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The model study on *d-excess* in a temperate forest

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1. Background

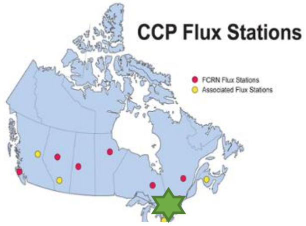
- The isotopic composition of atmospheric vapor is a good tracer for environmental change and vapor source; d-excess is thought to be very conservative , and has been used to investigate the vapor source and surface evapotranspiration contribution.
- There are many processes that could influence d-excess of water vapor, including advection, entrainment, canopy transpiration and soil evaporation; while the contribution of E & T has not been presented clearly until now.
- Currently, for the great error of HDO in flux vapor, d-excess of ET usually obtained by model, mainly by SiLSM model(ignore soil E), ISOLES model (large scale and complex), Iso-SPAC model (poor performed at night).

Assumption

Although soil evaporation is a relatively small portion of total evapotranspiration (usually less than 10%), it's large d-excess could be enough to contribute to d_v variability, therefore, we assumption that the influence of soil evaporation on d_v could not be neglected .

objective

Our study will combine SW model with leaf water enrich model and soil evaporation model, partition the ET components and calculate the isotopic composition of each components, according to the isoflux of d-excess to explore the contribution of ET and E on d_v variability.



2. Site and observation

Late May - late August. DOY 148-233.

