ISTerre PhD Congress

Program

June 22-23

Domaine de Bens

Le Sappey en Chartreuse

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SESSION 1 – IN THE LAB

Love Zetterberg

Creep vs relaxation in brittle disordered solids

***Authors**: Love Zetterberg (ISTerre, France), Jérôme Weiss (ISTerre, France), David Amitrano (ISTerre, France)*

When studying materials that are subjected to loading over long periods of time, two phenomena, creep and stress relaxation, emerge as a sort of mirror image of one another. Creep is defined as the slow deformation of a material under constant load, while relaxation is defined as a material held at constant strain and displaying a slow decrease of the internal stress. In the case of brittle heterogenous materials, these two phenomena can be linked to thermally activated microfracturing. Primary creep is most commonly modelled as a power law decrease of the strain rate with time. Similarly, relaxation is often observed as a logarithmic decrease of the stress with time, corresponding to a stress-rate decaying as 1/t. In both cases these descriptions remain phenomenological and do not explain the underlying process.

Modelling the material as a collection of subvolumes, each capable of deforming and damaging once a local “yield” stress is reached athermally, or by thermal activation, one can create more physically grounded models for creep and relaxation of disordered brittle materials. A 1st order approach, analytically tractable, is to describe primary creep from a statistical exhaustion model, assuming thermal activation of individual subvolume damage, but ignoring elastic stress redistribution. However, this idealized approach neglects spatially and temporally localized effects which have been shown to increase the strain rate and decrease the time to failure through internal stress redistribution.

In order to better understand the relationship between primary creep and relaxation in brittle materials, and aiming to clarify the relationship between these two phenomena, we analyze tests performed on concrete samples, and in particular acoustic emissions. This is compared to what is expected from a simple exhaustion model in order to reveal the combined role of quenched disorder, thermal activation and elastic stress redistributions on these processes.

Anne-Sarah Amblard

Adding a granular transition in a visco-elasto-brittle model

***Authors**: Anne-sarah Amblard (ISTerre, France), Véronique Dansereau (ISTerre – IGE, France), Jérôme Weiss (ISTerre, France)*

Sea ice is a complex material that exhibits various mechanical behaviors depending on its level of fragmentation. In compact and largely intact regions, it behaves as a cohesive, damageable solid that is reasonably well represented by continuum visco-elasto-brittle models (Dansereau et al., 2016; Rampal et al., 2019; Ólason et al., 2022). In contrast, where it becomes highly fractured but dense - such as within large linear kinematic features - it behaves as a frictional, decohesive granular media, a regime that is challenging to describe within a purely continuum framework. Here we do not consider marginal ice zone (MIZ) where the ice is higly fractured and looser. To better capture the transition between the two regimes in such a framework, we enhance an existing visco-elasto-brittle model with additional physical ingredients : a damage-dependence of the Poisson's ratio, a damage-dependence of the cohesion, a friction criterion, and lateral healing. We present results of a simple biaxial compression test in which each of these ingredients is included or not, and demonstrate the strong interaction between their effect, highlighting the necessity of introducing them simultaneously to accurately reproduce the intermittency and localization of sea ice deformation.

Louise Lizé

Crustal fracture classification and parameter estimation from InSAR displacement fields with interpretable descriptors

***Authors**: Louise Lizé (LISTIC, France), Christophe Lin-Kwong-Chon (LISTIC, France), Valérie Cayol (Laboratoire Magmas et Volcans, France)*

Satellite-based remote sensing enables large scale and precise monitoring of natural hazards. In particular, InSAR measures surface displacements that can be analyzed by inverse modelling to provide information on the processes driving deformation. Because inverse modelling is computationally costly, we investigate a machine learning approach to identify deformation source types from displacement fields, distinguishing magmatic intrusions from tectonic faults, while also exploring the estimation of physical parameters.

Inspired by the classification framework of Cayol et al. (2014), which uses ratios of surface displacement extrema to support mechanism diagnosis and parameter estimation, we introduce a machine learning based approach for more robust mechanism classification and parameter estimation. We compute interpretable descriptors from displacement fields, including global statistics and geometric characteristics of the displacement patterns, and train a random forest for classification. We also use random forest regression to explore the estimation of associated physical parameters.

