MEASUREMENT AND EVALUATION OF THE SOIL THERMAL PARAMETERS ON THE SURFACE ENERGY BALANCE IN AN AGRICULTURAL PLOT

Brut[1] A., De La Ruë Du Can[1] O., Poignard[1] M., Granouillac[1] G., Zawilski[1] B, Boone[2] A., Canut[2] C., Lothon[3] M., Lohou[3] F.

[1]CESBIO, University of Toulouse, CNES/CNRS/INRAE/IRD/UPS, 18, Avenue Edouard Belin, bpi 280, CEDEX 09, 31401 Toulouse, France ; [2]CNRM/Meteo France, Toulouse, France; [3]Laboratoire d'Aérologie, Toulouse, France

Contact : aurore.brut@iut-tlse3.fr

Context & Objectives

❖ **Non closure of SEB[1]** : improvement of the ground heat flux (G_0) accuracy

❖ $$G_0 = -\lambda \frac{\partial T}{\partial z}\Big|_z + \int_0^{z_r} \rho c \frac{\partial T}{\partial t} dz$$

measured at 5 cm depth — storage between the surface and 5cm estimated with a model

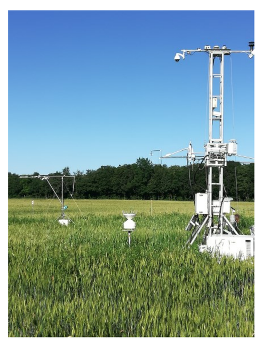
$$C_{mod} = \varphi_{min} \cdot \rho_{min} \cdot c^{sp}_{min} + \varphi_{org} \cdot \rho_{org} \cdot c^{sp}_{org} + \varphi_{aq} \cdot \rho_{aq} \cdot c^{sp}_{aq}$$ [2]

Soil composition			Density			Specific heat capacity		
percentage by weight			kg/m^2			$J/(kg)$		
φ_{min}	mineral	≈ 0.45	ρ_{min}	mineral	2650	c^{sp}_{min}	mineral	870
φ_{org}	organic	≈ 0.05	ρ_{org}	organic	1300	c^{sp}_{org}	organic	1920
φ_{aq}	soil water content	[0.2 0.5]	ρ_{aq}	water	1000	c^{sp}_{aq}	water	4180

❖**Objectives :** to evaluate the dynamics of soil thermal parameters over a wheat crop cycle as a function of soil water content and plant development in order to improve the accuracy of G_0.

Study Site

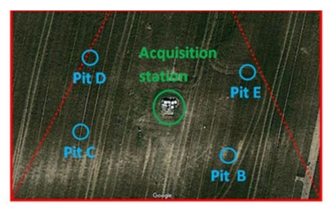
- **Study area: Lamasquère (FR-Lam)** is part of a livestock farm in southwestern France and follows a irrigated maize/winter wheat crop rotation (23.8 ha). Mean annual rain and air temperature are 680 mm and 12.6 °C respectively
- **Soil texture:** 50.3 % clay, 35.8 % silt, 11.2 % sand, 2.8 % OM.

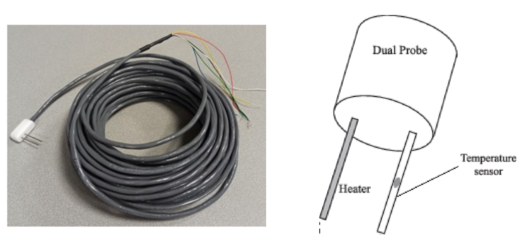


FR-Lam experimental site is heavily instrumented and monitored as a class 1 cropland station in the European ICOS network.

Sensors and Method

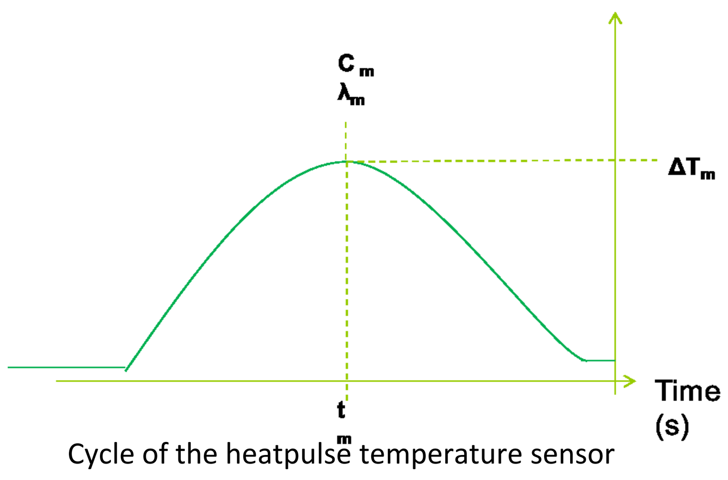
❖ This study is based on a unique and original data set : 12 heat pulse sensors located in 4 pits at 3 different depths (5, 10 and 30 cm) around a EC tower between December 2021 and June 2022.





