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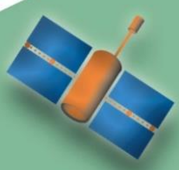

BKG Ntrip Client (BNC)

Version 2.12

Georg Weber, Leoš Mervart, Andrea Stürze, Axel Rülke, Dirk Stöcker

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Georg Weber [1], Leoš Mervart [2], Andrea Stürze [1], Axel Rülke [1], Dirk Stöcker [3]

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[3] Alberding GmbH, Wildau, Germany

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BKG Ntrip Client (BNC) Software Version 2.12

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CHAPTER 1

Introduction

1.1 Purpose

The BKG Ntrip Client (BNC) is a program for simultaneously retrieving, decoding, converting and processing or analyzing real-time GNSS data streams applying the 'Networked Transport of RTCM via Internet Protocol' (Ntrip) standard. It has been developed within the framework of the IAG sub-commission for Europe (EUREF) and the International GNSS Service (IGS). Although meant to be a real-time tool, it comes with some post processing functionality. It can be used for data coming from Ntrip Broadcasters like

- http://www.euref-ip.net/home
- http://www.igs-ip.net/home
- http://products.igs-ip.net/home
- http://mgex.igs-ip.net/home

or similar caster installation.

BNC has been written under GNU General Public License (GPL). Source code is available from Subversion software archive http://software.rtcm-ntrip.org/svn/trunk/BNC. Precompiled binaries of BNC are available for MS Windows, Linux, and Mac OS X systems. They can be downloaded from http://igs.bkg.bund.de/ntrip/download.

Promoting Open RTCM Standards for streaming GNSS data over the Internet has been a major aspect in developing BNC as Open Source real-time software. Basically, the tool enables the test, validation and further evolution of new RTCM messages for precise satellite navigation. With high-level source code at hand, it also allows university education to catch up with comprehensive state-of-the-art positioning and potentially contributes fresh ideas which are free from any licensing.

BNC was designed to serve the following purposes

- Retrieve real-time GNSS data streams available through Ntrip transport protocol;
- Retrieve real-time GNSS data streams via TCP directly from an IP address without using the Ntrip transport protocol;
- Retrieve real-time GNSS data streams from a local UDP or serial port without using the Ntrip transport protocol;
- Plot stream distribution map from Ntrip Broadcaster source-tables;
- Generate RINEX Observation and Navigation files to support near real-time GNSS post processing applications;
- Edit or concatenate RINEX files or carry out RINEX Quality Checks (QC);
- Convert RINEX Version 2 to RINEX Version 3 and vice versa;
- Compare SP3 files containing satellite orbit and clock data;
- Generate orbit and clock corrections to Broadcast Ephemeris through an IP port to
  - support real-time Precise Point Positioning on GNSS rovers;

  - support the (outside) combination of such streams as coming simultaneously from various correction providers;

- Generate ephemeris and synchronized or unsynchronized observations epoch by epoch through an IP port to support real-time GNSS network engines;
- Feed a stream into a GNSS receiver via serial communication link;
- Monitor the performance of a network of real-time GNSS data streams to generate advisory notes in case of outages or corrupted streams;
- Scan RTCM streams for incoming antenna information, observation types, message types and repetition rates and latencies and GLONASS slot numbers and frequency channels;
- Carry out real-time Precise Point Positioning to determine GNSS rover positions;
- Enable multi-station Precise Point Positioning for simultaneous processing of observations from a whole network of receivers;
- Plot positions derived via PPP from RTCM streams or RINEX files on maps from Google Map or OpenStreetMap;
- Simultaneously process several Broadcast Correction streams to produce, encode and upload combined Broadcast Corrections;
- Estimate real-time tropospheric zenith path delays and save them in SINEX troposphere file format;
- Read GNSS orbits and clocks in a plain ASCII format from an IP port. They can be produced by a real-time GNSS engine such as RTNET and should be referenced to the IGS Earth-Centered-Earth-Fixed (ECEF) reference system. BNC will then
  - Convert the IGS Earth-Centered-Earth-Fixed orbits and clocks into Broadcast Corrections with radial, along-track and out-of-plane components;
  - Upload Broadcast Corrections as an RTCM Version 3 stream to an Ntrip Broadcaster;
  - Refer the orbit and clock corrections to a specific reference system;
  - Log the Broadcast Corrections as Clock RINEX files for further processing using other tools than BNC;
  - Log the Broadcast Corrections as SP3 files for further processing using other tools than BNC;
  - Upload a Broadcast Ephemeris stream in RTCM Version 3 format;

BNC supports the following GNSS stream formats and message types:

- RTCM Version 2 message types;
- RTCM Version 3 ‘conventional’ message types;
- RTCM Version 3 message types for Broadcast Ephemeris;
- RTCM Version 3 ‘State Space Representation’ (SSR) messages;
- RTCM Version 3 ‘Multiple Signal Messages’ (MSM) and ‘High Precision Multiple Signal Messages’ (HP MSM);
- RTNET, a plain ASCII format defined within BNC to receive orbits and clocks from a serving GNSS engine.

BNC supports the following GNSS file formats:

- RINEX Version 2.11 & 3.03, Receiver Independent Exchange format for observations, navigation and meteorological data;
- SINEX Version 2.10, Solution Independent Exchange format for station position and velocity solutions;
- SINEX TRO Draft Version 2.00, Troposphere Solution Independent Exchange format for zenith path delay products;
- SP3 Version c format for orbit solutions;
- Clock RINEX Version 3.02 format for station and satellite clock solutions;

- ANTEX Version 1.4, Antenna Exchange format for Antenna Phase Center variations;
- NMEA Version 0813, National Marine Electronics Association format for satellite navigation data;

Note that BNC allows to by-pass decoding and conversion algorithms for incoming streams, leaves whatever is received untouched to save it in files or output it through local TCP/IP port.

1.2 Authors

The BKG Ntrip Client (BNC) with a Qt Graphical User Interface (GUI) and a Command Line Interface (CLI) has been developed for

Federal Agency for Cartography and Geodesy (BKG)
Department of Geodesy, Section Satellite Navigation
Frankfurt am Main, Germany

The software has been written by

Prof. Dr. Leos Mervart
Czech Technical University (CTU)
Department of Geomatics
Prague, Czech Republic

Prof. Mervart started working on BNC in 2005. His sole responsibility for writing the program code ended February 2015. In March 2015, Dipl.-Ing. Andrea Stürze took over the responsibility for maintaining and further developing BNC's source code.

1.3 Documentation

BNC provides context-sensitive help (*What's This*) related to specific objects. It furthermore comes with the here presented documentation, available as part of the software and as a PDF file. Responsible for offline documentation as well as online documentation at http://software.rtcm-ntrip.org/export/HEAD/ntrip/trunk/BNC/src/bnchelp.html and example configurations is Dr. Georg Weber.

Note that some figures presented in this documentation may show screen shots from earlier versions of BNC. If so, there is either no relevant change compared to the current appearance of the program or no change at all.

1.4 Contact

Feel free to send us comments, suggestions or bug reports. Any contribution would be appreciated.

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1.5 Acknowledgements

- Oliver Montenbruck, German Space Operations Center, DLR, Oberpfaffenhofen, Germany published a RTCM Version 2 decoder unter GNU GPL which has been integrated in BNC.

- Thomas Yan, Australian NSW Land and Property Information, proofread earlier versions of BNC's Help Contents. Up to Version 2.11 he also provides builds of BNC for Mac OS X systems.
- Scott Glazier, OmniSTAR Australia, has been helpful in finding BNC bugs in version 1.5.
- James Perlt, BKG, helped fixing bugs and redesigned BNC's main window in version 1.5.
- André Hauschild, German Space Operations Center, DLR, revised the RTCM Version 2 decoder.
- Zdenek Lukes, Czech Technical University Prague, Department of Geodesy, extended the RTCM Version 2 decoder to handle message types 3, 20, 21, and 22 and added the loss of lock indicator.
- Jan Dousa, Geodetic Observatory Pecny, Czech Republic, helped with fixing bugs in version 2.5.
- Denis Laurichesse, Centre National d' 'Etudes Spatiales (CNES), suggested synchronizing observations and clock corrections to reduce high frequency noise in PPP solutions.
- Lennard Huisman, Kadaster Netherlands, and Rolf Dach, Astronomical Institute University of Bern, assisted in handling satellite clocks in transformations from ITRF to regional reference frames.

1.6 Looking Back

A basic function of BNC is streaming GNSS data over the open Internet using the Ntrip transport protocol. Employing IP streaming for satellite positioning goes back to the beginning of our century. Wolfgang Rupprecht has been the first person who developed TCP/IP server software under the acronym of DGPS-IP *[1]* and published it under GNU General Public License (GPL). While connecting marine beacon receivers to PCs with permanent access to the Internet he transmitted DGPS corrections in an RTCM format to support Differential GPS positioning over North America. With approximately 200 bits/sec the bandwidth requirement for disseminating beacon data was comparatively small. Each stream was transmitted over a unique combination of IP address and port. Websites informed about existing streams and corresponding receiver positions.

To cope with an increasing number of transmitting GNSS reference stations, the Federal Agency for Cartography and Geodesy (BKG) together with the Informatik Centrum Dortmund (ICD) in Germany developed a streaming protocol for satellite navigation data called 'Networked Transport of RTCM via Internet Protocol' (Ntrip). The protocol was built on top of the HTTP standard and included the provision of meta data describing the stream content. Any stream could now be globally transmitted over just one IP port: HTTP port 80. Stream availability and content details became part of the transport protocol. The concept was first published in 2003 *[2]*, *[3]* and was based on three software components, namely an NtripServer pushing data from a reference station to an NtripCaster and an NtripClient pulling data from the stream splitting caster to support a rover receiver. (Note that from a socket-programmers perspective NtripServer and NtripClient both act as clients; only the NtripCaster operates as socket-server.) Ntrip could essentially benefit from Internet Radio developments. It was the ICECAST multimedia server, which provided the bases for BKG's 'Professional Ntrip Broadcaster' with software published first in 2003 and of course again as Open Source under GPL.

For BKG as a governmental agency, making Ntrip an Open Industry Standard has been an objective from the very beginning. The 'Radio Technical Commission for Maritime Services' (RTCM) accepted 'Ntrip Version 1' in 2004 as 'RTCM Recommended Standard' *[4]*. Nowadays there is almost no geodetic GNSS receiver which does not come with integrated NtripClient and NtripServer functionality as part of the firmware. Hundreds of Ntrip-Caster implementations are operated world-wide for highly accurate satellite navigation through RTK networks. Thousands of reference stations upload observations via NtripServer to central computing facilities for any kind of NtripClient application. In 2011 'Ntrip Version 2' was released *[5]* which cleared and fixed some design problems and HTTP protocol violations. It also supports TCP/IP via SSL and adds optional communication over RTSP/RTP and UDP.

With the advent of Ntrip as an open streaming standard, BKG's interest turned towards taking advantage from free real-time access to GNSS observations. International Associations such as the IAG Reference Frame Sub Commissions for Africa (AFREF), Asia & Pacific (APREF), Europe (EUREF), North America (NAREF) Latin America & Caribbean (SIRGAS), and the International GNSS Service (IGS) maintain continental or even global GNSS networks with the majority of modern receivers supporting Ntrip stream upload. Through operating BKG's NtripCaster software, these networks became extremely valuable sources of real-time GNSS information. In 2005, this was the starting point for developing the 'BKG Ntrip Client' (BNC) as a multi-stream Open Source

NtripClient that allows pulling hundreds of streams simultaneously from any number of NtripCaster installations world-wide. Decoding incoming RTCM streams and output observations epoch by epoch via IP port to feed a real-time GNSS network engine became BNC's first and foremost ability *[6]*. Converting decoded streams to short high-rate RINEX files to assist near real-time applications became a welcome by-product right from the start of this development.

Adding real-time Precise Point Positioning (PPP) support to BNC began in 2010 as an important completion in view of developing an Open RTCM Standard for that. According to the State Space Representation (SSR) model, new Version 3 messages are proposed to provide e.g. satellite orbit and clock corrections and ionospheric corrections as well as biases for code and phase data. The ultimate goal for SSR standardization is to reach centimeter level accuracy within seconds as an alternative to Network RTK methods such as VRS, FKP, and MAC. Because of interoperability aspects, an Open Standard in this area is of particular interest for clients. Regarding stand-alone PPP in BNC, it is worth mentioning that the program is not and can never be in competition with a receiver manufacturer's proprietary solution. Only software or services that are part of a receiver firmware could have the potential of becoming a thread for commercial interests. However, implementing or not implementing an Open PPP approach in a firmware is and will always remain a manufacturer's decision.

Implementing some post processing capability is essential for debugging real-time software in case of problems. So certain real-time options in BNC were complemented to work offline through reading data from files. Moreover, beginning in 2012, the software was extended to support Galileo, BeiDou, and QZSS besides GPS and GLONASS. With that, the Open Source tool BNC could be used for RINEX Version 3 file editing, concatenation and quality checks, a post processing functionality demanded by the IGS Multi-GNSS Experiment and not really covered at that time by UNAVCO's famous TEQC program with its limitation on GPS.

Over the years, the BNC Subversion (SVN) software archive received over seven thousand commits made by 11 contributors representing about one hundred thirty thousand lines of code. The well-established, mature codebase is mostly written in C++ language. Its publication under GNU GPL is thought to be well-suited for test, validation and demonstration of new approaches in precise real-time satellite navigation when IP streaming is involved. Commissioned by a German governmental agency, the overall intention has been to push the development of RTCM Recommended Standards to the benefit of IAG institutions and services such as IGS and the interested public in general.

In February 2014 the overall responsibility at BKG for the concept and realization of BNC was handed over from Georg Weber to Axel Rülke. He is in charge now for guiding the application and further evolution of the software in view of appearing new satellite navigation systems and services.

CHAPTER 2

BNC Overview

2.1 Supported GNSS and applications

BNC is permanently completed to finally support all existing GNSS systems throughout all features of the program. Table 2.1 shows in detail which GNSS systems are supported so far by particular applications when using the latest BNC version. Application areas named here are:

- Decoding of RTCM or RTNET [1] streams
- RINEX and SP3 file input and output
- Encoding of SSR and ephemeris messages
- Upload of SSR and ephemeris messages
- PPP (Precise Point Positioning)
- Combining/merging SSR or ephemeris messages from various real-time sources

It is indicated when a message implementation in BNC could so far only be based on a 'RTCM Proposal'.

[1] RTNet, GPS Solutions Inc., http://gps-solutions.com

Table 2.1: Status of RTCM Version 3 message implementations in BNC supporting various GNSS systems.

Message Type #	Description	GNSS	RTCM Proposal	Decoding	RINEX SP3	Encoding	Upload	PPP	Combin.
General									
1005,1006	Station			x					
1007,1008	Antenna			x					
1033	Receiver, Antenna			x					
1013	System Parameters			x					
Navigation									
1019	Ephemeris	GPS		x	x	x	x	x	x
1020	Ephemeris	GLONASS		x	x	x	x	x	x
1045	Ephemeris	Galileo F/Nav		x	x	x	x		
1046	Ephemeris	Galileo I/Nav	x	x	x	x	x	x	
1043	Ephemeris	SBAS	x	x	x	x	x		
1044	Ephemeris	QZSS		x	x	x	x		
63	Ephemeris	BDS	x	x	x	x	x	x	
Observation									
1001-4	Conventional Messages	GPS		x	x			x	
1009-12	Conventional Messages	GLONASS		x	x			x	
Observation									
1071-77	Multiple Signal Message	GPS		x	x			x	
1081-87	Multiple Signal Message	GLONASS		x	x			x	
1091-97	Multiple Signal Message	Galileo		x	x			x	
1101-07	Multiple Signal Message	SBAS	x	x	x				
1111-17	Multiple Signal Message	QZSS		x	x				
1121-27	Multiple Signal Message	BDS		x	x			x	
SSR I									
1057	Orbit Corrections	GPS		x	x	x	x	x	x
1063	Orbit Corrections	GLONASS		x	x	x	x	x	x
1240	Orbit Corrections	Galileo	x	x	x	x	x	x	
1246	Orbit Corrections	SBAS	x	x	x	x	x		
1252	Orbit Corrections	QZSS	x	x	x	x	x		
1258	Orbit Corrections	BDS	x	x	x	x	x	x	
1058	Clock Corrections	GPS		x	x	x	x	x	x
1064	Clock Corrections	GLONASS		x	x	x	x	x	x
1241	Clock Corrections	Galileo	x	x	x	x	x	x	
1247	Clock Corrections	SBAS	x	x	x	x	x		

Continued at next page

Message Type #	Description	GNSS	RTCM Proposal	Decoding	RINEX SP3	Encoding	Upload	PPP	Combin.
1253	Clock Corrections	QZSS	x	x	x	x	x		
1259	Clock Corrections	BDS	x	x	x	x	x	x	
1059	Code Biases	GPS		x	x	x	x	x	
1065	Code Biases	GLONASS		x	x	x	x	x	
1242	Code Biases	Galileo	x	x	x	x	x	x	
1248	Code Biases	SBAS	x	x	x	x	x		
1254	Code Biases	QZSS	x	x	x	x	x		
1260	Code Biases	BDS	x	x	x	x	x	x	
1061, 1062	User Range Accuracy, HR	GPS		x					
1067, 1068	User Range Accuracy, HR	GLONASS		x					
1244, 1245	User Range Accuracy, HR	Galileo	x	x					
1250, 1251	User Range Accuracy, HR	SBAS	x	x					
1256, 1257	User Range Accuracy, HR	QZSS	x	x					
1262, 1263	User Range Accuracy, HR	BDS	x	x					
1060	Comb. Orbits & Clocks	GPS		x	x	x	x	x	x
1066	Comb. Orbits & Clocks	GLONASS		x	x	x	x	x	x
1243	Comb. Orbits & Clocks	Galileo	x	x	x	x	x	x	
1249	Comb. Orbits & Clocks	SBAS	x	x	x	x	x		
1255	Comb. Orbits & Clocks	QZSS	x	x	x	x	x		
1261	Comb. Orbits & Clocks	BDS	x	x	x	x	x	x	
SSR II									
1264	VTEC	GNSS	x	x	x	x	x		
1265	Phase Biases	GPS	x	x	x	x	x		
1266	Phase Biases	GLONASS	x	x	x	x	x		
1267	Phase Biases	Galileo	x	x	x	x	x		
1268	Phase Biases	SBAS	x	x	x	x	x		
1269	Phase Biases	QZSS	x	x	x	x	x		
1270	Phase Biases	BDS	x	x	x	x	x		

2.2 Data Flow

BNC can be used in different contexts with varying data flows. Typical real-time communication follows the Ntrip protocol over TCP/IP (probably via SSL), RTSP/RTP or UDP, plain TCP/IP protocol, or serial communication links. Stream content could be observations, ephemeris, satellite orbit/clock products or NMEA sentences.

Fig. 2.1 shows a flow chart of BNC connected to a GNSS receiver providing observations via serial or TCP communication link for the purpose of Precise Point Positioning. Fig. 2.2 shows the conversion of RTCM streams to RINEX files. Fig. 2.3 shows a flow chart of BNC feeding a real-time GNSS engine which estimates precise orbits and clocks. BNC is used in this scenario to encode correctors to RTCM Version 3 and upload them to an Ntrip Broadcaster. Fig. 2.4 shows BNC combining several Broadcast Correction streams to disseminate the combination product while saving results in SP3 and Clock RINEX files.

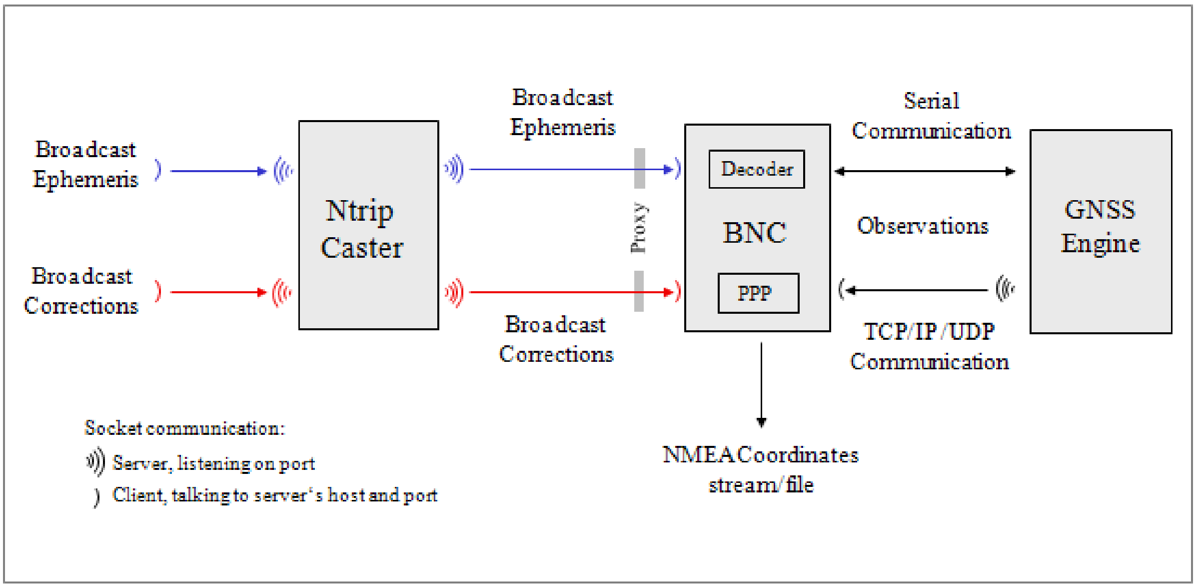


Fig. 2.1: Flowchart, BNC connected to a GNSS rover for Precise Point Positioning.

2.3 Handling

Although BNC is mainly a real-time tool to be operated online, it can be run offline

- To simulate real-time observation situations for debugging purposes;
- For post processing purposes.

Furthermore, apart from its regular window mode, BNC can be run as a batch/background job in a 'no window' mode, using processing options from a previously saved configuration or from command line.

Unless it runs offline, BNC

- Requires access to the Internet with a minimum of about 2 to 6 kbits/sec per stream depending on the stream format and the number of visible satellites. You need to make sure that the connection can sustain the required bandwidth;
- Requires the clock of the host computer to be properly synchronized;
- Has the capacity to retrieve hundreds of GNSS data streams simultaneously. Please be aware that such usage may incur a heavy load on the Ntrip Broadcaster side depending on the number of streams requested. We recommend limiting the number of streams where possible to avoid unnecessary workload.

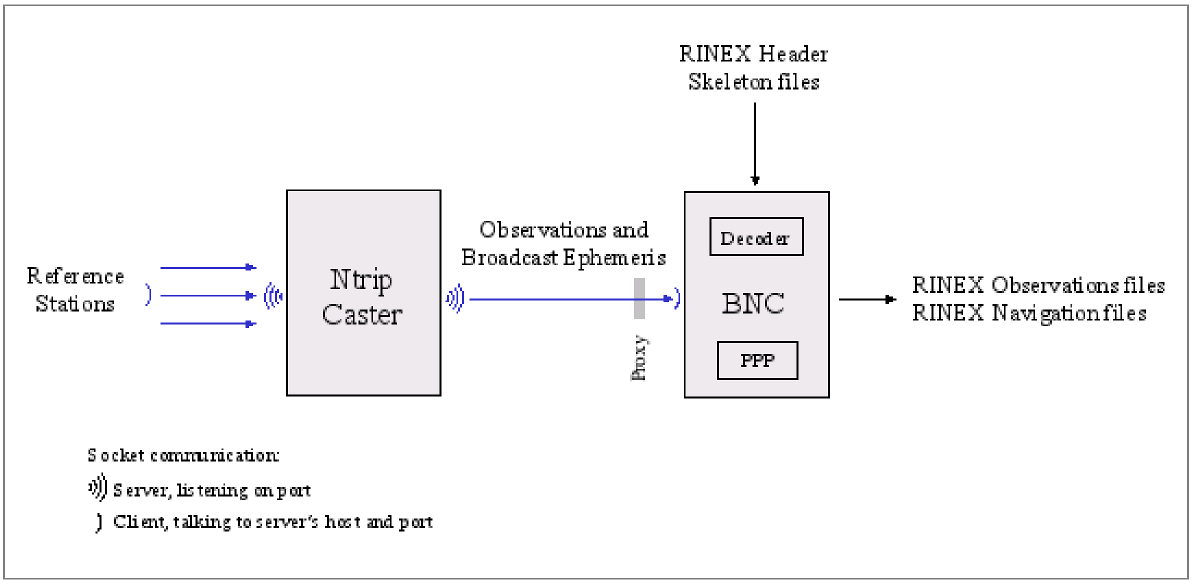


Fig. 2.2: Flowchart, BNC converting RTCM streams to RINEX batches.

The main window of BNC shows a 'Top menu bar' section, a 'Settings' sections with panels to set processing options, a 'Streams' section, a section for 'Log' tabs, and a 'Bottom menu bar' section (Fig. 2.5).

Running BNC in interactive mode requires graphics support. This is also required in batch mode when producing plots. Windows and Mac OS X systems always support graphics. However, when using BNC in batch mode on Linux systems for producing plots, you need to make sure that at least a virtual X-Server like 'Xvfb' is installed and the '-display' command line option is used.

The usual handling of BNC is that you first select a number of streams ('Add Stream'). Any stream configured to BNC shows up on the 'Streams' canvas in the middle of BNC's main window. You then go through BNC's various configuration panels to set a combination of input, processing and output options before you start the program ('Start'). Most configuration panels are dedicated to a certain function of BNC. If the first option field on such a configuration panel is empty, the affected functionality is deactivated.

Records of BNC's activities are shown in the 'Log' tab which is part of the 'Log' canvas. The bandwidth consumption per stream, the latency of incoming observations, and a PPP time series for coordinate displacements are also part of that canvas and shown in the 'Throughput', 'Latency' and 'PPP Plot' tabs.

Configuration options are usually first set using BNC's Graphical User Interface (GUI), then saved in a configuration file. For routine operations in batch mode all of BNC's configuration options can be extracted from the configuration file and applied using the program's Command Line Interface (CLI).

2.4 Limitations

- In Qt-based desktop environments (like KDE) on Unix/Linux platforms it may happen that you experience a crash of BNC at startup even when running the program in the background using the '-nw' option. This is a known bug most likely resulting from an incompatibility of Qt libraries in the environment and in BNC. Entering the command `unset SESSION\MANAGER` before running BNC may help as a work-around.
- Using RTCM Version 3 to produce RINEX files, BNC will properly handle most message types. However, when handling message types 1001, 1003, 1009 and 1011 where the ambiguity field is not set, the output will be no valid RINEX. All values will be stored modulo 299792.458 (speed of light).
- Using RTCM Version 2, BNC will only handle message types 18 and 19 or 20 and 21 together with position and the antenna offset information carried in types 3 and 22. Note that processing carrier phase corrections and pseudo-range corrections contained in message types 20 and 21 needs access to Broadcast Ephemeris.

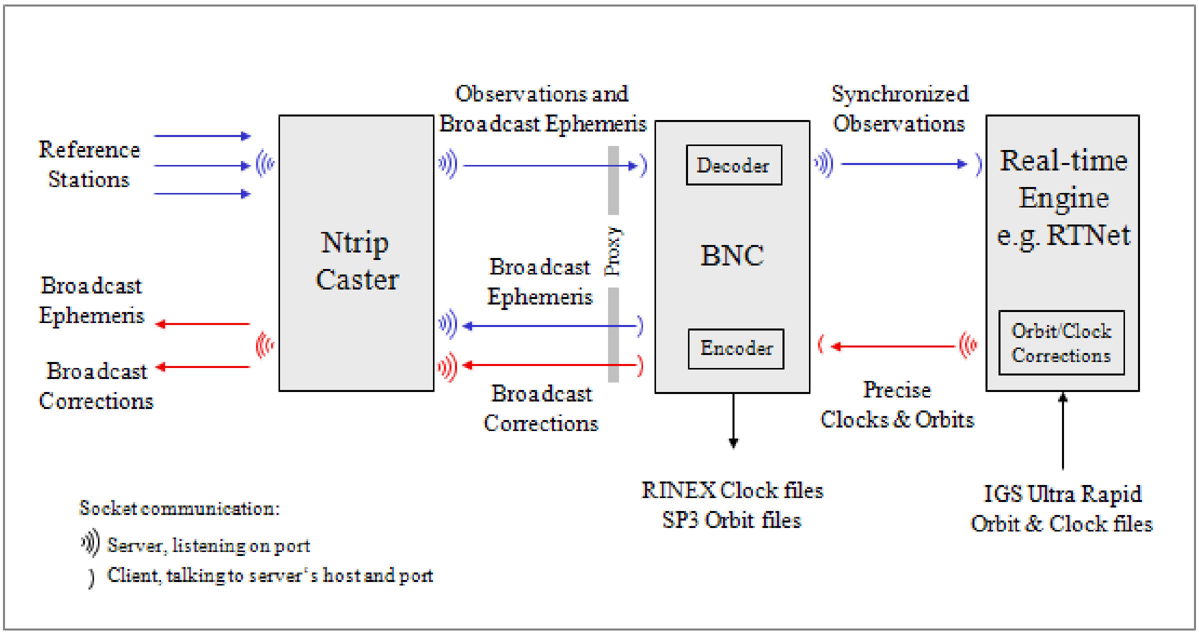


Fig. 2.3: Flowchart, BNC feeding a real-time GNSS engine and uploading encoded Broadcast Corrections

Hence, whenever dealing with message types 20 and 21, make sure that Broadcast Ephemeris become available for BNC through also retrieving at least one RTCM Version 3 stream carrying message types 1019 (GPS ephemeris) and 1020 (GLONASS ephemeris).

- BNC's 'Get Table' function only shows the STR records of a source-table. You can use an Internet browser to download the full source-table content of any Ntrip Broadcaster by simply entering its URL in the form of http://host:port. Data field number 8 in the NET records may provide information about where to register for an Ntrip Broadcaster account.
- EUREF as well as IGS adhere to an Open Data policy. Streams are made available through Ntrip Broadcasters at www.euref-ip.net, www.igs-ip.net, products.igs-ip.net, and mgex.igs-ip.net free of charge to anyone for any purpose. There is no indication up until now how many users will need to be supported simultaneously. The given situation may develop in such a way that it might become difficult to serve all registered users at the same times. In cases where limited resources on the Ntrip Broadcaster side (software restrictions, bandwidth limitation etc.) dictates, first priority in stream provision will be given to stream providers followed by re-broadcasting activities and real-time analysis centers while access to others might be temporarily denied.
- Once BNC has been started, many of its configuration options cannot be changed as long as it is stopped. See chapter 'Reread Configuration' for on-the-fly configuration exceptions.
- Drag and drop of configuration files is currently not supported on Mac OS X. On such system you have to start BNC via command line.

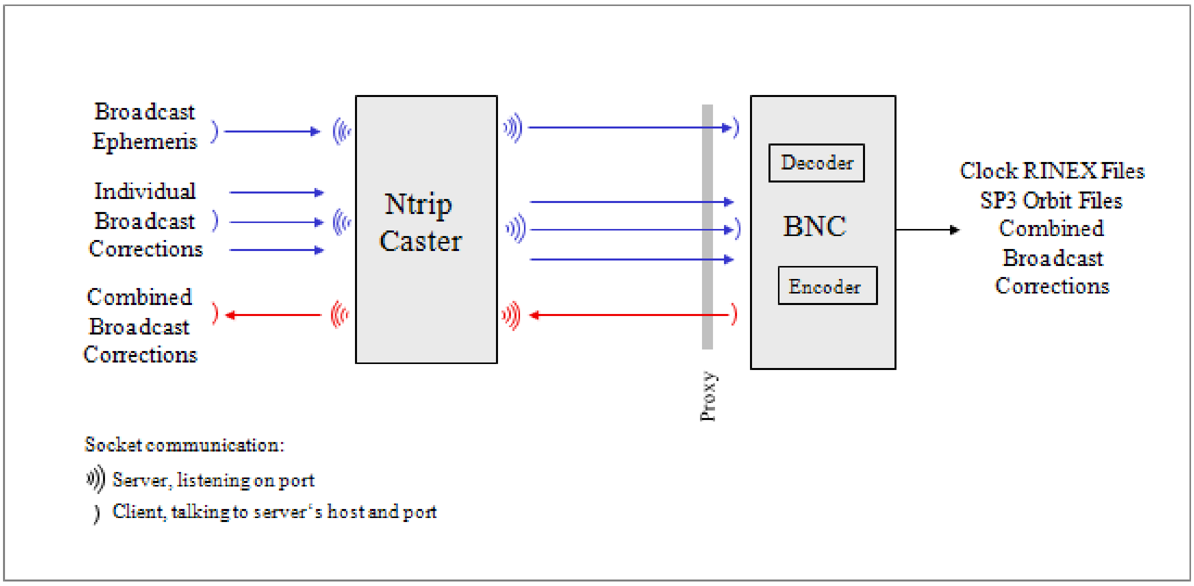


Fig. 2.4: Flowchart, BNC combining Broadcast Correction streams.

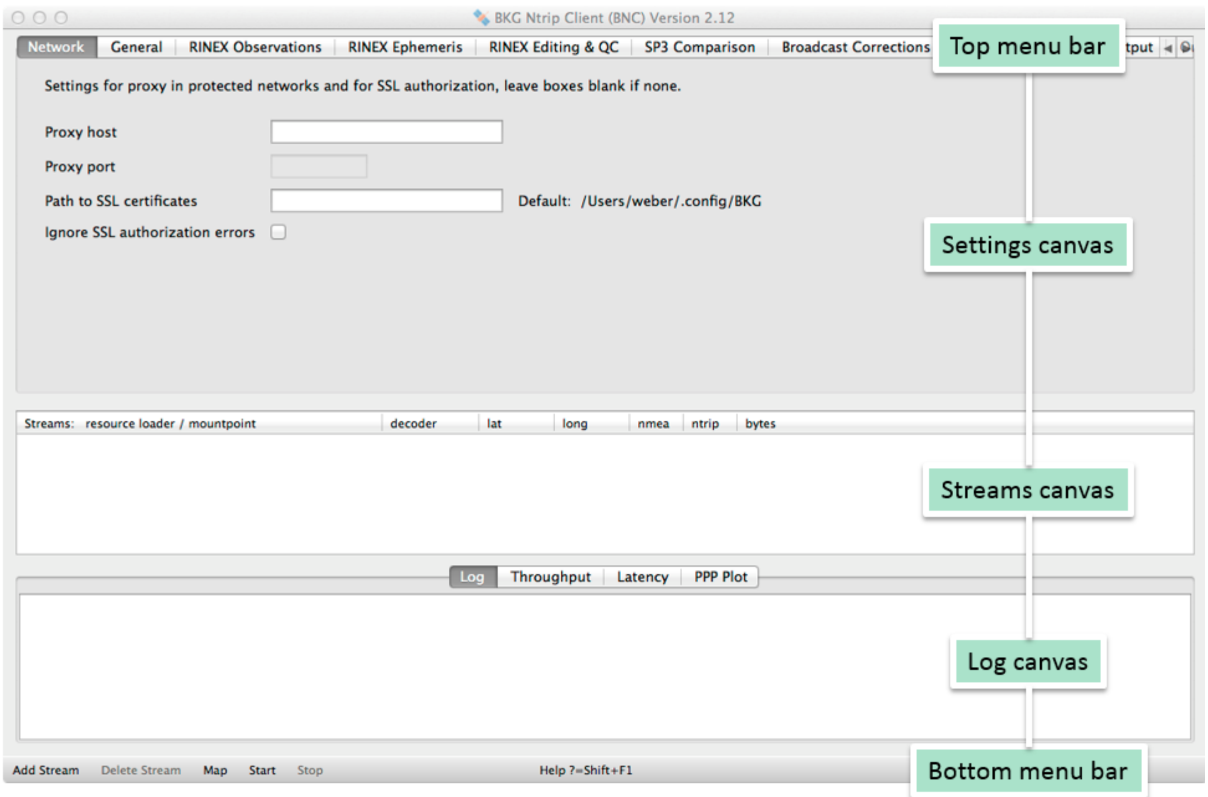


Fig. 2.5: Sections on BNC's main window.

CHAPTER 3

Installation

3.1 Pre-compiled builds

Precompiled builds of BNC are available for MS Windows, Linux, and Mac OS X systems. They can be downloaded for installation from http://igs.bkg.bund.de/ntrip/download. Please ensure that you always use the latest released version of the program.

MS Windows Build

A dynamically compiled shared library build for Mircrosoft Windows systems is provided as Microsoft Installer (MSI) file. MSI files are used for installation, storage, and removal of programs. The BNC files are contained in a MSI package, which is used with the program's client-side installer service, an .EXE file, to open and install the program. We used the MinGW Version 4.4.0 compiler to create BNC for Windows. After installation your *bnc.exe* file shows up e.g. under 'All Programs'.

Linux Build

Static library and shared library builds for BNC are provided for a selection of Linux distributions. Download the ZIP archive for a version which fits to your Linux system, unzip the archive and run the included BNC binary. A static build would be sufficient in case you do not want BNC to plot PPP results with Google Map (GM) or OpenStreetMap (OSM) maps in the background. GM/OSM usage requires BNC builds from shared libraries.

Mac OS X Build

A shared library `Disk iMaGe` (DMG) file is provided for BNC on OS X systems; it also comes in a ZIP archive. The DMG file format is used in the Mac for distributing software. Mac install packages appear as a virtual disk drive. After download, when the DMG file icon is double clicked, the virtual drive is 'mounted' on the desktop. Install BNC by dragging the `bnc.app` icon to your `Applications` folder. To start BNC, double click on `Applications/bnc.app`. You could also start BNC via Command Line Interface (CLI) using command `Applications/bnc.app/Contents/MacOS/bnc`.

3.2 Compilation

BNC has been written as Open Source and published under GNU General Public License (GPL). The latest source code can be checked out from Subversion repository http://software.rtcm-ntrip.org/svn/trunk/BNC. A ZIP archive available from http://igs.bkg.bund.de/ntrip/download provides the source code for BNC Version 2.12, developed using Qt Version 4.8.5.

The following describes how you can produce your own builds of BNC on MS Windows, Linux, and Mac systems. It is likely that BNC can also be compiled on other systems where a GNU compiler and Qt Version 4.8.5 or any later version is installed.

3.2.1 Static versus Shared Libraries

You can produce static or shared library builds of BNC. Static builds are sufficient in case you do not want BNC to produce track maps on top of Google Map (GM) or OpenStreetMap (OSM). GM/OSM usage would require the QtWebKit library which can only be part of BNC builds from shared Qt libraries. Hence, having a shared library Qt installation available is a precondition for producing a shared library build of BNC.

3.2.2 MS Windows Systems, Shared Library

This explains how to install a shared Qt 4.8.5 library on MS Windows systems to then create your own shared build of BNC.

Supposing that 'Secure Socket Layer (SSL)' is not available on you system, you should install OpenSSL libraries in `C:\OpenSSL-Win32`. They are available e.g. from http://igs.bkg.bund.de/root_ftp/NTRIP/software/Win32OpenSSL-1_0_1e.exe. See http://slproweb.com/products/Win32OpenSSL.html for other SSL resources. Ignore possibly occurring comments about missing components during installation.

1. Download MinGW compiler Version 4.4.0 e.g. from http://igs.bkg.bund.de/root_ftp/NTRIP/software/MinGW-gcc440_1.zip.
2. Unzip the ZIP archive and move its contents to a directory `C:\MinGW`. Now you can do either (4) or (5, 6, 8, 9, 10). Following (4) is suggested.
3. Download file `qt-win-opensource-4.8.5-mingw.exe` (317 MB) e.g. from https://download.qt.io/archive/qt/4.8/4.8.5/.
4. Execute this file to install a pre-compiled shared Qt library.
5. Download file `qt-everywhere-opensource-src-4.8.5.zip` (269 MB) e.g. from https://download.qt.io/archive/qt/4.8/4.8.5/.
6. Unzip the ZIP archive and move the contents of the contained directory into a directory `C:\Qt\4.8.5`.
7. Create somewhere a file `QtEnv.bat` with the following content

```
set QTDIR=C:\Qt\4.8.5
set PATH=%PATH%;C:\MinGW\bin;C:\Qt\4.8.5\bin
set QMAKESPEC=C:\Qt\4.8.5\mkspecs\win32-g++
```

8. Open a command line window and execute file `QtEnv.bat`.
9. Go to directory Qt directory and configure Qt using command

```
cd Qt\4.8.5
configure -fast -webkit -release -nomake examples -nomake tutorial
          -openssl -I C:\OpenSSL-Win32\include
```

10. Compile Qt using command `mingw32-make`. This may take quite a long time. Don't worry if the compilation process runs into a problem after some time. It is likely that the libraries you require are already generated at that time. Should you want to reconfiguring Qt following steps (8)-(10) you first need to clean the previous configuration using command `mingw32-make confclean`. Run command `mingw32-make clean` to delete previously compiled source code.
11. Download latest BNC from SVN repository http://software.rtcm-ntrip.org/svn/trunk/BNC.
12. Open command line window and execute file `QtEnv.bat`, see (7).
13. Go to directory BNC and enter command `qmake bnc.pro`.
14. Enter command `mingw32-make`.

15. Find binary file `bnc.exe` in directory named `src`.
16. Extend the Windows environment variable PATH by `C:\Qt\4.8.5\bin`.

Steps (11)-(15) can be repeated whenever a BNC update becomes available. Running `bnc.exe` on a windows system requires (1) when using the NTRIP Version 2s option for stream transfer over TLS/SSL.

3.2.3 Linux Systems

On Linux systems you may use the following procedure to install a shared Qt version 4.8.5 library:

Download file `qt-everywhere-opensource-src-4.8.5.tar.gz` (230 MB) available from https://download.qt.io/archive/qt/4.8/4.8.5/. Unzip file, extract tar archive and change to directory `qt-everywhere-opensource-src-4.8.5`. Run commands

```
./configure -fast -webkit -nomake examples -nomake tutorial
            -prefix /usr/local/Trolltech/Qt-4.8.5
gmake
gmake install
```

Qt will be installed into directory `/usr/local/Trolltech/Qt-4.8.5`. To reconfigure, run `gmake confclean` and `configure`. Note that the `-prefix` option allows you to specify a directory for saving the Qt libraries. This ensures that you do not run into conflicts with other Qt installations on your host. Note further that the following two lines

```
export QTDIR="/usr/local/Trolltech/Qt-4.8.5"
export PATH="$QTDIR/bin:$PATH"
```

need to be added either to `$HOME/.bash/profile` or `$HOME/.bashrc`. Once that is done, logout/login and start using Qt 4.8.5.

To compile the BNC program, you first download the source code from SVN repository http://software.rtcm-ntrip.org/svn/trunk/BNC. Go to directory BNC and run the following commands:

```
qmake bnc.pro
make
```

You will find a build of BNC in directory BNC.

3.2.4 Mac OS X Systems

Xcode and Qt installation

Xcode and Qt are required to compile BNC on OS X. Both tools are freely available. Xcode can be downloaded from the App Store or the Apple Developer Connection website. Once installed, run Xcode, go to 'Preferences->Downloads' and install the Command Line Tools component. Qt can be downloaded from the Qt Project website. We suggest installing version 4.8.4 or higher. The Qt libraries for Mac can be downloaded from http://www.qt.io/download. Once downloaded, mount the disk image, run the Qt.mpkg package and follow instructions from the installation wizard.

Compilation of bnc

The version of qmake supplied in the Qt binary package is configured to use the macx-xcode specification. This can be overridden with the `-spec macx-g++` option which makes it possible to use `qmake` to create a `Makefile` to be used by `make`.

From the directory where bnc.pro is located, run `qmake` to create the `Makefile` and then `make` to compile the binary:

```
qmake -spec macx-g++ bnc.pro
make
```

Refer to the following webpage for further information: http://doc.qt.io/qt-4.8/qmake-platform-notes.html.

Bundle Deployment

When distributing BNC it is necessary to bundle in all related Qt resources in the package. The Mac Deployment Tool has been designed to automate the process of creating a deployable application bundle that contains the Qt libraries as private frameworks. To use it, issue the following commands where `bnc.app` is located.

```
macdeployqt bnc.app -dmg
```

Refer to the following webpage for further information: http://doc.qt.io/qt-4.8/deployment-mac.html.

Once a DMG file for BNC is created, you can double click it and install BNC by dragging the `bnc.app` icon to your `Applications` folder. To start BNC, double click on `Applications/bnc.app`.

CHAPTER 4

Configuration

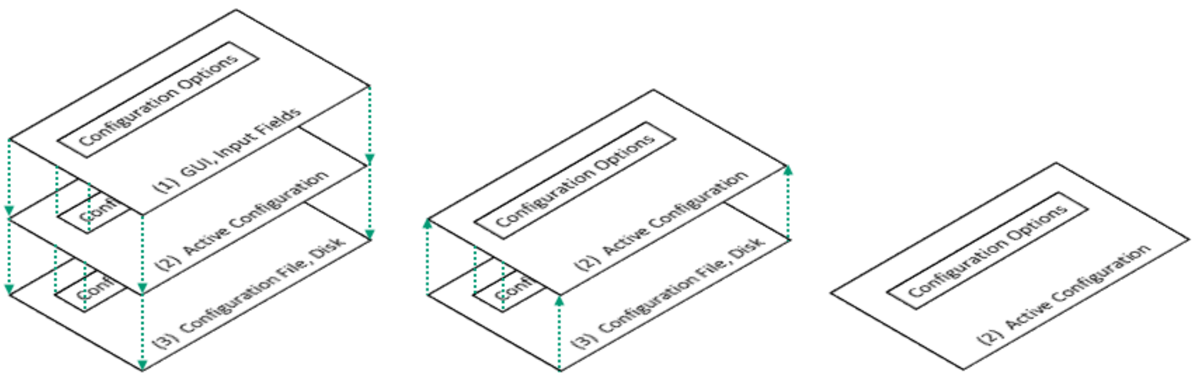
4.1 General procedure

As a default, configuration files for running BNC on Unix/Linux/Mac OS X systems are saved in directory `$HOME/.config/BKG`. On Windows systems, they are typically saved in directory `C:/Documents and Settings/Username/.config/BKG`. The default configuration filename is `BNC.bnc`.

The default filename `BNC.bnc` can be changed and the file content can easily be edited. On Graphical User Interfaces (GUI) it is possible to Drag & Drop a configuration file icon to start BNC (not on Mac OS X systems). It is also possible to start and configure BNC via command line. Some configuration options can be changed on-the-fly. See annexed Command Line Help for a complete set of configuration options.

BNC maintains configuration options at three different levels:

1. GUI, input fields level
2. Active configuration level
3. Configuration file, disk level



Left	BNC in graphics mode; active configuration options are introduced through GUI input fields and finally saved on disk
Middle	BNC in 'no window' mode; active configuration options are read from disk
Right	BNC in 'no window' mode without configuration file; default configuration options can be overwritten via command line options

Fig. 4.1: Management of configuration options in BNC.

Configuration options are usually specified using GUI input fields 1 after launching BNC. When hitting the 'Start' button, configuration options are transferred one level down to become BNC's active configuration 2, allowing the program to begin its operation. Pushing the 'Stop' button ends data processing so that the user can finally terminate BNC through 'File'->'Quit'->'Save Options' which saves processing options in a configuration file to disk 3. It is important to understand that:

- Active configuration options (2) are independent from GUI input fields and configuration file content.
- Hence changing configuration options at GUI level (1) while BNC is already processing data does not influence a running job.
- Editing configuration options at disk level (3) while BNC is already processing data does also not influence a running job. However, there are two exceptions which force BNC to update certain active options on-the-fly:
  - Pushing the 'Reread & Save Configuration' button lets BNC immediately reread its configuration from GUI input fields to make them active configuration options. Then BNC saves them on disk.
  - Specifying the 'Reread configuration' option lets BNC reread its configuration from disk at pre-defined intervals.
- A specific BNC configuration can be started in 'no window' mode from scratch without a configuration file if options for the active configuration level (2) are provided via command line.

4.2 Examples configuration files

BNC comes with a number of configuration examples which can be used on all operating systems. Copy the complete directory `Example_Configs` which comes with the software to your disc. It includes sub-directories `Input` and `Output`. There are several ways to start BNC using one of the example configurations:

- On graphical systems (except for Mac systems), you may use the computer mouse to 'drag' a configuration file icon and 'drop' it on top of BNC's program icon.
- You could also start BNC using a command line for naming a specific configuration file (suggested e.g. for Mac systems): `/Applications/bnc.app/Contents/MacOS/bnc --conf <configFileName>`
- On non-graphical systems or when running BNC in batch mode in the background you may start the program using a command line with a configuration file option in 'no window' mode (example for Windows systems): `bnc.exe --conf <configFileName> --nw`

Although it's not a must, we suggest that you always create BNC configuration files with filename extension `.bnc`.

We furthermore suggest for convenience reasons that you configure your system to automatically start BNC when you double-click a file with the filename extension `.bnc`. The following describes what to do on MS Windows systems to associate the BNC program to such configuration files:

1. Right-click a file that has the extension `.bnc` and then click 'Open'. If the 'Open' command is not available, click 'Open With' or double-click the file.
2. Windows displays a dialog box that says that the system cannot open this file. The dialog box offers several options for selecting a program.
3. Click 'Select the program from a list', and then click 'OK'.
4. The 'Open With' dialog box is displayed. Click 'Browse', locate and then click the BNC program, and then click 'Open'.
5. Click to select the 'Always use the selected program to open this kind of file' check box.
6. Click 'OK'.

Some of the presented example configurations contain a user ID 'Example' with a password 'Configs' for accessing a few GNSS streams from public Ntrip Broadcasters. This free generic account is arranged for convenience reasons only. Please be so kind as to replace the generic account details as well as the place holder's 'User' and 'Pass' by the personal user ID and password you receive following an online registration through http://register.rtcm-ntrip.org.

Note that the account for an Ntrip Broadcaster is usually limited to pulling a specified maximum number of streams at the same time. As running some of the example configurations requires pulling several streams, it is suggested to make sure that you do not exceed your account's limits.

Make also sure that sub-directories 'Input' and 'Output' which are part of the example configurations exist on your system or adjust the affected example configuration options according to your needs.

Some BNC options require Antenna Phase Center variations as made available from IGS through so-called ANTEX files at ftp://igs.org/pub/station/general. An example ANTEX file `igs08.atx` is part of the BNC package for convenience.

The example configurations assume that no proxy protects your BNC host. Should a proxy be operated in front of BNC then you need to introduce its name or IP and port number in the 'Network' panel.

4.3 List of example configuration files

You should be able to run all configuration file examples without changing contained options. However, configuration 'Upload.bnc' is an exception because it requires an input stream from a connected network engine.

1. Configuration File `RinexObs.bnc`

   Purpose: Convert RTCM streams to RINEX Observation files. The configuration pulls streams from Ntrip Broadcasters using Ntrip Version 1 to generate 15min 1Hz RINEX Version 3 Observation files. See http://igs.bkg.bund.de/ntrip/observations for observation stream resources.

2. Configuration File `RinexEph.bnc`

   Purpose: Convert a RTCM stream with navigation messages to RINEX Navigation files. The configuration pulls a RTCM Version 3 stream with Broadcast Ephemeris coming from the real-time EUREF and IGS networks and saves hourly RINEX Version 3 Navigation files. See http://igs.bkg.bund.de/ntrip/ephemeris for further real-time Broadcast Ephemeris resources.

3. Configuration File `BrdcCorr.bnc`

   Purpose: Save Broadcast Corrections from RTCM SSR messages in hourly plain ASCII files. See http://igs.bkg.bund.de/ntrip/orbits for various real-time IGS or EUREF orbit/clock correction products.

4. Configuration File `RinexConcat.bnc`

   Purpose: Concatenate several RINEX Version 3 files to produce one compiled file and edit the marker name in the file header. The sampling interval is set to 30 seconds. See section 'RINEX Editing & QC' in the documentation for examples on how to call BNC from command line in 'no window' mode for RINEX file editing, concatenation and quality check.

