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Monitoring of an existing dike with traditional and innovative sensors – challenges and first results

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OUTLINE

1. Introduction
2. Monitoring techniques
3. The case-study of the Salorno levee (Bolzano)
4. Final remarks

Levees and flood risk

Artificial levees are long-stretching structures that protect large areas from flood risk

Risk = *f* (p*I)

Probability of occurrence
(stable or increasing due to climate change)

Impact

Economic impact
(economic value of possible flooded property)

Human impact
(loss of lives, permanently injured)

Social impact
(risk aversion in the population)

European Commission. 2010 Risk Assessment and Mapping Guidelines for Disaster Management; Brussels

Reducing flood risk

Impact=*Exposure*Vulnerability*

(increasing population, increasing anthropization of territory)

(**reduce vulnerability by increasing resilience and reliability of protection structures to *reduce the overall flood related risk***)

STRUCTURAL HEALTH MONITORING OF LEVEES

European Commission. 2010 Risk Assessment and Mapping Guidelines for Disaster Management; Brussels

STRUCTURAL HEALTH MONITORING OF LEVEES

Monitoring networks integrated within the levee are forms of Structural Health Monitoring (SHM), where the damage associated with changes of the boundary conditions or of the intrinsic properties of the structures are constantly assessed

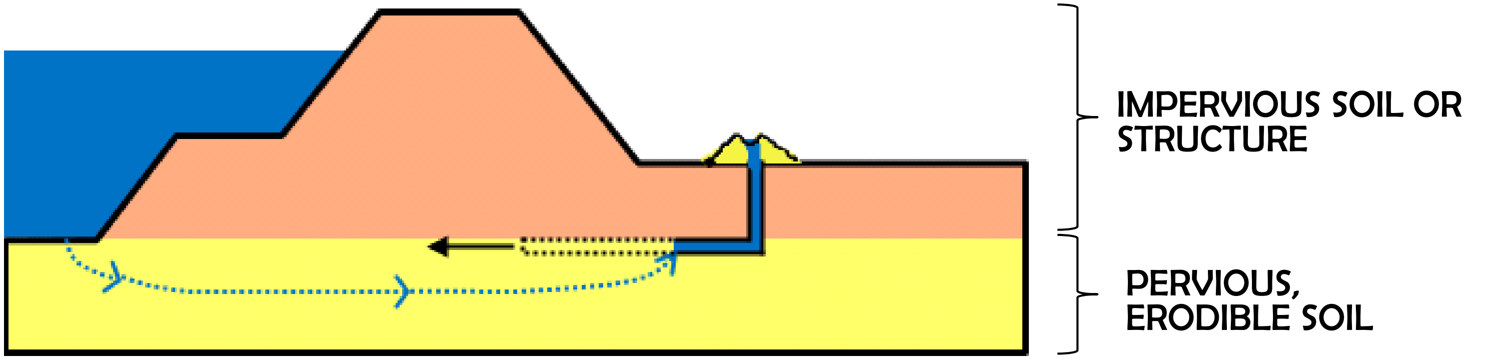
The biggest challenge is now represented by *reliable* long-term monitoring of levees. The monitoring network should be able to provide *consistent* data that allow the definition of the *funtional status* of the structure and its *resilience capacity*

Finding the «optimal monitoring network design»

Balance between:

- **Reliability of monitoring data**
- **Cost effectiveness**
- **Installation that does not reduce the overall safety of the structure**

MONITORING INTERNAL EROSION
Backward erosion piping



To monitor and detect backward erosion <u>indirect methods</u> are used that use as proxi

- Electrical Resistivity
- Self potential
- <u>Temperature</u>

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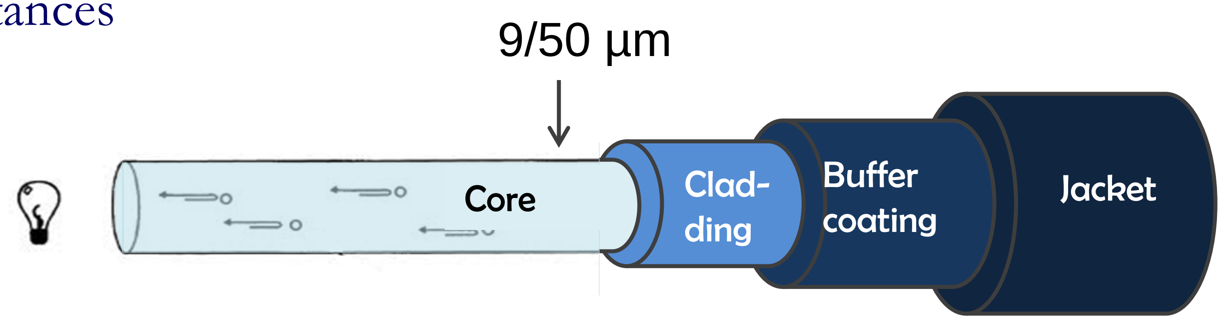
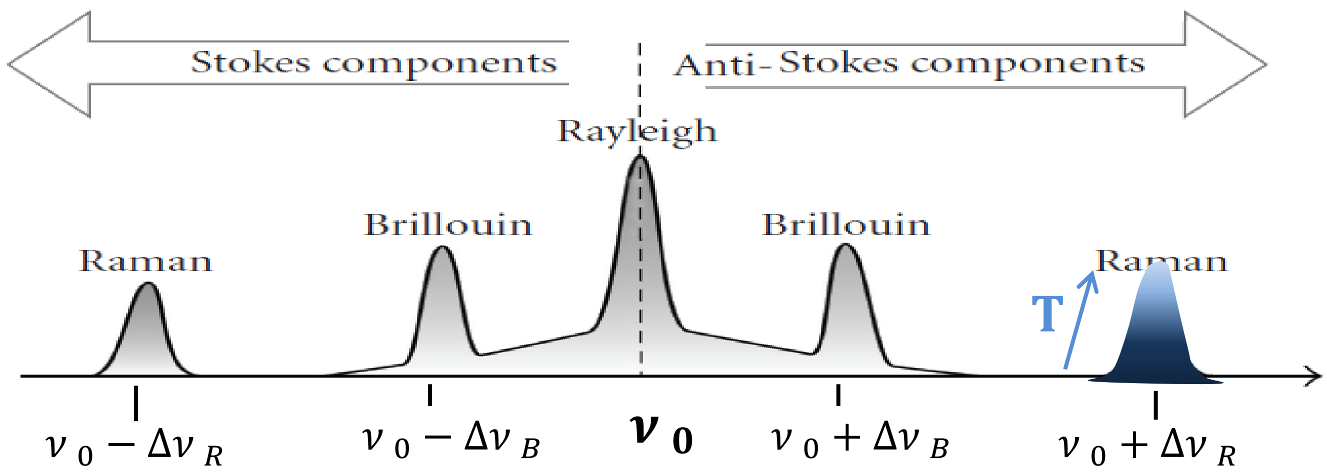
OPTICAL FIBER

An optical fiber is a guide to transmit light signals on longer distances



When a light impulse is injected in an optical fibre a backscattered light is generated by each point along the fibre. The spectrum of the backscattered light carries information about the local status of the fiber

