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FINAL TECHNICAL REPORT

SIAM Conference on
Inverse Problems: Geophysical Applications
December 16-19, Fish Camp, California

This conference was the second in a series devoted to a particular application area of inverse problems. The theme of this series is to discuss problems of major scientific importance in a specific area from a mathematical perspective. As the title suggests, the theme of this symposium was geophysical applications. In putting together the program we tried to include a wide range of mathematical scientists and to interpret "geophysics'' in as broad a sense as possible. Our speakers came from industry, government laboratories and from diverse departments in academia. In fact more than half of the 100 participants did not hail from an academic mathematics department. We managed to attract a geographically diverse audience; there was a participant from each of the five continents, and from most of the countries of western Europe. There were talks devoted to seismology, hydrology, the determination of the earth's interior on a global scale as well as oceanographic and atmospheric inverse problems. Some speakers concentrate on issues devoted to stable inversion of large data sets, others to regularization techniques. For some, modelling was a primary issue, for others it was analytic methods or numerical techniques. Many of the talks blended of all of these things.

We had 8 plenary speakers several of whom organised minisyposia consisting of 4 or 5 speakers. There were a total of 60 thirty-minute contributed papers and for the most part we were able to run these with only two parallel sessions. The conference site was an excellent choice and the SIAM staff ran all aspects of the meeting flawlessly. Finally, we would like to thank the Department of Energy who supplied partial funding for this meeting.

Submitted by

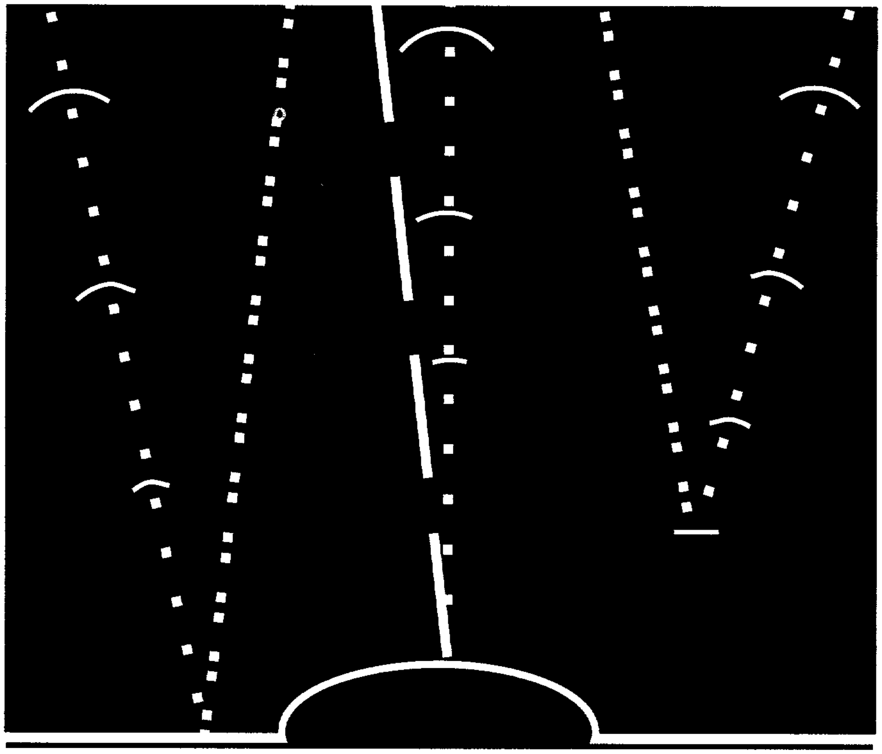
William Rundell
Conference Chair.

Society for Industrial and Applied Mathematics
3600 University City Science Center
Philadelphia, PA 19104-2688

Final

RB

SYMPOSIUM ON INVERSE PROBLEMS: GEOPHYSICAL APPLICATIONS



Marriott Tenaya Lodge at Yosemite
Fish Camp, California
December 16 - 19, 1995

Conducted by SIAM with the cooperation of Gesellschaft für Angewandte Mathematik und Mechanik (GAMM)

CONFERENCE SERIES ORGANIZING COMMITTEE

Heinz W. Engl (Co-chair)
Johannes-Kepler Universität, Austria

William Rundell (Co-chair)
Texas A&M University, College Station

David L. Colton
University of Delaware

Alfred Louis
Universität Saarlandes, Germany

CONTENTS

SYMPOSIUM THEMES

Groundwater Flow
Seismology
Geophysical Prospecting
Electromagnetic Waves

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CONFERENCE SERIES ADVISORY PANEL

■ **Mario Bertero**
Università di Genova, Italy

■ **Guy Chavent**
Université de Paris-Dauphine, and INRIA, France

■ **Margaret Cheney**
Rensselaer Polytechnic Institute

■ **Richard E. Ewing**
Texas A&M University, College Station

■ **Avner Friedman**
University of Minnesota, Minneapolis

■ **Rainer Kress**
Universität Gottingen, Germany

■ **Karl K. Kunisch**
Technische Universität Berlin, Germany

■ **Pierre Sabatier**
Université de Montpellier II, France

■ **William W. Symes**
Rice University

FUNDING AGENCY

SIAM would like to thank the Department of Energy for its support in conducting this symposium.

GET-TOGETHERS

■ Welcoming Reception
Friday, December 15
7:00 PM-9:00 PM
Tenaya 4

■ Yosemite Valley Mariposa Grove Tour
Sunday, December 17
12:30 PM-6:30 PM

Entering Yosemite National Park through the Southern entrance, Bass Lake Yosemite Tours will share with you all of the wonders of Yosemite. You will see all of the highlights including El Capitan, Half Dome, Bridalveil Falls, Yosemite Falls, Mariposa Grove of Giant Sequoias and much more.

Your driver/guide will entertain and educate you on the history of Yosemite, as well as the geology, current events, flora and fauna. They will share their knowledge and stories and answer any questions you may have.

In addition to a light nature walk in the Mariposa Grove and a lunch/shopping stop in Yosemite Valley (approximately one hour), there will be several "photo stops" for those postcard photo opportunities and views.

For lunch, guests are on their own. You will be dropped off at the Visitors Center where a full service deli, pizza, hamburgers, hot dogs and all of the accompaniments are available.
Cost per person: $29.00

WELCOME! ...

Dear Colleagues:

Welcome to Yosemite and the SIAM/GAMM Symposium on Inverse Problems in Geophysics!

This is the second symposium in a series with each meeting devoted to a different application area of inverse problems. The first was Inverse Problems in Diffusion Processes, and the next will be Inverse Problems in Medical Imaging and Non-Destructive Testing.

In putting together the program, we have tried to include a wide range of mathematical scientists and to interpret "geophysics" in as broad a sense as possible. Our speakers come from industry, government laboratories and from diverse departments in academia.

We have talks devoted to seismology, hydrology, the determination of the earth's interior on a global scale as well as oceanographic and atmospheric inverse problems. Some speakers will concentrate on issues devoted to stable inversion of large data sets, others to regularization techniques. For some, modelling will be a primary issue; for others, it will be analytic methods or numerical techniques. A great many of the talks will be a blend of all of these things.

We would like to take this opportunity to thank the many individuals who made this meeting possible, the members of the organizing committee, the SIAM staff and the numerous mathematical scientists who gave sage advice.

On behalf of the Organizing Committee, we hope that the scientific program and your visit to Yosemite was exciting and invigorating.

Thank you all for coming.

William Rundell and Heinz Engl
Conference Chairs

DISCLAIMER

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DISCLAIMER

PROGRAM-AT-A-GLANCE

Friday Evening, December 15

7:00 AM-6:00 PM **Registration opens**
Tenaya Ballroom Foyer

7:00-9:00 **Welcoming Reception**
Tenaya 4

Saturday Morning, December 16

7:00 AM-6:00 PM **Registration opens**
Tenaya Ballroom Foyer

8:45 **Welcoming Remarks**
William Rundell and Heinz Engl
Tenaya 1

9:00 IP1 **The Mathematics of Velocity Analysis**
William W. Symes
Tenaya 1

10:00 **Coffee**
Tenaya 4

10:30 AM-12:30 PM Concurrent Sessions

CP1 **Regularization Techniques I**
Tenaya 1

CP2 **Travel-Time Seismology**
Tenaya 2

Saturday Afternoon, December 16

12:30 **Lunch**

2:00 IP2 **Inverse Problems for Groundwater Contamination and Petroleum Applications**
Richard E. Ewing
Tenaya 1

3:00 **Coffee**
Tenaya 4

3:30-5:30 Concurrent Sessions

CP3 **Inverse Scattering**
Tenaya 2

CP4 **Remote Sensing**
Tenaya 1

CP4A **Seismic Velocities**
Madera

5:45 IP3 **The Inversion of Body Wave Attributes Derived from Seismic Refraction Data**
Robert L. Nowack
Tenaya 1

Sunday Morning, December 17

7:30-11:00 **Registration opens**
Tenaya Ballroom Foyer

8:30-11:00 Concurrent Sessions

CP5 **Earth Structure and Tectonics**
Tenaya 1

CP6 **Groundwater and Hydrology I**
Tenaya 2

11:00 **Coffee**
Tenaya 4

11:30 IP4 **Underground Imaging of Electrically Conducting Plumes**
James G. Berryman
Tenaya 1

12:30 **Lunch**

Afternoon is free or join the Yosemite Valley Mariposa Grove Tour.

Sunday Evening, December 17

7:00 IP5 **A Geometrical Analysis of the MBTT Approach to Inversion of Seismic Data**
Guy Chavent
Tenaya 1

8:00-10:00 Concurrent Sessions

CP7 **Seismology I**
Tenaya 1

CP8 **Regularization Techniques II**
Tenaya 2

CP9 **Spectral Methods**
Madera

Monday Morning, December 18

7:30-11:00 **Registration opens**
Tenaya Ballroom Foyer

8:30-11:00 Concurrent Sessions

CP10 **Data Inversion**
Tenaya 1

CP11 **Geo-Electrical Techniques**
Tenaya 2

11:00 **Coffee**
Tenaya 4

11:30 IP6 **Inverse Boundary Value Problems Arising in Geophysics**
Gunther Uhlmann
Tenaya 1

12:30 **Lunch**

Afternoon is free.

Monday Evening, December 18

7:00 IP7 **Inverse Problems in Geodesy**
Willi Freeden
Tenaya 1

8:00-10:00 Concurrent Sessions

CP12 **Groundwater and Hydrology II**
Tenaya 2

CP13 **Wave Propagation Methods**
Madera

CP14 **Gravimetry**
Tenaya 1

Tuesday Morning, December 19

7:30-11:00 **Registration opens**
Tenaya Ballroom Foyer

8:30 IP8 **Geologically Constrained Reflection Tomography**
Kurt J. Marfurt
Tenaya 1

9:30 **Coffee**
Tenaya 4

10:00 AM-12:30 PM Concurrent Sessions

CP15 **Seismology II**
Tenaya 1

CP16 **Heat Transfer and Diffusion**
Tenaya 2

CP17 **Acoustics**
Madera

CP18 **Groundwater and Hydrology III**
Mariposa

12:30 PM **Conference adjourns**

Times allowed for each presentation, including discussion:

30 minutes for a contributed presentation (CP)

60 minutes for an invited presentation (IP)

The organizing committee expects every speaker of a scheduled presentation to register and attend the conference. If it becomes inevitable for a speaker to cancel the presentation, the speaker is expected to find an alternate presenter or one of the speaker's co-authors should give the presentation.

