Improvements in lunar gravity field modeling and orbit determination from SELENE multi-satellite tracking data types

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The launch of SELENE, which acquired the first direct tracking data over the farside of the Moon by the use of 4-way Doppler data between a relay satellite and the main satellite, has resulted in a dramatic improvement of the knowledge of the global lunar gravity field[1,2]. In addition to the 4-way Doppler data, same-beam differential VLBI data between the two sub-satellites and two stations on Earth were also collected using the VERA network, and foreign stations in two international campaigns. The strength of differential VLBI data derives from the differencing out of common measurement errors, resulting in a precise measurement. Together with the SELENE 2-way and 4-way tracking data and historical tracking data, the VLBI data were processed into a new lunar gravity field model called SGM100i[3] (Fig. 1). The use of VLBI data allow longer arc lengths for the sub-satellites, increasing the sensitivity with respect to the lower degrees of the gravity field model. The resulting model shows a drastically improved performance in orbit determination, especially for edge-on geometries (where the satellite orbits over the deep farside). Correlations with topography also show an increase over the farside.

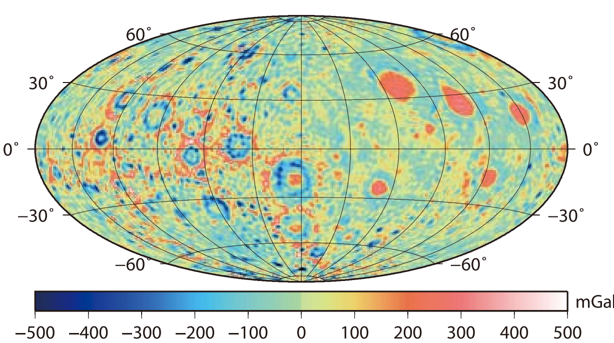

Figure 1: Free-air gravity anomalies at the lunar surface for the SGM100i model. The nearside is on the right.

SELENE was unique in the sense that it consisted of three satellites orbiting the Moon simultaneously, with a variety of terrestrial based tracking systems between all the satellites: 2-way tracking for each separate satellite, 4-way between one sub-satellite and the main satellite, and differential VLBI between the two sub-satellites. Using all these tracking data types, and data from the laser altimeter (at points where the ground tracks of different orbits intersect, the same topography should be measured), a comprehensive assessment of orbit precision was undertaken, and it was shown that the orbit precision of all satellites was improved when compared to the standard case using only 2-way data. The biggest improvements are for the main satellite during edge-on periods. Altimetry crossovers further help to obtain smooth orbit errors (computed from overlaps) at a level of 18 m throughout the mission[4] (Fig. 2).

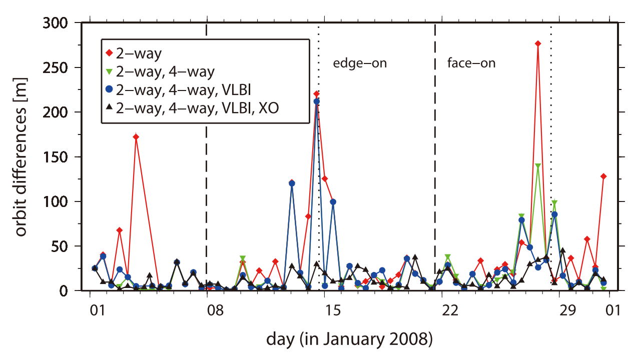

Figure 2: Orbit overlap results for the SELENE main orbiter using various tracking data types. The label "XO" stands for altimeter crossovers.

References

[1] Namiki, N., et al.: 2009, *Science*, **323**, 900.
[2] Matsumoto, K., et al.: 2010, *J. Geophys. Res.*, **115**, E06007.
[3] Goossens, S., et al.: 2011, *J. Geod.*, **85**, 205.
[4] Goossens, S., et al.: 2011, *J. Geod.*, in press.