

# Offline test of CLM4.0 lake model at lake Taihu

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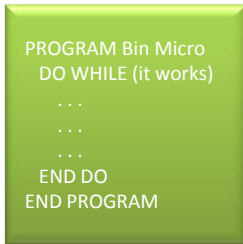
06/09/2011



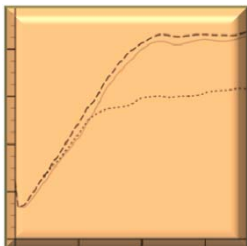
# Outline



## Introduction



## Model



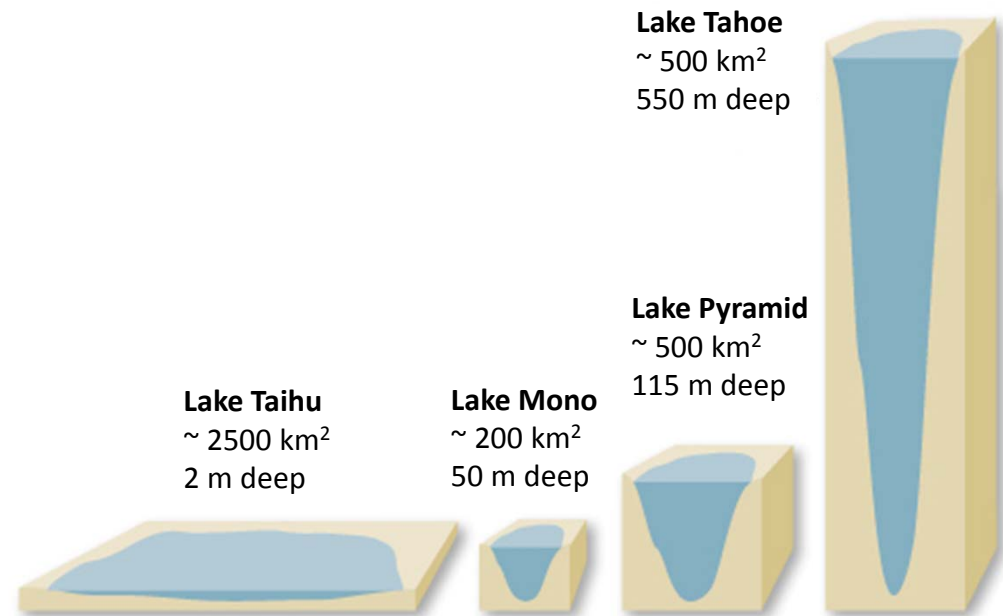
## Results



# Introduction (Taihu lake)



(Xiao et al., 2010)

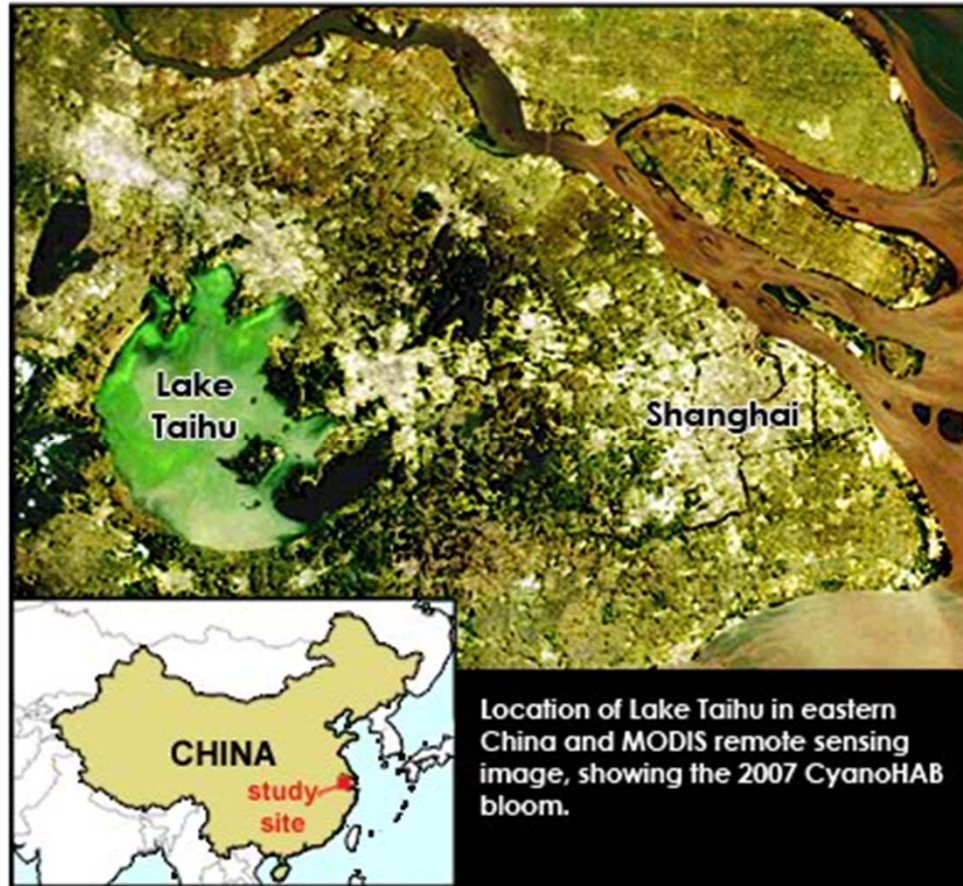


- Inflow from W and SW
- Outlet at SE
- Spatial variation of water quality
- Warm polymictic lake (too shallow to develop thermal stratification)
- Large surface-to-volume ratio
- Different vertical structure from deep lakes
- High evaporation (pronounced local cooling)
- Sensitive to climate change (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



