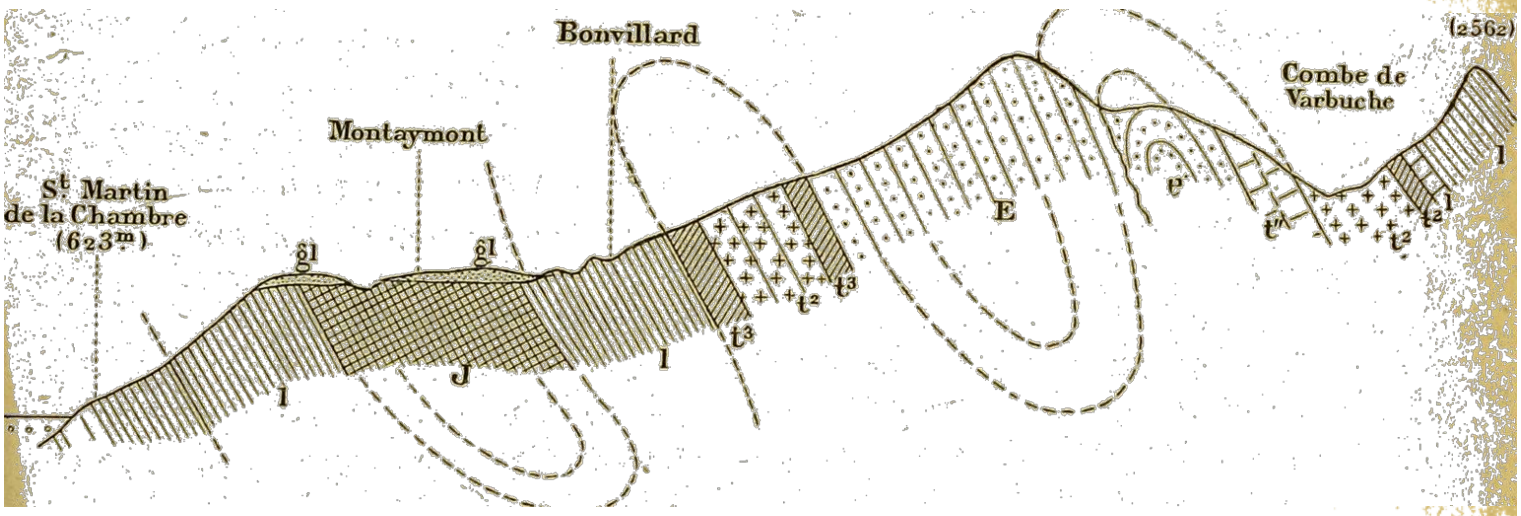
Student Congress



Autrans

29-30 March 2018

ISTerre

Nom	Prénom	Equipe	Heure
Pladys	Arnaud	Ondes	10h – 10h15
Carrara	Alexandre	Géophysique des Volcans	10h15 – 10h30
Sarr	Anta-Clarisse	TRB	10h30 – 10h45
Irnaka	Theodosius Marwan	Ondes	10h45 – 11h
Van Dinther	Chantal	Ondes	11h – 11h05
PAUSE			
Sanchez	Hugo	Ondes	11h15 – 11h30
Tartrat	Timothé	Géophysique des Volcans	11h30 – 11h35
Barajas	Andres	Ondes	11h35 – 11h40
Su	Sylvie	Géodynamo	11h40 – 11h55
Coperey	Antoine	Géophysique des Volcans	11h55 – 12h10
Salcedo Arciniega	Marco	Ondes	12h10 – 12h15
Gerick	Felix	Géodynamo	12h15 – 12h20
REPAS			
ACTIVITÉ			
Canel	Vincent	Ondes	17h30 – 17h35
Aslan	Gokhan	Cycle	17h35 – 17h50
Van Baarsel	Tobias	Ondes	17h50 – 18h05
Astorga	Arianna	Ondes	18h05 – 18h20
Oghalaei	Kaveh	Risques	18h20 – 18h35
PAUSE			
Pothon	Adrien	Ondes	18h45 – 19h
Le Boulzec	Hugo	Minéralogie	19h – 19h05
Brives	Jacques	Ondes	19h05 – 19h20
Dollet	Cyrielle	Ondes	19h25 – 19h30
Shible	Hussein	Risques	19h30 – 19h35
Gradon	Chloé	Ondes	19h35 – 19h50

VENDREDI			
Maubant	Louise	Cycle	9h – 9h05
Cosenza	Beatriz	Cycle	9h05 – 9h20
Marinière	Judith	Cycle	9h20 – 9h35
Thurin	Julien	Ondes	9h35 – 9h50
Bontemps	Noélie	Risques	9h50 – 10h05
Gérard	Benjamin	TRB/Cycle	10h05 – 10h10
Roy	Sandrine	TRB	10h10 – 10h25
PAUSE			
Guillemot	Antoine	Risques	10h40 – 10h55
Fiolleau	Sylvain	Risques	10h55 – 11h
Soergel	Dorian	Ondes	11h – 11h05
Le Roy	Gaëlle	Failles	11h05 – 11h20
Mathey	Margaux	Cycle	11h20– 11h25

Le Breton	Mathieu	Risques	11h25 – 11h30
REPAS			
Denys	Axel	Minéralogie	14h – 14h05
Smittarello	Delphine	Géophysique des Volcans	14h05 – 14h20
Zandanel	Amber	Minéralogie	14h20 – 14h25
DISCUSSION			

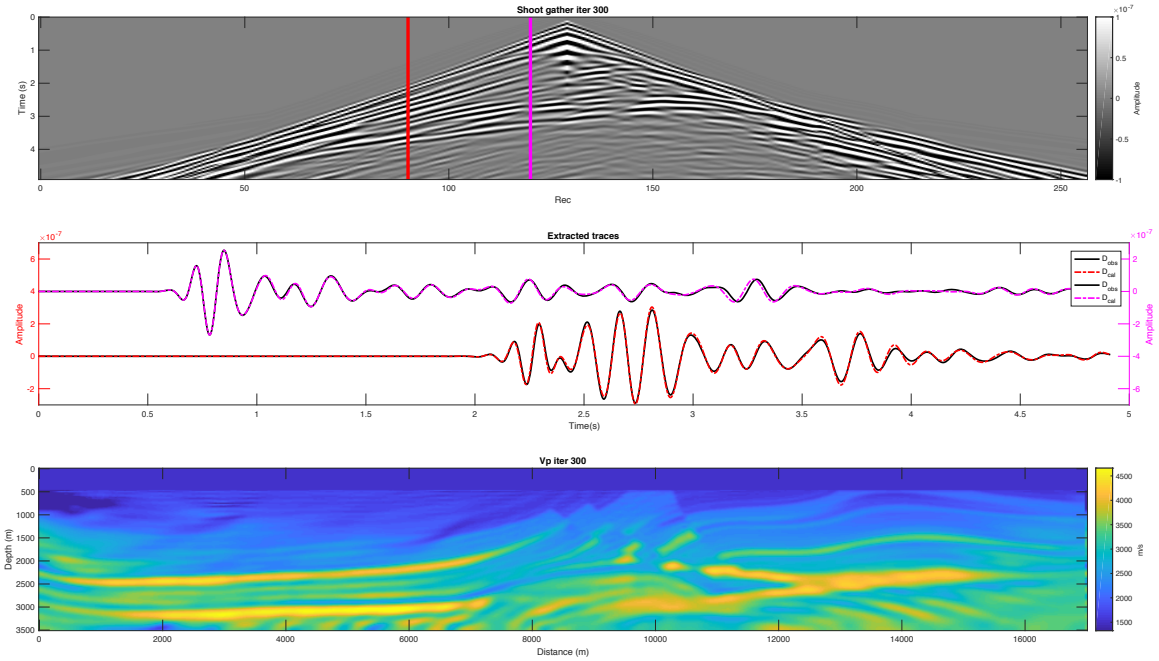
Arnaud PLADYS

2st year Phd Student

Waves and Structures

Full Waveform Inversion (FWI) is a promising high-resolution seismic imaging technic. This inverse problem aims at minimizing the residual between observed and synthetic data. This error measure is conventionally the L^2 norm of the difference between the two data-sets, but it suffers from the cycle-skipping issue.

I present here a 2D FWI tests performed on the Marmousi case, a well-known benchmark in the seismic imaging community, as presented in the Figure below. These results show the robustness of the 2D Optimal Transport misfit approach for FWI for a bad starting model. This example confirms that using alternative misfit functions could be the solution to mitigate the cycle-skipping sensitivity of FWI. However, there is still some work to do to assess the total robustness of such alternative in more complicated case, such as real data.



Reconstructed Vp model after 300 iterations of 2D Optimal Transport based Full Waveform Inversion on Marmousi synthetic models. Here the initial model used is a strongly smoothed version of the true model. We can observe an almost perfect fit in the data. The reconstructed Vp model is also excellent. In this case, using the conventional L^2 misfit formulation of the FWI would not allow any convergence toward a correct solution.

Alexandre CARRARA
1st year Phd Student
Volcano Geophysics

The reawakening of a volcano asleep for centuries or millennia remains a puzzling phenomenon. The complexity of reawakening stems from the semi-solid nature of the magma contained in the chamber underneath the volcano. The arrival of new magma causes the remobilization of the semi-solid host magma by heating and fluid input. Reawakening is thus the progressive transition from a medium where solid crystals are in contact to a liquid suspension where the continuous network of crystals is broken and eruption can occur (Burgisser and Bergantz, 2011). This transition affects the physical, elastic, and seismic properties of the host magma, rearranging crystals and changing the way seismic waves propagate across the chamber. Such variations could be detected by seismic noise correlation methods. By penetrating into the conduit, the remobilized magma could also generate seismic perturbations that can be detected at the Earth's surface.