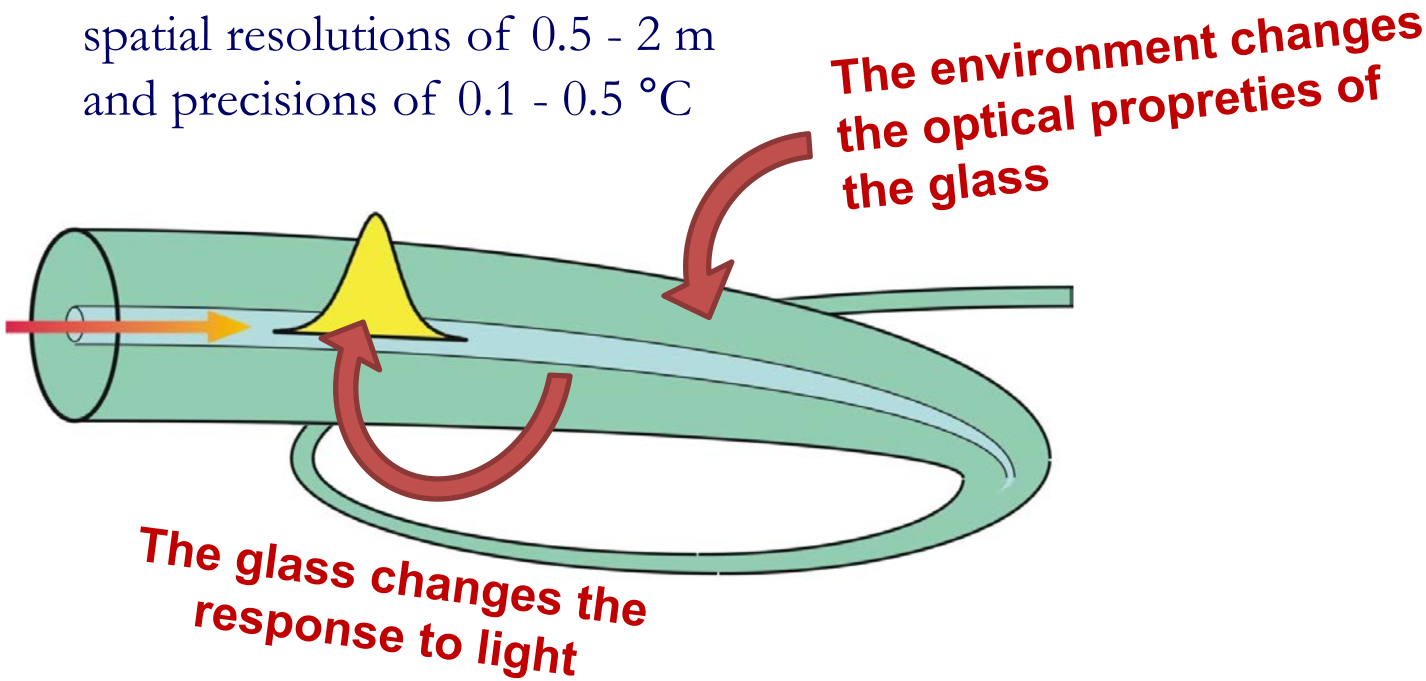


OPTICAL FIBERS FOR MONITORING TEMPERATURE

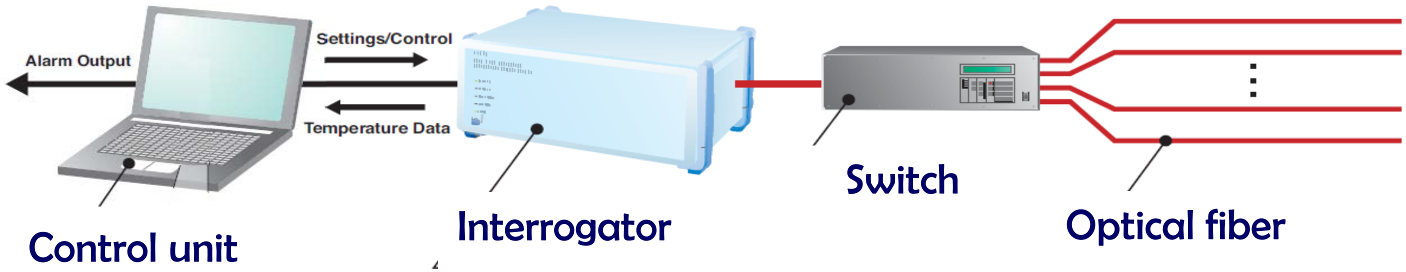
Local variations of temperature influence the optical properties of the fiber

The fiber *is* the sensor

With a single fiber it is possible to monitor km long strectches with spatial resolutions of 0.5 - 2 m and precisions of 0.1 - 0.5 °C



OPTICAL FIBERS FOR MONITORING TEMPERATURE



The interrogator sends a laser beam inside the fiber; then it reads the backscatter signal reconstructing the longitudinal profile of temperature.

OPTICAL FIBERS FOR MONITORING TEMPERATURE

Temperature variation as indirect measure

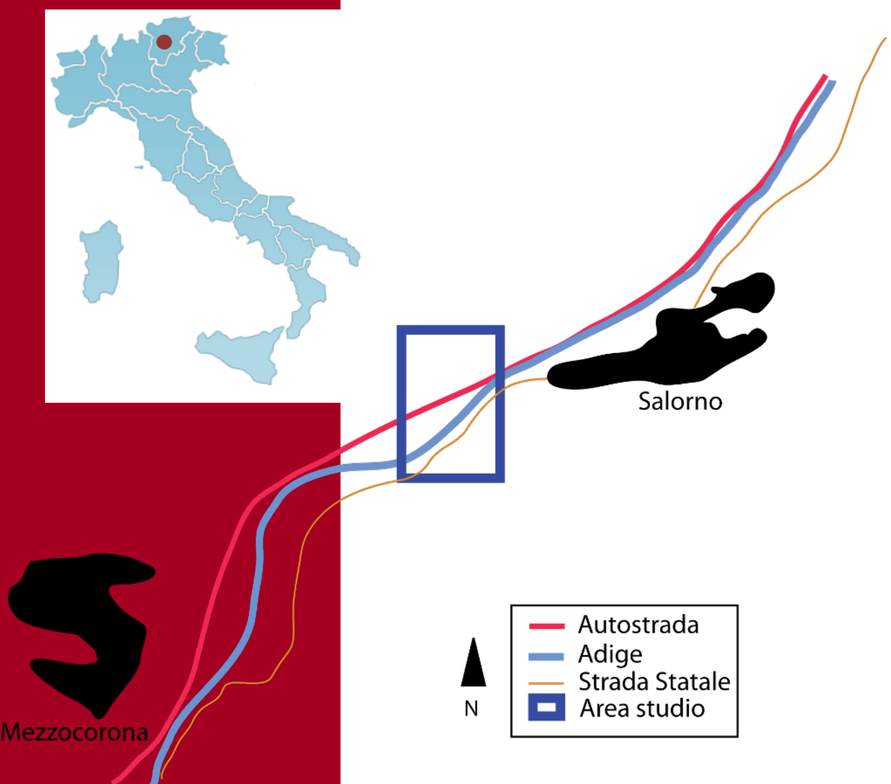
→ *Partially saturated soil* → Degree of saturation

