Léonard Seydoux

Professor in Geophysics & Artificial Intelligence

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Research statement

Earthquakes and volcanic eruptions are highly destructive, yet their mechanisms remain partially understood. My research analyzes subtle geophysical signals, including slow earthquakes, very long-period events, and scattered wavefields, using artificial intelligence and machine learning. I combine high-performance computing, array-based seismic analysis, and advanced signal processing to link these signals to major geological events. I focus on AI-driven hazard assessment, reconstruction of sparse or historical datasets, and multiscale monitoring of fault and volcanic systems, while integrating software development, teaching, and collaborative supervision to connect computational geophysics with practical understanding of Earth's dynamics.

Education

Diplomas

2016 **PhD in Geophysics and Signal Processing**
Institut de Physique du Globe de Paris and Langevin Institute, Paris, France.
Thesis advisors: Nikolai M. Shapiro and Julien de Rosny.

2013 **MSc in Engineering Sciences**
Pierre and Marie Curie University, Paris, France.

2011 **BSc in Physics**
Paul Sabatier University, Toulouse, France.

Additional trainings

Fall 2022 **High-performance computing** (7 hrs)
Lenovo, Institut de Physique du Globe de Paris, France

Fall 2016 **Probabilistic Graphical Models** (12 hrs)
Master Mathematics, Vision, Learning, École Normale Supérieure, Cachan, France

Fall 2014 **High-performance computing on GPU** (14 hrs)
ClusterVision, Institut de Physique du Globe de Paris, France

Fall 2013 **Scientific programming in C++** (60h)
Pierre and Marie Curie University, Paris, France

Research experience

Postgraduate experience

Since 2022 **Assistant Professor, Chaire de Professeur Junior**
Institut de Physique du Globe de Paris, Université Paris Cité.

2021–2022 **Postdoctoral associate**
MIT department of Earth, Atmospheric and Planetary Sciences.
Slow-slip and tectonic tremor location with deep learning.
Advisors: William B. Frank and Thomas Herring

2018–2021 **Postdoctoral visitor**
Rice University department of Computational and Applied Mathematics
Seismic signal clustering with deep scattering networks
Collaborators: Maarten V. de Hoop, Richard G. Baraniuk and Randall Balestriero

2017–2021 **Postdoctoral associate**
Institute of Earth Sciences (ISTerre), Grenoble Alpes University
European Research Council Advanced Grant F-IMAGE
Artificial-intelligence-based seismic signal detection and classification
Principal investigator: Michel Campillo

Fall 2017 **Research and teaching associate**
Institut de Physique du Globe de Paris, department of Seismology, France
Detecting seismic signals with machine learning and array processing

Undergraduate experience

2013–2016 **Graduate student and teaching assistant**
Institut de Physique du Globe de Paris and Langevin Institute, Paris, France
Covariance matrix analysis of seismic signals collected on seismic arrays
Thesis advisors: Nikolai M. Shapiro and Julien de Rosny.

Spring 2012 **Undergraduate research internship**
Jean le Rond d'Alembert Institute, Paris, France
Design of an optoelectronic sensor for high-rate string motion measurement
Advisors: Delphine Chadefaux and Jean-Loïc le Carrou

Spring 2011 **Undergraduate research memoir**
Paul Sabatier University, Toulouse, France
Heartbeat modeling with coupled Van der Pol oscillators
Advisor: Dominique Toublanc

Publications and communications

My full publication record is available in my Google Scholar profile.
Underlined authors indicate advised student or postdoc.

Peer-reviewed international journals

20. R. Steinmann, **L. Seydoux**, C. Journeau, N. M. Shapiro, and M. Campillo. 2024). Machine Learning Analysis of Seismograms Reveals a Continuous Plumbing System Evolution Beneath the Klyuchevskoy Volcano in Kamchatka, Russia. *Journal of Geophysical Research: Solid Earth*, 129(3):e2023JB027167. 10.1029/2023JB027167. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1029/2023JB027167

19. E. Beaucé, W. B. Frank, **L. Seydoux**, P. Poli, N. Groebner, R. D. van der Hilst, and M. Campillo. (2023). BPMF: A Backprojection and Matched-Filtering Workflow for Automated Earthquake Detection and Location. *Seismological Research Letters*, 95(2A):1030–1042. 10.1785/0220230230

