FUNDAMENTALS OF BIOMETEOROLOGY

INTERACTIONS OF ORGANISMS AND THE ATMOSPHERE

Volume I: The Physical Environment

WILLIAM P. LOWRY and PORTER P. LOWRY II

Foreword Preface

1. The earth as an Ecosystem Spaceship Earth and its ecosystems

The thermal environment of Earth	3
Feedback in systems	6
Earth's atmosphere: composition	7
Earth's atmosphere: the distribution of mass in the vertical	8
Climate and Life on Earth	9
Climate and Man	11
Box 1-1: An approximate bioclimatic history of Earth	12

1

38

38

39

2. Energy and Insolation

The Black Body

Planck's Law

Radiation terminology

Energy as the basic link in an ecosystem	15
Forms of energy	16
Heat and its forms	16
Heat transfer	17
Solar radiation: one form of heat transfer	19
Solar geometry: the sun and Earth seen from outer space	19
Solar geometry: movement of the sun as seen from Earth	22
Insolation	26
Albedo	30
Box 2-1: The Solar Constant	32
Box 2-2: Calculations of solar geometry	33
Box 2-3: Calculations of direct beam solar radiation	35
3. Radiation	
Introduction	37
Spectra	37

	Shortwave and longwave radiation	42
	Wien's Law	43
	The Stefan-Boltzmann Law	44
	Kirchhoff's Law	45
	Effective, or band, emissivity and absorptivity	47
	Emission and Absorption by living leaves	48
	Emission and Absorption by atmospheric gases	50
	The Greenhouse Effect	51
	The radiation inversion: nighttime cooling of air near	c 1
	Earth's surface	51
	Radiative properties of natural materials	53 54
	Energy balance of the Earth-Atmosphere system	54
	Box 3-1: Historical note on Black Body radiation laws Box 3-2: Mathematical and graphical forms of Planck's Law	57
	and Wien's Law	58
	Box 3-3: Effective temperatures and the Greenhouse Effect	63
4.	Environmental Temperature	
	Introduction	66
	Temperature versus Heat	66
	Observations of temperature near Earth's surface	68
	Temperature and flow of heat in soil and water	72
	Temperature and the storage of heat in air and soil	74
	The flow and storage of heat in soil	77
	Lapse rates and vertical motion in air	82
	Observations of lapse rates near Earth's surface	85
	Box 4-1: Scales of Temperature	91
	Box 4-2: Time and space variability of temperature near	
	Earth's surface	92
	Box 4-3: Thermal diffusivity and the dynamics of heat flow	• -
	in the soil	95
	Box 4-4: Mathematical analysis of field observations of air	00
	temperature profiles	98
5.	Environmental Moisture	
	Introduction	101
	Vapor pressure	102
	The Temperature-Relative Humidity-Vapor Pressure (TRe)	
	diagram	104
	Other measures of atmospheric moisture	108
	Vapor movement in the environment	108
	Moisture lapse rates and profiles just above the surface	111
	Principles of evaporation and evapotranspiration	115
	Soil moisture: basic considerations	117
	The soil moisture characteristic curve	120
	Soil moisture: liquid or film flow	120
	Soil moisture: vapor flow	123
	Soil moisture: field conditions	124

	Box 5-1: The latent heat involved in global evaporation Box 5-2: The Saturation Vapor Pressure of water	126 126
6.	Atmospheric Motion	
	Introduction	129
	The basic cause of motion	129
	Circulation cells in the atmosphere	131
	The concept of the boundary layer	133
	Wind profiles, patchiness, and plumes within boundary	
	layers	134
	Windflow around individual obstacles	136
	Windflow in complex terrain	137
	Advection	141
	Box 6-1: The variability of wind	145
7.	Structure and Transfer in a Boundary Layer	
	Introduction	150
	Turbulence	151
	Wind profiles	154
	Turbulent transfer	157
	Turbulent flux	160
	The gradient as a measure of source strength	167
	Microscale boundary layers	169
	Concluding remarks	172
	Box 7-1: Mathematical analysis of field observations on	
	wind speed profiles	173
	Box 7-2: Turbulent flux by eddy correlation	179
	Box 7-3: The aerodynamic and gradient methods for	-//
	estimating flux	181
	Box 7-4: Richardson's number and the effects of buoyancy	-0-
	on flux	182
8.	Structure and Transfer in a Canopy Layer	
	Introduction	185
	Canopy structure: the Leaf Area Index (LAI)	185
	Canopy profiles: wind speed	189
	Canopy profiles: radiation	191
	Canopy profiles: temperature	193
	Canopy profiles: water vapor	194
	Canopy profiles: carbon dioxide	194
	Profile, flux, and source strength	195
	Canopy resistance	197
	Box 8-1: Extinction and transmissivity in a canopy	200
	Box 8-2: Gradient, diffusivity, and flux in a vegetative	
	canopy	202
	Box 8-3: Series and parallel resistances in circuits	203

9. The Energy Balance Concept

Introduction	206
Terminology	207
Motivation for studies of energy balance	208
The temperature of a system	208
Four types of energy balance system	211
The radiation budget and net radiation	213
Energy Balance Type 1: observed variability of components	217
Energy Balance Type 1: estimation of components	223
Energy Balance Type 1: nature and effects of the soil heat	
flux, B	225
Energy Balance Type 2: observed variability of components	230
Energy Balance Type 2: estimation of components	234
Box 9-1: Mathematical expression of the energy balance system	236
Box 9-2: Calculations of the sensible and latent heat fluxes above Type 1 and Type 2 energy balance	-
systems	239
Box 9-3: The surface temperature as a dependent variable in a Type 1 energy balance system	240
Appendices	
A. Use of Sun Path Diagrams	244
B. Physical Units and Conversions	248
C. The Greenhouse Effect Debates	251
D. An Overview of Micrometeorological Instrumentation	263
E. Mathematical Proofs and Derivations	272
References	275
	279
Mathematical Symbols Problems	
Subject Index	300