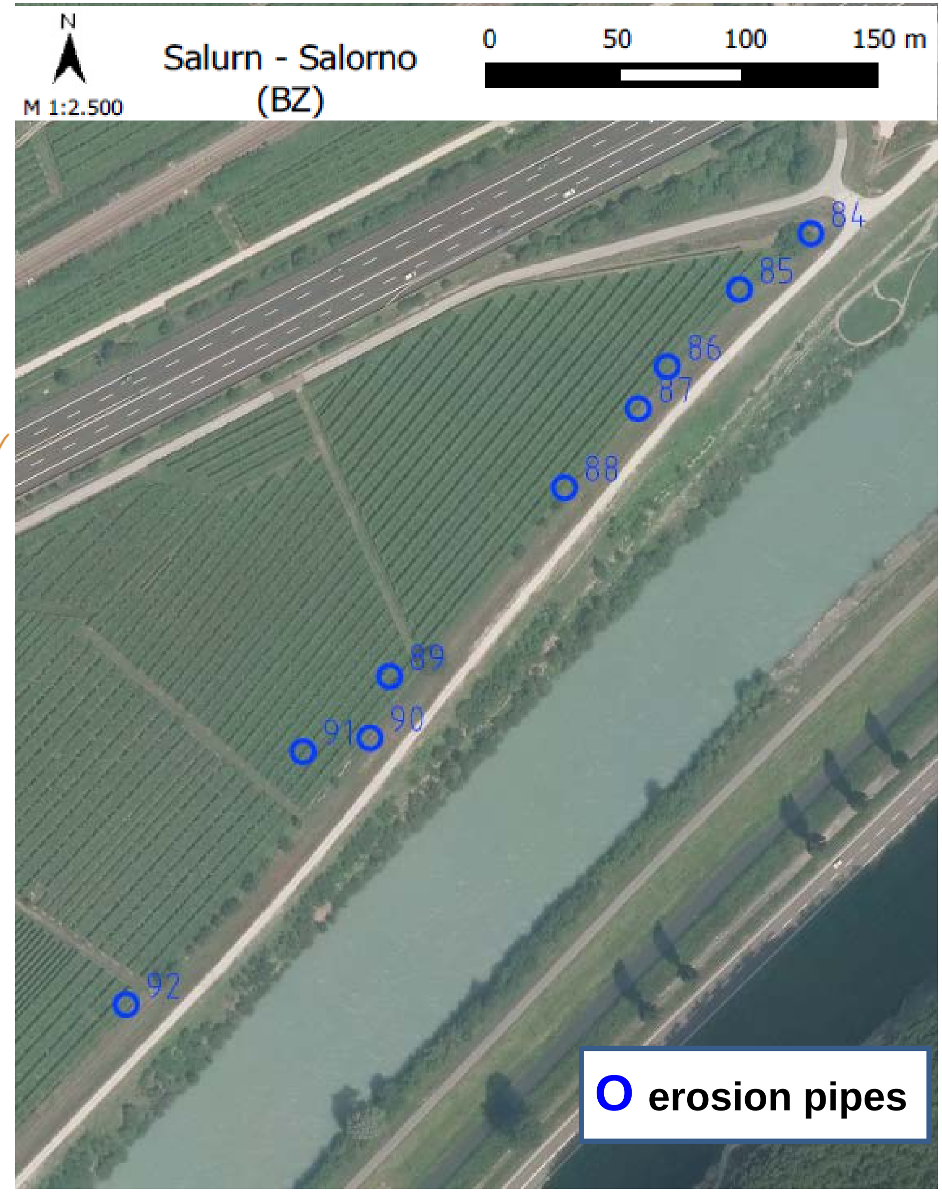
→ *Saturated soil* → Seepage rate

heat-pulse method: coupling electric cable to the fiber, the electric cable heats the fiber, measuring the heating time and the difference between zones it is possible to assess the flux of water around the cable (areas with higher water transport will rise to lesser temperatures)

CASE – STUDY: EXISTING LEVEE

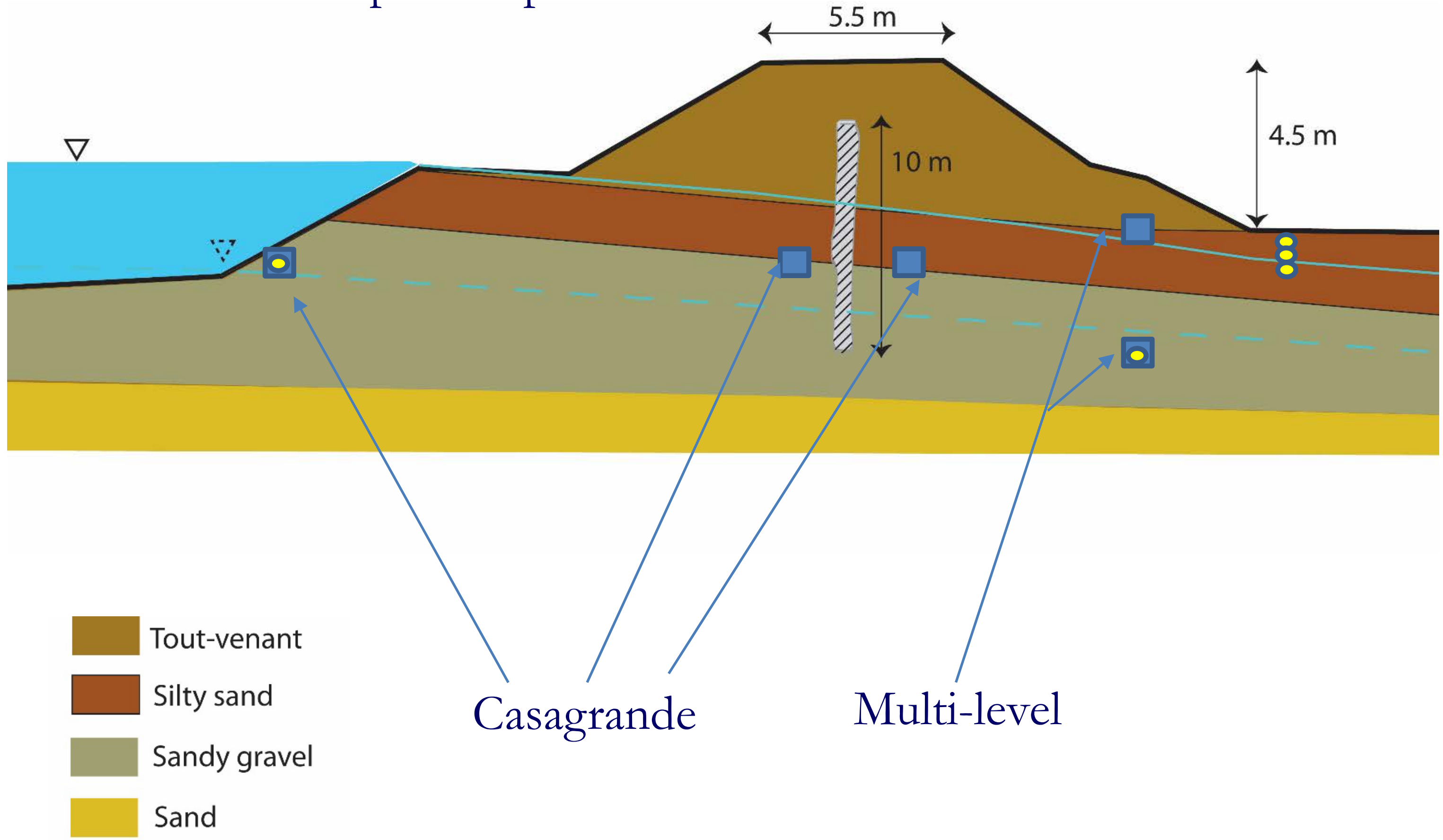
500 m long levee sector subject to backward erosion piping