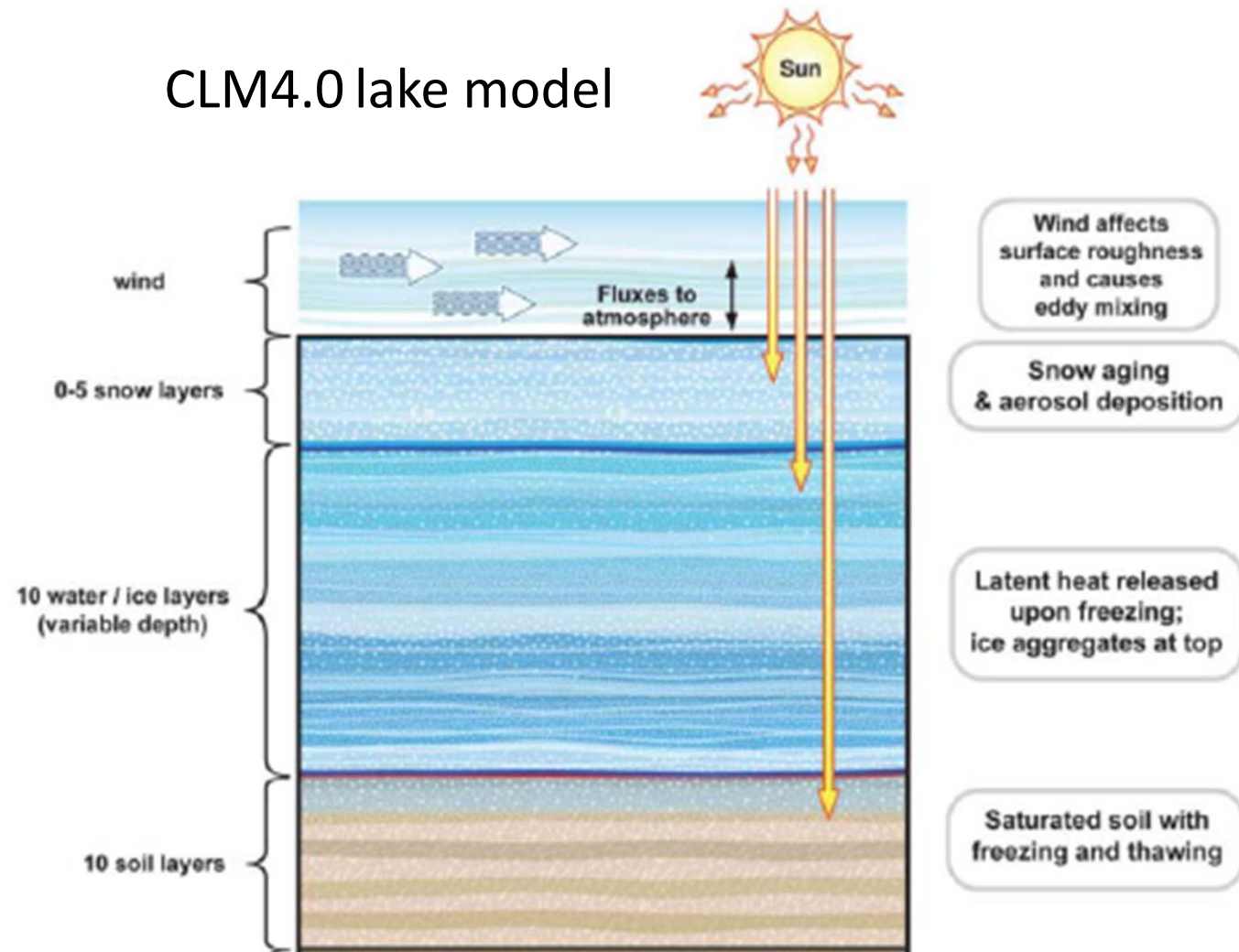
## Introduction

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In this study:

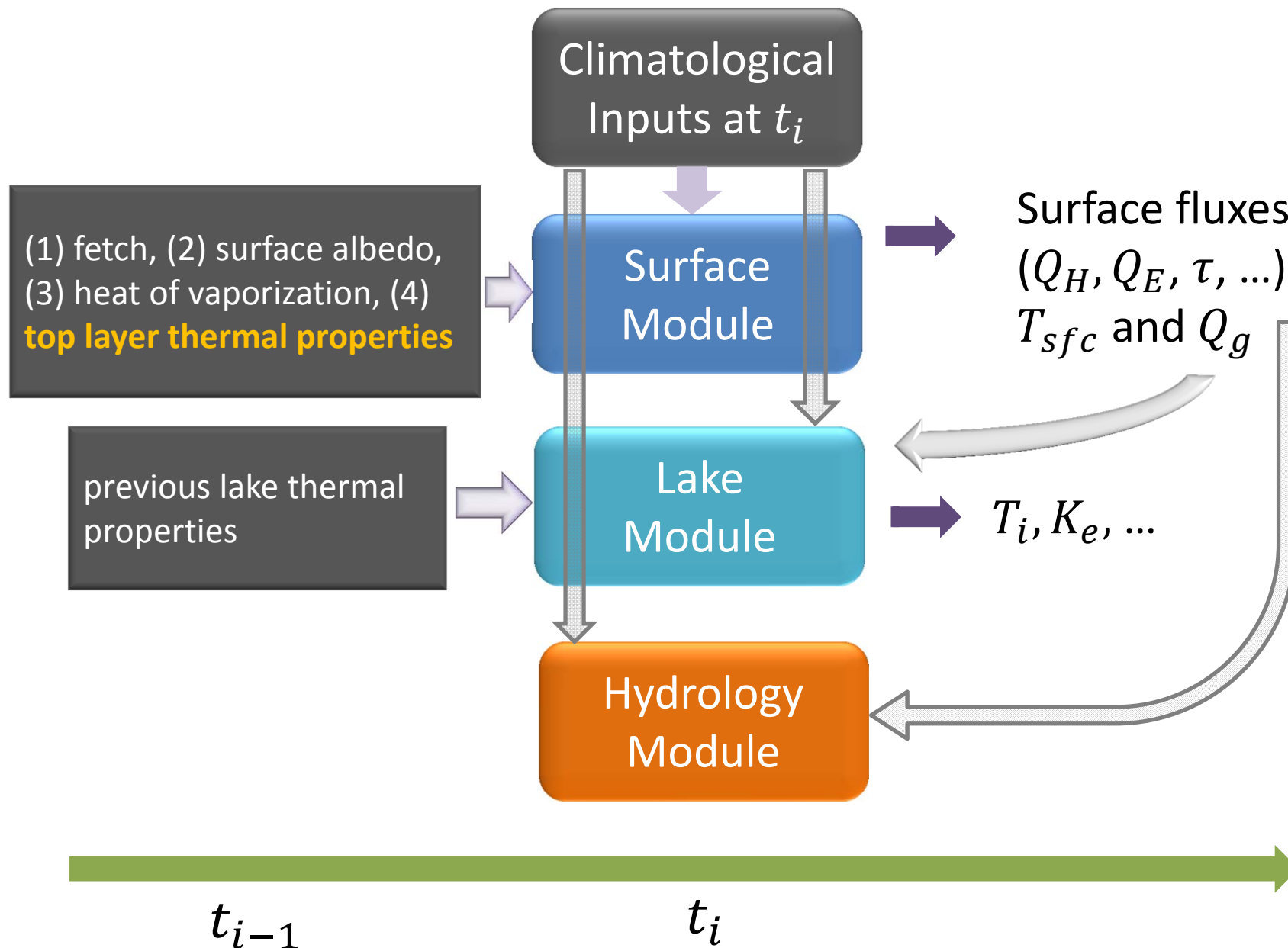
- (1) Evaluate and adapt CLM4.0 lake model for Taihu;
- (2) Couple CLM4.0 lake model into WRF to improve the weather prediction for Taihu region;

