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The isotope composition of vapor and flux and the coupling of SW model and C-G model in a temperate forest

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Outline

Part 1

Background

Site and observation

Part 2

Isotopes distribution and environmental factor

Vapor isotopes: δ_v and d_v

Flux isotopes: δ_{ET}/ δ_E and d_{ET}/ d_E

Part 3

SW model & C-G model

Method

Partition of evapotranspiration

Calcutated δ_{ET} and δ_E

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Summary

Background

- The isotopic composition of atmospheric vapor is a good tracer for environmental change and vapor source, and has been used wildly in Ecology, hydrology, atmospheric chemistry and other research.

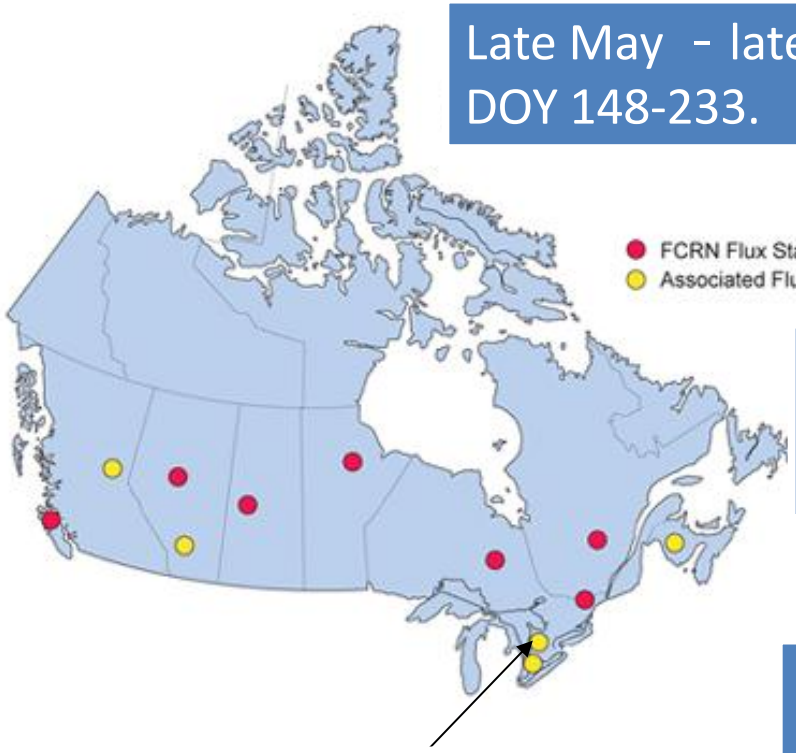
- There are many processes that could influence the isotopic composition of water vapor, including canopy transpiration and the evaporation, while the contribution of E & T to vapor isotopes and it's isotopic composition has not been presented clearly until now.

- C-G model has already been proofed that it could perfectly simulated the isotopic composition of evaporation in open water(eg. Lake); while the application on terrestrial ecosystem is more complex and lack of comparation between simulated with observed value.

- The coupling of SW model and C-G model could help to calculate the isotopic composition of soil evaporation and canopy transpiration in steady state.

Site and observation

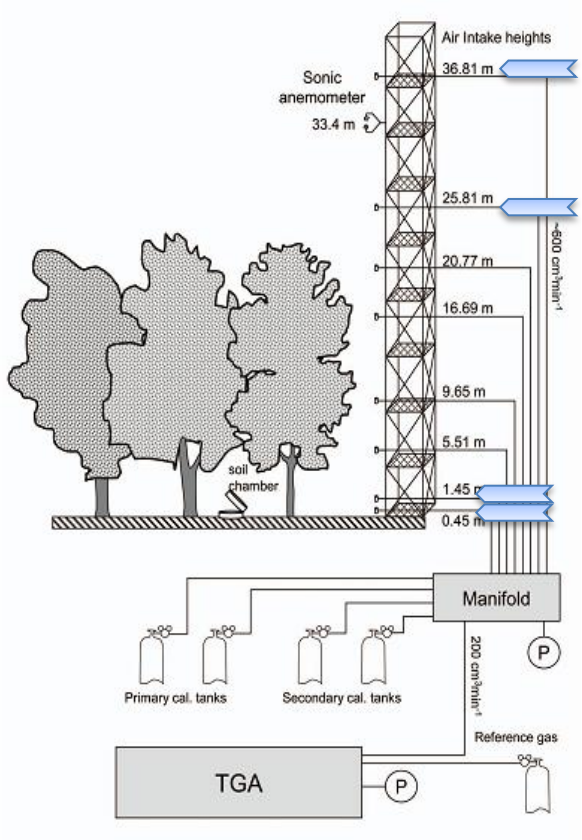
Late May - late August.
DOY 148-233.



Stand height:
22m
100 years old

Red maple,
Aspen, white ash

Environment Canada's Borden Forest Research Station



(Santos et al., 2012)

Figure 1. The site location and experiment setup.

R: heavier isotoper/lighter isotoper

$\delta^{18}O$ and δD of H_2O (‰):

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

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

Flux isotope ratio

$$R_{\text{ET}} = R_{\text{d}} \frac{x_2^{16} - x_1^{16}}{x_2^{18} - x_1^{18}} \times \frac{x_3^{18} - x_4^{18}}{x_3^{16} - x_4^{16}}$$

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2.1 The vapor isotope and environmental factors