A canceled presentation can cause serious inconvenience to the attendees and conference organizers.

NOTE: For papers with multiple authors, the speaker is shown in italics if known at press time.

PROCEEDINGS

The proceedings will be available in August 1996. All attendees will be notified and will be offered a special discount. The proceedings is not included in the registration fee.

Saturday Morning, December 16

7:00/Tenaya Ballroom Foyer

Registration Opens

8:45/Tenaya I

Opening Remarks

Heinz W. Engl, Johannes-Kepler Universitat, Austria and William Rundell, Texas A&M University, College Station

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9:00/Tenaya I

IP1/Chair: William Rundell, Texas A&M University, College Station

The Mathematics of Velocity Analysis

Seismologists record motion of the Earth's surface, resulting from seismic (elastodynamic) waves which have propagated through the interior of the Earth and thus carry information about its interior structure. The index of refraction, or wave velocity, is a central object of study in seismology: it is reasonably well correlated with the geology, and also regulates the relation of details in the seismograms (recorded in time) with causative subsurface heterogeneities (mapped in depth). Boundary value problems for (variants of) the elastodynamic wave equations model seismic wave motion. In these terms, the estimation of seismic wave velocity becomes an inverse problem in partial differential equations. With some simplifications (linearization at short scales) the map from mechanical parameters to seismogram may be expressed as an oscillatory integral (Fourier integral operator), and the task becomes the estimation of its phase. This very nonlinear problem has been studied for a century by seismologists. The modern theory of oscillatory integrals, developed over the last thirty years by Hormander and others, suggests some new approaches to this estimation problem that lead to very effective algorithms. Without the simplifying linearization at short scales (which is justified only in limited circumstances), other sources of nonlinearity must be taken into account, and many fundamental questions remain open.

William W. Symes

Department of Computational and Applied Mathematics, Rice University

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10:00/Tenaya 4

Coffee

10:30 AM-12:30 PM

Concurrent Sessions

CP1/Tenaya I

Regularization Techniques I

Chair: James G. Berryman, Lawrence Livermore National Laboratory

10:30 On the Local Regularization of Inverse Problems of Volterra Type
Patricia K. Lamm, Michigan State University

11:00 Fast Interpolation of 2-D Geophysical Scattered Data
Thomas Strohmer, University of Vienna, Austria

11:30 New Iterative Methods for Ill-posed Problems
Daniela Calvetti, Stevens Institute of Technology; Lothar Reichel and Qin Zhang, Kent State University

12:00 Distributed Parameter Identification in Elliptic Problems
T. Karkkainen and T. Raisanen, University of Jyvaskyla, Finland

CP2/Tenaya 2

Travel-time Seismology

Chair: Robert L. Nowack, Purdue University, West Lafayette

10:30 Inversion of Complex Seismic Data Through Migration-Based Travel Time Formulation and Continuation
Guy Chavent, Université de Paris-Dauphine, France and *Francois Clement* and Benoit Lavaud, INRIA-Rocquencourt, France

11:00 Singularity and Branching: A Path Following Formalism for Geophysical Inverse Problems
D.W. Vasco, Lawrence Berkeley Laboratory

11:30 Methods of Solving 3-D Wave Inverse Problems of Seismics and Their Applications
Anatolii B. Bakushinskii, Russian Academy of Sciences, Russia; Alexander V. Goncharsky and *Sergey Yu. Romanov*, Moscow State University, Russia

Saturday Afternoon, December 16

12:30-2:00

Lunch

2:00/Tenaya I

IP2/Chair: Heinz W. Engl, Johannes-Kepler Universität, Austria

Inverse Problems for Groundwater Contamination and Petroleum Applications

The purpose of mathematical reservoir simulation models in petroleum applications is to try to optimize the recovery of hydrocarbon from permeable underground reservoirs. In order to accomplish this, one must be able to predict the performance of the reservoir under various production schemes. Models must be constructed to describe the complex chemical, physical, and multiphase flow processes that accompany the various recovery techniques. The models require the estimation of various rock and fluid properties that influence the flow; optimal control techniques are used in this process. There are two basic types of parameters that arise in multiphase fluid flow problems. The first contains nonlinear functional parameters that depend upon only a few degrees of freedom that can be treated by a wide variety of Newton or quasi-Newton techniques. The second is a spatially variable class of parameters. Due to the large size of the three-dimensional reservoirs and the paucity of data, this is an extremely difficult problem. The speaker will discuss state-adjoint types of techniques for these problems.

Richard E. Ewing

Institute for Scientific Computation

Texas A&M University, College Station

3:00/Tenaya 4

Coffee

3:30-5:30 PM

Concurrent Sessions

CP3/Tenaya 2

Inverse Scattering

Chair: Gunther Uhlmann, University of Washington

3:30 Sinc Inversion of the Helmholtz Equation without Computing the Forward Solution
Frank Stenger and Michael O'Reilly, University of Utah

4:00 The Landweber Iteration for an Inverse Scattering Problem
Martin Hanke, Universität Karlsruhe, Germany; Frank Hettlich, Universität Erlangen-Nurnberg, Germany; and Otmar Scherzer, Texas A&M University, College Station

4:30 Uniqueness of an Inverse Electromagnetic Scattering Problem
Frank Hettlich, Universität Erlangen-Nurnberg, Germany

5:00 A Fast New Method to Solve Inverse Scattering Problems
Roland Potthast, Universtiy of Delaware

CP4/Tenaya 1

Remote Sensing

Chair: To be determined

3:30 Ozone Profiles from Solar Backscattered Ultraviolet (SBUV)
Lawrence E. Flynn, Software Corporation of America, Greenbelt, Maryland

4:00 Coastal Bathymetry and Currents from Shallow Water Waveform Inversion
Ralph A. Smith, Arete Associates, Sherman Oaks, California

4:30 Optimal Planification of Remote Sensed Observations
Sylvie Maggion, CESBIO, France and Bernard Pinty, JRC-IRSA, Italy

5:00 Using Neural Networks for Empirical Solution of Inverse Problems in Satellite Remote Sensing
Vladimir Krasnopolsky, General Sciences Corporation, Camp Springs, Maryland

CP4A/Madera

Seismic Velocities

Chair: William W. Symes, Rice Unviersity

3:30 Uncertainty in Velocity Estimation
Phillip Stark, University of California Berkeley

4:00 Optimization Approaches to Velocity Estimation
Mrinal K. Sen, P.L. Stoffa, C. Varela, and R. Chundru, University of Texas, Austin

4:30 Linearized Asymptotic Inversion in Caustic Backgrounds
Dirk Smit, A.P.E. ten Kroode, and A.R. Verdel, Shell Research

5:00 Uniformly Smooth Objective Functions for Velocity Estimation
William W. Symes, Rice University

5:45/Tenaya 1

IP3/Chair: Alfred Louis, Universität Saarlandes, Germany

The Inversion of Body Wave Attributes Derived from Seismic Refraction Data

Seismic attributes are derived from refraction data and used in the inversion for crustal velocity and attenuation structure. Seismic attributes include envelope amplitudes, weighted instantaneous frequencies, and phase times of different arrivals. The speaker will discuss simultaneous inversions of extracted seismic attributes applied to recent observed crustal seismic data. Iterative procedures from smooth to less smooth models result in combined velocity and attenuation models that fit the observed seismic attributes.

Robert L. Nowack
Department of Earth and Atmospheric Sciences
Purdue University, West Lafayette

Sunday Morning, December 17

7:30/Tenaya Ballroom Foyer

Registration Opens

8:30-11:00 AM

Concurrent Sessions

CP5/Tenaya 1

Earth Structure and Tectonics

Chair: Robert L. Nowack, Purdue University, West Lafayette

8:30 Inferring Earth Structure and Tectonic Evolution from Seismic Waves
John VanDecar, Carnegie Institution of Washington

9:00 Q Inversion From Earthquake Data: Examples from Loma Prieta and Pinon Flats, California
Jonathan M. Lees, Yale University

9:30 Resolving Low Velocity Layers with Surface Wave Data
Hendrik Jan van Heijst, University of Oxford, United Kingdom; Roel Snieder, Utrecht University, The Netherlands; and Robert Nowack, Purdue University, West Lafayette

10:00 Seismic Imaging using Both Asymptotic Forward Methods and Linear and Nonlinear Inversion Procedure
Pascal Amand, Alessandra Ribodetti and *Jean Virieux*, CNRS-UNSA, France

10:30 Gibbs' Sampler and Its Application to Nonlinear Geophysical Inversion
Mrinal K. Sen, University of Texas, Austin

CP6/Tenaya 2

Groundwater and Hydrology I

Chair: Richard E. Ewing, Texas A&M University, College Station

8:30 "Nonsmooth" Regularization
Curt Vogel, Montana State University

9:00 A Variational Method for the Aquifer Transmissivity Problem
Ian Knowles, University of Alabama, Birmingham

9:30 Inversion Methods for the Aperature Distribution in a Fracture
Carl R. Hagelberg and Bryan J. Travis, Los Alamos National Laboratory

10:00 From Nanometers to Centimeters Hierarchical Lowest Levels Saturated Contaminant Groundwater Transport. Mathematical Modeling and Numerical Experiments
V.S. Travkin, L. Tynkova, and I. Catton, University of California, Los Angeles

11:00/Tenaya 4

Coffee

11:30/Tenaya 1

IP4/Chair: William Rundell, Texas A&M University, College Station

Underground Imaging of Electrically Conducting Plumes

The use of electrical resistance tomography for applications to underground fluid remediation has now been established as a viable means of imaging conducting fluid plumes in the earth. A new method using electromagnetic induction rather than d.c.\ imaging techniques also shows promise of being able to image both conductors and conduction deficits (presence of hydrocarbons). Variational methods may be applied to image reconstruction for both techniques. The speaker will discuss these methods and highlight the similarities.

James G. Berryman

Lawrence Livermore National Laboratory

12:30

Lunch and Free Afternoon

Sunday Evening, December 17

7:00/Tenaya 1

IP5/Chair: Alfred Louis, Universitat Saarlandes, Germany

A Geometrical Analysis of the MBTT Approach to Inversion of Seismic Data

The Migration-based Travel-Time (MBTT) approach addresses the problem of determining a smooth slowness background of the underground and providing good imaging from highly redundant reflection seismic data recorded at the surface of the earth. The corresponding data misfit function suffers from non optimizability by local gradient algorithms since it possesses a large number of nonsignificant local minima caused by the phase-shifts associated with changes in the slowness unknown.

The speaker will describe methods that lead to overcoming the above difficulties. Duality methods replace the natural depth reflectivity unknown by one defined in the same space as the data, thus eliminating the phase shift problem, and Quantitative migrations provide high-quality imaging useable for the resimulation of the data. The speaker will illustrate by a geometrical analysis of the MBTT output the improvement with respect to the usual least-square formulation and numerical results on the inversion of synthetic as well as real data that shows the feasability of the approach.

