SSS6.8 Soil structure dynamics and its relevance to soil functions

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Evidence of pressure jump signatures linked to fast air-water displacement dynamics in macropores

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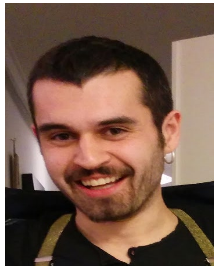


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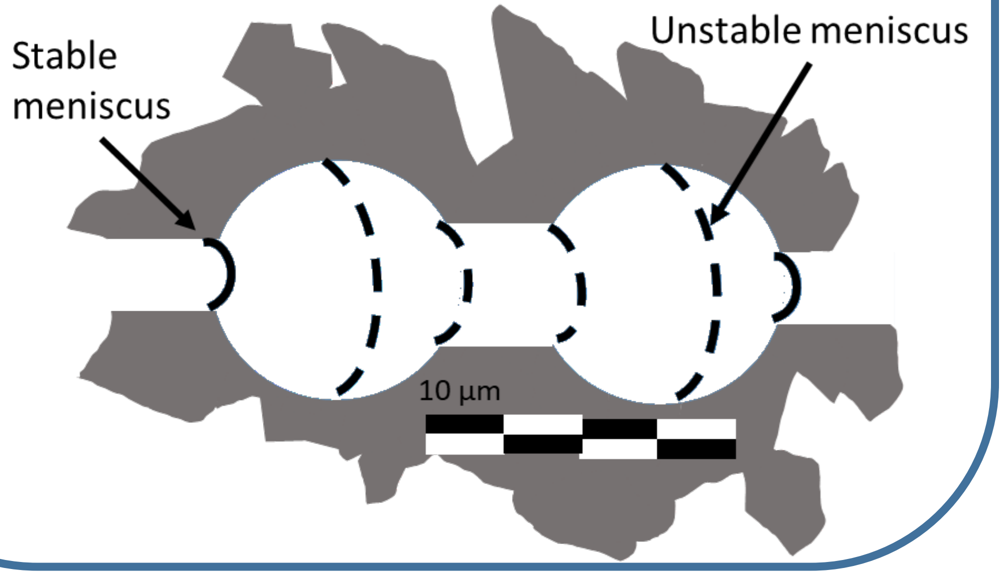
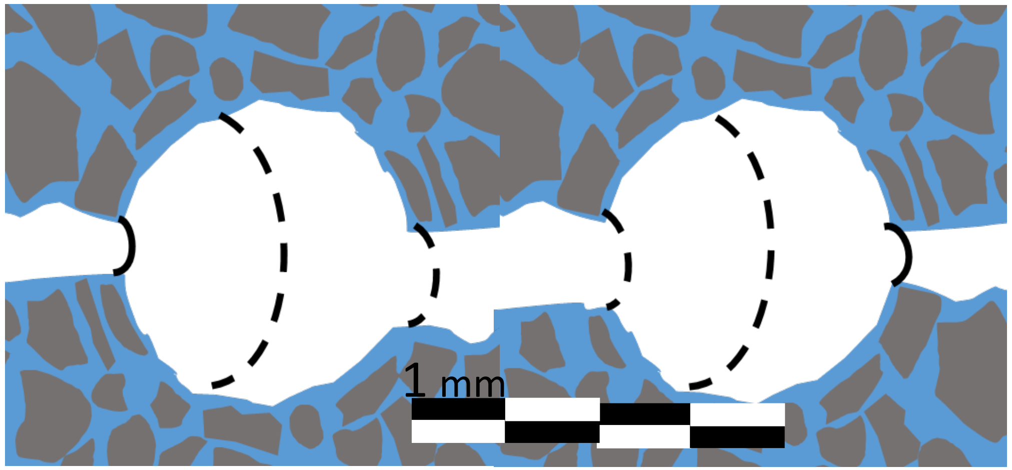
Pressure jumps

Need of stronger support to demonstrate a link between soil structure and fast phase displacements.

- Wetting-drying occurs as fast phase displacements in irregular pores (Haines 1927-30, Morrow 1970).
- Typical time scales of **milliseconds**, length < 1 mm.

