FODITS: A New Tool of the Bernese GPS Software to Analyze Time Series

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Introduction

Analysis, reassessment, and interpretation of GNSS time series results become more and more important. This is true in particular for station coordinates, where we are confronted with potential jump discontinuities and outliers due to equipment changes, earthquakes, other geophysical processes, data problems, etc.

The development version of the Bernese GPS Software (Dach et al., 2007) has been extended by a new tool, called FODITS (Find Outliers and Discontinuities In Time Series).

This tool includes the following functionality:
- detect outliers and jump discontinuities,
- check the time series for significant discontinuities at predefined epochs (e.g., due to reported equipment changes or nearby earthquakes),
- estimate parameters of a functional model describing
  - outliers,
  - discontinuities,
  - velocity changes, and
  - periodic functions.
- remove insignificant components of a pre-defined functional model,
- consider all available components simultaneously (using complete variance-covariance information).

Description of FODITS and its Embedding in the Bernese GPS Software

FODITS allows analysis of times series results stored in form of a PLT file, or given in form of a series of CRD files produced by ADDNEQ2. The setup of the functional model and parameters for statistical testing may be specified by the user. The information concerning equipment changes is taken from the station information (STA) file of the Bernese Software. Further event lists, such as ERQ (for earthquakes) and EVL (for all other possible events of interest) may be introduced (see Figure 1).
As a main result, FODITS provides an updated set of input files for subsequent ADDNEQ2 program runs (specifically for computation of a best possible combination). Outliers are excluded (not stacked) and detected jump discontinuities are adequately modeled.

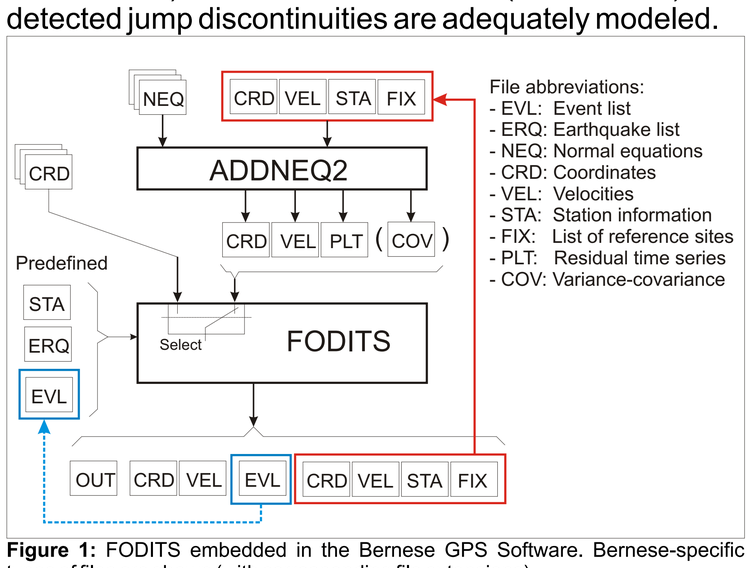

Figure 1: FODITS embedded in the Bernese GPS Software. Bernese-specific types of files are shown (with corresponding file extensions).

Functionality of FODITS

1) A first version of the functional model is defined. It describes known discontinuities at all epochs with events (taken from the input files) and the periodic functions selected by the user.
2) The parameters of the functional model are estimated by a least squares adjustment (using the data points of the time series as observations). The non-significant components are removed (step-by-step) from the functional model.
3) Outliers are removed when they exceed a user specified threshold. A new discontinuity and/or additional outliers is setup at the epoch, where it can optimally reduce the discrepancy between the time series and the functional model.
4) The algorithm is now repeated from step 1) until it becomes insignificant.