Picture and structure of a heat pulse sensor

During a measurement cycle (300s) , a heat pulse (~23J) is applied by the heater needle, and then the temperature is measured every second by the temperature sensor located in the second needle.



Cycle of the heatpulse temperature sensor

$$C_m = \frac{q}{4\pi\lambda\Delta T_m}\left(\varepsilon_1\left(\frac{L^2}{4\lambda t_m}\right) - \varepsilon_1\left(\frac{L^2}{4\lambda(t_m - t_0)}\right)\right)$$

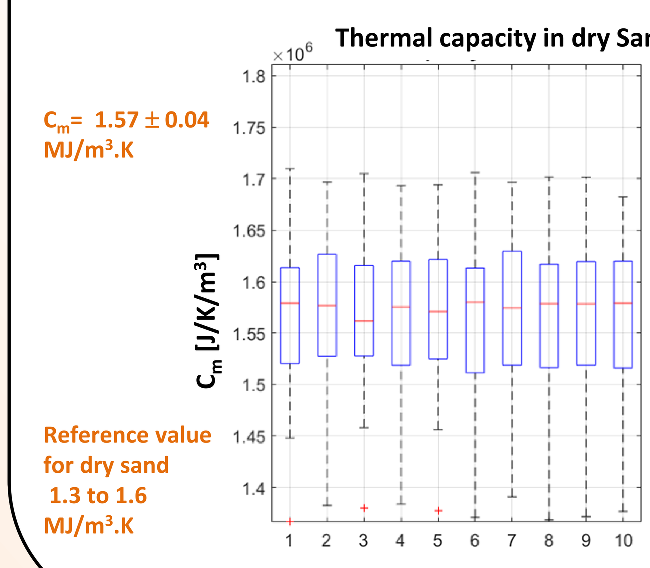
$$\lambda = \frac{L^2}{4}\left(\frac{\frac{1}{t_m - t_0} - \frac{1}{t_m}}{ln\left(\frac{t_m}{t_m - t_0}\right)}\right)$$

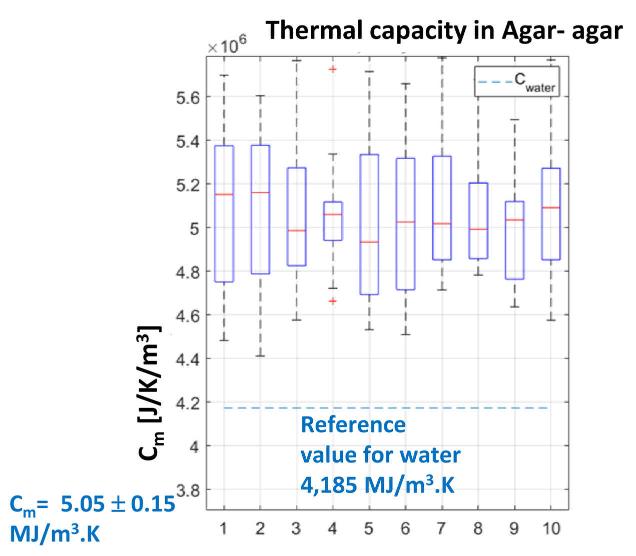
Q	linear energy	$J.m^{-1}$
q	linear power	$W.m^{-1}$
t_0	heating time	s
L	distance between needles	m
ε_1	exponential integral function	

To retrieve the soil thermal properties (heat capacity c_m, heat conductivity λ_m and diffusivity α from t_m and ΔT_m (solving the heat diffusion equation), we used a **continuous line heat source model** to represent the heater [3].

