

## **Changing Sea Levels**

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GSC's Vancouver office), and to build it from 1965 to present. Finally, he has pulled together two lists of historical interest: these give the numbers of permanent employees of the GSC prior to 1900 and list geologists active in Canadian universities established before 1900.

Even the casual reader will find much of interest in this volume. Be warned, though, that the articles vary widely as to scope and style. Some take a magnifying glass to a single facet of their subject's life, whereas others give an aerial view of an entire career and its impact. A few articles are so precise as to the provenance of each point made that the reading experience is akin to eating spinach that has not had all the sand washed off. Most, however, are a sheer delight to read from start to finish. The nice thing about a collection like this is that if one article proves heavy slogging and is far from your interest zone, you need only flip forward a few pages to find a more congenial one. The only other caution is that most of the articles are reprinted from the original, so the typesetting varies as the style guide changed at Geoscience Canada. Those articles from the mid-1980s, when our collective eyesight was much sharper, are printed in a very tiny type.

On a final note, I hope that the GAC will promote "Proud Heritage" strategically outside the geoscience community, and ensure that all academic libraries, whether public or private, are encouraged to add it to their holdings. This should increase the chances of future writers of Canadian history finding and using this valuable resource.

## Changing Sea Levels

by David Pugh

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"Down with sea level rise" was the message on a placard that greeted the author

of this book during a conference in the Maldives. As he explains in the preface to this interesting monograph, sea level rise associated with climate change is a matter of considerable public interest and concern, so this book should be a valuable reference for more than the undergraduates at whom it is primarily aimed.

David Pugh is the well-qualified author of the comprehensive 1996 "Tides, Surges and Mean Sea Level", now sadly out of print. This new volume is a slimmed down version, with new material on satellite altimetry and the effects of climate change. The author's easy and clear style makes the book a pleasure to read, although the desire to minimize the mathematical content means that the theoretical and dynamical underpinnings of many topics are omitted. Chapters end with thought-provoking questions, with answers and discussion given in an appendix. Pugh also provides helpful lists of further reading and refers the reader to more material at <http://publishing.cambridge.org/resources/0521532183>.

The book covers changes in sea level on time scales from minutes to tens of years. Thus, it excludes wind waves at one end of the spectrum and the effects of very long-term tectonic changes at the other, focussing on the effects of tsunamis, tides, storm surges and gradual changes over the last 200 years and in the future. The latter include the effects of vertical land movements as the earth recovers from glacial loading and also the response to changing ocean volume associated with glacial meltwater and ocean warming.

After an excellent opening chapter on observational techniques, from tide poles to satellite altimetry (timing short radar pulses to measure the height of the sea surface), more than half the book is, perhaps surprisingly, devoted to tides. The discussion of these is very good, with traditional material clearly explained, and also, to my delight, some discussion of important and interesting aspects that are typically ignored. For example, Pugh discusses the "age of the tide", the lag of spring and neap tides behind full and new moon at which the solar and lunar tidal forces combine. The lag is typically a day or two, and explained here in terms of the time it takes the ocean to respond to the forc-

ing. (It actually provides indirect information on the ocean's proximity to resonance and the amount of friction.) Pugh also emphasises the "nodal" variations of the tides over the 18.6 year cycle in which the moon's maximum declination (angle above or below the equator) varies between 18.3 and 28.6 degrees. This produces major changes in the lunar diurnal (once a day) tides, and so is important at places such as Victoria, where diurnal tides dominate.

I was also pleased to see a reference to David Cartwright's wonderful 1969 study of the tides at the island of Saint Helena in the South Atlantic, 208 years after Charles Mason (of Mason-Dixon fame) assisted Nevil Maskelyne in measuring sea level changes there; the project compensated for the cloudiness that prevented them from achieving their primary objective of observing the transit of Venus across the face of the Sun. Although Pugh does not report on this, Cartwright found a significant change in the timing of the diurnal tides, an observation which will help us check on the global tidal models that are beginning to be used to predict changes in tides over much longer (interglacial) time scales.

Near the coast, of course, tides can change because of port construction and landfill. A more natural change has occurred in the Bay of Fundy, where today's world record tides (albeit challenged by observations in Ungava Bay, at least keeping this an internal Canadian dispute!) have built up over several thousand years as mean sea level has risen. This topic is discussed in Pugh's final chapter, on Tidal Influences, which will be of more interest to the geological reader than much of the physical oceanography. Here, we find an introduction to the fascinating effects of the tides on sediment transport, plants and animals, and a brief discussion of the empirical relationship between the cross-sectional area of the entrance of an inlet and the product of its surface area and tidal range. As with some other topics in the book, though, this would have benefited from a more quantitative dynamical interpretation.

The discussion of other factors affecting sea level is good but less detailed than for the tides. For example, the role of wind-driven changes includes a review of how local wind-driven cur-

rents along a coast can, via the action of the Coriolis force, change coastal sea level, but does not describe how some wind-driven effects can propagate along continental boundaries as coastally trapped waves. Similarly, the discussion of the models used to predict damaging storm surges, whether in Bangladesh, the Gulf of Mexico, or elsewhere, is also rather cursory, although good references are provided.

The treatment of mean sea level rise is also clear but somewhat brief, relying on a summary of reviews by organizations such as the Intergovernmental Panel on Climate Change rather than analysing the details and the difficulties that lead to the wide error bars on assessment and prediction. The author does, however, have an excellent chapter on Extreme Sea Levels, starting from the simple point that, at least in places with significant tides and surges, the main effect of a gradual rise in mean sea level is to increase the probability of the combined effects causing flooding or other problems. Another way of expressing this is as a reduction of the "return period" for a particular sea level. Pugh even embarks on an economic analysis of the problem as well as discussing strategies for adapting to sea level rise.

In summary, while the book seems somewhat unbalanced in its treatment of different components of sea level change, and perhaps too keen to avoid dynamical approaches requiring mathematics, it is nonetheless a clearly written, well-organized, and authoritative account as a reference for the specialist or a text for an undergraduate course. In both cases, though, supplementary reading, starting with references provided by Pugh, is very desirable.

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