



150/2632  
INSTITUT  
FÜR METEOROLOGIE U. KLIMATOLOGIE  
UNIVERSITÄT HANNOVER  
HERRENHAUSER STR. 2 • 3000 HANNOVER 21

# Meso-scale Atmospheric Circulations

B. W. ATKINSON

*Queen Mary College, University of London*

1981



ACADEMIC PRESS

*A Subsidiary of Harcourt Brace Jovanovich, Publishers*  
London New York Toronto Sydney San Francisco

# Contents

<i>Preface</i>	vii
<i>Symbols</i>	xv

## Part I Introduction

1. The Meso-scale	3
I. Introduction	3
II. Observation	3
III. Theory	13
References	20

## Part II Topographically Induced Circulations A. Mechanically Induced Circulations

2. Lee Waves	25
I. Introduction	25
A. General mechanism of lee waves	28
II. Observation	30
A. Wave characteristics	31
B. Atmospheric conditions suitable for waves	40
III. Theory	42
A. Small amplitude theory	42
B. Large amplitude theory	67
IV. Hardware models	69
V. Momentum transfer by lee waves	73
References	76
3. Downslope winds	80
I. Introduction	80
II. Observation	83
A. Surface characteristics	84
B. Climatology	87
C. Synoptic background of downslope winds	90
D. Concluding remarks	92
III. Theory	93
IV. Hardware models	105
References	106



<b>4. Circulations in Wakes</b>	109
I. Introduction	109
II. Observation	110
A. Meso-scale lee lows	110
B. Meso-scale lee vortices	112
III. Theory	115
A. Meso-scale lee lows	115
B. Meso-scale lee vortices	117
IV. Hardware models	120
References	121
<b>B. Thermally Induced Circulations</b>	
<b>5. Sea/Land Breeze Circulation</b>	125
I. Introduction	125
A. The mechanism of the sea and land breeze	125
II. Observation	127
A. Climatology	127
B. Mean surface characteristics of the tropical sea/land breeze	134
C. The sea/land breeze circulation	138
D. Factors affecting the sea/land breeze circulation	151
III. Theory	158
A. Analytical results	158
B. Numerical results	178
IV. Hardware models	206
V. The role of sea/land breezes	207
References	209
<b>6. Slope and Valley Wind Circulation</b>	215
I. Introduction	215
A. Mechanism of the slope and valley wind	217
II. Observation	219
A. Climatology of slope and valley winds	219
B. Surface characteristics of the slope and valley winds	229
C. Slope wind circulation	233
D. Valley wind circulation	238
E. Mountain–plain circulation	249
F. Effects of stability and gradient wind	250
III. Theory	251
A. Downslope winds	255
B. Upslope winds	259
C. Valley and mountain winds	267
IV. Hardware models	274
V. The role of slope and valley winds	276
References	277

**Part III**  
**Free Atmosphere Circulations**

**A. Non-convective Circulations**

<b>7.</b>	<b>Moving Gravity Waves</b>	283
	I. Introduction	283
	II. Observation	285
	III. Theory	298
	References	307

**B. Convective Circulations**

<b>8.</b>	<b>Severe Local Storms</b>	313
	I. Introduction	313
	II. Observation	316
	A. Climatology	316
	B. Extra-tropical severe local storms	318
	C. Tropical severe local storms	362
	III. Theory	365
	A. Extra-tropical severe local storms	367
	B. Tropical severe local storms	387
	References	389
<b>9.</b>	<b>Shallow Cellular Circulations</b>	399
	I. Introduction	399
	II. Observation	401
	A. Two-dimensional cells	401
	B. Three-dimensional cells	403
	III. Theory	411
	A. Medium at rest	416
	B. Flowing medium	418
	References	419
<b>10.</b>	<b>Circulations in Cyclones</b>	421
	I. Introduction	421
	II. Observation	423
	A. Extra-tropical circulations	423
	B. Tropical circulations	450
	III. Theory	464
	A. Extra-tropical circulations	464
	B. Tropical circulations	470
	IV. Hardware models	473
	References	474

<i>Author index</i>	479
<i>Subject index</i>	487