ICIAM 2019 SEMA SIMAI Springer Series 6

María Isabel Asensio
Albert Oliver
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# Applied Mathematics for Environmental Problems


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SEMA SIMAI Springer Series

# ICIAM 2019 SEMA SIMAI Springer Series

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# Preface

The profound study of nature is the most fertile source
of mathematical discoveries.
Joseph Fourier

This book contains four papers from the contributions presented at the Applied Mathematics for Environmental Problems minisymposium during the International Congress on Industrial and Applied Mathematics (ICIAM) held in July 15–19, 2019, in Valencia, Spain.

Climate change, air and water pollution, deforestation, and soil degradation are some of the world's biggest environmental problems that humanity needs to face. They are major challenges with large economic and social impacts that, if not addressed, will increase in the near future.

How can mathematics and numerical modelling help us wrestle with these environmental problems? Mathematics is the common language of science and engineering for developing models that help understand nature and life. Numerical modelling allows scientists and engineers solve these models using computers and helps them understand, quantify, predict, and manage the consequences of these problems and devise potential solutions.

The contributions presented during this minisymposium cover several environmental models and their numerical and computational treatment. These models are based on partial differential equations and solved using different numerical methods, combined with efficient computational techniques to provide useful forecasting tools in decision-making and warning.

The first two papers are devoted to modelling wildfire, one of the environmental problems that climate change is worsening. Wildfire spread models can be an efficient aid to combat this growing problem, not only in wildfire management, but also in risk mapping, reforestation policies, and the major issue of alerts and evacuation plans. One of the papers deals with a simplified physical wildfire spread model, based on partial differential equations solved with finite element methods and integrated into a Geographical Information System to provide a useful and

efficient tool. The other paper focuses on one of the causes of the unpredictable behavior of wildfire, fire-spotting, through a statistical approach.

The third paper addresses low-level wind shear (LLWS) that represents one of the most relevant hazards during aircraft takeoff and landing. Specifically, it presents an experimental wind shear alert system based on predicting wind velocities obtained from the Harmonie-Arome model.

The final paper deals with the environmental impact of oil reservoirs. It presents high-order hybridizable discontinuous Galerkin (HDG) formulation combined with high-order diagonally implicit Runge-Kutta schemes to solve one-phase and two-phase flow problems through porous media.

We warmly thank all the speakers and participants for their contributions and discussions during and after the minisymposium. In addition, we would like to thank the anonymous reviewers of the papers for helping us to improve the quality of this volume. Finally, we acknowledge SEMA SIMAI Springer Series for their interest in publishing these contributions. We hope that the papers included in this book will be of interest to the SEMA SIMAI Springer Series community and will contribute to the development of new mathematical tools for environmental problems.

Salamanca, Spain — María Isabel Asensio
Las Palmas de Gran Canaria, Spain — Albert Oliver
Barcelona, Spain — José Sarrate

# Contents

# About the Editors

**María Isabel Asensio** received her PhD in mathematics from the University of Salamanca, where she is associate professor in the Department of Applied Mathematics and principal investigator of the Numerical Simulations and Scientific Computation Research Group. Her main research interests concern mathematical modelling of environmental problems with emphasis on forest fire spread modelling. She has coauthored many articles in international journals and refereed contributions in international congresses.

**Albert Oliver** received his PhD from the Universitat Politècnica de Catalunya and is currently an assistant professor at the University of Las Palmas de Gran Canaria. His research interest is the application of the finite element method in environmental problems, and particularly in the simulation of air quality and wind fields at the microscale level; he also works on the generation of tetrahedral adapted meshes for these problems.

**José Sarrate** obtained his PhD in applied sciences from the Universitat Politècnica de Catalunya, Barcelona, where he is associate professor in the Department of Civil and Environmental Engineering in Barcelona. His research interest is the numerical modelling of problems governed by partial differential equations in applied sciences and engineering. He has worked in more than 20 research projects funded by public and private institutions that lead to several contributions in indexed journals and international conferences.

# PhyFire: An Online GIS-Integrated Wildfire Spread Simulation Tool Based on a Semiphysical Model


**M. I. Asensio, L. Ferragut, D. Álvarez, P. Laiz, J. M. Cascón, D. Prieto, and G. Pagnini**

**Abstract** The PhyFire simplified physical wildfire spread model developed by the research group on Numerical Simulation and Scientific Computation at the University of Salamanca has been integrated into an online GIS interface in order to facilitate its use, automate the data input process, thereby reducing error and improving efficiency, and upgrade the graphical display of simulation results. The main features of the PhyFire model are presented: model equations, numerical solution and GIS integration. A description is provided of new advances in the PhyFire model related to the addition of random phenomena, such as fire-spotting. A real wildfire simulation with fire-spotting is also presented.

## 1 Introduction

Environmental issues are a global priority, with wildfires being a classic example, as they are becoming more serious as climate and climate change strongly influence their activity [2, 16], making catastrophic forest fires more likely every year: California, the Amazon, Australia... the list is endless.

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