Partitioning Evapotranspiration into Soil Evaporation and Canopy Transpiration via a Two-Source Variational Data Assimilation System

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Background

- Accurate estimates of soil evaporation (ET_S) and canopy transpiration (ET_C) are required in:
  - Climate forecast
  - Water resources planning and management
  - Monitoring crop condition, Irrigation scheduling
- In-situ measurements
  - Expensive
  - Sparse
  - Large-scale mapping is impossible
- Models
  - Diagnostic
  - Data Assimilation

- **The aim of this study:**
- to assess feasibility of the two-source variational data assimilation (TVDA) approach (developed by Bateni and Liang, 2012) in estimating ET_S and ET_C.
- to compare ET_S and ET_C estimates from the TVDA with those of the commonly used TSEB model introduce by Norman et al. (1995)

- **Land surface temperature (LST)**
- **lies in the heart of the surface energy balance (SEB) equation:**

  Has the signature of partitioning of net radiation (R_N) among the surface energy balance components

- **LST is hypothesized to be composed of soil surface temperature (T_S) and canopy temperature (T_C).**

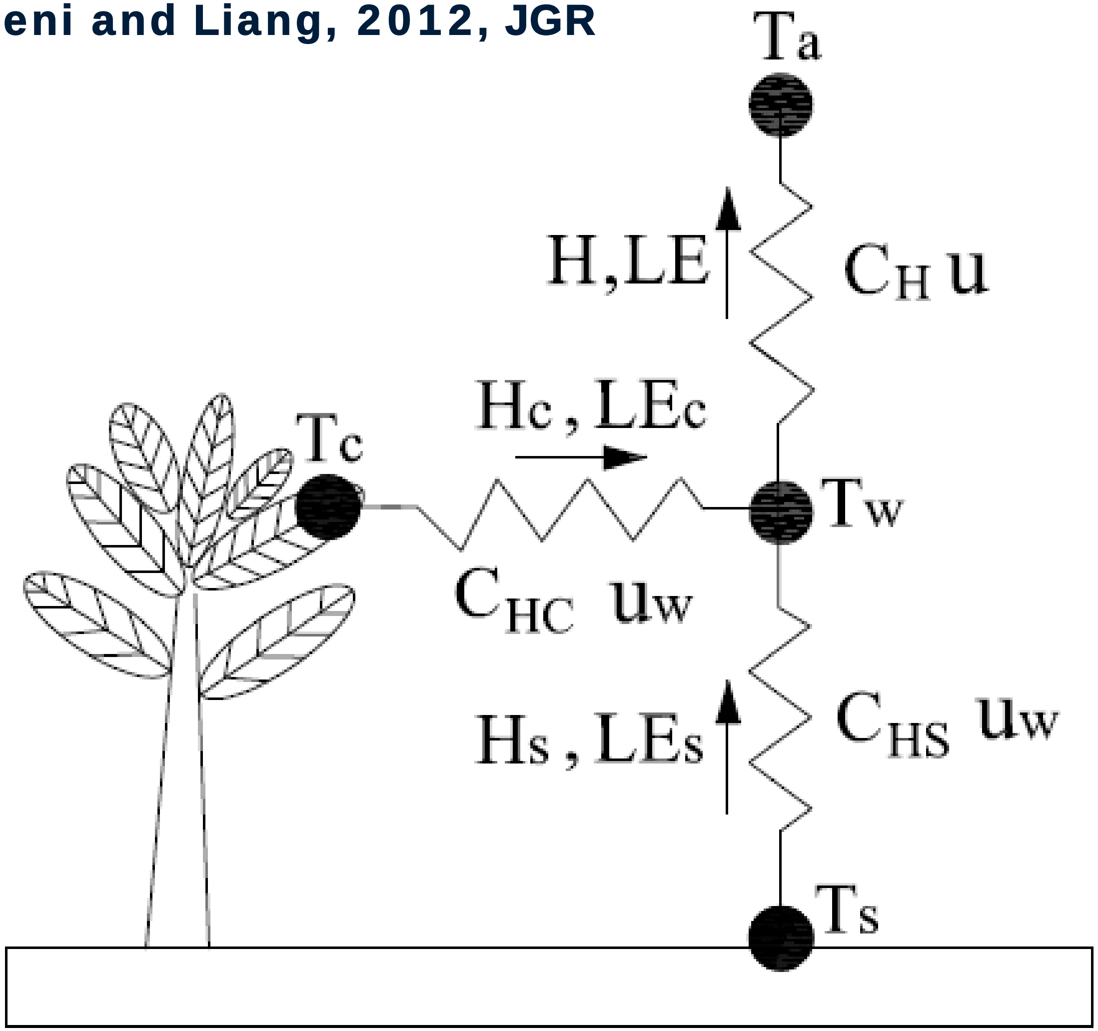
  The surface energy balance is created individually for each of these two sources.

  With LST, ET_S and ET_C can be estimated by diagnostic and data assimilation methods.

Two-source Surface Energy Balance Scheme

Considers the soil and vegetation as separate sources

Bateni and Liang, 2012, JGR



Methodology

- **Diagnostic Method**
  - **two-source surface energy balance (TSEB) model developed by Norman et al., 1995**
- **Data Assimilation Method:**
  - **A two-source variational data assimilation (TVDA) scheme developed by Bateni and Liang, 2012**
  - **The TVDA was based on TSEB, but introduced a heat diffusion equation to make full use of all available LST Obs. in the assimilation window. Thus, TVDA outperform TSEB in theory.**

C_{HN}=exp(*R*), function of vegetation phenology, and varies on a monthly time scale