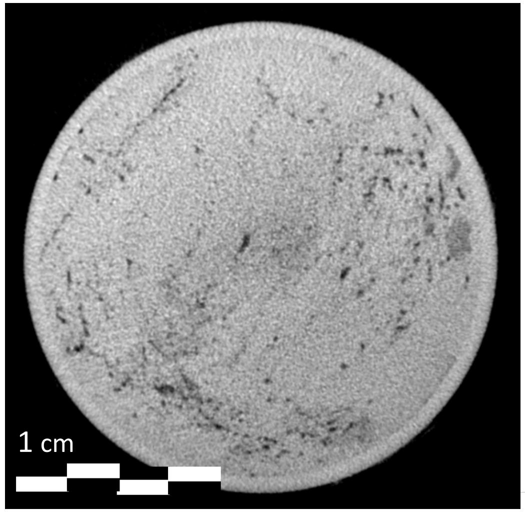


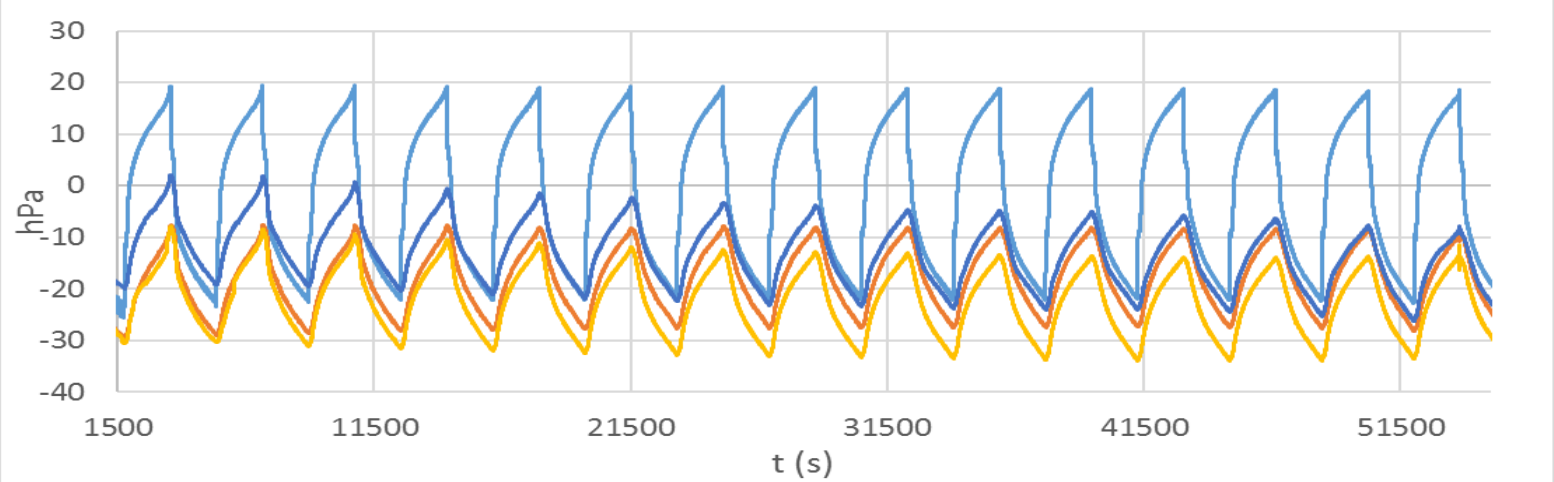
- Wetting-drying occurs as a fast phase displacements in structured soil (Soto et al., 2017, VZJ).
- Typical time scales of **seconds**, length > 1 mm
- Jumps can reveal fast non-linear transport phenomena at cm-scale.
- Linking Soto Jumps to structure needs stronger evidence.



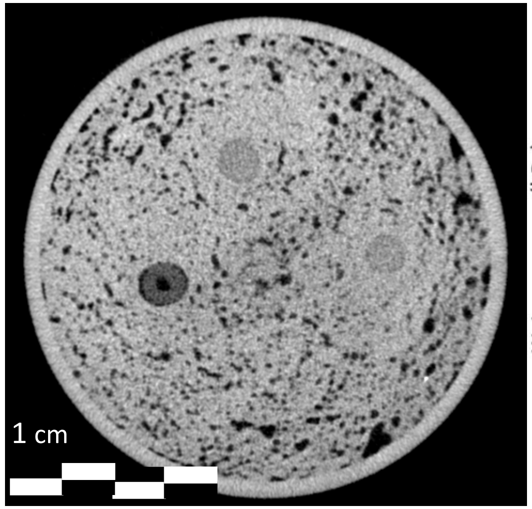
Occurrence of pressure jumps

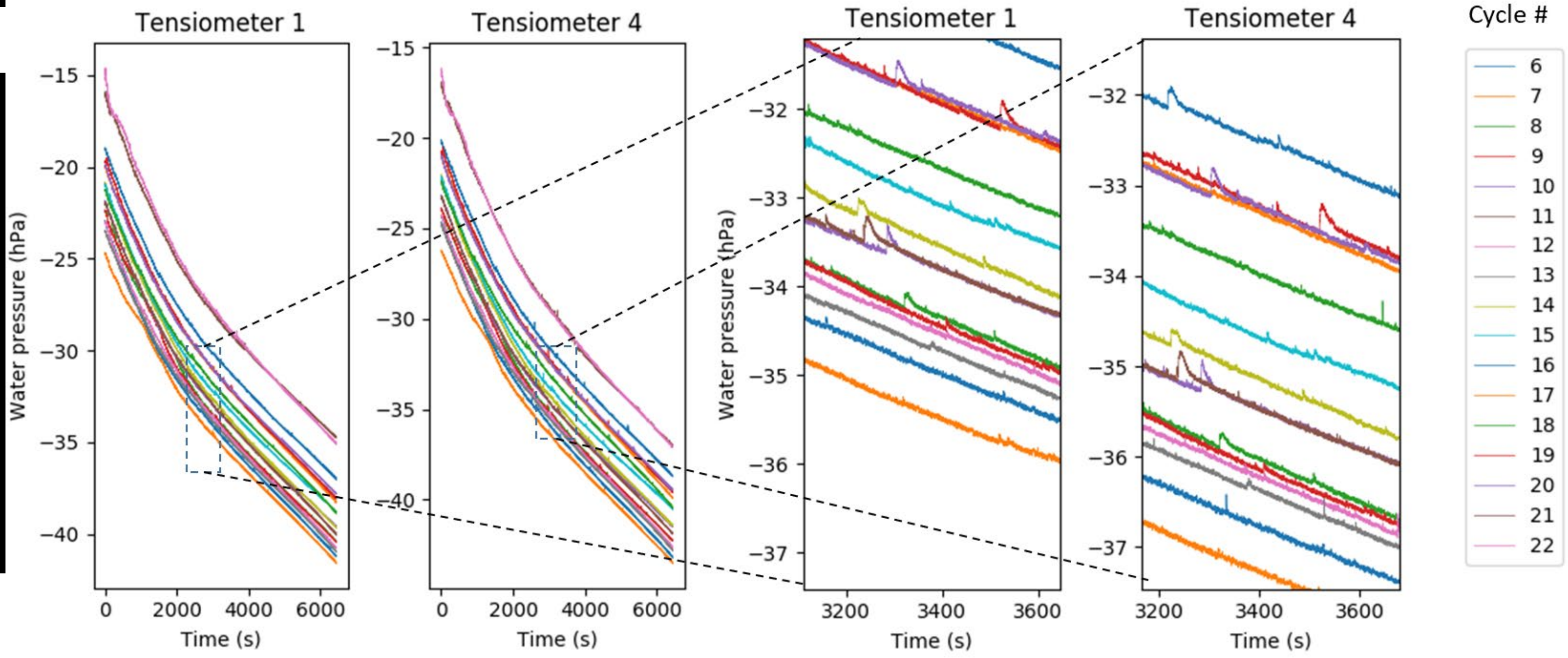
In non-structured sand there were a scarce occurrence of jumps.



