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IMA NEWSLETTER # 306

February 1–28, 2002

2001–2002 Program

MATHEMATICS IN THE GEOSCIENCES

See http://www.ima.umn.edu/geoscience/ for a full description of the 2001–2002 program on Mathematics in the Geosciences. IMA schedules are subject to revision, particularly during workshops. See http://www.ima.umn.edu/~seminar/sched and http://www.ima.umn.edu/newsltrs/ for the latest scheduling information.

News and Notes

IMA Workshop:

Reduced Descriptions of Coupled GFD Systems (Slow Manifolds in the Ocean and Atmosphere)

February 11–15, 2002
Organizers: Darryl D. Holm (Math Modeling, Los Alamos National Lab); and James C. McWilliams (Atmospheric Sciences, University of California, Los Angeles)

See http://www.ima.umn.edu/geoscience/winter/g6.html .

IMA Website

The IMA website includes a great deal of information about its programs, past, present and future, and how you may be a part of them at

http://www.ima.umn.edu.

The page is continually being updated. We encourage you to make use of this resource and recommend it to others who may be interested. We especially encourage your ideas about future progerams. We also invite comments or suggestions, which may be addressed to webmaster@ima.umn.edu. In particular, we appreciate any information about World-Wide Web links appropriate to current and upcoming IMA programs.

PARTICIPATING INSTITUTIONS: Centrum voor Wiskunde en Informatica (CWI), Consiglio Nazionale delle Ricerche, Georgia Institute of Technology, Indiana University, Iowa State University, Kent State University, Los Alamos National Laboratory, Michigan State University, Mississippi State University, Northern Illinois University, Ohio State University, Pennsylvania State University, Purdue University, Seoul National University (BK21 Math-SNU), Seoul National University (SRCCS), Texas A&M University, University of Chicago, University of Cincinnati, University of Houston, University of Illinois (Urbana), University of Iowa, University of Kentucky, University of Maryland, University of Michigan, University of Minnesota, University of Notre Dame, University of Pittsburgh, University of Wisconsin, Wayne State University.

PARTICIPATING CORPORATIONS: Boeing, Ford, General Motors, Honeywell, IBM, Lockheed Martin, Lucent, Motorola, Schlumberger, Siemens, Telcordia Technologies, 3M.

Version of February 28, 2002

Schedule for February 1–28, 2002

Friday, February 1

The 9:30 IMA break will be in Vincent Hall 502.

IMA/MCIM INDUSTRIAL PROBLEMS SEMINAR, 570 Vincent Hall:

10:10 am	**Benoît Couët** Schlumberger-Doll Research	How Do We Perform Stochastic Reservoir Optimization?

Abstract: New control and monitoring technologies are being introduced to further real-time reservoir management, which is considered key to improving reservoir productivity. Examples of new control technologies include advanced completions, also referred to as smart or intelligent wells. New monitoring technologies include permanently installed sensors for measurements of pressure, flow and voltage. The decision on implementing such technologies is solely based on a cost-benefit analysis. Hence, one must be able to estimate the value of these technologies in monetary terms, such as associated net present value. A crucial underlying factor is the uncertainty in the reservoir model and its properties, and in the financial variables. The former includes uncertainty in properties such as reservoir geometry or permeability in the reservoir, while the latter refers to uncertainty in financial parameters such as discount rates or hydrocarbon price.

Quantifying the value of real-time control and monitoring technologies in the presence of such uncertainties requires a stochastic optimization of the production strategy. Standard process to perform the optimization can be applied and will be described in the context of real case situations.

Can we do better? How do we mathematically describe the uncertainties? What if we do not know the probability density functions? Should we optimize for the mean? Is there a better workflow? All these questions will be raised. We hope they could be addressed in a convenient and practicable way.

This is joint work with Bahvani Raghuraman, Philip Savundararaj and Robert Burridge.

Monday, February 4

The 10:30 IMA break will be in Lind Hall 400.

Tuesday, February 5

The 10:30 IMA break will be in Lind Hall 400.

IMA POSTDOC SEMINAR, Lind Hall 409:

11:15 am	**Miao-Jung Ou** Inst. for Math. and its Applications	A Uniqueness Theorem of the 3-Dimensional Acoustic Scattering Problem in a Shallow Ocean with a Fluid-like Seabed

Abstract: We show that under the assumption of out-going radiation conditions at infinity, the time-harmonic acoustic scattered field off a sound-soft solid in a shallow ocean with a fluid-like seabed is unique in $C^2(M_1) \cap C^2(M_2) \cap C(R^3_h \setminus \Omega)$. Here M_1 is the water part, M_2 the seabed, R^3_h the waveguide and Ω is the solid object. The associated modal problem is studied and a representation formula for the solution in terms of the Green's function is derived.

The IMA Postdoc Seminar is organized by Selim Esedoglu and Michael Efroimsky.

DYNAMICAL SYSTEMS SEMINAR, Vincent Hall 570:

3:30 pm	**James Louisell** University of Minnesota	The effects of time dependence in linear delay differential equations: quenching and Markus-Yamabe instability

Wednesday, February 6

The 10:30 IMA break will be in Lind Hall 400.

Thursday, February 7

The 10:30 IMA break will be in Lind Hall 400.

