Yale-NUIST Center on Atmospheric Environment

Simulation on temperature and flux in submerged macrophytes region of Lake Taihu on the basis of two models

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Background

- There are over 2300 lakes which size is more than 1 km^2 in our country and lakes have notable influences on local weather and climate due to low albedo and high heat capacity.

- Weather and climate forecast in lake basins need to rely on lake models for surface momentum, heat and water fluxes as the boundary conditions.

- Vertical turbulent mixing is an important role in lakes, which controls the temperature profile and the distribution of dissolved oxygen, nutrients and phytoplankton.

- The structure of the hydro-dynamical part of one dimensional lake models can be classified into diffusive models with simple parameterization schemes and models based on turbulence closure schemes.

Model principle

CLM4-LISSS model:

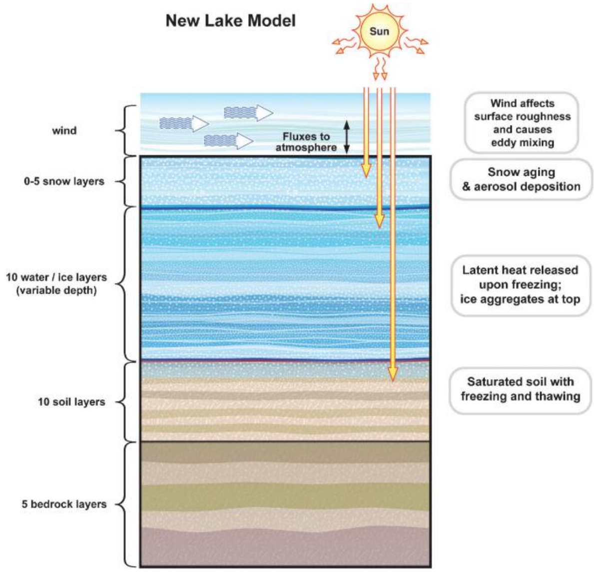


Figure 1 CLM4-LISSS model schematic (Subin 2012)

k- ε model:

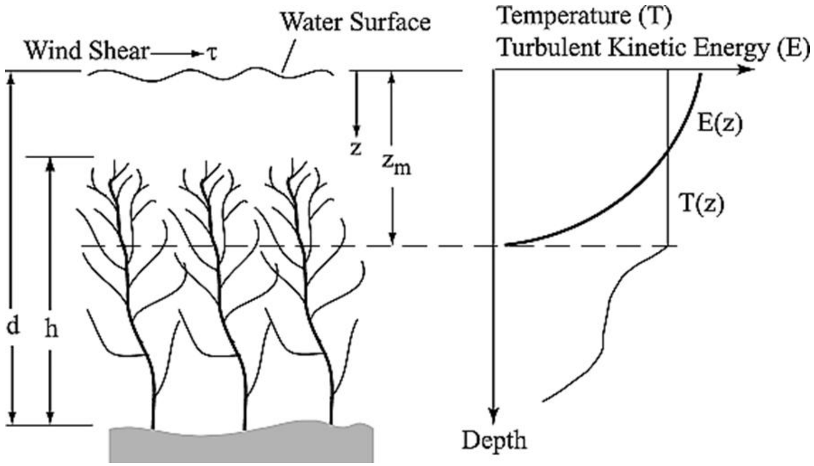


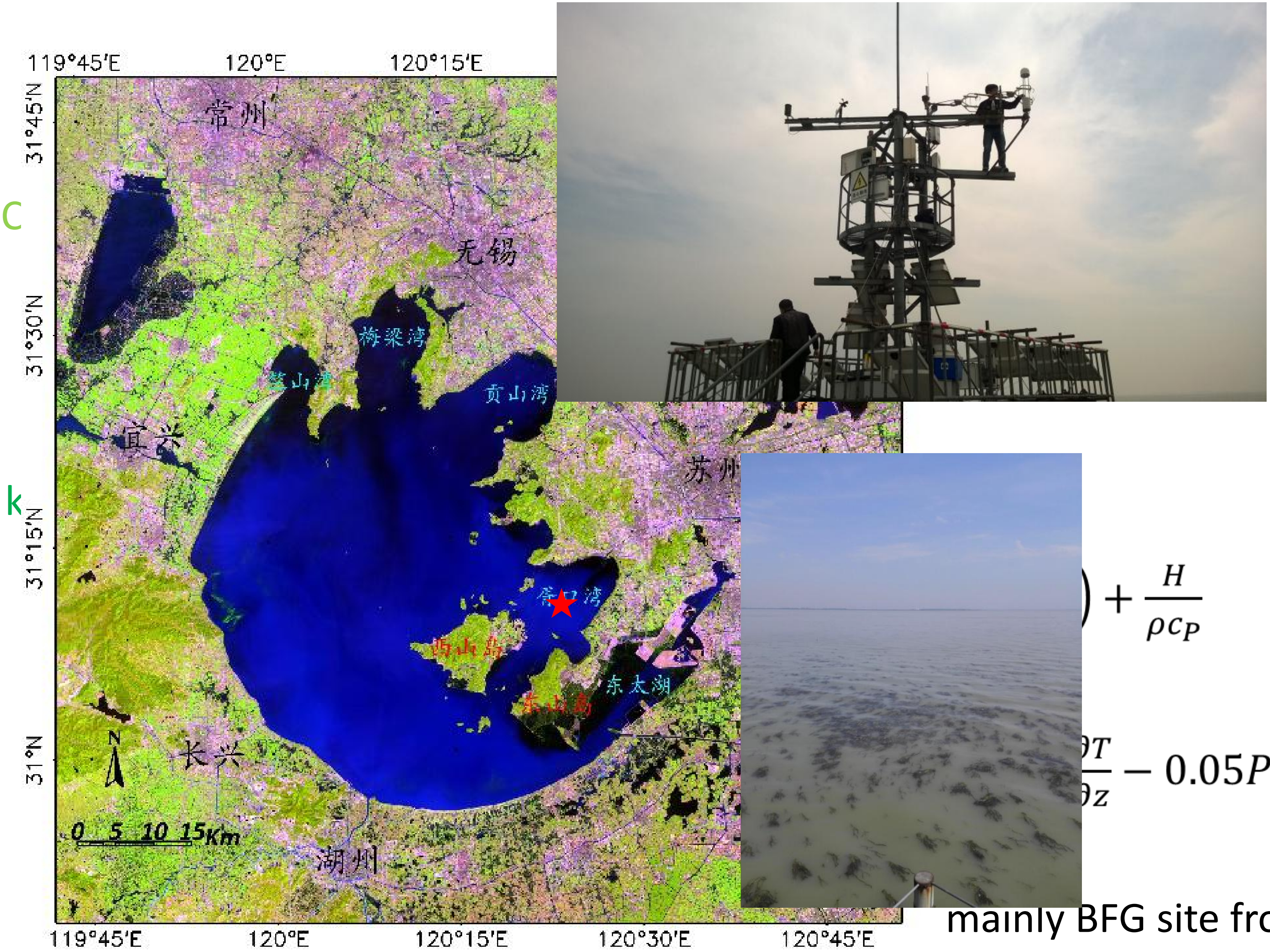
Figure 2 Parameterization of one-dimensional water column model with submerged macrophytes (Herb 2005)

Table 1 Comparison between different lake model's Parameterization schemes

Lake model	Vertical structure / number of layers	Parameterisation of turbulent fluxes at the lake-atmosphere interface	Turbulent mixing Parameterisation	Treatment of heat flux at the water-bottom sediments interface
CLM4-LISSS, Subin, 2012	Multilayer/10 layers	An extended scheme from CLM4 model, MOST	Henderson-Sellers parameterisation of eddy diffusivity, buoyant convection	Heat conductance in bottom sediments
k-ε model, Herb, 2005	Multilayer/50 layers	Empirical equations	Calculate K using TKE equation	Zero heat flux