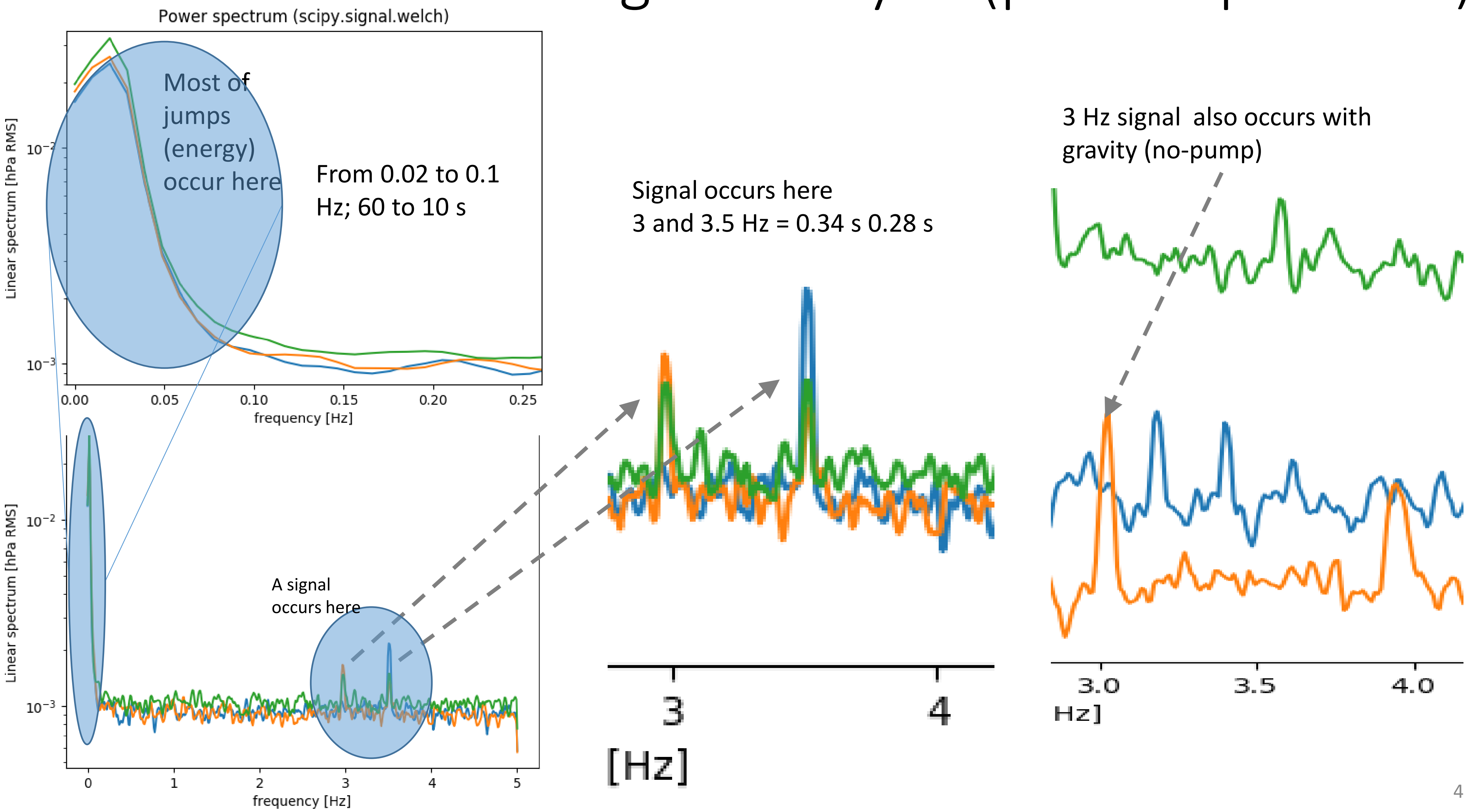


Pseudo-structure induced by injecting air bubbles led to a major occurrence of pressure jumps.