APPLIED MATHEMATICS AND NUMERICAL ANALYSIS SEMINAR, 570 Vincent Hall

11:30 am	**Robert O'Malley** Univ. of Washington	A Renormalization Method to Asymptotically Solve Weakly Nonlinear Systems

Abstract: This work seeks to solve certain systems of nonlinear ODEs by a renormalization technique that provides asymptotic solutions on longer time intervals than the classical approaches of averaging and multiple scales.

This is joint work with Blessing Madavanhu.

The 3:00 pm IMA break with special treats will be in Lind Hall 400.

Friday, February 8

The 9:30 IMA break will be in Vincent Hall 502.

IMA/MCIM INDUSTRIAL PROBLEMS SEMINAR, 570 Vincent Hall:

10:10 am	**Cristina U. Thomas** 3M Company	Mathematics and Materials: The Role of Mathematics in a Materials Development Laboratory

Abstract: Industrial scientists face the challenge of developing advanced materials by manipulating the relation between the chemical structure and the desired performance. Structure-Property predictions become a significant focus of computer modeling activities in the industrial world. In our laboratory, the Advanced Materials Technology Center, we contribute to the innovation process via the utilization of mathematical and computational models that simulate material behavior. This talk will include three cases describing the use of Mathematics for materials/product development. The first case is an application of fractals for the purpose of surface characterization. The second case utilizes Monte Carlo Methods for the simulation of fluids in confined spaces. The last case captures the morphology evolution in block-copolymer systems using a density functional approach commonly known as MesoDyn. The talk will highlight areas in need of mathematical advances for material purposes.

This is joint work with Sanat Mohanty and Miriam Freedman.

Monday, February 11

IMA Workshop:

Reduced Descriptions of Coupled GFD Systems (Slow Manifolds in the Ocean and Atmosphere)

February 11–15, 2002
Organizers: Darryl D. Holm (Math Modeling, Los Alamos National Lab); and James C. McWilliams (Atmospheric Sciences, University of California, Los Angeles)

See http://www.ima.umn.edu/geoscience/winter/g6.html .

A distinctive difficulty in climate-system modeling, analysis and prediction is the presence of two or more time scales in the problem. The atmosphere and oceans each support slow Rossby and fast inertia-gravity waves, while the characteristic times of atmosphere, oceans, and ice sheets are about a factor of 10 apart. Thus the proper treatment, via slaved-variable and slow-manifold theory of time-scale disparity within each subsystem and between subsystems is of the essence. The workshop topics will include

(i) the connection between the slow manifold, averaged descriptions, the quasi-geostrophic approximation, and intermediate balanced models;

(ii) models of the coupled ocean-atmosphere system; and

(iii) slow-manifold theory. Tools such as asymptotics, averaging, center manifold, inertial manifold, attractors and their approximations are indispensable for dealing with these problems.

Keywords: coupling, ENSO, intermediate models.

All talks are in EE/CS 3-180 unless otherwise noted.

8:30 am	**Coffee and Registration**	Reception Room EE/CS 3-176
9:15 am	**Douglas N. Arnold, Robert Gulliver, and Darryl Holm**	Welcome and Introduction
9:30 am	**William Dewar** Florida State University	A nonlinear, conceptual mid-latitude climate model

Abstract: Recent models of mid-latitude climate have speculated on the role of the North Atlantic ocean in modulating the North Atlantic Oscillation (NAO) Here this role is examined by means of numerical experimentation with a quasi-geostrophic ocean model underneath a highly idealized atmosphere. It is argued the dominant mid-latitude oceanic influence is due to the so-called inertial recirculations.

10:30 am	**Coffee Break**	Reception Room EE/CS 3-176
11:00 am	**James C. McWilliams** University of California, Los Angeles	The Theory and Theology of Nonlinear Balance

Abstract: A didactic presentation will be given on the premises, mathematical structure, regimes of validity, historical experience, evolutionary singularities, and unbalanced instabilities for the reduced fluid-dynamical system, the Balance Equations. The Balance Equations are an asymptotically consistent (but nonunique) set of approximations for rotating, stably stratified flows, built around the quasi-static momentum balances of hydrostacy in the vertical and gradient-wind balance in the horizontal divergence.

It is widely agreed that the vast majority of the energy in the general circulations of the ocean and atmosphere is in balanced motions. In this context, the organizing focus of the talk will be on the mystery of large-scale energy dissipation in the ocean and atmosphere: planetary forcing energizes large-scale balanced motions, including balanced instabilities of the directly forced flows; balanced flows are asymptotically characterized by an inverse energy cascade towards larger scales, but there are few and relatively inefficient dissipation mechanisms available are large scales (e.g., bottom drag and radiative cooling); thus, somehow the route to dissipation at small scales remains to be elucidated.

12:00 pm	**Lunch Break**	
2:00 pm	**Darryl Holm** Los Alamos National Laboratory	Lagrangian averages, averaged Lagrangians and dimension reduction in modeling GFD turbulence

Abstract: By using Averaged/Approximated Lagrangians one obtains a well known series of GFD model equations. Each of these preserves energetics and potential-vorticity/Kelvin-circulation dynamics at its own level of approximation. One is then faced with the additional task in these multiscale problems of reducing the number of degrees of freedom by finding an average description of the motion that incorporates the mean effects of the small scales on the large scales. This is the problem of subgrid-scale modeling.

Lagrangian averaging (LA) also preserves energetics and fluid transport properties in the process of averaging over fast times scales following Lagrangian fluid trajectories. This compatibility allows LA to be imposed at any level of this series of GFD model equations, in either order of approximation. The resulting nonlinear Lagrangian mean equations, however, are not closed.

