Real-time GNSS
Introduction

Andrea Stürze and Georg Weber

Federal Agency for Cartography and Geodesy Frankfurt, Germany

Material partly provided by
Ken MacLeod (NRCan), Leos Mervart (CTU), and Gerhard Wübbena (Geo++)

BKG

- Federal Agency for Cartography and Geodesy
- Based in Frankfurt, Leipzig, Wettzell, Concepcion, O-Higgins
- 250 Employees
- Task: Establish and maintain 3D Reference System for Germany
- Two Departments: Cartography + Geodesy
- National Mapping Agency
- Active in EUREF, EuroGeographics and IGS

Organizational Issues

- We both are not professional lecturers
- We would like to mix theory with some practical demonstration
- Feel free to follow the demonstrations with your Laptop
- We hope for WiFi Internet connection in this room
- Don‘t hesitate to ask at any time

October 25, Morning Session

- Introduction, Objectives of Training Course
- NTRIP Stream Transport Protocol
- NTRIP Broadcaster, Demonstration and Exercise

October 25, Afternoon Session

- Real-Time IGS Network, Data Flow and Access
- BKG NTRIP Client (BNC), Introduction
- BNC, RINEX Translation, Editing, Concatenation and QC, Demonstration and Exercise

October 26, Morning Session

- RTCM Formats, “State Space Representation” (SSR) and “Multiple Signal Messages” (MSM)
- Real-time IGS Pilot Project, Generation and Dissemination of Satellite Orbit/Clock Corrections
- BNC, Orbit/Clock Stream/File Generation in SSR/SP3 Format, Demonstration and Exercise

October 26, Afternoon Session

- BNC, Real-time Precise Point Positioning e.g. for Natural Hazards, Demonstration and Exercise
- NTRIP Broadcast Networks and Purposes, Conclusions for SIRGAS
- Closing Discussion

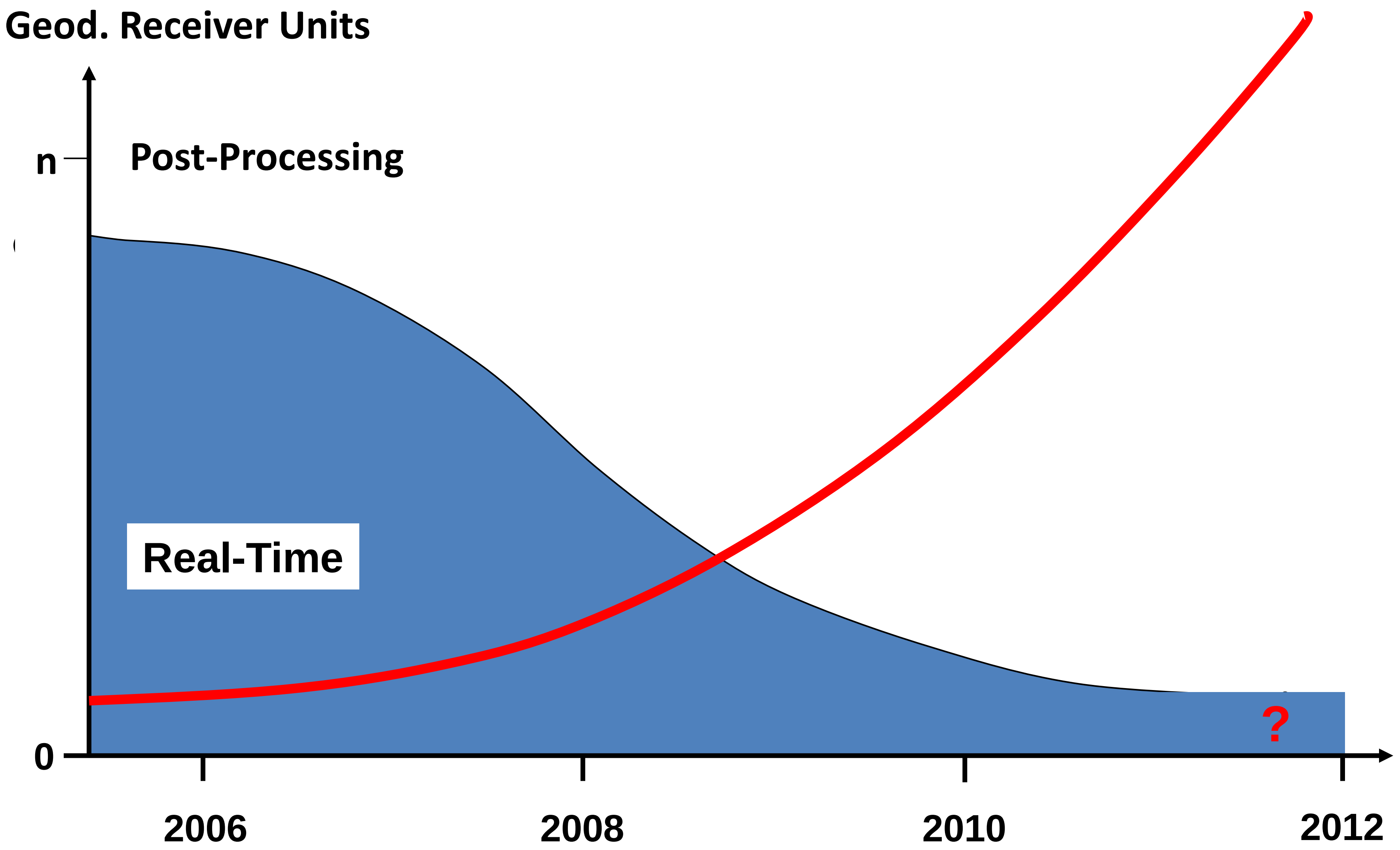
Post-Processing vs. Real-time

- Challenging Perspective for Service Providers
- Trimble‘s new RTX CenterPoint service is a stunning example
- Rising Confrontation & Competition

Post-Processing vs. Real-time

- The number of post-processing GNSS users decreases rapidly
- At the same time, the community of real-time users grows dramatically
- With the exception of high precision reference system maintenance, soon there will remain only a few positioning applications carried out in post-processing mode

Post-Processing vs. Real-time



The Challenge

- Are public (so far post-processing) service providers running out of business?
- Being mainly post-processing oriented, they could extend services towards real-time.
- How shall they cope with the new situation? Should they add new activities to their product portfolio and what could that be?
- What may be the right technology to follow?
- What could be an appropriate policy to align to?

Real-time GNSS

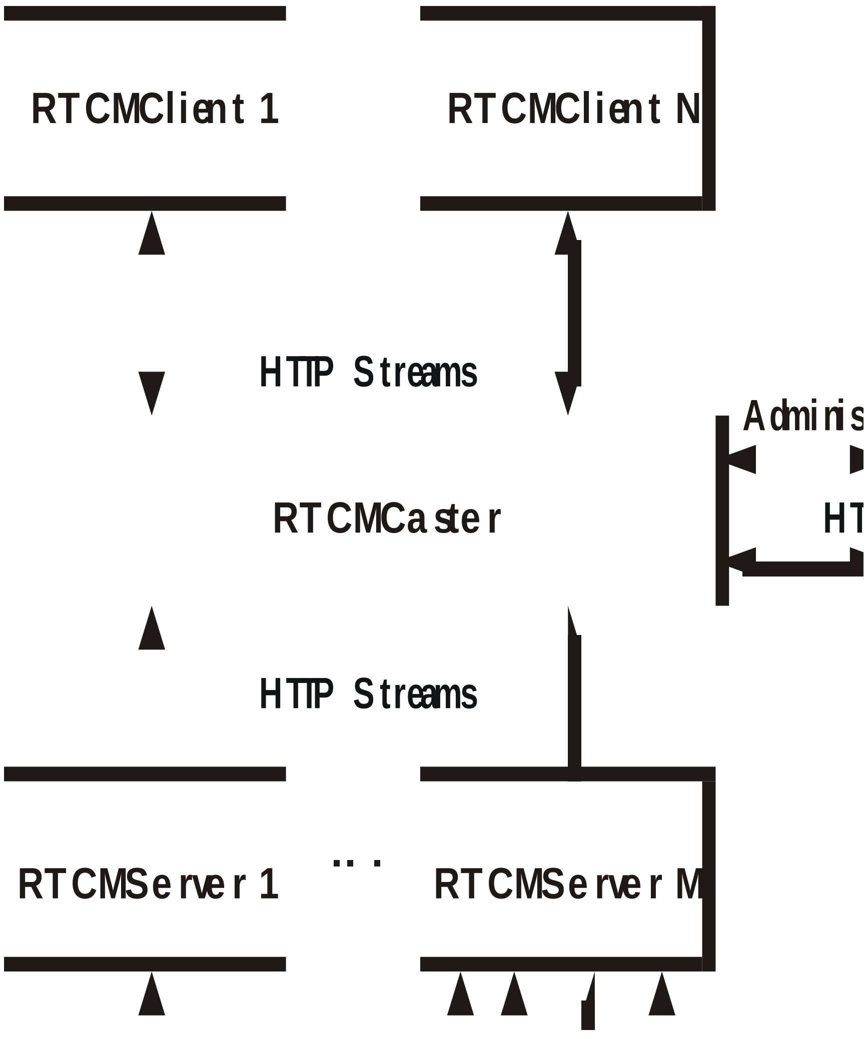
Networked Transport of RTCM via Internet Protocol (Ntrip)

Frequently used Abbreviations

- NTRIP – Networked Transport of RTCM via Internet Protocol, http://igs.bkg.bund.de/ntrip
- RTCM – Radio Technical Commission For Maritime Services, http://www.rtcm.org
- RTCA – Radio Technical Commission For Aeronautics http://www.rtca.org
- RTCM SSR – State Space Representation
- RTCM MSM – Multiple Signal Messages

Ntrip Concept

- Http application layer on top of TCP/IP
- Data streaming begins with selective http request
- Caster / Client / Server communication handled through http port
- Open documentation
- Major software components developed under „GNU General Public License“



Ntrip Characteristics

- Streaming protocol: Distribution of any kind of GNSS data
- Note the difference between stream format and transport protocol
- http: Easy to implement, usually not blocked by firewalls
- Streaming over any (mobile) IP network
- Handles meta-data
- Security: Stream providers and users not in contact
- Mass usage: Disseminating hundreds of streams simultaneously for a few thousand users when applying modified Internet Radio broadcasting software

Ntrip Version 1

- Developed at BKG and Informatik Centrum Dortmund in Germany
- Industry Standard since 2004
- Standardized in RTCM Special Committee 104
- Called
  - RTCM Recommended Standards for Networked Transport of RTCM via Internet Protocol (Ntrip), Version 1

Ntrip Version 2

- Completed in June 2009 by RTCM SC104 as
  - Networked Transport of RTCM via Internet Protocol (Ntrip), Version 2
- Cleared and fixed design problems and HTTP protocol violations in Version 1
- Replaced non standard directives
- Adds chunked transfer encoding
- Improves header records
- Provides for sourcetable filtering
- Provides for Real Time Streaming Protocol RTSP/RTP, UDP communication
- Fully downward compatible with Ntrip version 1

Note on Stream Formats & Transport Protocols

- Ever-growing number of vendor stream formats
- Scientific stream formats (BINEX)
- RTCM stream formats (RTCM v2/v3)
- Formats developed for archiving purposes (RINEX, SP3)

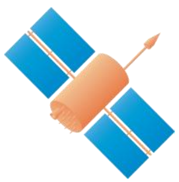
Recommendation:

- Use and promote open RTCM formats/protocols
- Extend RTCM v3 / Ntrip where necessary

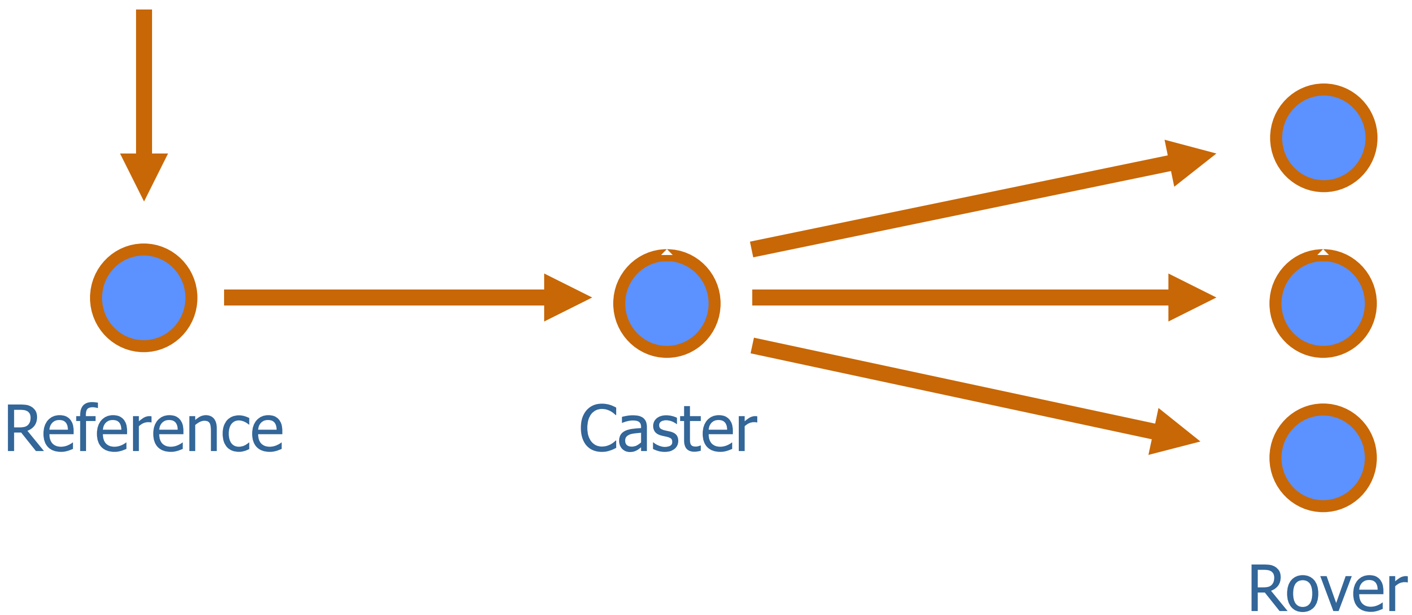
Missing Standards

- Current problems: L5 and Galileo, QZSS, Compass, SBAS, …
- Extend RTCM v3 to overcome today‘s limitation of handling e.g. only one code per frequency
- Develop new RTCM v3 messages that allow to transport any observation becoming available (SSR, MSM)

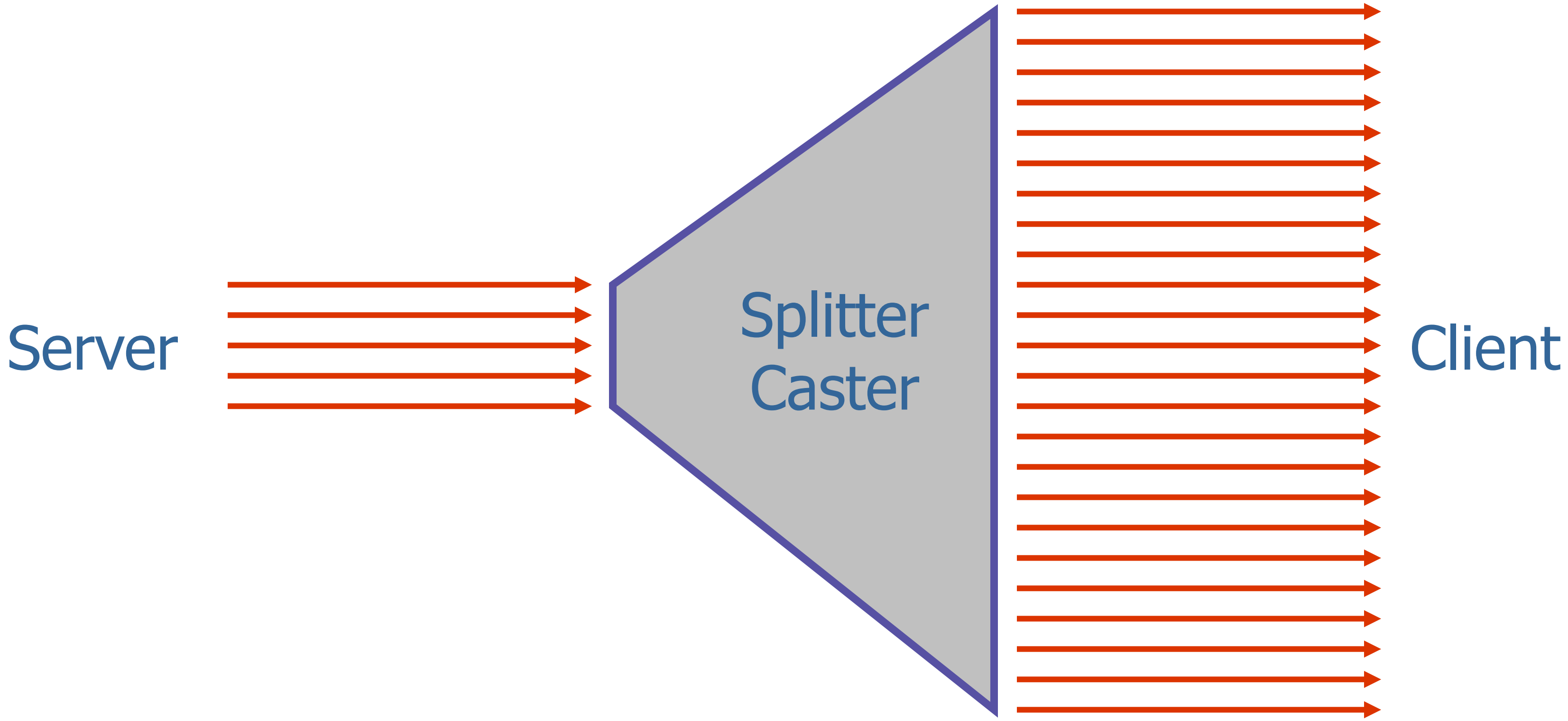
Networked **T**ransport of **R**TCM via **I**nternet **P**rotocol (**Ntrip**)



- GPRS/UMTS/EDGE Mobile Internet
- Based on HTTP



GNSS Internet Radio / IP-Streaming



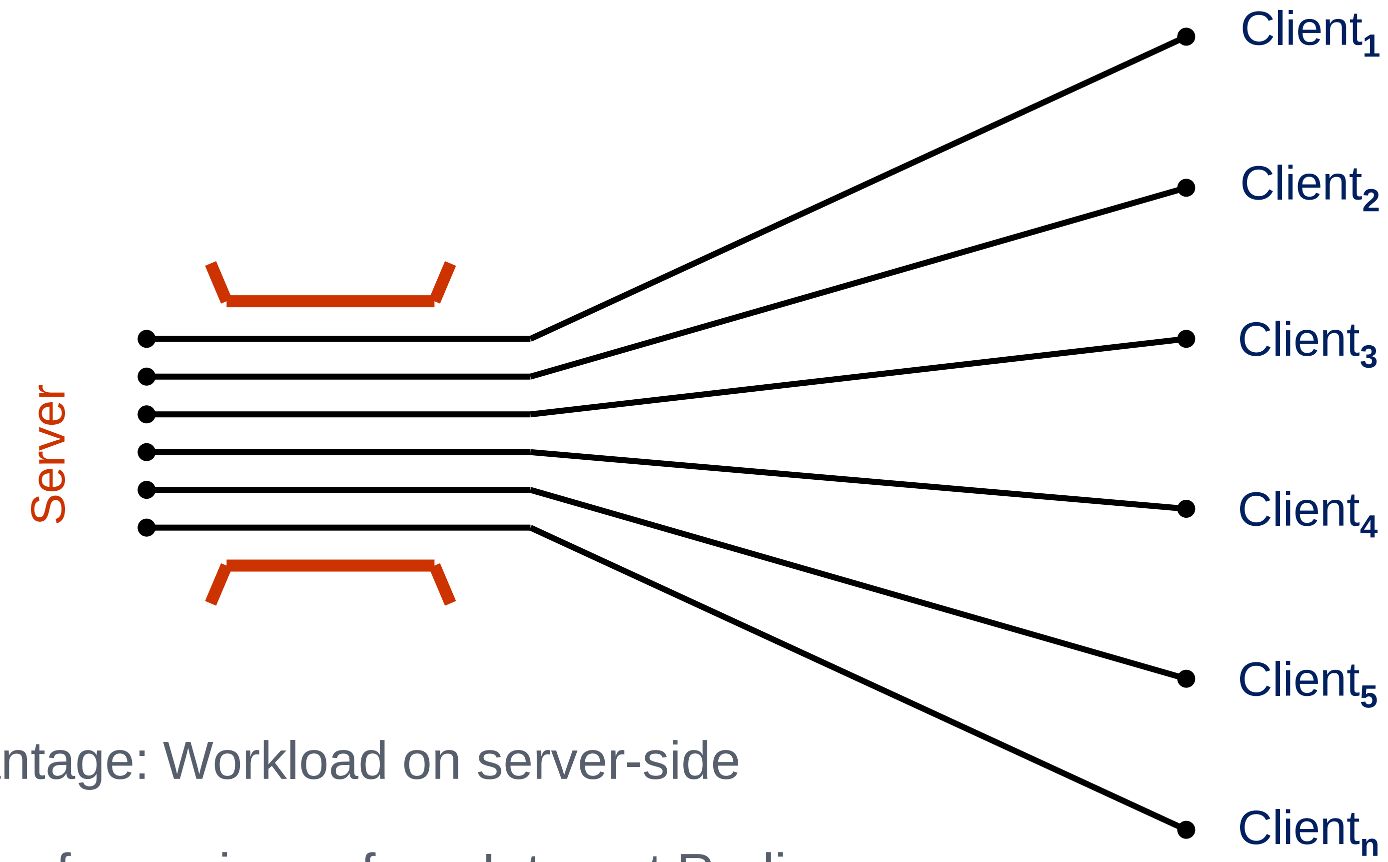
~5 kbit/s per GNSS Stream max.

DGPS/RTK Data Rates

- DGPS 0.5 kbits/s
- RTK 3 kbits/s

- Much less demanding than Internet Radio, Teleconferencing with …128… kbits/sec

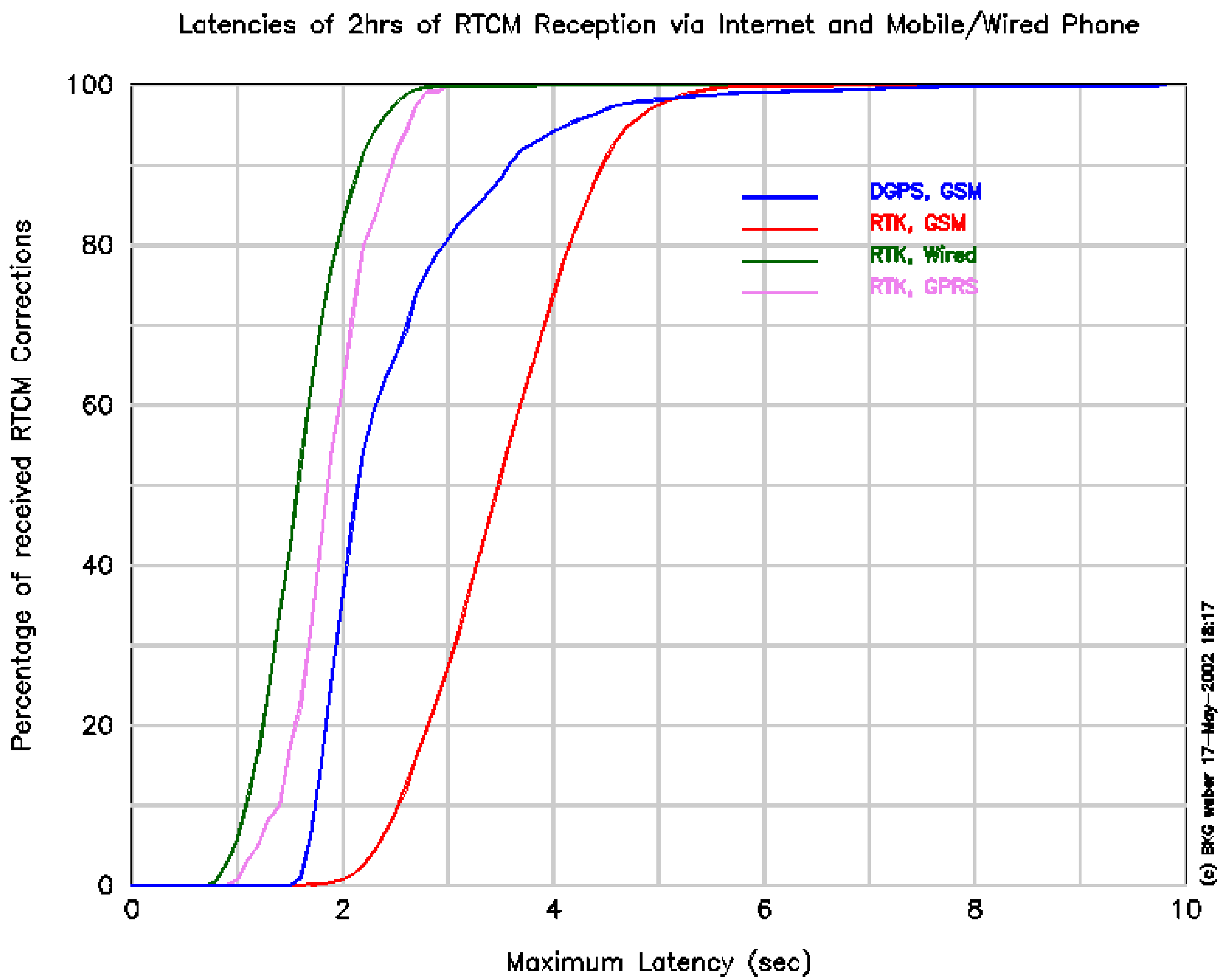
TCP/IP Unicast



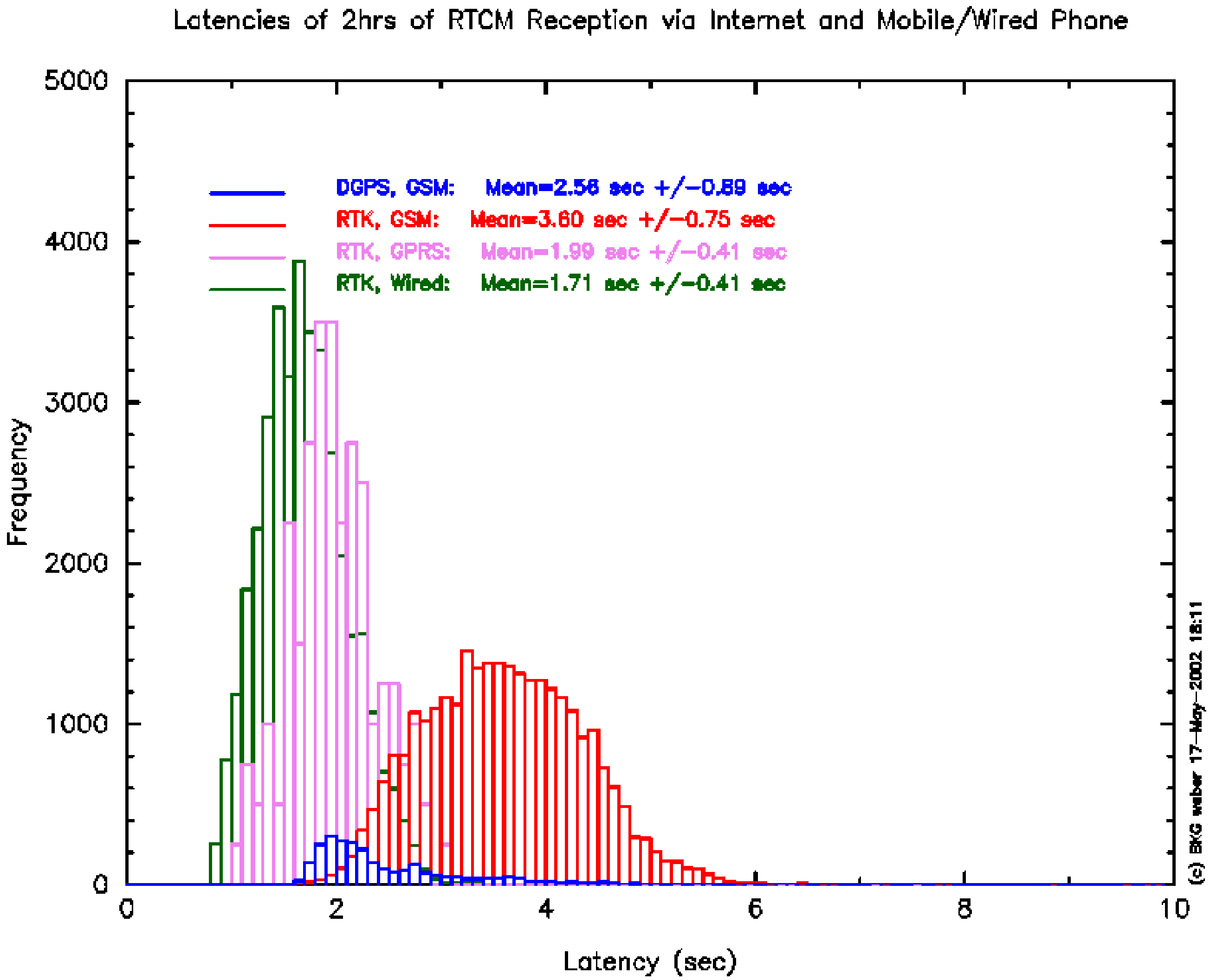
Disadvantage: Workload on server-side

But: Lots of experience from Internet Radio,
e.g. with handling of network congestion

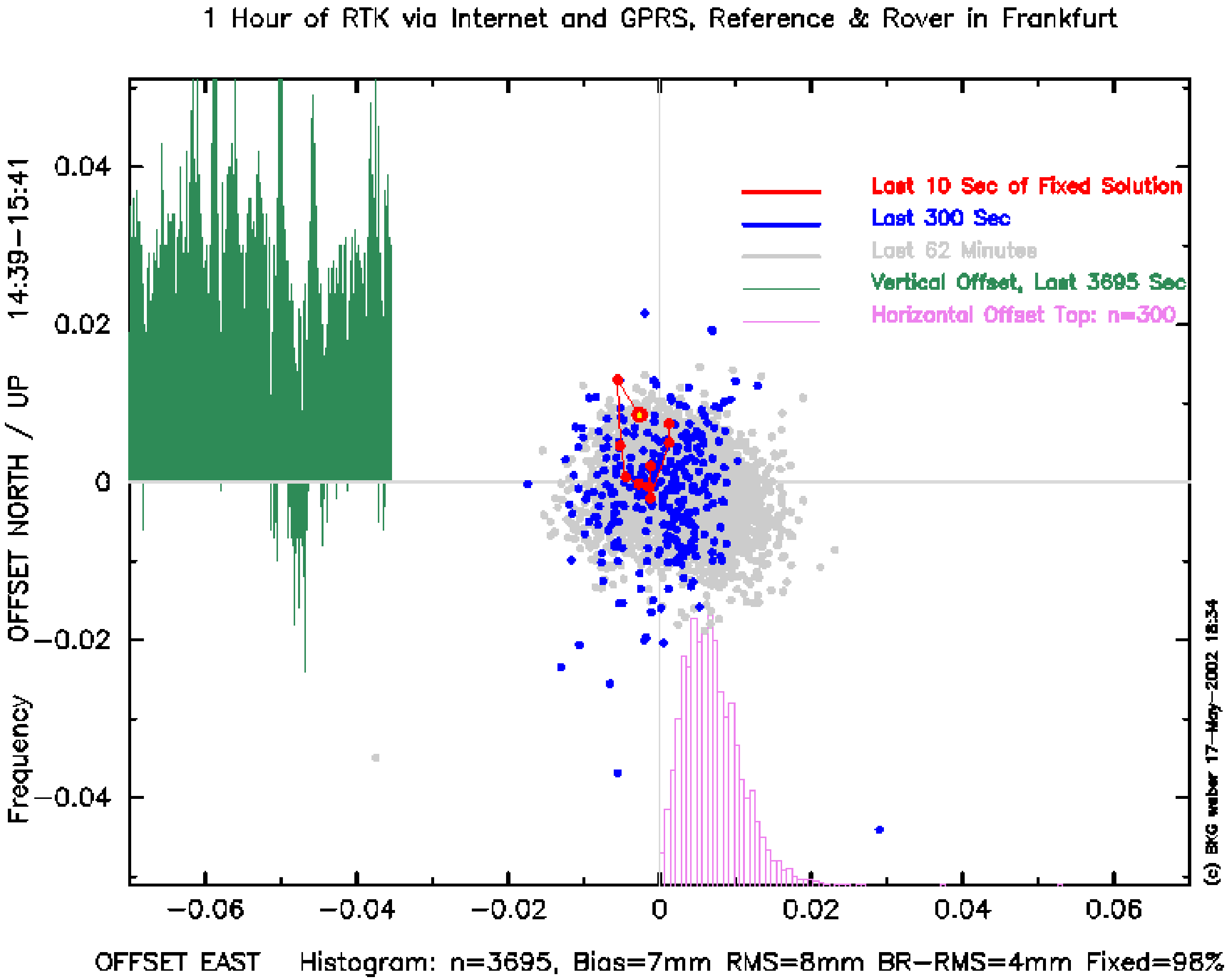
Latency of DGPS and RTK Corrections



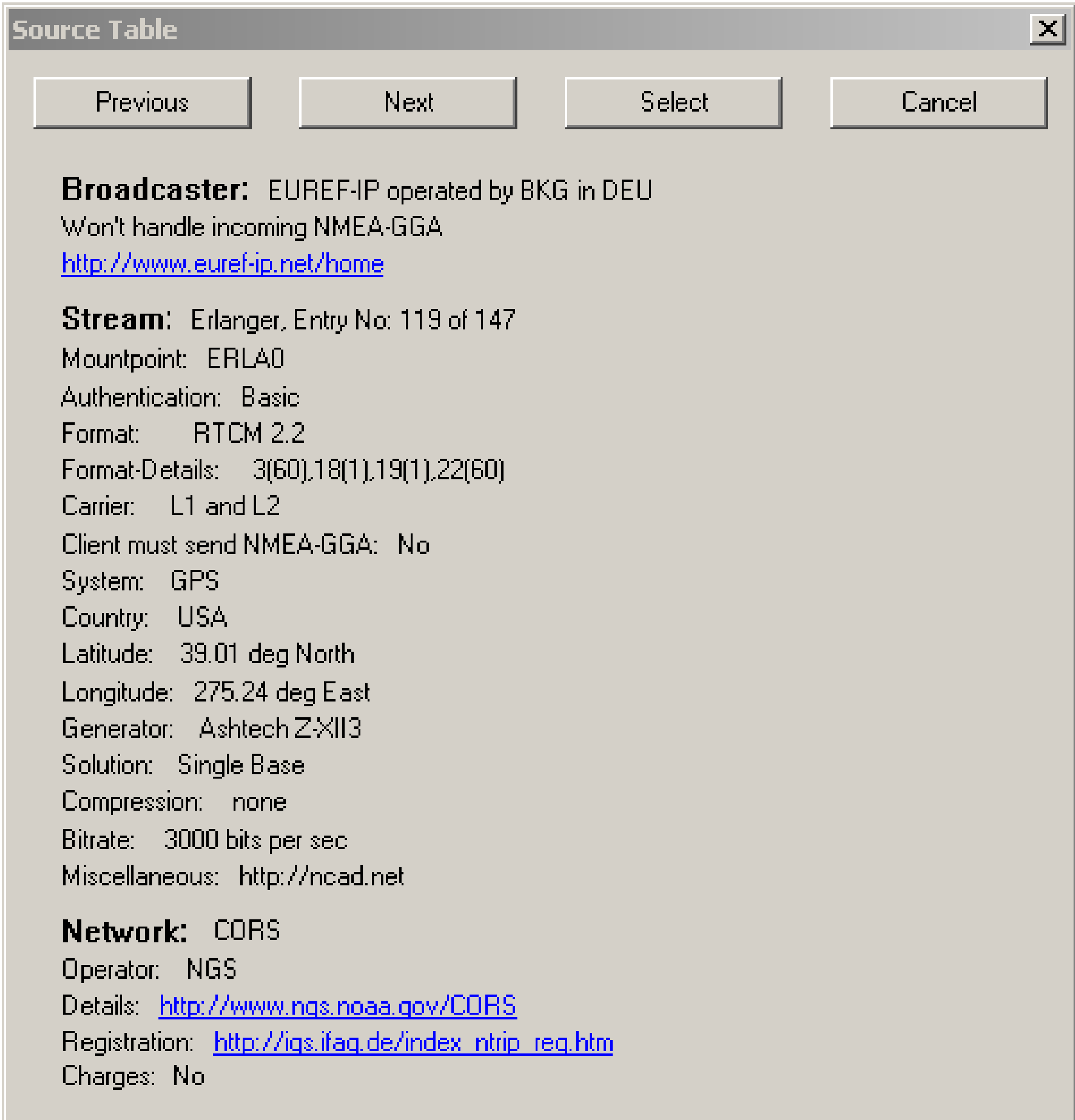
Latency of DGPS and RTK Corrections



RTK via Internet & GPRS



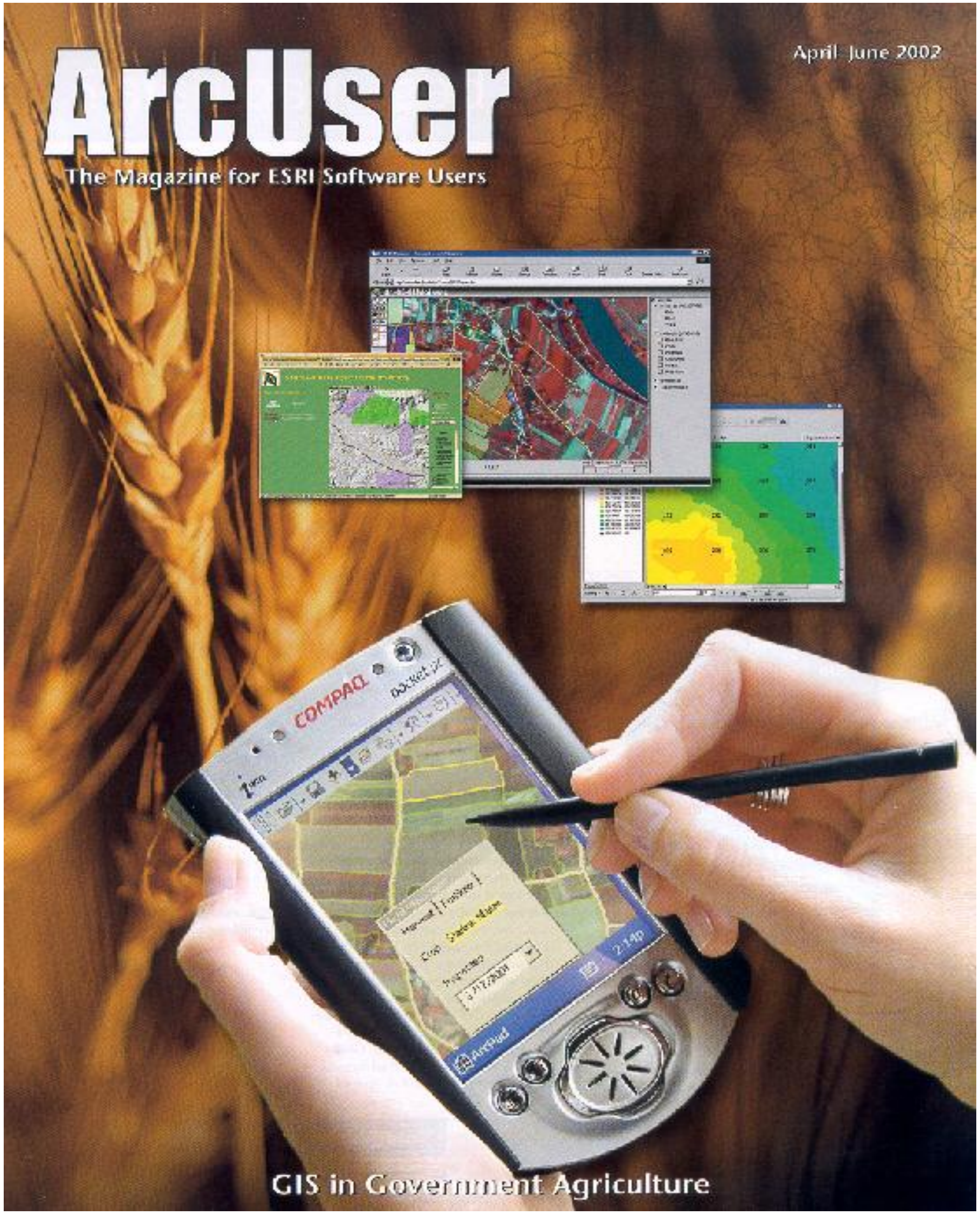
Meta-data


Source Table
Previous
Next
Select
Cancel
Broadcaster: EUREF-IP operated by BKG in DEU
Won't handle incoming NMEA-GGA
http://www.euref-ip.net/home
Stream: Erlanger, Entry No: 119 of 147
Mountpoint: ERLA0
Authentication: Basic
Format: RTCM 2.2
Format-Details: 3(60),18(1),19(1),22(60)
Carrier: L1 and L2
Client must send NMEA-GGA: No
System: GPS
Country: USA
Latitude: 39.01 deg North
Longitude: 275.24 deg East
Generator: Ashtech Z-XII3
Solution: Single Base
Compression: none
Bitrate: 3000 bits per sec
Miscellaneous: http://ncad.net
Network: CORS
Operator: NGS
Details: http://www.ngs.noaa.gov/CORS
Registration: http://igs.ifag.de/index_ntrip_reg.htm
Charges: No

Selection of Devices Supporting Ntrip

Simultaneous
Real-Time Access
to Distributed
Data:
GIS & Network RTK

Pocket PC & GPRS Modem



Ntrip Vers. 2, Concept and Details

- Version 2.0 is downwards compatible, includes SSL/TLS
- Full HTTP (RFC 2616) compatibility (proxy server)
  - Client-Caster communication &
  - Server-Caster communication
- UDP Unicast Transport (only Client-Caster communication)
  - Change to outband protocol design
  - Real-Time Streaming Protocol (RTSP) on top of TCP for stream control through “setup”, “play”, and “teardown”
  - Real-Time Transport Protocol (RTP) on top of UDP for data transport
- UDP Multicast Transport (only Client-Caster communication)
  - RTP on top of UDP for data transport and SRTP (Secure Real-Time Transport Protocol, RFC 3711) for stream protection

Client-Caster Communication

CLIENT → CASTER

```
GET /Mountpoint HTTP/1.1<CR><LF>
User-Agent: NTRIP GNSSInternetRadio/2.0.10<CR><LF>
Accept: */*<CR><LF>
Upgrade: Ntrip/2.0<CR><LF>
Connection: Upgrade<CR><LF>
<CR><LF>
```

CLIENT ← CASTER

```
HTTP/1.1 101 Switching Protocols<CR><LF>
Upgrade: Ntrip/2.0, HTTP/1.1<CR><LF>
Connection: Upgrade<CR><LF>
HTTP/1.1 200 OK<CR><LF>
Server: NTRIP Caster 2.0.1<CR><LF>
Content-Type: gnss/data<CR><LF>
Date: 25/Jan/2005:17:41:48 UTC<CR><LF>
<CR><LF>
GNSS Data
```

Server-Caster Communication:

SERVER → CASTER

NTRIP-SOURCE /Mountpoint HTTP/1.1<CR><LF>
User-Agent: NTRIP ServerCMD/1.5<CR><LF>
Authorization: Basic aHVnb2JlbjpodWdvYmVuMTIz<CR><LF>
NTRIP-STR: <STR-String><CR><LF> (optional)
Upgrade: Ntrip/1.1 <CR><LF>
Connection: Upgrade <CR><LF>
<CR><LF>

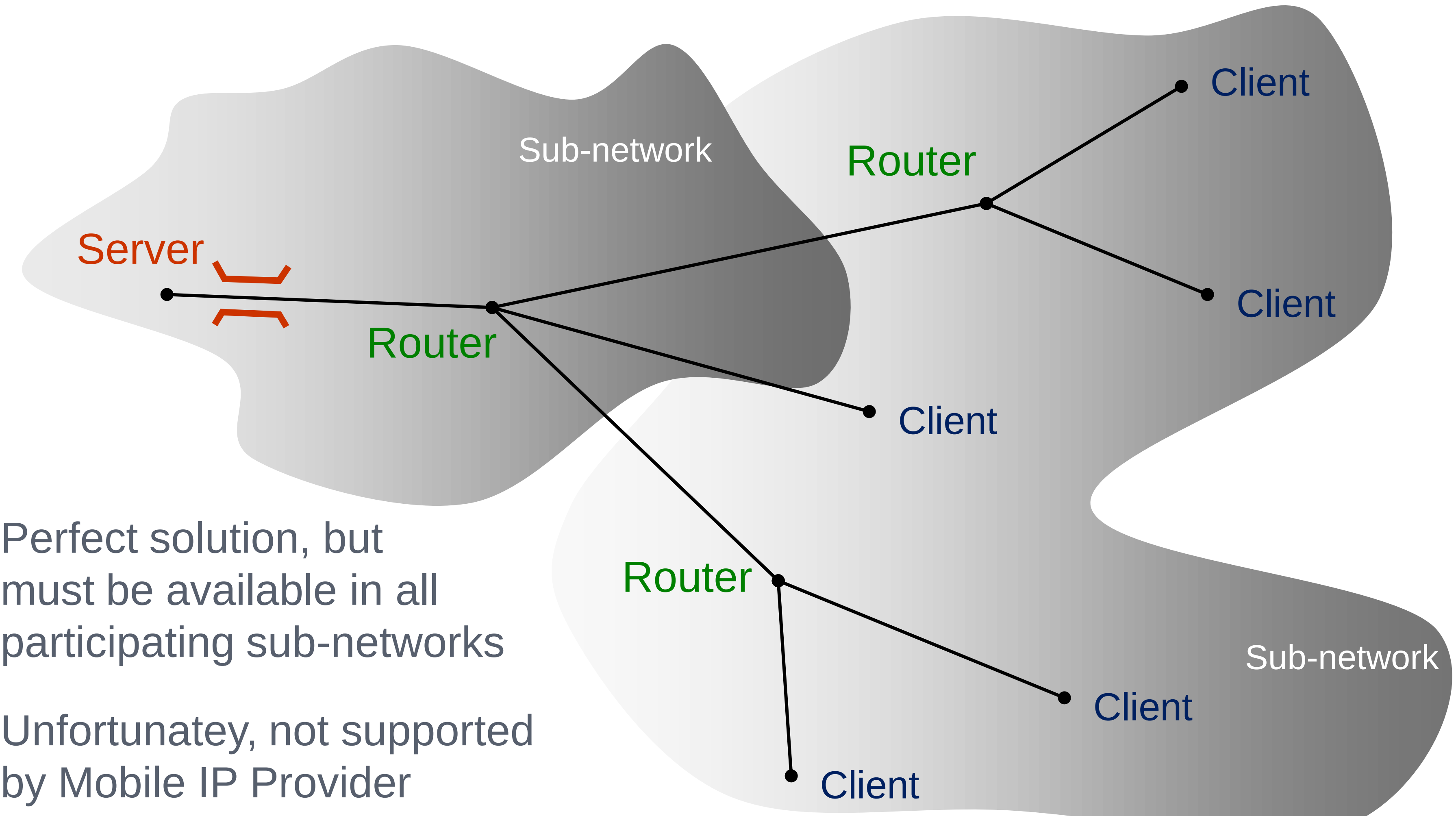
SERVER ← CASTER

HTTP/1.1 101 Switching Protocols<CR><LF>
Upgrade: Ntrip/2.0, HTTP/1.1<CR><LF>
Connection: Upgrade<CR><LF>
HTTP/1.1 200 OK<CR><LF>
<CR><LF>

SERVER → CASTER

GNSS Data

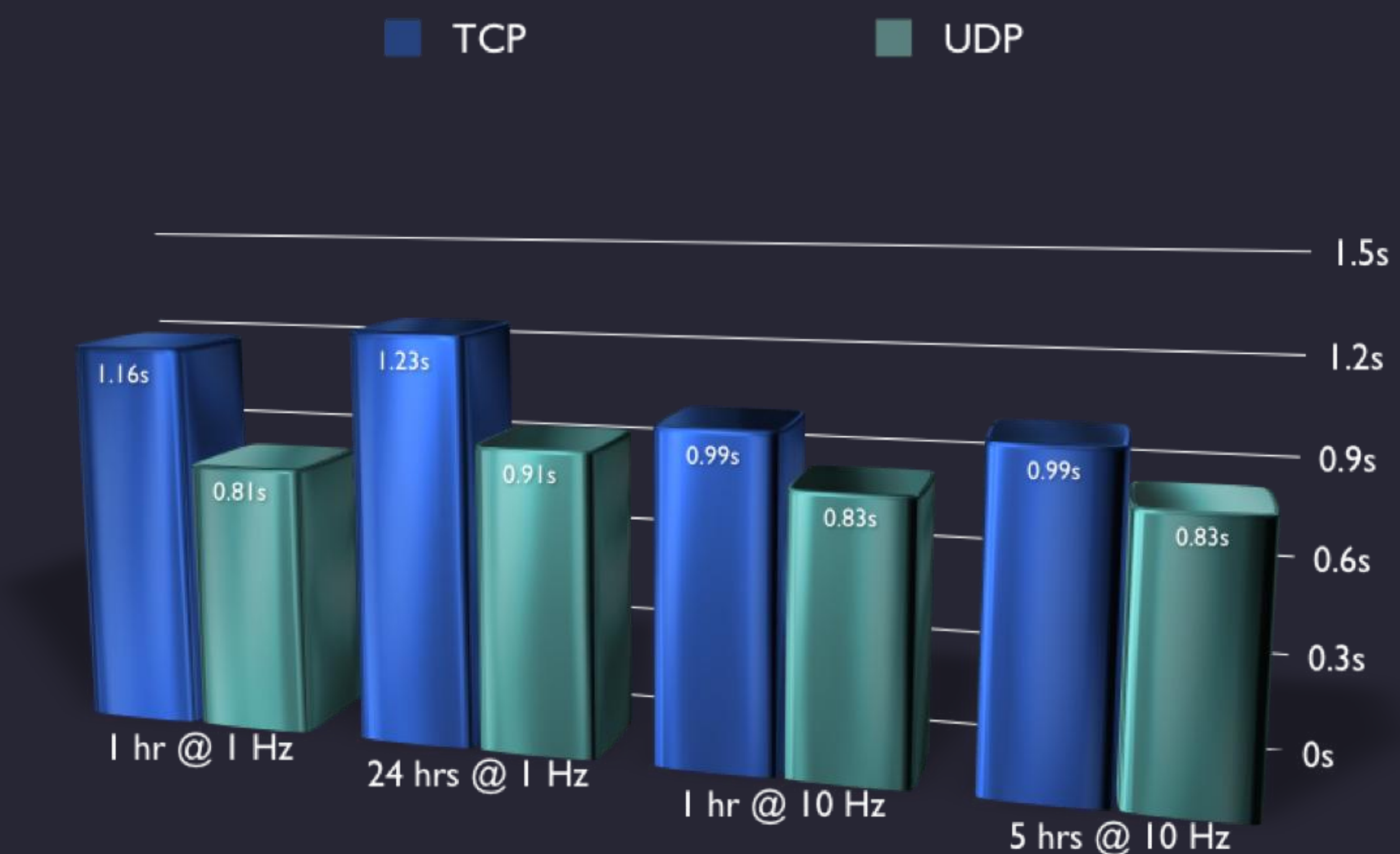
IP Multicast using UDP



Perfect solution, but must be available in all participating sub-networks

Unfortunatey, not supported by Mobile IP Provider

Latency Test Results



Ntrip Consequences

- Easy to become a provider
- Driver for development for real-time software
- End of special hardware for receiving streams
- Support of networking software
- Lots of potential for mass-usage

