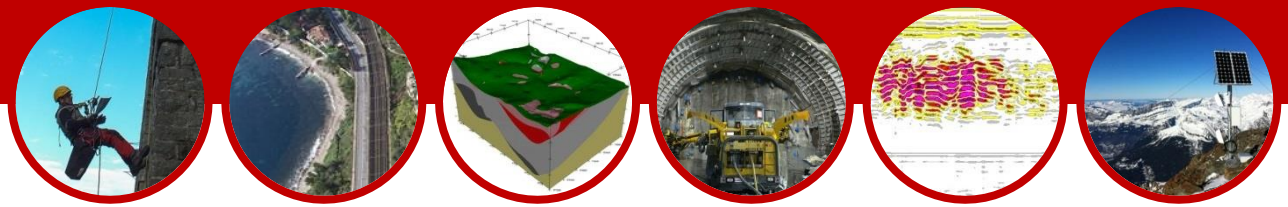

Radio-Frequency Identification (RFID), a new technique to monitor ground deformations

Mathieu Le Breton, PhD Student

L. Baillet, E. Larose, E. Rey, F. Guyoton, P. Benech, D. Jongmans

mathieu.le-breton@univ-grenoble-alpes.fr

WEGENER 2018 - Grenoble

Goal

Monitor ground deformation **>1cm**

of a **landslide**

with a **dense** resolution (space/time)

on a **100-meter** large earth surface

using Radio-Frequency Identification (**RFID**)

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What is Radio-Frequency Identification (RFID) ?

- Radio-Frequency barcode, for logistics, retail, manufacturing, transportation…
- Billions of tags produced per year
- Cost of one tag : 0.01-20€
- Tags can be localized (research)

Tags could track landslide displacements

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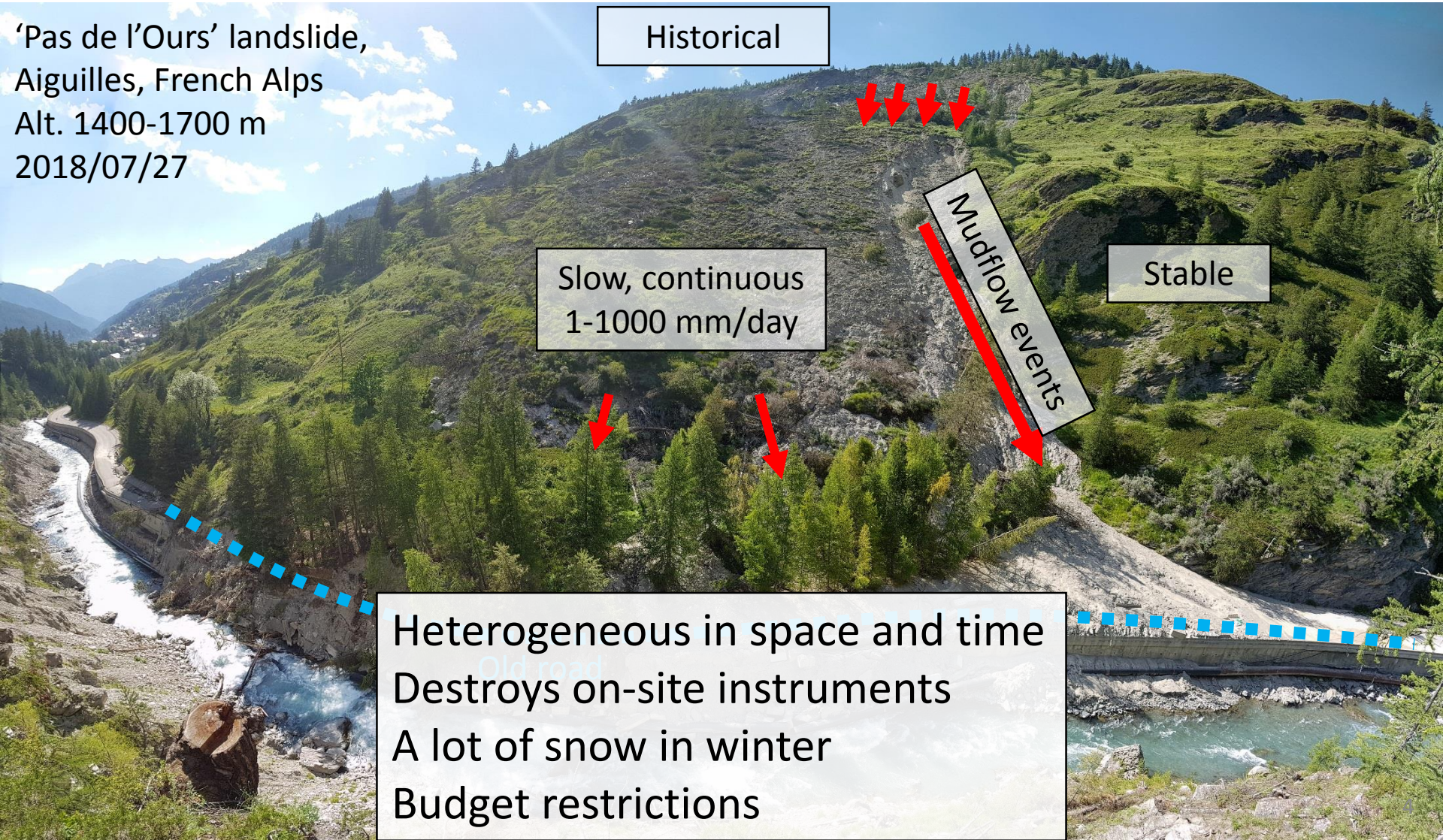
Why monitoring landslide displacements ?

