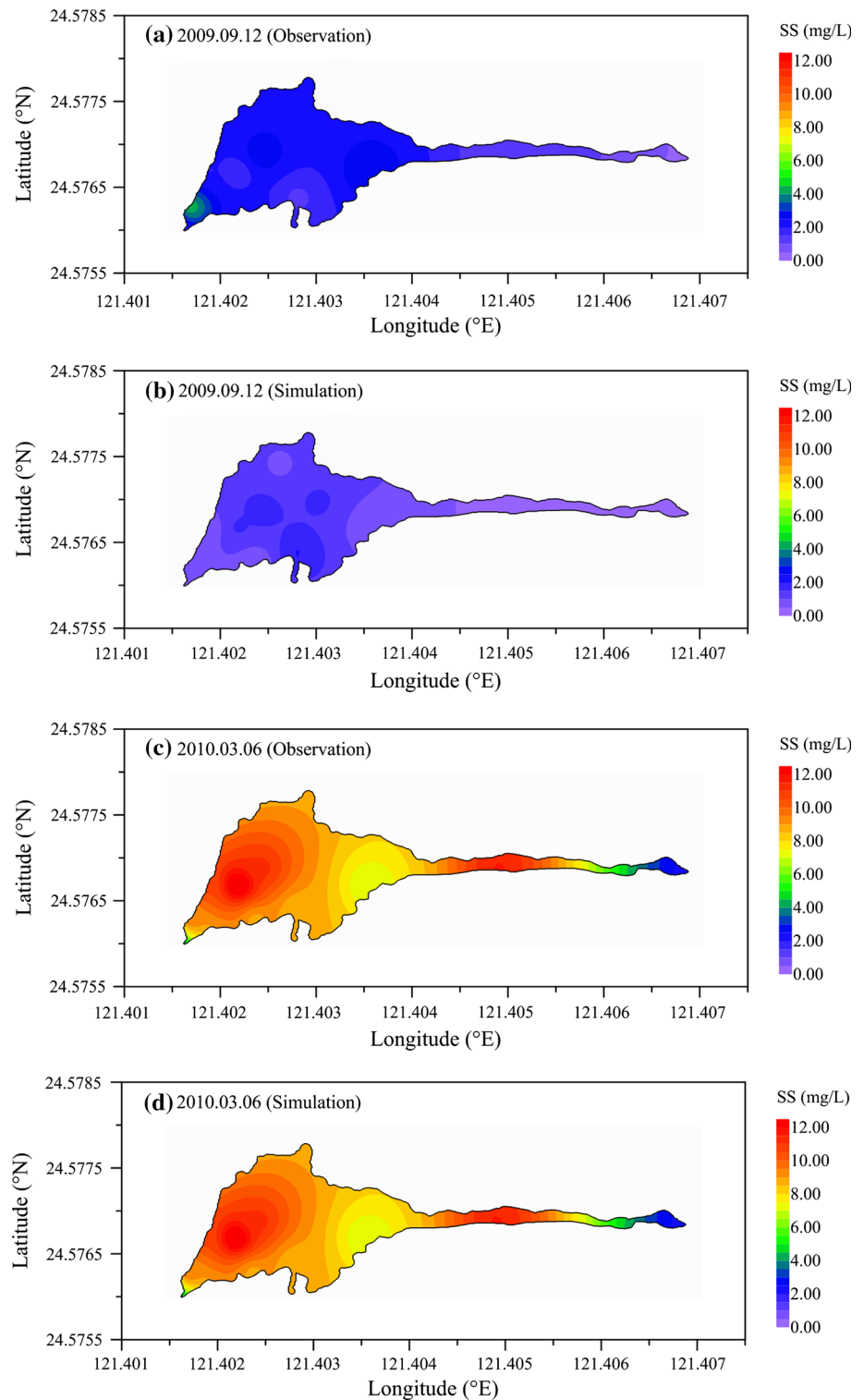
**Model implementation**

In this study, the bottom topography data in YYL, which were measured in August 2007, were obtained from the Academia Sinica, Taiwan. The greatest depth within the study area is 4.5 m near the buoy station (Fig. 1a). The structured model mesh for YYL consists of 700 grids in the horizontal direction (Fig. 1b). High solution grids, which include the grid size is 6 m × 7 m approximately, were used for YYL. It means that the grid sizes in the horizontal directions are not uniform. Model simulations were conducted using four layers in vertical direction. For this model grid, a large time step ( $\Delta t = 5$  s) was used in simulations with no sign of numerical instability.

