High temporal resolution ^{13}C tracing to link xylem–phloem pathways of carbon in oak trees

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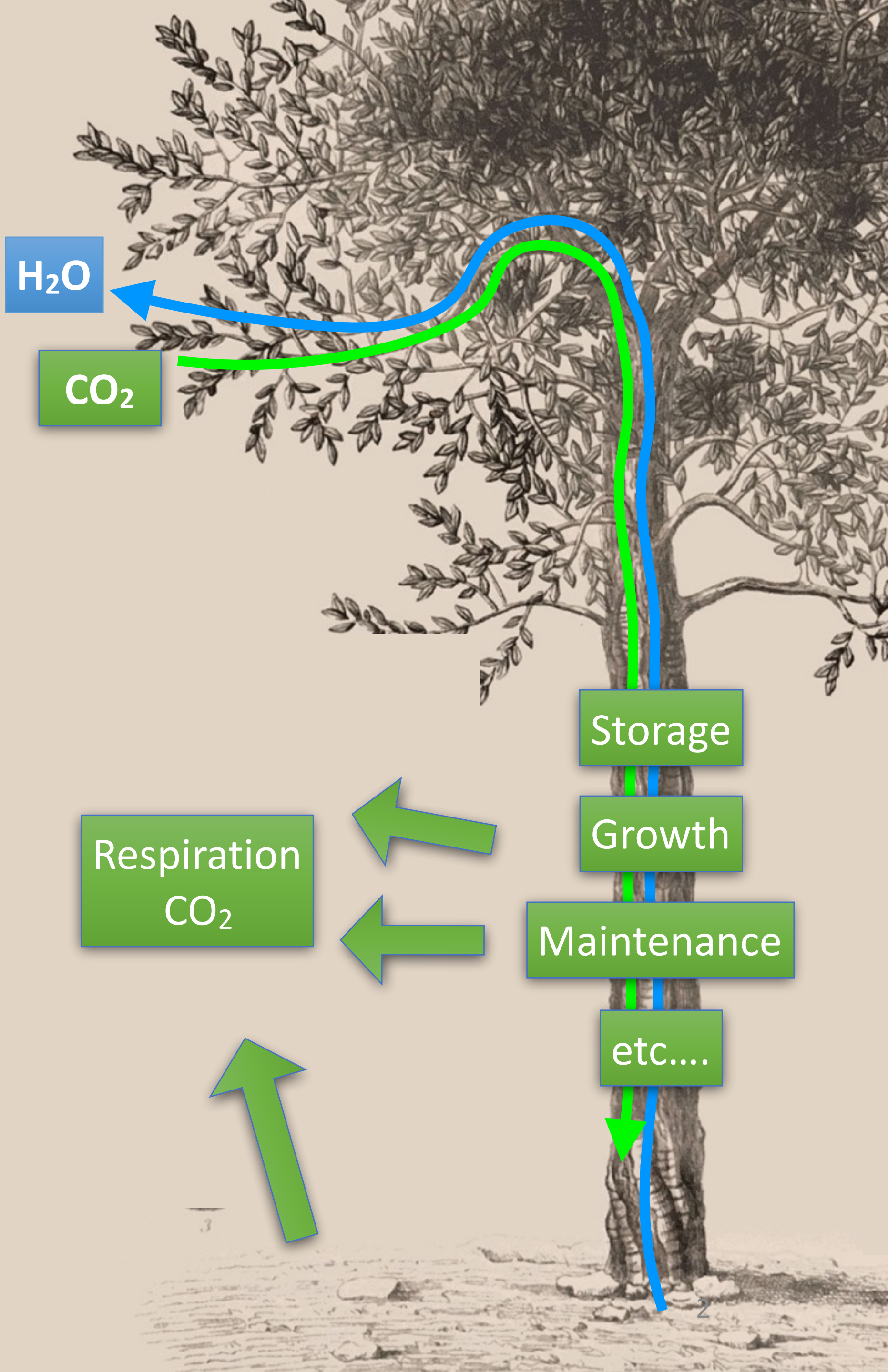
Der Wissenschaftsfonds.

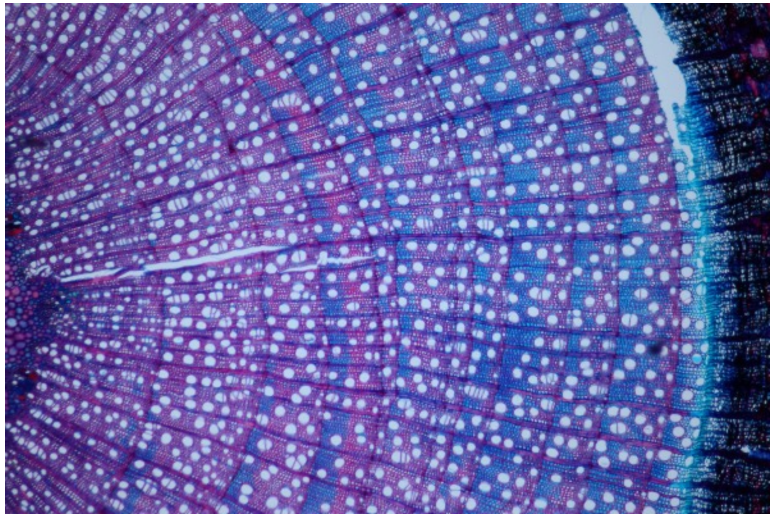
Tree's C and hydraulic cycle

- Photosynthesis assimilates CO_2 to form sugar.
- Sugar is transported to above- & belowground organs to support C sinks.
- CO_2 is released back to the atmosphere through plant respiration and soil respiration