The thesis aims at modeling the remobilization of a magmatic chamber thanks to numerical simulations coupling finite volumes and discrete elements (Bergantz et al. 2015) that are able to reproduce the physical change from a semi-solid to a mobile convective state. The complementary computation of synthetic seismograms (Jousset et al., 2003; Virieux, 1986) implies the study of the source mechanisms and the propagation of seismic waves in a complex medium at the micro- and macro scales present in a magmatic reservoir. Beyond the validation of the model outputs by comparison to canonical cases of volcanic eruptions (Pinatubo, 1991; Montserrat, 1995), the reawakening time of which are known, an exploratory predictive task is planned.

Anta-Clarisse SARR
3rd year Phd Student
Tectonics, Relief, Basins

Subsidence (and surrection) in SE Asia: from mantle dynamic to climate

The West Indonesian archipelago registered drastic paleogeography changes over the Plio-pleistocene in response to sea-level oscillations or basement vertical deformation that enabled the periodic emergence of the Sunda shelf, as emphasizes by our previous results, which suggest that the Sunda shelf is subsiding at rather high rate (0.2 mm/yr). The emergence of this wide continental platform in the heart of the Maritime Continent may have modified the regional/global climatic system. We investigate the effect of the Sunda shelf exposure on atmospheric and oceanic dynamics using a set of sensitivity experiments within the global coupled model (GCM) IPSL-CM5A2. Our results show that the diurnal heating of the continental platform surface enhances lower level convergence and convection, and results in increased seasonally air moisture input and local precipitations, which contrast with previous simulations within other GCM. This effect is modulated by increased turbulent heat flux driven by vegetated surface properties such as roughness. Increasing precipitation over the exposed platform also impacts the fresh water export into seawater (Indian ocean and Indonesian throughflow salinity).

Theodosius Marwan IRNAKA

2nd year Phd Student
Waves and Structures

Full Waveform Inversion (FWI) offers high-resolution seismic imaging and has been intensively developed and studied during the past years. FWI has been widely used in the seismic reflection in exploration scale, but these days, the application of FWI is moving towards the near-surface case where the elastic effect is non-negligible. The most prominent elastic effect on this near-surface scale is the presence of surface wave. This challenges of complex physics motivate the development of an acquisition technique so-called 3x3C seismic. This 3x3C seismic is seismic data acquisition which takes into account three orthogonal source and receiver directions, which make in total nine seismic recording for each source location.

This novel technology possesses a big question on how effective is this approach in relation with FWI. Answering this question, a sensitivity analysis of each seismic component has been carried out. It was shown that 3x3C seismic data is indeed brought more illumination of the medium which is represented by its parameter gradient. But based on this analysis, it was also known that the surface wave significantly influences the gradient; therefore this problem needs to be addressed properly. Some approaches such as performing separate inversion between surface and body wave or implement proper preconditioning.

A synthetic and real field 3D 3x3C seismic experiment has been performed to understand the benefit of 3x3C seismic data towards FWI. The synthetic (subSEAM) data was calculated based on SEAM model; SEAM is a benchmark model which was widely used in oil and gas industry. Several FWI will be performed based on the variation of source-receiver component and location. The real field acquisition was performed in April 2017 in collaboration with Karlsruhe Institue of Technology (KIT). The target is Etlinger Line, a defensive trench line which was built during the world war. In order to perform a proper FWI, there are several preprocessing need to be done, such as data stitching using the matched filter and building the initial model.

Chantal VAN DINTHER
1st year Phd Student
Waves and Structures

Monitoring of elastic properties in a medium with non-uniform scattering properties: numerical tests and applications to actual data

Diffuse (i.e scattered) waves have long been thought to be devoid of local information and therefore inappropriate for tomography. Recent theoretical works in the field of multiple scattering have demonstrated that the sensitivity of scattered waves to either temporal or spatial perturbations of the medium is in fact localized in the vicinity of singular points or surfaces. Imaging the small-scale elastic and anelastic fluctuations of parameters in the Earth, as well as their temporal variations is the aim of my part of the project. Preliminary results by the working group show that an accurate computation of sensitivity kernels is possible in the framework of transport theory. The goal of my PhD is to extend these first results to realistic configurations including the stratification of background velocity and the concentration of scatterers around specific structures such as fault zones.

The project consists of two steps:

1. mapping the attenuation structure of the fault zones, separating elastic and anelastic processes, in order to identify the damage volume.
2. monitoring the in-situ temporal charges of the brittle zone

Hugo SÁNCHEZ-REYES
3th year PhD Student
Waves and Structures

The kinematic source inversion is a well-known sparse, highly underdetermined, ill-posed problem when treated linearly. The non-unicity of its solution is evidenced by the variability on the inverted kinematic reconstructions that can be found for any given earthquake in the literature. Therefore, it is mandatory to provide a measurement of the uncertainties associated to the given solution of the inverse problem.

New bayesian inference algorithms based on basic physics, such as Hamiltonian mechanics, have demonstrated to be very powerful tools to tackle high-dimensional problems as the kinematic source inversion problem. Under this framework, some strategies could be applied to solve the linear inverse problem while still providing a measure of the associated uncertainties. Here we present the basic principles behind these strategies and a glace at their possible application to the progressive kinematic source inversion.

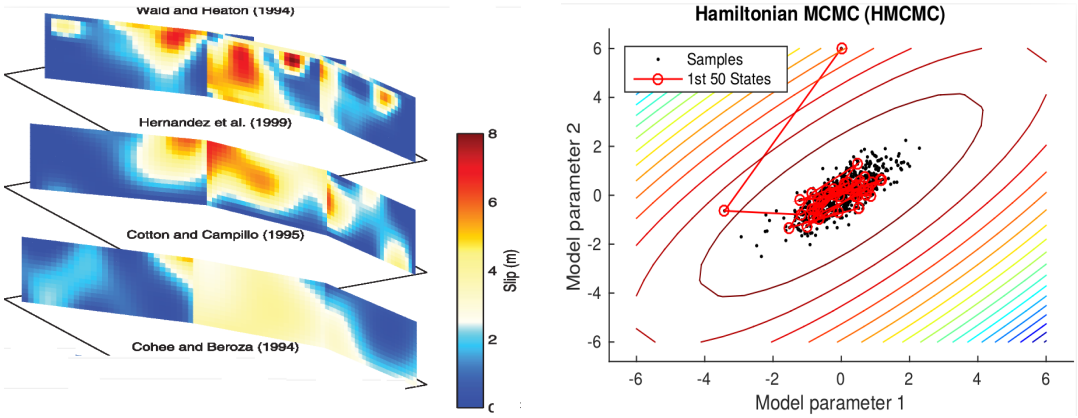


Figure 1: Variability on kinematic source inversion results for the 1992 Landers earthquake (left). Sketch of how Hamiltonian MCMC can explore the high-dimensional space of solutions to accurately map its probability distribution (right).

Timothé TARTRAT

First year Phd Student

Volcano geophysics

The French national radioactive waste management agency (ANDRA) is currently studying the storage of nuclear waste in an underground laboratory in Bure. An Excavated Damaged Zone (EDZ) is induced by the digging of galleries. The aim of this thesis is to characterize this EDZ, and mainly to get the permeability. To do so, we will use two different methods. The first one is the spectral induced polarization, which is the reversible storage of electrical charges inside the medium (here Callovo-Oxfordian Clay-rocks). It is then possible to link the parameters obtained by this geophysical method to the permeability.
For the second method we do an harmonic hydromechanical stimulation of the ground, then we measure the electrokinetic response of the medium. With this response the permeability of the medium can be imaged.

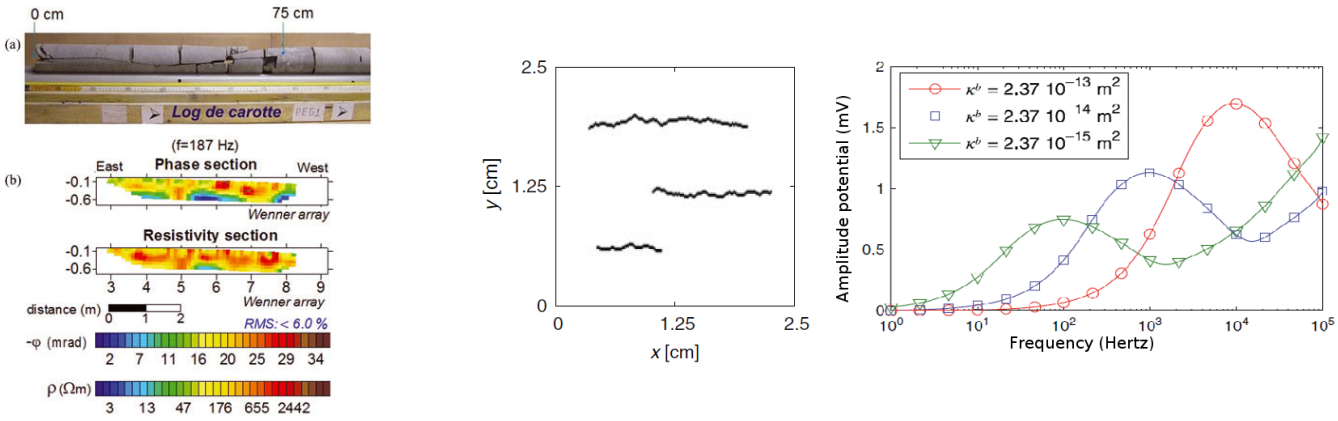


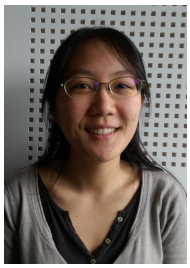
Figure 1: Left : example of induced polarization to caracterize fractures (*Okay et al., 2013*) Right : electrokinetic response to an harmonic hydromechanical stimulation depending on the permeability (*Jougnot et al., 2013)*

Andrés Barajas
1th year PhD Student
andres.barajas-ramirez[at]univ-grenoble-alpes.fr

Imaging for scattering properties of the crust

The last ten years have seen a growing use of random wavefields in seismic imaging. While diffuse (i.e scattered) waves have long been thought to be devoid of local information and therefore inappropriate for tomography, recent theoretical works in the field of multiple scattering have led to a profound revision of this common belief. It has been demonstrated, in particular, that the sensitivity of scattered waves to either temporal or spatial perturbations of the medium is in fact localized in the vicinity of singular points or surfaces. This, in turn, implies that it is possible to retrieve local properties of the medium using diffuse seismic waves.

