Yale

耶鲁大学-南京信息工程大学大气环境中心
Yale-NUIST Center on Atmospheric Environment

Application of E-ε turbulent kinetic energy closure thermodynamic process lake model in the East Taihu Lake

Xin Cheng

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Outline

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2. Method

3. Results

4. Conclusion

Background

- Submersed macrophytes can influence biological and physical characteristics, the East Taihu Lake is submersed macrophyte zone.

- The E-ε turbulent kinetic energy closure thermodynamic process lake model is formulated on the basis of a one-dimensional equation for turbulent kinetic energy coupled with a vertical heat transfer equation, which is applied to simulate vertical turbulent diffusion and stratification in a shallow lake with submersed macrophytes.

- The goal of the study is to evaluate the E-ε turbulent kinetic energy closure thermodynamic process lake model using the data obtained from Lake Taihu, simulating the water temperature and dynamics of vertical mixing.

Method

•Data

Site: BFG; Time: August, 2013

Data sources: micrometeorology system, temperature probes, eddy covariance system

•Model

E-ε turbulent kinetic energy closure lake model

A one-dimensional heat transfer equation

$$\frac{\partial T}{\partial t} = \frac{\partial}{\partial z}\left(K_z \frac{\partial T}{\partial z}\right) + \frac{H}{\rho c_p}$$

$$H(z) = (1-\alpha_l)(1-\beta) I_s \exp(-(K_{wc} + K_m p) z)$$

K_m: the specific light attenuation coefficient for macrophyte， P: the plant mass per unit volume

An equation for production, diffusion and dissipation of turbulent kinetic energy

$$\frac{\partial E}{\partial t} = \frac{\partial}{\partial z}\left(K_z \frac{\partial E}{\partial z}\right) + K_z \alpha g \frac{\partial T}{\partial z} - \varepsilon$$

$$\varepsilon = \hat{a} C_D E^{3/2} \qquad \hat{a} = 0.05 p$$

ε: dissipation $\hat{a}$: the plant surface area per unit volume P: the plant mass per unit volume

The CLM4-LISSS (Community Land Model version 4-Lake, Ice, Snow and Sediment Simulator) model

Results

✓ The observation data analysis

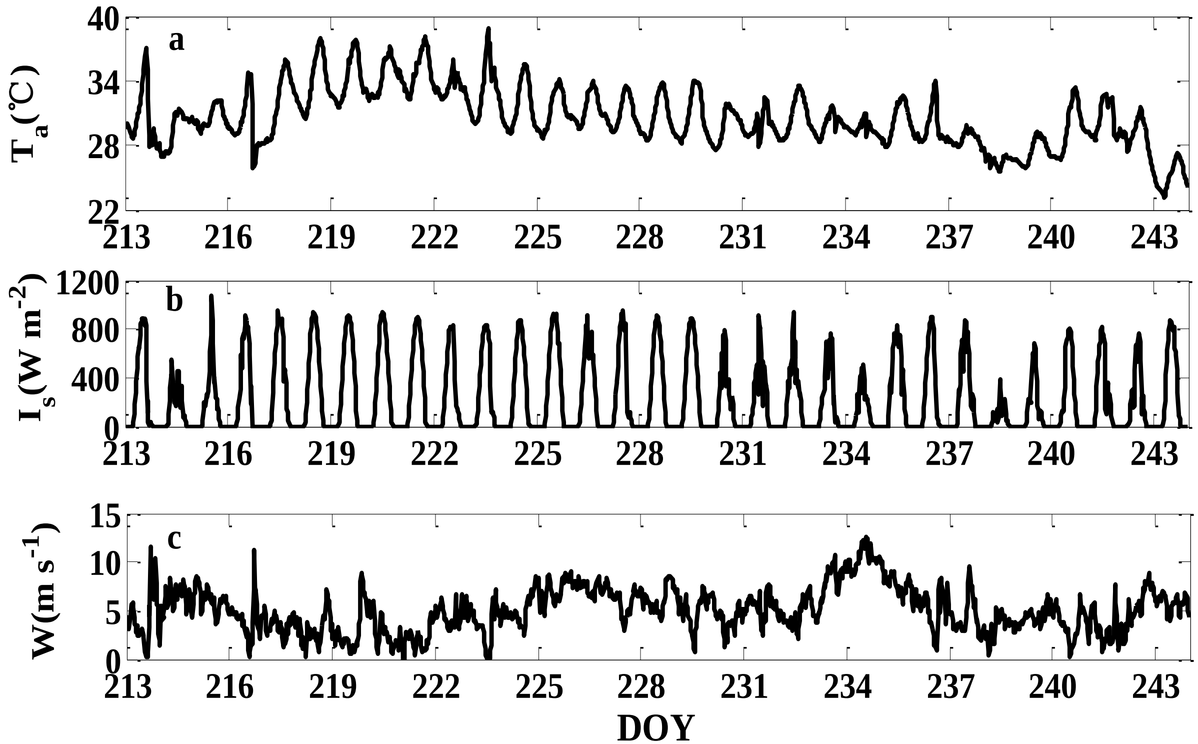
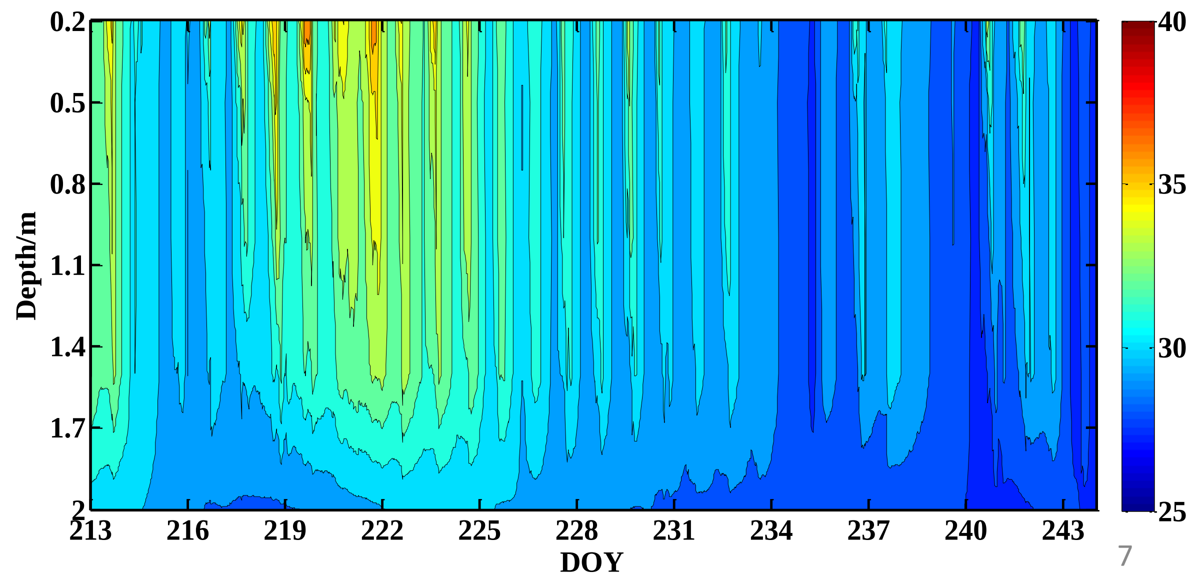


