Wave Inversion Technology Consortium

Campinas Karlsruhe Hamburg

Wave Inversion Technology
established 1996 in Karlsruhe, Germany

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Institute of Geophysics
University of Hamburg

Hamburg, Germany

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

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Preface

The University of Hamburg as the hosting organization of the WIT project is committed to sustainability, and all faculties have taken great strides towards sustainability in research and teaching. The WIT team in Hamburg is also part of the Center for Earth System Research and Sustainability (CEN), which is a central research center at the University of Hamburg.

Sustainability in research usually also requires sustainability in funding since the in-depth holistic or integral view on a subject is also a matter of time. The public funding schemes of most projects are usually of a short duration, i.e., funding periods rarely exceed more than 2-3 years. To achieve sustainable results in such a time frame is a challenge unless you manages to generate a series of follow-up projects on related topics. If you are lucky, you may be part of a priority program, which may last up to 6 years. If you are even luckier, you may be involved in a Collaborative Research Center, which can receive funding for more than 12 years. With the implementation of the so-called excellence initiative in Germany the most sustainable funding scheme was implemented. All longer lasting public funding schemes usually require the research of large teams of interdisciplinary nature on a common general subject.

WIT looks back on 20 years of research to develop the most accurate and efficient target-oriented seismic modeling, imaging, and inversion using elastic and acoustic methods. For many students, it often comes as a surprise that the industry-funded WIT project with its fairly narrow focus is the longest-lasting research project in the entire Department of Geosciences. We proudly conclude today that WIT research has made a sustainable impact in the international exploration community. The current WIT research is at an all-time high, however, it also coincides with the worst regression our industry has experienced over the last 20 years. It would be an understatement to describe the current funding situation at WIT as challenging. The sustainability of the WIT research is at stake.

Despite this uncomfortable funding situation, 2016 has seen a substantial progress and research output that is partly documented in the 200 pages of this report. We congratulate our graduate students Ivan Abakumov, Parsa Bakhtiari Rad, Manizheh Vefagh Nematollahy, Jan Walda, and Yan Yang for successfully defending their PhD theses, which you can find as electronic supplements to the report. In addition to publications in international journals, we had seven papers at the EAGE meeting in Vienna, Austria, and ten presentations at the SEG meeting in Dallas, Texas, USA. Last but not least, we are extremely pleased that WIT founding member Martin Tygel from WIT Campinas was selected as the 2017 SEG Latin America Honorary Lecturer, which constitutes a major honor and recognition of excellence. The subject on Martin's nomination was "Multiparametric traveltimes: Concepts and applications."

For 2017, among others, a workshop on "Linking Active and Passive Seismics" organized by Benjamin Schwarz (now at Oxford University), Ulrich Zimmer (Shell, Houston, USA), and Dirk Gajewski is scheduled for the EAGE meeting in Paris, France.

On behalf of the WIT teams, researchers, and students, I express my sincere gratitude to our sponsors and supporters. More than ever we rely on your support to keep WIT a sustainable research project.

Hamburg, 2017/20/02, Dirk Gajewski

Summary: WIT report 2016

IMAGING

Abakumov et al. propose a new type of auxiliary medium which utilize anisotropy to account for heterogeneity of the subsurface. The new auxiliary anisotropic medium incorporates properties of effective and optical auxiliary media and enables the derivation of the 3D extensions of the existing multidimensional moveout approximations.

Abakumov et al. introduce a formulation of the shifted hyperbola that is valid in three dimensions. The new 3D shifted hyperbola, is more accurate than the conventional 3D NMO. Hence, it bears the potential to provide an improved stacked volume and more reliable stacking parameters.

Barrera et al. show the derivation and approximation of the one-sided correlation-based interferometry equation for surface-data redatuming. Their numerical examples demonstrate that in a homogeneous overburden the resulting single-boundary direct-wave redatuming works perfectly. However, if the overburden is inhomogeneous, it suffers from artifacts, which get even worse if the complete wavefield is used instead of the direct wavefield. Therefore, this interferometric redatuming technique should always be applied using direct waves only.