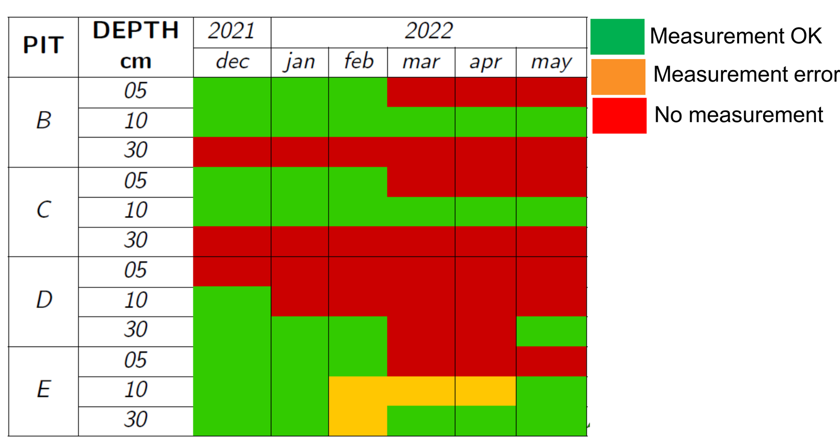
Results

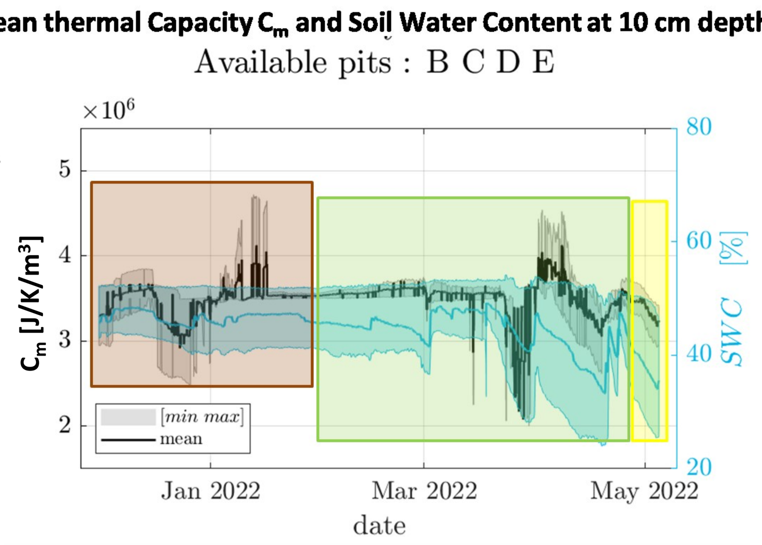
1. Evaluation of the sensors and method accuracy in different media (sand and water with agar-agar)



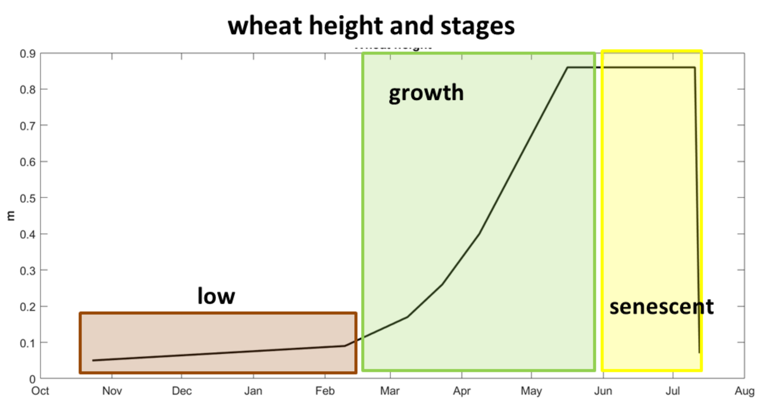


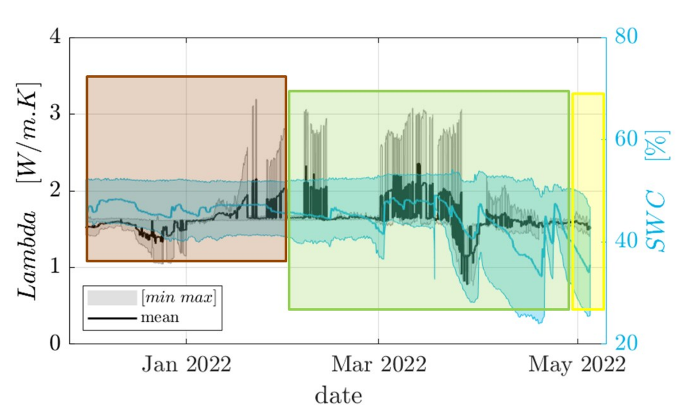
2. assessment of soil thermal parameters during the wheat season





- Noisier signal for thermal capacity during spring season
- Strong correlation between SWC at 10cm and C_m at the same depth.