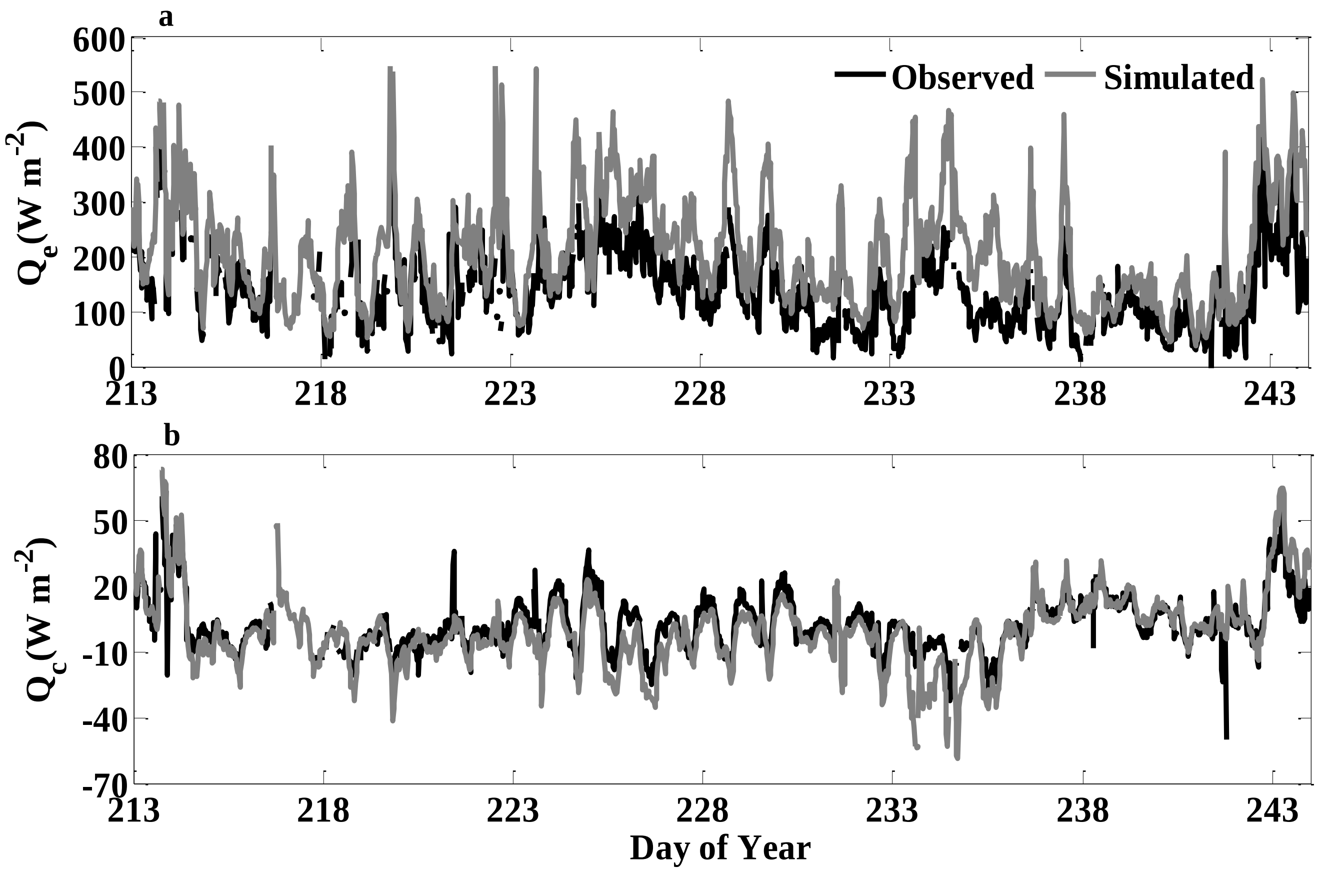
Figure 1. (a) air temperature, (b) downward shortwave radiation and (c) wind speed over Lake Taihu, in August 2013

