## Contents

1 Preliminaries

1.1 Geophysical Fluid Dynamics 1
1.2 The Rossby Number 2
1.3 Density Stratification 8
1.4 The Equations of Motion in a Nonrotating Coordinate Frame 10
1.5 Rotating Coordinate Frames 14
1.6 Equations of Motion in a Rotating Coordinate Frame 17
1.7 Coriolis Acceleration and the Rossby Number 20

2 Fundamentals

2.1 Vorticity 22
2.2 The Circulation 28
2.3 Kelvin's Theorem 33
2.4 The Vorticity Equation 34
2.5 Potential Vorticity 38
2.6 The Thermal Wind 42
2.7 The Taylor–Proudman Theorem 43
2.8 Geostrophic Motion 45
2.9 Consequences of the Geostrophic and Hydrostatic Approximations 51
2.10 Geostrophic Degeneracy 55

3 Inviscid Shallow-Water Theory

3.1 Introduction 57
3.2 The Shallow-Water Model 58
7.3 The Linear Stability Problem: Conditions for Instability 499
7.4 Normal Modes 508
7.5 Bounds on the Phase Speed and Growth Rate 514
7.6 Baroclinic Instability: the Basic Mechanism 518
7.7 Eady's Model 523
7.8 Charney's Model and Critical Layers 532
7.9 Instability in the Two-Layer Model: Formulation 547
7.10 Normal Modes in the Two-Layer Model: Necessary Conditions for Instability 551
7.11 Baroclinic Instability in the Two-Layer Model: Phillips' Model 555
7.12 Effects of Friction 562
7.13 Baroclinic Instability of Nonzonal Flows 567
7.14 Barotropic Instability 574
7.15 Instability of Currents with Horizontal and Vertical Shear 582
7.16 Nonlinear Theory of Baroclinic Instability 589
7.17 Instability of Nonparallel Flow 617

8 Ageostrophic Motion 624
8.1 Anisotropic Scales 624
8.2 Continental-Shelf Waves 628
8.3 Slow Circulation of a Stratified, Dissipative Fluid 637
8.4 The Theory of Frontogenesis 653
8.5 Equatorial Waves 670

Selected Bibliography 689

Index 705