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Non-destructive measurements for destructive experiments: how to assess damages ?

Guillaume Charrier, Thierry Ameglio

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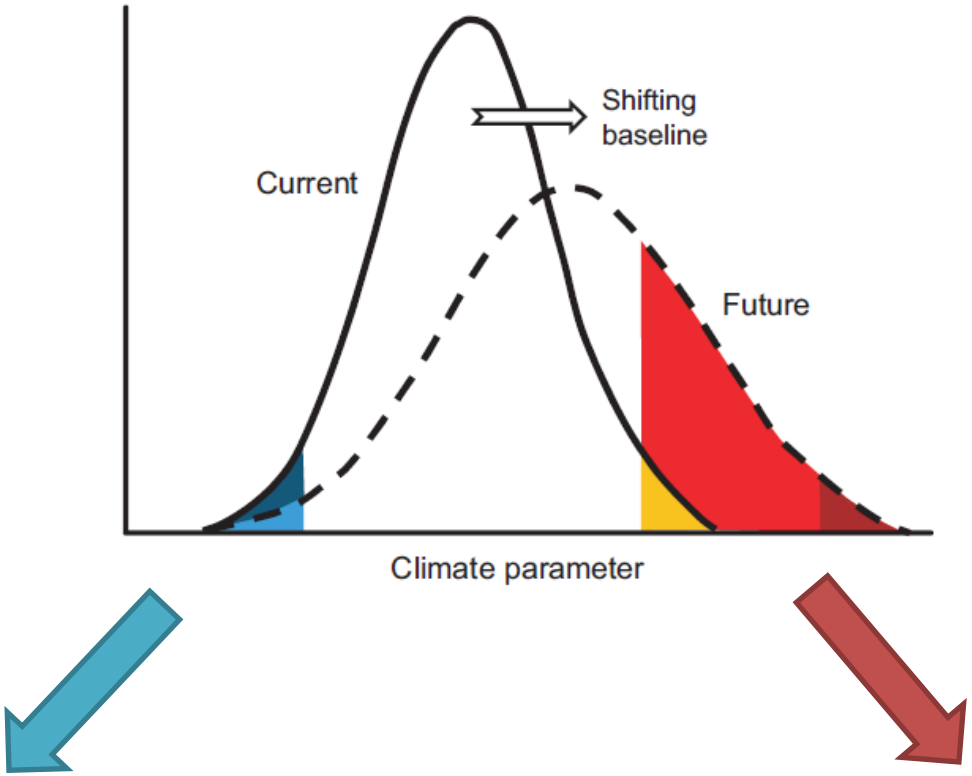
Survie au stress – Stress survival
Journée thématique CEFE

Non-destructive measurements for destructive experiments: how to assess damages?

