6th International Conference on Scour and Erosion
Paris, August 27-31, 2012

Improvement of leakage monitoring in dikes by the use of distributed fiber optics sensors

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Need for surveillance improving of dikes

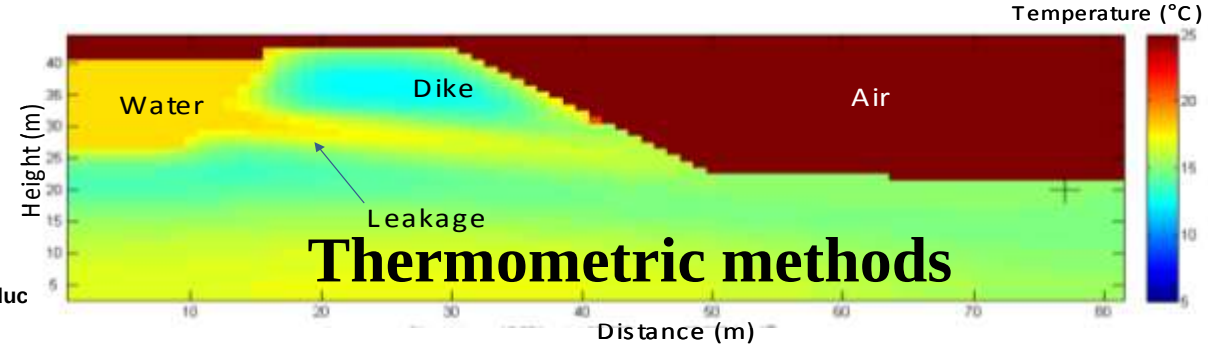
INTERNAL EROSION

- one of the main cause of failure of embankment dams
- leakage with departure of fine particles

Conventional tools for leakage surveillance:

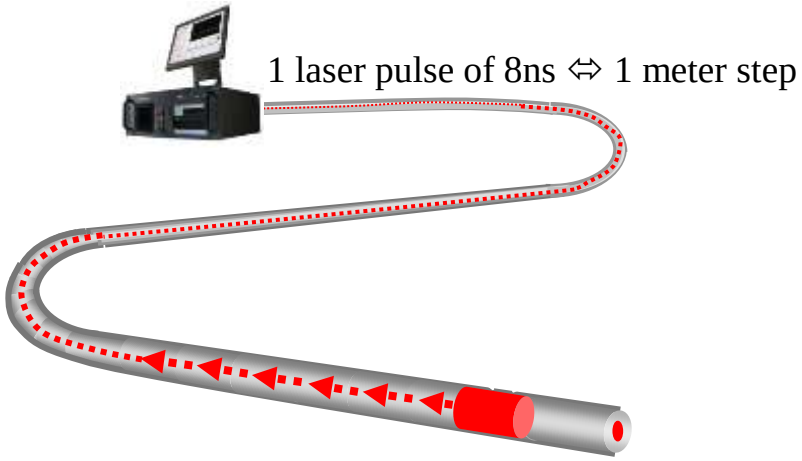
- **Visual inspection**
- **Monitoring** : - seepage velocity in the drainage system
  - piezometric level

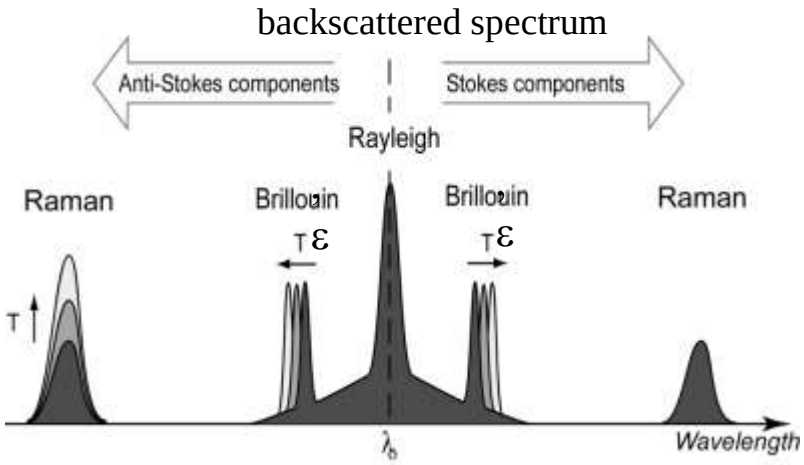
! NEED solutions for detection and quantification of seepage along earth dams !