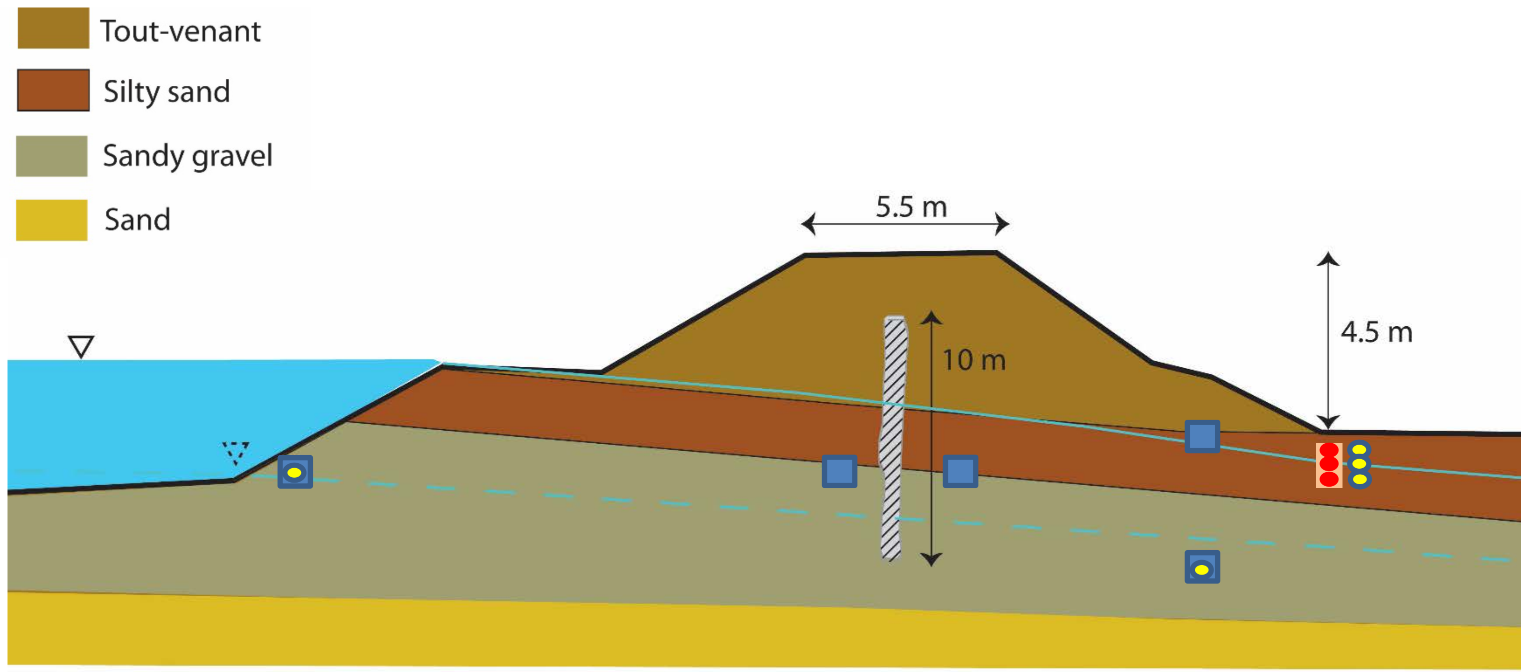


MONITORING WITH TRADITIONAL SENSORS

Piezometers + spot temperature sensors



MONITORING WITH OPTICAL FIBERS



Three levels of optical fiber about 50 cm apart along the vertical

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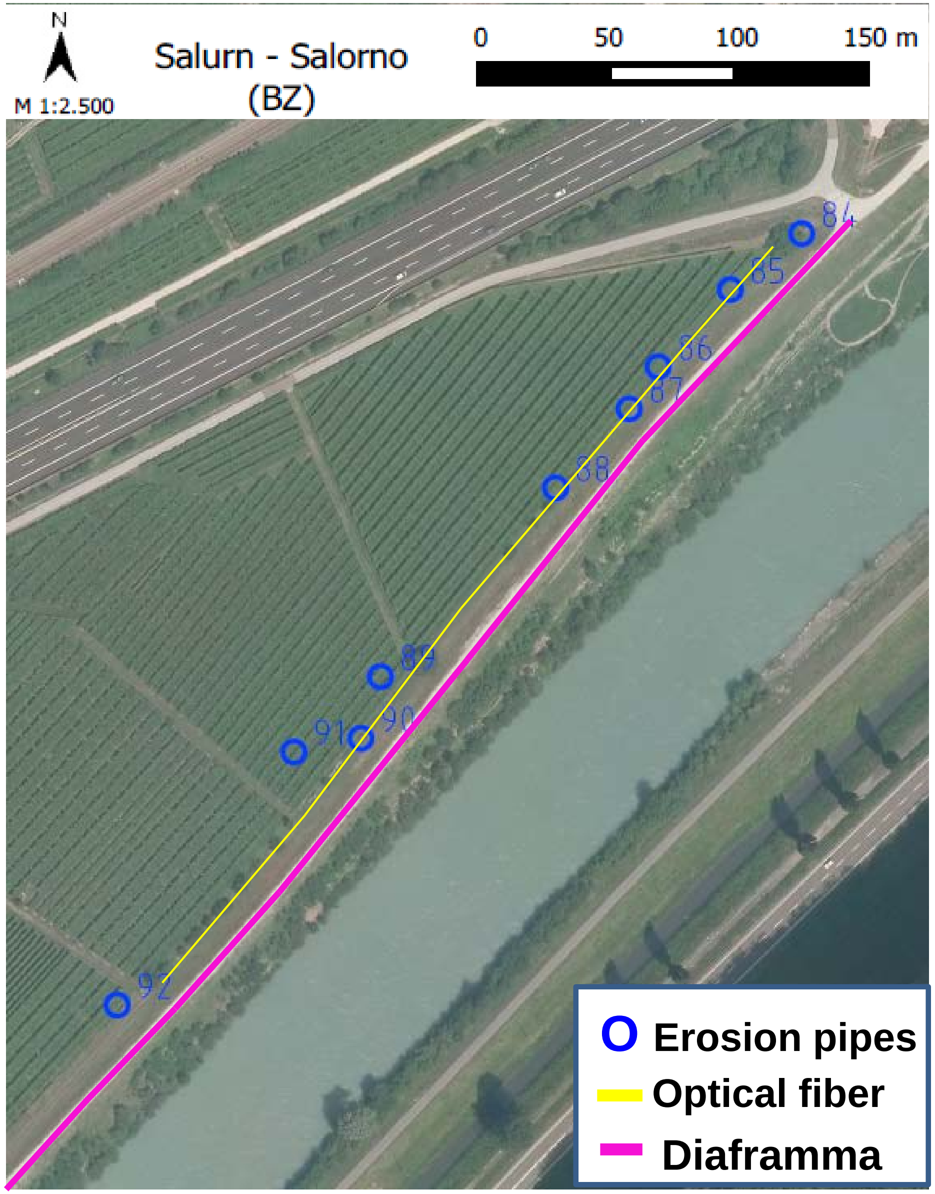
OPTICAL FIBER INSTALLATION

1050 m of fiber (350 m on 3 levels)



