

Contents

1	Computation of Green's Functions for Ocean Tide Loading	1
1	Introduction.	1
2	Equations of Motions and Rheology.	3
3	Spheroidal and Toroidal Motions.	6
4	Fluid Core.	12
5	Resonance Effects	16
6	Boundary Conditions	17
7	Simple Earth Models and Love Numbers	21
8	Degree-1 Response and Translational Invariance	26
9	Numerical Methods	28
10	Rheology: Viscosity and Anelasticity	32
11	Green's Functions	35
12	Final Remarks	40
	Appendix 1: Lyapunov-Transformed Matrices	41
	Appendix 2: Analytical Solution for a Homogeneous Earth	42
	Appendix 3: Analytical Solution for a Homogeneous Fluid Inner Sphere	47
	Appendix 4: Tiny Fluid Sphere	49
	Appendix 5: Gravity Green's Function and Kummer Transform	50
	References	50
2	General Relativity and Space Geodesy	53
1	Background.	53
1.1	Introduction.	54
1.2	Basic Implications of GRT for Space Geodesy Techniques	56
2	Satellite Laser Ranging.	56
2.1	Shapiro Delay	59
2.2	GRT Accelerations.	60
2.3	SLR Tests of General Relativity Theory	69
3	Global Positioning System	76
3.1	Reference Frame Issues.	76

3.2	Clock and Frequency Effects	76
3.3	General Relativistic Accelerations	84
3.4	Spatial Curvature Effect on Geodetic Distance.	85
4	Very Long Baseline Interferometry	85
4.1	Gravitational Delay	85
4.2	General Relativistic Tests Using VLBI	86
5	Concluding Remarks	89
	References	90
3	Global Terrestrial Reference Systems and Their Realizations	97
1	Introduction.	97
2	Basic Concepts and Fundamentals	100
3	International Terrestrial Reference System	101
3.1	ITRS Definition	101
3.2	Positions and Displacements of Reference Points.	103
4	International Terrestrial Reference Frame	106
4.1	IERS Network	106
4.2	History of ITRS Realizations.	110
5	The Latest Realization, the ITRF2008	112
5.1	ITRF2008 Input Data	112
5.2	ITRF2008 Data Analysis.	114
5.3	ITRF2008 Results	119
5.4	Comparison of ITRF2008 and DTRF2008.	120
5.5	Transformation Parameters from ITRF2008 to Past ITRF Realizations	122
6	Discussion and Challenges for the Future	124
6.1	IERS Network, Co-Location Sites and Local Tie Vectors	125
6.2	Input Data for the ITRF Computations	125
6.3	Nonlinear Station Motions.	126
6.4	Effect of Large Earthquakes	127
6.5	Combination Methodology and Datum Definition	128
	References	129
4	Photogrammetry	133
1	Introduction.	133
1.1	Definition and Short History	133
1.2	Applications and Limitations	136
2	Image Acquisition	137
2.1	Aerial Cameras	137
2.2	Planning the Photo Flight	149
3	Image Georeferencing.	155
3.1	Coordinate Systems in Photogrammetry	155
3.2	Indirect Georeferencing.	158
3.3	Semi-Direct Georeferencing.	165

3.4	Direct Georeferencing	167
4	Image Processing	171
4.1	Stereoplotting	172
4.2	Three-Dimensional Modelling	172
4.3	Orthorectification	178
	References	182
5	Regional Gravity Field Modeling: Theory and Practical Results	185
1	Introduction.	185
2	Fundamentals of Physical Geodesy	187
2.1	Reference Systems	187
2.2	Newton's Law of Gravitation and Potential	192
2.3	The Earth's Gravity Field	198
2.4	The Geoid and Heights	201
2.5	The Normal Gravity Field	208
2.6	Temporal Gravity Field Variations and the Atmosphere	212
3	Gravity Field Modeling	217
3.1	Geodetic Boundary Value Problems	217
3.2	Linearization of the Boundary Conditions	218
3.3	The Constant Radius Approximation	228
3.4	Solutions to Molodensky's Boundary Value Problem	232
3.5	Solutions to Stokes's Boundary Value Problem	235
3.6	The Spectral Combination Technique	237
3.7	Least-Squares Collocation	241
3.8	Astronomical Leveling	244
3.9	The Remove-Compute-Restore Technique and Topographic Effects	247
4	Practical Results	251
4.1	Data Requirements	251
4.2	The European Gravity and Geoid Project	255
4.3	The European Gravity and Terrain Data	256
4.4	Development of the European Quasigeoid Model EGG2008	261
4.5	Evaluation of the European Quasigeoid Model EGG2008	272
4.6	Summary and Outlook	281
	References	282
6	Regularization and Adjustment	293
	Part I: Regularized Solution to Ill-Posed Problems	293
1	Introduction.	293
2	Unstable Analysis of Least Squares Solution to Ill-Posed Observation Equation	294
3	Regularized Solution to Ill-Posed Observation Equations	297
3.1	Solution to Rank-Deficient Observation Equations	297
3.2	Regularized Solution to Ill-Posed Observation Equations	298

4	Determination of the Regularization Parameter	302
5	Numerical Cases	306
6	Summary	309
	Part II: Adjustment	310
7	Introduction.	310
8	Least Squares Adjustment.	310
	8.1 Least Squares Adjustment with Sequential Observation Groups	312
9	Sequential Least Squares Adjustment	314
10	Conditional Least Squares Adjustment	315
	10.1 Sequential Application of Conditional Least Squares Adjustment	317
11	Block-Wise Least Squares Adjustment	319
	11.1 Sequential Solution of Block-Wise Least Squares Adjustment	321
12	Equivalently Eliminated Observation Equation System.	323
	12.1 Diagonalized Normal Equation and the Equivalent Observation Equation	326
13	A Priori Constrained Least Squares Adjustment.	327
	13.1 A Priori Parameter Constraints.	328
	13.2 A Priori Datum	329
	13.3 Quasi-Stable Datum	331
14	Summary	333
	Bibliography	334
7	Very Long Baseline Interferometry for Geodesy and Astrometry. .	339
1	Introduction.	340
	1.1 Geometric Principle	340
	1.2 History and Technological Developments	341
	1.3 Data Acquisition	343
	1.4 Data Analysis	347
2	Theoretical Delays	348
	2.1 Station Coordinates at the Time of Observation.	348
	2.2 Earth Orientation	349
	2.3 General Relativistic Model for the VLBI Time Delay.	351
	2.4 Troposphere Delay Modeling.	355
	2.5 Antenna Deformation	358
	2.6 Axis Offsets	359
	2.7 Source Structure.	360
	2.8 A Few Examples of Constituents of the Delay.	360
3	Least-Squares Adjustment in VLBI	361
	3.1 The Concept of Piecewise Linear Offsets	362
	3.2 Global VLBI Solutions	363
4	Results from Geodetic VLBI and the IVS.	365

Contents	xix
5 The Next Generation VLBI System, VLBI2010.	369
6 Concluding Remarks	371
References	371
Index	377