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Preliminary results of the Russian Laser Ranging Network performance in the LARGE-3 campaign

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Abstract. The paper presents an analysis of results of the third campaign on tracking satellites of the global navigation systems GLONASS, Galileo and Compass (LARGE-3) with regard to the Russian laser ranging network (RLRN) performance. The authors state preliminary generalizations on performance of the RLRN stations and accuracy of experimental data, proposals for development of the RLRN so as to make it truly global, inclusive of the GGOS project.

Introduction

Laser ranging systems play a key role in increasing the accuracy of the global navigation systems as regards both verification of navigation error components at the expense of the space segment (ephemerides and time-frequency corrections) and monitoring the accuracy of transfer and distribution of geocentric reference frames.

Participants of the LARGE-1 mission had set a task of collecting the maximum amount of data on all the GLONASS spacecrafts since all of them were equipped with the retroreflector arrays, and successfully completed it. However, despite high performance rates of the ILRS stations, they failed to collect the amount of data necessary for GLONASS orbit calculation with the accuracy comparable with that for radio orbits. It is conditioned by that the most ILRS stations are located in the Northern hemisphere (NH) and that the most stations are unadjusted for daytime operation. Besides of that, considering other ILRS missions, it has become clear that the total number of the ILRS stations is insufficient when it comes to collecting data on the GLONASS SC and completing other missions.

Figure 1 represents measurement gaps in day passes and significant asymmetry of measurements collected in the NH relative to the ones collected in the Southern hemisphere (SH).
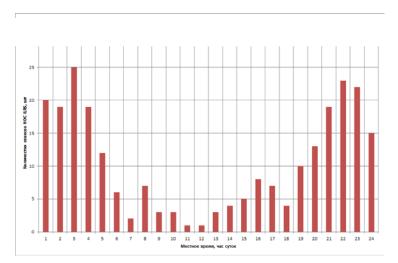

Figure 1. Dependency of the number of ILRS RLRN sessions from the local time

The LARGE-1 campaign resulted in producing recommendations on decreasing the number of the GLONASS spacecrafts to be observed by the ILRS stations and planning with more uniform measuring coverage of orbital arcs.

Goals and tasks of the experiment

The goal of the LARGE-3 campaign laid in collecting measurement data on 6 GLONASS SC in the amount necessary for calculating orbits with the accuracy comparable with the radio one or higher. Based on the potential capabilities of the global laser ranging network, a number of the LARGE-3 targets was selected from the GLONASS constellation using a pseudo uniform selection method with consideration of their health and upgradability.

The key recommendations given by the ILRS and used as a basis of the RLRN planning and use consisted in providing more uniform measuring coverage of SC passes in terms of both the path segments and TOD of performed sessions.

Key results of the experiment

Figure 2 illustrates the following distribution of normal points produced by the RLRN stations on the observed targets and navigation systems.
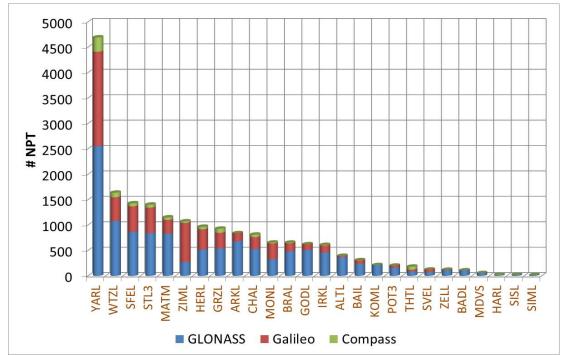

Figure 2. Distribution of normal points produced by the RLRN stations on the observed targets and navigation systems
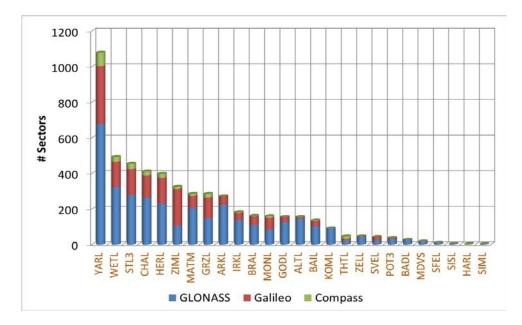
Figure 3. Distribution of generalized measurement sectors of the RLRN stations on the observed targets and navigation systems
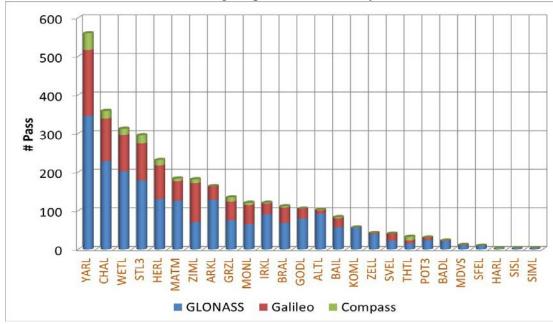
Figure 4 illustrates the distribution of targets' passes observed by the RLRN stations.

