



Prospects of Real-time Satellite Positioning using EPN Resources

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- **Motivation**
- **IGS-RT PP**
- **Standardization efforts**
- **Real-time concept**
 - **BKG Ntrip Server (BNS)**
 - **BKG Ntrip Client (BNC)**
 - **GNSS processing engine**
- **First results**
 - **Single Point Positioning**
 - **Zenith Total Delay parameters**
- **Conclusions and outlook**



- **GNSS real-time data streaming has been successfully developed within EUREF**
- **Special Project “EUREF-IP” was created in 2002**
- **Currently ~ 90 EPN stations with real-time capability**
- **SP EUREF-IP moved towards EPN routine operations end of 2007**

- **GNSS development has been accelerated**
 - from daily to hourly files (data)
 - from post-processing to near real-time (products)
- **Current evolution is going towards**
 - Real-time data streaming
 - Real-time monitoring and analysis
- **With the improvement of products and models the GNSS analysis has been extended**
 - From relative positioning
 - To single point positioning

- **Key objectives (selection):**
 - RT network
 - Generate RT products
 - Enhancement of (existing) IGS products
 - Investigation of standards and formats
- **CfP in June 2007 (IGS mail 5616), see <http://www.rtigs.net/pilot/index.php>**
- **25 proposals until October 2007**
- **Decision in December 2007 to accept them all (IGS mail 5692)**
- **Kickoff in March 2008 (mail by M. Caissy to the participants)**

➤ **Proposals to the individual categories**

- **RT tracking stations: 82+ (69+ plus 13 „possibly“)**
- **RT data centers**
 - **RT data-file centers: 5**
 - **RT data/product distribution centers: 9**
- **RT analysis centers: 7 (8)**
- **RT associate analysis centers: 1**
- **RT analysis center coordinator: 1 (Loukis Agrotis (ESOC))**
- **RT network management & monitoring: 7**
- **RT users: 13**

➤ IGS AC workshop 2-6 June 2008 – recommendations for RT issues

- Both NTRIP and UDPRelay will support dissemination of the Pilot Project Real Time products.
- The Pilot Project Analysis and Data Centre participants will initiate a requirements definition phase for formats of all Real Time products that are within the scope of the Pilot Project. It is assumed that the Data Centre participants will also cover the perspective of the User Community.
- A prototype format for orbits and clocks will be developed and hosted by the RT Data Centres. The timescale for this will be compatible with the schedule for the availability of the products (by January 2009 for individual ACs and March 2009 for the combination product).
- The RT Pilot Project will take an active role in the definition of final formats to support our requirements for all RT products, placing emphasis on influencing the evolution of existing international standards and in particular RTCM.
- IGS – become a member of RTCM SC 104
- That RINEX 3.0 be used to define RTIGS requirements for streamed data content and observation resolution
- That SP3c and Clock RINEX be used to define RTIGS requirements for streamed content and resolution for state space orbits and clocks

RTCM: Radio Technical Commission for Maritime Services



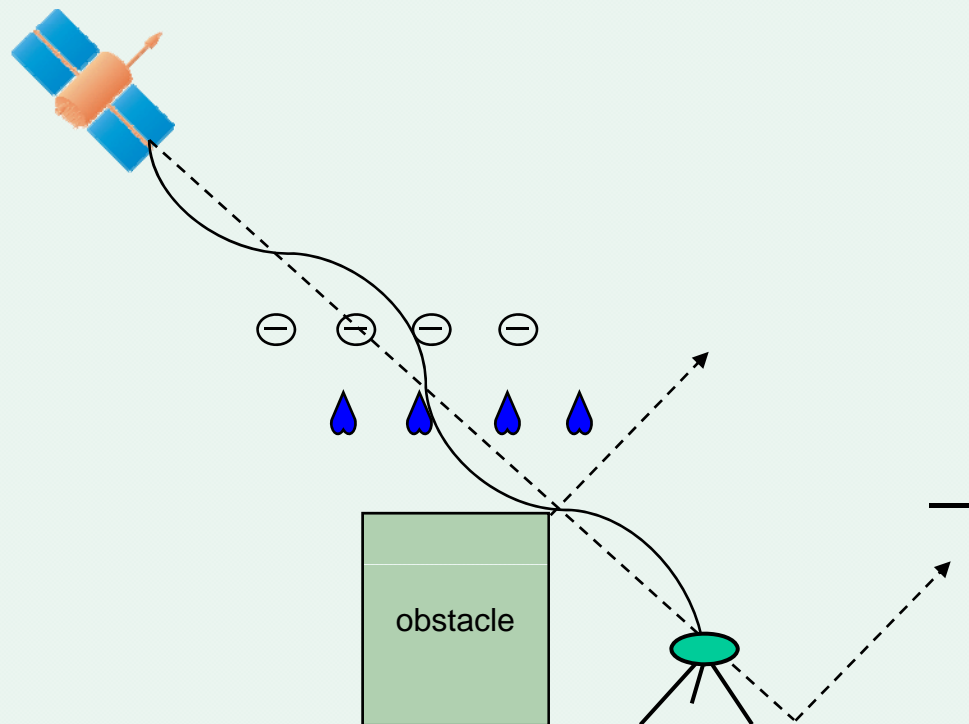
- Founded 1947 as U.S. State Department Advisory Committee
- Now an independent membership organization
- Supports development of standards and regulations
- Runs Special Committees:
 - SC-104 “Differential Global Navigation Satellite Systems”
- and different Working Groups:
 - Communication & data transfer:
 - WG Internet Protocol (e.g., NTRIP 2.0)
 - Modelling:
 - WG RTK Network MSG
 - WG State Space
 - Individual GNSS
 - WG Galileo
 - WG GLONASS
 - WG Version 3 (to accommodate the modernization of existing systems (GPS, GLONASS) and systems under development (EGNOS, Galileo))
 - E.g.: WG Synchronous Messages for Multi-Code/System Operation

Standardization: current efforts relevant for PPP

WG State Space

➤ State Space Principle:

- Provision of information on individual error sources, i.e. “State Space Representation”



Satellite signal delay
Satellite clock error
Satellite orbit error
Satellite antenna PCV
Ionosphere
Troposphere

RTCM State Parameters

Multipath
Receiver Antenna PCV
Receiver clock error
Receiver signal delay

WG State Space

- Additional issues in order to ensure consistent modelling
 - Treatment of site displacements
 - solid earth tides
 - pole tides
 - ocean loading
 - atmospheric loading
 - standardization of tropospheric correction models
 - geodetic datum / coordinate reference systems
 - global, regional and/or local services
 - higher order ionospheric effects
 - satellite attitude models
- ➔ The IERS conventions can serve as a reference for the standardization.

