Aftershocks and Foreshocks for deep Earthquakes

Proposer: Piero Poli

This PhD project is conducted within the framework of the **SODA ERC project**, which aims to advance the understanding of deep Earth deformation through innovative seismological observations and analysis. The project investigates the spatiotemporal evolution of aftershocks and foreshocks associated with deep earthquakes in order to constrain the physical processes and rheology governing deformation in the deep mantle. Large earthquakes generate transient stress perturbations that act as natural probes of the surrounding rocks, and the resulting seismic response provides insight into mechanisms such as creep, stress transfer, fluid-related processes, and potential thermal instabilities at depth.

The PhD student will exploit newly developed high-resolution seismic detection and analysis methods developed within the SODA project to construct enhanced aftershock catalogs with improved spatial resolution and magnitude completeness. These catalogs will allow detailed tracking of aftershock evolution in space and time, including migration patterns and clustering behavior, across a wide range of subduction environments. Particular emphasis will be placed on the identification and characterization of repeating earthquakes and on the analysis of their temporal evolution, source properties, and scaling behavior, providing novel constraints on the rheology of deep seismogenic volumes.

These methods will be applied to seismic data recorded by local networks following deep earthquakes (typically magnitude ≥5) in regions such as South America, Japan, the Hindu Kush, Vrancea, and Tonga. In addition, selected major deep earthquakes recorded by dense local networks will be reanalyzed to investigate deformation processes occurring at depths of several hundred kilometers. These analyses will enable quantification of deep deformation processes and assessment of whether seismicity is driven by mechanisms such as plastic flow, stress diffusion, fluid migration, or thermally induced instabilities.

Beyond the analysis of individual sequences, the project will examine the collective properties of deep aftershock sequences, including productivity, spatial organization, and migration styles. By comparing observations across multiple subduction zones, the study will explore how aftershock behavior relates to the physical properties of subducting slabs, such as their thermal structure and the possible presence of fluids. Machine learning approaches will be employed to identify relationships between seismicity characteristics and slab properties, providing additional constraints on the mechanisms controlling deep earthquakes.

Although the primary focus is on aftershocks, the project will also investigate the pre-seismic period to search for potential foreshock activity. While challenging, the detection of foreshocks would offer unprecedented insights into the nucleation and initiation of deep earthquakes.

The PhD project will be carried out in close collaboration with the principal investigator of the SODA ERC project and will involve active collaboration with international experts in earthquake detection, quantitative seismicity analysis, and subduction-zone geodynamics. Through these collaborations, the project will benefit from complementary expertise and data sets, fostering a strongly international and interdisciplinary research environment. Overall, this PhD will deliver a new quantitative framework for interpreting deep earthquake sequences and will significantly advance our understanding of deformation processes operating in the deep Earth.

Funding: ERC SODA + DOR + FINAS