Physical principle of temperature measurement by FO

- **Principle** : processing of backscattered signal





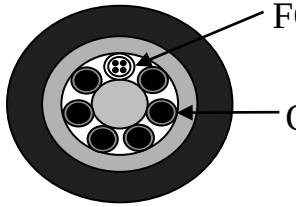
→ **Use of the Raman effect**: peak amplitude sensible to T (°C)

→ **Flight time of the pulse** □ spatial position along the fiber

Fiber Optics based Distributed Temperature Sensor

- Measurement over length and time
- Accuracy 0.1°C, range of 20 km, 1 meas./ m
- Time step : 1 meas./10 min to 1meas./1 year

Various analysis methods for leakage detection



- **<u>Detection/localization</u>** methods:

- « heating » approach:

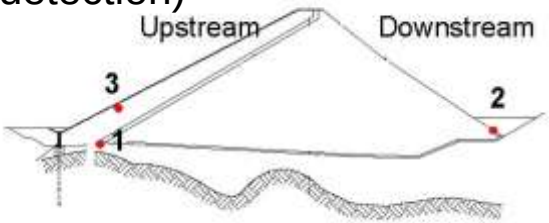
  → **<u>with heated fiber optic cable (Heat Pulse Method)</u>**

- « passive » approach:

  → **<u>Physico-statistical analysis</u>** model based on impulse response

  → **<u>Signal processing</u>** based analysis model

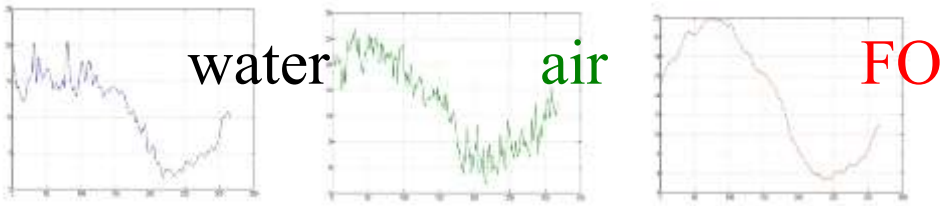
  (Daily Analysis Approach, Source separation for leakage detection)



- **<u>Quantification</u>** methods (under development) :

  → sensibility of the detection methods to flow velocity

  → 2D inverse models



→ **<u>Early detection</u>** system

→ **<u>Long-term monitoring</u>** system

Qualification methodology

- European Guide FD CEN TR 14748 : Non-destructive testing — Methodology for qualification of non-destructive tests

- Performances of measuring systems for a given application, by assessing uncertainties, function of sensitive parameters

- A step-by-step « from the lab to the field » methodology

In lab	In moke-up	On field tests
Out of the structure	with different scales	

Ageing influence

- 10 years of research

In laboratory

Metrological studies of the Distributed Temperature Sensor (DTS)

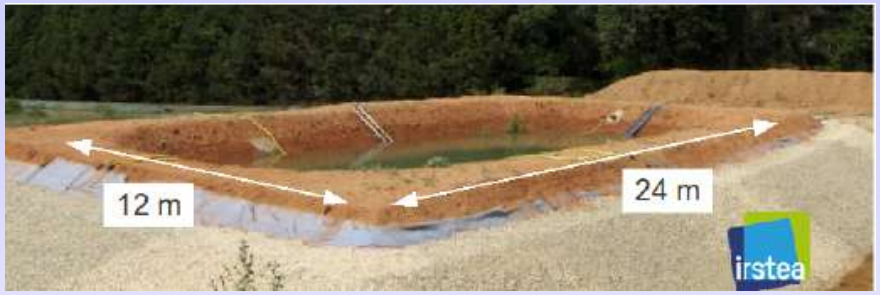
- Some specific metrological testing devices adapted to this technology

