Wave Inversion Technology Consortium

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Contents

Preface

The year 2008 was globally characterised by turbulence. The oil price has undergone changes leading to extremes on both ends, with neither of them being predicted by analysts. Similar developments could be observed on the stock market. In contrast to the current economical turbulence, the WIT consortium can look back to a steady and successful year 2008.

With eighteen sponsors, we have reached a historical high. This is the largest number of sponsors we have had since the consortium was established in 1997. In addition to the funding from our sponsors, all WIT research teams are supported through governmental and public agencies as well. This support not only covers staff salaries, infrastructure, computers, and CPU time on high performance computing systems, but it also provides for dedicated research projects. All of these contributions enable us to maintain an excellent and creative research environment.

Not surprisingly, these conditions are also very attractive for students. Thanks to close cooperation with our sponsors, our students not only receive a high level education but also have the opportunity to gain insight and experience working for the exploration industry.

As in previous years, WIT researchers were very active in 2008. They have participated in many meetings, workshops, and conferences including the EAGE and SEG annual meetings, as well as given invited presentations. You can find a detailed account of our activities and publications in 2008 on the WIT web site at `www.wit-consortium.de`

The 2008 Annual Report contains the results of our work. You will find not only a continuation and maturation of previous results but also new topics on leading edge methods for modelling and imaging in acoustic and elastic media. The further development of the CRS work-flow also plays a major role in the report. Considerable progress has been made on the use of CRS attributes for multiple suppression and the potential of partial CRS stacks for amplitude-preserving data regularisation and pre-stack data enhancement. For the second year now, you will find research results on full wave form inversion. We have also continued our work in the field of imaging with passive seismics. Finally, the topic of converted waves was picked up by the Hamburg and Campinas WIT teams. It will take on a prominent role in the future; as will the research related to wave-equation migration.

The year 2008 also held a number of intense collaborations between the WIT research teams as well as between WIT research teams and sponsors. Visits of sponsors and internships of students have led to fruitful activities. A detailed account of the collaborations will be given during the 2009 Annual Meeting. In the future, we will also document such activities on the WIT web site for convenience. To achieve this goal, a major overhaul of the WIT web site is planned for 2009.

The support we receive through the WIT consortium has played a significant part in the research documented in this report. It helps us on our mission to perform leading edge research in seismic exploration and to educate the next generation of geophysicists. On behalf of all WIT research teams, I want to express our sincere appreciation for your continuous support on this mission.

Dirk Gajewski

Summary: WIT report 2008

IMAGING

Amazonas et al. apply the complex Padé approximation to the acoustic wave equation for vertical transversely anisotropic (VTI) media to derive a more stable FD and hybrid FFD/FD migration for such media. Synthetic examples demonstrate the improved stability of the complex migration algorithms as compared to their real counterparts.

Amazonas et al. implement SSPSPI and complex Padé FFD migrations using the amplitude corrections determined by the true-amplitude one-way wave equations. They demonstrate the amplitude gain using these amplitude corrections on the synthetic SEG/EAGE salt model.

Anikiev et al. apply a modified diffraction stack for the localization of microtremors in a complex heterogeneous medium. The study shows that stacking is a suitable tool to localize acoustic emissions in strongly heterogeneous media. However, first arrival traveltimes might not be adequate to localize low frequency microtremor data even if the correct velocity model is assumed.

Baykulov and Gajewski performed partial CRS stacking to enhance the quality of sparse low fold seismic data. They describe an algorithm, which allows to generate NMO-uncorrected gathers without the application of inverse NMO/DMO. Gathers obtained by this approach are regularised and have better signal-to-noise ratio compared to original common-midpoint gathers. The method is verified on 2D synthetic data and applied to low fold land data from Northern Germany. Prestack depth migration of the generated partially stacked CRS supergathers produces significantly improved common-image gathers as well as depth migrated section.

Chira-Oliva et al. proposed the fourth-order CRS traveltime expansion as a new alternative for the seismic stacking. The fourth-order CRS operator tested on simple synthetic models provide good stacked sections with a higher S/N. Then, the investigated CRS operator simulates better the ZO sections than the conventional CRS operator within larger offsets.

Dümmong and Gajewski are presenting a continued development of a multiple suppression method using CRS attributes. Multiples are predicted on the CRS stacked section, prediction errors are addressed and prestack seismograms generated with CRS attributes are adaptively subtracted from the original data.