18. L. Moreau, **L. Seydoux**, J. Weiss, and M. Campillo. (2023). Analysis of microseismicity in sea ice with deep learning and Bayesian inference: application to high-resolution thickness monitoring. *The Cryosphere*, 17(3): 1327–1341. 10.5194/tc-17-1327-2023 . Publisher: Copernicus GmbH

17. C. Caudron, Y. Aoki, T. Lecocq, R. De Plaen, J. Soubestre, A. Mordret, **L. Seydoux**, and T. Terakawa. (2022). Hidden pressurized fluids prior to the 2014 phreatic eruption at Mt Ontake. *Nature Communications*, 13(1): 6145. 10.1038/s41467-022-32252-w

16. B. Giammarinaro, C. Tsarsitalidou, G. Hillers, J. de Rosny, **L. Seydoux**, S. Catheline, M. Campillo, and P. Roux. (2022). Seismic surface wave focal spot imaging: numerical resolution experiments. *Geophysical Journal International*, 232(1):201–222. 10.1093/gji/ggac247

15. R. Steinmann, **L. Seydoux**, and M. Campillo. (2022b). AI-Based Unmixing of Medium and Source Signatures From Seismograms: Ground Freezing Patterns. *Geophysical Research Letters*, 49(15). 10.1029/2022GL098854

14. C. Journeau, N. M. Shapiro, **L. Seydoux**, J. Soubestre, I. Y. Koulakov, A. V. Jakovlev, I. Abkadyrov, E. I. Gordeev, D. V. Chebrov, D. V. Droznin, C. Sens-Schönfelder, B. G. Luehr, F. Tong, G. Farge, and C. Jaupart. (2022). Seismic tremor reveals active trans-crustal magmatic system beneath Kamchatka volcanoes. *Science Advances*, 8(5):eabj1571. 10.1126/sciadv.abj1571

13. F. Aden-Antoniow, W. B. Frank, and **L. Seydoux**. (2022). An Adaptable Random Forest Model for the Declustering of Earthquake Catalogs. *Journal of Geophysical Research: Solid Earth*, 127(2). 10.1029/2021JB023254

12. R. Steinmann, **L. Seydoux**, E. Beauce, and M. Campillo. (2022a). Hierarchical Exploration of Continuous Seismograms With Unsupervised Learning. *Journal of Geophysical Research: Solid Earth*, 127(1). 10.1029/2021JB022455

11. S. Barkaoui, P. Lognonné, T. Kawamura, E. Stutzmann, **L. Seydoux**, M. V. de Hoop, R. Balestriero, J.-R. Scholz, G. Sainton, M. Plasman, S. Ceylan, J. Clinton, A. Spiga, R. Widmer-Schnidrig, F. Civilini, and W. B. Banerdt. (2021). Anatomy of Continuous Mars SEIS and Pressure Data from Unsupervised Learning. *Bulletin of the Seismological Society of America*, 111(6):2964–2981. 10.1785/0120210095

10. P. Shi, **L. Seydoux**, and P. Poli. (2021). Unsupervised Learning of Seismic Wavefield Features: Clustering Continuous Array Seismic Data During the 2009 L'Aquila Earthquake. *Journal of Geophysical Research: Solid Earth*, 126(1). 10.1029/2020JB020506

9. **L. Seydoux**, R. Balestriero, P. Poli, M. de Hoop, M. Campillo, and R. Baraniuk. (2020). Clustering earthquake signals and background noises in continuous seismic data with unsupervised deep learning. *Nature Communications*, 11(1):3972. 10.1038/s41467-020-17841-x

8. C. Journeau, N. M. Shapiro, **L. Seydoux**, J. Soubestre, V. Ferrazzini, and A. Peltier. (2020). Detection, Classification, and Location of Seismovolcanic Signals with Multicomponent Seismic Data: Example from the Piton de La Fournaise Volcano (La Réunion, France). *Journal of Geophysical Research: Solid Earth*, 125 (8). 10.1029/2019JB019333

7. M. Lott, P. Roux, **L. Seydoux**, B. Tallon, A. Pelat, S. Skipetrov, and A. Colombi. (2020). Localized modes on a metasurface through multiwave interactions. *Physical Review Materials*, 4(6):065203. 10.1103/PhysRevMaterials.4.065203

6. J. Soubestre, **L. Seydoux**, N. M. Shapiro, J. De Rosny, D. V. Droznin, S. Y. Droznina, S. L. Senyukov, and E. I. Gordeev. (2019). Depth Migration of Seismovolcanic Tremor Sources Below the Klyuchevskoy Volcanic Group (Kamchatka) Determined From a Network-Based Analysis. *Geophysical Research Letters*, 46(14):

