

SEVERE AND HAZARDOUS WEATHER

An Introduction to High Impact Meteorology

Active Learning Exercises
Third Edition

ROBERT M. **RAUBER**

JOHN E. **WALSH**

DONNA J. **CHARLEVOIX**

Department of Atmospheric Sciences
University of Illinois at Urbana-Champaign



KENDALL/HUNT PUBLISHING COMPANY
4050 Westmark Drive Dubuque, Iowa 52002

CONTENTS

PREFACE vii

CHAPTER ONE: PROPERTIES OF THE ATMOSPHERE 1

- Exercise 1.1: Geography Overview 1
- Exercise 1.2: Atmospheric Temperature 3
- Exercise 1.3: Atmospheric Pressure 5
- Exercise 1.4: Moisture in the Atmosphere 7
- Exercise 1.5: Latent Heat 9

CHAPTER TWO: METEOROLOGICAL MEASUREMENTS 11

- Exercise 2.1: Time Conversions 11
- Exercise 2.2: Interpreting a Sounding 13
- Exercise 2.3: Instruments Used for Weather Observations 15
- Exercise 2.4: Satellite and Radar Observations 17

CHAPTER THREE: WEATHER MAPS 19

- Exercise 3.1: Decoding Observations 19
- Exercise 3.2: Contouring Weather Maps 21
- Exercise 3.3: Understanding Constant Pressure Charts 23
- Exercise 3.4: Slope of Pressure Surfaces 25

CHAPTER FOUR: FORECASTING AND SIMULATING SEVERE WEATHER 27

- Exercise 4.1: Resolution of Numerical Model Grids 27
- Exercise 4.2: Accuracy of a Numerical Model Forecast 29
- Exercise 4.3: Model Resolution and Topography 31

CHAPTER FIVE: CLIMATE, CLIMATE CHANGE, AND GLOBAL WARMING 33

- Exercise 5.1: Seasonal Temperature Variations 33
- Exercise 5.2: Solar Heating and Temperature 35
- Exercise 5.3: The Earth's Orbital Parameters and Climate 37
- Exercise 5.4: Carbon Dioxide Concentrations in the Atmosphere 39
- Exercise 5.5: Global Warming: Myth or Fact? 41

CHAPTER SIX: ATMOSPHERIC STABILITY 43

- Exercise 6.1: Environmental Lapse Rates 43
- Exercise 6.2: Lifting Mechanisms 45
- Exercise 6.3: Stability and Soundings 47
- Exercise 6.4: Lifted Index and Thunderstorm Development 49

CHAPTER SEVEN: FORCES AND FORCE BALANCES 51

- Exercise 7.1: Forces in the Atmosphere 51
- Exercise 7.2: The Horizontal Pressure Gradient Force 53
- Exercise 7.3: The Geostrophic Wind 55
- Exercise 7.4: Fronts and the Jetstream 57

CHAPTER EIGHT: THE DEVELOPMENT OF HIGH- AND LOW-PRESSURE SYSTEMS 59

- Exercise 8.1: Curvature Effect 59
- Exercise 8.2: Jetstreak Effect 61
- Exercise 8.3: Convergence and Divergence and Surface Systems 63
- Exercise 8.4: Friction and Its Effect on Winds 65
- Exercise 8.5: High- and Low-Pressure Centers 67

CHAPTER NINE: AIRMASSES AND FRONTS 69

- Exercise 9.1: Airmass Identification 69
- Exercise 9.2: Which Front Passed the Station? 71
- Exercise 9.3: Can You Find the Cold Front? 73
- Exercise 9.4: Vertical Structure of a Front 75

CHAPTER TEN: EXTRATROPICAL CYCLONES FORMING EAST OF THE ROCKY MOUNTAINS 77

- Exercise 10.1: Weather Conditions Within a Cyclone 77
- Exercise 10.2: Jetstreaks, Troughs, and Surface Low-Pressure Centers 79
- Exercise 10.3: Soundings Through Cyclones 81
- Exercise 10.4: Fronts in a Cyclone's Southern Sector 83

CHAPTER ELEVEN: EXTRATROPICAL CYCLONES FORMING ALONG THE EAST AND GULF COASTS 85

- Exercise 11.1: The Rain-Snow Line and Nor'easters 85
- Exercise 11.2: Interacting Jetstreak Circulations 87
- Exercise 11.3: Where Is the Low-Pressure Center during Heavy Snow? 89
- Exercise 11.4: Wind Direction and Nor'easters 91

CHAPTER TWELVE: FREEZING PRECIPITATION AND ICE STORMS 93

- Exercise 12.1: Where Will Freezing Precipitation Occur? 93
- Exercise 12.2: Fronts, Soundings, and Precipitation Type 95
- Exercise 12.3: How Much Ice? 97
- Exercise 12.4: Freezing Drizzle Versus Freezing Rain 99

