

# Extracting Hydrofacies Patterns from a Real Time-lapse Electrical Resistivity Dataset



Using Time Series Clustering Approaches

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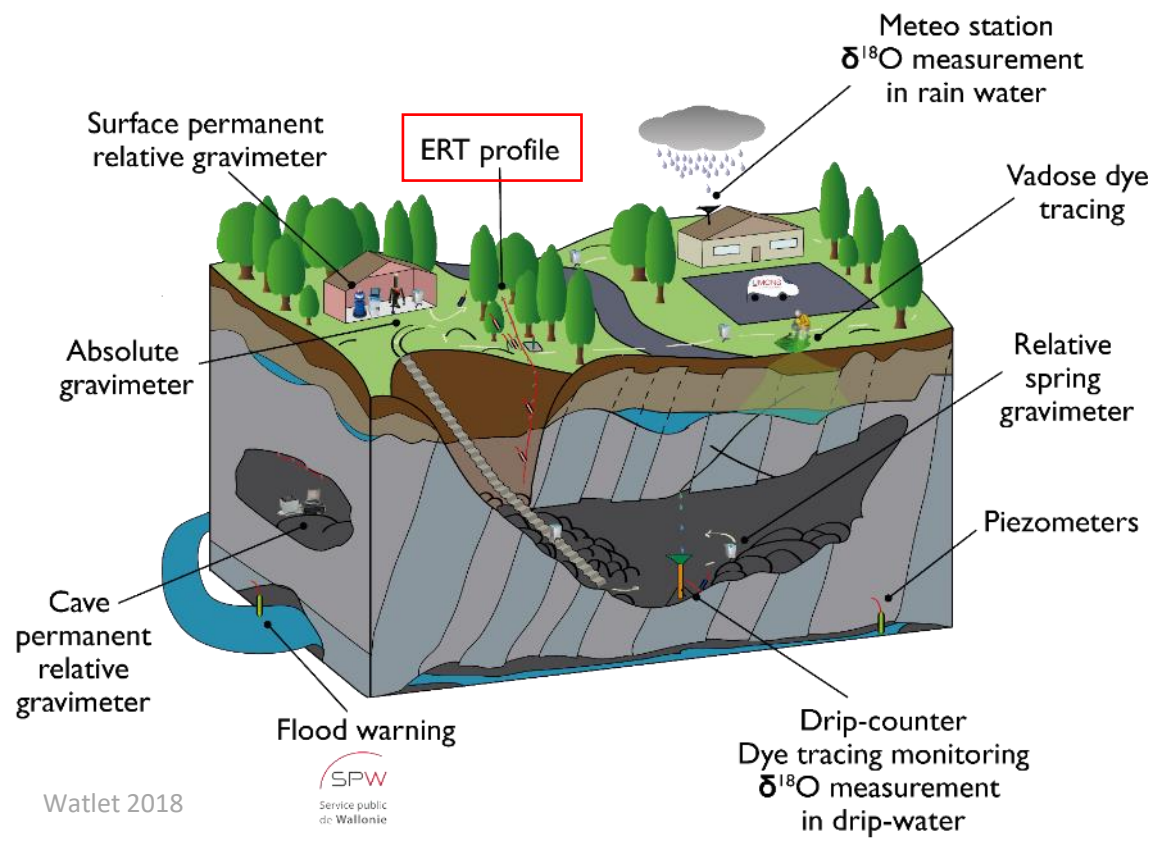
**AGU FALL MEETING**  
Online Everywhere | 1-17 December 2020

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# Electrical Resistivity Tomography (ERT) at the Rochefort caves, Belgium



Watlet 2018



KARAG- Karst Aquifer ReseArch by Geophysics  
www.karag.be 2013-2017



Pictures from [www.karag.be](http://www.karag.be) and M. Van Camp (ORB)