WG State Space

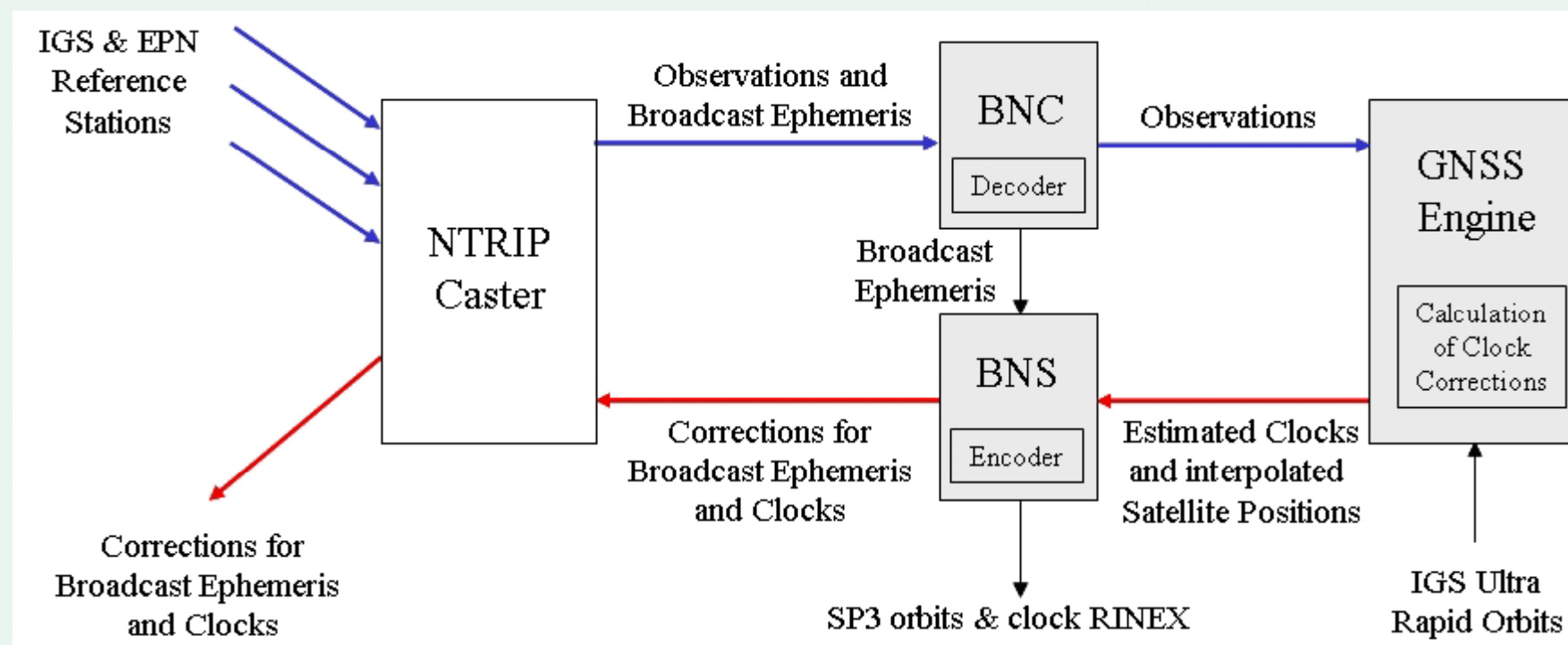
➤ WG Goal & Schedule:

- Development of State Space Representation concepts and messages for all types of accuracies, inclusive RTK:
 1. Messages for precise orbits and satellite clocks. This is compatible to the basic PPP mode using IGS products. Such messages will enable real time PPP for dual frequency receivers
 2. Vertical TEC (VTEC) messages. This will enable RT-PPP for single frequency receivers
 3. Slant TEC (STEC) messages, tropospheric messages and satellite signal delay messages. This will enable RTK-PPP

WG State Space

- State Space approach advantages
 - Defining state parameters as corrections to reference parameters or models allows a dramatic reduction of required bandwidth.
 - All or most parameters do not depend on reference station and frequency/signal.
 - Residual local errors of reference stations are eliminated or highly reduced in redundant networks.
 - Missing observations on individual reference stations do not result in missing state space information if the network has enough redundancy.
 - Satellite dependent parameters are globally valid.
 - Atmospheric parameters have global / regional / local validity depending on accuracy level.
 - Orbits and troposphere have high correlation in time, i.e. the update rates can be low.
 - Satellite clocks and ionospheric parameters may require higher update rates.

Orbit & clock correction concept (1)



➤ Purpose

- Calculate differences between BRDC and IGU orbits in radial, along track and out-of-plane components
- Model orbit differences through polynomials of low degree
- Provide model-based estimations of corrections for BRDC orbits
- Calculate differences between BRDC clocks and improved IGU clocks
- Model clock differences
- Provide model-based estimations of corrections for BRDC clocks

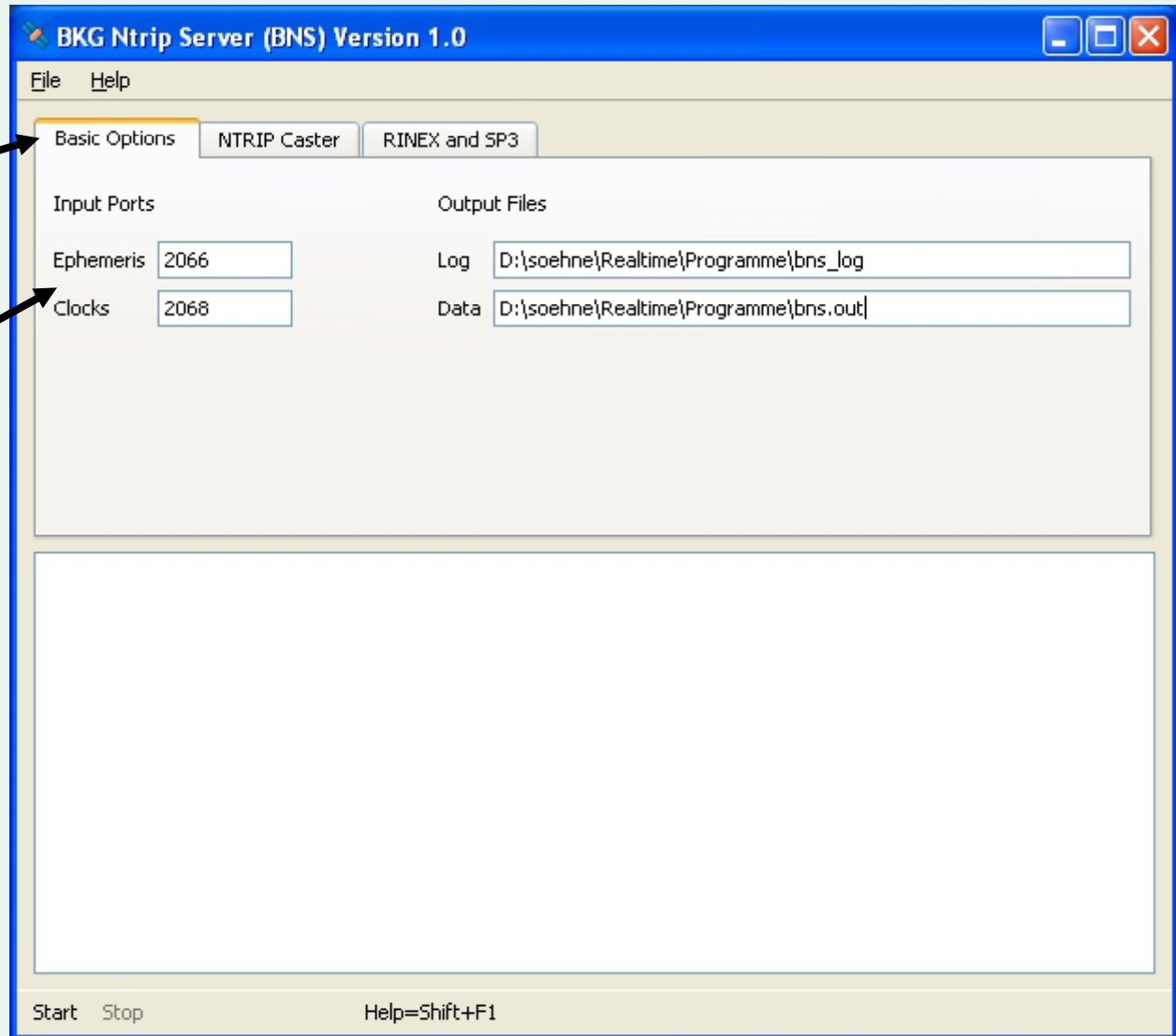
➤ First draft version since April 2008



BKG Ntrip Server (BNS)

selection using tabs

Two data stream inputs
necessary via port





BKG Ntrip Server (BNS)

