High-resolution monitoring of controlled water-table variations from seismic interferometry, field approach

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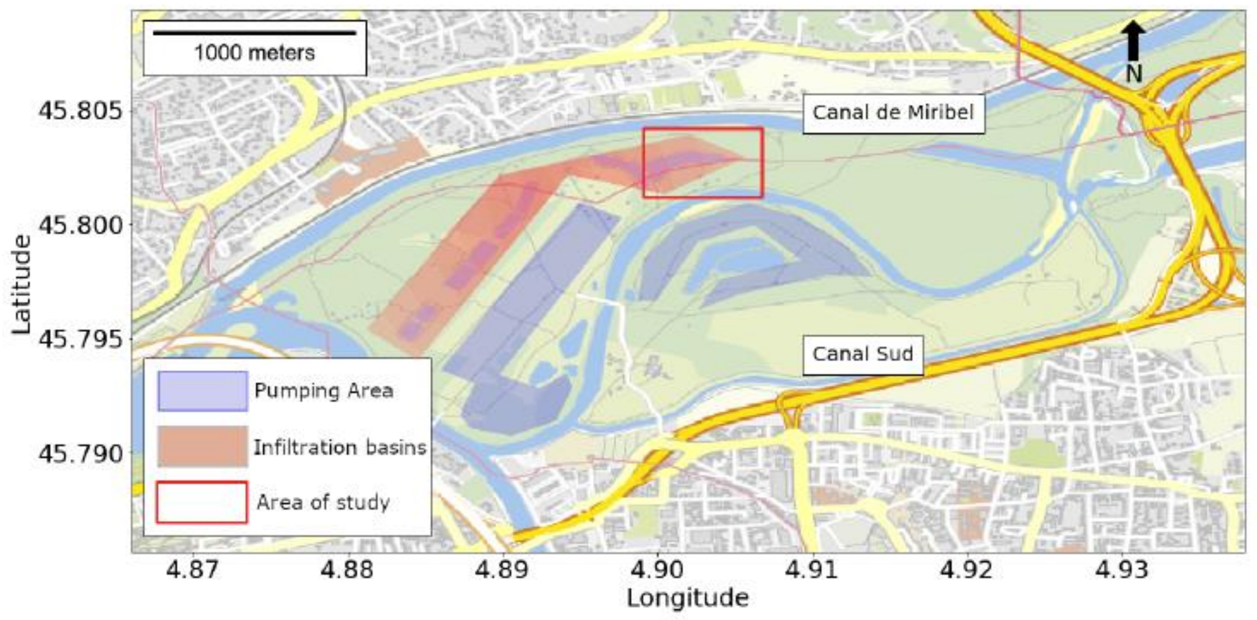
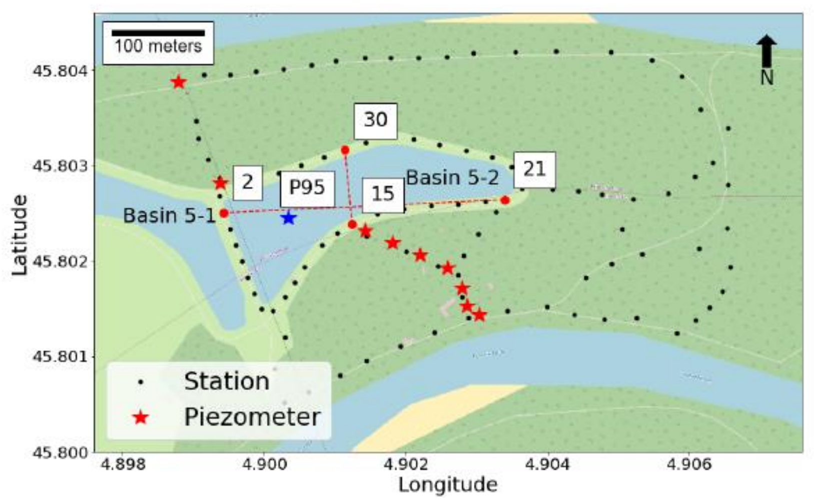
Problem and method

- This communication shows that fluid changes in the critical zone can be monitored using seismic interferometry.
- Some studies have shown that velocity variations can be related to changes in the water table (Garambois et al. 2019, Voisin et al. 2017).
- **It is therefore possible to use the two strong attributes of the seismic interferometry method in order to i) Compute velocity changes related to water table changes on dense array ii) Relocalize the information using tomography process (Mordret et al, 2010) to manage water-table change in this case.**

