Offline test of CLM4.0 lake model at lake Taihu

Bin Deng

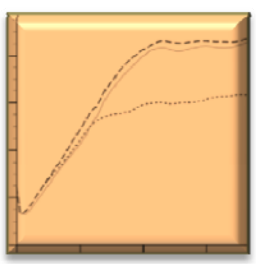
06/09/2011

Outline

Introduction

```
PROGRAM Bin Micro
  DO WHILE (it works)
     . . .
     . . .
     . . .
  END DO
END PROGRAM
```

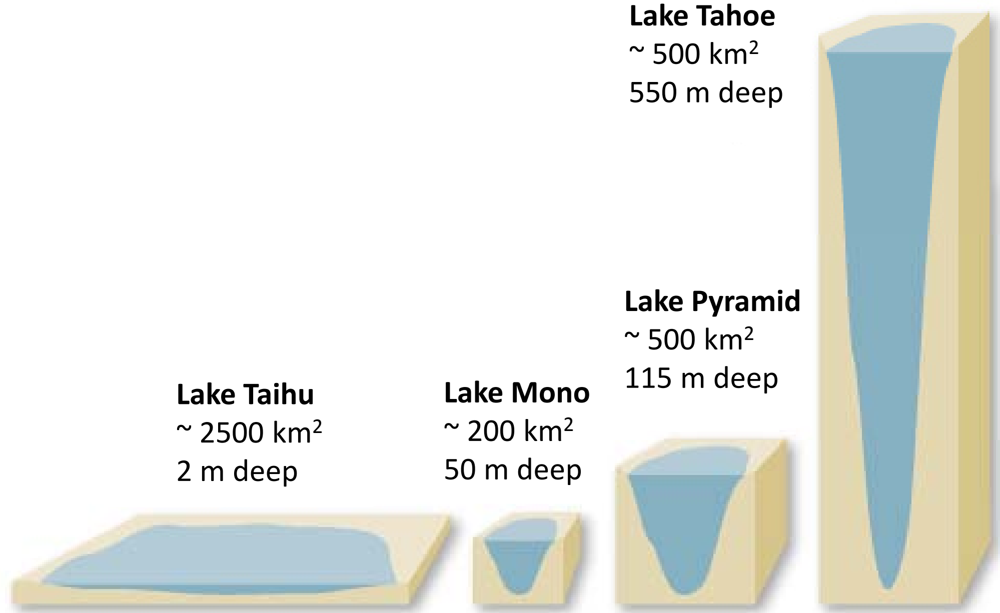
Model



Results

Introduction (Taihu lake)

(Xiao et al., 2010)

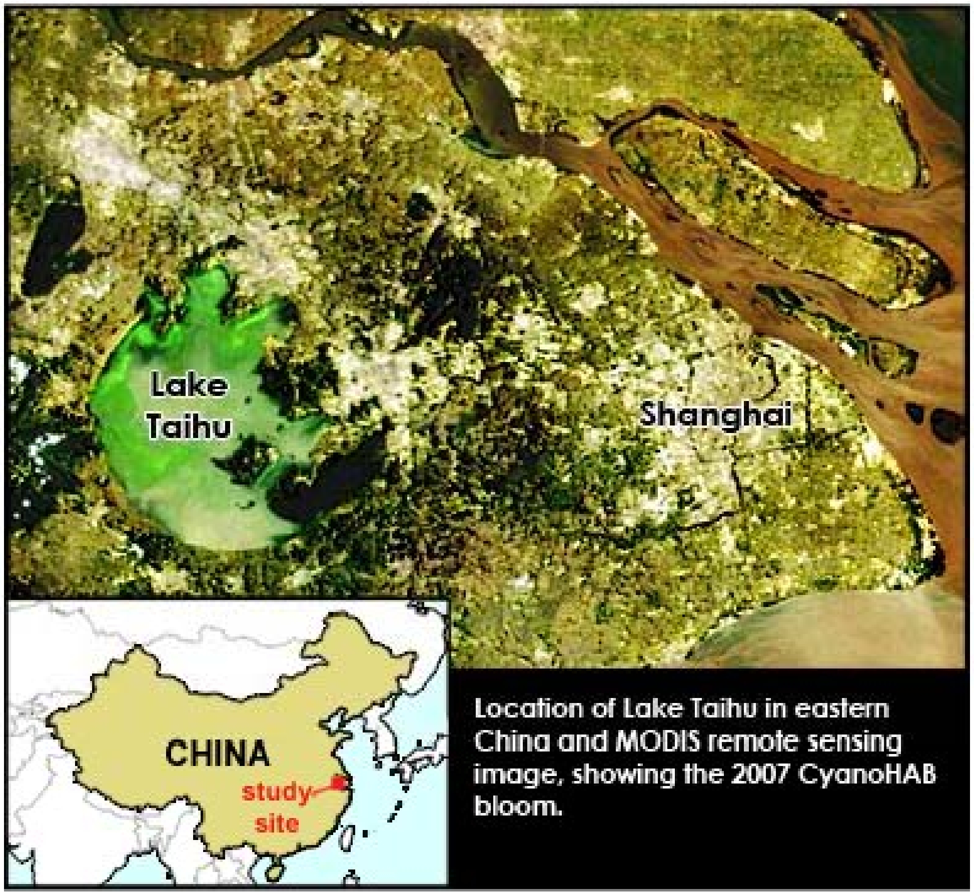


- Inflow from W and SW
- Outlet at SE
- Spatial variation of water quality
- Warm polymictic lake (too shallow to develop thermal stratification)

- Large surface-to-volume ratio
- Different vertical structure from deep lakes
- High evaporation (pronounced local cooling)
- Sensitive to climate change (e.g., drought) and anthropogenic perturbations

Introduction (algae bloom)

Algae outbreak on Jun, 2007



(Paerl et al., 2010)

- Pose a threat to water quality
- More than 6000 tons of algae removed with 2 months after the break

