Subject offered for a contract starting october 2015

SUBJECT TITLE: Multi-scale analysis of slow earthquakes associated with active deformation processes in subduction zones: from statistical signal analysis to source extraction and mechanics

Advisor: **Jean-Pierre Vilotte, Physicien, vilotte@ipgp.fr**
Second Advisor/ Supervisor:
Claudio Satriano, Physicien Adjoint, satriano@ipgp.fr

Host lab/ Team :
IPGP – Sismologie – UMR 7154

Financing: Doctoral contract with or without assignment

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Within the past decades, improved seismological networks have led to the discovery of an expanding variety of slow earthquakes in the context of active subduction zones. These new family of events can be classified according to observable frequency bands:

- Slow slip events (SSEs): transient slip at subduction plate interface, observed by GPS and borehole tiltmeters, lasting several days or months (*Dragert et al.*, 2001; *Obara et al.*, 2004);
- Non-volcanic deep low frequency tremors (LFT): long-lasting (minutes to days) weak-amplitude vibration at frequencies of 1-10 Hz (*Obara*, 2002);
- Low frequency earthquakes (LFEs): signals at frequencies of 1-10 Hz localised in time and often embedded in tremors coming from the subduction plate interface (*Shelly et al.*, 2006) that may coincide with slow slip events (*Rogerts and Draggert*, 2003; *Obara et al.* 2004);
- Deep very low frequency earthquakes (VLFEs): signals of 20-200s period, observed so far in southwest Japan by broadband seismometers and tiltmeters (*Ide et al.*, 2008).

Slow earthquakes and SSEs are distinctive phenomena that are fundamental for understanding active deformation processes that accommodate plate convergence within the seismic cycle. They obey a different energy-duration scaling law than regular earthquakes (*Ide et al.*, 2007), and they can be thought of as diverse manifestations of the same process. The weakness of these signals (barely emerging from noise), their complexity (mixing of sources) and their non-stationarity (and possible nonlinearity) makes it difficult to apply usual signal analysis to derive source characteristics.

An important question, yet unanswered, is to understand the physical and statistical mechanisms underlying the generation of those slow earthquakes. We do not have, to date, adequate physical models describing slow earthquakes mechanisms and interactions and their relation to active deformation processes. Today it is timely to tackle this problem thanks to new dense seismic networks, which can be seen as large-scale interferometers, and new statistical seismic processing techniques baring some similarity with astronomy and astrophysics.

A first objective of this thesis will build upon new methods for source detection and extraction developed in the team (*Poiata et al.*, 2014). The candidate will explore and develop innovative time-frequency-scale signal analysis methods to detect, locate and characterise the non-stationary signatures of slow earthquakes. The candidate will then extract scaling laws of their radiated energy content and phase structures that may constrain statistical physical models of their source processes.

A second objective is to derive activity maps of seismic energy release to constrain the space-time variability and interactions between the different manifestations of slow earthquakes (LFEs, LFTs, VLFEs) along the plate subduction interface and within the seismic cycle.

The thesis will focus first on southwest Japan, one of the best natural laboratories in the world, where the full spectrum of slow earthquakes (LFEs, LFTs, VLFEs, SSEs) can be observed, thanks to the dense network of high-sensitivity seismometers and tiltmeters (Hi-net; *Obara et al*., 2005), maintained by the National Research Institute for Earth Science and Disaster Prevention (NIED). Extension to other subduction zones will be considered during the thesis.

This thesis will involve statistical signal analysis, statistical physics and mechanics, mechanical and numerical modelling.
The work will be conducted within the framework of existing collaborations with the Earthquake Research Institute (ERI) at the University of Tokyo and the Astronomy-Astrophysics group at APC (Paris Diderot). During the thesis short time missions at ERI (Tokyo) are considered.

References

Dragert, H., Wang, K, and Rogers, G. Geodetic and seismic signals signatures of episodic tremor and slip in the northern Cascadia subduction zone. Earth Planets and Space, 56, 1143-1150, 2004.

Ide, S., Beroza, G.C., Shelly, D.R. and Uchide, T. A scaling law for slow earthquakes, Nature, 447, 76-79, 2007.

Ide, S., Imanishi, K., Yoshida, G., Beroza, C., and D.R. Shelly. Bridging the gap between seismically and geodetically detected slow earthquakes, Geophys. Res. Lett., 35, L10305, 2008.

Shelly, D.R., Beroza, G.C., Ide, S. and Nakamura, S. Low-frequency earthquakes in Shikoku, Japan, and their relationship to episodic tremor and slip, Nature, 442, 188-191, 2006.

Obara, K. Nonvolcanic tdeep tremor associated with subduction in southwest Japan, Science, 296, 1679-1681, 2002.

Obara, K., Hirose, H., Yamamizu, F., and Kasahara, K. Episodic slow slip events accompanied by non-volcanic tremors in southwest Japan subduction zone, Geophys. Res. Lett., 31, L23602, 2004.

Obara, K., Kasahara, K., Hori, S. and Okada, Y. A densely distributed high-sensity seismograph network in Japan: Hi-net by National Research Institute for Earth Disaster Prevention, Re. Sci. Instrum., 76, 2005.

Rogers, G. and Dragert, H. Episodic tremors and slip on the Cascadia subduction zone: the chatter of slilent slip, Science, 300, 5627, 1942-1943, 2003.