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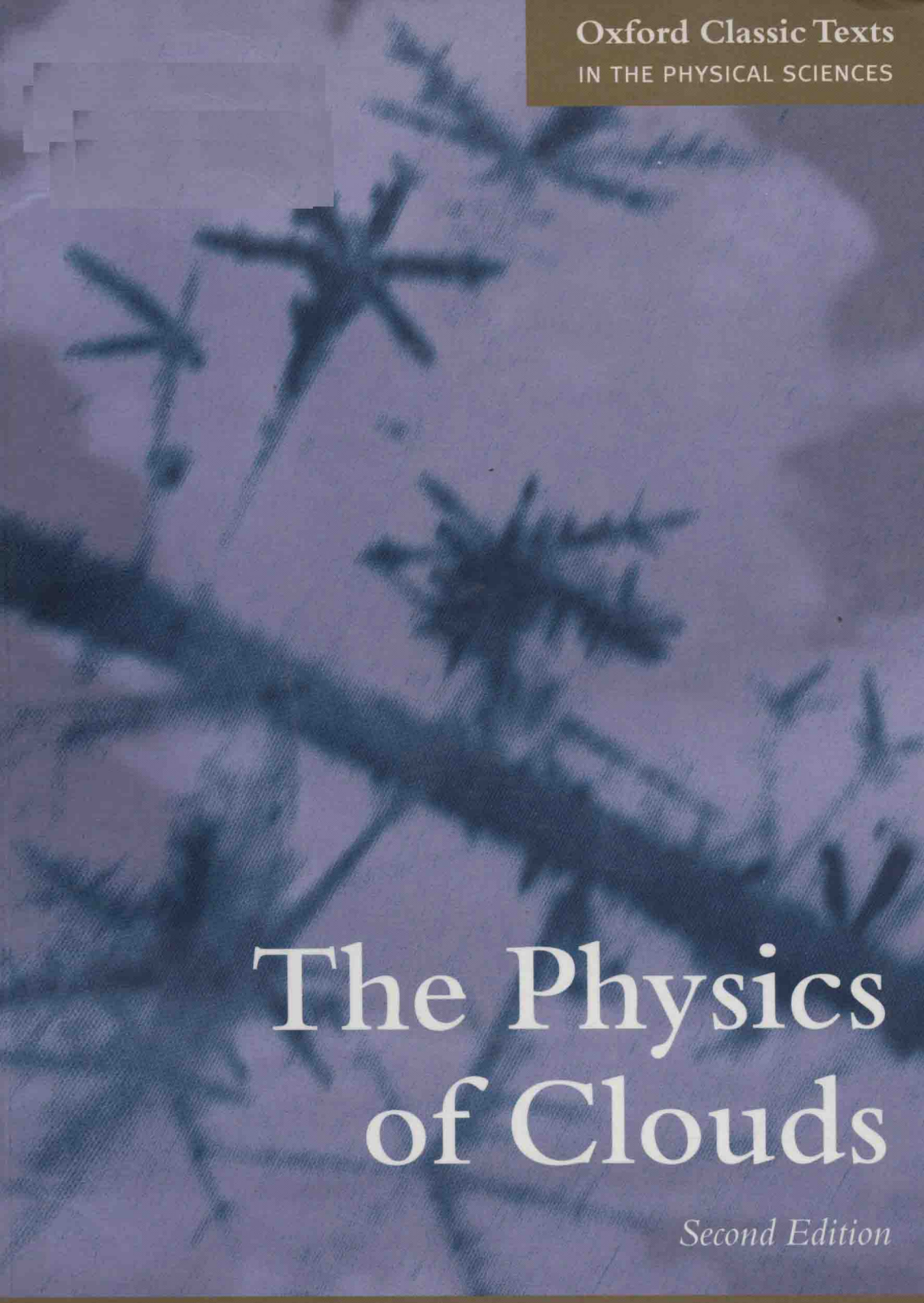

The Physics of Clouds

Second Edition

B.J. Mason

Cloud physics is concerned with those processes which are responsible for the formation of clouds and the release of precipitation. This classic book gives a comprehensive and detailed account of experimental and theoretical research on the microphysical processes of nucleation, condensation, droplet growth, initiation and growth of snow crystals, and the mechanisms of precipitation release. As a textbook it is designed to give the student the necessary background to carry out independent work. As a reference book for the research worker, it provides an integrated account of the major developments in this field. Although written primarily for the atmospheric physicist, it contains much of interest for those in the fields of nucleation phenomena, crystal growth, and aerosol physics.

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Mason

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THE PHYSICS OF CLOUDS

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SECOND EDITION

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Editor

P. A. SHEPPARD

Preface to the Second Edition

THIS book has the same structure and scope as the first edition, but the text has been completely re-written, revised, and enlarged to accommodate the significant advances that have taken place during the intervening decade. It attempts to provide a fairly complete and critical account of all the important developments up to the end of 1969 and includes some important work published in 1970.

