

Effective Groundwater Model Calibration

With Analysis of Data, Sensitivities,
Predictions, and Uncertainty



Mary C. Hill
Claire R. Tiedeman

Effective Groundwater Model Calibration With Analysis Of Data Sensitivities Predictions And Uncertainty

Jens Christian Refsgaard



Effective Groundwater Model Calibration With Analysis Of Data Sensitivities Predictions And Uncertainty:

Effective Groundwater Model Calibration Mary C. Hill, Claire R. Tiedeman, 2007-03-07 Methods and guidelines for developing and using mathematical models Turn to Effective Groundwater Model Calibration for a set of methods and guidelines that can help produce more accurate and transparent mathematical models The models can represent groundwater flow and transport and other natural and engineered systems Use this book and its extensive exercises to learn methods to fully exploit the data on hand maximize the model s potential and troubleshoot any problems that arise Use the methods to perform Sensitivity analysis to evaluate the information content of data Data assessment to identify a existing measurements that dominate model development and predictions and b potential measurements likely to improve the reliability of predictions Calibration to develop models that are consistent with the data in an optimal manner Uncertainty evaluation to quantify and communicate errors in simulated results that are often used to make important societal decisions Most of the methods are based on linear and nonlinear regression theory Fourteen guidelines show the reader how to use the methods advantageously in practical situations Exercises focus on a groundwater flow system and management problem enabling readers to apply all the methods presented in the text The exercises can be completed using the material provided in the book or as hands on computer exercises using instructions and files available on the text s accompanying Web site Throughout the book the authors stress the need for valid statistical concepts and easily understood presentation methods required to achieve well tested transparent models Most of the examples and all of the exercises focus on simulating groundwater systems other examples come from surface water hydrology and geophysics The methods and guidelines in the text are broadly applicable and can be used by students researchers and engineers to simulate many kinds systems

EFFECTIVE GROUNDWATER MODEL CALIBRATION: WITH ANALYSIS OF DATA, SENSITIVITIES, PREDICTIONS, AND UNCERTAINTY. Mary Catherine Hill, Aquifer Characterization Techniques Robert G. Maliva, 2016-05-26 This book presents an overview of techniques that are available to characterize sedimentary aquifers Groundwater flow and solute transport are strongly affected by aquifer heterogeneity Improved aquifer characterization can allow for a better conceptual understanding of aquifer systems which can lead to more accurate groundwater models and successful water management solutions such as contaminant remediation and managed aquifer recharge systems This book has an applied perspective in that it considers the practicality of techniques for actual groundwater management and development projects in terms of costs technical resources and expertise required and investigation time A discussion of the geological causes types and scales of aquifer heterogeneity is first provided Aquifer characterization methods are then discussed followed by chapters on data upscaling groundwater modelling and geostatistics This book is a must for every practitioner graduate student or researcher dealing with aquifer characterization Hydrogeology Alain Dassargues, 2018-09-03 This text combines the science and engineering of hydrogeology in an accessible innovative style As well as providing physical descriptions and characterisations

of hydrogeological processes it also sets out the corresponding mathematical equations for groundwater flow and solute heat transport calculations And within this the methodological and conceptual aspects for flow and contaminant transport modelling are discussed in detail This comprehensive analysis forms the ideal textbook for graduate and undergraduate students interested in groundwater resources and engineering and indeed its analyses can apply to researchers and professionals involved in the area

Uncertainties in Environmental Modelling and Consequences for Policy Making Philippe Baveye, Jaroslav Mysiak, Magdeline Laba, 2009-05-14 Mathematical modelling has become in recent years an essential tool for the prediction of environmental change and for the development of sustainable policies Yet many of the uncertainties associated with modelling efforts appear poorly understood by many especially by policy makers This book attempts for the first time to cover the full range of issues related to model uncertainties from the subjectivity of setting up a conceptual model of a given system all the way to communicating the nature of model uncertainties to non scientists and accounting for model uncertainties in policy decisions Theoretical chapters providing background information on specific steps in the modelling process and in the adoption of models by end users are complemented by illustrative case studies dealing with soils and global climate change All the chapters are authored by recognized experts in their respective disciplines and provide a timely and uniquely comprehensive coverage of an important field

