Offshore Landslides could be favored by Seismic Amplification due to Site Effects

EGU General Assembly 2020

UNIVERSITÉ CÔTE D'AZUR

ANR MODAL

EU project EMSO

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IRD Institut de Recherche pour le Développement FRANCE

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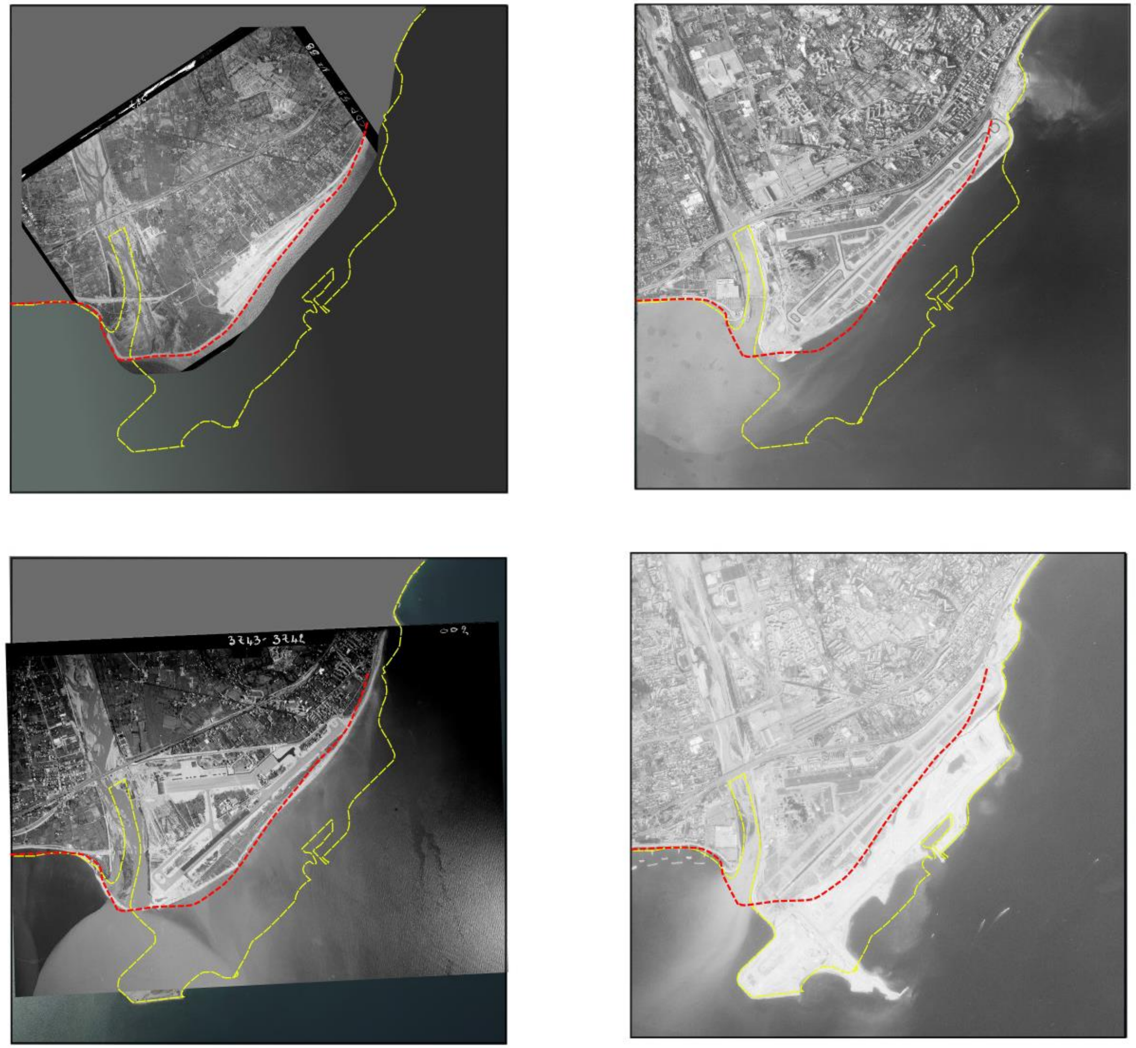
Temporal evolution of the Nice-Côte d'Azur airport runways from 1945 to 1979

1945

1971



1955

1979

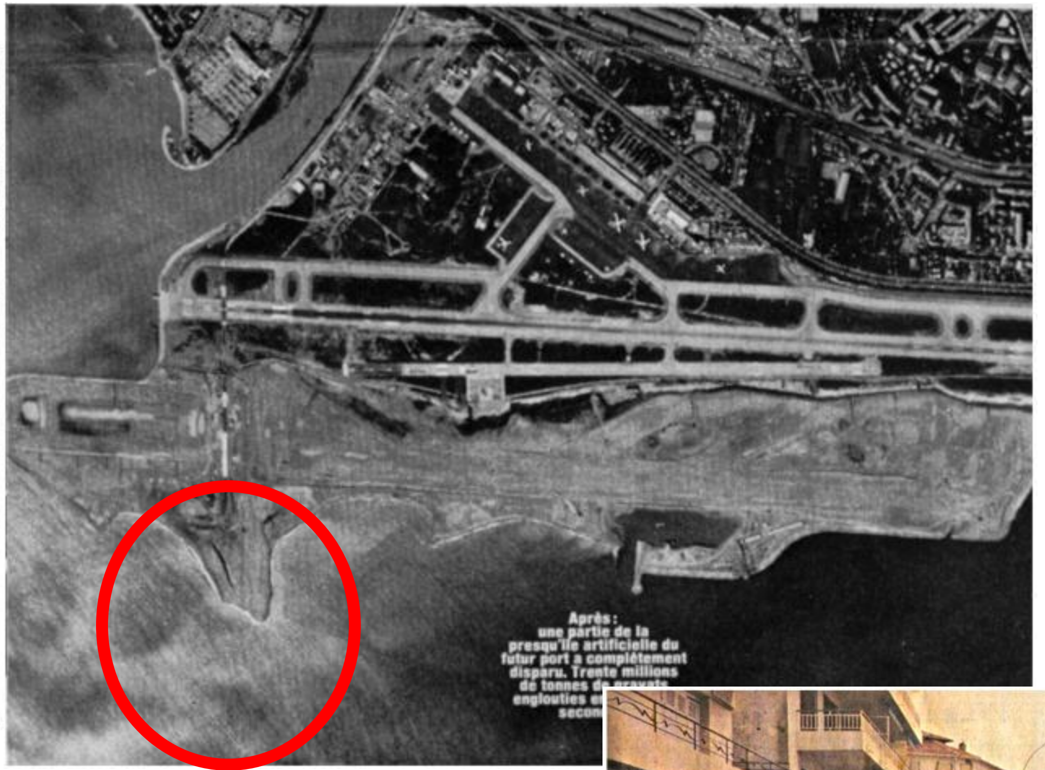
About 25 x10^{6} m^{3} of backfill to create the new runaways

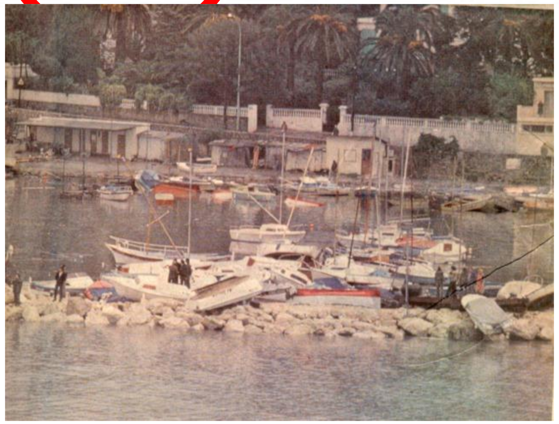
Cavalié, Sladen and Kelner, 2015, Nat Hazard

40 years ago, a submarine landslide generated a tsunami

BEFORE October 16th 1979

AFTER October 16th 1979





10 people died

It was in October ; Nobody on the beach

Courboulex et al., EGU 2020

The factors favoring submarine landslides in this area are :