**Model validation**

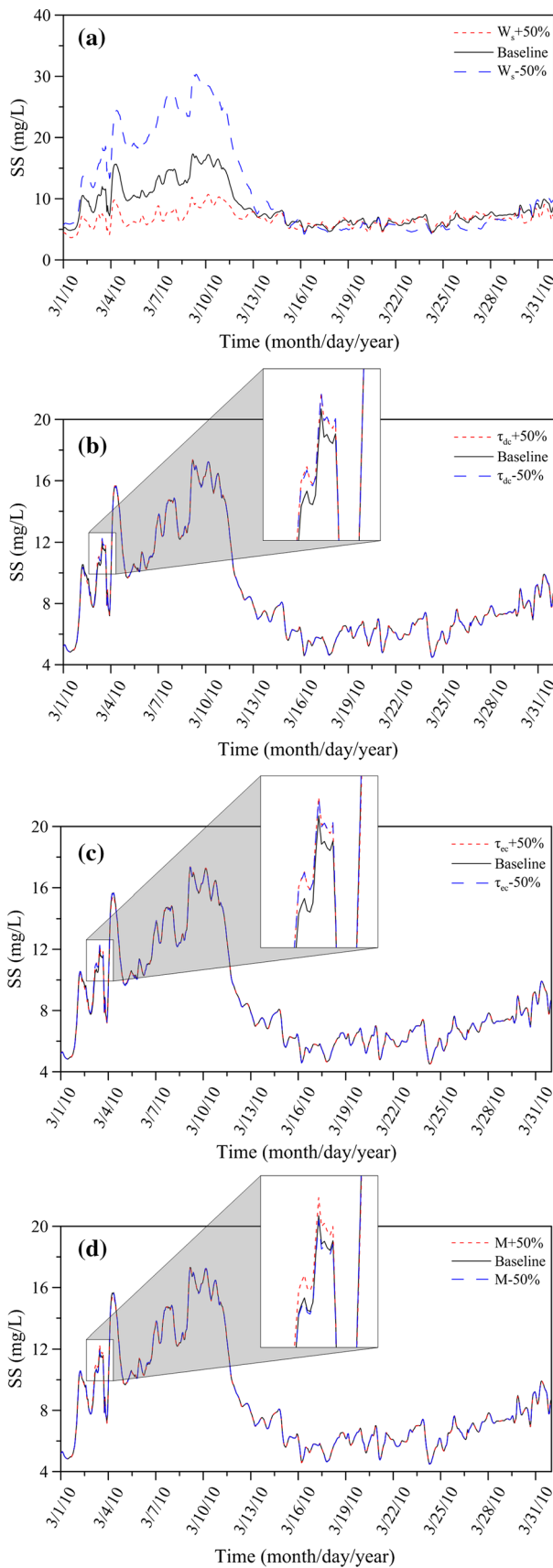
To ascertain the model accuracy for practical applications, the observational data are used to validate the model and to verify its capability for predicting water level and total

**Fig. 6** Comparison of spatial distributions of vertically averaged suspended sediment concentration between model simulation and observation on September 12, 2009 and March 6, 2010. **a, b** show the observation and simulation on September 12, 2009. **c, d** present the observation and simulation on March 6, 2010



suspended sediment in this study. The observational data collected from June 1, 2009 to May 31, 2010 were used for model validation. To warm up the model, the spin-up time is specified 15 days, therefore the model was run from May

17, 2009 to May 31, 2010. The initial conditions for water level and suspended sediment concentration are specified as 3.6 m and 4.0 mg/L, respectively, to start up running the hydrodynamic and suspended sediment transport model.



◀**Fig. 7** Model sensitivity for the **a** settling velocity ( $w_s$ ), **b** critical stress for erosion ( $\tau_{ec}$ ), **c** critical stress for deposition ( $\tau_{dc}$ ), and empirical erosion rate constant ( $M$ )

### Water level

The model validation of water level was conducted with daily discharge at the inflow and outflow in the lake (shown in Fig. 1a). Figure 3a presents the time-series inflow and outflow discharges. It indicates that several peak discharges occurred at the inflow due to the typhoon events. The observed water levels in the YYL from June 1, 2009 to May 31, 2010 were used to compare with model prediction shown in Fig. 3b.

