Wave Inversion Technology Consortium

Wave Inversion Technology
established 1996 in Karlsruhe, Germany

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Preface

New developments in our profession are often combined with big excitement (or even hype) in the community. This excitement is, e.g., reflected by the number of workshops and sessions in annual meetings related to these topics. Some 20 years ago, it was 3-D seismics, which is nowadays the standard for data acquisition. Some 10 years ago, wave equation processing and imaging generated a similar interest. The hype about full waveform inversion has not yet decreased and the next buzz word technique is already on the horizon: Machine learning in geosciences. The first EAGE/PESGB Workshop on Machine Learning took place in the end of 2018, and it was followed by the EAGE Workshop on Big Data and Machine Learning for E&P Efficiency in Kuala Lumpur in February of this year. Applied seismics has been involved in "big data" already long before this phrase was even introduced. Big data and machine learning are thus two partners for a fruitful marriage. I expect an enormous amount of work and projects on this topic in the near future.

Because of this importance and a foreseen great potential the WIT research team has carried out research in this field since about 2016 and first results where presented at the above-mentioned Kuala Lumpur meeting. The presentation introduced a deep learning approach for the interpretation of seismic attributes. Corresponding publications are soon to appear. Other work is related to pre-stack data enhancement for diffraction processing since the up-going wavefield in a shot gather is just a time shifted copy for each shot. For the focusing of diffractions and Common Reflection Point gathers, the identification of the corresponding events in the data is essential to focus contributions that belong to the same subsurface location. A collaborative project is currently in preparation where machine learning approaches will be used for de-noising, data regularization and interpolation. I am convinced that this list will grow.

The machine learning technology is very likely to bring major changes to the hydrocarbon industry, which will cover all areas from exploration to production. It is of great benefit that the company with the greatest experience in big data and machine learning provides its tools as open source software for free. GOOGLE's tensor flow is used by many researchers gaining experience in this field. This software is not just open source; it is also optimized for processing on GPU's and allows to perform high performance computing even for small enterprises and academic institutions since clusters of graphic cards are affordable. Because of these favorable conditions I expect quite some start ups spawning out of research institutions within the near future.

One of the many technical challenges to cope with might be the limited memory of GPU systems. Obviously, there does not exist a single deep structured network to solve all data analysis problems. Understanding the "grammar of the data" or in particular for applied seismics to understand the "grammar of seismograms" is essential for a successful deep learning approach. It will not take long until courses and lectures on artificial intelligence will become mandatory in many geosciences educational programs.

In 2018, the high standard of WIT research was again recognized by the geosciences community. This is not just reflected by the papers published in the top journals of our profession.

We are extremely pleased to announce that WIT alumni Dr. Benjamin Schwarz was awarded this year's DGG (Deutsche Geophysikalische Gesellschaft) Zoeppritz Medal. The medal was presented to Benny during the DGG's 79th annual meeting in March of this year. The Zoeppritz medal recognizes outstanding

contributions of a young scientist.

After last year's Honorary lecturer tour through South America by Martin Tygel, SEG awarded Dirk Gajewski as the 2019 Honorary Lecturer for Europe. Dirk will visit about 25 locations throughout Europe speaking about "Wavefront attributes – A tool for processing, imaging, and model building."

You may have realized by now that the WIT web site has undergone a complete overhaul. It can now be displayed on all kind of devices (PC, tablet, mobile phone) equally well now that the new site adjusts the structure and navigation to the capabilities of the individual devices.

Despite some changes in our approach to applied seismics as described above, the WIT mission to develop the most accurate and efficient seismic modeling, imaging, and inversion using elastic and acoustic methods has not changed. Our research plan though, now comprises the new topic "machine learning."

With your continuous support, we were able to follow the WIT mission for 22 years. We are ready and more than willing to keep this mission going.

Hamburg, March 2019
Dirk Gajewski

Summary: WIT report 2018

IMAGING

Bauer et al. introduce a fully unsupervised scheme for the global identification and tagging of diffractions with a common origin in depth and outline potential applications of the gained knowledge.

Diekmann et al. present a workflow for the localisation of passive seismic sources and simultaneous velocity model building. The method is based on wavefront attributes and uses wavefront tomography to approximate the velocity distribution and obtain consistent source excitation times for the passive events.

Glöckner et al. present method to improve time-migration velocities and images. Therefroe, they use the new generated migrated coherence section to obtain a velocity refinement. Furthermore, least-square migration together with demigration is used to improve the migrated image. The suggested process was succesfully applied to field data.

Glöckner et al. present a velocity-model building approach for 3D P-cable data. The special characteristic of P-cable data, short offset and a high frequnecy source, prohibit convetional VMB. Here, we present a diffraction-based processing and using wavefront tomography to obatin a velocity model without offset information.

Znak et al. test a novel wavefront attributes based tomographic method based on minimizing of backpropagated geometrical spreading. The authors recall the Fréchet derivatives formulas for computing the gradient of the new functional and also provide a reduced adjoint-state method formulation. Synthetic reflection data inversion was performed.