The objective is to image the small-scale elastic and anelastic fluctuations of parameters in the Earth, as well as their temporal variations. Preliminary results in simplified cases (no mode coupling, no depth dependence of the propagating medium) show that an accurate computation of sensitivity kernels is possible in the framework of transport theory. The goal is to extend these first results to realistic configurations including in particular the free surface condition and the stratification of background velocity. From the physical point of view, the challenge is to include the coupling between surface and body waves in a multiple-scattering framework. This coupling is key to quantify the depth and lateral resolving power of diffuse waves as a function of lapse-time and frequency.



Sylvie SU
2nd year PhD Student
sylvie.su[at]univ-grenoble-alpes.fr

Zonal flows, flows parallel to the equator, form a preferential family of motions in rotating fluids because they are the only motions that satisfy the geostrophic constraint. However, it is not yet clear what governs their formation and saturation. In planetary fluid cores, it is believed that zonal flows result from vigorous convective mixing of the potential vorticity carried by fluid columns aligned with the rotation axis by the Coriolis effect (Taylor-Proudman columns).

In order to mimic planetary cores conditions, we need to produce very vigorous deep thermal convection at very low Ekman number ($E_k < 10^{-7}$) for moderate or low Prandtl number (< 1). These regimes are not yet reachable in numerical simulations, so we propose to build a novel experiment set-up of thermal convection in a rotating sphere using gas as a working fluid. The goal is then to measure the resulting flows. Due to the important constraints (high rotation rate, temperature variations, turbulence) it is difficult to obtain quantitative measures with classical methods. We therefore use a new instrumental approach based upon acoustic modes, following strategies first developed in helioseismology. This method is first tested on known flows such as solidbody rotation and spin up before being applied to convective motions.

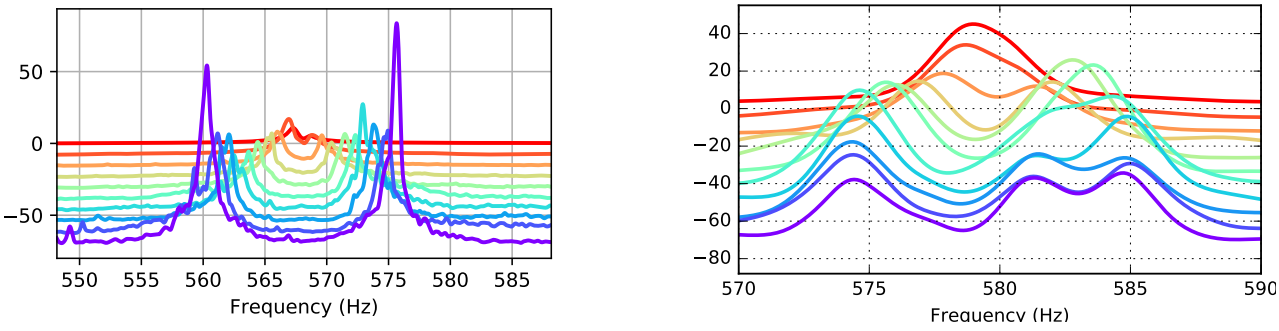


Figure 1: Acoustic spectra for mode ${}_0\mathcal{S}_1$, colours correspond to shell velocities. Left for solid body rotation, 0Hz (red) to 9Hz (purple), right for spin up flow, 1Hz (red) to 6Hz (purple).

Antoine COPEREY
2nd year Phd Student
Volcano geophysics

Geophysical imaging and monitoring applied to the optimization of shallow heat exchangers.

Heat exchangers implemented in the shallow subsurface for the production of energy involve complex heat and water transfers, especially when the ground freezes. We want to understand these complex processes in saturated to unsaturated conditions and with different type of soils in order to optimize heat exchangers design. We built an analogic experiment (i) in order to monitor heat transfer with saturated to unsaturated conditions, (ii) calibrate a numerical model of heat and fluid transfers and phase change, (iii) develop a relationship between temperature measurements and geophysical observables. A tank of 1.0 m^3 was filled with silica sand and all boundary conditions are fixed the position of the water table level, the volume of precipitations and temperatures at the bottom and at the top of tank (with temperature range -10^o C to +30^o C). Thermo-hydric transfers are monitored by 40 thermocouples, 4 water content sensors and 62 electrodes for geophysical monitoring. Geophysical methods include Electrical Resistivity Tomography (ERT), Induced Polarization (IP), Self-Potential measurements (SP). In this experiment, the reducing scale factors are 10 for geometric parameters and 100 for time scale (one real year is equal to 3.6 days). We plan to test numerical modeling and geophysical monitoring in Technolac site, where 5 heat exchangers were buried at a depth of 3.4 meters. Height and radius of spiral exchangers are 2,4 and 0,5 m respectively. Ground temperatures are recorded by 7 verticals profiles. A first experiment with a ERT profile, where the ground was cooled until the freezing of soil shows that geophysical sensitivity was not enough in order to have a correct localization of thermal anomalies. Therefore, we built a 3D geophysical array with 33 electrodes in boreholes and 31 electrodes on the surface.

Marco SALCEDO
1st year Phd Student
Waves and Structures

We would like to develop a new code for active and passive 3D tomography, which includes both velocity and attenuation reconstruction. Ideally, this code would be used at different scales (from laboratory to crust scales) and for different physics (seismic and EM). During this first year, we want to compare our results for velocity reconstruction with other conventional softwares, assess the advantages and disadvantages of our code using both synthetic and real data. We currently focus only on the velocity reconstruction using a fast-sweeping method based on the discontinuous Galerkin scheme to compute both the eikonal equation (traveltimes) and the adjoint field for the forward problem. The latter avoids the computation of rays. For the inversion approach, we will use the l-BFGS algorithm to update the velocity structure. For all the workflow of our code, we use several tools of SEISCOPE. Then, we start with the implementation of the attenuation. The measurement of attenuation before inversion will not be straightforward and some synthetic tests will be needed depending on the scale and the physics considered. It is noticeable that laboratory experiments acquired on carbonates using laser sources and sensors will be also used for testing, in collaboration with the LFC-R (University of Pau). This code will be used in active experiments for multi-physics imaging (seismic and electromagnetic) as well as for passive imaging in seismology. The images are dedicated to a better understanding of rock and fluid imaging for reservoir issues via rock physics approaches and the link between fluids and seismicity.

Felix GERICK
1st year PhD Student
Geodynamo

The effect of topography on magnetic waves in planetary cores

Nowadays, the main Earth's magnetic field is accurately monitored from satellites placed on a low orbit. Together with records of the Earth's rate of rotation,the magnetic field observations give precious information about magnetohydrodynamic waves in the Earth's fluid core. The propagation of these waves is sensitive to the properties of the core-mantle boundary: height of the interface with respect to a mean sphere; electrical conductivity of the solid mantle adjacent to the fluid core. The aim of the study is to develop a 2-D reduced model of the fluid dynamics that would account for the non-spherical core-mantle boundary. The simplification of the model rests on the invariance of the fluid velocity parallel to the rotation axis. Such a model has already been applied to investigate thermal convection without a magnetic field or to investigate the propagation of magnetic waves in a perfectly spherical cavity. The thesis consists in combining the two approaches.

Vincent CANEL

1st year Phd Student
Waves and Structures

My PhD focuses on the nucleation of earthquakes, it is part of an interdisciplinary effort involving seismology, mechanics and applied mathematics in the ERC project F-IMAGE supervised by Michel CAMPILLO. The main objective of this thesis is describing and modelizing this phenomenon resulting from the interplay of fault friction and bulk damage through the analysis of data obtained in controlled laboratory experiments and in finite elements numerical simulations.
A discontinuous Galerkin strategy for the numerical modelling of damage and wave propagation is developed with Ioan R. IONESCU. In parallel, I work at Institut Langevin with Xiaoping JIA in Paris to perform laboratory fracture and shear experiments with acoustic probing (Fig. 1A) to study the slip behaviour for different media we create (with mechanical state ranging from cohesive to granular). Prior to failure in a dry granular medium under a shear banding, a decrease of the shear coherent waves velocity is measured (Fig. 1C). The correlation function of the multiply scattered coda waves allows to monitor the stick-slip-like rearrangement of granular network during shear banding (Fig. 1B). The acoustic emission during fracture process can be detected and processed as actual seismological data are processed.

