

INTERNATIONAL GEOPHYSICS SERIES • VOLUME 21

WATER AT THE SURFACE OF THE EARTH

An Introduction to Ecosystem Hydrodynamics

DAVID H. MILLER

*Department of Geological Sciences
University of Wisconsin-Milwaukee
Milwaukee, Wisconsin*



ACADEMIC PRESS New York San Francisco London 1977
A Subsidiary of Harcourt Brace Jovanovich, Publishers

CONTENTS

PREFACE	xi
Chapter I	
Introduction	
Just What Is the Earth's Surface?	1
The Budget Idea	2
Water in Systems	5
Water Supplied by the Atmosphere to the Earth's Surface	5'
Chapter II	
Atmospheric Vapor Flows and Atmospheric Storms	
Water Vapor and Its Movement over the Earth's Surface	7
Atmospheric Storms	15
Sizes and Movement of Atmospheric Storms	25
Atmospheric Storms: Causes of Variability in Rainfall	34
References	35
Chapter III	
Point Rainfall—The Delivery of Water to an Ecosystem	
Measuring Rain and Snow	38
The Dimensions of Point Rainfall	42
The Frequency of Precipitation-Intensity Events	52
Water Delivery to Ecosystems	62
References	62
Chapter IV	
Hydrologic Storms	
The Area of Hydrologic Storms	65
Areal Syntheses	73
The Episodic Occurrence of Hydrologic Storms	81
	vii

Closing	87
References	88
Chapter V	
Large-Scale Organization of Rainfall	
Organization of Storms in Time	90
Spatial Grouping of Rainfall	97
Spatial Pattern of Annual Precipitation	107
Areal Pattern of Long-Term Changes in Rainfall	114
Associated Mass Fluxes	117
Time and Space Organization of the Water Delivered to Ecosystems	118
References	119
Chapter VI	
Reception of Water by Ecosystems	
Ecosystem Hydrodynamics	122
Delivery of Rain and Snow to Vegetation	125
Interception of Water by Vegetation	132
Storage of Rain and Snow on Foliage during Storms	134
The Outflows from Interception Storage of Rain and Snow	139
Evaporation as a Mode of Outflow from Interception Storage	145
Water Intercepted by Litter	149
Areal Redistribution of Water by Vegetation above the Soil	150
References	152
Chapter VII	
Water Detained on the Soil Surface	
Snow Cover	155
Liquid Water on the Ground	187
Outflows from Detention Storage	193
References	193
Chapter VIII	
Infiltration of Water into the Soil of an Ecosystem	
The Soil as Environment of Water	198
Infiltration of Water into the Soil	200
Influences of Vegetation on Infiltration	205
Time Differences in Infiltration	210
Infiltrated Water in Ecosystems	212
References	213
Chapter IX	
Soil Moisture	
Soil-Moisture Bookkeeping	215
Soil-Moisture Distributions in Space	224

Time Variations of Soil Moisture	228
Freezing and Melting of Soil Water	243
Outflows of Water from the Soil	247
References	248
Chapter X	
Evaporation from Wet Surfaces	
Determining Evaporation Rates	251
Evaporation from Deep Water Bodies	257
Evaporation from Shallow Water Bodies	265
Evaporation from a Wet Soil Surface	269
Evaporation	272
References	272
Chapter XI	
Evaporation from Well-Watered Ecosystems	
Transpiration of Water from Leaves	275
Evapotranspiration from Plant Communities	276
Empirical Patterns of Potential Evapotranspiration	297
Evaporation Differs with Ecosystems	301
References	301
Chapter XII	
Evaporation from Drying Ecosystems	
Bare Soil Surfaces	304
Evapotranspiration from a Drying Soil-Vegetation System	309
Variations in Evapotranspiration over Time	319
Large-Scale Patterns	334
The Era of Evaporation	341
References	342
Chapter XIII	
Water in the Local Air	
Water Vapor in the Local Air	345
Visible Forms of Water in the Local Air	353
Condensation of Vapor on the Underlying Surface	362
References	370
Chapter XIV	
Percolation from Ecosystems	
Shallow Percolation	373
Deeper Percolation	374
Mass Transports by Percolating Water	381
Significance of Percolation	386

Percolation and Recharge	389
References	389
Chapter XV	
Groundwater and Its Outflows into Local Ecosystems	
The Environments of Groundwater	392
Groundwater Recharge	394
The Volume of Stored Underground Water	395
Mass Budgets Associated with Groundwater	400
Local Outflows of Water from Underground Storage	402
Artificial Outflows from Underground Storage	410
Groundwater Budgets	419
References	420
Chapter XVI	
Surface Transports from Ecosystems	
Movement of Snow	423
Gravity-Powered Movement of Liquid Water	426
Other Forms of Mass Transport Associated with the Flow of Water at and near the Surface	442
Time Variations in Off-Site Flow	452
Off-Site Flows from Ecosystems	468
References	469
Chapter XVII	
Off-Site Yield of Ecosystems	
Outflows from Groundwater Storage	474
Water Yield as Associated with Biological Yield	485
Total Off-Site Movement of Water	492
Total Yield	514
References	515
Chapter XVIII	
Water in Ecosystems	
Environments of Water in Ecosystems	519
Unknowns and Uncertainties in Water Budgets	522
Patterns of Distribution	525
Water Is Everywhere	531
References	532
INDEX	533