We shall obtain closure by introducing a small amplitude expansion and Taylor's hypothesis of frozen-in turbulence into the Lagrangian at a given level of approximation, before averaging. This closure approximation also reduces the number of degrees of freedom by smoothing the solution.

The resulting equations are the alpha models, where alpha is the correlation length for Lagrangian trajectories.

We shall discuss applications that include

- Navier-Stokes$-\alpha$ models for incompressible turbulence and
- GFD$-\alpha$ models (if time allows).

3:00 pm	**Second Chances** David Levermore, Moderator	3:00 William Dewar 3:15 Jim McWilliams 3:30 Darryl Holm
3:45 pm	**Open Discussion**	David Levermore, Moderator
4:00 pm	**IMA Tea/Reception**	IMA, 400 Lind Hall

A variety of appetizers and beverages will be served.

Tuesday, February 12

All talks are in EE/CS 3-180 unless otherwise noted.

9:00 am	**Coffee**	Reception Room EE/CS 3-176
9:30 am	**Leslie Smith** University of Wisconsin, Madison	Population of Slow Manifolds in Strongly Stratified, Rotating Flows with Unbalanced Turbulent Forcing

Abstract: Numerical simulations are used to study the population of slow manifolds in rotating, stably stratified flow in the Boussinesq approximation, with rotation and stratification both in the vertical direction. Energy is injected through a three-dimensional, isotropic, white-noise forcing localized at small scales. The parameter range studied corresponds to Froude numbers smaller than an $O(1)$ critical value, below which energy is transferred to scales larger than the forcing scales. The values of the ratio N/f range from $1/2$ to infinity.

For purely stratified flows, there exist two distint classes of non-wave modes: the Vertically Sheared Horizontal Flow (VSHF) modes with dependence only on the vertical wavenumber, and the Potential Vorticity (PV) modes, existing for all wavevectors and with zero vertical velocity. For strongly stratified flows with $N/f \gg 1$, the only non-wave modes are the PV modes, while the VSHF modes have (small) wave frequency f or $-f$. Somewhat surprisingly, for all strongly stratified flows including the purely stratified case, our simulations show that the large scales generated by the turbulence are the VSHF modes. In this case, the PV modes play a secondary role, acting to inhibit the transfer of energy to large scales. On the other hand, for N/f between $1/2$ and 2, our simulations show that the inertial-gravity waves are insignificant and that the dynamics are completely dominated by the PV modes. This is quasi-geostrophic turbulence characterized by the inviscid conservation of two quadratic invariants and a $-5/3$ inverse energy cascade. The region $1/2 < N/f < 2$ is also exactly the region where resonant triad interactions cannot occur. These results suggest that $1/2 < N/f < 2$ is the domain of validity of the quasi-geostrophic model (for moderate aspect ratios), and that resonant wave interactions play an important role in the population of the slow, VSHF motions in strongly stratified flow.

10:30 am	**Coffee Break**	Reception Room EE/CS 3-176
11:00 am	**Beth A. Wingate** Los Alamos National Lab	The alpha-model of turbulence for GFD applications

Abstract: In this talk I discuss results related to using α-models for the primitive equations used in ocean modeling. Two thrusts are discussed, the first is baroclinic instability, the other the numerical simulations of rotating shallow water equations. We look at the wall-bounded, wind-forced double gyre problem and periodic decaying shallow water turbulence.

12:00 pm	**Lunch Break**	
2:00 pm	**Alex Mahalov** Arizona State University	Fast Singular Oscillating Limits and Global Regularity for the 3D Primitive Equations of Geophysics

Abstract: Fast singular oscillating limits of the three-dimensional "primitive" equations for stably stratified rotating geophysical fluid flows are analyzed. We prove existence on infinite time intervals of regular solutions to the 3D "primitive" Navier-Stokes equations for strong stratification (large stratification parameter). This uniform existence is proven for all domain aspect ratios, including the case of all three wave resonances in the limit resonant equations; smoothness assumptions for initial data are the same as for local existence theorems, that is initial data in $H_s,\ s > 3/4$. The global existence is proven using techniques of the Littlewood-Paley dyadic decomposition. Infinite time regularity for solutions of the 3D "primitive" Navier-Stokes equations is obtained by bootstrapping from global regularity of the limit resonant equations and strong convergence theorems. Algebraic geometry of resonant Poincare curves is also used to obtain regularity results in generic cases for solutions of 3D Euler "primitive" equations.

3:00 pm	**Second Chances** Darryl Holm, Moderator	3:00 Leslie Smith 3:15 Beth A. Wingate 3:30 Alex Mahalov
3:45 pm	**Open Discussion**	Darryl Holm, Moderator

Wednesday, February 13

All talks are in EE/CS 3-180 unless otherwise noted.

9:00 am	**Coffee**	Reception Room EE/CS 3-176
9:30 am	**David G. Dritschel** University of St. Andrews, Scotland	An explicit potential-vorticity conserving approach to modelling three-dimensional Boussinesq flows

Abstract: The Boussinesq equations are used to describe the dynamical behaviour of a rotating, stratified fluid, a prime example being the oceans. These equations consist of momemtum and mass conservation, together with the condition of incompressibility. As normally written, they obscure the underlying material conservation of a quantity called "potential vorticity", given by the product of the absolute vorticity (including the background rotation of the Earth) and the gradient of the density, itself materially conserved. For a stably-stratified fluid, density decreases monotonically with height everywhere, a situation typical of most of the oceans. Then, material conservation of potential vorticity amounts to the conservative advection of potential vorticity on surfaces of constant density (isopycnals).

