

CURRICULUM VITAE

Michael Shearer

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Education:

1969 - 1972 University of York, Heslington, York
B.A. Mathematics.
1972 - 1975 Wadham College and Mathematical Institute, Oxford
M.Sc., 1973, D. Phil., 1976

Experience:

Professor, North Carolina State University, 1988 - present.
Associate Professor, North Carolina State University, 1985 - 1988.
Assistant Professor, Duke University, 1979 - 1985.
Temporary Lecturer, University College London, 1978 - 1979.
Research Fellow, Fluid Mechanics Research Institute,
University of Essex, 1975 - 1978.

Professional Memberships:

Member of the Society of Industrial and Applied Mathematics (SIAM).
Member of the SIAM Activity Groups:
Analysis of Partial Differential Equations,
Nonlinear Waves and Coherent Structures.
Member of the American Mathematical Society (AMS); Fellow of the AMS.
Member of the American Physical Society (APS).

Research Interests:

Nonlinear Partial Differential Equations; Applications in solid mechanics and fluid mechanics;
Shock waves, including dispersive shock waves; Porous media flow; Granular materials;
Thin liquid films; Droplets on soft substrates.

Recent Grants:

Thin Layer Flow: Experiments, Modeling, and Analysis. Co-PI K. Daniels (Physics). NSF
\$482,771. 2006-2010.
EMSW21-RTG Mathematics of Materials: Model Development, Analysis, Simulation
and Control. (Co-PI) R. Smith (PI), Co-PIs M. Haider, N. Medhin, P. Gremaud. NSF.
\$1,169,089. 2007-2010.
FRG: Collaborative Research: Dynamics of Thin Liquid Films: Mathematics and Experiments.
Co-PI K. Daniels (Physics). NSF. \$780,951. 2010-2015.
Nonlinear Waves in Continuum Mechanics. NSF. \$286,253. 2015-2018.
Nonlinear Partial Differential Equations of Mechanics. NSF. \$299,777. 2018-2021.

Textbook:

Partial Differential Equations: An Introduction to Theory and Applications
by Michael Shearer and Rachel Levy. Princeton University Press 2015

Edited Conference Proceedings:

Nonlinear Evolution Equations that Change Type (with B.L. Keyfitz)

IMA Volumes in Mathematics and its Applications **27**. Springer, 1990.

Viscous Profiles and Numerical Methods for Shock Waves. SIAM, 1991.

Thin Liquid Films and Fluid Interfaces (with R. Behringer). Physica D, 2005.

Research Publications:

- Bifurcation from a multiple eigenvalue. *Proceedings of the 1976 Dundee Conference on Ordinary and Partial Differential Equations*. Springer Lecture Notes in Mathematics **564** (1976), 417-424.
- Small solutions of a nonlinear equation in Banach space for a degenerate case, Proc. Roy. Soc. Edinburgh **79A** (1977), 35-49.
- Bifurcation in the neighborhood of a non-isolated singular point, Israel J. Math. **30** (1978), 363-381.
- On the null spaces of linear Fredholm operators depending on several parameters, Math. Proc. Camb. Phil. Soc. **84** (1978), 131-142.
- Bifurcation of axisymmetric buckled states of a thin spherical shell J. Nonlinear Analysis - TMA. **4** (1980), 699-713.
- Secondary bifurcation for one-parameter families of bifurcation problems, University of Essex Report No. 97, 1978.
- Secondary bifurcation near a double eigenvalue, SIAM J. Math. Anal. **11** (1980), 365-389.
- One parameter perturbations of bifurcation from a simple eigenvalue, Math. Proc. Camb. Phil. Soc. **88** (1980), 111-123.
- (with I. C. Walton), On bifurcation and symmetry in Benard convection and Taylor vortices, Stud. Appl. Math. **65** (1981), 85-93.
- Coincident bifurcation of equilibrium and periodic solutions of evolution equations, J. Math. Anal. Appl. **84** (1981), 113-132.
- The Riemann problem for a class of conservation laws of mixed type, J. Differential Equations **46** (1982), 426-443.