# Model (schematic representation)



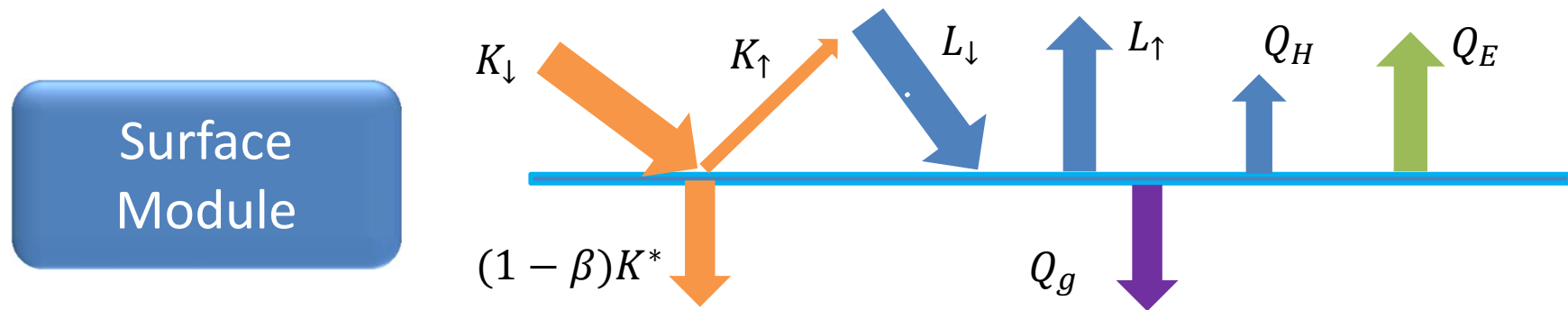
(Subin et al., 2011)

## Model (component modules)





## Model (surface module)



**Module solver** (based on surface layer heat budget):

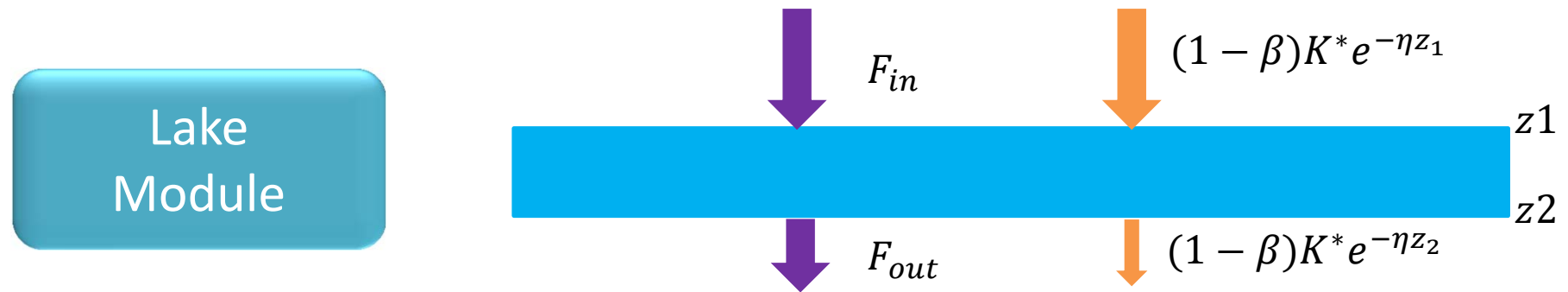
$$\beta(K_{\downarrow} - K_{\uparrow}) + L_{\downarrow} - L_{\uparrow}(T_{sfc}) - Q_H(T_{sfc}) - Q_E(T_{sfc}) - Q_g = 0$$

$\beta$ : fraction of  $K^*$  absorbed in the lake surface layer (0.4~0.6)

$Q_g$ : heat flux as boundary condition for the top layer

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

$\lambda = \lambda_m + \lambda_e$  ( $\lambda_e \sim 10^{2 \sim 3} \lambda_m$ ): highly affects the module outcomes



