

DETECTION OF BACKWARD EROSION USING MULTIPLE GEOPHYSICAL TECHNIQUES

Yara Maalouf^{(1),(2)}, Naji Khoury⁽²⁾, Christophe Voisin⁽¹⁾ and Grégory Bièvre⁽¹⁾

(1) University of Grenoble – Alpes, Grenoble – France

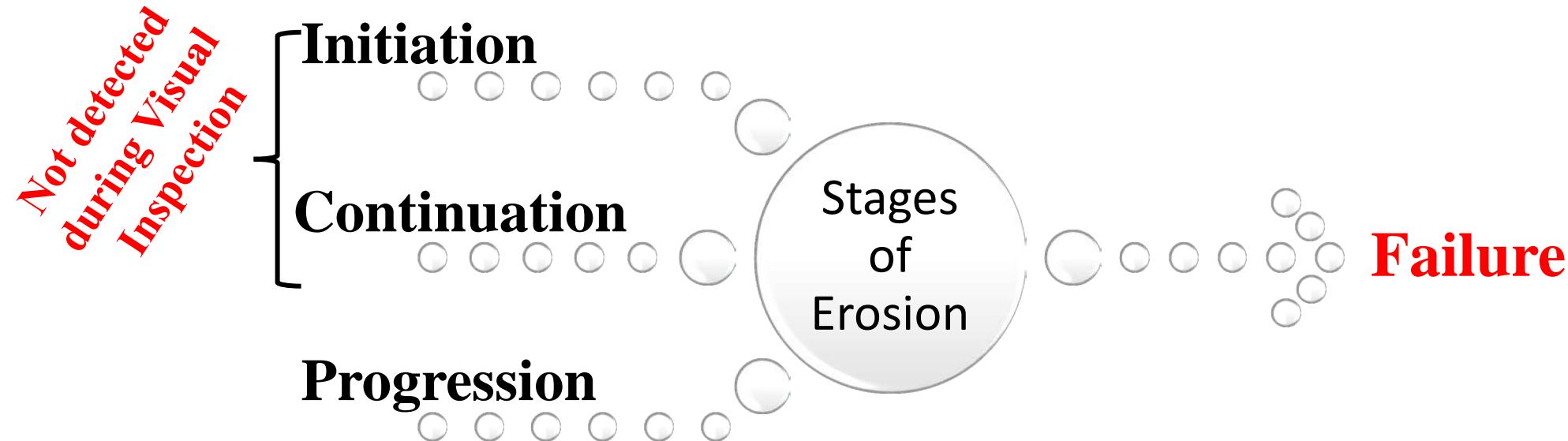
(2) Notre Dame University – Louaize, Zouk Mosbeh – Lebanon





FAILURE OF DAM IN BRAZIL (January, 2019)

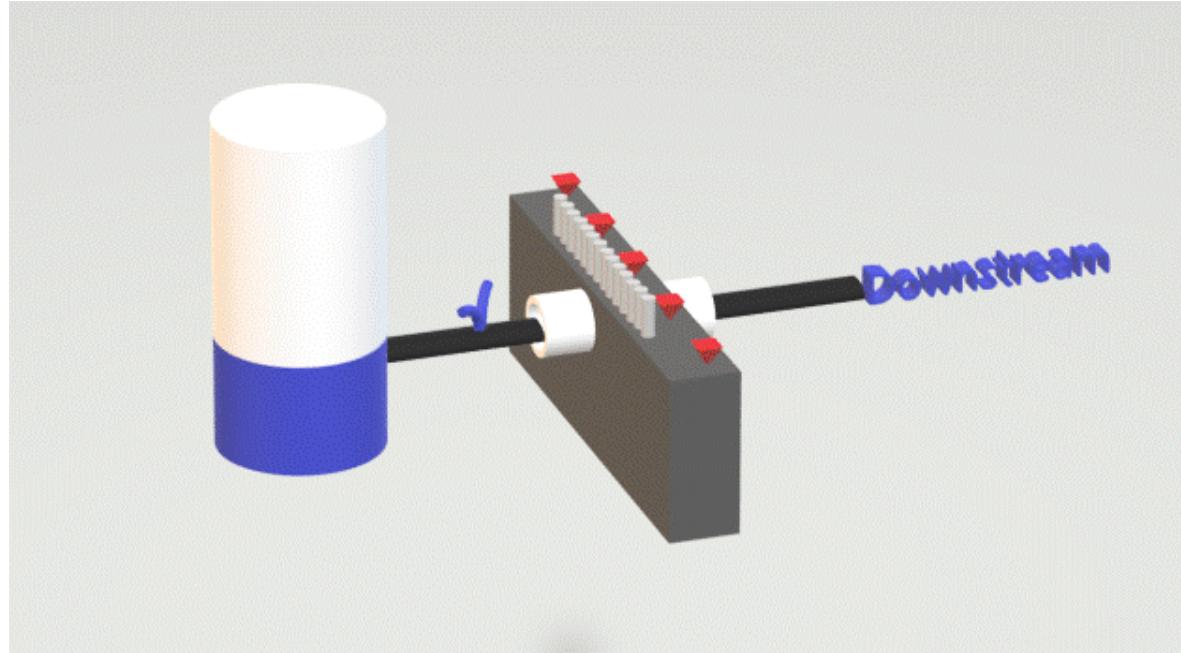




Breach/Failure → Fast mechanism

Short time between visual signs and failure



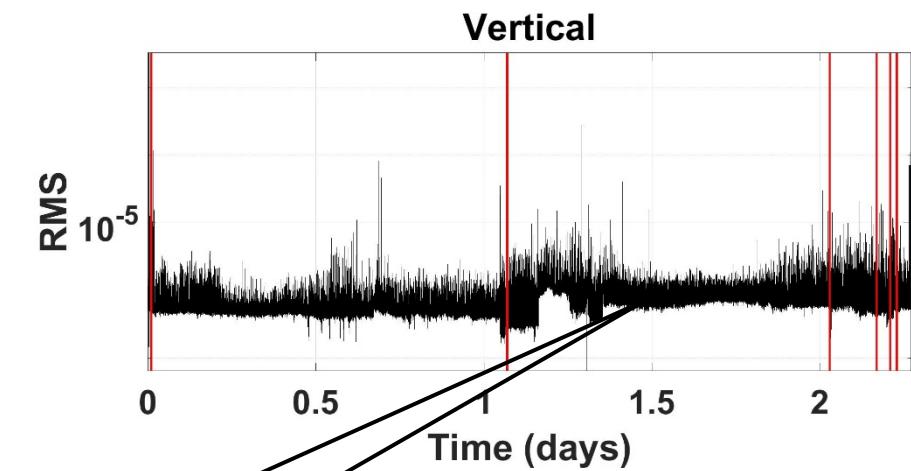
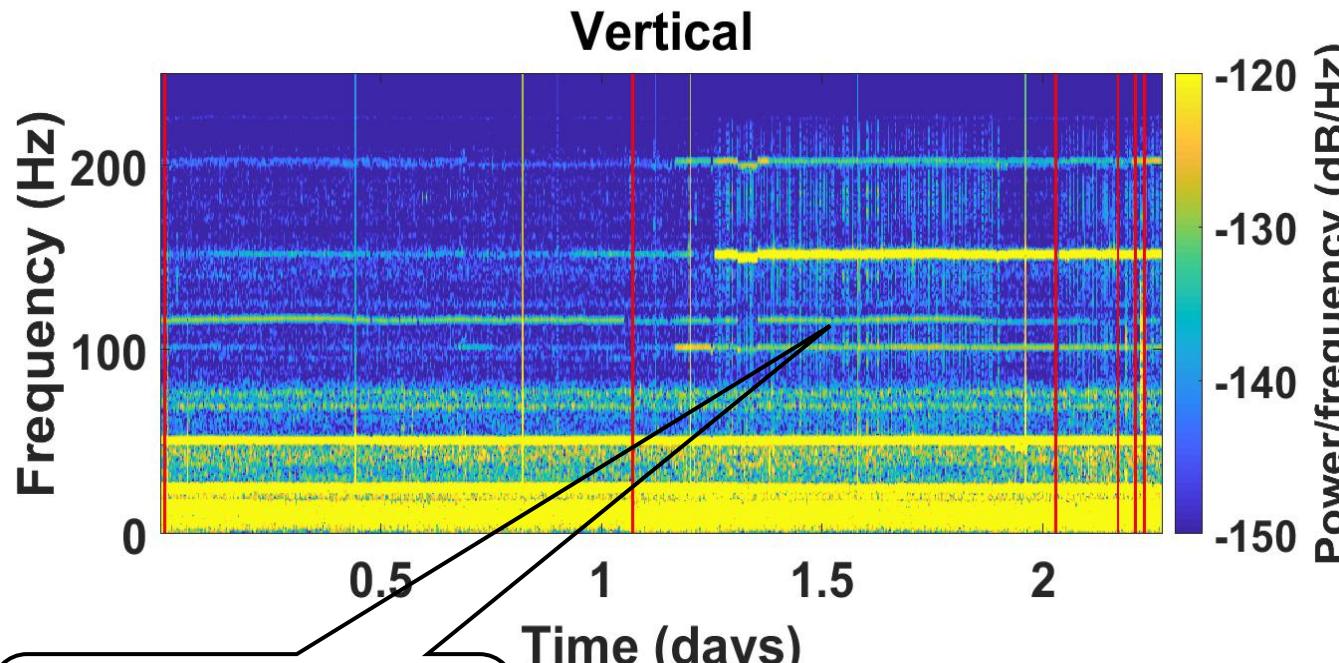


