Update on doctoral dissertation research: lake models application and comparison in Lake Taihu

ZHANG Zhen
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Outline

- Background
- Model principle
- Motivation
- Experimental design
- Model modification
- Preliminary results
- Future work

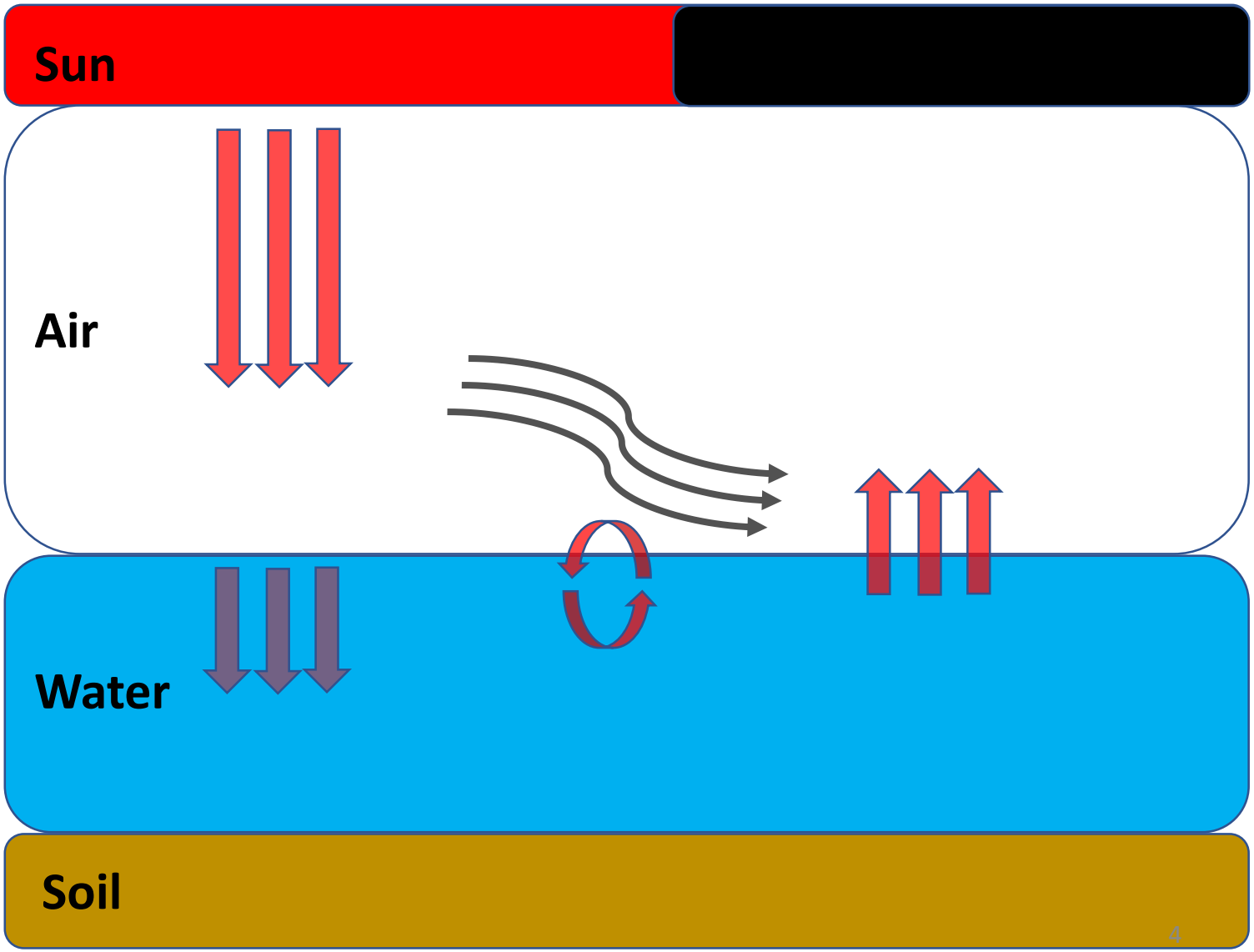
Background

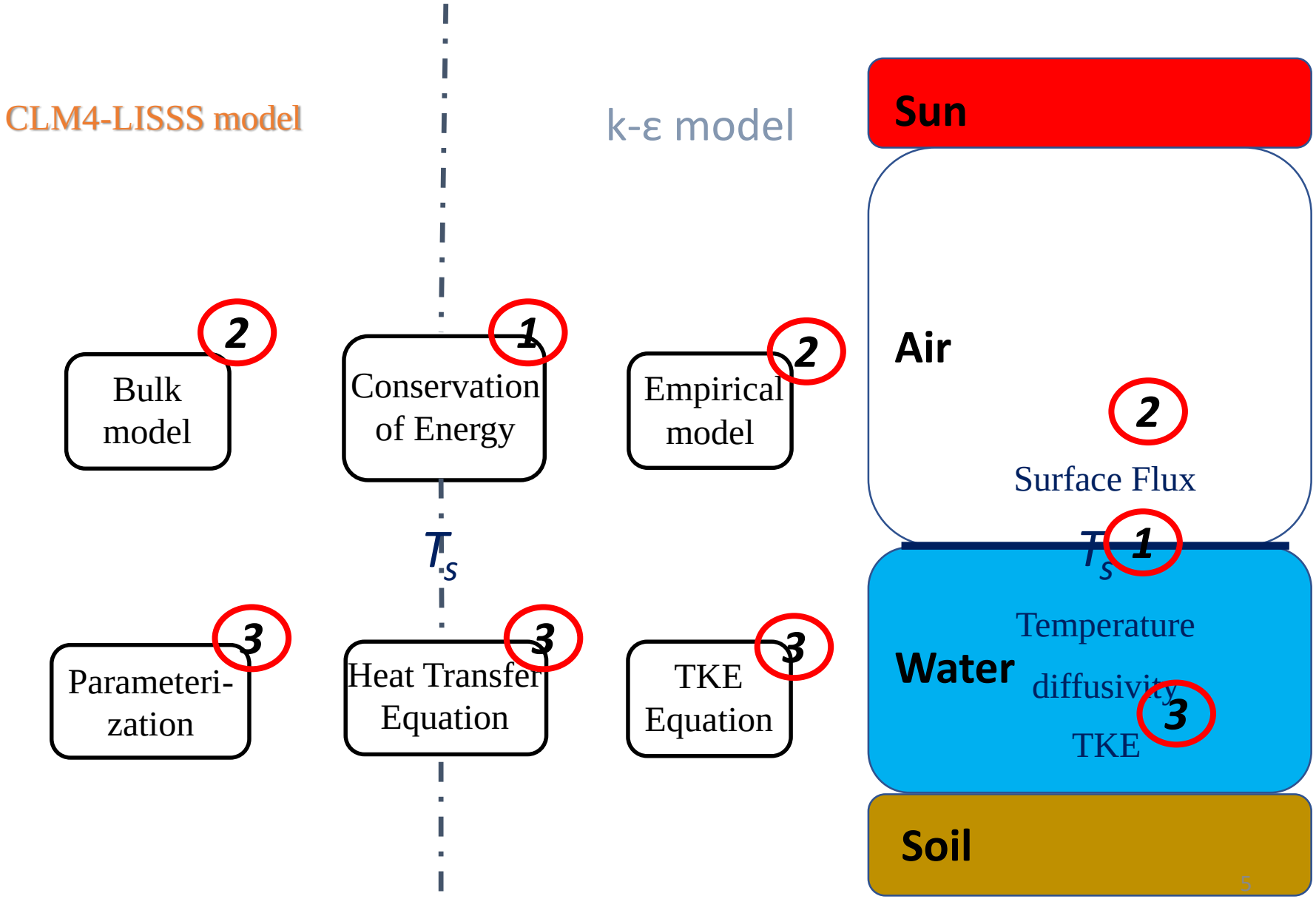
- Models for wind mixing and stratification of lakes have included integral energy models (Mironov 2005, 2008, 2010) , turbulent diffusion based models (Hostetler 1990, 1993, 1994; Subin 2012) and turbulent closure models (Goudsmit 2002; Peeters 2002; JOHNK 2005).

- Surface energy and radiation balance module is critical to surface flux calculation and lake body energy distribution. Especially surface flux calculation is relied on robust simulation of surface temperature.

- Vertical turbulent mixing is an important role in lakes, Production of TKE by wind shear *(forced convection)* and an unstable density stratification is produced in the water column *(natural convection)* are two main drivers.