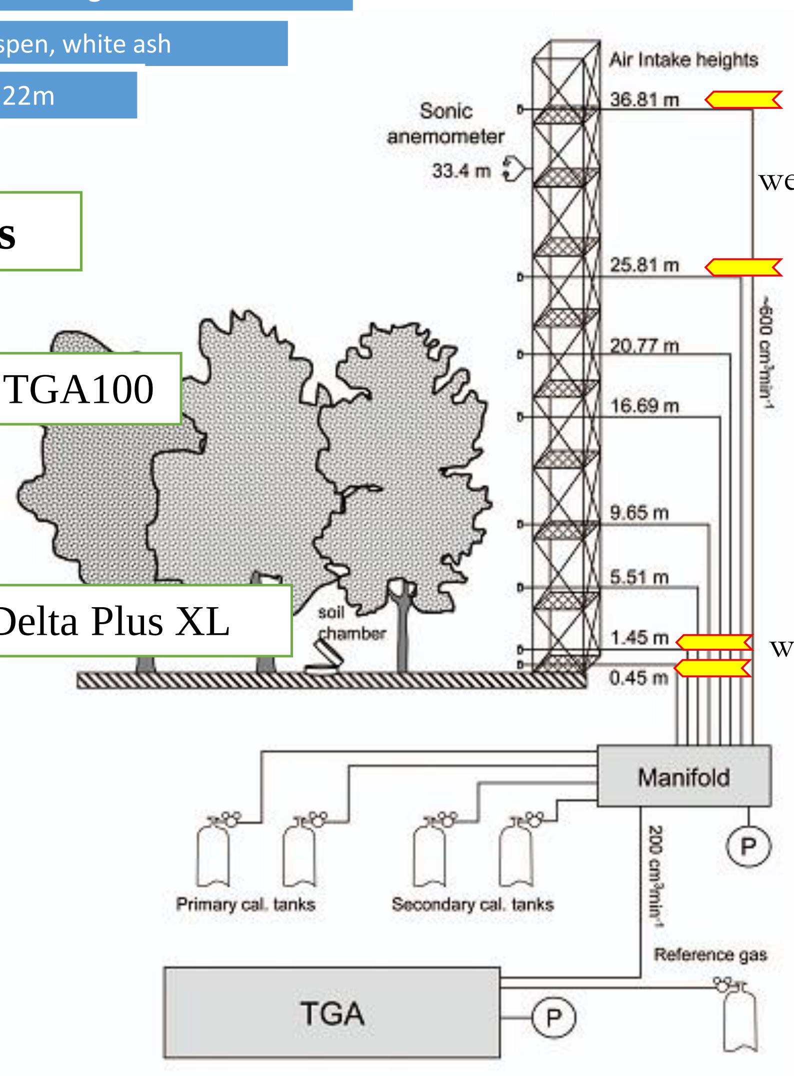
Red maple, Aspen, white ash

Stand height: 22m

isotopes

vapor： TGA100

liquid： Delta Plus XL



weekday

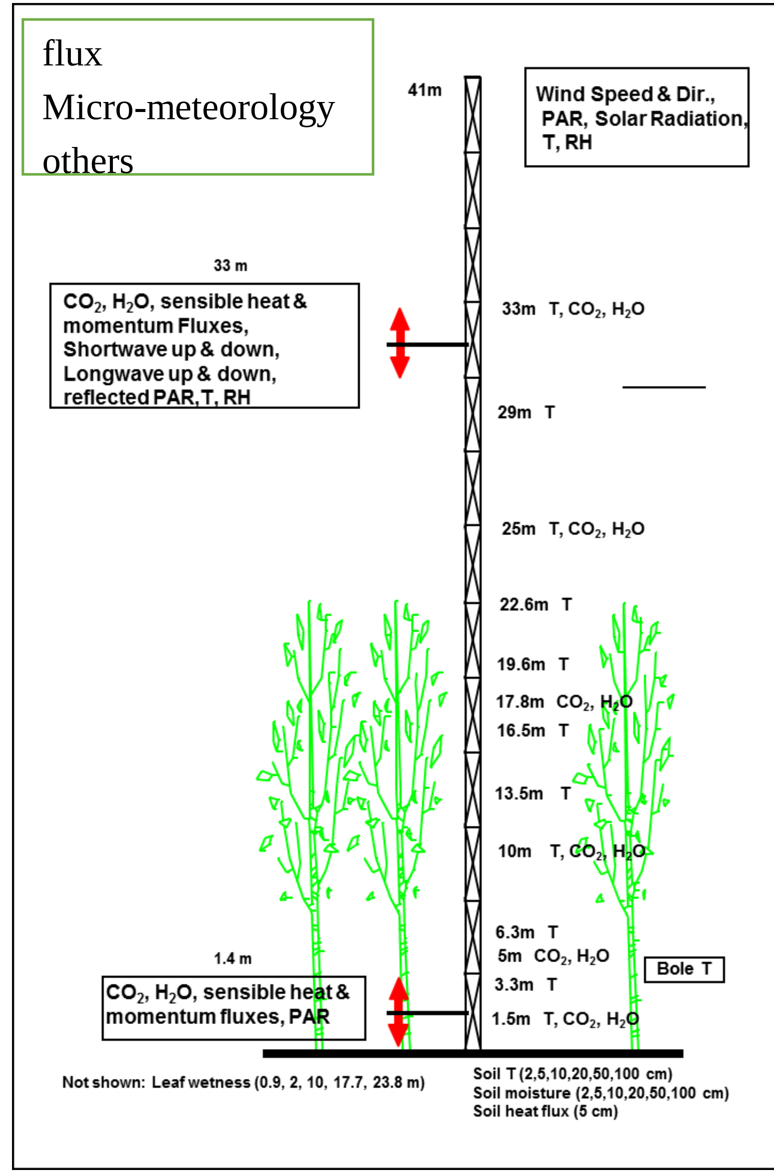
weekend

(Santos et al., 2012)

flux

Micro-meteorology

others



R: heavier isotoper/lighter isotoper

$\delta^{18}O$ and δD of H_2O (‰):

$$\delta = \left(\frac{R_{\text{Sampling}}}{R_{\text{VSMOW}}} - 1 \right) \times 1000$$

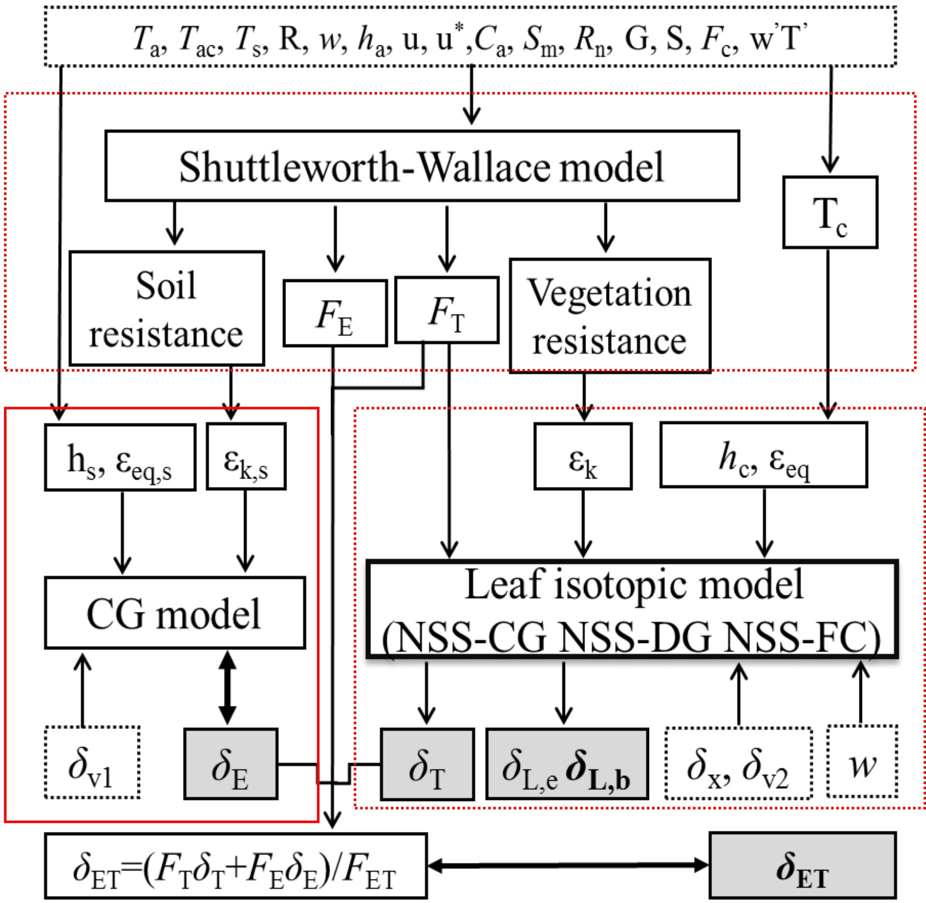
$$d_{excess} = \delta \mathrm{D} - 8\,\delta^{18}\mathrm{O}$$

Flux isotope ratio $$R_{\mathrm{ET}} = R_{\mathrm{d}} \frac{x_2^{16} - x_1^{16}}{x_2^{18} - x_1^{18}} \times \frac{x_3^{18} - x_4^{18}}{x_3^{16} - x_4^{16}}$$

Isoforcing $$\overline{w'\delta'} = \frac{F_{ET}}{Ca}(\delta_{ET} - \delta_a)$$

Model simulation

