PLANNED LLR STATION IN RUSSIA AND ITS IMPACT ON THE LUNAR EPHEMERIS ACCURACY

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ABSTRACT. Precise modern Lunar Ephemerides (DE/LE, USA; INPOP serias, France and EPM-ERA IAA, Russia) are based only on LLR (Lunar Laser Ranging) observations obtained at sixth LLR ground stations during 1969-2013 years. At present there are only four stations active: Grasse(Cerga), McDonald, Apache Point (Apollo) and Matera (Italy). To improve the accuracy of lunar ephemerides the new stations are necessary. Now exist two projects of new LLR stations: Altay (Russia) and Hartebeesthoek in South Africa (1m telescope). La Silla (Chilli) station is very promising but now only under theoretical consideration. In the paper, the impact of a installation of new LLR device on the 3.12 m telescope at Altay station Siberia, Russia is considered. To check the actuality of the project it should be shown, in particular, that the accuracy of the lunar ephemeris will visibly increase. The only way to prove that fact now is the numerical simulation.

1. INTRODUCTION

During about 45 years only LLR observations form the basis for modern Lunar ephemerides. About 18700 LLR observations (normal points, NP) have been obtained during the interval 1970–2013, which were used for obtaining the geodynamical and selenodynamical parameters and improving Lunar ephemeris. Improving the accuracy of LLR observations from 30 cm (1970) to several millimeters (2010-Apache Point station) required new and more sophisticated theories of orbital and rotational Moon motion. Now there are only 3 active stations at the Earth and the construction of new stations with modern lunar laser devices located at different points at the Earth can significantly improve the precision of Lunar ephemeris. One of such projects which is being realized in Russia (Altay station, Siberia region) is the main subject of our paper. The coordinates of the station are: 52N latitude, 82E longitude, H=385 m. The 3.12-meter telescope of the Altay Optical Laser Center will be used for LLR observations. The suggested accuracy of LLR observations (NP) is about 3 mm. The meteorological conditions are: 1400 clear nights hours, 240 nights per year. The main project participants are: OJC Research-and Production Corporation "Precision Systems and Instruments", VNIIFTRI and IAA RAS, the Russian Academy of Sciences. As it was mentioned above, the only way to prove the increase of the accuracy of Lunar ephemeris due to the new LLR station is numerical simulation.

2. NUMERICAL SIMULATION AND RESULTS

The main problem to perform reliable simulation is to create a plausible observational program for the planned LLR station for some time interval. We have analyzed LLR observations at operational LLR stations and made statistical distributions depending on a number of parameters. Three plots of such distributions are presented in Furure 1: reflectors distribution, elevation of the Moon distribution and distribution of real observations per day for every station. We tried to find some regularities that could be the basis for our numerical simulation. But as can be seen on these plots, there is no regularity or uniformity required. So, our conclusion was to use the observational program of real and most precise Apache Point and Grasse(Cerga) LLR stations as the basis to create simulated LLR measurements. Longitude-depended shift and other limitations were taken into account to transfer the observational program from the real LLR Apache Point or Grasse(Cerga) station to simulated the Altay one. Special SW was developed to simulate LLR observations and to estimate the adjusted parameters using both real and simulated LLR measurements within the frame of ERA system (Ephemeris Research in Astronomy)(Krasinsky, Vasilyev, 1996).

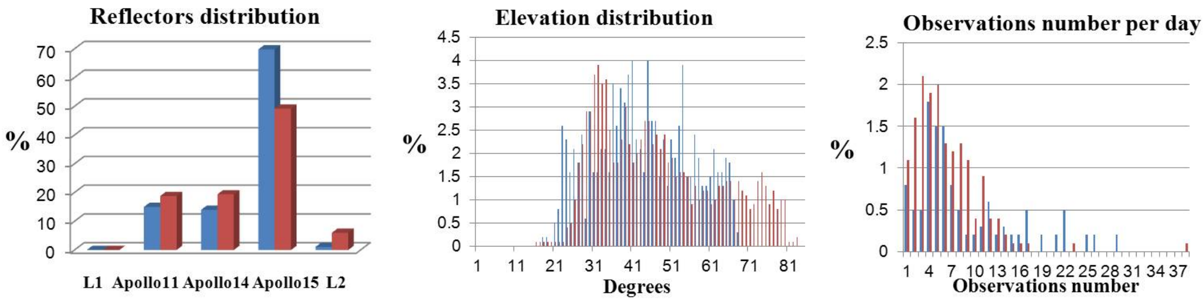

Figure 1: Reflectors distribution, Moon elevation distribution, and distribution of real observations per day.

