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«RESEARCH-AND-PRODUCTION CORPORATION
«PRECISION SYSTEMS AND INSTRUMENTS»

Preliminary results of the ILRS network performance in the LARGE-3 experiment

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Matera, 2015

Targets and definitions of the LARGE-3 experiment

Targets:

GLONASS-123, -125, -128, -129, -133, -134
Compass-M3
Galileo-101, -102, -103 and -104

Definitions:

NP length: 5 minutes or 1000 FR points.
Sector definition: The duration of each satellite's visibility is divided into 3-sectors (beginning, middle, and end).
Pass definition: A pass is counted for each visibility where a station tracked the satellite.

LARGE-3 requirements

This time we need (Third GNSS SLR Tracking Campaign):

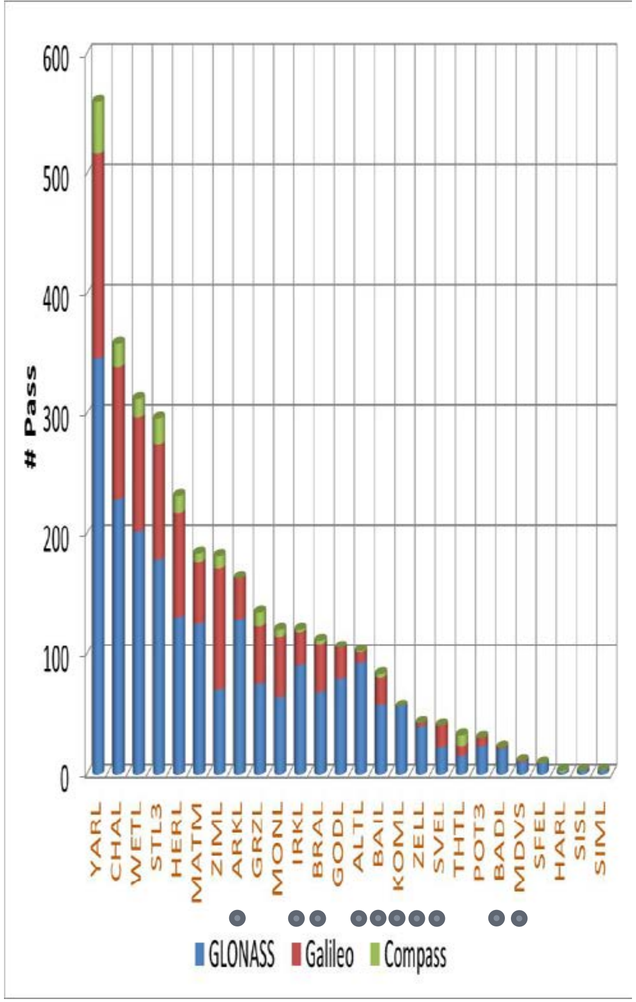
1. 9 normal points per one pass from each station:

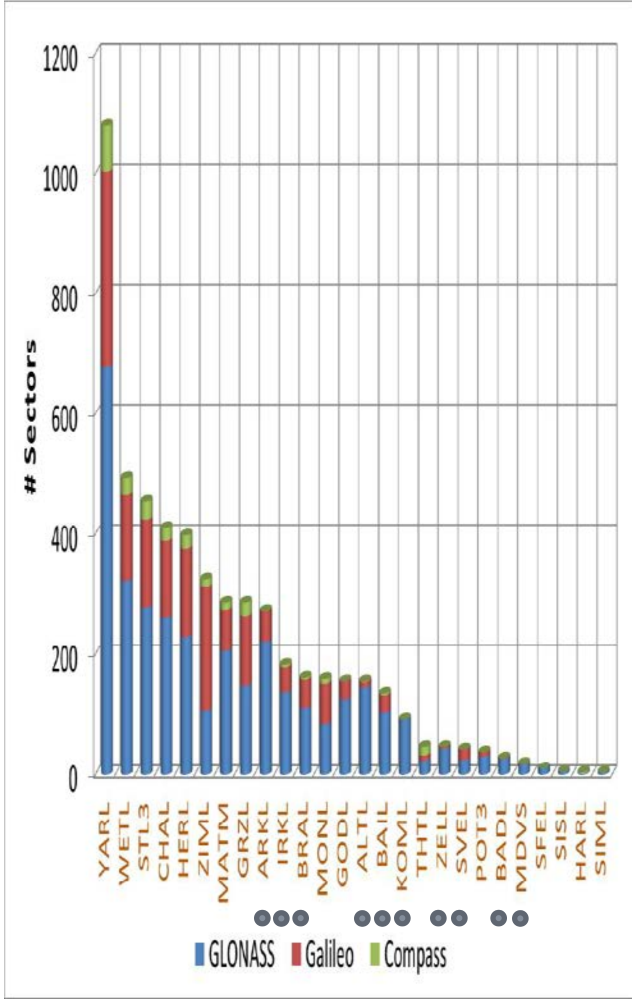
- **3 points in an ascending section(at the beginning of the pass),**
- **3 points in the middle section of the pass, about the traverse point, and**
- **3 points in the descending section (at the end of the pass).**