Laboratory Setup → Controlled Environment

Use of Geophysics → Monitoring and Detection of Internal Erosion



TWO-MINUTE MADNESS



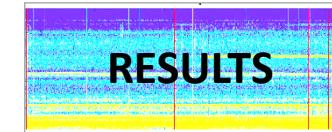
Increase in RMS at 80-120 Hz prior to failure

DETECTION OF BACKWARD EROSION USING MULTIPLE GEOPHYSICAL TECHNIQUES

Yara Maalouf^{(1),(2)}, Naji Khoury⁽²⁾, Christophe Voisin⁽¹⁾ and Grégory Bièvre⁽¹⁾

(1) University of Grenoble – Alpes, Grenoble – France

(2) Notre Dame University – Louaize, Zouk Mosbeh – Lebanon



DETECTION OF BACKWARD EROSION USING MULTIPLE GEOPHYSICAL TECHNIQUES

Yara Maalouf^{(1),(2)}, Naji Khoury⁽²⁾, Christophe Voisin⁽¹⁾ and Grégory Bièvre⁽¹⁾



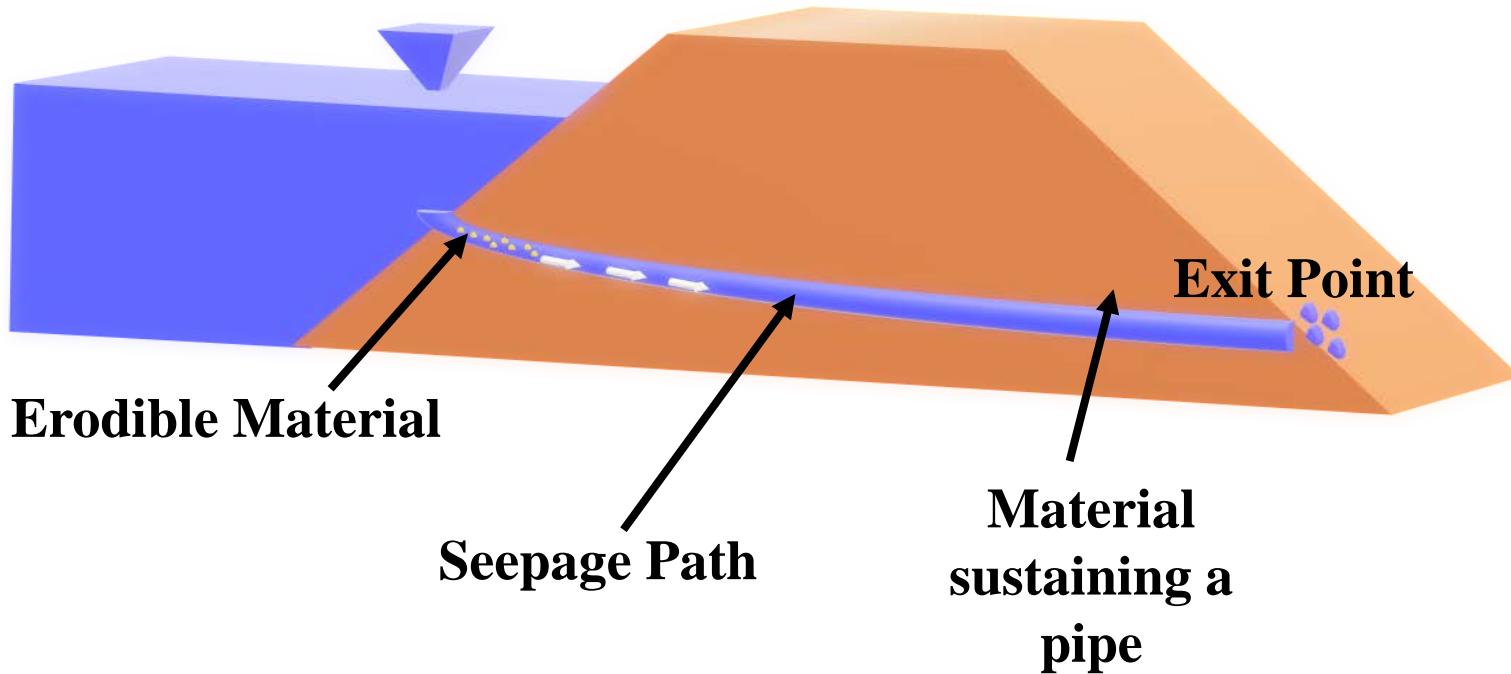
(1) University of Grenoble – Alpes, Grenoble – France
(2) Notre Dame University – Louaize, Zouk Mosbeh – Lebanon



INTRODUCTION



What is Internal Erosion?



