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Deuterium excess of water pools and fluxes in a deciduous forest in Canada

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Outline

- ✓ Background
- ✓ Objectives
- Experimental methods
- Results
  - water pools isotope ratio
  - vapor isotope ratio
  - flux isotope ratio
- Summary
- Next work

Background

- The study of stable water isotope ratio($^{18}O/^{16}O$, D/H) can provide us many additional information which is important for different scales of hydrological cycles . (Lai et al., 2011)

- Many studies about in situ observation of water vapor isotope, focused on either ^{18}O or D, have conducted without fully discovering the information those isotope tracer have contained. While D-excess, the combination of ^{18}O and D could take both equilibrium fractionation and kinetic fractionation into consideration.

- Variations in δD_v and $\delta^{18}O_v$ within forest canopies generally reflect the combined effect of several processes including atmospheric entrainment from the upper atmosphere, transpiration and the evaporation from the forest floor under fair weather conditions. (Welp et al., 2012)

- High temporal resolution measurements may provide us with new insights into the temporal dynamics of isotopes in the ecosystems. (Santos et al., 2012)

Objectives

- To investigate the temporal dynamics of ^{18}O/D and d-excess of water pools and flux in a temperate deciduous mixed forest.
- To investigate the vertical distribution of d-excess in the forest.
- To study the correlations between d-excess of evaportranspiration and environmental parameters.
- To evaluate the suitability of existing models (SiLSM, keeling plot) to estimate the variation of d-excess of E & T.

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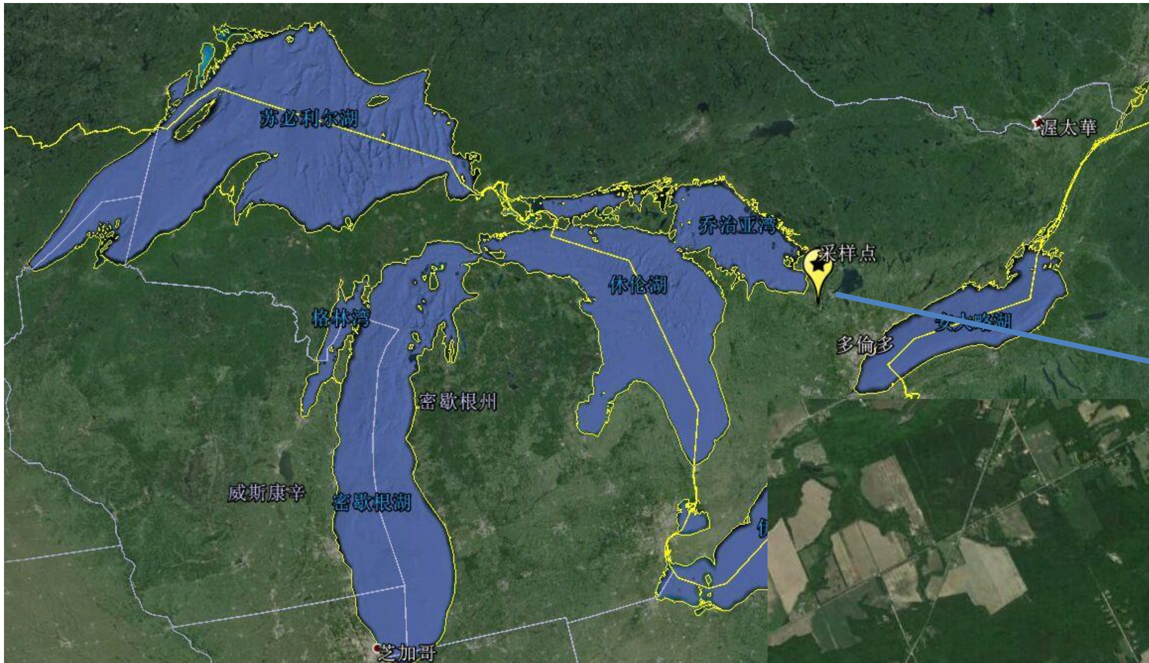
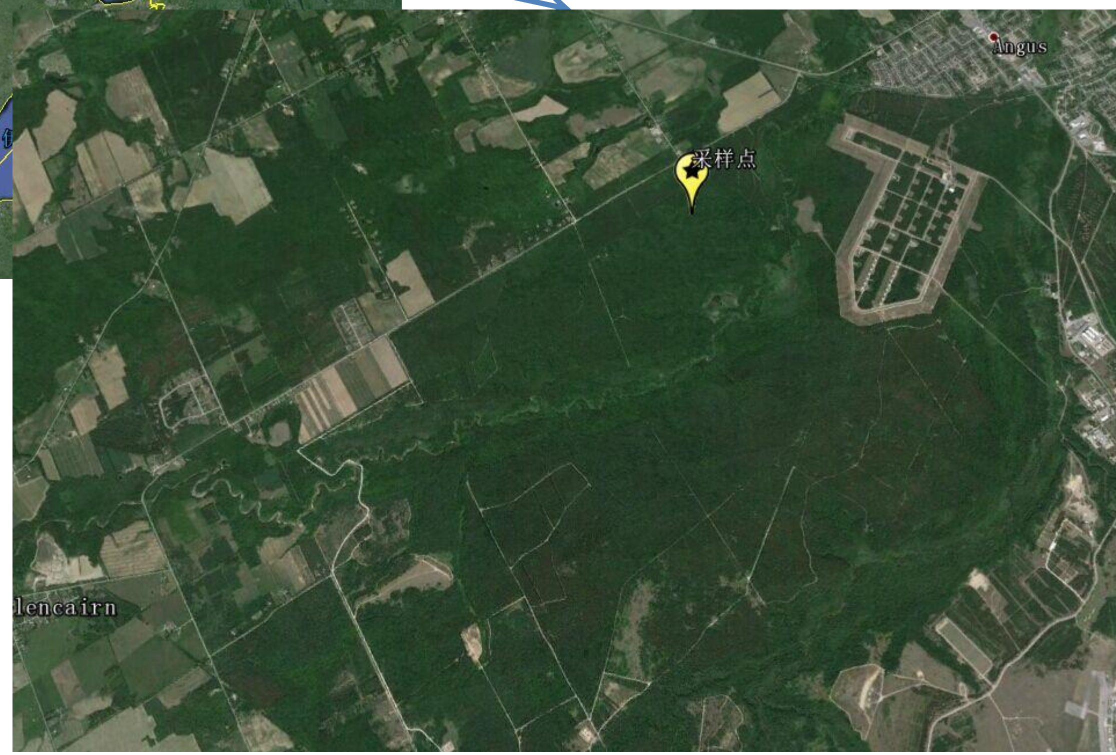
Experimental site