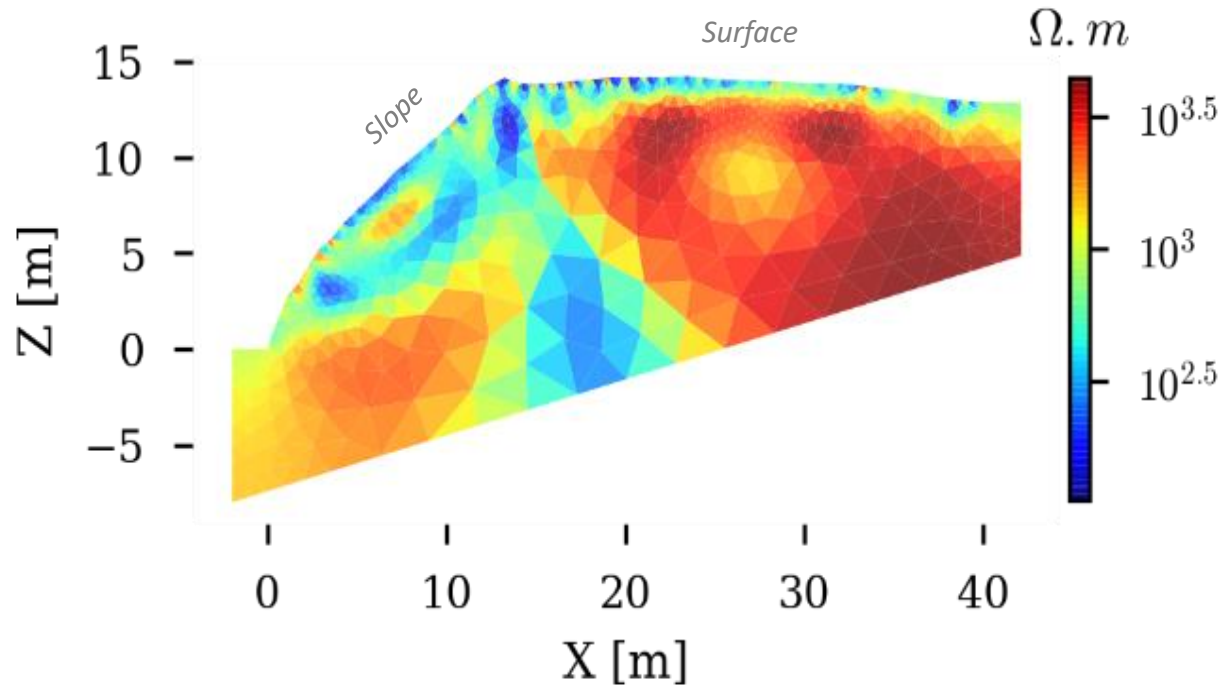




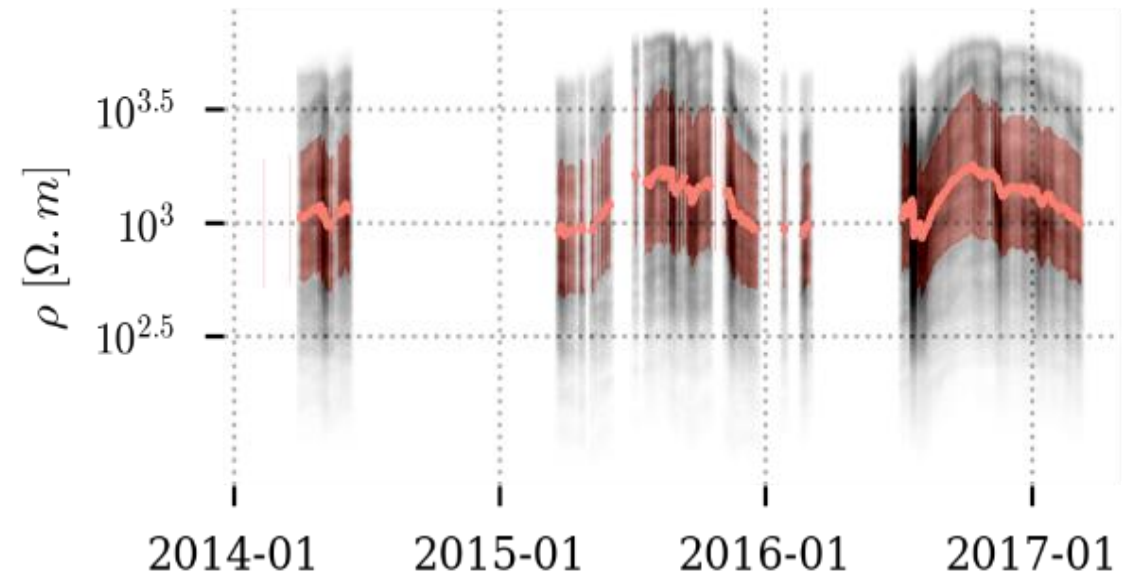
# Time-lapse Electrical Resistivity Tomography (ERT) Model