$$i > i_c$$



LabEx OSUG@2020

La Région
Auvergne-Rhône-Alpes



DETECTION OF BACKWARD EROSION USING MULTIPLE GEOPHYSICAL TECHNIQUES

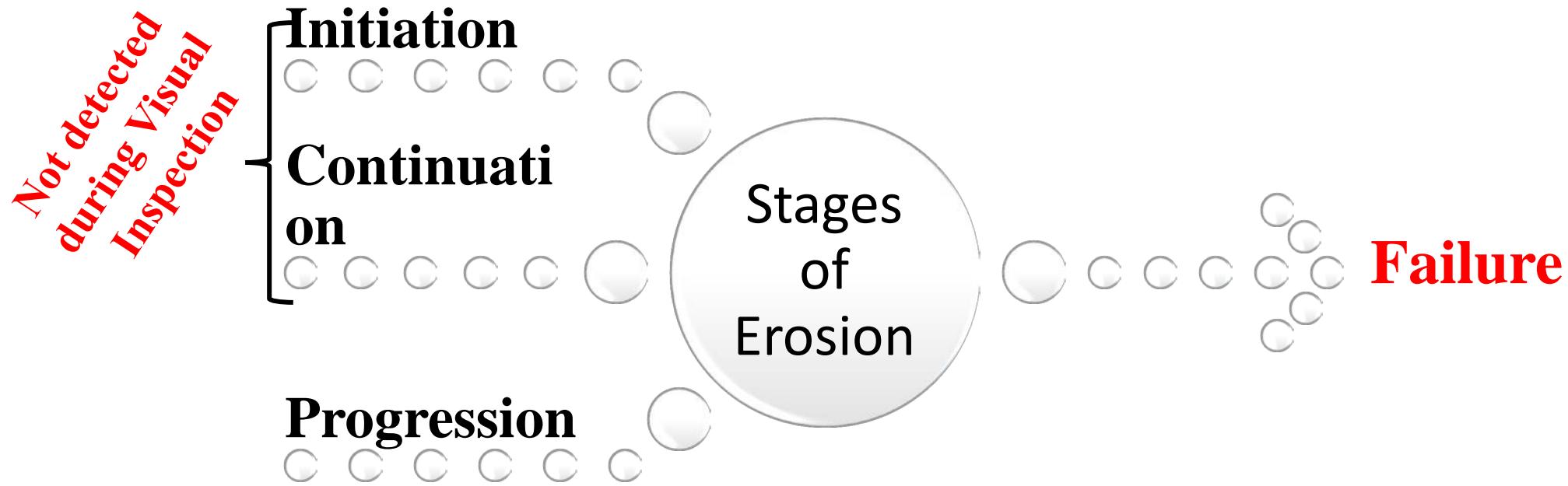
Yara Maalouf^{(1),(2)}, Naji Khoury⁽²⁾, Christophe Voisin⁽¹⁾ and Grégory Bièvre⁽¹⁾



(1) University of Grenoble – Alpes, Grenoble – France
(2) Notre Dame University – Louaize, Zouk Mosbeh – Lebanon



Introduction (Cont'd)



Therefore use of Non – Destructive Techniques (NDT) essential to detect early stages of internal erosion and prevent failure



OSUG²⁰²⁰

La Région
Auvergne-Rhône-Alpes



DETECTION OF BACKWARD EROSION USING MULTIPLE GEOPHYSICAL TECHNIQUES

Yara Maalouf^{(1),(2)}, Naji Khoury⁽²⁾, Christophe Voisin⁽¹⁾ and Grégory Bièvre⁽¹⁾



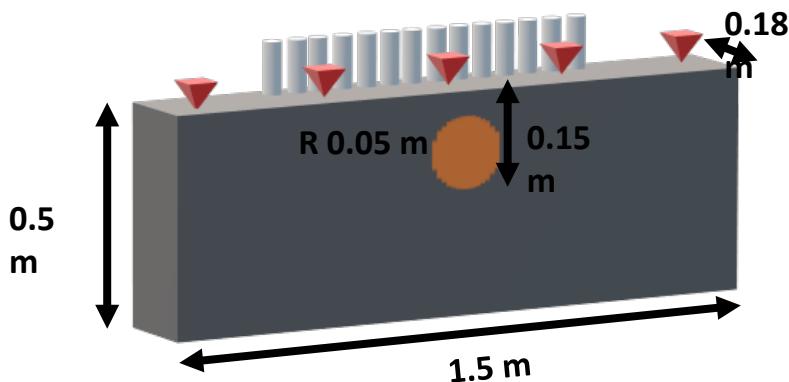
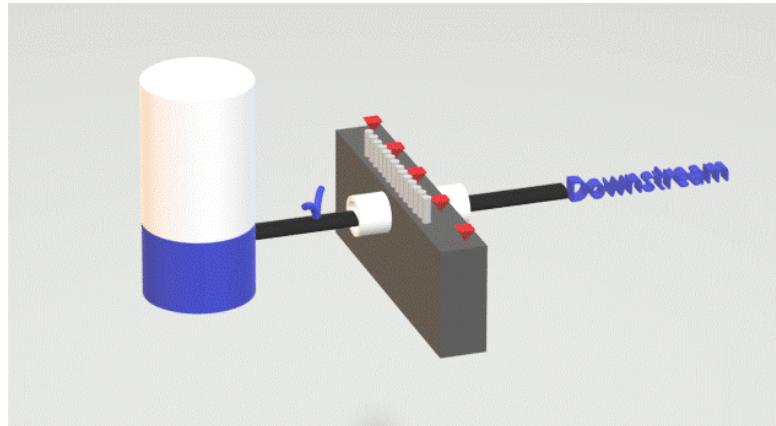
(1) University of Grenoble – Alpes, Grenoble – France
(2) Notre Dame University – Louaize, Zouk Mosbeh – Lebanon



METHODOLOGY



- Controlled testing
- Controlled hydraulic gradient
- Water flow **only** in weak zone
- Many soil mixtures can be conducted



OSUG²⁰²⁰

La Région
Auvergne-Rhône-Alpes



DETECTION OF BACKWARD EROSION USING MULTIPLE GEOPHYSICAL TECHNIQUES

Yara Maalouf^{(1),(2)}, Naji Khoury⁽²⁾, Christophe Voisin⁽¹⁾ and Grégory Bièvre⁽¹⁾



(1) University of Grenoble – Alpes, Grenoble – France
(2) Notre Dame University – Louaize, Zouk Mosbeh – Lebanon



Methodology (Cont'd)



Setup in the lab:

- 2 Horizontal Geophone
- 1 Vertical Geophone



DETECTION OF BACKWARD EROSION USING MULTIPLE GEOPHYSICAL TECHNIQUES

Yara Maalouf^{(1),(2)}, Naji Khoury⁽²⁾, Christophe Voisin⁽¹⁾ and Grégory Bièvre⁽¹⁾



(1) University of Grenoble – Alpes, Grenoble – France
(2) Notre Dame University – Louaize, Zouk Mosbeh – Lebanon

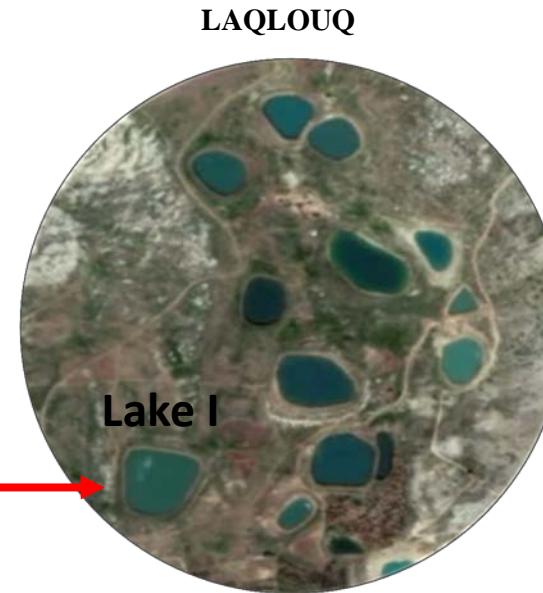


Methodology (Cont'd)



Materials Properties:

% Sand	65
% Clay	35
% Fines	>12
ERI	2
% Water Content	10.3
Dry Unit Weight	17.01 kN/m ³
Soil Classification	SM (Silty Sand)



