ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich

SED Schweizerischer Erdbebendienst Swiss Seismological Service

Entrepreneurial Risks

PhD opportunities at ETH Zürich

Swiss Seismological Service & Chair of Entrepreneurial Risks

The Statistical Seismology Group of the Swiss Seismological Service and the Chair of Entrepreneurial Risks invite candidates to apply for **two available PhD positions** to work on earthquake forecasting based on high-resolution fault network imagery, multi-scale strain-field analysis and stress-based probabilistic seismicity modeling. The two PhDs define the core of an ambitious interdisciplinary project between the Swiss Seismological Service (Prof. Domenico Giardini, Dr. J. Wössner) and the Chair of Entrepreneurial Risks (Prof. Didier Sornette, Dr. G. Ouillon).

The goal of this project is (i) to develop a new set of physics-based methods for forecasting earthquakes, based on past seismicity, and (ii) to understand the role of small events in the nucleation process of the largest ones. The proposed seismicity-based forecasts are founded on the fundamental recognition that seismicity and faulting are intimately interwoven: earthquakes occur on faults and faults grow through accumulation of earthquakes. An intrinsic limitation of present efforts to forecast earthquakes lies in the fact that only a limited part of the full fault network has been revealed, notwithstanding the best efforts combining geological and geophysical methods together with past seismicity. Neglecting the information from fault networks constitutes a major gap in the understanding of the spatio-temporal organization of earthquakes, thus limiting drastically the quality and efficiency of existing forecasting methods. We propose to address this gap by enhancing and developing novel methods using the fundamental earthquake-fault relationship to obtain physics-based forecasts or earthquake rates, strain and stress fields, using sophisticated statistical pattern recognition methods that better constrain the geometry of seismogenic zones. Taking account of all past events regardless of their size will also bring new insights about the role of small events in the triggering process of the major ones, a still unresolved and fundamental issue in the physics of the collective behavior of earthquakes.

Profile of applicants: We are especially interested in candidates with a M.Sc. or Diploma in geophysics, physics, statistics and numerical modeling. Strong analytical, programming and visualization skills, fluency in English and readiness to work in a multidisciplinary team are essential. Applicants should submit a letter of application including a short statement of research interests, names and addresses of two references and a curriculum vitae. Please address all correspondence to Dr. Guy Ouillon (Ouillon@aol.com) and Dr. J. Wössner (j.woessner@sed.ethz.ch). The PhD students will be located at the Swiss Seismological Service, to ensure optimal teamwork and collaboration with the different involved parties. The position is available from SEPTEMBER 2011 or soon after and is funded for three years, which is the anticipated time to obtain a Doctoral Degree at ETH Zurich.

Salary compensation and ETH Zurich: Each PhD student will benefit from a very attractive salary by international standard and its associated social security coverage. ETH Zurich is one of the leading international universities for technology and the natural sciences, striving to provide excellent education, groundbreaking basic research and applied results that are beneficial for society as a whole. ETH Zurich has more than 16,000 students from approximately 80 countries, 3,500 of whom are doctoral candidates. ETH Zurich regularly appears at the top of international rankings as one of the best universities in the world, and according to various professional surveys, Zurich was named the city with the best quality of life in the world as well as the wealthiest city in Europe.

The research will be developed in two major directions, defining two PhD subjects:

Subject 1: fault pattern reconstruction, stress transfer calculations and related earthquake forecasts. The goal of the student will be to invert the best possible fault network that explains a given earthquake catalog. This will be done using and improving methods developed in our group. Those methods allow to fit a catalog of events using planes (see ref. [1], [2]) or probability kernels [3] and taking account of location uncertainties. Emphasis will be put on the ability to deal with large datasets. This fault network will allow performing Coulomb stress transfer calculations with uncertainties, as well as to generate and evaluate Coulomb stress-based forecast models. Using the wealth of high quality data, we propose to combine Coulomb stress transfer modelling with rate and state friction process to forecast seismicity on an entire regional scale including information either from the reconstructed fault network or from the entire seismicity of the catalog. We intend to develop a probabilistic approach that includes all major sources of uncertainty. These type of models will be applied for short- and intermediate term predictions of seismicity on multiple resolution scales.

Subject 2: strain field computation and strain-based earthquake forecasts. The student will first use data inverted by the fault reconstruction algorithms provided by [1], [2] and [3]. He will then progressively add new data provided by the algorithms developed by Student 1. His main goal will be to perform slip pattern reconstruction on fault segments including uncertainties and to provide full time-space, strain-based forecasts and evaluations at different scales using linear and nonlinear techniques. Generalizing the standard point process approach into a coarse-grained model at the fault segment scale and at coarser ones, we intend to catch the relevant space-time correlations and memory effects at every scale using different space and time resolutions. This approach will also allow us to constrain the relationship that may exist between the size of upcoming events and the relevant scales that should be considered to forecast or predict them.

