

# Contents

## *Preface* xv

## **1** *Introduction to the atmosphere* 1

- Weather and Climate 2
- Composition of the Atmosphere 3
- The Ozone Problem 5
- Origin of the Atmosphere 8
- Exploring the Atmosphere 10
- Vertical Structure of the Atmosphere 14
  - Temperature Changes in the Vertical* 16
  - Vertical Variations in Composition* 20
  - The Ionosphere* 21

## **2** *Solar radiation* 26

- Earth-Sun Relationships 26
  - Motions of the Earth* 27
  - The Seasons* 27
  - What Are the Seasons?* 35
- Solar Radiation 35
- Mechanisms of Heat Transfer 38

Incoming Solar Radiation	40
<i>Scattering</i>	40
<i>Reflection</i>	42
<i>Absorption within the Atmosphere</i>	43
Terrestrial Radiation	44
Heat Budget	46
Latitudinal Heat Balance	48

### **3** *Temperature* 51

Heat and Temperature	51
Temperature Measurement	52
Temperature Scales	54
Air Temperature Data	56
Applications of Temperature Data	58
<i>Degree Days</i>	58
<i>Indices of Human Discomfort</i>	61
Controls of Temperature	65
<i>Land and Water</i>	65
<i>Ocean Currents</i>	67
<i>Altitude</i>	68
<i>Geographic Position</i>	70
World Distribution of Temperature	71
Cycles of Air Temperature	74

### **4** *Humidity, condensation, and atmospheric stability* 80

The Hydrologic Cycle	80
Changes of State	82
Humidity	83
Humidity Measurement	89
Condensation Aloft and Adiabatic Temperature Changes	92
Stability	94
<i>Determination of Stability</i>	94
<i>Stability and Daily Weather</i>	96
<i>Changes in Stability</i>	98
Forceful Lifting	100

Air Pollution 102

*Sources and Types of Air Pollution* 105

*Meteorological Factors Affecting Air Pollution* 107

Acid Precipitation 112

## **5** *Forms of condensation and precipitation* 118

Clouds 118

*Cloud Classification* 118

*Cloud Formation* 124

Formation of Precipitation 125

*Bergeron Process* 126

ESSAY: *Science and Serendipity,*

*by Duncan C. Blanchard* 129

*Collision-Coalescence* 131

Sleet, Glaze, and Hail 133

Precipitation Measurement 134

Fog 139

*Fogs Formed by Cooling* 139

*Evaporation Fogs* 140

Intentional Weather Modification 142

*Cloud Seeding* 143

*Fog and Cloud Dispersal* 146

*Hail Suppression* 148

*Frost Prevention* 150

## **6** *Air pressure and winds* 154

Behavior of Gases 154

Measuring Air Pressure 157

Factors Affecting Wind 160

Pressure Gradient Force 161

Coriolis Effect 165

The Geostrophic Wind 168

Curved Flow 170

Friction Layer Winds 173

How Winds Generate Vertical Motion 174

Wind Measurement 178

## **7** *Global circulation* 183

Idealized Global Circulation 185

Observed Distribution of Surface Pressure and Winds 189

The Westerlies 192

*Why Westerlies?* 193

*Jet Streams* 193

*Waves in the Westerlies* 197

Local Winds 199

*Land and Sea Breezes* 200

*Mountain and Valley Breezes* 200

*Chinook (Foehn) Winds* 201

*Katabatic Winds* 202

Global Distribution of Precipitation 202

*Zonal Distribution of Precipitation* 206

*Distribution of Precipitation over the Continents* 209

El Niño and Global Weather 212

## **8** *Air masses* 218

Source Regions 219

Classifying Air Masses 220

Air-Mass Modification 221

Properties of North American Air Masses 222

*Continental Polar (cP) and Continental Arctic (cA)*

*Air Masses* 224

*Maritime Polar (mP) Air Masses* 227

*Maritime Tropical (mT) Air Masses* 228

*Continental Tropical (cT) Air Masses* 230

## **9** *Weather patterns* 233

Fronts 234

*Warm Fronts* 235

*Cold Fronts* 237

*Stationary Fronts* 238

*Occluded Fronts* 238

- Wave Cyclone 240  
    *Life Cycle of a Wave Cyclone* 241  
    *Idealized Weather of a Wave Cyclone* 243  
Cyclogenesis 247  
Traveling Cyclones and Anticyclones 250  
Thermal Lows 254

