Pole coordinates from the analysis of LLR data

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1. Motivation and introduction

On July 21, 1969 the first retro-reflector was deployed on the Moon's surface by the Apollo 11 crew. Since then distance measurements (round-trip travel times of laser pulses) between stations on the Earth and the retro-reflectors have been carried out. The signal-to-noise ratio is rather weak, because of, e.g., energy loss, atmospheric extinction and geometric reasons. This makes Lunar Laser Ranging (LLR) challenging, so that only a few observatories worldwide are capable to track the Moon. The measurements are combined to so-called normal points (NP), about 17000 until 2009. These serve as observations for the data analysis. The whole 40-years LLR data set has been analysed to determine the dynamics of the Earth-Moon system (e.g., station and reflector coordinates, lunar orbit and rotation). In addition, Earth rotation parameters (ERP) like x_P and y_P, have been investigated.

2. ERP from post-processing

In a previous study, the ERP were determined in a post-processing step. After the global least-squares adjustment the residuals were sorted by station-reflector combinations and merged in daily sets. From more than 16000 observations (until 2007), 1179 daily sets for the station OCA in Grasse and 752 daily sets for the station McDonald in Texas were found. These sets were analysed in a second least-squares adjustment (daily decomposition method, see [1]). However, in this way the correlation between ERP and other parameters of the Earth-Moon system could not be considered, for more details see [2].

3. ERP from global adjustment

In our recent analysis, trends and corrections for x_P/y_P were fitted directly in the global adjustment. In this way it is possible to obtain correlations of x_P/y_P with other parameters of the Earth-Moon system.
Figure 1 shows the IERS C04 series including a linear drift for 1970-2007. From LLR data the respective drifts for the pole coordinates were also determined for 1970-2007. The values for the LLR based drifts and their accuracies are given in green. They differ slightly from the IERS C04 series drifts. The combined linear drift from LLR is 4.9 ± 0.3 mas/a for the period of 1970-2007. From the combination of space geodetic techniques, [3] obtained a linear drift in polar motion of 4.123 ± 0.002 mas/a for the time span 1976.7-1997.1.

Besides the linear drifts also correction values for x_P/y_P were fitted. Figure 2 shows the comparison between the IERS C04 series, results from VLBI (ivs quat combi) and LLR (erpLLR10). The LLR data were analysed under the constrain, that for every considered night at least 10 NP must be available. It is therefore obvious, that from LLR less values for x_P/y_P can be obtained. The LLR results agree well with the IERS C04 series.

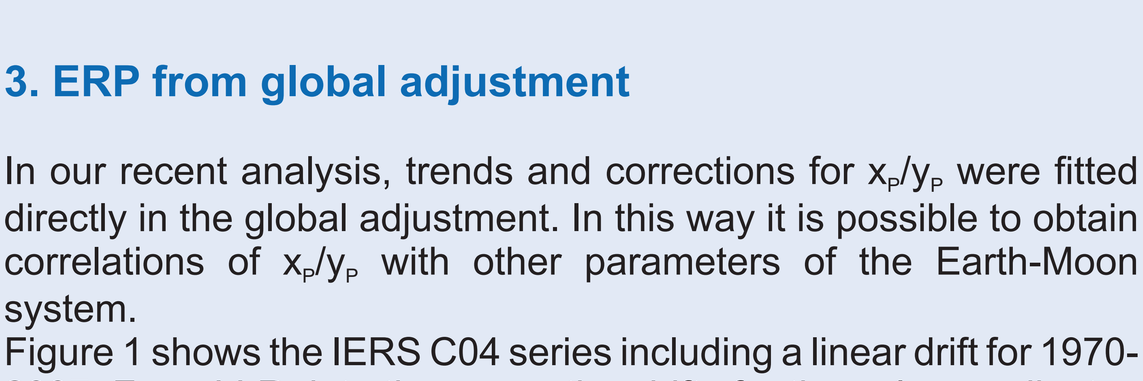

Fig. 1: Pole coordinates of the IERS C04 series with its linear drift in comparison to the sum of linear drift correction determined from LLR data and C04 linear drift

