

Contents

Introduction	1
1. Overview and Summary of Eddy Science	
By A.R. ROBINSON	3
1.1 Eddy Currents in the Ocean	3
1.1.1 Observing the Eddies	4
1.1.2 Modeling the Eddies	5
1.2 Status of Eddy Science	6
1.2.1 Distribution and Generation	6
1.2.2 Physics	6
1.2.3 Role in the General Circulation	8
1.3 Influences of Eddies	9
1.3.1 Scientific Processes and Practical Consequences	9
1.3.2 Dispersion and Mixing	11
1.3.3 Description and Prediction	11
1.4 Evolution and Outlook	12
1.4.1 A Time of Transition	12
1.4.2 A Decade of Eddy Research	13
1.4.3 Eddies in Marine Science	14
Regional Kinematics, Dynamics, and Statistics	17
2. Gulf Stream Rings	
By P.L. RICHARDSON	19
2.1 Introduction	19
2.2 History	19
2.3 Cold-Core Rings	21
2.3.1 Formation	21
2.3.2 Structure and Velocity	22
2.3.3 Distribution and number	29
2.3.4 Movement	31
2.3.5 Interaction and Coalescence with Gulf Stream	32
2.3.6 Decay	38
2.4 Warm-Core Rings	39
2.5 Gulf of Mexico Rings	41

2.6 Eastern Rings	42
2.7 Current Rings from Other Currents	43
3. Western North Atlantic Interior	
By C. WUNSCH	46
3.1 Introduction	46
3.2 Observations	48
3.2.1 Spectrum and Time Scales	48
3.2.2 Spatial Scales	49
3.2.3 Kinetic and Potential Energy	56
3.3 Other Data	62
3.4 Some Simple Conclusions	64
4. The Western North Atlantic – A Lagrangian Viewpoint	
By H.T. ROSSBY, S.C. RISER, and A.J. MARIANO	66
4.1 Introduction	66
4.2 The Data Base	66
4.3 The Mean Field	67
4.3.1 The Lagrangian View	68
4.3.2 The Equivalent Eulerian View, and the Eddy Kinetic Energy Distribution	70
4.4 Mixing and Dispersion	76
4.5 Topographic Influences	78
4.6 The Eastward Flow in the Subtropical Gyre	82
4.7 Discrete Eddies	84
4.8 The Path of the Gulf Stream	87
4.9 Concluding Remarks	88
5. The Local Dynamics of Eddies in the Western North Atlantic	
By J.C. McWILLIAMS et al.	92
5.1 Introduction	92
5.2 Scientific Objectives	93
5.2.1 Dynamical Balances	93
5.2.2 Synoptic Structures	93
5.2.3 Geostrophic Fine Scales	94
5.2.4 Surface Layer Mesoscale Eddies	94
5.2.5 The General Circulation	94
5.3 The Experiment	94
5.4 The Phenomena	96
5.5 Summary	112
6. Gulf Stream Variability	
By D.R. WATTS	114
6.1 Introduction	114
6.2 The Gulf Stream Path	115

6.3	Current Structure and Transport	124
6.4	Water Masses	131
6.5	Dynamics	137
6.6	Summary	143
7.	The Northeast Atlantic Ocean	
	By W.J. GOULD	145
7.1	Introduction	145
7.2	General Oceanographic Conditions and Mean Circulation	145
7.3	Data Sources	146
7.3.1	Hydrographic Data	146
7.4	XBT Observations	147
7.5	Direct Observation of Currents	149
7.6	Satellite Observations	151
7.7	Surveys of Individual Eddies	151
7.8	Summary	156
8.	Eddy Structure of the North Pacific Ocean	
	By R.L. BERNSTEIN	158
8.1	Introduction	158
8.2	Coastal Regions	158
8.3	Mid-Latitude Open Ocean	161
8.4	Tropical Region	164
8.5	Direct Current Measurements	166
9.	Subpolar Gyres and the Arctic Ocean	
	By G.T. NEEDLER	167
9.1	Introduction	167
9.2	The Arctic Ocean	167
9.3	Labrador Sea and Northwestern Atlantic	171
9.4	The Norwegian and Greenland Seas and Their Overflows	174
9.5	The Northeast North Pacific and Bering Sea	177
9.6	Summary	180
10.	Tropical Equatorial Regions	
	By G. SIEDLER	181
10.1	Latitudinal Changes of Mesoscale Processes	181
10.2	Eddy-Resolving Arrays in the Tropics	183
10.3	Mesoscale Features in Sections	187
10.4	Mesoscale Energy in the Tropics	198
11.	Eddies in the Indian Ocean	
	By J.C. SWALLOW	200
11.1	Introduction	200
11.2	Kinetic Energy of the Seasonal Circulation	200

