# Unrevealing tree carbon allocation beyond the stress – a case study of heat and drought impacts on *Pinus sylvestris*

Institute of Meteorology and Climate Research - Atmospheric & Environmental Research, Garmisch-Partenkirchen, Germany

**Romy Rehschuh**[1], Andreas Gast[1], Andrea Jakab[1], Marco Lehmann[2], Matthias Saurer[2], Arthur Gessler[2], Nadine Ruehr[1]

romy.rehschuh@kit.edu

1 Karlsruhe Institute of Technology KIT, Institute of Meteorology and Climate Research, 82467 Garmisch-Partenkirchen, Germany
2 Swiss Federal Research Institute WSL, 8903 Birmensdorf, Switzerland

## Motivation and Objectives

- Global climate predictions: combined heat & drought
→ Change of C allocation and storage → tree functioning?
- Scots pine = ecologically and economically important
- predictions about resilience of our forests

### Research questions:

1. How does **carbon allocation** to respiration, pools and biomass vary between recovery from heat and drought-heat stress?
2. Are the **retention times** of **recently assimilated C** in the different compartments and pools related to previous stress severity?
3. Is **recently assimilated C** preferably allocated to **growth** or **storage** shortly after stress release?

**Treatments: Control, Heat, Drought-Heat**
**Recovery: Re-watering & temperature decrease**

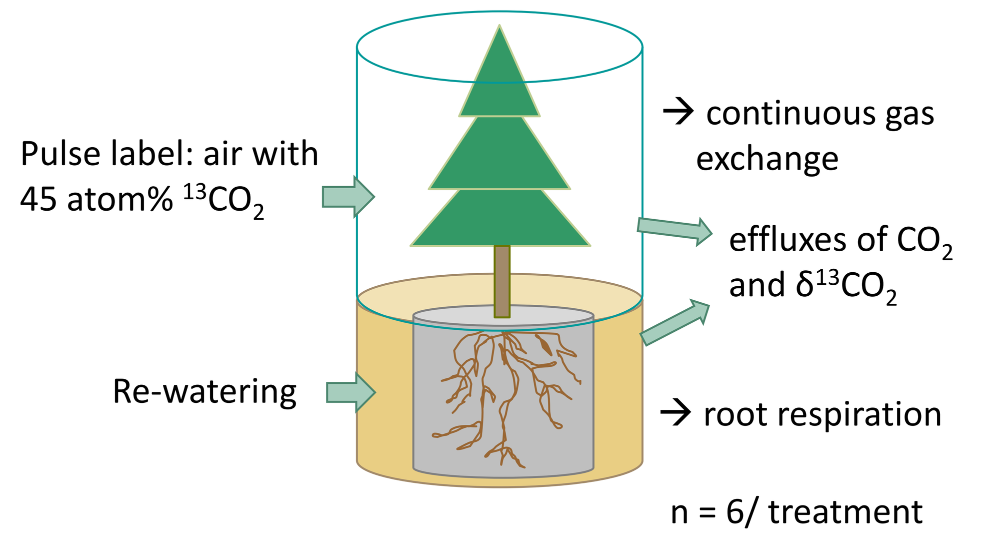


**Fig. 1:** Chambers separated in above- and belowground used for continuous gas exchange measurements and labeling. Pulse-labeling was conducted two days after stress release.

## Material and Methods

- 3-year-old *Pinus sylvestris* saplings
- in C-free substrate
- microbial wash
- separate tree chambers
- close-to-realistic heat-drought scenarios

### Measurements:

- Needle water potential (predawn & midday)
- Leaf temperature
- Dendrometer: Stem growth
- $\delta^{13}C$ analysis in plant tissues (bulk, water soluble compounds, starch & cellulose)

