Water ages at the soil-root interface and beyond

Stefan Seeger and Markus Weiler

Albert-Ludwigs-Universität Freiburg

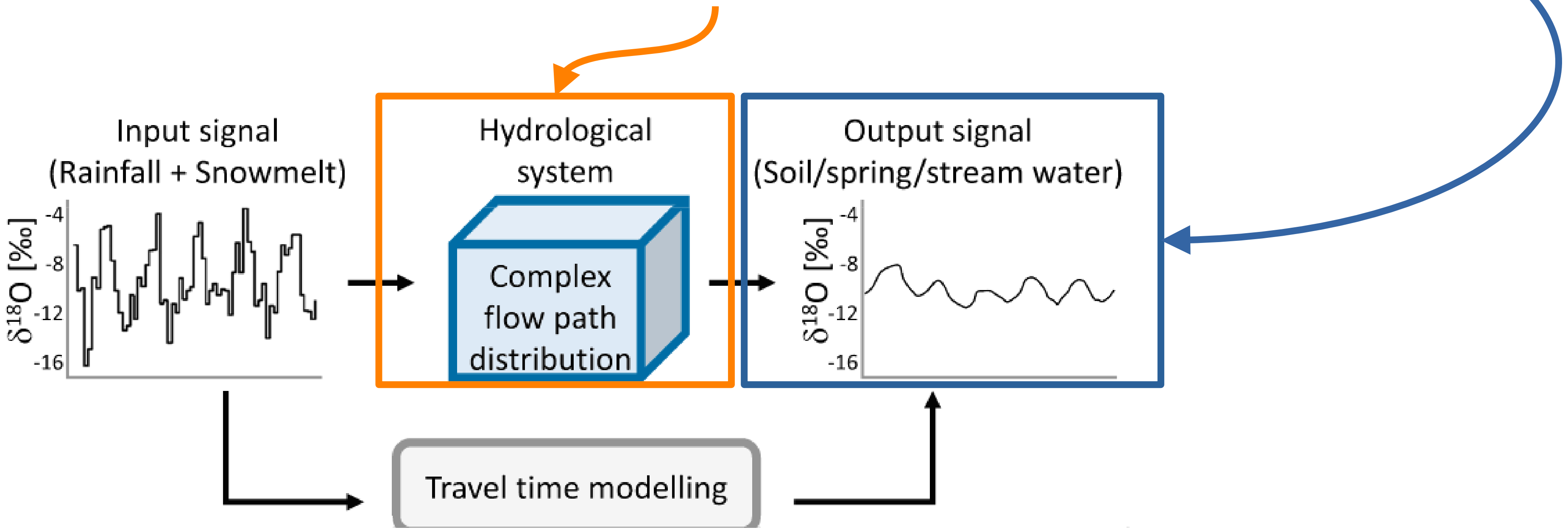
EGU: 2022-05-23

HYDROLOGY
UNI FREIBURG

Introduction

Getting this right...

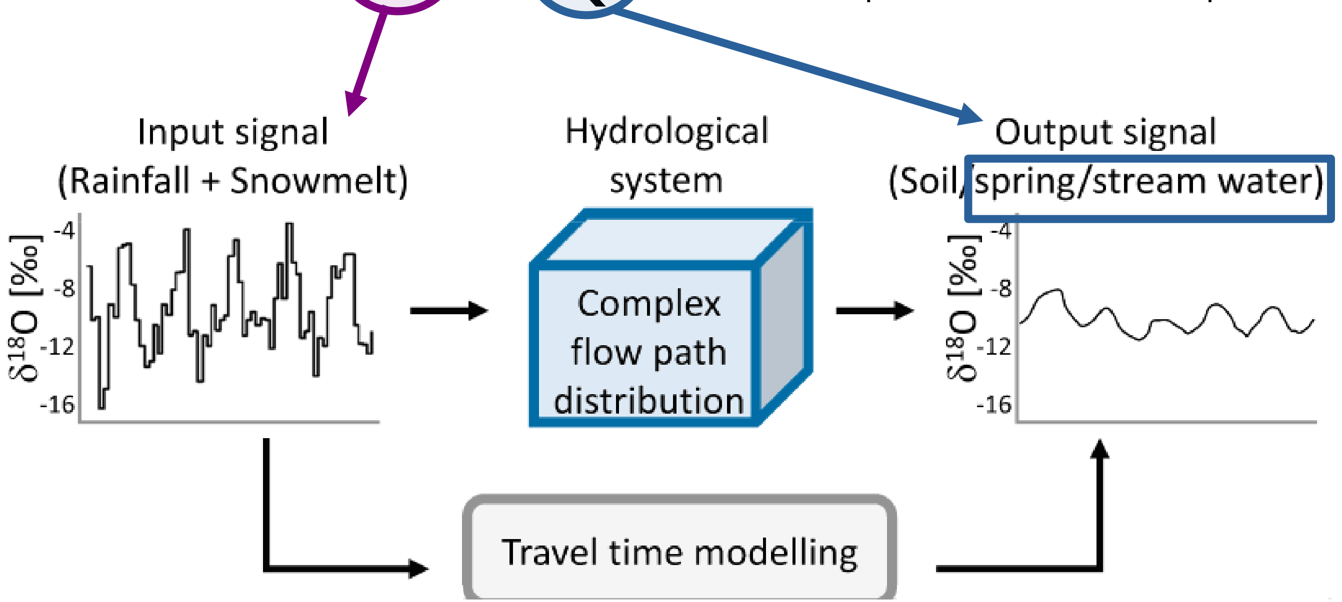
... increases confidence in our understanding of this.

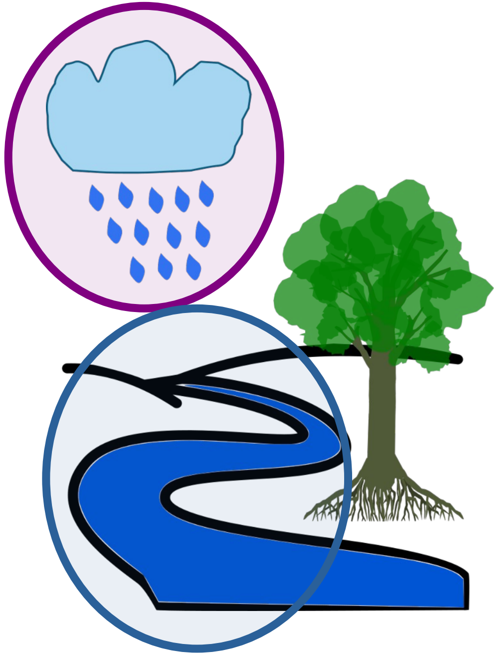


modified from Sprenger et al.: The demographics of water, ...
https://doi.org/10.1029/2018RG000633

Commonly focused on discharge:

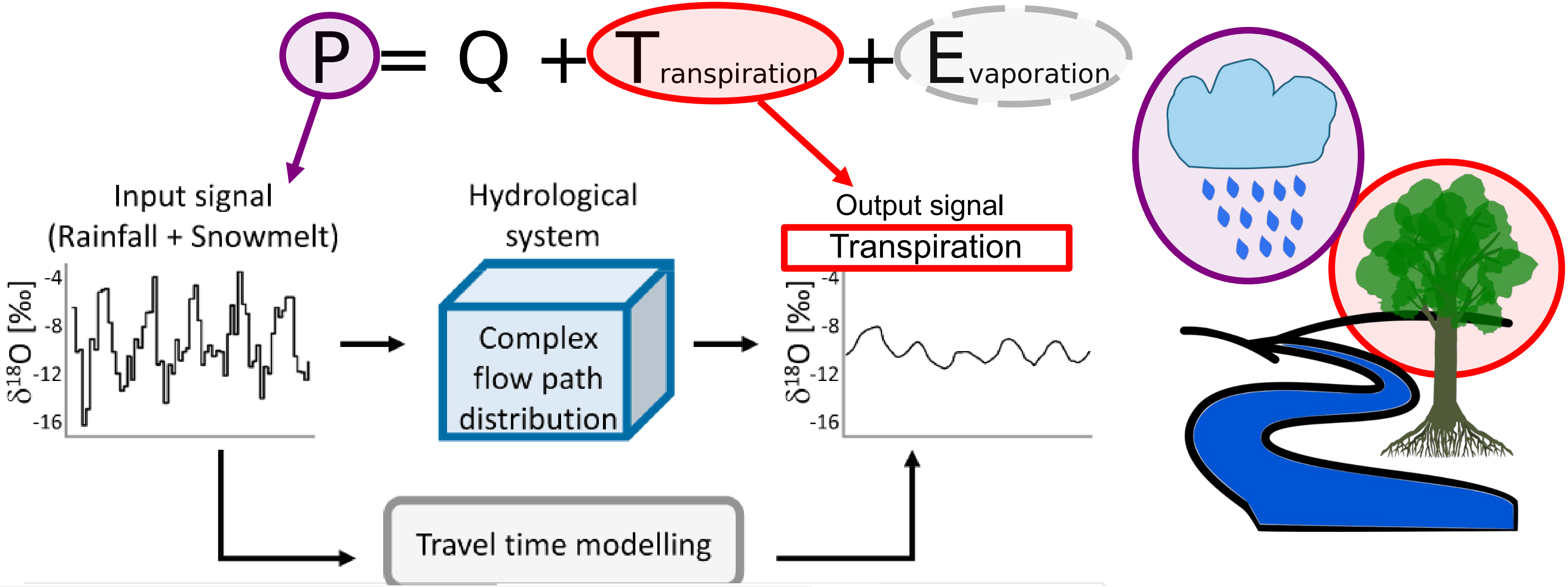
$$P = Q + T_{ranspiration} + E_{vaporation}$$





modified from Sprenger et al.: The demographics of water, ...
https://doi.org/10.1029/2018RG000633

But there are other ways out of the catchment!

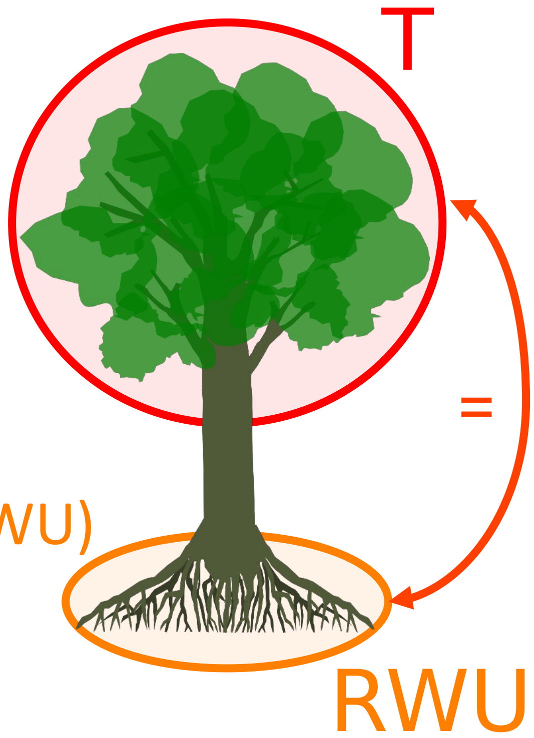


modified from Sprenger et al.: The demographics of water, ...
https://doi.org/10.1029/2018RG000633

Age distribution of RWU

- τ = age distribution of water sample
- δ = isotopic signature of water sample
- θ = volumetric soil water content

- Basic assumptions:
  - Transpiration (T) = Root water uptake (RWU)

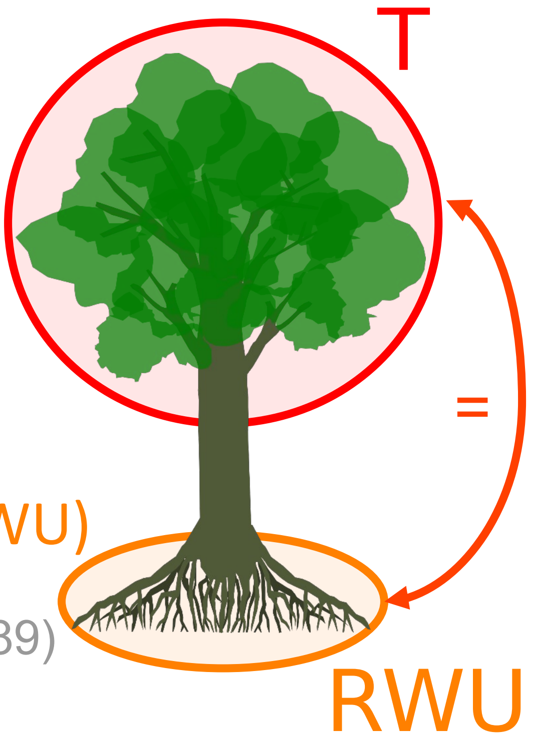


Age distribution of RWU

- τ = age distribution of water sample
- δ = isotopic signature of water sample
- θ = volumetric soil water content

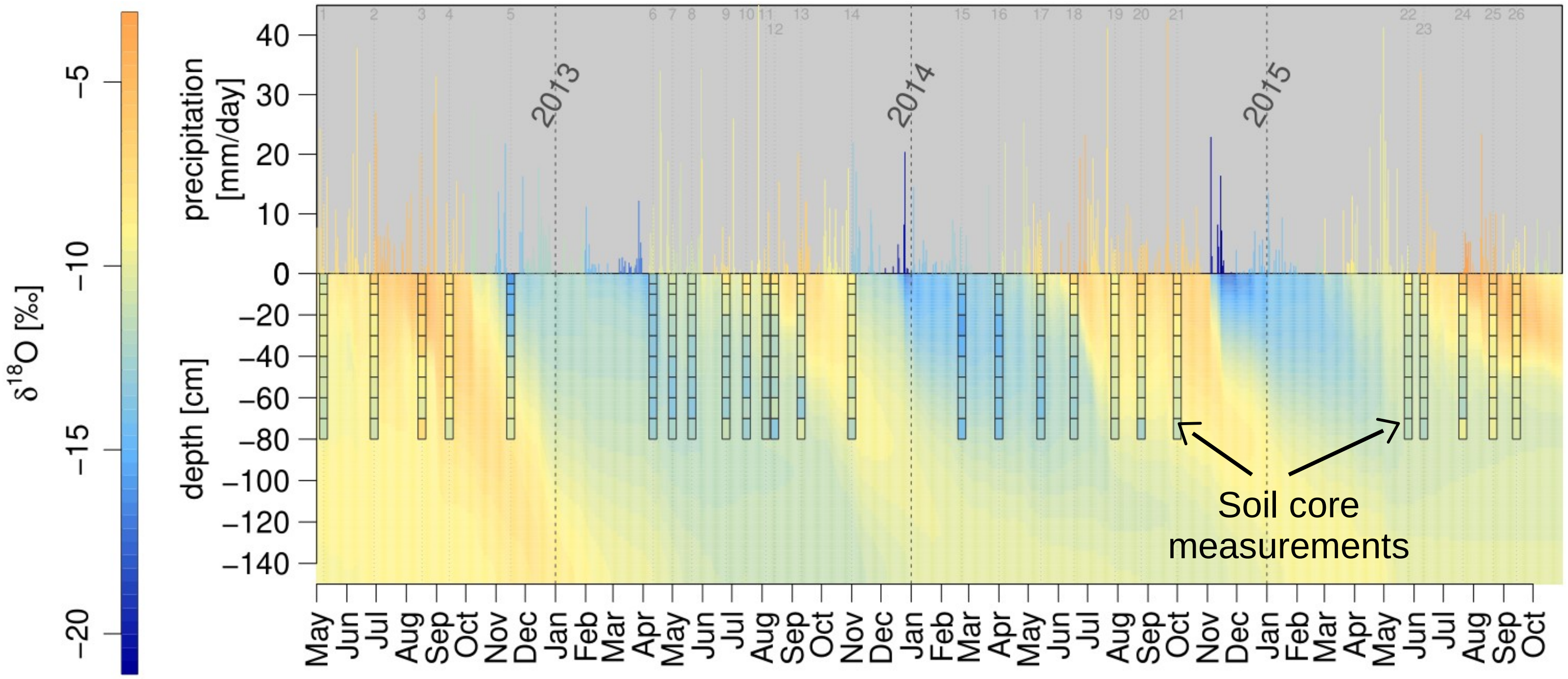
- Basic assumptions:
  - Transpiration (T) = Root water uptake (RWU)
  - RWU = f(R,α) Feddes et al. (1979), Jarvis (1989)

