SAPIENZA
UNIVERSITÀ DI ROMA

DEPARTMENT OF EARTH SCIENCES

Ph.D. School ''Vito Volterra''
Of Astronomy, Chemistry, Earth Sciences, Mathematics and Physics

Project proposal – Ph.D. in Earth Sciences
Academic discipline: GEO05

ADVANCED NON-INVASIVE AND HIGH-RESOLUTION MONITORING OF GROUND INSTABILITIES IN THE PERSPECTIVE OF MULTIHAZARD SCENARIOS

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1) Introduction and state of art

The analysis of geo-hazards, particularly landslides, in a multi-hazard framework is a relatively young field of research in natural hazard management in Italy. Therefore, this research project proposes a methodology developed taking into account the multi-hazard on the topic of the effects of ground instability. For the study of multi-hazard conditions through numerical modeling that will allow future scenarios to be analyzed.

Landslides are among the natural events related to the highest economic and social impact. In a multi-hazard perspective, seismic shaking, it is the second global triggering factor for landslides (the first being precipitation), as local seismic amplification can promote landslide (re)activation even under unexpected far-field conditions, thus increasing hazard (Bourdeau et al, 2017).

Recently, geophysical methods have emerged as alternative means to investigate the internal structure, hydrology, and mechanics of slopes. (Le Breton et al, 2017). Seismic geophysical methods, which measure the stiffness of LSs, can be divided into two main groups: (1) methods based on ambient noise (Anb) and (2) methods based on emitted signal (Esb). In the first type (ANb), changes in wavefield properties are detected as a consequence of variations in the landslide mass properties, which occur over time in the case of active processes. (Hussain, 2022)
This method approximates the impulsive response or Green's function of a medium to an excitation by cross-referencing the passively measured seismic noise from two sensors (Le Breton et al, 2017). In the event of precipitation, the crack/pores in the landslide material fill with water relative to the air cracks, so a change in velocities alter the surface wave velocity, which can be theoretically quantified in terms of dv/v calculated by ANI. (Hussain et al, 2018)
The advantages of using ANI for monitoring are several: firstly, it excluudes source parameters such as focal mechanism and source location. Secondly, it provides a dense and continuos data availability, which guarantees a high temporal coverage, and thirdly, it is non-destructive (D'Hour et al, 2015).

Nine landslides have been monitored by this method up to now. The potential for the relative change in seismic velocity to act as a precursor signal was recently confirmed in the case of the Montevecchio landslide, where the Rayleigh wave velocity decreased during the progressive acceleration of the landslide four days before its failure (Le Breton et al, 2017). However, part of the irresolution encountered by these techniques so far depends on the fact that they require continuous and significant recording times, of at least a few seasonal cycles, precisely to relate landslide activity to environmental variables and/or forcing factors. Therefore, further research on the suitability of these methods is needed to examine, enhance and improve their applications by certainly extending the recording times. (Hussain, 2019)

2) Research objective

2.1) General objective

Analysis of multi-hazard scenarios in view of georisk mitigation related to ground instabilities.

2.2) Specific objectives

Use of strategic and innovative monitoring methodologies to increase resilience. Installation of a long-medium term seismic monitoring network to study landslide activity and its potential evolution in space and time, focusing on the interaction between external forces (rainfalls and seismic events).

3) Implications and applications

This project is based on the prescriptions defined by the PNRR (National Recovery and Resilience Plan) for the improvement of technologies and methodologies for risk prediction and prevention, focusing on slope instability processes with particular attention to the management of urban areas and infrastructures. Refinement of this monitoring technique could provide insight into how the slope prepares for landslide reactivations related to triggers of periodic (e.g., seasonal) recurrence, such as precipitation, as well as more impulsive actions, such as earthquakes.

The acquisition of these data will make it possible to assess how and when the trigger acts on it and to perform future scenario analyses. This will make it possible to mitigate, through the estimation of a risk threshold, the impact that these phenomena could have on urban and areas and infrastructures.

4) Work plane

The case study for the proposed research project concerns the large landslide affecting the municipality of San Vito Romano (RM). The choice of this case study is guided by several factors, the main ones being: i) Visibility of landslide activity and its effects from both terrestrial and remote monitoring (satellite interferometry) ii) Past monitoring data iii) Documented response of landslide mobility to rainfall.

In this case study, a preliminary analysis of ambient noise has already been carried out, so the following activities will be performed as a part of this research project: i) Planning of investigation; ii) Analysis of spatio-temporal evolution of hazard; iii) Analysis of individual stations; iv) Interferometry of ambient noise; v) Verification of reliability of results v) Development of the empirical relationship between measured physical properties and weather-climate and remote sensing data.