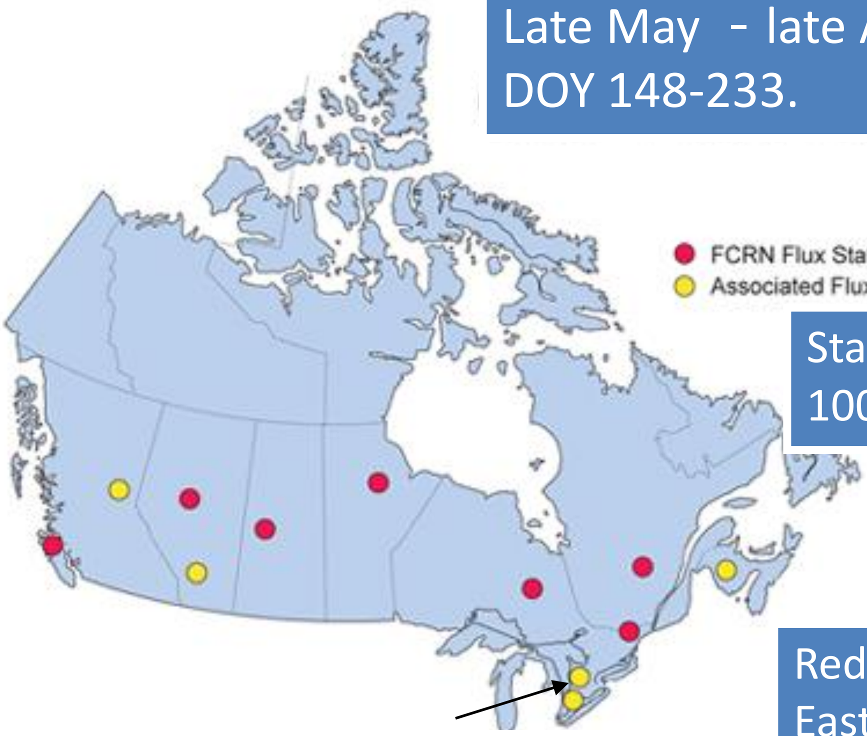


A mixed deciduous temperate forest on flat terrain in southern Ontario at the Environment Canada Research Station in Borden, ON, Canada (44°19′N, 79°56′W)



Site description

Late May - late August.
DOY 148-233.



Stand height: 22m
100 years old

Red maple,
Eastern white pine,
Aspen, white ash

Environment Canada's Borden Forest Research Station

1 km south : a 20-m deep and 40-m wide river
5 km northeast： a 6-km wide swamp

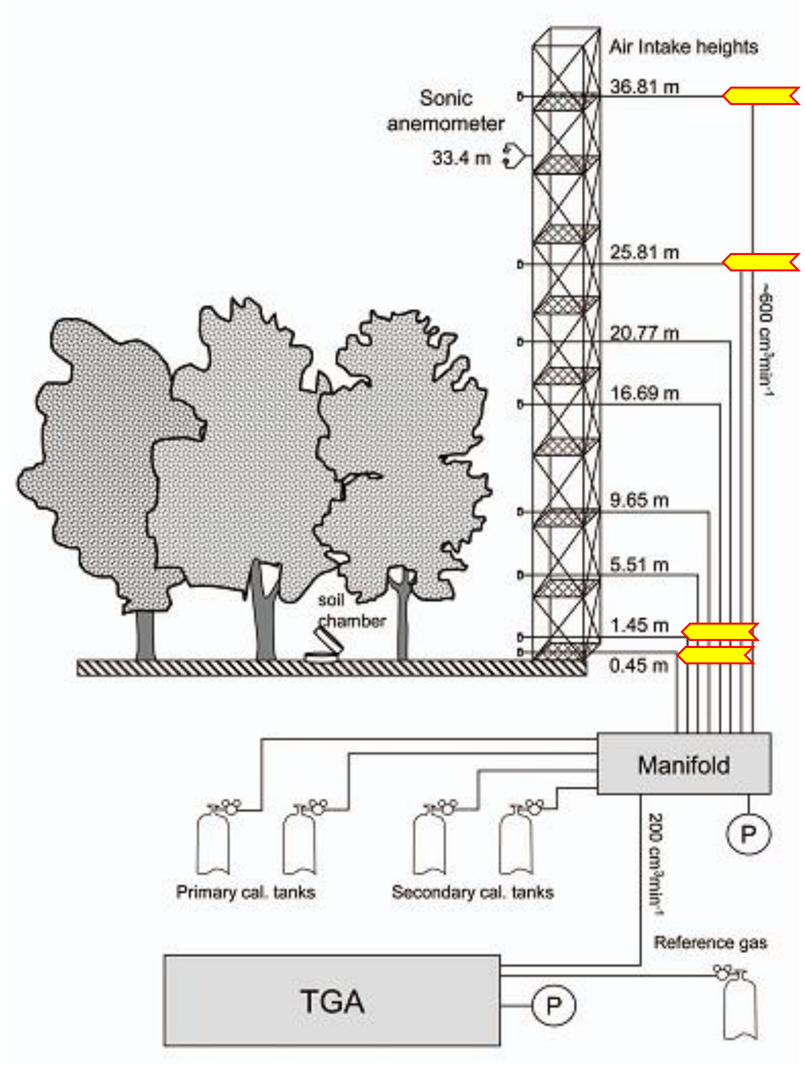
Isotope Measurements

Two air intakes:
week day: 25.8 m & 36.8 m
(above the canopy)
weekends: 0.45 m & 1.45 m
(close to the forest floor)

Sample manifold:

Each intake was measured for **15 s during 4 min.** At the end of each measurement cycle, **gas was sampled from calibration tanks during 1 min.**

Every week:
calibration of secondary standards using primary standards (NOAA-CMDL)



(Santos et al., 2012)

Isotope Measurements

Every 2–5 days : $H_2^{18}O$/HDO of leaf & twig water

Event based: $H_2^{18}O$/HDO of precipitation

Weekly: $H_2^{18}O$/HDO of Soil water measured at 5 cm, 10 cm, 50 cm.