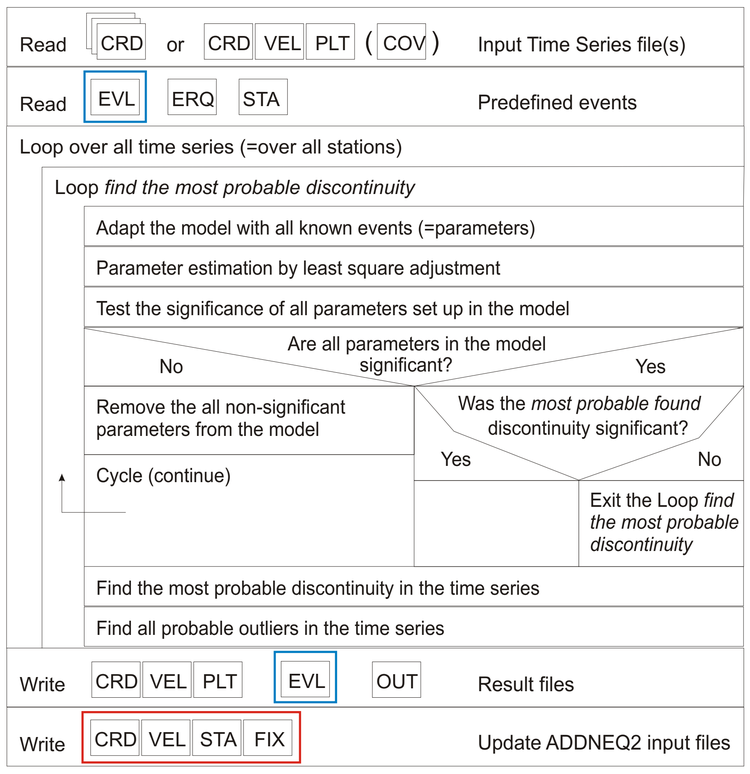

Figure 2: Flowchart for the FODITS program.

Time Series of CODE Global and EUREF-Combined Regional Station Coordinates

Figure 3 illustrates the result of a FODITS analysis. Daily station coordinates of CODE's IGS final analysis were used. Jump discontinuities due to earthquakes, equipment changes, and finally the prominent model update in GPS week 1400 (switch from the relative to an absolute GNSS satellite and receiver antenna phase center correction model) could be detected.

The algorithm may also be applied to weekly station coordinates results. The Figure 4 shows four examples for stations of the EUREF permanent network (EPN). Combined solutions computed at BKG were used. Again, the GPS week 1400 model change is very clearly visible.

