

Oliver G. Ernst

Curriculum Vitae

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Education and Qualifications

2001 Habilitation TU Bergakademie Freiberg
1994 Ph.D. Stanford University
1989 Dipl.-Math. Universität Karlsruhe (TH)

Current Positions

2013– **Professor of Numerical Analysis** (W3), Department of Mathematics,
TU Chemnitz

Previous Positions

2015–2018 Chair, GAMM Activity Group on Uncertainty Quantification
6–9/2017 Visiting Scholar, Institute for Computational and Mathematical Engineering,
Stanford University
2009–2013 apl. Professor, Department of Mathematics and Computer Science,
TU Bergakademie Freiberg
2006–2009 wissenschaftlicher Mitarbeiter, Department of Mathematics and Computer Science,
TU Bergakademie Freiberg
2001–2006 Oberassistent (C2), Privatdozent, Department of Mathematics and Computer Science,
TU Bergakademie Freiberg
2002–2003 Visiting Professor (Lehrstuhlvertretung, C4),
Bergische Universität Wuppertal
1997–1998 Postdoctoral Fellow, Institute for Advanced Computer Studies,
University of Maryland
1994–2001 wiss. Assistent (C1), Department of Mathematics and Computer Science,
TU Bergakademie Freiberg

Awards and Honors

2017 Invited Plenary Lecture, GAMM Annual Meeting, Weimar
2010 SIAM Lecture, International Linear Algebra Society Annual Meeting, Pisa, Italy
1997 CISE Postdoctoral Research Associate in Computational Science and Engineering
1996 Michael Jürgen Leisler Kiep Travel Fellowship

Professional Society Memberships

- Member, Society of Industrial and Applied Mathematics (SIAM)
SIAG/CSE, SIAG/LA, SIAG/UQ
- Member, Gesellschaft für Angewandte Mathematik und Mechanik (GAMM)
Activity Groups ANLA, UQ
- Member, American Mathematical Society (AMS)

Editorial Service

- *SIAM/ASA Journal on Uncertainty Quantification*, Member of the Editorial Board
- *International Journal on Uncertainty Quantification*, Member of the Editorial Board
- Guest Editor: Topical Issue of *International Journal on Geomathematics on Uncertainty Quantification in Subsurface Environments*, 2019
- Guest Editor: Special Issue of *Linear Algebra and its Applications (LAA) on Matrix Functions*, Vol. 456 (2014)

- Guest Editor: Special Volume of *Electronic Transactions on Numerical Analysis (ETNA) on Computational Methods with Applications*, Vol. 31 (2008).

Conference Organization

- *Uncertainty Quantification*, MFO Workshop 1911, Oberwolfach, 2019.
- *Frontiers of Uncertainty Quantification in Subsurface Environments (FrontUQ18)*, Pavia, 2018.
- *3rd GAMM AGUQ Workshop on Uncertainty Quantification*, TU Dortmund, 2018.
- *GAMM-WIAS Summer School on Uncertainty Quantification*, WIAS Berlin, 2016.
- *MS PDE Constrained Optimization with Uncertain Data*, SIAM Conference on Uncertainty Quantification, EPF Lausanne, 2016.
- *2nd GAMM-AGUQ Workshop on Uncertainty Quantification*, TU Chemnitz, 2015.
- Invited *MS Matrix Functions*, GAMM Annual Meeting, Graz, 2011.
- International Workshop *Numerical Analysis of Stochastic Partial Differential Equations (NASPDE 2010)*, TU Bergakademie Freiberg, 2010.
- Invited *MS Numerical Linear Algebra and Stochastic PDEs*, SIAM Conference on Applied Linear Algebra, Monterey, 2009.
- *MS Uncertainty Quantification in Subsurface Flows*, SIAM Conference on Mathematical and Computational Issues in the Geosciences, Leipzig, 2009.
- *MS Uncertainty Quantification in Groundwater Flow and Transport*, SIAM Conference on Mathematical and Computational Issues in the Geosciences, Santa Fe, 2007.
- *MS The Evaluation of Matrix Functions*, SIAM-GAMM Conference on Applied Linear Algebra, Düsseldorf, 2006.

