Report on Activities Associated with the SAMSI Program on Inverse Problem Methodology In Complex Stochastic Models

1 Introduction and Overview

In a diverse range of fields, including engineering, biology, physical sciences, material sciences, and medicine, there is heightening interest in the use of complex dynamical systems to characterize underlying features of physical and biological processes. For example, a critical problem in the study of HIV disease is elucidation of mechanisms governing the evolution of patient resistance to antiretroviral therapy, and there is growing consensus that progress may be made by representing the interaction between virus and host immune system by nonlinear dynamical systems whose parameters describe these mechanisms. Similarly, recovery of molecular information for polymers via light beam interrogation may be characterized by a dynamical system approach. Risk assessment is increasingly focused on deriving insights from physiologically-based pharmacokinetic dynamical systems models describing underlying processes following exposure to potential carcinogens.

In all of these applications, a main objective is to use complex systems to uncover such mechanisms based on experimental findings; that is, in applied mathematical parlance, to solve the relevant inverse problem based on observations of the system (data), or, in statistical terminology, to make inference on underlying parameters and model components that characterize the mechanisms from the data. In many settings, there is a realization that dynamical systems should incorporate stochastic components to take account of heterogeneity in underlying mechanisms, e.g., inter-cell variation in viral production delays in within-host HIV dynamics. In addition, heterogeneity may arise from data structure in which observations are collected from several individuals or samples with the broader focus on understanding not just individual-level dynamics but variation in mechanistic behavior across the population. In both cases, it is natural to treat unknown, unobservable system parameters as random quantities whose distribution is to be estimated. There is a large inverse problem literature for systems without such stochastic components; even here, forward solutions (i.e., solutions of the dynamics when parameters are specified) for complex systems often necessitate sophisticated techniques, so that inverse problem methodologies pose considerable challenges. Similarly, there is a vast statistical literature devoted to estimation and accounting for uncertainty in highly nonlinear models with random components, involving hierarchical specifications and complex computational issues.

Despite the potential overlap and emerging challenges, there has been little interaction between applied mathematicians and statisticians to develop relevant inverse problem/statistical inferential methodologies. When combined, the computational and theoretical hurdles posed by both mathematical and statistical issues are substantial, and their resolution requires an integrated effort. Thus, to advance both applied mathematical/statistical research developments and disciplinary science, there is an urgent need for a synergistic joint treatment of fundamental issues involved in fitting complex dynamical systems with stochastic components to data. The major thrust of the SAMSI Program on Inverse Problem Methodology in Complex Stochastic Models entailed facilitating the essential cooperative effort required to catalyze collaborative research in this direction.

A crucial first step, to promote communication between members of these two communities who otherwise work independently and introduce each to the perspective and methodologies of the other, took place in the Program Kick-off Workshop. Following the recommendations of the Workshop, short- and long-term future activities were devoted to supporting and energizing focused collaboration between applied mathematicians, statisticians, and disciplinary scientists. Goals and anticipated outcomes by which success of the Program were gauged are the forging of new research syntheses between applied mathematicians and statisticians to address timely disciplinary challenges, training of a "new breed" of mathematical-statistical scientist well-versed in the perspectives of both disciplines and poised to make immediate contributions, and dissemination of the new joint perspective at all levels of mathematical/statistical education. Details on these points are given in the following sections.

2 Program Activities and Goals

2.1 Program Leadership

The Program Leaders, H.T. Banks (Mathematics and CRSC, NCSU) and Marie Davidian (Statistics, NCSU), in conjunction with the Program Committee, are charged with guiding the conception and implementation of Program activities.