Root density distribution Water availability = f(θ)



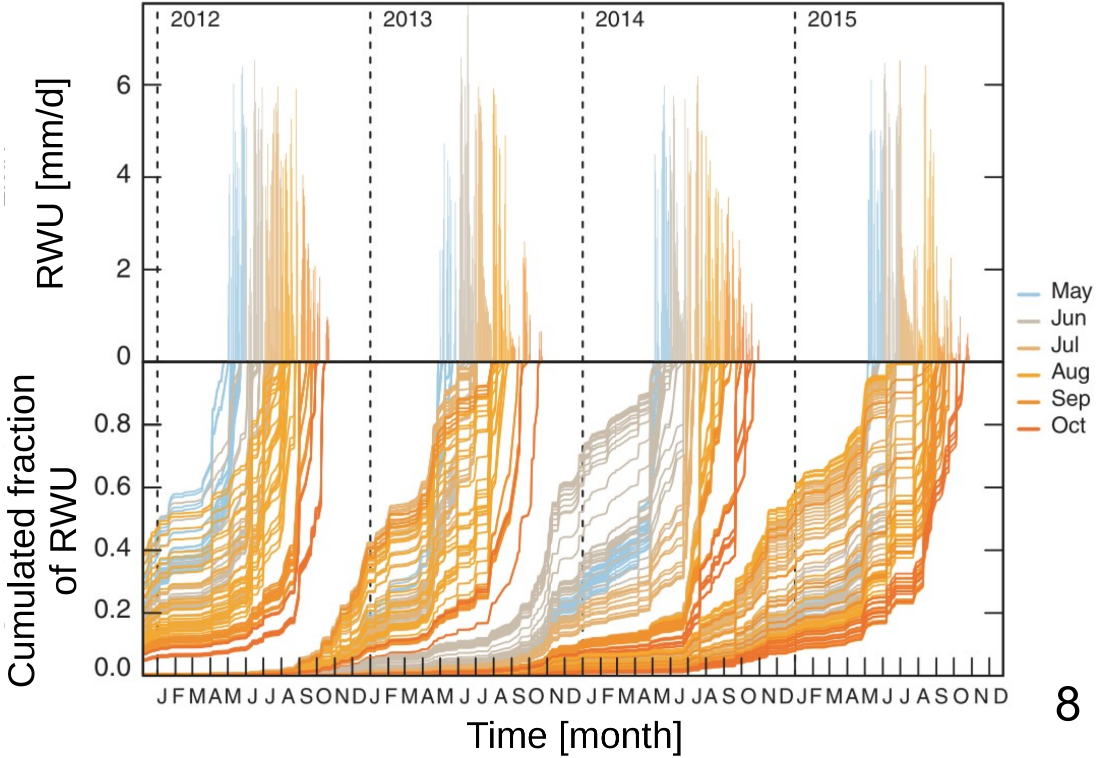
Age distribution of RWU

Step 1: Optimize soil hydraulic model to reach a good fit between simulated and observed soil isotopic depth profiles



Step 2: Application of virtual tracers in optimized soil hydraulic model to infer τ_{Soil} at each simulation day

- τ_{RWU} is determined by τ_{Soil} and RWU



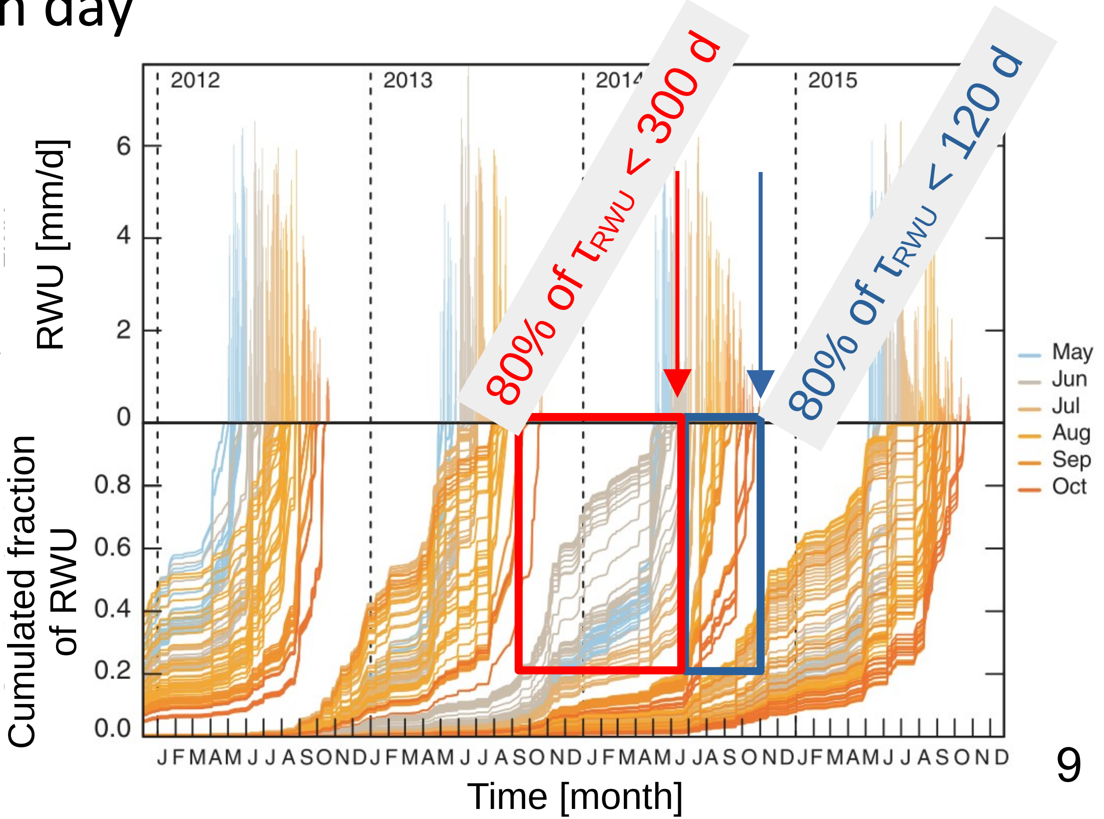
Age distribution of RWU

Step 2: Application of virtual tracers in optimized soil hydraulic model to infer τ_{Soil} at each simulation day

- τ_{RWU} is determined by τ_{Soil} and RWU

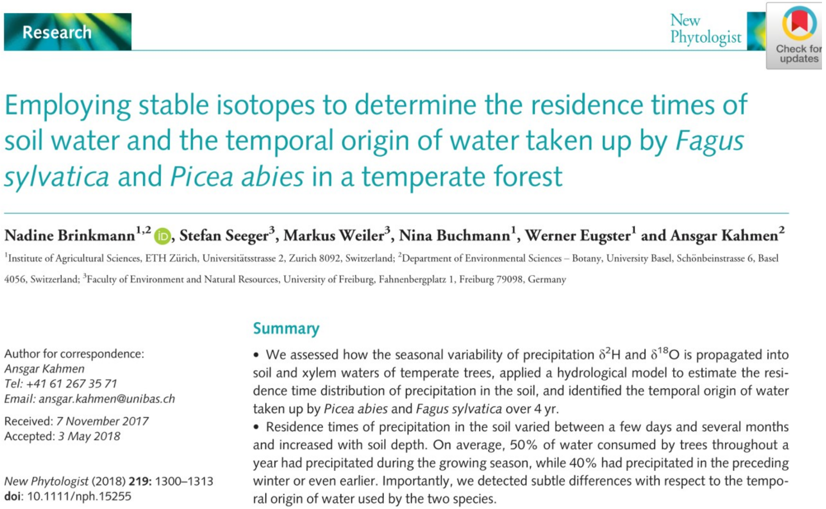
➔ Variability of τ_{RWU} is mainly tied to variability of τ_{Soil}

➔ Shifts of RWU source depths also shape τ_{RWU}



Validation of modeling approach

- Good agreement between modeled δ_{RWU} and measured twig xylem water samples.



