3.6.2.4 Forsvarets forskningsinstitutt (FFI)

Introduction

FFI has during the last 25 years developed a software package called GEOSAT (Andersen, 1995) for the combined analysis of VLBI, GNSS (GPS, GALILEO, GLONASS), SLR and other types of satellite tracking data (DORIS, PRARE and altimetry). The observations are combined at the observation level with a consistent model and consistent analyses strategies. The data processing is automated except for some manual editing of the SLR observations.

In the combined analysis of VLBI, GNSS and SLR observations, the data are processed in arcs of 24 hours defined by the duration of the VLBI session. The result of each analyzed arc is a state vector of estimated parameter corrections and a Square Root Information Filter array (SRIF) containing parameter variances and correlations. The individual arc results are combined into a multiyear global solution using a Combined Square Root Information Filter and Smoother program called CSRIFS. With the CSRIFS program any parameter can either be treated as a constant or a stochastic parameter between the arcs. The estimation of multiday stochastic parameters is possible and extensively used in the analyses. The advantages of the combination of independent and complementary space geodetic data at the observation level is discussed in (Andersen, 2000).

Status

After six years of development and validation a completely new version of the GEOSAT software is ready for routine processing of space geodesy observations and tracking data towards spacecrafts in the Solar system. The software will automatically detect if the spacecraft is in cruise mode or is orbiting around a central body. In the latter case, the central body is automatically identified and a state-of-the-art gravity field for the central body is read from a file. If the central body is the Earth, all dynamics will be represented in a local geocentric space-time frame of reference. If the central body is another body in the Solar system (any planet, natural satellite, or a „big“ comet or asteroid), all dynamics will be represented in a Solar system barycenter space-time frame of reference with the origin at the center of mass of the central body. If the spacecraft is in cruise mode, all dynamics will be represented in a Solar system barycenter space-time frame of reference with the origin at the center of mass of the Solar system. These celestial reference frames are consistent to the mm level for Earth satellites within GEOSAT. Another improvement is that all bodies between the spacecraft and the Sun is tested for possible eclipse effects and the fraction of reduction in light on the spacecraft is accounted for. If the spacecraft is not in cruise mode and the central body is not the Earth, the trajectory of the central body can be calculated if the data allow it.

In GEOSAT the „spacecraft“ can either be an artificial satellite, a planet, a natural satellite of a planet, an asteroid, or a comet. Preliminary orbits are available in GEOSAT for the 300 largest asteroids and for the largest comets. With this software it will be possible to reduce terrestrial error contributions in the analyses of deep space tracking data. Off cause, all „terrestrial-like“ parameters for a celestial body (different from the Earth) can, if the tracking data allow it, be estimated. Signal delays (for MW and SLR) through the neutral atmosphere of the Earth is calculated from 3D raytracing using time-series of numerical weather data from the European Center for Medium-range Weather Forecast. Other important improvements and changes have been described in previous IERS Annual Reports.

The new version of GEOSAT has two very useful features:

1) It can simultaneously combine data from virtually any number of VLBI, SLR, and GNSS instruments at a collocated site either observing simultaneously or in different time windows. All information will contribute to the estimation of the migration of an automatically selected master reference point at each station. Time series of eccentricity vectors will also be estimated.

2) The solve-for model parameters in combined processing of the VLBI + SLR + GNSS can either be instrument-dependent, technique-dependent, microwave-dependent, optical-dependent, or site-dependent. The switching between the different types is extremely simple. A simple application would be to in a first run treat the zenith wet delay parameters as instrument-dependent parameters which means that e.g. a station with two GPS receivers and one VLBI instrument will have three estimates of this parameter. If the results are consistent, these parameters can be estimated as a single parameter represented by a microwave-dependent parameter in a second run. The same can be tested for clock parameters for collocated clocks etc.

The project goal several years ago was to demonstrate the concept of simultaneous combination of different types of data at the single observation level with very limited amounts of data. Now we plan to go one step further with the processing of several years of VLBI+SLR+GNSS data including 100–200 GNSS stations per day. We have for this purpose installed an array of 10 computers with altogether 40 cpu’s, 60 GB Ram, and 10 TB disk space.

Present analysis status:

- We have produced OMC files (Observed minus Calculated and observation partial derivatives wrt potential solve-for parameters) for the period Jan 2000 to Dec 2007 for VLBI, GPS and SLR. Data from around 170 GPS stations are included.
- We have produced combined (at the observation level) approximately 1000 arcs (24 hours each) of either VLBI + SLR +

GPS (when VLBI is available) or SLR + GPS. We have performed extensive testing to find a proper parameterization at the combination level and found that one quite tightly constrained atmospheric parameter needs to be estimated for all MW data within a collocated station. Furthermore, if different MW instruments are connected to the same H-M clock, one single linear clock drift estimated parameter is sufficient. Off cause, each MW instrument must have each own estimated clock offset. One example is the GPS receivers NYAL and NYA1, and the VLBI instrument at Ny-Ålesund, where the estimated clock offsets of the two GPS receivers differ by typically 10–20 picoseconds. Note that the antennas and cables are not identical. The cable lengths are also different. For each arc a single combined set of coordinates is estimated for each station in addition to eccentricity vectors between the antenna phase centers.

Future plans

- Produce SRIF arrays for all VLBI + SLR + GPS or SLR + GPS arcs between Jan 2000 to Dec 2007.
- Combine these arrays to a multi-year global solution with times series of e.g. the coordinates of one reference marker per station and the eccentricity vectors.
- Write software to represent GEOSAT solutions in the SINEX format.
- Observations from the GALILEO navigation system will be applied when available. Only minor changes in GEOSAT are required for this extension.

References

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

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

Per Helge Andersen