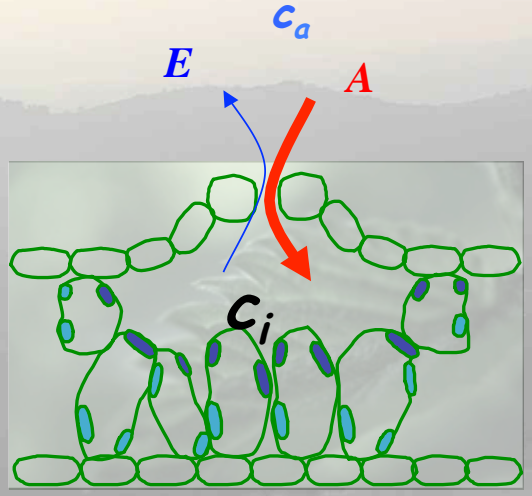
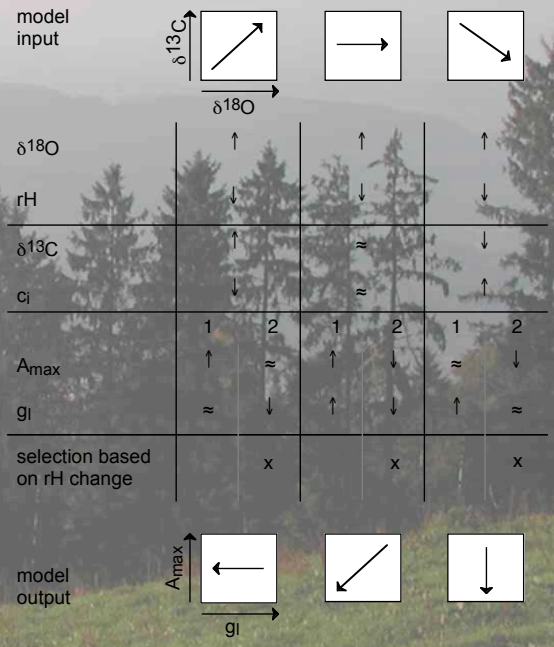
Is the combined C and O isotope approach still relevant?

Strengths and weaknesses of the dual isotope approach



$\delta^{13}C$



$\delta^{18}O$

Rolf Siegwolf

Carbon Isotope Discrimination in C3 Plants

Farquhar et al.; 1982; 1989

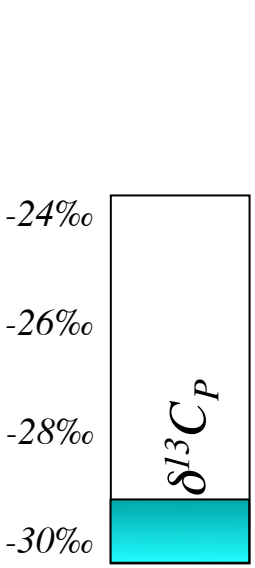
$$\Delta^{13}C = a_b \frac{C_a - C_s}{C_a} + a\frac{C_s - C_i}{C_a} + (b_s + a_l)\frac{C_i - C_c}{C_a} + b\frac{C_c}{C_a} - f\frac{\Gamma^*}{C_a} - e'\frac{R_d}{A + R_d}\frac{C_c - \Gamma^*}{C_a}$$

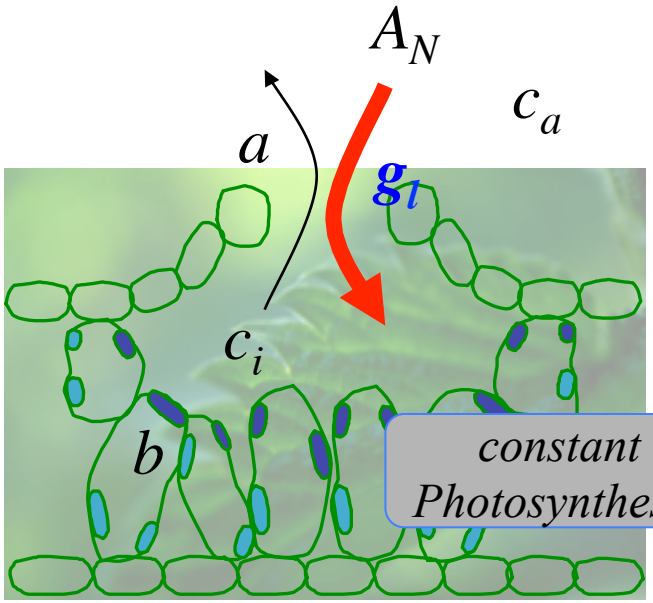
$$\Delta^{13}C = a + (a\text{-}b)\, c_i/c_a$$

