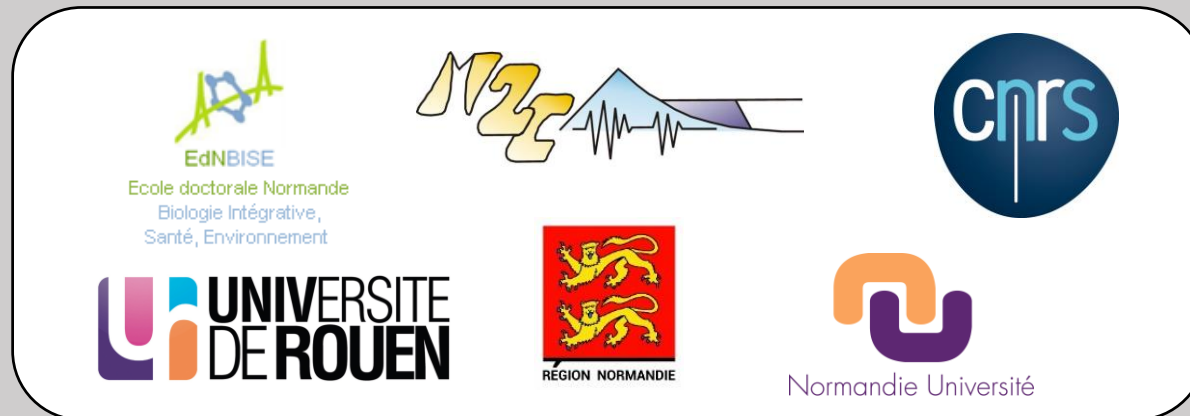


How to characterize karstified/fractured aquifers in distributed models ?

Interpretation of oscillatory pumping responses in karstified/fractured aquifers

*Pierre Fischer, Abderrahim Jardani, Nicolas Lecoq, Michael Cardiff
Hervé Jourde, Stéphane Chedeville, Xiaoguang Wang, Michel Simon*



PROBLEMATIC

SYNTHETIC CASE

MODELING

INTERPRETATION

APPLICATION

PROBLEMATIC

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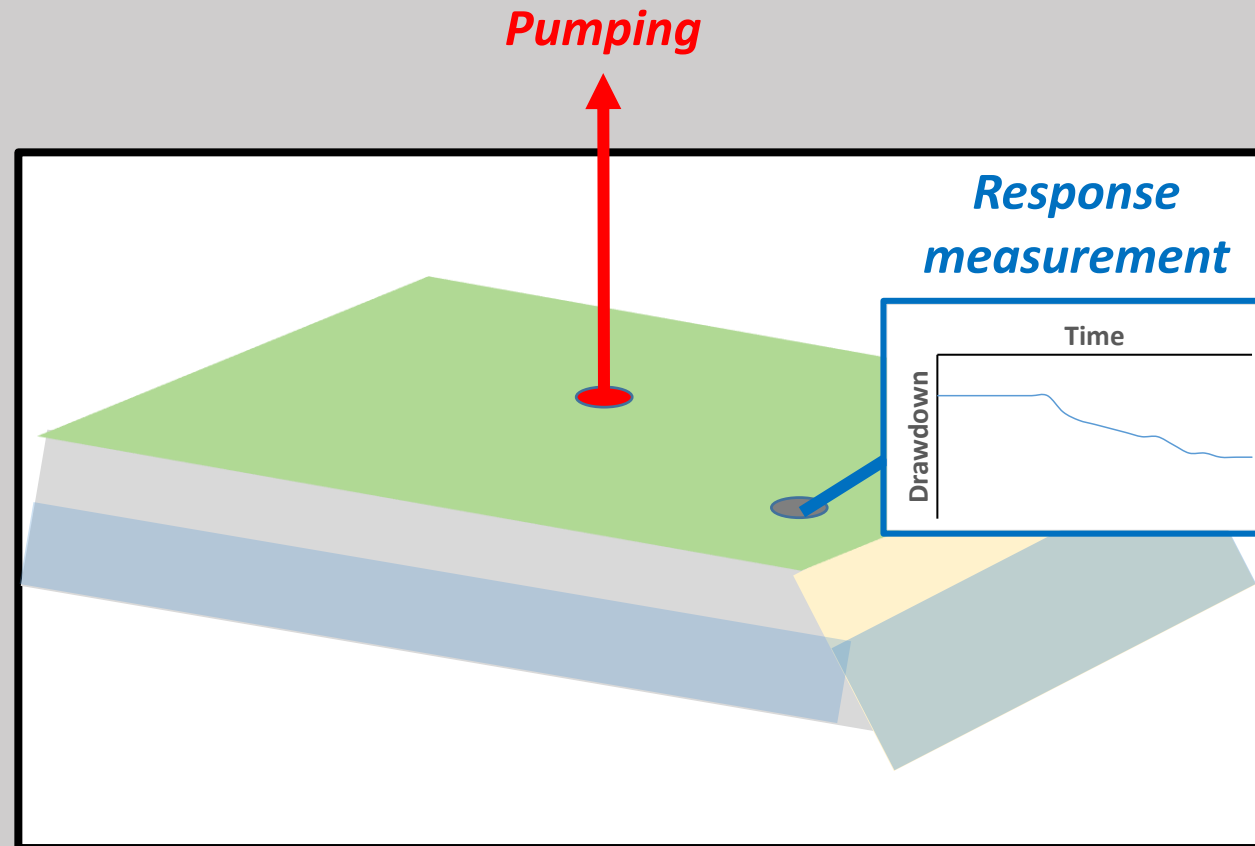
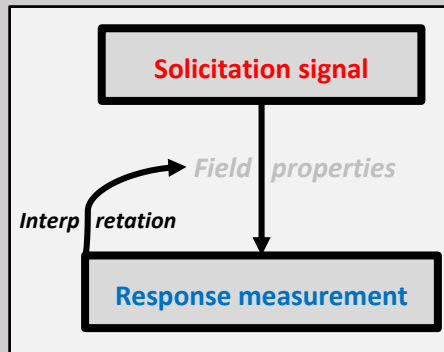
SYNTHETIC CASE

MODELING

INTERPRETATION

APPLICATION

Characterization of the properties of a subsurface field :



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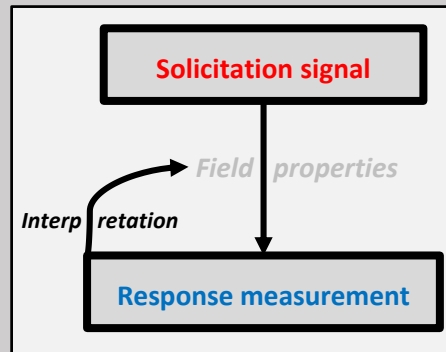
SYNTHETIC CASE

MODELING

INTERPRETATION

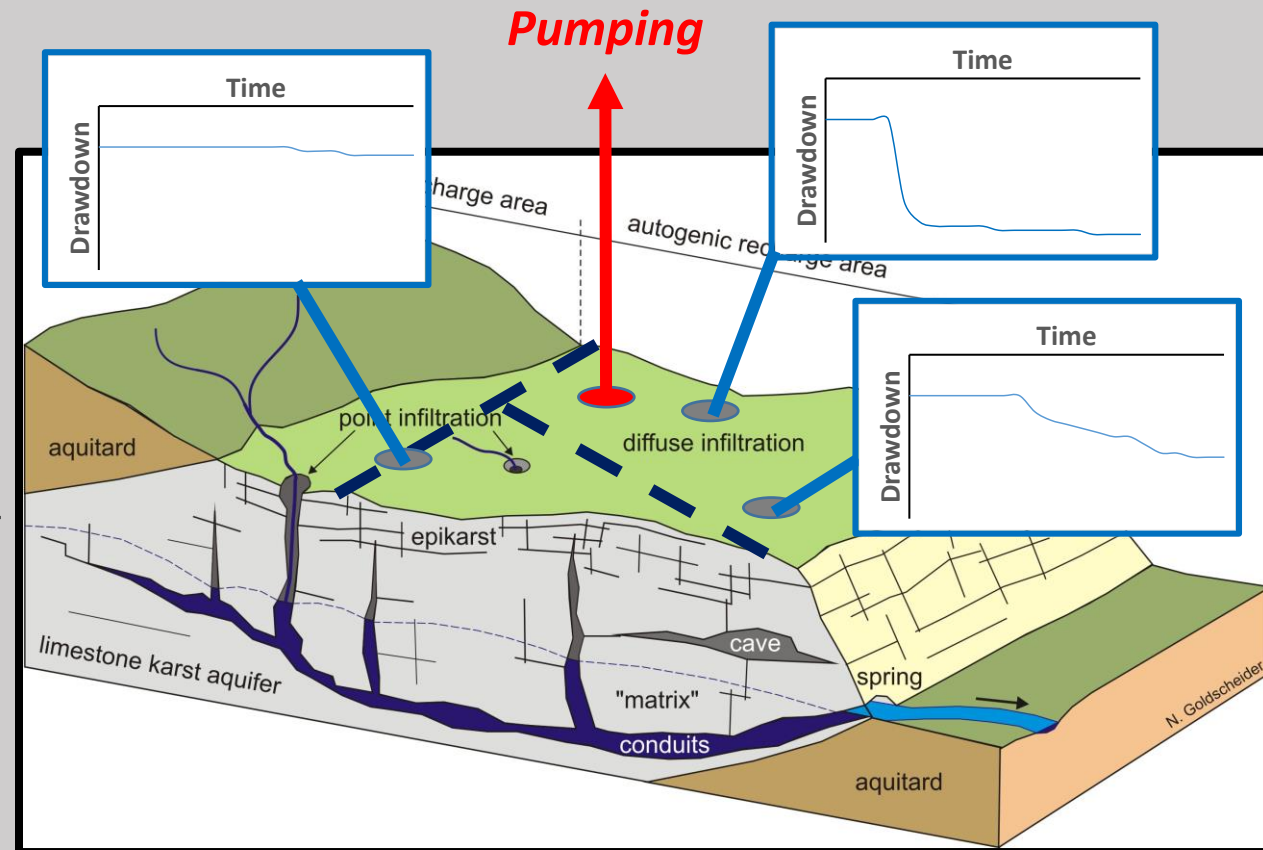
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Characterization of the properties of a heterogeneous field :