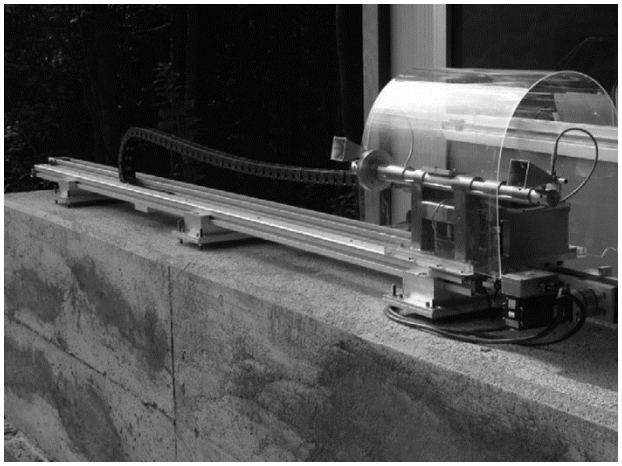
Investigation, research

Early Warning System



State of the art limitations : Cost of the station

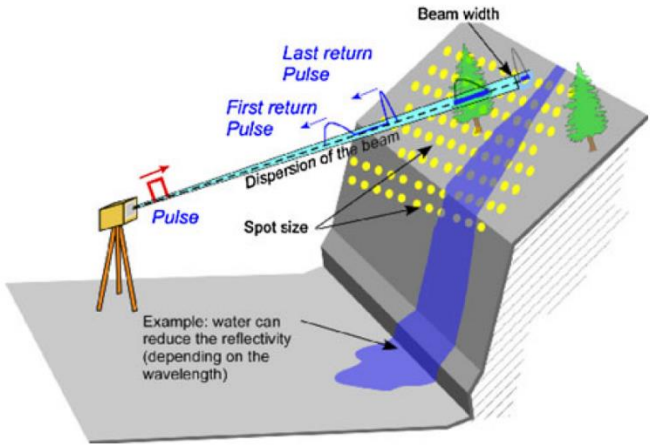
Radar Interferometer (GB-SAR)



Montserrat et al., 2014

100 k€

Laser scanner



Jaboyedoff et al., 2010

Total station

30 k€

RFID station : 5-10 k€

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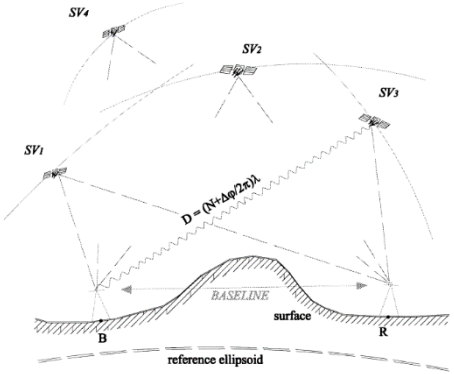
Cost per monitored point

DGPS



Gili et al., 2000

Extensometer

Angeli et al., 2000

Low-cost DGPS

Benoit et al., 2015

Active radio transponders

Kenney et al. 2009
Intrieri et al., 2018

10 000 €/pt → 200 €/pt + batteries, solar panel...

RFID tag : 20 €/pt
passive, no local power

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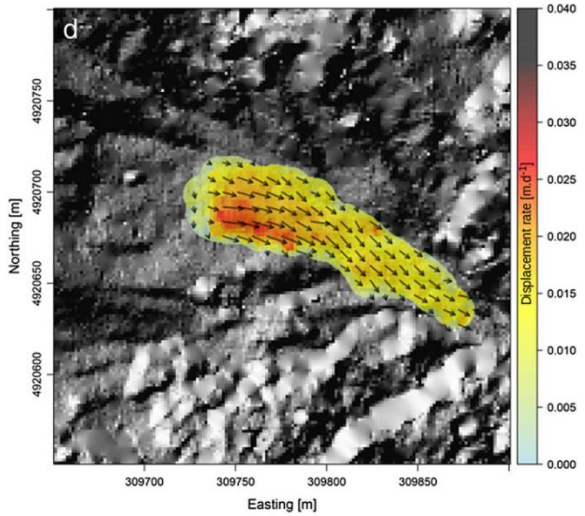
Time resolution

Satellite



Intrieri et al., 2018b, Stumpf et al., 2017

Ground-based
Image correlation

Travelletti et al., 2014

several days → 0.5 day

RFID : 3-30 milliseconds per point

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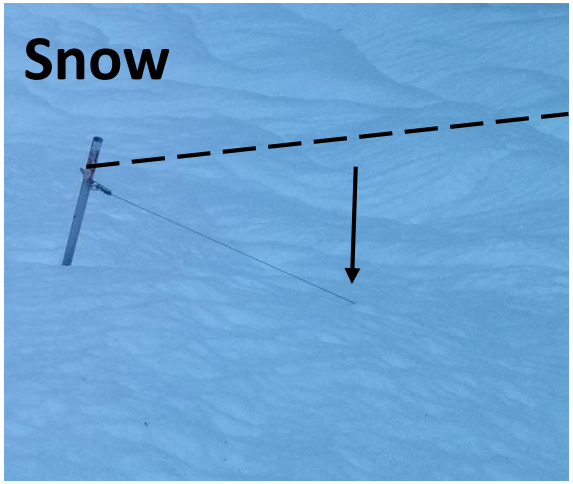
Problems that make data gaps