San Andreas fault

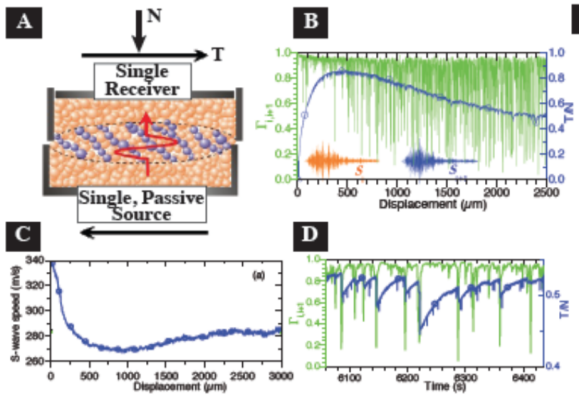


Figure 1: (A) Shear apparatus (B) Evolution of the shear with slip (in blue) and the cross-correlation of coda waves shown inset (in green) (C) Monitoring of the decrease of the shear wave speed (D) Zoom into Fig. B. *According to Y. Khidas and X. Jia. Probing the shear-band formation in granular media with sound waves. Physical Review E, 85(5):051302, May 2012.*

Gokhan ASLAN
3rd year Phd Student
Seismic cycle and transient deformations
The determination of the slip budget is essential to estimate seismic potential of faults. Studies based on Interferometric Synthetic-Aperture Radar (InSAR) and Global Positioning System (GPS) satellite observations until 2012 have shown that the central segment of the August 17, 1999 Izmit earthquake on the North Anatolian Fault (NAF) began slipping aseismically following the event. To monitor this long-lasting afterslip and characterize its spatio-temporal behavior, we compute InSAR time series by using 32 TerraSAR-X radar images acquired between 2011 and 2015 and 275 ascending and descending Sentinel 1A/B TOPS images acquired on three tracks, spanning the period from October 2014 to July 2017. Results over the period 2011-2017 show that afterslip on the central segment of 1999 Izmit fault rupture is still taking place for more than 18 years. Our results are in agreement with previous studies suggesting that surface creep on active faults may also initiate as postseismic afterslip that decays logarithmically with time lasting for a long period of time, possibly late in the earthquake cycle. Creep rate fluctuates along the fault and is maximum (6 mm/yr) on the segment that showed supershear rupture. Time series analysis reveals stable steady state creep of 6 mm/year and a large transient creep event (creep burst) in November 2016 with a total surface slip of 10 mm. Vertical velocity fields obtained with decomposition of velocity fields on ascending and descending tracks show a persistent subsidence on the hanging wall block of the Golcuk normal fault that also ruptured during the Izmit earthquake. These results demonstrate that high-resolution temporal InSAR data allow detecting deformation signals that were not seen previously and that active continental deformations in the east-southeast of Istanbul is more complex than what was previously assumed as they vary along the North Anatolian Fault both in space and in time.

Tobias VAN BAARSEL

2nd year Phd Student
Waves and Structures

The dynamic imaging of a gravity wave propagating at the air-water interface is a complex task that requires the sampling of every point at this interface. Using two source-receiver vertical arrays facing each other in a shallow water environment, we manage to isolate and identify each multi-reverberated eigenray that interacts with the air-water interface. The travel-time and amplitude variations of each eigenray are then measured during the crossing of the gravity wave.

In this work, we present an ultrasonic experiment in a 1 m-long, 5 cm-deep waveguide. At frequencies in the MHz range, the waveguide transfer matrix is recorded 100 times per second while a low-amplitude gravity wave is generated by a laser-induced breakdown above the water surface. The breakdown causes a blast wave that interacts with the air-water interface and penetrates into the water, creating ripples at the surface. The inversion performed from a few thousand eigenrays lead to accurate imaging of the dynamic of the air-water interface, using either the travel-time or the amplitude variation.

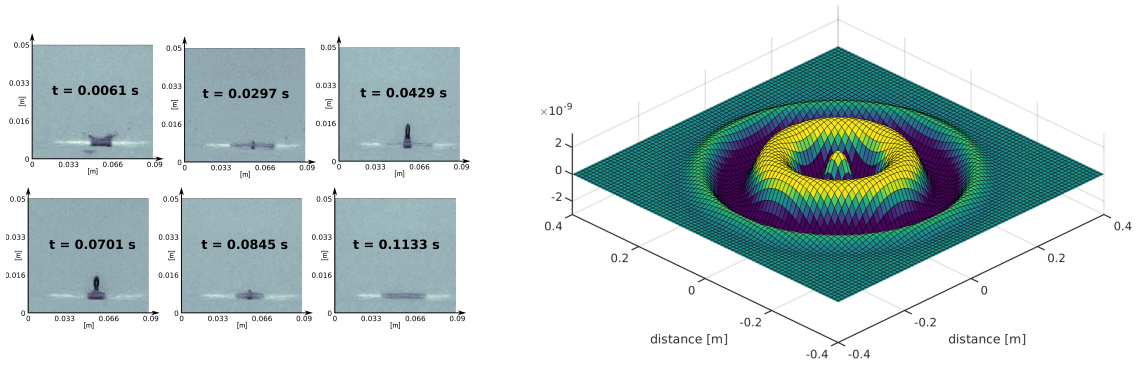


Figure 1: **Left:** Snapshots of the high-speed camera recording the water surface perturbed by the laser-induced shock wave. **Right:** Inversion result of the acoustic underwater system.

Ariana ASTORGA

2nd year PhD Student
Waves and Structures

In this study we analyze earthquake data collected in buildings to find evidence of nonlinear elastic response, which might be related to the structural state. We use time-frequency distributions to monitor transient variations of the fundamental frequency during earthquakes. We also analyze the long-term behavior of this elastic parameter to determine permanent changes that might be associated to damage. Elastic response, analyzed throughout fluctuations of elastic properties, is evidenced by nonlinearity (i.e. in the stress-strain relationship, shifts of frequency at low deformations) and slow dynamics. Slow dynamics is a signature of elasticity, manifested as a time-dependent recovery process in which the elastic properties return to values previous the excitation. This phenomenon seems to be related to the extent of cracks and defects in the material/system. Recovery is observed at short and long-term observation. At short-term it is divided in two intervals: before and after the end of the strongest motion. The first one is controlled by conditioning effects, but changes in the path of time-recovery of the second segment might be directly linked to the structural state.

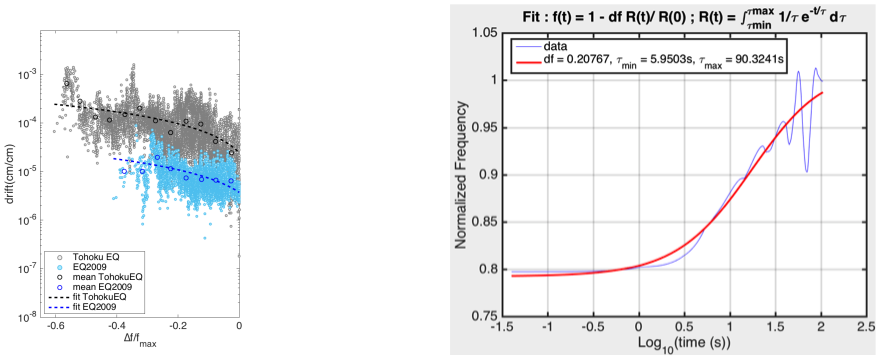


Figure 1: (Left) Variation of the normalized frequency as a function of drift for two different earthquakes. Responses of 24 buildings were included. (Right) Typical shape of the frequency recovery with time. Response of one building after one earthquake. (*xkcd.com*)

Kaveh OGHALAEI

2nd year Phd Student

Risks and environmental geophysics

The goal of my thesis is to evaluate the impact on building damages when the soil-basin behavior is 2D instead of 1D (Fig 1-right). To do that it has been computed (for 1D and 2D) the top displacement of around 170 buildings with different typology (reinforced concrete,steel,etc) using 60 synthetic earthquakes and about 900 basin models coming from NERA project (each basin have in-between 100-400 receivers), leading to an huge amount of data (2*170*60*900*250 i.e. 4.5 billion displacements). The interpretation will be done using Neural Network processing to extract the parameters (C,W,h,slopes,etc) that mainly control the building damages on 2D basin. Giving us the possibility to derivate damages maps for areas (cities) from these few simple parameters. We know that the f0 of RC buildings can be estimate as function of a constant parameter(Cst) and number of floors(N) and Cst is strongly local dependent (Construction habits,etc). So, the in-situ mesurement has done on Tehran buildings to define the Cst parameter on different building typologies. This is my second main objective (Fig 1-left). Finally, a third objective could be an application on Tehran basin linked to its building stock, depending on the data accessibility.

