This text is addressed to advanced students in oceanography, meteorology and environmental sciences as well as to professional researchers in these fields. It aims to acquaint them with the state of the art and recent advances in experimental and theoretical investigations of ocean–atmosphere interactions, a rapidly developing field in earth sciences.

Particular attention is paid to the scope and perspectives for satellite measurements and mathematical modelling. Current approaches to the construction of coupled ocean–atmosphere models (from the simplest zero-dimensional to the most comprehensive three-dimensional ones) for the solution of key problems in climate theory are discussed in detail. Field measurements and the results of numerical climate simulations are presented and help to explain climate variability arising from various natural and anthropogenic factors.
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Ocean–Atmosphere Interaction and Climate Modelling

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## Contents

**Preface**  
*page xi*

1 **Preliminary information**  
1.1 Definition of the climatic system  
1.2 Scales of temporal variability and its mechanisms  
1.3 Predictability and non-uniqueness  
1.4 Methods of experimental research  
1.4.1 Ground-based measurements  
1.4.2 Satellite measurements  

2 **Present state of the climatic system**  
2.1 Initial information  
2.2 Mass budget  
2.3 Heat budget  
2.4 Moisture budget  
2.5 Energy budget  
2.6 Angular momentum budget  
2.7 Carbon budget  

3 **Small-scale ocean–atmosphere interaction**  
3.1 Surface atmospheric layer  
3.2 Vertical distribution of the mean velocity over an immovable smooth surface: viscous sublayer; logarithmic boundary layer  
3.3 Vertical distribution of the mean velocity over an immovable rough surface: roughness parameter; hydrodynamic classification of underlying surfaces  


### Contents

3.4 Hydrodynamic properties of the sea surface 116  
3.5 Wind–wave interaction 123  
3.6 Vertical distribution of the temperature and passive admixture over an immovable surface 131  
3.7 Coefficients of resistance, heat exchange and evaporation for the sea surface 133  
3.8 The Monin–Obukhov similarity theory 135  
3.9 Transformation of the thermal regime of the surface atmospheric layer in the presence of wind–wave interaction 143  
3.10 Methods for estimating surface fluxes of momentum, heat and humidity 147  
3.11 Methods for estimating CO$_2$ flux at the ocean–atmosphere interface 154  
3.12 Features of small-scale ocean–atmosphere interaction under storm conditions 160  

4 Mesoscale ocean–atmosphere interaction 165  
4.1 The planetary boundary layer 165  
4.2 Problem of closure 168  
4.2.1 First-order closure 170  
4.2.2 Second-order closure 173  
4.3 Laws of resistance and heat and humidity exchange 179  
4.4 System of planetary boundary layers of the ocean and atmosphere 183  
4.4.1 Theoretical models using *a priori* information on the magnitude and profile of the eddy viscosity coefficient 186  
4.4.2 Simplest closed models 189  
4.4.3 Semiempirical models not using *a priori* information on the magnitude and profile of the eddy viscosity coefficient 193  

5 Large-scale ocean–atmosphere interaction 201  
5.1 Classification of climatic system models 201  
5.2 Similarity theory for global ocean–atmosphere interaction 203  
5.3 Zero-dimensional models 209  
5.4 One-dimensional models 213  
5.5 0.5-dimensional (box) models 219  
5.6 1.5-dimensional models 239  
5.7 Two-dimensional (zonal) models 244  
5.8 Three-dimensional models 251
Contents

5.9 ENSO as a manifestation of the inter-annual variability of the ocean–atmosphere system 281

6 Response of the ocean–atmosphere system to external forcing 292
6.1 Sensitivity of the climatic system: mathematical methods of analysis 292
6.2 Equilibrium response to a change in ocean–land area ratio 304
6.3 Equilibrium response to a change in the concentration of atmospheric CO₂ 308
6.4 Equilibrium response to a change in land surface albedo 322
6.5 Equilibrium response to a change in soil moisture content 328
6.6 Equilibrium response to a change in vegetative cover 331
6.7 Transient response to a change in the concentration of atmospheric CO₂ 337

References 358

Index 373
Preface

In 1963 when the principal concepts of the study of ocean–atmosphere interaction had only been outlined, a group of leading American geophysicists (see Benton et al., 1963) stated: ‘We are beginning to realize dimly, although our information on this score is far from complete, that the atmosphere and the oceans which together constitute the fluid portions of the Earth actually function as one huge mechanical and thermodynamical system.’ And further: ‘A physical understanding of the processes of air–sea interaction should be one of the major objectives of geophysics during the coming decade.’ Thirty years have now passed and one of the least developed branches of geophysics has been transformed into an independent discipline with the aim of integrating the varied information on the ocean and atmosphere into a unified and balanced ‘picture of the world’, in order to provide an explanation as to the natural variability of mutually adjusted fields of climatic characteristics, to detect those common and distinctive features in hydrothermodynamics of both media (ocean and atmosphere) that are important for understanding the evolution of the climate, and to create a climatic theory, on which basis to forecast potential consequences of natural and anthropogenic forcings.