Other Professional Activities

- Member, Mathematics Faculty Council (Fakultätsrat), TU Chemnitz (since April 2016).
- Member, Academic Senate (Senat), TU Chemnitz (since April 2015).
- Member, organizing committee, Chemnitz FE Symposium (since 2014).
- Member, Rector's Panel on Research (Rektoratskommission Wissenschaft), TU Bergakademie Freiberg, (2010–2013)
- Ph.D. examination committees
 - Björn Sprungk, TU Chemnitz, 2017 (supervisor)
 - Julia Weißflog, TU Bergakademie Freiberg, 2017 (reviewer)
 - Francesco Tesei, EPF Lausanne, 2015 (reviewer)
 - Nataliya Togobytska, TU Berlin, 2014 (reviewer)
 - Clemens Listner, TU Bergakademie Freiberg, 2014 (reviewer)
 - Antje Franke-Börner, TU Bergakademie Freiberg, 2013 (examiner)
 - Tuomas Airaksinen, University of Jyväskylä (Finland), 2010 (reviewer)
 - Eveline Rosseel, KU Leuven (Belgium), 2010 (reviewer)
 - Stefan Güttel, TU Bergakademie Freiberg, 2010 (examiner)
 - Frank Rabold, TU Bergakademie Freiberg, 2009 (examiner)
 - Elisabeth Ullmann, TU Bergakademie Freiberg, 2008 (supervisor)
 - Marina Popolizio, Università degli Studi di Bari (Italy), 2008 (reviewer)
- Grant proposal reviewer for
 - Deutsche Forschungsgemeinschaft
 - Fonds zur Förderung der wissenschaftlichen Forschung (Austria)
 - Schweizer Nationalfonds
 - Netherlands Organisation for Scientific Research
 - Academy of Sciences of the Czech Republic
 - Fonds de la Recherche Scientifique (Belgium)
 - Academy of Finland
- Book proposal reviewer for
 - Springer Verlag
 - SIAM Books

- Oxford University Press
- Verlag Walter de Gruyter
- Verlag Wiley-VCH
- Service on Hiring Committees (Berufungskommissionen)
 - *Numerical Solution of Stochastic Differential Equations* (W2), U Halle, 2017
 - *Applied Analysis* (W2), TU Chemnitz, 2017
 - *Research Methodology and Data Analysis in Biomechanics* (W2), TU Chemnitz, 2017
 - *Inverse Problems* (W2), TU Chemnitz, 2016
 - *Stochastics* (W3), TU Chemnitz, 2016
 - *Scientific Computing* (W3), TU Chemnitz, 2016
 - *Multiscale Modelling of Material Behavior* (W1), TU Bergakademie Freiberg, 2009
- Member, evaluation committee for jun. Prof. Sebastien Groh, TU Bergakademie Freiberg, 2013
- Member, advisory panel for high performance computing, TU Bergakademie Freiberg, (2001–2013)
- Member, academic panel (Studienkommission) of study program *Engineering & Computing*, TU Bergakademie Freiberg, 2004–2009