3. SiLSM2 model description



SW MODEL

$$\lambda ET = E_c + E_s = C_c PM_C + C_s PM_s$$

$$PM_c = \frac{\Delta R + (\rho C_p D - \Delta r_{ac} R_s)/(r_{aa} + r_{ac})}{\Delta + \gamma[1 + r_{sc}/(r_{aa} + r_{ac})]}$$

$$PM_s = \frac{\Delta R + [\rho C_p D - \Delta r_{as}(R - R_s)]/(r_{aa} + r_{ac})}{\Delta + \gamma[1 + r_{ss}/(r_{aa} + r_{as})]}$$

$$r_{sc} = \frac{1}{g_0 + a_1 f(\theta) P_n h_s / C_s} \times \frac{1}{1.6}$$

$$r_{ss} = \exp(8.206 - 4.225 \times \theta)$$

CG MODEL

$$\varepsilon_k^O = \frac{21 r_{ac} + 32 r_{sc}}{r_{aa} + r_{ac} + r_{sc}} \qquad \varepsilon_k^D = \frac{10 r_{ac} + 16 r_{sc}}{r_{aa} + r_{ac} + r_{sc}}$$

$$\delta_E = \frac{\delta_s/\alpha_{eq} - h_s\delta_v - \varepsilon_{eq} - (1-h_s)\varepsilon_k}{(1-h_s) + (1-h_s)(\varepsilon_k/1000)}$$