This mathematical result is well known but, in practise, little exploited. Using potential vorticity explicitly poses two major problems: (1) it forces one to solve a nonlinear diagnostic equation for one of the "primitive" variables (velocity, density, pressure or a combination thereof); and (2) numerical methods are traditionally not suited for conservative advection. In this talk, a new approach is presented which overcomes these two problems. Theoretically, the equations are reformulated in a

mathematically convenient way, revealing the existence of an underlying Monge-Ampere equation, a nonlinear diagnostic equation for one of the primitive variables. The reformulation uses the ageostophic horizontal vorticity, a first-order estimate for the "imbalanced" (wave-part) of the flow. Numerically, explicit potential vorticity conservation is handled by "contour advection", which tracks potential vorticity contours in a grid-free way on density surfaces. These contours are converted to gridded values for the purpose of solving the Monge-Ampere equation, and the remaining part of the numerical algorithm uses conventional methods (e.g. pseudo-spectral).

An example of a strongly anticyclonic vortex is presented. We focus on the behaviour of a notoriously difficult field, the vertical velocity, which is typically $10,000$ times weaker than the horizontal velocity. Our solutions are shown to be highly accurate, as judged indirectly by comparison with the vertical velocity diagnosed from an approximate balance relation (the "quasi-geostrophic ω equation"). The method also appears able to accurately quantify the radiation of internal-gravity waves.

10:30 am	**Coffee Break**	Reception Room EE/CS 3-176
11:00 am	**Jeroen Molemaker** University of California, Los Angeles	Unbalanced instabilities of the balanced quasi-manifold

Abstract: Under the influences of stable density stratification and Earth's rotation, large-scale flows in the ocean and atmosphere have a mainly balanced dynamics—sometimes called the slow manifold—in the sense that there are diagnostic hydrostatic and gradient-wind balances that constrain the fluid acceleration. The nonlinear Balance Equations are a successful approximate model for this regime, and we have identified mathematically explicit limits of their time integrability. We hypothesize that these limits are indicative, at least approximately, of the transition from the larger-scale regime of inverse energy cascades of anisotropic flows to the smaller-scale regimes of forward energy cascade to dissipation of more nearly isotropic flows and intermittently breaking inertia-gravity waves. In the oceans these regime transitions occur mostly in the scale range of 0.1-10 km—in between the mesoscale and fine-structure—where Rossby (Ro), Froude (Fr), and Richardson (Ri) numbers are typically neither small nor large. In an ongoing quest for the verification of this hypothesis, we have revisited several classical problems, including gravitational, centrifugal/symmetric, elliptical, barotropic, and baroclinic instabilities. In all cases we find definite evidence, albeit still incompletely understood, of fluid-dynamical transitions in the neighborhood of loss of balanced integrability.

12:00 pm	**Lunch Break**	
2:00 pm	**C.E. Leith** Lawrence Livermore Labs	Fast Manifolds
3:00 pm	**Second Chances** James McWilliams, Moderator	3:00 David Dritschel 3:15 Jeroen Molemaker 3:30 C.E. Leith
3:45 pm	**Open Discussion**	James McWilliams, Moderator

Thursday, February 14

All talks are in EE/CS 3-180 unless otherwise noted.

9:00 am	**Coffee**	Reception Room EE/CS 3-176
9:30 am	**Djoko Wirosoetisno** University of Twente, Netherlands	Nonlinear Averaging in GFD Systems and Higher-Order Balance Dynamics

Abstract: An averaging (or renormalization) procedure is used to obtain slow evolution equations for all degrees of freedom

of a parent model which contains fast and slow dynamics. In a GFD context, the parent model is the primitive equations, the slow dynamics consists of vortical motion and the fast dynamics consists of inertia-gravity waves. This procedure can be carried out (formally) to any order in the timescale separation parameter giving higher-order slow equations.

We will show a close connection between these slow equations and the more familiar classical balance models, which are obtained using a singular perturbation expansion and have a reduced number of degrees of freedom. Issues of convergence of these asymptotic procedures will be considered.

10:30 am	**Coffee Break**	Reception Room EE/CS 3-176

11:00 am	**Jacques Vanneste** University of Edinburgh	Dirac-bracket approach to Hamiltonian balanced models

Abstract: Balanced models can be viewed as constrained systems, obtained from the primitive equations by projection on a (slow) manifold devoid of inertia-gravity waves. Salmon showed how balanced models naturally inherit the Hamiltonian structure of the primitive equations if the constraints are implemented in the variational principle associated with the primitive equations. This, however, requires the introduction of an extended state space, using Lagrangian variables either as dependent or independent variables. Here, we demonstrate how this can be avoided and we derive Hamiltonian balanced models using exclusively the standard Eulerian formulation of the primitive equations. This is achieved by applying Dirac's theory of constrained systems to the Poisson structure of the fluid equations in Eulerian form. We consider multilayer primitive equations and implement general constraints which prescribe the velocity field as a pseudo-differential function of the mass field. This leads to the Poisson structure of a general class of balanced models which include (multilayer versions of) Salmon's L1 model, the semi-geostrophic model, and higher-order balanced models. The well-posedness of models in this class depends on certain invertibility issues which will be discussed.

