POTENTIAL OF THE ACTIVE HEAT PULSE METHOD WITH FIBER OPTIC TEMPERATURE SENSING FOR ESTIMATION OF WATER CONTENT AND INFILTRATION IN AGRICULTURAL SOILS

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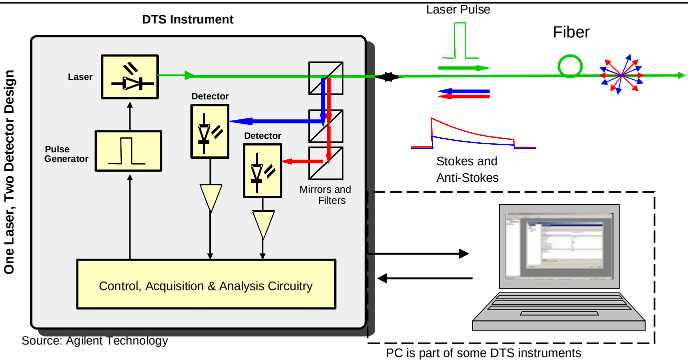
INTRODUCTION

The principle of temperature measurement along a fiber optic cable is based on the thermal sensitivity of the relative intensities of backscattered Raman Stokes and anti Stokes photons that arise from collisions with electrons in the core of the glass fiber. A laser pulse, generated by the Distributed Temperature Sensing unit DTS, traversing a fiber optic cable will result in Raman backscatter at two frequencies, referred to as Stokes and anti-Stokes.

The DTS quantifies the intensity of these backscattered photons and elapsed time between the pulse and the observed returned light. Based on the arrival time of the photons, the DTS is able to use the speed of light in the fiber to calculate the exact distances from the DTS that the photons were scattered. Ultimately, the DTS uses both arrival-time data and properties of the returning photons to calculate temperatures along the entire fiber, with spatial resolution as small as 0.25 m and temperature resolution approaching 0.01 ℃, depending on the instrument and configuration (Selker et al., 2006a).

The active heat pulse method with fiber optic temperature sensing (AHFO) for observation of subsurface water movement has been used since 2003 for several applications (Selker et al., 2006b). In the early approaches, the method could only distinguish qualitatively between dry, wet and saturated soils and small changes in soil water content could not be detected at levels above 6% [Weiss, 2003]. Lately, its accuracy has improved by using a different approach to data interpretation (Sayde et. al. 2010). Recently, it was used to observe infiltration variability in a pilot wetland on a distributed fiber optic cable located approximately 25 cm below ground (Gregory, 2009).



Source: Agilent Technology

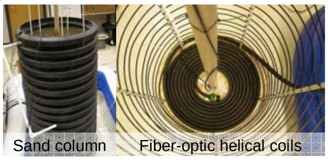
PC is part of some DTS instruments

OBJECTIVES

• To show the feasibility of AHFO to obtain precise, distributed, measurements of soil water content across spatial scales and over a broad range of soil water content.

• To show the perspectives of AHFO to detect spatial variability of water application in irrigation units and to estimate infiltration in irrigated fields.

SOIL MOISTURE MONITORING WITH HEATED FIBER OPTICS (Sayde et al. 2010)

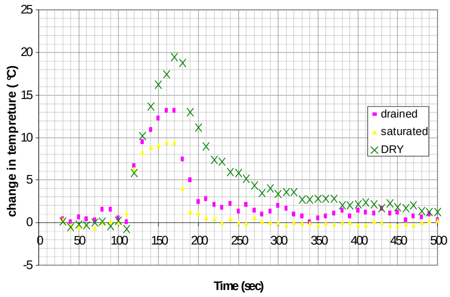


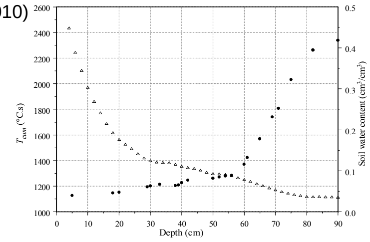
$$T_{cum} = \int_0^{t_0} \Delta T \, dt$$

Tcum = the cumulative temp. increase [℃] during the total time of integration t_0 [s].