Selected Invited Talks

- Schlumberger Cambridge Research, Cambridge, UK, *Fast Solution of the Radiative Helmholtz Equation by Imbedding*, 23.03.1995.
- University of Delaware, Department of Mathematics *Recent Developments in Krylov Subspace Techniques for Solving Large Sparse Non-Hermitian Linear Systems of Equations*, 29.03.1996.
- Courant Institute of Mathematical Sciences, New York University, *On Some Recurrent Theorems in the Theory of Krylov Subspace Methods*, 08.05.1998.
- Bell Labs, Murray Hill, NJ, *A Multigrid Method Using a Krylov Subspace Smoother for the Discrete Helmholtz Equation*, 24.03.1999.
- École Polytechnique, Paris, *Geometric Aspects in the Theory of Krylov Subspace Methods*, 06.04.1999.
- Institut für Informatik, TU München, *Ergänzung des Mehrgitterverfahrens durch Krylov-Unterraumverfahren zur Lösung der Helmholtz-Gleichung*, 17.01.2000.
- Oxford University Computing Laboratory, *Acceleration Strategies for Minimal Residual Methods*, 26.02.2001.
- SIAM Annual Meeting, San Diego, MS Computational Acoustics and Inverse Problems, *Krylov Subspace and Multigrid Methods for Discretized Acoustic Scattering Problems*, 11.07.2001.
- SIAM-EMS Conference on Mathematics in Our Changing World, Berlin. MS Recent Advances in Krylov Subspace Methods, *A Comparative Study of Accelerated Restarted Minimal Residual Methods*, 03.09.2001.
- Computational and Applied Numerical Linear Algebra 2002, Milovy, Czech Republic. *Acceleration of Restarted Minimal Residual Methods*, 08.09.2002.
- Dagstuhl Seminar Theoretical and Computational Aspects of Matrix Algorithms, Schloss Dagstuhl. *Parametrization of the Arnoldi Process*, 12.10.2003.
- ALGORITHMY 2005, Podbanske, Slovakia. *Computational Aspects of the Stochastic Finite Element Method*, 17.03.2005.
- SIAM-GAMM Conference on Applied Linear Algebra, Düsseldorf, MS Iterative Methods. *Superlinear Convergence of Krylov Subspace Methods: Potential Theory and Invariant Subspaces*, 24.07.2006.
- SIAM Geosciences Conference, Sante Fe, NM; MS Uncertainty Quantification in Groundwater Flow and Transport. *Efficient Linear Solvers for Stochastic Groundwater Simulations*, 21.03.2007.
- Householder Symposium XVII, Zeuthen, Germany. *A Posteriori Error Estimators for Krylov Subspace Approximations of Matrix Functions*, 01.06.2008.
- London Mathematical Society Symposium, Durham University, UK Computational Linear Algebra for Partial Differential Equations. *PDEs, Matrix Functions and Krylov Subspace Methods*, 15.07.2008.
- Fifth International Workshop on Numerical Analysis and Lattice QCD, Regensburg. *Restarted Krylov Subspace Methods for the Matrix Sign Function*, 06.09.2008.
- ALGORITHMY 2009, Podbanske, Slowakei; MS Krylov Subspace Methods—Theory and Applications. *Convergence of Krylov Subspace Methods for Matrix Functions*, 18.03.2009.

- 2nd Dolomites Workshop on Constructive Approximation and Applications, Canazei, Italien Session: Approximation Methods in Numerical Linear Algebra. *Deflated Restarting for Krylov Subspace Approximations to Matrix Functions*, 05.09.2009.
- ICMS Workshop on Uncertainty Quantification, Royal Society of Edinburgh, UK. *Efficient Solution of Large-Scale Covariance Eigenproblems*, 26.05.2010.
- SIAG-LA Speaker: 16th Conference of the International Linear Algebra Society, Pisa, Italy. *Krylov Subspace Approximations of the Action of Matrix Functions for Large-Scale Problems*, 22.06.2010.
- London Mathematical Society Symposium, Durham University, UK Numerical Analysis of Multiscale Problems. *On the Convergence of Generalized Polynomial Chaos Expansions*, 10.07.2010.
- 27. GAMM-Seminar, Leipzig. *Generalized Polynomial Chaos Expansions*, 26.01.2011.
- MATCH Workshop on Analytical and Numerical Methods for Multiscale Systems, Heidelberg. *Numerical Methods for PDEs with Random Inputs*, 15.02.2011.
- SIAM Computational Sciences and Engineering Conference, Reno, USA. *Efficient TEM forward modeling using Krylov subspace approximations*, 03.03.2011.
- Householder Symposium XVIII, Lake Tahoe, USA. *Krylov Subspace Methods for Geoelectrical Exploration Problems*, 16.06.2011.
- ENUMATH 2011, Leicester, UK. *Probabilistic UQ using PDEs with Random Data: A Case Study*, 09.09.2011.
- Workshop on Computational Stochastics, Annweiler am Trifels. *Probabilistic UQ using PDEs with Random Data: A Case Study*, 26.03.2012.
- SIAM UQ Conference 2012, Raleigh, USA; MS Stochastic Uncertainty: Modeling, Forward Propagation, and Inverse Problems. *Probabilistic UQ using PDEs with Random Data: A Case Study*, 03.04.2012
- King Abdullah University of Science and Technology, AMCS Seminar. *Covariance Eigenproblems and their Numerical Treatment*, 26.09.2012.
- Mathematisches Forschungsinstitut Oberwolfach, Workshop PDE-Constrained Optimization with Uncertain Data. *Travel Time Calculations at the WIPP: UQ for a Groundwater Flow Problem*, 31.01.2013.
- Hausdorff Center for Mathematics, U Bonn, Workshop on Numerical Methods for Uncertainty Quantification. *UQ for Groundwater Flow: Uncertainty Propagation and Inversion for the WIPP Problem*, 16.05.2013.
- SIAM Annual Meeting 2013, San Diego, USA; MS Recent Advances in Matrix Function Computations: Theory and Practice. *Rational Krylov Subspace Methods for Transient Electromagnetic Geophysical Forward Modeling*, 12.07.2013.
- WIAS Berlin, Workshop PDEs with Random Coefficients. *UQ for Groundwater Flow: Uncertainty Propagation and Inversion for the WIPP Problem*, 13.11.2013.
- King Abdullah University of Science and Technology, Workshop UQAW-2014. *Numerical Methods for Bayesian Inverse Problems*, 08.01.2014.
- GAMM Annual Meeting 2014, Erlangen; MS Uncertainty Quantification. *Bayesian Inversion for Groundwater Flow Problems*, 11.03.2014.
- SIAM UQ Conference 2014, Savannah, USA; MS PDEs with Random Coefficients of Lognormal Type and Applications to Subsurface Flow. *Stochastic Collocation for Random Elliptic PDEs: The Lognormal Case*, 02.04.2014.
- King Abdullah University of Science and Technology, Workshop UQAW-2015. *Metropolis-Hastings Algorithms in Function Space for Bayesian Inverse Problems*, 09.01.2015.
- University of Geneva, Numerical Analysis Seminar. *Bayesian Inversion for PDEs with Random Inputs*, 03.02.2015.
- University of Hamburg, Collatz Colloquium. *Bayesian Inverse Problems for Parameter Identification: Computational Methods for Quantifying Uncertainty*, 09.07.2015.
- SIAM Linear Algebra Conference 2015, Atlanta, USA. MS Celebration in Honor of Dianne P. O'Leary. *Towards Textbook Multigrid for the Helmholtz Equation*, 29.10.2015.
- WIAS Berlin, Workshop Direct and Inverse Problems for PDEs with Random Coefficients. *Metropolis-Hastings Algorithms in Function Space for Bayesian Inverse Problems*, 11.11.2015.
- DMV-GAMM Joint Annual Meeting 2016. Section Scientific Computing. *Computational Methods for Bayesian Inversion in Infinite Dimensions*, 10.03.2016.