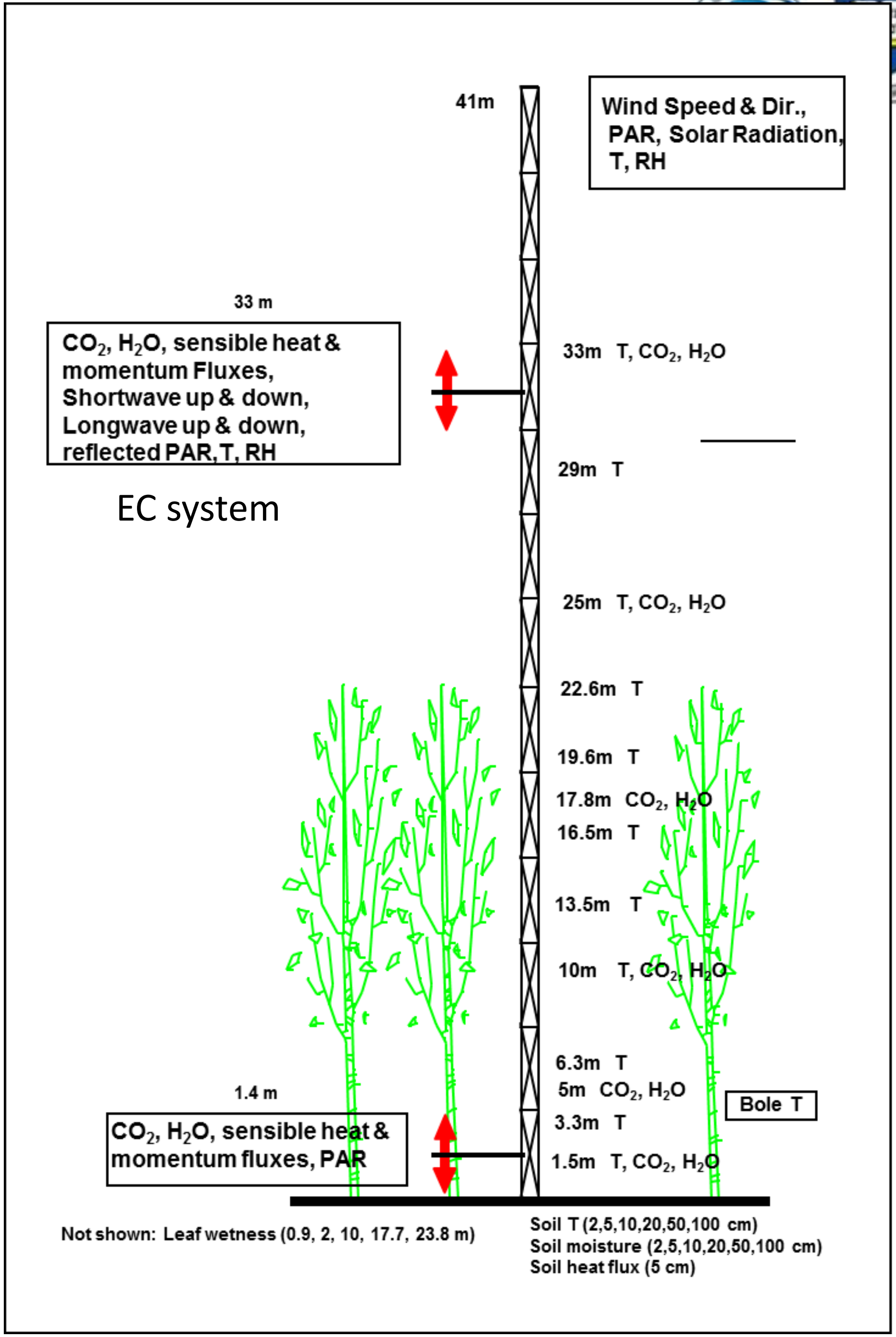
Meteorological variables

Soil T: 5, 10, 20, 50, 100 cm

Tree bole T: 2, 5, 9 m

Soil moisture: 2, 5, 10, 20, 50, 100 cm

Leaf wetness: 0, 5, 10, 18, 26, 33 m



Method

Flux isotope ratio

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

R: heavier isotoper/lighter isotoper

δ^{18}O and δD of H_2O (‰):

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

Useful data for flux:
exclude the periods of dew formation
(Gradient of water vapor > 200 ppm)
All data:
Wind direction: 90° – 255°