New Perspectives on Optimization Algorithms Research Germano Lambert-Torres, Gilberto Capistrano Cunha de Andrade, Carlos Henrique Valério De Moraes, 2025-07-16 Optimization processes are present in nearly all human activities aiming to reduce time and expenses conserve resources and maximize efficiency Classical numerical optimization methods were initially employed in more complex or elaborate problems This class of methods was convenient to use when equations could correctly and completely formulate all the attributes of the problem to be optimized and whose search space for the solution had convexity characteristics and was not multimodal Expressing a problem completely through equations is often a difficult if not impossible task because linguistic values or employing quantities that are not easily dealt with by classical optimization methods can only describe certain limitations and barriers Irregular and non convex search spaces also present problems for classical methods especially those with multiple local minima and maxima as they can lead to suboptimal solutions In this context researchers in optimization have presented new techniques to overcome these barriers introducing new concepts and methods that enable working with problems that are not well defined and in multimodal search spaces Many of these techniques utilize artificial intelligence methods and it is possible to optimize problems where their limitations are not clearly defined or where their search spaces contain different local maxima and minima This book is a contribution in this sense In it the reader will find two sections The first titled Methodologies presents the frontier of state of the art optimization techniques and their applications to various problems The second section titled Applications presents examples of practical applications of modern techniques in optimizing issues which can be easily adapted to others with similar characteristics

Thus the reader can use this book to optimize their problems by applying the solutions presented in the chapters and adapting them to their specific issues

Field Sampling Methods for Remedial Investigations Mark Edward Byrnes, 2022-09-28 Originally published in 1994 the first edition of *Field Sampling Methods for Remedial Investigations* soon became a premier resource in this field The Princeton Groundwater course designated it as one of the top books on the market that addresses strategies for groundwater characterization groundwater well installation well completion and groundwater sampling This long awaited third edition provides most current and most cost effective environmental media characterization methods and approaches supporting all aspects of remediation activities This book integrates recommendations from over one hundred of the most current US EPA State EPA US Geological Survey US Army Corps of Engineers and National Laboratory environmental guidance and or technical documents This book provides guidance examples and or case studies for the following subjects Implementing the EPA s latest Data Quality Objectives process Developing cost effective statistical non statistical sampling designs supporting all aspects of environmental remediation activities and available statistical sample design software Aerial photography surface geophysics airborne surface downhole building radiological surveys soil gas surveying environmental media sampling DNAPL screening portable X ray fluorescence measurements Direct push groundwater sampling well installation well development well purging no purge low flow standard groundwater sampling depth discrete ground sampling groundwater modeling Tracer testing slug testing waste container and building material sampling pipe surveying defining background conditions Documentation quality control sampling data verification validation data quality assessment decontamination health safety management of investigation waste A recognized expert on this subject author Mark Byrnes provides standard operating procedures and guidance on the proper implementation of these methods focusing on proven technologies that are acknowledged by EPA and State regulatory agencies as reputable techniques

Frontiers in PDE-Constrained Optimization Harbir Antil, Drew P. Kouri, Martin-D. Lacasse, Denis Ridzal, 2018-10-12 This volume provides a broad and uniform introduction of PDE constrained optimization as well as to document a number of interesting and challenging applications Many science and engineering applications necessitate the solution of optimization problems constrained by physical laws that are described by systems of partial differential equations PDEs As a result PDE constrained optimization problems arise in a variety of disciplines including geophysics earth and climate science material science chemical and mechanical engineering medical imaging and physics This volume is divided into two parts The first part provides a comprehensive treatment of PDE constrained optimization including discussions of problems constrained by PDEs with uncertain inputs and problems constrained by variational inequalities Special emphasis is placed on algorithm development and numerical computation In addition a comprehensive treatment of inverse problems arising in the oil and gas industry is provided The second part of this volume focuses on the application of PDE constrained optimization including problems in optimal control optimal design and inverse

problems among other topics *Calibration and Reliability in Groundwater Modelling* Jens Christian Refsgaard, 2008

