

Contents

List of Abbreviations	1
List of Related Publications	1
Chapter 1 Introduction	1
Chapter 2 High-Rate GNSS Seismology Using Real-Time PPP with Ambiguity Resolution	9
2.1 Introduction	9
2.2 Real-Time PPP System and Algorithms	11
2.2.1 <i>Real-Time PPP Service System</i>	11
2.2.2 <i>Observation Model</i>	14
2.2.3 <i>Real-Time Precise Point Positioning</i>	17
2.2.4 <i>Real-Time Estimation of the Uncalibrated Phase Delay</i>	18
2.2.5 <i>Ambiguity Resolution for Precise Point Positioning</i>	20
2.3 Accuracy Assessment in Real-Time Scenarios	21
2.4 Application to the 2011 Tohoku-Oki Earthquake	26
2.4.1 <i>GPS Data and Analysis</i>	26
2.4.2 <i>Comparing GPS and Seismic Waveforms</i>	29
2.4.3 <i>Fault Slip Inversion</i>	35

2.5	Application to the 2010 E1 Mayor-Cucapah Earthquake	38	
2.5.1	<i>GPS Data and Analysis</i>	38	
2.5.2	<i>Comparing GPS and Seismic Waveforms</i>	41	
2.5.3	<i>Fault Slip Inversion</i>	43	
2.6	Conclusions	47	
 Chapter 3 Augmented PPP for Seismological Applications			
	Using Dense GNSS Networks	50	
3.1	Introduction	50	
3.2	Augmented PPP Approach	52	
3.3	Application of Augmented PPP Approach and Results	56	
3.4	Conclusions	70	
 Chapter 4 Temporal Point Positioning Approach for GNSS Seismology Using a Single Receiver			72
4.1	Introduction	72	
4.2	Temporal Point Positioning Approach	74	
4.3	Application of TPP Approach and Results	78	
4.4	Single-Receiver Approaches for Real-Time GNSS Seismology	87	
4.4.1	<i>Comparison of Analysis Methods</i>	87	
4.4.2	<i>Error Analysis and Precision Validations</i>	96	
4.4.3	<i>Application to the 2011 Tohoku-Oki Earthquake</i>	109	
4.5	Conclusions	117	
 Chapter 5 Tightly-Integrated Processing of Raw GNSS and Accelerometer Data			120
5.1	Introduction	120	

5.2	Overview of Combining GPS and Accelerometer	
	Data	121
5.3	The Tightly-Integrated Algorithm	123
5.4	Results	127
	5.4.1 <i>Comparison of GPS, Seismic and Integrated</i>	
	<i>Waveforms</i>	128
	5.4.2 <i>Detection of P-Wave Arrival</i>	147
	5.4.3 <i>Extraction of Permanent Offset and Fault</i>	
	<i>Slip Inversion</i>	152
5.5	Conclusions	155
Chapter 6	Conclusions and Outlook	157
References	162
Acknowledgments	175