
Contents

<i>Preface to first edition</i>	xiii
<i>Preface to second edition</i>	xv
<i>Acknowledgements</i>	xvi
1 Some basic ideas	1
1.1 Planetary atmospheres	1
1.2 Equilibrium temperatures	2
1.3 Hydrostatic equation	3
1.4 Adiabatic lapse rate	4
1.5 Sandström's theorem	5
Problems	7
2 A radiative equilibrium model	9
2.1 Black-body radiation	9
2.2 Absorption and emission	10
2.3 Radiative equilibrium in a grey atmosphere	12
2.4 Radiative time constants	15
2.5 The greenhouse effect	15
Problems	17
3 Thermodynamics	19
3.1 Entropy of dry air	19
3.2 Vertical motion of saturated air	19
3.3 The tephigram	22
3.4 Total potential energy of an air column	23
3.5 Available potential energy	24

3.6	Zonal and eddy energy	29
	Problems	30
4	More complex radiation transfer	39
4.1	Solar radiation: its modification by scattering	39
4.2	Absorption of solar radiation by ozone	40
4.3	Absorption by single lines	41
4.4	Transmission of an atmospheric path	44
4.5	The integral equation of transfer	45
4.6	Integration over frequency	47
4.7	Heating rate due to radiative processes	48
4.8	Cooling by carbon dioxide emission from upper stratosphere and lower mesosphere	48
4.9	Band models	49
4.10	Continuum absorption	50
4.11	Global radiation budget	50
	Problems	52
5	The middle and upper atmospheres	57
5.1	Temperature structure	57
5.2	Diffusive separation	58
5.3	The escape of hydrogen	59
5.4	The energy balance of the thermosphere	65
5.5	Photochemical processes	66
5.6	Breakdown of thermodynamic equilibrium	70
	Problems	76
6	Clouds	80
6.1	Cloud formation	80
6.2	The growth of cloud particles	80
6.3	The radiative properties of clouds	82
6.4	Radiative transfer in clouds	83
	Problems	85
7	Dynamics	88
7.1	Total and partial derivatives	88
7.2	Equations of motion	89
7.3	The geostrophic approximation	92
7.4	Cyclostrophic motion	93

7.5	Surfaces of constant pressure	93
7.6	The thermal wind equation	94
7.7	The equation of continuity	95
	Problems	97
8	Atmospheric waves	105
8.1	Introduction	105
8.2	Sound waves	105
8.3	Gravity waves	106
8.4	Rossby waves	111
8.5	The vorticity equation	113
8.6	Three dimensional Rossby-type waves	115
	Problems	118
9	Turbulence	126
9.1	The Reynolds number	126
9.2	Reynolds stresses	127
9.3	Ekman's solution	129
9.4	The mixing-length hypothesis	131
9.5	Ekman pumping	132
9.6	The spectrum of atmospheric turbulence	133
	Problems	136
10	The general circulation	138
10.1	Laboratory experiments	138
10.2	A symmetric circulation	140
10.3	Inertial instability	143
10.4	Barotropic instability	145
10.5	Baroclinic instability	147
10.6	Sloping convection	150
10.7	Energy transport	151
10.8	Transport of angular momentum	153
10.9	The general circulation of the middle atmosphere	156
	Problems	159
11	Numerical modelling	165
11.1	A barotropic model	165
11.2	Baroclinic models	166
11.3	Primitive equation models	168

11.4	Inclusion of orography	169
11.5	Convection	169
11.6	Moist processes	170
11.7	Radiation transfer	171
11.8	Inclusion of clouds	174
11.9	Sub grid scale processes	175
11.10	Transfer across the surface	176
11.11	Forecasting models	177
11.12	Other models	179
	Problems	181
12	Global observation	189
12.1	What observations are required?	189
12.2	Conventional observations	190
12.3	Remote sounding from satellites	192
12.4	Remote sounding of atmospheric temperature	193
12.5	Remote measurements of composition	199
12.6	Other remote sounding observations	201
12.7	Observations from remote platforms	203
12.8	Achieving global coverage	203
	Problems	205
13	Atmospheric predictability and climatic change	210
13.1	Short-term predictability	210
13.2	Variations of climate	212
13.3	Atmospheric feedback processes	213
13.4	Different kinds of predictability	215
13.5	Jupiter's Great Red Spot	216
13.6	The challenge of climate research	218
	Problems	219
	Appendices	224
1	Some useful physical constants and data on dry air	224
2	Properties of water vapour	225
3	Atmospheric composition	226
4	Relation of geopotential to geometric height	227
5	Model atmospheres (0–105 km)	227
6	Mean reference atmosphere (110–500 km)	236
7	The Planck function	236

8	Solar radiation	238
9	Absorption of solar radiation by oxygen and ozone	240
10	Spectral band information	242
	<i>Bibliography</i>	252
	<i>References to works cited in the text</i>	255
	<i>Answers to problems and hints to their solution</i>	259
	<i>Index</i>	265