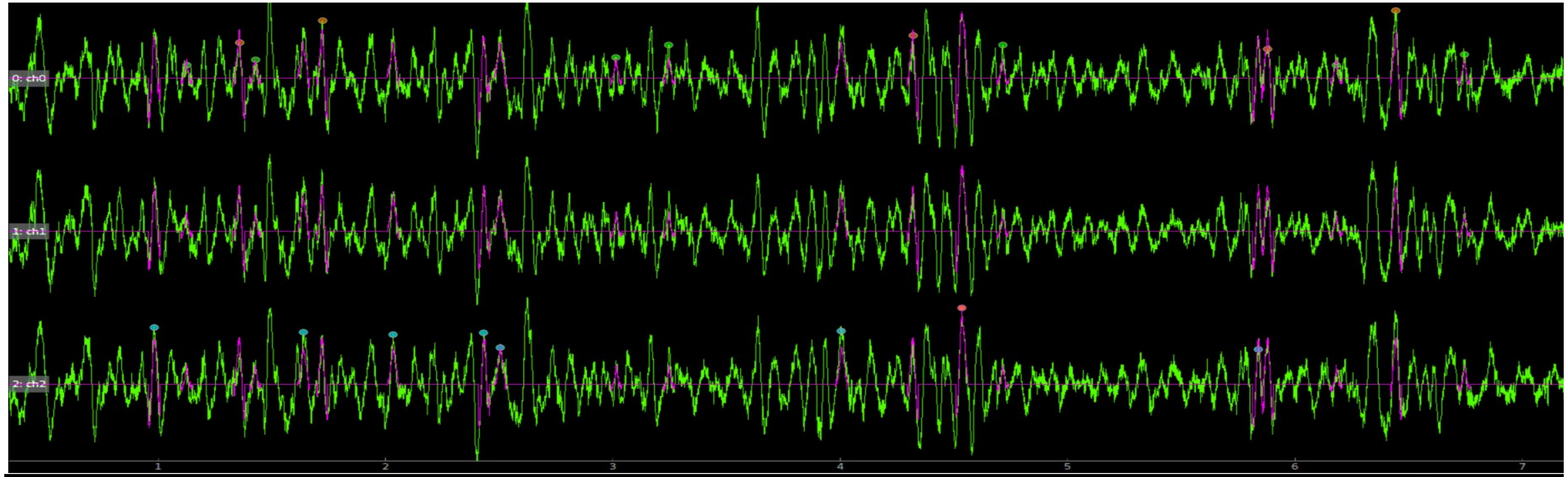


Signal analysis (power spectrum)