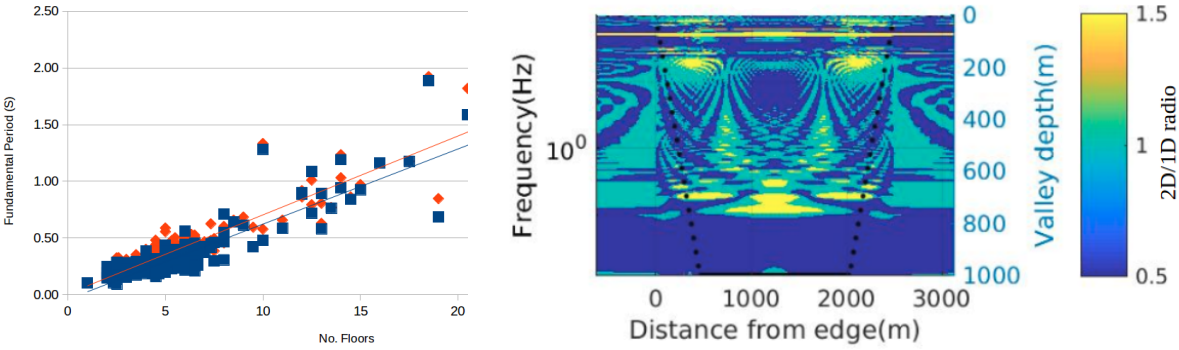


Figure 1: Left: Fundamental period across No. of Floors: longitudinal (blue) and transversal (red) direction for all building types (200 mesurements) Right: 2D/1D transfer function ratio on valley.(Black points: Valley shape:W=2500m,H=1000m,slope angle=65 deg)

Adrien POTHON
2th year Phd Student
Waves and Structures

Developing a new earthquake insurance scheme

The economic development in areas prone to earthquake risk leads to a significant increase in loss caused by natural catastrophes (nat cat) and especially earthquakes. In the same time, current insurance solutions show a limited growth, leaving more and more people unprotected. By consequence, it is priority to redesign an earthquake insurance scheme based on two requirements: capitalized enough to sustain extreme losses and the most affordable as possible to get the most people insured. In that respect, understanding uncertainties induced by each modeling step from the seismic source to the loss assessment is a necessity.
The ultimate goal of my PhD is to develop a new insurance scheme applicable to the widest range of seismic hazard and economic development.

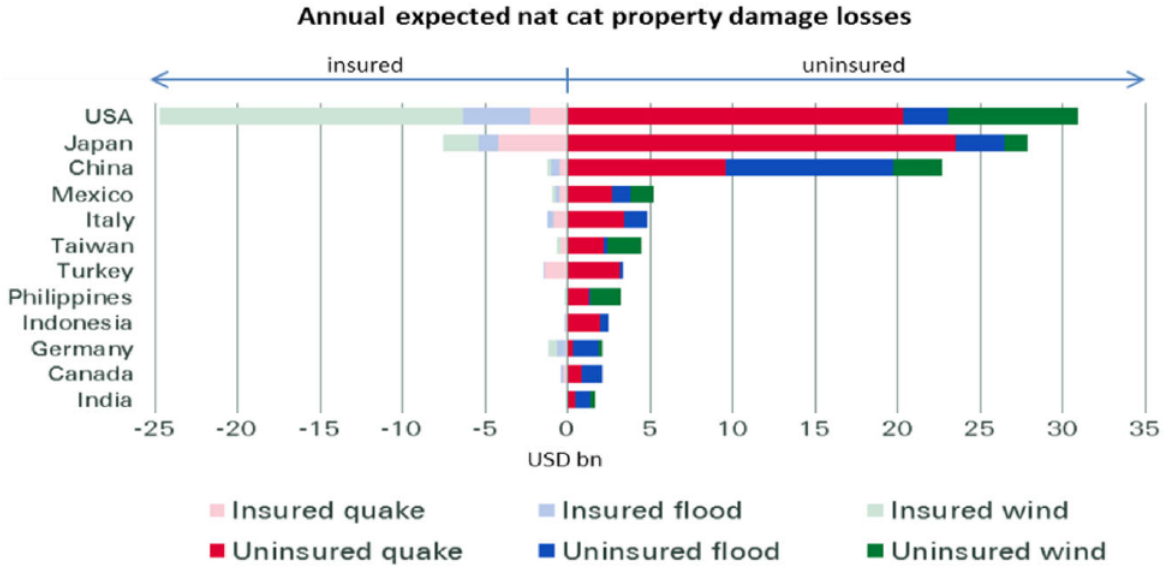


Figure 1: Expected insured and uninsured losses from natural catastrophes, in USD billion (Holzheu and Turner 2018).

Hugo LE BOULZEC
1st year Phd Student
Mineralogy and environment

Link between energy and raw materials for the energy transition

The Paris Agreements (COP21) plans to achieve global carbon neutrality by 2050. To achieve this goal, we need to build a new infrastructure of energy production, storage, transport and use, which will consume many raw materials. These latter require large quantities of resources to be produced, such as energy or water. Raw materials and energy issues are therefore strongly interlinked. The evolution towards low carbon energies will thus take place in a context of rapidly increasing demand due to the rapid emergence of developing countries, increasing urbanization and the development of new technologies. Indeed, requirements of raw materials for the development of renewable energies are much higher than for technologies representative of the current French electricity mix. At the global level, the needs are also important compared to the potentials of both primary production and recycling.

This thesis belongs to a project financed by the French organism ADEME. It aims at studying the needs in raw materials and energy for the development of renewable energies in France. The approach is interdisciplinary: geologic and economic. In a first step, this thesis will aim at quantifying the raw materials demand by technologies and sectors, using a data management and query tool developed by Cyril François at the Grenoble Institute of Earth Sciences (ISTerre). It aggregates databases of physical and monetary flows with raw material inventories derived from life cycle analyses. In a second step, the goal will be to quantify the evolution of the demand of raw materials and to study the impact of the raw material costs on scenarios. This modeling part will be based on dynamic material/energy models developed at ISTerre by Olivier Vidal and on the partial equilibrium model POLES developed at the Grenoble Applied Economics Laboratory (GAEL).

Jacques BRIVES
2nd year Phd Student
Waves and Structures

Ambient seismic noise correlation method (C1) has proved to be an efficient way to retrieve empirical Green's function between any station pair. This method is now extensively used for seismic tomography and monitoring and benefits from the development of dense array. Most of the time those dense arrays are not permanent and are swapped and/or moved several times in order to cover the area of study. Since all stations have not necessarily been deployed at the same time it is not always possible to retrieve empirical Green's function by computing C1s. By using a permanent backbone of stations and a higher order correlation methodology (i.e. correlation of coda of correlations, C3) we can measure surface wave travel times between pairs of stations that were not deployed at the same time. In this study we propose to revisit a dataset of broadband stations deployed within and around the Pyrenees massif between 2008 and 2014. Using the French permanent network and the Iberarray network in Spain as backbone array we show that we can dramatically improve the amount of dispersion measurements inside the massif using asynchronous C3 between the different dense lines of the Pyrope experiment. The stability and reliability of C3 functions are discussed and compared to C1 results. At the end the aim of the study is to improve the previous (C1-based) Pyrenean lithospheric model by merging both C1 and C3 measurements.

Cyrielle DOLLET
1st year Phd Student
Waves and Structures

Multicriteria analysis of the seismic regulation for public buildings. Elected officials responsability.

The consequences of earthquakes can be considerable for both people and property. The urban population continues to grow, wealth and infrastructure are concentrated in urban areas where moderate earthquakes are likely. Public buildings under the responsibility of elected officials are then the first to be damaged. For all these reasons, a new seismic regulation was created in France in 2010, for both high-risk and moderate-to-low risk areas. In view of the scientific file that enabled French zoning to be carried out, the question arises whether it is better to upgrade existing buildings or leave them as they are. All these new constructions or renovations would necessarily involve a very high financial cost.
The same applies to the positioning of the acceptable level of responsibility in the implementation of earthquake regulations, which is a key issue. Indeed, the responsibility of the elected officials but also the insurers in their prevention approach, are in the front line during natural disasters. The modification of seismic regulation has a direct impact on the level of responsibility. The aim of this research is to provide a decision support tool in the implementation of a public policy adapted to the level of risk of the territory to anticipate the seismic risk. For this, it is necessary to evaluate the impact of seismic regulation on the cost of construction and the benefit in terms of damage reduction which is important. Decision variables must be proposed, on which elected representatives can rely to guide their development policy.

Hussein SHIBLE

1st year Phd Student

Risks and environmental geophysics

The implementation of site specific seismic hazard studies needs, on one hand, to evaluate the amplification due to local site effects (numerical simulation-based or empirical methods), and on the other hand, to have "incident" ground motions adapted to the studied site "rock", as well as characteristics of regional seismic sources and crustal attenuation. Today, such reference ground motions are not available or suitable for low to moderate seismicity European areas. However, great progress has been made over the past few years. First, methodologies for establishing such incident ground motions were developed and validated on Japanese databases (thanks to a high characterization level of accelerometric stations). On the other hand, a European homogeneous database has been established ("Resorce" database) and the characterization of some French accelerometirc stations has been performed. Despite this progress, the "transposition" to low to moderate seismicity European context of methodologies developed on Japanese databases brings real scientific issues: how to address the lack of characterization of European accelerometric stations? How to extrapolate low magnitude records (or large epicentral distance records) to high magnitude, near field scenarios? In order to resolve these scientific issues, the PhD thesis work will address various topics: completion of the database "Resorce" with hard rock data, use of generalized inversion approaches, application of characterization methods on some key European accelerometric stations, application of methods of signal processing on the real accelerometric recordings... This work will lead to produce one or several ground motion prediction equations, directly usable for site-specific seismic hazard studies in low to moderate seismicity European context, particularly in the France.