Research

New Phytologist

Check for updates

Employing stable isotopes to determine the residence times of soil water and the temporal origin of water taken up by *Fagus sylvatica* and *Picea abies* in a temperate forest

Nadine Brinkmann[1,2], Stefan Seeger[3], Markus Weiler[3], Nina Buchmann[1], Werner Eugster[1] and Ansgar Kahmen[2]

[1]Institute of Agricultural Sciences, ETH Zürich, Universitätsstrasse 2, Zurich 8092, Switzerland; [2]Department of Environmental Sciences – Botany, University Basel, Schönbeinstrasse 6, Basel 4056, Switzerland; [3]Faculty of Environment and Natural Resources, University of Freiburg, Fahnenbergplatz 1, Freiburg 79098, Germany

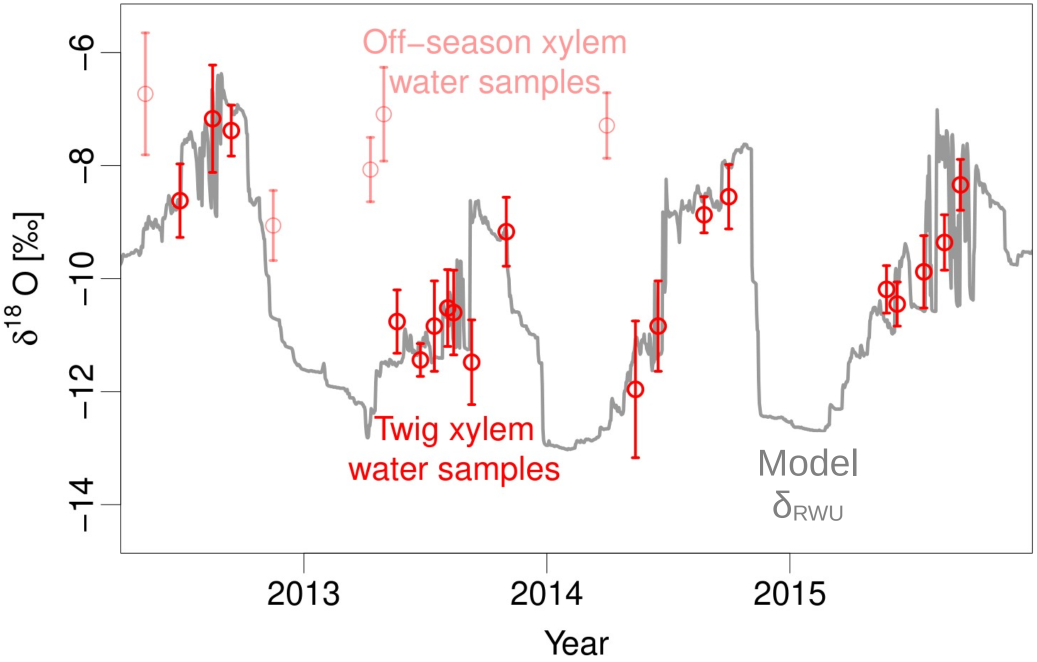
Author for correspondence:
Ansgar Kahmen
Tel: +41 61 267 35 71
Email: ansgar.kahmen@unibas.ch

Received: *7 November 2017*
Accepted: *3 May 2018*

New Phytologist (2018) **219:** 1300–1313
doi: 10.1111/nph.15255

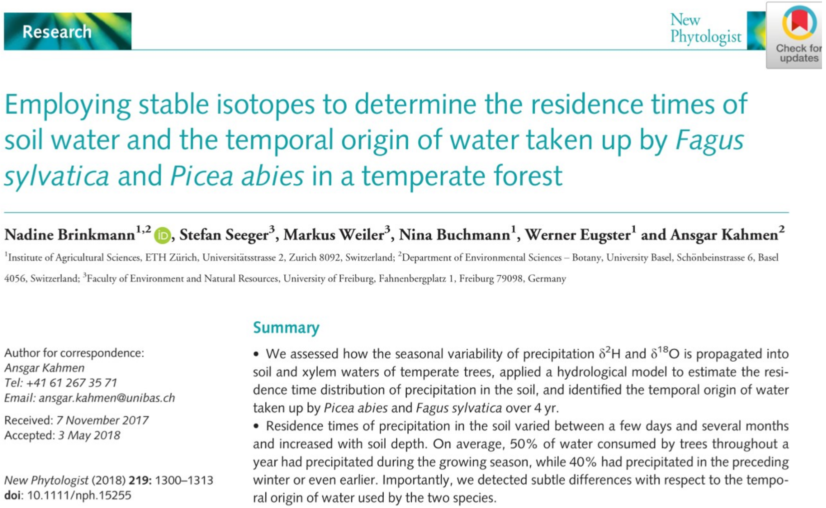
Summary

- We assessed how the seasonal variability of precipitation δ^2H and $\delta^{18}O$ is propagated into soil and xylem waters of temperate trees, applied a hydrological model to estimate the residence time distribution of precipitation in the soil, and identified the temporal origin of water taken up by *Picea abies* and *Fagus sylvatica* over 4 yr.
- Residence times of precipitation in the soil varied between a few days and several months and increased with soil depth. On average, 50% of water consumed by trees throughout a year had precipitated during the growing season, while 40% had precipitated in the preceding winter or even earlier. Importantly, we detected subtle differences with respect to the temporal origin of water used by the two species.



Validation of modeling approach

- Good agreement between modeled δ_{RWU} and measured twig xylem water samples.



Research

New Phytologist

Check for updates

Employing stable isotopes to determine the residence times of soil water and the temporal origin of water taken up by *Fagus sylvatica* and *Picea abies* in a temperate forest

Nadine Brinkmann[1,2], Stefan Seeger[3], Markus Weiler[3], Nina Buchmann[1], Werner Eugster[1] and Ansgar Kahmen[2]

[1]Institute of Agricultural Sciences, ETH Zürich, Universitätsstrasse 2, Zurich 8092, Switzerland; [2]Department of Environmental Sciences – Botany, University Basel, Schönbeinstrasse 6, Basel 4056, Switzerland; [3]Faculty of Environment and Natural Resources, University of Freiburg, Fahnenbergplatz 1, Freiburg 79098, Germany

Author for correspondence:
Ansgar Kahmen
Tel: +41 61 267 35 71
Email: ansgar.kahmen@unibas.ch