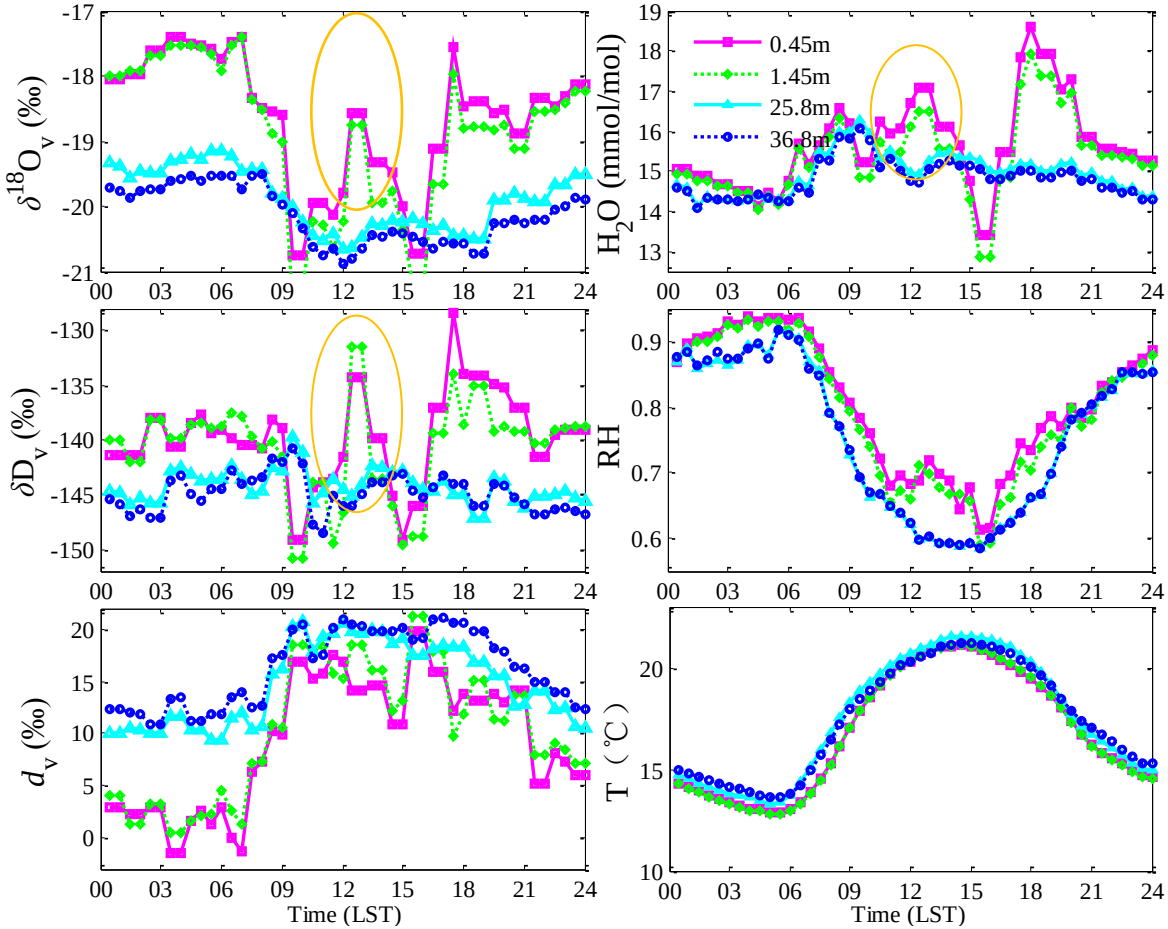

Figure 2. Mean diurnal cycles from May-August of vapor isotopes and main meterological factors.

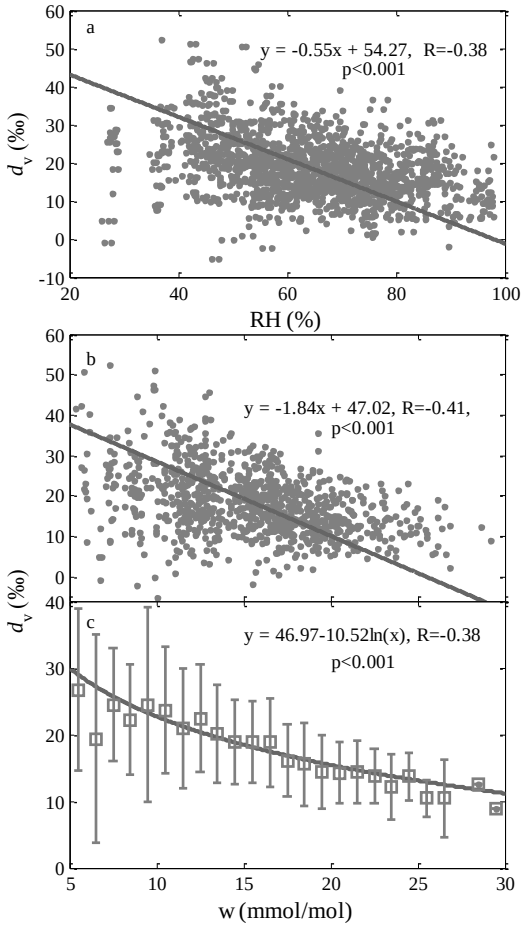

Figure 3. The relationship between d_v and (a) RH, (b) vapor mixing ratio w.

Table 1. Linear correlation between afternoon value of d_v and enviromental factors during May-August

		Mean value				Half hourly			
		m	b	R	P	m	b	R	P
Above C	w (mmol/mol)	**-1.24**	**38.15**	**-0.55**	**<0.01**	-1.88	47.84	-0.39	<0.01
Under C		**-1.04**	**33.76**	**-0.66**	**<0.01**	**-1.58**	**41.4**	**-0.42**	**<0.01**
All		**-1.21**	**37.37**	**-0.61**	**<0.01**	-1.84	47.02	-0.41	<0.01
Above C	RH_s (%)	**-0.36**	**42.13**	**-0.51**	**<0.01**	-0.55	54.33	-0.33	<0.01
Under C		**-0.39**	**43.20**	**-0.67**	**<0.01**	**-0.54**	**53.29**	**-0.47**	**<0.01**
All		**-0.37**	**42.71**	**-0.57**	**<0.01**	-0.55	54.27	-0.38	<0.01
Above C	*F*t/*F*e (mmol/m^2 s)	2.51	8.48	0.2	0.02	3.46	4.53	0.11	<0.01
Under C		392.25	5.89	0.33	0.04	589.68	2.56	0.22	<0.01
All		2.14	11.37	0.32	<0.01	3.08	7.61	0.2	<0.01
Above C	Tsc (℃)	-1.29	45.29	-0.11	0.21	-1.94	58.67	-0.11	<0.01
Under C		-1.45	44.64	-0.21	0.19	-2.01	53.72	-0.07	0.23
All		-1.39	46.34	-0.13	0.10	-2.03	60.01	-0.07	<0.01