BKG Ntrip Server (BNS) Version 1.0

File Help

Basic Options NTRIP Caster RINEX and SP3

Host Port

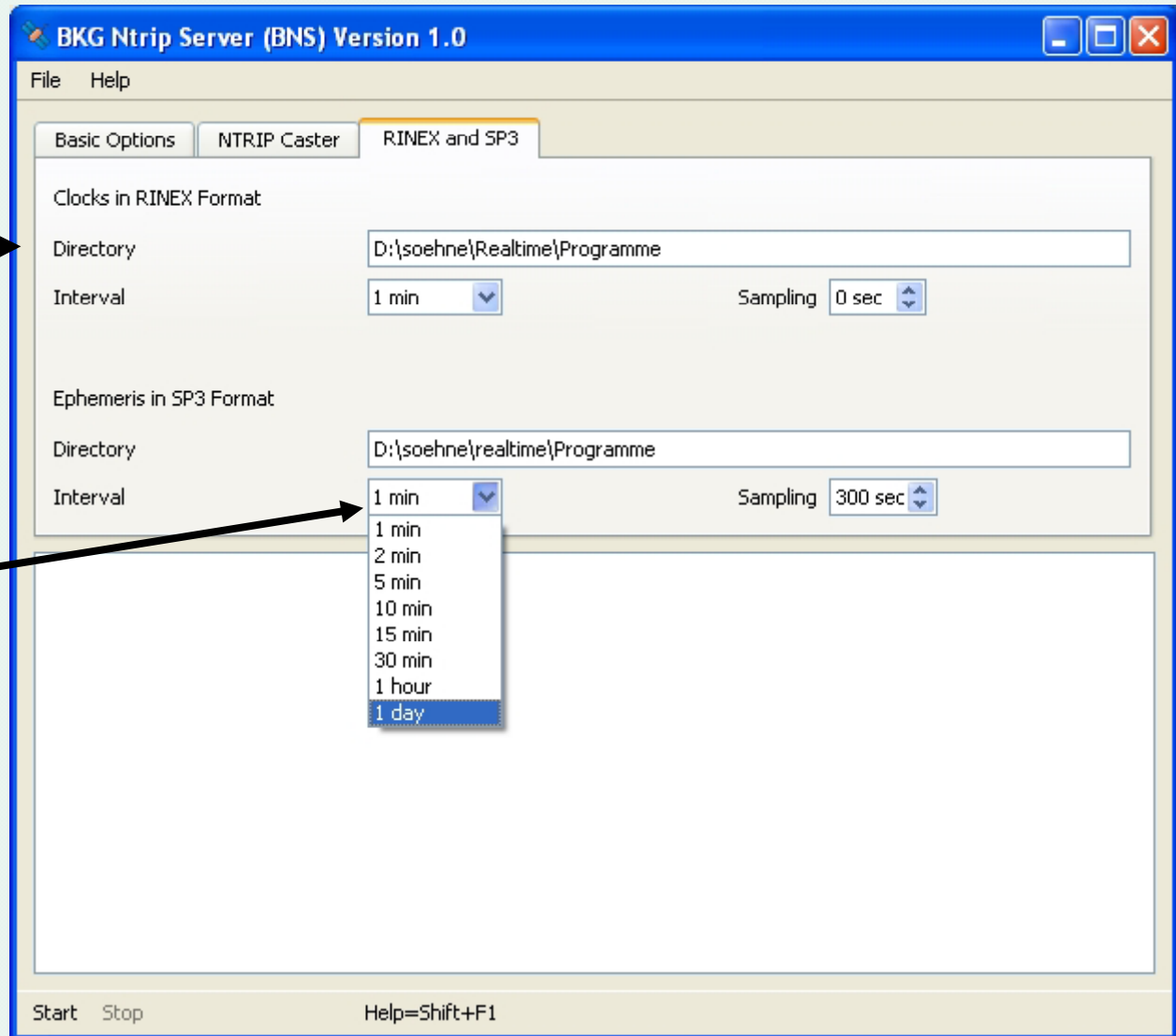
Mountpoint Password

Start Stop Help=Shift+F1

Output of clock
corrections to another
mountpoint on the
caster

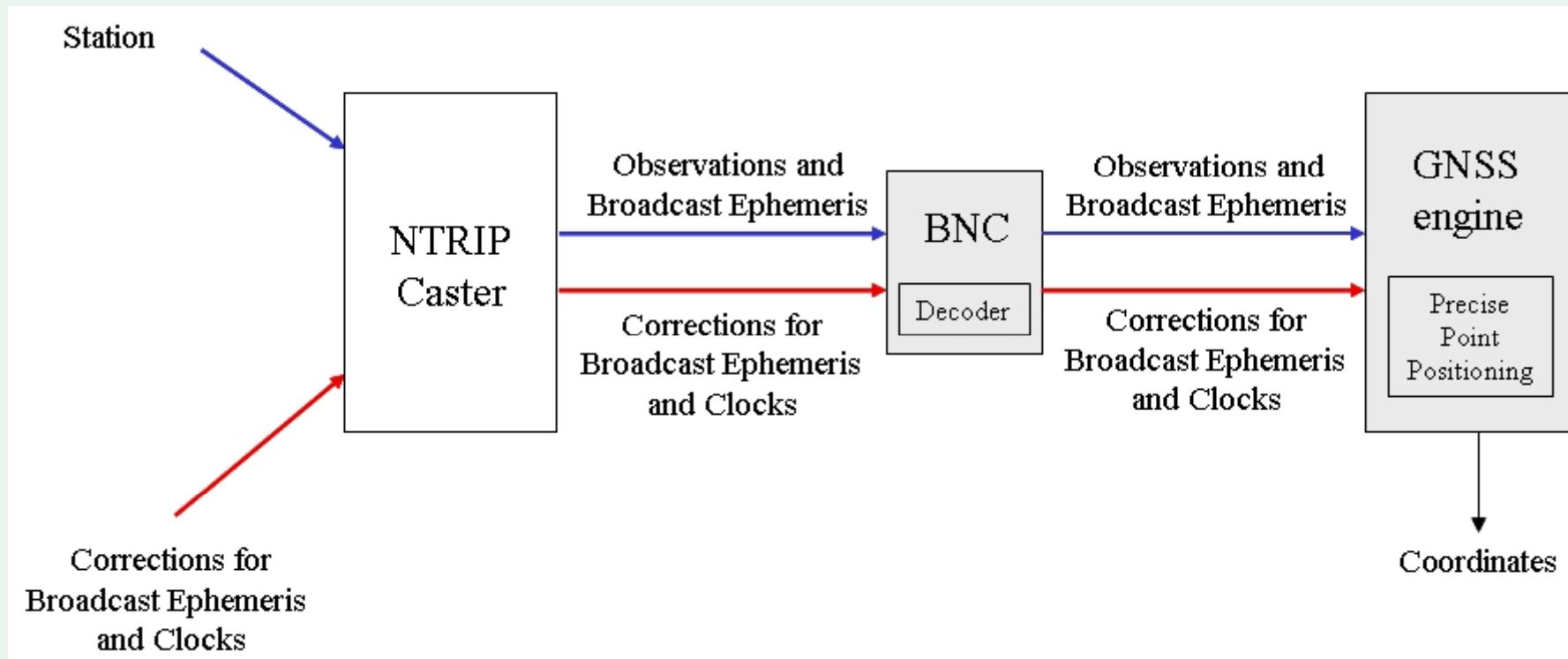
Option for output of
clocks and orbits in
well known file
formats

