

## Fall Meeting Announcement

The Fall 2012 Research Meeting of TCCS will take place in Austin, TX, November 12–13 and will be hosted by the Bureau of Economic Geology on the J. J. Pickle Research Campus.

Representatives of participating companies are invited to register for the meeting by following the link at <http://www.beg.utexas.edu/tccs/>



## Editorial

Welcome to the second *TCCS Newsletter!*

The Texas Consortium for Computational Seismology (TCCS) is a joint initiative of the Bureau of Economic Geology (BEG) and the Center for Numerical Analysis at the Institute for Computational Engineering and Science (ICES) at The University of Texas at Austin. Its mission is to address the most important and challenging research problems in computational geophysics as experienced by the energy industry while educating the next generation of research geophysicist and computational scientists. In the second issue of the *TCCS Newsletter*, you will find the latest news about our group's research, presentations by our members at the upcoming SEG Annual Meeting, and our new staff members. We are looking forward to your feedback, suggestions, and requests for research collaboration. See you in Las Vegas and Austin!

## TCCS Sponsors

TCCS appreciates the support of its sponsors: BGP, BP, Chevron, CGGVeritas, ConocoPhillips, ExxonMobil, Hess, Saudi Aramco, Schlumberger, Statoil, Total, and Z-Terra.

For sponsorship opportunities, please contact [sergey.fomel@beg.utexas.edu](mailto:sergey.fomel@beg.utexas.edu).



## Presentations at SEG in Las Vegas

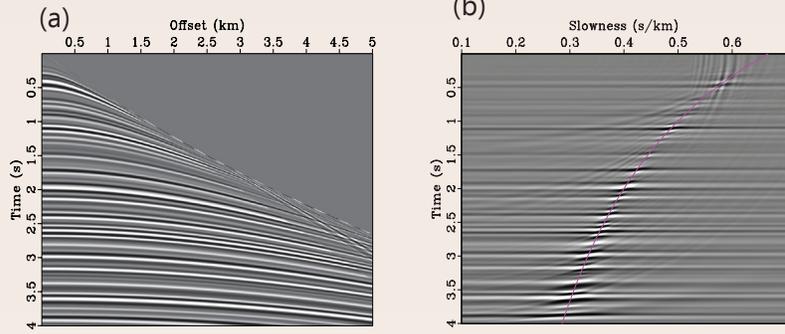
TCCS members and guests will make several presentations at the upcoming SEG 2012 Annual Meeting in Las Vegas.

