

Dr. Gregory S. Duane

PROFESSIONAL INTERESTS

Primary interests:

Geophysical Fluid Dynamics, Synchronized Chaos in Dynamical Systems, Self-Organization of the Climate System, Adaptive Modeling of Climate, Data Assimilation, Inertial Manifolds

Other interests:

Machine Vision, Neural Networks, Foundations of Quantum Mechanics

EDUCATION

- **Ph.D., Astrophysical, Planetary, and Atmospheric Sciences**
University of Colorado, 1997
-major thesis topic: application of low-order synchronized chaos to the prediction of relationships between large-scale weather patterns in the Northern and Southern hemispheres, using a Green's function method to represent the time-lagged coupling between the corresponding quasigeostrophic midlatitude channel models, truncated to a small number of modes
-minor thesis topic: development of global entropy metric for cloud systems to enable the formulation of a second-law constraint on cloud morphogenesis based on water-cycle throughput
- **M.S., Astrophysical, Planetary, and Atmospheric Sciences**
University of Colorado, 1995
- **M.S., Physics**
State Univ. of NY at Stony Brook, 1981
- **B.S., Physics, B.S., Math, B.S., Chemistry**
Massachusetts Institute of Technology, 1976
(National Merit Scholar; Hertz Scholar)

PROFESSIONAL ACADEMIC/SCIENTIFIC EXPERIENCE

Researcher – Marie Curie Fellow

Geophysical Institute - University of Bergen, Norway 2014-present
-PI on Marie Curie grant; senior investigator on STERCP grant to develop supermodel that combines state-of-the art climate models;

Research Associate

Dept. of Atmospheric and Oceanic Sciences - University of Colorado 2011-present
-Principal Investigator on DOE grant to develop a prototype climate “supermodel” by synchronizing a collection of existing models

Visiting Researcher

Macedonian Academy of Sciences and Arts (MANU) 2011-2013
-senior investigator and work-package leader on SUMO project funded by European Commission to develop supermodeling scheme that combines alternative models of the same physical process via non-linear synchronization dynamics

Scientist

Rosenstiel School of Marine and Atmospheric Sciences - University of Miami 2009
-co-Principal Investigator on NSF seed grant to develop and promote a synchronization-based scheme for consensus formation via supermodeling

Visiting Scientist

National Center for Atmospheric Research 2003-2008

-co-Principal Investigator on NSF's Collaborations in Mathematical Geosciences (CMG) program to apply chaos synchronization to data assimilation by synchronizing "truth" and "model", so as to improve on the Kalman filter in highly nonlinear regions of state space; lead author on the initial grant proposal
-developed scheme for parameter estimation, model learning, and fusion of models by extending a control theory result on synchronization of parameters to PDEs

Postdoctoral Fellow

Inst. for Mathematics and Its Applications 2001-2003

-continued research on application of synchronized chaos to 1) climate dynamics and data assimilation in PDE systems with inertial manifolds; and
2) neural networks for combinatorial optimization

Postdoctoral Fellow/Visiting Scientist

National Center for Atmospheric Research 1998-2000

-continued research in applications of synchronized chaos to 1) atmospheric teleconnections, using a QG channel model to show that inter-sectorial coupling of the small-scale flow components tend to synchronize the large scales and to predict conditions favorable to Atlantic-Pacific double blocking; and
2) reinterpretation of quantum mechanical Einstein-Podolsky-Rosen (EPR) correlations as synchronization of coupled deterministic systems

Graduate Research Assistant

University of Colorado, Boulder 1993-1997

-planned and executed research tasks to support Ph.D. thesis

TEACHING EXPERIENCE

Part-time adjunct

Mathematics Department, University of Wyoming Fall 2007

-taught two sections (17 and 35 students, resp.) of introductory Problem Solving for non-technical majors: mostly combinatorics, probability, graph theory; introduced new small-group format

