Isotopic techniques for tracing evapotranspiration at the field scale. Simple or complex?

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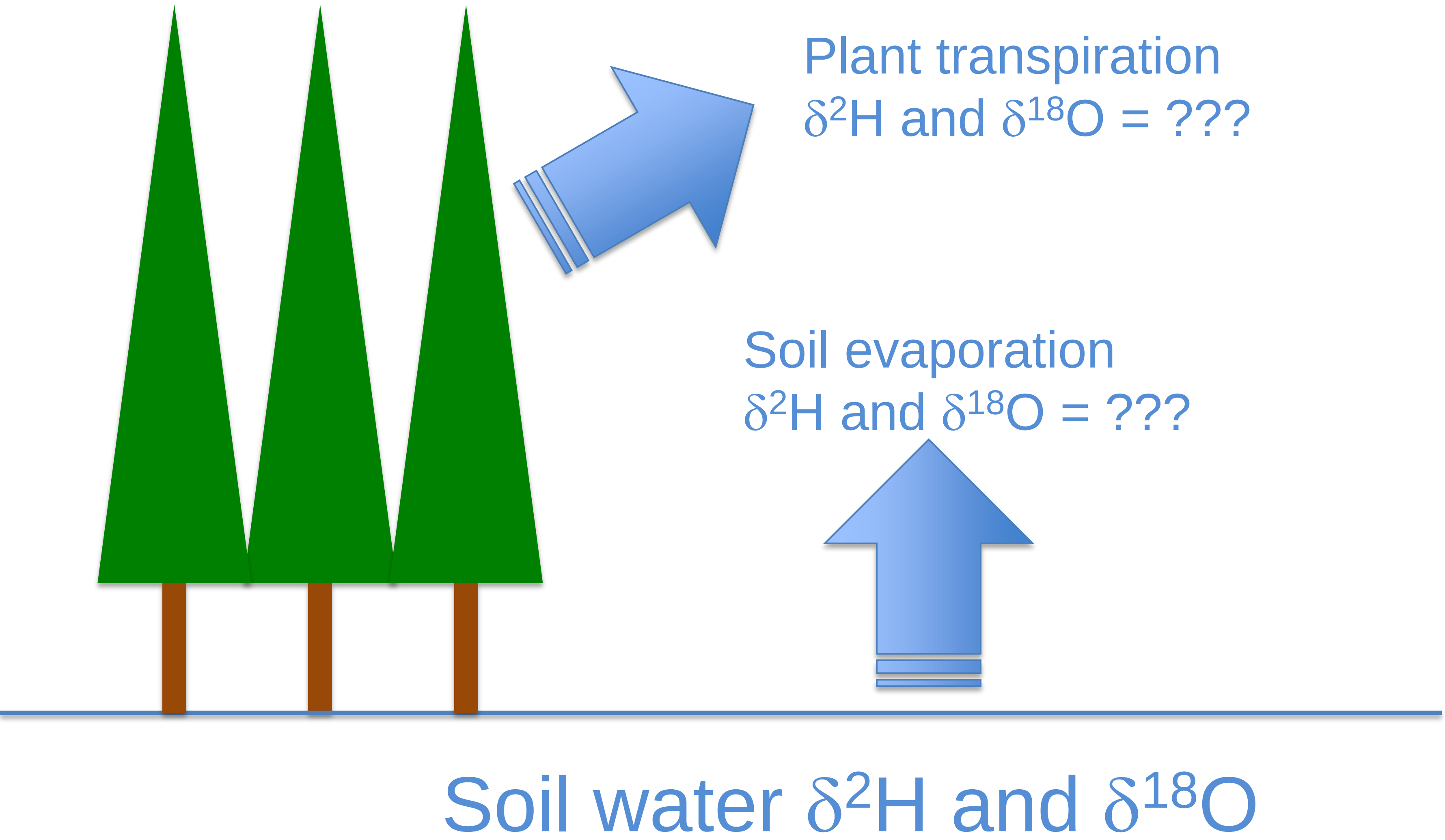
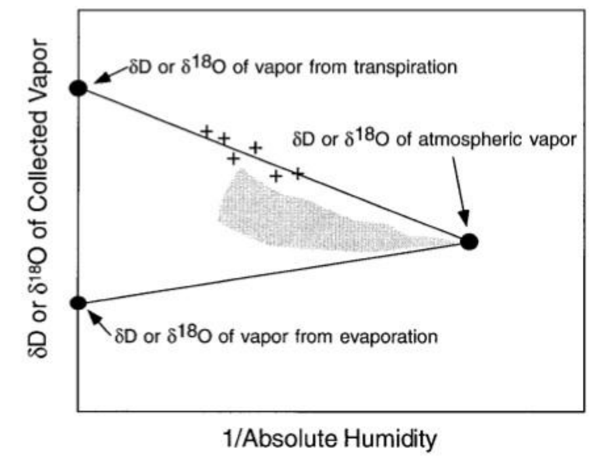
Isotopes of H and O in atmospheric water vapor reveal sources of evapotranspiration