Guy Chavent

Institut National de Recherche en Informatique et en Automatique, and Université de Paris-Dauphine, France

8:00-10:00 PM

Concurrent Sessions

CP7/Tenaya 1

Seismology I

Chair: William W. Symes, Rice University

8:00 An Example of a Computationally Feasible Approximate Resolution Matrix for Seismic Inverse Problems
Susan E. Minkoff and William W. Symes, Rice University

8:30 The Inversion of Transient Reflection Data from a Compact Source in a Stratified Elastic Body
Gerry R. Wickham, University of Manchester, England

9:00 Application of Bessel Beams in Seismic Inverse Problem
Ginette Saracco and Dominique Gibert, CNRS-UPR, France; and Matthias Holschneider, CNRS-Luminiy, France

CP8/Tenaya 2

Regularization Techniques II

Chair: Guy Chavent, Universite de Paris-Dauphine, and INRIA, France

8:00 Heuristic Approach to Numerical Investigation of Inverse Problems in Geophysics
Lubomir Alexandrov, Menlo Park, California

8:30 Efficient Solving of Regularized Ols-formulated Identification Problems by Two-grid Methods
Antti Niemisto, University of Jyvaskyla, Finland

9:00 Boundary Control Method in Inverse Problems for Partial Differential Equations
Sergei Avdonin, St. Petersburg University, Russia

9:30 Regularization Solutions of 2-D Radon Problem for both the Interior and Exterior
Kewang Zheng, Hebei Institute of Light Industry and Chemical Technology, People's Republic of China

CP9/Madera

Spectral Methods

Chair: Gunther Uhlmann, University of Washington

8:00 Mapping Pulsed Neutron Wellbore Measurements into Formation Parameters
Richard Odom, Computalog Research, Benbrook, Texas

8:30 Spectroelastic Evaluation of Inhomogeneous Materials
Lev Steinberg, University of Puerto Rico, Mayaguez

9:00 Some Aspects About Solution Inverse Problems of Spectroscopy
Tatyana A. Vasilyeva, Volgograd State University, Russia

Monday Morning, December 18

7:30/Tenaya Ballroom Foyer

Registration Opens

8:30-11:00 AM

Concurrent Sessions

CP10/Tenaya 1

Data Inversion

Chair: Willi Freeden, Universität Kaiserslautern, Germany

8:30 The Variance of Frequency Multiplet Obtained by Splitting of a Degenerated Eigenfrequencies and Its Inversion
Mikhail Brodsky, University of California, Berkeley

9:00 Mathematical Issues in Reentry Current Detection Problem in Magnetocardiography
M. Brio, and D. Marchesin, IMPA, Brazil

9:30 Gaussian Markov Random Fields, Kalman Filters, and Large-Scale State-Estimation
Toshio M. Chin and *Arthur J. Mariano*, University of Miami

10:00 Inversion for Velocity and Diffusivity from Short Tracer Time Series
Leonid I. Piterbarg and Boris L. Rozovskii, University of Southern California

10:30 Eventually Nonnegative Minimal Partial Realization
Boris G. Zaslavsky, Agrophysical Research Institute, Russia and Arizona State University

CP11/Tenaya 2

Geo-Electrical Techniques

Chair: James G. Berryman, Lawrence Livermore National Laboratory

8:30 Geoelectrical Imaging using Optimal Data
Elena Cherkaeva and Alan C. Tripp, University of Utah

9:00 On Resolution and Optimal Measurements of Time Domain Methods in Hydraulic and Electromagnetic Tomgraphy
Johannes Gottlieb, Karlsruhe University, Germany

9:30 2-D Inverse Cross- and Single- Well DC Tomography Problems: Feasible Formulations and Efficient Algorithms
Vladimir Druskin and Carlos Torres-Verdin, Schlumberger-Doll Research; and Sveta Schedrina, Central Geophysical Expedition, Russia

10:00 Crack Detection using the Schwarz-Christoffel Transformation
Alan Elcrat, Chenglie Hu and Victor Isakov, Wichita State University

10:30 Fast 3-D Resistivity Inversion in EOR Monitoring
Xiaoan Lu and Maurice B. Dusseault, University of Waterloo, Canada

11:00/Tenaya 4

Coffee

11:30/Tenaya 1

IP6/Chair: William Rundell,
Texas A&M University, College Station

Inverse Boundary Value Problems Arising in Geophysics

In this talk the speaker will consider several inverse boundary value problems that involve the determination, in both bounded and unbounded domains, of the sound speed of a medium by making measurements at the boundary. In particular he measures at the boundary the response of an impulse located at any point in the boundary for finite amount of time in the temporal domain or for a fixed frequency in the frequency domain. The inverse problem is to determine the sound speed from this information. The main technique is the use of geometrical optics techniques in the time domain and "complex geometrical optics" in the frequency domain.

Gunther Uhlmann
Department of Mathematics
University of Washington

12:30

Lunch and Free Afternoon

Monday Evening, December 18

7:00/Tenaya 1

IP7/Chair: Heinz W. Engl,
Johannes-Kepler Universitat, Austria

Inverse Problems in Geodesy

Geodesy is the scientific discipline concerned with the measurement and determination of the figure of the earth and the gravitational field in its exterior. Until the middle of this century, geodesy was occupied mainly with the refinement of the theories of the past. The technological revolution of the post-war period gave an entirely new dimension to the discipline. Probably no other scientific discipline profited so much from the possibilities that resulted from highly advanced electronic measurement concepts, modern computer technology and, most of all, artificial satellites. The formulation of new theories, inverse problems, and numerical models have followed. In this context a much more precise and detailed determination of the earth's gravitational field from space borne gravity sensors is very likely the greatest challenge. The speaker will present some of the modern concepts of (physical) geodesy, with particular emphasis on inverse problems of satellite geodesy.

Willi Freeden
Geomathematics Group
University of Kaiserslautern, Germany

8:00-10:00 PM

Concurrent Sessions

CP12/Tenaya 2

Groundwater and Hydrology II

Chair: Richard E. Ewing,
Texas A&M University, College Station

8:00 Transversal Flows, Collinearity and the Identification of Conductivity from Interior Data
Giovanni F. Crosta, Università degli Studi di Milano, Italy

8:30 Estimation of Hydraulic Conductivity from Field Data
Ben G. Fitzpatrick, North Carolina State University

9:00 Stochastic Characterization of Contaminanted Aquifer Properties with a Functional Inverse Method
Lynn B. Reid and Dennis McLaughlin, Massachusetts Institute of Technology

9:30 Recovering Permeability Distributions from Flow and Transport Data
Bryan J. Travis, Los Alamos National Laboratory

CP13/Madera

Wave Propagation Methods

Chair: William W. Symes, Rice University

8:00 Finite Difference Methods for Geometrical Optics and Related Nonlinear PDEs
E. Fatemi, B. Engquist, and S. Osher, University of California, Los Angeles

8:30 The Regularized Born Approximations and Its Investigation
Anatolii Bakushinskii, Russian Academy of Sciences, Russia

9:00 Two-Level Parallel Algorithms for Wave Propagation in Dispersive Media
Seongjai Kim, Purdue University

9:30 Interaction of Elastic Waves with a Discontinuity
V.V. Mansurov, G.P. Bystray, and Yu. A. Buyevich, Urals State University, Russia

CP14/Tenaya 1

Gravimetry

Chair: Willi Freeden,
Universitat Kaiserslautern, Germany

8:00 Gravitational Field Determination by Satellite Gradiometry
M. Schreiner, University of Kaiserslautern, Germany

8:30 New Methods for Earth's Gravitational Potential Determination from Space Born Data
Frank Schneider, University of Kaiserslautern, Germany

9:00 Absolute Ballistic Gravimeter Internal Inverse Problem Multimodel Solution
Alexander F. Kostin and Yevgenij M. Zanimonskij, Ukrainian State Research Institute of Metrology, Ukraine; and *Vadim D. Nagornyi*, Russian Academy of Sciences, Russia

Tuesday Morning, December 19

7:30/Tenaya Ballroom Foyer

Registration Opens

8:30/Tenaya 1

IP8/Chair: Heinz W. Engl,
Johannes-Kepler Universitat, Austria

Geologically Constrained Reflection Tomography

Reflection tomography is currently the workhorse in 2-D velocity analysis necessary for accurate prestack seismic imaging. During the past ten years, there has been considerable debate as to whether it is best to parameterize velocities with rectangular cells, B-splines or layers. Fortunately, prestack seismic imaging is quite robust, such that a large class of blocky or smoothed velocity models can produce an accurate depth image.

Unfortunately, petroleum engineers and geologists are singularly unimpressed with our velocity/depth models. The engineers want to map pressure and fractures. The geologists want to map sand/shale ratios and depositional environment. Both wish to map porosity and somehow infer permeability. All of us, engineers, geologists and geophysicists need to quantify errors in our estimates for use in financial "risk analysis." While tomographically derived depth and structural closure are components of risk analysis, velocity per se is not.

Clearly, we need to reparameterize models with velocity/depth as the dependent variable, while pore pressure, mineralogy, porosity, fluid content, formation depth, depositional environment and geologic age become the independent variables. The task of the geologist, engineer and rock physicist is then to generate perhaps basin specific empirical velocity laws, was well as constraints on the new independent variables. These constraints usually take the form of inequalities or clouds of measurements tracking an empirical trend. The task for the astute mathematicians in this audience is twofold: to develop more efficient constrained optimization algorithms and to develop more effective means to estimate and display the errors and interdependencies of each estimated parameter.

Kurt J. Marfurt
Amoco Exploration and Production Technology

9:30/Tenaya 4

Coffee

TUESDAY, DECEMBER 19

10:00 AM-12:30 PM

Concurrent Sessions

CP15/Tenaya 1

Seismology II

Chair: Kurt J. Marfurt, Amoco Exploration and Production Technology

10:00 Development of Three-Dimensional Finite Element Models for Geologic Structures
Lawrence D. Porter, Autonnic Research, Inc., Alamo, California

10:30 Time-Pulse Propagation and Inverse Problem Solution for Layered Medium
V.I. Klyatskin, K.V. Koshel and B.M. Shevtsov, Russian Academy of Sciences, Russia

11:00 Inverse Problem for Buried in Nonisotropic Medium Moving Oscillating Source
Vladimir A. Pozdnyakov, Alexandr A. Tuzovsky, and Dmitry V. Safonov, State University of Krasnoyarsk, Russia

11:30 Application of the Results of Analytical Function Approximation by Means of Rational Function with Prescribed Poleses and Quasi-Analytical Continuation to Decision Inverse Problem of Potential Two-Dimension Fields
G.C. Tumarkin, Moscow State Geology-Prospecting Academy, Russia

12:00 Regularizing an Inverse Seismic Problem for Oil Prospection
Susana Gomez, IIMAS National University of Mexico, Mexico

CP16/Tenaya 2

Heat Transfer and Diffusion

Chair: To be determined

10:00 Determination of the Surface Temperature from Interior Observations
Dinh Nho Hao, Universität GH Siegen, Germany

10:30 A Numerical Algorithm for Parameter Estimations
Jianping Zhu, Mississippi State University

11:00 Determining Heat Sources in Rock Dumps
Jerard M. Barry, Australian Nuclear Science and Technology Organisation, Australia

11:30 Inverse Approximation of a Hydrodynamic Flooding Problem
Theodore V. Hromadka, California State University, Fullerton

12:00 Inverse Problem of Heat Transfer in Geological Surrounding
L.S. Monastyrsky, A.S. Kokodyniak, and R.M. Kovtun, Lviv State University, Ukraine