Consultant for undergraduate research

Meteorology Department, University of Maryland Summer 2004

-provided scientific expertise and mentoring for a group of six undergraduate women on a project under the Research Internships in Science and Engineering (RISE) program to encourage women to pursue scientific careers; the students compared synchronization and data assimilation as applied to a toy model

Visiting Assistant Professor

School of Mathematics, University of Minnesota Spring 2004

-taught two courses in a sequence on advanced topics in elementary math for education majors, ~25 students each, including number sequences, combinatorics, graph theory, probability, classical and analytic geometry; introduced term projects in 2nd semester

PROFESSIONAL ENGINEERING/INDUSTRY EXPERIENCE

Research Physicist

Thunder Bay Regional Research Institute, Thunder Bay, Ontario, Canada 2010-2012

- optimized pulse sequences for Diffusion-Weighted Magnetic Resonance Imaging (MRI) to probe small-scale cellular/nuclear morphology

Senior Staff Engineer

Hughes Aircraft Company, Canoga Park, CA 1990-1991

- conceived and implemented improvements to neocognitron neural network architecture for translation-invariant object recognition

Principal Analyst

Ball Aerospace Systems Group, Boulder, CO 1987-1989

- developed scheme for low-level fusion of co-registered images from sensors of different types for improved recognition; validated using statistical binary-tree classifier
- conceived neural architecture for automatic stereo-matching based on combination of Hopfield optimization network and Grossberg FCS/BCS model of biological vision

Staff Engineer

Martin Marietta Corp., Orlando, FL and Denver, CO 1983-1987

- co-ordinated internal marketing activities to demonstrate capabilities of Artificial Intelligence Dept. to various program organizations within company
- developed proof-of-concept system for knowledge-based segmentation of road scenes for autonomous vehicle navigation
- knowledge-engineered a rule-based system to feedback information from automatic recognition system to assist in low-level delineation of objects in infra-red imagery

Engineer

General Dynamics Corp., San Diego, CA 1981-1983

- developed image segmentation algorithms, including a knowledge-based generalization of "superslice" algorithm for choice of grey-level threshold based on coincidence of thresholded object boundaries and detected edges

GRANTS

European Commission Grant (Marie Sklodowska-Curie Individual Fellowship) #658602 - COCLIMAT "Fusion of Alternative Climate Models by Dynamical Synchronization" 5/2015-10/2017 EUR 196K at University of Bergen, Norway

DOE Grant #DE-SC0005238 "An Interactive Multi-Model for Consensus on Climate Change" 10/2010-9/2014 \$301K, PI at Univ. of Colorado, with collaborating PIs: A.A. Tsonis (U. Wisconsin), L. Kocarev (UCSD), and co-PI B. Kirtman (U. Miami), \$680K total, leading a multi-institutional effort to use chaos synchronization to fuse different climate models in a way that would be superior to model averaging

NSF Grant #0838235 "Collaborative Research: Consensus on Climate Prediction by Adaptive Synchronization of Models" 1/2009-12/2009 \$80K, Co-PI with PIs: B. Kirtman (U. Miami), L. Kocarev (UCSD), and co-PI J. Tribbia (NCAR), \$100K total, continuing role as below toward the initiation of a longer-term project for model fusion, resulting in grants from DOE (above) and the European Research Council

NSF Grant #0327929 "CMG Collaborative Research: Data Assimilation by Synchronization of Truth and Model" 9/2003-8/2006, \$258K, Co-PI (responsible for writing project description and coordinating multi-institutional effort) with PIs: J. Tribbia (NCAR), E. Kalnay (U.Md.), L. Kocarev

(UCSD), and J.B. Weiss (U.Co.), \$1.1M total, resulting in a theory of data assimilation in the non-linear regime and synchronization-based model learning as described in 6 publications