Good model performance is indicated by the calculated absolute mean error (AME), root-mean-square error (RMSE) (e.g., Thomann and Mueller 1987) and skill score (SS) (Murphy 1988). AME is the average of the absolute values of differences between observed data and simulated values. RMSE basically specifies the overall difference in the sum of squares normalized to the number of observations. RMSE is similar to a standard error of the mean for the model’s uncertainty. SS is the ratio of root-mean-square error normalized by the standard deviation of the observation. Perfect agreement between model results and observations will yield a skill of one and complete disagreement yields a skill of zero. Model skill is evaluated for all prognostic quantities. The AME, RMSE, and SS between computed and observed water surface elevation are 0.037, 0.048 m, and 0.92, respectively. It reveals that the simulated results mimic the observed water levels. Based on the model validation, the roughness height was set to be 0.008 m for model simulation.

### Suspended sediment modeling

Together with settling velocity ( $w_s$ ), the critical stress for erosion ( $\tau_{ec}$ ), deposition ( $\tau_{dc}$ ), and the empirical erosion rate ( $M$ ) are difficult parameters to be determined in the lakes since they have a wide range of value within any one region. This variation results from a dependence on density (consolidation) of the bed, which is affected by interactions with physical, biological, chemical, and sediment composition (Houwing and Rijn 1998; Liu 2005; Young and Ishiga 2014; Chen et al. 2015). In this study, the suspended sediment concentration model is conducted to determine these parameters.

To validate the suspended sediment concentration, the monthly measured data collected from June 2009 to May 2010 was used to compare with simulated results. The water sample was taken from water surface and every 1 m

below the water surface to measure concentration of suspended sediment. Concentrations of suspended sediment were determined using the drying method after filtering samples through GF/F filters (APHA 1995). Figure 4 shows the comparison of model simulated and measured suspended sediment concentrations taken with vertical average at the buoy station. It reveals that simulated results fairly match the measured suspended sediment concentration. The AME, RMSE, and SS between computed and measured suspended sediment concentrations are 0.71, 1.16 mg/L, and 0.88, respectively.

The vertical profiles of simulated and measured suspended sediment concentrations at the buoy station are shown in Fig. 5. It indicates that the model simulation results catch the measured suspended sediment concentrations in vertical profiles. Note that since only four layers are set in the model the smoothing spline is used to smooth the simulated suspended sediment concentration in vertical profile. Table 1 presents statistical errors between simulated and measured suspended sediment concentrations for each measured date. It shows that the statistical errors on March 6 and May 29, 2010 exhibit larger AME and RMSE values.

Figure 6 presents the comparison of spatial distribution of vertically averaged suspended sediment concentration between simulated and observed results on September 12, 2009 and March 6, 2010. It can be seen that the simulated and observed suspended sediment concentrations in spatial distribution are quite similar. Through the model runs, the constant values of  $4.0 \times 10^{-5}$  m/s for settling velocity ( $w_s$ ),  $0.1 \text{ N/m}^2$  for  $\tau_{ec}$ ,  $0.05 \text{ N/m}^2$  for  $\tau_{dc}$ , and  $9 \times 10^{-6} \text{ kg/m}^2 \text{ S}$  for  $M$  were chosen for the sediment transport model.

## Model applications and discussion

### Sensitivity analysis

A primary use of the validated model is sensitivity analysis, in order to examine the behavior of the prototype in response to any alterations made. Sensitivity analysis is a powerful tool that can be applied to improve the understanding of the present suspended sediment concentration in the YYL due to parameters changed. In this study, model sensitivity analysis was performed to explore the effects of settling velocity ( $w_s$ ), the critical stress for erosion ( $\tau_{ec}$ ), deposition ( $\tau_{dc}$ ), and the empirical erosion rate ( $M$ ) on suspended sediment concentration and to find out the most important parameter which affects the suspended sediment concentration in the YYL.