Selection of sampling
rate and file length



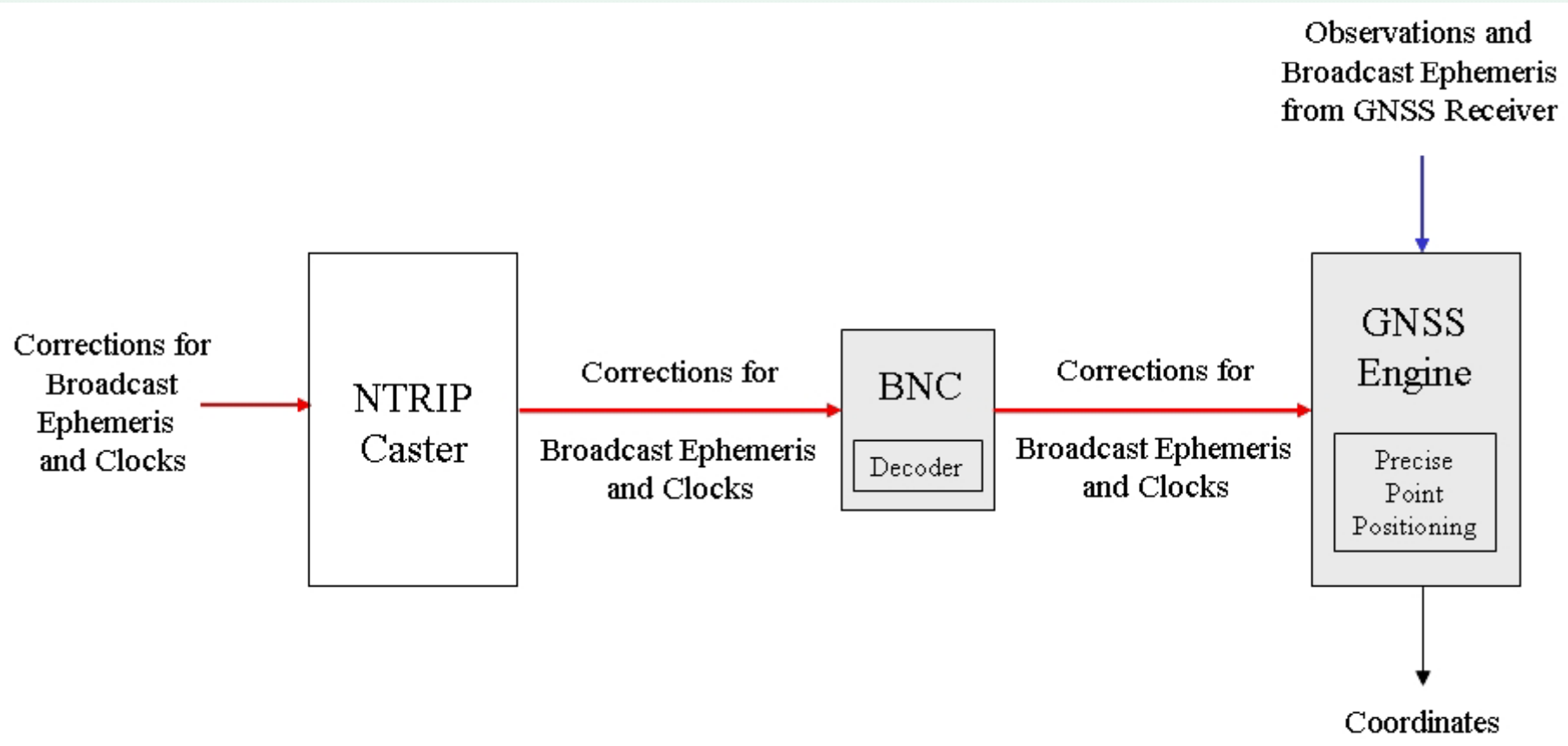


Orbit & clock correction concept (2)





Orbit & clock correction concept (3)



— = state space representation, orbits & clocks, RTCM v3 messages

➤ Purpose

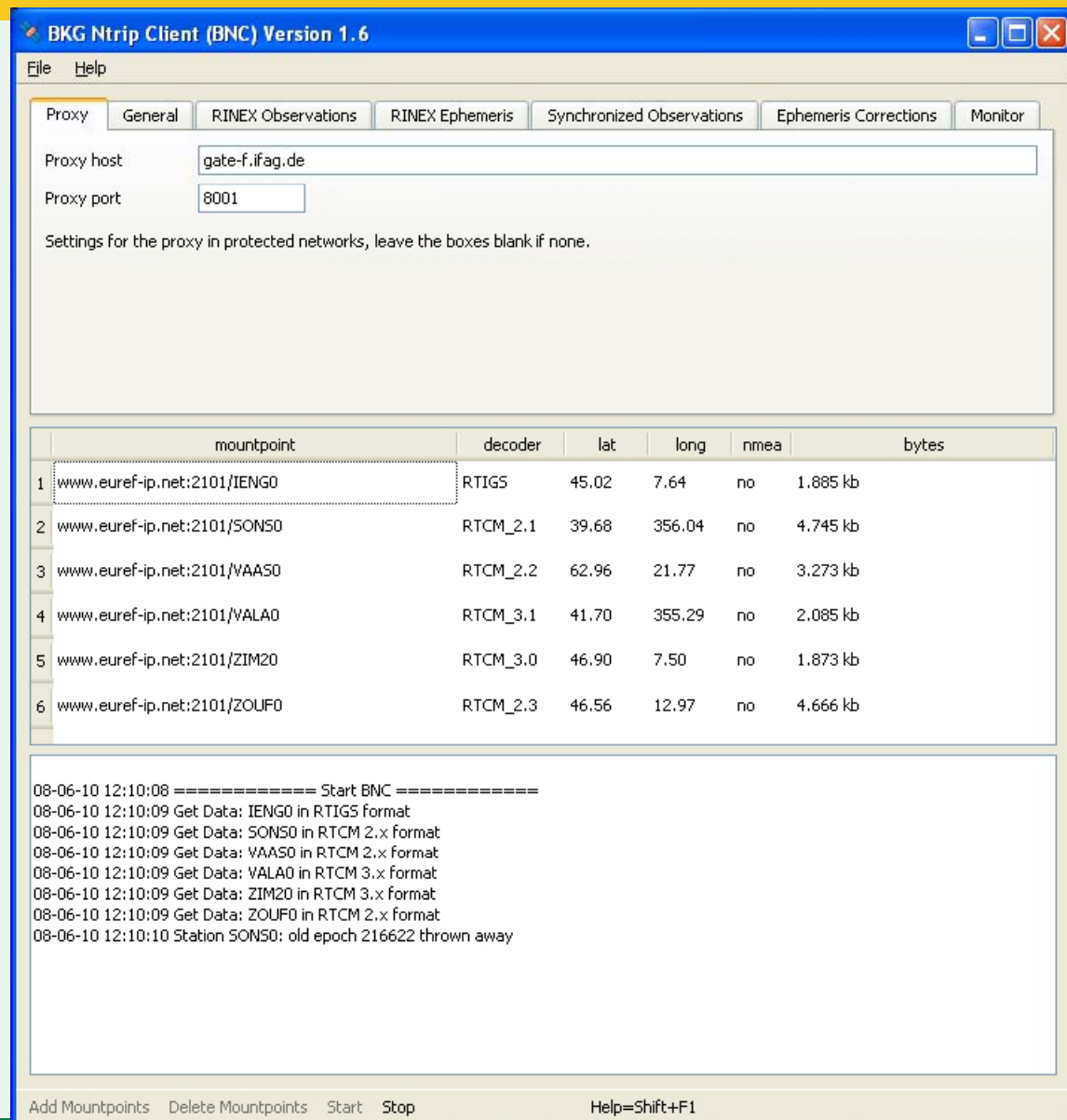
- GNSS data streams available through Ntrip
- Generation of high-rate RINEX OBS and NAV files
- Generation of EPH and synchronized OBS via port
- Monitoring of the performance of a real-time network

➤ Latest version 1.5 available for download since April 2008



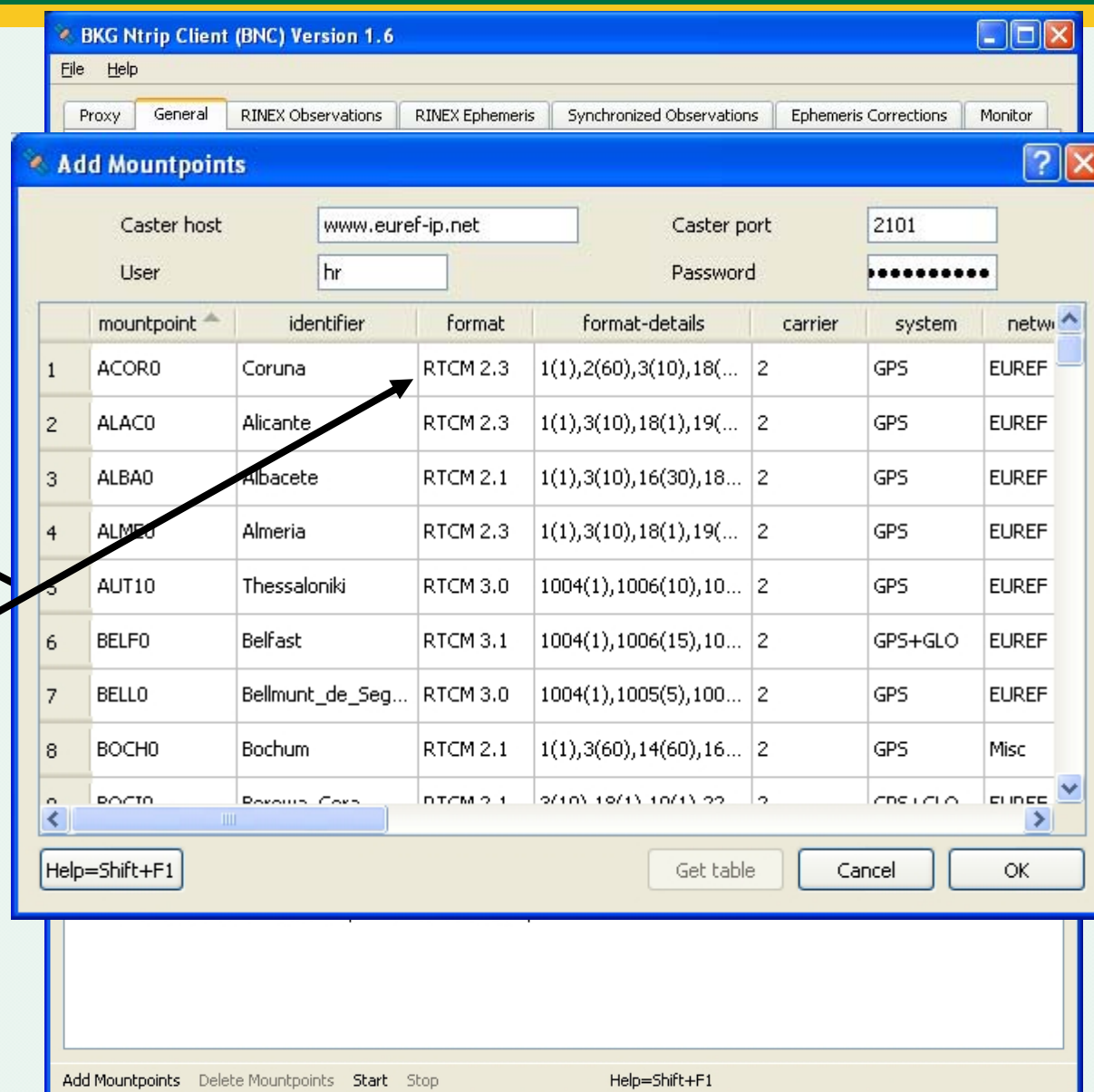
BKG Ntrip Client (BNC)