Figure 4. Distribution of targets' passes observed by the RLRN stations

Figure 5 gives the analysis of how laser ranging sessions were distributed depending on the local time in LARGE-3.
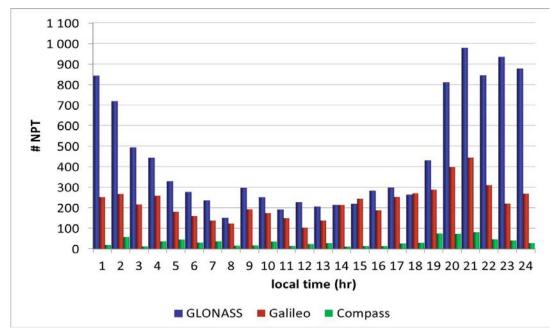
Figure 5. Dependency of SLR observations from the local time

The diagram on Figure 5 clearly illustrates that the most amount of measurements was collected in the night-time. At the same time, a number of stations showed more uniform distribution of sessions, which conditioned by development and further integration of special software into the structure of these RLRN stations. As a rule, the maximum amount of measurements was collected by the stations at 3 a.m. local time.

In addition to that, we see that the most amount of measurements was performed on night passes, and the number of sessions on shady parts of the targets' passes in the NH exceeds the number of sessions taken in the SH a few times. One can see nonuniformity of coverage of SC orbital arcs. There are cases of not having measurements on some passes at all.
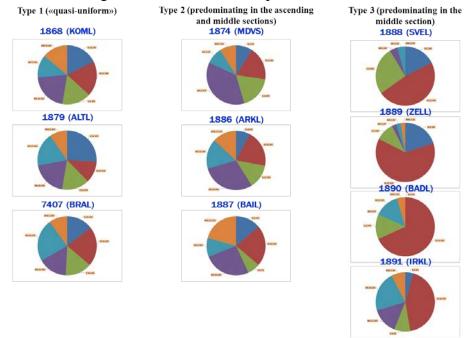

Figure 6. Typical distribution of measurements on sectors and passes

During the experiment, we analyzed the accuracy of measurements provided by the RLRN depending on the conditions under which these measurements had been taken. Laser measurements on GLONASS SC are characterized by the residual average value spread varying from -65,8 up to 86,0 mm with σ≤33,7 mm, the residual average value with the probability of 0.95 does not exceed 48,7 mm (Figure 7).
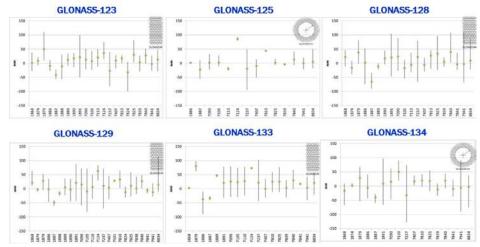

Figure 7. Results of the RLRN measurements accuracy analysis depending on the measuring conditions

Using the ILRS measurements on the 4-day measuring intervals, we have got the SC orbits differing from the radio ones by: σ_r~1.8 cm, σ_l~11.2 cm, σ_n~14.2 cm (Figure 8). The number of measurement sessions performed on a single measuring interval varies from 25 up to 44.
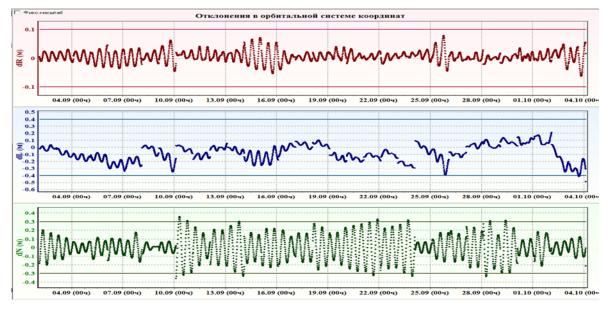

Figure 8. Deviations of the laser orbits from the radio ones during LARGE-3

LARGE-3 positive results

1.   During LARGE-3, the GLONASS SC were tracked by all the RLRN stations (totaling 11 units).
2.   We have taken measurements on all the planned targets.
3.   The performance rate of stations has significantly increased throughout the experiment (approximately, 2.5 times).

4. For the first time in the history of GLONASS laser ranging the accuracy of orbit calculation has equaled or even exceeded the one achieved by the GNSS means.
5. Direct comparison of the laser orbits with the radio ones taken from different analysis centers has showed the presence of a scale factor between both different GNSS analysis centers and laser orbits.
6. Preliminary analysis of the collected laser orbits has demonstrated the presence of unaccounted systematic errors in the retroreflector array offset values relative to the SC center of mass.
7. To find out the cause of these errors, it is necessary to continue the mission in regard to further GLONASS SC tracking.
8. Co-location of the on-board GLONASS laser means with the GNSS ones has allowed getting preliminary estimations of mismatch between respective reference frames. Unfortunately, in this experiment it's not possible to correlate the discovered mismatches to either of means.
9. We deem it expedient to connect VLBI to GLONASS for session-based work with the GLONASS navigation signals, which will allow us to compare and estimate the scales of the reference frames produced by both the laser ranging and GNSS means. Suggestions on VLBI stations planning can be developed in case of having a favorable decision made by the VLBI service.

LARGE-3 negative results

1. Measurements are non-uniformly distributed both on SC orbit passes and between Northern and Southern hemispheres of the Earth.
2. The number of measurements taken at night (local astronomical time) significantly (20 and more times) exceeds the number of daytime measurements.
3. In some cases, there are no measurements on some passes at all.

Propositions on further RLRN development

In the interests of making the RLRN truly global, inclusive of the GGOS project, we propose the following actions:

- To increase the number of daytime measurements, example – the Russian station in Brazil;

- When planning, it is necessary to provide more uniform coverage of GLONASS orbit arcs using the stations in the Northern and Southern hemispheres and on each pass.