5. Configuration File `RinexQC.bnc`

   Purpose: Check the quality of a RINEX Version 3 file by means of a multipath analysis. Results are saved on disk in terms of a plot in PNG format. See section 'RINEX Editing & QC' in the documentation for examples on how to call BNC from command line in 'no window' mode for RINEX file editing, concatenation and quality check.

6. Configuration File `RTK.bnc`

   Purpose: Feed a serially connected receiver with observations from a nearby reference station for conventional RTK. The stream is scanned for RTCM messages. Message type numbers and latencies of incoming observations are reported in BNC's logfile.

7. Configuration File `FeedEngine.bnc`

   Purpose: Feed a real-time GNSS engine with observations from remote reference stations. The configuration pulls a single stream from an Ntrip Broadcaster. You could also pull several streams from different casters. Incoming observations are decoded, synchronized, output through a local IP port and also saved into a file. Failure and recovery thresholds are specified to inform about outages.

8. Configuration File `PPP.bnc`

   Purpose: Precise Point Positioning from observations of a rover receiver. The configuration reads RTCM Version 3 observations, a Broadcast Ephemeris stream and a stream with Broadcast Corrections. Positions are saved in the logfile.

9. Configuration File `PPPNet.bnc`

   Purpose: Precise Point Positioning for several rovers or receivers from an entire network of reference stations in one BNC job. The possible maximum number of PPP solutions per job depends on the processing power of the hosting computer. This example configuration reads two RTCM Version 3 observation streams, a Broadcast Ephemeris stream and a stream with Broadcast Corrections. PPP Results for the two stations are saved in PPP logfiles.

10. Configuration File `PPPQuickStart.bnc`

    Purpose: Precise Point Positioning in Quick-Start mode from observations of a static receiver with precisely known position. The configuration reads RTCM Version 3 observations, Broadcast Corrections and a Broadcast Ephemeris stream. Positions are saved in NMEA format on disc. They are also output through IP port for real-time visualization with tools like RTKPLOT. Positions are saved in the logfile.

11. Configuration File `PPPPostProc.bnc`

    Purpose: Precise Point Positioning in post processing mode. BNC reads RINEX Version 3 Observation and Navigation files and a Broadcast Correction file. PPP processing options are set to support the Quick-Start mode. The output is saved in a specific post processing logfile and contains coordinates derived over time following the implemented PPP filter algorithm.

12. Configuration File `PPPGoogleMaps.bnc`

    Purpose: Track BNC's point positioning solutions using Google Maps or OpenStreetMap as background. BNC reads a RINEX Observation file and a RINEX Navigation file to carry out a 'Standard Point Positioning' solution in post processing mode. Although this is not a real-time application, it requires the BNC host to be connected to the Internet. Specify a computation speed, then hit button 'Open Map' to open the track map, then hit 'Start' to visualize receiver positions on top of GM/OSM maps.

13. Configuration File `SPPQuickStartGal.bnc`

    Purpose: Single Point Positioning in Quick-Start mode from observations of a static receiver with quite precisely known position. The configuration uses GPS, GLONASS and Galileo observations and a Broadcast Ephemeris stream.

14. Configuration File `SaveSp3.bnc`

    Purpose: Produces SP3 files from a Broadcast Ephemeris stream and a Broadcast Correction stream. The Broadcast Correction stream is formally introduced in BNC's 'Combine Corrections' table. Note that producing SP3 requires an ANTEX file because SP3 file content should be referred to CoM.

15. Configuration File `Sp3ETRF2000PPP.bnc`

    Purpose: Produce SP3 files from a Broadcast Ephemeris stream and a stream carrying ETRF2000 Broadcast Corrections. The Broadcast Correction stream is formally introduced in BNC's 'Combine Corrections' table. The configuration leads to a SP3 file containing orbits also referred to ETRF2000. Pulling in addition observations from a reference station at precisely known ETRF2000 position allows comparing an 'INTERNAL' PPP solution with a known ETRF2000 reference coordinate.

16. Configuration File `Upload.bnc`

    Purpose: Upload orbits and clocks from a real-time GNSS engine to an Ntrip Broadcaster. For that the configuration reads precise orbits and clocks in RTNET format. It also reads a stream carrying Broadcast Ephemeris. BNC converts the orbits and clocks into Broadcast Corrections and encodes them to RTCM Version 3 SSR messages to finally upload them to an Ntrip Broadcaster. The Broadcast Correction stream is referred to satellite Antenna Phase Center (APC) and reference system IGS08. Orbits are saved on disk in SP3 format and clocks are saved in Clock RINEX format.

17. Configuration File `Combi.bnc`

    Purpose: Pull several streams carrying Broadcast Corrections and a Broadcast Ephemeris stream from an Ntrip Broadcaster to produce a combined Broadcast Correction stream. BNC encodes the combination product in RTCM Version 3 SSR messages and uploads that to an Ntrip Broadcaster. The Broadcast Correction stream is referred to satellite Antenna Phase Center (APC) and not to satellite Center of Mass (CoM). Its reference system is IGS08. Orbits are saved in SP3 format (referred to CoM) and clocks in Clock RINEX format.

18. Configuration File `CombiPPP.bnc`

    Purpose: This configuration equals the 'Combi.bnc' configuration. However, the combined Broadcast Corrections are in addition used for an 'INTERNAL' PPP solution based on observations from a static reference station with known precise coordinates. This allows a continuous quality check of the combination product through observing coordinate displacements.

19. Configuration File `UploadEph.bnc`

    Purpose: Pull a number of streams from reference stations to get hold of contained Broadcast Ephemeris messages. They are encoded to RTCM Version 3 format and uploaded for the purpose of providing a Broadcast Ephemeris stream with an update rate of 5 seconds.

20. Configuration File `CompareSp3.bnc`

    Purpose: Compare two SP3 files to calculate RMS values for orbit and clock differences. GPS satellite G05 and GLONASS satellite R18 are excluded from this comparison. Comparison results are saved in a logfile.

21. Configuration File `Empty.bnc`

    Purpose: Provide an empty example configuration file for BNC which only contains default settings.

4.4 Command Line configuration options

The following configuration examples make use of BNC's 'Command Line Interface' (CLI). Configuration options are exclusively specified via command line. No configuration file is used. Examples are provided as shell scripts for a Linux system. They call BNC in 'no window' batch mode (command line option `-nw`). The scripts expect 'Example_Configs' to be the current working directory.

1. Shell Script `RinexQC.sh`

   Purpose: Equals configuration file example `RinexQC.bnc`, checks the quality of a RINEX Version 3 file by means of a multipath analysis. Virtual X-Server 'Xvfb' is operated while producing plot files in PNG format. BNC is offline. All results are saved on disk.

2. Shell Script `RinexConcat.sh`

   Purpose: Equals configuration file example `RinexConcat.bnc`, concatenates several RINEX Version 3 files to produce one compiled file and edit the marker name in the file header. The sampling interval is set to 30 seconds.

3. Shell Script `RinexEph.sh`

   Purpose: Equals configuration file example `RinexEph.bnc`, converts a RTCM stream with navigation messages to RINEX Navigation files. The configuration pulls a RTCM Version 3 stream with Broadcast Ephemeris coming from the real-time EUREF and IGS networks and saves hourly RINEX Version 3 Navigation files. BNC runs online until it's terminated after 10 seconds. See http://igs.bkg.bund.de/ntrip/ephemeris for further real-time Broadcast Ephemeris resources.

4. Shell Script `ScanLate.sh`

   Purpose: Scan an observation stream for contained RTCM message types, print observation latencies. The output is saved in a logfile. Latencies are reported every 10 seconds. BNC runs online until it's terminated after 20 seconds.

5. Shell Script `RinexObs.sh`

   Purpose: Equals configuration file example `RinexObs.bnc`, converts RTCM streams to RINEX Observation files. The configuration pulls streams from two Ntrip Broadcasters using Ntrip Version 1 to generate 15min 1Hz RINEX Version 3 Observation files. See http://igs.bkg.bund.de/ntrip/observations for observation stream resources. BNC runs online until it's terminated after 30 seconds.

4.5 Command Line configuration options overwriting Configuration File options

For specific applications you may like to use your own set of standard configuration options from a configuration file and update some of its content via command line. When using a configuration file together with command line configuration options in one BNC call, the command line configuration options will always overrule options contained in the configuration file:

Shell script `CompareSp3.sh`.

Purpose: Equals configuration file example `CompareSp3.bnc`, compares two SP3 files to calculate RMS values for orbit and clock differences. However, instead of excluding GPS satellite G05 and GLONASS satellite R18 from the comparison as specified in `CompareSp3.bnc`, GPS satellite G06 and all GLONASS satellites are excluded via command line option. BNC runs offline. Comparison results are saved in a logfile.

CHAPTER 5

BNC software settings

The general documentation approach is to create a separate chapter for each processing option in a sequence which follows the layout of BNC's Graphical User Interface (GUI). The advantage is that searching for help by means of the document's Table of Contents (TOC) is quite convenient.

The following chapters describe how to set BNC program options. They explain the 'Top Menu Bar', the 'Settings Canvas' with the processing options, the content of the 'Streams Canvas' and 'Logging Canvas', and the 'Bottom Menu Bar'.

5.1 Top Menu Bar

The top menu bar allows selecting a font for the BNC windows, save configured options, or quit the program execution. It also provides access to the program's documentation.

5.1.1 File

The 'File' button lets you

- Select an appropriate font. Use smaller font size if the BNC main window exceeds the size of your screen.
- Reread and save selected options in configuration file. When using 'Reread & Save Configuration' while BNC is already processing data, some configuration options become immediately effective on-the-fly without interrupting uninvolved threads while all of them are saved on disk. See section 'Reread Configuration' for a list of on-the-fly changeable configuration options.
- Quit the BNC program.

5.1.2 Help

The 'Help' button provides access to

- Help contents. You may keep the 'Help Contents' window open while configuring BNC.
- A 'Flow Chart' showing BNC linked to a real-time GNSS network engine such as RTNET.
- General information about BNC. Close the 'About BNC' window to continue working with BNC.

5.2 Network

You may need to specify a proxy when running BNC in a protected network. You may also like to use the Transport Layer Security (TLS) and its predecessor, Secure Sockets Layer (SSL) cryptographic protocols for secure Ntrip communication over the Internet.

5.2.1 Proxy - Usage in a protected LAN

If you are running BNC within a protected Local Area Network (LAN), you might need to use a proxy server to access the Internet. Enter your proxy server IP and port number in case one is operated in front of BNC. If you do not know the IP and port of your proxy server, check the proxy server settings in your Internet browser or ask your network administrator.

Note that IP streaming is often not allowed in a LAN. In this case you need to ask your network administrator for an appropriate modification of the local security policy or for the installation of a TCP relay to the Ntrip Broadcaster you need to access. If this is not possible, you might need to run BNC outside your LAN on a host that has unobstructed connection to the Internet.

5.2.2 SSL - Transport Layer Security

Communication with an Ntrip Broadcaster over Secure Sockets Layer (SSL) as well as the download of RINEX skeleton files when available from HTTPS websites requires the exchange of client and/or server certificates. Specify the path to a directory where you save certificates on your system. You may like to check out http://software.rtcm-ntrip.org/wiki/Certificates for a list of known Ntrip Server certificates. You may also just try communication via SSL to check out whether this is supported by the involved Ntrip Broadcaster.

SSL communication may involve queries coming from the Ntrip Broadcaster or from a HTTPS website hosting RINEX skeletons. Such a query could show up under BNC's 'Log' tab especially when self-signed SSL certificates are used. Example:

```
SSL Error
Server Certificate Issued by:
GNSS Data Center
BKG (Bundesamt für Geodäsie und Kartographie)
Cannot be verified

The issuer certificate of a locally looked up certificate could not be found
The root CA certificate is not trusted for this purpose
No certificates could be verified

Queries should not be received by a client when a server uses official SSL
 ↪ certificates.
```

Tick 'Ignore SSL authorization errors' if you generally trust the server and do not want to be bothered with this. Note that SSL communication is usually done over port 443 (Fig. 5.1).

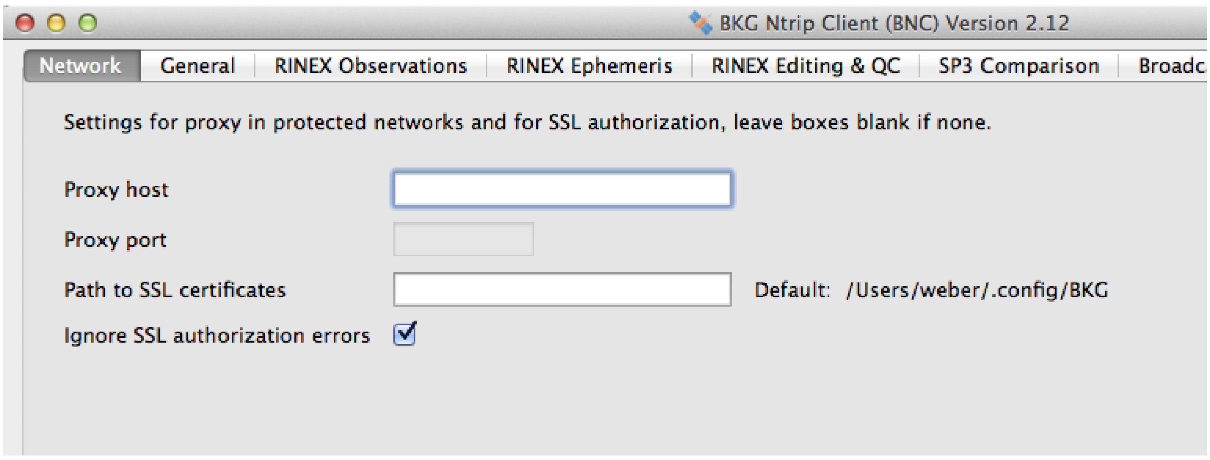


Fig. 5.1: BNC's 'Network' panel configured to ignore eventually occurring SSL error messages.

5.3 General

The following defines general settings for BNC's logfile, file handling, reconfiguration on-the-fly, and auto-start (Fig. 5.2).

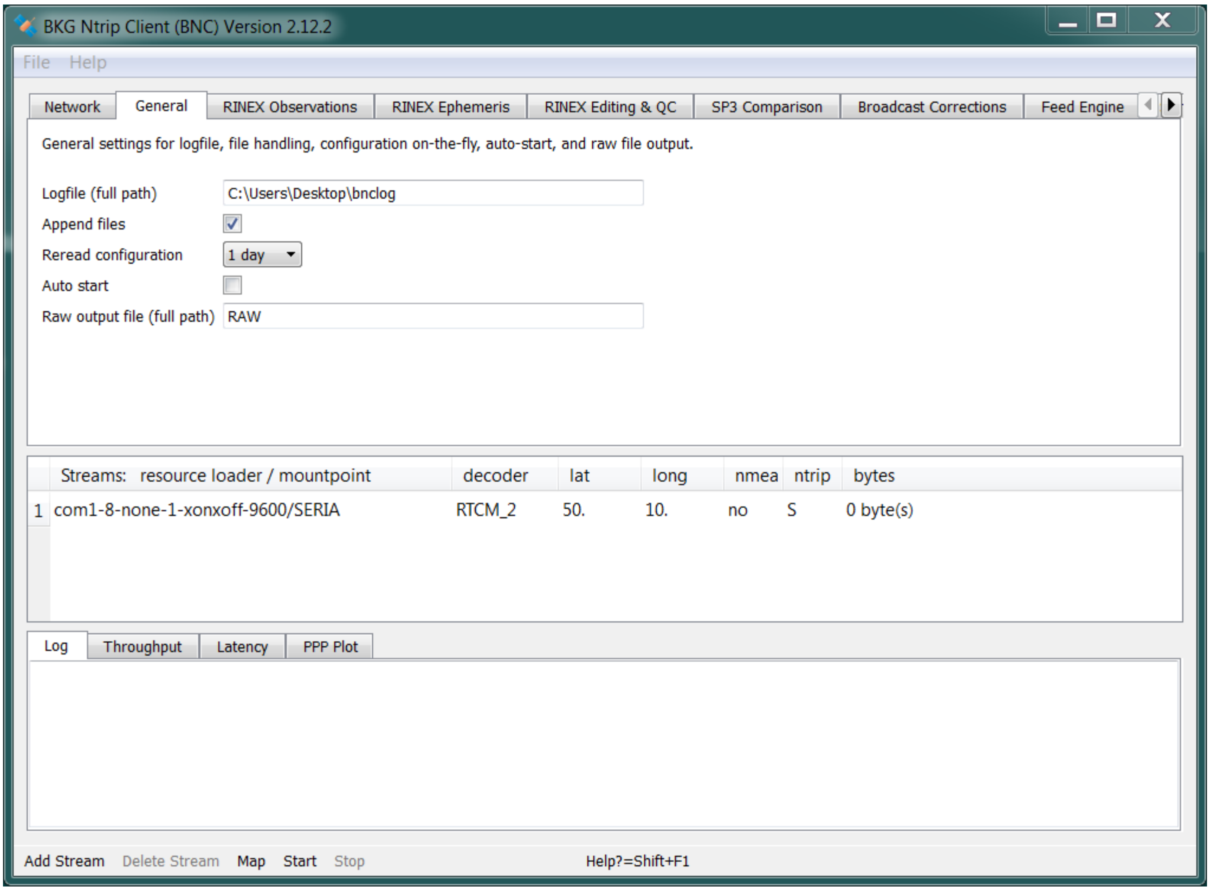


Fig. 5.2: General BNC options

5.3.1 Logfile - optional

Records of BNC's activities are shown in the 'Log' tab on the bottom of the main window. These logs can be saved into a file when a valid path is specified in the 'Logfile (full path)' field. The logfile name will automatically be extended by a string '_YYMMDD' for the current date. This leads to series of daily logfiles when running BNC continuously. Message logs cover the communication status between BNC and the Ntrip Broadcaster as well as problems that may occur in the communication link, stream availability, stream delay, stream conversion etc. All times are given in UTC. The default value for 'Logfile (full path)' is an empty option field, meaning that BNC logs will not be saved into a file.

The following is an example for the content of a logfile written by BNC when operated in Single Point Positioning (SPP) mode:

```
15-06-30 11:40:17 ========== Start BNC v2.12 (MAC) ==========
15-06-30 11:40:17 Panel 'PPP' active
15-06-30 11:40:17 CUT07: Get data in RTCM 3.x format
15-06-30 11:40:17 RTCM3EPH: Get data in RTCM 3.x format
15-06-30 11:40:17 Configuration read: PPP.conf, 2 stream(s)

15-06-30 11:40:21 2015-06-30_11:40:19.000 CUT07 X = -2364337.6814 Y = 4870283.8110
 ↪ Z = -3360808.3085 NEU:  -0.0000  -0.0000  -0.0000 TRP:  +2.4026  -0.0001
```

```
15-06-30 11:40:22 2015-06-30_11:40:20.000 CUT07 X = -2364337.6853 Y = 4870283.8130
 ↪  Z = -3360808.3082 NEU:  +1.1639  +0.6988  -2.1178 TRP:  +2.4018  +0.0003
15-06-30 11:40:23 2015-06-30_11:40:21.000 CUT07 X = -2364337.6862 Y = 4870283.8155
 ↪  Z = -3360808.3107 NEU:  +0.1317  -0.4655  -4.4614 TRP:  +2.4009  +0.0009
15-06-30 11:40:24 2015-06-30_11:40:22.000 CUT07 X = -2364337.6864 Y = 4870283.8106
 ↪  Z = -3360808.3099 NEU:  +0.1543  +0.2121  -1.0190 TRP:  +2.4022  +0.0009
15-06-30 11:40:25 2015-06-30_11:40:23.000 CUT07 X = -2364337.6861 Y = 4870283.8111
 ↪  Z = -3360808.3105 NEU:  -0.9782  +0.0916  -2.3544 TRP:  +2.4017  +0.0013
15-06-30 11:40:26 2015-06-30_11:40:24.000 CUT07 X = -2364337.6884 Y = 4870283.8123
 ↪  Z = -3360808.3103 NEU:  -0.5606  -0.0938  -1.9498 TRP:  +2.4018  +0.0016
15-06-30 11:40:27 2015-06-30_11:40:25.000 CUT07 X = -2364337.6913 Y = 4870283.8133
 ↪  Z = -3360808.3122 NEU:  -0.1799  -0.1525  -4.8142 TRP:  +2.4007  +0.0025
15-06-30 11:40:28 2015-06-30_11:40:26.000 CUT07 X = -2364337.6919 Y = 4870283.8171
 ↪  Z = -3360808.3184 NEU:  +0.7497  +0.7994  -2.0363 TRP:  +2.4018  +0.0032
15-06-30 11:40:29 2015-06-30_11:40:27.000 CUT07 X = -2364337.6923 Y = 4870283.8196
 ↪  Z = -3360808.3230 NEU:  +0.8099  +0.5592  -2.8552 TRP:  +2.4015  +0.0039
15-06-30 11:40:30 2015-06-30_11:40:28.000 CUT07 X = -2364337.6960 Y = 4870283.8219
 ↪  Z = -3360808.3222 NEU:  -0.2952  +1.9737  -4.5565 TRP:  +2.4008  +0.0047
15-06-30 11:40:31 2015-06-30_11:40:29.000 CUT07 X = -2364337.6982 Y = 4870283.8209
 ↪  Z = -3360808.3209 NEU:  +0.3563  +2.1067  -5.5327 TRP:  +2.4005  +0.0057
...
```

5.3.2 Append Files - optional

When BNC is started, new files are created by default and existing files with the same name will be overwritten. However, users might want to append existing files following a restart of BNC, a system crash or a BNC crash. Tick ‘Append files’ to continue with existing files and keep what has been recorded so far. Note that option ‘Append files’ affects all types of files created by BNC.

5.3.3 Reread Configuration - optional

When operating BNC online in ‘no window’ mode (command line option `-nw`), some configuration options can nevertheless be changed on-the-fly without interrupting the running process. For that, you force the program to reread parts of its configuration in pre-defined intervals from disk. Select ‘1 min’, ‘1 hour’, or ‘1 day’ to let BNC reread on-the-fly changeable configuration options every full minute, hour, or day. This lets in-between edited options become effective without interrupting uninvolved threads.

Note that following configuration options saved on disk can be changed/edited on-the-fly while BNC is already processing data:

- ‘mountPoints’ to change the selection of streams to be processed, see section ‘Streams Canvas’;
- ‘outWait’ to change the ‘Wait for full obs epoch’ option, see section ‘Feed Engine’;
- ‘outSampl’ to change the ‘Sampling’ option, see section ‘Feed Engine’;
- ‘outFile’ to change the ‘File’ name where synchronized observations are saved in plain ASCII format, see section ‘Feed Engine’.

5.3.4 Auto Start - optional

You may like to auto-start BNC at startup time in window mode with pre-assigned configuration options. This may be required e.g. immediately after booting your system. Tick ‘Auto start’ to supersede the usage of the ‘Start’ button. Make sure that you maintain a link to BNC for that in your Autostart directory (Windows systems) or call BNC in a script below directory `/etc/init.d` (Unix/Linux/Mac OS X systems).

See BNC’s command line option `-nw` for an auto-start of BNC in ‘no window’ mode.

5.3.5 Raw Output File - optional

BNC can save all data coming in through various streams in one daily file. The information is recorded in the specified 'Raw output file' in the received order and format. This feature allows a BNC user to run the PPP option offline with observations, Broadcast Corrections, and Broadcast Ephemeris being read from a previously saved file. It supports the offline repetition of a real-time situation for debugging purposes (Record & Replay functionality) and is not meant for post processing.

Data will be saved in blocks in the received format separated by ASCII time stamps like (example):

```
2010-08-03T18:05:28 RTCM3EPH RTCM_3 67
```

This example block header tells you that 67 bytes were saved in the data block following this time stamp. The information in this block is encoded in RTCM Version 3 format, comes from mountpoint RTCM3EPH and was received at 18:05:28 UTC on 2010-08-03. BNC adds its own time stamps in order to allow the reconstruction of a recorded real-time situation.

The default value for 'Raw output file' is an empty option field, meaning that BNC will not save all raw data into one single daily file.

5.4 RINEX Observations

Observations will be converted to RINEX if they come in either RTCM Version 2 or RTCM Version 3 format. Depending on the RINEX version and incoming RTCM message types, files generated by BNC may contain data from GPS, GLONASS, Galileo, SBAS, QZSS, and/or BDS (BeiDou). In case an observation type is listed in the RINEX header but the corresponding observation is unavailable, its value is set to zero '0.000' or left blank. Note that the 'RINEX TYPE' field in the RINEX Version 3 Observation file header is always set to 'M(MIXED)' or 'Mixed' even if the file only contains data from one system.

It is important to understand that converting RTCM streams to RINEX files requires a priori information on observation types for specifying a complete RINEX header. Regarding the RINEX Version 2 file header, BNC simply introduces all observation types defined in the Version 2 standard and later reports '0.000' for observations which are not received. However, following this approach is not possible for RINEX Version 3 files from RTCM Version 3 MSM streams because of the huge number of observation types, which might in principle show up. The solution implemented in BNC is to start with RINEX Version 3 observation type records from skeleton files (see section 'Skeleton Extension' and 'Skeleton Mandatory') and switch to a default selection of observation types when such file is not available or does not contain the required information. The following is the default selection of observation types specified for a RINEX Version 3 file:

```
C    9 C2I L2I S2I C6I L6I S6I C7I L7I S7I                  SYS / # / OBS TYPES
E   12 C1X L1X SX1 C5X L5X SX5 C7X L7X SX7 C8X L8X SX8      SYS / # / OBS TYPES
G   15 C1C L1C S1C C1W L1W S1W C2X L2X S2X C2W L2W S2W C5X  SYS / # / OBS TYPES
       L5X S5X                                              SYS / # / OBS TYPES
J   24 C1C L1C S1C C1S L1S S1S C1L L1L S1L C1X L1X S1X C2S  SYS / # / OBS TYPES
       L2S S2S C2L L2L S2L C2X L2X S2X C5X L5X S5X          SYS / # / OBS TYPES
R   12 C1C L1C S1C C1P L1P S1P C2C L2C S2C C2P L2P S2P      SYS / # / OBS TYPES
S    9 C1C L1C S1C C5I L5I S5I C5Q L5Q S5Q                  SYS / # / OBS TYPES
```

Please note that RTCM Version 3 messages 1084 for GLONASS observations do not contain the GLONASS channel numbers. These observation messages can only be converted to RINEX when you add messages which include the channel numbers. This could be done by means of an additional stream carrying 1087 GLONASS observation messages or an additional stream carrying 1020 GLONASS ephemeris messages. You could also consider setting up a stream which contains both, the 1084 and the 1020 messages.

The screenshot below shows an example setup of BNC when converting streams to RINEX. Streams are coming from various Ntrip Broadcasters as well as from a serial communication link. Specifying a decoder string 'ZERO' would mean to not convert the affected stream but save its content as received. The 'SSL Error' recorded in the 'Log' tab is caused by the fact that observation stream downloads from IGS and MGEX Broadcasters initiate the download of RINEX skeleton files from a HTTPS (TLS/SSL) website and BNC has been configured in this example to ignore SSL errors as shown in the preceding 'Network' panel screenshot (Fig. 5.3).

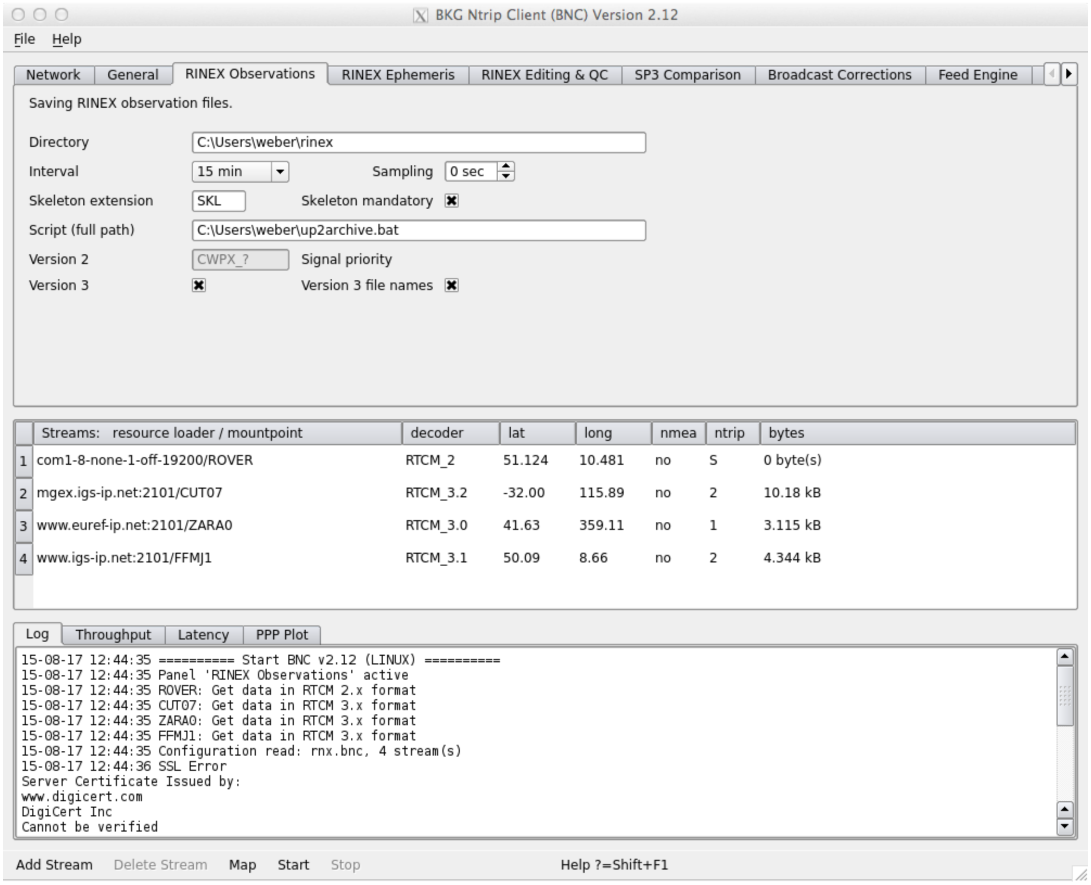


Fig. 5.3: BNC translating incoming observation streams to 15 min RINEX Version 3 Observation files.

5.4.1 RINEX Filenames

The default for RINEX filenames in BNC follows the convention of RINEX Version 2. However, the software provides options to alternatively follow the filename convention of RINEX Version 3. RINEX Version 2 filenames are derived by BNC from the first 4-characters of the corresponding stream's mountpoint (4-character Station ID). For example, data from mountpoints FRANKFURT and WETTZELL will have hourly RINEX Observation files named:

```
FRAN{ddd}{h}.{yy}O
WETT{ddd}{h}.{yy}O
```

where 'ddd' is the day of year, 'h' is a letter which corresponds to an hour long UTC time block and 'yy' is the year.

If there is more than one stream with identical 4-character Station ID (same first 4-characters for their mountpoints), the mountpoint strings are split into two sub-strings and both become part of the RINEX filename. For example, when simultaneously retrieving data from mountpoints FRANKFURT and FRANCE, their hourly RINEX Version 2 Observation files are named as:

```
FRAN{ddd}{h}_KFURT.{yy}O
FRAN{ddd}{h}_CE.{yy}O
```

If several streams show up with exactly the same mountpoint name (example: BRUS0 from www.euref-ip.net and BRUS0 from www.igs-ip.net), BNC adds an integer number to the filename, leading e.g. to hourly RINEX Version 2 Observation files like:

```
BRUS{ddd}{h}_0.{yy}O
BRUS{ddd}{h}_1.{yy}O
```

Note that RINEX Version 2 filenames for all intervals less than 1 hour follow the filename convention for 15 minutes RINEX Version 2 Observation files e.g.:

```
FRAN{ddd}{h}{mm}.{yy}O
```

where ‘mm’ is the starting minute within the hour.

In case of RINEX Version 3 filenames, the conventions are summarized in Table 5.1.

Table 5.1: Conventions of RINEX 3 file names.

Filename Parameter	# Characters	Meaning
Name	9	Site, station and country code
S	1	Data source
Start Time	11	YYYYDDDHHMM
Period	3	File period
Obs. Freq.	3	Observation frequency
Content	2	Content type
Format	3	File format
Compression	2-3	Compression method (optional)

Example for Mixed RINEX Version 3 GNSS observation filename, file containing 1 hour of data, one observation every second, ‘MO’ standing for ‘Mixed Observations’:

```
ALGO00CAN_R_20121601000_01H_01S_MO.rnx
```

Note that filename details are produced from the stream’s mountpoint as well as corresponding BNC settings and meta data from the Ntrip Broadcaster source-table.

5.4.2 Directory - optional

Here you can specify the path to where the RINEX Observation files will be stored. If the specified directory does not exist, BNC will not create RINEX Observation files. Default value for ‘Directory’ is an empty option field, meaning that no RINEX Observation files will be written.

5.4.3 File Interval - mandatory if ‘Directory’ is set

Select the length of the RINEX Observation file to be generated. The default value is 15 minutes.

5.4.4 Sampling - mandatory if ‘Directory’ is set

Select the RINEX Observation sampling interval in seconds. A value of zero ‘0’ tells BNC to store all received epochs into RINEX. This is the default value.

5.4.5 Skeleton Extension - optional

Whenever BNC starts to generate RINEX Observation files (and then once every day at midnight), it first tries to retrieve information needed for RINEX headers from so-called fully machine-readable public RINEX header skeleton files which are derived from sitelogs. An HTTP or HTTPS link to a directory containing these skeleton files may be available through data field number 7 of the affected NET record in the source-table. See http://www.epncb.oma.be:80/stations/log/skl/brus.skl for an example of a public RINEX header skeleton file for EPN station Brussels. Note that the download of RINEX skeleton files from HTTPS websites requires the exchange of client and/or server certificates. Clarify ‘SSL’ options offered through panel ‘Network’ for details.

Sometimes public RINEX header skeleton files are not available, their content is not up to date, or you need to put additional/optional records in the RINEX header. For that, BNC allows using personal skeleton files that contain the header records you would like to include. You can derive a personal RINEX header skeleton file from the information given in an up to date sitelog. A file in the RINEX Observations 'Directory' with a 'Skeleton extension' suffix is interpreted by BNC as a personal RINEX header skeleton file for the corresponding stream.

When producing RINEX Observation files from mountpoints (examples) 'BRUS0', 'FRANKFURT', and 'WETTZELL', the following skeleton filenames would be accepted:

```
brus.skl
fran.skl
wett.skl
```

if 'Skeleton extension' is set to 'skl'.

Note the following regulations regarding personal RINEX header skeleton files:

- If such a file exists in the 'RINEX directory', the corresponding public RINEX header skeleton file is ignored. The RINEX header is generated solely from the content of the personal skeleton.
- Personal skeletons should contain a complete first header record of type:

```
RINEX VERSION / TYPE
```

They should then contain an empty header record of type:

```
PGM / RUN BY / DATE
```

BNC will complete this line and include it in the RINEX file header.

- They should further contain complete header records of type:

```
MARKER NAME
OBSERVER / AGENCY
REC # / TYPE / VERS
ANT # / TYPE
APPROX POSITION XYZ
ANTENNA: DELTA H/E/N
WAVELENGTH FACT L1/2 (RINEX Version 2)
SYS / # / OBS TYPES (for RINEX Version 3 files, will be ignored in Version 2 files)
```

- They may contain any other optional complete header record as defined in the RINEX documentation.
- They should also contain an empty header record of type:

```
#/ TYPES OF OBSERV (only RINEX Version 2, will be ignored when in Version 3
→  files)
```

- BNC will include these lines in the final RINEX file header together with an additional

```
COMMENT
```

  line describing the source of the stream.

- They should finally contain an empty last header record of type:

```
END OF HEADER
```

- They must not contain a header record of type:

```
TIME OF FIRST OBS
```

If neither a public nor a personal RINEX header skeleton file is available for BNC, a default header will be used. The following is a skeleton example for a RINEX file:

```
                    OBSERVATION DATA    M (MIXED)           RINEX VERSION / TYPE
                                                            PGM / RUN BY / DATE
CUT0                                                        MARKER NAME
```

```
59945M001                                                   MARKER NUMBER
5023K67889          TRIMBLE NETR9       5.01                REC # / TYPE / VERS
4928353386          TRM59800.00     SCIS                    ANT # / TYPE
 -2364337.2699  4870285.5624 -3360809.8398                  APPROX POSITION XYZ
        0.0000        0.0000        0.0000                  ANTENNA: DELTA H/E/N
gnss@curtin.edu.au  CUT                                     OBSERVER / AGENCY
C   10 C1I L1I D1I S1I C6I L6I S6I C7I L7I S7I              SYS / # / OBS TYPES
E   13 C1X L1X D1X S1X C5X L5X S5X C7X L7X S7X C8X L8X S8X  SYS / # / OBS TYPES
G   13 C1C L1C D1C S1C C2W L2W S2W C2X L2X S2X C5X L5X S5X  SYS / # / OBS TYPES
J   19 C1C L1C D1C S1C C1X L1X S1X C1Z L1Z S1Z C2X L2X S2X  SYS / # / OBS TYPES
       C5X L5X S5X C6L L6L S6L                              SYS / # / OBS TYPES
R   13 C1C L1C D1C S1C C1P L1P S1P C2C L2C S2C C2P L2P S2P  SYS / # / OBS TYPES
S    7 C1C L1C D1C S1C C5I L5I S5I                          SYS / # / OBS TYPES
PORTIONS OF THIS HEADER GENERATED BY THE IGS CB FROM        COMMENT
SITELOG cut0_20150507.log                                   COMMENT
                                                            END OF HEADER
```

5.4.6 Skeleton Mandatory - optional

Tick check box 'Skeleton mandatory' in case you want that RINEX files are only produced when skeleton files are available for BNC. If no skeleton file is available for a particular source, then no RINEX observation file will be produced from the affected stream.

Note that a skeleton file contains RINEX header information such as receiver and antenna types. In case of stream conversion to RINEX Version 3, a skeleton file should also contain information on potentially available observation types. A missing skeleton file will force BNC to only save a default set of RINEX 3 observation types.

5.4.7 Script - optional

Whenever a RINEX Observation file is saved, you might want to compress, copy or upload it immediately via FTP. BNC allows you to execute a script/batch file to carry out these operations. To do that, specify the full path to such script/batch file. BNC will pass the RINEX Observation file path to the script as a command line parameter (%1 on Windows systems, $1 on Unix/Linux/Mac OS X systems).

The triggering event for calling the script or batch file is the end of a RINEX Observation file 'Interval'. If that is overridden by a stream outage, the triggering event is the stream reconnection.

As an alternative to initiating file uploads through BNC, you may like to call an upload script or batch file through your crontable or Task Scheduler (independent from BNC) once every one or two minutes after the end of each RINEX file 'Interval'.

5.4.8 Version 2 - optional

GNSS observation data are generally hold available within BNC according to attributes as defined in RINEX Version 3. These attributes describe the tracking mode or channel when generating the observation signals. Capital letters specifying signal generation attributes are A, B, C, D, I, L, M, N, P, Q, S, W, X, Y, and Z, see RINEX Version 3 documentation. Although RINEX Version 3 with its signal generation attributes is the internal default processing format for BNC, there are two applications where the program is explicitly required to produce data files in RINEX Version 2 format:

1. When saving the content of incoming observation streams in RINEX Version 2 files as described in this section.
2. When editing or concatenating RINEX 3 files to save them in Version 2 format, see section on 'RINEX Editing & QC'.

As the Version 2 format ignores signal generation attributes, BNC is forced to somehow map RINEX Version 3 to RINEX Version 2 although this cannot be done in one-to-one correspondence. Hence we introduce a 'Signal priority' list of attributes (characters, forming a string) for mapping Version 3 to Version 2.

Signal priorities can be specified as equal for all systems, as system specific or as system and frequency specific. For example:

- 'CWPX_?' (General signal priorities valid for all GNSS)
- 'C:IQX I:ABCX' (System specific signal priorities for BDS and IRNSS)
- 'G:12&PWCSLXYN G:5&IQX R:12&PC R:3&IQX' (System and frequency specific signal priorities)

The default 'Signal priority' list is defined as follows:

'G:12&PWCSLXYN G:5&IQX R:12&PC R:3&IQX E:16&BCX E:578&IQX J:1&SLXCZ J:26&SLX J:5&IQX C:IQX I:ABCX S:1&C S:5&IQX'

As an example the 'Signal priority' of 'CWPX_?' is explained in more detail:

- Signals with attribute 'C' enjoy the highest priority. If such a Version 3 observation becomes available, it is presented as RINEX Version 2 observation if that is the format you wish to see. Observations with other attributes are being ignored.
- If no signal with 'C' attribute is available but we have an observation with 'W' attribute, BNC presents that one as RINEX Version 2 observation and ignores all observations with other attributes. The same applies mutatis mutandis to observations with P and X attributes.
- If no signal with 'C', 'W', 'P', or 'X' attribute is available but a signal with undefined generation attribute (underscore character, '_') exists, BNC presents that one as RINEX Version 2 observation. Note that observation attributes should actually always be available in RINEX Version 3. Hence the underscore character makes only sense in a few very special cases.
- If no signal with 'C', 'W', 'P', 'X', or '_' generation attribute exists then the question mark '?' tells BNC to present the first of any other appearing signal as RINEX Version 2 observation.

You may like to specify your own 'Signal priority' string(s) for producing RINEX Version 2 files. If you neither convert observation streams to RINEX Version 2 nor concatenate RINEX Version 3 to Version 2 files, then the 'Version 2' option is meaningless.

5.4.9 Version 3 - optional

The default format for RINEX Observation files is RINEX Version 2.11. Select RINEX 'Version 3' if you would like to save RTCM Version 3 observation streams in RINEX Version 3.03 format. Note that it is possible to force an RTCM Version 2 stream to be saved in RINEX Version 3 file format. However, this is not recommended because such stream cannot be precisely mapped to RINEX Version 3 as the required information on tracking modes (observation attributes) is not part of RTCM Version 2.

5.4.10 Version 3 Filenames - optional

Tick check box 'Version 3 filenames' to let BNC create so-called extended filenames following the RINEX Version 3 standard. Default is an empty check box, meaning to still use filenames following the RINEX Version 2 standard although the file content is saved in RINEX Version 3 format.

5.5 RINEX Ephemeris

Broadcast Ephemeris can be saved in RINEX Navigation files when received e.g. via RTCM Version 3 message types 1019 (GPS) or 1020 (GLONASS) or 1044 (QZSS) or 1043 (SBAS) or 1045 and 1046 (Galileo) or 63 (BDS/BeiDou, tentative message number). The filename convention follows the details given in section 'RINEX Filenames' except that the first four characters are 'BRDC'. For RINEX Version 2 Navigation files the last character is 'N' or 'G' for GPS or GLONASS ephemeris in two separate files. Regarding RINEX Version 3 you will find all ephemeris data for GPS, GLONASS, Galileo, SBAS, QZSS, and BDS gathered in one Navigation file.

The following is an example for a RINEX Version 3 Navigation filename. The file contains one day's data. 'MN' stands for 'Multi Constellation Navigation' data.

```
BRDC00DEU_S_20121600000_01D_MN.rnx
```

Note that streams dedicated to carry Broadcast Ephemeris messages in RTCM Version 3 format in high repetition rates are listed on http://igs.bkg.bund.de/ntrip/ephemeris. Note further that BNC will ignore incorrect or outdated Broadcast Ephemeris data when necessary, leaving a note 'WRONG EPHEMERIS' or 'OUTDATED EPHEMERIS' in the logfile.

5.5.1 Directory - optional

Specify a path for saving Broadcast Ephemeris data in RINEX Navigation files. If the specified directory does not exist, BNC will not create RINEX Navigation files. Default value for Ephemeris 'Directory' is an empty option field, meaning that no RINEX Navigation files will be created.

5.5.2 Interval - mandatory if 'Directory' is set

Select the length of RINEX Navigation files. The default value is '1 day'.

5.5.3 Port - optional

BNC can output Broadcast Ephemeris in RINEX Version 3 format on your local host (IP 127.0.0.1) through an IP 'Port'. Specify an IP port number to activate this function. The default is an empty option field, meaning that no ASCII ephemeris output via IP port is generated.

The source code for BNC comes with an example Perl script `test_tcpip_client.pl` that allows you to read BNC's ephemeris ASCII output from the IP port.

5.5.4 Version - optional

Default format for RINEX Navigation files containing Broadcast Ephemeris is RINEX Version 2.11. Select 'Version 3' if you want to save the ephemeris data in RINEX Version 3.03 format. Note that this does not concern the Broadcast Ephemeris output through IP port, which is always in RINEX Version 3.03 format.

5.5.5 Version 3 Filenames - optional

Tick check box 'Version 3 filenames' to let BNC create so-called extended filenames following the RINEX Version 3 standard. Default is an empty check box, meaning to still use filenames following the RINEX Version 2 standard although the file content is saved in RINEX Version 3 format (Fig. 5.4).

5.6 RINEX Editing & QC

Besides stream conversion from RTCM to RINEX, BNC allows editing RINEX files or concatenate their content. RINEX Observation and Navigation files can be handled. BNC can also carry out a RINEX file Quality Check. In summary and besides Stream **T**ranslation, this functionality in BNC covers

- File **E**diting and concatenation
- File **Q**uality **C**heck
  - Multipath analysis sky plots
  - Signal-to-noise ratio sky plots
  - Satellite availability plots
  - Satellite elevation plots

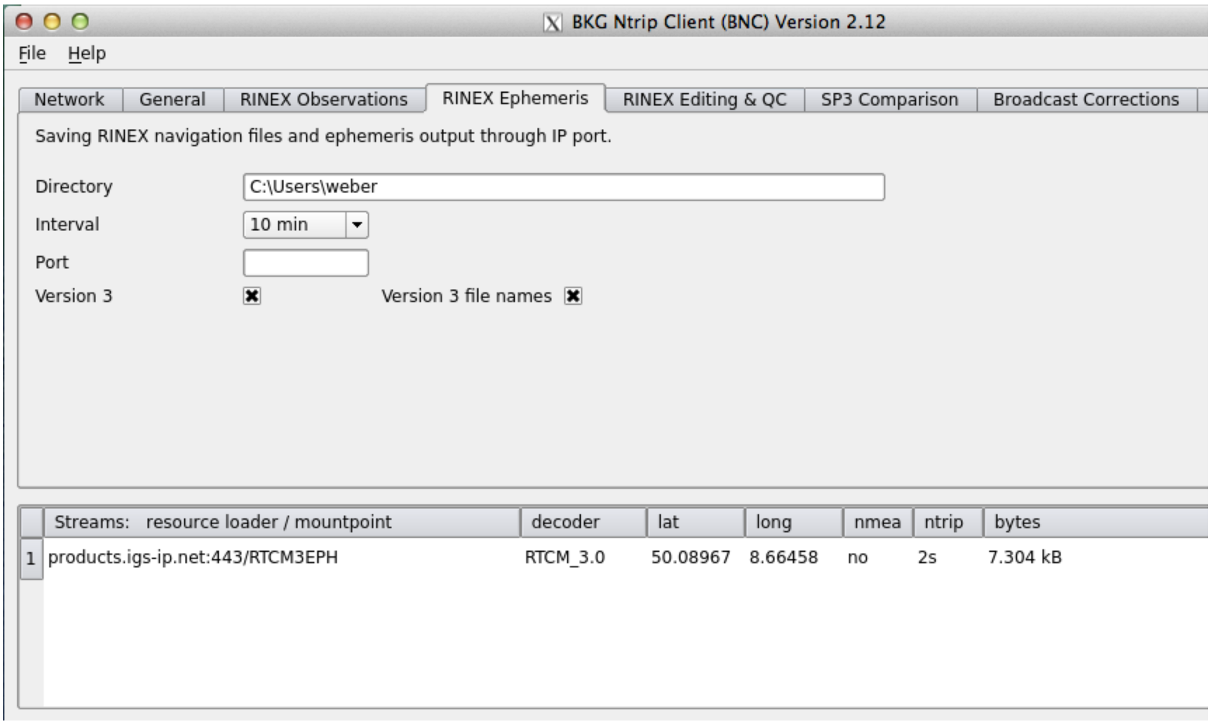


Fig. 5.4: BNC converting Broadcast Ephemeris stream to RINEX Version 3 Navigation files

- PDOP plots

and hence follows UNAVCO's famous teqc program (see *[7]*). The remarkable thing about BNC in this context is that it supports RINEX Version 3 under GNU General Public License with full GUI support and graphics output.

5.6.1 Action - optional

Select an action. Options are 'Edit/Concatenate' and 'Analyze'.

- Select 'Edit/Concatenate' if you want to edit RINEX file content according to options specified under 'Set Edit Options' or if you want to concatenate several RINEX files.
- Select 'Analyze' if you are interested in a quality check of your RINEX file content.

5.6.2 Input Files - mandatory

Specify full path to input RINEX Observation file(s), and specify full path to input RINEX Navigation file(s). When specifying several input files, BNC will concatenate their contents. In case of RINEX Observation input files with different observation type header records, BNC will output only one set of adjusted observation type records in the RINEX header which fits to the whole file content. Note that you may specify several RINEX Version 2 Navigation files for GPS and GLONASS.

5.6.3 Output Files - optional if 'Action' is set to 'Edit/Concatenate'

If 'Edit/Concatenate' is selected, specifying the full path to output RINEX Observation file(s) and specifying the full path to output RINEX Navigation file(s) is optional. Default are empty option fields, meaning that no RINEX files will be saved on disk.

