

# Contents

<b>1</b>	<b>Introduction</b>	1
1.1	Scope of the Book	1
1.2	Overview of Existing Literature	3
1.3	History of Wind Energy Generation	3
1.4	Potential of Wind Energy Generation	4
1.5	Present Status of Wind Energy Generation	5
1.6	Structure of This Book	6
	References	7
<b>2</b>	<b>Wind Regimes</b>	9
2.1	Global Circulation	9
2.2	Driving Forces	11
2.2.1	Hydrostatic Equation	11
2.2.2	Momentum Budget Equations for the Wind	12
2.3	Geostrophic Winds and Gradient Winds	14
2.4	Thermal Winds	15
2.5	Boundary Layer Winds	17
2.6	Thunderstorm Gusts and Tornados	18
2.7	Air Density	19
	References	20
<b>3</b>	<b>Vertical Profiles Over Flat Terrain</b>	23
3.1	Surface Layer (Prandtl Layer)	25
3.1.1	Logarithmic Wind Profile	28
3.1.2	Power Law	33
3.1.3	Comparison Between Logarithmic and Power Law	33
3.1.4	Vertical Wind Profile with Large Wind Speeds	40
3.2	Profile Laws Above the Surface Layer	40
3.2.1	Ekman Layer Equations	41
3.2.2	Inertial Oscillations in the Ekman Layer	42

3.2.3	Vertical Wind Profiles in the Ekman Layer . . . . .	42
3.2.4	Unified Description of the Wind Profile for the Boundary Layer . . . . .	43
3.3	Spectra . . . . .	48
3.4	Diurnal Variation of the Wind Profile . . . . .	50
3.4.1	Vertical Profiles of the Weibull Parameters . . . . .	51
3.4.2	Low Level Jets . . . . .	54
3.5	Internal Boundary Layers . . . . .	58
3.6	Wind and Turbulence Profiles Over Forests . . . . .	61
3.7	Winds in Cities . . . . .	62
3.7.1	Characteristics of Urban Boundary Layers . . . . .	63
3.7.2	Vertical Profiles of Wind and Turbulence . . . . .	65
3.7.3	Special Flow Phenomena in Urban Canopy Layers . . . . .	67
3.8	Summary for Flat Terrain . . . . .	69
	References . . . . .	70
<b>4</b>	<b>Winds in Complex Terrain . . . . .</b>	<b>75</b>
4.1	Characteristics of Boundary Layers Over Complex Terrain . . . . .	76
4.1.1	Mountain and Valley Winds . . . . .	78
4.1.2	Katabatic Winds . . . . .	80
4.2	Wind Profiles Over a Hill . . . . .	80
4.2.1	Potential Flow . . . . .	81
4.2.2	Modifications to the Potential Flow: Addition of an Inner Layer . . . . .	83
4.2.3	Modifications to the Potential Flow: Consideration of Thermal Stability . . . . .	86
4.2.4	Weibull Parameters over a Hill . . . . .	86
4.3	Wind Profiles Over an Escarpment . . . . .	87
4.4	Spectra . . . . .	91
4.5	Diurnal Variation . . . . .	91
4.6	Summary for Complex Terrain . . . . .	91
	References . . . . .	92
<b>5</b>	<b>Offshore Winds . . . . .</b>	<b>95</b>
5.1	Characteristics of Marine Boundary Layers . . . . .	96
5.1.1	Sea Surface Roughness and Drag Coefficient . . . . .	96
5.1.2	Fetch and Stability Dependent Wave Formation . . . . .	101
5.1.3	Extreme Wave Heights . . . . .	106
5.1.4	Wave Age . . . . .	108
5.1.5	Impact of the Vertical Moisture Profile . . . . .	109
5.1.6	Annual and Diurnal Variations . . . . .	110
5.2	Vertical Profiles . . . . .	110
5.3	Extreme Wind Speeds . . . . .	114

- 5.4 Turbulence . . . . . 115
  - 5.4.1 Turbulence Intensity . . . . . 116
  - 5.4.2 Wind Speed Variances. . . . . 120
  - 5.4.3 Turbulence Length Scales and Inclination Angles. . . . . 122
  - 5.4.4 Gust Events . . . . . 123
- 5.5 Weibull Parameter. . . . . 125
- 5.6 Coastal Effects . . . . . 128
  - 5.6.1 Land and Sea Winds . . . . . 128
  - 5.6.2 Low-Level Jets . . . . . 129
- 5.7 Summary for Marine Boundary Layers . . . . . 130
- References . . . . . 131
  
- 6 Physics of Wind Parks . . . . . 135**
  - 6.1 Turbine Wakes . . . . . 135
  - 6.2 Analytical Model for Mean Wind Speed in Wind Parks. . . . . 138
  - 6.3 Analytical Model for Wind Park Wakes. . . . . 144
  - 6.4 Application of the Analytical Model with  
FINO1 Stability Data . . . . . 146
  - 6.5 Risks that a Tornado Hits a Wind Park . . . . . 147
  - 6.6 Summary for Wind Parks . . . . . 150
  - References . . . . . 151
  
- 7 Outlook . . . . . 155**
  - 7.1 Size of Wind Turbines . . . . . 155
  - 7.2 Size of Offshore Wind Parks . . . . . 156
  - 7.3 Other Techniques of Converting Wind Energy . . . . . 156
  - 7.4 New Measurement and Modelling Tools to Assess  
Wind Conditions . . . . . 156
  - 7.5 Wind Resources and Climate Change . . . . . 157
  - 7.6 Repercussions of Large-Scale Wind Power Extraction  
on Weather and Climate. . . . . 158
  - References . . . . . 159
  
- Appendix A: Statistical Tools. . . . . 161**
  
- Appendix B: Remote Sensing of Boundary Layer  
Structure and Height. . . . . 177**
  
- Index . . . . . 193**



<http://www.springer.com/978-3-642-30522-1>

Wind Energy Meteorology  
Atmospheric Physics for Wind Power Generation  
Emeis, S.  
2013, XIV, 198 p., Hardcover  
ISBN: 978-3-642-30522-1