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Induced Polarization for monitoring solidification of cut-off walls : a first approach



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INDUCED POLARIZATION FOR MONITORING SOLIDIFICATION OF CUT-OFF WALLS

A FIRST APPROACH

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Soil + hydraulic binders (cement, lime...) mixes are often used :
Cut-off walls, slope stabilization, infrastructure subgrade...

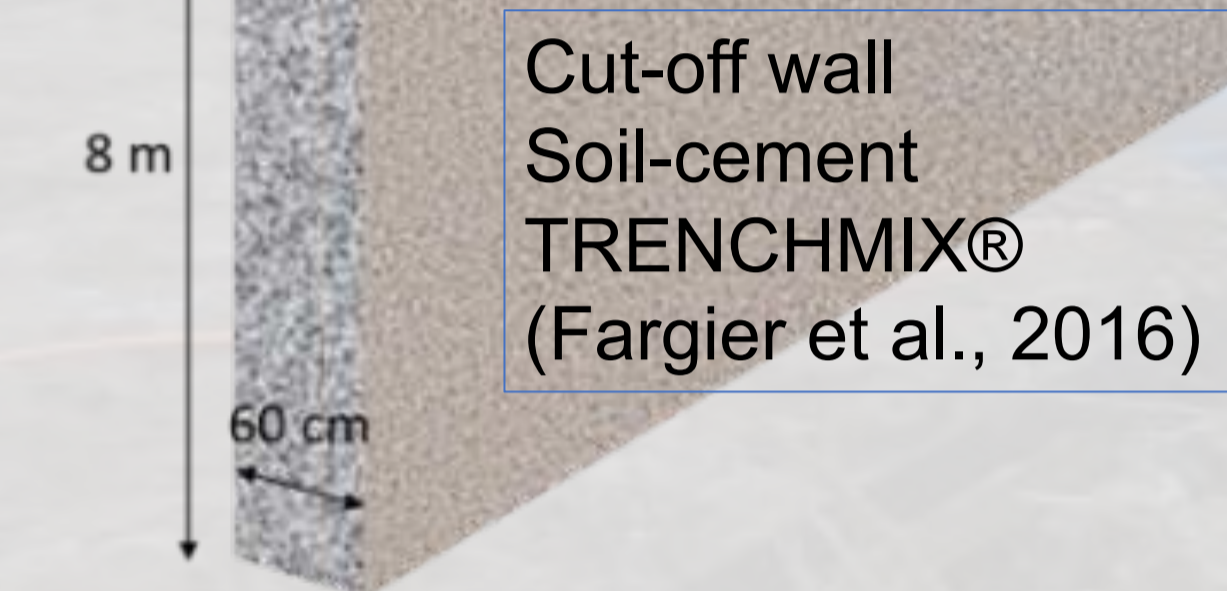


For cut-off walls, the main goals are :

- To create an **hydraulic barrier**;
- To reinforce against erosion.

The technique is :

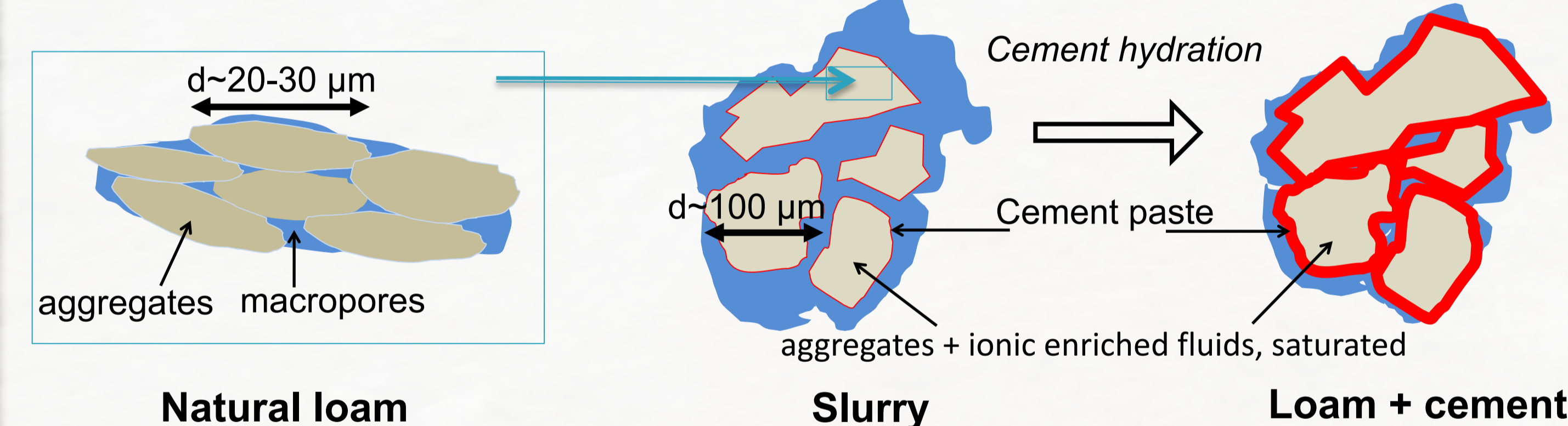
- Economic and known;
- An ecological compromise.



