Report of the Deform2015 School

Active Deformation, Faults and Earthquakes: from Measurements to Models

Yann Klinger (CNRS, IPGP, Paris, France)
Jean-Mathieu Nocquet (IRD, Geoazur, Nice, France)

Lecture material available at:

http://www.ipgp.fr/~klinger/deform2015/Deform2015lectures.html

Context & objectives of the deform2015 school

The many occurrences of larges earthquakes with major human and economic looses that affected various countries in the recent years remind us how the human society remains vulnerable. Hence, with the ever growing worldwide population it is now critical to make significant progress in our understanding of the earthquakes processes, including time and space distribution, to be more efficient in addressing seismic hazard and mitigation of future catastrophes that are looming over cities with several millions of inhabitants, in seismic prone areas worldwide.

In the recent years, progress, both qualitative and quantitative, have been made for observation of fault behavior at different time scale. On one hand, spatial geodesy (Insar, GPS, optical imagery) allows us to accurately quantify the deformation of the upper crust during the different phases of the earthquake cycle, meaning during the pre-, co- and post-seismic periods. One can point in particular the detection of transient motions on faults, which participate to the deformation process, although without generating massive seismic energy, and relate to complex frictional properties of the fault plane. On the other hand, combined progress in earthquake geology investigation (paleoseismology, fault geometry…) and in dating techniques brought first solid quantitative constrain on return time of earthquakes with several long times series of earthquakes (more than 10 earthquakes) published. Eventually, seismic source imaging has largely benefited from technical and methodological improvements of the global seismic networks and earthquake rupture are now image in details. Back propagation processing showing details of a complex seismic source or evidence for repeating foreshocks before a large event are only few among major discoveries in the recent years.

Therefore, although it seems that we are still away from any real-time earthquake forecast, the accumulation of observational data of various type leads to a better understanding of some of the physical processes that control the earthquake physics, in various tectonic settings. As for an example, the recent emergence of the coupling models for large subduction zone directly originate in an mixture of geodetic data along subduction and of the rate-and-state laws that come from experimental physics. These models, although not perfect, have been proven to explain a large part of the observations that can be done along subductions.

Hence, our main conclusion at that stage is that after twenty years of improving our capabilities to observe and collect new data about various phases of the earthquake cycle, there is a real need to move towards a better integration of these various data into conceptual earthquake physics models.

We have identified several hurdles that are currently slowing down progress in that direction:

1/ The variety of time scales that need to be considered

Source seismology allows for an accurate image of the rupture process that lasts from few seconds to few minutes for the largest earthquakes. Space geodesy brought crucial information about crustal deformation during the earthquake cycle but observational period cannot be longer than the technology itself, about twenty years maximum. This remains very short compared to the time of earthquake cycle that is to be counted in centuries to thousands of years. At the opposite, observations from geology (namely neotectonics and paleoseismology) are usually providing information averaged over several earthquake cycles, missing the details of individual earthquakes. Today there is no conceptual physical model that would integrate such a diversity of data and time scales in a consistent way. Indeed this lack of conceptual framework is partly related to the fact that it might be technically difficult to integrate such a wide range of time scales in one numerical model, but we believe that actually the main issue

now remains our fundamental difficulty to ponder the role of the different physical processes that have been identified by various scientific communities, into the big picture.

2/ Tendency to hyper specialization and small overlap between different scientific communities
Development of new observation most often involves hyper specialization of researchers and their PhD students. Hence, it appears quite difficult to devote time to know even the basic principles and sources of uncertainties of technics different to the one that each researcher would actually use in his/her daily work, although it might pertain to the same general topic such as the earthquake cycle. For example geodetic studies almost never consider paleoseismology results to bring some longer-term perspective on the earthquake cycle in the region of study. Similarly, most often geodesy and seismology would go parallel in studying specific earthquakes and it is only very recent that some attempts have been done to really integrate the two kinds of data in a consistent conceptual framework.

