

Low cost sensor

➤ for hydrological & environmental monitoring using electro-physiological signals from trees

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> Outline

- **Trees as environmental sensors**
- **Implementation**
 - Material & Methods
 - Study site
- **Results**
 - Circadian rhythms (photo-periodism)
 - Rainstorm of May 10th
 - Summertime monitoring
- **Conclusions & Perspectives**



➤ **Plants: key environmental witnesses**

**Since the 19th century
(Burdon-Sanderson, 1873 & Darwin, 1875)
we know that:**

**Various biotic and abiotic environmental
stimuli
produce in plant electrical signals,
causing physiological responses**

➤ Electric signals in plants

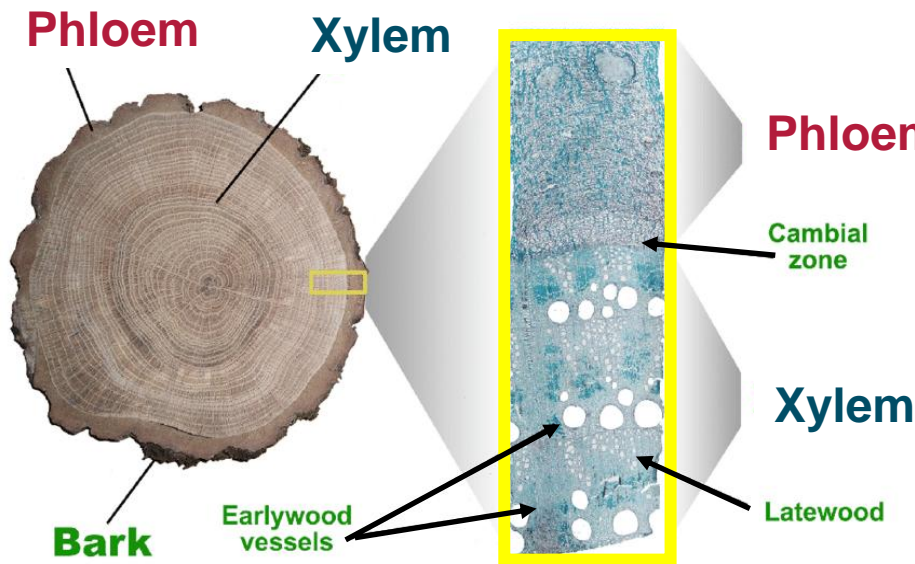
Three types of plant electrical signals:

1. **Local Electrical Potential:** sub-threshold response induced by environmental changes, not transferred to other parts of plant
2. **Action Potential:** induced by harmless stimuli transmitted rapidly over long distances via the **phloem** (follows the all-or-none law)
3. **Variation Potential:** induced by harmful stimuli, variable in magnitude and form, mainly transmitted via the **xylem** (decreases with distance)

➤ Sap flows in trees

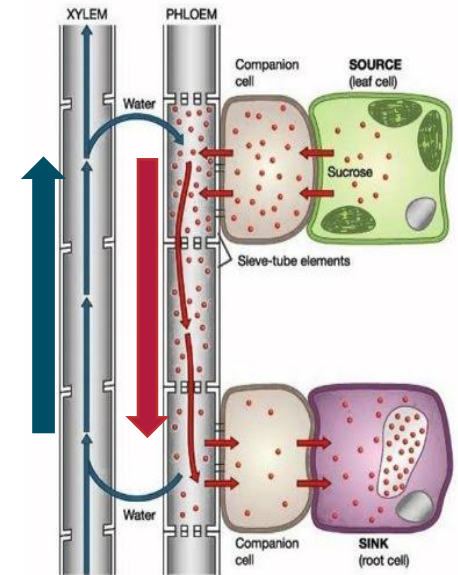
Plant metabolism generates electricity

Two kinds of electrical conductors: **Xylem** & **Phloem**
with opposite fluxes of electric charges



Transport of organic compounds from photosynthesis

Water and mineral transport from roots to leaves



➤ Work hypothesis

Is it possible to get from
voltage variations some
relevant data about the
tree environment?