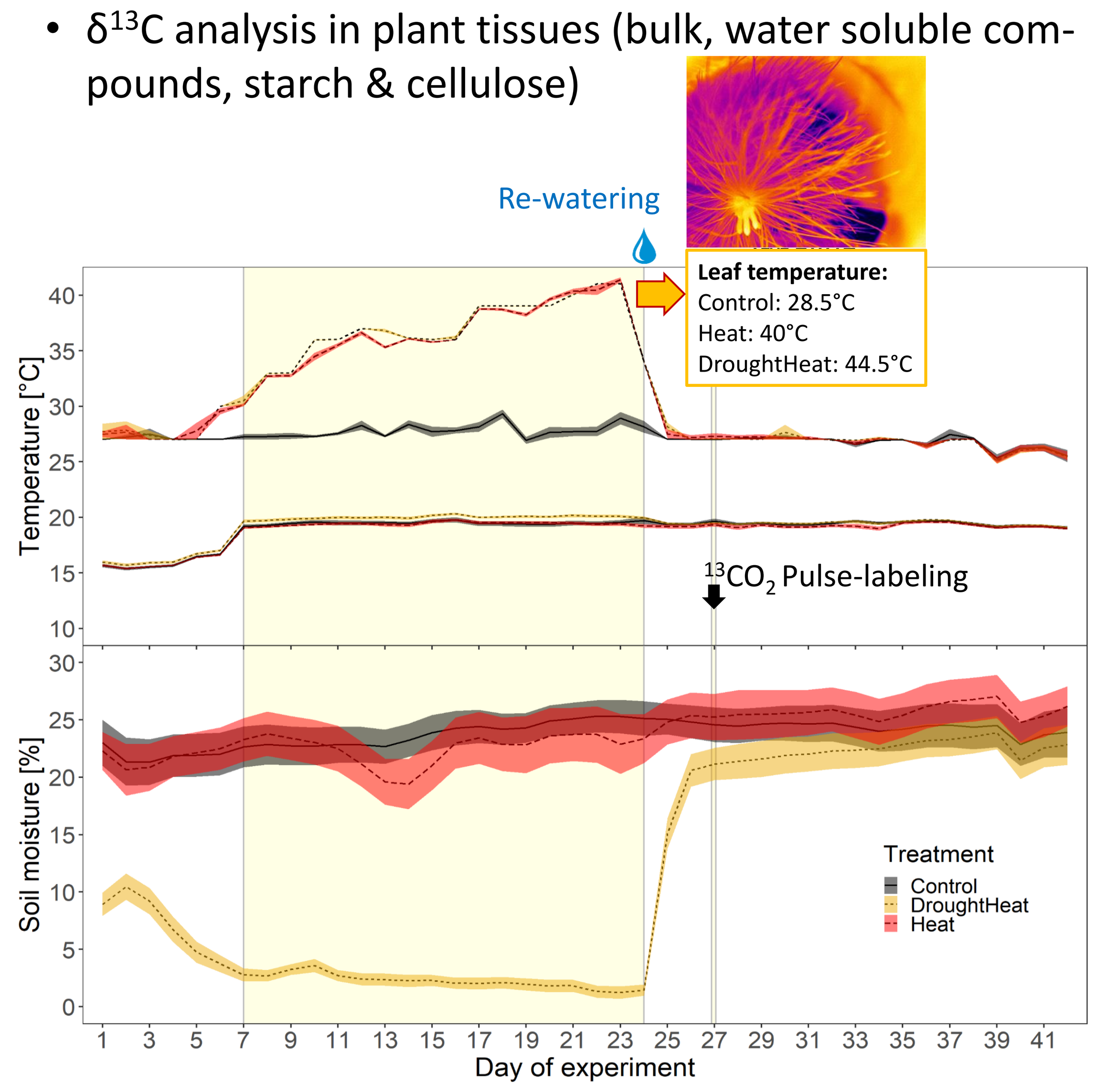


**Fig. 2:** Maximum and minimum daily temperature (upper panel) and daily mean soil moisture (lower panel) for the experimental period. Data are treatment averages and shaded areas show ± SE. The bright yellow box indicates the intense drought period. The bright yellow line highlights when $^{13}CO_2$ Pulse-labeling was conducted (2 days after re-watering).