~~Mechanical~~

~~Optical~~

Radio-Frequency : works without clear line of sight

Tags : simple, no connectors, sealed

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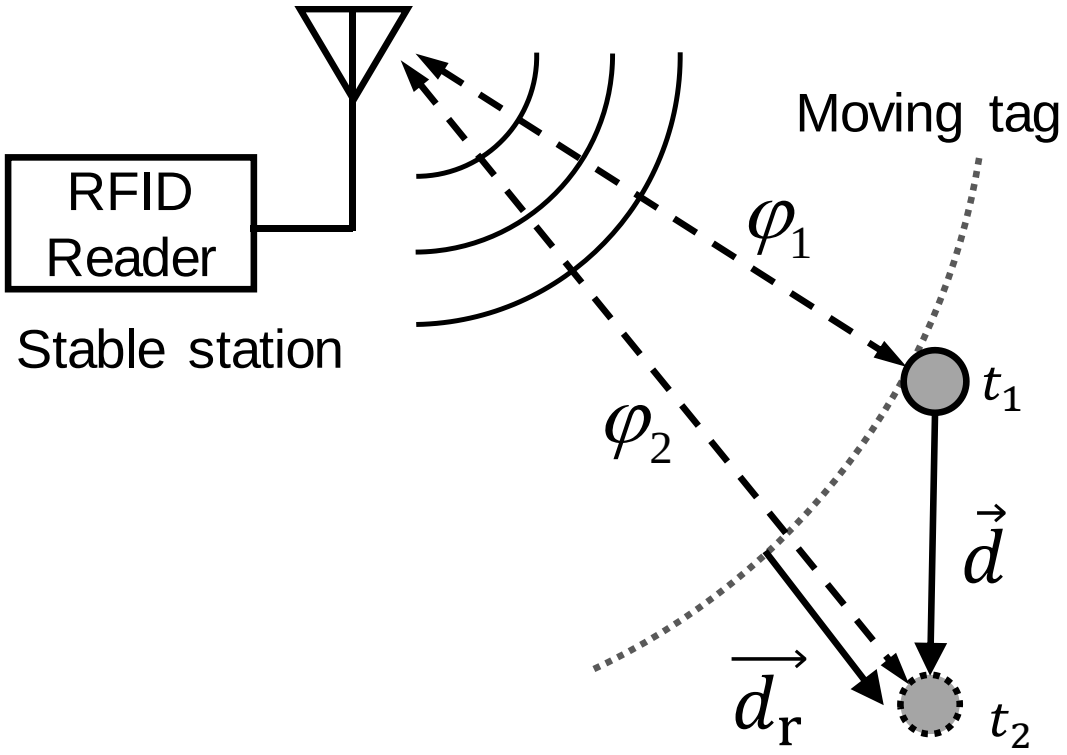
How to measure the displacement ?



Phase ⇔ Displacement