3/ Knowledge of physical processes
Finally, one additional difficulty is the capacity for the observers, what ever are their tools, to tight their data to some physically realistic model. Actually the few groups that have been able to make a significant step forward in term of understanding the earthquake cycle are the groups that have the capacity to connect the newly available observations to solid mechanic approaches. This capacity, to our analysis, remains only limited to very few groups in the world, although it is obviously needed to be able to achieve any progress.

To tackle these three issues, we organized a school that brought together young researchers and PhD students to provide them with the state-of-the-art knowledge. The lecture content of the Deform2015 school should now enable them to build a comprehensive and integrated vision of all the technics involved in understanding earthquake processes and crustal deformation. The different scales of space and time have been addressed with an emphasis on connections between scales. The meeting has been structured in a way that it encourages, beyond the key lectures in each of the major topics (seismology, geodesy and tectonics), strong interactions between the participants that will come from different disciplines. In addition, few keynote lectures were given in rupture mechanics and numerical modeling to provide a vision of a potential conceptual framework and of available integrative tools, respectively.

School schedule & attendance

The school took place 7-13 of February 2015, at Barcelonnette in the French Southern Alps. It was hosted by the Séolane facilities (http://eost.u-strasbg.fr/seolane).

65 students coming from more than 15 countries attended the school. The list of students is provided in Annex 1.

J. Freymueller (Univ. Fairbanks, USA), J.-M. Nocquet (Geoazur, France), C. Lasserre (ISTerre, France), M. Pierrot-Deseilligny (IGN, France) gave a first 2 days lecture on geodesy (GPS, InSAR & optical correlation) and its applications to earthquakes and crustal deformation studies.

The geodesy lecture was followed the next day by a presentation in seismology from both its observational side and the modeling of the seismic rupture by M. Vallée & H. Bhat (IPGP, France). F. Renard (ISTerre, France) gave a night seminar on laboratory experiment on friction.

The 4th day has been dedicated to the active tectonics, paleoseismology and an introduction to dating by J. Van der Woerd (EOST, France), Y. Klinger (IPGP, France). S. Dominguez (Geosciences

Montpellier, France), gave a night seminar on analogic experiments (sandboxes, foam…) on earthquake deformation and active tectonic process.

The 5th day, we had a field trip where some morphological features introduced the previous were seen in the field. J. C. Hyppolyte (CNRS, Cerege, Aix, France) led the trip where evidences from quaternary evidence of active deformation were shown in the Digne area. We had a "Beer & Poster Session" in the evening where students could present and discuss their current work, in a friendly atmosphere.

The last two days were dedicated to modeling of the earthquake cycle and application to seismic hazards assessment. S. Barbot (EOS, Singapore) presented the friction laws and its application to the understanding of the faults behaviours. L. Fleitout (ENS, France) introduced the rheological response of the earth to large earthquakes and showed the results obtained for the recent giant earthquakes in Sumatra, Chile & Japan.

The final day, B. Shaw (Lamont Obs., Columbia Univ., USA) gave a summary lecture on faults evolution and the related physics. Finally, S. Baize (IRSN, France) presented the steps and open question related the quantitative seismic hazards assessment.

In general, the days were organized as follows: two slots of 2 hours lectures in the morning with a 20mn coffee break. After lunch, the early afternoon was kept free for informal discussions. Specific topics were proposed by the students and several small group discussions took place. A 2.5 hours lecture occurred in the late afternoon. After diner, we either had an invited night speaker or short (5mn) talks by students.

Student evaluation of the school

Evaluation forms were given to the students at the end of the school, based on a questioner provided by CNRS. The majority of the attendants have returned an evaluation form on the last day of Deform2015. Here are the main positive and negative points that came out most often of the forms. In overall, the feedbacks are very positive, with a strong demand for a renewal of the school.