- SIAM UQ Conference 2016, Lausanne, CH; MS Advances in Sampling Methods for Bayesian Inverse Problems. *Metropolis-Hastings Algorithms in Function Space for Bayesian Inverse Problems*. 07.04.2016.
- USC Summer School on Uncertainty Quantification, Los Angeles. Invited lecturer, 16.08.2016.
- MCQMC 2016, Stanford University. MS MC and QMC Methods for Bayesian Inverse Problems; *Ensemble and Polynomial Kalman Filters in Bayesian Inverse Problems*. 19.08.2016.
- University of Wuppertal, Mathematisches Kolloquium. *Uncertainty Quantification and Inverse Problems*, 25.10.2016.
- Short Course: Introduction to Uncertainty Quantification, TU Denmark. Invited lecturer, 24.11.2016.
- GAMM Annual Meeting 2017, Weimar. Invited plenary speaker, 06.03.2017.
- University of Hagen, Mathematisches Kolloquium; *Uncertainty Quantification: Propagation und Inferenz*, 13.03.2017.
- University of Oldenburg, Mathematisches Kolloquium; *Uncertainty Quantification: Propagation und Inferenz*. 17.05.2017.
- INI Workshop: Surrogate Models for UQ in Complex Systems, Cambridge, UK; *High Dimensional Collocation for Lognormal Diffusion*. 08.02.2018.
- SIAM UQ Conference 2018, Garden Grove, USA. MS Advances in Sparse Polynomial Approximations with Applications to Complex Stochastic Modeling; *Convergence of Sparse Polynomial Collocation in Infinite Dimensions*. 17.04.2018.