## Results

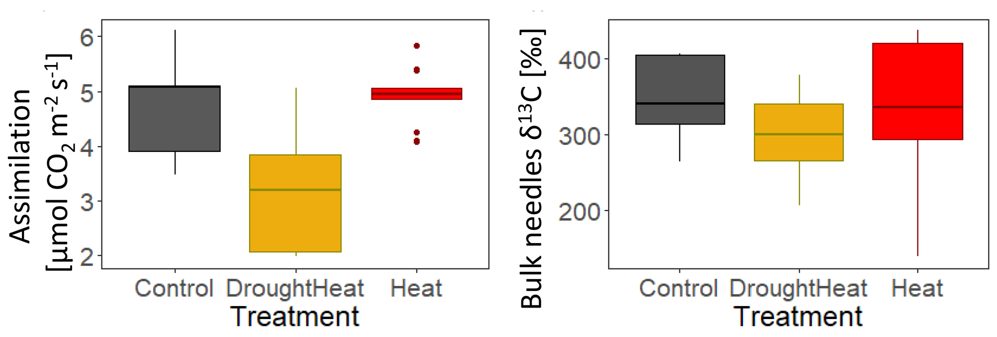


**Fig. 3:** Assimilation rate during pulse-labeling (left) and $\delta^{13}C$ of bulk needles directly after labeling (right) for the different treatments.

- Stable conditions when pulse-labeling was conducted
- similar uptake of label within the treatments

