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Spherical gravity inversion of GRAIL data

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Taking into account sphericity is one of the most relevant questions of interest for gravity researchers today. It's especially important in data analysis of regional surveys and satellite missions.

Modern satellite missions are characterized by high accuracy of measurements, as well as a high degree of detail, which makes it possible to construct detailed grid density models of Earth and Moon, however, when automating this process, the following problems arise:

- long duration of the inversion process;

- need for a large amount of RAM when using standard approaches to solving the linear inverse problem of gravity prospecting for grid models;

- high sensitivity of gravity inversion algorithms to the upper cells;

The first problem can be solved by inverting of gravity in the spectral domain using the fast Fourier transform. In this case, the time complexity of the inversion algorithms is reduced by times, which significantly accelerates the selection of the model.

To reduce the memory used, it is necessary to memorize the gravity spectrum for only one cell for each pair of coordinates depth - latitude, since cells with at the same depth and latitude have the same gravitational effects, shifted by the step of cells in the grid model.

Finally, to increase the sensitivity of the inversion algorithms to deep cells, you can use the variable parameter of the gradient descent step (learning rate in machine learning), depending on the depth as an exponential or any other function, in combination with regularization.

The proposed approach was applied to the data of the GRAIL mission, and as a result, a density model of the Moon was constrained with the following grid steps: 0.5^{o} in latitude, 0.7^{o} (pi / 512) in longitude and 10 km in depth.

The fitted model was used to estimate the possible parameters of the sources of lunar mascons. It stands to mention the differences in the geometry of the mascon sources, which can be divided into two groups: isometric sources and sources with channels ascending to the surface, through which, probably, lunar basalts entered the surface.

The proposed approach allows constrain density models of celestial bodies fast enough using a personal computer (less than an hour for a model with the parameters mentioned above), and also takes into account the weak sensitivity of standard inversion algorithms to deep cells.