Volcanisme sismicité et tectonique des Antilles

Rencontres scientifiques OVSM-IPGP-PREST

Saint-Pierre, Martinique

High resolution optical displacement sensor: Development and qualification for remote applications in seismology and volcanology

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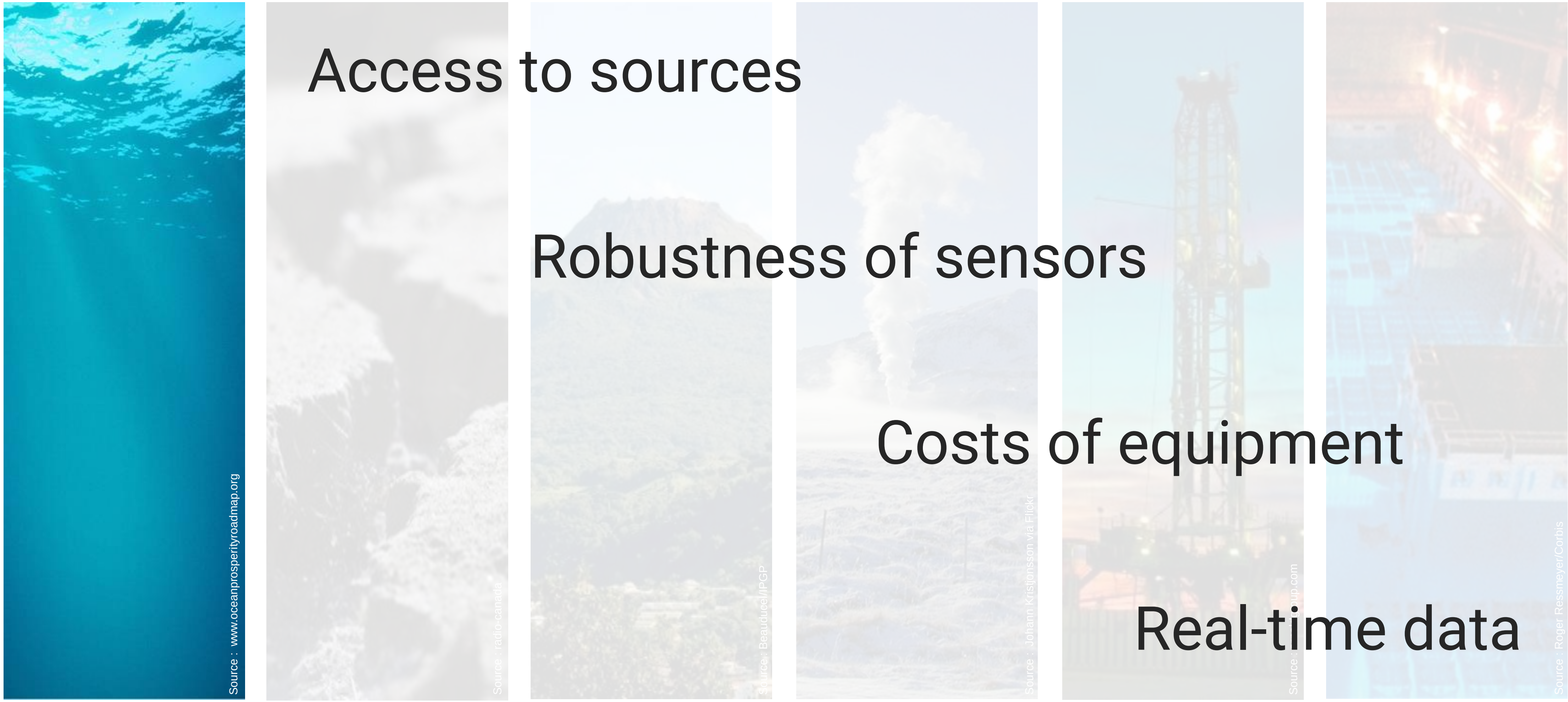
Context and purposes



Access to sources

Robustness of sensors

Costs of equipment

Real-time data

→ Move the most vulnerable part of the monitoring system away from the measurement point