In the case of karstified/fractured fields :

Responses are complex and **spatially highly variable** (high dependency to the network positioning)



(Goldscheider and Drew, 2007)

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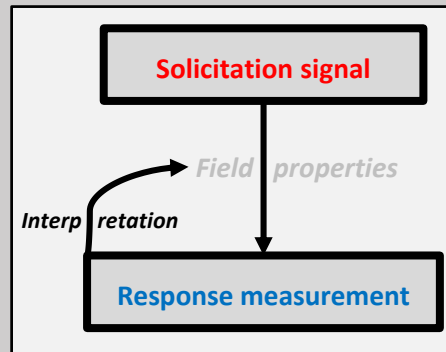
SYNTHETIC CASE

MODELING

INTERPRETATION

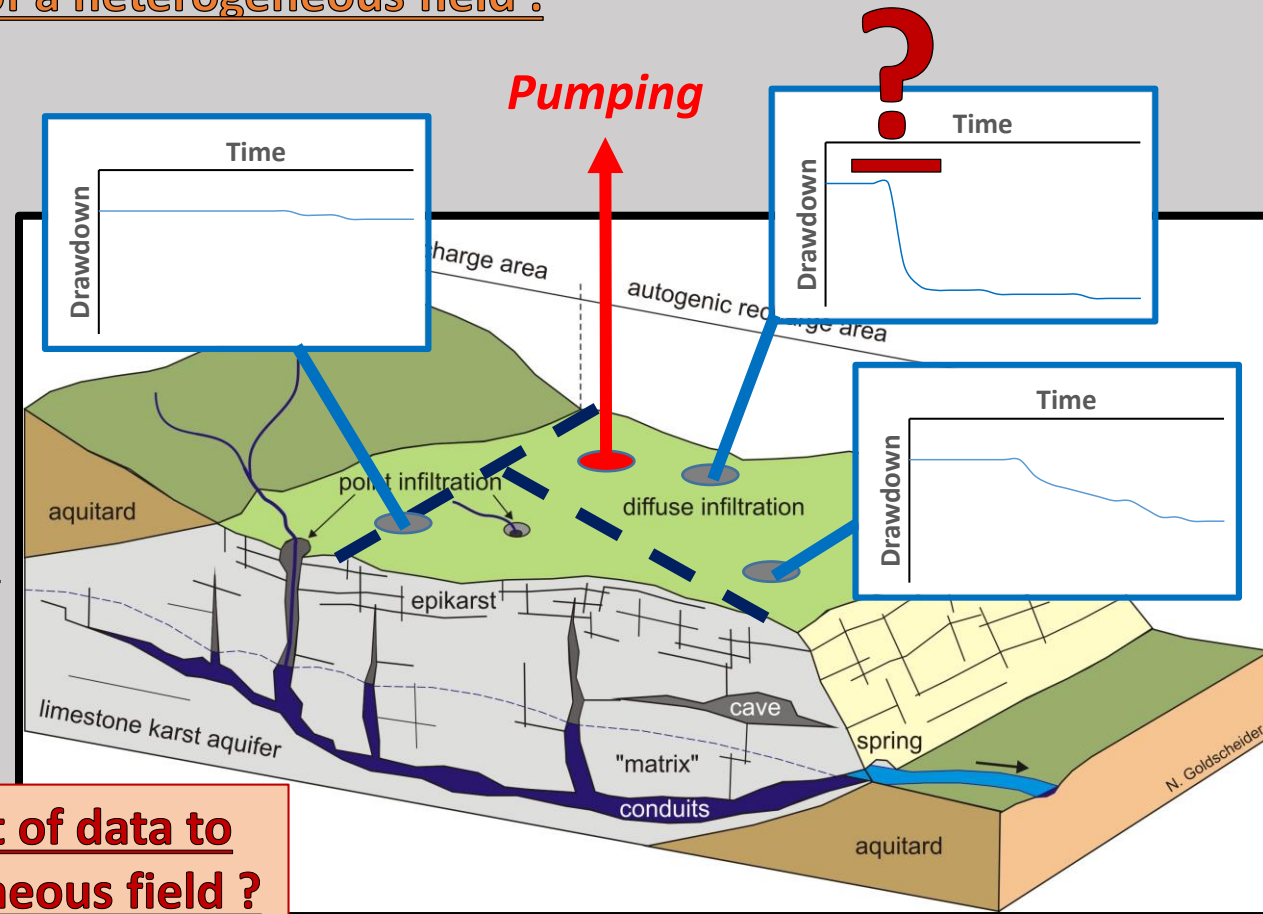
APPLICATION

Characterization of the properties of a heterogeneous field :



In the case of karstified/fractured fields :

- Need representative measurement points (amount, position)



What type and amount of data to characterize a heterogeneous field ?

(Goldscheider and Drew, 2007)

PROBLEMATIC

SYNTHETIC CASE

MODELING

INTERPRETATION

APPLICATION

SYNTHETIC CASE

SYNTHETIC CASE

PROBLEMATIC

SYNTHETIC CASE

MODELING

INTERPRETATION

APPLICATION

What would be the theoretical spatial responses to a oscillatory pumping in a karstic field ?

The synthetic case:

- 2-D modeling at a field scale (50x50 m²)
- Coupled discrete-continuum (Matrix = EPM; Conduit = DCN)
- Transient modeling + Steady periodic modeling
- Oscillatory pumping in a borehole
- Drawdown measurement in 7 other boreholes (representative of different behavior)