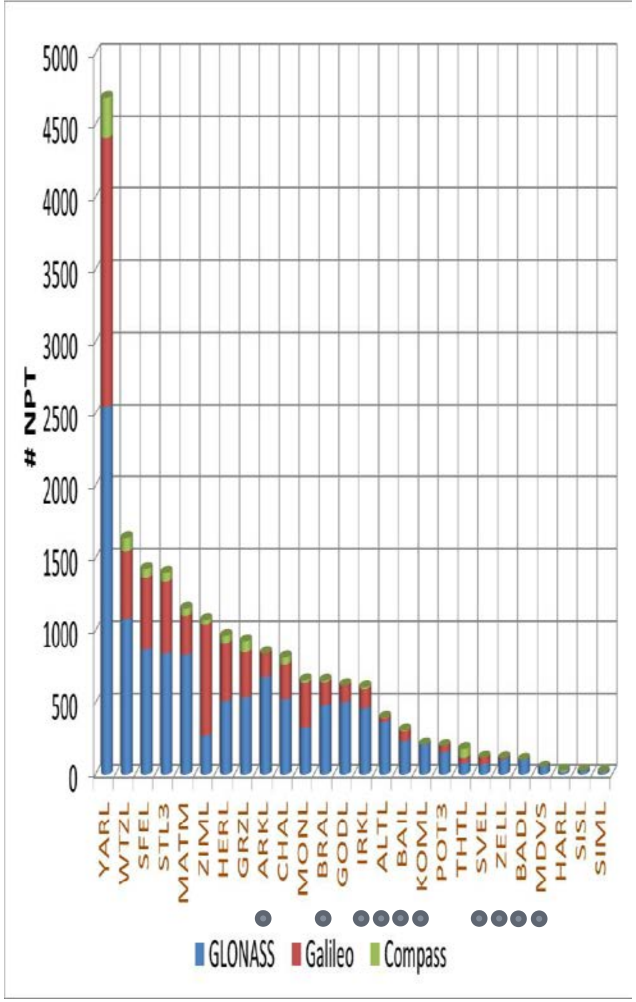
In each section NPs may be taken together of separately whatever is better for your operation.