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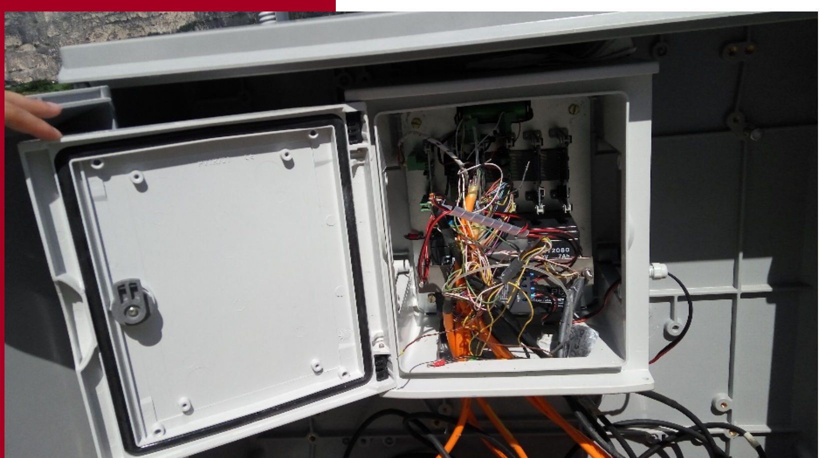
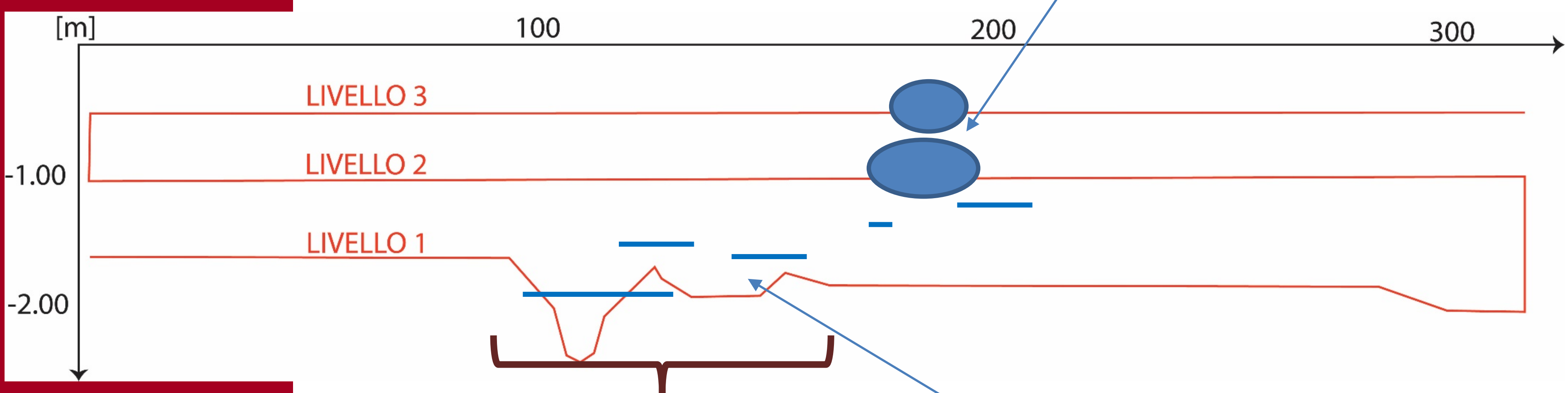


Since the installation work was performed on an existing and operative levee it was particularly important to guarantee that the excavation would not damage the overall stability of the structure