C

k



$$\frac{1}{c_w}\frac{ds}{dz}$$

$$) + \frac{H}{\rho c_P}$$

$$\frac{\partial T}{\partial z} - 0.05 P C_D E^{\frac{2}{3}}$$

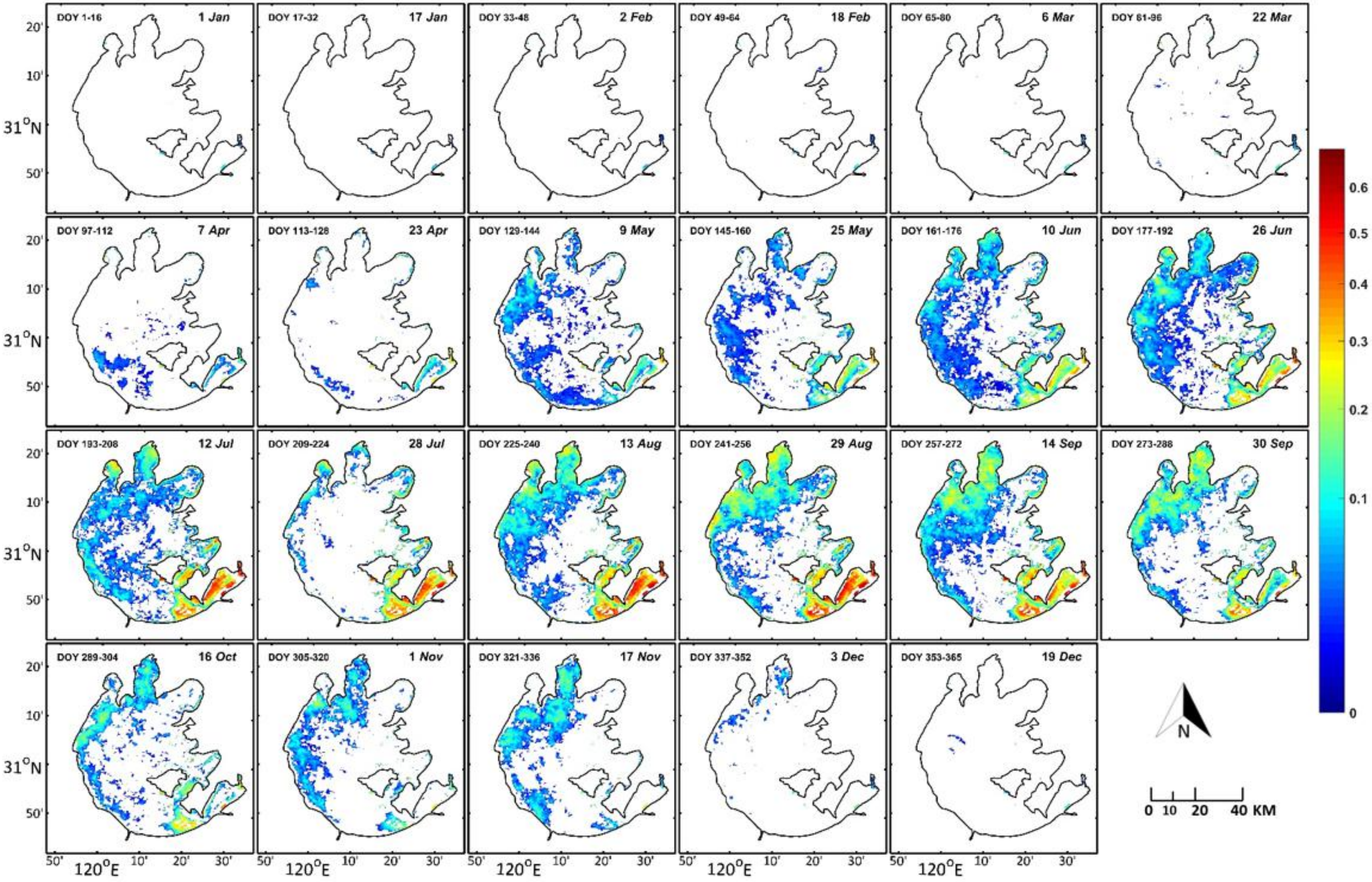
mainly BFG site from

January 2012 to December 2013

Model modification on Parameter adjustment

k- ε model:

Table 2 k-ε model parameter values



Dec

0

0

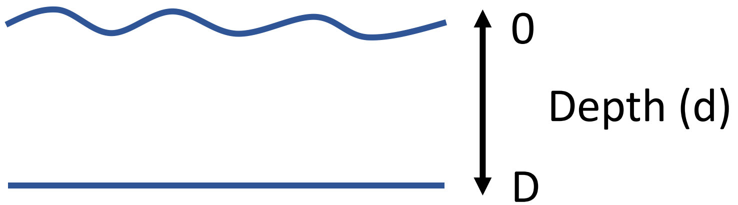
CLI

Model modification on eddy diffusivity

k- ε model: $K_z = C_k Z_m \sqrt{E}$

CLM4-LISSS model: $K_z = m_d(k_m + k_e);\ m_d$=0.02

$$K_e = K_{e0} f(R_i) \begin{cases} f(R_i) = (1 + 37R_i^2)^{-1} \\ \text{Neutral condition:} \\ K_{e0} = k u_* \underset{\substack{\Downarrow \\ D-d}}{z} \leftarrow u_* = u_{*0}\exp(-k^* \underset{\substack{\Downarrow \\ d}}{z}) \leftarrow k^* = 6.6U_2^{-1.84}\sqrt{sin\varphi} \end{cases}$$



```
ke(j) =0.02_r8* vkc*ws(c)*z_lake(c,j)/p0 *exp(-ks(c)*z_lake(c,j)) / (1._r8+37._r8*ri(j)*ri(j))
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⇩

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ke(j) =0.02_r8*vkc*ws(c)*(2-z_lake(c,j))/p0 * exp(-ks(c)*z_lake(c,j)) / (1._r8+37._r8*ri(j)*ri(j))
```