Chloe Gradon
2nd year Phd Student
Waves and Structures

A large part of seismology is dedicated to the detection and location of seismic events. With the development of dense arrays of sensors and cross-correlations techniques, it is now possible to detect smaller and smaller events coming from deep sources or events in the shallow crust. The goal of this study is to take advantage of a multi-scale seismic set of data acquired at the surface of the San Jacinto Fault Zone (SJFZ) in South California. The month-long continuous data was measured in June 2014 by a very dense array of sensors. This square array comprises 1108 seismometers set at 10 to 20 meters distance from each other. It covers a 600m by 600m area centered in the damaged part of the fault. The characteristics of this array were chosen to allow the detection of shallow events occurring in the first hundred meters of the crust on and around the array. Using a Match Field Processing (MFP) technique we determine the longitude, latitude and apparent velocity of the detected events occurring at the surface as well as below the array. This technique allows us to detect and discriminate surface sources as well as deep sources. The depth of the latter will then be constrained with a 3D MFP algorithm inverting for the 3 coordinates of the source. The adequacy of two different model that can be used for the inversion will be discussed.

Louise MAUBANT
1st year Phd Student
Seismic cycle and transient deformations

In Mexican subduction zone, two areas of recurrent Slow Slip events (SSE) are observables (Oaxaca/Guerrero). It has already been shown that a relationship between the seismicity and SSEs existed, but these relationship are still poorly understood. Recently, a sequence of large earthquakes stroke the Mexican subduction (Mw 8.1 Chiapas 09/2017, Mw 7.1 Mexico 09/2017, Mw 7.2 Oaxaca 01/2018), and the potentiel links between these earthquakes and ongoing aseismic processes (a large SSE occurred in Guerrero between April and October 2017), still has to be studied.

The existing data to monitor the deformation during the seismic cycle in that region consist in a network of GPS stations. In order to complement the GPS network, we will processspace-borne SAR interferometry (InSAR) using data from Sentinel-1 satellites (one image every 12 days since 2015) will be done, and perform time series analysis (over the entire 1500-km long Mexican subduction zone). This will allow us to have a better spatial and temporal coverage of deformation of the region. The objectif is to make a joint analysis of GPS and InSAR time series to study the different phases of the seismic cycle (inter-seismic coupling, co-seismic displacements, SSEs). To do so, we will perform joint inversions of the geodetic time series. In addition, we will also perform rate-and-state forward models to assess the frictional properties and mechanical interactions (between seismic and aseismic processes).

Beatriz COSENZA
3rd year PhD Student at UW-Madison
cosenzaa[at]univ-grenoble-alpes.fr

Fault slip and strain partitioning in Guatemala, from InSAR and air photos correlation

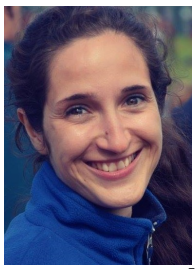
The zone of interaction between the Cocos, Caribbean and North America plates in Guatemala is defined by the sub-parallel Motagua and Polochic strike-slip faults, a series of north-south-trending extensional grabens immediately south of the Motagua Fault, the Middle America trench, and faults within the Middle America volcanic arc. Historical earthquakes associated with these faults include the destructive 1976 Mw 7.5 earthquake along the Motagua fault and the 2012 Mw 7.5 Champerico subduction-thrust earthquake. The published present-day kinematic models of the region, based on GPS data, show that strain accumulation from the NA/CA relative motion concentrates on the Motagua fault with no resolvable strain accumulation across the active Polochic fault, suggesting that slip varies with time as a result of mechanical interactions within the Motagua-Polochic fault system. As part of the efforts to quantify the present-day kinematics and slip behavior of these faults, we use radar interferometry, to measure the strain rates across faults in Guatemala and constrain slip partitioning among the different faults. We processed radar images in L-band acquired by ALOS-1, spanning from 2006 to 2011. We used three adjacent traces acquired in Strip Map mode (with ascendant orbits) covering the Polochic and Motagua faults, the Ipala and Guatemala City grabens, and part of the volcanic arc to the south. We present the preliminary results after applying the NSBAS processing chain. After further refining, we will perform time-series analysis and expect to extract the first InSAR-based maps of interseismic velocity for this region, which will be useful to refine the estimates of the interseismic locking across the Motagua-Polochic fault system, the subduction zone and other nearby faults. In complement, we also present our first attempts of image correlation to reconstruct the coseismic slip distribution of the 1976 earthquake, based on air photos acquired before and after the earthquake, that will be ultimately compared to coupling distribution along the Motagua fault.

Judith MARINIERE
2nd year Phd Student
Seismic cycle and transient deformations

Quito, the capital of Ecuador hosting two million inhabitants lies on an active reverse fault system within the Andes. Regular moderate size earthquakes (M∼5) occur on these faults, widely felt within the city and its surrounding. Despite a relatively small magnitude of M_w5.1, the 2014 August 12 earthquake triggered landslides that killed 4 people, cut off one of the main highways for several weeks and caused the temporary shutdown of the airport. Quantifying the seismic potential of the Quito fault system is therefore crucial for a better preparation and mitigation to seismic risk. Previous work using a limited GPS data set found that the Quito fault accommodates 4 mm/yr of EW shortening (Alvarado et al., 2014) at shallow locking depths (3-7 km). We combine GPS and new InSAR data to extend the previous analysis and better quantify the spatial distribution of locking of the Quito fault. GPS dataset includes new continuous sites operating since 2013. 18 ERS SAR scenes, spanning the 1993-2000 time period and covering an area of 85 km by 30 km, were processed using a Permanent Scatter strategy. We perform a joint inversion of both data set (GPS and InSAR) to infer a new and better- constrained kinematic model of the fault to determine both the slip rate and the locking distribution at depth. We find a highly variable level of locking which changes along strike. At some segments, sharp displacement gradients observed both for GPS and InSAR suggest that the fault is creeping up to the surface, while shallow locking is found for other segments. Previous Probabilistic Seismic Hazard Assessment studies have shown that the Quito fault fully controls the hazard in Quito city (Beauval et al. 2014). The results will be used to improve the forecast of earthquakes on the Quito fault system for PSHA studies.

Julien THURIN
2nd year Phd Student
Waves and Structures

Uncertainty estimation and quality control is a critical issue commonly faced in geophysical tomography applications. The few solutions to cope with that problem are often simply left aside in practical applications when problems are growing larger and involve more complexity. In my PhD project, I propose a mixed Full Waveform Inversion and Data Assimilation ensemble-based scheme, as a proof of concept for uncertainty estimation on the tomographic results.
The methodology I'm working on relies on a deterministic square root Ensemble Kalman Filter comonly used in the Data Assimilation community : the Ensemble Transform Kalman Filter. By combining it with a 2D visco-acoustic frequency domain Full Waveform inversion scheme we obtain a scheme allowing to access a low-rank approximation of the Posterior covariance matrix of the solution, yielding uncertainty information through ensemble-representation, that can conveniently be maped as variance and cross-covariance or correlation maps for robustness evaluation.
Part of my work is to fully develop the theoretical understanding of combination of such different methodologies. After setting up the Ensemble Transform Kalman Filter - Full Waveform Inversion scheme, we started to work un pinpointing the effect of undersampling on such a low-rank approximation of our problem's covariance.
Amongt the many things to try out, we would like to test different parameterisations for the filter, as we already did beetween redudant vs predictive ETKF-FWI algorithm. I also aim at moving toward multiparameter inversion, or sensor fusion by integrating other geophysical data for the inversion to constrain a bit more the analysis and see it's effect on result robustness.



Noélie BONTEMPS
2nd year Phd Student
Risks and environmental geophysics

Landslides cause almost 10 000 victims every year [Petley, 2012] triggered by four main forcings : (1) earthquakes, (2) precipitations, (3) fluvial erosion, (4) human activity. The relative part of each of these forcings to the landslide dynamics is poorly constrained in seismic active regions where their effects can be interdependent. The Colca Valley, South Peru, offers an exceptional site for studying these dynamics, with seasonal rainfalls and a strong seismic activity [Lacroix et al., 2014] impacting a dozen of active slow moving landslides situated along the Colca River in the valley.

I use two different approaches to identify the relative contribution of the seismotectonic and rainfalls forcings in the landslide dynamics of this area.

The first approach consists in studying the long-term dynamic of several landslides by using satellite optical images from the archive. 16 images acquired between 1986 and 2014 were used to generate 240 displacement maps by correlating these images in all possible combinations. Then, Displacement maps are inverted to obtain 28-years long robust time series of the displacement over the whole area. This method allows us to detect the impact of a local Mw 5.4 earthquake in 1991 on the kinematics of the Maca landslide, one of the main landslide of the area. Our results suggest that the earthquake accelerated the landslide and had an effect for several years on the precipitation threshold required for triggering a motion.

The second approach aims at having a better understanding of the mechanics of the Maca landslide during earthquakes and/or rainfall events thanks to three GPS and seismic stations located in the landslide and recording almost continuously since the end of 2015. Comparison between GPS and seismic ambient noise correlation, giving the variation of seismic waves in the landslide can give us information about the relation between the forcings, damage of the unstable mass, and its deformation.