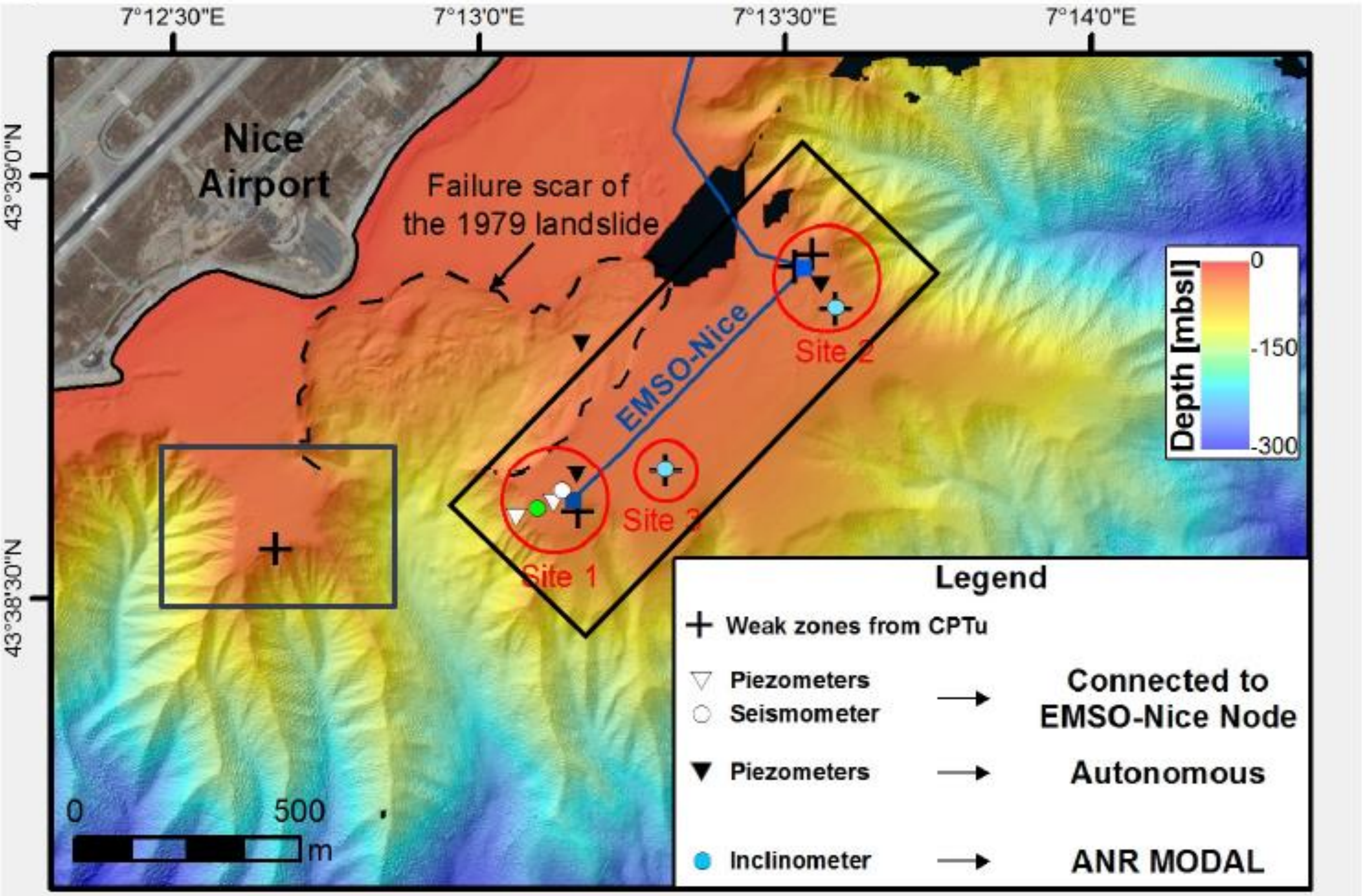
The slope : Off Nice airport, the continental shelf is very narrow and the slopes are then quickly steep

The high sedimentation rate due to the direct proximity of the mouth of the "Var" Coastal River

The possible overload due to artificial constructions

The possible effects of local earthquakes

Ongoing scientific projects on the area

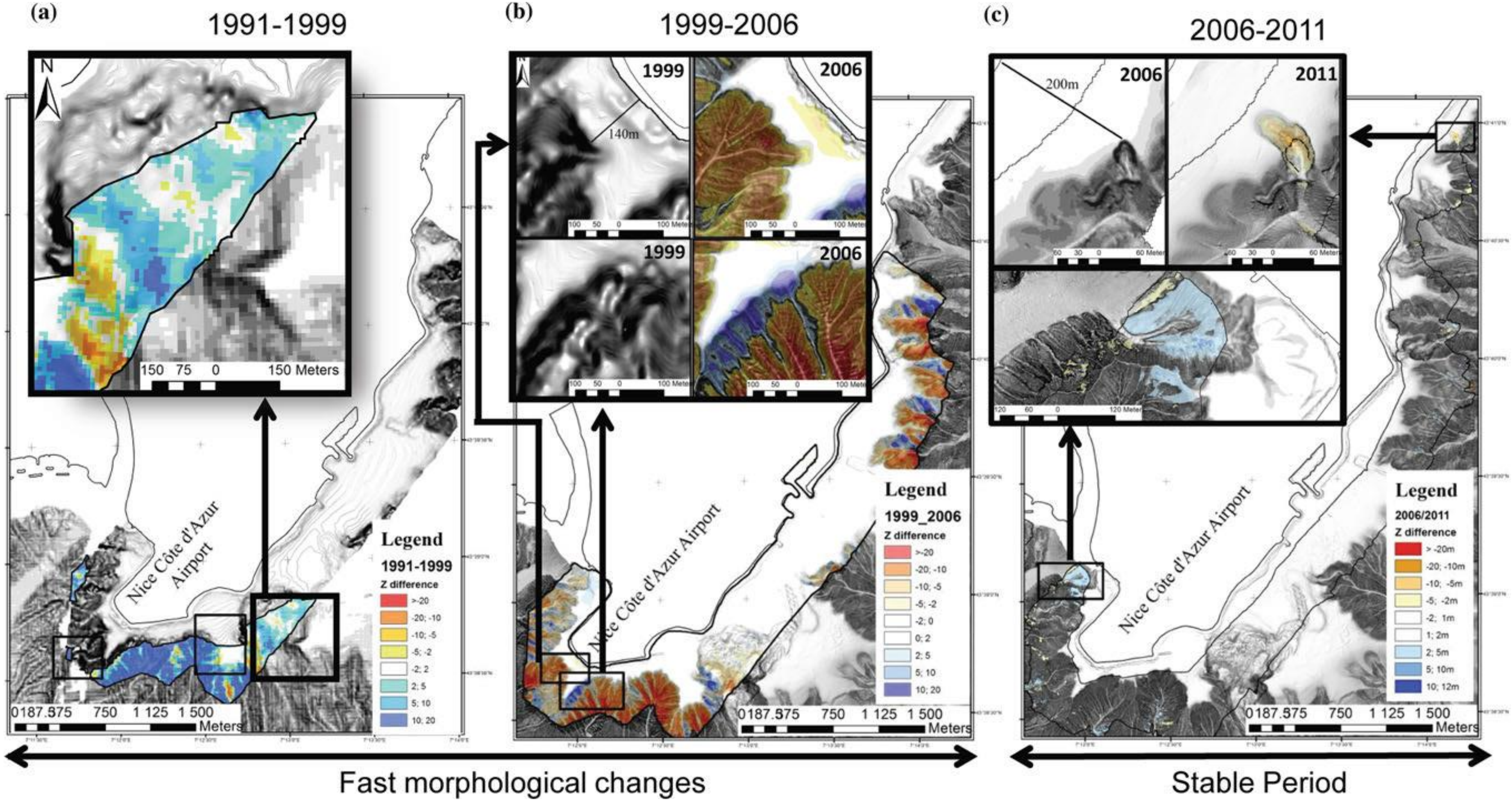


ANR MODAL
PI : Ifremer (Nabil Sultan)

ANR SEAFOOD
PI : Anthony Sladen (Géoazur)