The Temperature Performance of model

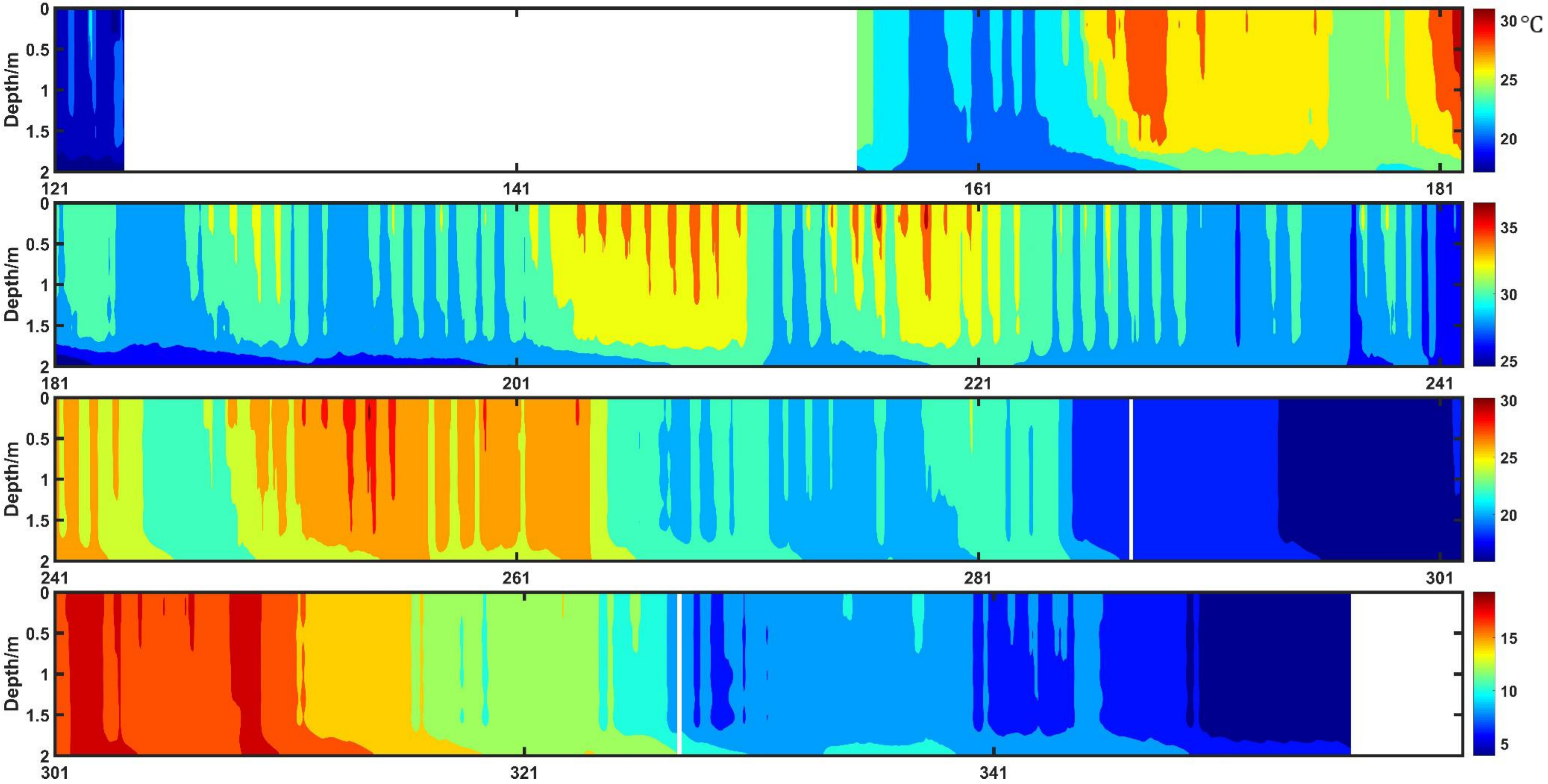


Figure 3 Time series of observed water temperature profile for DOY 121(2013)-365(2013) at BFG site