Figure 2. the observed water temperature in August 2013



✓ The simulation of the E-ε turbulent kinetic energy closure lake model

The heat flux



R 0.82
RMSE 54.72 W m^{-2}

R 0.86
RMSE 8.41 W m^{-2}

Figure 3. Comparison of simulated and observed surface energy fluxes in Lake Taihu (a) the latent heat flux (b) the sensible heat fux, in August 2013

Water temperature

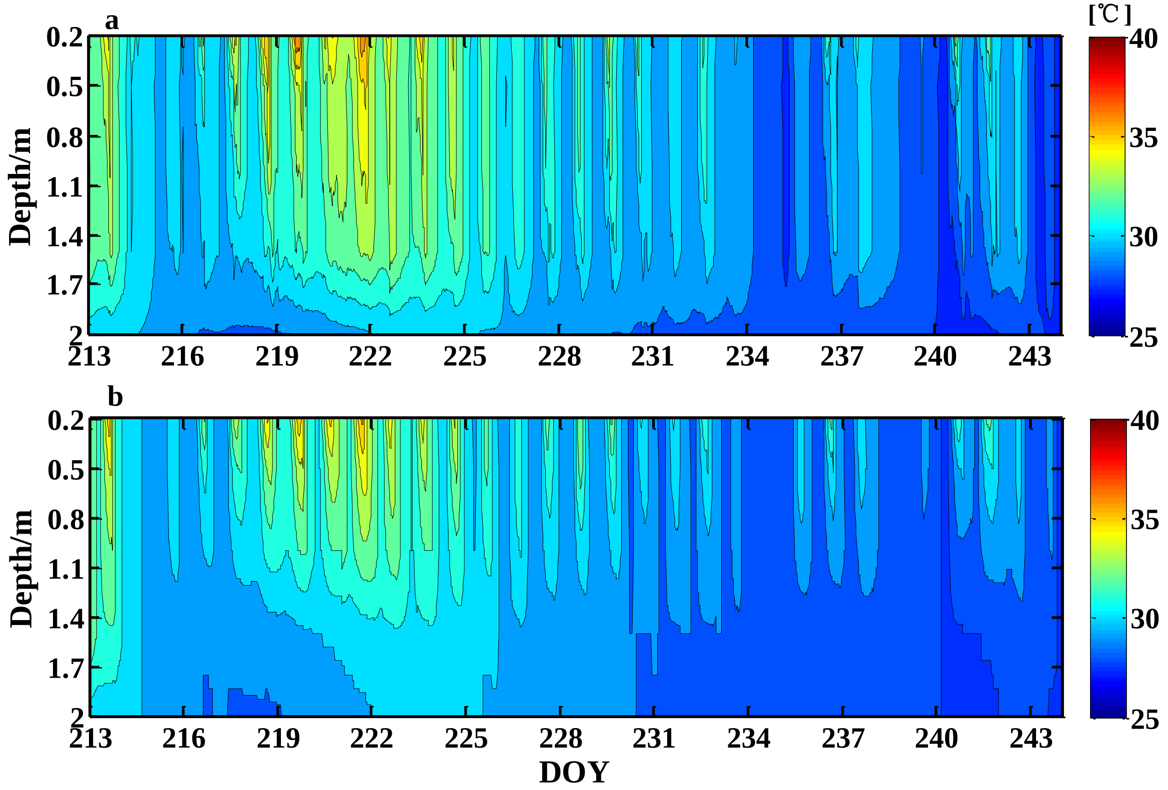


Figure 4. Comparison of simulated and observed Lake Taihu water temperature: (a) observed water temperature (b) simulated water temperature, in August 2013