$$\delta^{13}C_P = \delta^{13}C_A - a - (a\text{-}b)\, c_i/c_a$$

Carbon Isotope Discrimination in C3 Plants

Farquhar et al.; 1982; 1989





variable stomatal conductance

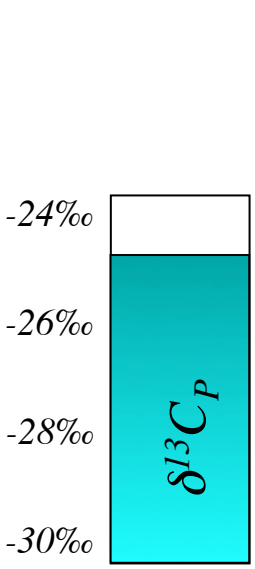
constant Photosynthesis

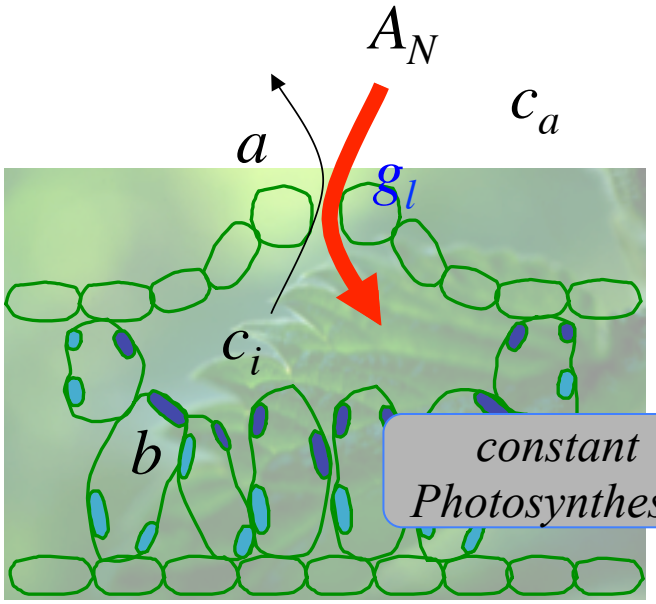
$c_i/c_a < 1$

$$\delta^{13}C_P = \delta^{13}C_A - a - (a\text{-}b)\, c_i/c_a$$

Carbon Isotope Discrimination in C3 Plants

Farquhar et al.; 1982; 1989





variable stomatal conductance

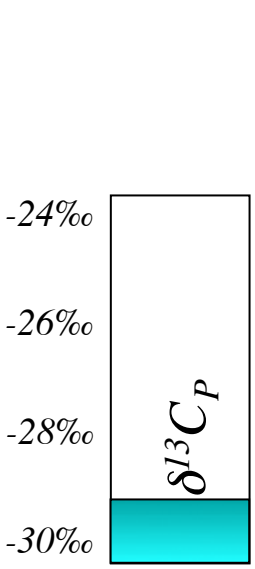
constant Photosynthesis

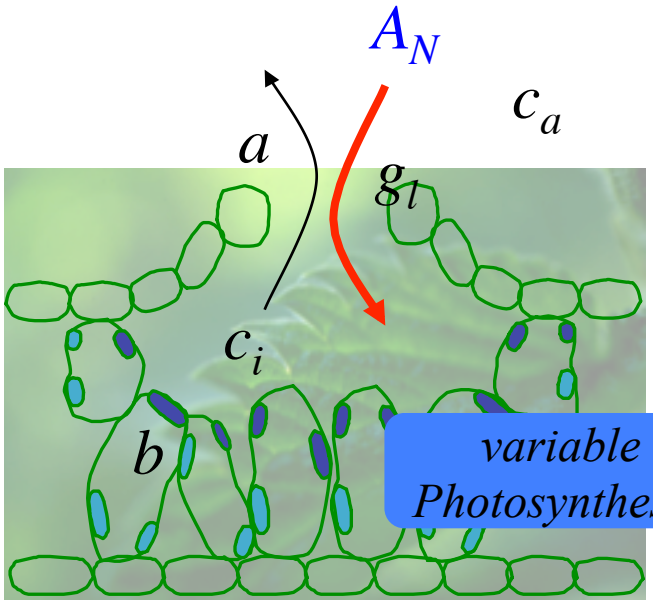
$c_i/c_a << 1$

$$\delta^{13}C_P = \delta^{13}C_A - a - (a\text{-}b)\, c_i/c_a$$

Carbon Isotope Discrimination in C3 Plants

Farquhar et al.; 1982; 1989





constant stomatal conductance

variable Photosynthesis

$c_i/c_a < 1$

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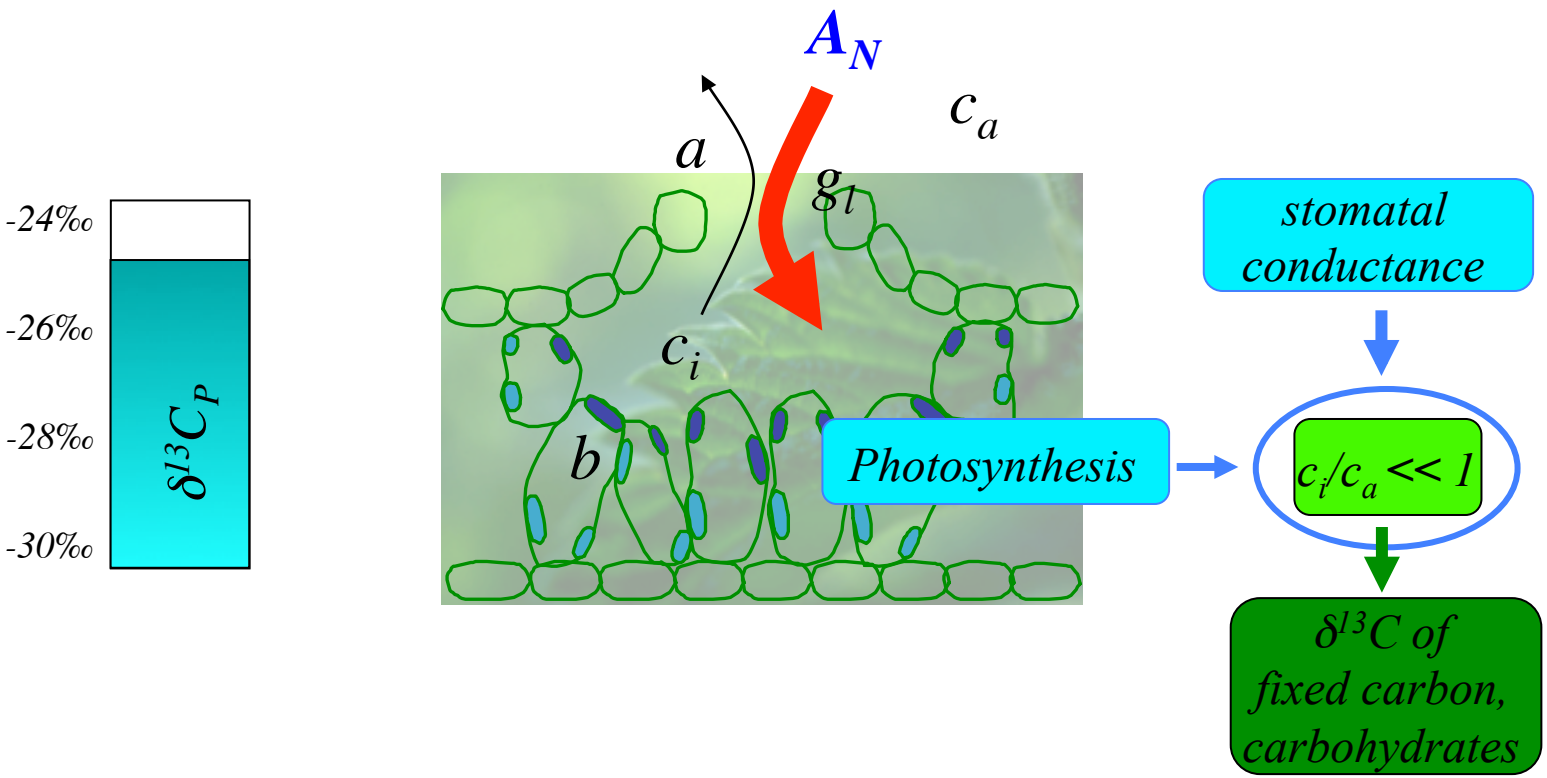
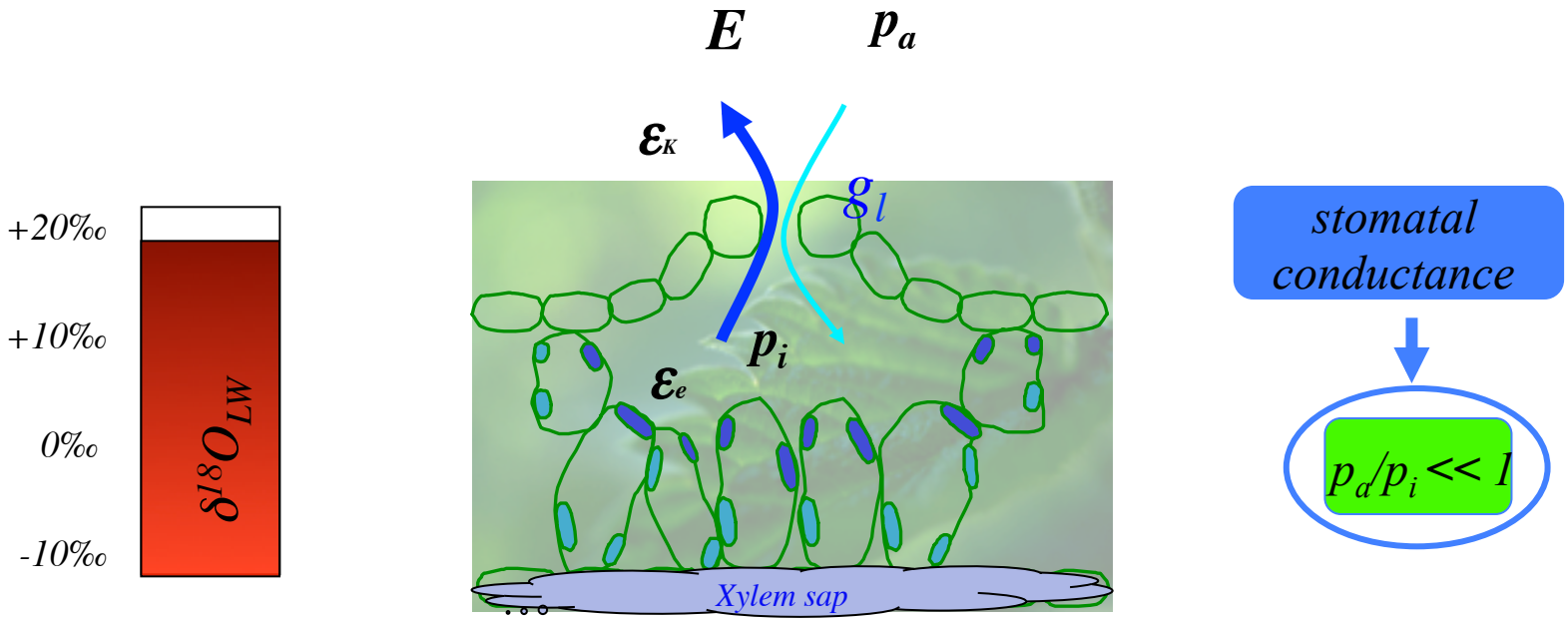
Farquhar et al.; 1982; 1989



Stomata or Photosynthesis?

Oxygen Isotope Discrimination in C3 Plants

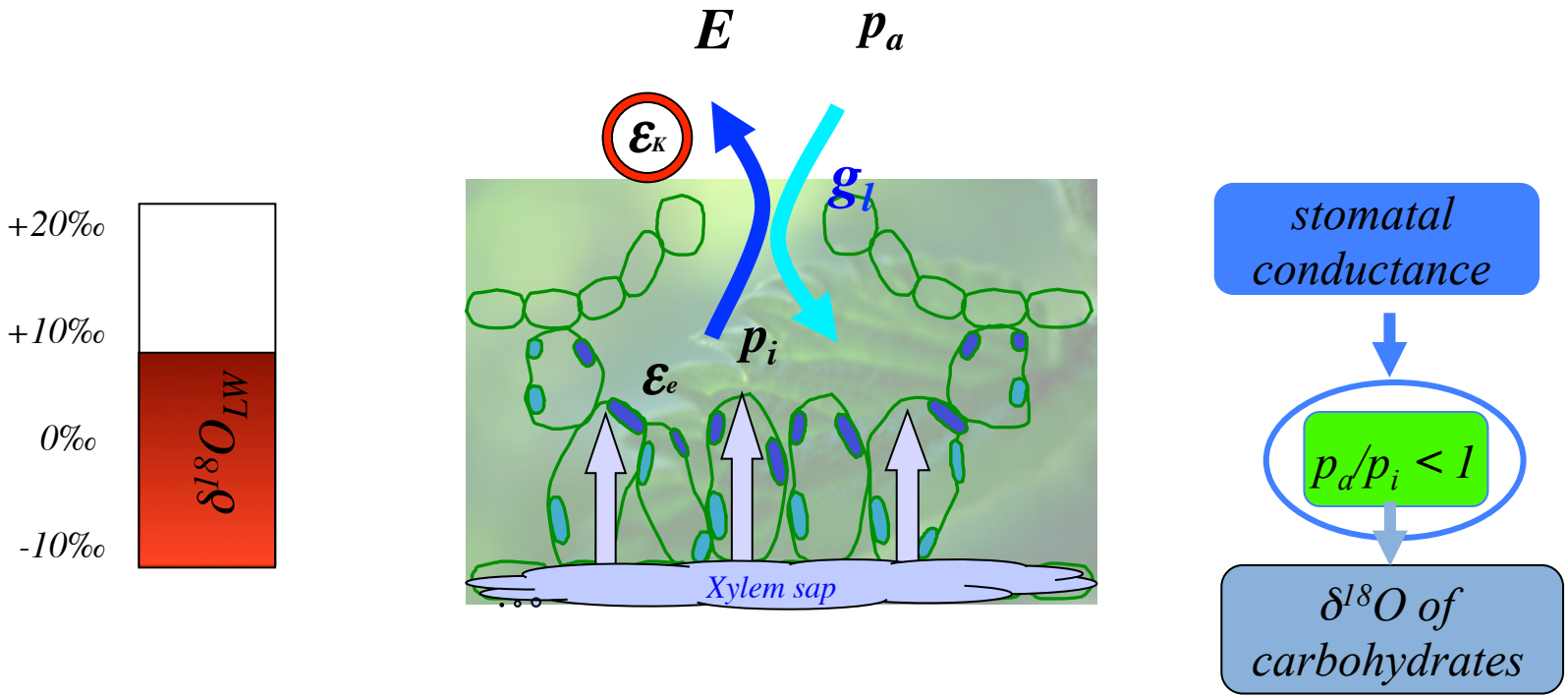
Dongmann et al.; 1974; Farquhar & Lloyd, 1993; Cernusack et al. 2003



