LAGRANGIAN ANALYSIS AND PREDICTION OF COASTAL AND OCEAN DYNAMICS

Written by a group of international experts in their field, this book is a review of Lagrangian observation, analysis and assimilation methods in physical and biological oceanography. In recent years a large number of floating and drifting research buoys have been deployed in the global oceans to study the state of the ocean and its variation in terms of water mass properties, circulation and heat transport. Lagrangian techniques are required to analyze the data from these buoys.

This multidisciplinary text contains observations, theory, numerical simulations, and analysis techniques. It presents new results on nonlinear analysis of Lagrangian dynamics, the prediction of particle trajectories, and Lagrangian stochastic models. It includes chapters on floats and drifters, Lagrangian-based analysis methods and models in marine biology, the statistics of particle trajectories in the ocean, numerical simulations and their relationship with classical turbulence results, and nonlinear Lagrangian-based theory for studying ocean transport and particle trajectories. The book contains historical information, up-to-date developments, and speculation on future developments in Lagrangian-based observations, analysis, and modeling of physical and biological systems.

Containing contributions from experimentalists, theoreticians, and modelers in the fields of physical oceanography, marine biology, mathematics, and meteorology this book will be of great interest to researchers and graduate students looking for both practical applications and information on the theory of transport and dispersion in physical systems, biological modeling, and data assimilation.

Cover illustration: The cover depicts the abrupt breakup of a large ocean eddy in the Gulf of Mexico. Eddy Fourchon was tracked by assimilating satellite data into the University of Colorado version of the Princeton Ocean Model (developed by L. H. Kantha). Lagrangian analysis by researchers at the University of Delaware (led by A. D. Kirwan, Jr.) and the City University of New York (A. C. Poje) produced the time sequence of marked particles in the middle of the Gulf between July 28 and August 17, 1998. On July 28, Fourchon appears to be a typical large elliptical ocean eddy. Over the next two and a half weeks, interactions with nearby mesoscale features split the core in half. The larger colored region is determined by computing the Lagrangian boundaries of the eddy on the initial day with red/yellow assigned to those particles within the eddy which eventually split to the north/south respectively. The contrasting inscribed circles show the stirring inherent in each sub-region during the evolution. Figure design by Patrick Fagan.

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Preface

This book has been motivated by the recent surge in the density and availability of Lagrangian measurements in the ocean, recent mathematical and methodological developments in the analysis of such data to improve forecasts and transport characteristics of ocean general circulation models, and numerous applications to dispersion of biological species. Another source of motivation has been the Lagrangian Analysis and Prediction of Coastal and Ocean Dynamics (LAPCOD) workshops (www.rsmas.miami.edu/LAPCOD/meetings.html).

The main purpose of this book is to conduct a review of Lagrangian observations, analysis and assimilation methods in physical and biological oceanography, and to present new methodologies on Lagrangian analysis and data assimilation, and new applications of Lagrangian stochastic models from biological dispersion studies. Some of the chapters included in this volume were presented at LAPCOD workshops, while others have been specifically written for this collection. Given the size of the Lagrangian field, the present work cannot be considered as an exhaustive effort, but one which is aimed to cover many of the central research topics. It was our intent to maintain a good balance between historical and state-of-the-art developments in Lagrangian-based observations, theory, numerical modeling and analysis techniques.

This book seems to be a first of its kind because the central theme is the Lagrangian viewpoint for studying the transport phenomena in oceanic flows. Another unique and timely aspect of this book is its multidisciplinary nature with contributions from experimentalists, theoreticians, and modelers from diverse fields such as physical oceanography, marine biology, mathematics, and meteorology.

The book starts with a historical perspective of the development and application of Lagrangian methods, while more recent measurements and results

are presented in Chapter 2. Some striking examples of Lagrangian trajectories are depicted by a collection of authors in Chapter 3. A number of new theoretical approaches to understand and describe particle motion are outlined in Chapters 4, 5, 6, and 9. New methods for assimilating Lagrangian data in ocean models to improve their forecast are described in Chapters 7 and 8. A suite of applications of Lagrangian techniques to transport of biological species are given in Chapters 10 to 12. Finally, we close with an extensive observational and theoretical review of Lagrangian techniques that were presented in the three LAPCOD workshops held in 2000, 2002, and 2005.

We would like to express special thanks to Dr. Manuel Fiedeiro from the US Office of Naval Research (ONR) for sponsoring much of the research presented in this book, while fostering collaboration between many groups of researchers and initiating LAPCOD workshops. We also thank Dr. Jerry Miller from ONR-London for supporting some of the LAPCOD workshops. Special thanks are also due to Edward Ryan, who has dedicated countless days to help organize this book. We also thank anonymous reviewers for many useful suggestions to help improve the chapters, and for maintaining a quality standard of scientific work. Finally, we thank all the scientists who have played important roles in the advancement of Lagrangian observations and analysis, but are not directly represented in this book.

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