The synthetic dataset used is generated from the Okada elastic model. In this model, the deformation source is a rectangular dislocation described by physical parameters. The resulting classes are well separable and the model achieves good performance, but considering simplified assumptions: a north-south fracture, a blind fracture and no atmospheric noise. The next step is to improve robustness under more realistic conditions. Perspectives include the test of others algorithms and feature selection strategies, before moving to real data and exploring deep learning approaches as complexity increases.

Hongyi Su

A bayesian framework for near-fault ground motion reconstruction from in-situ observation: case study of the 2019 Le Teil earthquake

***Authors**: Hongyi Su (ISTerre, France), Mathieu Causse (ISTerre, France), Cécile Cornou (ISTerre, France), Sébastien Hok (ASNR, France), Céline Gélis (ASNR, France)*

Near-fault ground motion (NFGM) plays a critical role in seismic hazard assessment, particularly in regions located close to surface-rupturing faults. However, global strong-motion networks remain sparse, and data are often unavailable in the immediate vicinity of ruptured faults. This limitation is exacerbated by the occurrence of earthquakes on faults which activity was not recognized, which prevents effective pre-event deployment of strong-motion instruments. A notable example is the 2019 Mw 4.9 Le Teil earthquake in southeastern France, which ruptured La Rouvière fault. Despite the absence of strong-motion instruments in the epicentral area, many in-situ observations, such as broken rocks, displaced grave slabs, and building damage in Le Teil were systematically documented shortly in the aftermath of the event.

We present a Bayesian framework for simulating NFGMs using kinematic source modelling constrained by in-situ observations. The primary aim of this work is to quantify how such in-situ observations can provide constraints on ground motion and source parameters. First, we generate prior NFGMs from a suite of kinematic rupture models on outcropping rocks. We conduct sensitivity analyses on key rupture parameters, including corner frequency, rise time, and nucleation position, and assess their impact on the resulting NFGMs. Some kinematic source parameters are already constrained by observations, such as a low-frequency slip model inverted from InSAR data and rupture duration constrained by far-field seismological observations. These prior NFGMs are then used to simulate the displacement of grave slabs and building-damage grades (with taking site effect into account), following the methods of Causse et al. (2021) and Iskandar et al. (2023). A likelihood function is constructed by comparing the simulations with the observations. By combining the prior NFGMs with the likelihood, we obtain posterior distributions of NFGMs. Evaluating which prior NFGMs yield predictions most consistent with the observations allows us to identify the most plausible kinematic rupture parameters. This approach demonstrates that kinematic rupture source parameters can be constrained even in the absence of strong-motion records and provides an alternative means of estimating these parameters when conventional strong-motion data are unavailable.

SESSION 2 – GRELOUS BY NATURE

Georges Sabback

High-Resolution Multi-Scale Multi-Dimensional Seismic Numerical Twin Based on Massively Parallel High-Performance Computing and Artificial Intelligence - Application to Microzonation of Alpine Valleys

***Authors**: Georges Sabback (BRGM, France & ISTerre France), Cécile Cornou (UGA, France), Florent De Martin (BRGM, France)*

The Grenoble basin (French Alps) is a deep alpine sedimentary valley where seismic site effects are strongly controlled by complex 3D wave propagation within kilometer-scale deposits and surrounding high-relief massifs. Reliable seismic microzonation in such settings requires physics-based modelling that goes beyond 1D assumptions and accounts for basin geometry and heterogeneities.

This study combines high-resolution numerical simulations and data-driven analysis within a Seismic Numerical Twin framework using the spectral-element code EFISPEC3D (up to 2 Hz). A variance-based global sensitivity analysis (Sobol indices) is performed on 512 3D simulations with vertically incident plane-wave excitation in two horizontal polarisations. Key uncertain parameters include P- and S-wave velocity gradients and sediment attenuation (Q factors), constrained by 1D dispersion inversions and combined velocity models (ESG2006 and Ito et al., 2021). So far, results for PGD show that sediment velocity structure and attenuation dominate ground-motion variability.