## ERT model (Watlet et al., 2018)

Resistivity at day 0 (1558 cells)



1558 time-series of 465 days

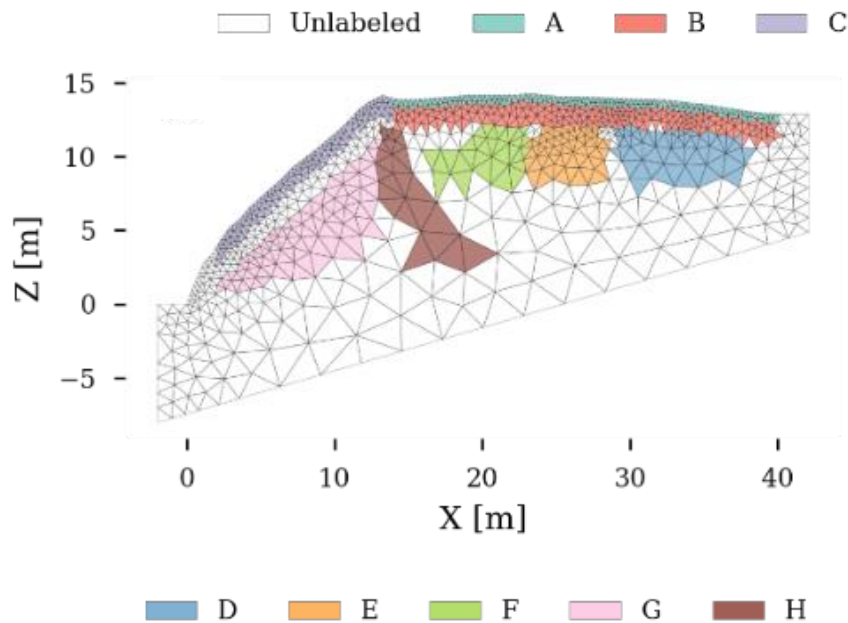




# Hydrofacies: Expert based classification vs. Time-series clustering

Hydrofacies = group of consistent lithology/pedology/hydrology

## Expert based classification (Watlet et al., 2018)



## Time-series clustering (Delforge et al., 2020)

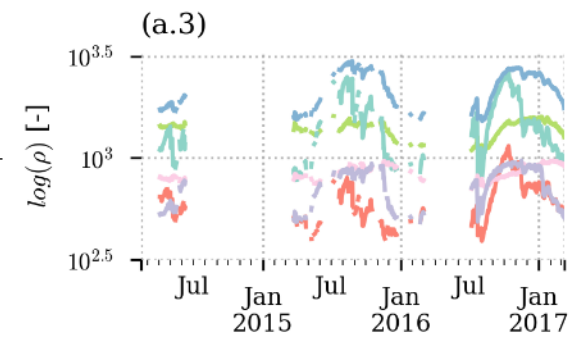
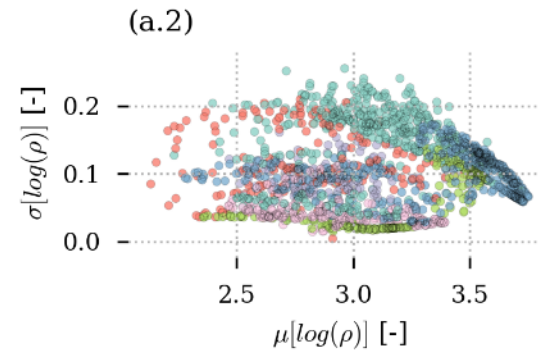
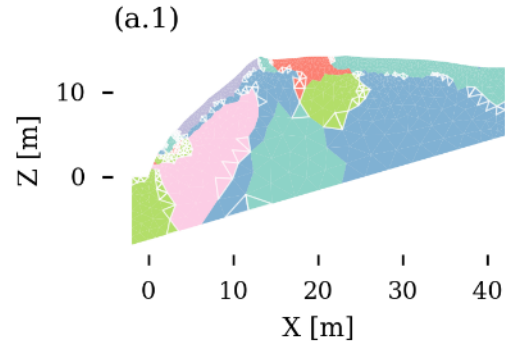
- Use machine learning to group time-series automatically