Garabito et al. propose a new method for migrating two-dimensional (2D) multicoverage seismic data to zero-offset section, i.e., Migration to Zero-Offset (MZO). It is based on the Commom Reflection Surface (CRS) stack formulas that are used to approximate the diffraction stack operator, and to produce a demigration of the zero-offset stacked data. This new approach, so called CRS-MZO, is applied to synthetic and real land datasets.

Köhn et al. discuss the first results of elastic full waveform tomography of synthetic multicomponent reflection seismic data. Starting from a long wavelength model for the elastic material parameters the waveform tomography result can resolve details below the seismic wavelength. The influence of different parameterizations and preconditioning operators on the tomography result will be discussed.

Kurzmann et al. investigate the performance of full waveform tomography (FWT) for a transmission and a reflection geometry. Especially the progress of the FWT for a reflection geometry is very sensitive to the starting model. Additionally we show possibilities to increase the performance of our time-domain implemention, such as step length optimization and shot parallelization.

Schleicher et al. show that image-wave propagation in the common-image gather (CIG) domain can be combined with residual-moveout analysis for iterative migration velocity analysis. For this purpose, the CIGs obtained by migration with an inhomogeneous macrovelocity model are continued starting from a constant reference velocity. The interpretation of continued CIGs as obtained from residual migrations leads to a correction formula that translates the residual flattening velocities into absolute time-migration velocities.

Schleicher and Costa demonstrate that information about the migration velocity can be extracted from path-integral migration. The idea of path-integral imaging is to sum over the migrated images obtained for a set of constant migration velocities. By doing so twice, weighting one of the stacks with the velocity value, the stationary velocities that produce the final image can then be extracted by a division of the two images.

Soleimani and Mann combine concepts of DMO correction and CRS stack to properly handle conflicting dip situations during stacking. Based on the CRS traveltime approximation for diffraction events, coherence analysis and stacking are performed separately for any fixed plausible emergence angle within a given range, followed by a superposition of all contributions. For synthetic data we demonstrate the enhancement of diffraction events in the stacked section and their undisturbed superposition with other events. For real data, the approach leads to an improved imaging of faults in the poststack migration results.

Vanelle and Gajewski suggest a new method to combine PP and PS data to obtain a shear velocity model. The method is based on the NIP wave tomography and uses wave field attributes determined with common reflection surface stacking of the data in combination with ray tracing.

Veile and Mann discuss the double diffraction stack method in the context of limited-aperture Kirchhoff migration. The common-reflection-surface stack method provides useful attributes to estimate the size of the optimum migration aperture for zero-offset and its displacement with increasing offset. In practice, the center of the aperture, the location of the stationary point, has to be associated with the corresponding depth point in the migrated domain, e. g. by numerical calculation of the dip of the migration operator. We investigate whether the double diffraction stack is a reliable alternative for that purpose and present first preliminary results.

MODELING

Kaschwich and Bolin: Illumination maps are a useful tool for survey planning and for QC of amplitudes picked on selected target horizons. The Simulated Migration Amplitude technique (SMA) is a ray-based un-weighted Kirchhoff migration of synthetic data around seismic reflectors. In order to enhance illumination mapping for hydrocarbon exploration and reservoir imaging in complex subsurface structures, we present the extension of the SMA to converted waves and in anisotropic media and incorporate noise and attenuation effects.

OTHER TOPICS

Gajewski et al. present a passive seismic real data case study of a hydraulic injection experiment at the German continental deep drilling site KTB and show the influence of anisotropy on the localization of events. For this data the location of events and the shape of the event cloud are substantially altered if the anisotropy is neglected.

Lima et al.: presents a new interactive platform, called BOTOSEIS, that is used to facilitate the application of the Seismic Unix (SU) package, which was developed by the Center of Wave Phenomena (CWP) of the Colorado School of Mines. The BOTOSEIS is built for applying the SU programs by means of graphical user interface. It is developed in Java programming language. The BOTOSEIS platform deserves for creating and managing projects, lines and flowcharts from only one interactive environment. By using the BOTOSEIS the user can run and control several process at one time, and also easily include new SU based applications.

Santos et al. show that the complete set of CRS parameters can be extracted from seismic data by an application of modern local-slope-extraction techniques. The necessary information about the CRS parameters is contained in the slopes of the common-midpoint and common-offset sections at the central point. In this way, the CRS parameter extraction can be sped up by several orders of magnitude.

