Wave Inversion Technology Consortium

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Preface

This is the fifteenth issue of the annual report since the foundation of WIT and the fifth issue since the move of the consortium leadership to Hamburg. We welcome you to celebrate these anniversaries with us and the 27 papers in this report, the highest number of papers we have shared with you in recent years.

It is also the first report to be printed in colour and we think that this is a suitable representation of the equally colourful portfolio of WIT: although we are, of course, pleased that the name of our consortium is associated with such a powerful tool like CRS, we are far more than CRS. Over the years, WIT leading edge research has grown to encompass a wide range of exciting topics as documented in this report.

The multi-parameter stacking techniques with CRS as one member of a whole portfolio of new stacking operators still represents a key research topic of WIT. Extensions to offset formulas, converted waves and anisotropy will be on the agenda of the upcoming years, and first developments are already discussed in this issue. These new operators are of double square root type, non-hyperbolic, and their accuracy can be steered according to the needs. Moreover, the accuracy performance at large offsets is superior to CRS or multi-focusing without losing the link to the physics of CRS wavefield attributes. This means that existing workflows need not to be changed but may be fed with better attributes.

Multi-parameter stacking still is and will be a core business of WIT. However, you as a sponsor know, that there is much more to WIT. In this report, you will find 14 papers on Seismic Imaging, 2 on Modelling, 5 on Full Waveform Inversion, and 6 on other topics, such as investigations of the new stacking operators, an algorithm for obtaining high-resolution velocity spectra, new ways of separation of diffractions, alternative measures of coherency, and more.

We are happy to announce that the M.Sc. thesis of Christina Raub of the Hamburg group, entitled "Seismic Imaging of the Dynamic Water Column" was presented with the award of the Hamburg Society "Harmonie von 1789" to support geosciences. Christina is one of the first students to successfully finish the new B.Sc. and M.Sc. programs established at the University of Hamburg. You can find her M.Sc. thesis on the WIT homepage and the CD along with the 2011 report.

Finally, we want to acknowledge your support. Without your sponsorship it would not be possible to provide so many research opportunities to students, nor to help us in our mission for leading edge research in applied seismics and to educate the next generation of geophysicists. Some of you have spent many years with WIT, which gave us a continuity in our research not possible by any public funding. Public funded programs for research on specific topics are limited to a few years of support. With WIT, we are now deep in the second decade of funding and we are confident that this support will continue and thus let us step ahead in our goal to establish a most accurate and efficient target-oriented seismic modelling, imaging, and inversion using elastic and acoustic methods.

Dirk Gajewski

Summary: WIT report 2011

IMAGING

Abakumov et al. introduce a new non-hyperbolic multiparameter stacking operator based on a double square root expression and a pragmatic search strategy for converted waves. The key step of their method is the simulation of a zero-offset section by the stack of γ-CMP gathers, which may be considered an approximation of common conversion point gathers. Numerical experiments confirm that the new expression is superior to the corresponding hyperbolic operator.

Amaro et al. compare a number of imaging conditions based on stabilized least-squares solutions. The conclude that imaging conditions that sum over all sources before deconvolution do not fully preserve amplitudes. As demonstrated on synthetic data of different complexity, the best imaging conditions, both in a true-amplitude sense and regarding migration artifacts are based on total least squares.

Behzadi and Gajewski present a new passive seismic imaging method based on move out correction and cross-correlation stacking. The point source and microtremor events related to a known hydrocarbon reservoir in a complex medium are localized. The maximum of image function obtained by this method provides the source location. Both first and most energetic arrivals are considered and the results of most energetic arrivals provided better source location.

Coimbra et al. present an approach to seismic diffraction imaging and velocity model improvement. This method that uses an approximate velocity as input requirement, provides a average velocity model and diffraction locations in depth domain as result. Our algorithm is based on focus of remigration trajectories over diffraction curves and velocity continuation. This method has been shown as low computational cost numerical method. Beyond that, the automatic location of diffraction points is achieved after image picking.