in order
to turn trees into
native and low-cost
environmental sensors



> Implementation

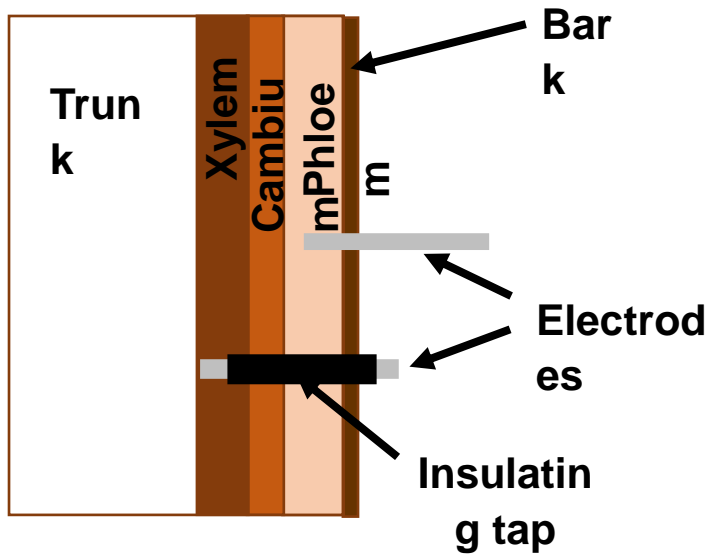
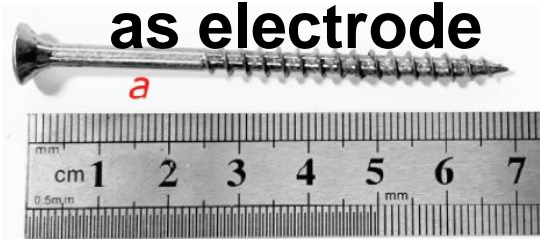
- **Design of a cost-effective, open-source remote monitoring system**
- **Field evaluation of our low-cost system**