selection using tabs



Data of the selected mountpoints will be streamed

Various formats are supported and can be selected from the broadcaster



BKG Ntrip Client (BNC) Version 1.6

File Help

VAAS162M00.080 - WordPad

Datei Bearbeiten Ansicht Einfügen Format ?

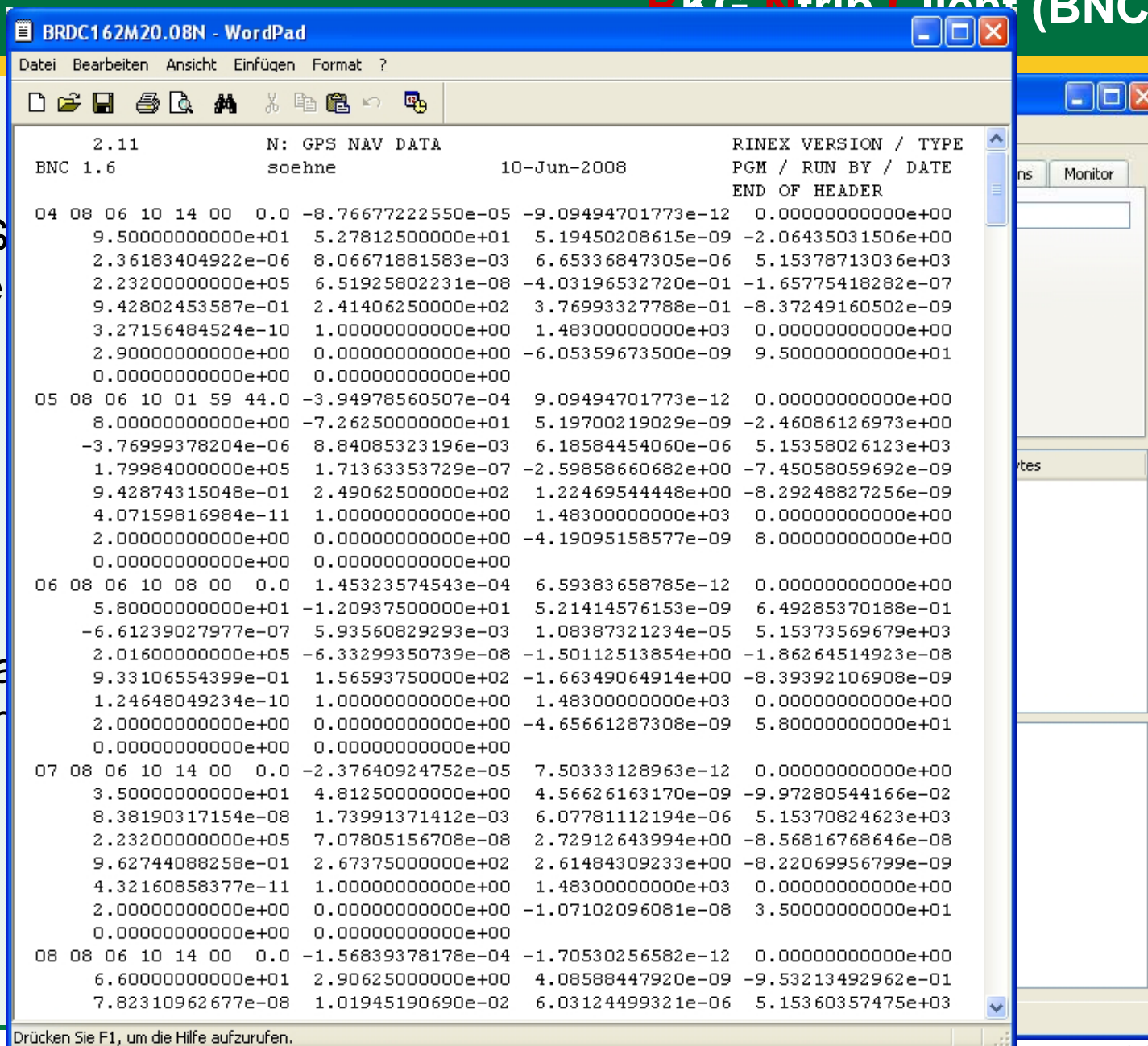
3.00 OBSERVATION DATA M (MIXED) RINEX VERSION / TYPE
 BNC 1.6 soehne 20080610 121012 UTC PGM / RUN BY / DATE
 VAAS MARKER NAME
 GEODETIC MARKER TYPE
 10511M001 MARKER NUMBER
 125 ASHTECH Z-XII3 CD00 REC # / TYPE / VERS
 195 ASH700936A_M SNOW ANT # / TYPE
 2699865.0000 1078264.0000 5658065.0000 APPROX POSITION XYZ
 0.0000 0.0000 0.0000 ANTENNA: DELTA H/E/N
 Prof. Ruizhi Chen FGI OBSERVER / AGENCY
 PORTIONS OF THIS HEADER GENERATED BY THE EPN CB FROM COMMENT
 SITELOG vaas_20050311.log COMMENT
 G 10 C1C C1P L1C S1C C2X C2P L2X S2X L2P S2P SYS / # / OBS TYPES
 R 10 C1C C1P L1C S1C C2C C2P L2C S2C L2P S2P SYS / # / OBS TYPES
 S 3 C1C L1C S1C SYS / # / OBS TYPES
 2008 06 10 12 10 24.0000000 GPS TIME OF FIRST OBS
 RTCM_2 www.euref-ip.net/VAAS0 COMMENT
 END OF HEADER
 > 2008 06 10 12 10 24.0000000 0 10
 G08 21097448.400 0.000 112041823.012 0 0.000 0.000 21097451.500 0.000 0.000 83415952.539 0
 0.000
 G10 21263100.340 0.000 115790378.152 0 0.000 0.000 21263103.560 0.000 0.000 88526785.652 0
 0.000
 G27 21203941.080 0.000 114816186.082 0 0.000 0.000 21203944.460 0.000 0.000 87409759.027 0
 0.000
 G06 24362261.560 0.000 132187959.328 0 0.000 0.000 24362265.820 0.000 0.000 99252943.895 0
 0.000
 G24 23642544.800 0.000 120075982.043 0 0.000 0.000 23642548.700 0.000 0.000 98891495.625 0
 0.000
 G25 22297970.400 0.000 118753515.184 0 0.000 0.000 22297971.960 0.000 0.000 90489598.355 0
 0.000
 G13 22878925.280 0.000 118214423.070 0 0.000 0.000 22878926.360 0.000 0.000 90419688.672 0
 0.000
 G03 23889199.220 0.000 121660335.090 0 0.000 0.000 23889203.880 0.000 0.000 97456085.906 0
 0.000
 G07 20923306.500 0.000 113046788.805 0 0.000 0.000 20923308.880 0.000 0.000 86414827.996 0
 0.000
 G26 23840597.080 0.000 123729923.523 0 0.000 0.000 23840600.880 0.000 0.000 99772597.621 0

Drücken Sie F1, um die Hilfe aufzurufen.