**Module solver** (vertical heat diffusion):

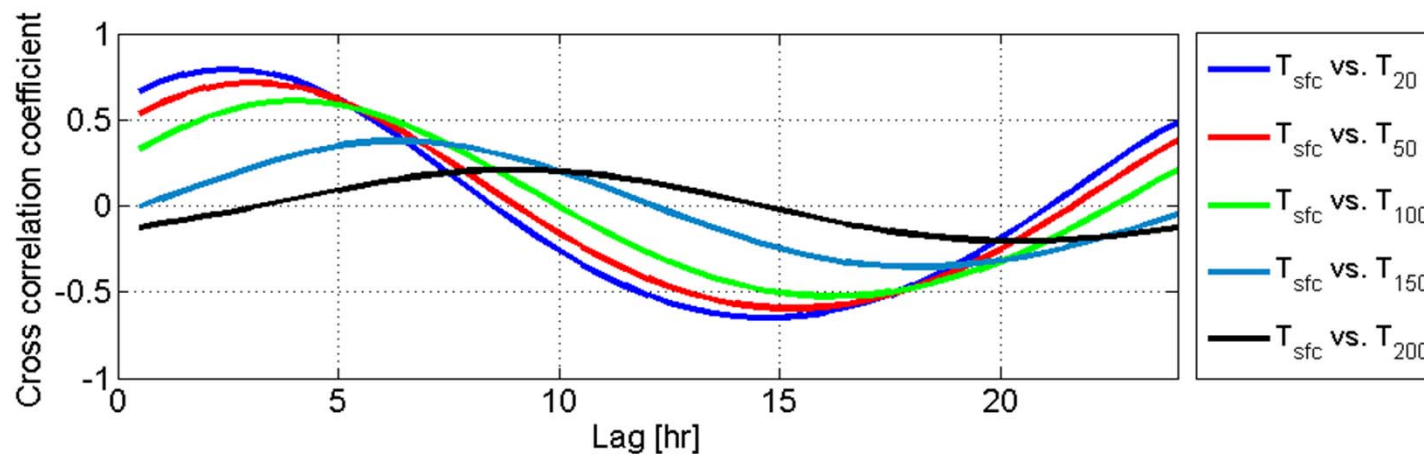
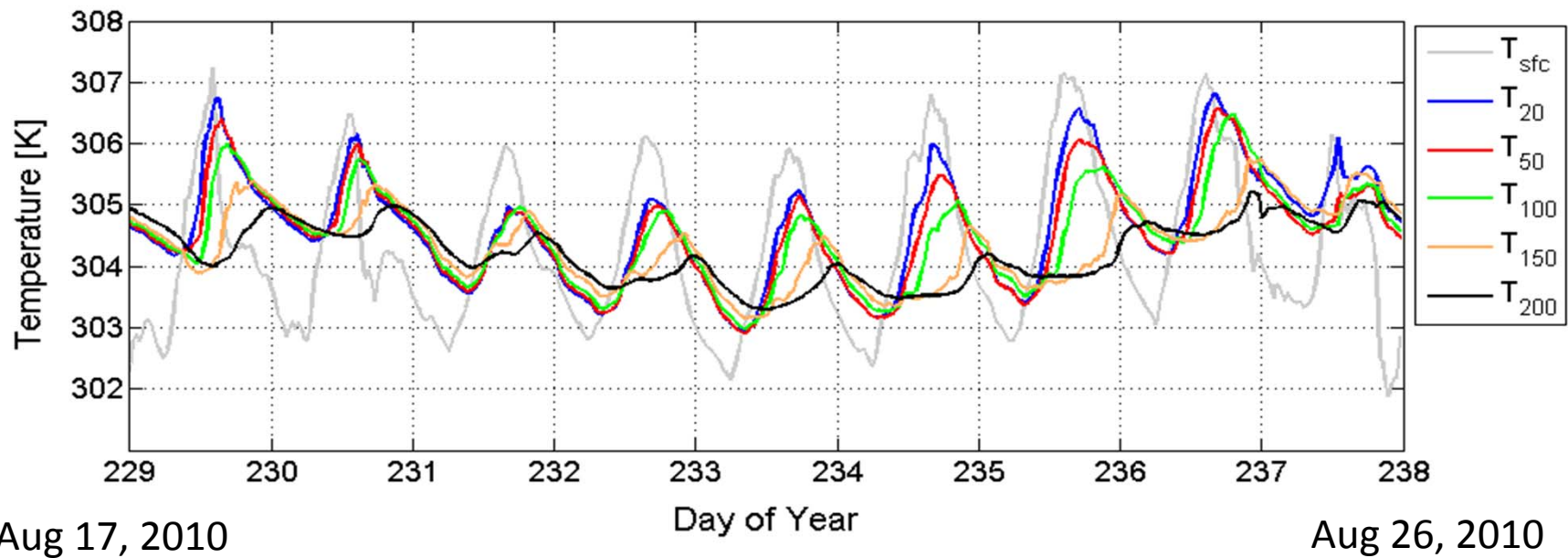
$$\frac{\partial T_i}{\partial t} = \frac{\partial}{\partial z} \left[ (K_m + K_{e,i}) \frac{\partial T_i}{\partial z} \right] + \frac{1}{c_{liq}} \frac{d\phi_i}{dz} \quad (i = 1, N_{lake} + N_{soil})$$

$$\begin{bmatrix} b_1 & c_1 & \cdot & \cdot & 0 \\ a_2 & b_2 & c_2 & \cdot & 0 \\ 0 & a_3 & b_3 & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & c_{n-1} \\ 0 & \cdot & \cdot & a_n & b_n \end{bmatrix} \begin{bmatrix} T_1 \\ T_2 \\ \cdot \\ \cdot \\ T_n \end{bmatrix} = \begin{bmatrix} r_1 \\ r_2 \\ \cdot \\ \cdot \\ r_n \end{bmatrix} \quad \begin{aligned} a_i &\sim f(T_{prev}, K_e) \\ b_i &\sim f(T_{prev}, K_e) \\ c_i &\sim f(T_{prev}) \\ r_i &\sim f(T_{prev}, K_e, \phi) \end{aligned}$$