- Questions:**
- Which algorithm?
  - How many groups?
  - **To standardize or not to standardize?**
  - Should the groups be in one piece?
  - **Sensitivity to clustering approaches?**
  - **How much data do we need to have robust groups?**



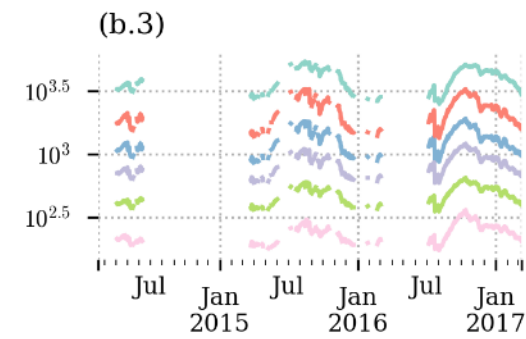
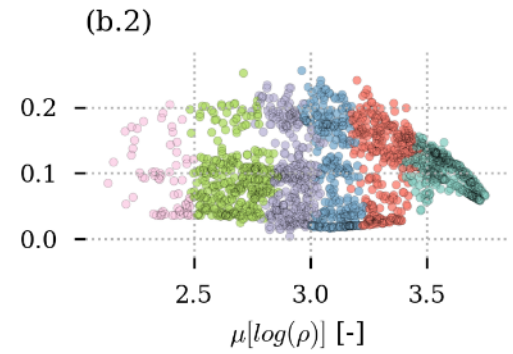
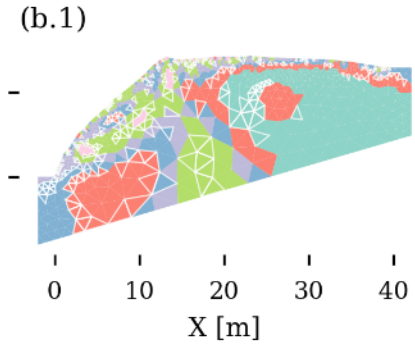
# To standardize or not to standardize?

