Combination of VLBI, GPS and SLR Data Analysis at FFI

Per Helge Andersen

Abstract

FFI's contribution to the IVS as an Analysis Center will focus primarily on a combined analysis at the observation level of data from VLBI, GPS and SLR using the GEOSAT software. This report shortly summarises the current status of analyses performed with the GEOSAT software. FFI is currently an Analysis Center for IVS and ILRS, a Technology Development Center for IVS, and a Combination Research Center for IERS.

1. Introduction

Recently, a number of colocated stations with more than one observation technique have been established. In principle, all instruments at a given colocated station move with the same velocity and it should be possible to determine one set of coordinates and velocities for each colocated site. In addition, a constant eccentricity vector from the reference point of the colocated station to each of the individual phase centers of the colocated antennas is estimated using constraints in accordance with a priori information given by the ground surveys. One set of Earth orientation parameters (EOP) and geocenter coordinates can be estimated from all involved data types. The present dominating error source of VLBI is the water content of the atmosphere which must be estimated. The introduction of GPS data with a common VLBI and GPS parameterization of the zenith wet delay and atmospheric gradients will strengthen the solution for the atmospheric parameters. The inclusion of SLR data, which is independent of water vapour, gives new information which will help in the de-correlation of atmospheric and other solved-for parameters and lead to more accurate parameter estimates. These, and many more advantages with the combination of independent and complementary space geodetic data at the observation level, are fully accounted for with the GEOSAT software ([2]) developed by FFI during the last 16 years.

2. Data Analysis

A set of VLBI data from January 1993 to July 2001 has been analyzed. This analysis will be referred to as the VLBI-alone analysis. A second analysis (referred to as the combined analysis) was performed where SLR data for Lageos I and Lageos II from the same period was combined with the VLBI data at the observation level using exactly the same strategy as for the VLBI-alone analysis. In addition approximately 100 days of GPS data was included in the combined analysis. The two analyses were performed in arcs of 24 hours using the GEOSAT software. The arc-results were combined into a multi-year VLBI-alone and a combined VLBI, GPS and SLR solution using the CSRIFS software ([1]) which is a part of the GEOSAT software. The VLBI analysis model and analysis strategy are described in Andersen ([3]). Station coordinates and velocities were estimated simultaneously with the Earth orientation parameters and radio source coordinates.

The results show that the use of SLR and GPS data in addition to VLBI data improves the precision of the estimated polar motion parameters from 0.2 mas to 0.1 mas, it improves the precision of the estimated UT1 parameters from 10 to 5 microseconds, and it improves the precision of the estimated nutation parameters from 0.2-0.3 mas to 0.15 mas. The formal precision of the nutation parameters indicates that the precision of these parameters in principle could be improved to the level of 0.05-0.08 mas. The analyses show that the applied VLBI, GPS and SLR models are consistent to a few mm.

In the CSRIFS program all correlations between the TRF, CRF and EOPs are accounted for and the estimated EOPs are expected to be 100% consistent with the two reference frames. The results (TRF, CRF and EOPs) have been transformed to ITRF2000 and ICRF95 for comparison with the IERS(EOP)C04 file. Since IERS does not consider the correlations between TRF, CRF and EOP it is expected that their EOPs are partly inconsistent with ITRF2000 and ICRF95. The results so far indicate that there is a drift in the IERS PM estimates of almost 0.1 mas/y and a drift in UT1 of 10 micro sec/y. This will be further investigated.

The results indicate that as long as SLR tracking of two Lageos satellites is available on a daily basis it might be better to have, say 3-4 VLBI sessions a week, with many participating stations rather than daily VLBI sessions with a small number of participating stations. The SLR data is fully capable of producing high precision estimates of these parameters for days where VLBI data are not available as long as the interval between succeeding VLBI sessions is not longer than a week. Further investigations are necessary in order to determine the consequence of enlarging (or reducing) the periods with no VLBI data on the precision of the estimates of the Earth orientation parameters.

It is observed from the solutions for the radio source positions that the inclusion of SLR data can lead to changes up to 0.3 mas in the estimated source coordinates. This is not unexpected since the two Lageos satellites used in the present analysis are physical objects in addition to the radio sources being used for the realization of CRF. It is a general trend in the formal uncertainties that the standard deviation in the right ascension is slightly improved with the inclusion of SLR data while the standard deviation in declination is significantly improved in some cases by as much as a factor of four. The inclusion of additional GPS data seems to further improve the declinations of the radio sources. This will be further investigated.

The results show that for the first time VLBI, GPS and SLR tracking data have been successfully combined at the observation level. Furthermore, it is the first time satellite tracking data successfully have been used for the direct determination of nutation parameters. Based on the analysis and preliminary experience with the combination of VLBI, SLR and GPS data, the author is convinced that the direct combination of high precision space geodetic data at the observation level within ten years will be the primary method for the realization of terrestrial and celestial reference frames and their interrelations.

More details of the analysis can be found in Andersen ([4]).

3. Technical Staff

Table 1 lists the FFI staff involved in IVS activities.

Table 1. Staff working at the FFI AC and TDC

Name	Background	Dedication	Agency
Per Helge Andersen	geodesy	40%	FFI

References

[1] Andersen, P. H. Multi-level arc combination with stochastic parameters. Journal of Geodesy (2000) 74: 531-551.

[2] Andersen, P. H. High-precision station positioning and satellite orbit determination. PhD Thesis, NDRE/Publication 95/01094.

[3] Andersen, P. H. Combined analysis of VLBI, GPS and SLR data at the observation level. Under preparation.

[4] Andersen, P. H. Determination of Earth orientation parameters using VLBI and SLR data combined at the observation level. Invited paper submitted 15 May, 2000, to Journal of Geodesy for the special issue on the theme “New methodologies for EOP combinations”.