Turbulent kinetic energy

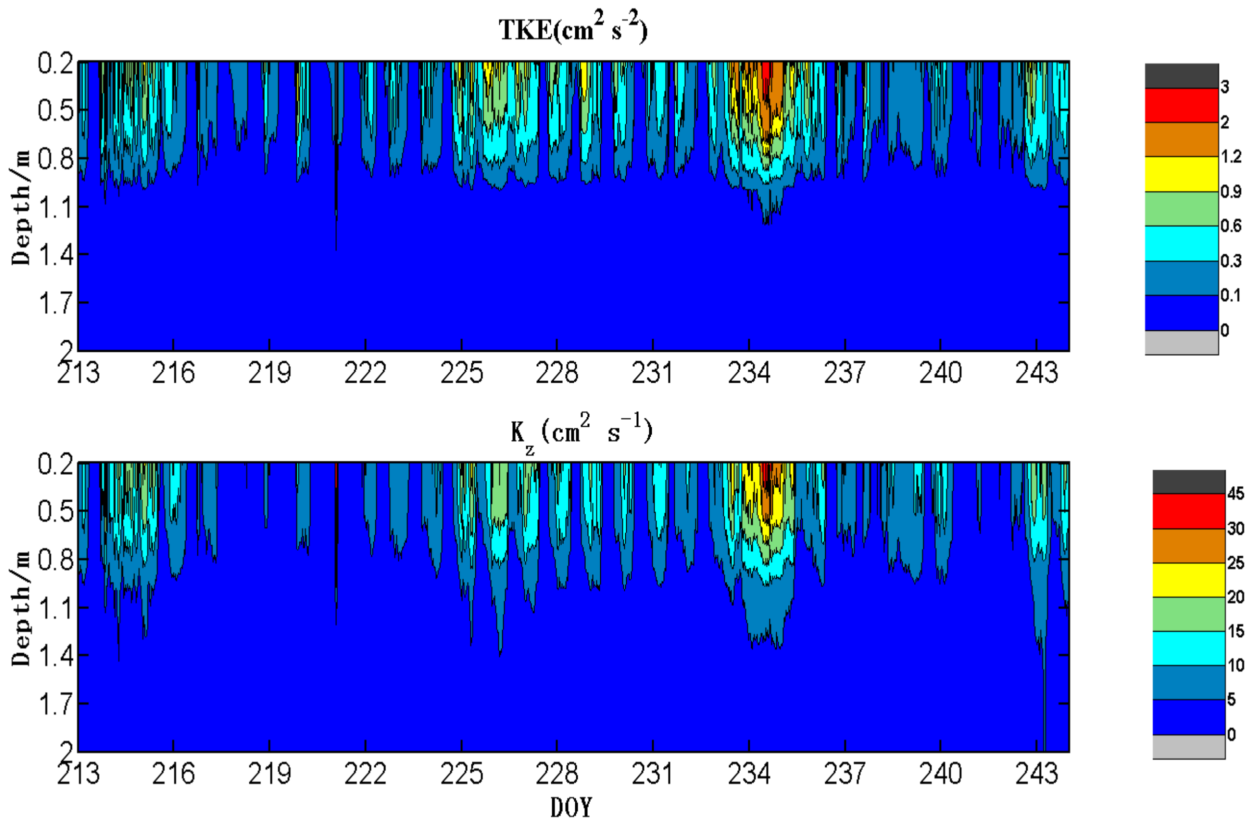


Figure 5. Simulated turbulent kinetic energy and turbulent diffusivity in August 2013: turbulent kinetic energy (above) turbulent diffusivity (below)