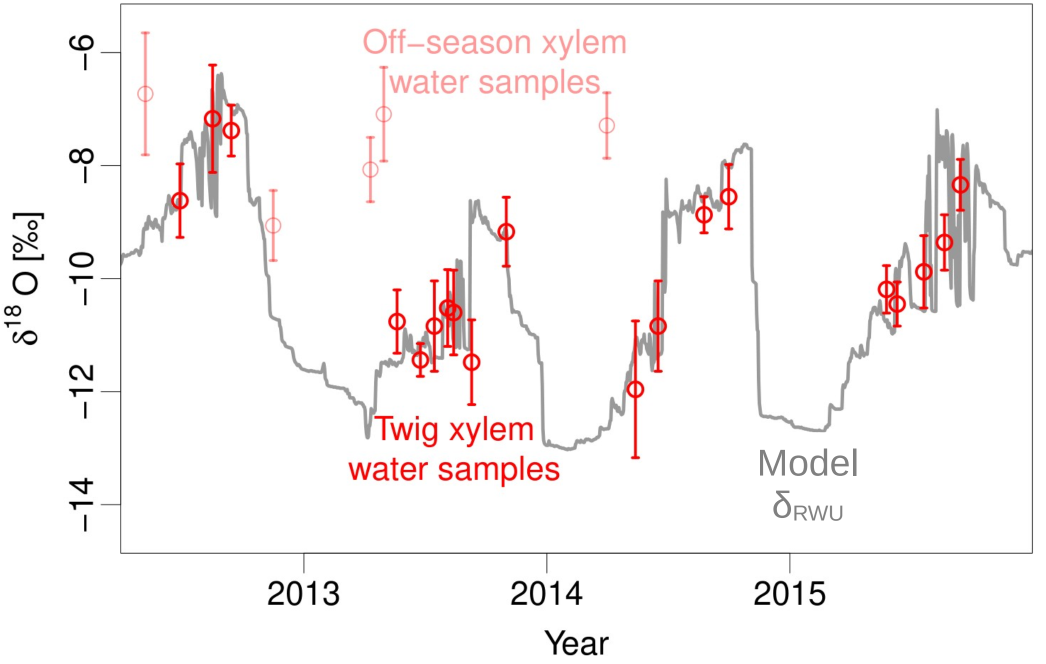
Received: *7 November 2017*
Accepted: *3 May 2018*

New Phytologist (2018) **219:** 1300–1313
doi: 10.1111/nph.15255

Summary

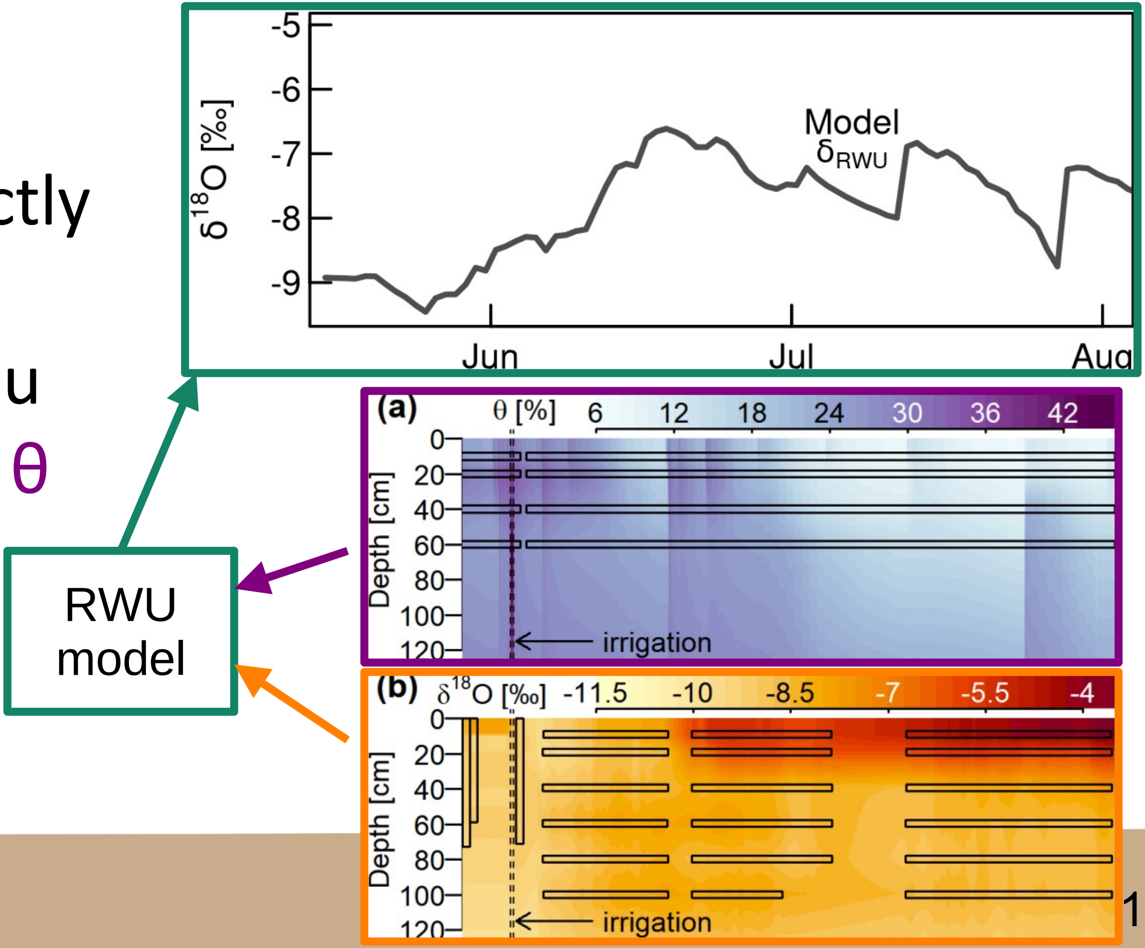
- We assessed how the seasonal variability of precipitation δ^2H and $\delta^{18}O$ is propagated into soil and xylem waters of temperate trees, applied a hydrological model to estimate the residence time distribution of precipitation in the soil, and identified the temporal origin of water taken up by *Picea abies* and *Fagus sylvatica* over 4 yr.
- Residence times of precipitation in the soil varied between a few days and several months and increased with soil depth. On average, 50% of water consumed by trees throughout a year had precipitated during the growing season, while 40% had precipitated in the preceding winter or even earlier. Importantly, we detected subtle differences with respect to the temporal origin of water used by the two species.

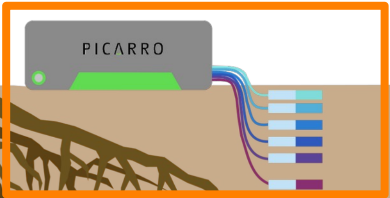
- But only 20 data points in 4 years!



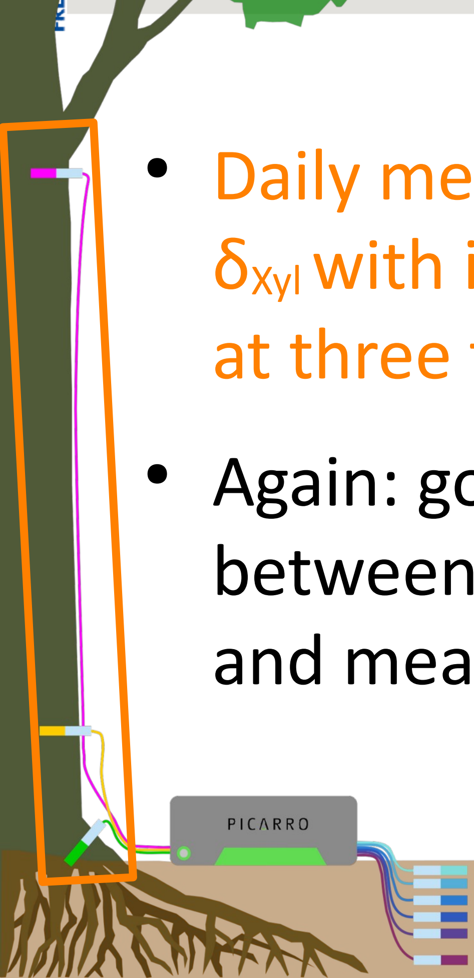
Higher temporal resolution with in-situ measurements

- δ_{RWU} inferred directly from spatially interpolated in-situ measurements of θ and δ_{Soil}

