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Title:	How Trees Die: Signature Imaging to Unravel Carbon Starvation and Dehydration Dynamics in Vegetation During Drought
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How Trees Die: Signature Imaging to Unravel Carbon Starvation and Dehydration Dynamics in Vegetation During Drought

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Abstract: We are using LANL's unique abilities in ultra-low field (ULF) magnetic resonance imaging (MRI), stable isotopes, and climate-driven vegetation mortality research to examine a basic question. ***How do plants die during drought?***

Background: The question of plant mortality in drought is one of the largest uncertainties in determining how plants will succumb to changing climate, and impedes DOE and international forecasts of future climate because models cannot simulate vegetation change and related climate effects. While the question of plant mortality is easy to conceptualize, it is difficult to study because of the spatial and temporal variation of processes over the plant. We lack basic understanding about whether mortality is primarily due to carbon starvation, (exhaustion of carbohydrate reserves), hydraulic failure, (failure to maintain water transport and subsequent desiccation), or both, as we hypothesize.

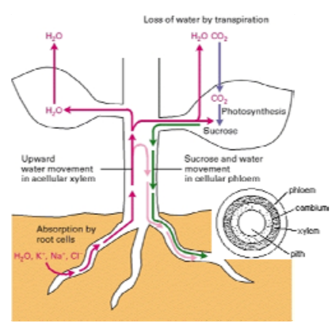


Figure 1. Water moves up within xylem, and carbohydrates move down within phloem. The interdependency of these processes is a focus of this work.

Preliminary data: We propose to leverage LANL's world-leading capability in ULF MRI to develop a portable system to image signatures of **both** water and carbon transport in a tree, and test an integrated theory of vegetation mortality, *in vivo*.

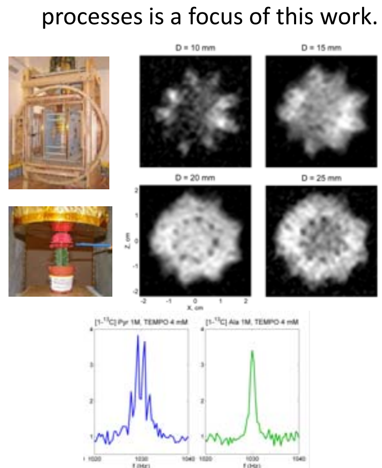


Figure 2. Sensitive detectors such as SQUIDs image a moon cactus. Dynamic Nuclear Polarization (DNP) was used to enhance polarization and for 13C spectra via J-coupling. Zotev et al., **J.Magn.Resonance 207:78-88,2010**

Research Approach:

Our specific technical goal is to develop and apply ULF-MRI to plant physiological research.

Our specific science goals are to determine 1) when embolism of water conducting conduits (dehydration) occurs, 2) when does refilling of embolized conduits occur, and 3) how does carbohydrate availability and movement drive, and depend upon, conduit embolization and refilling.

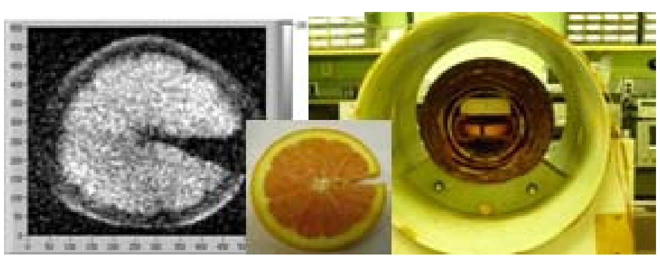
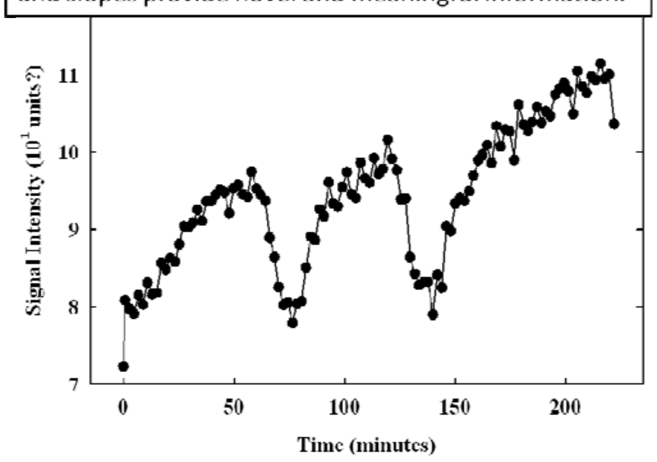