Monday, Nov. 5	1:50 pm	SVE E-P1: Miscellaneous Approaches	Y. Tao, M. Davidson, H. Swan, S. Fomel, J. Malloy, J. Howell, S. Chiu, and R. Olson	Constrained simultaneous automatic picking for VVAZ analysis
	2:45 pm	ANI 1: Theory Development and Case Studies	J. Cheng and W. Kang	Propagating pure wave modes in general anisotropic media, Part I: P-wave propagator
	3:10 pm	ANI 1: Theory Development and Case Studies	T. Wang, J. Cheng, and W. Kang	Pure-mode modeling and reverse-time migration of P-wave in HTI and orthorhombic media
	3:10 pm	ANI E-P1: Development and Application	W. Kang and J. Cheng	Propagating pure wave modes in general anisotropic media, Part II: SV and SH waves
	4:00 pm	SPNA 1: Matrix Decomposition, Regularization, and Interpolation	S. Fomel	Seismic data decomposition into spectral components using regularized nonstationary autoregression
Tuesday, Nov. 6	1:30 pm	SM P2: From Rays to Rock Physics	C. Wang, J. Cheng, and W. Kang	Separating wave-modes of prestack elastic seismograms using pure mode wave propagators in anisotropic media
	4:00 pm	SPMI 2: Gathers and Velocity Analysis	A. Klokov and S. Fomel	Optimal migration aperture for conflicting dips
Wednesday, Nov. 7	8:55 am	SVE 3: Tomography	S. Li, S. Fomel, and A. Vladimírsky	Prestack first-break traveltome tomography using the double-square-root eikonal equation
	1:30 pm	SM 2: Theory	J. Poulson, B. Engquist, S. Li, and L. Ying	A parallel sweeping preconditioner for frequency-domain seismic wave propagation
	1:50 pm	ANI P1: Theory Development and Case Studies	X. Song and T. Alkhalifah	Modeling of pseudo-acoustic P-waves in orthorhombic media with low-rank approximation
	1:50 pm	SPMUL E-P1: Prediction and Subtraction	J. Hu, S. Fomel, L. Demanet, and L. Ying	A fast butterfly algorithm for the hyperbolic Radon transform
	3:10 pm	SPMUL E-P1: Prediction and Subtraction	S. Ghosh and S. Fomel	Multiple suppression in the $t$ - $x$ - $p$ domain
	3:10 pm	SM 2: Theory	X. Song and T. Alkhalifah	A linearized dispersion relation for orthorhombic pseudo-acoustic modeling
Thursday, Nov. 8	3:35 pm	SM 2: Theory	X. Song, K. Nihei, and J. Stefani	Seismic modeling in acoustic variable-density media by Fourier finite differences
	10:10 am	SPMI 5: New Implementations	V. Bashkardin, J. Browaeys, S. Fomel, F. Gao, R. Kazinnik, S. Morton, S. Terentyev, A. Vladimírsky, and P. Williamson	Phase-space computation of multiarrival traveltimes, Part I: Theory and concepts
	10:35 am	SPMI 5: New Implementations	V. Bashkardin, T. J. Browaeys, S. Fomel, F. Gao, S. Morton, S. Terentyev, and A. Vladimírsky	Phase-space computation of multiarrival traveltimes: Part II: Implementation and application to angle-domain imaging
Friday, Nov. 9	11:00 am	INT 6: New Algorithms and Techniques	Y. Cai, S. Fomel, and H. Zeng	Spectral recomposition using separable nonlinear least squares
	11:45 am	W-17: Seismic Diffraction Methods for Fault and Fracture Detection	A. Klokov, S. Fomel, R. Bansal, W. Burnett, and E. Liu	Diffraction imaging and analysis in the Piceance Basin
	1:30 pm	W-17: Seismic Diffraction Methods for Fault and Fracture Detection	S. Fomel	Diffraction imaging as a tool for velocity estimation

# Research Highlights

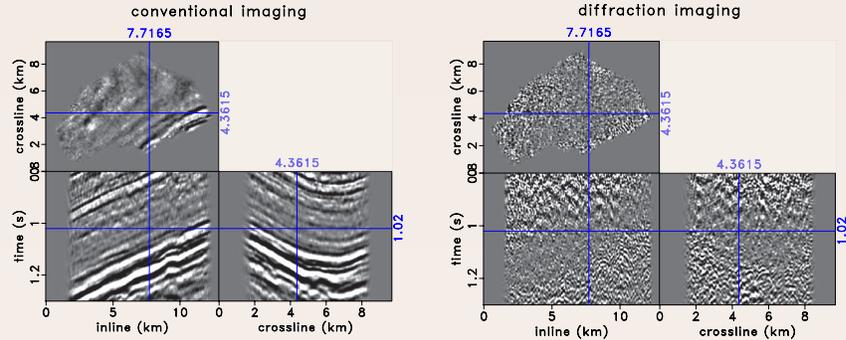
## Fast Hyperbolic Radon Transform

Jingwei Hu is working on fast algorithms for time-variant transforms, such as the hyperbolic Radon transform. Figure a is a synthetic CMP gather ( $N_t=N_x=1000$ ). Figure b shows the result by the fast butterfly algorithm ( $N_\tau=N_p=1000$ ). For this number of data, the fast algorithm runs in only 1.74 seconds, while the conventional time-domain integration takes 62.46 seconds.