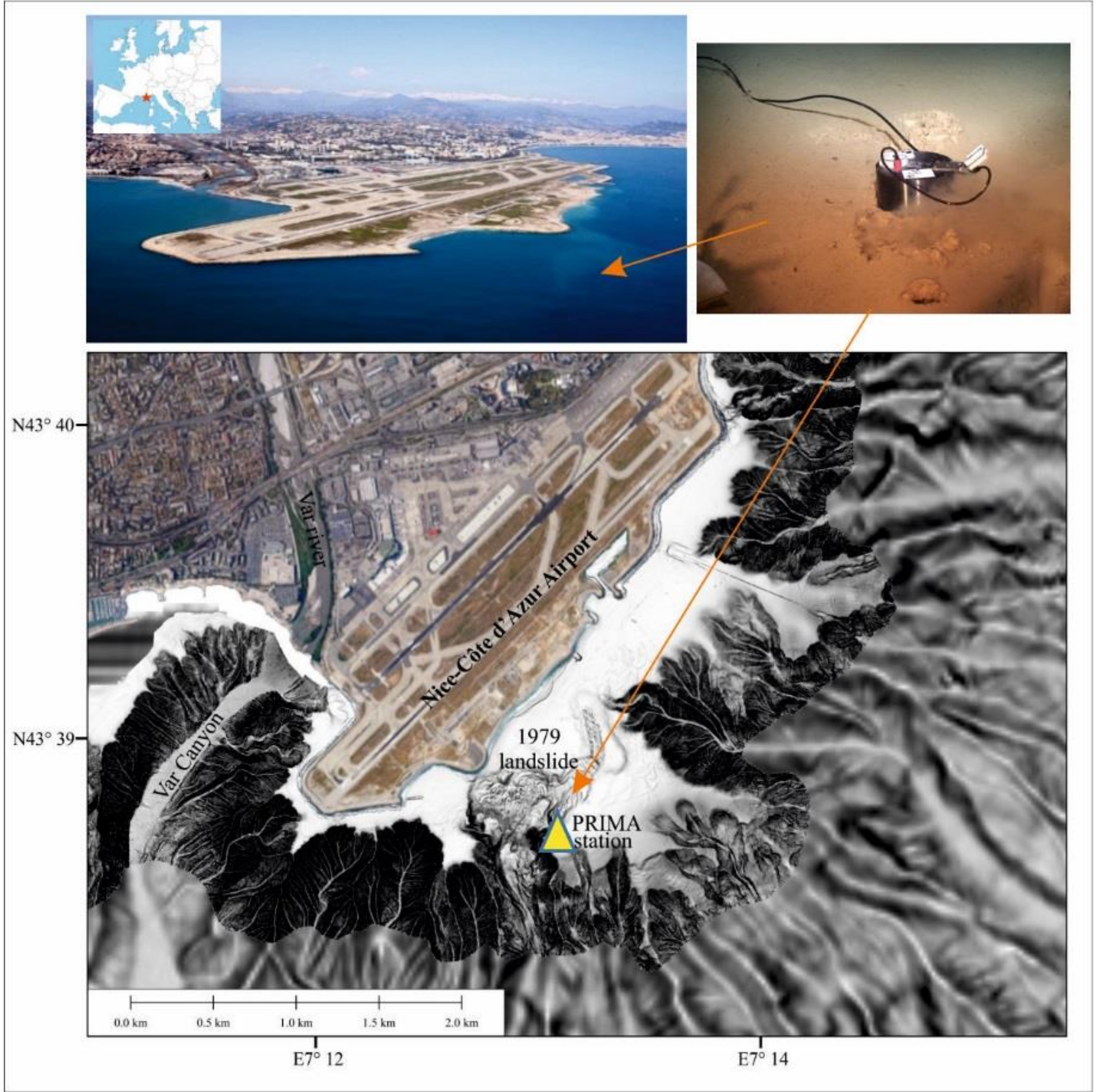
Courboulex et al., EGU 2020

Several small landslide scars



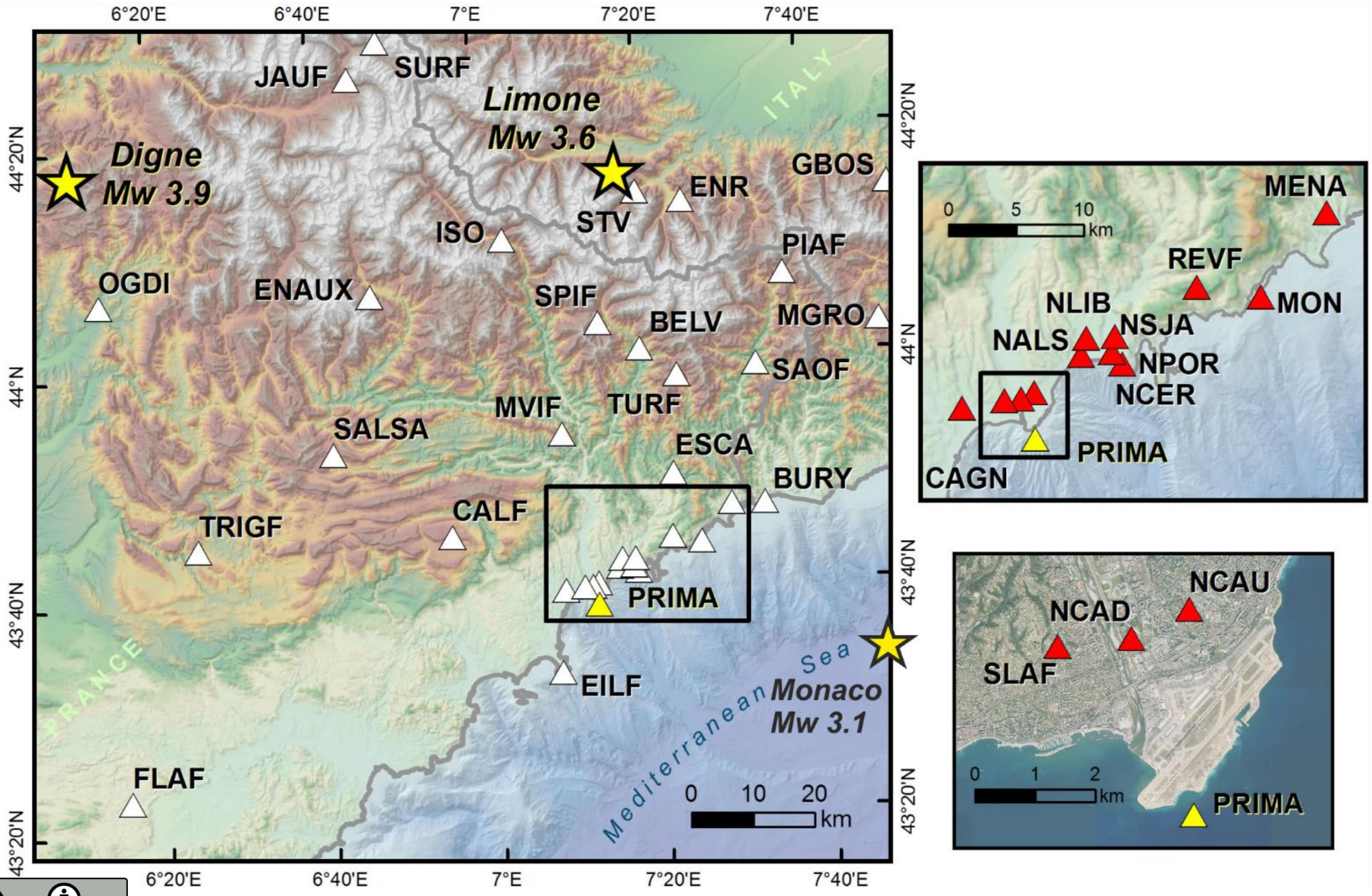
Phd Thesis of Maelle Kelner Dec. 2018 https://tel.archives-ouvertes.fr/tel-02102191v1

Top left: Photo of the airport runaways of Nice Coˆte d'Azur, situated at the western part of the city of Nice (southeastern France, see inset). Top right: photo of the PRIMA seismic station installed on the sediment slope of Nice airport at a depth of 18 meters, before it was covered by a semi-spherical plastic bell. Bottom: multibeam bathymetry data. The PRIMA station is located by a yellow triangle. The black line indicates the localization of the sparker profile. The place where the destructive 1979 landslide initiated is indicated



