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Identification of shallow land instability precursory signals with a semi-distributed optical fiber strain sensor: an experimental method.

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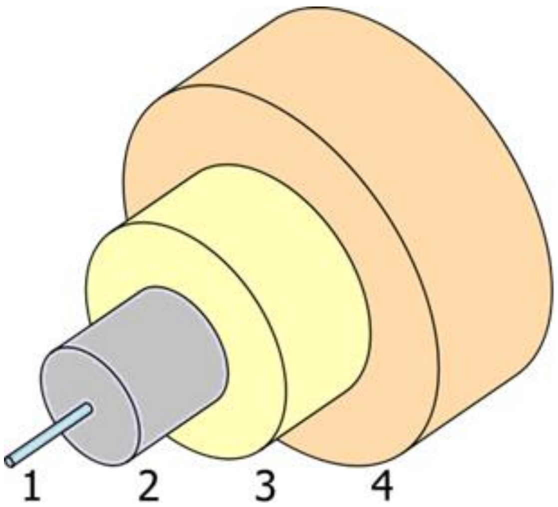
To verify the efficiency of the fiber optic sensor as a monitoring tool for shallow landslides

Phenomena of relatively small dimensions but potentially desctructive, provoked by intense meteorological events

Val Tartano, July 18th 1987

Filament of glass or polimeric material which allows for the transfer of light signal



Core:8 µm

Cladding, 125 µm

Buffer, 250 µm

Jacket, 400 µm

Advantages

- Light and compact
- High resistance and durability
- Velocity of signal transmissioned and low attenuation
- Multiplexing

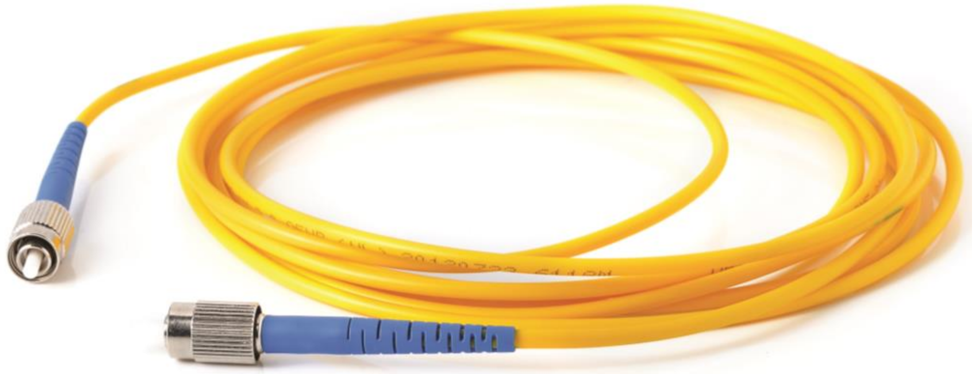
Disadvantages

- Cost of the interrogator
- Installation of the fiber sensors

Classification of optical fiber sensors:

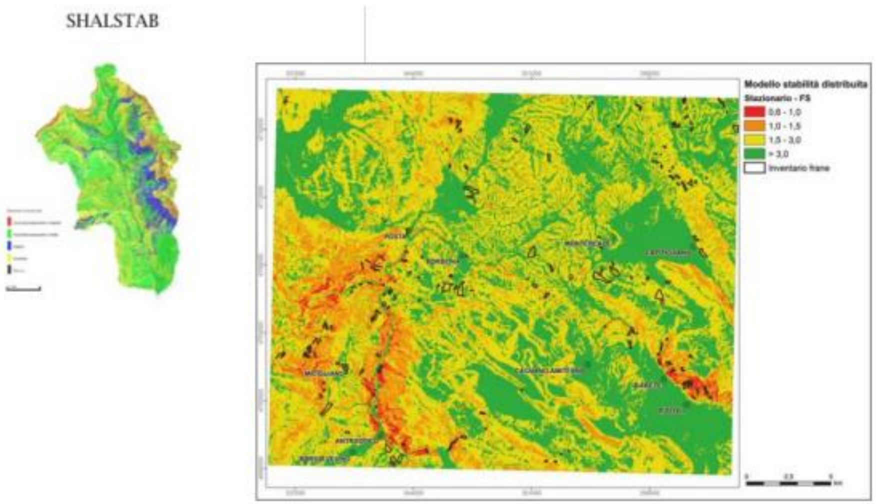
- Discrete: FBG (fiber Bragg Grating)
- Semi distributed: FBG in series (multiplexing)
- Distributed: OTDR (optical time domain reflectometry), BOTDA (Brillouin Optical Time Domain Analysis), BOTDR (Brillouin Optical Time Domain Reflectometry)

Interferometric - (semi distributed)



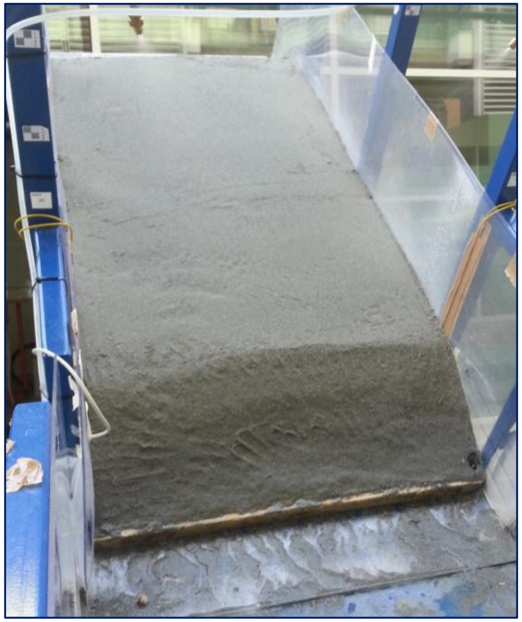
Analytical modelling

Forecast slopes' behaviour,
Generate risk scenarios
(SINMAP, SHALSTAB, etc.)