The original bases depend on the simulation of model validation from June 1, 2009 to May 31, 2010. The effect

**Table 2** Results of sensitivity run for different parameters

Parameter	Condition	Maximum rate of suspended sediment concentration (%)
Settling velocity ( $w_s$ )	$w_s + 50 \%$	-46.94
	$w_s - 50 \%$	114.80
Critical stress for erosion ( $\tau_{ec}$ )	$\tau_{ec} + 50 \%$	-12.8
	$\tau_{ec} - 50 \%$	58.1
Critical stress for deposition ( $\tau_{dc}$ )	$\tau_{dc} + 50 \%$	6.08
	$\tau_{dc} - 50 \%$	-4.34
Erosion rate ( $M$ )	$M + 50 \%$	7.52
	$M - 50 \%$	-7.90

Minus and plus represent decreasing and increasing suspended sediment concentrations, respectively

of these parameters on suspended sediment concentration was investigated with two alternative cases; one involves the value of model validation plus 50 % and the other involves the value of model validation minus 50 %. Figure 7 presents the model sensitivity results for four parameters during March 2010. This figure indicates that the settling velocity would be the most important parameter to affect the suspended sediment concentration. Table 2 summarizes the sensitivity results. It shows that an increase in settling velocity results in a decrease in the suspended sediment concentration. The maximum rates for decreasing and increasing suspended sediment concentration are 44.94 and 114.80 %, respectively. The maximum rate (MR) means that the maximum values were determined by the formula represented by

$$\text{MR} = \frac{C_{\text{base}} - C_{\text{sens}}}{C_{\text{base}}} \times 100 \%, \quad (7)$$

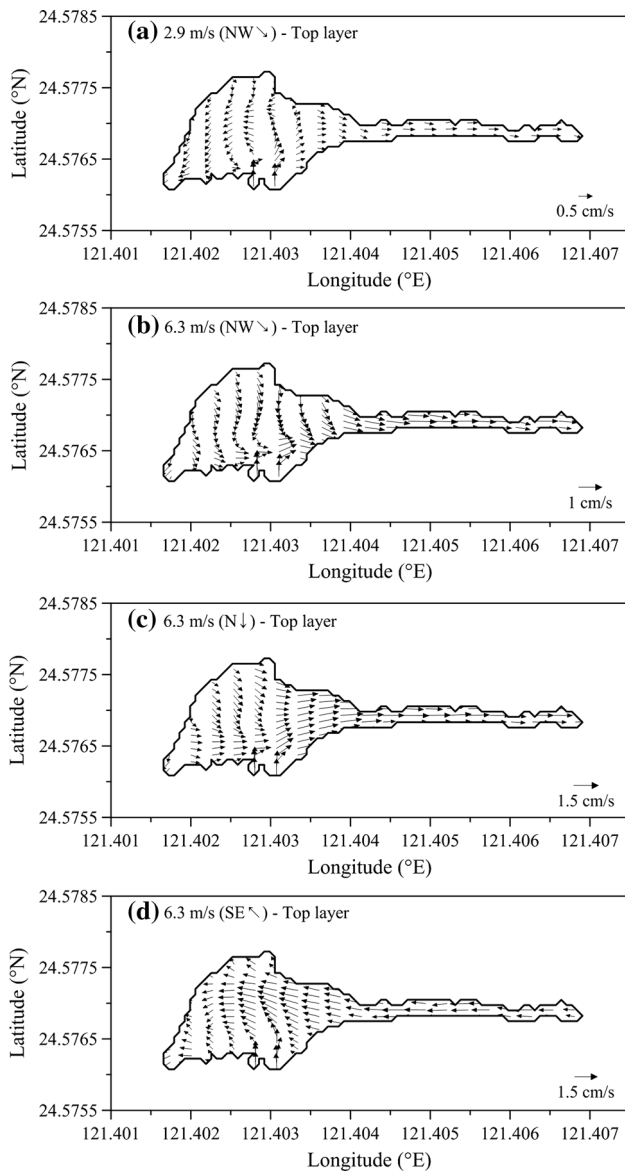
where  $C_{\text{base}}$  is the suspended sediment concentration for the base runs, shown in Fig. 4 and  $C_{\text{sens}}$  is the suspended sediment concentration for the sensitivity run shown in Fig. 7.

Lee et al. (2005) developed a one-dimensional resuspended and bed model to conduct model sensitivity to identify and compare quantitatively the important resuspension parameters in southern Lake Michigan. They found that the absolute magnitude of settling velocity was most crucial in controlling the suspended sediment concentration prediction. Their simulated results of sensitivity analysis were similar to the current study with a three-dimensional suspended sediment transport model.

