Seiscope Consortium
Scientific proposition for the period 2009-2011

The SEISCOPE consortium is devoted to the investigation of high-resolution seismic imaging based on full waveform inversion. We focus more specifically on the frequency domain formulation of full-waveform inversion applied to wide-aperture/wide-azimuth (or global offset) acquisition geometries.

The first period of this consortium 2006-2008 has been devoted to the development and to the validation of numerical tools related to 2D and 3D seismic imaging as improved forward modelling and more efficient parallel inversion algorithms. We have the feeling that a second round is necessary in order to reach our scientific objectives.

The second period is devoted to the validation of these new tools on both realistic synthetic and real data examples.

During this period, we intend to focus our research efforts towards:

Multiparametric inversion in a 2D model

Velocity, density and attenuation in the acoustic approximation:
The open source version FWT2D has this multiparametric inversion procedure in the beta version 5.2. We shall intend to focus on applicability and sensitivity analysis for these different parameters. Among realistic synthetic benchmarks, we shall use the velocity-density Marmousi model with attenuating inclusions, the isotrop acoustic version of the anisotropic overthrust model (Delt University) where attenuation can be set in the anisotropic layers and the velocity-density salt BP model. FWT2D will be applied to the 2 real data sets (OBC Valhall and OBS Nankai data sets) mentioned below for the reconstruction of these parameter sets.

Anisotropic parameters in the acoustic approximation:
The inversion code will be implemented for the reconstruction of the anisotropic parameters for the end of the first period of the SEISCOPE consortium. The present release of the beta version v5.2 already embeds the anisotropic forward problem for TTI visco-acoustic media. We do intend to investigate applicability and sensitivity for reconstruction of pertinent anisotropic parameters. The anisotropic parameters currently implemented in the forward problem are the Thomsen's parameters δ and ε as well as the locally-varying tilt angle θ. As realistic synthetic benchmark, we will use the anisotropic overthrust model (Delft University). The inversion code will be applied to the two real datasets mentioned below with a special emphasis on the Valhall data set for which a significant footprint of the anisotropy in the imaging is expected (personal communication of L. Sirgue).

Elastic parameters in the elastic approximation:
We intend to apply FWI to recover P wave velocity and S wave velocity in various contexts (onshore and offshore). Within this prospect, an accurate modelling tool was developed to take into account the liquid-solid interface and free surfaces of arbitrary shape. The inversion scheme will be intensively tested for synthetic data and for realistic configuration at the beginning of the next period of the consortium (i.e., 2009). It will provide the necessary

period for checking the robustness of the implementation achieved during the first period of the consortium. As realistic synthetic benchmarks, we may consider some targets of the Marmousi2 model, the isotrope version of the anisotropic overthrust model and a synthetic elastic foot-hills model. We will try to assess the potential contribution of surface waves in the imaging thanks to realistic synthetic case studies.
Real data case studies especially for the subsurface will be our concern. Application to the Valhall and Nankai data sets will be investigated during the second period of the consortium. Another possible application may be performed in foot-hills environment. Two-dimensional synthetic and real data sets should be considered and any proposition from our sponsors is welcome.

Three-dimensional full-waveform inversion in the acoustic approximation

A code is currently available for performing 3D FWI for velocity models of limited dimension. The forward problem is based on a finite-difference frequency-domain method based on a massively parallel direct solver.

Three-dimensional elastic full-waveform modeling/inversion

3D visco-elastic full-waveform modeling is currently investigated by V. Etienne during his PhD which started in October 2007. The aim of the first year of his PhD is to assess the feasibility of different possible numerical approaches. It is likely that the 3D approach developed in the acoustic approximation based either on direct or hybrid solvers will not be the approach of choice in 3D due to the memory requirement of direct solvers. V. Etienne may direct his efforts towards a time-domain approach for the forward problem to subsequently perform the inverse problem in the frequency domain as proposed by Sirgue et al. (2007) and Nihey and al. (2007). The alternative is to investigate iterative solvers based on a Krylov method preconditioned by a multigrid solution of the damped wave equation as those developed by Plessix (2007) and Riyanti and al. (2007). The convergence rate of this approach for the elastic wave equation could be firstly assessed in 2D and in sequential before moving eventually to the 3D case. The numerical stencil will be based on a parsimonious Discontinuous Galerkin method. Implementation of an efficient forward modeling code is scheduled during the second year of his PhD while the interfacing of the forward problem in a prototype inversion code is scheduled during the last year of his PhD.

Application to real data case studies:

Specific targets will be found for the application of the different high resolution imaging techniques.

Scheduled open positions:

2D FWI for imaging anisotropic media (sept. 2008 – sept. 2011)

One PhD thesis will be opened in September 2008 on 2D FWI for imaging TTI visco-acoustic media. This PhD will be focused on applications to synthetic examples for an estimation of the sensitivity of FWI to anisotropic parameters and to real data sets.

Two or three PhD may be open in September 2009.

3D visco-acoustic FWI on unstructured meshes and application to real data (sept. 2009-sept. 2012)

This PhD will investigate [i] the extension of 3D FWI on unstructured meshes using a Discontinous Galerkin method for the forward problem, [ii] an application of 3D visco-acoustic FWI to a real data set.

Application to 2D visco-elastic FWI to real datasets (sept. 2009-sept. 2012)
The aim of this PhD will be to investigate the performances of 2D visco-elastic FWI for different applications. This PhD will be the continuation of that of R. Brossier and will take advantage of the methodological work performed during this PhD. As mentioned above, the Valhall data set will provide one marine case study. We would like to investigate the applicability of FWI in complex onshore environments and assess the potential contribution of surface waves in addition to body waves.

PhD positions will be at Géosciences Azur and at LGIT at Grenoble with possible training periods in both institutes.

Nomenclature

FWI: Full-Waveform Inversion
FATT: First-Arrival Traveltime Tomography
DDM: Domain Decomposition Method
PSDM: PreStack Depth Migration
OBS: Ocean Bottom Seismometers