## Standardized log-resistivity



Broad range  
of raw resistivity

Dynamic  
patterns



## Raw log-resistivity

Smaller range  
of raw resistivity

No dynamic  
patterns



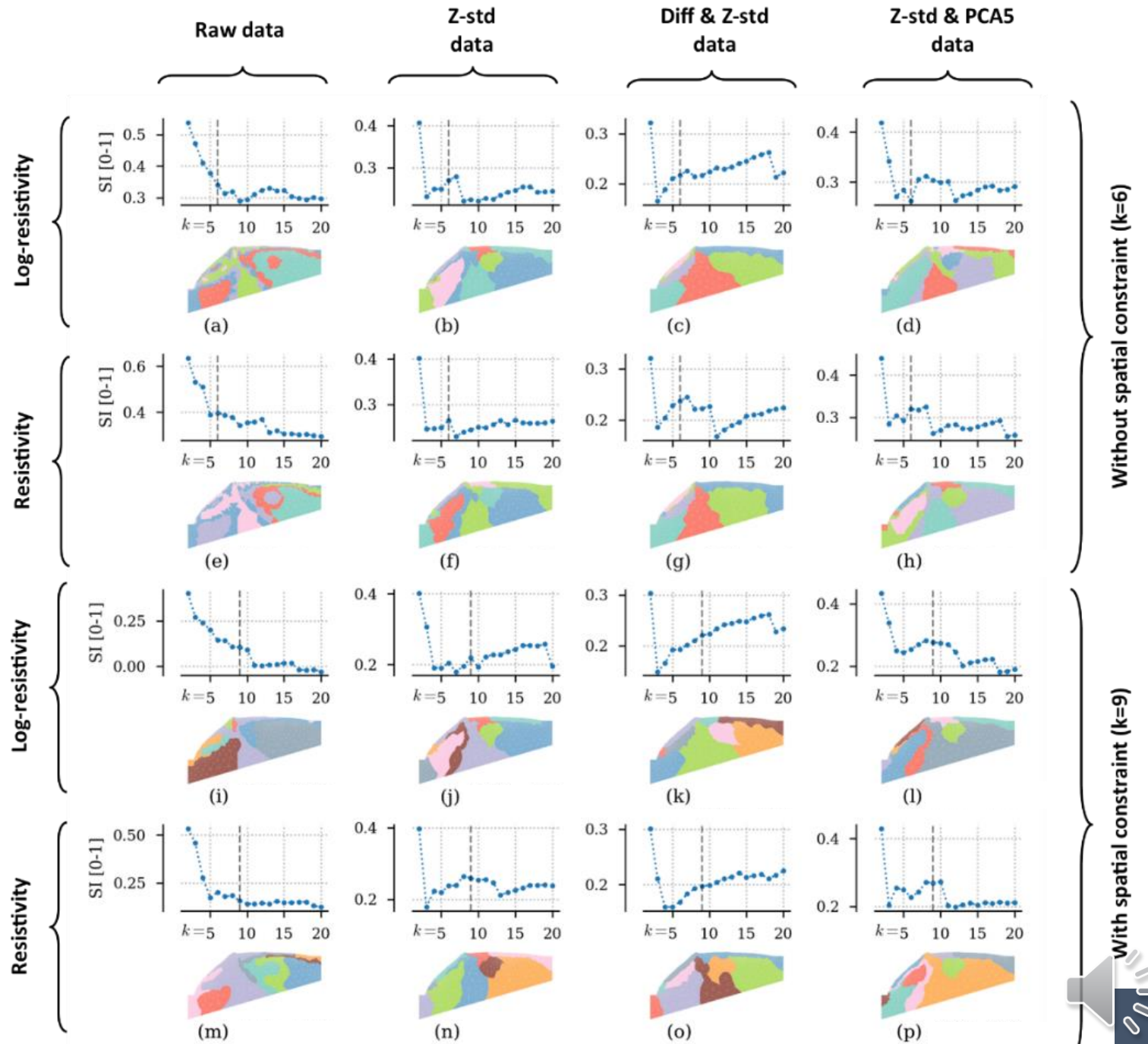
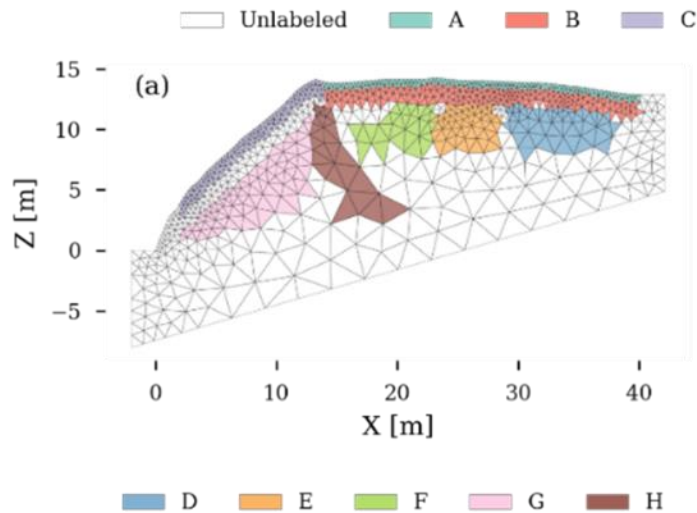
SAFARI