The effect of weather condition

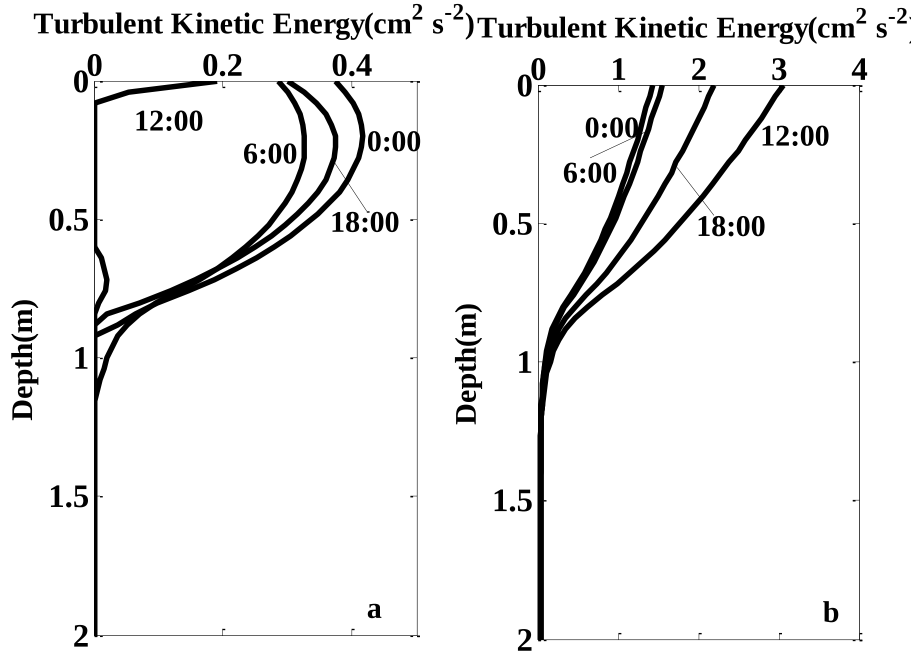


Figure 6. Turbulent kinetic energy profiles on (a) August 10 (b) August 22

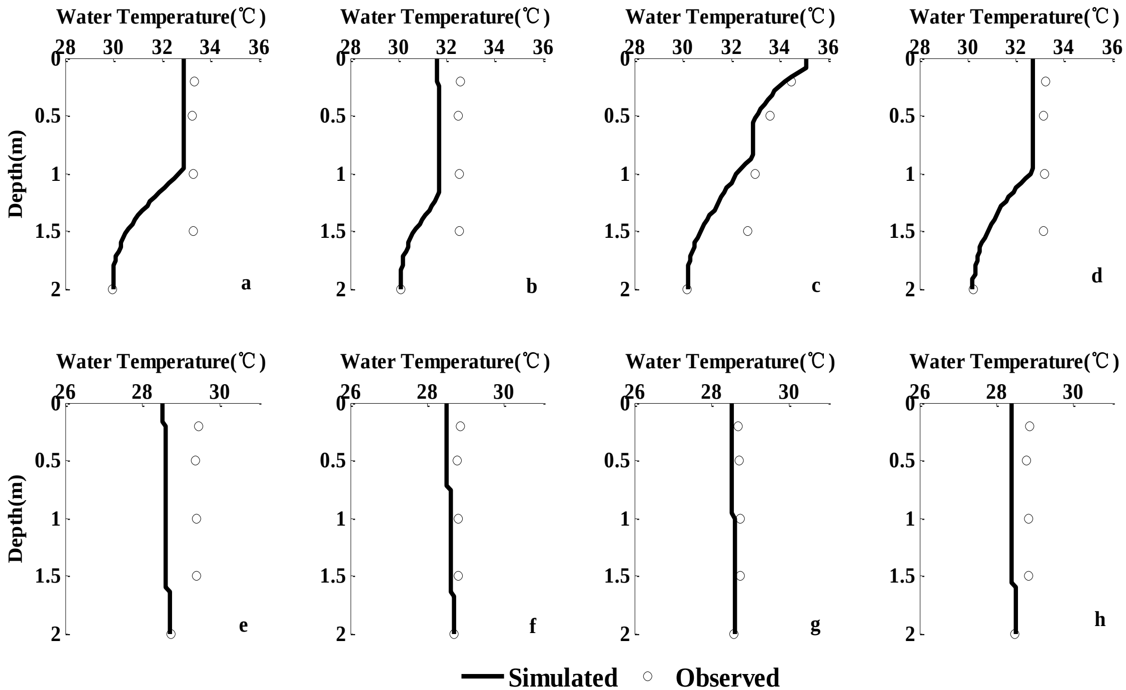


Figure 7. Comparison of the water temperature profiles at (a) 00: 00, August 10 (b) 06: 00, August 10 (c)12: 00, August 10 (d) 18: 00, August 10 (e) 00: 00, August 22 (f) 06: 00, August 22 (g) 12: 00, August 22 (h) 18: 00, August 22

