

AOSC 610: Dynamics of Atmosphere and Ocean - I

Instructor

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Room and Time (usual)

ATL 2428; 9:00-9:50am (M,W,F)

Extended meeting time (from 8:30am) when make-up lectures needed

Course Objective

AOSC 610 is the first of a two-semester course sequence on Dynamics of the Atmosphere and Oceans. It is a core course of the graduate program, and seeks to introduce the basic dynamical and thermodynamical principles governing geophysical flows. Quantitative analysis and rigor characterize the course, with the development of mathematical analysis skills a sought outcome.

Your coordinates and interests

Please send me an email with your contact information; include "AOSC 610" in the title line. Mention research interests, name of your advisor, degree sought, and a list of other courses being taken this semester. Let me know if you are auditing the course.

Course format

- Homework assignments: Collected but not graded; solutions passed after due date; good practice for the exams 0%
- 2 Mid-term exams (at approx. 4 week intervals) 60%
- Final Exam 40%

Detailed Course Outline

MIDLATITUDE ATMOSPHERIC CIRCULATION & DYNAMICS

1. Introduction

1.1 Dynamic Meteorology 1

1.2 Conservation of Momentum 4

1.2.1 Pressure Gradient Force 5

1.2.2 Viscous Force 6

1.2.3 Gravitational Force 8

1.3 Noninertial Reference Frames and "Apparent" Forces 9

1.3.1 Centripetal Acceleration and Centrifugal Force 10

1.3.2 Gravity Revisited 11

1.3.3 The Coriolis Force and the Curvature Effect 14

- 1.3.4 Constant Angular Momentum Oscillations 17
- 1.4 Structure of the Static Atmosphere 18
 - 1.4.1 The Hydrostatic Equation 18
 - 1.4.2 Pressure as a Vertical Coordinate 20
 - 1.4.3 A Generalized Vertical Coordinate 22
- 1.5 Kinematics 23
- 1.6 Scale Analysis 25
- Problems 26

2. Basic Conservation Laws

- 2.1 Total Differentiation 31
 - 2.1.1 Total Differentiation of a Vector in a Rotating System 33
- 2.2 The Vectorial Form of the Momentum Equation in Rotating Coordinates 35
- 2.3 Component Equations in Spherical Coordinates 37
- 2.4 Scale Analysis of the Equations of Motion 41
- 1.4 [Scales of Motion 14](#)
 - 2.4.1 Geostrophic Approximation and Geostrophic Wind 42
 - 2.4.2 Approximate Prognostic Equations: The Rossby Number 43
 - 2.4.3 The Hydrostatic Approximation 44
 - 5.6 [The Vertical Momentum Equation \(introduces Froude number\) 89](#)
- 2.5 The Continuity Equation 45
 - 2.5.1 A Eulerian Derivation 46
 - 2.5.2 A Lagrangian Derivation 47
 - 2.5.3 Scale Analysis of the Continuity Equation 48
- 2.6 The Thermodynamic Energy Equation 50
- 2.9 [Bernoulli's Theorem 45](#)
- 2.7 Thermodynamics of the Dry Atmosphere 53
 - 2.7.1 Potential Temperature 53
 - 2.7.2 The Adiabatic Lapse Rate 54
 - 2.7.3 Static Stability 54
 - 2.7.4 Scale Analysis of the Thermodynamic Energy Equation 56
 - 5.8 [The thermodynamic energy equation \(introduces Burger number\) 92](#)
- 2.8 The Boussinesq Approximation 57
- 7.1 [The Boussinesq Approximation 109](#)
- 7.2 [Anelastic Approximation 111](#)
- Problems 65

3. Elementary Applications of the Basic Equations

- 3.1 Basic Equations in Isobaric Coordinates 67
 - 3.1.1 The Horizontal Momentum Equation 67
 - 3.1.2 The Continuity Equation 68
 - 3.1.3 The Thermodynamic Energy Equation 69
- 3.2 Balanced Flow 69
 - 3.2.1 Natural Coordinates 70
 - 3.2.2 Geostrophic Flow 71