Introduction

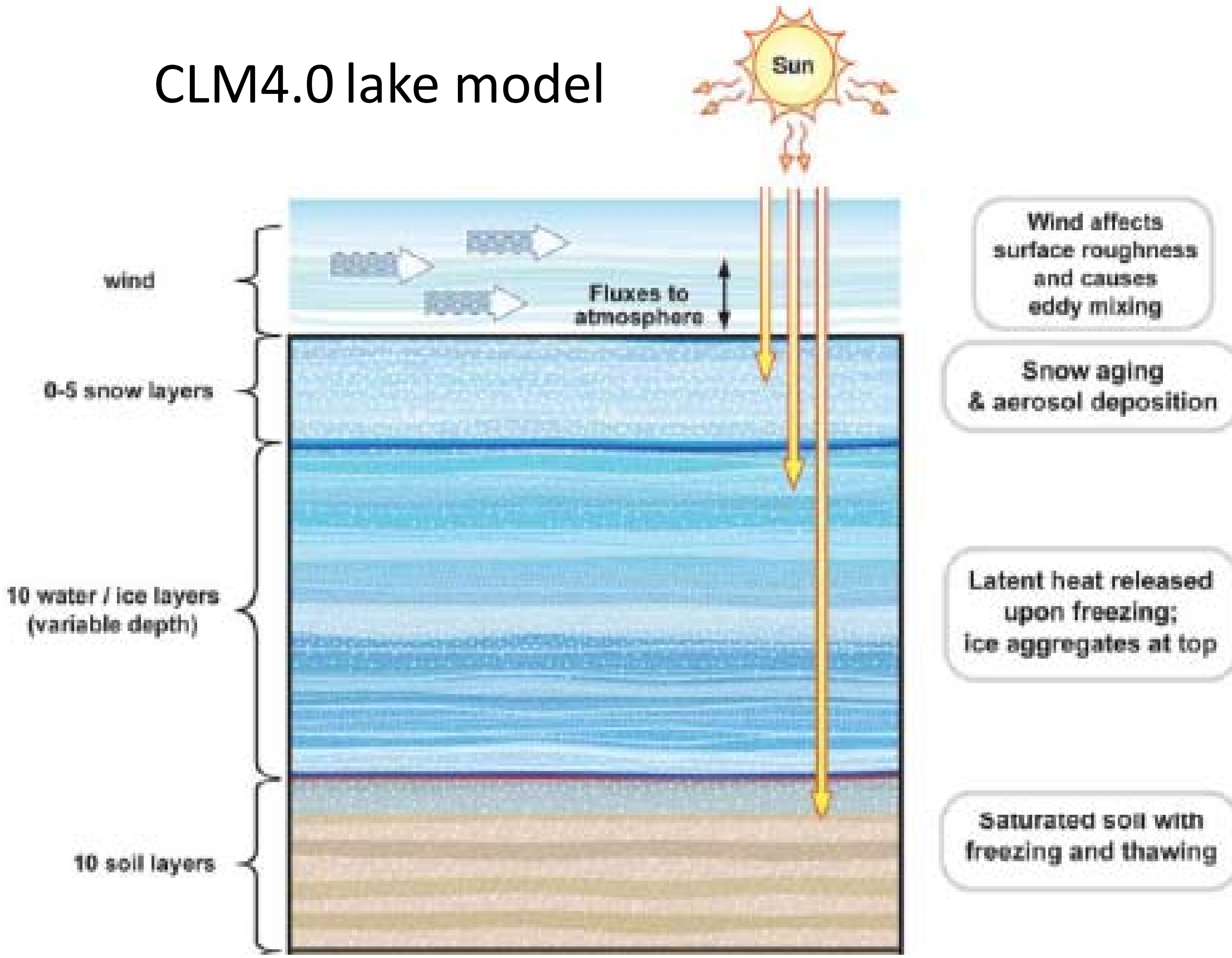
<u>In this study:</u>

(1) Evaluate and adapt CLM4.0 lake model for Taihu;

(2) Couple CLM4.0 lake model into WRF to improve the weather prediction for Taihu region;

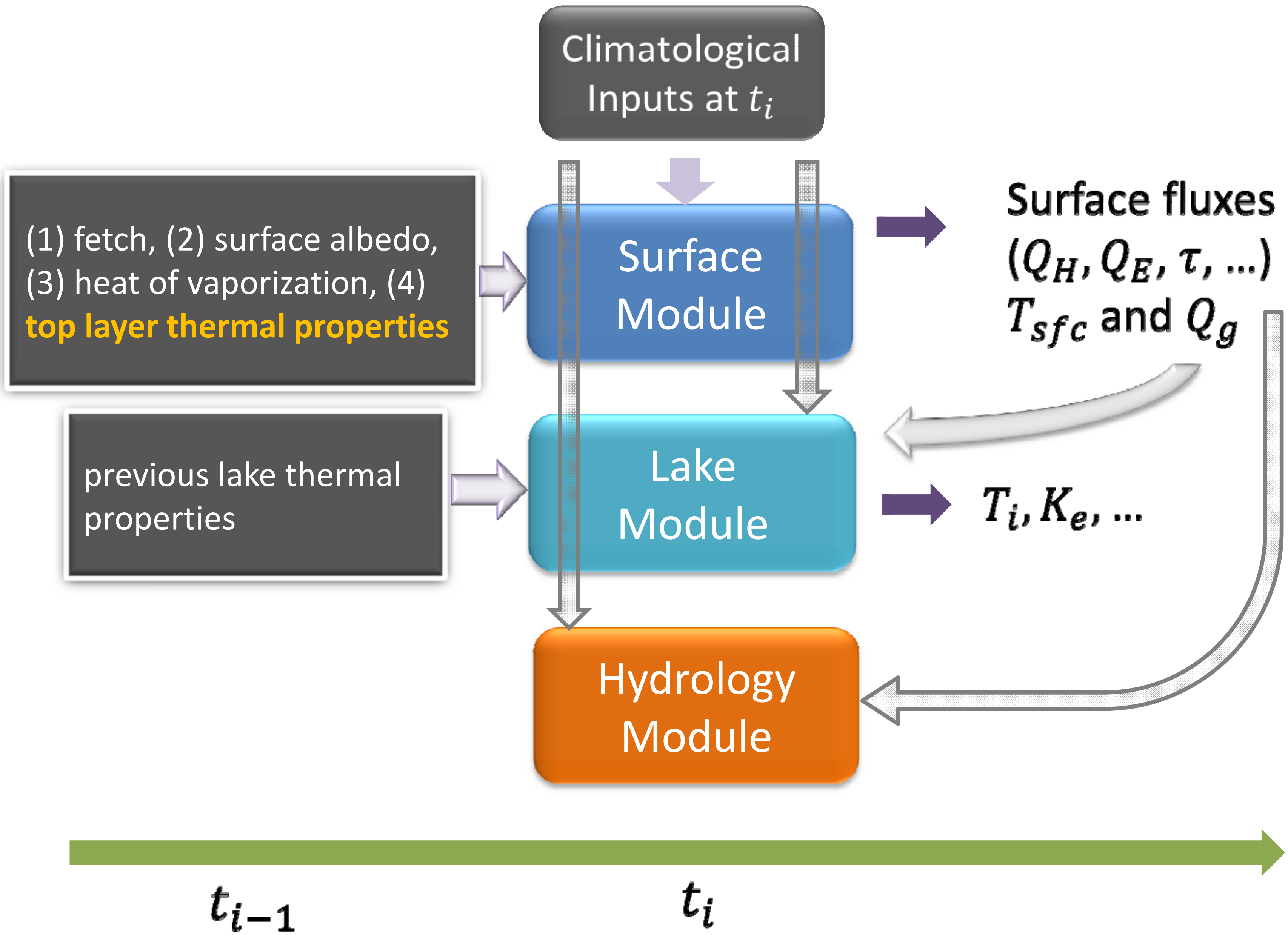
Model (schematic representation)

