

Geodätisch-geophysikalische Arbeiten in der Schweiz

(Fortsetzung der Publikationsreihe
«Astronomisch-geodätische Arbeiten in der Schweiz»)

herausgegeben von der

Schweizerischen Geodätischen Kommission
(Organ der Schweizerischen Akademie der Naturwissenschaften)

Sechzigster Band
Volume 60

Modeling and Validating Orbits and Clocks Using the Global Positioning System

SUB Göttingen
215 093 534

7



2002 B 3820

G2

Timon Anton Springer

2000

Contents

1	Introduction	1
2	The Global Positioning Systems and Their Observables	5
2.1	The GPS	5
2.2	The GLONASS	10
2.3	The Observation Equations	11
2.3.1	Code Observation Equation	12
2.3.2	Phase Observation Equation	12
2.3.3	Measurement Delays	13
2.4	Forming Differences	14
2.4.1	Single Differences	14
2.4.2	Double Differences	15
2.5	Relevant Linear Combinations and their Characteristics	15
2.5.1	The Ionosphere-free Linear Combination	16
2.5.2	The Geometry-free Linear Combination	17
2.5.3	The Wide-lane Linear Combination	17
2.5.4	The Melbourne-Wübbena Linear Combination	18
3	Modeling the Observables	19
3.1	Definitions of the Time Systems	19
3.1.1	Dynamical Time	19
3.1.2	Atomic Time	20
3.2	Reference Systems	21
3.2.1	Terrestrial Reference System	21
3.2.2	Celestial Reference System	22
3.2.3	Transformation between the Celestial and Terrestrial System	22
3.3	The Station Model	23
3.4	The Satellite Orbit Model	23
3.4.1	Equations of Motion	23
3.4.2	Orbit Improvement	25
3.4.3	Accelerations Acting on the GPS Satellites	27

4	The International GPS Service and its Products	29
4.1	The International GPS Service	29
4.2	The Center for Orbit Determination in Europe	30
4.2.1	Daily Global Routine Processing at CODE	32
4.2.2	Daily European Routine Processing at CODE	35
4.3	IGS Products and their Quality	36
4.3.1	Orbits	36
4.3.2	Earth Rotation	37
4.3.3	Station Coordinates and Velocities	37
4.4	Using IGS Products for EUREF	39
5	Investigations Based on CODE and IGS Products	43
5.1	Developments at CODE	43
5.1.1	Reference Frame Changes	43
5.1.2	Orbit and Clock Changes	46
5.1.3	ERP Estimation with Sub-Daily Resolution	48
5.1.4	Other Processing Changes	49
5.2	Open Issues	52
5.2.1	The Geocenter Y-Shift	52
5.2.2	Antenna Phase Center Offsets	54
5.3	Summary	58
6	Solar Radiation Pressure Models	61
6.1	Solar Radiation Pressure	61
6.1.1	Satellite Eclipses	62
6.1.2	Earth Albedo Radiation	63
6.2	The ROCK Models	64
6.2.1	Model Characteristics	66
6.2.2	The Y-Bias	66
6.2.3	Accuracy of the ROCK Models	67
6.2.4	Outgassing	68
6.3	The Extended CODE Orbit Model	68
6.3.1	Orbit Estimation Using GPS Observations	70
6.3.2	Orbit Determination Using GPS Orbits as Pseudo-Observations	71
6.4	Deriving the CODE Solar Radiation Pressure Model	76
6.5	Evaluation of the CODE Solar Radiation Pressure Model	82
6.6	Comparison of Different RPR Models	84
7	Orbit Validation using SLR Observations	87
7.1	Motivation	87
7.2	Basics of SLR	87
7.2.1	GPS Retroreflector Array	89

7.3	Validation of GPS-based Orbit Estimates	89
7.3.1	SLR Observations of Satellite Eclipses	93
7.4	Investigating the Microwave–SLR Bias	94
7.4.1	A Look at the GLONASS SLR Tracking Data	95
7.4.2	The Residuals	97
7.4.3	SLR-based Orbit Estimates of the GPS Satellites	98
7.5	Summary	102
8	Processing Undifferenced GPS Data	105
8.1	Cleaning Undifferenced GPS Data	105
8.1.1	Melbourne-Wübbena Data Screening	106
8.1.2	Geometry-Free Data Screening	108
8.1.3	Ionosphere-Free Data Screening	108
8.1.4	Code Smoothing	108
8.1.5	Reliability and Possible Enhancements	109
8.2	Time Transfer using the GeTT Terminals	110
8.2.1	Motivation	110
8.2.2	Clock Estimation	112
8.2.3	Zero and Short Baseline Tests	113
8.2.4	Long Baseline tests	117
8.3	IGS Satellite Clock Estimates	126
8.3.1	Precise Point Positioning	127
9	Summary and Outlook	129
A	The CODE RPR-Model	133
A.1	Time Series of the Parameters of the Extended Orbit Model	133
A.2	Direct Solar Radiation Pressure Accelerations	133
A.3	Y-bias Accelerations	133
A.4	Z1 Accelerations	134
A.5	Momentum Wheel Problems	134
A.6	The CODE RPR Model	134
B	SLR residuals	143
B.1	SLR Residuals as a Function of Elevation	143
	Bibliography	147