- Development works with DTS supplier

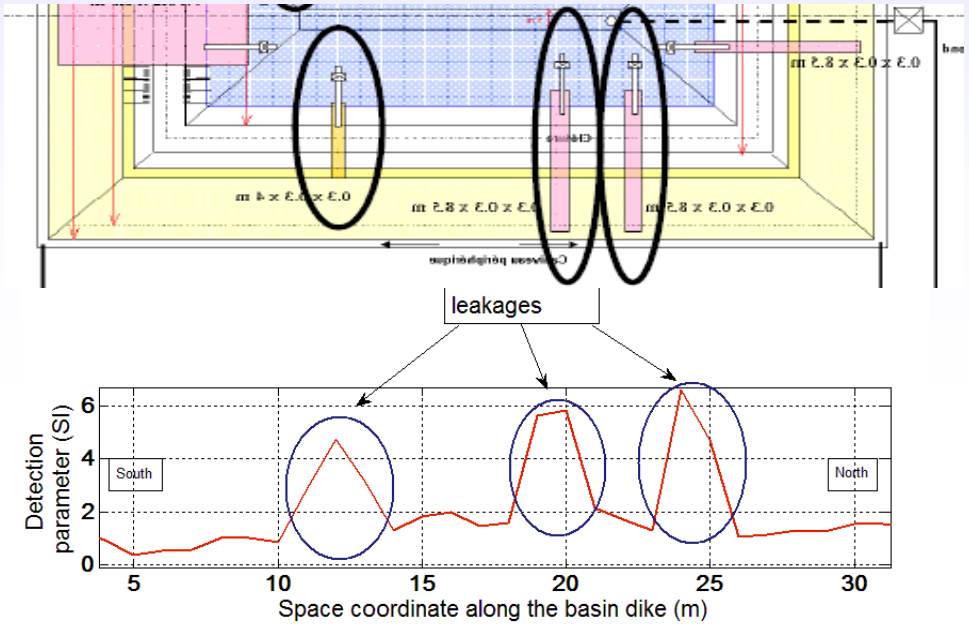
- Optimize the maintenance of the DTS

Controlled full-scale experiment

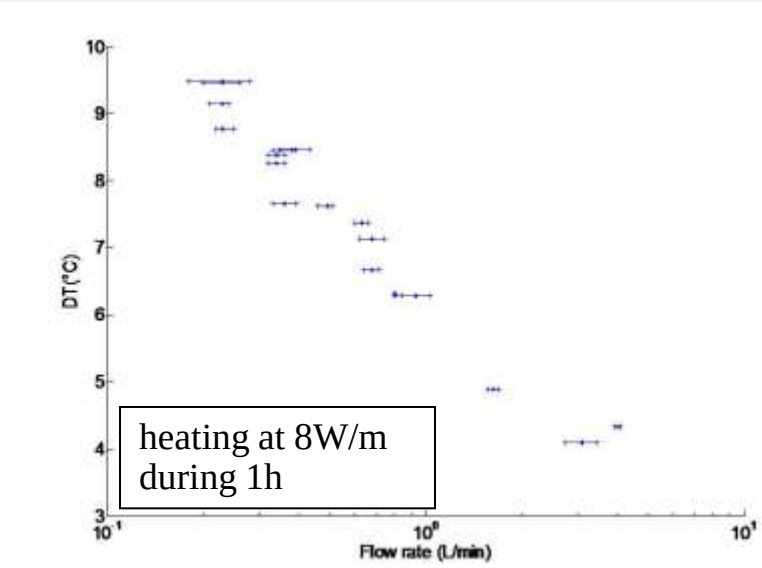
Experimental basin with provoked and controlled leakages (Aix-en-Provence)