2. More daytime ranging even if it is around sunrise and sunset.

Passes / Sectors / Normal points

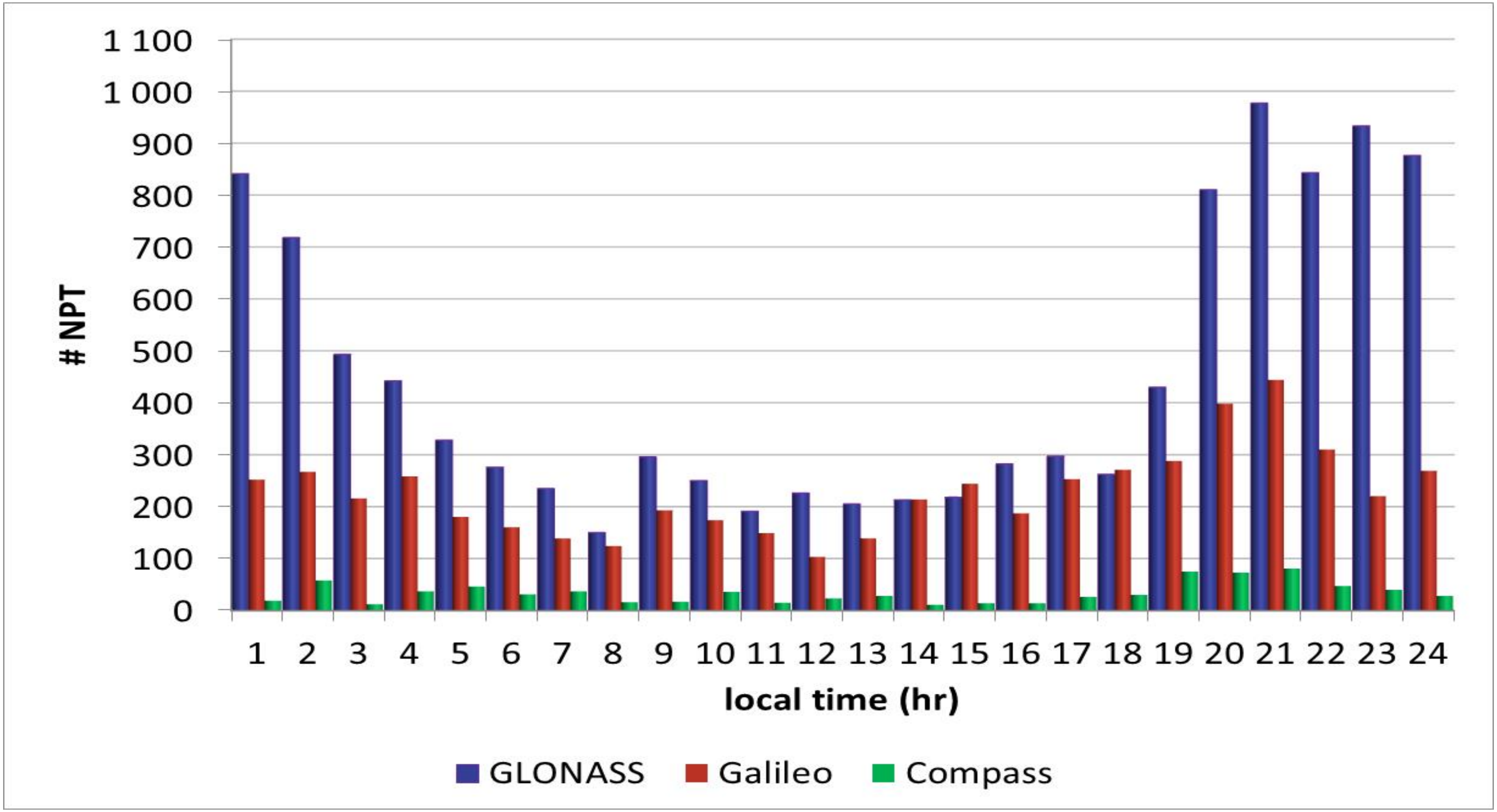






Conclusion: Required (expected) ratio P/S/NP = 1/3/9. Actual (LARGE-3): min=1/1.1/2.3 (CHAL), max=1/1.9/8.4 (YARL).

Dependency between a number of sessions and the local time

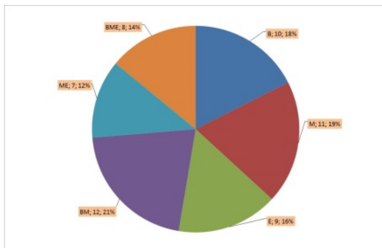


Conclusion: the majority of SLR observations complies with night conditions of functioning, maximum measurements taken at 9 p. m. local time

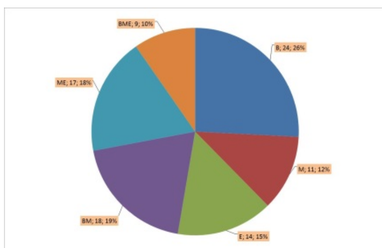
Typical distribution of NP on sectors and passes

Type 1 («quasi-uniform»)

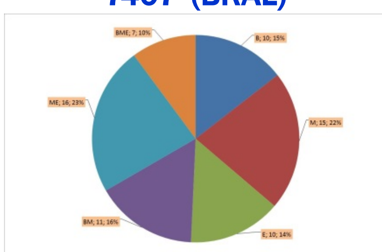
1868 (KOML)



1879 (ALTL)

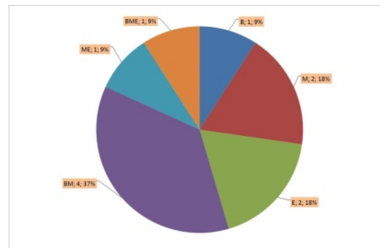


7407 (BRAL)

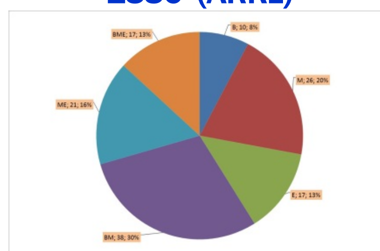


Type 2 (predominating in the ascending and middle sections)

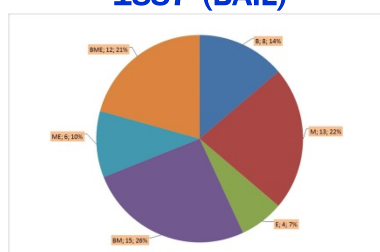
1874 (MDVS)