3.2 The flux isotope and meteorological factors

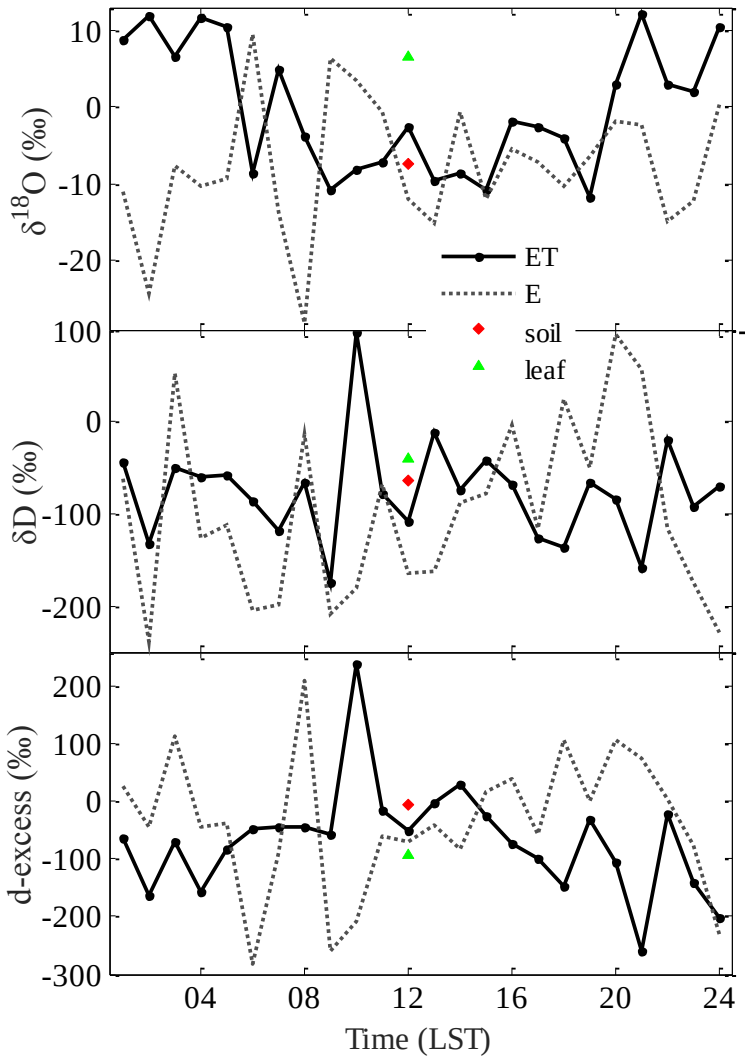

Table 2. Linear correlation between afternoon means of d_{ET} and meteorological factors during May-August

		12:00-18:00 mean			
		m	b	R	P
d_{ET}	RH_s (%)	**22.3**	**-1440**	**0.32**	**0.01**
d_E		\	\	\	\
d_{ET}	Tsc (℃)	**-79.6**	**1720**	**-0.30**	**0.02**
d_E		\	\	\	\

Figure 4. Mean diurnal cycles of isotopic flux ratios in the temperate forest.