Google Earth Image



LabEx OSUG@2020

La Région
Auvergne-Rhône-Alpes



DETECTION OF BACKWARD EROSION USING MULTIPLE GEOPHYSICAL TECHNIQUES

Yara Maalouf^{(1),(2)}, Naji Khoury⁽²⁾, Christophe Voisin⁽¹⁾ and Grégory Bièvre⁽¹⁾



(1) University of Grenoble – Alpes, Grenoble – France
(2) Notre Dame University – Louaize, Zouk Mosbeh – Lebanon



RESULTS



Data of Geophones:

- Monitor
- Horizontal perpendicular to flow
- Horizontal parallel to flow
- Vertical

TIME SERIES

SPECTROGRAM

RMS



OSUG²⁰²⁰

La Région
Auvergne-Rhône-Alpes



DETECTION OF BACKWARD EROSION USING MULTIPLE GEOPHYSICAL TECHNIQUES

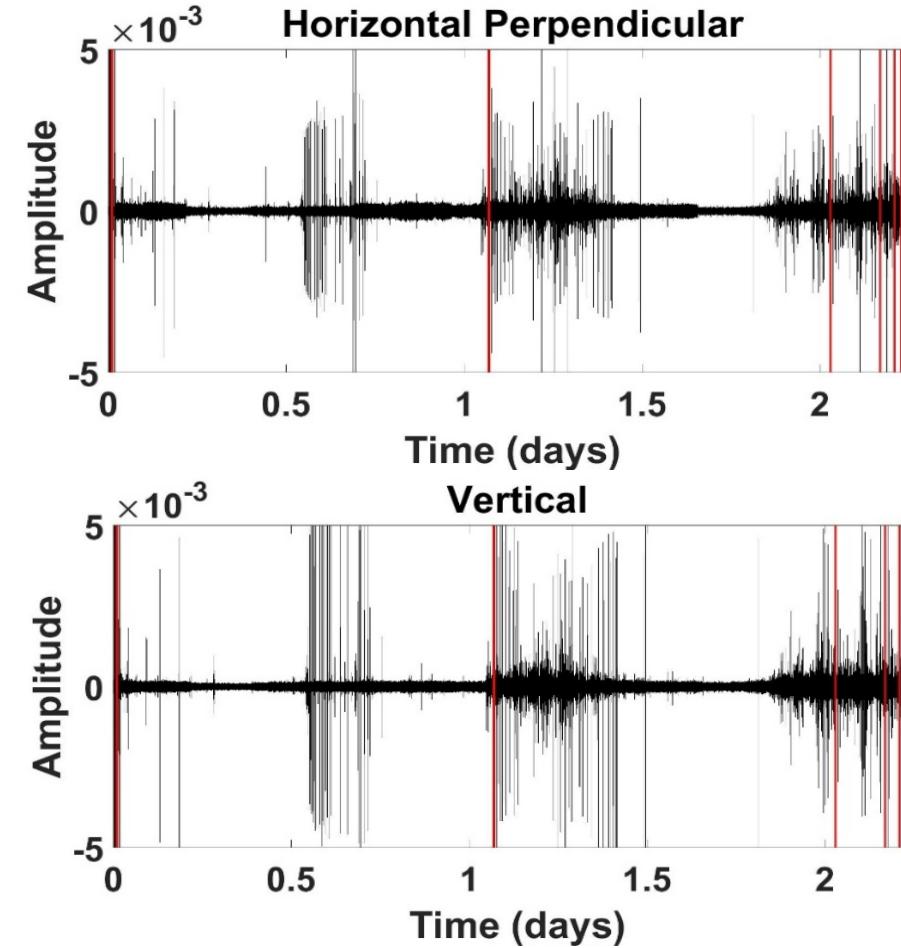
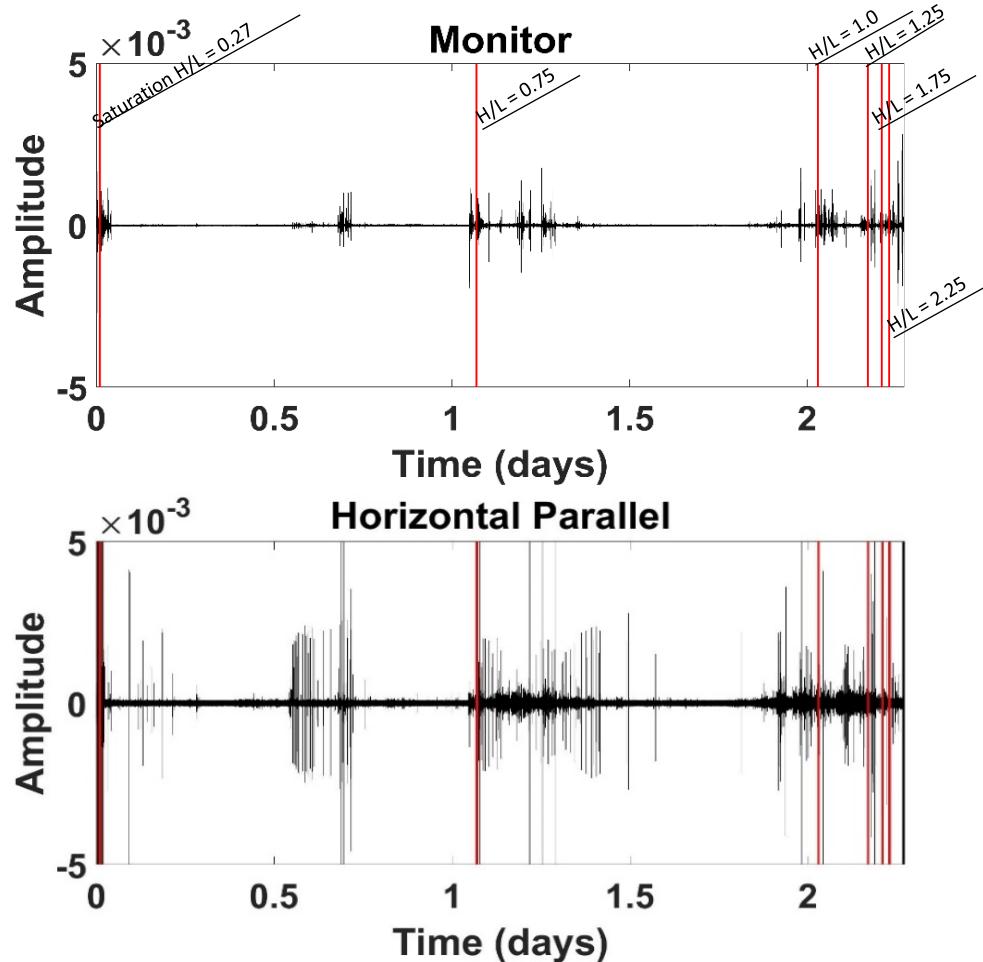
Yara Maalouf^{(1),(2)}, Naji Khoury⁽²⁾, Christophe Voisin⁽¹⁾ and Grégory Bièvre⁽¹⁾



(1) University of Grenoble – Alpes, Grenoble – France
(2) Notre Dame University – Louaize, Zouk Mosbeh – Lebanon



Results (Cont'd)



OSUG 2020

La Région
Auvergne-Rhône-Alpes



USAID

DETECTION OF BACKWARD EROSION USING MULTIPLE GEOPHYSICAL TECHNIQUES

Yara Maalouf^{(1),(2)}, Naji Khoury⁽²⁾, Christophe Voisin⁽¹⁾ and Grégory Bièvre⁽¹⁾