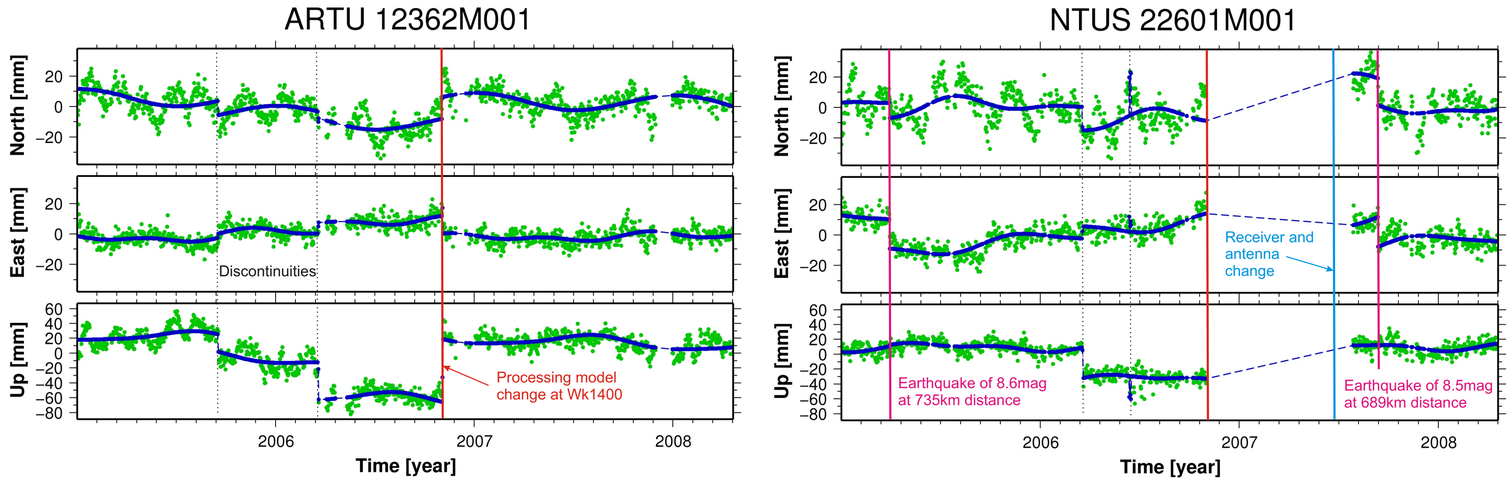

Figure 3: CODE daily solution time series, residuals (green) w.r.t. ADDNEQ2 solution and FODITS functional model (blue) are shown. Detected discontinuities (for unknown reason), outliers (for unknown reason), earthquakes, equipment changes, and processing model changes are indicated.