SERVICE

- Lead guest editor for Focus Issue of *Chaos: Synchronization in Large Networks and Continuous Media – Data, Models, and Supermodels*, eds: G.S. Duane, C. Grabow, F. M. Selten, and M. Ghil, December, 2017
- Convener of session, “Ensemble Methods for Combining Alternative Models of Climate Change” at Annual Meeting of the European Geophysical Union, Vienna, Austria, April 2014
- Convener of session, “Unification of Alternative Models in Climate and Geophysics via Interactive Ensembles, Stochastic Parameterization, and Networks” at Fall Meeting of the American Geophysical Union, San Francisco, CA, December 2013
- Organizer of Minisymposium, “Supermodeling Climate by Synchronization of Alternative Models” at SIAM Conference on Applications of Dynamical Systems, Snowbird, UT, May 2013
- Convener of session, “Ensemble Methods for Combining Alternative Climate Models” at Annual Meeting of the European Geophysical Union, Vienna, Austria, April 2013
- Convener of session, “Synchronized Chaos and Serendipitous Correlations in Nonlinear Geophysics” at the Fall Meeting of the American Geophysical Union, San Francisco, CA Dec. 2009
- Reviewer for: Quart. J. Royal Meteorological Soc., J.Geophys. Res., J. Atmospheric Sciences, Proc. Royal Soc. of London, IEEE Trans. on Systems, Man, and Cybernetics, Chaos, Physica D
- Mentor for McNair Program, Univ. of Colo., to encourage outstanding undergraduates from non-traditional backgrounds to pursue graduate study
- Mentor program coordinator for McNair Program (salaried position): recruited graduate students to mentor McNair undergraduates and supervised the mentoring process
- Mentor for the scientific writing component of the SOARS (Significant Opportunities in Atmospheric Research and Science) program at NCAR to engage undergraduates from underrepresented groups in research in the atmospheric sciences

PUBLICATIONS (peer-reviewed)

Sendera, M, Duane, G.S., and Dzwiniel, W., 2020: Supermodeling: The next level of abstraction in the use of data assimilation, In: Krzhizhanovskaya V. et al. (eds), *Computational Science – ICCS 2020. ICCS 2020. Lecture Notes in Computer Science*, **12142**, Springer, Cham, 133-147.

Duane, G.S., 2019: Tunneling through bridges: Bohmian non-locality from higher-derivative gravity, *Phys. Lett. A* **383**, 929-935.

Duane, G.S., 2017: “FORCE” learning in recurrent neural networks as data assimilation, *Chaos* **27**, 126804.

Duane, G.S., Wiegner, W., Selten, F.M., Shen, M.-L., and Keenlyside, N., 2017: Supermodeling: Synchronization of alternative dynamical models of a single objective process, in *Advances in Non-linear Geosciences*, ed. A.A. Tsonis, p. 101, Springer.

Shen, M.-L., Keenlyside, N., Bhatt, B.C., and Duane, G.S., 2017: Role of atmosphere-ocean interactions in supermodeling the tropical Pacific climate (Featured Article), *Chaos* **27**, 126704.

Selten, F.M., Schevenhoven, F.J., and Duane, G.S., 2017: Simulating climate with a synchronization- based supermodel (Featured Article), *Chaos* **27**, 126903.

Duane, G.S., 2015: Synchronicity from synchronized chaos, *Entropy*, **17**, 1701-1733.

Basnarkov, L., G.S. Duane, and L. Kocarev, 2014: Generalized synchronization and coherent structures in spatially extended systems, *Chaos, Solitons, and Fractals*, **59**, 35-41.

Duane, G.S., Y. Wang, B. Walters, and J.K. Kim, 2014: A pulse sequence optimization method for assessment of nucleus size in q-space analysis of idealized cells, *J. Magn. Resonance*, **238**, 115-125.

