G-Nut/Anubis (v3)

a tool for multi-GNSS data quality control (QC)

Tutorial 2021 (last update 2021/02/18)

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Outline

- Software introduction
- Inputs, outputs, help
- Standard XML configuration
- Advanced command-line settings
- Operation modes
- Output formats
- XTR format description

G-Nut/Anubis - multi-GNSS QC software

G-Nut/Anubis – end-user application for multi-GNSS data quality control

G-Nut – library for high-accuracy GNSS data analyses and other processes

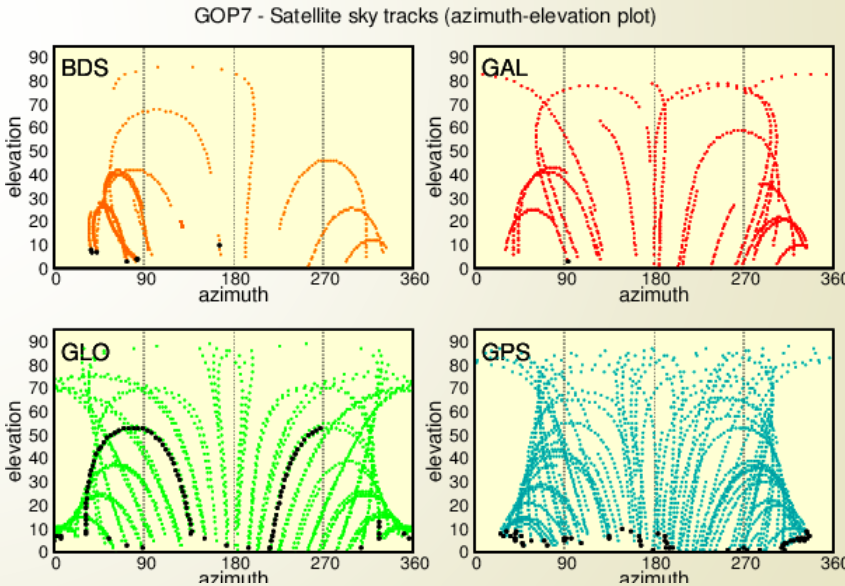
C++ (object-oriented) design, compatible with Linux, Windows, Mac

Developed by: **VÚGTK, Geodetic Observatory Pecny, https://www.pecny.cz**

G-Nut Software s.r.o. **http://www.gnutsoftware.com**

Fundamental software functionality:

- Summary statistics, key parameters
- Data availability – gaps, small pieces
- Observation-specific statistics
- Phase processing (cycle slips, clock jumps)
- Azimuth/elevation information for sky plots
- Pseudo-range multipath and signal noise
- Standard positioning, repeatability, DOP
- Format and metadata checking



Václavovic P, Douša J (2016), ***G-Nut/Anubis - open-source tool for multi-GNSS data monitoring****, IAG Symposia Series, Springer, Vol. 143*
Václavovic P, Douša J, Gyori G (2013) ***G-Nut software library - state of development and first results****, Acta Geodyn Geomater*

Available versions of G-Nut/Anubis

Anubis Free (open source)
fundamental functionality:

Observation statistics (signals, bands, satellites, etc.)

Data availability (data gaps and small pieces)

Pre-processing of carrier phases (cycle slips, clock jumps)

Satellite information (azimuth/elevations)

Single point positioning (repeatability, GDOP)

Code multipath and phase signal-to-noise ratio

Navigation data, information on satellite health status

Header and format validation

Anubis Pro (professional)
compared to Anubis Free:

Direct access to archive files (Hatanaka + gzip/compress)

Metadata and data editing, filtering and concatenating

Navigation / observation data file encoding (RINEX 3 & 2)

XML/SINEX input for modifying/validating site metadata

JSON output for plotting & support for visualization service

Enhanced configuration/help, predefined processing modes

Satellite health status applied for positioning, statistics, etc.

Parallel processing configuration (CPU, RAM, files)

Anubis RT (real-time)
compared to Anubis Pro:

Real-time data flow quality control (format, content, latency)

Observation and navigation output files (RINEX 3 & 2)

RTCM and BNC format decoder/encoder

TCP/NTRIP client

Inputs, outputs, help

Software inputs/outputs

Inputs files:

- **Observation RINEX 2/3** (one or more files)
- **Navigation RINEX 2/3** (one or more files, more sites, more constellations)
- **Precise ephemeris in SP3** (one or more files), may be combined with navigation)
- **Anubis Free (≥ 2.1)** IO handling: **gzip (.gz)** (no compress, no zip)
- **Anubis Pro/RT (≥ 3.0)** IO handling: **gzip (.gz), compress (.Z), Hatanaka (.crx)**

Outputs files (QC):

- **XTR** (native Anubis format) – detailed QC extractions
  - Include QC results - epoch-wise, satellite-specific and signal-specific
  - ASCII format - easy to grep for individual file as well as over file for cumulative plotting
  - Organized in sections and supports different levels of verbosity
- **XML/QC_GNSS** – summary extractions (new standard QC format for EPOS)
  - Principal QC metadata exchange, e.g. supporting remote RINEX file comparison
  - **XSD file** for validation of XML/QC_GNSS *(developed by Andras Fabian, ROB)*
- **JSON (Anubis Pro/RT)** – high-resolution QC outputs suitable for detail plotting
  - selected metadata, positioning results, satellite-/epoch-/signal-specific QC results

Multiple input/output files

- **Multiple input files**
  - Input RINEX data are first read and filtered, the QC is performed afterwards
  - Data are internally represented by a station 'id'
  - Data for the same station are concatenated (into internal container)
  - Data from different stations are kept separately
  - **Implicit operations on multiple input files:**
    - **'cc' (concatenation):** processing multiple files for a single station
    - **'net' (network):** processing multiple files from different stations
    - **'cmb' (combined):** both above could still be combined
    - data for any unique station 'id' are processed together
- **Multiple output files**
  - QC output is provided per a unique station by applying 'file-mask' using the internal station ID **$(rec)** and, optionally, internal time variables (**%Y, %y, %d, %m, %j, …**),

    i.e. **OUT_DIR/$(rec)_%y%j0.xtr** **OUT_DIR/$(rec)_%y%j0.xml**
  - **Implicit operations on multiple input files:**
    - **'cc':** a unique QC output files for the station is provided (multiple header records, QC over all)
    - **'net':** a set of individual QC output files for all stations (single header records)
    - **'cmb':** a combination of both above

Getting help

Get help (command-line options)

$$ Anubis –h

G-Nut/Anubis [2.3] compiled: Oct 11 2020 13:09:54 (Rev: 2958)
Usage:

-h | --help	.. this help
-V	.. software version
-x file	.. configuration input file
-z file	.. configuration output file
-X	.. configuration default values (stdout)
-Z	.. log-file without time stamps
:arguments	.. command-line arguments for detail XML settings (*:element:sub-element etc.*)

Get help (XML configuration)

$$ Anubis –X > default_options.cfg ➔

```
<?xml version="1.0" encoding="UTF-8" standalone="yes" ?>
<!DOCTYPE config>

<config>

 <!-- general description:
        beg    .. beg time            (default: empty=all)
        end    .. end time            (default: empty=all)
        int    .. data sampling       (default: empty=30s)
        rec    .. receiver(s)         (default: empty=all)
        sys    .. GNSS system(s)      (default: empty=all)
  -->
        ..... (default) settings description .....
```

Standard XML configuration

Anubis 3 (Pro/RT) - configuration changes

➔ **Legacy settings automatically adapted** (don't mix old & new elements!)