The effect of the submersed macrophyte

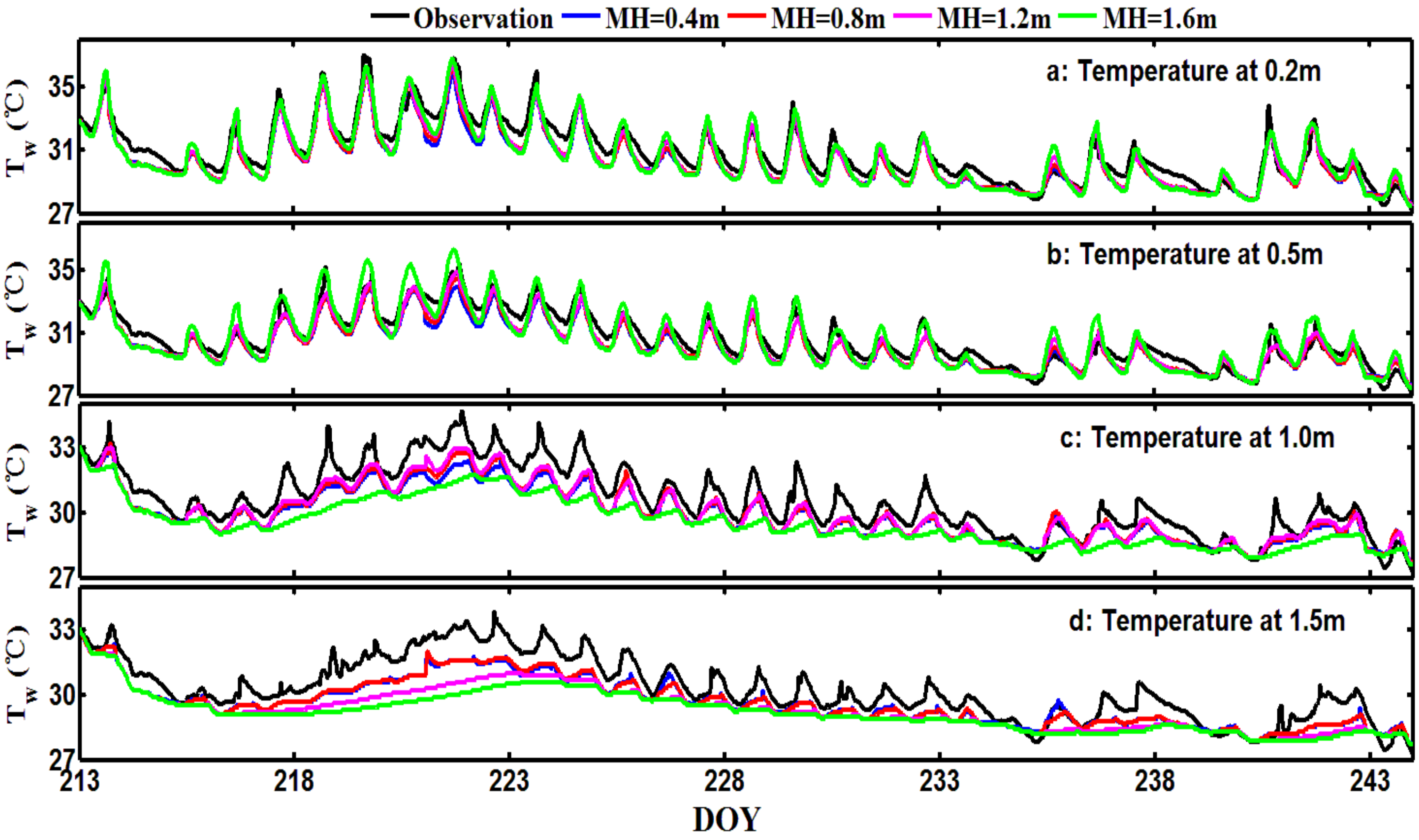


Figure 8. The effect of submersed macrophyte height on water temperature in different depth (a) 0.2m (b) 0.5m (c) 1.0m (d) 1.5m

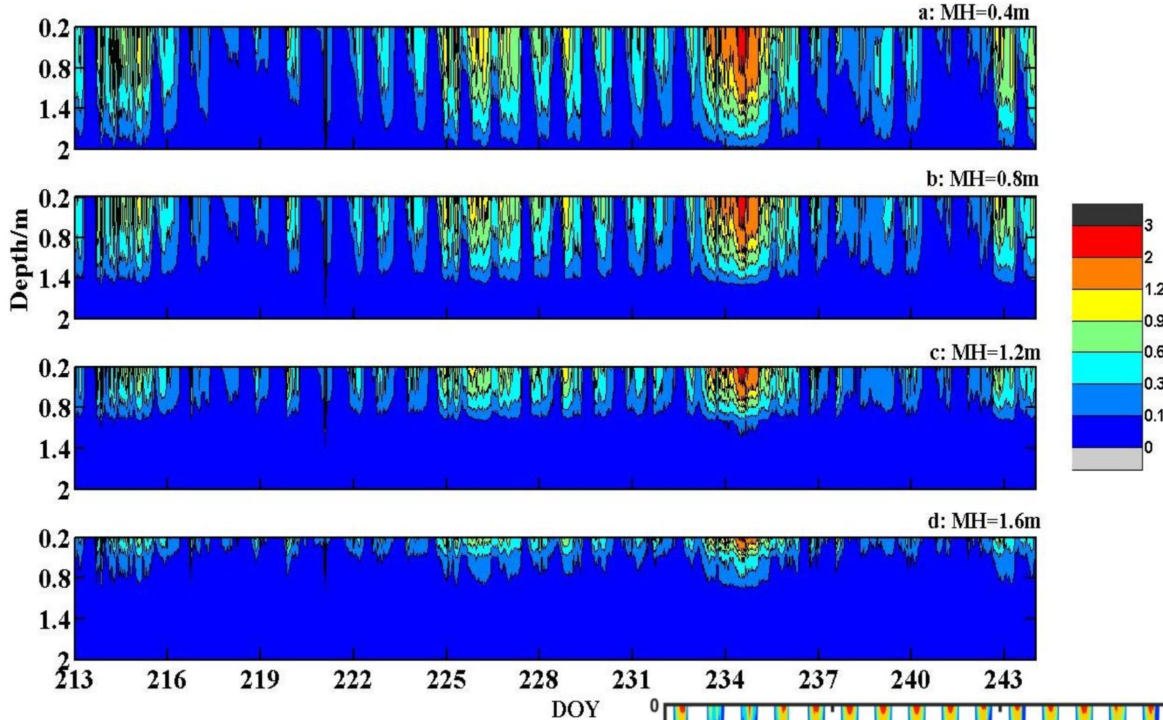


Figure 9. The effect of submersed macrophyte height on turbulent kinetic energy in different depth , the height of submersed macrophyte is (a) 0.4m (b) 0.8m (c) 1.2m (d) 1.6m