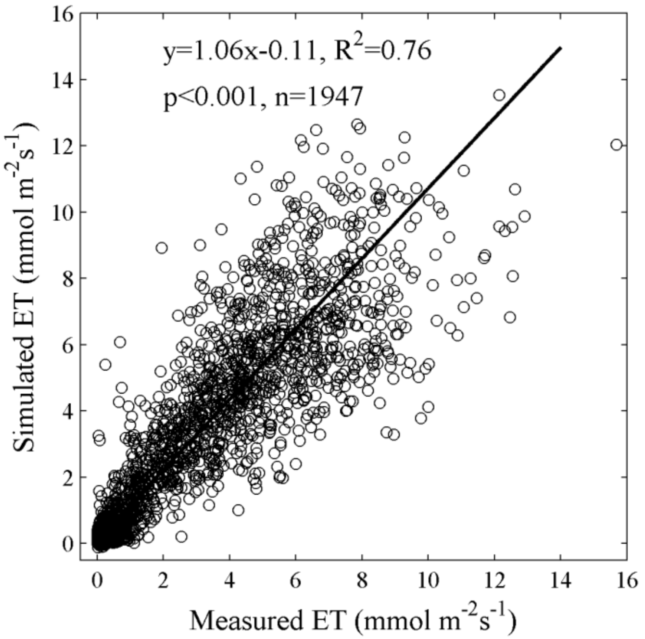
DG MODEL FC MODEL

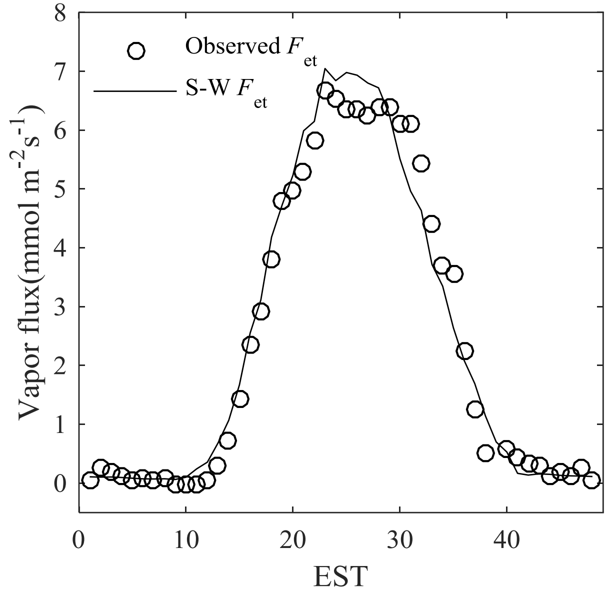
δ_E/δ_{ET}

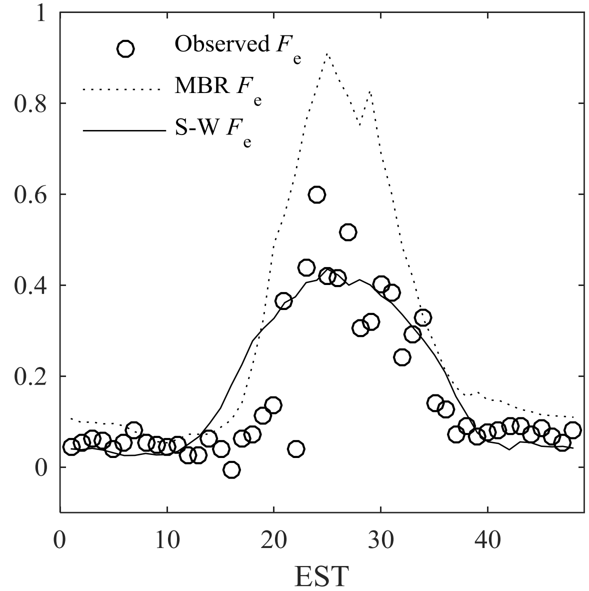
r_{ss} was estimated as as the function of soil water content (Lin and Sun, 1983);
r_{sc} is simulated by the modified Ball–Berry model (Wang and Leuning, 1998);
The 3 aerodynamic resistances: r_a , r_{ac}, r_{as} is calculated same approach as Shuttleworth and Wallace(1985).