$$\varphi_{air} = -\frac{4\pi}{\lambda} d_r$$

Nikitin et al., 2000

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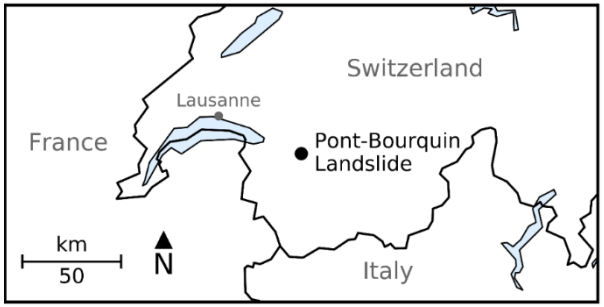
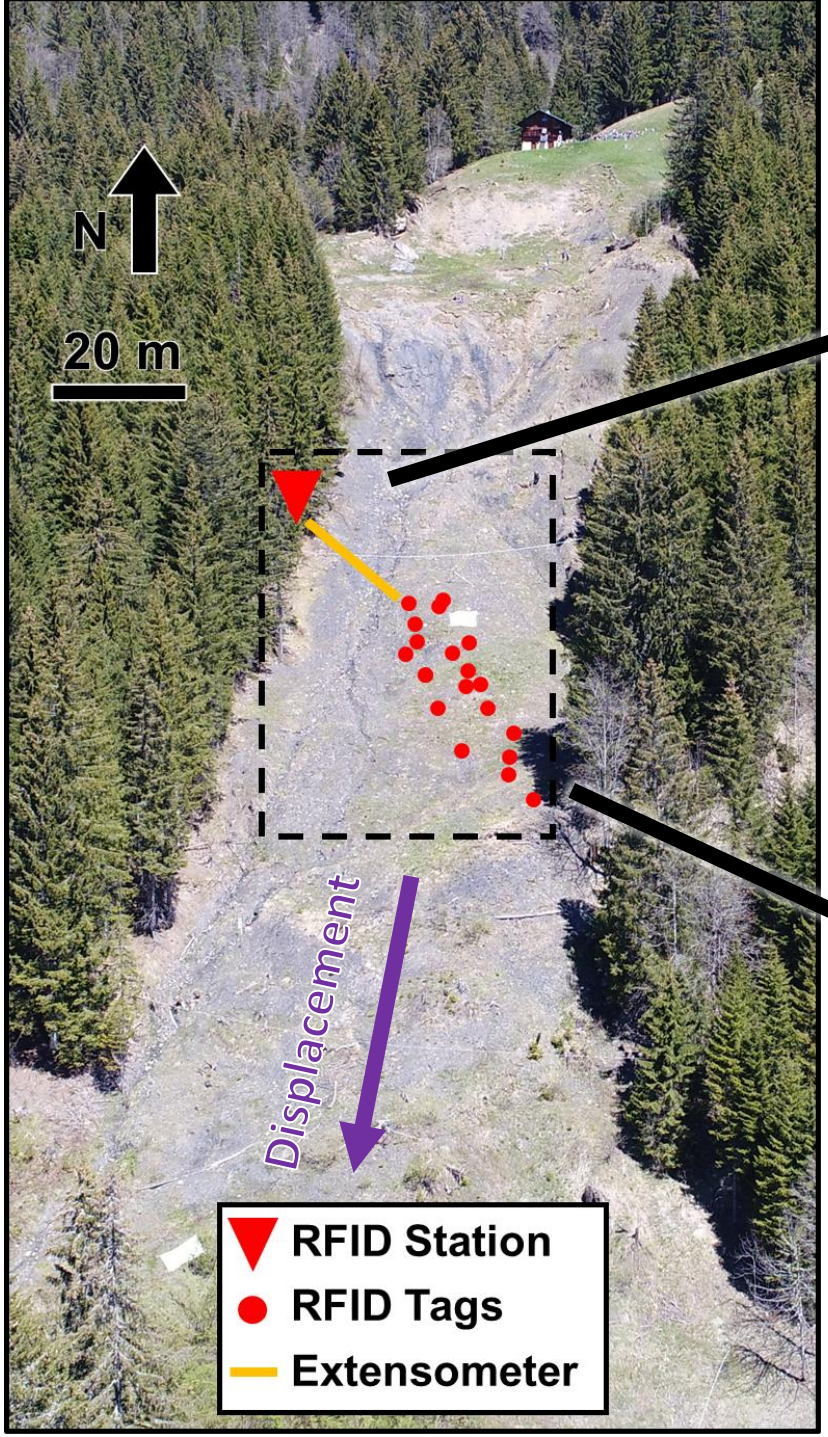
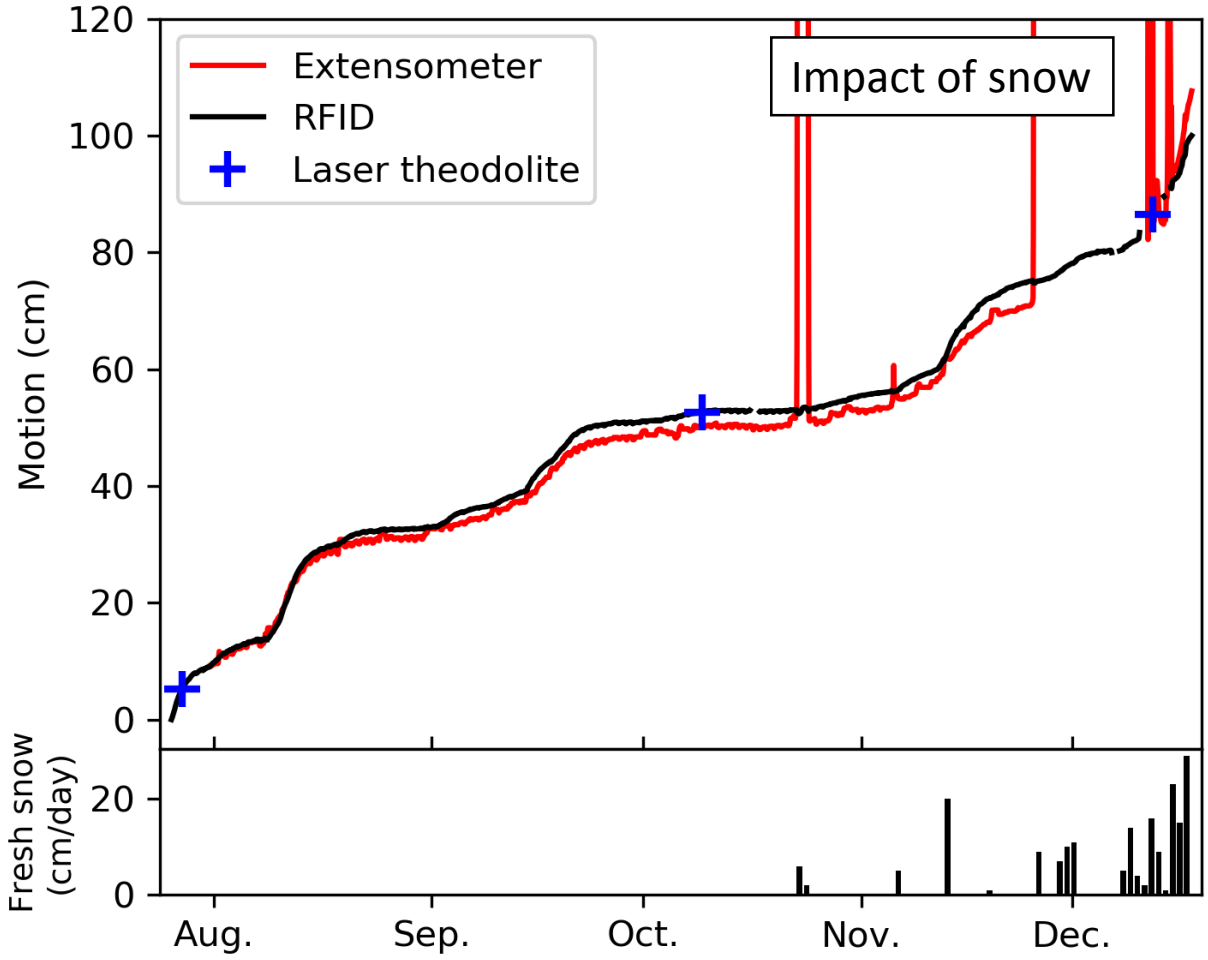
Test installation



