DYNAMICS OF SNOW AND ICE MASSES. Edited by SAMUEL C. COLBECK, New York: Academy Press, 1980. 468 p., index. Hardbound, $55.00 U.S.

Dr. Colbeck has provided the glaciological community with an excellent compilation and review of the core subjects of snow and ice dynamics. The selection of subjects, organization of material, and choice of contributors is superb. Seven prominent scientists active in snow or ice dynamics research have contributed detailed but lucid chapters on the subjects of ice sheets and ice shelves (Paterson), temperate valley glaciers (Raymond), sea ice dynamics (Hibler), iceberg drift and deterioration (Robe), freshwater ice dynamics (Ashton), seasonal snowcover properties and snow hydrology (Male), and avalanche dynamics (Perla). The book provides a valuable tool for scientists wishing to expand their overall understanding of a particular subject or, to develop a working knowledge of a snow/ice subject allied to their own expertise, or for students wishing to understand the basis of research in any of these fields. Extensive reference lists at the end of each chapter allow rapid assimilation of current research directions and progress, but the chapters are much more than mere annotations of this bibliography.

Each chapter opens with a conceptual description of the subject, often in terms of relevant physics or equations of motion, and leads the reader through essentially all major aspects necessary to an overall grasp of the subject. After reading a given chapter, one cannot necessarily embark on independent research in that subject, but the particular analyses discussed represent the framework and forefront of snow and ice research. Individual topics are presented in the context of the entire chapter subjects. The contributions are review in scope. No chapter develops solution methods to particular problems as would be characteristic of a mechanics text; rather basic equations or ideas are presented and results discussed in physical terms. The aim is for conceptual understanding of physical processes, but this approach is supplemented heavily by references and detailed mathematics where appropriate. The book is thus an excellent reference source but does not detail particular problems to be solved. The reader may ferret these out. One gains a thorough understanding of the basis of each particular subject and then can choose to what degree to pursue a more rigorous understanding through the references.

Chapters 1 (Paterson) and 2 (Raymond) encompass the full realm of ice sheet, ice shelf, and glacier dynamics. These two chapters are an excellent compliment to Paterson's earlier book *The Physics of Glaciers* (Pergamon Press, 1969). After initial description and theoretical groundwork, Paterson provides a description of the basic equations of flow for ice sheets including discussion of the flow law for ice, the sliding boundary condition, and conservation of momentum and heat transfer. Basic theoretical and observational work on the flow of ice sheets is then summarized. This well-written section touches on several diverse aspects of ice sheet flow including both steady-state and non-steady-state ice sheets, ideal plastic models and Antarctic and Greenland observations of profiles, effects of water at the bed, effects of depressed bedrock and margins of ice sheets, and a detailed but clear discussion of the relation between surface and bedrock topography. A very clear and welcome discussion is provided for time scales for ice cores in terms of both theoretical considerations and core data. A discussion on the variation of ice sheets from steady-state is presented in terms of measuring ice thickness changes, and again theory is compared to observation. References abound throughout these discussions. A brief presentation follows outlining the particular assumptions and equations of motion used in numerical modelling of ice-sheet changes (Mahaffy and Budd/Jenssen). Theory of ice shelf flow is presented, again substantiated by observation. The work of Thomas, Robin, and Weertman provide the bulk of this section, but those detailed analyses are very well summarized and put in context. In addition, the interaction of ice sheet and ice shelf dynamics in Antarctica is summarized. The chapter concludes with a discussion of both theory and observation of the temperature of ice sheets and ice shelves and its effect on flow. Again, this section is very well done, and references clarify the more detailed points. This discussion leads logically into consideration of ice sheet instability in mass balance, in ice shelf interaction, in surging, and in convection. Methods of erosion are touched on only briefly, and the response of ice sheets to climate fluctuations is not developed here but receives detailed discussion in Raymond's chapter on valley glaciers. Temperate valley glaciers are presented through a very lucid discussion and summary of glacier growth, structure, and flow coupled to a good summary of experimental behavior of ice creep and its application to glacier flow. The reader must seek out references here, but Raymond places these in a context which allows development of a working knowledge for applicability of experimental observation to glacier flow. Raymond has done extensive work in both field and theoretical glacier dynamics and is an excellent choice for author of this chapter. His three sections on variation of velocity and stress with depth, in cross section, and downstream are complete and very well written. These sections provide a good background before one wanders into the classic but less delicate papers of Budd or Nye. The detailed summary of sliding is welcome: the very complicated subject of actual basal physical processes is summarized to the extent that dynamicists can make sense of general processes for use in boundary conditions while still appreciating the enormous complexity and variability of physical, thermal, and chemical processes inherent in glacier flow over a bed. The chapter concludes with a discussion of the response of glaciers to climate, the development of kinematic waves, and the general difference between dynamic inherent fluctuations in flow and externally induced fluctuations.