Barrera et al. propose a new methodology to recover the up- and downgoing wavefield components at a new datum in depth from surface seismic data. The procedure is based on the one-way reciprocity theorems of convolution and correlation type and makes use of two wavefield estimates that can be simulated with the knowledge of an overburden model only. Their numerical examples demonstrate that the procedure works as theoretically predicted and that it does not suffer from the kind of non-physical events that are common in correlation-based redatuming.

Bauer et al. try to improve the resolution of velocity models obtained from wavefront tomography by systematically incorporating low-amplitude diffractions into the inversion. Simple and complex results suggest that utilizing diffractions for velocity inversion may help to improve the lateral resolution of the obtained velocity models as well as the results of depth migration.

Ferreira et al. develop a table-based ray-theory algorithm to be employed in AVO inversion by global optimisation using a genetic algorithm. The forward modelling algorithm has shown excellent performance, because it allows a large number of members in the population of the genetic algorithm. If used with the correct constraints, the algorithm is capable of recovering the original model with accuracy. However, without constraints, the non-uniqueness of the problem can cause the algorithm to converge to alternative, equally well-fitting solutions.

Gomes et al. implement the image continuation technique in the depth CIG domain to develop a rather inexpensive routine for migration velocity analysis starting at an extremely simple initial velocity model. Synthetic data examples demonstrate the method's potential of generating first migration velocity models in depth.

Li et al. compare three migration-based microseismic source location methods, namely, diffraction stacking, semblance-weighted stacking and cross-correlation stacking. They suggest that the stacking of squared values of waveforms has better imaging resolution than stacking of absolute values for all methods, when there is no polarization corrections. Diffraction stacking and semblance-weighted stacking share the same stacking operator, and the latter can suppress the noise better. Cross-correlation stacking utilizes the interferometric migration operator and exhibits more reliable results when considering velocity uncertainty. The numerical results demonstrate the feasibility and robustness of migration-based methods for locating low signal-to-noise ratio (S/N) microseismic events.

Vanelle et al. extend the Common Reflection Surface operator to account for arbitrary anisotropy in the zero-offset as well as finite-offset situation. The derivation is based on geometry and ray theory. The resulting expressions have the same shape and number of coefficients as their isotropic counterparts as long as they are expressed by traveltime derivatives. However, the expressions for the coefficients in terms of wavefront attributes differ from the isotropic case and additional parameters need to be introduced to account for the anisotropy, e.g., the zero-offset operator in 2D requires four attributes instead of three in the isotropic case. Numerical examples demonstrate the accuracy of the new operator.

Walda et al. compare multiparameter methods that can be parametrized by the same wavefront attributes, which are the common-reflection-surface (CRS), implicit CRS, non-hyperbolic CRS and multi-focusing. CRS-type operators use a velocity shift mechanism to account for heterogeneity. Multifocusing on the other hand uses a different mechanism: a shift of reference time. We formulate multifocusing such, that it uses the same mechanism as the CRS-type operators and compare them on a marine data set. In turn, we investigate the behavior of time-shifted versions of the CRS-type approximations. In order to provide fair comparison, we use a global optimization technique, differential evolution, which allows to accurately estimate a solution without initial bias. Our results show, that the velocity shift mechanism performs, in general, better than the one incorporating time shift. The non-hyperbolic operators are also less sensitive to the choice of aperture and perform better in the case of diffractions than conventional CRS, since diffractions are of higher order. Since the computational cost of non-hyperbolic CRS is almost the same as the one of conventional hyperbolic CRS but generally leads to a superior fit, we recommend its use in future.

Wißmath et al. present an extension of the prestack data enhancement method with partial CRS stacks, where finite-offset attributes are used instead of zero-offset attributes. In order to reduce the computational costs associated with finite-offset CRS processing, they suggest to obtain the finite-offset attributes by extrapolation from zero-offset attributes and a subsequent local optimisation. They investigate two different approaches to such an attribute prediction, namely a first-order prediction combined with a truncated operator, and a prediction that uses the first- and second-order attributes with the full operator. Application to marine field data confirms that partial stacking with finite-offset attributes using either of the two approaches leads to enhanced quality of the newly-generated prestack data.

