Research Areas

It is possible to apply mathematics to almost any field of human endeavor. Here are some of the fields we're working on now.

Scientific Computing and Numerical Analysis

Researchers: Loyce Adams, Bernard Deconinck, Randy LeVeque, Ioana Dumitriu, Anne Greenbaum, James Riley

Many practical problems in science and engineering cannot be solved completely by analytical means. Research in the area of numerical analysis and scientific computation is concerned with the development and analysis of numerical algorithms, the implementation of these algorithms on modern computer architectures, and the use of numerical methods in conjunction with mathematical modeling to solve large-scale practical problems. Major research areas in this department include computational fluid dynamics (CFD), interface and front tracking methods, iterative methods in numerical linear algebra, and algorithms for parallel computers. Current research topics in CFD include:

- high resolution methods for solving nonlinear conservation laws with shock wave solutions
- numerical methods for atmospheric flows, particularly cloud formation
- Cartesian grid methods for solving multidimensional problems in complicated geometries on uniform grids
- spectral methods for fluid stability problems
- front tracking methods for fluid flow problems with free surfaces or immersed interfaces in the context of porous media flow (ground water or oil reservoir simulation) and in physiological flows with elastic membranes.
- nonequilibrium flows in combustion and astrophysical simulation
- immersed interface methods for solidification or melting problems and seismic wave equations with discontinuous coefficients that arise in modeling the geological structure of the earth.

Another research focus is the development of methods for large-scale scientific computations that are suited to implementation on parallel computer architectures. Current interests include:

- preconditioners for the iterative solution of large linear or nonlinear systems
- methods for the symmetric and nonsymmetric eigenvalue problems
- methods for general interface problems in complicated domains.

The actual implementation and testing of methods on parallel architectures is possible through collaboration with the Department of Computer Science, the Boeing Company, and the Pacific Northwest Labs.

Nonlinear Waves and Coherent Structures

Researchers: Bernard Deconinck, Nathan Kutz, Randy LeVeque

Most problems in applied mathematics are inherently nonlinear. The effects due to nonlinearities may become important under the
right circumstances. The area of nonlinear waves and coherent structures considers how nonlinear effects influence problems involving wave propagation. Sometimes these effects are desirable and lead to new applications (mode-locked lasers, optical solitons and nonlinear optics). Other times one has no choice but to consider their impact (water waves). The area of nonlinear waves encompasses a large collection of phenomena, such as the formation and propagation of shocks and solitary waves. The area received renewed interest starting in the 1960s with the development of soliton theory, which examines completely integrable systems and classes of their special solutions.

**Mathematical Biology**

**Researchers:** Mark Kot, Hong Qian, Eric Shea-Brown, Emanuel Todorov, Elizabeth Halloran, Suresh Moolgavkar, Eli Shlizerman, Ivana Bozic

Mathematical biology is an increasingly large and well-established branch of applied mathematics. This growth reflects both the increasing importance of the biological and biomedical sciences and an appreciation for the mathematical subtleties and challenges that arise in the modelling of complex biological systems. Our interest, as a group, lies in understanding the spatial and temporal patterns that arise in dynamic biological systems. Our mathematical activities range from reaction-diffusion equations, to nonlinear and chaotic dynamics, to optimization. We employ a variety of tools and models to study problems that arise in development, epidemiology, ecology, neuroscience, resource management, and biomechanics; and we maintain active collaborations with a large number and variety of biologists and biomedical departments both in the University and elsewhere. For more information, please see the [Mathematical Biology page](#).

**Atmospheric Sciences and Climate Modeling**

**Researchers:** Chris Bretherton, Ka-Kit Tung, Dale Durran

Mathematical models play a crucial role in our understanding of the fluid dynamics of the atmosphere and oceans. Our interests include mathematical methods for studying the hydrodynamical instability of shear flows, transition from laminar flow to turbulence, applications of fractals to turbulence, two-dimensional and quasi-geostrophic turbulence theory and computation, and large-scale nonlinear wave mechanics. We also develop and apply realistic coupled radiative-chemical-dynamical models for studying stratospheric chemistry, and coupled radiative-microphysical-dynamical models for studying the interaction of atmospheric turbulence and cloud systems. These two topics are salient for understanding how man is changing the earth's climate. Our work involves a strong interaction of computer modelling and classical applied analysis. This research group actively collaborates with scientists in the Atmospheric Science, Oceanography, and Geophysics department, and trains students in the emerging interdisciplinary area of earth system modeling, in addition to providing a traditional education in classical fluid dynamics.

**Mathematical Methods**

**Researchers:** Bernard Deconinck, Robert O'Malley, Emanuel Todorov, Jim Burke, Archis Ghate, John Sylvester, Gunther Uhlmann

The department maintains active research in fundamental methods of applied mathematics. These methods can be broadly applied to a vast number of problems in the engineering, physical and biological sciences. The particular strengths of the department of applied mathematics are in asymptotic and perturbation methods, applied analysis, optimization and control, and inverse problems.

**Mathematical Finance**

**Researchers:** Tim Leung, Matt Lorig, Doug Martin
The department's growing financial math group is active in the areas of derivative pricing & hedging, algorithmic trading, portfolio optimization, insurance, risk measures, credit risk, and systemic risk. Research includes collaboration with students as well as partners from both academia and industry.

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