

## Contents

Preface	<i>page</i> ix
Acknowledgements	xi
List of symbols	xii
<b>1 Introduction and measurements</b>	<b>1</b>
1.1 Background	1
1.2 Changing sea levels	2
1.3 Historical ideas	7
1.4 Measuring sea levels	9
1.4.1 Datums	9
1.4.2 Direct surface measurements	13
1.4.3 Fixed sensors	16
1.4.4 Satellite altimetry	21
1.4.5 Data reduction and assimilation	25
Further reading	28
Questions	28
<b>2 Tidal forces and patterns</b>	<b>29</b>
2.1 Tidal diversity	29
2.2 Gravitational attraction	33
2.3 Tidal forces: a fuller description	37
2.3.1 The Equilibrium Tide	37
2.3.2 Solar tides	39
2.4 Tidal patterns	39
2.4.1 Diurnal tides	39
2.4.2 Spring–neap cycles	41
2.4.3 Nodal cycles	42
2.5 The geoid	43
Further reading	48
Questions	48
<b>3 Analysis and prediction</b>	<b>50</b>
3.1 Non-harmonic methods	51

## vi Contents

3.2	Basic statistics	52
3.3	Harmonic analysis	55
3.3.1	Basic concepts	55
3.3.2	Application of harmonic analysis	61
3.3.3	Accuracy of tidal constituents	63
3.3.4	Harmonic equivalents of some non-harmonic terms	64
3.3.5	Analysis of satellite altimetry data for harmonics	65
3.4	Response analysis	67
3.5	Analysis of currents	69
3.6	Tidal prediction	69
3.6.1	Reference or Standard Stations	69
3.6.2	Secondary or Subordinate Stations	71
	Further reading	74
	Questions	75
<b>4</b>	<b>Tidal dynamics</b>	<b>76</b>
4.1	Tides in the real world	76
4.2	Characteristics of long waves	78
4.2.1	Long-wave propagation	78
4.2.2	Standing waves and resonance	80
4.2.3	Long waves on a rotating earth	83
4.3	Ocean tides	86
4.4	Shelf tides	93
4.5	Internal tides	100
4.6	Tidal energy	103
	Further reading	106
	Questions	107
<b>5</b>	<b>Tides near the coast</b>	<b>108</b>
5.1	Hydrodynamic distortions	109
5.1.1	Bottom friction	109
5.1.2	Finite water depth	110
5.1.3	Flow curvature	111
5.2	Representation by higher harmonics	112
5.3	Southampton tides	114
5.4	Currents in channels	117
5.5	Tides in estuaries and rivers	119
5.5.1	Spring–neap effects	120
5.5.2	Tidal bores	121
5.6	Tidal energy: turbulence and dissipation	122
5.6.1	Bottom friction	122

5.6.2	Moving amphidromes	123
5.6.3	Tidal turbulence	125
	Further reading	128
	Questions	128
<b>6</b>	<b>Weather and other effects</b>	<b>129</b>
6.1	Background	130
6.2	Some statistics of meteorological residuals	131
6.3	Responses to atmospheric pressure	134
6.4	Responses to wind	136
6.4.1	Stress laws	137
6.4.2	Wind set-up	138
6.4.3	Ekman transport	139
6.5	Some regional examples of surges	141
6.6	Seiches	147
6.7	Tsunamis	149
	Further reading	155
	Questions	156
<b>7</b>	<b>Mean sea level</b>	<b>157</b>
7.1	Calculating mean sea level	159
7.2	Spatial changes in mean sea level	161
7.3	Observed annual and inter-annual changes	163
7.3.1	Seasonal (annual) changes	164
7.3.2	Air pressure effects	165
7.3.3	Ocean circulation	165
7.3.4	Nodal MSL changes	167
7.4	Isostatic adjustment	167
7.5	Changes of water volume	171
7.5.1	Thermal expansion	171
7.5.2	Melting ice	174
7.5.3	Other effects	175
7.6	Summary of recent MSL changes	175
	Further reading	178
	Questions	179
<b>8</b>	<b>Extreme sea levels</b>	<b>180</b>
8.1	Return periods and risk	180
8.2	Ways of estimating flooding risks	182
8.2.1	Regional factors	183
8.2.2	Annual maxima	183
8.2.3	Joint tide–surge probability estimates	185

## viii Contents

8.2.4	Other methods	188
8.3	Risks and climate change	188
8.3.1	Tidal changes	189
8.3.2	Trends in weather effects	189
8.3.3	Expected MSL changes	191
8.3.4	Combined effects on flooding risk	193
8.4	Responses to changing flooding risks	195
8.4.1	Impacts of changing sea levels	195
8.4.2	Is it worth paying for protection?	199
8.4.3	Examples of responses	201
	Further reading	206
	Questions	207
<b>9</b>	<b>Tidal influences</b>	<b>208</b>
9.1	Tidal inlets	208
9.1.1	Flow in tidal channels	209
9.1.2	Inlet cross-section and the tidal prism	211
9.2	Tidal asymmetry and sediment movements	212
9.3	Salt marshes and mangroves	213
9.4	Zonation of coastal plants and animals	214
9.4.1	Patterns of exposure and submersion	215
9.4.2	Rocky shores	218
9.4.3	Sedimentary shores	220
9.5	Behaviour adaptation	221
9.6	Mean sea level: the geological record	222
9.7	Tides past	224
9.8	Legal definitions of tidal boundaries	226
	Further reading	229
	Questions	230
	Appendix 1 Tidal potential	233
	Appendix 2 Answers to selected questions	236
	Glossary	241
	References	251
	Index	255

The colour plates are situated between pages 82 and 83.