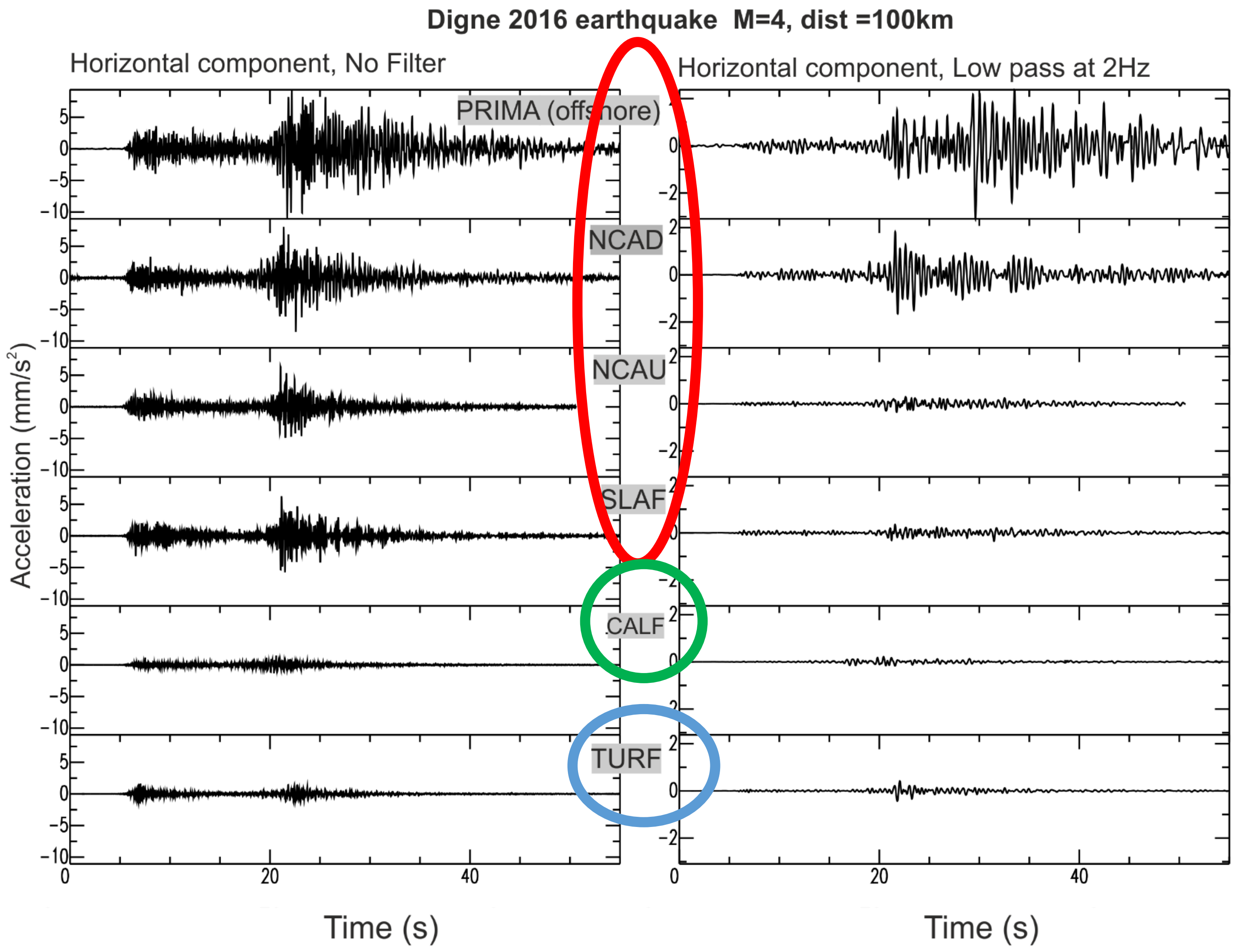
We installed an offshore broad-band seismometer 18 meters under the sea level : PRIMA station

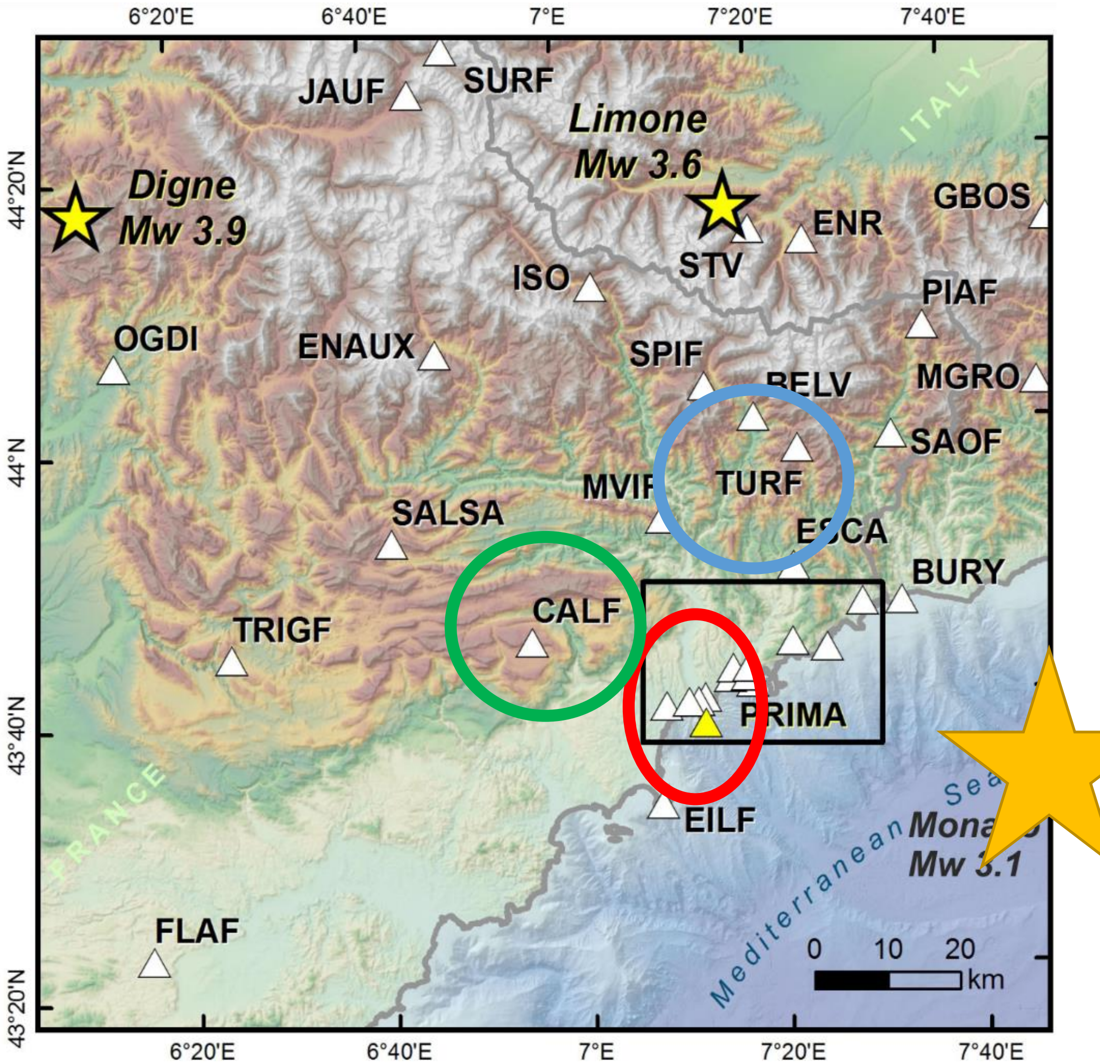
Data available through RESIF portal http://seismology.resif.fr/



