

Contents

| | |
|---|------------|
| Abstract | iii |
| Kurzfassung | vii |
| 1 Introduction | 1 |
| 1.1 Motivation | 1 |
| 1.2 State of research | 4 |
| 1.2.1 Measuring snow properties | 4 |
| 1.2.2 Deriving point snow instability | 5 |
| 1.2.3 Spatial variations of snow instability | 6 |
| 1.2.4 Causes of spatial variations | 7 |
| 1.3 Goals | 8 |
| 1.4 Outline | 9 |
| 2 Measuring snow properties relevant for snow avalanche release | 11 |
| 2.1 Introduction | 12 |
| 2.2 Methods | 14 |
| 2.2.1 Experimental data | 14 |
| 2.2.2 Miro-computed tomography of snow | 15 |
| 2.2.3 Snow micro-penetrometry | 16 |
| 2.2.4 Propagation saw test and particle tracking | 17 |
| 2.3 Results and discussion | 17 |
| 2.3.1 Density | 17 |
| 2.3.2 Effective modulus | 18 |
| 2.3.3 Fracture energy | 23 |
| 2.4 Conclusions | 24 |
| 3 A process-based approach for point snow instability estimation | 27 |
| 3.1 Introduction | 28 |
| 3.2 Methods | 31 |
| 3.2.1 Field data | 31 |

- 3.2.2 Snow micro-penetrometer 32
 - 3.2.3 Modeling 34
 - 3.3 Results 39
 - 3.3.1 Failure initiation 39
 - 3.3.2 Crack propagation 39
 - 3.3.3 Validation with signs of instability 40
 - 3.4 Discussion 42
 - 3.5 Conclusions 44
- 4 Relating simple drivers to snow instability 47**
 - 4.1 Introduction 48
 - 4.2 Methods 52
 - 4.2.1 Field data 52
 - 4.2.2 SMP signal analysis 52
 - 4.2.3 Failure initiation criterion 54
 - 4.2.4 Crack propagation propensity 54
 - 4.2.5 Drivers 55
 - 4.2.6 Relating snow instability to simple drivers 58
 - 4.3 Results 59
 - 4.3.1 General avalanche conditions 59
 - 4.3.2 Simple drivers 60
 - 4.4 Discussion 66
 - 4.5 Conclusions 69
- 5 Snow instability patterns at the scale of a small basin 73**
 - 5.1 Introduction 74
 - 5.2 Methods 79
 - 5.2.1 Field data 79
 - 5.2.2 Snow micro-penetrometer signal analysis 82
 - 5.2.3 Snow instability criteria 83
 - 5.2.4 Covariates for statistical modelling 83
 - 5.2.5 Geostatistical analyses 84
 - 5.2.6 Snow cover modelling and identification of meteorological drivers 88
 - 5.3 Results 90
 - 5.3.1 External drift model 90
 - 5.3.2 Spatial autocorrelation 92
 - 5.3.3 Spatial prediction 92
 - 5.3.4 Identifying causes of snow instability variations 101
 - 5.4 Discussion 104
 - 5.4.1 External drift model 105

5.4.2 Spatial autocorrelation 105

5.4.3 Spatial prediction 106

5.4.4 Causes of snow instability variations 107

5.5 Conclusions 108

6 Conclusions and Outlook 111

6.1 Conclusions 111

6.2 Outlook 113

A Additional data 117

Bibliography 119

Acknowledgments 139

Curriculum Vitae 141