Russian Laser Ranging Network in GGOS LARGE (Experience and Requirements)

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Questions for discussion

- Current status of the Russian network;
- SLR data analysis and requirements to SLR data;
- Next steps and proposals.

Russian current SLR network




RUSSIAN MoD

- **Komsomolsk.**

RUSSIAN SPACE AGENCY

- **Altay;**
- **Arkhys;**
- **Baikonur.**

RUSSIAN ACADEMY OF SCIENCES

- **Badary;**
- **Svetloe;**
- **Zelenchukskaya.**

RUSSIAN AGENCY OF STANDARDIZATION

- **Mendeleevo;**
- **Irkutsk.**

Top-targets are:

1. **GLONASS navigation SC.**
2. **Lageos SC.**
3. **Lares SC.**

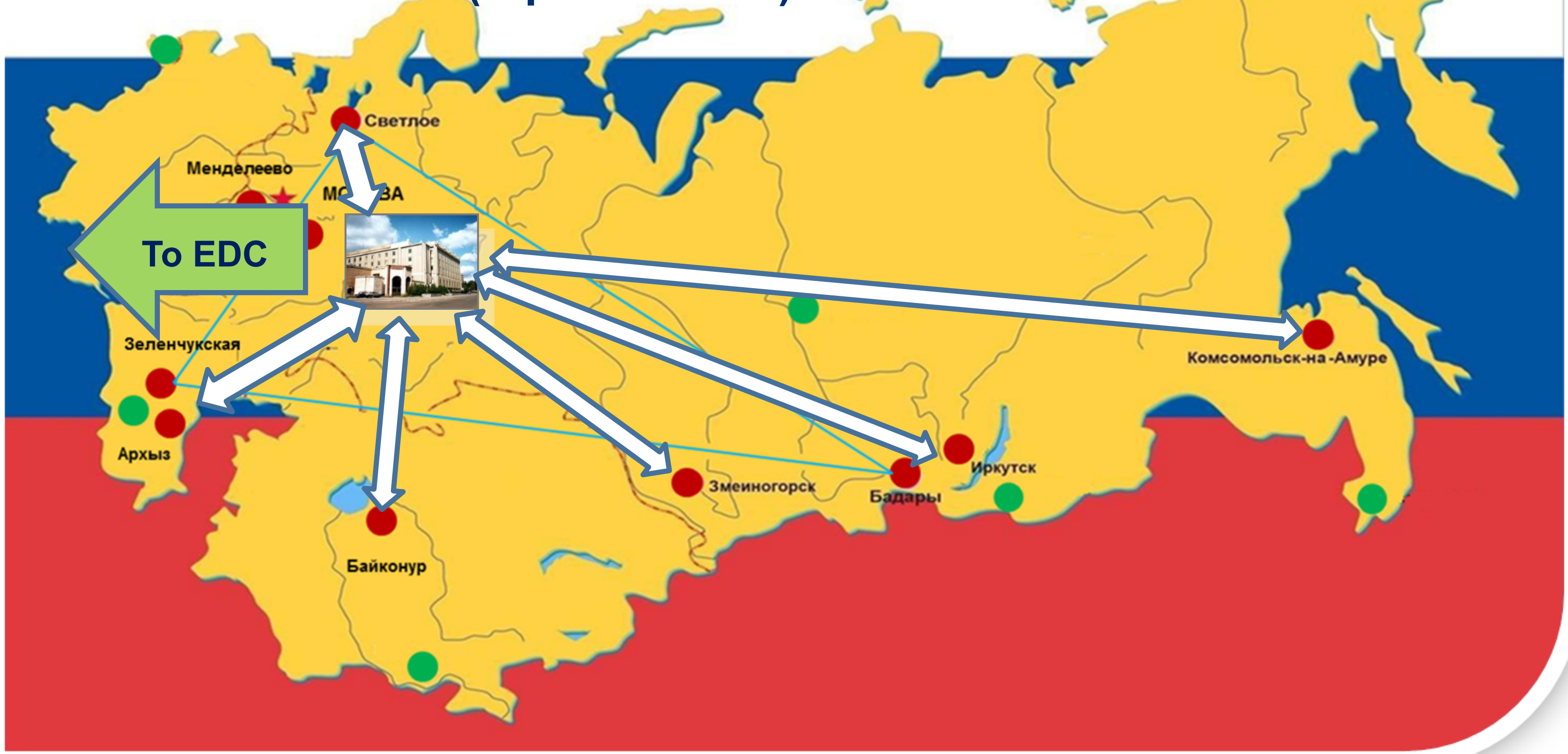
Data flow

CENTER → STATIONS

- ❑ Predictions (CPF);
- ❑ Priorities (plans);
- ❑ Performance (reports of QC).