➤ Electrode setup on the tree

70 mm stainless steel
screw

as electrode



Electrode implantation in the tree



➤ Reference electrode & overall set

Non-polarizable electrode for self potentials measurements

PM 9000
SDEC
France

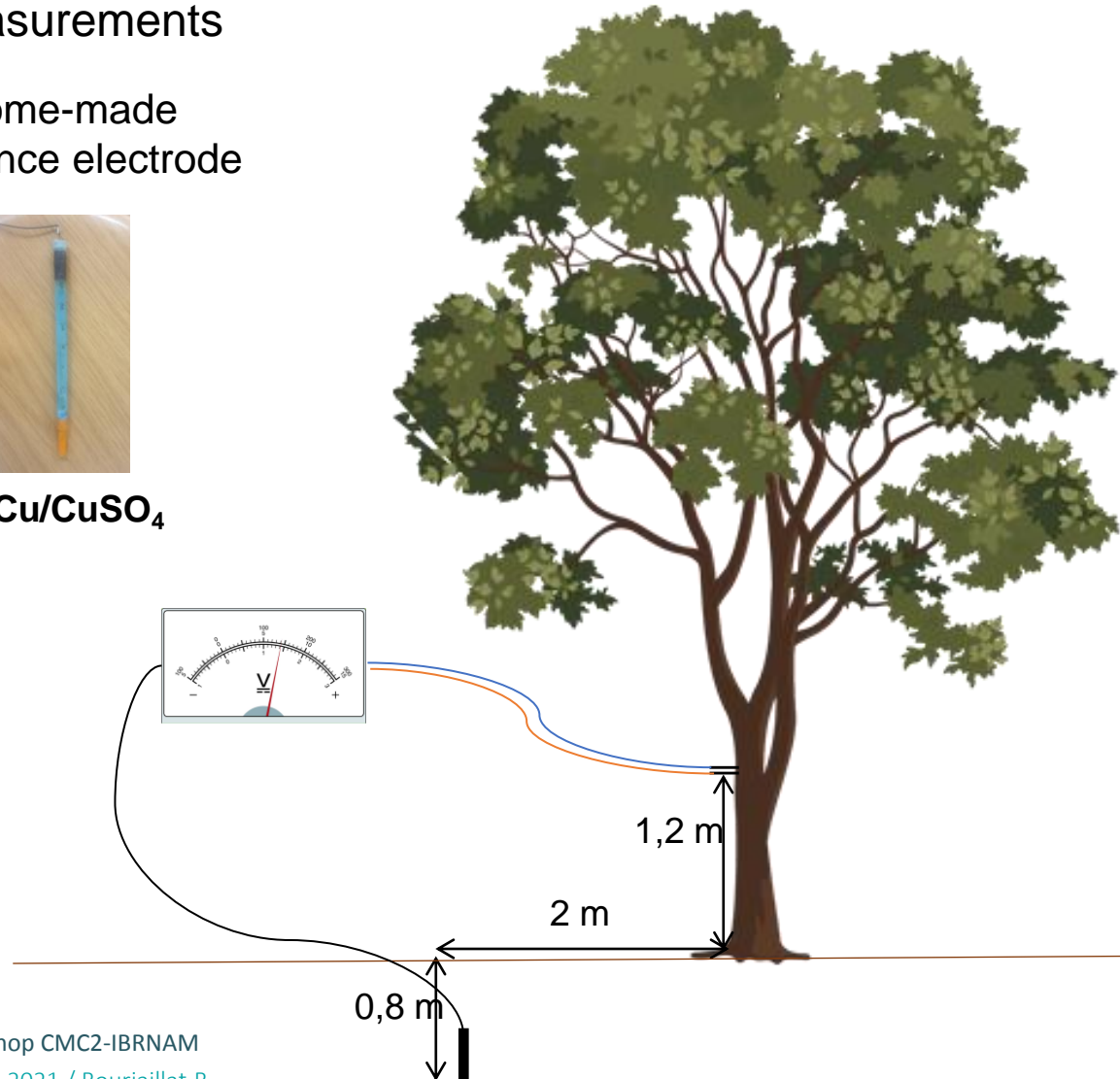


Pb/PbCl_2

Home-made
reference electrode



Cu/CuSO_4

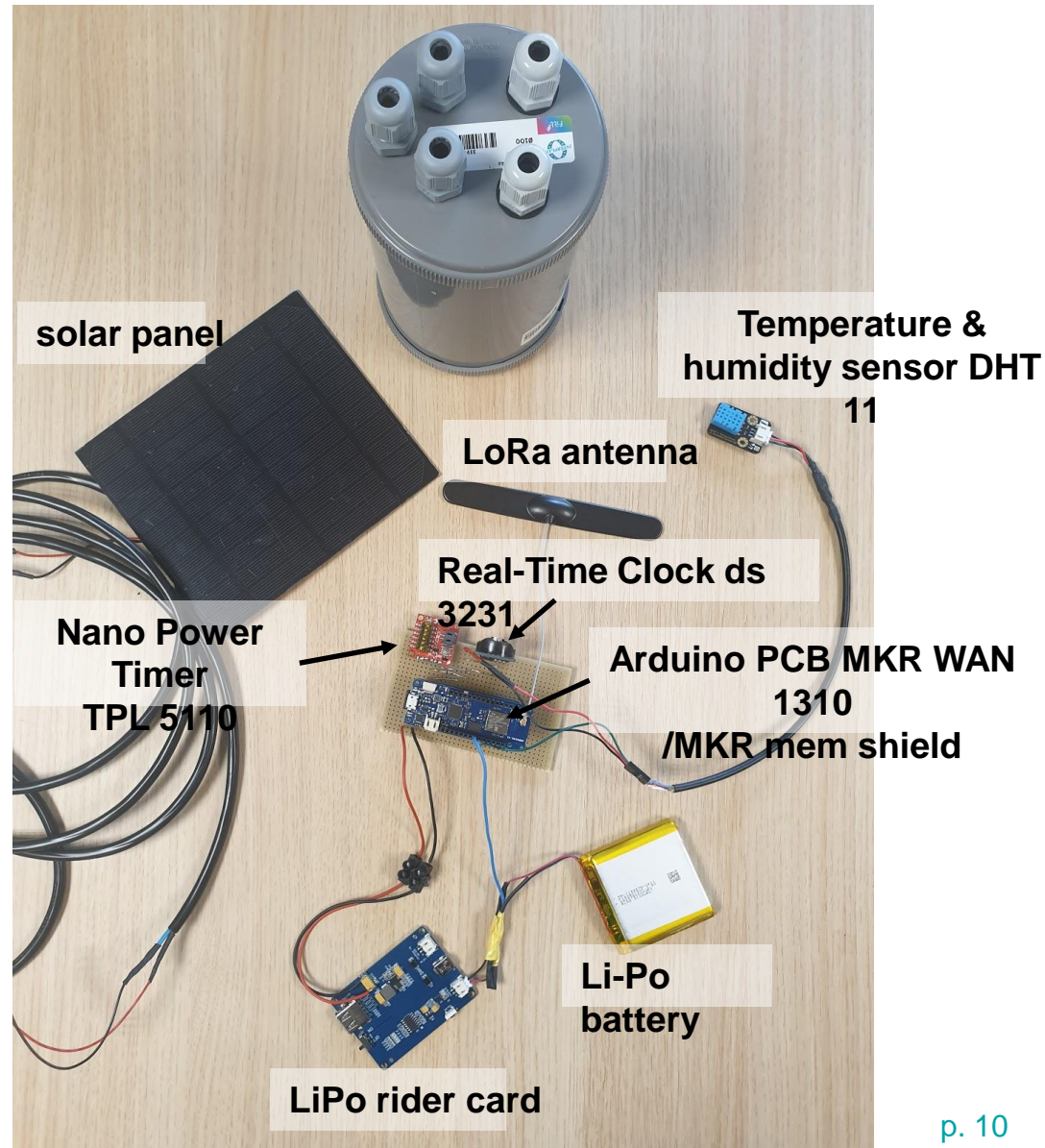