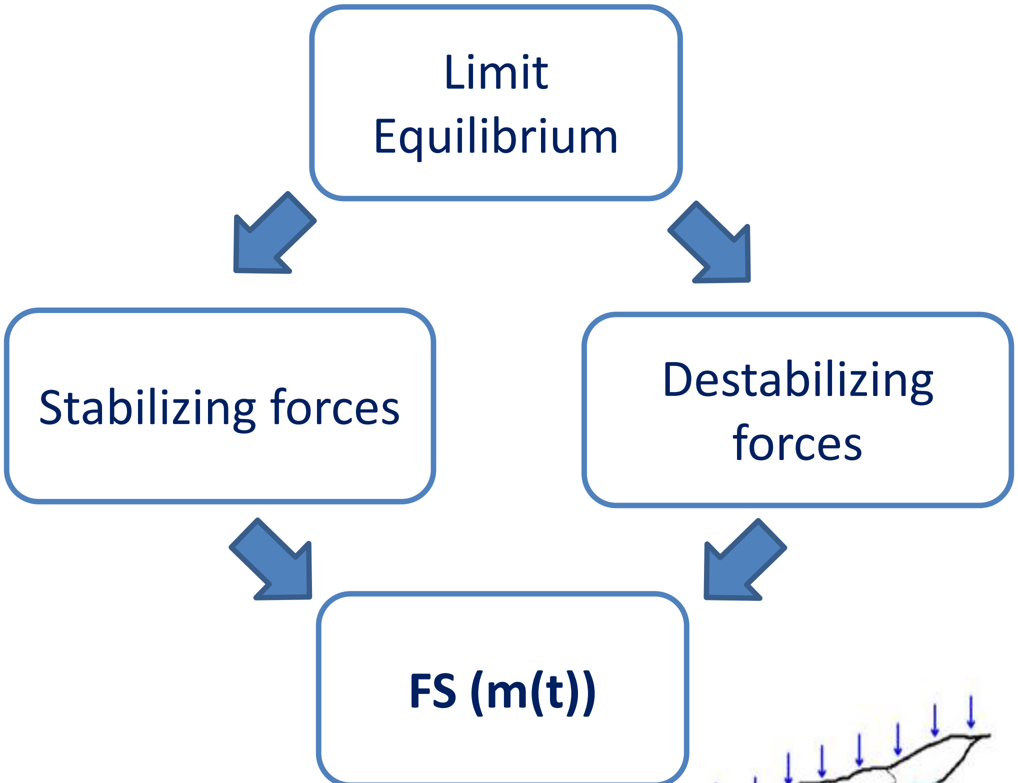
Physical modelling

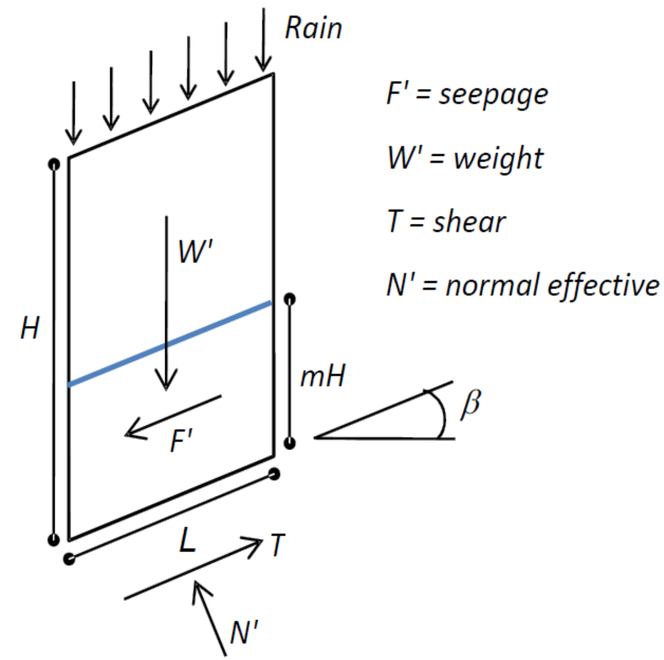
Study the onset and evolution of landslides at a reduced scale, moderate costs and time expense

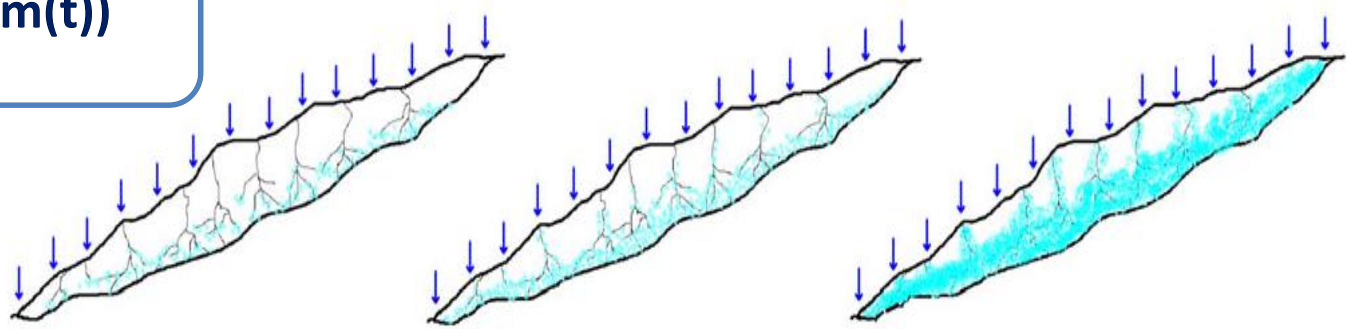


SLIP (Shallow Landslides Instability Prediction) Montrasio & Valentino (2008)