$$J(T, R, \ldots$$

$$\sum_{i=1}^{N}\int_{t_0}^{t_1}[T_{obs,i}(t) - T_i(t) \ldots (t) - T_i(t)]dt$$

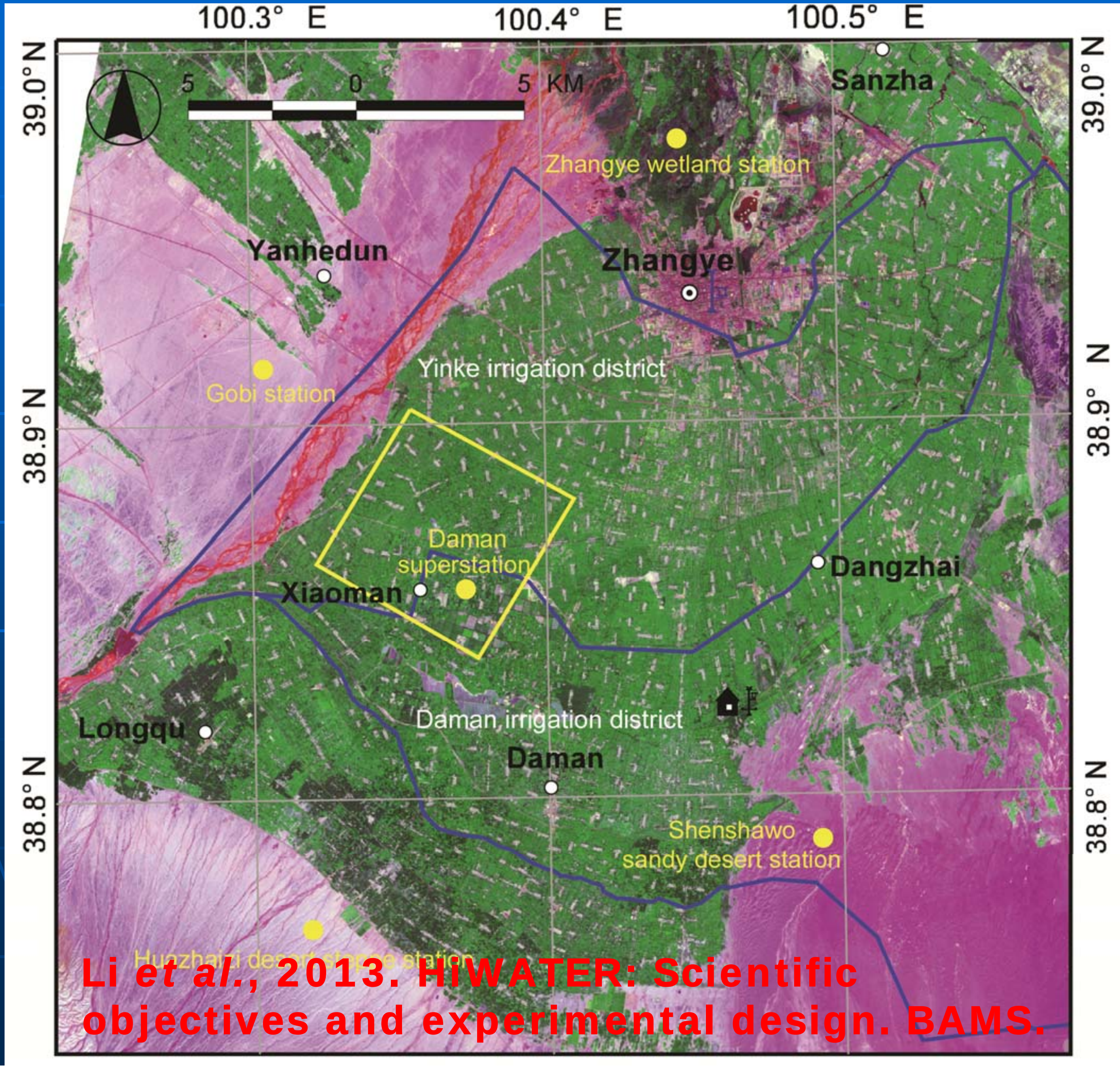
$$+(R-R^{'})^T K_R^{-1}(R-R^{'}) + \sum_{i=1}^{N}(EFs_i - EFs_i^{'})^T K_{EFs}^{-1}(EFs_i - EFs_i^{'})$$

$$+\sum_{i=1}^{N}(EFc_i - EFc_i^{'})^T K_{EFc}^{-1}(EFc_i - EFc_i^{'})$$

$$+2\sum_{i=1}^{N}\int_{t0}^{t1}\int_{0}^{l}\Lambda_i(z,t)[c\frac{\partial T_{si}(z,t)}{\partial t} - \frac{\partial}{\partial z}(\lambda\frac{\partial T_{si}(z,t)}{\partial z})]dzdt$$