Real-time GNSS

Ntrip Broadcaster Demonstration and Exercises

Andrea Stürze and Georg Weber

Federal Agency for Cartography and Geodesy, Frankfurt, Germany

October 25 and 26, 2012

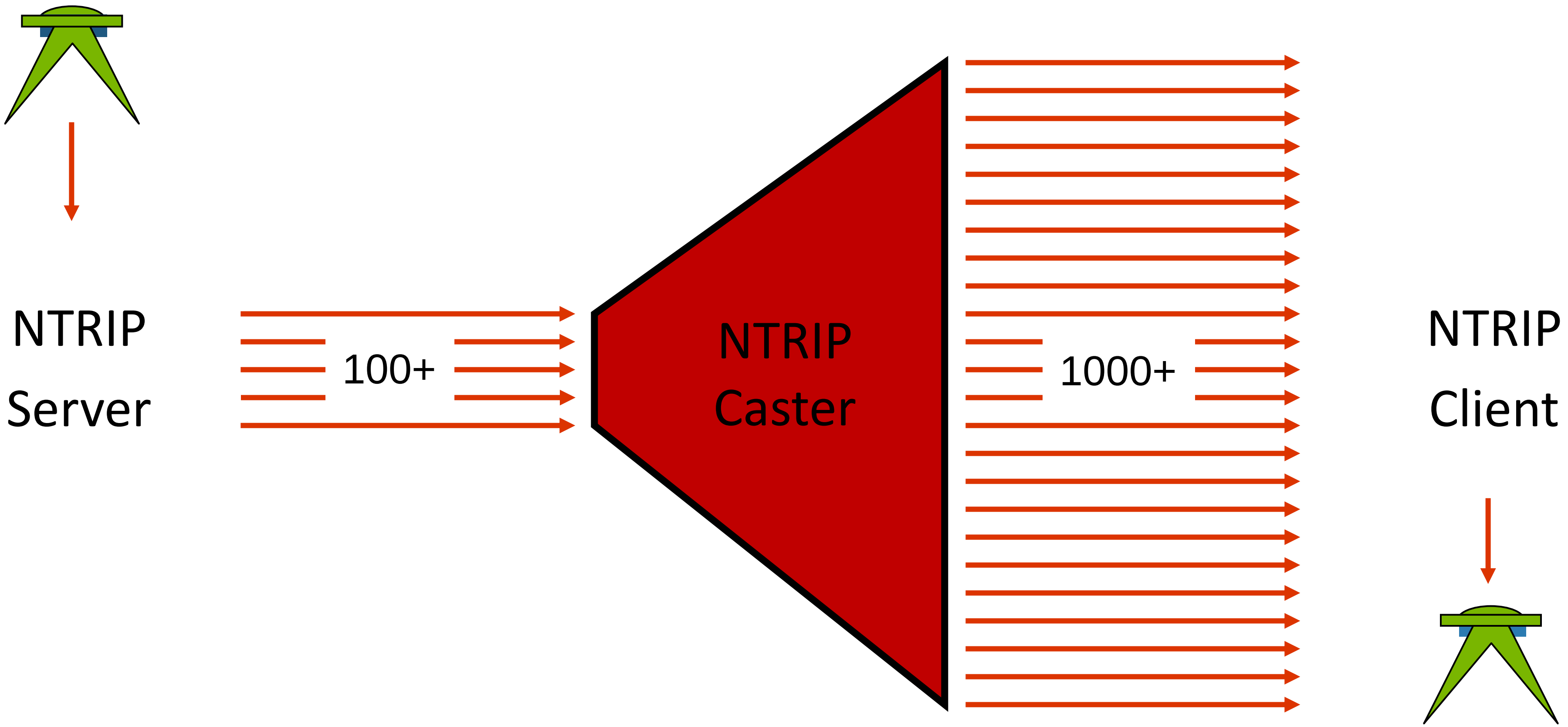
Outline

NetworkTransport of RTCM over Internet Protocol Caster

- Introduction
  - NTRIP system component Broadcaster
  - Communication example
  - Metadata handling
- Demonstration using BKG's NTRIP Professional Caster
  - Installation
  - Configuration
    - Setup of IP and Port
    - NTRIP Server & Client authorization concept
    - Metadata => source table
  - GNSS data upload & download possibilities
- Exercises using BKG's NTRIP components
  - NTRIP Casters www.igs-ip.net and products.igs-ip.net
  - BKG NTRIP Client

Introduction
Ntrip System Element Caster

- NTRIP Caster = NTRIP's major system component



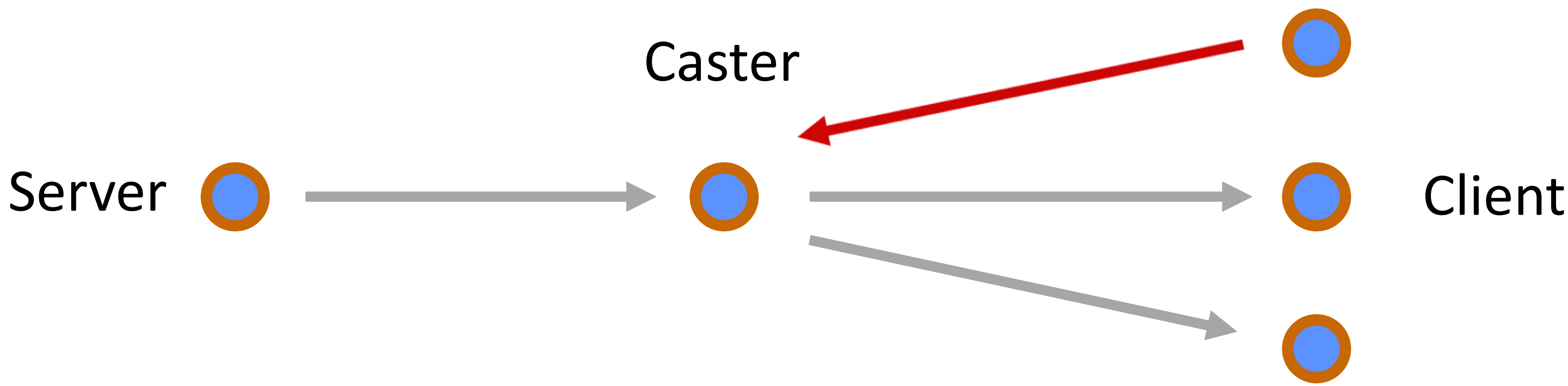
- Stream providers and users are not in contact

Introduction
NTRIP Caster

- Acting as server and supporting a subset of HTTP/RTSP request and response messages
  - HTTP(S) mode: communication and data transfer via TCP/HTTP
  - RTSP mode: communication via TCP/RTSP, data transfer via UDP/RTP
- Adjusted to low-bandwidth streaming data
  - 50-500 Bytes/sec per stream
- Accepts request-messages on a single port from either the
  - NTRIP Server or the
  - NTRIP Client
- Depending on theses messages the Caster decides whether there is streaming data
  - to receive or
  - to send

Introduction
NTRIP Caster Communication Example (I)

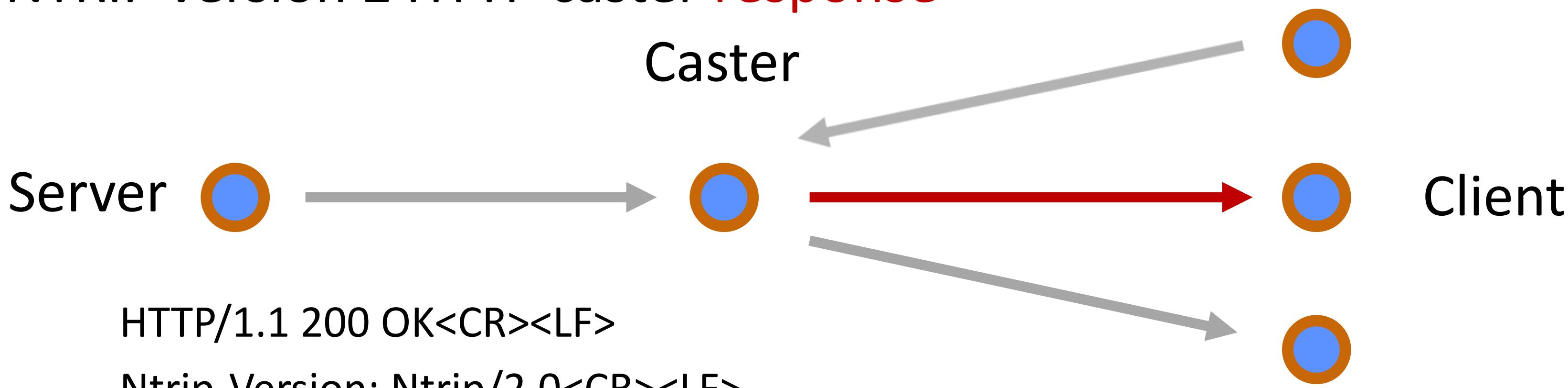
- NTRIP version 2 HTTP client request



GET /BRAZ0 HTTP/1.1<CR><LF>
Host: www.igs-ip.net<CR><LF>
Ntrip-Version: Ntrip/2.0<CR><LF>
User-Agent: NTRIP BKG NTRIP Client/2.0<CR><LF>
Authorization: Basic bnRyaXA6c2VjcmV0<CR><LF>
Connection: close<CR><LF> <CR><LF>

Introduction
NTRIP Caster Communication Example (II)

- NTRIP version 2 HTTP caster response



HTTP/1.1 200 OK<CR><LF>
Ntrip-Version: Ntrip/2.0<CR><LF>
Server: NTRIP www.igs-ip.net/2.0<CR><LF>
Date: Tue, 01 Jan 2012 14:08:15 GMT<CR><LF>
Cache-Control: no-store, no-cache, max-age=0<CR><LF>
Pragma: no-cache<CR><LF>
Connection: close<CR><LF>
Content-Type: gnss/data<CR><LF> <CR><LF>
Data...`.....|(......Q......'P....#...A).5........9...

Introduction
Metadata handling (I)

- NTRIP Caster source-table
  - CAS record = Caster entry
  - NET record = Network entry
  - STR record = Source entry
  - Data field content separated by “;”

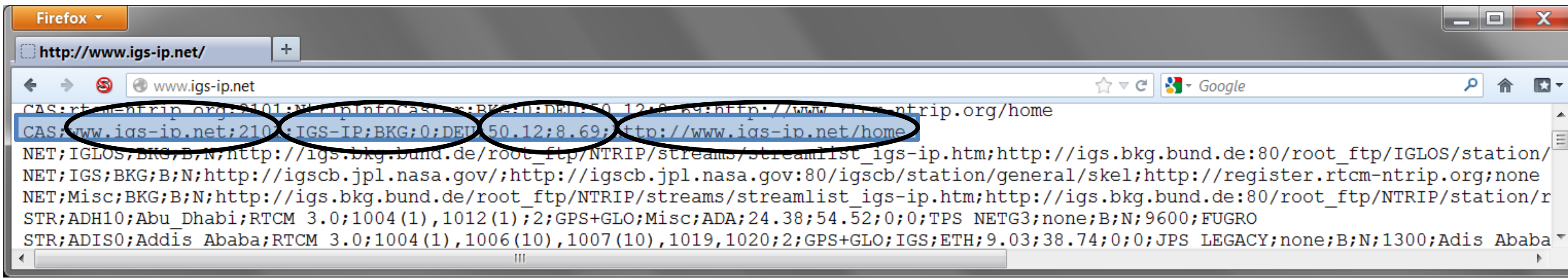
Firefox
http://www.igs-ip.net/
www.igs-ip.net

```
SOURCETABLE 200 OK
Server: NTRIP Caster 2.0.15/2.0
Date: Thu, 18 Oct 2012 06:57:32 GMT
Connection: close
Content-Type: text/plain
Content-Length: 22467

CAS;rtcm-ntrip.org;2101;NtripInfoCaster;BKG;0;DEU;50.12;8.69;http://www.rtcm-ntrip.org/home
CAS;www.igs-ip.net;2101;IGS-IP;BKG;0;DEU;50.12;8.69;http://www.igs-ip.net/home
NET;IGLOS;BKG;B;N;http://igs.bkg.bund.de/root_ftp/NTRIP/streams/streamlist_igs-ip.htm;http://igs.bkg.bund.de:80/root_ftp/IGLOS/station/
NET;IGS;BKG;B;N;http://igscb.jpl.nasa.gov/;http://igscb.jpl.nasa.gov:80/igscb/station/general/skel;http://register.rtcm-ntrip.org;none
NET;Misc;BKG;B;N;http://igs.bkg.bund.de/root_ftp/NTRIP/streams/streamlist_igs-ip.htm;http://igs.bkg.bund.de:80/root_ftp/NTRIP/station/r
STR;ADH10;Abu_Dhabi;RTCM 3.0;1004(1),1012(1);2;GPS+GLO;Misc;ADA;24.38;54.52;0;0;TPS NETG3;none;B;N;9600;FUGRO
STR;ADIS0;Addis_Ababa;RTCM 3.0;1004(1),1006(10),1007(10),1019,1020;2;GPS+GLO;IGS;ETH;9.03;38.74;0;0;JPS LEGACY;none;B;N;1300;Adis Ababa
STR;ADIS1;A-GPS-Addis_Ababa;RTCM 3.0;1019(5),1020(5);2;GPS;IGS;ETH;9.03;38.74;0;0;JPS LEGACY;none;B;N;1300;Adis Abbaba University
STR;AJAC0;Ajaccio;RTCM 3.1;1004(1),1006(15),1008(60),1012(1),1033(60);2;GPS+GLO;IGS;FRA;41.93;8.76;0;0;LEICA GRX1200GGPRO;none;B;N;4000
STR;ALGO0;Algonquin-Park;RTCM 3.0;1004(1),1006(10),1008(10);2;GPS;IGS;CAN;45.96;281.93;0;0;AOA BENCHMARK ACT;none;B;N;1300;NRCan
STR;ALIC0;Alice_Springs;RTCM 3.1;1004(1),1006(15),1008(15),1012(1);2;GPS+GLO;IGS;AUS;-23.67;133.88;0;0;LEICA GRX1200GGPRO;none;B;N;1600
STR;ARLI0;Arlington;RTCM 2.3;1(1),3(6),16(60),18(1),19(1),22(6),23(5),24(5);2;GPS;Test;USA;48.17;237.86;0;0;TRIMBLE NETRS;none;B;N;3600
STR;ASPA0;Pago-Pago;RTCM 3.0;1004(1),1006(60),1008(60),1012(1);2;GPS+GLO;IGS;ASM;-14.33;189.28;0;0;TRIMBLE NETR5;none;B;N;2000;realtime
STR;AUCK0;Auckland;RTCM 3.0;1004(1),1006(5),1008(5),1012(1),1013(5),1033(5);2;GPS+GLO;IGS;NZL;-36.60;174.83;0;0;TRIMBLE NETR9;none;B;N;
```

Introduction
Metadata handling (II)

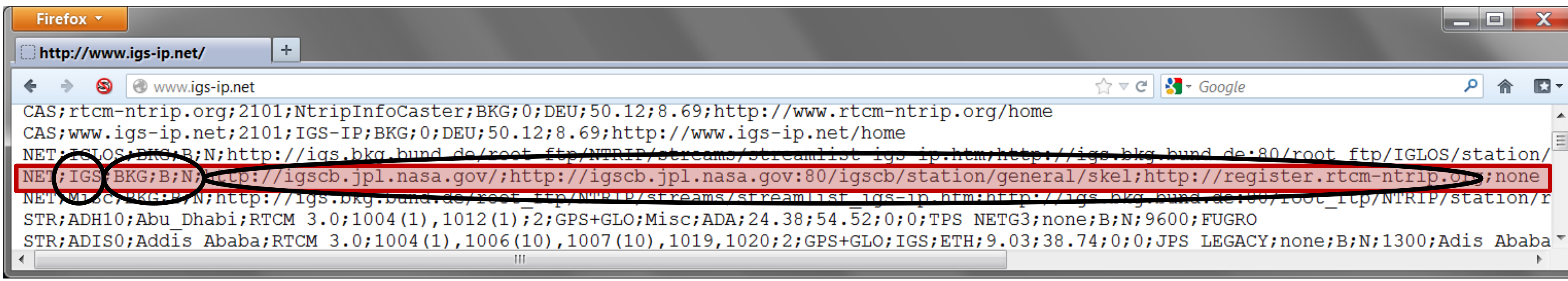
- NTRIP Caster source-table
  - CAS record



- Caster host and port
- Caster name; operator; NMEA support; 3 char country ID
- Latitude; longitude of the caster's location
- Fallback Caster IP/host

Introduction
Metadata handling (III)

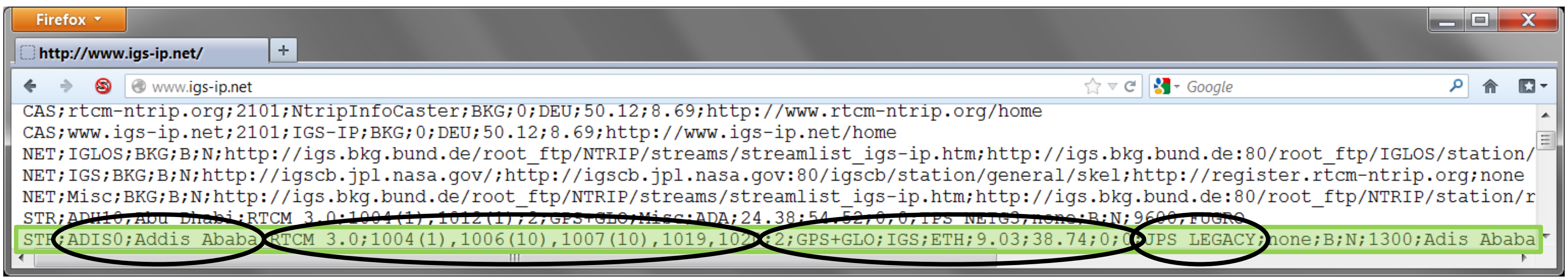
- NTRIP Caster source-table
  - NET record



- Network identifier
- Network operator; Authentication (None, Basic, Digest); fee (Yes, No)
- Web pages (Network, Streams, Registration, etc.)
- Miscellaneous information

Introduction
Metadata handling (IV)

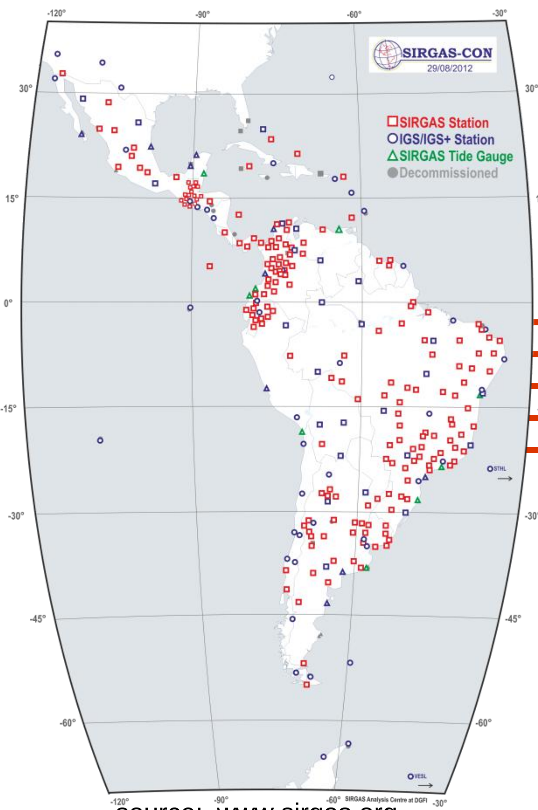
- NTRIP Caster source-table
  - STR record



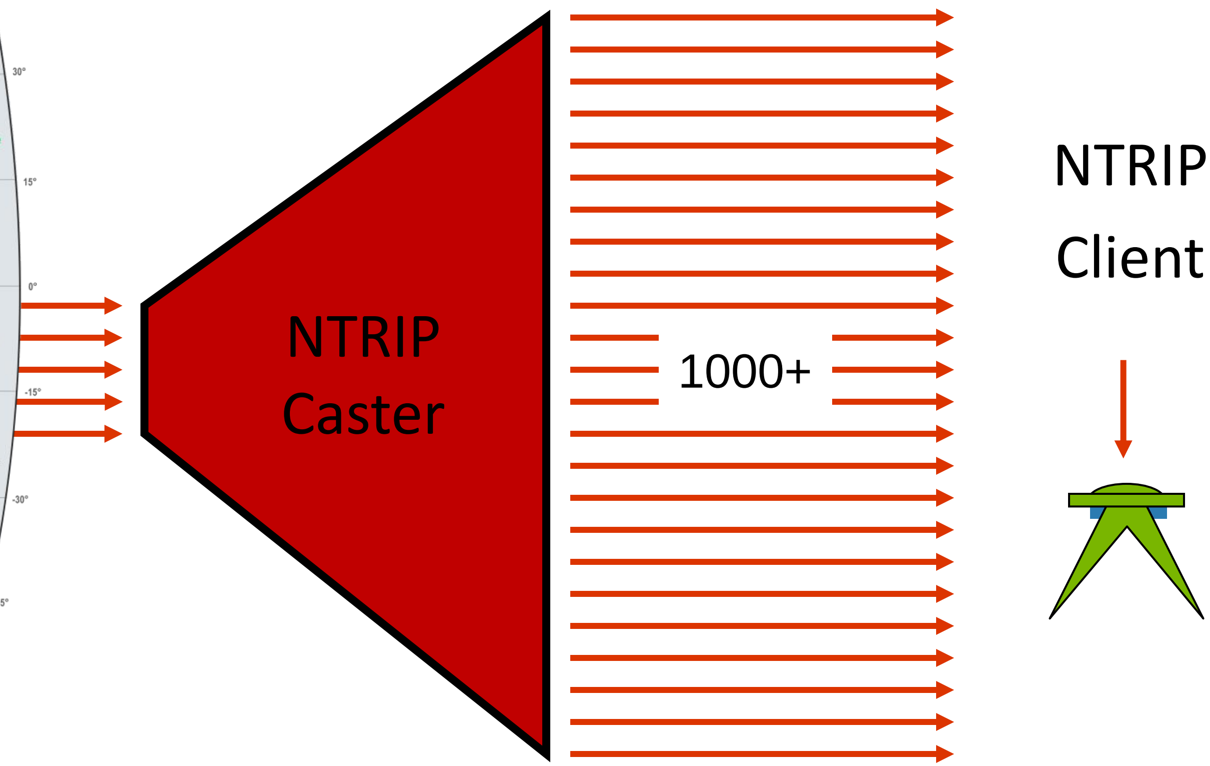
- “Mountpoint”; Identifier (Name of the city next to source location)
- Format; Format details
- Carrier; GNSS; network; 3 char country ID; Latitude; longitude; NMEA support solution (0 = reference station, 1 = network);
- Generator (hardware, software, receiver)
- ..

Demonstration
NTRIP Caster for SIRGAS

- What would be required to setup a SIRGAS NTRIP Caster?



source: www.sirgas.org



Demonstration
BKG NTRIP Caster Installation

(1) Copy it somewhere into an empty directory

(2) run bunzip2 ntripcaster-version.tar.bz2 and

(3) run tar xfv ntripcaster-version.tar for un-compression

(4) Run ./configure

- if you do not want the server to be installed in "/usr/local/ntripcaster" specify the desired path with ./configure --prefix=<path>

(5) Run make

(6) Run make install

(7) After that, the server files will be installed

- Binaries in /usr/sbin and /usr/bin
- configuration files in /etc/ntripcaster
- logs in /var/log/ntripcaster
- html templates in /usr/local/ntripcaster/templates

Demonstration
BKG NTRIP Caster Configuration

- Configuration files within the sub-directory /conf
  - for general administration
    - ntripcaster.conf
  - for NTRIP Server & Client authorization
    - clientmounts.aut [mount-points <=> NTRIP Client access/user group]
    - sourcemounts.aut [mount-points <=> NTRIP Server access/user group]
    - groups.aut [mount-points <=> NTRIP Server access/user group]
    - users.aut [mount-points <=> NTRIP Server access/user group]
  - to save metadata
    - sourcetable.dat

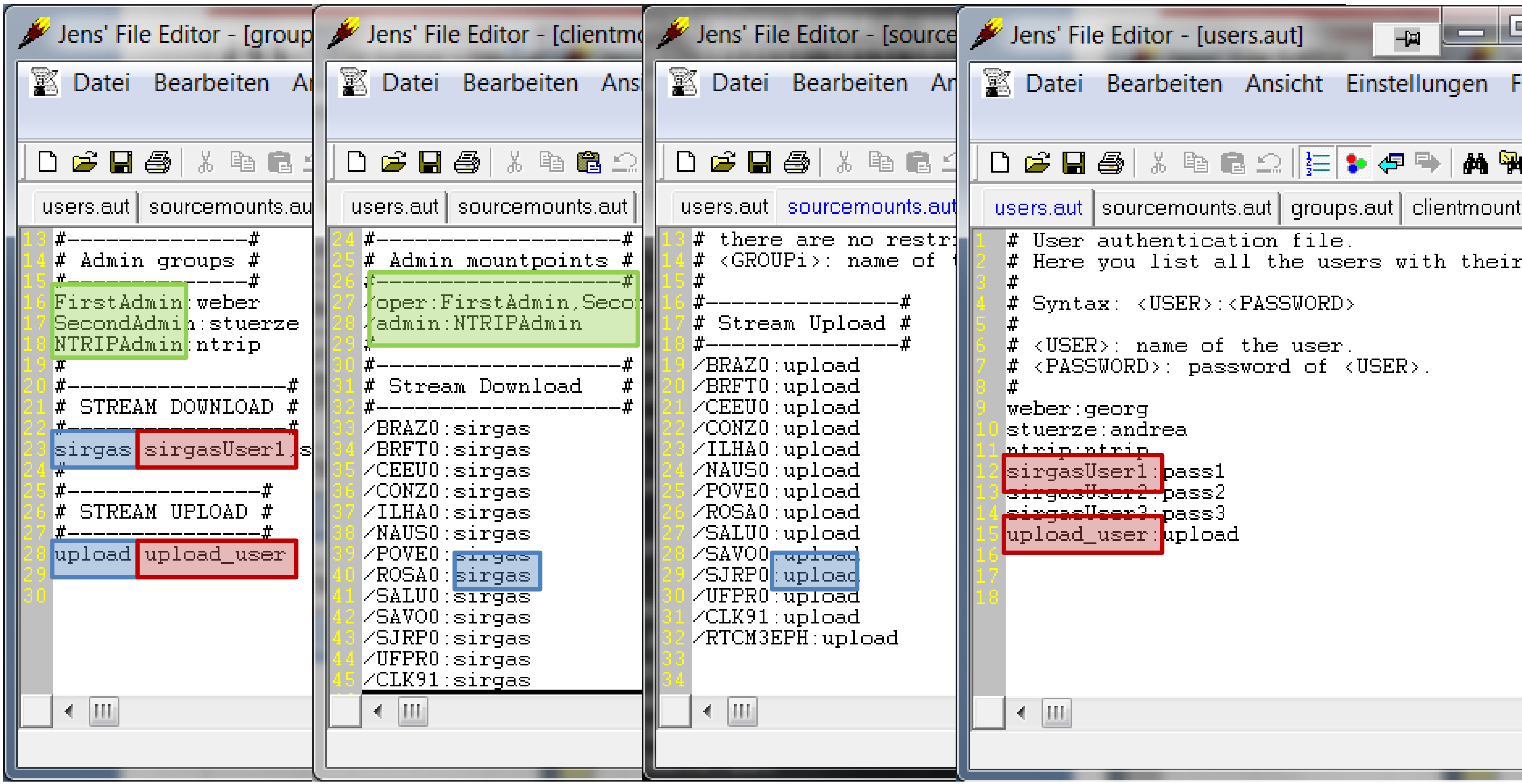
- Note: after installation the configuration files has to be re-named by removing the .dist suffix

Demonstration
BKG NTRIP Caster Administration

- via Web-Interface: http://NTRIP_CasterIP:port/admin
  - Definition of administrator and operator groups whose members perform administrative and operational duties and responsibilities

- Configuration concept:
  - *admin mount-points* with groups are defined in clientmounts.aut
    - /oper (unlimited rights)
    - /admin (limited rights)
  - *admin groups* with members (users) are defined in groups.aut
    - FirstAdmin, SecondAdmin
    - NTRIPAdmin
  - *admin group members* are defined in users.aut

Demonstration
NTRIP Caster Configuration for SIRGAS



Demonstration
Start & Stop the BKG NTRIP Caster

- Sub-directory /sbin
  - NTRIP Caster executable ntripdaemon

- Sub-directory /bin
  - start script ntripcaster
    - START: ./ntripcaster start
    - RE-START: ./ntripcaster restart
    - STOP: ./ntripcaster stop
  - shell script casterwatch to continuously watch the ntripdaemon process

- Note: casterwatch should never crash
  - In case ntripdaemon crashes or is shut down for re-configuration reasons, casterwatch shall re-start it within a few seconds.

Demonstration
BKG NTRIP Caster Web-Interface

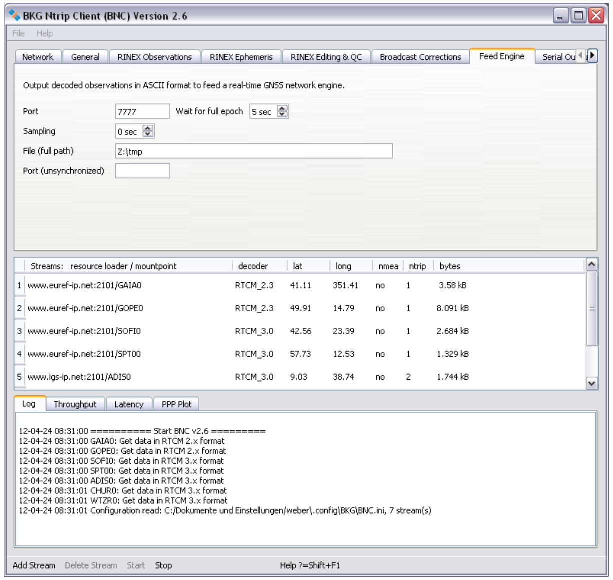
- Home page
  - http://NTRIP_CasterIP:port/home

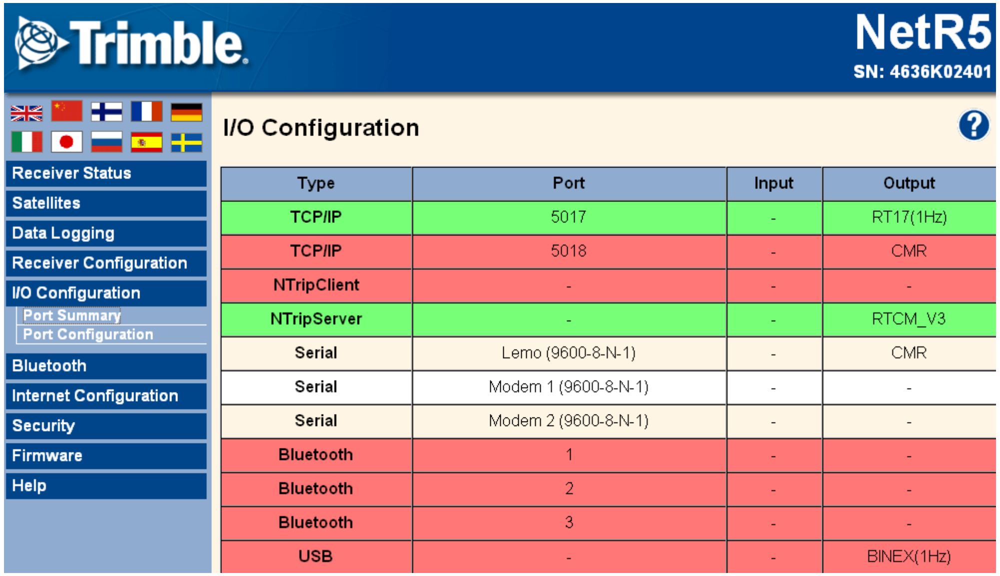
- Administrator Web Interface
  - http://NTRIP_CasterIP:port/admin
  - password protected

- Sub-directory /templates contains templates for both

Demonstration
BKG NTRIP Caster: Data up-/download

- GNSS data download
  - NTRP Client Software (for example BKG NTRIP Client)
- GNSS data upload
  - Stand alone NTRIP Server
  - NTRIP Server functionality included in modern GNSS receivers
  - NTRIP Client functionality implemented within NTRIP Caster





Exercises
Using BKG's Ntrip Components

- NTRIP Caster
  - GNSS observation data:
    - www.igs-ip.net
    - For example mount points : BRAZ0, POVE0, ROSA0, ..
  - GNSS navigation data / orbit and clock products:
    - http://products.igs-ip.net
    - RTCM3EPH for ephemeris
    - CLK91, CLK11, .. for satellite orbit and clock information
  - Available NTRIP client accounts:
    - sirgas1:pass1
    - sirgas2:pass2
    - sirgas3:pass3
- BKG NTRIP Client BNC
  - Download from http://igs.bkg.bund.de/ntrip/download

Real Time GNSS

IGS Network

Real Time IGS Network http://www.rtigs.net

- Real Time IGS Working Group since 2001
- Real Time IGS Pilot Project since 2007
- Analysis Centers:
  BKG, CNES, CTU, DLR, ESA, Geo++, GMV, GZF, NRCan, Wuhan
- Upcoming Real-time Service announced for end of this year

Why is IGS Involved in Real-Time GNSS?

Support research organizations, national mapping agencies, NGOs

- GNSS performance monitoring
- Rapidly detecting, locating, and characterizing hazardous events such as earthquakes and tsunamis
- Geophysical hazard detection and warning systems
- Space weather forecasting

Welcome to the Real Time Working Group's Home Page

The IGS Real Time Working Group (RTWG) has designed and developed a prototype IGS Real-time Tracking Network. The network is designed according to the architecture agreed to following the "Towards Real-time" workshop held in Ottawa in 2002. The prototype network has grown to over 50 active stations and currently the emphasis is on initiating a Real-time Pilot Project which is expected to begin in the October 2007 time frame.

Working Group Chair

- Mark Caissy Natural Resources Canada

Participating agencies

- Bundesamt fuer Kartographie und Geodaesie, Germany, (BKG)
- Crustal Dynamics Data Information System, NASA, USA, (CDDIS)
- ESA's European Space Operations Centre (ESOC)
- National Geodetic Survey, USA (NGS)
- Natural Resources Canada (NRCan)
- Polytechnic University of Catalonia, Spain, (UPC)
- GEO++
- GMV
- UNAVCO

Working Group Members

IGS Real Time Pilot Project (RTPP)

Welcome to the official home page for the IGS Real-time Pilot Project. In June 2007, the International GNSS Service (IGS), Real-Time Pilot Project Call For Participation (CFP) was released.

PDF version of RTPP CFP Document.

The main goals of the Real-Time Pilot Project include:

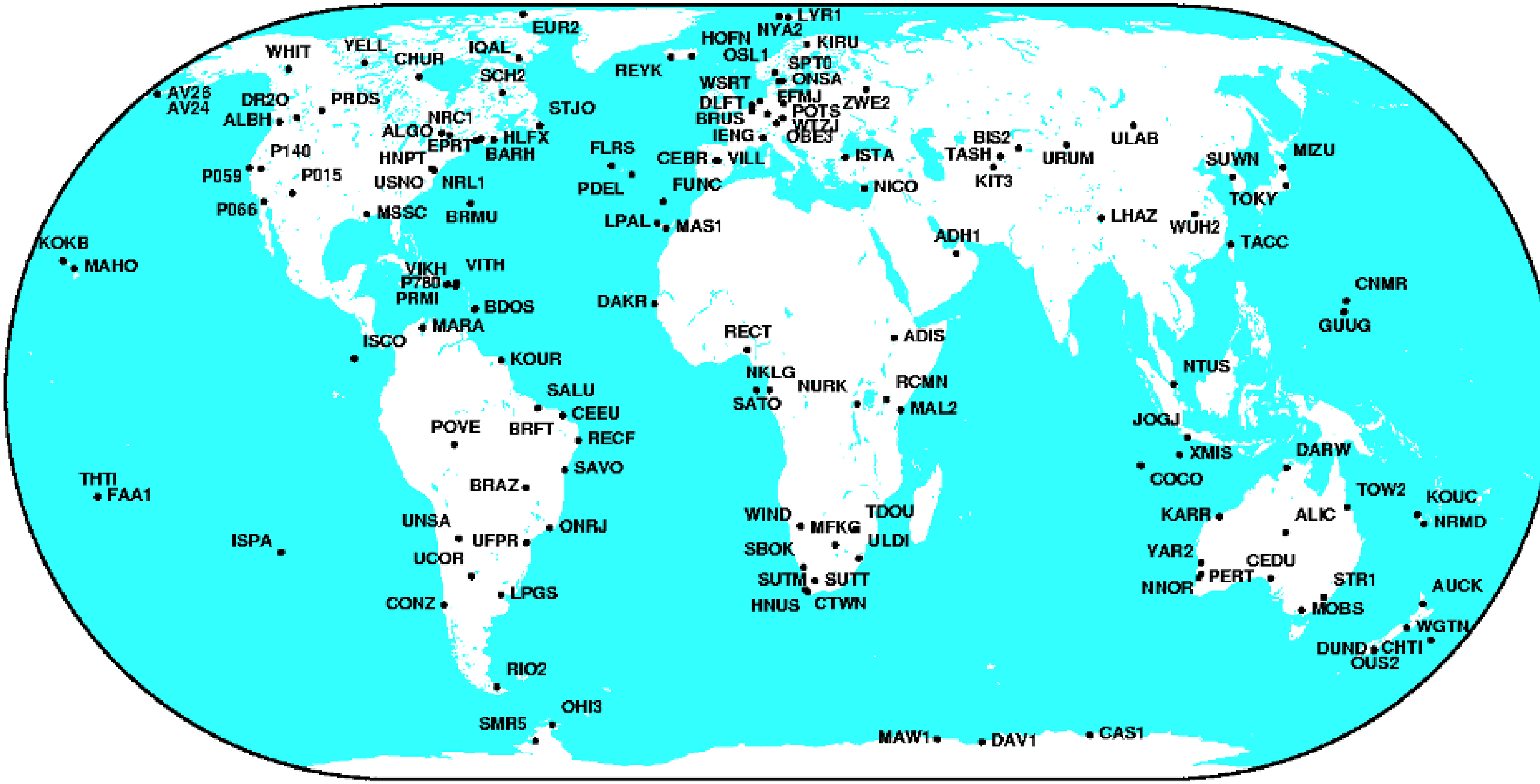
- Manage and maintain a global IGS real-time GNSS tracking network
- Generate combined real-time IGS analysis products
- Develop standards and formats for real-time data collection and distribution
- Develop standards and formats for the generation and distribution of real-time analysis products

Real-Time Pilot Project Organization

- RT Station Contributors
- RT Data Centers
- RT Analysis Centers
- RT Associate Analysis Centers
- RT Analysis Center Coordinator
- RT Network Management and Monitoring
- RT Users for Assessment, Evaluation and Feedback

If you have any questions or would like further information please use the Request Info link on the RTIGS Working Group (RTWG) pages.

IGS Real-time Tracking Network



GMT 2012 Jun 6 13:33:53

Real-time Tracking Stations

- Existing real-time IGS stations and those IGS station operators interested in participating by converting their stations to real time operations are asked to contribute

- Thematic networks currently not contributing

- Data quality, reliability and availability impact real-time products generated in the Pilot Project

IGS Station Operation Guidelines

- The stations contributing to the IGS Real-time Network must follow IGS site guidelines.

- Station operators required to follow network management guidelines including change management procedures.

Real-time Data Centers

- Two types of real-time data centers exist.

- The first type is an extension of the global data center model in which real-time streams will be used at the data center to generate high-rate and 30-second files.

- The second type of data center is a real-time stream supplier where users will have access to both real-time data and/or real-time product streams.

(1) Real-time Data-file Center

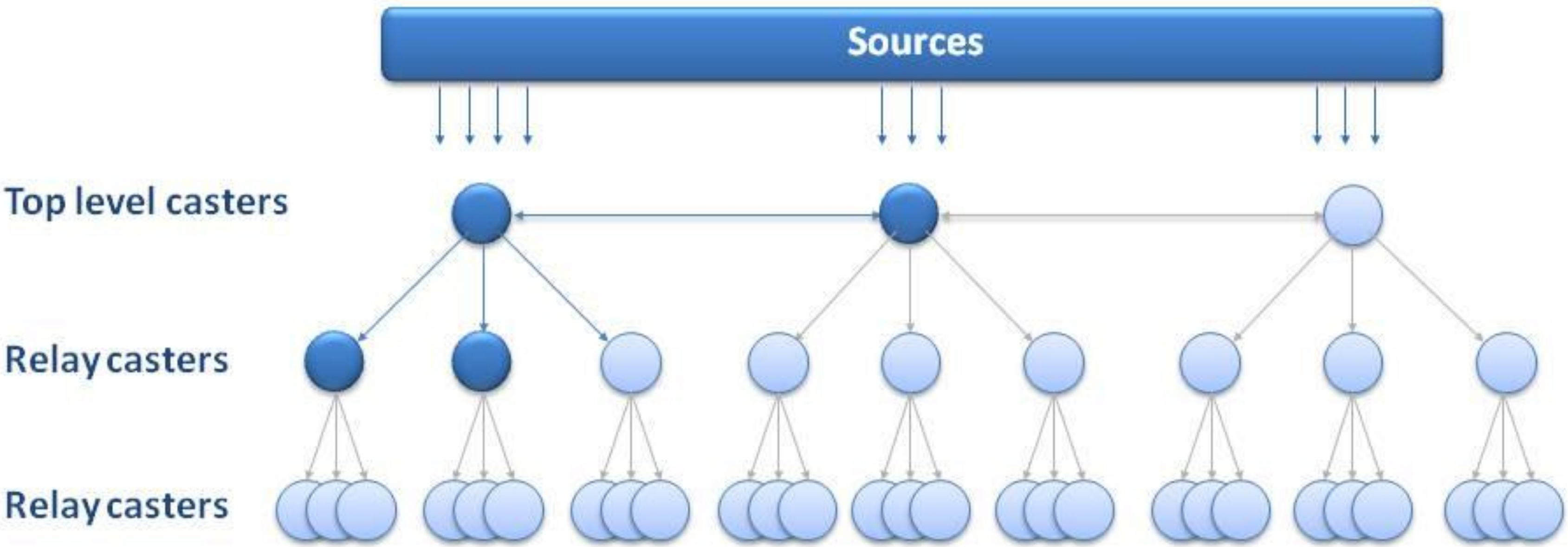
- The existing IGS Regional and Global Data Centers as well as agencies using or considering using real-time data streams for the purpose of generating station data files are invited to participate in assessing the feasibility of generating high-rate data files, and/or 30-second hourly files and/or 30-second daily files.

(2) Real-time Data/Product Distribution

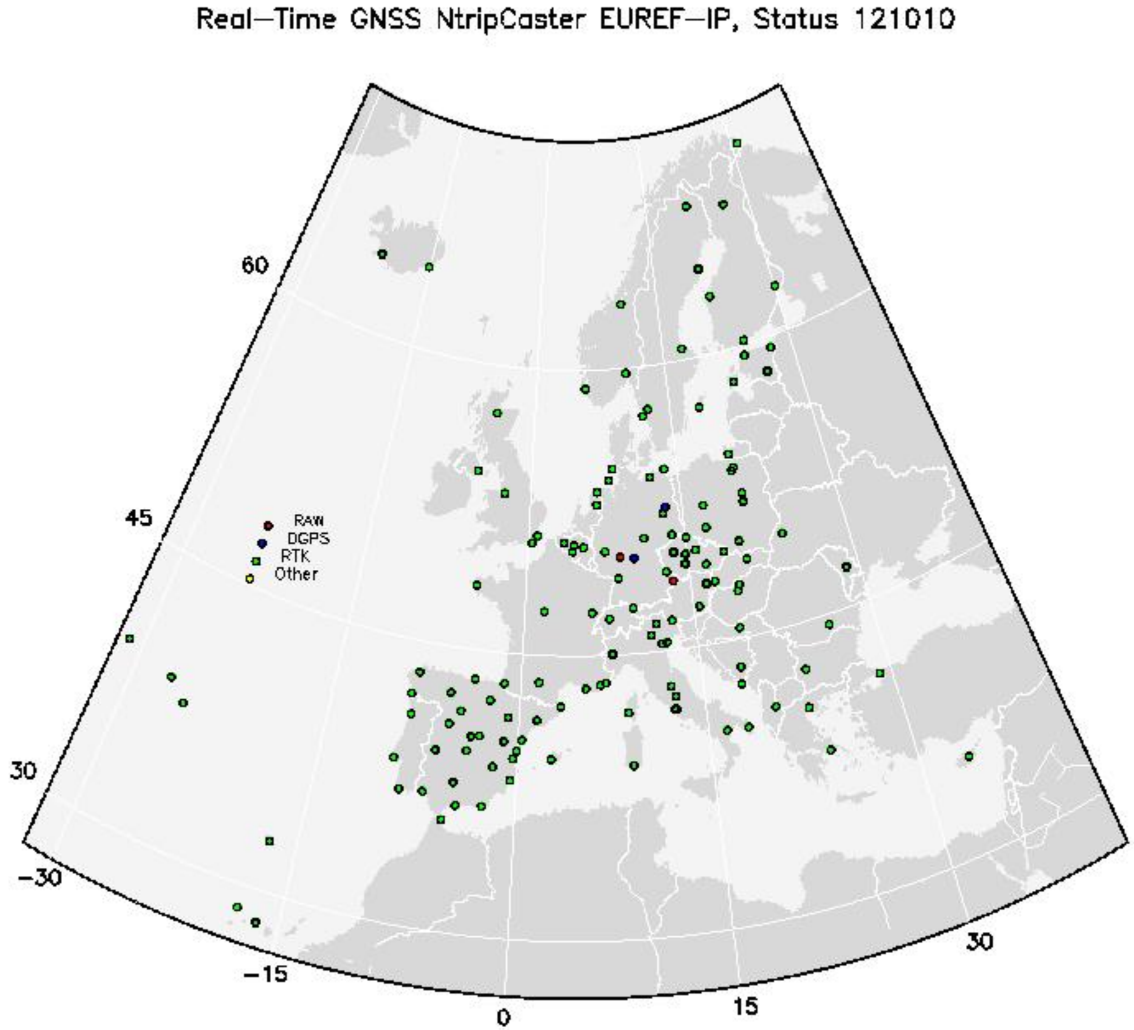
- Data distribution centers require sufficient bandwidth to accommodate their clients' needs. Bandwidth resources needed for data and product distribution will depend on the number of clients being served and the size of data and product streams. Bandwidth requirements may be estimated based on the following assumptions:

  Data streams: 3-kilobits/s per station request.
  Product streams: [Satellite clocks and satellite orbits]
  2 kilobits/s per client request.