- Duane, G.S., 2013: Data assimilation as artificial perception and supermodeling as artificial consciousness, in *Consensus and Synchronization in Complex Networks*, ed: L. Kocarev, Springer.
- Mirchev, M., G.S. Duane, W.K. Tang, and L. Kocarev, 2012: Improved modeling by coupling imperfect models, *Commun. Nonlin. Sci. Numer. Simul.*, **17**, 2741-2751.
- van den Berge, L.A., F.M. Selten, W. Wiegerinck, and G.S. Duane, 2011: A multi-model ensemble method that combines imperfect models through learning, *Earth Syst. Dynam.*, **2**, 161-177.
- Di Plinio, F., G.S. Duane, and R. Temam, 2011: On the time-dependent attractor for the oscillon equation, *Discrete and Continuous Dynamical Systems - Series A*, **29**, 141-167.
- Beechler, B.E., J.B. Weiss, G.S. Duane, and J. Tribbia, 2010: Jet alignment in a 2-layer quasigeostrophic channel using one-dimensional grid warping, *J. Atmos. Sci.* **67**, 2296-2306.
- Duane, G.S., 2009: A “cellular neuronal” approach to optimization problems, *Chaos*, **19**, 033114 (highlighted contribution).
- Duane, G.S., 2009: Synchronization of extended systems from internal coherence, *Phys. Rev. E*, **80**, 015202.
- Duane, G.S., and J.P. Hacker, 2008: Automatic parameter estimation in a mesoscale model without ensembles, in *Nonlinear Time Series Analysis in the Geosciences*, ed. R. Donner, Springer.
- Duane, G.S., D.-C. Yu, and L. Kocarev, 2007: Identical synchronization, with translation invariance, implies parameter estimation, *Phys. Lett. A*, **371**, 416-420.
- Duane, G.S., and J.J. Tribbia, 2007: Dynamical synchronization of truth and model as an approach to data assimilation, parameter estimation, and model learning, Ch. 17 in *Nonlinear Dynamics in the Geosciences*, ed. A. Tsonis, Springer, 604p.
- Duane, G.S., J.J. Tribbia, and J.B. Weiss, 2006: Synchronicity in predictive modelling: a new view of data assimilation, *Nonlin. Processes in Geophys.*, **13**, 601-612.
- Yang, S.-C., D. Baker, H. Li, K. Cordes, M. Huff, G. Nagpal, E. Okereke, J. Villafañe, E. Kalnay, and G.S. Duane, 2006: Data assimilation as synchronization of truth and model: Experiments with the three-variable Lorenz system, *J. Atmos. Sci.*, **63**, 2340-2354.
- Duane, G.S., 2005: Quantum nonlocality from synchronized chaos, *Int. J. Theor. Phys.*, **44**, 1917-1932.
- Duane, G.S. and J.J. Tribbia, 2004: Weak Atlantic-Pacific teleconnections as synchronized chaos, *J. Atmos. Sci.*, **61**, 2149-2168.
- Duane, G.S. and J.J. Tribbia, 2001: Synchronized chaos in geophysical fluid dynamics, *Phys. Rev. Lett.*, **86**, 4298-4301.
- Duane, G.S., 2001: Violation of Bell’s inequality in synchronized hyperchaos, *Found. Phys. Lett.*, **14**, 341-353.
- Duane, G.S., P.J. Webster, and J.B. Weiss, 1999: Co-occurrence of Northern and Southern Hemisphere blocks as partially synchronized chaos, *J. Atmos. Sci.*, **56**, 4183-4205.
- Duane, G.S., 1997: Synchronized chaos in extended systems and meteorological teleconnections, *Phys. Rev. E*, **56**, 6475-6493.
- Duane, G.S., and J.A. Curry, 1997 : Entropy of a convecting water-air system and the interpretation of cloud morphogenesis., *Quart. J. Roy. Met. Soc.*, **123**, 605-629.
- Wolfe, W.J., D. Mathis, C. Anderson, J. Rothman, M. Gottler, G. Brady, R. Walker, G. Duane, G. Alagband, 1991: K-Winner Networks, *IEEE Trans. on Neural Networks*, **2**, 310-315.