OPTICAL FIBER INSTALLATION

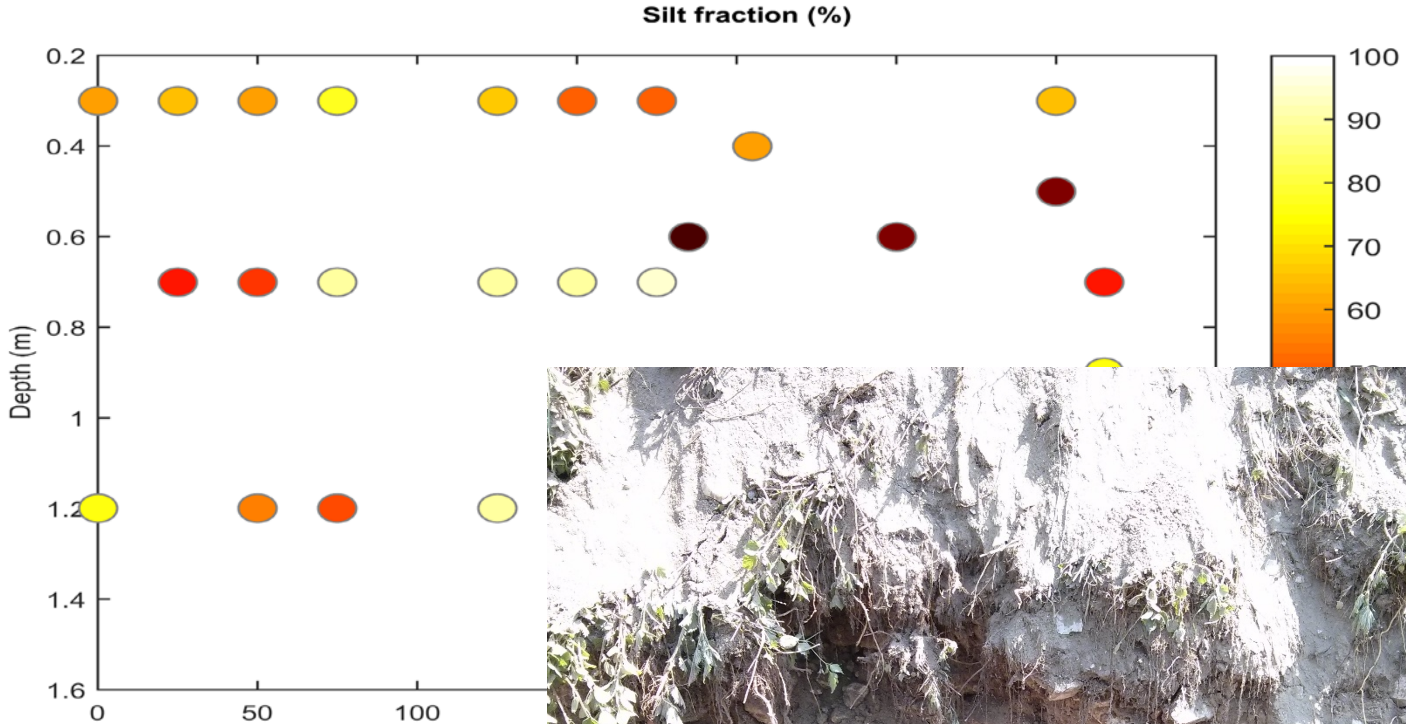
Gravel lenses



Excavation deepened to avoid the contact with the gravel layers

Small gravel layers

Geotechnical tests



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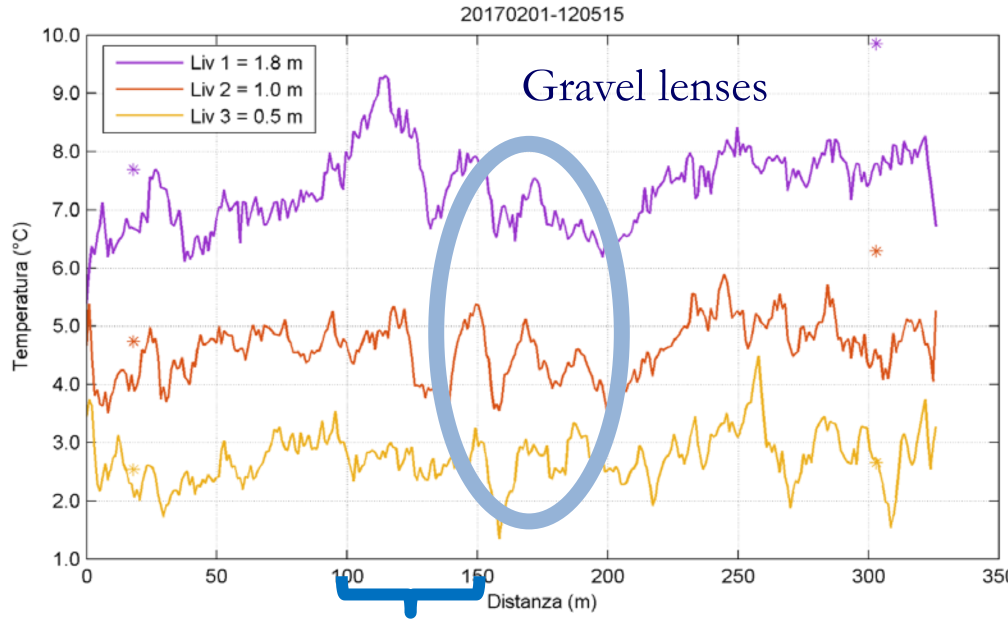
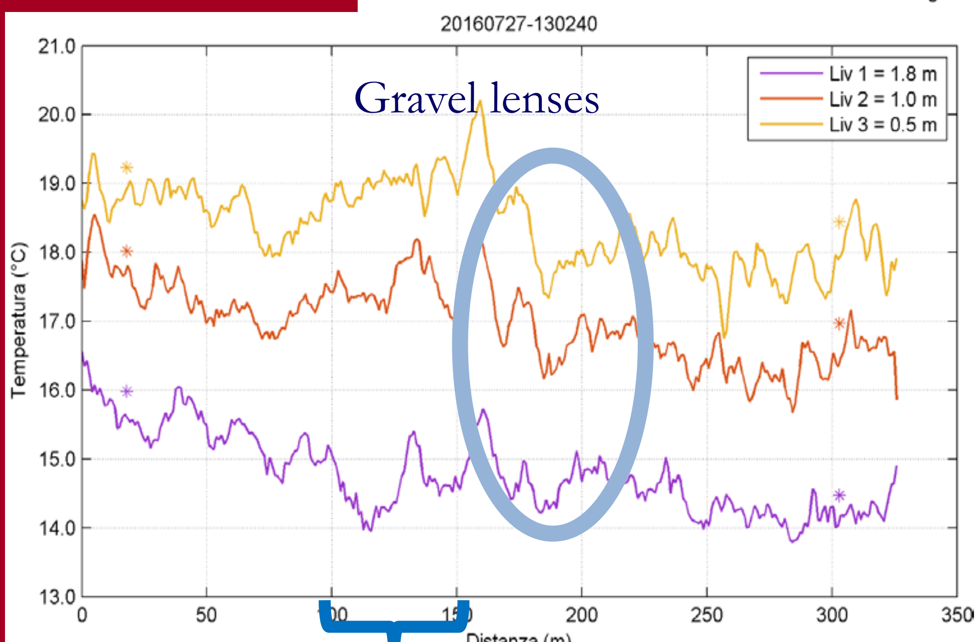
FIRST RESULTS – FIBER OPTIC MEASURES

Winter



Variable depth and heterogeneity



Summer

Variable depth and heterogeneity

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FIRST RESULTS – ERT MEASURES

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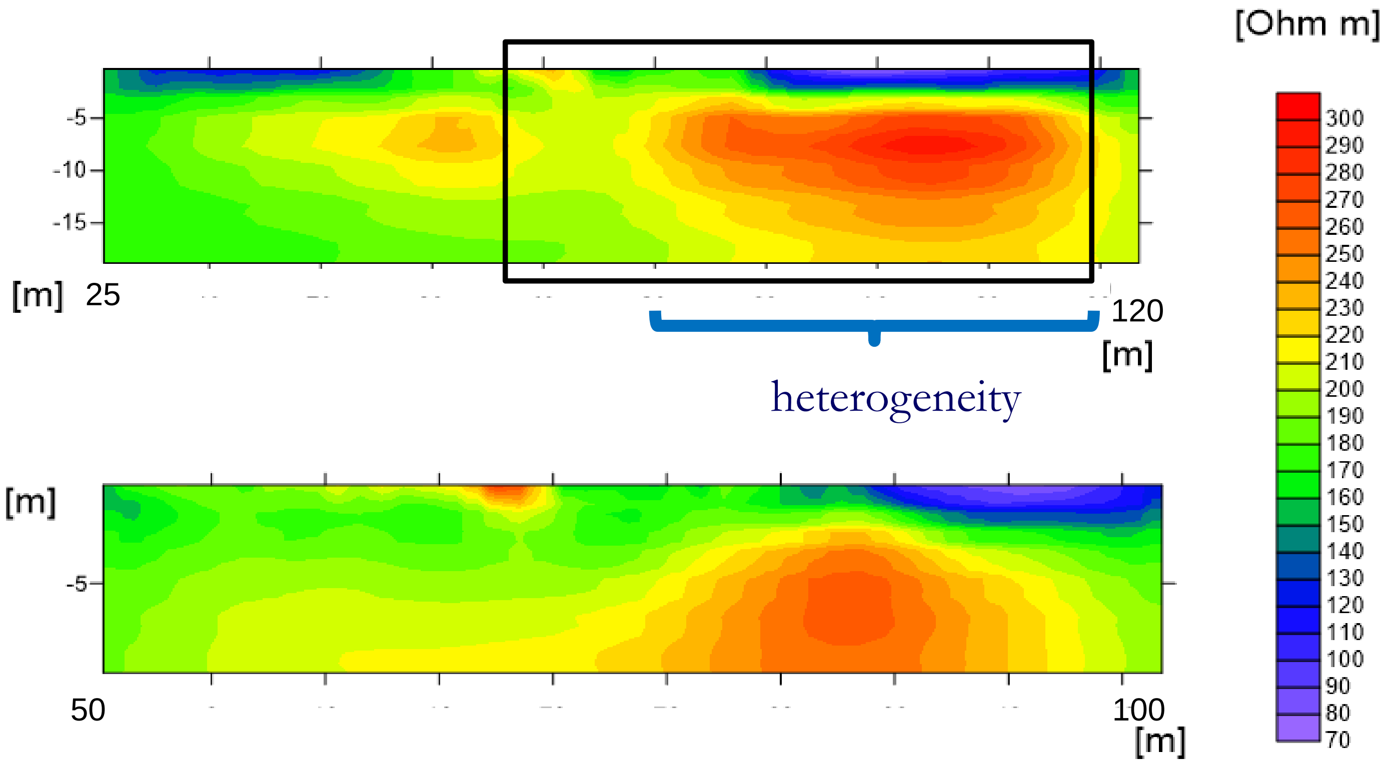


