



# European Training Programmes in Computational Seismology

Heiner Igel, LMU Munich and the SPICE Team

- European Funding Schemes
- The **SPICE** Research and Training Network (2004-2008)
  - Format and Implementation
  - Successes and failures
- The **QUEST** initial training network (2009-2013)\*

\* Contract pending





# Science Funding in the EU

## 7th framework programme


Cooperation  
32.400 MEuro

People  
4.800 MEuro

Ideas  
7.500 MEuro


Capacities  
4.200 MEuro





# The Human Mobility Programme: Marie Curie Research Training Networks

People  
4.800 MEuro

- Open to any topic (also methodology!)
  - At least 3 countries involved (multi-partner)
  - Funding for PhD and postdocs (no infrastructure or support staff) + admin (7%)
  - Researchers from *outside* host country
  - 4-year programme
  - ~90 proposals in „Environment“
  - Funding likelihood 5-10%
- 




# Seismic Wave Propagation and Imaging in Complex Media: a European Network

## Scale

- 14 institutions (INGV Rome, IPG, ENS Paris, Oxford, Utrecht, Munich, Bratislava, Prague, Oslo, Dublin, Naples, Hamburg, OGS Trieste, ETH Zurich)
- 14 postdocs and 14 PhDs
- 5.5 MEuro Budget

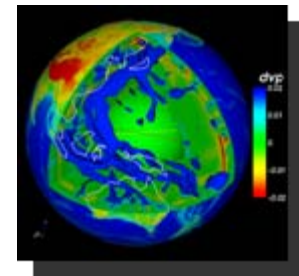
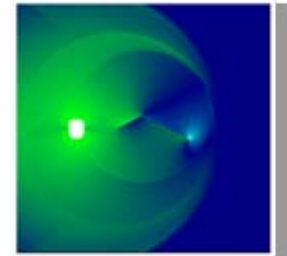
## Rationale

- Connect groups developing and using 3-D wave propagation and rupture *on all scales*
  - Train researchers in numerical methods and high-performance computing
  - Push Earth science in the fields of wave propagation, earthquake rupture, and associated fields
  - **Create a library with software, training material and benchmarking**
- 

# SPICE Implementation

## 5 Task Groups (TG meetings with invited guests)

- **Small Scale** (reservoirs, volcanoes)
- **Local Scale** (rupture, seismic hazard)
- **Planetary Scale** (global wave propagation, tomography)
- **Numerical Methods** (tetrahedral grids, time-frequency analysis, hybrid methods)
- **Digital Library**



11. **SPICE\_01**  
The SPICE01 Computer Code for Finite Difference Numerical Solution and Simulation of a 3D Elastic Hemisphere in a 3D Inhomogeneous Incompressible Medium using the Finite Element Method (FEM) and the Finite Difference Method (FDM).

12. **SPICE\_02**  
The SPICE02 Computer Code for Finite Difference Numerical Solution and Simulation of a 3D Elastic Hemisphere in a 3D Inhomogeneous Incompressible Medium using the Finite Element Method (FEM) and the Finite Difference Method (FDM).

13. **SPICE\_03**  
The SPICE03 Computer Code for Finite Difference Numerical Solution and Simulation of a 3D Elastic Hemisphere in a 3D Inhomogeneous Incompressible Medium using the Finite Element Method (FEM) and the Finite Difference Method (FDM).

14. **SPICE\_04**  
The SPICE04 Computer Code for Finite Difference Numerical Solution and Simulation of a 3D Elastic Hemisphere in a 3D Inhomogeneous Incompressible Medium using the Finite Element Method (FEM) and the Finite Difference Method (FDM).

15. **SPICE\_05**  
The SPICE05 Computer Code for Finite Difference Numerical Solution and Simulation of a 3D Elastic Hemisphere in a 3D Inhomogeneous Incompressible Medium using the Finite Element Method (FEM) and the Finite Difference Method (FDM).

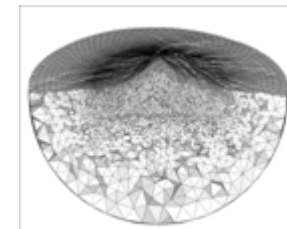
16. **SPICE\_06**  
The SPICE06 Computer Code for Finite Difference Numerical Solution and Simulation of a 3D Elastic Hemisphere in a 3D Inhomogeneous Incompressible Medium using the Finite Element Method (FEM) and the Finite Difference Method (FDM).