### Effect of wind stress on current and suspended sediment

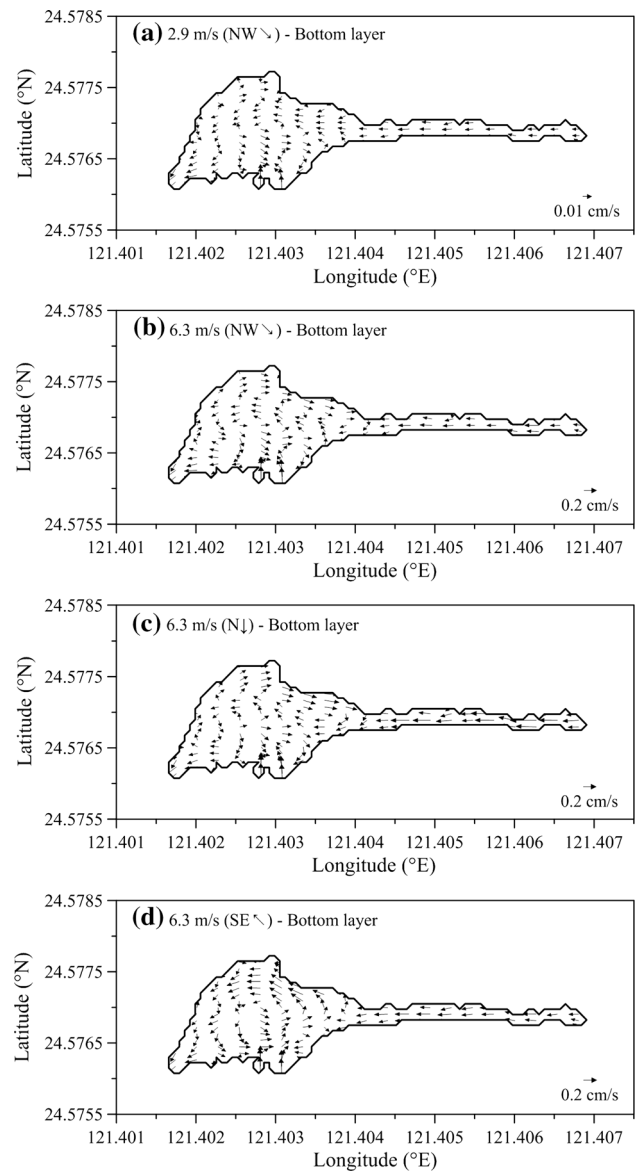
Wind blowing over the surface of shallow lakes can drive flows, surface waves, and sediment resuspension





**Fig. 8** Mean circulation at the *top* layer for different wind speeds and directions **a** northwest wind: 2.9 m/s, **b** northwest wind: 6.3 m/s, **c** north wind: 6.3 m/s, and **d** southeast wind: 6.3 m/s

(Kocyigit and Falconer 2004; Scheon et al. 2014). The mean circulation in the YYL would be one of the important factors responsible for the transport and distribution of suspended sediment within the lake. In order to examine how the suspended sediment could be distributed in the YYL, different wind speeds and directions including northwest wind: 2.9 m/s, northwest wind: 6.3 m/s, north wind: 6.3 m/s, and southeast wind: 6.3 m/s were used to drive the model simulation for yielding mean circulation and suspended sediment distribution. The wind speed and direction which are 2.9 m/s and northwest wind on June 13, 2009 were selected as baseline. The maximum wind speed is 6.3 m/s during the