If the mix is not well implemented, it can result in **major failure** of the structures. There is a **need for efficient monitoring techniques, minimally invasive**, to control the implementation.

Process

- I. Extract natural soil
- II. Mix with water and cement
- III. Fill the trench and wait for solidification



- Particles re-organization
- Cement hydration consume water molecules

The reactions transform the microstructure (pore network and interface composition), as well as the free water content and the electrolyte composition.

The mix hardens in several hours but the solidification and the increase of mechanical resistance continue over weeks.

Can IP measurements monitor the solidification process ?

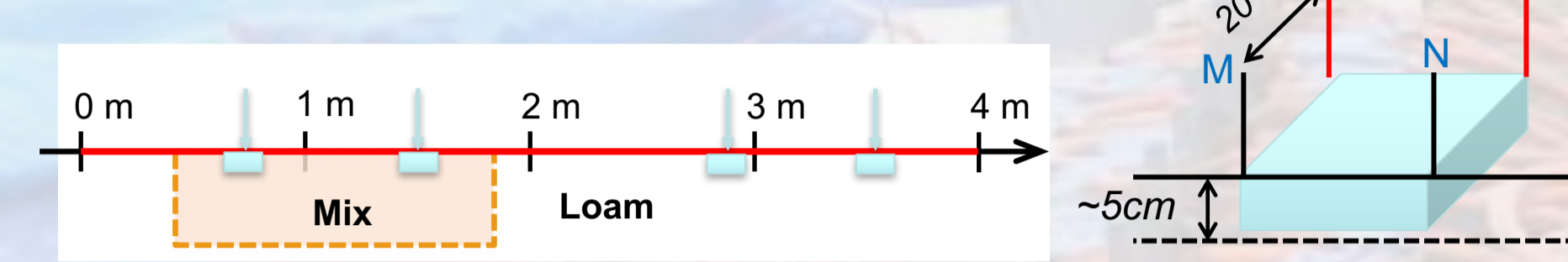
In this study, we assessed the **feasibility / practicability** of IP measurements to **monitor the solidification of soil-cement mixes in the field**.

We dug a small trench in an experimental levee. Then we filled it with the soil cement slurry and carried out **continuous measurements over 28 days**.

The IP setup was easily implemented and the unprocessed data seem promising.



For the sake of clarity, we only show the measurements for 4 points
Data are filtered for |self potential| < 50 mV



