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Changing Sea Levels: Effects of Tides, Weather and Climate, by David Pugh, Cambridge University Press, 2004, Paperback, USD 60.00, ISBN-13: 9780521532181, ISBN-10: 0521532183

I was drawn to this book by its title, as it promised to present one of my favorite topics in a concise way, but I was tricked by my preconceptions. Not knowing the author's past work (e.g., the book Tides, Surges and Mean Sea Level), I imagined from the title that the book dealt with the effects of global warming. Then I learned from the subtitle that climate came as the third and final part and that you cannot deal with sea level only from a global change perspective. Reading the book helped me to find a way among the thousand factors that influence sea level and to step further from my prejudice.

In the first pages the reader faces history. From Kepler and Newton to Bernoulli and Laplace, tidal cycles, as observed along the northeastern coasts of the Atlantic, were arguments used by some of the founders of modern science to develop gravitational theory and periodic mathematical descriptors. Beginning with Newlyn, in southwestern Britain, which is the reference point for sea level in the United Kingdom (and the most cited name in the book), and moving through benchmarks, tide poles, pressure gauges, and modern-day satellite altimetry, the reader is presented with the problems encountered in acquiring a record, along with information on the instruments that are used and their accuracy (Chapter 1). Next the author addresses tides, as expected by those who know the author's background, and from marine earthly things one is readily taken to the skies. The promise to keep mathematics at a minimum and leave details to the appendix and a website is respected throughout, helping those how may be scared by strict theory. Principles of gravitational theory are introduced, together with the definition of the equilibrium tide, a central concept to tidal analysis. The equilibrium tide is based on the simplified concept of an Earth covered with a single body of water that responds instantaneously to tidal forces and is acted upon by the moon and the sun.

The second central concept that is introduced at the beginning of the book and is necessarily simplified, is the geoid, or the undisturbed, equipotential surface that considers the uneven distribution of masses of the real Earth (Chapter 2). Having set the scene, Pugh moves to tidal analysis of observed data, following the three basic tools of tidal prediction: nonharmonic methods, harmonic analysis, and response methods. The basic assumption of harmonic analysis is that the waveform of tidal curves measured at specific sites, with characteristic amplitudes and periods, can be represented by a number of harmonic terms. Main constituent harmonics express meaningful variables, such as orbits of the moon and sun, their distance, declination, and hour angle. There are several hundred types of harmonics, but only the dominant ones are emphasized in the book. Other techniques of tidal analysis are considered only superficially, being too complex or requiring more formal treatments than one would expect in a book intended for a wide audience of students and scholars (Chapter 3).

Tides in the real world take the form of waves of water that travel in oceans and are reflected by continents, so the next step is to understand principles of wave propagation, resonance, and the influence of Earth's rotation. Particularly stressed are geostrophic currents, which give waves their actual shape (Kelvin waves), and are so important for describing tidal amplitudes and drawing co-tidal and co-range charts on geographic maps. It is one thing to propagate a wave in the open ocean, but it is another to do so in the much more frictional shelf areas where waves increase their amplitude. The book goes into some useful charts of the world oceans and shallow seas, such as the Red Sea, Yellow Sea, Gulf of Maine, and the shelf around northwestern Europe (Chapter 4).

Shallow water processes, such as standing wave generation and local resonances, can distort tides to extreme effects and are fully treated in the next chapter, being important to the management of coastal areas. Distortion due to bottom friction and irregularity of coasts, together with the harmonics needed to describe them, reappear in the pages dedicated to sea-level changes and tidal currents generated in channels, estuaries, and rivers (Chapter 5).