## 3-D Diffraction Imaging

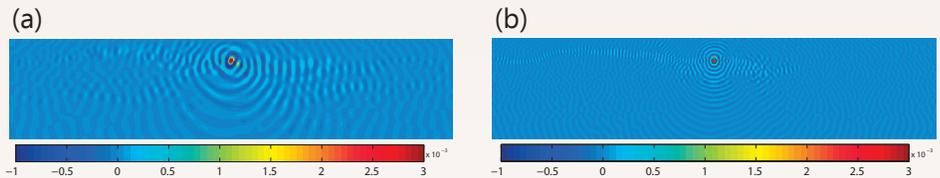
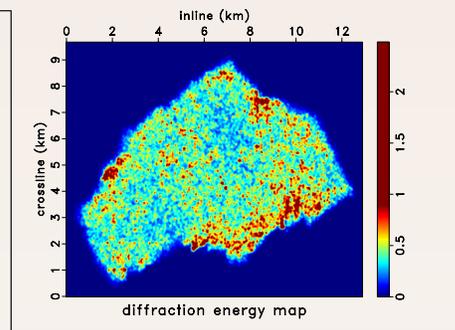
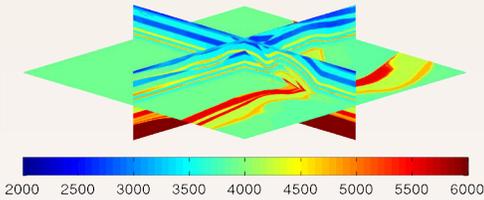
Alexander Klokov has extended diffraction imaging with dip-angle gathers to 3D input data. This example demonstrates that a diffraction image allows us to distinguish discontinuities in the reservoir at time levels between 0.9 and 1.2 seconds. These features are not clearly visible after conventional imaging.



## Helmholtz Solver with Spectral Elements

Paul Tsuji developed parallel sweeping preconditioners (based on the moving PML preconditioner presented by Engquist and Ying) for high-order spectral-element

discretizations of Helmholtz and time-harmonic linear elasticity equations. For the Helmholtz equation, the SEG Overthrust problem was solved at 10 Hz (Fig. a) using 1024 processors and at 20 Hz (Fig. b) using 2,048 processors.

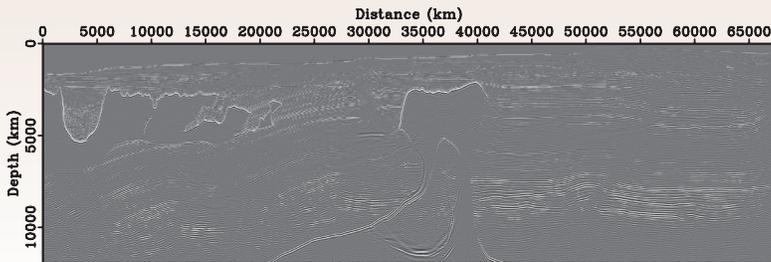


## Migration Gallery

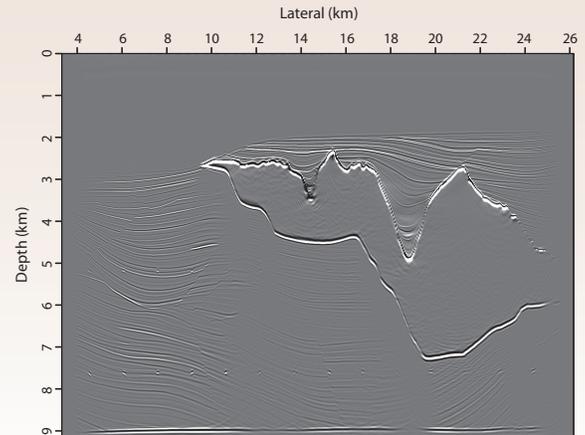
TCCS members have been busy completing the "migration gallery": a matrix, in which rows correspond to benchmark datasets and columns correspond to different migration methods. So far, the

matrix has 12 rows and 6 columns, not all of which are complete yet. Reproducible examples will be shared first with TCCS sponsors and eventually with the wide geophysical community so that students and researchers from

other universities can contribute their own rows and columns.