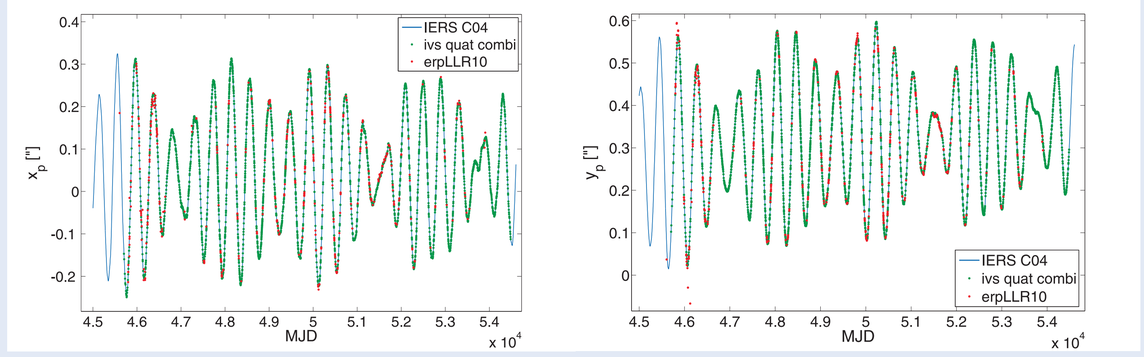

Fig. 2: Comparison between pole coordinates from IERS C04 series, IVS quaterly combined series and results from LLR

Figure 3 shows the LLR results for x_P/y_P in more detail including their error bars. In the early years the errors reach up to 50 mas for x_P and 30 mas for y_P. The rms for the whole data set is 10 mas for x_P and 12 mas for y_P. From the Nineties on, where the results are more homogeneous, the rms decreases to 3.5 mas for x_P and 2.6 mas for y_P. Compared to the rms of VLBI ivs quat combi (0.15 mas for x_P and 0.13 mas for y_P [4]), the LLR results are about 20 times worse.
Looking onto the correlations of x_P/y_P to other parameters of the Earth-Moon system, slight correlations of up to 20 % were found with nutation coefficients, motion of tectonic plates and the pole coordinates among each other.

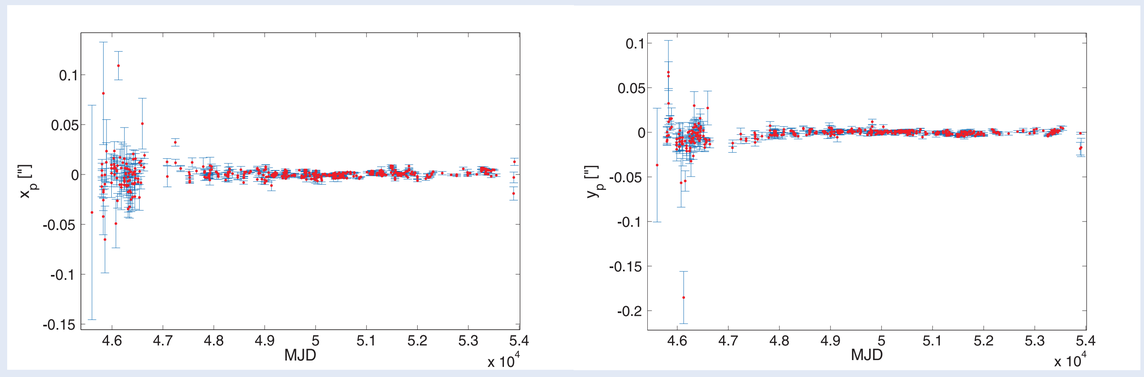

Fig. 3: Pole coordinate corrections from LLR analysis (red) with respective error bars (blue)

4. Conclusions

Linear drifts and correction values for x_P/y_P were determined from LLR data. The LLR rms is about 20 times larger in comparison to VLBI results. Based on initial values from IERS C04 series linear drifts for x_P/y_P are determined from LLR data. The combined LLR drift is similar to that from [3] covering a comparable time span.

References

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[3] Gross, R.S.; Vondrák, J. (1999): *Astrometric and space-geodetic observations of polar wander*, Geophys. Res. Lett., 26, 2085-2088.

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