Pont-Bourquin Landslide, Switzerland



Does it work ?



(Le breton et al., *submitted*)

RFID technique

Validated

+

More stable than wire extensometer under rain and snow

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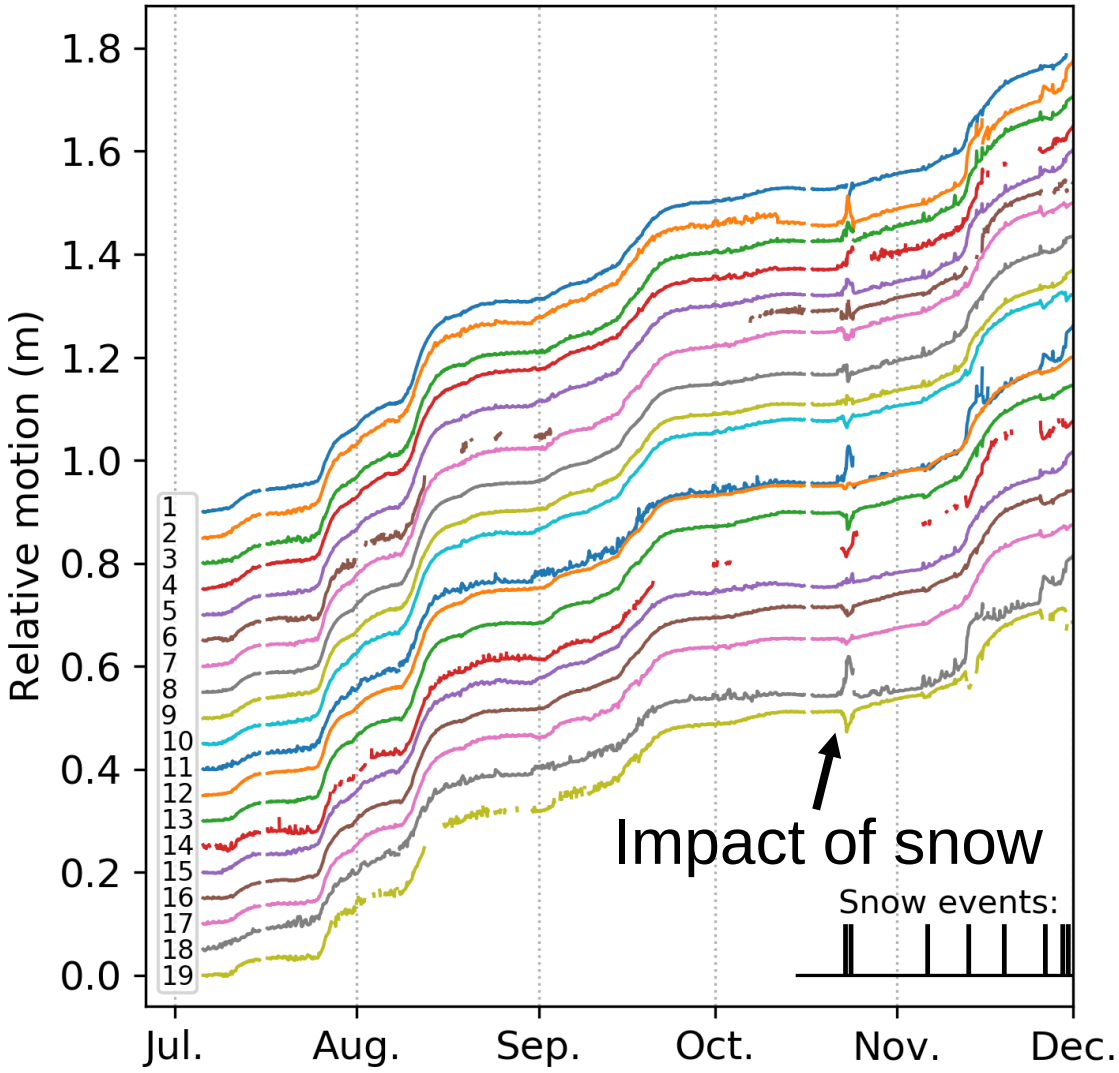
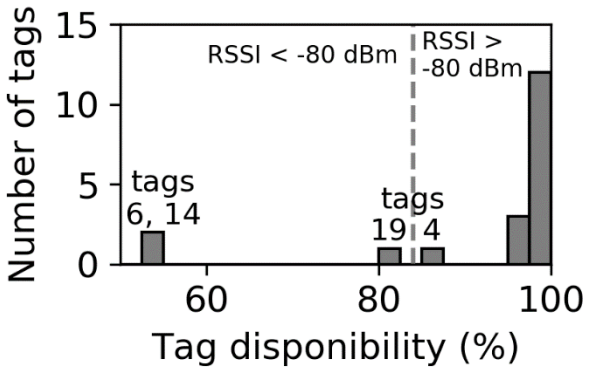
Does it work with multiple tags ?





Disponibility > 95%

For most of the tags

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Accuracy (99.7% confidence interval)

- Laboratory tests :
  (short distance, 6m)
  < 2 mm
  (Le breton et al., 2017)
- Real use case :
  (60-m distance, 19 tags)
  1 cm
  (Le breton et al., *submitted*)
- Exception of snow :
  4 cm

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Advantages

- 20€ / tag & simple installation => **spatially dense**
- 5 k€ a station => adequate for **moderate risk**
- Resolution 3-30 ms & light data => **Reactive** early warning
- Works with rain, snow and fog => **High disponibility**
- Accuracy 1cm => sufficient for landslides

Limitations

- Range 80 m => **small/medium area**
  - But recent research reaches 1km (Amato et al. 2018)
- Accuracy deteriorated with snow (4cm)
- Phase ambiguity (8 cm)

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Perspectives : new use cases ?

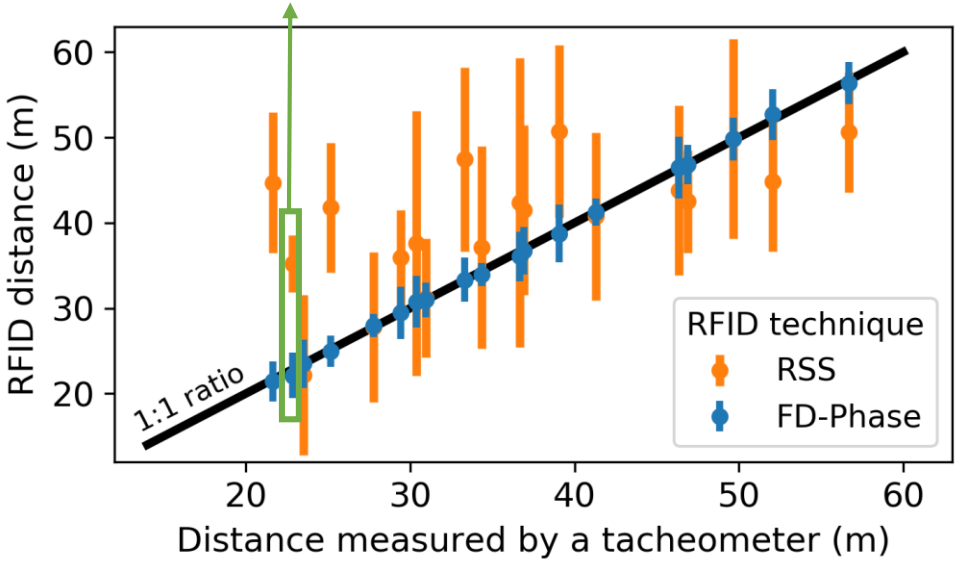
mathieu.le-breton
@univ-grenoble-alpes.fr