2.2 Kick-Off Workshop

The SAMSI Kick-off Workshop on Inverse Problems in Complex Stochastic Models was held September 21–24, 2002, with the goal of introducing the two communities to the research and perspectives of the other to foster new interdisciplinary research thrusts and collaborations. The program offered invited presentations by leading researchers involved in modeling of complex systems, statistical modeling and computation, and disciplinary science, including modeling of HIV dynamics and toxicokinetics (biology and medicine), dielectric materials (engineering), tomography (physics and medicine), and modeling of polymers (material sciences). Lectures provided overviews of the perspectives of applied mathematicians and statisticians in these contexts to demonstrate the need for an integrated framework. The first day featured introductory tutorials on differential equation modeling and statistical inference and modeling providing requisite background for members of each community to interpret and appreciate the perspectives of the other. The full program is given in the SAMSI Annual Report for Years 2003-2004.

The Workshop attracted 121 participants, with 54 and 51 describing themselves as primarily "applied mathematician" or "statistician," respectively, including many prominent researchers in statistics, mathematics, pharmacokinetics, engineering, and physics. Moreover, 68 of the participants were graduate students, postdocs, or young investigators with less than 5 years after receiving a doctoral degree, demonstrating that the Program theme of crossing traditional math/stat disciplinary boundaries has intrigued the future generation of researchers so that there is potential for considerable long-term impact. The Workshop also attracted a diverse group of participants, including 40 females, 9 Hispanics, and 6 African-Americans. The tutorials were attended by 90 participants.

The Workshop concluded with three Discussion Groups, each comprising participants from varied backgrounds and charged with, on the basis of the exposure provided by the Workshop, identifying important future directions for the Program and key issues not covered that should be included in subsequent Program activities, both of which were instrumental in guiding continuing Program development (Sections 2.3 and 2.4). Groups also offered additional ideas related to the Workshop theme. A consensus from these discussions was that the Workshop spurred recognition that inverse problems are indeed problems of statistical inference and that even small amounts of uncertainty in data should be taken into appropriate account. Thus, participants saw inverse problems as being at the *real intersection* between applied mathematics and statistics, and emphasized that true collaboration, an activity that SAMSI could spearhead, must take place; however, such collaboration is hampered by a "language barrier." In fact, participants found this reflected in the presentations, which were either mostly statistical or mostly mathematical in perspective, although focused on reaching the other group, and identified possible overlaps in methods; e.g., with regularization techniques and Bayesian inference, that need further elucidation. Accordingly, participants stressed that future SAMSI activities should focus promoting a "common language" that draws from the perspectives of both sides, to foster identification of common themes for which one community could exploit the perspectives of the other and development of joint approaches that build on the best of both. Such activity would arise naturally from pursuit of specific, scientific problems involving difficult statistical and mathematical challenges, whose resolution could not be obtained from a purely applied math or statistical perspective alone but requires a true collaborative effort.

2.3 Research Activities

The program had a number of important short-term (1 week to 1 month) visitors including Robert Anderssen (CSIRO, Canberra, Australia; 3 weeks), Karl Kunisch (Institute of Math, Graz, Austria; 2 1/2 weeks), and Fumio Kojima (System Function Science, Kobe University, Kobe, Japan; 1 month), who each played an important role in the Kick-off Workshop. Following up on the Workshop, we hosted a number of short term visitors during the remainder of the Program, a number of whom requested return visits after participating in the 4 day Workshop. These include (approximate 1 week visits were hosted):

1. Susie Bayarri, Statistician, University Valencia, Spain (Sept.1 - Nov. 21, 2002). Dr. Bayarri is an expert on statistical methods for estimation problems. She participated actively in both the Inverse Problems and Stochastic Computation programs at SAMSI. She also actively participated in weekly Inverse Problem meetings as well the special course taught by Banks and Davidian.

2. Sarah Holte, Fred Hutchinson Cancer Research Center (Nov. 4 - 8, 2002). Dr. Holte is a biostatistician who is collaborating with both applied mathematicians and statisticians on HIV models and methodology development.

3,4. Peter Mueller and Gary Rosner, MD Anderson Cancer Center (Feb. 23 - 26, 2003). Drs. Mueller and Rosner are statisticians, and we coordinated their visits with that of Ackleh to facilitate collaborations on HIV modeling and data analysis.