CLM4.0 lake model



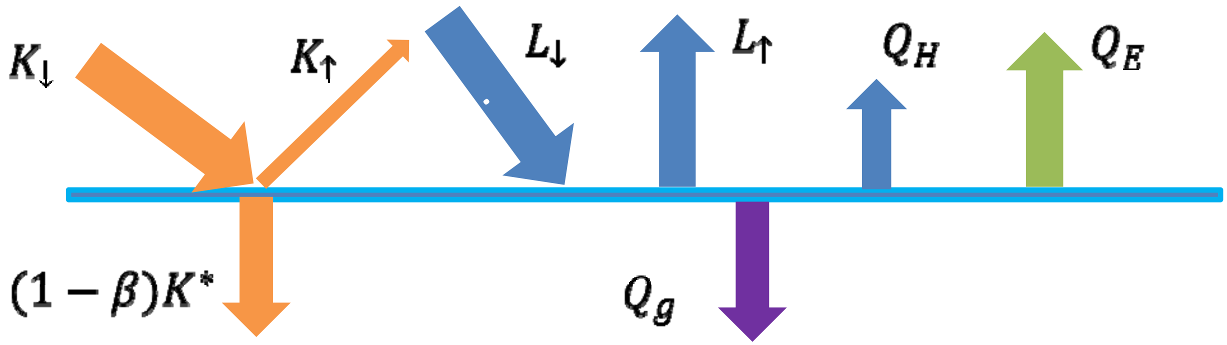
(Subin et al., 2011)

Model (component modules)



Model (surface module)

Surface Module



Module solver (based on surface layer heat budget):

$$\beta(K_\downarrow - K_\uparrow) + L_\downarrow - L_\uparrow(T_{sfc}) - Q_H(T_{sfc}) - Q_E(T_{sfc}) - Q_g = 0$$

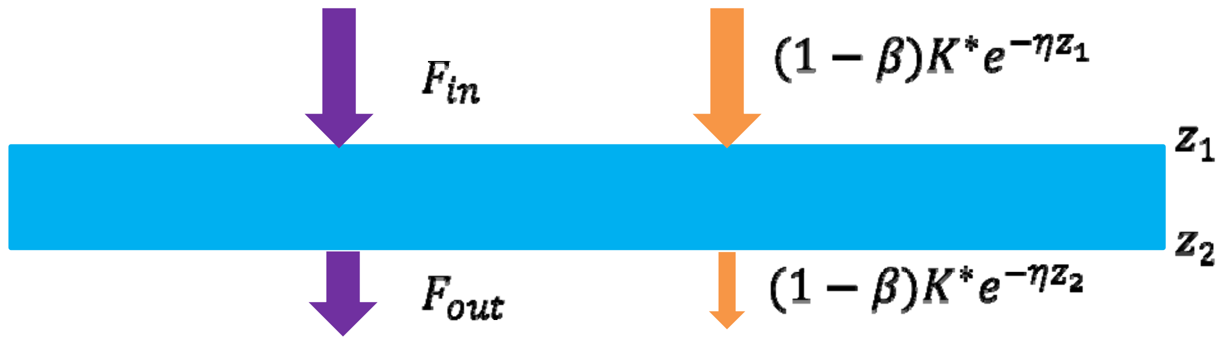
β: fraction of K^* absorbed in the lake surface layer (0.4~0.6)
Q_g: heat flux as boundary condition for the top layer

$$Q_g = \frac{\lambda(T_{sfc} - T_1)}{(\Delta z_1)/2}$$

$\lambda = \lambda_m + \lambda_e$ ($\lambda_e \sim 10^{2\sim3}\,\lambda_m$): highly affects the module outcomes

Model (lake module)

Lake Module



Module solver (vertical heat diffusion):

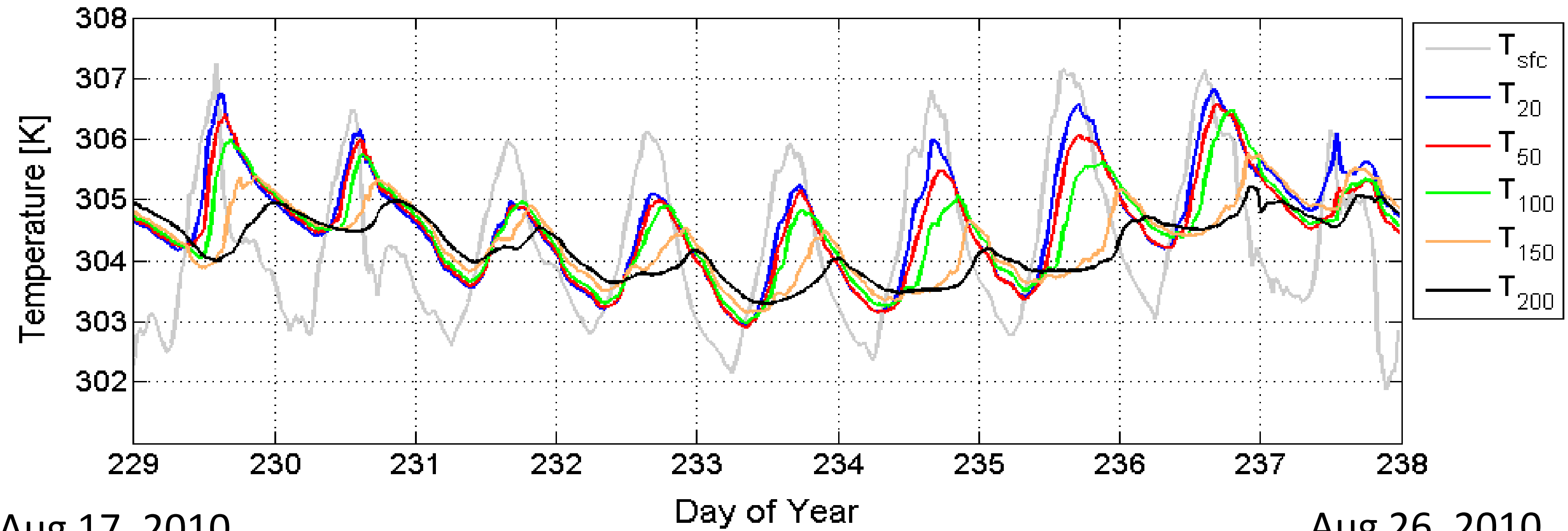
$$\frac{\partial T_i}{\partial t} = \frac{\partial}{\partial z}\left[\left(K_m + K_{e,i}\right)\frac{\partial T_i}{\partial z}\right] + \frac{1}{c_{liq}}\frac{d\phi_i}{dz} \quad (i = 1, N_{lake} + N_{soil})$$