RTM Image



PSPI wave equation image

## Professional Awards



At the SEG 2012 meeting in Las Vegas, Xiaolei Song will receive an Award of Merit, Best Student Poster, for her poster

*Lowrank finite-differences for wave extrapolation*, which was presented at the 2011 SEG Annual Meeting.

## Madagascar School



Madagascar is an actively developed open-source software package for geophysical data analysis and reproducible computational experiments. More than 50 people from different organizations around the world have participated in its development since 2006.

On July 20 and 21, 2011, some TCCS members participated in the Madagascar School on Reproducible Computational Geophysics in Austin. More than 40 people attended the school, representing 15 organizations (11 universities and 4 companies) from 5 different countries. One of the participants in the evaluation of Madagascar said: "I think it is the best open source project out there. I think that is not because of the programs (which are very good) themselves but because of the community and reproducibility framework." The school materials are available now on the Madagascar website: [http://www.ahay.org/wiki/Austin\\_2012](http://www.ahay.org/wiki/Austin_2012).

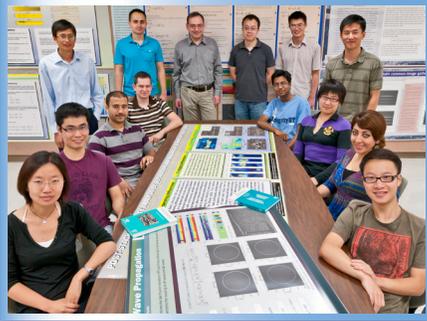


## Papers accepted and published 2011–2012

Accepted	Published 2012
<p>Z. Chen, S. Fomel, and W. Lu, 2012, Accelerated plane-wave destruction: <i>Geophysics</i>, accepted.</p> <p>B. Engquist and L. Ying, 2012, A fast algorithm for reiterated homogenization: <i>Communications in Mathematical Sciences</i>, accepted.</p> <p>S. Fomel, L. Ying, and X. Song, 2012, Seismic wave extrapolation using lowrank symbol approximation: <i>Geophysical Prospecting</i>, accepted.</p> <p>S. Fomel and R. Kazinnik, 2012, Nonhyperbolic common reflection surface: <i>Geophysical Prospecting</i>, accepted.</p> <p>J. Häggblad and B. Engquist, 2012, Consistent modeling of boundaries in acoustic finite-difference time-domain simulations: <i>Journal of Acoustical Society of America</i>, accepted.</p> <p>Y. Liu and S. Fomel, 2012, Seismic data analysis using local time-frequency transform: <i>Geophysical Prospecting</i>, accepted.</p> <p>J. Poulson, B. Marker, R. A. van de Geijn, J. R. Hammond, and N. A. Romero, 2012, Elemental: a new framework for distributed memory dense matrix computations, <i>ACM Transactions on Mathematical Software</i>, accepted.</p>	<p>A. Abdulle, E. Weinan, B. Engquist, and E. Vanden-Eijnden, 2012, The heterogeneous multiscale method: <i>Acta Numerica</i>, v. 21, 1-87.</p> <p>G. Ariel, B. Engquist, and Y.-H. R. Tsai, 2012, Oscillatory systems with three separated time scales: analysis and computation: <i>Numerical Analysis of Multiscale Problems (Lecture Notes in Computational Science and Engineering)</i>, v. 82, 23-45.</p> <p>L. Demanet, M. Ferrara, N. Maxwell, J. Poulson, and L. Ying, 2012, A butterfly algorithm for synthetic aperture radar imaging: <i>SIAM Journal on Imaging Sciences</i>, v. 5, 203-243.</p> <p>L. Demanet and L. Ying, 2012, Fast wave computation via Fourier integral operators: <i>Mathematics of Computation</i>, v. 81, 1455-1486.</p> <p>B. Engquist, H. Holst, and O. Runborg, 2012, Multiscale methods for wave propagation in heterogeneous media over long time: <i>Numerical Analysis of Multiscale Problems (Lecture Notes in Computational Science and Engineering)</i>, v. 82, 167-186.</p> <p>B. Engquist and L. Ying, 2012, Fast algorithms for high frequency wave propagation: <i>Numerical Analysis of Multiscale Problems (Lecture Notes in Computational Science and Engineering)</i>, v. 83, 127-161.</p> <p>B. Engquist, J. Häggblad and O. Runborg, 2012, On energy preserving consistent boundary conditions for the Yee scheme in 2D: <i>BIT Numerical Mathematics</i>, v. 52, 615-637.</p> <p>J. Hu and L. Ying, 2012, A fast spectral algorithm for the quantum Boltzmann collision operator: <i>Communications in Mathematical Sciences</i>, v. 10, 989-999.</p> <p>A. Klovov and S. Fomel, 2012, Separation and imaging of seismic diffractions using migrated dip-angle gathers: <i>Geophysics</i>, v. 77, S131-S143.</p> <p>L. Lin, J. Lu, L. Ying, W. E, 2012, Adaptive local basis set for Kohn-Sham density functional theory in a discontinuous Galerkin framework I: total energy calculation: <i>Journal of Computational Physics</i>, v. 231, 2140-2154.</p> <p>L. Lin, C. Yang, J. Lu, L. Ying, and W. E, 2012, A fast parallel algorithm for selected inversion of structured sparse matrices with application to 2D electronic structure calculations: <i>SIAM Journal on Scientific Computing</i>, v. 33, 1329-1351.