CHAPTER THIRTEEN: LAKE-EFFECT SNOWSTORMS 101

- Exercise 13.1: Lake-Effect Processes 101
- Exercise 13.2: Lake-Effect Snow Organizations 103
- Exercise 13.3: Wind Direction and Lake-Effect Snow 105

CHAPTER FOURTEEN: COLD WAVES 107

- Exercise 14.1: Wind Chill Temperatures 107
- Exercise 14.2: The Progression of a Cold Wave 109
- Exercise 14.3: Cold Waves in North America 111

CHAPTER FIFTEEN: GREAT PLAINS BLIZZARDS 113

- Exercise 15.1: Packing the Car for a Blizzard 113
- Exercise 15.2: Blizzard Facts 115
- Exercise 15.3: Which Type of Blizzard? 117
- Exercise 15.4: Where Is the Blizzard? 119

CHAPTER SIXTEEN: MOUNTAIN SNOWSTORMS 121

- Exercise 16.1: Western U.S. Mountain Geography 121
- Exercise 16.2: Pressure Patterns, Wind Flow, and Mountain Snows 123
- Exercise 16.3: Impacts of Mountain Snowstorms 125

CHAPTER SEVENTEEN: MOUNTAIN WINDSTORMS 127

- Exercise 17.1: Characteristics of Mountain Windstorms 127
- Exercise 17.2: Foehn or Bora? 129
- Exercise 17.3: Features of a Downslope Windstorm 131

CHAPTER EIGHTEEN: THUNDERSTORMS 133

- Exercise 18.1: Characteristics of Thunderstorms 133
- Exercise 18.2: Thunderstorm Features 135
- Exercise 18.3: Thunderstorm Sizes 137
- Exercise 18.4: Frontal Squall Line Structure 139
- Exercise 18.5: Supercell Thunderstorm Structure 141

CHAPTER NINETEEN: TORNADOES 143

- Exercise 19.1: Tornado: Myth or Fact? 143
- Exercise 19.2: Tornado Wind Speeds 145
- Exercise 19.3: Tornado-Like Vortices 147
- Exercise 19.4: Probability of Experiencing a Tornado 149

CHAPTER TWENTY: HAILSTORMS 151

- Exercise 20.1: Hailstone Sizes 151
- Exercise 20.2: Hail Distribution in Thunderstorms 153
- Exercise 20.3: Polarization Diversity Radars and Hail Detection 155
- Exercise 20.4: Hailstreaks and Hailswaths 157

CHAPTER TWENTY-ONE: LIGHTNING 159

- Exercise 21.1: Lightning: Myth or Fact? 159
- Exercise 21.2: Lightning Phenomena 161
- Exercise 21.3: Lightning in the United States 163
- Exercise 21.4: Lightning Development 165

CHAPTER TWENTY-TWO: DOWNBURSTS 167

- Exercise 22.1: Aircraft and Downbursts 167
- Exercise 22.2: Downburst Indications from Soundings 169
- Exercise 22.3: Downburst Detection with Surface-based Anemometers 171

CHAPTER TWENTY-THREE: EL NIÑO, LA NIÑA, AND THE SOUTHERN OSCILLATION 173

- Exercise 23.1: Impacts of El Niño and La Niña 173
- Exercise 23.2: ENSO and the Tropical Atmosphere and Ocean 175
- Exercise 23.3: The Southern Oscillation Index (SOI) 177

CHAPTER TWENTY-FOUR: TROPICAL CYCLONES 179

- Exercise 24.1: Hurricane Structure 179
- Exercise 24.2: Hurricane Tracks 181
- Exercise 24.3: Hurricane Winds and Saffir-Simpson Ratings 183
- Exercise 24.4: Tropical Cyclones: Physical and Dynamical Processes 185
- Exercise 24.5: Potential Hurricane Impacts at Landfall 187

CHAPTER TWENTY-FIVE: FLOODS 189

- Exercise 25.1: Flood Types 189
- Exercise 25.2: Flood Locations and Timing 191
- Exercise 25.3: Weather Phenomena and Floods 193
- Exercise 25.4: Flood Safety and Preparedness 195

CHAPTER TWENTY-SIX: DROUGHT 197

- Exercise 26.1: Types and Impacts of Drought 197
- Exercise 26.2: Precipitation Deficits and Drought 199
- Exercise 26.3: Understanding Drought 201
- Exercise 26.4: Drought Weather Patterns Aloft 203

CHAPTER TWENTY-SEVEN: HEAT WAVES 205

- Exercise 27.1: Heat Index Calculations 205
- Exercise 27.2: Inversions and Surface Heating 207
- Exercise 27.3: Meteorology of Heat Waves 209
- Exercise 27.4: Urban Heat Island 211