Global geodetic parameters obtained from 14 years Lageos 1 Satellite Laser Ranging

Nikolay Dimitrov[1], Ivan Georgiev[1], Anton Ivanov[1]

[1]National Institute of Geophysics, Geodesy and Geography – Bulgarian Academy of Sciences, Bulgaria

Abstract. Satellite Laser Ranging (SLR) data of the geodynamic satellite Lageos-1 (LAser GEOdynamics Satellite) for the period January 2000 - June 2013 are processed and analysed through sequential estimation to obtain multiyear solution for global geodetic parameters - coordinates and velocities of 37 stations located on the main tectonic plates. The analysis is carried out with the Satellite Laser Ranging Processor (SLRP) software, version 4.3, developed in the Department Geodesy of the National Institute of Geophysics, Geodesy and Geography at Bulgarian Academy of Sciences. The software consists of two main programs – orbit determination and parameter estimation modules. Total number of 202 447 measurements are processed and analysed by monthly batches. Arc dependent parameters, geogravitational parameter - GM, Earth Orientation Parameters (pole coordinates and length of the day - LOD), along track and solar radiation pressure coefficients are obtained from monthly solutions. The weighted root mean squares of the monthly station coordinates solution are between 2 and 16 mm. The analysis of monthly GM time series reveal value of the secular trend $\dot{G}/G$ = -3.31. $10^{-13}yr^{-1}$. The results obtained contribute to the monitoring of recent tectonics of the major continental plates and global geodynamic parameters.

Introduction

The laser ranging of satellites is one of the most accurate modern methods of satellite geodesy for estimation the absolute geocentric coordinates of tracking stations, satellite orbits, geocentric variations; the variations of Earth's potential over time; monitoring of movements of continental plates and post-glacial rebound. Laser ranging activities are organized under the International Laser Ranging Service (ILRS) which provides global satellite and lunar laser ranging data and their derived data products to support research in geodesy, geophysics, Lunar science and fundamental constants.

The Department of Geodesy of the National Institute of Geophysics, Geodesy and Geography (former Central laboratory of Geodesy) is an associate member of Analysis Centers of the International Laser Ranging Service, ILRS. The ILRS develops the necessary global standards/specifications for laser ranging activities and encourages international adherence to its conventions. The results of the analysis of laser measurements are fundamental to the International Terrestrial Reference Frame (ITRF), which is established and maintained by the International Earth Rotation and Reference Systems Service (IERS).

Software for processing and analysis of the laser measurements

Developed in the Department of Geodesy of the National Institute of Geophysics, Geodesy and Geography (NIGGG) a specialized software package for processing and analysis of Satellite Laser Ranging data - Satellite Laser Ranging Processor (SLRP v4.3), provides broad possibilities to explore the shape, size, and dynamics of the Earth and its interaction with the atmosphere and the oceans. The software consists of two modules - a dynamic orbital module for determining the satellite orbit, obtaining the partials of the evaluated parameters and design the observation equations. The second module is for parameter estimations and obtaining the final values of the unknowns.

The orbital module integrates the satellite motion and variational equations and design observational equations. They contain the epoch of observation and the geometric and dynamic partials to estimated parameters. Geometric parameters are: coordinates and velocities of the observation stations; range and time biases; Earth Orientation Parameters - pole coordinates and length of the day (LOD). Dynamic parameters are: the initial state (coordinates and velocities) of the satellite for the respective orbital arc; the constituents of the Earth and ocean tides; Love and Shida numbers; geogravitational parameter (GM) and the gravitational parameters of the Moon and the Sun; empirical force coefficient, radial acceleration and solar radiation pressure coefficients.

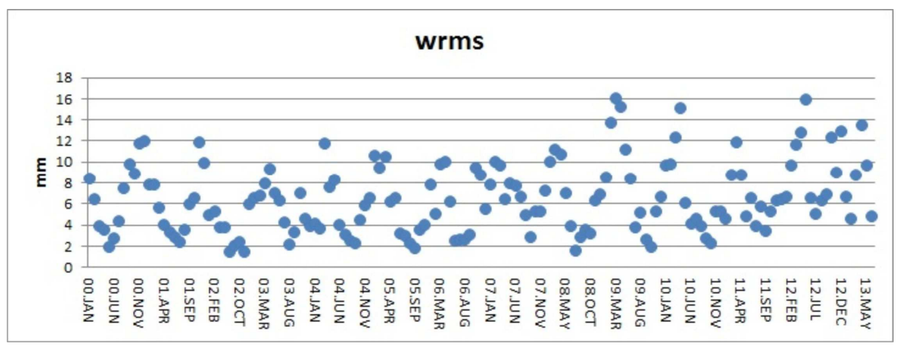

Figure 1. Weighted root mean square of the monthly solutions.