- 3.2.3 Inertial Flow 72
- 3.2.4 Cyclostrophic Flow 73
- 3.2.5 The Gradient Wind Approximation 74
- [Figure 5.2 Succinct classification 86](#)
- 3.3 Trajectories and Streamlines 78
 - [2.3 Stagnation Point 30](#)
- 3.4 The Thermal Wind 81
 - 3.4.1 Barotropic and Baroclinic Atmospheres 84
 - [3.6 The Taylor Proudman Theorem 61](#)
- 3.5 Vertical Motion 84
 - 3.5.1 The Kinematic Method 85
 - 3.5.2 The Adiabatic Method 87
- 3.6 Surface Pressure Tendency 87
- Problems 89
- 4. Circulation, Vorticity, and Potential Vorticity**
- 4.1 The Circulation Theorem 95
- 4.2 Vorticity 100
 - 4.2.1 Vorticity in Natural Coordinates 102
- 4.3 The Vorticity Equation 104
 - 4.3.1 Cartesian Coordinate Form 104
 - 4.3.2 The Vorticity Equation in Isobaric Coordinates 106
 - 4.3.3 Scale Analysis of the Vorticity Equation 107
- 4.4 Potential Vorticity 110
- 4.5 Shallow Water Equations 115
 - 4.5.1 Barotropic Potential Vorticity 118
- 5.7 *Rossby Waves*
 - 5.7.1 *Free Barotropic Rossby Waves 161*
- 4.6 Ertel Potential Vorticity in Isentropic Coordinates 120
 - 4.6.1 Equations of Motion in Isentropic Coordinates 120
 - 4.6.2 The Potential Vorticity Equation 121
- Problems 122

8. The Planetary Boundary Layer (was Chapter 5 in Holton 4th edition)

- 8.1 Atmospheric Turbulence 256
 - 8.1.1 Reynolds Averaging 256
- 8.2 Turbulent Kinetic Energy 259
- 8.3 Planetary Boundary Layer Momentum Equations 261
 - 8.3.1 Well-Mixed Boundary Layer 262
 - 8.3.2 The Flux–Gradient Theory 264
 - 8.3.3 The Mixing Length Hypothesis 264
 - 8.3.4 The Ekman Layer 266
 - 8.3.5 The Surface Layer 268
 - 8.3.6 The Modified Ekman Layer 269
- 8.4 Secondary Circulations and Spin Down 270
- Problems 275

- 6. Quasi-geostrophic Analysis** (from Holton 4th edition)
- 6.1 The Observed Structure of Extratropical Circulations 140
- [1.3 Transient Activity 11](#)
- 6.2 The Quasi-Geostrophic Approximation 146
 - 6.2.1 Scale analysis in isobaric coordinates 147
 - 6.2.2 The Quasi-Geostrophic Vorticity Equation 151
- 6.3 Quasi-Geostrophic Prediction 155
 - 6.3.1 Geopotential Tendency 157
 - 6.3.2 The Quasi-Geostrophic Potential Vorticity Equation 159
 - 6.3.3 Potential Vorticity Inversion 161
 - 6.3.4 Vertical Coupling Through Potential Vorticity 162
- 6.4 Diagnosis of Vertical Motion 164
 - 6.4.1 The Traditional Omega Equation 164
- 6.5 Idealized Model of a Baroclinic Disturbance 174
- [1.5 The Norwegian Frontal Model of Cyclones 15](#)
- Problems 176

MIDLATITUDE OCEAN CIRCULATION & DYNAMICS

- 2. An Introductory View of the Ocean** (from Williams & Follows; descriptive; schematic; observed structure)
- 2.1 [Ocean Circulation](#)
 - 2.1.1 How does the surface flow vary? 18
 - 2.1.2 How does the ocean vary in the vertical? 20
 - Why is there a thermocline? 21
 - 2.1.3 How do water masses spread over the globe? 22
 - 2.1.4 What is the effect of topography? 26
- 4. Physics Fundamentals** (from Williams & Follows; nice figures of observed flow)
- 4.2 [How is the surface circulation driven? 68](#)
 - 4.2.1 Geostrophic balance (introduces dynamic height) 70
 - 4.2.2 Ageostrophic and Ekman Flow (Figs. 4.7 and 4.8 are nice) 72
- 5. The Ekman Layer** (from Benoit Cushman-Roisin)
- 5.1 The importance of friction (introduces the Ekman number) 62
- 5.2 The Bottom Ekman layer 63
- 5.4 The Surface Ekman layer 68
- 5.6 The Ekman layer in real geophysical flows 72
- 8. Large-scale Ocean Circulation** (from Benoit Cushman-Roisin)
- 8.1 Some remarks on the ocean and atmosphere 109
- 8.2 A simple model of the midlatitude circulation 111
- 8.3 Sverdrup transport 114
- 8.4 Westward intensification 115
- 8.5 Discussion 116