3.6.2.5 Forsvarets forskningsinstitutt (FFI)

Introduction

FFI has during the last 21 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 analysed 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

The GEOSAT software has during 2005 undergone extensive changes and improvements. The most important changes implemented in 2005 are described in the following.

A new major software component of GEOSAT for 3D raytracing through the atmosphere has been developed and validated during the last two years. A complete 3D atmospheric model provided four times daily by ECMWF is input to the software. Based on the available tracking (VLBI, GPS, or SLR) for that specific date, a set of tables for each active station is automatically generated with information about the time delay in the different elevation and azimuth directions. If surfmet data are available for a given station the measured pressure values are used to re-scale the hydrostatic delay obtained from the raytracing calculations. Since the raytracing starts at the position of the phase centre for each instrument/antenna, the effect of different antenna heights will automatically be accounted for to the level of accuracy of the numerical weather model. The Grueger model is default for the MW refractive index and the Ciddor model is default for the optical or near optical wavelengths. The Ciddor model has been validated against Ciddor’s own software.

Also statistical information concerning the variability of relevant parameters are extracted from the ECMWF data. This information is used in the estimation filter as time-dependent parameter constraints in the estimation of atmospheric signal delay scaling parameters. The raytracing procedure can also be used to detect periods with rapidly changing atmospheric conditions which cannot be modelled accurately. This information can be used to edit such data leading to more stable values for the atmospheric scaling parameters. This strategy is expected to be especially valuable for the combined analysis of GPS and future Galileo tracking data due to the great redundancy of such datasets.

Also the GNSS part of GEOSAT has undergone extensive changes, e.g. with the inclusion of a second and third order ionospheric correction, absolute phase centre corrections for all antennas etc. The ionospheric correction for GNSS applications in GEOSAT is expected to be accurate to around 1 mm.

The pressure loading tables provided by Leonid Petrov is used by GEOSAT. For stations not included in these tables a simple pressure scaling model is used where the load scale parameter is automatically estimated in the analysis. A grid of reference pressure values has been derived by averaging the surface pressure levels provided by NCEP during the last 20 years.

In the global processing of several years of data the stable sources listed by Feissel et al. are automatically estimated as constants while the others are estimated as random walk parameters or session parameters.

The new version of GEOSAT is expected to be ready for routine processing within 2 years. The new version of GEOSAT will have two additional 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.

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 treat in a first run 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 colocated clocks etc.

A new software component for the generation of a Geophysical Events file has been included in GEOSAT. This file contains information about Earthquakes, the magnitude, and distance to stations included in the ITRF. Based on this information we plan to develop an estimation strategy where noise, dependent on the distance to the epicentre, is added to the station reference point motion for stations affected by Earthquakes.

Instrumental Events files for VLBI, GPS, and SLR have also been included in GEOSAT. These files give the epochs of changes in software or hardware of the instrument and the type of change. Every time an instrumental event occur noise will be added to the relevant estimated eccentricity vector.

The status is that twelve years of VLBI-only sessions have been analysed. A clear reduction in a posteriori residuals is observed.

The validation of GEOSAT with LAGEOS SLR tracking data is almost completed also with very promising results. The use of a detector-dependent centre of mass corrections, 3D raytracing, and taking into account a signal strength dependent range bias for some stations, lead to a slight change in the value of GM. The use of multicolour laser data has been implemented and gives excellent post-fit residuals. This will be further investigated in 2006 when we plan to estimate a new and consistent value for GM.

Future plans

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.

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