$\eta$  and  $K_e$  affect the heat redistribution within the lake

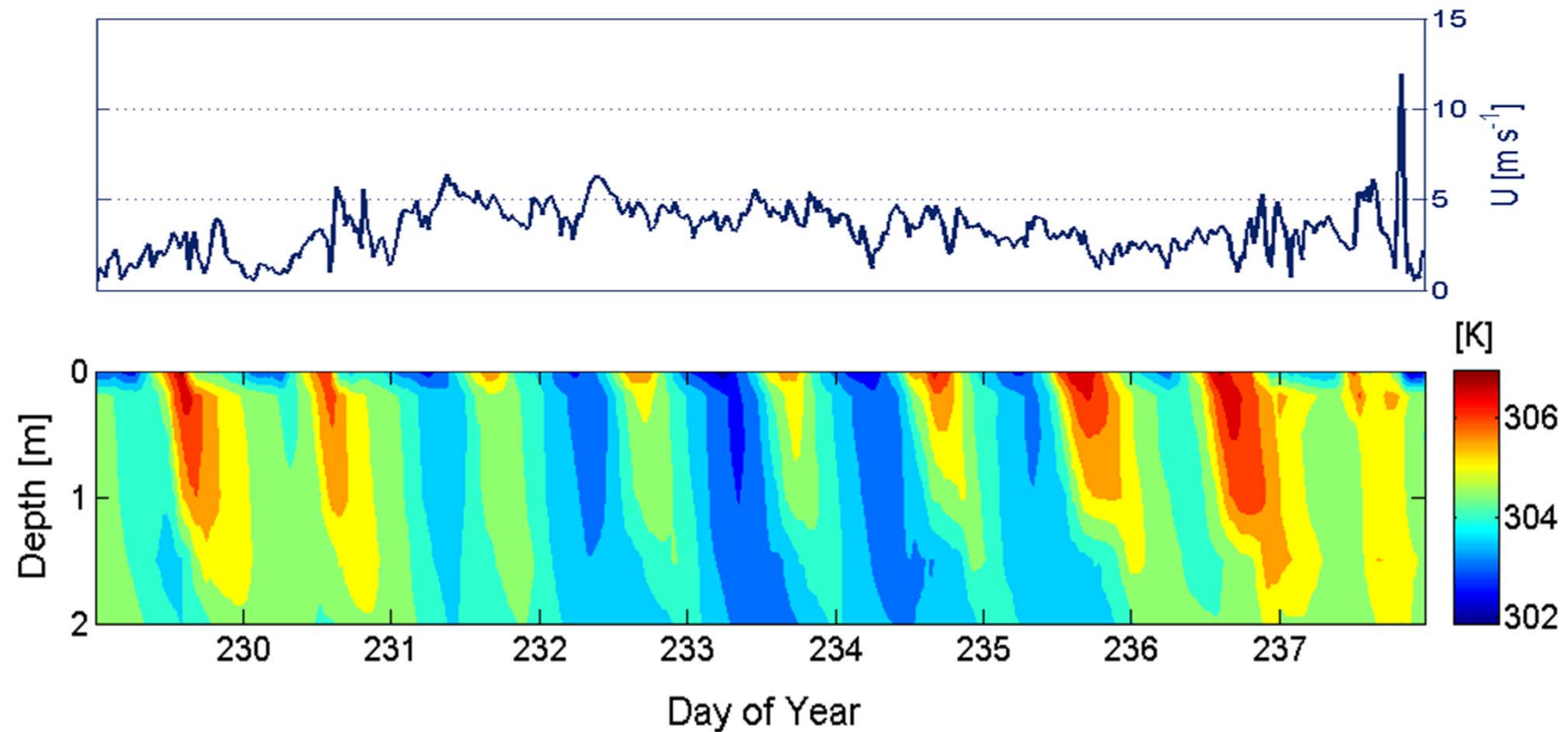


## Results (lake temperature measurements)





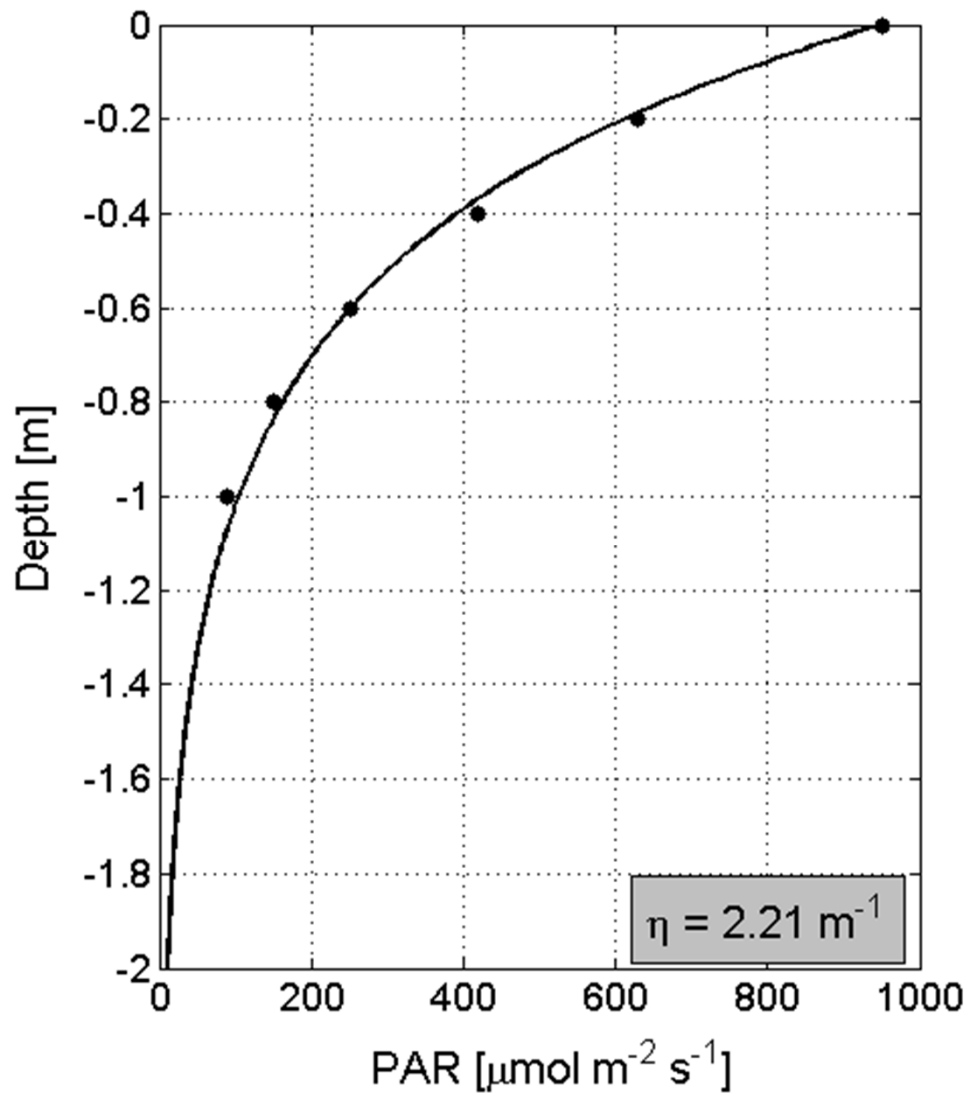
## Results (lake temperature measurements)