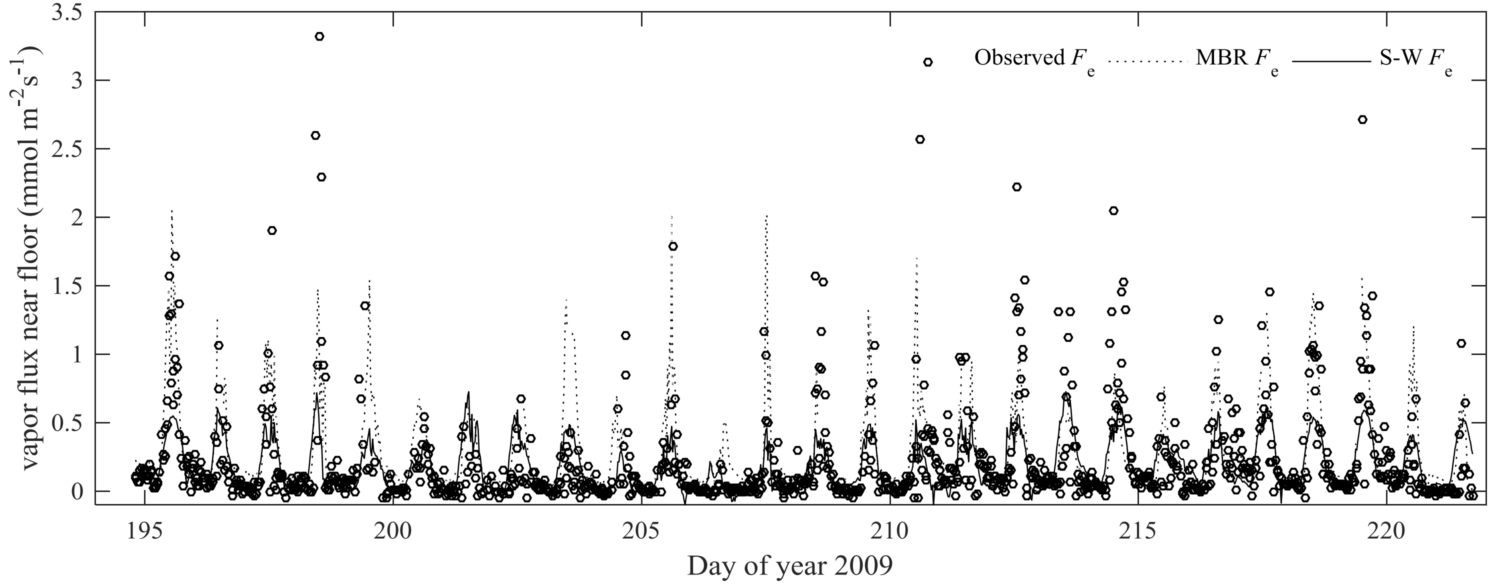
3. results

3.1 validation → F_E F_{ET} $\delta^{18}O_L$ δD_L $\delta^{18}O_{ET}$

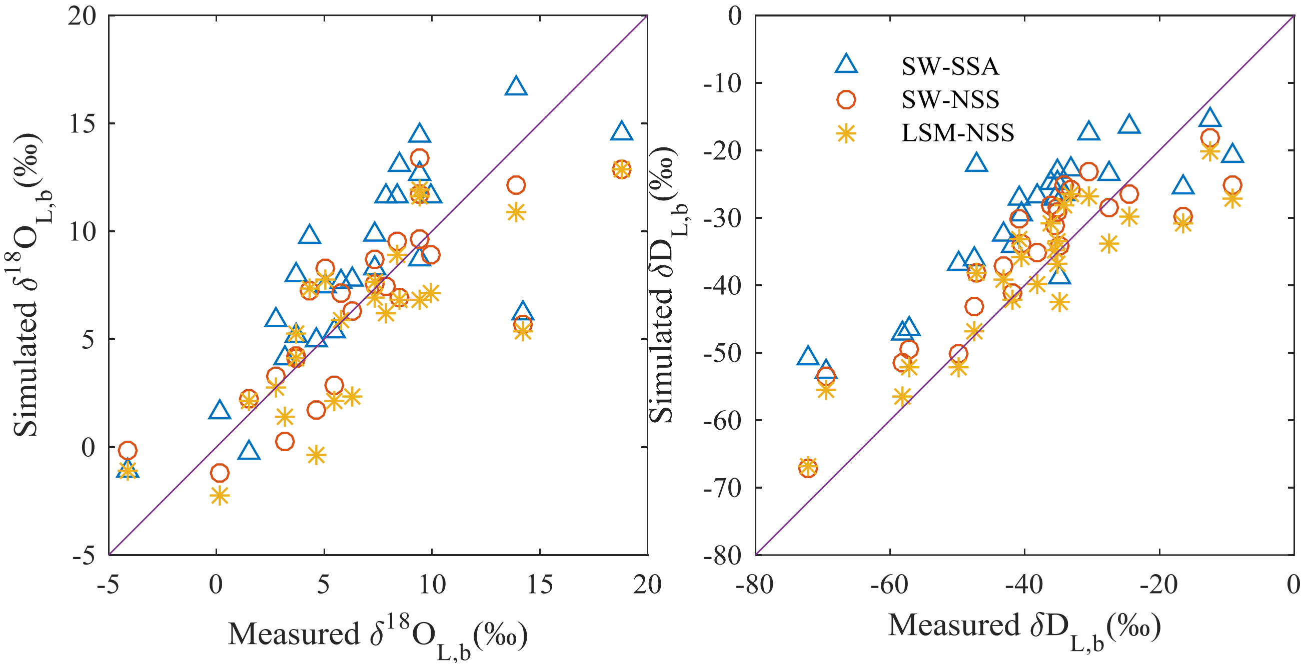






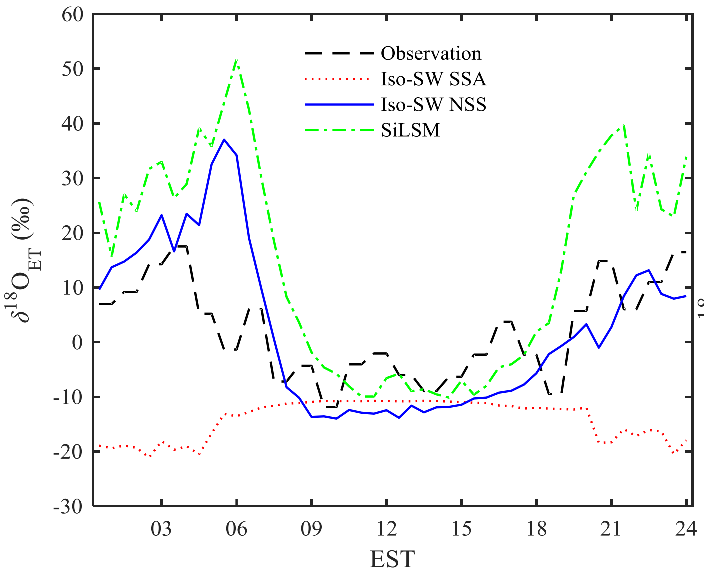


$\delta^{18}O_L$ δD_L

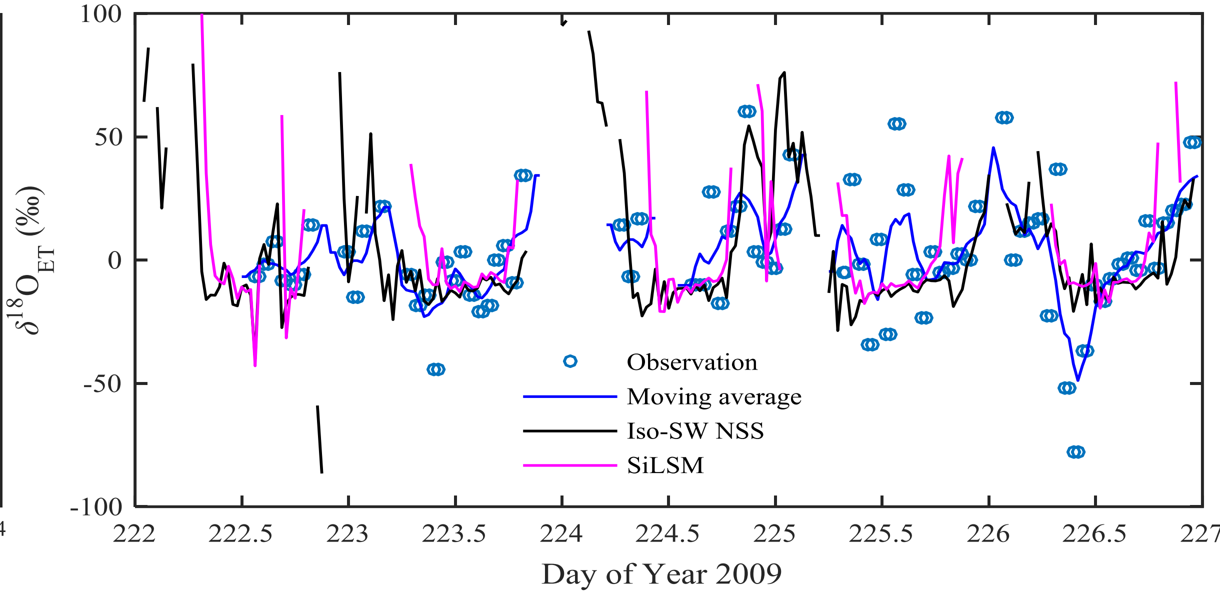


	SILSM2				SILSM			
	CG_ISS	CG_NSS	DG	FC	CG_ISS	CG_NSS	DG	FC
K	0.96**	0.74**	0.71*	0.78**	1.06**	0.83**	1.00**	0.99**
R	0.79	0.82	0.79	0.80	0.84	0.88	0.85	0.85
I	0.86	0.88	0.85	0.88	0.91	0.88	0.92	0.92
RMSD	3.56	2.88	3.19	2.96	2.87	3.07	2.76	2.72
ME	1.95	-0.16	-0.86	0.11	-0.0034	-1.34	0.11	0.03