## 10 *Severe weather* 256

- What's in a Name? 256  
Thunderstorms 257  
    *Stages in the Development of a Thunderstorm* 257  
    *Thunderstorm Formation* 260  
    *Thunder and Lightning* 263  
    ESSAY: *Lightning: Refuting the Misconceptions,*  
        *by H. Michael Mogil* 269  
Tornadoes 271  
    *The Development and Occurrence of Tornadoes* 272  
    *Tornado Destruction* 275  
    *Predicting Tornadoes* 279  
    *Doppler Radar* 281  
Hurricanes 282  
    *Profile of a Hurricane* 283  
    *Hurricane Formation and Decay* 285  
    *Hurricane Destruction* 286  
    *Hurricane Modification* 292

## 11 *Weather analysis* 295

- Synoptic Weather Charts 296  
Weather of a Wave Cyclone 301  
    ESSAY: *The National Weather Service,*  
        *by Richard E. Hallgren* 311  
Weather Forecasting 314  
Weather Forecasting and Upper-Level Flow 318  
Forecast Accuracy 321  
Satellites in Weather Forecasting 324

## 12 *Optical phenomena of the atmosphere* 331

Nature of Light 331

*Reflection* 332

*Refraction* 333

Mirages 336

Rainbows 339

Halos, Sun Dogs, and Solar Pillars 344

The Glory 347

The Corona 347

## 13 *The changing climate* 350

The Climate of Cities 350

*The Urban Heat Island* 351

*Urban-Induced Precipitation* 357

*Other Urban Effects* 361

Is Our Climate Changing? 362

Possible Causes of Climatic Change 366

*Plate Tectonics and Climatic Change* 367

*Volcanic Activity and Climate* 367

*Astronomical Theory* 372

*Solar Variability and Climate* 375

ESSAY: *Tree Rings: Predictors of Drought?*

*by Henry Lansford* 379

*Human Impact on Global Climate* 381

## 14 *World climates* 388

Climatic Classification 389

Climatic Controls: A Summary 390

*Latitude* 393

*Land and Water* 394

*Geographic Position and Prevailing Winds* 394

*Mountains and Highlands* 394

*Ocean Currents* 395

*Pressure and Wind Systems* 395

The Wet Tropics (Af and Am) 396  
*Temperature Characteristics* 397  
*Precipitation Characteristics* 398

Tropical Wet and Dry (Aw) 399  
*Temperature Characteristics* 400  
*Precipitation Characteristics* 401  
*The Monsoon* 402  
*The Cw Variant* 403

The Dry (B) Climates 403  
*What Is Meant by "Dry"?* 407  
*Tropical Desert and Steppe (BWh and BSh)* 408  
*West Coast Tropical Deserts* 412  
*Middle-Latitude Desert and Steppe (BWk and BSk)* 412

The Humid Subtropical Climate (Cfa) 413

The Marine West Coast Climate (Cfb and Cfc) 415

The Dry-Summer Subtropical Climate (Csa and Csb) 417

The Humid Continental Climate (Dfa, Dfb, Dwa, Dwb) 418

The Subarctic Climate (Dfc, Dfd, Dwc, Dwd) 421

The Polar (E) Climates 422  
*The Tundra Climate (ET)* 422  
*Ice Cap Climate (EF)* 425

**A** *Metric units* 429

APPENDIX

**B** *Explanation and decoding  
of the daily weather map* 433

APPENDIX

**C** *Correcting mercurial  
barometer readings* 443

APPENDIX

**D** *Forces and air motions* 449

APPENDIX

**E** *Laws relating to gases* 451

APPENDIX

# F

APPENDIX

*Worldwide extremes  
of temperature and precipitation  
recorded by continental area 454*

# G

APPENDIX

*Climatic data 457*

*Glossary 463*

*Index 485*