5. Azmy Ackleh, Mathematics, University of Louisiana (Feb. 23 - 28, 2003). Dr. Ackleh expressed a strong desire to move his research more toward problems involving variability in data and uncertainty in models. He is collaborateing with mathematicians and statisticians in problem-specific investigations entailing use of MCMC methods for parameter estimation as well as combining deterministic with statistical approaches.

A number of other visitors (who were not able to attend the Kick-off Workshop) who are interested in SAMSI-facilitated collaborations, were hosted. These included:

6. Max Gunzburger, Mathematics, Florida State University (Nov. 11 - 12, 2002). Dr. Gunzburger is an expert in reduced order modeling techniques, including Proper Orthogonal Decomposition (POD) and Centroidal Voronoi Tessellations (CVT). He visited to collaborate with both applied mathematicians and statisticians on development and use of these techniques in inverse problems, 3-D electromagnetic simulations and MCMC simulation methodologies.

7. M. Bendsoe, Mathematics, Technical University of Denmark (November 17 - 21, 2002). Dr. Bendsoe is an expert on shape optimization and design and visited to initiate long term collaboration on sensitivity analysis in complex systems depending on probability measures. Such sensitivity methodology will involve differentiation of solutions of nonlinear ordinary and partial differential equations with respect to probability distributions.

8. W. Ring, Institute of Math, Graz, Austria (Nov. 11 - 29, 2002). Dr. Ring is a young (pre-Habilitation) mathematician from Karl Kunisch's group in Graz who is an expert on level set methods in inverse problems. These methods are currently being developed and used with little or no acknowledgment or treatment of uncertainty in modeling or data. He initiated long term collaborations with both applied mathematicians and statisticians on the development of new methods to account for the the presence of variability in data in the context of inverse and imaging problems.

These visitors had an immediate impact on Program postdocs at SAMSI as well as the SAMSI Graduate Fellows assigned to the Inverse Problem Program.

In addition to the visitor activity, Banks and Davidian ran a seminar series followed by brown bag lunch research discussion session each Tuesday from 10:00 AM to 1:00 PM. Participants include local postdocs, students, and scientists from local labs and industry (Environmental Protection Agency, National Institute of Environmental Health Sciences, CIIT Centers for Health Research, GlaxoSmithKline, etc.).

Many of the non-students in these seminar/discussion sessions also sat in on the special topics course MA/ST 810Q, offered through NCSU with reciprocal enrollment through UNC-CH and Duke. This course, taught by Banks and Davidian on Wednesdays from 4:30-7:00 PM at SAMSI, targeted both applied mathematics and statistics graduate students. 23 students enrolled for credit, with an additional 15–17 post-Ph.D. non-students attending. The course description is given in Section 4. An important component of the course that reflects the Program philosophy of collaboration was the assignment of students to interdisciplinary teams to complete course work that involves the need for integration of statistical and mathematical concepts.

A Closing Workshop, to be held at SAMSI, summarizing and disseminating the results of these short-term activities, was originally planned for early January 2003. In the interim, IPAM at UCLA announced plans for an Inverse Problem Program (with a different theme from the SAMSI focus on applied mathematics/statistics collaboration), to be held in Fall 2003, with a kick-off workshop planned for May 18–23, 2003, in Lake Arrowhead, California. To promote synergism between the SAMSI and IPAM programs and to encourage and facilitate participation in both workshops by European and other attendees, the Program Closing Workshop was thus been moved to May 14–16, 2003. Invited speakers include L. Sheiner (UCSF), C. Wikle (U. Missouri, Columbia), H. Engle (U. Linz, Austria), E. Somersala (Tech. Univ., Helsinke).

2.4 Long-Term Activities

Several activities planned in the Program were specifically oriented toward long-term results. These include the following.