CP17/Madera

Acoustics

Chair: Pierre C. Sabatier, Université Montpellier 2, France

10:00 A Patchwork Approach to Inverse Problems
Pierre C. Sabatier, Université Montpellier 2, France

10:30 Globally Convergent Layer Stripping Method in Diffusion Tomography and Inverse Acoustics
Michael V. Klibanov, University of North Carolina, Charlotte

11:00 Multipath Identification and Truncated Total Least Squares Solution for Ocean Acoustic Tomography
Longji Tang, J. L. Barlow, S. Draganov, A. Fabrikant, and J. Spiesberger, Penn State University

11:30 The Inverse Problem of a Fourth Order Self-Adjoint Binomial Operator
Alan Elcrat and *Vassilis G. Papanicolaou*, Wichita State University

CP18/Mariposa

Groundwater and Hydrology III

Chair: Giovanni F. Crosta, Universita degli Studi di Milano, Italy

10:00 Applying Neural Networks to Groundwater Inverse Problems
Donna M. Rizzo and David E. Dougherty, University of Vermont

10:30 A Multi-Resolution Approach to Hydraulic Conductivity Estimation
Michael M. Daniel, Alan S. Willsky, and Dennis M. McLaughlin, Massachusetts Institute of Technology; and David J. Rossi, Schlumberger-Doll Research

11:00 A Hybrid Numerical Method for High Contrast Conductivity Problems
Liliana Borcea and George C. Papanicolaou, Stanford University

12:30

Conference Adjourns

SPEAKER INDEX

* Evening Sessions
CP = Contributed Presentation
IP = Invited Presentation

ABSTRACTS: CONTRIBUTED PRESENTATIONS
(in session order)

CP 1

On the Local Regularization of Inverse Problems of Volterra Type

We consider a local regularization method for the solution of first-kind Volterra integral equations with convolution kernel. The local regularization is based on a splitting of the original Volterra operator into "local" and "global" parts, and a use of Tikhonov regularization to stabilize the inversion of the local operator only. We present a convergence theory for the infinite-dimensional regularization problem and show how numerical implementation of these ideas leads to the notion of "sequential Tikhonov regularization" for Volterra problems. This approach has been shown in [Lamm and Eldén, preprint, 1995] to be as effective as Tikhonov regularization in numerical tests, but considerably more efficient computationally.

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Fast Interpolation of 2-D Geophysical Scattered Data

The problem of interpolating or approximating a 2-D function, sampled at arbitrarily located positions arises in many geophysical applications. We propose a fast smooth interpolation technique using trigonometric polynomials. The coefficients of the trigonometric polynomials can be computed by solving a linear system of equations. The system matrix is block-Toeplitz with Toeplitz blocks, which allows to use FFT techniques, solving the system of equations by the (Preconditioned) Conjugate Gradient method. We apply the proposed method to real geophysical data and show that it is superior compared to standard methods in terms of computational costs and accuracy.

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New Iterative Methods for Ill-posed Problems

We present a new class of iterative methods for the solution of large, symmetric, ill-conditioned linear systems. Like in classical Tikhonov regularization, the original linear system is replaced by a sequence of regularized linear system. The class of methods presented in this talk determine a sequence of regularization parameters according to the Morozov discrepancy principle. Unlike the truncated conjugate gradient iteration algorithm, the class of algorithms described automatically stops computing iterates. More specifically, we continue iterating until no better approximate solution can be computed from the given contaminated data. Computed examples illustrating the performance of these methods in signal and image restoration are presented.

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Distributed Parameter Identification in Elliptic Problems

Identification problem of a functional coefficient b in the elliptic equation $-\nabla \cdot (b \nabla u) = f$ is considered. For this purpose, new methods are introduced which combine the well-known output least squares and equation error formulations. Finite element method is used for the discretization.
Estimates of the rate of convergence are derived when a distributed observation of the solution is assumed to be known *a priori*. Numerical examples, which are calculated with the proposed methods, are included.

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Jyväskylä, Finland

CP 2

Mathematical Analysis of Residual Moveout and Velocity Analysis

We have developed a new velocity analysis meth... ...s
a velocity distribution by a macro model
mula to update velocity. Our form...
by computing a derivative f...
parameters that char... ...ground
medium conte... ...ing velocities,
this formula ... ...bolic residual move-
out. Test res... ...ysis method to be superior
for complex me... ...armousi model, a current industry
standard for test

CANCELLED

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Inversion of Complex Seismic Data through Migration-Based TravelTime Formulation and Continuation

This work addresses the automatic determination of background slownesses in 2D complex structures from common shot full waveform acoustic data. When setting this inverse problem as a minimization problem controlled by the background slowness and the reflectivity depth section, one encounters two difficulties: (1) for fixed reflectivity in depth, because of phase shifts, the criterion presents many local minima, and (2) for fixed (wrong) background slowness, when the structure to be imaged is complex, because of destructive interferences, the criterion is almost flat. The Migration-Based TravelTime (MBTT) formulation cures the phase shifts problem by introducing reflectivity unknowns in the time domain. They are related to the reflectivity in the depth domain through a migration step which depends on the current background slowness. In the case of complex structures, frequency continuation and spatial resolution continuation (for the background slowness) used together with time continuation have the benefit effect of widening the valley at the bottom of which lies the global minimum. This enables local minimization methods to reach the global minimum from poor initial guesses. We give numerical results of the inversion of the Marmousi data.

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Singularity and Branching: A Path Following Formalism for Geophysical Inverse Problems

A path following technique is presented as an alternative to the direct minimization of a misfit functional. The algorithm is based upon the iterative adjustment of an Earth model to fit a set of generated 'data'. These values vary from a purely artificial set, produced from some prior model, to the observed data. The changes in the model required to satisfy the conditions for minimum misfit are calculated at each iteration.
Multiple solutions appear when the path following equations become singular and linear approximations fail. Thus, the algorithm allows one to track multiple solutions to a given inverse problem.
The technique is used to infer velocity variations between two boreholes at the Conoco Borehole Test Facility. The path following algorithm is also applied to the problem of residual statics estimation.

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Methods of Solving 3-D Wave Inverse Problems of Seismics and Their Applications

We present some mathematical approaches of solving inverse ill-posed problem of inhomogeneity prospecting in geophysical medium by means of seismic or other physical fields. We have taken a scalar wave model described by 3-D hyperbolic equation. In this model the inverse problem is nonlinear one and consists of finding the coefficient in hyperbolic equation. First way of the solution is based on using the data obtained within some range of frequency. In this case the problem may be rewritten as a linear operator equation of first kind. The second way is based on Born's approximation of equation. In this case we suggest tomography methods of solving. We can show the connection with known migration methods. The third way is based on suggested nonlinear iterative methods. The efficiency of the algorithms is investigated by the way of computer simulation.

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Alexander V. Goncharsky and Sergey Yu. Romanov
Moscow State University, Moscow, Russia

CP 3

Sinc Inversion of the Helmholtz Equation without Computing the Forward Solution

Given the Helmholtz equation, $\nabla^2 u + \kappa^2(1+f)u = 0$, on a half space H, we give an explicit description for summing a linear combination of point sources located on the exterior of H, such that the resulting sum arbitrarily closely approximates a *delta function* at an arbitrary point on the interior of H. We are thus able to closely approximate the function f in the interior of H, without repeatedly computing the forward solution to the Helmholtz equation.

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The Landweber Iteration for an Inverse Scattering Problem

A Landweber iteration scheme is presented for the numerical solution of an inverse obstacle problem. The method uses a recently obtained characterization of the Fréchet derivative of the far field operator and its adjoint. The performance of the method is illustrated by some numerical examples. Some theoretical aspects are pointed out to motivate the use of nonlinear Landweber iteration.

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Frank Hettlich Institut für Angewandte Mathematik, Universität Erlangen-Nürnberg, D-91058 Erlangen, FRG

Otmar Scherzer Department of Mathematics, Texas A&M University, College Station, Texas 77843–3368, USA (on leave from Universität Linz, A–4040 Linz, Austria)

Uniqueness of an Inverse Electromagnetic Scattering Problem

Conductive boundary conditions for the time harmonic Maxwell equations arise in the modeling of eletromagnetic induction phenomena in the earth where penetrable scattering obstacles occur which are covered by a thin layer of high conductivity. A variational formulation of the scattering problem is presented. This can be used to show a uniqueness result for the important inverse obstacle problem which consists in the recovery of the shape of the obstacle from the far field patterns of scattered electromagnetic waves.

Frank Hettlich
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SATURDAY PM

CP 4

Ozone Profiles from Solar Backscattered Ultraviolet (SBUV)

The transformation of SBUV measurements into estimates of atmospheric ozone profiles requires inversion of Fredholm integral equations of the first kind. The Version 7 retrieval algorithm for NIMBUS-7 and NOAA-11 SBUV instruments is described. It uses "a priori" information (as regularization) in a maximum likelihood approach. The solution is obtained by an iterative Newton's method with linearization about the current estimate. Each profile is retrieved individually, and all field information is included in an "a priori" profile and covariance matrix.

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Coastal Bathymetry and Currents from Shallow Water Waveform Inversion

Depth variations and currents in the near-shore region modify the local wavelength of long water waves, leading to refraction and diffraction. We consider the problem of estimating depths and currents from wave patterns, which may be observed optically or by radar. We employ a probability-based inversion scheme and a parabolic model for wave propagation. This approach dramatically improves crude estimates for simulated data. Application to radar observations will be discussed.

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Optimal Planification of Remote Sensed Observations

Our bidirectional reflectance model describes the amount of energy received and reflected by a optically simple canopy (Sun/Sensor system).The fit against remote sensed observations deals with the limited sampling of the reflectance field. To assess the optimal illumination-observation angles, we develop a weigth function based on the angular derivatives. Then, we combine this approach with a simple planification criterium of the experiment plane to construct a prediction-correction algorithm.This process was applied to study MISR angular condition, using a Monte Carlo method.

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Using Neural Networks for Empirical Solution of Inverse Problems in Satellite Remote Sensing

The retrieval of geophysical parameters from radiometric observations acquired from satellite sensors is a particular case of the inverse problem. In many practical situations such an inverse problem can not be solved theoretically. In these cases we can estimate the solution (transfer function) from observations or model calculations in order to obtain an empirical transfer function. Because this function is frequently nonlinear and the exact analytic formof the nonlinearity may not be known a priori, a flexible methodology that can accommodate complicated nonlinear behavior is desirable. Neural networks (NNs) are well-suited to serve as flexible nonlinear models for a very broad class of transfer functions. Advantages and disadvantages of the NN approach to empirically solve inverse problems are discussed. General considerations are illustrated with recently developed NN algorithms for satellite retrievals.

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SEE PGS. A13 - A14
for CP4A

SUNDAY AM

CP 5

Inferring Earth Structure and Tectonic Evolution from Seismic Waves

We describe the extraction of various waveform parameters - e.g. phase, amplitude, and distortion - from broad-band (0.1 - 100 s) and short-period (1 s) seismic data, and the use of these parameters in the inversion for Earth structure. Problems encountered in such inversions include non-linearity, non-uniqueness, and the existence of gross outliers. We will discuss how these problems are attacked in the context of large data sets and numbers of unknowns - commonly 10**4 to 10**5 - to produce minimum-structure, robust solutions. Examples will be given of the application of these techniques to inferring the tectonic evolution of the Cascadia subduction zone of the U.S. Pacific Northwest and the cratons of Southeast Brazil.