Supervised Doctoral Students

current Toni Kowalewitz
 current Ingolf Busch
 2017 Björn Sprungk
 2008 Elisabeth Ullmann

Supervised Postdocs

current Jan Blechta
 2008–2011 Elisabeth Ullmann

Publications

Refereed research papers

1. Ernst, OG (1996). A Finite Element Capacitance Matrix Method for Exterior Helmholtz Problems. *Numerische Mathematik* **75**(2), 175–204.
2. Eiermann, M, OG Ernst, and O Schneider (2000). Analysis of Acceleration Strategies for Restarted Minimal Residual Methods. *Journal of Computational and Applied Mathematics* **123**, 262–292.
3. Ernst, OG (2000). Equivalent Iterative Methods for p-Cyclic Matrices. *Numerical Algorithms* **25**, 161–180.
4. Ernst, OG (2000). Residual-Minimizing Krylov Subspace Methods for Stabilized Discretizations of Convection-Diffusion Equations. *SIAM Journal on Matrix Analysis and Applications* **21**(4), 1079–1101.
5. Eiermann, M and OG Ernst (2001). Geometric Aspects of the Theory of Krylov Subspace Methods. *Acta Numerica* **10**, 251–312.
6. Elman, HC, OG Ernst, and DP O’Leary (2001). A Multigrid Method Enhanced by Krylov Subspace Iteration for Discrete Helmholtz Equations. *SIAM Journal on Scientific Computing* **23**(4), 1290–1314.
7. Elman, HC, OG Ernst, DP O’Leary, and M Stewart (2005). Efficient Iterative Algorithms for the Stochastic Finite Element Method with Applications to Acoustic Scattering. *Computer Methods in Applied Mechanics and Engineering* **194**, 1037–1055.
8. Eiermann, M and OG Ernst (2006). A Restarted Krylov Subspace Method for the Evaluation of Matrix Functions. *SIAM Journal on Numerical Analysis* **44**(6), 2481–2504.
9. Eiermann, M, OG Ernst, and E Ullmann (2007). Computational Aspects of the Stochastic Finite Element Method. *Computing and Visualization in Science* **10**(1), 3–15.
10. Afanasjew, M, M Eiermann, OG Ernst, and S Güttel (2008). A Generalization of the Steepest Descent Method for Matrix Functions. *Electronic Transactions on Numerical Analysis* **28**, 206–222.

11. Afanasjew, M, M Eiermann, OG Ernst, and S Güttel (2008). Implementation of a Restarted Krylov Subspace Method for the Evaluation of Matrix Functions. *Linear Algebra and its Applications* **429**(10), 2293–2314.
12. Börner, RU, OG Ernst, and K Spitzer (2008). Fast 3D simulation of transient electromagnetic fields by model reduction in the frequency domain using Krylov subspace projection. *Geophysical Journal International* **173**, 766–780.
13. Ernst, OG, CE Powell, D Silvester, and E Ullmann (2009). Efficient Solvers for a Linear Stochastic Galerkin Mixed Formulation of Diffusion Problems with Random Data. *SIAM Journal on Scientific Computing* **31**(2), 1424–1447.
14. Ernst, OG and E Ullmann (2010). Stochastic Galerkin Matrices. *SIAM Journal on Matrix Analysis and Applications* **31**(4), 1848–1872.
15. Busch, I, OG Ernst, and E Ullmann (2011). Expansion of random field gradients using hierarchical matrices. *PAMM* **11**(1), 911–914.
16. Eiermann, M, OG Ernst, and S Güttel (2011). Deflated Restarting for Matrix Functions. *SIAM Journal on Matrix Analysis and Applications* **32**(2), 621–641.
17. Elman, HC, OG Ernst, and E Ullmann (2012). Efficient Iterative Solvers for Stochastic Galerkin Discretizations of log-Transformed Random Diffusion Problems. *SIAM Journal on Scientific Computing* **34**(2), A659–A682.
18. Ernst, OG, A Mugler, HJ Starkloff, and E Ullmann (2012). On the Convergence of Generalized Polynomial Chaos Expansions. *M2AN* **46**(2), 317–339.
19. Seidel, J and OG Ernst (2014). Model Reduction for Cold Rolling Processes. *Steel Research* **85**(9), 1334–1339.
20. Ullmann, M, U Prüfert, J Seidel, OG Ernst, and C Hasse (2014). Application of Proper Orthogonal Decomposition Methods in Reactive Pore Diffusion Simulations. *Canadian Journal of Chemical Engineering* **92**(9), 1552–1560.
21. Börner, RU, OG Ernst, and S Güttel (2015). Three-dimensional transient electromagnetic modelling using rational Krylov methods. *Geophysical Journal International* **202**, 2025–2043.
22. Ernst, OG, B Sprungk, and HJ Starkloff (2015). Analysis of the Ensemble and Polynomial Chaos Kalman Filters in Bayesian Inverse Problems. *SIAM/ASA Journal on Uncertainty Quantification* **3**(1), 823–851.
23. Ernst, OG, B Sprungk, and L Tamellini (2018). Convergence of Sparse Collocation for Functions of Countably Many Gaussian Random Variables (with Application to Elliptic PDEs). *SIAM Journal on Numerical Analysis* **56**(2), 877–905.