1886 (ARKL)

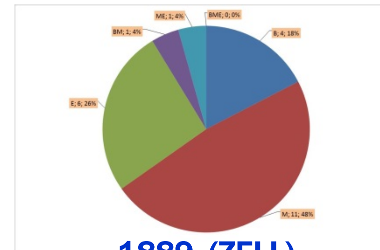


1887 (BAIL)

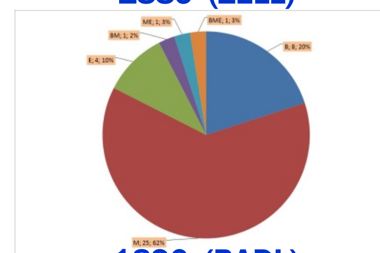


Type 3 (predominating in the middle section)

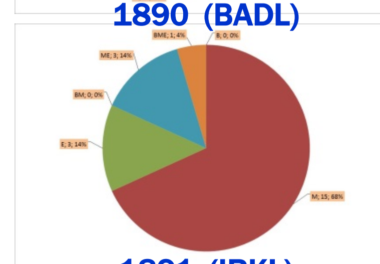
1888 (SVEL)



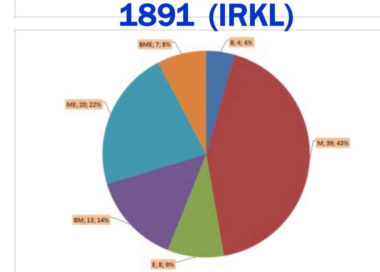
1889 (ZELL)



1890 (BADL)



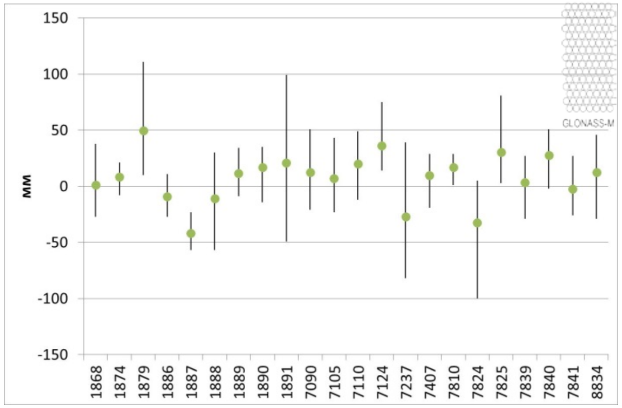
1891 (IRKL)



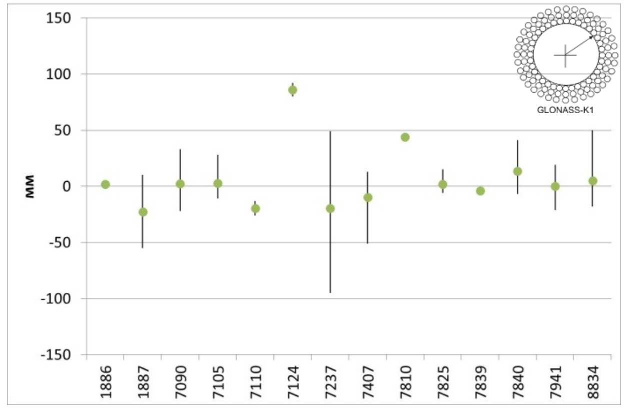
Conclusion: in LARGE-3, measurements from the RLRN stations do not fully comply with the requirements of uniform distribution of 9 NP per each pass.