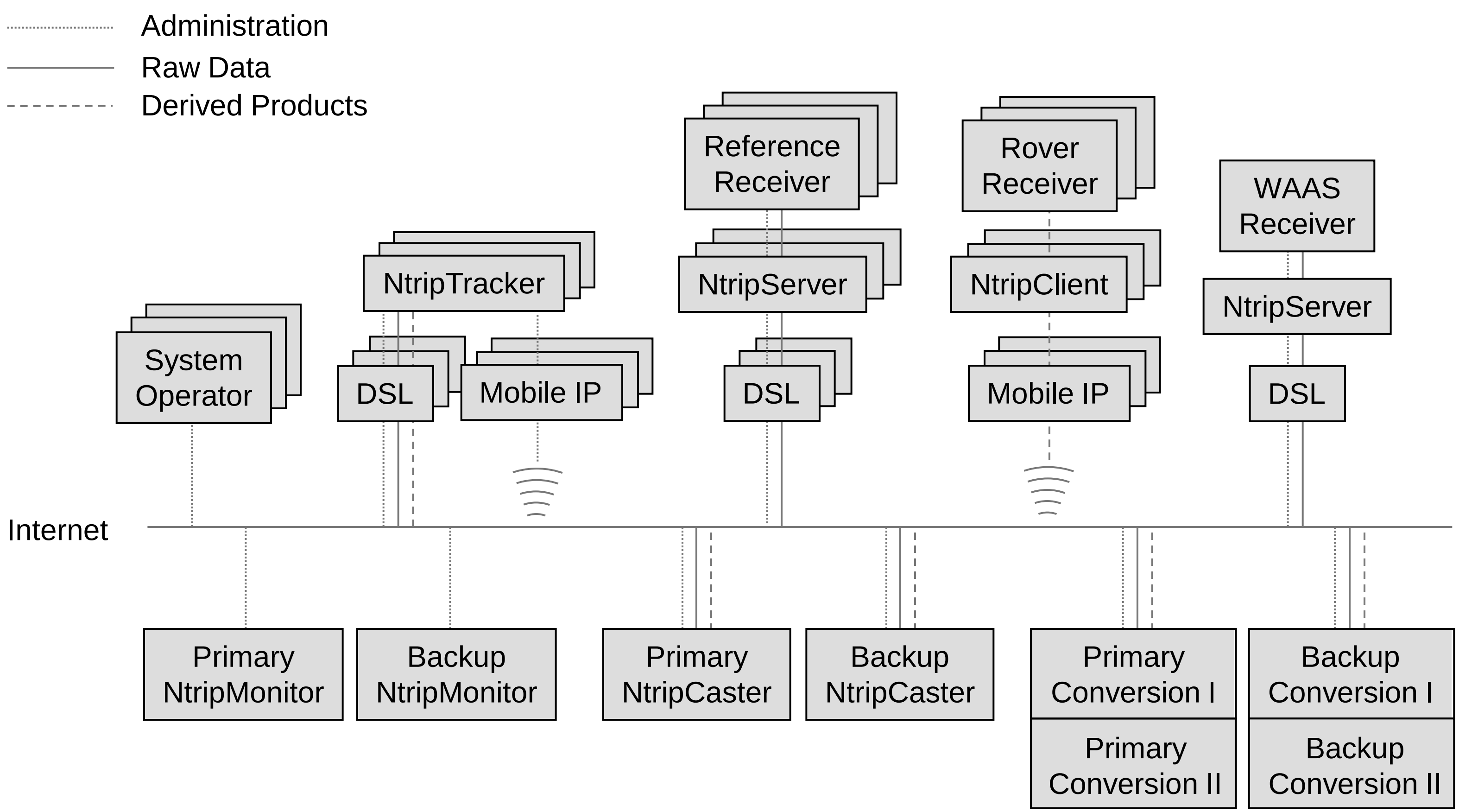
Ntrip Broadcast Concept



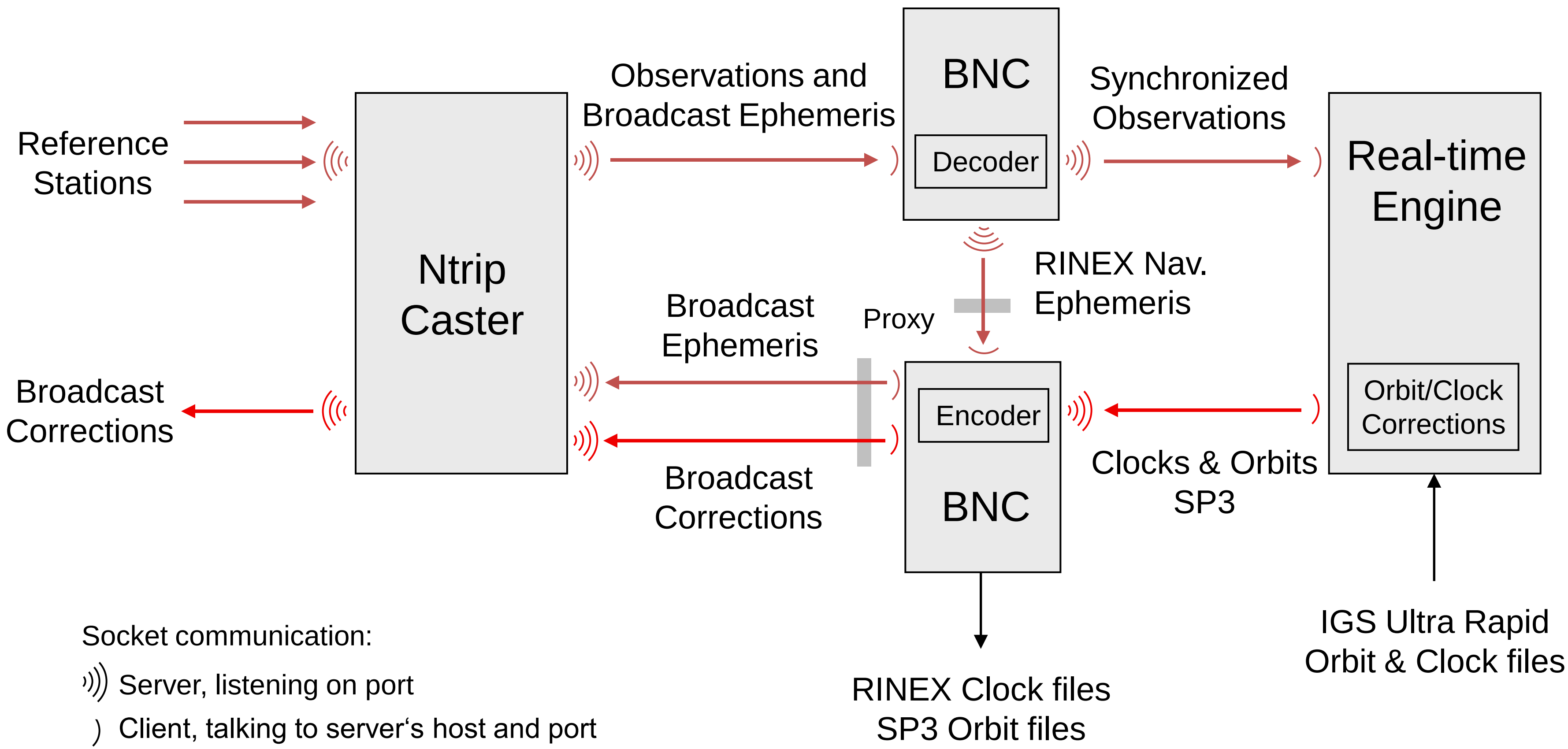
EUREF‘s Real-time Network



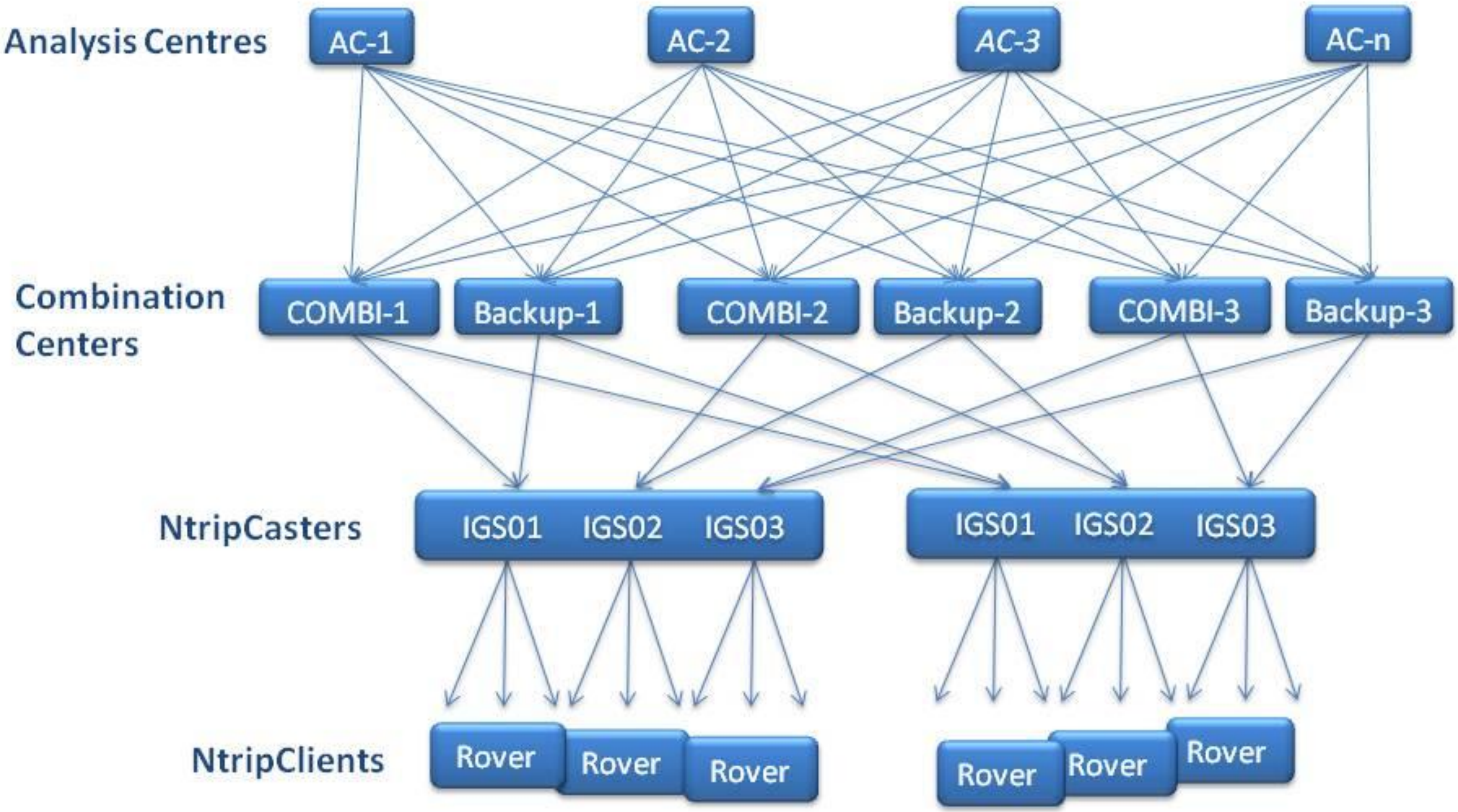
Real-time IGS Network, Data Flow



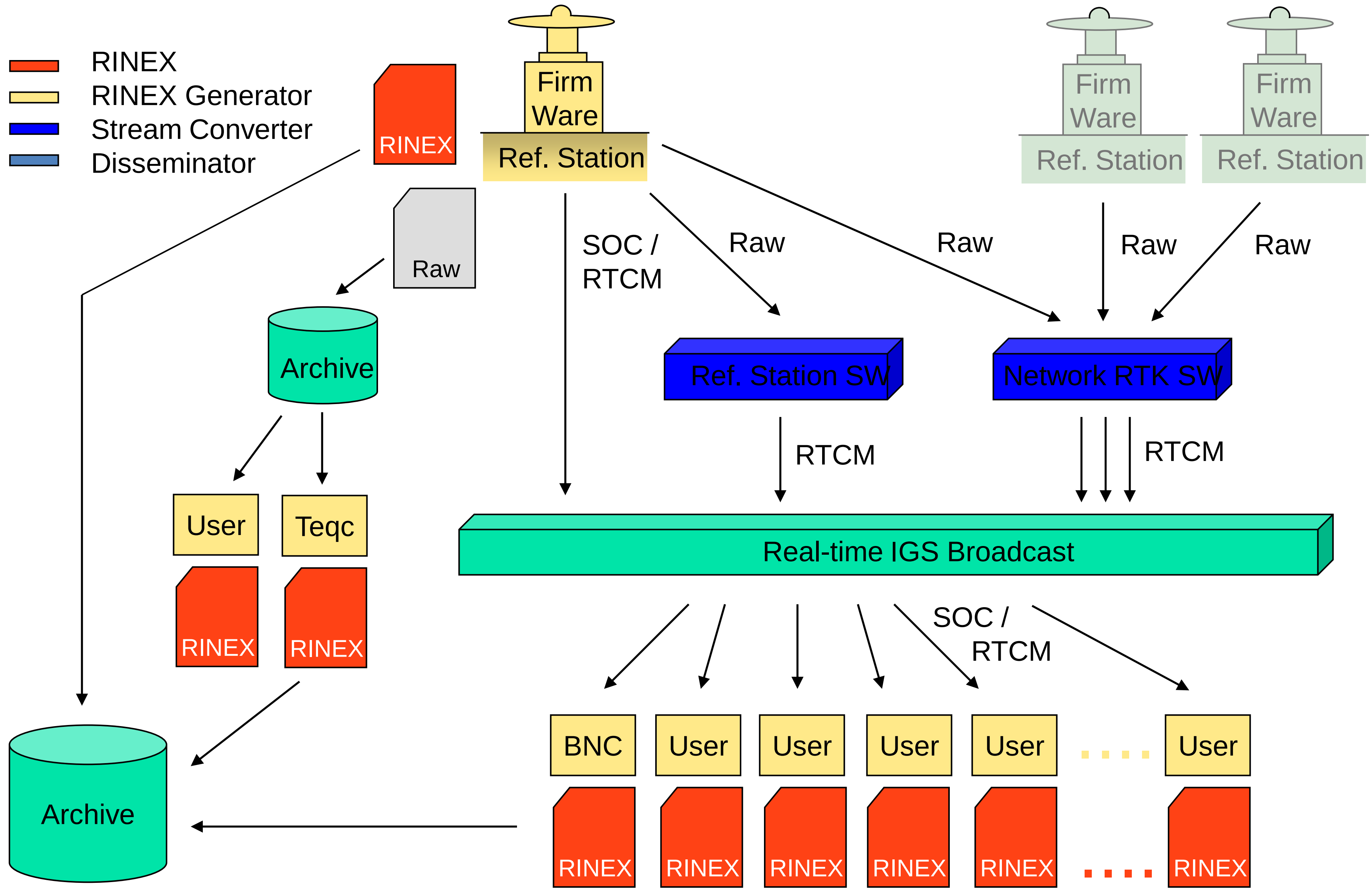
Real-time Clock & Orbit Flow Chart



24/7 Real-time Product Data Flow



GNSS Real-time and RINEX Observation Data Flow



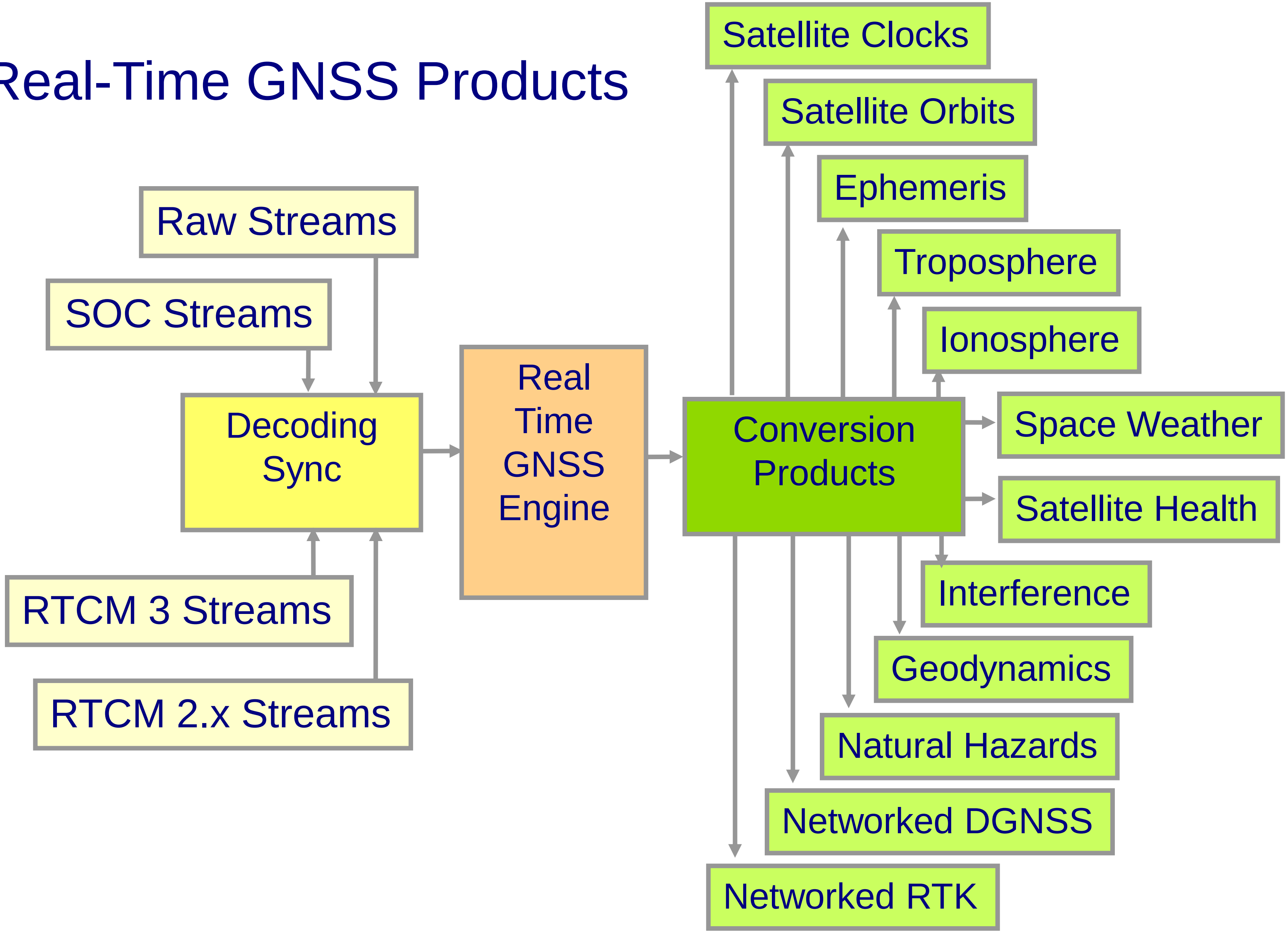
Real-time GNSS

BKG Ntrip Client (BNC) Introduction

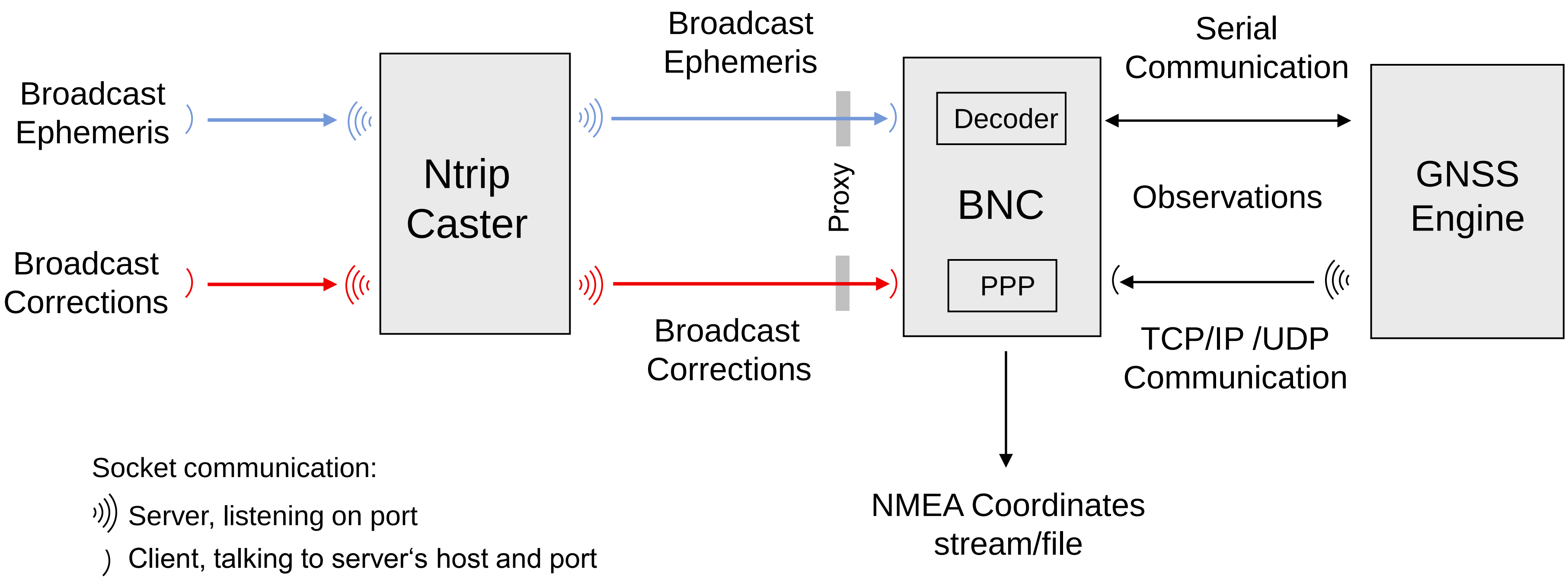
BNC‘s Intention

- Provide Open Source tool for real-time GNSS
- Push development and usage of RTCM standards
  - Ntrip
  - RTCM v2/v3
  - State Space Representation Messages
  - Multiple Signal Messages
- Provide tool which allows others to concentrate on development of real-time GNSS engines
  - Decoding, synchronization before engine
  - Encoding, conversion after engine

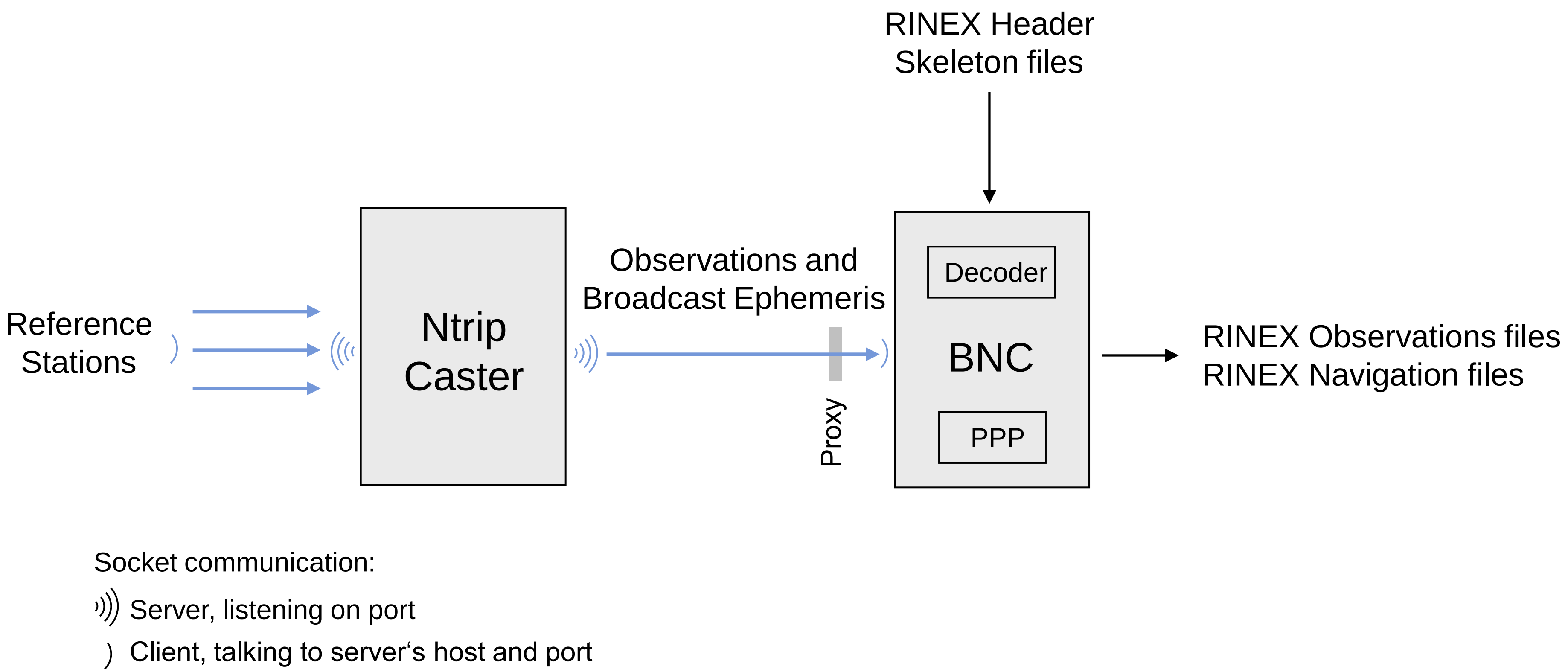
Real-Time GNSS Products



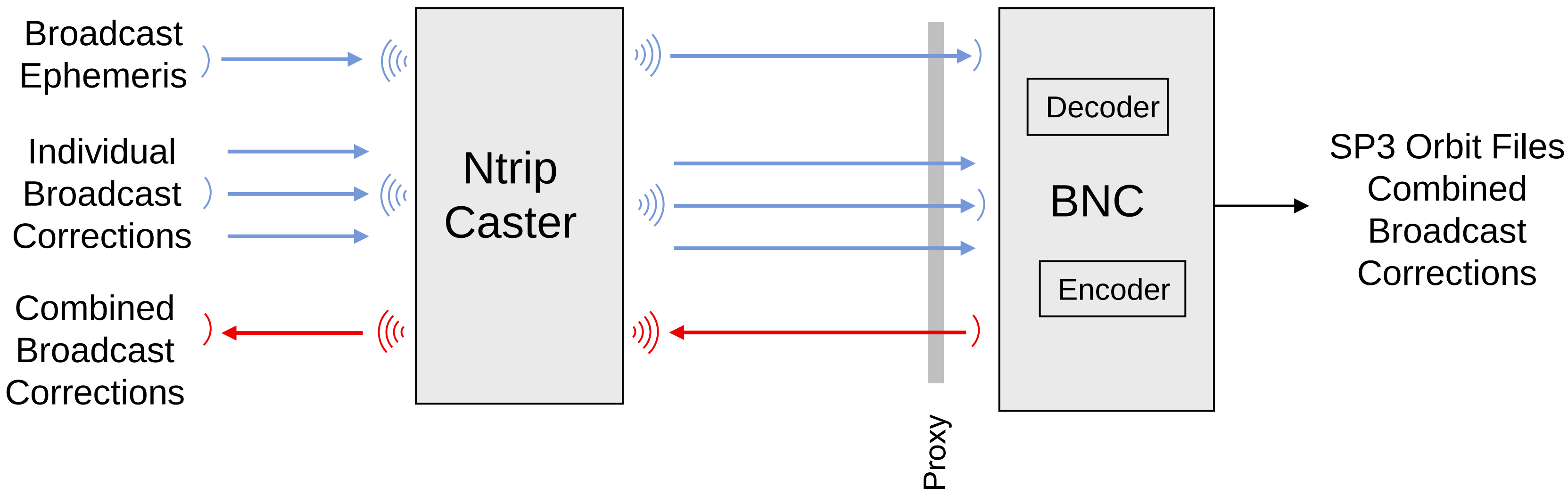
BKG Ntrip Client (BNC) – PPP Scenario



BKG Ntrip Client (BNC) – RINEX Scenario



BKG Ntrip Client (BNC) – Combining Corrections



Socket communication:

Server, listening on port

Client, talking to server‘s host and port

BNC‘s Technical Details (1/2)

- BNC from the programmer's point of view
  - BNC source consists currently of approximately 50.000 lines of code
  - Approximately 90 % is C++, 10 % standard C
  - BNC uses a few third-party pieces of software
  - RTCM decoders/encoders and a matrix algebra library)
  - Qt library is used for
    1. GUI,
    2. networking,
    3. threads,
    4. containers, streams, etc.

BNC‘s Technical Details (2/2)

- BNC is intended to be
  - user-friendly
  - cross-platform
  - easily modiable (by students, GNSS beginners)
  - useful (at least a little bit ...)

BNC Source Code

- Algorithms used in BNC are intended to be
  - correct, but
  - as simple as possible

```
//
////////////////////////////////////////////////////////////////////////////
void bncModel::kalman(const Matrix& AA, const ColumnVector& ll,
                      const DiagonalMatrix& PP,
                      SymmetricMatrix& QQ, ColumnVector& dx) {

  Tracer tracer("bncModel::kalman");

  int nObs = AA.Nrows();
  int nPar = AA.Ncols();

  UpperTriangularMatrix SS = Cholesky(QQ).t();

  Matrix SA = SS*AA.t();
  Matrix SRF(nObs+nPar, nObs+nPar); SRF = 0;
  for (int ii = 1; ii <= nObs; ++ii) {
    SRF(ii,ii) = 1.0 / sqrt(PP(ii,ii));
  }

  SRF.SubMatrix   (nObs+1, nObs+nPar, 1, nObs) = SA;
  SRF.SymSubMatrix(nObs+1, nObs+nPar)          = SS;

  UpperTriangularMatrix UU;
  QRZ(SRF, UU);

  SS = UU.SymSubMatrix(nObs+1, nObs+nPar);
  UpperTriangularMatrix SH_rt = UU.SymSubMatrix(1, nObs);
  Matrix YY  = UU.SubMatrix(1, nObs, nObs+1, nObs+nPar);

  UpperTriangularMatrix SHi = SH_rt.i();

  Matrix KT  = SHi * YY;
  SymmetricMatrix Hi; Hi << SHi * SHi.t();

  dx = KT.t() * ll;
  QQ << (SS.t() * SS);
}
```

SVN Archive

- BNC source code may be downloaded from the svn archive using a command

  A) svn co http://software.rtcm-ntrip.org/svn/trunk/BNC *or*

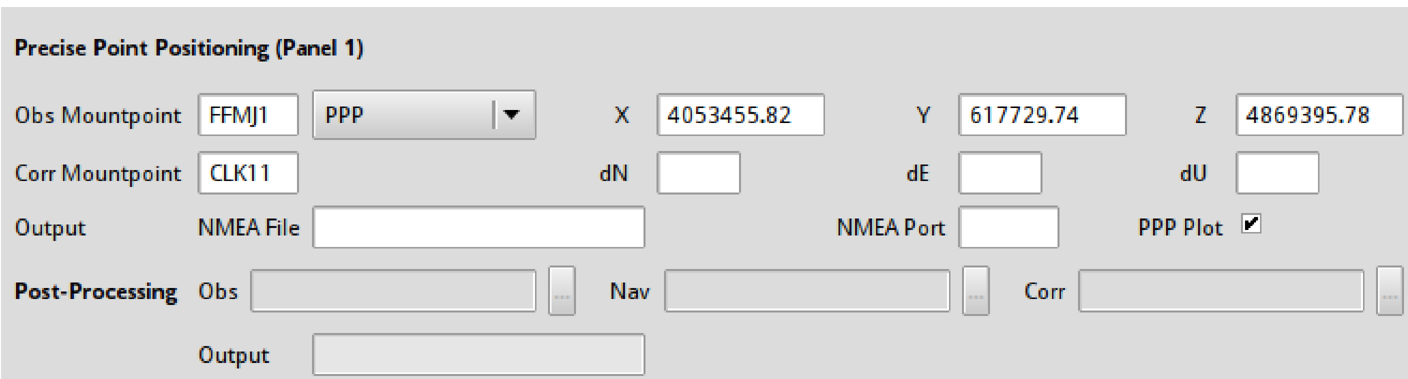
  B) svn co https://software.rtcm-ntrip.org/svn/trunk/BNC

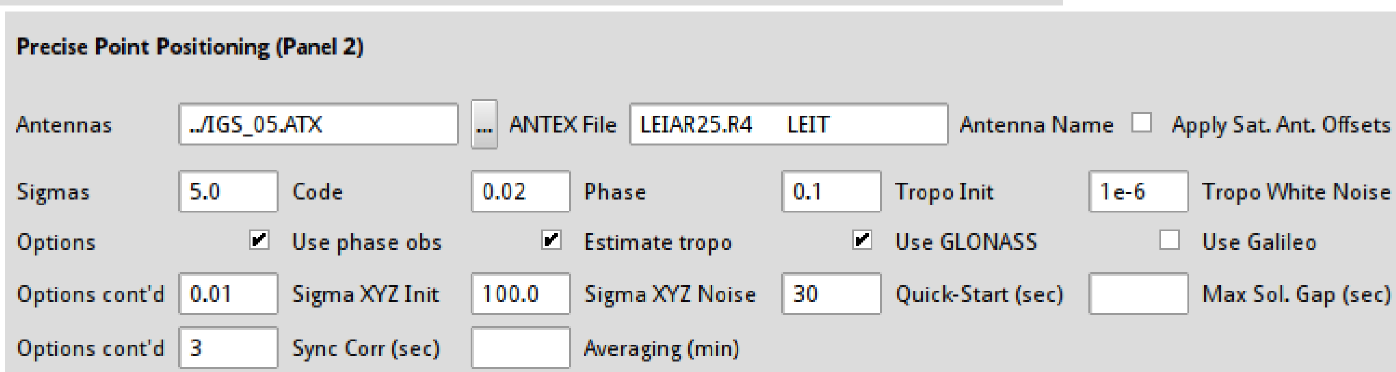
    - Option A) is a read-only access. Option B) is for the developers

- (read-write access). When the source code is downloaded using the https (secure protocol) currently an additional sub-directory is retrieved supporting orbit/clock combination
  - The sub-directory \combination" contains the source code of the BNC module that performs the combination of PPP corrections streams provided by several analysis centers (more about the combination algorithms below).

Precise Point Positioning Options

- Single station, SPP or PPP
- Real-time or post-processing
- Processing of code and phase ionosphere-free combinations, GPS, GLONASS, and Galileo





Combination of PPP Corrections

- User's dilemma:
  - There are so many different data streams with PPP corrections available on NTRIP caster. Which one should I use?

Use the combined one!

- Are the combined corrections always the best?

It depends ...

- The combination of the PPP corrections
  - increases the reliability, but
  - may (slightly) decrease the quality because the combination algorithm is (currently) not fully correct (the combination algorithms must neglect information that is not provided in correction streams).

Simple Combination of PPP Corrections

- The simple algorithm for the combination
  - subtracts the analysis-center specific biases
  - computes the mean over all corrections for each satellite
- However, for PPP clock accuracy on DD level matters!

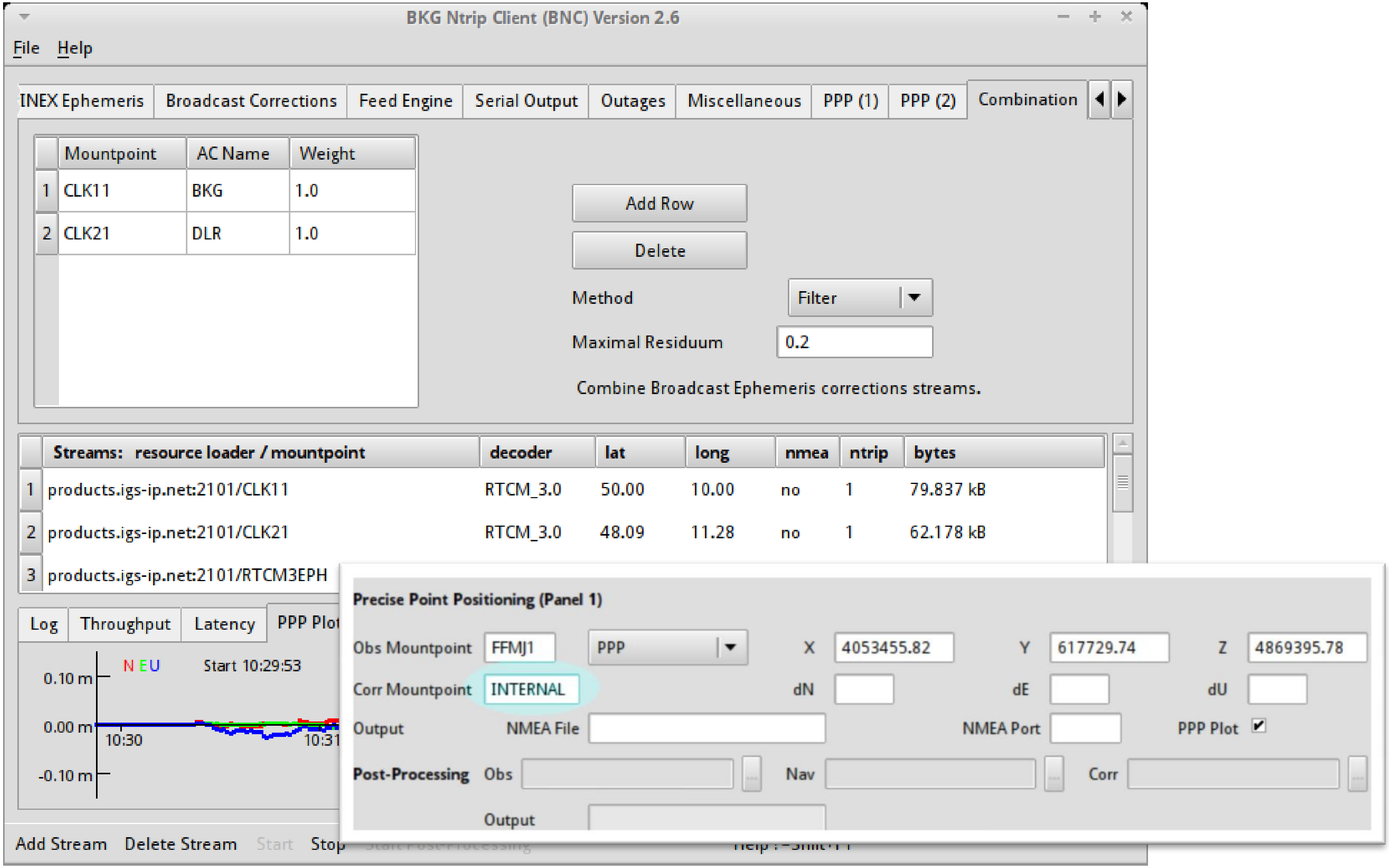
Observation equations for two satellites i ; j and two epochs t1; t2:

$$
\begin{aligned}
L^i(t_1) &= \varrho^i(t_1) + c\,\delta(t_1) - c\,\delta^i(t_1) + b^i \\
L^j(t_1) &= \varrho^j(t_1) + c\,\delta(t_1) - c\,\delta^j(t_1) + b^j \\
L^i(t_2) &= \varrho^i(t_2) + c\,\delta(t_2) - c\,\delta^i(t_2) + b^i \\
L^j(t_2) &= \varrho^j(t_2) + c\,\delta(t_2) - c\,\delta^j(t_2) + b^j
\end{aligned}
$$

Eliminating the clock parameters and the ambiguities (biases) is equivalent to forming a double difference (between two satellites and between two epochs):

$$
L^{ij}(t_1) - L^{ij}(t_2) = \varrho^{ij}(t_1) - \varrho^{ij}(t_2) - c\,\underbrace{\left[\left(\delta^i(t_1) - \delta^j(t_1)\right) - \left(\delta^i(t_2) - \delta^j(t_2)\right)\right]}_{\text{DD Clock}}
$$

Combination Options



Combination using Kalman Filtering

- The combination is performed in two steps
  1. The satellite clock corrections that refer to different broadcast messages (different IODs) are modified in such a way that they all refer to common broadcast clock value (common IOD is that of the selected \master" analysis center).
  2. The corrections are used as pseudo-observations for Kalman filter using the following model (observation equation):

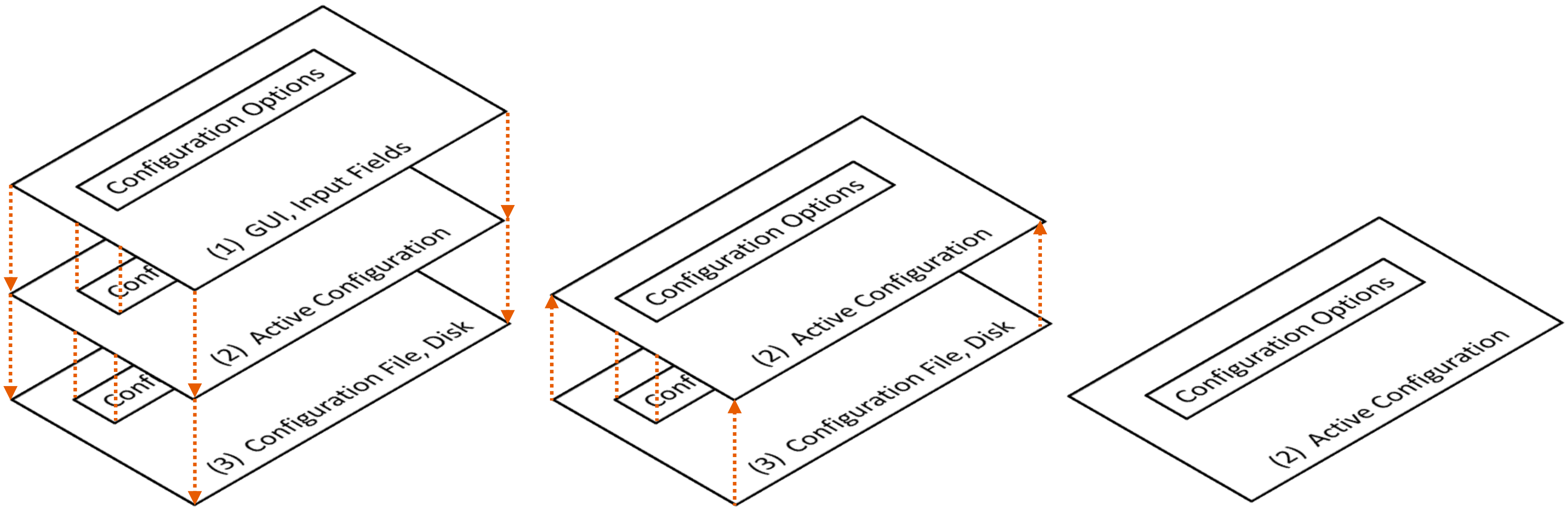
$$c_a^s = c^s + o_a + o_a^s$$

where

c_a^s	is the clock correction for satellite s estimated by the analysis center a,
c^s	is the resulting (combined) clock correction for satellite s,
o_a	is the AC-specific offset (common for all satellites), and
o_a^s	is the satellite and AC-specific offset.

The three types of unknown parameters c^s, o_a, o_a^s differ in their stochastic properties: the parameters c^s and o_a are considered to be epoch-specific while the satellite and AC-specific offset o_a^s is assumed to be a static parameter.

Memory Management in BNC



Graphics Mode　　‚No window' Mode　　Command Line Config.

Real-time GNSS

BNC - RINEX Editing & Quality Check

Motivation

	UNAVCO's TEQC	BNC REQC
Availability	Free ware	Open Source
RINEX support	RINEX Version 2	RINEX Version 2 and 3
Graphic tool	No	Yes
Operating systems	Linux, Windows	Several platforms
Input formats	Proprietary	RTCM 2 and 3

Functionality (I)

RINEX via BNC via command line

```
/home/user/bnc --conf /dev/null
        --key reqcAction Analyze
        --key reqcObsFile CUT02070.12O
        --key reqcNavFile BRDC2070.12P
        --key reqcOutLogFile CUT0.txt
        --key startTab 5
        --key autoStart 2
```

(Similar to TEQC)

Functionality (II)

RINEX Editing

- cut/concatenate RINEX Observation and Navigation files
- convert RINEX Version 2 to 3 and vice versa
- correct RINEX header data (marker/antenna/receiver names)
- specify sampling interval and operator
- add comment lines

Functionality (III)

RINEX Quality Check

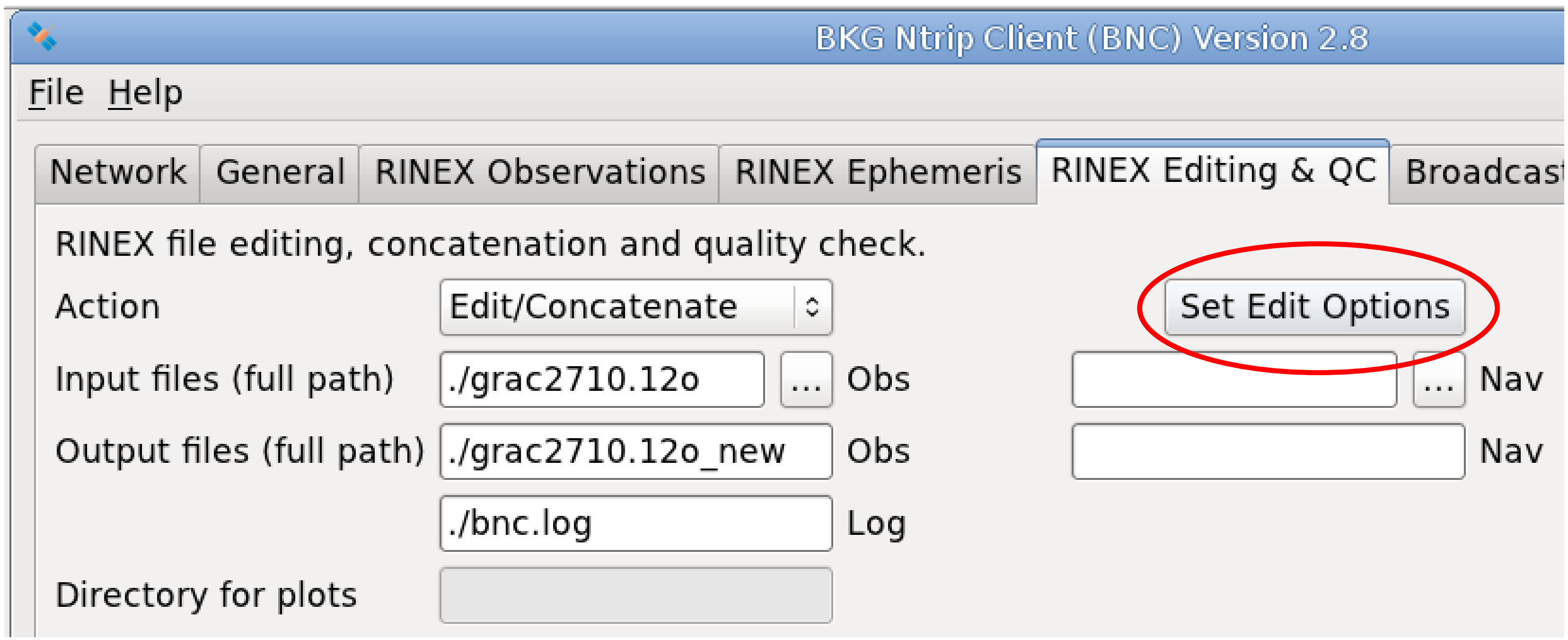
- Summary of file content
  - number of observations, satellites,…
- Multipath analysis sky plots
  - Estey and Meertens, 1999
- Signal-to-Noise sky plots
- Satellite availability plots
- Satellite elevation plots
- PDOP plots

Examples

- RINEX Editing
- RINEX Concatenation
- RINEX Quality Check

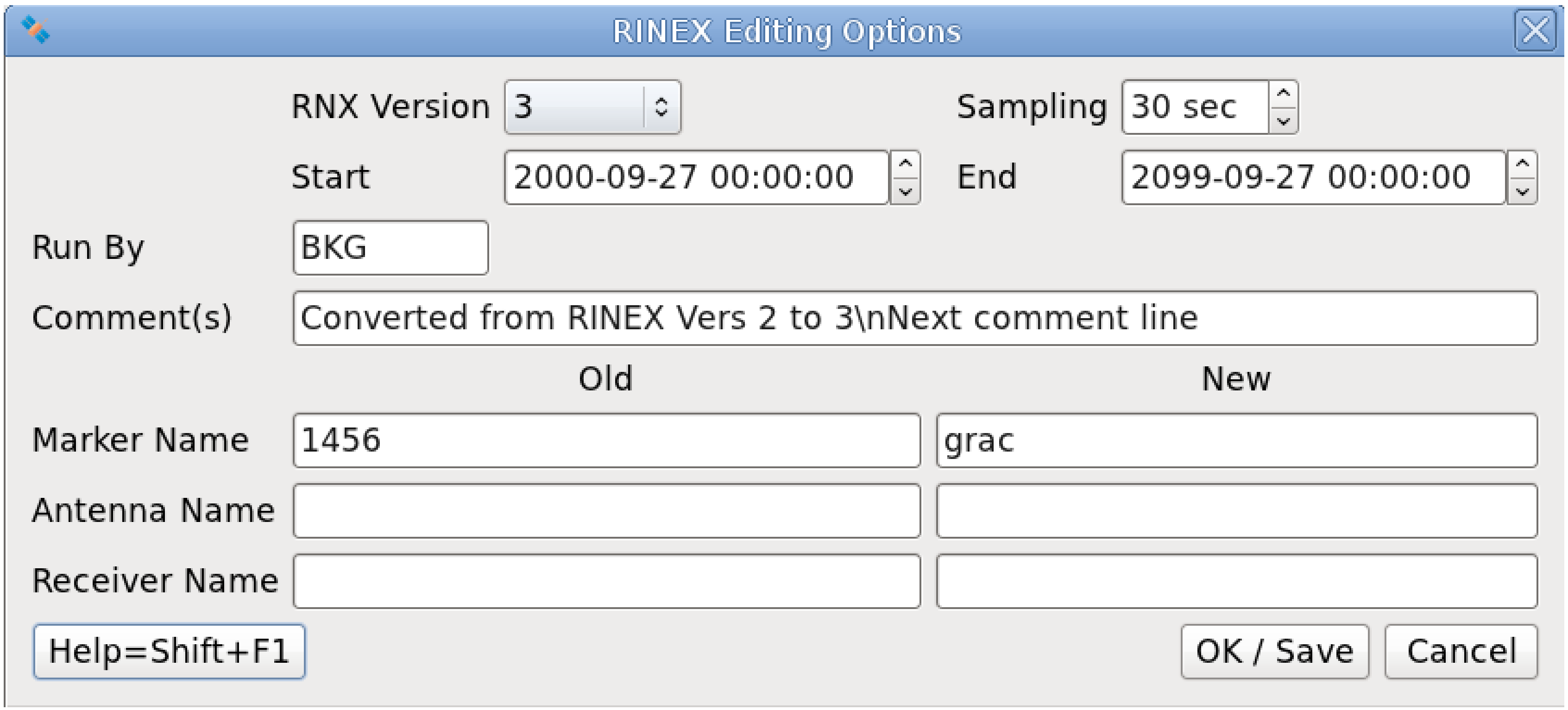
RINEX Editing

Specifying the path to in - and output RINEX file(s) is mandatory. Relevant settings can be done by „Set Edit Options“.



RINEX Editing (2)

The RINEX output file will be created with these settings.

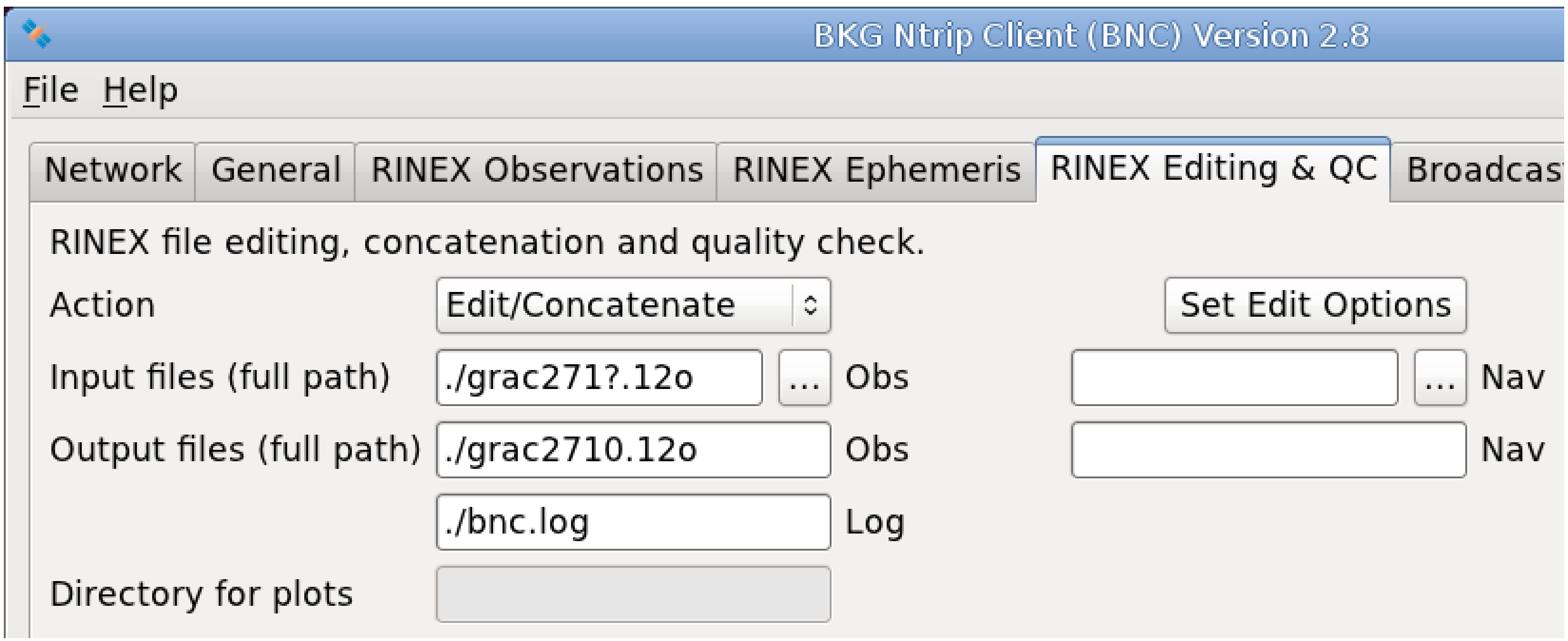


Examples

- RINEX Editing
- RINEX Concatenation
- RINEX Quality Check

RINEX Concatenation

Feasible for RINEX Observation or Navigation files. Using the wildcard characters '*' and/or question mark '?' simplifies the selection of RINEX input files. Options can be entered as before.



