BERNESE GNSS SOFTWARE V5.4

Detailed list of features

The following list of processing features and characteristics is only a selection on the very top level. It is related to the usual processing steps and some selected product aspects:

- *RINEX*
    - Support of RINEX 2.x, 3.x, and 4.x
    - Verification of the station name with respect to the filename
    - Extended verification of the RINEX headers w.r.t. an internal station information list including receiver/antenna+radome type, serial number, and antenna displacements.
    - Check the availability of antenna+radome phase center corrections
    - Removal of observations of systems without system-specific receiver antenna corrections
    - Automated exclusion of stations with equipment changes, or presenting a reduced data tracking, or with indicated data problems) when importing the data.
- *Preprocessing*
    - Detection and handling of inconsistencies between code and phase data regarding the receiver clock
    - Determination of unknown GLONASS frequency numbers
    - Baseline selection with advanced conditions regarding GNSS, marginally observed satellites, and beneficial baselines for ambiguity resolution.
    - Automated adjustment of the screening technology for the cycle slip detection and outlier rejection according to the baseline length
    - Automated exclusion of data intervals with exceptionally high number of cycle slips
    - Removal of satellites with unusual high number of data problems
    - Automated detection of misbehaving stations/satellites based on post-fit residuals Ambiguity resolution
    - Optimized multiple-step ambiguity resolution scheme with different algorithms according to the baseline length, even for very long baselines
    - Ambiguity resolution for PPP introducing consistent phase biases
    - Self-calibrating single-difference ambiguity resolution for GLONASS
    - Consider 1/4-cycle biases resulting from the simultaneous tracking of GPS L2C and L2P signals with some receiver types
    - Re-initialization of ambiguities resolution results for all or a specific GNSS Processing
    - Double-difference network solution with correct correlations
    - Zero-difference network solution solving for all receiver and satellite clock parameters (equivalent to a consistent double difference solution)
    - Precise Point Positioning (PPP) with ambiguity resolution
    - Multi-GNSS (GPS/GLONASS/Galileo/BeiDou/QZSS) solutions or single GNSS configurations for dual-frequency datasets
    - Numerous parameter types can be setup at the same time; generation of normal equations without inversion
    - Flexible observation sampling, in particular for epoch parameters

- *Modeling*
    - Modeling of tides, subdaily Earth rotation, and nutation are conforming with IERS Conventions (2010)
    - Interpolation of ocean tidal loading to 342 constituents (HARDISP) according to IERS Conventions (2010)
    - S1/S2 atmosphere pressure loading tidal corrections
    - Center of mass corrections for ocean and atmospheric tidal loading
    - Use of various gravity fields easily implementable
    - DE421 ephemeris series for planets as well as the gravitational effect of ocean and solid Earth tides in the orbit integrator (ORBGEN)
    - Piece-wise linear troposphere parameter representation, with possibility to enforce continuous parameterization at session boundaries
    - A priori model for hydrostatic component of troposphere (mapped with dry-GMF or VMF3 mapping function)
    - Horizontal troposphere gradient parameters
    - Introduction of (globally) estimated troposphere delays on normal equation level
    - Ionosphere corrections from global or regional ionosphere maps
    - Higher order ionosphere corrections (2nd and 3rd order and ray bending) including scaling factors
- *Station motion modelling*
    - Post-seismic deformations are applied according to the ITRF specification
    - Tools to use only linear velocities for a given interval to derive a linear velocity field
    - Station motions corrections for plate motions, tides, and ocean tidal loading
    - Geophysical deformation models can be introduced as grids and validated by estimating scaling factors
- *Normal equation handling*
    - Geodetic datum definition including automated verification of the reference coordinates
    - Efficient parameter transformation for various purposes (reduce the resolution of parameters in time; long-arc for orbit determination)
    - Flexible management to select parameters for pre-elimination or deletion (e.g., exclusion of boundaries of the normal equation to guarantee continuity or keep station dependent parameters for specific sites for collocation)
    - Manipulations of normal equations without inversion
    - Adaption of a priori values for most of the parameters
    - Selected parameters can be added to existing normal equations
    - SINEX generation based on "normal equation" or "covariance" representation
    - Computation of repeatability for parameters of the input normal equations
    - Evaluation of the time series by program FODITS (Find Outliers and Discontinuities in Time Series, see PhD thesis Ostini, 2012)
- *Antennas*
    - Import of antenna phase center corrections from ANTEX format
    - Receiver and satellite phase center corrections can be considered for each frequency to be processed
    - Antenna misalignment towards north may be considered (where applicable)
    - Individual GNSS-specific as well as receiver antenna corrections can be introduced
    - Receiver and satellite antenna phase center parameters can be estimated

- *Orbit modeling and estimation*
    - Satellite orbits import from precise orbit files depending on the accuracy code
    - Satellite attitude modelled according to the manufacturer specification (as far as known)
    - Estimation of six initial orbital elements and a set of up to nine dynamical orbit parameters in different frames:
        - ◦ Sun-oriented frame at the satellite center of mass
        - ◦ Terminator defined frame at the satellite center of mass
        - ◦ Flight direction oriented frame at the satellite center of mass

      For each satellite the frame can be defined individually depending on the satellite type, the elevation of the Sun above the orbital plane, and the satellite attitude mode
    - Macromodels for non-gravitational force modelling of LEO and GNSS satellites(direct Solar radiation and Earth Albedo effects)
    - Estimation of stochastic pulses during the orbit integration based on precise orbit files
    - Estimation of stochastic pulses or empirical accelerations from GNSS observation data during the orbit improvement
    - Detection and determination of GNSS repositioning events
- *LEO orbit determination*
    - Detailed non-gravitational force modelling (direct solar radiation pressure, Earth radiation pressure, air drag and lift) based on satellite macro model
    - Flexible estimation of scaling factors for non-gravitational forces
    - Zero-difference ambiguity resolution
    - New BSW format for satellite attitude quaternions, including conversion program
- *Observation specific System Biases*
    - Support of multi-GNSS code bias handling using observation specific biases
    - Estimation capability of multi-GNSS code biases including automated datum definition according to the IGS standards
    - Support of system, receiver-satellite or frequency dependent observation code bias estimation
    - Consider phase biases for PPP ambiguity estimation
    - Verification of the tracking technology by estimating multipliers
- *Clock product generation*
    - Combination of clock RINEX files
    - Automated selection of a reference clock
    - Extrapolation of series from clock RINEX file
    - Phase-based interpolation of clock corrections to generate high-rate clock products
- *Simulation of GNSS observations*
    - According to a given geometry (satellite orbits and station positions) GNSS observations can be computed
    - Assumptions with respect to the noise level, receiver/satellite clocks, ionosphere, troposphere, and cycle slips can be introduced
    - These synthetic data can be processed on zero-difference or double-difference level
    - The correct integer ambiguity is known to be zero in case of ambiguity resolution tests