$$\delta^{18}O_{craig} = \delta^{18}O_s + \varepsilon_k + \varepsilon_{eq} + (\delta^{18}O_v - \delta^{18}O_s - \varepsilon_k) * p_a/p_i$$

Oxygen Isotope Discrimination in C3 Plants

Dongmann et al.; 1974; Farquhar & Lloyd, 1993; Cernusack et al. 2003



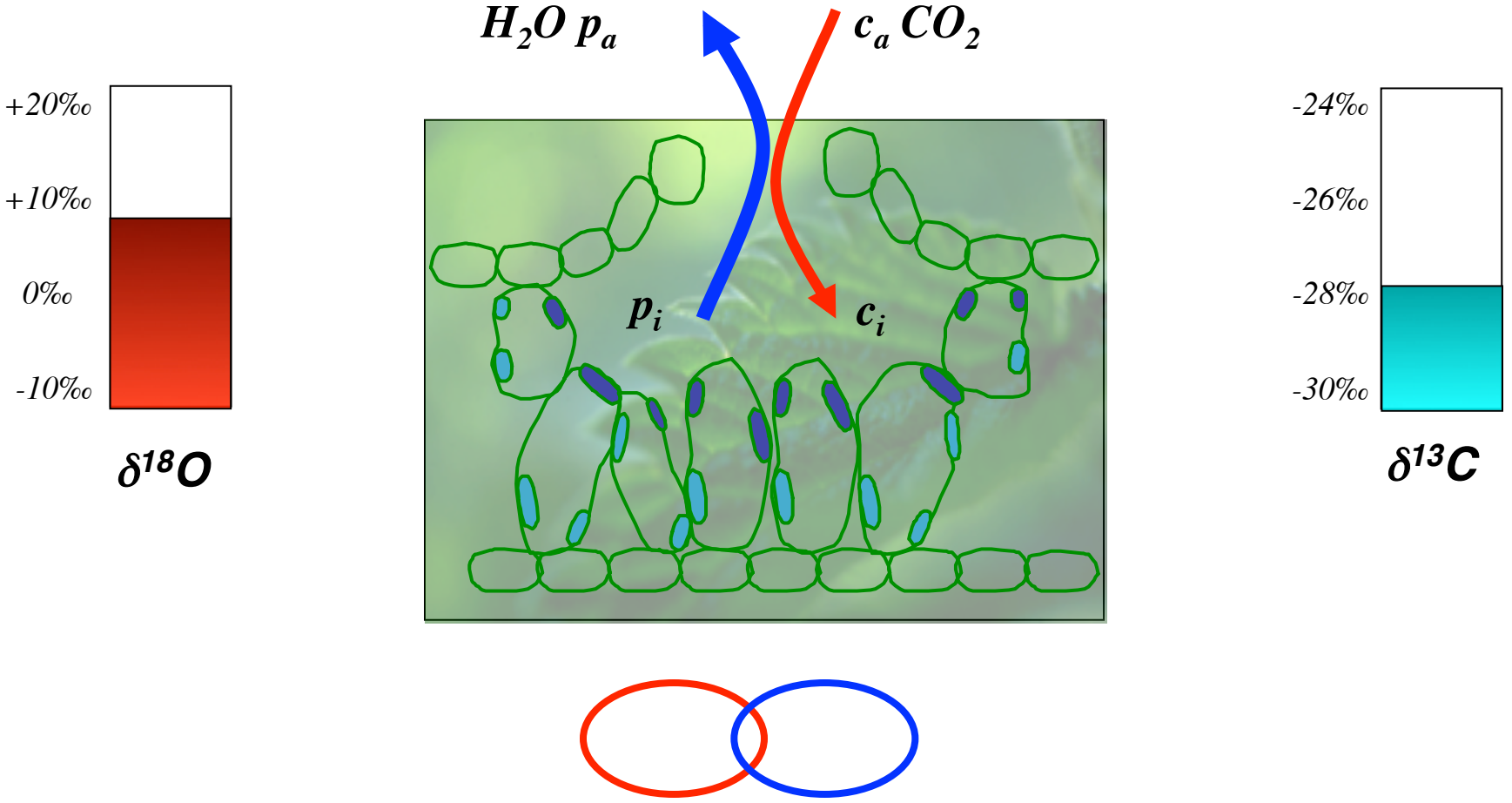
$$\delta^{18}O_{craig} = \delta^{18}O_s + \varepsilon_k + \varepsilon_{eq} + (\delta^{18}O_v - \delta^{18}O_s - \varepsilon_k) * p_a/p_i$$

$$\wp = LECD$$

$$\delta^{18}O_{leaf} = \delta^{18}O_s + (\delta^{18}O_{craig} - \delta^{18}O_s) * ((1 - e^{-\wp}) / \wp)$$

Linking ^{13}C and ^{18}O

Scheidegger et. al.; 2000



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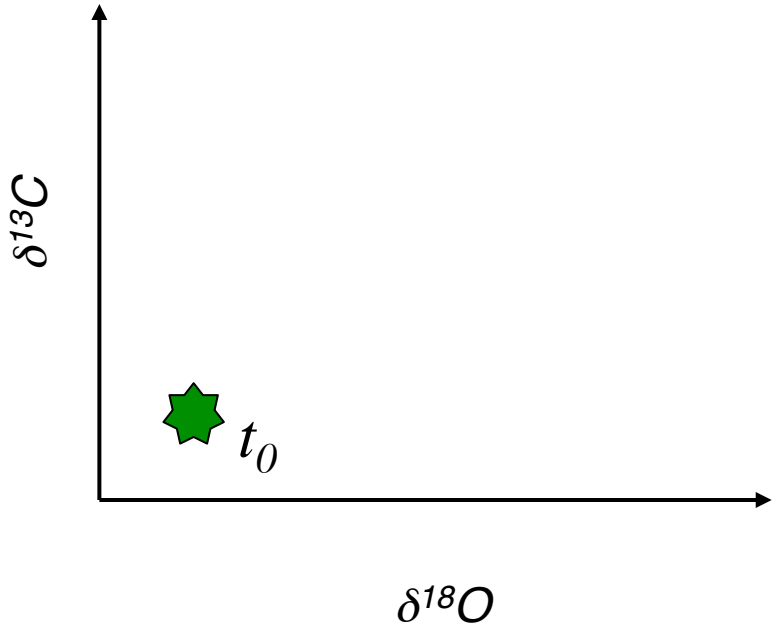

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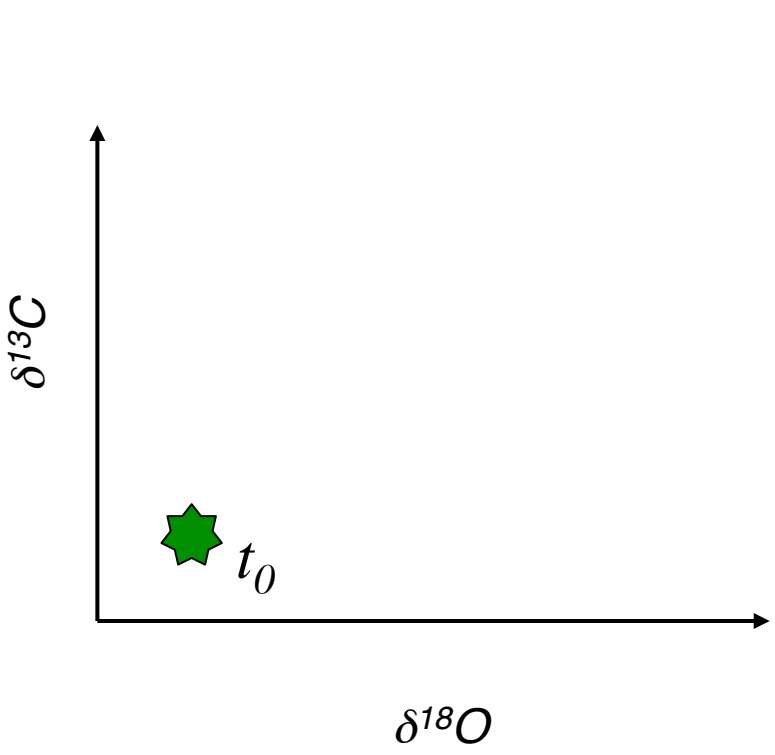
Environmental Impact