- 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

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

(2) CLM4.0 lake model

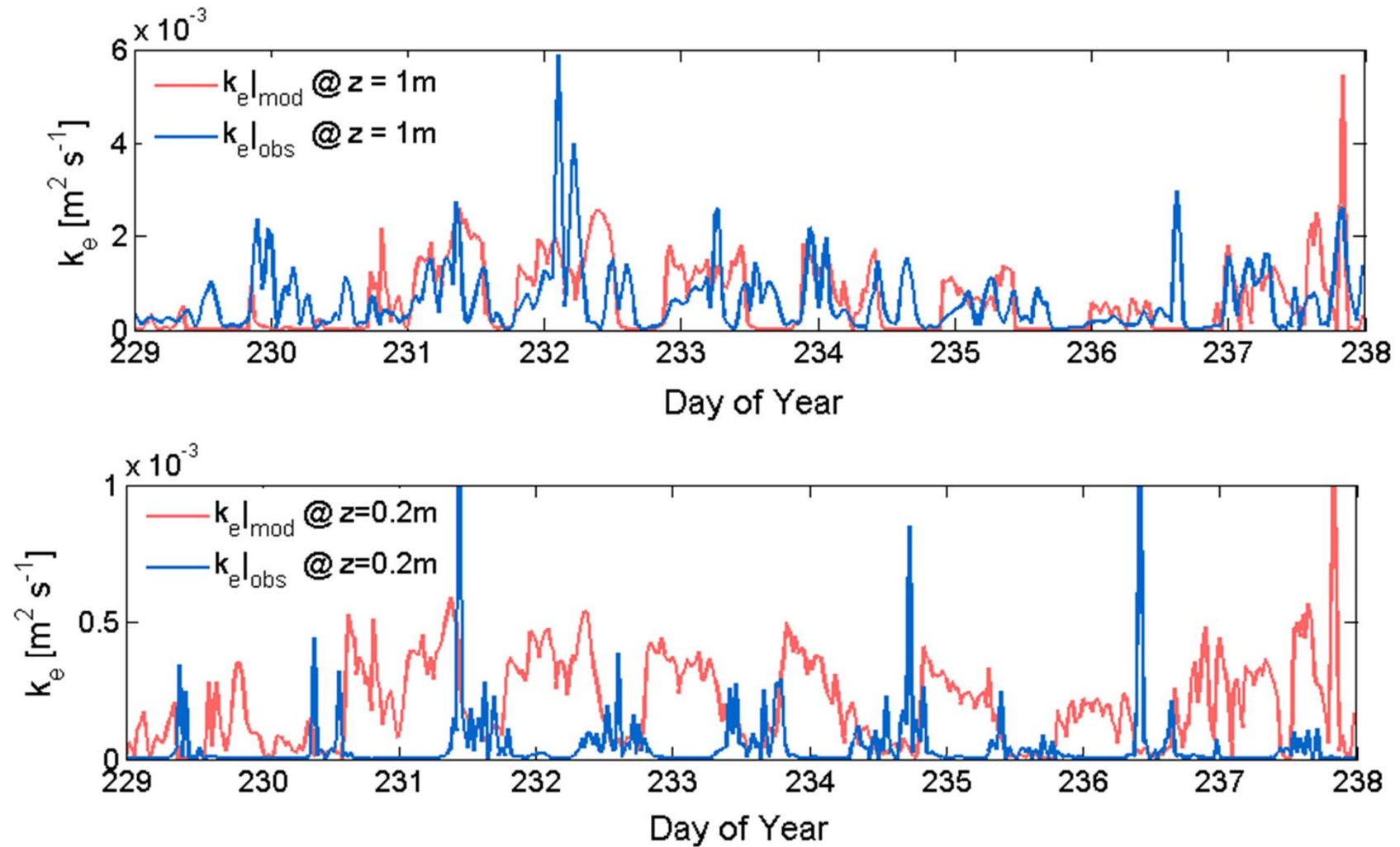
$$\eta = 1.1925 D^{-0.424}$$

(0.89 for Taihu based on this formula)



