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High resolution lunar gravity field models and their regularisation using Kaguya and historical tracking data

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Until Kaguya, lunar gravity field determination has been hampered by the lack of far side tracking data, due to the spin-orbit resonance of the Earth-Moon system. By employing a new measurement type called 4-way Doppler tracking, where a relay satellite in an eccentric polar orbit constitutes a link to the main or-biter in a low circular polar orbit while the latter is over the far side, the first tracking data over the far side have been obtained. This has resulted in a new view of the lunar far side gravity field, with basins being represented by central highs with negative anomalies surrounding them, unlike their near side counter parts. Filling in the far side gap has also resulted in the first lunar gravity field models that did not necessarily require regularisation of the ill-posed system, unlike pre-Kaguya models that required regularisation in the form of a priori information to obtain a stable solution. Due to data distribution and sensitivity, unregular-ised solutions using Kaguya data are possible up to about degree 70 in a spherical harmonics expansion. Nevertheless, tracking data, especially those of the Lunar Prospector satellite in its extended mission, carry information up to high degrees and orders.

In order to exploit the information present in the tracking data, for geophysical purposes and for precise orbit determination, a high-resolution global gravity field model up to degree and order 15 0 from Kaguya and historical tracking data is presented, with special focus on the regularisation of such a model. It is standard practice to use a so-called Kaula rule, where the variance in the power spectrum of the model fol-lows an a priori law. This way of smoothing affects the whole model, including those parts where the data are strong enough to determine the model without smoothing (i.e., the near side). Recently, a new way of regularising a model in spherical harmonics has been presented, which uses so-called local constraints. This method consists of using Slepian functions that are concentrated over a certain area, which allows to con-strain only local parts of the model, as opposed to the whole model. These Slepian functions are also ex-pressed in spherical harmonics, meaning that the localisation can be done by transforming the matrix sys-tem.

Results using this local constraint method are presented, by computing solutions that are constrained only over the far side. Results show how resolution in the unconstrained part (the near side of the Moon) are improved, by improved correlations with high-resolution topography. Boundary effects stemming from the local constraint are also investigated. Finally, it is explored how the localization procedure might be used for determining local solutions directly from the tracking data.

Keywords: Moon, gravity field, regularization, local gravity field