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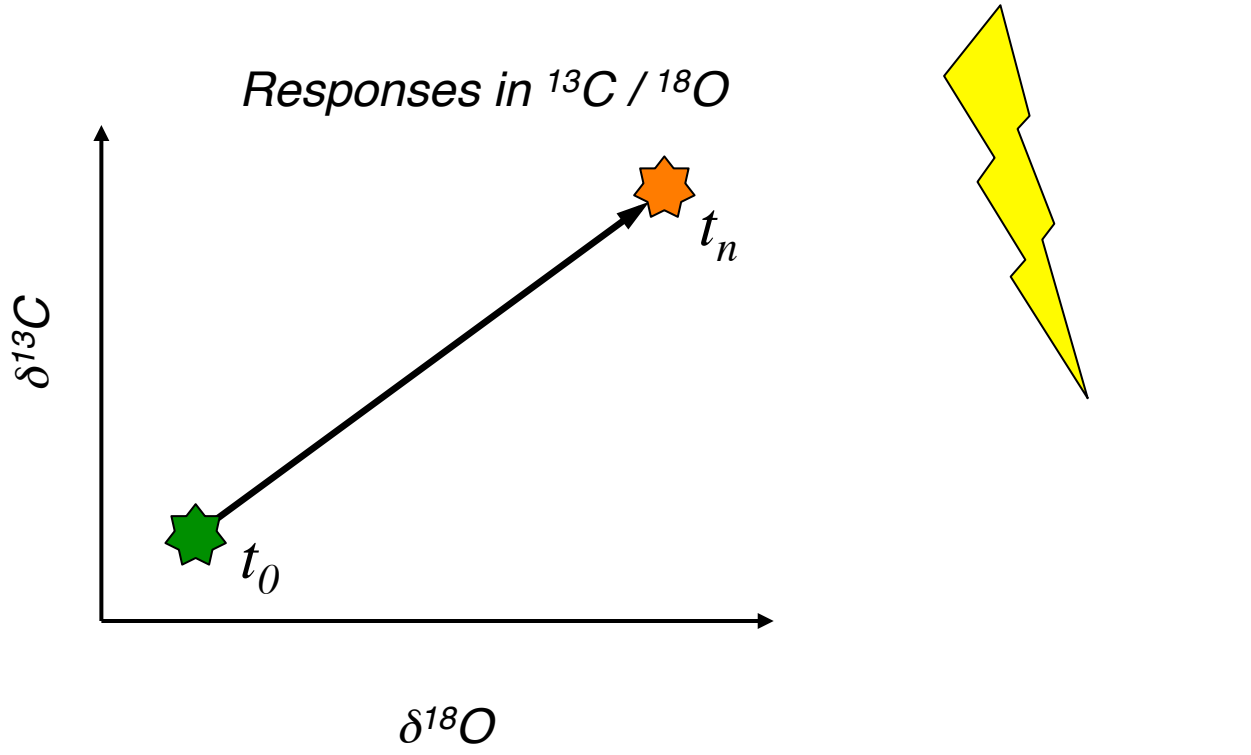

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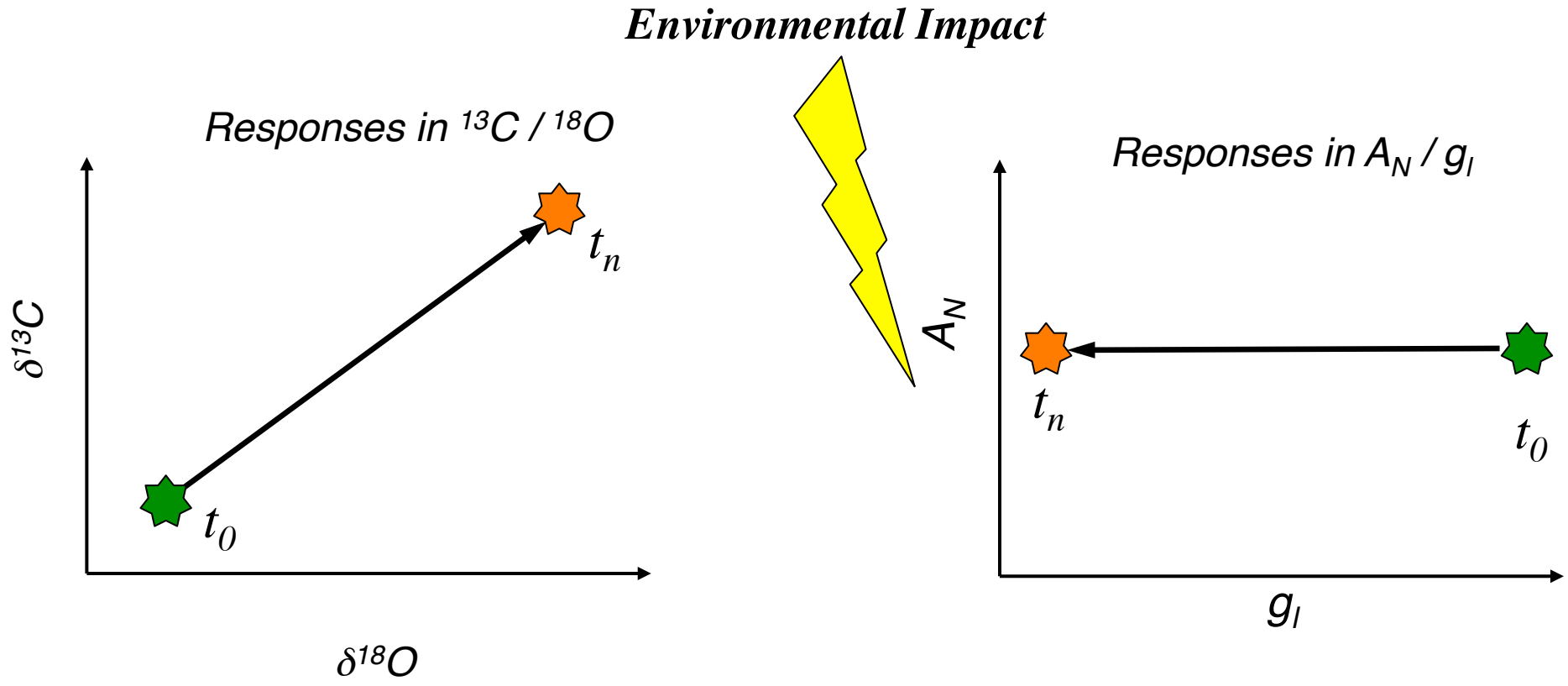

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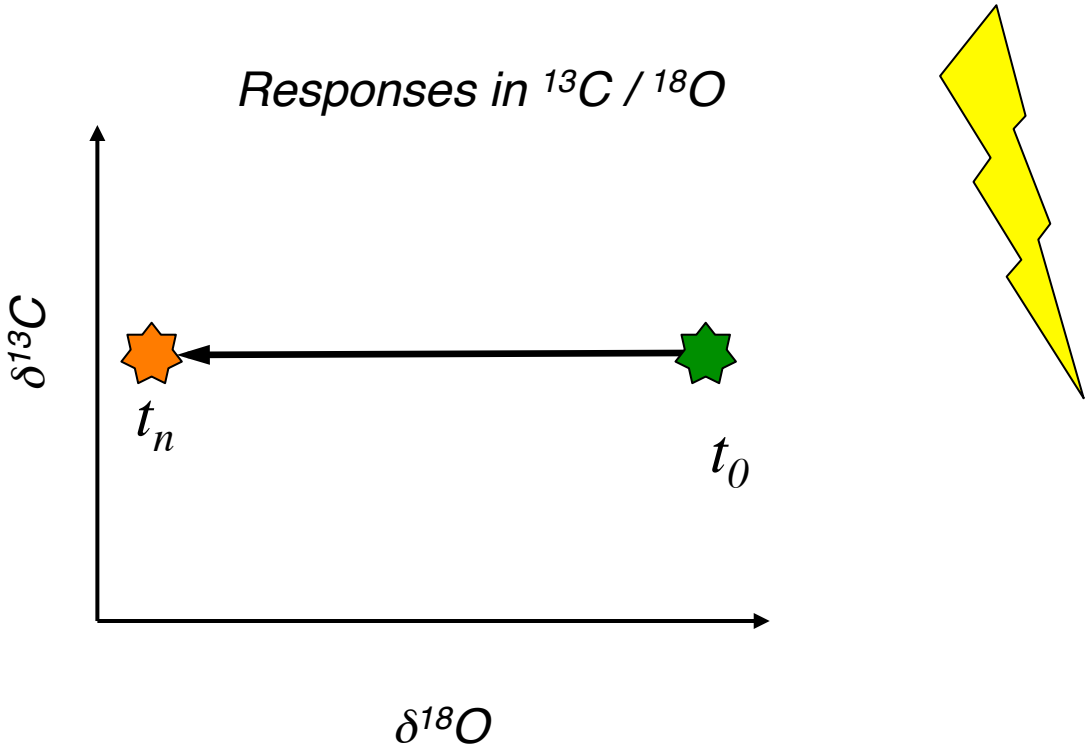