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Q Inversion From Earthquake Data: Examples from Loma Prieta and Pinon Flats, CA

Inversion for attenuation, or quality factor Q, represents a major challenge for earthquake seismologists trying to estimate site, path and source effects. Direct methods for estimating t* include nonlinear inversion for path and source parameters from amplitude spectra, and estimates associated with pulse width broadening.Inclusion of multi-taper spectral methods allow "spectral cleansing", thus improving estimates of spectral ratios and t*. Examples at Pinon Flat, CA, illustrate that, even at high frequency, signals are not random, even though pair-wise coherency between closely spaced stations is low. Three-dimensional tomographic inversions for velocity and attenuation at Loma Prieta, CA, suggest an association of pore fluid pressure variations with major earthquake ruptures.

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Resolving Low Velocity Layers with Surface Wave Data

Seismic velocities as a function of depth cannot be determined uniquely from seismic travel time data when a low velocity layer (LVL) is present. In this talk we investigate to what extend a structure with LVL can be resolved using surface wave data. It will be shown that using realistic datasets the structure can hardly be resolved in a statistically significant way. Furthermore higher modes are shown to play a crucial role in constraining the LVL structure. Therefore, we will discuss a cross correlation method that might help to measure higher mode properties.

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Robert Nowack
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Seismic Imaging using Both Asymptotic Forward Methods and Linear and Nonlinear Inversion Procedure

We have investigated the capability of efficient formulation of the propagation problem for improving our seismic imaging. We present two strategies for two different kinds of images of the Earth. The first approach tries to combine Ray and Born approximations in order to analytically invert diffracted seismograms using least square criterion of fitting. We find that, depending on the geometry of data acquisition, we are able to recover different kinds of Earth parameters as velocity perturbation, density perturbation and quality factor perturbation. This approach is fast enough to be performed on workstations for real data. The second approach exploit the intrinsic parallelism of the ray tracing method. We design by using PVM architecture a so fast forward problem for seismic reflection tomography that we are able to perform semi-global search method as the simulated annealing method (SA) or a combination between simulated annealing and simplex procedure (SAS) in order to recover shapes of reflectors. On synthetic examples, we show how SA and SAS methods performs. Combining semi-global search and linearized inversion will help to accurately recover images of the Earth where a-priori informations are unknown.

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Gibbs' Sampler and Its Application to Nonlinear Geophysical Inversion

In the Bayesian formulation, solution to a geophysical inverse problem is described by a posteriori probability density (PPD) function in model space. Conventional local and global optimization methods can be designed to find the global maximum of the PPD but they do not adequately describe the distribution. Often a Gaussian model is assumed and a Hessian at the maximum of the PPD is used to describe the posterior covariance. Most geophysical inverse problems are nonlinear and the error function is multimodal. Thus the point description of the PPD is not always adequate. We describe how a Gibbs' sampler can be designed to sample models from the PPD. Thus marginal PPD, mean, posterior model covariance and other measures of dispersion can be readily computed. We first validate the method by application to a dataset with small number of parameters where an exhaustive search is possible. Next we apply the technique to the inversion of marine seismic data set. The results are presented as marginal PPDs of compressional wave velocity, impedance and Poisson's ratio. The choice of data prior (or the distribution of error in the data), however, still remains debatable.

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CP 6

Estimation of Permeabilities in Laboratory Core Samples from MRI Velocity Data

The estimation of the spatially varying absolute permeability in a porus media core sample on the basis of knowledge of "distributed" Darcy velocity throughout the sample in single phase flow experiments is considered. This data can be obtained by certain recently-developed magnetic resonance imaging techniques.
Conventionally, the absolute permeability is estimated as a constant on the basis of press -drop measurements. In contrast, spatially distributed velocity d ates accurate determination of the spatially heterogenous pe
The presentati and numerical in focus. The inverse problem is c ain form of well-posedness of the solution is estab athematical assumptions. A robust computation d, along with examples.

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THIS PRESENTATION HAS BEEN WITHDRAWN, AND REPLACED BY CURT VOGEL'S PRESENTATION. SEE HIS ABSTRACT ON PAGE A14.

A Variational Method for the Aquifer Transmissivity Problem

For the differential equation $\nabla \cdot (p(x)\nabla u) = 0$, $x \in R^n$, the problem of computing the coefficient function p from a knowledge of the solution function u is of interest in connection with the modelling of underground aquifer systems, wherein u represents the piezometric head values and p the "transmissivity" (which measures the tendency of the water to move in the aquifer). We present a new method, based on iteration and minimization, for the robust computation of p in the presence of noisy data for u. This work is an outgrowth of recent work by the author and R. Wallace [Numer. Math. 70: 91–110 (1995)] on one-dimensional numerical differentiation.

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CP 7

Inversion Methods for the Aperature Distribution in a Fracture

Methods for estimating the aperature distribution using data from pressure tests on a fractured block are examined. Eleven holes were drilled into a 1m×1m×0.3m block of rock containing a horizontal fracture. Pressure differences for flow between each pair of holes was measured. We compare two methods for solving the inverse problem for permeability based on Tikhonov regularization. One method formulates the problem as a Fredholm integral equation with non-linear kernel, the other is a pde method based on computing representer functions. Solution techniques and computational requirements for each method are discussed.

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From Nanometers to Centimeters Hierarchial Lowest Levels Saturated Contaminant Groundwater Transport. Mathematical Modeling and Numerical Experiments

The smallest scales for continuum phenomena and their modeling for soil and groundwater contamination systems are the cornerstone areas of interest in groundwater modeling. The primary elements of a physical models and new mathematical models for nonlinear transport in different morphological pore systems were developed. Modeling at the smallest scale of continuum phenomena resulted in methods for including the effects of colloidal transport and nanoscale phenomena. Analysis of the impact and the numerical simulations show the importance of nonlinear and non-newtonian transport at the lowest morphology levels: pore surface, single pore, primary pore network, random pore size distribution morphology.

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On Unified Approach to Inverse Problems in Core Analysis

In the mathematical description of multiphase flow through porous medium the properties of fluids and rock are usually determined from laboratory experiments with the rock sample, i.e. core analysis. We review several interpretation problems in core analysis and show that they can be formally described by the same type of integral Volterra equation of the 1-st kind, which means that the problems have essentially the same properties. Therefore it seems reasonable to develop a unified approach for different interpretation problems formally based on numerical technique to solve the Volterra integral equation of the first kind. Some numerical examples of interpretation are presented. The reviewed problems are:

1. Dynamic displacement method to determine relative permeabilities in two or three-phase flow;
2. Centrifuge method to determine capillary pressure;
3. Multi-rate steady-state method to determine relative permeabilities.

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An Example of a Computationally Feasible Approximate Resolution Matrix for Seismic Inverse Problems

The resolution matrix measures whether inversion-estimated parameters are close to the true model parameters which generated the seismic data. For realistic seismic inverse problems, computing the resolution from the SVD of the forward operator (the standard technique) is computationally prohibitive. Instead we approximate the matrix from Lanczos estimates of eigenvectors of the normal operator. We apply the method to quantify estimates of the parameters (including the seismic source) which describe real plane-wave marine data from the Gulf of Mexico.

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The Inversion of Transient Reflection Data from a Compact Source in a Stratified Elastic Body

In this paper we consider the inverse scattering problem for a stratified linearly elastic body. For relative ease of computation, the wave motion in the body is taken to be two-dimensional, emanating from a compact source. By using the displacement to stress map across an arbitrary surface drawn in the body, it is shown how the wavefield may be split into "up-" and "down-going" components. The latter may be related by the reflection operator whose kernel is shown to satisfy a certain nonlinear integro-differential equation which is Riccati like. We show how this representation may be used to follow the wavefront as it penetrates the material and how the formulation provides a suitable vehicle for studying both the forward and inverse scattering problems. We present some numerical and asymptotic solutions.

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Application of Bessel Beams in Seismic Inverse Problem

We replace the spherical waves used usually in geophysical exploration by a directional beam of Bessel's type (=like a "torch lamp"). We propose a method to generate this beam approximatively, in any direction from a grid of monopole and dipole sources located at the interface. This defines a set of filters depending on the frequency of sources and the density of pointsources. These filters are used to recompose the seismic traces in a dirctional way.

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r-Solutions of Non-Linear Equations and Their Applications to Solve Inverse Problems of Wave Propagation Theory

The notion of r-solution for linear equations with a compact operator, based on its truncated SVD is generalized for nonlinear equation $F(x) = 0$: *vector x_r is called r-solution of this equation if $y = 0$ is the unique r-solution of linearized problem $DF(x_r) < y >= F(x_r)$.* of
truncated SVD can be considered as a regularization of ini
non-linear problem. Under some assumptions abo
solution is an approximation of the exact solutio
The correctness and meaningfulness of thi
stability with respect to some pertur
oretically and numerically. A n ... con–
Kantorovich technique) to ... d and ap-
plied to a non-linear ... n. The copling
of r-solution and ... on of the medium is
illustrated.

CANCELLED

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CP 8

Heuristic Approach to Numerical Investigation of Inverse Problems in Geophysics

We consider that inverse Geophysics problems are reduced to systems of nonlinear equations (SNLE). Investigation of SNLE is repeatedly solving in the meaning of least squares the SNLE with a purpose to: find all solutions in a defined domain of unknowns; determine the isolation each from other of the solutions with an estimation of their total error; define the degeneracy level of the SNLE in the solution; find the normal solution and the manifold of solutions for a degenerated SNLE. For the investigation of the SNLE is developed a methodology based on the simultaneous use of three different Levenberg-Marquardt-class of regularized Newton-type methods: autoregularized process of Gauss-Newton type (AR- processes); a new modification of the Marquardt method; a new modification of the Tikhonov-Glasko method "descend on parameter" (TG-processes).

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Efficient Solving of Regularized Ols-formulated Identification Problems by Two-grid Methods

We study a class of minimization problems containing the regularized output least square form to solve the problem of reconstructing the functional coefficient in an elliptic pde. We give the L^p and $W^{1,p}$ error bounds for the piecewise linear FE-approximation and suggest efficient two-level algorithms based on these estimates. We demonstrate the efficiency of the methods by results of numerical experiments.

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Boundary Control Method in Inverse Problems for Partial Differential Equations

Boundary control method is based on deep connections between the two central problems of the theory of inverse problems and boundary control theory. The first one is recovery of coefficients and continuation of "wave fields" inside the domain from the data on the boundary. The second one is the controllability problem for the corresponding initial boundary value problem. In the present talk we discuss generalization of the method to the nonselfadjoint case for various types of equations.

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Regularization Solutions of 2-D Radon Problem for Both the Interior and Exterior

In order to invert the Radon transforms with ill-posed nature, employing the usual polar coordinates we develop regularization approach for the interior as well as for the exterior. Notably, we are to construct directly their regularizing operators rather than make the use of any inversion formulas for finding approximate solution of the problems. The discrete aspects of the inversion procedures are discussed. The numerical tests show through examples that this is a more effective method.

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CP 9

Mapping Pulsed Neutron Wellbore Measurements Into Formation Parameters

The prevalent method for analyzing formation parameters behind wellbore casing is measurement of time and energy spectra of gamma radiation resulting from a pulse of fast neutrons. The mapping of these measurements into desired formation parameters generates multi-parametric, non-linear functional maps based on measured responses, environmental corrections, statistics and hardware limitations.