Model principle




CLM4-LISSS model
k-ε model
Sun
Air
Bulk model
2
Conservation of Energy
1
Empirical model
2
2
Surface Flux
T_s
T_s
1
Parameteri-zation
3
Heat Transfer Equation
3
TKE Equation
3
Water
Temperature
diffusivity
TKE
3
Soil

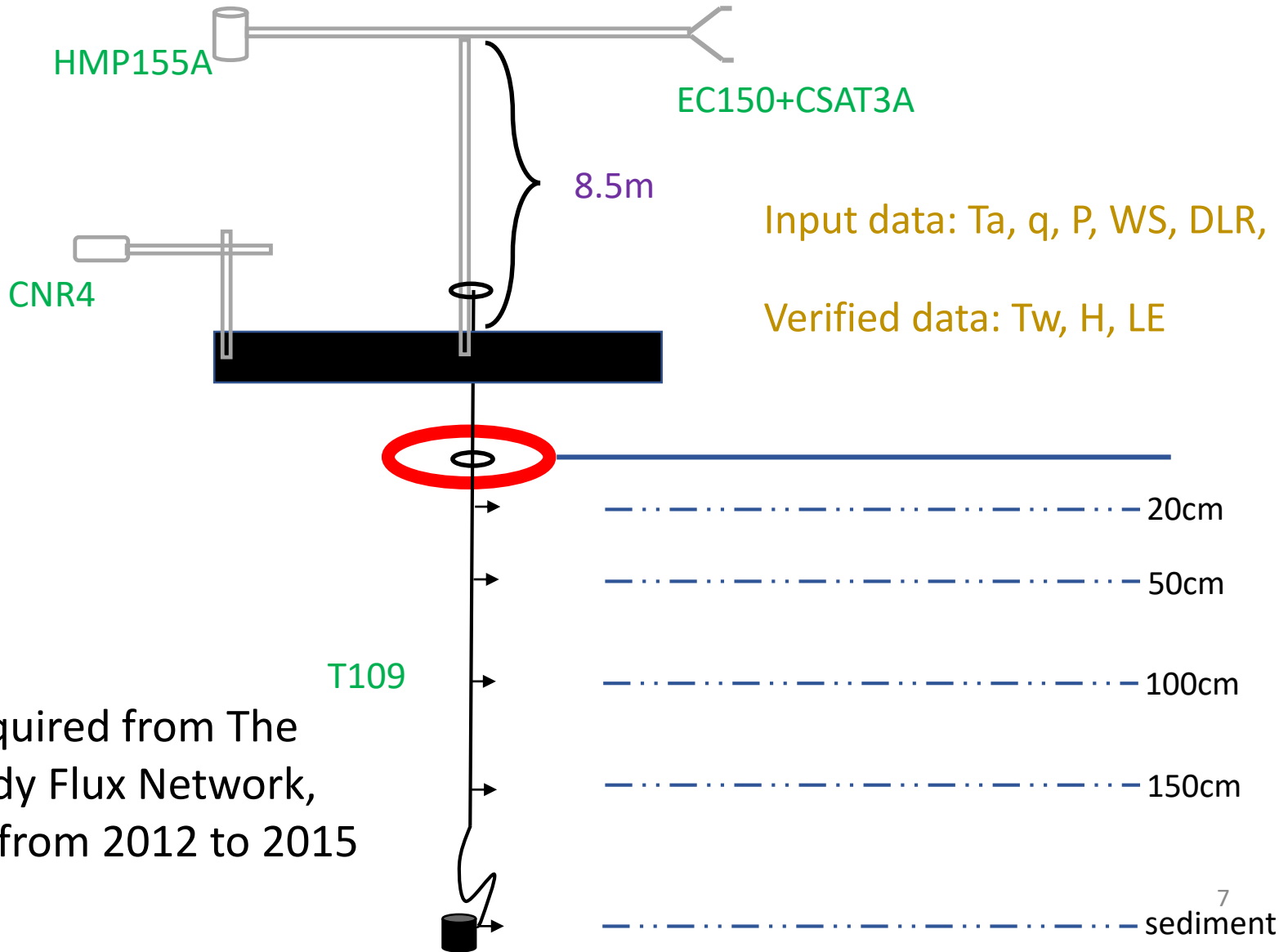
Motivation

- CLM4-LISSS model does integrated preparation on conservation of surface energy and surface flux calculation, Dose this model perform better in this respect ?

- k-ε model owns heat transfer equation and TKE equation, how about the turbulent diffusivity simulation results compared with CLM4-LISSS model?

- Find out the distribution of surface eddy diffusivity (K_e) in different season and different weather condition. The diurnal variation of K_e? which meteorological factor affect variation of K_e?

Experimental design



Input data: Ta, q, P, WS, DLR, Rn

Verified data: Tw, H, LE

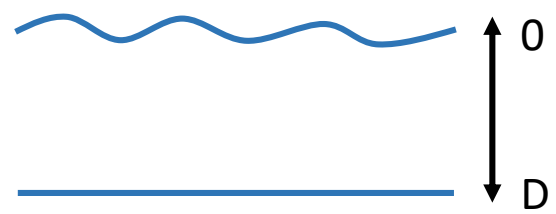
Data: acquired from The Taihu Eddy Flux Network, BFG site from 2012 to 2015

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

$$K_e = K_{e0} f(R_i) \begin{cases} f(R_i) = (1 + 37R_i^2)^{-1} \\ \text{Neutral condition:} \\ K_{e0} = k u_* z \end{cases}$$



$K_{e0} = k u_* z \leftarrow u_* = u_{*0}\exp(-k^* z) \leftarrow k^* = 6.6 U_2^{-1.84}\sqrt{sin\varphi}$

$\Downarrow$ $D - d$ $\qquad$ $\Downarrow$ d

```
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))
```

$\Downarrow$

```
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))
```

Model modification on Parameter adjustment

k- ε model:

Table 2 k-ε model parameter values

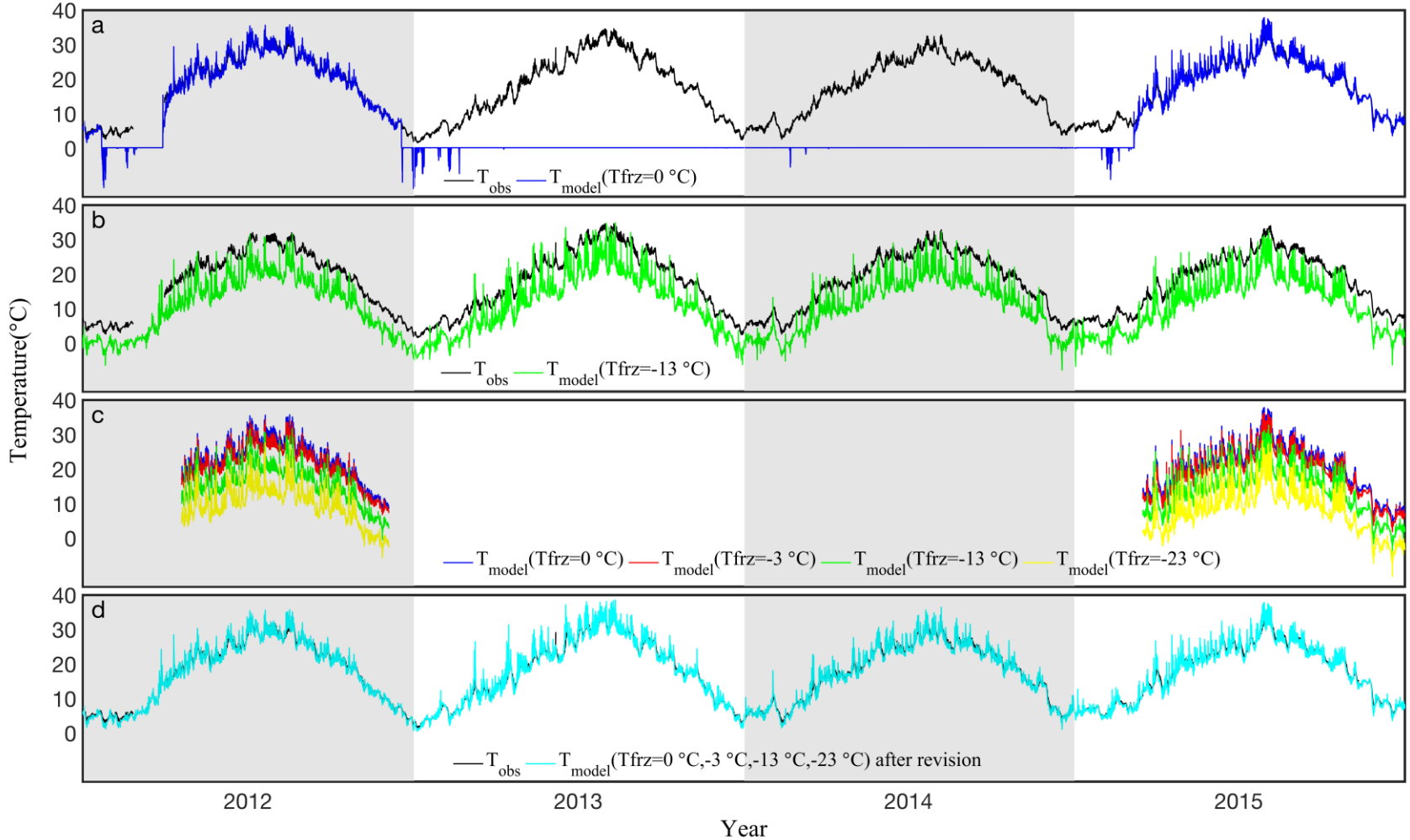
Parameter	Description	Nominal Value (units)
K_{wc}	light attenuation coefficient for water	$1\ \mathrm{m}^{-1}$
K_m	specific light attenuation coefficient for macrophytes	$0.01\ \mathrm{m}^{2}\mathrm{gDW}^{-1}$
d	water depth	2m
C_k	mixing length coefficient	0.1(Herb [2005])
C_D	drag coefficient	1.0 (Finnigan [2000])
K_h	hypolimnetic diffusivity	$0.03\ \mathrm{m}^2\ d^{-1}$(Herb [2005])
C_w	wind correction coefficient	1.0
nz	number of discrete depth increments	50
Δt	time increment	30min

month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Biomass (gdw/m^3)	0	0	0	20	40	60	80	100	75	50	25	0
Plant height (m)	0	0	0	0.32	0.64	0.96	1.28	1.6	1.2	0.8	0.4	0

