

Contents

List of Boxes	<i>page</i>	x	2.2.1 Isotherms and Temperature Maps	23
Preface		xi	2.2.2 Temperature Fronts	24
Introduction		xiii	2.2.3 Isobars and Pressure Maps	25
CHAPTER 1 Weather Variables		1	2.2.4 Highs, Lows, Ridges, and Troughs	25
1.1 Temperature		1	2.3 Upper-Level Maps	28
1.1.1 Heat and Temperature		2		
1.1.2 Thermometers		3	2.4 Radar	30
1.1.3 Temperature Measurements		4		
1.1.4 Temperature Scales		4	2.5 Satellites	32
1.1.5 Radiosonde Profiles		5	2.5.1 Visible Satellite Images	33
1.2 Pressure		6	2.5.2 Infrared Satellite Images	33
1.2.1 Force and Pressure		7	2.5.3 Water Vapor Images	36
1.2.2 Atmospheric Pressure		8	2.5.4 Geostationary Satellites	36
1.2.3 Vertical Distribution of Pressure		8	2.5.5 Polar-Orbiting Satellites	39
1.2.4 Barometers		10	Summary	42
1.2.5 Pressure Units		11	Review Questions	42
1.2.6 Some Useful Numbers		11		
1.3 Wind		12	Appendix 2.1 Important Satellite Cloud Signatures	44
1.3.1 Measuring Wind		12		
1.3.2 Reporting Wind		13	CHAPTER 3 Our Atmosphere: Origin, Composition, and Structure	46
1.3.3 Additional Sources of Wind Information		14	3.1 Aspect	46
1.4 Precipitation		15	3.2 Composition	46
1.5 Weather Stations		15	3.3 Origin and Evolution	48
Summary		17		
Review Questions		18	3.4 Future Evolution	51
Appendix 1.1 Instruments and the Birth of Modern Science		19	3.5 Vertical Structure	53
			Summary	56
			Review Questions	56
CHAPTER 2 Spatial Representations of Weather Data		20	Appendix 3.1 Dynamic Equilibrium	58
2.1 The Station Model		20	CHAPTER 4 Heat and Energy Transfer	59
2.2 Surface Maps		23	4.1 Conduction	60

4.2 Convection	60	5.7.3 Radiosonde Profiles	94
4.3 Radiation	61	5.7.4 Back to Relative Humidity	95
4.3.1 The Nature of Electromagnetic Radiation	61	5.7.5 How to Saturate	96
4.3.2 Temperature and Radiation	62	Summary	97
	62	Review Questions	97
4.4 Radiative Interactions	63	CHAPTER 6 Cloud Formation	99
4.4.1 Absorption	63	6.1 Adiabatic Processes	100
4.4.2 Reflection	65	6.2 Adiabatic Processes in the Atmosphere	102
4.4.3 Scattering	66	6.3 Dry Adiabatic Lapse Rate	103
4.4.4 Radiative Equilibrium	66	6.4 Relative Humidity during Adiabatic Processes	104
4.4.5 Selective Absorbers	68	6.5 Moist Adiabatic Lapse Rate	105
4.4.6 A Window to the Sky	70	6.6 Orographic Lifting	106
4.4.7 The Greenhouse Effect	71	6.7 Lifting by Convergence	110
4.5 Radiation and Weather	73	6.8 Frontal Lifting	111
4.5.1 Heat Imbalance	73	6.9 Atmospheric Stability and Clouds	111
4.5.2 Seasonal Variations	75	6.9.1 Stable Air	112
4.5.3 Diurnal Variations	76	6.9.2 Unstable Air and Thermals	113
4.5.4 The Influence of Clouds	78	6.9.3 Stable vs. Unstable	113
4.5.5 Land–Ocean Contrasts	78	6.9.4 Fair-Weather Cumulus Clouds	115
Summary	80	6.9.5 Conditional Instability and Cumulonimbus	118
Review Questions	81	Summary	121
	83	Review Questions	121
CHAPTER 5 Water	83	Appendix 6.1 A Cloud Family Album	123
5.1 The Water Cycle	83	Appendix 6.2 Skew-T, Log-P Diagram	127
5.2 Saturation	84	CHAPTER 7 Precipitation	130
5.3 Humidity	85	7.1 Warm vs. Cold Clouds	130
5.4 Relative Humidity	86	7.2 Collision and Coalescence	131
5.5 Humidity and Temperature	87		
5.5.1 Relative vs. Absolute Humidity	88		
5.5.2 Condensation	89		
5.6 Dew Point Temperature	91		
5.7 Applications of the Dew Point Temperature	92		
5.7.1 Surface Weather Maps	92		
5.7.2 Meteograms	92		

