Response of surface temperature to afforestation in Kubuqi desert, Inner Mongolia

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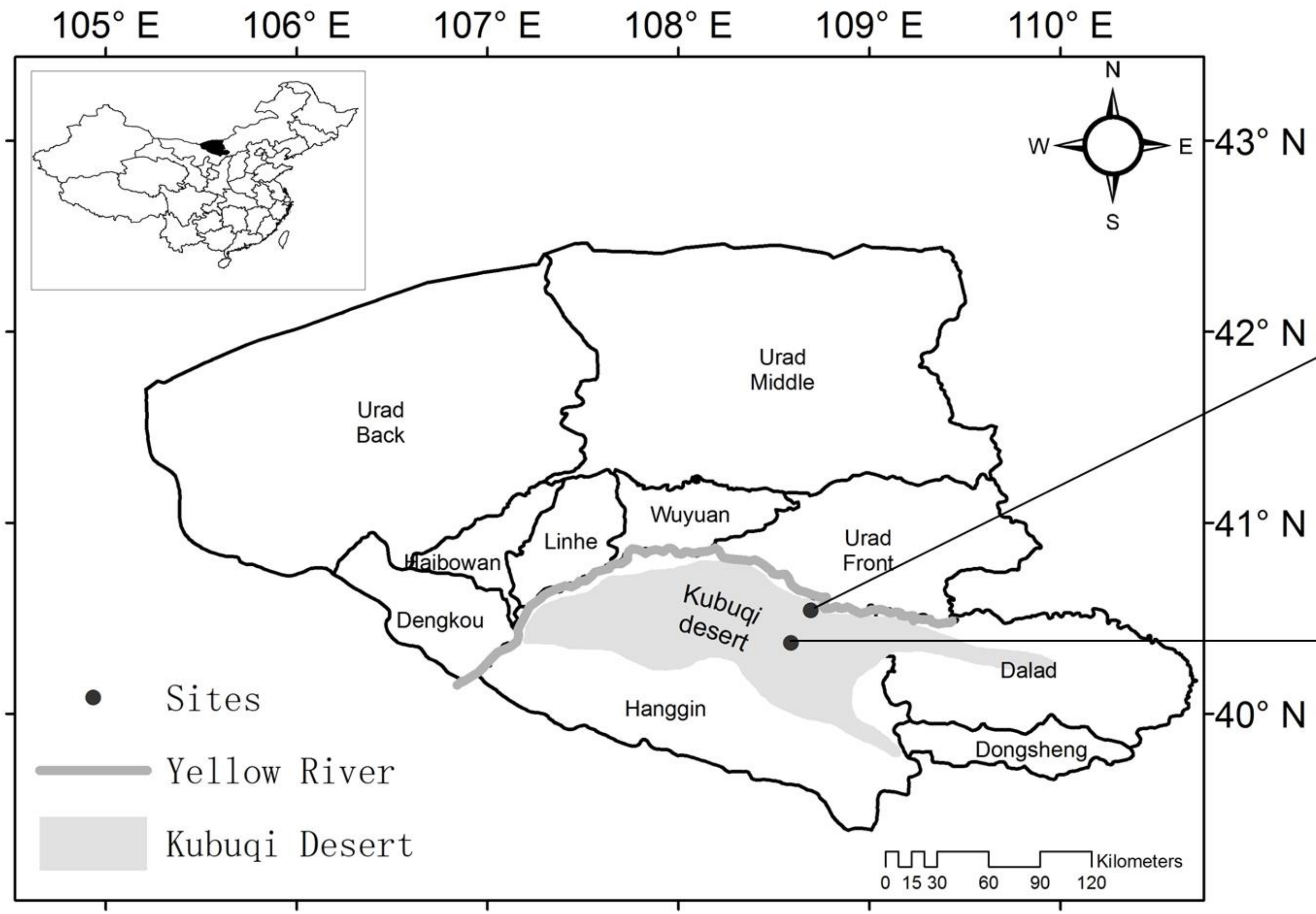
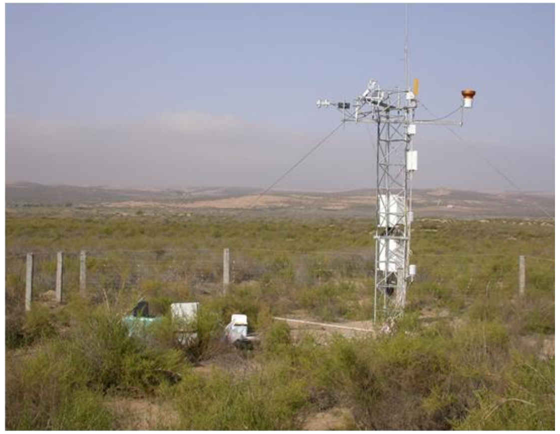
Liming Wang

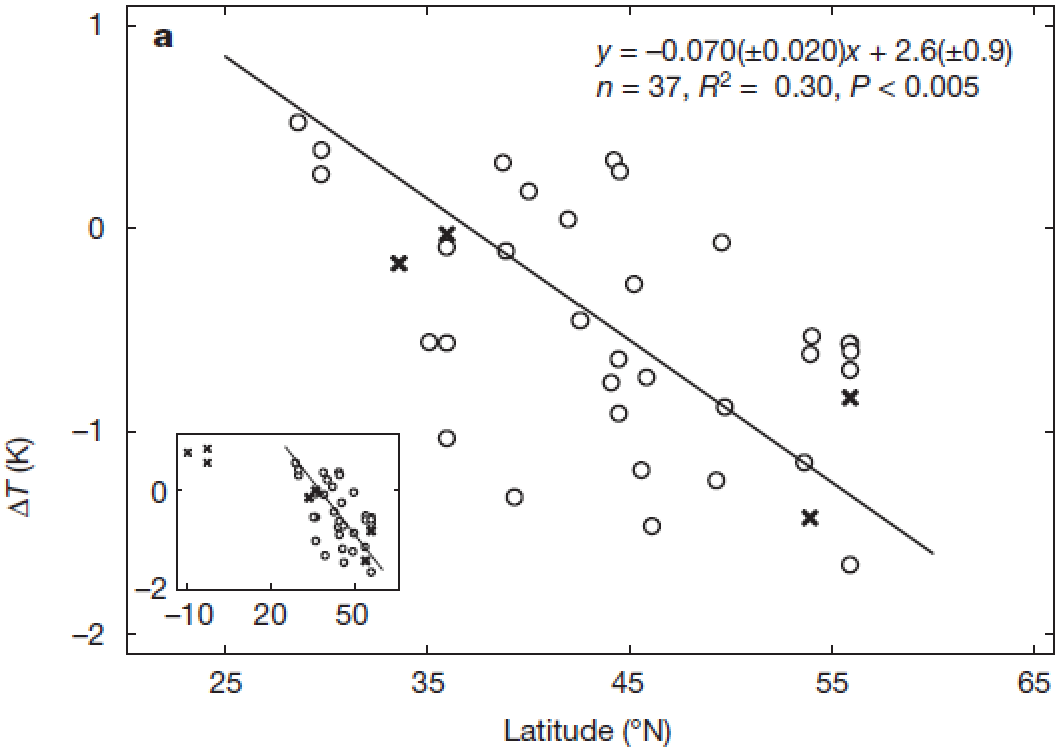
Study sites



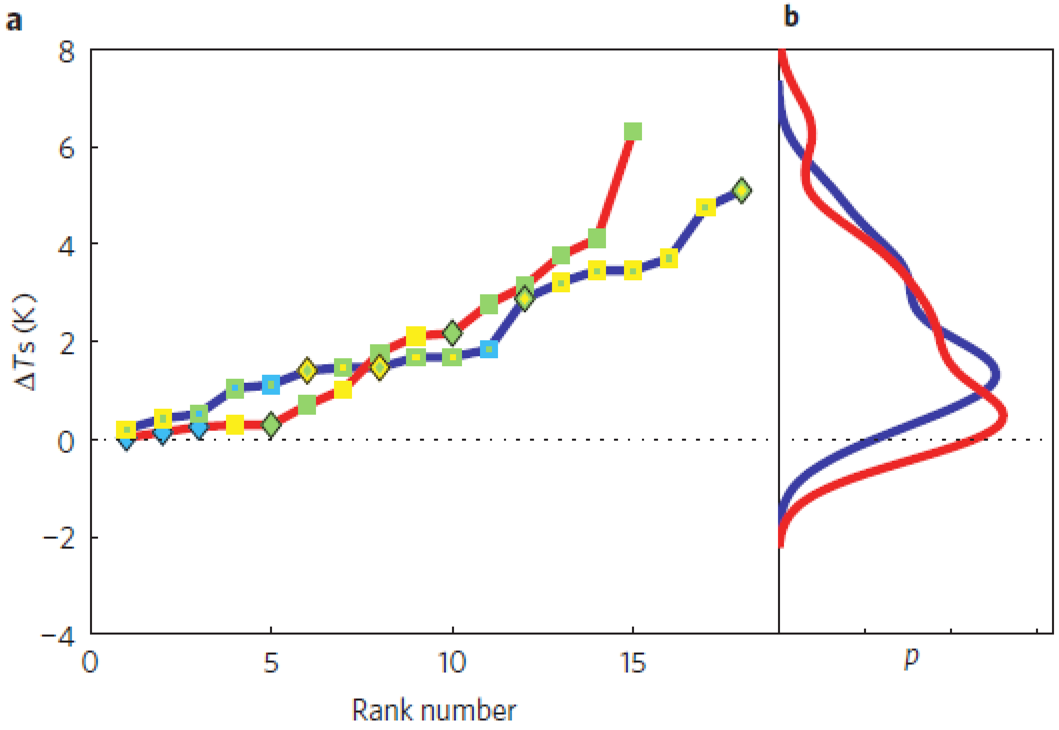


40°32′N, 108°41′ E

Δ*T* in temperate zone



(Lee, 2011)



(Luyssaert, 2014)

Δ*T* caused by deforestation

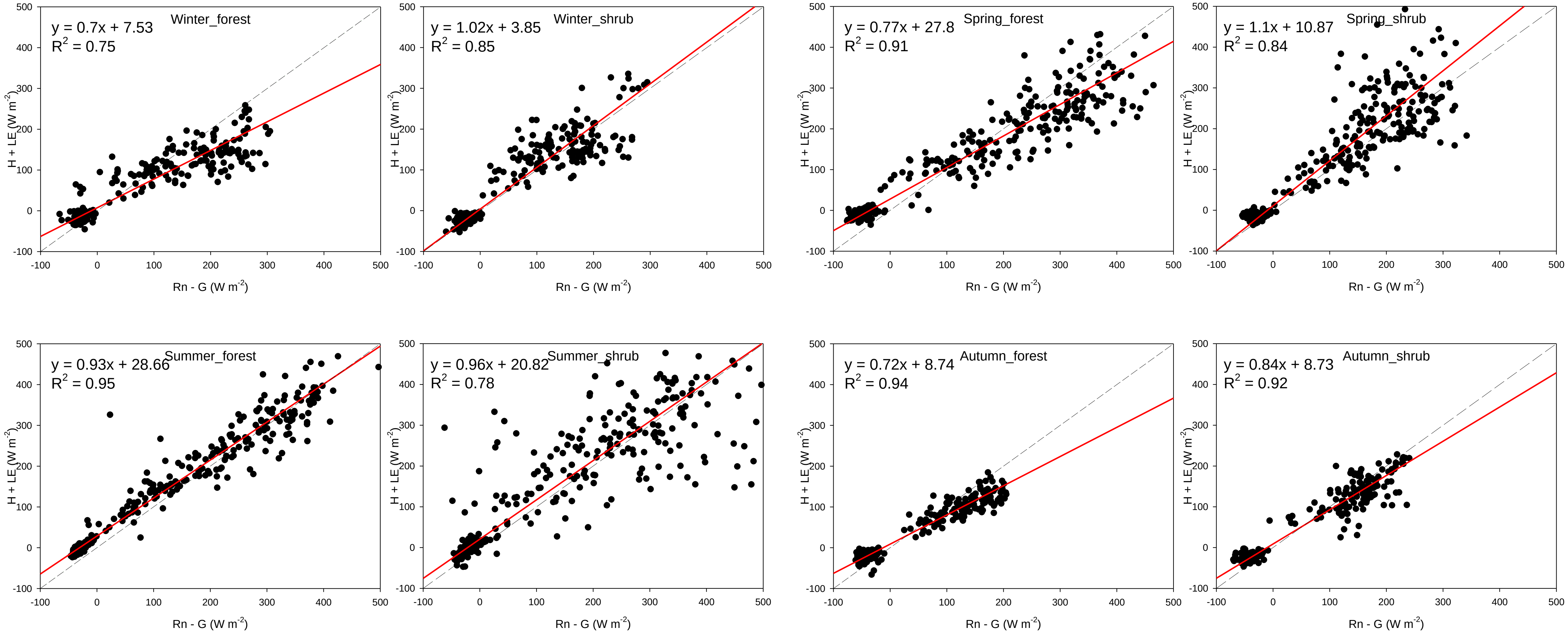
Purpose

- Evaluate the performance of the modified intrinsic biophysical mechanism (IBPM) theory.

