Preparing the Bernese GPS Software for the analysis of SLR observations to geodetic satellites

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INTRODUCTION

The Bernese GPS Software 5.0 (*Dach et al. 2007*) is capable to compute SLR residuals for given satellite orbits and station coordinates. For this application, CODE (Center for Orbit Determination in Europe) is currently acting as an associated analysis center of the ILRS performing quicklook analyses using SLR measurements to GNSS satellites (two GPS and three of the GLONASS satellites).
In cooperation with BKG the Bernese GPS Software is being generalized to analyze SLR observations to geodetic satellites, like Lageos and Etalon. The analysis includes initially the estimation of station coordinates, Earth orientation parameters, and satellite orbits (osculating elements and dynamical orbit parameters).
The poster presents the status of our LAGEOS-1 orbits using the data set of the ILRS Benchmark.

REFERENCES

Brockmann E. (1997): Combination of Solutions for Geodetic and Geodynamic Applications of the Global Positioning System (GPS). PhD thesis. Geodätisch-geophysikalische Arbeiten in der Schweiz, Vol. 55.

Dach R., U. Hugentobler, P. Fridez, M. Meindl (2007): Bernese GPS Software Version 5.0. Astronomical Institute, University of Bern.

PROCESSING STRATEGY

Following the specifications for the ILRS benchmark, we focus on the data set between October 10, 1999 and November 6, 1999, i.e., a time span of 28 days. This data set contains SLR observations of 13 stations to LAGEOS-1. As it is requested to divide the 28-day orbit into sub-arcs of 4 days for the dynamical orbit parameters, we perform the processing in two steps:

1. Generation of 4-day normal equations (NEQs) based on SLR observations. The NEQs contain the parameters of interest, i.e., osculating elements, dynamical orbit parameters, station coordinates, Earth rotation parameters.
2. Accumulation of the 4-day NEQs of step 1 to a 28-day solution by transforming the osculating elements to one common set, but estimating the dynamical orbit parameters separately for each 4-day interval (as it is described in *Brockmann, 1997*).

Concerning the parameters that are estimated, we generated several solution types. An overview of the solution types and their characteristics is given in *Tab. 1*. The 28-day solutions "B28" and "C28" correspond to the ILRS benchmark types "B" and "C", respectively.
In addition, we generated series of solutions covering a shorter time span: 8-, 12- and 16-day solutions (labeled accordingly in *Tab. 1*). Within each series, the solutions were generated using data sets shifted by one day. This allows us to perform repeatability studies from the overlapping days of adjacent orbital arcs.

	Oscul. Elem.	*Along const.*	*Rad. opr*	*Cross opr*	*Crd/EOP*
B8	8d	4d			fix
B12	12d	4d			fix
B16	16d	4d			fix
B28	28d	4d			fix
C28	28d	4d			loose
D8	8d	4d	4d	4d	loose

Table 1: *Estimated parameters and their temporal resolution in different solution types.*

ORBIT COMPARISONS

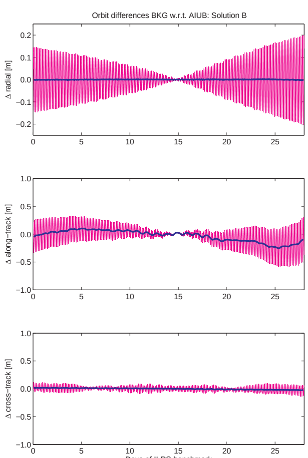

Figure 1: *Residuals of orbit comparison with BKG for benchmark solution type B (**blue**: mean over one revolution).*

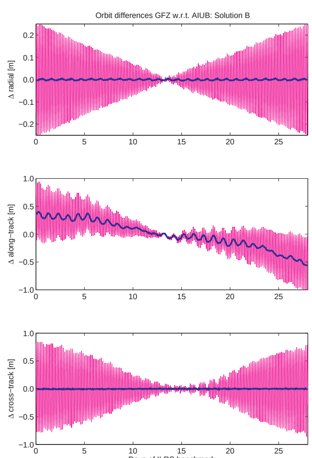

Figure 2: *Residuals of orbit comparison with GFZ for benchmark solution type B (**blue**: mean over one revolution).*