Electrical resistivity

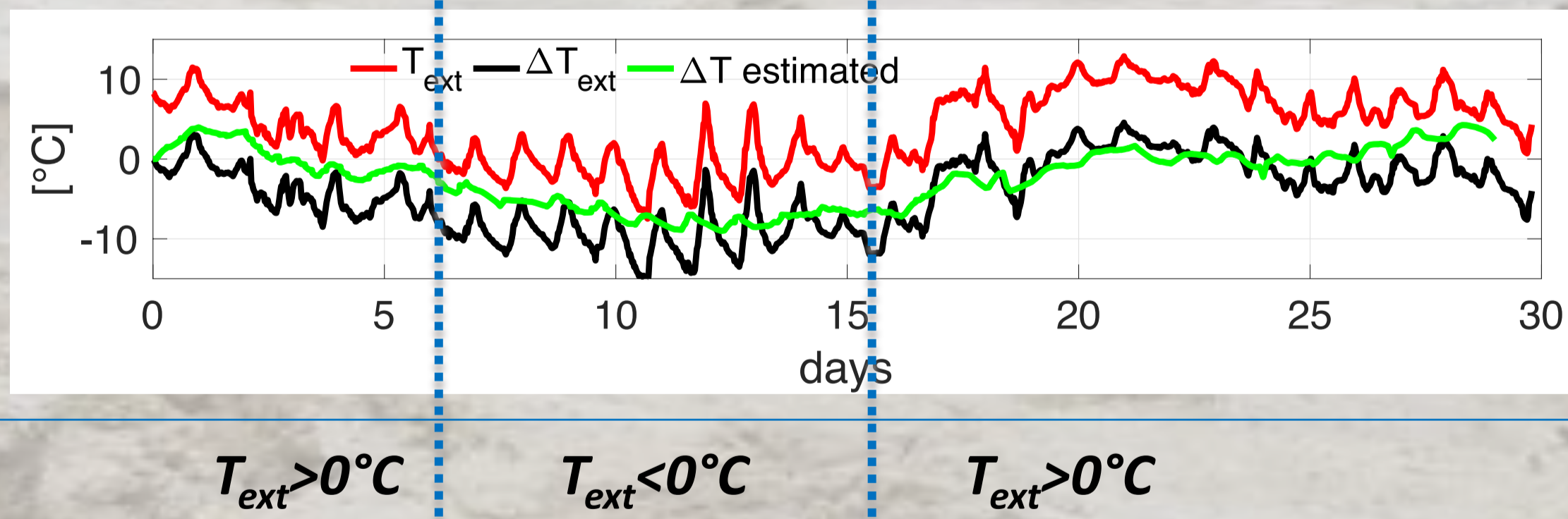
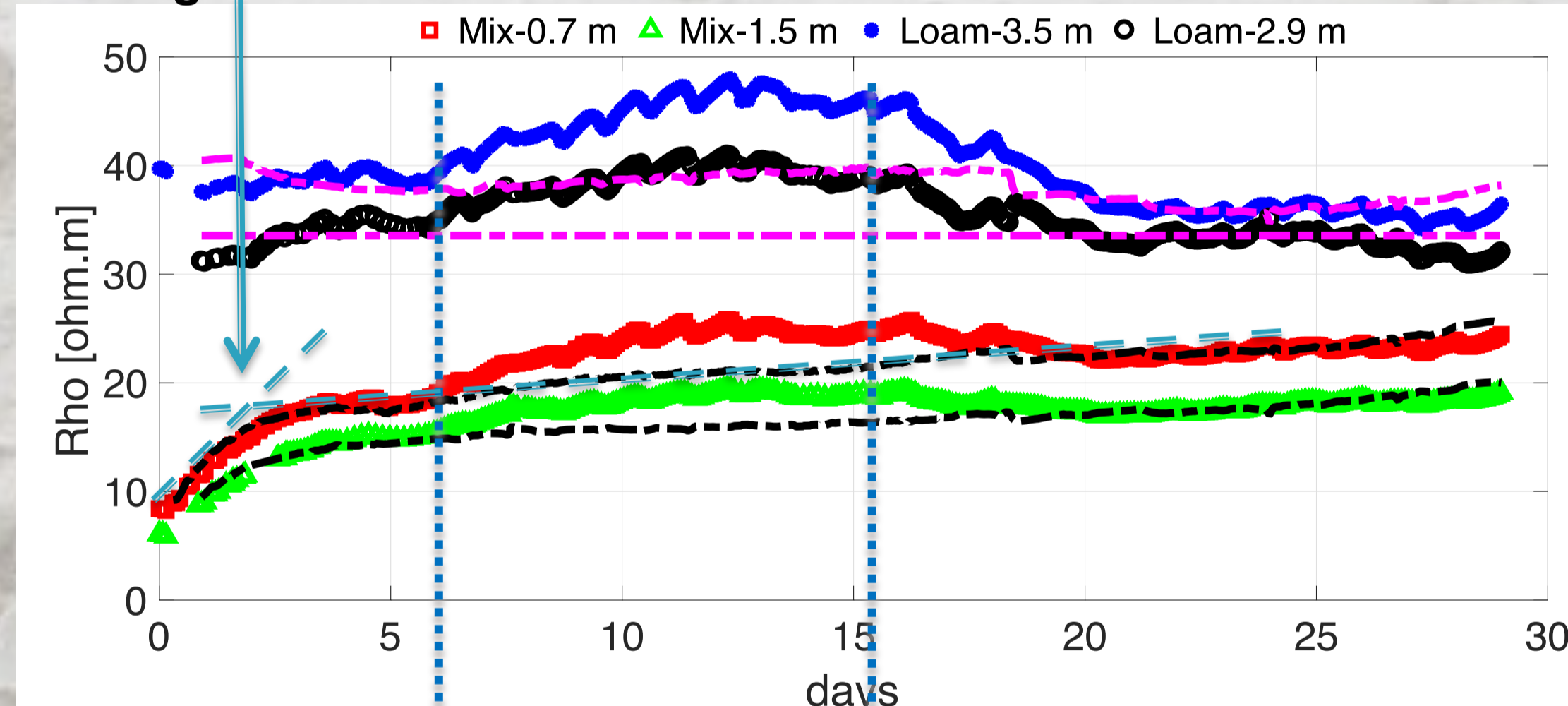
- Reflects the variation of temperature
- Differentiate the natural and the treated loam
- Increases with the solidification of the mix (expected)