➤ Data logger system

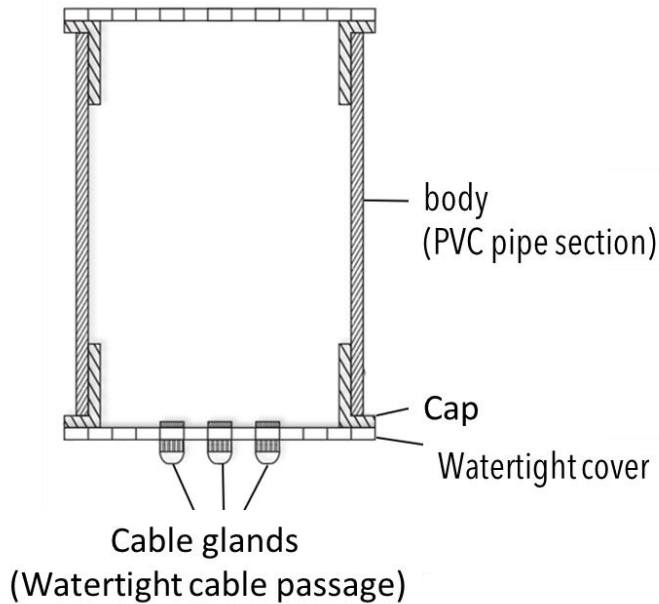
Objective

to build a
rugged,
self-powered
low-cost
data logger

Measuring mV range
electrical potentials
+
basic environmental
factors



➤ Data logger assembly & set-up in the tree

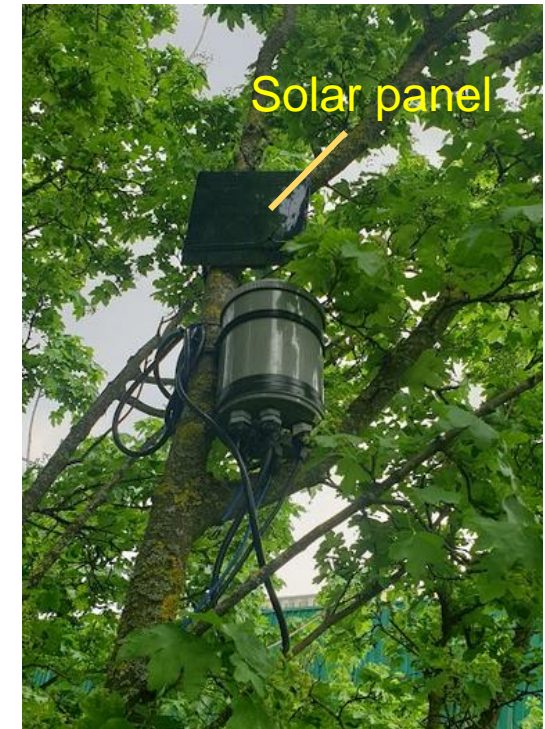


Encapsulation in a PVC pipe ($\varnothing = 100$ mm) closed by 2 caps with watertight seals