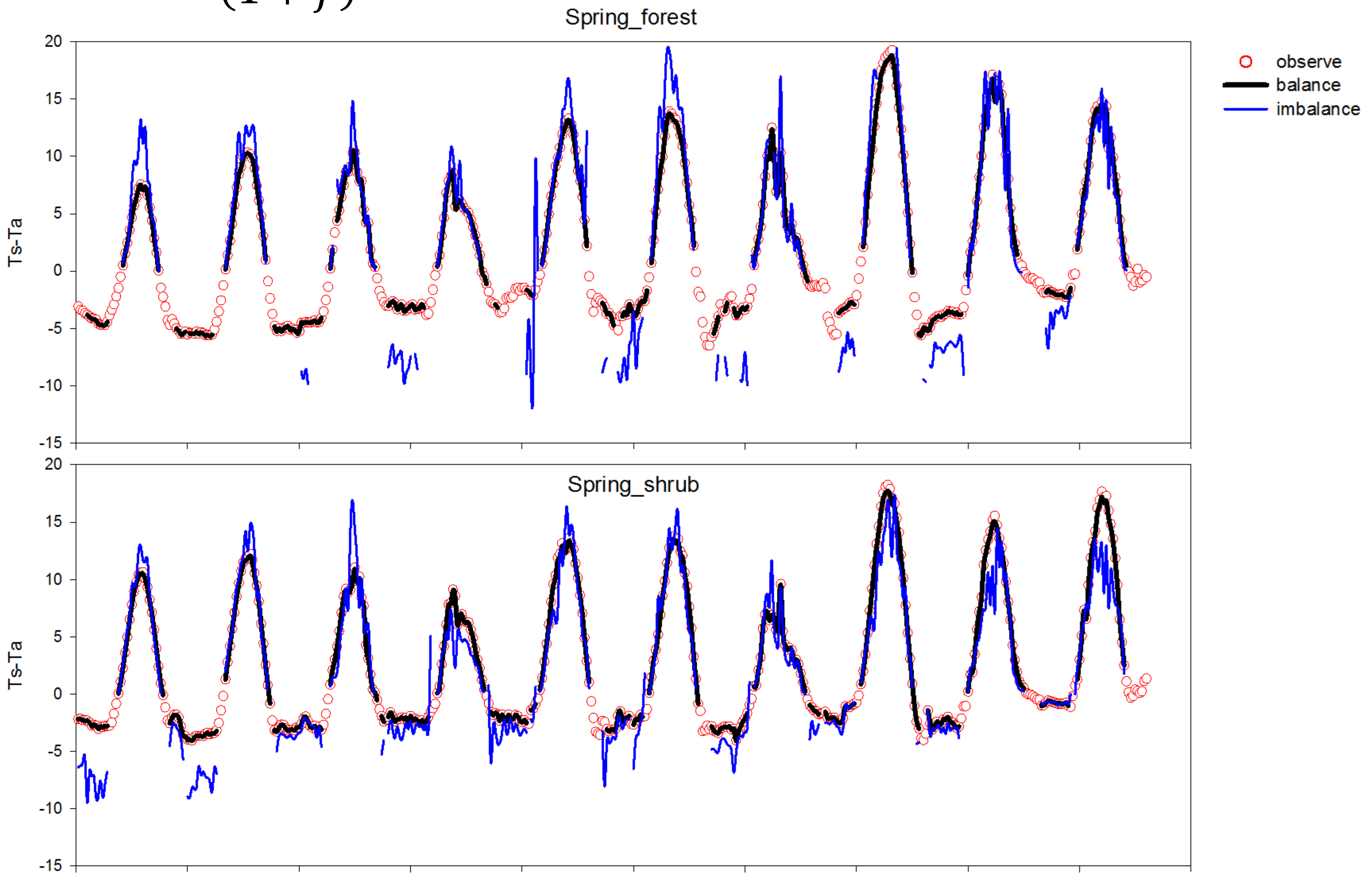
- Evaluating the ΔT_s caused by afforestation. Quantify the contributions of the composition of ΔT_s (surface temperature) over the diurnal and seasonal cycles.

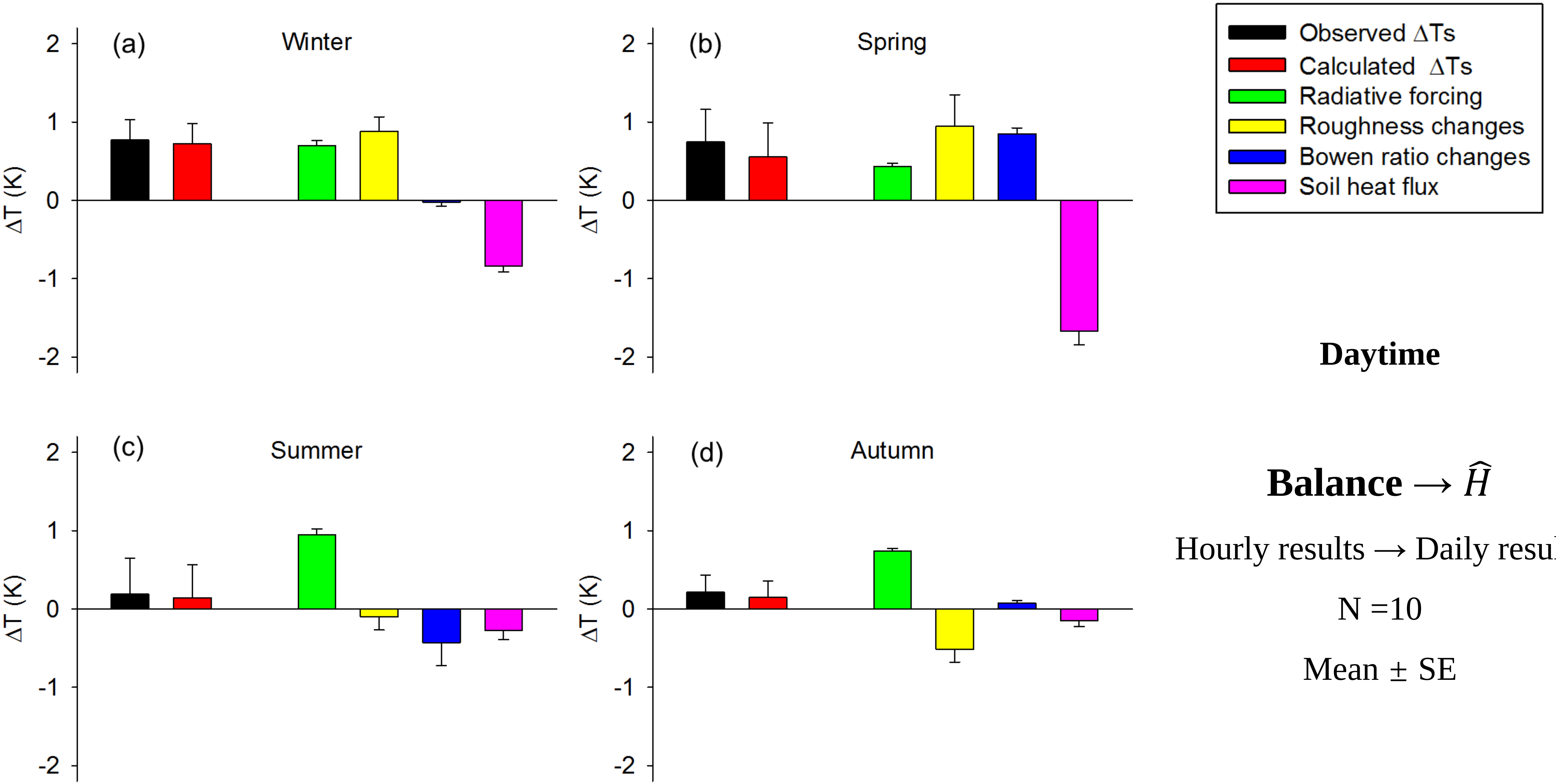
- Compare the ΔT_s decomposition results obtained with the IBPM and the DTM theory.