5.6.4 Logfile - optional

Specify the name of a logfile to save information on RINEX file Editing/Concatenation or Analysis. Default is an empty option field, meaning that no logfile will be saved. Note that logfiles from analyzing RINEX files may become quite large. Hence, BNC provides an option 'Summary only' to limit logfile content to some essential information in case 'Action' is set to 'Analyze'. The following is an example for a RINEX quality check analysis logfile:

```
QC Format Version  : 1.1

Navigation File(s) : BRDC2520.15P
Ephemeris          : 2985 OK   0 BAD

Observation File   : CUT02520.15O
RINEX Version      : 3.03
Marker Name        : CUT0
Marker Number      : 59945M001
Receiver           : TRIMBLE NETR9
Antenna            : TRM59800.00     SCIS
Position XYZ       :  -2364337.2699   4870285.5624  -3360809.8398
Antenna dH/dE/dN   :   0.0000   0.0000   0.0000
Start Time         : 2015-09-09 13.04.50.0
End Time           : 2015-09-09 23.59.58.0
Interval           : 1
Navigation Systems : 6    C E G J R S
Observation Types C: C2I L2I D2I S2I C6I L6I S6I C7I L7I S7I
Observation Types E: C1X L1X D1X S1X C5X L5X S5X C7X L7X S7X C8X L8X S8X
Observation Types G: C1C L1C D1C S1C C2W L2W S2W C2X L2X S2X C5X L5X S5X
Observation Types J: C1C L1C D1C S1C C1X L1X S1X C1Z L1Z S1Z C2X L2X S2X C5X L5X
 ↪  S5X C6L L6L S6L
Observation Types R: C1C L1C D1C S1C C1P L1P S1P C2C L2C S2C C2P L2P S2P
Observation Types S: C1C L1C D1C S1C C5I L5I S5I

  C: Satellites: 13
  C: Signals   : 3    2I 6I 7I

      C:   2I: Observations      : 396567 (  511017)    77.60 %
      C:   2I: Slips (file+found):        0 +       0
      C:   2I: Gaps              :     8676
      C:   2I: Mean SNR          :     41.7
      C:   2I: Mean Multipath    :     0.42

      C:   6I: Observations      : 396233 (  511017)    77.54 %
      C:   6I: Slips (file+found):        0 +       0
      C:   6I: Gaps              :     8761
      C:   6I: Mean SNR          :     44.4
      C:   6I: Mean Multipath    :     0.00

      C:   7I: Observations      : 396233 (  511017)    77.54 %
      C:   7I: Slips (file+found):        0 +       0
      C:   7I: Gaps              :     8761
      C:   7I: Mean SNR          :     43.6
      C:   7I: Mean Multipath    :     0.30

  E: Satellites: 5
  E: Signals   : 4    1X 5X 7X 8X

      E:   1X: Observations      :  74468 (  196545)    37.89 %
      E:   1X: Slips (file+found):        0 +       2
      E:   1X: Gaps              :     2758
      E:   1X: Mean SNR          :     45.1
      E:   1X: Mean Multipath    :     0.37
```

```
    E:   5X: Observations      :  74422 (  196545)    37.87 %
    E:   5X: Slips (file+found):        0 +       2
    E:   5X: Gaps              :     2785
    E:   5X: Mean SNR          :     45.2
    E:   5X: Mean Multipath    :     0.32

    E:   7X: Observations      :  74422 (  196545)    37.87 %
    E:   7X: Slips (file+found):        0 +       0
    E:   7X: Gaps              :     2785
    E:   7X: Mean SNR          :     44.2
    E:   7X: Mean Multipath    :     0.00

    E:   8X: Observations      :  74429 (  196545)    37.87 %
    E:   8X: Slips (file+found):        0 +       0
    E:   8X: Gaps              :     2784
    E:   8X: Mean SNR          :     49.9
    E:   8X: Mean Multipath    :     0.00

G: Satellites: 28
G: Signals   : 4    1C 2W 2X 5X

    G:   1C: Observations      : 439952 ( 1100652)    39.97 %
    G:   1C: Slips (file+found):        0 +      21
    G:   1C: Gaps              :    10901
    G:   1C: Mean SNR          :     44.0
    G:   1C: Mean Multipath    :     0.63

    G:   2W: Observations      : 422560 ( 1100652)    38.39 %
    G:   2W: Slips (file+found):        0 +      19
    G:   2W: Gaps              :    11133
    G:   2W: Mean SNR          :     31.1
    G:   2W: Mean Multipath    :     0.42

    G:   2X: Observations      : 205305 ( 1100652)    18.65 %
    G:   2X: Slips (file+found):        0 +      10
    G:   2X: Gaps              :     7269
    G:   2X: Mean SNR          :     43.3
    G:   2X: Mean Multipath    :     0.47

    G:   5X: Observations      : 120638 ( 1100652)    10.96 %
    G:   5X: Slips (file+found):        0 +       0
    G:   5X: Gaps              :     3330
    G:   5X: Mean SNR          :     49.9
    G:   5X: Mean Multipath    :     0.00

J: Satellites: 1
J: Signals   : 6    1C 1X 1Z 2X 5X 6L

    J:   1C: Observations      :  38040 (   39309)    96.77 %
    J:   1C: Slips (file+found):        0 +       0
    J:   1C: Gaps              :     1003
    J:   1C: Mean SNR          :     49.0
    J:   1C: Mean Multipath    :     0.33

    J:   1X: Observations      :  38040 (   39309)    96.77 %
    J:   1X: Slips (file+found):        0 +       0
    J:   1X: Gaps              :     1003
    J:   1X: Mean SNR          :     51.5
    J:   1X: Mean Multipath    :     0.32

    J:   1Z: Observations      :  38040 (   39309)    96.77 %
    J:   1Z: Slips (file+found):        0 +       0
    J:   1Z: Gaps              :     1003
```

```
    J:   1Z: Mean SNR          :     48.4
    J:   1Z: Mean Multipath    :     0.40

    J:   2X: Observations      :  38040 (   39309)    96.77 %
    J:   2X: Slips (file+found):        0 +       0
    J:   2X: Gaps              :     1003
    J:   2X: Mean SNR          :     48.7
    J:   2X: Mean Multipath    :     0.31

    J:   5X: Observations      :  38040 (   39309)    96.77 %
    J:   5X: Slips (file+found):        0 +       0
    J:   5X: Gaps              :     1003
    J:   5X: Mean SNR          :     53.0
    J:   5X: Mean Multipath    :     0.00

    J:   6L: Observations      :  38040 (   39309)    96.77 %
    J:   6L: Slips (file+found):        0 +       0
    J:   6L: Gaps              :     1003
    J:   6L: Mean SNR          :     50.6
    J:   6L: Mean Multipath    :     0.00

R: Satellites: 23
R: Signals   : 4    1C 1P 2C 2P

    R:   1C: Observations      : 323918 (  904107)    35.83 %
    R:   1C: Slips (file+found):        0 +      44
    R:   1C: Gaps              :     7295
    R:   1C: Mean SNR          :     44.9
    R:   1C: Mean Multipath    :     0.77

    R:   1P: Observations      : 323761 (  904107)    35.81 %
    R:   1P: Slips (file+found):        0 +      44
    R:   1P: Gaps              :     7305
    R:   1P: Mean SNR          :     43.4
    R:   1P: Mean Multipath    :     0.58

    R:   2C: Observations      : 323521 (  904107)    35.78 %
    R:   2C: Slips (file+found):        0 +      44
    R:   2C: Gaps              :     7305
    R:   2C: Mean SNR          :     40.8
    R:   2C: Mean Multipath    :     0.56

    R:   2P: Observations      : 321751 (  904107)    35.59 %
    R:   2P: Slips (file+found):        0 +      37
    R:   2P: Gaps              :     7317
    R:   2P: Mean SNR          :     40.3
    R:   2P: Mean Multipath    :     0.49

S: Satellites: 4
S: Signals   : 2    1C 5I

    S:   1C: Observations      : 152158 (  157236)    96.77 %
    S:   1C: Slips (file+found):        0 +       1
    S:   1C: Gaps              :     4013
    S:   1C: Mean SNR          :     40.4
    S:   1C: Mean Multipath    :     0.75

    S:   5I: Observations      :  76078 (  157236)    48.38 %
    S:   5I: Slips (file+found):        0 +       1
    S:   5I: Gaps              :     2007
    S:   5I: Mean SNR          :     44.1
    S:   5I: Mean Multipath    :     0.47
```

```
> 2015 09 09 13 04 50.0000000 23  1.2
R09   1.46   36.90   8  L1C s. 34.3  C1C  . 0.00  L1P s. 33.2  C1P  . 0.00  L2C s.
 ↪  26.4  C2C  . 0.00  L2P s. 22.1  C2P  . 0.00
R10  49.67   46.84   8  L1C .. 52.3  C1C  . 0.62  L1P .. 51.2  C1P  . 0.52  L2C ..
 ↪  42.9  C2C  . 0.51  L2P .. 42.4  C2P  . 0.40
R11  68.25 -168.71   8  L1C .. 52.1  C1C  . 0.32  L1P .. 50.2  C1P  . 0.38  L2C ..
 ↪  44.6  C2C  . 0.40  L2P .. 43.4  C2P  . 0.36
R12  15.62 -148.75   8  L1C .. 40.6  C1C  . 0.94  L1P .. 38.9  C1P  . 0.51  L2C ..
 ↪  41.1  C2C  . 0.61  L2P .. 40.7  C2P  . 0.45
R20  26.26  150.44   8  L1C .. 40.2  C1C  . 0.90  L1P .. 38.8  C1P  . 0.63  L2C ..
 ↪  44.8  C2C  . 0.57  L2P .. 44.4  C2P  . 0.46
R21  71.53 -163.80   8  L1C .. 53.3  C1C  . 0.32  L1P .. 51.6  C1P  . 0.40  L2C ..
 ↪  50.3  C2C  . 0.43  L2P .. 49.3  C2P  . 0.39
R22  40.38  -54.63   8  L1C .. 50.0  C1C  . 0.44  L1P .. 48.7  C1P  . 0.46  L2C ..
 ↪  47.1  C2C  . 0.49  L2P .. 46.7  C2P  . 0.44
E11  68.80  -54.74   8  L1X .. 49.9  C1X  . 0.22  L5X .. 49.8  C5X  . 0.19  L7X ..
 ↪  49.1  C7X  . 0.00  L8X .. 55.3  C8X  . 0.00
E12  58.84  141.76   8  L1X .. 50.0  C1X  . 0.14  L5X .. 49.4  C5X  . 0.21  L7X ..
 ↪  48.2  C7X  . 0.00  L8X .. 55.1  C8X  . 0.00
E18   0.00    0.00   8  L1X .. 53.5  C1X  . 0.11  L5X .. 51.0  C5X  . 0.15  L7X ..
 ↪  50.1  C7X  . 0.00  L8X .. 56.5  C8X  . 0.00
J01  21.34   23.40  12  L1C .. 41.2  C1C  . 0.59  L1X .. 43.2  C1X  . 0.38  L1Z ..
 ↪  41.3  C1Z  . 0.58  L2X .. 40.0  C2X  . 0.47  L5X .. 44.7  C5X  . 0.00  L6L ..
 ↪  41.6  C6L  . 0.00
S27  16.04  -73.53   4  L1C .. 37.8  C1C  . 0.81  L5I .. 39.9  C5I  . 0.41
S28  38.63  -50.63   4  L1C .. 45.5  C1C  . 0.49  L5I .. 47.4  C5I  . 0.48
S29  41.28   46.44   2  L1C .. 43.2  C1C  . 0.00
S37  41.28   46.44   2  L1C .. 42.1  C1C  . 0.00
C01  45.38   41.07   6  L2I .. 42.1  C2I  . 0.20  L6I .. 45.1  C6I  . 0.00  L7I ..
 ↪  46.0  C7I  . 0.22
C02  36.53  -53.83   6  L2I .. 37.1  C2I  . 0.31  L6I .. 42.6  C6I  . 0.00  L7I ..
 ↪  41.3  C7I  . 0.24
C03  53.80  -10.40   6  L2I .. 42.8  C2I  . 0.19  L6I .. 47.3  C6I  . 0.00  L7I ..
 ↪  46.0  C7I  . 0.21
C04  30.52   62.20   6  L2I .. 37.3  C2I  . 0.33  L6I .. 42.4  C6I  . 0.00  L7I ..
 ↪  41.3  C7I  . 0.25
C05  19.48  -71.66   6  L2I .. 36.6  C2I  . 0.40  L6I .. 40.0  C6I  . 0.00  L7I ..
 ↪  38.5  C7I  . 0.37
C07  63.30   26.64   6  L2I .. 48.5  C2I  . 0.41  L6I .. 49.3  C6I  . 0.00  L7I ..
 ↪  48.1  C7I  . 0.25
C08  76.83 -113.07   6  L2I .. 48.9  C2I  . 0.22  L6I .. 50.5  C6I  . 0.00  L7I ..
 ↪  48.7  C7I  . 0.24
C10  83.00  -66.65   6  L2I .. 48.8  C2I  . 0.20  L6I .. 50.0  C6I  . 0.00  L7I ..
 ↪  48.1  C7I  . 0.23
> 2015 09 09 13 04 52.0000000 33  0.9
...
```

Note that in addition to cycle slips recorded in the RINEX 'file', cycle slips identified by BNC are reported as 'found'.

5.6.5 Plots for Signals - mandatory if 'Action' is set to 'Analyze'

Multipath and signal-to-noise sky plots as well as plots for satellite availability, elevation and PDOP are produced (Fig. 5.5, 5.6, 5.7) per GNSS system and frequency with the multipath analysis based on CnC observation types (n = band / frequency). The 'Plots for signals' option lets you exactly specify the observation signals to be used for that and also enables the plot production. You can specify the navigation system (C = BDS, E = Galileo, G = GPS, J = QZSS, R = GLONASS, S = SBAS), the frequency, and the tracking mode or channel as defined in RINEX Version 3. Specifications for frequency and tracking mode or channel must be separated by ampersand character '&'. Specifications for each navigation systems must be separated by blank character ' '. The following string is an example for option field 'Plots of signals':

```
C:2&7 E:1&5 G:1&2 J:1&2 R:1&2 S:1&5
```

This default configuration will present:

- BDS plots for L2 and L7,
- Galileo plots for L1 and L5,
- GPS plots for L1 and L2,
- QZSS plots for L1 and L2,
- GLONASS plots for L1 and L2,
- SBAS plots for L1 and L5.

5.6.6 Directory for Plots - optional if 'Action' is set to 'Analyze'

If 'Analyze' (see Fig. 5.10) is selected, specifying the path to a directory where plot files will be saved is optional. Filenames will be composed from the RINEX input filename(s) plus suffix 'PNG' to indicate the plot file format in use. Default is an empty option field, meaning that plots will not be saved on disk.

5.6.7 Set Edit Options - mandatory if 'Action' is set to 'Edit/Concatenate'

Once the 'Edit/Concatenate' action is selected, you have to 'Set Edit Options' (see Fig. 5.8). BNC lets you specify the RINEX version, a signal priority list when mapping RINEX Version 3 to Version 2, the sampling interval, begin and end of file, operator, observation types, comment lines, and marker, antenna, receiver details. Note that some of the specifications for editing and concatenation (see Fig. 5.9) are only meaningful for RINEX Observation files but not for RINEX Navigation files.

A note on converting RINEX Version 3 to RINEX Version 2 and vice versa:

- The RINEX Version 2 format ignores signal generation attributes. Therefore, when converting RINEX Version 3 to Version 2 Observation files, BNC is forced to somehow map signals with attributes to signals without attributes although this cannot be done in one-to-one correspondence. Hence we introduce a 'Version 2 Signal Priority' list of attributes (characters, forming a string) for mapping Version 3 to Version 2, see details in section 'RINEX Observations/Version 2'. The default 'Version 2 Signal Priority' list of observation attributes when mapping RINEX Version 3 to Version 2 is 'CWPX_?'. Signal priorities can be specified either as equal for all systems or system specific. The following are example priority strings:
  - CWPX_? (Same signal priorities valid for all systems)
  - G:CWPX_? R:PCX_? E:CPX_? (Specific signal priorities for GPS, GLONASS and Galileo system)
- When converting RINEX Version 2 to Version 3 Observation files, the tracking mode or channel information in the (last character out of the 3-character) observation code is left blank if unknown. This is a compromise, knowing that it is not in accordance with the RINEX Version 3 documentation.

Optionally you may specify a 'RUN BY' string to be included in the emerging new RINEX file header. Default is an empty option field, meaning the operator's ID is automatically used as 'RUN BY' string.

You can specify a list of observation codes in field 'Use Obs. Types' to limit the output file content to specific observation codes. GNSS system characters in that list are followed by a colon and a 2- or 3-character observation code. A 2-character observation code would mean that all available tracking modes of the affected observation type and frequency will be accepted as part of the RINEX output file. Observation codes are separated by a blank character. Default is an empty option field, meaning that any input observation code will become part of the RINEX output file.

Specifying comment line text to be added to the emerging new RINEX file header is another option. Any introduction of a newline through '\n' in this enforces the beginning of a further comment line. Comment lines will be added to the header immediately after the 'PGM / RUN BY / DATE' record. Default is an empty option field, meaning that no additional comment line will be added to the RINEX header.

If you specify a ‘New’ but no ‘Old’ marker/antenna/receiver name, the corresponding data field in the emerging new RINEX Observation file will be filled accordingly. If you in addition specify an ‘Old’ marker/antenna/receiver name, the corresponding data field in the emerging new RINEX Observation file will only be filled accordingly where ‘Old’ specifications match existing file content.

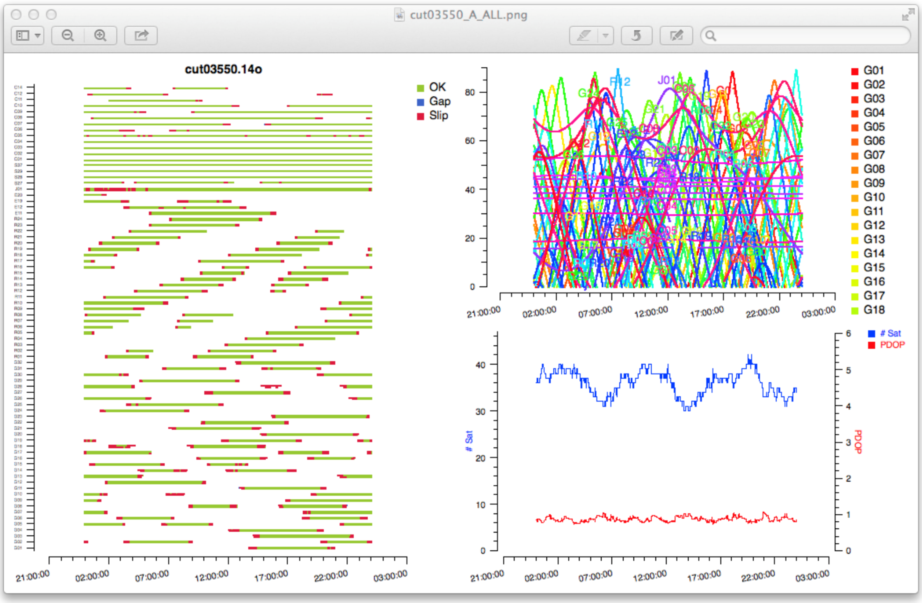


Fig. 5.5: Example for satellite availability, elevation and PDOP plots as a result of a RINEX Quality Check analysis with BNC

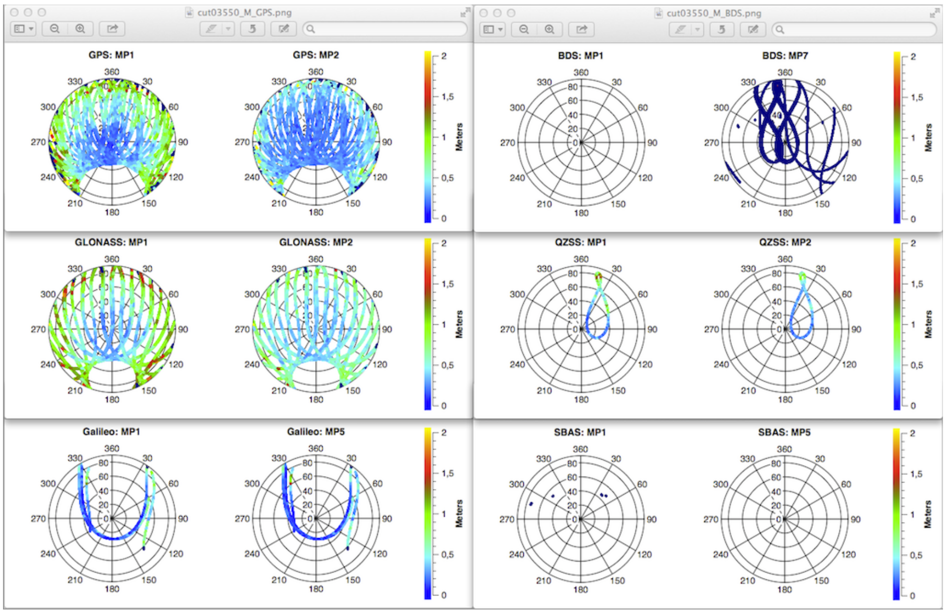


Fig. 5.6: Sky plot examples for multipath, part of RINEX quality check analysis with BNC

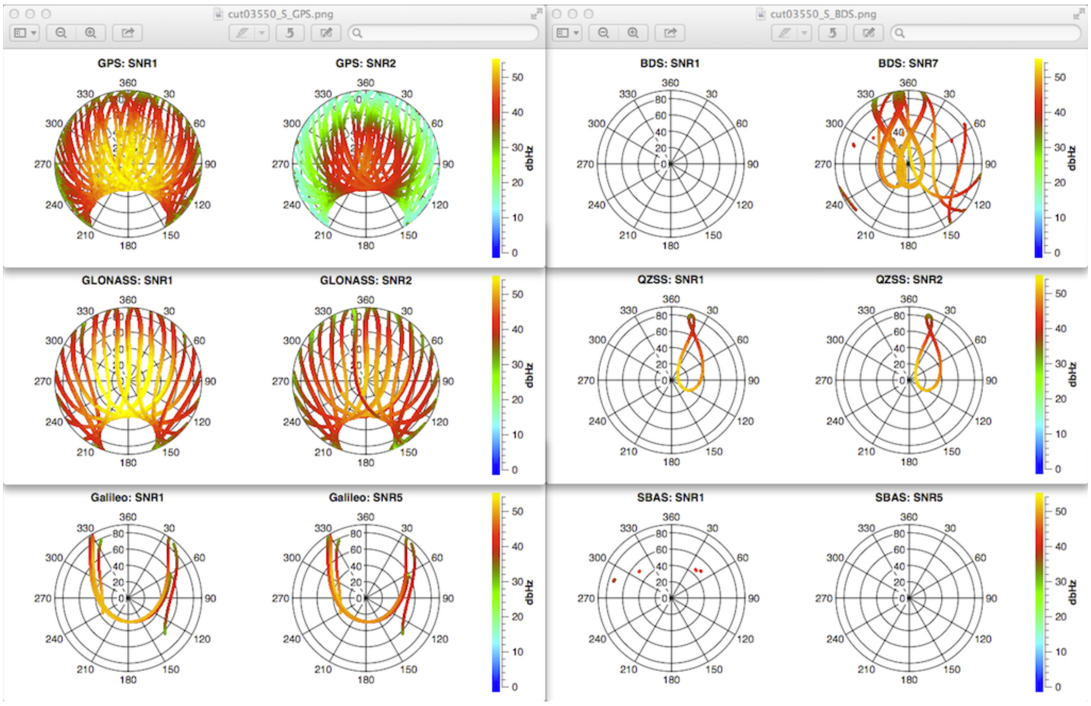


Fig. 5.7: Sky plot examples for signal-to-noise ratio, part of RINEX quality check analysis with BNC

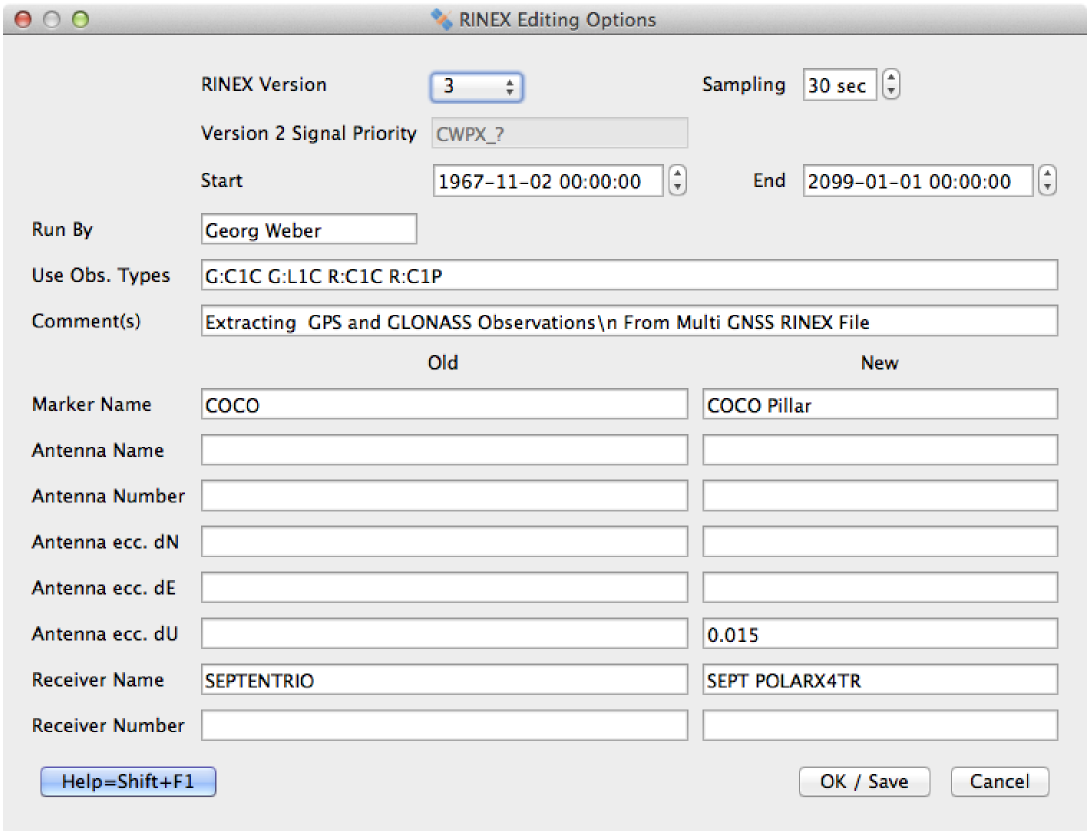


Fig. 5.8: Example for BNC's 'RINEX Editing Options' window

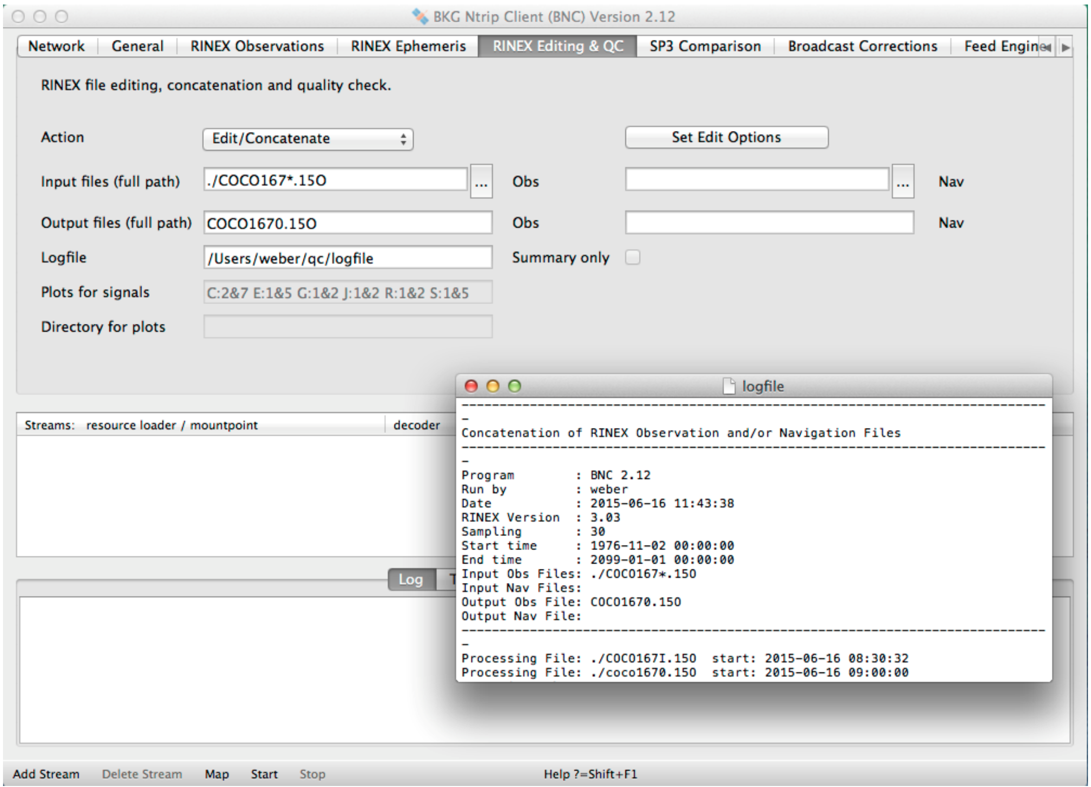


Fig. 5.9: Example for RINEX file concatenation with BNC

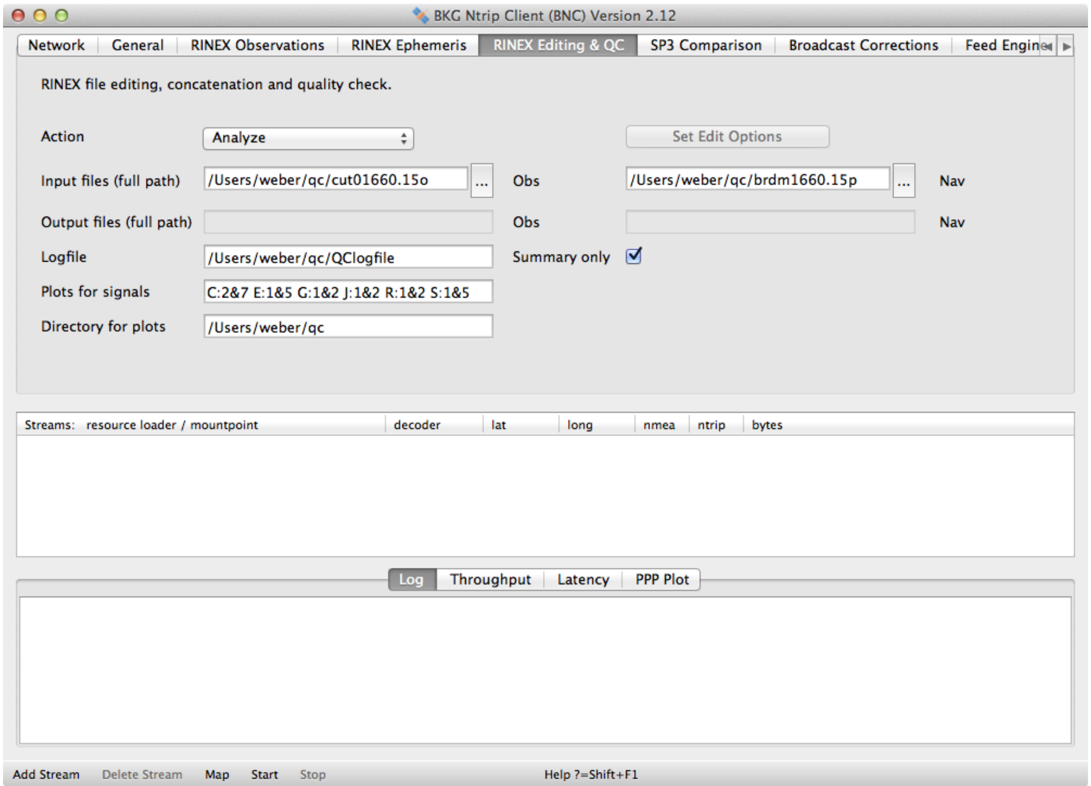


Fig. 5.10: Example for creating RINEX quality check analysis graphics output with BNC

5.6.8 Command Line, No Window - optional

BNC applies options from the configuration file but allows updating every one of them on the command line while the content of the configuration file remains unchanged, see section on 'Command Line Options'. Note the following syntax for Command Line Interface (CLI) options:

```
--key <keyName> <keyValue>
```

Parameter <keyName> stands for the name of an option contained in the configuration file and <keyValue> stands for the value you want to assign to it. This functionality may be helpful in the 'RINEX Editing & QC' context when running BNC on a routine basis for maintaining a RINEX file archive. The following example for a Linux platform calls BNC in 'no window' mode with a local configuration file 'rnx.conf' for concatenating four 15min RINEX files from station TLSE residing in the working directory to produce an hourly RINEX Version 3 file with 30 seconds sampling interval:

```
./bnc --nw --conf rnx.conf --key reqcAction Edit/Concatenate --key reqcObsFile
 ↪  "tlse119b00.12o,tlse119b15.12o,tlse119b30.12o,tlse119b45.12o" --key
 ↪  reqcOutObsFile tlse119b.12o --key reqcRnxVersion 3 --key reqcSampling 30
```

You may use asterisk '*' and/or question mark '?' wildcard characters as shown with the following globbing command line option to specify a selection of files in the working directory:

```
--key reqcObsFile "tlse*"
```

or

```
--key reqcObsFile tlse\*
```

The following Linux command line produces RINEX QC plots (see Estey and Meertens 1999) offline in 'no window' mode and saves them in directory `/home/user`. Introducing a dummy configuration file `/dev/null` makes sure that no configuration options previously saved on disc are used:

```
/home/user/bnc --conf /dev/null --key reqcAction Analyze --key reqcObsFile
 ↪  CUT02070.12O --key reqcNavFile BRDC2070.12P --key reqcOutLogFile CUT0.txt --key
 ↪  reqcPlotDir /home/user --nw
```

The following Linux command line produces the same RINEX QC plots in interactive autoStart mode:

```
/home/user/bnc --conf /dev/null --key reqcAction Analyze --key reqcObsFile
 ↪  CUT02070.12O --key reqcNavFile BRDC2070.12P --key reqcOutLogFile CUT0.txt --key
 ↪  startTab 4 --key autoStart 2
```

Table 5.2 gives a list of available key names for 'RINEX Editing & QC' (short: REQC, pronounced 'rek') options and their meaning, cf. section 'Configuration Examples'.

Table 5.2: Key names for 'RINEX Editing & QC' options and their meaning.

Keyname	Meaning
reqcAction	RINEX Editing & QC action
reqcObsFile	RINEX Observation input file(s)
reqcNavFile	RINEX Navigation input files(s)
reqcOutObsFile	RINEX Observation output file
reqcOutNavFile	RINEX Navigation output file
reqcOutLogFile	Logfile
reqcLogSummaryOnly	Summary of Logfile
reqcSkyPlotSignals	Plots for signals
reqcPlotDir	RINEX QC plot directory
reqcRnxVersion	RINEX version of emerging new file

Continued on next page

Table 5.2 – continued from previous page

Keyname	Meaning
reqcSampling	Sampling interval of emerging new RINEX file
reqcV2Priority	Version 2 Signal Priority
reqcStartDateTime	Begin of emerging new RINEX file
reqcEndDateTime	End of emerging new RINEX file
reqcRunBy	Operator name
reqcUseObsTypes	GNSS systems and observation types
reqcComment	Additional comment lines
reqcOldMarkerName	Old marker name
reqcNewMarkerName	New marker name
reqcOldAntennaName	Old antenna name
reqcNewAntennaName	New antenna name
reqcOldAntennaNumber	Old antenna number
reqcNewAntennaNumber	New antenna number
reqcOldAntennadN	Old component of north eccentricity
reqcOldAntennadE	Old component of east eccentricity
reqcOldAntennadU	Old component of up eccentricity
reqcNewAntennadN	New component of north eccentricity
reqcNewAntennadE	New component of east eccentricity
reqcNewAntennadU	New component of up eccentricity
reqcOldReceiverName	Old receiver name
reqcNewReceiverName	New receiver name
reqcOldReceiverNumber	Old receiver number
reqcNewReceiverNumber	New receiver number

5.7 SP3 Comparison

BNC allows to compare the contents of two files with GNSS orbit and clock data in SP3 format (Fig. 5.11). SP3 ASCII files basically contain a list of records over a certain period of time. Each record carries a time tag, the XYZ position of the satellite's Center of Mass at that time and the corresponding satellite clock value. Both SP3 files may contain some records for different epochs. If so, then BNC only compares records for identical epochs. BNC accepts that a specific GNSS system or a specific satellite is only available from one of the SP3 files. Note that BNC does not interpolate orbits when comparing SP3 files.

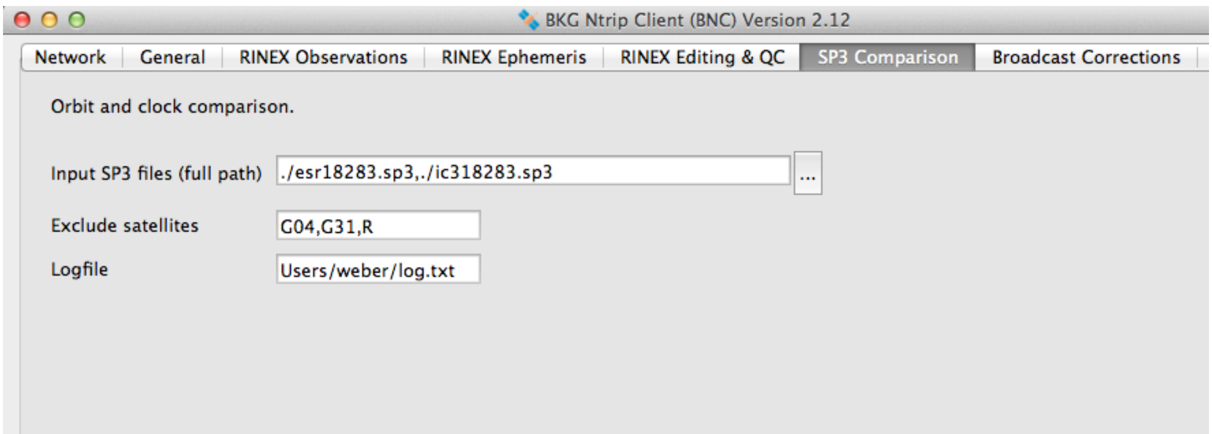


Fig. 5.11: Example for comparing two SP3 files with satellite orbit and clock data using BNC

To compare satellite clocks provided by the two files, BNC first converts coordinate differences dX,dY,dZ into along track, out-of-plane, and radial components. It then corrects the clock differences for the radial components of coordinate differences. RMS values of clock differences are finally calculated after introducing at first one offset 'per epoch for all satellites' and secondly one offset 'per satellite for all epochs'.

5.7.1 Input SP3 Files - optional

Specify the full paths of two SP3 files, separate them by comma.

5.7.2 Exclude Satellites - optional

You may want to exclude one or more satellites in your SP3 files from the comparison. Or you may like to exclude all satellites of a specific GNSS system from the comparison. The following are example strings to be entered for excluding satellites from the comparison:

- G05,G31 (excluding GPS satellites with PRN 5 and 31)
- G (excluding all GPS satellites)
- R (excluding all GLONASS satellites)
- R12,R24 (excluding GLONASS satellites with slot number 12 and 24)
- G04,G31,R (excluding GPS satellites with PRN 4 and 31 as well as all GLONASS satellites)

Default is an empty option field, meaning that no satellite will be excluded from the comparison.

5.7.3 Logfile - mandatory if 'Input SP3 Files' is set

Specify a logfile name to save results of the SP3 file comparison.

The following is an example for a SP3 Comparison logfile:

```
! SP3 File 1: esr18283.sp3
! SP3 File 2: rt218283.sp3
!
!  MJD       PRN  radial   along   out        clk    clkRed   iPRN
! ----------------------------------------------------------------
57043.000000 G01 -0.0001 -0.0318 -0.0354     0.0266  0.0267     1
57043.000000 G02 -0.0062 -0.0198  0.0111     0.0082  0.0143     2
57043.000000 G03  0.0052  0.0060  0.0032     0.0386  0.0334     3
57043.000000 G04 -0.0049 -0.0193 -0.0071    -0.1696 -0.1648     4
57043.000000 G05  0.0027  0.0154  0.0275     0.0345  0.0318     5
57043.000000 G06  0.0247 -0.0398 -0.0111     0.0483  0.0236     6
57043.000000 G07 -0.0052  0.2854 -0.0975    -0.0940 -0.0888     7
57043.000000 G08 -0.0247  0.0937 -0.0184    -0.1563 -0.1316     8
57043.000000 G09  0.0152  0.0583  0.0086    -0.0144 -0.0296     9
...
...
...
!
! RMS[m]
!
!   PRN  radial   along   out     nOrb    clk   clkRed   nClk    Offset
! ---------------------------------------------------------------------
!   G01  0.0151  0.0377  0.0196     96  0.0157  0.0154     96    0.0152
!   G02  0.0083  0.0278  0.0228     96  0.0097  0.0124     96   -0.0626
!   G03  0.0105  0.0311  0.0307     96  0.0352  0.0309     96    0.0898
!   G04  0.0113  0.0334  0.0154     94  0.0725  0.0707     94   -0.5087
!   G05  0.0103  0.0319  0.0299     96  0.0417  0.0403     96    0.1185
!   G06  0.0182  0.0509  0.0302     96  0.0218  0.0166     96    0.0040
!   G07  0.0337  0.1632  0.0463     96  0.0483  0.0435     96    0.3031
!   G08  0.0228  0.0741  0.0321     88  0.0616  0.0561     88   -0.2232
...
```

```
...
...
!   R20  0.0637  0.2115  0.1131     96  0.1580  0.1345     96    0.7371
!   R21  0.0475  0.1657  0.0880     96  0.1123  0.0840     96   -0.4133
!   R22  0.0125  0.1249  0.0646     96  0.0414  0.0444     96   -0.7375
!   R23  0.0435  0.1503  0.0573     96  0.0987  0.1099     96    0.6620
!   R24  0.0278  0.2026  0.1186     96  0.1446  0.1303     96   -1.1470
!
! Total  0.0262  0.0938  0.0492   5268  0.0620  0.0561   5268
```

The first part of this output uses the abbreviations in Table 5.3.

Table 5.3: Abbreviations in first part of BNC log files when comparing SP3 files

Abbreviation	Meaning
MJD	Modified Julian Date
PRN	Satellite specification
radial	Radial component of orbit coordinate difference [m]
along	Along track component of orbit coordinate difference [m]
out	Out-of-plane component of orbit coordinate difference [m]
clk	Clock difference [m]
clkRed	Clock difference reduced by radial component of orbit coordinate difference [m]
iPRN	BNC internal sequence number

The second part following string 'RMS' provides a summary of the comparison using the abbreviations in Table 5.4.

Table 5.4: Abbreviations in second part of BNC log files when comparing SP3 files

Abbreviation	Meaning
PRN	Satellite specification
radial	RMS of radial component of orbit coordinate differences [m]
along	RMS of along track component of orbit coordinate differences [m]
out	RMS of out-of-plane component of orbit coordinate differences [m]
nOrb	Number of epochs used in in orbit comparison
clk	RMS of clock differences [m]
clkRed	RMS of clock differences after reduction of radial orbit differences [m]
nClk	Number of epochs use in clock comparisons
Offset	Clock offset [m]

5.8 Broadcast Corrections

Differential GNSS and RTK operation using RTCM streams is currently based on corrections and/or raw measurements from single or multiple reference stations. This approach to differential positioning uses 'observation space' information. The representation with the RTCM standard can be called 'Observation Space Representation' (OSR).

An alternative to the observation space approach is the so-called 'state space' approach. The principle here is to provide information on individual error sources. It can be called 'State Space Representation' (SSR). For a rover position, state space information concerning precise satellite clocks, orbits, ionosphere, troposphere et cetera can be converted into observation space and used to correct the rover observables for more accurate positioning. Alternatively, the state information can be used directly in the rover's processing or adjustment model.

RTCM is currently developing Version 3 messages to transport SSR corrections in real-time. They refer to satellite Antenna Phase Center (APC). SSR messages adopted or recently proposed concern:

SSR, Step I:

- Orbit corrections to Broadcast Ephemeris

- Clock corrections to Broadcast Ephemeris
- High-rate clock corrections to Broadcast Ephemeris
- Combined orbit and clock corrections to Broadcast Ephemeris
- User Range Accuracy (URA)
- High Rate User Range Accuracy (HR URA)
- Code biases

SSR, Step II:

- Phase biases
- Vertical Total Electron Content (VTEC)

RTCM Version 3 streams carrying these messages may be used e.g. to support real-time Precise Point Positioning (PPP) applications.

When using clocks from Broadcast Ephemeris (with or without applied corrections) or clocks from SP3 files, it may be important to understand that they are not corrected for the conventional periodic relativistic effect. Chapter 10 of the IERS Conventions 2003 mentions that the conventional periodic relativistic correction to the satellite clock (to be added to the broadcast clock) is computed as

$$dt = -2(R * V)/c^2$$

where $R * V$ is the scalar product of the satellite position and velocity and c is the speed of light. This can also be found in the GPS Interface Specification, IS-GPS-200, Revision D, 7 March 2006.

Orbit corrections are provided in along-track, out-of-plane and radial components. These components are defined in the Earth-Centered, Earth-Fixed reference frame of the Broadcast Ephemeris. For an observer in this frame, the along-track component is aligned in both direction and sign with the velocity vector, the out-of-plane component is perpendicular to the plane defined by the satellite position and velocity vectors, and the radial direction is perpendicular to the along track and out-of-plane ones. The three components form a right-handed orthogonal system.

After applying corrections, the satellite position and clock is referred to the 'ionospheric free' phase center of the antenna which is compatible with the broadcast orbit reference.

The orbit and clock corrections do not include local effects like Ocean Loading, Solid Earth Tides or tropospheric delays. However, accurate single frequency applications can be corrected for global ionospheric effects using so-call VTEC messages for global ionospheric state parameters.

While we have a plain ASCII standard for saving Broadcast Ephemeris in RINEX Navigation files, we do not have an equivalent standard for corrections to Broadcast Ephemeris. Hence, BNC saves Broadcast Correction files following its own format definition. The filename convention for Broadcast Correction files follows the convention for RINEX Version 2 files except for the last character of the filename suffix which is set to 'C'.

5.8.1 Broadcast Correction file format

BNC's Broadcast Correction files contain blocks of records in plain ASCII format. Each block covers information about one specific topic and starts with an 'Epoch Record'. The leading 'Epoch Record' of each block in a Broadcast Correction file contains 11 parameters. Example:

```
> ORBIT 2015 06 17 11 43 35.0 2 53 CLK93
```

Their meaning is as follows:

1. Special character '>' is the first character in each 'Epoch Record' (as we have it in RINEX Version 3)
2. SSR message or topic descriptor, valid descriptors are: ORBIT, CLOCK, CODE_BIAS, PHASE_BIAS, and VTEC
3. Year, GPS time

4. Month, GPS time
5. Day, GPS time
6. Hour, GPS time
7. Minute, GPS time
8. Second, GPS time
9. SSR message update interval indicator:

- 0 = 1 sec
- 1 = 2 sec
- 2 = 5 sec
- 3 = 10 sec
- 4 = 15 sec
- 5 = 30 sec
- 6 = 60 sec
- 7 = 120 sec
- 8 = 240 sec
- 9 = 300 sec
- 10 = 600 sec
- 11 = 900 sec
- 12 = 1800 sec
- 13 = 3600 sec
- 14 = 7200 sec
- 15 = 10800 sec

10. Number of following records in this block
11. Mountpoint, source/stream indicator

Each of the following 'satellite records' in such a block carries information for one specific satellite. Undefined parameters in the 'satellite records' could be set to zero '0.000'.

Example for block 'ORBIT' carrying orbit corrections

```
> ORBIT 2015 06 17 11 43 35.0 2 53 CLK93
G01   9     0.5134     0.3692     0.6784        0.0000    -0.0000    -0.0000
G02  25    57.6817   139.0492   -91.3456        0.5436    -0.6931     1.0173
G03  79   -32.1768   191.8368  -121.6540        0.2695     0.2296     0.4879
...
G32  82     1.8174     1.1704     0.2200       -0.0002    -0.0000    -0.0001
R01  59     0.7819    -0.6968     0.7388       -0.0001     0.0004     0.0004
R02  59     0.5816    -0.5800    -0.2004        0.0001    -0.0006     0.0001
R03  59     0.4635    -0.9104    -0.3832        0.0001     0.0001     0.0005
...
R24  59     0.5935     2.0732    -0.6884       -0.0000     0.0004     0.0003
```

Records in this block provide the following satellite specific information:

- GNSS Indicator and Satellite Vehicle Pseudo Random Number
- IOD referring to Broadcast Ephemeris set

- Radial Component of Orbit Correction to Broadcast Ephemeris [m]
- Along-track Component of Orbit Correction to Broadcast Ephemeris [m]
- Out-of-plane Component of Orbit Correction to Broadcast Ephemeris [m]
- Velocity of Radial Component of Orbit Correction to Broadcast Ephemeris [m/s]
- Velocity of Along-track Component of Orbit Correction to Broadcast Ephemeris [m/s]
- Velocity of Out-of-plane Component of Orbit Correction to Broadcast Ephemeris [m/s]

Example for block 'CLOCK' carrying clock corrections

```
> CLOCK 2015 06 17 11 43 35.0 2 53 CLK93
G01   9      0.5412      0.0000      0.0000
G02  25     11.1811      0.0000      0.0000
G03  79     45.0228      0.0000      0.0000
...
G32  82     -1.5324      0.0000      0.0000
R01  59      4.2194      0.0000      0.0000
R02  59      2.0535      0.0000      0.0000
R03  59      1.8130      0.0000      0.0000
...
R24  59      2.7409      0.0000      0.0000
```

Records in this block provide the following satellite specific information:

- GNSS Indicator and Satellite Vehicle Pseudo Random Number
- IOD referring to Broadcast Ephemeris set
- C0 polynomial coefficient for Clock Correction to Broadcast Ephemeris [m]
- C1 polynomial coefficient for Clock Correction to Broadcast Ephemeris [m/s]
- C2 polynomial coefficient for Clock Correction to Broadcast Ephemeris [m/s**2]

Example for block 'CODE_BIAS' carrying code biases

```
> CODE_BIAS 2015 06 17 11 43 35.0 2 53 CLK93
G01     5   1C    -3.3100   1W    -3.7500   2W    -6.1900   2X    -5.7800   5I
 ↪  -5.4200
G02     5   1C     3.6000   1W     3.9300   2W     6.4800   2X     0.0000   5I
 ↪  0.0000
G03     5   1C    -2.1600   1W    -2.6500   2W    -4.3600   2X    -4.4800   5I
 ↪  -5.3400
...
G32     5   1C    -1.5800   1W    -1.1000   2W    -1.8200   2X     0.0000   5I
 ↪  0.0000
R01     4   1C    -2.4900   1P    -2.4900   2C    -3.1500   2P    -4.1200
R02     4   1C     0.3900   1P     0.2100   2C     0.4000   2P     0.3400
R03     4   1C     2.4800   1P     2.2800   2C     3.7800   2P     3.7700
...
R24     4   1C     2.7000   1P     2.7800   2C     3.9800   2P     4.6000
```

Records in this block provide the following satellite specific information:

- GNSS Indicator and Satellite Vehicle Pseudo Random Number
- Number of Code Biases, succeeded by code specific information:
  - Indicator to specify the signal and tracking mode
  - Code Bias [m]

  - Indicator to specify the signal and tracking mode
  - Code Bias [m]
  - etc.

Example for block 'PHASE_BIAS' carrying phase biases

```
> PHASE_BIAS 2015 06 17 11 43 35.0 2 31 CLK93
 0   1
G01 245.39062500   0.00000000    3   1C     3.9518   1   2   6   2W     6.3177   1
 ↪  2   6   5I     6.8059   1   2   6
G02 250.31250000   0.00000000    3   1C    -4.0900   1   2   5   2W    -6.7044   1
 ↪  2   5   5I     0.0000   1   2   5
G03 281.95312500   0.00000000    3   1C     2.9327   1   2   4   2W     4.6382   1
 ↪  2   4   5I     5.4120   1   2   4
...
G32 290.39062500   0.00000000    3   1C     1.2520   1   2   5   2W     2.0554   1
 ↪  2   5   5I     0.0000   1   2   5
```

The second record in this block provides the following consistency information:

- Dispersive bias consistency indicatory

  0 phase biases valid for non-dispersive signal only

  1 phase biases maintain consistency between non-dispersive and all original dispersive phase signals

- MW consistency indicator

  0 code and phase biases are independently derived

  1 consistency between code and phase biases is maintained for the MW combinations

Following records provide satellite specific information:

- GNSS Indicator and Satellite Vehicle Pseudo Random Number
- Yaw angle [°], restricted to [0°...360°]
- Yaw rate [$°/s$]
- Number of phase biases in this record, succeeded by phase specific information:
  - Signal and tracking mode indicator
  - Phase bias [m]
  - Signal integer indicator
  - Signal wide-lane integer indicator
  - Signal discontinuity counter

Example for block 'VTEC' carrying ionospheric corrections

```
> VTEC 2015 06 17 11 43 35.0 6 1 CLK93
 1  6  6   450000.0
   17.6800     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
    4.5200     8.8700     0.0000     0.0000     0.0000     0.0000     0.0000
   -4.6850    -0.3050     1.1700     0.0000     0.0000     0.0000     0.0000
   -2.2250    -1.3900    -1.0250    -0.1300     0.0000     0.0000     0.0000
    0.8750    -0.3800     0.2700    -0.1300     0.0400     0.0000     0.0000
    1.2150     0.9050    -1.0100     0.3700    -0.1450    -0.2450     0.0000
   -0.8200     0.4850     0.2300    -0.1750     0.3400    -0.0900    -0.0400
    0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
    0.0000    -0.0700     0.0000     0.0000     0.0000     0.0000     0.0000
```

```
    0.0000      0.5800     -1.4150      0.0000      0.0000      0.0000      0.0000
    0.0000     -0.6200     -0.1500      0.2600      0.0000      0.0000      0.0000
    0.0000      0.0700     -0.0900     -0.0550      0.1700      0.0000      0.0000
    0.0000      0.5000      0.3050     -0.5700     -0.5250     -0.2750      0.0000
    0.0000      0.0850     -0.4700      0.0600      0.0700      0.1600      0.0400
```

The second record in this block provides four parameters:

- Layer number
- Maximum degree of spherical harmonics
- Maximum order of spherical harmonics
- Height of ionospheric layer [m]

Subsequent records in this block provide the following information:

- Spherical harmonic coefficients C and S, sorted by degree and order (0 to maximum)

5.8.2 Directory, ASCII - optional

Specify a directory for saving Broadcast Corrections in files. If the specified directory does not exist, BNC will not create Broadcast Correction files. Default value for Broadcast Correction 'Directory' is an empty option field, meaning that no Broadcast Correction files will be created.