Costa et al. implement a 3D downward continuation FD migration without splitting in the space coordinates using a complex Padé approximation and implicit finite differences, eliminating numerical anisotropy at the expense of a computationally more intensive solution. They show that the use of the complex Padé approximation not only stabilizes the solution, but also acts as an effective preconditioner for the BICGSTAB algorithm, reducing the number of iterations as compared to implementation using the real Padé expansion.

Dell and Gajewski extended their approach for CRS-attributes based diffraction imaging to 3D geometry. The approach is based on a simultaneous application of the CRS-based diffraction operator and a diffraction filter to separate diffracted events. Also they introduced a technique to build migration velocities in both the depth and time domain. The migration velocities are determined using isolated diffracted events in the poststack domain.

de Figueiredo et al. further develop a method for the detection of diffractor points in a common-offset-gather domain. The method is based on pattern recognition using amplitude distribution along the diffraction operator. While the method, in principle, requires knowledge of the migration velocity field, i.e., RMS or interval velocities, it is very robust with respect to an erroneous model. A real GPR data example demonstrates the feasibility of the method.

Mondini et al. compare the performance of splitting techniques for 3D complex Padé Finite-Difference (FD) migration techniques in terms of image quality and computational cost. The compared splitting techniques are two and alternating four-way splitting. They also extend the Li correction for use with the complex Padé expansion and diagonal directions. From numerical examples in inhomogeneous media, they conclude that alternate four-way splitting is the most cost-effective strategy to reduce numerical anisotropy in complex Padé 3D FD migration.

Rueda et al. employ a smoothing procedure on Common-Reflection-Surface (CRS) parameters to eliminate fluctuations and outliers of stack sections. Application of the scheme attenuates random noise in the stacked sections, leading to an increase in signal-to-noise ratio and better continuity of the reflections. Application to a synthetic and real marine data sets provided encouraging results.

Sakamori and Biloti present a study on a numerical approach to describe the residual moveout observed in image gathers as a function of the migration-velocity correction factor and the dip of the reflector. The new description allows the incorporation of neighbouring image gather to stabilize and improve the the parameter estimates.

Schwarz et al. introduce two conceptually different parameterizations of the isotropic recursive stacking operator (RSO) in terms of the three well-known CRS parameters. While the first parameterization is based on the application of a time shift, the second one results from a Taylor series expansion of the squared RSO traveltime. Accuracy studies reveal that the time-shift-based parameterization behaves essentially the same as the planar multifocusing expression. The parameterization based on a Taylor series expansion turns out to provide higher accuracy than CRS and planar multifocusing over the full investigated range of reflector curvatures for constant vertical velocity gradient media of differing gradient strength.

Schwarz et al. apply two different parameterizations of the recursive stacking operator (RSO) in terms of the CRS attributes to different synthetic datasets. For the simple case of a spherical reflector in a constant vertical velocity gradient medium, application of RSO leads to higher semblance values and more reliable attribute estimates than CRS and planar multifocusing over the full range of reflector curvatures. This also results in an improved approximate attribute-based poststack time migration. Comparison of the stacking and migration results from application of RSO to those from CRS for the Sigsbee 2a model confirms the overall superior performance of RSO for a more complex subsurface setting.

Vanelle et al. suggest a new stacking operator, the recursive stacking operator (RSO), for curved subsurface structures in the presence of anisotropy. It is derived from evaluating Snell's law at a locally spherical interface. Examples show that the new operator performs well for a wide range of reflector curvatures from nearly planar reflectors to the diffraction limit.

Vanelle et al. suggest a new CRS-type hyperbolic stacking operator for converted waves. Although their operator was derived under the assumption of a constant v_p/v_s ratio, it has the advantage that CRS attributes from a monotypic stack can be used as intial values for the converted wave stack, even when v_p/v_s is varying, leading to a significant increase in computational efficiency of the optimisation procedure. Furthermore, monotypic and converted wave attributes can be evaluated for shear model building.