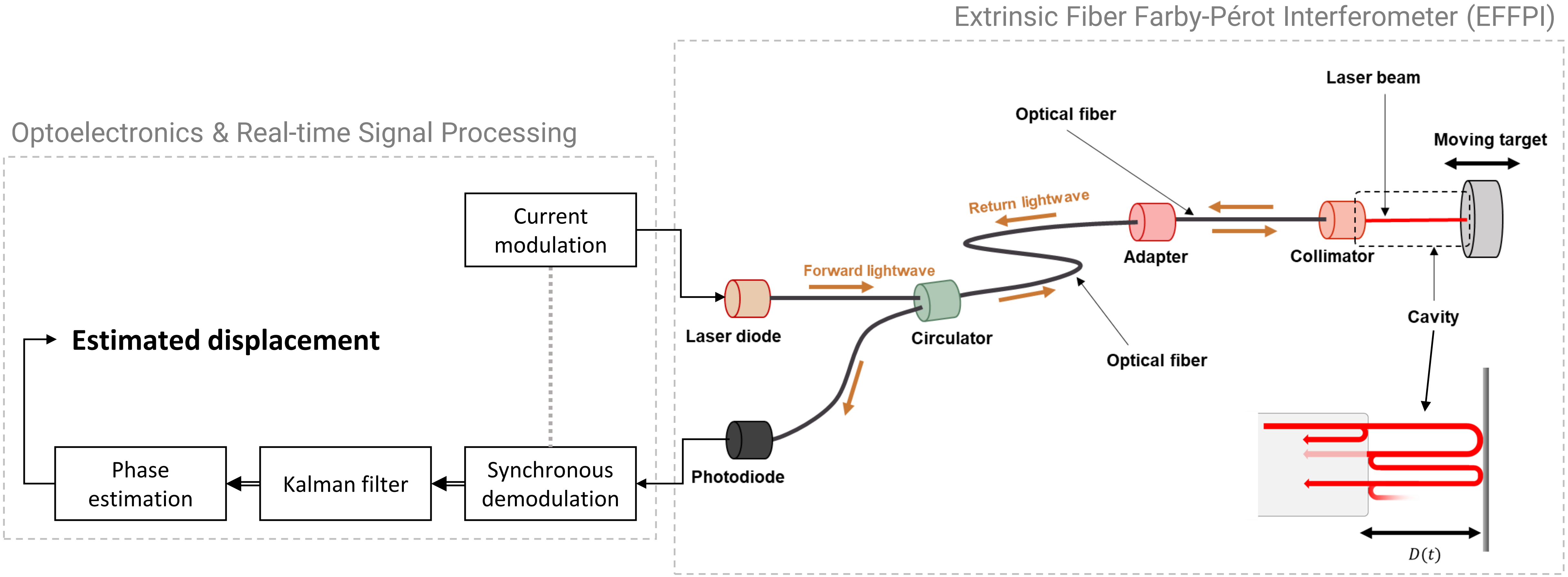
Outlines

An overview on 15 years of collaboration and development

Summary

- Principle of the measurement
- Optoelectronics interrogators
- Optical-tunned geophones
- Qualification Campaigns

Measurement principle



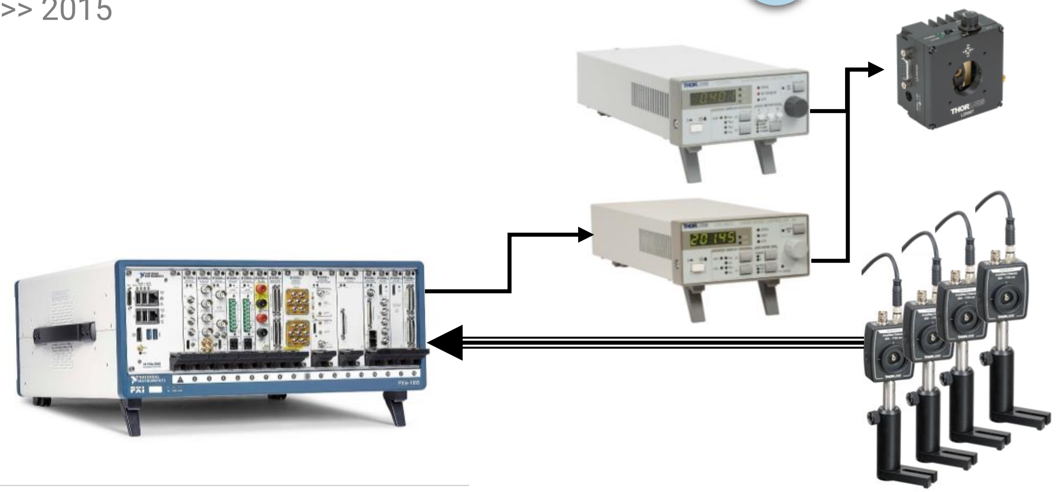
[Seat et al., 2012] Dual-modulation fiber Fabry-Perot interferometer with double reflection for slowly-varying displacements, Optics Letters, Vol. 37, Issue 14, pp. 2886-2888
[Chawah et al., 2012] Amplitude and Phase Drift Correction of EFPI Sensor Systems Using Both Adaptive Kalman Filter and Temperature Compensation for Nanometric Displacement Estimation. Journal of Lightwave Technology, 30(13) :2195–2202.