FULL WAVEFORM INVERSION

Athanasopoulos and Bohlen demonstrate the value of using elastic full-waveform inversion of seismic data for improved aquifer characterisation. After retrieving the elastic parameters through FWI they perform a qualitative comparison with GPR data to obtain a better structural characterisation of the aquifer. Combining the results of these two geophysical techniques provides more reliable subsurface models and reduces uncertainties on reconstructing the aquifer architecture.

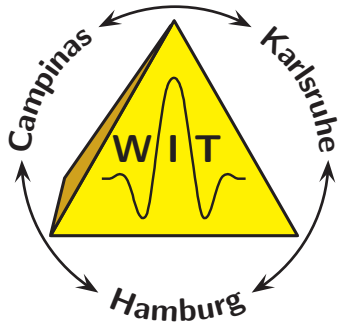
Gaßner et al. show an application of full-waveform inversion to ocean-bottom seismic data acquired in the Black Sea for the purpose of gas-hydrate detection. The inverted velocity model for one of the profiles has a clear indication of a bottom-simulating reflector, consistent with a reference towed-streamer seismic data set. The detailed models allow to estimate hydrate and gas saturation directly from the parameters rather than by means of reflectivity analysis.

Pan et al. review the multichannel analysis of surface wave (MSAW) and full-waveform inversion (FWI) methods to investigate their ability to reconstruct detailed subsurface models in near-surface applications.

Thiel et al. show acoustic and elastic full-waveform inversion (FWI) results of a marine 2D data set acquired offshore Angola where sediments containing a salt body with significant topology are present.

For this particular data set, elastic FWI leads to more consistent and reliable model updates with less artefacts compared to acoustic FWI which, at first glance, might seem unusual for towed-streamer data. Although 2D marine towed-streamer data are least favourable for the application of FWI compared to 3D data or ocean-bottom data, even for such data sets it is recommended to check on the existence of elastic effects before deciding on the final processing and imaging approach.

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 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 with the goal to establish the most accurate and efficient seismic modeling, imaging, and inversion using elastic and acoustic methods. Some of the topics are studied by more than one team, applying different approaches. The WIT research is divided into six subgroups:

Processing and Imaging

Wavefront attributes as derived from multi-parameter processing, like the Common Reflection Surface (CRS) concept, play a key role in the WIT research and represent the backbone of many research topics.

- estimation of CO wavefield attributes from ZO attributes
- amplitude-friendly multi-parameter processing
- improved conflicting handling
- wavefield decomposition using wavefield attributes and adaptive subtraction
- pre-stack diffraction/reflection separation by machine learning
- 5-D interpolation and pre-stack data enhancement by machine learning
- improved coherence measures (MUSIC, cross-correlation, analytical trace, etc.)
- data-driven isotropic and anisotropic time migration
- wavefield decomposition and filtering in the CSP domain
- construction of CRP gathers
- beam migration
- image wave re-migration
- event tagging using deterministic and machine learning approaches
- interpretation and attribute analyses by unsupervised machine learning

Model Building

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

- diffraction focusing velocity analysis
- passive seismic data velocity model building with wavefront attributes
- wavefront attribute based time to depth conversion
- focusing approach in wavefront tomography
- uncertainty estimates derived from focusing analysis
- anisotropic wavefront tomography
- focusing tomography of CRP gathers

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 pre-processing 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
- FWI of diffraction events as secondary sources

Modeling and RTM

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

- FE elastic wavefield modeling
- computational optimization of FD and spectral method approaches for acoustic, elastic, and anisotropic media, including benchmarking
- improved one-way wave equations
- reflection impedance description of reflection coefficients
- tuning effects in AVO and AVA

Passive Seismics

Passive seismic moveout is equivalent to diffraction events, which enables a unified workflow for processing and imaging of active and passive seismic data.

- passive seismic data enhancement and regularization with wavefront attributes
- source time estimation
- imaging with natural Green's functions
- simultaneous location and velocity model building
- joint wavefront tomography and passive seismic imaging
- source signature extraction
- localization uncertainties from focusing analysis
- real time processing methodology

Machine Learning in Processing and Imaging

This is a new topic to the WIT research portfolio. Since 2017 the potential of machine learning is investigated in the following fields:

- Pre-stack data enhancement of diffractions with “natural moveout”
- Event tagging of diffractions and passive seismic data
- Analysis of seismic attributes for interpretation
- Data regularization and de-noising

WIT STEERING COMMITTEES

Internal Steering Committee

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

External Steering Committee

Name	Sponsor
Dan Grygier	Landmark Graphics Corporation
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 several IBM Xeon-based 256 cores login nodes available with 1 TB memory each, of which 64 are reserved for our exclusive use, including a GTX 1080 GPU for deep learning tasks and four compute nodes for batch processing. 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 at the Karlsruhe Institute of Technology (KIT) consist of local Linux servers, Linux workstations and desktop computers. For large-scale computational tasks, the group has access to high-performance computing systems at KIT's Steinbuch Center for Computing (SCC; bwCLuster, ForHLR II), and dependent on project approval to supercomputers at the Jülich Supercomputing Centre (JSC; JURECA) and the High-Performance Computing Center in Stuttgart (HLRS; Hazel Hen).