Isotope approaches for separating ET fluxes

Isotope mass balance - **Keeling plots**
Relatively simple

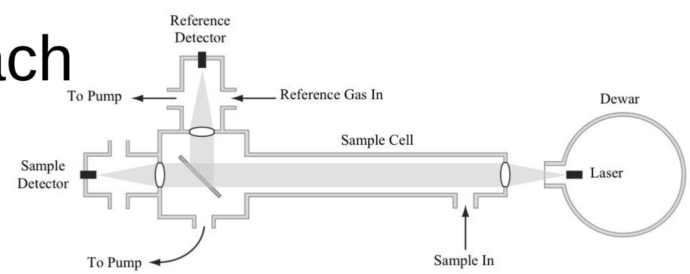


Isotope flux gradient approach
Somewhat complicated

centre of the fields. Significantly,
es were distinct from the short-
re calculated based on leaf scale
rrently with the air sampling. As
δ_p^{13} were consistent with δ_b^{13} values
lyses (Table 1). Note that δ_p^{13} and
0‰ higher in the corn field than
bove C_4 plants. The much smaller
eat and corn fields reflected small
ment and stomatal conductance

$$T = -\overline{K} \times \frac{\Delta C_T}{\Delta_z} = f_1\left(-\overline{K} \times \frac{C_b}{\Delta_z}\right) = f_1 \times ET$$

Eddy covariance approach
Very complicated
…and expensive

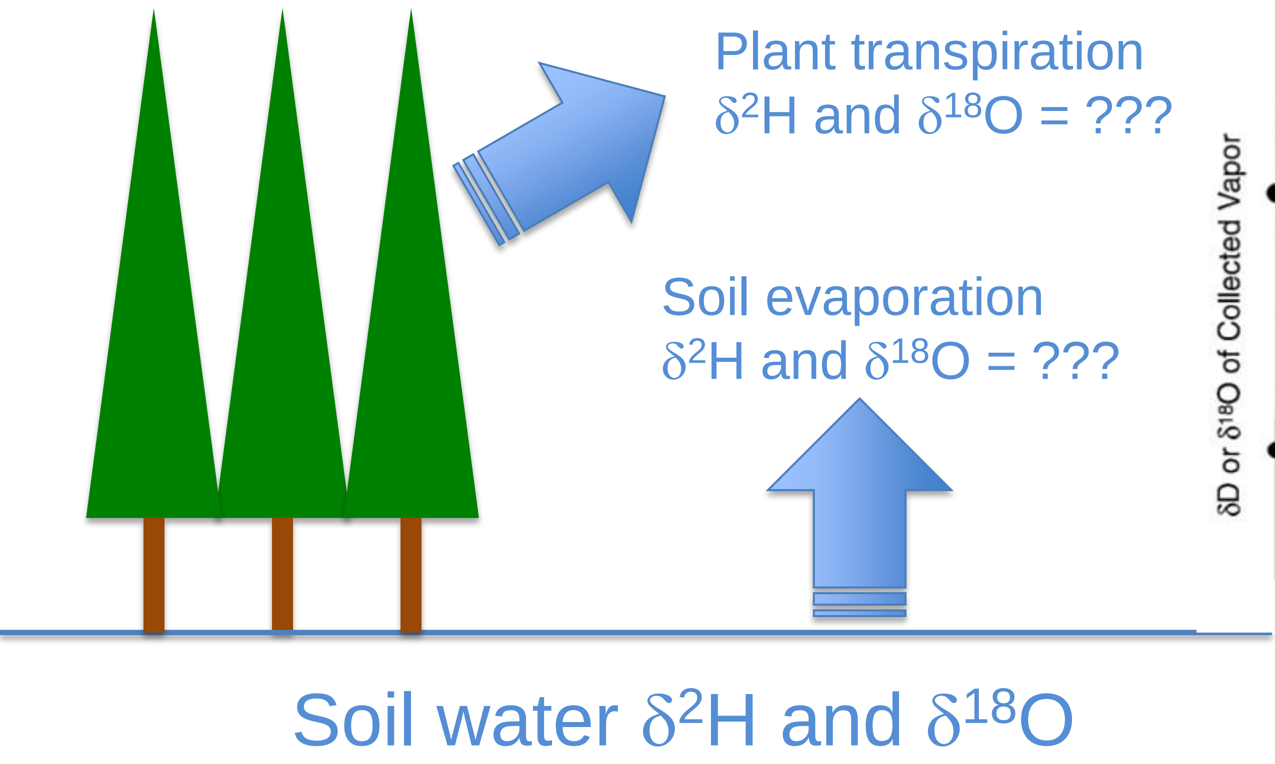


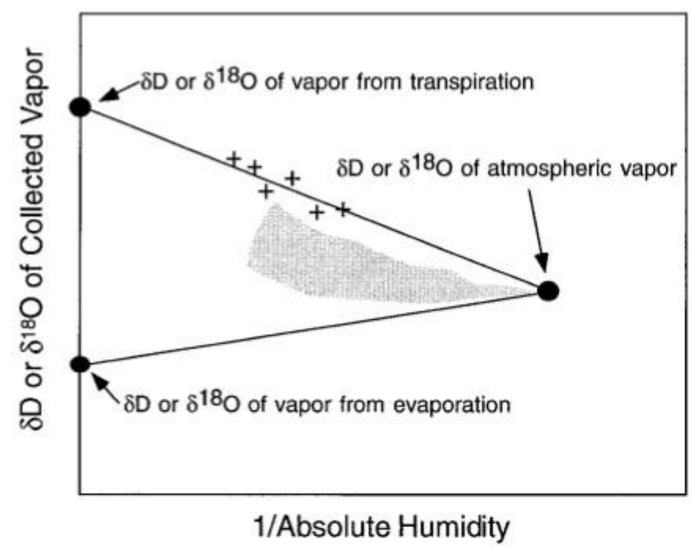
$$F^x = \overline{\rho}_a \overline{w' x'^x_w} + S^x$$