Encapsulation totally protected against weather, rodents & shocks



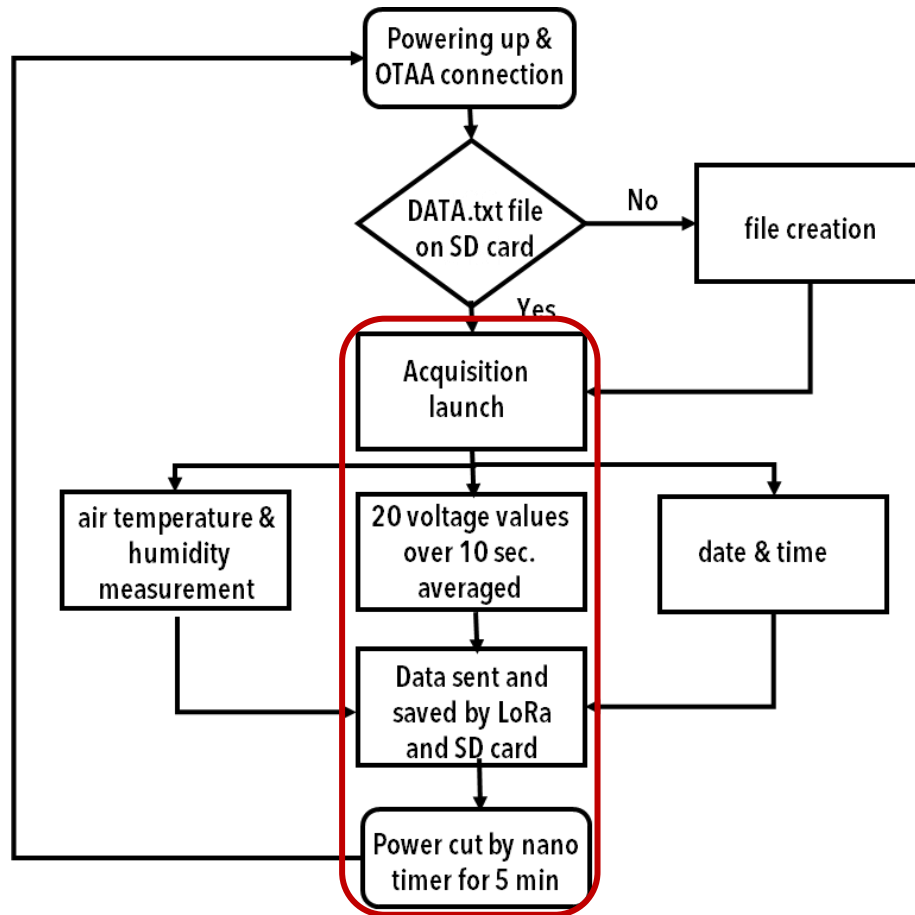
System view just before integration on field site



System inside a Norway maple

(*Acer platanoides*)
Cables passing through cable glands, directed downwards to reinforce the water-tightness^{p. 11}

➤ Monitoring program



- Data averaging (average & median over 20 data).
- Nano-timer controls the card's power supply (no energy waste when the card is in standby)
- LoRa ethics demands to transmit never more than 1% of the time (not overload the bandwidth)
- data acquisition every 5 min