➔ **New setting used in all examples in this tutorial** (i.e. Anubis 3.x settings)

Modified elements:

- <inputs> → <inp> e.g. :inp:rinexo INP_RINEX
- <outputs> → <out> e.g. :out:rinexo OUT_RINEX
- <rec> → <site> e.g. :site[NAME]:name=SITE_NAME

New element and settings:

- <nav> .. navigation data handling
- chk_record=bool .. [old] moved from <inputs chk_nav=bool>
- chk_health=bool .. [old] moved from <inputs chk_health=bool>
- chk_duplic=bool .. [new] set on filtering out redundant navigation data

- key_tot=bool .. [new] set on ToC for navigation data sorting
- chk_tot=bool .. [new] set on ToT checking (nav data validity)
- ext_nav=double .. [new] multiplicator for artificial extension of nav validity

+ nav data consolidation (BRDC output: requires multiple and redundant nav files):

- chk_header=bool .. [new] consolidate output file header
- chk_params=bool .. [new] consolidate key navigation parameters
- chk_others=bool .. [new] consolidate bias/health/source navigation parameters

New attributes for a multiple files processing:

- <gen max_cores=int> .. maximum number of threads in a parallel processing
- <gen max_files=int> .. maximum number of files in a single processing batch

Anubis 3 (Pro/RT) – configuration aliases

Prefix '--' for new command-line short cuts (configuration aliases)

--rinexo	file	=	:inp:rinexo	.. input RINEX observation file(s)
--rinexn	file	=	:inp:rinexn	.. input RINEX navigation file(s)
--sinex	file	=	:inp:sinex	.. input SINEX meta data file(s)
--xtr	file	=	:out:xtr	.. output QC xtr file
--xml	file	=	:out:xml	.. output QC xml file
--json	file	=	:out:json	.. output QC json file
--rxn2	file	=	:out:rinexn2	.. output RINEX 2 navigation file
--rxn3	file	=	:out:rinexn3	.. output RINEX 3 navigation file
--rxo2	file	=	:out:rinexo2	.. output RINEX 2 observation file
--rxo3	file	=	:out:rinexo3	.. output RINEX 3 observation file
--crx2	file	=	:out:crinexo2	.. output RINEX 2 observation file (Hatanaka compressed)
--crx3	file	=	:out:crinexo3	.. output RINEX 3 observation file (Hatanaka compressed)
--log	file	=	:out:log	.. output log file
--verb=int		=	:out:verb=int	.. output log verbosity

Default metadata (general modification for any station) - useful for EDIT & THIN QC modes

--modify=bool	=	:site[*]:modify=bool	.. site modification (true=enabled)

Configuration – data filtering

$$ Anubis -x MY.cfg

Anubis-Pro/3.x - advanced settings

```
<?xml version="1.0" encoding="UTF-8" standalone="yes" ?>
<!DOCTYPE config>
<config>

<gen max_cores=0  max_files=30 >
        <beg>      2017-05-29  00:00:00    </beg>
        <end>      2017-05-29  23:59:30    </end>
        <int>  30                          </int>
        <sys>  GPS GLO GAL BDS SBS QZS IRN  </sys>
        <rec>  BRUX GOPE MATE  POTS WTZR    </rec>
</gen>

<sys id="GPS">
  <sat> G01 G02 G04 </sat>
  <type> C L D S P </type
  <band> 1 2 5 </band>
  <attr> A B C D I L M N P Q S W X Y Z </attr>
  <gobs> C1P C2P L1P L2P </gobs>
</sys>

<sys id="GAL">
  <sat> E01 E02 E04 </sat>
  <nav> FNAV   INAV_E01   INAV_E07 </sat>
  <type> C L D S P </type>
  <band> 1 2 5 6 7 8 </band>
  <attr> A B C D I L M N P Q S W X Y Z </attr>
</sys>
                <!-- … OTHER SETTINGS … -->
</config>
```

```
<!– settings for parallel processing (Default: 0=any) -->
<!-- begin time RECOMMENDED (Default: first observation) -->
<!-- end time: RECOMMENDED (Default: last observation) -->
<!-- sampling: RECOMMENDED (Default: estimated from file) -->
<!– list of GNSS (Default: from the file; use '–' to remove any) -->
<!– list of station names (Default: site names from files)-->

<!– GPS filtering-->
<!-- list of satellites-->
<!-- list of observation types -->
<!-- list of observation bands-->
<!-- list of observation attributes -->
<!-- list of observation codes (has priority if requested) -->

<!– Galileo filtering-->
<!-- list of satellites -->
<!-- list of satellites -->
<!-- list of observation types -->
<!-- list of observation bands-->
<!-- list of observation attributes -->
```

Configuration – inputs/outputs and QC

$$ Anubis -x MY.cfg

Anubis-Pro/3.x - advanced settings

```
<!-- ... DATA FILTERING ... -->
<inp>
        <rinexn>    DATA/brdm1500.17p.gz                    </rinexn>    <!-- GNSS navigations files -->
        <sp3>       DATA/igs119512.sp3.gz                   </sp3>       <!-- GNSS orbit products (extra input) -->
        <rinexo>    DATA/brux1500.17o  DATA/gope1500.17o
                    DATA/mate1500.17o
                    DATA/mate1500.17o  DATA/pots1500.17o </rinexo>    <!-- GNSS observation files -->
</inp>

<out>
        <xtr>  LOG/EUREF/2017/150/$(rec)171500.xtr      </xtr>     <!-- native Anubis's report, may use $(rec) variable -->
        <xml>  LOG/EUREF/2017/150/$(rec)171500.xml      </xml>     <!-- standard QC-XML file, may use $(rec) variable -->
        <json>  LOG/EUREF/2017/150/$(rec)171500.json    </json>    <!-- file suitable for plotting, may use $(rec) variable -->
        <log>  LOG/EUREF/2017/150/anub171500.log        </log>     <!-- Anubis log may be used at Linux /dev/stdout -->
</out>

<qc     sec_sum="2"      <!-- [0-9] .. summary statistics (complete info only if navigation available) -->
        sec_hdr="2"      <!-- [0-9] .. header metadata information -->
        sec_obs="2"      <!-- [0-9] .. observation statistics -->
        sec_gap="2"      <!-- [0-9] .. data gaps and small pieces -->
        sec_pre="2"      <!-- [0-9] .. cycle-slip, clock-jumps -->
        sec_bnd="2"      <!-- [0-9] .. observation bands -->
        sec_est="2“      <!-- [0-9] .. estimated values (only if navigation available) -->
        sec_ele="2"      <!-- [0-9] .. azimuth/elevation (only if navigation available) -->
        sec_mpx="2"      <!-- [0-9] .. multipath calculation -->
        sec_snr="2"      <!-- [0-9] .. signal-to-noise ratio -->
        sec_sat="2"      <!-- [0-9] .. satellite information (only if navigation data available) -->
        sec_KPI="2"      <!-- [0-9] .. positioning KPIs (only if navigation data available) -->
/>
```

Advanced use cases of XML configuration

$$ Anubis -x MY.cfg

Anubis-Pro/3.x - advanced settings

```
-------------------------------------------------------------------------------------------------------------------------
<gen> <sys> –IRN –SBS –QZS </sys>   <!-- …  GEN SETTINGS -->  </gen> <!– default all systems, but regional/augmentation -->

-------------------------------------------------------------------------------------------------------------------------
<nav chk_record="true“ chk_health=“true”>  <!-- …  NAV SETTINGS -->  </nav> <!– NAV range-check, use healthy status -->

-------------------------------------------------------------------------------------------------------------------------
<inp>  <rinexo> GOPE00CZE_R_20203000000_01D_30S_MO.crx.gz                    <!– RINEX3 Hatanaka+GZ inputs –>

                ZIMM300.20d.Z   </rinexo>                                    <!– RINEX2 Hatanaka+Z inputs –>

      <rinexn> BRDC00GOP_R_20203000000_01D_MO.rnx.gz  </rinexn>          <!– RINEX3 navigation  input -->
</inp>
-------------------------------------------------------------------------------------------------------------------------
<out verb=“1“ append=“true”>  <!-- …  OUT SETTINGS -->   </out> <!– verbosity level, append mode -->

-------------------------------------------------------------------------------------------------------------------------
<out>                                                          <!– output navigation data after concatenation & consolidation-->

            <rinexn2> brdc1000.18n                                  </rinexn2>  <!– save RINEX 2 nav data  (for INGLE GNSS)  -->
            <rinexn3> BRD00GOP_R_2018100000_01D__MN.rnx.gz   </rinexn3>  <!– save RINEX 3 nav data  (for MULTI-GNSS) -->
            <rinexo> brdc1000.18n                                  </rinexn2>  <!– save RINEX 2 nav data  (for INGLE GNSS)  -->
            <rinexo> BRD00GOP_R_2018100000_01D__MN.rnx.gz   </rinexn3>  <!– save RINEX 3 nav data  (for MULTI-GNSS) -->

</out>
-------------------------------------------------------------------------------------------------------------------------
<proc auto_band=“true“    minimum_elev=“10” />                  <!– band selection mode, SPP elevation cut-off-->

-------------------------------------------------------------------------------------------------------------------------
<qc              <!-- …  QC SETTINGS … -->
            int_stp="900"   <!-- int[s] .. reporting interval -->
            int_gap="600"   <!-- int[s] .. interval for gaps -->
            int_pcs="1800“ <!-- int[s] .. interval for small pieces -->
            mpx_nep="20“  <!– int[#] .. epochs for MP -->
            mpx_lim="3.0"  <!– dbl .. sigma-factor MP cycle-slip/outlier detection -->
            col_sat="32"     <!-- int[#] .. satellites reported -->
            ele_cut="15"     <!-- int[deg] .. user elev cut-off (only for expt/have) -->
            pos_kin="false“ <!-- bool .. kinematic receiver (true = kinematic) -->
/>

-------------------------------------------------------------------------------------------------------------------------
<rec id=“GOPE“   name=“GOPE”  desc=“” domes=“”  X=“”  Y=“”  Z=“” REC=“” ANT=“” />    <!– user metadata for receivers-->

            ….. (optionally) time-specific settings: ANT, REC, X, Y, Z dX, dY, dZ, etc.
</rec>
```