In parallel, a clustering framework is developed for microzonation by integrating 1D and 3D response spectra, observed H/V ratios, and Eurocode 8 (EC8) parametric spectra. Features from 15 input accelerograms are analysed using k-means and learned embeddings to derive compact representations of site response. Clusters are consistent with sediment thickness, basin-edge effects, and resonance frequencies inferred from H/V data.

Overall, the sensitivity analysis identifies key physical controls on seismic response, while clustering translates heterogeneous datasets into coherent microzonation patterns. The combined approach provides a robust basis for uncertainty-aware seismic hazard characterisation in complex alpine valleys.

Alejandro Andrés-Escorihuela

Automatic detection and classification of seismic signals on an unstable rock slope in the Aiguilles Rouges massif (French Alps)

***Authors**: Alejandro Andrés-Escorihuela (ISTerre, France), Blandine Gardonio (ISTerre, France), Riccardo Vassallo (ISTerre, France), Clément Hibert (ITES, EOST, France), Joachim Rimpot (ITES, France), Laurent Metral (ISTerre, France)*

An unstable rock slope located on the western flank of the Chamonix Valley (French Alps), within the Aiguilles Rouges massif, is monitored to better understand slope processes and associated hazards. The site overlooks densely inhabited areas and critical infrastructure. A network of eight seismic sensors was deployed on and around it for over one year, complemented by extensometers.

Approximately 16000 seismic events were automatically detected from continuous recordings using a Short-Time Fourier Transform (STFT)-based detector combined with adaptive thresholding. Events were then classified using a self-supervised learning (SSL) framework adapted from Rimpot et al. (2025). Each event was converted into an image combining waveform and spectrogram information, from which feature embeddings were extracted. A two-step clustering approach, combining high-resolution K-means and hierarchical merging, was applied to group similar signals.

The classification reveals 375 clusters representing a wide diversity of sources, including anthropogenic activity, meteorological forcing, regional earthquakes, and slope-related processes such as rockfalls, rock granular flows, and microcracking. A distinct family of rockfall-related signals is identified and studied in detail. It is characterized by multi-peak waveforms and broadband frequency content, producing sharp, localized energy peaks in the spectrogram.

This automated workflow significantly reduces manual analysis effort and provides a scalable framework for long-term environmental seismic monitoring. The results demonstrate the potential of combining event-based detection and self-supervised learning to identify and characterize slope-related seismic activity in complex mountainous environments. However, some clusters remain difficult to clearly associate with a specific source, highlighting the inherent complexity of environmental seismic signals.

Quentin Portal

Lateglacial glaciers dynamics in the Mont Blanc foreland (Northern French Alps): model-data coupling in the Arve Valley

Authors*: Quentin Portal (ISTerre, France), Christian Crouzet (ISTerre, France), Jean-François Buoncristiani (EPHE, Biogéosciences, France), Tancrède Leger (Institute of Earth Surface Dynamics, Switzerland), Guillaume Jouvet (Institute of Earth Surface Dynamics, Switzerland), Julien Carcaillet (ISTerre, France)*

Despite several studies (Coutterand, 2010 and references theirin) over the past decades, the chronology of glaciers advances at the Last Glacial Maximum (LGM) and subsequent retreat during the Lateglacial period in the Northern French Alps remains poorly constrained, as data are still too scarce and sometimes contradictory. In this area, the interactions between major glaciers, such as the Rhône and Arve glaciers in the north and Isère glacier in the south, represent major challenges for reconstructing post-LGM glacial dynamics. We present a new framework for understanding Lateglacial glacial dynamics in the Arve Valley, integrating 18 new 10Be exposure ages from glacially-transported boulders, with revised geomorphological mapping based on LiDAR-derived DEMs.

Our results indicate that the deglaciation of the Arve Valley initiated with a phase of glacial thinning around 17.6 ka BP. The Arve glacier subsequently thinned progressively but persisted in the downstream sector of the valley until the end of a readvance phase at 15.9 ka BP. Then, the glacier retreated by over 30 km within 300 years, before withdrawing toward the Mont-Blanc massif ahead of the Younger Dryas readvance.