CLM4-LISSS model:

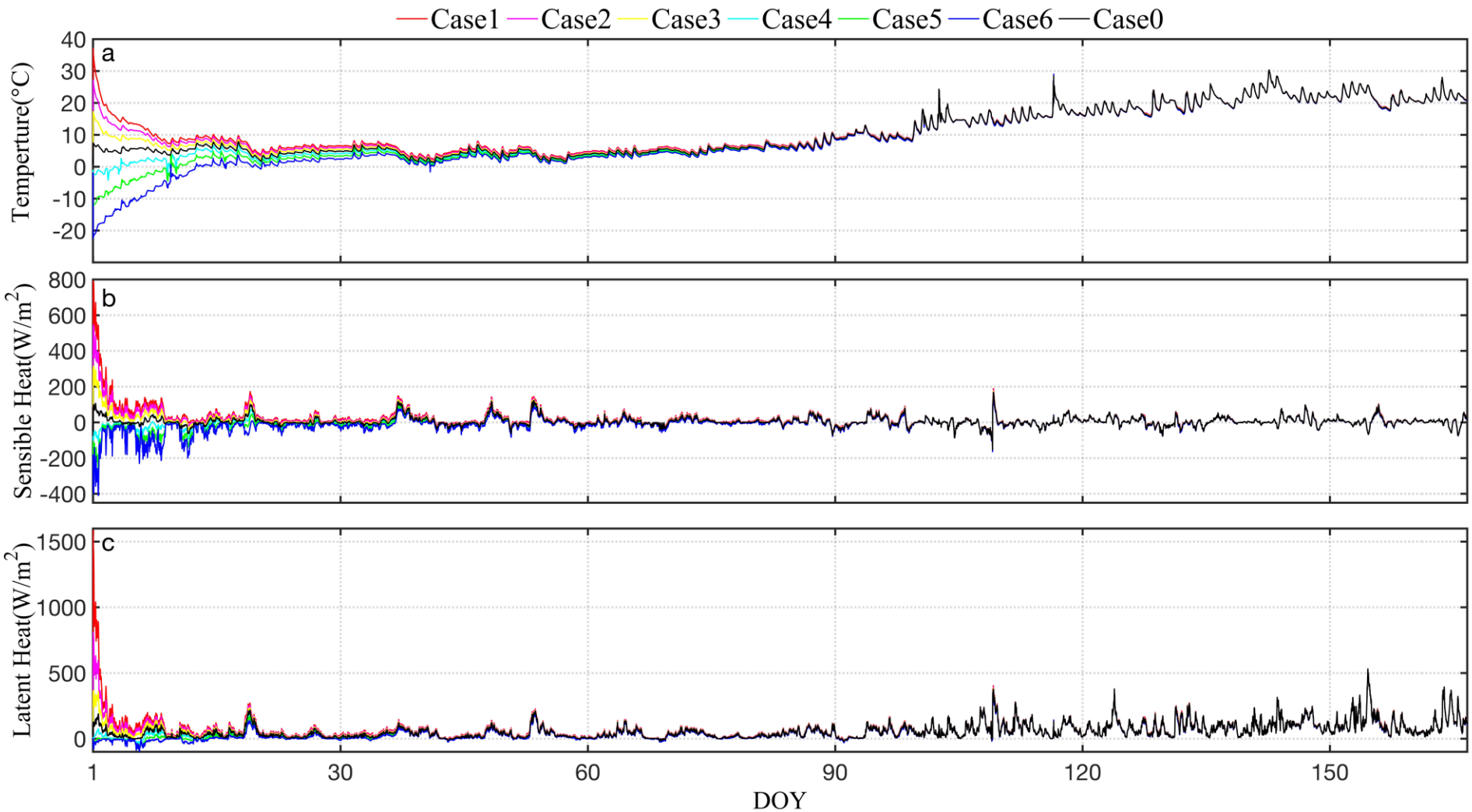
Parameter setting is roughly same with Deng's Paper