Passive Method results

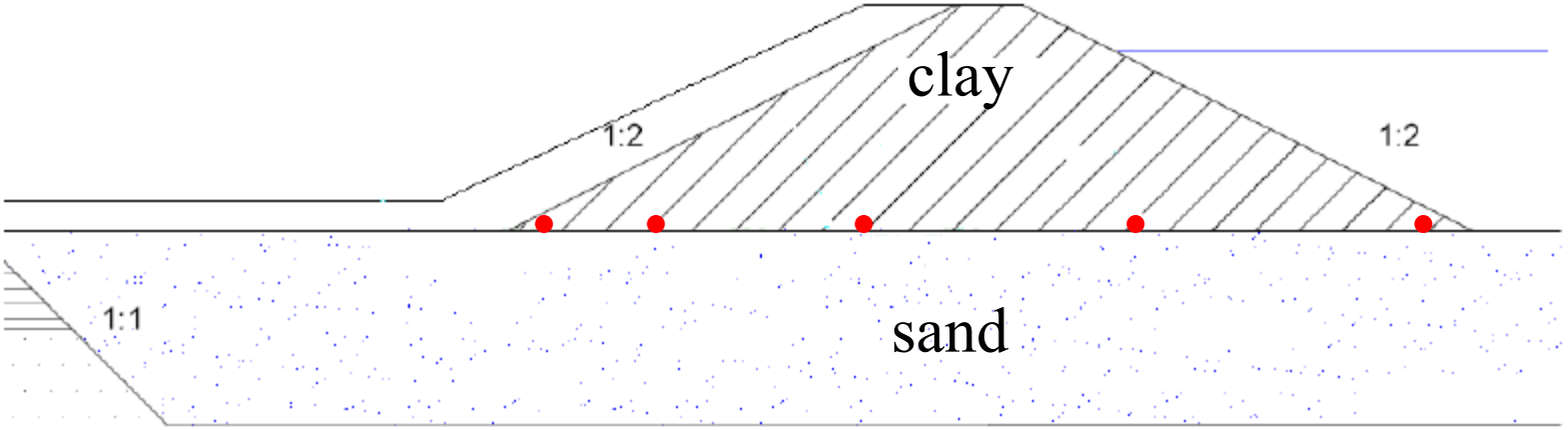


« Heating » Method results



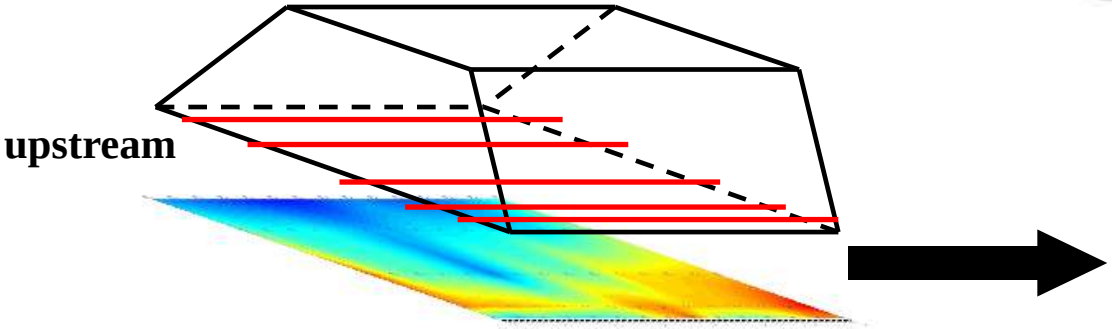
Early detection of piping erosion : IJKDIJK test

2009-IJKDIJK experimental site: « Piping tests »



