3IA postdoc position

Axis 3: AI for secure and smart spaces

Title: AI-based tsunami early warning from GNSS data

Supervisor : Quentin Bletery (bletery@geoazur.unice.fr)
Location : Géoazur, Sophia-Antipolis, France

Context and motivation

Earthquakes and subsequent tsunamis cause hundreds of thousands of fatalities and billions of euros of economic loss. They are the deadliest of the natural hazards and the most economically consequential (UN Office for Disaster Risk Reduction, 2020). To this day, we do not know how to predict these catastrophic events. Nevertheless, earthquake and tsunami early warning systems exist. They rely on the fact that seismic waves and tsunamis propagate slower than telecommunication messages. This allows using early earthquake signals obtained from instruments located close to the epicenter to estimate the ground shaking intensity in more distant areas and to forecast subsequent tsunamis in order to alert the populations and initiate automatic safety procedures in critical infrastructures. The critical part is to rapidly and reliably estimate the magnitude of large earthquakes. For fundamental reasons, estimations from seismic waves saturate for the largest events, which results in dramatic underestimation of the subsequent tsunamis.

We have developed in our group a deep learning algorithm that leverages information contained in low-amplitude gravity perturbations (coined PEGS for Prompt Elasto-Gravity Signals, Vallée et al., 2017) to provide rapid unsaturated magnitude estimates (Licciardi et al., 2022, Hourcade et al., 2025). The downfall of the approach is that because of the low amplitude nature of the signal, the algorithm becomes unreliable for magnitudes below 8. The aim of this postdoc project will be to adapt the algorithm to leverage information contained in real-time GNSS (Global Navigation Satellite System) data in order to provide reliable magnitude estimates for magnitudes between 7 and 8.

Research program

The project will aim to adapt PEGSGraph (Juhel et al., 2024), a graph neural network we designed for rapid magnitude estimation from PEGS (Hourcade et al., 2025) in order to leverage information contained in GNSS data. We will follow the same procedure than with PEGS: simulating synthetic GNSS records corresponding to an exhaustive set of possible earthquake scenarios, adding empirical noise recorded in past years on the corresponding GNSS stations, and treating each GNSS time series as a new node in the graph neural network architecture. To the difference of PEGS, the point-source approximation will not hold to model GNSS co-seismic signals. Therefore, we will generate an exhaustive set of realistic co-seismic slip distributions to compute synthetic GNSS data. We will compare the respective performances of a GNSS-only, a PEGS-only and a joint PEGS-GNSS graph neural network to assess the relative contributions of each dataset. We will apply the approach to different seismically active regions of the world, starting with Alaska, Japan, Chile and Peru.

Expected outcome

The expected outcome of the project is a fully operational graph neural network for rapid earthquake estimation from GNSS data and from PEGS and GNSS data.
The successful candidate is expected to publish the obtained results in peer-reviewed articles, present them in international conferences and to publish the algorithm in an open-source repository.
Depending on the results, the candidate may be involved in the implementation of the approach into an operational early warning system, in collaboration with the agencies operating the systems in Alaska, Peru and New Caledonia.

Candidate profile

Applicants should hold a PhD in Geophysics or data science.
Strong programming skills and experience in GNSS data processing are required.
Experience with graph neural network will be appreciated.

Application

Candidates shall send the following material to Quentin Bletery (bletery@geoazur.unice.fr):

- curriculum vitae and publication list
- motivation letter
- contact information for at least one reference
- links to representative publications, software, or research artifacts.

References

Vallée, M., Ampuero, J. P., Juhel, K., Bernard, P., Montagner, J. P., and Barsuglia, M. (2017). Observations and modeling of the elastogravity signals preceding direct seismic waves. *Science*, *358*(6367), 1164-1168. https://doi/10.1126/science.aao0746

Licciardi, A., Bletery, Q., Rouet-Leduc, B., Ampuero, J. P., and Juhel, K. (2022). Instantaneous tracking of earthquake growth with elastogravity signals. *Nature*, *606*(7913), 319-324. https://doi.org/10.1038/s41586-022-04672-7

Hourcade, C., Juhel, K., and Bletery, Q. (2025). PEGSGraph: a Graph Neural Network for fast earthquake characterization based on Prompt ElastoGravity Signals. *Journal of Geophysical Research: Machine Learning and Computation*, *1*, e2024JH000360. https://doi.org/10.1029/2024JH000360

Juhel, K., Hourcade, C., & Bletery, Q. (2024). PEGSGraph : GNN-based rapid earthquake characterization using prompt elastogravity signals (Version 1.0) [Computer software]. Zenodo. https://doi.org/10.5281/zenodo.12751347