- Admissibility criteria for shock wave solutions of a system of conservation laws of mixed type, Proc. Roy. Soc. Edinburgh **93A** (1983), 233-244.
- Elementary wave solutions of the equations describing the motion of an elastic string, SIAM J. Math. Anal. **16** (1985), 447-459.
- The interaction of transverse waves for the vibrating string. *Physical Mathematics and Nonlinear Partial Differential Equations* (ed. J.H. Lightbourne, S.M. Rankin). Lecture Notes in Pure and Applied Mathematics, Vol. 102. Marcel Dekker, 1985.
- The nonlinear interaction of smooth travelling waves in an elastic string. J. Wave Motion **7** (1985), 169-175.
- (with D.G. Schaeffer) Three phase flow in a porous medium and the classification of non-strictly hyperbolic conservation laws. *Proceedings of the Third Army Conference on Applied Mathematics and Computing*, May 1985.
- The Riemann problem for the planar motion of an elastic string. J. Differential Equations, **61** (1986), 149-163.
- Nonuniqueness of admissible solutions of Riemann initial value problems for a system of conservation laws of mixed type. Arch. Rat. Mech. Anal., **93** (1986), 45-59.
- Shock waves and bifurcation. *Proceedings of the Brazilian National Colloquium* (ed. L. Gama) 1986.
- (with D.G. Schaeffer), Recent developments in nonstrictly hyperbolic conservation laws. *Proceedings of the Fourth Army Conference on Applied Mathematics and Computing*, May 1986.
- (with D.G. Schaeffer), Three phase flow in porous media-recent developments in nonstrictly hyperbolic conservation laws. *Advances in Multiphase Flow and Related Problems* (ed. G. Papanicolaou). SIAM 1986.
- (with D. G. Schaeffer), The classification of 2×2 systems of non-strictly hyperbolic conservation laws, with application to oil recovery. Comm. Pure Appl. Math., **40** (1987), 141-178.
- (with D. G. Schaeffer, D. Marchesin and P. Paes-Leme), Solution of the Riemann problem for a prototype 2×2 system of non-strictly hyperbolic conservation laws. Arch. Rat. Mech. Anal. **97** (1987), 299-320.
- Phase jumps near the Maxwell line. Contemporary Mathematics **60** (1987), 111-114.
- (with D.G. Schaeffer), Riemann problems for nonstrictly hyperbolic 2×2 systems of conservation laws. Trans. A.M.S., **301** (1987), 267-306.

- Loss of strict hyperbolicity for the Buckley-Leverett equations of three phase flow in a porous medium. *Numerical Simulation in Oil Recovery* (ed. M. Wheeler). IMA Volumes in Mathematics and its Applications **11**. Springer, 1987.
- (with J. Fehribach) The elastic string equations: numerical results using Glimm's method, and two new exact solutions. CRSC Report, NC State Univ., 1987.
- Dynamic phase transitions in a van der Waals gas. *Quart. Applied Math.*, **46** (1988), 631-636.
- (with J. Fehribach) Approximately periodic solutions of the elastic string equations. *Applicable Anal.*, **32** (1989), 1-14.
- (with J. Trangenstein) Loss of real characteristics for models of three-phase flow in a porous medium. *Transport in Porous Media*, **4** (1989), 499-525.
- (with S. Schechter) Riemann problems involving undercompressive shocks. *PDE's and Continuum Models of Phase Transitions*. Proceedings, Univ. of Nice, 1988. (eds. M. Rascle, D. Serre, M. Slemrod). Springer Lecture Notes in Physics **344** (1989), 187-200.
- The Riemann problem for 2x2 systems of hyperbolic conservation laws with case I quadratic nonlinearities. *J. Differential Equations*, **80** (1989), 343-363.
- (with D.G. Schaeffer) The quasidynamic approximation in critical state plasticity. *Arch. Rat. Mech. Anal.*, **108** (1989), 267-280.
- (with D.G. Schaeffer and E.B. Pitman) Instability in critical state theories of granular flow. *SIAM J. Appl. Math.*, **50** (1990), 33-47.
- (with S. Schechter) Undercompressive shocks in systems of conservation laws. *Nonlinear Evolution Equations that Change Type* (eds. B.L. Keyfitz and M. Shearer). IMA Volumes in Mathematics and its Applications **27**. Springer, 1990.
- (with D.G. Schaeffer) Loss of hyperbolicity in yield vertex plasticity models under nonproportional loading. *Nonlinear Evolution Equations that Change Type* (eds. B.L. Keyfitz and M. Shearer). IMA Volumes in Mathematics and its Applications **27**. Springer, 1990.
- (with S. Schechter) Undercompressive shocks for systems of nonstrictly hyperbolic conservation laws. *J. Dynamics and Differential Equations*, **3** (1991), 199-271.
- (with S. Schechter) Transversality for undercompressive shocks in Riemann problems. *Viscous Profiles and Numerical Methods for Shock Waves* (ed. M. Shearer). SIAM 1991.
- (with D.G. Schaeffer) Scale invariant initial value problems for equations of elastoplasticity, with consequences for multidimensional dynamic plasticity. *European J. Applied Math.* **3** (1992), 225-254.