1. On October 3, we organized an "Electromagnetics Day" at SAMSI. Attendees included Kojima, Banks, Ito (Professor, NCSU), Bardsley (SAMSI Inverse Program Postdoctoral Fellow), Gibson (NCSU graduate student), Joyner (Assistant Professor, West Georgia State University), Pinter (Assistant Professor, University of Wisconsin, Milwaukee), Kepler (SAMSI Program Postdoctoral Associate), Benedict (SAMSI Graduate Associate), and Bill Winfree and

Buzz Wincheski (Nondestructive Evaluation Branch, NASA Langley Research Center). Presentations and discussions focused on modeling and data-driven computational methods for nondestructive electromagnetic interrogation of materials using signals in the microwave and terahertz frequency ranges. Long term plans for collaborations include use of model reduction techniques (POD, CVT) in 3-D imaging as well as inclusion of statistical methods to treat measurement and modeling uncertainties. Study of the use of MCMC/Bayesian methods in estimation problems is also planned. Participants have subsequently requested that this become an annual event.

2. The HIV collaborations begun this semester are part of a long term (> 4 years) effort on data-driven modeling and analysis of biological systems using statistical and applied mathematical methods led by Banks and Davidian. In addition to the HIV-specific research, special attention will be given to inverse problems arising in pharmacokinetic, toxicokinetic, and ecological problems. (Specific research teams have already been formed.) These investigations will involve biologists, applied mathematicians, and statisticians collaborating in a true example of the SAMSI philosophy of the coming together of domain scientists, applied mathematicians and statisticians to solve difficult data-driven problems for complex nondeterministic systems.

3 Anticipated Outcomes and Measures of Success

3.1 Program Impact on Research

The broad goal of the Program, and hence a key measure of its success, is the formation of real collaborations between applied mathematical and statistical scientists that have the potential to alter fundamentally the thinking in both disciplines and crystallize the realization that both communities share common objectives and interests that can best achieved by a joint effort. In particular, we envision that publications, conferences, and presentations that result from Program-driven collaborations will foster a broad awareness among applied mathematicians of the critical need to consider variation, uncertainty, and the connection between loss functions and statistical models of variable phenomena in the context of inverse problems. Likewise, we see statisticians learning to think outside the constraints of empirically-based models for biological and physical phenomena that focus on "what can be observed" and prediction rather than on uncovering underlying mechanisms that can be successfully described via mathematical constructs. A measure of how well these "culture shifts" have taken hold as a result of the Program will in be gauged initially by the appearance of joint-authored publications in mainline applied mathematical and statistical research journals that demonstrate not only advances in methodology that are possible from joint efforts but that highlight the potential for resulting greater advances in disciplinary science.

Indeed, ultimately, an important indicator of success of the Program will be with respect to its impact on the disciplinary science problems driving the joint mathematical/statistical modeling and inferential efforts. The broad goal is that Program-initiated collaborations will result in the publication and dissemination not only of innovative methodological advances but of new subject-matter insights, e.g., deeper understanding of the mechanisms underlying development of HIV drug resistance, that in turn suggest new hypotheses. Impact on advances in disciplinary science is of course difficult to quantify, but a general short-term measure will be the number of journal publications and conference presentations resulting from collaborative efforts spearheaded by the program; a long-term measure will be the extent to which these efforts are cited and built upon by the disciplinary community itself, reflecting an understanding of the benefits of mathematical and statistical approaches. Already, several Kick-off Workshop participants were disciplinary scientists (e.g., Lewis Sheiner, a physician and leading force in research in human pharmacokinetic analysis; Fumio Kojima, a leader in use of electromagnetic techniques in nondestructive evaluation of materials); thus, there is nascent appreciation of the potential for scientific advance that may be energized by the Program.

With respect to applied mathematical and statistical methodological research, a major objective is math/stat technology transfer, i.e., for the approaches of each community to be exploited by the other to advance both, jointly and separately. Two specific examples with rich potential are the Proper Orthogonal Decomposition dimension-reduction inverse problem computational techniques used by mathematicians and Markov chain Monte Carlo simulation methods used by statisticians. The immediate goal is to achieve this on a small scale through Program-sponsored activities, but with participants "spreading the word" through publications and presentations to effect long-term awareness. The extent to which such transfer occurs will be gauged by the number and significance of such endeavors.