SYNTHETIC CASE

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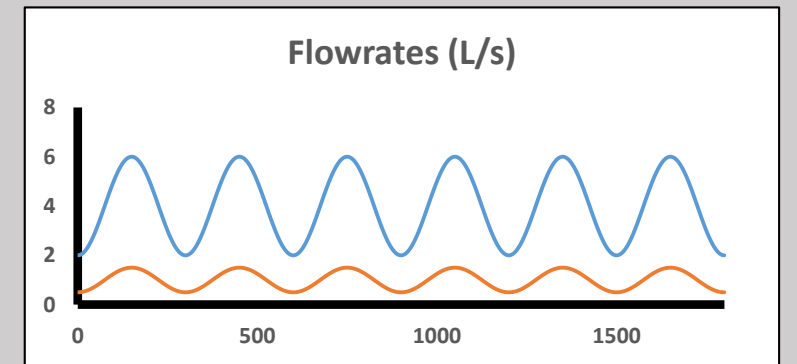
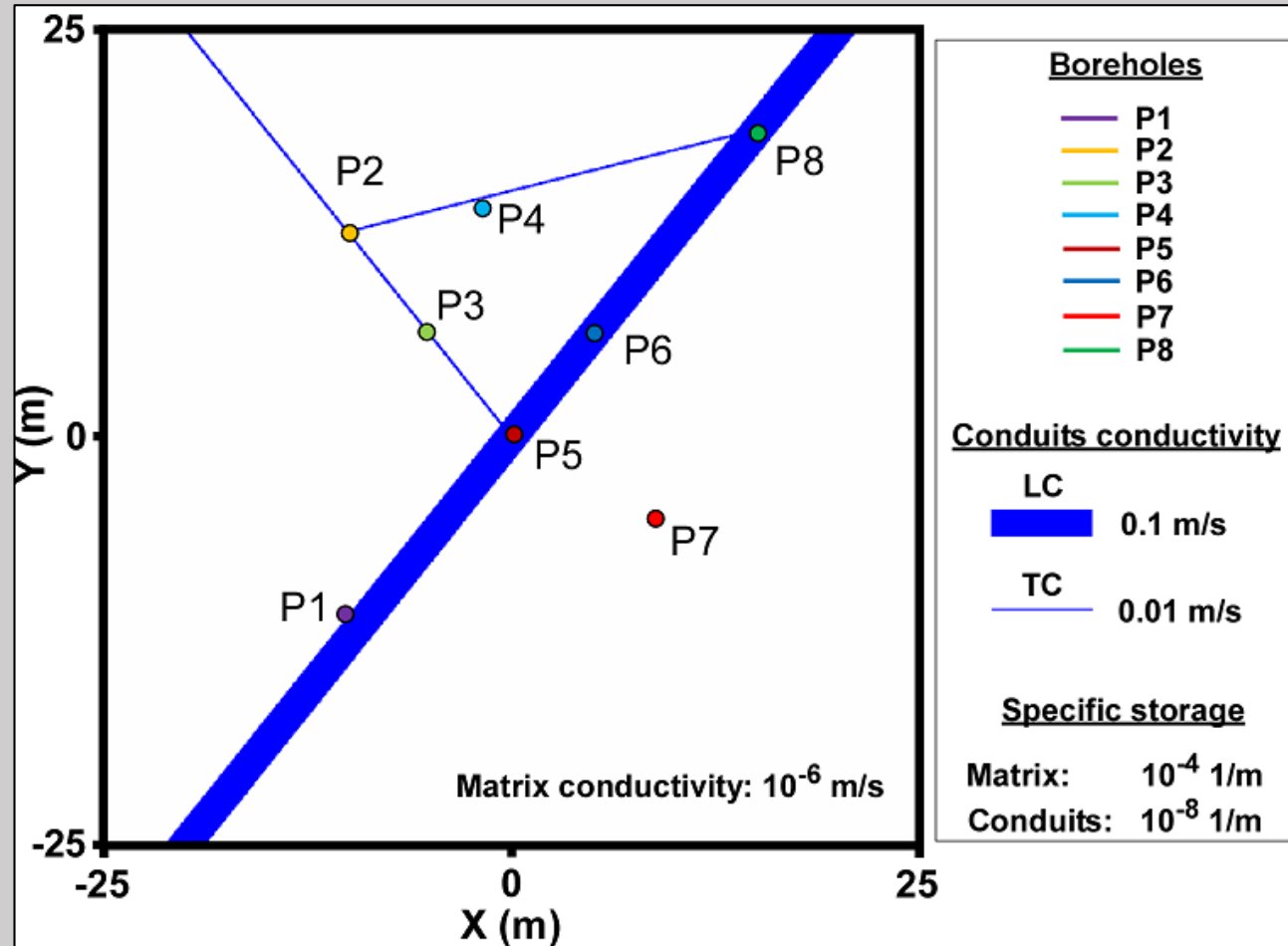
SYNTHETIC CASE

MODELING

INTERPRETATION

APPLICATION

The synthetic case:



PROBLEMATIC

SYNTHETIC CASE

MODELING

INTERPRETATION

APPLICATION

MODELING

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PROBLEMATIC

SYNTHETIC CASE

MODELING

INTERPRETATION

APPLICATION

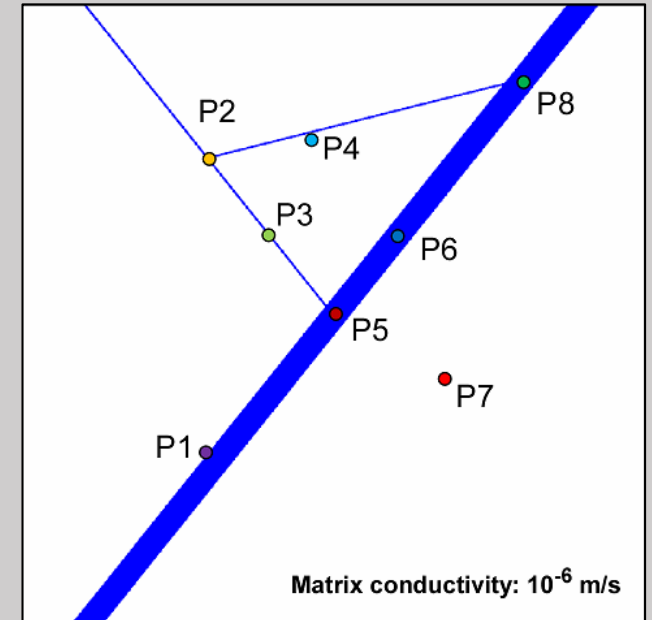
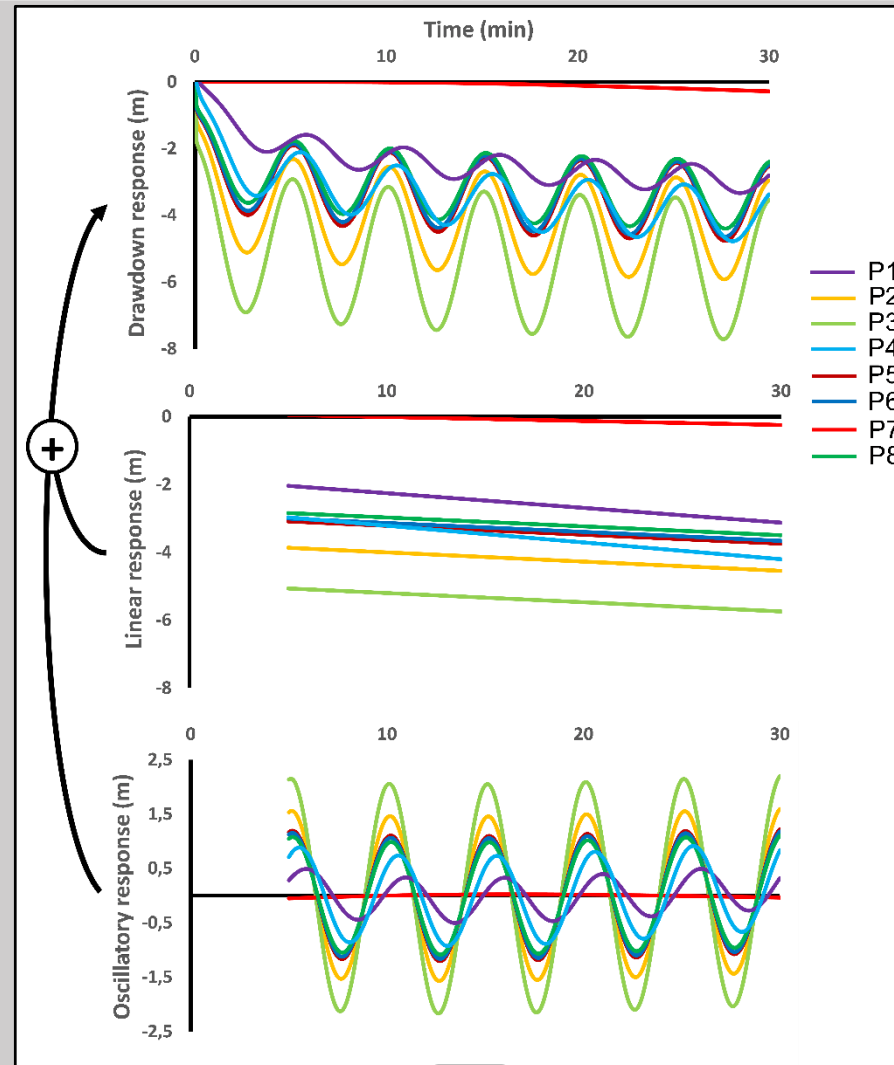
Transient result:

Pumping in P3 (Thin Conduit)

The drawdown signal can be decomposed in:

- A **linear** signal
- +
- A **oscillatory** signal

The oscillatory signals can be described by their relative **amplitudes** and relative **phase offset** values