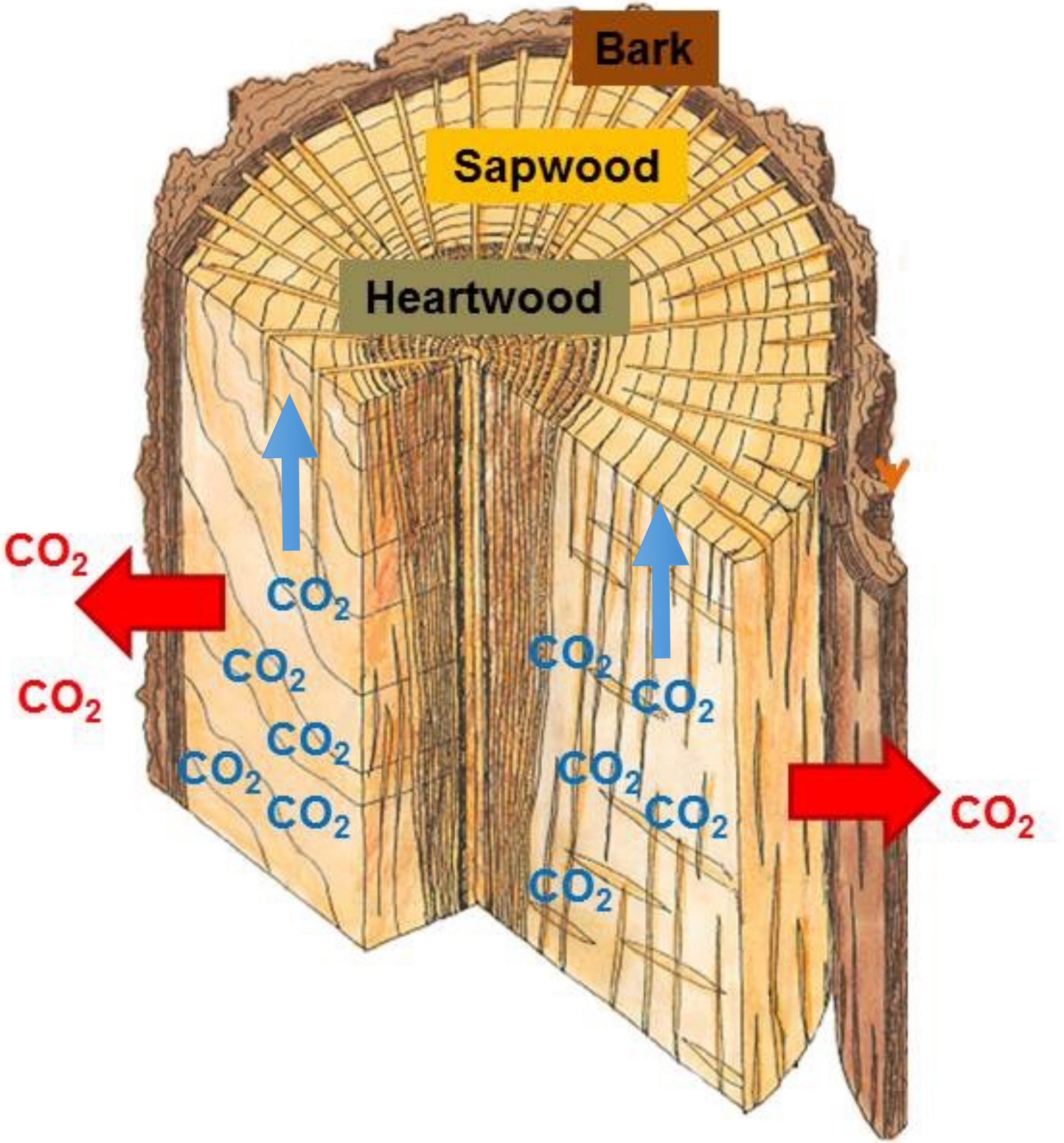


Fate of respired CO_2

- Living cells of plant (e.g. parenchyma) respire CO_2 which is released to the atmosphere from the bark



- Internal transport of dissolved CO_2 has been often ignored.



Upward and downward transport of C

New Phytologist

Rapid report | Free Access

Root-derived CO_2 efflux via xylem stream rivals soil CO_2 efflux

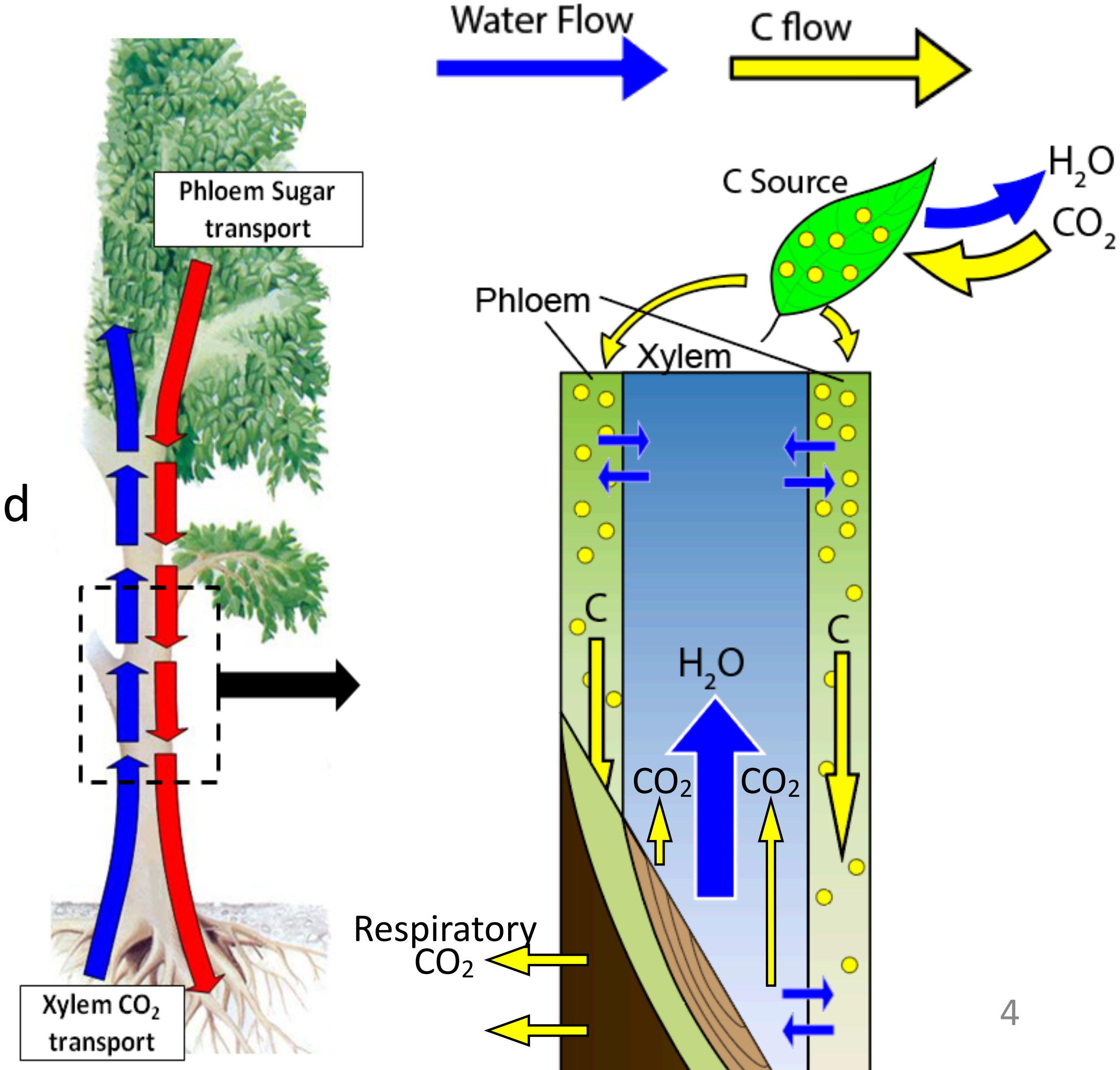
Doug P. Aubrey, Robert O. Teskey

First published:02 September 2009 | https://doi.org/10.1111/j.1469-8137.2009.02971.x |

- Results in underestimation of belowground respiration

- Potential re-fixation in leaves and green bark

- Unaccounted local source of C



Motivations of the research

Observe upward and downward movement and dynamics of C in trees, connecting above and belowground tissue.

Trace the fate of phloem transported sugar and xylem transported CO_2 in high temporal resolution.