3.2 Program Impact on Human Resources

3.2.1 Postdoc Activities:

There were three SAMSI funded postdocs in the IP Program: John Bardsley, Yanyuan Ma, and Danny Walsh. All three participated heavily in (indeed, helped lead) the June, 2003 Undergraduate Workshop on Inverse Problems. They have followed somewhat different courses since July, 2003.

1. After the year at SAMSI, Bardsley accepted a position as Assistant Professor of Mathematics at the University of Montana, Missoula, MT. He has remained active in research, producing three research papers [5, 9, 15], one ([5]) of which combines applied mathematical and statistical techniques in the SAMSI spirit to address electromagnetic interrogation problems.

2. Yanyuan Ma came to SAMSI with a Ph.D. in applied mathematics with the determined intention to become equally expert in statistical methods. Indeed, her goal was to become trained so as to follow a career in statistics, eventually obtaining a faculty position in a stat department at a Research I university. After the first year at SAMSI, she spent her 2nd year as a CRSC postdoc, working with statisticians (resulting in publications [16–19]) to improve her statistical contributions, while contributing to the HIV project (described below) at CRSC led by Banks and Davidian. She has been very successful in both her contributions and her career objectives. She has accepted a position beginning Fall, 2004, as Assistant Professor of Statistics at Texas A&M University.

3. After his year as a SAMSI postdoc in the IP Program, Walsh joined NISS as a postdoc, working on a model validation project. He has accepted a position in Statistics at Massey University, Auckland, NZ, beginning Fall semester, 2004.

3.2.2 Graduate Student Activities:

A number of graduate students participated in the IP Program. SAMSI Graduate Fellows included Karen Chiswell and Jeff Hood. SAMSI Graduate Associates included Brian Adams, Brandy Benedict and Nathan Gibson. They all participated in the working sessions, the IP course, and in the Undergrad Workshop in June, 2003. While they are still involved in completing their degree requirements, their research programs have been significantly impacted by their participation in the SAMSI IP Program. Karen Chiswell is pursuing a thesis on PBPK modeling with strong applied math and statistical components; both Banks and Davidian are serving on her graduate committee. Jeff Hood contributed efforts to organizing the notes from the IP course (taught by Banks and

Davidian) after the course was completed. He is now working on a thesis that combines statistical modeling and probabilistic molecular formulations with dynamical systems for reptation models of polymeric materials (viscoelastic fluids, rubbers, biotissues, etc.). Adams is playing a major role in a long term, NIGMS funded research program on HIV modeling that entails both applied math and statistical methodology. He contributed significant efforts to several papers [3,4] and his thesis on modeling of HIV will embody clear evidence of the SAMSI applied math/statistics synthesis. Gibson is working on problems in the other major research theme of the SAMSI IP Program, electromagnetics. The October, 2002, Electromagnetics Day, held at SAMSI as an IP activity, led to several interesting collaborations, including a NASA sponsored project on E&M interrogation of the shuttle foam for damages that is the focus of Gibsons thesis. In this effort he has used statistical methods to give uncertainty bounds on the estimation algorithms used to detect damage as reported in [12] as well as probabilistic modeling of polarization in complex materials [10].