7.3 Ice-Crystal Growth	132	9.4 Some Large-Scale Circulations	171
7.4 Precipitation Types	135	9.4.1 West Coast vs. East Coast	171
Summary	137	9.4.2 Antarctica	172
Review Questions	138	9.4.3 The Sahel	172
Appendix 7.1 Some Optical Phenomena	139	9.4.4 The Indian Monsoon	175
CHAPTER 8 Wind	141	9.4.5 El Niño	176
9.4.6 The Madden–Julian Oscillation		9.4.7 Summary	180
Review Questions		9.4.8 Review Questions	183
8.1 Force and Acceleration	141	Appendix 9.1 Winds of the World	185
8.2 Pressure Gradient Force	142	CHAPTER 10 Air Masses, Fronts, and	
8.3 Sea Breeze and Land Breeze	143	Midlatitude Cyclones	186
8.4 Coriolis Force	144	10.1 Air Masses	186
8.5 Geostrophic Wind	146	10.2 Fronts	187
8.6 Gradient Wind	149	10.2.1 Stationary Fronts	188
8.7 Surface Winds	150	10.2.2 Cold Fronts	188
8.8 Friction	152	10.2.3 Warm Fronts	188
8.9 Topography	155	10.2.4 Occluded Fronts	189
8.9.1 Mountain Breeze and Valley Breeze	155	10.2.5 Large-Scale Influences on	
8.9.2 Katabatic Winds	157	Cyclone Structure, and the	
Summary	158	T-bone Model	190
Review Questions	159	10.3 Midlatitude Cyclone Development	191
Appendix 8.1 History in Motion	160	10.3.1 The Life Cycle of a	
CHAPTER 9 Global Wind Systems	161	Midlatitude Cyclone	191
9.1 The Averaged Atmosphere	162	10.3.2 Vertical Structure of Cyclones	192
9.1.1 Surface Temperature	162	10.3.3 The February 2014 Cyclone	195
9.1.2 Upper-Level Heights	163	10.3.4 Where Do Cyclones Form?	197
9.1.3 Surface Pressure	167	Summary	204
9.1.4 Precipitation	167	Review Questions	205
9.2 The Single-Cell Model	169	Appendix 10.1 Southern Hemisphere	
9.3 The Three-Cell Model	170	Midlatitude Cyclones	207
		Appendix 10.2 The Bergen School	
		of Meteorology	208
		CHAPTER 11 Thunderstorms	
		and Tornadoes	209
		11.1 Ordinary Thunderstorm	210

11.2 Severe Thunderstorm	211	13.5 From Forecast Grids to Reliable Forecast Values	248
11.3 Lightning and Thunder	213	13.6 Making a Forecast	250
11.4 Supercells	215	13.6.1 Medium- to Long-Range Forecasting	251
11.5 Tornadoes	217	13.6.2 Seasonal Outlook	252
11.5.1 Description	217	Summary	252
11.5.2 Tornado Development	217	Review Questions	254
11.5.3 Tornado Alley	220		
Summary	222	Appendix 13.1 Data Assimilation: From Observations to Weather Forecast Grids	255
Review Questions	224		
CHAPTER 12 Tropical Cyclones	226	CHAPTER 14 Air Pollution	256
12.1 Facts and Figures	227	14.1 Pollutants	256
12.2 Tropical Cyclone Structure	228	14.1.1 Gases and Compounds	257
12.3 Tropical Cyclone Development	233	14.1.2 Particulates	257
12.3.1 Tropical Easterly Wave	233	14.1.3 Air Quality	258
12.3.2 Tropical Depression	233	14.1.4 Photochemical Smog	258
12.3.3 Tropical Storm	234		
12.3.4 Tropical Cyclone (Hurricane)	234	14.2 Wind and Stability	259
12.3.5 Tropical Cyclone Decay	234		
12.4 Tropical Cyclone Hazards	235	14.3 Large-Scale Patterns	262
		14.4 Topography	263
		Summary	263
		Review Questions	264
12.5 Conditions for Tropical Cyclone Development	236	CHAPTER 15 Climate Change and Weather	266
Summary	236		
Review Questions	237		
Appendix 12.1 In the Eye of the Storm	239	15.1 Past and Future	267
CHAPTER 13 Weather Forecasting	240	15.2 Changing Composition	269
13.1 Weather Forecasts and Uncertainty	241	15.3 A Warmer World	269
13.2 Prognostic Equations	241	15.4 An Altered Water Cycle	270
13.3 Ensemble Forecasting	244	15.5 Changing Global Wind Systems	272
13.4 Chaos and Weather Prediction	247	15.6 Midlatitude and Tropical Cyclones in a Warmer World	273

Contents

ix

15.7 Beyond Weather	273	Appendix: Contiguous United States Reference Map	279
15.8 The Forecast	274	Glossary	280
Summary	275	References	292
Review Questions	276	Credits	293
		Index	297
Appendix 15.1 Modeling Earth's Climate	278		