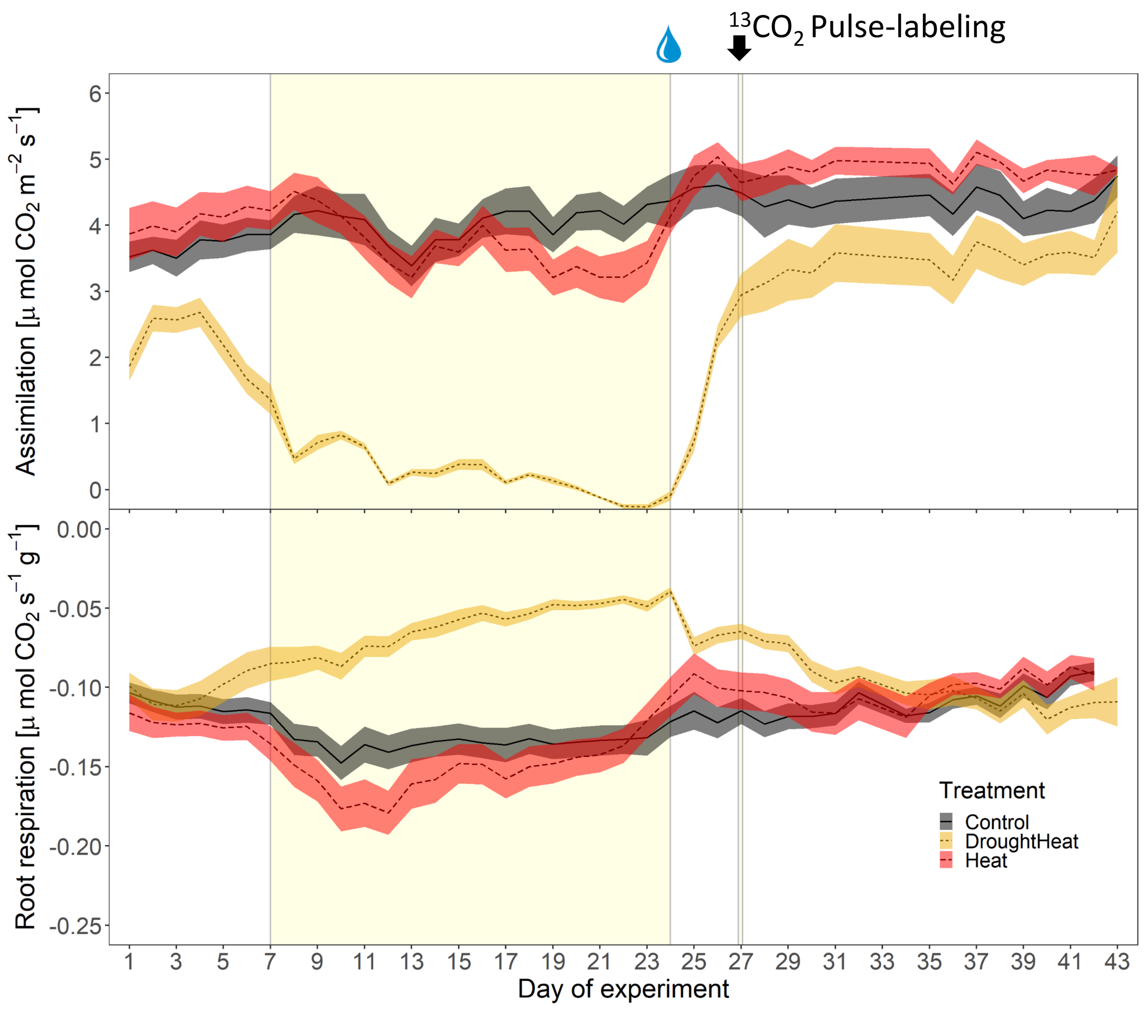


**Fig. 4:** Daily means of shoot assimilation rate (upper panel) and root respiration (lower panel) for the experimental period within the whole-tree chambers.

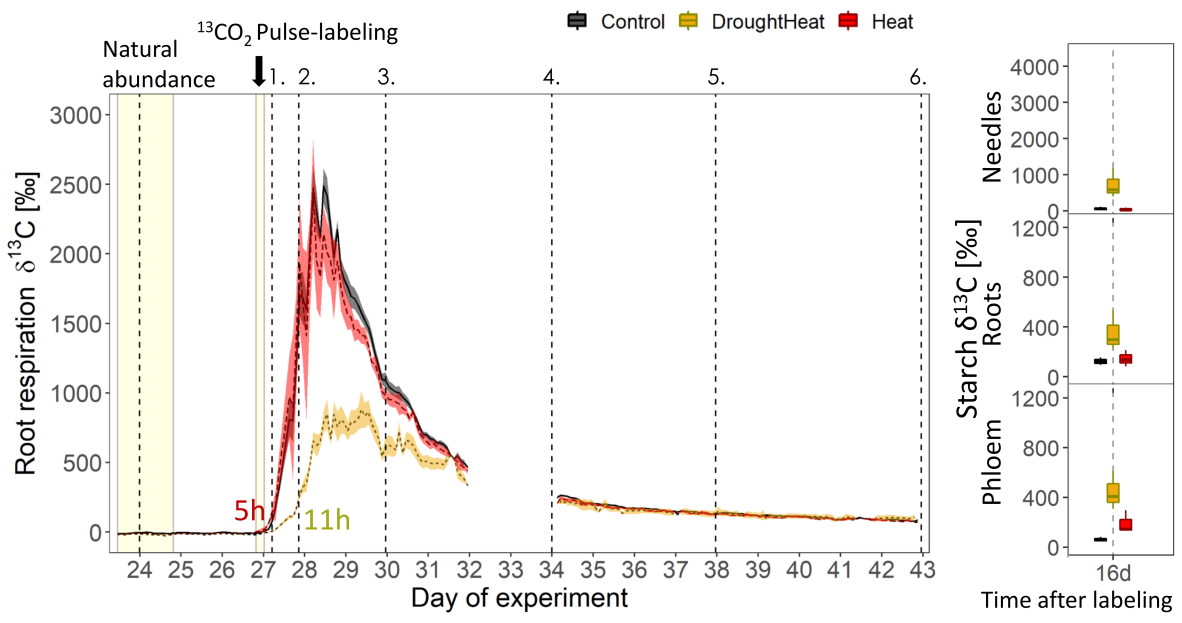


**Fig. 5:** Left: $\delta^{13}C$ of root respiration after pulse-labeling, averaged for 2h per treatment. Tissue sampling for natural abundance at the end of stress and six times after labeling are indicated. Right: $\delta^{13}C$ of starch in different tissues at the end of the experiment (16 days after labeling).