G. Charrier & T. Améglio

2019/09/09

Context – Facing extreme climatic events

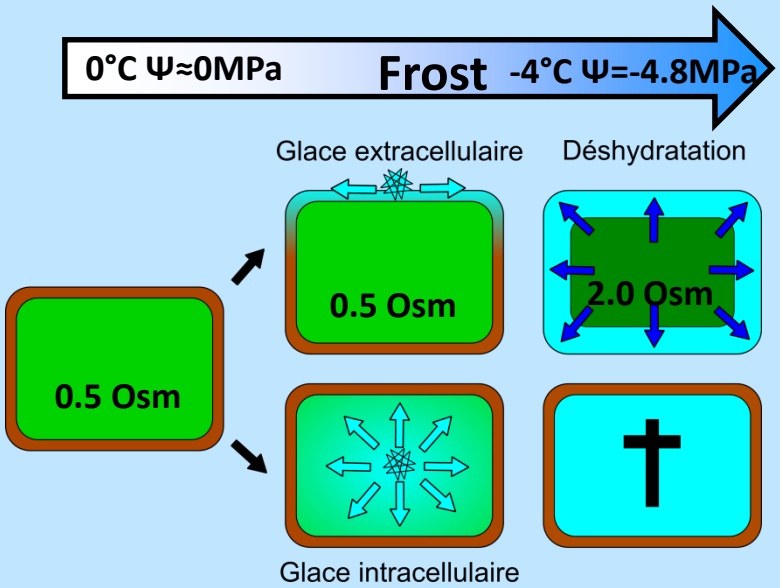


Still some frost events

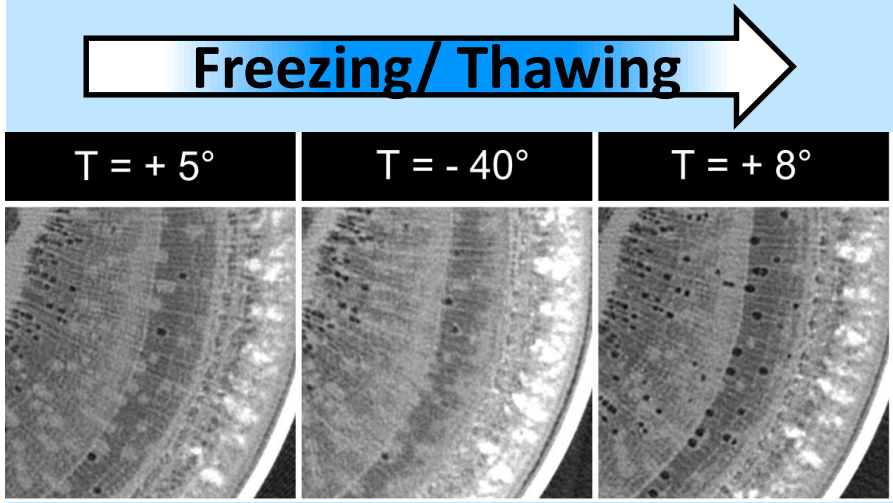
More heat-waves and drought events

Abiotic stress – Physiological damages

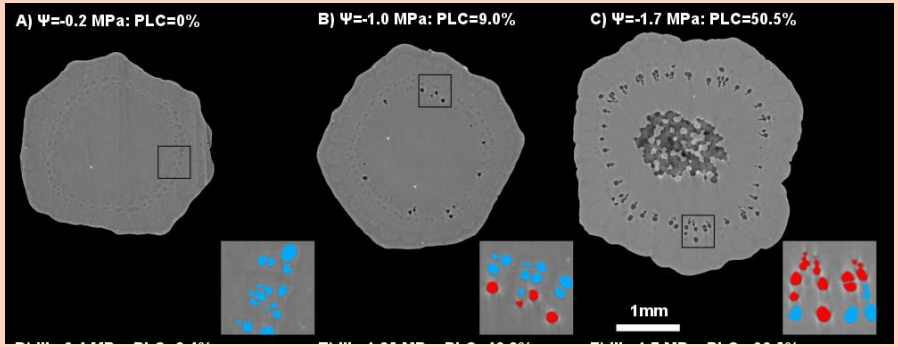
Living cells



Hydraulic system



Charra-Vaskou *et al.*, J. Exp. Bot. 2015

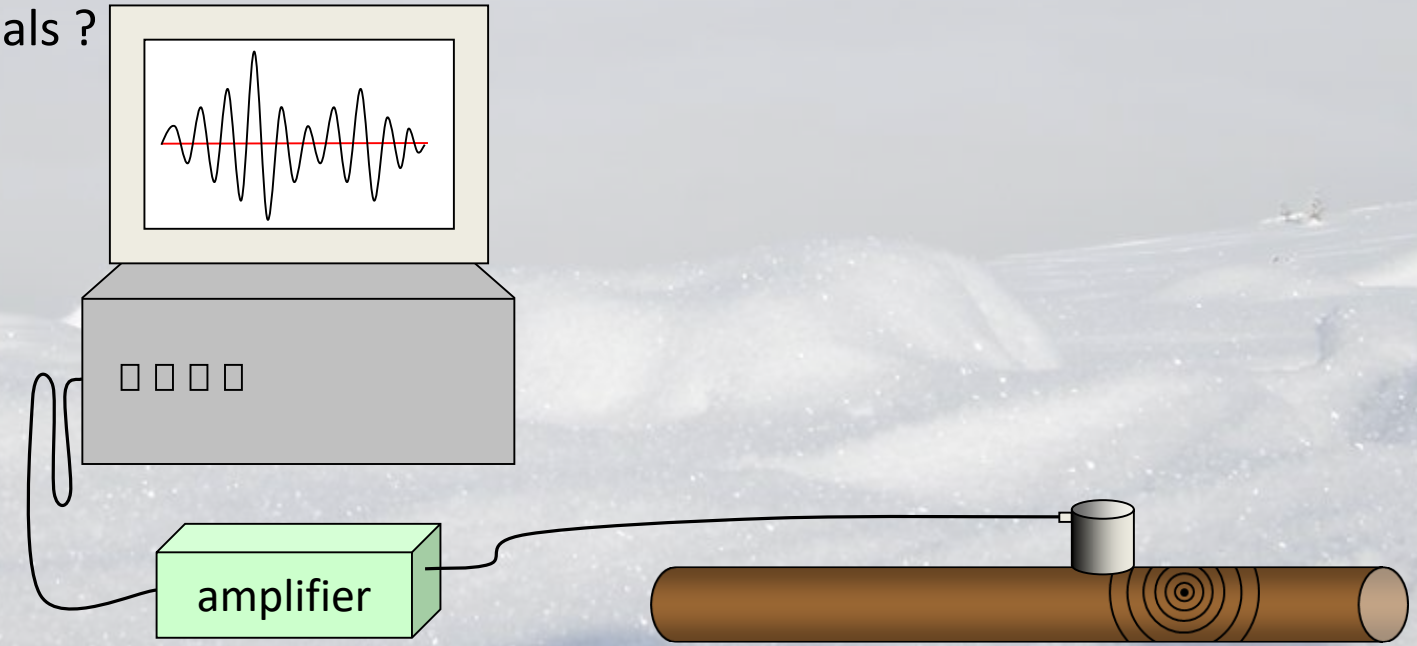


Charrier *et al.*, Plant Physiology 2016

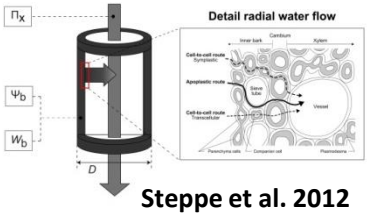
Non-invasive techniques to monitor damages *in situ*

- Dendrometer
  - Water fluxes (drought and frost stress)
  - Growth (resilience to stress)

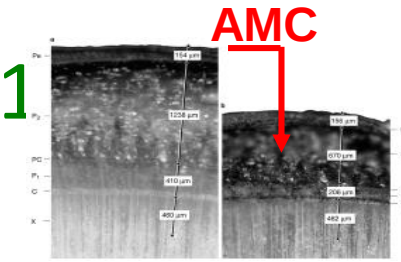
- Ultrasonic acoustic analysis
  - Cavitation events (drought and frost stress)
  - Other signals ?



adial growth monitoring since 191



Steppe et al. 2012



Zweifel *et al*. 2000

Daniel Trembly MACDOUGAL (1919)
Hydration and growth. Proc. Amer. Phil. Soc. 58: 346-372.

Walnut

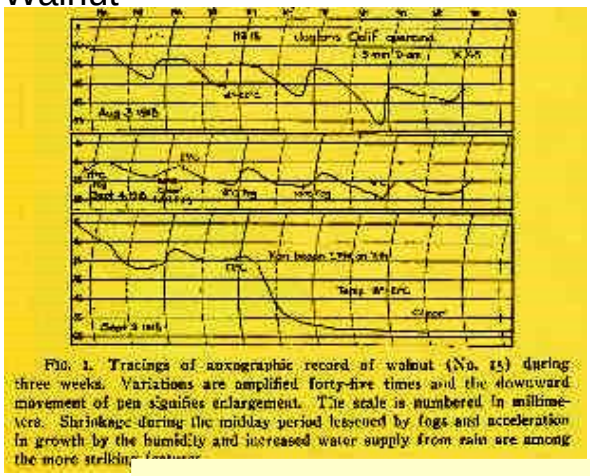
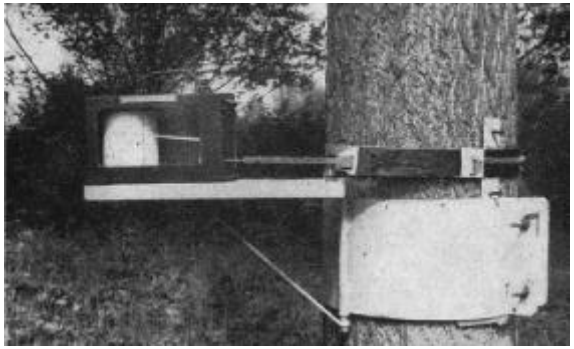


FIG. 1. Tracings of auxographic record of walnut (No. 15) during three weeks. Variations are amplified forty-five times and the downward movement of pen signifies enlargement. The scale is numbered in millimeters. Shrinkage during the midday period lessened by fogs and acceleration in growth by the humidity and increased water supply from rain are among the more striking features.