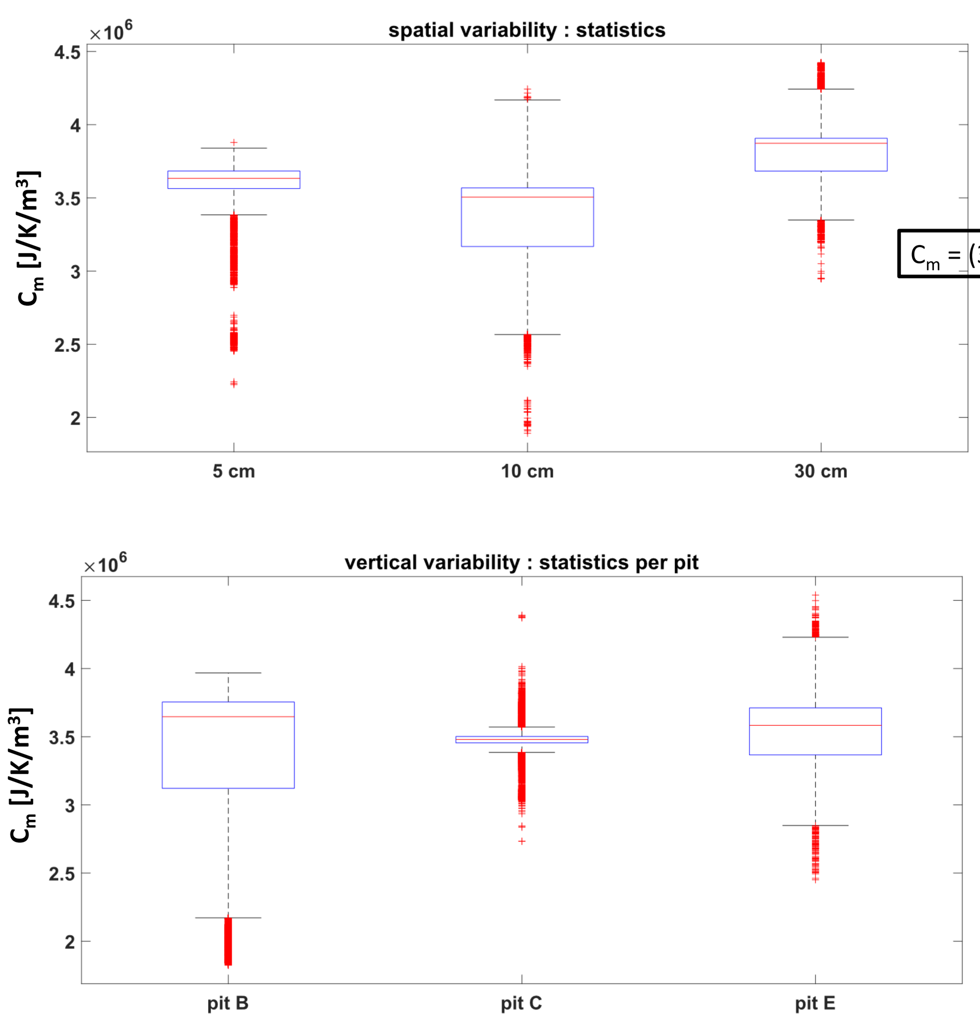




λ_m = 1.4 W/m/K

- Noisier signal for thermal conductivity λ during wheat development (Feb. - April)
- Less impact of SWC on λ when wheat is well developed