17. **SPICE\_07**  
The SPICE07 Computer Code for Finite Difference Numerical Solution and Simulation of a 3D Elastic Hemisphere in a 3D Inhomogeneous Incompressible Medium using the Finite Element Method (FEM) and the Finite Difference Method (FDM).

18. **SPICE\_08**  
The SPICE08 Computer Code for Finite Difference Numerical Solution and Simulation of a 3D Elastic Hemisphere in a 3D Inhomogeneous Incompressible Medium using the Finite Element Method (FEM) and the Finite Difference Method (FDM).

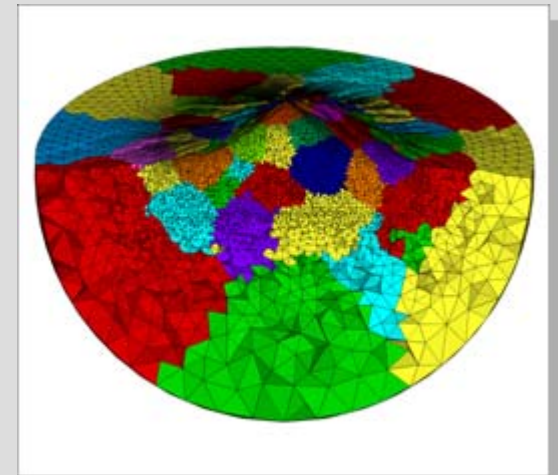
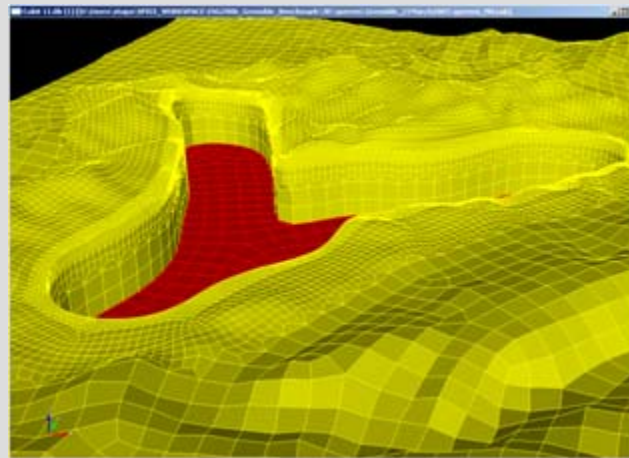
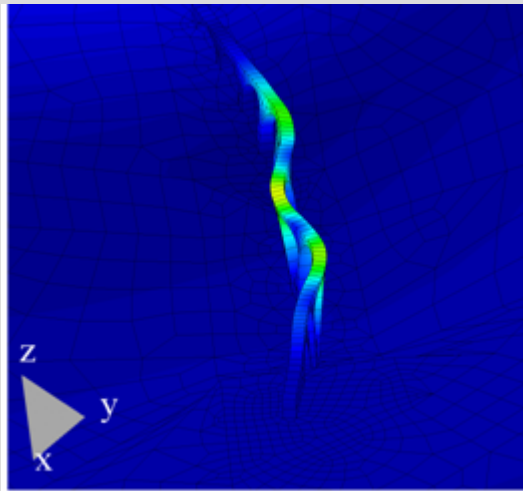
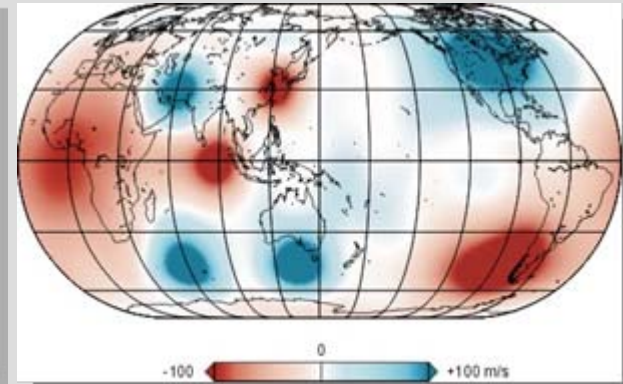
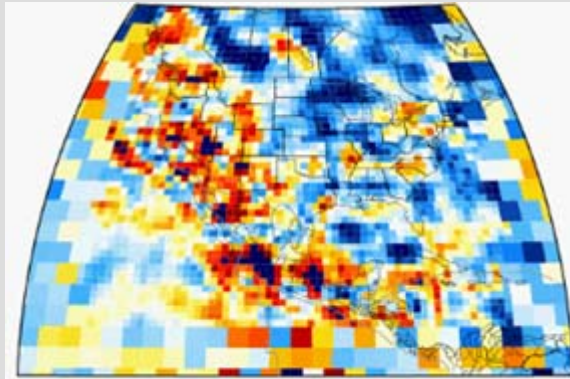
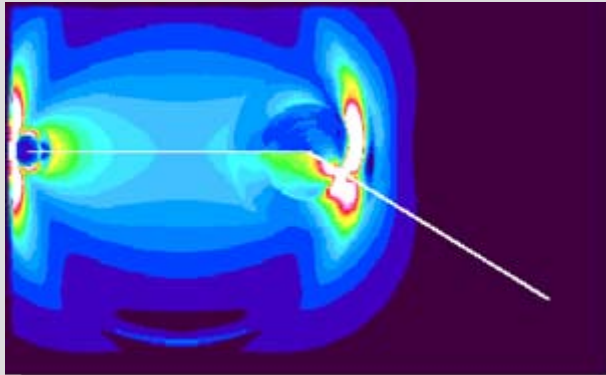
19. **SPICE\_09**  
The SPICE09 Computer Code for Finite Difference Numerical Solution and Simulation of a 3D Elastic Hemisphere in a 3D Inhomogeneous Incompressible Medium using the Finite Element Method (FEM) and the Finite Difference Method (FDM).