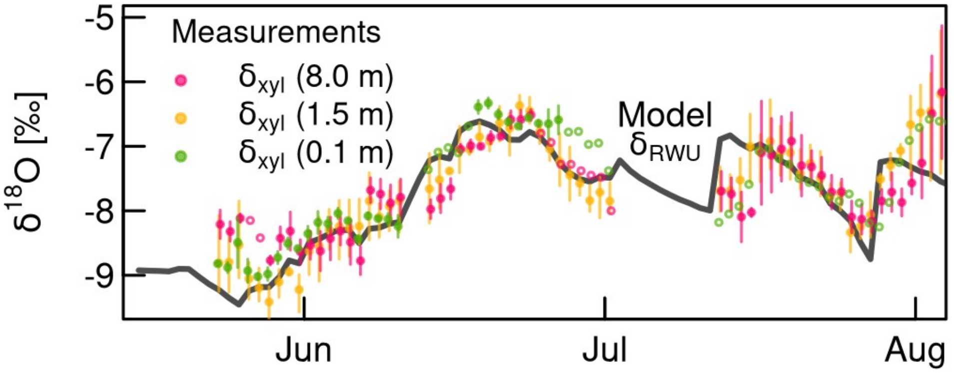




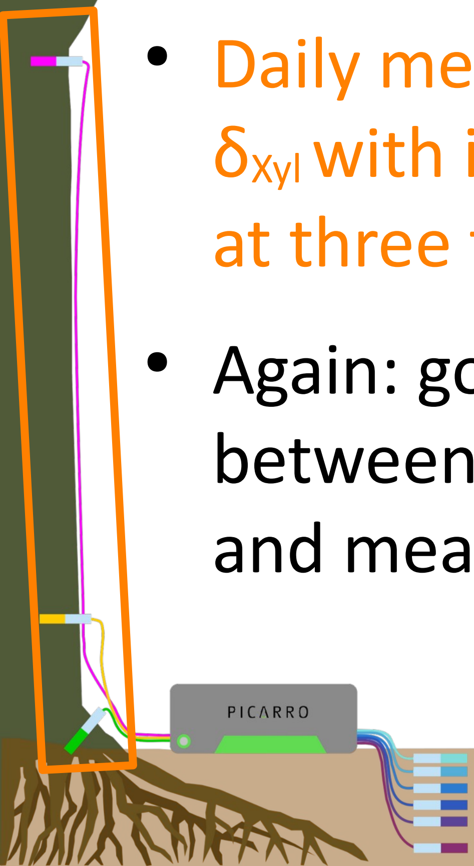
Higher temporal resolution with in-situ measurements



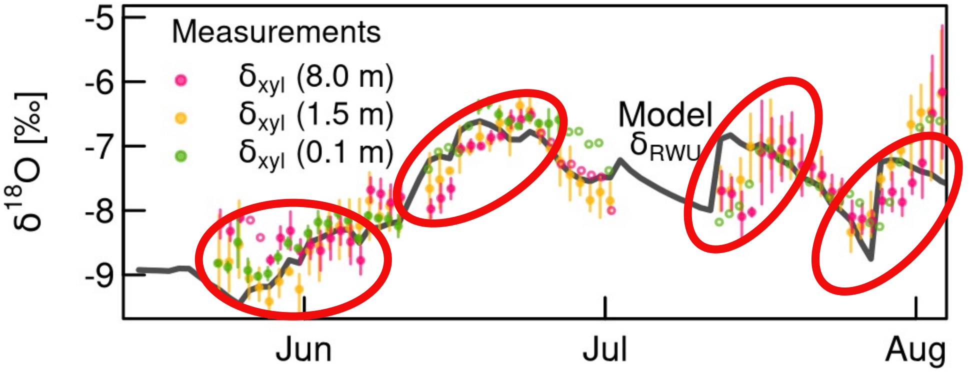
- Daily measurements of δ_{Xyl} with in-situ probes at three trunk heights
- Again: good agreement between modeled δ_{RWU} and measured δ_{Xyl}



Higher temporal resolution with in-situ measurements



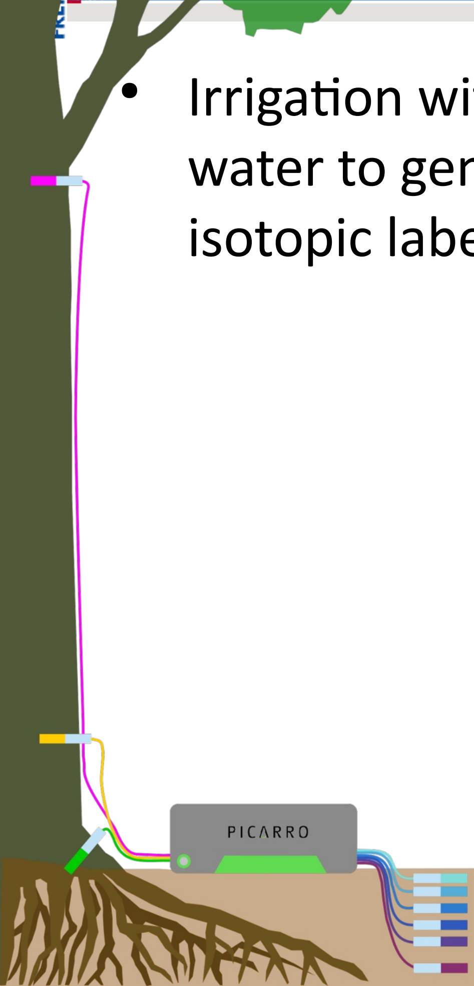
- Daily measurements of δ_{Xyl} with in-situ probes at three trunk heights
- Again: good agreement between modeled δ_{RWU} and measured δ_{Xyl}

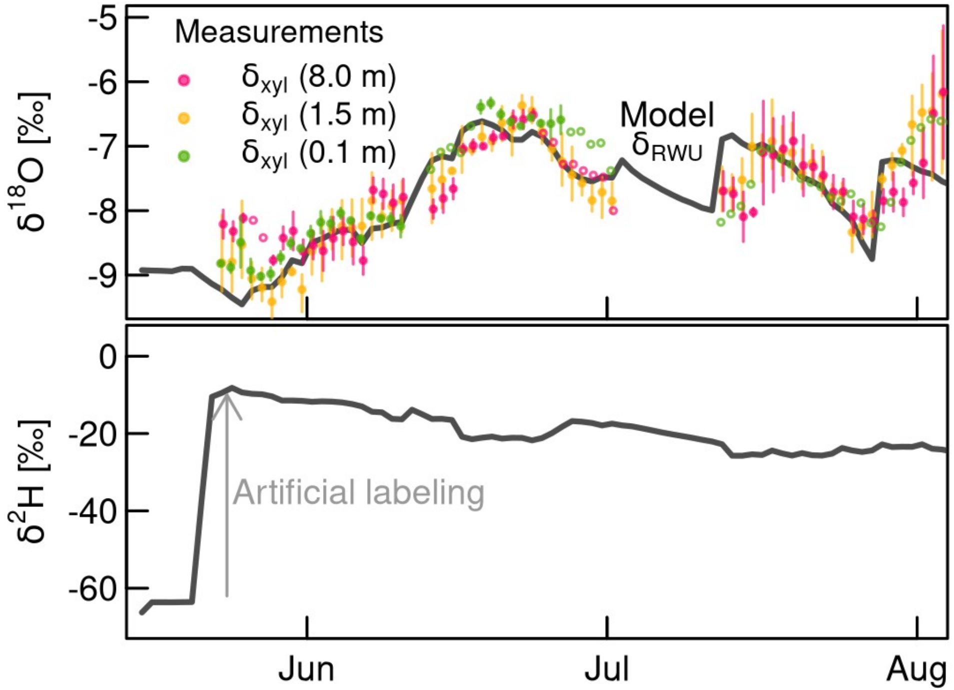


- … but is that a delay between δ_{RWU} and δ_{Xyl} ?