STATIONS → CENTER

- ❑ Row measurement data (SLR/GLONASS/GPS).



Organisation of GLONASS SC ranging by Russian network of stations

Statistics for GLONASS SC tracking by Russian network (01.11.13 – 20.04.14)

Station	Number of Passes	Number of Satellites	Number of NP
Komsomolsk (1868)	458	25	1447
Mendeleyevo (1874)	48	18	278
AOLC (1879)	770	25	3087
Arkhyz (1886)	465	25	1654
Baikonur (1887)	124	21	477
Svetloe (1888)	40	7	162
Zelenchukskaya (1889)	420	25	1267
Badary (1890)	158	23	463
Ikutsk	2	2	11
Total: 9	2475	26	8846

NP accuracy is 4-8 mm

The use of laser data to improve the accuracy of GLONASS (1)

Improving accuracy of the geodetic support with two-way laser ranging

The result of applying in GLONASS	Measurement method using SLR
Refinement of coordinates of measurement means, refinement of reference FGCS to the Earth center of mass, refinement FGSC to ITRF translation parameters with millimeter level accuracy	Determination the coordinates of sites from laser observation of SC Lageos (Blits) and network adjustment, including collocation data SLR and GMS
Formation of combined solutions, harmonization of the measurement model of the orbit, Earth orientation parameters and sites coordinates with millimeter level accuracy	Laser observation of SC Lageos (Blits) and NSC Glonass on collocation sites SLR, VLBI, GMS