3.2.3 Impact on Young Researchers

A number of young researchers who visited SAMSI several times during the IP Program on inverse problems have visibly benefited from their participation. Among these are A. Ackleh (Univ. Louisiana, Lafayette), J. Banks (Univ. Washington, Tacoma), C. Cole (Meredith College), S. Ghosh (NCSU), G. Pinter (University of Wisconsin, Milwaukee) and C. Wikle (Univ. Missouri). Ackleh is now leading his group in combining statistical and applied math methods in the area of biological models [1, 2] and has collaborated with C. Cole on some of this work. J. Banks, a biologist, has collaborated with Adams [4] on dynamical and statistical methods for inverse problems in pesticide management of insects, while Ghosh has become involved in the stat/applied math HIV modeling project at NCSU, one component of which combines Bayesian methods with a Prohorov framework for estimation of parameters. Pinter, after extensive participation in the IP Program, has become very active in using probabilistic methods to model dynamical systems arising in materials [7,8,11]. Wikle, a statistician who has been an extensive visitor to SAMSI after initial participation in the IP Program, has recently begun collaborations with applied mathematicians on modeling of migratory patterns of of birds.

3.2.4 Impact on Senior Researchers

Among senior researchers (along with their students) who have clearly been affected by the SAMSI IP Program are H.T. Banks (NCSU), D. Cioranescu (U. Paris VI), and J. Whiteman and S. Shaw (Brunel University). Cioranescu and her students have become involved in comparing homogenization methods with probabilistic averaging in inverse problems in electromagnetics while Whiteman and Shaw have begun collaborations with the authors of [7, 8, 11] on probabilistic methods for viscoelastic system inverse problems.

3.3 Program Impact on Education and Outreach

The Program is having an immediate impact on the training of applied mathematicians and statisticians through the course MA/ST 810Q. The course emphasizes integration of applied mathematical and statistical perspectives through collaboration and serves as what we hope is a prototype for a future, regular course at NCSU that carries forward the Program philosophy to general graduate education in applied mathematics and statistics. Banks and Davidian plan to compile the course material into a monograph that will serve as inspiration for similar courses at other institutions. Experimentation with and adoption of this new educational model by colleagues in applied mathematics and statistics at other institutions will be an important gauge of the influence of the Program on education.

Outreach activities are already planned. Members of the Inverse Problem Program will participate fully in the June, 2003 Workshop for Undergraduates by presenting a 4 day summary of the Program activities. The Workshop is designed to recruit students to graduate studies and careers in the fields of mathematics and statistics. Follow-up of participants will measure the impact of the Program.

4 Course Description, MA/ST 810Q

A special topics course was in connection with the SAMSI Program on "Inverse Problem Methodology in Complex Stochastic Models."
MA/ST 810Q-003– Inverse Problem Methodology in Complex Stochastic Models (3 credit hours)

Official course description: Overview of mathematical modeling of complex dynamical systems and statistical considerations for fitting these models to data, with emphasis on the interface between applied mathematics and statistics. Ordinary and partial differential equation modeling of biological, physical, and other phenomena; time, space, and state-dependent coefficient estimation; nonlinear mechanisms; identifiability, ill-posedness, stability, and regularization in inverse problems; and computational methods. Fundamentals of statistical modeling and inference; sources of variation in complex data structures; frequentist and Bayesian methods for parameter estimation and assessment of uncertainty. Mathematical and statistical topics will be integrated through discussion of numerous examples from the biological and physical sciences and engineering.

Prerequisites:

For mathematics students: Undergraduate-level differential equations (required), MATLAB or similar computing experience (desirable), Numerical analysis (desirable).

For statistics students: Statistical inference (at the level of Casella and Berger; required), Linear models theory (required), Splus, R, MATLAB, or similar computing experience (desirable).

(Mathematics students need not have statistics student prerequisites, and vice versa.)

The course will meet at a time to be announced in the NISS building in Research Triangle Park.

Please direct questions to Marie Davidian (`davidian@stat.ncsu.edu`).

Background: A current "hot topic" in biological sciences, physical sciences, engineering, epidemiology, and a host of other areas is the use of complex nonlinear dynamical systems models to characterize phenomena of scientific interest. These models involve (mostly) deterministic systems of ordinary and partial differential equations that are used to characterize interactions among various components of a biological, physical, or other system. For example, there is much current interest in using these models to describe known and hypothesized mechanisms involved in the interplay over time between the HIV virus and the immune system within organisms (like humans), understanding of which has the potential to suggest new treatment strategies. In general, such models allow a formal description of mechanisms in terms of parameters (some of which may be functions rather than real-valued). In the HIV example, parameters might include viral clearance rates, immune cell infection rates, and new virus production rates.