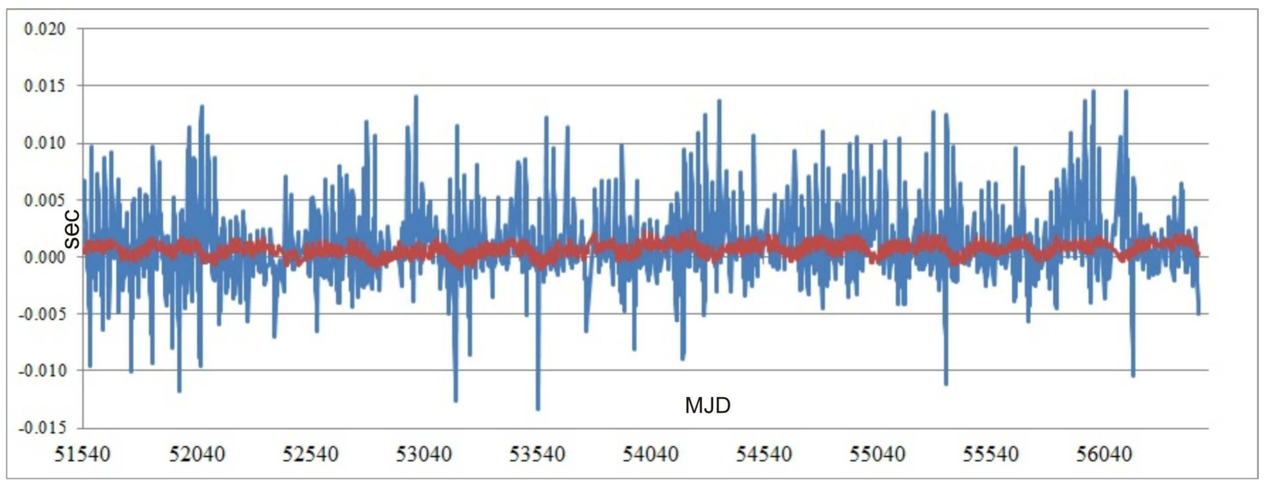

Figure 2. Comparison between SLRP v 4.3 obtained LOD (blue line) and C04 IERS solution (red line).

Results

The results obtained show the reliability of the monthly and multiyear global solutions and demonstrate the capabilities of the SLRP 4.3 software. The SLR_ESTIM 1.0 parameter evaluation module, allows easy and flexible treatment and combination of observational equations and normal matrices in laser data analysis: from the elimination of unknowns to sequential evaluation without limitations on the length of the orbital arc - from several days to a month. The software allows obtaining time series with estimates of different parameters as well as a multiyear global solution.

References

Chapanov Ya., Georgiev I,. Strategy for parameter evaluation in the SLRP software complex, Geodesy 21, ISSN 0324-1114, Bulgaria 2008, pp 87-104.

Chapanov, Y., I. Georgiev (2018). Radiation Pressure, Along Track Acceleration and Gravity Variation from LAGEOS 1 and LAGEOS 2 SLR Data Processing for the Period 1984.3 – 2012.0. Annual of the University of Architecture, Civil Engineering and Geodesy, Sofia, Volume 51, Issue 9, p. 45-55, ISSN 2534-9759.

Lin-Sen Li, Secular influence of the evolution of orbits of near-Earth asteroids induced by temporary variation of G and solar mass-loss, Monthly Notices of the Royal Astronomical Society, Volume 431, Issue 4, 1 June 2013, Pages 2971–2974, https://doi.org/10.1093/mnras/stt248

Presentation of this work is supported by Contract No D01-282/17.12.2019 (Project "National Geoinformation Center (NGIC)" financed by the National Roadmap for Scientific Infrastructure 2017-2023.