20. **SPICE\_10**  
The SPICE10 Computer Code for Finite Difference Numerical Solution and Simulation of a 3D Elastic Hemisphere in a 3D Inhomogeneous Incompressible Medium using the Finite Element Method (FEM) and the Finite Difference Method (FDM).





# SPICE Science





# SPICE Digital Library



Software — SPICE Homepage - Mozilla Firefox

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http://www.spice-rtn.org/library/software

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## Software

Advanced search for software products

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www.spice-rtn.org



# SPIICE (heroic) codes

## 1DFD\_DS

The Fortran95 Computer Code for Finite-Difference Numerical Generation and Simulation of a 1D Seismic Wavefield in a 1D Heterogeneous Viscoelastic Medium Using the Displacement-Stress Staggered-Grid Finite-Difference Scheme

## 1DFD\_DVS

The Fortran95 Computer Code for Finite-Difference Numerical Generation and Simulation of a 1D Seismic Wavefield in a 1D Heterogeneous Viscoelastic Medium Using the Displacement-Velocity Staggered-Grid Finite-Difference Scheme

## 1DFD\_VS

The Fortran95 Computer Code for Finite-Difference Numerical Generation and Simulation of a 1D Seismic Wavefield in a 1D Heterogeneous Viscoelastic Medium Using the Velocity-Stress Staggered-Grid Finite-Difference Scheme

## 3DFD\_DVS

The program is designed for calculating the seismic wavefield in a 3D heterogeneous surface geologic structure. It uses a staggered-grid finite-difference scheme for the surface and near-surface portions of the model.

## Direct Solution Method

DSM software for calculating the seismic wavefield in a spherically symmetric earth model.

## FD3S

Finite-difference solver of the wave equation in a spherically symmetric earth model. It allows to model seismic wave propagation in a spherically symmetric earth model. The finite difference scheme is second order in time. Arbitrary order of accuracy is possible.

## FD3S(AD)

FD3S(AD) is an extension of FD3S. It allows to model seismic wave propagation in a spherically symmetric earth model. The finite difference scheme is second order in time. Arbitrary order of accuracy is possible. It uses the adjoint method.

## Analytical\_Poroelastic

An analytical solution to poroelastic wave propagation in a homogeneous medium

## Couplage

Modelling of propagation of surface waves in 3D structures by mode coupling

Wave propagation  
Dynamic rupture  
Ray theory  
Processing  
Visualization and grid generation  
Reflectivity  
Normal Modes  
Phase velocities  
Analytical solutions  
(partly external links)

Directional Source (Lamb's  
TIC/ELASTIC Interface,  
Compressional Source (Garvin's  
spherically symmetric media  
spherically symmetric Earth  
by a point dislocation at the  
etic seismograms in global  
of uniform solid layers to  
the Reflectivity Method (RM).  
tropic) homogeneous material

due to a point force source.