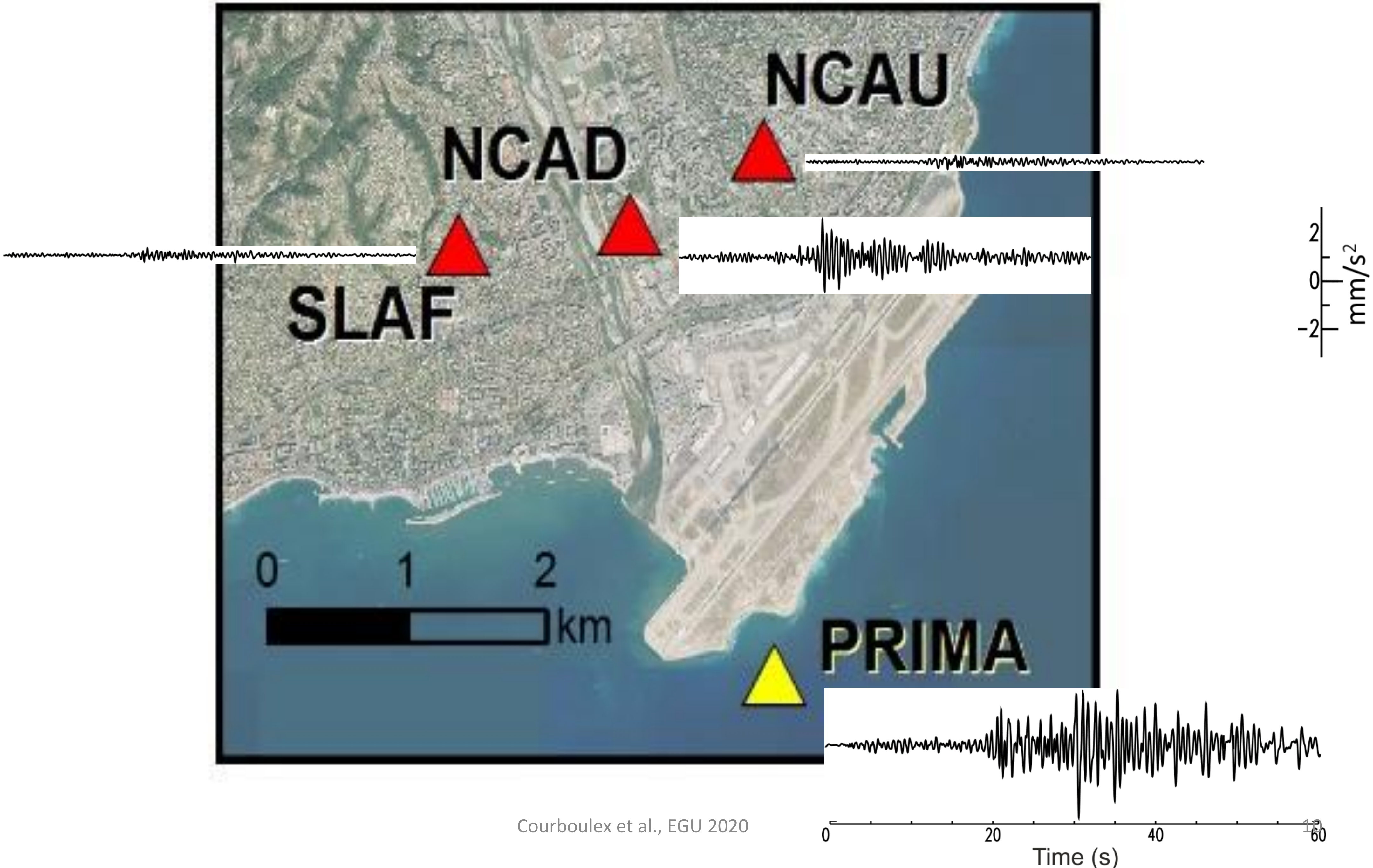
Left: permanent seismic network in the southeast of France (RESIF network) and west of Italy (Italian network). Each station is represented by a white triangle. Almost all the stations are equipped with both a broadband sensor and an accelerometric one, except the stations in the black rectangle around Nice that are equipped with accelerometric sensors only. The locations of local earthquakes studied in this paper are indicated by stars. Top right: zoom on the Nice area. Red triangles represent the permanent accelerometric stations (RAP-RESIF). Bottom right: zoom on the airport zone and the three stations (SLAF, NCAU, NCAD) mainly used in this study. The PRIMA station is represented by a yellow triangle