Advanced command-line settings

Advanced command-line settings

- starting Anubis without preparing XML configuration in advance
- modifying Anubis initial XML configuration (adding/modifying only, no removal !)
- saving Anubis command-line configuration or modification **$$ Anubis -Z NEW.cfg**

Anubis-Pro/3.x - advanced settings

Flexible command-line arguments:

➔ full configuration can be handled as a sequence of **command-line arguments**:

***:element*:sub-element "SUB-ELEMENTS"**	e.g. :out:log MY.LOG
***:element:sub-element*:attribute=ATRIBUTE**	e.g. :out:verb=2

- Anubis started with **command-line arguments only**

```
$$ Anubis   :inp:rinexo  GOPE1730.17o   :inp:rinexn   BRDC173O.17p   \
            :out:xml     GOPE1730.xml   :out:xtr      GOPE1730.xtr   \
            :out:log     GOPE1730.log   :out:json     GOPE1730.json  \
            :gen:beg "2017-06-22 00:00:00" :gen:end "2017-06-23 00:00:00"
```

- command-line arguments **may overwrite an initial XML configuration**

```
$$ Anubis  -x MY.CFG   :out:log MY.LOG   :out:verb=3   :gen:sys "GPS GLO"
```

Examples of command-line settings

All the settings via command line arguments:

```
$$ Anubis \
        :inp:rinexo     GOPE1730.17o        :inp:rinexn     BRDC173O.17p    \
        :out:xml        GOPE1730.xml        :out:xtr        GOPE1730.xtr    \
        :out:log        GOPE1730.log        :out:verb=1                     \
        :gen:sys        "GPS GLO"           :gen:int 30                     \
        :gen:beg        "2017-06-22 00:00:00"   :gen:end "2017-06-23 00:00:00"
```

Initial XML settings and its modification:

- ✓ an initial configuration **(-x MY.CFG)**, e.g. generic QC settings
- ✓ resulting configuration **(-z MY_USED.CFG)**, e.g. dynamic lists of files for input directories
- ✓ each command-line argument overwrites(!) the initial XML configuration

```
$$ year="2020"
$$ doy="173"
$$ Anubis -x MY.CFG      -z MY_USED.CFG                                  \
        :inp:rinexo "$(ls DIR/????[0-9][0-9]DEU_*_30S_MO.rnx)"           \
        :inp:rinexn "$(ls DIR/BRDC[0-9][0-9]IGS*_MN.rnx.gz)"             \
        :out:xtr  $OUTDIR/'$(rec)'_${year}${doy}.xtr
```

Few examples of special settings

User elevation angle settings for existing/expected ratio statistics

→ ratio in sec_sum, not elevation-dependent data filtering!

$$ Anubis –x MY.cfg :qc:ele_cut=10 *<qc ele_cut="10" />*

Elevation angle cut-off settings for positioning

→ Used in Standard Point Positioning (SPP) solution

$$ Anubis –x MY.cfg :proc:minimum_elev=5 *<proc minimum_elev="5" />*

Satellite healthy status

→ Apply satellite health status in various QC procedures: 1) all, 2) statistics, 3) position

$$ Anubis –x MY.cfg :qc:use_health="position" *<qc use_health="position" />*

Kinematic positioning

→ Rover mode considered in pre-processing, positioning and elevation/azimuth calculations

$$ Anubis –x MY.cfg :qc:pos_kin=true *<qc pos_kin="true" />*

High-rate data processing

→ QC statistics normalized to 1sec sampling (noted in the report)!

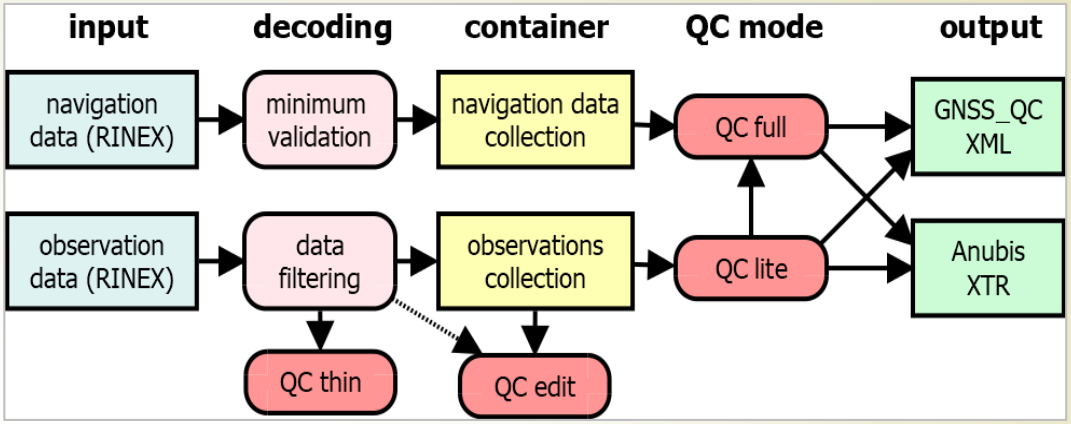
$$ Anubis –x MY.cfg :gen:int 0.01 *<int> 0.01 </int>*

Operation modes

Anubis/Pro operating modes & inputs

Operating modes:

- **Thin mode** (header/meta control)
- **Edit mode** (data/metadata)
- **Lite mode** (quantitative control)
- **Full mode** (qualitative + complex)
- **Summary** (full mode with less output, i.e. some processes run on background)



Inputs for various operating modes:

- ✓ File format header & meta data control for **single or multiple files** (decoding header only)
  - ✓ Format – check availability of mandatory & optional RINEX 2/3 header fields
  - ✓ Meta data – confronts file(s) header(s) user settings provided through **XML<SITE>** or **SINEX** input
  - ✓ ***Note:*** *provides ERROR/WARNING messages on error output and with each ERROR increases process return CODE*
- ✓ File editing of **a single data file** decoding, filtering & modifying:
  - ✓ Header (fast edit) – no changes in data-related block (plan for Anubis Pro 3.1)
  - ✓ Data (full edit) – changes in both header and data blocks (and data may be re-organized by Anubis)
  - ✓ ***Note:*** *User metadata provided through **XML<SITE>** or **SINEX** input*
- ✓ **Quantitative control** requires **observation data**, can be performed in QC lite mode
- ✓ **Qualitative/complex control** requires both **observation and navigation data,** includes processing algorithms and approximations, needs to be performed in QC full mode

Anubis/Pro operating modes settings

- Operating modes can be configured only via a **command-line** !

  Anubis-Pro **--thin | --edit | --summ | --full | --lite | --kpis**

- Each mode defines a priori settings for individual XTR sections (see table)
- A priori setting for each section can be still modified in a command-line sequence

Operating mode	Thin	Edit	Lite	Full	Summ	KPIs
sec_sum=	0	0	1	2	2	3
sec_hdr=	0	0	1	1	1	1
sec_obs=	0	0	1	1	1	1
sec_gap=	0	0	1	1	-1	1
sec_bnd=	0	0	1	1	-1	1
sec_pre=	0	0	1	1	-1	0
sec_est=	0	0	0	1	0	0
sec_ele=	0	0	0	1	0	0
sec_mpx=	0	0	0	1	-1	-1
sec_snr=	0	0	0	1	0	0
sec_sat=	0	0	0	1	0	0
sec_kpi=	0	0	0	0	0	9

Note: *negative verbosity represents forced processing which is mandatory, but remains silent*

Operating modes examples

QC thin mode:

EXIT + RETURN CODE after reporting header issues → no QC, no BRDC needed

$$ Anubis --thin --rinexo IN_RINEX ; (echo STATUS=$?)