The last version of the lunar ephemeris EPM-ERA2012 which is used for numerical simulation was described in (Vasilyev, Yagudina, 2014). Several scenarios of simulations have been used to show the result of the impact of the simulated observations at the new Altay station:

I.1.18700 real observations (1970–2013 years) + the simulated observations from 2006 till 2013 at the Altay station just as it was observed at the Apache (Apollo) and the Grasse(Cerga) stations (in simulation-“Apache 2006”, “Cerga2006”).

I.2. 18700 real observations (1970–2013 years) + the simulated observations from 2006 (-1 month shift) till 2013 at the Altay station just as it was observed at Apache Point and Grasse(Cerga) stations (in simulation — “Apache 2006shift”, “Cerga2006shift”).

II. 18700 real observations (1970–2013 years) + the simulated observations from 2008 till 2013 at the Altay station just as it was observed at the Apache Point and Grasse(Cerga) stations (in simulation — “Apache 2008”, “Cerga2008”).

III. 18700 real observations (1970–2013 years) + the simulated observations from 2012 till 2013 at the Altay station just as it was observed at the Apache Point and Grasse(Cerga) stations (in simulation — “Apache 2012”, “Cerga2012”).

The impact on parameter’s accuracy of the “Apache 2006” and the “Cerga2006” scenarios are presented in Fig. 2. Here are shown the visible improvement of the parameters under consideration depending on the reference station. It shall be noted that a more intense observational program generated from the Apache Point one gives more promising results. These parameters are: initial coordinates and velocity of the Moon (1–6), Libration angles and theirs derivatives (7–12), the coordinates of the ground stations(23-40) and reflectors (13–22), Lag of the Moon (60), Lag of the Earth (54) and other parameters (totally 67 parameters).

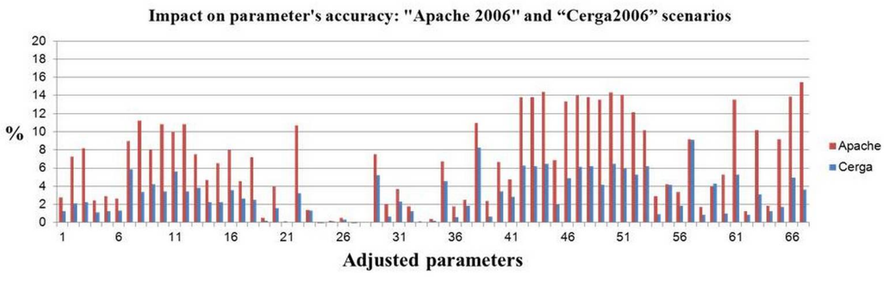

Figure 2: Adjusted parameters.

Next three plots are shown in Fig. 3. Here are presented three graphs for “Lag of the Moon”, “Lag of the Earth” and “K_2 Moon” — Love number of the Moon which demonstrate the accuracy vs. observation interval for these adjusted parameters. In case of the Apache Point based scenario we have observed accuracy growth (the improvement is 14 percent for K_2, while at the same time for Grasse(Cerga) scenario improvement is rather small and almost the same vs years). It demonstrates the importance of intensive observation program for the Altay station, because its geographical positions are closer to Grasse(Cerga) station than to Apache Point one. One additional remark: two last points on each graphs show the simulation precision.