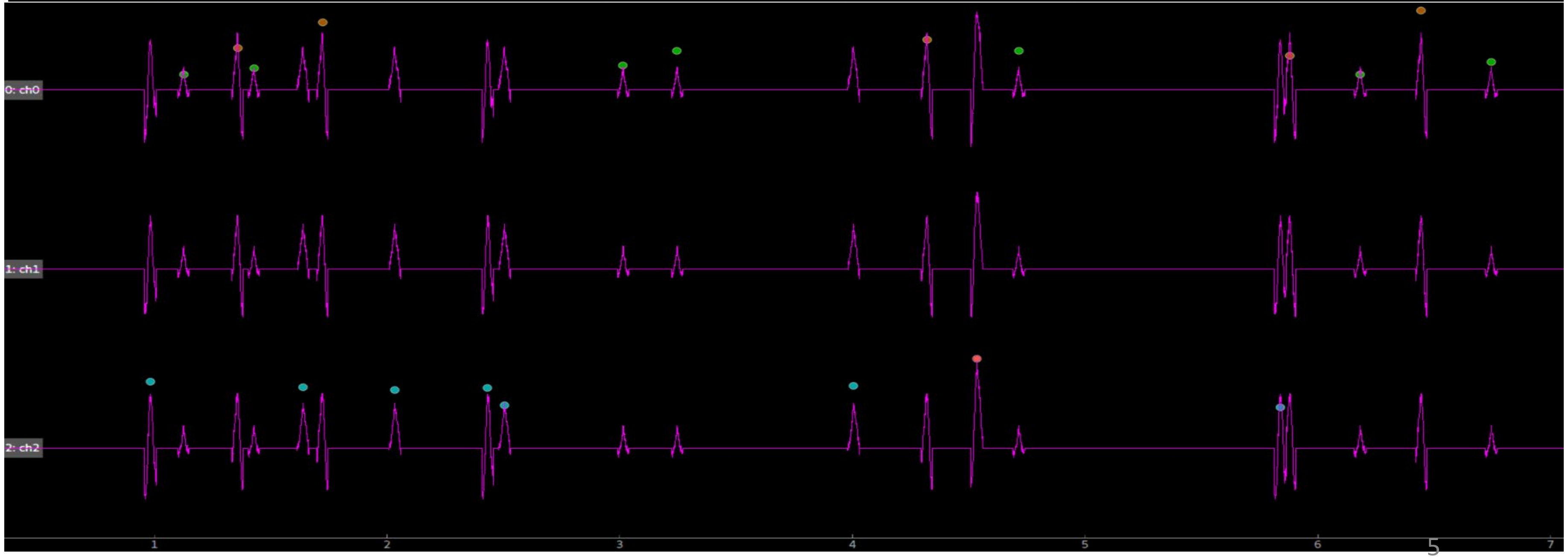


Identification of significant peaks and waveform selection

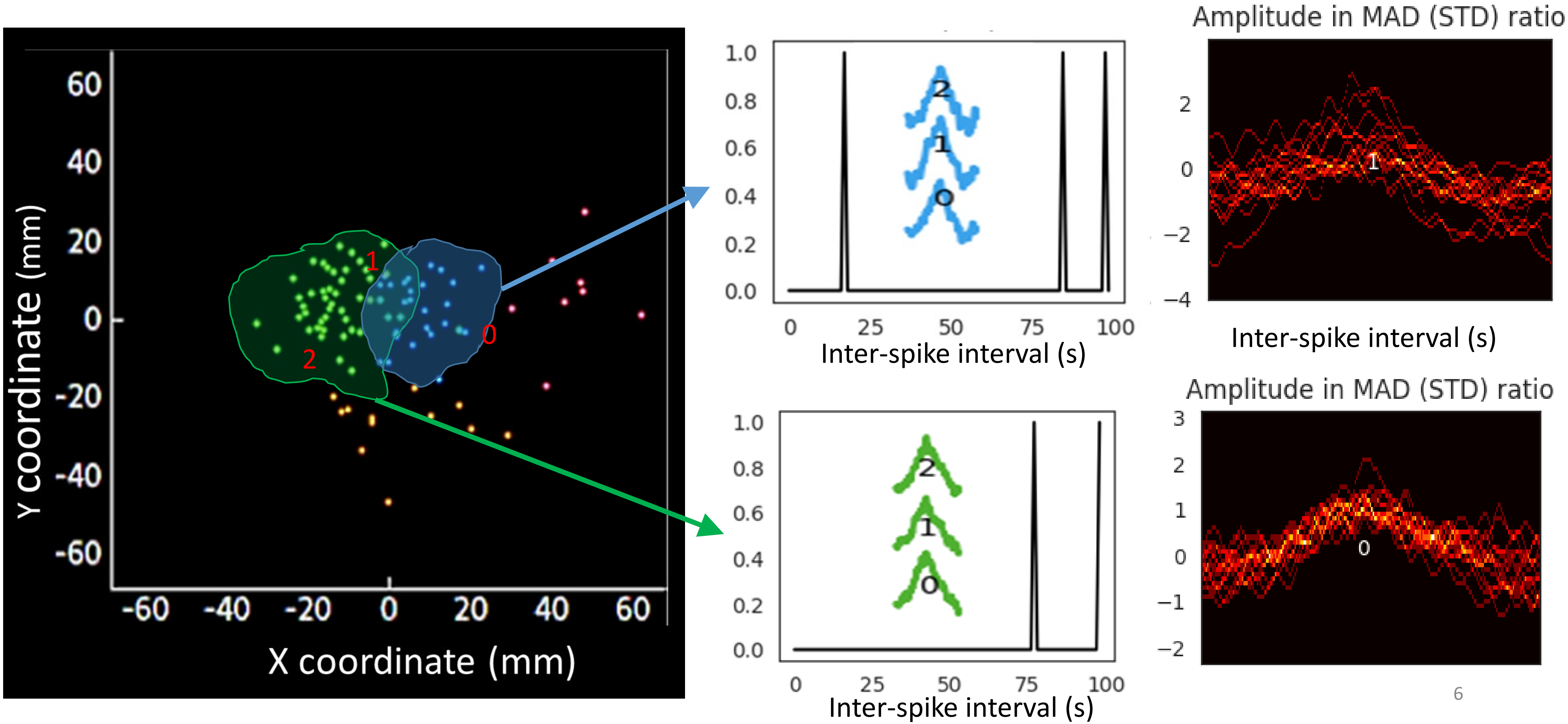
Peak detection: three channels corresponding to three tensiometers [0,1,2]. Threshold over the Median Absolute Deviation (MAD).



Waveform selection: on the basis of waveform template. Signals almost replicate with a small lag (300 ms lag).

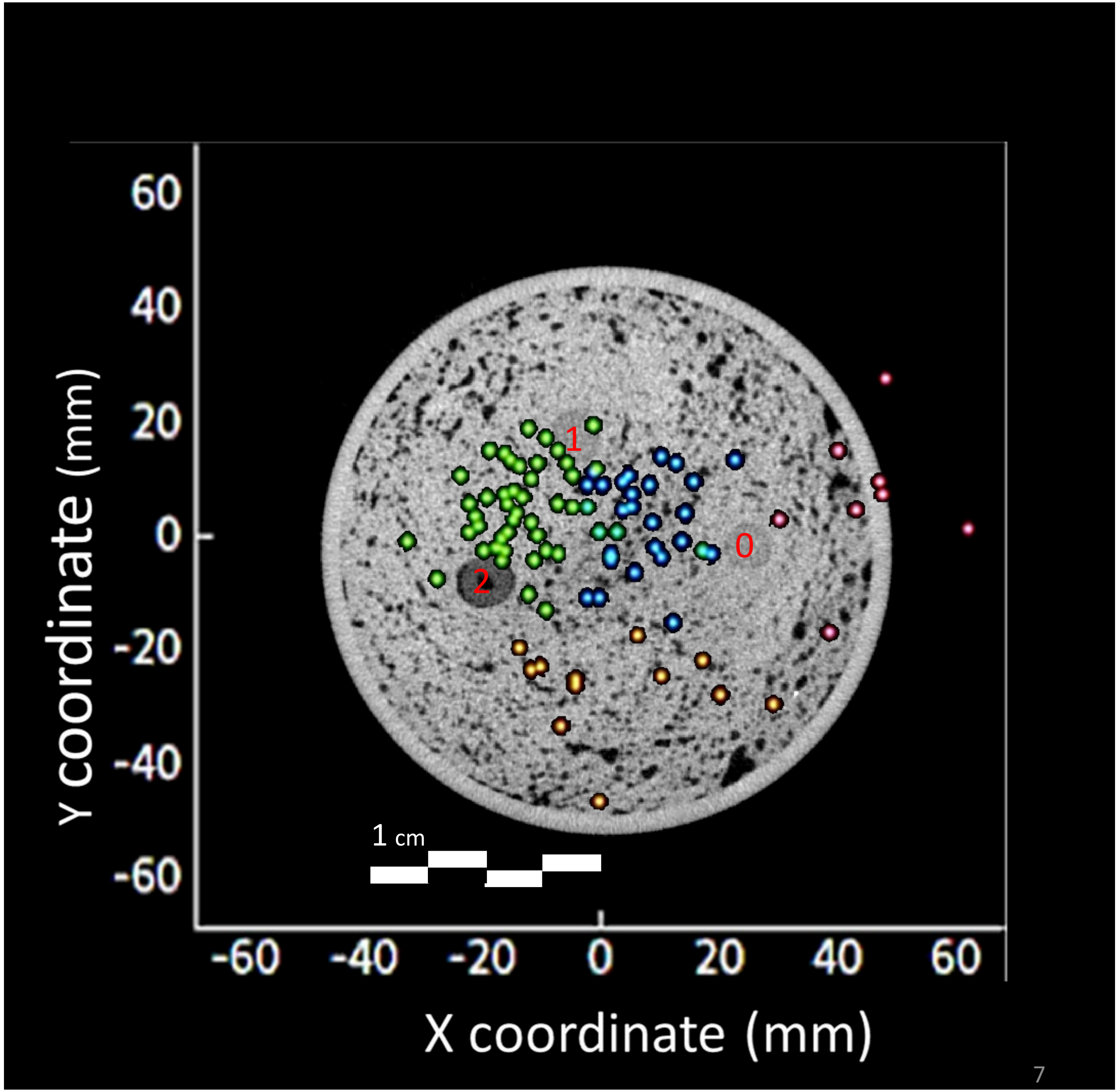


Waveform clustering



Summary

1. Identification of significant peaks from an array of high sensitivity tensiometers (channels [0,1,2]).
2. Waveform extraction (template).
3. Followed by classification and clustering of waveforms using principal component analysis, k-means.
4. Tracking of the sources of pressure waves in soil pore space. Normalized peak-to-peak amplitude difference, normalized peak-to-peak arrival time difference.