Observe potential mixing of C in xylem and phloem through lateral transport and CO_2 re-fixation.

Methods: Xylem–phloem dual-labeling

- We used two types of pulse labeling to trace C in young oak trees (*Quercus rubra; n = 3*):
    - **Canopy $^{13}CO_2$ labeling** *(n = 3)* and **xylem $^{13}CO_2$ infusion labeling** *(n = 4)*

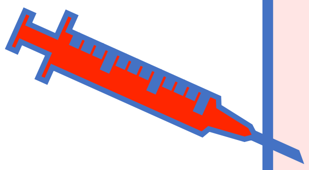
- The goal is to trace detect **phloem transported CO_2** and **xylem transported CO_2** in respiration and biomass.

- We also aimed to detect connectivity between the two pools of C (transfer between the two)

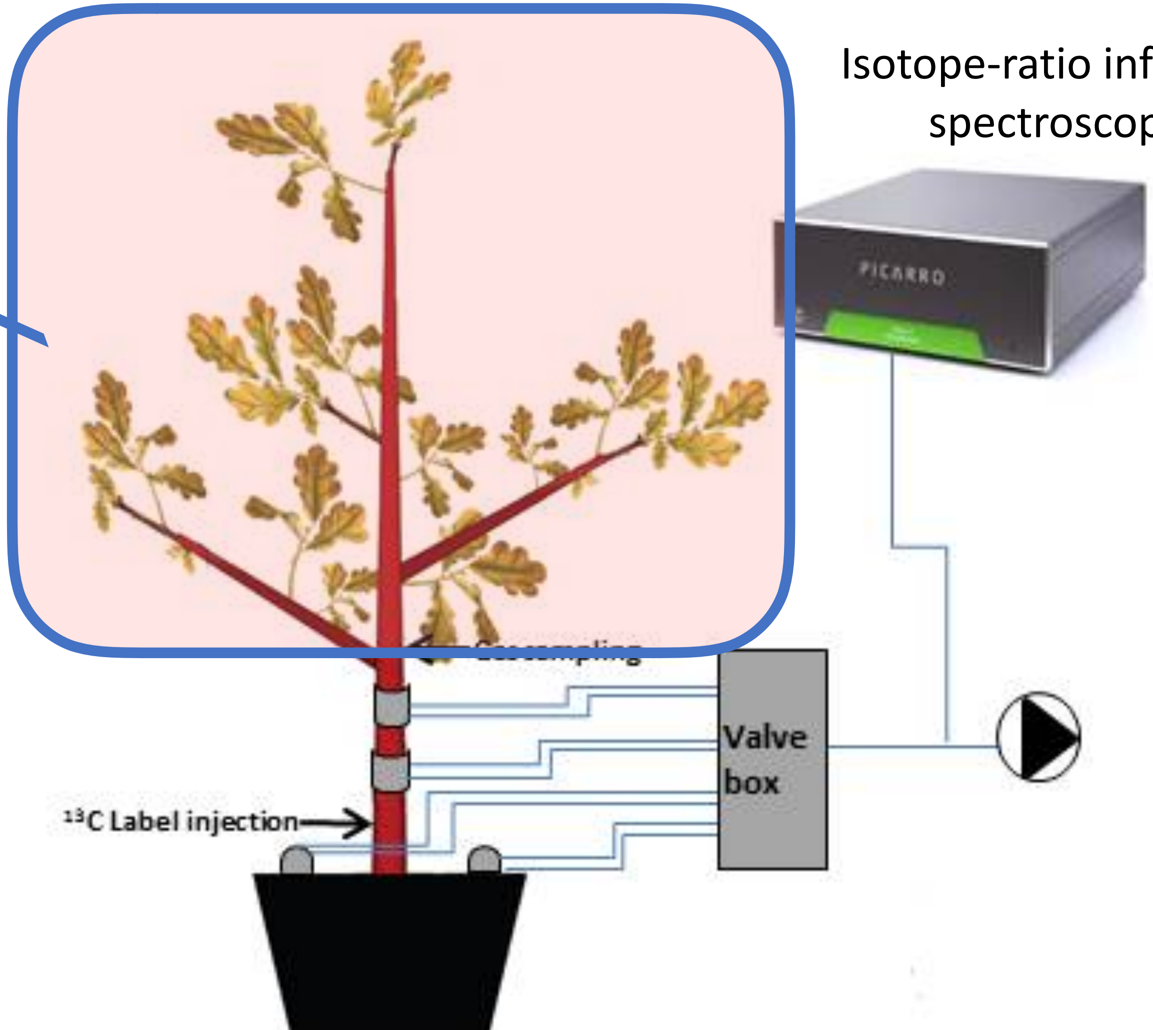
- Experiment was conducted in Innsbruck University Botanical garden during 2015 and 2016 by Jasper Bloemen