The optoelectronics interrogator

LI GAIA

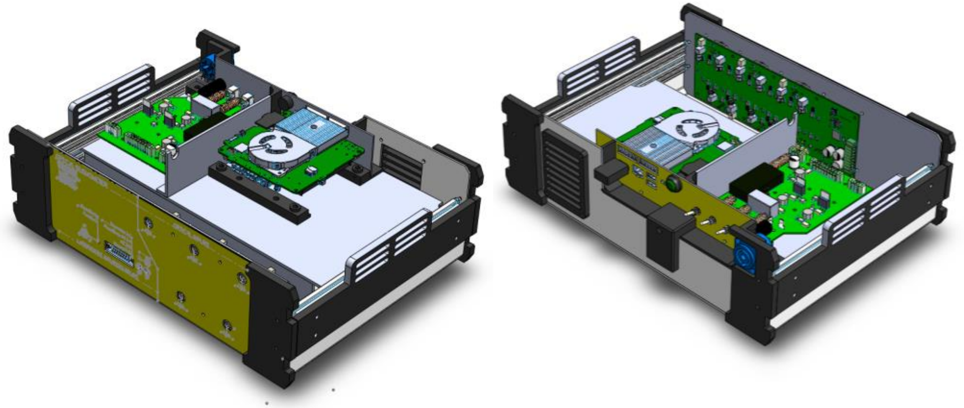
Phase 1 : Laboratory instrumentation LI

>> 2015



Phase 2 : GAIA interrogator GAIA

>> 2018



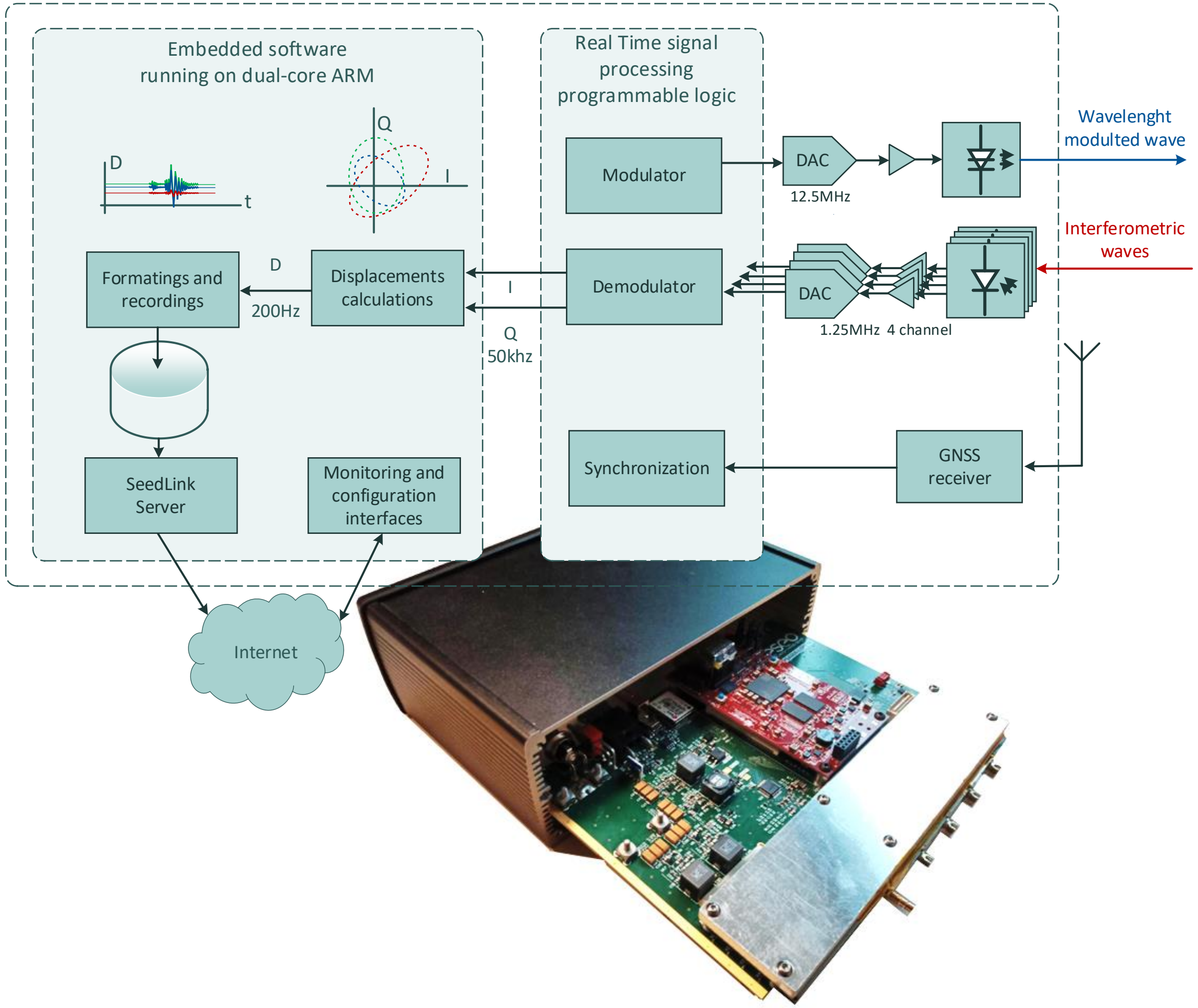
	Phase 1	Phase 2
Embedded Signal Processing	e	e
Processing Architecture	ni	intel NUC
Power supply	THORLABS	e
Laser diode driver	THORLABS	e
Photodiode conditionning	THORLABS	e
Signal generation / acquisition	ni	ni
miniSEED data encoding	X	e
NTP synchro	ni	intel NUC
GNSS synchro	X	X
Power consumption (4 ch)	>200 W	30 W

The optoelectronics interrogator

LI GAIA LOKI

Phase 3 : LOKI interrogator LOKI

2021



	Phase 1	Phase 2	Phase 3
Embedded Signal Processing			
Processing Architecture		intel NUC	*
Power supply	THORLABS		
Laser diode driver	THORLABS		
Photodiode conditionning	THORLABS		
Signal generation / acquisition			
miniSEED data encoding	X		
NTP synchro		intel NUC	
GNSS synchro	X	X	

Power consumption (4 ch)	>200 W	30 W	7 W

*Xilinx Zynq-7000 Avnet SOC based

The passive geophone

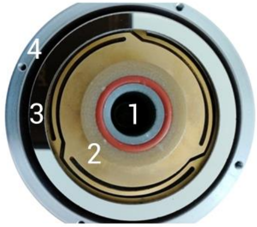
L22C GHIP

Phase 1 : Custom L22 L22C

>> 2018

Passive

Optical adapt.



Inside view

1 center core
2 spring
3 annular mirror
4 geophone enclosure

Outside view

5 geophone cap (fixed part)
6 geophone cap (tunabled part)

Phase 2 : Geophone HIPERSIS (GHIP) GHIP

2019

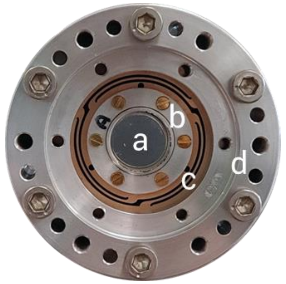
Passive

Optical int.