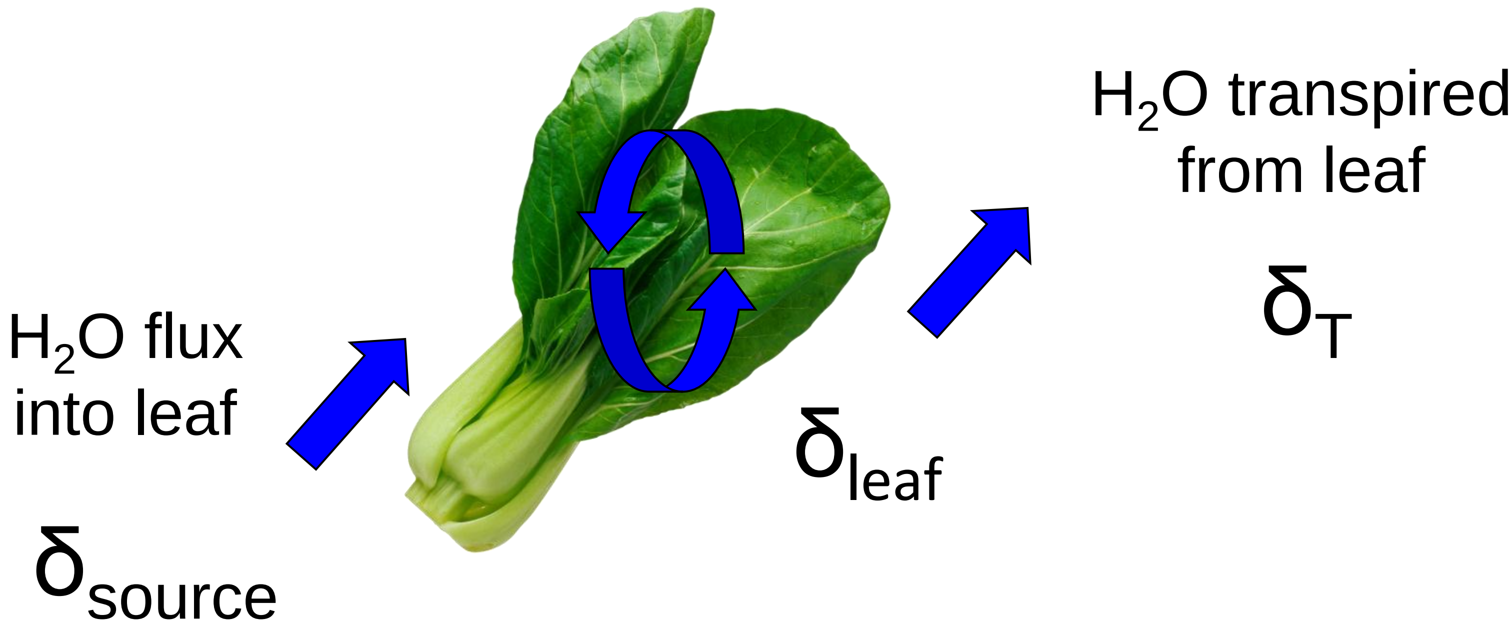
$$\delta_F = \left(\frac{F^{18}/F^{16}}{R_{std}} - 1\right) \times 1000$$

Assumptions of Keeling plot approach

- Source and background values are stable
- Only evapotranspiration (no dew formation)
- Isotopic steady state of plant transpiration