MODELING

Bloot et al. present a general elastic wave equation in weakly anisotropic VTI media by linearizing the stiffness tensor. Using zero-order ray theory, they derive the associated eikonal and transport equations for q-P, q-SV and q-SH waves in general and pseudo-acoustic VTI media.

de Figueiredo et al. use ultrasonic surveys to investigate the influence of source frequency on elastic parameters (the Thomsen parameter γ and shear-wave attenuation) of fractured anisotropic media. Under controlled conditions, they prepared anisotropic models containing penny-shaped rubber inclusions in a solid epoxy resin matrix with 10 to 17 layers, crack density ranging from 0 to 6.2%, and number of uniform rubber inclusions per layer ranging from 0 to 100. S-wave splitting measurements have shown that scattering effects are more prominent in models where the crack aperture to seismic wavelength ratio ranges from 1.6 to 13.3 than other models where the ratio was varied from 2.3 to 23.

FULL WAVEFORM INVERSION

Dunkl gives an overview about 3D elastic full waveform inversion. She shows the performance of the inversion code for the example of a random medium model in transmission geometry.

Kurzmann investigates the influence of attenuation on acoustic 2D full waveform tomography. Acoustic tomography – with or without involvement of attenuation – is applied to viscoacoustic data. The resulting error in velocity reconstruction is quantified.

Macedo decomposes the Fréchet-derivative sensitivity kernels for the full wavefield using a scattering-based approach and assuming acoustic-only data. Those results provide for the decomposition of current FWI kernels into different sub-kernels which have explicitly different levels of nonlinearity with respect to data. This capability to discern levels of nonlinearity within FWI kernels is key to understanding model convergence in gradient-based, iterative FWI.

Przebindowska et al. analyse the role of the density information in the reconstruction of subsurface model by means of full waveform inversion.

Schäfer et al. discuss the effects of geometrical spreading corrections for a 2D full waveform inversion of shallow seismic surface waves. They show synthetic inversion results with line source wavefields and amplitude corrected point source wavefields as observations. They conclude that not only an amplitude correction but also a phase-transformation must be applied to the point source seismograms. Therefore they introduce possible transformations known from literature for body waves and test them for surface waves.

OTHER TOPICS

Asgedom et al. Introduces a new way of diffraction separation in a common-offset section. They utilized a special version of the CRS moveout equation employing a constant-offset central ray and demonstrated the possibility of diffraction separation using both synthetic and real data.

Barros et al. propose an iteratively implementation of MUltiple Signal Classification (MUSIC) algorithm, used for obtainment of high resolution velocity spectra. They also propose a new MUSIC algorithm, based on the spatial covariance matrix of seismic data.

Biloti introduces GêBR, a graphical user interface for seismics processing packages, describing its most appealling features.

Das and Gajewski make an attempt to understand the dependence of coherency measure for velocity analysis. A comparative study of normalized cross-correlation sum and semblance; which are two different measures of coherency is undertaken. The two coherency measures are applied on a large number of synthetic datasets involving different situations. The results of these applications show that the normalized cross-correlation sum measure is better than semblance method in most of the cases, in terms of resolution and identification of events in complex situations.

Minarto and Gajewski discuss the conjugate direction method for the minimization of an objective function. Numerical tests on an analytical example demonstrate the ability of this method to find the global minimum in situations were the Nelder-Mead optimization method gets stuck in a local minimum. The application of the conjugate direction procedure to CRS using the SIGSBEE data revealed that the determination of CRS attributes has a computational advantage of about 4-5 compared to the Nelder-Mead method.

Perroud et al. investigate a recently proposed moveout, of non-hyperbolic character but depending on the conventional common-reflection-surface (CRS) parameters. Such moveout, valid for 2D and 3D models, is referred to as non-hyperbolic CRS traveltime. The few synthetic experiments, available only for 2D models, show that the new moveout exhibits impressive accuracy in long offsets, which encourages its use in the CRS method. In this ongoing research, still restricted to 2D, the sensitivity of the non-hyperbolic CRS moveout to its parameters is evaluated with the aim of the design of parameter estimation strategies. By means of a controlled parameter perturbation in selected configurations, which extend those used in conventional CRS, the study confirms the high potential of the new moveout as an optimal choice for CRS.