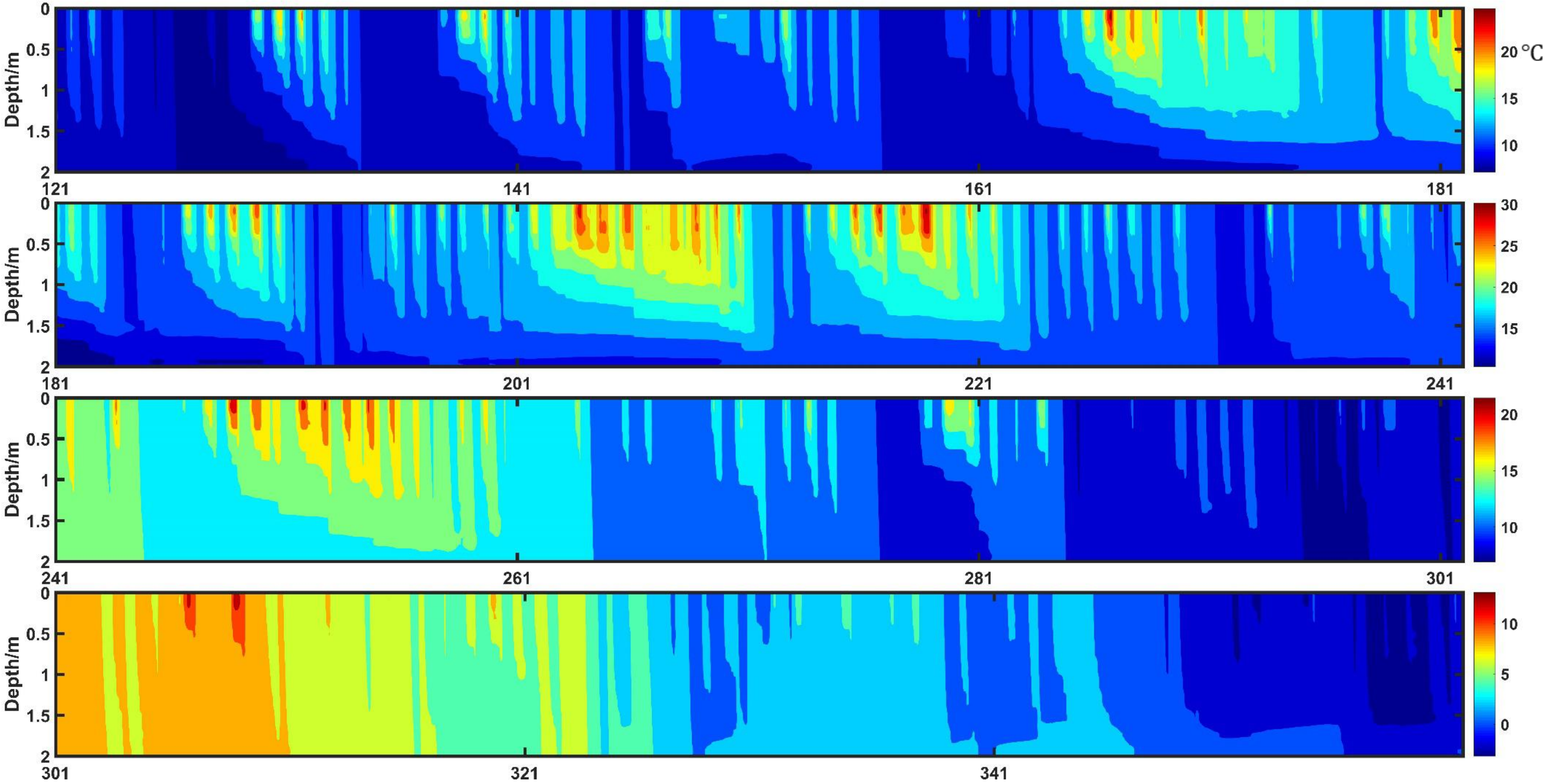


Figure 4 Time series of predicted water temperature profile for DOY 121(2013)-365(2013) at BFG site calculated by CLM4-LISSS model

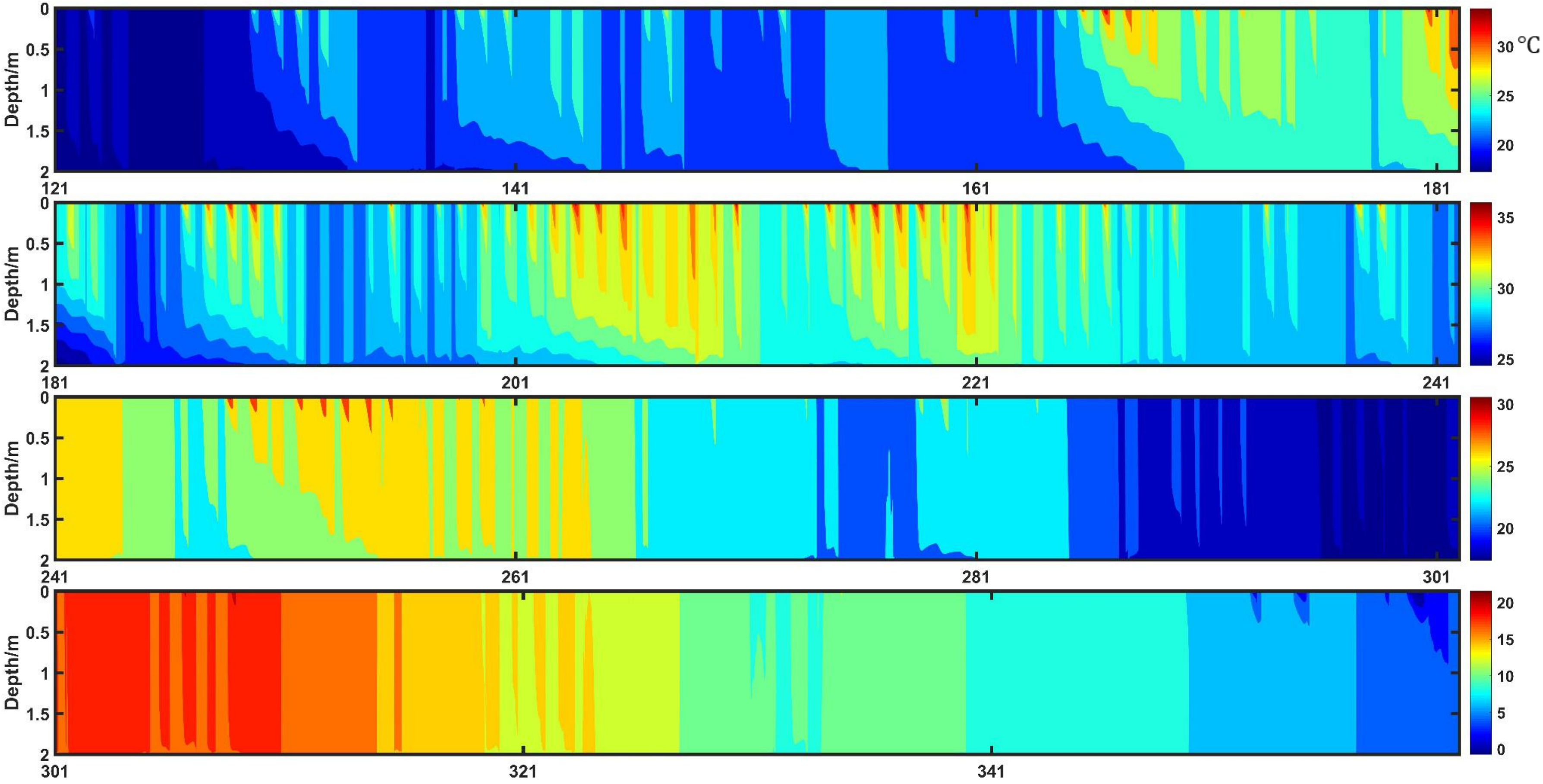
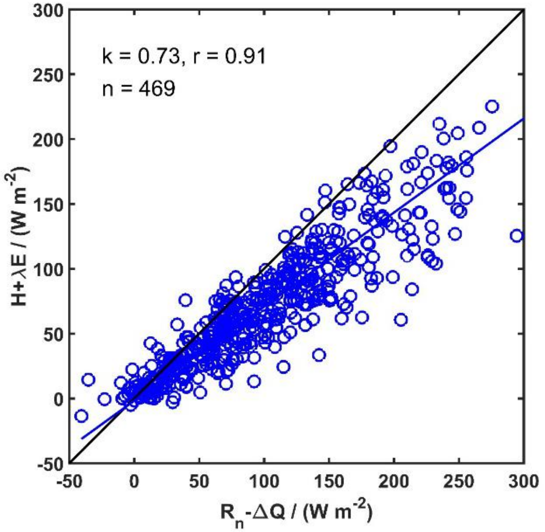