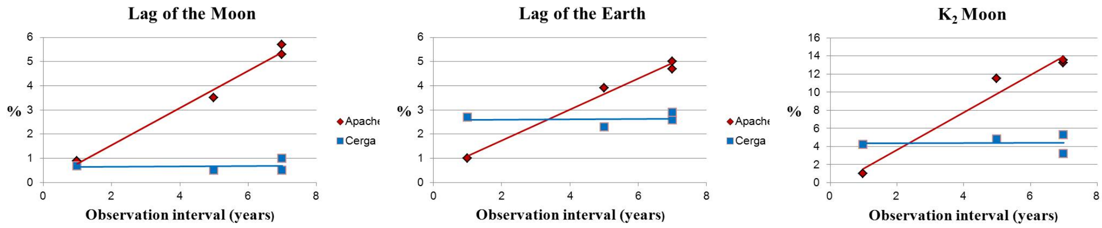

Figure 3: Improvement of the parameters vs observational interval.

3. COMPARISON WITH LA SILLA

There is another project, connected with the probable installation of LLR device at 3.6 m telescope at La Silla station. It would be interesting to compare the conditions at the two stations. The SHELLI (Southern Hemisphere Lunar Laser Instrumentation) project is located at ESO, La Silla, Chile (29 N-latitude, 70 W-longitude, H=2400m). It is a twin of the Apache Point in terms of quality and regularity of the produced data. Meteorological conditions: ESO, bordering the southern extremity of the Atacama desert in Chile.

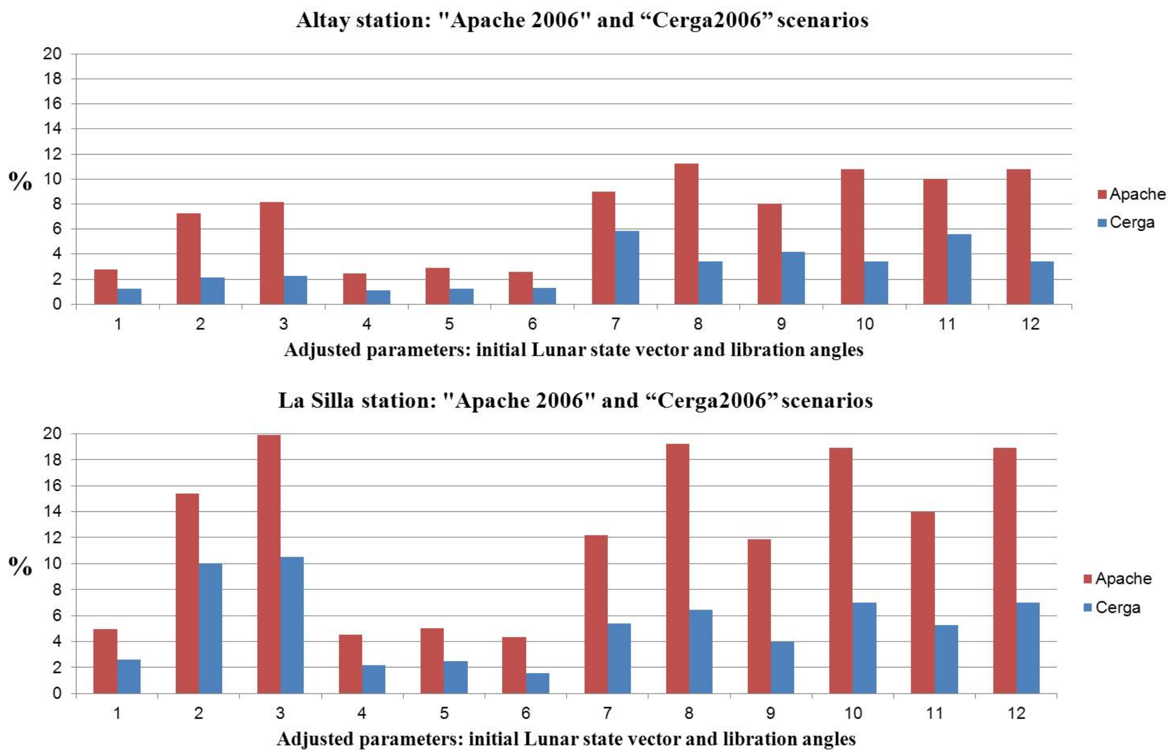

Figure 4: Comparison of the improvement of the parameters for the Altay and the La Silla stations.