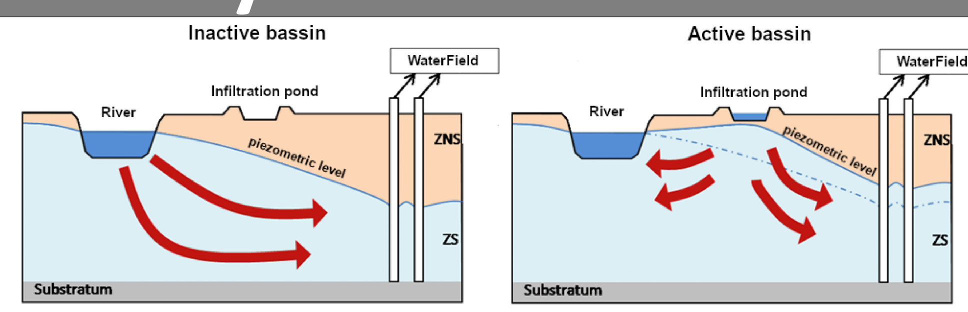
The field experiment



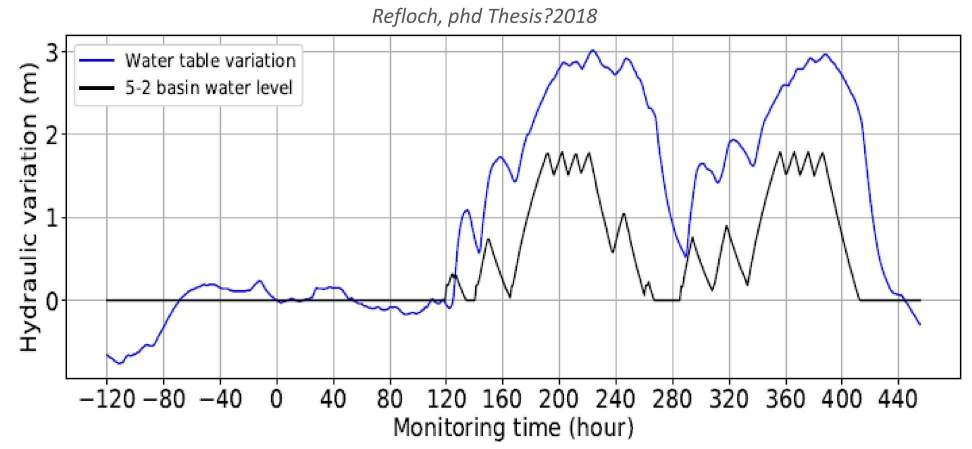
99 nodes 3-C sensor, Fs = 250 Hz, 19 days of recording



Hydraulic barrier



Refloch, phd Thesis?2018

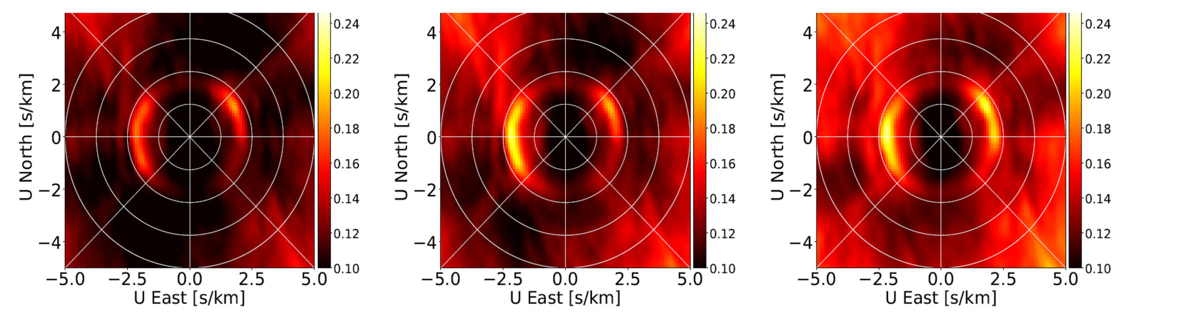


In order to protect the water table from possible pollution caused by the surrounding rivers an hydraulic barrier is set up by filling an artificial lake. The hydraulic barrier has two states:

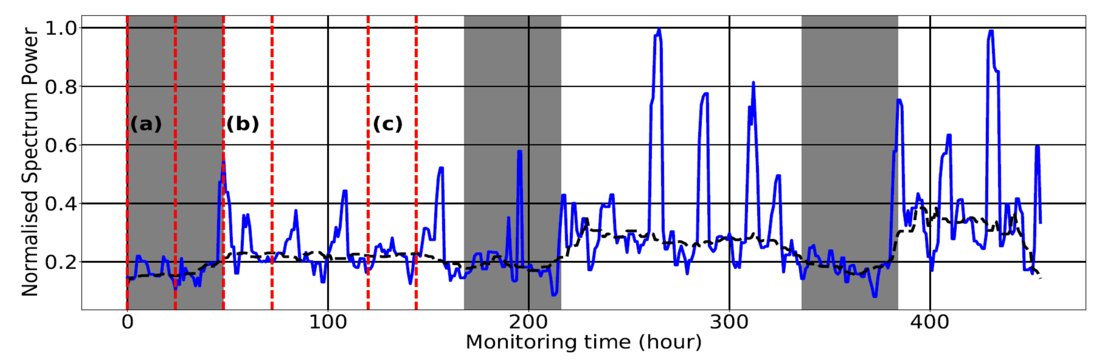
- **Inactive** : The groundwater drains the river
- **Active** : The groundwater discharges into the river

During the 19 days of monitoring, There were two forced imbitition of the infiltration basin 5-2 leading to the formation of an hydraulic barrier(at the following starting hour : 119 , 287)

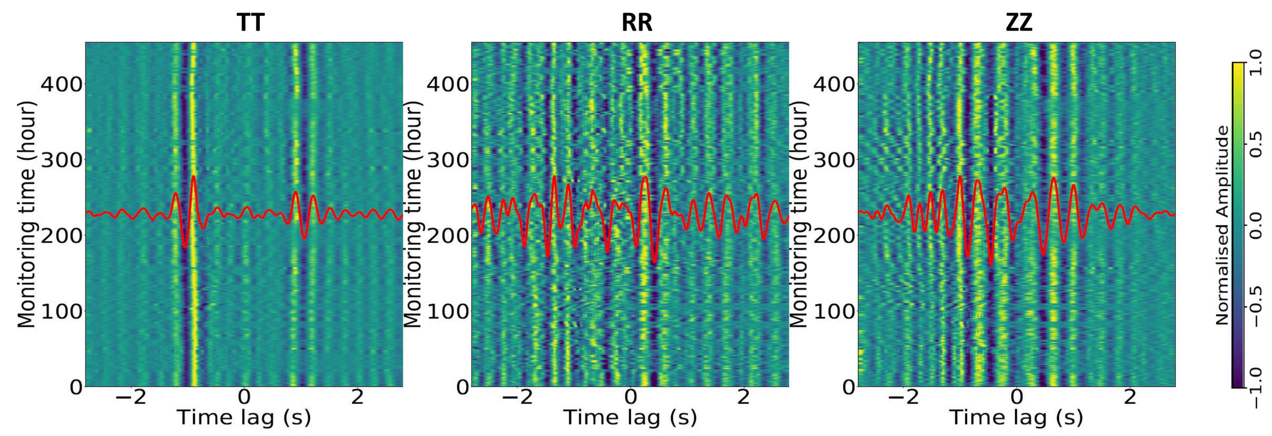
Array processing



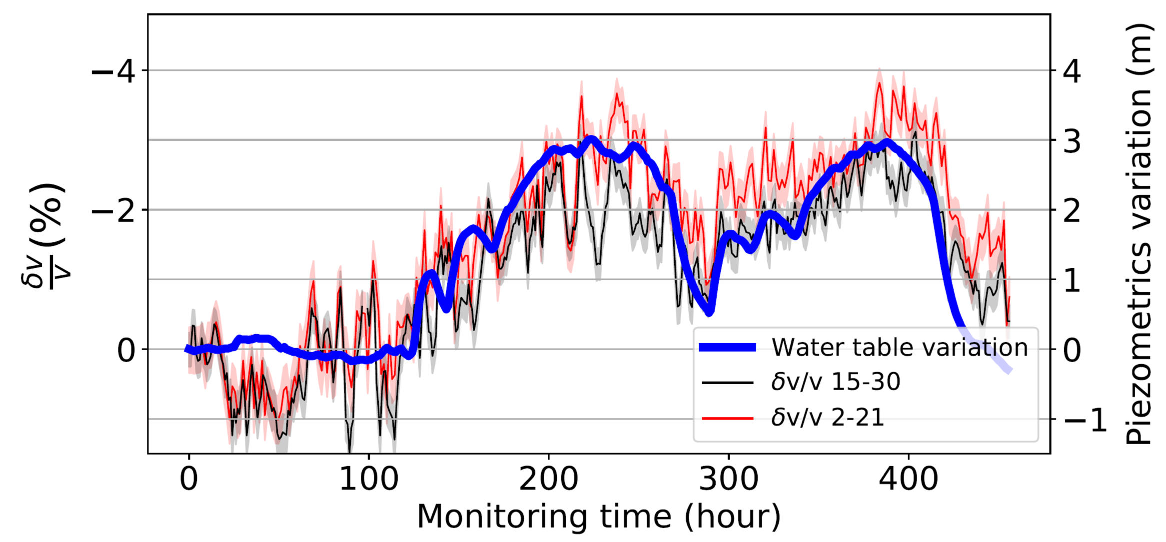
- 3 beamformers coming from 3 different days of the monitoring (a), (b), (c).
- **Strong East-West directionality (highway traffics).**