The dotted lines (black & magenta) represent the resistivity corrected for temperature variations $\rho(T_{ref})$ using :

$$\rho(T) = \frac{\rho(T_{ref})}{1 + 0.02(T - T_{ref})}$$

$\Delta T = T - T_{ref}$ is estimated assuming the electrical properties of the natural loam are unchanged during the experiment.

Change of kinetic



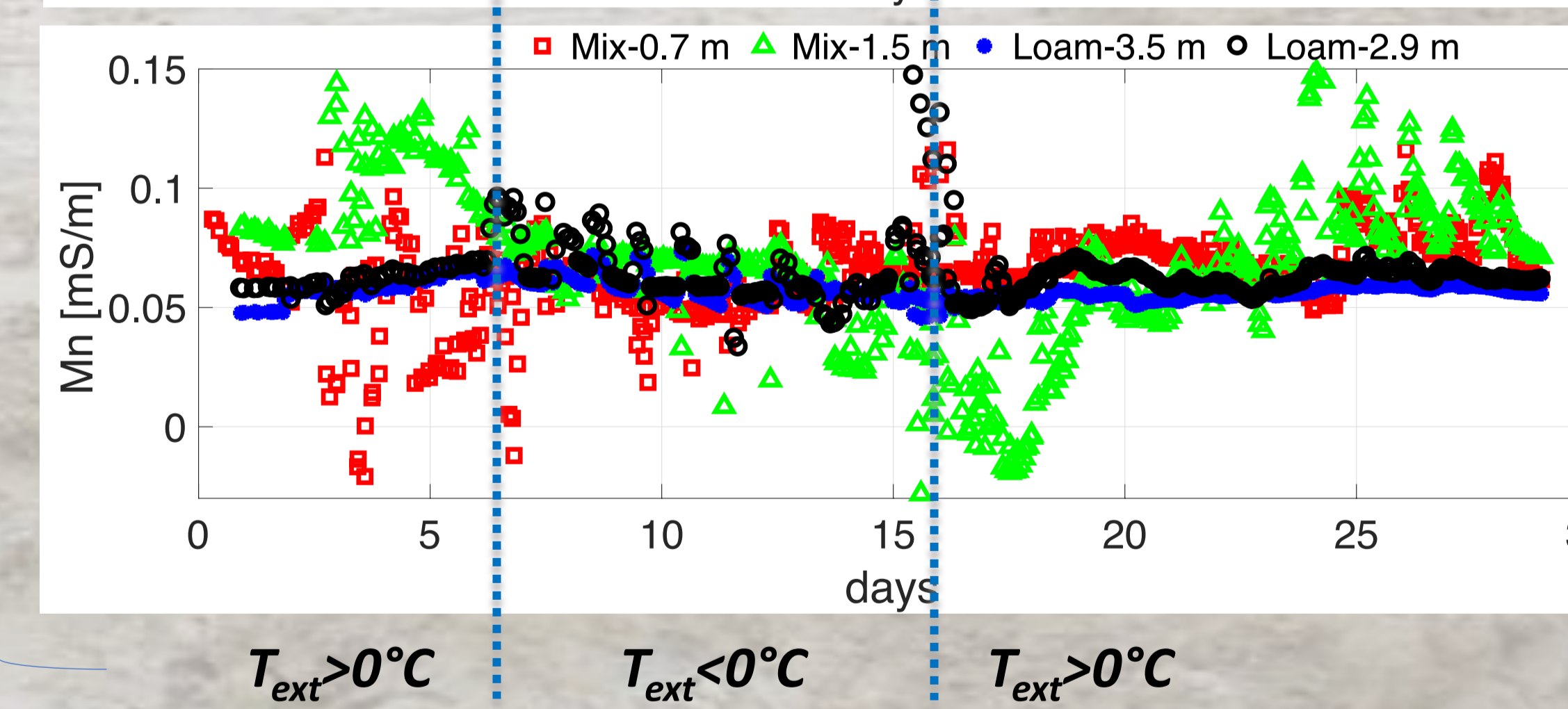
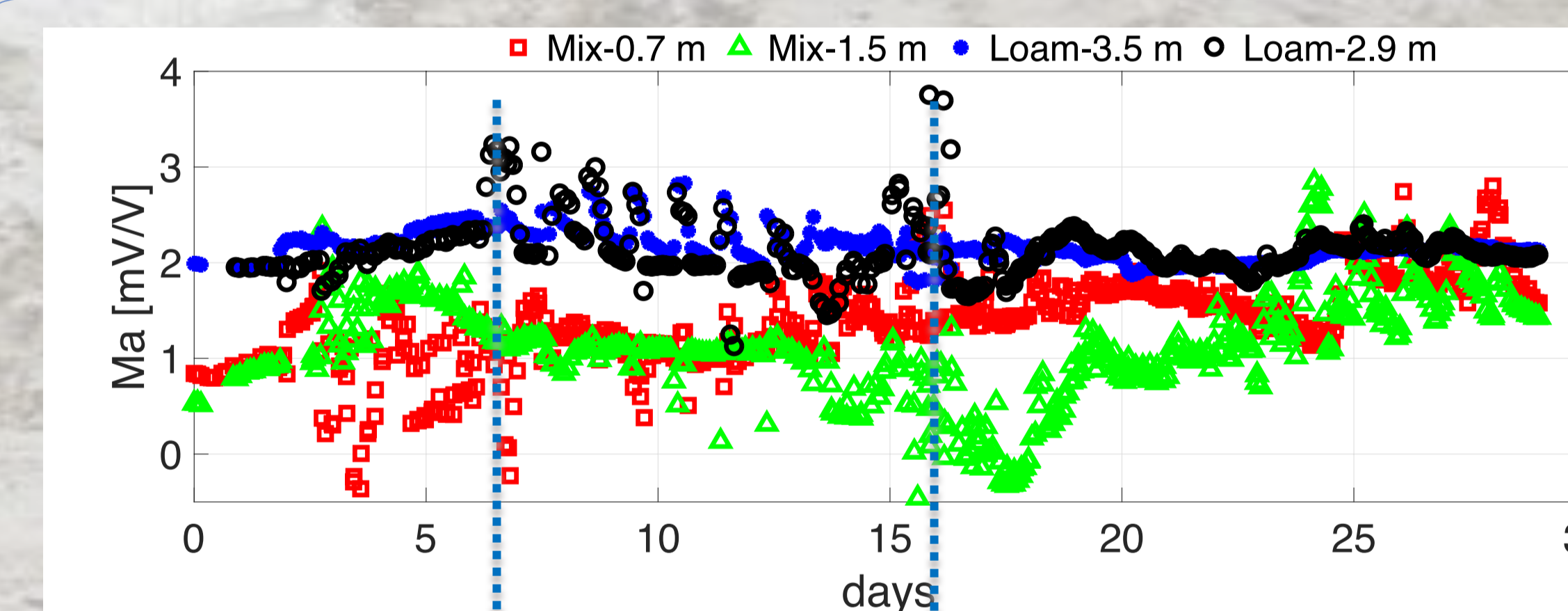
Chargeability

M_a (Apparent chargeability) and M_n (normalized)

- No clear trend or evolution
 - Affected by freezing /thawing
- We used $M_n = M_a / \rho(T_{ref})$. M_n shows no clear difference between the two materials.

Chargeability curves :

- Inflection and amplitude different between the materials.
- Repeatable over time on the natural loam.
- The mix chargeability curve changes over time.



Data collection :

- 1 Contact resistance check sequence every 2 tomography sequences
- 569 valid sequences (with each of the 20 dipoles interrogated at least once).