To further refine our understanding, we confront 10Be exposure ages with numerical simulations of the deglaciation at 200 m resolution using the Instructed Glacier Model (IGM, Leger et al., 2025). This will enable us to analyse possible deglaciation rates and spatial patterns in the Mont Blanc foreland, as well as the influence of key parameters such as geography, topography, and climate.

Martin Huraut

Chronostratigraphy in the Miocene Digne-Valensole basin (SE France): Magnetostratigraphy and U-Pb dating of fossil oysters.

Authors*: M. Huraut (ISTerre, France), J. Léger (ISTerre, France), D. Bienveignant (ISTerre, France), A. De Leeuw (ISTerre, France), A. Villand-Jacquet (ISTerre, France), W. Krijgsman (Dep. Of Earth Sciences, The Netherlands), M. Krasnoperov (Dep. Of Earth Sciences, The Netherlands)*

The sedimentary records of the Digne-Valensole Basin provide an excellent window into the tectonic and climatic history of the Alpine foreland during the Miocene. However, this basin lacks a robust chronostratigraphic framework because it lacks volcanic ash and fossils of stratigraphic interest. The present study presents new chronostratigraphic data based on two methods: magnetostratigraphy and U–Pb dating of calcite of oyster fossils.

The marine molasse of the Digne Basin yielded U–Pb ages for 12 stratigraphic levels. The paleomagnetic study, meanwhile, is based on the analysis of 260 samples distributed over 800 m of sedimentary thickness. The interval studied corresponds to the transition from marine to continental molasse, and the results of this study suggest that the transition is dated to around 13.8 Ma (Langhian–Serravallian transition, Middle Miocene). This date corresponds to a major climatic event: the Mid-Miocene climatic transition (mMCT), that follow the Middle Miocene Climate Optimum (mMCO).

U—Pb dating of oyster fossils remains an emerging application of the U–Pb method. Magnetostratigraphy thus appears to be a method that allows 1) the validity of U–Pb ages to be assessed, 2) the section to be dated at higher resolution, and 3) dating to be extended to continental sediments.

SESSION 3 – HEADING EAST, TOWARDS THE RISING SUN

Juliette Raabe

Evaluation of tropospheric corrections for InSAR processing over the Western Alps.

Authors*: Juliette Raabe (ISTerre, France; Centre national d'études spatiales (CNES), France), Marie-Pierre Doin (ISTerre, France), Andrea Walpersdorf (ISTerre, France), Christian Sue (ISTerre, France)*

Using the InSAR-related NSBAS chain processing (Doin et. al 2011, Thollard et. al. 2021) and the 2016-2025 Sentinel-1 radar data, we aim at obtaining a velocity map over the European Alps with a target uncertainty of a mm/yr. Mountainous areas present inherent challenges for InSAR study such as geometric distortions, decorrelation due to vegetation or snow cover changes. To achieve millimeter-per-year precision, we must consider the atmospheric contribution (especially troposphere) since it has spatial and temporal variations that does not cancel when forming interferograms. Tropospheric variations are still a major factor limiting the accuracy of InSAR measurements: a change of 20% of relative humidity between two acquisitions is responsible for a 10 cm error in deformation interpretation (Zebker and Rosen, 1997). Moreover, if the differential troposphere delay between two considered dates goes beyond 5.6 cm, troposphere can be the source of unwrapping errors during processing.

Therefore, we explore the different possibilities available to mitigate the tropospheric contribution before unwrapping but also to remove its contribution from timeseries and avoid as much misinterpretation as possible in deformation analysis.

Tropospheric impact has been widely studied and several methods have been proposed to mitigate tropospheric noise. Among them, we focus on two main approaches: mitigation by trying to separate stochastic noise from signal (for example, exploiting empirical relationship between elevation and troposphere) and by the usage of external data. For the latter, two main sources of data are available. We can benefit from data from Global Atmosphere Models (GAM) (particularly the ERA5 and CERRA reanalyses of the ECMWF) or from Zenithal Troposphere Delays (ZTD) estimated during the GNSS processing.