11.3	Arabian Sea	206
11.4	Somali Current	209
11.5	Bay of Bengal	212
11.6	Equatorial Zone	212
11.7	South Equatorial Current	214
11.8	Deep Currents in the Indian Ocean	217
11.9	Significance of Indian Ocean Eddies	218
12.	The South Pacific Including the East Australian Current	
	By A.F. BENNETT	219
12.1	Introduction: The Subtropical South Pacific	219
12.2	Observations: The Tasman Sea	223
	12.2.1 The East Australian Current	223
	12.2.2 The Tasman Front	235
12.3	Theories	237
	12.3.1 A Line Vortex and a Wall	237
	12.3.2 A Free Inertial Jet	237
	12.3.3 Baroclinic Instability of a Western Boundary Flow	239
12.4	The Significance of Eddies	240
	12.4.1 Physical Significance	240
	12.4.2 Biological Significance	241
12.5	Future Research	242
	12.5.1 The Mid-Ocean	242
	12.5.2 The East Australian Current	242
13.	Eddies in the Southern Indian Ocean and Agulhas Current	
	By M.L. GRÜNDLINGH	245
13.1	Introduction	245
13.2	South Eastern Indian Ocean	246
	13.2.1 Vicinity of the South Equatorial Current	247
	13.2.2 West of Australia	248
	13.2.3 Vicinity of the Subtropical Convergence	251
13.3	South Western Indian Ocean	252
	13.3.1 Eddies South of Madagascar	254
	13.3.2 Larger Southwestern Indian Ocean	254
	13.3.3 Adjacent to the Agulhas Current	259
	13.3.4 The Agulhas Retroflexion Area	260
	13.3.5 The Vicinity of the Agulhas Plateau	261
13.4	Discussion	261
14.	The Southern Ocean	
	By H. BRYDEN	265
14.1	Introduction	265
14.2	Observations of Eddies in the Southern Ocean	267

14.3	Eddy Generation and Decay	270
14.4	Effects Eddies and Implications for Models the Southern Ocean	275
15.	Global Summaries and Intercomparisons: Flow Statistics from Long-Term Current Meter Moorings	
	By R.R. DICKSON	278
15.1	Introduction	278
15.2	Global Kinetic Energy Estimates from Shift-Drift Analysis	279
15.3	The North Atlantic	282
15.3.1	Introduction	282
15.3.2	Ocean-Scale Patterns of Kinetic Energy	293
15.3.3	A Transect of the Western Basin	294
15.3.4	A Transect of the Eastern Basin	296
15.4	The North Pacific	301
15.4.1	The Kuroshio	301
15.4.2	Western Pacific	304
15.4.3	East-Central Pacific	305
15.4.4	Central and Eastern Tropical Pacific	306
15.5	The Equatorial Zone	307
15.6	South Atlantic	311
15.7	High Latitudes	311
15.7.1	The Antarctic Circumpolar Current	311
15.7.2	Weddell Sea	318
15.7.3	The West Spitsbergen Current	318
15.7.4	Arctic Ocean	321
15.8	Summary	323
15.8.1	Horizontal Distribution of Eddy Kinetic Energy at Midlatitudes	323
15.8.2	Vertical Structure of the Eddy Field at Midlatitudes	324
15.8.3	Vertical Eddy Structure in Ice-Covered Seas	327
15.8.4	Eddy Time Scales at Midlatitudes	327
15.8.5	Eddy Time Scales in the Equatorial Zone	328
15.8.6	Relationship of K_E to K_M Worldwide	328
16.	Global Summary: Review of Eddy Phenomena as expressed in Temperature Measurements	
	By W. EMERY	354
16.1	Introduction	354
16.2	Standard Deviation of Temperature	355
16.3	The North and Equatorial Atlantic	359
16.4	The North and Equatorial Pacific	369
16.5	Discussion	373

Models	377
17. Eddy-Resolving Numerical Models of Large-Scale Ocean Circulation	
W.R. HOLLAND, D.E. HARRISON, and A.J. SEMTNER, Jr. . .	379
17.1 Introduction	379
17.2 Review of ECGM Results	380
17.2.1 What Processes Account for the Presence of Mesoscale Variability?	381
17.2.2 Do Mesoscale Phenomena Play a Fundamental Role in the Character and Dynamics of the Time-Mean Circulation?	385
17.2.3 Where the Effects of Mesoscale Circulations Are Important, Can They Be Parametrized in Terms of Mean-Field Quantities?	390
17.2.4 How Do the Answers to Questions About the Role of Mesoscale Eddies Change as the Model Physical Processes Change?	393
17.3 Comparisons with Observations	395
17.4 Unsolved Problems and Future Prospects	401
18. Periodic and Regional Models	
By D.B. HAIDVOGEL	404
18.1 Introduction	404
18.2 Two-Dimensional Turbulence	407
18.3 The Effects of β	411
18.4 Mean Flow Generation by Localized Forcing	414
18.5 Turbulent Cascades in a Stratified Fluid	418
18.6 Scattering by Topography	423
18.7 Regional Models and Non-Local Effects	426
18.8 Comparison with Observations	432
18.9 Conclusions and Future Directions	436
Effects and Applications	439
19. Eddies in Relation to Climate	
By A.E. GILL	441
19.1 Introduction	441
19.2 Heat Flux Carried by Eddies	441
19.3 Indirect Effects of Eddies on the Heat Balance	443
20. Eddies and Coastal Interactions	
By P.C. SMITH	446
20.1 Introduction	446
20.2 Theoretical Considerations	448