During the application phase, the students will apply their techniques on the premium target region of California. In addition, our methodologies may be applied to other regions of interest for which high quality data and existing forecast models to compare with can be used.

Supervising staff and facilities:

Prof. D. Sornette is associated with the Department of Earth Sciences and already collaborated with Dr. Stephan Husen and Dr. Jochen Wössner on improving earthquake location techniques and on preliminary approaches to fault network reconstruction in an SNF funded project. He will be the "Doktorvater" and supervisor of one PhD student.

Prof. D. Giardini is Professor of Seismology and Geodynamics at the ETH Zurich and Director of the Swiss Seismological Service. He coordinates the FP7-EU projects Seismic Hazard Harmonization in Europe (SHARE, www.share-eu.org) and Network of European Research Infrastructures for Earthquake Risk Assessment and Mitigation (NERA, www.nera-eu.org). SHARE targets to provide a harmonized long-term probabilistic seismic hazard assessment for the Euro-Mediterranean region. In NERA, a joint research activity (JRA4) focuses on providing new methods for time-dependent hazard and seismic risk assessement. He will be the "Doktorvater" of one PhD student.

Dr. G. Ouillon is an independent senior researcher mainly collaborating with the Chair of Entrepreneurial Risk (DMTEC) and the SED at ETH Zürich. He co-advises PhD student Yaming Wang at the SED and is the main scientific contact of post-doc researcher Ching-Yi Tsai at the chair of *Prof. D. Sornette*. He is mainly working on the statistical physics of earthquakes and fault networks and is an expert in data mining procedures applied to catalogs of tectonic objects.

Dr. J. Wössner is Oberassistant with ETH Zurich and associated with the Swiss Seismological Service working in the Statistical Seismology group with special focus on data quality assessment, seismicity analysis and their relation to earthquake physics, time-independent and dependent seismic hazard assessment and earthquake prediction research. He is project manager of the FP7-EU project SHARE and involved in the Collaboratory for the Study of Earthquake Predictability (CSEP) at the European node of the testing centers. He will closely supervise one of the PhD students working on the stress transfer model.

ETH Zurich will provide access to office space, computer facilities, and libraries. Our computer resources are divided among four categories:

1) 20 desktop PCs, each with 2 or 4 cores, running a combination of GNU/Linux, Mac OS and Windows.
2) Private rack-mounted cluster. We have purchased a rack and filled half of it with 5 computer nodes running GNU/Linux. Each node has 4 quad-core processors, giving a total of 80 cores dedicated solely to our group. The nodes are connected with a high speed switch.
3) Two high-speed dedicated database servers with 8 TB of commercial-grade RAID direct attached backup storage.
4) ETH Zurich Brutus cluster. As of February 2010 at which the last upgrade occurred, Brutus now contains 10'000 CPU cores (9864 in compute nodes and 136 in servers). Most nodes are connected to a high-speed network (InfiniBand QDR, 40 Gb/s). Special nodes with up to 128 GB of shared memory are available. As a shareholder, our group is entitled to higher priority in the job submission queuing system and up to 1,000 cores per job with run-times of up to 36 hours (7 days for smaller jobs).
5) The SED is well equipped with PCs, has access to the ETH Brutus cluster and is well connected to the ETH Supercomputing Center at Manno. The SED owns by now 4 32 core SunFire machines that are suitable for parallel computing tasks.

In addition, it goes without saying that we have access to the seismic catalogs relevant to the research discussed in this project.

References

[1] Ouillon, G., C. Ducorbier, and D. Sornette (2008), Automatic reconstruction of fault networks from seismicity catalogs: Three-dimensional optimal anisotropic dynamic clustering, Journal of Geophysical Research-Solid Earth, 113(B1) B01306, doi:10.1029/2007JB005032
[2] Wang, Y.M., G. Ouillon, J. Woessner, S. Husen, and D. Sornette (2010), Reconstruction of fault networks from seismicity catalogs with location uncertainty information, ESC 2010 abstract, Montpellier.
[3] Ouillon, G., and D. Sornette (2011), Segmentation of Fault Networks Determined from Spatial Clustering of Earthquakes, J. Geophys. Res., 116, B02306, doi:10.1029/2010JB007752 (available at http://arxiv.org/abs/1006.0885).