RINEX Concatenation (2)

BNC writes a logfile for the concatenation process:

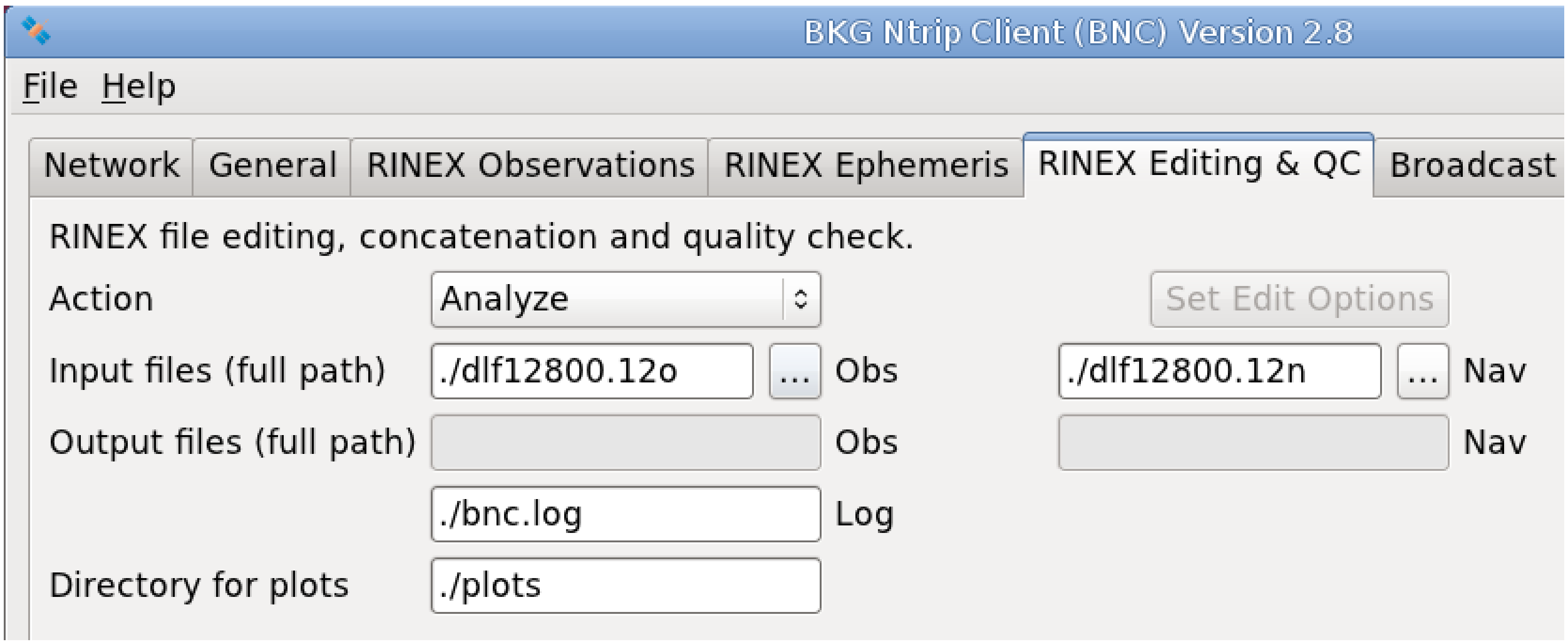
```
---------------------------------------------------------------------------
Concatenation of RINEX Observation and/or Navigation Files
---------------------------------------------------------------------------
Program           : BNC 2.8
Run by            : BKG
Date              : 2012-10-12 08:33:18
RINEX Version     : 3.01
Sampling          : 30
Start time        : 2000-09-27 00:00:00
End time          : 2099-09-27 00:00:00
Input Obs Files: /home/user/grac271?.12o
Input Nav Files:
Output Obs File: /home/user/grac2710.12o
Output Nav File:
---------------------------------------------------------------------------
Processing File: /home/user/grac271a.12o  start: 2012-09-27 00:00:00
Processing File: /home/user/grac271b.12o  start: 2012-09-27 01:00:00
Processing File: /home/user/grac271c.12o  start: 2012-09-27 02:00:00
...
```

Examples

– RINEX Editing
– RINEX Concatenation
– RINEX Quality Check

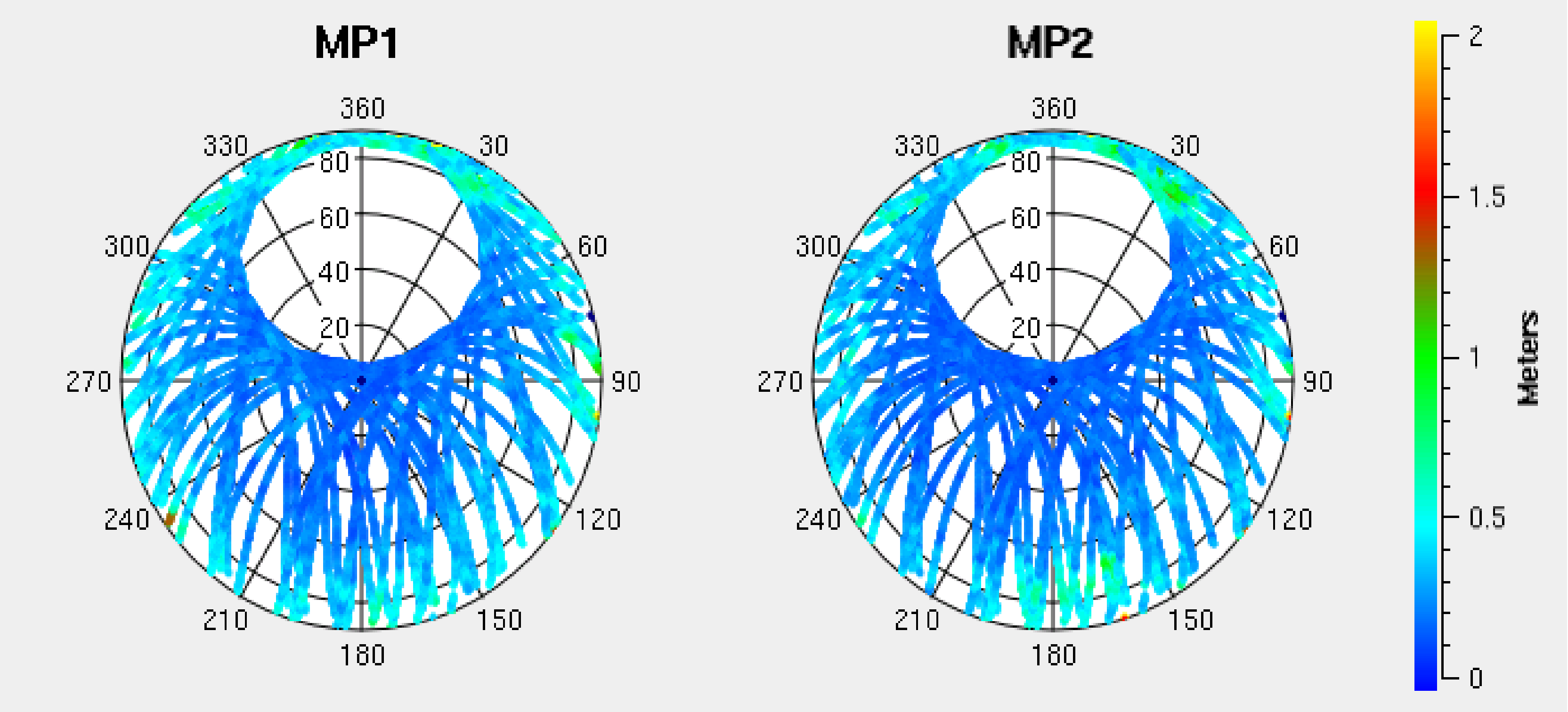
RINEX Quality Check

Checking a RINEX Observation file for quality analysis requires the input of the respective RINEX Navigation file (GPS resp. GLONASS).



RINEX Quality Check (2)

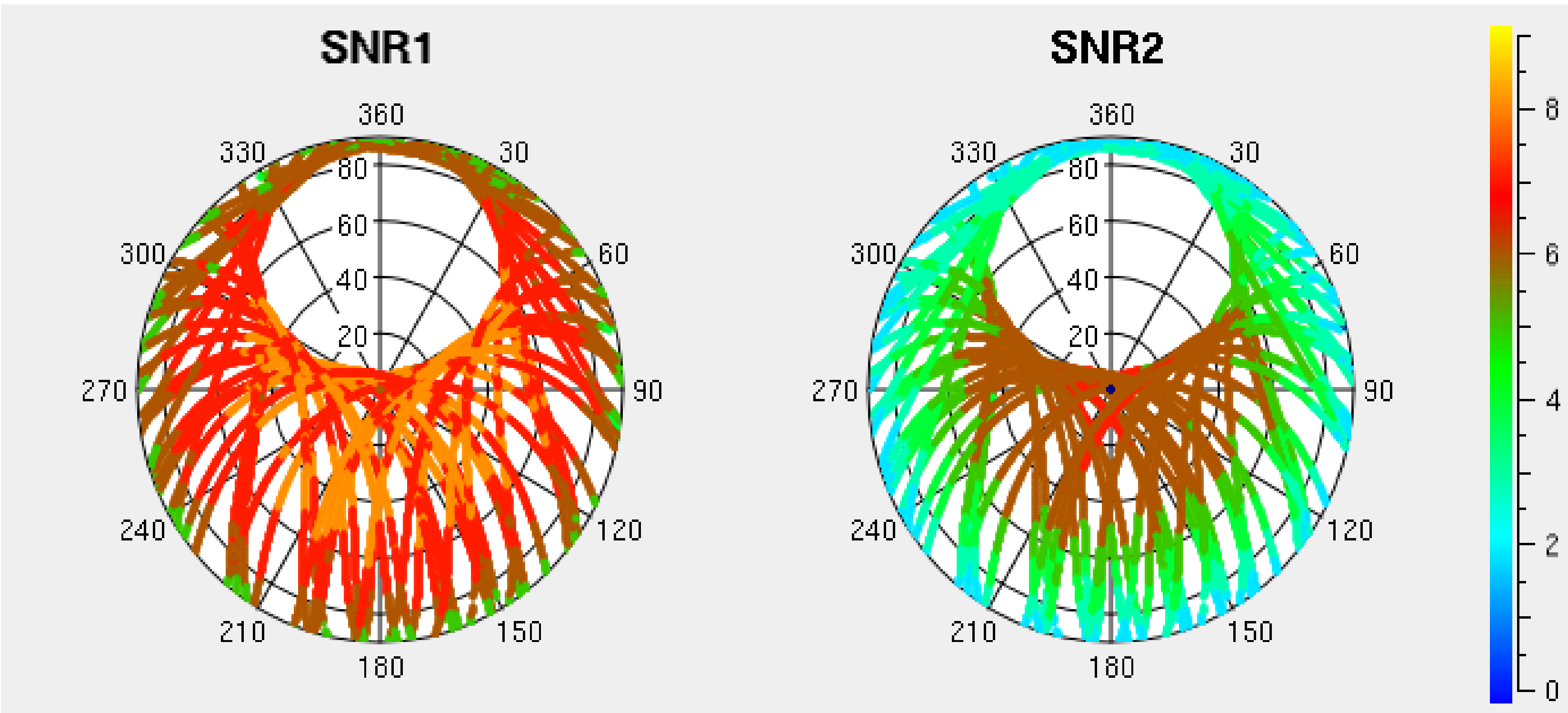
multipath analysis sky plot for dlf12800.12o (GPS):



SIRGAS 2012, Concepcion, Chile

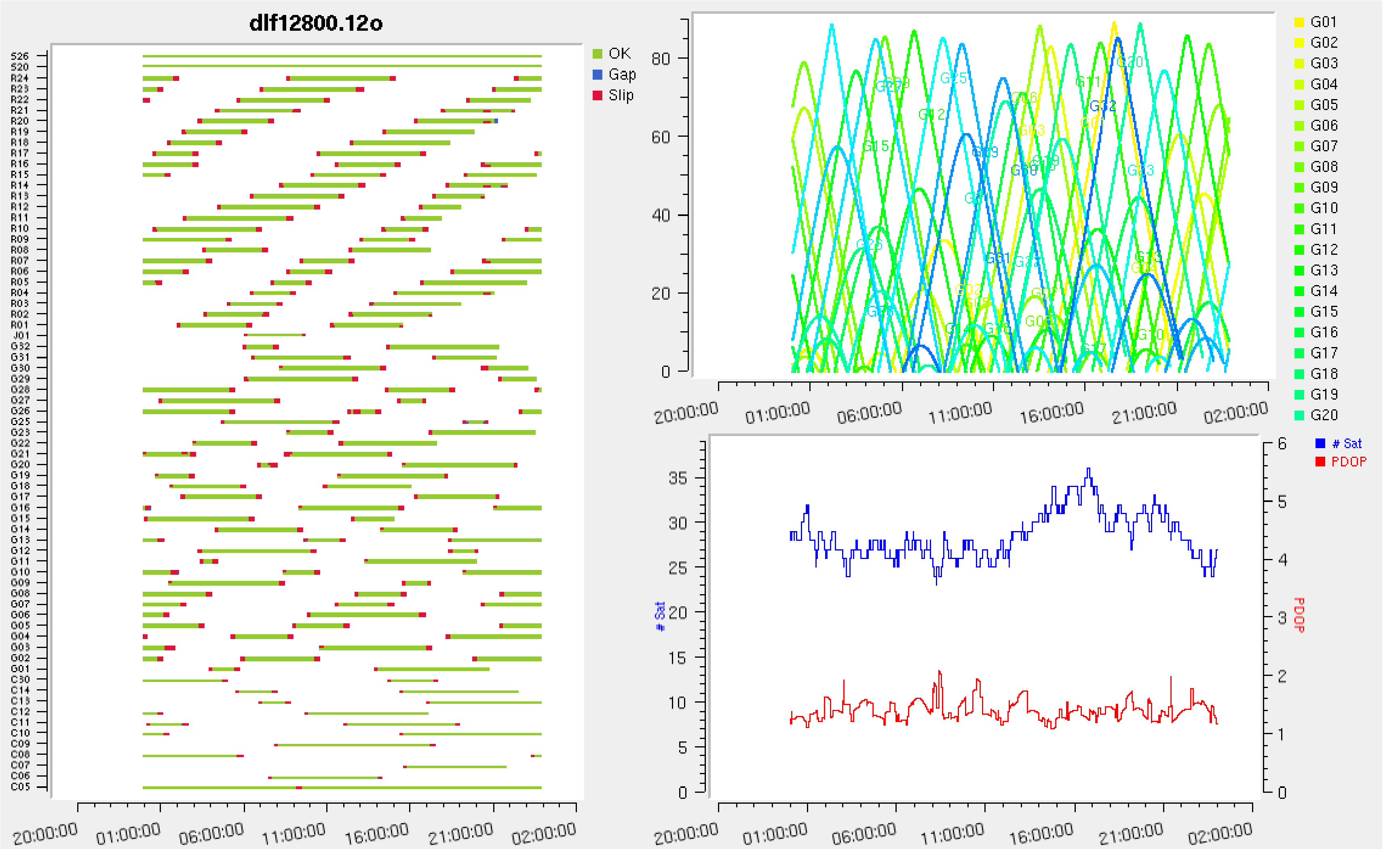
RINEX Quality Check (3)

signal-to-noise ratio analysis sky plot for dlf12800.12o (GPS):



RINEX Quality Check (4)

satellite availability, elevation and PDOP plots for dlf12800.12o (GPS):



RINEX Quality Check (5)

Specifying a logfile to output quality check results is mandatory. The following is a logfile example.

```
Analyze File
------------
File:             /home/user/dlf12800.12o
Marker name:      DELFT-22
Receiver:         TRIMBLE NETR9
Antenna:          LEIAR25.R3      LEIT
Start time:       2012-10-06 00:00:00.000
End time:         2012-10-06 23:59:30.000
Interval:         30
# Sat.:           56
# Obs.:           60652
# Slips (file):   84
# Slips (found):  43
Mean MP1:         0.204832
Mean MP2:         0.192316
Mean SNR1:        5.84435
Mean SNR2:        4.89711
```

Real-time GNSS

State Space Representation & Multiple Signal Messages by RTCM

SIRGAS 2012, Concepcion, Chile

Outline

- Standardization within the GNSS area: RTCM
- RTCM SSR & RTCM MSM Messages
  - Motivation
  - Principle
  - Status and Plans
  - Realization
- Summary and Outlook

GNSS Standardization

- Development of international open standards

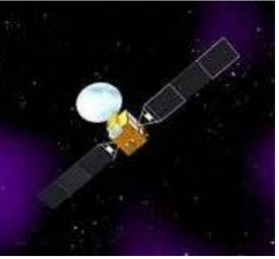
- RTCM SC-104: DGNSS Standards
  - Working Groups examples regarding
    - communication and data transfer: WG Internet Protocol (NTRIP)
    - modeling: WG RTK network MSG, WG State Space
    - GNSS: WG Galileo, WG GLONASS
    - multi constellation concepts: WG Version 3

- WG State Space

- WG Multiple Signal Messages

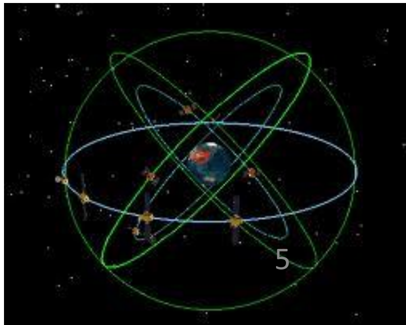
Multiple Signal Messages Motivation

	Heritage Messages	(HP)MSM
Constellations	GPS, GLONASS, (SBAS)	GPS, GLONASS, GALILEO, ...
Signals	1 signal per frequency (either C/A or P(Y) on L1/L2)	Multiple signals per frequency, ➔ all RINEX v3 signals
Observation types	▪ Pseudo-range, ▪ Carrier Phase ▪ C/N0	▪ Pseudo-range ▪ Carrier Phase ▪ C/N0 ▪ Doppler
Resolution	Pseudorange: 20 mm Carrier Phase: 0.5 mm C/N0: 0.25 dB Hz	Pseudorange: ~0.6 mm Carrier Phase: ~0.14 mm C/N0: 0.1 dB Hz Doppler: 0.1 mm/s



Multiple Signal Messages Principle

- Intention to generate GNSS observables in a universal manner
- Ability to support all GNSS and their signals that are available today & future
- MSMs are designed to cover the following:
  - maximum compatibility with RINEX-3
  - universality for all existing and future GNSS signals
  - compactness of presentation
  - no ambiguity in interpretation
  - simplicity of generation/decoding
  - flexibility and scalability



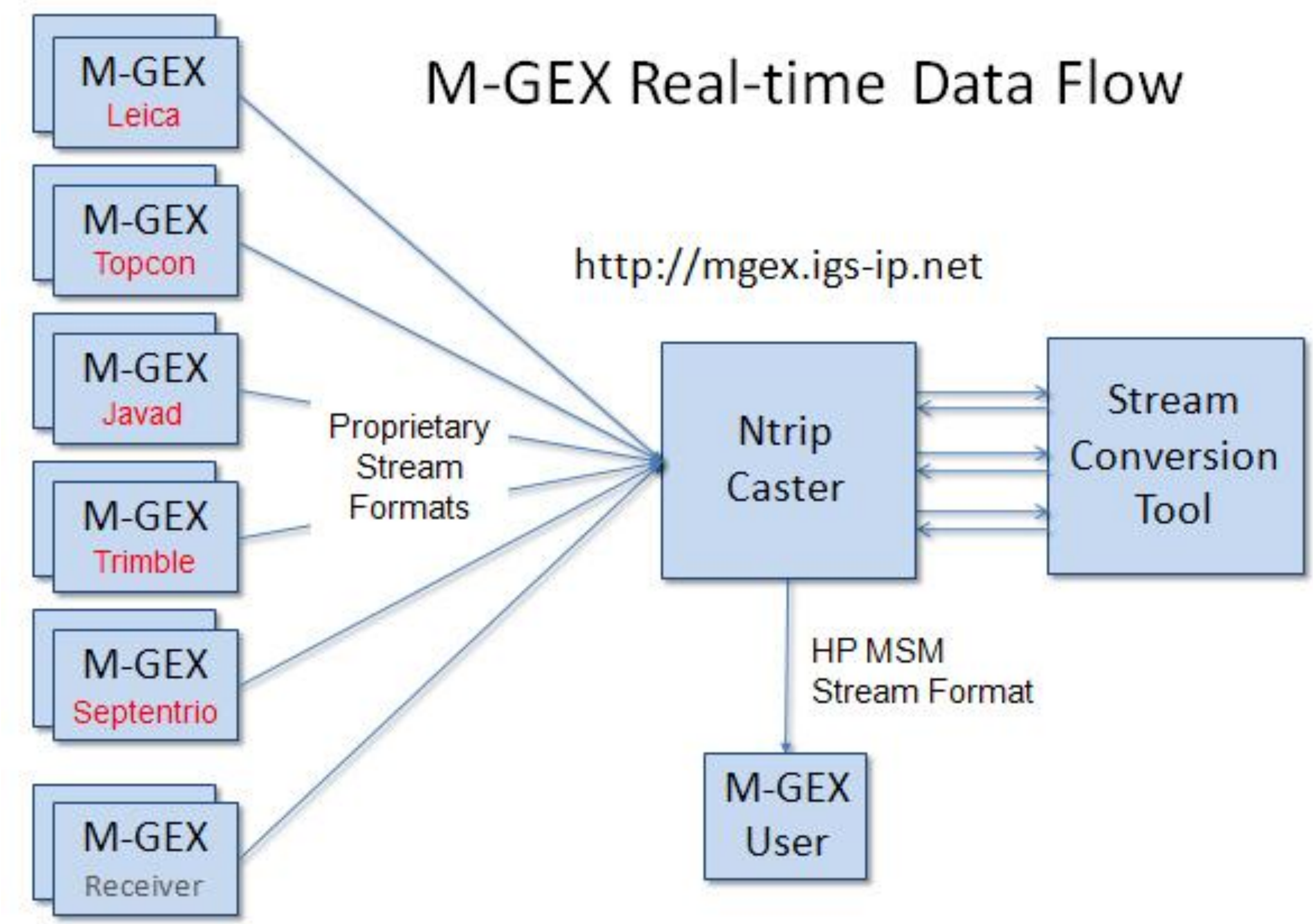
Multiple Signal Messages
Status & Plans

- MSMs support all signals defined in RINEX v3 standard for GPS, GLONASS and GALILEO

System	Observation type
GPS [20]	C1C L1C D1C S1C C2X L2X D2X S2X C1W L1W D1W S1W C2W L2W D2W S2W C5X L5X D5X S5X
GLO [16]	C1C L1C D1C S1C C2C L2C D2C S2C C1P L1P D1P S1P C2P L2P D2P S2P
GAL [8]	C1X L1X D1X S1X C5X L5X D5X S5X
SBAS [8]	C1C L1C D1C S1C C5X L5X D5X S5X

- MSMs are extendable for new navigation systems and future signals

Multiple Signal Messages Realization (I)



Multiple Signal Messages Realization (II)

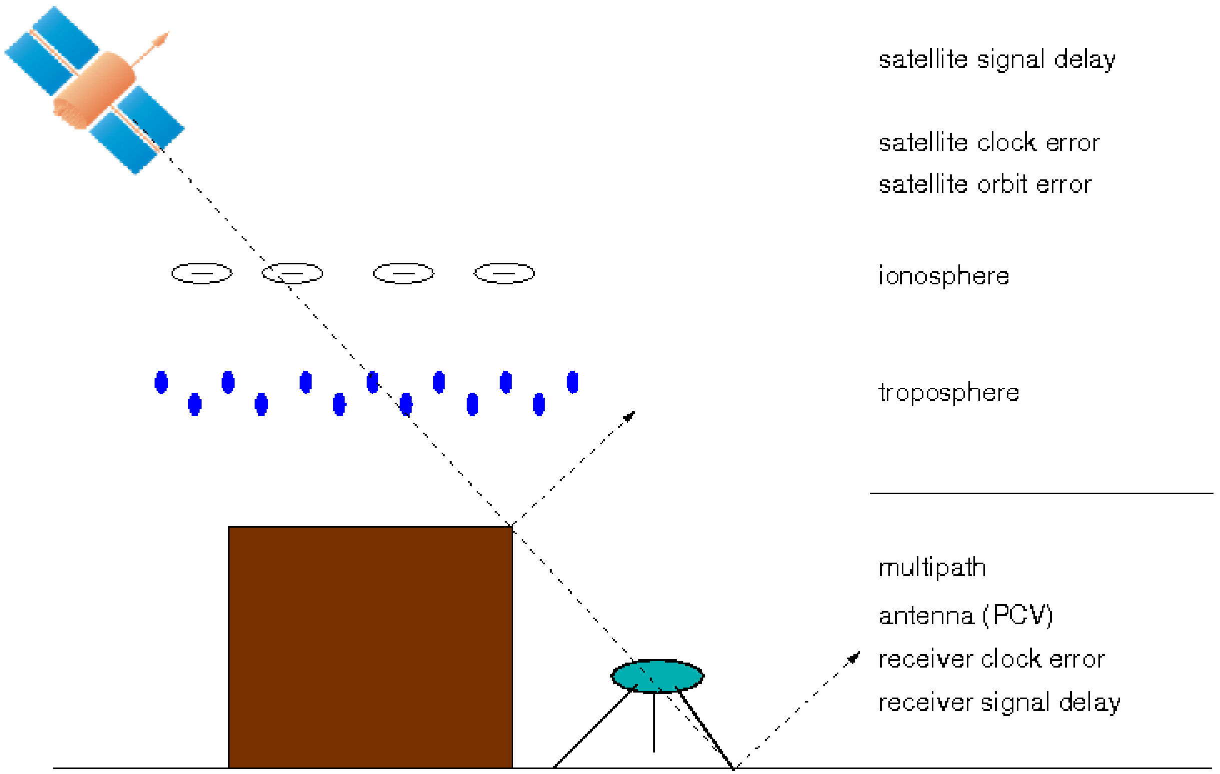
- M-GEX MSM stream conversion tool
  - currently supported receivers / GNSS:

Manufacturer	GPS	GLONASS	Galileo	SBAS	QZSS	Compass
Javad	YES	YES	YES	YES	YES	YES
Leica	YES	YES	YES	YES	NO	NO
Septentrio	YES	YES	YES	YES	YES	YES
Topcon	YES	YES	YES	YES	YES	NOT YET
Trimble	YES	YES	YES	YES	YES	YES
Ashtech	NOT YET	NOT YET	NOT YET	NOT YET	NOT YET	NOT YET

- The Open Source BKG NTRIP Client is able to decode observations encoded to MSM

State Space Representation
Motivation (I)

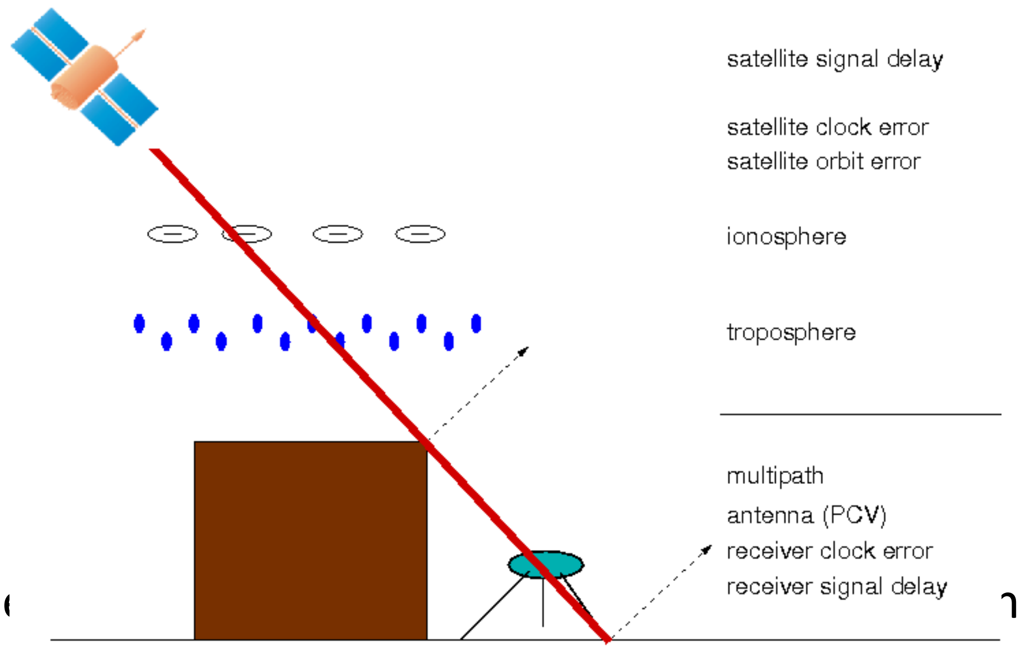
- Precise GNSS positioning requires the knowledge of all error components with corresponding accuracy



How this information can be provided?

State Space Representation Motivation (II)

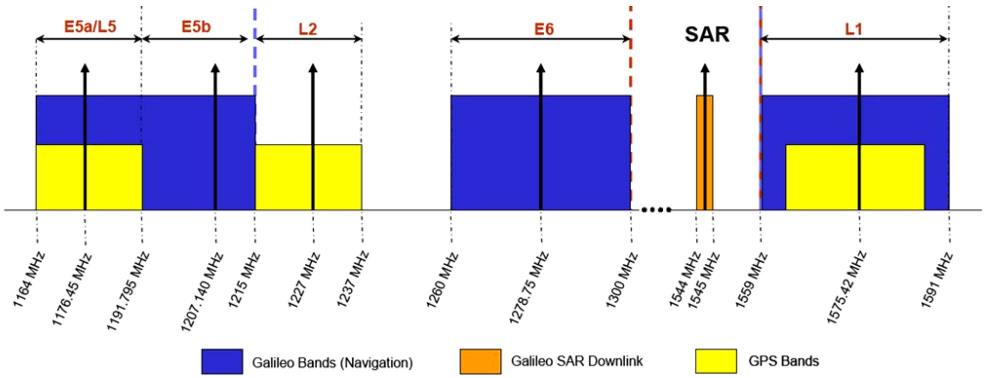
I. OSR: sum of GNSS errors per station, GNSS, frequency / signal



- Distance depend[...] reference station observations
- RTK networking with current RTCM standards: VRS,FKP,..
  - RTK service uses network of reference stations
  - RTK rover uses reference station observations and RTK corrections

State Space Representation Motivation (III)

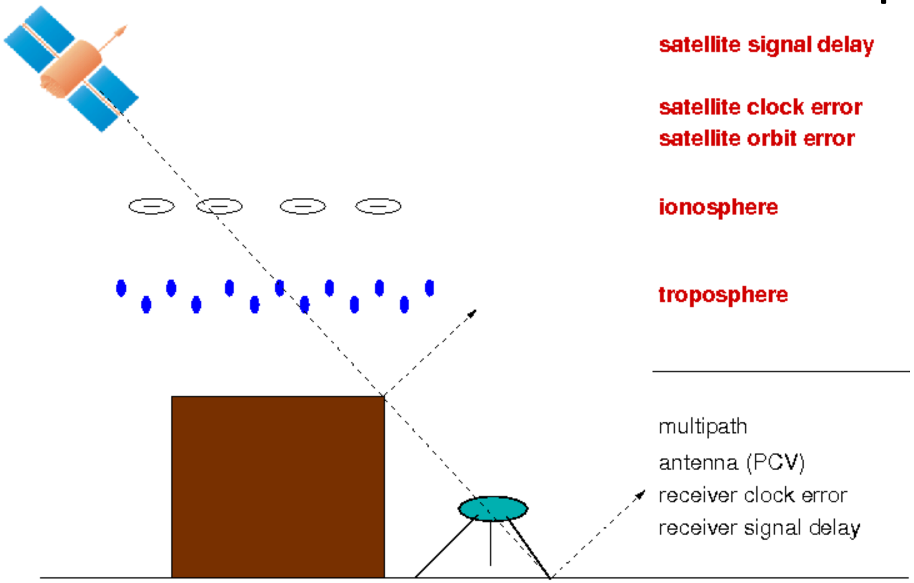
- OSR Disadvantages:
  - only satellites / signals tracked within the RTK network are usable



  - no reduction of reference station dependent errors
  - update rate of the corrections depends on component with highest dynamics (satellite clock, ionosphere)
  - limited spatial validity of corrections

State Space Representation Principle (I)

II. Transmission of individual GNSS error components



- Functional and optional stochastic state description
- Precise Point Positioning (PPP):
  - observations of single GNSS receiver
  - rover uses state space information (e.g. IGS products)
  - global or regional real-time network

State Space Representation Principle (II)

- SSR Advantages:
  - high reduction of reference station dependent errors through high redundancy within the network
  - independent from single reference stations
  - more realistic physical models for individual errors enables better modeling and interpolation
  - update rate can be optimized for different state parameters
  - scalability of accuracy and hence of the derived services
  - broadcasting of parameters possible

- SSR Disadvantages:
  - higher standardization and implementation effort
    - site displacements (solid earth/pole tides, ocean/atmospheric loading)
    - phase wind up effect, antennae PCO/PCV
    - higher order ionosphere effects
    - standardization of troposphere correction models

  ➔ IERS Conventions are the reference for standardization

State Space Representation
Status &Plans

I. Satellite orbits, clocks, code biases, quality Indicator

- enable Real-Time PPP for dual frequency users
- compatible to basic PPP mode using IGS products

➔ **5/2011: Recommended Standard, included in RTCM 3**

II. Vertical Total Electron Content (VTEC) and satellite phase biases

- enable Real-Time PPP for single frequency users

III. Slant Total Electron Content (STEC) and troposphere

- enable PPP-RTK

➔Potential to use hierarchically networks:

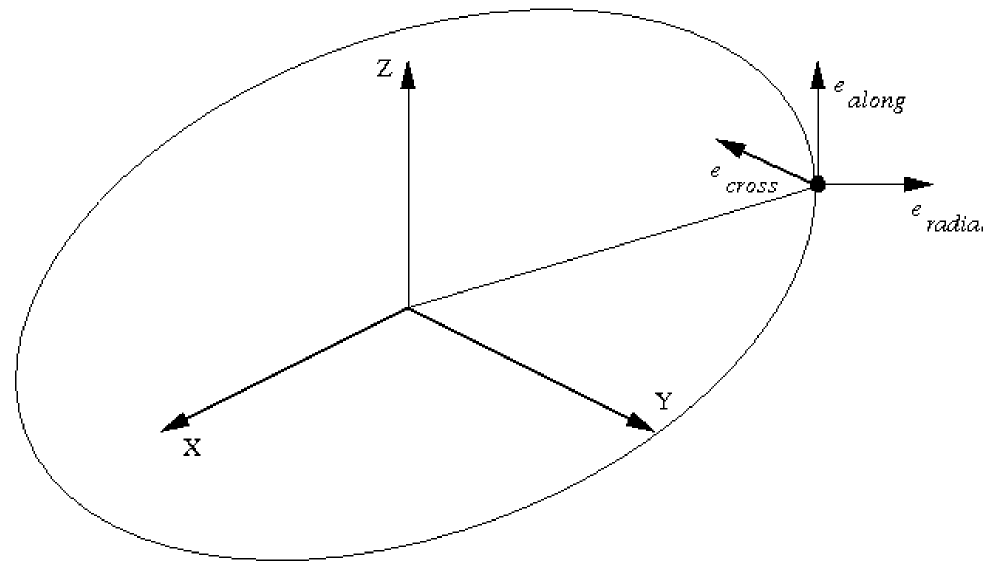
RTK

State Space Representation Realization - Messages Step I

Message	Contents
1057	SSR GPS orbit correction
1058	SSR GPS clock correction
1059	SSR GPS code bias
1060	SSR GPS combined orbit and clock correction
1061	SSR GPS User Range Accuracy (URA)
1062	SSR GPS high rate clock correction
1063	SSR GLONASS orbit correction
1064	SSR GLONASS clock correction
1065	SSR GLONASS code bias
1066	SSR GLONASS combined orbit and clock correction
1067	SSR GLONASS User Range Accuracy (URA)
1068	SSR GLONASS high rate clock correction

State Space Representation Realization - Satellite Orbit Message (I)

- Orbit corrections refer to broadcast orbits
  - reduces bandwidth



$$\boldsymbol{X}_{orbit} = \boldsymbol{X}_{broadcast} - \delta\boldsymbol{X}$$

$\boldsymbol{X}_{orbit}$ .. satellite position corrected by SSR orbit correction message,

$\boldsymbol{X}_{broadcast}$ .. satellite position computed according to respective GNSS ICD

$\delta\boldsymbol{X}$ .. satellite position correction

State Space Representation Realization - Satellite Orbit Message (II)

- Orbit corrections
  - defined radial, along-track and cross-track

$$\delta \boldsymbol{X} = [\boldsymbol{e}_{radial} \quad \boldsymbol{e}_{along} \quad \boldsymbol{e}_{cross}]\, \delta \boldsymbol{O}$$

  - consists of correction and velocity correction term

$$\delta \boldsymbol{O} = \begin{bmatrix} \delta O_{radial} \\ \delta O_{along} \\ \delta O_{cross} \end{bmatrix} + \begin{bmatrix} \delta \dot{O}_{radial} \\ \delta \dot{O}_{along} \\ \delta \dot{O}_{cross} \end{bmatrix} (t - t_0)$$

t	.. time
t_0	.. reference time obtained from SSR orbit correction message
$\delta O_i, \delta \dot{O}_i$	.. orbit correction term from SSR orbit message; i = {radial, along, cross}

State Space Representation Realization - Satellite Clock Messages (I)

- Clock corrections refer to broadcast clocks
  - clock correction terms: C0, C1, C2 polynomial coefficients
  - reduces bandwidth

$$t_{satellite} = t_{broadcast} - \frac{\delta C}{Speed\ of\ light}$$

$t_{broadcast}$ .. satellite time computed according to corresponding GNSS ICD

$t_{satellite}$ .. satellite time corrected by SSR clock correction message,

δC .. clock correction obtained from SSR clock correction message.

$$\delta C = C_0 + C_1(t - t_0) + C_2(t - t_0)^2$$

t .. time

t_0 .. reference time obtained from SSR clock correction message

C_i .. polynomial coefficients from SSR clock correction message; i = {0,1,2}

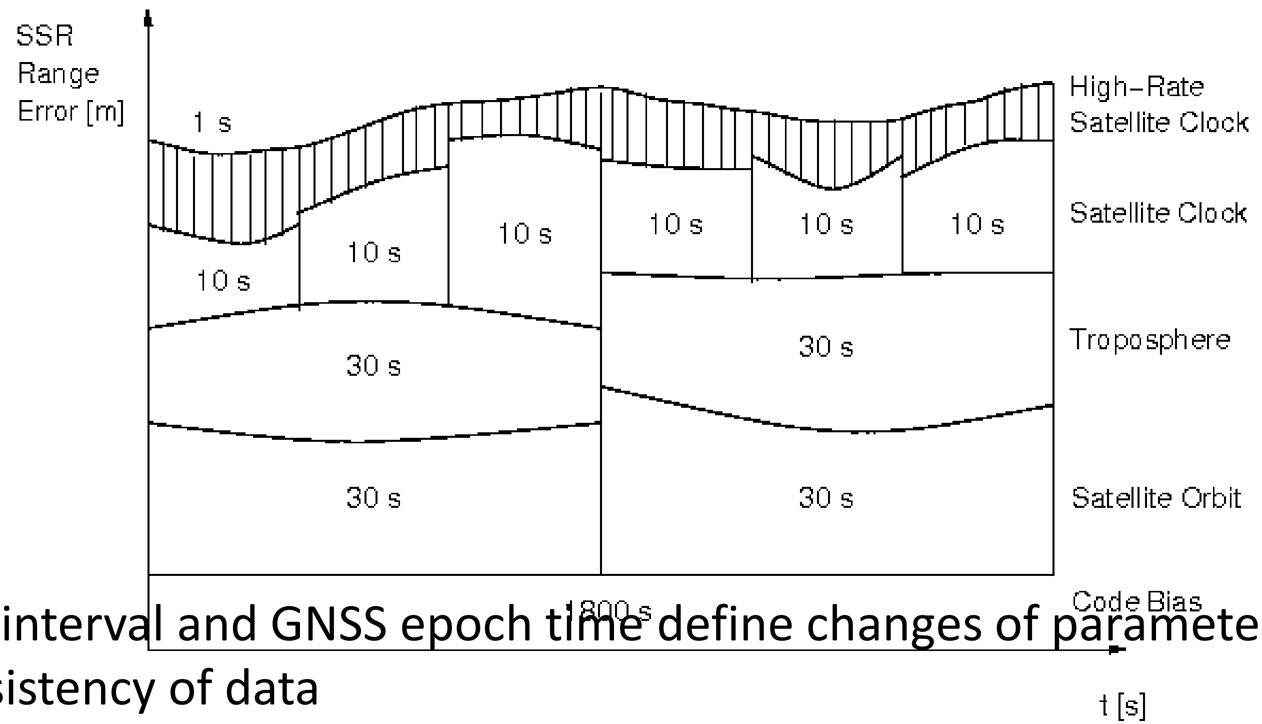
State Space Representation Realization - Satellite Clock Messages (II)

- High rate clock
  - additional and optional message type
  - both, polynomial and high rate clock describes the complete clock state
  - enables higher resolution and update rates

- Satellite code bias
  - absolute correction term
  - for every signal and tracking mode
  - enables higher resolution update rates

State Space Representation Realization - SSR Message Consistency

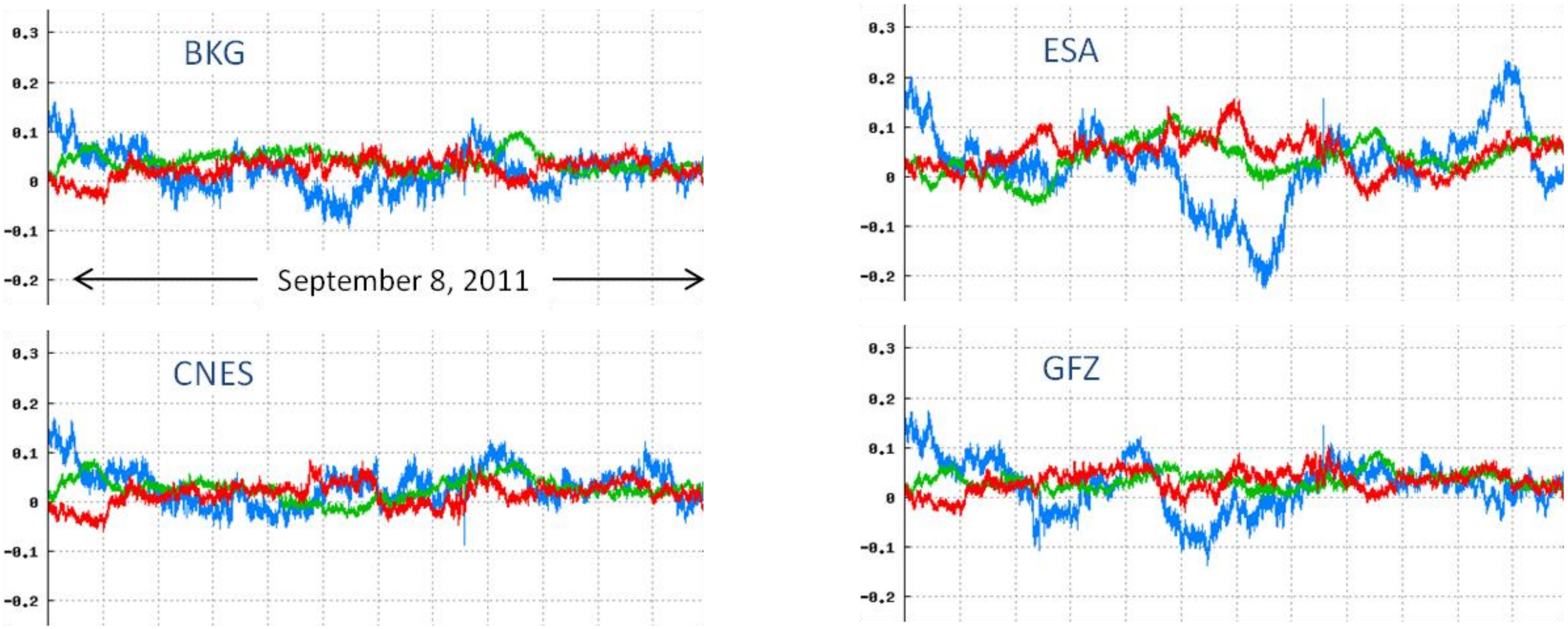
- Basic concept:
  - SSR messages support different update rates, accuracy requirements
  - additional SSR message types adds additional resolution/position accuracy



  - SSR update interval and GNSS epoch time define changes of parameters and ensure consistency of data

State Space Representation Realization - PPP

- Real-Time PPP performance (North, East, Up displacements)
  - 24h time series of PPP applying RTCM-SSR of different AC's
  - PPP monitor at http://igs.bkg.bund.de/ntrip/ppp



- 2D RMS of 4-5 cm after convergence

Summary and Outlook

- Status
  - RTCM-SSR & RTCM-MSM products are available
  - for interested users who may want to test these products:
    - BKG NTRIP client available from http://igs.bkg.bund.de/ntrip/download
    - RTCM-SSR data available from http://products.igs-ip.net/home
    - RTCM-MSM data available from http://mgex.igs-ip.net/home
  - SSR can replace OSR techniques for all types of GNSS processing
- Future steps
  - for SSR is further standardization effort required
  - next SSR standardization steps are more complex
  - MSM has to become recommended RTCM standard
- SSR & MSM add accuracy and therefore applications

➔ **Final goal: Open Standard for PPP up to PPP-RTK**

Real-time GNSS
IGS Pilot Project

Outline

- IGS Real-time Pilot Project – Call for Participation
- Current status of analysis and products
- Dissemination of data and products

IGS Real-Time Pilot Project

- Pilot Project started in 2007
- Main tasks
  - Manage and maintain a global IGS real-time GNSS tracking network
  - Generate combined real-time IGS analysis products
  - Develop standards and formats for real-time data collection and distribution
  - Develop standards and formats for the generation and distribution of real-time analysis products
  - Monitor the integrity of IGU predicted orbits and GNSS status

IGS Real-Time Pilot Project

Main goals

- Enable access to a global reference frame in real-time through the availability of real-time clock and orbit correction information
- Make this information available through IP channels
- Targeted accuracies
  - 0.3 ns for clocks
  - 5-6 cm for orbits
  - latency < 10 sec

IGS-RT PP – Call for Participation

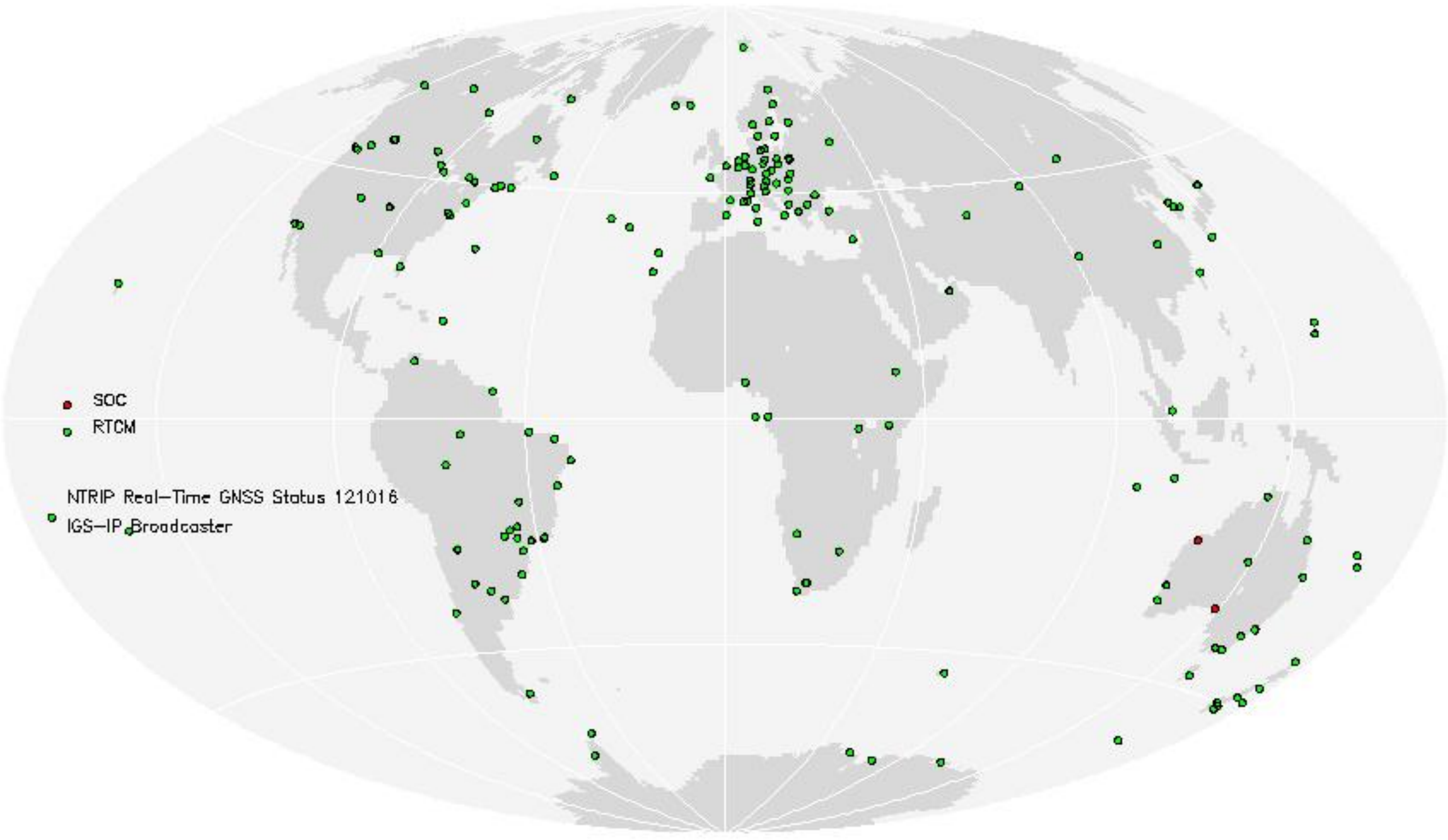
- Activities
  - RT Station Contributors
  - RT Data Centres
  - RT Analysis Centres
  - RT Associate Analysis Centres
  - RT Analysis Center Coordinator
  - RT Network Management and Monitoring
  - RT Users for Assessment, Evaluation and Feedback