Residuals of laser measurements on GLONASS SC in relation to the «laser» orbit

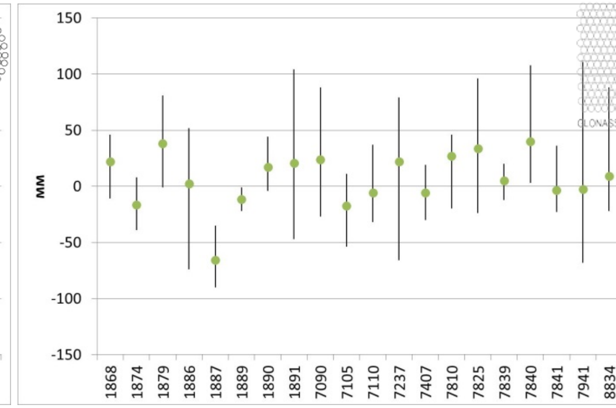
GLONASS-123



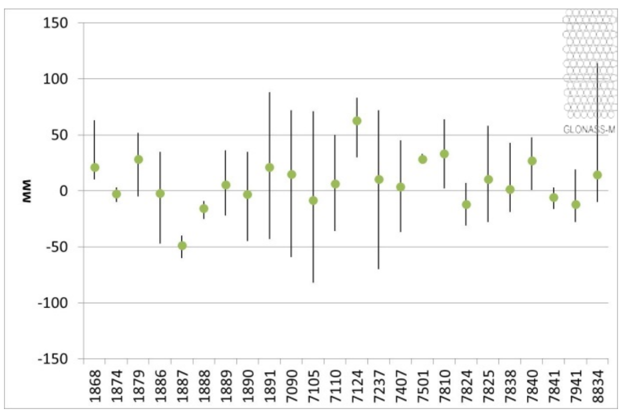
GLONASS-125



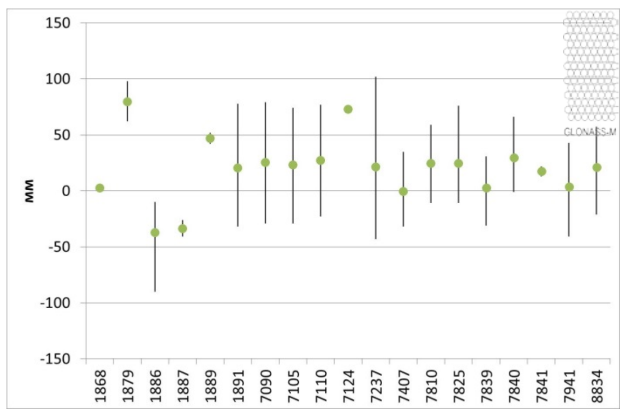
GLONASS-128



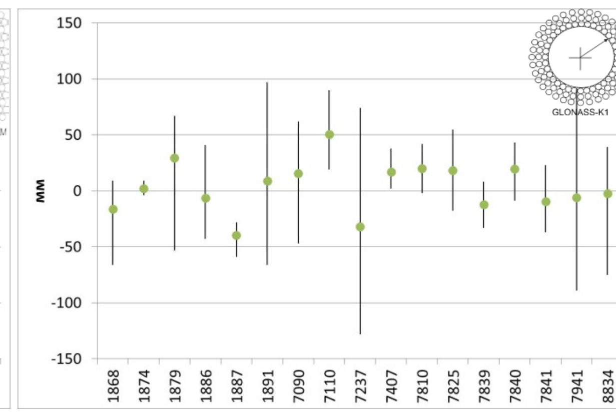
GLONASS-129



GLONASS-133



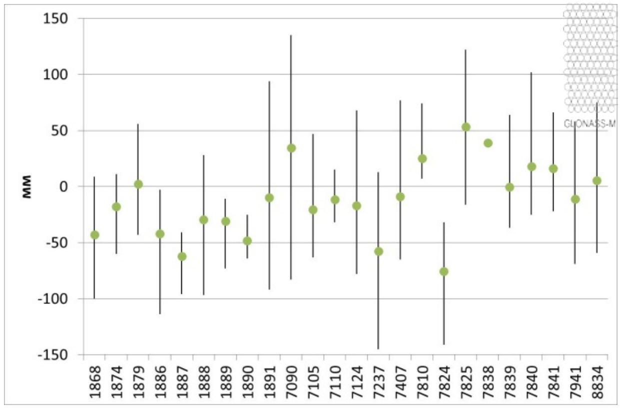
GLONASS-134



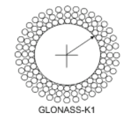
Conclusion: Laser measurements on GLONASS SC are characterized by spread of residual average values for different means varying from -65.8 to 86.0 mm with σ≤33.7 mm. Given that the probability equals 0.95, the residual average value deviation for all the means does not exceed 48.7 mm.