## Results (lake parameters)

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



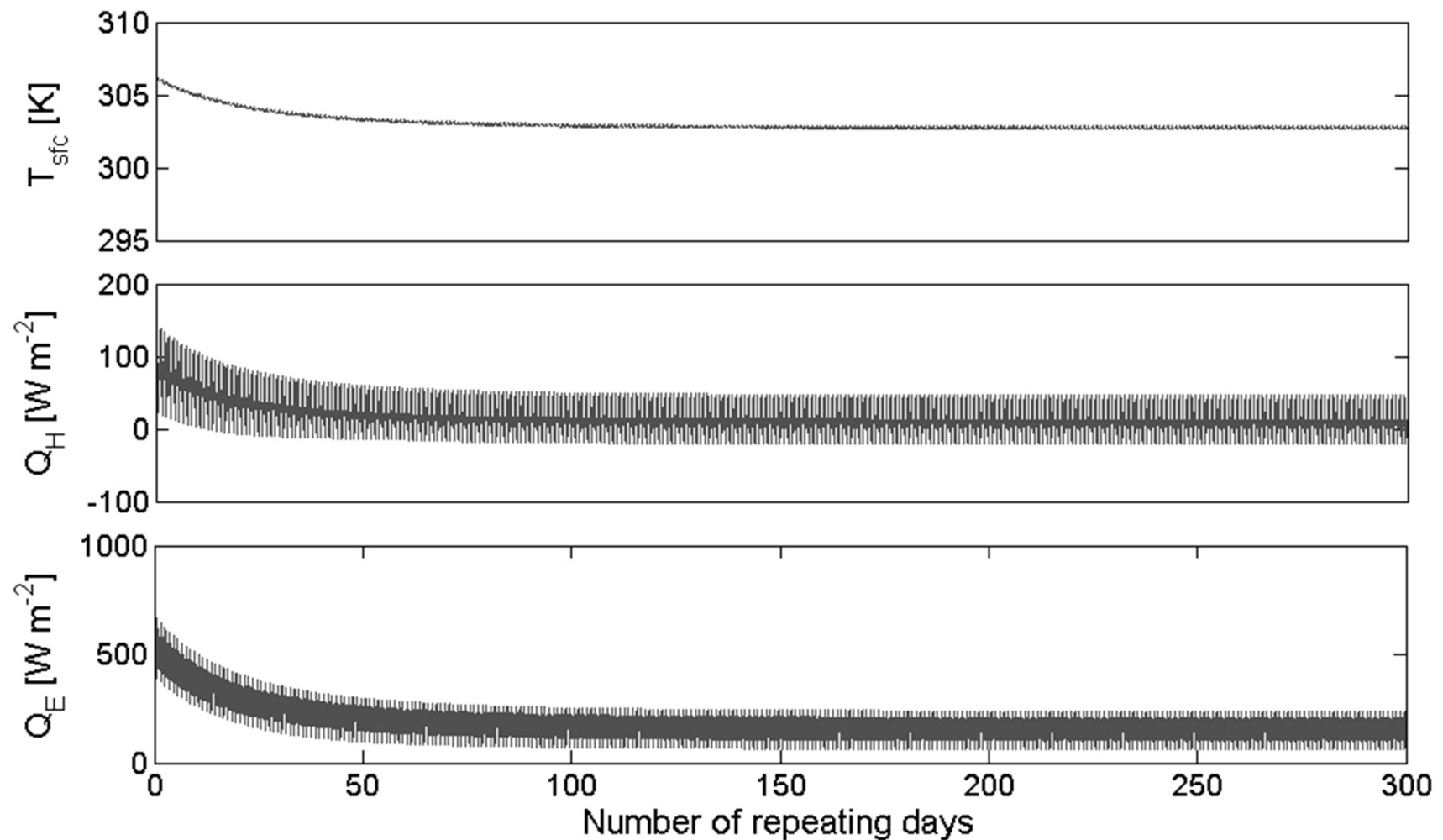
$K_e$  deserves more attention



## Results (model spin-up time)

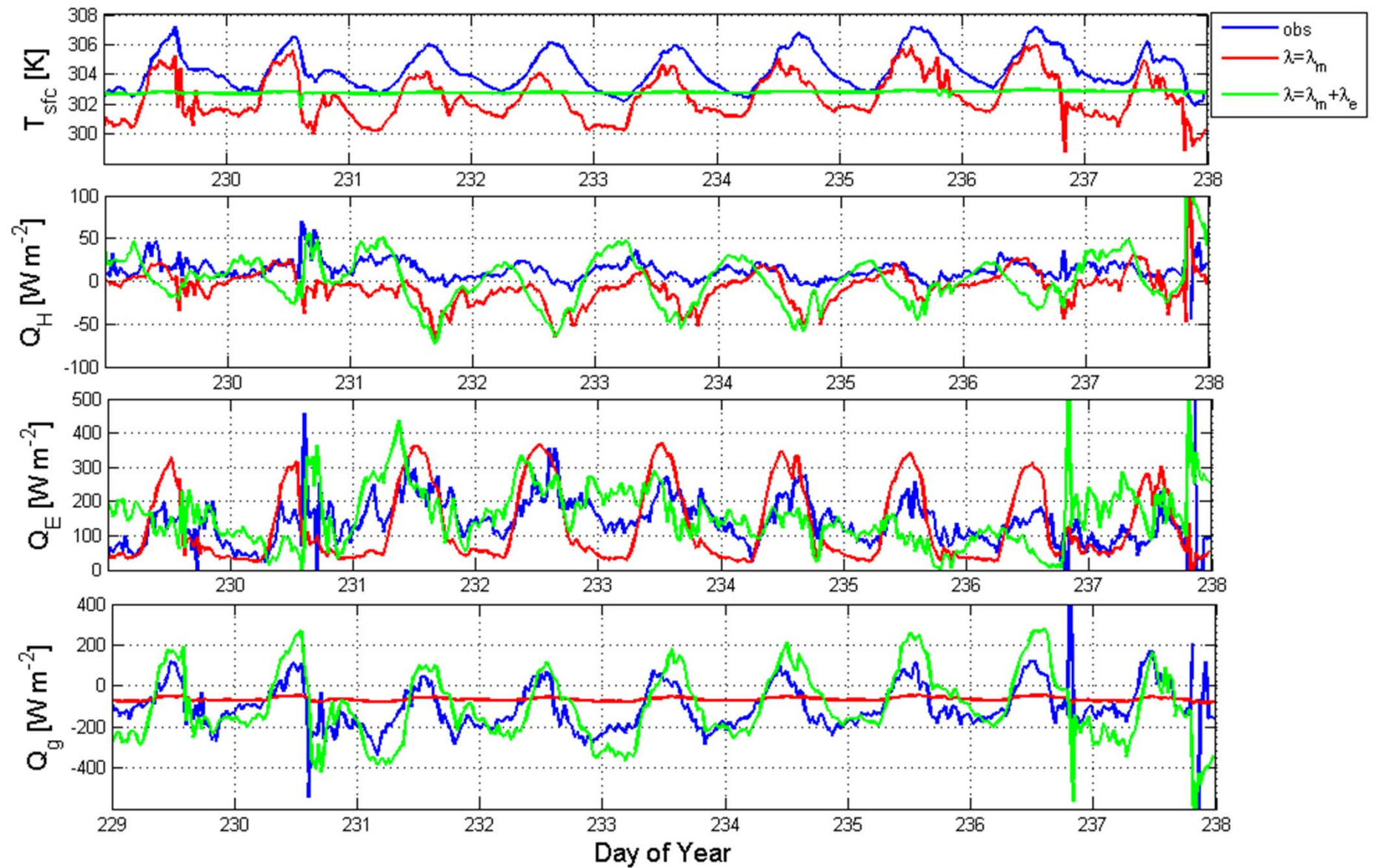
Model spin-up time (the time model takes to reach an equilibrium state)