IGS-RT PP – Call for Participation

Participation from 34 organisations

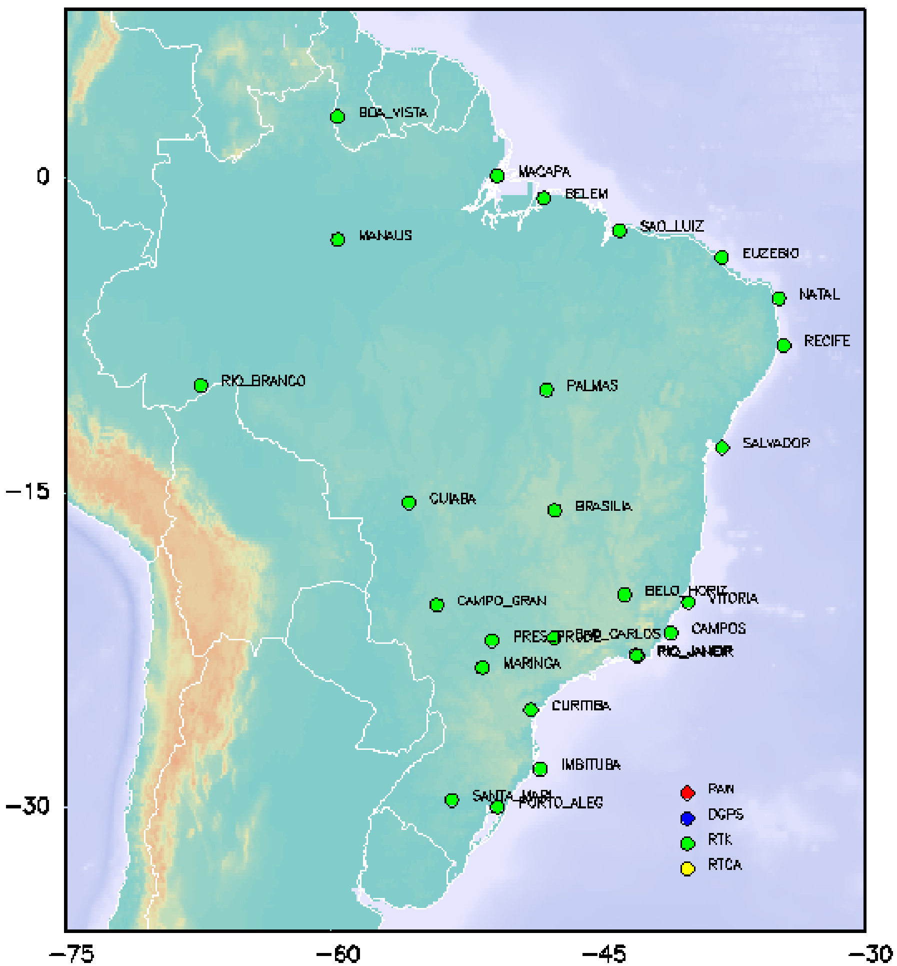
- 10 Analysis Centres
- ESOC as AC Coordinator
- > 100 RT observation streams
- Ntrip infrastructure from BKG

Network available from www.igs-ip.net

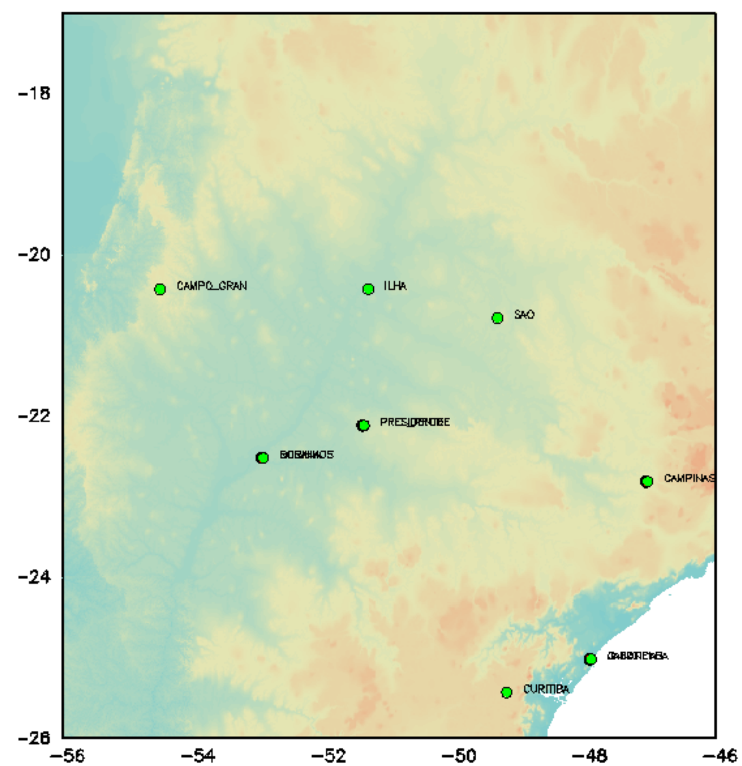


Example Contributions from South America

Real–Time GNSS NtripCaster IBGE, Status 120831



Real–Time GNSS NtripCaster UNESP, Status 120831



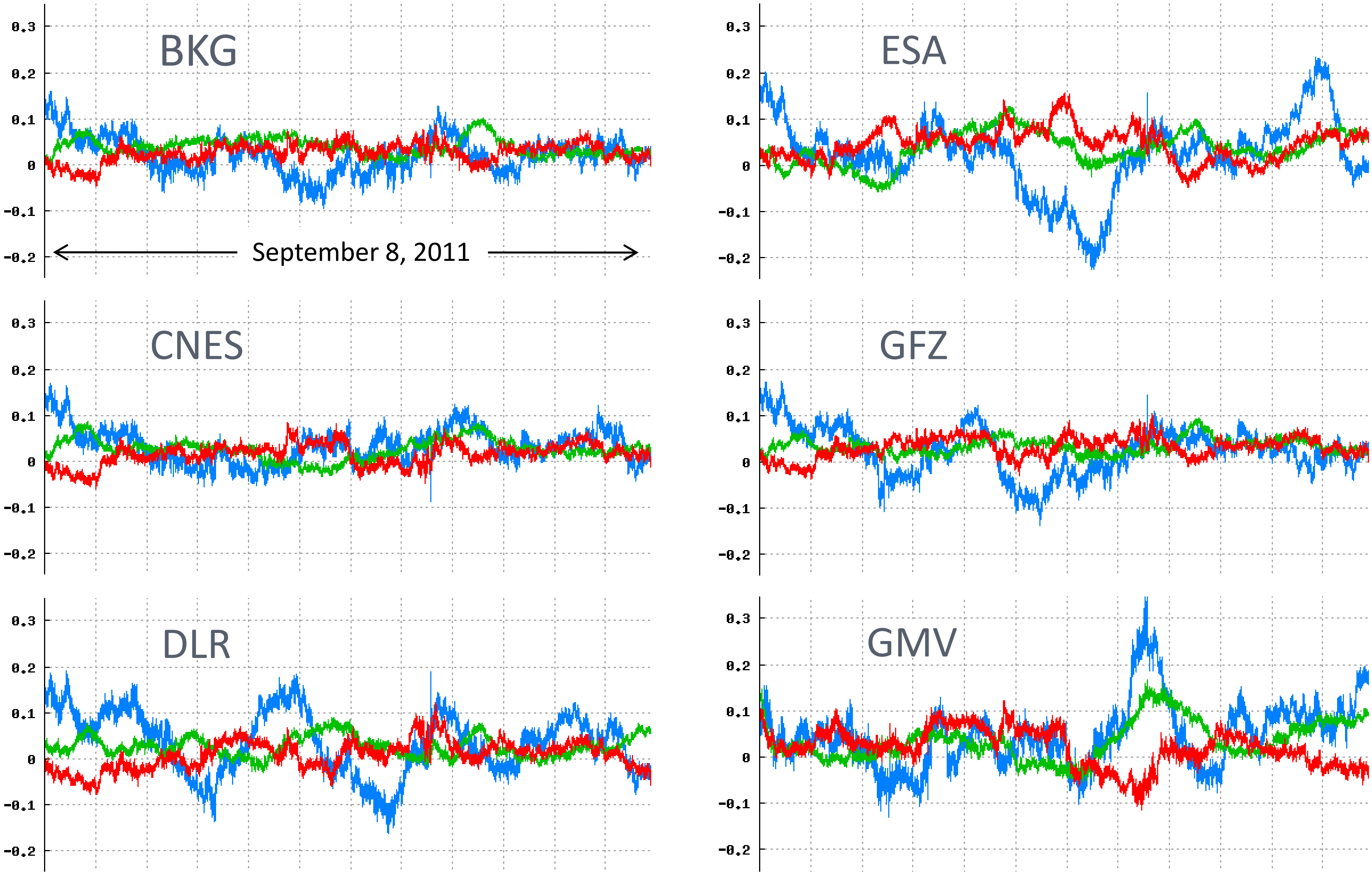
Redundancy Concept

- Real-time data streams shall be sent from the receiver to two different broadcasters in parallel
- Currently
  - Streams uploaded to one global broadcaster
  - Other broadcasters pulling data from there
- Also:
  - Real-time data streams being sent to national/regional broadcaster, example: gps-ntrip.ibge.gov.br
  - Different global broadcaster pulling data from there

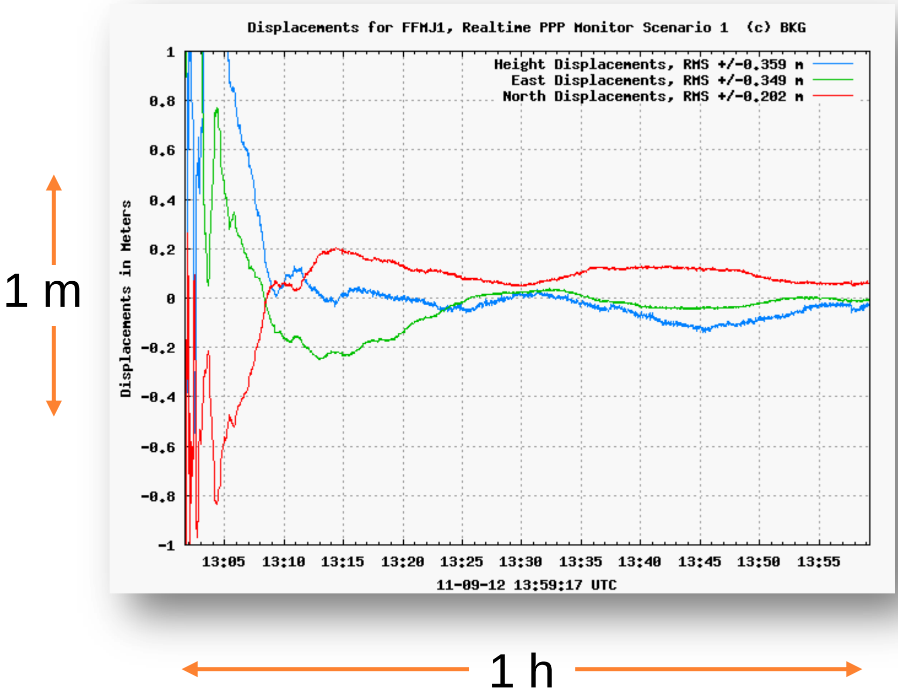
IGS-RT Pilot Project – Clock Performance

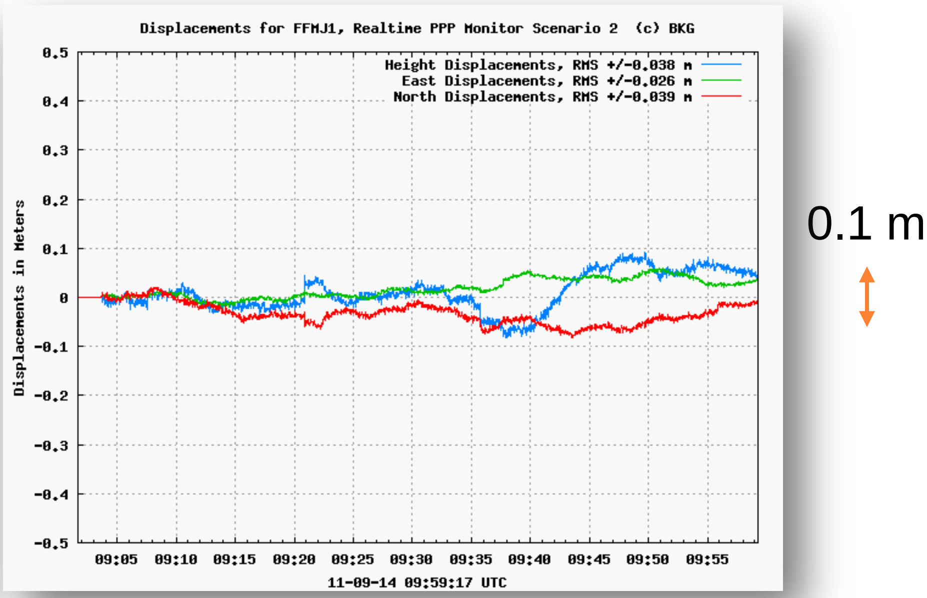
AC	June 15 2011	
	Clock RMS (ns)	Clock Sigma (ns)
Combi	0.14	0.07
BKG	0.30	0.07
CNES	0.30	0.03
DLR	0.25	0.12
ESOC	0.17	0.12
GFZ	0.33	0.06
NRC	0.23	0.07
GMV	0.34	0.10

24h time series of PPP NEU displacements – Applying different orbit/clock corrections



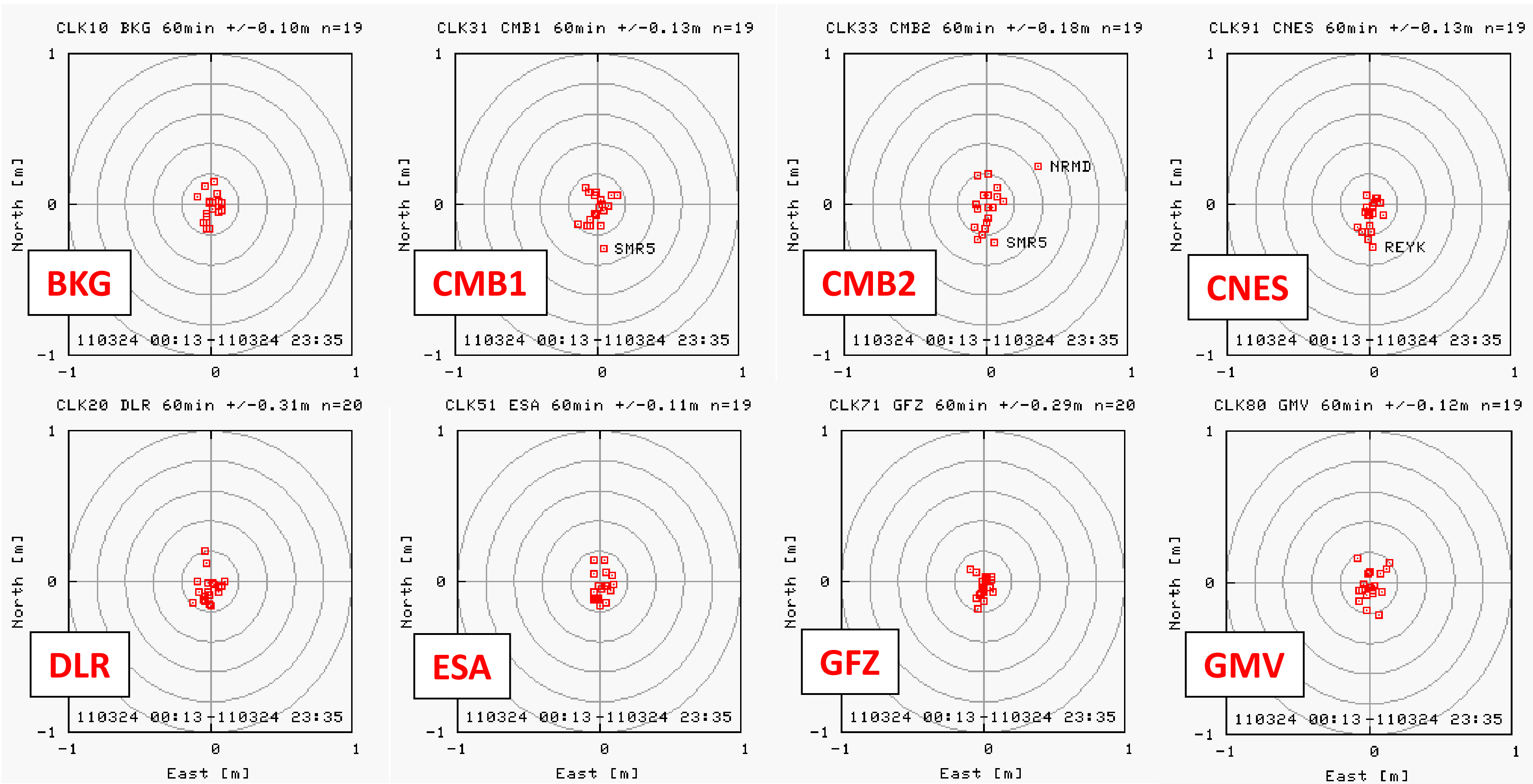
Real-time PPP - Performance





„Quick-Start“, initial position constrained

PPP tests were performed in fully kinematic mode for globally distributed IGS sites. Each test continued over 60 minutes and was carried out using the BKG Ntrip Client (BNC).



Motivation for Combination

(1) Outages of several AC product streams can be mitigated through merging them into a combined product

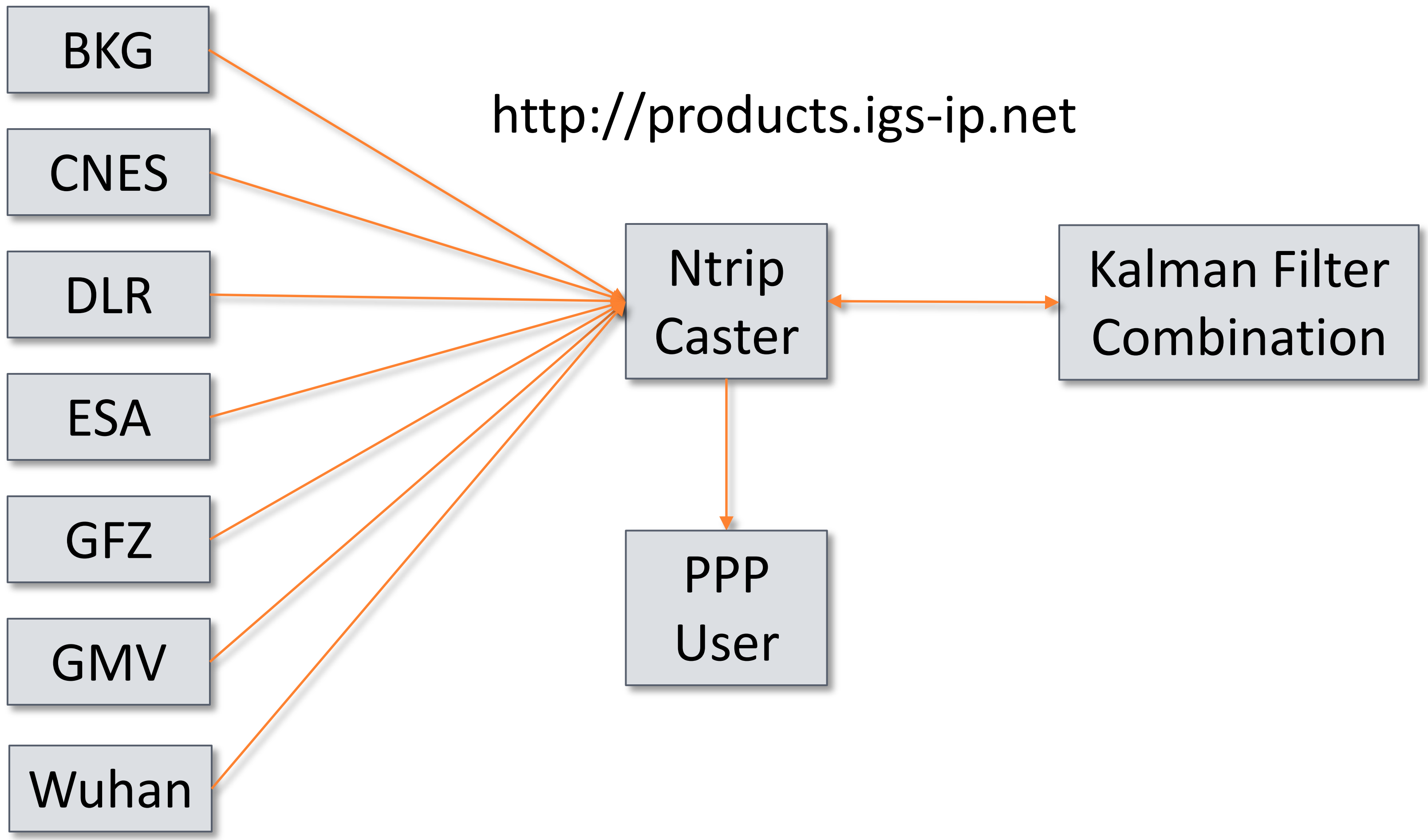
(2) Generating a combination product from several AC products allows detecting and rejecting Outliers

(3) Policy to offer one solution representing IGS results

Limitations of combined solution:

- Additional latency of a few seconds
- Inconsistencies when orbit solutions in contributions differ

Real-time Orbit/Clock Combination Data Flow



Further Steps

- Ambiguity Fixing
  - WG established in 2010 studying techniques for PPP ambiguity fixing
  - CNES and GFZ now computing products for PPP ambiguity fixing
  - Discussion group in RTCM about parameters to be delivered
- Add messages for biases and global ionosphere

Further Steps

- Operational Real-time IGS Service
  - Start in December 2012
  - GPS-only combination by ESOC
  - GPS + GLONASS Kalman Filter combination by BKG, based on contributions from BKG, CNES, DLR and GMV

Summary

- 8 Analysis Centers provide real-time satellite orbit and clock corrections to Broadcast Ephemeris
- All streams use RTCM v3 SSR format and NTRIP transport protocol, update rate is 5 to 10 sec
- Orbit and clock qualities monitored through
  - Offline clock comparison with IGS post processing products
  - Real-time PPP and comparison with IGS coordinates

Summary

- Combining individual products via Kalman Filter for Precise Point Positioning
- Outages and Outliers reduced
- Combination approach implemented in OS software

PPP-RTK & Open Standards Symposium and Workshop, 12-13 March 2012 Frankfurt am Main, Germany

- RTCM SSR
- Global Ionosphere
- Regional and Local Augmentations
- Phase Biases and Ambiguity Resolution
- Existing/Emerging PPP Services
- Product Dissemination
- Markets and Applications

Real-time GNSS

SP3 and Clock RINEX File Generation with BNC Using BRDC and SSR Orbit & Clock Streams

Motivation

Precise orbits and clock generation

Broadcast Ephemeris + Orbit/Clock correction
[referred to APC]

↓

Precise Orbits and Clocks
[referred to CoM]

for comparison with IGS products

Contents

- Input:
  - Broadcast Ephemeris Streams in RTCM3
  - Satellite Orbit and Clock Corrections to BRDC
- Output:
  - SP3-c Orbit Format,
  - Clock RINEX Format
- Transformation from APC to CoM
  - Antenna (PCO/PCV) Exchange Format, ANTEX
- Example:
  - BNC – Orbit/Clock File Generation

Input I: Broadcast Ephemeris Streams

- Several NTRIP broadcasters/provider disseminate streams carrying only RTCM v3 message types 1019 and 1020 for GPS and GLONASS ephemeris
- They derive their stream contents from a globally distributed selection of EUREF and IGS reference stations.
- Ephemeris message repetition rates vary between 1 and 5 seconds

Input I: Broadcast Ephemeris Streams

Caster IP:Port	Mountpoint	GNSS	Messages	Analysis Center	Register for access
products.igs-ip.net:2101	RTCM3EPH	GPS+GLO	1019(5) 1020(5)	BKG	Registration
wox.geopp.de:2101	WW_EPH	GPS+GLO	1019(1) 1020(1)	Geo++	support@geopp.de
www.dgpsonline.eu:2101	RTCM3EPH	GPS+GLO	1019(1) 1020(1)	Alberding GmbH	info@alberding.eu
gnss.gsoc.dlr.de:2101	BCEP1	GPS+GLO +GAL	1019(10) 1020(10) 1045(10) 1046(10)	GSOC/DLR	andre.hauschild@dlr.de

Input II: Orbit/Clock Corrections

- RTCM-SSR
  - Orbit corrections are provided in along-track, cross-track and radial components
  - The components are defined in the reference frame of the broadcast ephemeris
  - After applying corrections, the satellite position and clock is referred to the 'ionosphere free' phase center of the antenna (APC) which is compatible with the broadcast orbit reference

Input II: Orbit/Clock Corrections

- RTCM 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

Input: BRDC & SSR Streams

Caster IP:Port	Mountpoint & Input Streams	Ref. Point	GNSS	Messages	Orbits	Reference System	Analysis Center & SW	Register for access
products.igs-ip.net:2101	IGS01	APC	GPS	1059,1060	IGS Ultra Rapid	ITRF2008	SE Combination RETINA	Registration
products.igs-ip.net:2101	CLK44	APC	GPS GLO	1059,1060 1065,1066	IGS Ultra Rapid	SIRGAS2000	BKG & CTU RTNet + BNS	Registration
products.igs-ip.net:2101	IGS03	APC	GPS GLO	1057,1058,1059,1063, 1064,1065	CODE Ultra Rapid	ITRF2008	KF Combination BNC	Registration
products.igs-ip.net:2101	RTCM3EPH	APC	GPS GLO	1019,1020	Broadcast Ephemeris	WGS84 PZ90.2	BKG	Registration

Excerpt from products.igs-ip.net

Output I: SP3-C Format

- A standardized orbit format is needed for orbit exchange.
- SP3-C format is an ASCII format, independent from computer operating systems
- SP3-C contents always refers to the Center of Mass (CoM)
- Format description available from:
- http://igscb.jpl.nasa.gov/igscb/data/format/sp3c.txt

Output I: SP3-C Format

Example:

CODE Rapid Orbits

```
#cP2012  10  3  0  0  0.00000000   96  d    IGS08   FIT AIUB
## 1708 259200.00000000 900.00000000 56203 0.0000000000000
+   55 G01G02G03G04G05G06G07G08G09G10G11G12G13G14G15G16G17
+      G18G19G20G21G22G23G25G26G27G28G29G30G31G32R01R02R03
+      R04R05R06R07R08R09R10R11R12R13R14R15R16R17R18R19R20
+      R21R22R23R24  0  0  0  0  0  0  0  0  0  0  0  0  0
+        0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
++       5  5  5  5  5  5  6  6  6  5  5  5  5  5  5  5  5
++       5  5  5  5  5  5  6  6  6  5  5  5  5  5  5  5  5
++       5  5  5  5  5  5  6  6  6  5  5  5  5  5  5  5  5
++       6  5  5  5  0  0  0  0  0  0  0  0  0  0  0  0  0
++       0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
%c M c GPS ccc cccc cccc cccc cccc ccccc ccccc ccccc ccccc
%c c c ccc ccc cccc cccc cccc cccc ccccc ccccc ccccc ccccc
%f 1.2500000  1.025000000  0.00000000000 0.000000000000000
%f 0.0000000  0.000000000  0.00000000000 0.000000000000000
%i 0  0  0  0  0  0  0  0  0  %i  0  0  0  0  0  0  0  0 0
/* Center for Orbit Determination in Europe (CODE)
/* Rapid GNSS orbits and GPS clocks for year-day 12277
/* Note: Last day of a 3-day arc GPS/GLONASS solution
/* PCV:IGS08      OL/AL:FES2004  NONE   YN ORB:CoN CLK:CoN
2012 10 3 0 0 0.00000000
PG01  -2901.041290  16726.625280 -20429.743569  276.125514
PG02  21246.300668 -14279.909386   6145.994558  404.758309
PG03 -10008.429659  19919.796025  13756.427337  109.484028
```

Output II: Clock RINEX Format

- A format specifically made for distributing clock information
- Clock RINEX format is an ASCII format, independent from computer operating systems
- Format description available from:
- http://igscb.jpl.nasa.gov/igscb/data/format/rinex_clock300.txt

Output II: Clock RINEX Format 3.00

```
     3.00           C                                       RINEX VERSION / TYPE
BNC                                       20121005 000030     PGM / RUN BY / DATE
     1    AS                                                  # / TYPES OF DATA
unknown                                                       ANALYSIS CENTER
    54                                                        # OF SOLN SATS
G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G12 G13 G14 G15 PRN LIST
G16 G17 G18 G19 G20 G21 G22 G23 G25 G26 G27 G28 G29 G30 G31 PRN LIST
G32 R01 R02 R03 R05 R06 R07 R08 R09 R10 R11 R12 R13 R14 R15 PRN LIST
R16 R17 R18 R19 R20 R21 R22 R23 R24                         PRN LIST
     0    IGS08                                               # OF SOLN STA / TRF
                                                              END OF HEADER
AS G01  2012 10 05 00 00 30.000000  1    2.764046810000e-04
AS G02  2012 10 05 00 00 30.000000  1    4.049562260000e-04
AS G03  2012 10 05 00 00 30.000000  1    1.103490550000e-04
AS G04  2012 10 05 00 00 30.000000  1    6.647731000000e-06
```

Example: Clock RINEX file generated by BNC

APC => CoM Transformation: ANTEX File

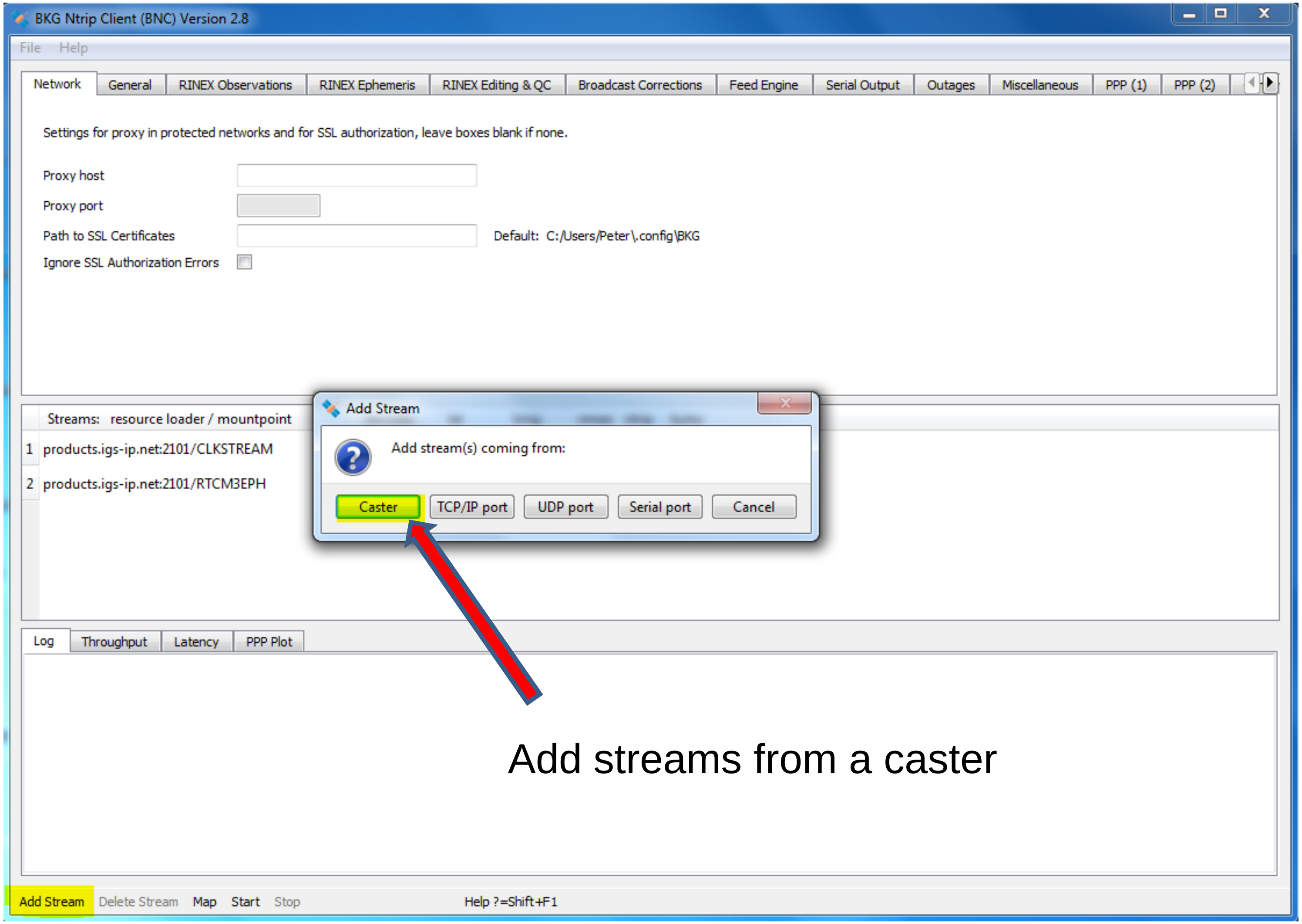
- A set of antenna phase center offsets and elevation-dependent phase center corrections
- Always needed if Orbit/Clock corrections should be transformed between
  - Center of Mass (CoM) and
  - Antenna Phase Center (APC)
- Actual File since GPS Week 1708:
- http://igscb.jpl.nasa.gov/igscb/station/general/igs08_1708.atx

APC => CoM Transformation: ANTEX File

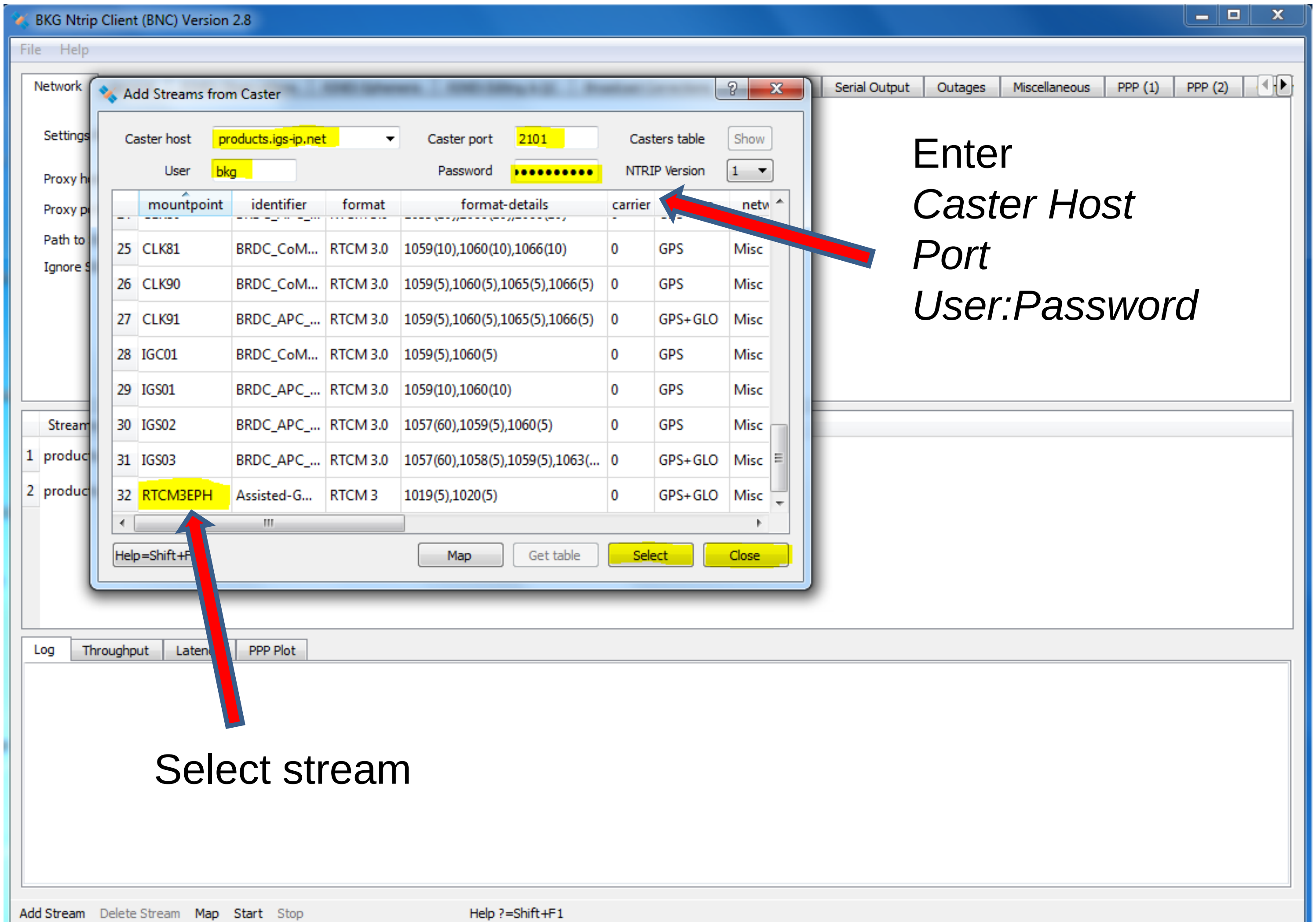
Excerpt from igs08_1708.atx:

```
START OF ANTENNA
LEIAT303        LEIC                                        TYPE / SERIAL NO
ROBOT                   Geo++ GmbH                43    25-MAR-11 METH / BY / # / DATE
     5.0                                                    DAZI
     0.0  90.0   5.0                                        ZEN1 / ZEN2 / DZEN
     2                                                      # OF FREQUENCIES
IGS08_1700                                                  SINEX CODE
Number of Calibrated Antennas GPS:      043                 COMMENT
Number of Individual Calibrations GPS:  220                 COMMENT
   G01                                                      START OF FREQUENCY
     -0.47      0.55     61.64                              NORTH / EAST / UP
NOAZI  0.00 -0.18 -0.68 -1.39 -2.20 -2.99 -3.75 -4.45 -5.08 -5.55 -5.74 -5.49 -4.71 -3.38
-1.59  0.54  2.91  5.52  8.41
  0.0  0.00 -0.14 -0.58 -1.23 -1.99 -2.79 -3.58 -4.38 -5.14 -5.75 -6.06 -5.90 -5.18 -3.90
-2.19 -0.18  2.08  4.64  7.62
  5.0  0.00 -0.14 -0.59 -1.25 -2.03 -2.83 -3.64 -4.44 -5.21 -5.84 -6.17 -6.04 -5.34 -4.08
-2.37 -0.34  1.94  4.52  7.51
 10.0  0.00 -0.14 -0.60 -1.28 -2.06 -2.87 -3.69 -4.50 -5.28 -5.92
```

Example: BNC – Add Streams



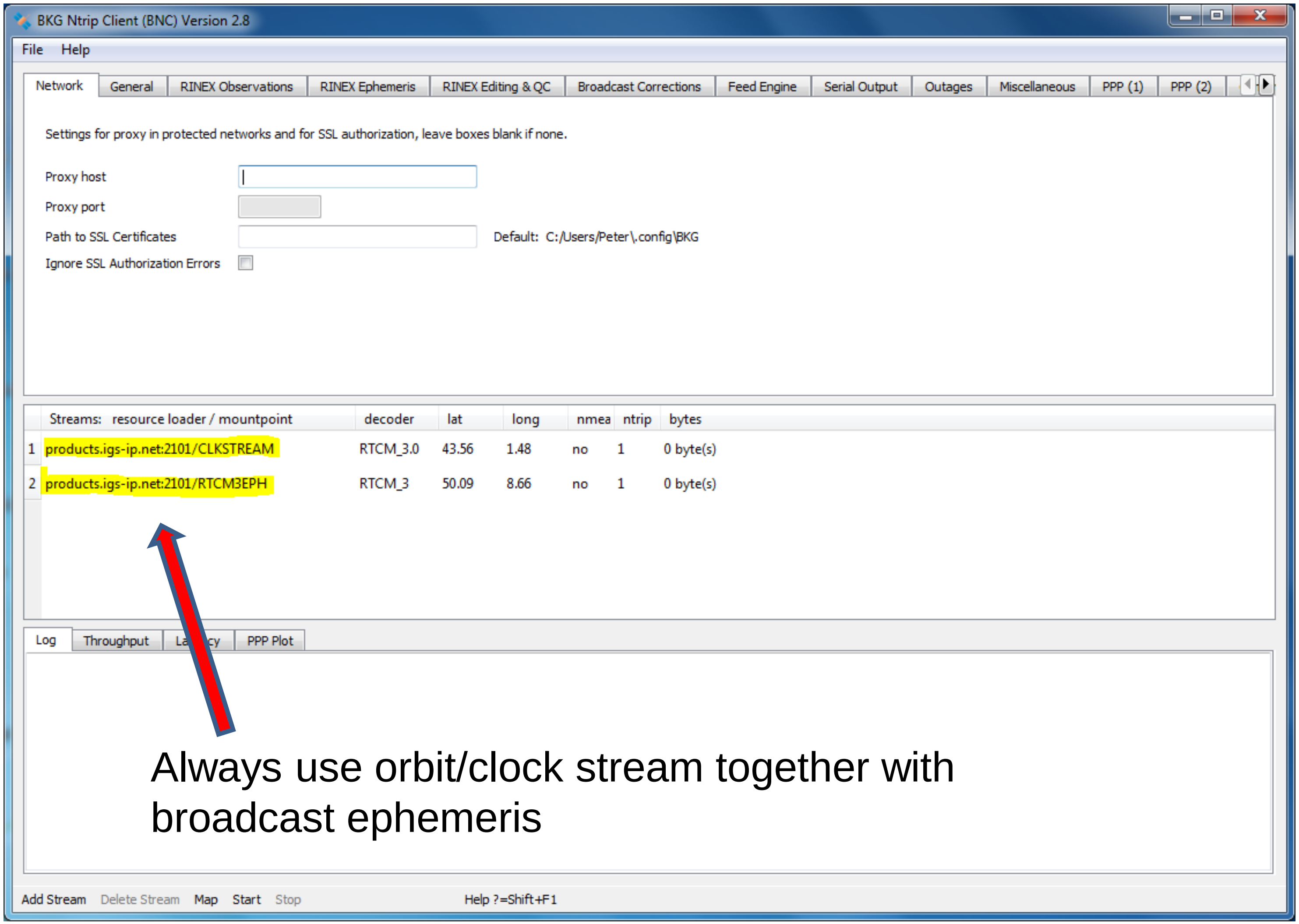
Example: BNC – Add Streams



Enter
Caster Host
Port
User:Password

Select stream

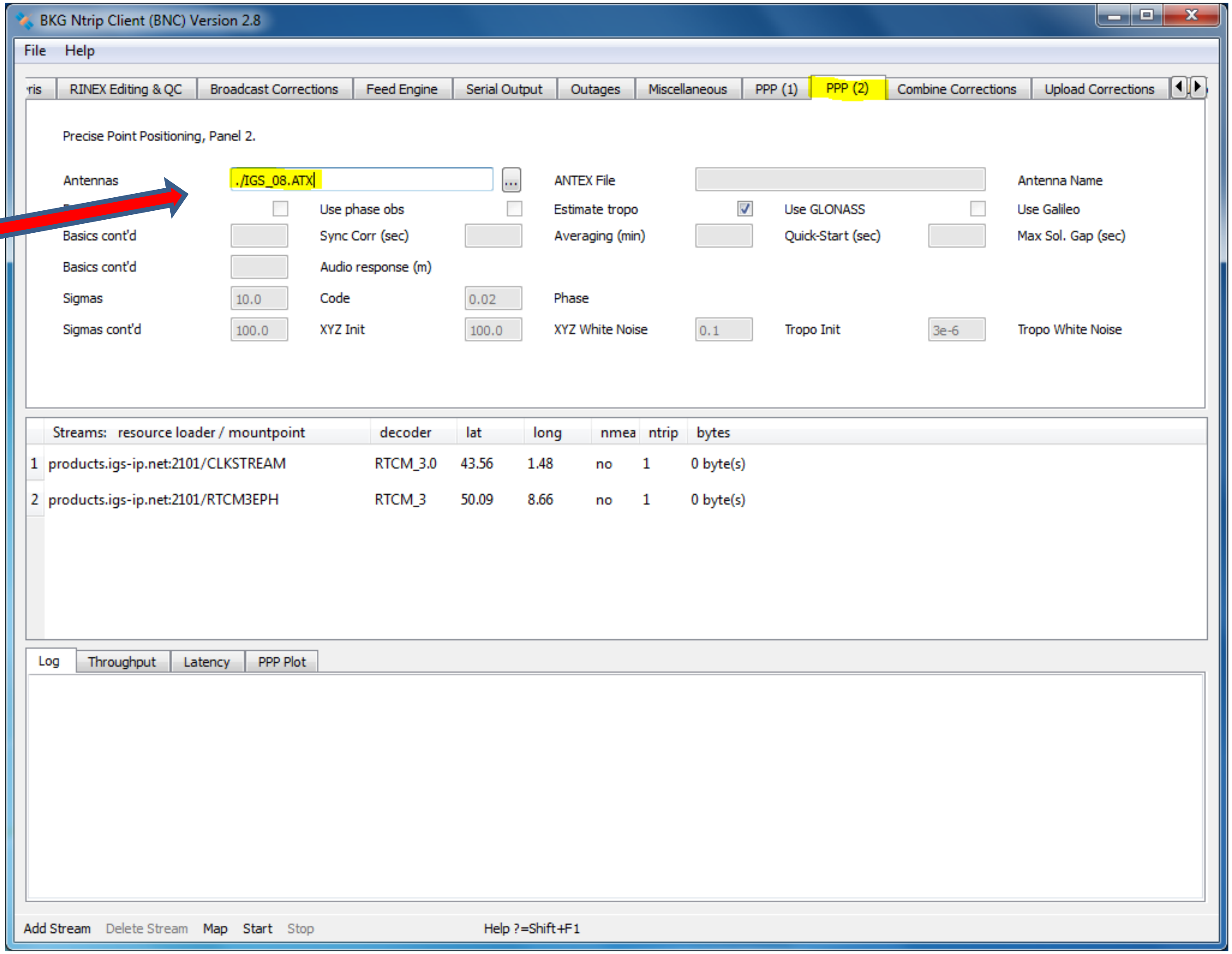
Example: BNC – Add Streams



Always use orbit/clock stream together with broadcast ephemeris

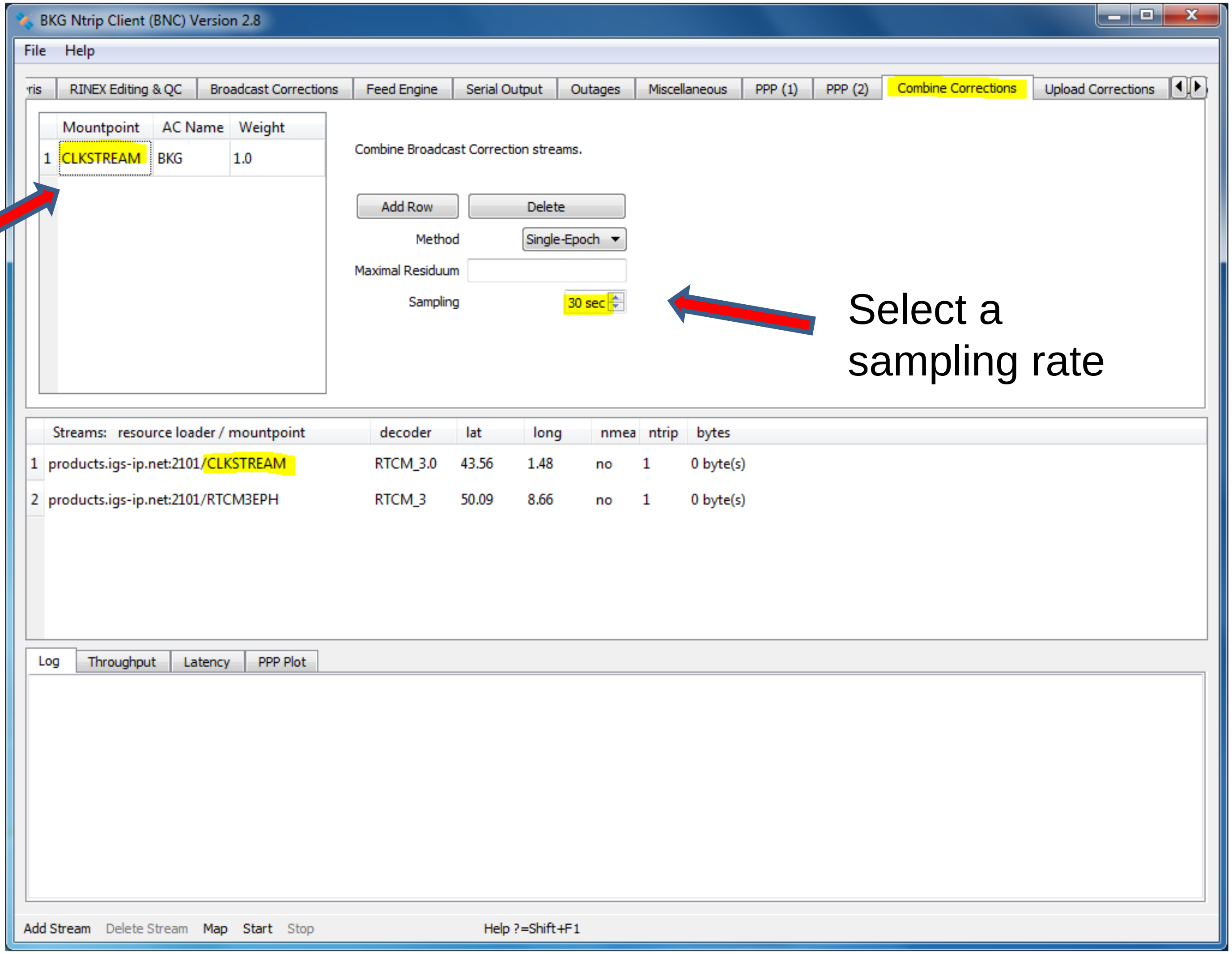
Example: BNC – Use ANTEX

An ANTEX file is needed if your orbit/clock stream is referring to the Antenna Phase Center (APC)



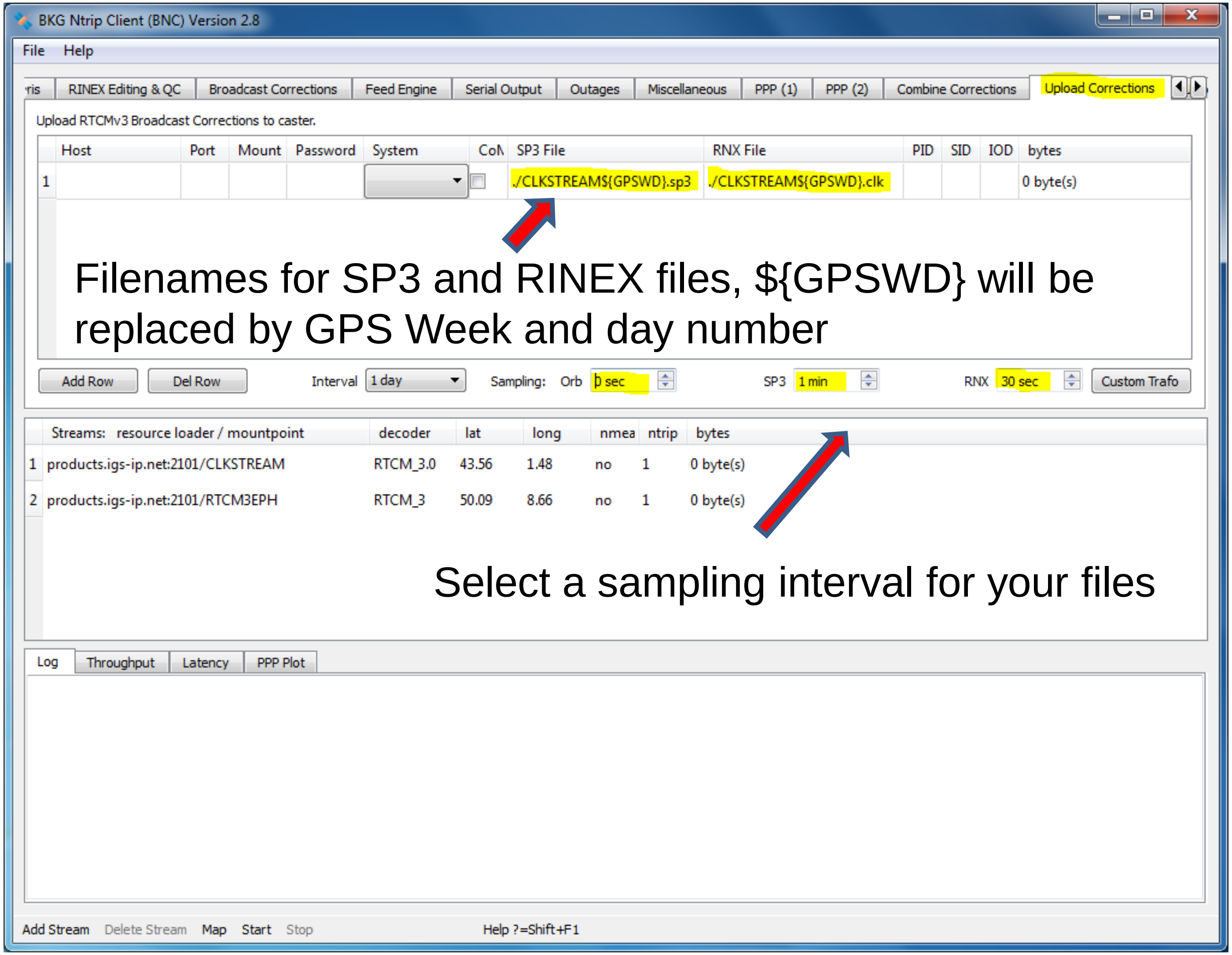
Example: BNC – Orbit&Clock Stream

Choose your orbit/clock stream from which files should be generated



Select a sampling rate

Example: BNC – Define SP3/Clock Output



Input II: Orbit/Clock Corrections

- Based on the RTCM-SSR concept, the streams can be available for different reference frames
- Helmert Transformation Parameters for Transformation to Regional Systems:

Regional System	Tx, Ty, Tz (m)	dTx, dTy, dTz (m/y)	Rx, Ry, Rz (mas)	dRx, dRy, dRz (mas/y)	S (10**-9) dS (10**-9/y)	T0 for Rates
ETRF2000	0.0541 0.0502 -0.0538	-0.0002 0.0001 -0.0018	0.891 5.390 -8.712	0.081 0.490 -0.792	0.40 0.08	2000.0
NAD83	0.9963 -1.9024 -0.5219	0.0005 -0.0006 -0.0013	-25.915 -9.426 -11.599	-0.067 0.757 0.051	0.78 -0.10	1997.0
GDA94	-0.07973 -0.00686 0.03803	0.00225 -0.00062 -0.00056	0.0351 -2.1211 -2.1411	-1.4707 -1.1443 -1.1701	6.636 0.294	1994.0
SIRGAS2000	-0.0051 -0.0065 -0.0099	- - -	0.150 0.020 0.021	- - -	- -	no rates
SIRGAS95	0.0077 0.0058 -0.0138	- - -	0.00 0.00 -0.03	- - -	1.57 -	no rates

Input II: Orbit/Clock Corrections

References

- **ETRF2000:** Claude Boucher, Zuheir Altamimi 2008: 'Specifications for reference frame fixing in the analysis of EUREF GPS campaign', see http://etrs89.ensg.ign.fr/memo-V7.pdf.
- **NAD83:** Chris Pearson, Robert McCaffrey, Julie L. Elliott, Richard Snay 2010: 'HTDP 3.0: Software for Coping with the Coordinate Changes Associated with Crustal Motion', Journal of Surveying Engineering.
- **GDA94:** John Dawson, Alex Woods 2010: 'ITRF to GDA94 coordinate transformations', Journal of Applied Geodesy, 4 (2010), 189-199 6, de Gruyter 2010. DOI 10.1515/JAG.2010.019
- **SIRGAS2000:** Personal communication with CGED-Coordenacao de Geodesia, IBGE/DGC - Diretoria de Geociencias, Brazil.
- **SIRGAS95**: Personal communication with Laboratorio de Geodesia Fisica y Satelital at Zulia University (LGFS-LUZ), transformation parameters based on values from Table 4.1 of 'Terrestrial Reference Frames (April 10, 2009), Chapter 4', see http://tai.bipm.org/iers/convupdt/convupdt_c4.html.