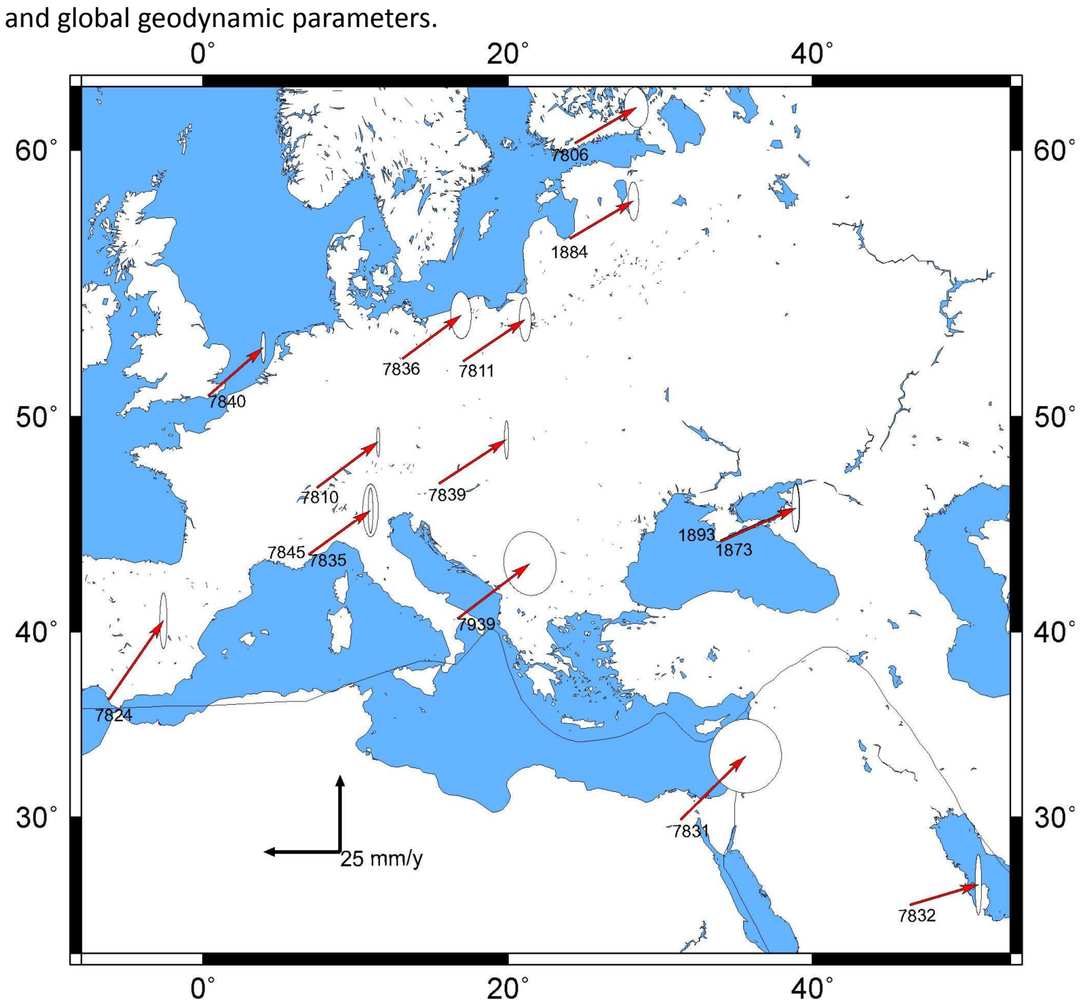

Figure 3. Velocities for the European tracking sites along with 3σ error ellipses.