Energy balance



$$model(T_s - T_a) = \frac{\lambda_0}{(1+f)}(R_n^* - G)$$





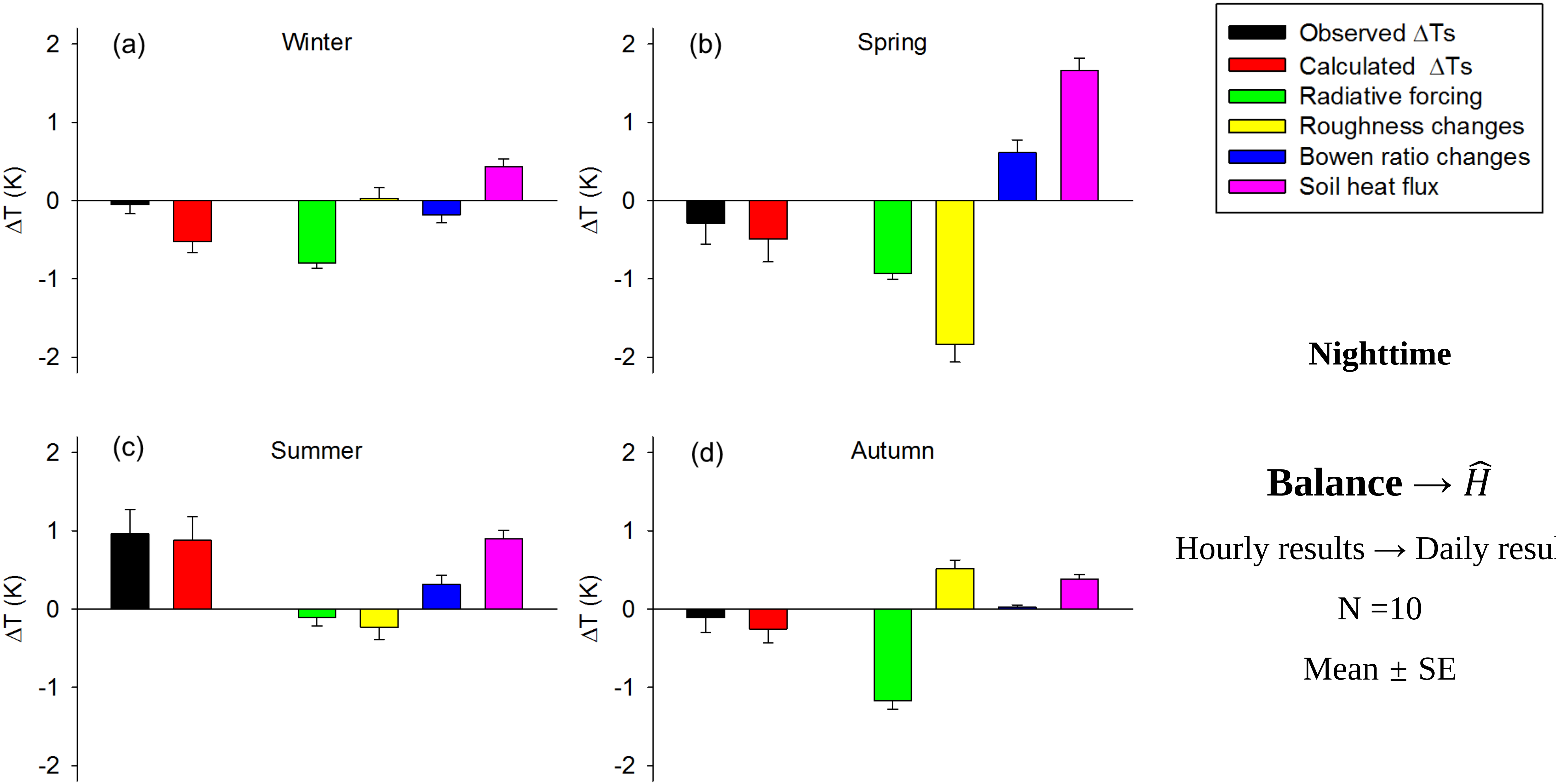
Daytime

Balance → $\widehat{H}$

Hourly results → Daily results

N =10

Mean ± SE



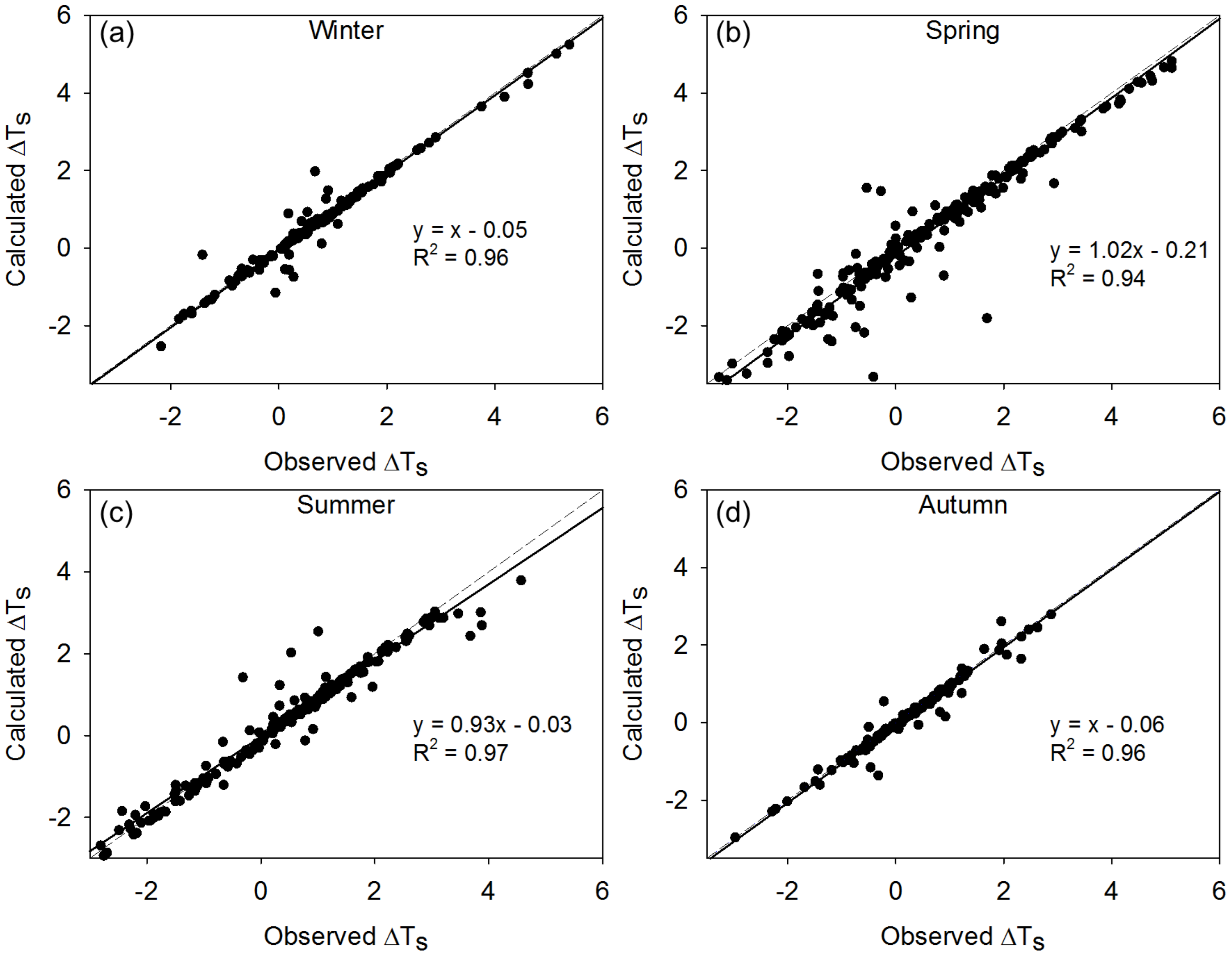
Nighttime

Balance → $\widehat{H}$

Hourly results → Daily results

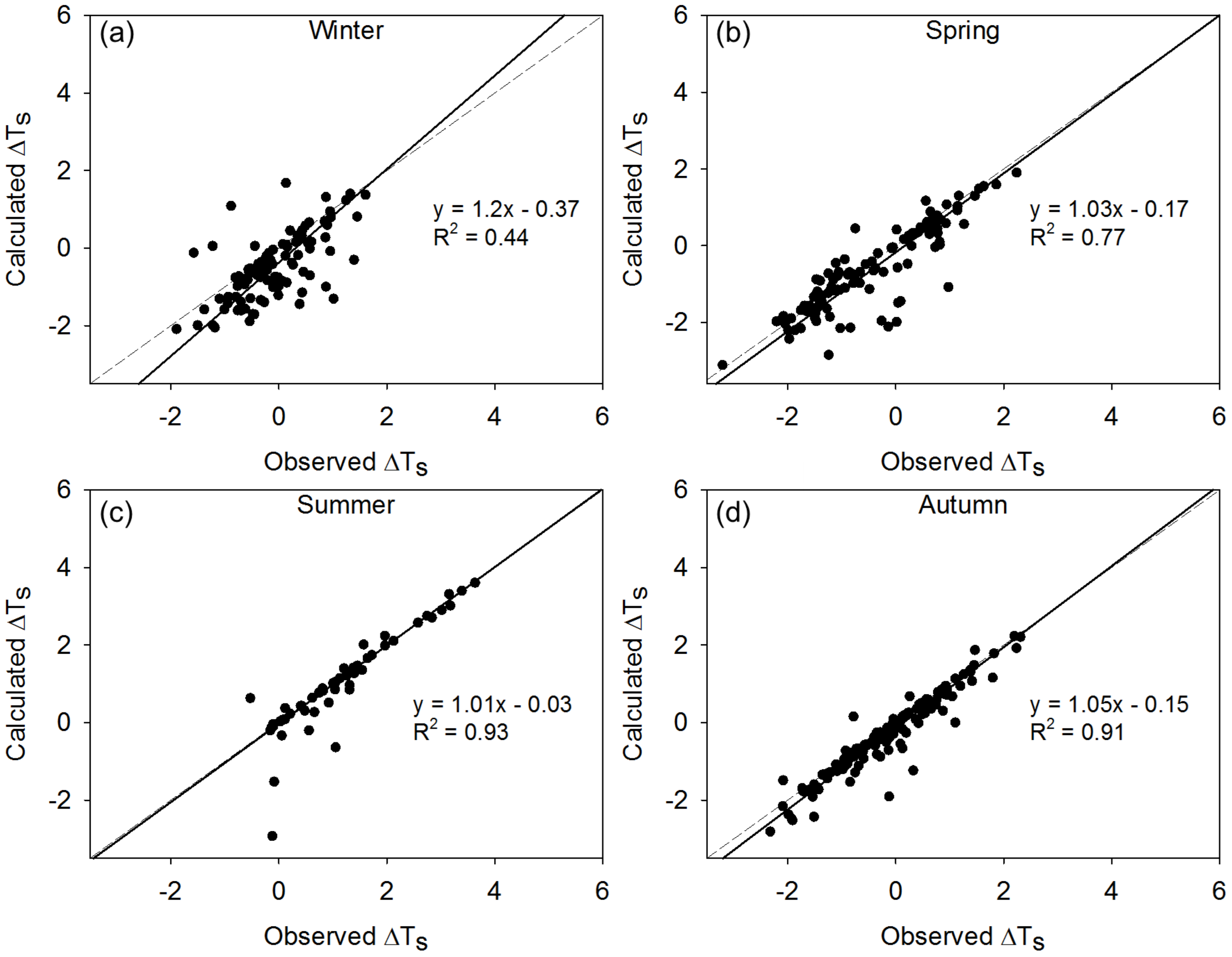
N =10

Mean ± SE



Daytime

Half hour results



Nighttime

Half hour results

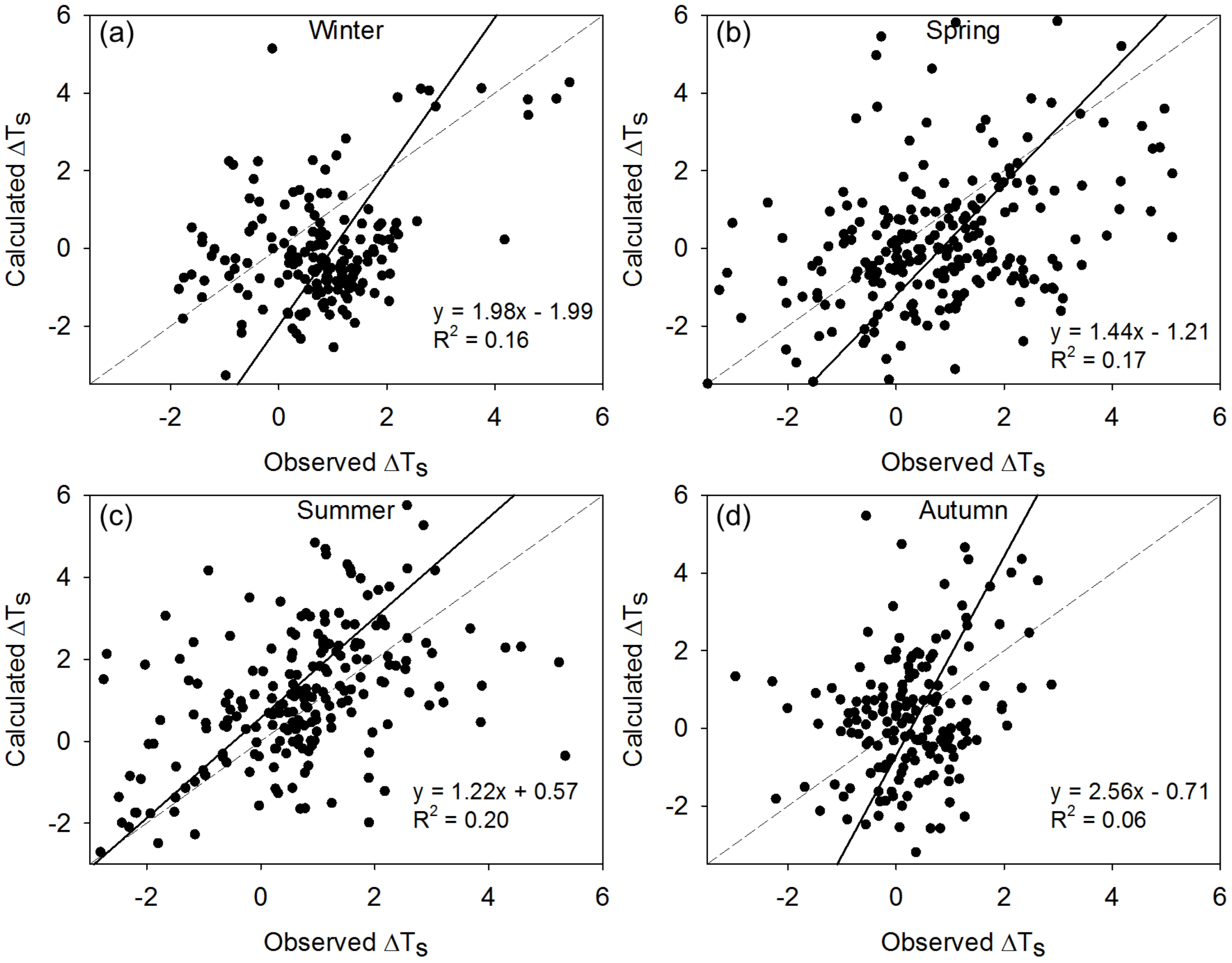
Prognostic calculation

$$r_t = r_a + r_{ex} + r_r$$

$$r_a = \frac{\left[\ln\left(\frac{z-d}{z_0}\right) - \Psi_M\right]\left[\ln\left(\frac{z-d}{z_0}\right) - \Psi_H\right]}{k^2 u}$$