Real-time GNSS

Precise Point Positioning with BNC e.g. for Natural Hazards

Contents

- Precise Point Positioning with BNC
- Input Parameter
  - Orbit/Clock Corrections
  - Antex File
  - Observation Stream
- Output
  - Logfile
  - NMEA Sentences
- Settings

Precise Point Positioning with BNC General

- BNC provides a good framework for the PPP client (observations, orbits, and corrections stand for disposal).
- Main reasons for the PPP module in BNC have been:
  - monitoring the quality of incoming data streams
  - providing a simple easy-to-use tool for the basic PPP positioning
- The mathematical model of observations and the adjustment algorithm are implemented in such a way that they are correct without any shortcomings.
- we have preferred simplicity to transcendence, and the list of options the BNC users can select is limited.

(Introduction to BKG Ntrip Client (BNC) Usage, L. Mervart, Frankfurt, March 2012)

Precise Point Positioning with BNC Corrections

PPP and several corrections by BNC

- Solid Earth Tides and Phase Windup: corrected
- Satellite Antenna Phase Center (APC) Offsets: not corrected (orbit/clock corr. refer. to APC)
- Satellite APC Variations: neglected (less than 2 cm)
- Receiver Antenna Offset: optional (receiver APC or Antenna Reference Point)
- Receiver APC Variations: not included (mostly smaller a few cm)
- Ocean and atmospheric loading: neglected (pretty small, Ocean load up to 10 cm for coastal stations)
- Polar Tides: not corrected (less than 2 cm)

Contents

- Precise Point Positioning with BNC
- Input Parameter

  - Orbit/Clock Corrections

  - Antex File

  - Observation Stream
- Output

  - Logfile

  - NMEA Sentences
- Settings

Input Parameter: Orbit +Clock Corrections

- RTCM Version 3 messages transports satellite clock and orbit corrections in real-time:
  - Orbit corrections to Broadcast Ephemeris
  - Clock corrections to Broadcast Ephemeris
  - Code biases
  - Combined orbit and clock corrections to Broadcast Ephemeris
  - User Range Accuracy (URA)
  - High-rate GPS clock corrections to Broadcast Ephemeris

- Streams listed at: http://igs.bkg.bund.de/ntrip/orbits

Input Parameter: Orbit +Clock Corr. RTCM 1057

RTCMv3 message type number | SSR update 0 = 1 sec | GPS Week | Second in Week | VPR# |

In case of RTCM message types 1057 or 1063 (see Annex) these parameters are followed by :

IOD Broadc. Eph. | Rad. Orbit Corr. [m] | Along Orbit Corr. [m] | Cross Orbit Corr. [m] |
Vel. Rad. Orbit Corr. [m/s] | Vel. Along Orbit Corr. [m/s] | Vel. Cross Orbit Corr. [m/s] |

...
1057 0 1538 211151.0 G18 1 0.034 0.011 -0.064 0.000 0.000 0.000
1057 0 1538 211151.0 G16 33 -0.005 0.194 -0.091 0.000 0.000 0.000
1057 0 1538 211151.0 G22 50 0.008 -0.082 -0.001 0.000 0.000 0.000
...
1063 0 1538 211151.0 R09 111 -0.011 -0.014 0.005 0.000 0.000 0.000
1063 0 1538 211151.0 R10 43 0.000 -0.009 -0.002 0.000 0.000 0.000
1063 0 1538 211151.0 R21 75 -0.029 0.108 0.107 0.000 0.000 0.000
...

Input Parameter: Antex File

- IGS provides a file containing absolute phase center corrections for GNSS satellite and receiver antennas in ANTEX format.

  current file: http://igs.org/igscb/station/general/igs08.atx

- This ANTEX file:
  - is required for correcting observations for antenna phase center offsets and variations
  - allows you to specify the name of your receiver's antenna (as contained in the ANTEX file) to apply such corrections

Input Parameter: Observations

- BNC can generate and pull synchronized or unsynchronized observations
- Observations can be streamed out and/or saved
- Output is in plain ASCII format and comprises following parameters:

  `StationID | GPSWeek | GPSWeekSec | PRN, G=GPS, R=GLO | SlotNumber (if GLO) | Band/Frequency & trackingMode | Code | Phase | Doppler | SNR | SlipCount | ....`

  - Note on 'SlipCount':
    - o different slip counts could be referred to different phase meas. (i.e. L1C and L1P)
    - o only one slip count in RTCM Version 3 for all phase measurements

=> BNC output is one slip count per phase measurement

Input Parameter: Observations CUT07 1683

```
...
CUT07 1683 493688.0000000 G05 1C 24584925.242 129195234.317
   3639.020 38.812 40 2P 24584927.676 100671636.233 0.0 22.812 -1
   2X 24584927.336 100671611.239 0.0 39.500 -1
CUT07 1683 493688.0000000 G04 1C 22598643.968 118756563.731 -
   1589.277 42.625 40 2P 22598649.391 92537559.230 0.0 29.125 -1
CUT07 1683 493688.0000000 G02 1C 23290004.062 122389588.008 -
   445.992 46.375 -1 2P 23290003.567 95368508.986 0.0 29.188 -1
CUT07 1683 493689.0000000 R16 -1 1C 19210052.313 102616872.230
   364.063 53.375 42 1P 19210053.445 102616393.224 0.0 52.312 42
   2P 19210057.785 79813218.557 0.0 50.188 -1
CUT07 1683 493689.0000000 R15 0 1C 20665491.149 110430900.266 -
   2839.875 49.188 -1 1P 20665491.695 110430900.278 0.0 47.625 -1
   2P 20665497.559 85890714.522 0.0 48.000 -1
```

…

Contents

- Precise Point Positioning with BNC
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Output: Log

In Logfile and BNC Interface-Log:

- Values are saved about once a second
- Date, selected mounpoint, PPP time stamp in GPS Time, number of processed satellites, XYZ coordinates with formal errors [m]
- outlier and cycle slip detection: accepted residuals max. 10 m for code obs
  max. 10 cm for phase obs

Listed in Logfile only:

- code and phase residuals for GPS and GLONASS and Galileo [m]
- receiver clock errors [m]
- a-priori and correction values of tropospheric zenith delay [m]
- time offset between GPS time and Galileo time [m]
- L3 biases ('floated ambiguities’) per satellite.

Output: NMEA Sentences

- NMEA 0183
  - is a specification for communication between marine electronic devices (echo sounder, sonars, anemometer, gyrocompass, autopilot, GPS receivers…)
  - Defined by the U.S.-based National Marine Electronics Association
  - uses simple ASCII and
  - serial communications protocol
  - Defines how data is transmitted in a "sentence" from one "talker" to multiple "listeners”
  - At application level: defines the contents of each sentence (message) type => listeners can parse messages accurately
- BNC generates following sentences per second:
  - GPRMC sentences (date and time info)
  - GPGGA sentences (latitude, longitude, and height values)

Output: NMEA Sentences GPRMC

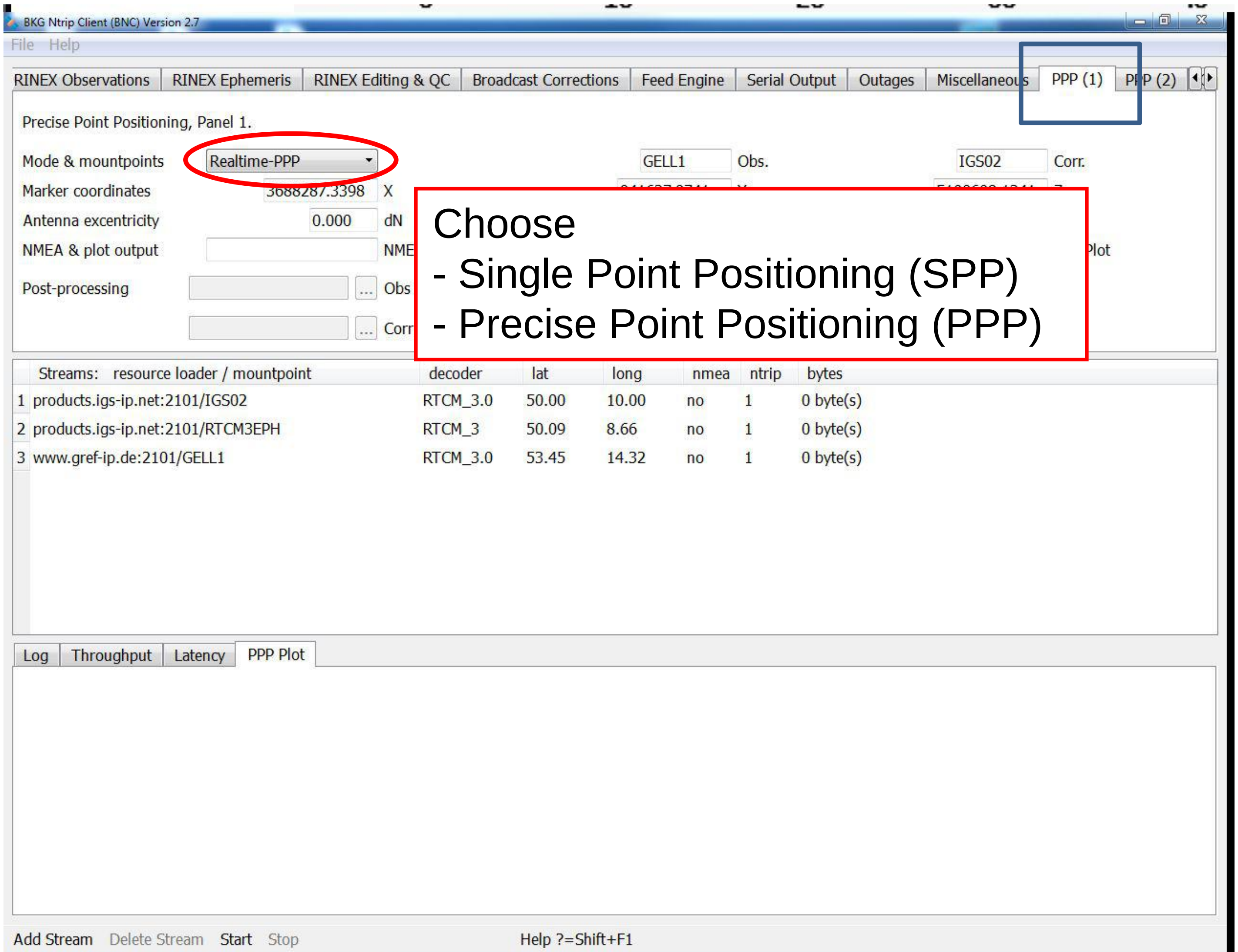
```
$GPRMC,191410, A,4735.5634,N,00739.3538,E,0.0,0.0,181102,0.4,E,A*19
               |           | |               |                           |     |     |       |        |
                |           | |               |                 |     |    |         |        |
                |          | |               |                  |     |    |        |        Mode of Determination
                |          | |               |                  |     |    |        |        A=autonomous
                |          | |               |                  |     |    |        |        D=differential
                |          | |               |                  |     |    |        |        E=estimated
                |          | |               |                  |     |    |        |        N=not valid
                |          | |               |                  |     |    |        |        S=simulator
                |          | |               |                  |     |    |        Deviation (with direction)
                |          | |               |                  |     |   Date: 18.11.2002
                |          | |               |                  |    Direction in degree (true)
                |          | |               |                 Velocity above ground (Knoten)
                |          | |               Longitude with direction (E=East, W=West)
                |          | |               007° 39.3538, East
                |          | Latitude with direction (N=North, S=South)
                |          | 46° 35.5634' North
                |          Status : A=Active; V=void
               Time: 19:14:10 (UTC)
```

Output: NMEA Sentences GPGGA

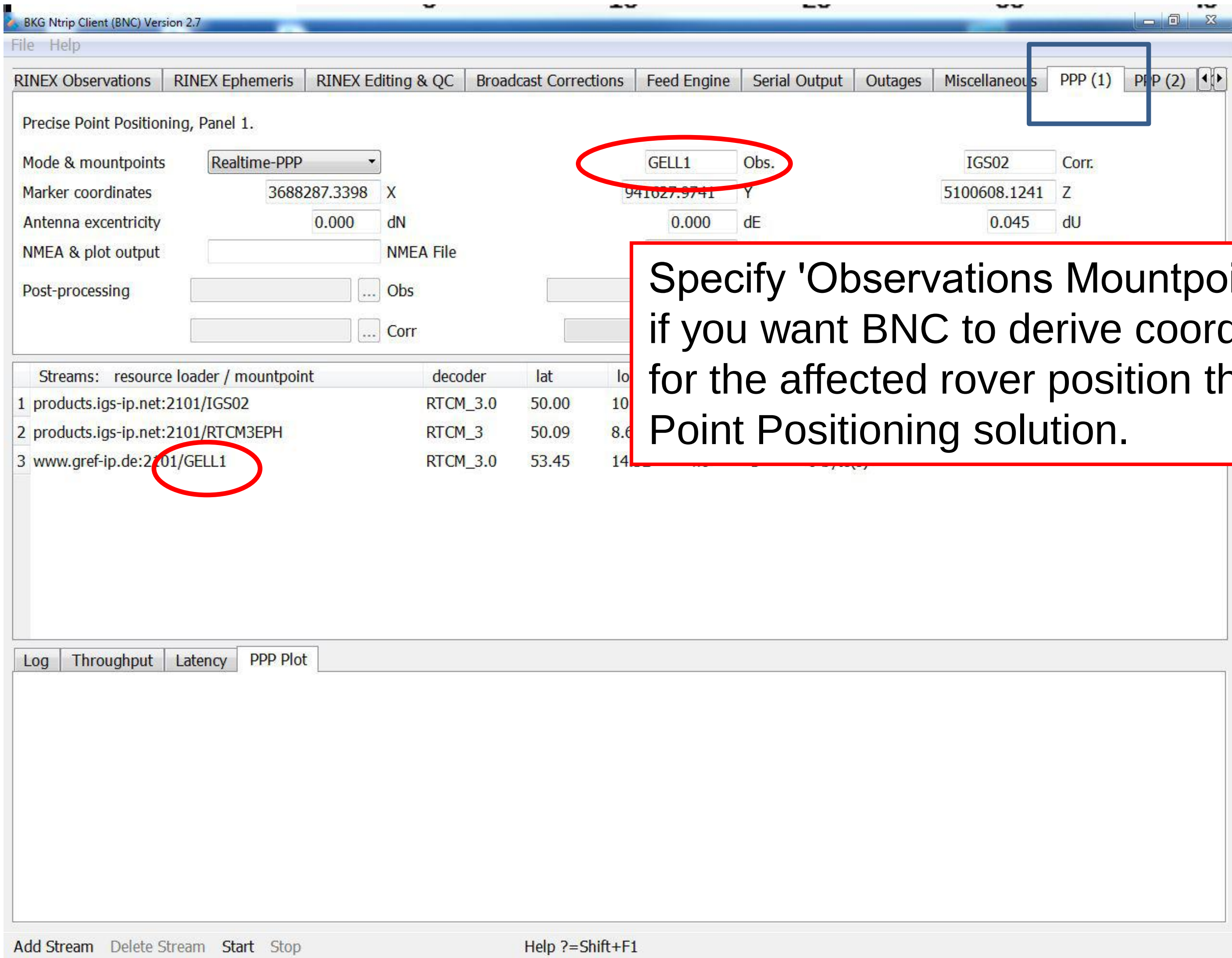
```
$GPGGA,191410,4735.5634,N,00739.3538,E,1,04,4.4,351.5,M,48.0,M,,*45
    |      |        |             | |  |  |       |
    |      |        |             | |  |  |          Height Geoid less
    |      |        |             | |  |  |          Height Ellipsoid (WGS84)
    |      |        |             | |  |  |          in m (48.0,M)
    |      |        |             | |  | Height above sealevel (above Geoid)
    |      |        |             | |  | in m (351.5,M)
    |      |        |             | |  |
    |      |        |             | | HDOP (horizontal dilution
    |      |        |             | |  of precision) Accuracy
    |      |        |             | Number of tracked satellites
    |      |        |        Quality of measuremant
    |      |        |        (0 = not valid)
    |      |        |        (1 = GPS)
    |      |        |        (2 = DGPS)
    |      |        |        (6 = estimated)
    |      |    Longitude
    |    Latitude
   Time
```

Contents

Settings: Mode

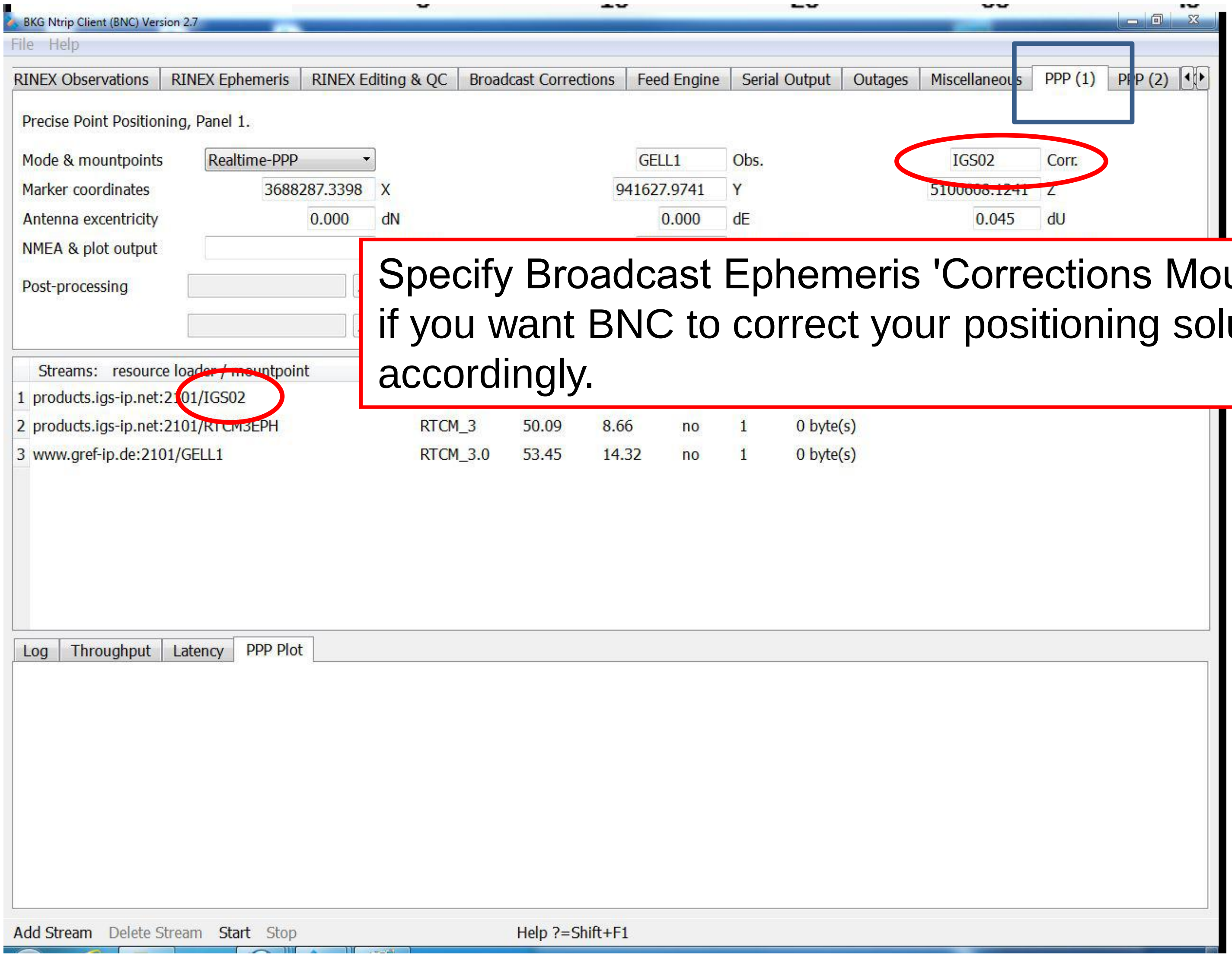


Settings: Observations Mountpoint



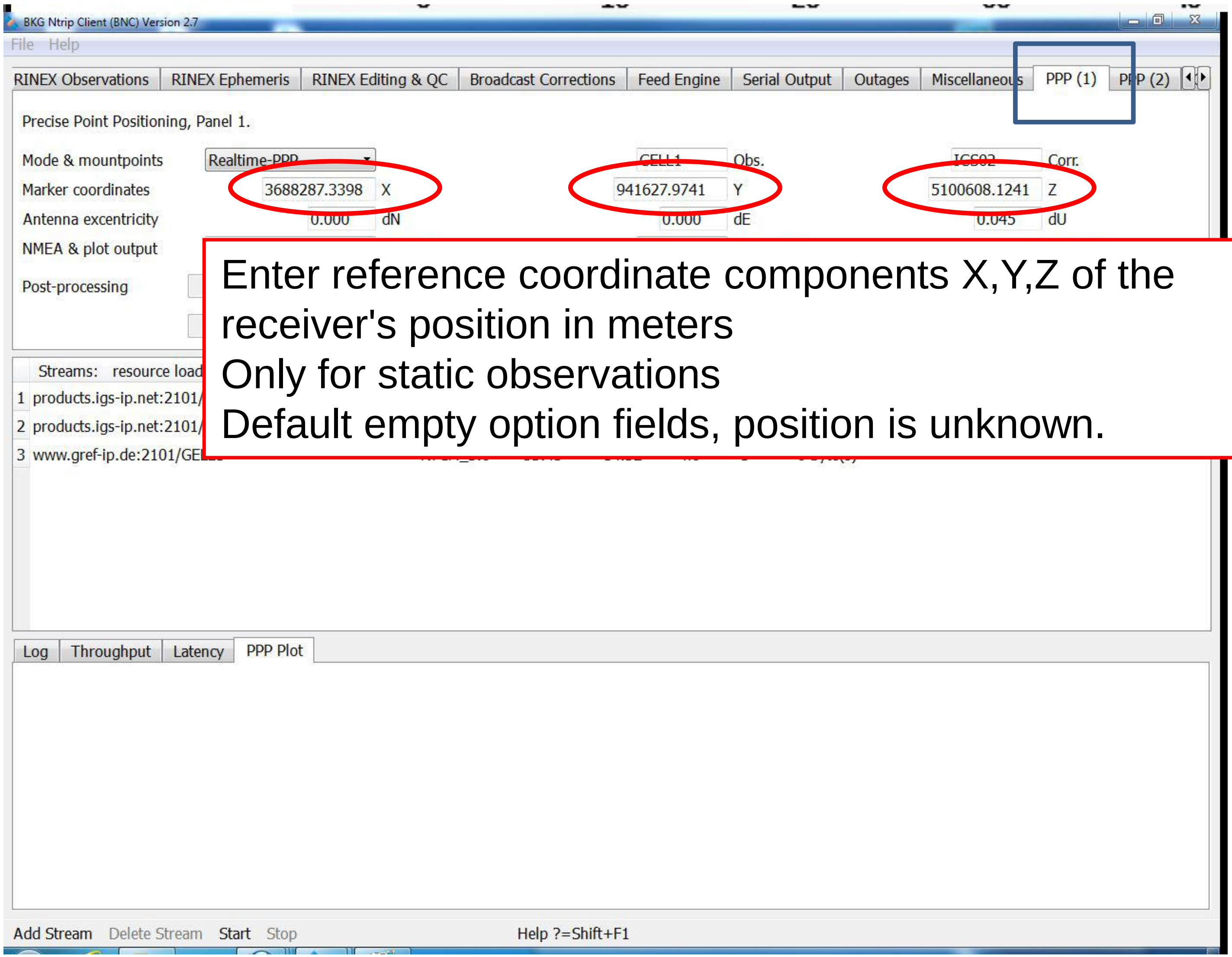
Specify 'Observations Mountpoint' if you want BNC to derive coordinates for the affected rover position through a Point Positioning solution.

Settings: Corrections Mountpoint



Specify Broadcast Ephemeris 'Corrections Mountpoint' if you want BNC to correct your positioning solution accordingly.

Settings: Reference Coordinates

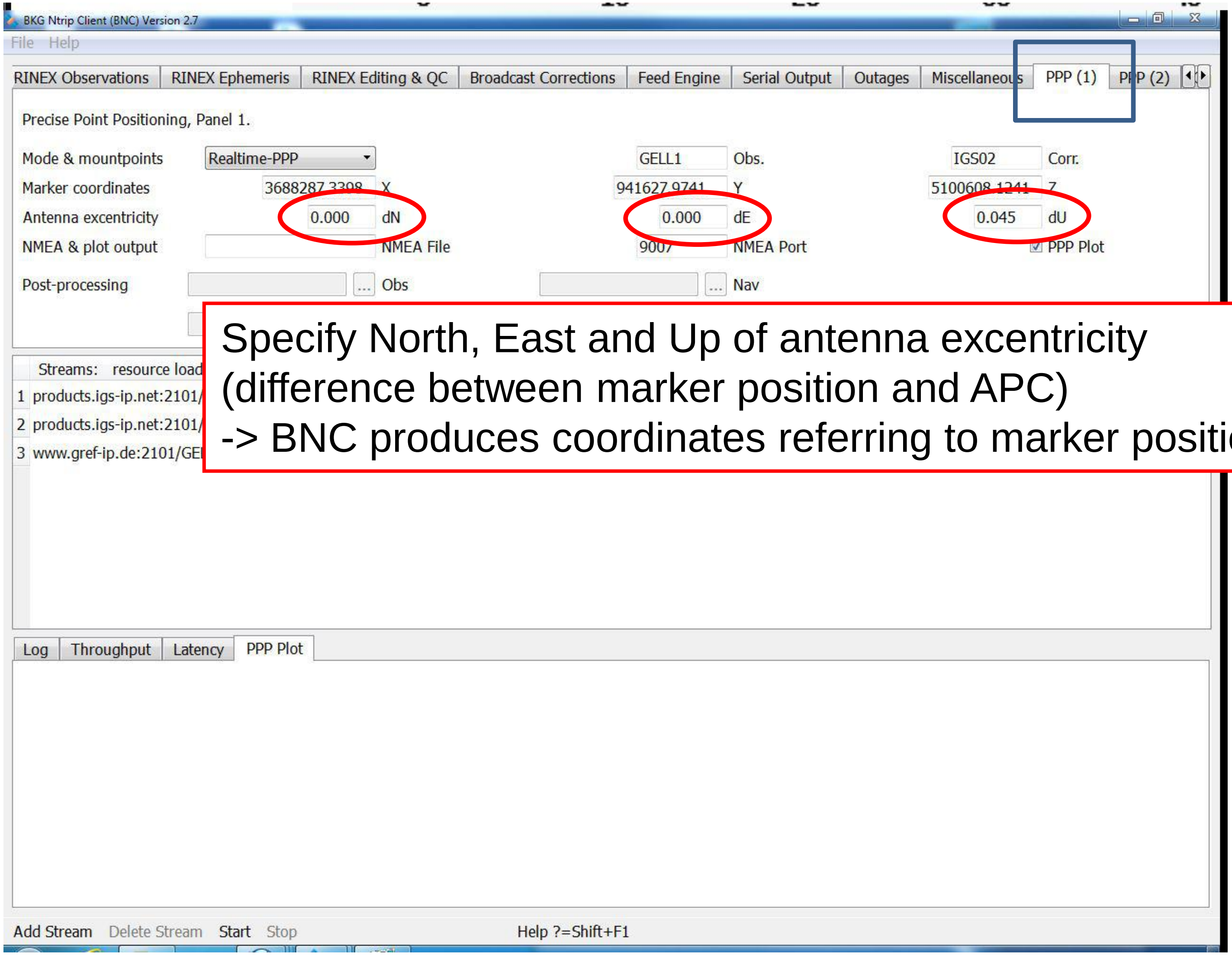


Enter reference coordinate components X,Y,Z of the receiver's position in meters

Only for static observations

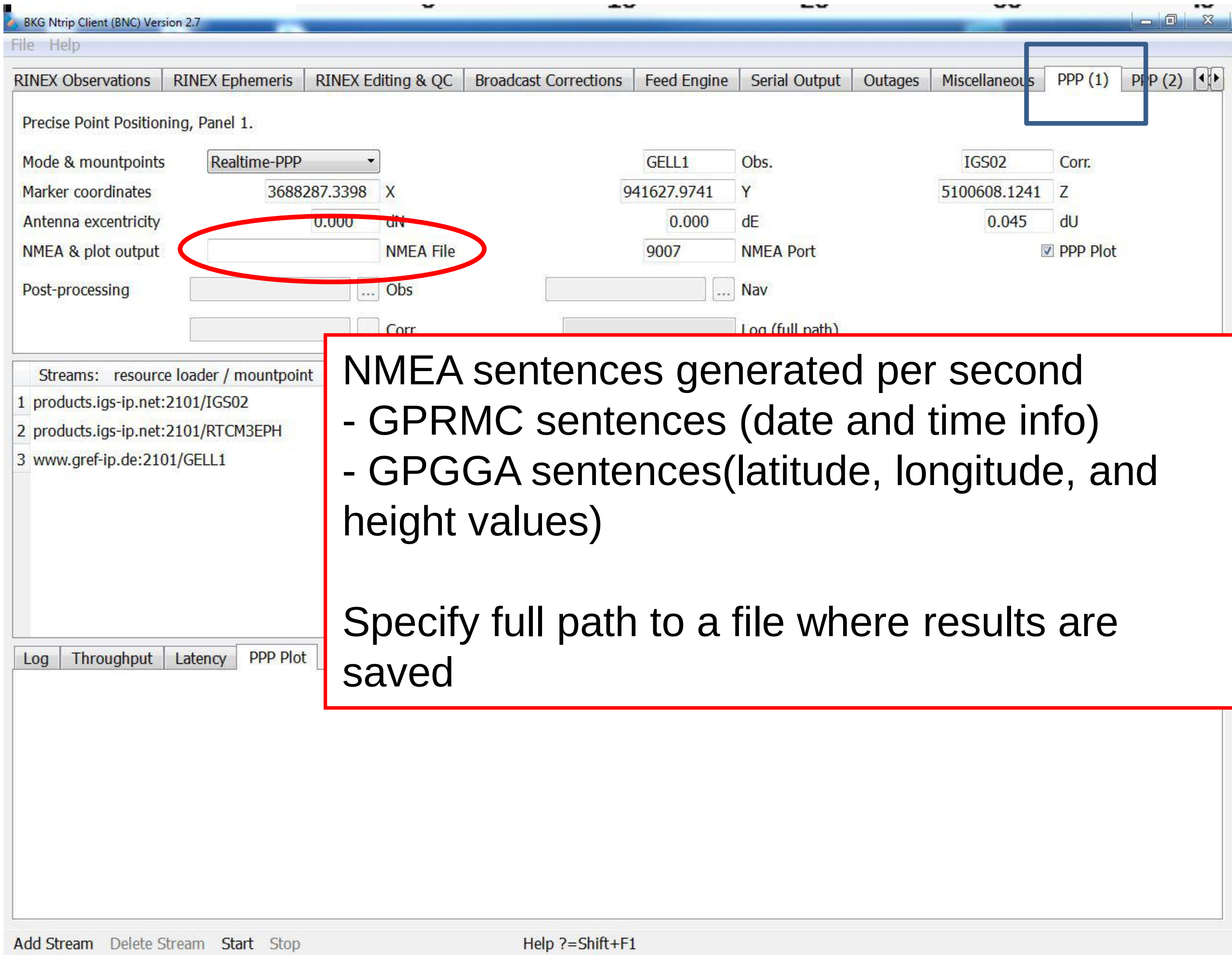
Default empty option fields, position is unknown.

Settings: Antenna Excentricity



Specify North, East and Up of antenna excentricity (difference between marker position and APC)
-> BNC produces coordinates referring to marker position

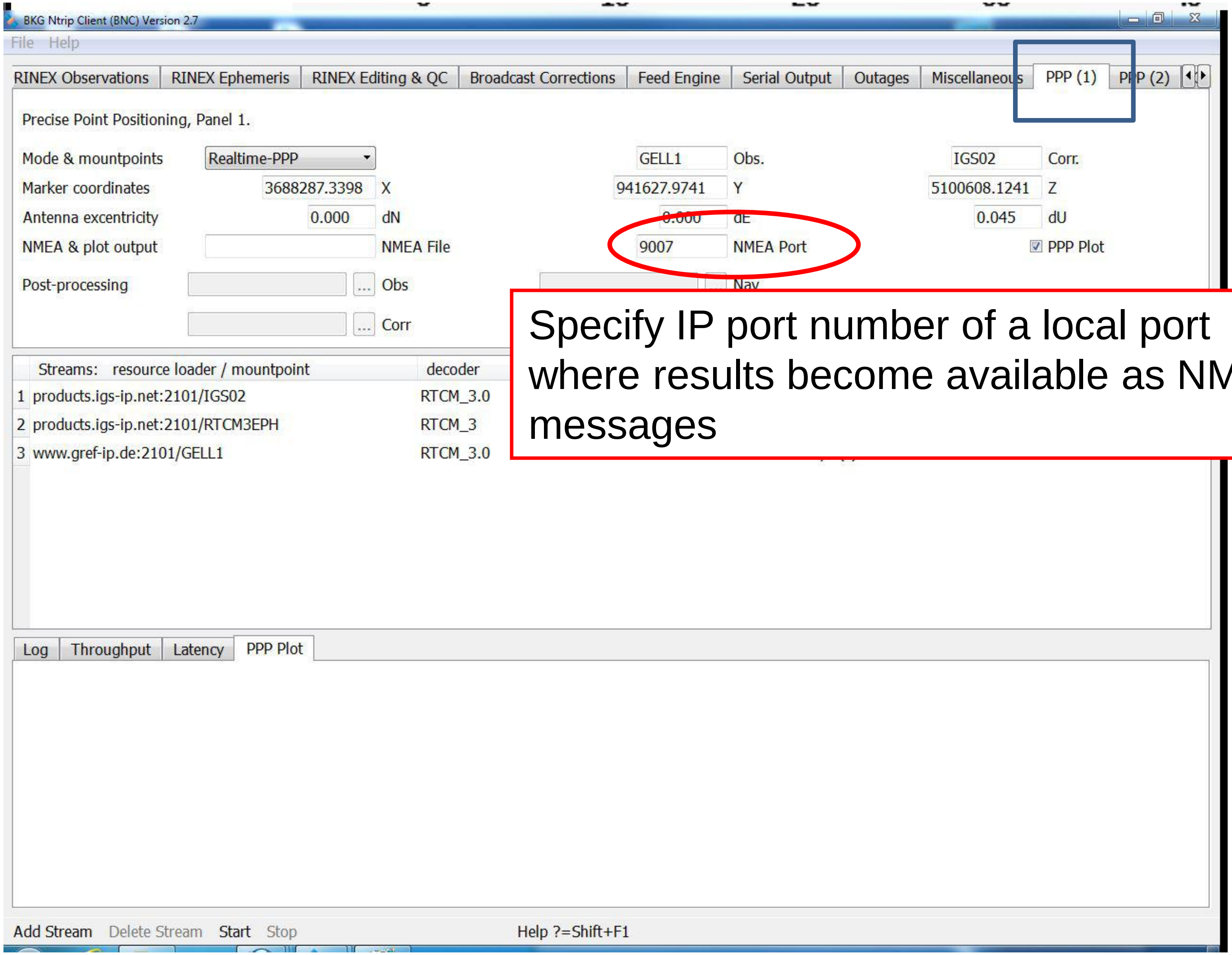
Settings : NMEA sentences



NMEA sentences generated per second
- GPRMC sentences (date and time info)
- GPGGA sentences(latitude, longitude, and height values)

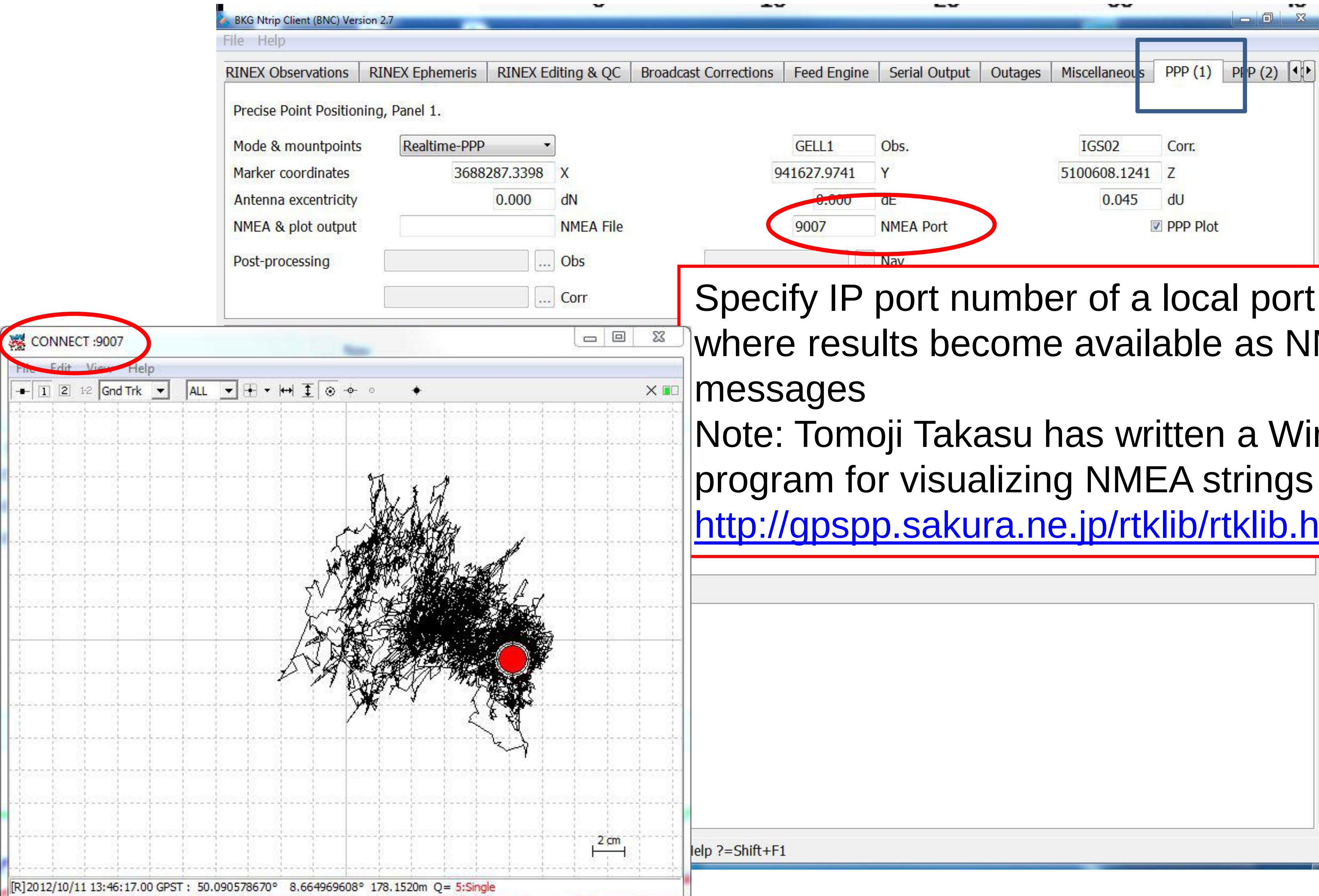
Specify full path to a file where results are saved

Settings : NMEA messages



Specify IP port number of a local port where results become available as NMEA messages

Settings : NMEA messages RTKPlot

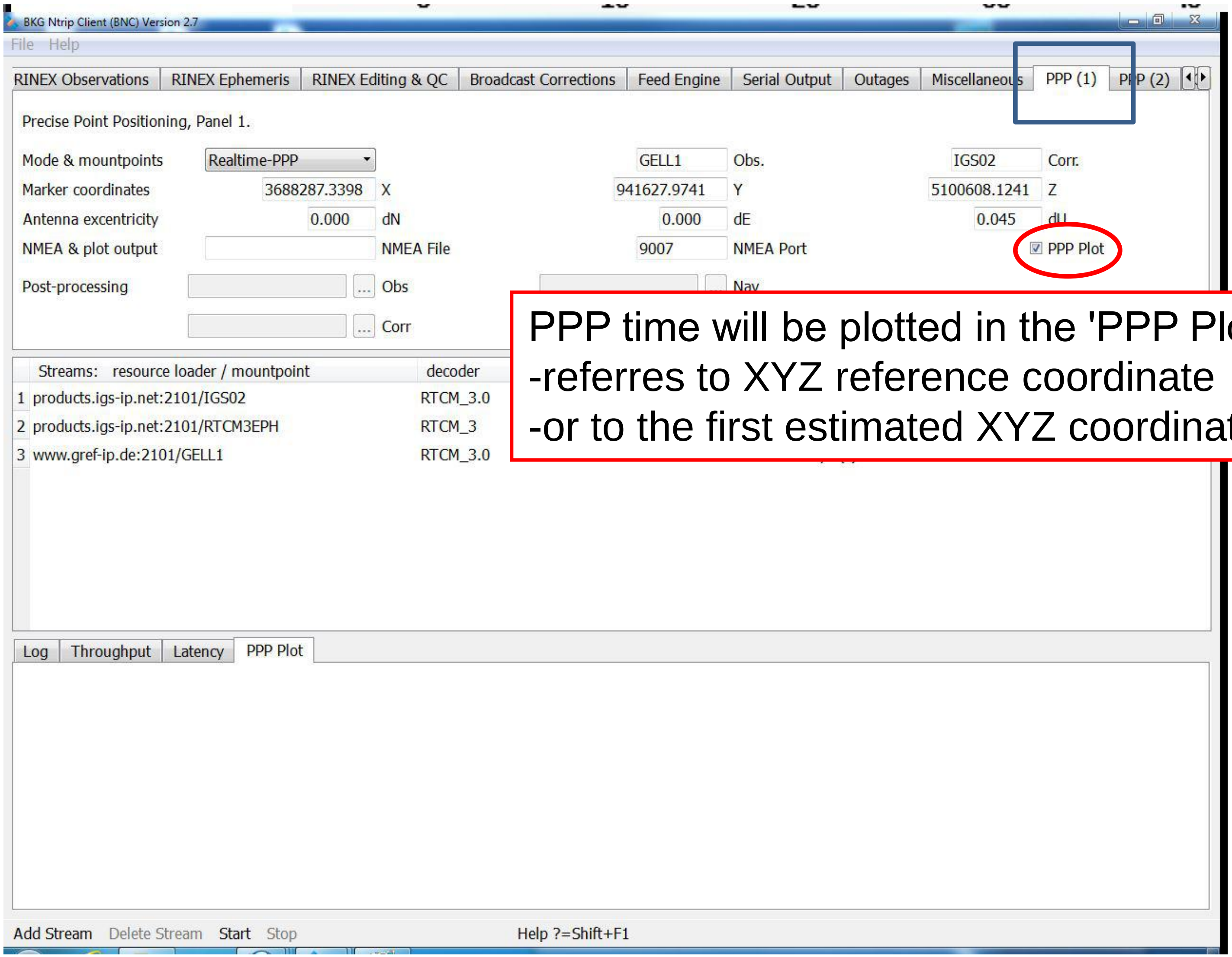


Specify IP port number of a local port where results become available as NMEA messages

Note: Tomoji Takasu has written a Windows program for visualizing NMEA strings

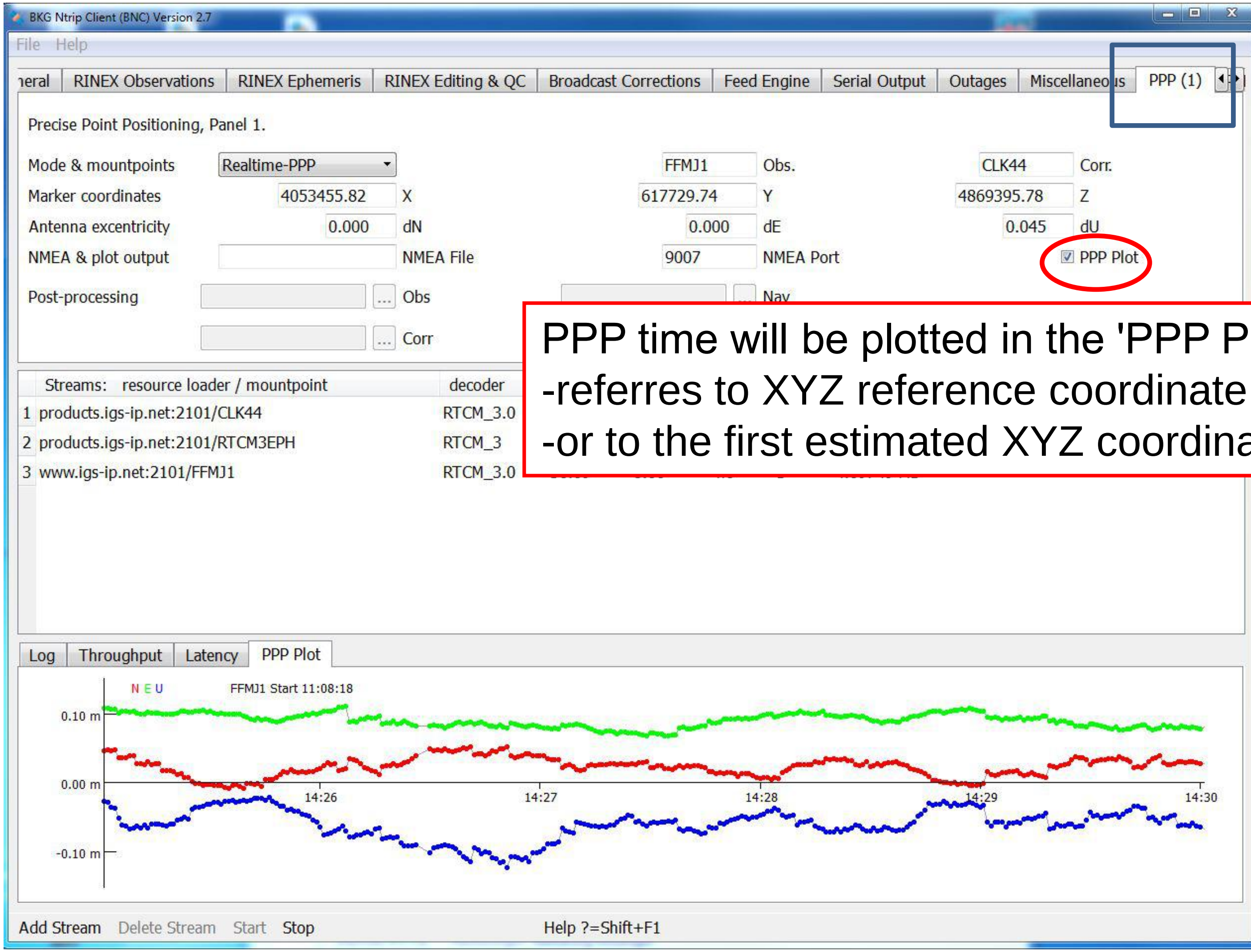
http://gpspp.sakura.ne.jp/rtklib/rtklib.htm

Settings: PPP Plot



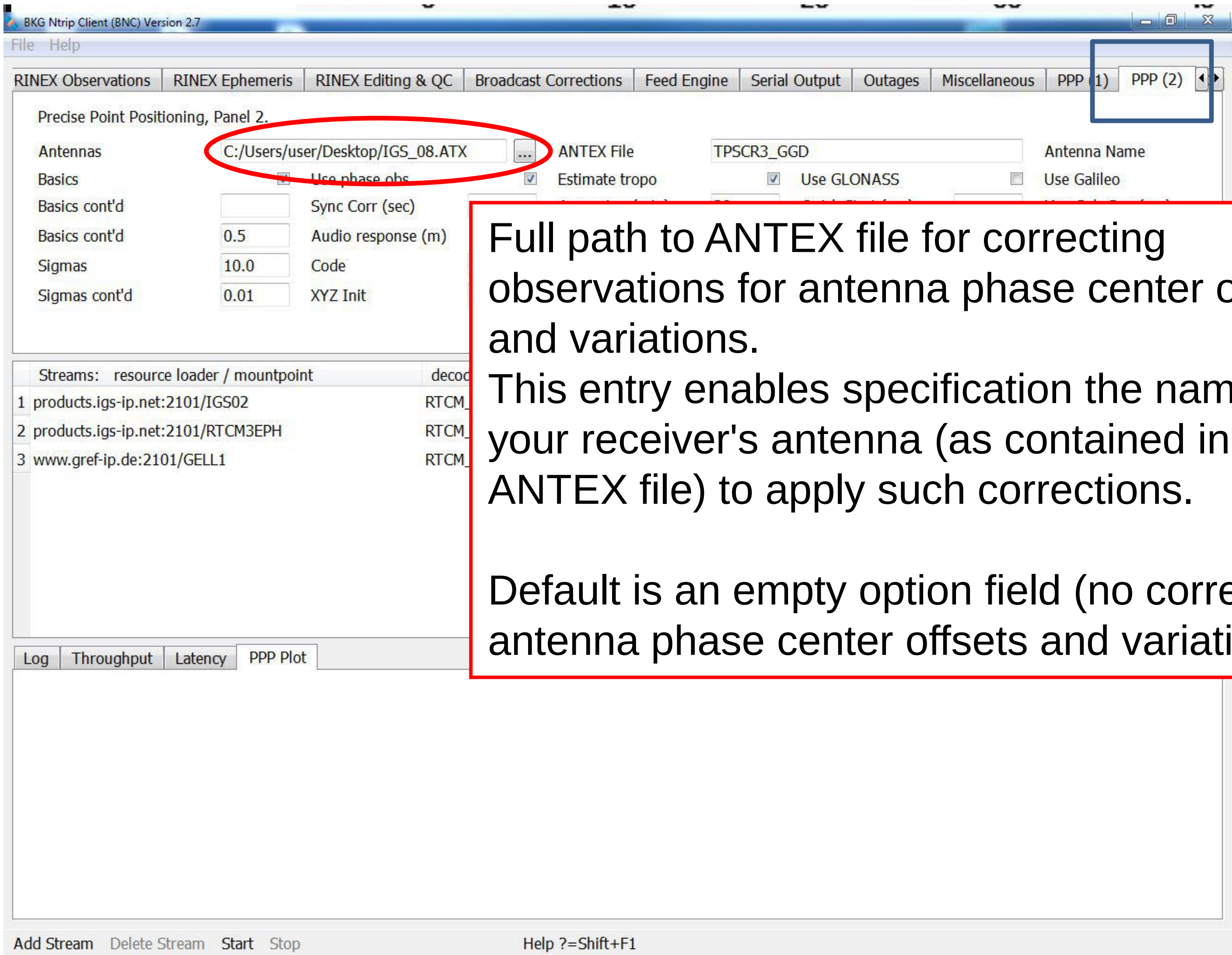
PPP time will be plotted in the 'PPP Plot'
-referres to XYZ reference coordinate
-or to the first estimated XYZ coordinate.