Model modification on freezing temperature

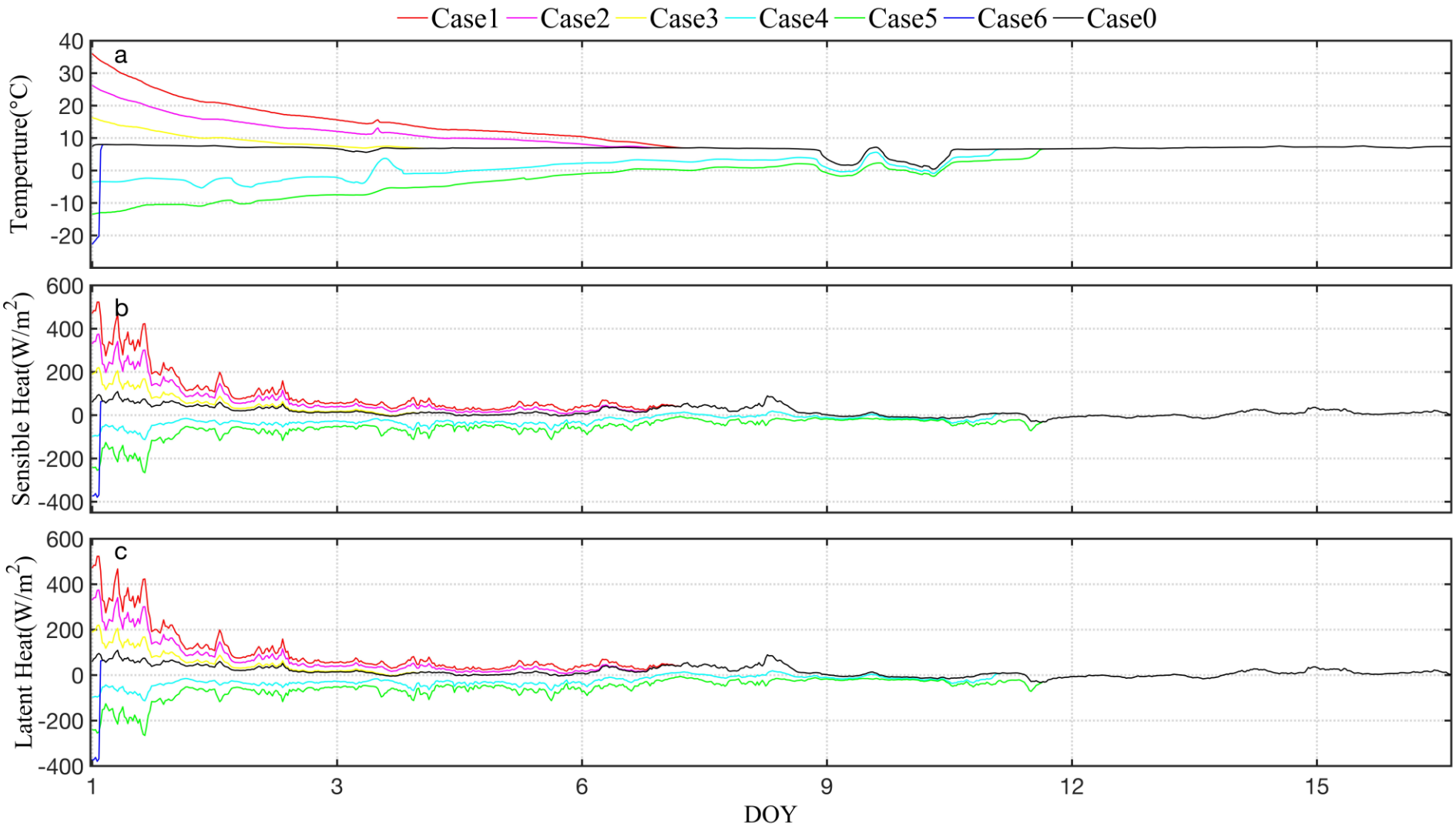


About spin up

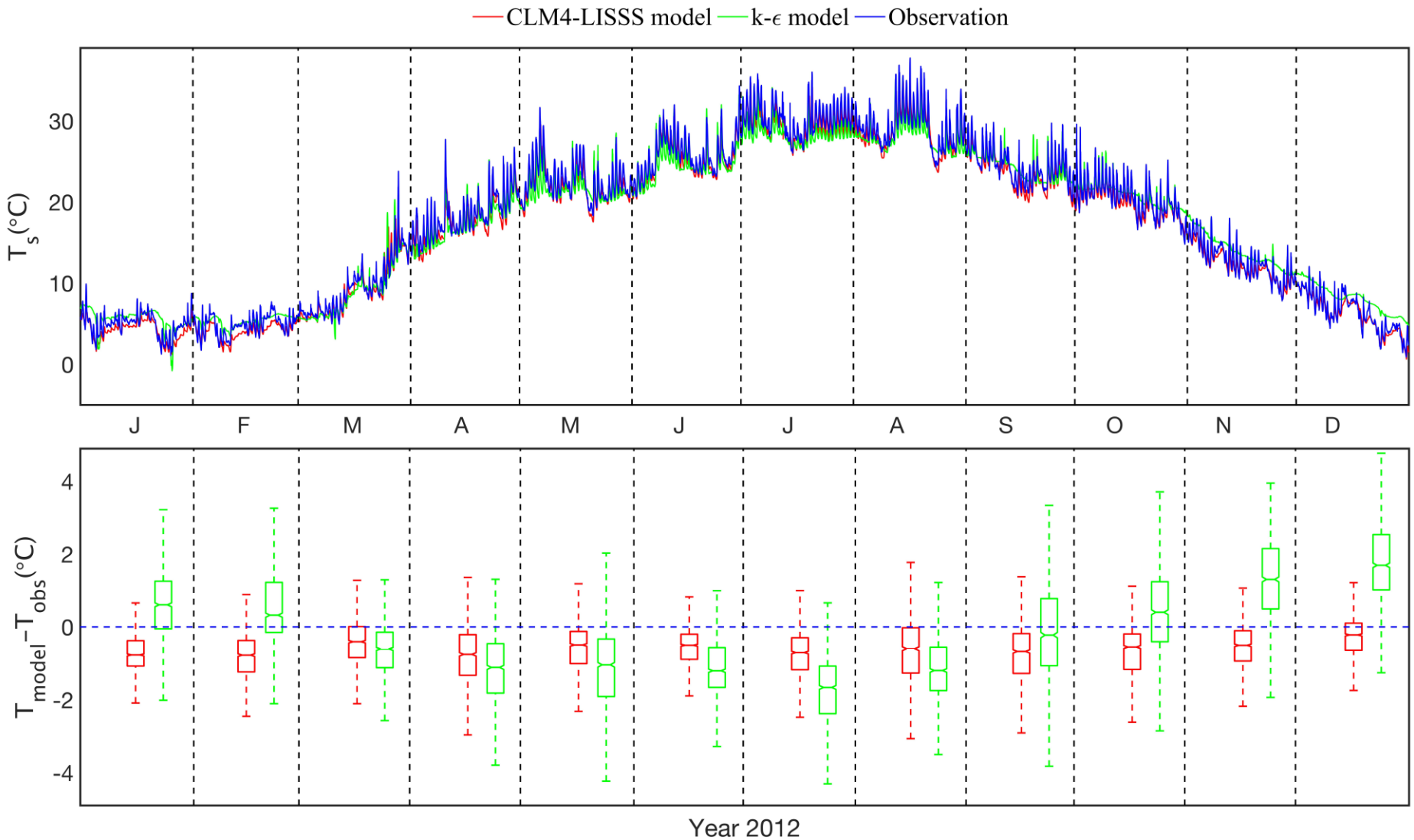
CLM4-LISSS model:

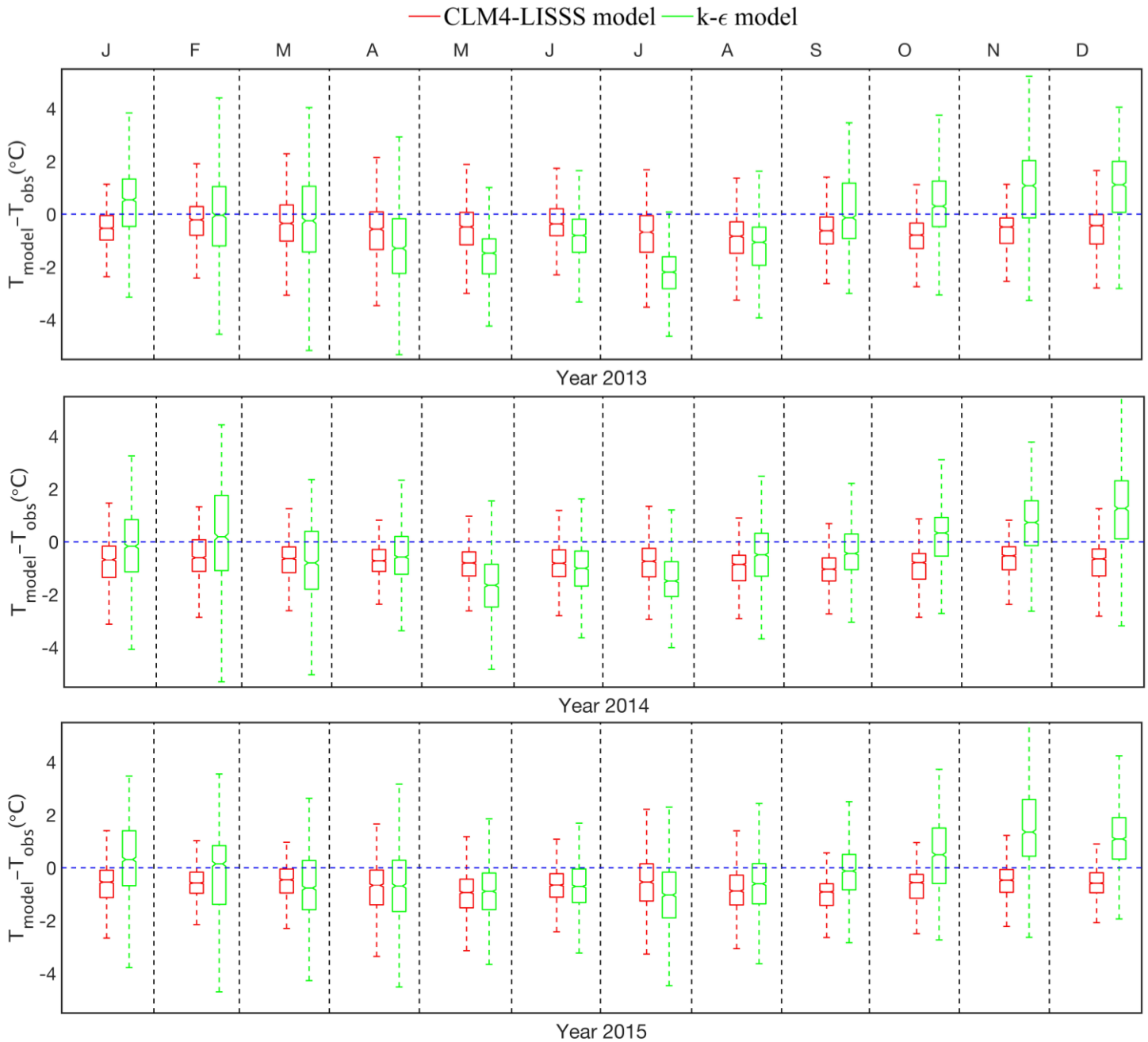


k- ε model:


Case1
Case2
Case3
Case4
Case5
Case6
Case0
a
b
c
Temperture(°C)
Sensible Heat(W/m2)
Latent Heat(W/m2)
DOY
40
30
20
10
0
-10
-20
600
400
200
0
-200
-400
1
3
6
9
12
15