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

Bessam Alubeyid received his Bachelor of Petroleum Engineering at Al-Baath University (Syria) in 2012. Subsequently, he worked at Hayan Petroleum Company as process engineer. Currently, he is a student enrolled in the Master's program in Geophysics at KIT, working on his Master's thesis. His thesis deals with 3D simulation of seismic wave propagation in a tunnel model for EPB-tunnel boring machines with processing of synthetic and field data.

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.

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.

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 studied geophysics in Hamburg. He received his B.Sc. in 2016 and his M.Sc. in 2018. His research interests focus on localization of passive seismic events and model building using wavefront attributes.

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 "Wave phenomena" on 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 PhD from China University of Geosciences (Wuhan) in 2016. Now she is

a Postdoc researcher at Zhejiang University. Currently, she is a visiting scholar at KIT working on high-frequency surface-wave methods.

Laura Gaßner studied Geophysics at Karlsruhe Institute of Technology (KIT) and received a BSc degree in 2011, an MSc degree in 2014, and a PhD in 2018. Throughout 2018 she has worked on the characterization of gas hydrate deposits with full-waveform inversion within the project SUGAR (SUbmarine GAs hydrate Resources).

Martina Glöckner is a Ph.D. student at the University of Hamburg. Her research interests focus on time migration and demigration. She received her M.Sc. (2014) and B.Sc. (2012) in geophysics at the University of Hamburg. Topics of her work were the application of multiparameter stacking operators.

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.

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.

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.

Stefan Knispel reveived his BSc in Geophysics/Oceanography in Hamburg in 2017. In his BSc thesis, he investigated the processing of diffractions in the shot gather domain. For his MSc thesis, he is continuing his work on this topic including machine learning methods.

Valérie Krampe received a BSc degree in Geophysics in 2016 and an MSc degree in Geophysics in

2018, both from Karlsruhe Institute of Technology (KIT). Her Master's thesis focused on anisotropic full-waveform inversion.

Daniel Krieger received his BSc degree in Geophysics from Karlsruhe Institute of Technology (KIT) in 2017. He is currently working on his Master's thesis in which he studies the application of 2D elastic full-waveform inversion in areas with topographic variations of the free surface.

Fabian Kühn received a BSc degree in Geophysics in 2016 and an MSc degree in Geophysics in 2018, both from Karlsruhe Institute of Technology (KIT). His Master's thesis focused on the application of full-waveform inversion in the field of medical imaging.

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.

Lei Li received his B.Sc. in Earth Information Science and Technology in 2012 from Central South University. Now he is a Ph.D. student at the Institute of Acoustics, Chinese Academy of Sciences. His main research interests are seismic wave propagation and modeling, passive seismic location and imaging. He is a visiting student for one year.

Tingting Liu received an MSc degree from Jilin University in China and started her PhD studies at Karlsruhe Institute of Technology (KIT) in 2018. Her research field is full-waveform inversion of shallow-seismic surface waves in poroelastic media.

Manuel Lotze is a M.Sc. student in the Hamburg WIT group. He received his B.Sc in geophysics in 2016 with a thesis on 2D velocity model building, by utilizing diffractions for the NIP-wave tomography. His research interest is the improvement of the NIP-wave tomography in 3D.

Daniel Macedo received a B.Sc. (2004) in Physics and an M.Sc. (2010)in Geosciences from University of Campinas (UNICAMP), Brazil. Since 2010 he has been a Ph.D. student in Petroleum Science andEngineering at UNICAMP. His research interests include wave phenomena, seismic imaging and inversion methods, particularly full waveform inversion, and scattering theory. He is a member of SEG, EAGE and SBGf.

Jonas Müller studies Geophysics at Karlsruhe Institute of Technology (KIT) and received a BSc degree in 2018. He is now working on his Master's thesis on full-waveform inversion in the context of non-destructive testing.

Leo Nesemann received his MSc in computational mathematics in 2006 from Brunel University (London) and a PhD in applied mathematics from the University of Hannover in 2010. Since 2011, he is working as a scientist in the HPC department of the Fraunhofer ITWM in Kaiserslautern. His research interests are highly scalable, efficient applications of FEM and FDM for linear acoustic and elastic equations.

Amélia Novais received her M.Sc. in Mathematics from the Brazilian Institute of Pure and Applied Mathematics (IMPA) in 1993 and her PhD in Applied Mathematics from State University of Campinas

(Unicamp) in 1998. From 1996 to 2002, she was a professor for Mathematics at the Federal University of São Carlos (UFSCar), Brasil. She has joined Unicamp in April 2002 as an Assistant Professor and since 2009 as an Associate Professor. Her research interests focus on partial differential equations and include seismic forward modeling and imaging. In particular, she works with finite differences to obtain the solution of the acoustic, elastic and image wave equations, as well as with the Born and Kirchhoff approximations. Presently, she also studies image-wave equations. She is a member of SEG, SBGf, SBMAC, and SBM.

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