Benjamin GERARD
2nd year PhD Student
Tectonics, Relief and Basins - Seismic cycle and transient deformations

Tectonics and exhumation processes in the Abancay hinge

Located at the northern edge of the Peruvian Altiplano, the Abancay hinge marks the transition between the northern narrow Andes and the southern wide Andes. As a matter of fact, this area is a unique and exceptional anomaly at the Andes' scale. Numerous intrusive massifs are co-located with intersecting fluvial basins, and 1km-deep gorges together with curved fault systems in this peculiar part of the Eastern Cordillera (EC). Despite significant differences in their tectonics, but similarly to the Himalayan syntaxes, the Abancay hinge entrains major orogen-traversing rivers. Morphologically, this arched transition zone extends over ∼200km and presents deflected inherited faults, that strike almost perpendicular to the principal elongation axis of the Andes. Moreover, the Abancay hinge is characterized by the highest elevation peaks (Salcantay – 6271m.a.s.l) east of the Altiplano, and on the contrary to the Western Cordillera (WC), is not characterized by any volcanic or seismic activity. Finally, none of the active orogenic processes at work for the last 20Ma in this part of the Andes are known nor dated nor described yet.

The objective of my thesis is to discuss the role of tectonic in the orogenic processes and topography building during the latest phase of the Andes uplift (∼20My). Several authors stated that active landscapes at the orogenic scale contain an important archive and record the differential deformation and erosion patterns. Following this approach, I first focused on fieldwork for the quantification of the exhumation to constrain the timing of the Abancay uplift and sampled 50 sites to report new thermochronological data (LTT). I also ran quantitative geomorphology analysis to unravel the exhumation history of the studied area at different times scales (1 to ∼20My).

My preliminary geomorphic analysis shows a strong disequilibrium in the core of the Abancay hinge suggesting a very recent surface uplift (<1My). Furthermore, Preliminary LTT results highlight a differential exhumation between the EC (higher rates) and the WC (lower rates) suggesting a vertical tectonic decoupling between the two cordilleras.

Sandrine Roy

1^{st} *year Phd Student*
Tectonic, Reliefs, Basins
Supervisors: J. Martinod, R. Vassallo

The Magallanes-Fagnano fault is a major strike-slip system, across the southernmost part of Patagonia in Tierra del Fuego region. The fault extends from the North-Scotia ridge toward the west through the Lake Fagnano and reaches the Southern Chile Trench Triple junction (Figure 1). The fault accommodates the left-lateral slip between South America and Scotia plates, over the 600 kilometers across the continent in an E-W axis. The present-day relative velocity between them, is estimated by GPS measurements at 6.6 $mm.yr^{-1}$ (± 3.5 $mm.yr^{-1}$). Morphological markers are deformed by the repeated motion along the fault. In 2017 onsite measurements: positive flowers, shutter ridge, river shifted, and decameter push-ups provide an unprecedented set of information on recent ruptures. Indeed, two major earthquakes of similar magnitudes above Mw 7 occurred in 1949 and 1879, and are only the most recent events of a long-lasting cumulated deformation, started at the Neogene. Our approach will combine morphotectonic and profile Beryllium dating in order to compare slip rates and fault behavior at different time-scales, for primordial stage of seismic hazard assessment. Then, the results issued from this analysis will be used for landscape modeling in order to test the long-term response of river catchments bounding the fault.

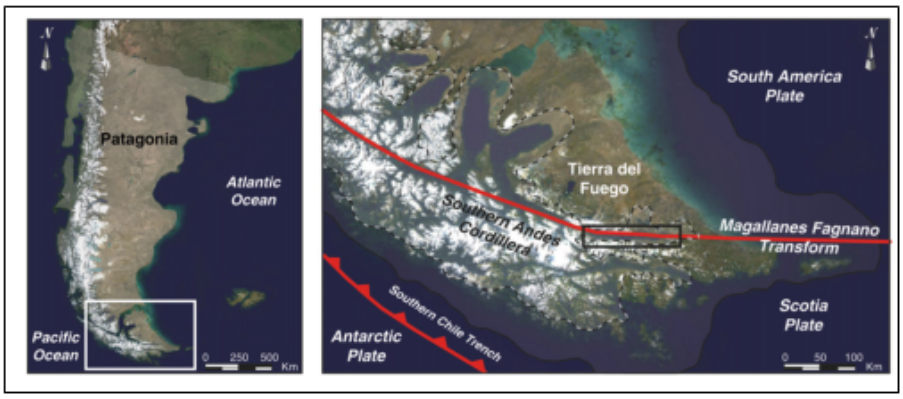


Figure 1: Localization of the Magallanes-Fagnano fault (red line), the last glaciers maximum extent (dashed line), and the Lake Fagnano region (black rectangle).

Antoine GUILLEMOT
1st year Phd Student
Risks and Environmental Geophysics

Seismic monitoring of rock glaciers : toward understanding an emerging risk

As ice-rich mountain permafrost areas with large amounts of potential disturbed materials, active rock glaciers are primarily concerned by hazardous effects generated by permafrost degradation on mountainous steep slopes. Rock glaciers are creeping landforms made of debris supersaturated by ice, and moving downslope usually at a rate of a few cm/yr to dm/yr. Several measures have already been recorded on rock glaciers, including geodetical surveys, repeated geoelectrical campaigns and continuous recording of meteorological variables. Another technique based on seismic ambient noise and microseismic activity has been applied to measure seismic waves velocity changes inferred by mechanical changes. With this in mind, seismic sensors have been set up in October 2015 on the Gugla-Breithorn rock glacier (Valais, Switzerland). Such a two-years long database is a world-premiere in this field, and aims to better understand rock glacier dynamic with complementary strategies : 1) relative change of seismic velocity (due to variations of rigidity and density) by seismic noise correlation, 2) analysis of micro-seismicity (quakes, rockfalls, ...), 3) evolution of resonance frequencies, 4) numerical modelling (modal and temporal) by finite element method. Finally, the use of seismology as a precursor signal of global slope destabilization will be addressed.
In addition, an ongoing seismic instrumentation on Laurichard rock glacier (Hautes-Alpes, France) will provide another set of data, allowing a comparison between two occurrences of this permafrost landform.

Sylvain FIOLLEAU
1st year Phd Student

Risks and Environmental Geophysics

Slow-moving landslides (from a few cm/yr and a few m/yr) are widely spread in fine-grained formations. Mechanisms controlling the evolution from slide to flow are still very poorly understood. Monitoring of geophysical parameters (such as seismic velocity) appears then a very promising way to follow the evolution of physical changes operating during rupture and/or fluidization. On the 27^{th} of June 2016, the Harmaliere earthslide underwent a spectacular reactivation (Lacroix et al. in review) accompanied by several minor reactivations. Between June 2016 and early February 2017, the regression is estimated to be up to 30 m. In the central part of the slide, the clayey formations evolved into a flow in the days following the main reactivation. The top of the landslide was equipped with a semi-permanent seismological and geodetic network (3 seismometers and 3 GPS). This network is completed by permanent meteorological, geodetical and seismological data from the nearby French National Observatory OMIV-Avignonet site (a few hundred meters away).
The first goal of my work is to analyze in detail this unique dataset with the ongoing permanent measurements, in order to better understand the mechanisms leading to the rupture. In a second part, I'll focus on the fluidization which take place few days after a major reactivation in the central part of the landslide. To do so, I'll study this transition mechanism by combining remote-sensing, geodetical, geophysical and mechanical approaches.

Dorian SOERGEL

First year Phd Student
Waves and Structures

Methods using cross-correlation of seismic noise are enjoying a growing popularity. However, while in theory they provide the Green's function between two points if the noise sources are basically uncorrelated and homogeneously distributed, these conditions are usually not met. To correct for the inhomogeneous distribution of noise sources, one possibility is to not look at the correlations, but to take the coda of the correlations and process them as seismic coda with established methods for coda-cross-correlation. In this case, the distribution of sources can be better controlled because it is related to the station distribution.
In my Phd I will try to use the coda of cross-correlations to invert for the azimuthal anisotropy for Rayleigh waves in the Alps using mainly the data of AlpArray. Correlation of the coda of correlations (C3) is well suited for this task because one needs a good azimuthal coverage to do it effectively. By controlling our 'noise' sources with C3 we can ensure a good coverage. So far I have been studying the properties of the coda of some correlations from the AlpArray network.

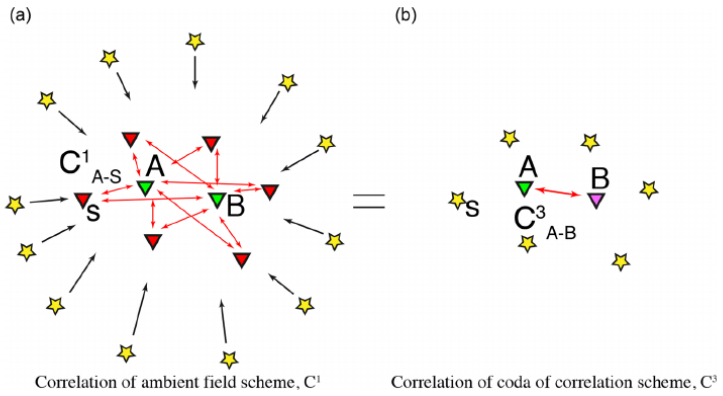


Figure 1: Noise cross-correlation (a) and C3 (b) methods. The stations used in cross-correlation are used as sources in C3. (*Spica et al, 2016)*

Gaëlle LE ROY
2nd year Phd Student
Fault Mechanics

Characterizing rock fall parameters (localization, volume and propagation path) is a key point to improve the mitigation of the hazards associated and to better prevent them. However, due to a limited number of natural events observations, these parameters stay poorly constrain. With the densification of seismometer networks, seismic data analysis proved to be a powerful tool for a remote detection and characterization of gravitational events. Here, we present the analysis of small ($1-100m^3$) rockfalls dynamics through the monitoring of the top and talus slope of the Mont Saint-Eynard limestone cliffs (French Alps) by a local seismological network composed by four seismic stations. Combine to this network, diachronic photogrammetric survey and a near-continuous survey (1 photography each 10 mn) are used to monitor the erosion of the cliff. Seismic signals emitted by rock falls were compared to topographic data in order to identify the different phases of the rock falls (detachment, impact on the ground, propagation along the slope). First, by studying the seismic signal obtained, we identified different event types depending on their propagation modes (free fall, rolling/sliding, mixed). Secondly, for each type, we established scaling laws connecting the signal features (amplitude, duration, frequency) to the rock fall characteristics (volume, height of free fall, kinetic energy, propagation path). These laws offer the possibility of a direct estimation of the mass and dynamic features of rock falls from the generated seismic signal and allow us to link rock falls seismic signals characteristics to their propagation mode.