$$r_{ex} = \frac{\ln(\frac{z_0}{z_h})}{ku^*}$$

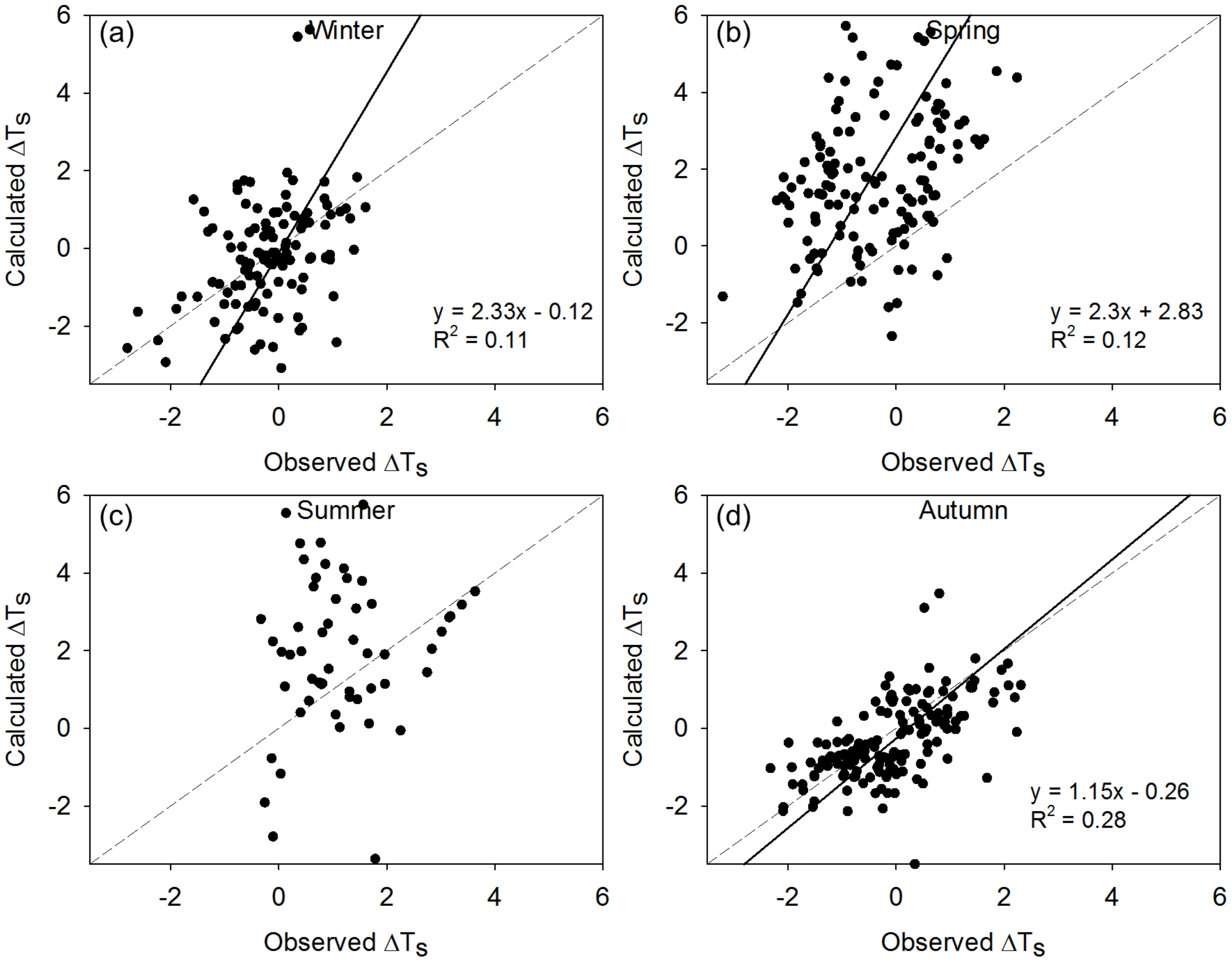
	Forest	Shrub
r_r day (60≤DOY≤240)	24.4exp(−0.5LAI)	24.4exp(−0.5LAI)
r_r day (DOY<60, DOY>240)	14.9exp(−0.2LAI)	14.9exp(−0.2LAI)
r_r night (s m^{-1})	$0.0049DOY^2$ −1.96DOY+258	$0.0011DOY^2$ −0.6726DOY+172



Daytime

Prognostic model

Half hour results



Nighttime

Prognostic model

Half hour results

DTM model

$$\Delta T_s = \lambda_0 \Delta S + \lambda_0 \Delta L_{\downarrow} - \lambda_0 (\Delta LE + \Delta H) - \lambda_0 \Delta G$$

$$\widehat{H} = \frac{\beta}{1+\beta}(R_n - G)$$

$$T_s'^4 \approx T_s^4 + 4T_s^3 (T_s' - T_s)$$

$$\widehat{LE} = \frac{1}{1+\beta}(R_n - G)$$

$$\Delta T_s = T_s' - T_s \approx \frac{1}{4T_s^3}\left(T_s'^4 - T_s^4\right)$$

$$= \frac{1}{4\sigma T_s^3}\left(\sigma T_s'^4 - \sigma T_s^4\right)$$

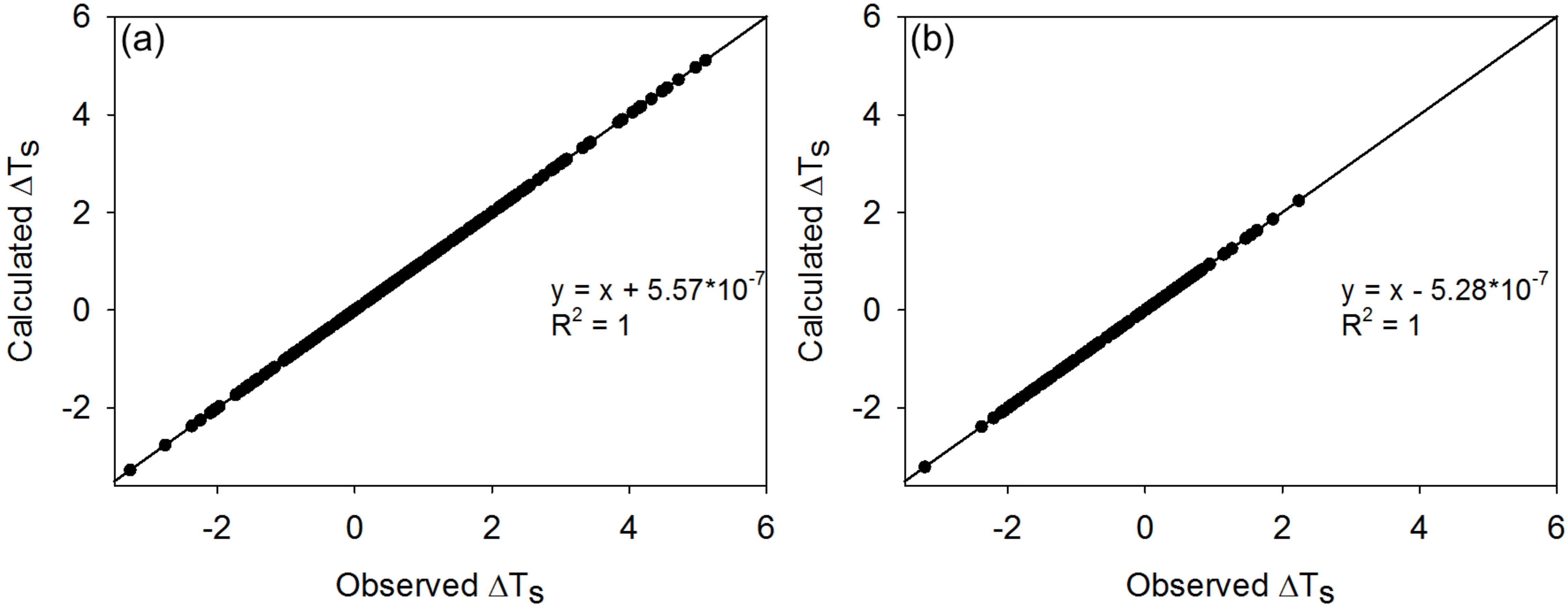
$$= \lambda_0 [\Delta S + \Delta L_{\downarrow} - (\Delta S + \Delta L_{\downarrow} - (\sigma T_s'^4 - \sigma T_s^4)]$$

$$= \lambda_0 [\Delta S + \Delta L_{\downarrow} - \Delta R_n]$$

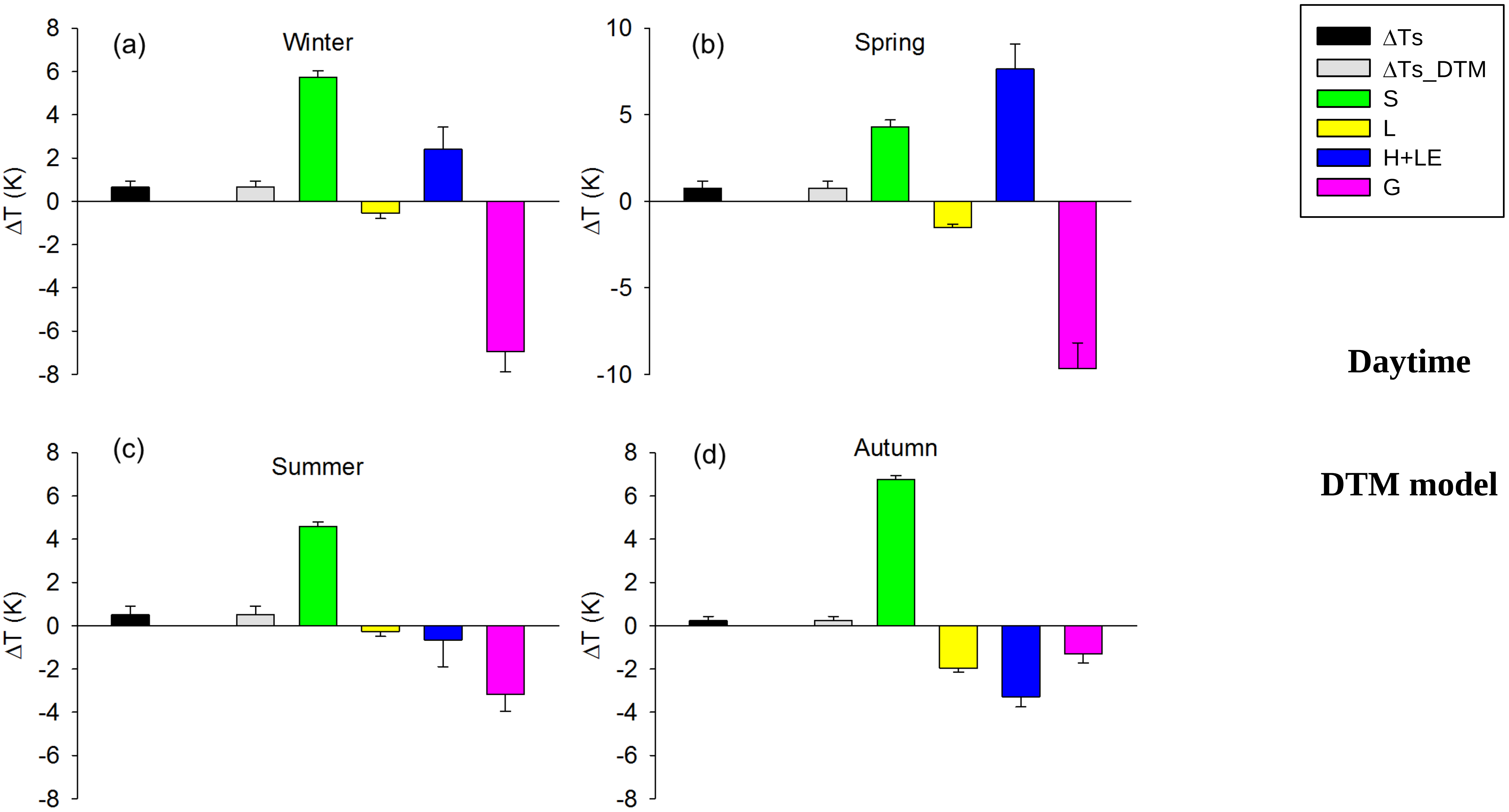
$$= \lambda_0 [\Delta S + \Delta L_{\downarrow} - \Delta LE - \Delta H - \Delta G]$$