The next three chapters deal with the dynamics of ungrounded ice: sea ice (Hibler), iceberg drift (Robe), and river and lake ice (Ashton). Dynamics of ice in this environment are intimately tied to atmospheric and oceanic or freshwater dynamics and thermal balances which in turn drive the observed motion of the ice. However, ice thickness and mobility determine how the external dynamic and thermal regimes control the motion of ungrounded ice. Thus, each of these chapters deals with ice drift and decay in terms of thermodynamic response to water or atmospheric dynamics. Hibler's presentation on sea ice takes this interaction one step further in that the large extent of sea ice allows for significant feedback of the ice cover to altering the behavior of atmosphere and ocean. His aim is to provide a clear understanding of the complex interaction of the air-water-sea ice system in terms of the ultimate dynamics of the ice through observational constraints and theoretical modelling of the mechanisms: his review is excellent. He initially provides a summary of data and observations on the temporal (seasonal) and spatial variations of sea ice. This information not only clarifies the activity of interaction but also provides the constraints that dynamic models must be able to match. Basic ice drift is then correlated to oceanic transport drift. Ice thickness variations are introduced in terms of yearly variations and the effects of ridging. The growth and deformation of sea ice is presented in terms of basic equations for thickness changes tied to thermodynamic fluctuations and for flow and deformation from imposed stresses of sea currents and geostrophic wind flow. Discussion of these stresses and of sea ice rheology and strength is well done. The rest of the chapter is a detailed presentation on methods and results of numerical simulations of arctic and Antarctic sea ice dynamics. This section is also quite well done and understandable because of the previous development of the chapter.

Robe's chapter on iceberg drift and deterioration is somewhat of a departure from previous presentations in the book. Because icebergs are small compared to glaciers, ice sheets, or sea ice fields, there is very little internal deformation to be termed dynamics. Because of the paucity of monitoring data before satellite tracking of large bergs, the modelling of drift and the interaction of icebergs with wind and ocean stresses is difficult to verify. Yet it is important to understand iceberg drift and decay for purposes of preventing ship disasters and, recently, of considering transport of this large freshwater source. Thus, Robe points out that other than considering the dynamics inherent in the calving phenomena both at the glacier source and from spallation off an iceberg itself, the dynamics of iceberg drift and deterioration requires an understanding of thermodynamic and mechanical processes at the air-ice or water-ice boundary. This chapter is perhaps more review in scope than others in that much discussion is given to descriptions of iceberg sources and general characteristics, yet this is justifiable given the variation in arctic and Antarctic sources. Global drift patterns are discussed and the effect on iceberg survival is predicted for each of several regions. It is when one considers local drift effects that fluid dynamic and thermal stresses become significant to the dynamicist. Robe presents a good discussion of each of the pertinent forces or stresses acting on deteriorating and accelerating icebergs. No effort is made to tie all the interactions together to predict specific deterioration models, but given the actual physical complexity of wind and water drag, turbulent local boundary layers at both air and sea interfaces, heat transport by wave action and local flow fields, and surface radiation, all acting on a constantly chang-

ing mass, one gets a good feeling of the subject by considering constituent effects rather than a cumbersome dynamic-interaction model. The chapter is hence well suited to its aim.

The third chapter dealing with ungrounded ice is Ashton's presentation on freshwater ice growth, motion, and decay. The emphasis is on river and lake ice; the subject is introduced by consideration of thermal energy balance for river ice in terms of heat flux and mixing of the ice-covered water and of thickness changes and ice growth driven by the heat flux. These sections are clear and very well presented. Ashton next presents the problem of ice floe accumulation and initiation of an ice clog in a river. Particular solutions defining the criteria by which a clog is able to resist fluid shear are not available, yet an amazing amount of interesting flow dynamics is presented by considering rheological changes in the fluidized ice mass. This leads logically to motion of the river ice. The complications of ice motion in open channel flow are presented and dealt with very clearly. However, one is left realizing that a great amount of theoretical, experimental, or field work is ripe to be done. A good summary is presented on ice jam breakup, but rigorous treatment is not available. A shorter but similar treatment is then given to lake ice formation and motion. Very little work has been done on this subject due to its inherent complexity, so this section is review in scope. The final two sections cover primarily the effects of thermal effluents on river and lake ice. The presentation is detailed but again summary in scope with some application to navigation problems. A final summary brings in a few additional references on subjects not covered here.

The last two chapters deal with snow dynamics. Male's chapter on the seasonal snowcover is basically a presentation of thermo-mechanics of dry and wet snow with a large section devoted to the dynamics of blowing snow. Dry metamorphism is covered in terms of compaction, of equitemperature density changes, and of thermally driven changes. These sections are well presented and replete with references. A major section of this chapter is devoted to blowing snow. Both turbulent diffusion and saltation are discussed in detail drawing from both field and theoretical studies. Russian studies, notably that of Dyunin, are discussed briefly and introduce the importance of snow sublimation during transport. Sublimation is apparently a small contribution to mass redistribution, but depends critically on particle size, air temperature, and humidity — little work has been done yet. The transport, accumulation, or erosion/ablation of snow is important for large ice sheet mass balance studies, but also is of great significance for snowpack equivalent water studies and hydrology. Thus, the blowing snow section provides a prelude to a second extensive section on snowmelt and hydrology of wet snow. These sections are packed with summary information and references, and are a very good introduction to particular works or symposia volumes. It appears that all subjects of interest and tractable in a review sense are discussed, and the sections on waterflow through snow tend to synthesize much of the previous information.