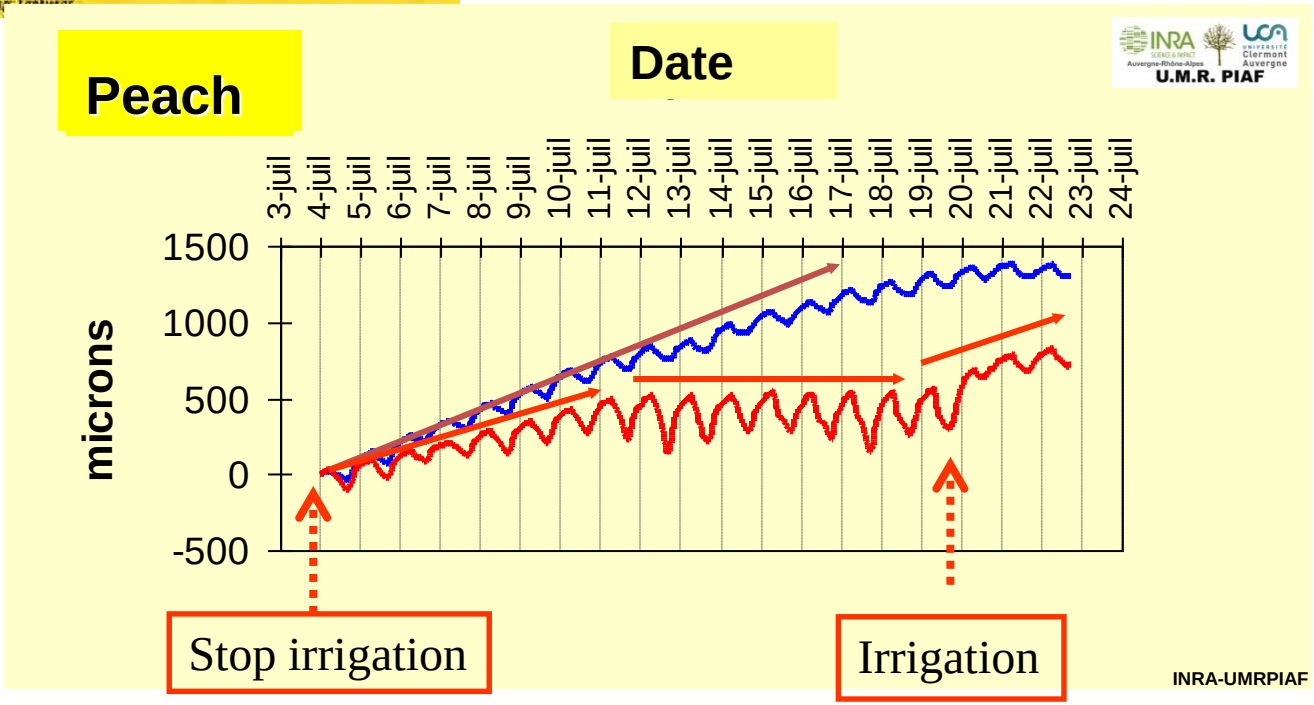


Dendrographe: Fritts HC (1955)

Patent INRA " **Pepista** ", JG Huguet (1985**)**

Pépi = thirst **sta**= stabilize

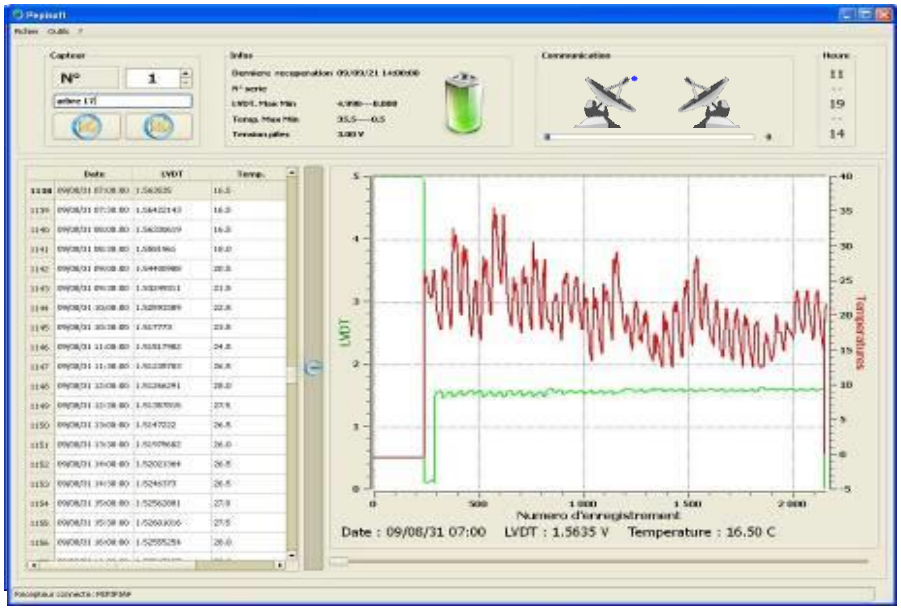
For automatic fruit trees irrigation

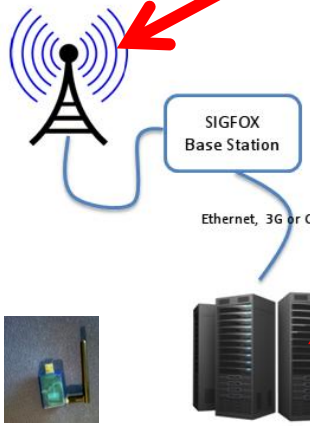


From the Pépista to the PepiPIAF

A LVDT sensor and a sensor holder (invar)

Acquisition of data
Measurement of T_{air} °C
Power supply (2 AA)
2.4 GHz Radio Transmitter
and Sigfox or LoRa networks





