PROJECT TITLE: **Advancing earthquake forecasting with better physical models and machine learning**

DTP Research Theme(s): Dynamic Earth
Lead Institution: University of Bristol
Lead Supervisor: Dr Max Werner, University of Bristol, School of Earth Sciences
Co-Supervisor: Dr Margarita Segou, British Geological Survey
Co-Supervisor: Dr Jonty Rougier, University of Bristol, School of Mathematics
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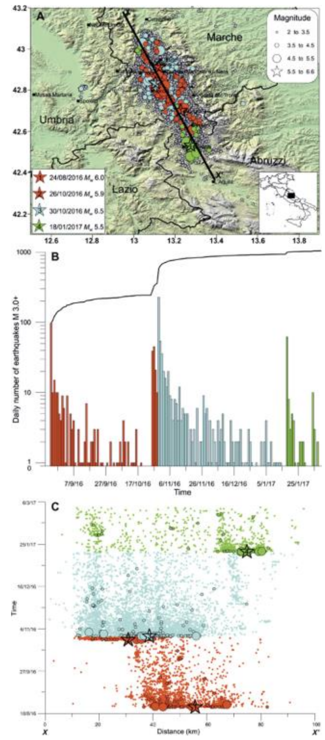
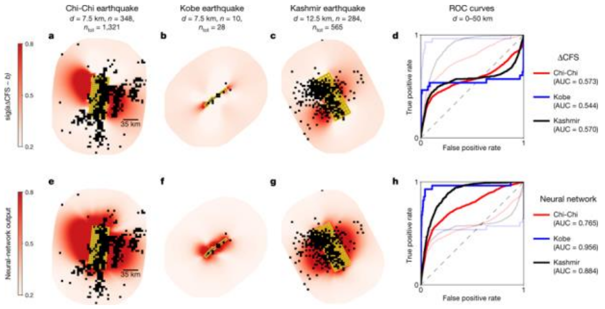
Project keywords: earthquakes, seismology, natural hazards, geophysics, machine learning





Left: New observational capabilities provide unprecedented views into evolving earthquake sequences with multiple mainshocks and thousands of aftershocks. Shown here is the 2016 Amatrice (Italy) earthquake sequence. From Marzocchi et al. (2017).

Top: Aftershock forecasts of a neural network outperform those of a standard physics-based forecast. a–d, Spatial patterns of Coulomb stress change for three earthquakes, along with ROC curves that indicate forecast performance (d). e–h, Analogous to a–d but for the neural network. From DeVries et al. (2018).

Project Background

Probabilistic earthquake forecasts are important for society because they provide best estimates of future ground shaking that buildings need to withstand, and they can provide timely information about ongoing earthquake sequences in real time. Earthquake sequences comprise the foreshocks and aftershocks that accompany the occasionally multiple mainshocks. Much progress has recently been made in developing better models of such sequences, both in terms of the underlying physics and in our operational real-time capability. New data capabilities are providing fascinating new windows into the complex interplay between faults, the stress field and the evolving aftershock sequence. This project seeks to advance earthquake forecasting by exploiting the latest insights into the physics of earthquakes and the power of machine learning.

Project Aims and Methods

Machine learning (ML) is transforming science. In seismology, ML algorithms have begun to improve the state-of-the-art in earthquake detection and location, and, most recently, in aftershock forecasting. DeVries et al. (2018) trained a deep neural network on hundreds of observed aftershock patterns and found that the ML algorithm performed better than a standard – but outdated – physical model. This project will experiment with ML algorithms to forecast the spatio-temporal evolution of sequences.

In addition, recent improvements in data quality have dramatically improved our window into the physics of earthquake sequences. The tiny earthquakes now routinely detected are providing a rich picture of the interplay between the fault network, the evolving stress field, and the aseismic and seismic responses of the crust. This project will integrate seismic and aseismic mechanics in realistically complex fault networks to provide the next generation of physical models of earthquake sequences.

Candidate Requirements

We seek an enthusiastic student with broad interests in earthquakes and seismology, with a first degree in geophysics, physics, maths, computer science, engineering, geology or other quantitative subject. The ideal candidate will have some experience and a strong interest in numerical modelling. The candidate will communicate effectively in verbal and written form, and present their work at international conferences. We seek a person that is highly motivated to work independently as well as in a team.

Training

The student will be trained in machine learning, data analysis, probabilistic forecasting and the physics and statistics of earthquakes and their aftershocks. Main supervisor Dr Max Werner will support the student in numerical modelling of earthquakes. Dr Margarita Segou will help the student model the stress field during earthquake sequences. Dr Jonty Rougier will train the student in statistical machine learning.

References / Background reading list

Bergen et al. (2019). Review: Machine learning for data-driven discovery in solid Earth geoscience. *Science*, 363.
Beroza (2018). Machine learning improves forecasts of aftershock locations. *Nature*, 560.
Cattania et al. (2018). The forecasting skill of physics-based seismicity models during the 2010–2012 Canterbury, New Zealand, earthquake sequence. *Seismological Research Letters*, 89 (4): 1238–1250.
DeVries et al. (2018). Deep learning of aftershock patterns following large earthquakes. *Nature*, 560.
LeCun, Y., Bengio, Y., & Hinton, G. (2015). Deep learning. *Nature*, 521.
Stein, R. (2003). Earthquake Conversations. *Scientific American*, 288 (1).

Useful links

Links:
School: http://www.bristol.ac.uk/earthsciences/courses/postgraduate/

NERC GW4+ DTP Website:
For more information about the NERC GW4+ DTP, please visit http://nercgw4plus.ac.uk/

Bristol NERC GW4+ DTP Prospectus:
http://www.bristol.ac.uk/study/postgraduate/2020/doctoral/phd-great-western-four-dtp/

How to apply to the University of Bristol:
http://www.bristol.ac.uk/study/postgraduate/apply/

The application deadline is 1600 hours GMT Monday 6 January 2020 and interviews will take place between 10 and 21 February 2020

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