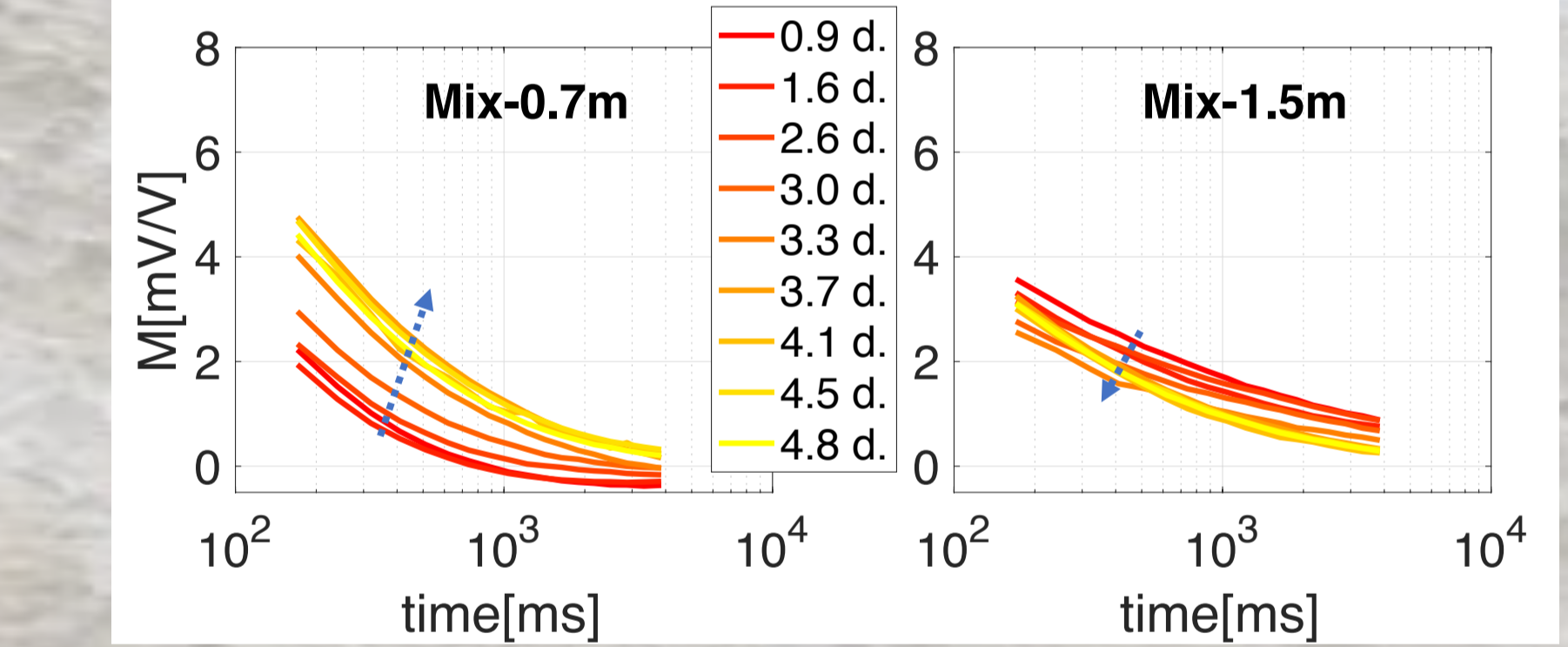
Experimental set-up

- Syscal Pro (Iris Instrument) with ComSys
- Injection : 21 stainless steel electrodes
- Potential : 21 Petiau electrodes
- Injection and potential cables separated
- Square configuration : 20 cm spacing