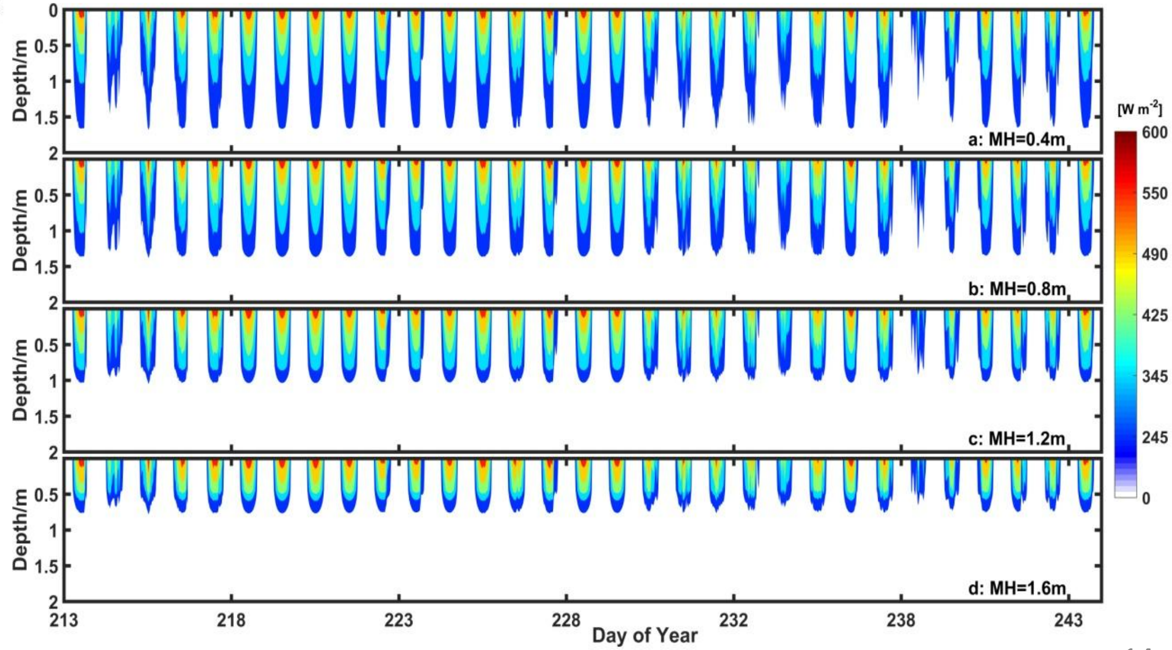


Figure 10. The effect of submersed macrophyte height on solar radiation in different depth , the height of submersed macrophyte is (a) 0.4m (b) 0.8m (c) 1.2m (d) 1.6m

✓Comparison between E-ε turbulent kinetic energy closure lake model and CLM4-LISSS model

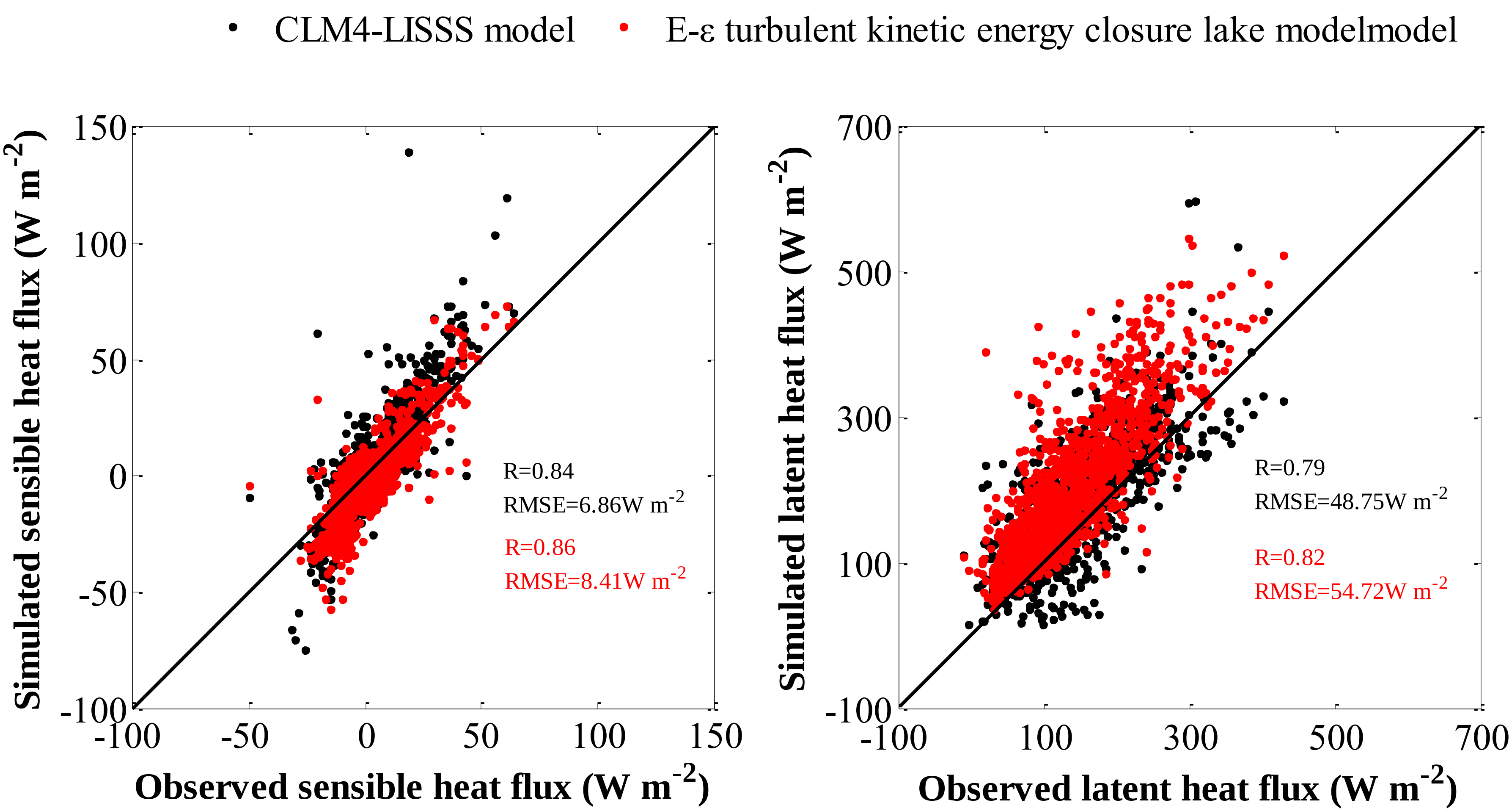


Figure 11. Comparison between the CLM4-LISSS model-predicted and E-ε turbulent kinetic energy closure lake model-predicted the heat flux from DOY 213 to DOY 243,2013