Early detection of piping erosion : IJKDIJK test

Downstream and **upstream** of the experimental dam

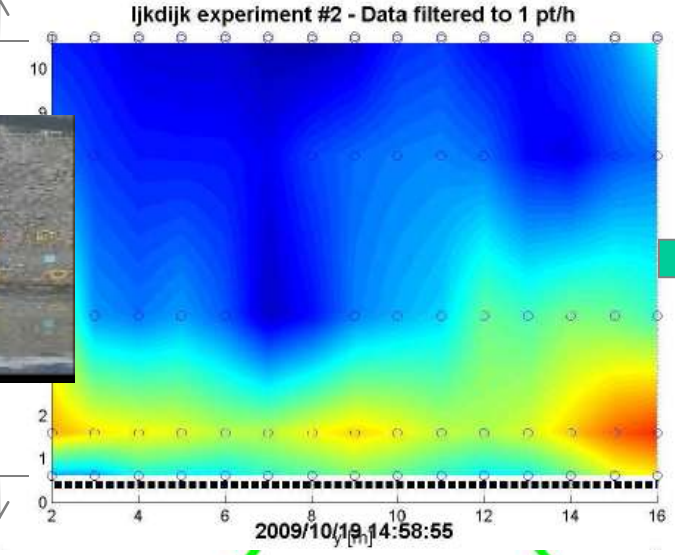


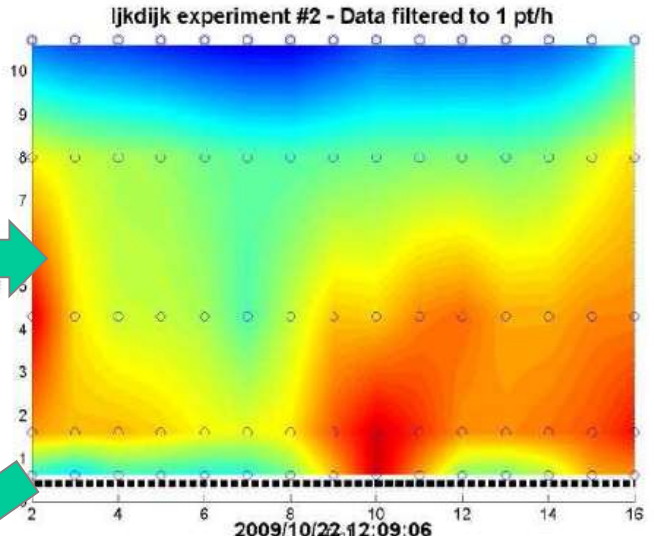
MONITORING OF SEEPAGE

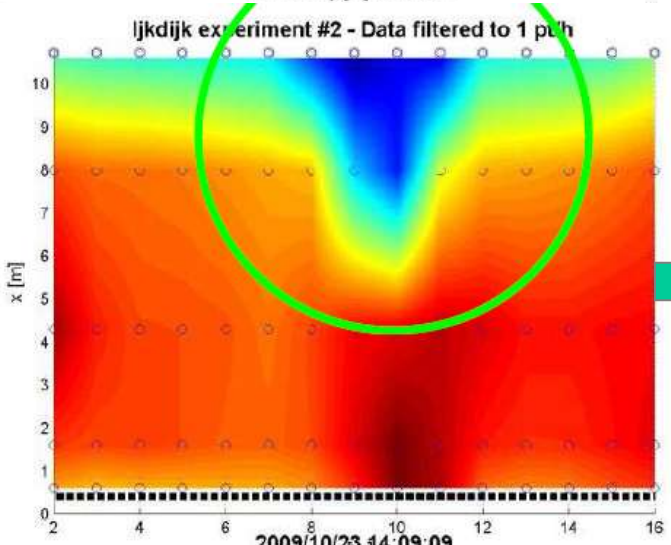
Ijkdijk piping test n°2 (2009): raw data