$$\begin{bmatrix} b_1 & c_1 & . & . & 0 \\ a_2 & b_2 & c_2 & . & 0 \\ 0 & a_3 & b_3 & . & . \\ . & . & . & . & c_{n-1} \\ 0 & . & . & a_n & b_n \end{bmatrix} \begin{bmatrix} T_1 \\ T_2 \\ . \\ . \\ T_n \end{bmatrix} = \begin{bmatrix} r_1 \\ r_2 \\ . \\ . \\ r_n \end{bmatrix}$$

$$a_i \sim f\left(T_{prev}, K_e\right)$$
$$b_i \sim f\left(T_{prev}, K_e\right)$$
$$c_i \sim f\left(T_{prev}\right)$$
$$r_i \sim f\left(T_{prev}, K_e, \phi\right)$$

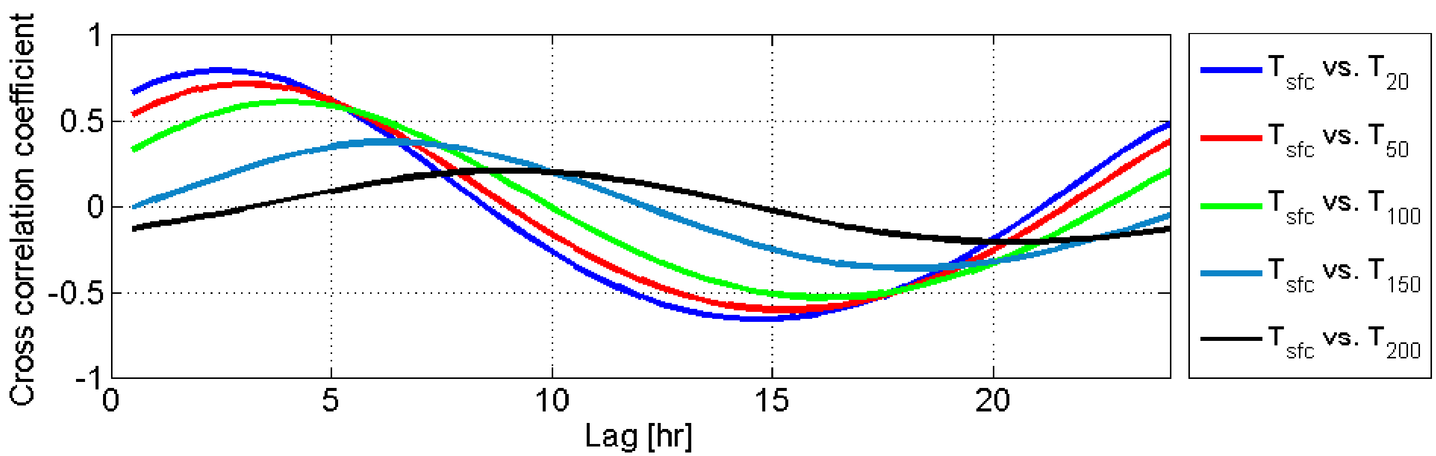
$\boldsymbol{\eta}$ and $\boldsymbol{K_e}$ affect the heat redistribution within the lake

Results (lake temperature measurements)