Conclusions

- Pressure diffusion waveforms were detected with an array of high-sensitivity tensiometers embedded in pseudo-structured packed sand.
- Waveform detection evidence of seconds-scale pressure jumps linked to the occurrence of macropores.
- Tracking the jump source was carried out by waveform sorting and classification.
- Jumps reveal fast phase displacements in macropores with implications in transport (e.g., release of gases, colloids, increased solute transport).

Thank you for your attention

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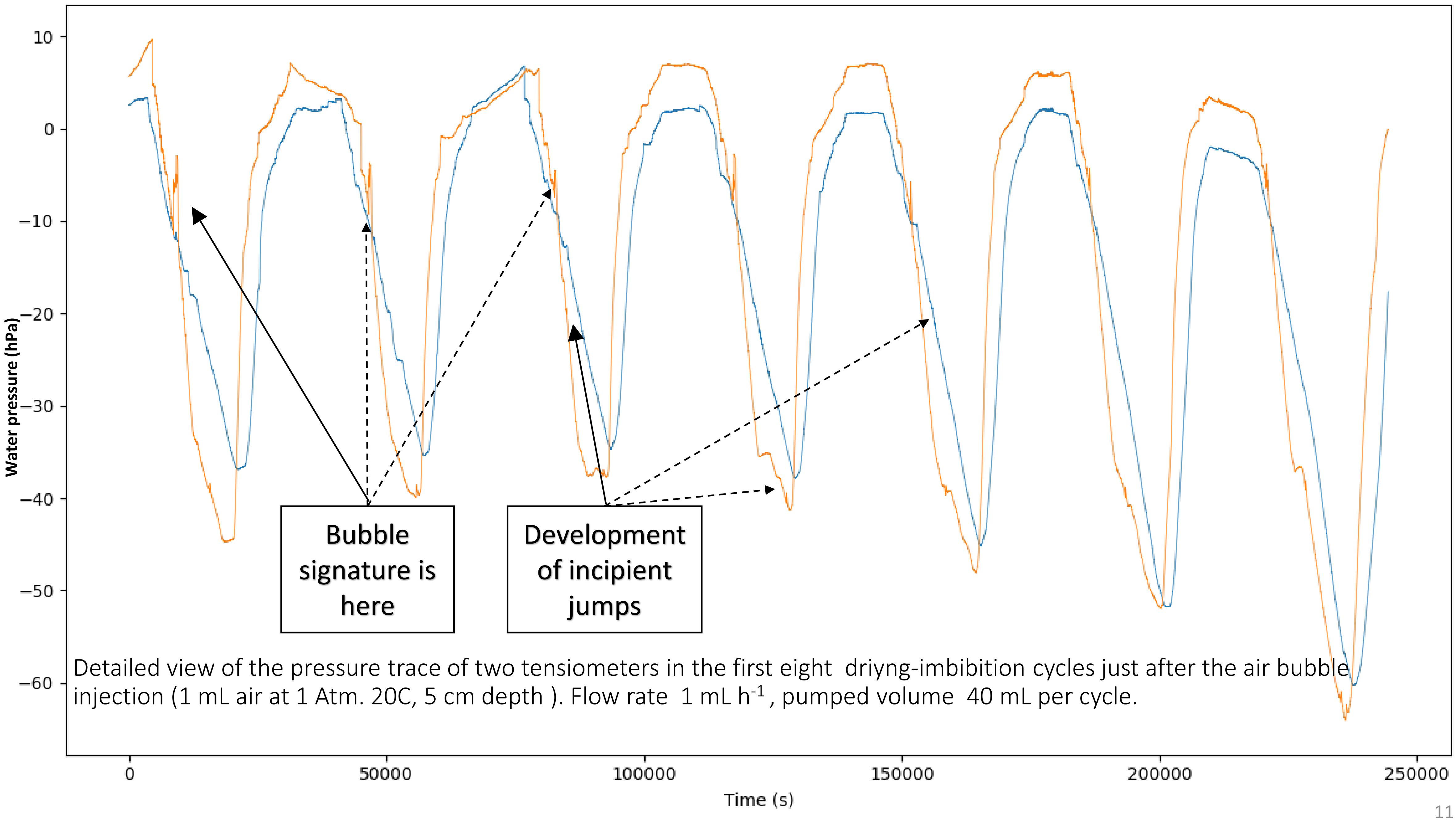
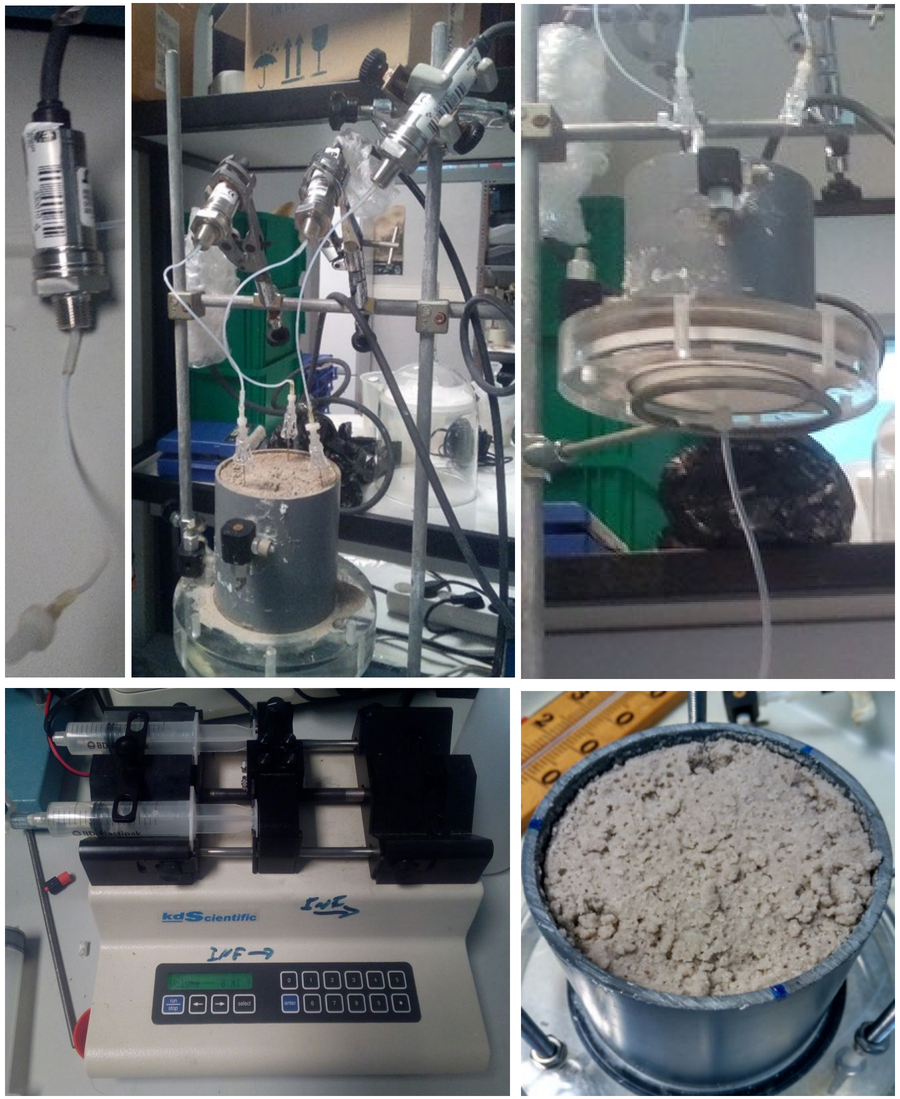
Supplementary information