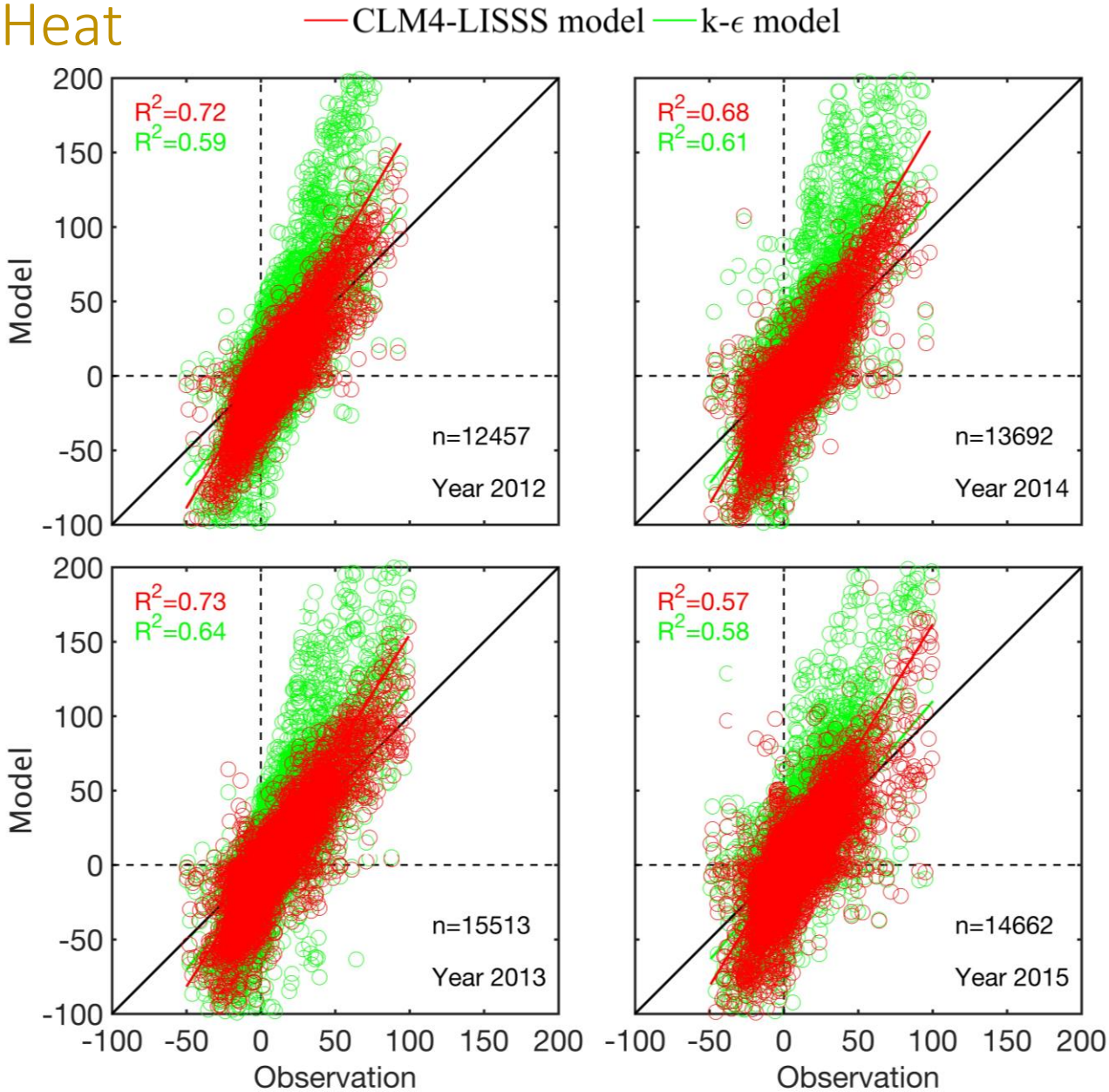
Surface Temperature Performance




CLM4-LISSS model
k-ϵ model
J
F
M
A
M
J
J
A
S
O
N
D
$T_{model}-T_{obs}$ (°C)
4
2
0
-2
-4
Year 2013
Year 2014
Year 2015