The solution of the system of differential equations implies an expression (that is likely not available in a closed form) for quantities of interest at any time point. For example, a system to model HIV dynamics determines expressions for the concentration of virus (or "viral load"), concentration of T-cells (an immune system component), etc., present in the organism at any time following administration of antiretroviral therapy. Given the values of the parameters that describe the system and some initial conditions, evaluating such expressions must in general be carried out via complex numerical techniques; this is referred to as "forward solution."

As development of these models and computational strategies for evaluating them have improved, there is great interest in applying them to data. For example, data on "viral load" and measures of immune status may be collected longitudinally on one or more organisms; that is, values of the system at certain time points have been observed (possibly subject to variation due to measurement error and other sources). From such data, it is of interest to learn about the underlying mechanisms (values of parameters). Thus, for application to data, the problem is the reverse of "forward solution:" given (possibly error-prone) values taken on by system components at known time points, can the values of the parameters be recovered, knowledge of which may provide insight into the underlying mechanisms? Recovering the values of the parameters is a form of what is known in this literature as an "inverse problem." Of course, statisticians would call this "parameter estimation," and would be concerned about taking proper account of the various sources of variation, development of valid inferential strategies, and efficiency of estimation. This requires that the complex dynamical systems be embedded in a statistical framework appropriate to the data structure.

The key feature of applying complex dynamical systems to data in this way is that they inherit the computational challenges of both the mathematical and statistical elements. For example, to fit a statistical model in which the mathematical model has been incorporated via maximum likelihood optimization or Bayesian computational techniques, evaluation at any time point requires the forward solution to be computed at the current value of the parameters. How to resolve the joint computational challenge is part of the focus of the SAMSI Inverse Problem program and is an area where new research directions will be established.

This course is meant to give statistics and applied mathematics students the necessary background to appreciate both the "big picture" and some of the specific mathematical and statistical challenges in this endeavor. For statistics students, the course will serve as an introduction to differential equation modeling, assuming no prior exposure, focusing on the aspects that are most important for statisticians to understand. For applied mathematics students, the course will serve as an introduction to statistical inference and considerations involved in statistical modeling (e.g. the need to take appropriate account of multiple sources of variation in complex data structures). These topics will be highlighted by discussion of subject-matter examples from numerous fields of application.

The diversity of the audience will provide a unique forum for students to learn about this area and relevant applications and to understand the perspectives of applied mathematicians and statisticians and the terminology each group uses.

5 Publications

References

[1] Ackleh, A.S., K. Deng, C. Cole and H.T. Tran, "Existence-Uniqueness And Monotone Approximation For An Erythropoiesis Age-Structured Model, " CRSC-TR03-21, April, 2003; submitted to J. Math. Anal. Appl.

[2] Ackleh, A.S., H.T. Banks, K. Deng, S. Hu, "Parameter Estimation In A Coupled System Of Nonlinear Size-Structured Populations," to be submitted.

[3] Adams, B.M., H.T. Banks, M. Davidian, H.D. Kwon, H.T. Tran, S.N. Wynne and E.S. Rosenberg, "HIV Dynamics: Modeling, Data Analysis, And Optimal Treatment Protocols," CRSC-TR04-05, February, 2004; J. Comp. and Appl. Math., submitted.

[4] Adams, B.M., J.E. Banks, H.T. Banks and J.D. Stark, "Population Dynamics Models In Plant-Insect-Herbivore-Pesticide Interactions," CRSC-TR03-12, March, 2003, Revised, August, 2003; Math. Biosci., submitted.

