

COST-STSM-ES0701-3710 Scientific Report

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1 Introduction

Since several years, Institut für Astronomische und Physikalische Geodäsie (IAPG, TU Munich) and Astronomisches Institut der Universität Bern (AIUB, University of Bern) have a close cooperation in improving the Bernese GPS Software and computing global GNSS solutions. The purpose of the visit was:

- Merging of the latest software and processing changes and modifications between TU Munich and AIUB.
- Quality check of the CODE reprocessed GPS time series, i.e., detection of outliers and discontinuities.
- Preparation of implementation and testing of orbit modeling improvements for the Bernese GPS Software (e.g., albedo and solar radiation pressure).

2 Work carried out/Results

2.1 Software Merging

Recent software developments from Munich were merged into the Bernese version in Bern. The most important developments are:

- implementation of a new coordinate and velocity format including reference epochs and validity intervals for each station
- splitting of stations with discontinuities within one normal equation
- modified relative constraints for stations with discontinuities
- modified station information file (discontinuities, relative constraints)
- applying local ties for coordinates and troposphere parameters.

Several solution types computed with the original and the modified software version were compared to ensure consistency of the modifications with the current software.

Several changes w.r.t. the operational processing are necessary for a reprocessing effort. These adoptions as regards station and satellite information as well as scripts for the automated processing were improved in Munich based on the experiences of the reprocessing effort. The changes were ported to Bern to guarantee consistency between the reprocessing in Munich and the operational processing in Bern.

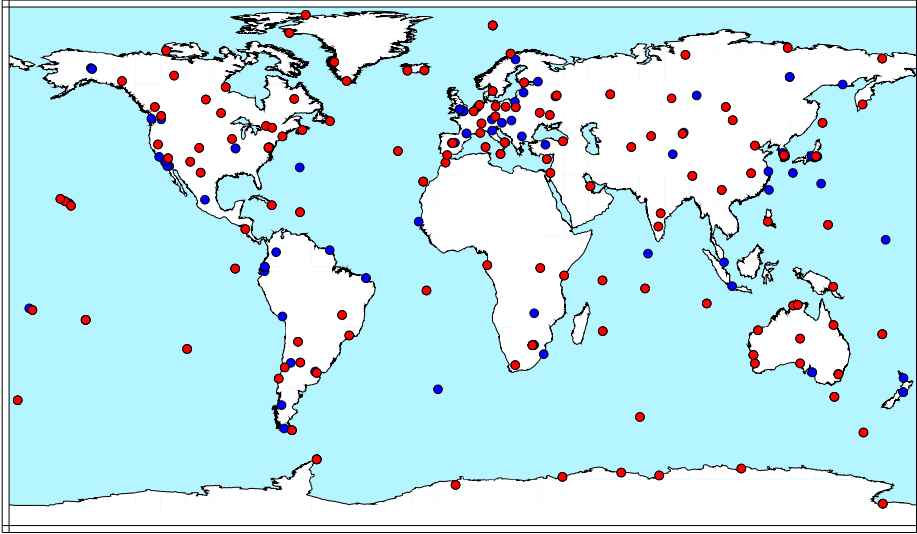


Figure 1: Tracking network of the CODE reprocessing effort. IGS05 datum stations are given in red, other stations in blue.

2.2 Exchange of Reprocessed Products

At IAPG the CODE contribution to the 1st IGS reprocessing campaign is computed. The analyzed tracking network includes 244 stations, see Figure 1. Besides the final products of the CODE reprocessing effort (weekly station coordinates and Earth rotation parameters, troposphere zenith delays and gradients, satellite orbits), also intermediate products have been exchanged. These products include normal equation files and cleaned single-difference files with fixed ambiguities. These intermediate products enable AIUB and IAPG to share the work of testing different modeling options described in Section 3.

2.3 Time Series Analysis

The reprocessed time series of the 1-day solution for the time period 1996 till 2007 were inspected for outliers and discontinuities. A new program of the Bernese GPS Software called FODITS (Find Outliers and Detect Discontinuities in Time Series) was used. The functional model of FODITS consists of one or more linear velocities per station, discontinuities, outliers, and a set of periodic functions. For the current analysis, annual, semi-annual, monthly, and semi-monthly periods have been estimated. The adaption of the functional model is performed iteratively in an ATI (adaption, test, and identification) procedure.