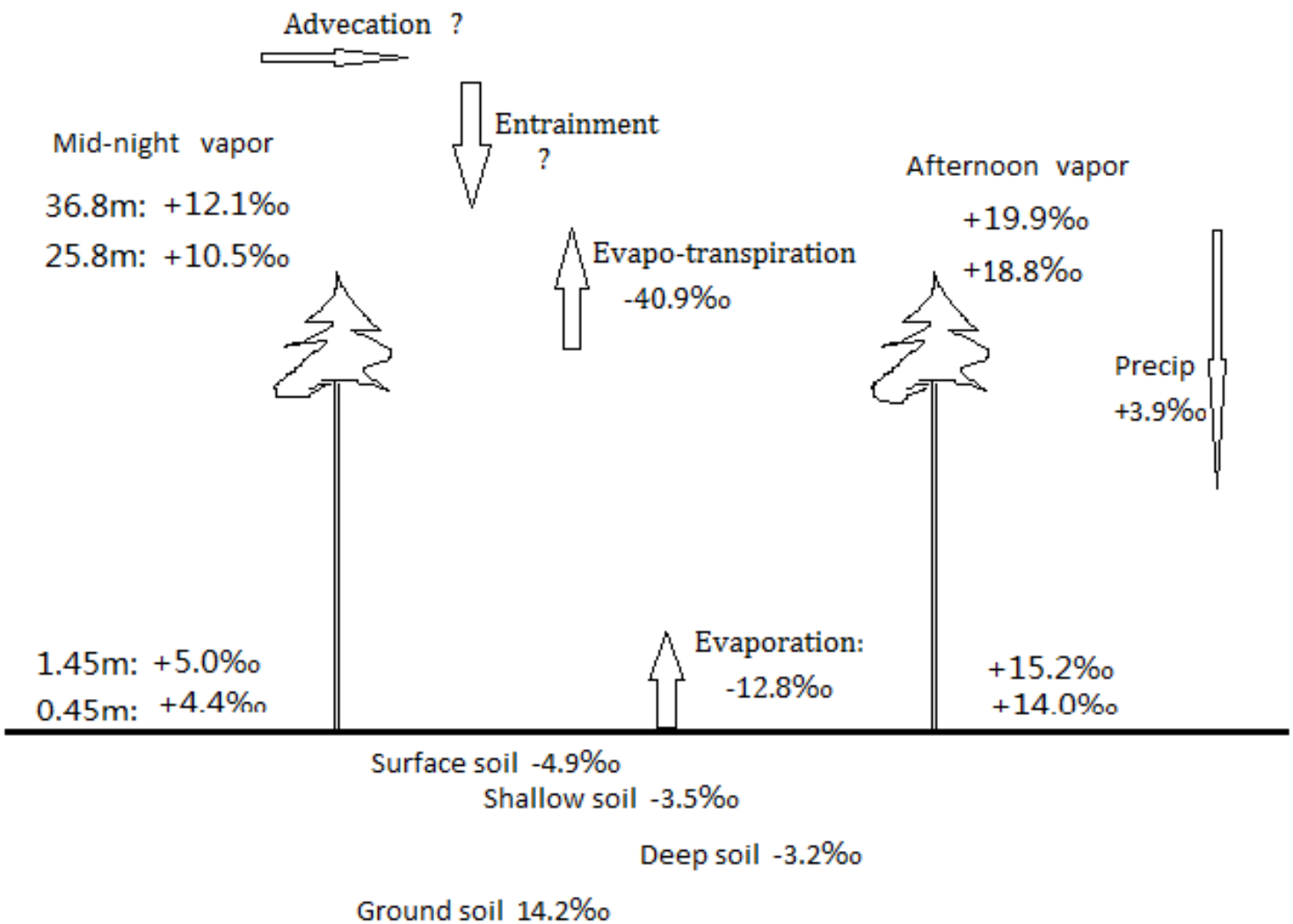

Figure 5. Schematic representation of the major processes and the *d* in these processes

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3.1 Method

T_a, T_{sk}, RH, VPD, u, C_s, Sm, R_n, G, PAR_i, GPP, S…

SW MODEL

$$r_{ss} = b_1 \times (\theta_s / \theta)^{b_2} + b_3$$

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

$$f(\theta) = \frac{\theta - \theta_w}{\theta_f - \theta_w}$$

r_a r_{ac} r_{as}

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

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

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

$$C_c = \frac{1}{1 + \rho_a \rho_c / [\rho_s(\rho_a + \rho_c)]}$$

$$C_s = \frac{1}{1 + \rho_a \rho_s / [\rho_c(\rho_a + \rho_s)]}$$

r_a r_{ac} r_{as} r_{sc} r_{ss}

ET F_t F_e

C-G MODEL

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

$$\alpha_{eq} = f(T_{sk}) \qquad \varepsilon_{eq} = (1 - 1/\alpha_{eq}) * 1000\ (‰)$$

$$\varepsilon^0_{k,s} = \frac{32 r_{ss}}{r_a + r_{as} + r_{ss}}$$

$$\varepsilon^0_{k,c} = \frac{21 r_{ac} + 32 r_c}{r_a + r_{ac} + r_c}$$

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).

3.2 Partition of evapotranspiration

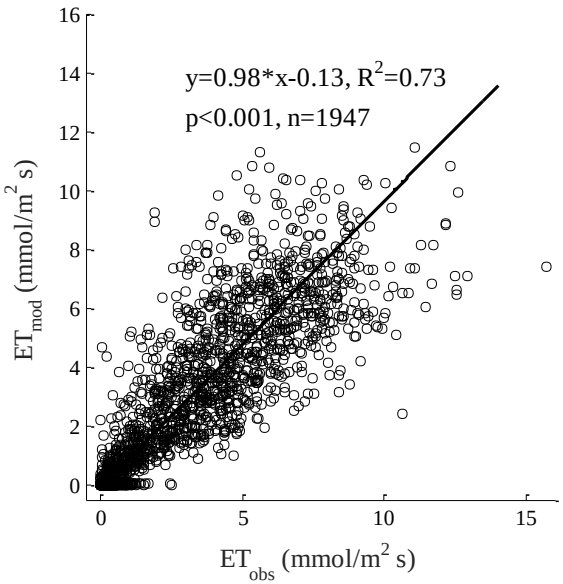


Figure 6. ET simulation on 30- min scale.