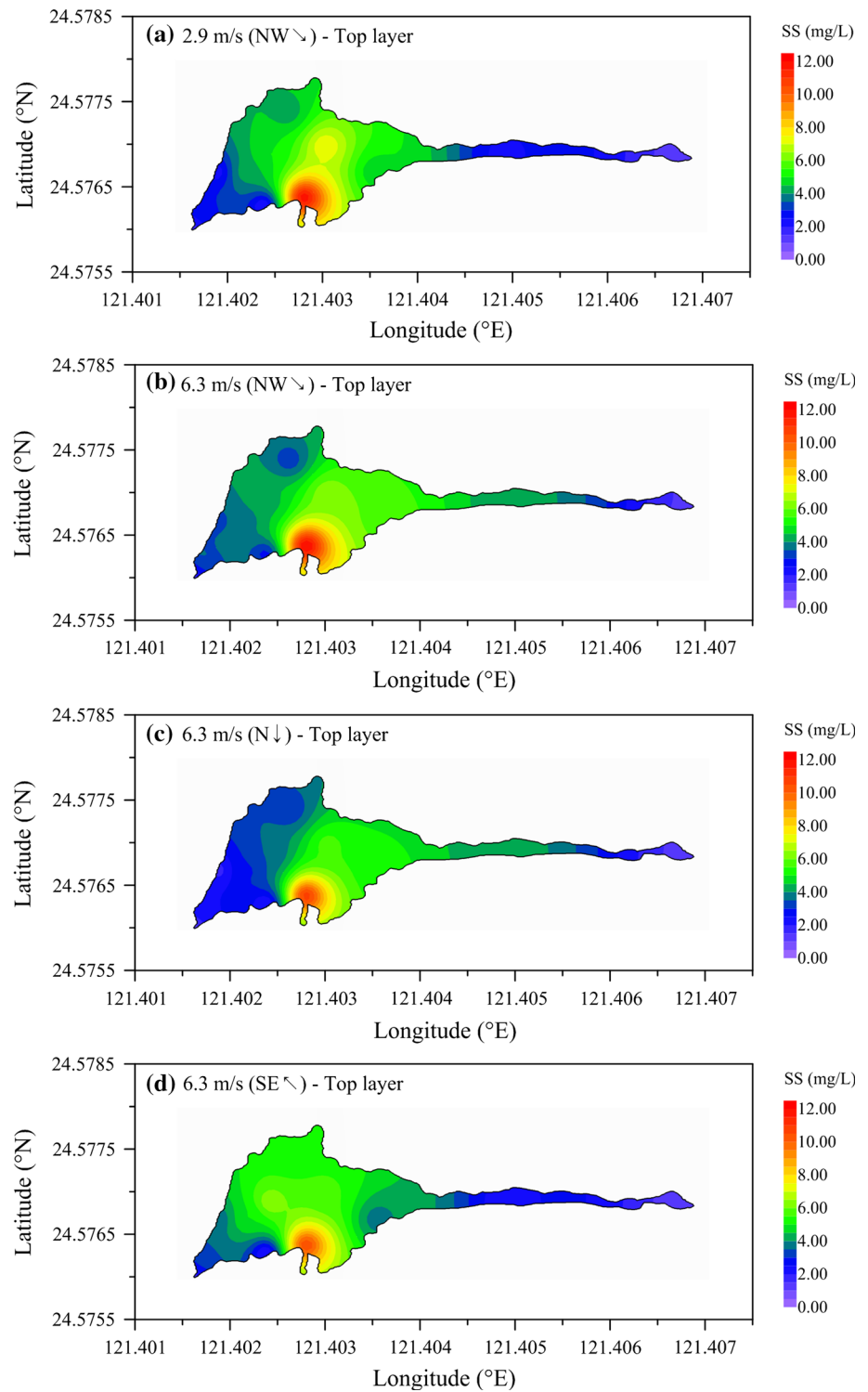


**Fig. 9** Mean circulation at the *bottom* layer for different wind speeds and directions **a** northwest wind: 2.9 m/s, **b** northwest wind: 6.3 m/s, **c** north wind: 6.3 m/s, and **d** southeast wind: 6.3 m/s

model validation period and prevailing wind directions are northwest, north, and southwest adopted for model simulations to compare with the baseline condition.

Figures 8 and 9 present the mean current at the top and bottom layers, respectively, for baseline condition and for different wind speeds and directions. They show that the bottom currents are in opposite direction as surface currents due to return flows. The bottom currents are smaller than surface currents. No remarkable cyclonic and anticyclonic circular gyres were found in the lake through the simulated mean currents. The mean surface currents between 0.012 and 4.0 cm/s, while the mean bottom currents between 0.002 and 2.0 cm/s.