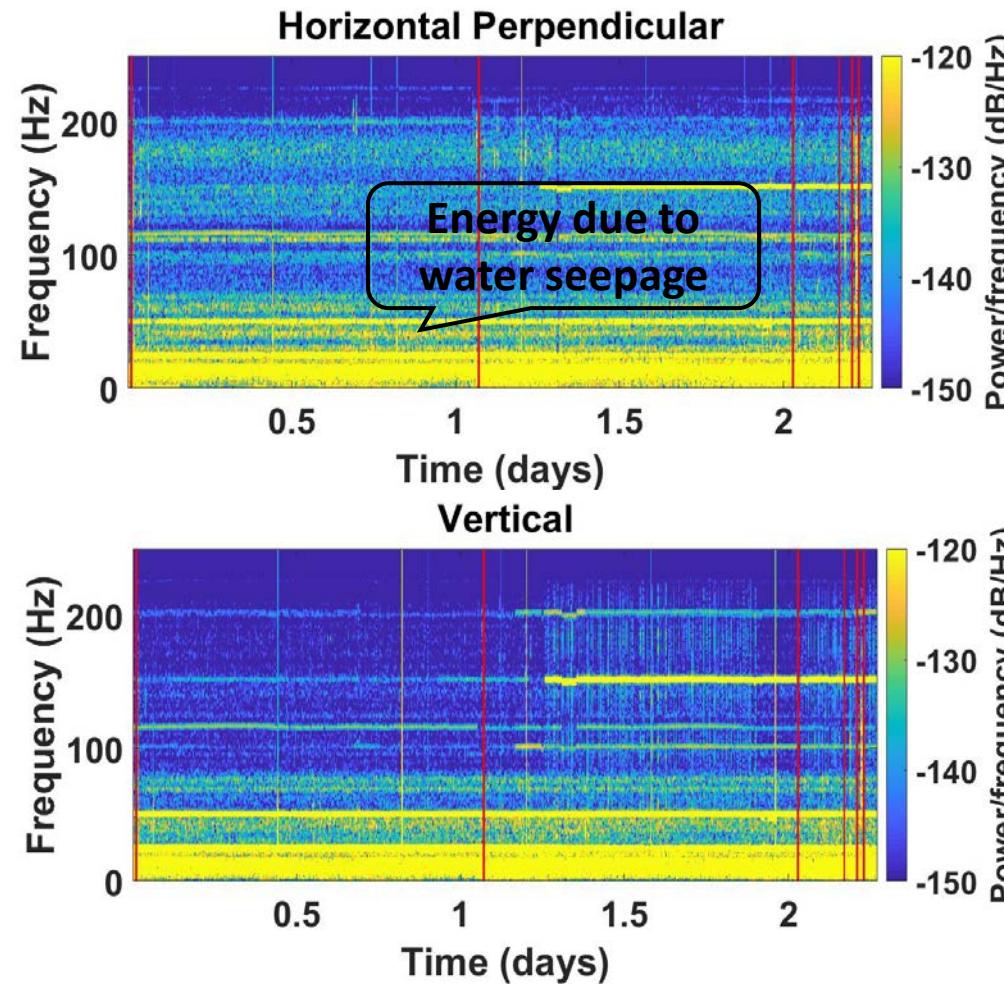
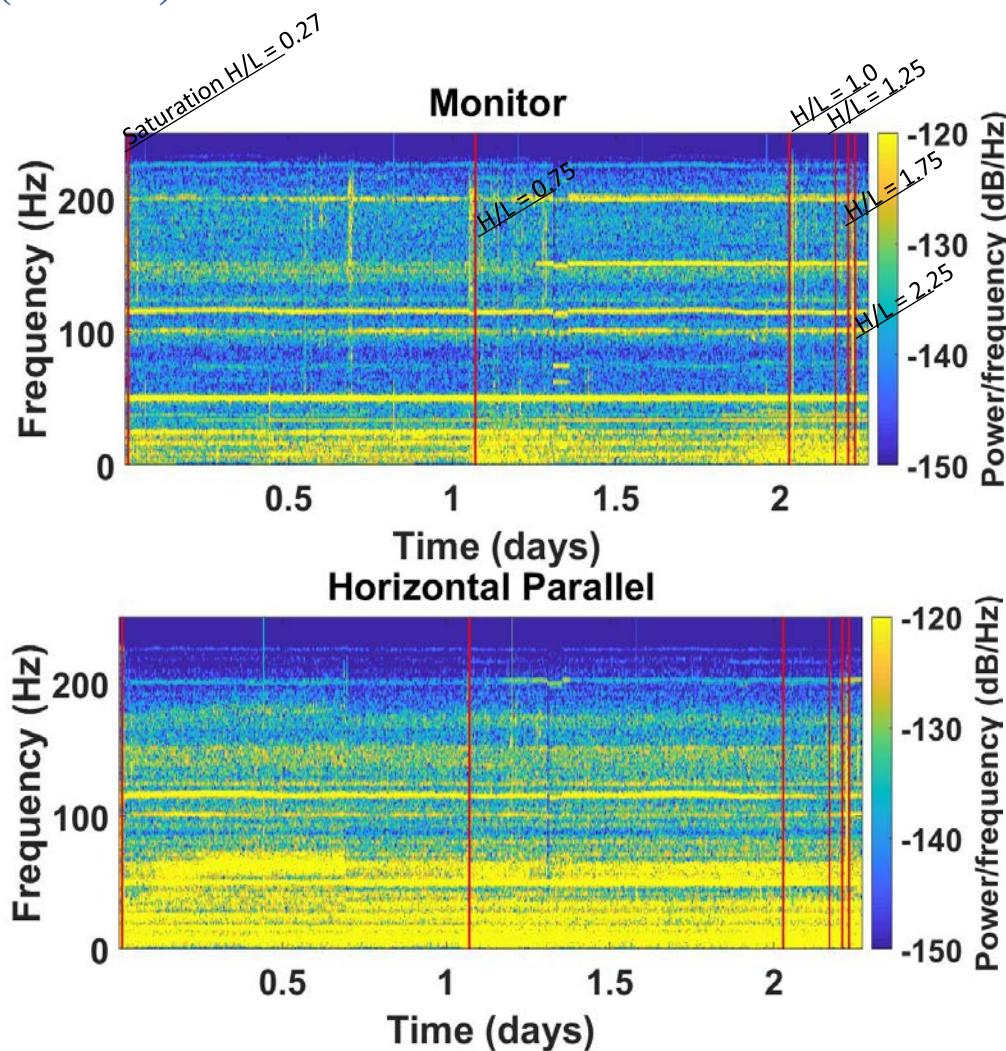


(1) University of Grenoble – Alpes, Grenoble – France

(2) Notre Dame University – Louaize, Zouk Mosbeh – Lebanon



Results (Cont'd)



DETECTION OF BACKWARD EROSION USING MULTIPLE GEOPHYSICAL TECHNIQUES

Yara Maalouf^{(1),(2)}, Naji Khoury⁽²⁾, Christophe Voisin⁽¹⁾ and Grégory Bièvre⁽¹⁾