Improving accuracy of the ephemeris support with two-way laser ranging

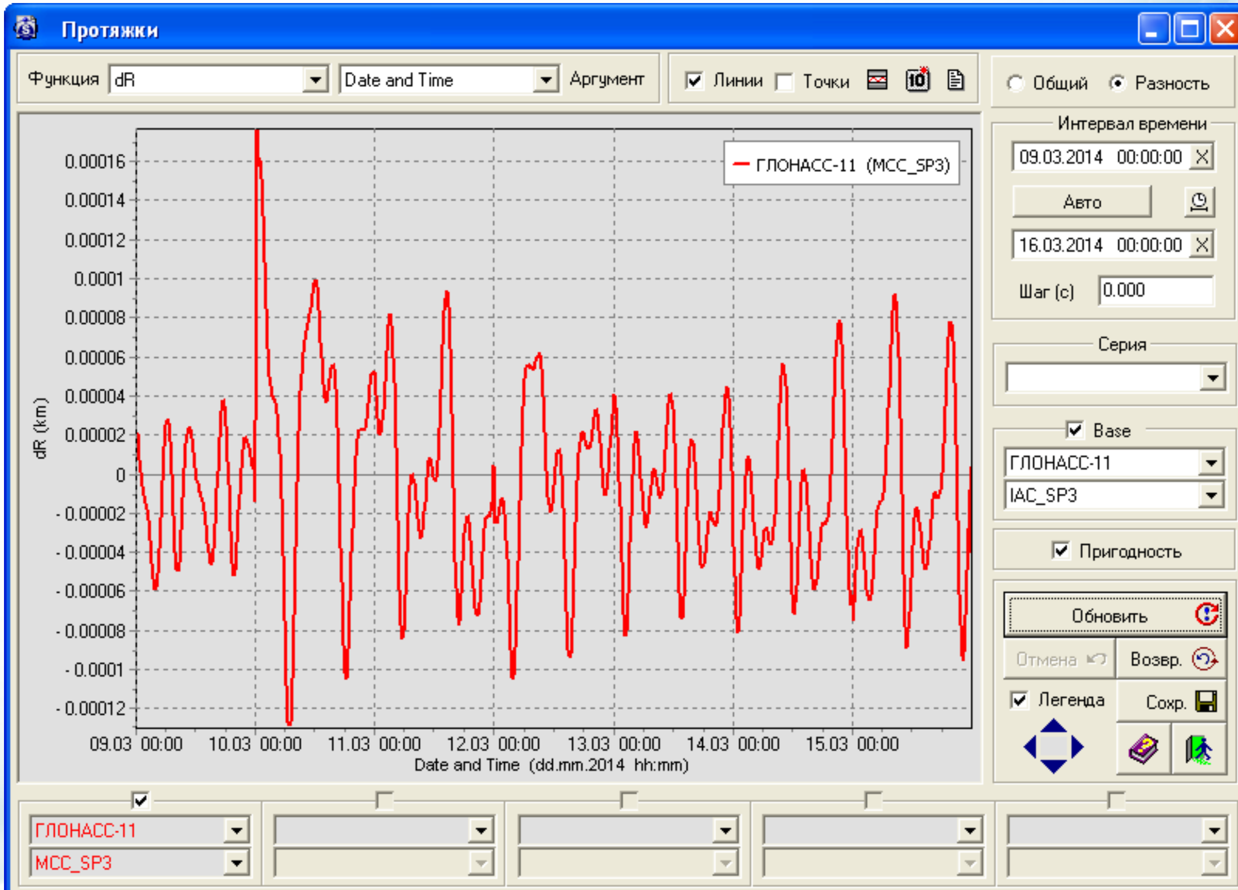
The result of applying in GLONASS	Measurement method using SLR
GLONASS ephemeris control with millimeter level accuracy	○ Comparison of laser range and the projection of the ephemeris data NSC to the inclined range. Comparison orbit of NSC obtained from laser measurements and obtained from monitor stations ○ SLR and “microwave” orbit comparison
Control of translation of the Federal Geocentric Coordinate System by GLONASS ephemeris with millimeter level accuracy	Determination the coordinates of sites from laser observation of SC Lageos (Blits) and comparison with coordinates of the same site obtained from laser observation of NSC Glonass and data of navigation message

The use of laser data to improve the accuracy of GLONASS (2)