The Wave Inversion Technology (WIT) Consortium

Wave Inversion Technology
established 1996 in Karlsruhe, Germany

The Wave Inversion Technology Consortium (WIT) was established in 1996 and is organized by the Institute of Geophysics of the University of Hamburg. It consists of three integrated working groups, one at the University of Hamburg and two at other universities, being the Mathematical Geophysics Group at Campinas University (UNICAMP), Brazil, and the Geophysical Institute of the Karlsruhe University. In 2003, members of the Geophysical Department at the Federal University of Pará, Belém, Brazil, have joined WIT as an affiliate working group. In 2007, NORSAR joined WIT as research affiliate. In 2010, Fraunhofer ITWM joined WIT as research affiliate.

The WIT Consortium offers the following services to its sponsors:

a.) research as described below;

b.) deliverables;

c.) technology transfer and training.

The ultimate goal of the WIT Consortium is a most accurate and efficient target-oriented seismic modelling, imaging, and inversion using elastic and acoustic methods. Within this scientific context it is our aim to educate the next generations of exploration geophysicists.

Exploration and reservoir seismics aims at the delineation of geological structures that constrain and confine reservoirs. It involves true-amplitude imaging and the extrapolation of the coarse structural features of logs into space. The goals on seismic resolution are constantly increasing which requires a complementary use of kinematic and wave equation based techniques in the processing work flow. At WIT we use a cascaded system of kinematic and full wave form model building and imaging techniques. Since our data and inversions are never perfect it is the challenge to find those techniques which produce the best images for erroneous velocities and faulty wave forms.

RESEARCH TOPICS

The WIT consortium has the following main research directions, which aim at characterizing structural and stratigraphic subsurface properties:

WIT Research Group Campinas

- Imaging and Inversion in 2, 2.5, and 3D:
  - Further development of migration and demigration for layered inhomogeneous media;
  - Study of particular aspects of migration: trace interpolation, choice of migration aperture, resolution estimates, depth conversion of time migrated sections, amplitudes, etc;
  - Angle-domain migration;
  - Extension of true-amplitude concepts beyond Kirchhoff migration;
  - Time-to-depth conversion;
  - True-amplitude redatuming.
- AVO and inversion:
  - New approximations for elastic reflection coefficients using the concept of reflection impedance;
  - AVA and AVO in the presence of tuning.
- Macrovelocity model building and updating:
  - Image-wave remigration (velocity continuation);
  - Transfer of CRS techniques to the migrated domain;
  - Stereotomography and tomographic inversion of CRS attributes;
  - Extension of model-building techniques to anisotropic media;
  - Use of additional data attributes.
  - Improved description of and inversion for wave parameters in VTI media.
- Local event slopes:
  - Fast and reliable detection
  - Autopicking and use in stereotomography
  - Velocity model building using slope information
  - Migration velocity analysis using local slopes
  - CRS parameter determination from local slopes
- CRS field data processing:
  - Comparison of CRS and conventional processing and imaging in 2D/3D: spatial and vertical resolution, validation and interpretation of imaging results;
  - Applications of CRS attributes: Multiple elimination, Kirchhoff time migration, separation of reflections and diffractions;
  - Development and optimal use of CRS code: introduction of search strategies and algorithms, optimal apertures, code improvements and parallelization;
  - Improved attribute detection, development and testing of signal processing alternatives other than conventional semblance.

