# ÉCOLE DOCTORALE
## SCIENCES DE LA TERRE ET DE L'ENVIRONNEMENT ET PHYSIQUE DE L'UNIVERS, PARIS

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**Subject title: From the earthquake cycle to permanent deformation of the forearc in subduction zones**


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Financing: Doctoral contract with or without teaching assignment

## *Presentation of the subject:* (Maximum 2 pages)

In subduction zones, long quiet periods during which stress and strain accumulate are abruptly ended by large, devastating megathrust earthquakes. Over these long so called "interseismic" periods, the relative continuous motion of convergence of tectonic plates leads to the buildup of elastic energy over hundreds of years in the vicinity of locked regions of the subduction interface, the megathrust. This elastic energy is released during the co- and post-seismic phase, with meters of slip on the megathrust over tens of seconds. In addition, slow slip events release part of this elastic energy episodically, silently. During the co- and post-seismic periods, meters of vertical motion are observed along the coastline, with large, centimeter-scale displacements observed several hundreds of kilometers inland. Such motion is, in theory, balanced over cycles of earthquakes and current models of the earthquake cycle in subduction zones do not account for internal deformation of the overriding plate.

Over millions of years however, it is clear that the overriding plate deforms. Some of the highest mountain ranges in the world, including the Himalayas or the Andes are a clear reminder that this first-order, purely elastic view of the earthquake cycle does not hold at geological time scales. In particular, recent publications have highlighted a clear relationship between interseismic coupling, internal deformation, off-fault seismicity and the building of topography in the forearc. This means that part of the energy from plate convergence will not fuel megathrust earthquakes but rather drive uplift in the forearc, modifying our understanding of seismic hazard.

These converging observations are pointing toward the idea of a fingerprinting of the interseismic period in the building of forearc topography, but we are missing (1) a generic description of vertical motion in a subduction zone over all phases of the earthquake cycle and (2) and quantitative elasto-plastic model that would explain both the cycle of megathrust earthquakes and the building of topography.

In Chile, we are now in a position to build a generic description of vertical motion over all phases of the earthquake cycle from geodetic data. The PhD candidate would begin by extracting a generic description of vertical motion over Chile from the 20 yr-long time series of surface motion at 300+ sites evenly distributed across Chile. Such study will be complemented by the post-processing of the 6 yr-long time series of InSAR data processed by the FlatSim initiative (CNES/ESA). Chile has been struck over the past 20 years by several large magnitude earthquakes (>7), is experiencing slow slip events and uplift rates over the quaternary are relatively well-known all along the Chilean coastline. The second objective will be to build a Bayesian visco-elastic coupling map over the whole Chilean subduction megathrust to identify portions that are locked in between large megathrust earthquakes. The third objective will be to experiment numerical models of internal damage in the forearc, using the boundary conditions imposed by the coupling distribution, in order to separate persistent deformation from elastic strain.

The LG-ENS has a long standing expertise in geodesy, geology and numerical modeling, in particular with application to the Chilean subduction zones. All tools, including geodetic post-processing tools, a finite element numerical modeling software and numerical models of damage rheology are available and already developed to conduct this project, which should benefit from decades of research by the advising team. Depending on the candidate's profile and interests, he/she may be required to participate in one or more field data acquisition campaigns (GNSS, in particular in Chile) in addition to their analysis and modelling.

More information can be obtained from the advising team and by reading the following list of papers:


> Métois et al (2016) Interseismic Coupling, Megathrust Earthquakes and Seismic Swarms Along the Chilean Subduction Zone (38°–18°S), *Pure and Applied Geophysics*, doi: 10.1007/s00024-016-1280-5
> Jolivet et al (2020) Interseismic loading of subduction megathrust drives long-term uplift in northern Chile, *Geophysical Research Letters,* doi: 10.1029/2019GL085377
> Klein et al (2021) Interplay of seismic and a-seismic deformation during the 2020 sequence of Atacama, Chile, *Earth and Planetary Science Letters,* doit: 10.1016/j.epsl.2021.117081
> Klein et al (2022) A 20 year-long GNSS solution across South America with focus in Chile, *BSGF*
> Madella & Ehlers (2021) Contribution of background seismicity to forearc uplift,
*Nature Geoscience,* doi: 10.1038/s41561-021-00779-0
> Malatesta et al (2021) Co-location of the Downdip End of Seismic Coupling and the Continental Shelf Break, *Journal of Geophysical Research: Solid Earth*, doi: 10.1029/2020JB019589