QC lite mode (input observations RINEX):

quantitative control – no navigation messages (BRDC) used

$$ Anubis --lite --rinexo IN_RINEX --xtr MY.xtr -z MY.cfg --log MY.log --verb=1

QC full/summ mode (input observation + navigation RINEX):

qualitative + complex control – requires navigation data

$$ Anubis --full --log MY.log --xtr MY.xtr --xml MY.xml --json MY.json

$$ Anubis --summ --log MY.log --xtr MY.xtr --xml MY.xml --json MY.json

EDIT mode (input observations RINEX):

RINEX data filtering & header editing

$$ Anubis --edit -x EDIT.cfg :inp:rinexo IN_RINEXo3 :out:rinexo3 OUT_RINEXo3

$$ Anubis --edit -x EDIT.cfg :inp:rinexo IN_RINEXo2 :out:rinexo2 OUT_RINEXo2

CC mode:

output merged navigation/observation files into a single one

$$ Anubis --rinexo "FILE1 FILE2 FILE3" :out:rinexo3 OUT_RINEXo3

$$ Anubis --rinexn "FILE1 FILE2 FILE3" :out:rinexn3 OUT_RINEXn3

THIN mode

READ HEADER + EXIT CODE: reporting header format & metadata issues vs USER settings

USER settings: can be provided either from XML configuration (1) or SINEX file (2)

$$ Anubis --thin --rinexo MY.rxo --log MY.log --verb=2 -x META.xml

$$ Anubis --thin --rinexo MY.rxo --log MY.log --verb=2 --sinex META.snx

Example: Anubis-Pro --thin :inp:rinexo "$(ls obs/2020/300/*crx.gz)" -x My-Stations.xml

5 errors: $?=2 (return CODE)

(sample of metadata incompatibilities)

*** Warning: RINEX:HDR !! AZGR00PRT - object inconsistent 2020-10-26 00:00:00 DOMES: 31902M004 !! AZGR

*** Error: RINEX:HDR !! ABFC00NGA - object inconsistent 2020-10-26 00:00:00 ECC: 0.0000 0.0000 0.1800 !! 0.0000 0.0000 0.1710

*** Warning: RINEX:HDR !! GR0200ITA - object inconsistent 2020-10-26 00:00:00 DOMES: 12724M005 !! Unknown

*** Error: RINEX:HDR !! GR0200ITA - object inconsistent 2020-10-26 00:00:00 ANT: SEPCHOKE_B3E6 NONE !! SEPCHOKE_B3E6

*** Warning: RINEX:HDR !! MPTB00MOZ - object inconsistent 2020-10-26 00:00:00 DOMES: 39308M001 !! Unknown

*** Error: RINEX:HDR !! PAGU00PRT - object inconsistent 2020-10-26 00:00:00 ANT: TRM55971.00 NONE !! TRM57971.00 NONE

(samples of format incompatibility)

*** Warning: INTERVAL not available! .. file://obs/2020/300/ABFC00NGA_R_20203000000_01D_30S_MO.crx.gz

*** Error: GLO BIASES not available! .. file://obs/2020/300/FTNA00WLF_R_20203000000_01D_30S_MO.crx.gz

*** Error: GLO SLOT/FREQ not available! .. file://obs/2020/300/PAGU00PRT_R_20203000000_01D_30S_MO.crx.gz

*** Warning: BDS band changed: B1->B2 for RINEX 3.02 .. file://obs/2020/300/SUBI00PRT_R_20203000000_01D_30S_MO.crx.gz

QC modes (Anubis Pro)

Input: (Hatanaka | +Z | +gz) RINEXo v2 | v3 file for input & output (any combination)

Pre-settings: --lite | --full | --summ

$$ Anubis --lite --rinexo MY.rxo --xtr MY.xtr

$$ Anubis --full --rinexo MY.rxo --xtr MY.xtr --xml MY.xml --json MY.json

$$ Anubis --summ --rinexo MY.rxo --xtr MY.xtr --xml MY.xml --json MY.json

CUI settings example:

```
Anubis-Pro    --summ                                          \
              --out /dev/stdout --verb=2                      \
                :gen:beg "YYYY-MM-DD HR:MN:SC"                \    # define interval
                :gen:end "YYYY-MM-DD HR:MN:SC"                \    # define interval
                :gen:sys "GPS GAL GLO BDS"                    \    # filter out regional systems
                :inp:rinexo  "RINEXo2 RINEXo3 RINEXo3"        \    # input observation files
                :inp:rinexn  "RINEXn2 RINEXn3 RINEXn3"        \    # NAV data - optimally BRDC
                :out:xtr     "\$(rec)-%M-%d-%m.xtr"           \    # XTR QC output
                :out:xml     "\$(rec)-%M-%d-%m.xml"           \    # XML QC summary
                :out:json    "\$(rec)-%M-%d-%m.json"          \    # JSON QC high-resolution data
                :qc:sec_pos=2 :qc:sec_ele=2 :qc:sec_mpx=2     \    # modify SUMM pre-settings
                :qc:use_healthy="all"                         \    # apply SAT health in all sections
                :gen:max_cores=0   :gen:max_files=30               # all CPUs for max 30 site-batch
```

EDIT meta data (Anubis Pro)

Input: (Hatanaka | +Z | +gz) RINEXo v2 | v3 file for input & output (any combination)

EDIT/USER settings: can be provided either from XML configuration (1) or SINEX file (2)

$$ Anubis --edit --rinexo MY.rxo --log MY.log --verb=2 -x META.xml

$$ Anubis --edit --rinexo MY.rxo --log MY.log --verb=2 --sinex META.snx

Current limitations:

- *only a single file is currently supported (a multi-editing is foreseen in future release)*
- *only RINEX2->RINEX2 / RINEX3->RINEX3 editing and data filtering is supported*
- *only principal RINEX header metadata is editable so far*

CUI settings example: *(a priori USER XML or SINEX input metadata can be combined with 'XML-modify' flag)*

```
Anubis-Pro    --edit                                          \
                :inp:rinexo RINEXo2   :out OUT_RINEXo2        \
                :site[SITE].name="MY_NAME"                    \
                :site[SITE].domes="MY_DOMES"                  \
                :site[SITE].ant="MY_ANT+DOME"                 \
                :site[SITE].rec="MY_REC"                      \
                :site[SITE].X="1111111.000"                   \
                :site[SITE].Y="2222222.000"                   \
                :site[SITE].Z="3333333.000"                   \
                :site[SITE].DN="1.0"                          \
                :site[SITE].DE="2.0"                          \
                :site[SITE].DU="3.0"                          \
                :gen:sys "GPS GAL GLO BDS"                        # FILTER OUT REGIONAL SYS
```

Note: QC and data filtering

QC and data filtering:

- QC procedures are performed on filtered data
- QC results are normalized to 1Hz in case of high-rate data (>1Hz)
- Filters are performed during data decoding by applying
  - **<gen>** general settings : <int>, <beg>, <end>, <sys>
  - **<sys>** individual GNSS settings : <nav>, <sat>, <type>, <band>, <attr>, <gobs>
- Filtered data counts are recorded in QC-XML output (xINT, xBEG, xEND, xSYS)
- QC on RT streams may apply 30s data filtering for QC comparable to daily RINEX files

Internal handling of GNSS frequency bands:

- **BEIDOU:** frequency mixing
  - → B1 frequency from BeiDou-III is accepted from RINEX 3.04
  - → B1 frequency from BeiDou is corrected to B2 for RINEX 3.02 (during data filtering)
- **GLONASS:** multipath estimates possible only with satellite slot numbers available
  - → requires navigation data/RINEX 3.03 requested!

Full QC: GOP BRDC archive

Full QC requires optimal information about all GNSS satellites
➔ need for a reliable archive of GNSS navigation files (BRDC)

A unique multi-constellation historical archive (globally merged, controlled and consolidated) is maintained by

Geodetic Observatory Pecny (GOP) of the
Research Institute of Geodesy, Topography and Cartography (RIGTC)

primarily in support of multi-GNSS data QC, and for other purposes such as signal-in-space error monitoring, data processing etc.