Margot MATHEY
1st year Phd Student
seismic cycle team

The Western Alps are characterized by a weak to moderate seismic activity. Permanent GPS measurements showed that the main deformation signal is an uplift up to 2 mm/yr in the high chain, without any correlated shortening. The horizontal deformation across western Alps corresponds to a transtensional motion from the Adriatic plate regarding stable Eurasia, with 0-0.3 mm/yr of extension and strike-slip. The vertical deformation shall then have other origins than the plate tectonics. The subject has then a double aim : (i) define more precisely the origin of the uplift and (ii) bring geophysical constraints to probabilistic seismic hazard assessment. Thus, the PhD focuses on links between horizontal and vertical deformation, and between crustal deformation and seismicity. The weak strain rate represents the main challenge of this work. On the other hand, we benefit from one of the most dense -and one of the longest- instrumented area in Europe. Three kind of data are going to be used together throughout the thesis : (i) seismological data from SISMalp (35000 seismic events recorded since 1989), (ii) gps data from permanent stations (RENAG network since 1998) and from surveys, and (iii) interferometric radar data acquired since 2014 from Sentinel-1 satellite.

Mathieu LE BRETON

2nd-3rd year Phd Student

Risks and Environmental Geophysics

My PhD investigates the usage of multiple 868 MHz radio-frequency identification (RFID) passive tags, to track landslide motions at low cost. In the first year, we identified the sources of environmental drift outdoors, to increase the long-term accuracy. After correcting this drift, the measurement accuracy was improved from several centimeters, to below 2 millimeters per month. In the second year, we validated the technique on a real landslide. Eighteen tags were installed on an active landslide, from 20m up to 55m of a stable base station, during five months. The motion measured by RFID was validated with a wire extensometer and three tacheometric surveys. The accuracy and the robustness (95% of working time during the test, including snow events) of the RFID method were better than with the extensometer. This technique proved appropriate to monitor landslide motion, with many sensors, in real time and at low-cost. It allowed for fine comparison with other physical measurements, such as hydro-meteorological, or ambient noise correlation monitoring, to better understand the behavior of our test site.

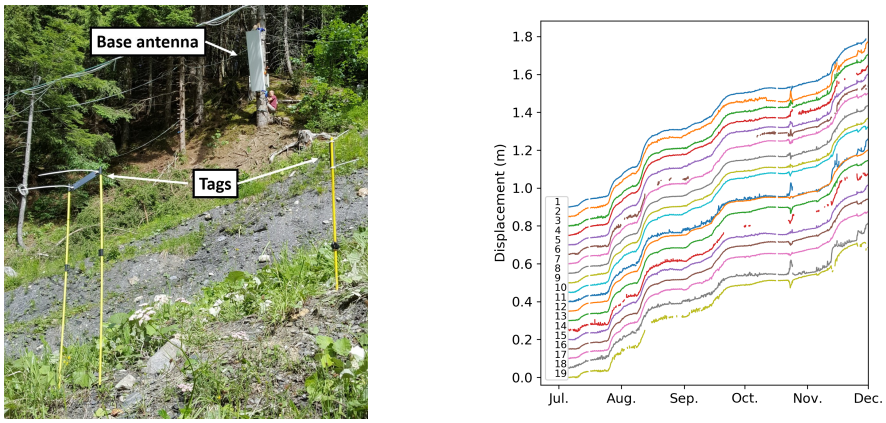


Figure 1: Motion sensors on a landslide (left), and their results over five months (right)

Axel DENYS

1st year Phd Student
Mineralogy and environments

Rare Earth Elements (REE), the 15 elements of the lanthanide family and Y, but also, are critical resources and a new challenge for future prospecting. The REE use in high technology devices (smart phones, digital cameras, computer hard disks, flat screen tv) and industrial applications (chemical catalysts, metal alloys, glass polishing and permanent magnets) put them at the top of actual metal global demand. Currently, REE are primarily produced from two types of ore deposit: ion adsorption clay deposit (only in Southern China) and carbonatites/alkaline igneous rocks with the highest REE concentration. Ion adsorption clay deposits form by the weathering of granitic rocks. The groundwater is responsible to the mobilization, fractionation and re-distribution of REEs along the profile. Petrological models behind these types of deposits are still controversial: they certainly depend of the weathering conditions and the primary geochemistry of the bedrock (also possibly controlled by late stage hydrothermal fluids). The mineral hosting REE, physicochemical conditions of alteration and sequestration mechanisms are actively investigated. In the purpose to understand which phases are carrying REEs (REE bearing minerals or adsorption) and the influence of fluid/rocks interactions on REEs mobilization and repartition during alteration, we investigated two weathered regoliths. The first is a well investigated lateritic profile developed on granitic rocks from Madagascar (300ppm REE), but for which the adsorbed contribution on the REE distribution remains to be addressed. Currently, sequential extractions experiments are running on natural and synthetics samples to understand the repartition of adsorbed REE in different mineral fractions (ion-exchangeable, organic matter, Mn and Fe oxides). The second regolith corresponds to saprolite and colluvium over REE-rich alkaline rocks (REE up to 3000ppm) from the Pilanesberg Complex (South Africa). In a first stage, we determine the petrology and geochemistry of the parent bedrock and samples in the incipient stages of weathering.

Delphine SMITTARELLO
2nd year Phd Student
Volcano geophysics

Propagation of Basaltic Intrusions : Insight from Inversion of InSAR and GNSS data of the May 2016 Eruption of Piton de la Fournaise Volcano (La Réunion, France).

Magma stored beneath basaltic volcanoes is often transported by propagation of planar intrusions (dikes or sills), which may lead to fissural eruptions when intersecting the Earth's surface. This propagation is an unsteady process controled by the magma-crust interaction, which generates seismicity and surface deformation before the eruption onset. To gain information into the dynamics of magma propagation we invert complementary ground deformation datasets recorded during the 8 hours preceding the May 2016 eruption onset at Piton de la Fournaise volcano. We combine SAR interferograms ensuring good spatial resolution and continuous GNSS data providing high temporal resolution. We use 3-D boundary element models combined with a Monte Carlo inversion method. We first retrieve the final geometry of the intrusion based on four interferograms, spanning the whole propagation phase. The imaged intrusion consists in a 2700 meters long sill located at an altitude of 800 meters and connected to the eruptive fissure by a 880 meters subvertical dike. Then, we invert the continuous GNSS data performing a succession of independant inversions in order to localize either a planar ellipse or the pressurized area of the geometry previously retrieved from InSAR data. We also take advantage of one Sentinel-1 image acquired during the propagation phase to constrain our temporal inversion. We show that the knowledge brought by the InSAR data helps to estimate the intrusion depth otherwise poorly constrained by the GNSS network used. We evidence that the horizontal part of the intrusion is already opened a few tens of minutes after the begining of the crisis, the intrusion being then stalled, while the pressure increases, until the last part of the intrusion propagates vertically to feed the eruption. These observations (propagation delay, pressure increase, change of direction) might indicate the presence of barriers to propagation.

Amber ZANDANEL
1st year Phd Student
Géochimie, Minéralogie et Environnements

Data collected by the Cassini-Huygens mission by directly sampling the geysers emitting from the surface of Saturn's moon Enceladus shows the geysers comprise a complex chemistry of inorganic and organic constituents. Of particular interest is the chemical evidence of a liquid ocean below the icy crust of Enceladus and current hydrothermal activity at the ocean floor. The discovery has invigorated existing interest in the habitability of liquid oceans on icy satellites and similarities to terrestrial hydrothermal vents that are proposed as an origin of life on Earth. The PhD project focusses on a series of experiments observing water-rock interaction in ammonia-rich fluids simulating water-rock interaction on Enceladus.
A first set of experiments uses open reactors with constant fluid flow observe olivine dissolution in an ammonia-rich fluid to calculate dissolution rates and thermodynamic constants. A second set of experiments uses closed-system reactors to observe water-rock-organic interaction between ammonia-rich fluid and selection of minerals and organic constituents common in the solar system. Fluid samples from both experiment sets are analyzed for element concentrations and pH, and solid samples recovered from both experiments sets are analyzed for secondary mineral phases. Fluid samples from closed experiments will be further be analyzed to observe organic alteration and gas samples from closed experiments are analyzed for hydrogen, CO2 and methane. Results of flow-through kinetic experiments will constrain thermodynamic rates of olivine dissolution in ammonia-rich fluids. The results of the static reaction experiments will constrain inorganic and organic reaction products in ammonia-rich conditions at pressures and temperatures thought to be present on Enceladus. The results of these experiments will refine current geochemical models of water-rock processes applied to icy moons in the solar system.

Cover page image from SGF library: W. KILIAN, Massif de la Setaz Vieille, structure géologique des chaînes alpines, 1891