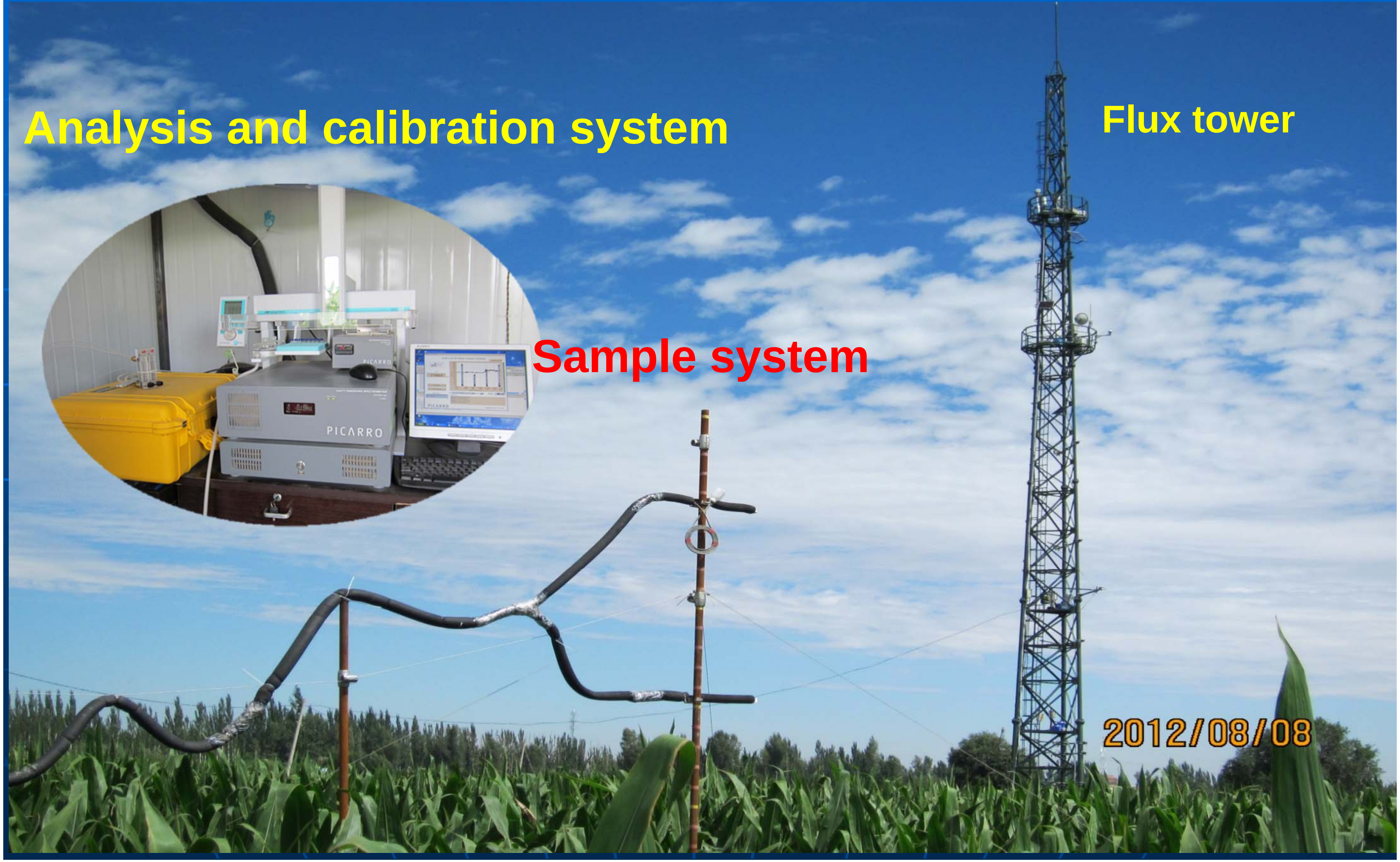
Xu et al., 2014, JGR

Data Sets

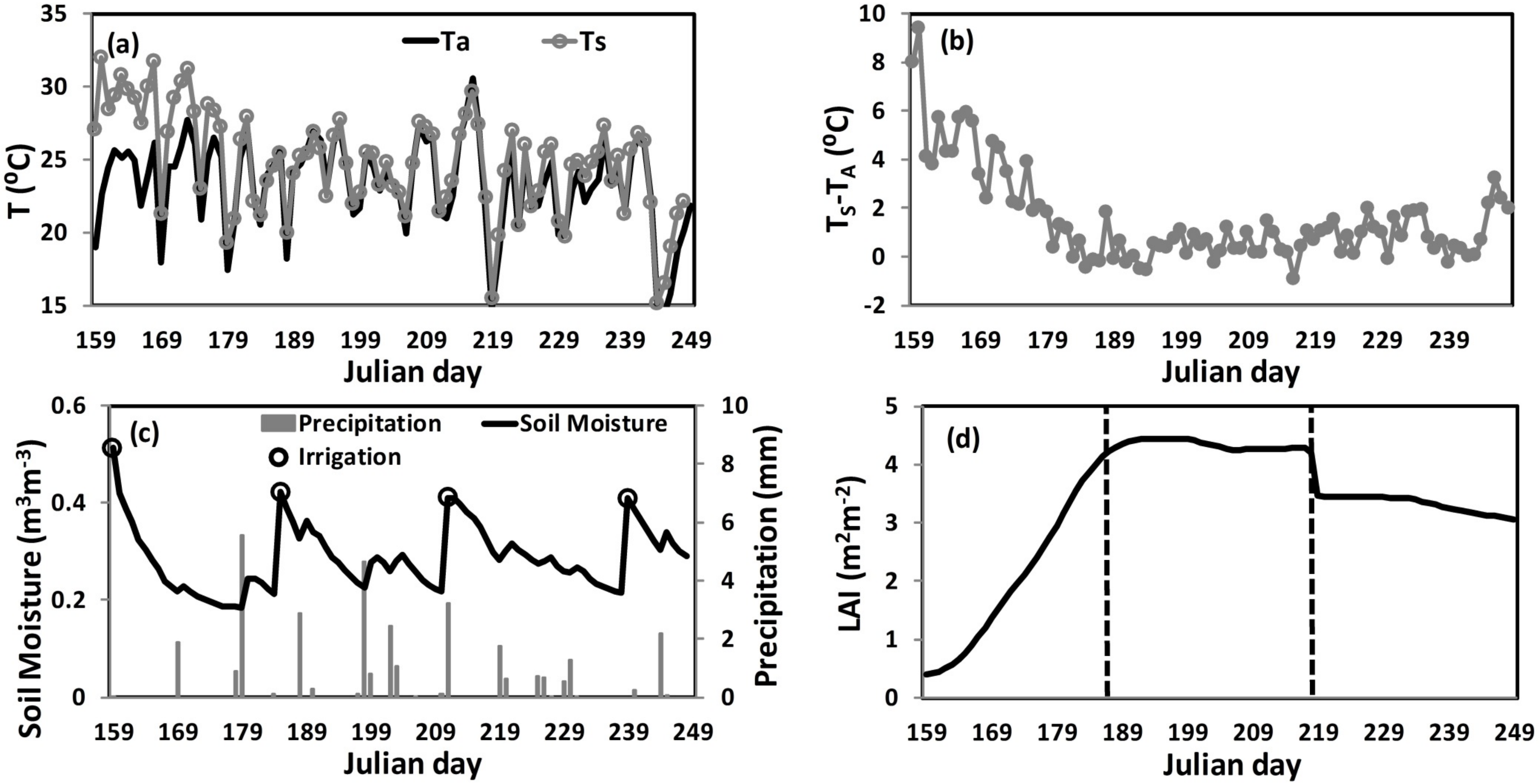


Li *et al.*, 2013. HiWATER: Scientific objectives and experimental design. BAMS.

A combination of eddy covariance-based ET measurements and stable isotope-based measurements of ratio of evaporation and transpiration to total evapotranspiration (ET_S/ET and ET_C/ET)