DOI: 10.24414/c4ba-kf16

Range: 01/1994 - open

Access: ROB: **ftp://epncb.oma.be/pub/obs/BRDC/WWWW/**
GOP: **ftp://ftp.pecny.cz/LDC/orbits_brd/gop3/WWWW/**

➔ **BRDC00GOP_R_YYYYDOY0000_01D_MN.rnx.gz**

with WWWW = GPS week, YYYY = Year, DOY = day of year

Full QC: handling satellite healthy status

Satellite health status is necessarily considered for a comparable performance of various stations (sites tracking all or healthy satellites)

Setting attributes for QC-specific satellite health usage:

- **<nav>** chk_health="true | false"
- **<qc>** use_health="position | statistics | all"

Configuration attribute	**Value**	**Value**	**Value**	**Value**
:nav:chk_health= *:qc:use_health=*	*"false"* *n/a*	*"true"* *"position"*	*"true"* *"statistics"*	*"true"* *"all"*
Functioning	**Used satellites**	**Used satellites**	**Used satellites**	**Used satellites**
Positioning	All	**healthy**	**healthy**	**healthy**
Statistics Observations	All All	All All	**healthy** **healthy**	**healthy** **healthy**
Azimuth/ elevations Frequency/bands	All All	All All	All All	**healthy** **healthy**
Phase pre-processing Code multipath and noise Signal-to-noise ratio Satellite information	All All All All	All All All All	All All All All	All All All All

CC & QC of navigation data

… merging and checking navigation data (e.g. GOP'BRDC archive)

partly supported by G-Nut/Anubis, optimally implemented in G-Nut/Aset

- **NAV data managing (G-Nut/Anubis)**
  - Concatenation
  - Quality control
  - Saving in RINEX2 (system-specific) / RINEX3 (multi-GNSS)

  … RINEX2: can be saved only in case of a single GNSS data
- **NAV concatenation (G-Nut/Anubis)**
  - Enabling/disabling NAV record duplicitous (special CMD settings)
  - X levels: site-specific RINEX2/RINEX3 files
- **NAV QC (optimally implemented in G-Nut/Aset)**
  - Navigation data range check (internal, message-specific)
  - Time-series analysis & penalty system (internal, daily files)
  - Comparison to precise SP3 products (external, daily files)

Output formats

Anubis outputs

Actual configuration file – command-line option (-Z file.cfg)

→ Save the final configuration (includes modifications from the command line)

Log output – <LOG> file

→ File log according to the verbosity requested (in Linux STDOUT could also be used)

Native Anubis QC output – <XTR> file

→ Full QC report with system/satellite/epoch-specific outputs, section verbosity (on/off)

→ Easy to grep, but merging relevant information needs a tool for the XTR file processing

EPOS QC-XML standard output – <XML> file

→ A minimum QC metadata, i.e. values characterizing actual content of the file

→ XSD supporting validation of the XML format/content

→ Designed for EPOS GNSS TCS and populated to the EPOS GNSS database

→ Unique characteristics of actual content of the file (suitable for remote file comparison)

JSON output - <JSON> file **(G-Nut/Anubis Pro | RT)**

→ High-resolution data suitable for dissemination and generating data-file plots

→ Fundamental metadata, positioning and epoch-/satellite-/signal-specific QC results

I/O naming conventions

Naming conventions are compliant with the RINEX3 specification:

- **System:** GNSS (3-char/1-char satellite system identification)
  - GPS NAVSTAR (GPS/G), GLONASS (GLO/R), Galileo (GAL/E), BeiDou (BDS/C),
  - QZSS (QZS/J), SBAS (SBS/S), IRNSS (IRN/I)
- **Satellite:** GNSS satellites
  - 3chars: G01..., R02..., E03…, C04…
- **Band:** observation frequency/band number
  - 1char (number): 1, 2, 3, ….
- **Signal:** observation attribute characterizing its tracking mode
  - 1char: A, B, C, …
- **Observation type:** pseudo range, carrier phase, Doppler, signal strength
  - 1char: C or P, L, D, S
- **Observation code:** combination of observation type + band + attribute
  - 3char: e.g. P1C, or legacy C1, P1
- **Epoch:** observation timestamp for synchronously observed satellites

Log example

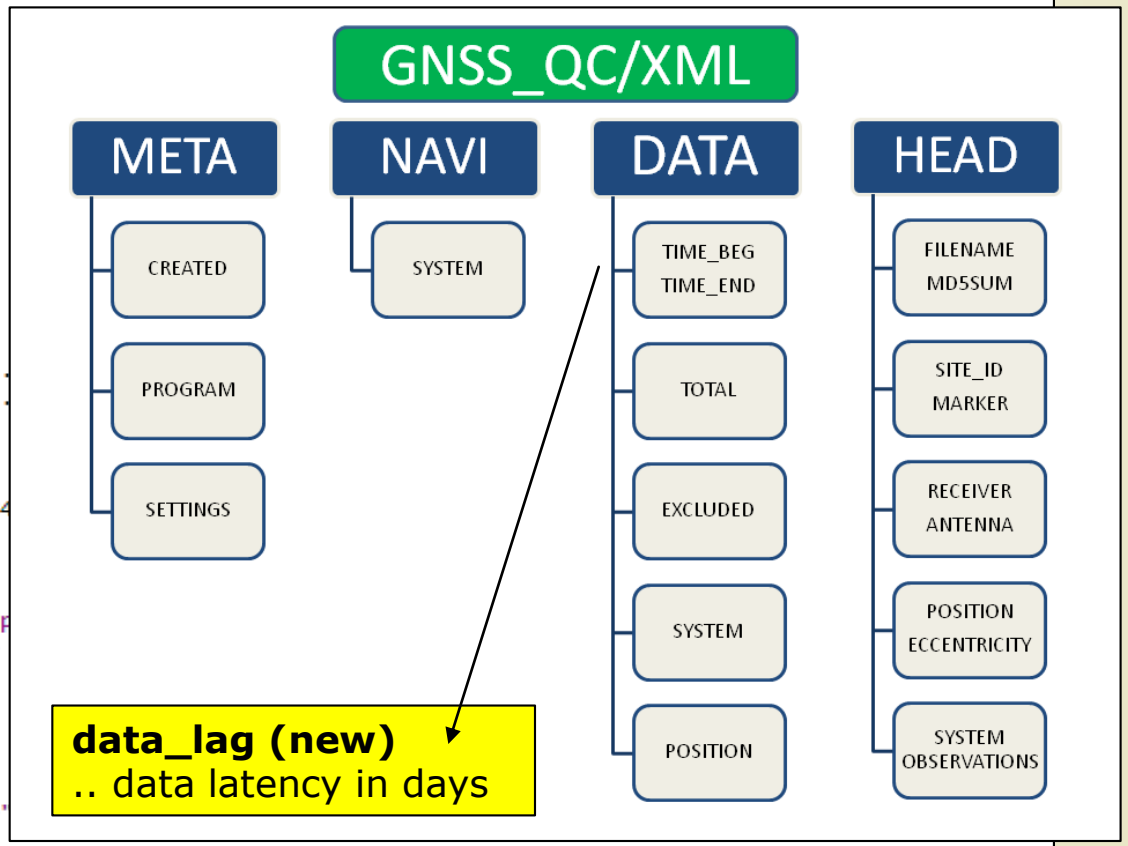
$$ Anubis –x BRUX_EXAMPLE.cfg :out:log /dev/stdout :out:verb=1

```
2017-10-23 16:40:38 [main:0] READ: file://TEST/BRDC00IGS_R_20172900000_01D_MN.rnx.gz  1.729 sec
2017-10-23 16:40:38 [main:1] READ: file://TEST/BRUX2900.17O started
2017-10-23 16:40:38 [rinexo:0] FILE: short site name: BRUX (4-CH)
2017-10-23 16:40:38 [gallobj:1] add new obj BRUX
2017-10-23 16:40:38 [rinex:1] Object created, using RINEX header: BRUX 2017-10-17 00:00:00
2017-10-23 16:40:38 [gobj:0] Warning: object BRUX completed (Name): BRUX
2017-10-23 16:40:38 [gobj:0] Warning: object BRUX completed (Domes): 13101M010
2017-10-23 16:40:38 [gobj:0] Warning: object BRUX completed (Antenna): JAVRINGANT_DM   NONE
2017-10-23 16:40:38 [gobj:0] Warning: object BRUX completed (Coordinates):  4027881.848  306998.261  4919498.655
2017-10-23 16:40:38 [gobj:0] Warning: object BRUX completed (NEU Eccentricity):  0.001  0.000  0.469
2017-10-23 16:40:38 [gobj:0] Warning: object BRUX completed (XYZ Eccentricity):  0.295  0.022  0.364
2017-10-23 16:40:38 [grec:0] Warning: object BRUX completed (Receiver): SEPT POLARX4TR
2017-10-23 16:40:41 [main:0] READ: file://TEST/BRUX2900.17O  3.016 sec
2017-10-23 16:40:41 [main:0] Error: RUN BY not available!
2017-10-23 16:40:41 [main:0] Warning: LEAPSEC not available!
2017-10-23 16:40:41 [main:0] Error: GLO BIASES not available!
2017-10-23 16:40:41 [main:1] Single-thread summary: BRUX started
2017-10-23 16:40:41 [gxtrqc:0] SITE: BRUX TEST/LOG/BRUX172900.xtr
2017-10-23 16:40:41 [gxtrqc:1] Sync XTR step 2017-10-17 00:00:00 -> 2017-10-17 00:00:00
2017-10-23 16:40:41 [gxtrqc:0] Warning: no receiver settings.
2017-10-23 16:40:41 [gxtrqc:0] BRUX header [9]:  0.000
2017-10-23 16:40:43 [gxtrqc:0] BRUX satview[9]:  2.000
2017-10-23 16:40:44 [gxtrqc:0] BRUX obsview[9]:  1.000
2017-10-23 16:40:44 [gxtrqc:0] BRUX estima [9]:  0.000
2017-10-23 16:40:44 [gxtrqc:0] BRUX observ [9]:  0.000
2017-10-23 16:40:45 [gxtrqc:0] BRUX nbands [9]:  1.000
2017-10-23 16:40:45 [gxtrqc:0] BRUX pieces [9]:  0.000
2017-10-23 16:40:51 [gxtrqc:0] BRUX prepro [9]:  6.000
2017-10-23 16:40:53 [gxtrqc:0] BRUX skyplt [9]:  2.000
2017-10-23 16:40:56 [gxtrqc:0] BRUX mlpath [9]:  3.000
2017-10-23 16:40:57 [gxtrqc:0] BRUX snoise [9]:  1.000
2017-10-23 16:40:57 [gxtrqc:0] BRUX summar [9]:  0.000
2017-10-23 16:40:57 [main:0] Single-thread summary: BRUX  16.602 sec
2017-10-23 16:40:57 [main:0] total time:  21.467 sec
```

