Adiabatic Invariants in Large-scale Atmospheric Dynamics

Michael V. Kurgansky
Department of Atmospheric and Oceanic Physics, University of Concepcion, Concepcion, Chile

and

A. M. Obukhov Institute of Atmospheric Physics, Moscow, Russia
CONTENTS

FOREWORD TO THE ENGLISH EDITION vii
PREFACE ix
INTRODUCTION 1

CHAPTER 1. Equations of Motion and Conservation Laws 9
  1.1. Equations of compressible fluid dynamics 9
  1.2. Adiabatic approximation. Potential vorticity theorem 18
  1.3. Vorticity charge (potential vorticity substance) 23
  1.4. Helicity 26
  1.5. Energy and entropy of the atmosphere 31
  1.6. Atmospheric angular momentum 43

CHAPTER 2. Reduced Equations of Atmospheric Dynamics 51
  2.1. Two-dimensional atmospheric models
       ('shallow-water' approximation) 52
  2.2. Adjustment of fluid dynamic fields 62
  2.3. Filtered (quasi-geostrophic) equations 72
  2.4. Rossby waves 78
  2.5. Continuous (spontaneous) wave emission 82

CHAPTER 3. Hydrodynamic Instability of Conservative Motions 89
  3.1. Barotropic instability 89
  3.2. Baroclinic instability 97
  3.3. Linear analysis (Eady model) 106
  3.4. Two-layer Phillips' model 110
  3.5. Vertical stability of atmospheric motions. Richardon's criterion 115

CHAPTER 4. Isentropic Analysis of Large-Scale Processes 123
  4.1. Isentropic coordinates 123
  4.2. Theorem on potential vorticity 128
  4.3. Precise formulation of the available potential energy concept 130
  4.4. Diabatic transformation of potential vorticity 136
4.5. General properties of air adiabatic motion 141
  1. Gauge invariance in potential vorticity definition 141
  2. Topological invariants 143
  3. Account for compressibility of motion on isentropic surfaces 147
  4. Invariant flux tubes and their deformation 149

4.6. Isentropic potential vorticity maps and invariant flux tubes 154

4.7. Distribution of adiabatic invariants in the atmosphere 167

4.8. The concept of atmospheric vorticity charge and its applications 169

CHAPTER 5. Dissipative Processes in the Atmosphere 187
  5.1. Surface boundary layer 187
  5.2. Ekman boundary layer 193
  5.3. Ekman friction mechanism 198
  5.4. Turbulent Ekman layer 202

REFERENCES 207

INDEX 219