Ursin et al. extend the kinematical approach of the PP + PS = SS method to second-order traveltimes of the SS-waves. By using the concept and properties of surface-to-surface propagator matrices, the propagator matrix of the SS-wave of a target reflector is explicitly obtained from the propagators of the PP- and PS-wave of the same reflector. Given that the elastic parameters describing S-wave velocities are known along the acquisition surface, this permits to determine the relative geometric spreading of the SS-wave, leading to a better reconstruction of the amplitude of the simulated SS-wave. Under isotropic conditions, the second-order derivatives of the SS-traveltime can, in the same way as for PP-waves, be applied to a tomographic estimation of the S-wave velocity model.

Vanelle and Gajewski suggest a method to evaluate Snell's law in the presence of anisotropy. Their technique is based on first-order perturbation theory and can be used to solve the reflection/transmission problem at a boundary between two anisotropic media with arbitrary symmetry.

The Wave Inversion Technology (WIT) Consortium

The Wave Inversion Technology Consortium (WIT) was established in 1997 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, members of the Institute of Geophysics of the TU Bergakademie Freiberg, Germany, and of NORSAR joined WIT as research affiliates.

The WIT Consortium offers the following services to its sponsors:

a.) research as described in the topic "Research aims" below;

b.) deliverables;

c.) technology transfer and training.

RESEARCH AIMS

The ultimate goal of the WIT Consortium is a most accurate and efficient target-oriented seismic modeling, imaging, and inversion using elastic and acoustic methods. Traditionally, 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. Today an understanding is emerging on how sub-wavelength features such as small-scale disorder, porosity, permeability, fluid saturation etc. influence elastic wave propagation and how these properties can be recovered in the sense of true-amplitude imaging, inversion and effective media.

The WIT consortium has the following main research directions, which aim at characterizing structural and stratigraphic subsurface characteristics and extrapolating fine grained properties of targets:

1. Multi-parameter stacking and inversion
2. Macromodel determination
3. Seismic image and configuration transformations (data mapping)
4. True-amplitude imaging, migration and inversion
5. Seismic and acoustic methods in real media
6. Passive monitoring of fluid injection and production
7. Fast and accurate seismic forward modeling
8. Modeling, imaging and inversion in anisotropic media

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COMPUTING FACILITIES

The Hamburg group has access to a 24 nodes (8 CPUs and 64 GB each) NEC SX-6 supercomputer at the German Computer Center for Climate Research (Deutsches Klimarechenzentrum, DKRZ) for numerically intensive calculations, and also to a SUN Linux cluster with 256 nodes (2 dual core Opteron, 16 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 SUN workstations and Linux PCs.

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.

In Karlsruhe, the research project uses computer facilities that consist of mainly Hewlett-Packard, Silicon Graphics, and Linux workstations. These are networked with a local compute server, a Silicon Graphics Origin 3200 (6 processors, 4 GB shared memory). For large-scale computational tasks, a Hewlett-Packard XC 6000 Linux cluster is available on campus. It is currently equipped with 128 nodes (allowing a theoretical peak power of 1.9 Tflops), 2 TB memory, and a 10 TB Lustre file system.

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.

The Institute of Geophysics at TU Bergakademie Freiberg is equipped with 21 Linux PCs with Intel dual- and quad-core processors. They are linked by GBit Ethernet and are used for small-scale computations. For large-scale computations, the Freiberg group has access to the Chemnitz High performance Linux Cluster (CHiC). Furthermore, it is planned to use the SGI Altix 4700 at the ZIH (Zentrum für Informationsdienste und Hochleistungsrechnen), TU Dresden.

WIT research personnel

Rafael Aleixo received a B.Sc. (2003) in Mathematics and an M.Sc. (2007) in Applied Mathematics from University of Campinas (UNICAMP), Brazil. Since 2007 he has been a Ph.D. student at UNICAMP. His research interests include seismic imaging methods, seismic modeling, anisotropy, and image-wave propagation. He is a member of SEG, EAGE, SBGf, and SBMAC.

Daniela Amazonas graduated in Mathematics (2004) and received her M.Sc. in Geophysics (2007), both from Federal University of Pará (UFPa), Belém, Brazil, where she is working toward a Ph.D. in seismic methods. Her research interests are concentrated in wave-equation migration methods. She is a member of SEG and SBGf.

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.