</p> <p>P. Schmitz and L. Ying, 2012, A fast direct solver for elliptic problems on general meshes in 2D: <i>Journal of Computational Physics</i>, v. 231, 1314-1338.</p> <p>A. Stovas and S. Fomel, 2012, Shifted hyperbola moveout approximation revisited: <i>Geophysical Prospecting</i>, v. 60, 395-399.</p> <p>A. Stovas and S. Fomel, 2012, Generalized non-elliptic approximation in tau-p domain: <i>Geophysics</i>, v. 77, U23-U30.</p> <p>N. M. Tanushev, Y.-H. R. Tsai, and B. Engquist, 2012, A coupled finite difference – Gaussian beam method for high frequency wave propagation: <i>Numerical Analysis of Multiscale Problems (Lecture Notes in Computational Science and Engineering)</i>, v. 82, 401-420.</p> <p>P. Tsuji, B. Engquist, and L. Ying, 2012, A sweeping preconditioner for time-harmonic Maxwell's equations with finite elements: <i>Journal of Computational Physics</i>, v. 231, 3770-3783.</p> <p>P. Tsuji and L. Ying, 2012, A sweeping preconditioner for Yee's finite difference approximation of time-harmonic Maxwell's equations: <i>Frontiers of Mathematics in China</i>, v. 7, 347-363.</p> <p>L. Ying, 2012, A pedestrian introduction to fast multipole methods: <i>Science China Mathematics</i>, v. 55, 1043-1051.</p>
<p>T. Alkhalifah and S. Fomel, 2011, Angle gathers in wave-equation imaging for transversely isotropic media: <i>Geophysical Prospecting</i>, v. 59, 422-431.</p> <p>T. Alkhalifah and S. Fomel, 2011, The basic components of residual migration in VTI media using anisotropy continuation: <i>Journal of Petroleum Exploration and Production Technology</i>, v. 1, 17-22.</p> <p>G. Ariel, B. Engquist, N.M. Tanushev, R. Tsai, 2011, Gaussian beam decomposition of high frequency wave fields using expectation-maximization: <i>Journal of Computational Physics</i>, v. 230, 2303-2321.</p> <p>W. Burnett and S. Fomel, 2011, Azimuthally anisotropic 3D velocity continuation: <i>International Journal of Geophysics</i>, Article ID 484653.</p> <p>L. Casasanta and S. Fomel, 2011, Velocity-independent tau-p moveout in a vertically-1 varying VTI medium: <i>Geophysics</i>, v. 76, U45-U57.</p> <p>L. Demanet and L. Ying, 2011, Discrete symbol calculus: <i>SIAM Review</i>, v. 53, 71-104.</p> <p>B. Engquist, H. Holst, and O. Runborg, 2011, Multi-scale methods for wave propagation in heterogeneous media: <i>Communications in Mathematical Sciences</i>, v. 9, 33-56.</p> <p>B. Engquist and L. Ying, 2011, Sweeping preconditioner for the Helmholtz equation: hierarchical matrix representation: <i>Communications in Pure and Applied Mathematics</i>, v. 64, 697-735.</p> <p>B. Engquist and L. Ying, 2011, Sweeping preconditioner for the Helmholtz equation: moving perfectly matched layers: <i>Multiscale Modeling and Simulation</i>, v. 9, 686-710.</p> <p>S. Fomel, 2011, Theory of 3-D angle gathers in wave-equation seismic imaging: <i>Journal of Petroleum Exploration and Production Technology</i>, v. 1, 11-16.</p> <p>S. Jiang, B. Ren, P. Tsuji, L. Ying, 2011, Second kind integral equations for the first kind Dirichlet problem of the biharmonic equation in three dimensions: <i>Journal of Computational Physics</i>, v. 230, 7488-7501.</p> <p>L. Lin, C. Yang, J. Meza, J. Lu, L. Ying, and W. E, 2011, SellInv—an algorithm for selected inversion of a sparse symmetric matrix: <i>ACM Transactions on Mathematical Software</i>, v. 37, 40:1-40:19.</p> <p>L. Lin, J. Lu, and L. Ying, 2011, Fast construction of hierarchical matrix representation from matrix-vector multiplication: <i>Journal of Computational Physics</i>, v. 230, 4071-4087.</p> <p>G. Liu, S. Fomel, and X. Chen, 2011, Stacking angle-domain common-image gathers for normalization of illumination: <i>Geophysical Prospecting</i>, v. 59, 244-255.</p> <p>G. Liu, S. Fomel, and X. Chen, 2011, Time-frequency characterization using local attributes: <i>Geophysics</i>, v. 76, P23-P34.</p> <p>Y. Liu and S. Fomel, 2011, Seismic data interpolation beyond aliasing using regularized nonstationary autoregression: <i>Geophysics</i>, v. 76, V69-V77.</p> <p>X. Song and S. Fomel, 2011, Fourier finite-difference wave propagation: <i>Geophysics</i>, v. 76, T123-T129.</p> <p>P. Tsuji and L. Ying, 2011, A fast directional algorithm for high-frequency electromagnetic scattering: <i>Journal of Computational Physics</i>, v. 230, 5471-5487.</p> <p>P. Tsuji, D. Xiu, and L. Ying, 2011 A fast method for high-frequency acoustic scattering from random scatterers: <i>International Journal of Uncertainty Quantification</i>, v. 1, 99-117.</p>	