Methods: Canopy $^{13}CO_2$ labeling

99% $^{13}CO_2$

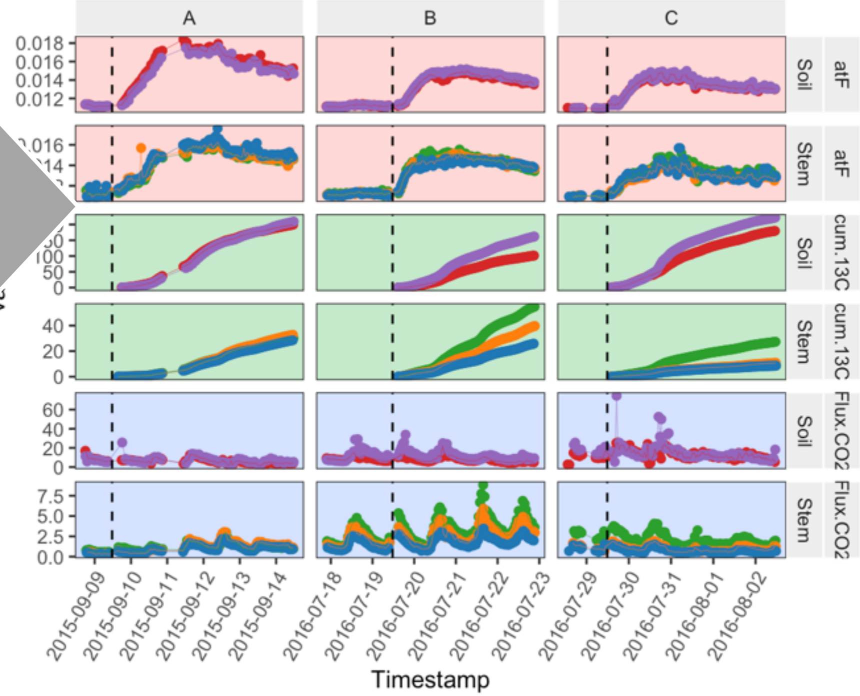


Labeling chamber



Isotope-ratio infrared spectroscopy

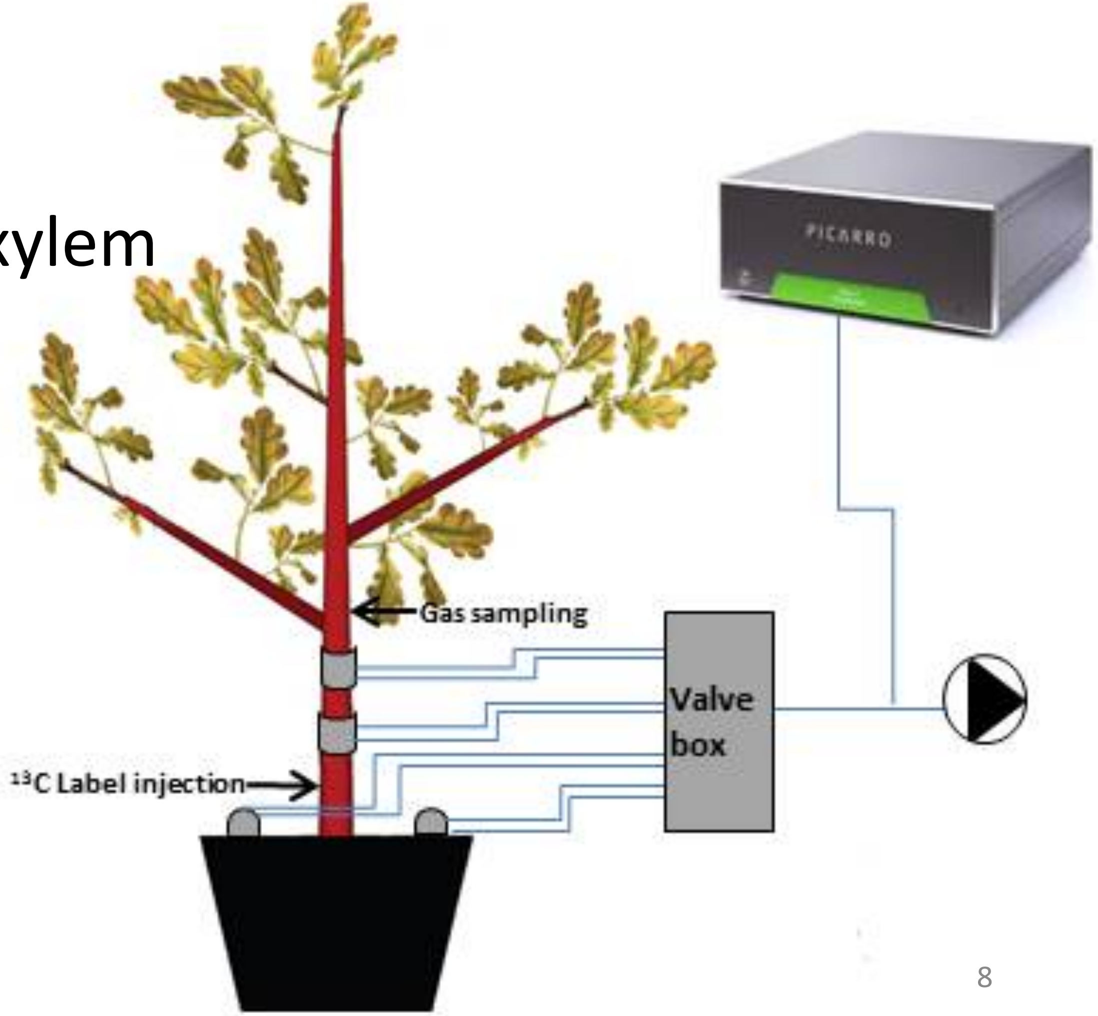
High resolution time-series data



Methods: Xylem $^{13}CO_2$ infusion labeling

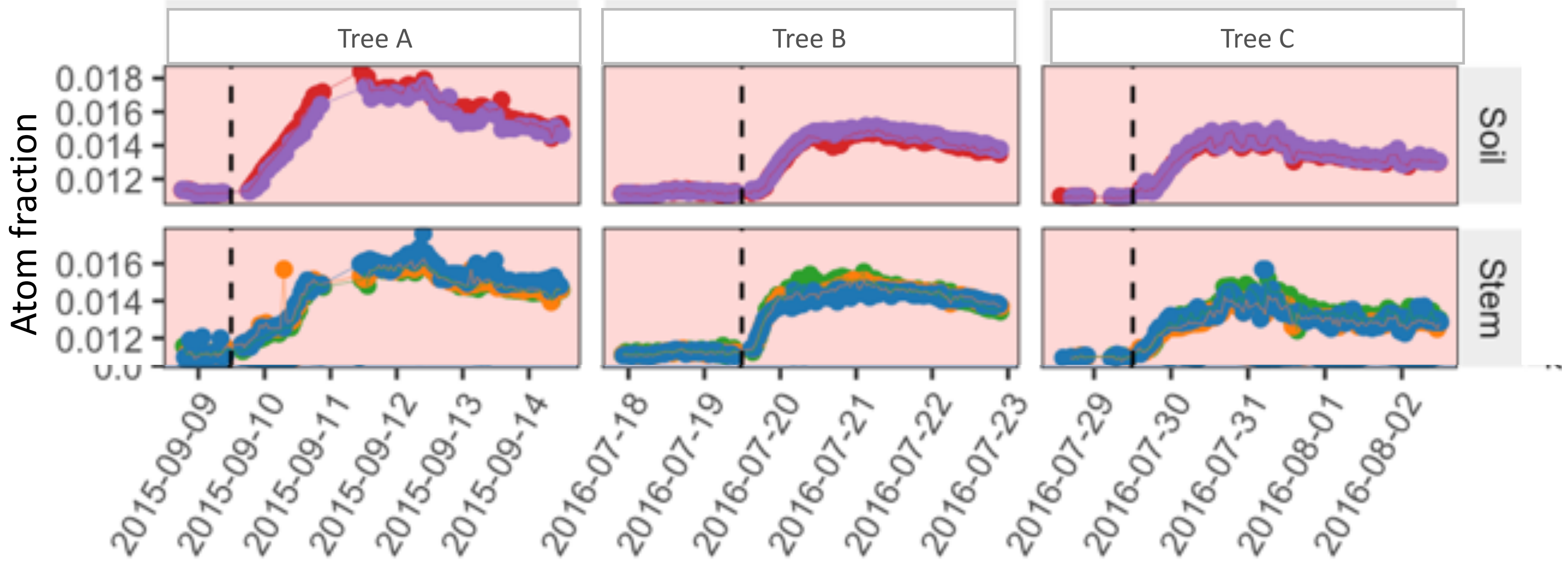
- $^{13}CO_2$ gas was dissolved in DI water amended with KCl
- Infused water was carried upward on xylem stream.