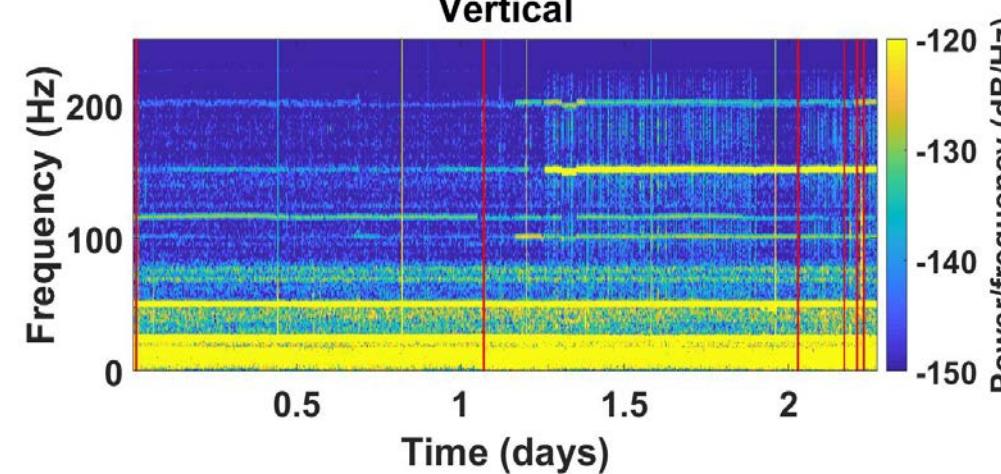
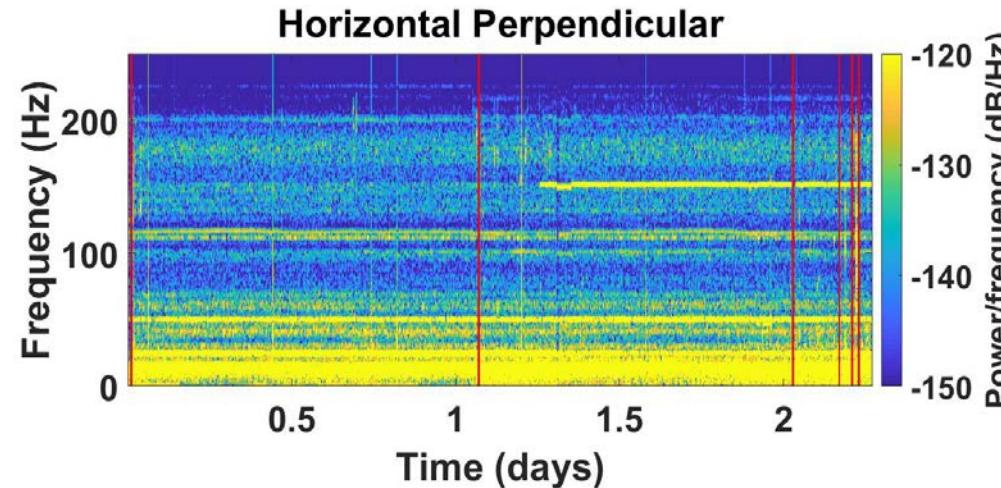
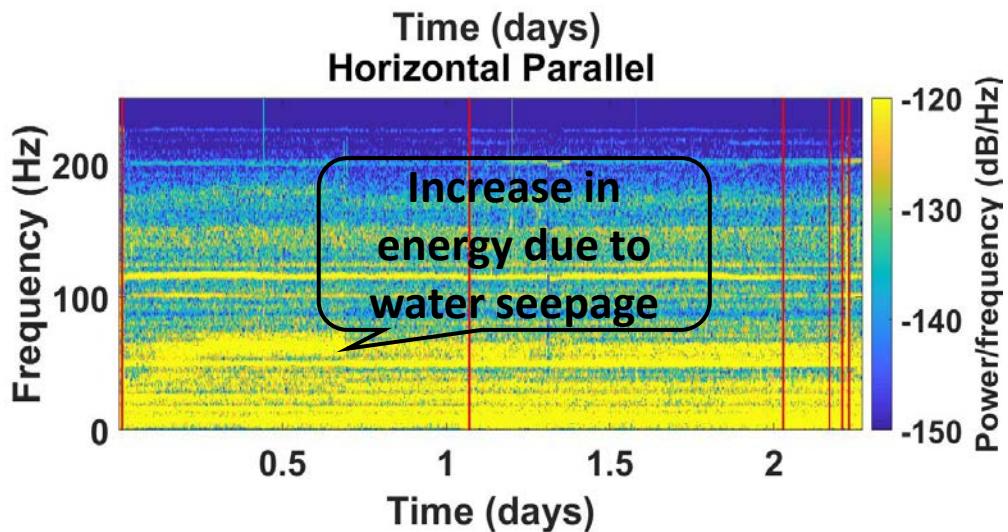
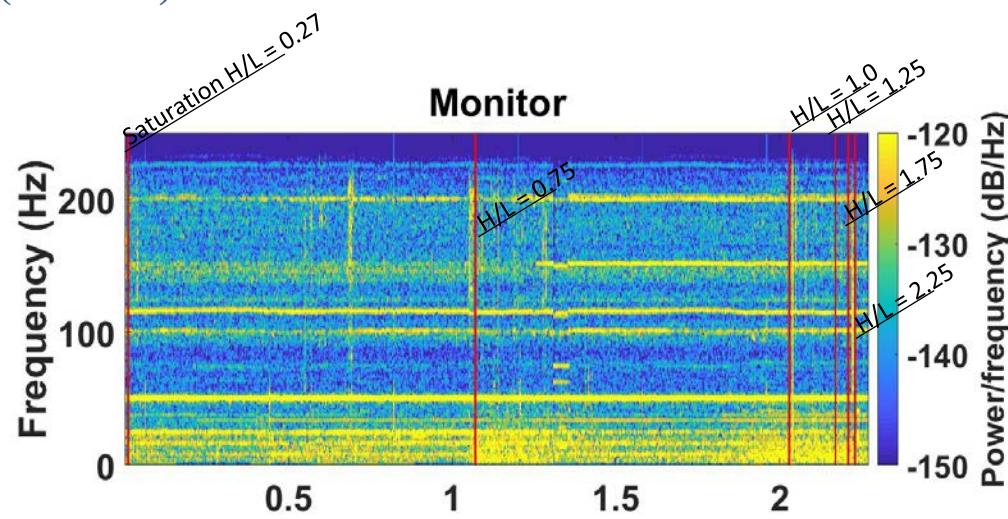


(1) University of Grenoble – Alpes, Grenoble – France

(2) Notre Dame University – Louaize, Zouk Mosbeh – Lebanon



Results (Cont'd)



OSUG 2020

La Région
Auvergne-Rhône-Alpes



DETECTION OF BACKWARD EROSION USING MULTIPLE GEOPHYSICAL TECHNIQUES

Yara Maalouf^{(1),(2)}, Naji Khoury⁽²⁾, Christophe Voisin⁽¹⁾ and Grégory Bièvre⁽¹⁾