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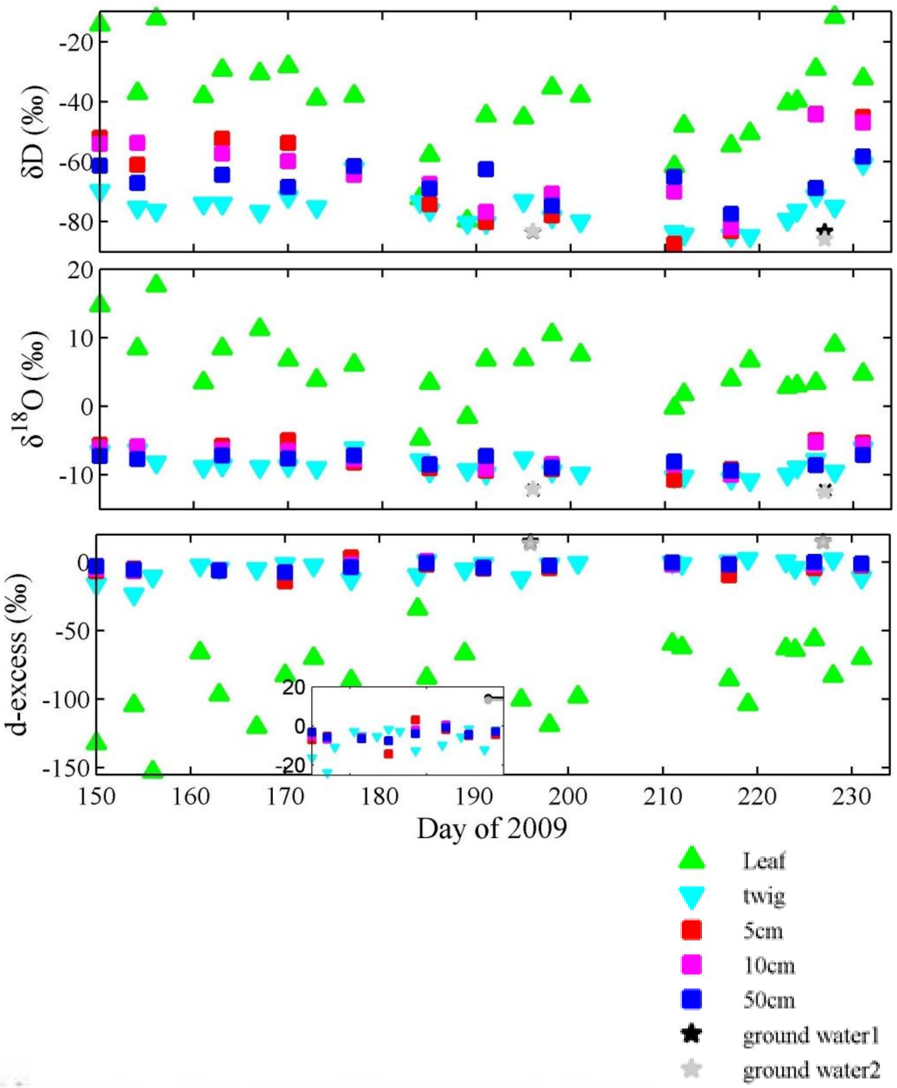
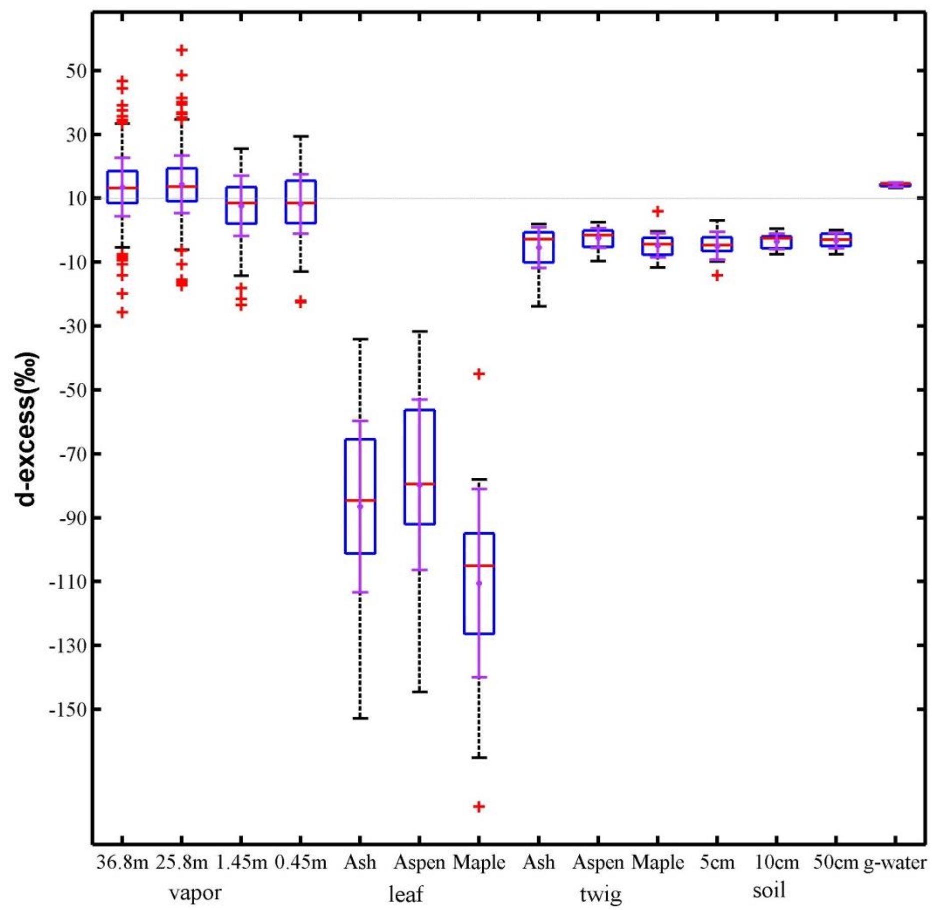
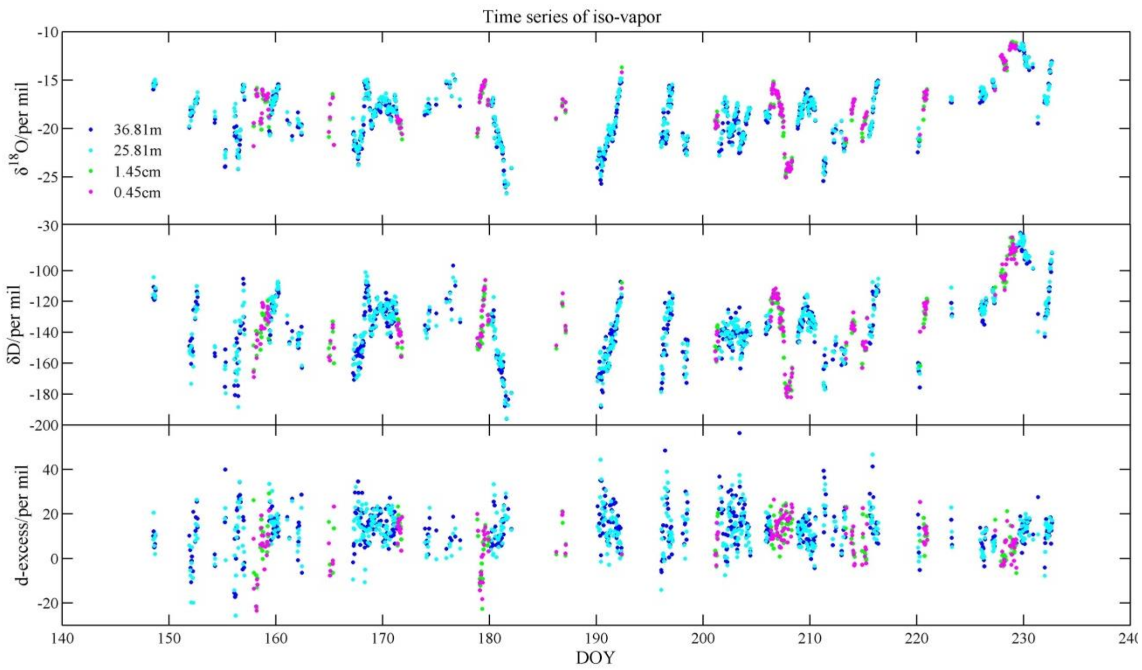
Vertical distribution of water pools isotope

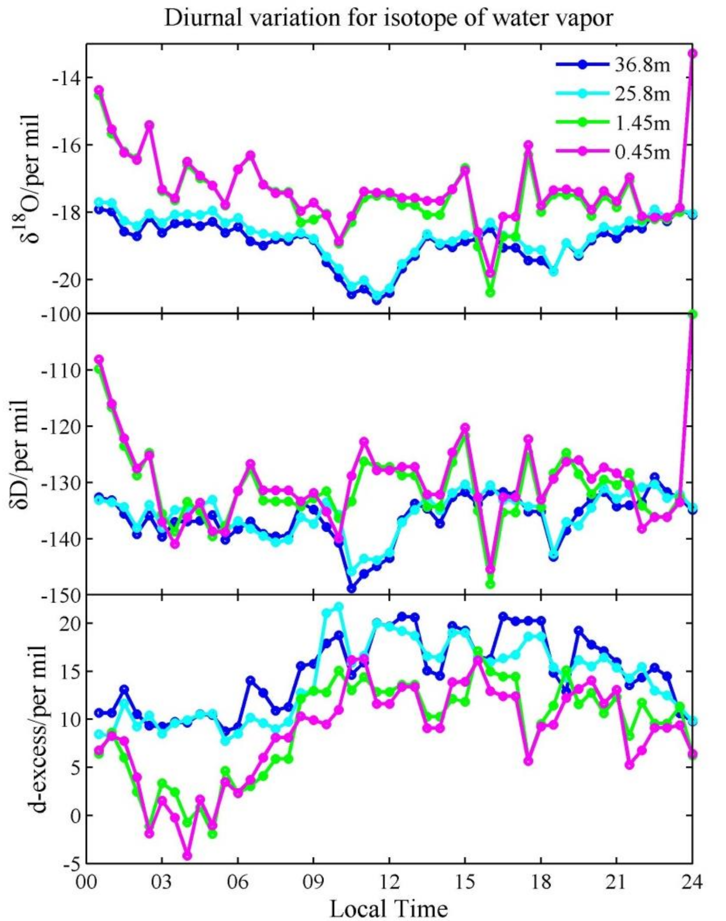
Isotope of leaf, twig of ash and different depth of soil