MODELING

PROBLEMATIC

SYNTHETIC CASE

MODELING

INTERPRETATION

APPLICATION

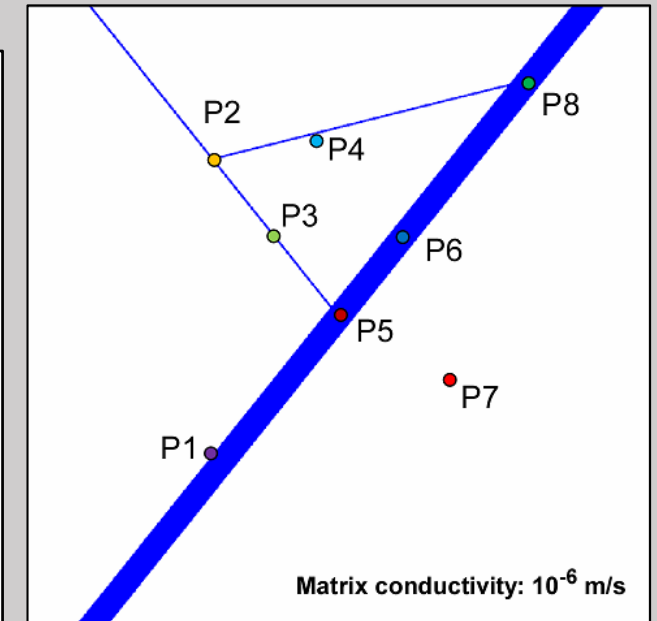
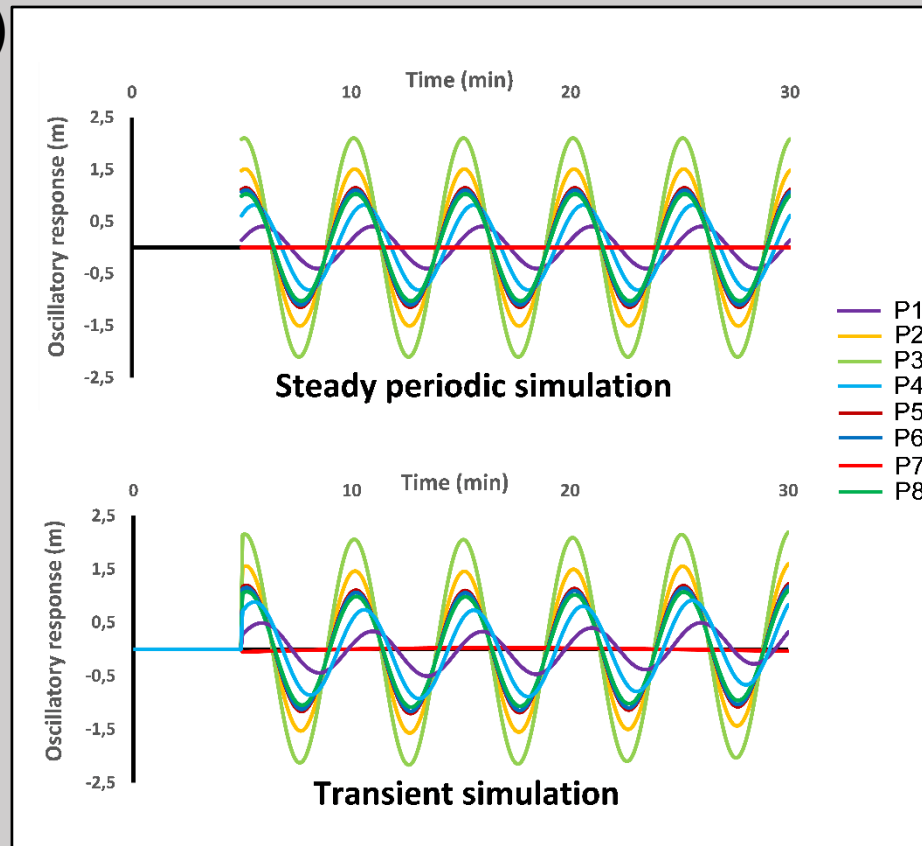
Transient / Steady periodic result:

Pumping in P3 (Thin Conduit)

A steady periodic modeling gives the **same results** as a transient for oscillatory signals

Advantages:

- Faster
- Directly provides amplitudes and phase offset values
- No signal decomposition



PROBLEMATIC

SYNTHETIC CASE

MODELING

INTERPRETATION

APPLICATION

INTERPRETATION

INTERPRETATION

PROBLEMATIC

SYNTHETIC CASE

MODELING

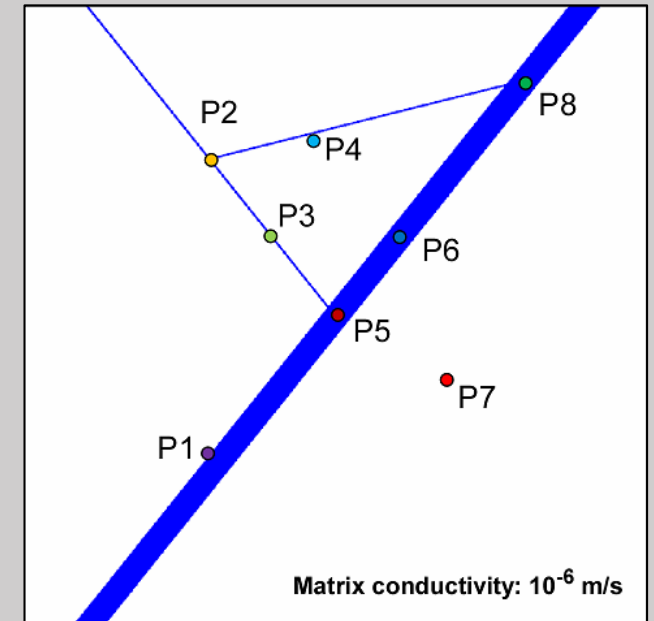
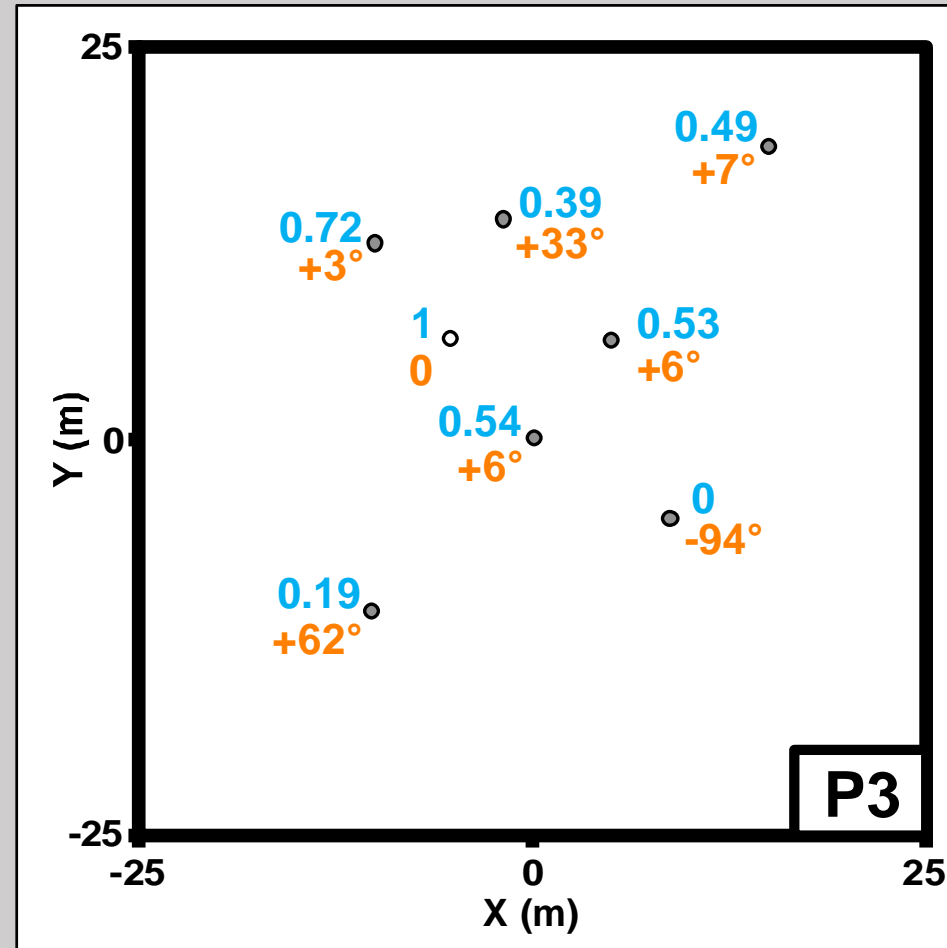
INTERPRETATION

APPLICATION

Interpretation of different responses behaviors

3 types of behaviors:

- **Connected** by conduits (same phase + amplitude response)
- **Semi-connected** near a conduit (amplitude response but different phase)
- **Not connected** (no responses)