20.2.1	Stratification, β -Effect	448
20.2.2	Abrupt Topography: Scattering and Reflection . . .	450
20.2.3	Refractive Effects	453
20.2.4	Bottom Friction	454
20.2.5	Longshore Currents	454
20.2.6	Generating Mechanisms and Initial Value Problems	455
20.3	Observations and Analysis	459
20.3.1	The New England Continental Rise	459
20.3.2	The East Australian Shelf	461
20.3.3	The Southeastern Coast of the U.S.	462
20.3.4	The West Florida Shelf	463
20.3.5	The Scotian Shelf	464
20.4	Anatomy of a Warm-Core Ring Interaction with the Continental Margin	465
20.4.1	Low-Frequency Current Data, Summer 1976	467
20.4.2	Offshore Forcing	471
20.4.3	Analysis and Interpretation	474
20.5	Conclusions	480
21.	Eddy-Induced Dispersion and Mixing	
	D.B. HAIDVOGEL, A.R. ROBINSON, and C.G.H. ROTH . . .	481
21.1	Introduction	481
21.2	Two-Dimensional Dispersal in the Mid-Ocean	482
21.3	Streakiness	483
21.4	Particle Motions	488
21.5	Gyre-Scale Dispersal Effects	489
21.6	Tracer Evidence for Dispersal Processes	489
22.	Eddies and Biological Processes	
	By M.V. ANGEL and M.J.R. FASHAM	492
22.1	Introduction	492
22.2	Frontal Eddies	493
22.2.1	Formation	493
22.2.2	Air-Sea Interaction Within a Ring	494
22.2.3	Horizontal Exchanges Between the Ring and Its Surroundings	495
22.2.4	Horizontal Exchange of Plankton Between a Ring and Its Surrounding Water	498
22.3	Mid-Ocean Eddies	499
22.3.1	Biological Processes in a Single Eddy	500
22.3.2	Spatial Spectrum	501
22.4	Observational Data	504
22.4.1	Scripps Transects	504
22.4.2	Gulf Stream Ring Structures	506

22.4.3	East Australian Current Rings	515
22.4.4	Incidental Observations	517
22.5	Sampling Procedures	521
22.6	Conclusions	523
23.	Eddies and Acoustics	
	By R.C. SPINDEL and Y.J-F. DESAUBIES	525
23.1	Introduction	525
23.2	Dynamic Ocean	527
23.3	Sound Propagation in a Range-Dependent Environment	529
23.3.1	Geometrical Acoustics	529
23.3.2	Normal Modes	530
23.3.3	The Parabolic Approximation	532
23.4	Analytical and Numerical Studies of Sound Propagation Through Eddies	533
23.5	Acoustic Measurements in Eddies	535
23.6	Acoustic Eddy Monitoring	540
23.7	Conclusions	541
24.	Instruments and Methods	
	By R.H. HEINMILLER	542
24.1	Introduction	542
24.2	Moored Instrumentation	543
24.2.1	Moorings	543
24.2.2	Fixed Depth Moored Current Meters	547
24.3	Moored Profiling Current Meters	552
24.4	Temperature Recorders	554
24.5	Other Moored Instrumentation	555
24.6	Drifting Instruments	556
24.6.1	Surface Drifters	556
24.6.2	Deep Drifters	556
24.6.3	Problems and Interpretations	557
24.7	Profiling Instruments	559
24.7.1	Temperature and Salinity Instruments	559
24.7.2	Nansen Bottles	559
24.7.3	CTD and STD	560
24.8	Expendable Bathythermographs	561
24.9	Current Profilers	563
24.9.1	Electromagnetic Velocity Profiler	563
24.9.2	The White Horse	564
24.9.3	Schmitz-Richardson Profiler	564
24.9.4	Other Velocity Profilers	565
24.9.5	Calibration and Intercomparison	565

Contents	XXI
24.10 Remote and Inverse Techniques	565
24.10.1 Satellite and Airborne Measurements	565
24.10.2 Tomography	566
24.11 Intercomparison Between Instrument Types	567
References	568
Subject Index	602