Omnitilt

Robust

Low cost

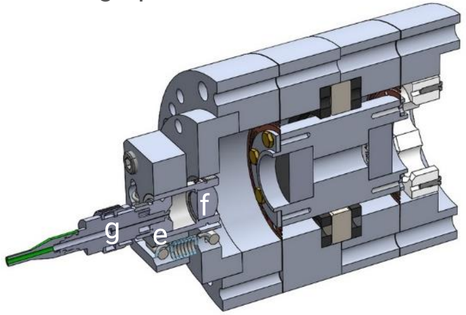


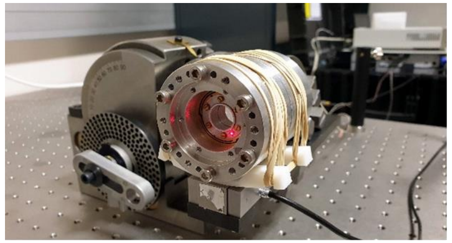
Inside view

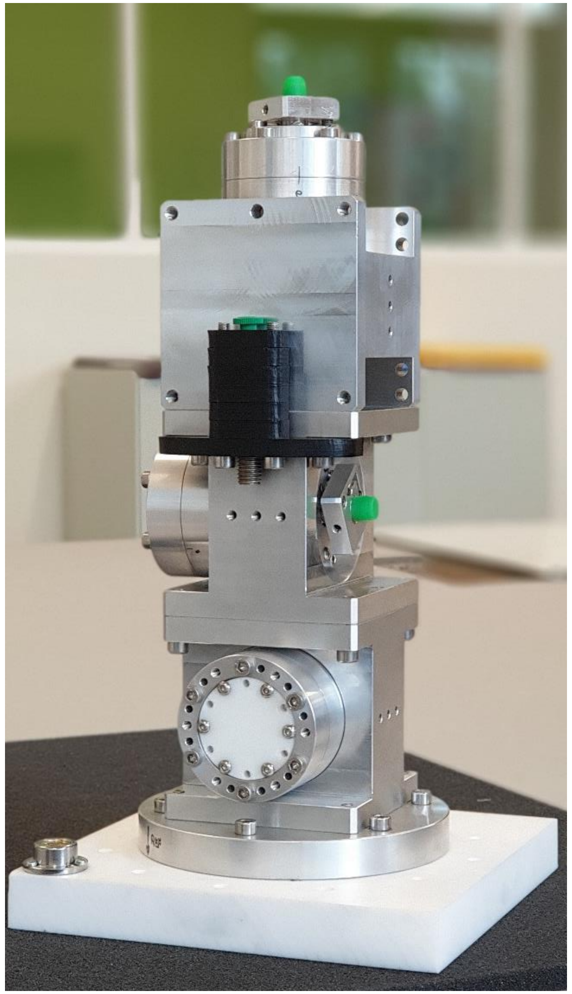
a mirror
b mobile mass
c spring
d geophone enclosure