WIT Research Group Hamburg

- CRS and imaging topics:
  - Multiple suppression using CRS attributes and blended shots
  - Processing by data mapping (generation of CSP gathers, velocity analysis, data separation, multiple and diffraction suppression, filtering).
  - Generation of reflection-only and diffraction-only sections in 3-D
  - Synthetic study on the use of diffractions in reflection imaging
  - Local high resolution reflection imaging using localized diffractions
  - Diffraction velocity analysis (3-D)
  - 3-D CRS super-gathers (WAZ, NAZ data)
  - Data regularization and interpolation using CRS partial stacks (3-D)
  - Implementation of CRS software modules on clusters
  - New (non-pragmatic) 2-D and 3-D CRS ZO and offset implementation using local slopes for CRS parameter estimation
  - Alternative optimization procedures for simultaneous determination of CRS attributes
  - Implementation and validation of a CRS algorithm for PS-converted waves
  - Application of PS-CRS parameters in NIP-wave tomography for shear velocities
- Multi-parameter processing (MPP):
  - Non-hyperbolic MPP stacking operators for PP, PS, and anisotropy
  - Implementaion of new operators into CRS software package
  - Relation of MPP stacking parameters to CRS attributes
  - Time domain applications to synthetic and field data, comparison with CRS
- Passive seismics and passive seismic imaging:
  - Localization by reverse modeling
  - Localization of passive seismic events and micro-tremors by diffraction stacking.
  - Velocity model building using the passive seismic method
  - Quantification of localization uncertainties: influence of apertures, bandwidth and velocity errors
  - Synthetic study on the use of full waveform localization techniques
  - High resolution waveform based relative localization
  - Passive events for local high resolution reflection imaging
  - Parallel implementation and real time processing
  - Field data applications

WIT Research Group Karlsruhe

- Full Waveform Inversion (FWI):
  - Application of 2-D acoustic/elastic FWI to marine industry reflection seismic data
    - Generation of starting velocity and density models for FWI from borehole information, first arrival tomopgraphy and NIP wave tomography
    - Development of robust pre-processing steps to prepare 2-D reflection seismic data for FWI
    - Reduction of the non-linearity of FWI

  - Application of 2-D acoustic/elastic FWT to marine industry reflection seismic survey
  - Multiparameter FWI (P-velocity, S-velocity, density)
  - FWI of shallow seismic surface waves
  - Development of 3-D acoustic and elastic FWI using high performance computers

- Forward Modelling:
  - Optimization of 2-D, 2.5-D, and 3-D finite-difference simulation codes for elastic, viscoelastic and anisotropic media

- Migration and tomography:
  - Inversion beyond NIP wave tomography: 3D velocity model building from exact diffraction traveltimes
  - Optimization of 2-D/3-D Reverse Time Migration based on Finite-Difference forward modeling for acoustic and elastic media

WIT PUBLIC RELATIONS COMMITTEE

Name	University	Area
Dirk Gajewski	Hamburg	Coordination and contact to representatives
Claudia Vanelle	Hamburg	Administration and contact to representatives, WIT Report and annual meeting organisation

WIT STEERING COMMITTEES

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Matthias Riede	RWE Dea AG
Bertrand Duquet	Total E&P RD
Henning Trappe	TEEC

COMPUTING FACILITIES

The Hamburg group has access to a 264 nodes (16 dual core CPUs, 8448 cores in total) IBM p575 "Power6" cluster at the German Computer Center for Climate Research (Deutsches Klimarechenzentrum, DKRZ) for numerically intensive calculations. It is equipped with 20 TeraByte of memory and its performance per core is 18.8 GigaFlops. There is also access to a SUN Linux cluster with 256 nodes (2 quad core Opteron, 32 GB each). A SUN Fire X4600 (8 dual core Opteron, 32 GB) is exclusively available for the group's computing demands. Additional computer facilities consist of several Linux workstations and Linux PCs. Furthermore, a Maxeler MaxWorkstation with a 24 GB memory MAX3 acceleration card which is FPGA based has recently been ordered.

The research activities of the Campinas Group are carried out in the Computational Geophysics Laboratory. The Lab has many PC Linux workstations and Sun Ultra 60/80 workstations connected by a dedicated network, suitable for parallel processing. Educational grants provide seismic packages from leading companies such as Landmark and Paradigm. Besides State Government funds, substantial support both for equipment and also scholarships are provided by the Brazilian Oil Company Petrobras. An extension of the Lab with substantial increase of computer power and space is being built in the new facilities of the Center of Petroleum Studies. The new Lab, expected to be in operation next year, will also have remote access to the computing facilities of the Petrobras Research Center in Rio de Janeiro.