8018–8030. 10.1029/2019GL083465

5. J. Soubestre, N. M. Shapiro, **L. Seydoux**, J. de Rosny, D. V. Droznin, S. Y. Droznina, S. L. Senyukov, and E. I. Gordeev. (2018). Network-Based Detection and Classification of Seismovolcanic Tremors: Example From the Klyuchevskoy Volcanic Group in Kamchatka. *Journal of Geophysical Research: Solid Earth*, 123 (1):564–582. 10.1002/2017JB014726
4. **L. Seydoux**, J. de Rosny, and N. M. Shapiro. (2017). Pre-processing ambient noise cross-correlations with equalizing the covariance matrix eigenspectrum. *Geophysical Journal International*, 210(3):1432–1449. 10.1093/gji/ggx250
3. **L. Seydoux**, N. M. Shapiro, J. De Rosny, and M. Landès. (2016b). Spatial coherence of the seismic wavefield continuously recorded by the USArray: COHERENCE OF SEISMIC WAVES AT USARRAY. *Geophysical Research Letters*, 43(18):9644–9652. 10.1002/2016GL070320
2. **L. Seydoux**, N. M. Shapiro, J. De Rosny, F. Brenguier, and M. Landès. (2016a). Detecting seismic activity with a covariance matrix analysis of data recorded on seismic arrays. *Geophysical Journal International*, 204 (3):1430–1442. 10.1093/gji/ggv531
1. J.-L. Le Carrou, D. Chadefaux, **L. Seydoux**, and B. Fabre. (2014). A low-cost high-precision measurement method of string motion. *Journal of Sound and Vibration*, 333(17):3881–3888. 10.1016/j.jsv.2014.04.023

Invited conference talks

5. **L. Seydoux**, R. Steinmann, S. Mouaoued, R. Esfahani, and M. Campillo. Revealing and interpreting patterns from continuous seismic data with unsupervised learning. In *EGU General Assembly Conference Abstracts*, page 8924, 2024)
4. **L. Seydoux**, R. Balestriero, P. Poli, M. V. de Hoop, R. Baraniuk, and M. Campillo. Seismic signals and noises clustering with unsupervised deep representation learning. volume 2019, pages S52A–04. American Geophysical Union Fall Meeting, (2019b)
3. **L. Seydoux**, R. Balestriero, P. Poli, M. De Hoop, R. Baraniuk, and M. Campillo. Unsupervised clustering of continuous seismograms with deep learning. Cargèse Workshop Lectures, 2019a)
2. **L. Seydoux**, M. De Hoop, R. Balestriero, and M. Campillo. Unsupervised detection and clustering of seismic sources with trainable scattering network. Machine learning in solid earth geosciences 2, 2019c)
1. **L. Seydoux**, N. Shapiro, J. de Rosny, and M. Landes. A Spatial Coherence Analysis of Seismic Wavefields Based on Array Covariance Matrix : Application to One Year of the USArray Data. volume 2015, pages S34B–04. American Geophysical Union Fall Meeting, (2015)

Teaching experience

** indicates a course conducted in French*

Short schools

Fall 2024 **Machine learning and artificial intelligence for geosciences** (3 days), Barcelona Supercomputing Center, Barcelona, Spain. Lectures and practicals.

Spring 2023 **An introduction to machine learning and deep learning** (2 days), Réseau thématique NuTS, Lyon. Lectures and practicals.

Spring 2023 **An introduction to deep learning** (1 day), SPIN ITN Short Course 3, Pitlochry, Scotland. Lectures and practicals.

University lectures

Since 2022 **Scientific Computing for Geophysical Problems** (32 hrs/yr)
Master of Geophysics, Institut de Physique du Globe de Paris

2022–2024 **Python Programming for Geosciences*** (20 hrs/yr)
Bachelor of Geophysics, Institut de Physique du Globe de Paris

Since 2022 **Earth Data Sciences** (12 hrs/yr)
Master of Geophysics, Institut de Physique du Globe de Paris

2019–2021 **Machine Learning in Geophysics** (12 hrs)
Master of Geophysics, Grenoble-Alpes University

2019–2021 **Engineering Seismology** (20 hrs)
Master of Geomechanics, Civil Engineering and Risks, Grenoble-Alpes University

