Subject offered for a contract starting October 2018

SUBJECT TITTLE: 3D RUPTURE DYNAMICS ON COMPLEX FAULT GEOMETRIES TO INVESTIGATE SURFACE RUPTURE HAZARD AND NEAR FAULT GROUND MOTIONS

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CONTEXT AND MOTIVATIONS

Seismic Hazard Assessment (or SHA) is usually based on empirical models. However the number of data in fault vicinity (ground motions) or on the fault (fault ruptures) is still relatively limited, and uncertainties linked to earthquake source are significant. Indeed, the source detailed characteristics have an impact on the ground motions and deformations, and part of the variability of prediction directly comes from the details of the source process. Recently, this has pushed the international community of seismic hazard (academic and industrial) towards introducing more rupture physics into hazard assessment methodologies, with the goal to reduce the uncertainties still associated to hazard estimations close to faults. A large research effort has to be done in order to develop, validate and make proper usage of the physics-based models for SHA.

Surface displacement is the only direct observation of an earthquake rupture, yet not enough compared to the deeper rupture process. It should allow us to better understand the characteristics of the earthquake source. Geodesy today's development allows precise measuring of a fault surface rupture along its whole length after an earthquake. Large recent earthquakes indicate that surface displacement is very variable and complex (influences of fault geometry, underground nature, deeper fault displacement characteristics, etc.). In 2013, a large earthquake stroke Baluchistan (M7.7, 250 km of rupture). Surface ruptures have been studied up to a never-reached detail level, showing a diversity of characteristics: relays between fault segments, fault dip angle variations, secondary ruptures, etc.
Can we explain these surface observations by spontaneous ruptures on complex fault segments? Can we precise the mechanisms for secondary faulting? This earthquake seems to be an ideal case to confront modeling of surface rupture and real data, opening a new way for a better understanding of the earthquake dynamics and surface rupture hazard.

The comparison of the models results against data is an essential step, and can also drastically improve our knowledge of the earthquake rupture processes. These are the two aspects of this thesis, which will be one of the first contributions towards the physics-based modeling of ground motions and deformations, particularly close to faults.

METHODS AND DATA

The PhD candidate will use a 3D rupture dynamics code based on Boundary Integral Equation Method (BIEM), developed continuously since the years 2000 by colleagues from ENS and NIED (Japan). The code is optimized for running on HPC clusters. IRSN recently joined a huge HPC infrastructure (CCRT in Bruyères-Le-Châtel) and this will benefit to the thesis.

One advantage of BIEM code is the simplicity to compute spontaneous ruptures on 3D faults and 3D fault networks. The free surface was introduced in the code by S. Hok (Hok & Fukuyama 2011), making the surface rupture possible, using multiple faults (principal and secondary), as well as the production of deformations maps comparable to what is now obtained from geodesy after an earthquake.

Using optical correlation techniques, Y. Klinger and his students have been mapping large amounts of surface deformation data (multiple rupture traces, gradients of deformation), especially for Baluchistan earthquake (Vallage et al. 2015). Those data will be confronted to the rupture models outputs.

THESIS OBJECTIVES AND PROPOSED STRUCTURATION

In the first part and core of the thesis (first one year and a half), the priority will be to compare the numerical method with the surface data. This task consists in comparing observational data (surface deformations and ruptures) with the results of the numerical approach. We will start with the Baluchistan earthquake data, for which previous work have revealed interesting cases for comparison, such as secondary rupture off the main fault, step overs, etc. Other quakes with interesting features could also be tested (e.g. Kumamoto, Kaikoura, Napa, etc.).

The second part of the thesis will be dedicated to sensitivity studies of the validated model. Parametric explorations and analyses will cover a wide range from source physical parameters to the ground motions predicted by the model. A task will consist in studying and understanding the conditions for surface rupture emergence, and its characteristics. The surface ruptures seem variable in terms of amplitude, style (distributed or not), and their characteristics depending on magnitude, depth, or mechanism of the earthquake need to be clarified. The focus will be put on fault properties as a function of depth and fault geometry. An additional task will be to identify possible relationships between surface rupture and ground motions. The near fault ground motions are supposed to be controlled mostly by local source effects, so we propose to take benefit of achieved developments in the surface rupture modeling in the first tasks to check this.

The PhD candidate will conduct numerical experiments, with a strong emphasis on data comparison. The candidate will be hosted at IRSN (Seismic Hazard Team) and IPGP (Tectonics Team).

IRSN PhD candidates are required once a year to write reports and present their work (posters, oral presentation). It is also expected that he/she will present the work at international meetings and in scientific publications.