APPLIED MATHEMATICS AND NUMERICAL ANALYSIS SEMINAR, 570 Vincent Hall

11:30 am	**Milton Lopes** U. Campinas, Brazil	Large time behavior of vortex evolution on the half-plane

Abstract: The dynamics of vorticity is a convenient way to describe incompressible, ideal fluid motion in 2D. One important feature of 2D vortex motion is the behavior of vortex pairs, a well-known class of nonlinear waves. Due to symmetry, vortex pairs are travelling wave solutions of half-plane vortex motion. We investigate the long-time behavior of half-plane vortex motion arising from a smooth, compactly supported and single signed initial vorticity configuration through linear rescaling of the solution in both space and time, which highlights the wavelike behavior. We use vortex confinement results and weak convergence techniques to obtain information on the broad structure of the possible scattering states.

12:00 pm	**Lunch Break**	

2:00 pm	**Vladimir Tseitline** Université P. et M. Curie, France	Frontal geostrophic adjustment, slow manifold and nonlinear wave phenomena in 1d rotating shallow water model

Abstract: We study the problem of nonlinear adjustment of localized front-like perturbations to a state of geostrophic equilibrium. By using Lagrangian coordinates within the framework of rotating shallow-water equations with no dependence on the along-front coordinate we first develop a perturbative in the cross-front Rossby number adjustment procedure and demonstrate splitting of slow and fast dynamical variables for non-negative potential vorticities. We prove that wave-trapping is impossible in localized adjusted jets and fronts and, hence, adjustment is always complete. We then give a nonperturbative proof of existence and uniqueness of the adjusted state (slow manifold) for configurations with non-negative initial potential vorticities and show that retarded adjustment may occur if quasi-stationary states decaying via

tunneling across a potential barrier exist on the background of a corresponding adjusted state. We also describe finite-amplitude periodic non-linear waves in configurations with constant potential vorticity. Finally, shocks are analysed and semi-quantitative criteria based on the values of initial gradients and relative vorticity of initial states are established for wave-breaking and shock formation showing, again, essential differences between the regions of positive and negative vorticity.

3:00 pm	**Second Chances** C.E. Leith, Moderator	3:00 Djoko Wirosoetisno 3:15 Jacques Vanneste 3:30 Vladimir Tseitline
3:45 pm	**Open Discussion**	C.E. Leith, Moderator
6:00 pm	**Workshop Dinner**	Caspian Bistro, 2418 University Ave, S.E.

The restaurant has no visible sign; across University Ave. from Day's Inn.

Friday, February 15

All talks are in EE/CS 3-180 unless otherwise noted.

9:00 am	**Coffee**	Reception Room EE/CS 3-176
9:30 am	**C. David Levermore** University of Maryland	A Shallow-Water Model with Eddy Viscosity for Basins with Varying Bottom Topography

Abstract: The motion of an incompressible fluid confined to a shallow basin with a varying bottom topography is considered. We introduce appropriate scalings into a three dimensional anisotropic eddy viscosity model to derive derive a two dimensional shallow water model. The global regularity of the resulting model is proved. The anisotropic form of the stress tensor in our three dimensional eddy viscosity model plays a critical role in ensuring the resulting shallow water model dissipates energy.

10:30 am	**Coffee Break**	Reception Room EE/CS 3-176
11:00 am	**Edriss S. Titi** University of California, Irvine	Global Well-posedness and Long-Term Dynamics for Certain Geophysical Models

Abstract: The basic problem faced in geophysical fluid dynamics is that a mathematical description based only on fundamental physical principles, which are called the "Primitive Equations," is often prohibitively expensive computationally, and hard to study analytically. In this talk I will present a formal derivation of more manageable shallow water approximate models for the three dimesional Euler equations in a basin with slowly spatially varying topography, the so called "Lake Equation" and "Great Lake Equation," which should represent the behavior of the physical system on time and length scales of interest. These approximate models will be shown to be globally well-possed. I will also show that the Charney-Stommel model of the gulf-stream, which is a two dimensional damped driven shallow water model for ocean circulation, has a global attractor. Whether this attractor is finite or infinite dimensional is still an open question. Other results concerning the global well-posedess of three dimensional viscous planetary geostrophic models will be presented.

12:00 pm	**Lunch Break**	
2:00 pm	**George R. Sell** University of Minnesota	The Search for El Nino: An Update

3:00 pm	**Second Chances** Vladimir Tseitline, Moderator	3:00 Alex Mahalov 3:15 David Levermore 3:30 George Sell
3:45 pm	**Open Discussion**	Vladimir Tseitline, Moderator

Monday, February 18

Special IMA Short Course:

Wavelet methods in Seismology: application of wavelets to multiscale analysis and non-linear estimation

February 18–20, 2002
Speakers: Felix Herrmann, Massachusetts Institute of Technology

All talks are in the Seminar Room, Lind Hall 409.

In this three-day mini-course the application of the wavelet and related transforms to seismology will be discussed. Attention will be paid to characterization as well as to non-linear solution of linear inversion problems, such as denoising and deconvolution. First a brief overview of (exploration) seismology will be given, followed by a review of the continuous wavelet transform as a tool to characterize the scaling of broadband upper sedimentary records (well-log data). Mallat's Wavelet Transform Modulus Maxima method will be introduced to calculate the Hölder regularity as well as the multifractal singularity spectra. Secondly, methods will be discussed that aim to estimate local coarse-grained Hölder exponents from essentially bandwidth limited seismic data. These methods consist of extensions of the Modulus Maxima framework and of a Matching Pursuit Algorithm with Fractional Spline Wavelet Packets as a dictionary. Finaly, examples will be shown how to apply basis function expansions to the non-linear solution of linear inverse problems.