Book chapters

1. Ernst, OG and GH Golub (1992). “A Domain Decomposition Approach to Solving the Helmholtz Equation with a Radiation Boundary Condition”. In: *Domain Decomposition Methods in Science and Engineering: The Sixth International Conference on Domain Decomposition, June 15-19, 1992, Como, Italy*. Ed. by A Quarteroni. Vol. 157. Contemporary Mathematics. AMS, pp.177–192.
2. Elman, HC and OG Ernst (2000). Numerical Experiences with a Krylov-enhanced Multigrid Solver for Exterior Helmholtz Problems. In: *Proceedings of the Fifth International Conference on Mathematical and Numerical Aspects of Wave Propagation, Waves 2000 (Santiago de Compostela)*. Ed. by A Bermúdez, D Gómez, C Hazard, P Joly, and JE Roberts. Philadelphia: SIAM, pp.797–801.
3. Ernst, OG and MJ Gander (2011). Why it is Difficult to Solve Helmholtz Problems with Classical Iterative Methods. In: *Numerical Analysis of Multiscale Problems*. Ed. by I Graham, T Hou, O Lakkis, and R Scheichl. Vol. 83. Lecture Notes in Computational Science and Engineering. Berlin Heidelberg: Springer-Verlag, pp.325–361.
4. Ernst, OG and MJ Gander (2013). “Multigrid Methods for Helmholtz Problems: A Convergent Scheme in 1D Using Standard Components”. In: *Direct and Inverse Problems in Wave Propagation and Applications*. Ed. by IG Graham, U Langer, JM Melenk, and M Sini. Vol. 14. Radon Series on Computational and Applied Mathematics. Berlin/Boston: Walter de Gruyter GmbH, pp.135–185.
5. Ernst, OG and B Sprungk (2014). “Stochastic Collocation for Elliptic PDEs with Random Data - the Lognormal Case”. In: *Sparse Grids and Applications - Munich 2012*. Ed. by J Garcke and D Pflüger. Lecture Notes in Computational Science and Engineering. Springer-Verlag, pp.29–53.
6. Ernst, OG, B Sprungk, and HJ Starkloff (2014). “Bayesian Inverse Problems and Kalman Filters”. In: *Extraction of Quantifiable Information from Complex Systems*. Ed. by Sea Dahlke. Vol. 102. Lecture Notes in Computational Science and Engineering. Springer-Verlag, pp.133–159.

Theses

1. Ernst, OG (1989). “Über einige Anwendungen komplexer Orthogonalpolynome in der Numerik”. Diplomarbeit, Institut für Praktische Mathematik, Universität Karlsruhe.
2. Ernst, OG (1994). “Fast Numerical Solution of Exterior Helmholtz Problems with Radiation Boundary Condition by Imbedding”. PhD thesis, Stanford University.

3. Ernst, OG (2001). "Minimal and Orthogonal Residual Methods and their Generalizations for Solving Linear Operator Equations". Habilitation Thesis, TU Bergakademie Freiberg.

Other Publications

1. Eiermann, M, OG Ernst, and W Queck (1996). A Very Short Finite Element Tutorial. In: *Simulationstechniken in der Materialwissenschaft*. Ed. by P Klimanek and W Pantleon. Vol. B 279. Freiburger Forschungshefte. TU Bergakademie Freiberg, pp.17–40.
2. Ernst, OG and KA Cliffe (Oct. 2012). Uncertainty Quantification 2012: Probabilistic UQ for PDEs with Random Data: A Case Study. *SIAM News* 45(8).
3. Ernst, OG (2017). Quantifizierung von Unsicherheit: Propagation und Inferenz. *GAMM Rundbrief* 2, 4–9.