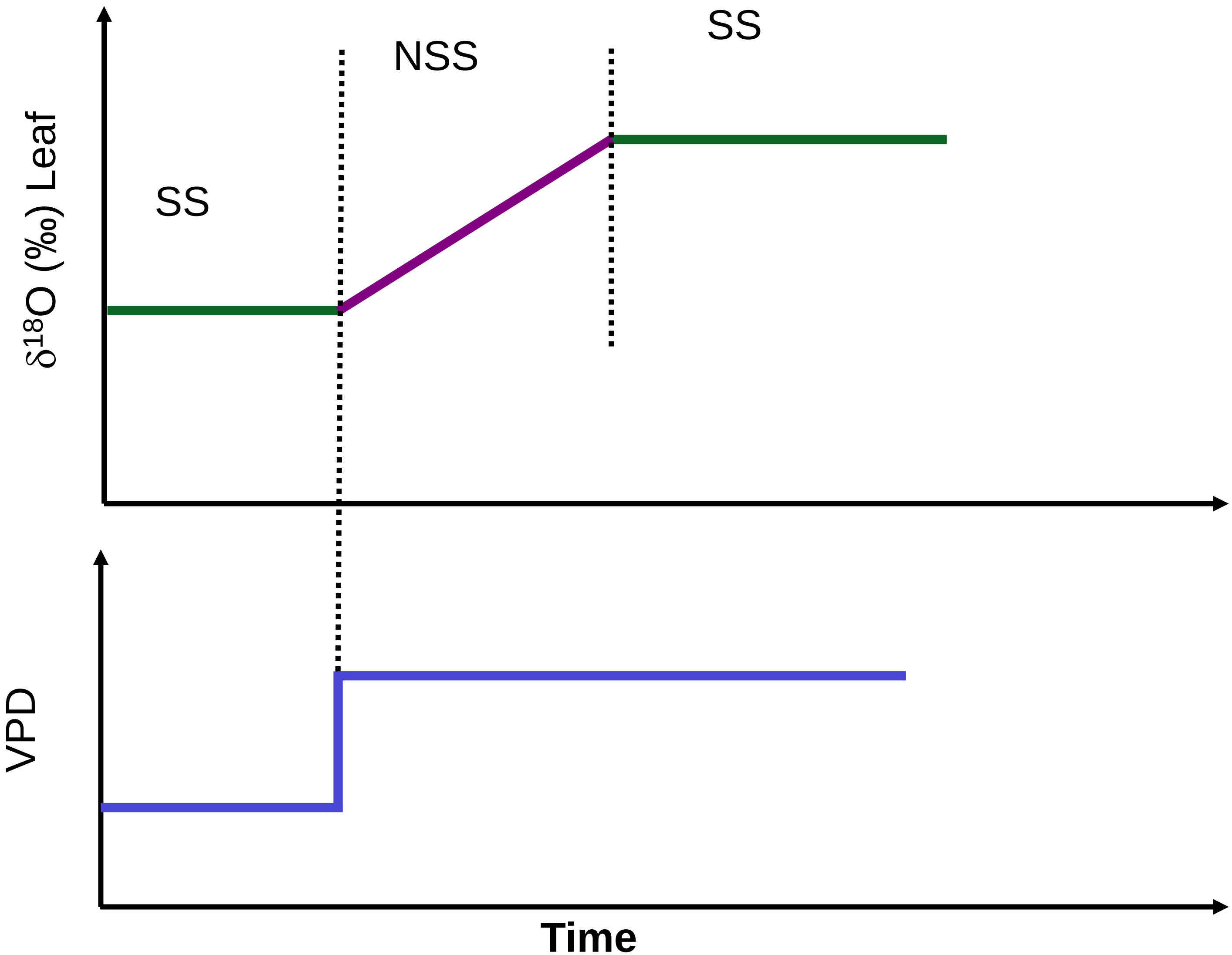




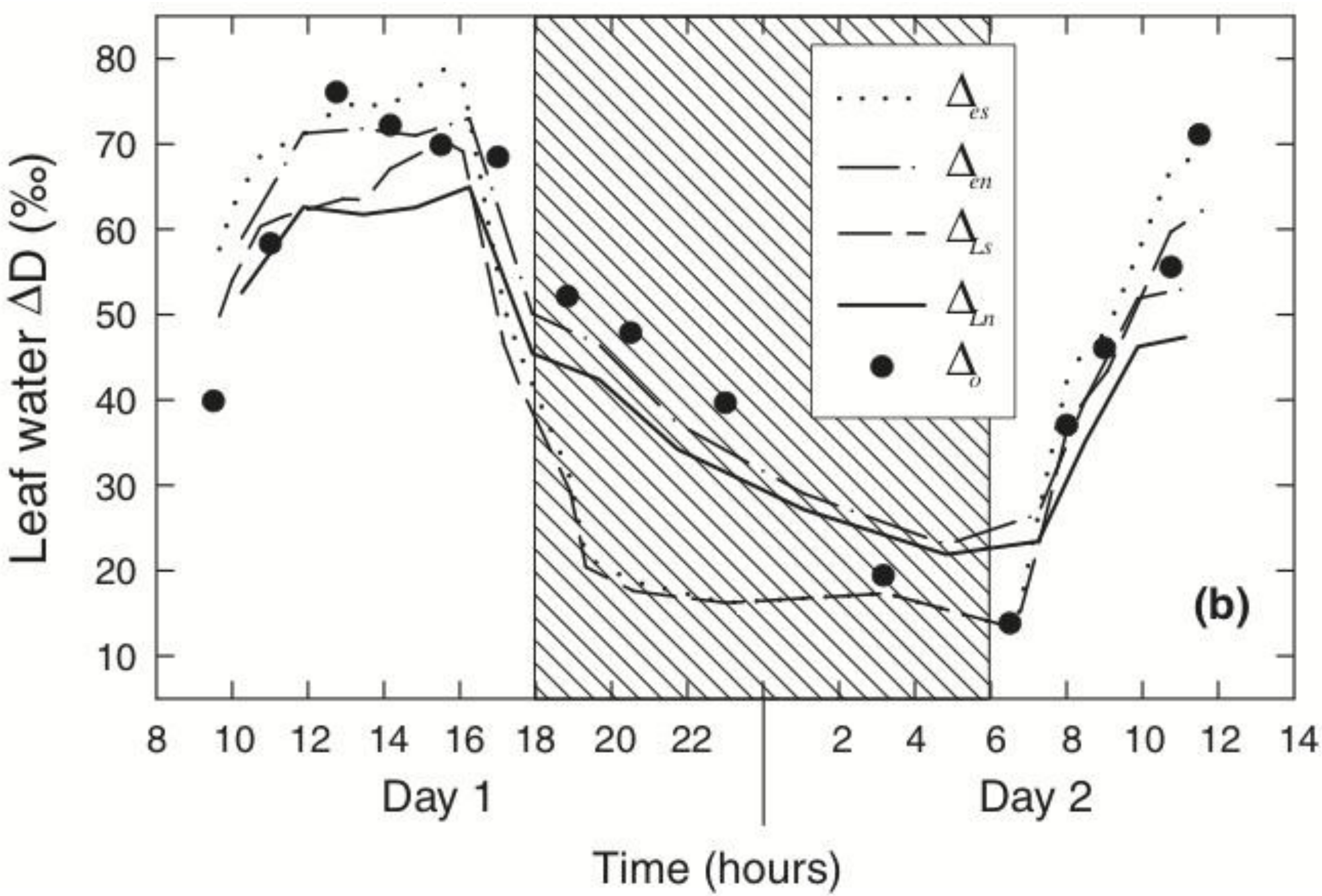
At isotopic steady state, $\delta_T = \delta_{source}$