5.8.3 Interval - mandatory if 'Directory, ASCII' is set

Select the length of the Broadcast Correction files. The default value is '1 day'.

5.8.4 Port - optional

BNC can output epoch by epoch synchronized Broadcast Corrections in ASCII format on your local host (IP 127.0.0.1) through an IP 'Port'. Specify an IP port number to activate this function. The default is an empty option field, meaning that no Broadcast Correction output via IP port is generated.

The output format is similar to the format used for saving Broadcast Corrections in a file.

The following is an example output for the stream from mountpoint CLK93:

```
> ORBIT 2015 06 19 16 41 00.0 2 53 CLK93
G01  85     0.5891    -0.5124    -0.0216       -0.0001    -0.0002     0.0000
G02  25  -150.1820    11.4676    84.5216        0.4130    -0.6932     1.0159
G03  79    15.1999   141.9932  -156.4244        0.6782    -0.8607    -0.8211
...
G32  39     1.8454     0.4888    -0.3876       -0.0001    -0.0001     0.0001
R01  79    -0.0506     1.9024    -0.0120        0.0004     0.0002    -0.0000
R02  79     0.1623     0.9012     0.3984        0.0001     0.0001     0.0002
R03  79     0.3247    -2.6704    -0.0240        0.0005    -0.0002     0.0002
...
R24  79     0.7046    -0.5088    -0.0160       -0.0000     0.0000    -0.0002
> CLOCK 2015 06 19 16 41 00.0 2 53 CLK93
G01  85  -116.9441     0.0000     0.0000
G02  25  -110.4472     0.0000     0.0000
G03  79   -96.8299     0.0000     0.0000
...
G32  39  -119.2757     0.0000     0.0000
R01  79     1.5703     0.0000     0.0000
R02  79    -1.4181     0.0000     0.0000
R03  79     0.2072     0.0000     0.0000
...
```

```
R24  79     1.1292     0.0000     0.0000
> CODE_BIAS 2015 06 19 16 41 00.0 0 56 CLK93
E11    3   1B     1.3800   5Q     2.4800   7Q     2.5000
E12    3   1B     0.3900   5Q     0.6900   7Q     0.5300
E19    3   1B    -1.7800   5Q    -3.1900   7Q    -3.0700
G01    5   1C    -3.3100   1W    -3.7500   2W    -6.1900   2X    -5.7800   5I
 ↪  -5.4200
G02    5   1C     3.6000   1W     3.9300   2W     6.4800   2X     0.0000   5I
 ↪  0.0000
G03    5   1C    -2.1600   1W    -2.6500   2W    -4.3600   2X    -4.4800   5I
 ↪  -5.3400
...
G32    5   1C    -1.5800   1W    -1.1000   2W    -1.8200   2X     0.0000   5I
 ↪  0.0000
R01    4   1C    -2.4900   1P    -2.4900   2C    -3.1500   2P    -4.1200
R02    4   1C     0.3900   1P     0.2100   2C     0.4000   2P     0.3400
R03    4   1C     2.4800   1P     2.2800   2C     3.7800   2P     3.7700
...
R24    4   1C     2.7000   1P     2.7800   2C     3.9800   2P     4.6000
> PHASE_BIAS 2015 06 19 16 41 00.0 2 31 CLK93
 0   1
G01 309.37500000   0.00000000    3   1C     3.9922   1   2   6   2W     6.3568   1
 ↪  2   6   5I     6.8726   1   2   6
G02 263.67187500   0.00000000    3   1C    -4.0317   1   2   7   2W    -6.6295   1
 ↪  2   7   5I     0.0000   1   2   7
G03 267.89062500   0.00000000    3   1C     3.1267   1   2   4   2W     4.9126   1
 ↪  2   4   5I     5.6478   1   2   4
...
G32 255.93750000   0.00000000    3   1C     1.3194   1   2   5   2W     2.1448   1
 ↪  2   5   5I     0.0000   1   2   5
> VTEC 2015 06 19 16 41 00.0 6 1 CLK93
 1  6  6   450000.0
   16.7450     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
    4.9300     8.1600     0.0000     0.0000     0.0000     0.0000     0.0000
   -4.4900     0.2550     1.0950     0.0000     0.0000     0.0000     0.0000
   -2.2450    -1.9500    -0.7950    -0.4700     0.0000     0.0000     0.0000
    1.0250    -0.9000    -0.0900     0.1050     0.1450     0.0000     0.0000
    1.5500     0.9750    -0.8150     0.3600     0.0350    -0.0900     0.0000
   -0.4050     0.8300     0.0800    -0.0650     0.2200     0.0150    -0.1600
    0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
    0.0000    -0.1250     0.0000     0.0000     0.0000     0.0000     0.0000
    0.0000     1.0050    -0.7750     0.0000     0.0000     0.0000     0.0000
    0.0000    -0.2300     0.7150     0.7550     0.0000     0.0000     0.0000
    0.0000    -0.4100    -0.1250     0.2400     0.2700     0.0000     0.0000
    0.0000     0.0850    -0.3400    -0.0500    -0.2200    -0.0750     0.0000
    0.0000     0.2000    -0.2850    -0.0150    -0.0250     0.0900     0.0650
```

The source code for BNC comes with an example Perl script 'test_tcpip_client.pl' that allows to read BNC's Broadcast Corrections from the IP port for verification.

5.9 Feed Engine

BNC can produce synchronized or unsynchronized observations epoch by epoch from all stations and satellites to feed a real-time GNSS network engine. Observations can be streamed out through an IP port and/or saved in a file. The output is always in the same plain ASCII format and sorted per incoming stream.

Each epoch in the synchronized output begins with a line containing the GPS Week Number and the seconds within the GPS Week. Following lines begin with the mountpoint string of the stream which provides the observations followed by a satellite number. Specifications for satellite number, code, phase, Doppler and signal strength data follow definitions presented in the RINEX Version 3 documentation. In case of phase observations, a 'Lock Time

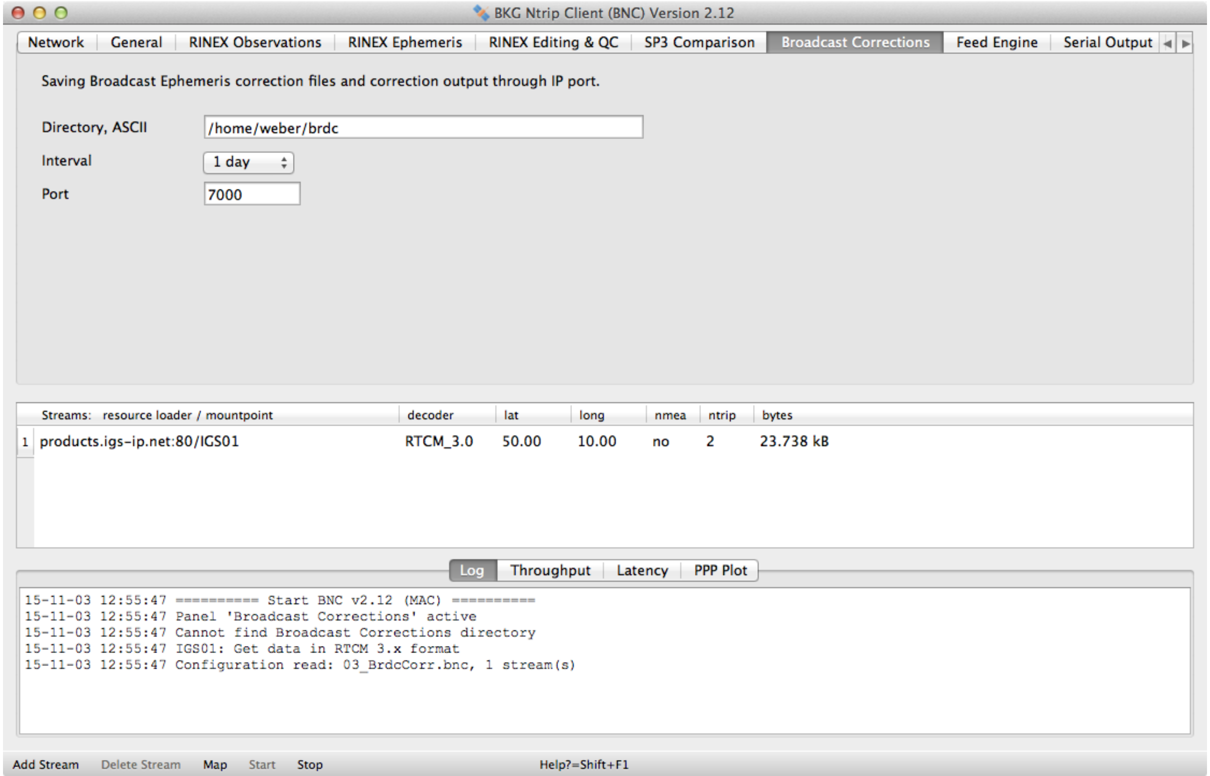


Fig. 5.12: Example for pulling, saving and output of Broadcast Corrections using BNC

Indicator' is added. The end of an epoch is indicated by an empty line.

A valid 'Lock Time Indicator' is only presented for observations from RTCM Version 3 streams. The parameter provides a measure of the amount of time that has elapsed during which the receiver has maintained continuous lock on that satellite signal. If a cycle slip occurs during the previous measurement cycle, the lock indicator will be reset to Zero. In case of observations from RTCM Version 2 streams, the 'Lock Time Indicator' is always set to '-1'.

Table 5.5 describes the format of BNC's synchronized output of GNSS observations which consists of 'Epoch Records' and 'Observation Records'. Each Epoch Record is followed by one or more Observation Records. The Observation Record is repeated for each satellite having been observed in the current epoch. The length of an Observation Record is given by the number of observation types for this satellite.

Table 5.5: Contents and format of synchronized output of observations feeding a GNSS engine

Identifier	Example	Format
Epoch Record		
Record Identifier	>	A1
GPS Week Number	1850	1X,I4
GPS Seconds of Week	120556.0000000	1X,F14.7
Observation Record		
Mountpoint	WTZR0	A
Satellite Number	G01	1X,A3
Pseudo-Range Data		
Observation Code	C1C	1X,A3
Pseudo-Range Observation	25394034.112	1X,F14.3
Carrier Phase Data		
Observation Code	L1C	1X,A3
Carrier Phase Observation	133446552.870	1X,F14.3
Lock Time Indicator	11	1X,I4
Doppler Data		
Observation Code	D1C	1X,A3
Doppler Observation	-87.977	1X,F14.3
Signal Strength		
Observation Code	S2W	1X,A3
Observed Signal Strength	34.750	1X,F8.3

The following is an example for synchronized file and IP port output, which presents observations from GPS, GLONASS, Galileo, BDS (BeiDou), QZSS, and SBAS satellites as collected through streams FFMJ1, WTZR0 and CUT07:

```
> 1884 206010.0000000
FFMJ1 G02 C1C   23286796.846 L1C  122372909.535  127 S1C   49.000 C2W
 ↪  23286793.846 L2W   95355531.583  127 S2W   36.000
...
FFMJ1 G26 C1C   24796690.856 L1C  130307533.550  127 S1C   42.000 C2W
 ↪  24796697.776 L2W  101538315.510  127 S2W   25.000
FFMJ1 S20 C1C   38682850.302 L1C  203279786.777  127 S1C   42.000
FFMJ1 S36 C1C   38288096.846 L1C  201205293.221  127 S1C   47.000
FFMJ1 R03 C1C   23182737.548 L1C  124098947.838  127 S1C   48.000 C2P
 ↪  23182746.288 L2P   96521352.130  127 S2P   42.000
...
FFMJ1 R21 C1C   22201343.772 L1C  118803851.388  127 S1C   52.000 C2P
 ↪  22201348.892 L2P   92402993.884  127 S2P   44.000
CUT07 G01 C1C   25318977.766 L1C  133052476.488  521 D1C       2533.500 S1C
 ↪  33.688 C2W   25318993.668 L2W  103677584.878  521 S2W   15.625 C2X
 ↪  25318991.820 L2X  103676566.850  521 S2X   35.375 C5X   25318993.461 L5X
 ↪  99357161.238  521 S5X   39.812
...
CUT07 G27 C1C   20251005.351 L1C  106420601.969  627 D1C        250.937 S1C
 ↪  50.312 C2W   20251014.512 L2W   82924447.644  627 S2W   45.125 C2X
 ↪  20251014.246 L2X   82924648.644  627 S2X   53.188 C5X   20251015.480 L5X
 ↪  79469461.619  627 S5X   56.375
CUT07 R01 C1C   20312587.149 L1C  108583395.373  625 D1C      -2456.703 S1C
 ↪  52.875 C1P   20312586.192 L1P  108582844.382  625 S1P   51.000 C2C
 ↪  20312593.422 L2C   84452892.610  625 S2C   43.625 C2P   20312593.836 L2P
 ↪  84453114.622  625 S2P   42.312
...
CUT07 R24 C1C   19732223.242 L1C  105517564.659  630 D1C         -7.477 S1C
 ↪  47.375 C1P   19732222.609 L1P  105517564.669  630 S1P   46.375 C2C
 ↪  19732227.660 L2C   82069550.193  630 S2C   38.125 C2P   19732227.316 L2P
 ↪  82068477.204  630 S2P   37.375
...
```

```
CUT07 E11 C1X   28843071.547 L1X  151571208.816  405 D1X      -2221.055 S1X
 ↪  29.000 C7X   28843082.531 L7X  116138795.418  405 S7X   27.188 C8X
 ↪  28843085.699 L8X  114662585.261  405 S8X   33.688 C5X   28843086.281 L5X
 ↪  113186518.907  405 S5X   30.375
...
CUT07 E30 C1X   28096037.289 L1X  147645296.835  630 D1X      -2020.613 S1X
 ↪  34.688 C7X   28096054.070 L7X  113131111.635  630 S7X   36.875 C8X
 ↪  28096055.684 L8X  111692702.565  630 S8X   40.375 C5X   28096058.008 L5X
 ↪  110254591.278  630 S5X   36.188
CUT07 S27 C1C   40038220.843 L1C  210402303.982  616 D1C        104.688 S1C
 ↪  36.125 C5I   40038226.375 L5I  157118241.003  616 S5I   40.875
...
CUT07 S37 C1C   37791754.594 L1C  198596881.251  704 D1C        106.605 S1C
 ↪  37.875
CUT07 J01 C1C   33076065.781 L1C  173816471.106  674 D1C        169.765 S1C
 ↪  48.375 C1Z   33076063.086 L1Z  173815528.437  674 S1Z   48.625 C6L
 ↪  33076065.652 L6L  141084039.422  674 S6L   52.688 C2X   33076070.523 L2X
 ↪  135440679.474  674 S2X   50.500 C5X   33076076.496 L5X  129797319.733  674 S5X
 ↪  54.188 C1X   33076065.492 L1X  173815529.101  674 S1X   52.375
CUT07 C01 C2I   37725820.914 L2I  196447455.374  704 D2I         90.898 S2I
 ↪  41.312 C6I   37725810.168 L6I  159630204.932  704 S6I   44.875 C7I
 ↪  37725815.196 L7I  151906389.245  704 S7I   45.812
...
CUT07 C14 C2I   23351041.328 L2I  121594621.501  592 D2I       2422.203 S2I
 ↪  45.688 C6I   23351032.926 L6I   98805869.415  592 S6I   48.500 C7I
 ↪  23351041.996 L7I   94024977.673  592 S7I   45.688
WTZR0 G02 C1C   23641481.864 L1C  124236803.604  127 S1C   47.500 C2W
 ↪  23641476.604 L2W   96807881.233  127 S2W   39.250
...
WTZR0 G26 C1C   24681555.676 L1C  129702453.534  127 S1C   43.750 C2W
 ↪  24681561.256 L2W  101066873.870  127 S2W   37.750
WTZR0 R03 C1C   22982596.508 L1C  123027564.682  127 S1C   47.000 C2P
 ↪  22982598.368 L2P   95688085.627  127 S2P   43.250
...
WTZR0 R21 C1C   22510252.692 L1C  120456902.811  127 S1C   47.500 C2P
 ↪  22510253.132 L2P   93688698.401  127 S2P   44.000

> 1884 206011.0000000
...
```

The source code for BNC comes with a Perl script named ‘test_tcpip_client.pl’ that allows to read BNC’s (synchronized or unsynchronized) ASCII observation output from the IP port and print it on standard output for verification.

Note that any socket connection of an application to BNC’s synchronized or unsynchronized observation ports is recorded in the ‘Log’ tab on the bottom of the main window together with a connection counter, resulting in log records like ‘New client connection on sync/usync port: # 1’.

The following figure shows the screenshot of a BNC configuration where a number of streams is pulled from different Ntrip Broadcasters to feed a GNSS engine via IP port output.

5.9.1 Port - optional

BNC can produce synchronized observations in ASCII format on your local host (IP 127.0.0.1) through an IP ‘Port’. Synchronized means that BNC collects all observation data for a specific epoch, which become available within a certain number of seconds (see ‘Wait for Full Obs Epoch’ option). It then - epoch by epoch - outputs whatever has been received. The output comes block-wise per stream following the format specified in Table 5.5. Enter an IP port number here to activate this function. The default is an empty option field, meaning that no synchronized output is generated.

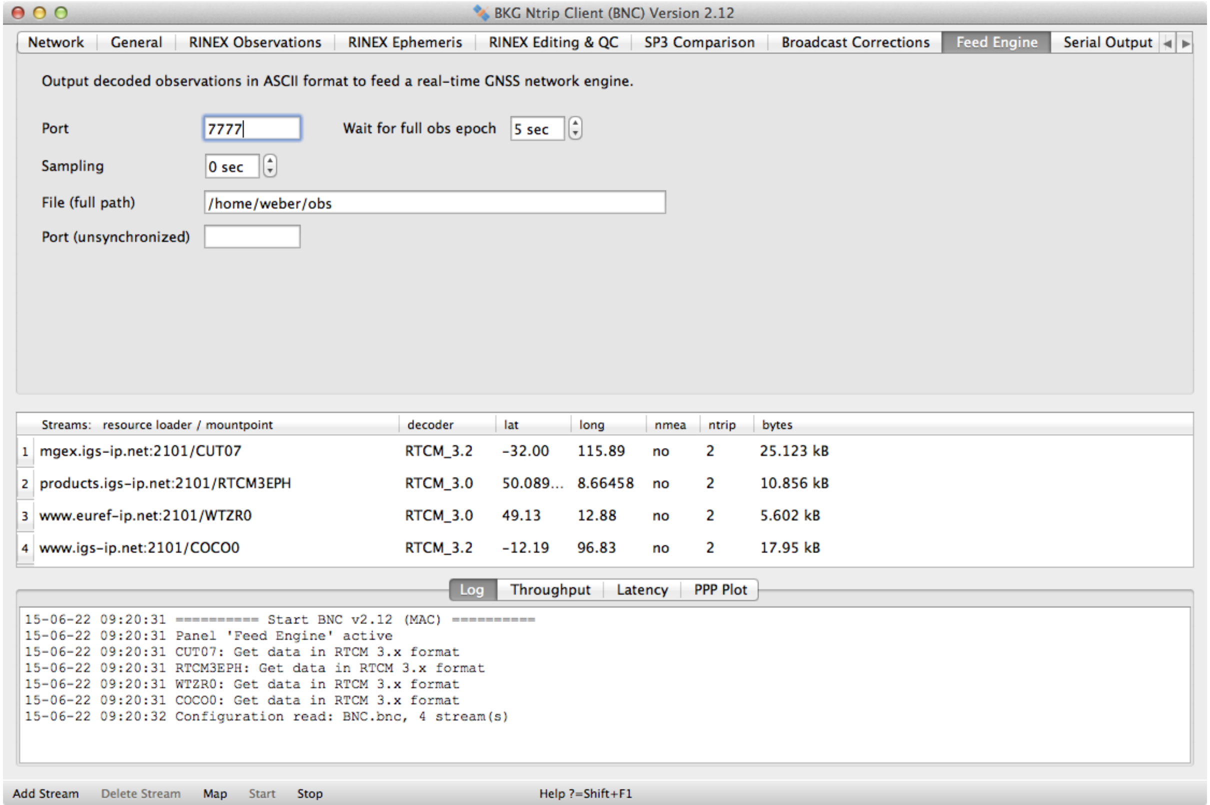


Fig. 5.13: Synchronized BNC output via IP port to feed a GNSS real-time engine

5.9.2 Wait for Full Obs Epoch - mandatory if 'Port' is set

When feeding a real-time GNSS network engine waiting for synchronized observations epoch by epoch, BNC drops whatever is received later than 'Wait for full obs epoch' seconds. A value of 3 to 5 seconds could be an appropriate choice for that, depending on the latency of the incoming streams and the delay acceptable for your real-time GNSS product. Default value for 'Wait for full obs epoch' is 5 seconds.

Note that 'Wait for full obs epoch' does not affect the RINEX Observation file content. Observations received later than 'Wait for full obs epoch' seconds will still be included in the RINEX Observation files.

5.9.3 Sampling - mandatory if 'File' or 'Port' is set

Select a synchronized observation output sampling interval in seconds. A value of zero '0' tells BNC to send/store all received epochs. This is the default value.

5.9.4 File - optional

Specify the full path to a 'File' where synchronized observations are saved in plain ASCII format. The default value is an empty option field, meaning that no ASCII output file is created.

Beware that the size of this file can rapidly increase depending on the number of incoming streams. To prevent it from becoming too large, the name of the file can be changed on-the-fly. This option is primarily meant for test and evaluation.

5.9.5 Port (unsynchronized) - optional

BNC can produce unsynchronized observations from all configured streams in ASCII format on your local host (IP 127.0.0.1) through an IP 'Port'. Unsynchronized means that BNC immediately forwards any received observation to the port. Nevertheless, the output is produced block-wise per stream. Specify an IP port number here to activate this function. The default is an empty option field, meaning that no unsynchronized output is generated.

The following is an example for unsynchronized IP port output which presents observations from GPS and GLONASS as collected through stream WTZR0. The format for synchronized and unsynchronized output of observations is very much the same. However, unsynchronized output does not have 'Epoch Records' and 'Observation Records'. Instead each record contains the 'GPS Week Number' and 'GPS Second of Week' time tag between the mountpoint string and the satellite number, see Table 5.5 for format details.

```
WTZR0 1884 209623.0000000 G02 C1C   22259978.112 L1C  116976955.890  127 S1C
 ↪  49.250 C2W   22259974.472 L2W   91150855.991  127 S2W   44.500
WTZR0 1884 209623.0000000 G03 C1C   24426736.058 L1C  128363272.624  127 S1C
 ↪  43.500 C2W   24426741.838 L2W  100023289.335  127 S2W   39.000
...
WTZR0 1884 209623.0000000 G29 C1C   25275897.592 L1C  132825869.191   90 S1C
 ↪  35.250 C2W   25275893.692 L2W  103500567.110    8 S2W   28.500
WTZR0 1884 209623.0000000 G30 C1C   23670676.284 L1C  124390283.441  127 S1C
 ↪  46.750 C2W   23670679.784 L2W   96927531.685  127 S2W   39.500
WTZR0 1884 209623.0000000 R04 C1C   20758122.104 L1C  111158778.398  127 S1C
 ↪  50.000 C2P   20758121.664 L2P   86456803.800  127 S2P   47.000
WTZR0 1884 209623.0000000 R05 C1C   19430829.552 L1C  103868912.028  127 S1C
 ↪  45.750 C2P   19430829.672 L2P   80786936.849  127 S2P   46.750
...
```

5.10 Serial output

You may use BNC to feed a serially connected device like a GNSS receiver. For that, an incoming stream can be forwarded to a serial port. Depending on the stream content, the receiver may use it for Differential GNSS, Precise Point Positioning or any other purpose supported by its firmware. Note that receiving a VRS stream requires the receiver sending NMEA sentences (option 'NMEA' set to 'Manual' or 'Auto') to the Ntrip Broadcaster. Fig. 5.14 shows the data flow when pulling a VRS stream or a physical (non-VRS) stream.

Fig. 5.15 shows the screenshot of an example situation where BNC pulls a VRS stream from an Ntrip Broadcaster to feed a serially connected RTK rover.

5.10.1 Mountpoint - optional

Enter a 'Mountpoint' to forward its corresponding stream to a serially connected GNSS receiver. When selecting one of the serial communication options listed below, make sure that you pick those configured to the serially connected receiver.

5.10.2 Port Name - mandatory if 'Mountpoint' is set

Enter the serial 'Port name' selected on your host for communication with the serially connected receiver. Valid port names are summarized in Table 5.6.

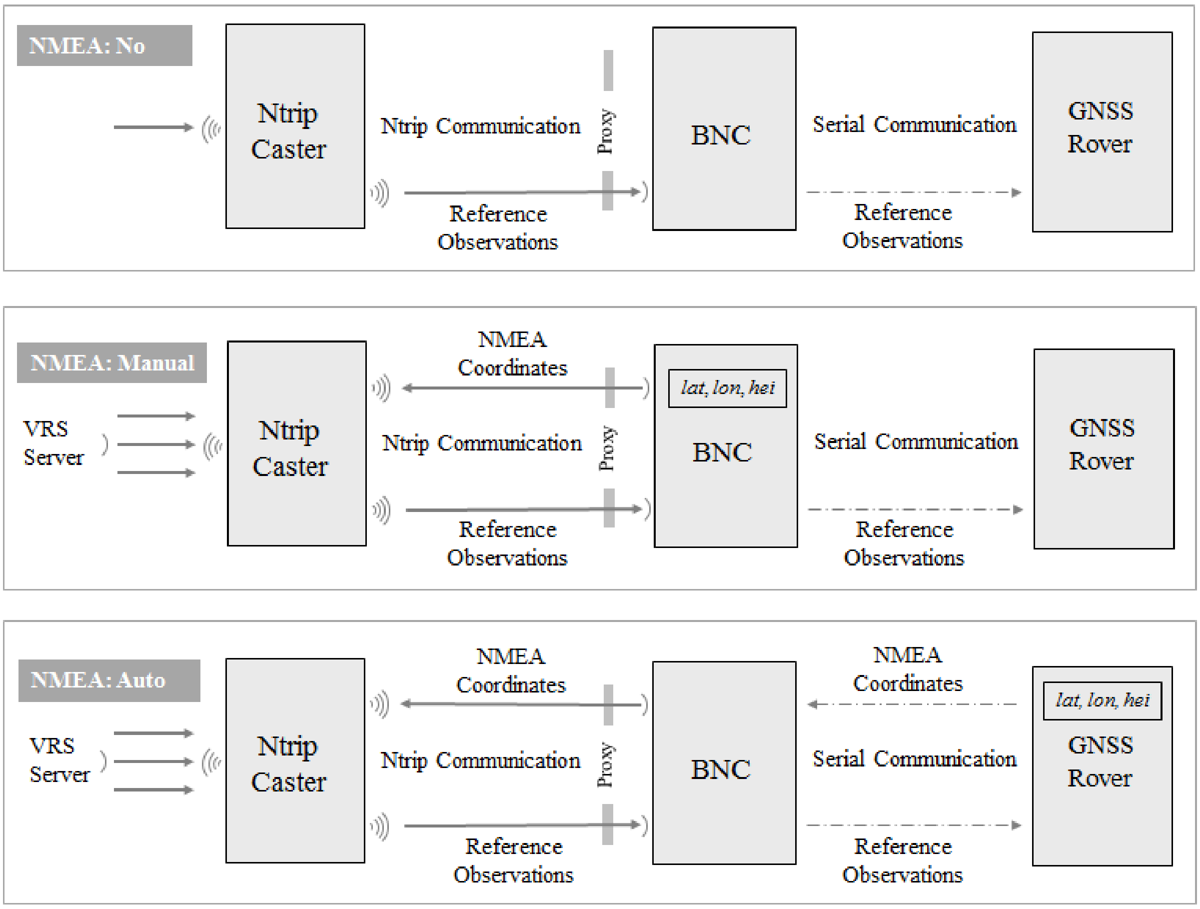


Fig. 5.14: Flowcharts, BNC forwarding a stream to a serially connected receiver; sending NMEA sentences is mandatory for VRS streams

Table 5.6: Valid port names for serially connected receivers.

OS	Port Names
Windows	COM1, COM2
Linux	/dev/ttyS0, /dev/ttyS1
FreeBSD	/dev/ttyd0, /dev/ttyd1
Digital Unix	/dev/tty01, /dev/tty02
HP-UX	/dev/tty1p0, /dev/tty2p0
SGI/IRIX	/dev/ttyf1, /dev/ttyf2
SunOS/Solaris	/dev/ttya, /dev/ttyb

Note that you must plug a serial cable in the port defined here before you start BNC.

5.10.3 Baud Rate - mandatory if 'Mountpoint' is set

Select a 'Baud rate' for the serial output link. Note that using a high baud rate is recommended.

5.10.4 Flow Control - mandatory if 'Mountpoint' is set

Select a 'Flow control' for the serial output link. Note that your selection must equal the flow control configured to the serially connected device. Select 'OFF' if you do not know better.

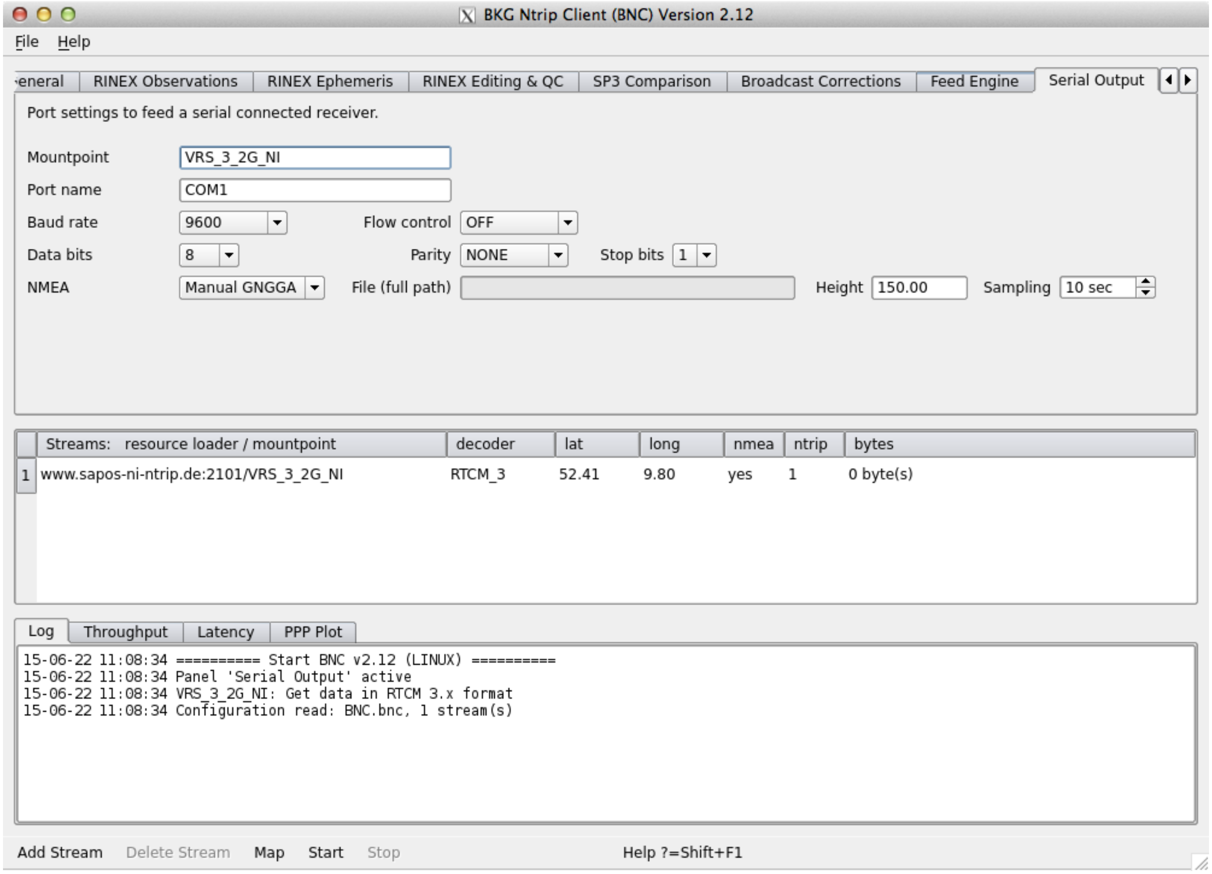


Fig. 5.15: BNC pulling a VRS stream to feed a serially connected RTK rover

5.10.5 Parity - mandatory if 'Mountpoint' is set

Select the 'Parity' for the serial output link. Note that parity is often set to 'NONE'.

5.10.6 Data Bits - mandatory if 'Mountpoint' is set

Select the number of 'Data bits' for the serial output link. Note that often '8' data bits are used.

5.10.7 Stop Bits - mandatory if 'Mountpoint' is set

Select the number of 'Stop bits' for the serial output link. Note that often '1' stop bit is used.

5.10.8 NMEA - mandatory if 'Mountpoint' is set

The 'NMEA' option supports the so-called 'Virtual Reference Station' (VRS) concept which requires the receiver to send approximate position information to the Ntrip Broadcaster. Select 'no' if you do not want BNC to forward or upload any NMEA sentence to the Ntrip broadcaster in support of VRS.

Select 'Auto' to automatically forward NMEA sentences of type GGA from your serially connected receiver to the Ntrip broadcaster and/or save them in a file.

Select 'Manual GPGGA' or 'Manual GNGGA' if you want BNC to produce and upload GPGGA or GNGGA NMEA sentences to the Ntrip broadcaster because your serially connected receiver does not generate them. A Talker ID 'GP' proceeding the GGA string stands for GPS solutions while a Talker ID 'GN' stands for multi-constellation solutions.

Note that selecting 'Auto' or 'Manual' works only for VRS streams which show up under the 'Streams' canvas on BNC's main window with 'nmea' stream attribute set to 'yes'. This attribute is either extracted from the Ntrip broadcaster's source-table or introduced by the user through editing the BNC configuration file.

5.10.9 File - optional if 'NMEA' is set to 'Auto'

Specify the full path to a file where NMEA sentences coming from your serially connected receiver are saved. Default is an empty option field, meaning that no NMEA sentences will be saved on disk.

5.10.10 Height - mandatory if 'NMEA' is set to 'Manual'

Specify an approximate 'Height' above mean sea level in meters for the reference station introduced through 'Mountpoint'. Together with the latitude and longitude from the Ntrip broadcaster source-table, the height information is used to build GGA sentences to be sent to the Ntrip broadcaster.

For adjusting latitude and longitude values of a VRS stream given in the 'Streams' canvas, you can double click the latitude/longitude data fields, specify appropriate values and then hit Enter.

This option is only relevant when option 'NMEA' is set to 'Manual GPGGA' or 'Manual GNGGA' respectively.

5.10.11 Sampling - mandatory if 'NMEA' is set to 'Manual'

Select a sampling interval in seconds for manual generation and upload of NMEA GGA sentences.

A sampling rate of '0' means that a GGA sentence will be sent only once to initialize the requested VRS stream. Note that some VRS systems need GGA sentences at regular intervals.

5.11 Outages

At any time an incoming stream might become unavailable or corrupted. In such cases, it is important that the BNC operator and/or the stream providers become aware of the situation so that measures can be taken to restore the stream. Furthermore, continuous attempts to decode a corrupted stream can generate unnecessary workload for BNC. Outages and corruptions are handled by BNC as follows:

Stream outages: BNC considers a connection to be broken when there are no incoming data detected for more than 20 seconds. When this occurs, BNC will try to reconnect at a decreasing rate. It will first try to reconnect with 1 second delay and again in 2 seconds if the previous attempt failed. If the attempt is still unsuccessful, it will try to reconnect within 4 seconds after the previous attempt and so on. The waiting time doubles each time with a maximum of 256 seconds.

Stream corruption: Not all chunks of bits transferred to BNC's internal decoder may return valid observations. Sometimes several chunks might be needed before the next observation can be properly decoded. BNC buffers all outputs (both valid and invalid) from the decoder for a short time span (size derived from the expected 'Observation rate') to then determine whether a stream is valid or corrupted.

Outage and corruption events are reported in the 'Log' tab. They can also be passed on as parameters to a shell script or batch file to generate an advisory note to BNC's operator or affected stream providers. This functionality lets users utilize BNC as a real-time performance monitor and alarm system for a network of GNSS reference stations, see Fig. 5.16 for an example setup.

5.11.1 Observation Rate - optional

BNC can collect all returns (success or failure) coming from a decoder within a certain short time span to then decide whether a stream has an outage or its content is corrupted. This procedure needs a rough a priori estimate of the expected observation rate of the incoming streams.

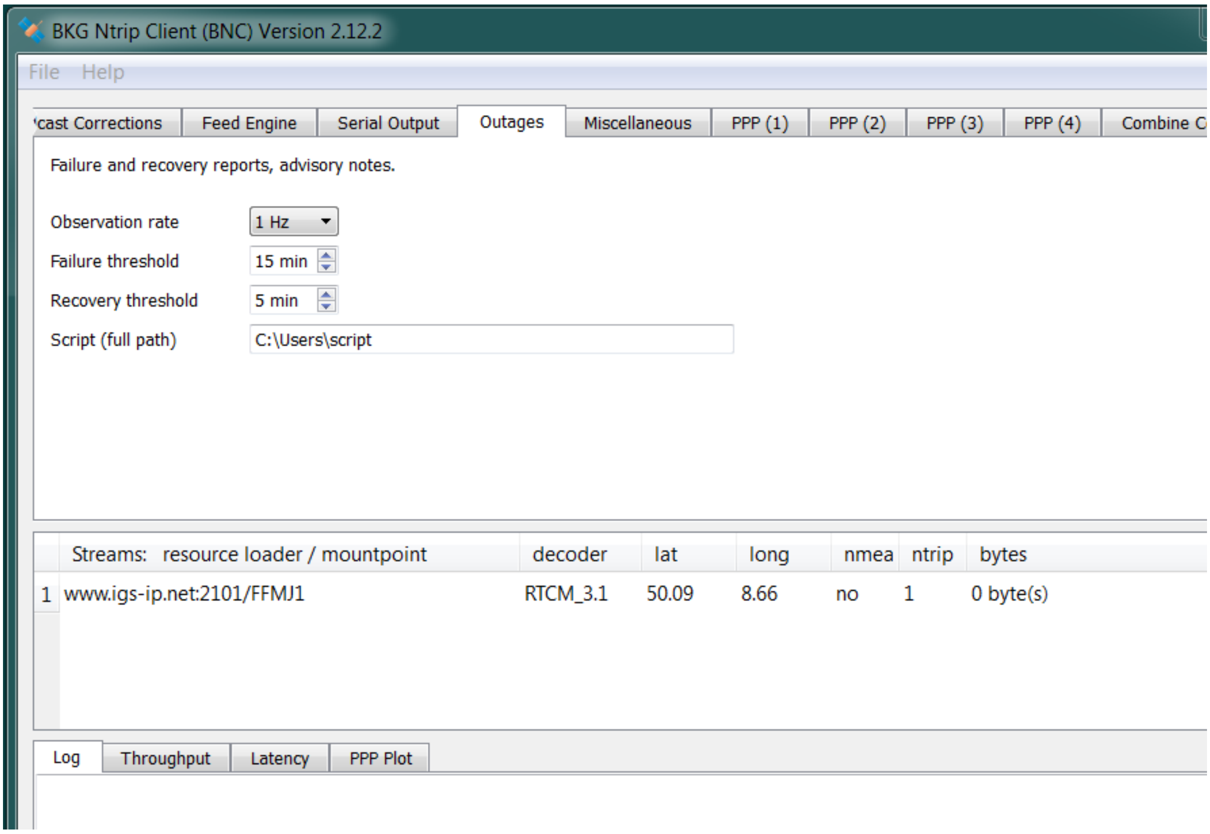


Fig. 5.16: Specifying thresholds for stream outage and recovery

An empty option field (default) means that you do not want explicit information from BNC about stream outages and incoming streams that cannot be decoded.

5.11.2 Failure Threshold - mandatory if 'Observation rate' is set

Event 'Begin_Failure' will be reported if no data is received continuously for longer than the 'Failure threshold' time. Similarly, event 'Begin_Corrupted' will be reported when corrupted data is detected by the decoder continuously for longer than this 'Failure threshold' time. The default value is set to 15 minutes and is recommended as to not inundate users with too many event reports.

Note that specifying a value of zero '0' for the 'Failure threshold' will force BNC to report any stream failure immediately. Note also that for using this function you need to specify the 'Observation rate'.

5.11.3 Recovery Threshold - mandatory if 'Observation rate' is set

Once a 'Begin_Failure' or 'Begin_Corrupted' event has been reported, BNC will check when the stream again becomes available or uncorrupted. Event 'End_Failure' or 'End_Corrupted' will be reported as soon as valid observations are detected continuously throughout the 'Recovery threshold' time span. The default value is set to 5 minutes and is recommended as to not inundate users with too many event reports.

Note that specifying a value of zero '0' for the 'Recovery threshold' will force BNC to report any stream recovery immediately. Note also that for using this function you need to specify the 'Observation rate'.

5.11.4 Script - optional if 'Observation rate' is set

As mentioned before, BNC can trigger a shell script or a batch file to be executed when one of the described events is reported. This script can be used to email an advisory note to network operator or stream providers. To enable this feature, specify the full path to the script or batch file in the 'Script' field. The affected stream's mountpoint and type of event reported ('Begin_Outage', 'End_Outage', 'Begin_Corrupted' or 'End_Corrupted') will then be passed on to the script as command line parameters (%1 and %2 on Windows systems or $1 and $2 on Unix/Linux/Mac OS X systems) together with date and time information.

Leave the 'Script' field empty if you do not wish to use this option. An invalid path will also disable this option.

Examples for command line parameter strings passed on to the advisory 'Script' are:

```
FFMJ0 Begin_Outage 08-02-21 09:25:59
FFMJ0 End_Outage 08-02-21 11:36:02 Begin was 08-02-21 09:25:59
```

Sample script for Unix/Linux/Mac OS X systems:

```
#!/bin/bash
sleep $((60*RANDOM/32767))
cat > mail.txt <<EOF
Advisory Note to BNC User,
Please note the following advisory received from BNC.
Stream: $*
Regards, BNC
EOF
mail -s "NABU: $1" email@address < mail.txt
```

Note the sleep command in this script, which causes the system to wait for a random period of up to 60 seconds before sending the email. This should avoid overloading your mail server in case of a simultaneous failure of many streams.

5.12 Miscellaneous

This section describes several miscellaneous options which can be applied to a single stream (mountpoint) or to all configured streams. Fig. 5.17 shows RTCM message numbers and observation types contained in stream 'CUT07' and the message latencies recorded every 2 seconds.

5.12.1 Mountpoint - optional

Specify a mountpoint to apply one or several of the 'Miscellaneous' options to the corresponding stream. Enter 'ALL' if you want to apply these options to all configured streams. An empty option field (default) means that you do not want BNC to apply any of these options.

5.12.2 Log Latency - optional

BNC can average latencies per stream over a certain period of GPS time, the 'Log latency' interval. Mean latencies are calculated from the individual latencies of one (first incoming) observation or Broadcast Correction per second. The mean latencies are then saved in BNC's logfile. Note that computing correct latencies requires the clock of the host computer to be properly synchronized. Note further that visualized latencies from the 'Latency' tab on the bottom of the main window represent individual latencies and not the mean latencies for the logfile.

Latency

Latency is defined in BNC by

$$l = t_{UTC} - t_{GPS} + t_{leap}$$

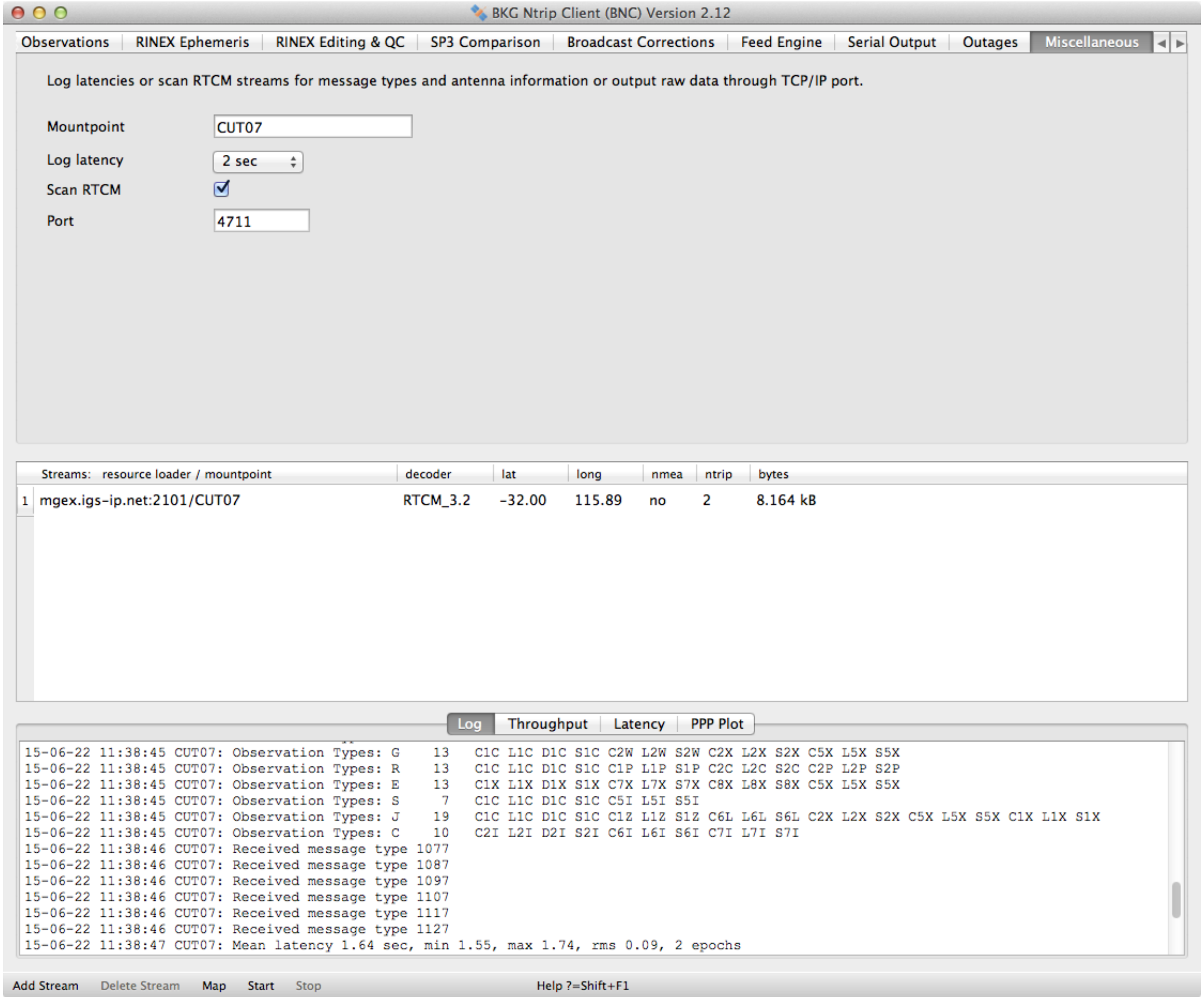


Fig. 5.17: RTCM message numbers, latencies and observation types logged by BNC

with latency l, UTC time provided by BNC's host t_{UTC}, GPS time of currently processed epoch t_{GPS} and Leap seconds between UTC and GPS time t_{leap}.

Statistics

BNC counts the number of GPS seconds covered by at least one observation. It also estimates an observation rate (independent from the a priori specified 'Observation rate') from all observations received throughout the first full 'Log latency' interval. Based on this rate, BNC estimates the number of data gaps when appearing in subsequent intervals.

Latencies of observations or corrections to Broadcast Ephemeris and statistical information can be recorded in the 'Log' tab at the end of each 'Log latency' interval. A typical output from a 1 hour 'Log latency' interval would be:

```
08-03-17 15:59:47 BRUS0: Mean latency 1.47 sec, min 0.66, max 3.02, rms 0.35, 3585
 ↪ epochs, 15 gaps
```

Select a 'Log latency' interval to activate this function or select the empty option field if you do not want BNC to log latencies and statistical information.

5.12.3 Scan RTCM - optional

When configuring a GNSS receiver for RTCM stream generation, the firmware's setup interface may not provide details about RTCM message types and observation types. As reliable information concerning stream content should be available e.g. for Ntrip Broadcaster operators to maintain the broadcaster's source-table, BNC allows to scan RTCM streams for incoming message types and printout some of the contained meta-data. Contained observation types are also printed because such information is required a priori for the conversion of RTCM Version 3 MSM streams to RINEX Version 3 files. The idea for this option arose from 'inspectRTCM', a comprehensive stream analyzing tool written by D. Stöcker.

Tick 'Scan RTCM' to scan RTCM Version 2 or 3 streams and log all contained

- Numbers of incoming message types
- Antenna Reference Point (ARP) coordinates
- Antenna Phase Center (APC) coordinates
- Antenna height above marker
- Antenna descriptor.

In case of RTCM Version 3 streams the output includes

- RINEX Version 3 Observation types

Note that in RTCM Version 2 message types 18 and 19 carry only the observables of one frequency. Hence it needs two type 18 and 19 messages per epoch to transport observations from dual frequency receivers.

Please note further that RTCM Version 3 message types 1084 for GLONASS do not contain GLONASS channel numbers. Observations from these messages can only be decoded when you include 1020 GLONASS ephemeris messages to your stream which contain the channels. You could also consider adding a second stream carrying 1087 GLONASS observation messages or 1020 GLONASS ephemeris messages as both contain the GLONASS channel numbers.

Logged time stamps refer to message reception time and allow understanding repetition rates. Enter 'ALL' if you want to log this information from all configured streams. Beware that the size of the logfile can rapidly increase depending on the number of incoming RTCM streams.

This option is primarily meant for test and evaluation. Use it to figure out what exactly is produced by a specific GNSS receiver's configuration. An empty option field (default) means that you do not want BNC to print message type numbers and antenna information carried in RTCM streams.

5.12.4 Port - optional

BNC can output streams related to the above specified 'Mountpoint' through a TCP/IP port of your local host. Enter a port number to activate this function. The stream content remains untouched. BNC does not decode or reformat the data for this output. Be careful when keyword 'ALL' is specified as 'Mountpoint' for involving all incoming streams together because the affiliation of data to certain streams gets lost in the output. An empty option field (default) means that you do not want BNC to apply the TCP/IP port output option.