Residuals of laser measurements on GLONASS SC in relation to the «radio» orbit

GLONASS-123

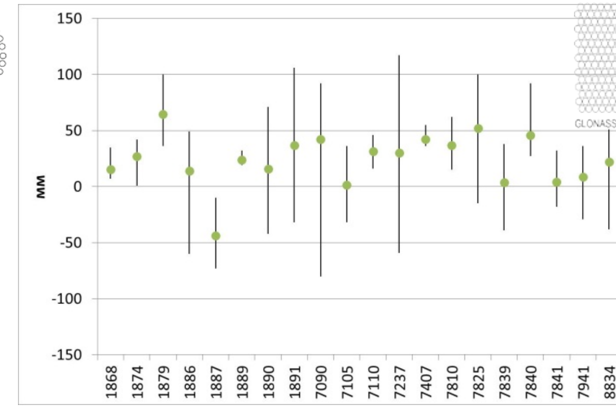


GLONASS-125

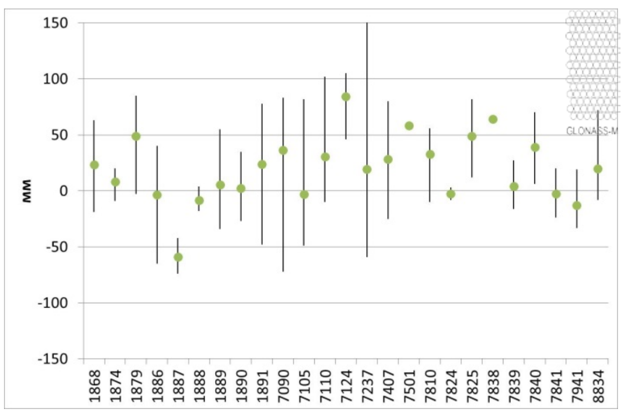


«Radio» orbit is N/A

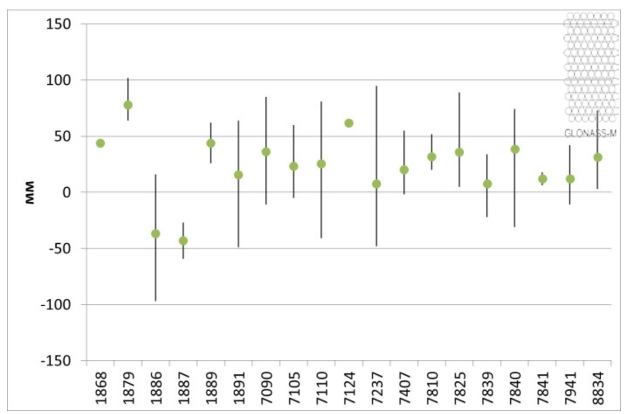
GLONASS-128



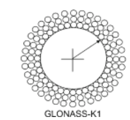
GLONASS-129



GLONASS-133



GLONASS-134



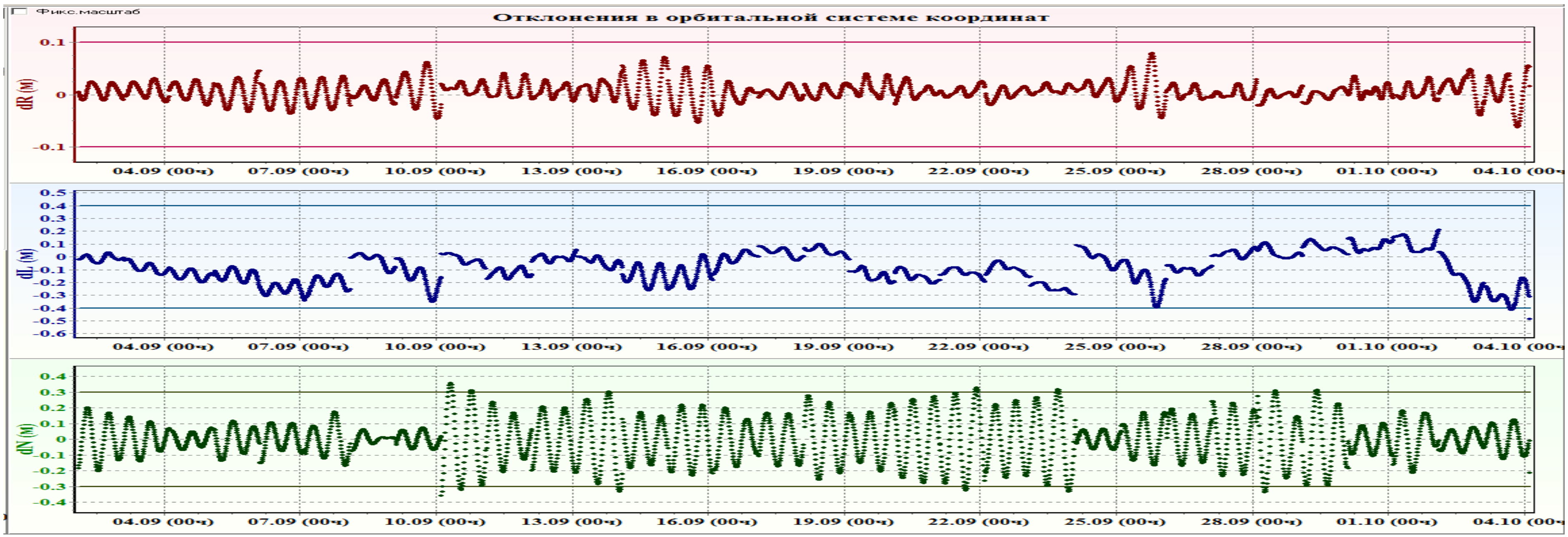
«Radio» orbit is N/A

Conclusion: laser measurements on GLONASS SC are characterized by spread of residual average values for different means varying from -75.5 to 84.3 mm with $\sigma \leq 36.3$ mm. Given that the probability equals 0.95, the residual average value deviation for all the means does not exceed 62.0 mm.

