

Contents

PREFACE TO SECOND EDITION	ix	<i>Mixing ratio</i>	26
PREFACE TO FIRST EDITION	xi	<i>Specific humidity</i>	27
1 CLIMATOLOGY AND MODERN SCIENCE	1	<i>Relative humidity</i>	27
Additional reading	2	<i>Dew-point temperature</i>	28
2 THE COMPOSITION AND STRUCTURE OF THE ATMOSPHERE	3	<i>Precipitable water</i>	28
The vertical temperature distribution	4	The condensation process	28
The chemical composition of the atmosphere	5	<i>Aerosol characteristics</i>	28
Additional reading	10	<i>Growth of cloud droplets</i>	29
3 PRESSURE, TEMPERATURE AND DENSITY RELATIONSHIPS	11	Warm-cloud precipitation	31
Pressure	11	Cold-cloud precipitation	33
Temperature	11	<i>Ice-crystal formation</i>	33
The equation of state	12	<i>Ice-crystal growth</i>	33
The hydrostatic equation	14	<i>Precipitation</i>	34
The pressure–height relationship	14	Cloud modification and rainfall augmentation	36
Additional reading	16	<i>Warm-cloud modification</i>	36
4 THE ADIABATIC PROCESS	17	<i>Cold-cloud modification</i>	37
Sensible and latent heat	17	<i>Fog dissipation</i>	37
The first law of thermodynamics	18	<i>Hail suppression</i>	38
Adiabatic processes and lapse rates	18	Additional reading	38
Potential temperature	19	6 THE TEPHIGRAM	39
Stability and instability	19	Tephigram applications	39
<i>Unsaturated air</i>	19	<i>Plotting the data</i>	39
<i>Saturated air</i>	21	<i>Normand's proposition</i>	40
Conditional instability	22	<i>Using the tephigram</i>	41
Potential (convective) instability	23	Stability and instability on tephigrams	45
Additional reading	23	<i>Absolute stability and instability</i>	45
5 MOISTURE AND PRECIPITATION	24	<i>The effect of ascent and descent on lapse rates</i>	46
Water vapour in the atmosphere	24	<i>Conditional instability</i>	46
<i>Vapour pressure</i>	25	<i>Latent instability</i>	49
		<i>Potential instability</i>	50
		<i>Changes in instability</i>	51
		<i>Stability indices</i>	51
		Additional reading	52
		7 ATMOSPHERIC HEAT TRANSFER	53
		The structure of the sun and its radiation	53
		Solar radiation	54

<i>Variations in solar output</i>	55	<i>Some effects of the thermal wind</i>	92
<i>The Milankovitch theory</i>	55	The gradient wind	93
<i>Daily and seasonal variations in solar radiation</i>	56	<i>The relative sizes of cyclones and anticyclones</i>	94
The electromagnetic spectrum	58	Comparison of gradient and geostrophic wind velocities	95
Radiation laws	58	Cyclostrophic flow	96
The attenuation of radiation	61	Inertial flow	96
<i>Absorption</i>	61	Additional reading	96
<i>Scattering</i>	62		
<i>Reflection</i>	64		
<i>Total attenuation</i>	65		
The effective temperature of the earth	67	9 VERTICAL MOTION AND CUMULUS CONVECTION	98
Terrestrial radiation	67	Classification of cumulus convective activity	99
The radiation balance	69	Radar reflectivity patterns	100
The energy balance	71	Single-cell storms	101
<i>Sensible heat flux</i>	72	<i>The thunderstorm downdraught</i>	102
<i>Latent heat flux</i>	74	<i>Mesoscale considerations</i>	104
<i>The Bowen ratio</i>	75	Multi-cell storms	104
<i>Soil heat flux</i>	75	Supercell storms	106
Advective heat transfer	76	Line storms	111
Adiabatic heat transfer	77	Inter-annual variability	113
Diurnal and annual changes in energy balance	78	Tornadoes	113
The energy balance of the earth-atmosphere system	79	Lightning and thunder	114
Sunshine and radiation over southern Africa	82	Additional reading	116
Additional reading	82		
8 HORIZONTAL MOTION AND WINDS	83	10 LARGE-SCALE WEATHER-PRODUCING PROCESSES AND SYSTEMS	117
Concepts and forces	84	The nature of convergence and divergence	117
<i>The gravitational force</i>	84	The equation of continuity	119
<i>Linear and angular momentum</i>	85	The effect of latitude	120
<i>The pressure-gradient force</i>	85	The effect of changing pressure gradients	121
<i>Coriolis force</i>	86	<i>Changes in space</i>	121
<i>The centrifugal force</i>	87	<i>Changes in time</i>	122
The geostrophic wind	87	The effect of changing radius of curvature	122
The effect of changing pressure gradients	88	Vorticity	124
<i>Changes in space</i>	88	<i>The conservation of absolute vorticity</i>	125
<i>Changes in time</i>	89	Wave perturbations	128
The effect of friction at the surface	90	<i>Gravity waves</i>	128
The effect of horizontal temperature gradients: the thermal wind	91	<i>Kelvin waves</i>	128
		<i>Rossby waves</i>	130