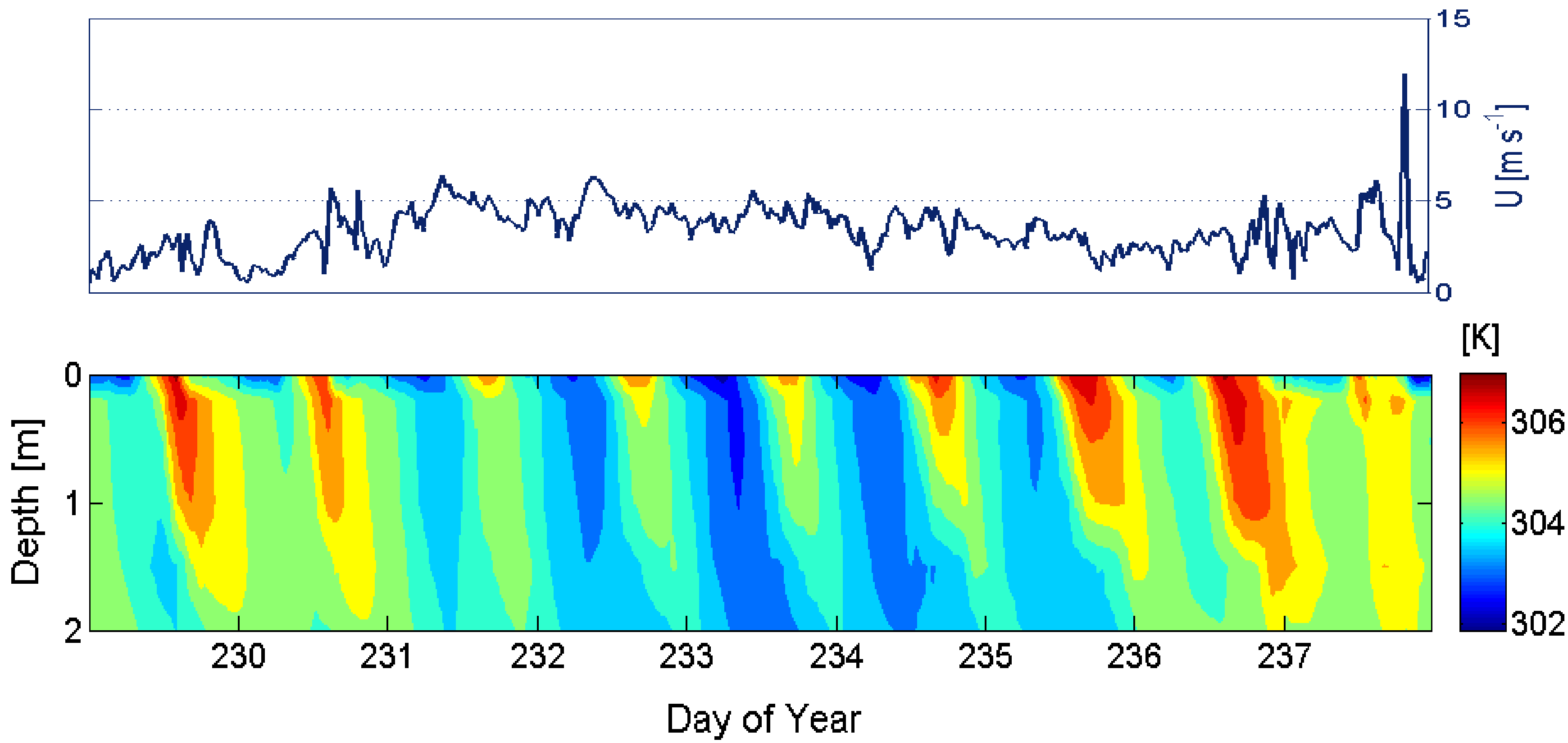


Aug 17, 2010

Aug 26, 2010

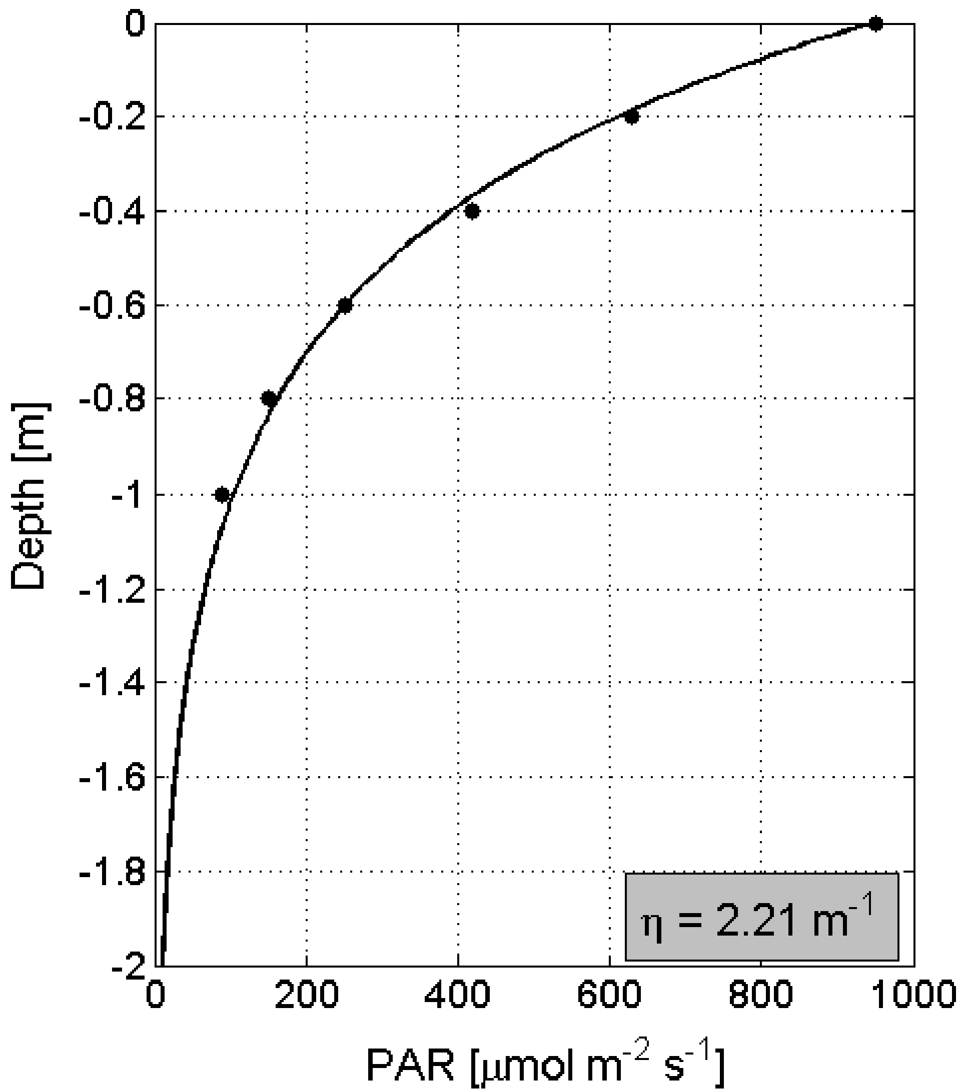


Results (lake temperature measurements)



- Temperature overturn occurs on daily basis
- Isothermal lines tilt as a result of time lag
- Wind plays an important role in SEB of shallow lake

Results (lake parameters)



Data source: Qin et al. (2007)