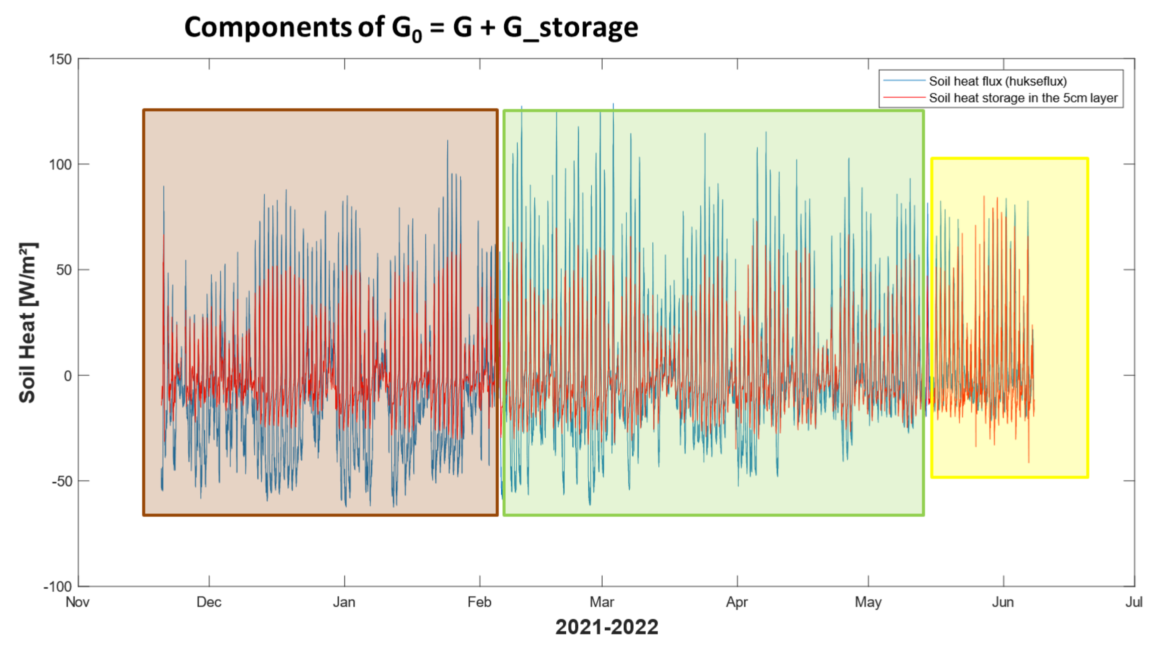
3. Variability of C_m



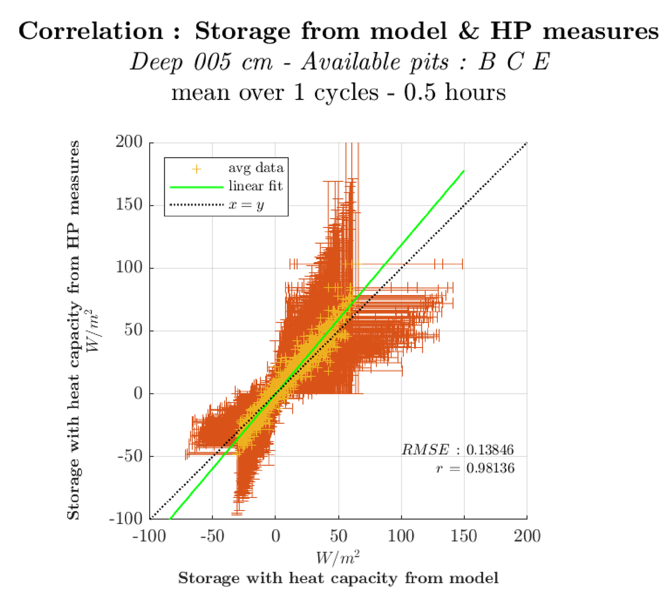
C_m = (3.6 ± 0.35)x 10^6 J/K/m³

In the tillage bed, the dispersion of the observed volumetric heat capacity measurements is similar both vertically and horizontally. It is mainly related to the water content of the soil.

4. Impact on the ground heat storage term



G storage (estimated with measured c_m) can reach the same order of magnitude of the soil heat flux from mid-May, over developed vegetation.



Excellent correlation, with a slight overestimation for storage measured with Heatpulse sensor.

Conclusions

1. Fragility of the sensors for a long-term campaign in very clayey soil
2. Better repeatability of measurements and reduced scatter of the soil thermal parameters in a dry medium.
3. Good correlation between the heat capacity and soil water content over the wheat growth season, less impact of the SWC on heat conductivity when winter wheat is fully developed.
4. The measurements of the heatpulse sensors allowed to verify the model (De Vries and Philip, 1986) of heat capacity as a function of texture and water content

Aknowledgement :

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