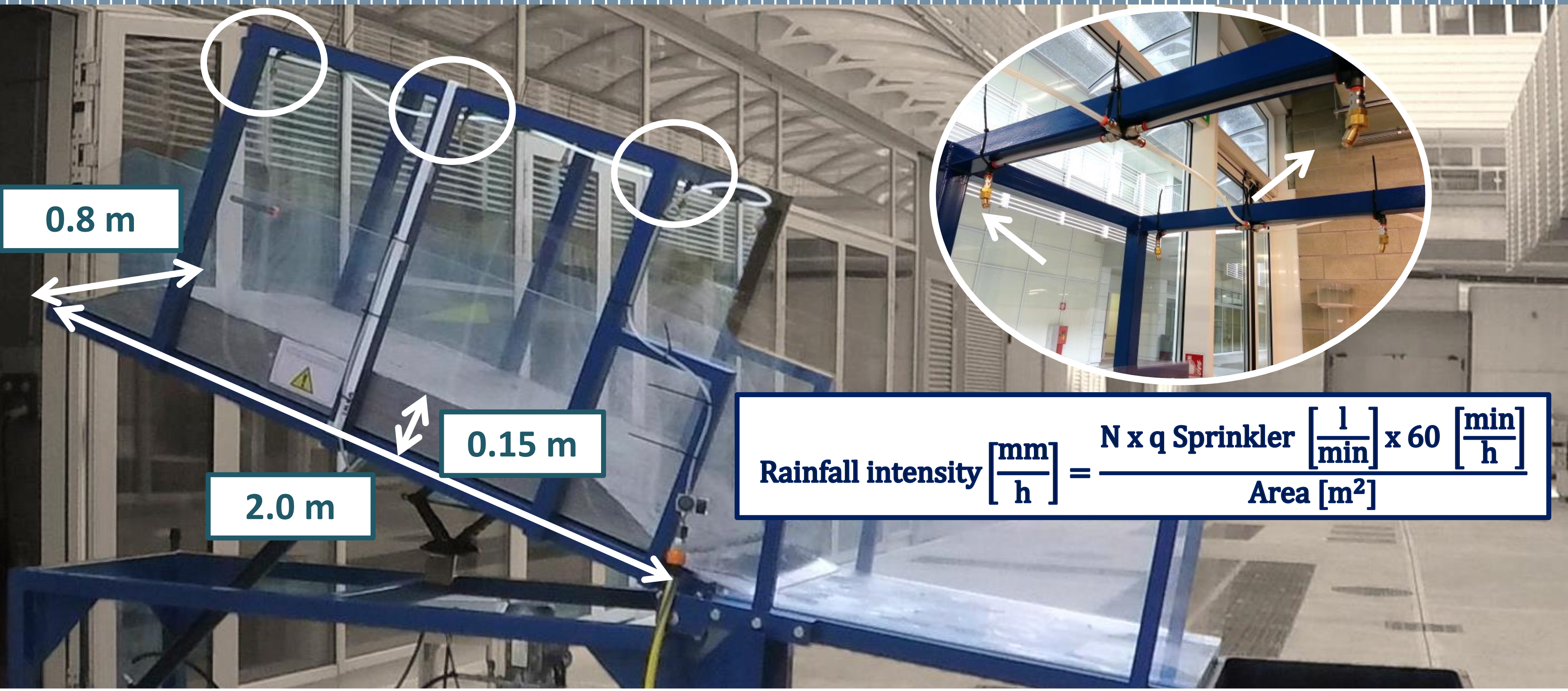
Safety factor, FS as a function of hydrology and geology



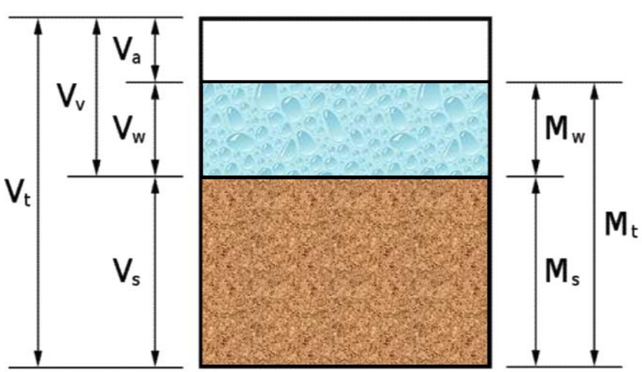




Physical modelling



$$\text{Rainfall intensity}\left[\frac{mm}{h}\right] = \frac{N \times q\ \text{Sprinkler}\left[\frac{l}{min}\right] \times 60\left[\frac{min}{h}\right]}{\text{Area}\ [m^2]}$$