9:30 am	**Felix Herrmann** MIT	Brief overview of seismology with the emphasis on exploration seismology.

Topics: • Outline of the course emphasizing characterization *versus* inversion;
• Relation linearized (inverse) scattering and wavelets.

The 10:30 IMA break will be in Lind Hall 400.

11:00 am	**Felix Herrmann** MIT	Multiscale analysis by the Wavelet transform

Topics: • Modulus Maxima Method;
• Local singularity order estimation via wavelet coefficient decay along Modulus Maxima;
• Open problems: sensitivity to noise, bandwidth limitation.

Tuesday, February 19

9:30 am	**Felix Herrmann** MIT	Multifractal Analysis

Topics: • Hausdorff dimensions;
• Partition functions;
• Singularity Spectra;
• Modulus maxima partitioning;
• Partition function by Modulus Maxima;
• Some remarks on link to Regularity Estimation and Besov spaces.

The 10:30 IMA break will be in Lind Hall 400.

IMA POSTDOC SEMINAR, Lind Hall 409:

11:15 am	**Daniel Kern** Inst. for Math. and its Applications	Compartmental Model for Cancer Evolution

Abstract: A model is presented that examines the role of drug resistance in the evolution of cancer subject to treatment with a single cytotoxic (chemotherapeutic) agent. The model starts from a single cell and generates the evolution of the cancer. The roles of natural occurring, and acquired, resistance from chemotherapy can be seen throughout the development of the cancer or treatment history. Numerical examples illustrate the effects of resistance on chemotherapy treatment scheduling.

The IMA Postdoc Seminar is organized by Selim Esedoglu and Michael Efroimsky.

2:00 pm	**Felix Herrmann** MIT	Monoscale Analysis I

Topics: • Generalization of the Modulus Maxima Method by Fractional Calculus;
• Application to seismic stratigraphy.

Wednesday, February 20

9:30 am	**Felix Herrmann** MIT	Monoscale Analysis II

Topics: • Fractional Splines;
• Fractional Spline Wavelets;
• Wavelet Packets;
• Fractional Spline Matching Pursuit;
• Atomic decomposition and reconstruction;

The 10:30 IMA break will be in Lind Hall 400.

11:00 am	**Felix Herrmann** MIT	Non-linear estimation I

Topics: • non-adaptive denoising by Thresholding;
• Deconvolution using by combining Fourier and Wavelet Methods;
• Wavelet-Vaguelette methods;
• Application to Seismic data.

Thursday, February 21

The 10:30 IMA break will be in Lind Hall 400.

APPLIED MATHEMATICS AND NUMERICAL ANALYSIS SEMINAR, 570 Vincent Hall

11:30 am	**Anna Vainchtein** Univ. of Pittsburgh	Non-isothermal dynamics of phase transitions and hysteresis

Abstract: Materials undergoing stress-induced martensitic phase transformations (such as shape-memory alloys) often exhibit hysteretic behavior when subjected to cyclic loading. The hysteresis consists of a rate-independent part, which persists at quasistatic loading, and rate-dependent hysteresis, whose size increases with applied strain rate. The hysteresis loops exhibit serrations accompanied by nucleation events and often by very irregular, "jerky" motion of phase boundaries.

To model hysteresis, we consider a non-isothermal one-dimensional dynamic model that incorporates a finite bar with a non-monotone temperature-dependent stress-strain law and nonzero latent heat. Inertia is taken into account and two dissipation mechanisms are considered: heat conduction and the internal viscous dissipation of kinetic origin, proportional to the strain rate. Time-dependent mechanical loading and ambient temperature are prescribed at the ends of the bar.

We will show that the model is capable of predicting both rate-independent isothermal hysteresis at quasistatic loading and rate-dependent hysteresis due to thermal effects. The isothermal hysteresis is caused primarily by metastability of equilibria and phase nucleation. It persists even when the loading is very slow, and viscosity effects are minor. The hysteresis loops are serrated, and a stick-slip interface motion is observed. Such motion is also observed at either high or low enough heat conductivity, or small latent heat. At intermediate values of heat conductivity, faster loading or larger latent heat, the stick-slip motion is partially replaced by a smooth, yet irregular, slow-fast interface motion accompanied by damped oscillations in the end load and released heat. These nonlinear oscillations are due to the combination of heat conduction and viscosity and persist even when inertia is neglected. The model also predicts self-heating of the bar, formation of multiple interfaces and larger hysteresis at faster loading, in qualitative agreement with experiments. If time permits, effect of convection will also be discussed.

Friday, February 22

The 9:30 IMA break will be in Vincent Hall 502.

IMA/MCIM INDUSTRIAL PROBLEMS SEMINAR, 570 Vincent Hall:

10:10 am	**Eric van den Berg** Telcordia Technologies	Mathematical modeling in support of Service Level Agreements

Abstract: To save costs, corporations are increasingly using the shared infrastructure of network service providers to connect their various locations. Subscription to a so called 'virtual private network' service is an economical alternative to leasing dedicated lines. Similarly, e-commerce companies can have their web-sites hosted on 'server farms' of web hosting companies, instead of maintaining the servers and internet connections themselves.