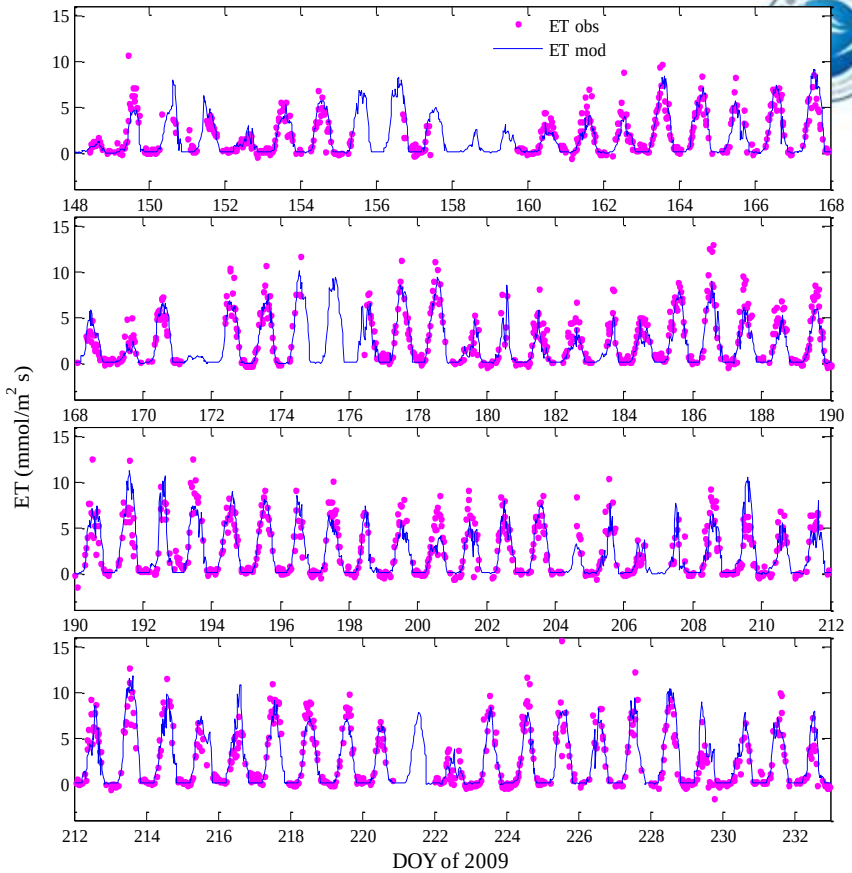
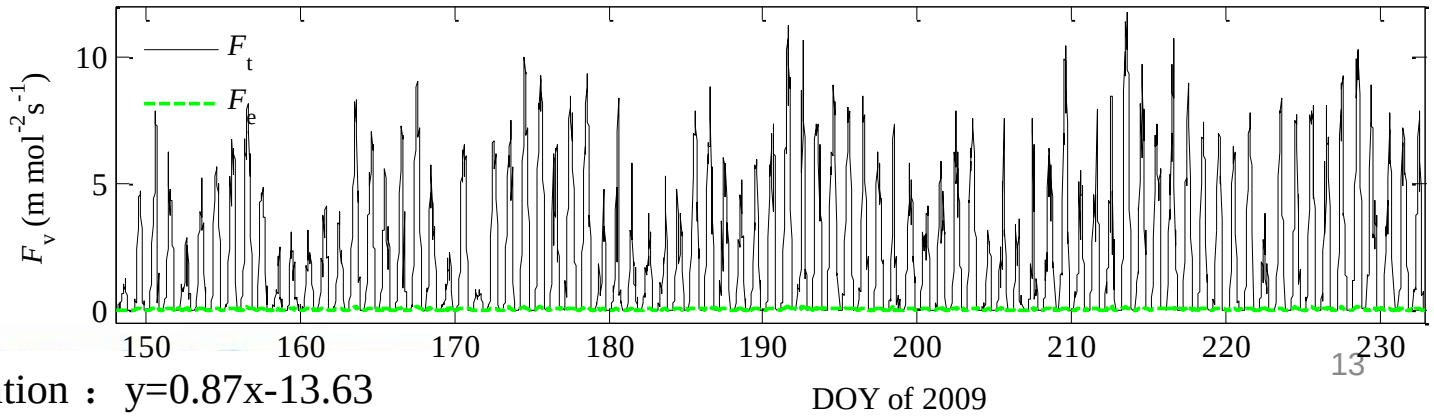


Figure 7. Time series of ET measurements (dots) and simulation (line).

Figure 8. Time series of ET components.