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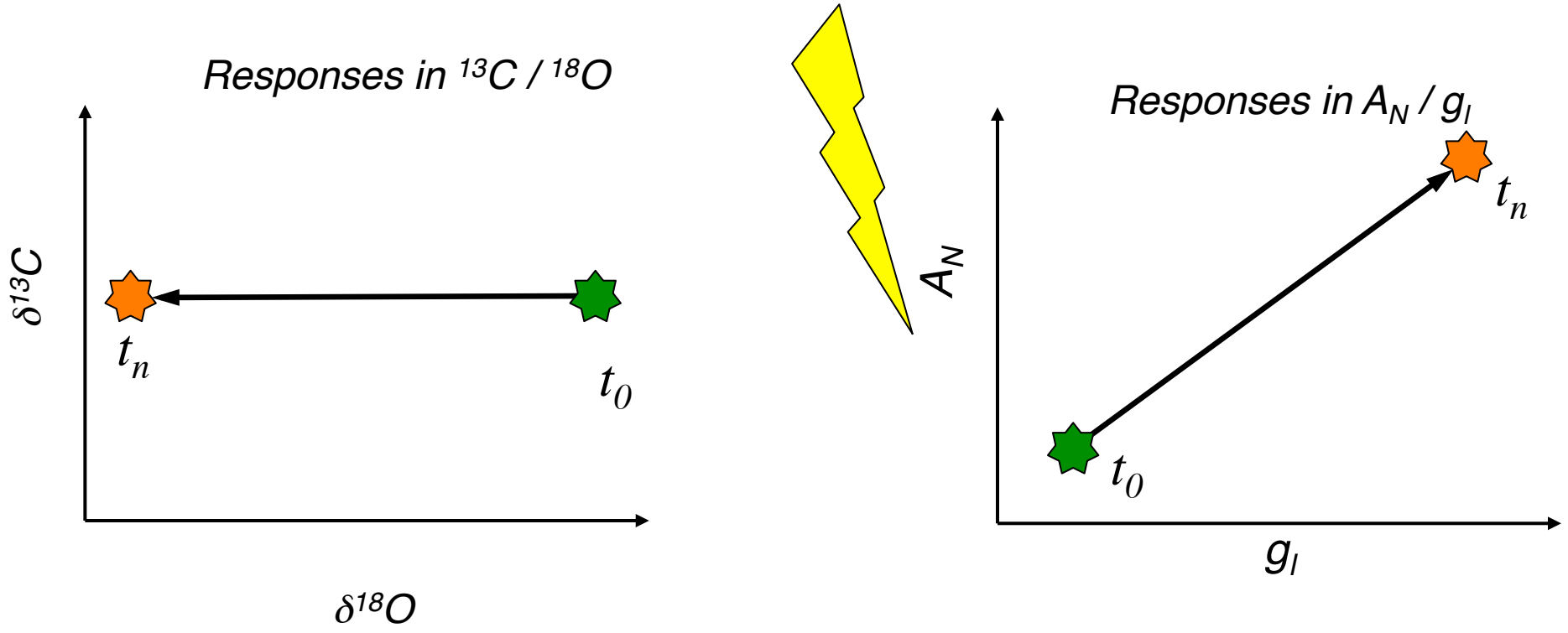
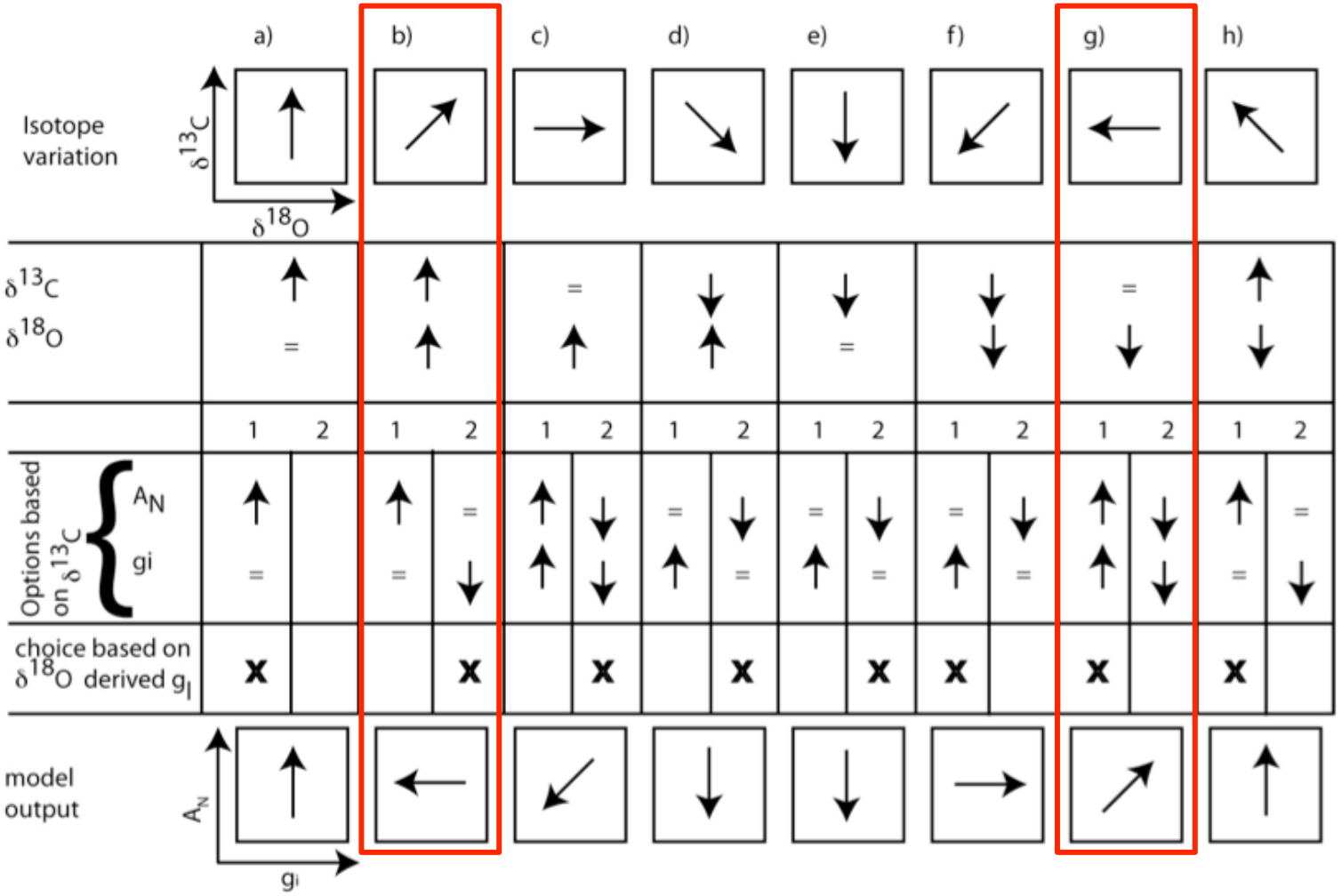


Combining C and O isotopes allows the distinction between A and g_I

Scheidegger et. al.; 2000



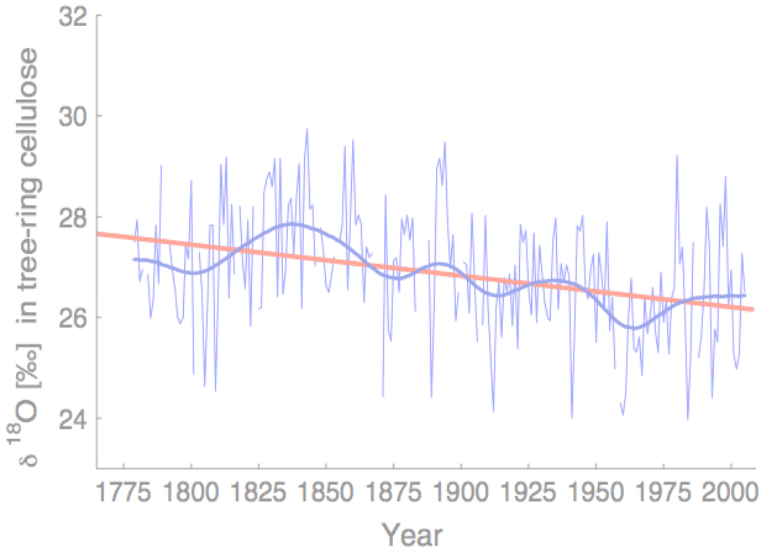
WHY Dual Isotope

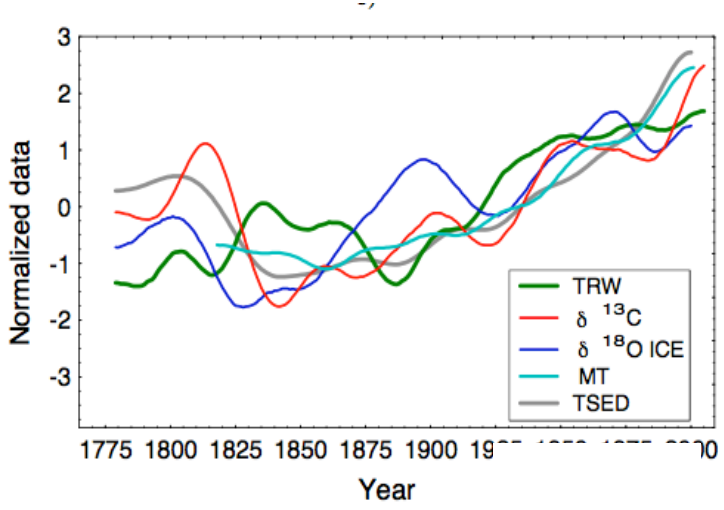
- *Its **LINK** to the **PHYSIOLOGY** of plants (Photosynthesis and stomatal conductance*