The local facilities of the WIT group in Karlsruhe mainly consist in about 20 clustered quad-core Linux workstations. For large-scale computational tasks, a Hewlett-Packard XC3000 Linux cluster is available on campus. It hosts about 300 nodes with two quad cores each. The total nominal peaker power is 27 TFlops, the total main mmemory 10 TByte. About 300 TByte disk space are availble via a Lustre file system and an InfiniBand interconnect. In addition, we have access to the computing facilities of the state-owned bwGRiD consisting of a total of 101 IBM blades centers distributed over seven universities in Baden-Württemberg. Furthermore, our successful project proposal at the JÏich Supercomputing Centre (JSC) has granted us access and a large volume of computing hours for the Juropa Clustercomputer. This super computer consists of 8640 cores total, 52 Terabyte main memory, 101 Teraflops peak performance and will be used for large scale forward simulation and full waveform tomographies.

The main computing facility at the Geophysics Graduation Program in Belém is the Seismic Processing Lab (ProSis). The hardware resources include: workstations (RS3600) from IBM and a SUN SparkStation 20, all networked to a local server SUN Enterprise-3500 with 2 processors; several networked Linux-PCs; for large-scale applications, a cluster of PCs with 20 dual-processor nodes. The proprietary software packages available for seismic applications are ProMAX, Disco-Focus, and Gocad.

WIT research personnel

Ivan Abakumov is a Master student in St. Petersburg State University. His research interests are time imaging, converted waves, time-lapse seismic, geophysical data processing and computer programming. Ivan is a student member of EAGE, SGE and SPE.

Khawar Ashfaq Ahmed received a B.Sc. from the University of the Punjab in Lahore, Pakistan, in 2005. He received a M.Sc. in Geophysics in 2007 and a M.Phil. in Geophysics in 2009, both from the Quaid-i-Azam University in Islamabad, Pakistan, where he also worked for three years as teaching and research associate in the Department of Earth Sciences. Since 2010, he is enrolled at the University of Hamburg as a Ph.D. student in Geophysics. His current research interests are 3D seismic imaging, CRS stacking, and NIP wave tomography.

Denis Anikiev is studying for a bachelor degree at the Department of Physics of Earth at St.Petersburg State University, Russia. He participated in an exchange program with Hamburg University in 2006,2007 during his work on the "Localization of Seismic Events by Diffraction Stacking". His present research interests include localization of seismic events, inverse problems for acoustic media, and virtual source technology. He is a student member of SEG, EAGE, SPE.

Alexander Bauer is a B.Sc. student in the Hamburg WIT group. He will write his B.Sc. thesis in summer 2012 and his research interests focus on multiparameter stacking operators.

Mehrnoosh Behzadi has received her M.Sc. in seismology from Islamic Azad University of Iran in 2009. Since 2011, she is a Ph.D. student in the Hamburg WIT group. Her research interests include passive seismics, site effects, and exploration seismology.

Ricardo Biloti received his B.Sc.(1995), M.Sc. (1998) as well as Ph.D. (2001) in Applied Mathematics from the State University of Campinas (UNICAMP), Brazil. He worked at Federal University of Paraná (UFPR), Brazil, as an Adjoint Professor, at the Department of Mathematics, from May 2002 to September 2005, when he joined Unicamp as an Assistant Professor. He has been a collaborator of the Campinas Group since his Ph.D. His research areas are multiparametric imaging methods, like CRS for instance. He has been working on estimating kinematic traveltime attributes and on inverting them to construct velocity models. He is also interested in Numerical Analysis, Numerical Linear Algebra, and Fractals. He is a member of SBMAC (Brazilian Society of Applied Mathematics), SIAM and SEG.

Martina Bobsin is a B.Sc. student in the Hamburg WIT group. Her research interests focus on seismic modeling.

Thomas Bohlen received a Diploma of Geophysics (1994) and a Ph.D. (1998) from the University of Kiel, Germany. From 2006 to 2009 he has been Professor of Geophysics at the Institute of Geophysics at the Technical University Freiberg where he has been the head of the seismics and seismology working groups. Since 2009, he is Professor of Geophysics at the Geophysical Institute of the Karlsruhe Institute of Technology. He is the head of the applied geophysics group. His research interests and experience include: seismic modelling, full waveform inversion, surface wave inversion and tomography, reflection seismic imaging. He is a member of SEG, EAGE, AGU, ASA, and DGG (member of the executive board).