Monaco Mw=3.1 earthquake



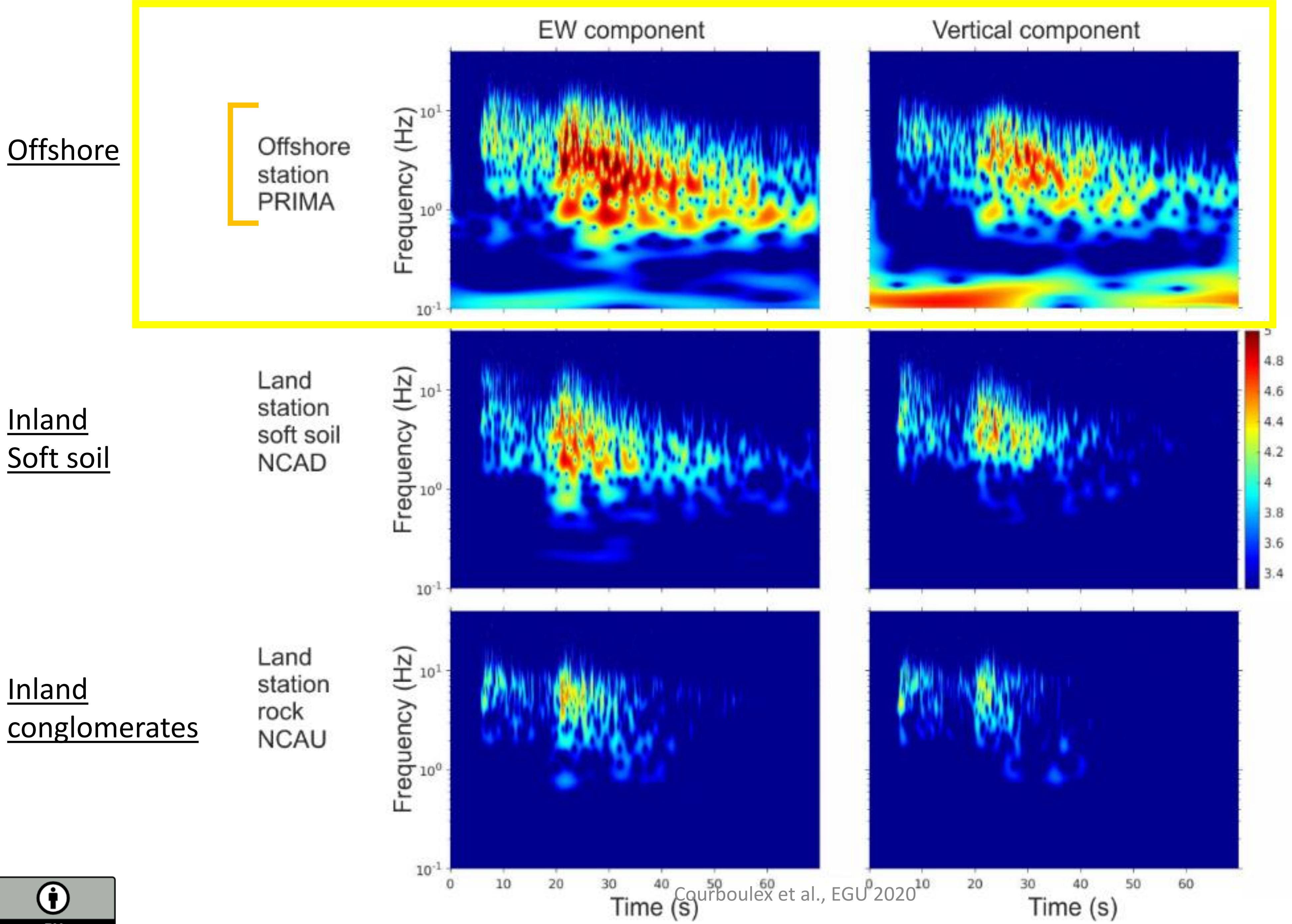


Monaco Mw=3.1 earthquake



Courboulex et al., EGU 2020

Spectrograms



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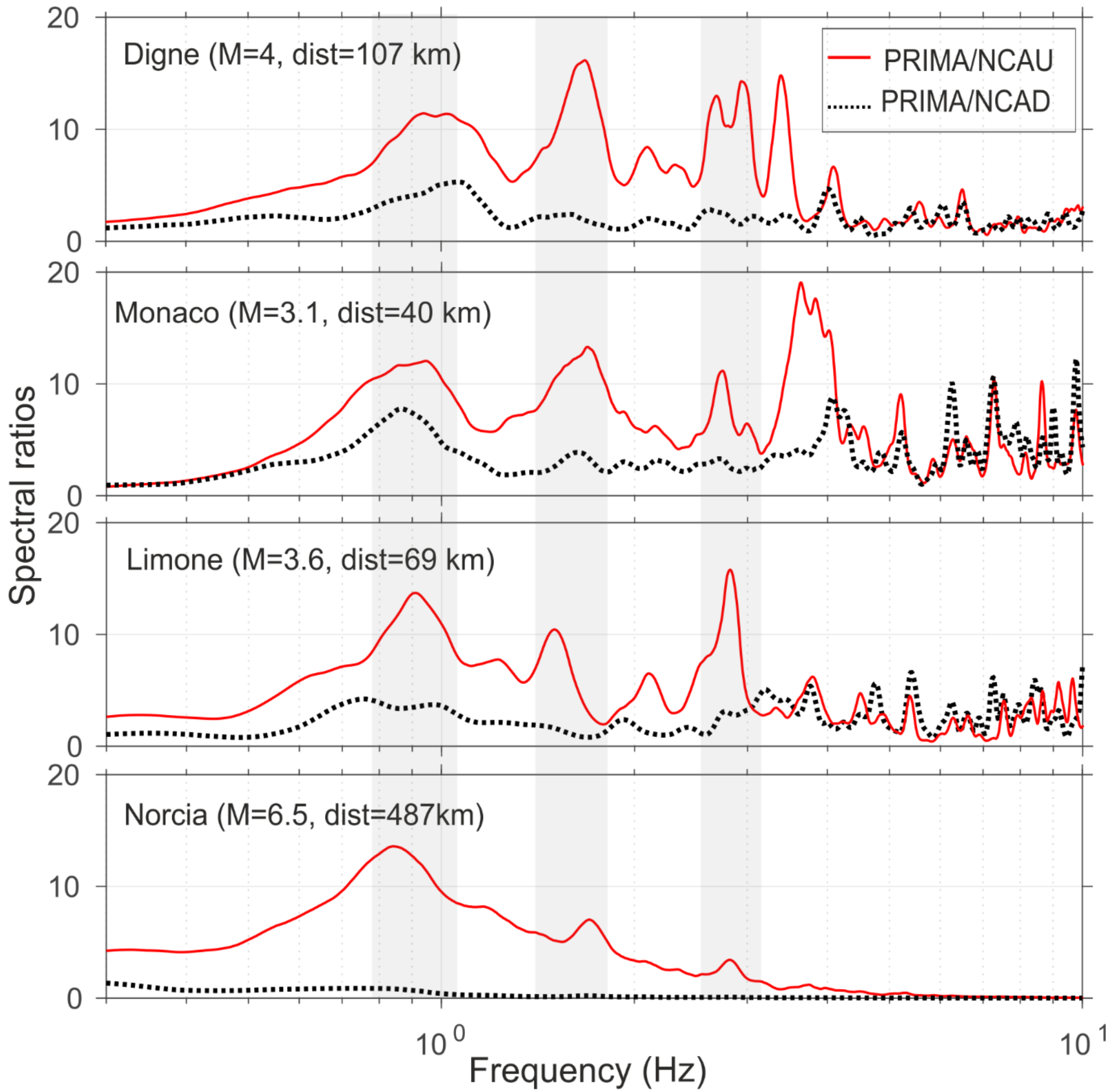
Standard Spectral Ratio

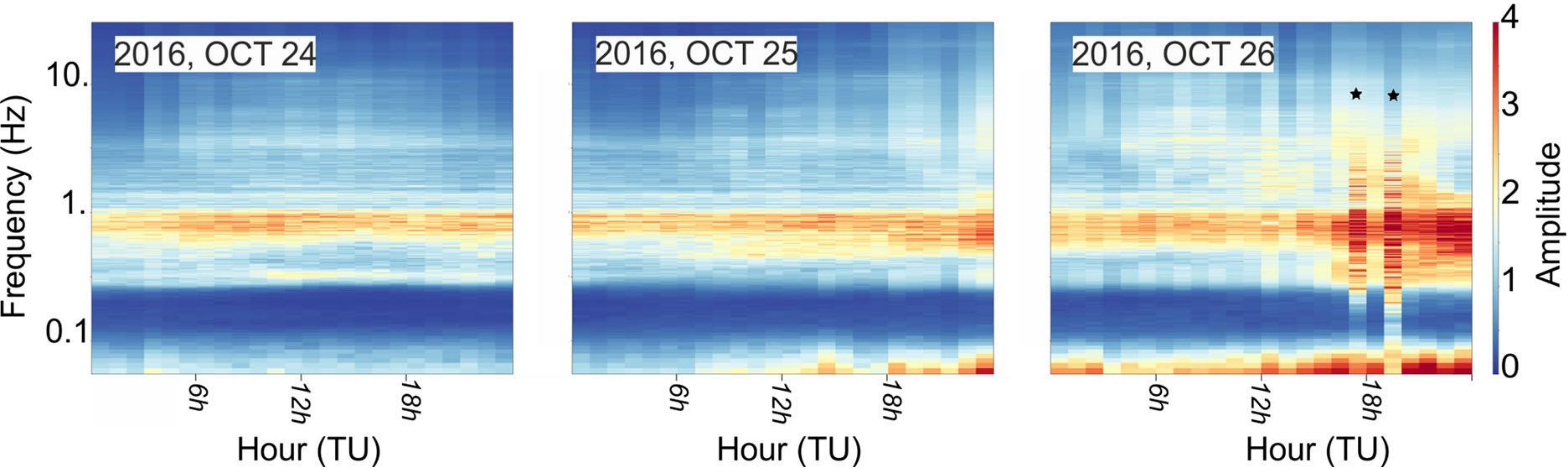
NCAU = reference station



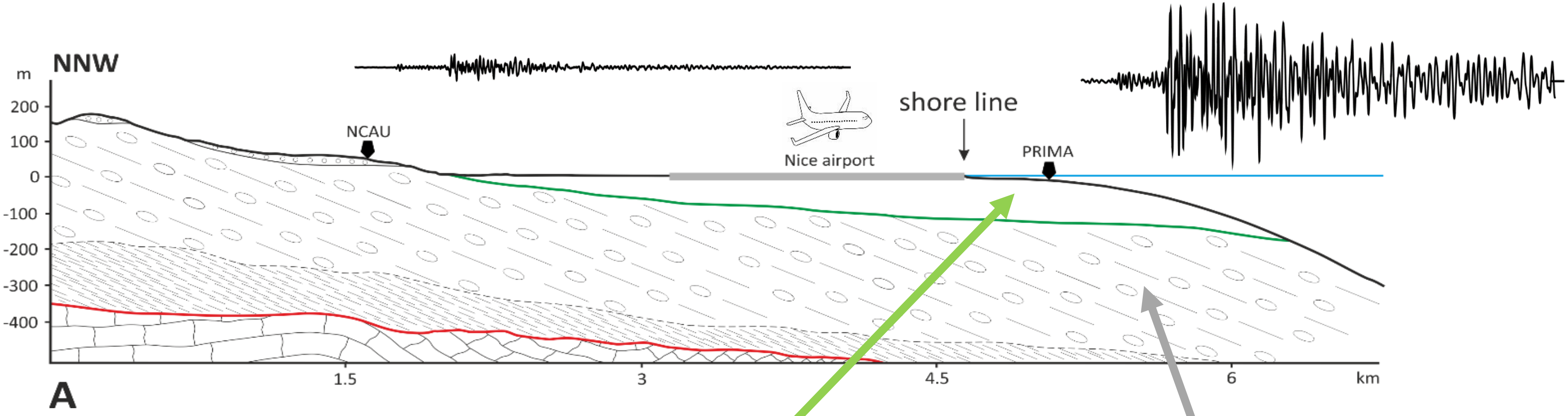
For frequencies around 0.9 Hz, the signal is 12 times larger at PRIMA than at NCAU

Standard Spectra Ratio (EW components) for the recordings of three local (Digne, Monaco and Limone) and one regional earthquake (Norcia events). The continuous lines represent the spectral ratios between PRIMA and NCAU (left side of the Var valley). Shadow zones underline the main frequencies where amplifications are detected around 0.9, 1.8 and 3–4 Hz. Dotted lines represent the spectral ratio between PRIMA and NCAD (center part of the Var valley) only for the local earthquakes