(1) CLM2.0 lake model

$\eta = 0.1\ m^{-1}$

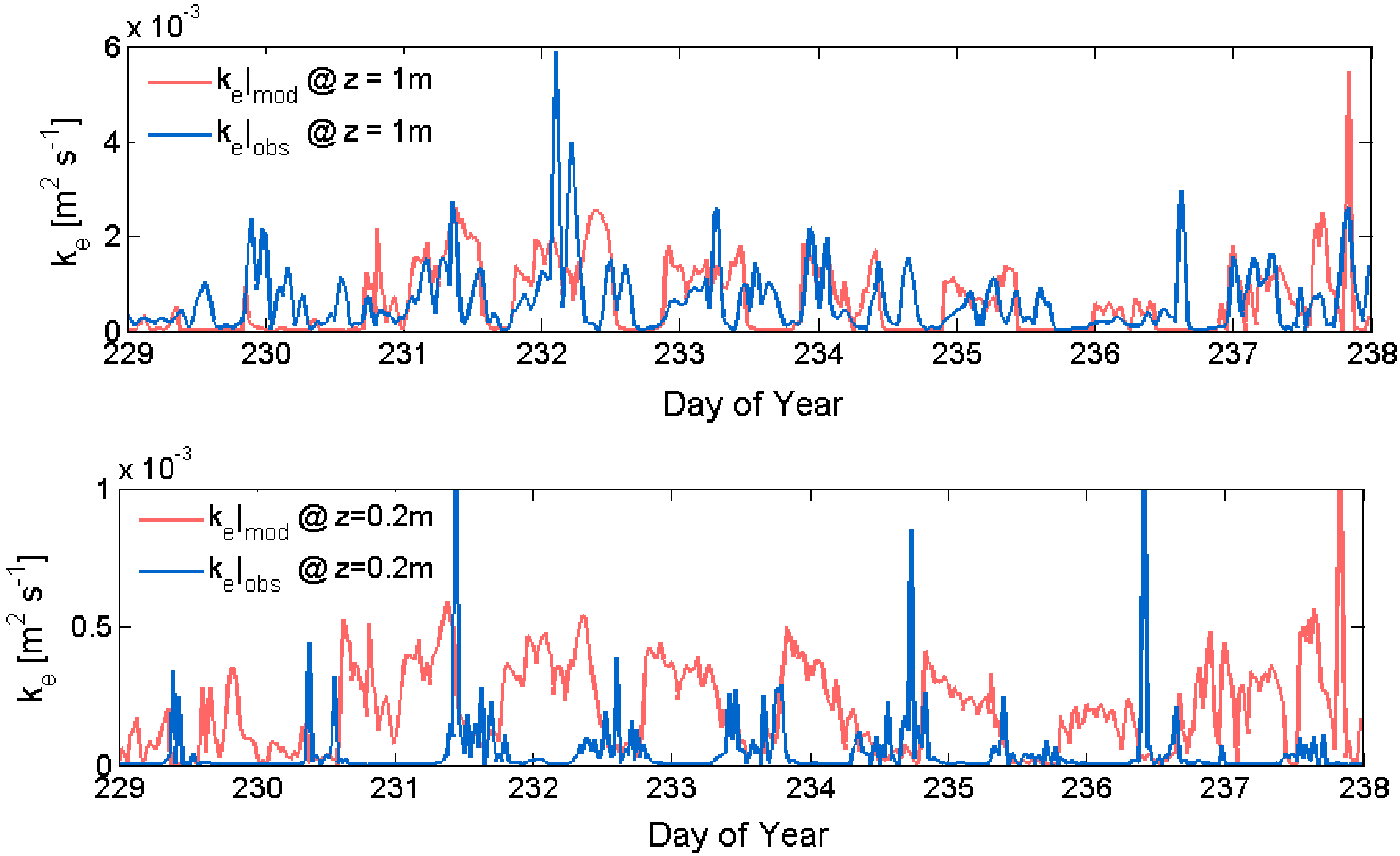
(2) CLM4.0 lake model

$\eta = 1.1925 D^{-0.424}$

(0.89 for Taihu based on this formula)

Results (lake parameters)

K_e (wind driven turbulence, enhanced diffusion due to unresolved 3D processes*)