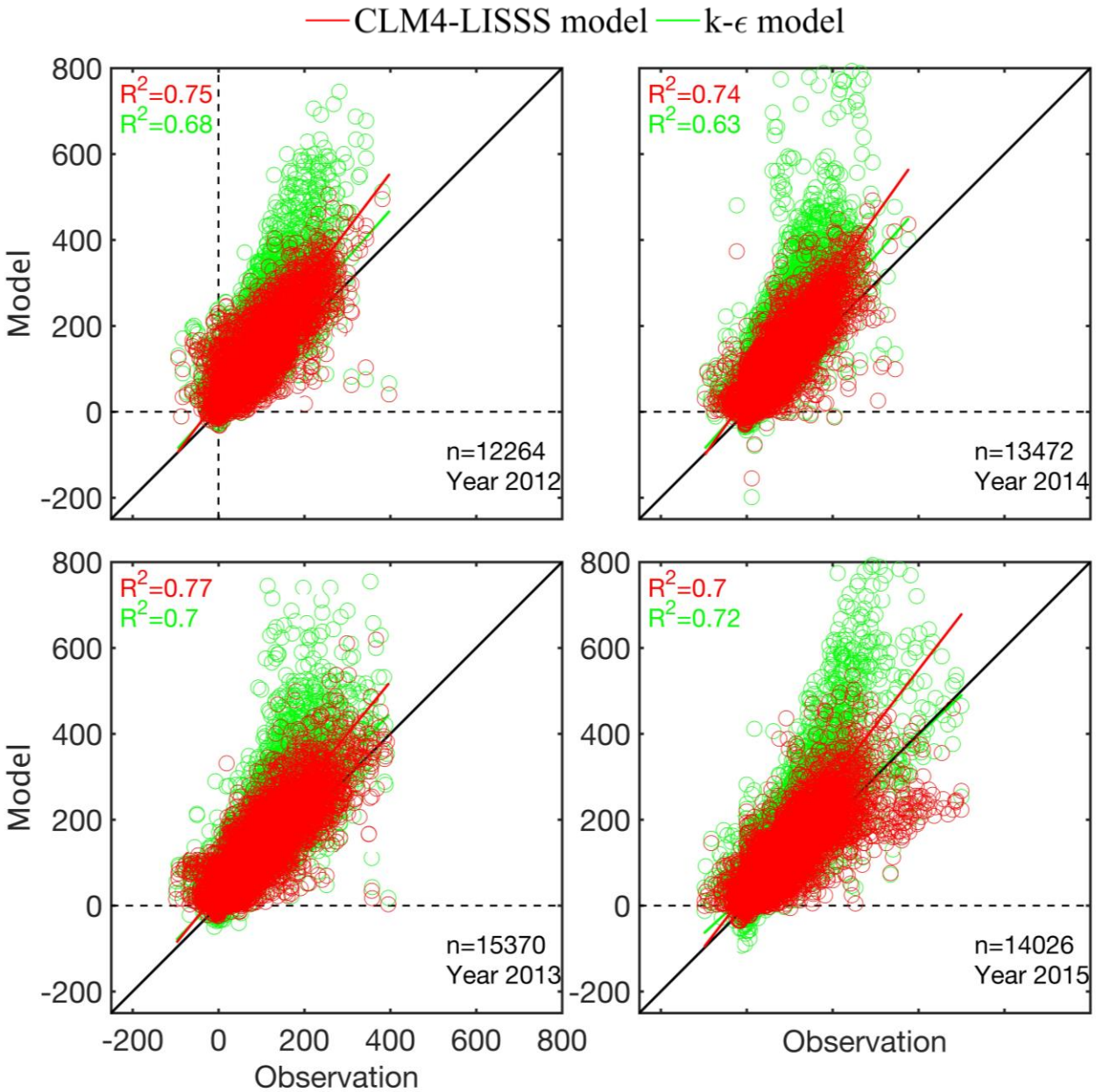
Surface Flux Performance

Sensible Heat



’n’ represents the total number of half-hourly observations

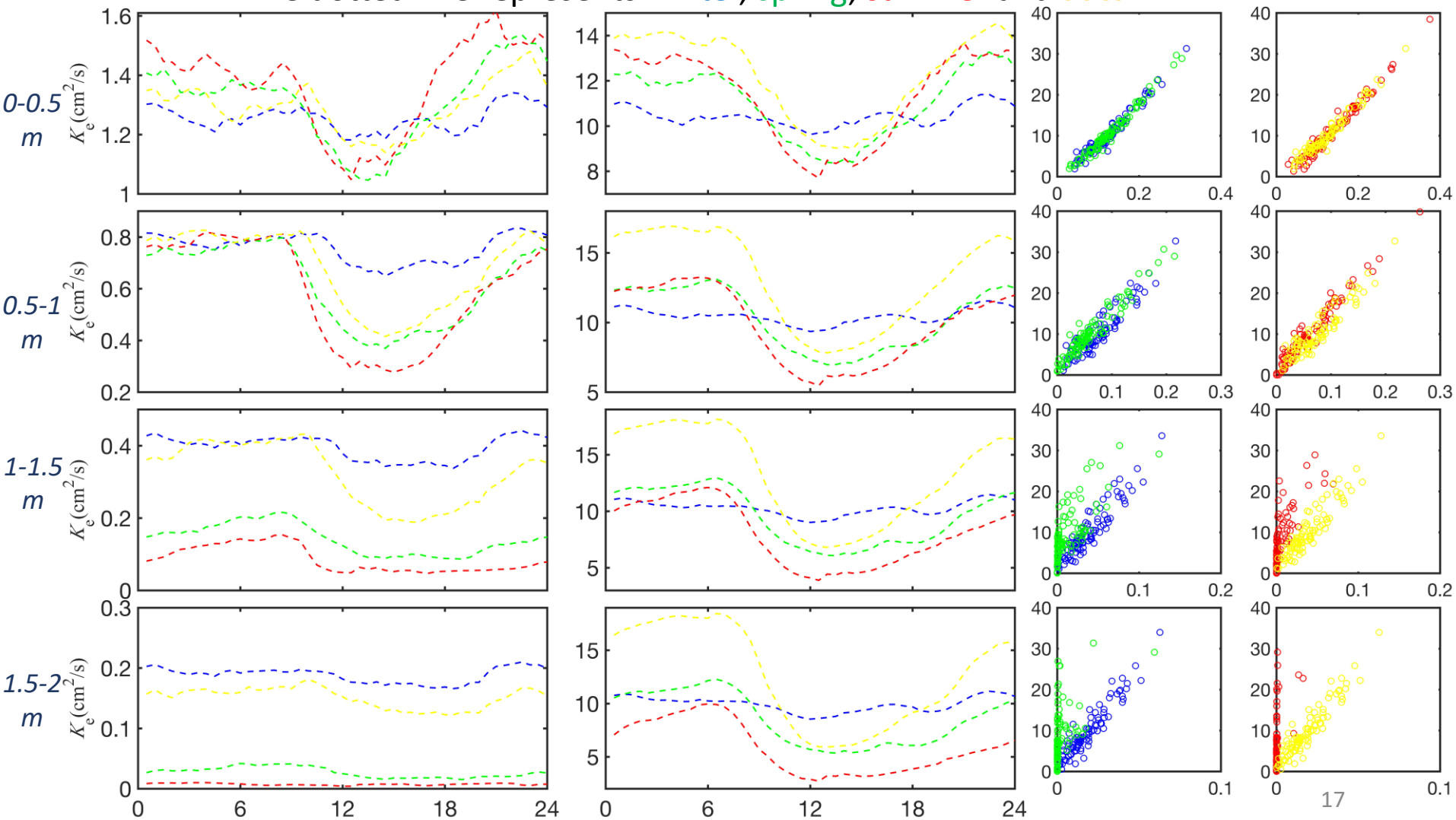
Latent Heat


CLM4-LISSS model
k-ϵ model
R2=0.75
R2=0.68
n=12264
Year 2012
R2=0.74
R2=0.63
n=13472
Year 2014
R2=0.77
R2=0.7
n=15370
Year 2013
R2=0.7
R2=0.72
n=14026
Year 2015
Model
Observation
800
600
400
200
0
-200

Turbulent diffusivity Performance

2012 CLM4-LISSS model k- ε model

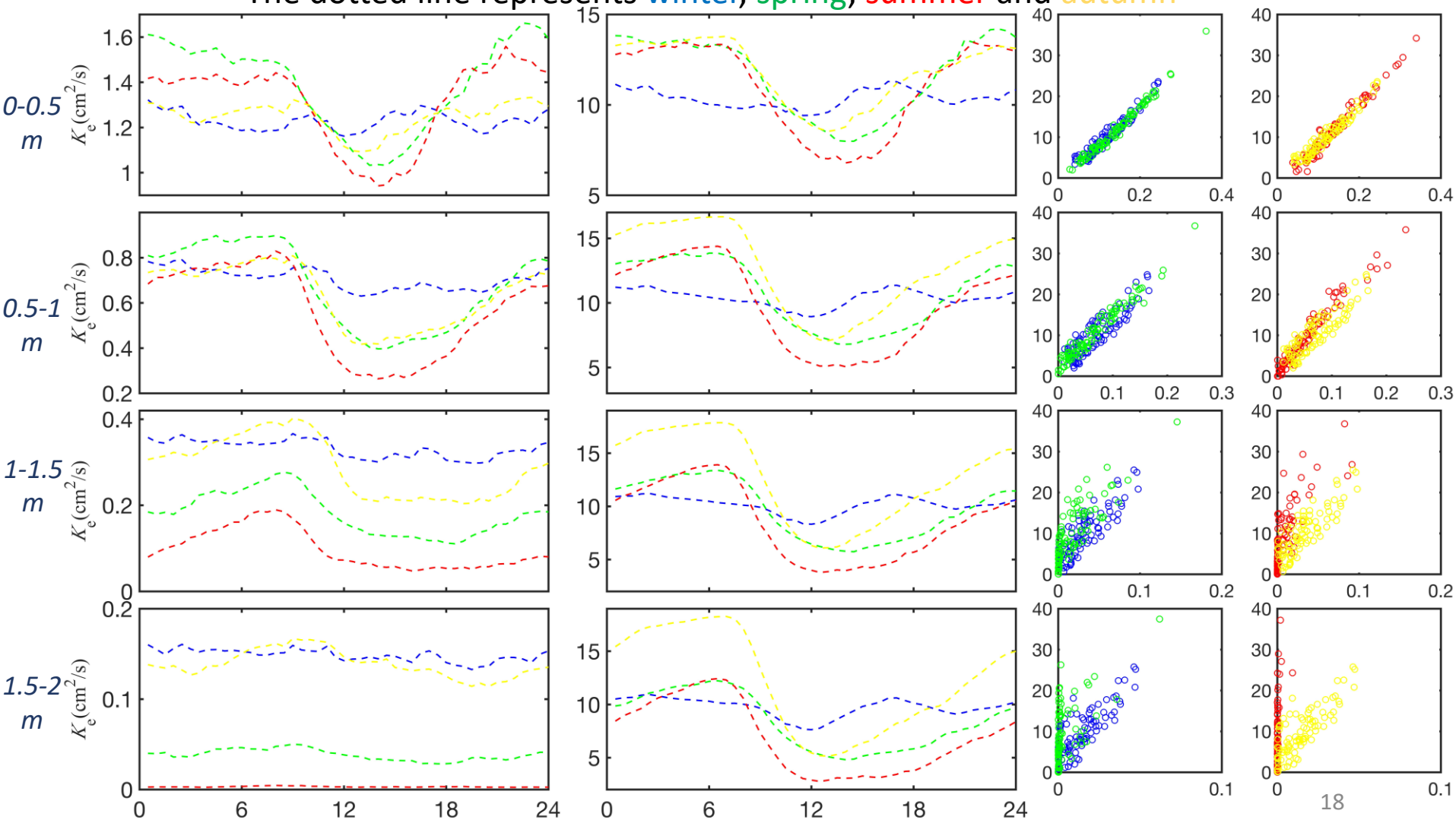
The dotted line represents winter, spring, summer and autumn



2013

CLM4-LISSS model k- ε model

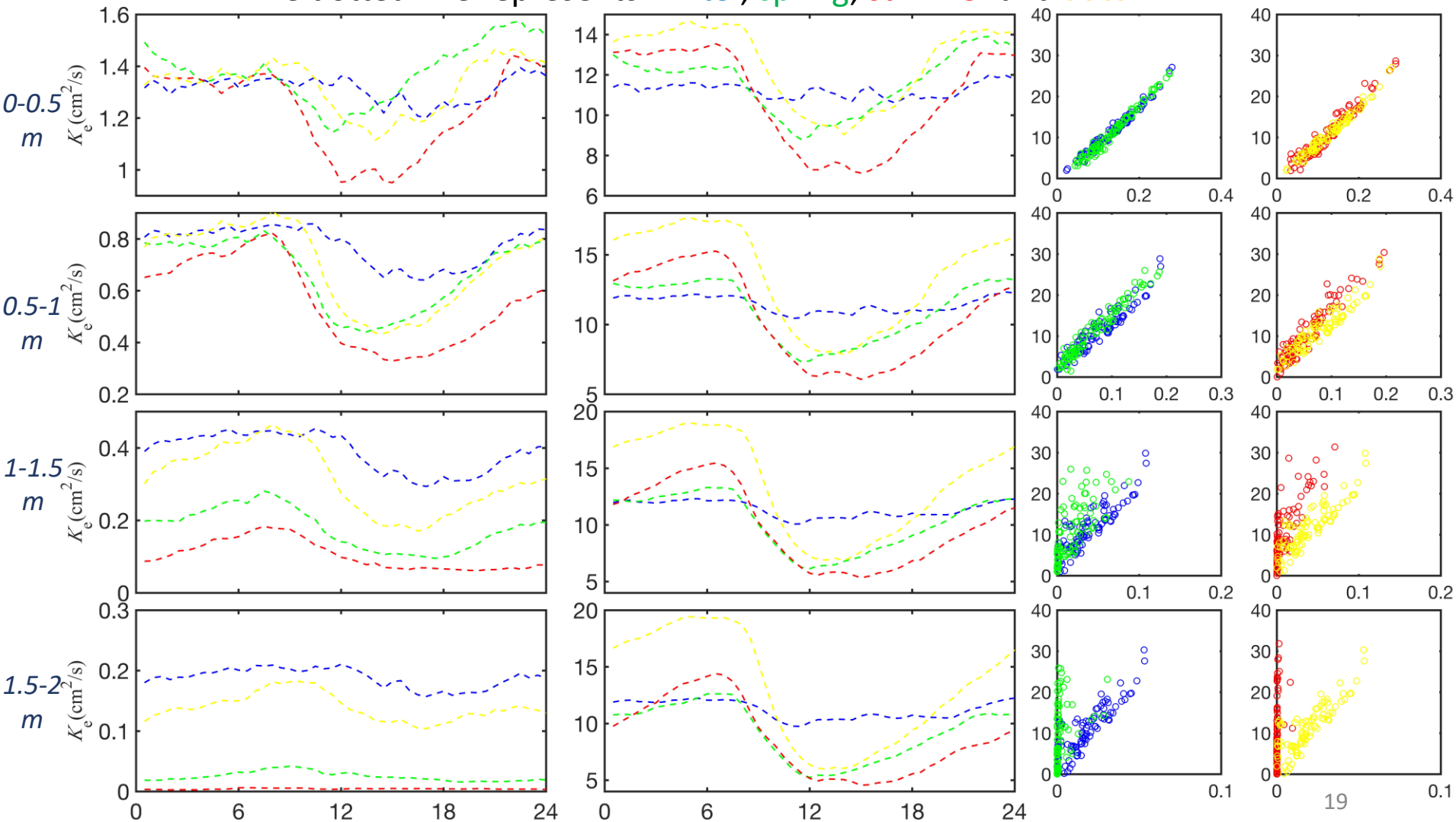
The dotted line represents winter, spring, summer and autumn