- Recently assimilated C is respired faster and in higher amounts from roots in control and previously heat-stressed trees compared to drought-heat stressed trees
- This is supported by a longer retention time of $^{13}C$ in needles of drought-heat stressed trees during the 3-weeks recovery period
- These trees allocate significantly more new C to starch in almost all tissues compared to control and previously heat-stressed trees

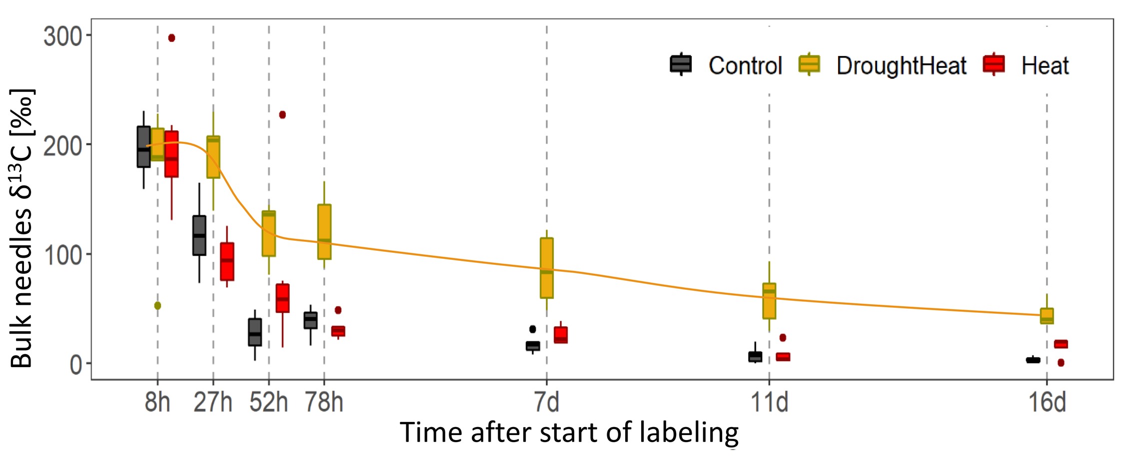


**Fig. 6:** $\delta^{13}C$ of bulk needles for the time after the start of labeling.

- Needle water potential declined to -2.8 MPa in drought-heat stressed trees and recovered close to control values within 1d
- Recovery of assimilation: Heat: overcompensation compared to control
  Drought-heat: fast recovery, ca. 90% of control
- Recovery of root respiration: Heat: fast recovery
  Drought-heat: gradually, higher than control at end