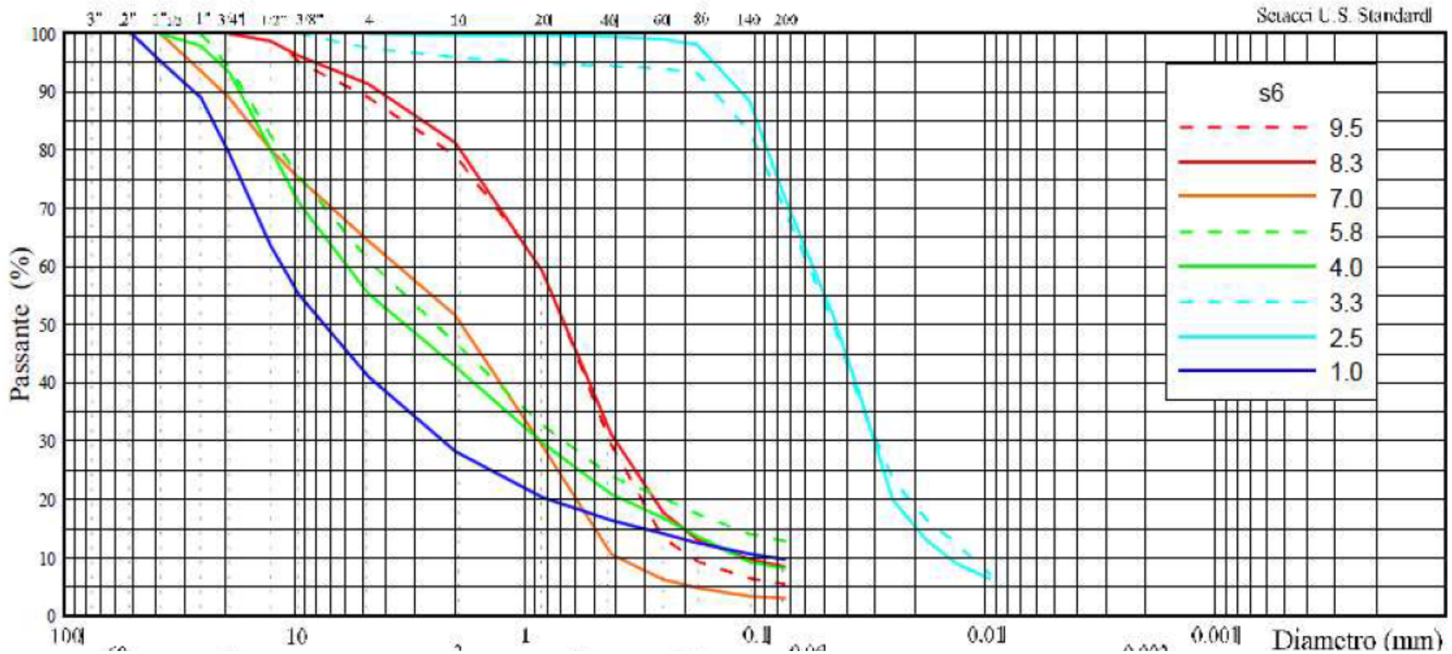
FINAL REMARKS

- Structural Health Monitoring (SHM) will became even more central in the following years, especially for defense works for natural hazard mitigation. The cost effectiveness of SHM is advantageous with respect of the increasing exposed elements, risk aversion of population and of the costs associated with the enlargement of existing structures.
- The implementation of low-cost, distributed, indirect measurement techniques will greatly benefit the availability and usability of monitoring system that could control long stretches of levees
- These systems could be also used for alert purposes, to inform civil protection actors of the imminence of the collapse of a section of the levee and therefore to guide evacuation and other responses.

FINAL REMARKS

- Soil heterogeneity plays a central role in the seepage dynamic, and therefore for the overall stability, of levees
- Distributed sensors like FOSs seem extremely useful to detect areas where water fluxes are more pronounced
- The tests that are performed in the Salorno area will be valuable to calibrate and assess the potentiality of FOSs for the detection of areas more prone to backward erosion piping
- The heat-pulse method technique could provide new information from optical fibers, giving a estimate of the actual water flux around the cable

THANK YOU FOR YOUR ATTENTION



Soil grading tests for the material forming the levee and below

Quantification of the effect of soil heterogenity

Estimation of results variability

Target field investigation

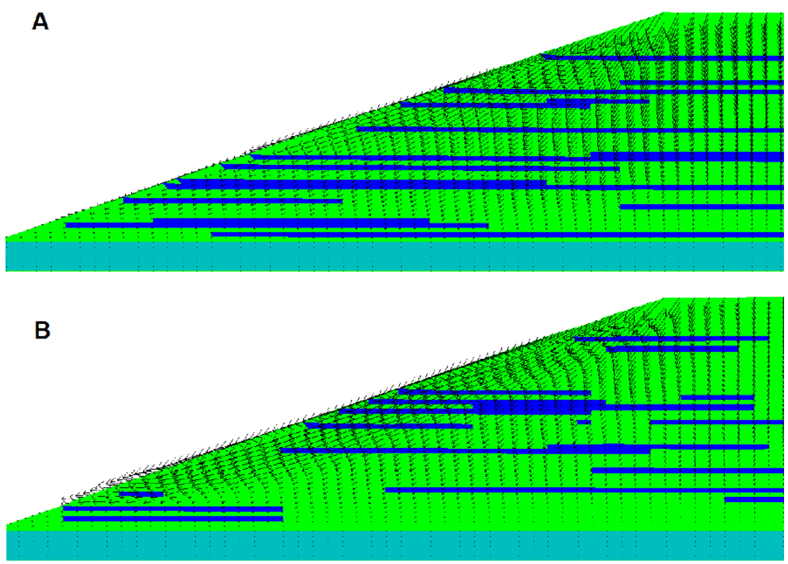
BoSG Method

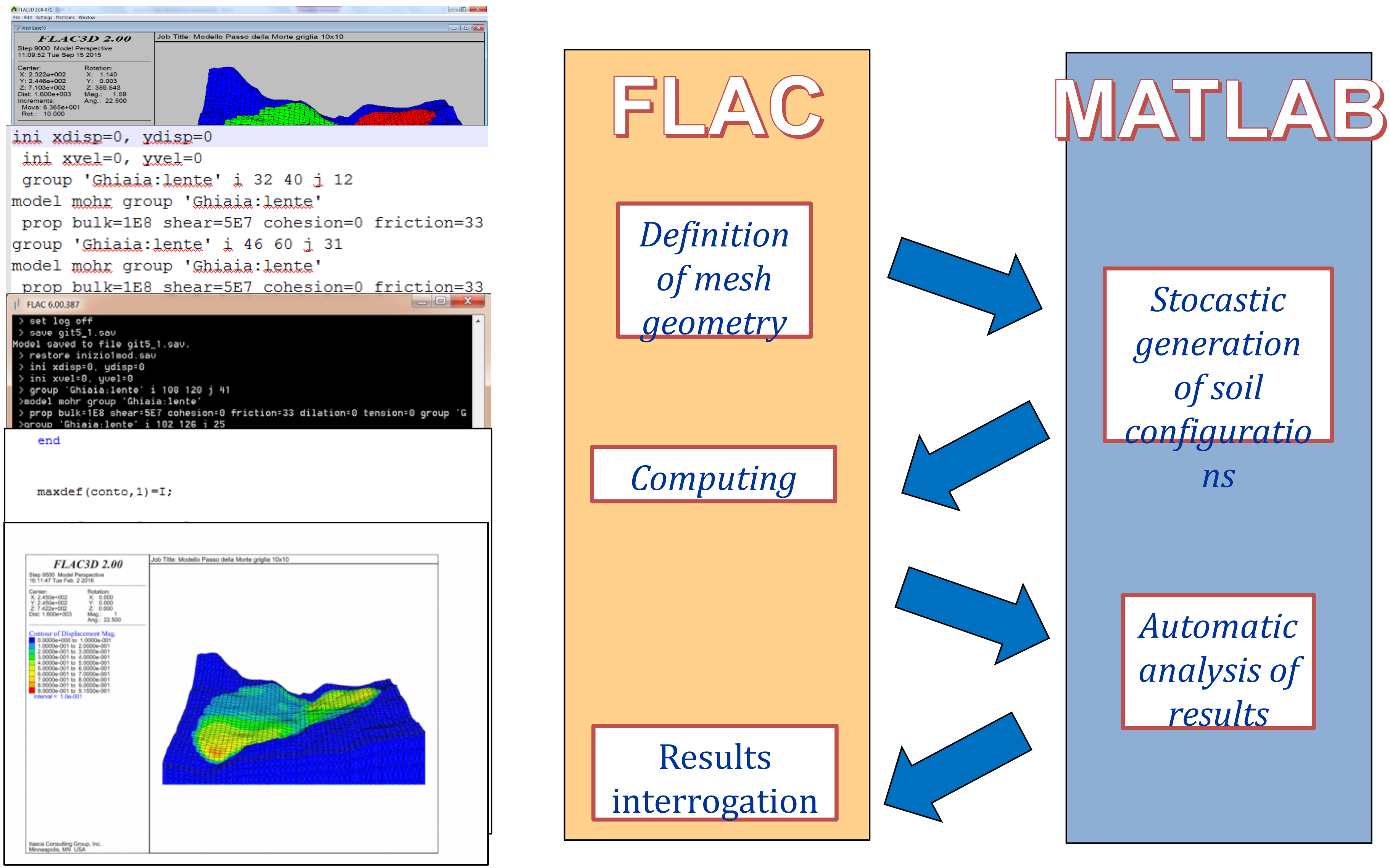
- ✓ Stochastic approach → *Generating different soil configurations in order to obtain a large dataset*