Xylem infusion

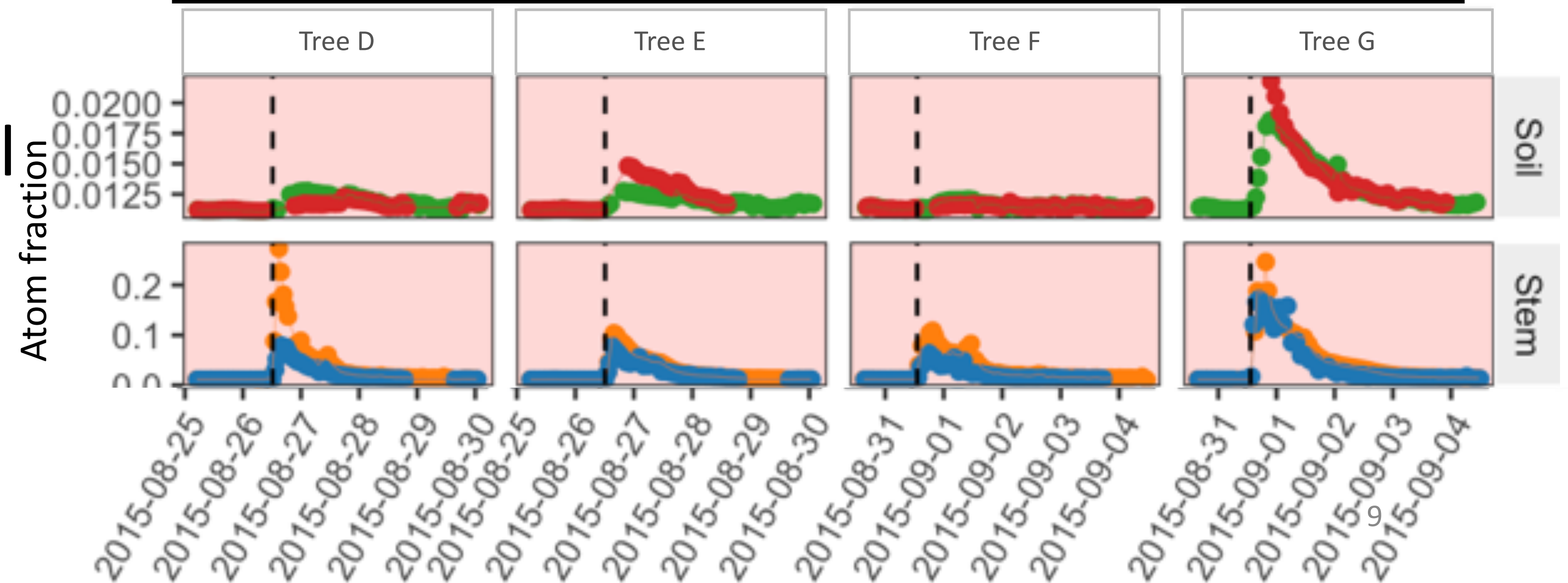


- Label follows a decay due to depletion of label
- Short mean residency time for xylem infused $^{13}CO_2$ (5 - 16 h)
- Xylem infused $^{13}CO_2$ remained in CO_2 efflux several days after labeling