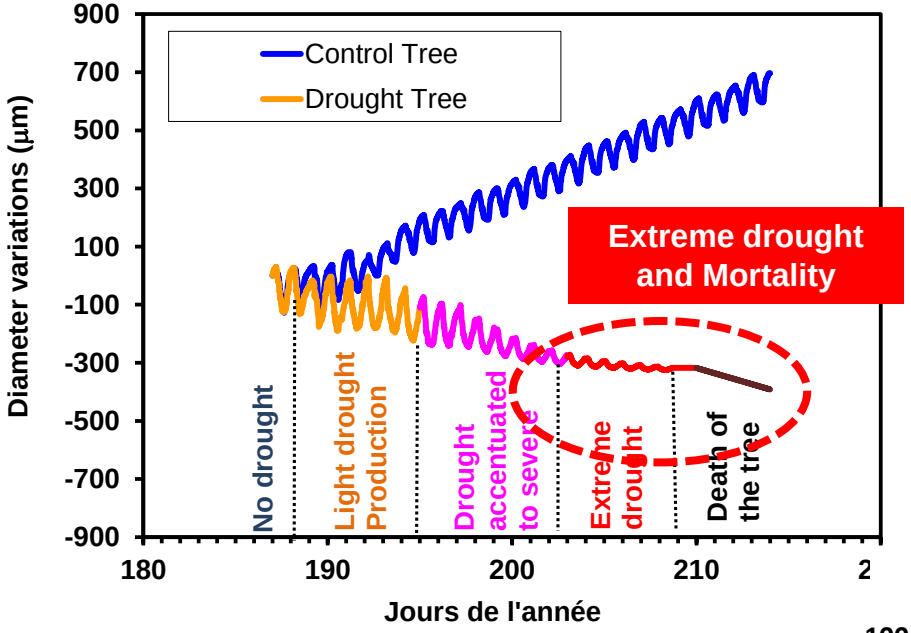
Receiver USB
Pépidatasoft software

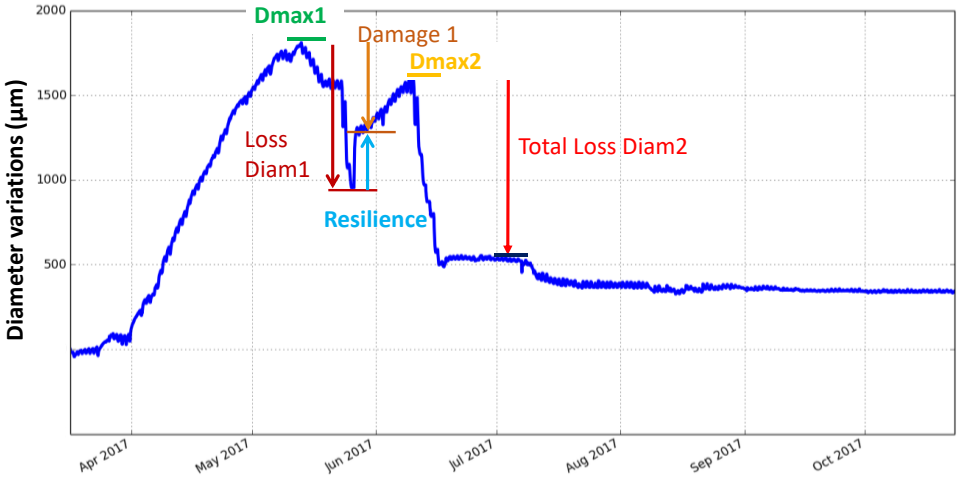
Mini data logger integrated :

- LVDT (resolution <1µm (16 bit acquisition) & Temperature sensor (± 0.5 ° C)
  Power Supply: 2 AA Autonomy for 12 months)
- Memorization: average according to selected frequency (1, 5, 10, 15, 30 mn, 1h, 3h)
- Memorization: from 2160 to 10800 measurements (ex, for 30 mn = a history over 45 to 225 days)
- Authorized distributor: Hydrasol licensed INRA Transfert
- PépiDataSoft remote download software, allowing to view and dialogue with the PépiPIAF and to edit the data in txt or excel format and to interpret them)
- PC Transmission; Radio HF 43.3 Mhz: range of 150 m to PS and Sigfox or LoRa

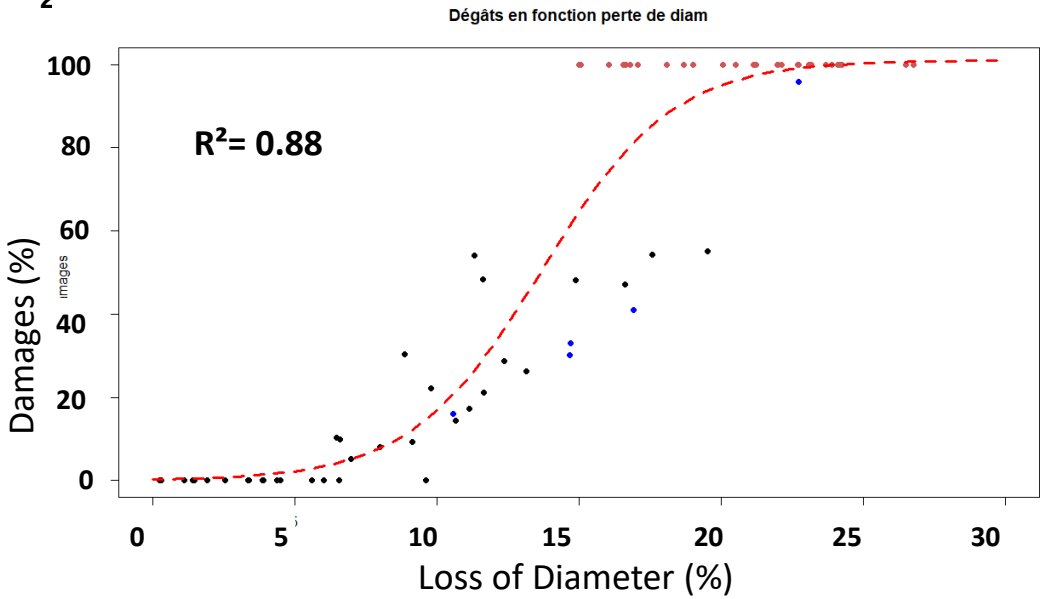
Hydrasol les racines et l'eau du sol · INRA Transfert · Lycée LA FAYETTE Clermont-Ferrand · INRA · UCA Université Clermont Auvergne · U.M.R. PIAF