# Clustering Sensitivity

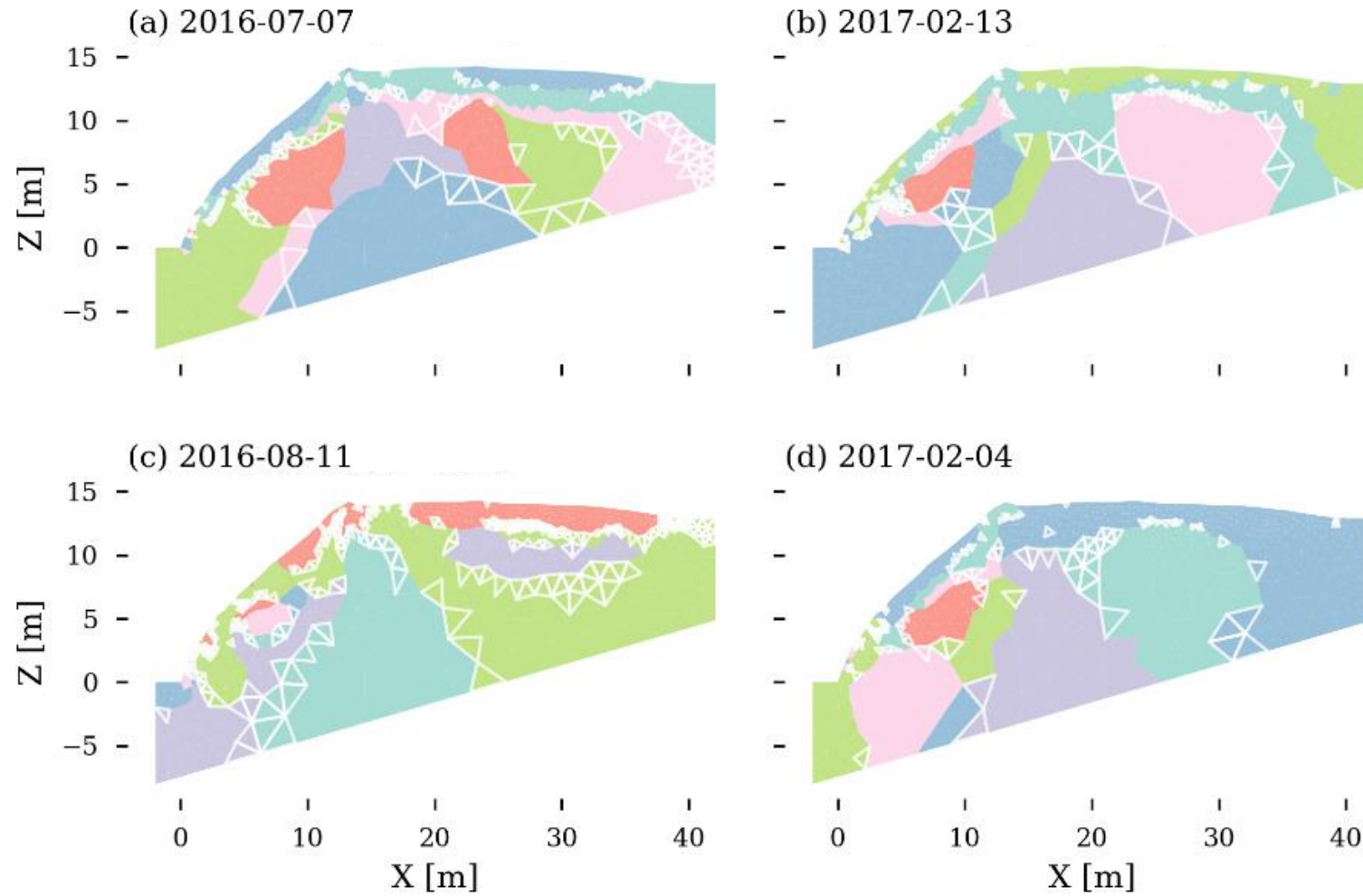
## Clustering: many ways to do it

- The optimal number of clusters  $k$  varies
- Spatial distribution of clusters varies
- But some features are redundant





# Sensitivity to time



**Example:** Clustering ( $k=6$ ) on 20 continuous days ( $/465d$ ) of standardized log-resistivity





# Conclusion

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## **What we have done:**

- Time-series clustering on a particularly long ERT model at a heterogeneous study site to retrieve hydrofacies

## **What we have shown:**

- Difficult to have consistent hydrofacies both in terms of lithology and hydrological behavior
- Sensitivity to different approaches
- Clustering based on dynamic similarity is sensitive to time





# Perspective

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## What we should do?

- Uncertainty/sensitivity analysis
- Thinking hydrofacies
- Get more data or cross different datasets
- Other studies (Empirical results)

## How to get better clusters?

- Relativism: “every approach is worth”
  - ➔ do consensus clustering
- Rationalism: “there is one way to do it”
  - ➔ do virtual or controlled experiments





# Additional information

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## Papers:

- Delforge, D. et al. **2020**: *Time-series clustering approaches for subsurface zonation and hydrofacies detection using a real time-lapse electrical resistivity dataset*. Journal of Applied Geophysics, doi:[10.1016/j.jappgeo.2020.104203](https://doi.org/10.1016/j.jappgeo.2020.104203).
- Watlet, A. et al. **2018**: *Imaging groundwater infiltration dynamics in the karst vadose zone with long-term ERT monitoring*. Hydrology and Earth System Sciences, doi:<https://doi.org/10.5194/hess-22-1563-2018>.

## Data & Code:

- Time-lapse ERT model: <https://zenodo.org/record/1158631>
- Clustering code: <http://dx.doi.org/10.17632/zh5b88vn78.2>



**KARAG- Karst Aquifer ReseArch by Geophysics**

[www.karag.be](http://www.karag.be)