Add Mountpoints Delete Mountpoints Start Stop Help=Shift+F1

GPS + GLONASS
ephemeris can be
stored

We introduced a
number of special
mountpoints in the
different regions of
the world



The screenshot shows the BNC software interface with a WordPad window titled "BRDC162M20.08N - WordPad". The window displays RINEX NAV DATA for station "soehne" on "10-Jun-2008". The data is organized into sections for different epochs: 2.11, 05 08, 06 08, 07 08, and 08 08. Each section contains a header with "N: GPS NAV DATA", "soehne", and the date, followed by a table of ephemeris data. The data is presented in a grid-like format with columns for epoch, station name, and multiple columns of numerical values representing the ephemeris data. The status bar at the bottom of the WordPad window indicates "Drücken Sie F1, um die Hilfe aufzurufen."

```

2.11      N: GPS NAV DATA      RINEX VERSION / TYPE
BNC 1.6    soehne              10-Jun-2008    PGM / RUN BY / DATE
                                           END OF HEADER

04 08 06 10 14 00 0.0 -8.76677222550e-05 -9.09494701773e-12 0.00000000000e+00
          9.50000000000e+01 5.27812500000e+01 5.19450208615e-09 -2.06435031506e+00
          2.36183404922e-06 8.06671881583e-03 6.65336847305e-06 5.15378713036e+03
          2.23200000000e+05 6.51925802231e-08 -4.03196532720e-01 -1.65775418282e-07
          9.42802453587e-01 2.41406250000e+02 3.76993327788e-01 -8.37249160502e-09
          3.27156484524e-10 1.00000000000e+00 1.48300000000e+03 0.00000000000e+00
          2.90000000000e+00 0.00000000000e+00 -6.05359673500e-09 9.50000000000e+01
          0.00000000000e+00 0.00000000000e+00

05 08 06 10 01 59 44.0 -3.94978560507e-04 9.09494701773e-12 0.00000000000e+00
          8.00000000000e+00 -7.26250000000e+01 5.19700219029e-09 -2.46086126973e+00
          -3.76999378204e-06 8.84085323196e-03 6.18584454060e-06 5.15358026123e+03
          1.79984000000e+05 1.71363353729e-07 -2.59858660682e+00 -7.45058059692e-09
          9.42874315048e-01 2.49062500000e+02 1.22469544448e+00 -8.29248827256e-09
          4.07159816984e-11 1.00000000000e+00 1.48300000000e+03 0.00000000000e+00
          2.00000000000e+00 0.00000000000e+00 -4.19095158577e-09 8.00000000000e+00
          0.00000000000e+00 0.00000000000e+00

06 08 06 10 08 00 0.0 1.45323574543e-04 6.59383658785e-12 0.00000000000e+00
          5.80000000000e+01 -1.20937500000e+01 5.21414576153e-09 6.49285370188e-01
          -6.61239027977e-07 5.93560829293e-03 1.08387321234e-05 5.15373569679e+03
          2.01600000000e+05 -6.33299350739e-08 -1.50112513854e+00 -1.86264514923e-08
          9.33106554399e-01 1.56593750000e+02 -1.66349064914e+00 -8.39392106908e-09
          1.24648049234e-10 1.00000000000e+00 1.48300000000e+03 0.00000000000e+00
          2.00000000000e+00 0.00000000000e+00 -4.65661287308e-09 5.80000000000e+01
          0.00000000000e+00 0.00000000000e+00

07 08 06 10 14 00 0.0 -2.37640924752e-05 7.50333128963e-12 0.00000000000e+00
          3.50000000000e+01 4.81250000000e+00 4.56626163170e-09 -9.97280544166e-02
          8.38190317154e-08 1.73991371412e-03 6.07781112194e-06 5.15370824623e+03
          2.23200000000e+05 7.07805156708e-08 2.72912643994e+00 -8.56816768646e-08
          9.62744088258e-01 2.67375000000e+02 2.61484309233e+00 -8.22069956799e-09
          4.32160858377e-11 1.00000000000e+00 1.48300000000e+03 0.00000000000e+00
          2.00000000000e+00 0.00000000000e+00 -1.07102096081e-08 3.50000000000e+01
          0.00000000000e+00 0.00000000000e+00

08 08 06 10 14 00 0.0 -1.56839378178e-04 -1.70530256582e-12 0.00000000000e+00
          6.60000000000e+01 2.90625000000e+00 4.08588447920e-09 -9.53213492962e-01
          7.82310962677e-08 1.01945190690e-02 6.03124499321e-06 5.15360357475e+03
  
```



BKG Ntrip Client (BNC)

Output of
synchronized
observation via port

BKG Ntrip Client (BNC) Version 1.5

File Help

Proxy General RINEX Observations RINEX Ephemeris Synchronized Observations Monitor

Port: 1966
Wait for full epoch: 5 sec
File (full path): D:/soehne/Realtime/Programme/Daten
Sampling: 0 sec
Output synchronized observations epoch by epoch.

	mountpoint	decoder	lat	long	nmea	bytes
1	www.igs-ip.net:2101/ADIS1	RTCM_3.0	9.03	38.74	no	139.53 kb
2	www.igs-ip.net:2101/CONZ2	RTCM_3.0	-36.84	286.98	no	136.96 kb
3	www.igs-ip.net:2101/FFMJ2	RTCM_3.0	50.09	8.66	no	141.914 kb

08-04-08 13:10:17 Get Data: DAEJU in RTCM 2.x format
08-04-08 13:10:17 Get Data: GOPE0 in RTCM 2.x format
08-04-08 13:10:17 Get Data: ZIM20 in RTCM 3.x format
08-04-08 13:13:37 ===== Start BNC =====
08-04-08 13:13:38 Get Data: ADIS1 in RTCM 3.x format
08-04-08 13:13:38 Get Data: CONZ2 in RTCM 3.x format
08-04-08 13:13:38 Get Data: FFMJ2 in RTCM 3.x format
08-04-08 13:15:09 ===== Start BNC =====
08-04-08 13:15:09 Get Data: ADIS1 in RTCM 3.x format
08-04-08 13:15:09 Get Data: CONZ2 in RTCM 3.x format
08-04-08 13:15:09 Get Data: FFMJ2 in RTCM 3.x format
08-04-08 13:16:23 ===== Start BNC =====
08-04-08 13:16:24 Get Data: ADIS1 in RTCM 3.x format
08-04-08 13:16:24 Get Data: CONZ2 in RTCM 3.x format
08-04-08 13:16:24 Get Data: FFMJ2 in RTCM 3.x format

