Combined analysis of GNSS and SLR observations for the GIOVE satellites

EGU General Assembly 2009
EGU2009-2671

D. Thaller, A. Steinbach, R. Dach
Astronomical Institute, University of Bern (AIUB), Switzerland

INTRODUCTION

Microwave-based solution

The egsp (Galileo Geodetic Service Provider) is responsible to provide the geodetic reference of the future European GNSS, the Galileo system. The AIUB is one partner of the consortium of seven scientific institutions. The data of 13 GESS (Galileo Experimental Sensor Stations) are processed together with the GPS data of about 120 IGS (International GNSS Service) sites (see ***Fig. 1*** for the network). Apart from the station coordinates, the GNSS satellite orbits, Earth rotation parameters (ERPs), and clock corrections are computed.
Since the GESS provide data for the two GIOVE satellites and the active GPS satellites, a combined processing is carried out on observation level. Due to the sparse network of GESS, the GPS data highly support the Galileo-related products, especially the satellite orbits of the two GIOVEs. Nevertheless, orbit comparisons (internal and between the GGSP partners) show that the quality of the estimated GNSS-only GIOVE orbits is limited to about 20 cm, whereas the orbit quality of the GPS satellites is about 2 cm.

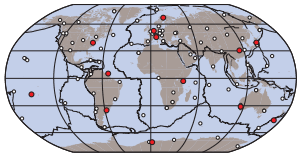

***Figure 1**: Network of GESS (red dots) and GPS-only stations (white circles) that are analysed.*

SLR-based solution

GIOVE-A and -B (E01, E16, respectively) are equipped with retro-reflector arrays. The satellites are tracked by the ILRS (International Laser Ranging Service), as it is already done for the two GPS satellites equipped with retro-reflectors (G05, G06) and some of the GLONASS satellites. The SLR sites that were tracking the GIOVE satellites are shown in ***Fig. 2***. The colour scheme indicates how many SLR observations are available in total for each site for the time span studied.

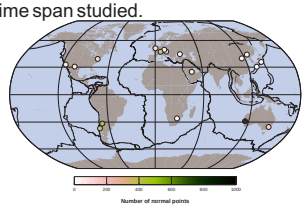

***Figure 2**: Network of SLR stations tracking GIOVE satellites. The colours indicate how much observations the individual sites provided in total for the time span analysed.*

Validation and combination

The availability of SLR data allows a validation of the satellite orbits determined from microwave observations. The range residuals show whether there is any systematic difference between the GNSS and SLR system and, thus, may help to improve the orbit modeling for the GIOVE satellites.
The time span analysed starts on August 31, 2008 and lasts until February 28, 2009, i.e., half a year of data.

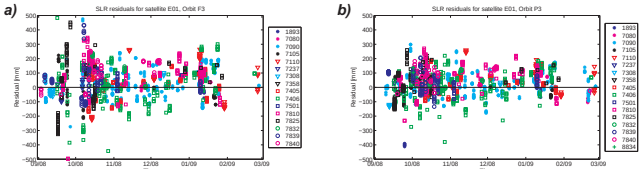

***Figure 3**: SLR residuals for GIOVE-A. **a)** nominal, **b)** estimated antenna phase center model.*

SLR RESIDUALS TO GNSS ORBITS

In a first step, only the residuals for the SLR observations were derived, i.e., the GNSS-derived orbits and ERPs as well as the station coordinates of the SLR sites were introduced as known values.
Within the GGSP, only the nominal offset (no variation) for the GNSS satellite antenna phase center (PCV) is used for the GIOVE. ***Fig. 3a*** shows the corresponding SLR residuals for GIOVE-A. We estimated a model for the satellite PCV of GIOVE from the six months of data. The PCVs for the GPS satellite antennas as well as for the ground station antennas were fixed. After applying the PCV model, the scatter of the SLR residuals is reduced by about 20-30% (***Fig. 3b***).
For 7-day arcs (using the estimated PCV), the residuals to both GIOVE satellites and one GPS satellite are shown in the left column of ***Fig. 4*** (solution labeled "**R7**"). It is obvious that the scatter of the SLR residuals to the GIOVE satellites is much larger than for the GPS satellites (see also ***Tab. 1*** exemplarily for some stations).
It is striking that the mean bias of the residuals is different for the three satellites shown (the GIOVE satellites have even opposite sign than the GPS satellites).
Due to this behaviour, one range bias per station and per satellite was set up in a second step of the analyses (solution labeled "**R7A**"). The resulting SLR residuals are shown in the right column of ***Fig. 4***. As expected, the residuals are now centered around zero. The scatter of the residuals is reduced (see ***Tab. 1***), but the residuals within one satellite pass still differ much more for the GIOVE than for the GPS satellites.
In order to investigate the impact of the sparse network of the GESS on the GNSS orbits, we generated orbits for the GPS satellites G05 and G06 from the 13 GESS only. However, nearly no degradation of these orbits compared to the orbits derived from the full network was detectable.