Figure 5 Time series of predicted water temperature profile for DOY 121(2013)-365(2013) at BFG site calculated by k- ε model

Before calibration



Forcing energy balance closure on daily scale

After calibration

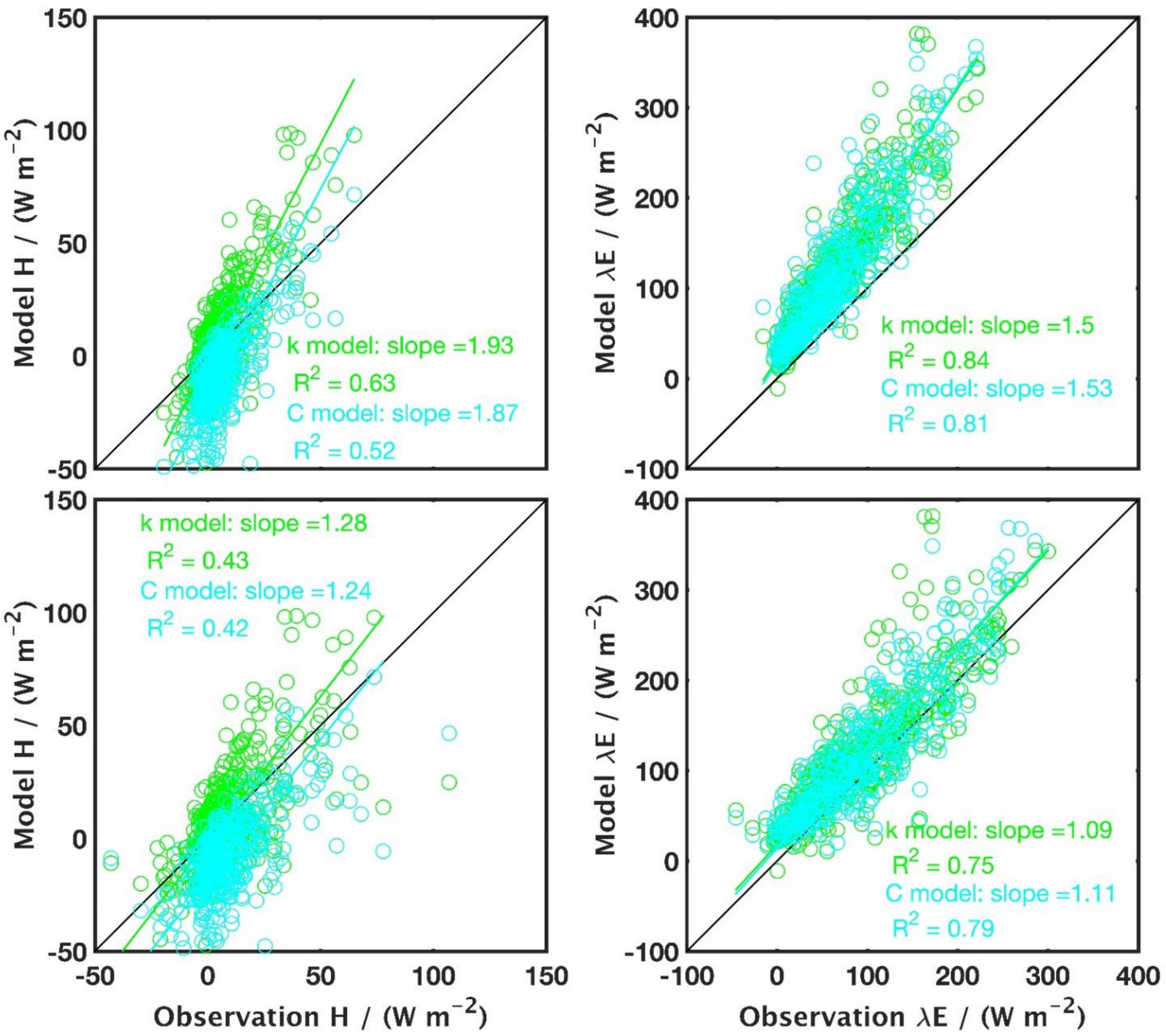


Figure 6 The relationship between measured and predicted Sensible heat flux and latent heat flux in daily scale (green dots: k- ε model and cyan dots: CLM4-LISSS model)