This paper describes current research in models and methods for data from the Computalog Pulsed Neutron Decay system. Application of computational tools such as neural networks, non-linear regressions, and computer based simulations are discussed.

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SPECTROELASTIC EVALUATION OF INHOMOGENEOUS MATERIALS

The goal of the paper is to formulate inverse spectral problems for a determination multidimensional distribution of moduli elasticity and density in nonhomogeneous materials as well as to develope constructive methods of their solution. Our treatment of the problems is within the framework of linear elasticity and is based on some iteration algorithms.

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Some Aspects About Solution Inverse Problems of Spectroscopy

Let us consider inverse problems, which appear in experimental physics and relate to ill-posed problems. These problems lead to the solution of the first kind of Fredgolm integral equation. In this paper we suggest application of regularizing fast Foufier conversion to the solution of inverse problems in gamma-resonance spectroscopy. According to numerical investigations the optimal stabilizing functional for such problems was defined. The given algorithm allows handling of experimental spectres. Numerical results demonstrate the resource of the algorithm.

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MONDAY AM

CP 10

The Variance of Frequency Multiplet Obtained by Splitting of a Degenerated Eigenfrequency and its Inversion

Study of free oscillations of the Earth shows that the behavior of its eigenfrequencies is consistent with the suggestion of its shperically symmetrical structure. It has been proven that the average of the frequencies from a multiplet, obtained by splitting an eigenfrequency of a spherically symmetric body by small non-spherical perturbation, is equal to the unperturbed frequency. A formulae for the variance of the frequencies of such a multiplet is presented, and a possibility for its inversion is discussed.

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Mathematical Issues in Reentry Current Detection Problem in Magnetocardiography

The reentry current detection problem consists of determining the center, the size and the region of slow velocity of the abnormal localized circular electrical activity from the magnetic field measurements. In our presentation we stress the common features with other inverse problems arising in geophysical sciences. We propose a solution based on iterative least squares and Kalman filtering type ideas which allow for real-time data processing suitable for clinical applications. We discuss the "goodness" of our model, its consistency, well-posedness and robust computability.

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Gaussian Markov Random Fields, Kalman Filters, and Large-Scale State-Estimation

The dynamic state (e.g. velocities and geopotentials) of ocean circulations can be inferred by incorporating sparse, noisy measurements into geophysical variants of the Navier-Stokes Equations. Gaussian Markov Random Field (GMRF) representation of the oceanic variables can lead to numerical conciseness desirable in such a large dimensional state-estimation problem, which involves inversion of the GMRF operators sequentially in time. The GMRF operator implies the spatial correlation among the state variables, and it must be updated temporally based on the dynamic model equations. A tradeoff between numerical conciseness and statistical optimality exists during time-updating of GMRF; however, favoring conciseness does not seem to affect the state-estimates much. A more crucial issue is designing an updating algorithm ensuring such properties as symmetry and positive definiteness of the GMRF.

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Inversion for velocity and diffusivity from short tracer time series

Estimating velocity and diffusivity from passive scalar observations is one of the most important problems in oceanography. Modern satellite facilities provide accurate measurements of tracer concentration with a high space resolution, but the time series are often short.

We use the maximum likelihood method to estimate the unknown parameters of the diffusion/advection equation. The asymptotical behaviour of the estimators is studied when the number of observed modes indefinitely increases whereas the number of time observations is fixed. Simulation results are also presented.

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Eventually Nonnegative Minimal Partial Realization

A minimal realization of finite sequence of Markov parameters is called a minimal partial realization. Minimal partial realizations extrapolate the movements of the unknown systems away from zero over an unlimited time interval. In many biological, medical, economical, chemical etc. models input and output vectors are expected to be nonnegative (nonpositive). In that event minimal partial realization is called eventually nonnegative. Eventually nonnegative realizations extrapolate finite sequences of Markov parameters ad infinitum. We provide a complete solution of the problem in the terms of matrix invarians and the properties of reduced graphs associated with a Jordan forms.
Zaslavsky B.G. "Eventually nonnegative realization of difference control systems, In: Advanced Series Dynamical Systems, v.9, Proceed. Int. Conf. Dynamical systems and Related Topics, Nagoya, 1990, ed.

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CP 11

Geoelectrical Imaging using Optimal Data

In order to determine the conductivity of a body or of a region of the earth, currents are injected on the surface and the surface voltage responses are measured. Then the data are inverted and a function of conductivity is chosen to fit the measurements. Most inversion schemes that have been developed in application to geoelectrical imaging deal with data 'as they are'. A new approach is suggested based on using optimal data. A special choice of measurements permits a simple inversion algorithm. The data used are measurements generated by the optimal currents, i.e. the currents which maximize the voltage difference on the boundary for the real and an assumed background media. The simplest algorithm iteratively focuses the currents to the region of the inclusion. An example is given of iterative use of this algorithm in application to numerical modeling a geoenvironmental problem of monitoring a contaminated area.

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On Resolution and Optimal Measurements of Time Domain Methods in Hydraulic and Electromagnetic Tomgraphy

During the last years several tomographic methods were developed to study the inhomogeneities of soil and to observe transport processes. Such methods are electrical impedance tomography, electromagnetical reflection methods and the hydraulic tomography.
An important question is, which experimental regime and measurement configuration gives an optimal image quality of the subsoil. We discuss this problem for time domain methods in hydraulic and electromagnetic tomgraphy. Beginning with the concept of resolution for X-ray tomography, which bases on Shannon's sampling theorem, we generalize this concept to other tomographical methods. Optimal=B7measurement configurations are derived on the bases of th= e singular value decomposition.

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2-D Inverse Cross- and Single-Well DC Tomography Problems: Feasible Formulations and Efficient Algorithms

We invert for an unknown, axially symmetric, electrical conductivity from measurements of DC potential fields acquired at different transmitter-receivers combinations along one or two vertical wells. This problem arises in the characterization of oil and water reservoirs as well as in flooding and waste clean-up experimental studies. However, in these applications large contrasts in electrical conductivity and sharp discontinuities render otherwise linear inversion procedures impractical. First, based on a general uniqueness theorem [Druskin, 1982] we identify the kinds of inverse problems that can be solved in principle. Then we present a solution to such problems using two modifications of a fixed-point iteration algorithm.

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Crack detection using the Schwarz-Christoffel Transformation

The Schwarz-Christoffel transformation gives a formula for the conformal mapping derivative of a canonical domain, traditionally the upper half plane or the unit disk, to the interior of a polygon. If there are more than three sides accessory parameters, the preimages of the vertices, must be determined by solving a system of nonlinear equations numerically. After appropriate normalization this system of equations is essentially that the side lengths come out right. Although the formula goes back to the 19th century the first successful numerical implementation was done about fifteen years ago. Maps are now routinely computed using the widely circulated package SCPACK written by L.N. Trefethen. Trefethen also formulated the idea of a 'generalized Schwarz-Christoffel parameter problem'. He used it solving a resistor trimming problem in which the length of a slit into a polygonal domain is varied in order to achieve a desired electrical resistance between electrodes held at constant potentials on the boundary of the domain. In recent work we have turned this idea around to prescribe resistance between electrode pairs in order to determine a polygonal slit into a domain. This will be described along with recent work for interior slits which uses a doubly connected version of the SC transformation. This problem was motivated by problems in 'crack detection' in which a break which is inaccessible to direct measurement must be determined.

For example, if a linear crack of unknown length and angle starts from an unknown point on the interior boundary of a doubly connected domain, three pairs of resistances must be substituted for the lost geometrical conditions in the Schwarz-Christoffel formula. In the simply connected case there is a uniqueness result if flux is specified on an arc of the boundary, but if only a finite number of resistances are known the situation is unresolved.

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Fast 3-D Resistivity Inversion in EOR Monitoring

A semi-analytic solution is obtained for the electrical potential due to a point current source in a laminated resistivity structure. Based on the semi-analytic solution and the reciprocity principle in electrical conduction a Fredholm integral equation of the first kind (F-1)

$$\delta\phi(x,y,z) = \int_A G(x,y,z;\xi,\eta)\delta\sigma(\xi,\eta)d\xi d\eta$$

is established for reconstructing the change in conductivity $\delta\sigma$ in an oil reservoir from the differenced potential $\delta\phi$. In the above equation A is the mid-plane of the oil reservoir. The differenced potential response $\delta\phi$ is studied and it is found that good resolution in $\delta\sigma$ can be achieved by subsurface current sources and surface potential measurements. Due the nature of the semi-analytic kernel $G(x,y,z;\xi,\eta)$ in the F-1 integral equation some fast inversion algorithms can be developed for EOR monitoring. These algorithms are expected to have small storage requirements and to be implementable on small computers.

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CP 12

Transversal Flows, Collinearity and the Identification of Conductivity from Interior Data

Position dependent thermal or hydraulic conductivity in two and higher dimensional domains satisfies a stationary transport equation. The transversality of flows, the Ito - Kunisch collinearity and other non local conditions provide the uniqueness of conductivity from interior source term and potential data. Said conditions are met e.g., in groundwater flow modelling. The related stability estimates in $W(^{1,p})$ are presented. Since the identified conductivity appears in subsequent direct (simulation) problems, the stability of the composed data-to-output map must be estimated. When structural analogies exist between the inverse and the direct problems e.g., when the dual property of collinearity holds, the estimation procedure simplifies and the constants improve.

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Estimation of Hydraulic Conductivity from Field Data

The modeling of groundwater flow is a crucial step in any quantitative analysis of subsurface contamination. From site characterization to remediation, flow models provide important decision-making tools. The main difficulty in applying such flow models is the determination of flow parameters such as hydraulic conductivity, which may vary by several orders of magnitude over a particular field site. In this paper, we examine a least squares parameter estimation technique which allows models to be calibrated to field data. Hydraulic conductivity is estimated using piecewise constant functions and total variation contraints.

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Stochastic Characterization of Contaminanted Aquifer Properties with a Functional Inverse Method

Subsurface site characterizations attempt to infer large-scale hydrogeologic properties from scattered small-scale measurements of related variables such as piezometric head or solute concentration. Many hydrogeological parameter estimation techniques rely upon spatial zonation to estimate a few areas with constant properties. We present an efficient way to solve groundwater flow and transport inverse problems in situations when the unknown property (e.g. log hydraulic conductivity) may be represented as a random function of space. The unknown log conductivity function is expanded in terms of basis functions which depend on prior geological information, on the configuration of the sampling networks, and on the mathematical operators which relate concentration, head and log conductivity. The coefficients of the basis functions are estimated with a nonlinear maximum *a posteriori* approach. We demonstrate the technique with a three-dimensional application to a field site contaminated with coal tar wastes.

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Recovering Permeability Distributions from Flow and Transport Data

Inverse solution methods establish well- posedness by applying constraints on the set of possible solutions, such as positivity and maximum smoothness of the solution or some of its derivatives. The permeability and porosity distributions of soils and rocks are generally not continuous and smoothly varying; they may however be approximately fractal within a lithologic unit. Between units, abrupt changes in properties are freqently seen. Two- dimensional models have been developed to explore the value of these characteristics as constraints in the context of recovering permeability from pressure and solute concentration measurements at a set of wells.