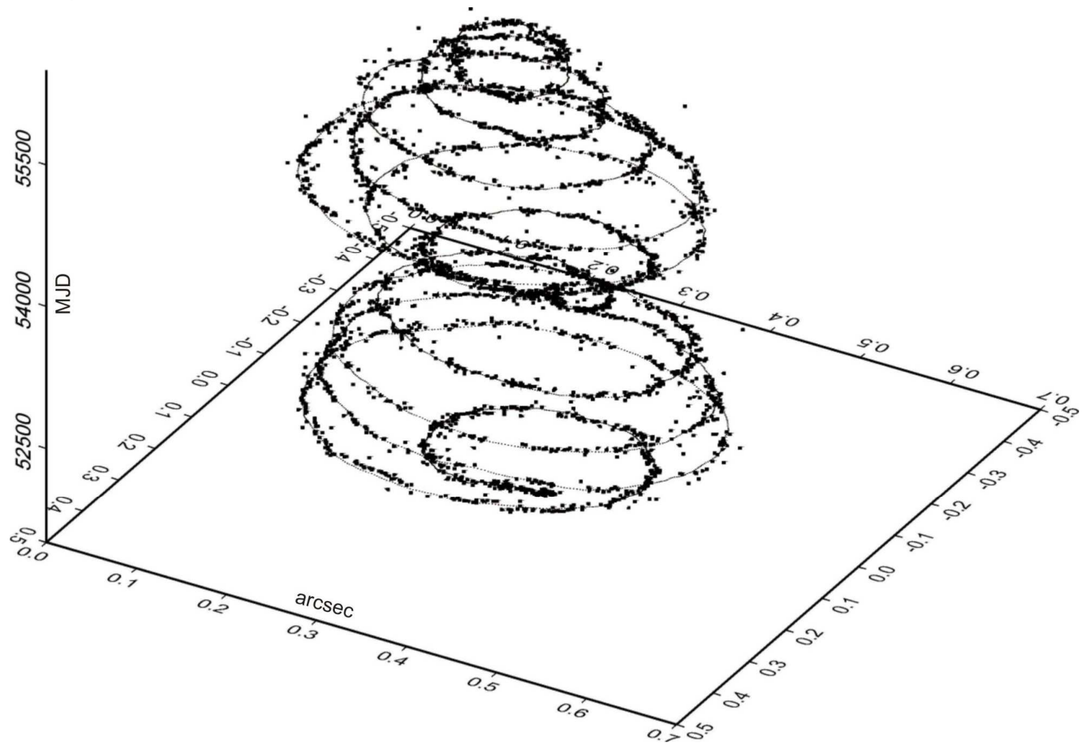

Figure 4. Comparison between obtained pole coordinates (dots) and C04 IERS solution (red curve).

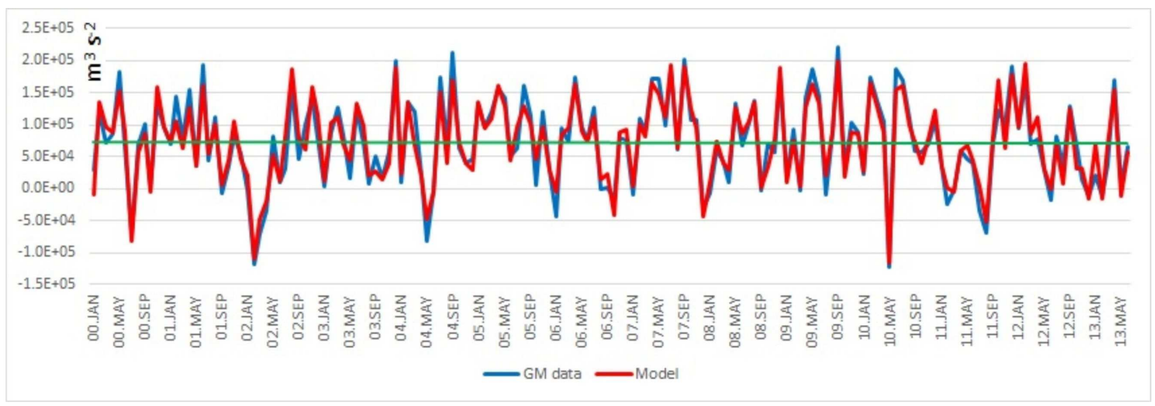

Figure 5. Monthly GM values (blue), the model (red) and the secular drift (green) of the GM

202 447 laser observations of the Lageos 1 geodynamic satellite from 37 tracking stations for the period 2000 – 2013 are processed and analyzed. The weighted root mean squares of the monthly station coordinates solution are between 2 and 16 mm and are quite satisfactory given the number of laser stations selected for the processing. Time series with monthly parameter solutions that take into account unmodelled satellite orbit effects, such as the radial acceleration and along track acceleration, show values close to nominal and comparable to other solutions (Chapanov Ya. and Georgiev I., 2008). The same is valid for the solar radiation pressure coefficient. The horizontal velocities of the observation stations obtained from the multiyear solution are consistent at high level with the ITRF2000 velocity field.

The GM time series analysis gives relative secular trend (decrease) of the gravity constant $\dot{G}/G$ of -3.31. 10^{-13} yr^{-1}. This value is very close to the estimates of other authors. (Lin-Sen Li, 2013, Chapanov Ya. and Georgiev I., 2018).