QC-XML standard format (EPOS)

- defined specifically for EPOS-IP EPOS DB
- particularly to summarize a minimum QC parameters

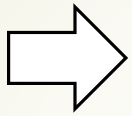
```
▼<QC_GNSS xmlns="https://software.pecny.cz/anubis" xmlns:gml="http://www.opengis.net/gml/3.2" xmlns:xsi="https://
 gml:id="KISA_20170605T000000_20170605T235930" xsi:schemaLocation="https://software.pecny.cz/anubis qc_gnss.xsd"
  ▼<meta>
     <created>2017-11-24T14:30:51</created>
     <program>G-Nut/Anubis [2.1.0]</program>
    ▶<settings>...</settings>
   </meta>
  ▶<navi>...</navi>
  ▼<data>
     <time_beg>2017-06-05T00:00:00</time_beg>
     <time_end>2017-06-05T23:59:30</time_end>
     <data_int>30.00</data_int>
     <numb_epo>2880</numb_epo>
     <numb_gap>0</numb_gap>
    ▶<total>...</total>
    ▶<excluded>...</excluded>
    ▶<system type="GPS" nsat="31" xele="50">...
    ▶<position type="GPS" source="analysis">...
   </data>
  ▼<head file_numb="1">
     <file_name>KISA1560.17O</file_name>
     <file_md5sum>d41d8cd98f00b204e9800998ecf84
     <file_format>RINEX 2.11</file_format>
     <site_id>KISA</site_id>
     <marker_numb>KISA</marker_numb>
     <receiver_type>TRIMBLE NETR9</receiver_typ
     <receiver_numb>5418R48284</receiver_numb>
     <antenna_type>TRM57971.00</antenna_type>
     <antenna_dome/>
     <antenna_numb>5000119409</antenna_numb>
     <software>teqc 2010Oct21</software>
     <data_int>0.000</data_int>
    ▶<position type="GNS" source="rinex_header"
    ▶<system type="GPS">...</system>
   </head>
 </QC_GNSS>
```



JSON high-resolution format

- defined specifically for a single file plotting (a condensed output)
- Includes a full resolution epoch-/satellite-/signal QC data

```
{
  "META": {"key": "value", … },
  "DATA": {"POS": … },
          {"SAT": … }
},
```




```
"META": {
    "marker": "GOP7",
    "number": "11502M006",
    "version": "3.02",
    "anttype": "SEPCHOKE_B3E6",
    "antdome": "SPKE",
    "antnumb": "5287",
    "rectype": "TRIMBLE NETR9",
    "recnumb": "49084",
    "recvers": "5.37"
}
```



```
"DATA": {
  "POS": {
    "GPS": {
      "2020-08-31T00:00:00": {
        "XYZ": [
          3979326.8572,
          1050313.9106,
          4857068.3713,
          -2.0514
        ],
        "SAT": [
          12,
          2
        ],
        "DOP": [
          1.5,
          1.4,
          0.6,
          1.1
        ],
        "NEU": [
          -3.548,
          -0.651,
          7.7434
        ]
      }
    }
  }
}
```



```
"DATA": {
  "SAT": {
    "GPS": {
      "2020-08-31T00:00:00": {
        "06": {
          "AZI": 108.029,
          "ELE": 7.322,
          "CBN": 3,
          "LBN": 3,
          "S1C": 34.1,
          "S2W": 29.3,
          "S2X": 37.5,
          "S5X": 40.7,
          "M1C": 40.52,
          "M2W": 27.17,
          "M2X": 42.25,
          "M5X": 30.83
        },
        "10": {
          "AZI": 286.661,
          "ELE": 12.563,
          "CBN": 3,
          "LBN": 3,
          "S1C": 37.3,
          "S2W": 21.7,
          "S2X": 37.9,
          "S5X": 41.9,
          "M1C": 42.13,
          "M2W": 20.77,
          "M2X": 35.46,
          "M5X": 39.33
        }
      }
    }
  }
}
```


Hash representations:

{META}{KEY} = value; # metadata
{DATA}{POS}{SYS}{EPO} {XYZ|DOP|SAT|NEU} = array; # position
{DATA}{SAT}{SYS}{EPO}{PRN}{AZI|ELE|MPT|SNR...} = value; # sat info

Current values for DATA->POS arrays:

- ❑ XYZ - X, Y, Z, CLK
- ❑ SAT - # of used satellites, # of excluded satellites
- ❑ DOP - gdop, pdop, hdop, vdop
- ❑ NEU - N,E,U residuals (to Sys-specific REF XYZ)

Current values for DATA->SAT maps:

- ❑ AZI/ELE - azimuth/elevation
- ❑ CBN/LBN - # of code/phase frequency bands
- ❑ S??/M?? - SNR/MPT signal-specific (??) values

XTR format description

XTR output - Sections

[sec_sum] Summary information: Overview over all the systems. System-specific statistics: epochs, usable/incomplete, data interruptions, clock jumps, multipath, observation-specific data percentages for zero/user elevation cut-off angle, satellite view information.

[sec_hdr] Header information: Summary of site meta data stemming from file headers and a user configuration. Reports of signals/satellites availability from file header and actual data in the file.

[sec_est] Parameter estimates: Site coordinates calculated using code observations and navigation data. Standalone GNSS processing enables comparisons of observation and navigation data quality.

[sec_obs] Observation types: Actual content of data file: constellations, satellites, observation types.

[sec_sum] Available bands: Available frequencies/bands for all satellites in the observation file.

[sec_gap] Gaps and pieces: Data gaps and short data blocks within the observation period.

[sec_pre] pre-processing results: Data pre-processing of all frequencies/bands and signals and receiver clock jumps detection. Phase cycle slips for any constellation providing dual-frequency observations at least, and multiple frequencies handled via a cascade approach.

[sec_ele] Elevation and azimuth: Elevation and azimuth for available satellites calculated a with user defined time resolution. Requires the availability of dual-frequency observations for the satellite.