Station PRIMA : H/V spectrograms of ambient noise during 3 days



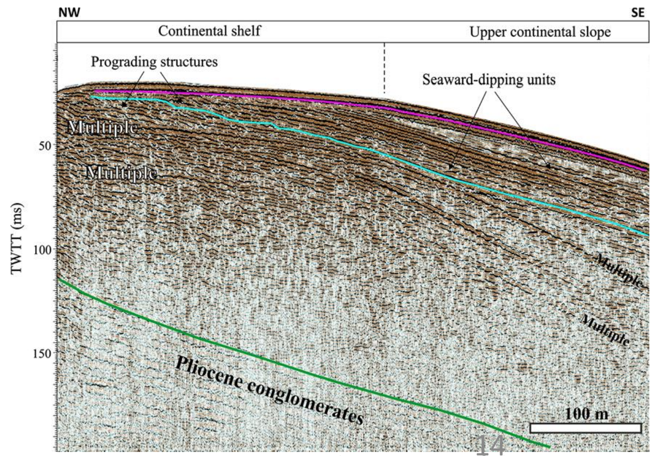
H/V spectral ratios over 3 days of ambient vibrations at the PRIMA station. The main frequency peak around 0.7–1 Hz is clear all along the time period. Black stars indicates the hour of two earthquakes from Central Italy (17:10, Mw = 5.5 and 19:18, Mw = 6.1. distance * 500 km)



We hypothesize that the special site effect at PRIMA station comes from :

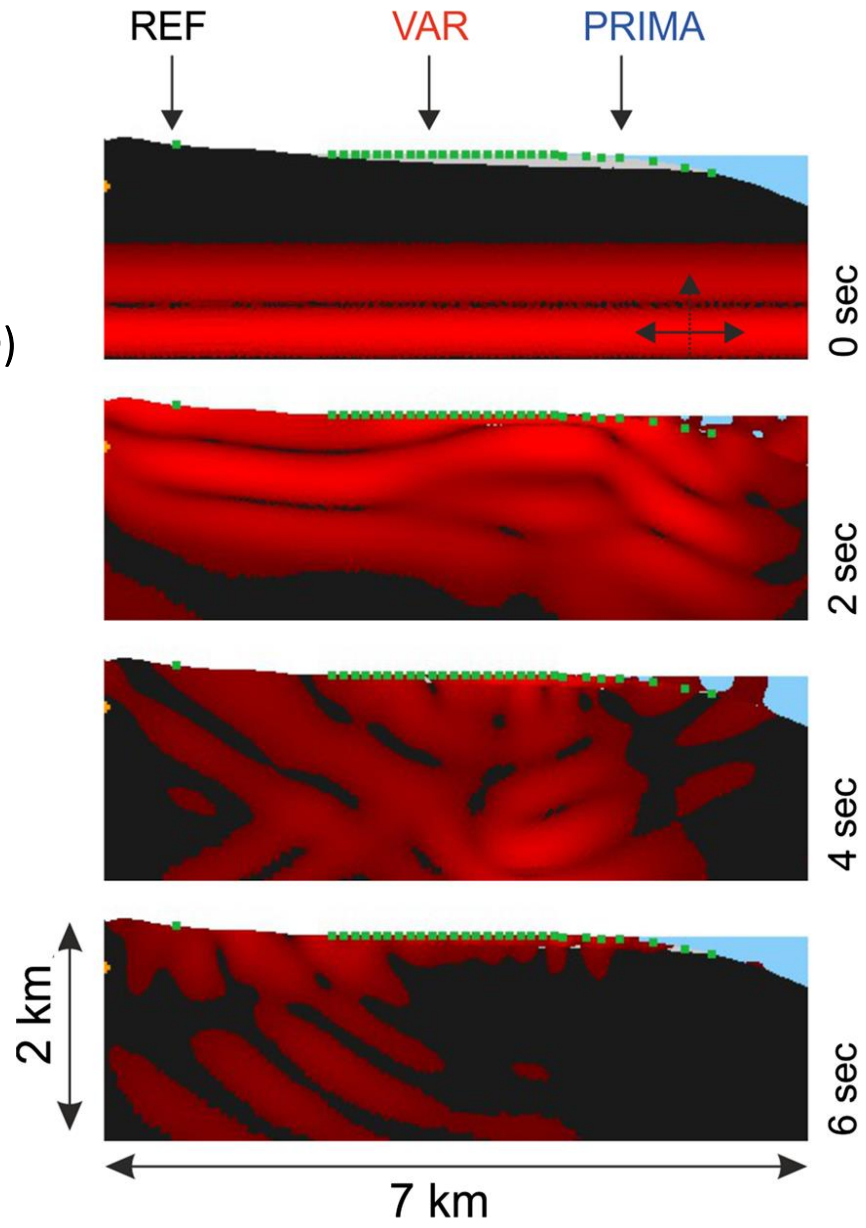
1. The contrast of velocity between the plio-quaternary layer (limit in green) and the hard conglomerate

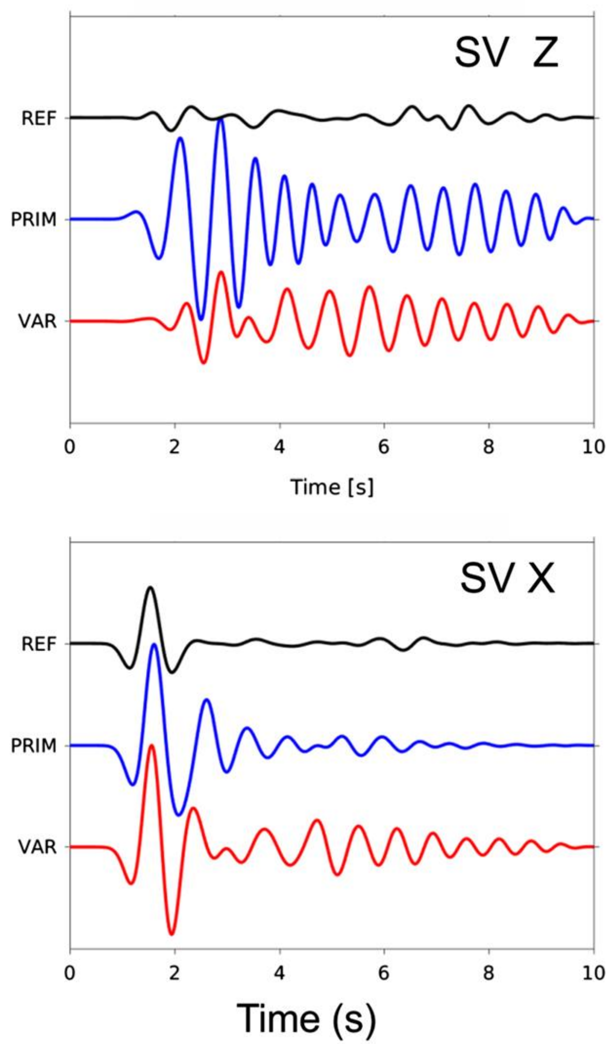
2. The pinch out shape of the termination of the plio-quaternary layer



Sparker profile

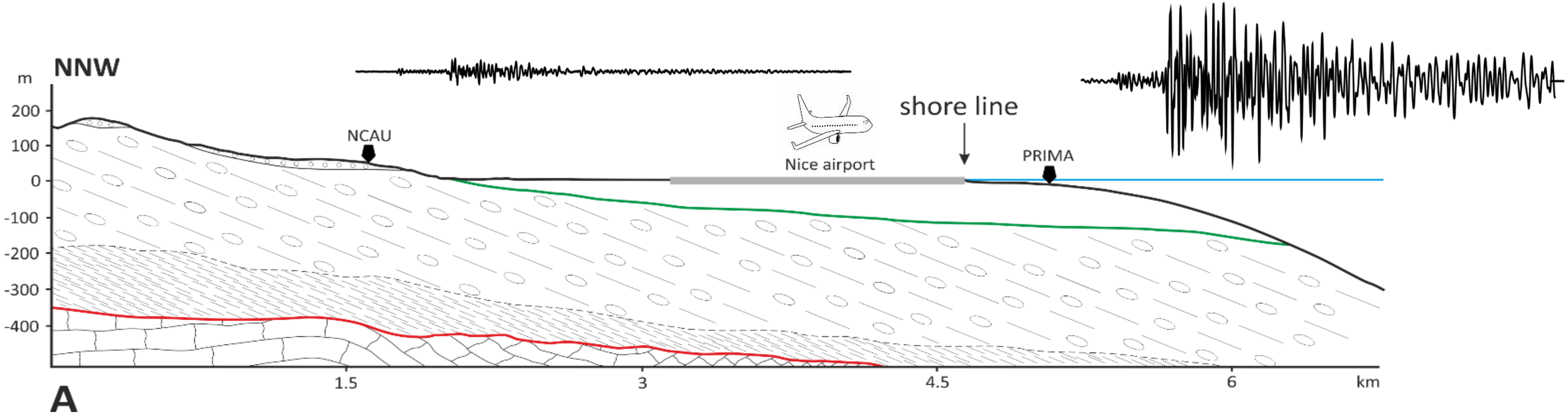
Numerical simulations (2D) using SPECFEM code.