# Interactive Benchmarking



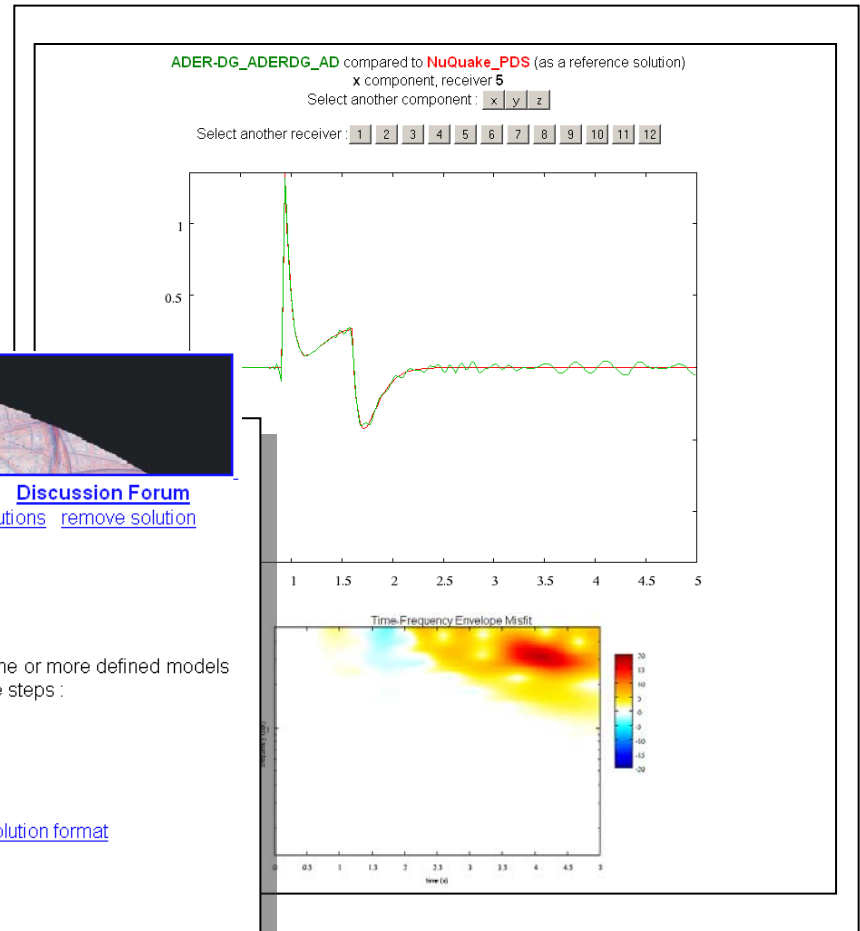
[Home](#)   [About the SPICE Code Validation](#)   [Discussion Forum](#)  
[registration](#)   [model](#)   [solution format](#)   [upload your solution](#)   [view/compare solutions](#)   [remove solution](#)

## The SPICE Code Validation home

To participate in the SPICE Code Validation (that is, calculate your solution for one or more defined models and compare it with solutions submitted by other participants), please follow these steps :

0. go to [registration](#) (do it only once for each method)
1. choose and download a [model](#) description
2. perform a computation with your code
3. convert your solution into a format appropriate for upload - see [solution format](#)
4. [upload your solution](#) (your solution will be stored on the server)
5. [view/compare solutions](#)

comments and suggestions to [spice\\_cv@nuquake.eu](mailto:spice_cv@nuquake.eu)



Moczo et al., 2006



electure - Mozilla Firefox

http://www.spice-rtn.org/videos/woodhouse/normaltheory/


Guitar Tabs, Guitar Ch... Sparkasse Landsberg ... DB BAHN - Verbindung...

### 2nd SPICE R+T Workshop

Smolenice Castle, September 4 - 10, 2005

#### "Introduction to Normal mode theory and observation"

**Speaker: Prof. John Woodhouse**  
University of Oxford  
Department of Earth Sciences  
UK  
<http://www.earth.ox.ac.uk/research/seismology.htm>

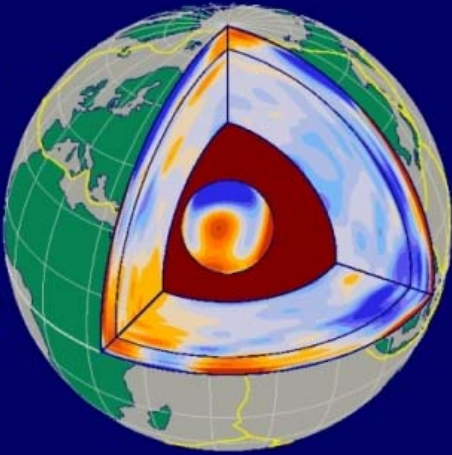


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## Intoduction to Normal mode theory and observation

*John Woodhouse*  
*Smolenice, September 2005*

- A central goal of global seismology is to map the Earth's internal structure in three dimensions
- Imaging employs very large data sets of globally recorded seismograms
- Research aims to invent methods of analyzing seismic waveforms to maximize the retrieval of structural information and to use such information in large scale inverse problems



Model S20RTS: Ritsema, van Heijst and Woodhouse 1999,2004

1 of 33

Übertragen der Daten von www.spice-rtn.org...