Extreme drought conditions to determine mortality



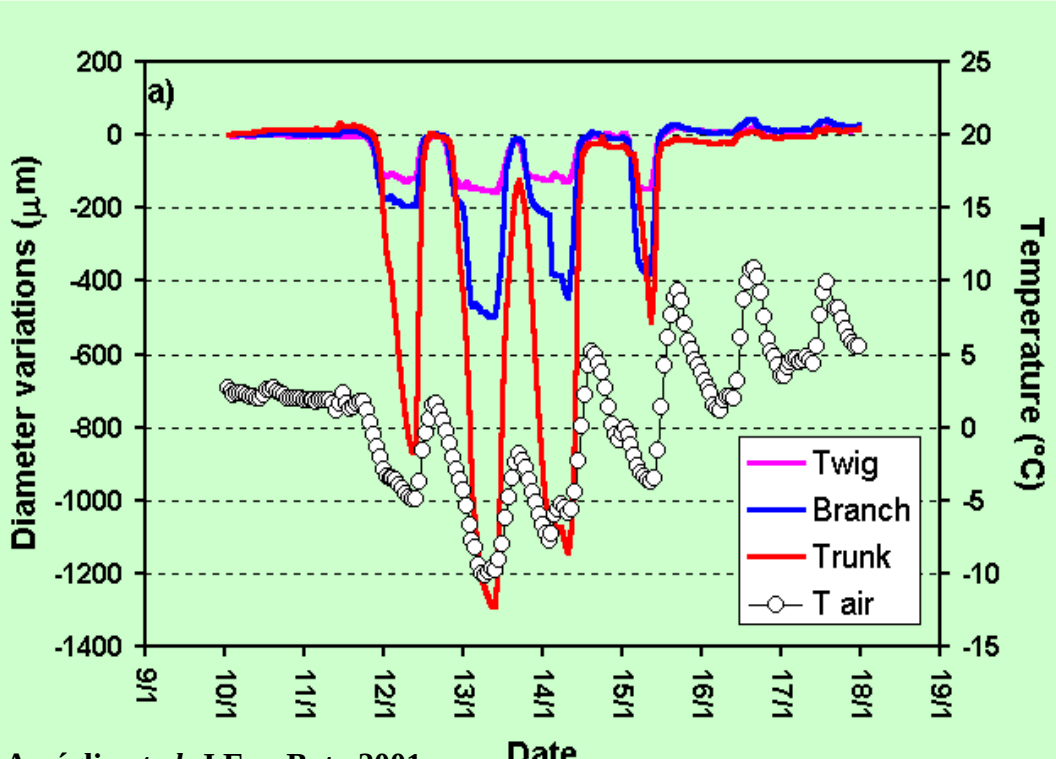


Work in progress of a PhD student Lia Lamacque (UMR PIAF- Iteipmai) on the links between extreme drought and mortality on Lavanda



iteipmai

Winter damages



Améglio *et al*. J.Exp.Bot., 2001

Journal of Experimental Botany, Vol. 52, No. 364, pp. 2135–2142, November 2001

Journal of Experimental Botany

Stem diameter variations and cold hardiness in walnut trees

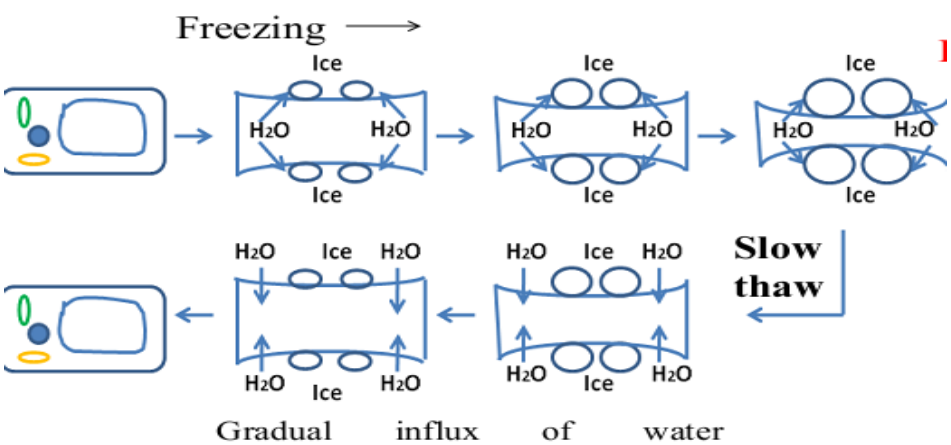
Thierry Améglio[1,3], Hervé Cochard[1] and Frank W. Ewers[2]

The Ψ of ice changes at about 1.16 MPa·K^{-1} decrease in temperature.

Rajashekar and Burke (1982)
Rajashekar et al. (1983),

If the ice formation start at -5°C when the temperature decrease at -10°C,the Ψ decrease about ≈-6,0 Mpa

Similar to Extreme drought stress!



INRA SCIENCE & IMPACT Auvergne-Rhône-Alpes
UCA UNIVERSITÉ Clermont Auvergne
U.M.R. PIAF