2014

CLM4-LISSS model k- ε model

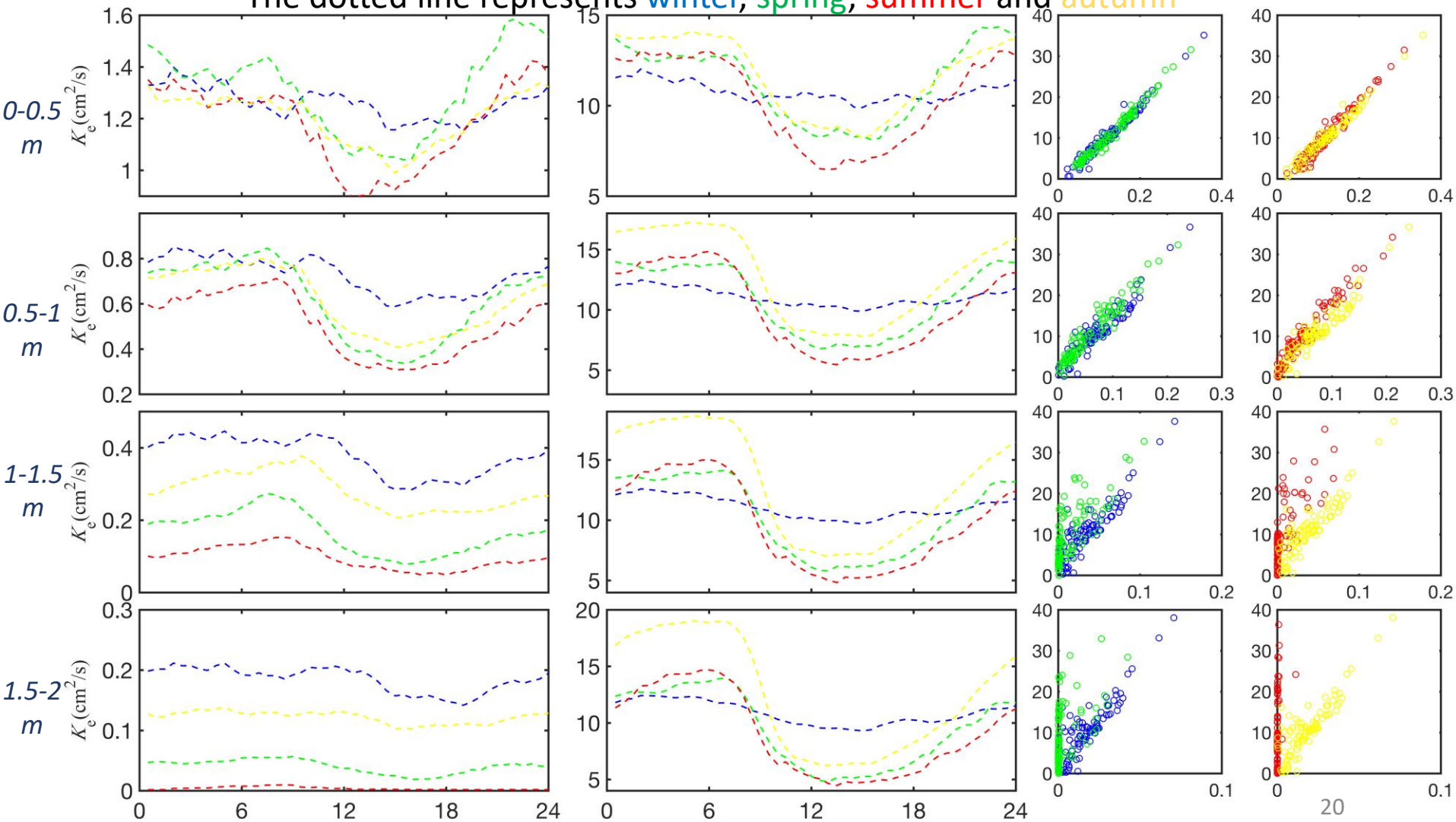
The dotted line represents winter, spring, summer and autumn