The distribution of eddy diffusivity

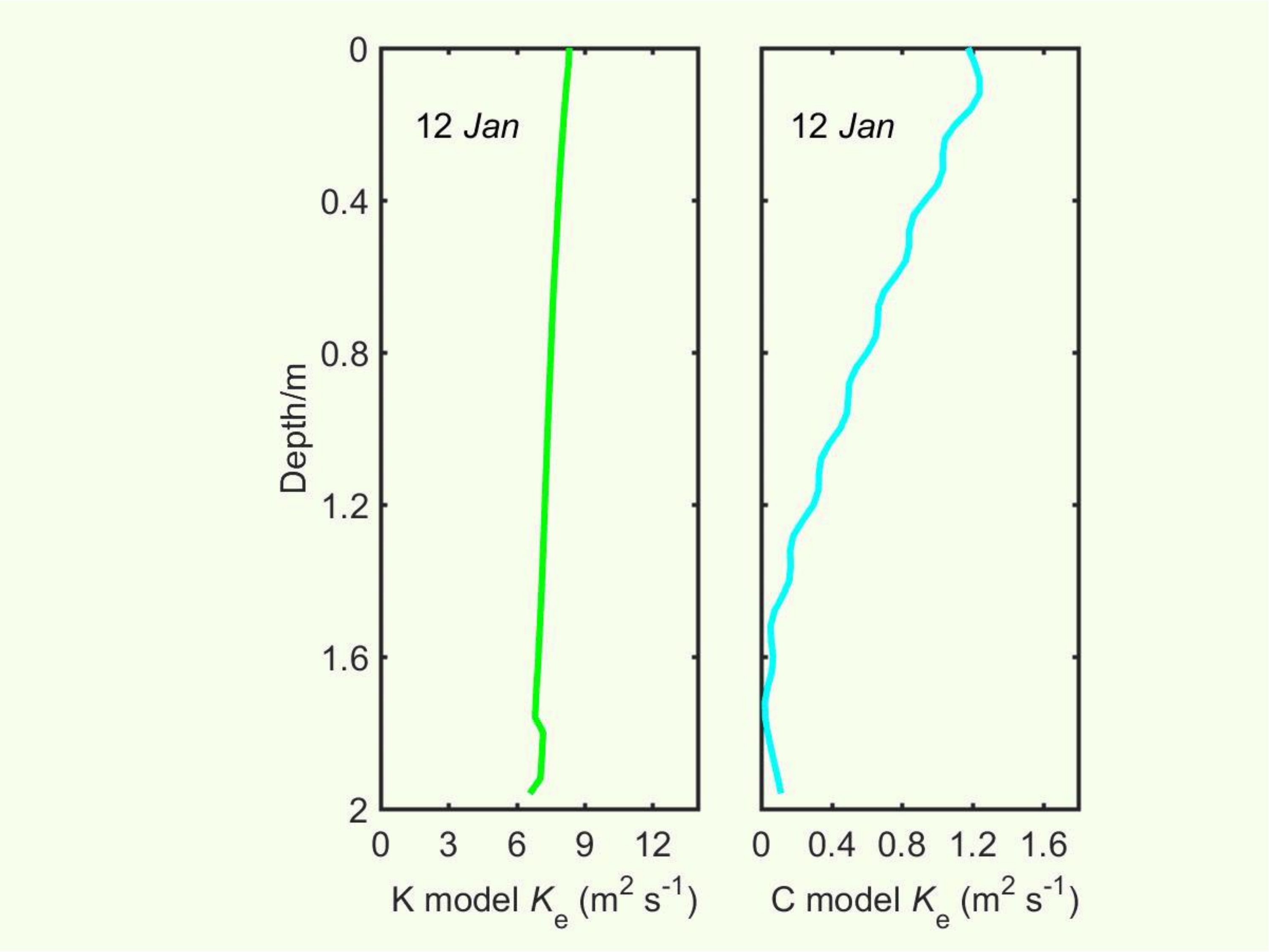


Figure 7 Monthly-average eddy diffusivity profile at BFG station simulated by CLM4-LISSS model (cyan line) and k- ε model (green line) over two full year cycle