Again the emphasis is on the microphysical processes of condensation of water vapour to form droplets, the supercooling, nucleation, and freezing of water droplets, the growth and aggregation of snow crystals, the mechanisms of raindrop, snowflake, and hailstone formation, the radar detection of precipitation elements, and the various processes of cloud electrification, with only sufficient background information on the structure and dynamics of cloud systems to allow realistic discussion of the particle physics. However, in the preceding preface, written thirteen years ago, reference was made to the strong interactions that exist between these microphysical processes and the air motions in and around clouds, and to the importance of acquiring a much deeper understanding of the cloud dynamics for the development of the subject as a whole. The hopes expressed then for much greater effort and progress in this direction, and for the appearance of a major text on this aspect of the subject, have yet to be realized, but there is now a much greater awareness of the need. For, while considerable progress has been made in establishing the physical laws that govern the nucleation, growth, and aggregation of particles, extrapolation of the knowledge obtained under controlled laboratory conditions to the evolution of populations of particles in the vastly more complex environment of a natural cloud requires great caution while our understanding of cloud dynamics is so rudimentary. Indeed it may be difficult to identify the important gaps in our current understanding of the microphysical events until this has been formulated in a dynamical context and tested against the results of observation, measurement, and prediction. The use, in recent years, of new, especially Doppler, radar techniques, of modern methods of data processing, and of numerical models, has given the subject a new impetus in this direction. I hope that this may lead, in the next decade, to advances comparable to those made in the laboratory during the 1950s and 1960s and which form the basis of this book.

Again, I am grateful to the learned societies, publishers, and authors, acknowledged in the text, for permission to reproduce many of the diagrams.

I am indebted to Miss Heather May and Mrs Janet Bolton for their help in preparing diagrams and an earlier typescript of the text, and especially to my present secretary, Miss Eileen Forde, for her invaluable assistance in producing the final manuscript, the index, and the bibliography. Lastly, I wish to acknowledge the skill and care which the Clarendon Press have exercised in the production of the book.

Bracknell B. J. MASON
January 1971

Preface to the First Edition

Cloud physics is concerned with those processes which are responsible for the formation of clouds and the release of precipitation. The subject has expanded enormously during the last decade and is now one of the most flourishing branches of meteorological physics. During this short period it has developed from the pursuit of a few individual scientists with modest resources into a group activity requiring elaborately instrumented aircraft, radar, and a wide range of laboratory facilities. This rapid development along a broad front has produced a large and diverse literature, the growth of which has made life increasingly difficult for the research worker and impossible for the student. Accordingly, it appeared that an account of the present state of the subject might serve a useful purpose although the disadvantages of writing a book at a time when the field is rapidly growing have become only too apparent. In this volume I have attempted to give a fairly comprehensive account of recent researches, both experimental and theoretical, on the micro-physical processes of nucleation, condensation, droplet growth, the initiation and growth of ice crystals, and the mechanisms of precipitation release. There follow also discussions on the present status of rain-making experiments, which have stimulated much of the fundamental research; on radar studies of precipitating clouds; and on the electrification of clouds which, I feel, should be regarded as an integral part of cloud physics.

Although the emphasis here is upon the *micro-physical* processes, it is important to recognize that these are largely controlled by the atmospheric motions which are manifest in clouds. These *macro-physical* features of cloud formation and growth, which might more properly be called a *dynamics*, provide a framework of environmental conditions confining the rates and duration of the microphysical events. For example, the growth or freezing of cloud droplets is accompanied by the release of great quantities of latent heat, profoundly influencing the motion of cloudy air masses, while the motions which ultimately cause evaporation of the cloud determine its duration, and will set a limit to the size which its particles can attain. Progress in cloud physics has been hindered by a poor appreciation of these interrelations between processes ranging from nucleation phenomena on the molecular scale to the dynamics of extensive cloud systems on the scale of hundreds or thousands of kilometres.

Unfortunately, our present understanding of the large-scale physics of clouds is rudimentary. This is partly because this aspect of the

subject has not received the attention it deserves, but mainly because of the difficulty of obtaining observational information about air motions on a scale too large to be simulated in the laboratory and yet too small to be defined by the observational network used in weather forecasting. Because I am convinced that future progress will be largely governed by our improved understanding of cloud dynamics, I hope that the next few years will see a greatly increased effort in this direction. At this stage it seems advisable to stress only those aspects which are firmly based upon observation and which are necessary to provide an adequate background for discussion of the micro-physical processes. Cloud dynamics will, I hope, eventually form the subject of a separate volume.

In attempting to write a coherent and integrated account of the subject as I see it at present, I have aimed at being critical rather than exhaustive, and consequently the treatment reflects, to some extent, my personal views. In a new and rapidly growing field there is, of course, room for differences of opinion and of interpretation; it is difficult and perhaps undesirable to remain dispassionate in the heat of the battle. However, I have done may best to provide an up-to-date review of the subject and to point out those gaps in our knowledge which appear to merit urgent attention. I shall be pleased if it proves to be of some use to my fellow research workers, and if it draws the attention of the student to a field which offers enormous scope for research into a wide range of phenomena, both in the free atmosphere and in the laboratory, and by theoretical methods. I hope also that I have managed to convey a little of the continual pleasure and excitement which I have experienced while working in this field during the last few years.

In the preparation of this book I have received help from a number of people to whom I should like to express my grateful thanks. To my colleague, Mr. F. H. Ludlam, I am greatly indebted not only for writing the Introduction on 'The Large-scale Physics of Clouds' but also for many stimulating discussions on all aspects of the subject during the last seven years. I am very grateful to those friends who, by sending me their papers in advance of publication, have ensured that this book will appear only a few months out of date. For permission to reproduce many of the diagrams I am indebted to those learned societies, publishers, and authors acknowledged in the text. I am particularly indebted to Mrs. S. M. Devers, Miss E. M. Lea, Miss M. L. J. Pinhard, Mrs. M. Brookfield, and Miss S. A. Latta for their invaluable assistance in preparing the typescript and diagrams, and to the Clarendon Press for the skill and care which they have exercised in the production of the book. Lastly, I owe much to my

wife who typed a good deal of the manuscript, and without whose continual help and encouragement this book would not have been written.

B. J. M.

Imperial College, London
February 1957

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