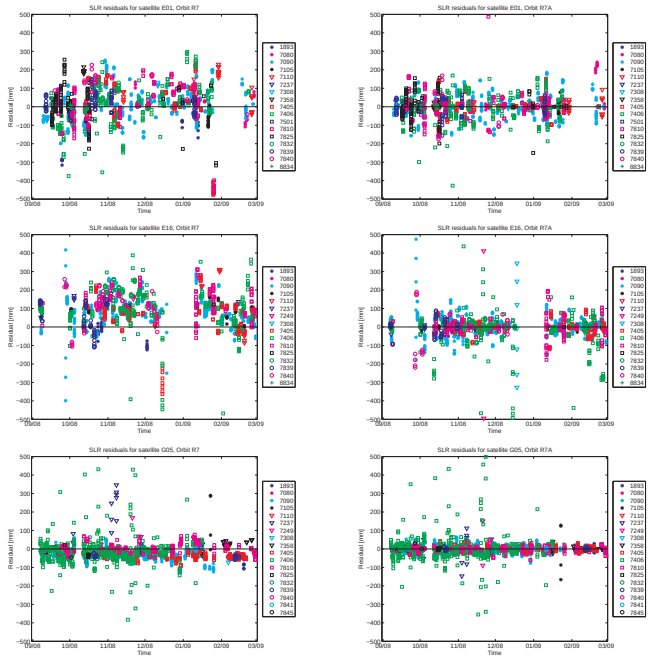

***Figure 4**: SLR residuals to 7-day GNSS orbits. **Left:** Only residuals. **Right:** Estimate range biases.*

SLR+GNSS ORBITS

The small number of SLR observations to the GIOVE satellites and a bad distribution of the regularly observing SLR sites (see ***Fig. 2***) do not allow to generate an SLR-only orbit better than from GNSS data. Nevertheless, a combined analysis of GNSS and SLR data may help to understand the reason for the large residuals and to improve the GIOVE orbits. For this purpose, we did a combined GNSS+SLR analysis with satellite orbits and ERPs as common parameters.
We computed 5-day orbits for the time span after October 2008 shifted by one day. The resulting orbit of the mean day was then compared to the orbit of the previous 5-day arc. ***Fig. 5*** shows the RMS of these orbit overlaps exemplarily for GIOVE-A. Unfortunately, the comparison between the GNSS-only orbit and the combined orbit shows that the SLR observations can contribute only very little to the stability of the orbit determination. Solely if the GNSS-only orbit is very weak, we can see an improvement.
In addition, there are obviously some systematic differences between the two systems (i.e., GNSS and SLR) that are not yet well understood, so that a combined analysis becomes difficult.

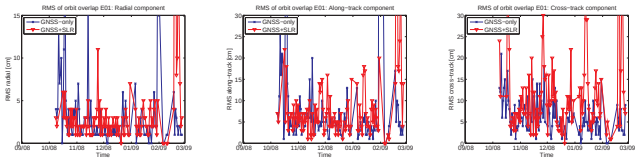

***Figure 5**: RMS of orbit overlaps for GNSS-only and combined GNSS+SLR orbits for GIOVE-A.*

CONCLUSIONS

The comparison with SLR observations confirmed the level of orbit quality for GIOVE already seen from the GNSS analysis. The reason for the larger scatter of the residuals is still not clear. Tests showed that neither the network, nor the satellite antenna phase center model, nor SLR range biases can reduce the scatter to the level seen for the two GPS satellites.
First tests for a combined GNSS+SLR orbit determination could not show a big improvement for the stability of the orbit determination of GIOVE.

	GIOVE-A		GIOVE-B		G05		G06	
	R7	**R7A**	**R7**	**R7A**	**R7**	**R7A**	**R7**	**R7A**
7090	89.9	67.3	80.8	60.1	24.7	18.8	28.9	23.1
7405	135.9	60.5	97.1	42.2	17.4	13.9	24.3	15.5
7406	113.0	79.4	117.6	117.2	70.5	70.0	70.7	56.5
7810	115.5	68.4	72.6	57.8	25.5	14.6	52.5	33.2
7839	62.1	39.7	83.9	41.8	10.2	8.4	23.5	13.0

***Table 1**: RMS of SLR residuals given in [mm]. **R7:** Only residuals; **R7A:** Estimate range biases per station and per satellite.*

Acknowledgement:
The effort of the ILRS stations to track the GNSS satellites is highly acknowledged.

Poster compiled by D. Thaller, April 2009
Astronomical Institute of the University of Bern
daniela.thaller@aiub.unibe.ch