## TCCS Staff

The TCCS group consists of people from nine different countries who have come together to move science forward.



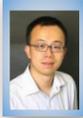
Our research staff includes Principal Investigators, Postdocs, Ph.D. students, M.S. students, B.S. Honors students, and a Senior Research Fellow:

Salah Al-Hadab (M.S. 3rd year)  
Vladimir Bashkardin (Ph.D. 6th year)  
Lubna Barghouty (B.S. Honors)  
Yangkang Chen (Ph.D. 1st year)  
Luke Decker (M.S. 1st year)  
Björn Engquist (PI)  
Sergey Fomel (PI)  
Shaunak Ghosh (Ph.D. 2nd year)  
Jingwei Hu (Postdoc)

Parvaneh Karimi (Ph.D. 3rd year)  
Alexander Klokov (Postdoc)  
Siwei Li (Ph.D. 4th year)  
Jack Poulson (Ph.D. 4th year)  
Karl Schleicher (Senior Research Fellow)  
Xiaolei Song (Ph.D. 5th year)  
Yanadet Sripanich (B.S. Honors)  
Junzhe Sun (Ph.D. 1st year)  
Paul Tsuji (Ph.D. 3rd year)  
Haizhao Yang (Ph.D. 2nd year)  
Lexing Ying (PI)

