Léonard Simon Seydoux

Professor in Geophysics & Artificial Intelligence

Phone   +33 (0) 1 83 95 75 37

Email   seydoux@ipgp.fr

Address   Institut de Physique du Globe de Paris
Université Paris Cité
Équipe de Sismologie
1, Rue Jussieu, 75005 Paris

Research statement

Earthquakes and volcanic eruptions are among the most devastating events. The signatures of these events in geophysical data allow us to understand only partially their mechanism and cycles. During quiescent periods, weaker signals, such as slow earthquakes, are regularly observed, whose roles in the seismic and volcanic cycle remain poorly understood. My research focuses on identifying and modeling these signatures in a data-driven manner by viewing geophysical data through the lens of artificial intelligence. I aim to objectively define these observables and highlight the physical processes that link them to significant events in active geological systems.

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 free courses

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**
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

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 ⬏

Submitted papers

1. L. Moreau, **L. Seydoux**, J. Weiss, and M. Campillo. Analysis of micro-seismicity in sea ice with deep learning and Bayesian inference: application to high-resolution thickness monitoring. preprint, Sea ice/Sea Ice, (2022)

Invited conference talks

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**, 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)

2. **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)

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)

Invited seminars

6. **Institut de Physique du Globe de Paris**, France (2021)
Multiscale observations for the physical characterization of fault systems and volcanoes with artificial intelligence. Link : www.ipgp.fr/fr/seminaires

5. **Physics Laboratory** (φ-lab), École Normale Supérieure de Lyon, France (2021)
Analysis of complex physical systems with information theory and statistical learning. Link : www.ens-lyon.fr/PHYSIQUE/seminars/machine-learning-and-signal-processing

4. **Department of Earth Sciences**, École Normale Supérieure de Lyon, France (2020)
What can we learn from seismic data?

3. **Rice University**, Department of Computational and Applied Mathematics, Houston, TX (2018)
Learnable scattering transform for seismic signal analysis.

2. **Laboratory of Planetology and Geodynamics**, Nantes University, France (2018)
Array-based analysis of random seismic wavefields. Link: lpg-umr6112.fr

1. **Biomedical Imaging Laboratory**, University of Paris, France (2016)
Seismic detection with a covariance matrix analysis of data recorded on seismic arrays.

Teaching experience

* indicates a course conducted in French

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

Since 2022 **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
With: Michel Campillo

Graduate students

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

Since 2019 **René Steinmann**, Institute of Earth Sciences (ISTerre), Grenoble, France
Unsupervised analysis of seismicity in the North-Anatolian fault zone
With: Michel Campillo

Undergraduate students

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

Spring 2018 **Cyril Journeau**, Institute de Physique du Globe de Paris, France

Analysis of seismovolcanic tremors with principal component analysis
With: Nikolai Shapiro

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

Service

Professional associations

2019–present   **European Geosciences Union**

2013–present   **American Geophysical Union**

Session Convener

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

Departmental service

Summer 2018   **Master's thesis committee member for Estelle Romani**
Institute of Earth Sciences (ISTerre), Grenoble, France
Seismic precursors in central Italy from correlation functions coherency
Advisor: Christophe Voisin

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