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

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2017.04.21
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

(Santos et al., 2012)
R: heavier isotoper/lighter isotoper

$\delta^{18}O$ and $\delta D$ 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

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

Isoforcing

$$w' \delta' = \frac{F_{ET}}{Ca} \left( \delta'_{ET} - \delta'_{a} \right)$$

Model simulation
3. SiLSM2 model description

\[ \lambda ET = E_c + E_s = C_c PM_c + C_s PM_s \]

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

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

\[ r_{sc} = \frac{1}{g_0 + a_1 f(\theta) P_h / C_s} \times \frac{1}{1.6} \]

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

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

\[ \delta_{ET} = (F_T \delta_T + F_E \delta_E) / F_{ET} \]

\( r_{ss} \) was estimated 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

$F_E$, $F_{ET}$, $\delta^{18}O_L$, $\delta D_L$, $\delta^{18}O_{ET}$
<table>
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<tr>
<th></th>
<th>SILSM2</th>
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<tr>
<td></td>
<td>CG_ISS</td>
<td>CG_NSS</td>
<td>DG</td>
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<tr>
<td>K</td>
<td>0.96**</td>
<td>0.74**</td>
<td>0.71*</td>
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<td>RMSD</td>
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<tr>
<td>ME</td>
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<td>-0.86</td>
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</tbody>
</table>
3.2 ET partitioning

![Graph showing ET partitioning with E/ET: 10%]
4. Discussion

4.1 $d_v$ variation and the main factors

1. There is no remarkable seasonal variation for $d_v$ during the growing season.
2. $d_v$ 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 significant 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 verified our assumption that soil evaporation playa an important role in diurnal $d_v$ variability.
Summary

- The SiLSM2 model performed well in the simulation of $F_{ET}$, $F_E$, $\delta_L$ and $\delta_{ET}$, 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!