Cross-section

e collimator (frame)
f lens
g optical fiber termination







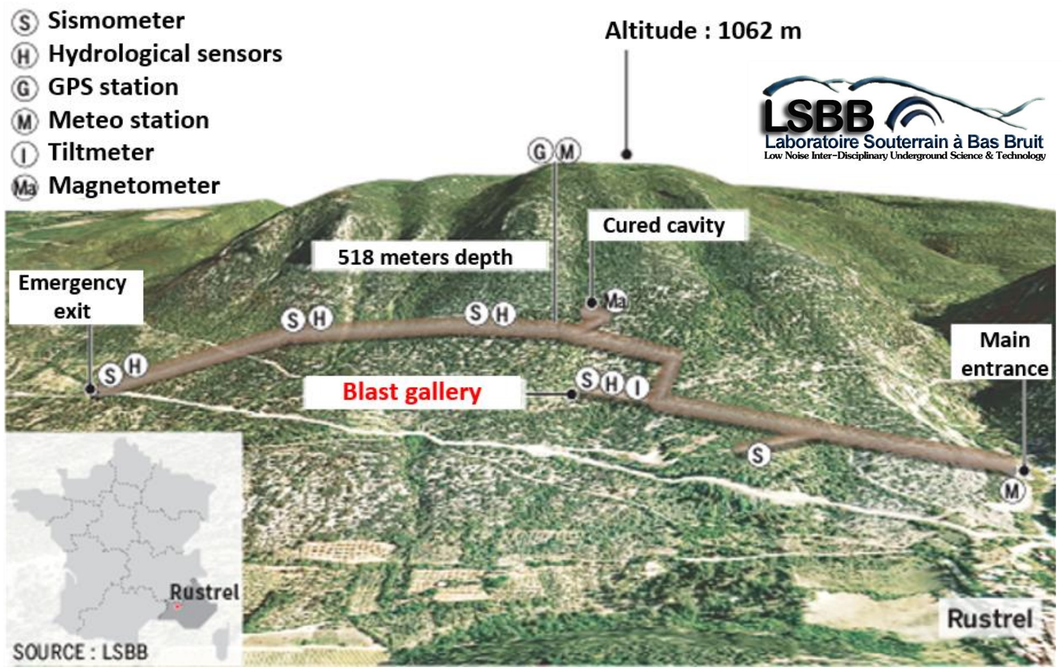
Qualification campaigns & results

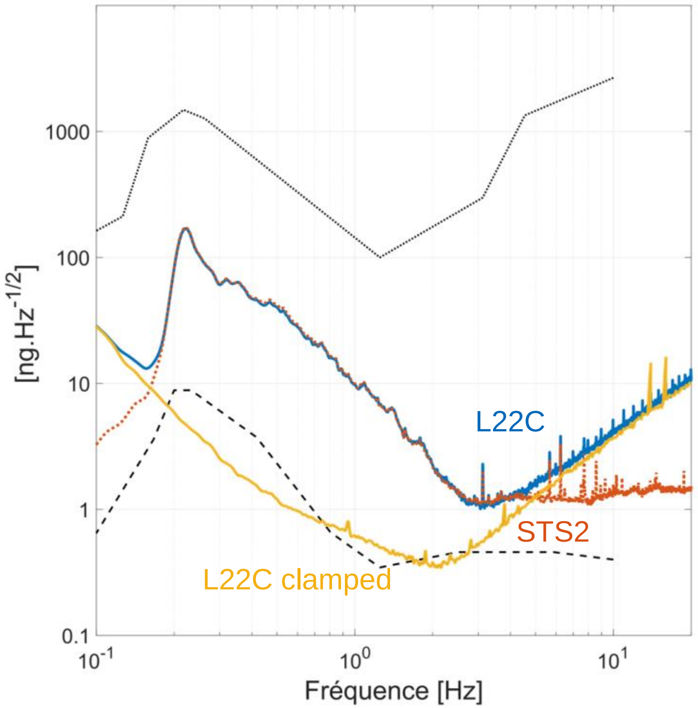
Low-Noise Underground Laboratory

Rustrel, Provence-Alpes-Côte d'Azur, France
2010 - 2015

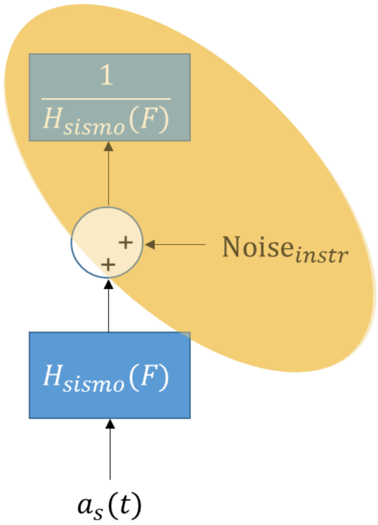
LI L22C

Purposes
- Test and qualify signal processing algorithms
- Install instruments in quiet place to evaluate the instrument floor noise
- Compare results with reference seismometer (STS2)





Acceleration noise curves (PSD) recorded at LSBB



[Bernard et al., 2019] Onland and Offshore Extrinsic Fabry–Pérot Optical Seismometer at the End of a Long Fiber. Seismological Research Letters, 90(6) :2205–2216.

Qualification campaigns & results

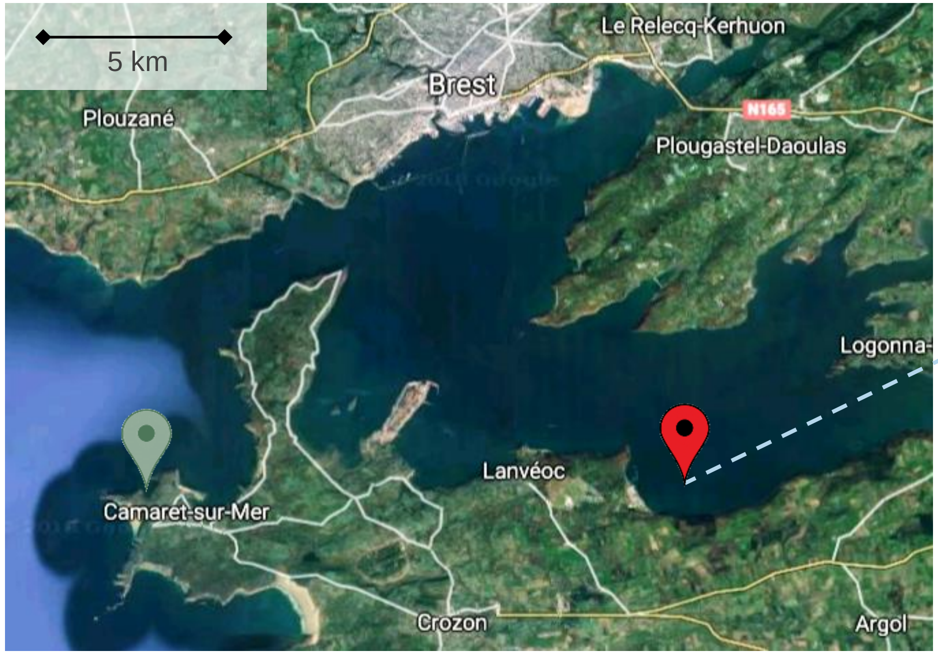
Sea Test Base (offshore)