2015

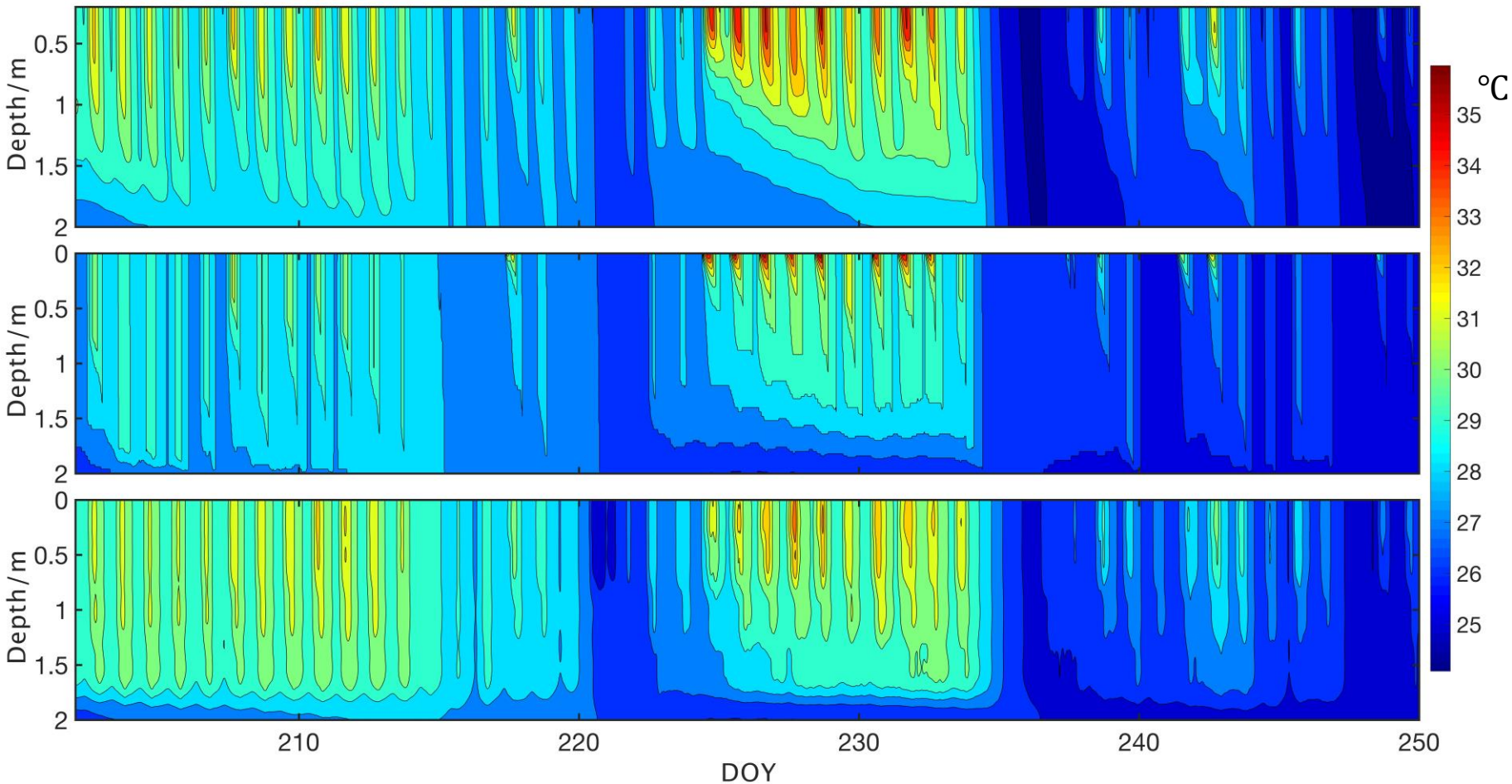
CLM4-LISSS model k- ε model

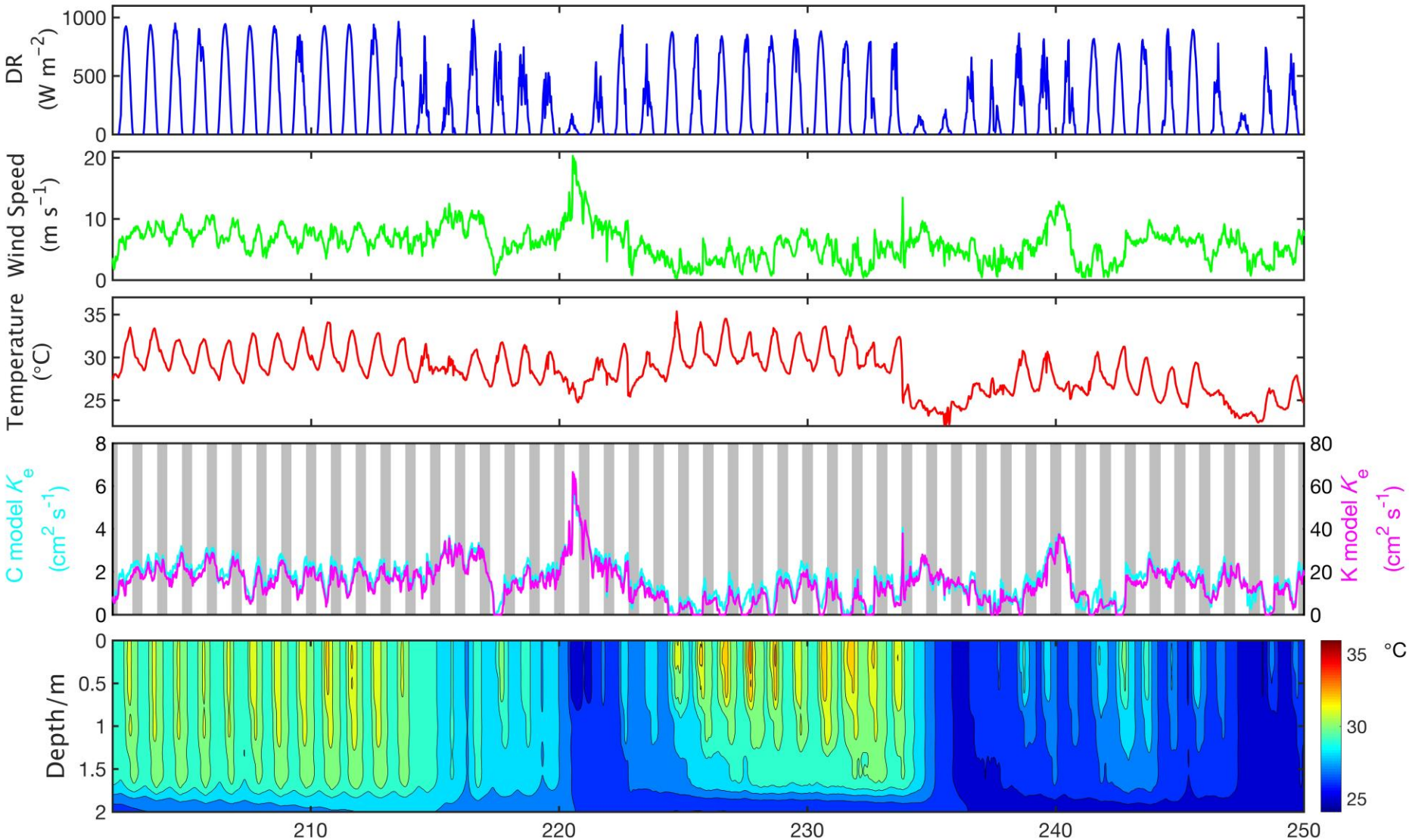
The dotted line represents winter, spring, summer and autumn



Case analysis: *DOY 202-250 Year 2012*

Water temperature profile performance (CLM4-LISSS model, k-ε model, observation)




DR
(W m^{-2})
1000
500
0
Wind Speed
(m s^{-1})
20
10
0
Temperature
(°C)
35
30
25
C model K_e
(cm^2 s^{-1})
8
6
4
2
0
K model K_e
(cm^2 s^{-1})
80
60
40
20
0
Depth/m
0
0.5
1
1.5
2
°C
35
30
25
210
220
230
240
250

CLM-LISSS model						
Variation rate (T)	-30%	-20%	-10%	10%	20%	30%
K_e	3.9%	2.8%	1.5%	-1.6%	-2.8%	-4%
Variation rate (DR)	-30%	-20%	-10%	10%	20%	30%
K_e	0.13%	0.04%	0.01%	-0.02%	-0.07%	-0.12%
Variation rate (U)	-30%	-20%	-10%	10%	20%	30%
K_e	-33%	-22%	-11%	11%	21%	32%
k-ε model						
Variation rate (T)	-30%	-20%	-10%	10%	20%	30%
K_e	6%	3.9%	1.9%	-1.9%	-3.2%	-4.2%
Variation rate (DR)	-30%	-20%	-10%	10%	20%	30%
K_e	2.21%	1.42%	0.67%	-0.75%	-1.43%	-1.91%
Variation rate (U)	-30%	-20%	-10%	10%	20%	30%
K_e	-38%	-25%	-13%	13%	26%	40%

Summary

- Both CLM4-LISSS model and k-ε model have been applied in Lake Taihu, CLM4-LISSS model have better performance in simulation of surface temperature and surface energy flux.

- Two models have similar simulation trend on turbulent diffusivity. But there exists magnitude difference of vertical turbulent diffusivity and difference expend with depth.

- Wind variation seems to be leading factor of turbulent kinetic energy distribution.

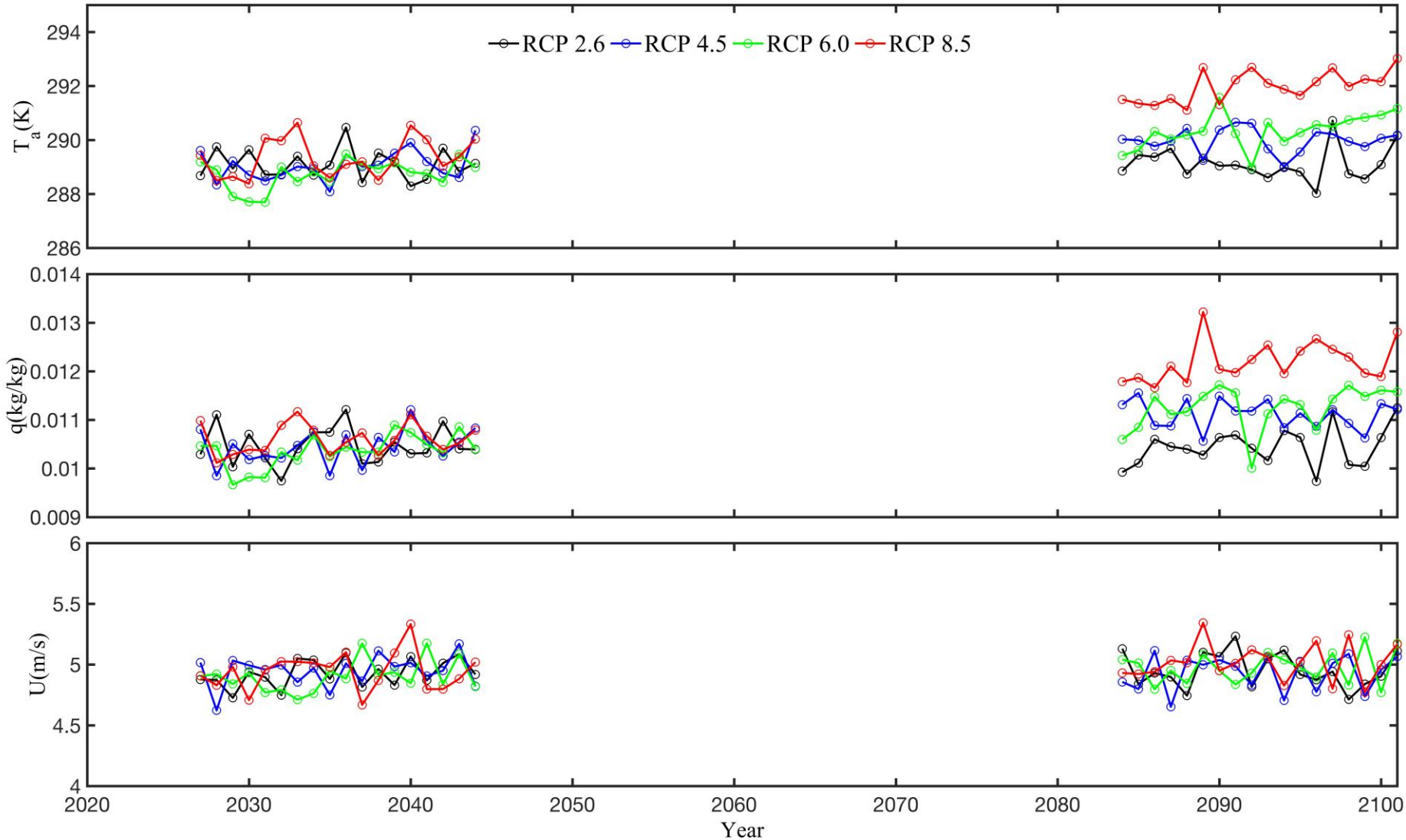
Future work

- It is still doubtful that the result of spring and winter's predicted water temperature, turbulent kinetic energy and the magnitude of vertical turbulent diffusivity.

- Aim to quantify the contribution of turbulent kinetic energy distribution.

- Try to establish lake surface flux dataset based on BCC_AGCM's future scenarios climate data and verify it.

Upcoming…


RCP 2.6
RCP 4.5
RCP 6.0
RCP 8.5
T_a (K)
294
292
290
288
286
q(kg/kg)
0.014
0.013
0.012
0.011
0.01
0.009
U(m/s)
6
5.5
5
4.5
4
2020
2030
2040
2050
2060
2070
2080
2090
2100
Year

Thank you