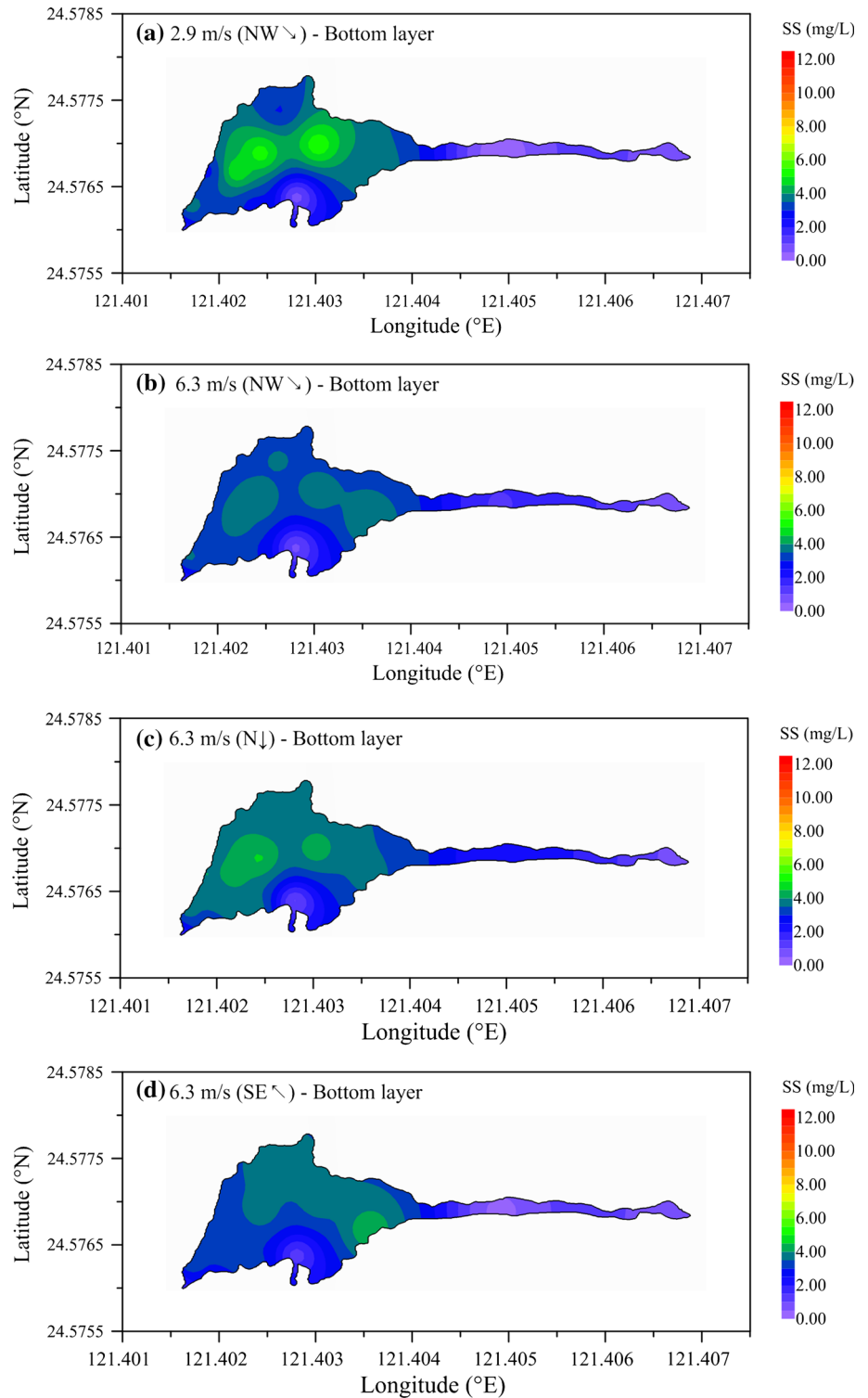
**Fig. 10** The distribution of mean suspended sediment concentration at the *top* layer for different wind speeds and directions **a** northwest wind: 2.9 m/s, **b** northwest wind: 6.3 m/s, **c** north wind: 6.3 m/s, and **d** southeast wind: 6.3 m/s



Figures 10 and 11 show the distributions of suspended sediment concentration at the top and bottom layers, respectively, for baseline condition and for different wind speeds and directions. They indicate that the distributions of suspended sediment concentration are obviously different depended on the wind speed and direction. The bottom