Mikhail Baykulov received his diploma in geophysics in 2004 from Saratov State University, Russia. He confirmed his diploma in 2005 at the University of Hamburg with a thesis on the "Application of the CRS stack to reflection data from the crystalline crust of Northern Germany". Since 2005 he has been a Ph.D. student at the University of Hamburg. His present research interests include CRS imaging, migration velocity analysis, and depth inversion applied to deep seismic reflection data.

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.

Thomas Bohlen received a Diploma of Geophysics (1994) and a Ph.D. (1998) from the University of Kiel, Germany. Since 2006 he is a Professor of Geophysics at the Institute of Geophysics at the Technical University Freiberg where he is the head of the seismics and seismology working groups. 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).

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 his is Associate Professor in the Geophysics Department, UFPA. His fields of interest include seismic anisotropy, traveltime tomography and seismic modeling.

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.

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 Ekaterinburg (Russia) in 1997. Currently, he is a Diploma student in Geophysics at the University of Hamburg. His primary research interest is seismic imaging, and his Diploma thesis deals with CRS stacking and time migration.

Denise De Nil received a diploma in geophysics from Ruhr-Universität Bochum in 2001 with a theoretical and numerical thesis on surface wave progation. From 2001 to 2006 she has been a research associate at Christian-Albrechts-Universität zu Kiel, where she has been involved with the development of new analyzing techniques for low quality data in ocean bottom, tunnel and borehole seismics. Since 2006 she is a research associate at Technische Universität Bergakademie Freiberg. Her present research focusses on tunnel seismics and numerical modeling of seismic wave propagation. She is a member of Deutsche Geophysikalische Gesellschaft.

Stefan Dümmong received his diploma in Geophysics in 2006 from the University of Hamburg. Since 2006 he is PhD student in the Institute of Geophysics at the University of Hamburg. His research interests are imaging procedures and multiple removal techniques. He is a member of EAGE.

Tatjana Feskova is diploma student at the Geophysical Institute, Karlsruhe University. Since 2006 she is a research student in the working group 'Seismic rock physics'. Her research topics include finite-differecne modeling and effective media theories.

Dirk Gajewski received a diploma in geophysics in 1981 from Clausthal Technical University and a PhD from Karlsruhe University in 1987. Since 1993, he has been associate Professor (Applied Geophysics) at Hamburg University. After his PhD, he spent two years at Stanford University and at the Center for Computational Seismology at the Lawrence Berkeley Lab in Berkeley, California. From 1990 until 1992, he worked as an assistant professor at Clausthal Technical University. His research interests include high-frequency assymptotics, seismic modeling, and processing of seismic data from isotropic and anisotropic media. Together with Ivan Psencîk, he developed the ANRAY program package. He is a member of AGU, DGG, EAGE, and SEG, and serves as an Associate Editor for Geophysical Prospecting (section anisotropy).

German Garabito received his BSc (1986) in Geology from University Tomás Frias (UTF), Bolivia, his MSc in 1997 and PhD in 2001 both in Geophysics from the Federal University of Pará (UFPA), Brazil. Since 2002 he has been full professor at the geophysical department of UFPA. His research interests are data-driven seismic imaging methods such as the Common-Refection-Surface (CRS) method and velocity model inversion. He is a member of SEG, EAGE and SBGF.

Håvar Gjøystdal is Research Manager of Seismic Modelling at NORSAR in Kjeller, near Oslo. He also holds an adjunct position of Professor of Geophysics at the Department of Earth Science, University of Bergen. In 1977 he joined NORSAR and started building up research activities within the field of seismic modelling, which to-day include both R&D projects and services and software products for the petroleum industry. Key topics are ray tracing, seismic tomography, and time lapse seismic modelling. He is a member of SEG and OSEG.

Anderson B. Gomes obtained his Bachelor Degree in Mathematics in 2004, and his Masters Degree in Geophysics in 2006, both in the University of Pará (UFPA), Brazil. Presently, he is a doctor student in the Graduate Course in Geophysics of UFPA in the area of seismic methods applied to oil and gas exploration. He is member of SEG and of SBGF.

Ellen de Nazaré Souza Gomes received her diploma in Mathematics in 1990 from University of Amazônia. She received her Master degree in Applied Mathematics in 1999 from the Mathematics Departament, Federal University of Pará. In 2003, she received her Doctor degree in Geophysics from Geophysics Department at the same University. Her fields of interest are anisotropy and seismic modeling. She has been professor at the Federal University of Pará since 1997.