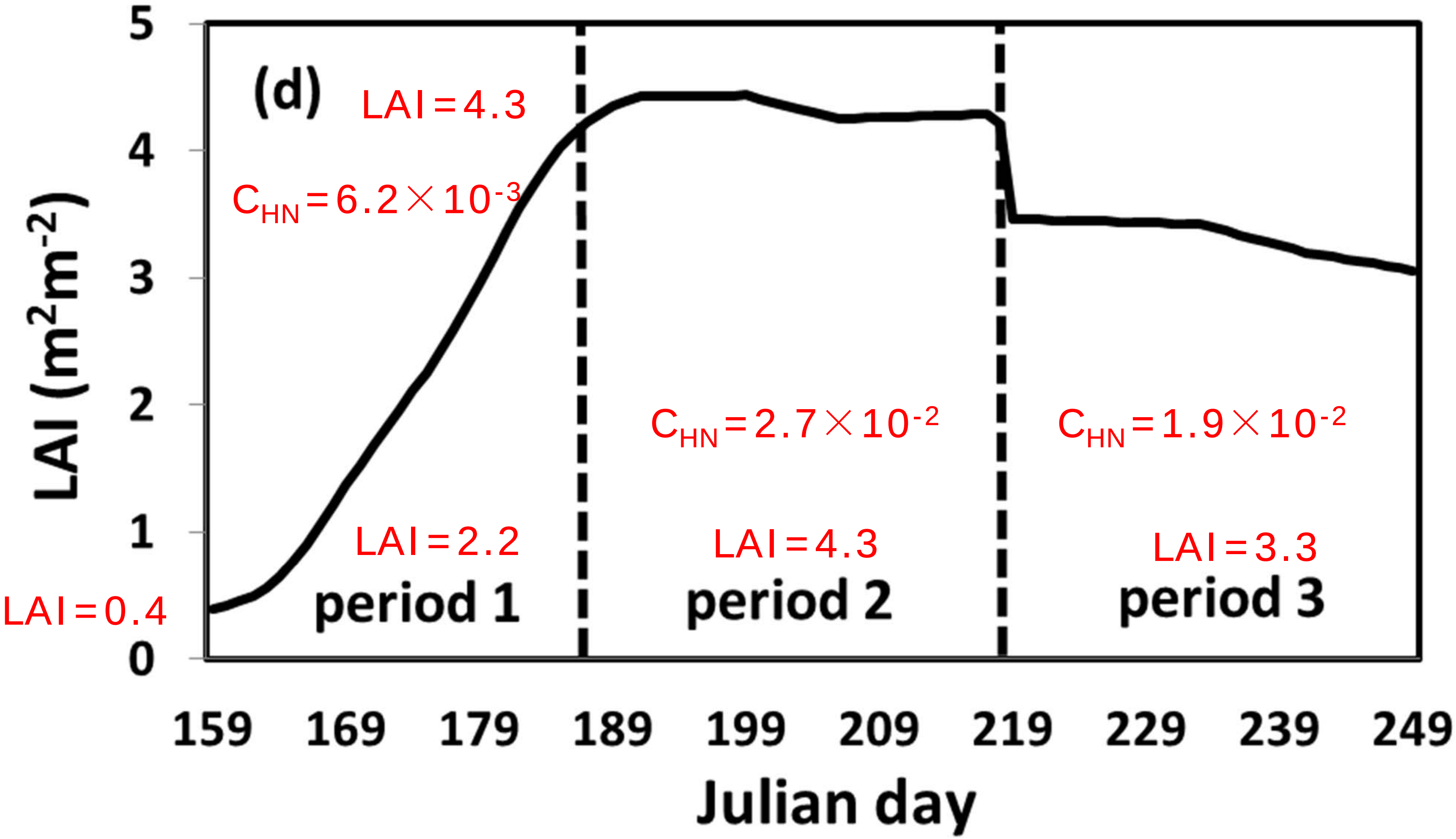
Environmental conditions



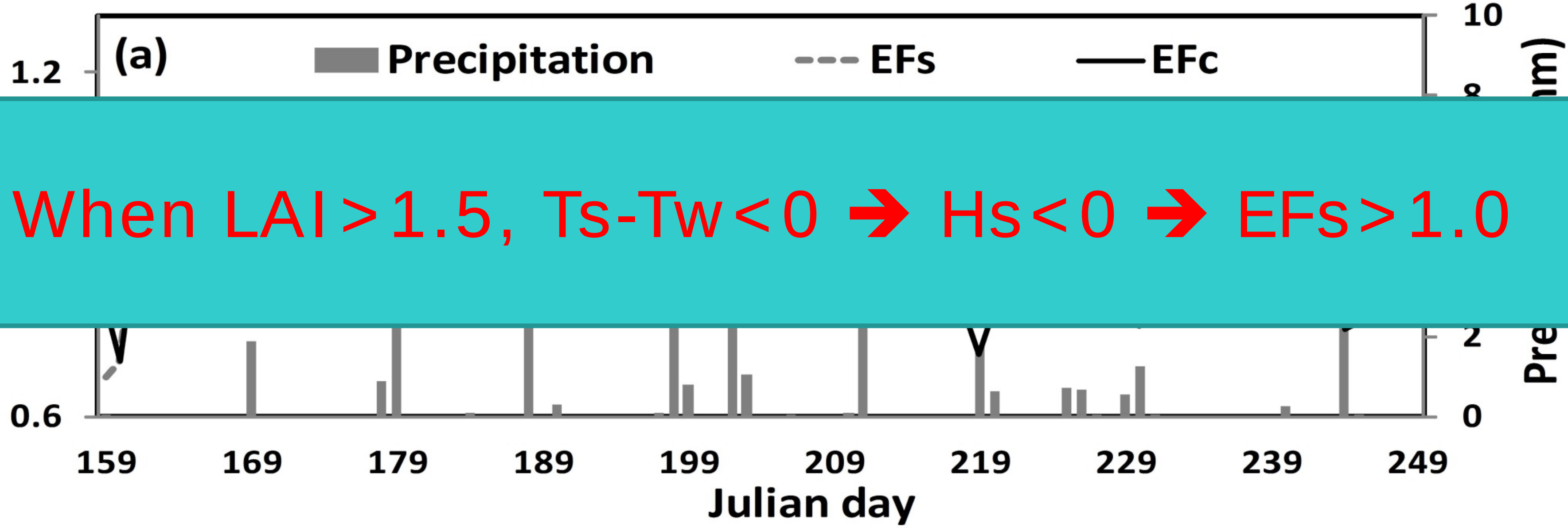
Results

- **Neutral Heat Transfer Coefficient (C_{HN}) and Evaporative Fraction (EF_C and EF_S)**