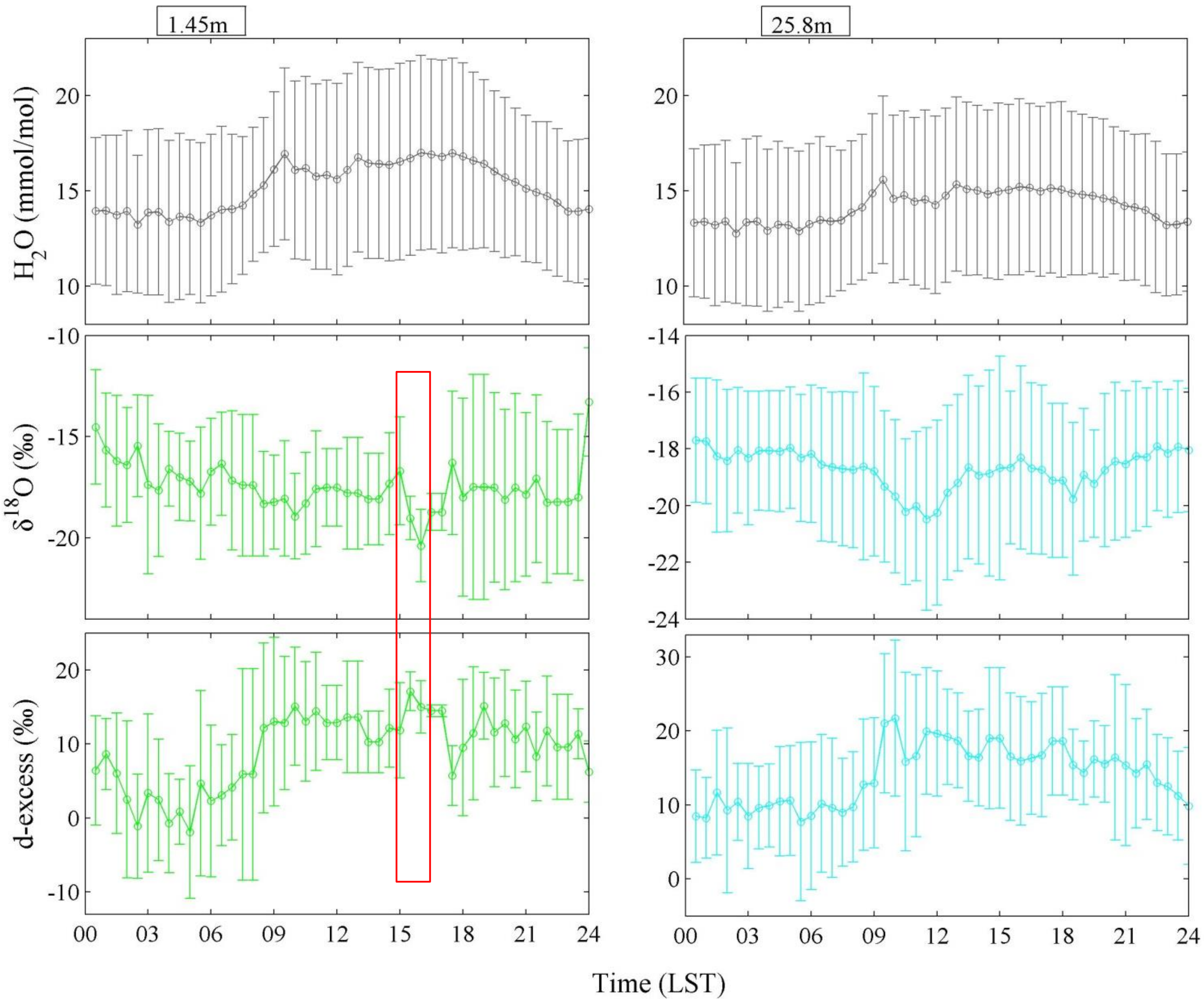


Temporal dynamics of vapor isotope ratio

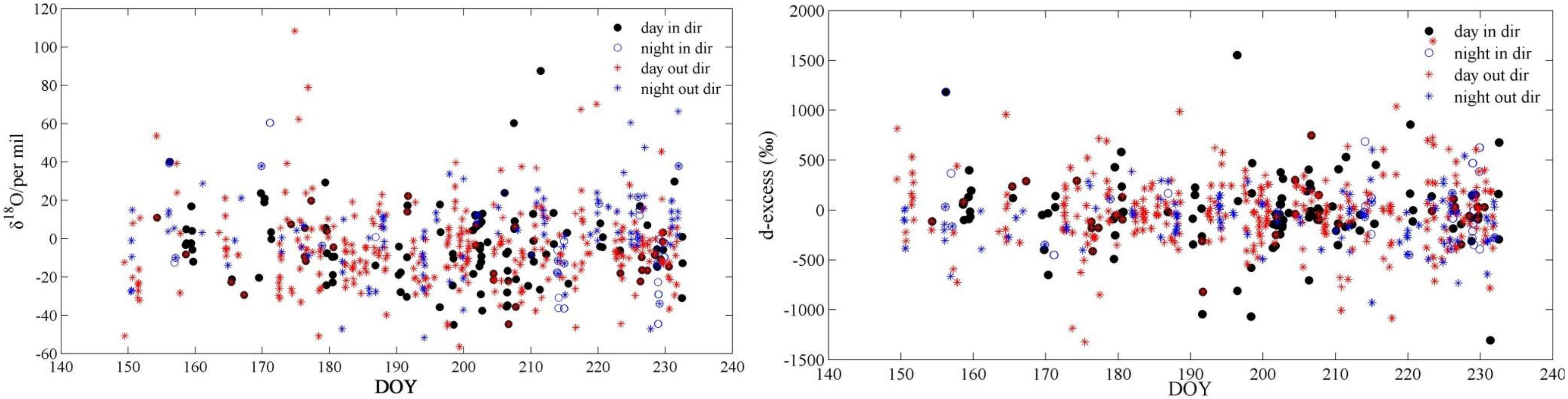


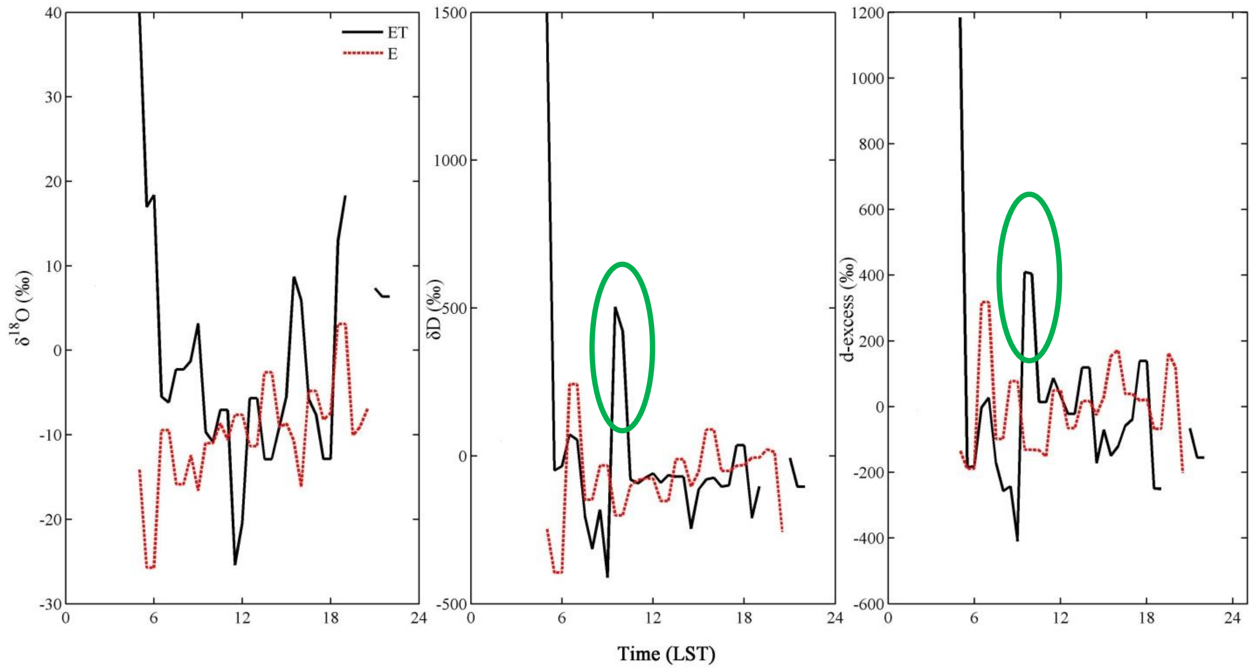


Half-hourly H_2O mixing ratio and isotopic ratio of vapor

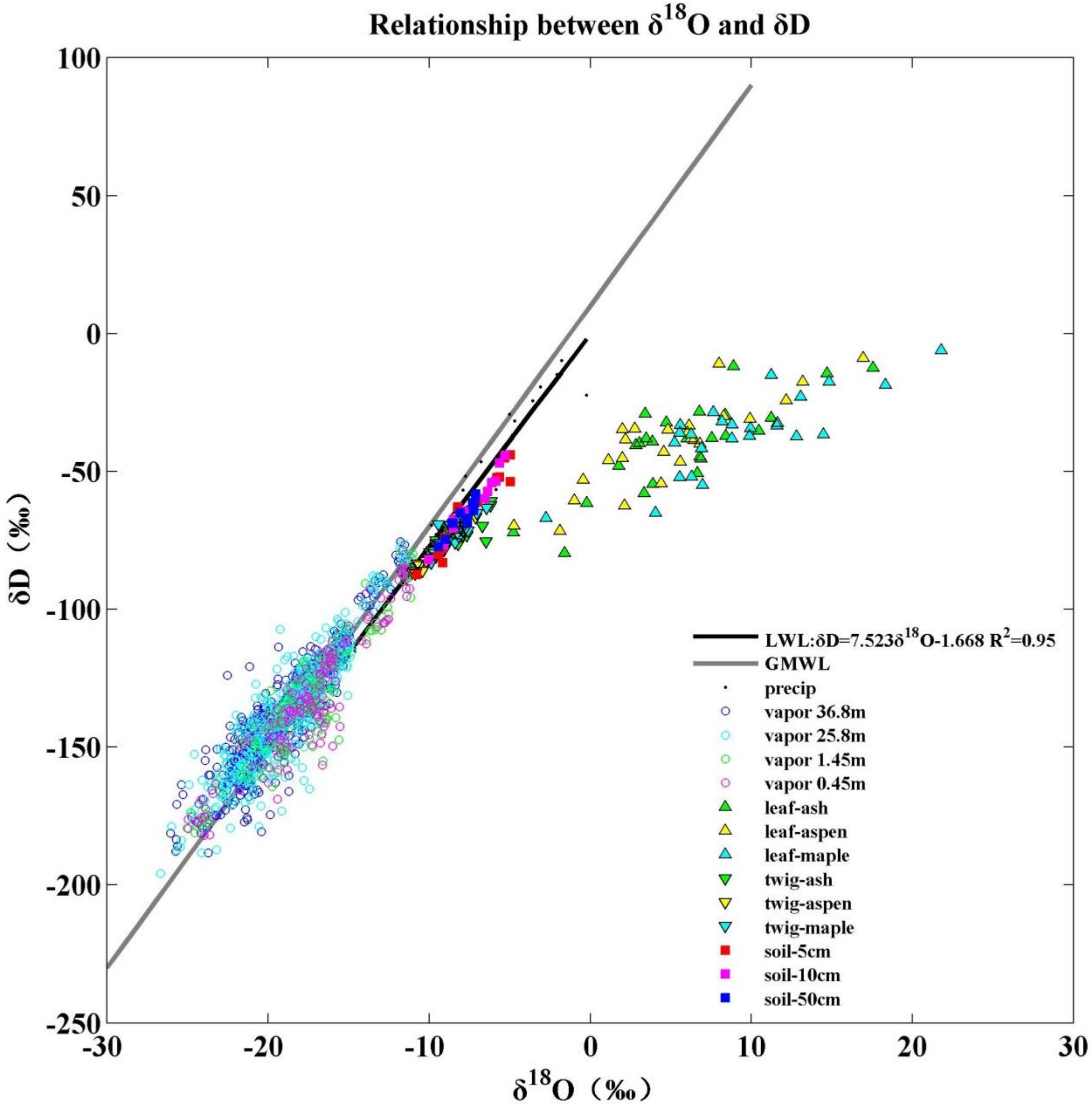


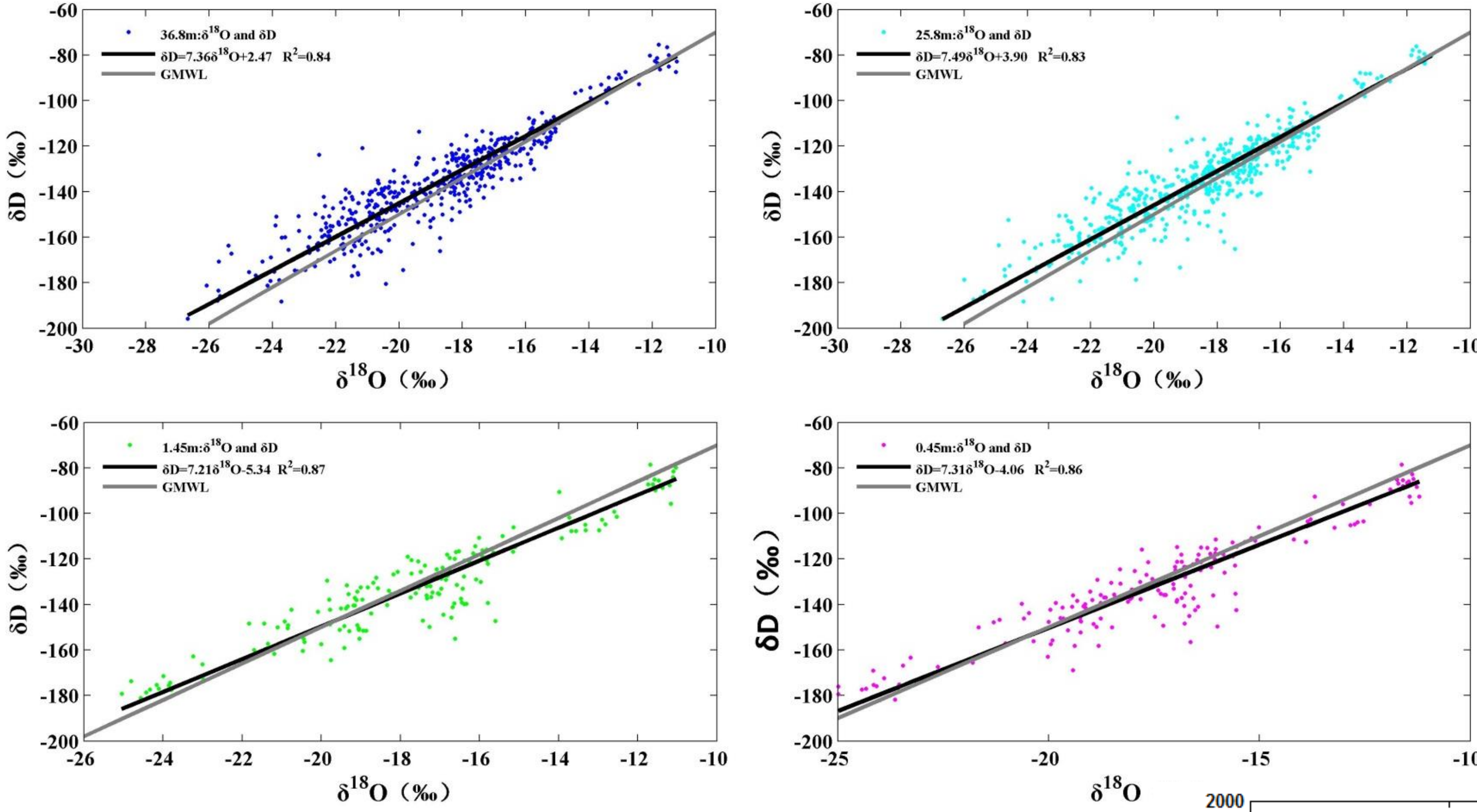
Temporal dynamics of flux isotope ratio



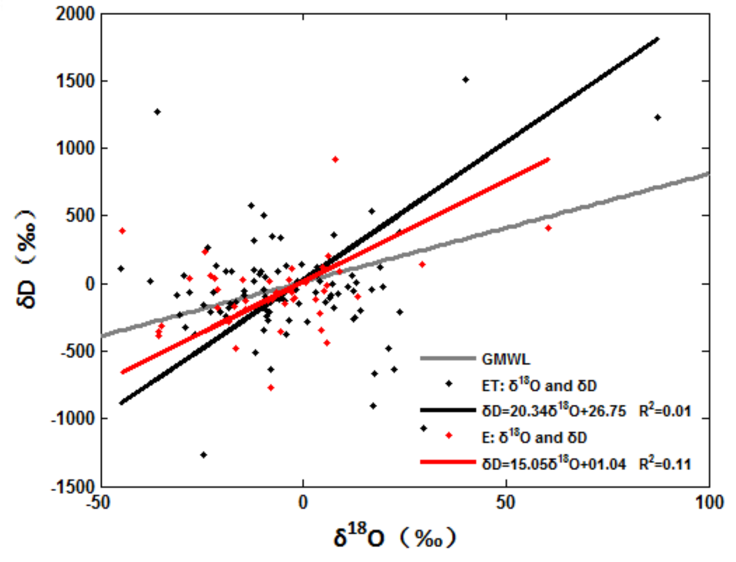


Relationship between $\delta^{18}O$ and δD





Relationship between δ^{18}O and δD for vapor and flux



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Summary

1. The mean value of d-excess in the mixing deciduous forest are 16.57‰，11.86 ‰ for vapor overstory and understory, respectively, and -26.31 ‰ and -21.02 ‰ for flux of ET and E.
2. For liquid water in forest ecosystem, leaf contained the lower d-excess than twig and soil water, which contrary the distribution of $\delta^{18}O$ and δD .
3. During our observational time, there is no obvious seasonal variation of $^{18}O/D$ and d-excess both for water pools, vapor and flux. While the diurnal variation existing clearly for vapor and flux.
4. D-excess showed a pattern of high values during afternoon in different heights of water vapor.
5. The vapor d-excess is positive with air temperature while negative with relative humidity. While the d-excess of flux showed no significant relationship with temperature and relative humidity.