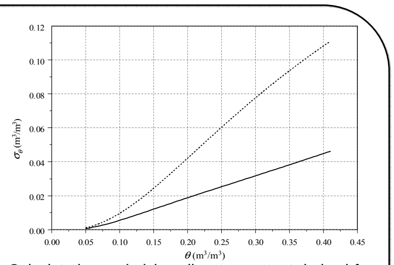
ΔT = the DTS reported temperature change from the pre-pulse temperature [℃].

Temperature changes during heating and cooling (100V 1-min pulse at 41 m)





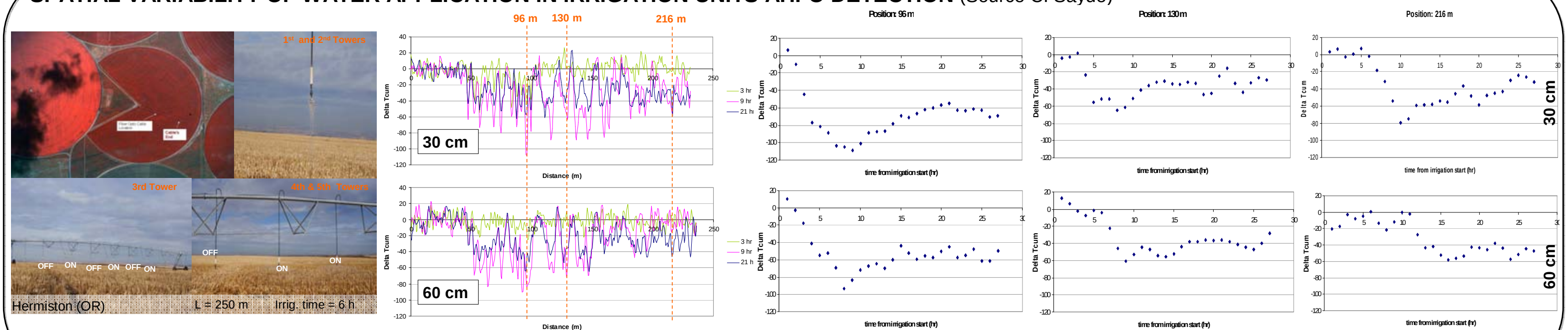
Measured soil water content (circles), and cumulative temperature increase (triangles) as function of depth for a 2-minute 20 W/m heat pulse.



Calculated error (σ_θ) in soil water content derived from Tcum (solid line), and from ΔT_{120s} (dotted line), as function of soil water content (θ).

The accuracy of the soil water content measurements varied approximately linearly with water content. The uncertainty could be further reduced by averaging several heat pulses and by using higher performance fiber optic sensing system.

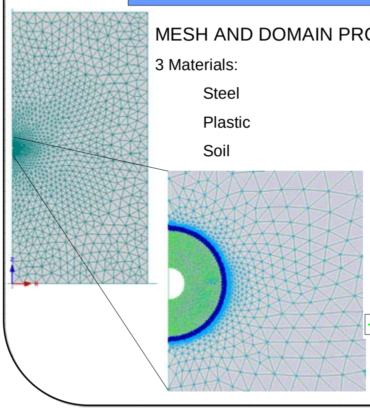
SPATIAL VARIABILITY OF WATER APPLICATION IN IRRIGATION UNITS AHFO DETECTION (Source C. Sayde)



Delta T_{cum}= diff. of T_{cum} between the initial state and the time shown

SIMULATION OF WATER AND HEAT FLUXES WITH HIDRUS 2D/3D

Steady state conditions, water flux= 0.00286 mm/s
Heating pulse of 10 W/m during 60 s
Sandy uniform soil



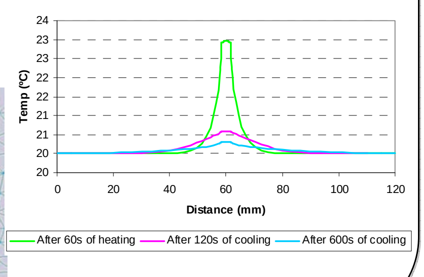
MESH AND DOMAIN PROPERTIES

3 Materials:

Steel

Plastic

Soil



PERSPECTIVES

• Currently research in irrigated lands is promising. The AHFO could distinguish soil water content variability at different depths along a centre pivot irrigation line. Thus, the relationship between water application by the irrigation system and its distribution in the soil could be further accomplished.

• HYDRUS-2D/3D could be used to simulate water flow and heat transport within the soil around the cable. Then, its calibration with experimental measurements will lead to water flux predictions.

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