Figure 3. Results from room-temperature coil-based systems showing MRI of an orange.

Figure 4 Proton signal evolution during H_2O/D_2O cycling. Complete cycling (turnover) was demonstrated by full recovery after D_2O introduction. The troughs and slopes provide novel and meaningful information.



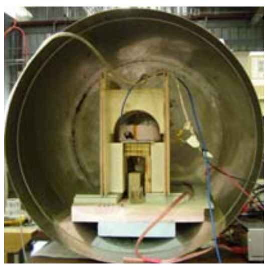


Figure 5. Photo of system used in water cycling experiment. Resnick et al., Proceedings of the 52nd *ENC.*

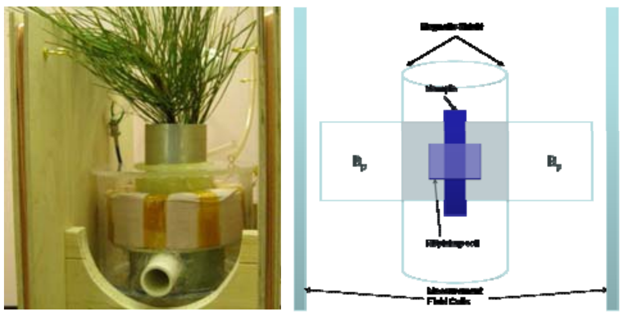


Figure 6. Redesigned system . Pre-polarization with air cooling. The large shield is replace with a small local shield to allow for access and light.

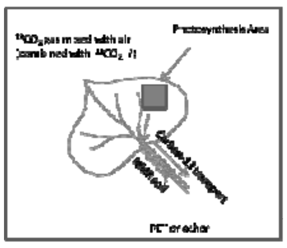


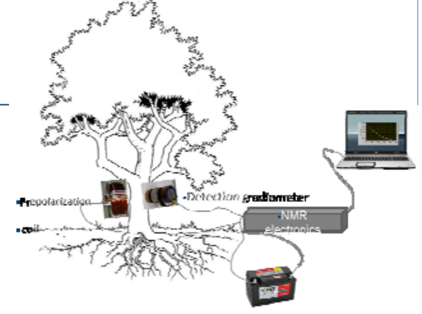
Figure 7. In future work $^{13}CO_2$ will be traced with ULF NMR.

Specific activities in relation to our overall science goals:

1) When does cavitation occur? We will use the H_2O/D_2O signal to visualize the water content with ~ 2-3 mm spatial resolution within plant stems (the primary water and carbon conducting unit in plants). In general we expect that cavitation is greatest when xylem water tension increases fastest in the morning (from acoustic emissions).

2) When does refilling occur and does it require carbohydrates? Refilling is thought to occur at night, to be impacted by drought, to depend on carbohydrates for creation of osmotic potential, and to be a tipping point for mortality To trace the role of carbohydrates, we will combine non-invasive studies using ^{13}C exogenously applied by either giving the plant enriched CO_2 (or injecting sugars to different parts. We will track refilling, and trace carbon using ULF-MRI and use mass spectroscopy to determine composition and dynamic changes of carbohydrates in xylem

3) Does xylem water maintain phloem flow? This is a hypothesized mechanism by which carbohydrate transport depends upon xylem water. We will use time dependent measurement of H_2O/D_2O gradient via ULF-MRI to trace the signatures of xylem water movement (or lack thereof) into phloem and the subsequent movement of ^{13}C tracers within the phloem.



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