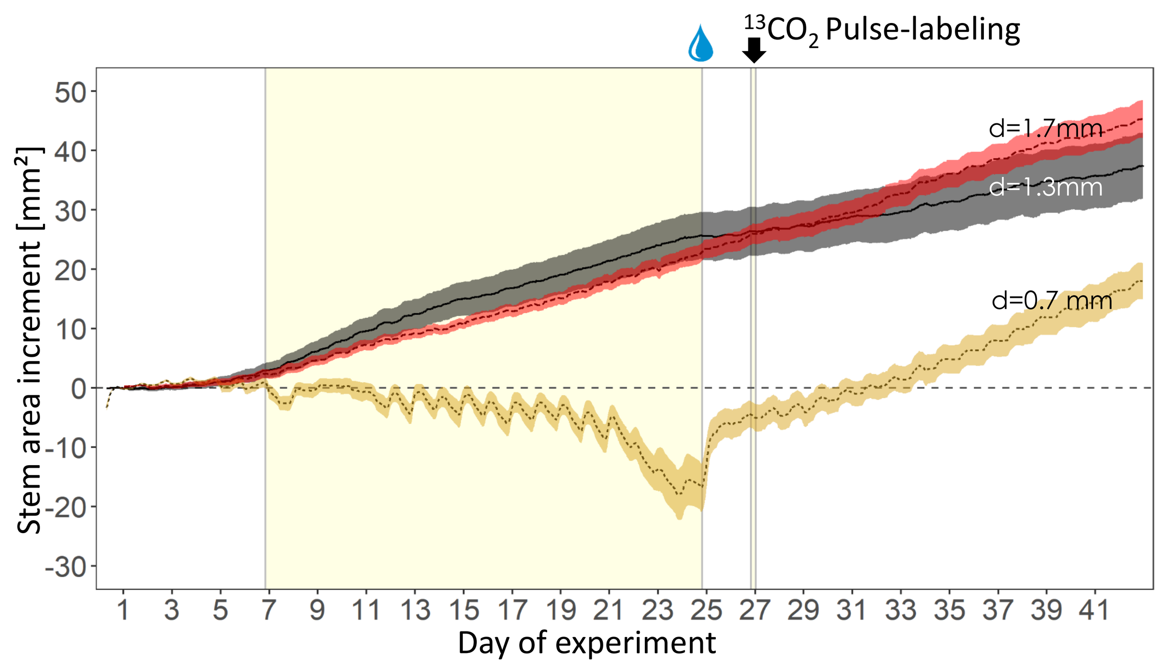


**Fig. 7:** Stem area increment measured by dendrometers for the experimental period. Diameter increment from the beginning of the experiment is indicated for every treatment.

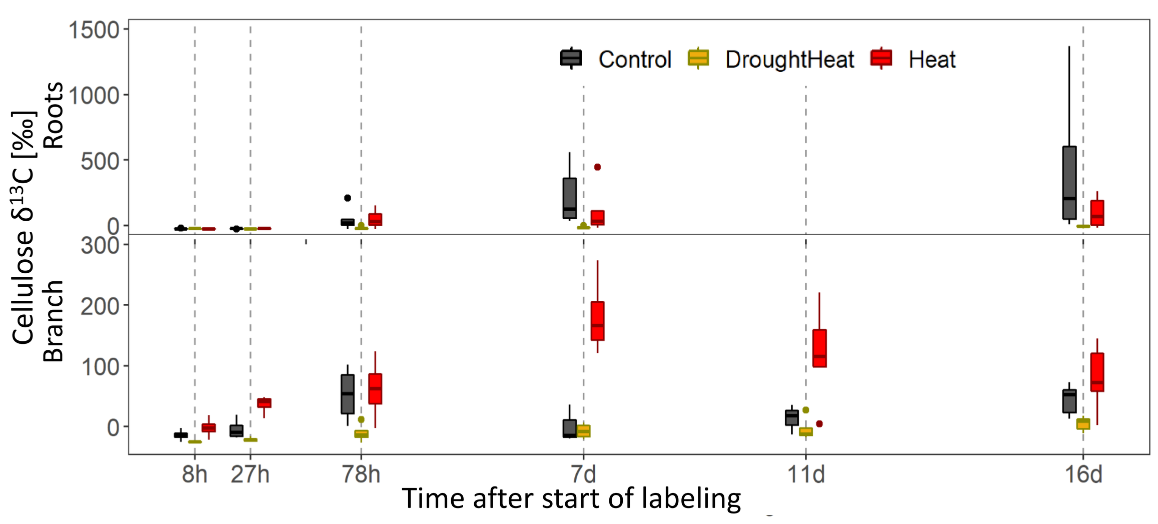


**Fig. 8:** $\delta^{13}C$ of cellulose in roots (upper panel) and branches (lower panel) for the time after the start of labeling.

- Control trees invest new C especially in root cellulose; previously heat-stressed trees particularly in branch and stem growth, which was confirmed by dendrometer measurements

## Conclusion and Outlook

- delayed C transport capacity in previously drought-heat stressed trees indicates ongoing repair processes
- After stress release, these trees prioritize storage formation over growth to ensure future survival
- Heat stress alone did not result in a persistent damage of trees, but rather in a compensation of stress-induced reductions in C uptake and growth
- Further steps: Compartmental modeling

KIT - The Research University in the Helmholtz Association

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