Accuracy of GLONASS SC «laser» orbits

Measuring interval (MI): 4 days.
Number of laser measurements on the MI (LARGE-3): from 25 to 44 sessions.
«Laser» orbit: average (2nd and 3rd) days of the MI.

GLONASS-129



Note: «Radio» orbit – SVOEVP / SHPDETC (www.glonass-svoevp.ru)

Conclusion: difference between the GLONASS SC «radio» and «laser» orbits is characterized by σ_r~1.8 cm, σ_l~11.2 cm, σ_n~14.2 cm.

Accuracy of GLONASS SC «laser» orbits

Measuring interval (MI): 4 days.
Number of laser measurements on the MI (LARGE-3): from 25 to 44 sessions.
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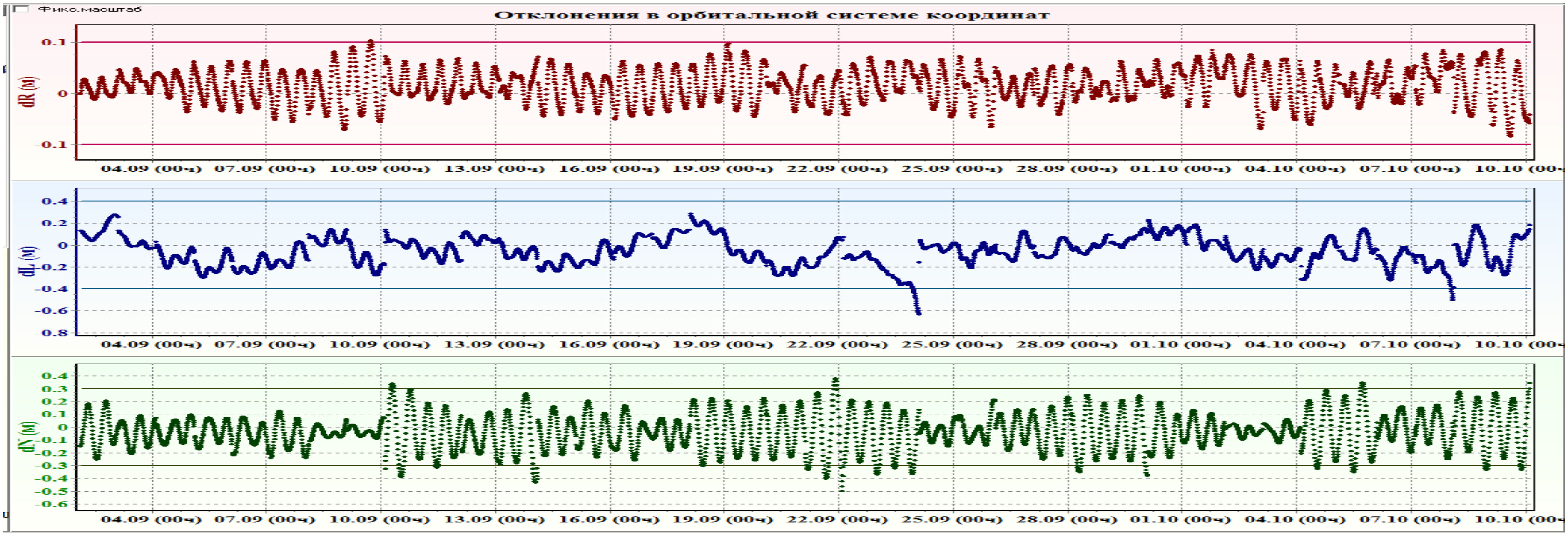
GLONASS-129