Laurens Oostwegel

Using the urban fabric and morphometrics to analyze the vulnerability of the built environment

***Authors**: Laurens J.N. Oostwegel (GFZ, Germany; ISTerre, France), Danijel Schorlemmer (GFZ, Germany; ETH, Zurich), Philippe Guéguen (ISTerre, France)*

Recently, increasingly detailed building footprint datasets that characterize the built environment are becoming available. The semantic information that is relevant for seismic risk assessment in these datasets is still incomplete. Enriching these datasets with more complete and accurate information increases our understanding of the built environment and reduces uncertainties in seismic risk assessment (Oostwegel et al., 2025).

We explore how the study of urban form can be used to enrich building footprints with properties relevant for seismic risk. Our method is based on the Urban Taxonomy (Fleischmann et al., 2025), a hierarchical framework that characterizes urban fabric through quantifiable metrics (morphometrics) derived from building geometry and street networks. Building plots are approximated by a Voronoi tessellation of building centroids, and building blocks are created by clustering buildings within a street network. Using these three levels of building geometries (single building, building plot, and building block), together with the street network, we compute 144 morphometric attributes. These serve as input features for an extreme gradient boosting algorithm.

Our initial results show that these morphometrics can predict building occupancy type and year of construction with accuracies of 94% and 55% respectively. These results raised the question whether morphometrics can serve as a proxy for vulnerability itself. We use the 2023 Kahramanmaraş earthquake sequence in Turkey as a case study, as post-earthquake damage observations have been recorded that provide ground truth at the building level. This allows us to train and evaluate a model that links urban fabric characteristics directly to observed structural damage.

Vulnerability remains a component of the risk chain that has high uncertainties. Even if we know the exact structural properties of a building, it is difficult to predict the level of damage according to shaking intensities. Mostly, we don’t even know the structural properties. As the building geometries are much more widely available, this method method has the potential to produce high-resolution vulnerability maps from openly available geodata alone.

Laureen Maury

Large Scale Slope Deformation in Upper Mustang (Nepal): Factors and Impacts

***Authors**: Laureen Maury (ISTerre, France), Kristen Cook (ISTerre, France), Basanta Raj Adhikari (Tribhuvan Univeristy, Nepal), Pascal Lacroix (ISTerre, France)*

Climate change is expected to have a significant impact on geomorphological activity, especially in high mountain ranges. Models predict increased ground movement due to (1) an increase in water infiltration from melting snow, (2) reduced soil and rock cohesion caused by permafrost degradation, and (3) post-glacial slope decompression. This project focuses on slow-moving landslides (~1 m/y), which allow detailed monitoring of their physical properties. We focus on Upper Mustang, a high-altitude (>3,000 m), dry sedimentary valley located between the Himalayas and the Tibetan Plateau. Its landscapes are highly sensitive to climate variations and marked by large-scale slope deformations, making it ideal for studying landslide evolution. Although these landslides have been recognized for a long time, their characteristics (location, extent, speed) have never been systematically studied, largely due to the valley's remote location and high altitude. Our approach combines two remote sensing methods: optical image correlation and InSAR (Interferometric Synthetic Aperture Radar). By analyzing high-resolution Pleiades images (2013–2025) and Sentinel-1 InSAR data (2014-2025), we mapped ground deformation over a decade, creating an exhaustive landslide inventory. Time-series of displacement were generated using PlanetScope images (2016–2025) for landslides moving at cm/y to m/y, and Sentinel-1 data for slower deformations (mm/y to cm/y). A field mission helped to characterize the landscapes of major landslide areas (Muktinath, Dhe, Yara-Ghara). The results highlight the complementary nature of InSAR and optical image correlation for mapping and monitoring slope deformation in Upper Mustang, which has so far enabled the detection of ~200 landslides covering 90 km^2 (9.6% of the study area), predominantly in upper valleys, suggesting permafrost influence. Their temporal evolution varies which could indicate different triggering and controlling factors (climate, human activity, geology). This study demonstrates the critical role of slow-moving landslides as indicators for understanding broader landslide mechanisms, including both slow and rapid events.