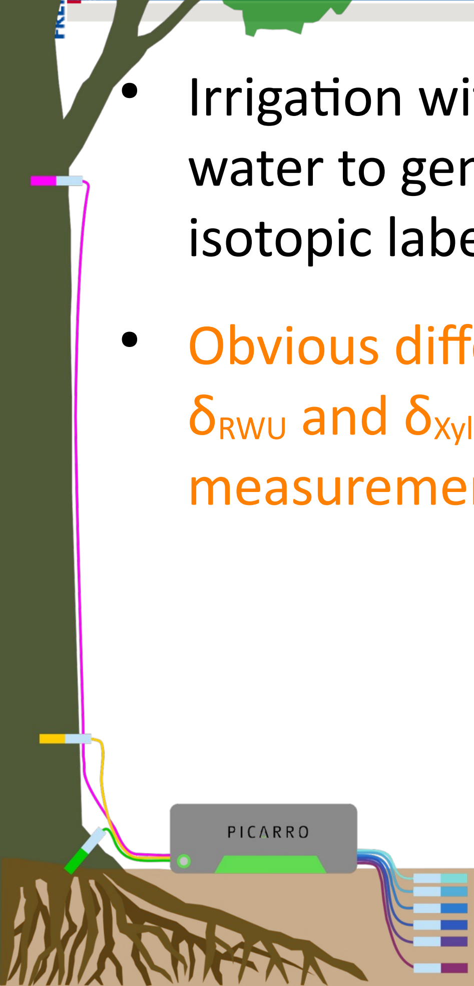
Higher temporal resolution with in-situ measurements

- Irrigation with D_2O labeled water to generate a strong isotopic labeling pulse



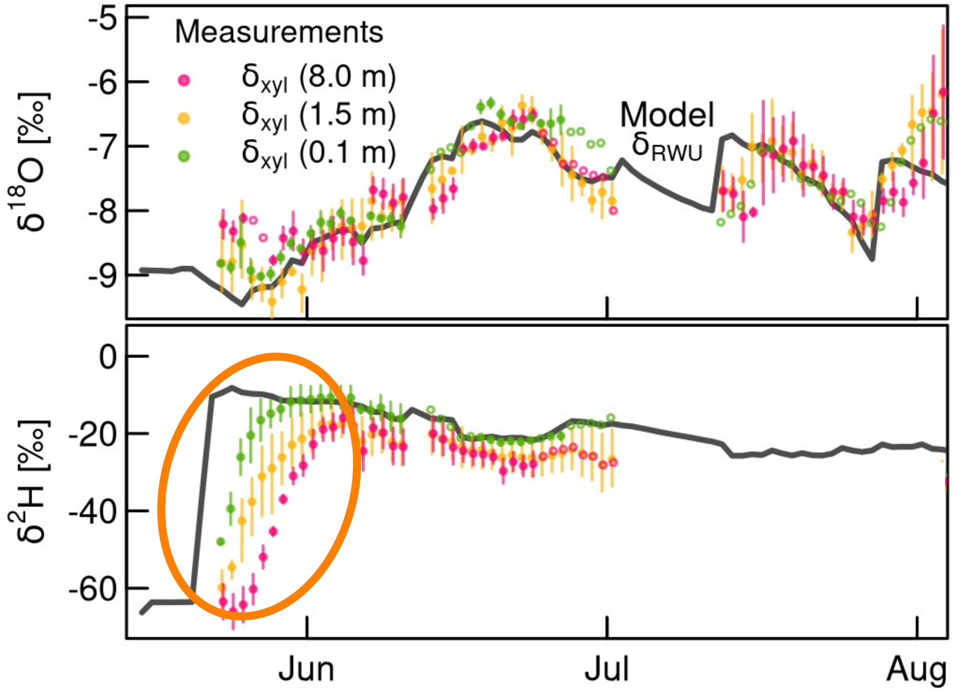


Higher temporal resolution with in-situ measurements

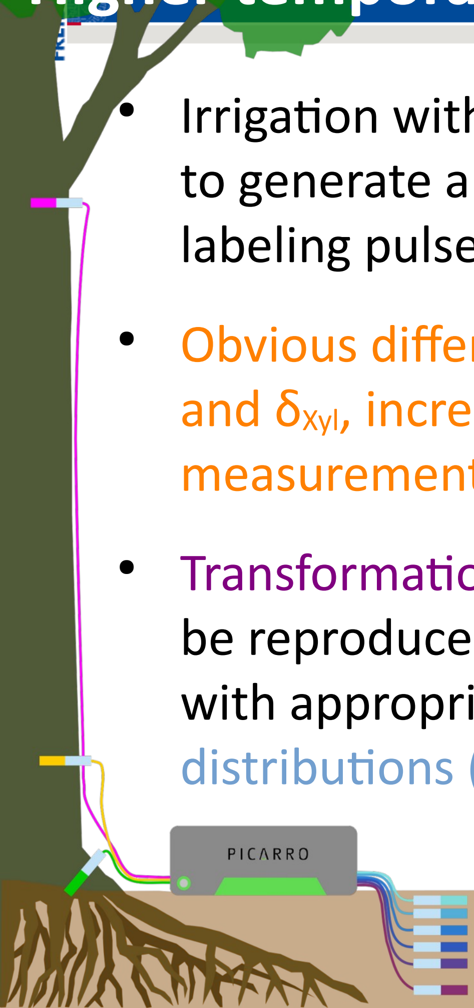


- Irrigation with D_2O labeled water to generate a strong isotopic labeling pulse

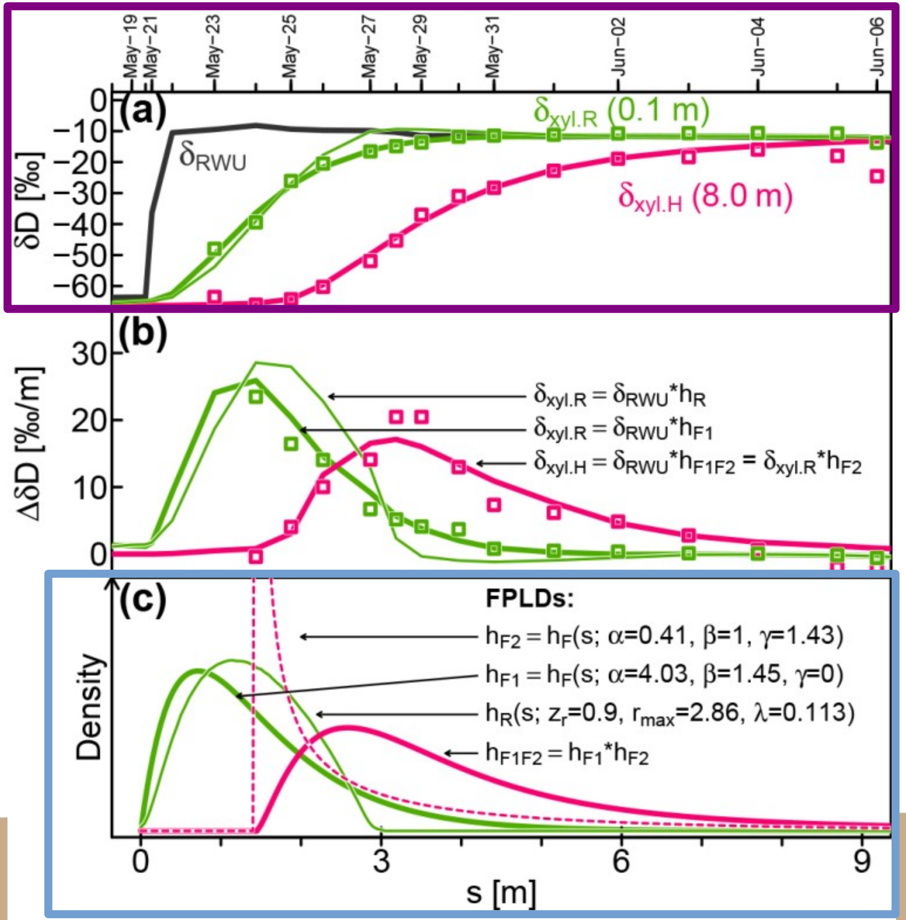
- Obvious difference between δ_{RWU} and δ_{Xyl}, increasing with measurement height