Additional Slides…

RF absolute ranging techniques

$$\delta r = -\frac{v}{4\pi f}\delta\varphi_{air}$$

Time series on the next slide



Signal strength (RSS) :

$$r_i \approx r_{ref} \sqrt[4]{P_{ref} / P_i}$$

$\Rightarrow$ Error of up to 25m

$\Rightarrow$ Sensitive to interferences and antenna positions

Frequency-domain phase, using multiple carrier frequencies :

$$r = \frac{\delta\varphi_{air}}{\delta f}\frac{v}{4\pi} + r_0$$

=> Better, but still an error of +/- 2m

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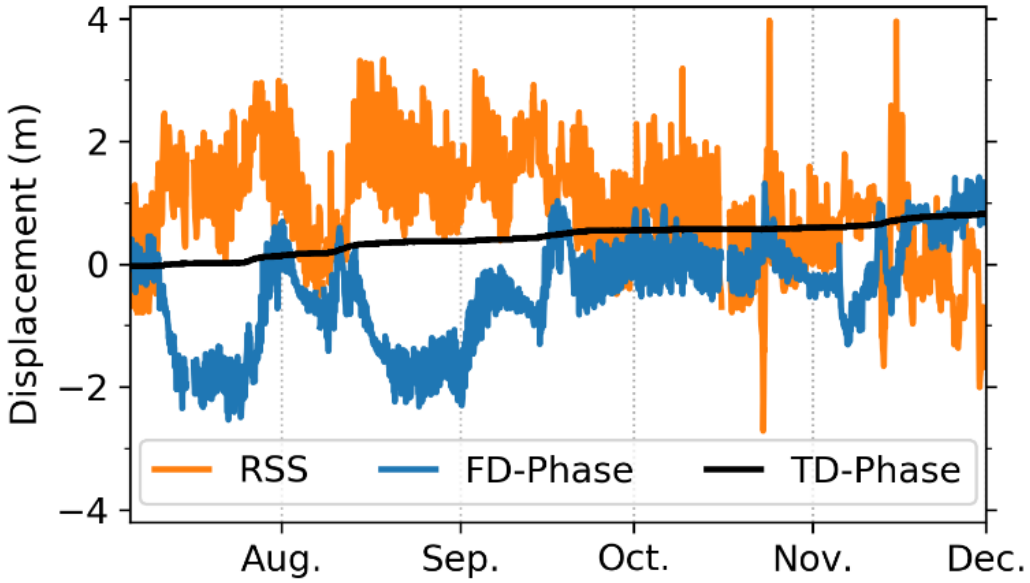
Displacement time series, with relative/absolute ranging techniques



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Limits	State of the art		RFID
Station cost	Radar, Laser scanner, Fiber optics Total station	100 k€ ↓ 30 k€	5-10 k€
Cost per point	DGPS, Extensometer, Low-cost GPS Active transponder	10 000 € ↓ 200 €+battery	20 € / tag
Time resolution	Satellite sensing Ground photo	3 days 1 day	3-30 ms/pt
Bad weather	Optical Mechanical	Fog, rain, snow Water, ice	Radio Sealed tags

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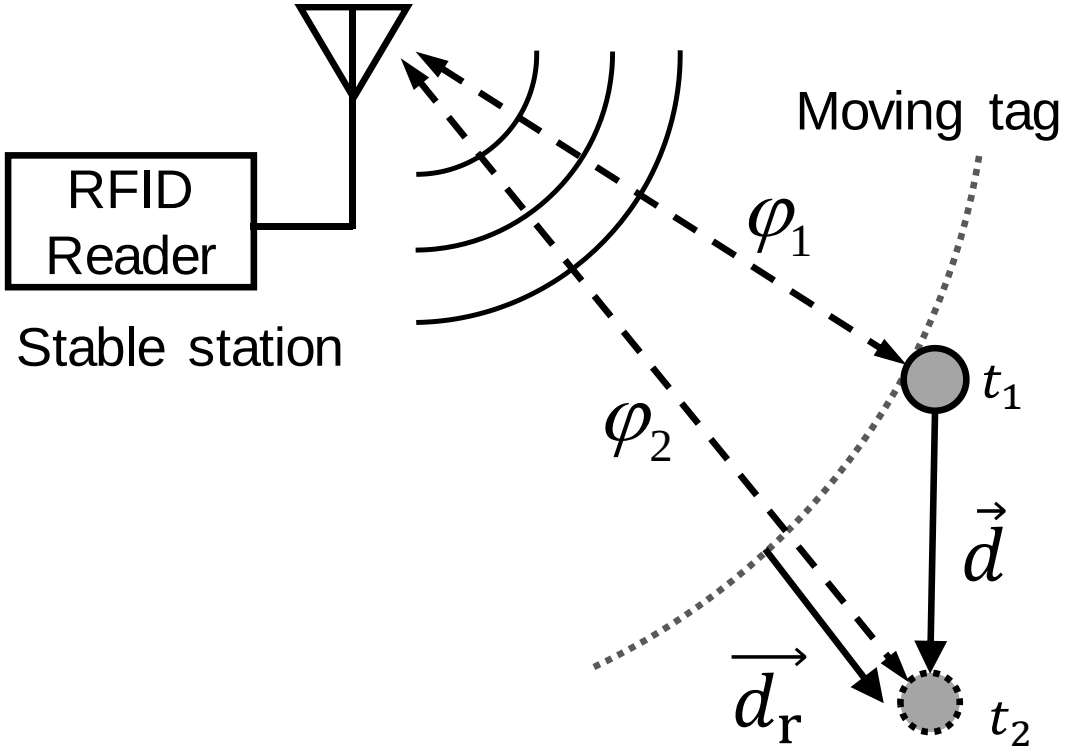
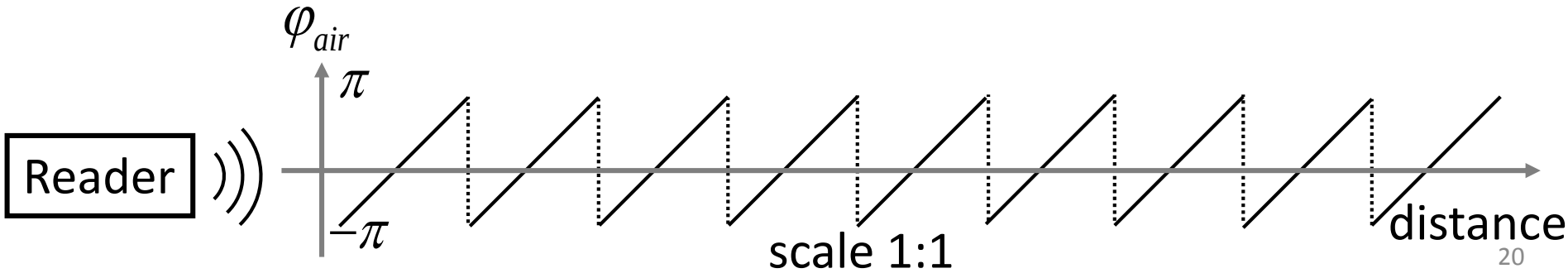
How to measure the displacement ?