5.13 PPP Client

BNC can derive coordinates for rover positions following the Precise Point Positioning (PPP) approach. It uses code or code plus phase data from one or more GNSS systems in ionosphere-free linear combinations P3, L3, or P3&L3. Besides pulling streams of observations from a dual frequency GNSS receiver, this

- Requires pulling in addition a stream carrying satellite orbit and clock corrections to Broadcast Ephemeris in the form of RTCM Version 3 'State Space Representation' (SSR) messages. Note that for BNC these Broadcast Corrections need to be referred to the satellite's Antenna Phase Center (APC). Streams providing such messages are listed on (http://igs.bkg.bund.de/ntrip/orbits) *[8]*. Stream 'CLK11' on Ntrip Broadcaster 'products.igs-ip.net:2101' is an example.

- May require pulling a stream carrying Broadcast Ephemeris available as RTCM Version 3 message types 1019, 1020, 1043, 1044, 1045, 1046 and 63 (tentative). This becomes a must only when the stream coming from the receiver does not contain Broadcast Ephemeris or provides them only at very low repetition rate. Streams providing such messages are listed on http://igs.bkg.bund.de/ntrip/ephemeris. Stream 'RTCM3EPH' on caster 'products.igs-ip.net:2101' is an example.

Note that Broadcast Ephemeris parameters pass a plausibility check in BNC which allows to ignore incorrect or outdated ephemeris data when necessary, leaving a note 'WRONG EPHEMERIS' or 'OUTDATED EPHEMERIS' in the logfile.

When using the PPP option, it is important to understand which effects are corrected by BNC:

- BNC does correct for Solid Earth Tides and Phase Windup.
- Satellite Antenna Phase Center offsets are corrected.
- Satellite Antenna Phase Center variations are neglected because this is a small effect usually less than 2 centimeters.
- Observations can be corrected for a Receiver Antenna Offset and Receiver Antenna Phase Center Variation. Depending on whether or not these corrections are applied, the estimated position is either that of the receiver's Antenna Phase Center or that of the receiver's Antenna Reference Point.
- Ocean and atmospheric loading is neglected. Atmospheric loading is pretty small. Ocean loading is usually also a small effect but may reach up to about 10 centimeters for coastal stations.
- Rotational deformation due to polar motion (Polar Tides) is not corrected because this is a small effect usually less than 2 centimeters.

The provider of an orbit/clock correction stream may switch with his service at any time from a duty to a backup server installation. This shall be noted in the SSR stream through a change of the Issue Of Data (IOD SSR) parameter. The PPP option in BNC will immediately reset all ambiguities in such a situation.

PPP options are specified in BNC through the following four panels:

- PPP (1): Input and output, specifying real-time or post processing mode and associated data sources
- PPP (2): Processed stations, specifying sigmas and noise of a priori coordinates and NMEA stream output
- PPP (3): Processing options, specifying general PPP processing options
- PPP (4): Plots, specifying visualization through time series and track maps

5.13.1 PPP (1): Input and Output

This panel provides options for specifying the input and output streams and files required by BNC for real-time or post processing PPP, see Fig. 5.18 for an example screenshot.

Data Source - optional

Choose between input from 'Real-time Streams' or 'RINEX Files' for PPP with BNC in real-time or post processing mode.

Real-time Streams

When choosing 'Real-time Streams' BNC will do PPP solutions in real-time. This requires pulling GNSS observation streams, Broadcast Ephemeris messages and a stream containing corrections to Broadcast Ephemeris. Streams must come in RTCM Version 2 or RTCM Version 3 format. If you do not pull Broadcast Corrections, BNC will switch with its solution to 'Single Point Positioning' (SPP) mode. With RTCM Version 2 an ionosphere free linear combination of code-only observations cannot be processed.

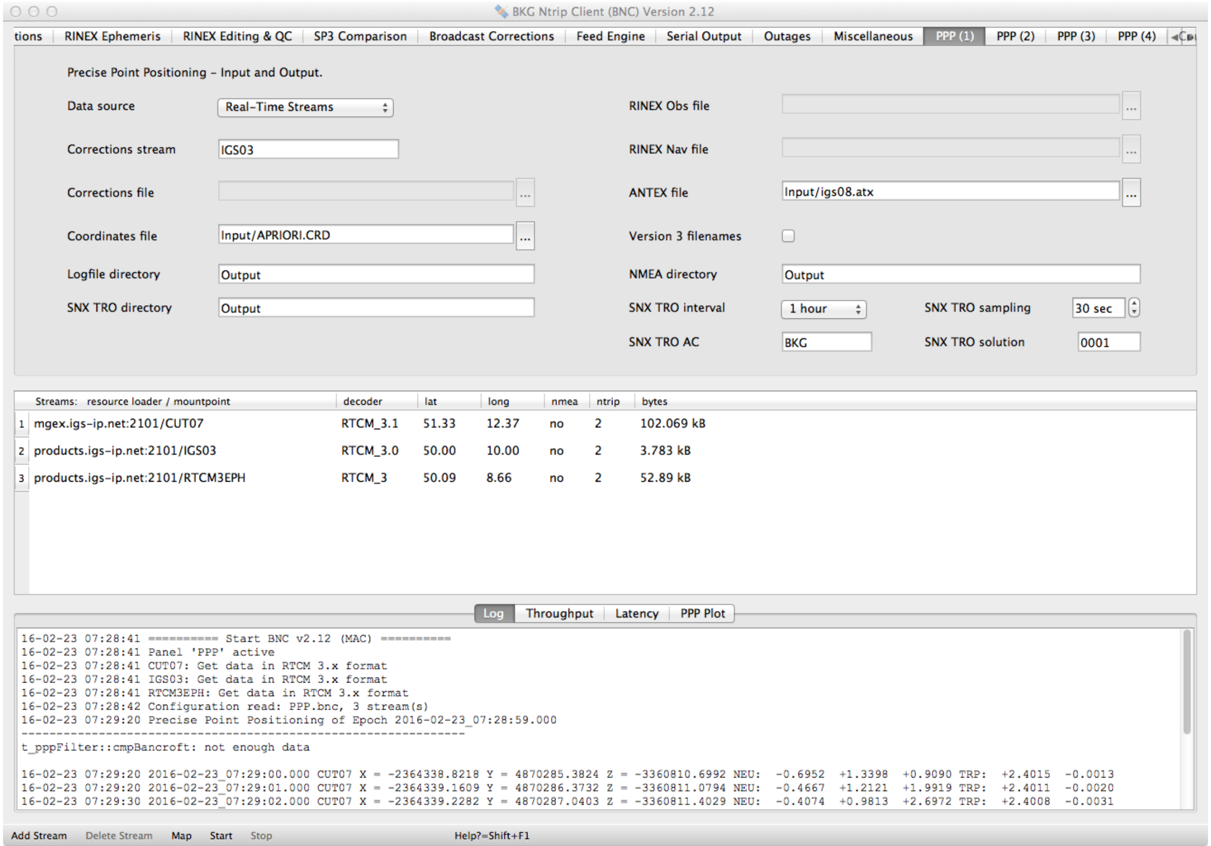


Fig. 5.18: Real-time Precise Point Positioning with BNC, PPP Panel 1

RINEX Files

This input mode allows to specify RINEX Observation, RINEX Navigation and Broadcast Correction files. BNC accepts RINEX Version 2 as well as RINEX Version 3 Observation or Navigation file formats. Files carrying Broadcast Corrections must have the format produced by BNC through the 'Broadcast Corrections' panel. Specifying only a RINEX Observation and a RINEX Navigation file and no Broadcast Correction file leads BNC to a 'Single Point Positioning' (SPP) solution.

Debugging

Note that for debugging purposes, BNC's real-time PPP functionality can also be used offline. Apply the 'File Mode' 'Command Line' option for that to read a file containing synchronized observations, orbit and clock correctors, and Broadcast Ephemeris. Example:

```
bnc.exe --conf c:\temp\PPP.bnc --file c:\temp\RAW
```

Such a file (here: 'RAW') must be saved beforehand using BNC's 'Raw output file' option.

RINEX Observation File - mandatory if 'Data source' is set to 'RINEX Files'

Specify a RINEX Observation file. The file format can be RINEX Version 2 or RINEX Version 3.

RINEX Navigation File - mandatory if 'Data source' is set to 'RINEX Files'

Specify a RINEX Navigation file. The file format can be RINEX Version 2 or RINEX Version 3.

Corrections Stream - optional if 'Data source' is set to 'Real-Time Streams'

Specify a Broadcast 'Corrections stream' from the list of selected 'Streams' you are pulling if you want BNC to correct your satellite ephemeris accordingly. Note that the stream's orbit and clock corrections must refer to the satellite Antenna Phase Center (APC). Streams providing such corrections are made available e.g. through the International GNSS Service (IGS) and listed on http://igs.bkg.bund.de/ntrip/orbits. The stream format must be RTCM Version 3 containing so-called SSR messages. Streams 'IGS03' and 'CLK11' supporting GPS plus GLONASS are examples. If you do not specify a 'Corrections stream', BNC will fall back from a PPP solution to a Single Point Positioning (SPP) solution.

Corrections File - optional if 'Data source' is set to 'RINEX Files'

Specify a Broadcast 'Corrections file' as saved beforehand using BNC. The file content is basically the ASCII representation of a RTCM Version 3 Broadcast Correction (SSR) stream. If you do not specify a 'Correction file', BNC will fall back from a PPP solution to a Single Point Positioning (SPP) solution.

ANTEX File - optional

IGS provides a file containing absolute phase center corrections for GNSS satellite and receiver antennas in ANTEX format. Entering the full path to such an ANTEX file is required for correcting observations in PPP for Antenna Phase Center offsets and variations. Note that for applying such corrections you need to specify the receiver's antenna name and radome in BNC's 'Coordinates file'.

Default value for 'ANTEX file' is an empty option field, meaning that you do not want to correct observations for Antenna Phase Center offsets and variations.

Coordinates File - optional

Enter the full path to an ASCII file which specifies all observation streams or files from stationary or mobile receivers you possibly may want to process. Specifying a 'Coordinates file' is optional. If it exists, it should contain one record per stream or file with the following parameters separated by blank characters:

- Input data source, to be specified either through
  - the 'Mountpoint' of an RTCM stream (when in real-time PPP mode), or
  - the first four characters of the RINEX observations file (when in post processing PPP mode).

  Having at least this first parameter in each record is mandatory.
- Only for static observations from a stationary receiver: Approximate a priori XYZ coordinate [m] of the station's marker; specify '0.0 0.0 0.0' if unknown or when observations come from a mobile receiver.
- Nort, East and Up component [m] of antenna eccentricity which is the difference between Antenna Reference Point (ARP) and a nearby marker position; when specifying the antenna eccentricity BNC will produce coordinates referring to the marker position and not referring to ARP; specify '0.0 0.0 0.0' if eccentricity is unknown or the ARP itself is understood as the marker.

Receiver's antenna name as defined in your ANTEX file (see below); Observations will be corrected for the Antenna Phase Center (APC) offsets and variations, which may result in a reduction of a few centimeters at max; the specified name must consist of 20 characters; add trailing blanks if the antenna name has less than 20 characters; examples:

```
'JPSREGANT_SD_E       ' (no radome)
'LEIAT504        NONE' (no radome)
'LEIAR25.R3      LEIT' (radome is LEIT)
```

Leave antenna name blank if you do not want to correct observations for APC offsets and variations or if you do not know the antenna name. * Receiver type following the naming convention for IGS equipment as defined in https://igscb.jpl.nasa.gov/igscb/station/general/rcvr_ant.tab. Specifying the receiver type is only required when saving SINEX Troposphere files. In those files it becomes part of the 'SITE/RECEIVER' specifications, see section 'SNX TRO Directory'.

Records in the 'Coordinates' file with exclamation mark '!' in the first column or blank records will be understood as comment lines and ignored.

The following is the content of an example 'Coordinates file'. Here each record describes the mountpoint of a stream available from the global IGS real-time reference station network. A priori coordinates are followed by North/East/Up eccentricity components of the ARP followed by the antenna name, radome and the receiver name in use.

```
!
! Station    X[m]          Y[m]          Z[m] North[m]  EAST[m]  UP[m]  Antenna
↪  Radom Receiver
! ---------------------------------------------------------------------------------
↪  -------------------
ADIS0  4913652.6612  3945922.7678   995383.4359  0.0000  0.0000  0.0010 TRM29659.00
↪  NONE JPS LEGACY
ALIC0 -4052052.5593  4212836.0078 -2545104.8289  0.0000  0.0000  0.0015 LEIAR25.R3
↪  NONE LEICA GRX1200GGPRO
BELF0  3685257.8823  -382908.8992  5174311.1067  0.0000  0.0000  0.0000 LEIAT504GG
↪  LEIS LEICA GRX1200GGPRO
BNDY0 -5125977.4106  2688801.2966 -2669890.4345  0.0000  0.0000  0.0000
↪  ASH701945E_M    NONE TRIMBLE NETR5
BRAZ0  4115014.0678 -4550641.6105 -1741443.8244  0.0000  0.0000  0.0080 LEIAR10
↪  NONE LEICA GR25
CTWN0  5023564.4285  1677795.7211 -3542025.8392  0.0000  0.0000  0.0000 ASH701941.B
↪  NONE TRIMBLE NETR5
CUT07 -2364337.4408  4870285.6055 -3360809.6280  0.0000  0.0000  0.0000 TRM59800.00
↪  SCIS TRIMBLE NETR9
GANP0  3929181.3480  1455236.9105  4793653.9880  0.0000  0.0000  0.3830 TRM55971.00
↪  NONE TRIMBLE NETR9
HLFX0  2018905.6037 -4069070.5095  4462415.4771  0.0000  0.0000  0.1000 TPSCR.G3
↪  NONE TPS NET-G3A
LHAZ0  -106941.9272  5549269.8041  3139215.1564  0.0000  0.0000  0.1330 ASH701941.B
↪  NONE TPS E_GGD
LMMF7  2993387.3587 -5399363.8649  1596748.0983  0.0000  0.0000  0.0000 TRM57971.00
↪  NONE TRIMBLE NETR9
MAO07 -5466067.0979 -2404333.0198  2242123.1929  0.0000  0.0000  0.0000 LEIAR25.R3
↪  LEIT JAVAD TRE_G3TH DELTA
NICO0  4359415.5252  2874117.1872  3650777.9614  0.0000  0.0000  0.0650 LEIAR25.R4
↪  LEIT LEICA GR25
NKLG7  6287385.7320  1071574.7606    39133.1088 -0.0015 -0.0025  3.0430 TRM59800.00
↪  SCIS TRIMBLE NETR9
NURK7  5516756.5103  3196624.9684  -215027.1315  0.0000  0.0000  0.1300 TPSCR3_GGD
↪  NONE JAVAD TRE_G3TH DELTA
ONSA0  3370658.3928   711877.2903  5349787.0603  0.0000  0.0000  0.9950 AOAD/M_B
↪  OSOD JAVAD TRE_G3TH DELTA
PDEL0  4551595.9072 -2186892.9495  3883410.9685  0.0000  0.0000  0.0000 LEIAT504GG
↪  NONE LEICA GRX1200GGPRO
RCMN0  5101056.6270  3829074.4206  -135016.1589  0.0000  0.0000  0.0000 LEIAT504GG
↪  LEIS LEICA GRX1200GGPRO
REUN0  3364098.9668  4907944.6121 -2293466.7379  0.0000  0.0000  0.0610 TRM55971.00
↪  NONE TRIMBLE NETR9
REYK7  2587384.0890 -1043033.5433  5716564.1301  0.0000  0.0000  0.0570 LEIAR25.R4
↪  LEIT LEICA GR25
RIO27  1429907.8578 -3495354.8953 -5122698.5595  0.0000  0.0000  0.0350
↪  ASH700936C_M    SNOW JAVAD TRE_G3TH DELTA
SMR50   927077.1096 -2195043.5597 -5896521.1344  0.0000  0.0000  0.0000 TRM41249.00
↪  TZGD TRIMBLE NETR5
SUWN0 -3062023.1604  4055447.8946  3841818.1684  0.0000  0.0000  1.5700 TRM29659.00
↪  DOME TRIMBLE NETR9
TASH7  1695944.9208  4487138.6220  4190140.7391  0.0000  0.0000  0.1206
↪  JAV_RINGANT_G3T NONE JAVAD TRE_G3TH DELTA
```

```
UFPR0  3763751.6731 -4365113.9039 -2724404.5331  0.0000  0.0000  0.1000 TRM55971.00
 ↪  NONE TRIMBLE NETR5
UNB30  1761287.9724 -4078238.5659  4561417.8448  0.0000  0.0000  0.3145 TRM57971.00
 ↪  NONE TRIMBLE NETR9
WIND7  5633708.8016  1732017.9297 -2433985.5795  0.0000  0.0000  0.0460
 ↪  ASH700936C_M    SNOW JAVAD TRE_G3TH DELTA
WTZR0  4075580.3797   931853.9767  4801568.2360  0.0000  0.0000  0.0710 LEIAR25.R3
 ↪  LEIT LEICA GR25
WUH27 -2267749.9761  5009154.5504  3221294.4429  0.0000  0.0000  0.1206
 ↪  JAV_RINGANT_G3T NONE JAVAD TRE_G3TH DELTA
YELL7 -1224452.8796 -2689216.1863  5633638.2832  0.0000  0.0000  0.1000 AOAD/M_T
 ↪  NONE JAVAD TRE_G3TH DELTA
```

Note again that the only mandatory parameters in this file are the ‘Station’ parameters in the first column, each standing for an observation stream’s mountpoint or the 4-character station ID of a RINEX filename. The following shows further valid examples for records of a ‘Coordinates file’.

```
!
! Station     X[m]         Y[m]          Z[m]     N[m]   E[m]   U[m]  Antenna
 ↪  Radom Receiver
! ---------------------------------------------------------------------------------
 ↪  ----------------
WTZR0   4075580.3797  931853.9767  4801568.2360  0.000  0.000  0.071 LEIAR25.R3
 ↪  LEIT LEICA GR25
CUT07  -2364337.4408 4870285.6055 -3360809.6280  0.000  0.000  0.000 TRM59800.00
 ↪  SCIS
FFMJ1   4053455.7384  617729.8393  4869395.8214  0.000  0.000  0.045
TITZ1   3993780.4501  450206.8969  4936136.9886
WARN
SASS1         0.0          0.0           0.0     0.000  0.000  0.031 TPSCR3_GGD
 ↪  CONE TRIMBLE NETR5
```

In this file

- Record ‘WTZR0’ describes a stream from a stationary receiver with known a priori marker coordinate, antenna eccentricity, antenna and radome type and receiver type.
- Record ‘CUT07’ describes a stream from a stationary receiver with known a priori marker coordinate, antenna eccentricity and antenna and radome type. The receiver type is unknown.
- Record ‘FFMJ1’ describes a stream from a stationary receiver with known a priori marker coordinate and antenna eccentricity but unknown antenna, radome and receiver type.
- Record ‘TITZ1’ describes a stream coming from a stationary receiver where an a priori marker coordinate is known but antenna eccentricity, name and radome and receiver type are unknown.
- The 4-character station ID ‘WARN’ indicates that a RINEX observations file for post processing PPP is available for station ‘WARN’ but an a priori marker coordinate as well as antenna eccentricity, name and radome are unknown.
- Record ‘SASS1’ stands for a mountpoint where the stream comes from a mobile rover receiver. Hence an a priori coordinate is unknown although antenna eccentricity, name and radome and receiver type are known.

Version 3 Filenames - optional

Tick ‘Version 3 filenames’ to let BNC create so-called extended filenames for PPP logfiles, NMEA files and SINEX Troposphere files to follow the RINEX Version 3 standard, see section ‘RINEX Filenames’ for details. Default is an empty check box, meaning to create filenames following the RINEX Version 2 standard. The file content is not affected by this option. It only concerns the filename notation. Table 5.7 and Table 5.8 give filename examples for RINEX version 2 and 3, respectively.

Table 5.7: File name examples vor RINEX version 2.

Filename	Description
CUT018671.nmea	NMEA filename, suffix 'nmea'
CUT018671.ppp	PPP logfile name, suffix 'ppp'
CUT018671J30.tro	SINEX Troposphere filename, suffix 'tro'

Table 5.8: File name examples vor RINEX version 3.

Filename	Description
CUT000AUS_U_20152920000_01D_01S.nmea	NMEA filename, suffix 'nmea'
CUT000AUS_U_20152920000_01D_01S.ppp	PPP logfile name, suffix 'ppp'
CUT000AUS_U_20152920945_15M_01S.tra	SINEX Troposphere filename, suffix 'tra'

Logfile Directory - optional

Essential PPP results are shown in the 'Log' tab on the bottom of BNC's main window. Depending on the processing options, the following values are presented about once per second (example):

```
...
15-10-21 13:23:38 2015-10-21_13:23:38.000 CUT07 X = -2364337.4505 Y = 4870285.6269
 ↪  Z = -3360809.6481 NEU:  -0.0046  -0.0006  +0.0306 TRP:  +2.4018  +0.1006
15-10-21 13:23:39 2015-10-21_13:23:39.000 CUT07 X = -2364337.4468 Y = 4870285.6244
 ↪  Z = -3360809.6453 NEU:  -0.0043  -0.0029  +0.0258 TRP:  +2.4018  +0.0993
15-10-21 13:23:40 2015-10-21_13:23:40.000 CUT07 X = -2364337.4455 Y = 4870285.6215
 ↪  Z = -3360809.6466 NEU:  -0.0070  -0.0027  +0.0238 TRP:  +2.4018  +0.0978
15-10-21 13:23:41 2015-10-21_13:23:41.000 CUT07 X = -2364337.4447 Y = 4870285.6248
 ↪  Z = -3360809.6445 NEU:  -0.0039  -0.0049  +0.0249 TRP:  +2.4018  +0.0962
15-10-21 13:23:42 2015-10-21_13:23:42.000 CUT07 X = -2364337.4426 Y = 4870285.6238
 ↪  Z = -3360809.6424 NEU:  -0.0031  -0.0063  +0.0223 TRP:  +2.4018  +0.0950
15-10-21 13:23:43 2015-10-21_13:23:43.000 CUT07 X = -2364337.4453 Y = 4870285.6386
 ↪  Z = -3360809.6518 NEU:  -0.0033  -0.0104  +0.0395 TRP:  +2.4018  +0.0927
15-10-21 13:23:44 2015-10-21_13:23:44.000 CUT07 X = -2364337.4435 Y = 4870285.6354
 ↪  Z = -3360809.6487 NEU:  -0.0027  -0.0106  +0.0348 TRP:  +2.4018  +0.0908
15-10-21 13:23:45 2015-10-21_13:23:45.000 CUT07 X = -2364337.4445 Y = 4870285.6381
 ↪  Z = -3360809.6532 NEU:  -0.0049  -0.0109  +0.0396 TRP:  +2.4018  +0.0884
15-10-21 13:23:46 2015-10-21_13:23:46.000 CUT07 X = -2364337.4437 Y = 4870285.6365
 ↪  Z = -3360809.6548 NEU:  -0.0073  -0.0109  +0.0389 TRP:  +2.4018  +0.0855
15-10-21 13:23:47 2015-10-21_13:23:47.000 CUT07 X = -2364337.4498 Y = 4870285.6317
 ↪  Z = -3360809.6395 NEU:  +0.0049  -0.0033  +0.0294 TRP:  +2.4018  +0.0833
...
```

Each row reports the PPP result of one epoch. It begins with a UTC time stamp (yy-mm-dd hh:mm:ss) which tells us when the result was produced. A second time stamp (yyyy-mm-dd_hh:mm:ss) describes the PPP's epoch in 'GPS Time'. It is followed by the derived XYZ position in [m], its North, East and Up displacement compared to an introduced a priori coordinate, and the estimated tropospheric delay [m] (model plus correction). If you require more information, you can specify a 'Logfile directory' to save daily logfiles per station (filename suffix 'ppp') with additional processing details on disk:

```
Precise Point Positioning of Epoch 2015-10-21_13:23:47.000
---------------------------------------------------------------
2015-10-21_13:23:47.000 SATNUM G  9
2015-10-21_13:23:47.000 SATNUM R  6
2015-10-21_13:23:47.000 SATNUM E  0
2015-10-21_13:23:47.000 SATNUM C  9
2015-10-21_13:23:47.000 RES C01   P3    0.3201
2015-10-21_13:23:47.000 RES C02   P3    0.3597
2015-10-21_13:23:47.000 RES C03   P3   -0.8003
2015-10-21_13:23:47.000 RES C04   P3    2.7684
2015-10-21_13:23:47.000 RES C05   P3    4.9738
2015-10-21_13:23:47.000 RES C06   P3    0.1888
```

```
2015-10-21_13:23:47.000 RES C07   P3   -2.8624
2015-10-21_13:23:47.000 RES C08   P3   -2.9075
2015-10-21_13:23:47.000 RES C10   P3   -1.5682
2015-10-21_13:23:47.000 RES G05   P3    0.3828
2015-10-21_13:23:47.000 RES G16   P3   -3.7602
2015-10-21_13:23:47.000 RES G18   P3    0.8424
2015-10-21_13:23:47.000 RES G20   P3    0.4062
2015-10-21_13:23:47.000 RES G21   P3    0.8683
2015-10-21_13:23:47.000 RES G25   P3   -1.3367
2015-10-21_13:23:47.000 RES G26   P3    1.4107
2015-10-21_13:23:47.000 RES G29   P3    1.1870
2015-10-21_13:23:47.000 RES G31   P3   -0.5605
2015-10-21_13:23:47.000 RES R01   P3   -0.1458
2015-10-21_13:23:47.000 RES R02   P3   -2.1184
2015-10-21_13:23:47.000 RES R14   P3    1.8634
2015-10-21_13:23:47.000 RES R15   P3   -1.3964
2015-10-21_13:23:47.000 RES R18   P3    0.5517
2015-10-21_13:23:47.000 RES R24   P3    1.5750
2015-10-21_13:23:47.000 RES C01   L3   -0.0040
2015-10-21_13:23:47.000 RES C02   L3    0.0070
2015-10-21_13:23:47.000 RES C03   L3    0.0093
2015-10-21_13:23:47.000 RES C04   L3   -0.0017
2015-10-21_13:23:47.000 RES C05   L3   -0.0008
2015-10-21_13:23:47.000 RES C06   L3   -0.0031
2015-10-21_13:23:47.000 RES C07   L3   -0.0016
2015-10-21_13:23:47.000 RES C08   L3   -0.0089
2015-10-21_13:23:47.000 RES C10   L3    0.0051
2015-10-21_13:23:47.000 RES G05   L3   -0.0408
2015-10-21_13:23:47.000 RES G16   L3    0.0043
2015-10-21_13:23:47.000 RES G18   L3    0.0017
2015-10-21_13:23:47.000 RES G20   L3   -0.0132
2015-10-21_13:23:47.000 RES G21   L3    0.0188
2015-10-21_13:23:47.000 RES G25   L3   -0.0059
2015-10-21_13:23:47.000 RES G26   L3    0.0028
2015-10-21_13:23:47.000 RES G29   L3    0.0062
2015-10-21_13:23:47.000 RES G31   L3    0.0012
2015-10-21_13:23:47.000 RES R01   L3    0.0260
2015-10-21_13:23:47.000 RES R02   L3   -0.0121
2015-10-21_13:23:47.000 RES R14   L3    0.0055
2015-10-21_13:23:47.000 RES R15   L3   -0.0488
2015-10-21_13:23:47.000 RES R18   L3    0.0475
2015-10-21_13:23:47.000 RES R24   L3    0.0103

2015-10-21_13:23:47.000 CLK      45386.971 +-  0.163
2015-10-21_13:23:47.000 TRP       2.402 +0.083 +-  0.013
2015-10-21_13:23:47.000 OFFGLO       1.766 +-  0.250
2015-10-21_13:23:47.000 OFFGAL       0.000 +- 1000.001
2015-10-21_13:23:47.000 OFFBDS      29.385 +-  0.218
2015-10-21_13:23:47.000 AMB C01    239.913 +-  0.149   epo = 180
2015-10-21_13:23:47.000 AMB C04    151.821 +-  0.149   epo = 180
2015-10-21_13:23:47.000 AMB C05    137.814 +-  0.150   epo = 180
2015-10-21_13:23:47.000 AMB C06   -368.848 +-  0.149   epo = 180
2015-10-21_13:23:47.000 AMB C07   -102.508 +-  0.149   epo = 180
2015-10-21_13:23:47.000 AMB C08   -145.358 +-  0.150   epo = 180
2015-10-21_13:23:47.000 AMB C10    195.732 +-  0.149   epo = 180
2015-10-21_13:23:47.000 AMB G25     58.320 +-  0.159   epo = 180
2015-10-21_13:23:47.000 AMB G26    110.077 +-  0.159   epo = 180
2015-10-21_13:23:47.000 AMB G29   -555.466 +-  0.159   epo = 180
2015-10-21_13:23:47.000 AMB G31    -47.938 +-  0.159   epo = 180
2015-10-21_13:23:47.000 AMB R01   -106.913 +-  0.193   epo = 180
2015-10-21_13:23:47.000 AMB R02    168.316 +-  0.194   epo = 180
2015-10-21_13:23:47.000 AMB R24    189.793 +-  0.193   epo = 180
2015-10-21_13:23:47.000 AMB C02    -50.146 +-  0.149   epo = 175
```

```
2015-10-21_13:23:47.000 AMB G05   -185.211 +-  0.173   epo = 175
2015-10-21_13:23:47.000 AMB R14   -509.359 +-  0.194   epo = 175
2015-10-21_13:23:47.000 AMB R15     65.355 +-  0.194   epo = 175
2015-10-21_13:23:47.000 AMB R18   -105.206 +-  0.204   epo = 170
2015-10-21_13:23:47.000 AMB G16    215.751 +-  0.160   epo = 165
2015-10-21_13:23:47.000 AMB G18   -168.240 +-  0.159   epo = 165
2015-10-21_13:23:47.000 AMB G20   -284.129 +-  0.159   epo = 165
2015-10-21_13:23:47.000 AMB G21    -99.245 +-  0.159   epo = 165
2015-10-21_13:23:47.000 AMB C03   -117.727 +-  0.149   epo = 30

2015-10-21_13:23:47.000 CUT07 X = -2364337.4498 +- 0.0279 Y = 4870285.6317 +-
↪  0.0388 Z = -3360809.6395 +- 0.0313 dN = 0.0049 +- 0.0248 dE = -0.0033 +- 0.0239
↪  dU = 0.0294 +- 0.0456
```

Depending on selected processing options you find ‘GPS Time’ stamps (yyyy-mm-dd_hh:mm:ss.sss) followed by

- SATNUM: Number of satellites per GNSS,
- RES: Code and phase residuals for contributing GNSS systems in [m]

  Given per satellite with cIF/lIF for ionosphere-free linear combination of code/phase observations,
- CLK: Receiver clock errors in [m],
- TRP: A priori and correction values of tropospheric zenith delay in [m],
- OFFGLO: Time offset between GPS time and GLONASS time in [m],
- OFFGAL: Time offset between GPS time and Galileo time in [m],
- OFFBDS: Time offset between GPS time and BDS time in [m],
- AMB: L3 biases, also known as ‘floated ambiguities’

  Given per satellite with ‘nEpo’ = number of epochs since last ambiguity reset,
- MOUNTPOINT: Here ‘CUT07’ with XYZ position in [m] and dN/dE/dU in [m] for North, East, and Up displacements compared to a priori marker coordinates.

Estimated parameters are presented together with their formal errors as derived from the implemented filter. The PPP algorithm includes outlier and cycle slip detection.

Default value for ‘Logfile directory’ is an empty option field, meaning that you do not want to save daily PPP logfiles on disk. If a specified directory does not exist, BNC will not create PPP logfiles.

NMEA Directory - optional

You can specify a ‘NMEA directory’ to save daily NMEA files with Point Positioning results recorded as NMEA sentences. Such sentences are usually generated about once per second with pairs of

- GPGGA sentences which mainly carry the estimated latitude, longitude, and height values, plus
- GPRMC sentences which mainly carry date and time information.

The following is an example for an NMEA output file from BNC:

```
$GPRMC,112348,A,3200.233,S,11553.688,E,,,300615,,*A
$GPGGA,112348,3200.2332035,S,11553.6880127,E,1,13,1.4,23.971,M,0.0,M,,*5D
$GPRMC,112349,A,3200.233,S,11553.688,E,,,300615,,*B
$GPGGA,112349,3200.2332035,S,11553.6880127,E,1,13,1.4,23.971,M,0.0,M,,*5C
$GPRMC,112350,A,3200.233,S,11553.688,E,,,300615,,*3
$GPGGA,112350,3200.2332035,S,11553.6880127,E,1,13,1.4,23.971,M,0.0,M,,*54
$GPRMC,112351,A,3200.233,S,11553.688,E,,,300615,,*2
$GPGGA,112351,3200.2332035,S,11553.6880127,E,1,13,1.4,23.971,M,0.0,M,,*55
$GPRMC,112352,A,3200.233,S,11553.688,E,,,300615,,*1
$GPGGA,112352,3200.2332035,S,11553.6880127,E,1,13,1.4,23.971,M,0.0,M,,*56
$GPRMC,112353,A,3200.233,S,11553.688,E,,,300615,,*0
```

```
$GPGGA,112353,3200.2332035,S,11553.6880127,E,1,13,1.4,23.971,M,0.0,M,,*57
$GPRMC,112354,A,3200.233,S,11553.688,E,,,300615,,*7
$GPGGA,112354,3200.2332035,S,11553.6880127,E,1,13,1.4,23.971,M,0.0,M,,*50
$GPRMC,112355,A,3200.233,S,11553.688,E,,,300615,,*6
$GPGGA,112355,3200.2332035,S,11553.6880127,E,1,13,1.4,23.971,M,0.0,M,,*51
$GPRMC,112356,A,3200.233,S,11553.688,E,,,300615,,*5
$GPGGA,112356,3200.2332035,S,11553.6880127,E,1,13,1.4,23.971,M,0.0,M,,*52
...
```

The default value for 'NMEA directory' is an empty option field, meaning that BNC will not save NMEA sentences into files. If a specified directory does not exist, BNC will not create NMEA files. Note that Tomoji Takasu has written a program named RTKPLOT for visualizing NMEA sentences from IP ports or files. It is available from http://www.rtklib.com and compatible with the 'NMEA Directory' and port output of BNC's 'PPP' client option.

SNX TRO Directory - optional

BNC estimates the tropospheric delay according to equation

$$T(z) = T_{apr}(z) + dT/cos(z)$$

where T_{apr} is the a priori tropospheric delay derived from Saastamoinen model.

You can specify a 'SNX TRO Directory' for saving SINEX Troposphere files on disk, see https://igscb.jpl.nasa.gov/igscb/data/format/sinex_tropo.txt for a documentation of the file format. Note that receiver type information for these files must be provided through the coordinates file described in section 'Coordinates file'. The following is an example for a troposphere file content:

```
 %=TRO 2.00 BKG 16:053:42824 BKG 16:053:42824 16:053:43199 P 00376 0  T
 +FILE/REFERENCE
  DESCRIPTION        BNC generated SINEX TRO file
  OUTPUT             Total Troposphere Zenith Path Delay Product
  SOFTWARE           BNC 2.12
  INPUT              Ntrip streams, additional Orbit and Clock information from
 ↪  IGS03
 -FILE/REFERENCE

+SITE/ID
 *CODE PT DOMES____ T _STATION DESCRIPTION__ APPROX_LON_ APPROX_LAT_ _APP_H_
  CUT0  A           P AUS                    115 53 41.3 -32  0 14.0    24.0
 -SITE/ID

 +SITE/RECEIVER
 *SITE PT SOLN T DATA_START__ DATA_END____ DESCRIPTION_________ S/N__ FIRMWARE___
  CUT0  A 0001 P 16:053:42824 16:053:43199 TRM59800.00     SCIS ----- -----------
 -SITE/RECEIVER

 +SITE/ANTENNA
 *SITE PT SOLN T DATA_START__ DATA_END____ DESCRIPTION_________ S/N__
  CUT0  A 0001 P 16:053:42824 16:053:43199 TRM59800.00     SCIS -----
 -SITE/ANTENNA

 +SITE/ECCENTRICITY
 *                                             UP______ NORTH___ EAST____
 *SITE PT SOLN T DATA_START__ DATA_END____ AXE ARP->BENCHMARK(M)_________
  CUT0  A 0001 P 16:053:42824 16:053:43199 UNE   0.0000   0.0000   0.0000
 -SITE/ECCENTRICITY

 +TROP/COORDINATES
 *SITE PT SOLN T STA_X_______ STA_Y_______ STA_Z_______ SYSTEM REMARK
  CUT0  A 0001 P -2364337.441  4870285.605 -3360809.628 ITRF08 BKG
```

```
-TROP/COORDINATES

+TROP/DESCRIPTION
*KEYWORD________________________ VALUE(S)_______________
 SAMPLING INTERVAL                                     1
 SAMPLING TROP                                         1
 ELEVATION CUTOFF ANGLE                                7
 TROP MAPPING FUNCTION          Saastamoinen
 SOLUTION_FIELDS_1              TROTOT STDEV
-TROP/DESCRIPTION

+TROP/SOLUTION
*SITE EPOCH________ TROTOT STDEV
 CUT0 16:053:42824    0.0   0.0
 CUT0 16:053:42825 2401.7 100.0
 CUT0 16:053:42826 2401.8 100.0
 CUT0 16:053:42827 2401.8  99.9
 CUT0 16:053:42828 2402.1  99.9
...
...
-TROP/SOLUTION
%=ENDTROP
```

The default value for 'SNX TRO Directory' is an empty option field, meaning that BNC will not save SINEX Troposphere files. If a specified directory does not exist, BNC will not create SINEX Troposphere files.

SNX TRO Interval - mandatory if 'SINEX TRO Directory' is set

Select the length of SINEX Troposphere files. Default 'Interval' for saving SINEX Troposphere files on disk is '1 day'.

SNX TRO Sampling - mandatory if 'SINEX TRO Directory' is set

Select a 'Sampling' rate in seconds for saving troposphere parameters. Default 'Sampling' rate is '0', meaning that all troposphere estimates will be saved on disk.

SNX TRO Analysis Center - Mandatory if 'SINEX TRO Directory' is set

Specify a 3-character abbreviation describing you as the generating Analysis Center (AC) in your SINEX troposphere files. String 'BKG' is an example.

SNX TRO Solution ID - Mandatory if 'SINEX TRO Directory' is set

Specify a 4-character solution ID to allow a distingtion between different solutions per AC. String '0001' is an example.

5.13.2 PPP (2): Processed Stations

This panel allows to enter parameters specific to each PPP process or thread. Individual sigmas for a priori coordinates and a noise for coordinate variations over time can be introduced. Furthermore, a sigma for model-based troposphere estimates and the corresponding noise for troposphere variations can be specified. Finally, local IP server ports can be defined for output of NMEA streams carrying PPP results.

BNC offers to create a table with one line per PPP process or thread to specify station-specific parameters. Hit the 'Add Station' button to create the table or add a new line to it. To remove a line from the table, highlight it by clicking it and hit the 'Delete Station' button. You can also remove multiple lines simultaneously by highlighting them using +Shift or +Ctrl. BNC will simultaneously produce PPP solutions for all stations listed in the 'Station' column of this table, see Fig. 5.19) for an example screenshot.

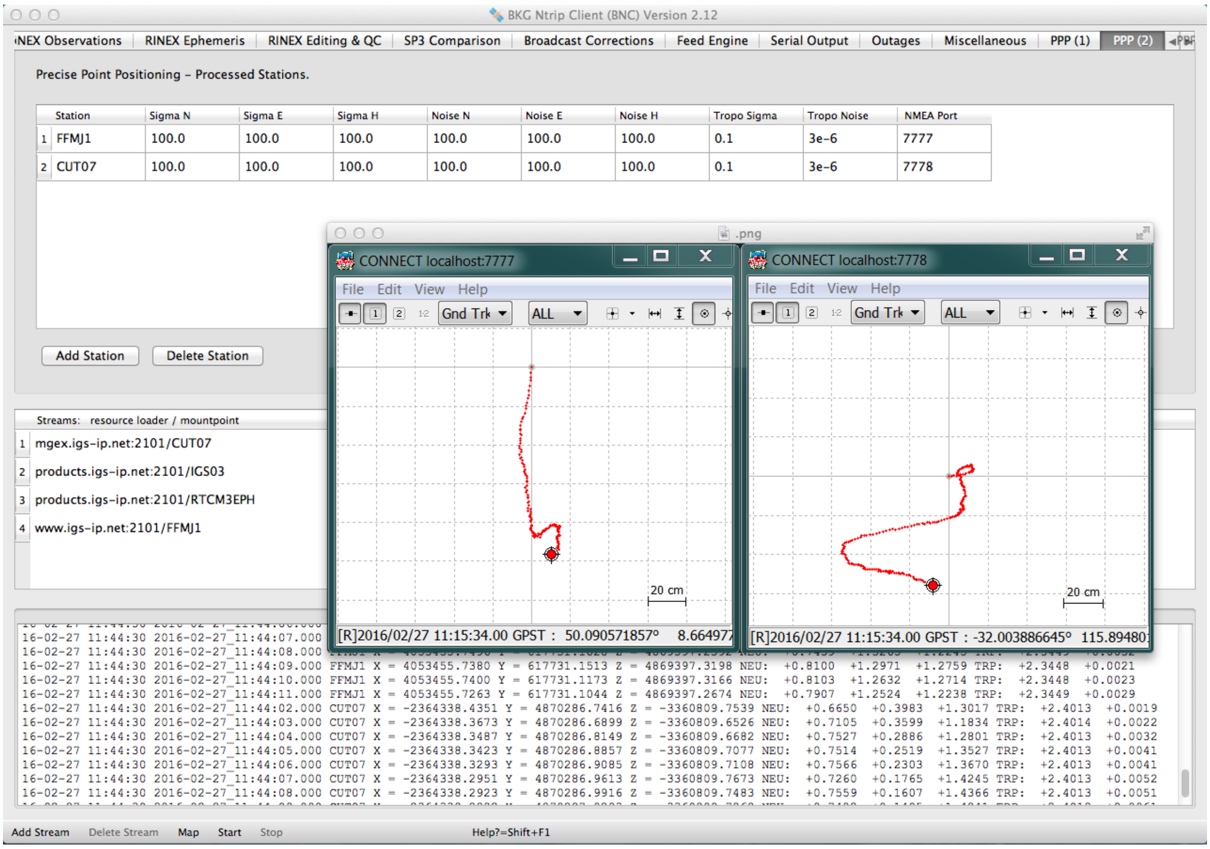


Fig. 5.19: Precise Point Positioning with BNC, PPP Panel 2, using RTKPLOT for visualization

Station - mandatory

Hit the 'Add Station' button, double click on the 'Station' field, then specify an observation's mountpoint from the 'Streams' section or introduce the 4-character Station ID of your RINEX observation file and hit Enter. BNC will only produce PPP solutions for stations listed in this table.

Sigma North/East/Up - mandatory

Enter sigmas in meters for the initial coordinate components. A value of 100.0 (default) may be an appropriate choice. However, this value may be significantly smaller (e.g. 0.01) when starting for example from a station with a well-known position in so-called Quick-Start mode.

Noise North/East/Up - mandatory

Enter a white 'Noise' in meters for estimated coordinate components. A value of 100.0 (default) may be appropriate when considering possible sudden movements of a rover.

Tropo Sigma - mandatory

Enter a sigma in meters for the a priori model based tropospheric delay estimation. A value of 0.1 (default) may be an appropriate choice.

Tropo Noise - mandatory

Enter a white 'Noise' in meters per second to describe the expected variation of the tropospheric effect. Supposing 1Hz observation data, a value of 3e-6 (default) would mean that the tropospheric effect may vary for 3600 * 3e-6 = 0.01 meters per hour.

NMEA Port - optional

Specify the IP port number of a local port where Point Positioning results become available as NMEA sentences. The default value for 'NMEA Port' is an empty option field, meaning that BNC does not provide NMEA sentences via IP port. Note that NMEA file output and NMEA IP port output are the same.

Note also that Tomoji Takasu has written a program named RTKPLOT for visualizing NMEA sentences from IP ports or files. It is available from http://www.rtklib.com and compatible with the NMEA file and port output of BNC's 'PPP' client option.

Furthermore, NASA's 'World Wind' software (see http://worldwindcentral.com/wiki/NASA_World_Wind_Download) can be used for real-time visualization of positions provided through BNC's NMEA IP output port. You need the 'GPS Tracker' plug-in available from http://worldwindcentral.com/wiki/GPS_Tracker for that. The 'Word Wind' map resolution is not meant for showing centimeter level details.

5.13.3 PPP (3): Processing Options

BNC allows using various Point Positioning processing options depending on the capability of the involved receiver and the application in mind. You can introduce specific sigmas for code and phase observations as well as for a priori coordinates and troposphere estimates. You could also carry out your PPP solution in Quick-Start mode or enforce BNC to restart a solution if the length of an outage exceeds a certain threshold. The intention of this panel is to specify general processing options to be applied to all PPP threads in one BNC job, see Fig. 5.20 for an example setup.

Linear Combinations - mandatory

Specify on which ionosphere-free Linear Combinations (LCs) of observations you want to base ambiguity resolutions *[9]*. This implicitly defines the kind of GNSS observations you want to use. The specification is to be done per GNSS system ('GPS LCs', 'GLONASS LCs', 'Galileo LCs', 'BDS LCs').

- Selecting 'P3' means that you request BNC to use code data and the so-called P3 ionosphere-free linear combinations of code observations.
- 'P3&L3' means that you request BNC to use both, code and phase data and the so-called P3 and L3 ionosphere-free linear combinations of code and phase observations.

Note that most geodetic GPS receivers support the observation of both, code and phase data. Hence, specifying 'P3&L3' would be a good choice for GPS when processing data from such a receiver. If multi-GNSS data processing is your intention, make sure your receiver supports GLONASS and/or Galileo and/or BDS observations besides GPS. Note also that the Broadcast Correction stream or file, which is required for PPP, also supports all the systems you have in mind.

Specifying 'no' means that you do not at all want BNC to use observations from the affected GNSS system.

Code Observations - mandatory

Enter a 'Sigma C1' for C1 code observations in meters. The bigger the sigma you enter, the less the contribution of C1 code observations to a PPP solution based on a combination of code and phase data. '2.0' meters is likely to be an appropriate choice. Specify a maximum for residuals 'Max Res C1' for C1 code observations in a PPP solution. '3.0' meters may be an appropriate choice for that. If the maximum is exceeded, contributions from the corresponding observation will be ignored in the PPP solution.

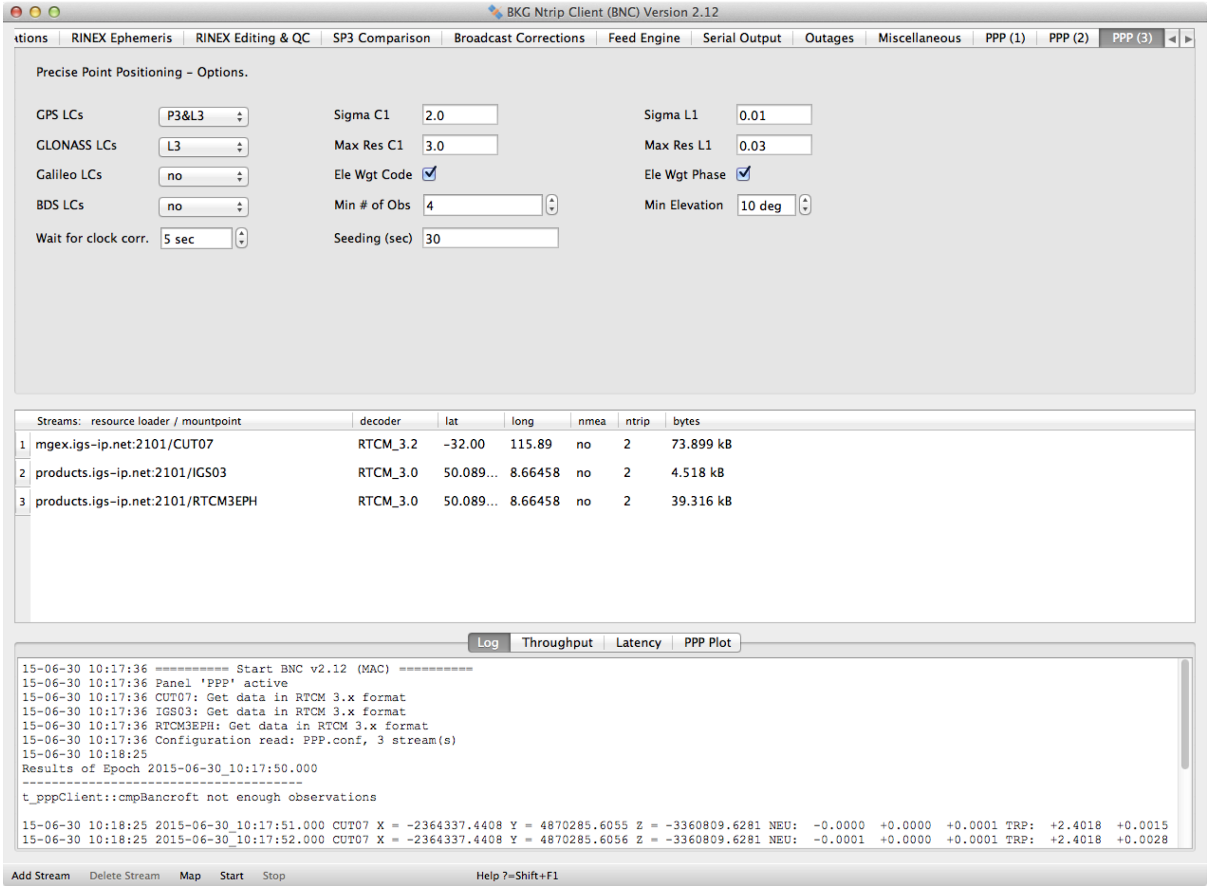


Fig. 5.20: Precise Point Positioning with BNC, PPP Panel 3

Phase Observations - mandatory

Enter a ‘Sigma L1’ for L1 phase observations in meters. The bigger the sigma you enter, the less the contribution of L1 phase observations to a PPP solutions based on a combination of code and phase data. ‘0.01’ meters is likely to be an appropriate choice. Specify a maximum for residuals ‘Max Res L1’ for L1 phase observations in a PPP solution. ‘0.03’ meters may be an appropriate choice for that. If the maximum is exceeded, contributions from the corresponding observation will be ignored in the PPP solution.

As the convergence characteristic of a PPP solution can be influenced by the ratio of sigmas for code and phase, you may like to introduce sigmas which differ from the default values:

- Introducing a smaller sigma (higher accuracy) for code observations or a bigger sigma for phase observations leads to better results shortly after program start. However, it may take more time until you finally get the best possible solution.
- Introducing a bigger sigma (lower accuracy) for code observations or a smaller sigma for phase observations may lead to less accurate results shortly after program start and thus a prolonged period of convergence but could provide better positions in the long run.

Elevation Dependent Weighting - mandatory

BNC allows elevation dependent weighting when processing GNSS observations. A weight function

$$P = cos^2 * z$$

with z being the zenith distance to the involved satellite can be applied instead of the simple weight function ‘P = 1’ independent from satellite elevation angles:

- Tick ‘Ele Wgt Code’ if you want Elevation Dependent Weighting for code observations.
- Tick ‘Ele Wgt Phase’ if you want Elevation Dependent Weighting for phase observations.

Default is using the plain weight function ‘P = 1’ for code and phase observations.

Minimum Number of Observations - mandatory

Select the minimum number of observations you want to use per epoch. The minimum for parameter ‘Min # of Obs’ is 4. This is also the default.

Minimum Elevation - mandatory

Select a minimum for satellite elevation angles. Selecting ‘10 deg’ for option ‘Min Elevation’ may be an appropriate choice. Default is ‘0 deg’, meaning that any observation will be used regardless of the involved satellite elevation angle.

