Gravity Field Determination at the AIUB - the Celestial Mechanics Approach

IAG GS002-Gravity Field

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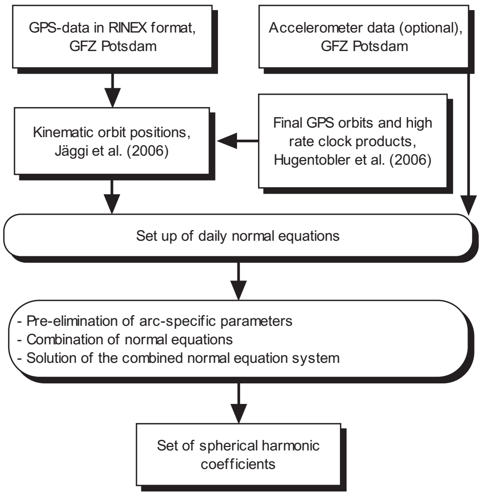
Introduction

Our approach of gravity field estimation is based on GPS-derived positions and accelerometer observations of low Earth orbiters (LEOs). Kinematic satellite positions are used as pseudo-observations in order to solve for the fully normalized spherical harmonic (SH) coefficients of the Earth's gravity field in a generalized orbit determination problem. Apart from the SH coefficients, arc-specific parameters are estimated. Pseudo-stochastic pulses absorb modeling deficiencies, e.g., non-gravitational forces, without affecting gravitational signal too much.

Model fact sheet: gravity field model AIUB-CHAMP01Sp

Maximum degree:	90
Method:	general orbit determination by numerical integration
Parametrization:	along-track polynomial, empirical 1/rev coefficients, pseudo-stochastic pulses, initial conditions
Regularization:	none
Arc length of orbits:	1 day
Used data:	CHAMP 30s GPS data (March 2002 – March 2003), no accelerometer data

Processing scheme



Ground coverage and solution quality

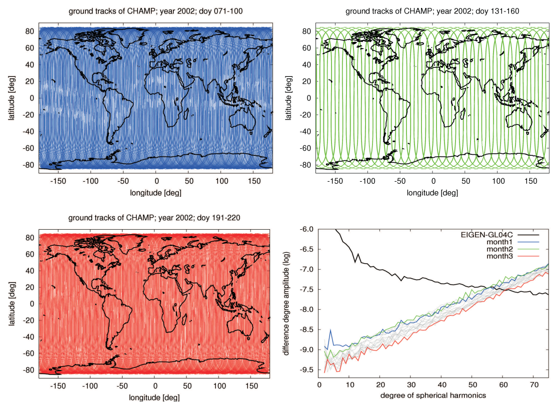


Fig. 1 Comparison of ground track coverage and difference degree amplitudes of three monthly CHAMP solutions (month1: days 71-100, month2: days 131-160, month3: days 191-220).

The figures show a strong influence of the ground track coverage on the gravity field solution. Repeat orbits (month2) result in a lower quality of the estimated SH coefficients. Systematic data gaps nearly parallel to the equator cause even worse results (month1).

Impact of different background models

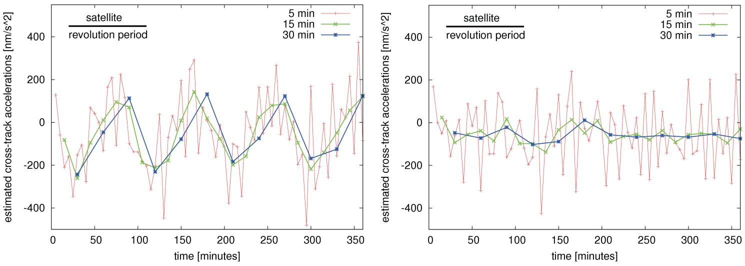
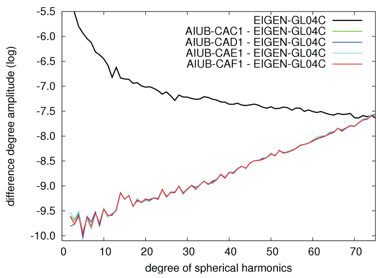


Fig. 2 (above) Estimated piecewise constant accelerations of CHAMP in cross-track direction on DOY 196, 2002 when using an ocean tide model up to degree 4 (above left picture) and degree 20 (above right picture), respectively.