Applied Hydrogeology C. W. Fetter, David Kreamer, 2021-12-28 There is a continued demand for well trained and competent hydrogeologists especially in the environmental sector For decades Fetter's Applied Hydrogeology has helped prepare students to excel in careers in hydrogeology or other areas of environmental science and engineering where a strong background in hydrogeology is needed The text's long standing tradition as a vital resource is further enhanced in the fifth edition by Kreamer's added expertise Stressing the application of mathematics to problem solving example problems throughout the book provide students the opportunity to gain a much deeper understanding of the material Some important topics include the properties of aquifers the principles of groundwater flow water chemistry water quality and contamination and groundwater development and management The addition of new case studies and end of chapter problems will strengthen understanding of the occurrence and movement of ground water in a variety of geological settings **Saline**

Groundwater - Surface Water Interaction in Coastal Lowlands J.R. Delsman, 2015-05-07 Coastal zones are among the world's most densely populated and economically important areas but these factors put pressure on the often limited available freshwater resources Global change will undoubtedly increase this pressure through the combined effects of increased population economic development rising sea levels increased evapotranspiration over extraction and the salinization of coastal aquifers decreasing river discharges and accelerating land subsidence Saline groundwater exfiltration is a common problem in the coastal zone of the Netherlands but the hydrological processes and physiographic factors that affect this are not fully understood The research presented in this book aims to identify the processes and physiographic factors controlling the spatial variability and temporal dynamics of the exfiltration of saline groundwater to surface water and hence the contribution of saline groundwater to surface water salinity Topics covered include a paleo hydrogeological model simulation of the Holocene evolution of groundwater salinity as a result of paleo geographic changes surface water salinity dynamics in a densely drained lowland catchment hydrograph separation in an agricultural catchment observations of heads flow solute concentration and temperature to constrain a detailed variable density groundwater flow and transport model and a model to simulate the salinity dynamics of exfiltrating groundwater to support operational water management of freshwater resources in coastal lowlands The book further outlines the implications of these findings for freshwater management in the Netherlands The book demonstrates that the salinity of groundwater exfiltrating in polders in the Netherlands and hence surface water salinity varies on a wide range of spatial and temporal scales **Application of the**

LSQR Algorithm to the Calibration of a Regional Groundwater Flow Model Christopher T. Muffels, 2008

Subsurface Hydrology David W. Hyndman, 2007-01-09 Published by the American Geophysical Union as part of the Geophysical Monograph Series Volume 171 Groundwater is a critical resource and the Principal source of drinking water for over 1.5 billion people In 2001 the National Research Council cited as a grand challenge our need to understand the

processes that control water movement in the subsurface This volume faces that challenge in terms of data integration between complex multi scale hydrologic processes and their links to other physical chemical and biological processes at multiple scales Subsurface Hydrology Data Integration for Properties and Processes presents the current state of the science in four aspects Approaches to hydrologic data integration Data integration for characterization of hydrologic properties Data integration for understanding hydrologic processes Meta analysis of current interpretations Scientists and researchers in the field the laboratory and the classroom will find this work an important resource in advancing our understanding of subsurface water movement

The Software Encyclopedia ,1986 *Microbially Induced Calcite Precipitation for in Situ Radionuclide Remediation and Soil Stabilization* Tammer Hisham Barkouki,2009 Book Review Index - 2009 Cumulation Dana Ferguson,2009-08 Book Review Index provides quick access to reviews of books periodicals books on tape and electronic media representing a wide range of popular academic and professional interests The up to date coverage wide scope and inclusion of citations for both newly published and older materials make Book Review Index an exceptionally useful reference tool More than 600 publications are indexed including journals and national general interest publications and newspapers Book Review Index is available in a three issue subscription covering the current year or as an annual cumulation covering the past year