The relationship between low- and upper-level airflow	130
Jet streams	131
Air masses	133
Fronts, frontogenesis and frontolysis	134
Cyclones and cyclogenesis	138
Anticyclones and their effect on weather	144
Tropical cyclones	146
Additional reading	150

11 THE GENERAL

CIRCULATION OF THE SOUTHERN HEMISPHERE	151
Scales of motion	151
Energy and momentum balance considerations	152
Mean temperature and moisture conditions	153
The pressure field	154
The wind field	159
Inter-tropical convergence	161
Fronts, cyclones and anticyclones	165
Zonal and meridional patterns	167
Wave structure and semi-stationary waves	168
Travelling wave disturbances	169
Major convergence zones and cloud bands	171
The Walker Circulation	174
Monsoon systems	174
Additional reading	175

12 ATMOSPHERIC CIRCULATION

AND WEATHER OVER SOUTHERN AFRICA	176
Mean circulation patterns	176
Synoptic and other weather perturbations	178
Circulation types	185
Fine weather and mildly disturbed conditions	185
<i>Subtropical anticyclones</i>	185
<i>Coastal lows and Berg winds</i>	190

Tropical disturbances in the easterlies	191
<i>Easterly waves and lows</i>	191
<i>Subtropical lows</i>	195
Temperate disturbances in the westerlies	195
<i>Westerly waves</i>	195
<i>Cut-off lows</i>	196
<i>Southerly meridional flow</i>	197
<i>Ridging anticyclones</i>	200
<i>West-coast troughs</i>	200
<i>Cold fronts</i>	202

Other important rain-producing systems	205
<i>Thunderstorms</i>	205
<i>Tropical cyclones</i>	208
Necessity and sufficiency of synoptic and thermal forcing	209
Composite synoptic types	211
Cloud bands	212
Circulation types, cloud systems and rainfall	214
Additional reading	217

13 OCEAN-ATMOSPHERE

INTERACTIONS	218
Wind and ocean movement	218
Thermohaline circulation	222
The ocean heat engine	227
Coupled ocean-atmosphere variability	228
The Walker Circulation and ENSO	228
ENSO and South African rainfall	233
Coupled ocean-atmosphere variability in the vicinity of southern Africa	236
Additional reading	244

14 BOUNDARY-LAYER

PHENOMENA	245
Turbulence in the boundary layer	246
<i>Momentum flux</i>	246
<i>Variations in the turbulence regime</i>	246
<i>Wind-speed profiles</i>	248

<i>The Richardson number</i>	249	Pre-Quaternary changes in climate	305
<i>Heat flux</i>	249	Quaternary changes in climate	309
<i>Moisture flux</i>	250	Precessional forcing of rainfall	311
Boundary-layer modification by urban areas	252	The Last Glacial Maximum to the Holocene Altithermal	312
<i>Urban-rural contrasts</i>	252	Conditions after the Holocene Altithermal	314
<i>Airflow around buildings</i>	252	Regional coherence of late-Holocene climatic changes	317
<i>The urban heat island</i>	253	Global teleconnections	319
<i>An urban-heat-island model</i>	259	The period of historical record	321
Air-pollution climatology	260	The period of meteorological record	322
<i>Stability characteristics</i>	261	Temperature changes	323
<i>Surface inversions</i>	261	Links with rainfall elsewhere in Africa	324
<i>Elevated inversions</i>	264	Environmental implications of droughts	325
Air-pollution dispersion	264	Variations in atmospheric circulation	328
<i>Effective stack height</i>	265	<i>The wet-spell situation</i>	332
<i>Plume behaviour</i>	267	<i>The dry-spell situation</i>	334
<i>The Gaussian Plume Model</i>	268	Palaeoclimatic circulation changes	336
Mesoscale air circulations	271	Abrupt climatic changes	336
<i>Local winds on slopes and across shorelines</i>	271	Additional reading	338
<i>Regional topographically induced winds</i>	275		
<i>Some environmental implications of local winds</i>	281		
Additional reading	284		
15 THE TRANSPORT OF AEROSOLS AND TRACE GASES	285	17 THE PREDICTION OF FUTURE CONDITIONS	339
The process of transport	285	Numerical forecasting of weather	340
Trajectory modelling	286	Climate modelling and prediction	345
Local and mesoscale transport	286	Regional climatic-change scenarios for southern Africa	351
Synoptic-scale transport	288	Future modelling	354
The southern African haze layer	289	Other modelling applications	355
Transport patterns	293	Additional reading	355
<i>Transport across the Indian Ocean</i>	293		
<i>Mean transport pathways</i>	296	SYMBOLS	357
Recirculation	297	UNITS AND CONVERSIONS	360
Mean mass transport	299	GLOSSARY	364
Inter-hemispheric transport from South Africa	301	REFERENCES	377
The plume to the Indian Ocean	302	ACKNOWLEDGEMENTS	385
Additional reading	304	INDEX	387
16 CLIMATIC CHANGE AND VARIABILITY	305		