2017 **Introduction to Algorithmic with Python*** (28 hrs)
Associate Level in Informatics, GRETA, Corbeil-Essonnes, France

2017 **Passive Seismic Interferometry Practicals** (4 hrs)
Master of Geophysics, Institut de Physique du Globe de Paris

2017 **Modal Analysis with Musical Analogy** (12 hrs)
Bachelor of Earth and Environment, Institut de Physique du Globe de Paris

2014–2017 **General Physics Practicals*** (88 hrs)
Bachelor of Environment Engineering, Denis Diderot University, Paris, France

2014–2016 **Data Analysis in Earth Sciences*** (84 hrs)
Bachelor of Environment Engineering, Denis Diderot University, Paris, France

2013–2014 **Scientific Programming in MATLAB*** (44 hrs)
Bachelor of Environment Engineering, Denis Diderot University, Paris, France

2013 **Internet and Office Automation Certification*** (22 hrs)
Bachelor Level, Denis Diderot University, Paris, France

2013 **Scientific Programming in C** (18 hrs)
Master of Remote Sensing and Geomatics, Denis Diderot University, Paris, France

Supervision

Postdoctoral researchers

2019–2021 **Soyoun Son**, Institute of Earth Sciences (ISTerre), Grenoble, France
Application of array-based waveform clustering to the dense seismic data from the SJFZ, CA w. Michel Campillo

Graduate students

Spring 2025 **Miriana Corsaro**, University of Catania, Italy
AI-based location of seismic events recorded with DAS at Campi Flegrei. Visiting for two months.

Since 2023 **Adèle Doucet**, Institut de physique du globe de Paris, France
AI-based seismovolcanic activity monitoring of dormant volcanic systems. Co-advisors: Jean-Philippe Métaxian and Nobuaki Fuji.

Since 2023 **Rodrigo Flores-Allende**, Institut de physique du globe de Paris, France
Spatio-temporal study of seismicity in subduction zones from inhomogeneous seismic networks with artificial intelligence. Co-advisor: Fabian Bonilla.

Since 2022 **Sarah Mouaoued**, Institute of Earth Sciences (ISTerre), Grenoble, France
AI-based analysis of the scattered seismic wavefield from the Mars InSight data w. Michel Campillo

2019–2022 **René Steinmann**, Institute of Earth Sciences (ISTerre), Grenoble, France
Unsupervised analysis of seismicity in the North-Anatolian fault zone w. Michel Campillo.

Undergraduate students

Spring 2025 **Agathe Brisot**, Deep seismicity at Stromboli with an array of OBS sensors.

Spring 2025 **Noémie Divoux**, Enhancing earthquake location with machine learning.

Spring 2024 **Thibaut Ceci**, Exploration of seismic signals generated by dense granular flows.

Spring 2024 **Lorette Drique**, InSAR bias estimation over vegetated terrains with machine learning.

Spring 2024 **Farzaneh Mohammadi**, Enhancing earthquake location with domain adaptation.

Spring 2023 **Zhiyang Guo**, Enhancing earthquake location with domain adaptation.

Spring 2023 **Rodrigo Flores Allende**, Analyzing the Mw 8.8 Maule earthquake with AI and template matching.

Spring 2023 **Laure Manceau**, Unsupervised analysis of very long-period earthquakes at Stromboli w. Eleonore Stutzmann et Jean-Philippe Métaxian.

Fall 2020 **Zhong Min Khoo**, Earth Observatory of Singapore, Nanyang Technological University
Monitoring the volcanic activity of Mt. Merapi with infrasonic and seismic data w. Benoit Taisne

Spring 2018 **Cyril Journeau**, Institute de Physique du Globe de Paris, France
Analysis of seismovolcanic tremors with principal component analysis w. Nikolai Shapiro

Spring 2017 **Jean Soubestre**, Institute de Physique du Globe de Paris, France
Analysis of the seismovolcanic activity at Kamchatka, w. Nikolai Shapiro

Service

Professional associations

2019–present **European Geosciences Union**

2013–2019 **American Geophysical Union**

Session Convener

Spring 2025 **European Geosciences Union General Assembly**
Machine learning for time series in geophysics
Vienna, Austria. Abstract: meetingorganizer.copernicus.org/EGU25/session/53581

Autumn 2021 **General Assembly of the European Seismological Commission**
Machine learning solutions to seismic problems
Corfu, Greece. Abstract: erasmus.gr/UsersFiles/microsite1193