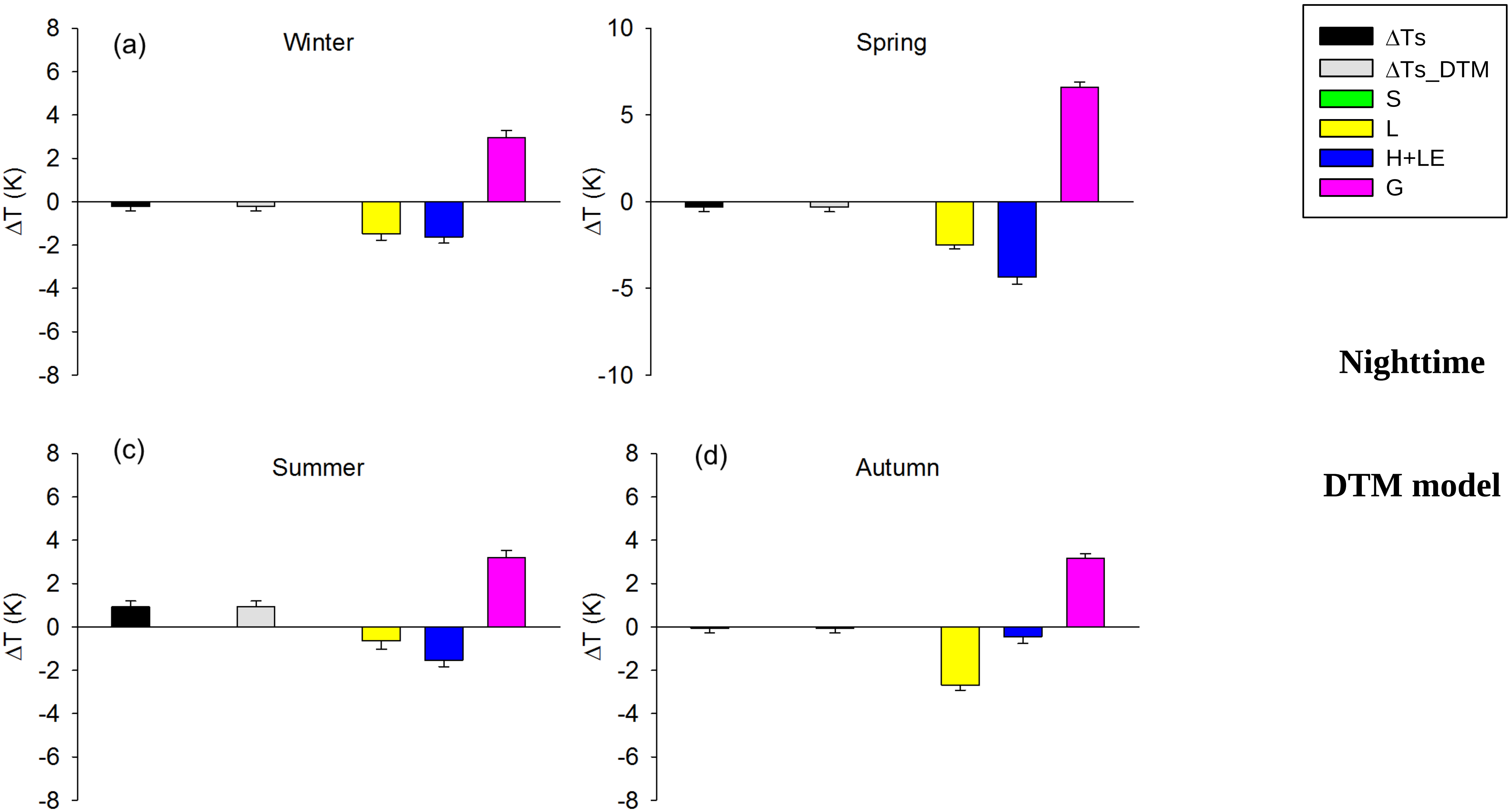
$$= \lambda_0 \Delta S + \lambda_0 \Delta L_{\downarrow} - \lambda_0 (\Delta LE + \Delta H) - \lambda_0 \Delta G$$

$$R_n = LE + H + G$$



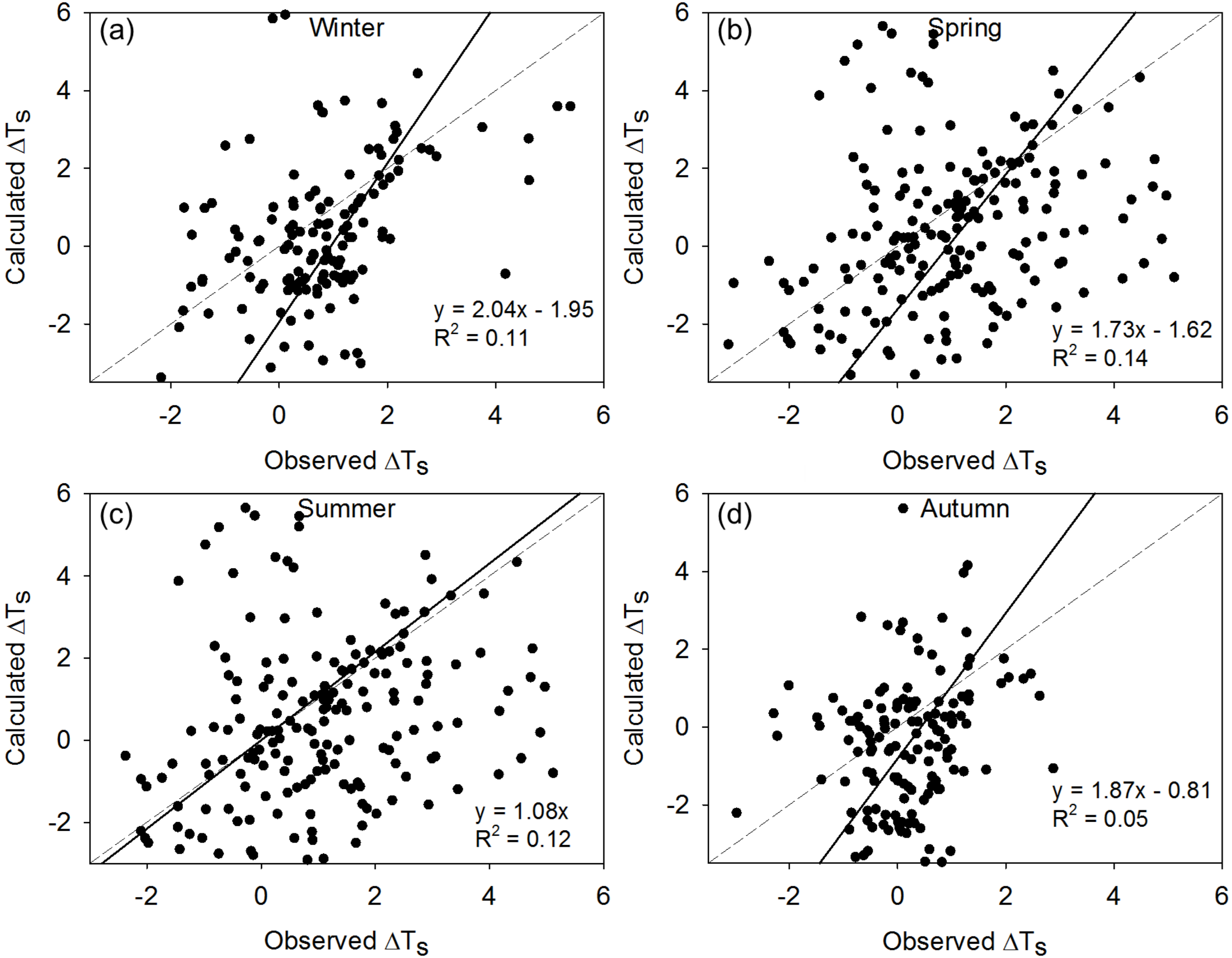
Relationship between half-hour calculated ΔT_s and observed ΔT_s in spring according to decomposition temperature metric (DTM) in daytime (a) and nighttime (b).


(a)
Winter
(b)
Spring
(c)
Summer
(d)
Autumn
ΔT (K)
ΔTs
ΔTs_DTM
S
L
H+LE
G
Daytime
DTM model



(a)
Winter
Spring
(c)
Summer
(d)
Autumn
ΔT (K)
8
6
4
2
0
-2
-4
-6
-8
10
5
-5
-10
ΔTs
ΔTs_DTM
S
L
H+LE
G
Nighttime
DTM model

