SEISMOLOGICAL IMAGING

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Course Goal

to provide practical skills in the use of seismic tomography and other methods of seismological imaging for different applications.

The Course Includes

- the theoretical background for seismic imaging methods;
- an overview of seismological methods used for imaging the Earth's interior;
- an overview of geological stories based on multiscale seismological studies;
- practical exercises for working with different versions of seismic tomography algorithms;
- processing experimental seismological data.

Course Format:

- simple language, minimum of mathematical formulas;
- combining classical background and recent achievements;
- practical work with real tomography codes based on synthetic and experimental data.

Course Summary:

This course is primarily oriented towards students with a Master's level geophysical specialty. However, it is also suitable for specialists in adjacent disciplines such as geology, volcanology, and tectonics. The course does not require deep initial knowledge of geophysics and mathematics, but after completing the course, the students will be able to work with several practical tomography codes. The experience accumulated during the practical exercises within the course will be enough to conduct research with the use of seismic tomography.

The course starts with a historical overview in the fields of seismology and studying interior structures of the Earth (Section 1). In particular, it shows that seismic tomography is a relatively new method that continues to actively develop.

The tomography method is introduced with descriptions of the main difficulties and challenges related to strong non-linearity, high noise level, discrete and uneven data distribution etc. (Sections 2 and 3). To overcome these difficulties and to reduce the non-linear integral problem to a system of linear equations, some basic assumptions and approximations should be applied. In this section, the major elements of tomography inversion are considered: linearization, parameterization, regularization etc. All together, they compose a basic algorithmic kernel that is effectively used as a major inversion engine in a series of different tomography codes, some of which are presented later within the course. The theoretical description of the method is supported by practical exercises with a simplified version of the tomography code, BASIC_TOMO, that is based on straight rays. Working with the code gives practical skills operating with console-type software, exploring the role of different parameters, building models and ray geometries.

Section 4 presents methods for solving the forward problem of seismic ray construction in a 3D velocity model. Several methods are considered including shooting, bending, and numerical solution to the eikonal equation. In Section 5, we present an active-source tomography code PROFIT (2D version with the use of refracted rays), which is implemented as an instrument in many practical and scientific applications. Students are required to perform full inversions for several experimental datasets with different sizes and ray geometries.

In Section 6, we present the problem of earthquake locations. We consider several methods of finding the coordinates and origin time of a source. The source location algorithm is an important element in the method of passive-source tomography code (Section 7). In this section, we present the LOTOS code for local earthquake tomography. Students learn the main workflow of the LOTOS code and perform practical exercises consisting of building velocity models based on several experimental datasets.

The next series of lectures (7, 8 and 9) describe surface waves and their use in studying the Earth’s structure. In one of the lectures, we describe the basic principles of the analysis of seismic noise to reveal surface waves suitable for performing the tomographic inversion. We also present a practical version of the surface-wave tomography code and run calculations for several experimental datasets.

The additional possibilities for tomography studies described in the following sections (10, 11 and 12) include studying seismic anisotropy, attenuation, and revealing temporal velocity changes.

An important element of any tomography study is verification (Section 14), which should present solid arguments that the constructed seismic velocity anomalies really represent the actual geological structures inside the Earth. In this section, we present several informal and formal methods for verification. Here, we perform several practical exercises based on the tomography codes learned within the previous sections.

The course concludes by describing several recipes to interpret the derived seismic tomography models (Section 15). At the end of the course, we will present several geological stories based on seismic tomography studies on different scales.