Wait for Clock Corrections - optional

Specifying ‘no’ for option ‘Wait for clock corr.’ means that BNC processes each epoch of data immediately after arrival using satellite clock corrections available at that time. A non-zero value means that epochs of data are buffered and the processing of each epoch is postponed until satellite clock corrections not older than ‘Wait for clock corr.’ seconds are available. Specifying a value of half the update rate of the clock corrections (e.g. 5 sec) may be appropriate. Note that this causes an additional delay of the PPP solutions in the amount of half of the update rate.

Using observations in sync with the corrections can avoid a possible high frequency noise of PPP solutions. Such noise could result from processing observations regardless of how late after a clock correction they were received. Note that applying the ‘Wait for clock corr.’ option significantly reduces the PPP computation effort for BNC.

Default is an empty option field, meaning that you want BNC to process observations immediately after their arrival through applying the latest received clock correction.

Seeding - optional if a priori coordinates specified in ‘Coordinates file’

Enter the length of a startup period in seconds for which you want to fix the PPP solution to a known position, see option ‘Coordinates file’. Constraining a priori coordinates is done in BNC through setting their white ‘Noise’ temporarily to zero.

This so-called Quick-Start option allows the PPP solutions to rapidly converge after startup. It requires that the antenna remains unmoved on the known position throughout the defined period. A value of ‘60’ seconds is likely to be an appropriate choice for ‘Seeding’. Default is an empty option field, meaning that you do not want BNC to start in Quick-Start mode.

You may need to create your own reference coordinate beforehand through running BNC for an hour in normal mode before applying the ‘Seeding’ option. Do not forget to introduce realistic North/East/Up sigmas under panel ‘PPP (2)’ corresponding to the coordinate’s precision.

‘Seeding’ has also a function for bridging gaps in PPP solutions from failures caused e.g. by longer lasting outages. Should the time span between two consecutive solutions exceed the limit of 60 seconds (maximum solution gap, hard-wired), the algorithm fixes the latest derived coordinate for a period of ‘Seeding’ seconds. This option avoids time-consuming reconvergences and makes especially sense for stationary operated receivers where convergence can be enforced because a good approximation for the receiver position is known.

Fig. 5.21 provides the screenshot of an example PPP session with BNC showing the beginning of a time series plot when seeding is set to 30 seconds..

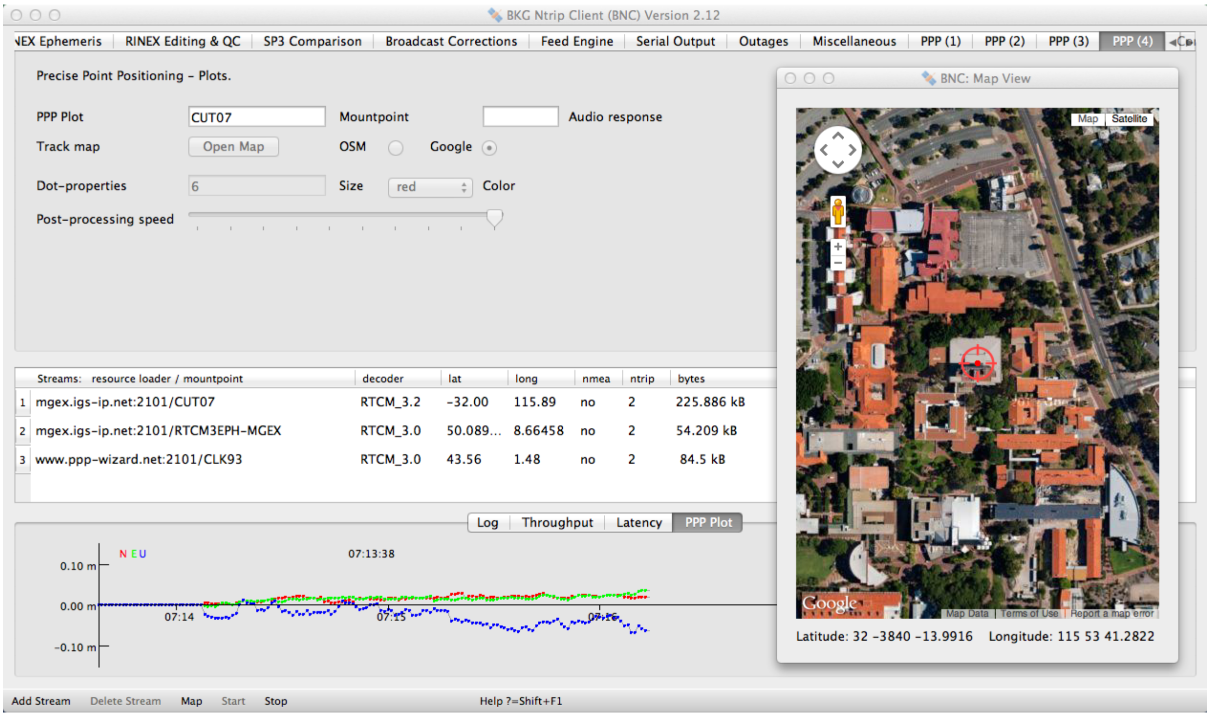


Fig. 5.21: Precise Point Positioning with BNC in 'Quick-Start' mode, PPP Panel 4

5.13.4 PPP (4): Plots

This panel presents options for visualizing PPP results as a time series plot or as a track map with PPP tracks on top of OSM or Google maps.

PPP Plot - optional

PPP time series of North (red), East (green) and Up (blue) displacements will be plotted under the 'PPP Plot' tab when a 'Mountpoint' is specified. Values will be referred to an XYZ reference coordinate (if specified, see 'Coordinates file'). The sliding PPP time series window will cover the period of the latest 5 minutes. Note that a PPP dicplacements time series makes only sense for a stationary operated receiver.

Audio Response - optional

For natural hazard prediction and monitoring landslides, it may be appropriate to generate audio alerts. For that you can specify an 'Audio response' threshold in meters. A beep is produced by BNC whenever a horizontal PPP coordinate component differs by more than the threshold value from the specified marker coordinate. Default is an empty option field, meaning that you do not want BNC to produce acoustic warnings.

Track Map - optional

You may like to track your rover position using Google Maps or OpenStreetMap as a background map. Track maps (example Fig. 5.22) can be produced with BNC in 'Real-time Streams' mode or in 'RINEX Files' post processing mode with data coming from files.

Google/OSM - mandatory before pushing 'Open Map'

Select either 'Google' or 'OSM' as the background map for your rover positions (Fig. 5.23).

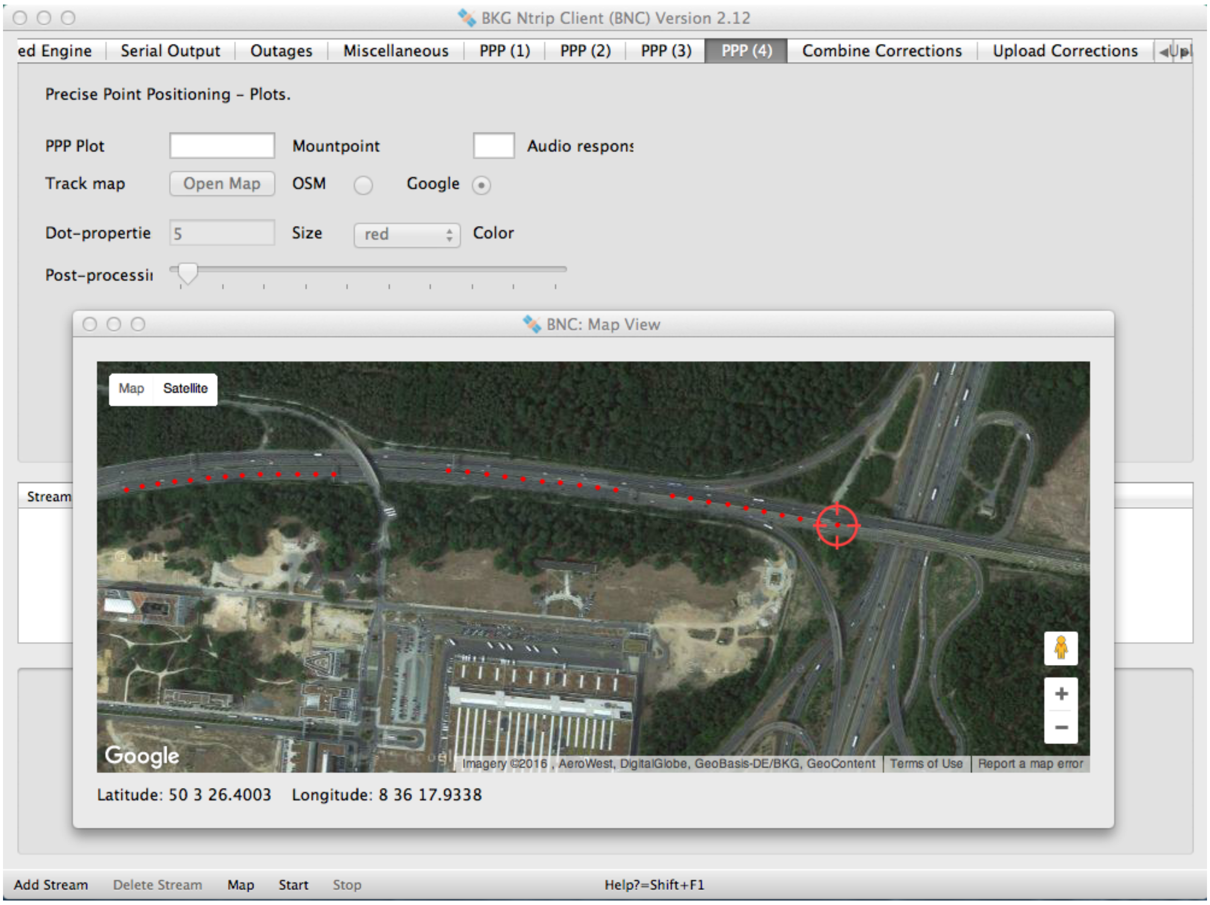


Fig. 5.22: Track of positions from BNC with Google Maps in background

Dot-properties - mandatory before pushing 'Open Map'

PPP tracks are presented on maps through plotting one colored dot per observation epoch.

Size - mandatory before pushing 'Open Map'

Specify the size of dots showing the rover position. A dot size of '3' may be appropriate. The maximum possible dot size is '10'. An empty option field or a size of '0' would mean that you do not want BNC to show the rover's track on the map.

Color - mandatory before pushing 'Open Map'

Select the color of dots showing the rover track.

Post Processing Speed - mandatory before pushing 'Open Map'

With BNC in PPP 'RINEX File' post processing mode, you can specify the speed of computations as appropriate for visualization. Note that you can adjust 'Post-processing speed' on-the-fly while BNC is already processing your observations.

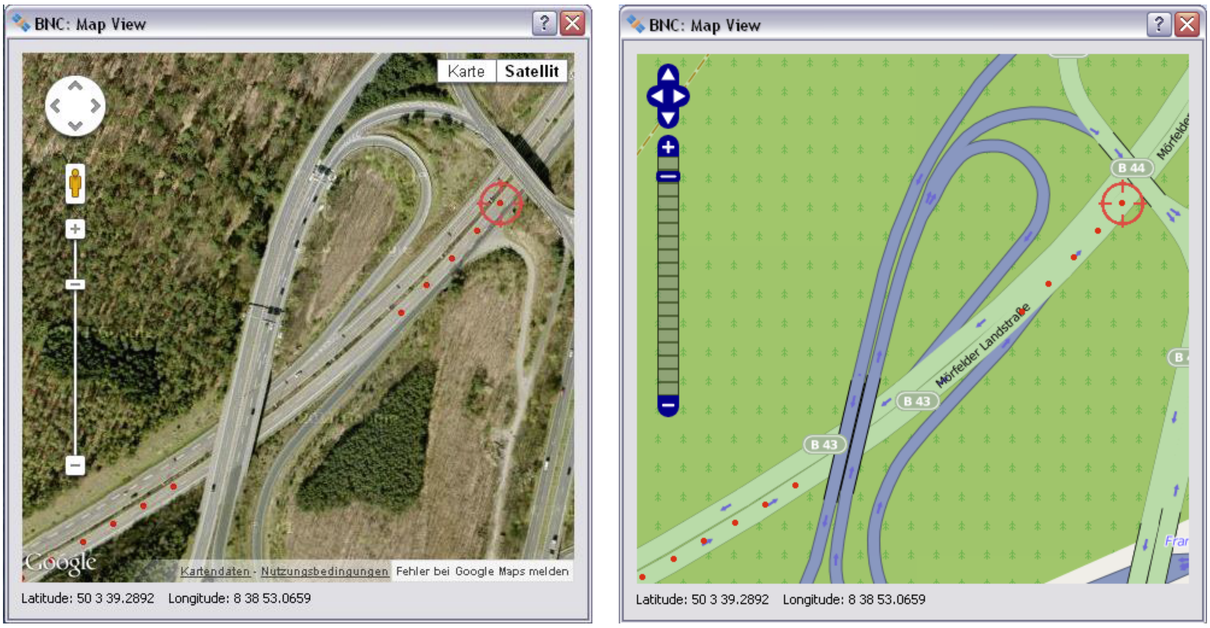


Fig. 5.23: Example for background map from Google Maps and OpenStreetMap (OSM)

5.14 Combine Corrections

BNC allows processing several orbit and clock correction streams in real-time to produce, encode, upload and save a combination of Broadcast Corrections from various providers. All corrections must refer to satellite Antenna Phase Centers (APC). It is so far only the satellite clock corrections which are combined by BNC while orbit corrections in the combination product as well as product update rates are just taken over from one of the incoming Broadcast Correction streams. Combining only clock corrections using a fixed orbit reference imposes the potential to introduce some analysis inconsistencies. We may therefore eventually consider improvements on this approach. The clock combination can be based either on a plain 'Single-Epoch' or on a Kalman 'Filter' approach.

In the Kalman Filter approach, satellite clocks estimated by individual Analyses Centers (ACs) are used as pseudo observations within the adjustment process. Each observation is modeled as a linear function (actually a simple sum) of three estimated parameters: AC specific offset, satellite specific offset common to all ACs, and the actual satellite clock correction, which represents the result of the combination. These three parameter types differ in their statistical properties. The satellite clock offsets are assumed to be static parameters while AC specific and satellite specific offsets are stochastic parameters affected by white noise.

The solution is regularized by a set of minimal constraints. In case of a change of the 'SSR Provider ID', 'SSR Solution ID', or 'IOD SSR' (see section 'Upload Corrections'), the satellite clock offsets belonging to the corresponding analysis center are reset in the adjustment.

Removing the AC-dependent biases as well as possible is a major issue with clock combinations. Since they vary in time, it can be tricky to do this. Otherwise, there will be artificial jumps in the combined clock stream if one or more AC contributions drop out for certain epochs. Here the Kalman Filter approach is expected to do better than the Single-Epoch approach.

In view of IGS real-time products, the 'Combine Corrections' functionality has been integrated in BNC *[10]* because:

- The software with its Graphic User Interface and range of supported Operating Systems represents a perfect platform to process many Broadcast Correction streams in parallel;
- Outages of single AC product streams can be mitigated through merging several incoming streams into a combined product;
- Generating a combination product from several AC products allows detecting and rejecting outliers;

- A Combination Center (CC) can operate BNC to globally disseminate a combination product via Ntrip broadcast;
- An individual AC could prefer to disseminate a stream combined from primary and backup IT resources to reduce outages;
- It enables a BNC PPP user to follow his own preference in combining streams from individual ACs for Precise Point Positioning;
- It allows an instantaneous quality control of the combination process not only in the time domain but also in the space domain; this can be done by direct application of the combined stream in a PPP solution even without prior upload to an Ntrip Broadcaster;
- It provides the means to output SP3 and Clock RINEX files containing precise orbit and clock information for further processing using other tools than BNC.

Note that the combination process requires real-time access to Broadcast Ephemeris. Therefore, in addition to the orbit and clock correction streams BNC must pull a stream carrying Broadcast Ephemeris in the form of RTCM Version 3 messages. Stream 'RTCM3EPH' on caster products.igs-ip.net is an example for that. Note further that BNC will ignore incorrect or outdated Broadcast Ephemeris data when necessary, leaving a note 'WRONG EPHEMERIS' or 'OUTDATED EPHEMERIS' in the logfile.

A combination is carried out following a specified sampling interval. BNC waits for incoming Broadcast Corrections for the period of one such interval. Corrections received later than that will be ignored. If incoming streams have different rates, only epochs that correspond to the sampling interval are used.

With respect to IGS, it is important to understand that a major effect in the combination of GNSS orbit and clock correction streams is the selection of ACs to include. It is likely that a combination product could be improved in accuracy by using only the best two or three ACs. However, with only a few ACs to depend on, the reliability of the combination product could suffer and the risk of total failures increases. So there is an important tradeoff here that must be considered when selecting streams for a combination. The major strength of a combination product is its reliability and stable median performance which can be much better than that of any single AC product.

This comment applies in situations where we have a limited number of solutions to combine and their quality varies significantly. The situation may be different when the total number of ACs is larger and the range of AC variation is smaller. In that case, a standard full combination is probably the best.

The following recursive algorithm is used to detect orbit outliers in the Kalman Filter combination when Broadcast Corrections are provided by several ACs:

1. We do not produce a combination for a certain satellite if only one AC provides corrections for it.
2. A mean satellite position is calculated as the average of positions from all ACs.
3. For each AC and satellite, the 3D distance between individual and mean satellite position is calculated.
4. We find the greatest difference between AC specific and mean satellite positions.
5. If that is less than a threshold, the conclusion is that we do not have an outlier and can proceed to the next epoch.
6. If that is greater than a threshold, then corrections of the affiliated AC are ignored for the affected epoch and the outlier detection restarts with 1.

The screenshot in Fig. 5.24 shows an example setup of BNC when combining Broadcast Correction streams CLK11, CLK21, CLK91, and CLK80.

Note that BNC can produce an internal PPP solution from combined Broadcast Corrections. For that you have to specify the keyword 'INTERNAL' as 'Corrections stream' in the PPP (1) panel. The example in Fig. 5.25 combines correction streams IGS01 and IGS02 and simultaneously carries out a PPP solution with observations from stream FFMJ1 to allow monitoring the quality of the combination product in the space domain.

5.14.1 Combine Corrections Table - optional

Hit the 'Add Row' button, double click on the 'Mountpoint' field, enter a Broadcast Correction mountpoint from the 'Streams' section and hit Enter. Then double click on the 'AC Name' field to enter your choice of an abbrevi-

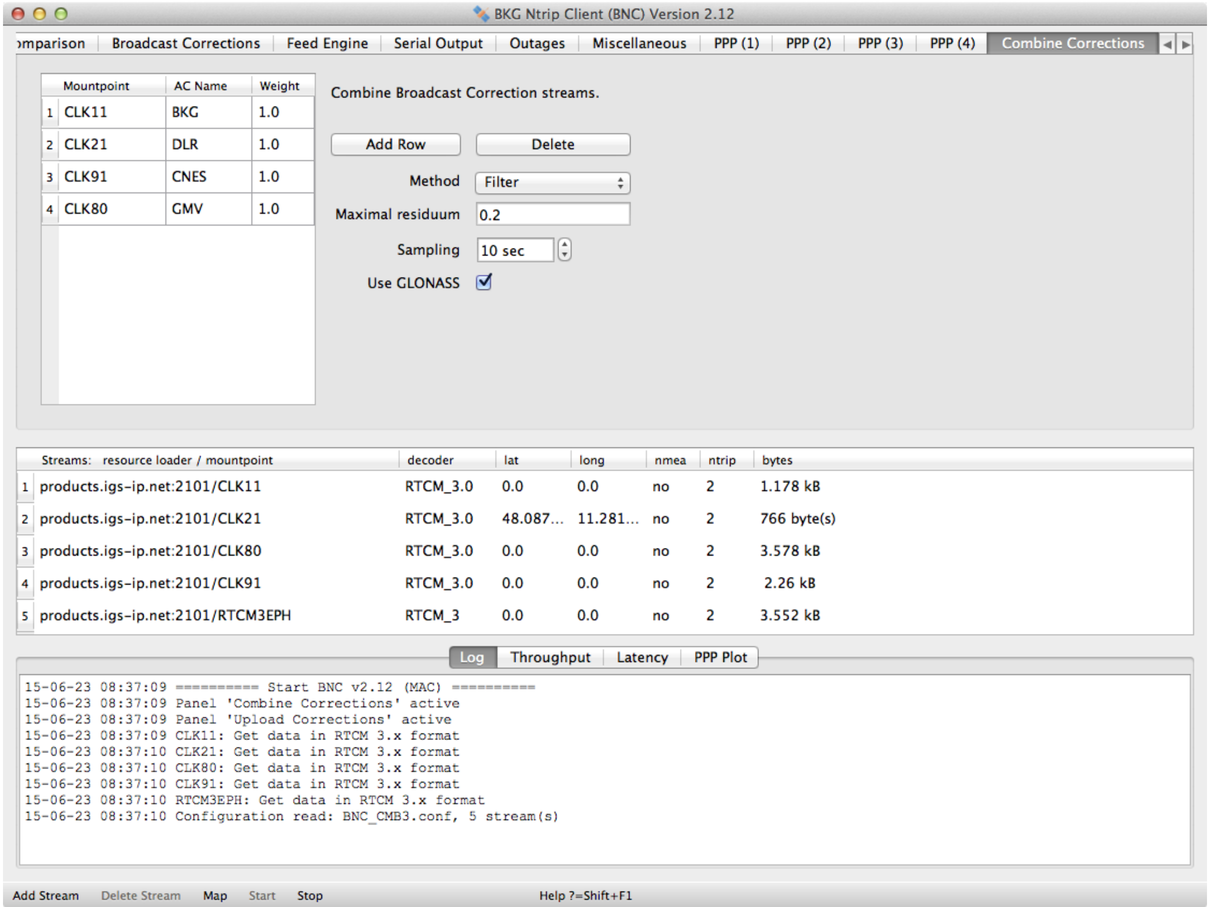


Fig. 5.24: BNC combining Broadcast Correction streams

ation for the Analysis Center (AC) providing the Antenna Phase Center (APC) related correction stream. Finally, double click on the 'Weight' field to enter a weight to be applied to this stream in the combination.

The sequence of entries in the 'Combine Corrections' table is not of importance. Note that the orbit information in the final combination stream is just copied from one of the incoming streams. The stream used for providing the orbits may vary over time: if the orbit-providing stream has an outage then BNC switches to the next remaining stream for getting hold of the orbit information.

It is possible to specify only one Broadcast Ephemeris correction stream in the 'Combine Corrections' table. Instead of combining corrections from several sources, BNC will then merge the single corrections stream with Broadcast Ephemeris to allow saving results in SP3 and/or Clock RINEX format when specified accordingly under the 'Upload Corrections' panel. Note that in such a BNC application you must not pull more than one Broadcast Ephemeris correction stream even if a second stream would provide the same corrections from a backup caster.

Default is an empty 'Combine Corrections' table, meaning that you do not want BNC to combine orbit and clock correction streams.

5.14.2 Add Row, Delete - optional

Hit 'Add Row' button to add another row to the 'Combine Corrections' table or hit the 'Delete' button to delete the highlighted row(s).

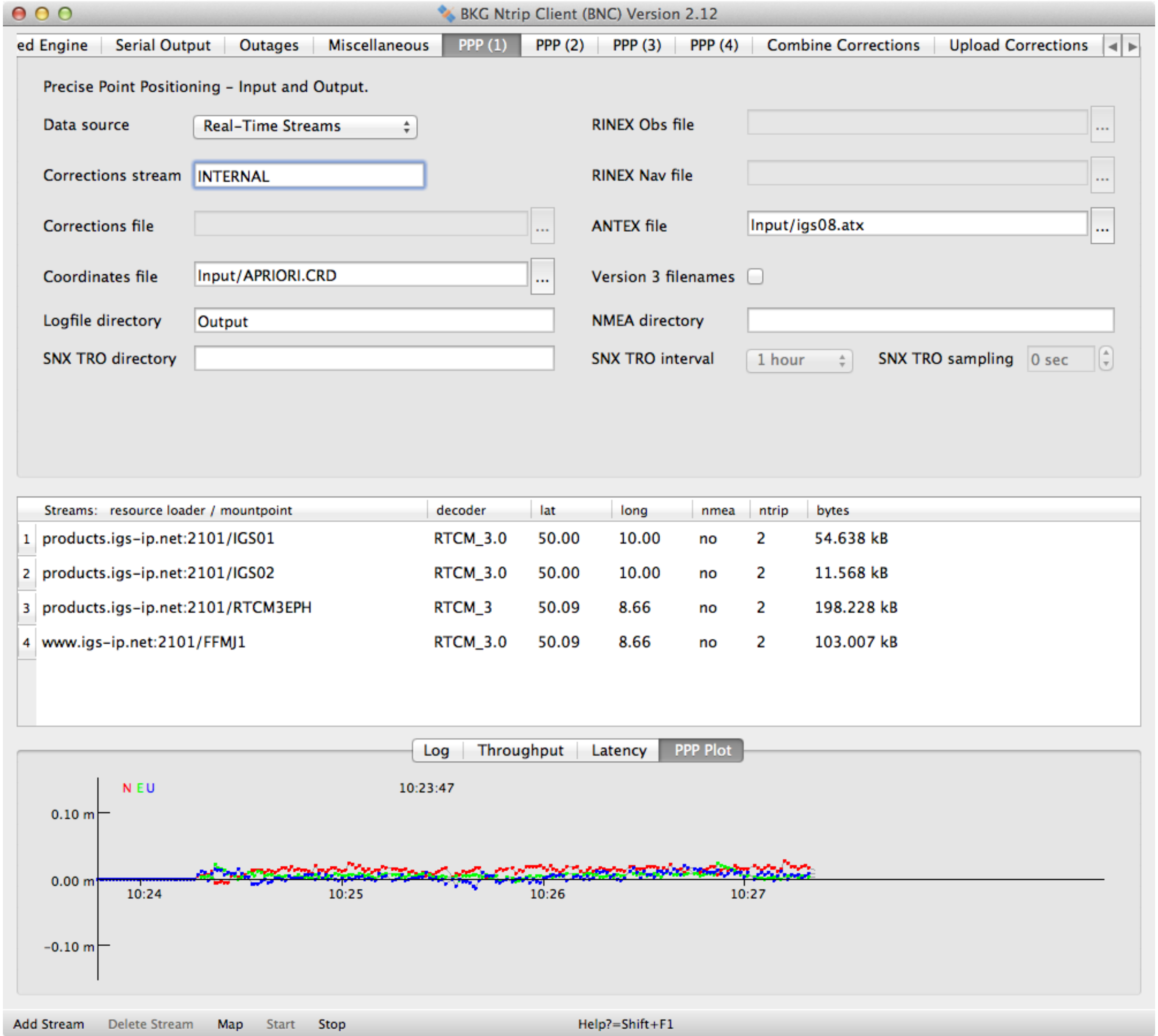


Fig. 5.25: 'INTERNAL' PPP with BNC using a combination of Broadcast Corrections

5.14.3 Method - mandatory if 'Combine Corrections' table is populated

Select a clock combination method. Available options are Kalman 'Filter' and 'Single-Epoch. It is suggested to use the Kalman Filter approach in case the combined stream of Broadcast Corrections is intended for Precise Point Positioning.

5.14.4 Maximal Residuum - mandatory if 'Combine Corrections' table is populated

BNC combines all incoming clocks according to specified weights. Individual clock estimates that differ by more than 'Maximal Residuum' meters from the average of all clocks will be ignored. It is suggested to specify a value of about 0.2 m for the Kalman Filter combination approach and a value of about 3.0 meters for the Single-Epoch combination approach. Default is a 'Maximal Residuum' of 999.0 meters.

5.14.5 Sampling - mandatory if 'Combine Corrections' table is populated

Specify a combination sampling interval. Orbit and clock corrections will be produced following that interval. A value of 10 sec may be an appropriate choice.

5.14.6 Use GLONASS - optional

You may tick the 'Use GLONASS' option in case you want to produce a GPS plus GLONASS combination and both systems are supported by the Broadcast Correction streams participating in the combination.

5.15 Upload Corrections

BNC can upload streams carrying orbit and clock corrections to Broadcast Ephemeris in radial, along-track and out-of-plane components if they are:

1. either generated by BNC as a combination of several individual Broadcast Correction streams coming from an number of real-time Analysis Centers (ACs), see section 'Combine Corrections',
2. or generated by BNC while the program receives an ASCII stream of precise satellite orbits and clocks via IP port from a connected real-time GNSS engine. Such a stream would be expected in a plain ASCII format and the associated 'decoder' string would have to be 'RTNET', see format description below.

The procedure taken by BNC to generate the orbit and clock corrections to Broadcast Ephemeris and upload them to an Ntrip Broadcaster is as follow:

- Continuously receive up-to-date Broadcast Ephemeris carrying approximate orbits and clocks for all satellites. Read new Broadcast Ephemeris immediately whenever they become available. This information may come via a stream of RTCM messages generated from another BNC instance.

Then, epoch by epoch:

- Continuously receive the best available orbit and clock estimates for all satellites in XYZ Earth-Centered-Earth-Fixed IGS08 reference system. Receive them every epoch in plain ASCII format as provided by a real-time GNSS engine such as RTNET or generate them following a combination approach.
- Calculate XYZ coordinates from Broadcast Ephemeris orbits.
- Calculate differences dX,dY,dZ between Broadcast Ephemeris and IGS08 orbits.
- Transform these differences into radial, along-track and out-of-plane corrections to Broadcast Ephemeris orbits.
- Calculate corrections to Broadcast Ephemeris clocks as differences between Broadcast Ephemeris clocks and IGS08 clocks.
- Encode Broadcast Ephemeris orbit and clock corrections in RTCM Version 3 format.
- Upload Broadcast Correction stream to Ntrip Broadcaster.

The orbit and clock corrections to Broadcast Ephemeris are usually referred to the latest set of broadcast messages, which are generally also received in real-time by a GNSS rover. However, the use of the latest broadcast message is delayed for a period of 60 seconds, measured from the time of complete reception of ephemeris and clock parameters, in order to accommodate rover applications to obtain the same set of broadcast orbital and clock parameters. This procedure is recommended in the RTCM SSR standard. Because the stream delivery process may put a significant load on the communication link between BNC and the real-time GNSS engine, it is recommended to run both programs on the same host. However, doing so is not compulsory.

The usual handling of BNC when uploading a stream with Broadcast Corrections is that you first specify Broadcast Ephemeris and Broadcast Correction streams. You then specify an Ntrip Broadcaster for stream upload before you start the program.

'RTNET' Stream Format

When uploading an SSR stream generated according to 2. then BNC requires precise GNSS orbits and clocks in the IGS Earth-Centered-Earth-Fixed (ECEF) reference system and in a specific ASCII format named 'RTNET' because the data may come from a real-time engine such as RTNET. The sampling interval for data transmission should not exceed 15 sec. Note that otherwise tools involved in IP streaming such as Ntrip Broadcasters or Ntrip Clients may respond with a timeout.

Below you find an example for the 'RTNET' ASCII format coming from a real-time GNSS engine. Each epoch begins with an asterisk character followed by the time as year, month, day of month, hour, minute and second. Subsequent records can provide

```
* 2015 6 11 15 10 40.000000
```

Subsequent records can provide

- Satellite specific parameters

A set of parameters can be defined for each satellite as follows:

```
<SatelliteID> <key> <numValues> <value1 value2 ...>
              <key> <numValues> <value1 value2 ...> ...
```

The satellite specific keys and values currently specified for that in BNC are listed in Table 5.9.

Table 5.9: Keys for satellite specific parameters used in BNC.

KeyName	Values
APC	Satellite Antenna Phase Center coordinates in meters
Clk	Satellite clock correction in meters, relativistic correction applied like in broadcast clocks
Vel	Satellite velocity in meters per second
CoM	Satellite Center of Mass coordinates in meters
CodeBias	Satellite Code Biases in meters with two characters for frequency and tracking mode per bias as defined in RINEX 3 and preceded by total number of biases
YawAngle	Satellite Yaw Angle in radian, restricted to be in $[0, 2\pi]$ which shall be used for the computation of phase wind-up correction
YawRate	Satellite Yaw Rate in radian per second which is the rate of Yaw Angle
PhaseBias	Satellite Phase Biases in meters with two characters for frequency and tracking mode per bias as defined in RINEX 3, preceded by total number of biases and followed by Signal Integer Indicator, Signals Wilde-Lane Integer Indicator as well as Signal Discontinuity Counter

- Non-satellite specific parameters

The following syntax will be used:

```
<key> <value1 value2 ...>
```

The non-satellite specific keys and values currently specified in BNC are listed in Table 5.10.

Table 5.10: Keys for non-satellite specific parameters used in BNC.

KeyName	Values
IND	Phase bias information followed by Dispersive Bias Consistency Indicator and MW Consistency Indicator
VTEC	Vertical TEC information followed by Update Interval and Number of Ionospheric Layers

If key VTEC is specified, a data set for each layer contains within its first line the Layers Number, followed by Maximum Degree, Maximum Order and Layer Height. After that, Cosine and Sinus Spherical Harmonic Coefficients will follow, one block each.

Because each keyword is associated to a certain number of values, an 'old' BNC could be operated with an incoming 'new' RTNET stream containing so far unknown keys - they would just be skipped in BNC.

Example for 'RTNET' stream content and format:

```
* 2015 6 11 15 10 40.000000
VTEC 0 1 0 6 6 450000.0 20.4660 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 5.3590
 ↪ 9.6580 0.0000 0.0000 0.0000 0.0000 0.0000 -6.3610 -0.1210 1.1050 0.0000 0.0000
 ↪ 0.0000 0.0000 -2.7140 -1.8200 -0.9920 -0.6430 0.0000 0.0000 0.0000 1.9140
 ↪ -0.5180 0.2530 0.0870 -0.0110 0.0000 0.0000 2.2950 1.0510 -0.9540 0.6220
 ↪ -0.0720 -0.0810 0.0000 -0.9760 0.7570 0.2320 -0.2520 0.1970 -0.0680 -0.0280
 ↪ 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.2720 0.0000 0.0000
 ↪ 0.0000 0.0000 0.0000 0.0000 1.1100 -1.0170 0.0000 0.0000 0.0000 0.0000 0.0000
 ↪ -1.1500 0.5440 0.9890 0.0000 0.0000 0.0000 0.0000 -0.3770 -0.1990 0.2670
 ↪ -0.0470 0.0000 0.0000 0.0000 0.6550 -0.0130 -0.2310 -0.4810 -0.3510 0.0000
 ↪ 0.0000 0.2360 -0.0710 0.0280 0.1900 -0.0810 0.0710
IND 0 1
G01 APC 3   -14442611.532   -13311059.070   -18020998.395 Clk 1   -1426.920500 Vel
 ↪ 3  2274.647600   -28.980300 -1787.861900 CoM 3   -14442612.572   -13311059.518
 ↪ -18020999.539 CodeBias 6 1W -3.760000 1C -3.320000 2W -6.200000 2X -5.780000 1H
 ↪ -3.350000 5I -5.430000 YawAngle 1 -0.315600 YawRate 1 0.0 PhaseBias 3 1C
 ↪ 3.9473 1 2 4 2W  6.3143 1 2 4 5I 6.7895 1 2 4
G02 APC 3    -8859103.160    14801278.856    20456920.800 Clk 1  171219.083500 Vel
 ↪ 3 -2532.296700  -161.275800 -1042.884100 CoM 3    -8859103.418    14801279.287
 ↪ 20456921.395 CodeBias 6 1W  3.930000 1C  3.610000 2W  6.480000 2X  0.000000 1H
 ↪ 3.580000 5I  0.000000 YawAngle 1 -0.693500 YawRate 1 0.0 PhaseBias 2 1C -4.0902
 ↪ 1 2 4 2W -6.7045 1 2 4
G03 APC 3   -13788295.679   -22525098.353     2644811.508 Clk 1  104212.074300 Vel
 ↪ 3   102.263400  -429.953400 -3150.231900 CoM 3   -13788296.829   -22525099.534
 ↪ 2644811.518 CodeBias 6 1W -2.650000 1C -2.160000 2W -4.360000 2X -4.480000 1H
 ↪ -2.070000 5I -5.340000 YawAngle 1 -0.428800 YawRate 1 0.0 PhaseBias 3 1C
 ↪ 2.9024 1 2 2 2W  4.6124 1 2 2 5I 5.3694 1 2 2
...
R01 APC 3    -6783489.153   -23668850.753     6699094.457 Clk 1 - 45875.658100 Vel
 ↪ 3  -267.103000  -885.983700 -3403.253200 CoM 3    -6783489.307   -23668853.173
 ↪ 6699095.274 CodeBias 4 1P -2.496400 1C -2.490700 2P -4.126600 2C -3.156200
R02 APC 3   -11292959.022   -10047039.425    20577343.288 Clk 1   41215.750900 Vel
 ↪ 3  -476.369400 -2768.936600 -1620.000600 CoM 3   -11292959.672   -10047040.710
 ↪ 20577345.344 CodeBias 4 1P  0.211200 1C  0.391300 2P  0.349100 2C  0.406300
R03 APC 3    -9226469.614     9363128.850    21908853.313 Clk 1   13090.322800 Vel
 ↪ 3  -369.088600 -2964.934500  1111.041000 CoM 3    -9226470.226     9363129.442
 ↪ 21908855.791 CodeBias 4 1P  2.283800 1C  2.483800 2P  3.775300 2C  3.785500
...
E11 APC 3     2965877.898    17754418.441    23503540.946 Clk 1   33955.329000 Vel
 ↪ 3 -1923.398100  1361.709200  -784.555800 CoM 3     2965878.082    17754418.669
 ↪ 23503541.507 CodeBias 3 1B  1.382100 5Q  2.478400 7Q  2.503300
E12 APC 3   -14807433.144    21753389.581    13577231.476 Clk 1 -389652.211900 Vel
 ↪ 3 -1082.464300   825.868400 -2503.982200 CoM 3   -14807433.366    21753389.966
 ↪ 13577231.926 CodeBias 3 1B  0.386600 5Q  0.693300 7Q  0.534700
E19 APC 3   -15922225.351     8097517.292    23611910.403 Clk 1   -2551.650800 Vel
 ↪ 3  -183.377800 -2359.143700   684.105100 CoM 3   -15922225.569     8097517.329
 ↪ 23611910.995 CodeBias 3 1B -1.777000 5Q -3.186600 7Q -3.069100
...
EOE
```

Note that the end of an epoch in the incoming stream is indicated by an ASCII string 'EOE' (for End Of Epoch).

When using clocks from Broadcast Ephemeris (with or without applied corrections) or clocks from SP3 files, it may be important to understand that they are not corrected for the conventional periodic relativistic effect. Chapter 10 of the IERS Conventions 2003 mentions that the conventional periodic relativistic correction to the satellite clock (to be added to the broadcast clock) is computed as

$$dt = -2(R * V)/c^2$$

where $R * V$ is the scalar product of the satellite position and velocity and c is the speed of light. This can also be found in the GPS Interface Specification, IS-GPS-200, Revision D, 7 March 2006.

5.15.1 Add, Delete Row - optional

Hit 'Add Row' button to add a row to the stream 'Upload Table' or hit the 'Delete' button to delete the highlighted row(s). Having an empty 'Upload Table' is default and means that you do not want BNC to upload orbit and clock correction streams to any Ntrip Broadcaster.

5.15.2 Host, Port, Mountpoint, Password - optional

Specify the domain name or IP number of an Ntrip Broadcaster for uploading the stream. Furthermore, specify the caster's listening IP port, an upload mountpoint and an upload password. Note that Ntrip Broadcasters are often configured to provide access through more than one port, usually ports 80 and 2101. If you experience communication problems on port 80, you should try to use the alternative port(s).

BNC uploads a stream to the Ntrip Broadcaster by referring to a dedicated mountpoint that has been set by its operator. Specify the mountpoint based on the details you received for your stream from the operator. It is often a 4-character ID (capital letters) plus an integer number.

The stream upload may be protected through an upload 'Password'. Enter the password you received from the Ntrip Broadcaster operator along with the mountpoint(s).

If 'Host', 'Port', 'Mountpoint' and 'Password' are set, the stream will be encoded in RTCM's 'State Space Representation' (SSR) messages and uploaded to the specified broadcaster following the Ntrip Version 1 transport protocol.

5.15.3 System - mandatory if 'Host' is set

BNC allows configuring several Broadcast Correction streams for upload so that they refer to different reference systems and different Ntrip Broadcasters. You may use this functionality for parallel support of a backup Ntrip Broadcaster or for simultaneous support of various regional reference systems. Available options for transforming orbit and clock corrections to specific target reference systems are:

- IGS08 which stands for the GNSS-based IGS realization of the International Terrestrial Reference Frame 2008 (ITRF2008), and
- ETRF2000 which stands for the European Terrestrial Reference Frame 2000 adopted by EUREF, and
- NAD83 which stands for the North American Datum 1983 as adopted for the U.S.A., and
- GDA94 which stands for the Geodetic Datum Australia 1994 as adopted for Australia, and
- SIRGAS2000 which stands for the Geodetic Datum adopted for Brazil, and
- SIRGAS95 which stands for the Geodetic Datum adopted e.g. for Venezuela, and
- DREF91 which stands for the Geodetic Datum adopted for Germany, and
- 'Custom' which allows a transformation of Broadcast Corrections from the IGS08 system to any other system through specifying up to 14 Helmert Transformation Parameters.

Because a mathematically strict transformation to a regional reference system is not possible on the BNC server side when a scale factor is involved, the program follows an approximate solution. While orbits are transformed in full accordance with given equations, a transformed clock is derived through applying correction term

$$dC = (s - 1)/s * \rho/c$$

where s is the transformation scale, c is the speed of light, and is the topocentric distance between an (approximate) center of the transformation's validity area and the satellite.

From a theoretical point of view, this kind of approximation leads to inconsistencies between orbits and clocks and is therefore not allowed *[11]*. However, it has been proved that resulting errors in Precise Point Positioning are on millimeter level for horizontal components and below one centimeter for height components. The Australian GDA94 transformation with its comparatively large scale parameter is an exception in this as discrepancies may reach up there to two centimeters.

IGS08: As the orbits and clocks coming from real-time GNSS engine are expected to be in the IGS08 system, no transformation is carried out if this option is selected.

ETRF2000: The formulas for the transformation 'ITRF2008->ETRF2000' are taken from 'Claude Boucher and Zuheir Altamimi 2008: Specifications for reference frame fixing in the analysis of EUREF GPS campaign', see http://etrs89.ensg.ign.fr/memo-V8.pdf. The following 14 Helmert Transformation Parameters were introduced:

```
Translation in X at epoch To:  0.0521 m
Translation in Y at epoch To:  0.0493 m
Translation in Z at epoch To: -0.0585 m
Translation rate in X:  0.0001 m/y
Translation rate in Y:  0.0001 m/y
Translation rate in Z: -0.0018 m/y
Rotation in X at epoch To:  0.891 mas
Rotation in Y at epoch To:  5.390 mas
Rotation in Z at epoch To: -8.712 mas
Rotation rate in X:  0.081 mas/y
Rotation rate in Y:  0.490 mas/y
Rotation rate in Z: -0.792 mas/y
Scale at epoch To : 0.00000000134
Scale rate: 0.00000000008 /y
To: 2000.0
```

NAD83: Formulas for the transformation 'ITRF2008->NAD83' are taken from *[12]*:

```
Translation in X at epoch To:  0.99343 m
Translation in Y at epoch To: -1.90331 m
Translation in Z at epoch To: -0.52655 m
Translation rate in X:  0.00079 m/y
Translation rate in Y: -0.00060 m/y
Translation rate in Z: -0.00134 m/y
Rotation in X at epoch To: -25.91467 mas
Rotation in Y at epoch To:  -9.42645 mas
Rotation in Z at epoch To: -11.59935 mas
Rotation rate in X: -0.06667 mas/y
Rotation rate in Y:  0.75744 mas/y
Rotation rate in Z:  0.05133 mas/y
Scale at epoch To : 0.00000000171504
Scale rate: -0.00000000010201 /y
To: 1997.0
```

GDA94: The formulas for the transformation 'ITRF2008->GDA94' are taken from *[13]*:

```
Translation in X at epoch To: -0.08468 m
Translation in Y at epoch To: -0.01942 m
Translation in Z at epoch To:  0.03201 m
Translation rate in X:  0.00142 m/y
Translation rate in Y:  0.00134 m/y
Translation rate in Z:  0.00090 m/y
Rotation in X at epoch To:  0.4254 mas
Rotation in Y at epoch To: -2.2578 mas
Rotation in Z at epoch To: -2.4015 mas
Rotation rate in X: -1.5461 mas/y
Rotation rate in Y: -1.1820 mas/y
Rotation rate in Z: -1.1551 mas/y
Scale at epoch To : 0.000000009710
Scale rate: 0.000000000109 /y
To: 1994.0
```

SIRGAS2000: The formulas for the transformation 'ITRF2008->SIRGAS2000' were provided by *[14]*:

```
Translation in X at epoch To:  0.0020 m
Translation in Y at epoch To:  0.0041 m
```

```
Translation in Z at epoch To:  0.0039 m
Translation rate in X:  0.0000 m/y
Translation rate in Y:  0.0000 m/y
Translation rate in Z:  0.0000 m/y
Rotation in X at epoch To:  0.170 mas
Rotation in Y at epoch To: -0.030 mas
Rotation in Z at epoch To:  0.070 mas
Rotation rate in X:  0.000 mas/y
Rotation rate in Y:  0.000 mas/y
Rotation rate in Z:  0.000 mas/y
Scale at epoch To : -0.000000001000
Scale rate: 0.000000000000 /y
To: 0000.0
```

SIRGAS95: The formulas for the transformation 'ITRF2005->SIRGAS95' were provided by *[15]* , parameters based on values from *[16]*, Table 4.1:

```
Translation in X at epoch To:  0.0077 m
Translation in Y at epoch To:  0.0058 m
Translation in Z at epoch To: -0.0138 m
Translation rate in X:  0.0000 m/y
Translation rate in Y:  0.0000 m/y
Translation rate in Z:  0.0000 m/y
Rotation in X at epoch To:  0.000 mas
Rotation in Y at epoch To:  0.000 mas
Rotation in Z at epoch To: -0.003 mas
Rotation rate in X:  0.000 mas/y
Rotation rate in Y:  0.000 mas/y
Rotation rate in Z:  0.000 mas/y
Scale at epoch To : 0.00000000157
Scale rate: -0.000000000000 /y
To: 1995.4
```

DREF91 14 Helmert transformation parameters have been introduced *[17]*:

```
Translation in X at epoch To: -0.0118 m
Translation in Y at epoch To:  0.1432 m
Translation in Z at epoch To: -0.1117 m
Translation rate in X:  0.0001 m/y
Translation rate in Y:  0.0001 m/y
Translation rate in Z: -0.0018 m/y
Rotation in X at epoch To:   3.291 mas
Rotation in Y at epoch To:   6.190 mas
Rotation in Z at epoch To: -11.012 mas
Rotation rate in X:  0.081 mas/y
Rotation rate in Y:  0.490 mas/y
Rotation rate in Z: -0.792 mas/y
Scale at epoch To : 0.00000001224
Scale rate: 0.00000000008 /y
To: 2000.0
```

Custom: Feel free to specify your own 14 Helmert Transformation parameters for transformations from IGS08/ITRF2008 into your own target system (see Fig. 5.26).

5.15.4 Center of Mass - optional

BNC allows to either refer Broadcast Corrections to the satellite's Center of Mass (CoM) or to the satellite's Antenna Phase Center (APC). By default, corrections refer to APC. Tick 'Center of Mass' to refer uploaded corrections to CoM.

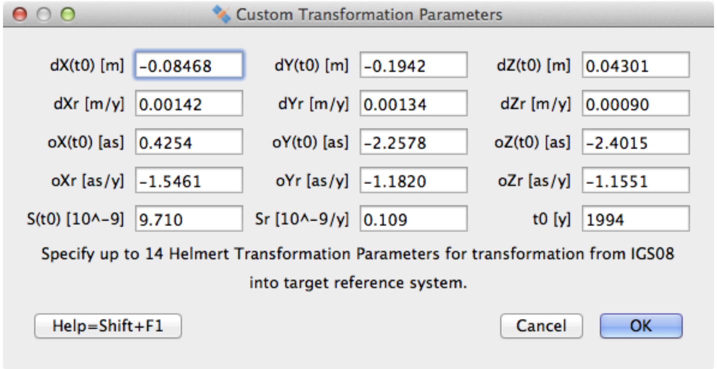


Fig. 5.26: Setting BNC's Custom Transformation Parameters window, example for 'ITRF2008->GDA94'

5.15.5 SP3 File - optional

Specify a path for saving the generated orbit corrections as SP3 orbit files. If the specified directory does not exist, BNC will not create SP3 orbit files. The following is a path example for a Linux system:

```
/home/user/BNC${GPSWD}.sp3
```

Note that '${GPSWD}' produces the GPS Week and Day number in the filename. Default is an empty option field, meaning that you do not want BNC to save the uploaded stream content in daily SP3 files.

As a SP3 file content should be referred to the satellites' Center of Mass (CoM) while Broadcast Corrections are referred to the satellites' APC, an offset has to be applied which is available from an IGS ANTEX file (see option 'ANTEX File' below). Hence, you should specify the 'ANTEX File' path there if you want to save the stream content in SP3 format. If you do not specify an 'ANTEX File' path, the SP3 file content will be referred to the satellites APCs.

The filenames for the daily SP3 files follow the convention for SP3 filenames. The first three characters of each filename are set to 'BNC'. Note that clocks in the SP3 orbit files are not corrected for the conventional periodic relativistic effect.

In case the 'Combine Corrections' table contains only one Broadcast Correction stream, BNC will merge that stream with Broadcast Ephemeris to save results in files specified here through SP3 and/or Clock RINEX file path. In such a case you have to define only the SP3 and Clock RINEX file path and no further option in the 'Upload Corrections' table.

Note that BNC outputs a complete list of SP3 'Epoch Header Records', even if no 'Position and Clock Records' are available for certain epochs because of stream outages. Note further that the 'Number of Epochs' in the first SP3 header record may not be correct because that number is not available when the file is created. Depending on your processing software (e.g. Bernese GNSS Software, BSW) it could therefore be necessary to correct an incorrect 'Number of Epochs' in the file before you use it in post processing.

5.15.6 RNX File - optional

The clock corrections generated by BNC for upload can be logged in Clock RINEX format. The file naming follows the RINEX convention.

Specify a path for saving the generated clock corrections as Clock RINEX files. If the specified directory does not exist, BNC will not create Clock RINEX files. The following is a path example for a Linux system:

```
/home/user/BNC${GPSWD}.clk
```

Note that '${GPSWD}' produces the GPS Week and Day number in the filename. Note further that clocks in the Clock RINEX files are not corrected for the conventional periodic relativistic effect.

5.15.7 PID, SID, IOD - optional

When applying Broadcast Ephemeris corrections in a PPP algorithm or in a combination of several correction streams, it is important for the client software to receive information on the continuity of discontinuity of the stream contents. Here you can specify three ID's to describe the contents of your Broadcast Ephemeris correction stream when it is uploaded.

- A 'SSR Provider ID' is issued by RTCM SC-104 on request to identify a SSR service (see e.g. url{http://software.rtcm-ntrip.org/wiki/SSRProvider}). This ID is globally unique. Values vary in the range of 0-65535. Values in the range of 0-255 are reserved for experimental services.
- A provider may generate several Broadcast Ephemeris correction streams with different contents. The 'SSR Solution ID' indicates different SSR services of one SSR provider. Values vary in the range of 0-15.
- A change of the 'IOD SSR' is used to indicate a change in the SSR generating configuration which may be relevant for the rover. Values vary in the range of 0-15.

5.15.8 Interval - mandatory if 'Upload Table' entries specified

Select the length of Clock RINEX files and SP3 Orbit files. The default value is 1 day.

5.15.9 Sampling

BNC requires an orbit corrections sampling interval for the stream to be uploaded and sampling intervals for SP3 and Clock RINEX files. The outgoing stream's clock correction sampling interval follows that of incoming corrections and is therefore nothing to be specified here.