Extreme stress at the treeline: Winter drought

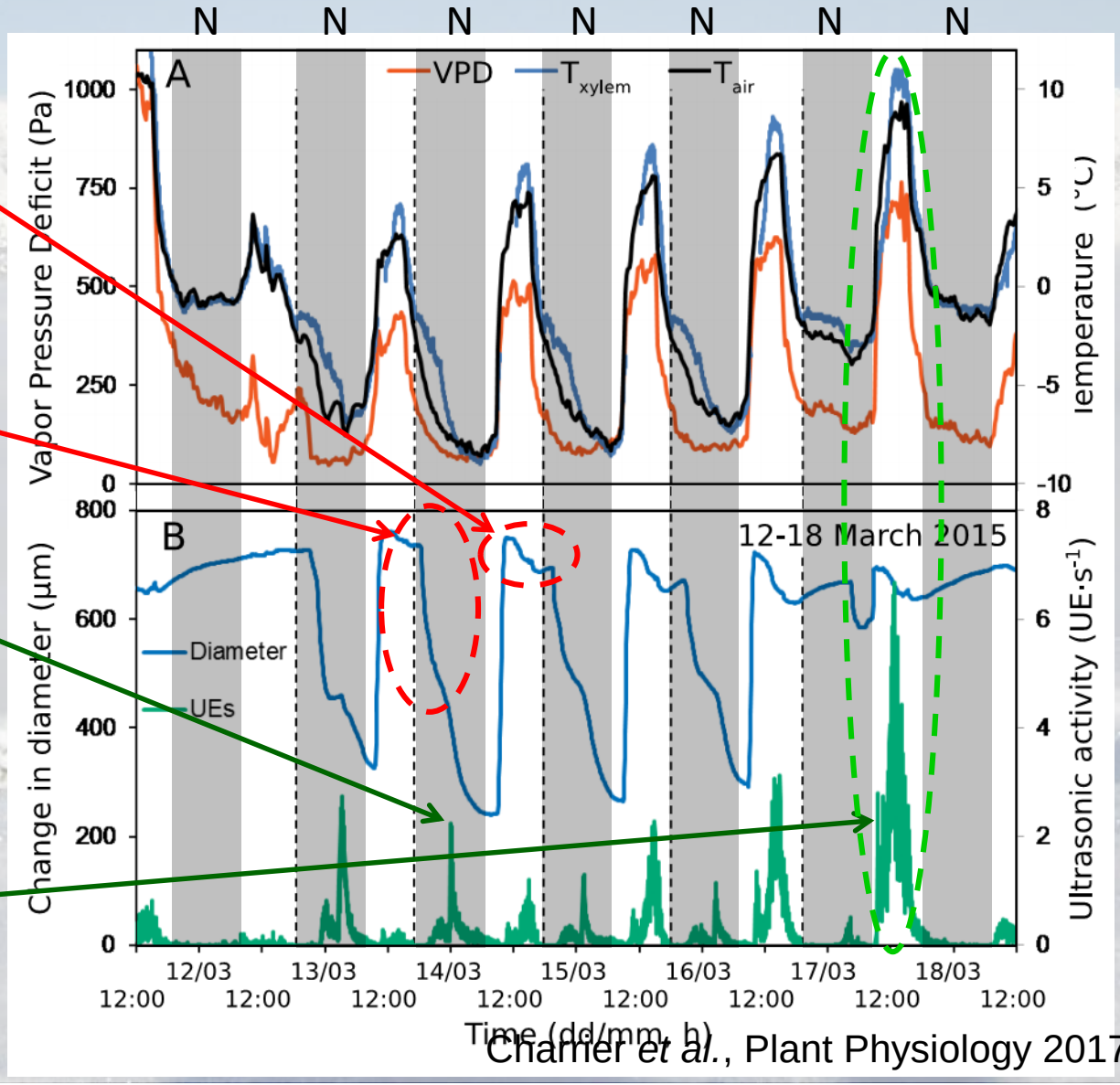
Daytime shrinkage (E)

Nighttime shrinkage (Ψ_{ice})