At isotopic non-steady state, $\delta_T \neq \delta_{source}$

Non steady state

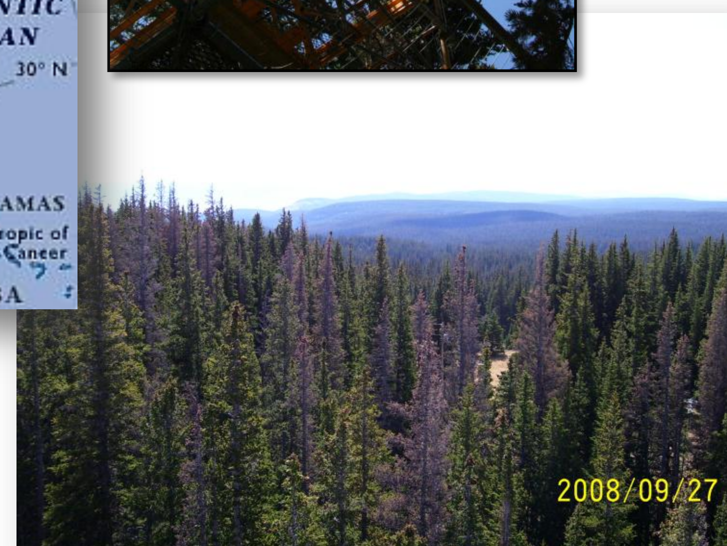


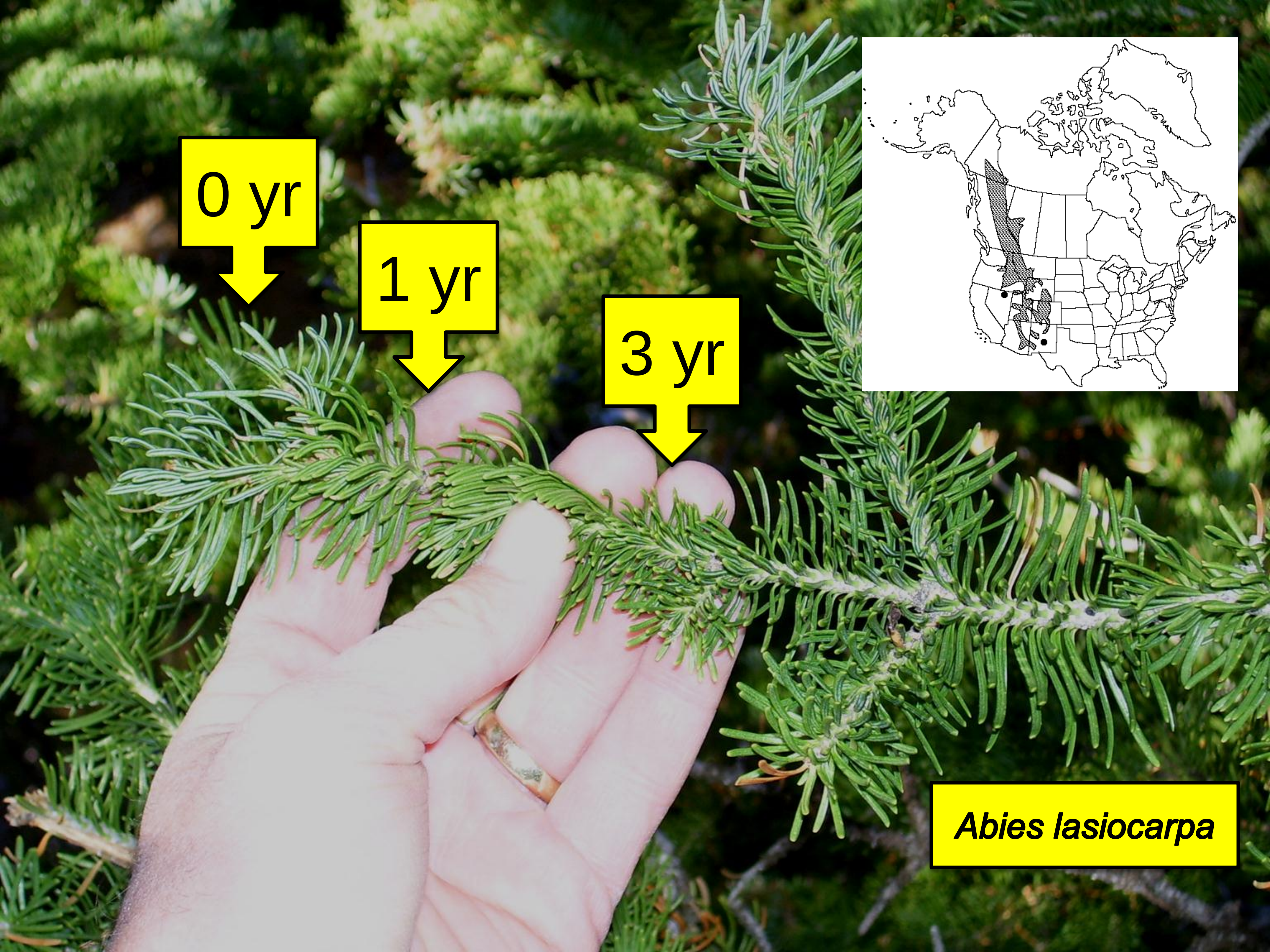
Leaf transpiration at isotopic steady state