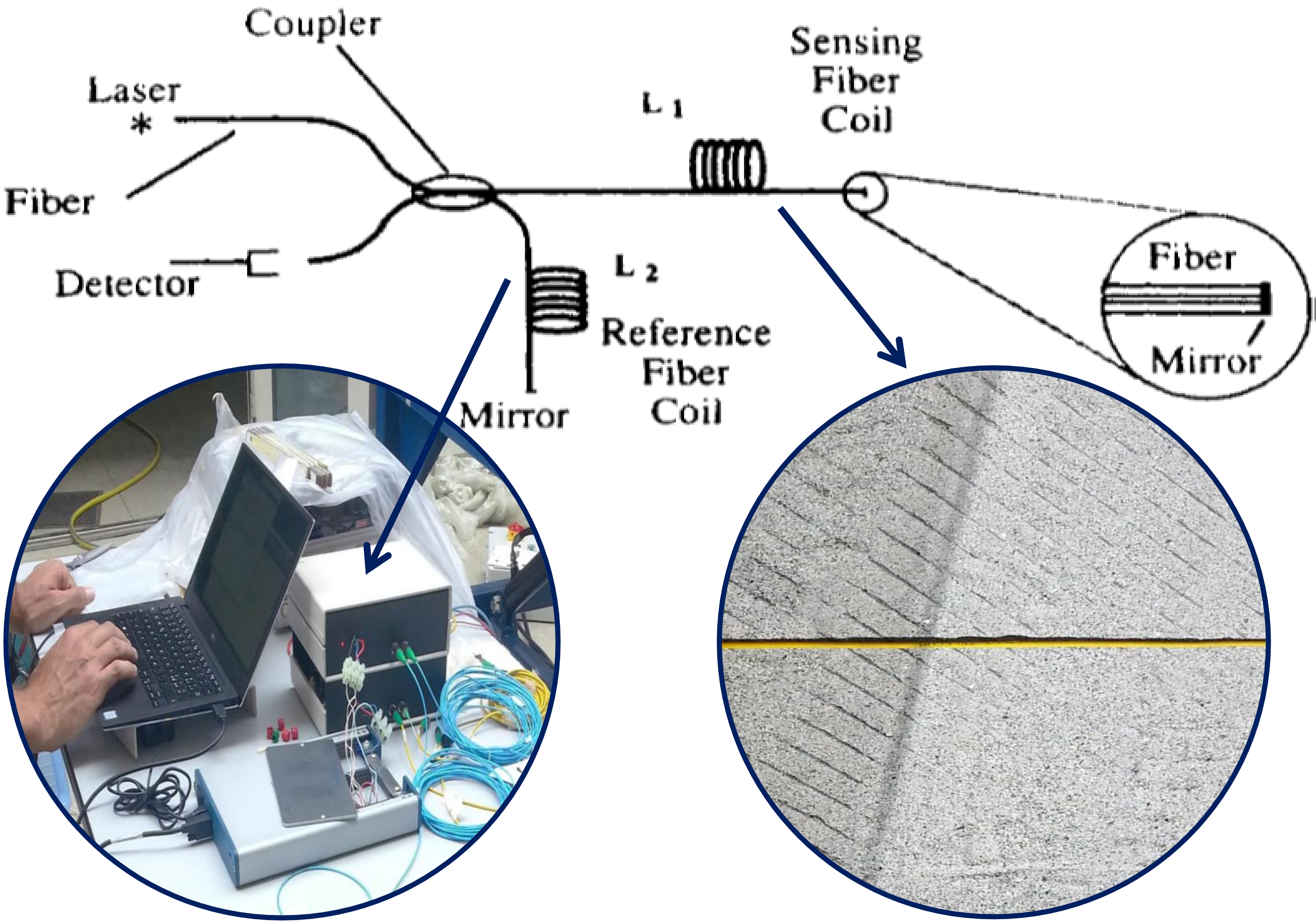


- Water content
- Porosity
- Permeability

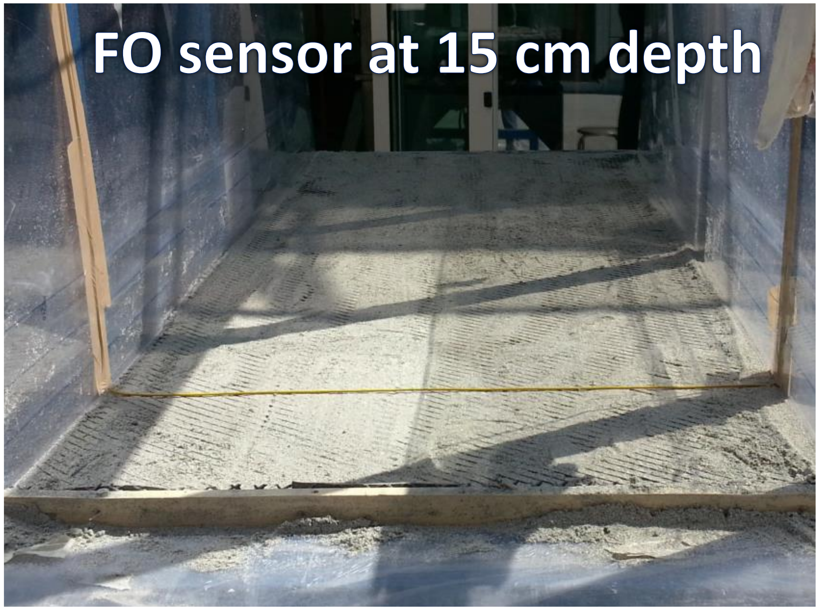
Infinite slope assumed: h/L < 1/10

Physical modelling

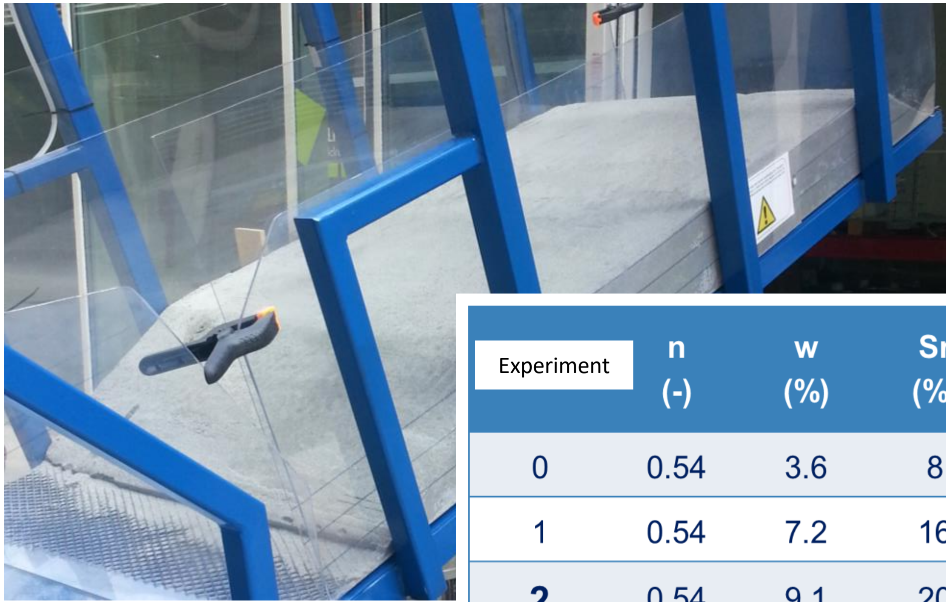
Michelson's Interferometer

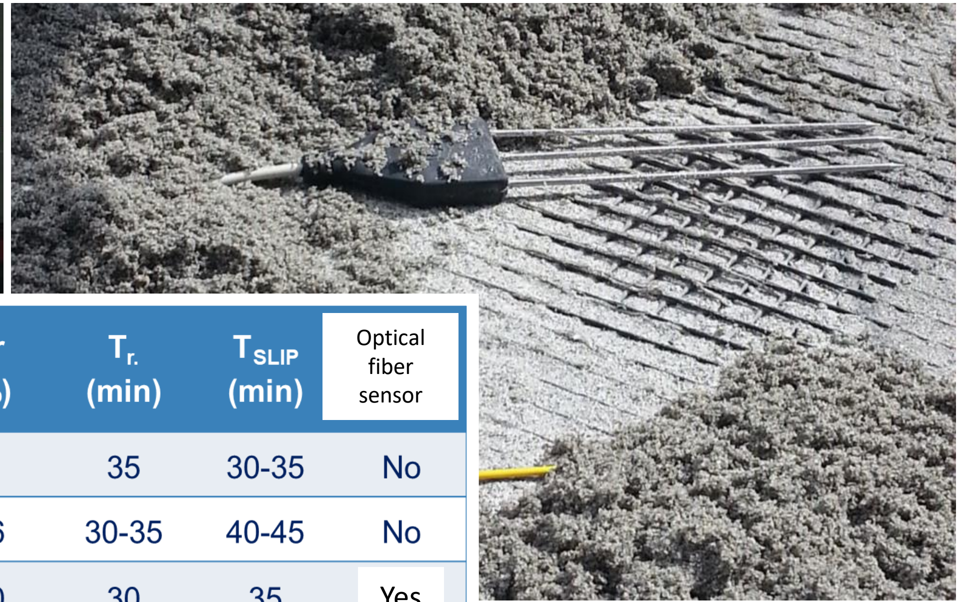


Experimental setup: optical fiber

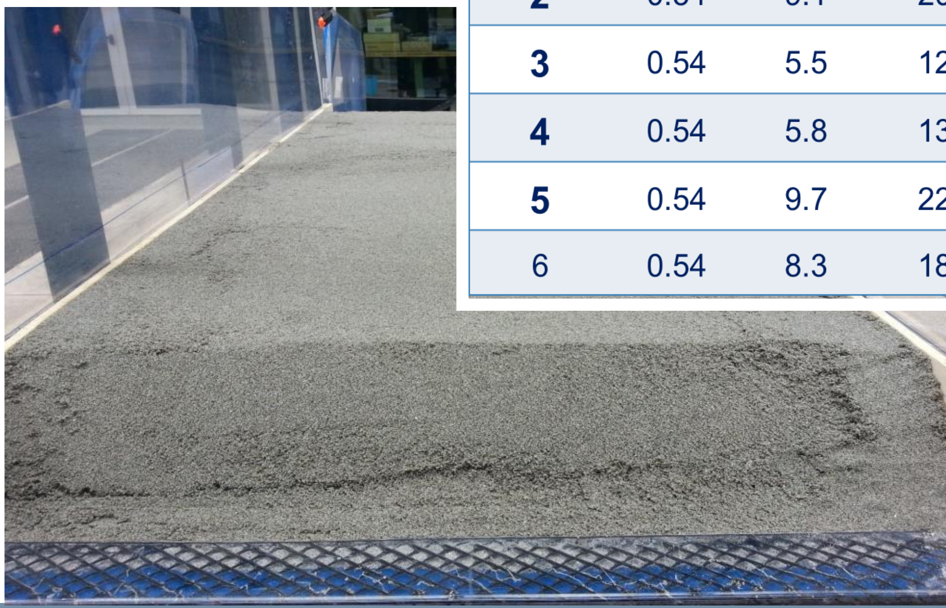