- (with D.G. Schaeffer and S. Schechter) Nonstrictly hyperbolic conservation laws with a parabolic line. *J. Differential Equations*, **103** (1993), 94-126.
- (with D.G. Schaeffer) The initial value problem for a system modelling unidirectional longitudinal elastic-plastic waves. *SIAM J. Math. Anal.*, **24** (1993), 1111-1144.
- (with D.G. Schaeffer) Unloading near a shear band: a free boundary problem for the wave equation. *Comm. P.D.E.*, **18** (1993), 1271-1298.
- (with D.G. Schaeffer) Unloading near a shear band in granular material. *Quart. Appl. Math.*, **52** (1994), 579-600.
- (with F.X. Garaizar, D.G. Schaeffer and J. Trangenstein) Formation and development of shear bands in granular material. *Transactions of the 11th Army Conference on Applied Mathematics and Computing* (1994), 15-28.
- (with Y. Yang) The Riemann problem for a system of conservation laws of mixed type with a cubic nonlinearity. *Proc. A, Royal Soc. Edinburgh*, **125A** (1995), 675-699.
- (with D. Jacobs and W. McKinney) Travelling wave solutions of the modified Korteweg-deVries-Burgers Equation. *J. Differential Equations*, **116** (1995), 448-467.
- (with D.G. Schaeffer) A class of fully nonlinear 2×2 systems of partial differential equations. *Comm. P.D.E.*, **20** (1995), 1105-1131.
- (with D.G. Schaeffer) Fully nonlinear hyperbolic systems of partial differential equations related to plasticity. *Comm. P.D.E.*, **20** (1995), 1133-1153.
- Fully nonlinear hyperbolic systems related to hypoplasticity. *Proc. Fifth Int. Conf. on Hyperbolic Problems: Theory, Numerics, Applications*, ed. J. Glimm, M.J. Graham, J.W. Grove, and B.J. Plohr. World Scientific, 1996.
- (with D.G. Schaeffer) Riemann problems for 5×5 systems of fully nonlinear equations related to hypoplasticity. *Math. Methods in the Applied Sciences*, **19** (1996), 1433-1444.
- (with D.G. Schaeffer) The influence of material nonuniformity preceding shear-band formation in a model for granular flow. *Euro. J. Applied Math.*, **8** (1997), 457-483.
- (with F.X. Garaizar and M.K. Gordon) Formation of shear bands in models of granular materials. *Proc. IUTAM Symposium on Mechanics of Granular and Porous Materials*, (N.A. Fleck and A.C.F. Cocks, eds.). Kluwer, 1997.
- (with M.K. Gordon and D.G. Schaeffer) Plane shear waves in a fully saturated granular medium with velocity and stress controlled boundary conditions. *Int. J. Nonlinear Mechanics*, **32** (1997), 489-503.

