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MODELING THE LUNAR PHYSICAL PARAMETERS USING COMPLEX SYSTEMS METHODS

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Introduction

Analysis of spin-orbital evolution and tidal dissipation of the multilayered Moon [1], construction of appropriate analytical and numerical theories of the Moon's rotation and, subsequently, other multilayered bodies of the Solar system [2], considering the effects of tidal dissipation and the impact of processes occurring at the core-mantle boundary on the rotation of the planet [3], applying the results of theoretical researches to the processing of modern high precision observations to provide a number of space missions to the Moon are the modern and urgent tasks [4].The aim of this work is analysis of stochastic and dynamic features of time series describing the satellite measurements of gravitational fields and lunar physical parameters (LPP) [5]. We developed the modern methods of multi-parameter analysis, revealing types of interrelationships and cross-correlations, statistical memory effects, providing a certain level of stochastic and frequency-phase similarity for the future determination of statistical LPP for objects being studied [6, 7].

Methods

New methods of processing and analyzing time series were developed on the basis of modern achievements of non-equilibrium statistical physics of complex systems [8]. The methods were developed to generalize theoretical approaches to the case of a local-temporal description. The analysis of local samples of optimal time duration and an investigation of event correlations was made. These events occur in non-equidistant time series recorded with a random sampling step in a series of satellite observations of the LPP. As result the method was developed analysis of complex multi-parameter systems based on the determination of fractal dimensions and fractal coefficients of self-similarity.

Results: Computer programs were developed for the reduction of satellite observations. The software package "Automated coordinate transformation system" (ASTC) was created. The software modules included in the ASTC allow solving overdetermined and normal systems of conditional linear algebraic equations. There is the possibility of using step-by-step regression analysis, which is used to obtain a model with fewer observations. When modeling observations from the lunar surface, a software complex developed by the authors of the project built on the basis of the analysis of LPP are used. In particular, the 4 maps of lunar marginal zone were created (using methods of multiparameter harmonic analysis) and studied using fractal analysis. The first two were constructed by the classical approach of heliometric observations (Model 1 and Model 2). Both models are based on the same heliometric set of observations lasting more than 50 years. Also the models of libration zone built on the basis of harmonic analysis by the modern missions (Model 3 – Apollo, Clementine) and (Model 4 – Kaguya, Smart-1, Zond, LRO) were taken. The comparison of macrosurfaces of various maps on the basis of fractal analysis has not been done before in international practice.

Table 1 In the Table 1 the mean values of fractal dimensions for chosen areas of the Moon's librational zone on corresponding areas of position angle *p*. It can be noted that the results within the error limits are consistent with each other, except the case of *p*=270°-315°. Considering the fact that in the present work the models of the Moon's librational zone displaying the same relief were taken, we may conclude the method of fractal dimension calculation allows to obtain reliable maps similarity estimates. In addition the values of fractal dimension show the reference surfaces for altitude data have no influence on the models' similarity estimates.

p (deg)	Model 1	Model 2	Model 3	Model 4
0^0–45^0	1.42	1.39	1.44	1.40
45^0–90^0	1.34	1.34	1.37	1.35
90^0–135^0	1.44	1.36	1.40	1.43
135^0–180^0	1.30	1.32	1.30	1.34
180^0–225^0	1.40	1.34	1.44	1.43
225^0–270^0	1.37	1.31	1.40	1.43
270^0–315^0	1.33	1.79	1.42	1.38
315^0–360^0	1.30	1.27	1.30	1.33

Conclusion

Applying the modern methods of multi-parameter analysis allowed revealing types of interrelationships and cross-correlations, statistical memory effects, providing a certain level of stochastic and frequency- phase similarity for the accuracy determination of selenophysical parameters for objects being studied. The work is relevant because new high-precision models and methods of LPP analysis were developed on the basis of modern experimental data, obtained during space investigations of the Moon, and modern methods of planetary geodesy. It helps improve the navigational support significantly and increases the accuracy of landing on the Moon's surface for descent modules within the planned space lunar missions.

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