INTERPRETATION

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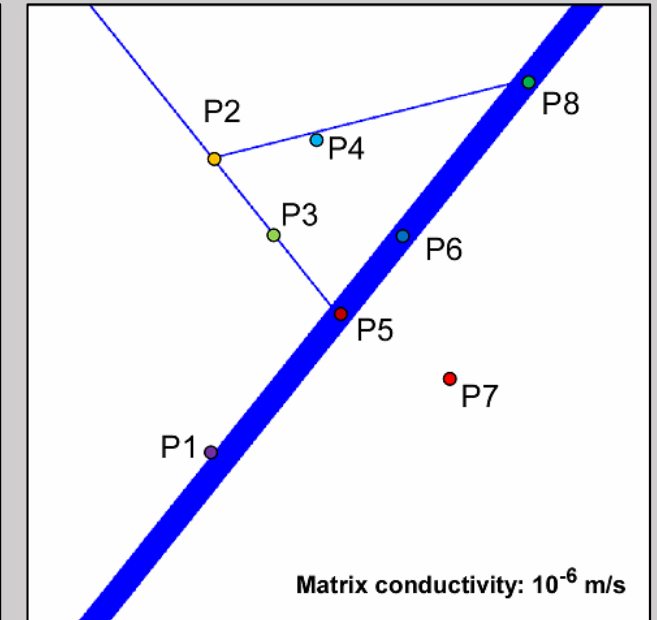
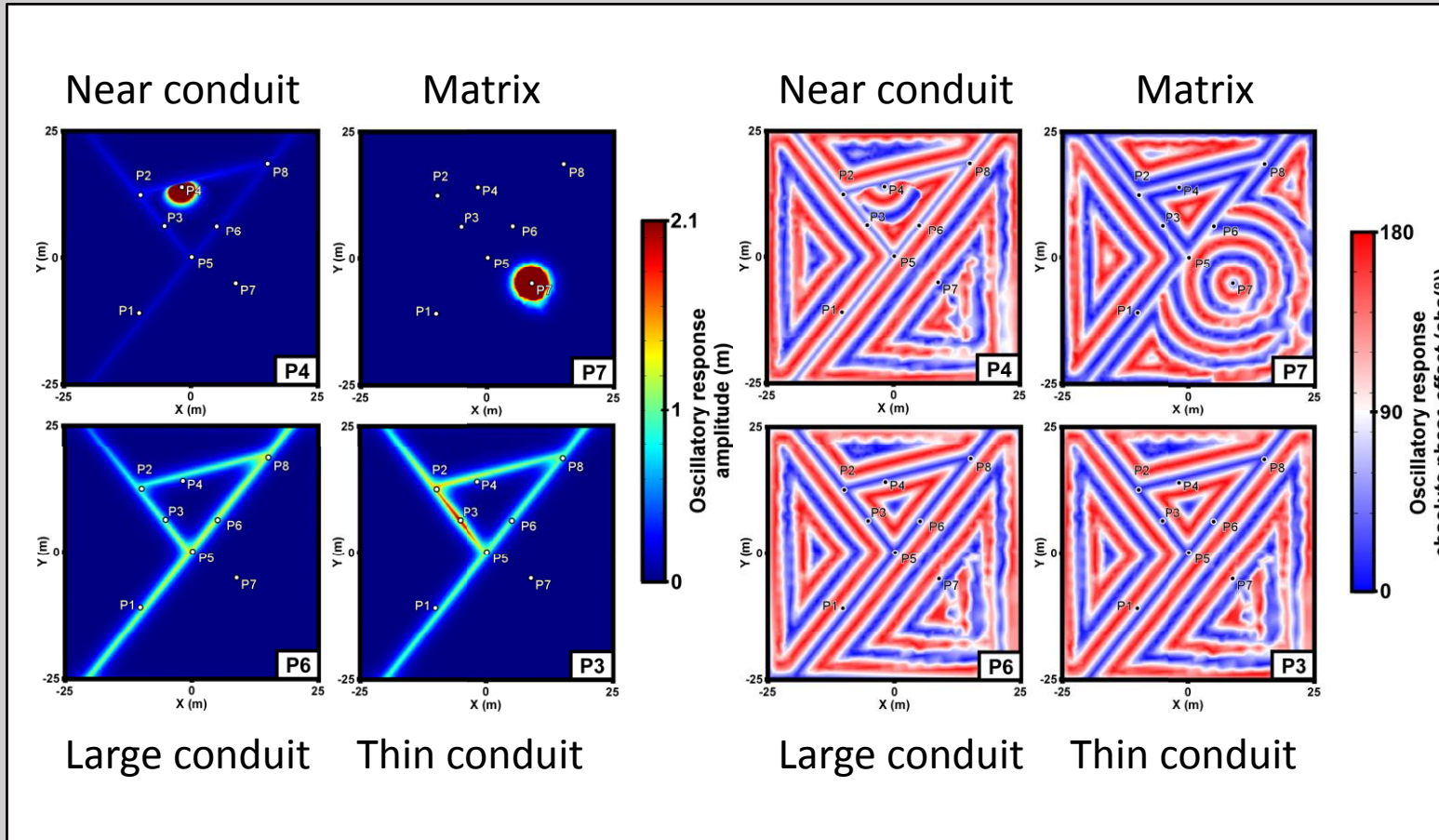
SYNTHETIC CASE

MODELING

INTERPRETATION

APPLICATION

Interpretation of different responses behaviors



INTERPRETATION

PROBLEMATIC

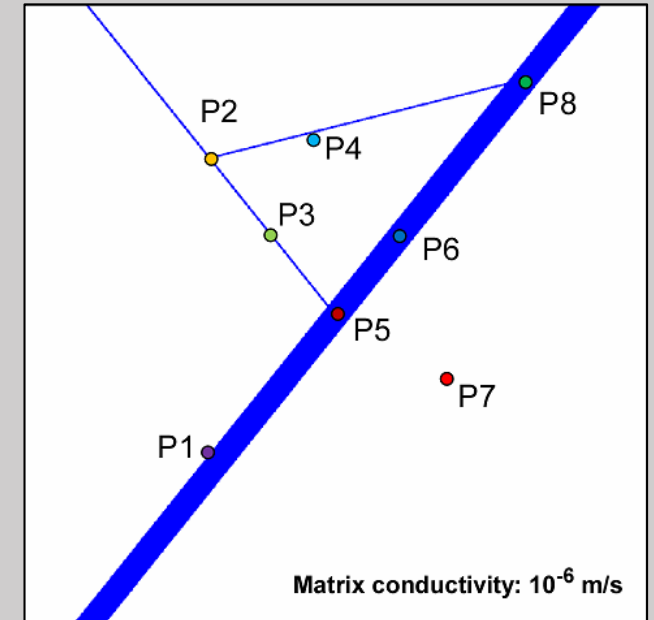
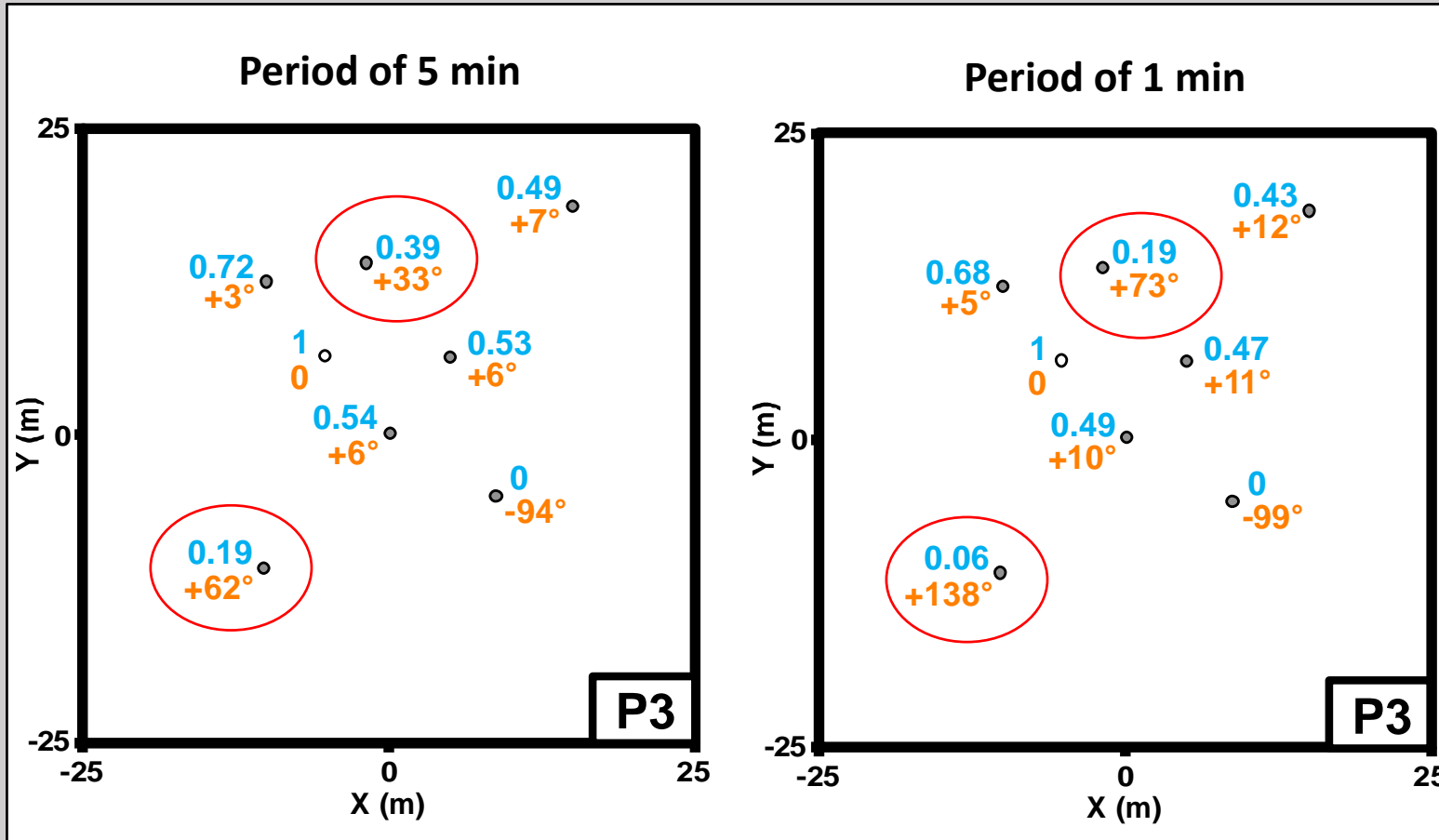
SYNTHETIC CASE