Detailed view of the pressure trace of two tensiometers in the first eight driyng-imbibition cycles just after the air bubble injection (1 mL air at 1 Atm. 20C, 5 cm depth). Flow rate 1 mL h^{-1}, pumped volume 40 mL per cycle.

Material and laboratory methods



Setup

- Wet packed sand columns (84 mm i.d., 100 mm high), (fritted disk 90 mm i.d. at the bottom).
- Three fast-response tensiometers (5 cm depth):
    - Sensitivity 0.05 hPa, full scale 0 to -100 hPa. Scan rate 10 Hz, 16 bit.
    - Controls of noise sources: kinetic and electromagnetic.

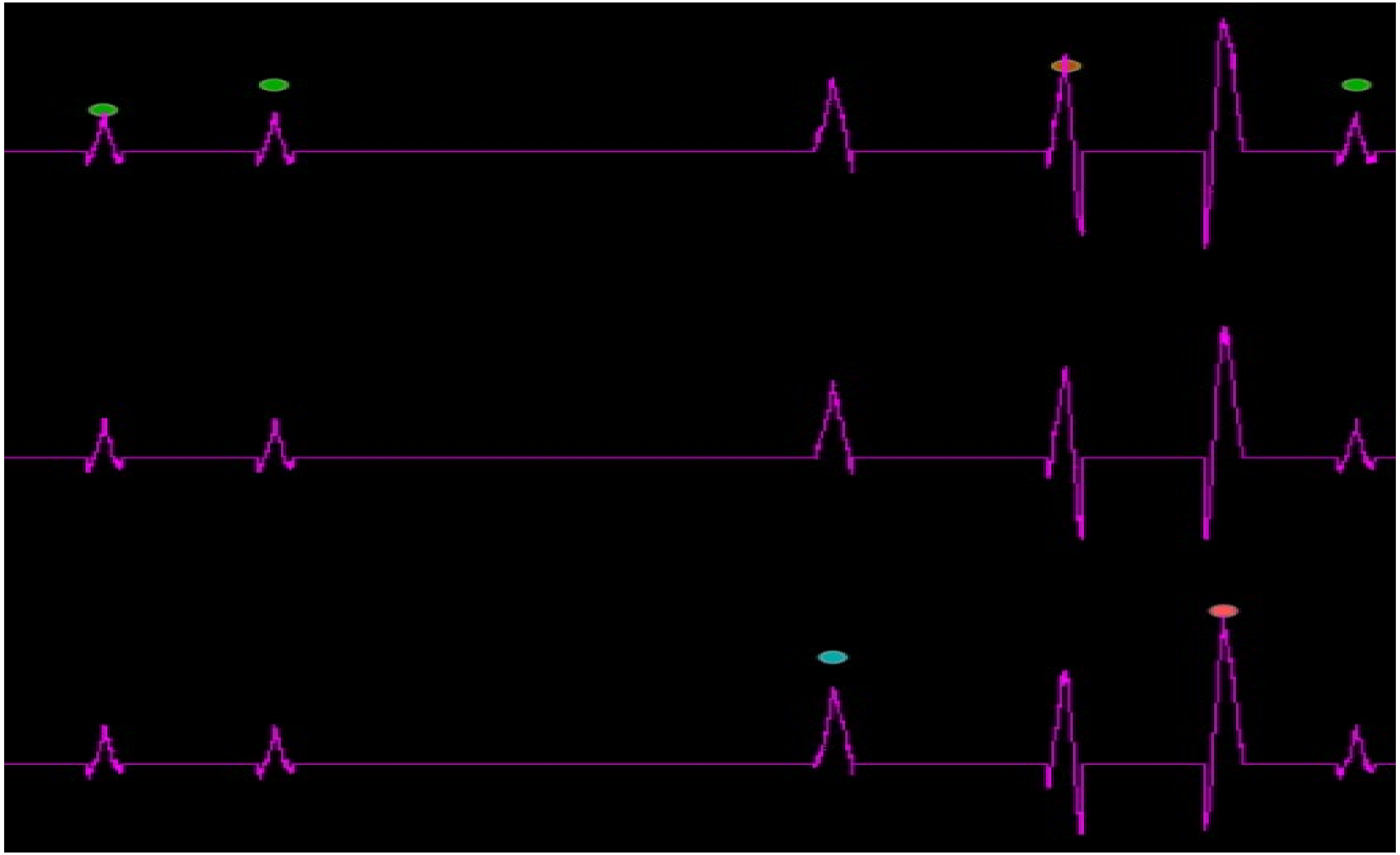
Trials

- Up to 15 pump-driven imbibition-drainage cycles from the bottom with flow rates of 1 and 5 mL/min. (pulseless pump, 40 mL per cycle).
- Gravity driven drainage in:
    1. Undisturbed sand (no structure).
    2. Pseudo-structured sand generated by injection of air bubbles in saturated sand with a syringe.

3. Waveform location

Waveform assignation to a channel:

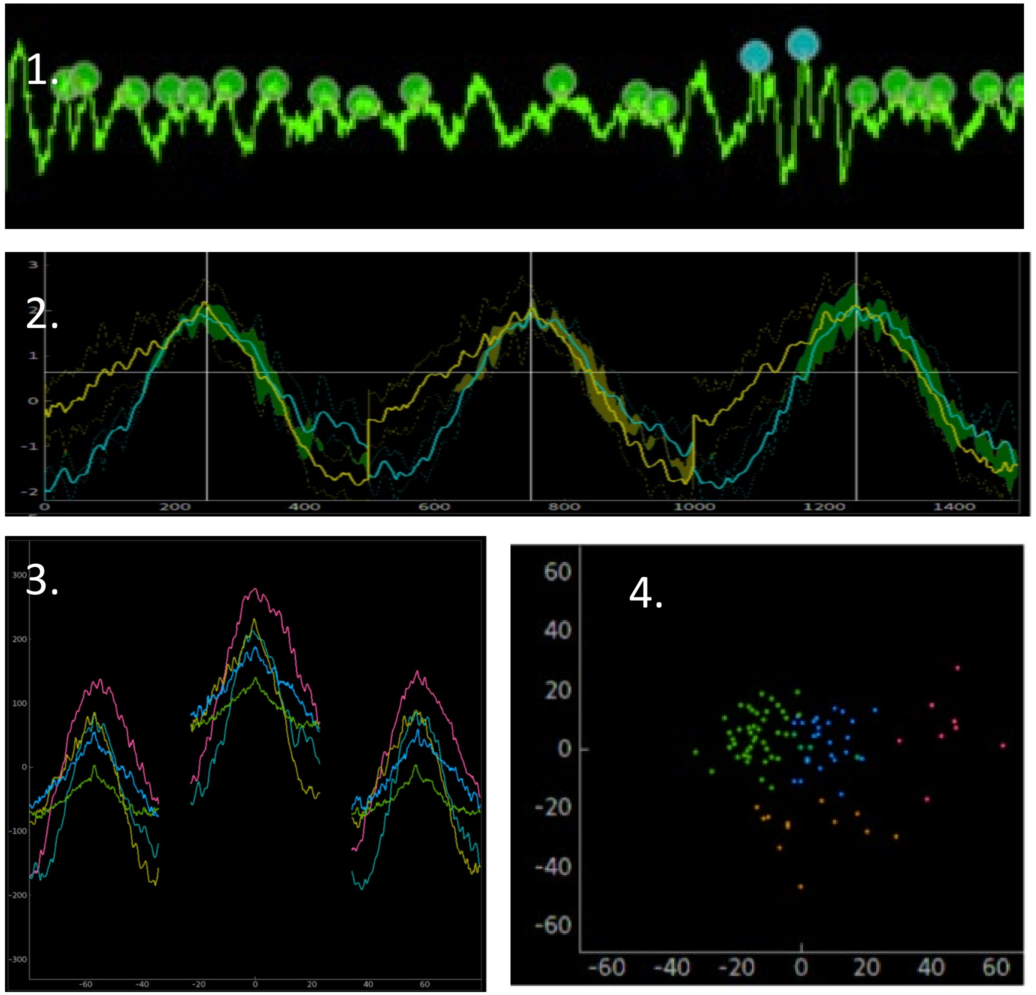
Wave amplitude decreases with the travel distance and arrival time is related with the phase displacement velocity (4 to 2 cm s^{-1}).*



Pressure Jump from capillary displacement at pore –thoat (ms) (From Armstrong y Berg, 114 2013)
https://doi.o rg/10.1103/PhysRevE.88.043010.

Data analysis (spike sorting method [1])

1. Signal processing, remove low frequency and noise. Frequency analysis.
2. Identification of significant waveforms over the median absolute deviation (MAD).
3. Waveform extraction (template matching). Classification and clustering: principal component analysis, k-means.
4. Tracking: normalized peak-to-peak amplitude difference, normalized peak-to-peak arrival time difference.



[1] **Garcia S. et al. (2014) Neo: an object model for handling electrophysiology data in multiple formats**. Frontiers in Neuroinformatics 8:10: doi:10.3389/fninf.2014.00010.

Tridesclous, spike sorting package: Samuel García, Cristophe Pouzat