Higher temporal resolution with in-situ measurements

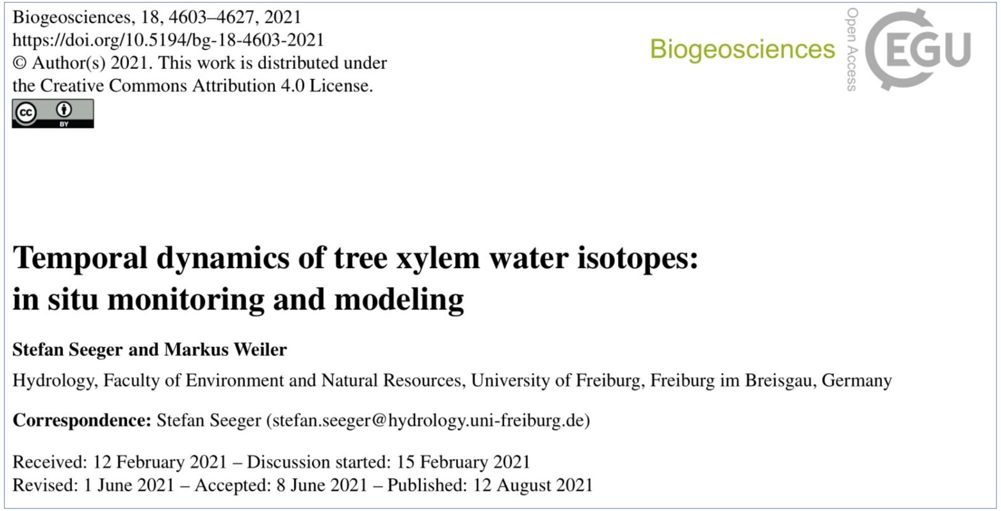


- Irrigation with D_2O labeled water to generate a strong isotopic labeling pulse
- Obvious difference between δ_{RWU} and δ_{Xyl}, increasing with measurement height
- Transformation of δ_{RWU} to δ_{Xyl} can be reproduced via convolution with appropriate flow path length distributions (FPLDs)



Travel times between RWU and δ_{Xyl} measurement

- FPLDs combined with sap flow velocities → τ_{Xyl}
- Older fractions of water sampled at higher heights can be weeks older than RWU

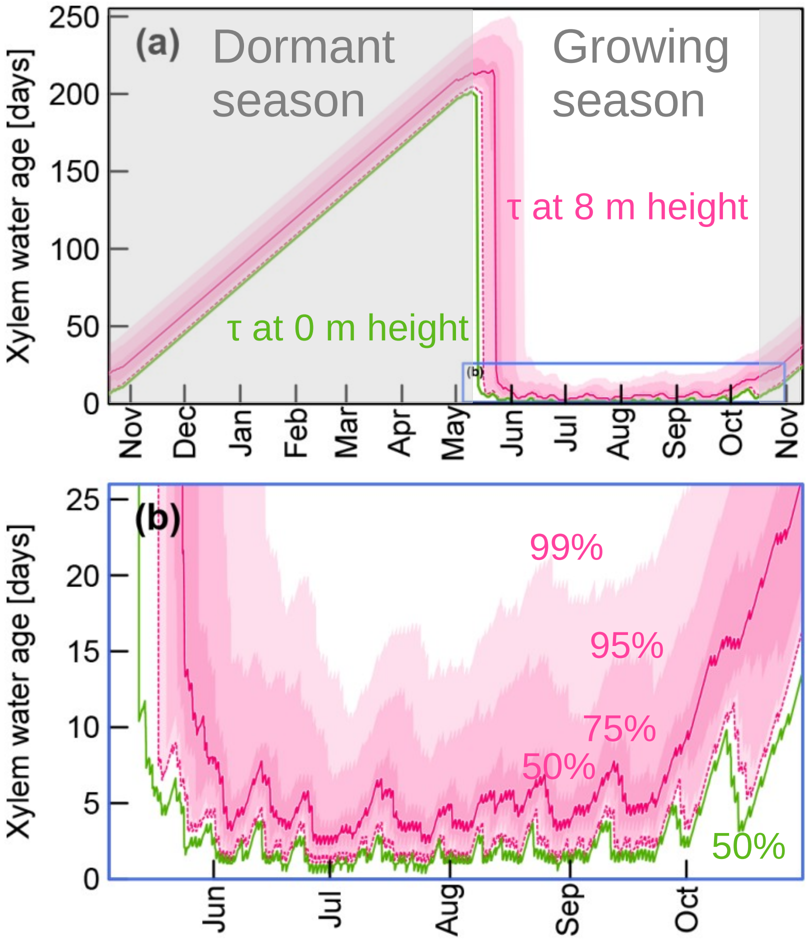

Biogeosciences, 18, 4603–4627, 2021
https://doi.org/10.5194/bg-18-4603-2021

Biogeosciences
Open Access
EGU

Temporal dynamics of tree xylem water isotopes: in situ monitoring and modeling

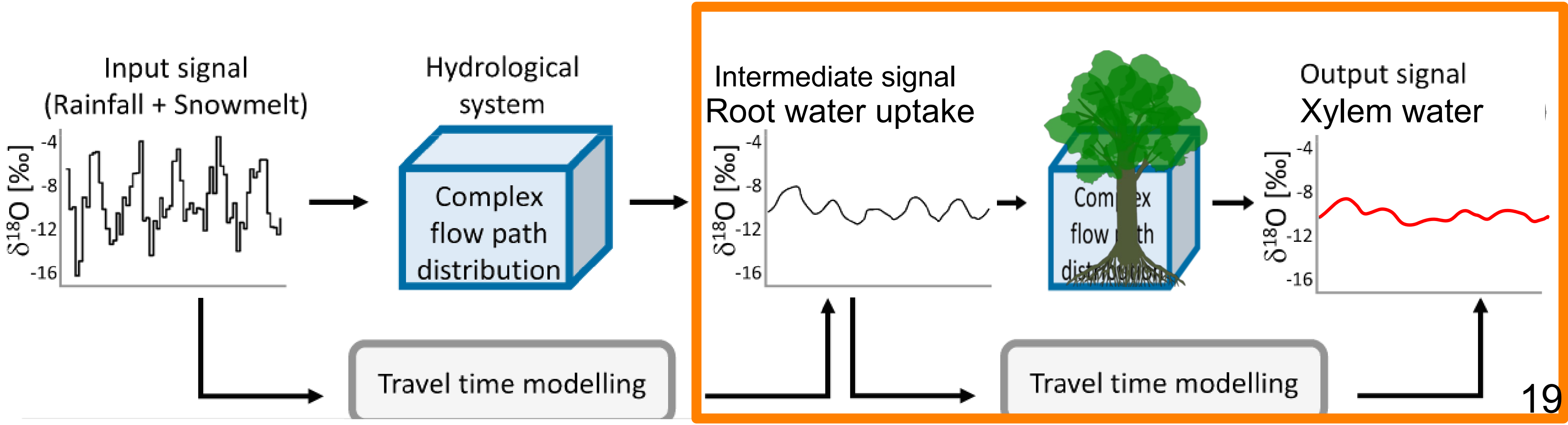
Stefan Seeger and Markus Weiler
Hydrology, Faculty of Environment and Natural Resources, University of Freiburg, Freiburg im Breisgau, Germany
Correspondence: Stefan Seeger (stefan.seeger@hydrology.uni-freiburg.de)

Received: 12 February 2021 – Discussion started: 15 February 2021
Revised: 1 June 2021 – Accepted: 8 June 2021 – Published: 12 August 2021



Conclusion

- Established RWU models work fairly well to predict δ_{RWU}
- At higher temporal resolutions representation of tree internal travel times might be necessary for comparisons between modeled δ_{RWU} and measured δ_{Xyl}



Thank you for your attention!

In case of questions and/or suggestions:

stefan.seeger@hydrology.uni-freiburg.de

My work on researchgate:

Related contribution at this conference:
BG3.23, EGU22-8274
Fri, 27 May, 14:02–14:07 Room 3.16/17