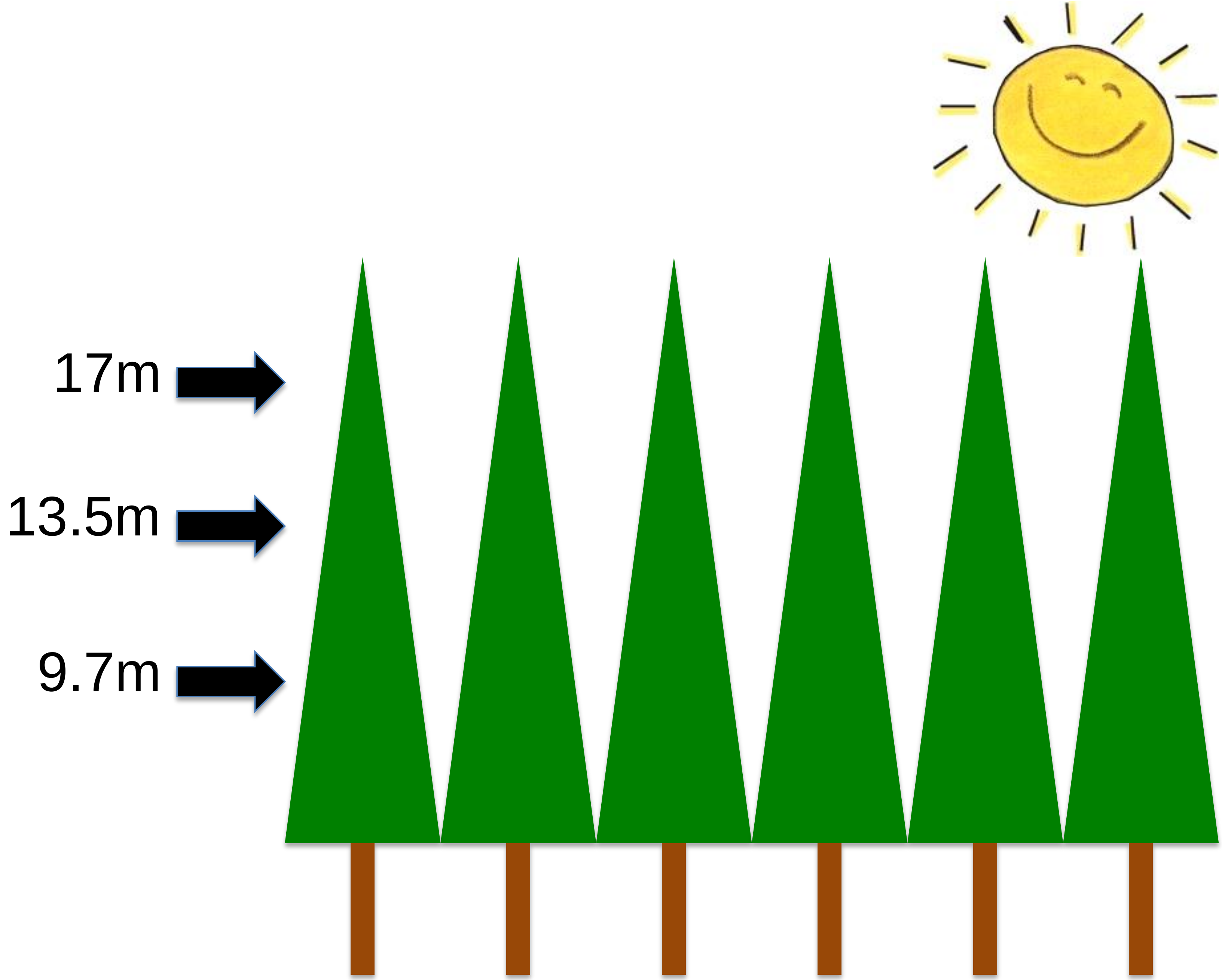
Cernusak et al. 2002

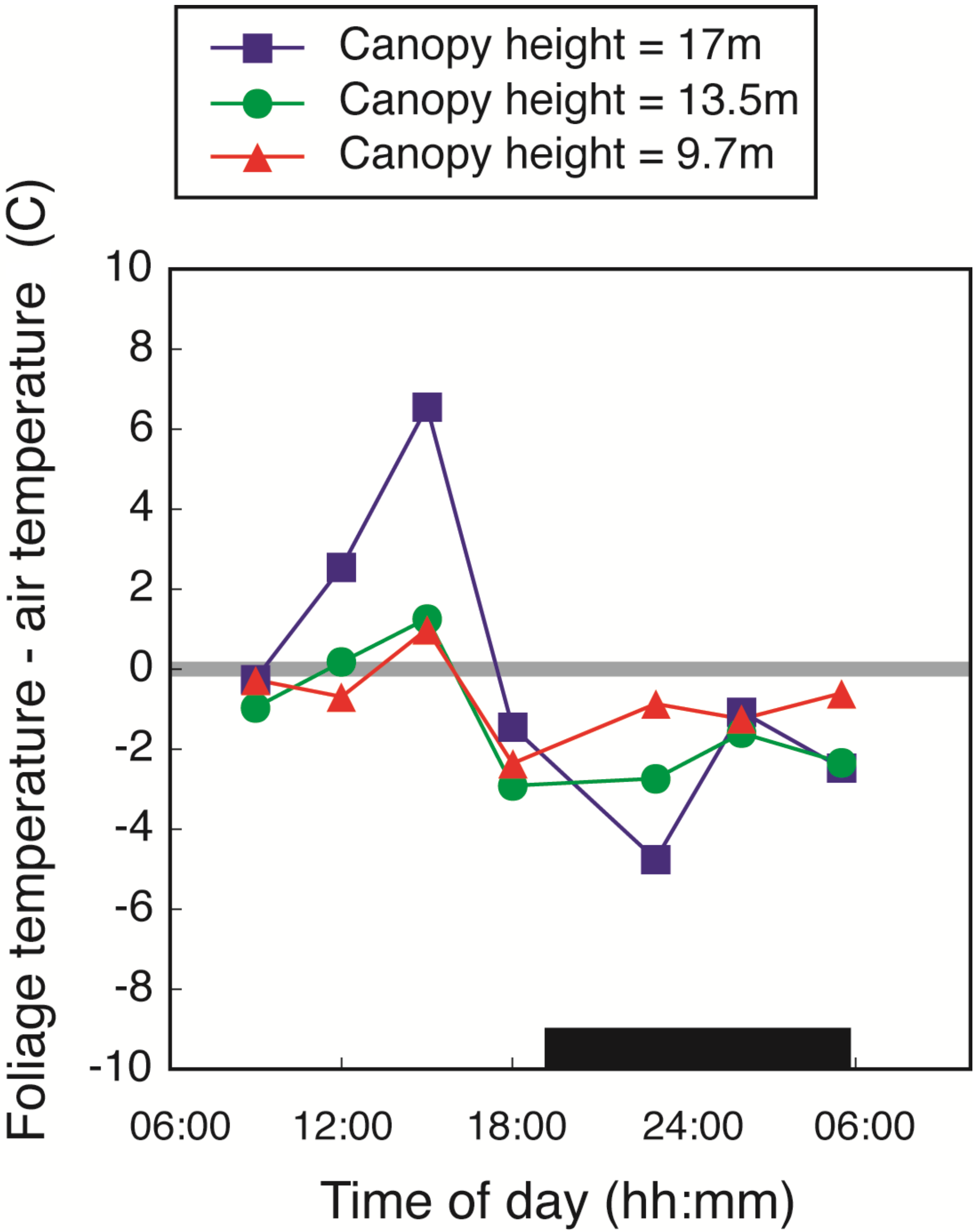
Glacier Lakes Ecosystem Experiments Site (GLEES) U.S. Forest Service