- (with D.G. Schaeffer) Models of Stress Fluctuations in Granular Materials. *Proc. Powders and Grains*, ed. R.P. Behringer and J. Jenkins. Balkema, 1997.
- (with D.G. Schaeffer) Stress fluctuations in granular materials. *Mechanics of Deformation and Flow of Particulate Materials*, ed. C.S. Chang, A. Misra, R.Y. Liang, and M. Babic. ASCE Publications, 1997.
- (with F.X. Garaizar and M.K. Gordon) An Elastoplasticity Model for Antiplane Shearing with a Non-Associative Flow Rule: Genuine Nonlinearity of Plastic Waves. *J. Math. Anal. Appl.*, **219** (1998), 344–363.
- (with L. Howle, D.G. Schaeffer and P. Zhong) Lithotripsy: The Treatment of Kidney Stones with Shock Waves. *SIAM Review*, **40** (1998), 356–371.
- (with D.G. Schaeffer) A simple model for stress fluctuations in plasticity with application to granular materials. *SIAM J. Appl. Math.*, **58** (1998), 1791–1807.
- (with Y. Horie and O.J. Schwarz) Discrete element investigation of stress fluctuation in granular flow at high strain rates. *Phys. Review E* **57** (1998), 2053-2061.
- (with B.L. Hayes) Undercompressive shocks for scalar conservation laws with non-convex fluxes, *Proc. A Royal Soc. Edinburgh*, 129A (1999), 733-754.
- (with M.R. Schulze) Undercompressive shocks for a system of hyperbolic conservation laws with cubic nonlinearity, *J. Math. Anal. Appl.* **229** (1999), 344–362.
- (with A.L. Bertozzi and A. Münch) Undercompressive shocks in thin film flows. *Physica D*, **134** (1999), 431-464.
- (with A.L. Bertozzi and A. Münch) Undercompressive shocks in thin film flow: Experiment, computation and theory. *AMS/IP Studies in Advanced Mathematics* **13** (1999), 43–68.
- (with P. Gremaud and D.G. Schaeffer) Numerical determination of flow corrective inserts for granular materials in conical hoppers. *International Journal of Non-linear Mechanics*, **35** (2000), 869-882
- (with P. Gremaud and J.V. Matthews) Similarity solutions for granular flows in hoppers. *Proceedings of the SIAM/AMS Conference on Nonlinear PDEs, Dynamics and Continuum Physics*, J. Bona, K. Saxton, R. Saxton, Eds., *AMS Contemporary Mathematics Series* **255** (2000), 79–95.
- (with A.L. Bertozzi) Existence of undercompressive traveling waves in thin film equations. *SIAM J. Math. Anal.*, **32** (2000), 194–213.
- (with R.A. Segal, X. Guan and T.B. Martonen) Mathematical model of airflow in the lungs of children I: Effects of tumor sizes and location. *J. Theoretical Medicine*, **2** (2000), 199–213.

- (with R.A. Segal, X. Guan and T.B. Martonen) Mathematical model of airflow in the lungs of children II: Effects of ventilatory parameters. *J. Theoretical Medicine*, **3** (2000), 51–62.
- (with B.L. Hayes) A nonconvex scalar conservation law with a trilinear flux. *Quart. Appl. Math.* **59** (2001), 615–635.
- (with A.L. Bertozzi, A. Münch and K. Zumbrun) Stability of compressive and undercompressive thin film travelling waves. *European J. Applied Math.*, **12** (2001), 253-291.
- (with T.P. Witelski and D.G. Schaeffer) A discrete model for an ill-posed nonlinear parabolic PDE. *Physica D*, **160** (2001), 189-221.
- (with R.A. Segal, C.S. Kim and T.B. Martonen) Computer simulations of particle deposition in the lungs of chronic obstructive pulmonary disease patients. *Inhalation Toxicology*, **14** (2002), 705-720.
- (with R. Buckingham and A.L. Bertozzi) Thin film traveling waves and the Navier slip condition. *SIAM J. Applied Math.* **63** (2003), 722-744.
- (with T.P. Witelski and D.G. Schaeffer) Stability of shear bands in an elastoplastic model for granular flow: The role of discreteness. *Math. Models Methods Appl. Sciences.* **13** (2003), 1629-1671.
- (with P.G. LeFloch) Nonclassical Riemann solvers with nucleation. *Proc. Roy Soc Edinburgh.*, **134A** (2004), 961-984.
- (with R. Levy) Comparison of Dynamic Contact Line Models for Driven Thin Liquid Films. *Euro. J. Applied Math.*, **15** (2004), 625-642.
- (with R. Levy) Kinetics and nucleation for driven thin film flow. *Physica D*, **209** (2005), 145-163.
- (with J.M.N.T. Gray and A.R. Thornton) Time-dependent solutions for particle-size segregation in shallow granular avalanches. *Proc. Roy Soc.*, **462** (2006), 947-972.
- (with R. Levy) The Motion of a Thin Liquid Film Driven by Surfactant and Gravity. *SIAM J. Applied Math.*, **66** (2006), 1588-1609.
- (with R. Levy and T.P. Witelski) Growing Surfactant Waves in Thin Liquid Films Driven by Gravity. *AMRX* **2006** (2006), 1-21.
- (with R. Levy and T.P. Witelski) The influence of insoluble surfactant on the flow of a thin liquid film down an inclined plane. *Euro. J. Appl. Math.* **18** (2007), 679-708.