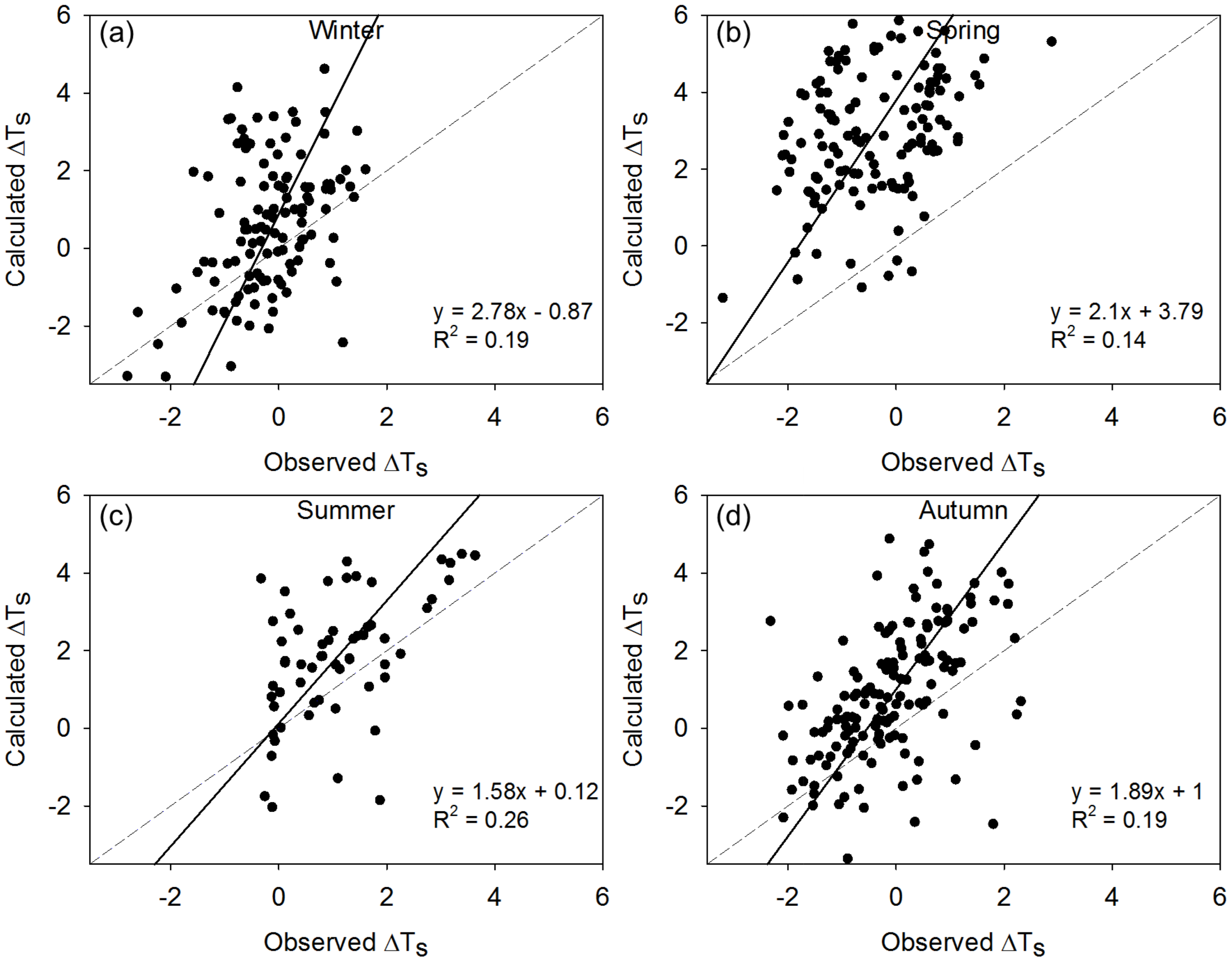
Important of energy balance



Daytime

Energy imbalance

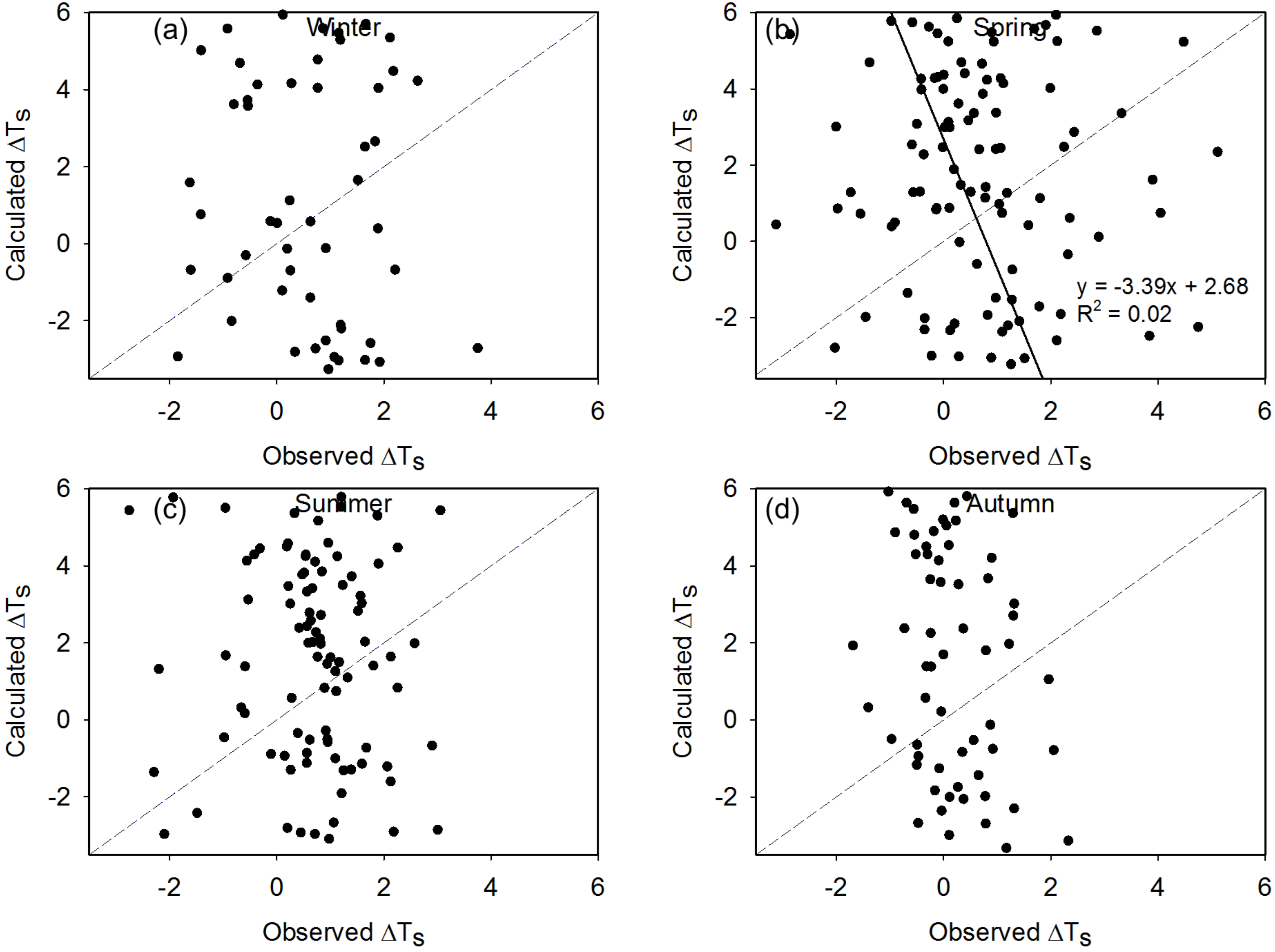
IBPM



Nighttime

Energy imbalance

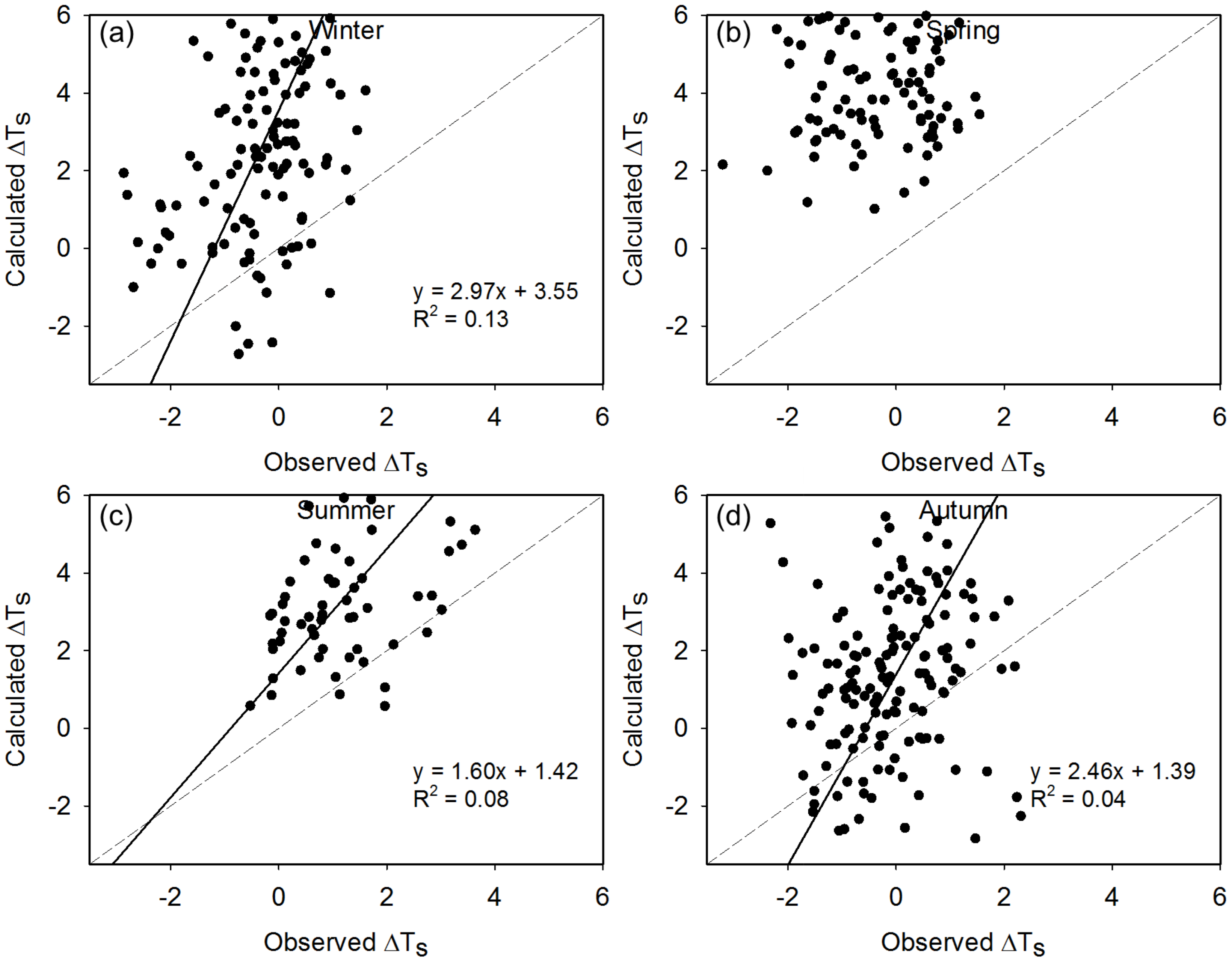
IBPM



Daytime

Energy imbalance

DTM



Nighttime

Energy imbalance

DTM

Summary

- a) Calculated ΔT_s of the modified IBPM is close to observed ΔT_s after considering $\Delta L_{\downarrow}$ and T_a related term.

- b) The forest has a cooling effect in the daytime and summer night and warming effect in the nighttime of other seasons.

  Influence of roughness and Bowen ratio had big seasonal variation.

  Influence of radiative and soil heat flux almost kept constant.

- c) For DTM, some of the component contributions are an order of magnitude greater than related term of IBPM.

- d)Energy balance is important for both IBPM and DTM, especially for DTM.

Regional scale study

2010 Land use

2010 meteorology

Control 1 (c1)

→

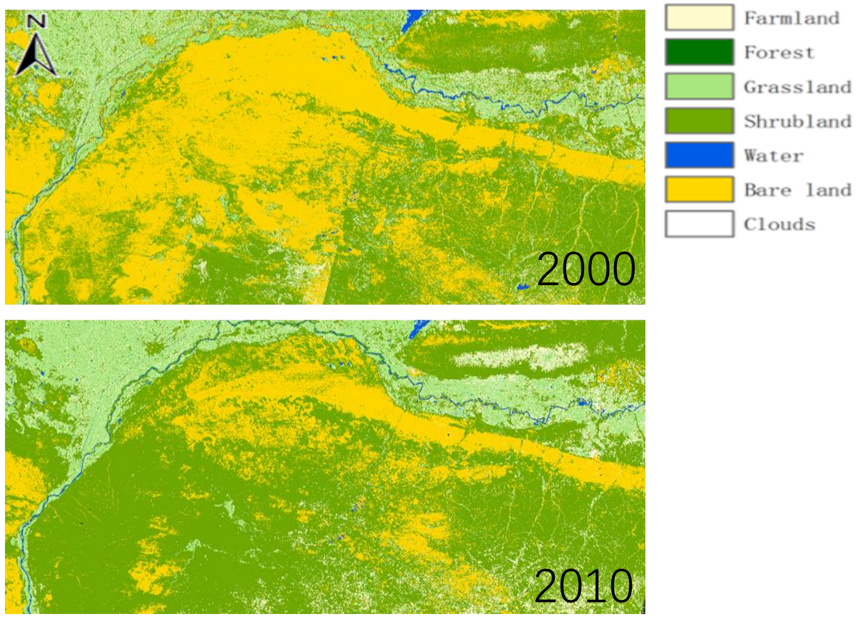
WRF output

TSK
Ta (2m)
RH (2m)
Wind speed
PPT
……

Compare with observation

→

Evaluate model performance



2000 Land use

2010 meteorology

Experiment 1 (e1)