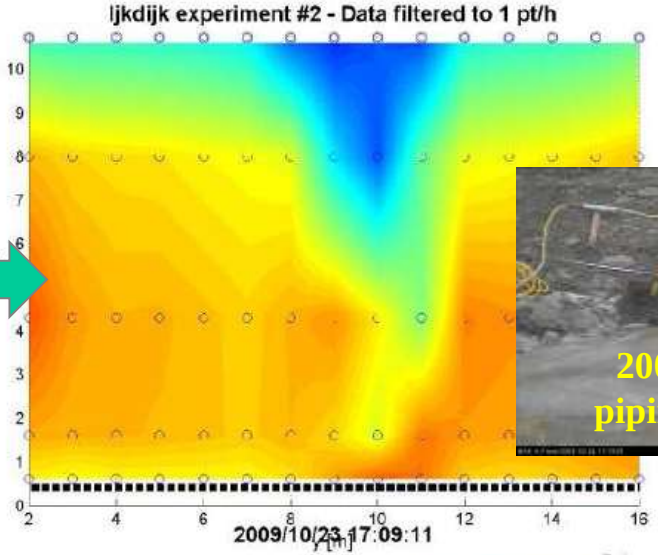
upstream

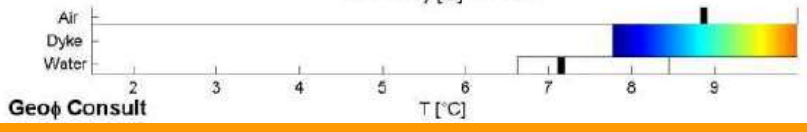
downstream

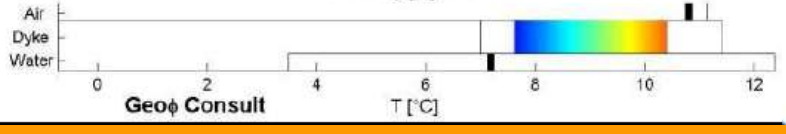








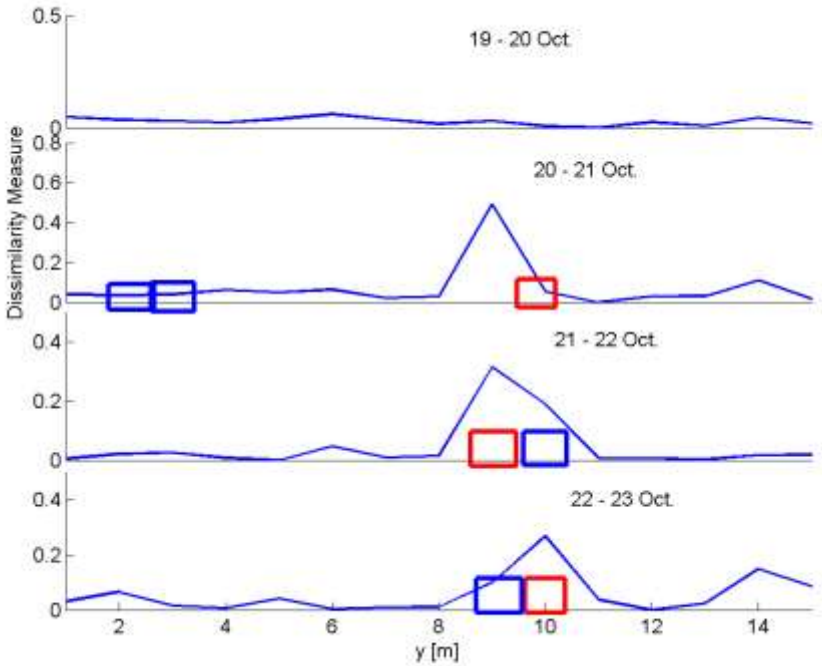


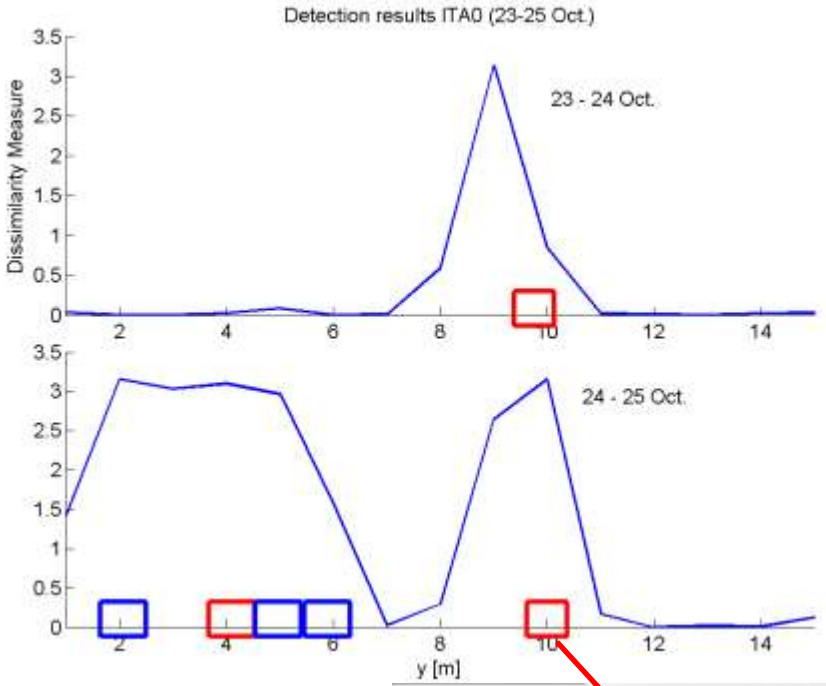


→ leakage detection **2 days** before rupture (Test duration = **6 days**)