Millary Agung Widiawaty

Mangrove and coral reef interplay: insights from geological, geomorphological and oceanic factors in Indonesia

***Authors**: Millary Agung Widiawaty (ISTerre, France), Gino de Gelder (ISTerre, France), Laurent Husson (ISTerre, France)*

Mangroves and coral reefs are critical ecosystems in tropical coastal zones, yet the local environmental and geological settings that govern their distribution and development are often poorly known. This study investigates the spatial distribution and characteristics of these ecosystems in Indonesia, with a focus on the island of Sumba, by examining the underlying geological, geomorphological, and oceanic-climatic controls. We integrate geospatial big data from multiple sources, including thematic maps, field surveys, and optical and radar satellite imageries. Analytical methods include swath profile analysis, coastal transects, and geological interpretation to identify key environmental drivers. Preliminary results reveal that mangroves are predominantly associated with sedimentary and intertidal environments, where salinity, wave energy, temperature, tidal dynamics, and the presence of river estuaries shape their occurrence. In contrast, coral reefs are primarily found in clear-water marine environments characterized by suitable bathymetry, low sediment input, stable sea-surface temperatures, and moderate hydrodynamic conditions. Notably, both mangrove and reef distributions are controlled by the regional geological history: tectonic uplift and Quaternary sea-level fluctuations have controlled the staircase coastal morphology around Sumba Island, which is the main factor influencing reef and mangrove accommodation space. These findings offer critical insights for the conservation, management, and rehabilitation of coastal ecosystems in Indonesia.

SESSION 4 – HEADING WEST, CROSSING THE ATLANTIC

Laetitia Drumare

A phase-field modeling approach to sea-ice fracturing

Authors*: Laetitia Drumare (ISTerre, France & Njord Centre, Norway), Vidar Skogvoll (Njord Centre, Norway), François Renard (ISTerre, France & Njord Centre, Norway), Luiza Angheluta (Njord Centre, Norway), Véronique Dansereau (ISTerre, France & IGE, France)*

The thin ice that covers the polar oceans is a complex geomaterial that is constantly stressed and fractured by winds and ocean currents. In the central Arctic, this forcing produces deformations in the form of shear bands, within which individual ice plates detach, locally generating a granular medium. Capturing this transition from a continuous to a granular sea-ice cover has implications for the adequate representation of the mechanical and dynamical behavior of sea-ice in regional and large-scale models used for operational and climate prediction purposes. Our work investigates the feasibility of a phase-field approach to capture this granularization processes and focuses on fracture propagation in the material. The model combines a double-well free-energy formulation with an overdamped displacement response. The governing equations are solved using a spectral method in Fourier space. The implementation accounts for body forces, representative of the main forcings on sea-ice, and remains computationally tractable despite the highly nonlinear character of the double-well energy formulation. We first validate the framework against a benchmark problem: the opening of an inclusion embedded into an elastic matrix under tensile loading. Then, additional simple shear configurations are investigated: an inclusion solicited under plane shear and a cylindrical Couette experiment, for which the analytical solution of the displacement field is known. The resulting fracture patterns and displacement fields demonstrate that our phase-field framework captures key features of tensile and shear fracture propagation, including the linear scaling between crack speed and applied load predicted by the Griffith's theory.

Yannick Boucharat

Dynamic topography atop the Caribbean double subduction

***Authors**: Yannick Boucharat (ISTerre, France), Laurent Husson (ISTerre, France), Diane Arcay (Géosciences Montpellier, France), Nestor Cerpa (Géosciences Montpellier, France)*

Understanding the link between subduction dynamics and surface topography in subduction zones is essential for biogeographic reconstructions. Here we focus on the Caribbean Plate, overriding plate of the Pacific subduction zone to the west and the Atlantic subduction zone to the east. In this study, we test different processes that may control vertical velocity variations in the upper plate using thermo-mechanical models in simple Cartesian configurations. In particular, the isolation of the upper mantle by the two subducting slabs could cause variations in dynamic topography. We quantify these variations to decipher their contributions at the surface, to later reconstruct the paleogeography using more complex models, allowing us to establish a link with the biodiversity of the Caribbean during the Cenozoic era. We show here that the total convergence velocity of the facing slabs and the rheology of the upper plate control upper mantle dynamic pressure, and thus dynamic topography. A weak rheology of the upper plate and low velocities allow slab rollback, leading to continuous depression of the upper mantle and surface subsidence, whereas strong rheology and fast velocities anchor trench positions, leading to slab folding at the mantle transition zone and cyclic overpressure and underpressure, resulting in cyclic uplift and subsidence. Such process could have allow successive emersions and drownings of terrestrial pathways in the Caribbean, controlling terrestrial flora and fauna migrations across the Lesser and Greater Antilles.