Orbits (Orb) - mandatory if 'Upload Table' entries specified

Select the stream's orbit correction sampling interval in seconds. A value of 60 sec may be appropriate. A value of zero '0' tells BNC to upload all orbit correction samples coming in from the real-time GNSS engine along with the clock correction samples to produce combined orbit and clock corrections to Broadcast Ephemeris (1060 for GPS, 1066 for GLONASS).

Configuration examples:

Let us suppose a real-time network engine supporting BNC every 5 sec with GPS Broadcast Corrections for orbits, clocks and code biases in 'RTNET' stream format:

With 'Sampling Orb' set to '0' BNC will produce

- Every 5 sec a 1059 message for GPS code biases,
- Every 5 sec a 1060 message for combined orbit and clock corrections to GPS Broadcast Ephemeris.

With 'Sampling Orb' set to '5' BNC will produce

- Every 5 sec a 1057 message for GPS orbit corrections to Broadcast Ephemeris,
- Every 5 sec a 1058 message for GPS clock corrections to Broadcast Ephemeris,
- Every 5 sec a 1059 message for GPS code biases.

With 'Sampling Orb' set to '10' BNC will produce

- Every 10 sec a 1057 message for GPS orbit corrections to Broadcast Ephemeris,
- Every 5 sec a 1058 message for GPS clock corrections to Broadcast Ephemeris,
- Every 5 sec a 1059 message for GPS code biases.

Note that only when specifying a value of zero '0' (default) for 'Sampling Orb', BNC produces combined orbit and clock correction messages.

SP3 - mandatory if 'SP3 File' is specified

Select the SP3 orbit file sampling interval in minutes. A value of 15 min may be appropriate. A value of zero '0' tells BNC to store all available samples into SP3 orbit files.

RINEX (RNX) - mandatory if 'RNX File' is specified

Select the Clock RINEX file sampling interval in seconds. A value of 10 sec may be appropriate. A value of zero '0' tells BNC to store all available samples into Clock RINEX files.

5.15.10 Custom Trafo - optional if 'Upload Table' entries specified

Hit 'Custom Trafo' to specify your own 14 parameter Helmert Transformation instead of selecting a predefined transformation through 'System' button.

5.15.11 ANTEX File - mandatory if 'SP3 File' is specified

IGS provides a file containing absolute phase center variations for GNSS satellite and receiver antennas in ANTEX format. Entering the full path to such an ANTEX file is required here for referring the SP3 file content to the satellite's Center of Mass (CoM). If you do not specify an ANTEX file, the SP3 file will contain orbit information which is referred to Antenna Phase Center (APC) instead of CoM.

The screenshot in Fig. 5.27 shows the encoding and uploading of a stream of precise orbits and clocks coming from a real-time network engine in 'RTNET' ASCII format. The stream is uploaded to Ntrip Broadcaster 'products.igs-ip.net'. It is referred to APC and IGS08. Uploaded data are locally saved in SP3 and Clock RINEX format. The SSR Provider ID is set to 3. The SSR Solution ID and the Issue of Data SSR are set to 1. Required Broadcast Ephemeris are received via stream 'RTCM3EPH'.

The screenshot in Fig. 5.28 shows the encoding and uploading of several Broadcast Ephemeris correction streams combined from streams CLK11, CLK21, CLK80, and CLK91. Combined streams are uploaded to different Ntrip Broadcasters and referred to different reference systems. One of the uploaded streams is locally saved in SP3 and Clock RINEX format. Different SSR Provider IDs, SSR Solution IDs and Issue of Data IDs are specified. Required Broadcast Ephemeris are received via stream 'RTCM3EPH'.

5.16 Upload Ephemeris

BNC can generate a stream carrying only Broadcast Ephemeris in RTCM Version 3 format and upload it to an Ntrip Broadcaster (Fig. 5.29). Note that Broadcast Ephemeris received in real-time have a system specific period of validity in BNC which is defined in accordance with the update rates of the navigation messages.

- GPS ephemeris will be interpreted as outdated and ignored when older than 4 hours.
- GLONASS ephemeris will be interpreted as outdated and ignored when older than 1 hour.
- Galileo ephemeris will be interpreted as outdated and ignored when older than 4 hours.
- BDS ephemeris will be interpreted as outdated and ignored when older than 6 hours.
- SBAS ephemeris will be interpreted as outdated and ignored when older than 10 minutes.
- QZSS ephemeris will be interpreted as outdated and ignored when older than 4 hours.

A note 'OUTDATED EPHEMERIS' will be given in the logfile and the data will be disregarded when necessary. Furthermore, received Broadcast Ephemeris parameters pass through a plausibility check in BNC which allows to ignore incorrect ephemeris data when necessary, leaving a note 'WRONG EPHEMERIS' in the logfile.

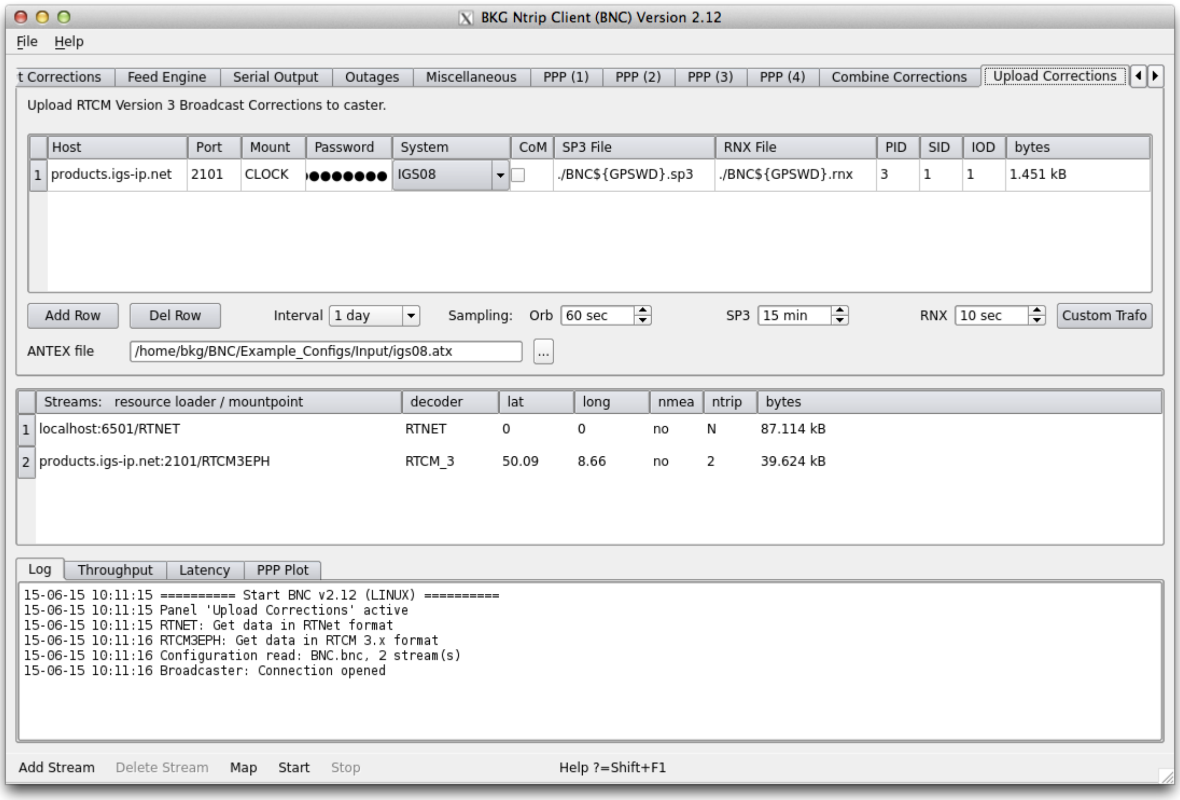


Fig. 5.27: BNC producing Broadcast Corrections from incoming precise orbits and clocks and uploading them to an Ntrip Broadcaster

5.16.1 Host & Port - optional

Specify the 'Host' IP number or URL of an Ntrip Broadcaster to upload the stream. An empty option field means that you do not want to upload Broadcast Ephemeris. Enter the Ntrip Broadcaster's IP 'Port' number for stream upload. Note that Ntrip Broadcasters are often configured to provide access through more than one port, usually ports 80 and 2101. If you experience communication problems on port 80, you should try to use the alternative port(s).

5.16.2 Mountpoint & Password - mandatory if 'Host' is set

BNC uploads a stream to the Ntrip Broadcaster by referring it to a dedicated mountpoint that has been set by its operator. Specify the mountpoint based on the details you received for your stream from the operator. It is often a 4-character ID (capital letters) plus an integer number. The stream upload follows Ntrip Version 1 and may be protected through an upload 'Password'. Enter the password you received from the Ntrip Broadcaster operator along with the mountpoint.

5.16.3 Sampling - mandatory if 'Host' is set

Select the Broadcast Ephemeris repetition interval in seconds. Default is '5', meaning that a complete set of Broadcast Ephemeris is uploaded every 5 seconds.

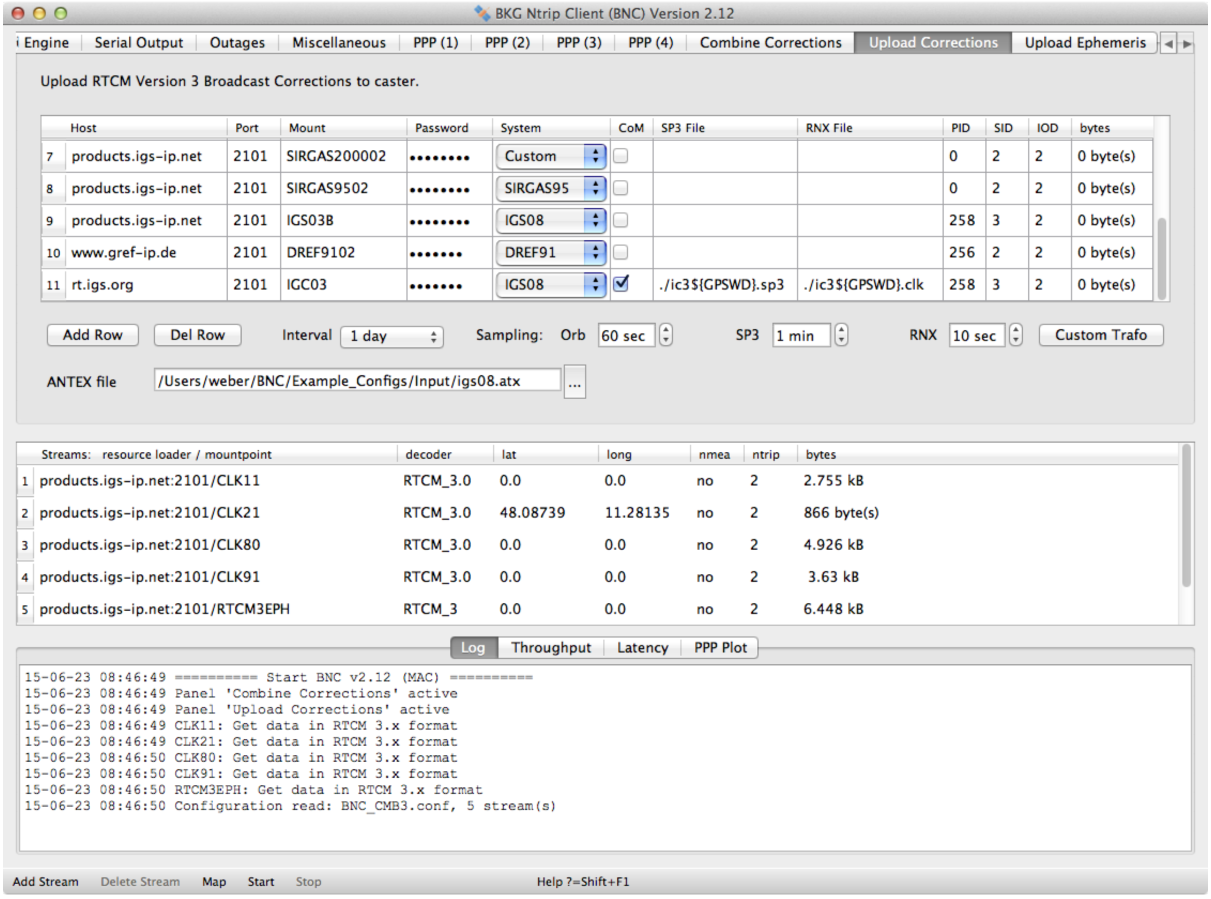


Fig. 5.28: BNC uploading a combined Broadcast Correction stream

5.17 Streams Canvas

Each stream on an Ntrip Broadcaster (and consequently on BNC) is defined using a unique source ID called mountpoint. An Ntrip Client like BNC accesses the desired stream by referring to its mountpoint. Information about streams and their mountpoints is available through the source-table maintained by the Ntrip Broadcaster. Streams selected for retrieval are listed under the 'Streams' canvas on BNC's main window. The list provides the following information either extracted from source-table(s) produced by the Ntrip Broadcasters or introduced by BNC's user (Table 5.11).

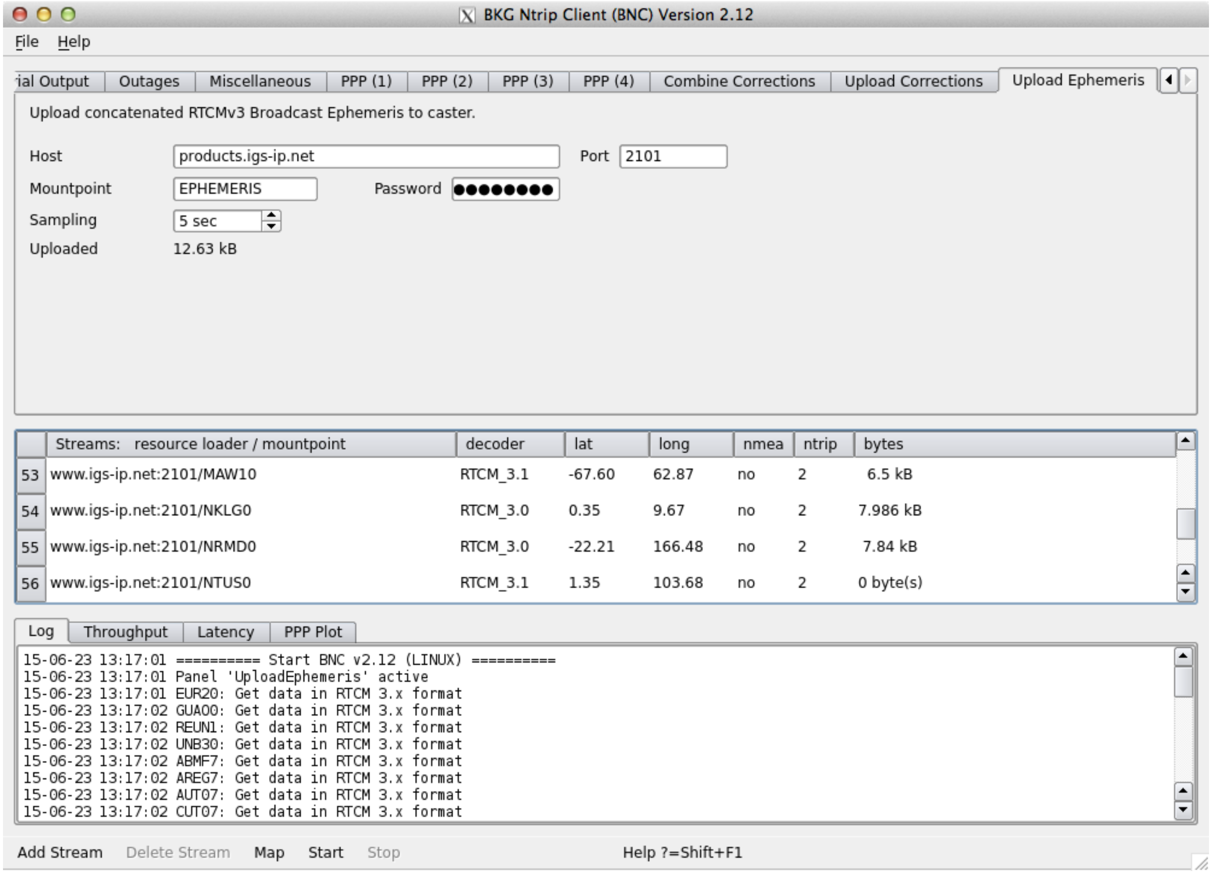


Fig. 5.29: BNC producing a Broadcast Ephemeris stream from navigation messages of globally distributed RTCM streams and uploading them in RTCM Version 3 format to an Ntrip Broadcaster

Table 5.11: Source table information listed in BNCs Stream Canvas.

Keyword	Meaning
resource loader	Ntrip Broadcaster URL and port, or TCP/IP host and port, or UDP port, or Serial input port specification.
mountpoint	Mountpoint introduced by Ntrip Broadcaster, or Mountpoint introduced by BNC's user.
decoder	Name of decoder used to handle the incoming stream content according to its format; editable.
lat	Approximate latitude of reference station, in degrees, north; editable if 'nmea' = 'yes'.
long	Approximate longitude of reference station, in degrees, east; editable if 'nmea' = 'yes'.
nmea	Indicates whether or not streaming needs to be initiated by BNC through sending NMEA-GGA message carrying position coordinates in 'lat' and 'long'.
ntrip	Selected Ntrip transport protocol version (1, 2, 2s, R, or U), or 'N' for TCP/IP streams without Ntrip, or 'UN' for UDP streams without Ntrip, or 'S' for serial input streams without Ntrip.
bytes	Number of bytes received.

5.17.1 Edit Streams

BNC automatically allocates one of its internal decoders to a stream based on the stream's 'format' and 'format-details' as given in the source-table. However, there might be cases where you need to override the automatic selection due to an incorrect source-table for example. BNC allows users to manually select the required decoder by editing the decoder string. Double click on the 'decoder' field, enter your preferred decoder and then hit Enter. Accepted decoder strings are 'RTCM_2.x', 'RTCM_3.x' and 'RTNET'.

In case you need to log the raw data as it is, BNC allows users to by-pass its decoders and directly save the input in daily logfiles. To do this, specify the decoder string as 'ZERO'. The generated filenames are created from the characters of the streams mountpoints plus two-digit numbers each for year, month, and day. Example: Setting the 'decoder' string for mountpoint WTZZ0 to 'ZERO' and running BNC on March 29, 2007 would save raw data in a file named WTZZ0_070329.

BNC can also retrieve streams from virtual reference stations (VRS). To initiate these streams, an approximate rover position needs to be sent in NMEA format to the Ntrip Broadcaster. In return, a user-specific data stream is generated, typically by Network RTK software. VRS streams are indicated by a 'yes' in the source-table as well as in the 'nmea' column on the 'Streams' canvas in BNC's main window. They are customized exactly to the latitude and longitude transmitted to the Ntrip Broadcaster via NMEA GGA sentences.

If NMEA GGA sentences are not coming from a serially connected GNSS rover, BNC simulates them from the default latitude and longitude of the source-table as shown in the 'lat' and 'long' columns on the 'Streams' canvas. However, in many cases you would probably want to change these defaults according to your requirement. Double-click on 'lat' and 'long' fields, enter the values you wish to send and then hit Enter. The format is in positive north latitude degrees (e.g. for northern hemisphere: 52.436, for southern hemisphere: -24.567) and eastern longitude degrees (example: 358.872 or -1.128). Only streams with a 'yes' in their 'nmea' column can be edited. The position should preferably be a point within the VRS service area of the network. RINEX files generated from these streams will contain an additional COMMENT line in the header beginning with 'NMEA' showing the 'lat' and 'long' used.

Note that when running BNC in a Local Area Network (LAN), NMEA strings may be blocked by a proxy server, firewall or virus scanner when not using the Ntrip Version 2 transport protocol.

5.17.2 Delete Streams

To remove a stream from the 'Streams' canvas in the main window, highlight it by clicking on it and hit the 'Delete Stream' button. You can also remove multiple streams simultaneously by highlighting them using +Shift or +Ctrl.

5.17.3 Reconfigure Stream Selection On-the-fly

The streams selection can be changed on-the-fly without interrupting uninvolved threads in the running BNC process.

Window mode: Hit 'Reread & Save Configuration' while BNC is in window mode and already processing data to let changes of your stream selection immediately become effective.

No window mode: When operating BNC online in 'no window' mode (command line option -nw), you force BNC to reread its 'mountPoints' configuration option from disk at pre-defined intervals. Select '1 min', '1 hour', or '1 day' as 'Reread configuration' option to reread the 'mountPoints' option every full minute, hour, or day. This lets a 'mountPoints' option edited in between in the configuration file become effective without terminating uninvolved threads. See section 'Configuration Examples' for configuration file examples and section 'Reread Configuration' for a list of other on-the-fly changeable options.

5.18 Logging Canvas

The 'Logging Canvas' above the bottom menu bar on the main window labeled 'Log', 'Throughput', 'Latency', and 'PPP Plot' provides control of BNC's activities. Tabs are available for continuously showing logfile content, for a plot controlling the bandwidth consumption, a plot showing stream latencies, and for time series plots of PPP results.

5.18.1 Log

Records of BNC's activities are shown in the 'Log' tab. They can be saved into a file when a valid path is specified in the 'Logfile (full path)' field.

5.18.2 Throughput

The bandwidth consumption per stream is shown in the 'Throughput' tab in bits per second (bps) or kilobits per second (kbps). Fig. 5.30 shows an example for the bandwidth consumption of incoming streams.

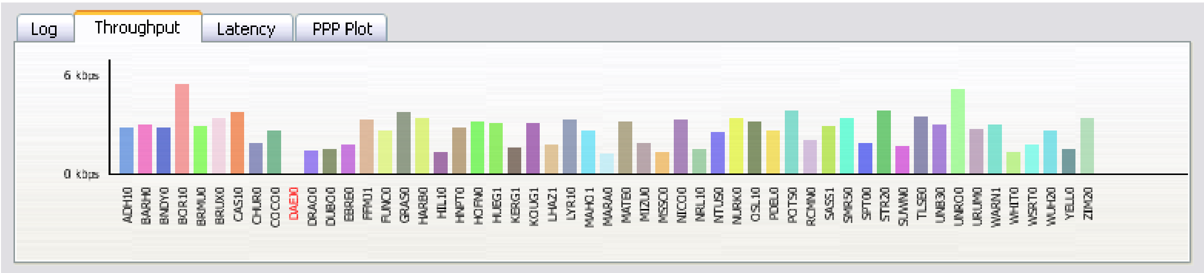


Fig. 5.30: Bandwidth consumption of RTCM streams received by BNC

5.18.3 Latency

The latency of observations in each incoming stream is shown in the 'Latency' tab in milliseconds or seconds. Streams not carrying observations (e.g. those providing only Broadcast Ephemeris messages) or having an outage are not considered here and shown in red color. Note that the calculation of correct latencies requires the clock of the host computer to be properly synchronized. Fig. 5.31 shows an example for the latency of incoming streams.

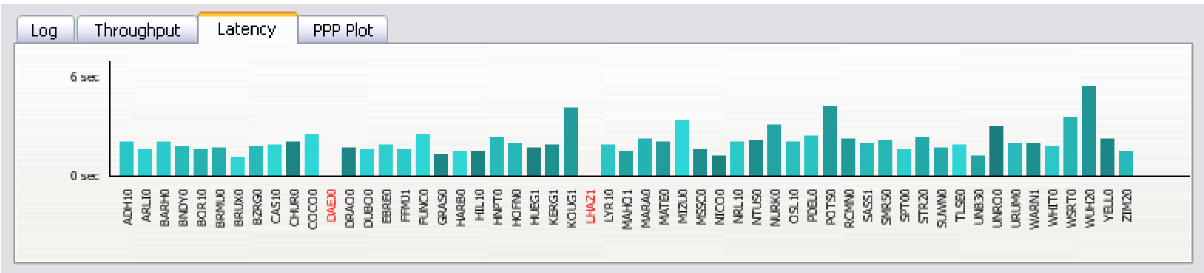


Fig. 5.31: Latency of RTCM streams received by BNC

5.18.4 PPP Plot

Precise Point Positioning time series of North (red), East (green) and Up (blue) coordinate components are shown in the 'PPP Plot' tab when a 'Mountpoint' option is defined under PPP (4). Values are referred to a priori reference coordinates. The time as given in format [hh:mm] refers to GPS Time. The sliding PPP time series window covers a period of 5 minutes. Note that it may take up to 30 seconds or more until the first PPP solutions becomes available. Fig. 5.32 shows the screenshot of a PPP time series plot of North, East and Up coordinate displacements.

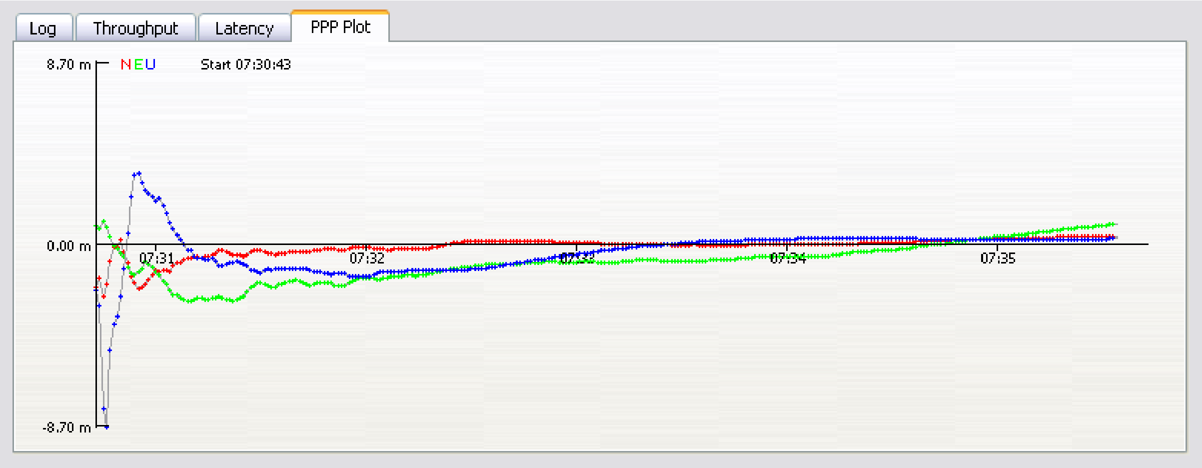


Fig. 5.32: Example for time series plot of displacements produced by BNC

5.19 Bottom Menu Bar

The bottom menu bar allows to add or delete streams to or from BNC's configuration and to start or stop it. It also provides access to BNC's online help function. The 'Add Stream' button opens a window that allows users to select one of several input communication links, see Fig. 5.33.

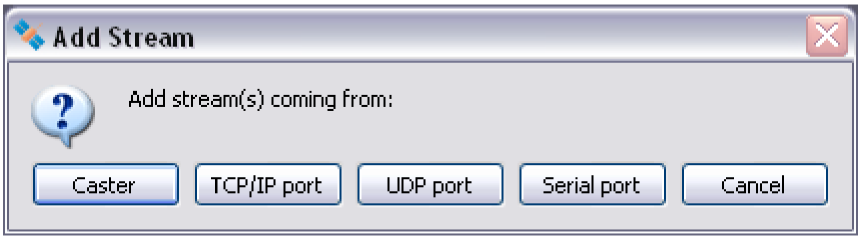


Fig. 5.33: Steam input communication links accepted by BNC

5.19.1 Add Stream

Button 'Add Stream' allows you to pull streams either from an Ntrip Broadcaster or from a TCP/IP port, UPD port, or serial port.

5.19.2 Add/Delete Stream - Coming from Caster

Button 'Add Stream' > 'Coming from Caster' opens a window that allows users to select data streams from an Ntrip Broadcaster according to their mountpoints and show a distribution map of offered streams.

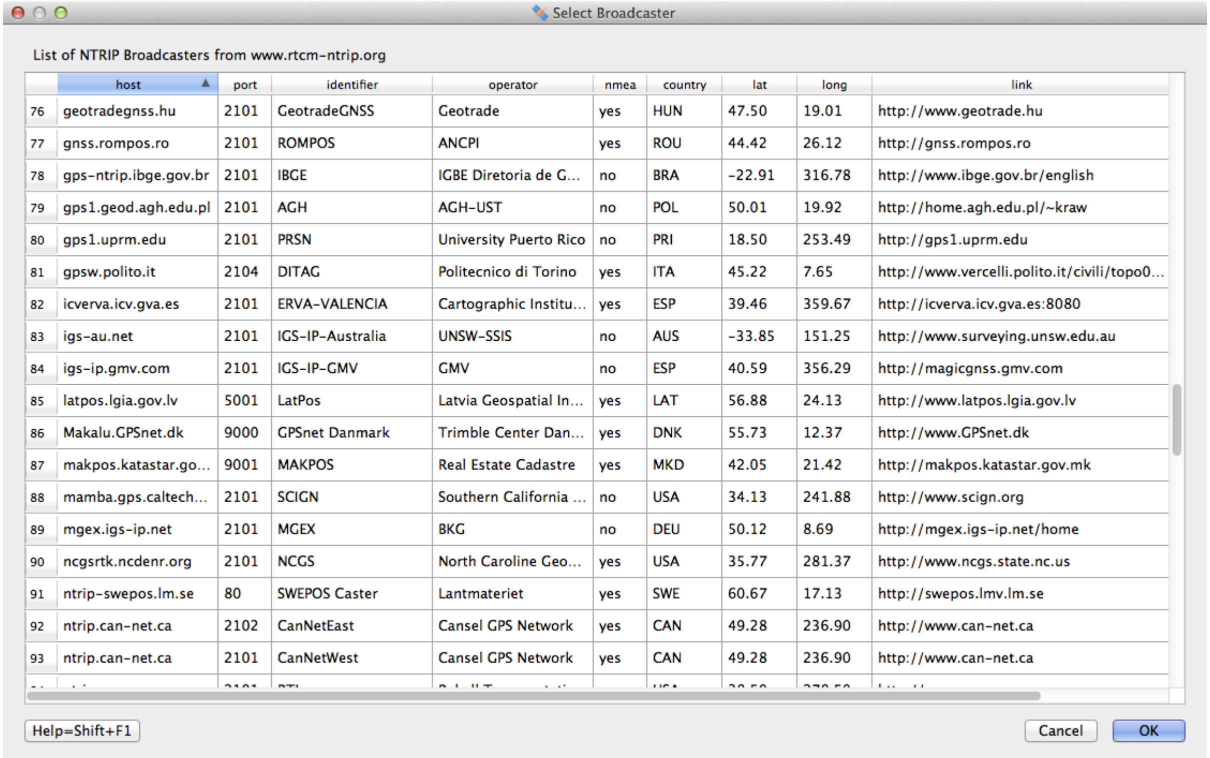
Button Delete Stream allows you to delete streams previously selected for retrieval as listed under the Streams canvas on BNCs main window.

Caster Host and Port - mandatory

Enter the Ntrip Broadcaster host IP and port number. Note that EUREF and IGS operate Ntrip Broadcasters at http://www.euref-ip.net/home, http://www.igs-ip.net/home, http://products.igs-ip.net/home and http://mgex.igs-ip.net/home.

Casters Table - optional

It may be that you are not sure about your Ntrip Broadcaster's host and port number or you are interested in other broadcaster installations operated elsewhere. Hit 'Show' for a table of known broadcasters maintained at www.rtcm-ntrip.org/home. A window opens which allows selecting a broadcaster for stream retrieval, see Fig. 5.34.



	host	port	identifier	operator	nmea	country	lat	long	link
76	geotradegnss.hu	2101	GeotradeGNSS	Geotrade	yes	HUN	47.50	19.01	http://www.geotrade.hu
77	gnss.rompos.ro	2101	ROMPOS	ANCPI	yes	ROU	44.42	26.12	http://gnss.rompos.ro
78	gps-ntrip.ibge.gov.br	2101	IBGE	IGBE Diretoria de G...	no	BRA	-22.91	316.78	http://www.ibge.gov.br/english
79	gps1.geod.agh.edu.pl	2101	AGH	AGH-UST	no	POL	50.01	19.92	http://home.agh.edu.pl/~kraw
80	gps1.uprm.edu	2101	PRSN	University Puerto Rico	no	PRI	18.50	253.49	http://gps1.uprm.edu
81	gpsw.polito.it	2104	DITAG	Politecnico di Torino	yes	ITA	45.22	7.65	http://www.vercelli.polito.it/civili/topo0...
82	icverva.icv.gva.es	2101	ERVA-VALENCIA	Cartographic Institu...	yes	ESP	39.46	359.67	http://icverva.icv.gva.es:8080
83	igs-au.net	2101	IGS-IP-Australia	UNSW-SSIS	no	AUS	-33.85	151.25	http://www.surveying.unsw.edu.au
84	igs-ip.gmv.com	2101	IGS-IP-GMV	GMV	no	ESP	40.59	356.29	http://magicgnss.gmv.com
85	latpos.lgia.gov.lv	5001	LatPos	Latvia Geospatial In...	yes	LAT	56.88	24.13	http://www.latpos.lgia.gov.lv
86	Makalu.GPSnet.dk	9000	GPSnet Danmark	Trimble Center Dan...	yes	DNK	55.73	12.37	http://www.GPSnet.dk
87	makpos.katastar.go...	9001	MAKPOS	Real Estate Cadastre	yes	MKD	42.05	21.42	http://makpos.katastar.gov.mk
88	mamba.gps.caltech...	2101	SCIGN	Southern California ...	no	USA	34.13	241.88	http://www.scign.org
89	mgex.igs-ip.net	2101	MGEX	BKG	no	DEU	50.12	8.69	http://mgex.igs-ip.net/home
90	ncgsrtk.ncdenr.org	2101	NCGS	North Caroline Geo...	yes	USA	35.77	281.37	http://www.ncgs.state.nc.us
91	ntrip-swepos.lm.se	80	SWEPOS Caster	Lantmateriet	yes	SWE	60.67	17.13	http://swepos.lmv.lm.se
92	ntrip.can-net.ca	2102	CanNetEast	Cansel GPS Network	yes	CAN	49.28	236.90	http://www.can-net.ca
93	ntrip.can-net.ca	2101	CanNetWest	Cansel GPS Network	yes	CAN	49.28	236.90	http://www.can-net.ca

Fig. 5.34: BNC's 'Select Broadcaster' table

User and Password - mandatory for protected streams

Streams on Ntrip Broadcasters may be protected. Enter a valid 'User' ID and 'Password' for access to protected streams. Accounts are usually provided per Ntrip Broadcaster through a registration procedure. Register through http://register.rtcm-ntrip.org for access to protected streams from EUREF and IGS.

Get Table

Use the 'Get Table' button to download the source-table from the Ntrip Broadcaster. Pay attention to data fields 'format' and 'format-details'. Keep in mind that BNC can only decode and convert streams that come in RTCM Version 2, RTCM Version 3, or RTNET format. For access to observations, Broadcast Ephemeris and Broadcast Corrections in RTCM format, streams must contain a selection of appropriate message types as listed in the Annex, cf. data field 'format-details' for available message types and their repetition rates in brackets. Note that in order to produce RINEX Navigation files, RTCM Version 3 streams containing message types 1019 (GPS) and 1020 (GLONASS) and 1043 (SBAS) and 1044 (QZSS) and 1045, 1046 (Galileo) and 63 (BDS/BeiDou, tentative message number) are required. Select your streams line by line, use +Shift and +Ctrl when necessary. Fig. 5.35 provides an example source-table.

The content of data field 'nmea' tells you whether a stream retrieval needs to be initiated by BNC through sending an NMEA-GGA message carrying approximate position coordinates (Virtual Reference Station, VRS).

Hit 'OK' to return to the main window. If you wish, you can click on 'Add Stream' and repeat the process of retrieving streams from different casters.

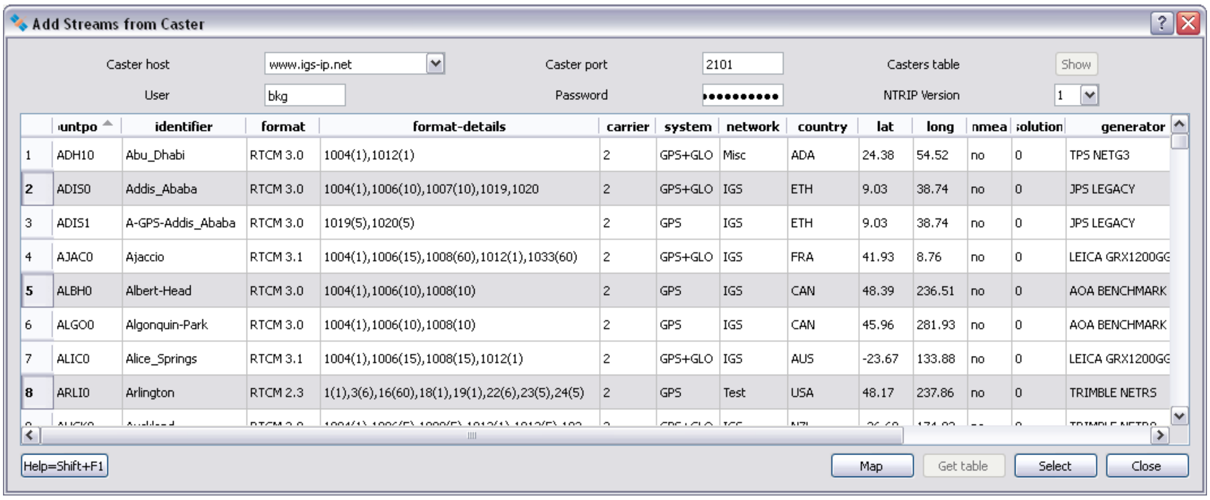


Fig. 5.35: Broadcaster source-table shown by BNC

Ntrip Version - mandatory

Some limitations and deficiencies of the Ntrip Version 1 stream transport protocol are solved in Ntrip Version 2. Improvements mainly concern a full HTTP compatibility in view of requirements coming from proxy servers. Version 2 is backwards compatible to Version 1. Options implemented in BNC are summarized in Table 5.12.

Table 5.12: Ntrip options implemented in BNC.

Option	Meaning
1	Ntrip Version 1, TCP/IP
2	Ntrip Version 2 in TCP/IP mode
2s	Ntrip Version 2 in TCP/IP mode via SSL
R	Ntrip Version 2 in RTSP/RTP mode
U	Ntrip Version 2 in UDP mode

If Ntrip Version 2 is supported by the broadcaster:

- Try using option '2' if your streams are otherwise blocked by a proxy server operated in front of BNC.
- When using Ntrip Version 2 via SSL (option '2s') you need to specify the appropriate 'Caster port' for that. It is usually port number 443. Clarify 'SSL' options offered in panel 'Network'.
- Option 'R' or 'U' may be selected if latency is more important than completeness for your application. Note that the latency reduction is likely to be in the order of 0.5 sec or less. Note further that options 'R' (RTSP/RTP mode) and 'U' (UDP mode) are not accepted by proxy servers and a mobile Internet Service Provider may not support it.

Select option '1' if you are not sure whether the broadcaster supports Ntrip Version 2.

Map - optional

Button 'Map' opens a window to show a distribution map of the caster's streams (Fig. 5.36). You may like to zoom in or out using the mouse. Left button: draw a rectangle to zoom, right button: zoom out, middle button: zoom back.

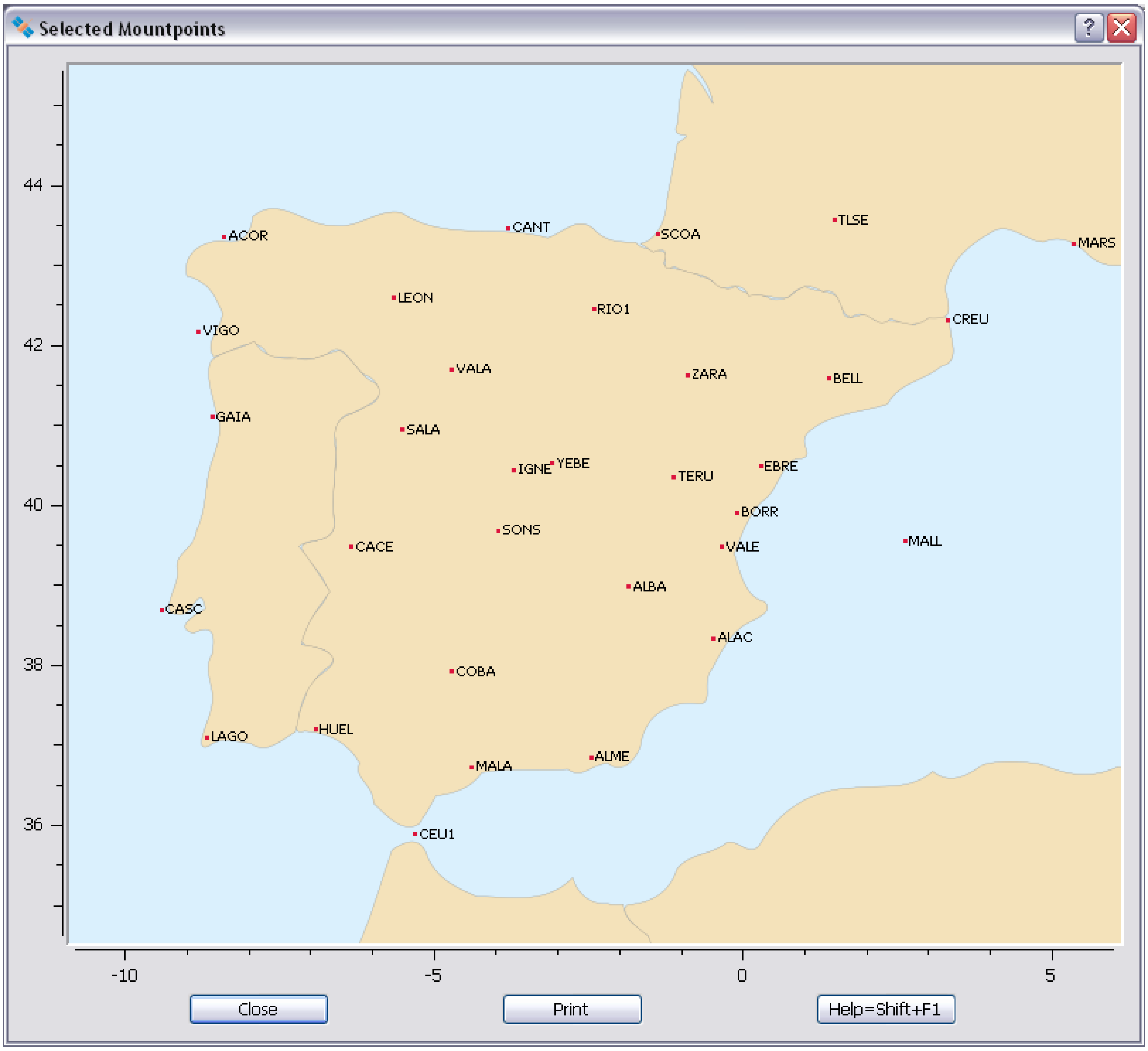


Fig. 5.36: Stream distribution map shown by BNC as derived from Ntrip Broadcaster source-table

5.19.3 Add Stream - Coming from TCP/IP Port

Button 'Add Stream' > 'Coming from TCP/IP Port' allows to retrieve streams via TCP directly from an IP address without using the Ntrip transport protocol. For that you:

- Enter the IP address of the stream providing host.
- Enter the IP port number of the stream providing host.
- Specify a mountpoint. Recommended is a 4-character station ID. Example: FFMJ
- Specify the stream format. Available options are 'RTCM_2', 'RTCM_3', 'RTNET', and 'ZERO'.
- Enter the approximate latitude of the stream providing rover in degrees. Example: 45.32.
- Enter the approximate longitude of the stream providing rover in degrees. Example: -15.20.

Streams directly received from a TCP/IP port show up with an 'N' for 'No Ntrip' in the 'Streams' canvas on BNC's main window. Latitude and longitude are to be entered just for informal reasons. Note that this option works only if no proxy server is involved in the communication link.

5.19.4 Add Stream - Coming from UDP Port

Button 'Add Stream' > 'Coming from UDP Port' allows to pick up streams arriving directly at one of the local host's UDP ports without using the Ntrip transport protocol. For that you:

- Enter the local port number where the UDP stream arrives.
- Specify a mountpoint. Recommended is a 4-character station ID. Example: FFMJ
- Specify the stream format. Available options are 'RTCM_2', 'RTCM_3', 'RTNET', and 'ZERO'.
- Enter the approximate latitude of the stream providing rover in degrees. Example: 45.32.
- Enter the approximate longitude of the stream providing rover in degrees. Example: -15.20.

Streams directly received at a UDP port show up with a 'UN' for 'UDP, No Ntrip' in the 'Streams' canvas section on BNC's main window. Latitude and longitude are to be entered just for informal reasons.

5.19.5 Add Stream - Coming from Serial Port

Button 'Add Stream' > 'Coming from Serial Port' allows to retrieve streams from a GNSS receiver via serial port without using the Ntrip transport protocol. For that you:

- Specify a mountpoint. Recommended is a 4-character station ID. Example: FFMJ
- Specify the stream format. Available options are 'RTCM_2', 'RTCM_3', 'RTNET', and 'ZERO'.
- Enter the approximate latitude of the stream providing receiver in degrees. Example: 45.32.
- Enter the approximate longitude of the stream providing receiver in degrees. Example: -15.20.
- Enter the serial 'Port name' selected on your host for communication with the receiver. Valid port names are listed in Table 5.13.
- Select a 'Baud rate' for the serial input. Note that using a high baud rate is recommended.
- Select the number of 'Data bits' for the serial input. Note that often '8' data bits are used.
- Select the 'Parity' for the serial input. Note that parity is often set to 'NONE'.
- Select the number of 'Stop bits' for the serial input. Note that often '1' stop bit is used.
- Select a 'Flow control' for the serial link. Select 'OFF' if you do not know better.

When selecting one of the serial communication options listed above, make sure that you pick those configured to the serially connected GNSS receiver. Streams received from a serially connected GNSS receiver show up with an 'S' (for Serial Port, no Ntrip) in the 'Streams' canvas section on BNC's main window. Latitude and longitude are to be entered just for informal reasons.

Table 5.13: Valid port names in BNC.

OS	Valid port names
Windows	COM1, COM2
Linux	/dev/ttyS0, /dev/ttyS1
FreeBSD	/dev/ttyd0, /dev/ttyd1
Digital Unix	/dev/tty01, /dev/tty02
HP-UX	/dev/tty1p0, /dev/tty2p0
SGI/IRIX	/dev/ttyf1, /dev/ttyf2
SunOS/Solaris	/dev/ttya, /dev/ttyb

Fig. 5.37 shows a BNC example setup for pulling a stream via serial port on a Windows operating system.

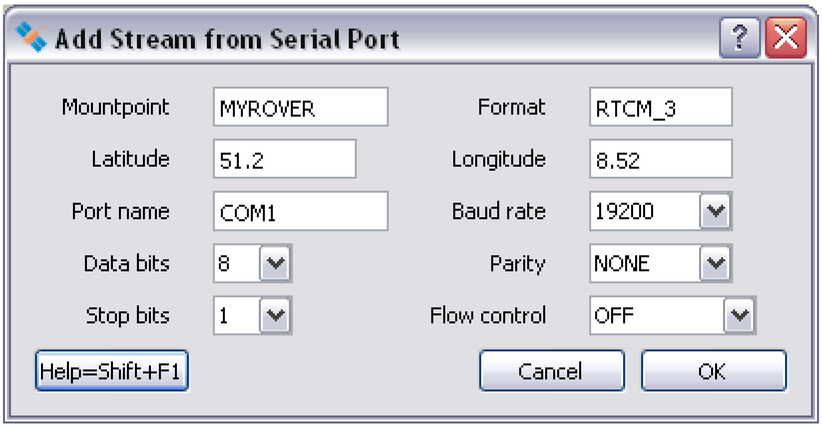


Fig. 5.37: BNC configuration for pulling a stream via serial port

5.19.6 Map

Button 'Map' opens a window to show a distribution map of the streams selected for retrieval as listed under the 'Streams' canvas. You may like to zoom in or out using the mouse. Left button: draw a rectangle to zoom, right button: zoom out, middle button: zoom back.

5.19.7 Start/Stop

Hit 'Start' to start retrieving, decoding or converting GNSS data streams in real-time. Note that 'Start' generally forces BNC to begin with fresh RINEX files which might overwrite existing files when necessary unless option 'Append files' is ticked.

Hit the 'Stop' button in order to stop BNC.

5.19.8 Help? = Shift+F1

BNC comes with a 'What's This' help system providing information about its functionality and usage. Short descriptions are available for any widget and program option. Focus to the relevant object and press Shift+F1 to request help information. A help text appears immediately; it disappears as soon as the user does something else. The dialogs on some operating systems may provide a '?' button that users can click; click the relevant widget to pop up the help text.

5.20 Command Line Options

Command line options are available to run BNC in 'no window' mode or let it read previously recorded input offline from one or several files for debugging or post processing purposes. It is also possible to introduce a specific configuration filename instead of using the default filename 'BNC.bnc'. The self-explaining content of the configuration file can easily be edited. In addition to reading processing options from the involved configuration file, BNC can optionally read any configuration option from command line. Running BNC with command line option 'help'

```
bnc --help (MS Windows: bnc.exe --help | more)
```

provides a list of all available command line options.

5.20.1 Version - optional

Command line option `--version` lets BNC print its version number.

```
bnc --version (MS Windows: bnc.exe --version | more)
```

5.20.2 Display - optional

On systems which support graphics, command line option `--display` forces BNC to present the BNC window on the specified display.

```
bnc.exe --display localhost:10.0
```

5.20.3 No Window Mode - optional

Apart from its regular windows mode, BNC can be started on all systems as a batch job with command line option '-nw'. BNC will then run in 'no window' mode, using processing options from its configuration file on disk. Terminate BNC using Windows Task Manager when running it in 'no window' mode on Windows systems.

```
bnc.exe --nw
```

It is obvious that BNC requires graphics support when started in interactive mode. However, note that graphics support is also required when producing plots in batch mode (option `-nw`). Windows and Mac OS X systems always support graphics. For producing plots in batch mode on Linux systems you must make sure that at least a virtual X-Server such as 'Xvfb' is installed and the `-display` option is used. The following is an example shell script to execute BNC in batch mode for producing QC plots from RINEX files. It could be used via `crontab`:

```
#!/bin/bash
# Save string localhost
echo "localhost" > /home/user/hosts

# Start virtual X-Server, save process ID
/usr/bin/Xvfb :29 -auth /home/user/hosts -screen 0 1280x1024x8 &
psID=`echo $!`

# Run BNC application with defined display variable
/home/user/BNC/bnc --conf /dev/null --key reqcAction Analyze --key reqcObsFile
 ↪  ons12090.12o --key reqcNavFile brdc2090.12p --key reqcOutLogFile multi.txt
 ↪  --key reqcPlotDir /home/user --display localhost:29 --nw

# BNC done, kill X-server process
kill $psID
```

5.20.4 File Mode - optional

Although BNC is primarily a real-time online tool, for debugging purposes it can be run offline to read data from a file previously saved through option 'Raw output file' (Record & Replay functionality). Enter the following command line option for that

```
--file <inputFileName>
```

and specify the full path to an input file containing previously saved data, e.g.

```
./bnc --file /home/user/raw.output_110301
```

Note that when running BNC offline, it will use options for file saving, interval, sampling, PPP etc. from its configuration file. Note further that option `--file` forces BNC to apply the '-nw' option for running in 'no window' mode.