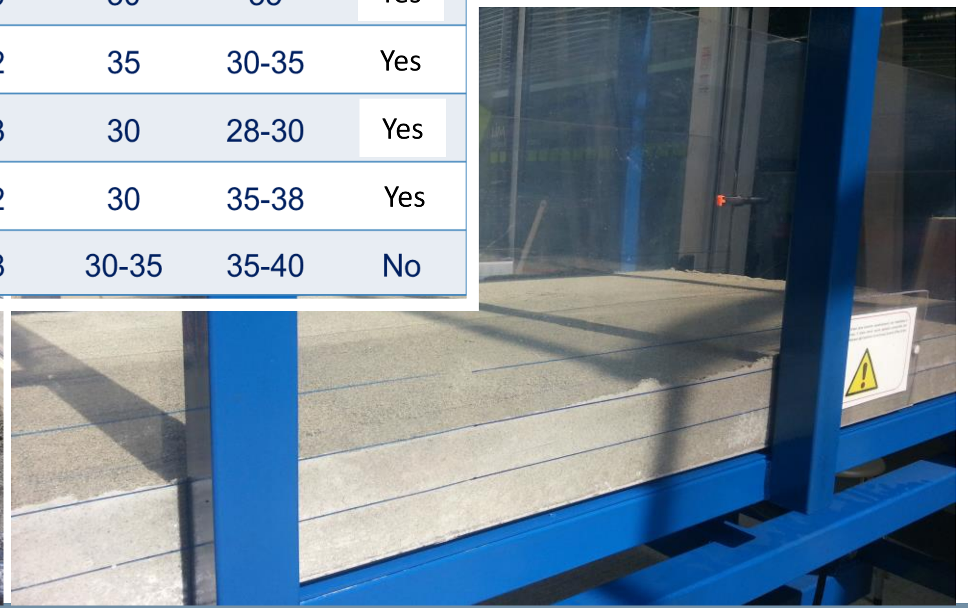
Simulations



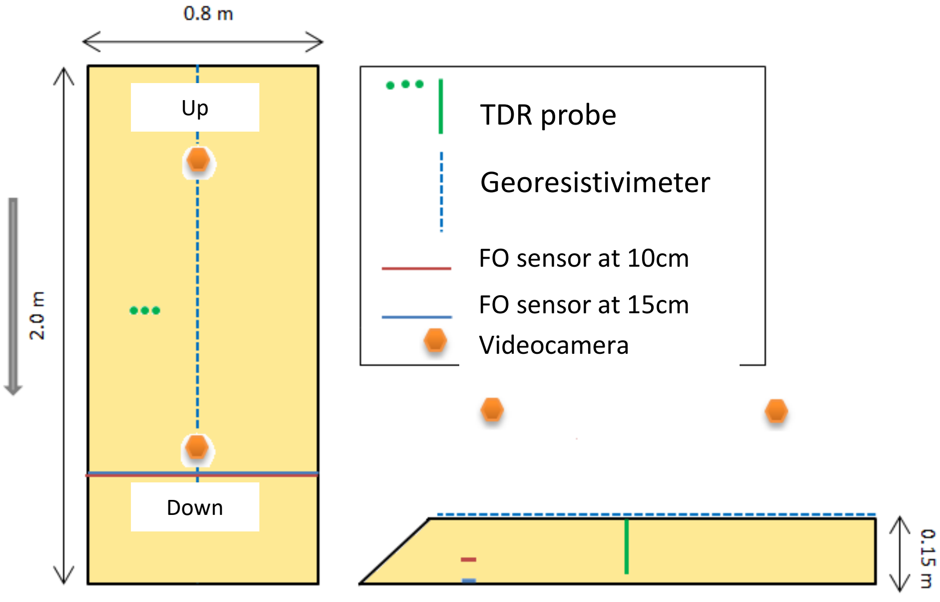


Experiment	n (-)	w (%)	Sr (%)	$T_{r.}$ (min)	T_{SLIP} (min)	Optical fiber sensor
0	0.54	3.6	8	35	30-35	No
1	0.54	7.2	16	30-35	40-45	No
2	0.54	9.1	20	30	35	Yes
3	0.54	5.5	12	35	30-35	Yes
4	0.54	5.8	13	30	28-30	Yes
5	0.54	9.7	22	30	35-38	Yes
6	0.54	8.3	18	30-35	35-40	No