The energy closure equation： y=0.87x-13.63

3.3 Simulated δ_E

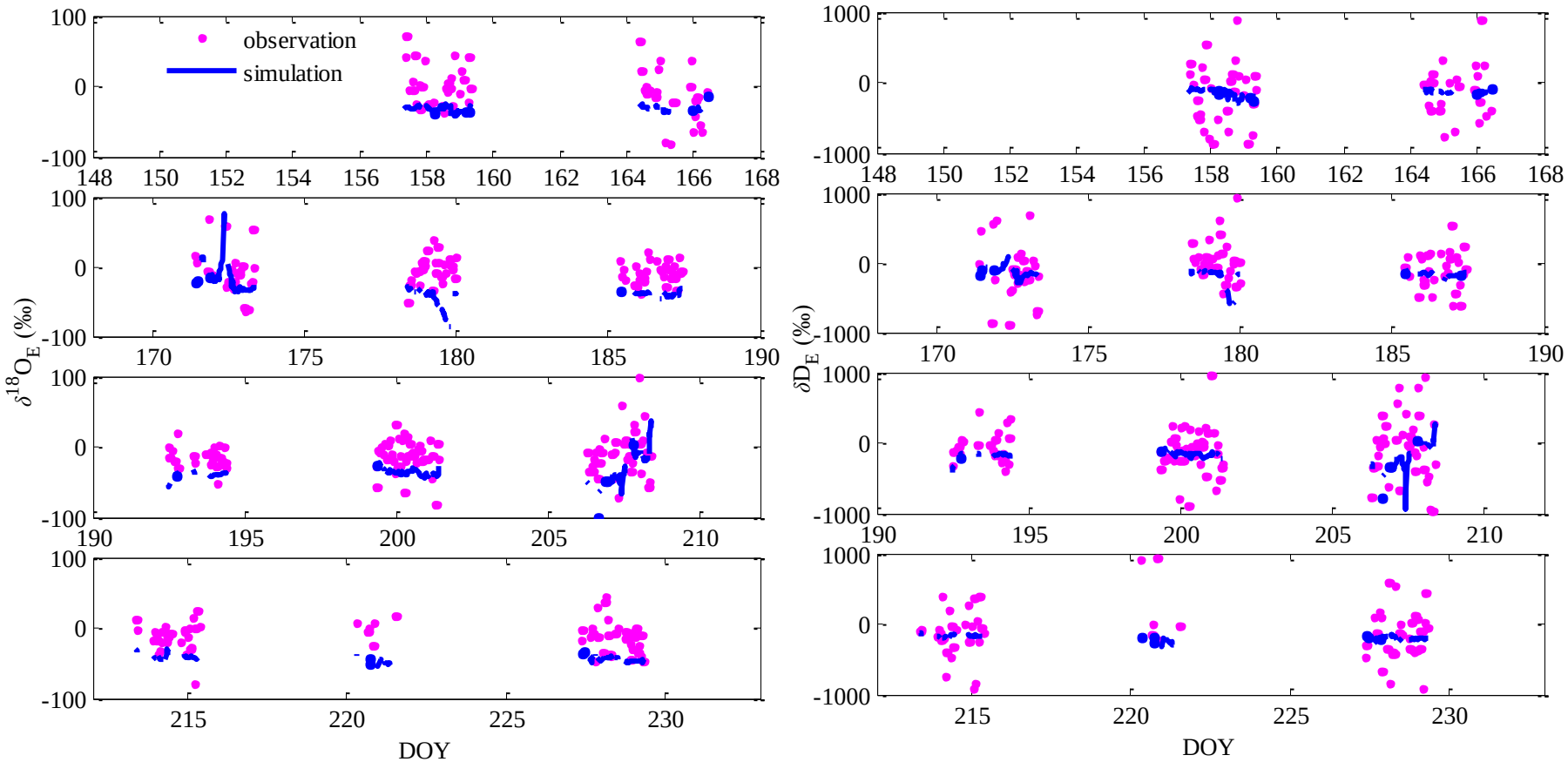


Figure 9. Time series of $\delta^{18}O_E$ and δD_E measurements (dots) and simulation (line) by C-G model.

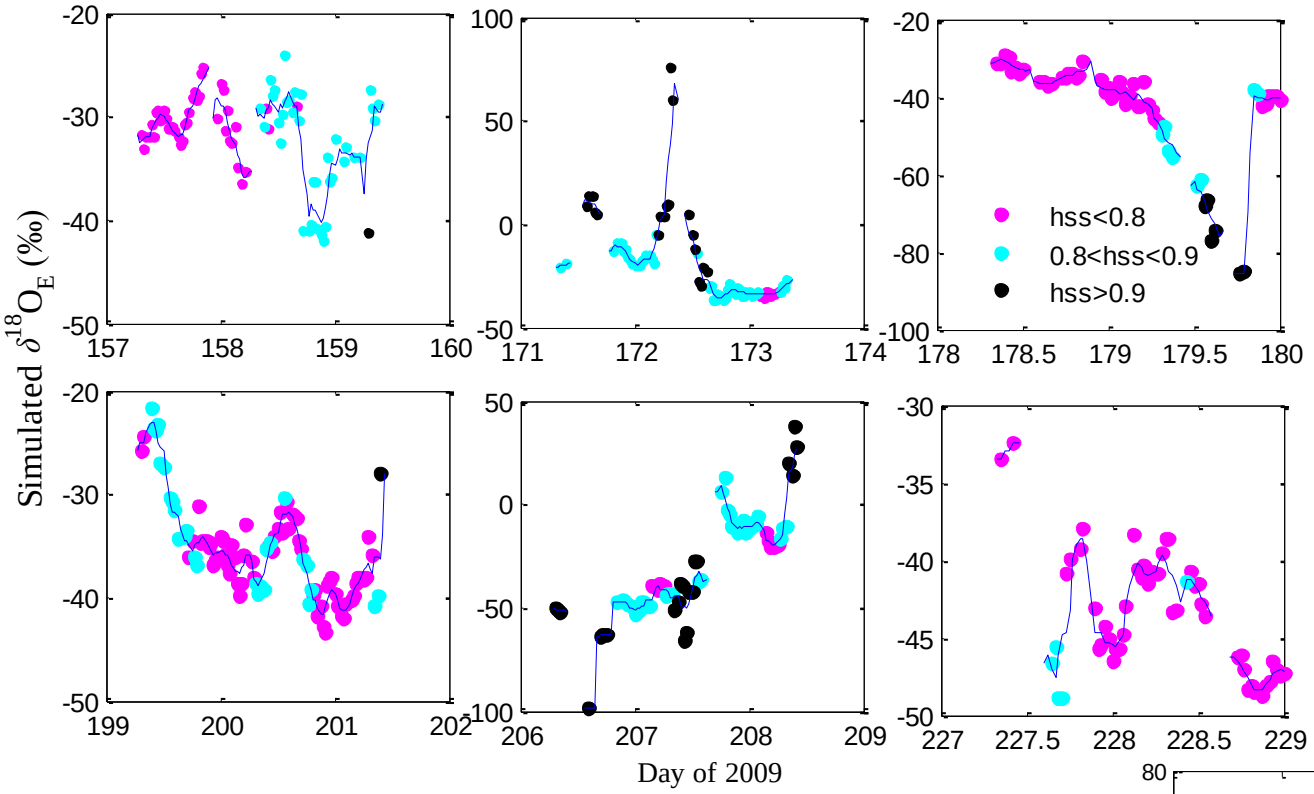


Figure 10. Time series of simulated $\delta^{18}O_E$ by C-G model in the temperate forest.

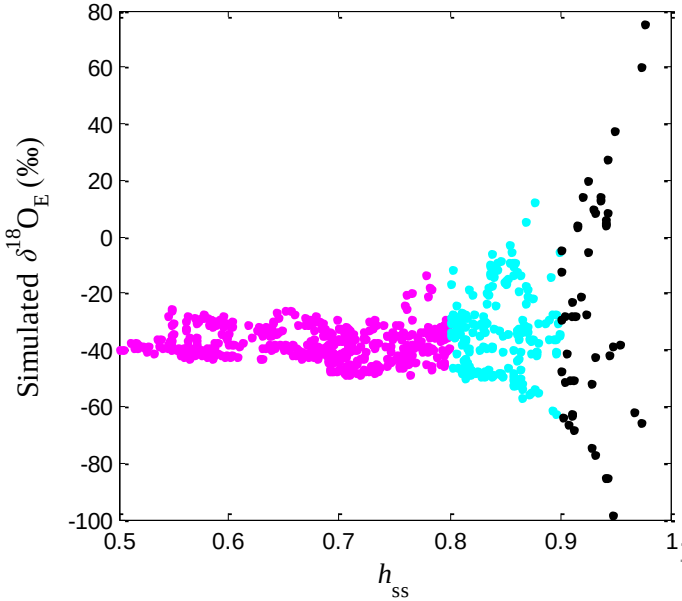


Figure 11. Effect of relative humidity (h_{ss}) on soil evaporation $\delta^{18}O_E$ in the temperate forest.