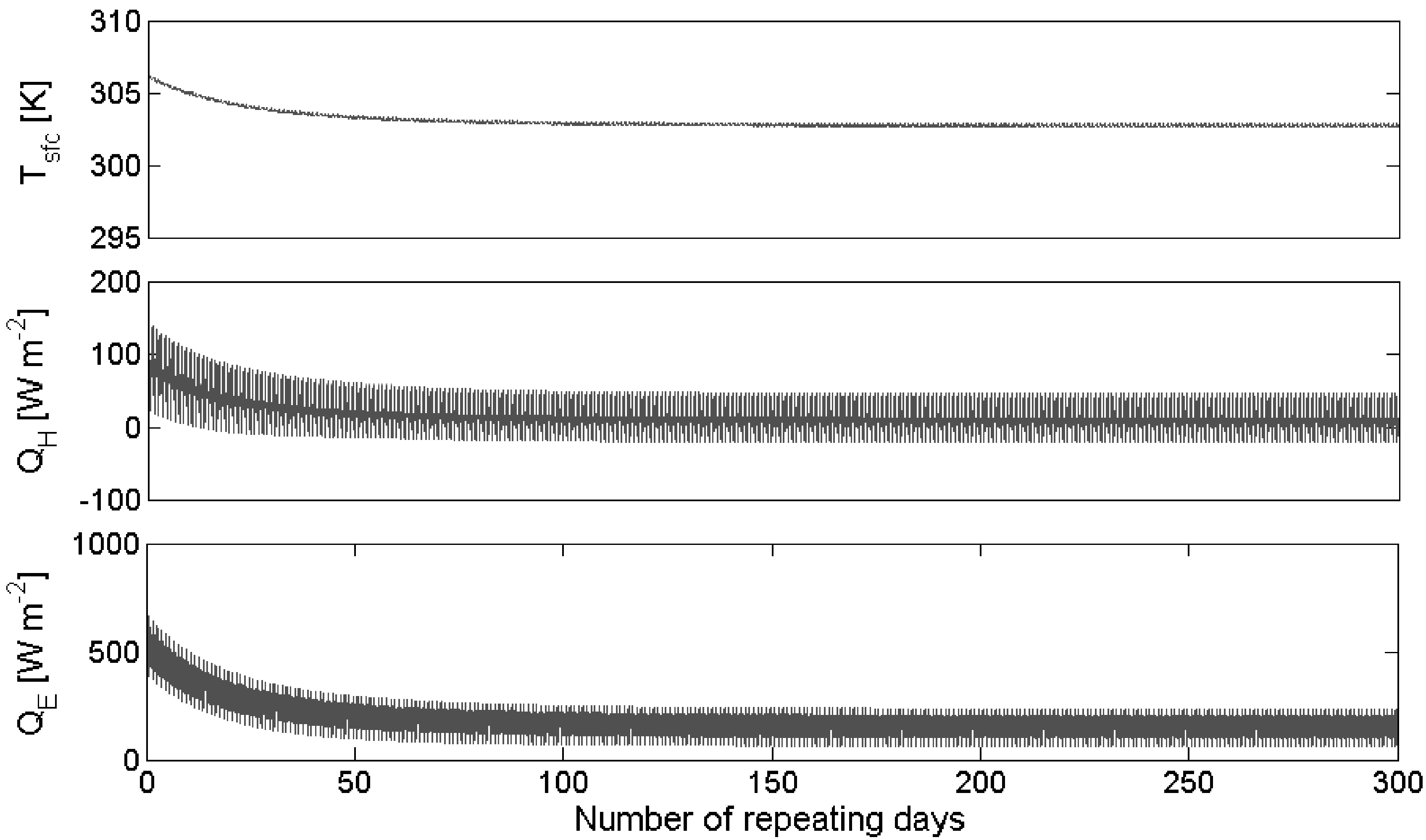


K_e deserves more attention

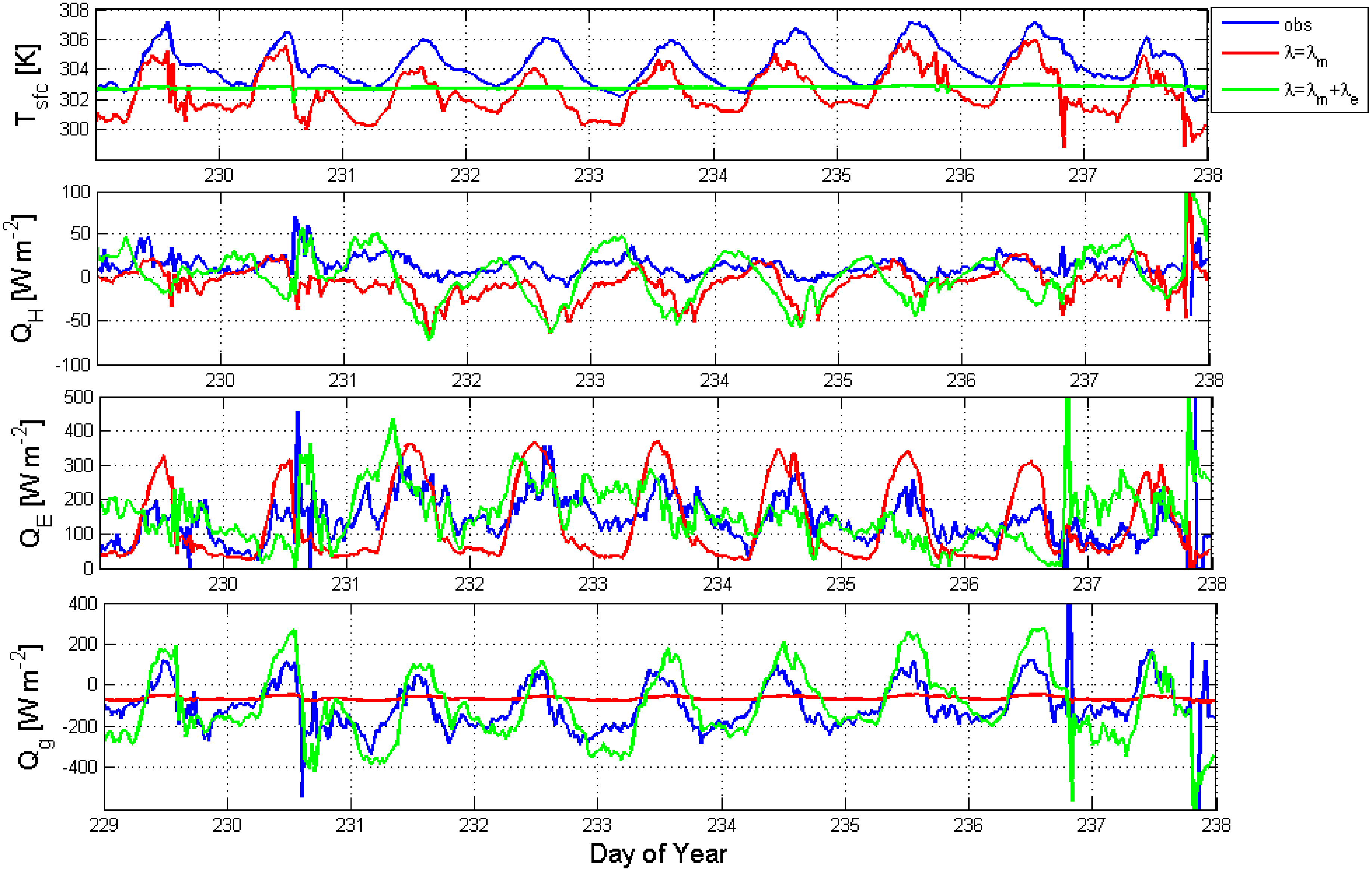
Results (model spin-up time)

Model spin-up time (the time model takes to reach an equilibrium state)