Lanvéoc, Bretagne, France
2018 / 03-11

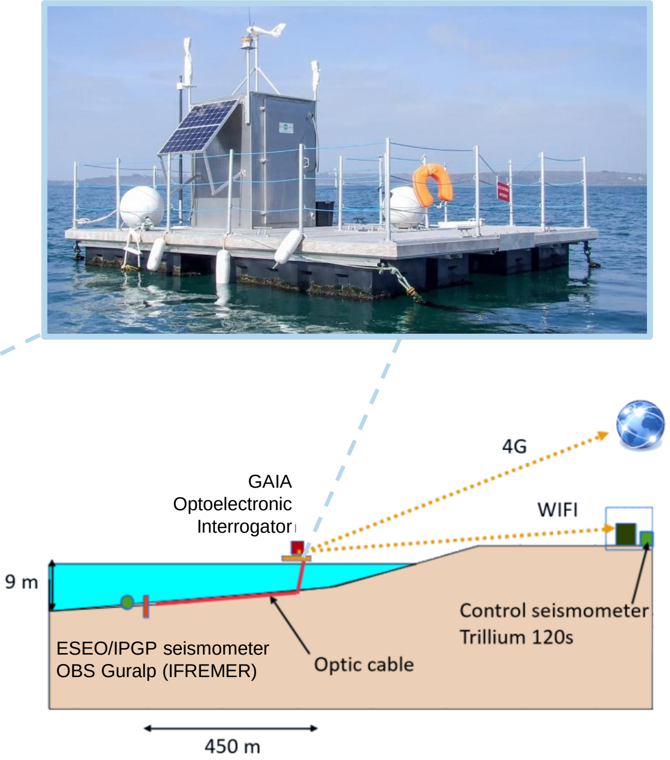
GAIA L22C

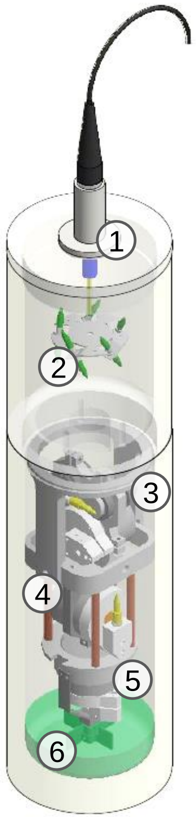
SEA TEST BASE

Purposes
- Test and qualify GAIA interrogator
- Evaluate the instrument robustness and performances under real-life conditions
- Compare results with reference seismometers (OBS GURALP and STS2)



ESEO/IPGP and IFREMER seismometers
CAMF seismic station (STS2)





1 sealed feedthrough
2 optical connections
3 y-axis (NS)
4 x-axis (EO)
5 z-axis (V)
6 Oil

[Bernard et al., 2019] Onland and Offshore Extrinsic Fabry–Pérot Optical Seismometer at the End of a Long Fiber. Seismological Research Letters, 90(6) :2205–2216.

Qualification campaigns & results

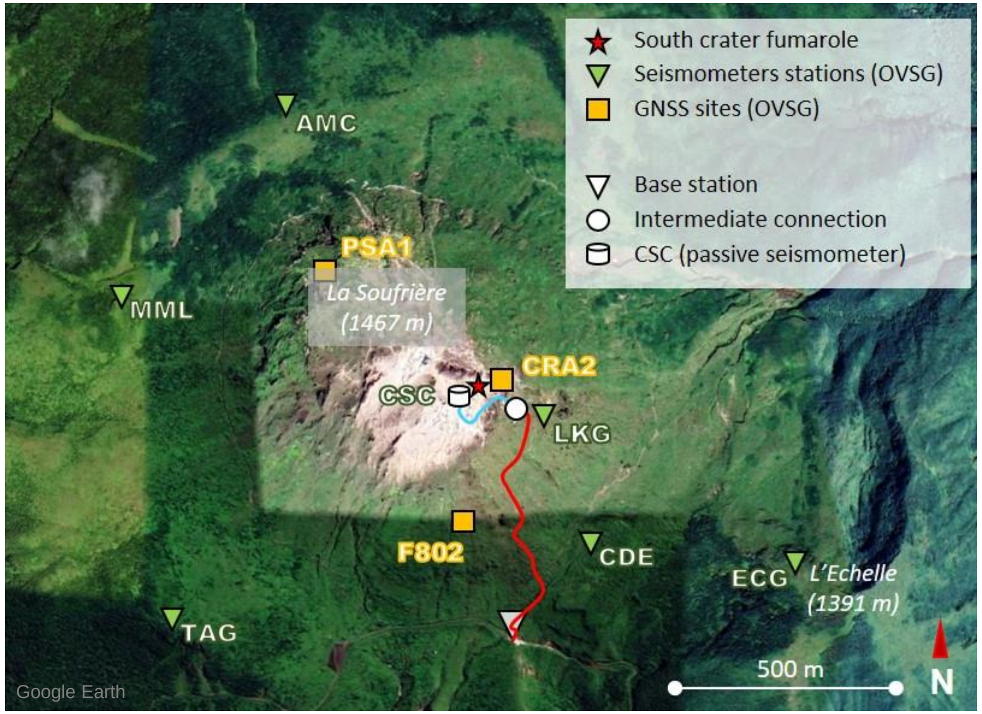
La Grande Soufrière

Saint-Claude, Guadeloupe, France
2019 - Present

LOKI
GAIA
GHIP

Purposes

- Test and qualify GHIP based seismometer
- Evaluate the instrument robustness and performances under "harsh" conditions
- Contribute to the study of volcanic microseismicity