- *The **EXPLICATIVE strength** translating isotopic patterns to physiological processes*

- *A **powerful DIAGNOSTIC TOOl***
  - *Makes Anomalities much easier visible*
  - *Indicates where what is not plausible*

Application in climate reconstruction





Tree ring width

$\delta^{13}C$ from tree ring cellulose

$\delta^{18}O$ from ice cores

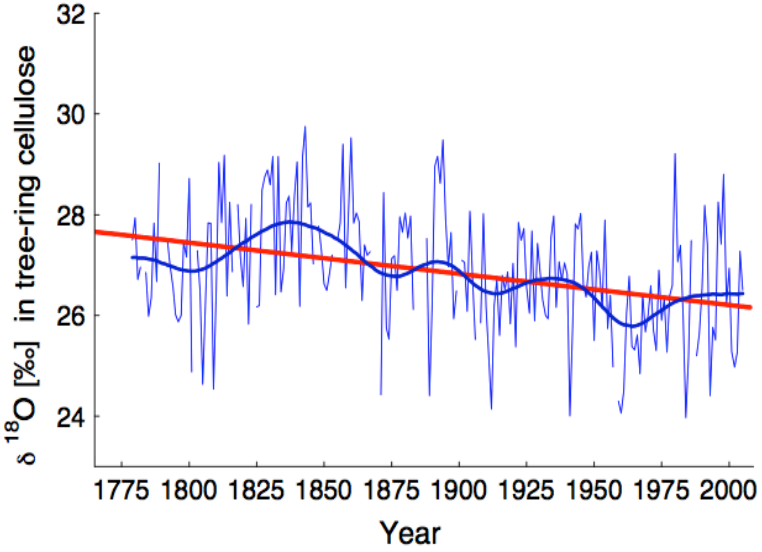
Ice melting index

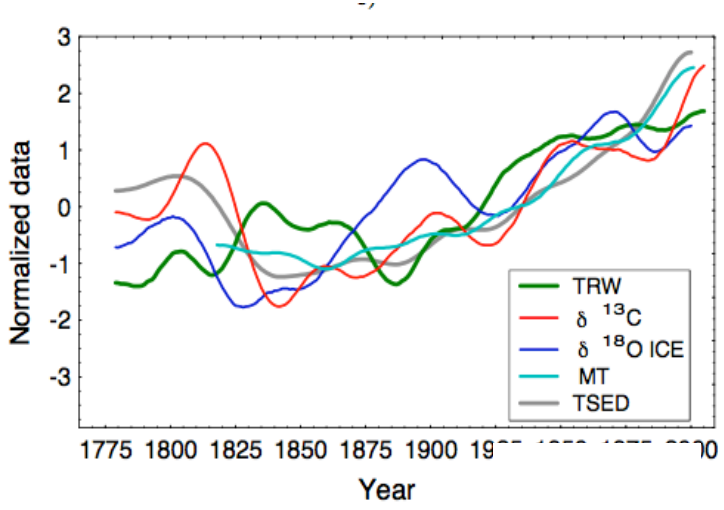
Lake sediments

Sidorova et al.; Clim Dyn. DOI 10.1007/s00382-010-0989-6, 2011

BUT What if …

$\delta^{18}O$ in tree rings decreases, which is in contrast to other proxies





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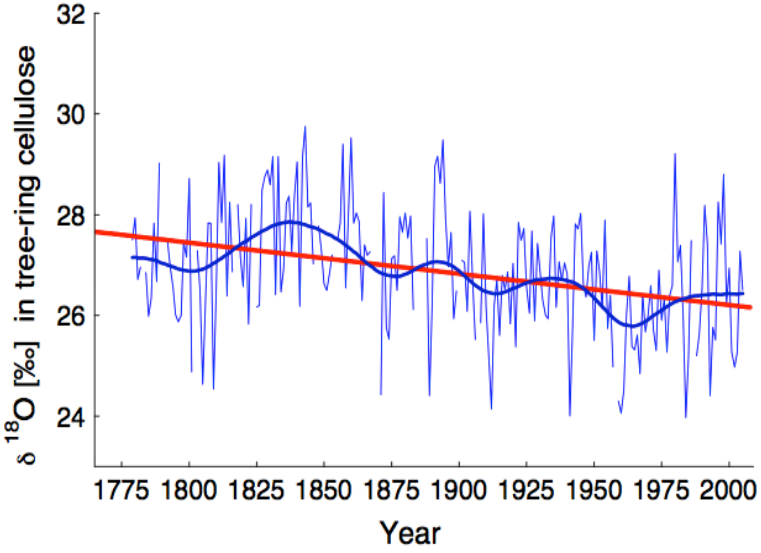

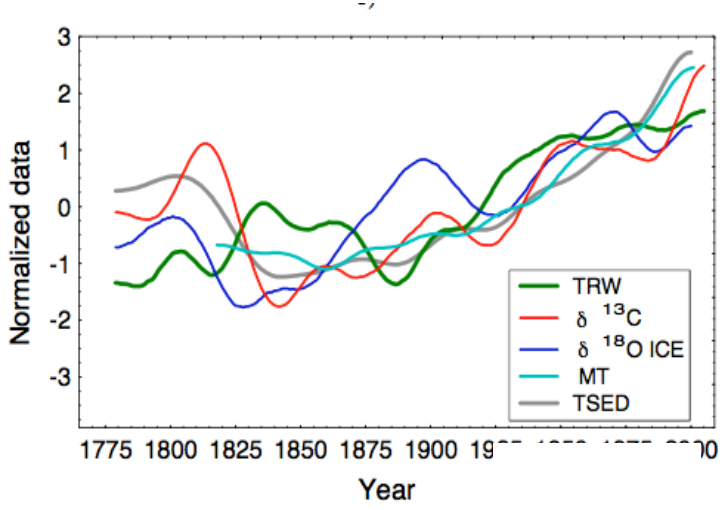

Tree ring width

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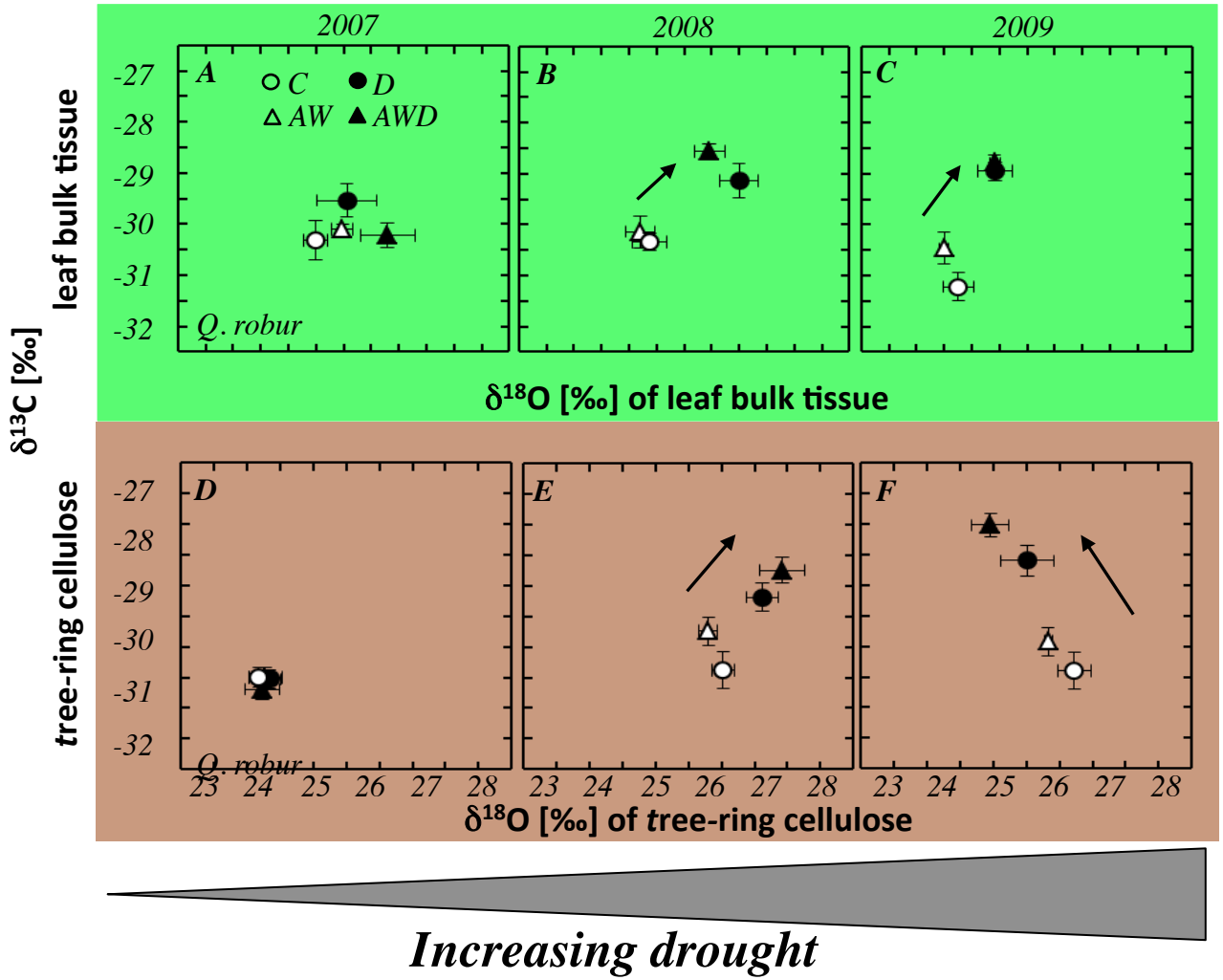
Lake sediments

The source water does not reflect the precipitation water?