Add Mountpoints Delete Mountpoints Start Stop Help=Shift+F1



Ephemeris
corrections can be
stored in different
intervals

Mountpoint of the clock
corrections

CLCK1162M16.08C - WordPad

1483	216960.0	G02	23	3.391	0.015	0.426	-0.008
1483	216960.0	G06	61	1.264	0.726	0.936	0.123
1483	216960.0	G07	35	-1.211	-0.007	0.855	-0.542
1483	216960.0	G08	66	-7.024	1.472	-2.882	1.319
1483	216960.0	G10	39	5.639	0.729	2.267	0.509
1483	216960.0	G13	8	1.760	1.771	0.117	0.224
1483	216960.0	G15	3	0.035	0.110	0.362	0.009
1483	216960.0	G24	46	1.761	1.484	1.553	0.266
1483	216960.0	G25	106	3.587	0.842	-0.250	0.242
1483	216960.0	G26	70	-16.223	1.179	-0.809	0.198
1483	216960.0	G27	31	-0.922	0.806	-2.846	0.990
1483	216960.0	G28	171	8.477	1.516	-0.337	0.069
1483	216960.0	R07	18	-1.204	3.000	0.005	1.871
1483	216960.0	R08	18	-0.506	3.839	-5.356	2.960
1483	216960.0	R10	18	-4.353	2.352	4.990	-3.177
1483	216960.0	R11	10	2.059	37.009	29.719	263.894
1483	216960.0	R17	10	-4.159	-1.538	3.347	-0.778
1483	216960.0	R24	2	-4.234	89.070	-136.325	418.076
1483	216961.0	G02	23	3.392	0.016	0.426	-0.009
1483	216961.0	G06	61	1.263	0.726	0.937	0.123
1483	216961.0	G07	35	-1.212	-0.007	0.855	-0.543
1483	216961.0	G08	66	-7.025	1.471	-2.883	1.319
1483	216961.0	G10	39	5.639	0.729	2.267	0.509
1483	216961.0	G13	8	1.761	1.771	0.117	0.224
1483	216961.0	G15	3	0.035	0.110	0.362	0.009
1483	216961.0	G24	46	1.760	1.484	1.553	0.266
1483	216961.0	G25	106	3.586	0.843	-0.251	0.241
1483	216961.0	G26	70	-16.223	1.180	-0.810	0.199
1483	216961.0	G27	31	-0.925	0.806	-2.845	0.989
1483	216961.0	G28	171	8.476	1.517	-0.338	0.070
1483	216961.0	R07	18	-1.205	3.000	0.006	1.871
1483	216961.0	R08	18	-0.506	3.840	-5.356	2.960
1483	216961.0	R10	18	-4.353	2.352	4.991	-3.177
1483	216961.0	R11	10	2.058	37.005	29.730	263.935
1483	216961.0	R17	10	-4.158	-1.544	3.348	-0.777
1483	216961.0	R24	2	-4.235	89.058	-136.375	418.095
1483	216962.0	G02	23	3.393	0.016	0.426	-0.009
1483	216962.0	G06	61	1.263	0.726	0.937	0.123

Drücken Sie F1, um die Hilfe aufzurufen.



BKG Ntrip Client (BNC)

Settings for the
monitoring

showing latency and
availability

Proxy General RINEX Observations RINEX Ephemeris Synchronized Observations Ephemeris Corrections **Monitor**

Observation rate: 1 Hz
Failure threshold: 0 min
Recovery threshold: 0 min
Script (full path): D:/soehne/Realtime/Programme/doiit.pl
Performance log: 1 min
Pause ☐

Network monitoring, outages, handling of corrupted streams, latencies, statistics.

	mountpoint	decoder	lat	long	nmea	bytes
1	www.euref-ip.net:2101/BRUS0	RTIGS	50.80	4.36	no	38.881 kb
2	www.euref-ip.net:2101/GAIA0	RTCM_2.3	41.11	351.41	no	86.006 kb
3	www.euref-ip.net:2101/GANP0	RTCM_3.0	49.03	20.32	no	47.213 kb

08-06-10 12:15:37 ===== Start BNC =====
08-06-10 12:15:37 Get Data: CLCK1 in RTCM 3.x format
08-06-10 12:18:13 ===== Start BNC =====
08-06-10 12:18:13 Get Data: BRUS0 in RTIGS format
08-06-10 12:18:13 Get Data: GAIA0 in RTCM 2.x format
08-06-10 12:18:13 Get Data: GANP0 in RTCM 3.x format
08-06-10 12:18:46 GAIA0: Mean latency 1.37 sec, min 0.58, max 1.72, 32 epochs
08-06-10 12:18:47 GANP0: Mean latency 1.22 sec, min 0.49, max 3.25, 33 epochs
08-06-10 12:18:48 BRUS0: Mean latency 1.96 sec, min 1.41, max 2.58, 33 epochs
08-06-10 12:19:46 GAIA0: Mean latency 1.37 sec, min 0.58, max 1.73, 60 epochs
08-06-10 12:19:46 GANP0: Mean latency 1.2 sec, min 0.47, max 2.67, 60 epochs
08-06-10 12:19:48 BRUS0: Mean latency 1.99 sec, min 1.39, max 2.59, 60 epochs
08-06-10 12:20:46 GANP0: Mean latency 1.14 sec, min 0.5, max 1.63, 60 epochs, 0 gaps
08-06-10 12:20:47 GAIA0: Mean latency 1.32 sec, min 0.6, max 1.69, 60 epochs, 0 gaps
08-06-10 12:20:48 BRUS0: Mean latency 2.02 sec, min 1.33, max 2.76, 60 epochs, 0 gaps

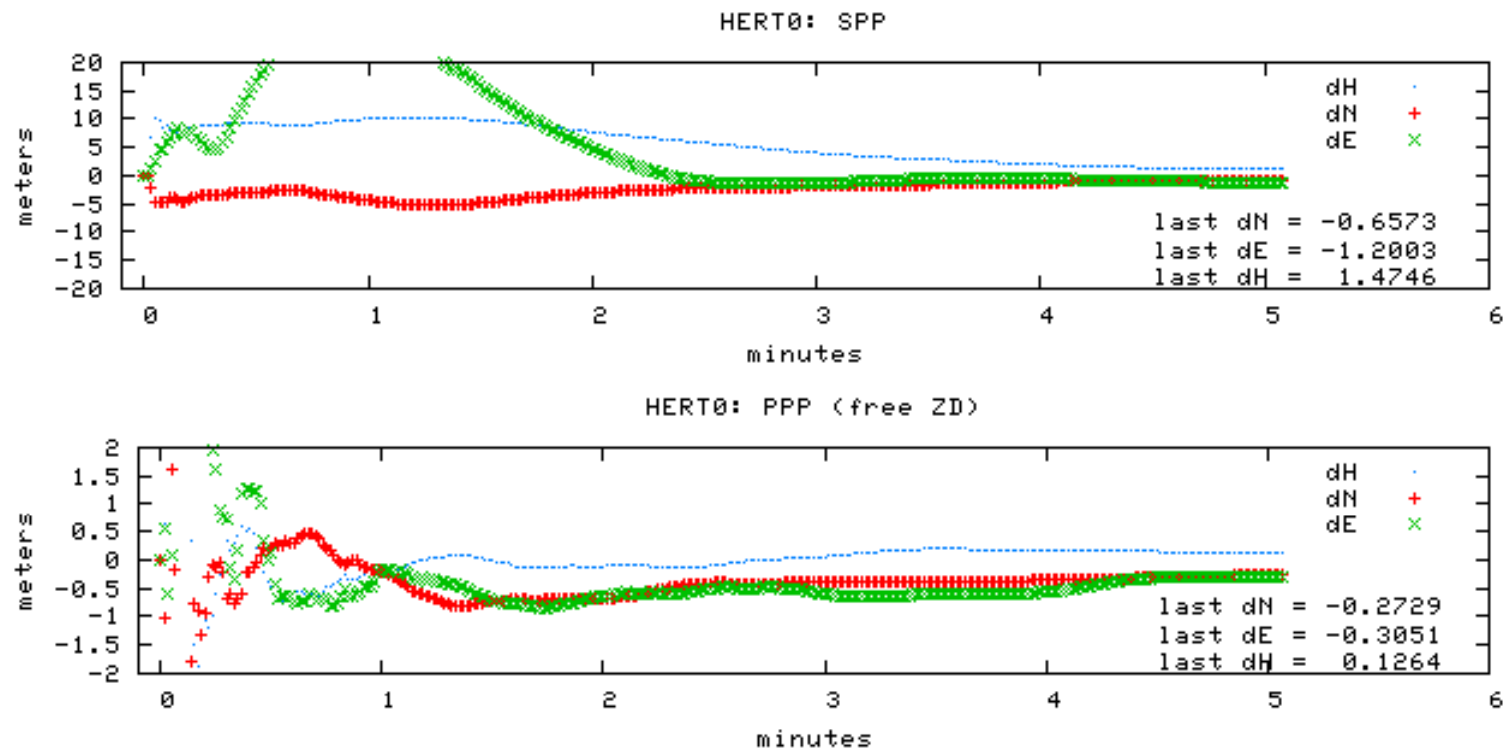
Add Mountpoints Delete Mountpoints Start Stop Help=Shift+F1

➤ RTNet

- By “GPS solutions” / L. Mervart
- Used for
 - either clock correction and ZTD estimation (network solution)
 - or coordinate estimation (PPP)
- Clock correction estimation successfully tested for Europe (GPS only and GPS+GLONASS), North America and Australia