- More power during the week than the weekend (grey area), signature of town activity



- 3 Component correlograms (TT – RR – ZZ) computed from 10 min whitenned projected signal with a 2.8s maxlag window, sensor 2-21.
- **TT component is both symmetric and dominated by a single arrival with an apparent velocity close to 400 m/s (Love wave) .**
- RR is noisy, ZZ is symmetric and dominated by both body and surface wave.



- **From two pairs of sensors with orthogonal direction (2-21 and 15-30), we get similar results for the TT component. The velocity variation obtained by a stretching technique (Zens et al., 2006) is mostly anti-correlated to the water table variation over the monitoring time (in hour).**

References

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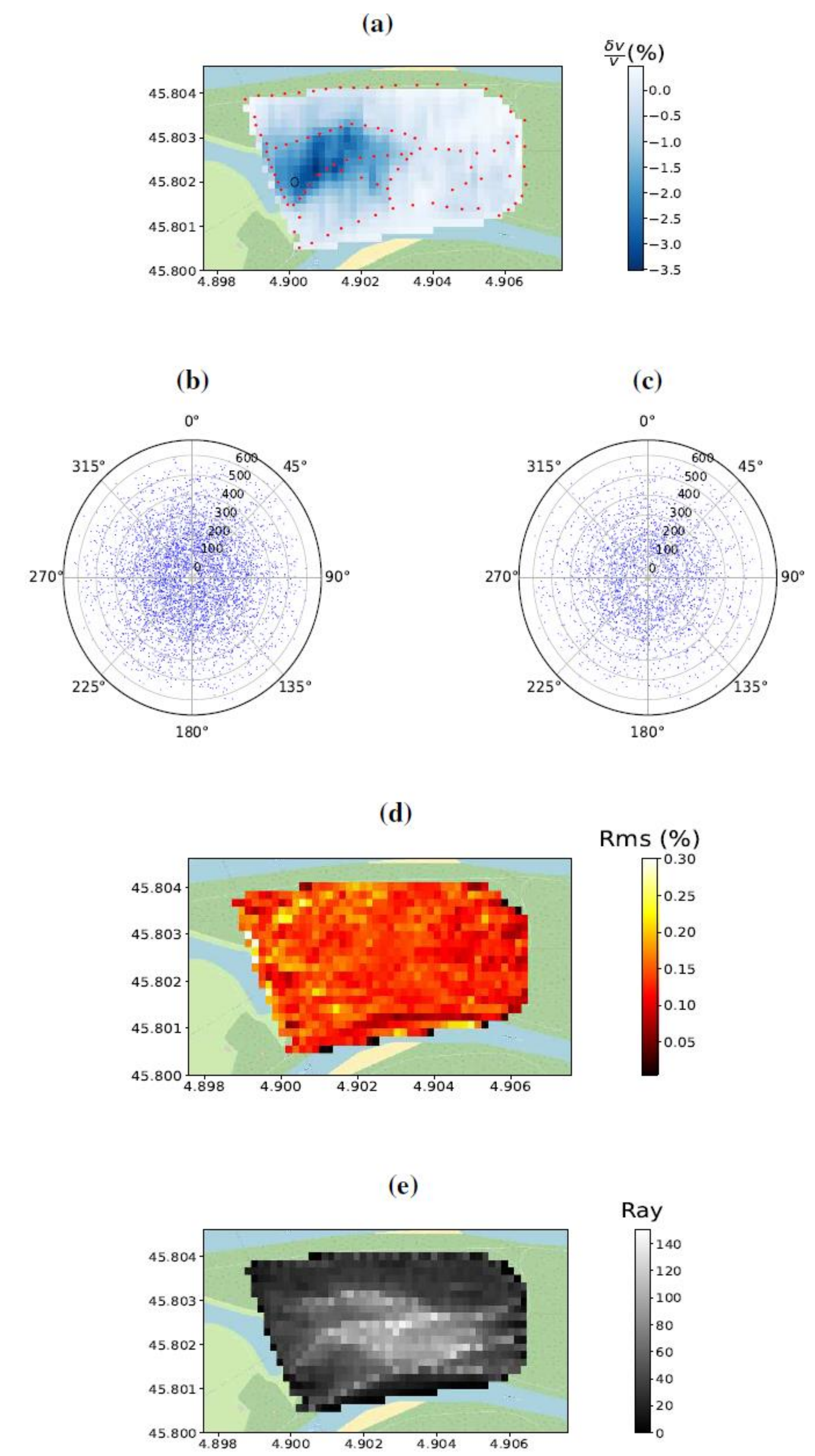
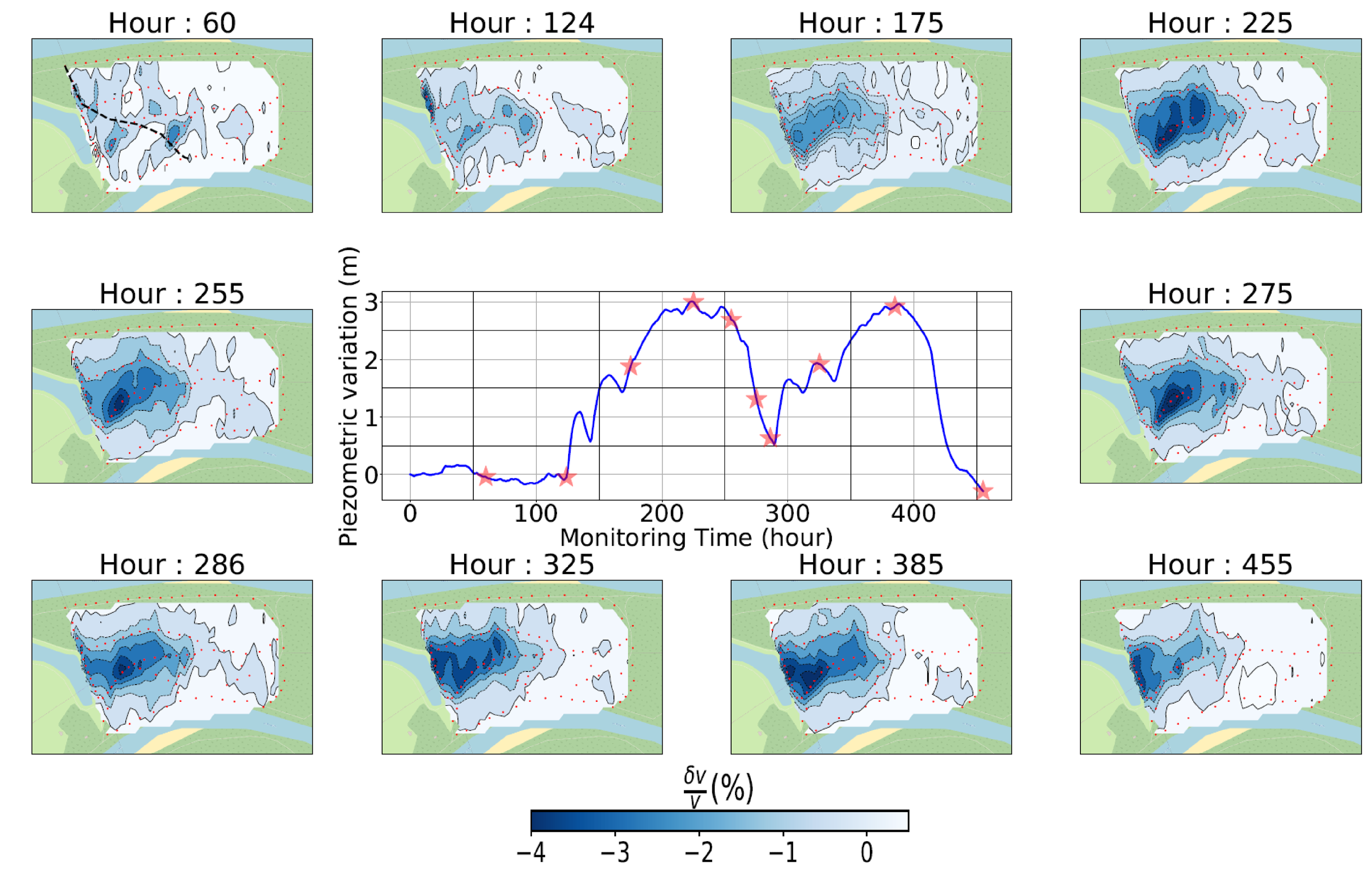
Tomography method