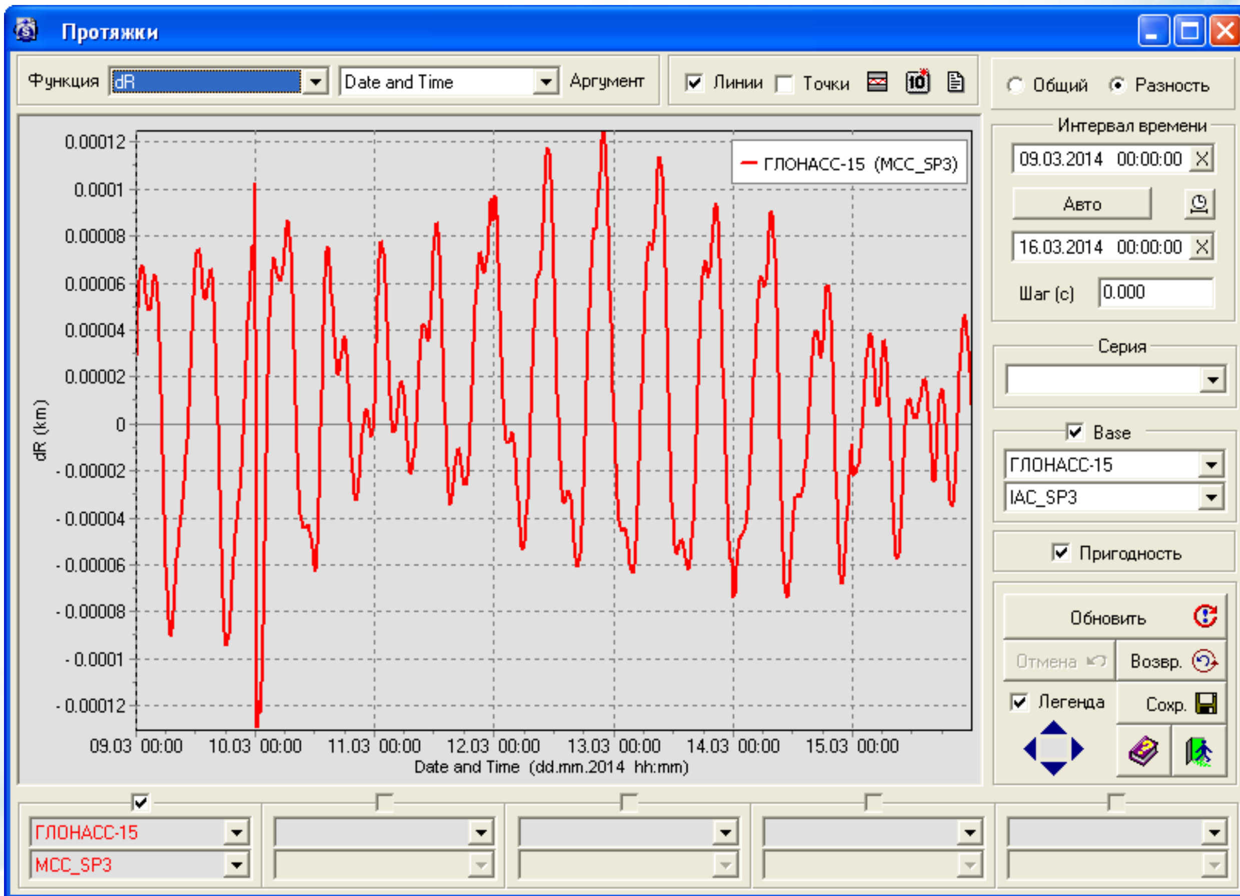
Improving accuracy of the time-frequency support with one-way and two-way laser ranging

The result of applying in GLONASS	Measurement method using SLR
Frequency-time correction control with accuracy 0.05 ns	Determination of difference of laser range and laser pseudorange
Remote on-ground time scales control with accuracy 0.05 ns	Comparison of on-ground time scales with a time scale of the same NSC
Calibration of monitor stations with centimeter level accuracy	Comparison of laser pseudorange and RF pseudorange
Calibration of two-way RF rangefinders with millimeter level accuracy	Comparison of laser range and radiofrequency range

Differences between SLR and “microwave” orbits (1)

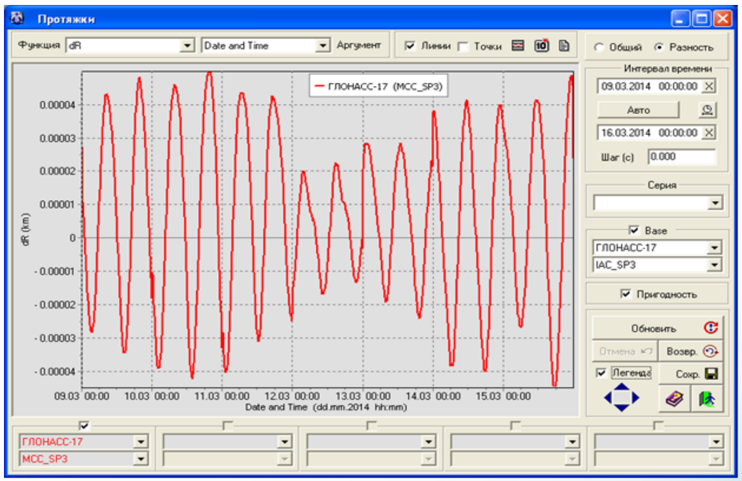


Differences between SLR and "microwave" orbits (2)