$\delta^{18}O_{ET}$

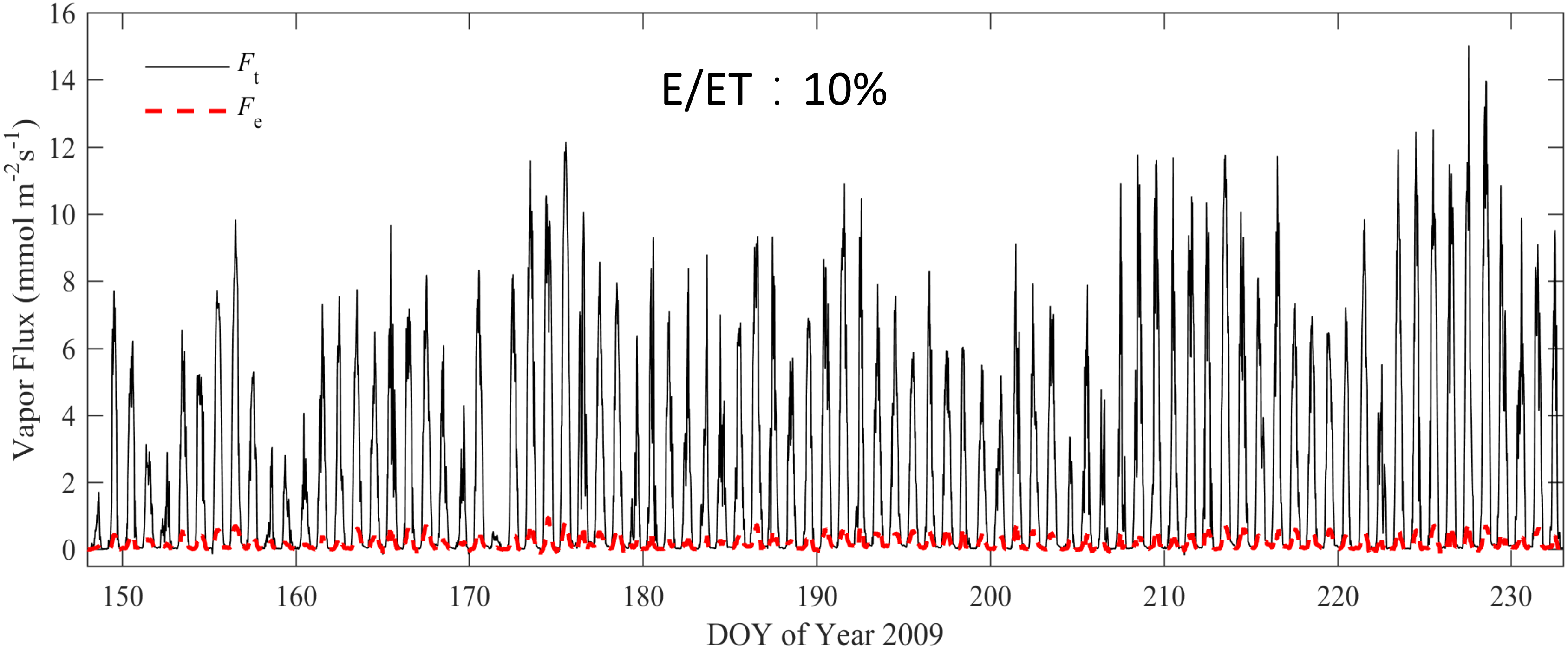


Observation
Iso-SW SSA
Iso-SW NSS
SiLSM
$\delta^{18}O_{ET}$ (‰)
EST



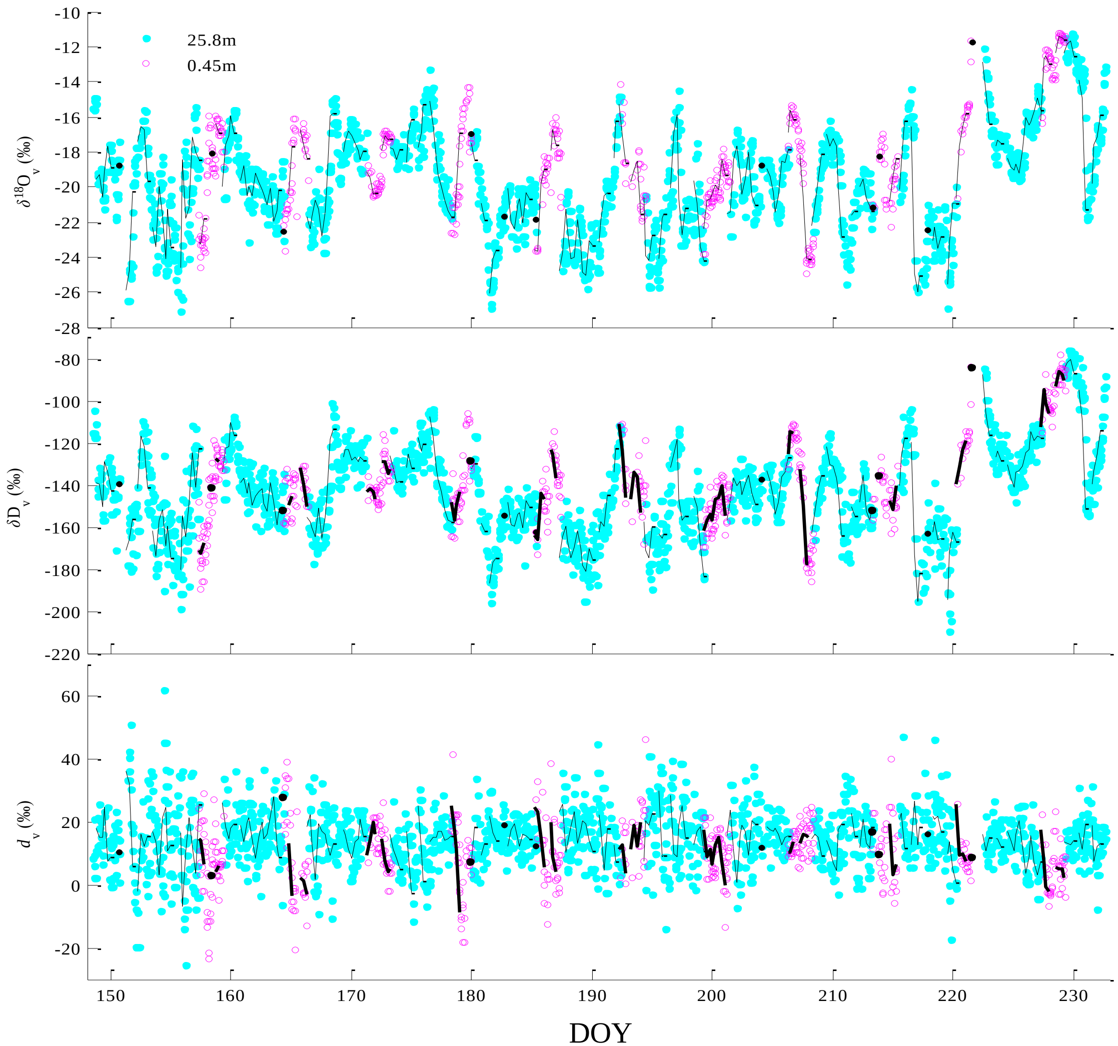
Observation
Moving average
Iso-SW NSS
SiLSM
$\delta^{18}O_{ET}$ (‰)
Day of Year 2009