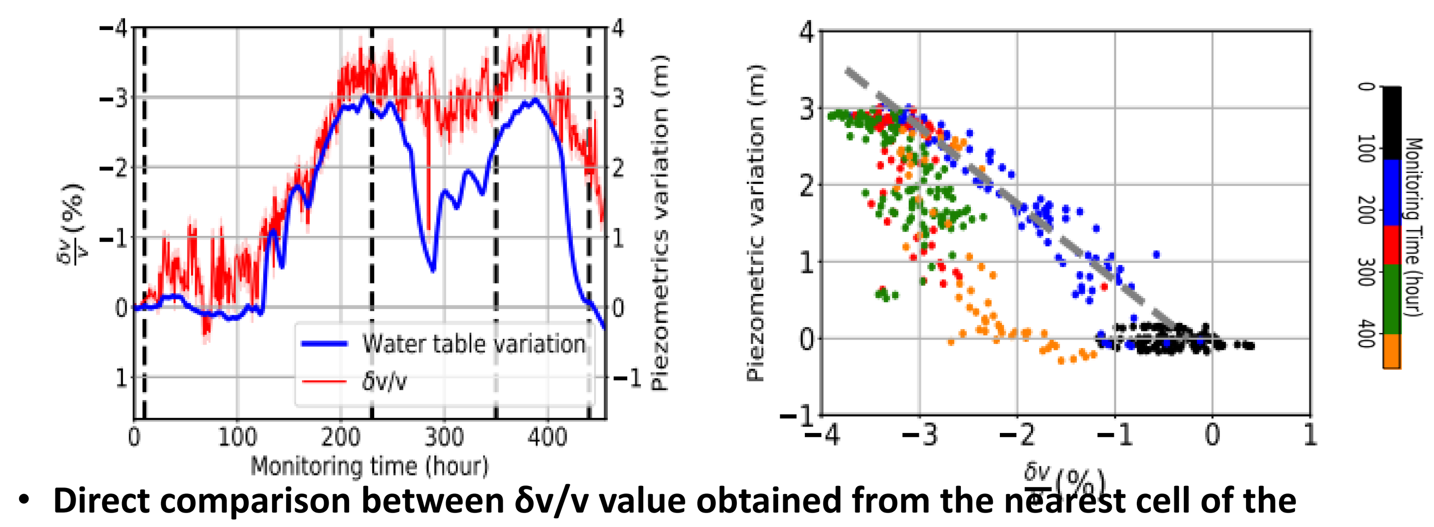
- Adapted from Barmin et al. 2001 tomography in straight ray theory (Mordret et al. 2010)
- (b) Initial distribution distance/azymuth, (c) final distribution for one hour
- Ponderation of the value by the lenght of each ray in each cell.
- Gaussian smoothing
- 1 Tomography per hour
- **Max ray density = 170 ,min = 5, median = 80.**

Tomography results



- Hourly tomography process coming from 4851 δv/v * 24 hour * 19 days of monitoring
- **Monitoring of the development of the hydraulic barrier based on velocity variations**

Effect of the unsaturated zone



- **Direct comparison between δv/v value obtained from the nearest cell of the piezometer P95**
- During the first imbibition (blue point) we can observe a linear relation between the water table and the velocity variations.
- During the successive drainage and imbibition processes a strong hysteresis occurs between the two value
- **Unsatured zone have strong influence on the δv/v value**

Conclusion

- ➢ Dense array allows to obtain robust information on the wavefield
- ➢ The Seismic interferometry method offers the ability **to provide maps of water content changes** with an unprecedented spatial resolution.
- ➢ This method permits to monitor the development of an hydraulic barrier and can be helpful to detect its weaknesses, and can be easily extended to other types of geological reservoirs.
- ➢ **Imbibition/drainage hysteresis is clearly observed** but would need a numerical analysis to be fully interpreted
- ➢ The unsaturated zone plays a significant role in the observed velocity variations

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