For more information, see <http://www.beg.utexas.edu/tccs/staff.php>

## Departing



At the end of 2012, Lexing Ying, one of the TCCS principal investigators, will depart UT Austin to start a position at Stanford University, where he will be affiliated with the

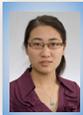
Department of Mathematics and the Institute for Computational and Mathematical Engineering (ICME). We wish Lexing success in his new assignment and will continue active collaboration with him and his students. The TCCS Advisory Committee will meet in late November to develop recommendations on the program transition with Lexing's departure from Austin.



In May 2012, Yihua Cai completed his M.S. thesis *Spectral recomposition and multicomponent seismic image registration* and joined Shell in Houston.



In September 2012, Paul Tsuji defended his Ph.D. thesis *Fast algorithms for frequency-domain wave propagation*. He is joining the Sandia National Laboratory in Livermore, California, as a postdoc.



In November 2012, Xiaolei Song is scheduled to defend her Ph.D. thesis *Application of Fourier finite differences for seismic modeling and subsalt imaging*. In 2013, she is planning to join BP in Houston.



In November 2012, Jack Poulson is scheduled to defend his Ph.D. thesis *Fast parallel solution of heterogeneous 3D time-harmonic wave equations*. In 2013, he will follow Lexing to Stanford as a postdoc.

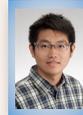


In fall 2012, Salah Al-Hadab is completing his M.S. thesis *Diffraction imaging of sediment drifts in Canterbury Basin* and returning to Saudi Arabia, where he will continue his work at Saudi Aramco.

## Arriving



Yangkang Chen graduated from China University of Petroleum (Beijing) with a B.S. degree in Exploration Geophysics. As an undergraduate, he worked with Prof. Xiaohong Chen and Jingye Li on research topics in rock physics and with Dr. Jitao Ma on multiple attenuation using L1-norm matching and noise attenuation using Empirical Mode Decomposition.



Junzhe Sun graduated from a joint education program between China University of Petroleum-East China and Missouri University of Science and Technology with a Bachelor's degree in Geophysics in 2012. He worked with Prof. Stephen Gao on seismic anisotropy and mantle flow when he was at Missouri S&T.



Luke Decker earned a B.A. in physics with a minor in mathematics from Whitman College in 2008, authoring an honors thesis *The effect of aluminum doping on the molecular sol gel silicate glasses*. After graduation he went to work in the oilfield as a mudlogger for King Canyon Buffalo until December 2010, when he enrolled at Western Washington University to earn a B.A. in geophysics,

which he completed in December 2011. After completing his Master's, Luke hopes to join industry as an exploration geophysicist.



Jiubing Cheng, an Associate Professor from Tongji University, who was awarded a fellowship under the State Scholarship Fund, will spend 1 year at TCCS.

His research interests include wave propagation, imaging and velocity model building in anisotropic media, fracture characterization based on azimuth-preserved local angle-domain seismic imaging, rock-facies classification and hydrocarbon prediction by integration of statistical rock physics and seismic inversion, and geophysical technique for shale-gas exploration and development.



Gang Fang has been awarded a scholarship under the China State Scholarship Fund. Gang is currently pursuing a Ph.D. in Geophysics at China University of Petroleum (East China) under the supervision of Prof. Qizhen Du. He received his Master's degree in Geophysics from China University of Petroleum (Beijing). His research interests focus on true-amplitude seismic imaging for acoustic and elastic media.

## Testimonials

### Xiaolei Song:

"TCCS is like a big family for me, where people from multidisciplines work together. TCCS has also been building a great connection between academia and industry. During my 4-year stay, I learned a lot from people and grew to be an exploration geophysicist. I feel fortunate and proud to be part of the family."

### William Burnett, alumnus of TCCS and currently a geophysicist at ExxonMobil:

"It has been a privilege to be part of it and watch TCCS grow so quickly in the last few years. I look forward to watching the group develop even more—I know the best is yet to come!"