Positives items:

- On one hand, prerequisite and level of the classes were fine to allow anyone, including non specialist, to follow the classes. On the other hand, level of details was high enough that most of the attendees have learned something even in their own field of expertise.
- The Deform2015 classes all together, with 14 speakers, covered a large part of the topics related to Earthquake processes.
- The attendees have in a vast majority noted the good interaction between students and speakers, including during free time periods (the 3h mid-day break was a success)
- Students appreciated to have the opportunity to discuss their own research topic during short presentations and the poster session.
- To very few exceptions, the one-day field trip to see regional Quaternary deformation was welcomed.
- Need for renewal of such school.
- Logistic (accommodation) was plebiscited.

Negative (or suggested) items:

- The daily schedule was not stated clearly enough and students had the impression of too many last minute changes. Several students suggested a more rigorous schedule.
- The days were very long with 3 sessions per day (9h-13h, 16h-19h, 20h30-22h30). Several students suggested to shorten the days and instead to add few more days.
- Several students have expressed their interest for sessions with exercises and examples of application of the methods taught.
- Large request for written notes and possibly videos of the lectures.
- The question session at the end of the classes were not enough geared toward the students that felt overwhelmed by the discussion between the different speakers and would not dare asking more basic questions.
- Request for a wrap-up session at the end of Deform2015.

Financial report

The overall budget of the school was 52 293 €. The main sponsors by order of contribution were: International Union of Geodesy & Geophysics (IUGG), Centre National de la Recherche Scientifique (CNRS), Institut de Radio-Protection & Sûreté Nucleaire (IRSN), Centre National d'Etudes Spatiales (CNES), with additional support from each organizer institution.

The level of sponsorship enables us to keep a low registration fee (200 €).

The costs include the use of Soleane facilities (accommodation, full board for students and professors, transportation organized from/to Marseille airport and Aix railway station), field trip and travel expenses for the professors. IUGG funds were largely used to provide travel grants for students.

Details about costs & revenues are provided in annex 3.

Deform2015 Follow-up

All lecture materials are freely available by the professors at
http://www.ipgp.fr/~klinger/deform2015/Deform2015lectures.html

Despite the large number of attendees (65), we had about 30 applicants left on the waiting list. Furthermore, many feedback forms suggested to renew a similar school. At present, following our initial plan, a proposal has been submitted for the organization of a similar school in Quito, Ecuador. Depending on the success of this proposal, a Deform2016 school will be organized, offering the opportunity for students from South America to benefit from a similar training.

Finally, it is worth noting that two regional newspapers and a local TV reported about the school.

ANNEX 1: Deform2015 Circular

Thematic School

Active Deformation, Faults and Earthquakes: from Measurements to Models

7-13 February 2015
Barcelonnette, France
www.ipgp.fr/~klinger/deform2015

Objectives

Over the past years, considerable advances have been made in observing crustal deformation at scales from seconds to thousands of years. However, a unified view of the earthquake cycle is still missing.
The thematic school aims at brining together students and scientists working on different aspects of active faulting and earthquakes processes.
The school will provide a state-of-the-art view of the techniques used to study active deformation as well as a perspective on the current models integrating the growing corpus of available data.

Organizers

Y. Klinger (IPGP)
J.-M. Nocquet (Geoazur)

Registration

www.ipgp.fr/~klinger/deform2015
Inquire to: deform2015@gmail.com

Content

GPS, InSAR, optical correlation
Earthquake seismology & mechanics
Geomorphology, dating
Paleoseismology, fault geometry
Rheology & friction
Earthquake cycle modeling
Seismic Hazards

Speakers

J. Freymueller (Univ. Fairbanks)
J.-M. Nocquet (Geoazur)
C. Lasserre (ISTerre)
M. Deseilligny (IGN)
M. Vallée (IPGP)
H. Bhat (IPGP)
Y. Klinger (IPGP)
J. Van der Woerd (EOST)
S. Barbot (EOS Singapore)
L. Fleitout (ENS)
B. Shaw (Lamont, Colombia Univ.)
S. Baize (IRSN)

When, where

The school will take place February7th to 13th, 2015 at Soleane, Barcelonnette, southern Alps, France. Transportation will be organized from Marseille airport and Aix-TGV railway station.