here the model is driven by repeating measurements from DOY 229





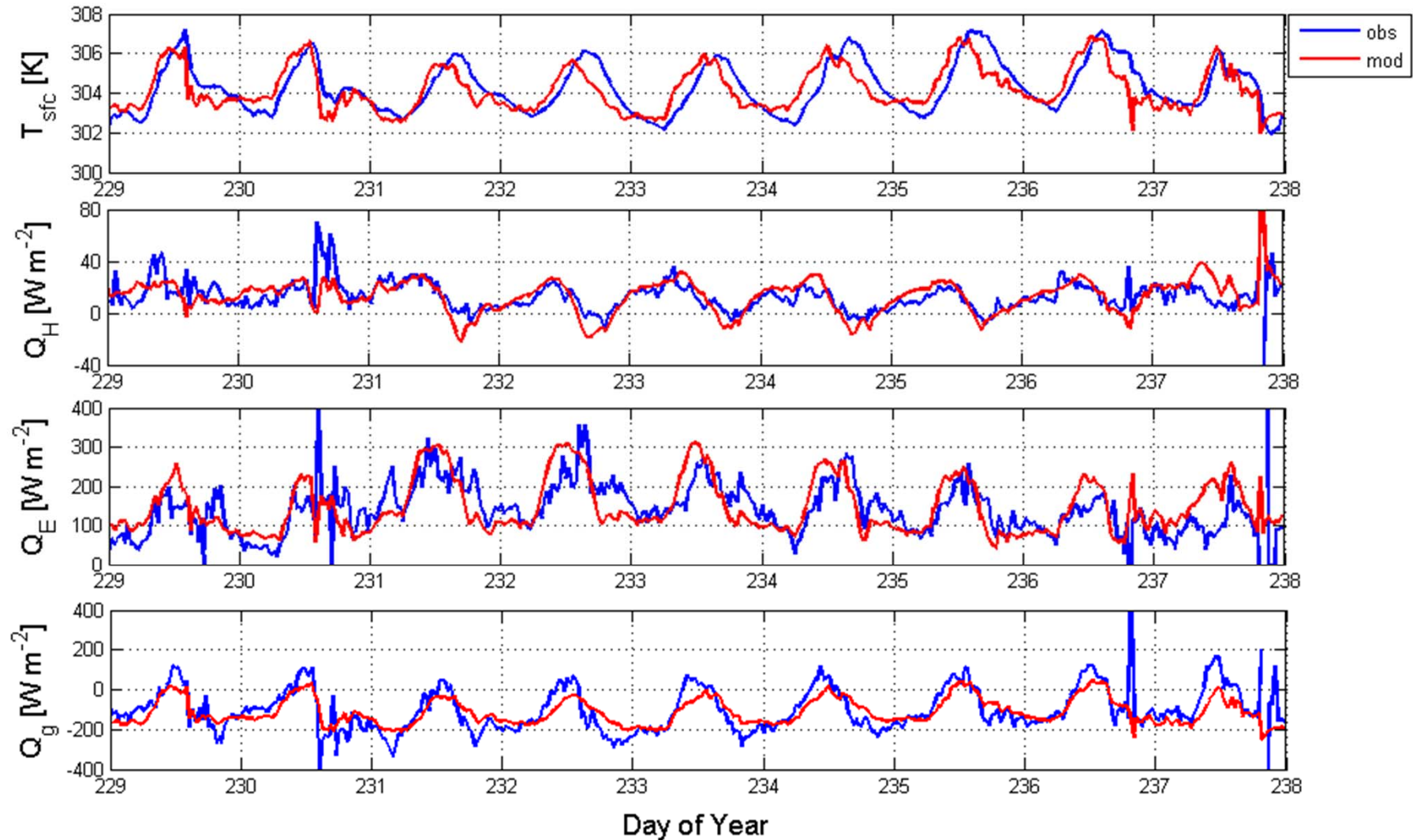
## Results (CLM4.0 surface module outputs)



(parameter setting:  $z_{0m}=z_{0h}=z_{0q}=0.01$  m,  $\beta=0.4$ ,  $\eta=0.89$  m<sup>-1</sup>)



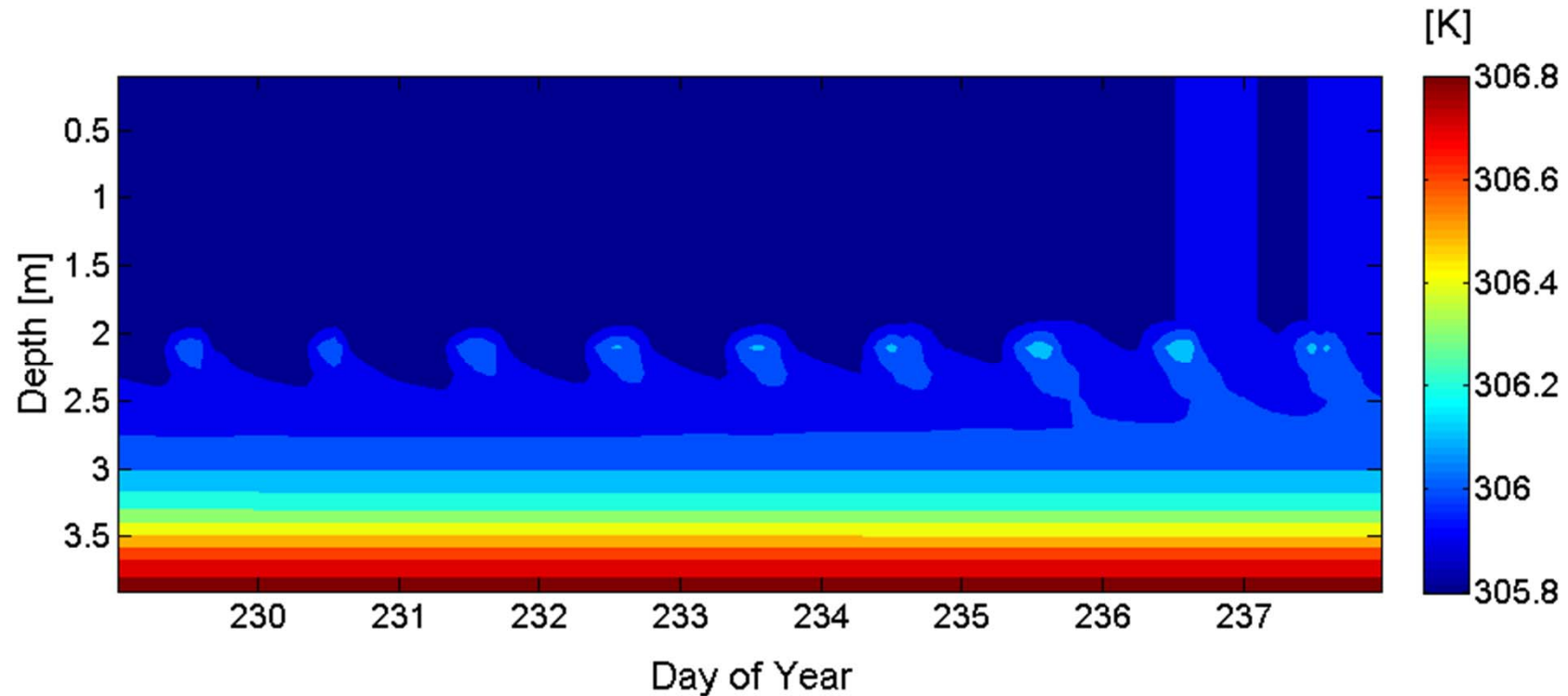
## Results (CLM4.0 surface module outputs)



(parameter setting:  $z_{0m}=z_{0h}=z_{0q}=0.001$  m,  $\lambda=10\lambda_m$ ,  $\beta=0.4$ ,  $\eta=0.89$  m<sup>-1</sup>)



## Results (CLM4.0 lake module outputs)



(parameter setting:  $z_{0m}=z_{0h}=z_{0q}=0.001$  m,  $\lambda=10\lambda_m$ ,  $\beta=0.4$ ,  $\eta=0.89$  m<sup>-1</sup>)

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  $\lambda$  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);