Phase ⇔ Displacement

$$\varphi_{air} = -\frac{4\pi}{\lambda} d_r$$

Nikitin et al., 2000



Conclusions

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www.geolithe.com

Premiers travaux de localisation RFID en extérieur

Adapté à la surveillance de glissements de terrain

Mesure de déplacements relatifs

1 mesure toutes les 0.03 secondes

Précision < 1cm

Portée standard 60 m (prototype : 120m)

Fiable : 95% de fonctionnement

Coût faible (5k€ l'installation, 20€/tag)

Perspectives d'utilisation

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Surveillance de glissement de taille moyenne, en temps réel, avec un réseau de capteurs dense.

Chute de blocs ?

Structure génie civil ?

Travaux en cours

- Étudier le fonctionnement sous la neige
- Suivre un mouvement en 3D
- Améliorer la portée : 60m => 200m

Comparision of techniques

Technique / Comparison	RFID	Automatic Theodolite	Extenso meter
Range (m)	100	1 000	10
1-D Accuracy (mm)	5	1	20
Cost of the base (€)	5 000	30 000	1 000
Cost per point (€)	20	100	1 000
Robust to problems (rain, snow, ice, shocks, destruction, theft)	++	+	-
Time to measure (s)	0.01	20	0.01
Possible mismatch	Phase ambiguity	Target identification	no
Complementary data	Yes (signal quality, doppler, basic sensing)	Little (signal quality)	No

Portée

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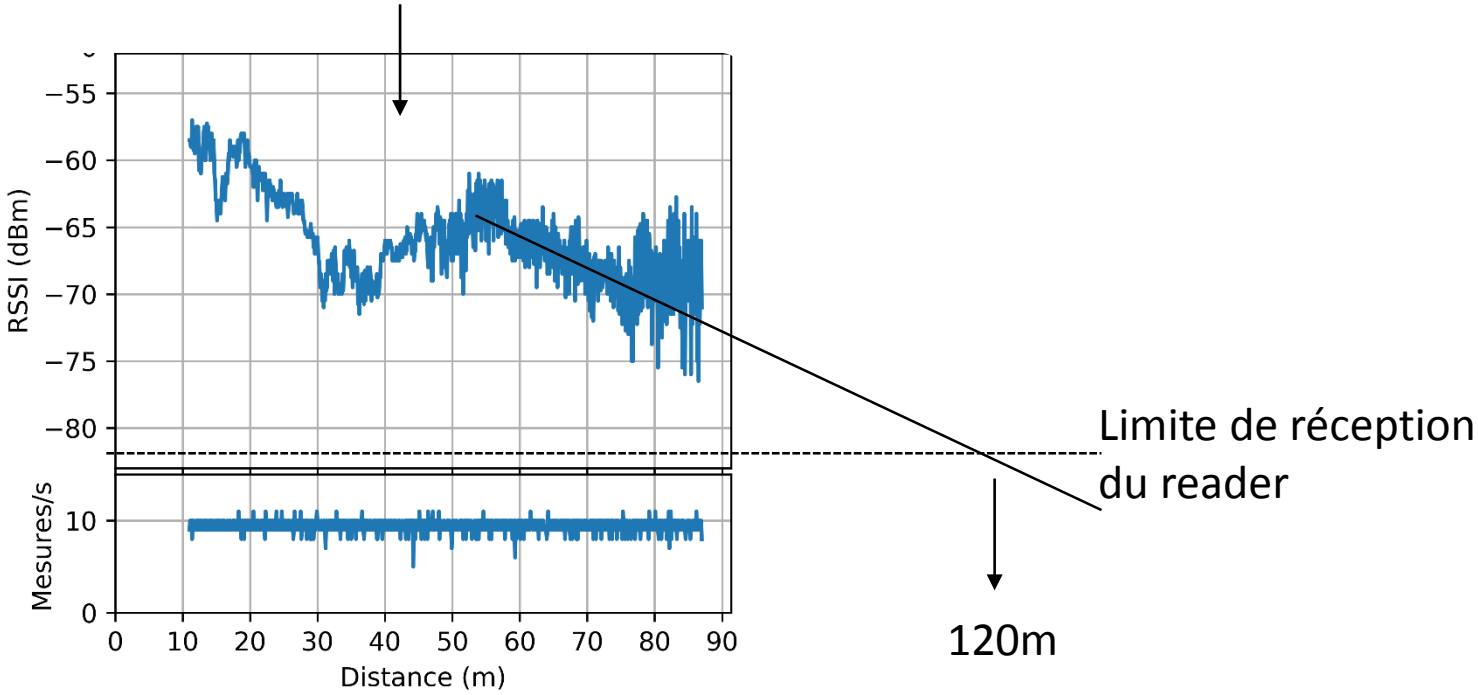
Aujourd'hui :

Tag industriel : 60m

Développements en cours pour doubler la portée

Tag maison : 120m



How to use motion tracking ?
Ex: Deconvolution of an impulse response

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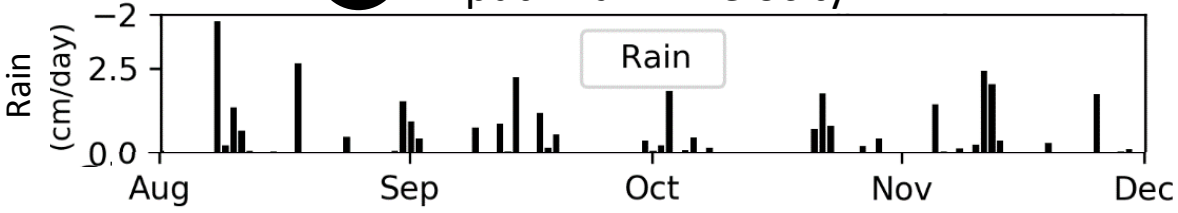
1 Input : Rain + velocity