Who

The school is primary intended for PhD students and post-docs, but is also open to Master students and researchers.

Sponsors

IRSN
GeoAzur
cnes
cnrs
International Union of Geodesy and Geophysics

ANNEX 2: List of Deform2015 attendees

NAME	First Name	Status	Ville	Pays	Organisme
AHMAD	Bashir	CHERCHEUR	SRINAGAR	INDIA	SRIP RATAP SCHOOL
BALLU	Valerie	CHERCHEUR	La Rochelle	FRANCE	LIENSs
BESEDINA	Alina	CHERCHEUR	Moscow	Russian Federation	Institute of Geosphere Dynamics RAS
BOUGRINE	Amina	CHERCHEUR	Algiers	Algeria	CRAAG
CHOI	Jin-Hyuck	CHERCHEUR	Paris	Republic of Korea	Institut de Physique du Globe de Paris (IPGP)
DEKKICHE	Hicham	CHERCHEUR	Arzew	Algérie	Centres des Techniques Spatiales
EVANS	Eileen	CHERCHEUR	Menlo Park	USA	U.S. Geological Survey
HEDDAR	Aicha	CHERCHEUR	Dely Ibrahim-Alger	Algerie	CRAAG
KARAOGLU	Haydar	CHERCHEUR	Paris	France	Institut de Physique du Globe de Paris (IPGP)
KÜRÇER	Akin	CHERCHEUR	Ankara	Turkey	General Directorate of Mineral
LARROQUE	Christophe	CHERCHEUR	Valbonne	France	Géoazur
METOIS	Marianne	CHERCHEUR	Roma	Italie	Isituto Nazionale di Geofisica e Vulcanologia
PHILIBOSIAN	Belle	CHERCHEUR	Paris	France	Institut de Physique du Globe de Paris (IPGP)
ROLLAND	Lucie	CHERCHEUR	Valbonne	France	Géoazur
SINGH	Tejpal	CHERCHEUR	Bangalore	India	CSIR-Fourth Paradigm Institute
THOMAS	Marion	CHERCHEUR	Paris	France	Institut de Physique du Globe de Paris (IPGP)
TSODOULOS	Ioannis	CHERCHEUR	IOANNINA	GREECE	UNIVERSITY OF IOANNINA
VARGAS EASTON	Gabriel	CHERCHEUR	Santiago	Chili	Universidad de Chile
VILLEGAS LANZA	Juan Carlos	CHERCHEUR	Lima	Pérou	Instituto Geofisico del Peru
AMEY	Ruth	ETUDIANT	Leeds	England	University of Leeds
ANSBERQUE	Claire	ETUDIANT	Aix en Provence	France	CEREGE
BAI	Kangchen	ETUDIANT	Pasadena	USA	California Institute of Technology
BARBA	Magali	ETUDIANT	Monterey Park	United States	California State Polytechnic University Pomona
BENJELLOUN	Yacine	ETUDIANT	Grenoble	France	ISTerre
CHOUNET	Agnès	ETUDIANT	Paris	France	Institut de Physique du Globe de Paris (IPGP)
DAK-HAZIRBABA	Yildiz	ETUDIANT	Carbondale	United States	SOUTHERN ILLINOIS UNIVERSITY
DAOUT	Simon	ETUDIANT	Grenoble	France	ISTerre
DE LA TAILLE	Camille	ETUDIANT	Aix les Bains	France	ISTerre
DUVERGER	Clara	ETUDIANT	Paris	France	Institut de Physique du Globe de Paris (IPGP)