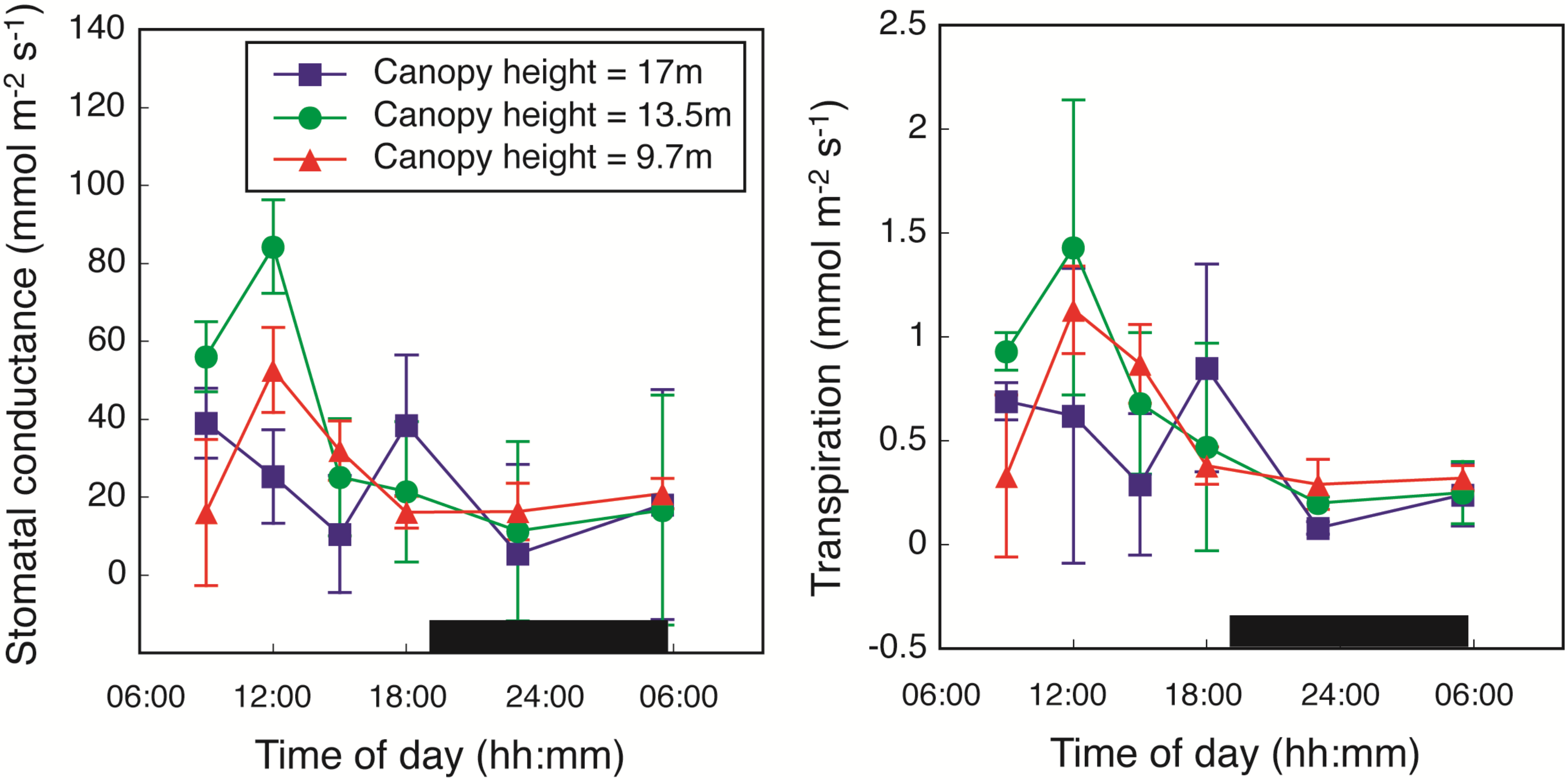


0 yr
1 yr
3 yr
Abies lasiocarpa

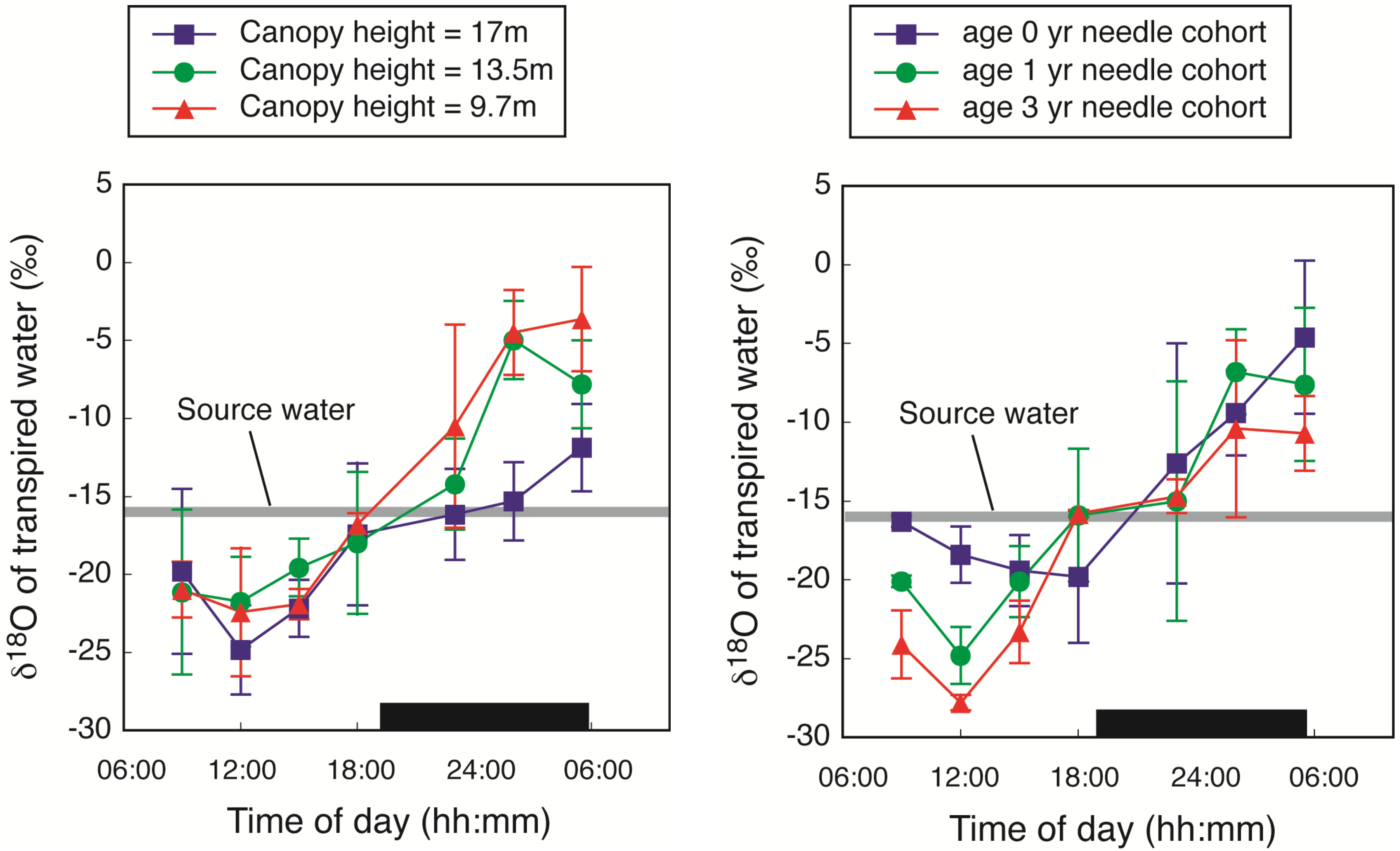

17m
13.5m
9.7m



Canopy height = 17m
Canopy height = 13.5m
Canopy height = 9.7m
Foliage temperature - air temperature (C)
10
8
6
4
2
0
-2
-4
-6
-8
-10
06:00
12:00
18:00
24:00
06:00
Time of day (hh:mm)



Stomatal conductance (mmol m-2 s-1)
140
120
100
80
60
40
20
0
Canopy height = 17m
Canopy height = 13.5m
Canopy height = 9.7m
06:00
12:00
18:00
24:00
06:00
Time of day (hh:mm)
Transpiration (mmol m-2 s-1)
2.5
2
1.5
1
0.5
0
-0.5
06:00
12:00
18:00
24:00
06:00
Time of day (hh:mm)



Canopy height = 17m
Canopy height = 13.5m
Canopy height = 9.7m
age 0 yr needle cohort
age 1 yr needle cohort
age 3 yr needle cohort
δ18O of transpired water (‰)
Source water
5
0
-5
-10
-15
-20
-25
-30
06:00
12:00
18:00
24:00
06:00
Time of day (hh:mm)

Transpiration in *Abies lasiocarpa* operated predominantly at isotopic **non**-steady state

Systematic variation in leaf water ^{18}O enrichment and transpired water with canopy height and leaf age

Next step:
Model isotopic non-steady state of canopy transpiration considering complexity of canopy physiological processes and micro-environment