Early detection of piping erosion : IJKDIJK test

Results from the daily analysis model

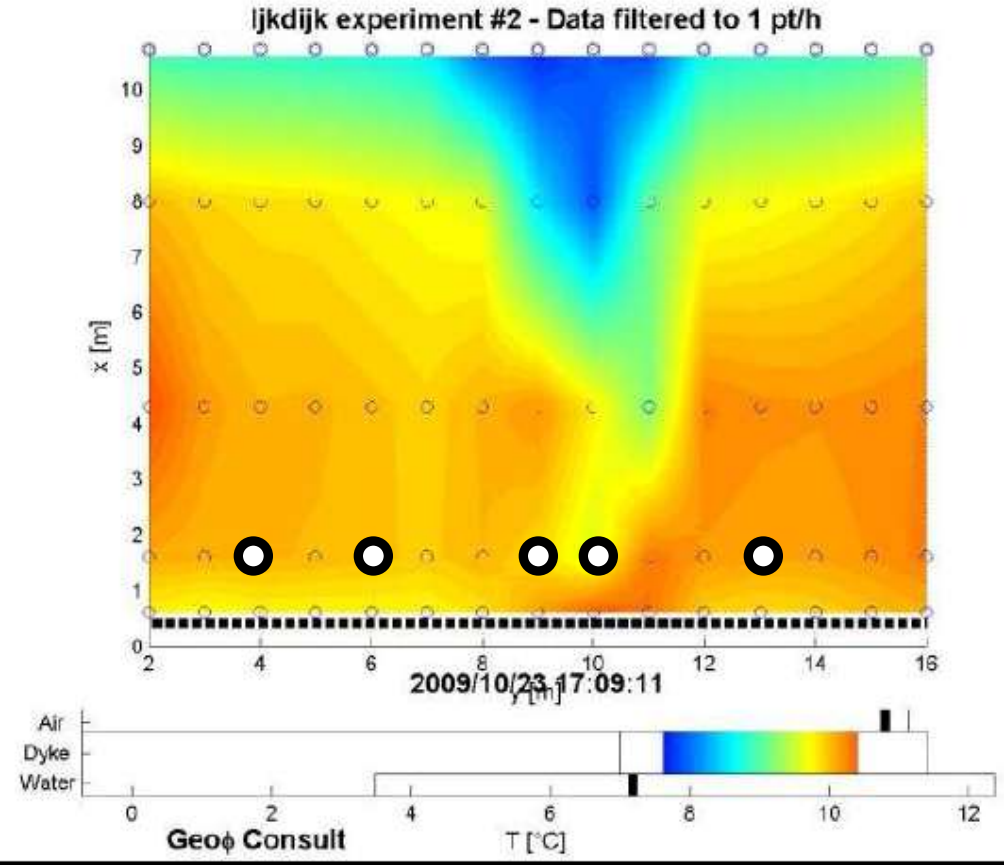


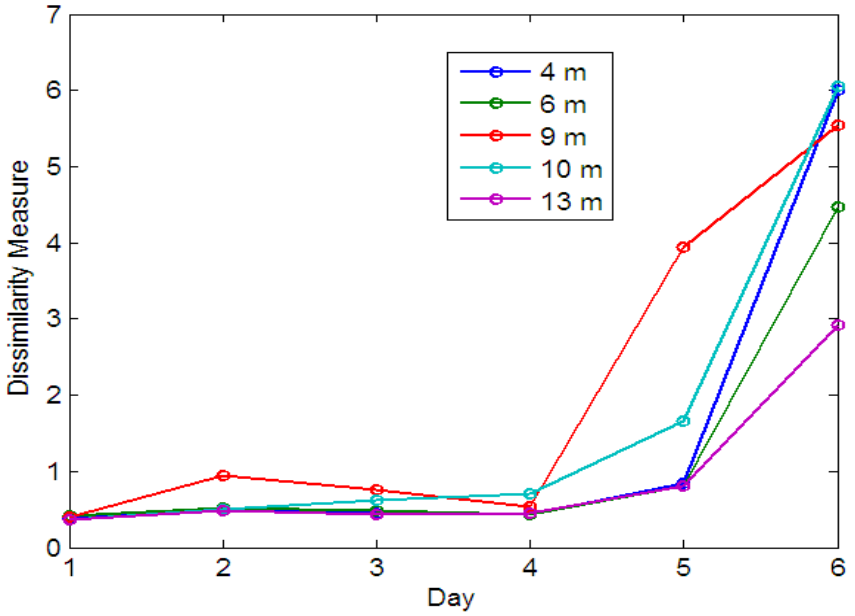


→ **Signal processing** (Daily Analysis Approach)
= anomalies' detection **5 days** before rupture