FIGUEIREDO	Paula	ETUDIANT	Alhos vedros	Portugal	Institute Dom Luiz -Lisbon University
GOMBERT	Baptiste	ETUDIANT	Strasbourg	France	Institut de Physique du Globe de Strasbourg
GONZALEZ	Josè	ETUDIANT	Santiago	Chile	University of Chile
HARDY	Sandra	ETUDIANT	El Paso, TX	USA	University of Texas at El Paso
HOSTE COLOMER	Roser	ETUDIANT	SAINT MICHEL SUR ORG	FRANCE	CEA
INGLEBY	Tom	ETUDIANT	Leeds	UK	University of Leeds
JARA	Jorge	ETUDIANT	Grenoble	France	ISTerre
KILIC	Irfan	ETUDIANT	Kyoto	Japan	Kyoto University
KURTZ	Robin	ETUDIANT	Montepllier	France	Université de Montpellier 2
LEFEVRE	Marthe	ETUDIANT	Colombes	France	Institut de Physique du Globe de Paris (IPGP)
LOWE	Katherine	ETUDIANT	Ann Arbor, MI	United States	University of Michigan
MACKENZIE	David	ETUDIANT	Oxford	UK	University of Oxford
MARLIYANI	Gayatri Indah	ETUDIANT	Tempe, AZ	USA	Arizona State University
MENESES	Gianina	ETUDIANT	Paris	France	Ecole Normale Superieure
MKRTCHYAN	Mushegh	ETUDIANT	Montpellier	France	Université Montpellier 2
MURRAY	Kyle	ETUDIANT	Socorro	United States	New Mexico Tech
PASTIER	Anne-Morwenn	ETUDIANT	Rennes	France	Universite de Rennes 1
PIÑA VALDES	Jesus	ETUDIANT	Saint Martin D'heres	France	ISTerre
POUSSE	Lea	ETUDIANT	Chambery	France	Isterre
PROVOST	Floriane	ETUDIANT	Chartres	FRANCE	EOST
RESSURREICAO	Ricardo	ETUDIANT	Lisboa	Portugal	LNEG -Laboratorio Nacional de Energia e Geologia
RIESNER	Magali	ETUDIANT	Sevres	france	Institut de Physique du Globe de Paris (IPGP)
ROMANET	Pierre	ETUDIANT	Arcueil	France	Institut de Physique du Globe de Paris (IPGP)
ROUSSET	Baptiste	ETUDIANT	Grenoble	France	ISTerre
RUDERSDORF	Andreas	ETUDIANT	Berlin	Germany	RWTH Aachen University
SAKIC	Pierre	ETUDIANT	La Rochelle	France	Université de La Rochelle
SALTOGIANNI	Vasso	ETUDIANT	Patras	Greece	University of Patras
SVIGKAS	Nikos	ETUDIANT	Athens	Greece	Aristotle University of Thessaloniki
THOMAS	Franck	ETUDIANT	Aix-en-Provence	France	CEREGE
URRUTIA	Isabel	ETUDIANT	Potsdam	Germany	GFZ Potsdam
VALLAGE	Amaury	ETUDIANT	Paris	France	Institut de Physique du Globe de Paris (IPGP)
VICIC	Blaz	ETUDIANT	Ljubljana	Slovenia	University of Trieste
VILLALOBOS	Angelo	ETUDIANT	Santiago	Chile	University of Chile
WALWER	Damian	ETUDIANT	Paris	France	ENS
YALCN	Hilal	ETUDIANT	SAKARYA	TURKEY	SAKARYA UNIVERSITY
ZHOU	Yu	ETUDIANT	Oxford	United Kingdom	University of Oxford