5.20.5 Configuration File - optional

The default configuration filename is `BNC.bnc`. You may change this name at startup time using command line option `--conf <confFileName>`. This allows running several BNC jobs in parallel on the same host using different sets of configuration options. 'confFileName' stands either for the full path to a configuration file or just for a filename. If you introduce only a filename, the corresponding file will be saved in the current working directory from where BNC is started, e.g.

```
./bnc --conf MyConfig.bnc
```

This leads to a BNC job using configuration file 'MyConfig.bnc'. The configuration file will be saved in the current working directory.

5.20.6 Configuration Options - optional

BNC applies options from the configuration file but allows updating every one of them on the command line while the content of the configuration file remains unchanged. Note the following syntax for Command Line Interface (CLI) options:

```
--key <keyName> <keyValue>
```

Parameter <keyName> stands for the key name of an option contained in the configuration file and <keyValue> stands for the value you want to assign to it. The following is a syntax example for a complete command line:

```
bnc --nw --conf <confFileName> --key <keyName1> <keyValue1> --key <keyName2>
 ↪  <keyValue2> ...
```

Configuration options which are part of the configuration files PPP section must be prefixed by 'PPP/'. As an example, option 'minObs' from the PPP section of the BNC configuration file would be specified as 'PPP/minObs' on a command line.

Values for configuration options can be introduced via command line exactly as they show up in the configuration file. However, any value containing one or more blank characters must be enclosed by quotation marks when specified on command line.

CHAPTER 6

Annex

6.1 Revision History

Dec 2006	Version 1.0b	[Add] First Beta Binaries published based on Qt 4.2.3.
Jan 2007	Version 1.1b	[Add] Observables C2, S1, and S2
		[Add] Virtual reference station access
		[Bug] RTCM2 decoder time tag fixed
		[Mod] Small letters for public RINEX skeleton files
		[Add] Online help through Shift+F1
Apr 2007	Version 1.2b	[Bug] Output only through IP port
		[Bug] Method 'reconnecting' now thread-save
		[Add] ZERO decoder added
		[Mod] Download public RINEX skeletons once per day
		[Mod] Upgrade to Qt Version 4.2.3
		[Mod] Replace 'system' call for RINEX script by 'QProcess'
		[Add] HTTP Host directive for skeleton file download
		[Add] Percent encoding for user IDs and passwords
		[Bug] Exit execution of calling thread for RTCM3 streams
		[Bug] Signal-slot mechanism for threads
May 2007	Version 1.3	[Add] Source code published.
Jul 2007	Version 1.4	[Bug] Skip messages from proxy server
		[Bug] Call RINEX script through 'nohup'
Apr 2008	Version 1.5	[Add] Handle ephemeris from RTCM Version 3 streams
		[Add] Upgrade to Qt Version 4.3.2
		[Add] Optional RINEX v3 output
		[Add] SBAS support
		[Bug] RINEX skeleton download following stream outage
		[Add] Handle ephemeris from RTIGS streams
		[Add] Monitor stream failure/recovery and latency
		[Mod] Redesign of main window
		[Bug] Freezing of About window on Mac OS X
		[Bug] Fixed problem with PRN 32 in RTCM v2 decoder
		[Bug] Fix for Trimble 4000SSI receivers in RTCM v2 decoder
		[Mod] Major revision of input buffer in RTCM v2 decoder
Dec 2008	Version 1.6	[Mod] Fill blank columns in RINEX v3 with 0.000
		[Add] RTCM v3 decoder for orbit and clock corrections
		[Add] Check RTCM v3 streams for incoming message types
		[Add] Decode RTCM v2 message types 3, 20, 21, and 22
		[Add] Loss of lock and lock time indicator
		[Bug] Rounding error in RTCM v3 decoder concerning GLONASS height
		[Mod] Accept GLONASS in RTCM v3 when transmitted first

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Table 6.1 – continued from previous page

		[Add] Leap second 1 January 2009
		[Add] Offline mode, read data from file
		[Add] Output antenna descriptor, coordinates and eccentricities from RTCM v3
		[Add] Reconfiguration on-the-fly
		[Mod] Binary output of synchronized observations
		[Add] Binary output of unsynchronized observations
		[Bug] Fixed problem with joined RTCM v3 blocks
Dec 2008	Version 1.6.1	[Mod] HTTP GET when no proxy in front
Nov 2009	Version 1.7	[Bug] RINEX Navigation file format
		[Add] Upgrade to Qt Version 4.5.2
		[Add] Support of Ntrip v2
		[Add] Rover support via serial port
		[Add] Show broadcaster table from www.rtcm-ntrip.org
		[Add] Enable/disable panel widgets
		[Add] User defined configuration filename
		[Mod] Switch to configuration files in ini-Format
		[Add] Daily logfile rotation
		[Add] Read from TCP/IP port, by-pass Ntrip transport protocol
		[Add] Save NMEA sentences coming from rover
		[Add] Auto start
		[Add] Drag and drop ini files
		[Add] Read from serial port, by-pass Ntrip transport protocol
		[Mod] Update of SSR messages following RTCM 091-2009-SC104-542
		[Add] Read from UPD port, by-pass Ntrip transport protocol
		[Mod] Output format of Broadcast Corrections
		[Add] Throughput plot
		[Add] Latency plot
Nov 2009	Version 1.8	[Mod] On-the-fly reconfiguration of latency and throughput plots
Feb 2010	Version 2.0	[Mod] Change sign of Broadcast Corrections
		[Add] Real-time PPP option
Jun 2010	Version 2.1	[Bug] SSR GLONASS message generation
		[Add] PPP in post processing mode
		[Mod] Update of SSR messages following draft dated 2010-04-12
		[Mod] Generating error message when observation epoch is wrong
Jul 2010	Version 2.2	[Bug] GLONASS ephemeris time
Aug 2010	Version 2.3	[Mod] Internal format for saving raw streams
		[Bug] Outlier detection in GLONASS ambiguity resolution
		[Mod] Format of PPP logs in logfile
		[Bug] Complete acceleration terms for GLONASS ephemeris
		[Bug] Handling ephemeris IOD's in PPP mode
Dec 2010	Version 2.4	[Add] Output of averaged positions when in PPP mode
		[Mod] Use always the latest received set of Broadcast Ephemeris
		[Add] QuickStart PPP option
		[Mod] Improvement of data sharing efficiency among different threads
		[Mod] Design of PPP panel section
		[Add] Sigmas for observations and parameters
		[Add] Stream distribution map
		[Bug] GPS Ephemeris in RINEX v3 format
Feb 2011	Version 2.5	[Add] PPP option for sync of clock observations and corrections
		[Add] Drafted RTCM v3 Galileo ephemeris messages 1045
		[Add] Drafted RTCM v3 Multiple Signal Messages
		[Add] Optional specification of sigmas for coordinates and troposphere in PPP

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Table 6.1 – continued from previous page

		[Add] Include Galileo in SPP
		[Add] Include Galileo observations in output via IP port
		[Add] Include Galileo observations in output via RINEX v3 files
		[Mod] Interface format for feeding a real-time engine with observations
		[Add] Correct observations for Antenna Phase Center offsets
		[Add] Combine orbit/clock correction streams
		[Add] Specify corrections mountpoint in PPP panel
Apr 2011	Version 2.6	[Add] Complete integration of BNS in BNC
		[Add] SP3 and Clock RINEX output
		[Add] PPP in post processing Mode
		[Add] Some RINEX editing & QC functionality
		[Add] Threshold for orbit outliers in combination solution
		[Add] Real-time engine becomes orbit/clock server instead of client
		[Mod] 'EOE' added to orbit/clock stream from engine
		[Add] Correction for antenna eccentricities
		[Add] Quick start mode for PPP
		[Mod] Design of format for feeding engine changed to follow RINEX v3
		[Mod] Implementation of SSR message encoding modified according to standard
		[Add] SSL/TLS Support of Ntrip Version 2
		[Mod] Switch to Qt version 4.7.3
		[Add] RINEX editing, concatenation and quality check
		[Add] Reading all configuration options from command line
		[Mod] RTCM v3 Galileo Broadcast Ephemeris message 1045
		[Mod] Change default configuration file suffix from 'ini' to 'bnc'
		[Add] Specific rates for orbits and clocks in streams and SP3/RNX files
		[Add] Version 2.6 published, May 2012
Sep 2012	Version 2.7	[Bug] Bug in L5 decoding fixed
		[Bug] Bug in on-the-fly configuration fixed
		[Add] Clock RINEX file header extended
		[Add] Decoding/converting BeiDou and QZSS added
		[Add] Work on RINEX v2 and v3 quality check started
		[Mod] Source code completely re-arranged
		[Add] QWT and QWTPOLAR graphics libraries added
		[Add] RINEX QC through multipath analysis sky plot
		[Add] RINEX QC through signal-to-noise ratio sky plot
		[Add] RINEX QC through satellite availability plot
		[Add] RINEX QC through satellite elevation plot
		[Add] RINEX QC through PDOP plot
		[Bug] Short periodic outages in PPP time series when 'Sync Corr' set to zero
		[Add] Log observation types contained in RTCM Version 3 MSM streams
		[Add] Reading RINEX v3 observation type header records from RINEX skeleton
		[Add] Logfile for RINEX file editing and concatenation
		[Add] Save PNG plot files on disk
		[Mod] Plot stream distribution map from Ntrip Broadcaster source-table
		[Add] Plot stream distribution map from selected sources
		[Add] Version 2.7 published
Sep 2012	Version 2.8	[Mod] Started work on new version in Sep 2012
		[Bug] Epoch special event flag in RINEX concatenation
		[Bug] Limit RINEX v2 records length to 80 characters
		[Bug] SSR message update interval indicator
		[Bug] Fixed SSR stream encoding and upload
		[Add] Concatenate RINEX v3 navigation files containing Galileo ephemeris

Continued on next page

Table 6.1 – continued from previous page

		[Mod] Plausibility check of GLONASS ephemeris
		[Add] Correcting clocks for scale factor involved in transformation
		[Mod] Orbit/clock interpolation in SSR stream encoding and upload to caster
		[Add] Version 2.8 published, Mar 2013
Mar 2013	Version 2.9	[Add] Started work on new version in Mar 2013
		[Bug] SSR stream upload buffering disabled
		[Mod] Format for feeding a connected GNSS engine
		[Mod] RTNET format for receiving data from a connected GNSS engine
		[Add] Include Galileo in SPP
		[Add] RINEX QC multipath an SNR sky plots for GLONASS and Galileo
		[Add] Bias estimation for GLONASS clocks in PPP
		[Add] Trace positions on GM or OSM maps
		[Add] Version 2.9 published, Jul 2013
Aug 2013	Version 2.10	[Add] Started work on new version in Aug 2013
		[Bug] Clock RINEX und SP3 file generation on Windows systems
		[Bug] Broadcast Ephemeris generation
		[Add] Transformation ITRF2008 to NAD83 and DREF91
		[Add] CodeBias added to RTNET stream format
		[Bug] GPS L2 in 'Feed Engine' output
		[Mod] Made C1 in BeiDou default observation type instead of C2
		[Add] Feed engine output sorted per stream
		[Add] Feed engine output filename change on-the-fly
		[Add] 'Append files' option for RINEX observation files
		[Mod] Broadcast Correction ASCII file output for message 1058 & 1064 modified
		[Bug] GPS L2 phase data in RINEX2
		[Bug] GLONASS frequency numbers
		[Add] RTCM v3 Galileo Broadcast Ephemeris message 1046
		[Add] Reset ambiguities in PPP when orbit/clock correction IDs change
		[Add] Satellite clock offsets are reset in adjustment for combination when orbit/clock correction IDs change
		[Add] Version 2.10 published in Dec 2013
Dec 2013	Version 2.11	[Add] Started work on new version in Dec 2013
		[Mod] SIRGAS transformation parameters adjusted
		[Mod] ANTEX file updated
		[Mod] RTCM SSR messages updated
		[Bug] GLONASS code biases
		[Mod] Maximum number of GNSS observations increased
		[Mod] Loss of lock handling changed
		[Add] Raw stream output through TCP/IP port
		[Add] Version 2.11.0 published in Sep 2014
Sep 2014	Version 2.12	[Add] Started work on new version in Sep 2014
		[Mod] RINEX file concatenation
		[Add] Observation code selection in RINEX file editing
		[Mod] Routine handling of data input and output in RINEX format re-written
		[Mod] QC routines re-written with the goal of handling all signal types
		[Add] Machine-readable output of RINEX QC
		[Add] PPP client functionality for parallel processing of an arbitrary number of stations in separate threads
		[Bug] Receiver antenna PCO in ionosphere-free PPP mode
		[Add] NMEA output for any station processed in PPP mode
		[Add] PPP processing of any number of linear combinations of GNSS measurements selected by user

Continued on next page

Table 6.1 – continued from previous page

		[Add] Encoding/Decoding RTCM SSR I messages for Galileo, BDS, SBAS and QZSS
		[Add] Encoding/Decoding RTCM SSR phase bias messages
		[Add] Encoding/Decoding RTCM SSR ionospheric model messages, single-layer model for total electron content
		[Add] RTCM SSR I messages for Galileo, BDS, SBAS and QZSS support from RTNET interface
		[Add] RTCM SSR II messages (phase biases and SSR ionospheric model) support from RTNET interface
		[Add] Computation of VTEC and STEC from SSR ionospheric model messages for usage in PPP mode
		[Add] Handle old-fashioned SNR values in RINEX
		[Mod] SNR and MP visualization depending on RINEX observation attribute
		[Bug] Saastamoinen tropospheric correction for very high elevation receivers
		[Add] Comparison of SP3 files
		[Add] Encoding/Decoding of RTCM v3 proposal for Galileo Broadcast Ephemeris message 1046
		[Add] Encoding/Decoding of RTCM v3 QZSS Broadcast Ephemeris message 1044
		[Add] Encoding/Decoding of RTCM v3 SBAS Broadcast Ephemeris message 1043
		[Add] Encoding/Decoding of RTCM v3 BDS Broadcast Ephemeris message 63
		[Add] RINEX v3 support of Galileo, BDS, SBAS and QZSS Broadcast Ephemerides
		[Add] Consideration of the aspect that Galileo NAV message can be provided for the same epoch but with different flags (I/NAV, F/NAV, DVS)
		[Bug] VRS support in sending NMEA in Auto/Manual mode to Ntrip Broadcaster
		[Add] Forwarding NMEA GNGGA to Ntrip Broadcaster
		[Bug] Stream failure/recovery reports
		[Add] Compute IODs for BDS and SBAS from CRC over Broadcast Ephemeris and clock parameters
		[Mod] PPP default options
		[Add] Example configuration for SP3 file comparison
		[Add] Choose between code and phase observations when in PPP SSR I mode
		[Bug] Reset time series plot when restarting PPP in post processing mode
		[Add] Broadcast ephemeris check regarding allowed age of data sets
		[Add] Code bias usage for PPP SSR I mode
		[Add] Code bias, phase bias and VTEC usage in extended PPP mode
		[Mod] Consideration of the full antenna PCO vector in all PPP modes
		[Add] Allow GPS-only and GLONASS-only RINEX v2 Navigation files
		[Mod] SSR clock correction converted to seconds to be consistent with broadcast values
		[Add] Support Galileo I/NAV Broadcast Ephemeris
		[Add] Extended RINEX v3 filenames
		[Add] Stream's country added to configuration string 'mountPoints'
		[Add] Distinction of GEO/MEO satellites during BDS velocity determination
		[Bug] Velocity determination for geostationary BDS satellites
		[Add] Set TOE from BDS week and second
		[Add] Use BDS observations and ephemerides in PPP SSR I mode

Continued on next page

Table 6.1 – continued from previous page

		[Add] Considering that yaw angle restricted to -180 to +180 deg
		[Mod] Read local RINEX skeleton files
		[Add] Update interval for VTEC in RTNET stream format
		[Bug] SBAS IODN
		[Bug] Galileo week number
		[Add] Phase shift records in RINEX v3 headers
		[Add] Output GLONASS slot numbers from scanning stream content
		[Add] Decoder interface for PPP SSR I+II messages for Galileo/QZSS/SBAS/BDS
		[Mod] Renaming BDS first frequency from '1' to '2'
		[Add] RINEX QC, receiver/antenna information editable
		[Add] Support of new RINEX header lines regarding phase shifts, GLONAQSS slots and GLONASS biases during file merging
		[Add] Switch to port 443 for skeleton file download from https website
		[Mod] Default observation types for RINEX v3 files
		[Bug] RTCM v2 decoder
		[Add] SINEX Troposphere file output
		[Add] Comments with respect to RINEX v3 to RINEX v2 observation file conversion [Add] String for Operating System in logfile output
		[Add] Full integration of 'rtcm3torinex'
		[Add] Extended command line help
		[Add] Version 2.12.0 published in April 2016
Apr 2016	Version 2.13	[Add] Started work on new version in Apr 2016

6.2 RTCM Standards

The Radio Technical Commission for Maritime Services (RTCM) is an international non-profit scientific, professional and educational organization. Special Committees provide a forum in which governmental and non-governmental members work together to develop technical standards and consensus recommendations in regard to issues of particular concern. RTCM is engaged in the development of international standards for maritime radionavigation and radiocommunication systems. The output documents and reports prepared by RTCM Committees are published as RTCM Recommended Standards. Topics concerning Differential Global Navigation Satellite Systems (DGNSS) are handled by the Special Committee SC 104.

Personal copies of RTCM Recommended Standards can be ordered through http://www.rtcm.org/orderinfo.php.

6.2.1 Ntrip Version 1

'Networked Transport of RTCM via Internet Protocol' Version 1.0 (Ntrip) stands for an application-level protocol streaming Global Navigation Satellite System (GNSS) data over the Internet. Ntrip is a generic, stateless protocol based on the Hypertext Transfer Protocol HTTP/1.1. The HTTP objects are enhanced to GNSS data streams.

Ntrip Version 1 is an RTCM standard designed for disseminating differential correction data (e.g. in the RTCM-104 format) or other kinds of GNSS streaming data to stationary or mobile users over the Internet, allowing simultaneous PC, Laptop, PDA, or receiver connections to a broadcasting host. Ntrip supports wireless Internet access through Mobile IP Networks like GSM, GPRS, EDGE, or UMTS.

Ntrip is implemented in three system software components: Ntrip Clients, Ntrip Servers and Ntrip Broadcasters. The Ntrip Broadcaster is the actual HTTP server program whereas Ntrip Client and Ntrip Server are acting as HTTP clients.

Ntrip is an open none-proprietary protocol. Major characteristics of Ntrip's dissemination technique are:

- Based on the popular HTTP streaming standard; comparatively easy to implement when having limited client and server platform resources available;

- Application not limited to one particular plain or coded stream content; ability to distribute any kind of GNSS data;
- Potential to support mass usage; disseminating hundreds of streams simultaneously for thousands of users possible when applying modified Internet Radio broadcasting software;
- Considering security needs; stream providers and users do not necessarily get into contact, streams often not blocked by firewalls or proxy servers protecting Local Area Networks;
- Enables streaming over mobile IP networks because of using TCP/IP.

The Ntrip Broadcaster maintains a source-table containing information on available Ntrip streams, networks of Ntrip streams and Ntrip Broadcasters. The source-table is sent to an Ntrip Client on request. Source-table records are dedicated to one of the following: Data Streams (record type STR), Casters (record type CAS), or Networks of streams (record type NET).

Source-table records of type STR contain the following data fields: 'mountpoint', 'identifier', 'format', 'format-details', 'carrier', 'nav-system', 'network', 'country', 'latitude', 'longitude', 'nmea', 'solution', 'generator', 'compr-encryp', 'authentication', 'fee', 'bitrate', 'misc'.

Source-table records of type NET contain the following data fields: 'identifier', 'operator', 'authentication', 'fee', 'web-net', 'web-str', 'web-reg', 'misc'.

Source-table records of type CAS contain the following data fields: 'host', 'port', 'identifier', 'operator', 'nmea', 'country', 'latitude', 'longitude', 'misc'.

6.2.2 Ntrip Version 2

The major changes of Ntrip Version 2 compared to Version 1.0 are:

- Cleared and fixed design problems and HTTP protocol violations;
- Replaced nonstandard directives;
- Chunked transfer encoding;
- Improvements in header records;
- Source-table filtering;
- RTSP communication.

Ntrip Version 2 allows to communicate either in TCP/IP mode or in RTSP/RTP mode or in UDP mode whereas Version 1 is limited to TCP/IP only. It furthermore allows using the Transport Layer Security (TLS) and its predecessor, Secure Sockets Layer (SSL) cryptographic protocols for secure Ntrip communication over the Internet.

6.2.3 RTCM Version 2

Transmitting GNSS carrier phase data can be done through RTCM Version 2 messages. Please note that only RTCM Version 2.2 and 2.3 streams may include GLONASS data. Messages that may be of interest here are:

- Type 1 message is the range correction message and is the primary message in code-phase differential positioning (DGPS). It is computed in the base receiver by computing the error in the range measurement for each tracked SV.
- Type 2 message is automatically generated when a new set of satellite ephemeris is downloaded to the base receiver. It is the computed difference between the old ephemeris and the new ephemeris. Type 2 messages are used when the base station is transmitting Type 1 messages.
- Type 3 and 22 messages are the base station position and the antenna offset. Type 3 and 22 are used in RTK processing to perform antenna reduction.
- Type 6 message is a null frame filler message that is provided for data links that require continuous transmission of data, even if there are no corrections to send. As many Type 6 messages are sent as required to fill in the gap between two correction messages (type 1). Message 6 is not sent in burst mode.

- Type 9 message serves the same purpose as Type 1, but does not require a complete satellite set. As a result, Type 9 messages require a more stable clock than a station transmitting Type 1 ‘s, because the satellite corrections have different time references.
- Type 16 message is simply a text message entered by the user that is transmitted from the base station to the rover. It is used with code-phase differential.
- Type 18 and 20 messages are RTK uncorrected carrier phase data and carrier phase corrections.
- Type 19 and 21 messages are the uncorrected pseudo-range measurements and pseudo-range corrections used in RTK.
- Type 23 message provides the information on the antenna type used on the reference station.
- Type 24 message carries the coordinates of the installed antenna’s ARP in the GNSS coordinate system coordinates.

6.2.4 RTCM Version 3

RTCM Version 3 has been developed as a more efficient alternative to RTCM Version 2. Service providers and vendors have asked for a standard that would be more efficient, easy to use, and more easily adaptable to new situations. The main complaint was that the Version 2 parity scheme was wasteful of bandwidth. Another complaint was that the parity is not independent from word to word. Still another was that even with so many bits devoted to parity, the actual integrity of the message was not as high as it should be. Plus, 30-bit words are awkward to handle. The Version 3 standard is intended to correct these weaknesses.

RTCM Version 3 defines a number of message types. Messages that may be of interest here are:

- Type 1001, GPS L1 code and phase.
- Type 1002, GPS L1 code and phase and ambiguities and carrier-to-noise ratio.
- Type 1003, GPS L1 and L2 code and phase.
- Type 1004, GPS L1 and L2 code and phase and ambiguities and carrier-to-noise ratio.
- Type 1005, Station coordinates XYZ for antenna reference point.
- Type 1006, Station coordinates XYZ for antenna reference point and antenna height.
- Type 1007, Antenna descriptor and ID.
- Type 1008, Antenna serial number.
- Type 1009, GLONASS L1 code and phase.
- Type 1010, GLONASS L1 code and phase and ambiguities and carrier-to-noise ratio.
- Type 1011, GLONASS L1 and L2 code and phase.
- Type 1012, GLONASS L1 and L2 code and phase and ambiguities and carrier-to-noise ratio.
- Type 1013, Modified Julian Date, leap second, configured message types and interval.
- Type 1014 and 1017, Network RTK (MAK) messages.
- Type 1019, GPS ephemeris.
- Type 1020, GLONASS ephemeris.
- Type 1043, SBAS ephemeris.
- Type 1044, QZSS ephemeris.
- Type 1045, Galileo F/NAV ephemeris.
- Type 1046, Galileo I/NAV ephemeris.
- Type 63, BeiDou ephemeris, tentative.
- Type 4088 and 4095, Proprietary messages.

The following are so-called 'State Space Representation' (SSR) messages:

- Type 1057, GPS orbit corrections to Broadcast Ephemeris
- Type 1058, GPS clock corrections to Broadcast Ephemeris
- Type 1059, GPS code biases
- Type 1060, Combined orbit and clock corrections to GPS Broadcast Ephemeris
- Type 1061, GPS User Range Accuracy (URA)
- Type 1062, High-rate GPS clock corrections to Broadcast Ephemeris
- Type 1063, GLONASS orbit corrections to Broadcast Ephemeris
- Type 1064, GLONASS clock corrections to Broadcast Ephemeris
- Type 1065, GLONASS code biases
- Type 1066, Combined orbit and clock corrections to GLONASS Broadcast Ephemeris
- Type 1067, GLONASS User Range Accuracy (URA)
- Type 1068, High-rate GLONASS clock corrections to Broadcast Ephemeris
- Type 1240, Galileo orbit corrections to Broadcast Ephemeris
- Type 1241, Galileo clock corrections to Broadcast Ephemeris
- Type 1242, Galileo code biases
- Type 1243, Combined orbit and clock corrections to Galileo Broadcast Ephemeris
- Type 1244, Galileo User Range Accuracy (URA)
- Type 1245, High-rate Galileo clock corrections to Broadcast Ephemeris
- Type 1246, QZSS orbit corrections to Broadcast Ephemeris
- Type 1247, QZSS clock corrections to Broadcast Ephemeris
- Type 1248, QZSS code biases
- Type 1249, Combined orbit and clock corrections to QZSS Broadcast Ephemeris
- Type 1250, QZSS User Range Accuracy (URA)
- Type 1251, High-rate QZSS clock corrections to Broadcast Ephemeris
- Type 1252, SBAS orbit corrections to Broadcast Ephemeris
- Type 1253, SBAS clock corrections to Broadcast Ephemeris
- Type 1254, SBAS code biases
- Type 1255, Combined orbit and clock corrections to SBAS Broadcast Ephemeris
- Type 1256, SBAS User Range Accuracy (URA)
- Type 1257, High-rate SBAS clock corrections to Broadcast Ephemeris
- Type 1258, BDS orbit corrections to Broadcast Ephemeris
- Type 1259, BDS clock corrections to Broadcast Ephemeris
- Type 1260, BDS code biases
- Type 1261, Combined orbit and clock corrections to BDS Broadcast Ephemeris
- Type 1262, BDS User Range Accuracy (URA)
- Type 1263, High-rate BDS clock corrections to Broadcast Ephemeris\
- Type 1264 SSR Ionosphere VTEC Spherical Harmonics
- Type 1265 SSR GPS Satellite Phase Bias

- Type 1266 SSR Satellite GLONASS Phase Bias
- Type 1267 SSR Satellite Galileo Phase Bias
- Type 1268 SSR Satellite QZSS Phase Bias
- Type 1269 SSR Satellite SBAS Phase Bias
- Type 1270 SSR Satellite BDS Phase Bias

The following are so-called 'Multiple Signal Messages' (MSM):

- Type 1071, Compact GPS pseudo-ranges
- Type 1072, Compact GPS carrier phases
- Type 1073, Compact GPS pseudo-ranges and carrier phases
- Type 1074, Full GPS pseudo-ranges and carrier phases plus signal strength
- Type 1075, Full GPS pseudo-ranges, carrier phases, Doppler and signal strength
- Type 1076, Full GPS pseudo-ranges and carrier phases plus signal strength (high resolution)
- Type 1077, Full GPS pseudo-ranges, carrier phases, Doppler and signal strength (high resolution)
- Type 1081, Compact GLONASS pseudo-ranges
- Type 1082, Compact GLONASS carrier phases
- Type 1083, Compact GLONASS pseudo-ranges and carrier phases
- Type 1084, Full GLONASS pseudo-ranges and carrier phases plus signal strength
- Type 1085, Full GLONASS pseudo-ranges, carrier phases, Doppler and signal strength
- Type 1086, Full GLONASS pseudo-ranges and carrier phases plus signal strength (high resolution)
- Type 1087, Full GLONASS pseudo-ranges, carrier phases, Doppler and signal strength (high resolution)
- Type 1091, Compact Galileo pseudo-ranges
- Type 1092, Compact Galileo carrier phases
- Type 1093, Compact Galileo pseudo-ranges and carrier phases
- Type 1094, Full Galileo pseudo-ranges and carrier phases plus signal strength
- Type 1095, Full Galileo pseudo-ranges, carrier phases, Doppler and signal strength
- Type 1096, Full Galileo pseudo-ranges and carrier phases plus signal strength (high resolution)
- Type 1097, Full Galileo pseudo-ranges, carrier phases, Doppler and signal strength (high resolution)
- Type 1121, Compact BeiDou pseudo-ranges
- Type 1122, Compact BeiDou carrier phases
- Type 1123, Compact BeiDou pseudo-ranges and carrier phases
- Type 1124, Full BeiDou pseudo-ranges and carrier phases plus signal strength
- Type 1125, Full BeiDou pseudo-ranges, carrier phases, Doppler and signal strength
- Type 1126, Full BeiDou pseudo-ranges and carrier phases plus signal strength (high resolution)
- Type 1127, Full BeiDou pseudo-ranges, carrier phases, Doppler and signal strength (high resolution)
- Type 1111, Compact QZSS pseudo-ranges
- Type 1112, Compact QZSS carrier phases
- Type 1113, Compact QZSS pseudo-ranges and carrier phases
- Type 1114, Full QZSS pseudo-ranges and carrier phases plus signal strength
- Type 1115, Full QZSS pseudo-ranges, carrier phases, Doppler and signal strength

- Type 1116, Full QZSS pseudo-ranges and carrier phases plus signal strength (high resolution)
- Type 1117, Full QZSS pseudo-ranges, carrier phases, Doppler and signal strength (high resolution)

The following are proposed 'Multiple Signal Messages' (MSM) under discussion for standardization:

- Type 1101, Compact SBAS pseudo-ranges
- Type 1102, Compact SBAS carrier phases
- Type 1103, Compact SBAS pseudo-ranges and carrier phases
- Type 1104, Full SBAS pseudo-ranges and carrier phases plus signal strength
- Type 1105, Full SBAS pseudo-ranges, carrier phases, Doppler and signal strength
- Type 1106, Full SBAS pseudo-ranges and carrier phases plus signal strength (high resolution)
- Type 1107, Full SBAS pseudo-ranges, carrier phases, Doppler and signal strength (high resolution)\

6.3 Command Line Help

Command line option `--help` provides a complete list of all configuration parameters which can be specified via BNC's Command Line Interface (CLI). Note that command line options overrule configuration options specified in the configuration file. The following is the output produced when running BNC with command line option '–help':

6.3.1 Usage

```
bnc --help (MS Windows: bnc.exe --help | more)
    --nw
    --version (MS Windows: bnc.exe --version | more)
    --display {name}
    --conf {confFileName}
    --file {rawFileName}
    --key  {keyName} {keyValue}
```

6.3.2 Network Panel keys

KeyName	Meaning
proxyHost	Proxy host, name or IP address [character string]
proxyPort	Proxy port [integer number]
sslCaCertPath	Full path to SSL certificates [character string]
sslIgnoreErrors	Ignore SSL authorization errors [integer number: 0=no,2=yes]

6.3.3 General Panel keys

KeyName	Meaning
logFile	Logfile, full path [character string]
rnxAppend	Append files [integer number: 0=no,2=yes]
onTheFlyInterval	Configuration reload interval [character string: 1 day|1 hour|5 min|1 min]
autoStart	Auto start [integer number: 0=no,2=yes]
rawOutFile	Raw output file, full path [character string]

6.3.4 RINEX Observations Panel keys

KeyName	Meaning
rnxPath	Directory [character string]
rnxIntr	File interval [character string: 1 min|2 min|5 min|10 min|15 min|30 min|1 hour|1 day]
rnxSampl	File sampling rate [integer number of seconds: 0,5|10|15|20|25|30|35|40|45|50|55|60]
rnxSkel	RINEX skeleton file extension [character string]
rnxOnlyWithSKL	Using RINEX skeleton file is mandatory [integer number: 0=no,2=yes]
rnxScript	File upload script, full path [character string]
rnxV2Priority	Priority of signal attributes [character string, list separated by blank character, example: G:CWPX_? R:CP]
rnxV3	Produce version 3 file content [integer number: 0=no,2=yes]
rnxV3filenames	Produce version 3 filenames [integer number: 0=no,2=yes]

6.3.5 RINEX Ephemeris Panel keys

KeyName	Meaning
ephPath	Directory [character string]
ephIntr	File interval [character string: 1 min|2 min|5 min|10 min|15 min|30 min|1 hour|1 day]
ephOutPort	Output port [integer number]
ephV3	Produce version 3 file content [integer number: 0=no,2=yes]
ephV3filenames	Produce version 3 filenames [integer number: 0=no,2=yes]

6.3.6 RINEX Editing and QC Panel keys

KeyName	Meaning
reqcAction	Action specification [character string: Blank|Edit/Concatenate|Analyze]
reqcObsFile	Input observations file(s), full path [character string, comma separated list in quotation marks]
reqcNavFile	Input navigation file(s), full path [character string, comma separated list in quotation marks]
reqcOutObsFile	Output observations file, full path [character string]
reqcOutNavFile	Output navigation file, full path [character string]
reqcOutLogFile	Output logfile, full path [character string]
reqcLogSummaryOnly	Output only summary of logfile [integer number: 0=no,2=yes]
reqcSkyPlotSignals	Observation signals [character string, list separated by blank character, example: C:2&7 E:1&5 G:1&2 J:1&2 R:1&2 S:1&5]
reqcPlotDir	QC plots directory [character string]
reqcRnxVersion	RINEX version [integer number: 2|3]
reqcSampling	RINEX output file sampling rate [integer number of seconds: 0|5|10|15|20|25|30|35|40|45|50|55|60]
reqcV2Priority	Version 2 priority of signal attributes [character string, list separated by blank character, example: G:CWPX_? R:CP]
reqcStartDateTime	Start time [character string, example: 1967-11-02T00:00:00]
reqcEndDateTime	Stop time [character string, example: 2099-01-01T00:00:00]
reqcRunBy	Operators name [character string]
eqcUseObsTypes	Use observation types [character string, list separated by blank character, example: G:C1C G:L1C R:C1C RC1P]
reqcComment	Additional comments [character string]

Continued on next page

Table 6.2 – continued from previous page

KeyName	Meaning
reqcOldMarkerName	Old marker name [character string]
reqcNewMarkerName	New marker name [character string]
reqcOldAntennaName	Old antenna name [character string]
reqcNewAntennaName	New antenna name [character string]
reqcOldAntennaNumber	Old antenna number [character string]
reqcNewAntennaNumber	New antenna number [character string]
reqcOldAntennadN	Old north eccentricity [character string]
reqcNewAntennadN	New north eccentricity [character string]
reqcOldAntennadE	Old east eccentricity [character string]
reqcNewAntennadE	New east eccentricity [character string]
reqcOldAntennadU	Old up eccentricity [character string]
reqcNewAntennadU	New up eccentricity [character string]
reqcOldReceiverName	Old receiver name [character string]
reqcNewReceiverName	New receiver name [character string]
reqcOldReceiverNumber	Old receiver number [character string]
reqcNewReceiverNumber	New receiver number [character string]

6.3.7 SP3 Comparison Panel keys

KeyName	Meaning
sp3CompFile	SP3 input files, full path [character string, comma separated list in quotation marks]
sp3CompExclude	Satellite exclusion list [character string, comma separated list in quotation marks, example: G04,G31,R]
sp3CompOutLogFile	Output logfile, full path [character string]

6.3.8 Broadcast Corrections Panel keys

KeyName	Meaning
corrPath	Directory for saving files in ASCII format [character string]
corrIntr	File interval [character string: 1 min|2 min|5 min|10 min|15 min|30 min|1 hour|1 day]
corrPort	Output port [integer number]

6.3.9 Feed Engine Panel keys

KeyName	Meaning
outPort	Output port, synchronized [integer number]
outWait	Wait for full observation epoch [integer number of seconds: 1-30]
outSampl	Sampling rate [integer number of seconds: 0|5|10|15|20|25|30|35|40|45|50|55|60]
outFile	Output file, full path [character string]
outUPort	Output port, unsynchronized [integer number]

6.3.10 Serial Output Panel keys

KeyName	Meaning
serialMountPoint	Mountpoint [character string]
serialPortName	Port name [character string]
serialBaudRate	Baud rate [integer number: 110|300|600|1200|2400|4800|9600|19200|38400|57600|115200]
serialFlowControl	Flow control [character string: OFF|XONXOFF|HARDWARE
serialDataBits	Data bits [integer number: 5|6|7|8]
serialParity	Parity [character string: NONE|ODD|EVEN|SPACE]
serialStopBits	Stop bits [integer number: 1|2]
serialAutoNMEA	NMEA specification [character string: no|Auto|Manual GPGGA|Manual GNGGA]
serialFileNMEA	NMEA filename, full path [character string]
serialHeightNMEA	Height [floating-point number]
serialHeightNMEASampling	Sampling rate [integer number of seconds: 0|10|20|30|...|280|290|300]

6.3.11 Outages Panel keys

KeyName	Meaning
adviseObsRate	Stream observation rate [character string: 0.1 Hz|0.2 Hz|0.5 Hz|1 Hz|5 Hz]
adviseFail	Failure threshold [integer number of minutes: 0-60]
adviseReco	Recovery threshold [integer number of minutes: 0-60]
adviseScript	Advisory script, full path [character string]

6.3.12 Miscellaneous Panel keys

KeyName	Meaning
miscMount	Mountpoint [character string]
miscIntr	Interval for logging latency [character string: Blank|2 sec|10 sec|1 min|5 min|15 min|1 hour|6 hours|1 day]
miscScanRTCM	Scan for RTCM message numbers [integer number: 0=no,2=yes]
miscPort	Output port [integer number]

6.3.13 PPP Client Panel 1 keys

KeyName	Meaning
PPP/dataSource	Data source [character string: Blank|Real-Time Streams|RINEX Files]
PPP/rinexObs	RINEX observation file, full path [character string]
PPP/rinexNav	RINEX navigation file, full path [character string]
PPP/corrMount	Corrections mountpoint [character string]
PPP/corrFile	Corrections file, full path [character string]
PPP/antexFile	ANTEX file, full path [character string]
PPP/crdFile	Coordinates file, full path [character string]
PPP/v3filenames	Produce version 3 filenames, [integer number: 0=no,2=yes]
PPP/logPath	Directory for PPP log files [character string]
PPP/nmeaPath	Directory for NMEA output files [character string]
PPP/snxtroPath	Directory for SINEX troposphere output files [character string]
PPP/snxtroIntr	SINEX troposphere file interval [character string: 1 min|2 min|5 min|10 min|15 min|30 min|1 hour|1 day]
PPP/snxtroSampl	SINEX troposphere file sampling rate [integer number of seconds: 0|30|60|90|120|150|180|210|240|270|300]
PPP/snxtroAc	SINEX troposphere Analysis Center [character string]
PPP/snxtroSol	SINEX troposphere solution ID [character string]

6.3.14 PPP Client Panel 2 keys

KeyName	Meaning
PPP/staTable	Station specifications table [character string, semi-colon separated list, each element in quotation marks, example:"FFMJ1,100.0,100.0,100.0,100.0,100.0,100.0,0.1,3e-6,7777;CUT07,100.0,100.0,100.0,100.0,100.0,100.0,0.1,3e-6,7778"]

6.3.15 PPP Client Panel 3 keys

KeyName	Meaning
PPP/lcGPS	Select linear combination from GPS code or phase data [character string; P3|P3&L3]
PPP/lcGLONASS	Select linear combination from GLONASS code or phase data [character string: no|P3|L3|P3&L3]
PPP/lcGalileo	elect linear combination from Galileo code or phase data [character string: no|P3|L3|P3&L3]
PPP/lcBDS	Select linear combination from BDS code or phase data [character string: no|P3|L3|P3&L3]
PPP/sigmaC1	Sigma for code observations in meters [floating-point number]
PPP/sigmaL1	Sigma for phase observations in meters [floating-point number]
PPP/maxResC1	Maximal residuum for code observations in meters [floating-point number]
PPP/maxResL1	Maximal residuum for phase observations in meters [floating-point number]
PPP/eleWgtCode	Elevation dependent waiting of code observations [integer number: 0=no,2=yes]
PPP/eleWgtPhase	Elevation dependent waiting of phase observations [integer number: 0=no,2=yes]
PPP/minObs	Minimum number of observations [integer number: 4|5|6]
PPP/minEle	Minimum satellite elevation in degrees [integer number: 0-20]
PPP/corrWaitTime	Wait for clock corrections [integer number of seconds: no|1-20]
PPP/seedingTime	Seeding time span for Quick Start [integer number of seconds]

6.3.16 PPP Client Panel 4 keys

KeyName	Meaning
PPP/plotCoordinates	Mountpoint for time series plot [character string]
PPP/audioResponse	Audio response threshold in meters [floating-point number]
PPP/useOpenStreetMap	OSM track map [character string: true|false]
PPP/useGoogleMap	Google track map [character string: true|false]
PPP/mapWinDotSize	Size of dots on map [integer number: 0-10]
PPP/mapWinDotColor	Color of dots and cross hair on map [character string: red|yellow]
PPP/mapSpeedSlider	Offline processing speed for mapping [integer number: 1-100]

6.3.17 Combine Corrections Panel keys

<table>
<tr><th>KeyName</th><th>Meaning</th></tr>
<tr><td>cmbStreams</td><td>Correction streams table [character string, semicolon separated list, each element in quotation marks, example:"IGS01 ESA 1.0;IGS03 BKG 1.0"]</td></tr>
<tr><td>cmbMethodFilter</td><td>Combination approach [character string: Single-Epoch|Filter]</td></tr>
<tr><td>cmbMaxres</td><td>Clock outlier residuum threshold in meters [floating-point number]</td></tr>
<tr><td>cmbSampl</td><td>Clock sampling rate [integer number of seconds: 10|20|30|40|50|60]</td></tr>
<tr><td>cmbUseGlonass</td><td>Use GLONASS in combination [integer number: 0=no,2=yes]</td></tr>
</table>

6.3.18 Upload Corrections Panel keys

<table>
<tr><th>KeyName</th><th>Meaning</th></tr>
<tr><td>uploadMountpointsOut</td><td>Upload corrections table [character string, semicolon separated list, each element in quotation marks, example: "www.igs-ip.net,2101,IGS01,pass,IGS08,0, /home/user/BNC$[GPSWD}.sp3, /home/user/BNC$[GPSWD}.clk,258,1,0; www.euref-ip.net,2101,EUREF01,pass,ETRF2000,0,,,258,2,0"]</td></tr>
<tr><td>uploadIntr</td><td>Length of SP3 and Clock RINEX file interval [character string: 1 min|2 min|5 min|10 min|15 min|30 min|1 hour|1 day]</td></tr>
<tr><td>uploadSamplRtcmEphCorr</td><td>Orbit corrections stream sampling rate [integer number of seconds: 0|5|10|15|20|25|30|35|40|45|50|55|60]</td></tr>
<tr><td>uploadSamplSp3</td><td>SP3 file sampling rate [integer number of minutes: 0-15]</td></tr>
<tr><td>uploadSamplClkRnx</td><td>Clock RINEX file sampling rate [integer number of seconds: 0|5|10|15|20|25|30|35|40|45|50|55|60]</td></tr>
</table>

6.3.19 Custom Trafo keys

KeyName	Meaning
trafo_dx	Translation X in meters [floating-point number]
trafo_dy	Translation Y in meters [floating-point number]
trafo_dz	Translation Z in meters [floating-point number]
trafo_dxr	Translation change X in meters per year [floating-point number]
trafo_dyr	Translation change Y in meters per year [floating-point number]
trafo_dzr	Translation change Z in meters per year [floating-point number]
trafo_ox	Rotation X in arcsec [floating-point number]
trafo_oy	Rotation Y in arcsec [floating-point number]
trafo_oz	Rotation Z in arcsec [floating-point number]
trafo_oxr	Rotation change X in arcsec per year [floating-point number]
trafo_oyr	Rotation change Y in arcsec per year [floating-point number]
trafo_ozr	Rotation change Z in arcsec per year [floating-point number]
trafo_sc	Scale [10^-9, floating-point number]
trafo_scr	Scale change [10^-9 per year, floating-point number]
trafo_t0	Reference year [integer number]

6.3.20 Upload Ephemeris Panel keys

KeyName	Meaning
uploadEphHost	Broadcaster host, name or IP address [character string]
uploadEphPort	Broadcaster port [integer number]
uploadEphMountpoint	Mountpoint [character string]
uploadEphPassword	Stream upload password [character string]
uploadEphSample	Stream upload sampling rate [integer number of seconds: 5|10|15|20|25|30|35|40|45|50|55|60]

6.3.21 Add Stream keys

KeyName	Meaning
mountPoints	Mountpoints [character string, semicolon separated list, example:
	"//user:pass@www.igs-ip.net:2101/FFMJ1 RTCM_3.1 DEU 50.09 8.66 no 2;
	//user:pass@www.igs-ip.net:2101/FFMJ2 RTCM_3.1 DEU 50.09 8.66 no 2"
ntripVersion	Ntrip Version [character string: 1|2|2s|R|U]
casterUrlList	Visited Broadcasters [character string, comma separated list]

6.3.22 Appearance keys

KeyName	Meaning
startTab	Index of top panel to be presented at start time [integer number: 0-17]
statusTab	Index of bottom panel to be presented at start time [integer number: 0-3]
font	Font specification [character string in quotation marks, example: "Helvetica,14,-1,5,50,0,0,0,0,0"]

6.3.23 Example command lines

The syntax of some command line configuration options slightly differs from that used in configuration files: Configuration file options which contain one or more blank characters or contain a semicolon separated parameter list must be enclosed by quotation marks when specified on command line.

1. `/home/weber/bin/bnc`
2. `/Applications/bnc.app/Contents/MacOS/bnc`
3. `/home/weber/bin/bnc --conf /home/weber/MyConfigFile.bnc`
4. `bnc --conf /Users/weber/.config/BKG/BNC.bnc -nw`
5. `bnc --conf /dev/null --key startTab 4 --key reqcAction Edit/Concatenate --key reqcObsFile AGAR.15O --key reqcOutObsFile AGAR_X.15O --key reqcRnxVersion 2 --key reqcSampling 30 --key reqcV2Priority CWPX_?`
6. `bnc --key mountPoints "//user:pass@mgex.igs-ip.net:2101/CUT07 RTCM_3.0 ETH 9.03 38.74 no 2;//user:pass@www.igs-ip.net:2101/FFMJ1 RTCM_3.1 DEU 50.09 8.66 no 2"`
7. `bnc --key cmbStreams "CLK11 BLG 1.0;CLK93 CNES 1.0"`

8. `bnc --key uploadMountpointsOut "products.igs-ip.net,98756,TEST, letmein,IGS08,2,/Users/weber/BNC${GPSWD}.clk„33,3,2; www.euref-ip.net,333,TEST2,aaaaa,NAD83,2„,33,5,5"`
9. `bnc --key PPP/staTable "FFMJ1,100.0,100.0,100.0,100.0,100.0,100.0, 0.1,3e-6,7777;CUT07,100.0,100.0,100.0,100.0,100.0,100.0,0.1,3e-6, 7778"`

6.4 Further Reading

Ntrip	http://igs.bkg.bund.de/ntrip/index
EUREF-IP Ntrip Broadcaster	http://www.euref-ip.net/home
IGS-IP Ntrip Broadcaster	http://www.igs-ip.net/home
IGS products Ntrip Broadcaster	http://products.igs-ip.net/home
IGS M-GEX Ntrip Broadcaster	http://mgex.igs-ip.net/home
IGS Central Bureau Ntrip Broadcaster	http://rt.igs.org
IGS Real-time Service	http://rts.igs.org
Distribution of IGS-IP streams	http://www.igs.oma.be/real_time
Completeness and latency of IGS-IP data	http://www.igs.oma.be/highrate/
Ntrip Broadcaster overview	http://www.rtcm-ntrip.org/home
Ntrip Open Source software code	http://software.rtcm-ntrip.org
EUREF-IP Project	http://www.epncb.oma.be/euref_IP
Radio Technical Commission for Maritime Services	http://www.rtcm.org

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Acronyms

AC	Analysis Center.
AFREF	IAG Reference Frame Sub-Commission for Africa.
ANTEX	Antenna Exchange Format.
APC	Antenna Phase Center.
APREF	IAG Reference Frame Sub-Commission for Asia and Pacific.
ARP	Antenna Reference Point.
BKG	Bundesamt für Kartographie und Geodäsie.
BNC	BNK Ntrip Client.
BSW	Bernese GNSS Software.
CC	Combination Center.
CLI	Command Line Interface.
CoM	Center Of Mass.
DGNSS	Differential GNSS.
DGPS-IP	Differential GPS via Internet Protocol.
DMG	Disk Image File.
DREF91	Geodetic Datum for Germany 1991.
ECEF	Earth-Centred-Earth-Fixed.
EDGE	Enhanced Data Rates for GSM Evolution.
EoE	End of Epoch.
ETRF2000	European Terrestrial Reference Frame 2000.
EUREF	IAG Reference Frame Sub-Commission for Europe.
FKP	Flächen-Korrektur-Parameter.
FTP	File Transfer Protocol.

GDA94 Geodetic Datum Australia 1994.

GM Google Maps.

GNSS Global Navigation Satellite System.

GNU GNU's Not Unix.

GPL General Public License.

GPRS General Packet Radio Service.

GPSWD GPS Week and Day.

GSM Global System for Mobile Communications.

GUI Graphical User Interface.

HP MSM High Precision Multiple Signal Messages.

HR URA High Rate User Range Accuracy.

HTTP Hypertext Transfer Protocol.

HTTPS Hypertext Transfer Protocol Secure.

IAG International Association of Geodesy.

ICECAST Streaming Media Server.

IGS International GNSS Service.

IGS08 IGS Reference Frame 2008.

IOD Issue of Data.

IP Internet Protocol.

ITRF2008 International Terrestrial Reference Frame 2008.

L3 Ionosphere-Free Linear Combination Of Phase Observations.

LAN Local Area Network.

LC Linea Combination.

M-GEX Multi GNSS-Experiment.

MAC Master Auxiliary Concept.

MJD Modified Julian Date.

MSI Microsoft Installer, File.

MSM Multiple Signal Messages.

MW Melbourne Wübbena Linear Combination.

NAD83 North American Datum 1983.

NAREF IAG Reference Frame Sub-Commission for North America.

NMEA National Marine Electronics Association Format.

NTRIP Networked Transport of RTCM via Internet Protocol.

OSM OpenStreetMap.

OSR Observation Space Representation.

P3 Ionosphere-Free Linear Combination Of Code Observations.

PDOP Positional Dilution Of Precision.

PNG Portable Network Graphics.

PPP Precise Point Positioning.

QT Cross-Platform Application Framework.

REQC RINEX Editing and Quality Checking.

RINEX Receiver Independent Exchange Format.

RTCM SC-104 Radio Technical Commission for Maritime Services, Special Committee 104.

RTK Real Time Kinematic.

RTKPLOT View and Plot Positioning Solutions Software, Part of RTKLIB.

RTNET Real-Time Network Format.

RTP Real-Time Transport Protocol.

RTSP Real-Time Streaming Protocol.

SBAS Space Based Augmentation System.

SINEX Solution Independent Exchange Format.

SINEX TRO Troposphere Solution Independent Exchange Format.

SIRGAS IAG Reference Frame Sub-Commission for Latin America and Caribbean.

SIRGAS2000 Geodetic Datum for Latin America and Caribbean 2000.

SIRGAS95 Geodetic Datum for Latin America and Caribbean 1995.

SP3 Standard Product # 3.

SPP Single Point Positioning.

SSL Secure Sockets Layer.

SSR State Space Representation.

SVN Subversion, Revision Control System.

TCP Transmission Control Protocol.

TEQC Translation, Editing and Quality Checking.

TLS Transport Layer Security.

UDP User Datagram Protocol.

UMTS Universal Mobile Telecommunications System.

URA User Range Accuracy.

VRS Virtual Reference Station.

VTEC Vertical Total Electron Content.

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