4.1) Data acquisition

Pairs of triaxial velocimeters produced by SARA instrumentation (already in the Department's possession) with respective connectivity modules for remote connection and data transmission will be used for data acquisition.

This acquisition phase will have a duration of 1 year and 6 months so as to encompass multiple seasonal cycles and establish the threshold value of dv/v beyond which to give an alarm.

4.2) Data processing

Data processing, will be performed on open access platforms such as MSNoise (Lecocq et al., 2014) and other python-based codes that extract mechanical properties from the recorded surface waves. By cross-correlating the recorded seismic motion at two different points, the seismic response at those points can be inferred. This correlation extracts the so-called Green's function (the signal that would be recorded at one station if an impulsive force were applied to the other station or vice versa). Identifying the travel time between all pairs of receivers can then be used to produce a tomographic image that provides the velocity distribution of the medium separating two receivers. Continuous monitoring of these parameters will allow, at a later stage, to perform future prospective scenario analyses by modeling, accurately identifying possible landslide triggers and thus returning, under certain forcing, multiple occurrence scenarios.

4.3) Data Validation

In the selected case study, the reliability of the ANI results can be improved by comparing them with the deformations obtained from the collected data-in fact, it is possible to carry out a verification of the data obtained from satellite interferometry techniques, which in this field have yielded positive results, allowing the correlation of ground displacement with the damage to the building above. In addition, numerical models dedicated to the reproduction of multi-risk scenarios from a predictive perspective will be calibrated

5) Milestone

During the three years of the PhD research the following stages miestones will be reached:

- in the first year the monitoring network will be installed and data acquisition will begin, environmental data acquisition and retrieval and other monitoring techniques (e.g. satellite interferometry) will be activated for comparison;

- in the second year, the acquisition will continue by starting to use and refine the analysis procedures using MSNoise and other python-based codes;

- the third year will be dedicated to validate the monitoring outputs and calibrate numerical models, in view of deriving forward scenarios

7) Dissemination plan

During the first my PhD, I will attend the following events:

- 8th conference AIGAA 2024 scheduled for June 2024 in Naples
- PhD Day organized by spoke 2 (ground instabilities) RETURN project
- 39th General assembly of the european seismological commission scheduled for September 2024 in Corfu, Greece
- 18th ''World conference on Earthquake Engineering'' scheduled for July in Milan

8) Training activities

I intend to take part to following courses:

- Summers Schools in the framework of the RETURN project (PNRR-PE3)

- Internationale course on geotechnical and structural monitoring by NHAZCA

- PhD courses organized by ''Vito Volterra'' school of doctoral studies

9) Mobility abroad

My mobility plan will include an internship at the University of Liège, Department of Geology where I will be hosted by Prof. Hans-Balder Havenith.

10) GAANT chart – Time schedule

Research activity	Year	1st				2nd				3nd			
	Trimester	I	II	III	IV	I	II	III	IV	I	II	III	IV
Bibliographic update		■	■	■	■	■	■	■	■	■	■	■	■
Monitoring station location		■	■										
Training activities				■	■	■	■						
Seismic noise monitoring				■	■	■	■	■	■	■	■		
CCF MSNoise (dV/V)								■	■	■			
Calibrate numerical models									■	■	■	■	
Analysis of future scenarios										■	■	■	
Mobility abroad						■	■						
PhD Theisis													■

References

- Bourdeau C., Lenti L., Martino S., Oguz O., Yalcinkaya E., Bigarrè P., Coccia S., 2017. Comprehensive analysis of the local seismic response in the complex Büyükçekmece landslide area (Turkey) by engineering-geological and numerical modelling

- D'hour, V. (2015). Medium change monitoring using ambient seismic noise and coda wave interferometry: examples from intraplate NE Brazil and the Mid-Atlantic Ridge.

- Hussain, Y., Cardenas-Soto, M., Martino, S., Moreira, C., Borges, W., Hamza, O., ... & Martinez-Carvajal, H. (2019). Multiple geophysical techniques for investigation and monitoring of Sobradinho landslide, Brazil. *Sustainability*, *11*(23), 6672.

- Hussain, Y., Schlögel, R., Innocenti, A., Hamza, O., Iannucci, R., Martino, S., & Havenith, H. B. (2022). Review on the Geophysical and UAV-Based Methods Applied to Landslides. *Remote Sensing*, *14*(18), 4564.

- Le Breton, M., Bontemps, N., Guillemot, A., Baillet, L., & Larose, É. (2021). Landslide monitoring using seismic ambient noise correlation: challenges and applications. *Earth-Science Reviews*, *216*, 103518.

- Lecocq, T., Caudron, C. and Brenguier, F. (2014). MSNoise, a Python package for monitoring seismic velocity changes using ambient seismic noise. *Seismological Research Letters* 85(3), 715-725