> Results

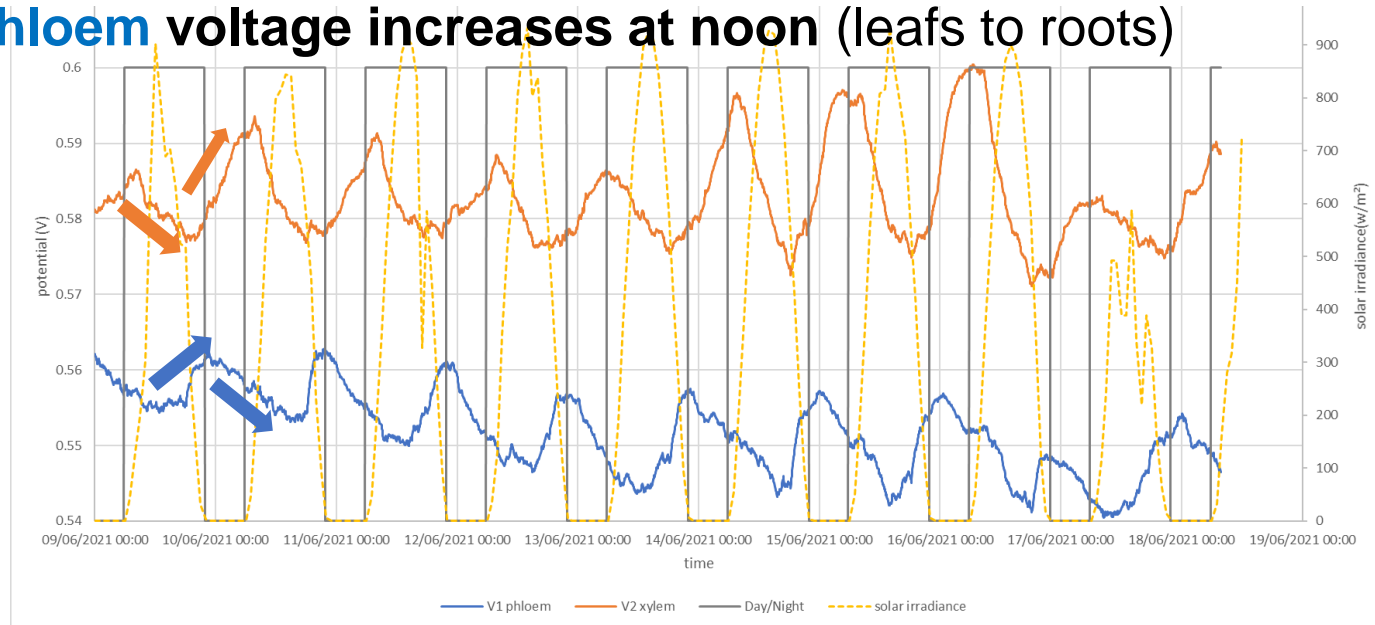
- **Circadian rhythms (photoperiodism)**
- **Rainstorm of May 10th**
- **Summertime monitoring**



➤ Circadian rhythms (photoperiodism)

The 2 voltages have a 24-hour periodic cycle, with a phase shift

- **Xylem** voltage decreases at sunrise (roots to leaf)
- **Phloem** voltage increases at noon (leaf to roots)