In such cases, the service provider and customer sign a contract outlining the service quality to be delivered, the so called Service Level Agreement (SLA). SLAs can be quite comprehensive, encompassing not only network performance metrics, but also metrics for service reliability, disaster recovery, security, customer care and trouble handling. When SLAs are not met, customers are typically entitled to rebates. In order to determine whether SLA requirements are violated, careful monitoring is necessary. In fact, SLAs should contain for each metric: a precise definition, the acceptable value range, and the measurement technique.

Mathematical modeling can help build a framework for determining appropriate SLAs. In this talk, I will review several approaches taken to model network phenomena influencing the structure of SLAs. In particular, I will focus on the use of statistical techniques to help set achievable thresholds for SLA metrics.

Monday, February 25

The 10:30 IMA break will be in Lind Hall 400.

Tuesday, February 26

The 10:30 IMA break will be in Lind Hall 400.

IMA POSTDOC SEMINAR, joint with COMPUTATIONAL GEOSCIENCES SEMIONAR, Lind Hall 409:

11:15 am	**Peter Lynch** Met Eireann	Resonant Triads and Swinging Springs

Abstract:

1: An Interesting Analogy. A Powerful Equivalence.

The oscillations of the atmosphere fall into two categories, the low frequency Rossby waves and the high frequency gravity waves. The Swinging Spring is a simple mechanical system also having low frequency and high frequency oscillations. There are several illuminating analogies between the spring's behavior and that of the atmosphere. The equivalence between the systems allows us to deduce properties of atmospheric motion from the behavior of the spring. The talk will include a demonstration with a real-life swinging spring and a Java applet illustrating some characteristics of its motion.

2: Resonant Motions and Stepwise Precession of the Spring.

The three-dimensional motion of the swinging spring is investigated using a perturbation approach. If the Lagrangian is approximated by keeping terms up to cubic order, the system has three independent constants of motion; it is therefore completely integrable. When the ratio of the vertical and horizontal oscillations is approximately two-to-one, an interesting resonance phenomenon occurs, in which energy is transferred periodically between predominantly vertical and predominantly horizontal oscillations. The motion has two distinct characteristic times, that of the oscillations and that of the resonance envelope, and a multiple time-scale analysis is found to be productive. The modulation equations are the well-known Three-Wave Equations that also apply to many other physical systems. As the oscillations change from horizontal to vertical and back again, it is observed that each horizontal excursion is in a different direction. Expressions for the precession of the swing-plane are derived. The approximate solutions are compared to numerical integrations of the exact equations, and are found to give a realistic description of the motion.

3: Rossby Wave Triads and the Swinging Spring

The relationship between the spring dynamics and large-scale Rossby waves in the atmosphere will be described. Rossby waves are of fundamental importance for atmospheric dynamics. The nonlinear interactions between these waves determine the primary characteristics of the energy spectrum. These interactions take place between triplets of waves known as 'resonant triads' and, for small amplitude, they are described by the three-wave equations. The characteristic stepwise precession of the swing-plane, so obvious from observation of the physical spring pendulum, is also found for the Rossby triads. This phenomenon has not been previously noted and is an example of the insight coming from the mathematical equivalence of the two systems. The implications of the precession for predictability of atmospheric motions are considered. The pattern of breakdown of unstable Rossby waves is very sensitive to unobservable details of the perturbations, making accurate prediction very difficult.

The IMA Postdoc Seminar is organized by Selim Esedoglu and Michael Efroimsky.

Wednesday, February 27

The 10:30 IMA break will be in Lind Hall 400.

Thursday, February 28

The 10:30 IMA break will be in Lind Hall 400.

CURRENT IMA PARTICIPANTS

POSTDOCTORAL MEMBERS FOR 2001–2002 PROGRAM YEAR

NAME	PREVIOUS INSTITUTION
Jamylle Carter	UCLA
Vittorio Cristini	Yale University
Dacian Daescu	University of Iowa
Gregory S. Duane	NCAR
Michael Efroimsky	University of Oxford
Selim Esedoglu	Courant Inst. of Mathematical Sci.
Daniel Kern	University of Illinois-Chicago
Anna Mazzucato	Yale University
Miao-Jung Ou	University of Delaware
Jianliang Qian	Rice University
Toshio Yoshikawa	University of Utah

POSTDOCTORAL MEMBERS IN INDUSTRIAL MATHEMATICS

NAME	PREVIOUS INSTITUTION	INDUSTRIAL AFFILIATION
Santiago Ignacio Betelú	Univ. Nac. del Centro Prov. Buenos Aires	Seagate
Christine Cheng	Johns Hopkins University	Telcordia Technologies
Aurelia Minut	Michigan State University	3M

VISITORS IN RESIDENCE (as of January 29)