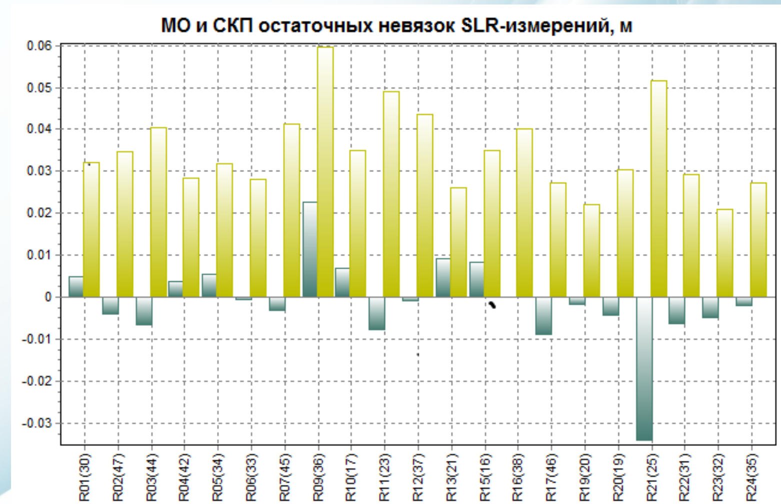


Two comparison methods

For statistic analysis of all SC and all stations



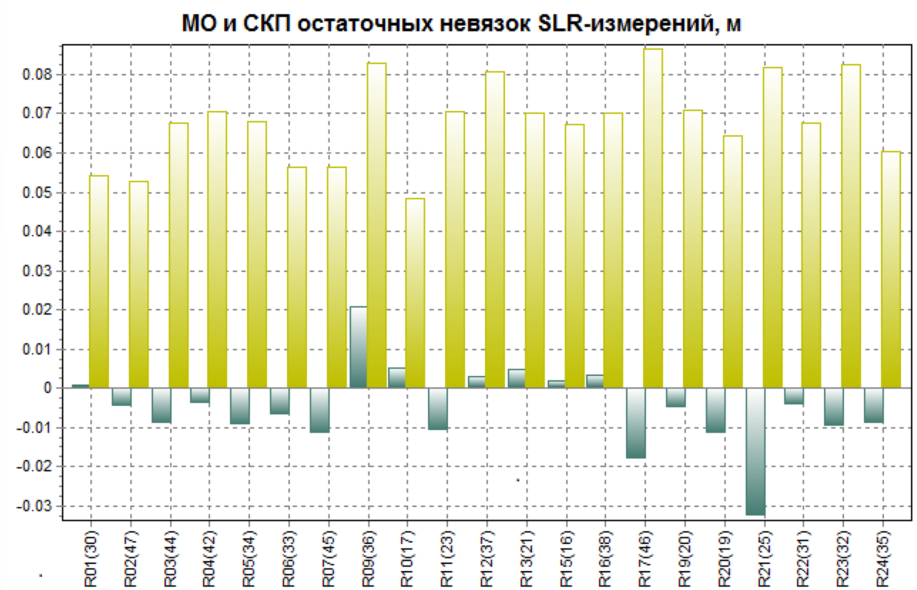
Differences between SLR and "microwave" orbits



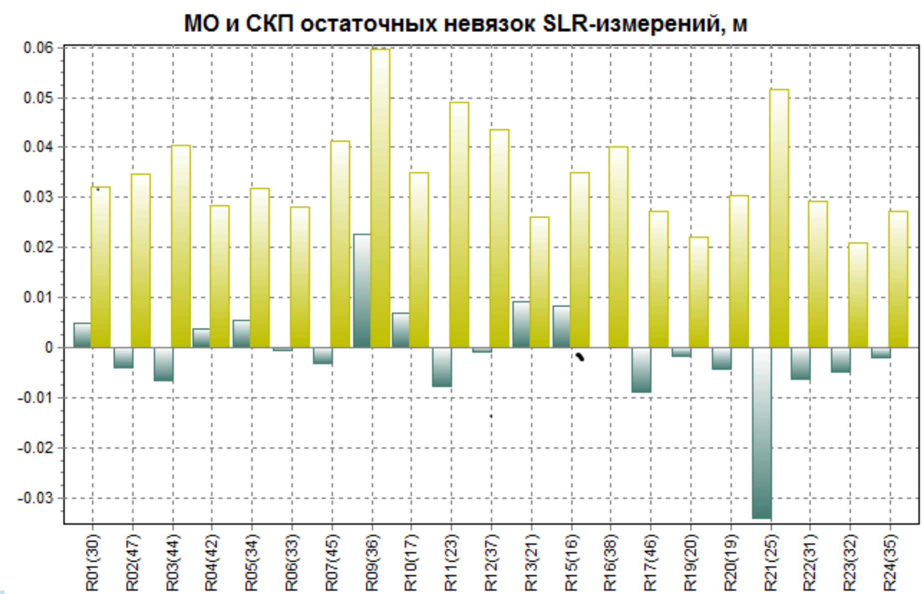
(Residuals statistics for all GLONASS SC)