Atom fraction after Canopy $^{13}CO_2$ labeling

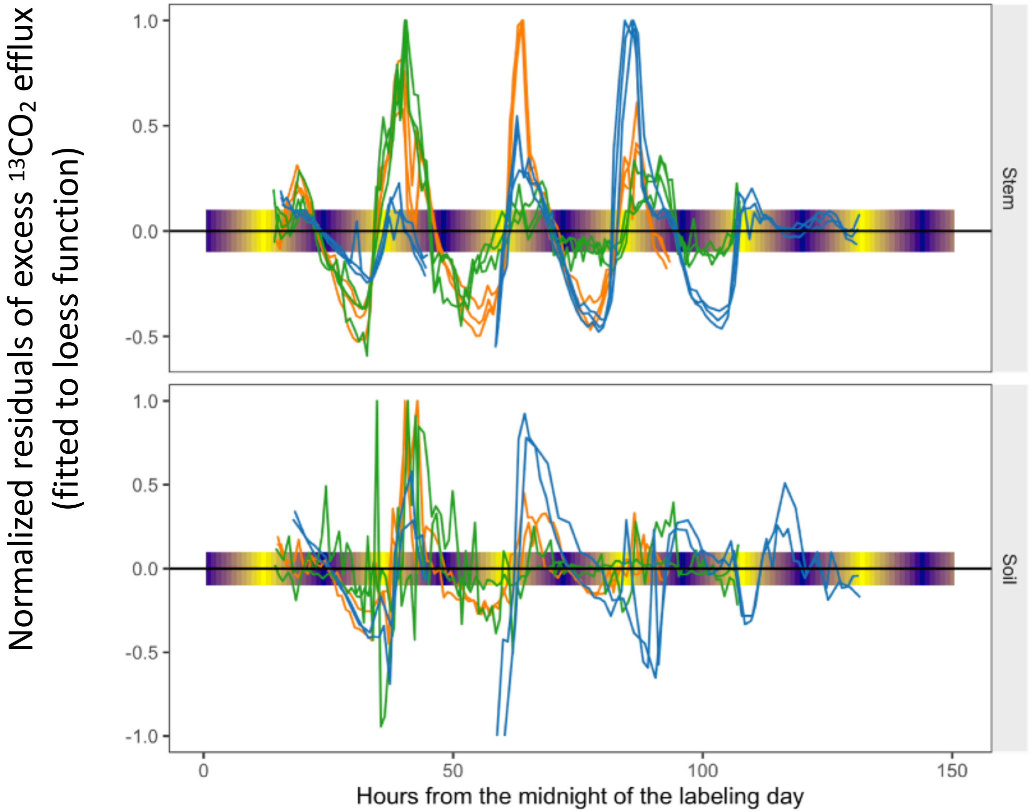


Atom fraction after Xylem $^{13}CO_2$ infusion labeling

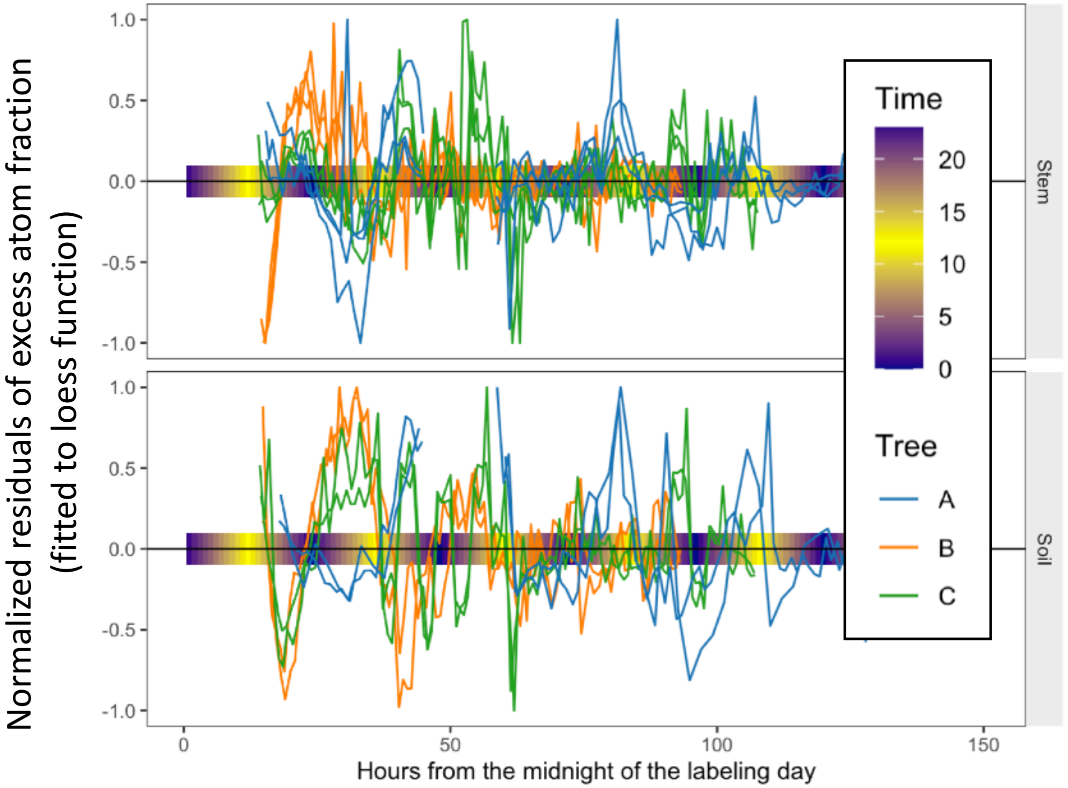


Residuals of **canopy labeled** tree

- Residual of fitted model shows diurnal pattern of **excess $^{13}CO_2$ efflux**, primarily driven by dynamics of respiration.

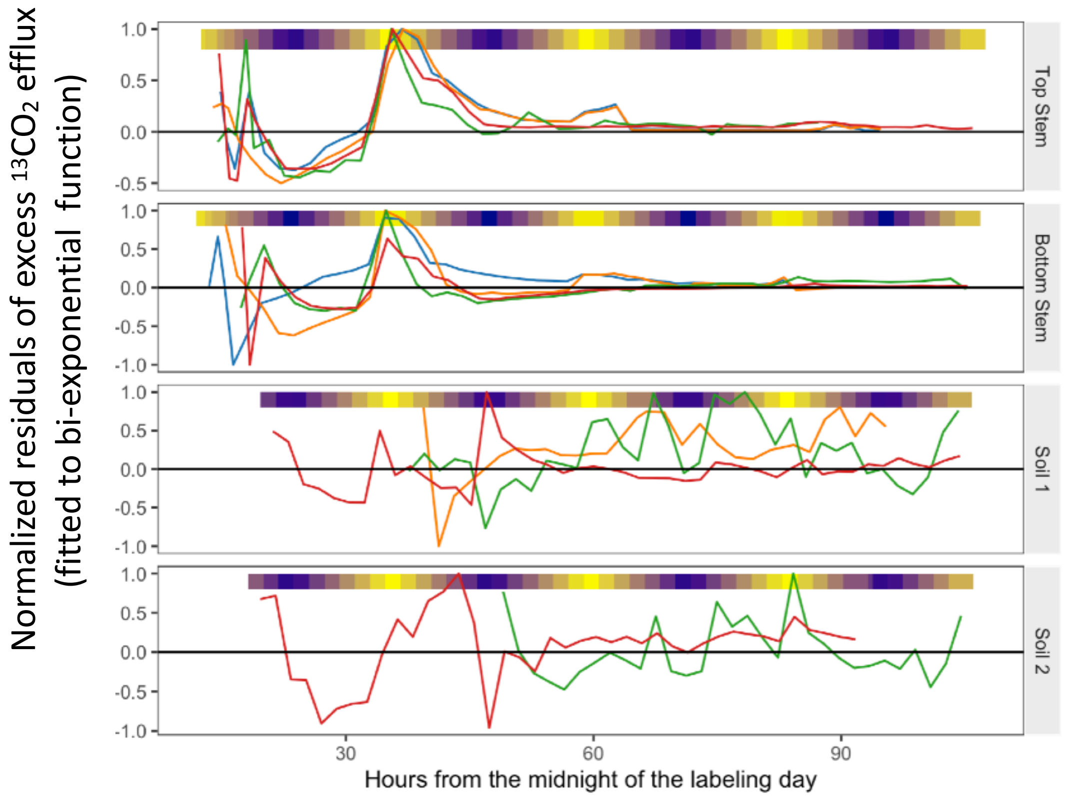


- **Isotopic composition** (atom fraction) of CO_2 efflux doesn't show a clear diurnal pattern.

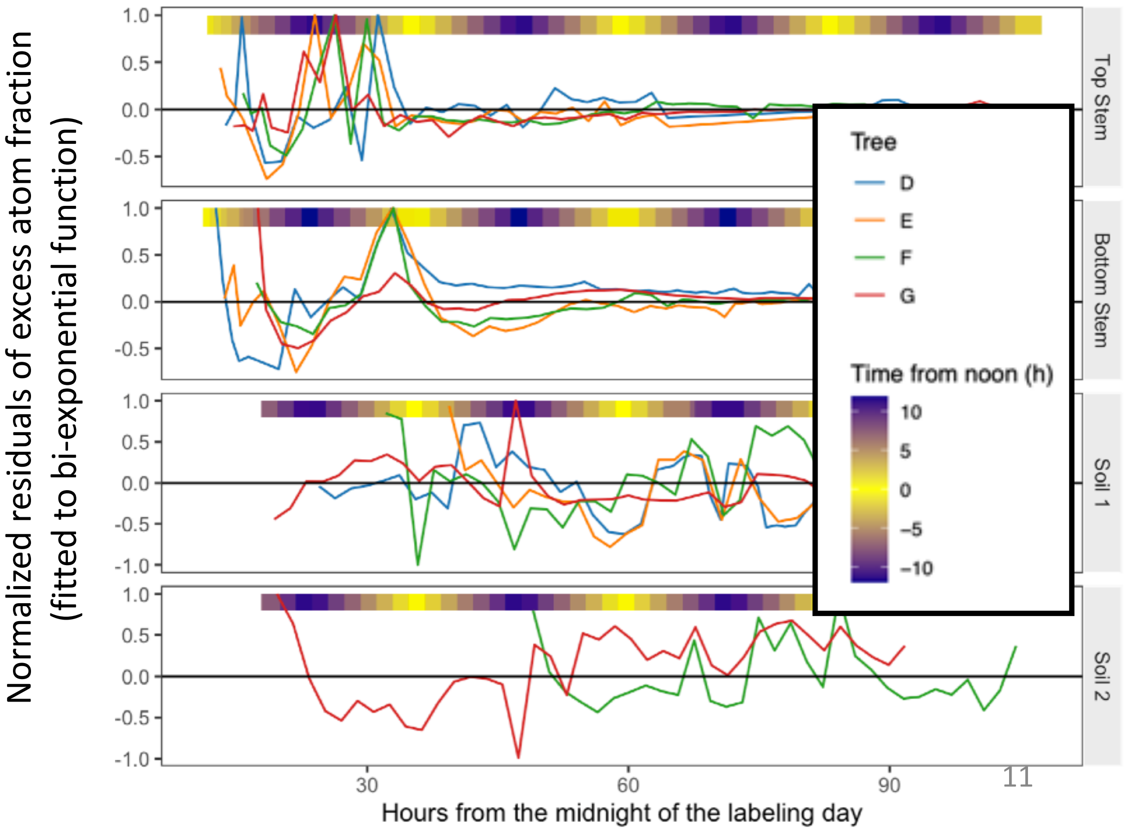


Residuals of **xylem labeled** tree

- Residual of fitted model shows increased daytime **excess $^{13}CO_2$ efflux** from the stem.