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CP 13

Finite Difference Methods for Geometrical Optics and Related Nonlinear PDEs

Numerical solution of inverse problems usually relies on a method for solving a forward problem. We have developed finite difference methods to solve the nonlinear PDEs approximating some solutions of the Helmholtz equation in high frequency regime. These methods rely on a mesh that is not directly dependent on the frequency of the wave and could substantially reduce size of calculations. Numerical methods are developed for solving the geometrical optics approximation, classical asymptotic expansion, and a new perturbed geometrical optics system. The geometrical optics system fails to represent diffraction phenomena and we propose a perturbed geometrical optics system to recover such phenomena. We present some numerical examples computed using the finite difference schemes developed for the above systems.

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The Regularized Born Approximations and Its Investigation

The Born approximation is the well-known and general purpose construction for the approximate solution of nonlinear inverse problems.
The formal theory of BA: the existention, the error of this approximation, e.t.c. don't exist now.
We suggest the construction of regularized Born approximation and some approach to its mathematical investigation.
Some applications to inverse problems in the Scattering theory are discussed too.

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Two–Level Parallel Algorithms for Wave Propagation in Dispersive Media

A two–level parallel iterative procedure is considered for solving wave equations in the frequency domain in 2– and 3–dimensional spaces. Since a numerical method requires choosing at least 6 to 8 grid points per wavelength, the coarse–level problem itself is not an easy task for high–frequency applications. We solve the coarse–level problem using a nonoverlapping domain decomposition method. To accelerate the convergence of the iteration, a relaxation parameter is introduced and an automatic strategy for finding the parameter is discussed. Numerical results on parallel computers are given to demonstrate the effectiveness of the algorithm. Applications to higher–order finite elements and inverse problems are included.

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Interaction of Elastic Waves with a Discontinuity

Simple model problems are considered to describe main features of the interaction of an elastic wave with a "contact dislocation". The later may be either a fracture within a solid body or a contact surface separating two bodies. It may also be a representative of an interlayer between monolithic rocks, such as an infiltrated porous layer, provided the interlayer thickness essentially exceeding the elastic wave length. Properties of dislocations which are relevant to the elastic wave propagation may be effectively reflected by means of few parameters. They are shown to affect reflection and penetration coefficients and phase shifts of both longitudinal and transverse waves to a considerable extent, what gives a good opportunity to judge about the properties by properly interpreting experiments on the elastic response. The influence of the contact surfase roughness as well as of elastic properties of the touching bodies and of an externally applied load is discussed at some length.

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CP 14

Gravitational Field Determination by Satellite Gradiometry

Satellite Gradiometry is a space experiment for the determination of the earth's gravitational field at a height of about 200 km - 500 km. Besides the problem of the so-called downward continuation of the potential one has to cope with the fact that the spaceborne measurements are linear combinations of second order partial derivatives. The talk presents existence and uniqueness results of the described problem and a numerical solution method based on tensor valued spherical splines.

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New Methods for Earth's Gravitational Potential Determination from Space Born Data

In modern satellite geodesy one is provided with millions of measurements of different types at satellite altitudes. So the resulting inverse problem of the determination of the gravitational potential in the neighbourhood of the earth's surface from given input at satellite orbits has to be done numerically in an efficient way. For that purpose one is interested in powerful algorithms which are able to process these large datasets. In this lecture we want to present some methods which combine classical ideas of regularization with modern approximation technique like spherical spline interpolation and spherical wavelet analysis.

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The Direct Methods of Solving the Inverse Problems of Gravimetry

Well known methods that allow to determine s
parameters of geological model without n y
prediction about the form and distrib
density. Integrals are solved fr
functions, which are not abl
have to be calculated th
The integral correla
the anomaly grav
masses. The inal
limits. I effect of an
anomaly gr luded. This gives
the opport ne depth of the
center of b nod have been tested and
gives good r the interpretation of the
practical inv gations.

CANCELLED

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Absolute Ballistic Gravimeter Internal Inverse Problem Multimodel Solution

There are two kinds of inverse problems associated with ballistic gravimeters. External one, known also as inverse problem of gravimetry, deals with determination of underground mass distribution using gravity values affected by the masses. The internal problem is connected with obtaining of every single gravity value. It arises due to the fact that measured coordinates of ballistic gravimeterts falling body accelerated by gravity in question must be converted to the gravity value itself. The better internal problem is solved, the more accurate and precise is measured gravity value, and consequently the higher are chances for successful solution of external inverse problem. Internal problem solution implies accounting for a wide range of effects which both randomly and systematically deteriorate the measured coordinates of falling body. There are different ways of such accounting entailing different mathematical models of ballistic gravimeter. It is possible to combine all the components: that leads to a thorough but rather bulky and unresolvable model, while separate modeling of each component may cause improper estimating of their cumulative effects and lead to missing of understanding of the gravimeter as unite system. The way we chose is to group certain components. Each group is adequately depicted by its own sub-model, while the latters constitute the self-consistent aggregate model of ballistic gravimeter. The sub-models we used are of two kinds. First, the classical model depicting the measured acceleration as function of measured falling bodyts coordinates is combined with the new one, depicting measured acceleration directly trough the acceleration of falling body. Second, the model linear in parameters was combined with non-linear one. The approach to the solution of internal inverse problem helped to mitigate successfully by software methods those effects which previously could be mitigated only by hardware. That enabled the creation of ballistic gravimeters of low weight and relatively simple construction with the characteristics approaching to those of best modern devices. One of such gravimeters was build by prof. Z.Zabek in Warsaw Polytechnical University and is now being used for investigating of geodynamics in Poland.

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CP 15

Development of Three-Dimensional Finite Element Models for Elastic Waves in Geologic Structures

For the Golden Gate three-dimensional finite element models have been constructed for the geology in a rectangular parallelepiped below the bridge. The normal cubic elements are distorted to model the azimuthal course and dip of the geologic structure.

Velocities are assigned to each formation and transfer functions are calculated for the entire model using soil-structure interaction computer programs. Realistic time histories for strong ground shaking are obtained by synthesizing the input motions from the five principal elastic wave types.

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Time-Pulse Propagation and Inverse Problem Solution for Layered Medium

The one-dimensional nonstationary boundary-value problem (layered medium) of a wave incidence on a layer of inhomogeneous medium is considered. Combining the imbedding method and singularity method the relations between wave amplitude on the pulse front and medium refractive coefficient is determined. These relations allow to solve the following inverse problems:
1. The space structure reconstruction for refractive coefficient provided time dependence for a wave reflected from a layer is given.
2. The structure reconstruction for refractive coefficient inside a some space provided time dependence for a field in a fixed point is given.
This procedure allows to find an analytical solution in some cases, e.g. for wave fields exponentially depending upon time in a media.

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Inverse Problem for Buried in Nonisotropic Medium Moving Oscillating Source

There is considered an inverse problem of determining the spatial position of this continuously oscillating source moving within a medium. Wawe field is recorded by stationary receivers having arranged on some surface observations. For determining the vector of unknowns $R(t,x,y,z)$ the system of N unknowns is solved under assumption that we have equally accurate and uncorrelated data. Algorithms of iteration system solution are elaborated at given initial approximation. Numerical modelling the bearing problems of continuously oscillating source has been carried out for the case of nonisotropic medium.

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Application of the Results of Analytical Function Approximation by Means of Rational Function with Prescribed Poleses and Quasi-Analytical Continuation to Decision Inverse Problem of Potential Two-Dimension Fields

Analytic Functions and the Approximation Theory by Rational Functions are widely used for investigation of two-dimensional potential fields. We apply our generalisation of Walsh's results on approximation by rational functions with preassigned poles to to Inverse Problems. Necessary and sufficient conditions on functions approximable in different metrics on domain's Boundaries are connected with the problems of quasy-analytic continuation. Such generalised continuations may be the corresponding models to inhomogeneous properties of boundary layers of Earth surface (with important practical applications in down-ward continuation).

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Regularizing an Inverse Seismic Problem for Oil Prospection

The inverse problem that estimates velocities in a 2-D wave equation to fit noisy seismic data, produces a nonconvex, ill-conditioned, expensive and extremely large global optimization problem. To get rid of the multiple spurious solutions we use the MBTT formulation, which transforms the problem to work in time rather than in the space domain. We address here the stabilization problem in the presence of noisy data. We will show that the above described problem can be efficiently solved by using multiscale grids to aproximate the optimal global solution. Also the regularization properties of a new version of a truncated Newton-CG method will be tested. Numerical experiments will be presented.

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CP 16

Dertemination of the Surface Temperature from Interior Observations

In many areas of heat transfer it is frequently necessary to determine the surface temperature and surface heat flux from histories measured at an accessible interior location. These so-called inverse heat conduction problems (IHCPs) have been extensively studied over the last 30 years. The linear IHCPs lead us mainly to consider the following problem: Find $a(x,t)u_x(x,t)|_{x=1}$ from the following noncharacteristic Cauchy problem for linear parabolic equations

$$u_t(x,t) = (a(x,t)u_x)_x + b(x,t)u_x + c(x,t)u + f(x,t) \quad (0.1)$$
$$0 < x < 1, \quad 0 < t \le T,$$
$$u(0,t) = \varphi(t), \quad 0 < t \le T, \quad (0.2)$$
$$-a(0,t)u_x(0,t) = g(t), \quad 0 < t \le T, \quad (0.3)$$

where a, b, $c \in L_\infty((0,1)\times(0,T))$, $a \ge \mu > 0$, $f \in L_2(Q_T)$, $Q_T := (0,1)\times(0,T)$. The problem (1)-(3) is is well known to be severely ill-posed. A solvability criterion for this problem is established and a new variational method for it is proposed. The conjugate gradient method based on Nemirovskii's stoping rule and a sequential procedure is suggested. The numerical results of our method are very satisfactory. Several generalizations to multi-dimensional problems and related problems are discussed.

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A Numerical Algorithm for Parameter Estimations

In this presentation, we will discuss a numerical algorithm for estimating unknown paramters in diffusion equations. The method is based on the first order pertubations. The senstivity coefficients are obtained efficiently without using either the adjoint equations or repeated simulation runs. Applications of this method to the estimation of conductivity coefficient in the heat equation and the permeability distribution in a porous media flow model will also be disccussed.

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Determining Heat Sources in Rock Dumps

The rate of generation of pollutants in rock dumps may be estimated by solving the inverse problem to determine the strength and location of pockets of oxidisation. A one-dimensional model is solved with regularisation. In this situation temperature data recorded in the dumps is very sparse, and the boundary conditions at the top and bottom of the dumps were not clearly identified. The inverse solution is compared to oxygen depletion readings taken in the dump.

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Inverse Approximation of a Hydrodynamic Flooding Problem

Currently, little attention has been paid towards developing approximation of the source of flooding, given flood depth versus time data. In this paper, the inverse problem is approximated by use of the United States Geological Survey Diffusion Hydrodynamic Model (DHM), as originally developed by this author in 1986. The DHM is extended to solve the inverse problem, i.e., the source of flooding, given flow hydrographs at specified locations in the flood plain. This approach may be important to flood plain managers who deal with issues regarding flood protection, and who work with flood mitigation measures.

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Inverse Problem of Heat Transfer in Geological Surrounding

One of the inverse problems of heat-transfer is founding parameters of surrounding if we know temperature-coordinate dependence in it. Such distribution may be obtained in experiment or by numerical solving nonlinear nonstationary differential heat-transfer equation for set means of diffusivity of heat. In inverse heat problems, such as in inverse diffusion problems for research temperatures dependence of diffusivity of heat a(T) may be used Matano method (grafical of numerical).