- **Surface energy balance components**
- **ET_S and ET_C estimates**

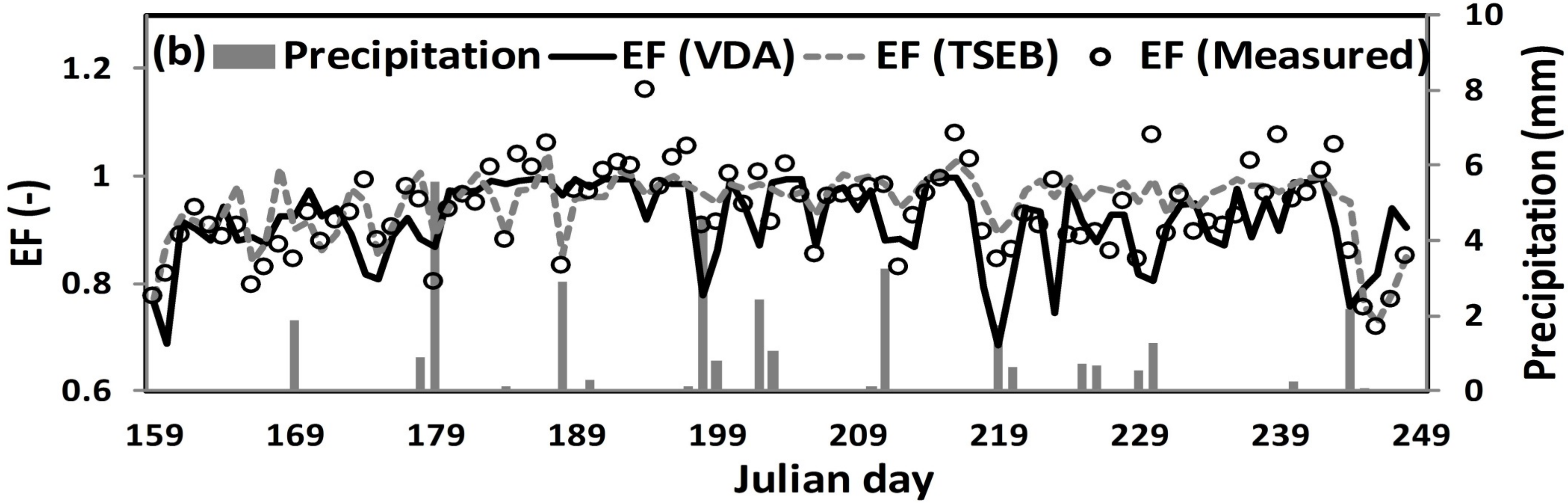
Neutral Heat Transfer Coefficient (C_{HN})



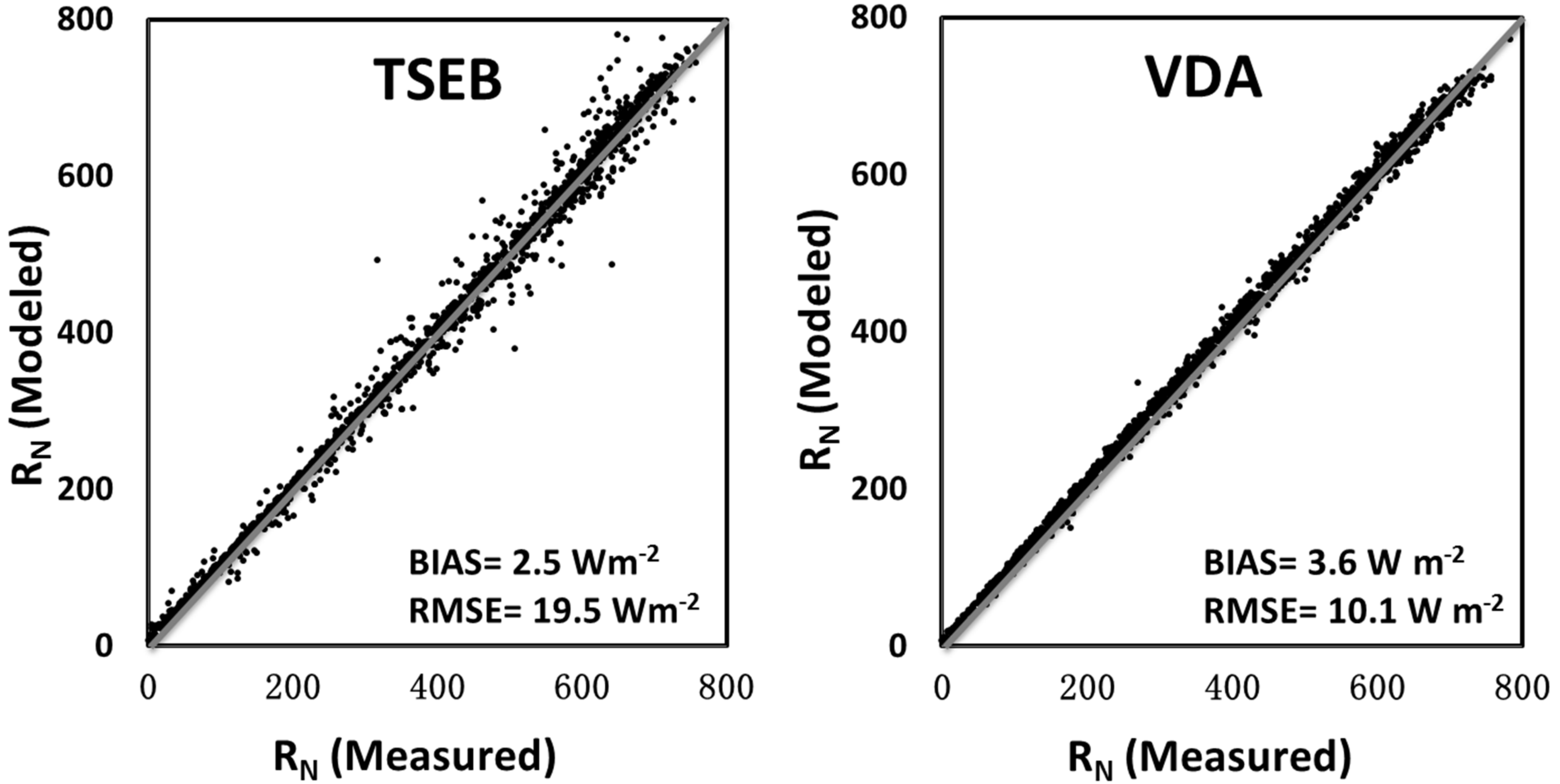
Evaporative Fraction (EF)