- **Isotopic composition** (atom fraction) of stem efflux also show a diurnal pattern.

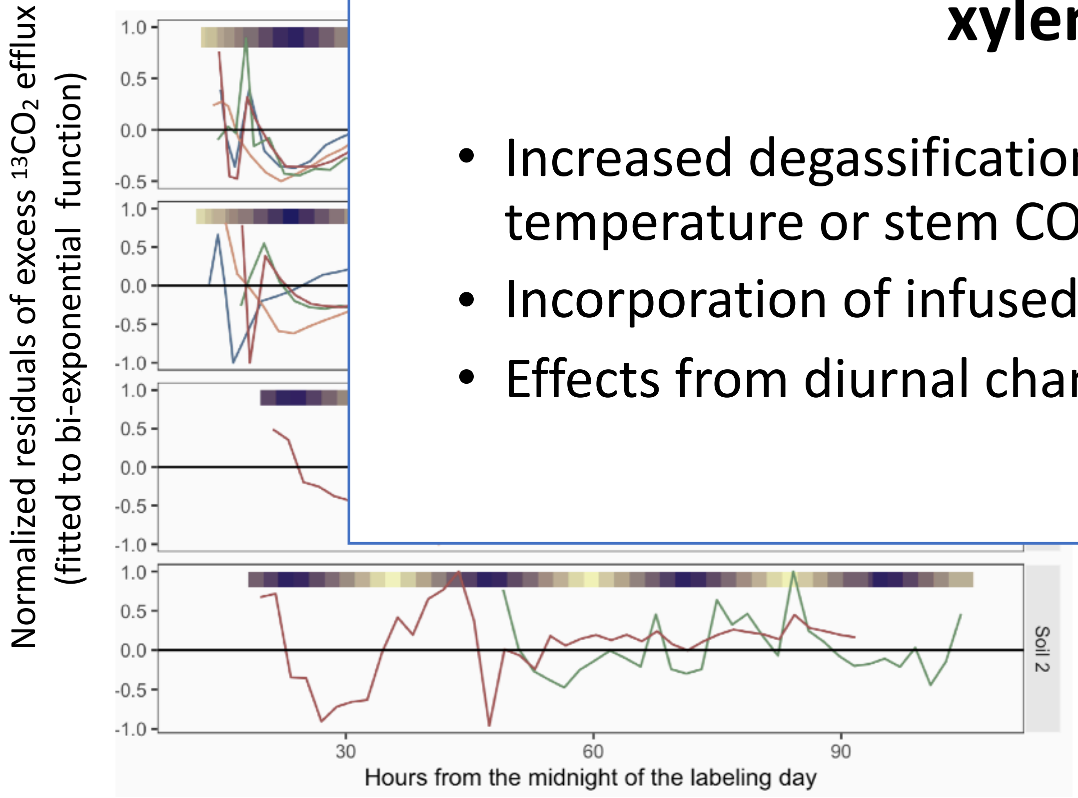


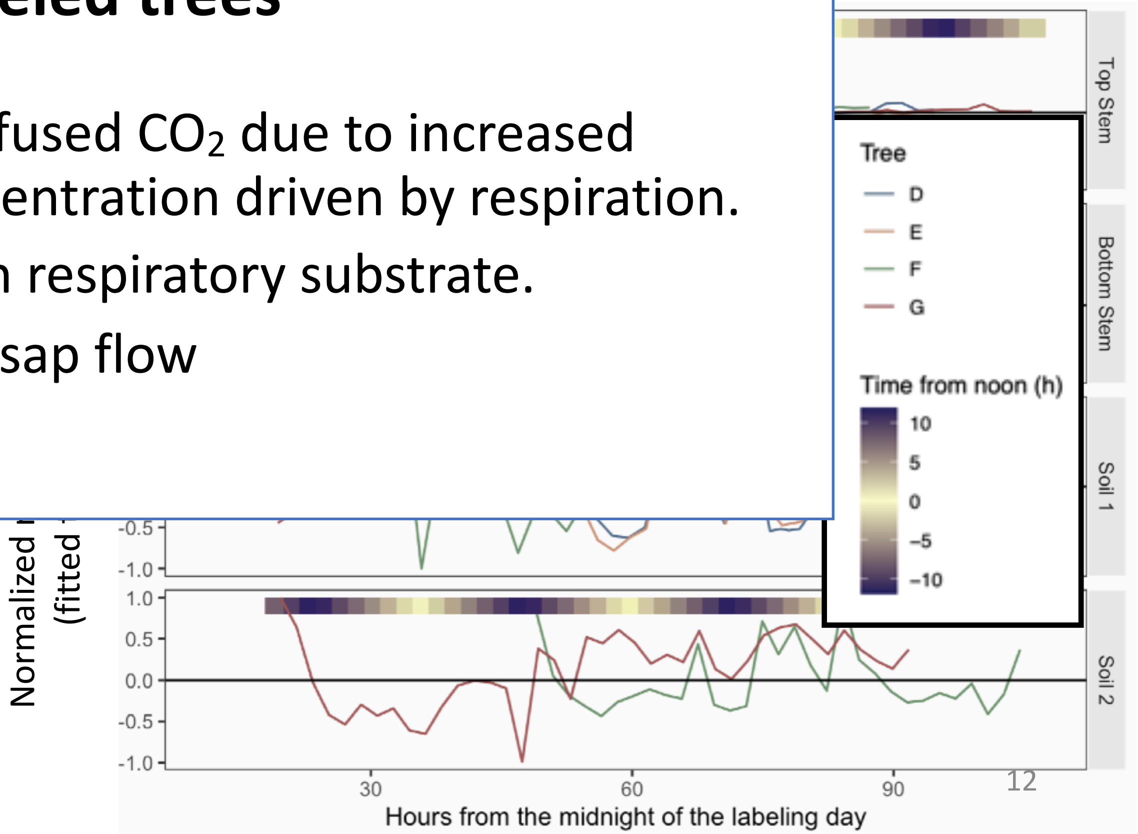
Residuals of **xylem labeled** tree

- Residual of … fraction)
  daytime **ex**…

Potential mechanisms of diurnal ^{13}C dynamics in xylem labeled trees

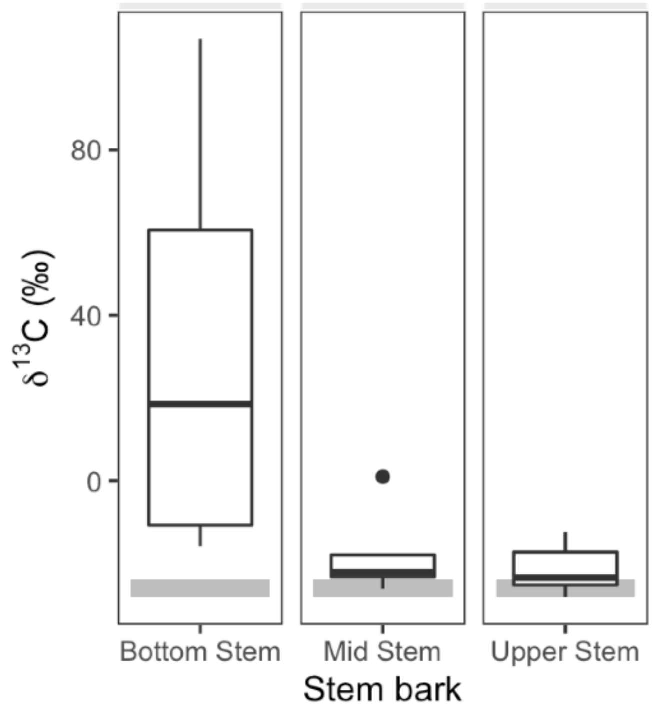
- Increased degassification of infused CO_2 due to increased temperature or stem CO_2 concentration driven by respiration.
- Incorporation of infused CO_2 in respiratory substrate.
- Effects from diurnal change in sap flow



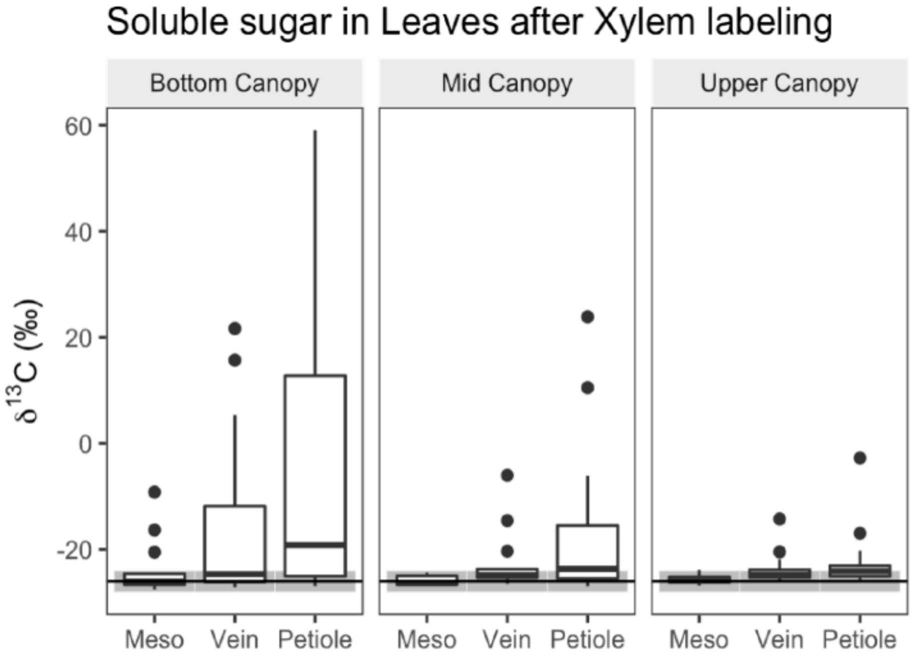


^{13}C labels found in biomass after **xylem labeling**