MODELING

INTERPRETATION

APPLICATION

Effect of the pumping period



INTERPRETATION

PROBLEMATIC

SYNTHETIC CASE

MODELING

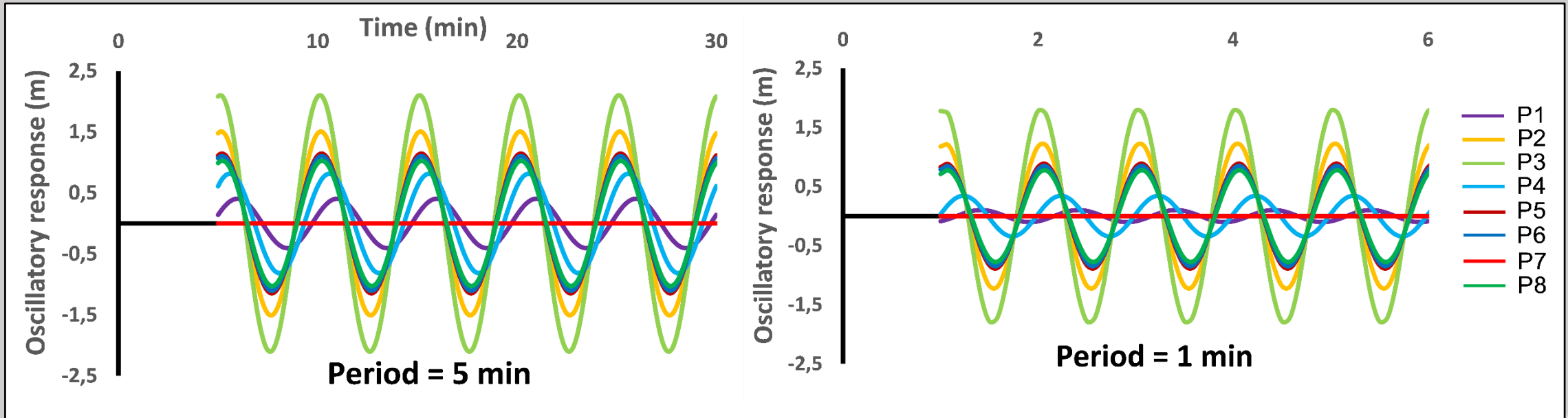
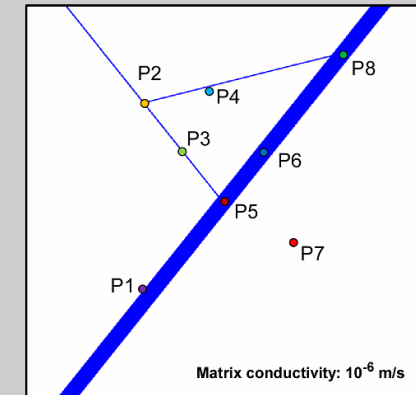
INTERPRETATION

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Effect of the pumping period

The use of different pumping period allows a better characterization of the boreholes connectivity:

- A **high frequency** characterize the **direct connectivity** between boreholes (conduit)
- A **lower frequency** characterize **indirect connectivity** as well (near conduit or fissures)



PROBLEMATIC

SYNTHETIC CASE

MODELING

INTERPRETATION

APPLICATION

APPLICATION

APPLICATION

PROBLEMATIC

SYNTHETIC CASE

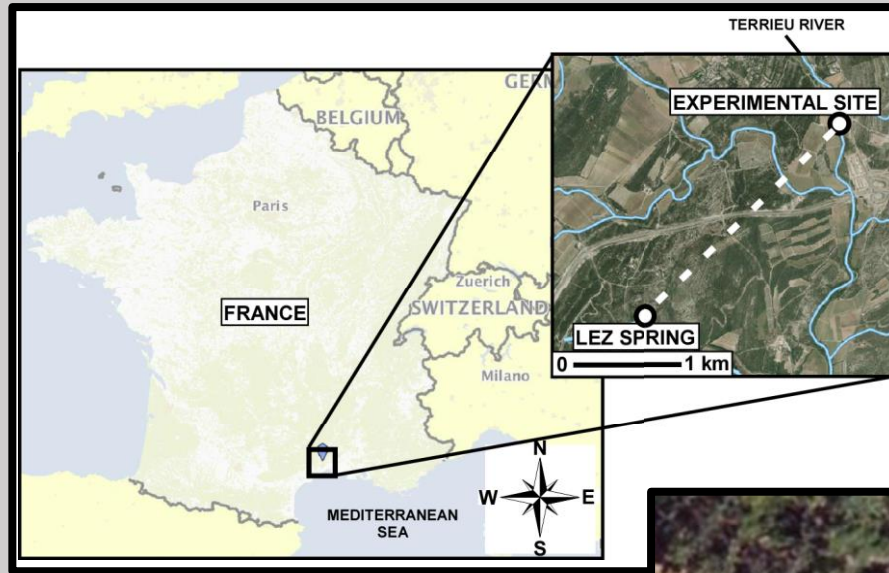
MODELING

INTERPRETATION

APPLICATION

Terrieu karstic experimental site (Lez aquifer, France)

- Montpellier, South of France
- Connected to the Lez spring
- Area of $\sim 2,500 \text{ m}^2$
- Observed main conduits with 20 to 50 cm aperture
- SNO Karst Network / Medycyss



(Map and aerial photography :
Géoportail.fr)



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PROBLEMATIC

SYNTHETIC CASE

MODELING

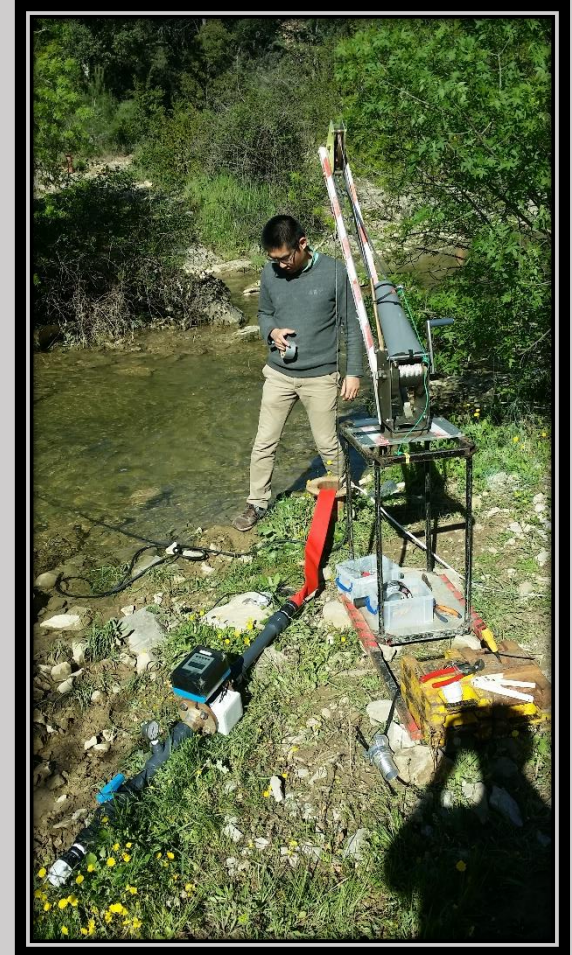
INTERPRETATION

APPLICATION

Investigation in the Terrieu karstic experimental site (Lez aquifer, France)