Xie and Gajewski extend the partial 3D CRS method into a 5D interpolation and regularization technique, where the CRS wavefront attributes are determined by a global search strategy, e.g., the evolutionary-based DE algorithm. Then an azimuth-based regularization within each 3D CMP gather is presented. With the 3D SEG/EAGE C3WA data as an example, our results indicate that the partial 3D CRS can perform well in the 5D interpolation and regularization if a global search strategy together with the azimuth-based regularization are considered.

FULL WAVEFORM INVERSION

Gassner and Bohlen present the application of 2D acoustic full waveform inversion to an OBS data set recorded in the Black Sea. The aim of the study is to recover elastic parameters, e.g. v_P, of the subsurface to characterize sub seafloor gas hydrate deposits. The recovered compressional wave velocity distribution gives hints on the distribution of hydrates and the occurrence of free methane gas.

Thiel and Bohlen apply the Full Waveform Inversions (FWI) on the problem of reconstructing salt layers. Acoustic FWI was performed for a marine 2D field data profile. They show the successful inversion of a salt layer in the synthetic and field data case. During the inversion process wavefield separation was performed and Flooding Technique used.

Wittkamp and Bohlen investigate the performance of the individual 2-D elastic full-waveform inversion (FWI) of Rayleigh and Love waves as well as the feasibility of a simultaneous joint FWI of both wave types. In synthetic reconstruction tests they compare the performance of the individual wave type inversions and explore the benefits of a simultaneous joint inversion. Subsequently, they recorded a near-surface field dataset to verify the results by a realistic example.

The Wave Inversion Technology (WIT) Consortium

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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 2007, NORSAR joined WIT as research affiliate, and in 2010, Fraunhofer ITWM joined WIT, also 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. Some of the topics are studied by more than one team, applying different approaches. The WIT research is divided into five subgroups:

Processing and Imaging

The Common Reflection Surface (CRS) concept plays a key role in the WIT research on processing and imaging. The WIT hyperbolic CRS and non-hyperbolic i-CRS stacking operators are based on this concept and represent the backbone of many research topics.

- global (ZO CRS) vs. local (CO CRS) approximations
- estimation of CO CRS attributes from ZO attributes
- amplitude-friendly CRS processing
- improved conflicting dip processing
- 3-D i-CRS operator
- wavefield decomposition using stacking attributes (multiples, reflections, diffractions)
- utilizing super resolution
- pre-stack diffraction/reflection separation
- 5-D CRS and i-CRS interpolation and pre-stack data enhancement
- improved coherence measures (MUSIC, cross-correlation, analytical trace, etc.)
- optimization of multi-dimensional coherence analysis
- data driven isotropic and anisotropic time migration
- wavefield decomposition and filtering in the CSP domain
- inverse CSP mapping
- CRS and diffraction processing of 3-D hard rock data
- angle domain migration
- beam migration
- image wave re-migration
- migrated-domain CRS methods

Model Building

Most of our model building approaches also exploit the CRS concept, which may be applied in the data or time migrated domain.

- diffraction focusing velocity analysis
- diffraction stereotomography
- passive seismic data velocity model update
- CRS based time to depth conversion
- tomographic inversion of stacking attributes

Full Waveform Inversion

Research on Full Waveform Inversion (FWI) is moving toward applications to marine reflection seismic data and near surface seismic data (surface waves) and three-component Vibroseis data acquired in crystalline rocks.

- development of robust preprocessing of seismic data for FWI
- multi-parameter FWI
- source wavelet inversion
- accurate methods for geometrical spreading correction
- implementation of 3-D acoustic/elastic/viscoelastic FWI on HPC machines
- FWI in viscoelastic media
- optimization of Finite-Difference forward solvers used in FWI with respect to MPI communication, higher order time integration, variable spatial discretization and smooth free surface topography
- application of pseudo spectral methods in FWI

Modeling and RTM

In modeling and RTM we use FD, FE, and pseudo spectral approaches. Optimizations of the computational effort is highest on the agenda.

- 2-D and 3-D RTM for VTI and TTI media (spectral methods)
- 2-D and 3-D acoustic and elastic RTM (FD methods)
- finite element (FE) elastic wavefield modeling
- computational optimizations of FD and spectral method approaches for acoustic, elastic, and anisotropic media, including benchmarking
- improved one-way wave equation
- reflection impedance description of reflection coefficients
- tuning effects in AVO and AVA

Passive Seismics

Passive seismic signals as a diffraction event provide the link to reflection seismics. Located diffractions or micro-earthquakes provide natural Green's functions for reflection imaging.