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CP 17

A Patchwork Approach to Inverse Problems

In many problems of Ocean geophysics, a three dimensional phenomenon is reconstructed from boundary measurements seated locally, close to the phenomenon. Yet, the basin extends far away, and a global analysis justifying uniqueness theorems should involve far away information. In the present lecture, it is shown when and how the coupling of subdomains can be treated to justify the local analysis.

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Globally Convergent Layer Stripping Method in Diffusion Tomography and Inverse Acoustics

We present an essentially novel approach to multi-dimensional Inverse Scattering Problems (ISP) arising in Diffusion Tomography and Inverse Acoustics. Applications: (i) ground penetrating radars, (ii) acoustical imaging, and (iii) early non-ionising breast cancer diagnosis. Sources of radiation are (i) electropragmatic, (ii) acoustical, and (iii) lasers respectively.

Our approach is based on the so-called Carleman's Weight Method, which provides a stable layer stripping procedure with guaranteed global convergence, c. f. SIAM J. Math. Anal, 26 (1995), 147-174.

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Multipath Identification And Truncated Total Least Squares Solution for Ocean Acoustic Tomography

Ocean acoustic tomography is a technique where travel time measurements in the ocean are used to infer ocean properties such as temperature and current velocity. Large-scale fluctuations of temperature in the ocean affect the weather, climate, ocean circulation and the distribution of marine organisms. Therefore, solving this problem by using modern computing methods is an important research project. Mathematically, the ocean acoustic tomography leads to a nonlinear ill-posed integral equation. To solve it, An adjoint algorithm for multiraypath identification and a truncated total least squares algorithm for solving linearized travel time equation are given, regularization effect on TLS algorithm and numerical simulation is discussed.

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The Inverse Problem of a Fourth Order Self-Adjoint Binomial Operator

Consider the binomial operator $L = (d/dx)^4 + q(x)$, acting on $(,\pi)$, with Dirichlet boundary conditions. We examine the associated inverse spectral problem under the assumptions that q is symmetric, i.e. $q(\pi - x) = q(x)$. Our approach is inspired by the well-known work of G. Borg for the Sturm-Liouville case. The main achievement of the present work is the derivation of the eigenfunction asymptotics. At the end we examine briefly how to recover $q(x)$ from the spectrum, by adapting the Rayleigh-Ritz method of O. Hald.

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CP 18

Applying Neural Networks to Groundwater Inverse Problems

Groundwater inverse problems are solved using a new application of artificial neural networks. A system of neural networks interacts with a groundwater simulator and self-adapts as new data are received. Fields are estimated using both quantitative and qualitative information measured from pumping tests and descriptive well logs. We apply the method to identifying a discrete hydraulic conductivity field given hard and soft data from 195 *in situ* tests (*i.e.* slug tests and pumping tests) and 89 borings.

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A Multi-resolution Approach to Hydraulic Conductivity Estimation

Heterogeneities of hydraulic conductivity across multiple spatial scales can significantly affect the flow of groundwater and petroleum, yet the sparsity of subsurface observations does not allow accurate reconstruction at all such scales. Instead, a common approach is to estimate an effective parameter which predicts large scale variations in flow. We build a new framework upon *Maximum a Posteriori* inversions to directly address the problems of scale. This framework consists of (1) a prior model for conductivity which is an auto-regressive (AR) process evolving from coarse to fine scale, and (2) a measurement model in which each observation is well-approximated by a linear functional of the AR process at some scale. This framework efficiently incorporates multiple measurement sources and produces a conductivity estimate with spatially varying resolution tailored to the measurement sampling geometry.

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A Hybrid Numerical Method for High Contrast Conductivity Problems

Natural porous media exhibit strong spatial variability in most of their properties, such as electrical conductivity, dielectric permeability, etc, even on mesoscopic length scales where some averaging has been incorporated into the modelling. Strong variability or high contrast in material parameters presents difficulties in numerical computations because they require fine meshes and are poorly conditioned. We introduce and test extensively a numerical method for computing efficiently the flow fields in media with high contrast conductivity. This method combines our analytical understanding of the form of the flow field near narrow channels with standard numerical methods elsewhere in the flow regime and so it is a hybrid numerical method.

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ADDENDUM CP4A
SATURDAY PM

Uncertainty in Velocity Estimation

The most common procedure for estimating seismic velocity from travel times, and assigning uncertainties to the estimate, is to fit a parametric model by least-squares collocation, and report the formal uncertainty in the least-squares estimate. Simple functional analysis and computational examples illustrate that this procedure is biased, and can grossly underestimate the uncertainty. Two alternatives are more promising for making valid inferences in seismology: minimax estimation, and ''strict bounds.'' Both approaches require prior physical constraints on the unknown velocity model, and both involve solving infinite-dimensional constrained optimization problems, whose optimal values can be bounded above and below by finite-dimensional problems. I will present computational examples of estimating a one-dimensional model of velocity in Earth's outer core using ''strict bounds'' with a thermodynamic constraint on the radial velocity gradient, and of estimating the minimax uncertainty in the shape of Earth's core-mantle boundary subject to a smoothness constraint.

Phillip Stark
University of California at Berkeley
Berkeley, CA 94720-3860

Optimization Approaches to Velocity Estimation

Determination of distribution of seismic wave velocitites in the subsurface is one of most challenging problems in the processing, analysis and interpretation of seismic data. We investigated the effects of several combinations of the following factors to determine 1-D and 2-D velocity structure from seismic data. (1) Optimization Methods (Global, Local or a combination of the two), (2) Cost functions, (3) Data Space or Image space (common shot, common offset, common ray-parameter),(4) Successive relaxation in the data domain, and (5) Velocity model representation. We will show several examples of analysis of real and syntheic data for 1D and 2D velocity structures. Although the basic algorithm remains the same, its implementation in 3D remains a computationally challenging task.

Mrinal K. Sen (SPEAKER), P. L. Stoffa, C. Varela, and R. Chunduru
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Uniformly Smooth Objective Functions for Velocity Estimation

The error between predicted and observed reflection seismograms is a highly nonlinear function of trial velocity, and becomes more oscillatory with increasing source frequency content. This circumstance creates well known obstacles to efficient velocity estimation through reduction of fit error. Replacement of the fit error by alternative objective functions having less sensitivity to frequency might circumvent these obstacles. Such alternative objective functions exist, but are highly constrained: they are determined by certain pseudodifferential operators whose symbols are functions of trial velocity. I will describe high frequency asymptotic ("Kirchhoff") computations of these objective functions and their gradients, illustrate their behaviour using synthetic and field data examples, and discuss the degree to which velocity is resolved by extremizing these functions.

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Linearized Asymptotic Inversion in Caustic Backgrounds

The well known techniques of high frequency asymptotics represent the forward scattering operator as a Fourier Integral Operator. Provided there are no multiple ray paths between any two points in the medium, the composition of the forward operator with its adjoint is a pseudo-differential operator, and the calculus of such operators leads to a Fourier Integral expression for a generalized inverse scattering operator. However, in practical geophysical situations the condition that no multiple ray paths exist is often violated and the ray system will develop caustics. In this case the standard analysis of the generalized inverse operator breaks down. The construction and analysis of the generalized inverse in arbitrarily smoothly varying media is the main subject of this talk. We show that the inversion technique mentioned above can be extended under certain conditions to allow for caustics. We give an explicit formula for the inversion operator. When caustics are absent this formula reduces to the expression derived by Beylkin.

Dirk Smit (SPEAKER), A. P. E. ten Kroode, and A. R. Verdel, Shell Research KSEPL
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The Netherlands

ADDED TO SESSION CP6 (replacing Gordon Wade)

"Nonsmooth" Regularization

Classical linear regularization, or filtering, techniques are often inappropriate for applications in which the solution is not smooth. We will review theoretical and computational aspects of some recently developed alternative methods from the field of image processing, which allow the recovery of nonsmooth images. In particular, we will discuss the utility of these new methods for geophysical inverse problems.

Curt Vogel
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ADDITION TO SESSION CP3

A Fast New Method to Solve Inverse Scattering Problems

In this talk we will present a new method for solving inverse obstacle scattering problems where the far field for many incident plane waves is known. The main idea of the method is to approximate point sources by a superposition of incident plane waves and to use a characterization of the obstacle in terms of the location of these point sources. We will describe the method and provide numerical examples.

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U.S.A.

Announcing...

Conference on Inverse Problems of Wave Propagation and Diffraction

September 23-27, 1996
Aix les Bains, France

PRESENTATION

This conference will be the fourth of a series devoted to different fields of inverse problems. The general theme is "Inverse Problems of Wave Propagation and Diffraction" (especially acoustic and elastic waves, electromagnetic waves, quantum waves).

OBJECTIVES

The theme "Modeling, Mathematical Analysis, and Numerical Solution of Inverse Problems of Wave Propagation and Diffraction" follows the overall theme of the series of conferences, focused on validating inverse problems. This conference, partly inspired by applied mathematics and partly by mathematical physics, has a large variety of fields of application, giving it a strong multidisciplinary character. The conference will put emphasis on the three fundamental steps of inverse modeling: modeling of inverse problems of a certain field, mathematical analysis of these problems, and numerical solving.

CONFERENCE CHAIRS

G. Chavent

Universite Paris-Dauphine/INRIA Rocquencourt, France

P. C. Sabatier

Université de Montpellier II, France

INSTRUCTIONS toAUTHORS

Authors should send an abstract and a full paper, or, as a minimum, a one page abstract, in three copies, before March 1, 1996. The accepted papers will be distributed to the participants.

Send contributions to: INRIA Rocquencourt, M.-C. SANCE, Relations exterieures, Bureau des cours et colloques, B.P. 105, 78153 LE CHESNAY Cedex (France).

DATES to REMEMBER

March 1, 1996: deadline for contributions to be received by INRIA

April 15, 1996: author notification of acceptance or rejection

June 15, 1996: preliminary program mails

Conducted by INRIA with the cooperation of SIAM.

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Inverse Problems in Diffusion Processes

Proceedings of the GAMM–SIAM Symposium

Heinz W. Engl and William Rundell

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This collection of expository papers encompasses both the theoretical and physical application side of inverse problems in diffusion processes. This topic is of interest to mathematical scientists and engineers engaged in areas such as heat transfer, flow in porous media, and other diffusion processes where parametric estimation is a critical factor.

The list of important applications of inverse problems spans the entire range of applied science. Many of them, such as medical imaging and geophysical prospecting, are known well beyond the scientific community. This volume is the first in a series that designed to encompass some of this range. It is devoted to inverse problems that arise in diffusion processes, such as groundwater flow, heat conduction, and nondestructive evaluation, and includes a variety of applications and techniques.

The papers presented in this volume are based on some of the invited talks given at the GAMM-SIAM Conference on Inverse Problems in Diffusion Processes.

Contents

Audience

Mathematicians interested in inverse problems or related fields, theoretical engineers working in diffusion, and computational scientists interested in problems at the interface of modern mathematics and industrial applications will find this proceedings of great interest.

About the Authors

Heinz Engl is Professor of Industrial Mathematics and Head of Christian Doppler Laboratory for Mathematical Modelling and Numerical Simulation at the Johannes Kepler Universitat, Linz, Austria. Professor Engl is also president of ECMI. *William Rundell* is Professor of Mathematics and of Computer Science as well as Head of the Department of Mathematics at Texas A&M University.