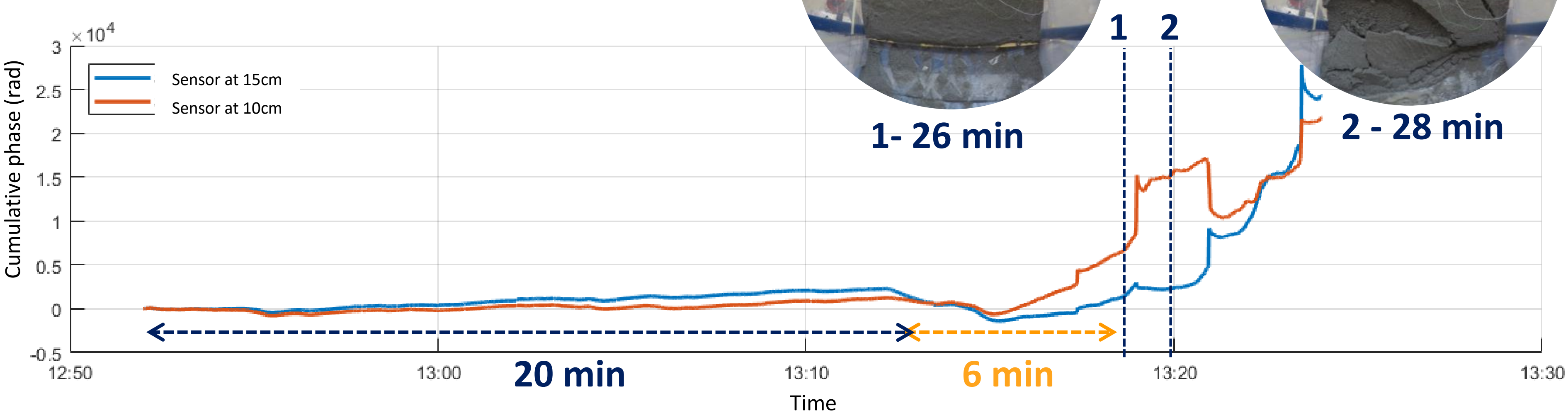
Experiment #2



Top view

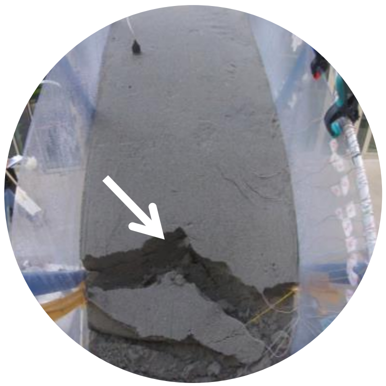
Side view

Date and time	22 May 2017 Start 12.52 End: 13.22
Initial conditions	Inclination: 40° , n= 0.54 ϴ= 11%, Sr= 20%
Precipitation	48 mm/h for 10 mins Rainfall paused for 10 mins 81 mm/h for 10 mins
SLIP	Instability at 35 min



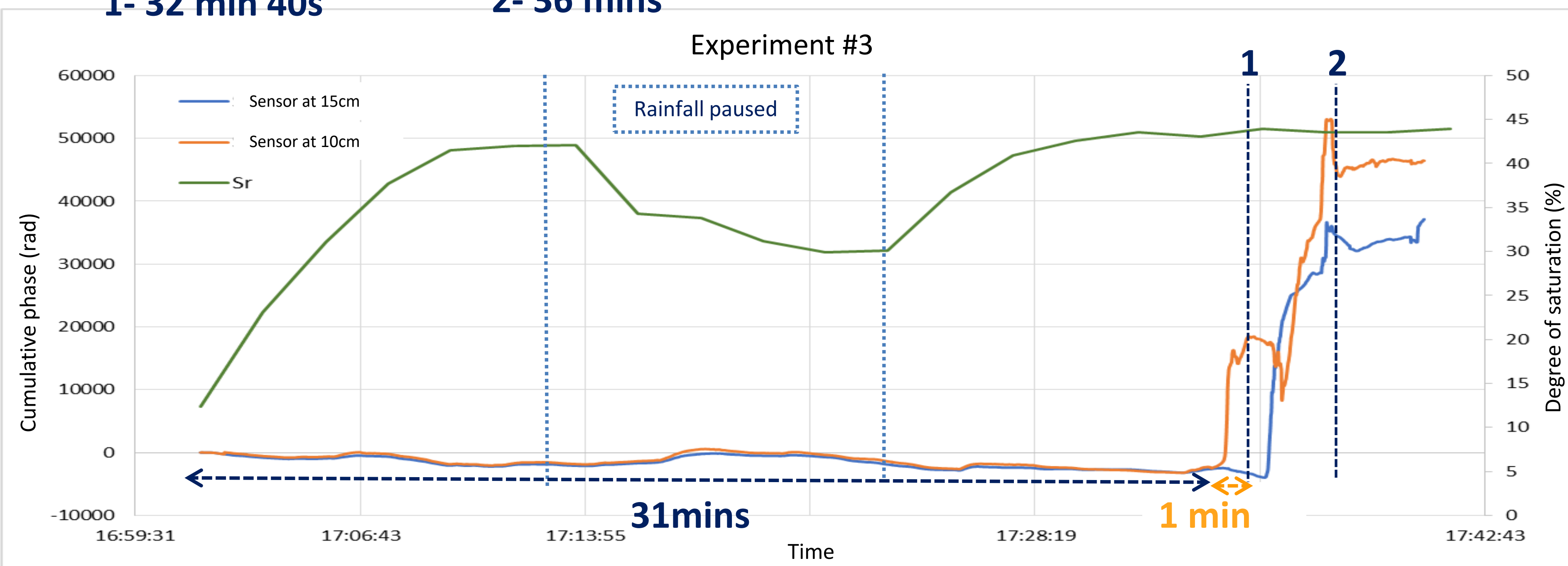
Experiment #3

Date and time	22 May 2017 Start: 17.02 End: 17.40
Initial conditions	Inclination: 40°, n= 0.54 ϴ= 6.7%, Sr= 12%
Precipitation	54 mm/h for 10 mins Rainfall paused for 10 mins 94.5 mm/h for 18 mins
SLIP	Instability at 30-35 min



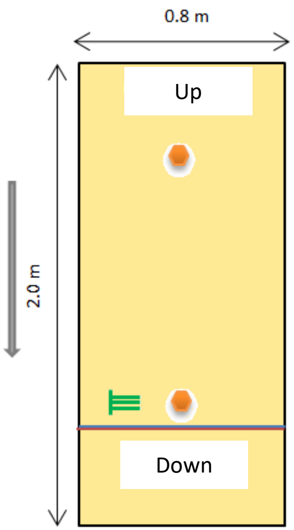
1- 32 min 40s

2- 36 mins

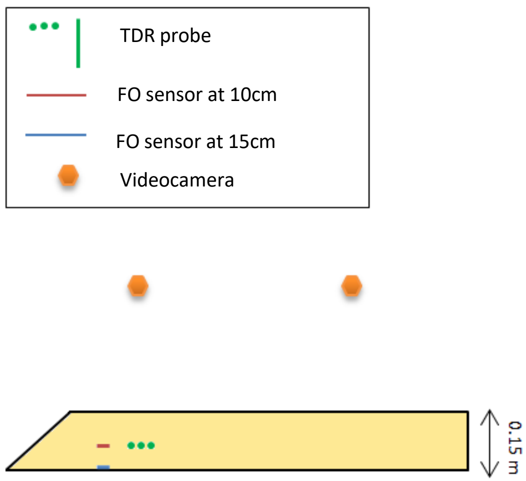


Experiment #4

Date and time	26 May 2017 Start: 11.54 End: 12.27
Initial conditions	Inclination: 40°, n= 0.54 ϴ= 7%, Sr= 13%
Precipitation	54 mm/h for 10 mins Rainfall paused for 10 mins 94.5 mm/h for 13 mins
SLIP	Instability at 28- 30 min