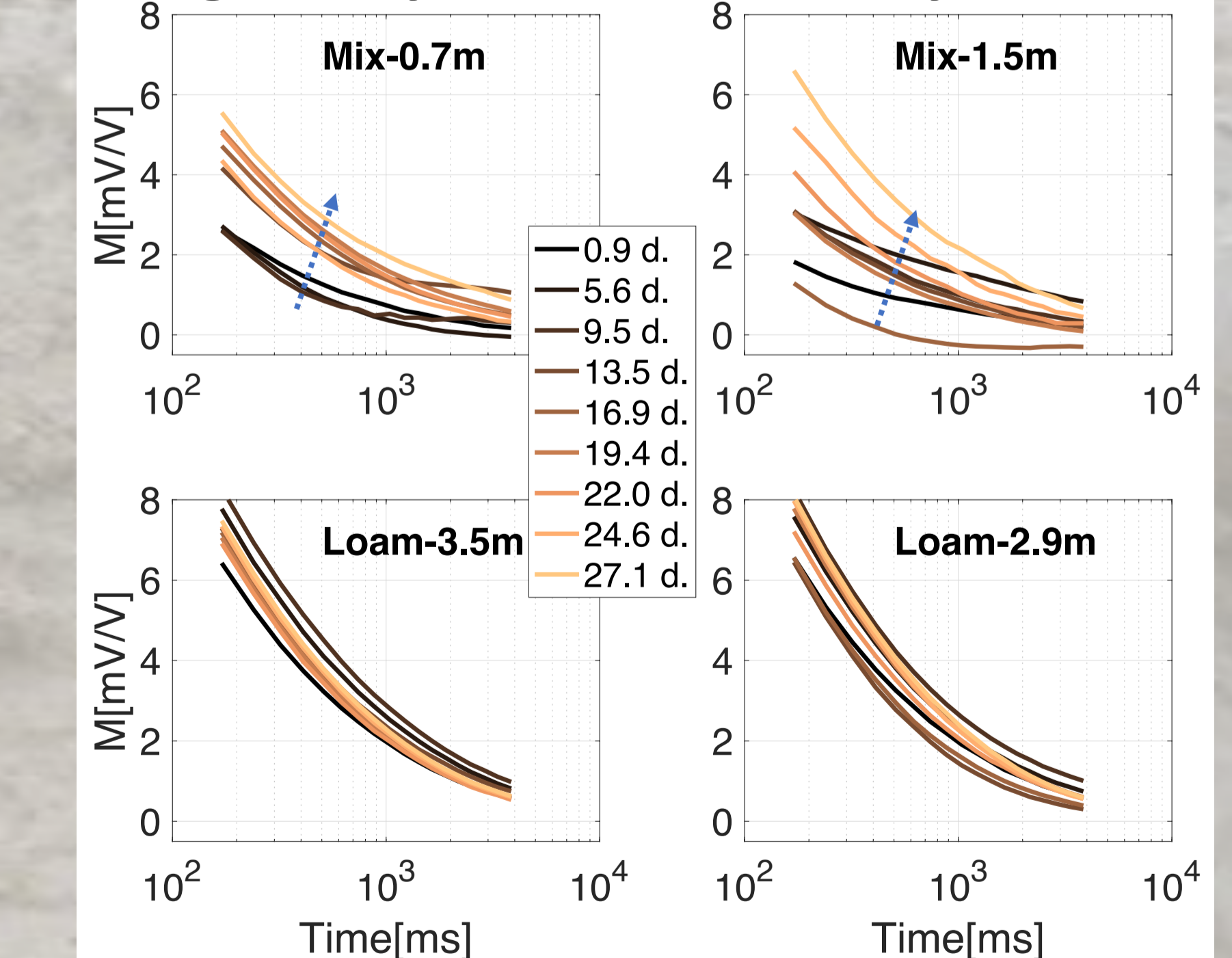
Acquisition parameters

- Unchanged over the 28 days
- T_{ON} = T_{OFF} = 4 sec
- 20 chargeability windows (preset cole-cole configuration)
- Controlled Output tension : 800 mV
- Specific acquisition sequence to avoid consecutive use of the electrodes.

"Early time" (<5 days)