The probable participants: ESO, Geoazur(OCA), INSU. In Table 1. the geographical and meteorological data for different stations (real and planned Altay and La Silla stations) are shown to compare observational conditions at the stations. Figure 5 demonstrates that Altay station is not located in the best conditions as compare with the Grasse(Cerga) and Apache Point stations: elevation of the Moon is lower than at the Apache Point and Grasse(Cerga) stations. As for meteorological conditions (2400 m La Silla and 385 m Altay!) are also guaranteed more observational nights at La Silla station.

Station	Latitude	Longitude	Altitude, m	Telescope
Apache	33 N	254 W	2788	3.5m
Cerga	45 N	7 W	1270	1.54m
Altay	51 N	82 E	385	3.12m
La Silla	29 S	70 W	2400	3.6m

Table 1: Geographical and meteorological conditions at different stations (comparison).

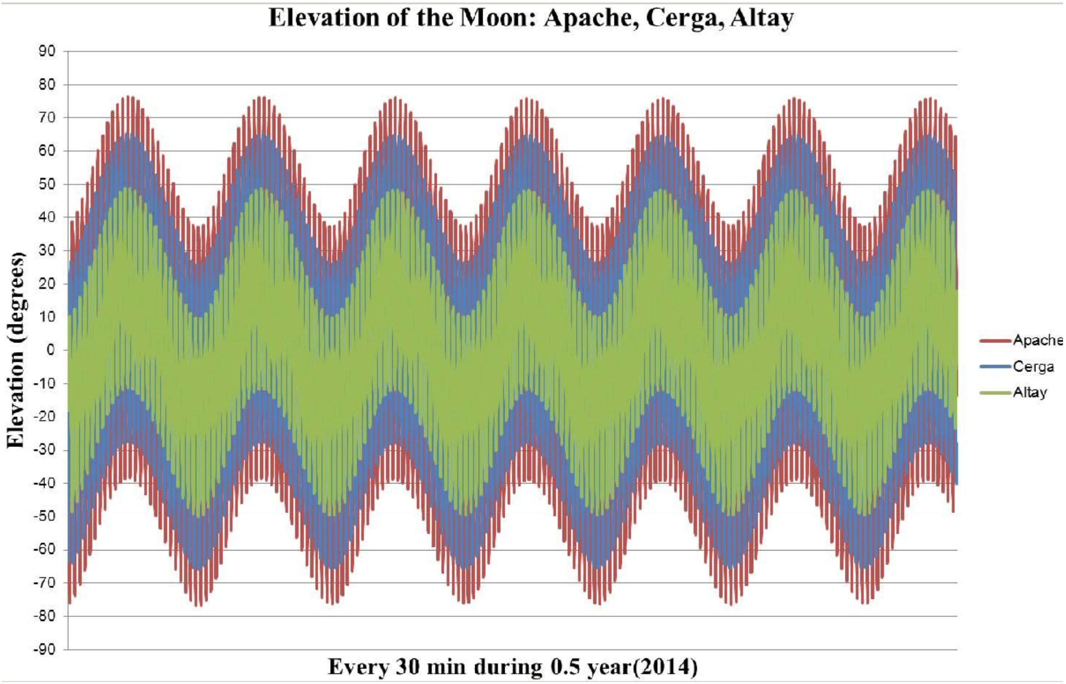

Figure 5: Elevation of the Moon at 3 stations: Apache Point, Grasse(Cerga), and Altay.

4. CONCLUSION

1. According to our simulations new Russian LLR observations will provide visible accuracy improvement of the Lunar ephemeris and corresponding physical models: about 2–16% depending on the adjusted parameters.

2. Simulation SW was developed estimating the impact of the new LLR stations on the accuracy of Lunar ephemeris.

3. Russian LLR station has observational limitations due to geographical position. Thus,its observational program should be very intense to provide the impact comparable with other modern LLR stations. The results obtained are in good agreement with the similar work in the field (Fienga, et al., 2014).

4. Russian LLR station can make significant contribution into the common world database of LLR data.

5. REFERENCES

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