- optimization of model domain stacking and time domain localization approaches
- high resolution full waveform relative event localization
- microtremor localization
- interferometric re-localization
- development of fast time-domain localization technique
- localization uncertainties (apertures, velocities, bandwidth, acquisition footprint)
- real time processing methodology

WIT STEERING COMMITTEES

Internal Steering Committee

Name	WIT team
Thomas Bohlen	Karlsruhe
Norman Ettrich	ITWM
Dirk Gajewski	Hamburg
Tina Kaschwich	NORSAR
Jörg Schleicher	Campinas
Martin Tygel	Campinas
Claudia Vanelle	Hamburg

External Steering Committee

Name	Sponsor
Mikhail Baykulov	Addax Petroleum Services
Shinichi Itoh	Hanshin Consultants
Dan Grygier	Landmark Graphics Corporation
Rune Øverås, Jon Sandvik	PSS-Geo
Henning Trappe	TEEC

COMPUTING FACILITIES

The Hamburg group has access to a 3.000 nodes (100.000 cores in total) bullx B700 DLC sytem at the German Computer Center for Climate Research (Deutsches Klimarechenzentrum, DKRZ) for numerically intensive calculations. It is equipped with 240 TeraByte of memory and its peak performance is 3.14 PetaFlops. For medium sized problems there are an IBM Xeon-based 64 cores login node with 512 MB memory and four compute nodes for batch processing accessible. Additional computer facilities consist of several Linux workstations and Linux PCs.

The research activities of the Campinas Group are carried out in the Computational Geophysics Laboratory. The Lab has 15 Linux PC workstations connected by a dedicated high-speed 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 in the new facilities of the Center of Petroleum Studies went fully operational in 2012. The new Lab extension counts on another 30 Linux PC workstations that rely on resources shared by a high-performance server and provide access to a 3Tflops cluster with 2TB RAM. The LGC also has remote access to the computing facilities of the Petrobras Research Center in Rio de Janeiro.

The computing facilities of the WIT group in Karlsruhe consist of several local and external clusters, Linux workstations and Linux PCs. For large-scale computational tasks, the WIT group in Karlsruhe co-funded and has exclusive access to the SCC Institutscluster 2 (IC2) with 480 nodes, each consisting of 16 cores. The performance is 135.5 TFlops and 28 TeraByte of memory are available. About 300 Terabyte disk space are available via a Lustre file system and an InfiniBand interconnect. The group has also access to one of the most powerful cluster at the KIT, the ForHLR (522 nodes, each with 20 cores, 216 TFlops in total and 41 TB memory), funded by the state of Baden-Wuerttemberg and the German research foundation (DFS). We have now access to the second phase of the ForHLR, the ForHLR II, which was launched in 2016. It is composed of 1152 nodes with 20 cores each. Together with several fat nodes this cluster obtains a perfomance of 1 PetaFlops. Furthermore, successful project proposals at the Jülich Supercomputing Centre (JSC) have granted access to a large volume of computing hours for one of the newest and best supercomputers in Europe, the JURECA Clustercomputer. This supercomputer consists of 1872 nodes, each with 24 cores with a theoretical computational power of 1.8 PetaFlops. In 2015 the WIT group in Karlsruhe also acquired the new SGI UV20. With its 96 cores and 512 GB shared memory it is ideal for small test computations and code development. The cluster is already used extensively by our Master and PhD students.

Fraunhofer ITWM builds up new compute clusters early 2014. The largest machine consists of 192 dual Intel Xeon E5-2670 ("Sandy Bridge") (i.e. 16 CPU cores per node) with 64 GB RAMeach, 300 GB HDD, 2x Gigabit Ethernet and FDR Infiniband interconnect. In total, 3072 CPU cores, 12 TB main memory, and 57 TB disk space. Estimated peak performance is 56 TFlops. In addition, 4 quad Intel Xeon E5-4650L ("Sandy Bridge") (i.e. 32 CPU cores per node) with 256 GB RAM, 2x 500 GB HDD will be available. The storage system consists of 12 storage servers, connected via FDR Infiniband an 10 Gigabit Ethernet with a total capacity of 200 TB via the Fraunhofer file system. In addition, the HPC department of ITWM runs a cluster with 92 compute nodes, among them 60 Intel Xeon E5-2680 IvyBridge nodes. Disk capacity will be 270 TBytes.