The final chapter is that of avalanche release, motion, and impact, contributed by Ron Perla. The chapter is an excellent follow-up to Male's snow cover presentation, and in fact the two chapters seem to mesh together as well as Paterson's and Raymond's do on glacier dynamics. Basically, Perla presents a two-part chapter covering (a) mechanisms of avalanche initiation and (b) avalanche motion, acceleration, and impact pressure. A generalized discussion on loose snow and slab avalanches precedes a well presented section on stress analysis for slab release. Boundary conditions are significant for avalanche initiation because they determine not only the inherent stability of the snow (or ice) mass at a given slope but also the degree to which external factors (wind, water percolation, and so on) must work in order to overcome boundary sustaining stresses. Perla's presentation is clear and well organized. Ice avalanches are discussed which ties this presentation back to that on valley glacier dynamics. Following initiation the motion of avalanches is basically determined by a balance of gravitational acceleration of a changing mass and frictional drag both at the base (ignoring cushioning) and from air drag across the descending head. Despite the potential detailed complexities in such analysis, Perla points out that the basic physics for modelling can be significantly reduced (based on observations) and the motion model he summarizes is succinct but quite clear. Flow velocity and runout-distance models are calculated given different cases of entrainment rate and frictional drag. This analysis leads ultimately to a discussion of impact pressure during transport, but before that discussion, Perla presents additional analysis pertaining to the channelized fluid flow analog model of Voellmy and a summary of laboratory modelling to avalanche flow (similar to submarine turbidity flow modelling). The Voellmy model is apparently used by Swiss engineers to great predictive success even though the model is simplified and particular assumptions are poorly justified. Perla points out that the Voellmy model is perhaps best suited to wet avalanches, but a complete discussion is given showing differences in drag for wet or dry avalanches. A brief discussion of development of local shock surges is presented. The section on laboratory modelling discusses similarity transforms between model and nature and flume experiments. The section on impact pressure presents an interesting area of research, that of measuring or calculating impact during flow or as the avalanche comes to rest. Data are provided for impact pressure both from experiments carried out on avalanches and by damage observations. The theoretical problem is complicated because the dynamic component of the load peaks before the static component does: static compaction of the original low density flow will peak after the avalanche comes to rest, and Perla shows that this component may be a dominant part of the load. A summary of the factors to be considered in calculating the dynamic contribution shows this to be an area for keen future research.

The entire book is very well presented, the subjects are thoroughly covered and the level of mathematical description is sufficient to clarify arguments but is far from being cumbersome. It is indeed a fine contribution to the glaciological literature and will be used by many scientists, engineers, and students as a classic reference and introduction into the several fields of snow and ice dynamics. Dr. Colbeck and all contributors are to be thanked for their efforts.

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STORIES FROM THE CANADIAN NORTH. Edited by MURIEL WHITAKER. Edmonton: Hurtig Publishers Ltd., 1980. 191 p., illustrations. $12.95.

The literary imagination, like maple syrup and crankcase oil, flows more readily in warmer climates. At least, such would appear true after briefly surveying the horde of contemporary novels set in the Canadian North. By way of distinguishing creative writing from such nonfictional varieties as travel and biography, we customarily refer to it as "imaginative literature," yet in spite of this convention, few traces of imagination can be found in the bulk of northern fiction. Iron-jawed trappers, their teeth glinting preternaturally from deep within ice-rimmed beards, repeatedly gaze off across miles of vast, empty spaces; the primordial struggle between man and his environment is so often reduced to its most elemental level that the reader no longer cares who wins, as long as the battle comes to an end; the temptation to succumb to the delicious sleep beckoning the exhausted traveller as he lies face down in the drifting snow has appeared so frequently that the reader himself will surely give in to Lethe's charms, even though the northern hero manages to withstand them. If "imagination" can be said to be working at all in such stories, it is certainly one of severe limitation, one that scarcely reshapes a handful of plots acted out by a few stock characters. At best, the easily entertained reader can expect several hours of fanciful escape. In themselves, these circumstances create no serious problems, as we all need some bulk in our literary diets; the difficulty lies in the smokescreen that this plethora of second- and third-rate novels casts over northern writing in general. The reader who wishes to stimulate his imaginative faculties while he feeds his northern curiosity is too easily lost in an uncharted wasteland of arctic thrillers where he is destined to wander aimlessly from one stereotype to another.

Stories from the Canadian North establishes some major landmarks in this wilderness. Edited by Muriel Whitaker, a professor of literature at the University of Alberta, the collection brings together the work of fourteen writers who draw their material from Canada's northern latitudes. This anthology — a sampler of writing that is northern in focus and imaginative in execution — includes such household names as Jack London and Farley Mowat, but its greater value lies in the less familiar writers it brings to light, names such as R. M. Patterson, George Whalley, and Rudy Wiebe. Nearly all of these tales about the Canadian North are told by Canadians, in itself a refreshing change; more crucial still, these tales are rich with creative energy and originality.