Ricardo Aguilera Cortés

Dendroseismological constraints on recent activity of the Magallanes-Fagnano Fault (Eastern Tierra del Fuego, Chile)

Authors: *Ricardo Aguilera-Cortés (ISTerre, France), Laurent Astrade (EDYTEM, France), Joseph Martinod (ISTerre, France), Riccardo Vassallo (ISTerre, France), Christian Sue (ISTerre, France)*

We applied dendroseismological analysis to lenga beech trees (Nothofagus pumilio) growing on or near scarps of the Magallanes-Fagnano Fault in Tierra del Fuego, Chile, to evaluate whether tree-ring disturbances recorded the historical 1879 and 1949 major earthquakes. Two sectors located ~60 km apart were analyzed: western Lake Fagnano and Almirantazgo Gulf (Capo Toto). We combined anatomical observations from trunk sections with percent growth change (PGC) analysis from ring-width series, and we compare with reference trees that record the regional climatic signal.

The strongest dendroseismological evidence is provided by tree-ring anomalies observed in samples from western Lake Fagnano, where trees growing on or close to mapped fault scarps show eccentric growth, abrupt growth drops, and asymmetric ring development around the timing of the 1949 earthquake (Figure 1). These anomalies are result from tree tilting, growth compensation, and possible root or slope disturbance following coseismic deformation or strong shaking. PGC analysis supports this interpretation: the clearest 1949 signal is observed at Lake Fagnano sites located directly on an active scarp of the Magallanes-Fagnano Fault, where several trees record post-1949 growth increase. At Capo Toto, the 1949 signal is weak or absent in both anatomical observations and averaged PGC results.

For both sites, tree disturbances for 1879 remain unclear. Although at Capo Toto few trees show positive growth anomalies close to 1879, both sites lack of enough tree samples older than 1879 that may contribute a more conclusive result. Our results support the interpretation that the 1949 surface rupture propagated at least to western Lake Fagnano but probably did not continue farther west into the Almirantazgo Gulf. Conversely, the 1879 rupture may have involved a broader western segment of the fault. This study highlights the value of combining anatomical tree-ring evidence with PGC analysis to constrain historical ruptures in forested strike-slip fault zones.

Gabin Simonet

Ambient seismic sources and velocity structure inversion from cross-correlation with membrane waves

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Ambient seismic noise has been widely investigated over the past 20 years, particularly for Earth imaging applications. Several natural and anthropogenic processes induce seismic noise, among these, ocean gravity waves are dominant at specific frequencies. By recording seismic waves travelling along the Earth's surface and computing the cross-correlation between receivers, coherent wave propagation can be extracted. However, since noise sources depend on factors like ocean state, large variations of the ambient wavefield in amplitude, frequency content and directionality are observed both through space and time. It is therefore well known that the surface wavefield does not meet the criterion to retrieve the exact Green's function as the theory of interferometry would suggest.

While this is of major concern for ambient noise tomography, implying careful processing and selection of the data, cross-correlations can also help us describe the noise sources themselves. Several studies have investigated source imaging, and in the recent years ambient noise full waveform inversion has emerged. It aims to find both the best source model and Earth structure that would fit the observed cross-correlations. However, the computational cost of modelling seismic wave propagation increases exponentially with frequency, currently limiting applications to long periods.

In this project, we aim to model both Rayleigh and Love wave cross-correlations with the membrane wave assumption. Because the observed cross-correlations are dominated by surface waves propagating in two dimensions, full 3D Earth modelling is often unnecessary. A 2D sphere approximation, referred to as membrane, is sufficient to simulate cross-correlations while substantially reducing computational cost. To begin with, we aim to map seismic ambient sources at long period with a global-scale network. Then, we will model surface wave velocity in Europe using the Adria Array, a temporary network covering the Adriatic plate and its active margins in the central Mediterranean.