→

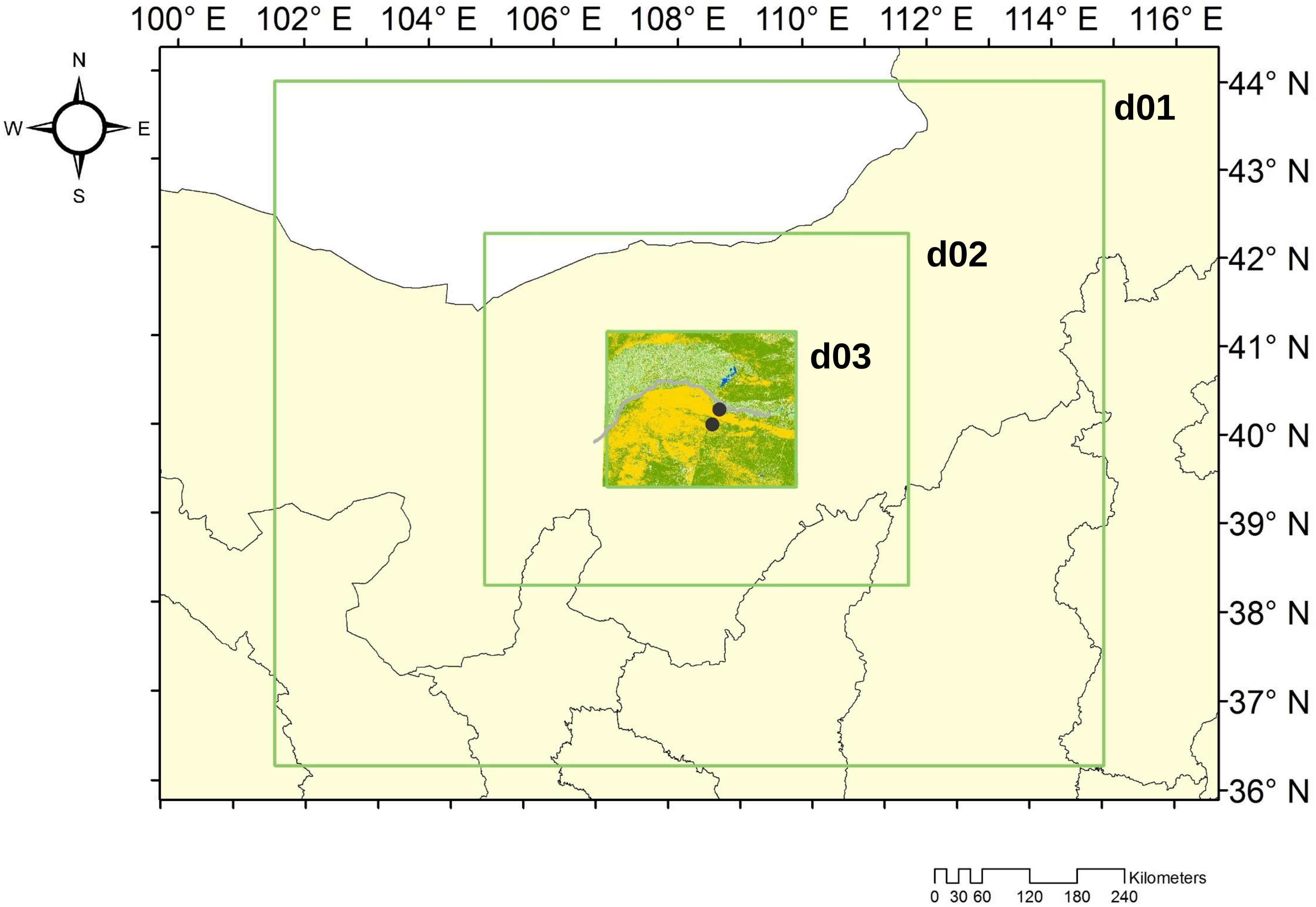
WRF output

TSK
Ta (2m)
RH (2m)
Wind speed
PPT
……

Evaluate the effect of land use change

Weather Research and Forecasting (WRF) Model

Domains

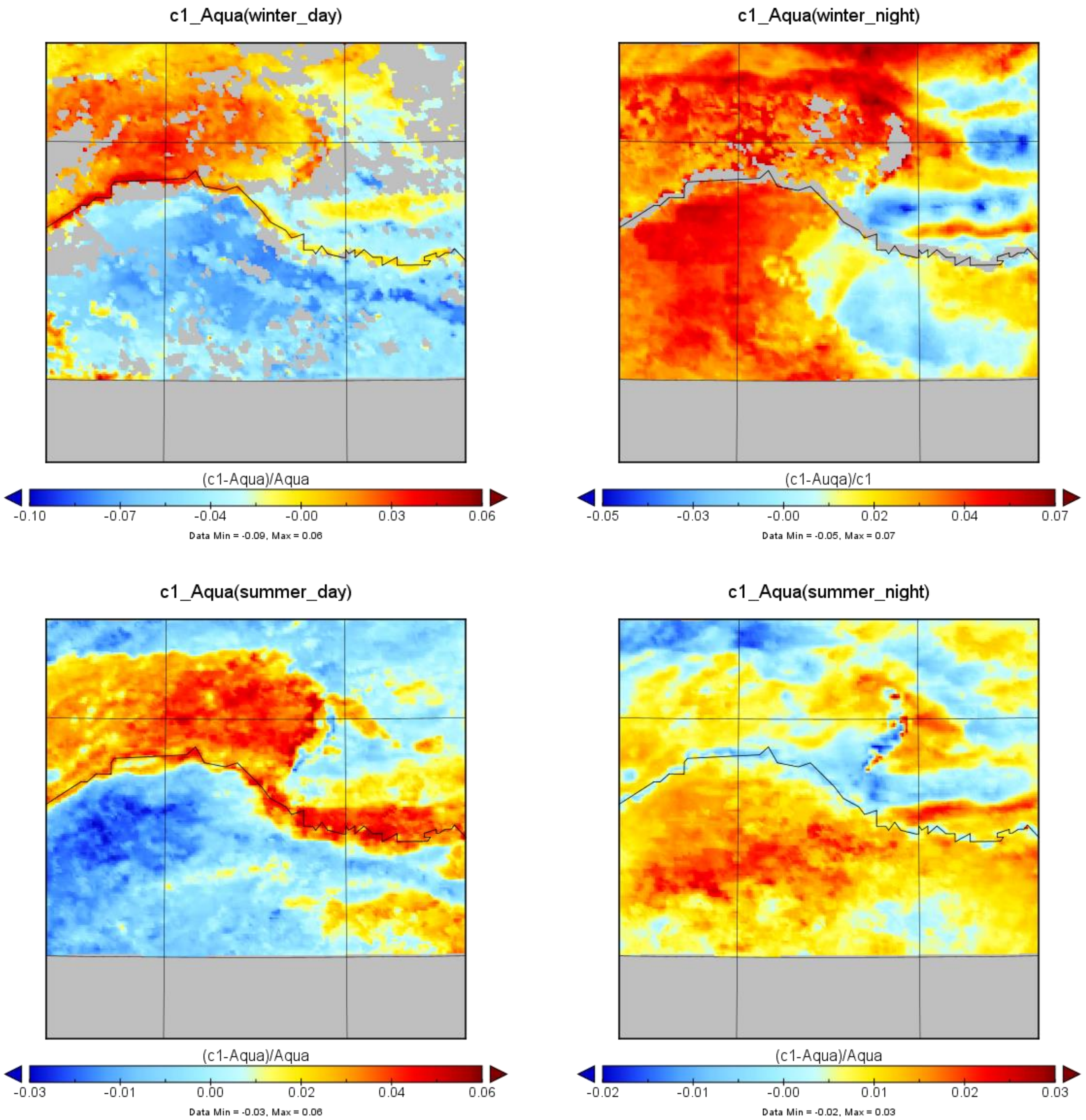

N
W
E
S
100° E
102° E
104° E
106° E
108° E
110° E
112° E
114° E
116° E
44° N
43° N
42° N
41° N
40° N
39° N
38° N
37° N
36° N
d01
d02
d03
0
30
60
120
180
240
Kilometers

Hypothesis

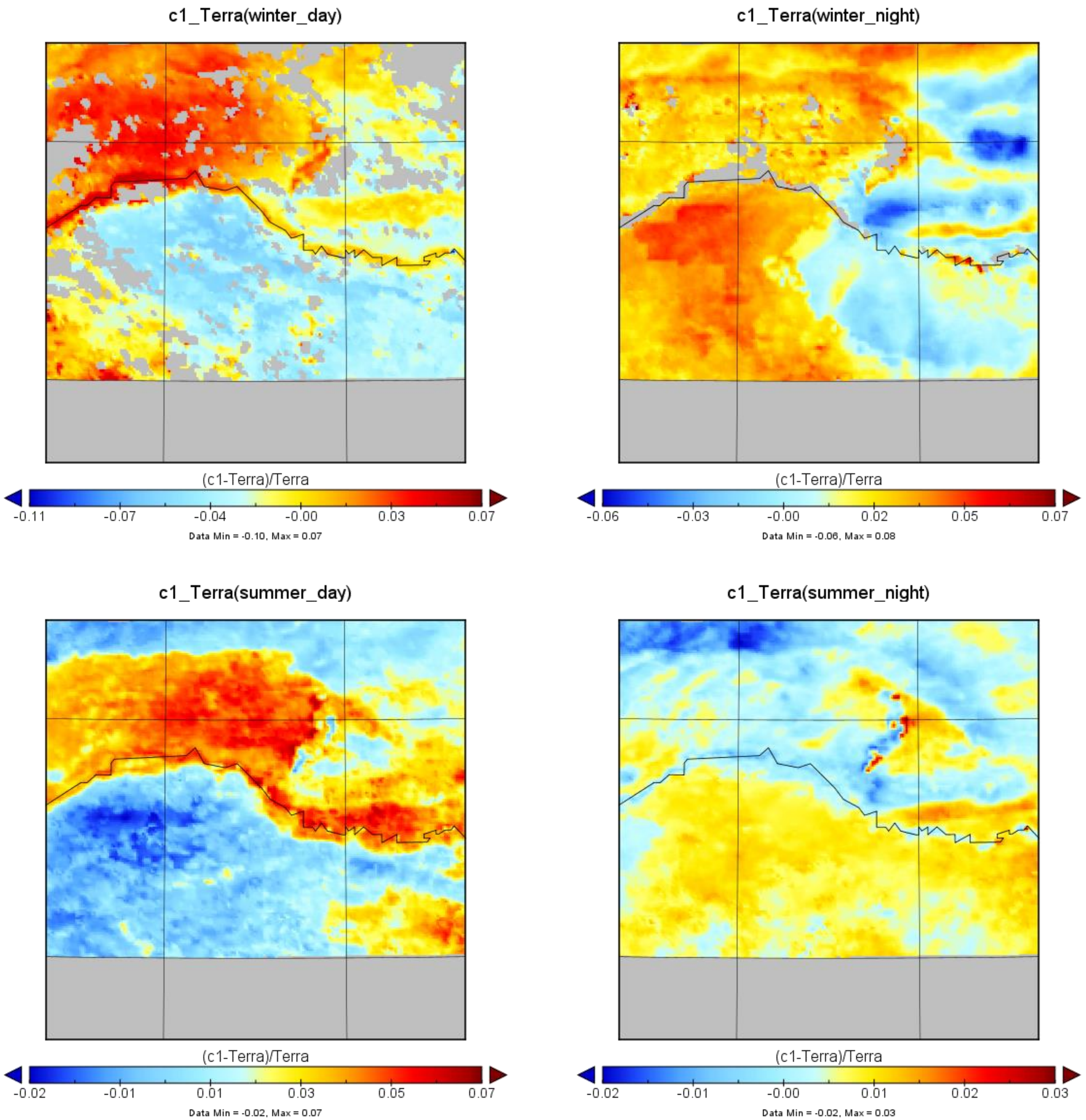
T_forest – T_shrub	Daytime	Nighttime
Winter	-0.8 K	+0.1K
Summer	-0.2 K	-1 K

T_vegetation – T_openland	Daytime	Nighttime
Winter	cooling	warming
Summer	cooling	cooling

c1 Vs real

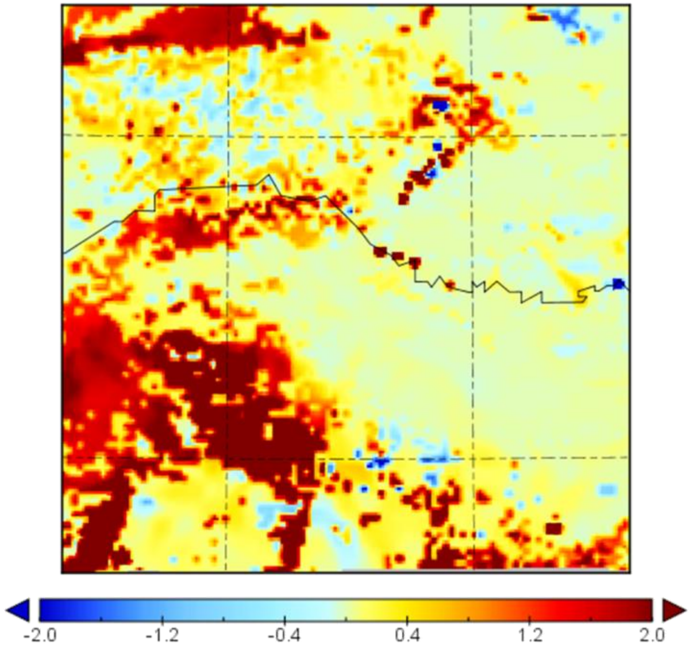

c1_Aqua(winter_day)
(c1-Aqua)/Aqua
-0.10 -0.07 -0.04 -0.00 0.03 0.06
Data Min = -0.09, Max = 0.06
c1_Aqua(winter_night)
(c1-Auqa)/c1
-0.05 -0.03 -0.00 0.02 0.04 0.07
Data Min = -0.05, Max = 0.07
c1_Aqua(summer_day)
(c1-Aqua)/Aqua
-0.03 -0.01 0.00 0.02 0.04 0.06
Data Min = -0.03, Max = 0.06
c1_Aqua(summer_night)
(c1-Aqua)/Aqua
-0.02 -0.01 -0.00 0.01 0.02 0.03
Data Min = -0.02, Max = 0.03