Fig. 3 (right) Different one-year gravity field solutions with the same parametrization: CAC1 and CAD1 use an ocean tide model up to degree 4, CAE1 and CAF1 use an ocean tide model up to degree 20. CAC1 and CAE1 use accelerometer data while CAD1 and CAF1 don't. The solutions show that the pseudo-stochastic pulses compensate for mismodelled forces very efficiently. All gravity field solutions are very similar.



Parametrization optimization and quality assessment

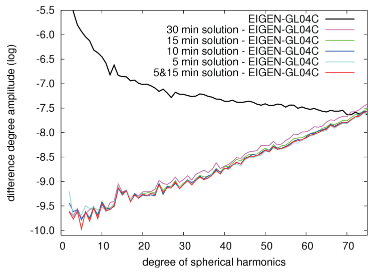


Fig. 4 One-year CHAMP solutions using different pulse interval lengths. Pulse intervals of 15 min produce the best solutions for the low degree SH coefficients while intervals of 5 min give good estimates for the higher degrees. A superposition of both delivers a good overall solution (=> AIUB-CHAMP01Sp).

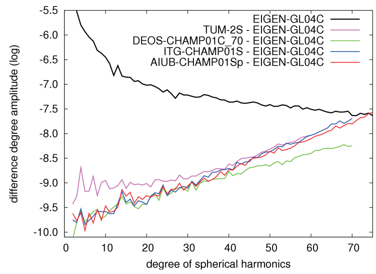


Fig. 5 Comparison of the AIUB-CHAMP01SP with well known CHAMP-only gravity field solutions (see ref.). The ITG-CHAMP01S is the best comparable model, because it is based on a comparable approach, uses the same data set of one year CHAMP data, and is also not affected by regularization.

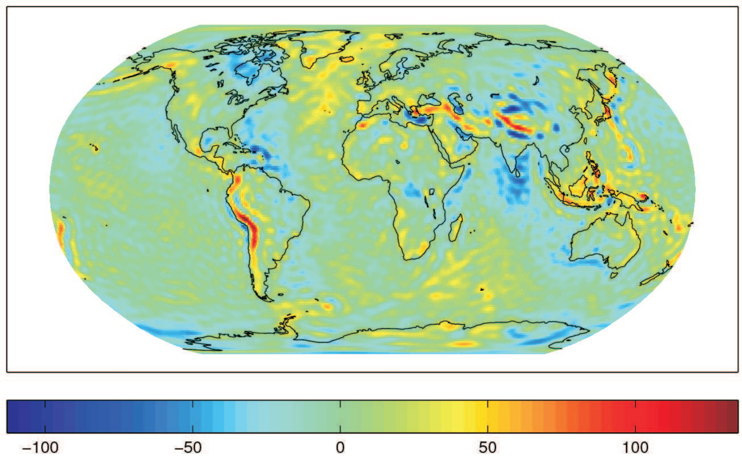


Fig. 6 Gravity anomalies [mGal] of the AIUB-CHAMP01Sp gravity field model up to degree 70.

Comparison of selected gravity field models (see ref.) with EIGEN-GL04C on a latitude-weighted 1x1 degree grid

Compared models	Type of comparison		Spectral range of SH coefficients 0-30	0-50	0-70
EGM96 – EIGEN-GL04C	undulation [cm]:	RMS	8.2	16.7	22.4
		max.	111.5	375.4	631.3
		min.	-93.3	-248.5	-417.2
	anomaly [mGal]:	RMS	0.29	0.97	1.69
ITG-CHAMP01S – EIGEN-GL04C	undulation [cm]:	RMS	1.3	5.5	26.4
		max.	6.7	31.2	153.9
		min.	-6.2	-31.1	-161.2
	anomaly [mGal]:	RMS	0.04	0.37	2.57
AIUB-CHAMP01Sp – EIGEN-GL04C	undulation [cm]:	RMS	1.4	5.2	22.2
		max.	7.7	30.5	137.6
		min.	-7.6	-32.9	-127.3
	anomaly [mGal]:	RMS	0.05	0.35	2.15

Summary

The comparison with other models using the same one-year set of CHAMP data shows that the Celestial Mechanics approach provides comparable results like other CHAMP-only models. The strength of our method is its flexible handling of pulses. The number of pulses as well as their constraints can be adjusted to the amount of the remaining model deficiencies on the normal equation level. So even the use of accelerometer data becomes dispensable without degrading the quality of the gravity field solution. The resulting preliminary solution shows its potential especially in the upper part of the SH spectrum. On the other hand there are still minor problem in the low degree SH coefficients.

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