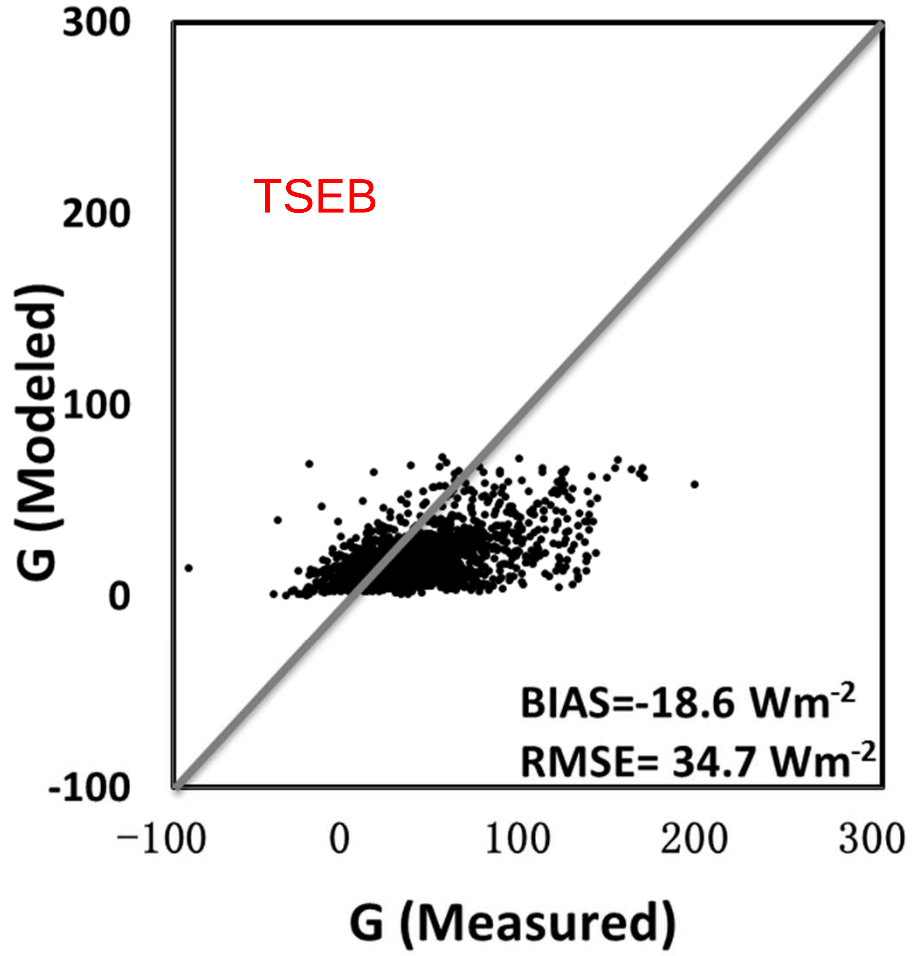
When LAI>1.5, Ts-Tw<0 ➔ Hs<0 ➔ EFs>1.0

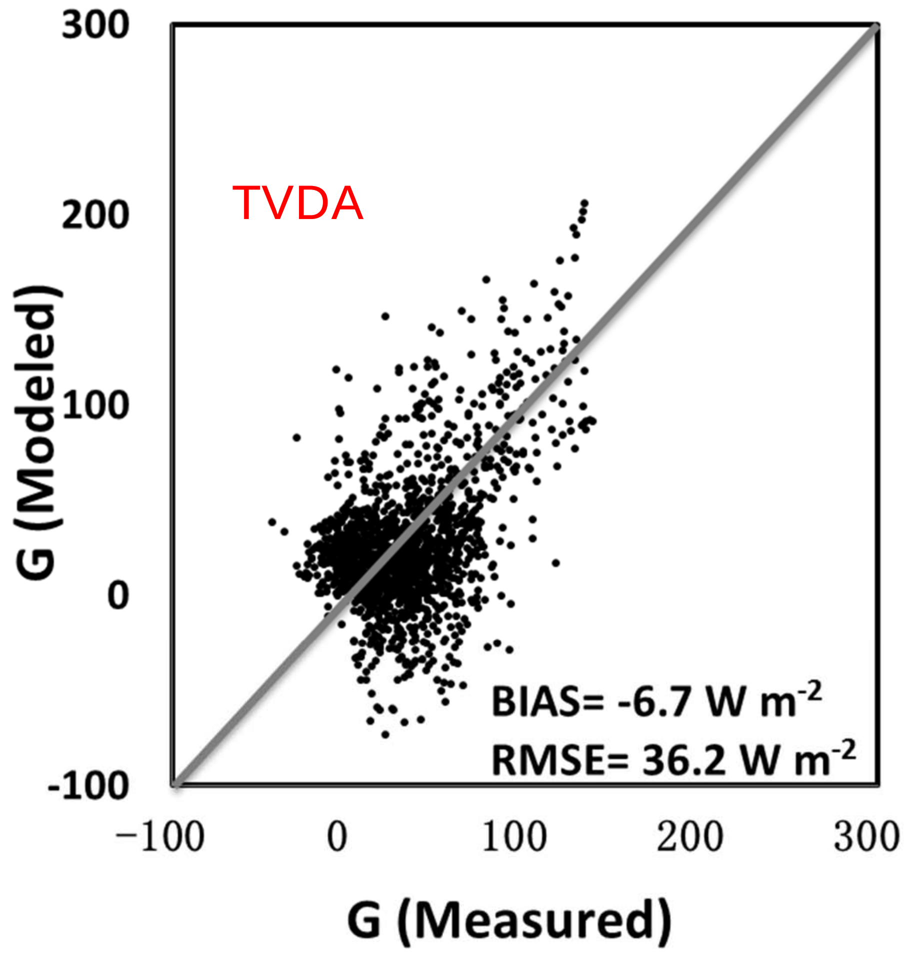


Net radiation



Ground heat flux





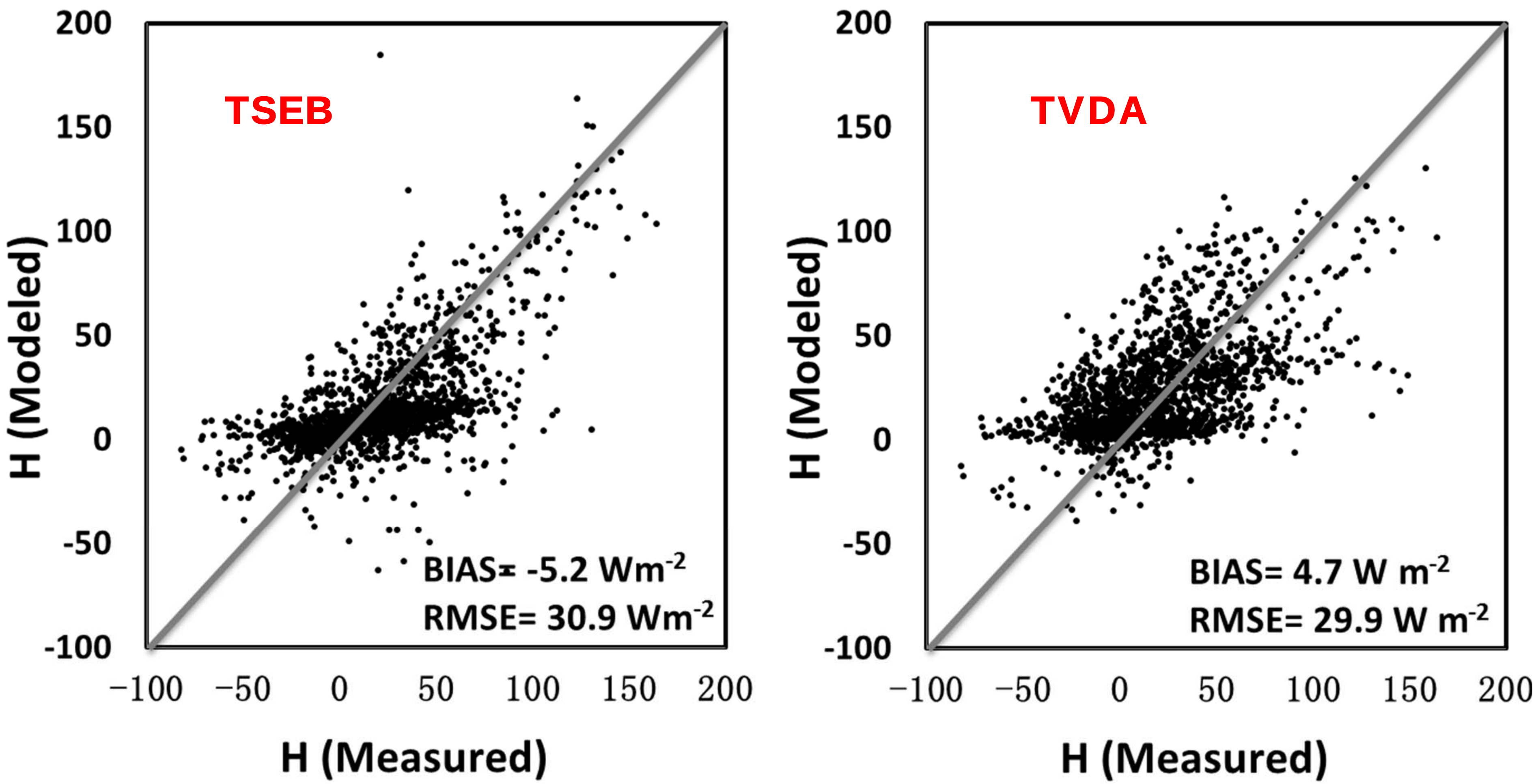
In TSEB

$$G = R_{NS}\left\{a \cdot \cos\left[\frac{2\pi}{b}(t+c)\right]\right\}, \qquad R_{NS} > 0$$

