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

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Subject title: **Short-term dynamics of subducted slabs from satellite gravity**

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Presentation of the subject:

At the interface between a continental plate and an oceanic plate plunging into the mantle, subduction zones are geological boundaries where most great earthquakes (Mw > 8) occur. Although seismology and ground motion measurements describe the shallow deformations and the seismic ruptures with great accuracy, the deep aseismic deformation processes and their contribution in a rupture initiation remain difficult to observe. To document these deeper motions in subduction systems, an original approach consists in analyzing the gravity signals caused by the corresponding mass redistributions, using GRACE satellite observations on the space-time gravity variations. This way, we have evidenced anomalous gravity changes of deep origin during the months before the 11 March 2011 Tohoku earthquake (Mw 9.0, Japan) and the 27 February 2010 Maule earthquake (Mw 8.8, Chile)(Panet et al., 2018 ; Bouih et al., 2022). The gravity signals suggest an extension of the subducted plates in the upper mantle, between 150 and 300km depth, which could have contributed to create favourable conditions to the initiation and the propagation of these large ruptures. These results reveal the existence of a rapid dynamics of subducted slabs in the upper mantle, able to deform aseismically at short time scales. Following these studies, our objective here is to identify in real time short-term (~months) gravity anomalies before great ruptures to describe how they are initiated at depth.

To understand the interaction of deeper slab motions with seismic events, we need to determine (1) whether all great earthquakes are preceeded by such signals, (2) if there is a minimum magnitude, below which the rupture does not involve deep pre-seismic motions in the subduction system, and (3) if conversely, we can find signals from deeper slab motions, that are not followed by a large earthquake. To answer these questions, we propose to perform a systematic investigation of the gravity signals that may be associated with transient slab deformations at depth along the Pacific subduction belt during the period of observation of GRACE, in particular (but not only) before great shallow subduction earthquakes. This concerns the September 15, 2006 and the January 13, 2007 Kuril earthquakes (M_w 8.3/8.1) along the Northwest Pacific subduction, the December 26, 2004 Sumatra (M_w 9.2), March 28, 2005 Nias (M_w 8.7) and September 12, 2007 Bengkulu (M_w 8.5) earthquakes along the Indonesian subduction, and the September 29, 2009 Tonga earthquake (M_w 8.1) along the Tonga-Kermadec subduction.

To decipher deep solid Earth signals from the predominant water cycle signals and the artefacts in the gravity field models, we will use methods of space-time analysis of the Earth's gravity gradients developed in previous work (Panet et al., 2018, 2022 ; Bouih et al., 2022). We will search for fast gravity signals aligned with subduction boundaries, such that the shape, location and/or amplitude of the signals differ from those expected for geofluid sources. The existing procedures will be adapted for a systematic monitoring of the entire circum-Pacific subduction belt: we will take into account the change of plate boundary orientation in different regions, and automatically identify spatial patterns of anomalies differing from those predicted by a whole ensemble of global hydrological, oceanic and atmospheric mass redistribution models. This will allow us to identify gravity anomalies, potentially associated with deep mass redistributions in the subduction system.

In areas where deep gravity signals are found, we will carry out a more detailed study of the regional and tectonic context, and investigate existing geodetic and seismicity data. To characterize the potential deep deformations, we will perform a forward modelling of the gravity signals using dislocation models in a visco-elastic Earth, and compare the gravity-based equivalent slip model to known crustal displacements and earthquakes sequences.

Even in absence of deep gravity signals, the results will contribute to answer the points 1-3 above. By providing a detailed set of gravitational observations and their interpretation in terms of slab motions along the Pacific subduction belt, this work will pursue the investigation of a new class of short-term deep anomalies occurring before great earthquakes. This could provide an important contribution for the evaluation of the seismic hazards, and support the development of future satellite gravity missions with enhanced performances to carry out such monitoring over the long term.

References

Bouih, M., et al. (2022), *EPSL*, 584, 117465.
Panet, I., et al. (2022), *JGR*, 127(8), e2022JB024542.
Panet, I., et al. (2018), *Nat. Geosc.*, 11(5), p. 367-373.