Settings: PPP Plot



PPP time will be plotted in the 'PPP Plot'
-referres to XYZ reference coordinate
-or to the first estimated XYZ coordinate.

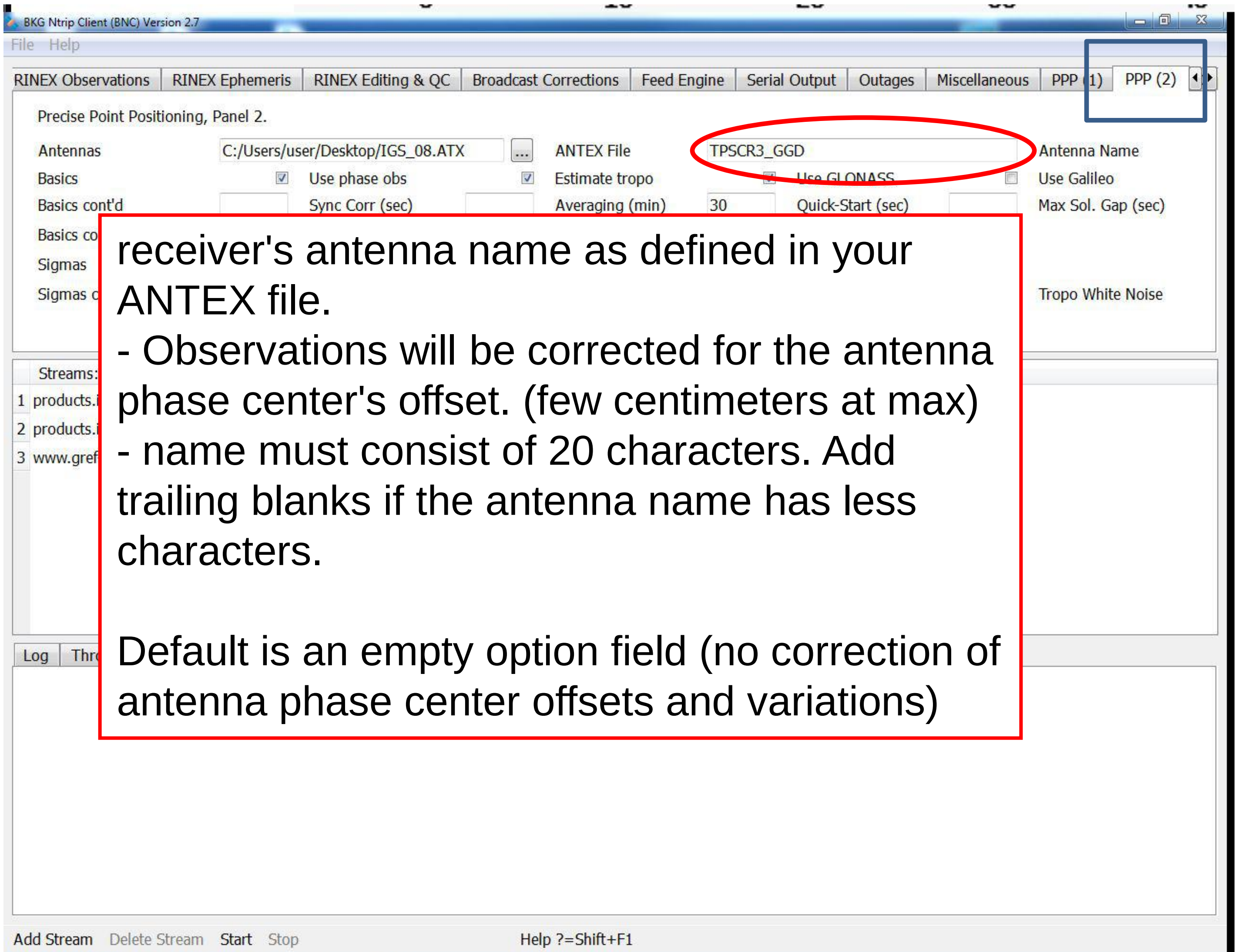
Settings: Antex File



Full path to ANTEX file for correcting observations for antenna phase center offsets and variations.
This entry enables specification the name of your receiver's antenna (as contained in the ANTEX file) to apply such corrections.

Default is an empty option field (no correction of antenna phase center offsets and variations)

Settings: Antenna Name

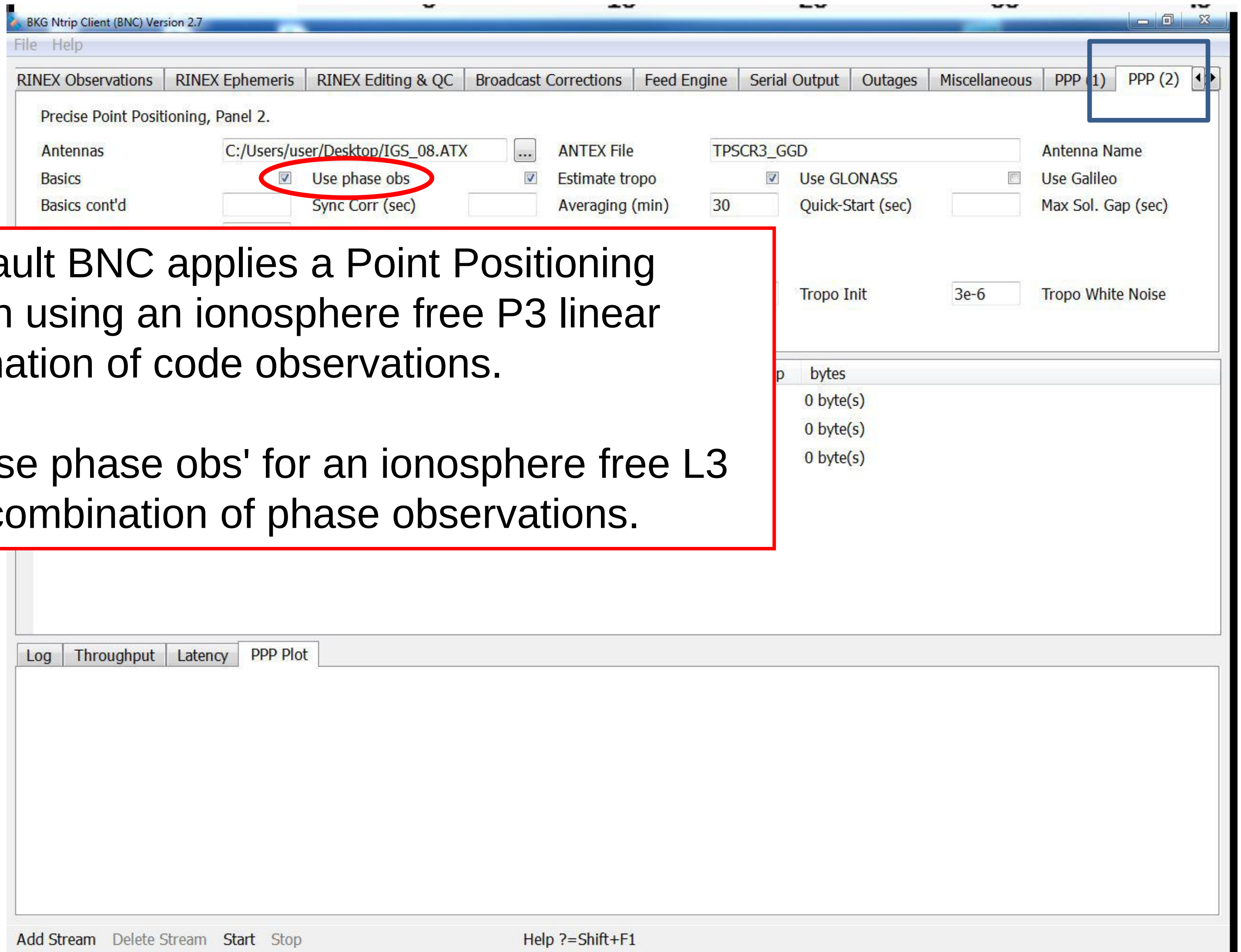


receiver's antenna name as defined in your ANTEX file.

- Observations will be corrected for the antenna phase center's offset. (few centimeters at max)
- name must consist of 20 characters. Add trailing blanks if the antenna name has less characters.

Default is an empty option field (no correction of antenna phase center offsets and variations)

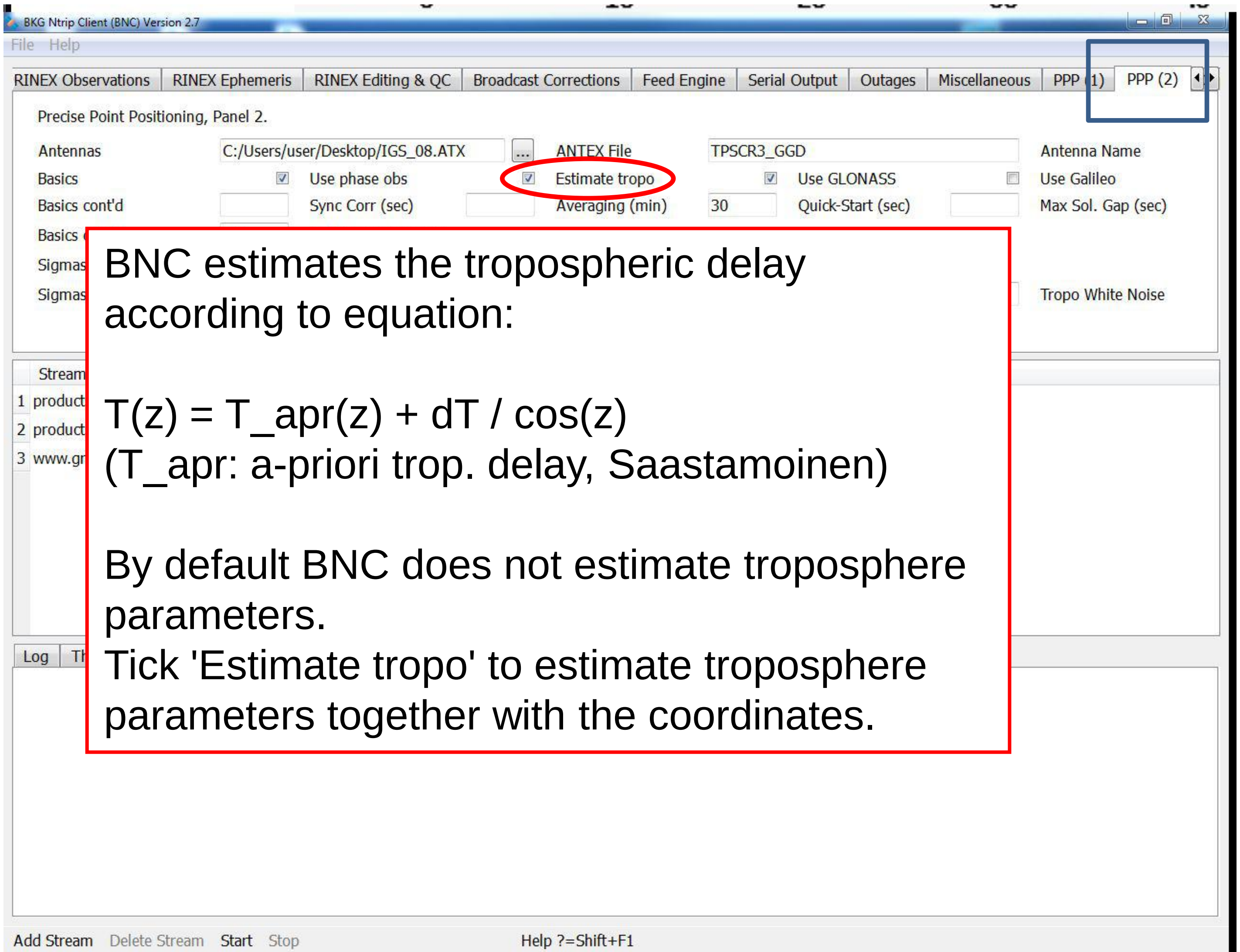
Settings: Mode of Ionospheric Combination



By default BNC applies a Point Positioning solution using an ionosphere free P3 linear combination of code observations.

Tick 'Use phase obs' for an ionosphere free L3 linear combination of phase observations.

Settings: Mode Tropospheric Delay

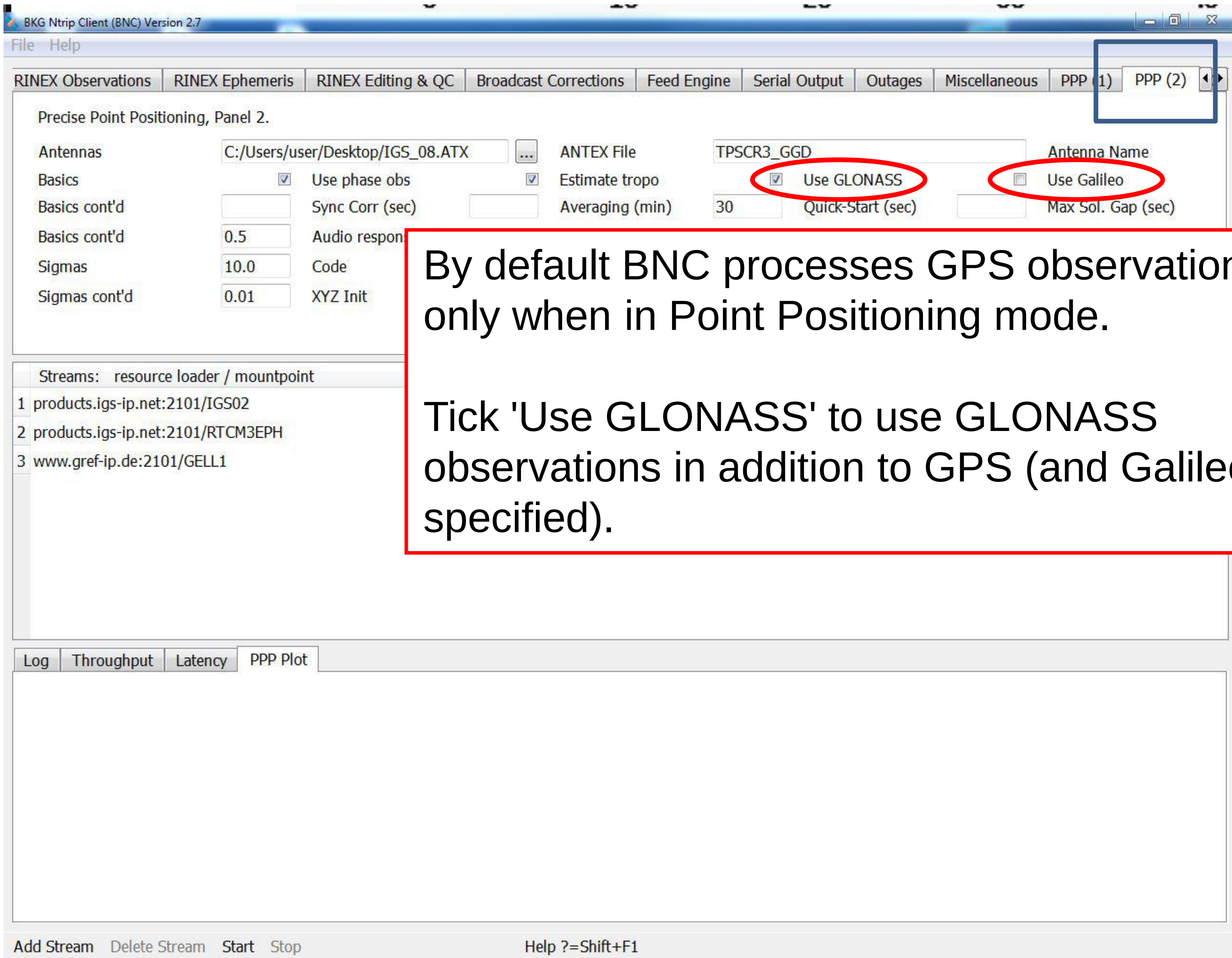


BNC estimates the tropospheric delay according to equation:

T(z) = T_apr(z) + dT / cos(z)
(T_apr: a-priori trop. delay, Saastamoinen)

By default BNC does not estimate troposphere parameters.
Tick 'Estimate tropo' to estimate troposphere parameters together with the coordinates.

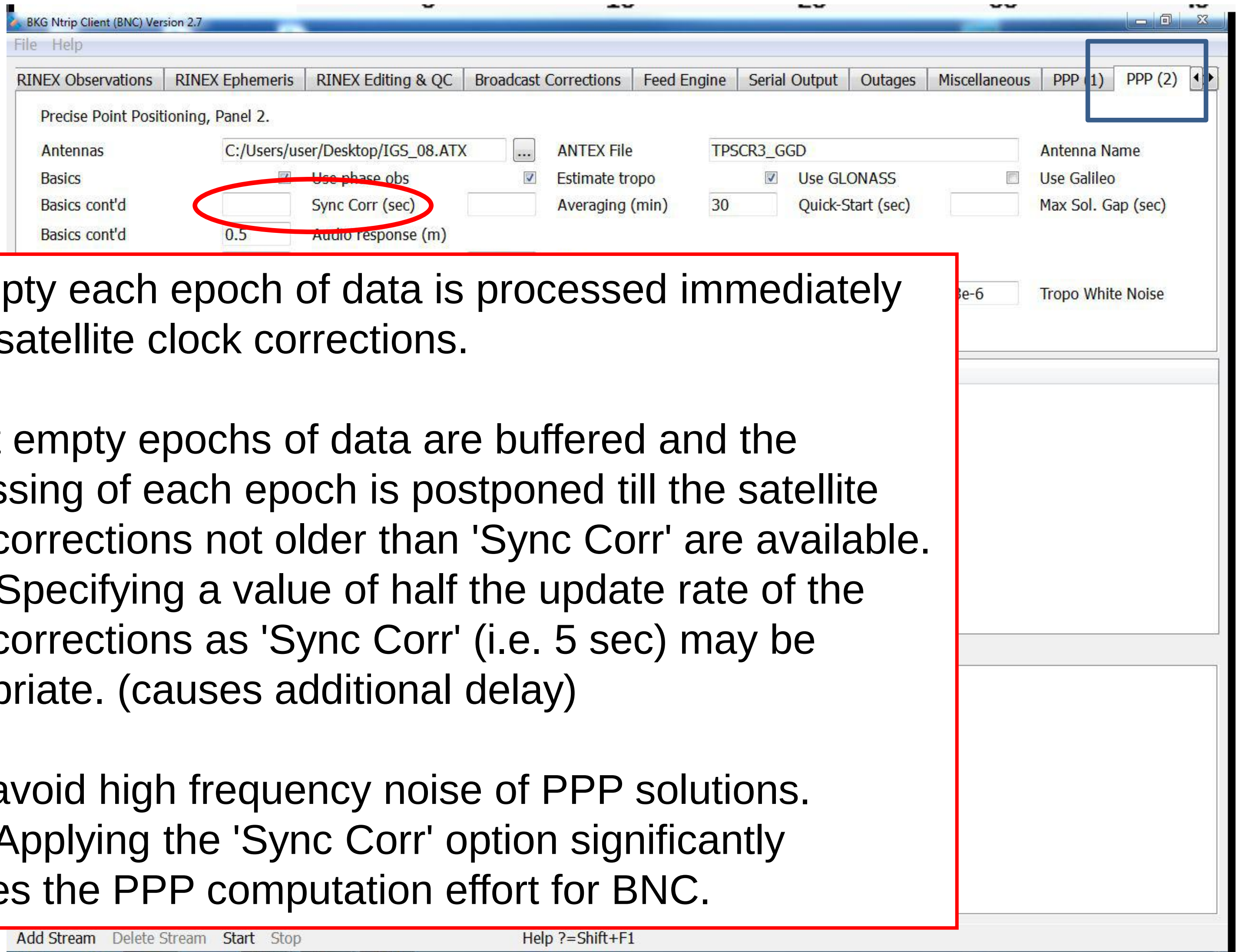
Settings: Satellite Systems



By default BNC processes GPS observations only when in Point Positioning mode.

Tick 'Use GLONASS' to use GLONASS observations in addition to GPS (and Galileo if specified).

Settings: Synchronization to Corrections

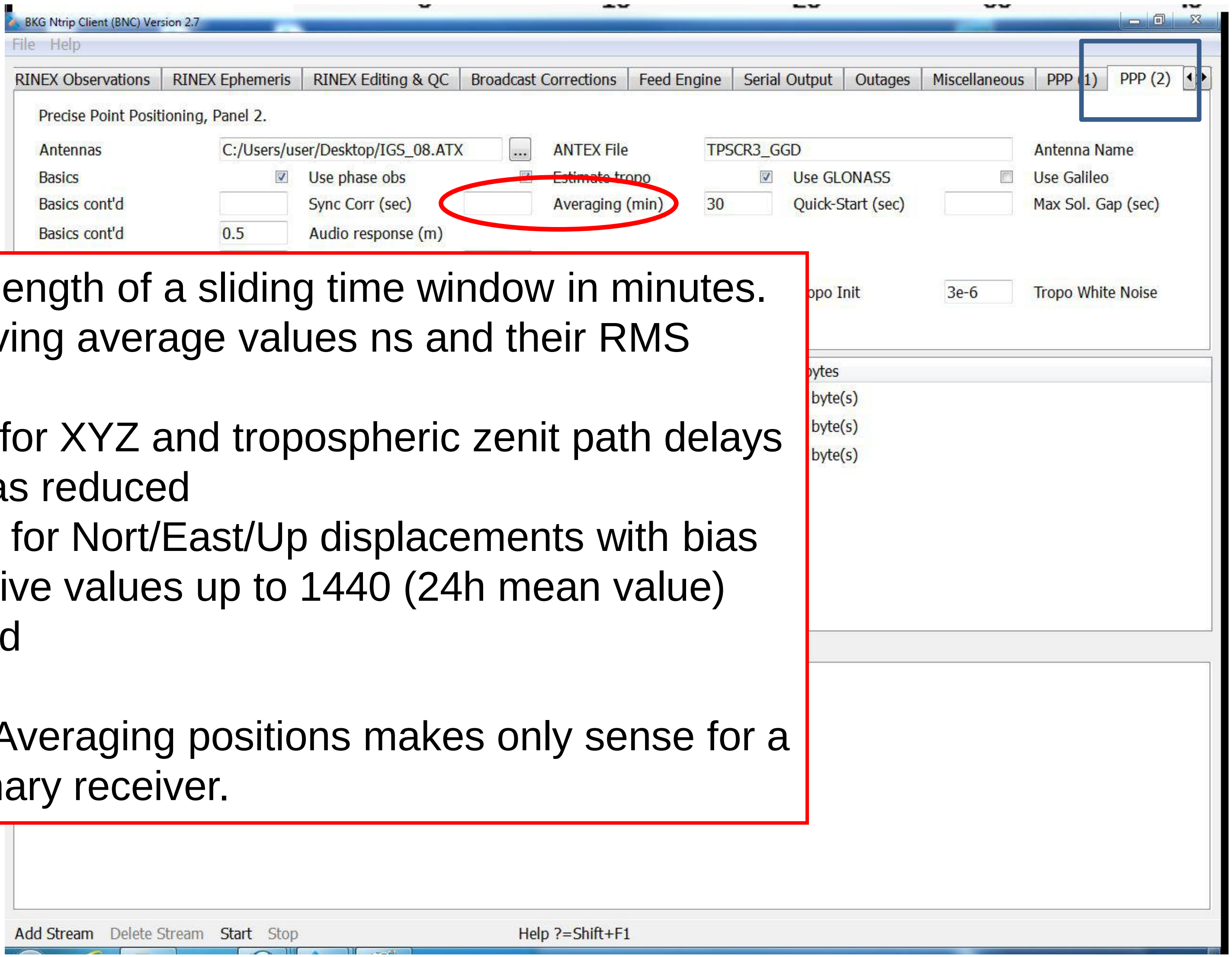


- If empty each epoch of data is processed immediately using satellite clock corrections.

- If not empty epochs of data are buffered and the processing of each epoch is postponed till the satellite clock corrections not older than 'Sync Corr' are available. Note: Specifying a value of half the update rate of the clock corrections as 'Sync Corr' (i.e. 5 sec) may be appropriate. (causes additional delay)

- can avoid high frequency noise of PPP solutions. Note: Applying the 'Sync Corr' option significantly reduces the PPP computation effort for BNC.

Settings: Averaging Values

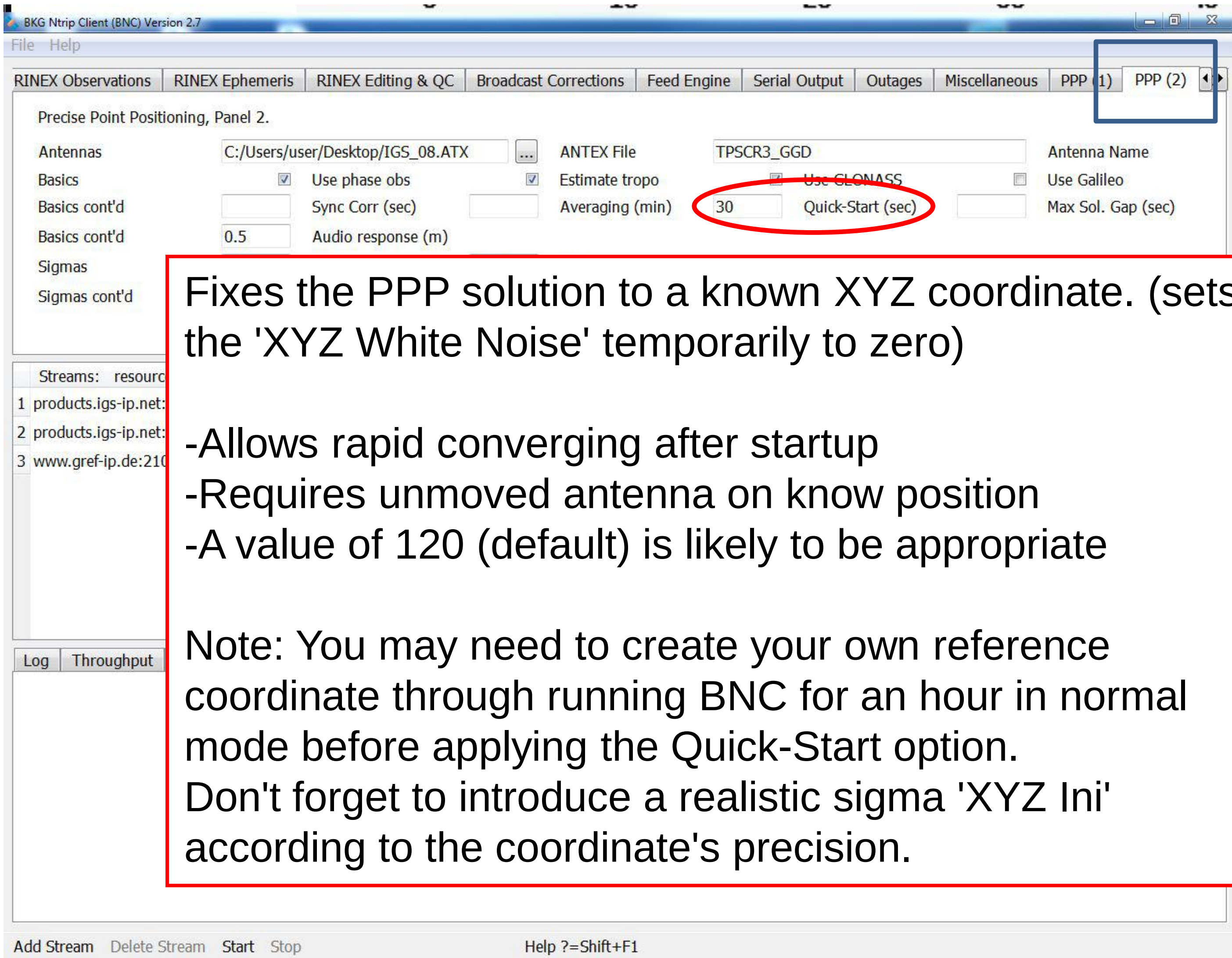


Enter length of a sliding time window in minutes.
-> moving average values ns and their RMS

-RMS for XYZ and tropospheric zenit path delays are bias reduced
- RMS for Nort/East/Up displacements with bias
- Positive values up to 1440 (24h mean value) allowed

Note: Averaging positions makes only sense for a stationary receiver.

Settings: Quick-Start

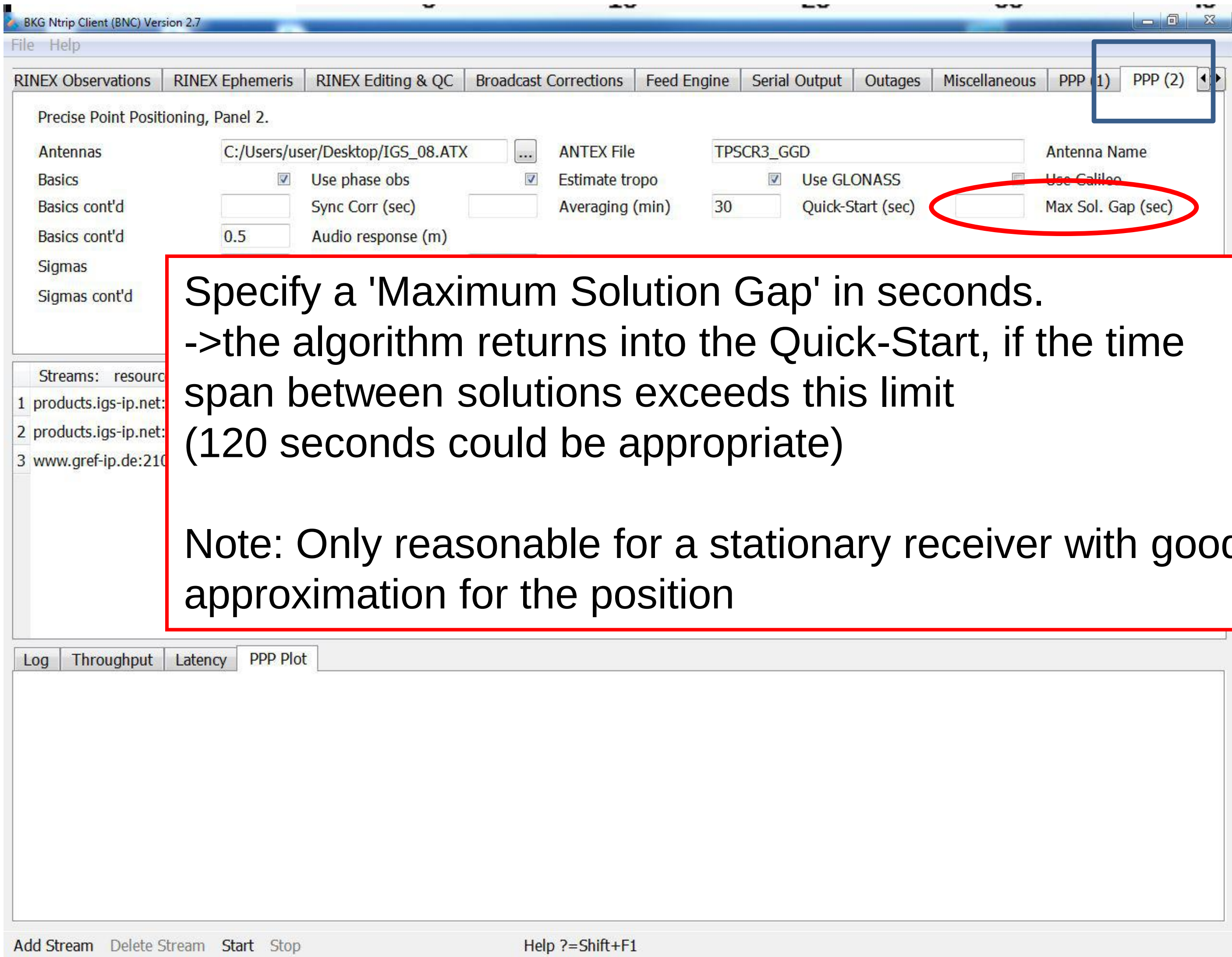


Fixes the PPP solution to a known XYZ coordinate. (sets the 'XYZ White Noise' temporarily to zero)

-Allows rapid converging after startup
-Requires unmoved antenna on know position
-A value of 120 (default) is likely to be appropriate

Note: You may need to create your own reference coordinate through running BNC for an hour in normal mode before applying the Quick-Start option.
Don't forget to introduce a realistic sigma 'XYZ Ini' according to the coordinate's precision.

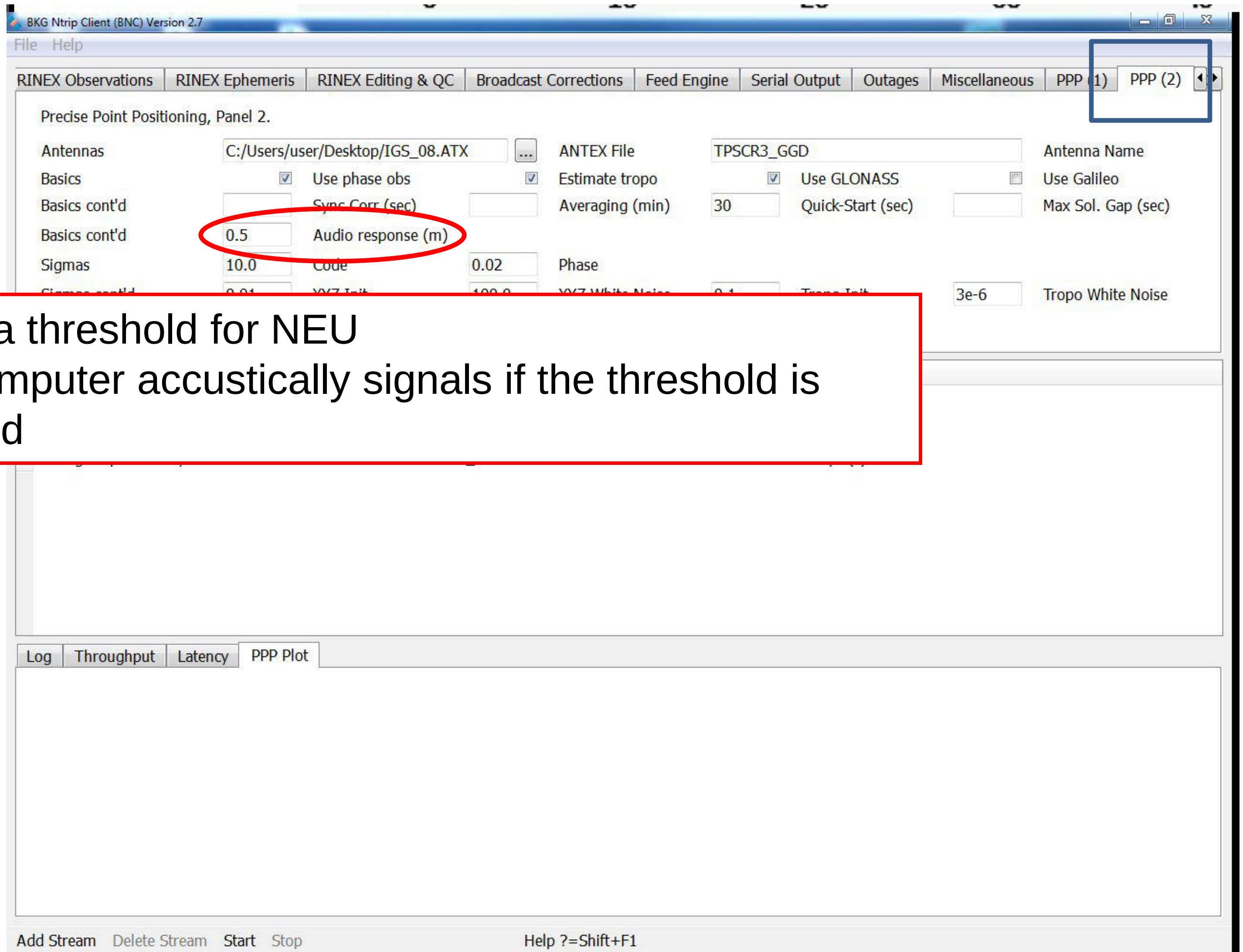
Settings: Max. Solution Gap



Specify a 'Maximum Solution Gap' in seconds.
->the algorithm returns into the Quick-Start, if the time span between solutions exceeds this limit
(120 seconds could be appropriate)

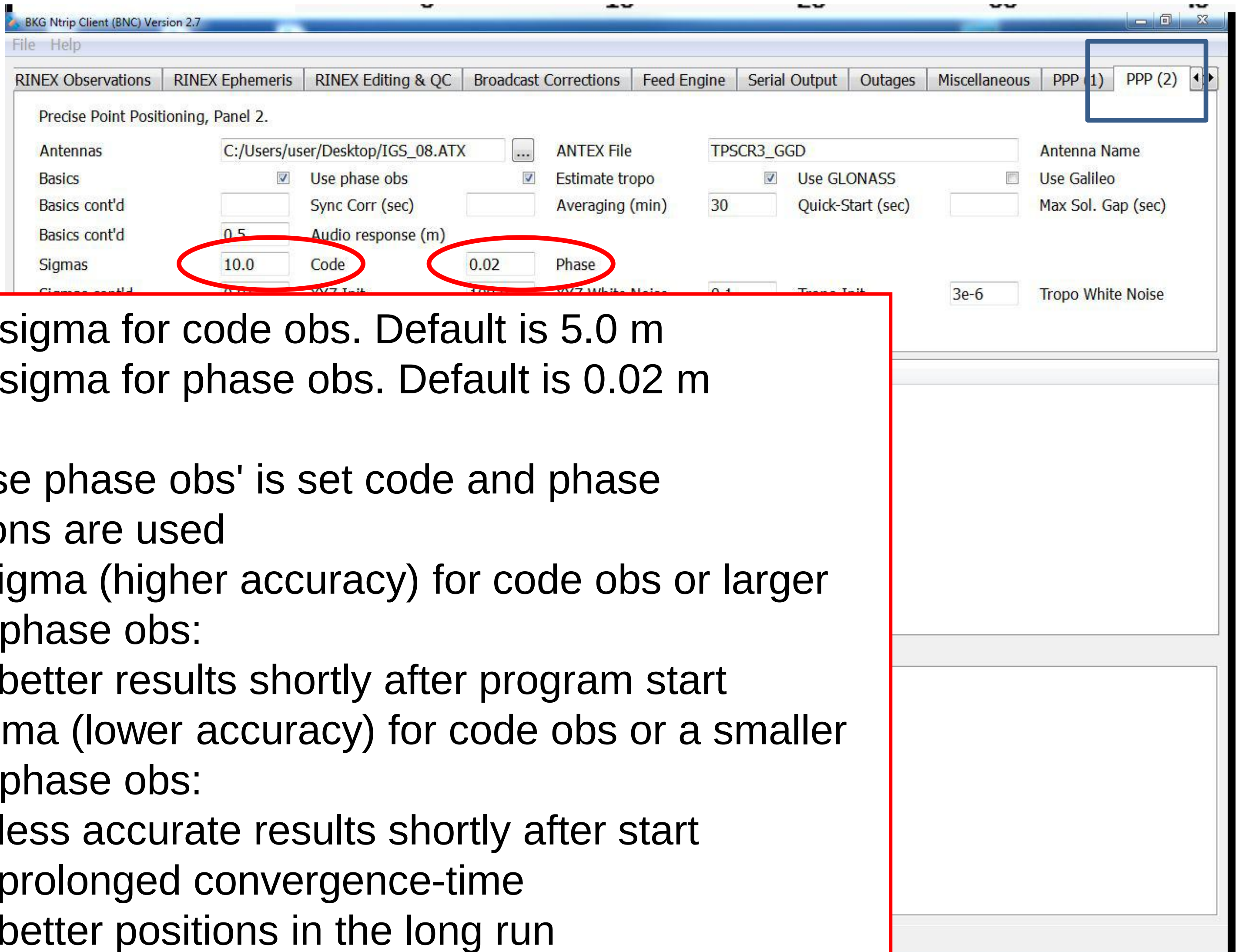
Note: Only reasonable for a stationary receiver with good approximation for the position

Settings: Audio Response



Specify a threshold for NEU
->the computer accustically signals if the threshold is exceeded

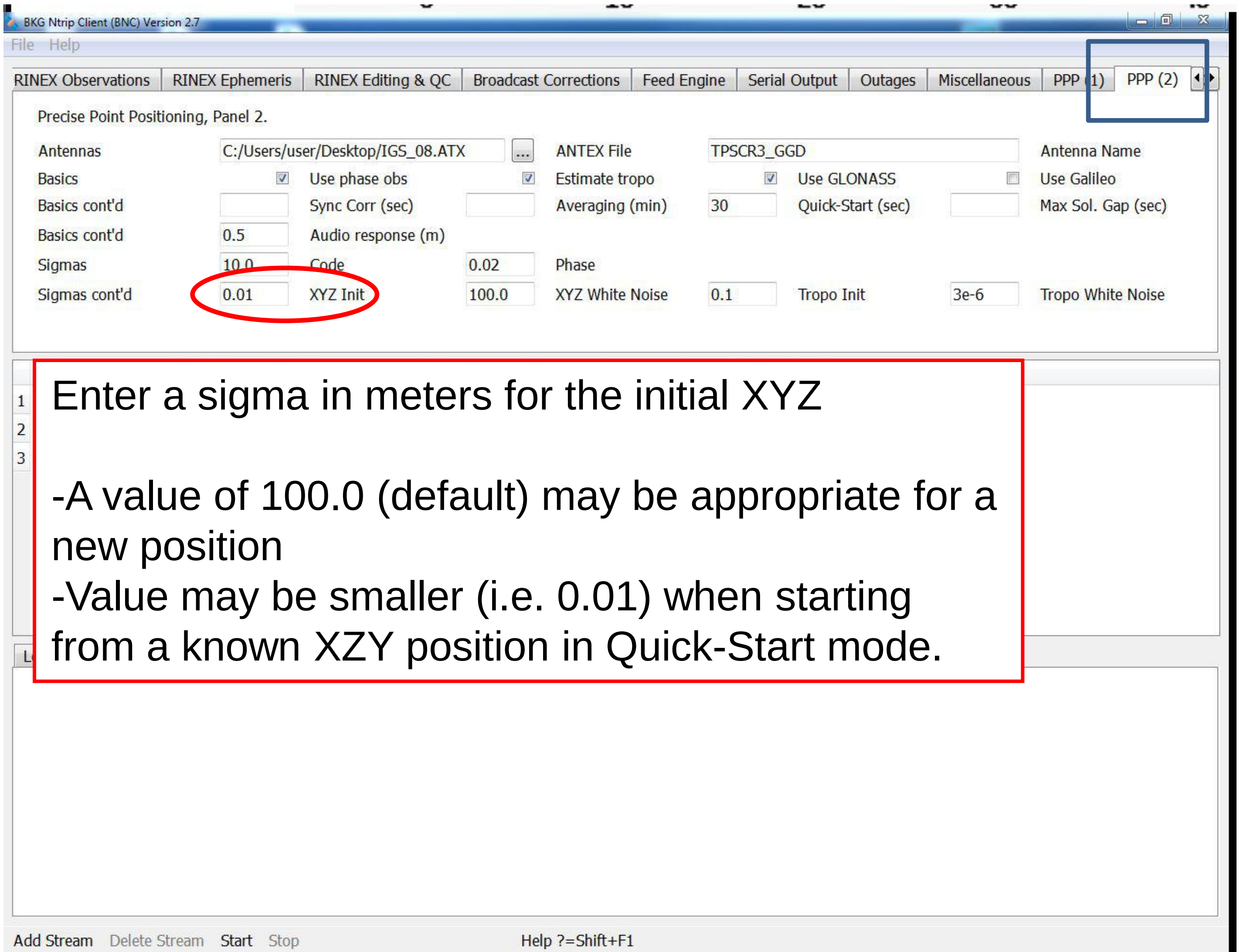
Settings: Code / Phase Sigmas



Specify a sigma for code obs. Default is 5.0 m
Specify a sigma for phase obs. Default is 0.02 m

-When 'Use phase obs' is set code and phase observations are used
-smaller sigma (higher accuracy) for code obs or larger sigma for phase obs:
 -better results shortly after program start
-larger sigma (lower accuracy) for code obs or a smaller sigma for phase obs:
 -less accurate results shortly after start
 -prolonged convergence-time
 -better positions in the long run

Settings: XYZ Sigma

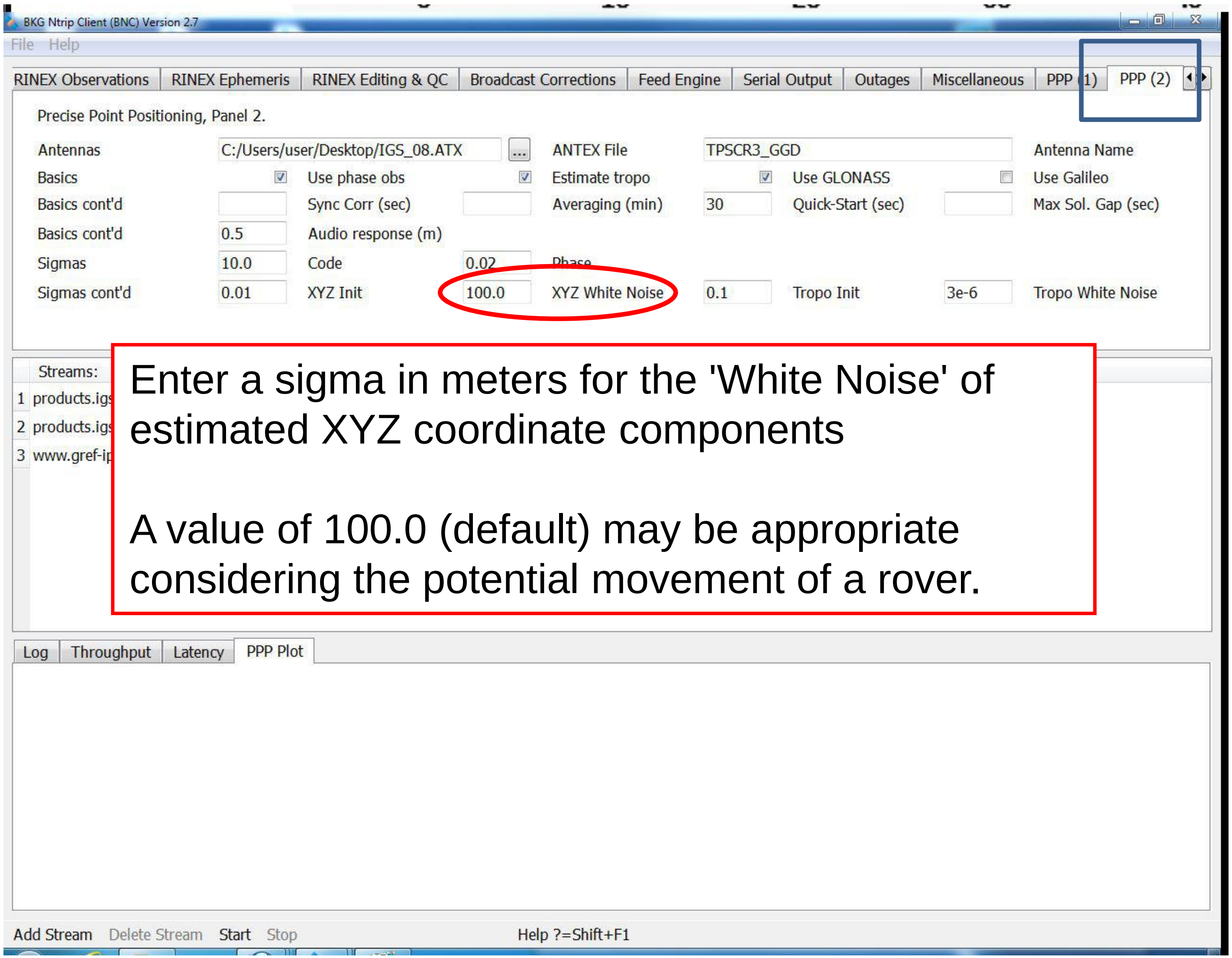


Enter a sigma in meters for the initial XYZ

-A value of 100.0 (default) may be appropriate for a new position

-Value may be smaller (i.e. 0.01) when starting from a known XZY position in Quick-Start mode.