Itamara Campos graduated in Physics (2008) and received her M.Sc. in Geophysics (2011), both at Federal University of Pará (UFPa), Belém, Brazil, where she continues her studies to pursue a doctoral degree in seismic methods. Her research interests are concentrated in wave-equation migration methods. She is a member of SEG and SBGf.

Pedro Chira Oliva, received his diploma in Geological Engineering (UNI-Peru/1996). He received his MSc., in 1997 and PhD., in 2003, both in Geophysics, from Federal University of Pará (UFPA/Brazil). He took part of the scientific research project "3D Zero-Offset Common-Reflection-Surface (CRS) stacking" (2000-2002) sponsored by Oil Company ENI (AGIP Division - Italy) and the University of Karlsruhe (Germany). Currently he is full Professor at the Institute of Coastal Studies (IECOS) of UFPA. His research interests include seismic stacking and seismic modeling. He is member of GOCAD consortium (France) and SBGf.

Tiago A. Coimbra received a B.Sc. (2007) in Mathematics from Federal University of Espirito Santo (UFES) and an M.Sc. (2010) in Applied Mathematics from University of Campinas (UNICAMP), Brazil. Since 2010 he has been a Ph.D. student in Applied Mathematics at UNICAMP. His research interests include seismic modeling, particularly ray theory, velocity analysis, offset continuation, and image-wave theory. He is a member of SEG and SBGf.

Carlos Costa graduated in Physics (2008) and received his M.Sc. in Geophysics (2011), both from Federal University of Pará (UFPA), Belém, Brazil, where he is working toward a Ph.D. in seismic methods. His research interests include wave-equation migration methods and full-waveform inversion. He is a member of SEG, EAGE and SBGf and SBF.

Jessé Carvalho Costa received his diploma in Physics in 1983 from the Physics Department, Federal University of Pará (UFPA) and a Doctor degree in Geophysics in 1993 from the Geophysics Department at the same University. He was a Summer Student at Schlumberger Cambridge Research in 1991 and 1992. He spent 1994 and 1995 as a post-doc in the Stanford Tomography Project at Stanford University. He held a faculty position the Physics Department at UFPA from 1989 to 2003. Currently he is Associate Professor in the Geophysics Department, UFPA. His fields of interest include seismic anisotropy, traveltime tomography and seismic modeling.

Joõ Carlos Ribeiro Cruz received a BSc (1986) in geology, a MSc (1989), and a PhD (1994) in geophysics from the Federal University of Pará (UFPA), Brazil. From 1991 to 1993 he was with the reflection seismic research group of the University of Karlsruhe, Germany, while developing his PhD thesis. Since 1996 he has been full professor at the geophysical department of the UFPA. His current research interests include velocity estimation, seismic imaging, and application of inverse theory to seismic problems.

Sergius Dell received a diploma in Physics from the University of Yekaterinburg (Russia) in 1997. He received his diploma in Geophysics in 2009 from the University of Hamburg. Since 2009 he has been a Ph.D. student at the University of Hamburg. His present research interests include CSP data mapping and time migration velocity analysis on CSP gathers, CRS imaging of the time-migrated reflections and velocity model building by Image Incident Point Tomography, extraction of diffraction events using the CRS stack and poststack time migration velocity analysis.

Vishal Das is a final year student of Integrated Master of Science course in Applied Geophysics at the Indian School of Mines. He did his summer internship at the WIT group in University of Hamburg where he worked on the influence of various coherency measures on velocity analysis. His research interests include seismic modelling, inversion, and reservoir characterization. He is a student member of EAGE, SEG, SPE, and SPG (Society of Petroleum Geophysicists).

Jesper Sören Dramsch participated in the junior studies programme at the University of Hamburg in 2006. He continued his studies in Geophysics at the same university and finished his BSc thesis in 2010. Recently he is participating in the postgraduate programme in Geophysics at the University of Hamburg. He is currently working on partial CRS stacks and trace interpolation.

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