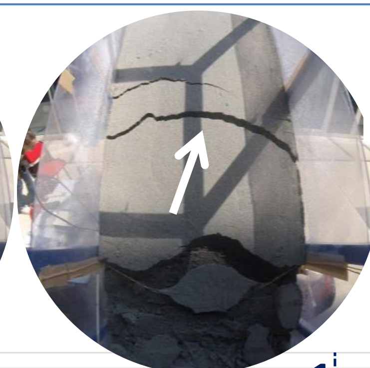


Top view

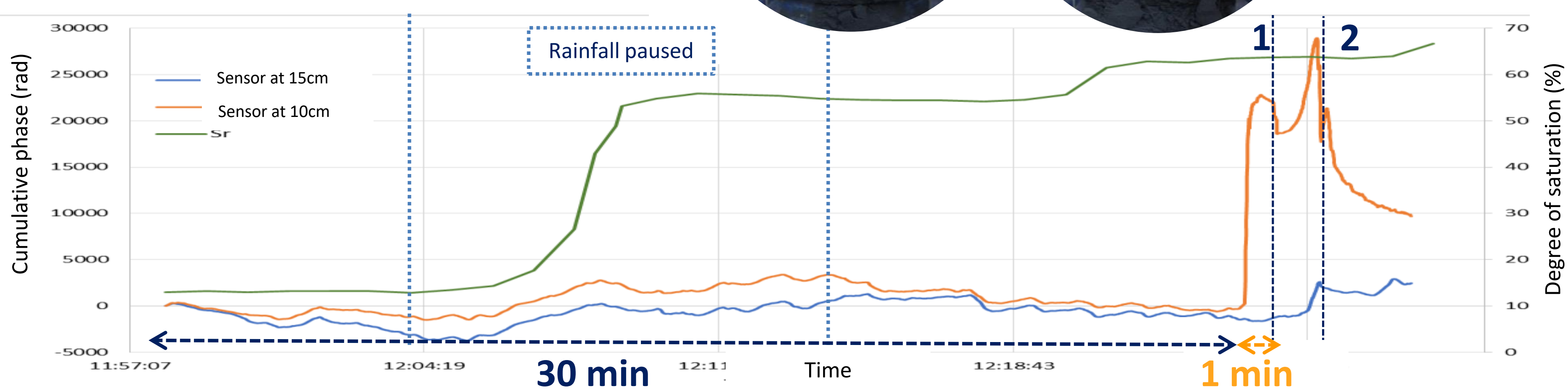


Side view

1- 31 min



2- 32 min 30sec

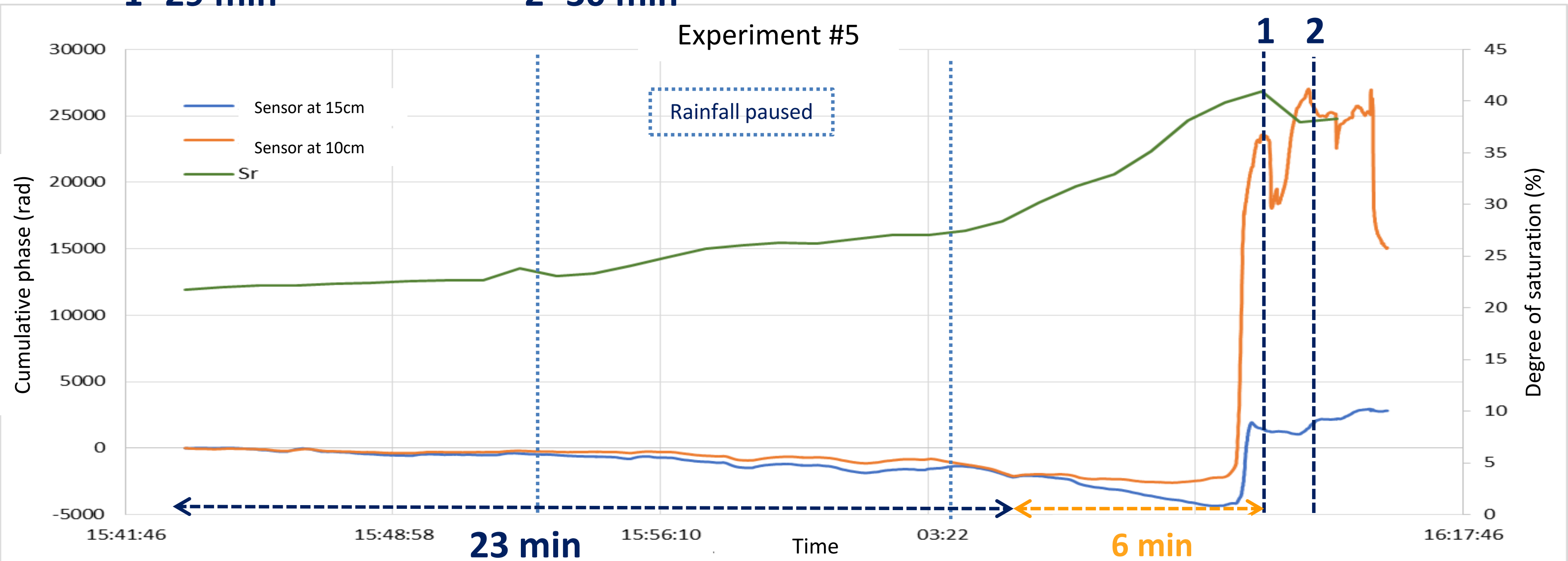


Experiment #5

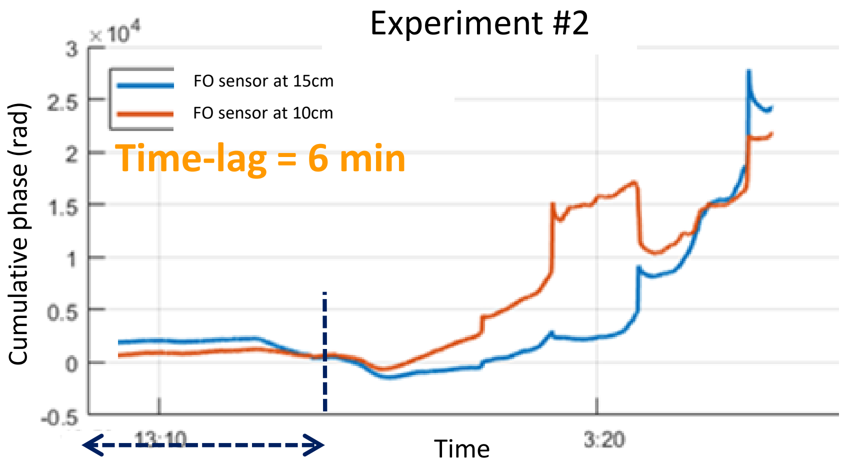
1- 29 min

2- 30 min

Data and time	26 May 2017 Start: 15.43 End: 16.18
Initial conditions	Inclination: 40° n= 0.54 ϴ= 11.7%, Sr= 22%
Precipitation	48 mm/h for 10 mins Rainfall paused for 10 mins 81 mm/h for 10 min
SLIP	Instability at 35 min

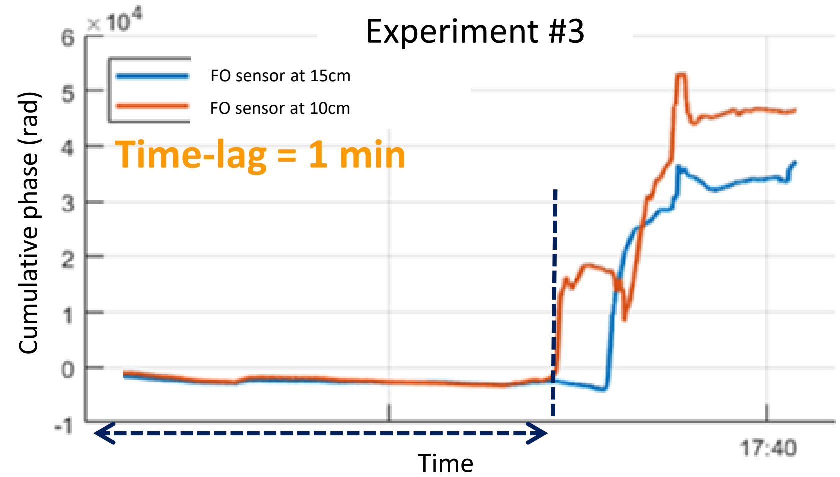


Results



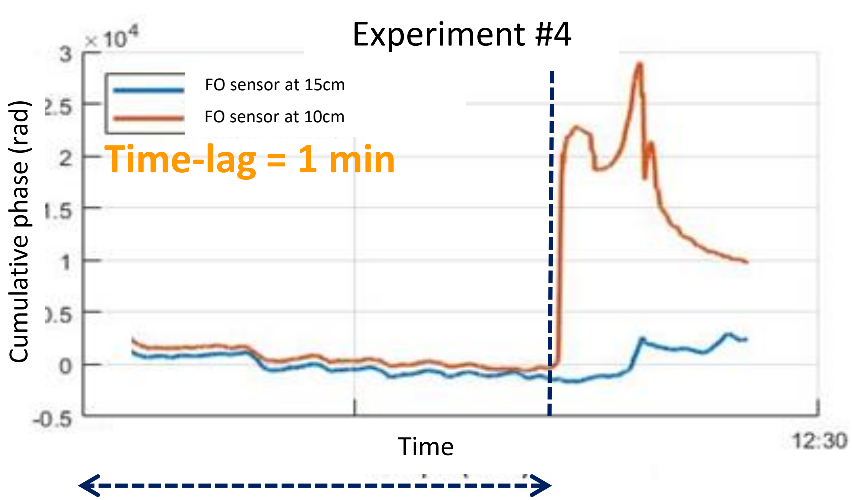
$FS_i = 7.48$ $FS_f = 2.00$

$Sr_i = 20\%$ $Sr_f = 40\%$



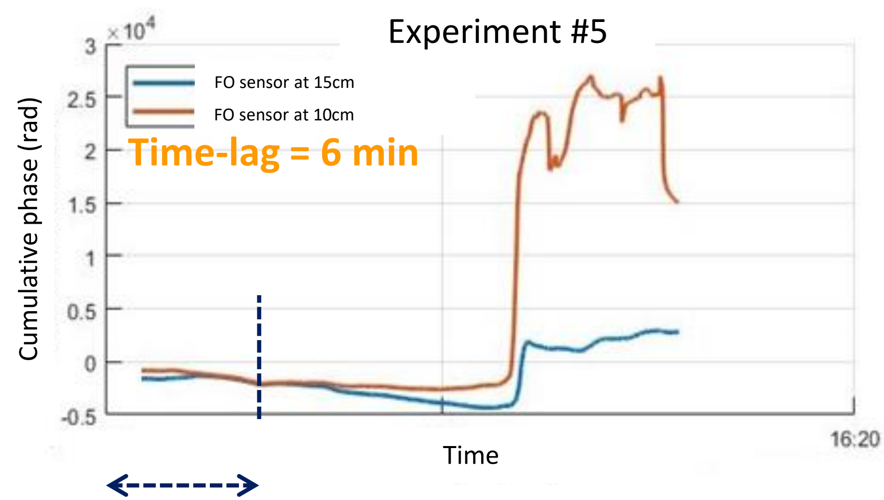
$FS_i = 5.50$ $FS_f = 1.22$

$Sr_i = 12\%$ $Sr_f = 40\%$



$FS_i = 4.91$ $FS_f = 1.28$

$Sr_i = 13\%$ $Sr_f = 60\%$



$FS_i = 7.51$ $FS_f = 1.97$

$Sr_i = 22\%$ $Sr_i = 35\%$

Conclusions

The sensor forecasted the instability in advance as follows:

- With water content Sr = 20-22%   FS ≈ 2.00
- With water content Sr = 12-13%   FS ≈ 1.25

Future prospects:

- To execute further simulations with different intensity and duration of the precipitation
- To execute simulations with heterogeneous terrain
- To evaluate the possibility to use alternative fiber optic sensors
- Inclinometers with fiber optics sensor

Thank you for your attention!