ARNOLD, DOUG	Inst. for Mathematics & its Applications	SEP 1 - AUG 31
BETELÚ, SANTIAGO	Inst. for Mathematics & its Applications	SEP 1 - AUG 31
BRENNER, SUSAN	Inst:Univ. of South Carolina	JAN 31 - FEB 2
BRUINING, HANS	Techn. Univ. Delft	JAN 20 - FEB 8
BURRIDGE, ROBERT	Massachusetts Inst. of Technology	JAN 6 - JUN 30
CALDERER, M. CARME	Univ. of Minnesota	SEP 1 - AUG 31
CARTER, JAMYLLE	Inst. for Mathematics & its Applications	SEP 1 - AUG 31
CHENG, CHRISTINE	Inst. for Mathematics & its Applications	SEP 1 - AUG 31
COUËT, BENOÎT	Schlumberger-Doll Research	JAN 30 - FEB 1
CRISTINI, VITTORIO	Inst. for Mathematics and its Applications	SEP 1 - AUG 31
DAESCU, DACIAN	Inst. for Mathematics & its Applications	SEP 1 - AUG 31
DEWAR, WILLIAM	Florida State Univ.	FEB 10 - 15
DOKKEN, DOUG	Univ. of St. Thomas	SEP 1 - JUN 30
DRITSCHEL, DAVID G.	The Univ. of St. Andrews	FEB 10 - 15
DUAN, JINQIAO	Illinois Inst. of Technology	FEB 11 - 15
DUANE, GREGORY S.	Inst. for Mathematics & its Applications	SEP 1 - AUG 31
EFROIMSKY, MICHAEL	Inst. for Mathematics & its Applications	SEP 1 - AUG 31
ESEDOGLU, SELIM	Inst. for Mathematics & its Applications	SEP 1 - AUG 31
GAO, HONGJUN	Nanjing Normal Univ.	SEP 22 - MAR 23
GULLIVER, ROBERT	Inst. for Mathematics & its Applications	SEP 1 - AUG 31
HERRMANN, FELIX	Massachusetts Inst. of Technology	OCT 1 - MAY 31
HOLM, DARRYL	Los Alamos National Laboratory	FEB 10 - 15
JOLLY, MICHAEL	Indiana Univ.	FEB 10 - MAR 7
KALACHEV, LEONID V.	Univ. of Montana	FEB 10 - 16
KNOX, JOHN	Univ. of Georgia	FEB 9 - 15
KUSKE, RACHEL	Univ. of Minnesota	SEP 1 - AUG 31
LEITH, C.E.	Lawrence Livermore National Laboratory	FEB 10 - 17
LEVERMORE, DAVID	Univ. of Maryland	FEB 10 - 15
LOWENGRUB, JOHN	School of Math, Minnesota	SEP 1 - AUG 31
LYNCH, PETER	Met Eireann	JAN 31 - FEB 28

MAHALOV, ALEX	Arizona State Univ.	FEB 9 - 15
MARCHESIN, DAN	Instituto de Matematica Pura e Aplicada	JAN 7 - FEB 9
MAZZUCATO, ANNA	Yale Univ.	JAN 1 - JUN 30
MCWILLIAMS, JAMES C.	Univ. of California, Los Angeles	FEB 10 - 14
MILLER, WILLARD	Univ. of Minnesota	SEP 1 - AUG 31
MINUT, AURELIA	Inst. for Mathematics & its Applications	SEP 1 - AUG 31
MOLEMAKER, JEROEN	Univ. of California, Los Angeles	FEB 10 - 15
NORBURY, JOHN	Univ. of Oxford	FEB 10 - 15
O'MALLEY, ROBERT	Univ. of Washington	JAN 2 - MAR 31
OU, MIAO-JUNG	Inst.for Mathematics & its Applications	SEP 1 - AUG 31
PARK, JEONG-SOO	Chonnam National Univ./SRCCS	SEP 5 - AUG 31
PELINO, VINICIO	CNMCA, Italian Weather Service	FEB 10 - 16
POUTKARADZE, VAKHTANG	Univ. of New Mexico	FEB 10 - 15
QIAN, JIANLIANG	Inst. for Mathematics & its Applications	SEP 1 - AUG 31
REITICH, FERNANDO	Univ. of Minnesota	SEP 1 - AUG 31
SANTOSA, FADIL	Inst. for Mathematics & its Applications	SEP 1 - AUG 31
SCHOLZ, KURT	Univ. of St. Thomas	JAN 1 - JUN 30
SELL, GEORGE	Univ. of Minnesota	SEP 1 - AUG 31
SHCHERBAKOV, VALERA, P.	Geophysical Observatory "Borok"	FEB 15 - MAY 15
SHEN, JIANHONG	Univ. of Minnesota	SEP 1 - AUG 31
SMILEY, MICHAEL W.	Iowa State Univ.	FEB 10 - 15
SMITH, LESLIE	Univ. of Wisconsin-Madison	FEB 10 - 15
ŠVERÁK, VLADIMIR	Univ. of Minnesota	SEP 1 - AUG 31
THAYER, JAVIER F.	MITRE Corporation	SEP 1 - AUG 31
TITI, EDRISS	Univ. of California, Irvine	FEB 10 - 15
TRIBBIA, JOE	NCAR	FEB 10 - 15
TSEITLINE, VLADIMIR	Universite de Paris P. et M. Curie	FEB 10 - 17
VANNESTE, JACQUES	Univ. of Edinburgh	FEB 9 - 15
WALEFFE, FABIAN	Univ. of Wisconsin-Madison	FEB 10 - 15
WANG, SHOUHONG	Indiana Univ.	FEB 10 - 15
WINGATE, BETH	Los Alamos National Laboratory	FEB 10 - 15
WIROSOETISNO, DJOKO	Univ. of Twente	FEB 9 - 16
WU, JIANHUA	Shaanxi Normal Univ.	JAN 8 - MAR 7
YAVNEH, IRAD	Technion	FEB 10 - 15
YOSHIKAWA, TOSHIO	Inst. for Mathematics & its Applications	SEP 1 - AUG 31

See also URL: `http://www.ima.umn.edu/people/`