Title

GRASIMU: A software toolbox for gravity modelling and survey design in lunar exploration

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Abstract

Lunar missions including SELENE and the Lunar Reconnaissance Orbiter have identified pit craters which may present skylights into lunar lava tubes, e.g. in the Marius Hills region of the Moon. In order to verify that the pit craters are actual openings of lava tube structures, we have proposed a rover-based gravity survey. Gravity observations could detect lava tubes in depth and orientation, as well as constrain if the tube is open or filled after a collapse. Due to the challenging mission constraints posed on such a rover survey, we have developed a survey design tool which allows for the optimization of the survey in terms of duration, station number and path for selected lava tube models.

An interactive software toolbox with user-defined inputs and real-time visualization was developed. This fully portable, platform independent, toolbox was developed in Dash, a Python visualization package that uses the Flask web development framework. The toolbox contains three main components, i) a target selection tool (lava tube models, simple shapes or Earth analogues) with parameter selection (depth, densities, shape and size), ii) a survey parameter tool (instrument specifications, terrain, survey path, number of stations, occupation time), and iii) a real-time interactive visualization tool (2-D and 3-D plots of target and gravity parameters, use selectable profiles).

3D-model files representing cavities or other subsurface structures can be uploaded by the user, after which a few standard parameters such as density contrast, cavity depth and cavity size are selected. The user can then interactively determine the survey station coordinates on a map or choose from predefined patterns like square grids or spiral paths. After numerous optional settings such as terrain generation and measurement uncertainty, the toolbox calculates the theoretical gravity anomalies at each survey location by subdivision of the 3D-model into voxels and integrating over the density volume. The results are presented in the form of 2D- and 3D- interpolated maps of the gravity acceleration in vertical direction as well as the gradient of this acceleration. Geophysical corrections including Bouguer, terrain and free-air, are also applicable. The key feature of the toolbox is the interactivity and the versatility, creating the possibility of comparison among every configuration of target, instrument and survey design. If representative terrain and subsurface models are used, this software toolbox can provide insight in the minimum size, depth or density contrast needed for a cavity to be detectable by a certain gravimeter, as well as the optimum station pattern. This software toolbox offers exciting potential in situations where field surveys are difficult or expensive, such as in lunar exploration. Despite the initial focus on lunar lava tubes, the toolbox can be used for any gravity survey design for any exploration target on Earth, planets, asteroids or moons.

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Keywords

Gravity modelling, software toolbox, lunar exploration, lunar lava tubes