[sec_mpx] Code multipath: Code mean multipath estimated for all available systems, satellites, frequencies and signals. The multipath value includes code signal noise as expressed with a standard deviation of code residuals of the multi-path linear combination within a sequence of data epochs.

[sec_snr] Signal-to-noise ratio: Values directly extracted from the file.

[sec_sat] Satellite information: Satellite health status and navigation data availability.

XTR output - summary (1)

First line – total statistics motivated and modified from TEQC short summary
➔ counts are applied for selected phase observations over all GNSS constellations
➔ phase observation type selected per GNSS with a maximum # of observations

```
# G-Nut/Anubis [2.1.0] compiled: Oct 23 2017 16:08:19 ($Rev: 2020 $)

#====== Summary statistics (v.9)
#TOTSUM First_Epoch________ Last_Epoch_________ Hours_ Sample MinEle #_Expt #_Have %Ratio o/slps woElev Exp>10 Hav>10 %Rt>10
=TOTSUM 2017-10-17 00:00:00 2017-10-17 23:59:30  24.00  30.00   0.01  99022  90319  91.21    346   3098  75518  74675  98.88
```

- **Hours** - data length in hours total number of epochs × sampling rate)
- **Sample** - data sampling interval (the most frequent sampling from histogram)
- **MinEle** - data minimum elevation angle observed
- **#_Expt** - number of expected observations above the horizon
- **#_Have** - number of existing observations above the horizon
- **%Ratio** - ratio of existing and expected observations above the horizon
- **o/slps** - number of observations per cycle slip
- **woElev** - number of epochs without elevation (i.e. no satellite position available)
- **Expt>10** - number of expected observations above the user mask (10 deg)
- **Have>10** - number of existing observations above the user mask (10 deg)
- **%Rat>10** - ratio of existing and expected observations above the user mask

XTR output - summary (2)

GNSS-specific summary:

➔ expected counts of observations require defined data period and sampling intervals

```
#GNSSUM 2017-10-17 00:00:00 Epoch_Statistics_ Excl_Epochs&Satellites_  CycleSlips/Interruptions_And_Other_Discontinuities Code_Mpth
#GNSSUM 2017-10-17 00:00:00 ExpEp HavEp UseEp xCoEp xPhEp xCoSv xPhSv  csAll csEpo csSat csSig nSlp nJmp nGap nPcs  mp1  mp2
=GPSSUM 2017-10-17 00:00:00  2880  2880  2880     0     0   254   265    378     0   138   206   34     0     0     0 21.0 21.0
=GALSUM 2017-10-17 00:00:00  2880  2880  2880     0     0   249   249    393     0   121    61  211     0     0     0 15.0    -
=GLOSUM 2017-10-17 00:00:00  2880  2880  2880     0     0  1866  1890    868     0   110   160  598     0     0     0 38.3 31.2
=BDSSUM 2017-10-17 00:00:00  2880  2880  1796  1061  1084  2074  2148    109     0    29    80    0     0     0     0    - 41.4
```

- **ExpEp** - number of expected data epochs
- **HavEp** - number of actual data epochs
- **UseEp** - number of usable epochs **(≥ 4 satellites in epoch with dual-frequency data/GNSS**)
- **xCoEp** - number of epochs with only single-frequency pseudoranges or < 4 satellites
- **xPhEp** - number of epochs with only single-frequency carrier-phases or less than 4 satellites
- **xCoSv** - number of single-frequency (only) pseudorange observations
- **xPhSv** - number of single-frequency (only) carrier-phase observations
- **csTot** - number of total phase cycle-slips or other interruptions (→ new ambiguity)
- **csEpo** - number of interruptions due to missing epochs (counted over observed satellite)
- **csSat** - number of interruptions due to missing satellites (whenever satellite expected)
- **csSig** - number of interruptions due to missing signal (whenever others are available)
- **nSlp** - number of phase cycle-slips when continuous tracking available
- **nJmp** - number of receiver clock jumps (discontinuities in phase & code observations)
- **nGap** - number of data total gaps (according to the setting **int_gap="600"** in seconds)
- **nPcs** - number of small data pieces (according to the setting **int_pcs="1800"** in seconds)
- **mpX** - mean code multipath moving average RMS [cm] for the 1st..8th band

XTR output - summary (3)

sec_sum="1" - provides individual observation types of all available GNSS constellations.

- **nSat** - number of observed satellites
- **ExpObs** - number of expected observations above the horizon
- **HavObs** - number of existing observations above the horizon
- **%Ratio** - ratio of existing and expected observations above the horizon
- **Exp>10** - number of expected observations above the user mask (10 deg)
- **Hav>10** - number of existing observations above the user mask (10 deg)
- **%Rt>10** - ratio of existing and expected observations above the user mask

sec_sum="2" - histograms of observations above specific elevation angles:

>**0, >5, >10, >15, >20, >30, >50, >70**

#GNSxxx	2017-10-17	00:00:00	nSat	ExpObs	HavObs	%Ratio	Exp>10	Hav>10	%Rt>10	wo/Ele	Ele>0	Ele>5	Ele>10	Ele>15	Ele>20	Ele>30	Ele>50	Ele>70
=GPSC1C	2017-10-17	00:00:00	32	35787	32514	90.85	26033	26000	99.87	875	31639	28921	25223	22309	19613	14691	7062	2599
=GPSC1W	2017-10-17	00:00:00	32	35782	32406	90.57	26029	25996	99.87	870	31536	28907	25223	22309	19613	14691	7062	2599
=GPSC2L	2017-10-17	00:00:00	19	21582	19254	89.21	15065	15040	99.83	2	19252	17428	15039	13360	11773	9173	5038	1812
=GPSC2W	2017-10-17	00:00:00	32	35782	32406	90.57	26029	25996	99.87	870	31536	28907	25223	22309	19613	14691	7062	2599
=GPSC5Q	2017-10-17	00:00:00	12	13815	12167	88.07	9336	9318	99.81	9	12158	10669	9310	8384	7527	5921	3395	1398
=GPSL1C	2017-10-17	00:00:00	32	35787	32505	90.83	26033	26000	99.87	875	31630	28920	25223	22309	19613	14691	7062	2599
=GPSL2L	2017-10-17	00:00:00	19	21582	19254	89.21	15065	15040	99.83	2	19252	17428	15039	13360	11773	9173	5038	1812
=GPSL2W	2017-10-17	00:00:00	32	35781	32391	90.53	26028	25995	99.87	869	31522	28904	25223	22309	19613	14691	7062	2599
=GPSL5Q	2017-10-17	00:00:00	12	13815	12167	88.07	9336	9318	99.81	9	12158	10669	9310	8384	7527	5921	3395	1398
=GPSS1C	2017-10-17	00:00:00	32	35787	32514	90.85	26033	26000	99.87	875	31639	28921	25223	22309	19613	14691	7062	2599
=GPSS1W	2017-10-17	00:00:00	32	35782	32406	90.57	26029	25996	99.87	870	31536	28907	25223	22309	19613	14691	7062	2599
=GPSS2L	2017-10-17	00:00:00	19	21582	19254	89.21	15065	15040	99.83	2	19252	17428	15039	13360	11773	9173	5038	1812
=GPSS2W	2017-10-17	00:00:00	32	35782	32406	90.57	26029	25996	99.87	870	31536	28907	25223	22309	19613	14691	7062	2599
=GPSS5Q	2017-10-17	00:00:00	12	13815	12167	88.07	9336	9318	99.81	9	12158	10669	9310	8384	7527	5921	3395	1398
=GALC1C	2017-10-17	00:00:00	18	21090	18385	87.17	15178	15024	98.99	198	18187	16830	14848	13006	11681	8987	4888	1863
=GALC5Q	2017-10-17	00:00:00	17	20895	18303	87.60	15004	14850	98.97	3	18300	16830	14848	13006	11681	8987	4888	1863
=GALC7Q	2017-10-17	00:00:00	17	20895	18305	87.60	15004	14850	98.97	3	18302	16830	14848	13006	11681	8987	4888	1863
=GALC8Q	2017-10-17	00:00:00	17	20898	18146	86.83	15007	14775	98.45	6	18140	16654	14770	12977	11681	8987	4888	1863
=GALL1C	2017-10-17	00:00:00	18	21090	18385	87.17	15178	15024	98.99	198	18187	16830	14848	13006	11681	8987	4888	1863
=GALL5Q	2017-10-17	00:00:00	17	20895	18303	87.60	15004	14850	98.97	3	18300	16830	14848	13006	11681	8987	4888	1863
=GALL7Q	2017-10-17	00:00:00	17	20895	18305	87.60	15004	14850	98.97	3	18302	16830	14848	13006	11681	8987	4888	1863
=GALL8Q	2017-10-17	00:00:00	17	20898	18146	86.83	15007	14775	98.45	6	18140	16654	14770	12977	11681	8987	4888	1863