Simulated δ_{ET}

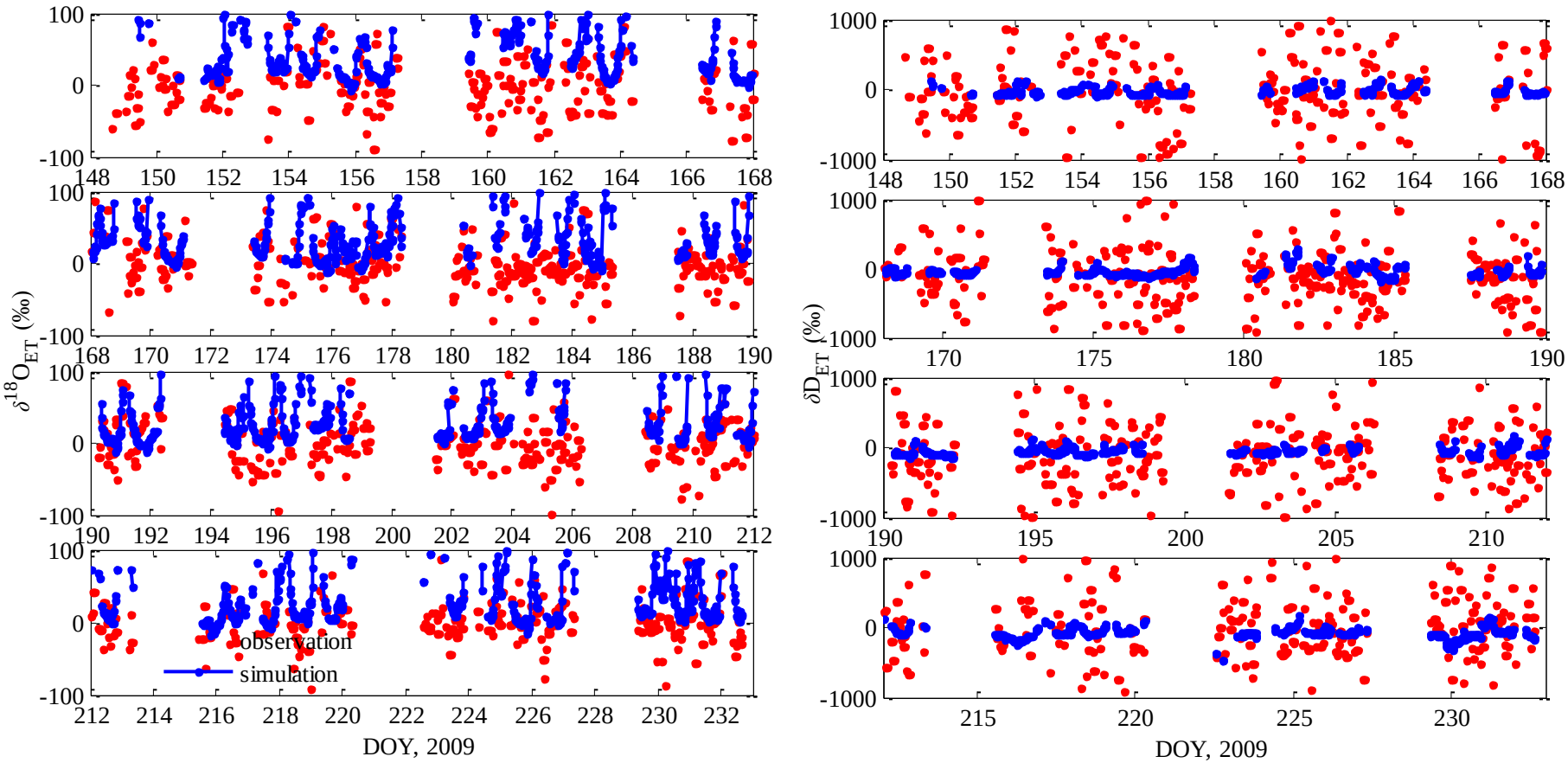


Figure 12. Time series of $\delta^{18}O_{ET}$ and δD_{ET} measurements (dots) and simulation (line) by C-G model in the temperate forest.

