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SESSION Session 1: satellite tracking and scheduling

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TITLE How many SLR observations and how many stations are needed for deriving high-quality multi-GNSS orbits?

ABSTRACT

Multi-GNSS Experiment (MGEX) was initiated by the International GNSS Service (IGS) due to emerging of both, new navigation satellite systems, i.e., Galileo, BeiDou, QZSS, NavIC, and modernized GPS and GLONASS. All new navigation satellites are equipped with Laser retroreflectors for Satellite Laser Ranging (SLR). The growth of the number of multi-GNSS constellation induces the International Laser Ranging Service (ILRS) to provide a support in the form of special SLR-GNSS tracking campaigns and the priority list for SLR station to track. This work summarizes three special tracking campaigns which took place in the period: 2014.0-2017.0. Range measurements to multi-GNSS constellation typically are employed for the validation of microwave products. However, SLR observations can also be used for the multi-GNSS orbit determination. In this work, we aim at addressing the following questions: (1) How many SLR observations to multi-GNSS satellites are necessary to provide multi-GNSS orbits of a decent quality using solely SLR data? (2) What is an optimal geometry of observations and how many stations are needed to determine a high-quality GNSS orbit? Moreover, we test 3-, 5-, 7- and 9-day GNSS orbital arcs based on SLR data and we develop a common strategy for multi-GNSS orbit determination in order to both, increase the number of SLR observations and not allow orbit parameters to obsolete. We consider the whole GLONASS constellation, all active Galileo satellites, four BeiDou spacecraft (1 MEO, 3 IGSO) and the first QZSS satellite, QZS-1. In order to be as consistent as possible with MGEX, we use official MGEX products from the Center for Orbit Determination in Europe (CODE). CODE's orbits serve as both, a priori data and as a reference microwave orbits. Orbit quality is assessed as a difference between reference CODE products and calculated SLR orbits in the radial, along-track and cross-track directions. For all MEO satellites we obtain orbits with the accuracy at the level of 4, 10 and 18 cm in the radial, along-track and cross-track direction, respectively when compared to microwave orbits, from just 60 SLR observation gathered in a 3-day period. With the increase of the number of observation to 100, the accuracy grows to 2, 8 and 11 cm for the radial, along-track, and cross-track direction, respectively. The minimum number of SLR tracking stations is 5 for the orbit quality at sub-meter level. The solution obtained from 10 stations results in orbit at the level of 5, 10 and 20 cm in the radial, along-track and cross-track direction, respectively. Calculating 3-day arcs leads to an insufficient quality of multi-GNSS orbits when using solely SLR data for most of the GNSS satellites. The compromise between the quality and efficiency in calculations are 5- and 7-day arcs. 9-day arcs lead to the degradation in orbit quality in the along-track direction. The best orbit solution was obtained for the GLONASS R07 spacecraft on 15 July 2015. The 5-day solution was calculated using 129 SLR observations provided by 12 homogeneously distributed SLR stations. During the 5-day period the satellite R07 was tracked by 2 stations from North

America, 3 from Asia, 2 from Australia, and 5 from Europe, all of which provided an even and supreme geometry of observations. The RMS of differences between microwave-based and SLR-based orbits for the best 5-day solution of GLONASS R07 equals 8, 24, 19 mm in the radial, along-track and cross-track direction, respectively.