(→ Caused by permafrost-melting)

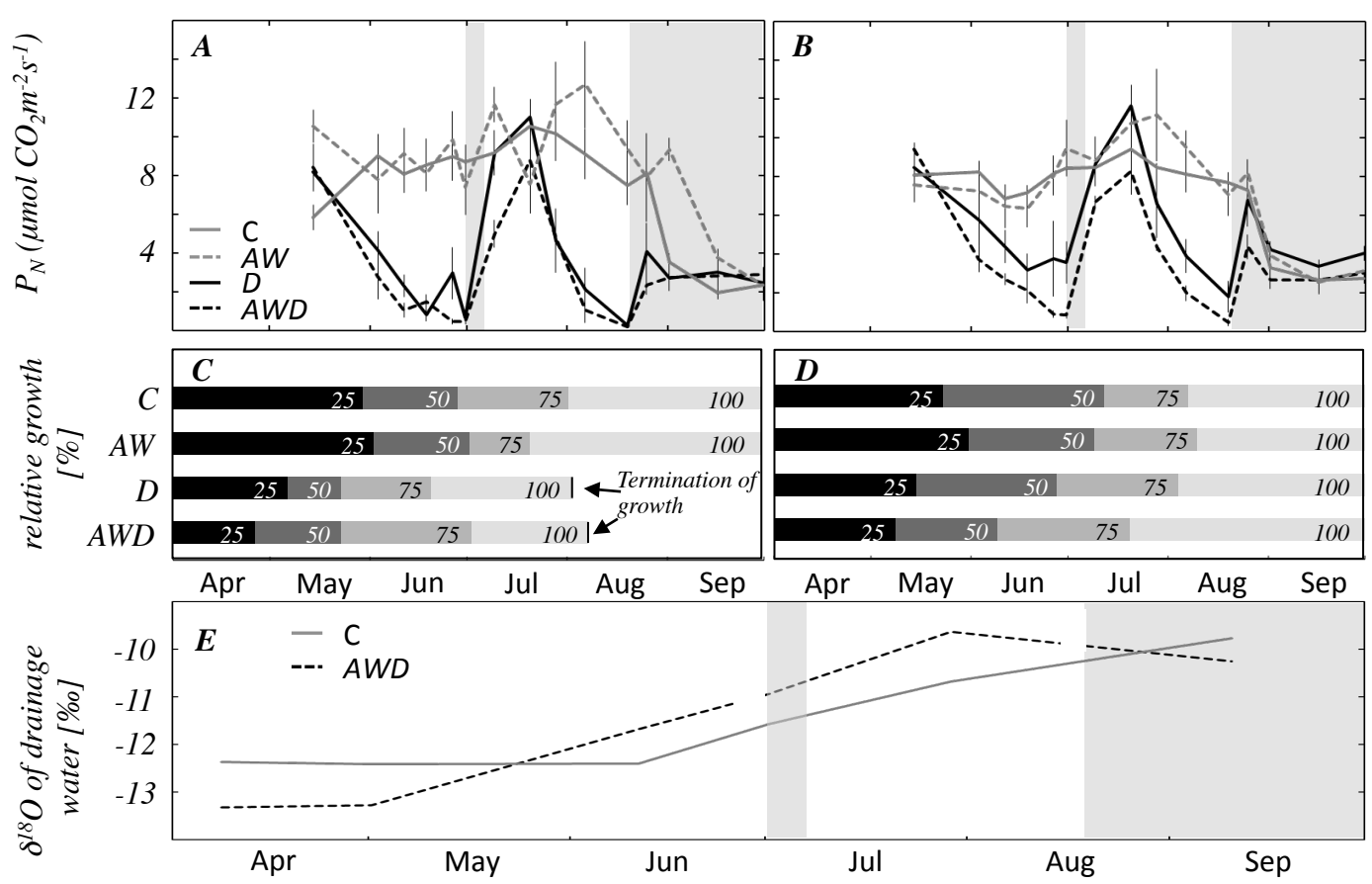
Sidorova et al.; Clim Dyn. DOI 10.1007/s00382-010-0989-6, 2011

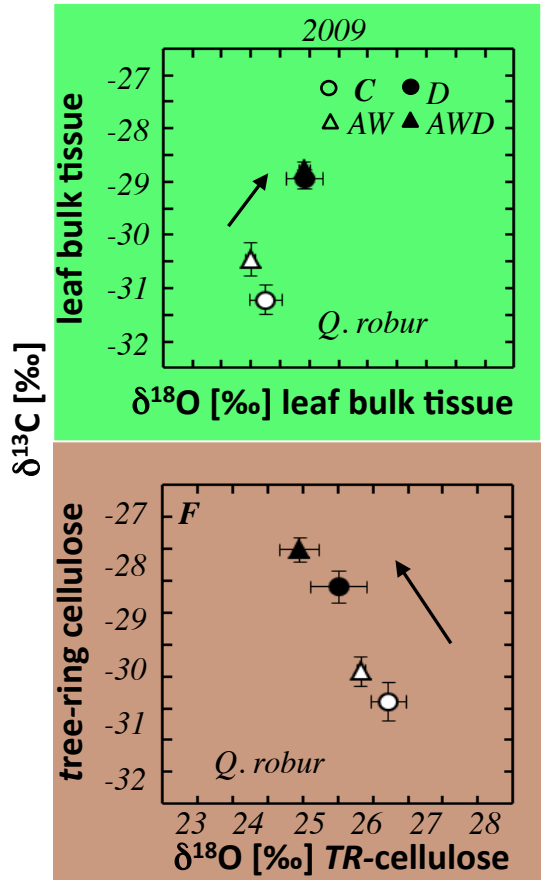
… or the Isotopic Trends Indicate a non Plausible Response



Pflug et alTree Phys. ; doi:10.1093/treephys/tpv079 , *2015*

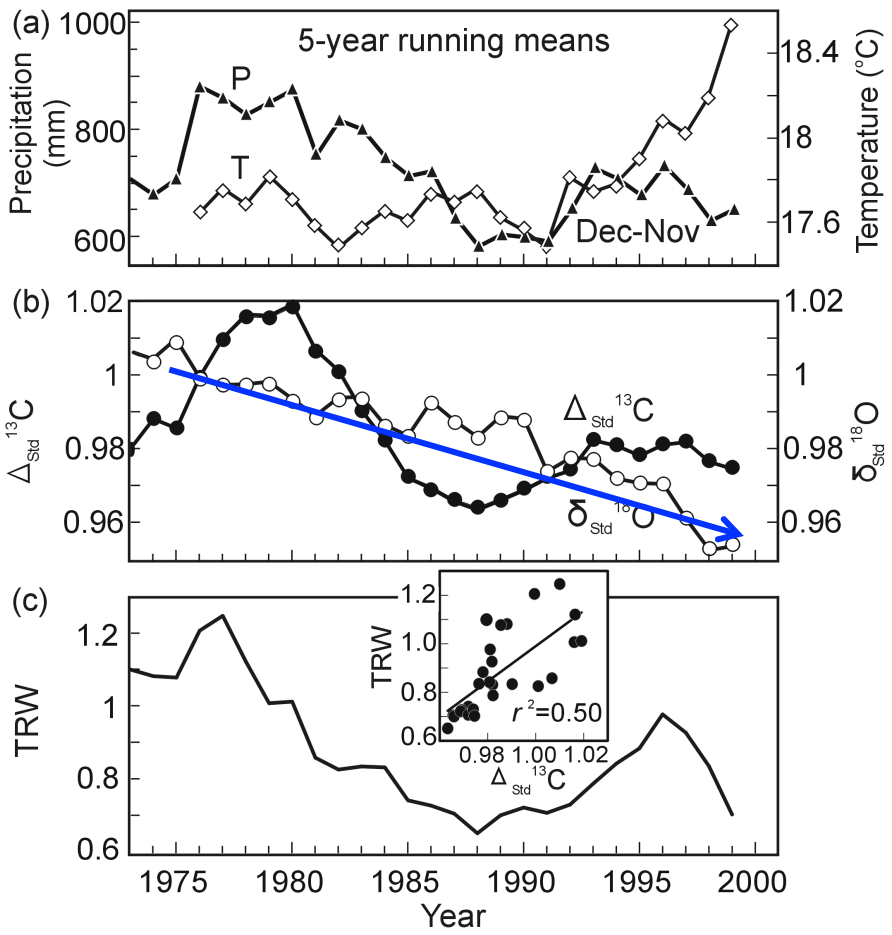
Cessation of Tree Ring growth → no Isotopic Signal