- (with T.P. Witelski and D.G. Schaeffer) Boundary-Value Problems for Hyperbolic Equations Related to Steady Granular Flow. *Mathematics and Mechanics of Solids* **12** (2007), 665-699.
- (with R. Levy and P. Taylor) Automated Review of Prerequisite Material for Intermediate-level Undergraduate Mathematics, *PRIMUS*, **17** (2007), 167-180.
- (with J.M.N.T. Gray and A.R. Thornton) Stable solutions of a scalar conservation law for particle-size segregation in dense granular avalanches. *Euro. J. Appl. Math.* **19** (2008), 61-86.
- (with M. McIntyre, E.L. Rowe, J.M.N.T. Gray and A.R. Thornton) Evolution of a Mixing Zone in Granular Avalanches. *Appl. Math. Research Express. (AMRX)* **2008** (2008), article abm008, 12 pages.
- (with E. R. Peterson, R. Levy, T. P. Witelski) Stability of Traveling Waves in Thin Liquid Films Driven by Gravity and Surfactant. *Hyperbolic Problems (HYP2008)*, ed. E. Tadmor, J.-G. Liu, A. Tzavaras. AMS 2009.
- (with P. Gremaud and K. Kleiner) Periodic motion of a mass-spring system. *IMA J. Appl. Math.* page hxp032, 2009.
- (with N. Giffen) Shock Formation and Breaking in Granular Avalanches. *Discrete and Continuous Dynamical Systems.* **27 (2)** (2010), 693-714.
- (with L.B.H. May and K.E. Daniels) Scalar Conservation Laws with Nonconstant Coefficients with Application to Particle Size Segregation in Granular Flow. *J. Nonlinear Science.* DOI 10.1007/s00332-010-9069-7 **20** (2010), 689-707.
- (with L.B.H. May, L. A. Golick, K. C. Phillips, and K. E. Daniels) Shear-driven size segregation of granular materials: modeling and experiment. *Physical Review E*, **81(1)** (2010), 051301.
- (with L.B.H. May, N. Giffen, K.E. Daniels) The Gray-Thornton Model of Granular Segregation. *Proc. Joint IUTAM-ISIMM Symposium on *Mathematical Modeling and Physical Instances of Granular Flows**. Eds. J.D. Goddard, J.T. Jenkins, P. Giovine. American Inst. Physics, 2010, 371-378.
- (with C.M. Dafermos) Finite time emergence of a shock wave for scalar conservation laws. *J. Hyperbolic Eqns.* **7 (1)** (2010), 107-116.
- (with E.R. Peterson) Radial spreading of surfactant on a thin liquid film. *Appl. Math. Res. Express* (2010) doi: 10.1093/amrx/abq015
- (with K. Spayd) The Buckley-Leverett equation with dynamic capillary pressure. *SIAM J. Appl. Math.*, **71** (2011), 1088-1108
- (with K. Spayd and Z.Z. Hu) Stability of plane waves in two phase porous media flow. *Applicable Analysis*, **91** (2012), 295-308.