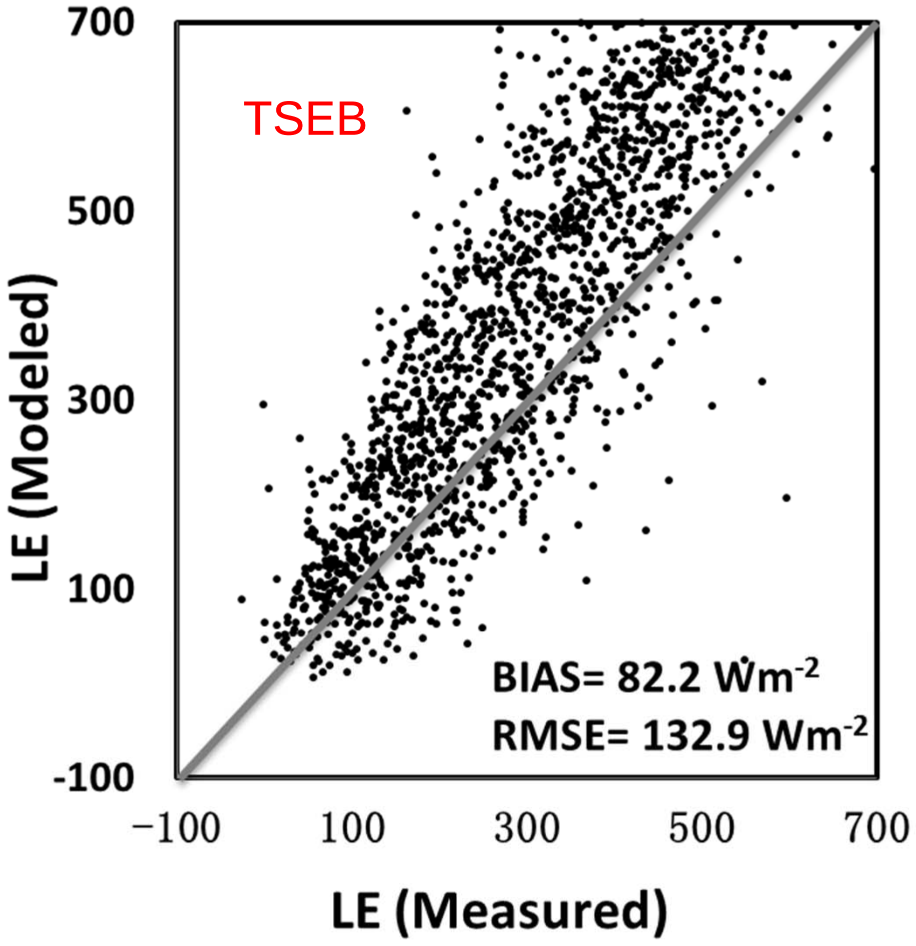
In TVDA

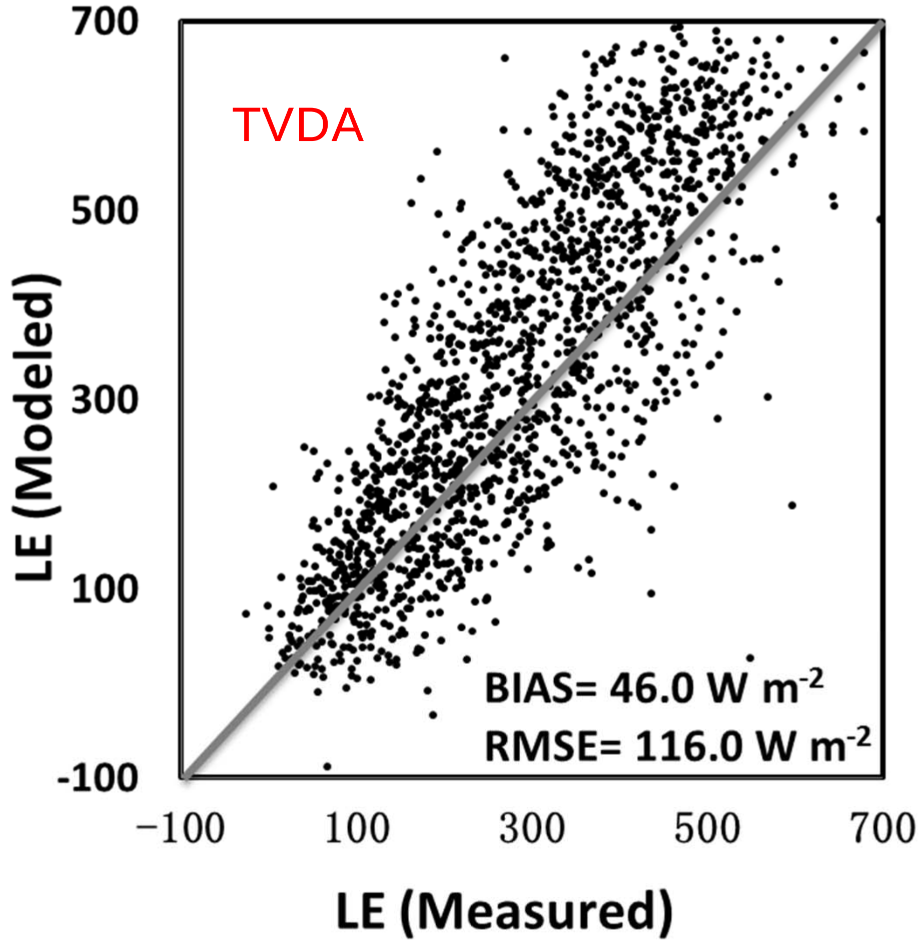
G=Rn-H-LE

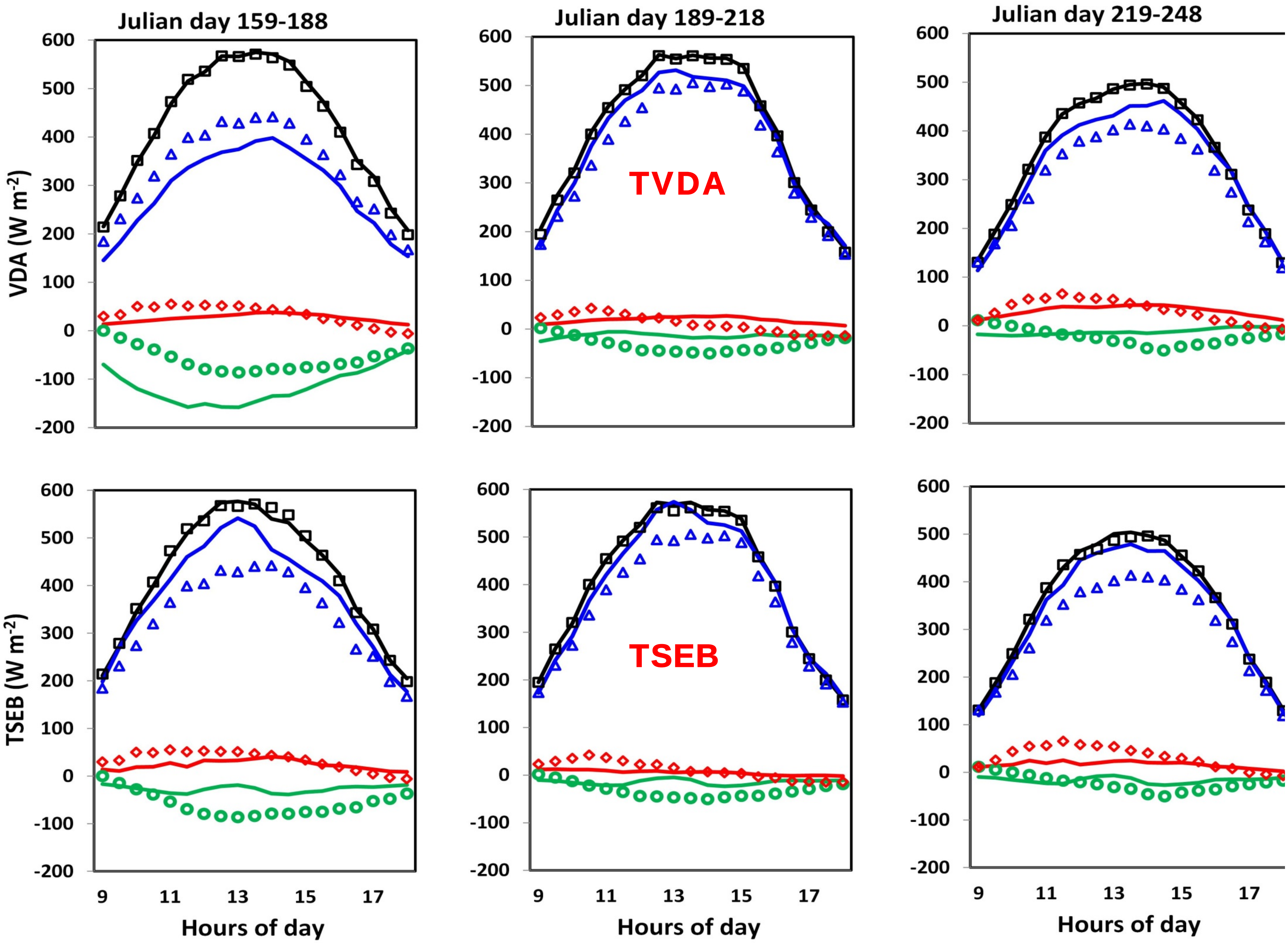
Sensible heat flux



Latent heat flux

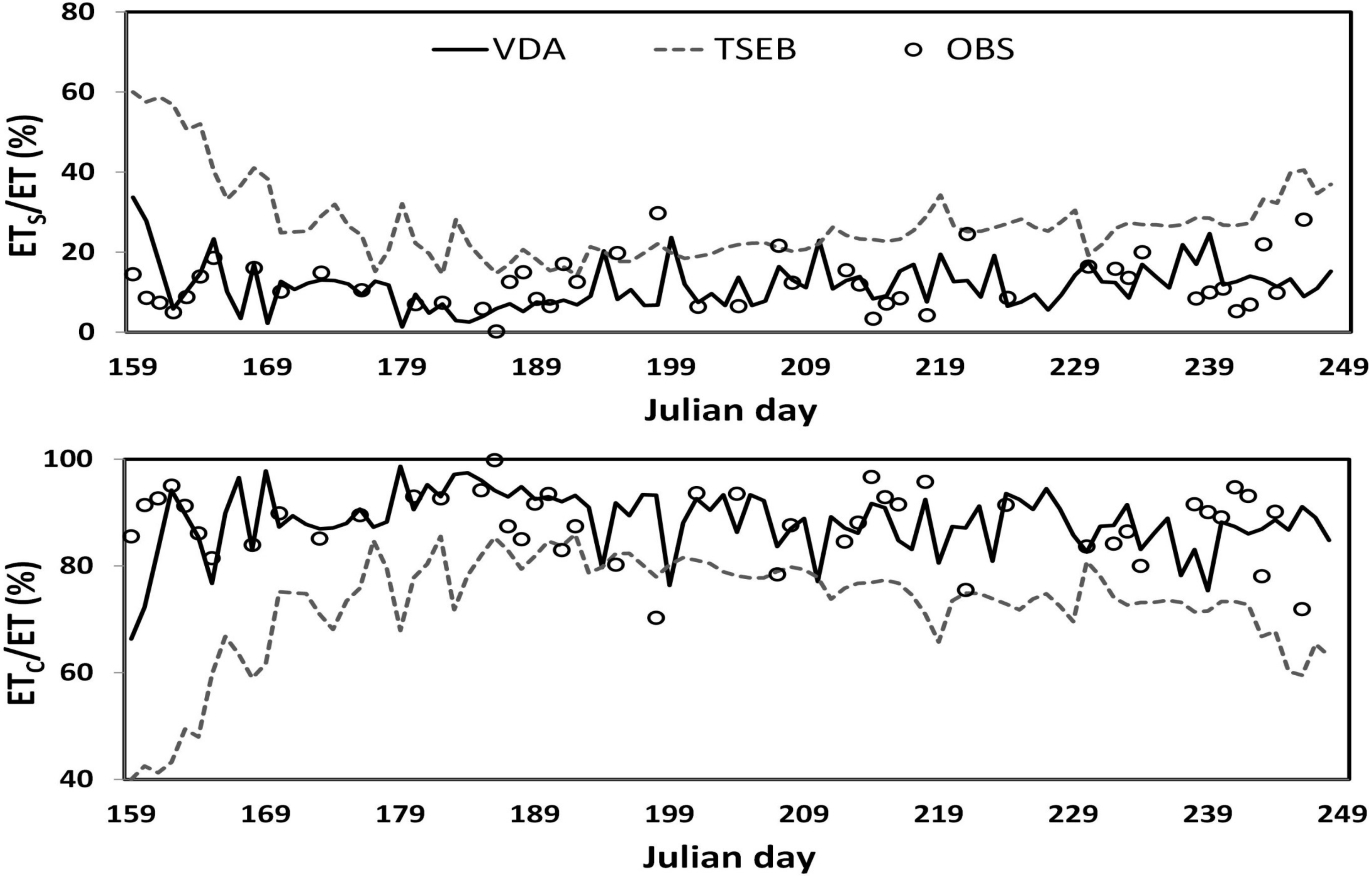


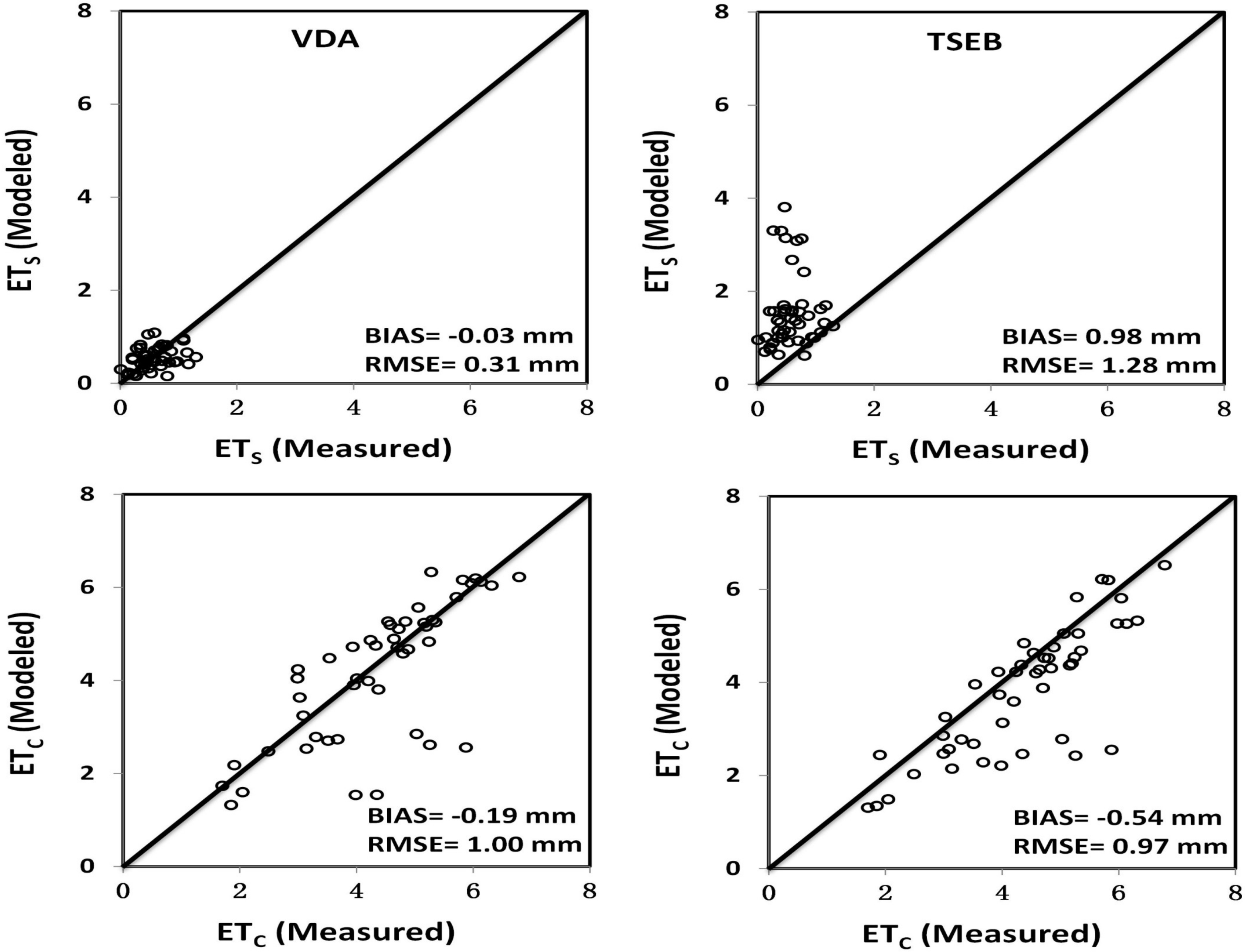




Julian day 159-188
Julian day 189-218
Julian day 219-248
VDA (W m-2)
TSEB (W m-2)
TVDA
TSEB
600
500
400
300
200
100
0
-100
-200
9
11
13
15
17
Hours of day

ETs and ETc Estimates





VDA
TSEB
BIAS= -0.03 mm
RMSE= 0.31 mm
BIAS= 0.98 mm
RMSE= 1.28 mm
BIAS= -0.19 mm
RMSE= 1.00 mm
BIAS= -0.54 mm
RMSE= 0.97 mm
ETS (Modeled)
ETS (Measured)
ETC (Modeled)
ETC (Measured)
0
2
4
6
8

Main Conclusion

- Compared to the TSEB model, the TVDA scheme makes full use of land surface temperature (LST) data within the modeling period by introducing a dynamic model (heat diffusion equation), and thus can produce more accurate fluxes.
- The TVDA model can partition ET into ET_S and ET_C efficiently by comparing to ground measurements, acquired by combining eddy covariance based ET measurements and stable isotope measurements of ratio of evaporation and transpiration to total evapotranspiration (ET_S/ET and ET_C/ET).
- Future studies should focus on C_{HN} parameterization with LAI to improve the model flux estimates in vegetation fast growth conditions.

Thank you!