The British National Bibliography Arthur James Wells,2007 **Proceedings of the ECMWF Workshop on Representing Model Uncertainty and Error in Numerical Weather and Climate Prediction Models** ,2011 The Use of Regularized Inversion in Groundwater Model Calibration and Prediction Uncertainty Analysis Catherine Rylance Moore,2005 **Assessment of Parametric and Model Uncertainty in Groundwater Modeling** Dan Lu,2012

ABSTRACT Groundwater systems are open and complex rendering them prone to multiple conceptual interpretations and mathematical descriptions When multiple models are acceptable based on available knowledge and data model uncertainty arises One way to assess the model uncertainty is postulating several alternative hydrologic models for a site and using model selection criteria to 1 rank these models 2 eliminate some of them and or 3 weight and average predictions statistics generated by multiple models based on their model probabilities This multimodel analysis has led to some debate among hydrogeologists about the merits and demerits of common model selection criteria such as AIC AICc BIC and KIC This dissertation contributes to the discussion by comparing the abilities of the two common Bayesian criteria BIC and KIC theoretically and numerically The comparison results indicate that using MCMC results as a reference KIC yields more accurate approximations of model probability than does BIC Although KIC reduces asymptotically to BIC KIC provides consistently more reliable indications of model quality for a range of sample sizes In the multimodel analysis the model averaging predictive uncertainty is a weighted average of predictive uncertainties of individual models So it is important to properly quantify individual model s predictive uncertainty Confidence intervals based on regression theories and credible intervals based on Bayesian theories are conceptually different ways to quantify predictive uncertainties and both are widely

used in groundwater modeling This dissertation explores their differences and similarities theoretically and numerically The comparison results indicate that given Gaussian distributed observation errors for linear or linearized nonlinear models linear confidence and credible intervals are numerically identical when consistent prior parameter information is used For nonlinear models nonlinear confidence and credible intervals can be numerically identical if parameter confidence and credible regions based on approximate likelihood method are used and intrinsic model nonlinearity is small but they differ in practice due to numerical difficulties in calculating both confidence and credible intervals Model error is a more vital issue than differences between confidence and credible intervals for individual models suggesting the importance of considering alternative models Model calibration results are the basis for the model selection criteria to discriminate between models However how to incorporate calibration data errors into the calibration process is an unsettled problem It has been seen that due to the improper use of the error probability structure in the calibration the model selection criteria lead to an unrealistic situation in which one model receives overwhelmingly high averaging weight even 100% which cannot be justified by available data and knowledge This dissertation finds that the errors reflected in the calibration should include two parts measurement errors and model errors To consider the probability structure of the total errors I propose an iterative calibration method with two stages of parameter estimation The multimodel analysis based on the estimation results leads to more reasonable averaging weights and better averaging predictive performance compared to those with considering only measurement errors Traditionally data worth analyses have relied on a single conceptual mathematical model with prescribed parameters Yet this renders model predictions prone to statistical bias and underestimation of uncertainty and thus affects the groundwater management decision This dissertation proposes a multimodel approach to optimum data worth analyses that is based on model averaging within a Bayesian framework The developed multimodel Bayesian approach to data worth analysis works well in a real geostatistical problem In particular the selection of target for additional data collection based on the approach is validated against actual data collected The last part of the dissertation presents an efficient method of Bayesian uncertainty analysis While Bayesian analysis is vital to quantify predictive uncertainty in groundwater modeling its application has been hindered in multimodel uncertainty analysis because of computational cost of numerous models executions and the difficulty in sampling from the complicated posterior probability density functions of model parameters This dissertation develops a new method to improve computational efficiency of Bayesian uncertainty analysis using sparse grid method The developed sparse grid based method for Bayesian uncertainty analysis demonstrates its superior accuracy and efficiency to classic importance sampling and MCMC sampler when applied to a groundwater flow model

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