Snapshots of the displacement field in red (vector moduli) at different simulation times. At 0 s the incident horizontal SV input wave, at 2 s the reflected wavefield at the surface begins to interact with the incoming and the converted waves in the sedimentary layer. At 4 s and 6 s
the surface wave train is already formed and can be clearly seen in the sedimentary layer, emitting some body waves at both sides of the sedimentary layer tips. The size of the simulation domain is 7000 m length by 2000 m height. The elastic bedrock subdomain is shown in black, the sedimentary layer is shown in gray and the water layer in light blue. The green dots represent receiver positions.
The reference station (REF), a station on the top of the sedimentary layers of the Var valley (VAR), and offshore station (PRIMA) are shown by vertical arrows. Right: synthetic seismograms of the displacement field at the three virtual stations REF, VAR and PRIMA on the vertical (top) and the horizontal components (bottom)

… but is not fully understood yet (certainly a 3D effect) → numerical simulation



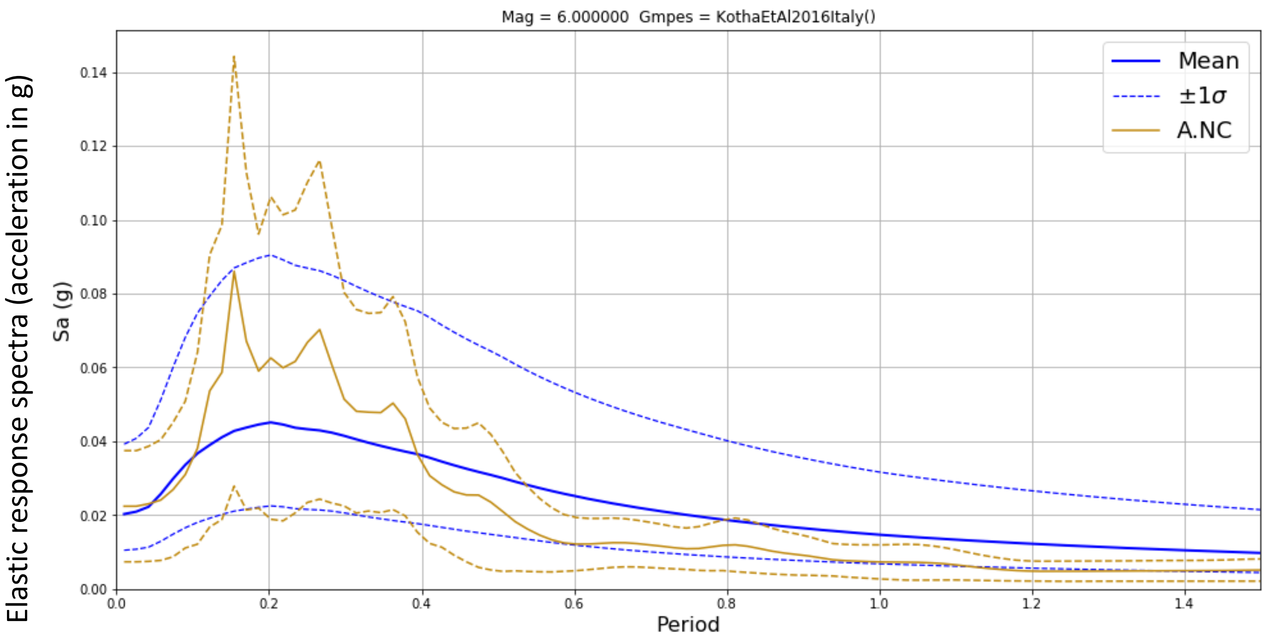
→ THIS STRONG OFFSHORE SITE EFFECT COULD HAVE A CRUCIAL IMPACT ON **THE POTENTIAL TRIGGERING OF SUBMARINE LANDSLIDES BY AN EARTHQUAKE**

Simulation of a a larger earthquake

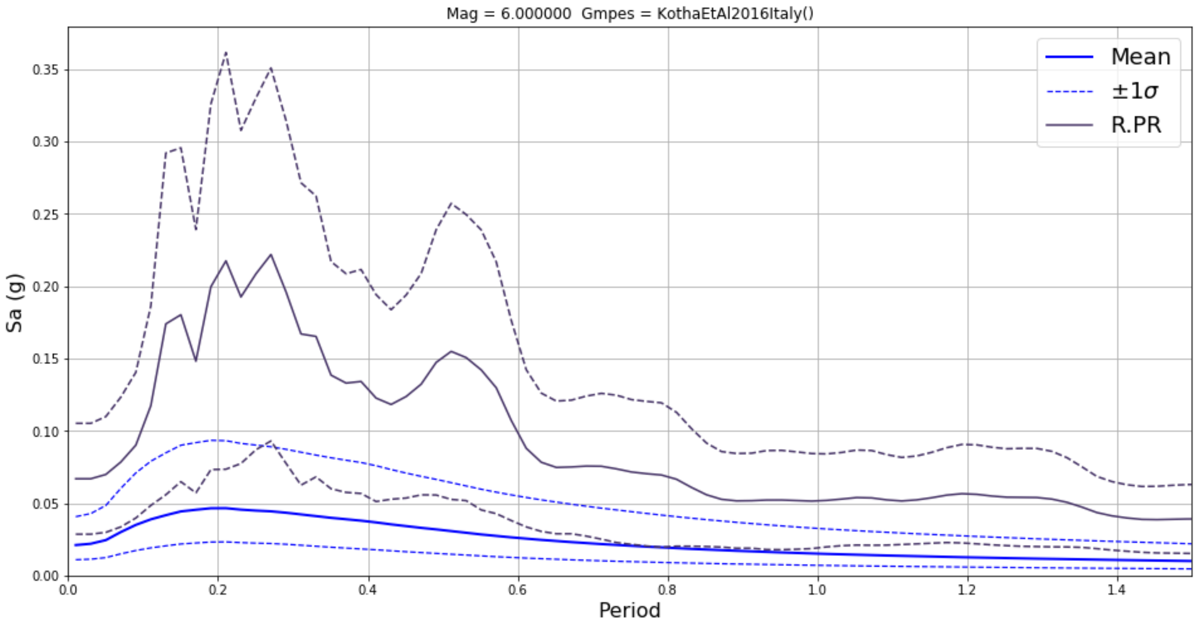
We used the Monaco (M 3.1) earthquake as an EGF and simulated the ground motion generated by a Mw= 6 event at the same place

Hybrid stochastic-EGF simulation method

NCAU (Var vallée)



PRIMA (airport slope, underwater)



Simulation results compared with Kotha et al. (2016, Italy) GMPE

→A Magnitude 6 eq generate a PGA value expected from a Magnitude 7 event at the same place

CONCLUSION

What we knew before : Sedimentary valleys amplify the seismic waves

What we have learned : Seismic waves amplification could even be stronger offshore

What we knew before : Factor favoring offshore landslides in Nice airport zone are : The slope, the high sedimentation rate due to the direct proximity of the mouth of the "Var" River, the possible overload due to artificial constructions

What we have learned : The effect of local earthquakes would be much larger than expected (+1 magnitude)

→ THIS STRONG OFFSHORE SITE EFFECT COULD HAVE A CRUCIAL IMPACT ON **THE POTENTIAL TRIGGERING OF SUBMARINE LANDSLIDES BY AN EARTHQUAKE**

A part of the results presented here have been published on January 2020 :

Courboulex, F., Mercerat, E., Deschamps, A. *et al.* Strong Site Effect Revealed by a New Broadband Seismometer on the Continental Shelf Offshore Nice Airport (Southeastern France). *Pure Appl. Geophys.* (2020). https://doi.org/10.1007/s00024-019-02408-9

Link to open acces : https://rdcu.be/b3PUS