Xylem infused $^{13}CO_2$ were found in stem phloem at various height.

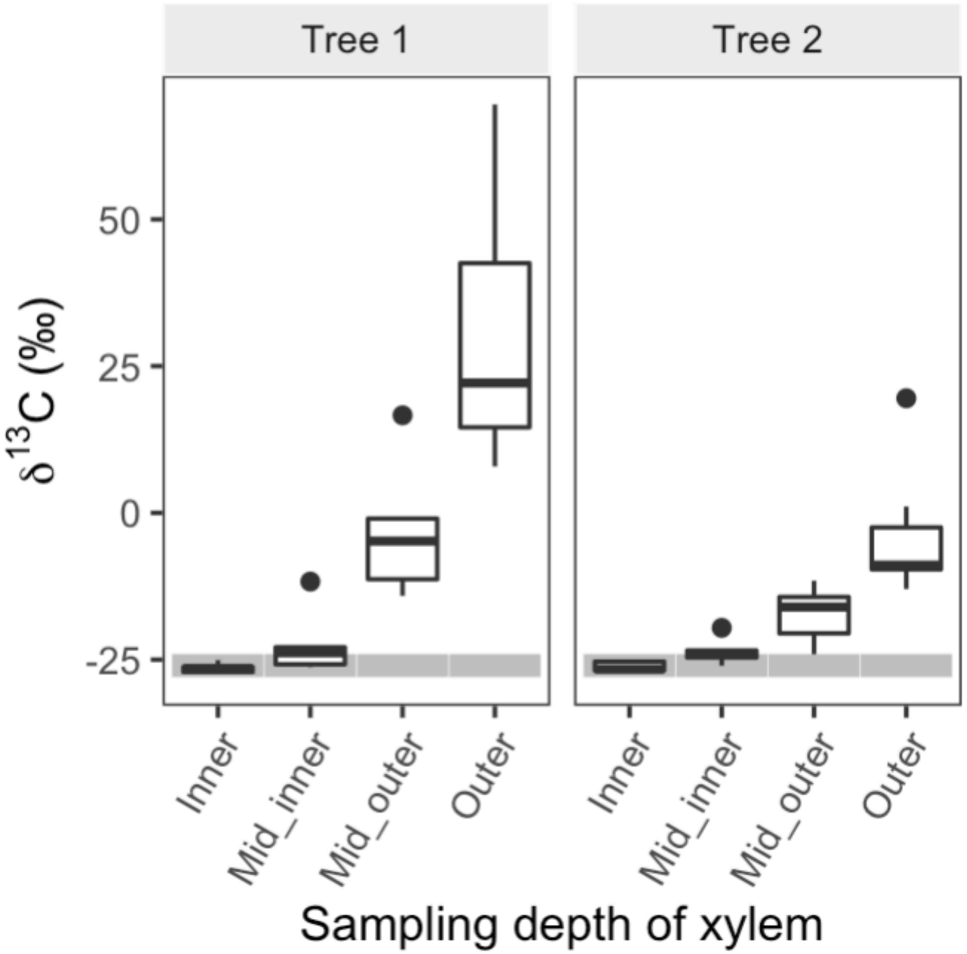


Strong ^{13}C signal in petiole and veins suggests recycling of xylem transported CO_2 as a source of sugar.



^{13}C labels found in biomass after **canopy labeling**

Lateral transport of C from phloem to xylem was observed after canopy labeling.



Conclusion

- Soluble sugar from phloem were laterally transported to inner xylem within a few days.

- CO_2 transported upward through xylem had relatively short residency time, but was re-assimilated as soluble sugar.

- Pathway of xylem transported CO_2 and phloem transported sugar is linked, connecting two of the C pools within a few days.