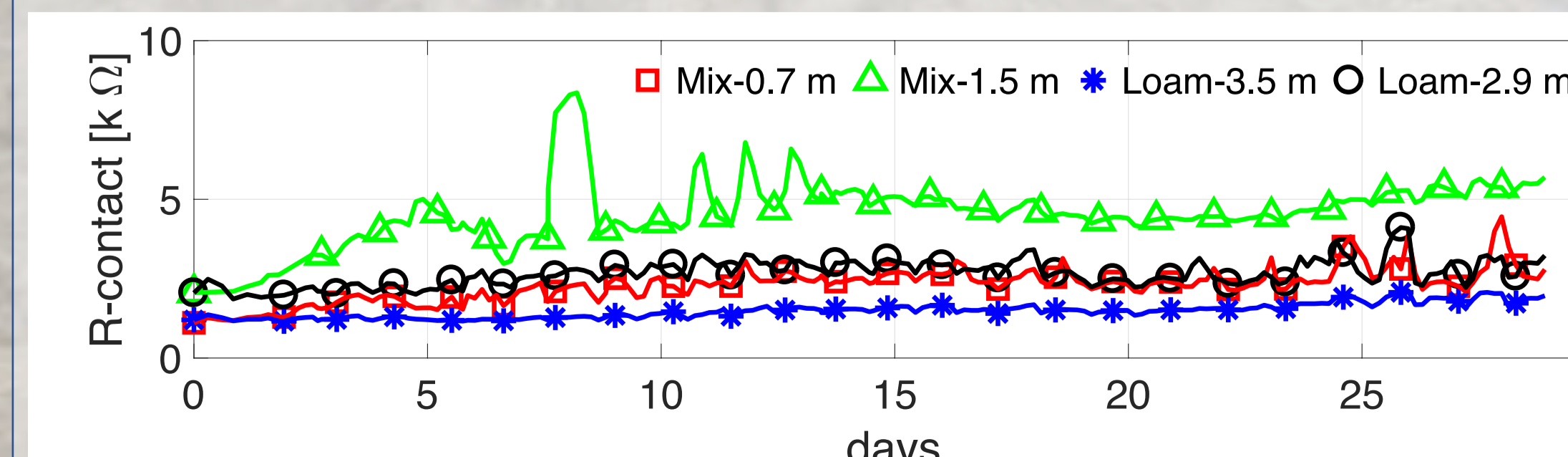


Chargeability curves over 28 days

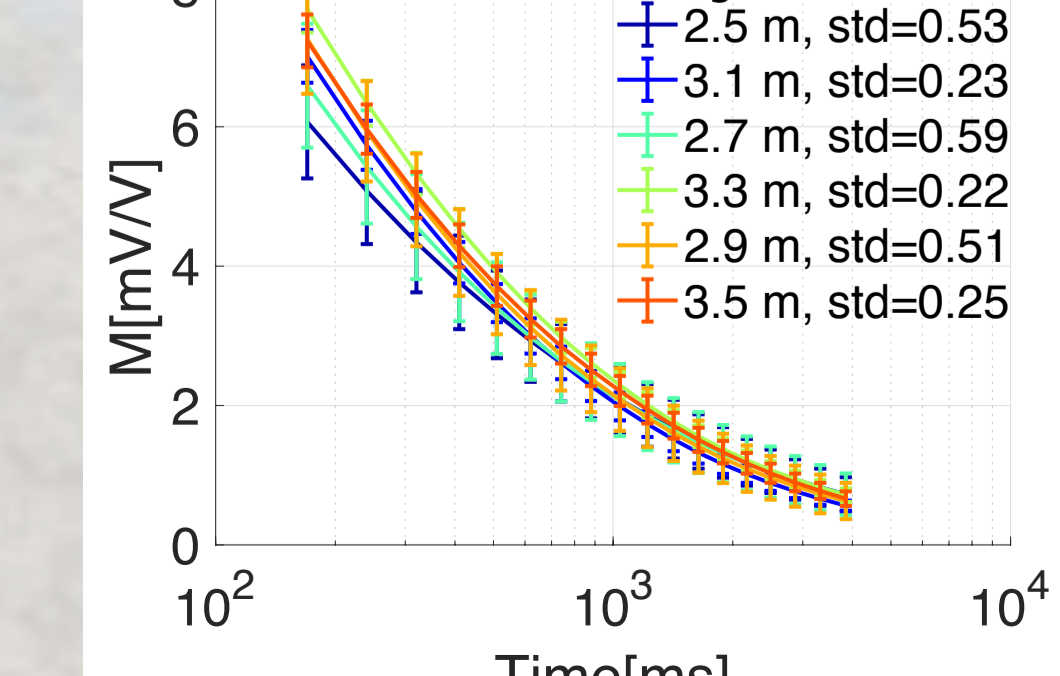


Results quality. The contact resistance stayed low over the 28 days, despite freezing/thawing cycles. The variability is less than 1 mV/V for 8 over 12 measurements on the natural loam (undisturbed during the experiment).

Contact resistance low (symbols are downsampled for clarity)



Low variability



| Property | Value |
|-----------------------------|----------------------|
| Compacted loam | |
| gravimetric water content w | =18 % |
| Apparent density | 1.7 t/m ³ |
| d | ~20-30 µm |
| Soil cement mix | |
| w | ~40-45 % |
| Apparent density | 2 t/m ³ |
| Cement content | ~11 % (w.t.) |
| Water/Cement | = 0.6 |

Acknowledgement :

This data collection would not have been possible without CEREMA technicians: Karim El-Daby, Dany Curot and Carl Calmo. Special thanks to Ontash & Ermac, Inc. especially Konstantin Evdokimov, who made this presentation possible

Reference :

Fargier, Y. et al. (2016) Renforcement des digues de Loire par la méthode du deep soil mixing : apport des techniques géophysiques pour le contrôle, Journées Nationales de Géologie et Géotechniques, Nancy, France.