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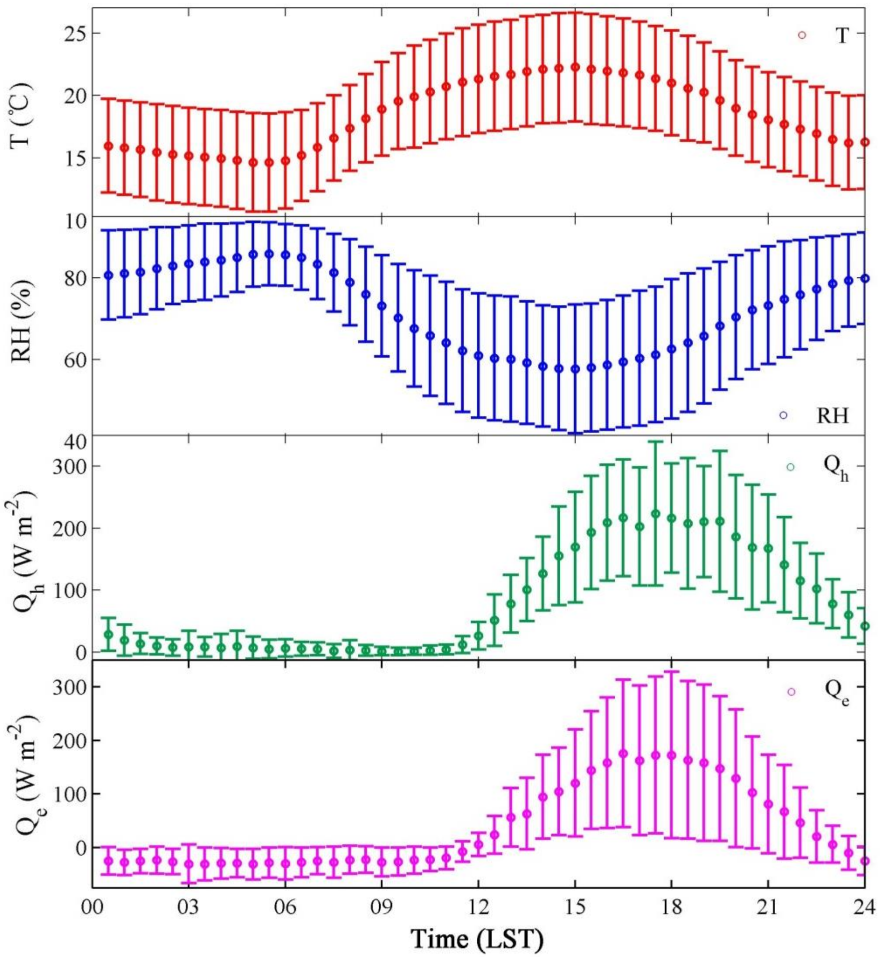
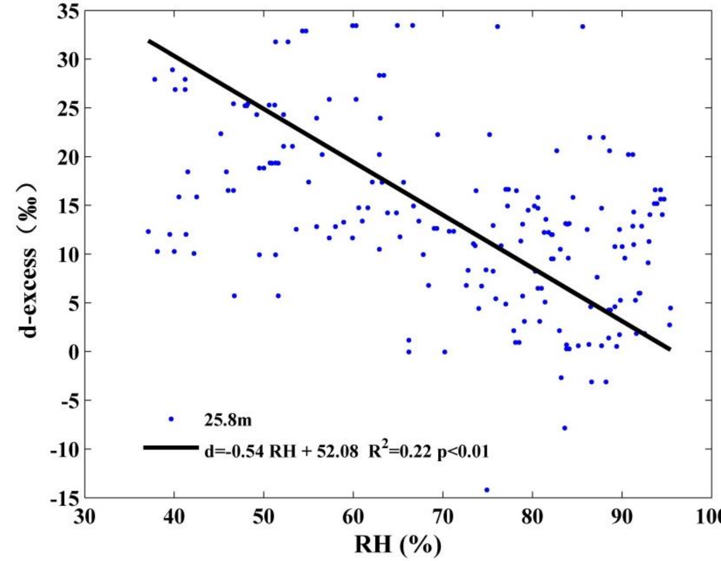
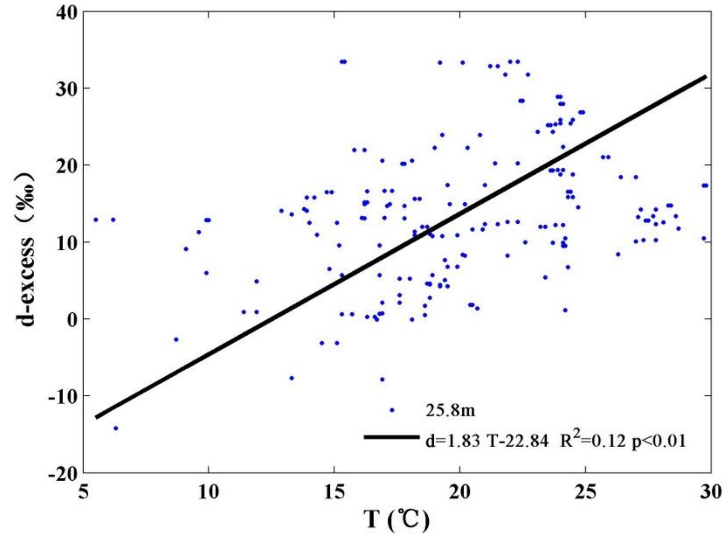
D-excess & meteorological factors





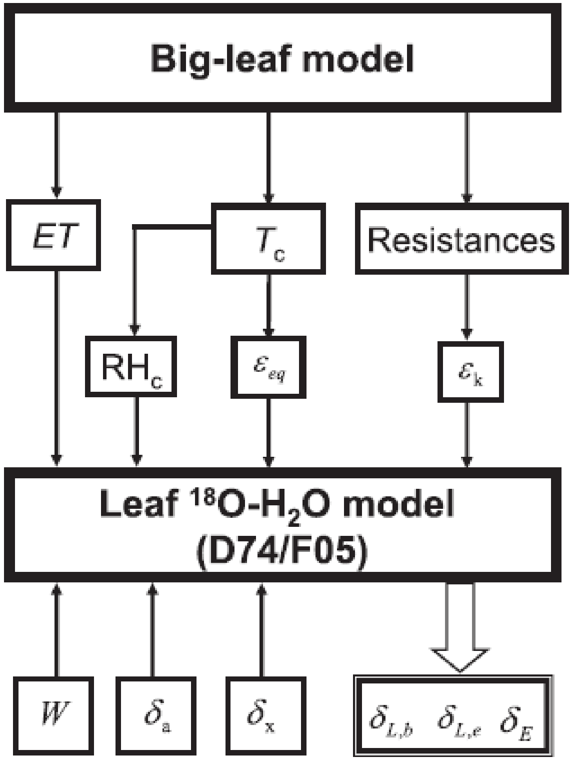


For flux d-excess, there is no significant relationships with air T and RH

Model

- Keeling plot: $\delta_s = \frac{(\delta_a - \delta_b)c_a}{c_s} + \delta_b$
- ^{18}O-H_2O submodel of SiLSM model (Xiao et al., 2012)

modified Shuttleworth-Wallace model
(shen et al.,2015)



Thanks