Nighttime AEs: Freezing-cavitation = bubbles formation

Daytime AEs: Embolism development due to transpiration

Ψ_{stem}

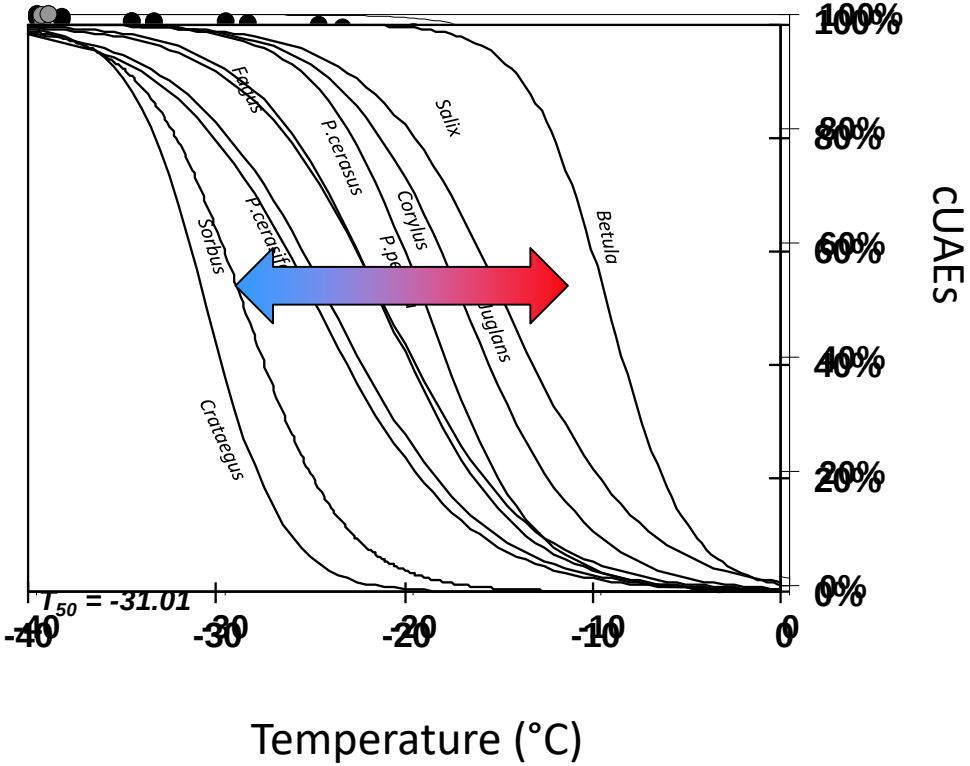


Charrier *et al.*, Plant Physiology 2017

Frost-induced acoustic emissions
Interspecific variability

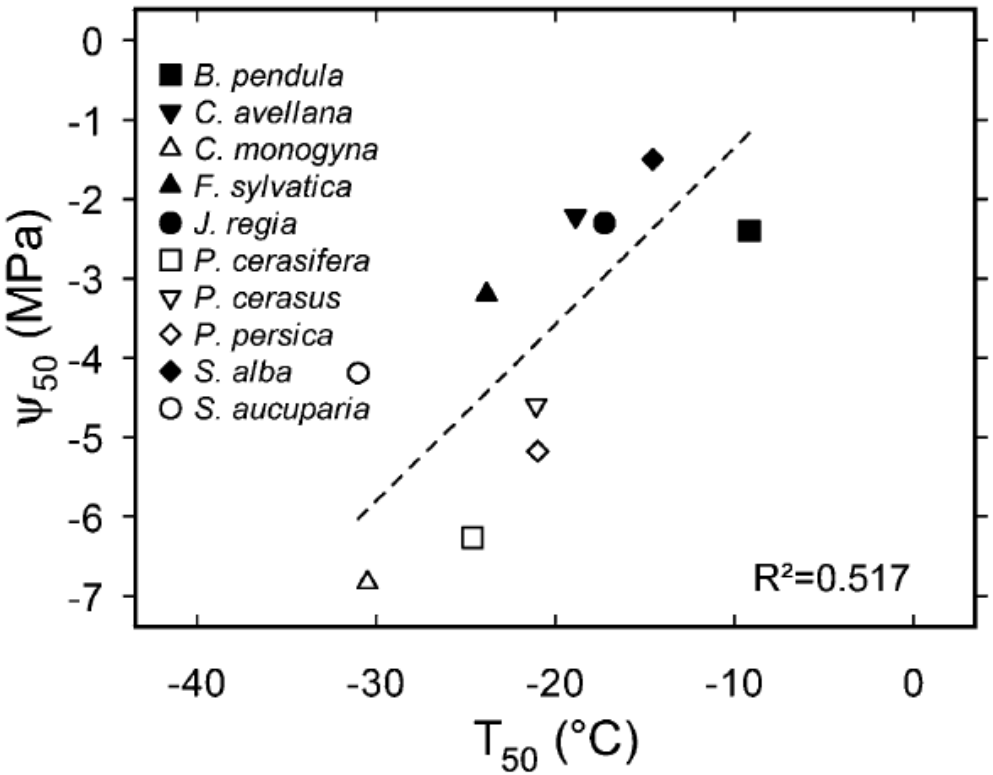
Sigmoid relation with temperature,
($0.928 < R^2 < 0.994$)

Wide variability in T_{50},
($-10 < T_{50} < -32°C$)



Charrier *et al*. (2014) *Plant Physiology*

Frost-induced acoustic emissions is related to drought resistance



Freeze-Thaw expansion hypothesis with Ψ_{ice} as driving force:

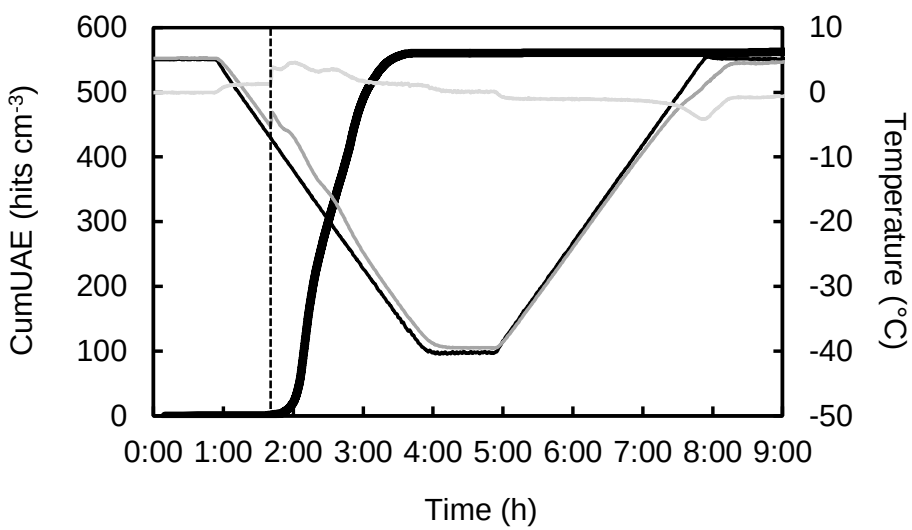
=> displacement of the air-water menisci in pits

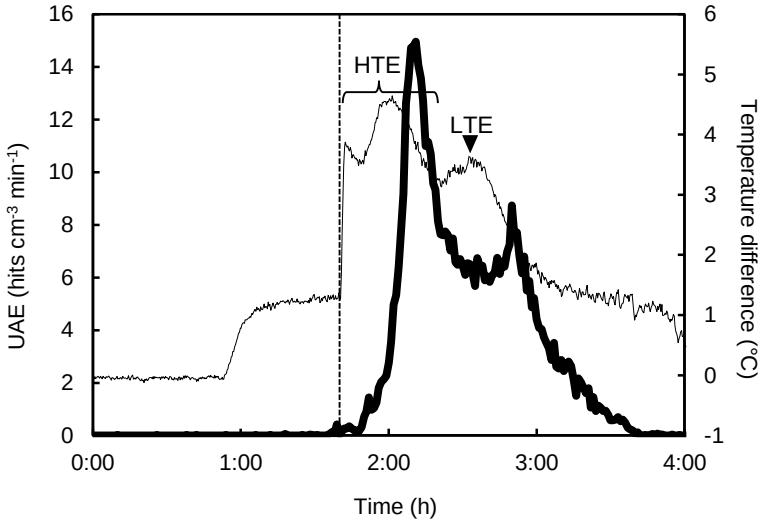
=> cause bubble to expand or collapse

Drought-induced and frost-induced embolisms may share the same mechanism.