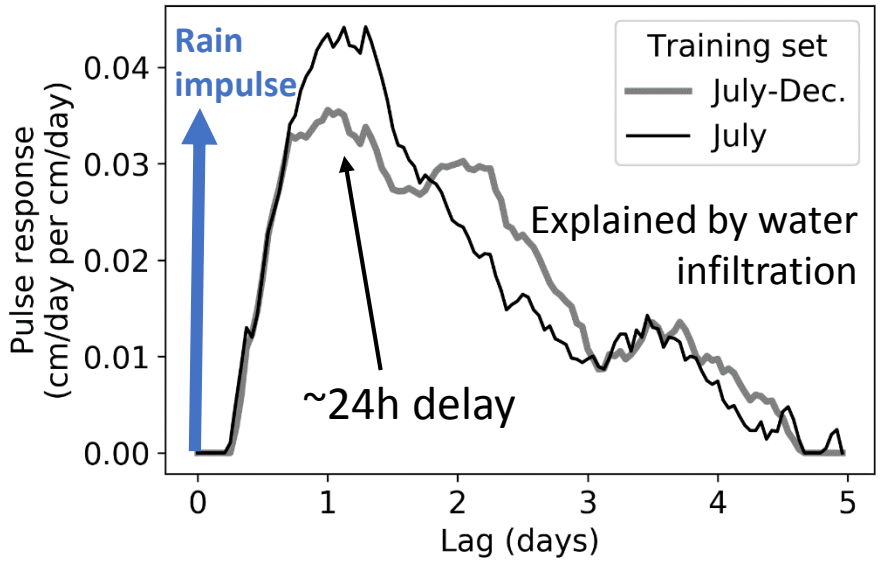


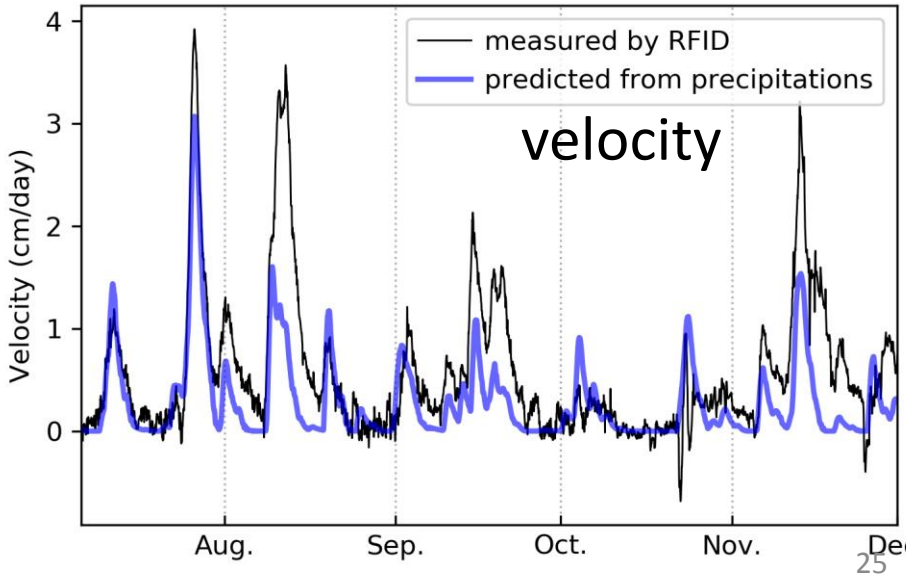
Deconvolution
(Rain, velocity)

Convolution
(Rain, Impulse response)

2 Impulse response to rain

3 Rain-based prediction





Estimation of the accuracy

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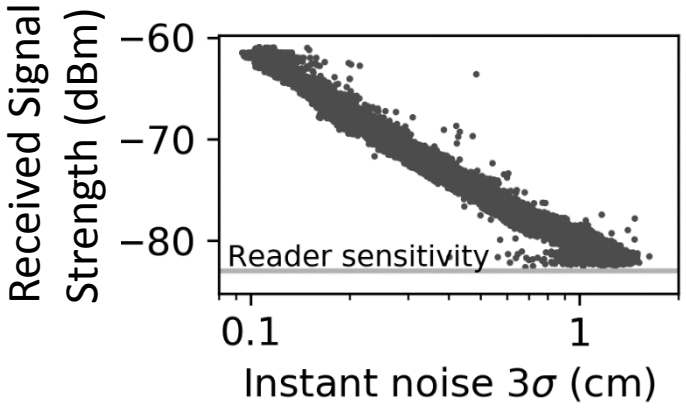
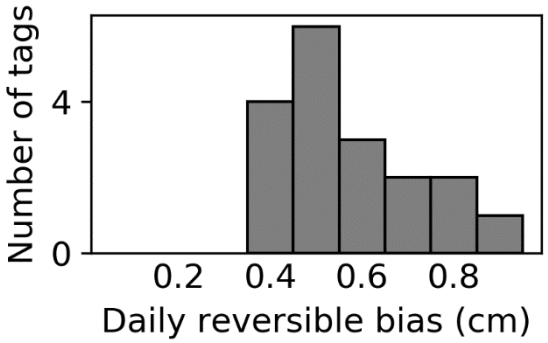


Short-term

⇒ < 2cm

⇒ Stacking reduces this error (ex: 1 minute average)

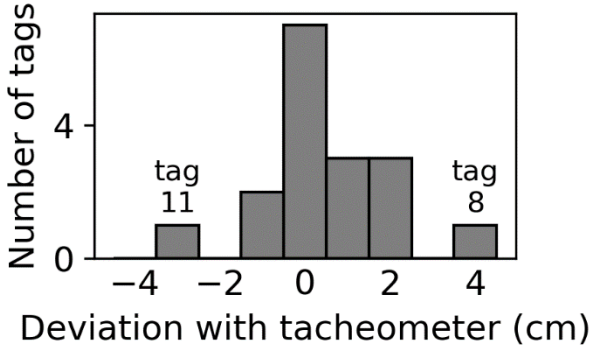


Daily

⇒ < 1 cm on dry days

Conclusion :

Accuracy ≈ 1 cm



Long-term

⇒ Centered on zero

⇒ Spread = error of the tacheometer levees