Gravity field determination at the AIUB based on GPS data

Abstract

We use GPS-derived kinematic LE0 satellite positions as pseudo-observations in order to solve for the spherical harmonic (SH) coefficients of the Earth's gravity field in a generalized orbit determination problem (Celestial Mechanics Approach). Apart from the (SH) coefficients, each daily arc is characterized by a set of initial conditions, dynamical orbit parameters, and pseudo-stochastic pulses. The daily solutions are combined on the normal equation level.

The gravity field model AIUB-CHAMP01S (Prange et al., 2008), based on one year of CHAMP kinematic orbit positions (Jäggi et al., 2006), was generated using the described Celestial Mechanics Approach without making use of accelerometer data. External validations show that our results are comparable in quality with the best alternative approaches based on GPS data only. Experiments with real data revealed that our results do not improve when including CHAMP accelerometer data in our approach. This empirical finding is supported by a simulation study presented here.

Last but not least the latest efforts in GPS-based gravity field determination at the AIUB are outlined.

AIUB-CHAMP01S fact sheet

Maximum degree: 90
Method: orbit determination by numerical integration of variational equations
Parametrization: along-track polynomial, empirical 1/rev coefficients, pseudo-stochastic pulses (interval: 5/15 minutes), initial conditions
Orbit arc length: 1 day
Regularization: none
Data: CHAMP kinematic orbit positions (March 2002-March 2003, 943 235 observation epochs), no accelerometer data

Internal validation

Fig. 1 Differences of the AIUB-CHAMP01S and other solutions with EIGEN-GL04C

Fig. 2 Differences between terrestrial measured geoid heights and geoid heights derived from different gravity field models (AIUB-CHAMP01S, ITG-CHAMP01E, EIGEN-GL04C) in Germany. Cutoff degree 60. Unit: m.

Simulation study

In order to get more insight into our gravity field estimation technique and to study the influence of different error sources, a simulation study was performed. CHAMP orbit parameters were generated for a time period of 20 days. The gravity field model EIGEN-GL04C up to degree 120 served as truth. Different versions of the orbit positions have been generated with different non-gravitational acceleration models switched on or off. The non-gravitational forces were taken from real accelerometer data. From the simulated orbits positions (see Tab. 3) and gravity field parameters have been estimated using different parameterizations. In the gravity field estimation process different model defects have been "activated" to study their impact on the solutions.

Scenario 1: omission errors only
Scenario 2: unmodeled non-gravitational accelerations only
Scenario 3: Scenario 1 + Scenario 2
Scenario 4: Scenario 3 + noise (RMS of position: 2 cm)

The simulation study showed, how dynamical (without acc. data: constant acceleration and coefficients of a periodic function in radial, along-track and cross-track direction) and pseudo-stochastic orbit parameters compensate for unmodeled gravitational and non-gravitational effects. In order to compensate for the omission errors, the estimation of many orbit parameters is necessary for our approach. However, the orbit parameters cannot completely absorb this effect. In a realistic scenario (presence of omission errors and observation noise) the impact of the non-gravitational accelerations becomes even more obvious.

The remaining non-gravitational effects can be sufficiently absorbed by the orbit parameters, which have to be estimated anyway in order to compensate for the omission errors. This renders the effect of accelerometer data negligible in a realistic scenario.

GPS orbit and clock reprocessing

With support of the CODE IGS analysis center, located at the AIUB, a reprocessing of the GPS satellite orbits and clock corrections has been initiated. The reprocessing incorporates the latest IGS satellite and clock changes. The goal is to have a fully consistent up-to-date set of GPS orbit and clock products for the years 2002 to 2007. This allows the computation of consistent CHAMP and GRACE orbits, which will be the basis for future multi-year gravity field solutions. Based on these reprocessed GPS products the generation of GPS satellite clocks with the higher sampling rate of 10s is performed, allowing us to benefit from the full sampling rate of the CHAMP and GRACE GPS receivers.

Summary

We use the Celestial Mechanics approach for gravity field determination at the AIUB. Our first official solution AIUB-CHAMP01S is based on one year of CHAMP kinematic orbit positions. The external validations show that our results are comparable in quality with the best gravity field models using the same data set as the AIUB-CHAMP01S was produced without the use of accelerometer data. We accomplished a simulation study, which clearly showed that the estimation of many pseudo-stochastic orbit parameters not only compensates for omission errors and modeling errors (e.g. inconsistent solid earth tides), but also for unmodeled non-gravitational effects. The validation and the simulation study proved the suitability and good performance of the Celestial Mechanics Approach for gravity field determination based on kinematic orbit positions. Our current activities concentrate on the generation of a consistent set of GPS orbits and clock corrections using the improved data input set and standard deviation model.

References

L. Prange, Lars Prange, June 2008 Astronomical Institute of the University of Bern 

Poster compiled by Lars Prange, June 2008 Astronomical Institute of the University of Bern 

Poster ID: S2-181