ANNEX 3: Financial summary

Items	Revenues	Cost
CNRS	**12 500 €**	
IUGG	**16 275 €**	
IRSN	**7 000 €**	
CNES	**1318 €**	
Students registration	**13 200 €**	
Geoazur	**1000 €**	
IPG Paris	**1000 €**	
Soleane bill: accommodation, meals, bus		**33 446 €**
Overhead IPG Paris on IUGG support		**1205 €**
Travel grants (Students)		**9 600 €**
Travel grants (Professors)		**7518 €**
Running costs (Field trip booklet)		**524 €**
TOTAL	**52 293 €**	**52 293 €**

ANNEX 4

Deform2015 thematic school
February, 7-13, 2015, Barcelonnette, France

Syllabus of lectures

Requirements

Several courses plan to include exercise on laptops.
The students are asked to bring a laptop, with Matlab installed, if possible.

Geodesy

GPS
Teachers : J. Freymueller (Univ. Fairbanks, USA), J.-M. Nocquet (Geoazur, Nice, France)

- Introduction to geodesy for tectonics & earthquake cycle
- principle of GPS: orbits, signal, propagation, positioning concepts, observation equations and coordinates estimation
- reference frame
- kinematics positioning: principle, application to seismology
- See floor geodesy
- GPS time series: properties, non tectonic contributions, velocity estimation and related uncertainties
- Analysis of GPS velocity fields: rigid block modeling, estimating strain rates from GPS
- Examples & Case studies

InSAR
Teacher: C. Lasserre (ISTerre, Grenoble, France)

- radar satellite systems: some generalities; Synthetic Aperture Radar; amplitude and phase characteristics of radar images
- SAR interferometry : principle; phase difference components (main equations)
- InSAR applications and associated specificities in processing : coseismic ; post seismic and interseismic (time series analysis of interferograms, improvement of

signal to noise ratio) deformation ; more on interseismic : from averaged velocity maps to space and time variations of the deformation ; main challenges for the next years

Photogrammetry for earth scientist
Teacher: Marc Pierrot Deseilligny (IGN Paris, France)

- fundamentals of photogrammetry
- "modern" fully automatic photogrammetric pipeline for 3D modelization of a rigid scene
- application of photogrammetry
- photogrammetry for computing deformation, basic theory of image correlation
- photogrammetry for monitoring dynamic object (glacier, landslide ...)
- existing software, with emphasis on MicMac

Kinematic Modeling of Geodetic Results
Teachers : J. Freymueller (Univ. Fairbanks, USA), J.-M. Nocquet (Geoazur, Nice, France), C. Lasserre (ISTerre, Grenoble, France)

- the elastic rebound & earthquake cycle
- Basics of inverse problems
- modeling co-seismic slip distribution
- Modeling of the interseismic deformation
- elastic block modeling
- Modeling (kinematically) the time dependent deformation

Earthquake Seismology

Teachers : M. Vallée (IPG Paris, France), H. S. Bhat, (IPG Paris) & F. Renard (UJF, Grenoble)

Illustrating how seismology provides information on the fault activity during earthquakes (M. Vallée)

In a first part, the fundamental relations relating a force/moment acting in the Earth to the displacements observed at the surface will be presented. These initial relations will be used to show how seismologists are able to quantitatively determine the mechanism, magnitude, depth and moment rate functions of earthquakes. We will show how these determinations provide information on some generic earthquake characteristics. Going beyond these global characterizations of the earthquake process, the following part of the course will concentrate on the spatio-temporal characteristics of the earthquake process. Different methods able to give insights on these aspects (such as Deterministic and Empirical Green Function approaches; line source versus bidimensional analyses) will be detailed, before showing examples of application, including a focus on the determination of the rupture velocity. The implications in terms of rupture and fault mechanics will be discussed.