Spring 2020 **European Geosciences Union General Assembly**
Machine Learning in Solid Earth Geosciences
Vienna, Austria. Abstract: copernicus.org/EGU2020/session/35908

Spring 2019 **European Geosciences Union General Assembly**
Machine learning for seismic signal analysis
Vienna, Austria. Abstract: copernicus.org/EGU2019/session/31898

Summer 2019 **Applied Inverse Problems Mini-symposia**
How to see inside the Earth? Theory and applications of inverse problems

Grenoble, France. Abstract: aip2019-grenoble.fr

PhD defense jury

Sep. 2025 **Joachim Rimpot** Exploration automatisée et analyse de flux de données sismologiques par méthodes d'apprentissage machine supervisées et non-supervisées

Jun. 2025 **Julius Grimm**, Détection et caractérisation de signaux sismiques par mesures acoustiques distribuées sur fibre optique (DAS)

Dec. 2024 **Gabriela Arias Mendez** Alerte tsunami à partir de signaux élasto-gravitationnels par apprentissage profond

Feb. 2024 **José Cunha Teixeira**, Exploitation du monitoring sismique du sous-sol en milieu ferroviaire

Dec. 2023 **Théotime de la Selle**, Détection, classification non-supervisée et investigation des mécanismes d'émission de multiplets acoustiques associés à la fissuration par fatigue

Nov. 2023 **Alexander Yates**, Vers une surveillance précise des volcans explosifs par interférométrie de bruit sismique

Departmental service

Since 2025 **President of the NuTS CNRS-INSU funded thematic network**

Since 2025 **Fellow at PR[AI]RIE-PSAI**
Fellow at the PRAIRIE *Paris School of AI/*

Since 2024 **Member of the scientific board of the doctoral school STEP'UP**
Member of the council, and the selection jury.
STEP'UP: Sciences of the Earth, Environment, the Planets, and Physics of the Universe

Since 2024 **Member of the carbon impact evaluation board of IPGP**

Since 2023 **Elected member of the board of directors of IPGP**

Since 2022 **Member of various PhD committees**
Member of the PhD committee of Selina Wetter (IPGP), Aurelia Ditto (CEA Grenoble), Matthieu Nougaret (IPGP).

Since 2022 **Master's thesis committee member**
Jury member within one to three master thesis defense per year.

Community involvement

2020 **Development of the open-source Python package *CovSeisNet***
Co-developers: Nikolai Shapiro, Jean Soubestre, Cyril Journeau and Francis Tong
Webpage: covseisnet.gricad-pages.univ-grenoble-alpes.fr

Winter 2019 **Deployment of seismic sensors on the San Jacinto fault zone, California**
Seismic event detection for the ERC Consolidator Grant FaultScan; PI: Florent Brenguier
Webpage: sites.google.com/site/florentbrenguier/Home/research

2017 **Workshop organizer and speaker on *Artificial intelligence applications in Geophysics***
Institut de Physique du Globe de Paris. Notes: github.com/leonard-seydoux/ML-Geosciences

Spring 2014 **Workshop organizer and speaker in *PhD student annual meeting***
Institut de Physique du Globe de Paris. Website (developed): educatix.ipgp.fr/cdd2014

Spring 2011 **Open day organization (1 week)**
Paul Sabatier University, Toulouse, France

Reviewer

Geophysical Journal International
Journal of Geophysical Research
Geophysical Research Letters
Comptes Rendus Geosciences
Nature Communications
Acta Geophysica
Chapter from Nakata et al. (2018)
Advances in Space Research

Technical skills

Software and Libraries

GMT	Plotting tools
AxiSEM	3D spectral elements
PhaseNet	AI-based seismic phase picking
ObsPy	Seismic data management
Scikit-learn	Machine learning
TensorFlow	Deep learning

Developed libraries

SymJAX	Symbolic deep learning
SciTools	Geophysics
Cartopy	Geographical mapping
CovSeisNet	Array processing

Scientific programming

Languages	Python, Matlab, C++
HPC	MPI, OpenMP, SLURM, OAR
GPU	CuPy and CUDA

Spoken Languages

English	Fluent
French	Native
Italian	Good
Spanish	Notions

Other Skills

Transportation	Driving license
Scuba diving	Adv. Open Water & Rescue (CMAS II)
Music	Flutes, Piano, Guitar