# Soil embedded networked systems for studying soil carbon dynamics: the A-MARSS project

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## Introduction

**A-MARSS** (*Automated-Minirhizotron and Arrayed Rhizosphere Soil Sensors*) is a NSF biocomplexity instrumentation grant to study mycorrhizae, soil ecology, and has application to soil carbon dynamics. The role of soil microorganisms is still a black box in global change research (Treseder and Allen 2000) because soil processes are difficult to quantify in space and time (Klironomos et al. 1999) (Figure 1).

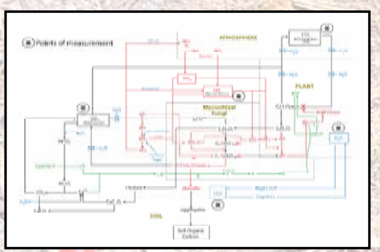


**Figure 1:** Carbon model centered on mycorrhizal fungi

## Minirhizotron Cameras

We are developing robotic minirhizotron cameras in completely buried tubes and exchange data and instructions through the wireless *embedded network*. Having multiple minirhizotron cameras capable of responding to remote commands or environmental triggers (e.g., rainfall) coupled with data-filtering software will enable us to collect and use currently unattainable data at varying time scales and simultaneously at multiple spatial scales (Figure 2).

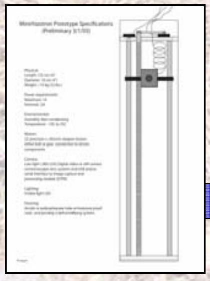


**Figure 2:** (Bottom) Minirhizotron images of the same 1 $cm^2$ frame at intervals of three months and three days. Arrows indicate region where changes can be seen at both long and short time scales. (Left) Design of robotic minirhizotron camera (by Wimbrow and Taggert)

**Robotic camera**


**Image acquisition**

**A-MARSS** is a system composed of wireless sensors and actuators embedded in the soil profile that connects the sensed area to the virtual world (*Internet*) for real time data acquisition. The goal is to spatially measure soil moisture, temperature, nitrate, and $CO_2$, coupled to an automated camera to observe roots and mycorrhizae in soils (Figure 3).

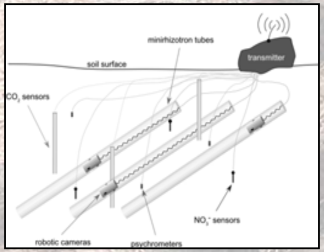



**Figure 3:** Schematic of field installation under construction

## Preliminary Results

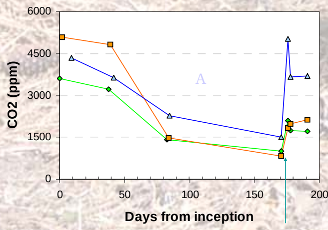



**Figure 4:** $CO_2$ concentration (ppm) at three depths. Arrow indicates simulated rainfall after period of extended drought.

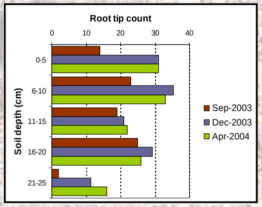



**Figure 5:** Mycorrhizal root tip counts derived from minirhizotron images.

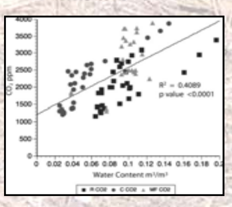



**Figure 6:** $CO_2$ concentration (*ppm*) vs. soil water content (*$m^3/m^3$*) at 5 cm depth using solid state $CO_2$ sensors.

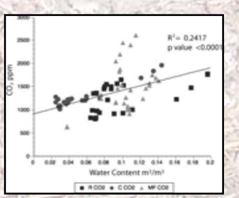
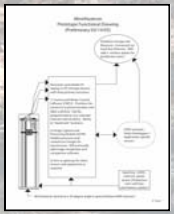



**Figure 7:** $CO_2$ concentration (*ppm*) vs. soil water content (*$m^3/m^3$*) at 10 cm depth using solid state $CO_2$ sensors.

## Wireless Processing

The CC1010 has a very low power consumption with a data rate up to 76.8 kBits/s. Only a few external components are necessary to make a powerful embedded system with wireless communication capabilities, sensor interfacing possibilities and processing power.

**Figure 8:** (Below) CC1010 for wireless connectivity. Data acquisition can be parameterized (e.g. max. and min. $CO_2$ expected values) and outlier readings will be "flagged" before sending data to central server. (Left) Diagram of sensor interface with wireless capabilities.



## Comments

- Complexity in the environment can be understood most effectively through the synthesis and integration of information across relevant temporal, spatial, and thematic scales.
- Soil $CO_2$ concentration, soil temperature and moisture are being monitored within a network sensor array at the James Reserve CA (www.jamesreserve.edu), coupled with a Networked Infomechanical Systems NIMS (www.cens.ucla.edu).
- For a better understanding of soil carbon dynamics high sampling resolution data is required. Soil embedded networked systems is an alternative tool to obtain large amount of data and opens new possibilities for environmental modeling such as wavelet analysis (Li and Loehle 1995).

## Acknowledgements

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## References

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