Having concluded the essentials of tidal prediction, the author finally considers the role of weather, coming to the second part of the subtitle and further approaching the real world. Meteorological disturbances are presented as those that transform ordinary tides, phenomena to which coastal populations are accustomed, into the disastrous flooding events feared by people living near coastal areas and their governments. Here, the author deals with weather effects, pressure variations, and responses to winds, and includes several actual cases of surges from around the world. Sections on resonant oscillations and tsunamis, although unrelated to weather, conclude the chapter that introduces issues of concern for management of

coastal areas (Chapter 6). When coming to the full treatment of measures and variations of mean sea level (MSL), the reader is well aware that this is but one aspect of climate change. In the words of the author (p. 157), "increased risks of flooding will depend on changes in the tide and the surge characteristics of a coastal area, not just on increases in MSL." The chapter covers how to calculate MSL, its historical measures, and the effects of isostatic adjustment, thermal expansion, and ice melting. In this section Pugh constantly emphasizes the importance of not estimating long-term trends from insufficient data, where insufficient data could be even 10 years of MSL change. The difficulties of separating the effects of changing ocean circulation with respect to vertical land movements from isostatic adjustment suggest how complex it is to finally get to measure changes in global water volume, whether due to ice melting or thermal expansion—eustasy at last.

This is the point in the book where Pugh considers what is perhaps the final question that the average reader has in mind: is MSL rising? By this time, the thoughtful person is aware that the answer is not as simple as the question. Some of the answers reached in 2001 by the Intergovernmental Panel on Climate Change (IPCC), and citing here only those that are related to human activities and to which governments must adapt their actions, include: (1) records older than 50–60 years report a MSL rise in the range of 1–2 mm per yr; (2) this rate is higher than in the 19th century; and (3) no significant increase in rate has been detected during the 20th century (Chapter 7). Please note that the 2001 IPCC report was the one available at the time Pugh was writing. A newer report is now available, "Climate Change 2007," the Fourth Assessment Report (see Hopkin, 2007).

The chapter that follows is dedicated to the prediction of future changes in flooding risks; that is, the combined effects of a rise in MSL, tides, and surges. An important concept is that rate of change is more important than the magnitude, and that natural, social, and economic systems may be in a condition to adapt to change. Reasons for concern include the fact that the number of people living in coastal areas that face increased flooding risk (the majority of the world's population) will increase between 2002 and 2080 from 10 to 240 million people, and that wetlands, salt marshes, coral reefs, and agricultural systems are all sensitive to MSL rise (IPCC 2001 data; Chapter 8).

The last chapter deals with coastal ecosystems structured around tidal influences—the interface between the biosphere and the periodical change of sea level—with an eye to phenomena developed in geological time. Here the topics become perhaps more familiar to readers of PALAIOS: mangroves, reefs, and salt marshes. One thing that strikes me, after having read the book, is Pugh's sensibility for understanding the biotic adaptations to changing sea levels in the widest sense, that is, to see human, animal, and plant systems alike, and his ability to read past signals and present behaviors, as well as to suggest future responses (Chapter 9).

This book is a concise and comprehensive account of all one needs to know about the way sea level changes in space and time, with useful links to supplementary readings and stimulating questions at the end of each chapter. The questions are not intended to be just for students, and the answers are included at the end of the book. The author walks a thin line between the necessary theoretical background and the need to attract a wide audience. The issues at stake are of great concern, and the aim to raise consciousness motivates his approach. Pugh always adheres strictly to the facts, and although he maintains a rather nonquantitative approach, he still does not avoid the complexities of the calculations necessary to fully develop the analyses. References are generally good, although now in need of update. This is a very well-written book recommended to anyone generally concerned with the management of coastal areas facing increased flooding risks, policymakers and eco-activists alike, whether focused on the fate of human populations or of any other part of the ecosystem. It also would be interesting to those with particular interests in different fields of research, such as tidal periodicities, sedimentary dynamics in shallow water basins, and biotic adaptations to coastal habitats. The range of possible reasons to read this book is thus wide, and it is simply too hard to say which type of reader would benefit most from it.

References

Hopkin, M., 2007, Climate panel offers grounds for optimism: Nature, v. 447, p. 120–121.

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