March 2017
Oscillatory pumping
investigation



APPLICATION

PROBLEMATIC

SYNTHETIC CASE

MODELING

INTERPRETATION

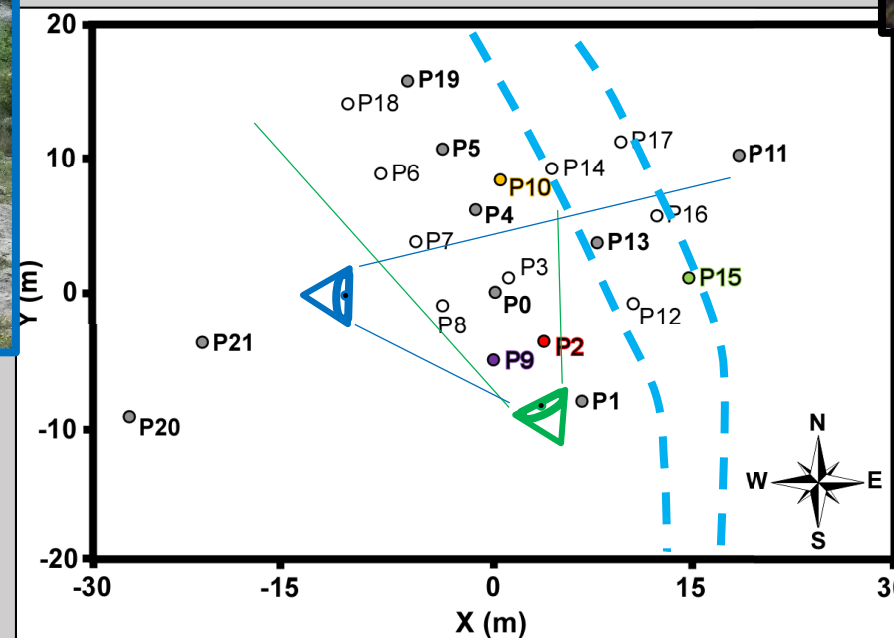
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Investigation in the Terrieu karstic experimental site (Lez aquifer, France)

Measured responses :

Oscillatory pumping in P15 at a 5 min period

- Drawdowns responses in 12 boreholes



APPLICATION

PROBLEMATIC

SYNTHETIC CASE

MODELING

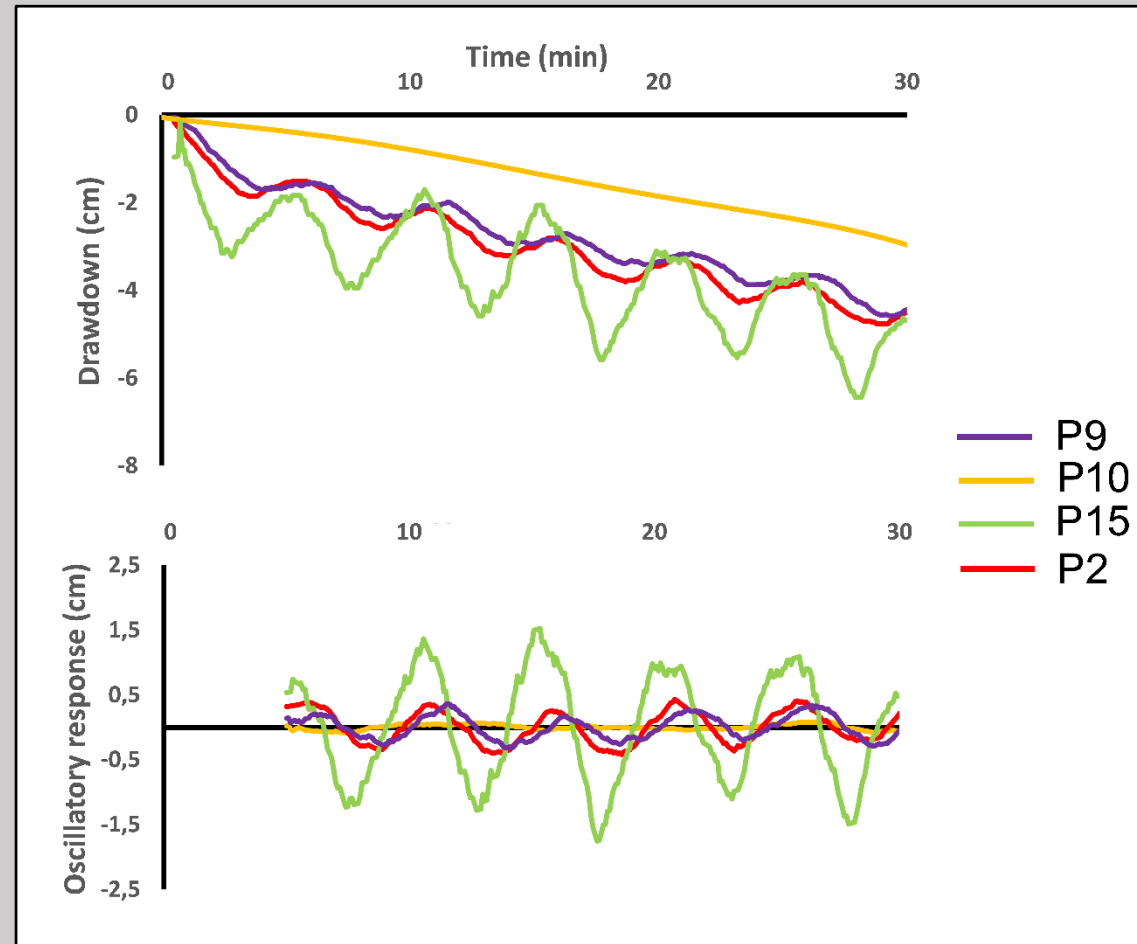
INTERPRETATION

APPLICATION

Drawdowns measurement examples

Coherent to the theoretical responses:

- 3 types of behaviors can be highlighted
- The signal can be decomposed in a linear one and in a oscillatory one



APPLICATION

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SYNTHETIC CASE

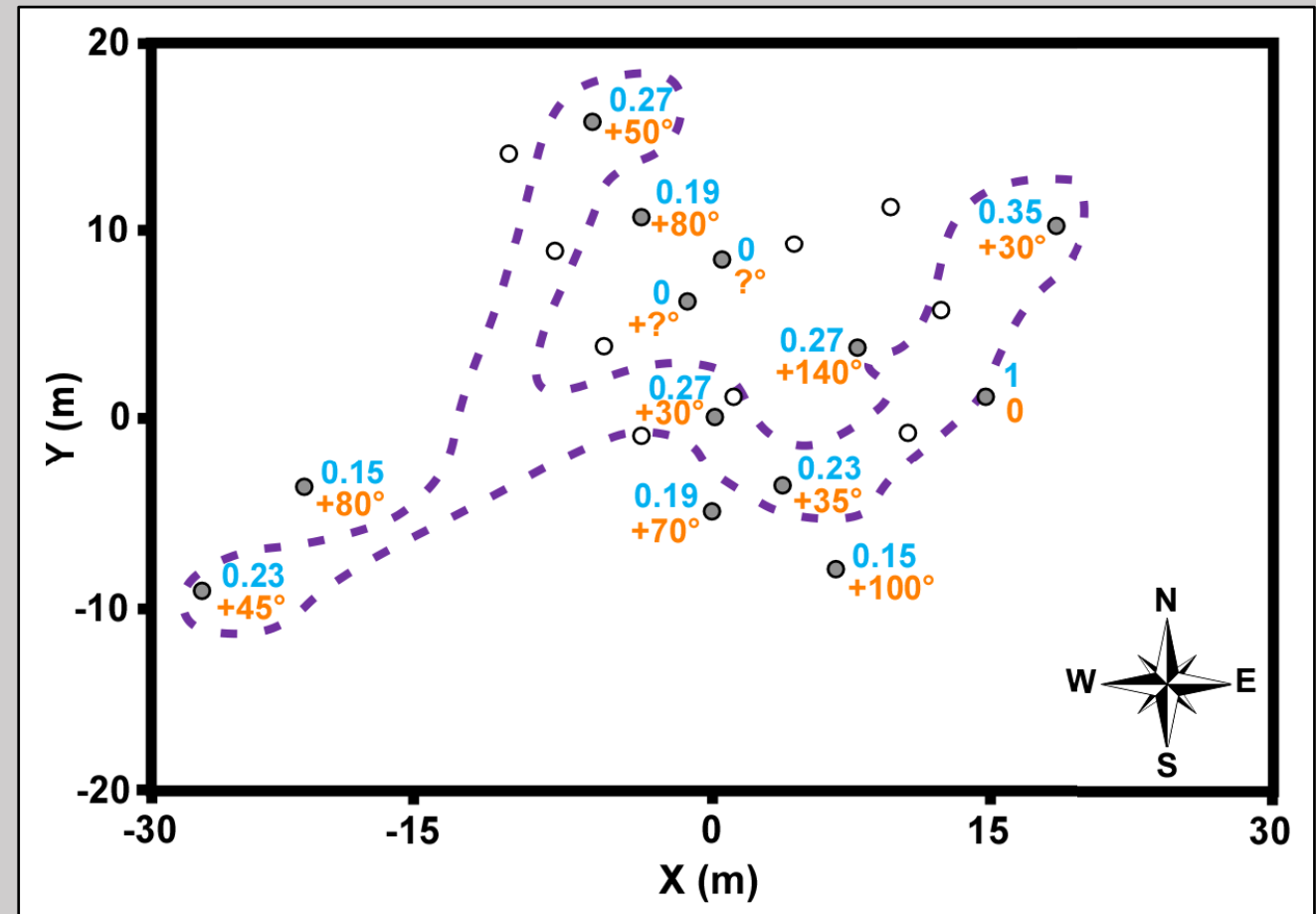
MODELING

INTERPRETATION

APPLICATION

Interpretation of the oscillations parameters (amplitude, phase)