WIT research personnel

Ivan Abakumov received his MSc from St. Petersburg University in 2013 and defended his Ph.D. thesis at the University of Hamburg in 2017. His research interests are time imaging, converted waves, time-lapse seismic, full waveform inversion, geophysical data processing and computer programming. Ivan is a student member of EAGE, SGE and SPE.

Nikolaos Athanasopoulos, M.Sc. (IDEA LEAGUE Joint Master in Applied Geophysics, 2015), started his Ph.D. studies at the Karlsruhe Institute of Technology (KIT) in 2015. He is working in the field of Full Waveform Inversion (FWI). His research focus is the elastic FWI of shallow seismic surface waves and its application in field data. He is member of the EAGE.

Parsa Bakhtiari Rad received a B.Sc. in Mine Exploration Engineering from the Islamic Azad University, Iran, in 2005 and received a M.Sc. in Exploration Seismology in 2008 from the same university with a thesis title "Application of Karhunen-Loeve Filter in Multiple Attenuation Camparison with Radon Transform on Seismic Reflection Data". He also worked for almost three years as a Data Analyst in 2D/3D seismic data processing center of OEOC-CGG companies in Tehran and as a geophysicist in data acquisition fields for geophysical section of National Iranian Oil Company(NIOC) as well. In 2012, he enrolled at the University of Hamburg as a Ph.D. student in Geophysics, where he defended his thesis in 2016. His main research interest is processing and imaging of seismic diffractions.

Alexander Bauer received an M.Sc. in Geophysics from Hamburg University in 2014 and is currently a PhD student in the Hamburg WIT group. His research interests focus on seismic diffraction imaging and velocity model building. He is a member of DGG, EAGE and SEG.

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 married in 2015 and changed her name to Martina Glöckner.

Thomas Bohlen received a Diploma of Geophysics (1994) and a Ph.D. (1998) from the University of Kiel, Germany. From 2006 to 2009 he was Professor of Geophysics at the Institute of Geophysics at the Technical University Freiberg where he was the head of the seismics and seismology working groups. Since 2009, he has been 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, and DGG.

Alexandre William Camargo received his BS (2011) in Applied Mathematics from the State University of Campinas (UNICAMP), Brazil. He is currently about to finish the Master Science in Applied Mathematics in the same university. His professional interests include seismic modeling and numerical methods for differential equations. He is member of SEG (Society of Exploration Geophysicists).

Tiago A. Coimbra received a B.Sc. (2007) in Mathematics from Federal University of Espirito Santo (UFES), M.Sc. (2010) and Ph.D. (2014) in Applied Mathematics from University of Campinas (UNICAMP), Brazil. He is now a researcher at the Center for Petroleum Studies (CEPETRO) 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, EAGE and SBGf.

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.

Sergius Dell received his diploma (2009) and a Ph.D. (2012) in geophysics from the University of Hamburg. In 2012-2015, he worked at Fugro and CGG (UK). Since 2016 he has been self-employed. His key interests are least-squares seismic migration, multiple migration, travel-time tomography, diffraction processing, ray tracing, and dual-semblance analysis. He is a member of EAGE and SEG.

Leon Diekmann is a M.Sc. student in geophysics at the University of Hamburg. He received his B.Sc. in geophysics in 2016. His research interest is localization of passive seismic events.

Norman Ettrich received his diploma in geophysics in 1993 from the Technical University of Clausthal-Zellerfeld, and a Ph.D. in geophysics (1997) from the University of Hamburg. In 1998-2002, he worked at the research center of Statoil, Trondheim. In 2002, he joined the Fraunhofer Institut für Techno- und Wirtschaftsmathematik in Kaiserslautern, Germany. Since 2005, he has been contributing to building up research activities in the fields of seismic migration, processing and visualisation. His key interests are seismic migration, seismic processing, ray tracing, and anisotropy. He is a member of EAGE and SEG.