Theoretical and Experimental approaches towards understanding Earthquake Ruptures (H. S. Bhat)

1. Basic Modes of Fracture

2. Some Examples of Analytical Models of Steady State Ruptures
3. Earthquakes through Complex Fault Systems
4. Supershear Earthquakes
5. Laboratory Earthquakes (Bi-Material, Damage effects on Rupture)

Variety of fault slip processes: what do we learn from laboratory experiments? (F. Renard)

1. Introduction
   - The origin of friction: Amontons (1699), to Coulomb (1821), and Bowden&Tabor (1939)
   - The rate&state friction law (Dietrich, 1979)
2. Friction at low velocity
   - Parameters of the r&s friction law
3. Dynamic rupture and related friction & damage
   - Rupture velocity: from super slow to supershear
   - Damage related to propagating rupture
   - Evolution of friction with sliding
4. Postseismic slip and creep
   - Mechanisms of creep deformation
   - Evolution of the gouge
5. Conclusion: what are the open questions and which experiments will solve them ?
   - Range of velocities of dynamic ruptures
   - Seismic vs. aseismic sliding
   - Predictability of a rupture

Geomorphology, Dating Technics, Fault Geometry, Paleoseismology

Teachers : Y. Klinger (IGP Paris), J. Van der Woerd (EOST, France)

Part I : long-term geomorphology

1) Geomorphic offsets
   - surface fault traces : in the field, in satellite or air-borne images
   - geomorphic features : what kind ?
   - tectonic/geomorphology relations (i.e., top/base of riser, fill/cut/strath terraces)

2) Dating geomorphic offset
   - methods (14C, OSL, 10Be, U-Th, …)
   - 10Be cosmogenic method : particularity/problems

3) Examples : description and problems

4) Practical exercise : from the image interpretation to the tectonic quantification

Part II : short-term seismic deformation

1) Measurements of coseismic offsets
   - recent events, older events;
   - HR imagery; HR topography

2) Slip function
- significance of along-strike variations

3) Paleoseismology
- trenching (strike-slip faults, thrusts ?)
- subduction paleoseismology
- recurrence time of earthquakes (slip models)

Seismic cycle experimental modeling
Teacher : Stéphane Dominguez (Géosciences Montpellier, France)

- Kinematic and mechanic evolution of earthquake cycles at the scale of tens of seismic cycles.

Rheology and friction, Earthquake cycle modeling

Viscoelastic models of the earthquake cycle
Teacher : Luce Fleitout (ENS Paris, France)

- Viscoelastic rheologies: Equations for elastic, viscous and viscoelastic (Maxwell and Burger) rheologies. What we know and what we don't know about mantle viscosities for various time-scales. Mechanisms involved at a microscopic scale.

- Deformations during the seismic cycle associated with subduction megaearthquakes: Constraints brought by the analysis of the postseismic data after Aceh, Maule and Tohoku earthquakes Spectral methods versus finite element methods Elastic versus viscoelastic backslip and the seismic cycle

Earthquake cycle in the context of geodesy modeling.
Teacher : Sylvain Barbot (EOS, Singapore)

- rate and state equations,
- critical nucleation size,
- simulations of slow-slip events and seismic ruptures.
- Examples of afterslip modeling with matlab.

Earthquakes, scaling laws and fault systems
Teacher : B. Shaw (Lamont Observatory, USA)

- Surface slip observations and earthquake scaling
- Fault system and earthquakes

Seismic Hazards Analysis

Teacher : S. Baize (IRSN, Fontenay-aux-Roses, France)

This section of the DEFORM2015 School will give an overview of the main geoscience data, hypotheses, tools and outcomes that are involved in the Seismic Hazard Analyses. In this course, I will focus on SHA that aims at providing the probability of occurrence of a given ground motion amplitude at a site or in a region. I will develop the level of detail necessary to integrate geological data in SHA and show the key role of propagating data uncertainties in the analysis. Seismological and geodetic datasets will also be discussed. These topics will be illustrated through case examples. The required level of knowledge is a basic background in earthquake geology, seismology and geodesy.

One-day Field Trip

Geomorphology and tectonic structures
Lead by JC Hippolyte (CEREGE, France) & S. Baize (IRSN, France)