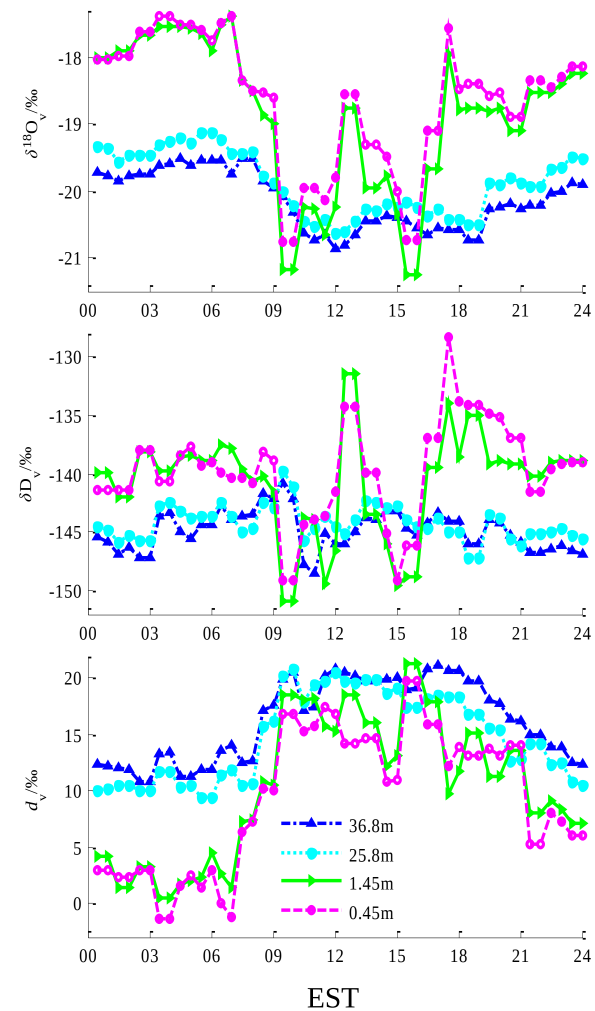
3.2 ET partitioning



4.Discussion

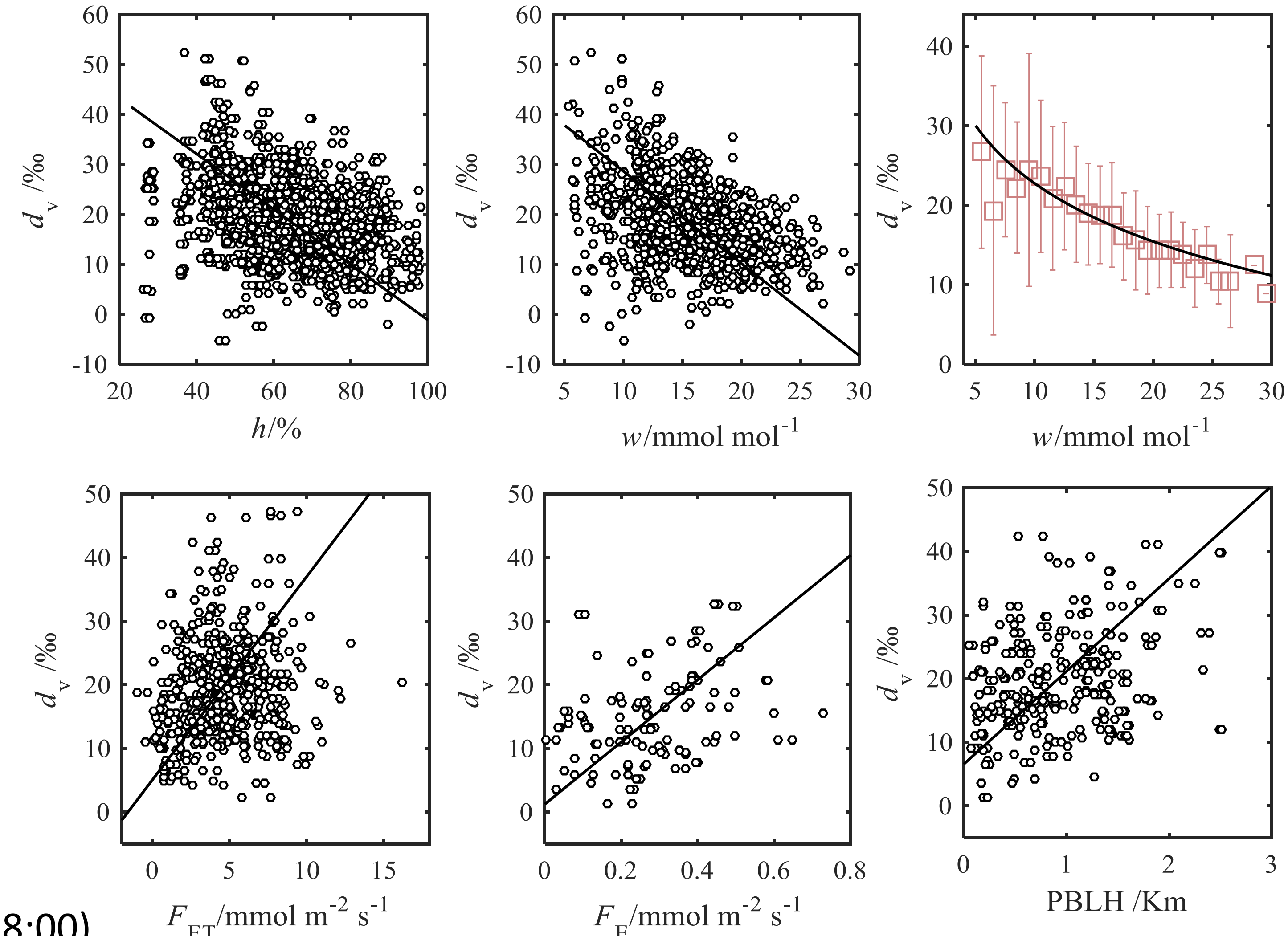
4.1 d_v variation and the main factors





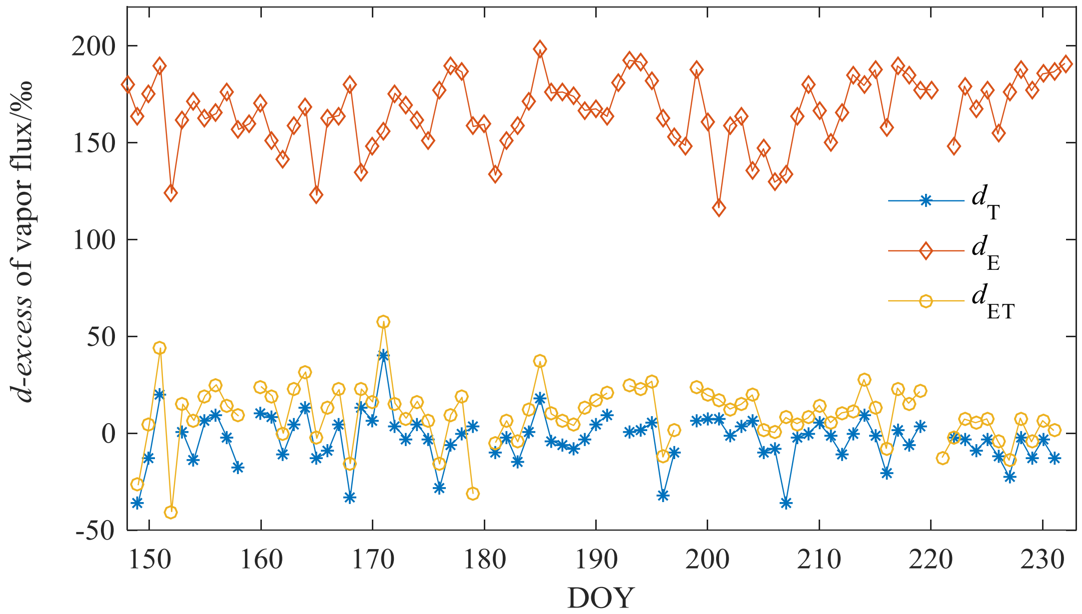
1. There is no remarkable seasonal variation for dv during the growing season.
2. dv is much large during midday, and the value at the four height is most close.

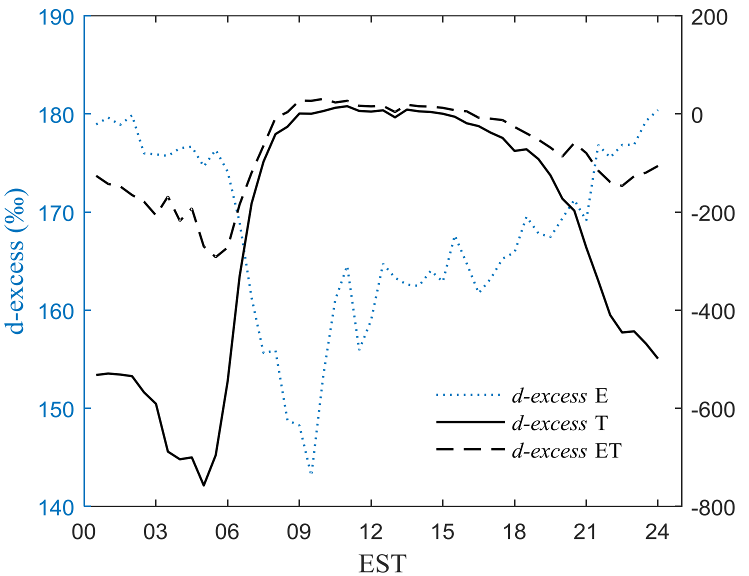
The relationship between d_v and the main environmental factors