- ✓ Boolean Logic → *Soil is either matrix or lens*

Boolean Stochastic

Generation Method (BoSG)

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ini xvel=0, yvel=0
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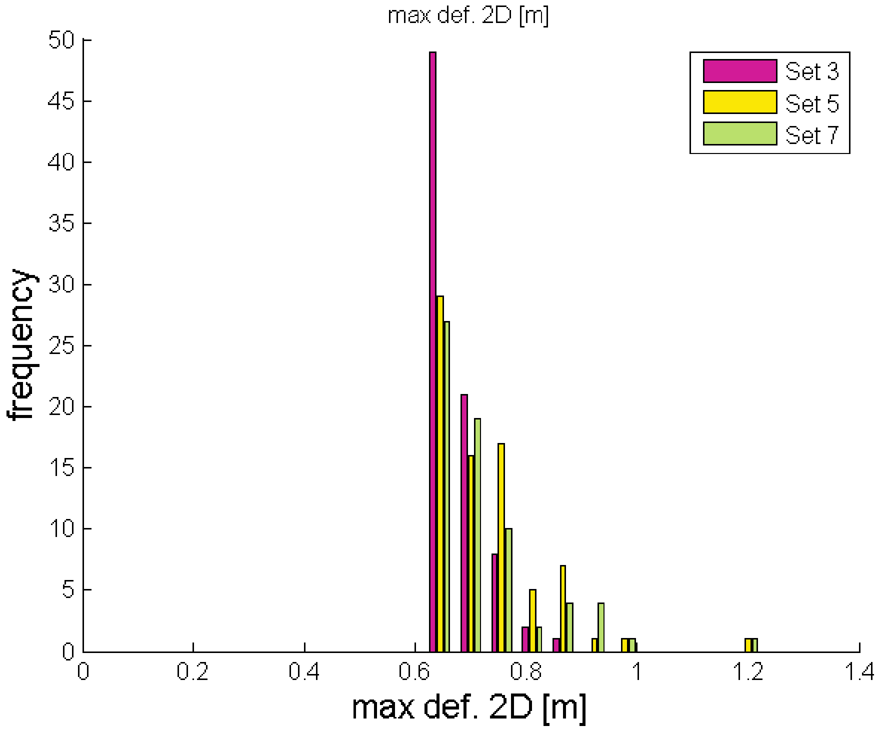
model mohr group 'Ghiaia:lente'
prop bulk=1E8 shear=5E7 cohesion=0 friction=33
group 'Ghiaia:lente' i 46 60 j 31
model mohr group 'Ghiaia:lente'
prop bulk=1E8 shear=5E7 cohesion=0 friction=33
FLAC 6.00.387
> set log off
> save git5_1.sav
Model saved to file git5_1.sav.
> restore inizio1mod.sav
> ini xdisp=0, ydisp=0
> ini xvel=0, yvel=0
> group 'Ghiaia:lente' i 108 120 j 41
>model mohr group 'Ghiaia:lente'
> prop bulk=1E8 shear=5E7 cohesion=0 friction=33 dilation=0 tension=0 group 'G
end
maxdef(conto,1)=I;
FLAC3D 2.00
Job Title: Modello Passo della Morte griglia 10x10
Contour of Displacement Mag.
FLAC
Definition of mesh geometry
Computing
Results interrogation
MATLAB
Stocastic generation of soil configurations
Automatic analysis of results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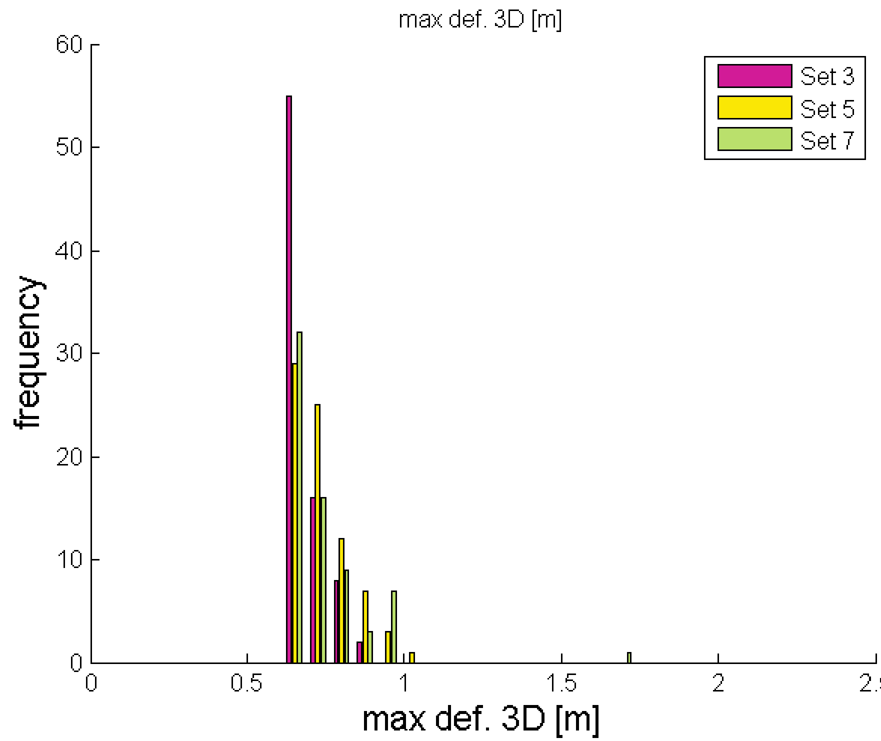
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2
2.5
max def. 3D [m]