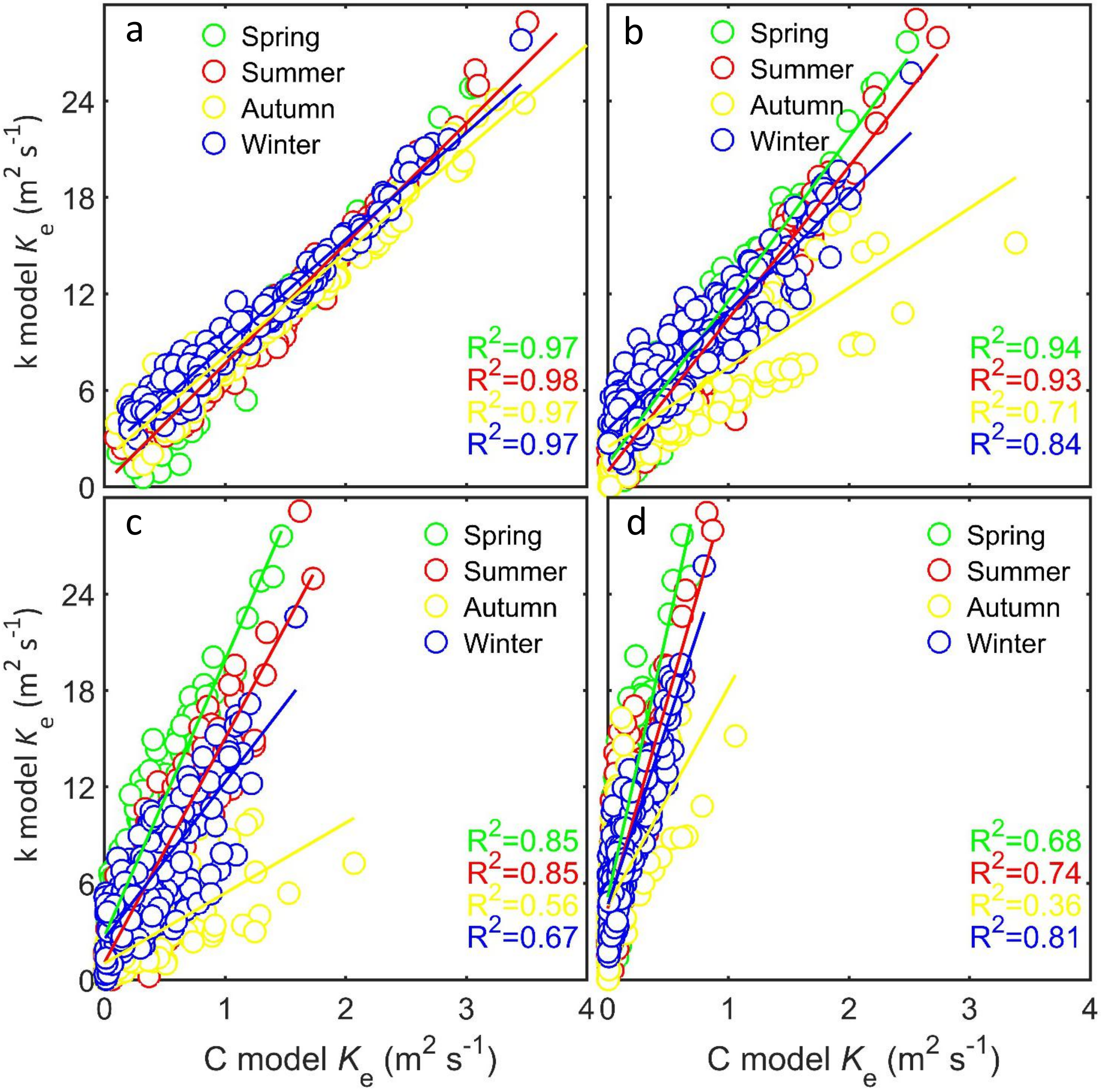


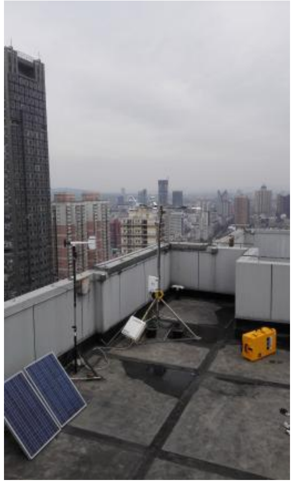
Figure 8 Comparison on daily-mean predicted eddy diffusivity (a: 0-0.5m; b: 0.5-1m; c: 1-1.5m; d: 1-2m) in different season (green dots: Spring; red dots: Summer; yellow dots: Autumn; blue dots: Winter) at BFG site between k- ε model and CLM4-LISSS model

Try to establish a integrated lake model consisting of surface flux calculated by MOST theory and water temperature and eddy diffusivity calculated by thermal diffusivity equation, turbulent diffusivity equation and turbulent dissipation equation.

Conclusions

- CLM4-LISSS model and k-ε model has good performance in water temperature and surface flux prediction.
- There exists similar diurnal composite of mean eddy diffusivity in spring, summer and autumn at BFG station, The trend of winter is reversed compared with other seasons.
- Eddy diffusivities simulated by both model exist difference in number but have well linear relationship, especially in shallow layer. However, tuned eddy diffusivity didn’t bring better water temperature performance results.



Thank you