Olaf Hellwig studied geophysics at TU Bergakademie Freiberg, Germany. Between 2004 and 2005 he spent one year at NTNU Trondheim, Norway. He received his diploma in geophysics in 2007. Since 2008 he is Ph.D. student in the Institute of Geophysics at TU Bergakademie Freiberg. His research interests focus on modeling of seismic wave propagation in boreholes and imaging of reflectors ahead of the drill.

Einar Iversen received Cand.scient. (1984) and Dr. philos. (2002) degrees in geophysics, both from the University of Oslo, Norway. He has worked for NORSAR since 1984 and is currently a senior research geophysicist within NORSAR's Seismic Modeling Research Programme. He received the Best Paper Award in Geophysical Prospecting in 1996. His professional interests are seismic ray theory and its application to modeling, imaging, and parameter estimation. He is a member of SEG and EAGE.

Stefan Jetschny received a Bachelor in Geophysics in 2003 at the TU Bergakademie Freiberg. After finishing internships at RWE Dea, Hamburg, Baker Hughes Inteq, Celle and Eastern Atlas, Berlin, he continued his studies in 2004 at the Institute of Geophysics, TU Bergakademie Freiberg. In 2005 he wrote his Diploma thesis at Baker Hughes Inteq in Houston, USA and received a Diploma (Master) in Geophysics in 2006 at the TU Bergakademie Freiberg. His research interests focus on LWD and wireline imaging tools, processing of borehole imaging data, 2D/3D seismic modelling of full elastic wavefields and the propagation of tunnel surface-waves. He is a member of DGG, SEG, AGU, EAGE and IAMG.

Shin Duck Kang is a new PhD candidate in the Karlsruhe WIT group. His field of interest is the implementation and application of a CRS-based 3D inversion scheme using model-based diffraction traveltimes. This strategy allows a refinement of the results of 3D NIP-wave tomography beyond the second-order approximation inherent to the CRS methodology. He is member of EAGE and SEG.

Tina Kaschwich received her diploma in geophysics (2001) and a Ph.D. in geophysics (2006), both from the University of Hamburg. Since 2005 she has been a research fellow at the seismic modelling group at NORSAR, Norway. Her research interests are ray tracing and wavefront construction methods, imaging and illumination studies for survey planning and quality control for different model and wave types. She is a member of EAGE, OSEG and SEG.

Boris Kashtan obtained his MSc in theoretical physics from Lenigrad State University, USSR, in 1977. A PhD (1981) and a Habilitation (1989) were granted to Boris by the same University. He is Professor at St. Petersburg State University, Russia, and since 1996 Boris is head of the Laboratory for the Dynamics of Elastic Media. His research interests are in high frequency methods, seismic modeling, inversion, anisotropy, and imaging. He regularily visits Germany and spends from weeks to several month at the University of Hamburg every year.

Daniel Köhn received his diploma in geophysics from Kiel University in 2005 with a thesis on modeling of elastic waves by finite differences on a spatially variable grid. From 2005 to 2006 he has been a PhD student at the Institute of Geophysics at Kiel University, where he has been involved in the "Scherseis 3D" project funded by the German Research Society (DFG). Since 2007 he is a research associate at the Technische Universität Bergakademie Freiberg. His research interests are Time-Domain-Full-Waveform-Inversion and numerical modeling of seismic wave propagation.

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Isabelle Lecomte received an M.S. (1987) in geophysics, an Engineering Geophysics (1988) degree, and a Ph.D. (1991) in geophysics, all from the University of Strasbourg, France. In 1988-1990, she worked as a Ph.D. fellow at IFREMER/University of Strasbourg. In 1991-1992, she was a post-doctoral fellowship at NORSAR, Norway (grant from EU in 1991, and the Research Council of Norway in 1992). Since 1993, she joined NORSAR permanently as a senior research geophysicist in R&D seismic modelling, and is now a principal research geophysicist. Since 2003, she is also a part-time researcher at the International Centre for Geohazards (ICG, Oslo), acting as the theme coordinator for geophysics. She received the EAGE Eötvös award (best paper, Geophysical Prospecting) in 2001. Her main research interests are seismic modelling (finite-differences, ray-tracing, Eikonal solvers, hybrid RT-FD), with applications to seismic reflection, refraction and tomography in oil exploration, and seismic imaging (generalized diffraction tomography) including resolution studies. More recent studies concerned seismic imaging with SAR-type processing, and simulation of PSDM images. She is a member of EAGE, OSEG, and SEG.

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