- By using the same responses interpretation as in the theoretical case a **karstic connectivity can be highlighted**
- The responses of the non connected boreholes is **coherent to the theoretical case** as well



PROBLEMATIC

SYNTHETIC CASE

MODELING

INTERPRETATION

APPLICATION

WHAT NEXT ?

WHAT NEXT ?

PROBLEMATIC

SYNTHETIC CASE

MODELING

INTERPRETATION

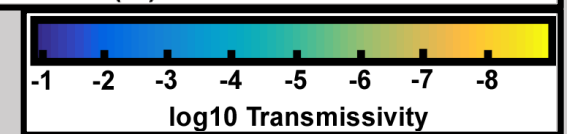
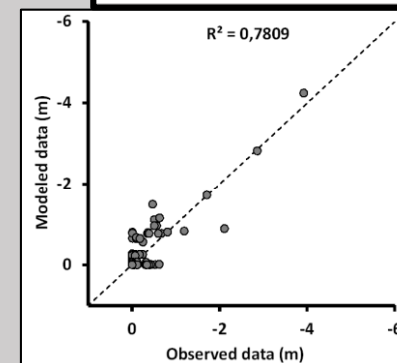
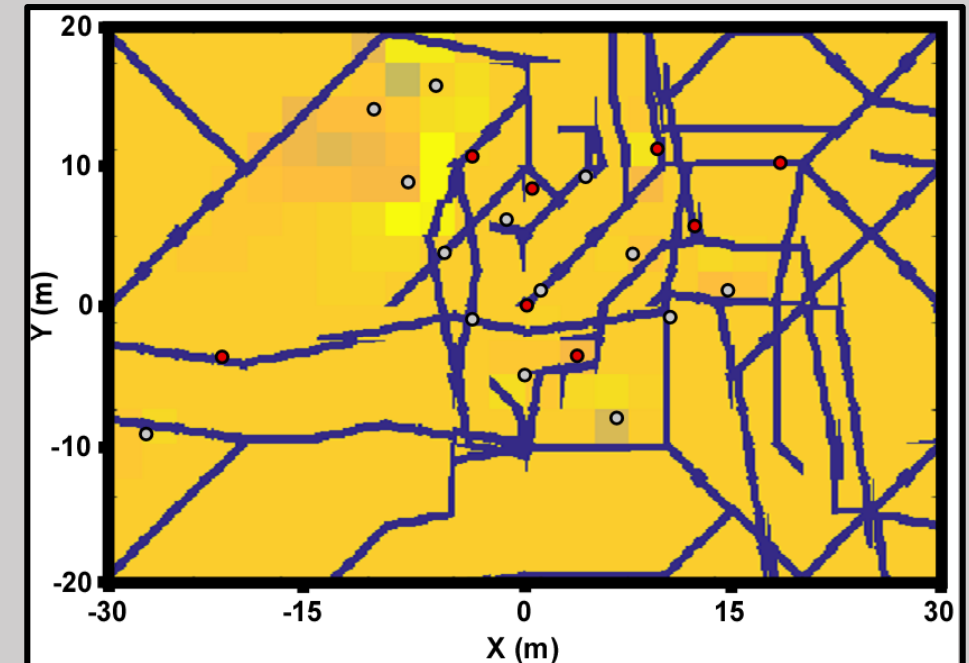
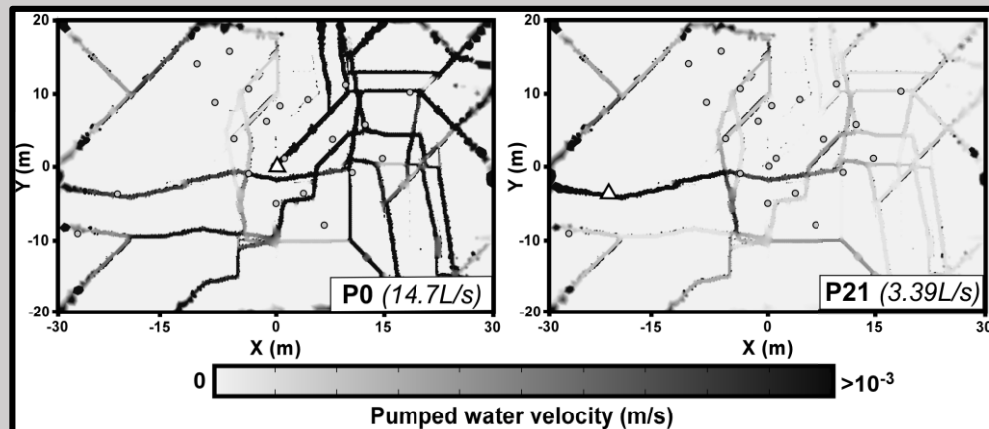
APPLICATION

How to interpret a large oscillatory data set ?

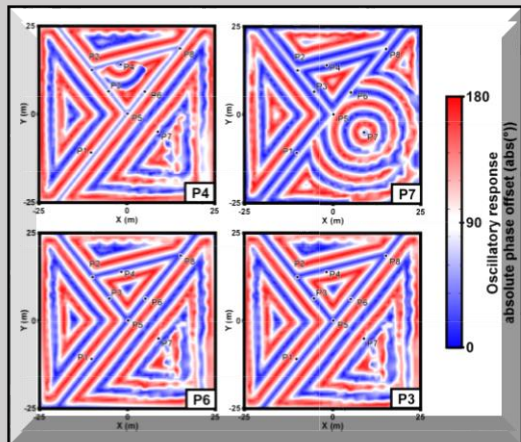
- 4 different pumping points (P3, P9, P15, P20)
- Different periods (1min, 2min, 5min)

Interpret a karstic network reproducing amplitude and phase offset values in a structurally distributed steady periodic model (faster computation)

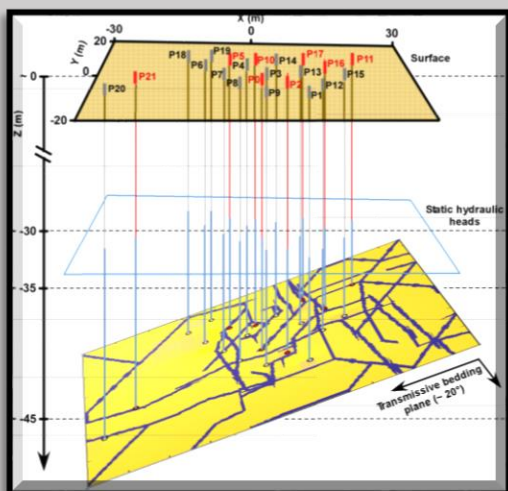
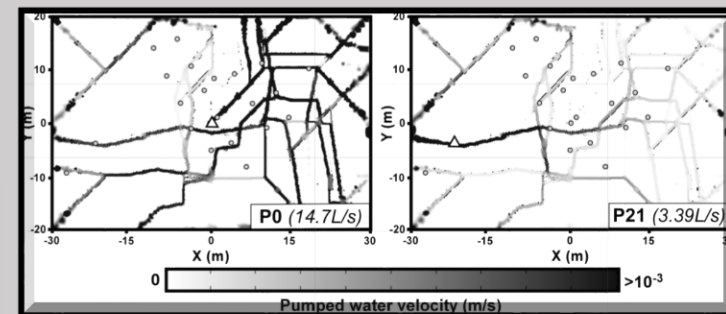
➤ **Cellular Automata-based Deterministic Inversion**



(Fischer et al., submitted)



*Thank you for
your attention*



12, 13, 14 juin 2017