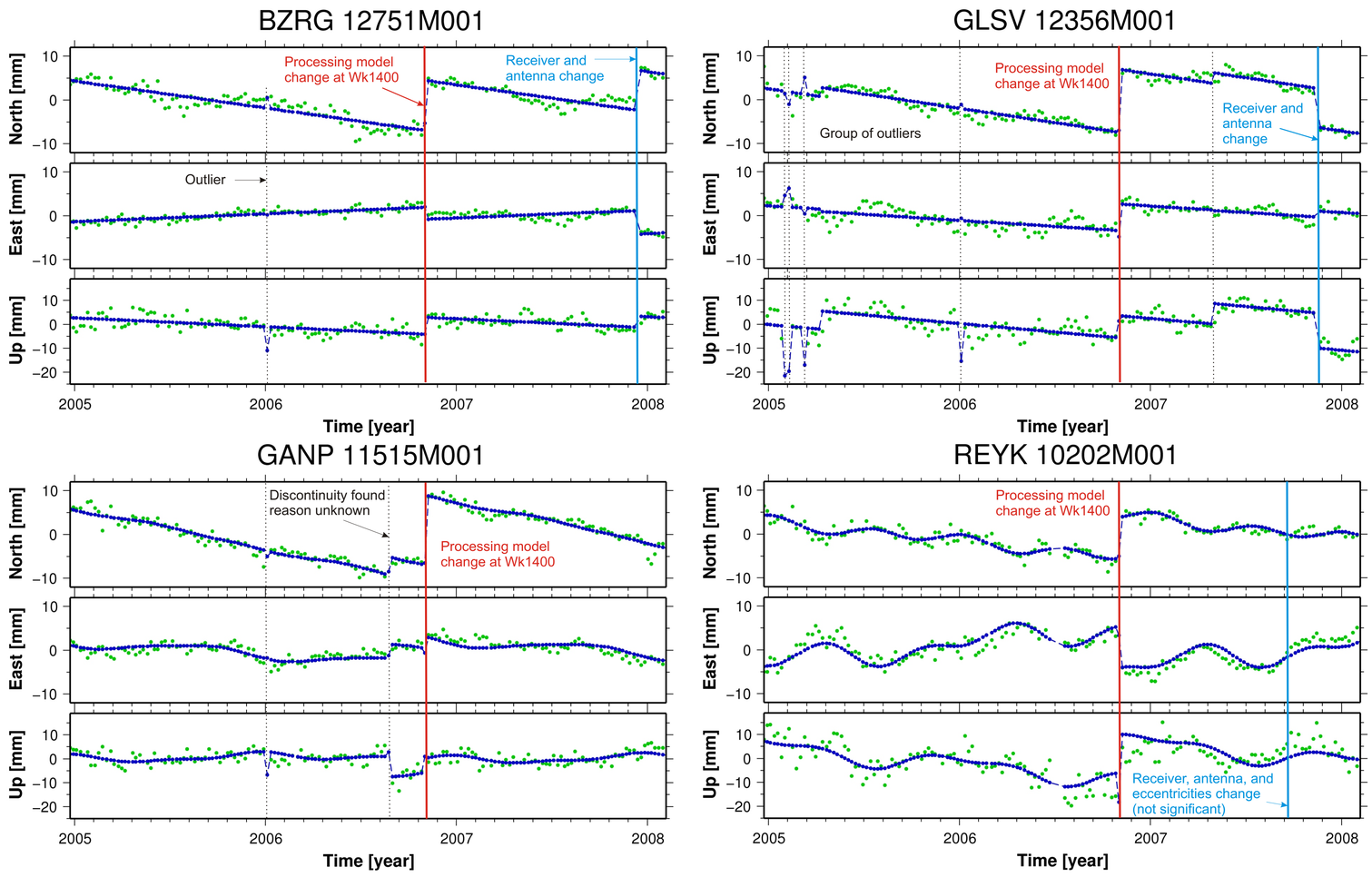

Figure 4: EUREF combined coordinate time series, residuals (green) w.r.t. ADDNEQ2 solution and FODITS functional model (blue) are shown. Detected discontinuities (for unknown reason), outliers (for unknown reason), earthquakes, equipment changes, and processing model changes are indicated.

Use of FODITS for Other Applications

The algorithm to analyze time series cannot only applied to daily or weekly coordinate time series but also to the results from a kinematic positioning or any other parameter – as far as they may be provided in a PLT file format. The Figure 5 gives an example. It shows the time series of P1-P2 DCB corrections for two GNSS stations for the last 15 years. The possibility to predefine the specific components of the functional model for time intervals in the event list (EVL) input file is very useful for these examples.

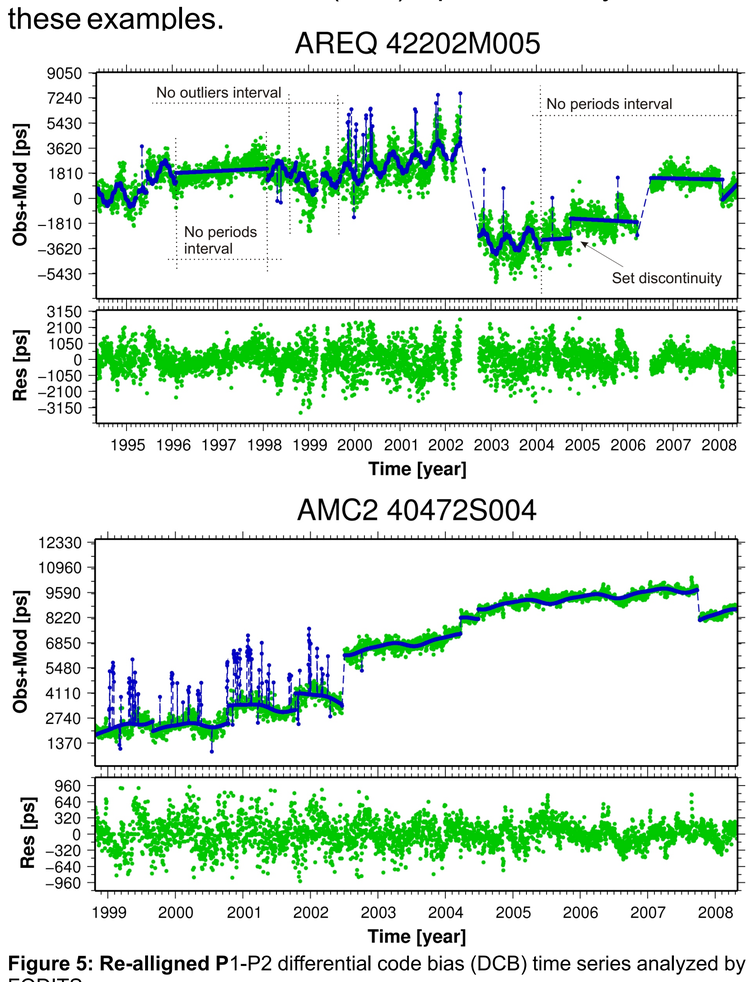

Figure 5: Re-alligned P1-P2 differential code bias (DCB) time series analyzed by FODITS.

References

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