Qualification campaigns & results

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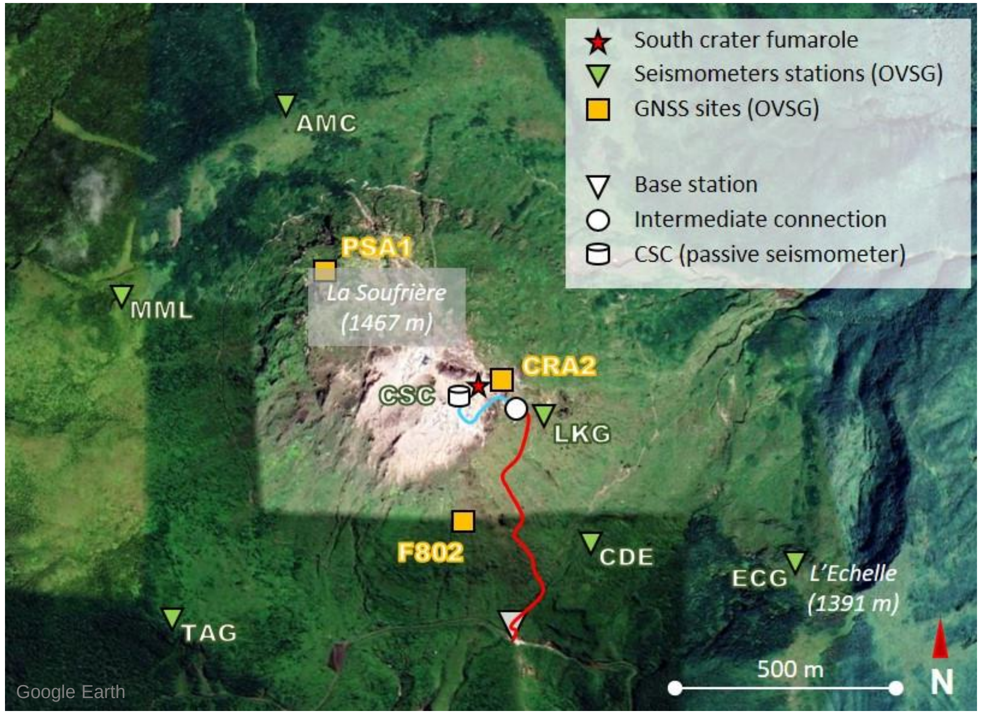
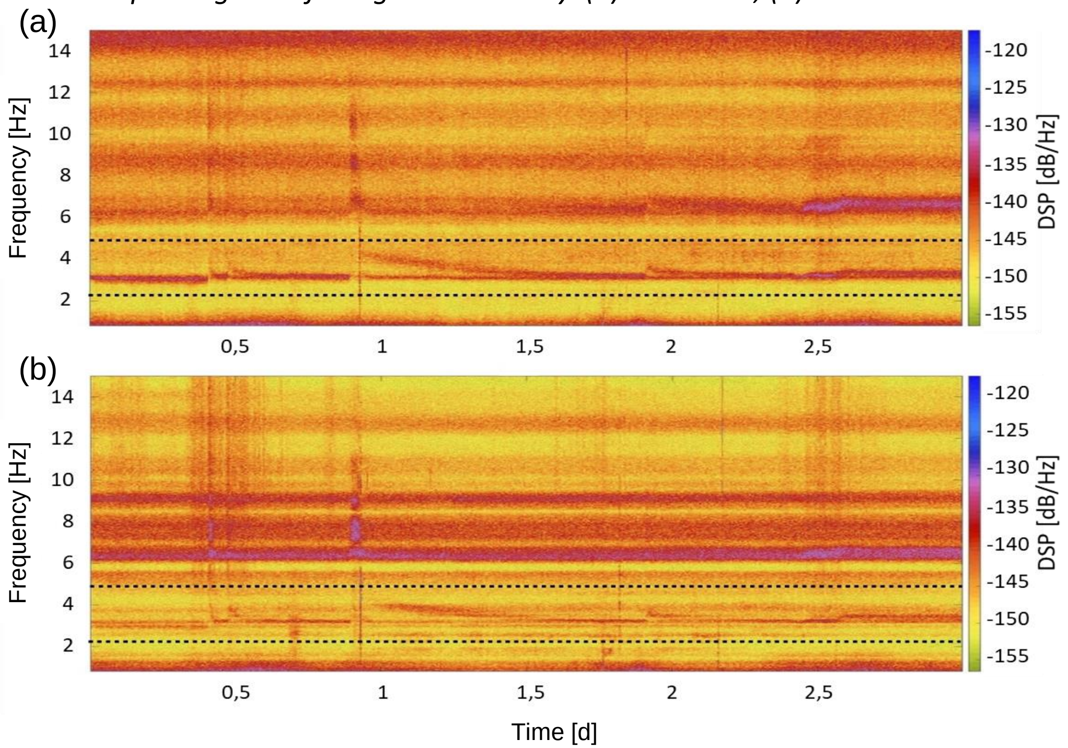


Spectrogram of the ground velocity. (a) CSC north; (b) LKG north



[Feron et al., 2020] First Optical Seismometer at the Top of La Soufrière Volcano, Guadeloupe. Seismological Research Letters, 91(5) :2448–2457