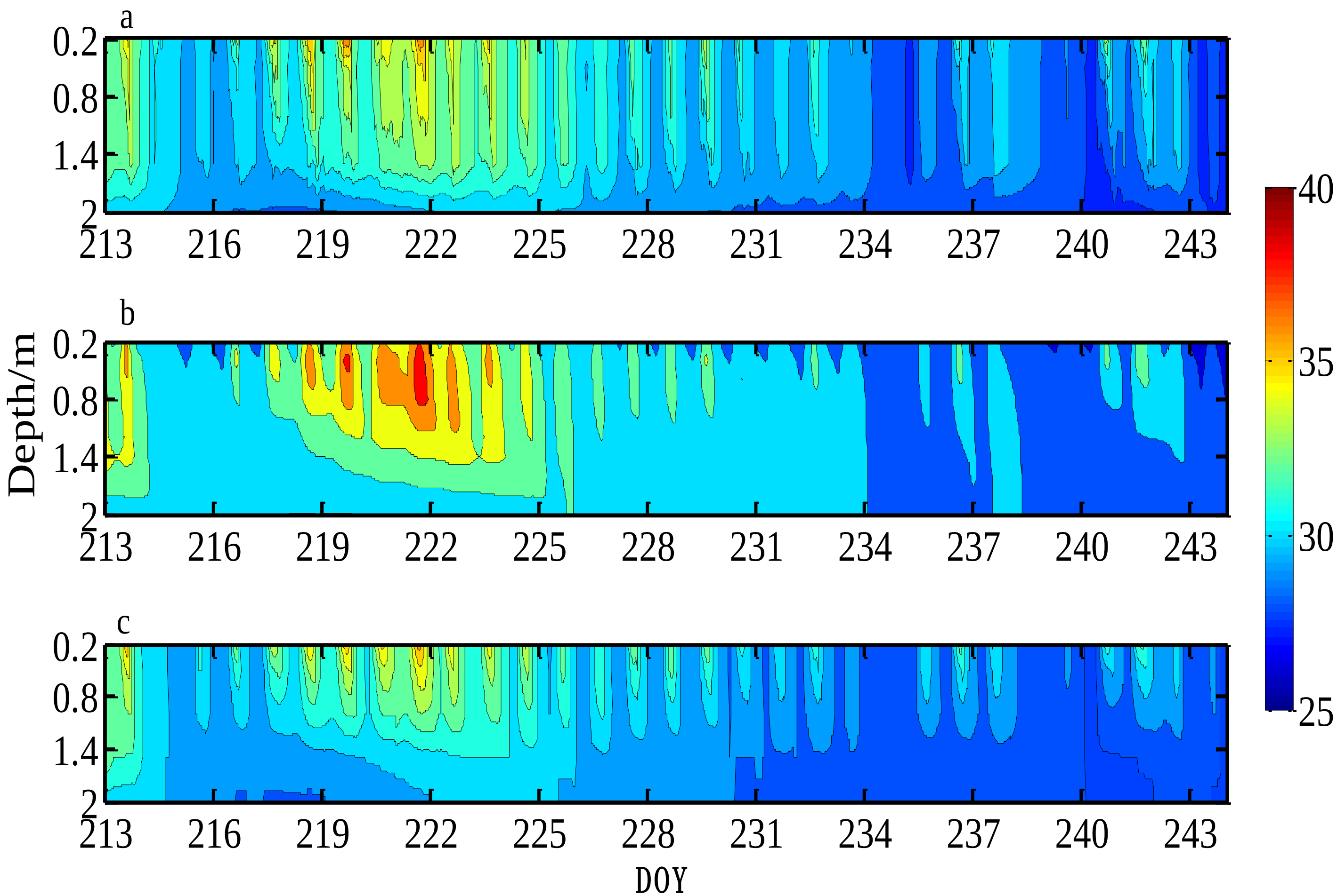


Figure 12. Comparison between the observed and the model-predicted water temperature from DOY 213 to DOY 243,2013. a: the observed water temperature, b: the CLM4-LISSS model, c: the E-ε turbulent kinetic energy closure lake model

Conclusion

- The E-ε turbulent kinetic energy closure lake model is adopted to simulate the lake-air exchanges , thermal structure and dynamical distribution over East Taihu Lake in August 2013. The simulated water temperatures, sensible heat flux and latent heat flux are in good agreement with the observations.

- Because the water depth is shallow, the weather conditions can impact vulnerably the stratification of the water temperature. The thermal stratification is significant in sunny condition with small wind. The high wind speed drove the water mixing strongly, then the thermal stratification disappeared.

- Submerged macrophyte can increase the extinction coefficient, reduce internal heat in the lake, and add resistance to the movement of water, and then influence the distribution of the turbulence kinetic energy and water temperature.

Thank you