c1 Vs real

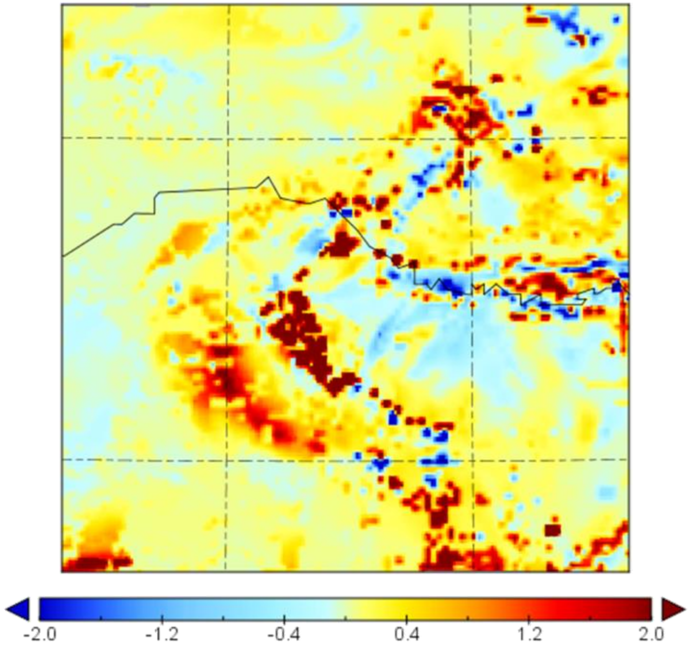

c1_Terra(winter_day)
(c1-Terra)/Terra
-0.11 -0.07 -0.04 -0.00 0.03 0.07
Data Min = -0.10, Max = 0.07
c1_Terra(winter_night)
(c1-Terra)/Terra
-0.06 -0.03 -0.00 0.02 0.05 0.07
Data Min = -0.06, Max = 0.08
c1_Terra(summer_day)
(c1-Terra)/Terra
-0.02 -0.01 0.01 0.03 0.05 0.07
Data Min = -0.02, Max = 0.07
c1_Terra(summer_night)
(c1-Terra)/Terra
-0.02 -0.01 -0.00 0.01 0.02 0.03
Data Min = -0.02, Max = 0.03

c1 Vs e1

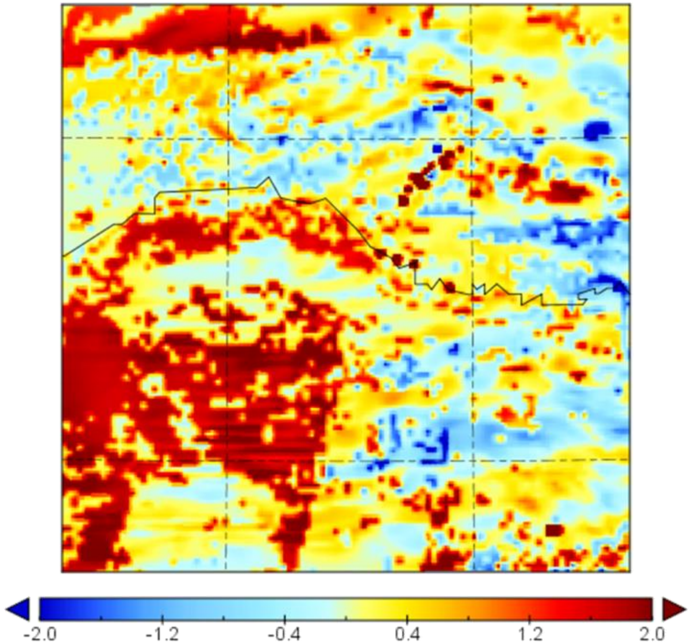
TSK_c1 - TSK_e1 Winter day



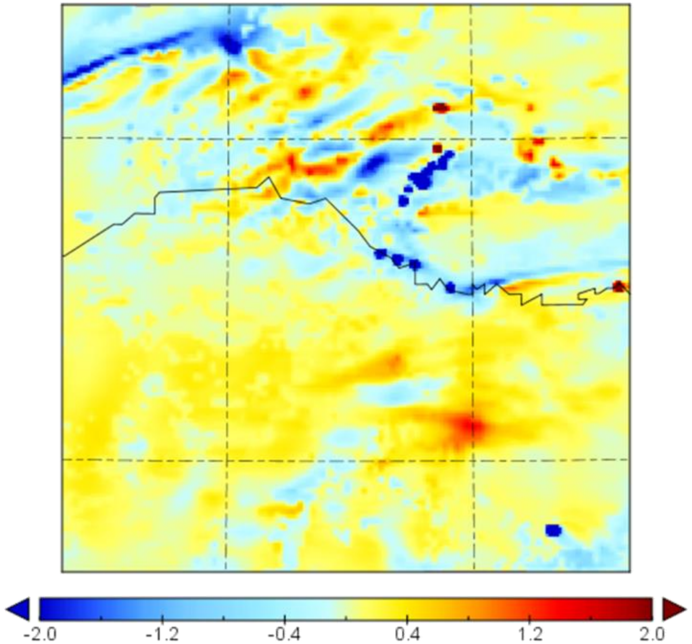
TSK_c1 - TSK_e1 Winter night



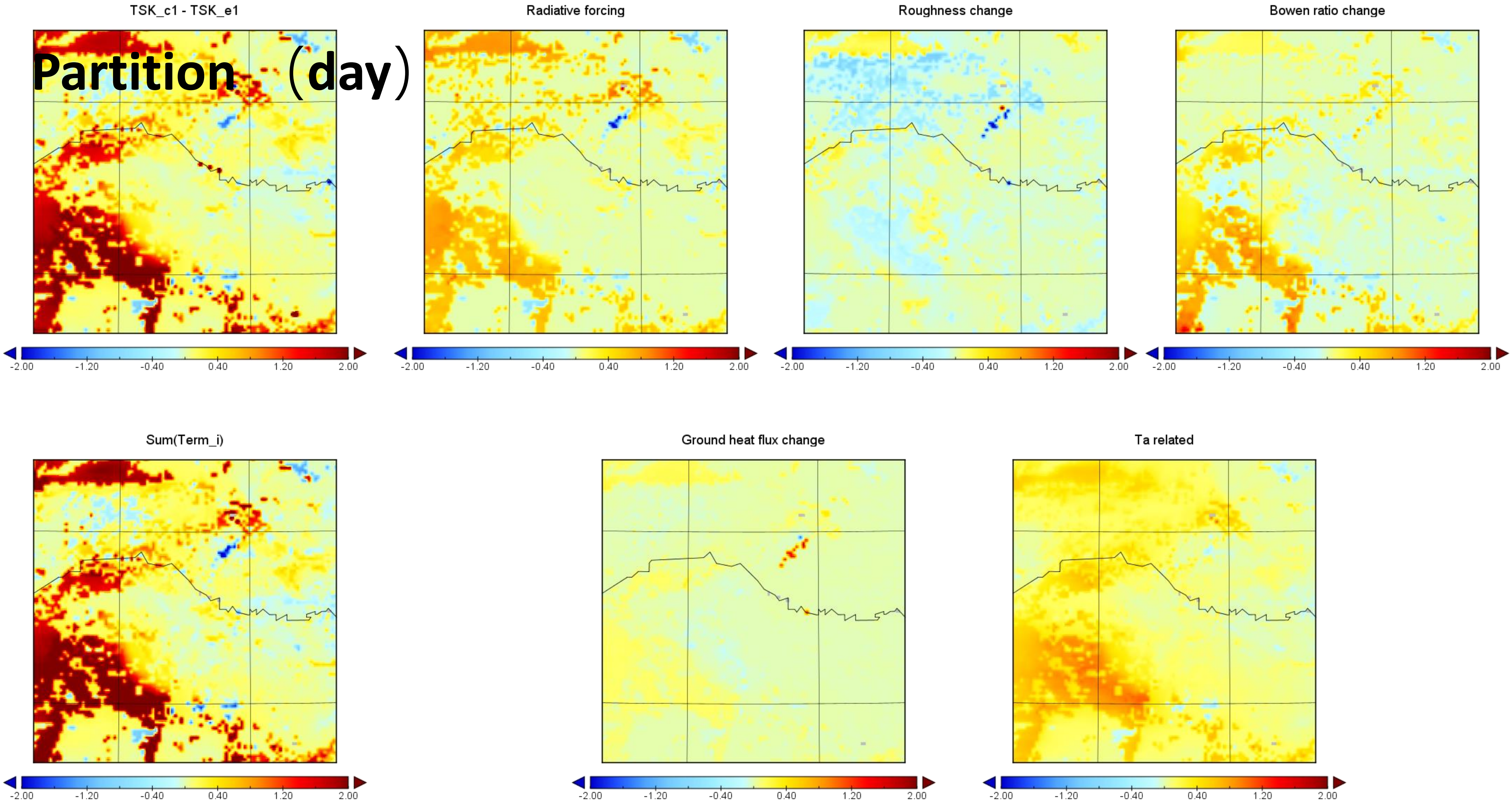
TSK_c1 - TSK_e1 Summer day



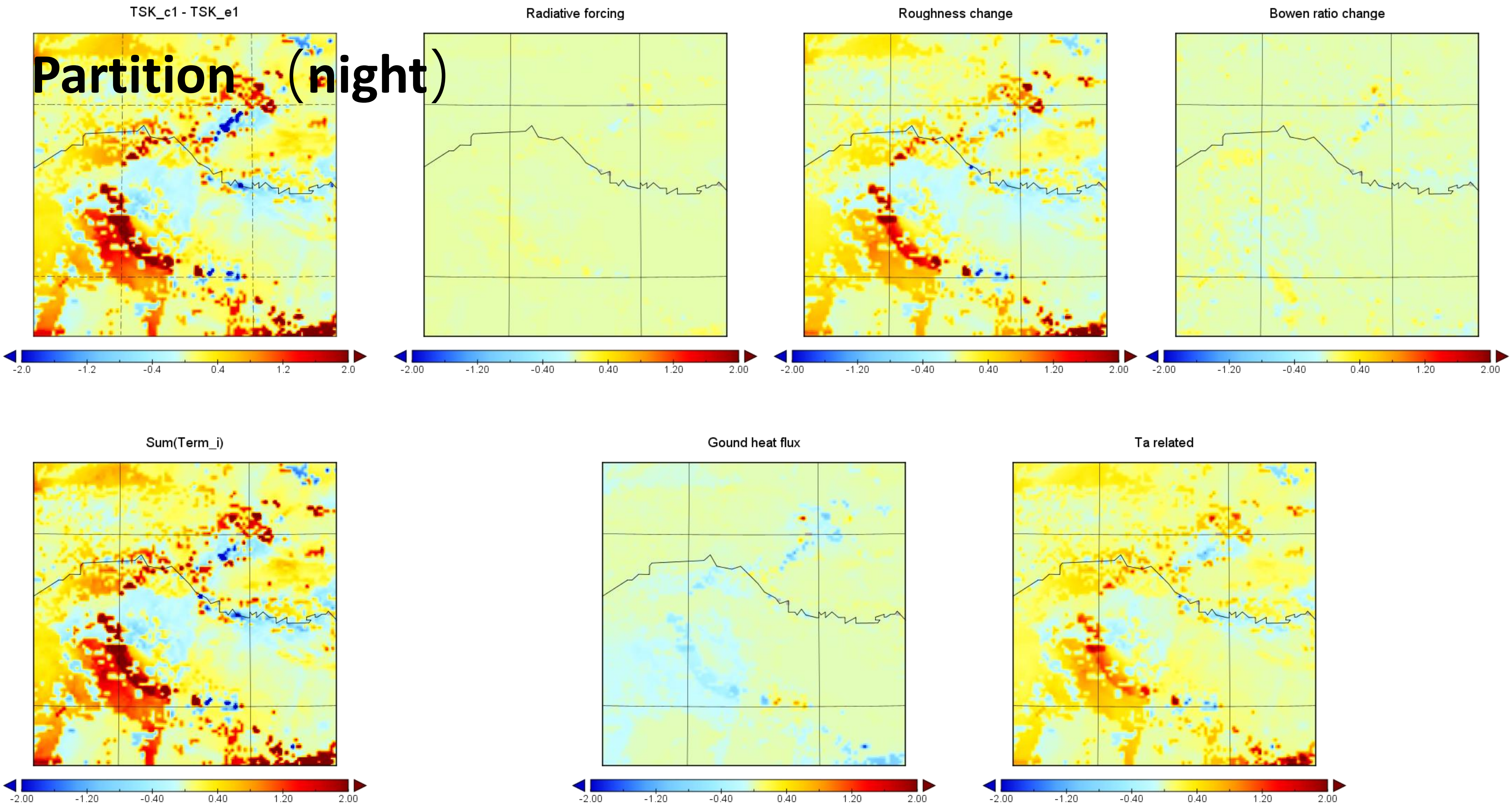
TSK_c1 -TSK_e1 Summer night



Partition（day）



Partition （night）



Thank you!