Combination of Results at FFI – Software Development

Per Helge Andersen

Abstract

FFI's contribution to the IVS as a Technology Development Center will focus on the development of software (GEOSAT) for a combined analysis at the observation level of data from VLBI, GPS and SLR. This report shortly summarises the current status of the GEOSAT software development and validation including some future plans.

1. Introduction

FFI is centrally located in the Kjeller area, 30 minutes east of Oslo (near Lillestrøm). Here approximatelu 2400 people are engaged in several research establishments, technical institutions, university branches and Air Force Material Command. FFI is a state operated, civilian research establishment reporting directly to the Ministry of Defence. The number of employees is approximately 550.

For many years FFI has performed research in space science and remote sensing using satellites. As a part of this research FFI has developed a highly sophisticated software (GEOSAT, [2]) for satellite orbit determination and space geodesy. With this software all types of high precision space geodetic observations can be combined and analyzed at the observation level.

2. Goals for FFI's Contribution to the IVS

Based on contributions from a number of analysis centers the International Earth Rotation Service (IERS) calculates on a regular basis realizations of a terrestrial and a celestial reference frame including their interconnections given by the Earth Orientation Parameters (EOP). It is a serious problem that the individual solutions submitted to the IERS are calculated using different software with partly inconsistent models and strategies. This can lead to inconsistencies within one technique of several mm in station coordinates. The between-technique inconsistencies can be as high as 1 cm in the combined IERS solution for the terrestrial reference frame. The GEOSAT software will for the first time make it possible to perform analyses of VLBI and satellite tracking data with one consistent model and strategy.

Analysis of data from any of the IERS techniques requires the calculation of a large number of parameters. Some of these parameters are highly correlated leading to a reduction in accuracy. The strength of VLBI is in the determination of distances and directions while the satellite techniques are especially important for the determination of the Earth's center of mass. In order to obtain high-precision results with VLBI and GPS the water vapor content of the troposphere or the zenith wet delay must be precisely estimated. The introduction of SLR data, independent of the water vapor, will contribute to the decorrelation of the zenith wet delay parameter from all the other estimated parameters especially the height component of the station coordinates. In general, the combination of independent and complementary information from different types of data will reduce the parameter correlations and lead to more accurate results.

There are several additional advantages with the combination of VLBI and satellite tracking data: the estimated satellite orbital elements, radio source coordinates, and EOPs will be realized in a long-term stable celestial reference frame realized primarily by the radio sources. This means that the GPS and SLR observations for the first time can be used in the determination of UT1 itself and not only the length of day (LOD). Another advantage is that all estimates of geodetic and geodynamic parameters are given in the same realization of a terrestrial reference frame. Finally, the combined analysis of VLBI, GPS, and SLR can be used to estimate the eccentricity vectors between the different antenna phase centers within each colocated station. It is a fact that much eccentricity information is missing and some of the existing information is quite unreliable or inaccurate.

FFI will, as a Technology Development Center for IVS, develop the GEOSAT software to demonstrate the feasibility and potential of a combination of VLBI, GPS and SLR data at the observation level. We will especially focus on the establishment of consistent observation models for all three techniques. The a posteriori residuals will be investigated in order to detect systematic technique-dependent errors. Solutions for the individual techniques will be compared with a combined solution to evaluate the contribution from each technique to the determination of important geodetic and geodynamical parameters.

The different data types are combined for each arc at the observation level using a UD-factorized filter. The arc length is defined by the length of the VLBI session. The arc-by-arc state vectors and complete covariance matrices are combined into a multi-year solution using a highly sophisticated and flexible Square-Root-Information-Filter-and-Smoother (CSRIFS, [1]). Four parameter levels are available in the CSRIFS program and any parameter can, at each level, either be represented as a constant or a stochastic parameter. The batch length can be made time- and parameter-dependent. The state vectors will include station coordinates and velocities for some selected multi-technique stations in addition to Earth orientation parameters (EOP), radio source coordinates, and other geophysical and geodynamical parameters.

3. Status

All planed components of GEOSAT have been successfully validated with a combination of data from VLBI, GPS and SLR. Consistent models for all techniques have been verified at the sub-ppb level. The processing at the arc and session levels are completely automated using C-shell scripts. In some cases the processing crashes and additional work must be done in order to make the processing scheme more robust against errors in the input data.

The CSRIFS program for combining arcs has been successfully applied in the generation of a VLBI-only solution covering 623 sessions during the last 10 years. A paper containing the mathematics of CSRIFS and the results of the VLBI analysis has recently been submitted for publication in Journal of Geodesy.

4. Technical Staff

Table 1 lists the FFI staff involved in IVS activities. The development and validation of GEOSAT have resulted in a substantial theoretical understanding and practical experience with all available types of high-precision space geodetic data (VLBI, GPS, SLR, PRARE, DORIS and radar altimetry).

Table 1. Staff working at the FFI AC and TDC

Name	Background	Dedication	Agency
Per Helge Andersen	geodesy	40%	FFI

5. Outlook

The computation time for the processing of 24 hours of VLBI, GPS, and SLR data is presently approximately 14 hours using a HP C180 (one CPU) computer. We plan to buy a new computer within the end of this year or early next year, probably a HP J5000 (with two CPUs) or a HP J7000 (with four CPUs) including 1 Gb RAM. This should give an increase of a factor 5 or 10 in processing capacity. The disk storage capacity will be extended from 65 Gb to 100 Gb with additional 30 Gb each year. With such computation power it should be possible to generate global combined multi-technique solutions based on a large number of arcs.

References

[1] Andersen, P. H. (1999) Multi-level arc combination with stochastic parameters. Paper submitted for publication in Journal of Geodesy.

[2] Andersen, P. H. (1995) High-precision station positioning and satellite orbit determination. PhD Thesis, NDRE/Publication 95/01094.