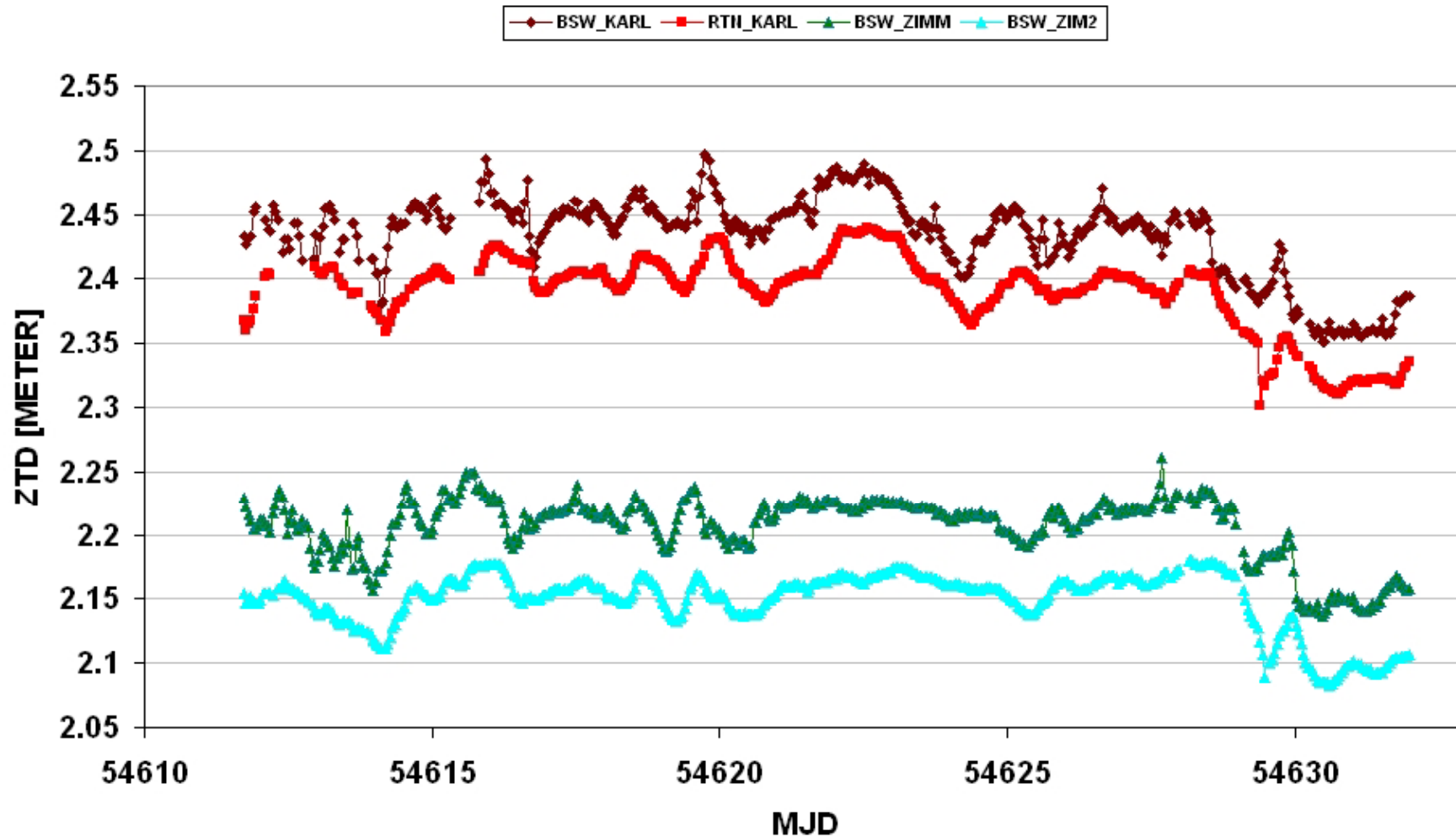
GNSS processing engine – results





GNSS processing engine – results

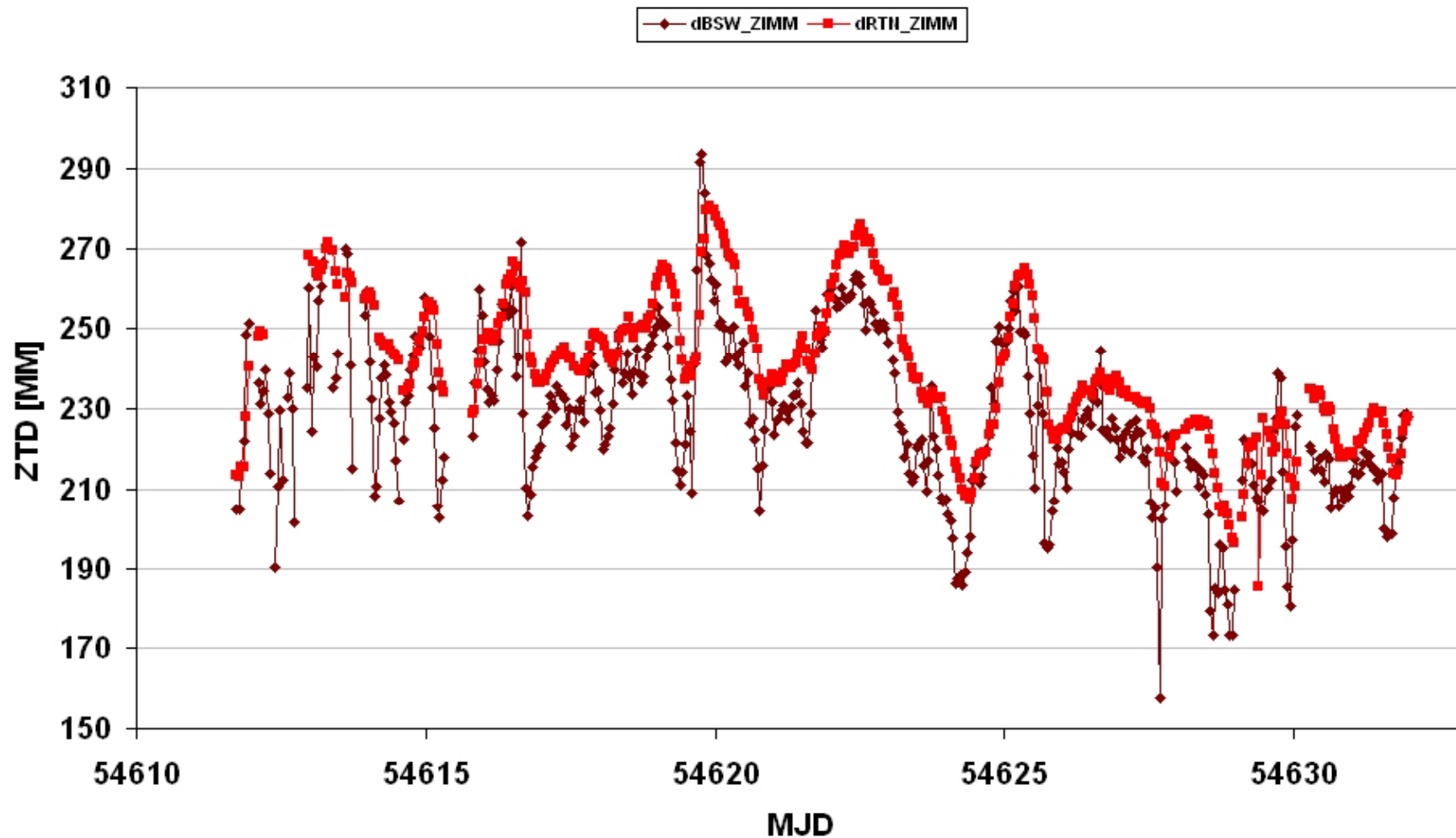
ZTD parameter from NRT with BSW5.0 (1h sampling) and RTNet (1 sec sampling)





GNSS processing engine – results

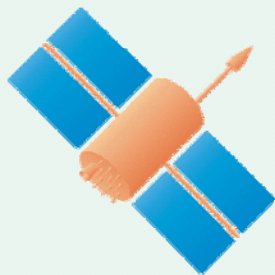
ZTD parameter from NRT with BSW5.0 (1h sampling) and RTNet (1 sec sampling)



- **EPN real-time data streaming widely-used**
- **Moved to EPN routine operations**
- **Strategies of orbit and clock correction computation and dissemination is on an advanced level**
- **EUREF is going to launch a new SP about the enhancement of real-time data streams**



Thank you for your attention!



Information & Downloads:

<http://igs.bkg.bund.de>

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