This progress has been achieved as a result of the realization of large experimental programmes on the one hand, and of the introduction of physical models on the other. Both these approaches are mutually complementary: the theoretical approach assumes the utilization of experimental data to test the models; the experimental approach assumes the introduction of conceptual ideas to be confirmed by modelling results.

Among the large experimental programmes performed in the past, and still continuing, mention should be made of the Global Atmospheric Research Programme (GARP), the First GARP Global Experiment (FGGE), the Joint
Preface

Air–Sea Interaction Experiment (JASIN), the Tropical Ocean and Global Atmosphere Programme (TOGA), the Global Energy and Water Cycle Experiment (GEWEX), the Atmosphere–Ocean Chemistry Experiment (AEROCE), the International Geosphere–Biosphere Programme (IGBP), the World Ocean Circulation Experiment (WOCE), the Joint Global Ocean Flux Studies (JGOFS), the Soviet programme ‘Sections’ for studies of energy exchange in the energy active ocean zones, and, finally, the World Climate Research Programme (WCRP).

For the last 30 years the comparatively new technology of field measurements has been tested successfully. This involves the creation of a network of satellite scanned drifting and anchored buoys, as well as satellite and acoustic measurements. In the near future satellite measurements will become the basis of a global network of continuous registration of radiative fluxes, cloudiness, vertical temperature and humidity distribution in the atmosphere, sea surface temperature, wind velocity, wind stress, latent heat flux, wave parameters and ocean level elevations. New perspectives are also being discovered through the use of acoustic tomography of the ocean. This technique measures the travel times of sound pulses between pairs of transducers. Therefore, the difference in the times for travel in opposite directions yields an estimate of the water velocity along the path, averaged along the path, and this estimate, in turn, may be used to evaluate heat and mass transport across the path, heat storage inside the triangles formed by triplets of transducers, and the integral (over the area of the triangles) vertical component of potential vorticity.

The last three decades have been marked by an unprecedented growth of activity in the area of mathematical modelling of ocean–atmosphere interaction and by the creation of an entire hierarchy of models of the ocean–atmosphere system from the simplest zero-dimensional up to high-resolution, three-dimensional models ensuring solution of the key problems of climate theory, among them those which cannot be solved by any other means. Much has been achieved in this field, of which the most important is the realization that oscillations of climate with periods ranging from several years to several decades and more, as well as the climate response to external forcings (e.g. increasing the atmospheric CO₂ concentration, destruction of the vegetation, secular variations of the Earth’s orbital elements, etc.), may be simulated only within the framework of models of the ocean–atmosphere system.

Extrapolating the development of activity within the scope of ocean–atmosphere interaction, one may say with confidence that over the next decade the main means of progress will be numerical experiment and satellite monitoring. This, properly speaking, determined the content of this book,
whose aims are to expound current representations of the climatic system as a totality of the interacting atmosphere, ocean, lithosphere, cryosphere and biosphere; to introduce the reader to new methods and results of theoretical and experimental researches; to give him or her an opportunity to perceive the extraordinary complexity of real problems which, as a rule, do not have unquestionably final solutions; and thereby to stimulate the reader to independent thinking. By the way, the above-mentioned developments in the science place special demands on the future specialist, who has to be equally well qualified in three closely connected directions: in theory, modelling and observations.

And lastly, this book is written by an oceanologist for oceanologists. This fact, as well as a willingness to emphasize the leading role of the ocean in the long-period variability of the ocean–atmosphere system, has determined the choice of subjects, the arrangement of priorities and even the sequence of the words in the title. This is not to undermine the role of the atmosphere. I have simply shifted accents in an effort to facilitate perception of the subject matter.

When preparing the book I employed the help of, and was influenced by, many people. I am grateful to my teachers, D. L. Laikhtman, A. S. Monin and V. V. Timonov, who gave me a worthy example of world perception. I cannot deny myself the pleasure of thanking my colleagues and friends from the P. P. Shirshov Institute of Oceanology, the Russian Academy of Sciences, and from the Russian State Hydrometeorological Institute: G. I. Barenblatt, A. Yu. Benilov, D. V. Chalikov, L. N. Karlin, N. B. Maslova, A. V. Nekrasov, V. A. Ryabchenko, A. S. Safray, N. P. Smirnov and S. S. Zilitinkevich for their permanent support and helpful advice. I would like to note my special thanks to my students, whose reactions, albeit often completely unexpected, initiated the appearance of this book.

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