Charrier *et al.* (2014) *Plant Physiology*

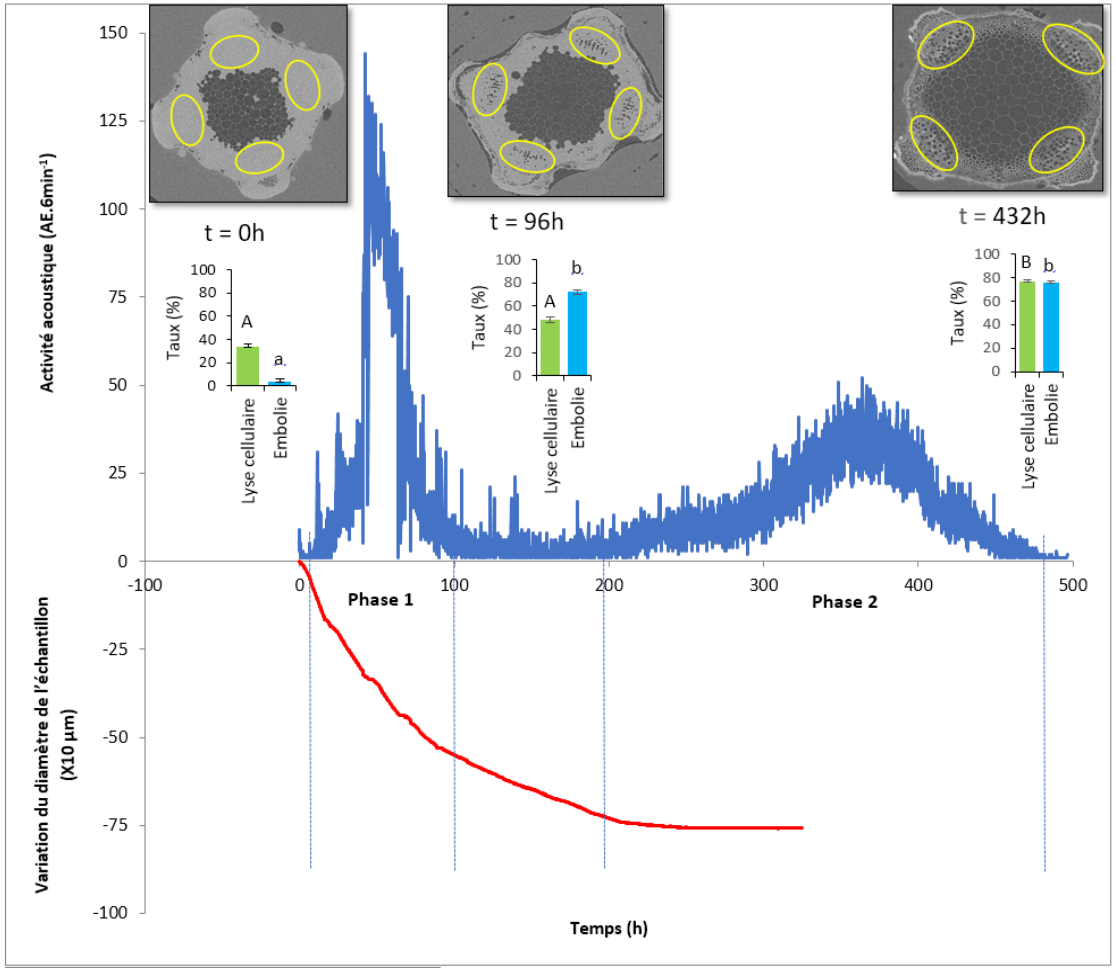
Are UEs only from vessel origin?





Kasuga *et al*. (2015) *Journal of Experimental Botany*

Are AEs only from vessel origin?

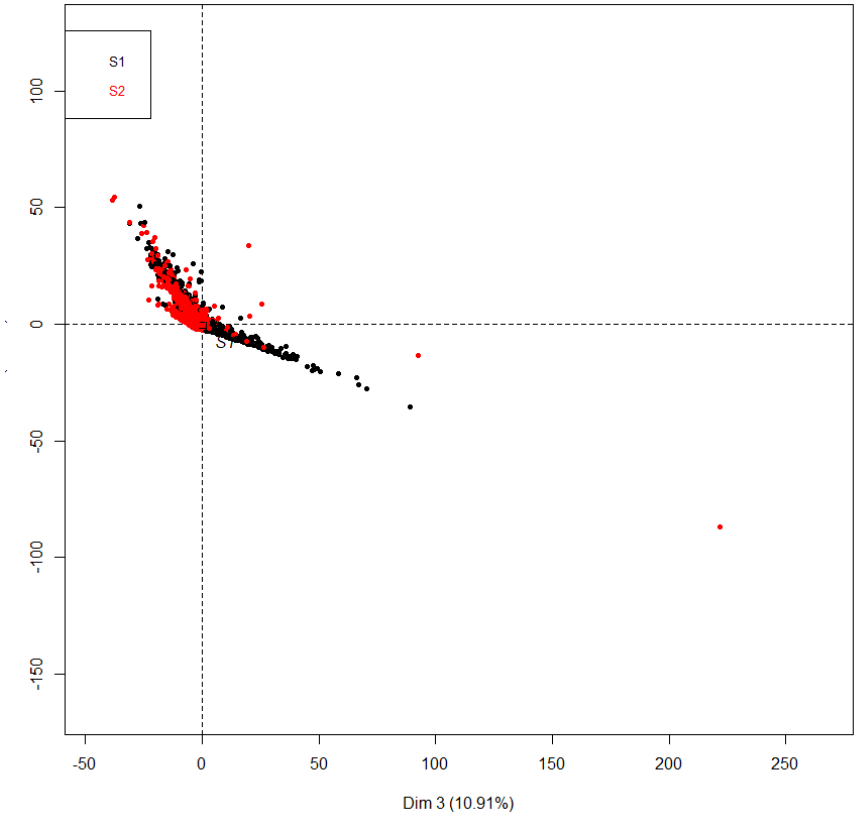


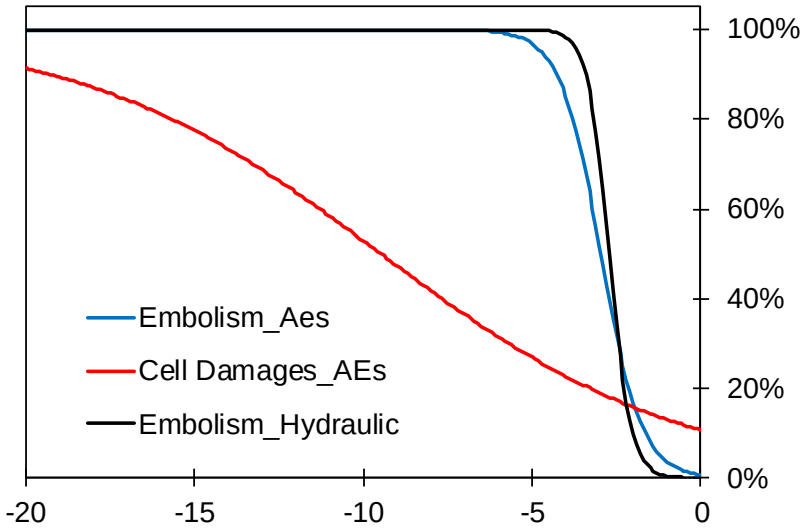
- 2 stages of AEs

  1st => embolism & cell damages

  2nd => cell damages

Capturing acoustic parameters across stages to predict PLC and cell damages





Sounds promising !

Thank you for your attention

guillaume.charrier@inra.fr
thierry.ameglio@inra.fr

INRA SCIENCE & IMPACT Auvergne-Rhône-Alpes
UNIVERSITÉ Clermont Auvergne
U.M.R. PIAF

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