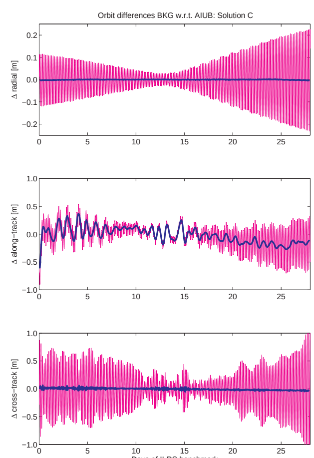

Figure 3: *Residuals of orbit comparison with BKG for benchmark solution type C (**blue**: mean over one revolution).*

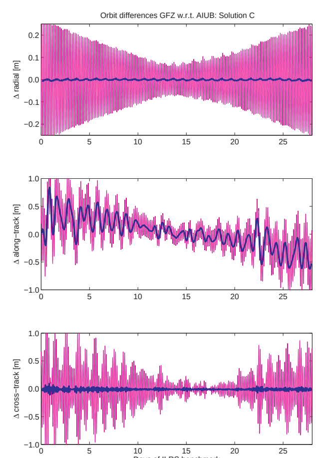

Figure 4: *Residuals of orbit comparison with GFZ for benchmark solution type C (**blue**: mean over one revolution).*

As an external validation, we compared our 28-day orbits for benchmark types B and C (B28, C28) to the corresponding orbits computed by BKG using the UTOPIA software (developped at CSR, Texas) and by GFZ using EPOS. *Fig. 1* and *Fig. 2* show the residuals in radial, along-track and cross-track components for the comparison with BKG and GFZ, respectively. The blue lines represent the mean residual for one revolution. Thus, we see that the residuals in radial and cross-track components mainly have a once-per-revolution signature, whereas the residuals in along-track additionally have a daily signature. The origin of these differences still has to be investigated further.
Similar conclusions can be drawn from the orbit comparisons for the solution type C (see *Fig. 3* and *Fig. 4*).
It is especially important to see that the radial component, what is the major component to be determined by SLR, agrees quite well.

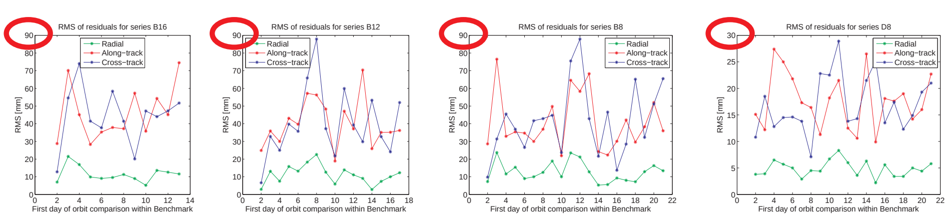

Figure 5: *Comparing adjacent orbital arcs for different solution types. Note the different scale of the y-axis in the rightmost figure (D8)!*

For an internal validation we compare adjacent orbital arcs for the 8-, 12- and 16-day solution series type B, and for the 8-day solution series type D. The rms of the residuals for these comparisons are shown in *Fig. 5*. Again, it is important to see that the radial component shows a good repeatability.
The level of the repeatability does not differ much between different arc lengths of one solution type (B8, B12, B16). But the repeatability can be clearly improved by estimating once-per-revolution terms in radial and cross-track direction in addition to constant along-track accelerations (i.e., D8 compared to B8). This behavior may be an indication that the dynamical orbit parameters absorbe deficiencies in the modeling.

CONCLUSIONS

The orbits of LAGEOS generated with the Bernese GPS Software have a quality that is comparable to that of other ILRS analysis centers. Nevertheless, there are several improvements to be done. Our next steps to improve the SLR analysis with the Bernese GPS Software are:
- improve/extend apriori models (troposphere, Earth albedo)
- improve the estimation of range biases in order to follow the specifications of ILRS
- develop a procedure for screening observations in order to detect outliers automatically and reliably

Poster compiled by D. Thaller, October 2008
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