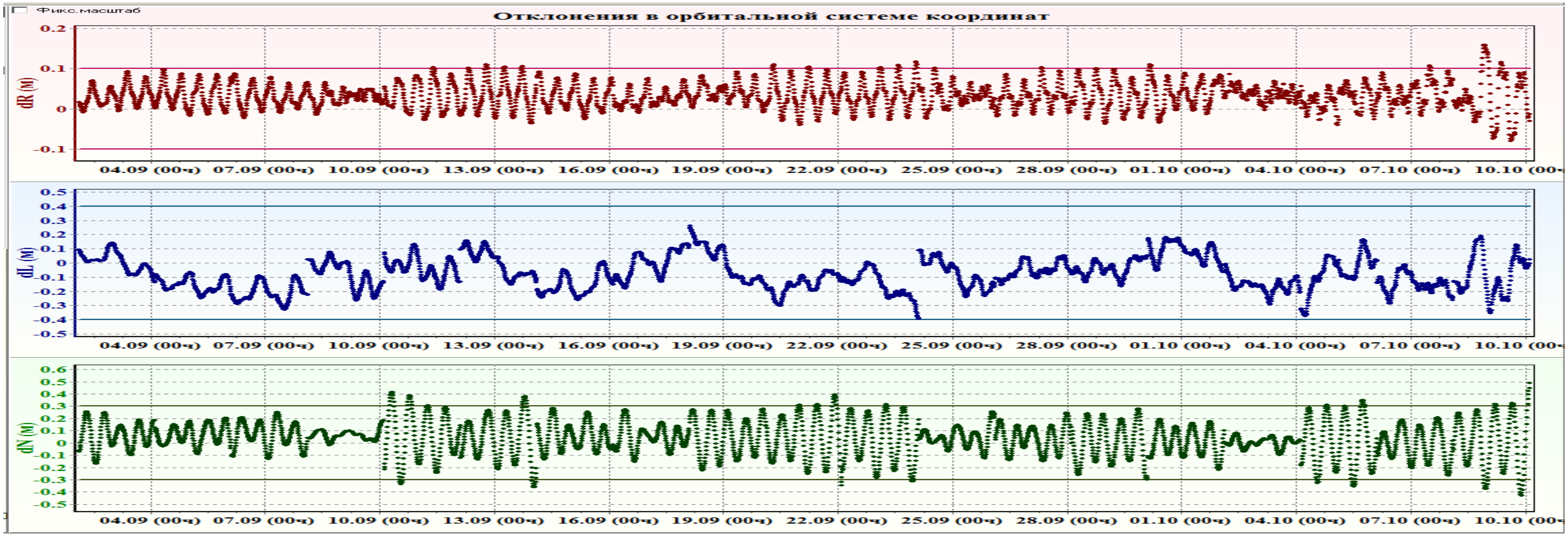
Note: «Radio» orbit – IAC TSNIIMASH (www.glonass-iac.ru)

Conclusion: difference between the GLONASS SC «radio» and «laser» orbits is characterized by σ_r~3.2 cm, σ_l~12.4 cm, σ_n~14.3 cm

Accuracy of GLONASS SC «laser» orbits

Measuring interval (MI): 4 days.
Number of laser measurements on the MI (LARGE-3): from 25 to 44 sessions.
«Laser» orbit: average (2nd and 3rd) days of the MI.

GLONASS-129



Note: «Radio» orbit – AC CODE (www.aiub.unibe.ch)

Conclusion: difference between the GLONASS SC «radio» and «laser» orbits is characterized by σ_r~3.1 cm, σ_l~11.2 cm, σ_n~14.0 cm

LARGE-3 experiment generalizations (positive)

1. **Within the framework of LARGE-3, GLONASS SC have been tracked by 23 ILRS and 10 RLRN stations.**
2. **We have taken measurement on all planned targets.**
3. **The performance rate of stations has significantly increased on the interval of the experiment duration – it was up to 15-20 normal points from the ILRS network.**
4. **It is the first time the LARGE-3 experiment has provided an opportunity to determine SC «laser» orbits more accurately than the IGS orbits, but to achieve a theoretically possible accuracy it is necessary to increase the amount of measurements taken at least two times.**

LARGE-3 experiment generalizations (negative)

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

Propositions on further SLR development

1. **To increase the number of daytime measurements. Examples – stations in Graz, Wettzell, Yarragadee and Brasilia.**
2. **When planning SLR observations, it is necessary to provide a more uniform coverage of GNSS orbit arcs by measurements taken using the stations in the Northern and Southern hemispheres and on each pass.**
3. **When developing the new generation millimeter accuracy SLR stations, it is required to increase their production rates with regard to GNSS SC to 12-24 NP per hour.**

Our next report called «Satellite radio laser ranging stations for application in GNSS: requirements for the technical characteristics and methods of their implementation» is dedicated to study on how to significantly increase the number of SLR observations on each GNSS SC.

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