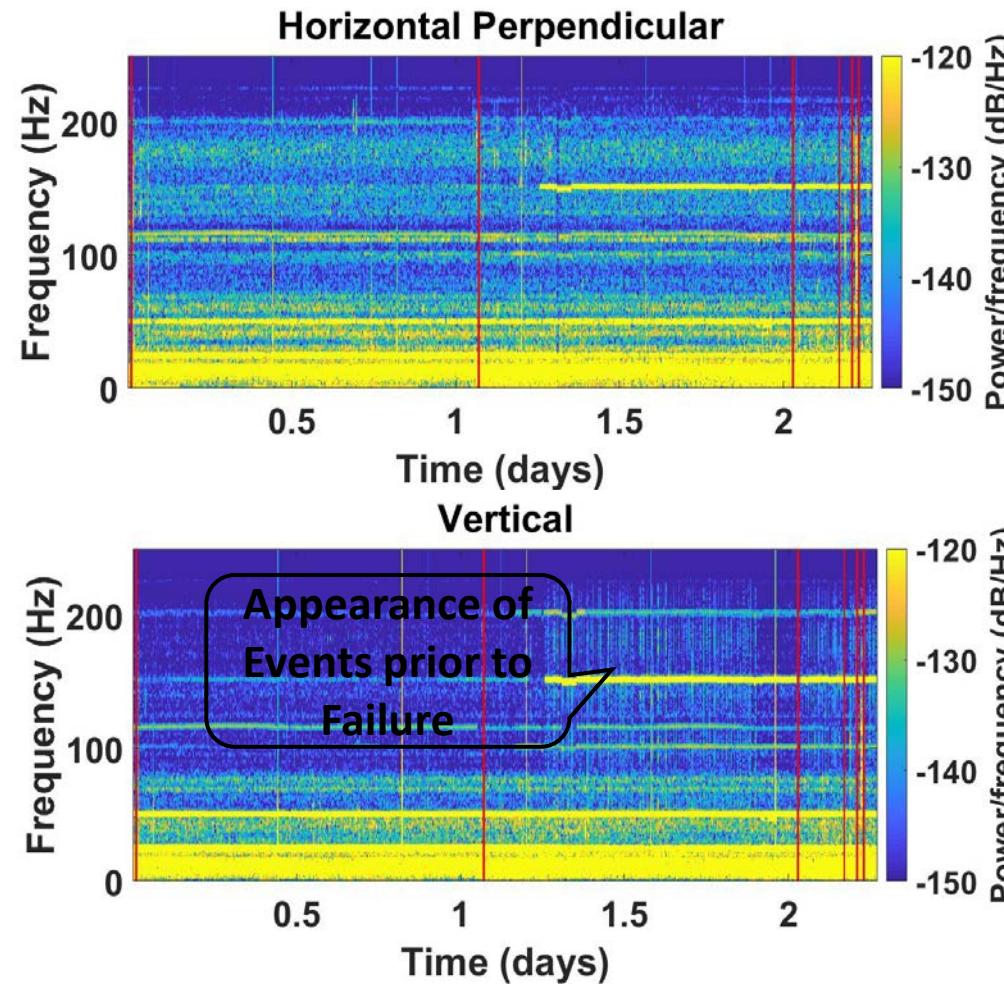
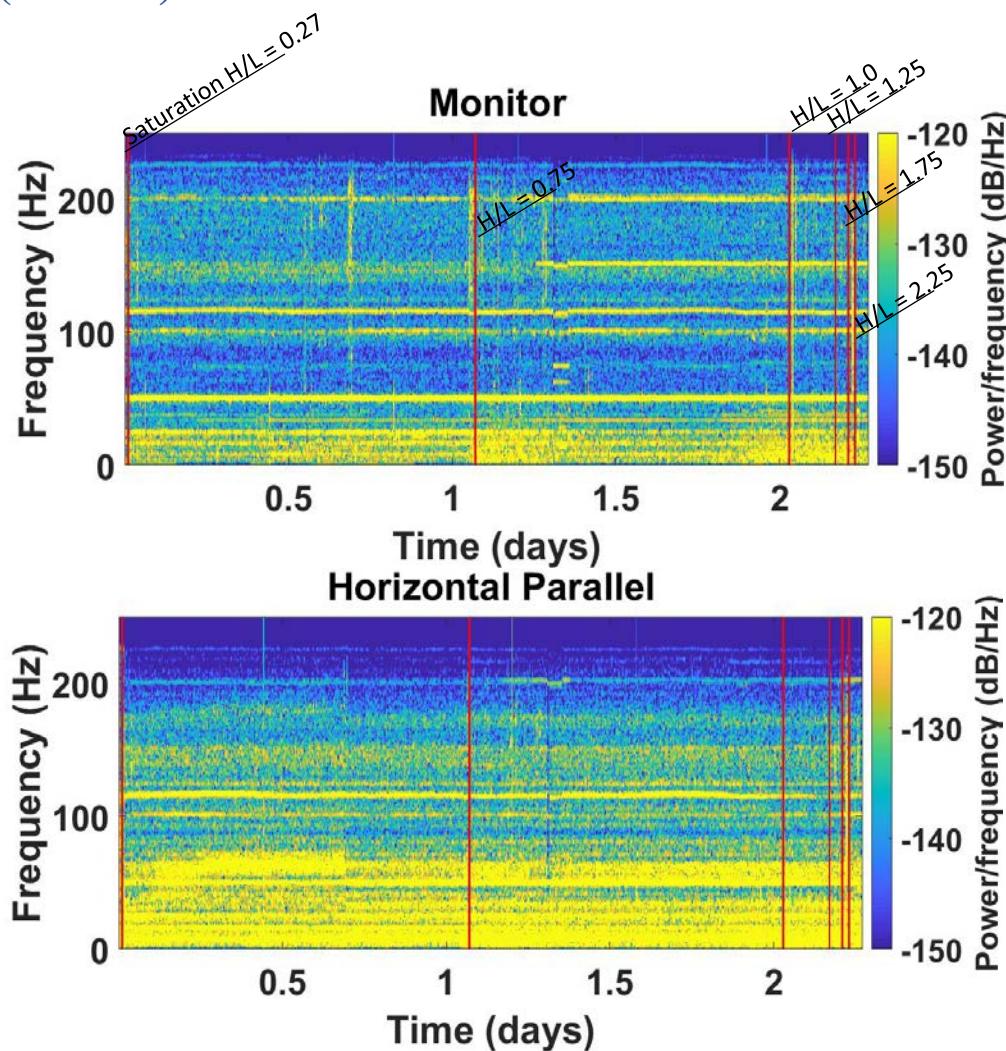


(1) University of Grenoble – Alpes, Grenoble – France

(2) Notre Dame University – Louaize, Zouk Mosbeh – Lebanon



Results (Cont'd)



OSUG²⁰²⁰

La Région
Auvergne-Rhône-Alpes



DETECTION OF BACKWARD EROSION USING MULTIPLE GEOPHYSICAL TECHNIQUES

Yara Maalouf^{(1),(2)}, Naji Khoury⁽²⁾, Christophe Voisin⁽¹⁾ and Grégory Bièvre⁽¹⁾