[5] Banks, H.T., and J. Bardsley, "Parameter Identification For A Dispersive Dielectric In 2D Electromagnetics: Forward And Inverse Methodology With Statistical Considerations," CRSC-TR03-48, December, 2003; Inverse Problems, submitted.

[6] Banks, H.T., D.M. Bortz, G.A. Pinter, and L.K. Potter, "Modeling And Imaging Techniques With Potential For Application In Bioterrorism," to appear as a Chapter in "Biomathematical Modeling Applications for Homeland Security" (H.T.Banks and C.C.Chavez, eds.), SIAM Frontiers in Applied Mathematics. SAMSI 2003-1, January 30, 2003

[7] Banks, H.T., N.G. Medhin and G.A. Pinter, "Multiscale Considerations In Modeling Of Nonlinear Elastomers," CRSC-TR03-42,October, 2003; J. Comp. Meth. Sci. and Engr., to appear.

[8] Banks, H.T., N.G. Medhin and G.A. Pinter, "Nonlinear Reptation In Molecular Based Hysteresis Models For Polymers," CRSC-TR03-45, December, 2003; Quarterly Applied Math., to appear.

[9] Banks, H.T., and J. Bardsley, "Well-Posedness For Systems Arising In Time Domain Electromagnetics In Dielectrics," CRSC-TR03-27, July, 2003; Communications in Applied Analysis, to appear.

[10] Banks, H.T. and N.L. Gibson, "Well-Posedness In Maxwell Systems With Distributions Of Polarization Relaxation Parameters," CRSC-TR04-01, January, 2004; Applied Math. Letters, submitted.

[11] Banks, H.T. and G.A. Pinter, "A Probabilistic Multiscale Approach To Hysteresis In Shear Wave Propagation In Biotissue," CRSC-TR04-03, January, 2004; SIAM J. Multiscale Modeling and Simulation, submitted.

[12] Banks, H.T., N.L. Gibson and W.P. Winfree, "Electromagnetic Crack Detection Inverse Problems Using Terhertz Interrogating Signals," CRSC-TR03-40, October, 2003; Inverse Problems, submitted.

[13] Banks, H.T., Y. Ma and L.K. Potter, “A Simulation Based Comparison Between Parametric And Semiparametric Methods In A PBPK Model,” J. Inverse and Ill-posed Problems, to be submitted.

[14] Banks, H.T., Grove, S., Hu, S. and Ma, Y., “A Hierarchical Bayesian Approach for Parametric Estimation in HIV Models,” Inverse Problems, 21, 1803-1822. (2005)

[15] Bardsley, J., “A Bound-Constrained Levenberg-Marquardt Algorithm For A Parameter Identification Problem In Electromagnetics,” J. Inverse and Ill-posed Problems, submitted.

[16] Ma, Y. and A.A. Tsiatis, “Closed Form Semiparametric Estimators For Mixed Models With Complete Sufficient Statistic,” Satistica Sinica, in press.

[17] Ma, Y. and M.G. Genton, “A Semiparametric Class of Generalized Skew-Elliptical Distributions,” Scandanavian Journal of Statistics, 31, 459-468.

[18] Ma, Y., M.G. Genton and M. Davidian, “Linear Mixed Effect Models with Semiparametric Generalized Skew-Elliptical Random Effects,” Skew-Elliptical Distributions and their Applications: A Journey Beyond Normality, Genton, M. G. (editor), Chapman & Hall / CRC, 339-358. (2004)

[19] Ma, Y., M.G. Genton and A.A. Tsiatis, “Locally Efficient Semiparametric Estimators For Generalized Skew-Elliptical Distributions,” J. American Statistical Association, 100, 980-989.

[20] Molina, G., Bayarri, M.J., and Berger, J.O., “Statistical Inverse Analysis For A Network Microsimulator,” Technometrics 47, pp. 388-398 (2005).

[21] Tsiatis, A.A., and Y. Ma, “Locally Efficient Semiparametric Estimators For Functional Measurement Error Models,” Biometrika, 91, 835-848.