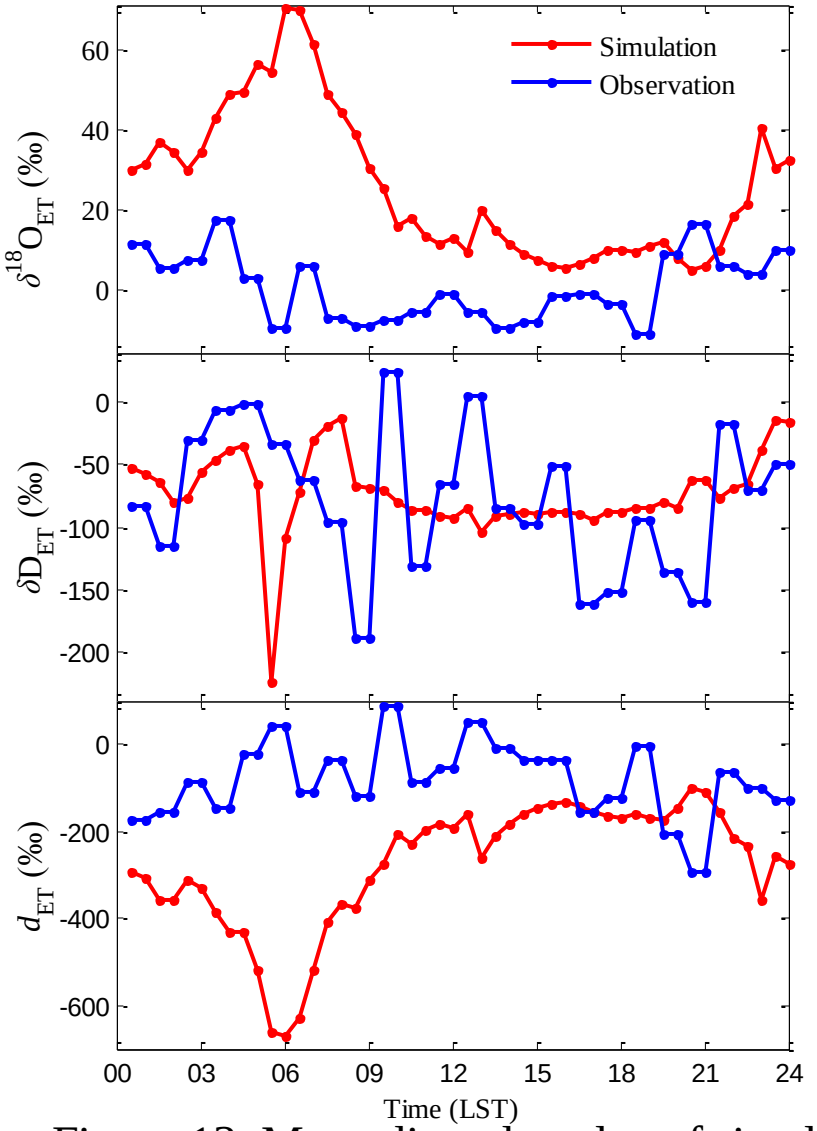


Figure 13. Mean diurnal cycles of simulated isotopic flux ratios in the temperate forest.

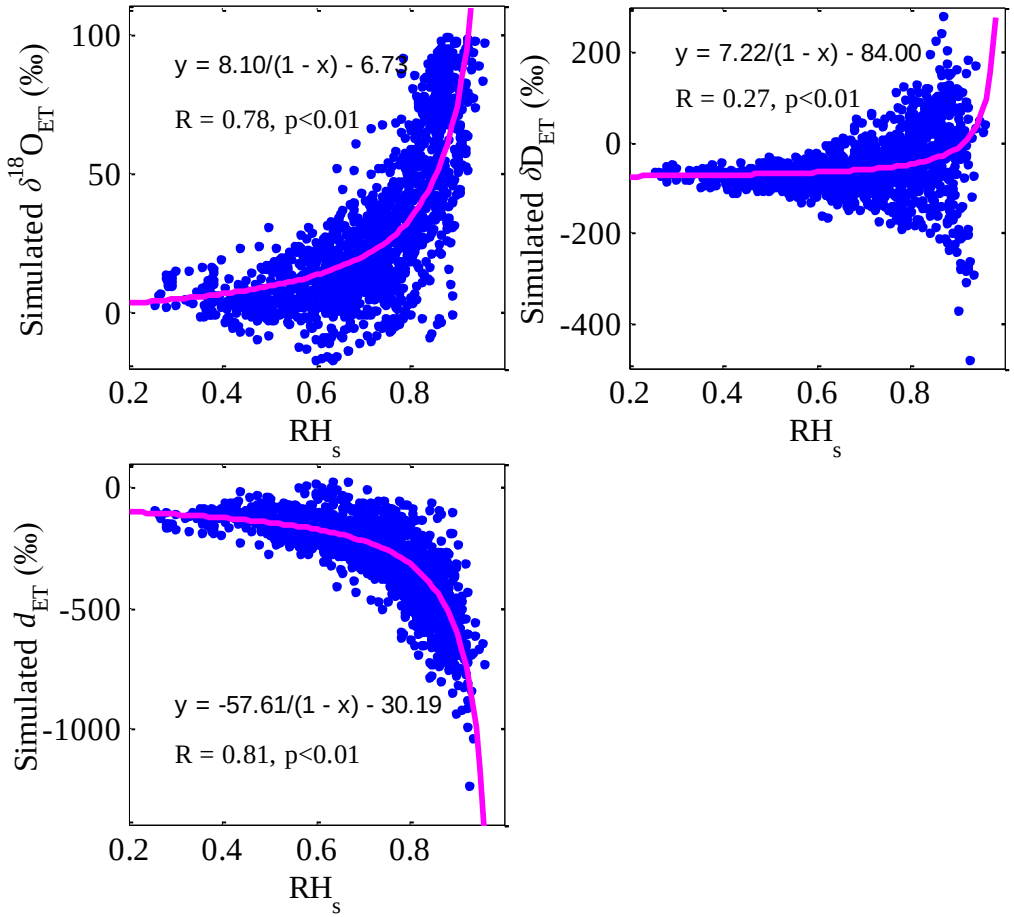


Figure 14. Effect of relative humidity (RH_s) on canopy transpiration $\delta^{18}O_{ET}$ /δD_{ET} and d_{ET} in the temperate forest.

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1. $\delta^{18}O_v$ and δD_v near the ground in this forest present a 'W' diurnal distribution while a 'U' type for $\delta^{18}O_v$ over canopywith a light rise up during afternoon.

2. The water vapor content in atomosphere is the main factor that driven δ_v and d_v variation, which could been proved by the mean diurnal cycle and linear correlation of RH and vapor mixing ratio.

3. Observaed $\delta^{18}O_{ET}$ showed a two peak partten in daytime, in which time the δD_{ET} and d_{ET} decreased gragually, there is no obvious variation for isotope of evaporation.

4. The SW model is well played on the simulation of ET, but the F_e/F_{et} is almost zero in this study.

5. C-G model simulated poorly in this study, both for δ_{ET} and δ_E, a mean reason is RH, which bias much as greater than 90%.

Thank you for your attention!