# Workshop Sequence - Philosophy



Research

2004 Wave propagation Physics -  
Numerical Methods

2005 Large scale applications - parallel  
computing

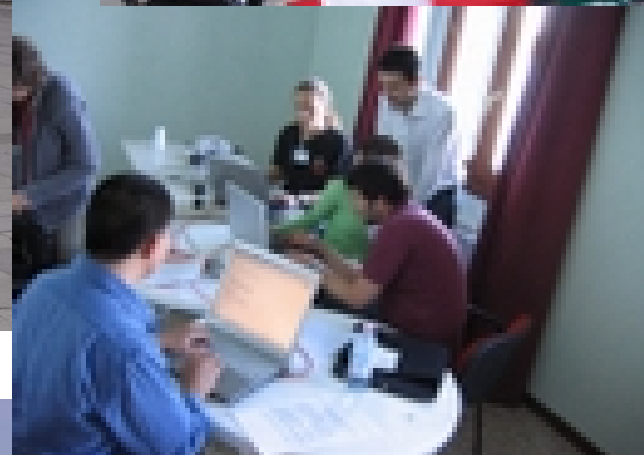
2006 Inverse problems

2007 Links to other fields (acoustics,  
helioseismology, oceanography)



Training





Venice 2004  
Workshop I







Smolenice 2005  
Workshop II





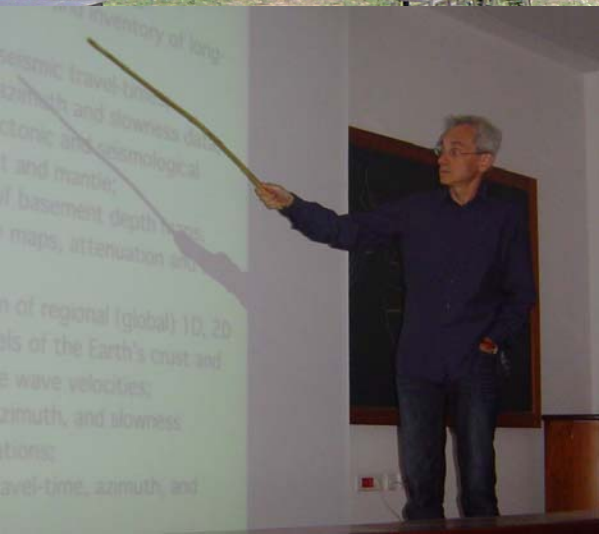
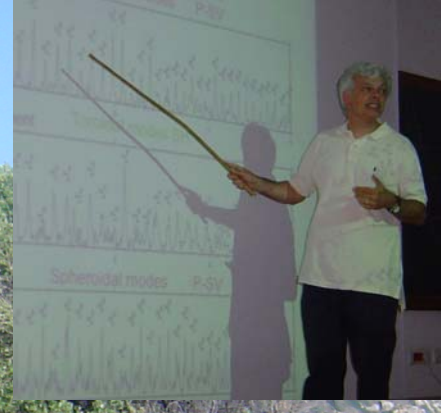