Qualification campaigns & results

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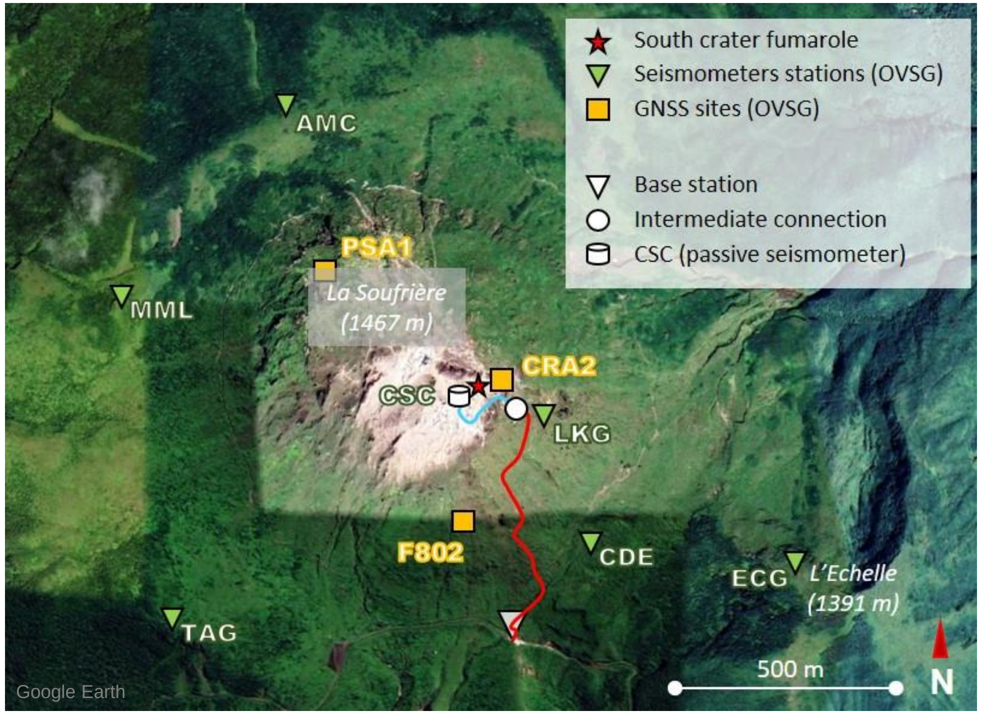
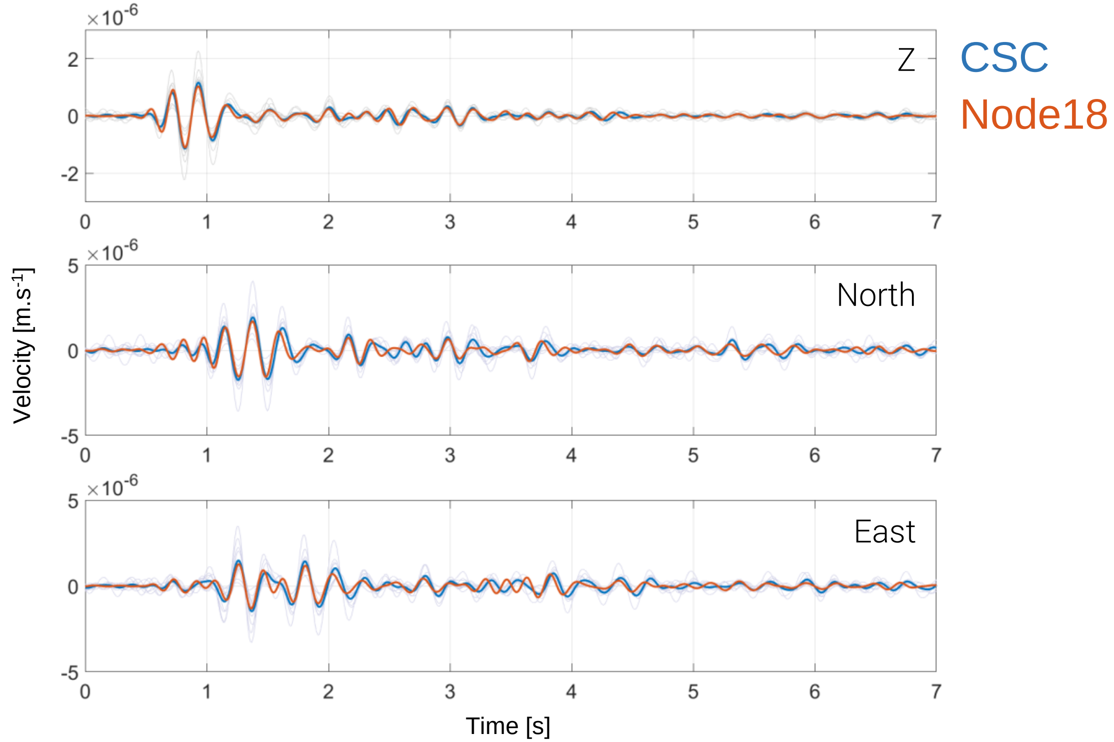
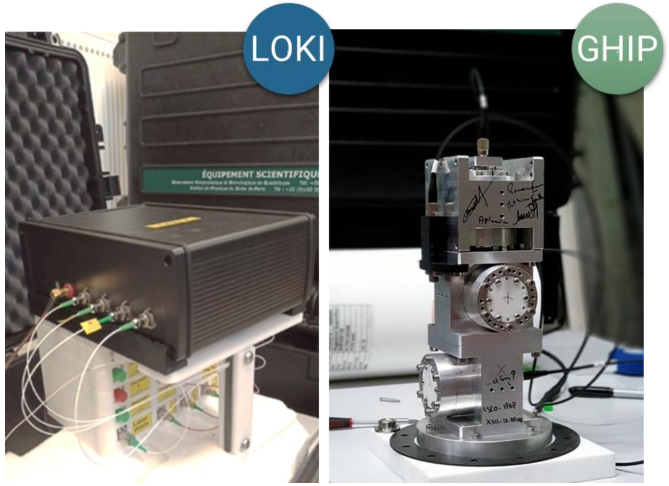




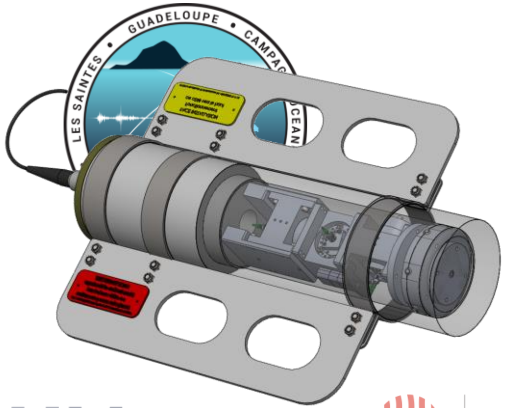
November 21, 2020 microseismic sequence
VT1 events stack (grey), CSC stack (blue) and 2017 Node 18 master event (red)
Signal filtered in [3-6] Hz range

Conclusion

Design and qualify an innovative, high-resolution, low-cost optical seismometer to improve real-time monitoring of high-hazard regions.



- Access to sources – plurikilometric optical cable can be used in "harsh" environment (high temperatures, electromagnetic perturbations / lightning, acidic)
- Robustness of sensors – equipment can be deployed on variety of sites, such as the top of volcano or off the coast.
- Costs of equipment – the mechanical part of sensor is now without electronics, which makes its possible loss much less detrimental. Moreover, number of channels can be easily increase without too much cost.
- Real-time data – data are available in real-time (almost).



eseo INNOVATION MAKES SENSE

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IPGP

Université Paris Cité

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PREST Interreg V Caraïbes