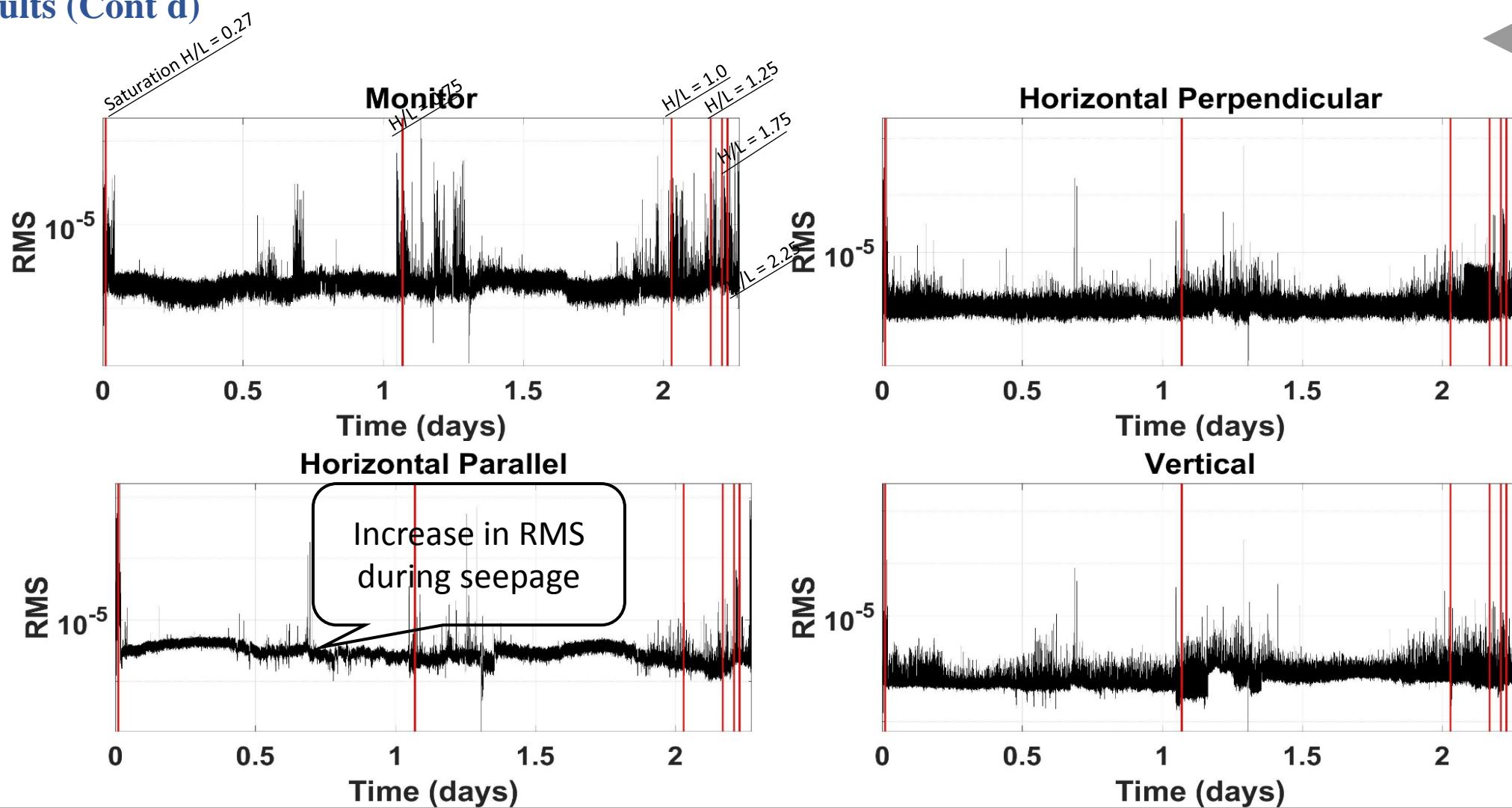


(1) University of Grenoble – Alpes, Grenoble – France

(2) Notre Dame University – Louaize, Zouk Mosbeh – Lebanon



Results (Cont'd)



LabEx

OSUG 2020

La Région
Auvergne-Rhône-Alpes



DETECTION OF BACKWARD EROSION USING MULTIPLE GEOPHYSICAL TECHNIQUES

Yara Maalouf^{(1),(2)}, Naji Khoury⁽²⁾, Christophe Voisin⁽¹⁾ and Grégory Bièvre⁽¹⁾

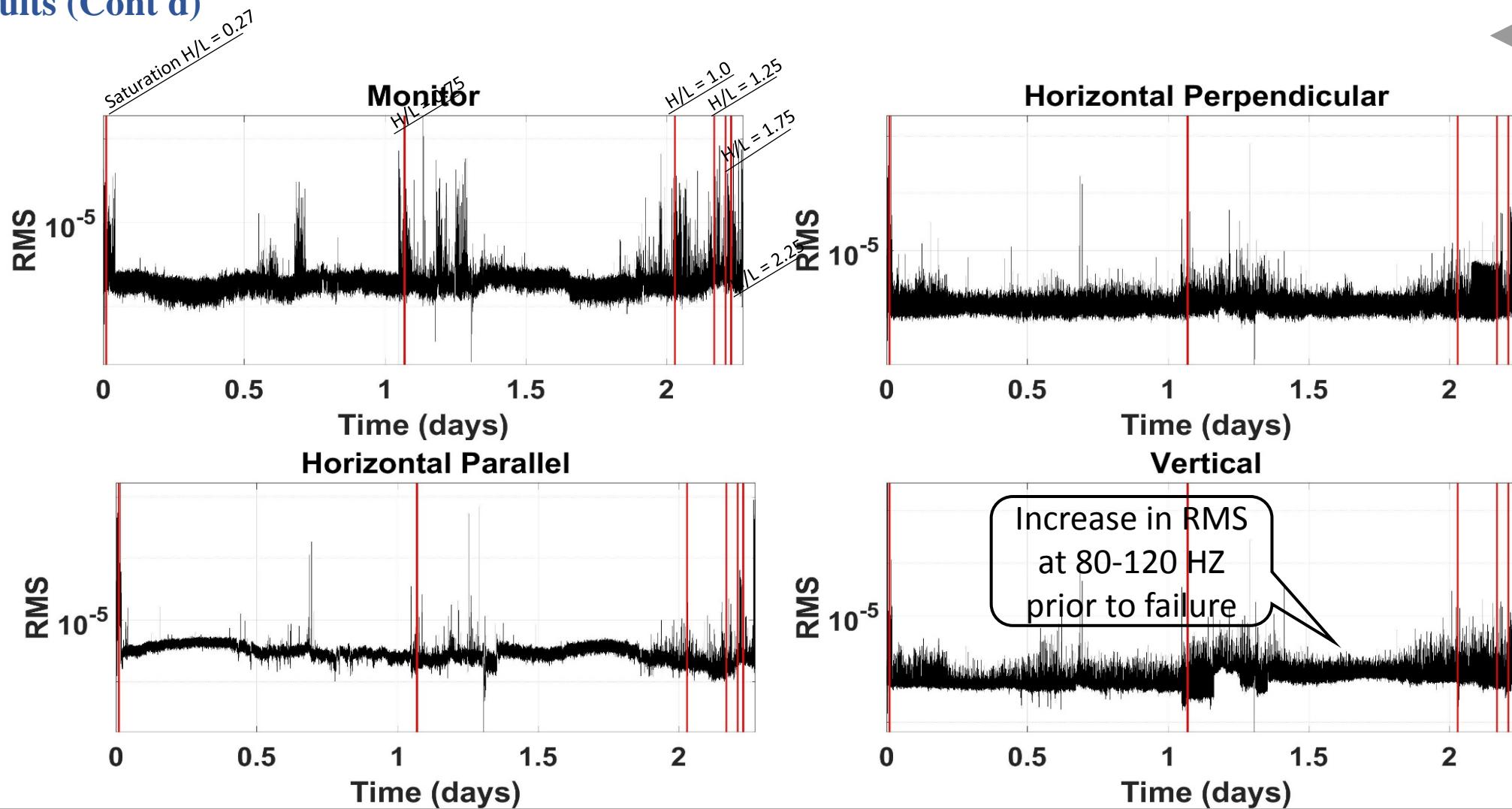


(1) University of Grenoble – Alpes, Grenoble – France

(2) Notre Dame University – Louaize, Zouk Mosbeh – Lebanon



Results (Cont'd)



CONCLUSIONS

- ✓ Controllable laboratory → backward erosion
- ✓ Horizontal geophone, parallel → flow of water
- ✓ Vertical geophone → events
 - Grain rearrangement
 - Grain movement



Aqoura Dam Failure – Lebanon, 2015