- (with E.R. Peterson) Simulation of surfactant spreading on a thin liquid film. *Appl. Math. Comp.* **218(9)** (2012), 5157–5167. doi:10.1016/j.amc.2011.11.002
- Smooth Periodic Solutions of a 2×2 System of Hyperbolic Conservation Laws. *Appl. Math. Res. Express* (2013) DOI: 10.1093/amrx/abt006
- Two Fluid Flow in Porous Media. HYP2012, Padua, Italy. *AIMS Appl. Math.* **8** (2013), 212-232.
- (with J. B. Bostwick and K.E. Daniels) Elastocapillary deformations on partially-wetting substrates: rival contact-line models. *Soft Matter*, **10** (2014), 7361-7369.
- (with E.R. Swanson, S. Strickland and K.E. Daniels) Surfactant Spreading on a Thin Liquid Film: Reconciling Models and Experiments. *J. Engineering Math.* **94** (2015) pp 63-79. URL <http://arxiv.org/abs/1306.4881>.
- (with E.R. Swanson and K. R. Spayd) Traveling Waves for Conservation Laws with Cubic Nonlinearity and BBM Type Dispersion. *J. Differential Eqns.* **259** (2015), 3216-3232.
- (with S. L. Strickland, and K. E. Daniels) Spatiotemporal measurement of surfactant distribution on gravity-capillary waves. *J. Fluid Mech.* **777** (2015) 523-543. URL <http://arxiv.org/abs/1502.03467>
- (with Gennady A. El and Mark A. Hoefer) Expansion shock waves in regularized shallow water theory. *Proc. A Roy. Soc. London.* **472** (2016) DOI: 10.1098/rspa.2016.0141.
- (with Gennady A. El and Mark A. Hoefer) Dispersive and diffusive-dispersive shock waves for non-convex conservation laws. *SIAM Review* **59(1)** (2017), 1-59. URL <http://arxiv.org/abs/1501.01681>
- (with J. B. Bostwick and J.A. Dijksman) Wetting dynamics of a collapsing fluid hole. *Phys. Rev. Fluids.* **2** (2017), 1-14. URL <http://arxiv.org/abs/1512.07826>
- (with Gennady A. El and Mark A. Hoefer) Stationary Expansion Shocks for a Regularized Boussinesq System. *Studies Appl. Math.* **139(4)** (2017) 1-22. DOI: 10.1111/sapm.12191. URL <http://arxiv.org/abs/1601.01071>
- (with T. Barker, D.G. Schaeffer and J.M.N.T. Gray) Well-posed continuum equations for granular flow with compressibility and $\mu(I)$ rheology. *Proc. Royal Society, London.* **473** (2017). DOI: 10.1098/rspa.2016.0846
- (with Aaron Bardall and Karen E. Daniels) Deformation of an Elastic Substrate Due to a Resting Sessile Droplet. *European J. Applied Mathematics.* **29** (2018), 281-300. <https://doi.org/10.1017/S0956792517000134>
- (with Elisabeth M. Brown) A Scalar Conservation Law for Plume Migration in Carbon Sequestration. *SIAM J. Applied Math.* Vol. **78**, No. **3** (2018), 1823-1841.

- (with Zhu Tang, Theodore A. Brzinski and Karen Daniels) Nonlocal rheology of dense granular flow in annular shear experiments. *Soft Matter*, 14 (2018), 3040–3048. DOI: 10.1039/c8sm00047f
- (with Gennady A. El, Thibault Congy and Mark A. Hoefer) Nonlinear Schrödinger equations and the universal description of dispersive shock wave structure. *Studies in Applied Mathematics* (2018), 1-28. DOI: 10.1111/sapm.12247.
- (with D. G. Schaeffer, T. Barker, P. Gremaud, D. Tsuji and J.M.N.T. Gray) Well-posed equations for compressible granular flow in the inertial regime. *J. Fluid Mechanics* (2019), vol. 874, pp. 926–951.
- (with Aaron Bardall, Shih-Yuan Chen and Karen E. Daniels) Gradient Induced Droplet Motion Over Soft Solids. *IMA Journal of Applied Mathematics*. Submitted. Arxiv: <http://arxiv.org/abs/1908.09413>
- (with Aaron Bardall, Shih-Yuan Chen and Karen E. Daniels) Distinguishing deformation mechanisms in elastocapillary experiments. *Soft Matter*. To appear. Arxiv: <http://arxiv.org/abs/1908.11855>