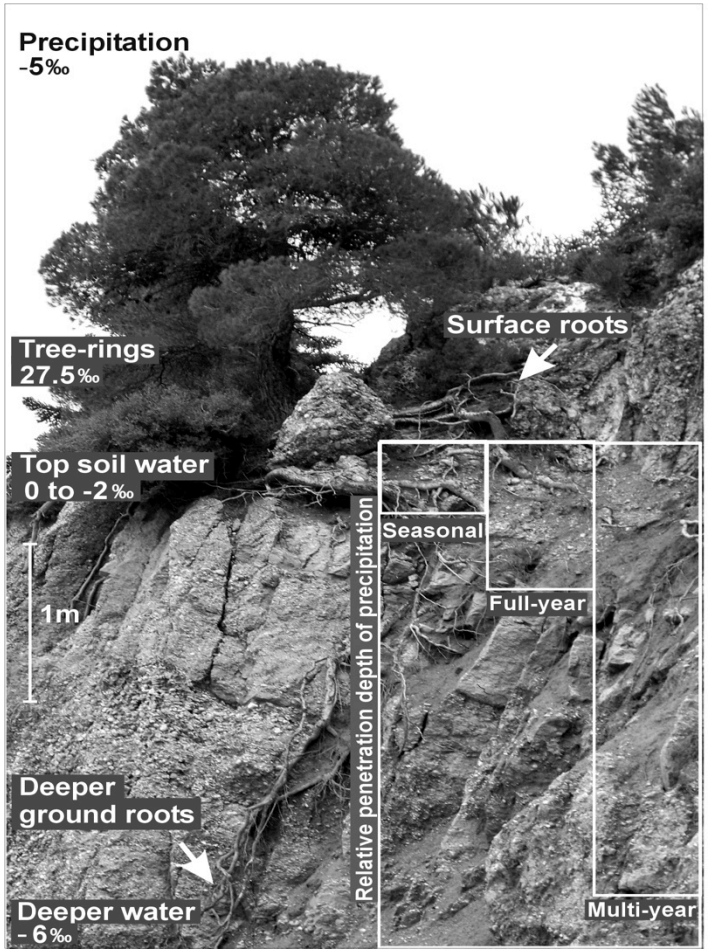




Pflug et alTree Phys. ; doi:10.1093/treephys/tpv079 , *2015*

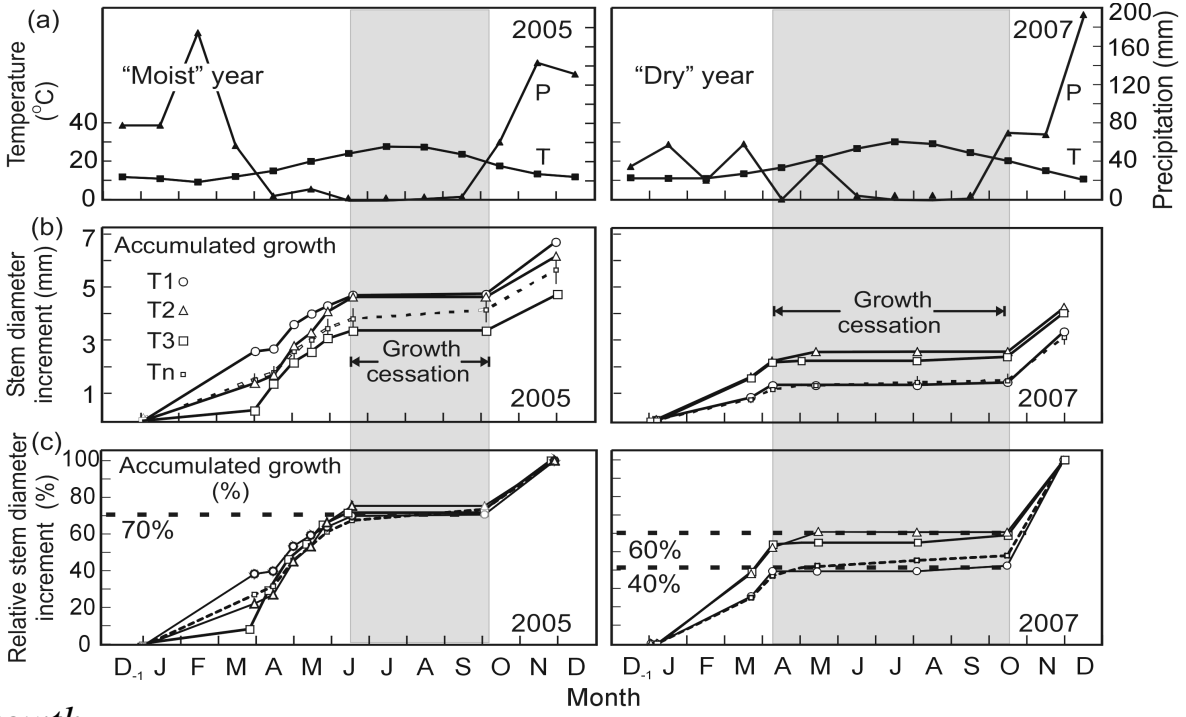
… or
Changes in the Source Water AND…

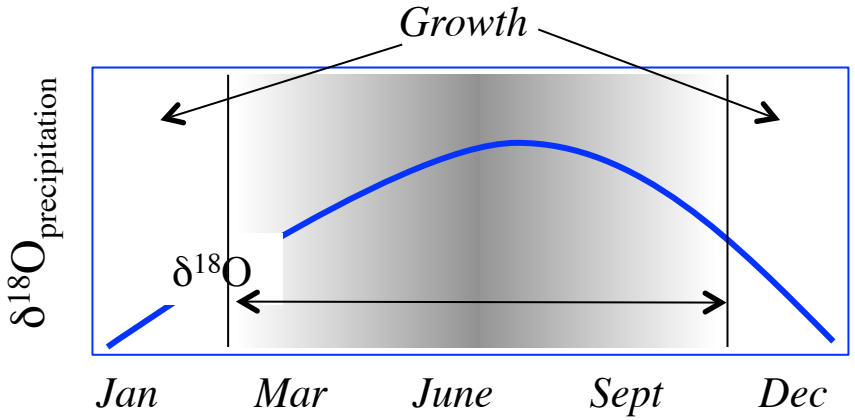


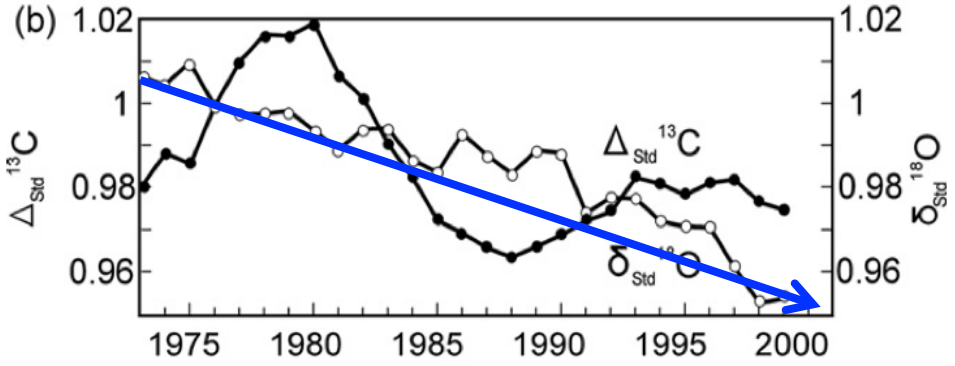


Sarris et al; Agric & Forest Met. ; 168, 59-, 2014

… Cessation of tree Ring Growth







Sarris et al; Agric & Forest Met. ; 168, 59-, 2014

Things to watch out for

- *Not all plants show the same stomatal sensitivity* → ***know your plants***
- *Soil water enrichment might mimic or at least enhance the effect of stomatal closure leading to an overestimation of the stomatal activity*
- *The ^{18}O enrichment-effect can be masked by dilution of the O-Isotope signal through xylem water during the transport of carbohydrates or by stored CnH2n*
- *Plant growing under humid conditions wont show large responses in g_l thus hardly in ^{18}O*
- *Disturbance of the A / g relationship: Air pollutants, e.g. Ozone -→ increase n PEP-Cx activity -→ $b \neq 27‰$*
- *Severe drought reduced transp. No growth, not signal storage*
- *Watch for the different scaling of the axes between isotopes and gas exchange*
- *Caution with regression analysis Horizontal / vertical lines have a physiological relevance even if r is very low*

Roden & Siegwolf Tree Physiology 32, 1179–1182

Conclusions

The dual isotope approach is a highly convenient ***diagnostic tool*** *even if the fractionation models yield unexpected results, i.e. if the plant is*

- severely stressed (air pollutants, severe drought, heavy N-fertilization)

Caution *is needed when applying this approach it won't just solve your problems*
ALWAYS *use it in the physiological context*


THANKS to …
…the PSI-SIRG lab and all the many colleagues who contributed with data and their valuable discussions
Photo by Anastasya Knorre