Jorge H. Faccipieri received a B.Sc. (2010) in Physics from University of Campinas (UNICAMP) and a M.Sc. (2012) in Petroleum Science and Engineering at the same University. He is now a researcher at the Center for Petroleum Studies (CEPETRO) and also a Ph.D. student in Petroleum Science and Engineering, both at UNICAMP. His research interests include multiparametric traveltimes, velocity analysis and diffractions. Jorge is a student member of EAGE and SBGf.

Mario Rubén Fernandez received his M.Sc. at the Institut de Physique du Globe de Paris and started his Ph.D studies at the Karlsruhe Institute of Technologies (KIT) in 2015. He is working for the CRC 1173 Ẅave phenomenaön the implementation of full waveform inversion of seismic wave attenuation.

José Jadsom de Figueiredo received a B.Sc. (2006) in Physics from Federal University of Paraiba (UFPB), an M.Sc. (2008) in Physics, and a PhD (2012) in Petroleum Science and Engineering from the State University of Campinas (UNICAMP), Brazil. During his PhD, he spent one year (2010-2011) at Allied Geophysical Laboratories at Houston University. In October 2012, he has joined the Faculty of Geophysics at Federal University of Pará (UFPA) as an Associate Professor. His research interests include seismic imaging methods, particularly diffraction imaging, physical modeling of seismic phenomena, anisotropy and rock physics . He is a member of EAGE, SEG, SBGf and SPE.

Dirk Gajewski holds the chair of Applied Seismics at the University of Hamburg. Until 2006 he worked at the same institution as associate professor. He received a diploma in geophysics in 1981 from Clausthal Technical University and a Ph.D from Karlsruhe University in 1987. After his Ph.D, 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 asymptotic, seismic modeling, and processing of seismic data from isotropic and anisotropic media. Together with Ivan Psencík, he developed the ANRAY program package. He is a member of AGU, DGG, EAGE, and SEG, and served as Associate Editor for Geophysical Prospecting (section anisotropy). Since 2009 he is a member of the research committee of the EAGE. Besides his activities in WIT he is vice director of the Centre for Marine and Climate Research.

Lingli Gao received her Ph.D. from China University of Geosciences (Wuhan) in 2016. Now she is a postdoc researcher in Zhejiang University. She is now working on high-frequency surface-wave method. She is a visiting scholar for 2 years.

Laura Gaßner studied geophysics at the Karlsruhe Institute of Technology (KIT) and received a B.Sc in 2011 and a M.Sc degree in 2014. She is now a Ph.D. student at the Geophysical Institute of KIT and works on the characterization of gas hydrate deposits with full waveform inversion within the project SUGAR (SUbmarine GAs hydrate Resources).

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.

Carina Guntern received her B.Sc. in geophysics in 2013 with a Bachelor thesis on diffraction imaging with the CRS and i-CRS operator and her M.Sc. in 2016 for her work on diffraction imaging and multiparameter stacking operators.

Peter Michael Habelitz studied mechanical engineering at the Duale Hochschule Baden-Württemberg Mannheim (DHBW) and received his B.Eng. in 2012. Thereafter he began to study geophysics at the Karlsruhe Institute of Technology (KIT) where he graduated with B.Sc with the quantification of the error in finite-difference simulation caused by staircase interfaces. Currently he is working on his Master thesis in the area of full wave form inversion.

Thomas Hertweck received a diploma in Geophysics (2000) and a doctor's degree of natural sciences (2004) from the University of Karlsruhe, Germany. He joined Fugro in September 2004 as researcher and software developer before becoming an R&D manager in 2007 and global head of R&D in 2011. In 2013 Thomas became an R&D manager for external research at CGG following the successful takeover of Fugro's Geoscience Division. At CGG he was also a member of the business line's R&D management team, the company's technology board, and its IP and HSE committees. After more than 12 years in the UK Thomas returned to Germany in January 2017 when he joined KIT's Geophysical Institute as senior research fellow and teaching assistant. Thomas' research interests include all aspects of seismic acquisition, processing and imaging as well as HPC software development. He serves as reviewer for various journals and is a member of SEG, EAGE, DGG and the Editorial Board of JSE.

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.

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.

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