Kinsale 2006  
Workshop III





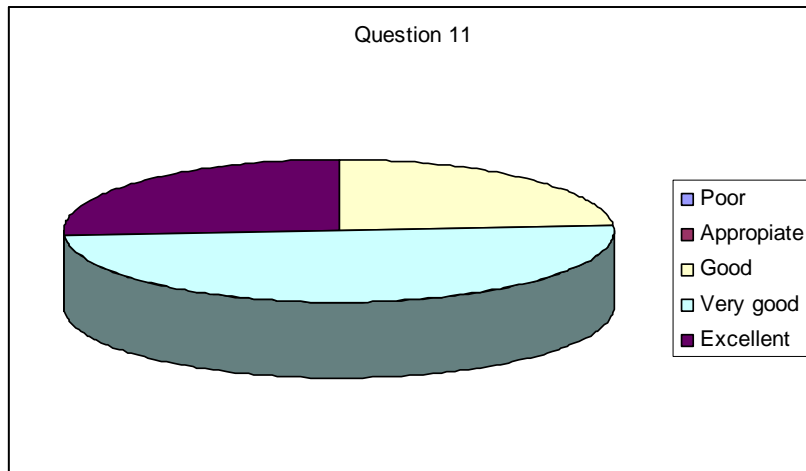
# Corsica 2007 Workshop IV



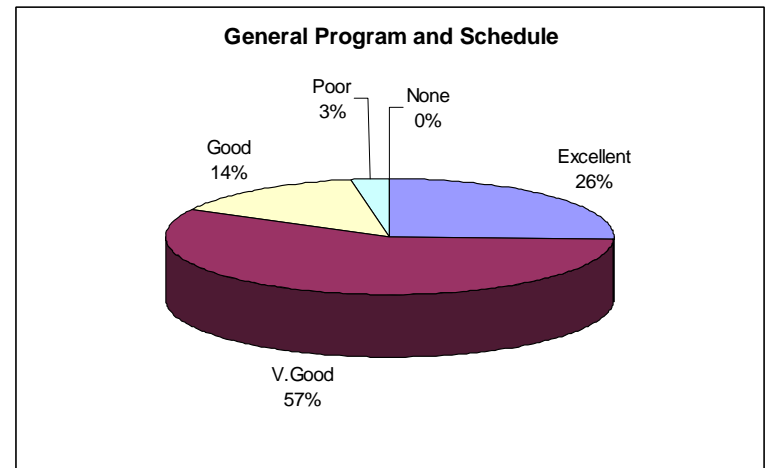


# Student Evaluation

## Venice



## Smolenice





## SPICE Publications (2004-2007)

Papers in reviewed journals:

Total (inv. PhD or postdoc): 178

At least two partners: **13**

Presentations: ~1000 (90 invited)






## SPICE Exchange visits (2004-2007)

Promised: 2520

Actual: 400

*„Each researcher funded through the project is expected to spend 2-3 months per year at other participating institutions“  
(SPICE contract)*





# SPICE - conclusion

- It **did** create the lasting network we wanted
- SPICE was more than SPICE (a lot of other institutions/researchers could be involved)
- A wonderful way to **spot talents!**
- It **did** create careers!
- We created standards, there is less duplication
- Amazing *chemistry* between network researchers
- **Individuals** drive it, get the right ones!
- SPICE benefitted from CIG

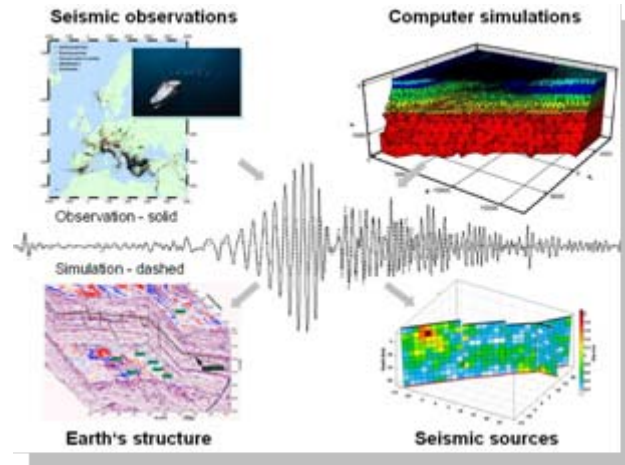
## Problems:

- Very hard to fill 28 positions in a field like computational seismology!
- The right workshop **format**, the right **venue**
- Level of training partly too ambitious (maths)
- Computational practicals have to be very well prepared to work!
- Unfortunately no support for infrastructure (or software engineering, it has to come from elsewhere)
- Relatively little mobility between partners (is it necessary?)
- No sustainability because project can not be prolonged



# QUEST

**QU**antitative estimation of  
Earth's sources and **ST**tructure



15 partners, 19 PhDs, 7 postdocs

**Industry involvement** was the key to success!

e.g., Schlumberger Cambridge, **IBM Research Centre** Zurich, SpectraSeis Zurich, Microseismic Inc, Houston, **GOCAD**, **DEISA**, **Munich Centre for Advanced Computing (MCAC)**

Project start Sep-Dec 2009.





... and hopefully continuous good collaborations,  
joint workshops with CIG!

Thank you!