Early detection of piping erosion : IJKDIJK test

Temporal evolution of leakages



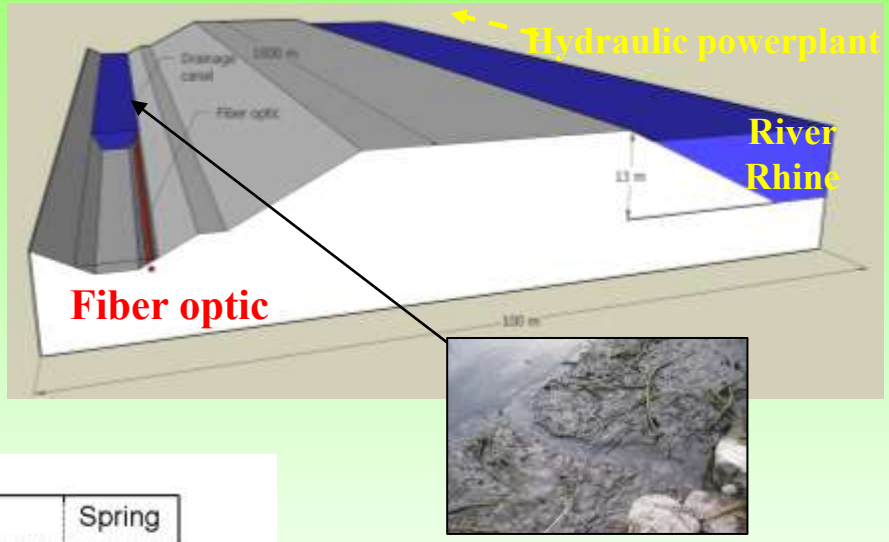


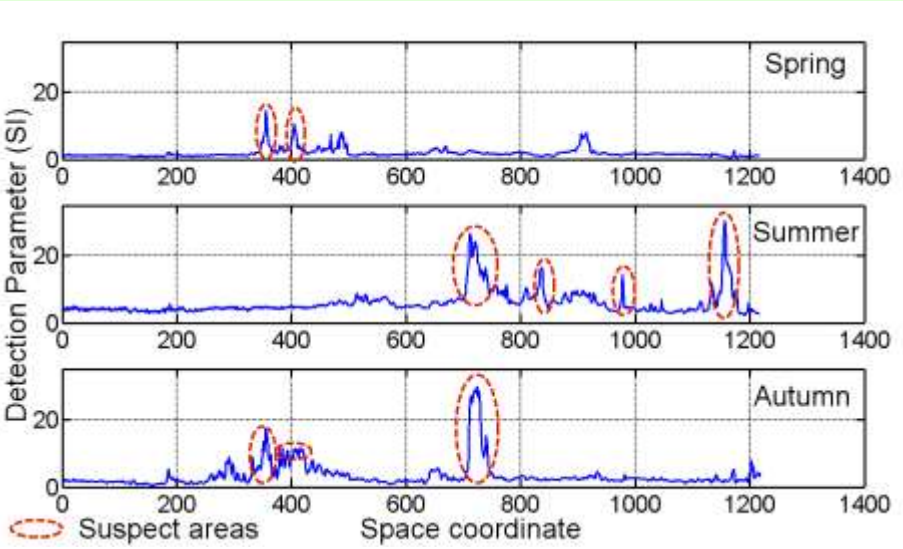
→The detection parameter's temporal evolution seems to be an interesting way to **monitor leakage evolution** !

Experiment on real site

Two experimental installations on industrial sites: - Durance river (2001)

- Rhine river (2006)





Conclusions

→ Distributed temperature sensor based on fiber optics:

- **Relevant for seepage detection and monitoring**
- **Efficient for monitoring of large sections of the dike with a high spatial and temperature resolution**
- **Complementarity of existing methods (“heating” and passive)**
- **Developed analysis model :**

  - necessary for an easy detection

  - a tool for alarm (short term) and monitoring (long term)

→Improvement: (under development)

estimation of the flow velocity (or its evolution)

seems to be possible

NEXT STEP: experimental surveillance of a 5 km intake canal instrumented by 11 km of fibre optics

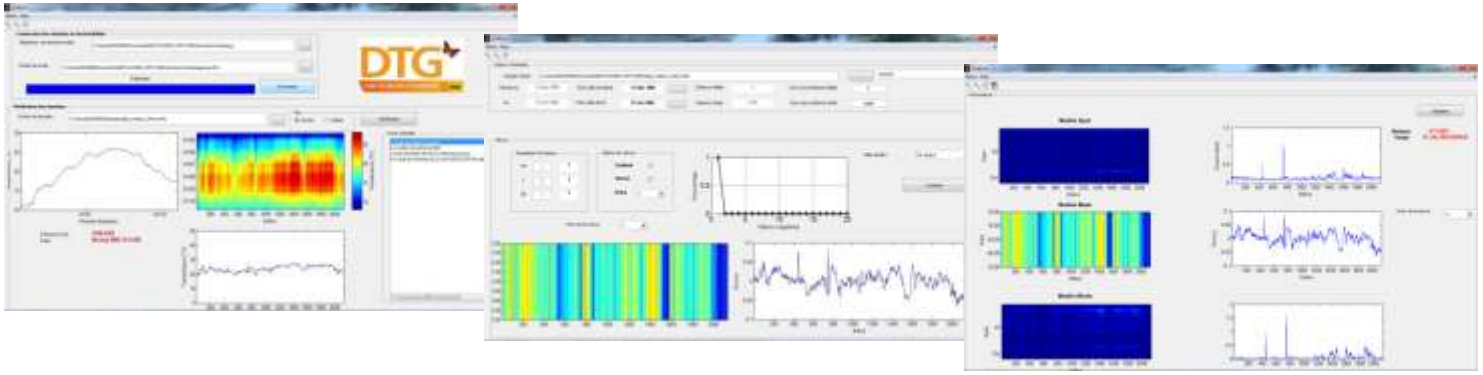
OBJECTIVES:

✓ **Comparison of FO results with conventional drainage systems**

→Comparison with 31 drains (each ~300 meter long)

→ Testing of ACTIVE and PASSIVE method

✓ **Developpement of an industrial tool for data interpretation**



✓ **Establishment of an internal organization in order to integrate this new technology**


Thank you for your attention