IUTAM Symposium on Scaling Laws in Ice Mechanics and Ice Dynamics

SOLID MECHANICS AND ITS APPLICATIONS
Volume 94

Series Editor: G.M.L. GLADWELL
Department of Civil Engineering
University of Waterloo
Waterloo, Ontario, Canada N2L 3GI

Aims and Scope of the Series

The fundamental questions arising in mechanics are: *Why?, How?,* and *How much?* The aim of this series is to provide lucid accounts written by authoritative researchers giving vision and insight in answering these questions on the subject of mechanics as it relates to solids.

The scope of the series covers the entire spectrum of solid mechanics. Thus it includes the foundation of mechanics; variational formulations; computational mechanics; statics, kinematics and dynamics of rigid and elastic bodies: vibrations of solids and structures; dynamical systems and chaos; the theories of elasticity, plasticity and viscoelasticity; composite materials; rods, beams, shells and membranes; structural control and stability; soils, rocks and geomechanics; fracture; tribology; experimental mechanics; biomechanics and machine design.

The median level of presentation is the first year graduate student. Some texts are monographs defining the current state of the field; others are accessible to final year undergraduates; but essentially the emphasis is on readability and clarity.

For a list of related mechanics titles, see final pages.

IUTAM Symposium on

Scaling Laws in Ice Mechanics and Ice Dynamics

Proceedings of the IUTAM Symposium
held in Fairbanks, Alaska, U.S.A.,
13–16 June 2000

Edited by

J.P. DEMPSEY

Clarkson University,
Department of Civil and Environmental Engineering,
Potsdam NY, U.S.A.

and

H.H. SHEN

Clarkson University,
Department of Civil and Environmental Engineering,
Potsdam NY, U.S.A.

Springer-Science+Business Media, B.V.

A C.I.P. Catalogue record for this book is available from the Library of Congress.

ISBN 978-90-481-5890-4 ISBN 978-94-015-9735-7 (eBook)
DOI 10.1007/978-94-015-9735-7

Printed on acid-free paper

Originally published by Kluwer Academic Publishers in 2001.
Softcover reprint of the hardcover 1st edition 2001

CONTENTS

PREFACE

This Volume constitutes the Proceedings of the IUTAM Symposium on 'Scaling Laws in Ice Mechanics and Ice Dynamics', held in Fairbanks, Alaska from 13th to 16th of June 2000. Ice mechanics deals with essentially intact ice: in this discipline, descriptions of the motion and deformation of Arctic/Antarctic and river/lake ice call for the development of physically based constitutive and fracture models over an enormous range in scale: 0.01 m - 10 km. Ice dynamics, on the other hand, deals with the movement of broken ice: descriptions of an aggregate of ice floes call for accurate modeling of momentum transfer through the sea/ice system, again over an enormous range in scale: 1 km (floe scale) - 500 km (basin scale).

For ice mechanics, the emphasis on lab-scale (0.01 - 0.5 m) research contrasts with applications at the scale of order 1 km (ice-structure interaction, icebreaking); many important upscaling questions remain to be explored. In ice dynamics, the general opinion is that continuum mechanics and rheological models can be used at scales above 10 km. While elastic-plastic and viscous-plastic macroscopic laws provide satisfactory results at climatological scales, attempts to downscale these models have met with less success regarding time scales of the order of a day and regional scales (50 km). Apparently, rheological models must be properly chosen for the scale of interest. Reliable rheological models that can accurately describe the internal resistance of an aggregate of ice floes at various scales are currently lacking, as is the ability to downscale and interface with knowledge at the scale of 1 km. Direct numerical simulation techniques developed in the granular flow community have been applied successfully to model the surface transport of ice in rivers, as well as to explain the physical process of ridging in the Arctic. However, the description of mesoscale and geophysical scale processes based on these techniques is far from developed. Clearly, what science is done is set by an individual's decision to work at a certain scale. Intuitively, the study of ice is divided into the analysis of subsets of processes based on scale and their interactions with adjacent scales. However, the methodologies applied at each scale differ hugely, with little communication downscale or upscale. Certainly, the relative merits, limits and deficiencies of the approaches at each scale are not well understood.

The objective of the proposed symposium is to bring together researchers who have made significant contributions at various scales in the study of ice, and those who have made significant contributions to the mechanics of

heterogeneous media in other fields. At this time, there is no clear guidance as to the range of applicability of different constitutive laws, and a lack of ability to link the behavior at smaller scales (the scale of the discrete phase) with successive geophysical scales. The aim is to ignite a process that will integrate these areas, so that an organized approach to understand the scaling problem can be established in the ice mechanics and ice dynamics community. There is every possibility that the mechanics community can play a major role in this development.

The symposium consisted of 36 lectures, all of which were invited and accorded equal weight in the program. In addition, a number of poster boards, which were set up for the duration of the symposium, allowed a further 12 invited presentations. The content of 33 of the lectures and six of the poster presentations are included in this volume.

The International Scientific Committee responsible for the Symposium comprised the following:

Prof. J.P. Dempsey (USA), Chair
Prof. I. F. Collins (New Zealand)
Prof. P. Duval (France)
Dr. R. V. Gol'dstein (Russia)
Prof. M. Maattanen (Finland)
Prof. R. Wang (China)
Prof. H.H. Shen (USA), Co-Chair
Dr. K. R. Croasdale (Canada)
Dr. B. Erlingsson (Iceland)
Prof. K. Hutter (Germany)
Prof. H. Saeki (Japan)

The Committee gratefully acknowledges financial support for the Symposium from the International Union of Theoretical and Applied Mechanics (IUTAM), the United States Army Research Office (ARO), Department of the Interior (DOI), National Science Foundation (NSF) and Office of Naval Research (ONR), BP Amoco (BP), and the International Arctic Research Center, University of Alaska Fairbanks (IARC). In this context, let it be noted that the views, opinions, and/or findings contained in this book are those of the authors and should not be construed as an official ARO, BP, DOI, IARC, IUTAM, NSF or ONR position, policy, or decision, unless so designated by other documentation.

The smooth running of the Symposium owes much to the unstinting efforts of the sole member of the local organizing committee, Dr. L.H. Shapiro, Geophysical Institute, University of Alaska Fairbanks.