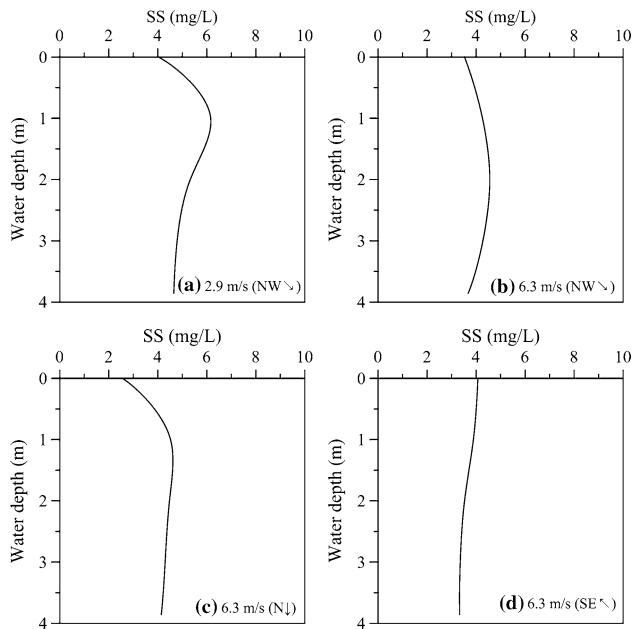
suspended sediment concentrations are slightly smaller than surface suspended sediment concentrations. It may be the reason that the deposition flux ( $J_d$ ) is higher than the resuspension flux ( $J_r$ ) during strong wind. It means that net flux of sediment ( $J_b = J_r - J_d$ ) between the water column and the sediment bed becomes downward (sink). The

**Fig. 11** The distribution of mean suspended sediment concentration at the *bottom* layer for different wind speeds and directions **a** northwest wind: 2.9 m/s, **b** northwest wind: 6.3 m/s, **c** north wind: 6.3 m/s, and **d** southeast wind: 6.3 m/s



highest concentration exhibits at the inlet, while the lowest concentration appears at the outlet and shallow zone of the YYL. The mean surface concentrations are between 0.01 and 12.5 mg/L, while the mean bottom concentrations are between 0.005 and 5.3 mg/L. We found that the spatial distribution of suspended sediment concentration was

subject to wind stress. Figure 12 illustrates the simulated results of vertical suspended sediment profile at the buoy station under different wind speeds and directions. It shows that the suspended sediment concentrations in vertical direction are homogenous under northwest wind and southeast wind of 6.3 m/s, while there was slight



**Fig. 12** Vertical suspended sediment profiles at the buoy station under different wind speeds and directions

stratification under northwest wind of 2.9 m/s and north wind of 6.3 m/s. The different wind speeds and directions also produced different patterns in vertical suspended sediment profile. It implies that the water quality conditions in the lake may be affected by the wind stress. Jin and Ji (2004) reported that the wind-induced current and wind-induced resuspension on suspended sediment transport were important factors to affect the suspended sediment concentration in the Lake Okeechobee. In the current study, we also found that wind stress has significant influence on mean circulation and suspended sediment transport in a shallow lake.

## Conclusions

A three-dimensional hydrodynamic and suspended sediment transport model was implemented and applied to the Yuan-Yang lake (YYL) in the north-central region of Taiwan. The model was validated with observed water level and suspended sediment concentrations in 2009 and 2010. The predicted results quantitatively agreed with measured data in the lake.

The validated model was applied to comprehend the crucial factor which affects the suspended sediment distribution in the lake. The sensitivity analysis indicates that the settling velocity is the most important parameter to influence the suspended sediment concentration. The model was also used to probe the mean current and suspended sediment distribution in the YYL. Wind speed and direction are the

dominant factors to drive the current patterns. The simulated results reveal that the bottom currents are in opposite direction as surface currents due to return flows. The distributions of suspended sediment concentration are obviously different depending on the wind speed and direction. Strong wind speeds result in high mean currents and suspended sediment concentrations due to the effect of resuspension.

It should be noted that the description of the sedimentary processes remains still empiric and a subject on which conceptual progress is still required. More sophisticated sediment transport models are still in development for the better understanding of sand-mud transport. Great efforts concerning interdisciplinary approaches as well as extensive and intensive field work are needed to improve the knowledge of the lake functioning. More data will be crucial to improve the validation of numerical models.

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