The Physics of Glaciers

Fourth Edition

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References and other supplemental materials can be found on
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Preface to Fourth Edition

Current concerns about global warming have produced widespread scientific interest in the behavior of glaciers in general and the polar ice sheets in particular. This increased interest, coming at a time of unprecedented advances in observational capabilities, has fueled a major expansion of the literature since the third edition went to press. A new edition to update the content and assess the current state of research was therefore overdue.

Reflecting the increased engagement of glacier studies with broad themes in environmental geophysics, the updated edition features new chapters on "Ice Sheets and the Earth System" and "Ice, Sea Level, and Contemporary Climate Change." The chapter on ice core studies is significantly expanded from the previous version and much of it is new material. The content and arrangement of chapters on glaciological fundamentals broadly follow the outline of the third edition, although many discussions have been revised extensively. All the material about flow of mountain glaciers, ice sheets, ice streams, and ice shelves has been amalgamated into a single lengthy chapter entitled "Flow of Ice Masses." Material about iceberg calving and basal melt now find their place in a chapter that reviews together all of the mass balance processes. In general the level of treatment remains unchanged, but several key topics are illuminated at a higher level of detail than in previous editions.

Many acknowledgments are due. We first must thank Shawn Marshall for conducting a first round of research and synthesis of topics presented in Chapters 4, 5, and 6. We gratefully acknowledge the scientists who reviewed individual chapters: Richard Alley, Bob Bindschadler, Jason Box, Roland Burgmann, Garry Clarke, Tim Creyts, Paul Duval, Andrew Fountain, Inez Fung, Hilmar Gudmundsson, Michael Hambrey, Will Harrison, Neal Iverson, Jo Jacka, Georg Kaser, Thomas Mölg, Tavi Murray, Tad Pfeffer, Eric Rignot, Jeff Severinghaus, Throstur Thorsteinsson, Françoise Vimeux, Ed Waddington, Joe Walder, Ian Willis, and Eric Wolff. Charlie Raymond deserves special thanks for commenting on the whole manuscript. Jeff Kavanaugh contributed helpful suggestions and graciously provided the cover photograph. Yosuke Adachi proofread the final manuscript. Mark Carey, glacier historian, suggested several of the chapter-head quotes. All of the reviewers offered excellent suggestions, some of which could not be accommodated for lack of space. We, of course, take full responsibility for the content and for the tough choices about what material to include.

Completion of the project would not have been possible without assistance from Delores Dillard and Darin Jensen of U.C. Berkeley's Department of Geography. Delores worked on digitization and manuscript acquisition while Darin took on the nearly unthinkable task of drafting more than 200 figures. KC gives additional thanks to Jean Lave and Michael Johns for their wise counsel, and to the Division of Geological and Planetary Sciences at the California Institute of Technology, and especially Jess Adkins and John Eiler, who hosted a sabbatical visit at the start of this project. Finally, we express our deepest gratitude to Lyn Paterson and Pete Lombard for their many years of support and encouragement.

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February, 2010

Preface to First Edition

The aim of this book is to explain the physical principles underlying the behaviour of glaciers and ice sheets, as far as these are understood at the present time.

Glaciers have been studied scientifically for more than a century. During this period, interest in glaciers has, like the glaciers themselves, waxed and waned. Periods of activity and advance have alternated with periods of stagnation and even of retrogression when erroneous ideas have become part of conventional wisdom. The past 20 years, however, have seen a major advance in our knowledge. Theories have been developed which have explained many facts previously obscure; improved observational techniques have enabled these theories to be tested and have produced new results still to be explained.

This seems an appropriate time to review these recent developments. At present there is, to my knowledge, no book in English which does this. The present book is a modest attempt to fill the gap. To cover the whole field in a short book is impossible. I have tried to select those topics which I feel to be of most significance, but there is undoubtedly some bias towards my own particular interests.

While this book is intended primarily for those starting research in the subject, I hope that established workers in glacier studies, and in related fields, will find it useful. The treatment is at about the graduate student level. The standard varies, however, and most chapters should be intelligible to senior undergraduates.

I am much indebted to Dr. J. F. Nye for reading the whole manuscript and making many helpful suggestions. I am grateful to Drs. S. J. Jones, G. de Q. Robin and J. Weertman for reviewing individual chapters. I should also like to thank Drs. J. A. Jacobs and J. Tuzo Wilson for general comments and encouragement. The responsibility for the final form and contents of the book of course remains my own.

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Ottawa, Canada
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