PREFACE

Over the past decade there have been significant advances in our understanding of turbulence and the emergence of coherent structures in fluids, plasmas and nonlinear media. New theoretical, modeling and experimental and observational techniques have been developed for tackling the complex interactions of turbulence with coherent structures, mean flows and waves.

A workshop on Turbulence and Coherent Structures in Fluids, Plasmas and Nonlinear Media was held at the Australian National University, Canberra, 10 to 13 January 2006 and was sponsored by the Australian Research Council's Complex Open Systems Network and CSIRO Complex Systems Science. The aim of the workshop was to bring together researchers from the often-disparate disciplines of fluid mechanics, plasma physics, atmosphere and ocean dynamics and dynamical systems theory to codify recent developments in our understanding of the dynamics and statistical dynamics of turbulence and coherent structures. The workshop covered topics ranging from instability theory, to bifurcation and singularity theory, and stochastic modeling, through chaos and predictability theory, turbulence, coherent structures, multiple equilibria and hysteresis, to subgrid-scale processes and statistical dynamics and renormalization. It is expected that many of the methodologies presented may also be applicable to other Complex Systems.

Presentations were given on the theoretical, numerical modeling, observational and experimental studies of turbulence and coherent structures in quasi-two-dimensional geophysical flows, such as oceans and atmospheres, and in plasmas and in three-dimensional flows, such as the turbulent boundary layer. The works presented form the basis of this volume in the World Scientific Lecture Notes in Complex Systems entitled Frontiers in Turbulence and Coherent Structures.

The first two chapters consider the topics of dynamical systems and instability theory. The chapter by Ball and Holmes details the historical development of dynamical systems theory, stability and chaos as well as interesting applications to a wide range of phenomena. The following chapter by Frederiksen focuses on atmospheric applications of instability theory, predictability and chaos. These papers were presented at the Summer School

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on *Turbulence and Coherent Structures in Fluids, Plasmas and Nonlinear Media* held at the Australian National University, Canberra immediately following the workshop. They are included here to provide a pedagogical basis for many of the subsequent papers that rely heavily upon an understanding of dynamical systems and instability theory.

For the remainder of the volume the papers are grouped into four general themes that emerged during the workshop. Following on from the introductory chapter by Frederiksen on atmospheric disturbances, Chapters 3 to 7 collect papers on the interaction of turbulence and coherent structures in the atmosphere and ocean. Works are presented employing bifurcation and instability theory, examining regime transitions and multiple equilibria, detailing the properties of coherent structures and teleconnection patterns, and presenting modeling and observational studies of atmospheric and oceanic flows. These large-scale flows in the atmosphere and oceans are quasi-geostrophic, with an approximate balance between Coriolis and pressure forces, and share many properties with two-dimensional turbulence.

Chapters 8 to 12 review recent progress in three-dimensional turbulence including boundary layer turbulence and the formation of coherent structures. The studies include dynamical systems theory approaches and Lagrangian dispersion in three-dimensional turbulence as well recent developments in experiments and modeling of high Reynolds number turbulent flows.

Chapters 13, 14 and 15 appraise the current state of turbulence closure models, based on renormalized perturbation theory, for both two-dimensional and three-dimensional homogeneous turbulence. Recent developments in the generalization of closures to inhomogeneous turbulence interacting with mean flows, coherent structures and topography, and to Rossby wave turbulence, are outlined. Applications of closure theory to subgrid-scale parameterizations, and ensemble prediction and data assimilation in the presence of developing coherent blocking structures, are presented.

The final theme, in chapters 16 through 21, brings together a collection of studies on regime transitions in magnetized fusion plasmas. A major focus in fusion plasma research has been understanding the low- to high-confinement transitions that can occur due to the formation of zonal shear flows that break up coherent eddies responsible for turbulent transport. Theoretical, modeling and experimental studies of the dynamics of plasmas are presented. The close connections between the equations for the fluid description of magnetized plasmas and those for quasi-geostrophic geophysical fluids are brought out.

We thank the ARC Complex Open Systems Research Network convened by Prof. Robert Dewar, and the Commonwealth Scientific and Industrial Research Organization, through CSIRO Complex Systems Science directed by Dr. John Finnigan, for sponsoring this workshop. We thank Dr. Michael Shats for help in organizing the workshop. The Workshop in Canberra was immediately followed by the 19th Canberra International Physics Summer School and the Lecture Notes (editors M. Shats and H. Punzmann) have been published by World Scientific, 2006 under the title "Turbulence and Coherent Structures in Fluids, Plasmas and Nonlinear Media".

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