**Phase shift attributed to the sap fluxes
(time to go to/from leaves to the electrodes in the trunk)**

➤ Rainy event of May 10th

**infiltration basin totally flooded
after the rainstorm of May 10th**

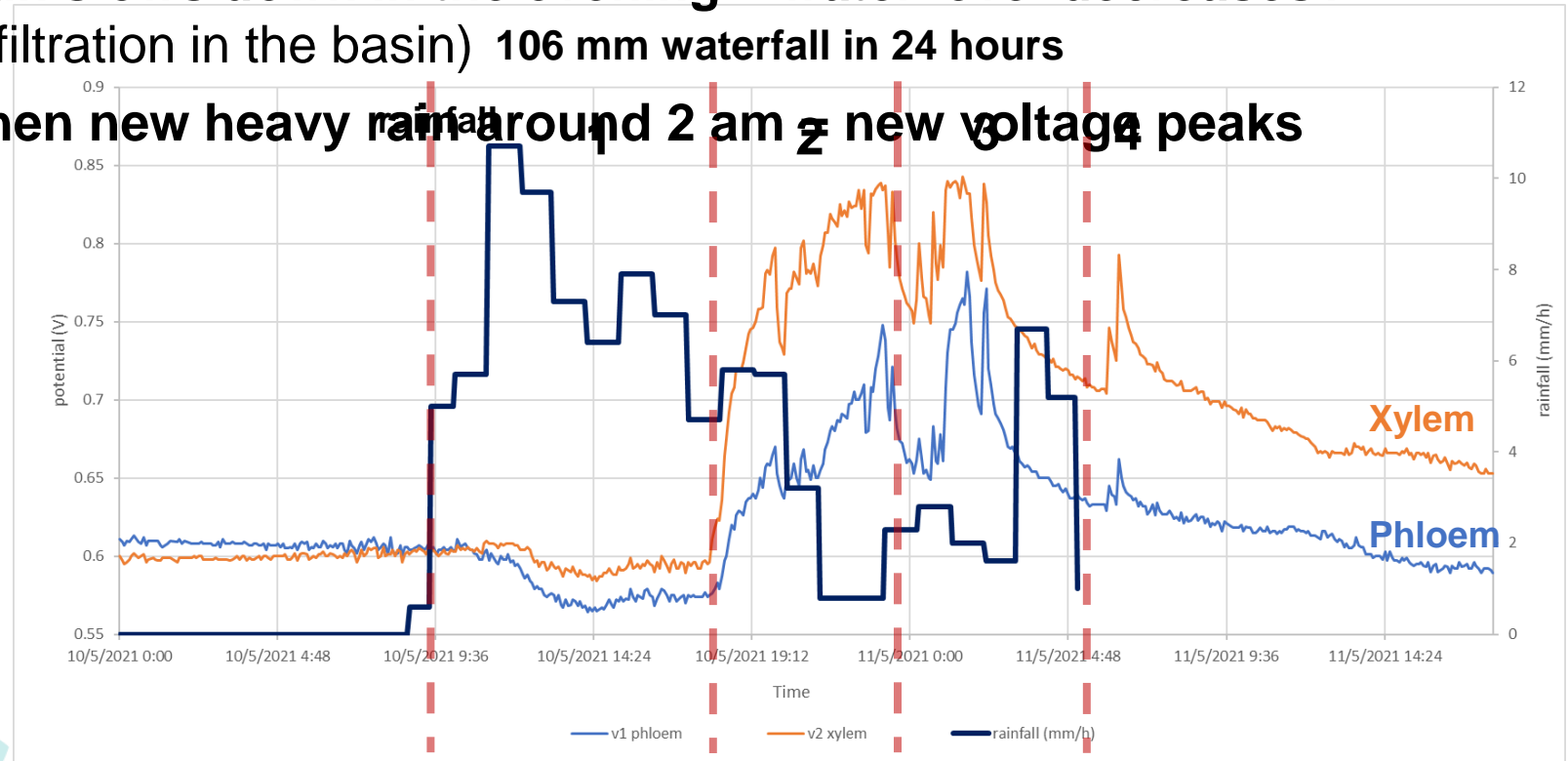


Tree trunk totally underwater

**Infiltration basin sized for rainfall events with a 1
year return period and able to accept rainfall with
a 20 year return period**