here the model is driven by repeating measurements from DOY 229

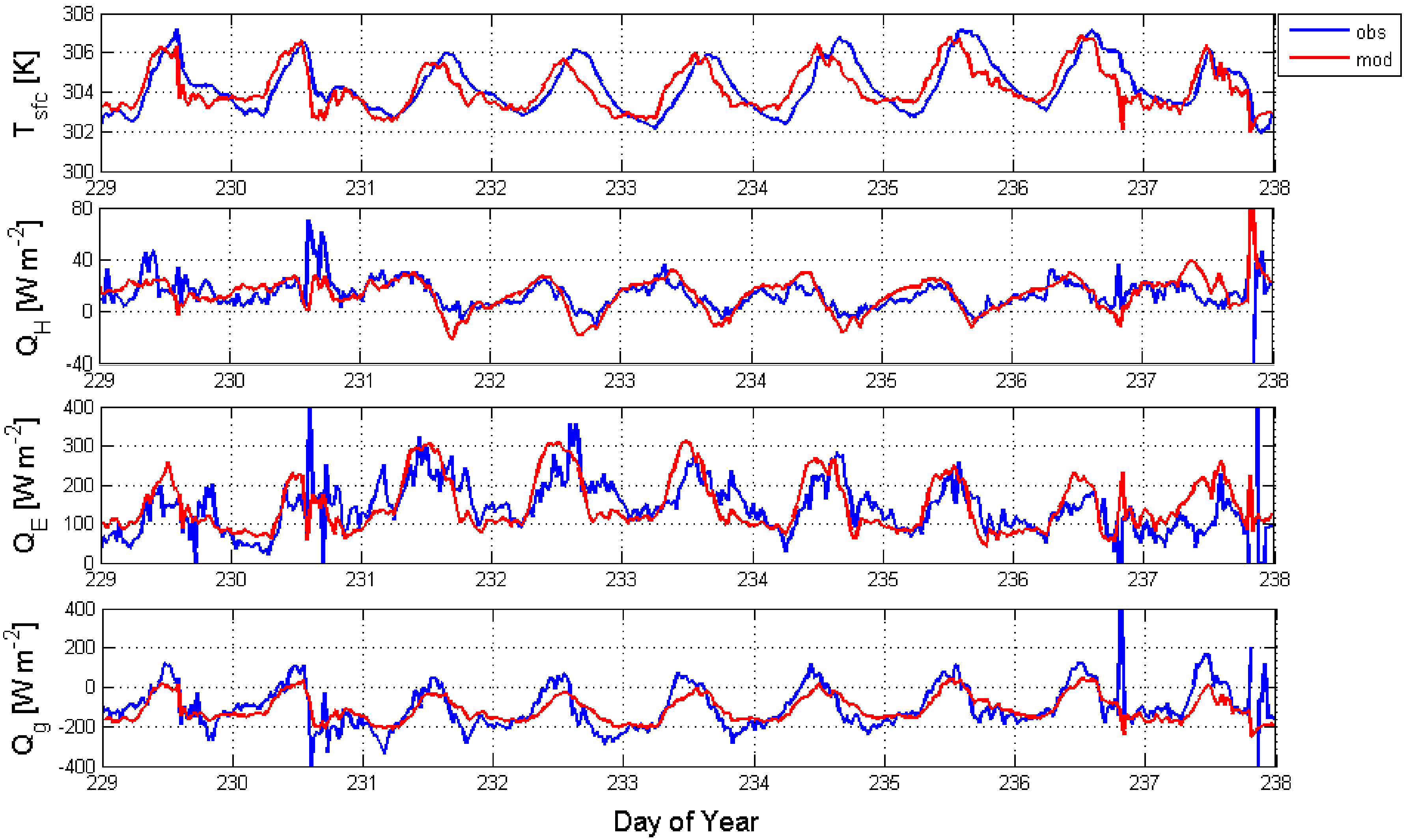


Results (CLM4.0 surface module outputs)



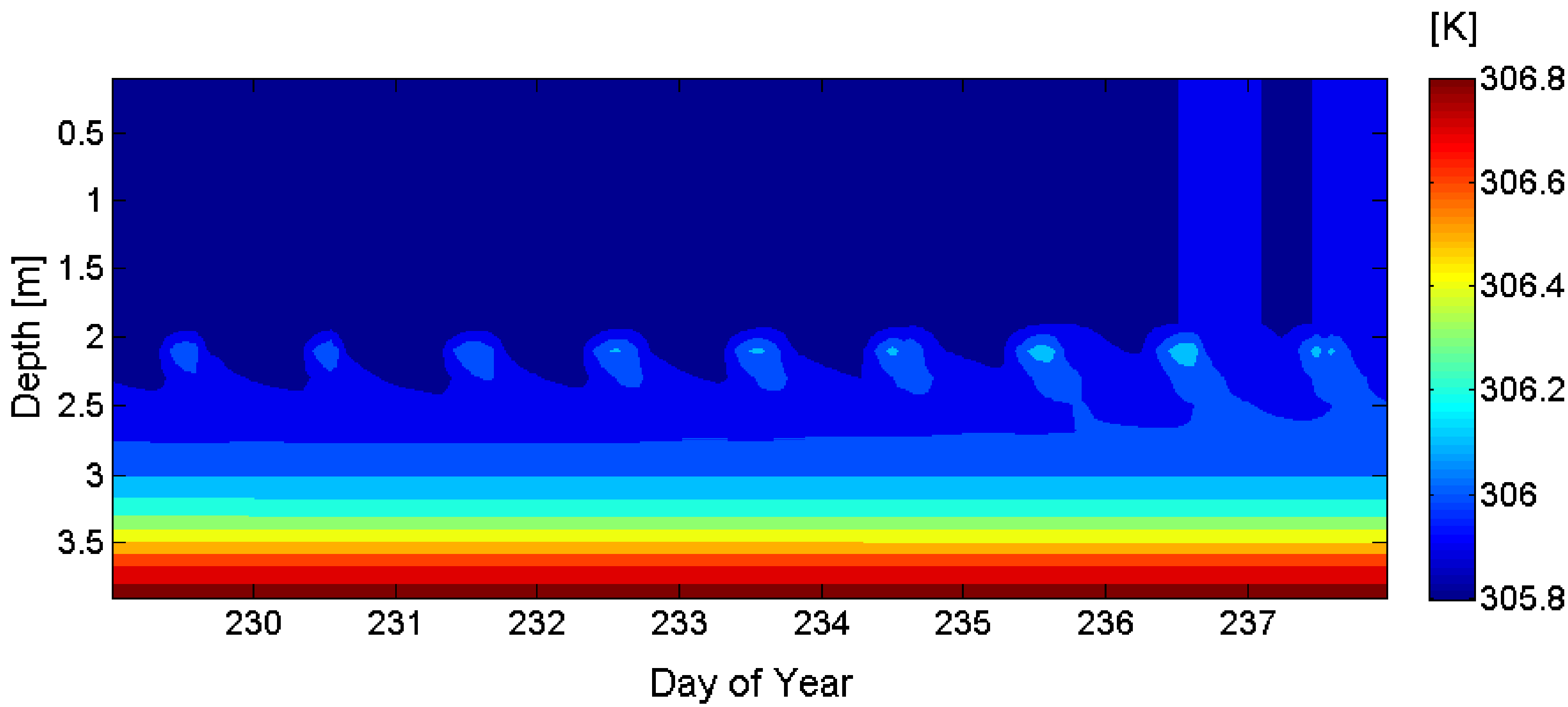
(parameter setting: z_{0m}=z_{0h}=z_{0q}=0.01 m, β=0.4, η=0.89 m^{-1})

Results (CLM4.0 surface module outputs)



(parameter setting: z_{0m}=z_{0h}=z_{0q}=0.001 m, λ=10λ_m, β=0.4, η=0.89 m^{-1})

Results (CLM4.0 lake module outputs)



(parameter setting: z_{0m}=z_{0h}=z_{0q}=0.001 m, λ=$10\lambda_m$, β=0.4, η=0.89 m^{-1})

Soil layers are not properly scaled in above figure

Future work:

(1) Surface module needs:

- Site-specific roughness lengths for resistance estimation;
- Realistic estimates of λ and T_1 to increase the coupling between climatological drivers and the lake;
- Longer testing period;

(2) Lake module needs:

- K_e for the lake
- More work (particularly the tridiagonal matrix);