Changes in the station equipment (i.e., antenna, radome, and receiver) as well as earthquakes with a magnitude larger than five are tested for significant discontinuities. Furthermore, discontinuities without any known reason are detected. An overview of altogether 151 discontinuities detected with FODITS is given in Tab. 1. Outliers deviating from the functional model by five times the formal errors or by an absolute value of 5 mm for the horizontal and 10 mm for the vertical component have been detected. These outliers were excluded in the 3-day and weekly solutions that have been computed after the STSM.

Reason	No. of Discontinuities
Earthquakes	31
Equipment changes	31
Unknown	89

Table 1: Discontinuities in the reprocessed 1-day solutions for the time interval 1996 till 2007.

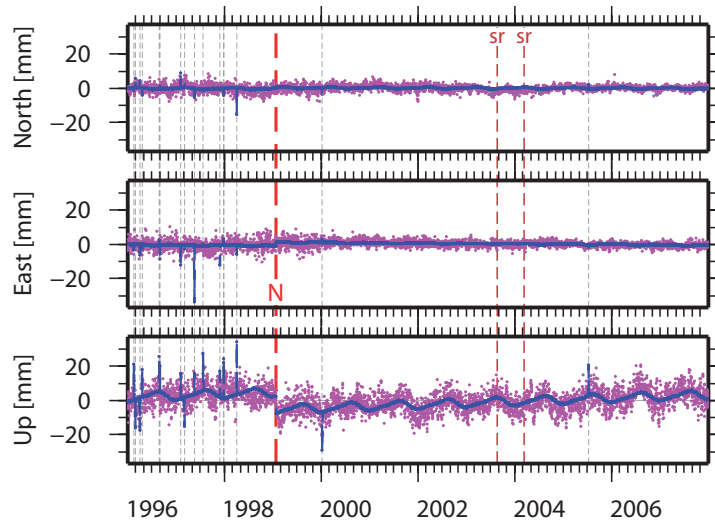


Figure 2: GPS coordinate time series of the reprocessed CODE 1-day solution: Onsala (Sweden). Outliers are indicated by gray vertical lines. The left red line indicates a discontinuity due to a radome change with $\Delta_N = 0.5$ mm, $\Delta_E = 2.1$ mm $\Delta_U = -10.1$ mm. The other two red line indicate non-significant discontinuities due to receiver changes.

Figure 2 shows an example of the FODITS analysis: for the station Onsala in Sweden, several outliers and a discontinuity due to a radome change have been detected. Two receiver changes did not cause significant discontinuities.

2.4 Discussion of future Software Developments

New features for the station information file were discussed and a new was format defined. The new features include:

- Setup of harmonic coefficients for all type of parameters
- Grouping of stations within a certain area: the station coordinates, velocities, troposphere zenith delays and gradients can be constrained to be identical (except for a bias for the troposphere zenith delays). This option is useful for stations like Wettzell where several IGS stations are operated in parallel.
- Automated setup of discontinuities in case of equipment changes. This feature is in particular important for the operational processing. If no significant discontinuity appears, the two coordinates can be stacked on the normal equation level without any reprocessing of raw observation data.
- Automatic constraining of velocities before and after discontinuities due to equipment changes.
- More flexible handling of station problems: pre-elimination as soon as possible, before stacking, after stacking; disabling the stacking of parameters; exclusion of stations from the datum definition; disabling of ambiguity resolution.

3 Outlook

The features described in Section 2.4 will be implemented in the Bernese GPS Software in the near future. These modifications provide the basis for a more sophisticated Terrestrial Reference Frame (TRF) solution. It is planned to compute such a TRF solution after the implementation of the software modifications by the end of 2009. This TRF solution will provide valuable input to Working Group 4 "GIA model optimization and ice mass balance computations" of the COST Action ES0701.

The cleaned single-difference files with fixed ambiguities of the CODE reprocessing effort provide the possibility to easily test different modeling approaches for a reasonable time span. The following comparisons in the framework of WG 1 "Geodetic observation-level modeling and systematic biases" are planned to be presented at the conferences given in parentheses:

- Orbit modeling improvements, e.g., solar radiation pressure, albedo (IAPG, International Association of Geodesy Scientific Assembly 2009)
- Comparison of different atmospheric loading corrections (AIUB, International Association of Geodesy Scientific Assembly 2009)
- Higher order ionospheric corrections (AIUB, American Geophysical Union Fall Meeting 2009)