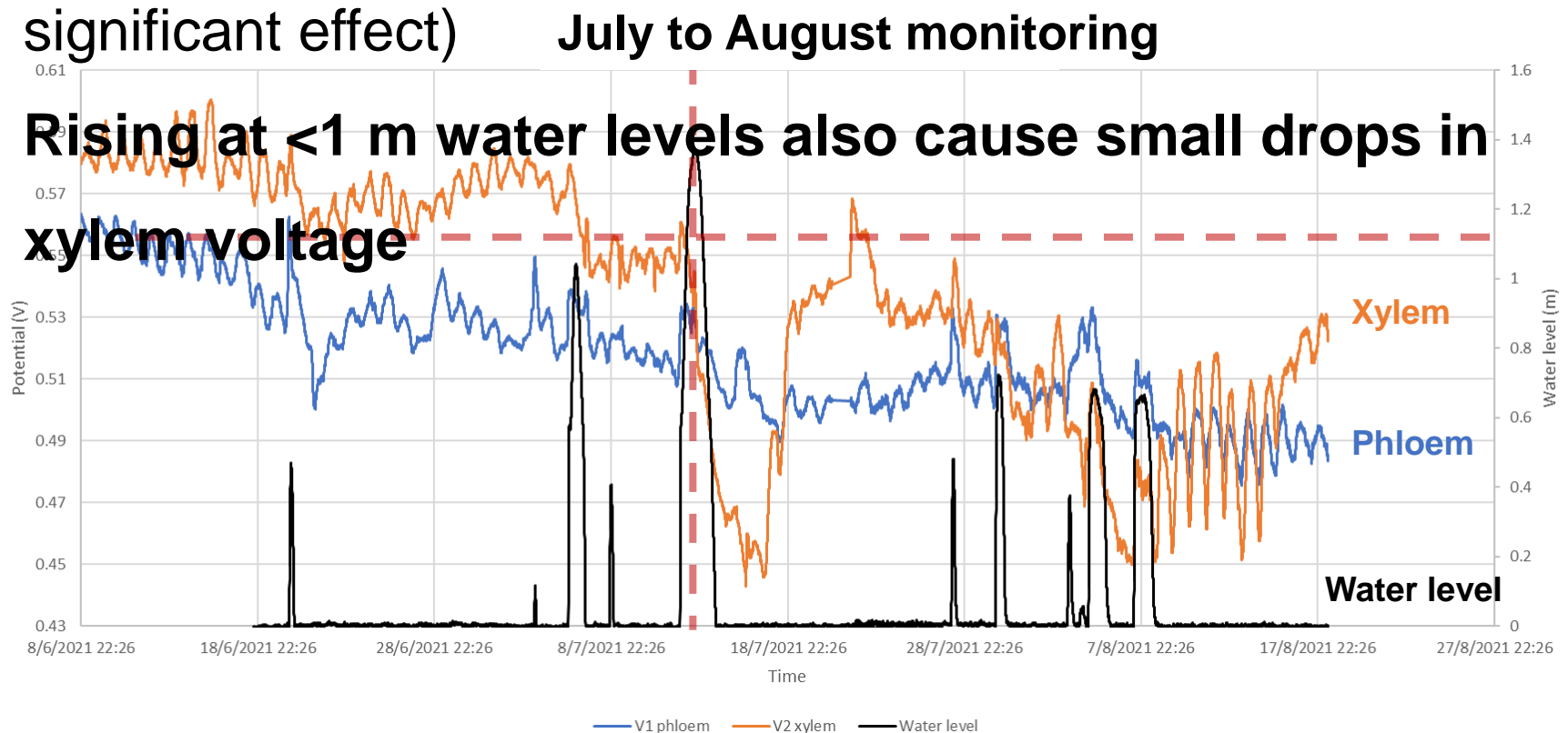
➤ Rainy event of May 10th

1. **Phloem & Xylem** potentials decrease at the storm's beginning (with a small time lag)
2. **Voltages increase abruptly** (when the rain decreases but water level rises in basin)
3. **Rain slows down in the evening = water level decreases?**
(infiltration in the basin) 106 mm waterfall in 24 hours
4. **Then new heavy rain around 2 am = new voltage peaks**



➤ Summertime monitoring

- Voltage changes according to the water level in the basin
- The basin filled up at several times (but >1.4 m →



> Conclusions

- **Operational remote monitoring system**
 - **low cost monitoring sensor** (2 stainless steel screws + 1 reference electrode)
 - Data transfer via **LoRaWAN** protocol
 - Sharing on **OpenDataEau** platform
 - **Total cost \approx 200 € HT**
- **Yes, trees are environmental sensors**
 - **Circadian cycles** with a **6-hour phase shift** between **xylem & phloem** (difference due to chemistry & flux speed of the 2 sap fluxes ?)
 - **Extreme disruptions monitored** (flooding, roots in waterlogged soil)



> Perspectives

- **Monitoring** must go on to observe **winter periods & summer droughts**
- Requires **signal processing algorithms** to interpret the signal
- Need for **additional environmental data** (e.g. water level, solar irradiance, winds, ...)
- Paving the way for **citizen empowerment** in **environmental monitoring**





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➤ Thank you for your kind attention

any questions?



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