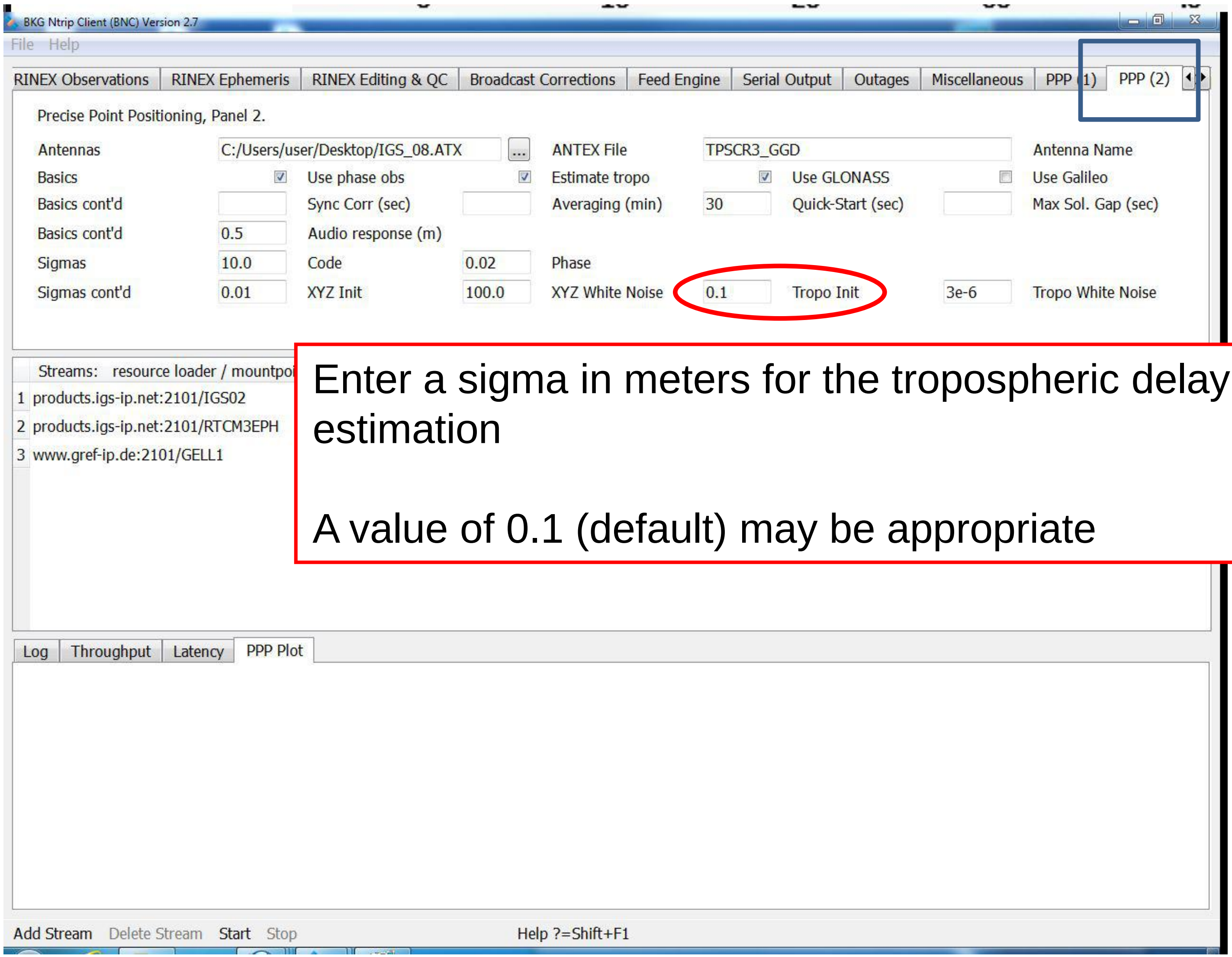
Settings: XYZ White Noise Sigma



Enter a sigma in meters for the 'White Noise' of estimated XYZ coordinate components

A value of 100.0 (default) may be appropriate considering the potential movement of a rover.

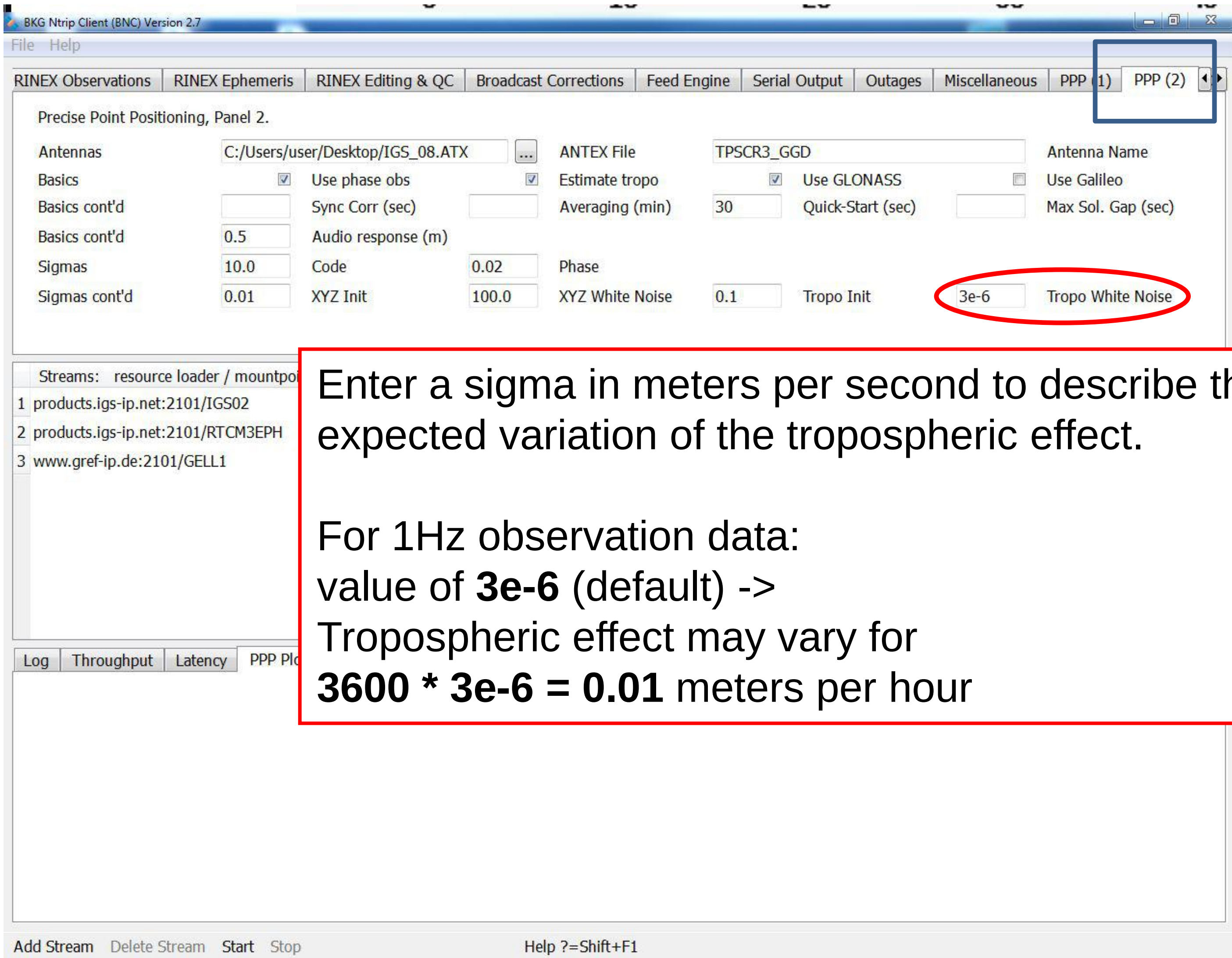
Settings: Tropo Sigma



Enter a sigma in meters for the tropospheric delay estimation

A value of 0.1 (default) may be appropriate

Settings: Tropo White Noise Sigma



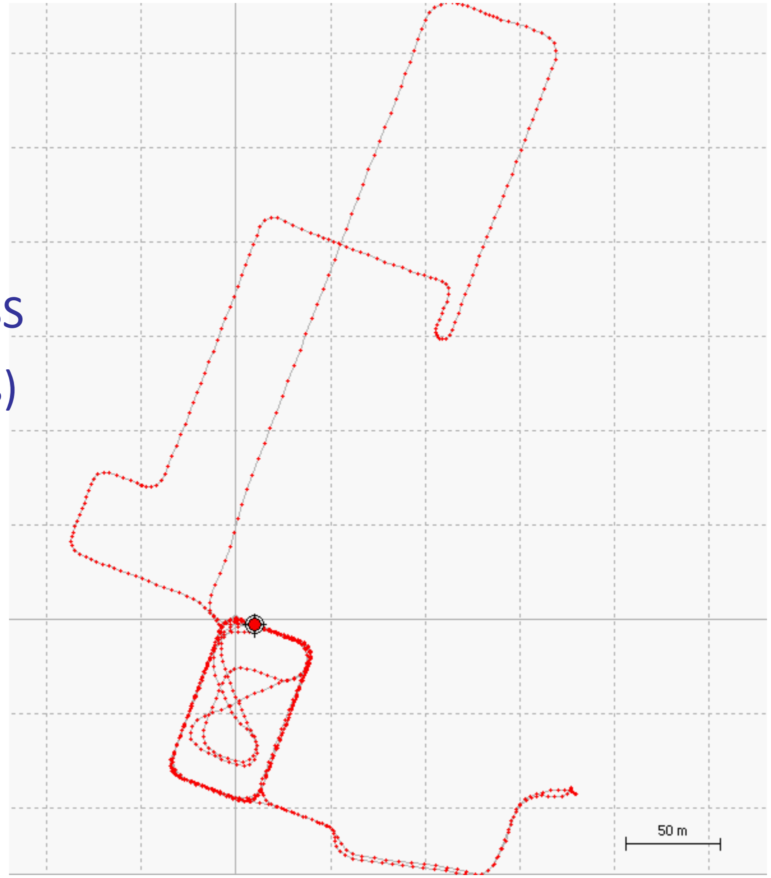
Enter a sigma in meters per second to describe the expected variation of the tropospheric effect.

For 1Hz observation data:
value of **3e-6** (default) ->
Tropospheric effect may vary for
3600 * 3e-6 = 0.01 meters per hour

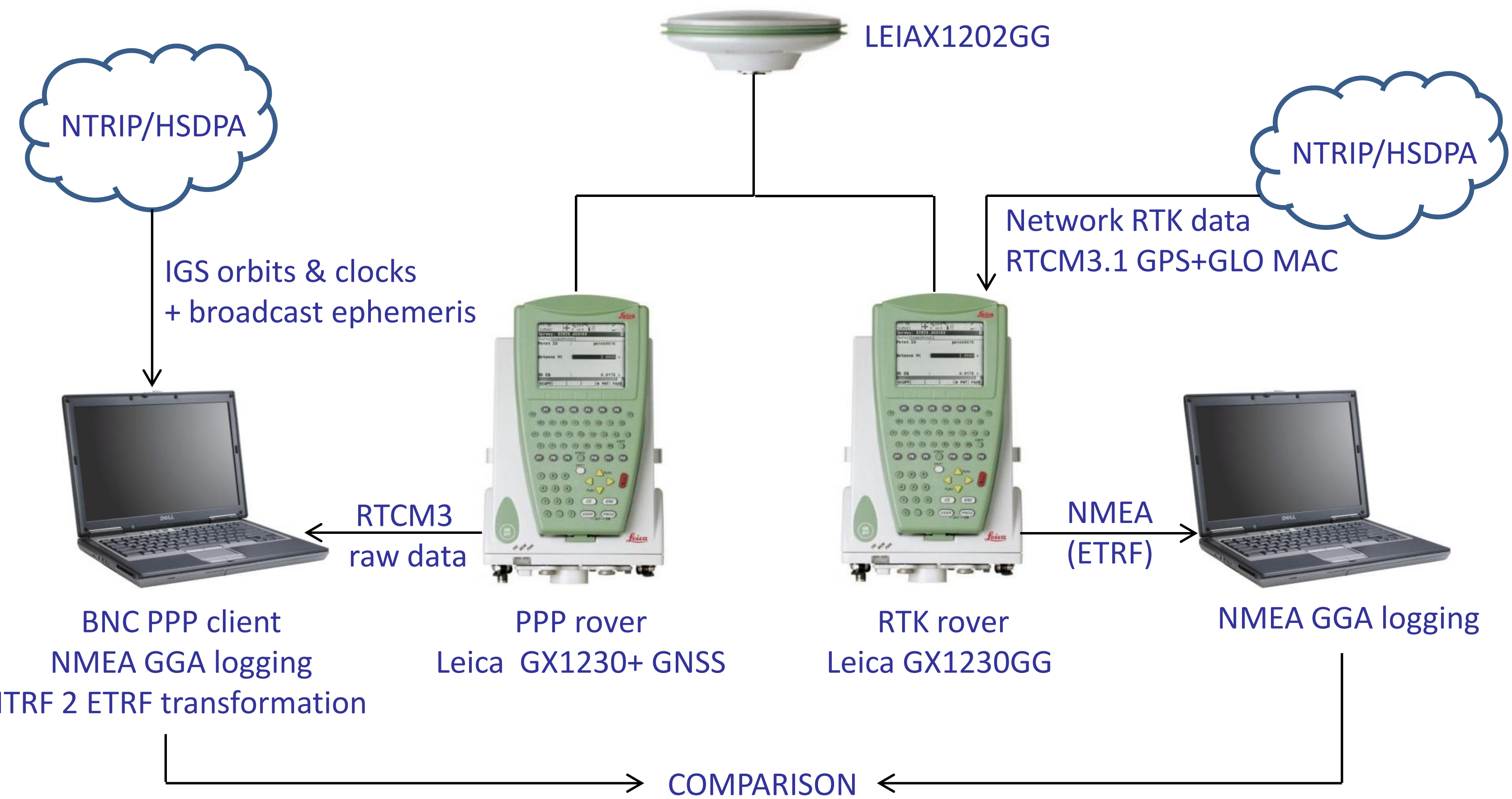
Real-time GNSS Conclusions for SIRGAS

Kinematic PPP test

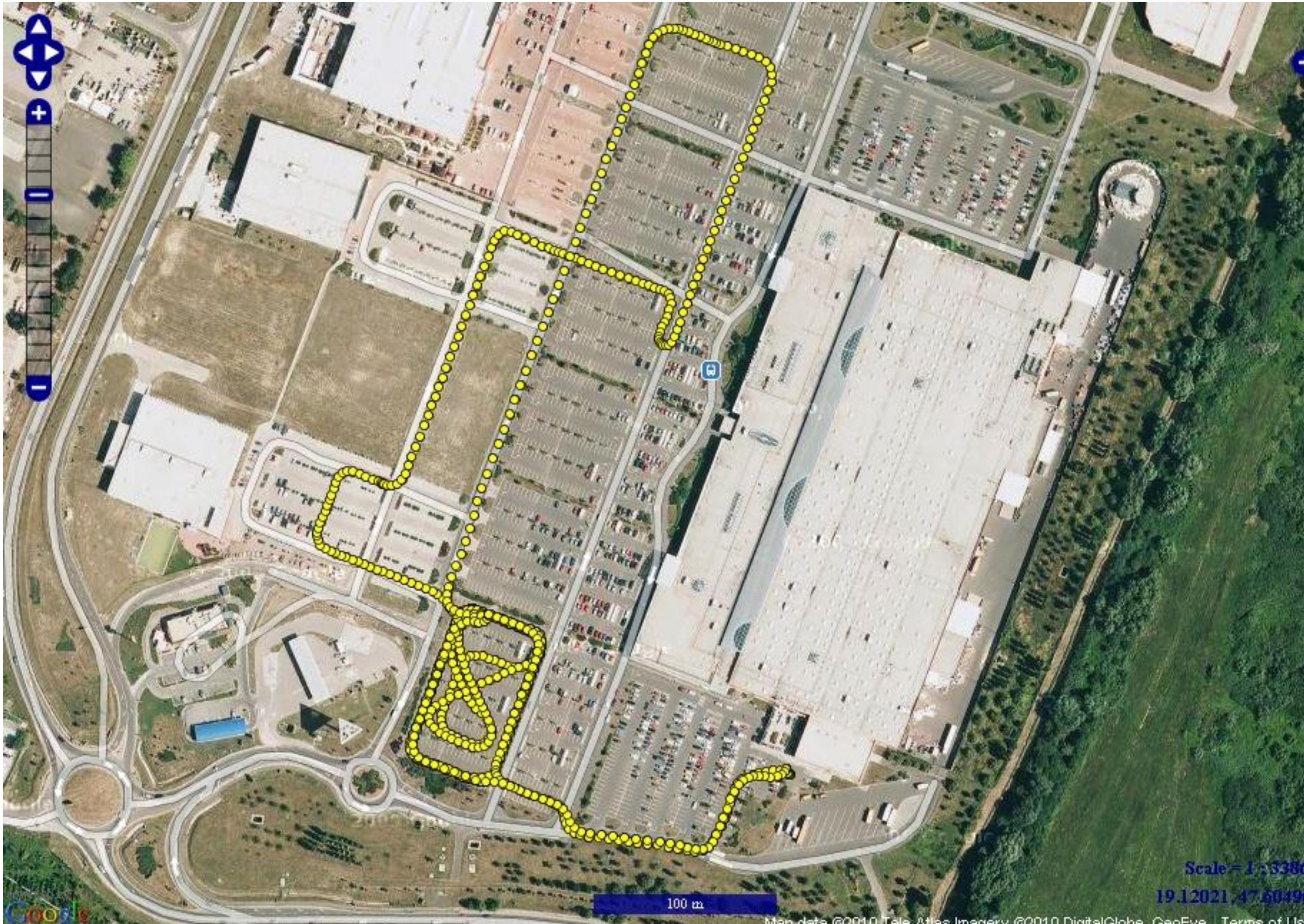
- **Date:** 28 September 2010
- **PPP client sw:** BKG Ntrip Client (BNC)
- **Location:** Budapest, Hungary
- **Reference frame:** ITRF2005 → ETRF2000
- **Observations:** 1Hz, dual frequency, GPS+GLONASS
- **Orbit/clock corrections sw:** RTNet (GPS Solutions)
- **Orbit/clock corrections:** CLK11 (BKG & TUP)
- **Broadcast ephemeris:** RTCM3EPH (BKG & TUP)
- **PPP mode:** Fully kinematic
- **Ratio of sigma-code to sigma-phase:** 250
- **RTK “truth”:** RTCM3.1 MAC GPS+GLO via Ntrip
- **Car speed:** 15-30 km/h



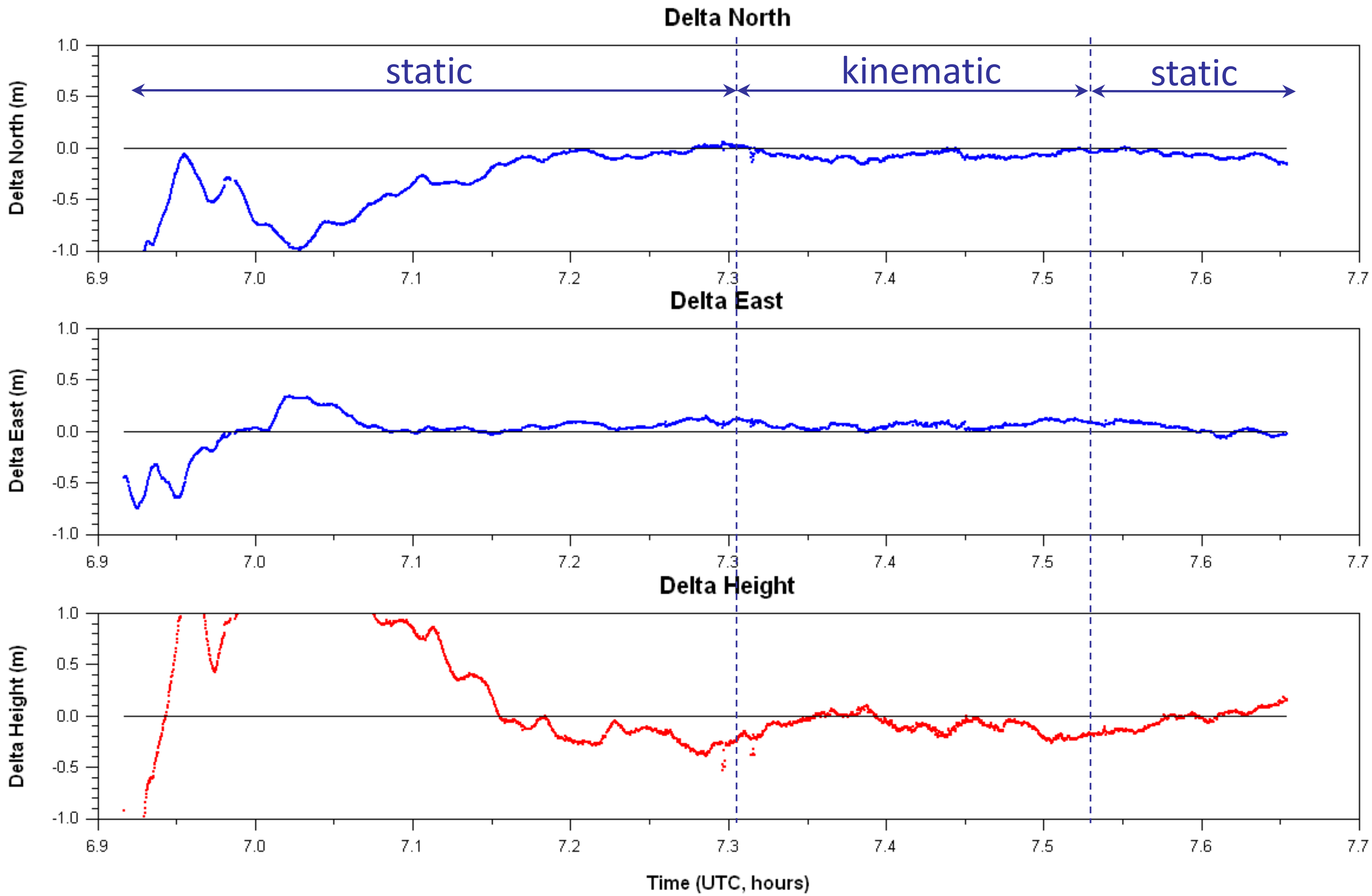
Kinematic PPP test configuration



Kinematic PPP test equipment


Scale = 1 : 3386
19.12021 , 47.60496
100 m
Map data ©2010 Tele Atlas Imagery ©2010 DigitalGlobe, GeoEye - Terms of Use
Google

Kinematic PPP test equipment



Kinematic PPP test (kinematic period 07:18-07:32)

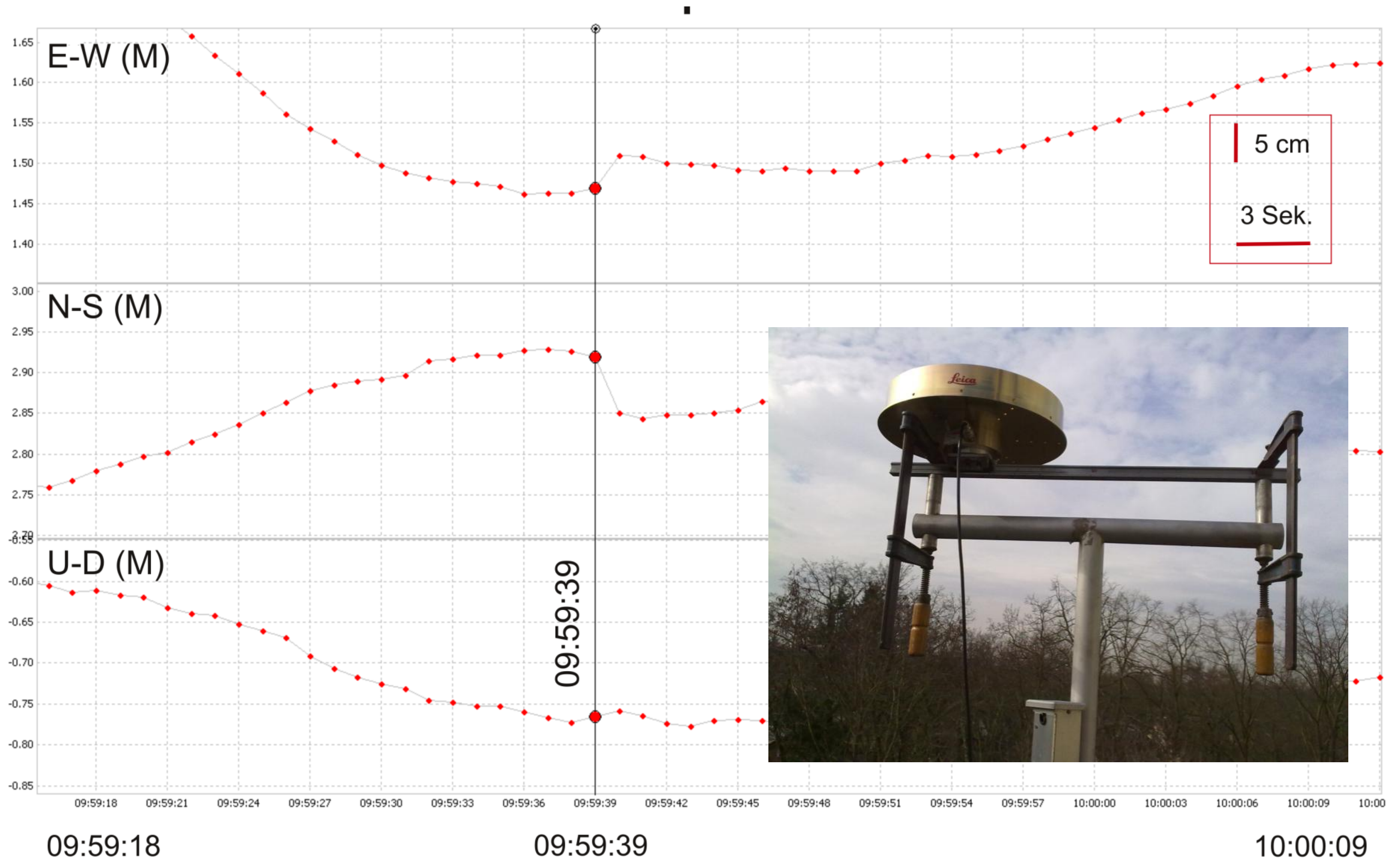
	Mean	Std_Dev	RMS
2D	0.11	0.03	0.11
3D	0.16	0.08	0.18

Real-time Applications in SIRGAS Context

- Natural hazards, early warning
- Stream to RINEX conversion for NRT solutions
- Linking national networks
- Linking local RTK networks
- Support PPP services
- IGS Multi-GNSS (M-GEX) Experiment

PPP for Monitoring Natural Hazard

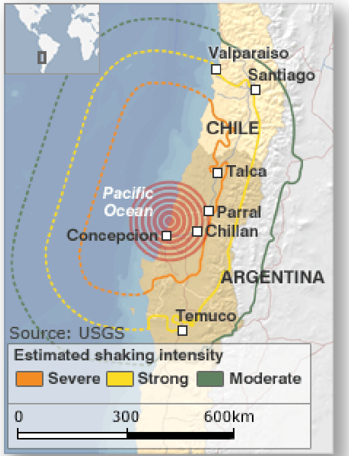
Horizontal Displacement: 10 cm

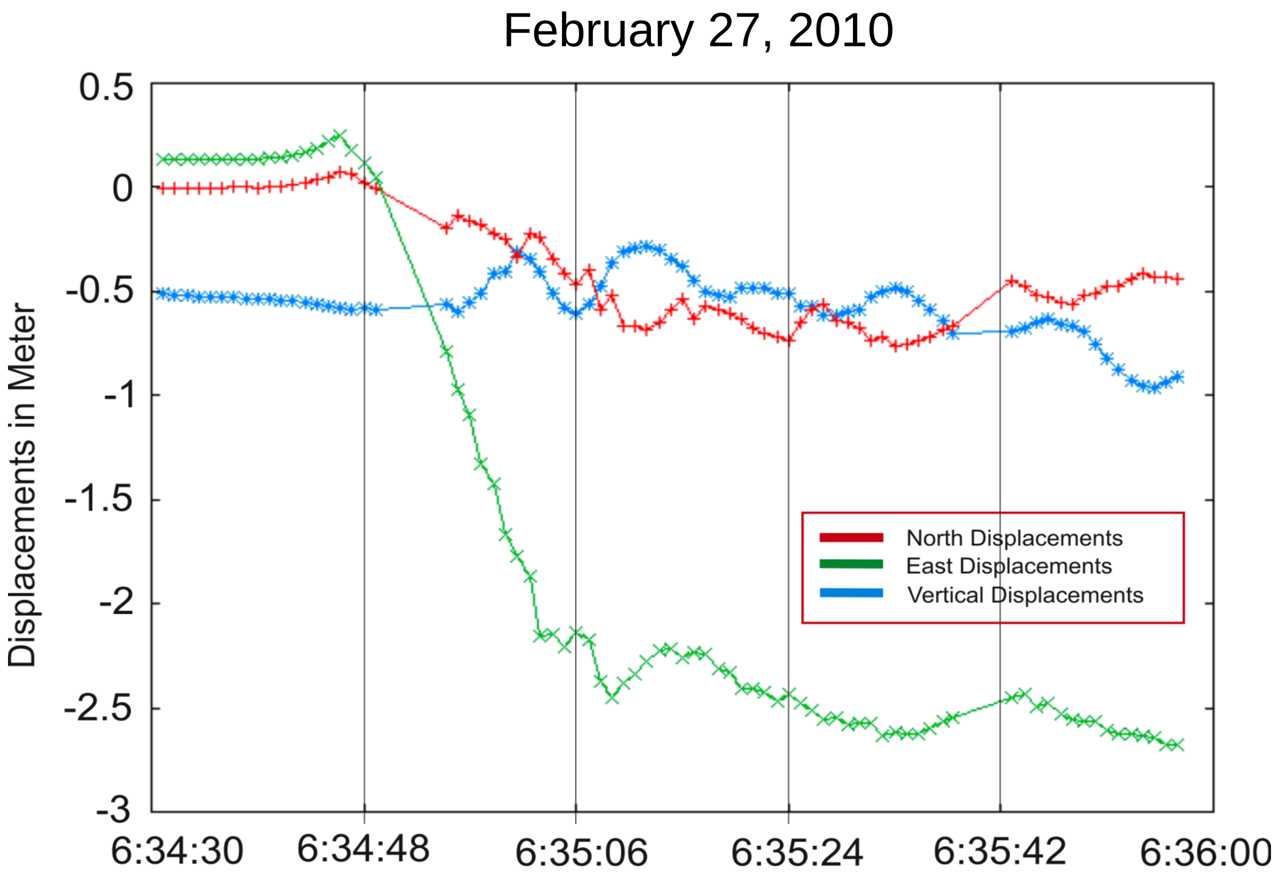


Real-time PPP during earthquake using RTNet by GPSS

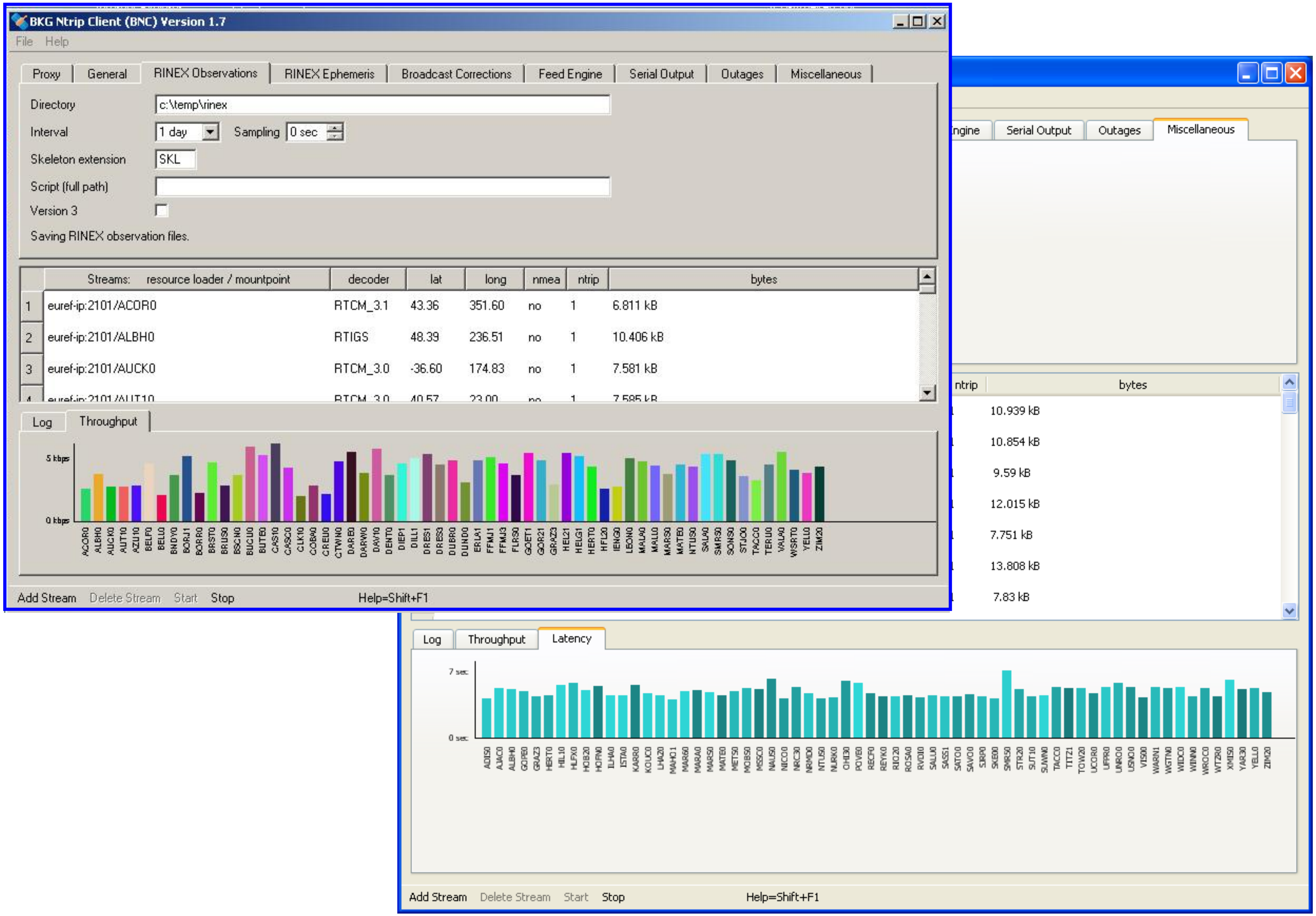
GNSS Receiver CONZ

Earthquake Epicenter

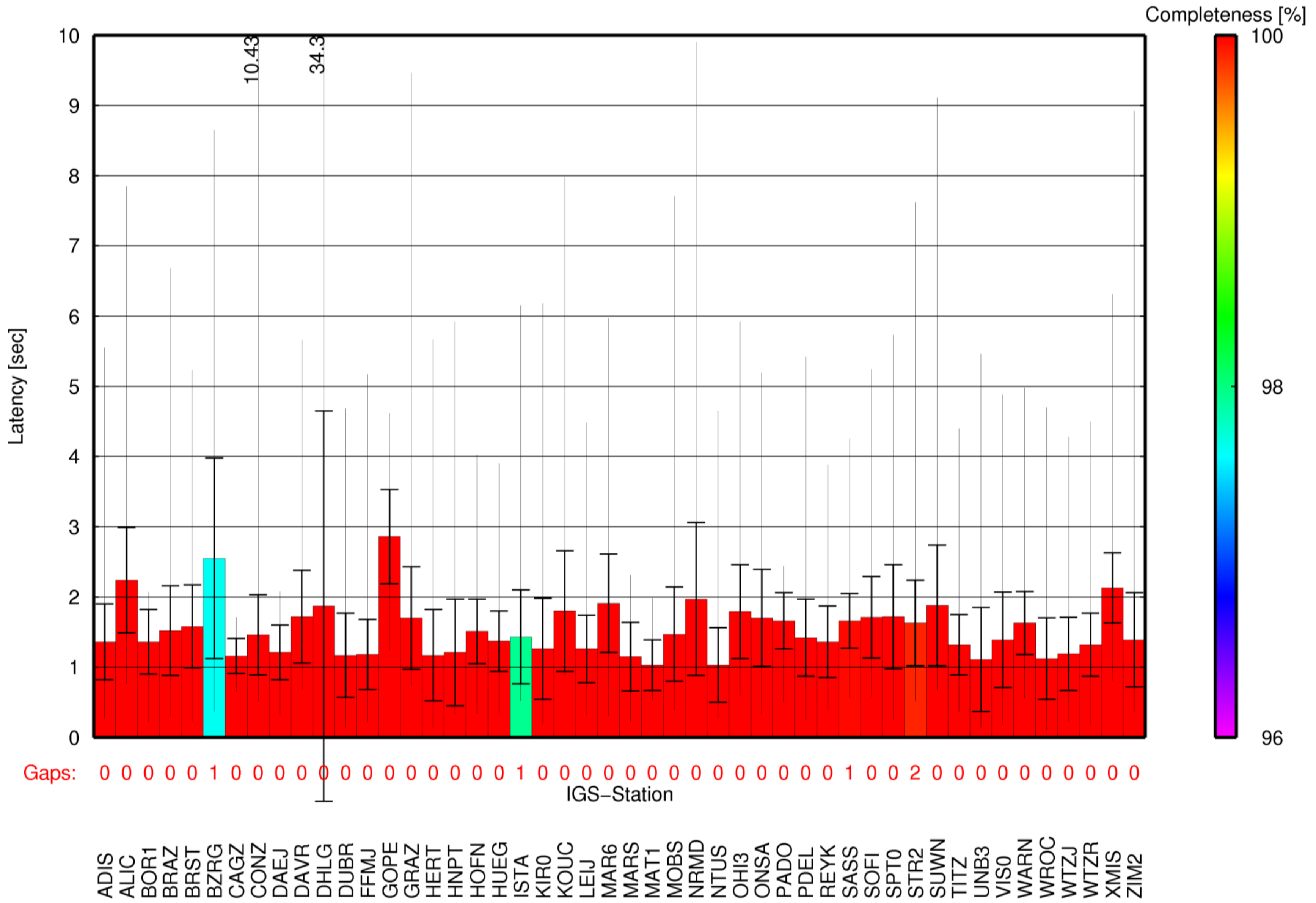




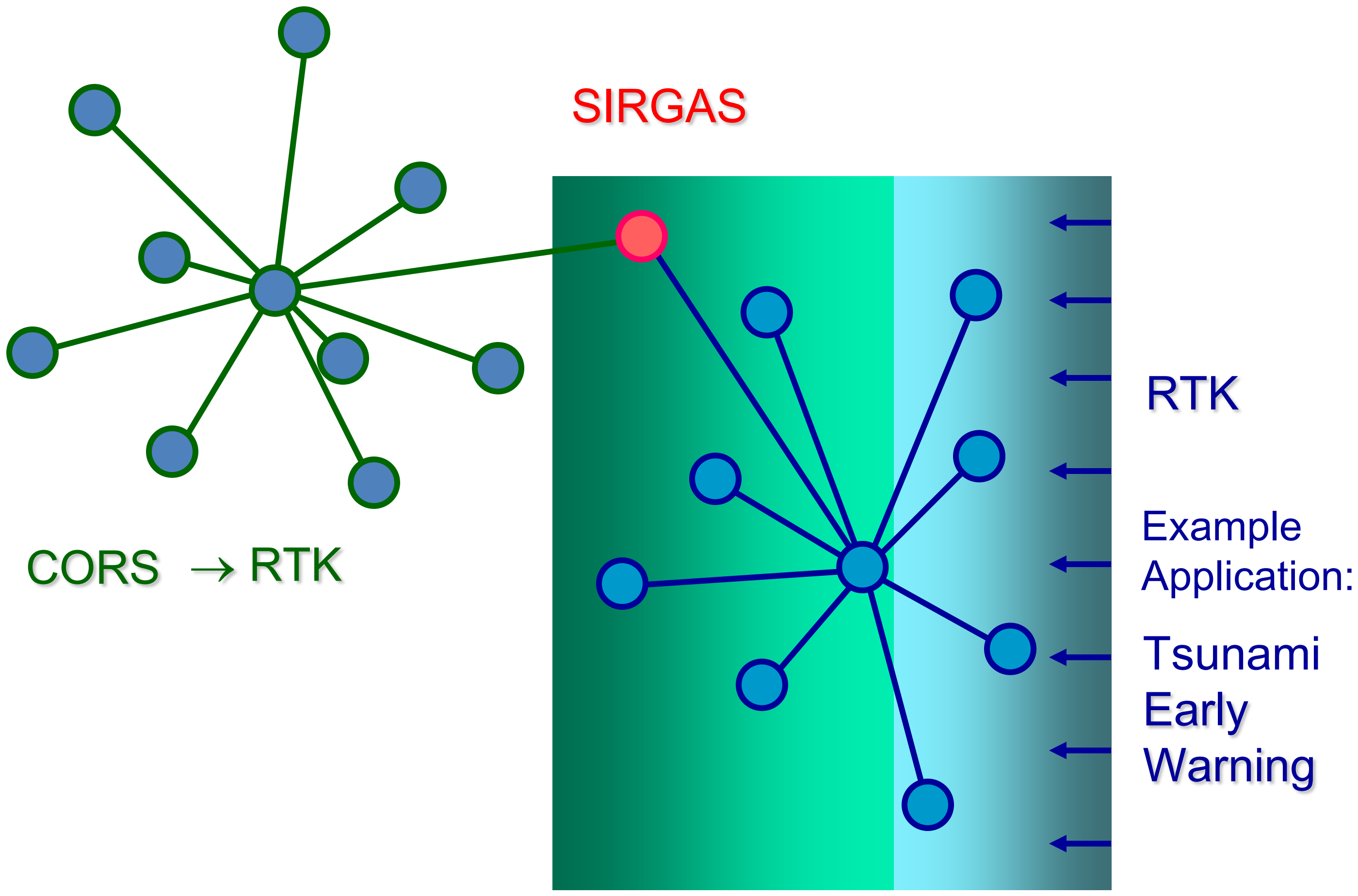
BNC, Feeding an Engine or a RINEX Archive



Latency and completeness of highrate RINEX from RTCMv3 stream conversion over an example period of one hour

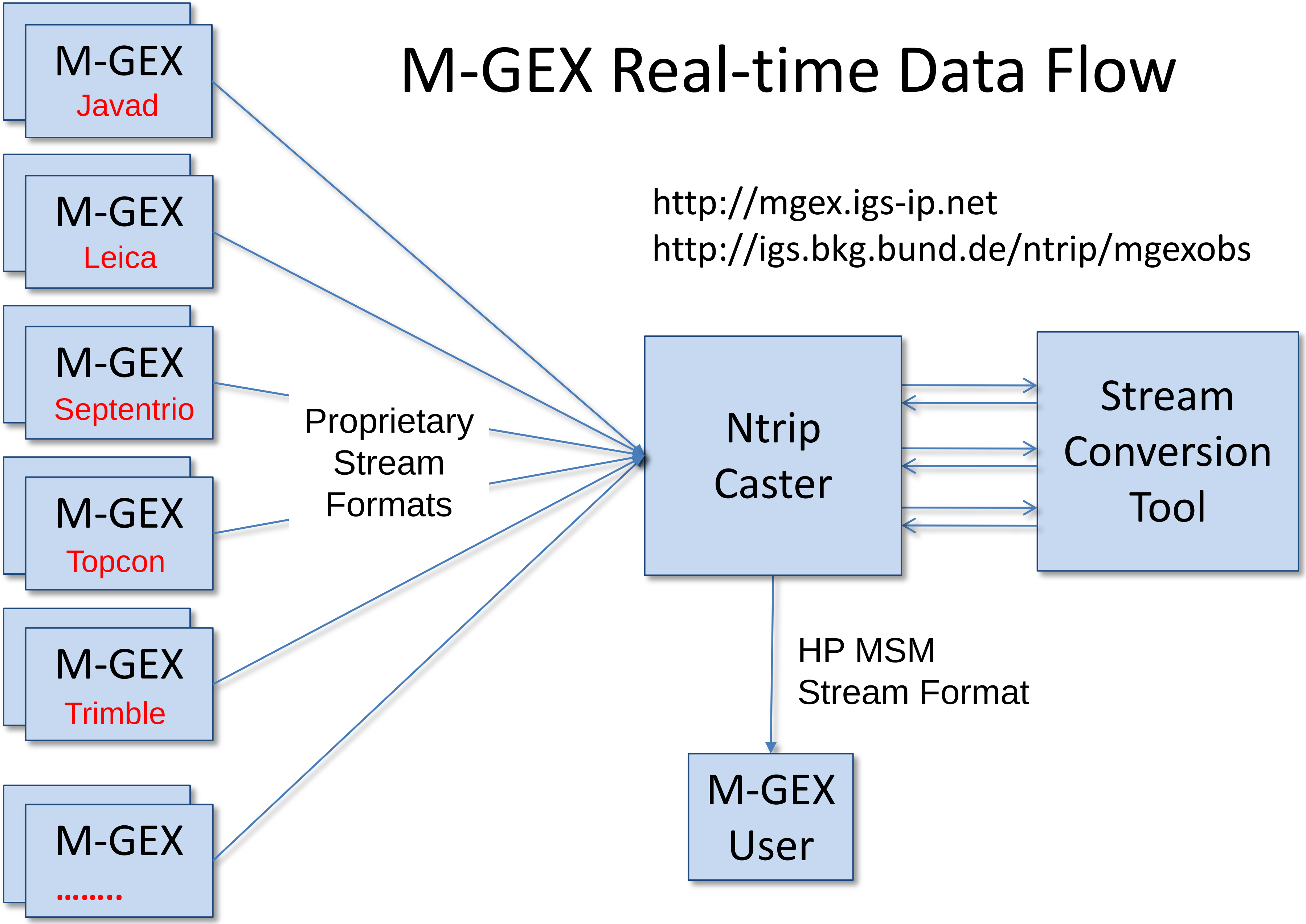


SIRGAS: Linking RTK Networks



M-GEX Real-time Data Flow

http://mgex.igs-ip.net
http://igs.bkg.bund.de/ntrip/mgexobs



Real-time Stream Provider Recommendation

- Upgrade all reference stations to real-time
- Provide access to any stream continuously available
- Support RTCM formats
- Disseminate high-rate data
- Share global network of Ntrip broadcasters
- Monitor stream flow and content
- Assist existing real-time GNSS services
- Participate in global stream exchange

What’s the future?

- Almost any GNSS reference receiver streams data over the Internet in real-time
- Global sharing of real-time GNSS stream resources
- New real-time GNSS products coming up
- Public and private sectors cooperate
- Commercial networks exists, value-added services made available

Real-time PPP Standardization

- SSR Step-2: Messages for global ionosphere and receiver phase biases
- SSR Step-3: Messages for instantaneous cm positioning, STEC ionosphere, troposphere, satellite phase biases
  - Requires SIRGAS plus national, regional, and local networks
  - PPP-RTK (or augmented PPP)

PPP-RTK optinal Alternative to Network RTK

- Network RTK: "One Stop Shop" solutions
  - Occasionally using a few selected reference coordinates from SIRGAS & IGS
- PPP-RTK: Continuously stacking information from independent solutions/services from
  - Global network (IGS)
  - Continental networks (SIRGAS)
  - National networks
  - Regional/local networks

SIRGAS – PPP Service Provider ?

- Change of current balance in efforts for
  - Making the reference system (post processing, mm), and
  - Providing access to the reference system (real-time, cm)
- Cooperate in PPP-RTK with National Mapping Agencies

What to do in SIRGAS?

- Cooperate with IGS Analysis Centers like BKG, CNES, CTU, DLR, ESA, NRCan, GFZ, GMV, Geo++, Wuhan for access to real-time software
- Establish reliable infrastructure for a South American PPP product at decimeter level
- Push manufacturers to support RTCM SSR in receiver firmware

Real-time GNSS
Closing Discussion

Real-time GNSS Issues

- Reference Frame
- Monumentation
- GNSS Receiver
- Data Access
- Operation & Business Model
- Pruduct and Service

Reference Frame Issues

SIRGAS

- International Terrestrial Reference Frame definition, maintenance & access, to support scientific applications
- Requires 4D position-time series integrity
- Core sites collocated with other space geodesy stations
- Sparse CORS network is sufficient

Commercial Provider

- ITRF &/or national datums, with stability monitoring
- Local datum is sufficient for some PP applications
- WGS84 „confusion“
- Variety of ways to account for „dynamic datum“
- Typically with minimal (local station) stability monitoring
- Dense (& perhaps uneven) network coverage

Monumentation Issues

SIRGAS

- Ultra-stable monument & site
- Expensive to build
- Best data quality (low multipath, RFI)
- IGS standards/guidelines
- Antenna/radom specs
- Long-term commitment to station operations
- Continuity valued above all

Commercial Provider

- „Fit-for-purpose“, cost-effective
- Variable guidelines
- Siting criteria influenced by dominant user application
- Very different agency or company practices
- Likelihood for duplication
- Possibility for defining jurisdictional „Standards & Specifications“

GNSS Receiver Issues

SIRGAS

- Multi-GNSS receiver
- Multi-frequency top-of-the-line receivers
- Software-based, or custom-design receivers
- Reluctance to change instrumentation
- Industry standards & scientific outputs

Commercial Provider

- Multi-GNSS & other options
- Possibility for lower cost, duel-frequency receivers & antennas, within „mixed“ networks
- Upgrade cycle driven by market/user needs
- Industry standard outputs, e.g. for real-time operations
- More rapidly changed

Data Access Issues

SIRGAS

- Raw data & derived products freely available through IGS/SIRGAS
- Increasingly RT data streams, in addition to RINEX, becoming available
- Some project/region-specific data restrictions for „exclusivity“ or security reasons
- Challenge integrating data with non-IGS CORS

Commercial Provider

- Variable data access policies (or restrictions)
- Data may be provided free for „research purposes“
- Derived products of services offered on commercial basis
- Raw RT data may also be viewed as commercial, esp. from private CORS
- Onerous data policies or high access charges can drive duplication of CORS

Operation & Business Model Issues

SIRGAS

- „Best effort“ operations
- Not commercial
- Distributed governance
- Funded by national agencies for science
- IGS/IGS plays coordinating role
- Increased service levels (esp. accuracy)

Commercial Provider

- Highly variable, from free-to-air to full commercial
- Variety of government agency roles, from providing basic PP infrastructure, to wholesaler of retailer of raw data or services
- Industry- of geographically-organized service providers
- Variety of fee models

Product and Service Issues

SIRGAS

- IGS is product generator
- Independent (& redundant) analysis centers
- Plus individual researchers
- Continuous product improvement is a driver
- Predominantly post-processed using „scientific software“
- RT GNSS geodesy a future goal
- Influences government policies re scientific CORS

Commercial Provider

- Market driven
- Variety of value-added (e.g. RTK) services
- Possibly using same CORS
- Based on commercial SW
- Variety of business models
- Varity of product „channels“
- Variable quality assurance
- Interoperability kept to a minimum
- Innovation is the „market opener“