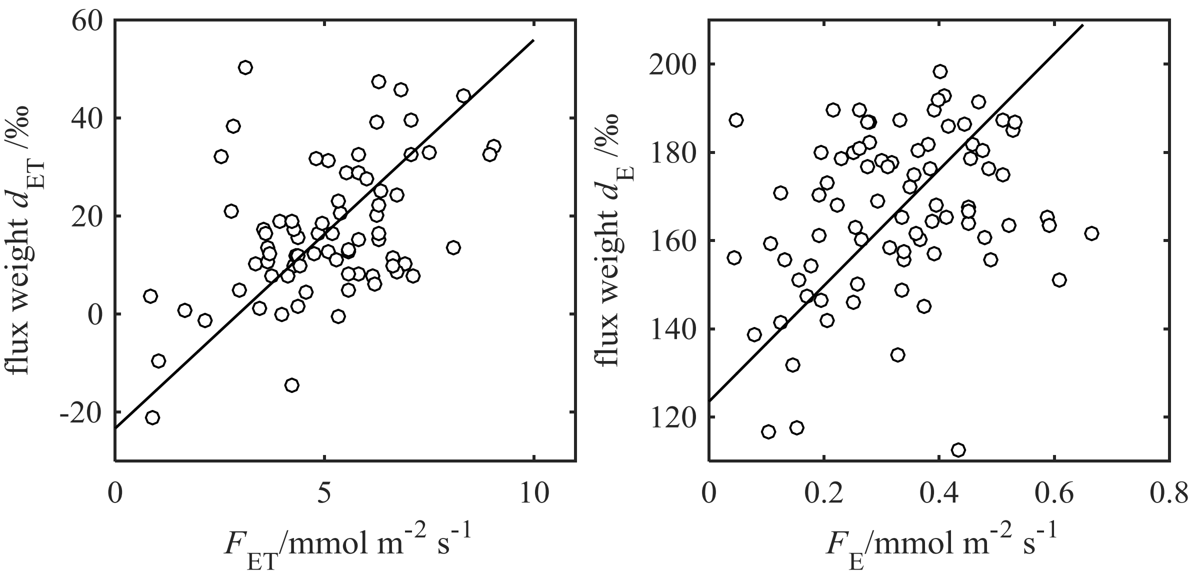


(12:00-18:00)

4.2 seasonal and diurnal $d_E/d_T/d_{ET}$

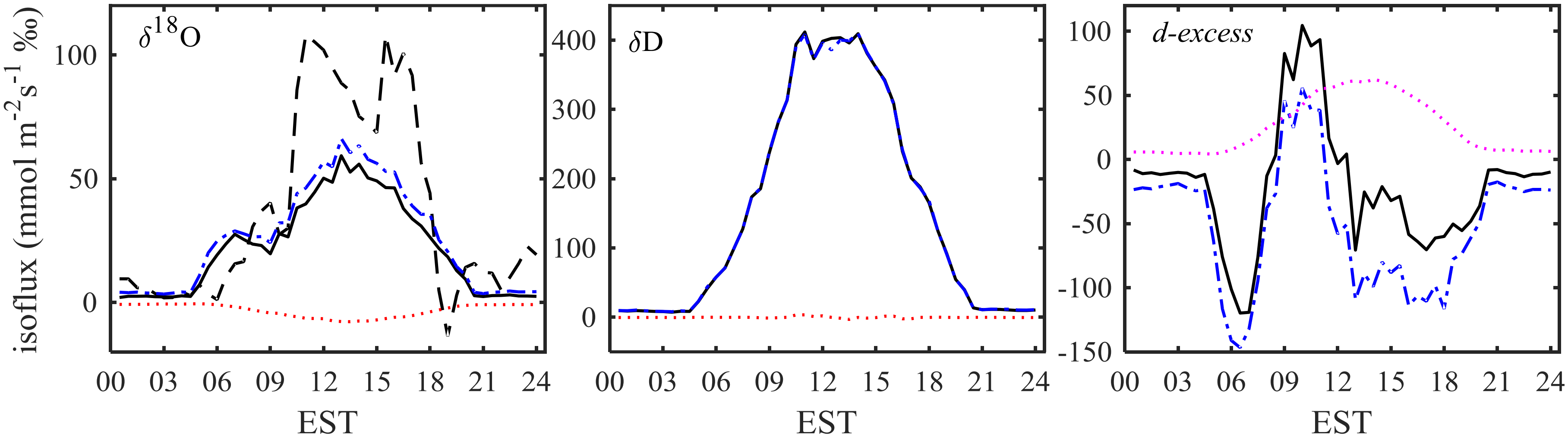






1. Soil E showed the large value of d-excess
2. Midday flux weight mean d_{ET} showed highly significate relationship with F_{ET} (R=0.47, P<0.001), and the relationship between d_E and F_E is R=0.29, P<0.01.

4.3 Isoforcing of *d-excess*



1. The maximum d_{ET}-isoflux is 104.5 mmol m^{-2} s^{-1} ‰ at 10:00; and maximum d_{E}-isoflux is 62.5 mmol m^{-2} s^{-1} ‰ at 14:00.

2. The transpiration will enrich atmospheric vapor isotopes, while soil evaporation seems to deplete.

3. Transpiration promote d_v increase on late morning but decrease d_v during midday, while soil evaporation will promote the increase of d_v during all the daytime.

4. The significant difference between d_{ET}-isoflux and d_{T}-isoflux during afternoon verifed our assumption that soil evaporation playa an important role in diurnal dv variability.

Summary

- The SiLSM2 model performed well in the simulation of F_{ET}, F_E, δ_L and δ_{ET}, and compared with SiLSM model, there is a necessary to consider the soil evaporation in forest ecosystem.
- Midday d_v showed a significant relationship with w, RH, F_{ET}, F_E and plat boundary layer height; Midday d_{ET} and d_E showed a significant relationship with F_{ET}, F_E.
- evapotranspiration decrease d_v during afternoon, while d_v at both over and under forest showed a increase during afternoon, indicate that other processes dominant this change, such as entrainment.

Thank you!