Mathematical expectation and root-mean-square error of SLR-measurements residuals relative to the reference orbit built on phase measurements of the IGS stations world network

Test results of GLONASS SC tracking data processing obtained for the period of 01.03.2014 – 20.04.2014



(for all stations)



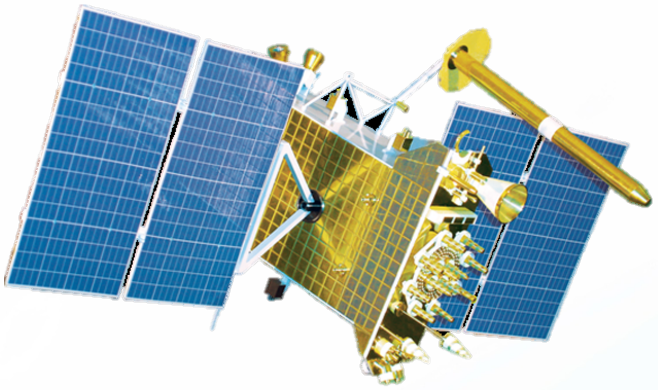
(for stations with “good” positions)

Mathematical expectation and root-mean-square error of SLR-measurements residuals relative to the reference orbit built on phase measurements of the IGS stations world network

SLR planning

Object	Plan
GLONASS navigation SC (flight development testing, operational testing)	3 equally distributed sessions 3-5 min long on each circle
GLONASS navigation SC (normal operation)	2 sessions 3-5 min long for each SC on each circle (day and night)
Lageos SC	2 sessions 5 min long every 24-hours for each SC
LARES SC	1 session every 24-hours in SC visibility zone
Other SC	ILRS recommendations

NEW Glonass-K SC in orbit since February 26, 2011



Glonass-K key features:

Position: 3rd plain, 21st orbital slot

Frequency channel: -5, **Status**: flight test

Lifetime	10 years
Mass	935 kg
Power supply	2 265 W
Signals	FDMA: L1OF; L1SF; L2OF; L2SF CDMA: L3OC
Clock stability	1×10^{-14}

Proposal – include Glonass-K to the ILRS priority list for testing of:

- Methods and mathematical software for new SC series ephemerides determination (SC center of mass reference, reflectors, etc.);
- Laser measurements from new retroreflector;
- Ephemerides accuracy valuation in cooperation with the IGS.

Work methods:

- IAC PNT provides predictions for Glonass-K (*.cpf format);
- Short time interval for tracking (as agreed with the ILRS).

Next steps for analysis

- ❑ Use the accurate and agreed coordinates of <u>all</u> SLR stations;
- ❑ Determine an interval (intervals???) for data processing and further comparison of results obtained by different Analysis Centers;
- ❑ Come to an agreement about the contents of results and their derivation methods;
- ❑ Make calculations for a specified interval and analyse obtained results, generate recommendations for further steps.

CONCLUSIONS

- The laser stations should largely contribute into GNSS accuracy increase.
- It is necessary to make GNSS SC laser tracking global and continuous with forming 9-14 normal points of the laser network measurements for each NSC on every cycle for the orbits accuracy monitoring.
- Taking into consideration the station's average capacity to form 20 normal points per day (regarding weather conditions), no less than 25-30 globally distributed stations operating according to the coordinated plan are required.
- Resources of ILRS and the Russian SLR network as applied to fully populated GLONASS constellation, all the SC of which are equipped with laser retroreflectors, allow to provide the given capacity within the limits of LARGE.
- It is reasonable to start LARGE with tracking of a newly modified GLONASS-K1 SC with the improved retroreflector system of annular type.