XTR output - summary (4)

Necessary details about satellite availability

- for calculating 'expected number of observations',
- for each individual satellite from all systems

SKYxxx – time of satellite being above the horizon

MSKxxx – time of satellite being above the user elevation cut-off (default 15deg)

Time [h] – length of satellite visibility

ExptObs – number of time epochs when satellite is visible

```
#SKYxxx Ascending_Horizon__ Descending_Horizon_ Time[h] ExptObs
=SKYC05 2017-10-17 00:00:00 2017-10-18 00:00:00  24.000    2880
=MSKC05 2017-10-17 00:00:00 2017-10-18 00:00:00  24.000    2880
. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
=SKYE01 2017-10-17 00:00:00 2017-10-17 05:06:03   5.101     612
=SKYE01 2017-10-17 12:43:04 2017-10-17 15:31:59   2.815     338
=MSKE01 2017-10-17 00:00:00 2017-10-17 04:35:46   4.596     552
=MSKE01 2017-10-17 13:49:11 2017-10-17 14:26:49   0.627      75
=SKYE02 2017-10-17 06:22:37 2017-10-17 11:12:19   4.828     579
=SKYE02 2017-10-17 16:56:59 2017-10-18 00:00:00   7.050     846
=MSKE02 2017-10-17 06:55:55 2017-10-17 10:38:18   3.706     445
=MSKE02 2017-10-17 17:25:33 2017-10-18 00:00:00   6.574     789
=SKYE03 2017-10-17 02:24:28 2017-10-17 04:30:33   2.101     252
=SKYE03 2017-10-17 12:49:00 2017-10-17 21:43:20   8.906    1069
=MSKE03 2017-10-17 13:21:05 2017-10-17 21:13:18   7.870     944
```

XTR output – header metadata

- **List for comparison of (the section might undergo a major revision in future)**
  - ➔ RINEX HEADER
  - ➔ USER SETTINGS (expectation or request)

```
#====== Header information (v.9)
#RNXHDR 2017-10-17 00:00:00 _RINEX_HEADER_____________ _RINEX_HEADER_____________ _RINEX_HEADER_____________
=RNXVER 2017-10-17 00:00:00 3.03                      M                           2017-10-18 00:02:23
=RNXPGM 2017-10-17 00:00:00 sbf2rin-11.3.2            -
=RNXAGE 2017-10-17 00:00:00 ROB                       ROB

#RNXHDR 2017-10-17 00:00:00 _RINEX_HEADER_____________________________________ _USER_REQUEST_____________________________________
=BEGEND 2017-10-17 00:00:00 2017-10-17 00:00:00     2017-10-17 23:59:30       2017-10-17 00:00:00     2017-10-18 00:00:00
=INTHDR 2017-10-17 00:00:00 30.000                                             30.000
=MARKER 2017-10-17 00:00:00 BRUX 13101M010
=RECEIV 2017-10-17 00:00:00 SEPT POLARX4TR      2.9.6               3001376
=ANTENN 2017-10-17 00:00:00 JAVRINGANT_DM   NONE00464

#RNXHDR 2017-10-17 00:00:00 _RINEX_HEADER_____________________________________ _USER_REQUEST_____________________________________
=XYZAPR 2017-10-17 00:00:00     4027881.8478     306998.2610     4919498.6554          0.0000          0.0000          0.0000
=XYZECC 2017-10-17 00:00:00           0.0000          0.0000          0.0000          0.0000          0.0000          0.0000
=ENUECC 2017-10-17 00:00:00           0.0000          0.0010          0.4689          0.0000          0.0000          0.0000
```

- Initially, it was foreseen for usage in cross-checking of RINEX header meta data with any meta data validated centrally (e.g. within the EPOS GNSS dissemination)
- The EPOS system does a cross-validation within the EPOS DB API service
- Currently, the Anubis's XTR and XML
  - ➔ does not do any validation, but reporting when trying to merge metadata from more sources
  - ➔ enables grepping over many XTR files (historical or network groups)
  - ➔ reports HEADER metadata in XML for validation within the EPOS DB API service

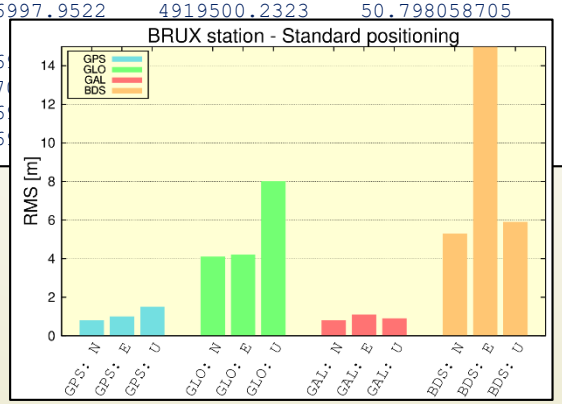
XTR output – estimated values

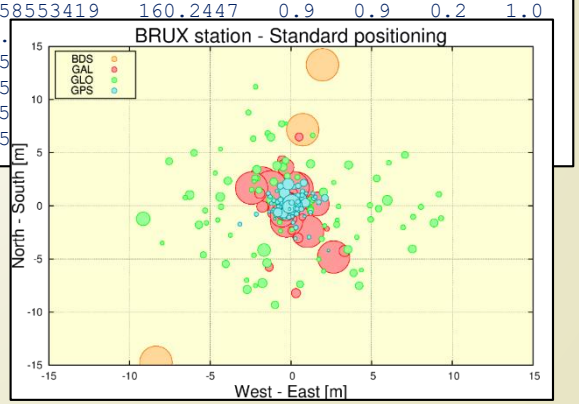
- Standard point positioning (SPP) - performed independently for each global constellation:
  ➔ requires navigation data ➔ SP3 can support SPP **(but no GLONASS without a sat slots!)**
- Position estimated using a common sampling rate of 15 minutes.
- GDOP values are calculated in addition

sec_est="1" - mean coordinates (XYZ/BLH) and repeatability (XYZ/NEU)
sec_est="2" - results from epoch-to-epoch positioning + DOP values, # Sat, Rec clocks corrections
minimum_elev=5 – could be used to set elevation angle cut-off mask for the positioning

```
#====== Estimated values (v.9)
=PERIOD 2017-10-17 00:00:00 2017-10-17 00:00:00     2017-10-17 23:59:30
=SAMPLE 2017-10-17 00:00:00 30.000
=XYZGPS 2017-10-17 00:00:00     4027882.4905     306998.5610    4919500.2234     1.0     0.6     1.4    95     1
=XYZGAL 2017-10-17 00:00:00     4027881.9460     306998.6773    4919499.7808     0.7     0.6     0.9    86    10
=XYZGLO 2017-10-17 00:00:00     4027883.0126     306998.6388    4919500.5285     5.0     2.7     7.4    92     0
=XYZBDS 2017-10-17 00:00:00     4027883.4427     307010.4951    4919502.7730     8.3    17.3     3.1    24     0
=BLHGPS 2017-10-17 00:00:00     50.798063862     4.358562887        159.7652     0.8     1.0     1.5    95     1
=BLHGAL 2017-10-17 00:00:00     50.798065850     4.358563983        159.1284     0.8     1.1     0.9    87     9
=BLHGLO 2017-10-17 00:00:00     50.798061928     4.358563425        160.3344     4.1     4.2     8.0    92     0
=BLHBDS 2017-10-17 00:00:00     50.798065416     4.358730641        162.9144     5.3    28.0     5.9    24     0

#POSGNS 2017-10-17 00:00:00           X [m]           Y [m]           Z [m]        B [deg]        L [deg]       H [m]   GDOP  PDOP  HDOP  VDOP
 POSGPS 2017-10-17 00:00:00     4027882.7667     306995.9220    4919503.9910    50.798084746    4.358525267   162.7321   0.8   0.8   0.2   0.9
 POSGPS 2017-10-17 00:15:00     4027883.3539     306996.6801    4919501.5488    50.798066391    4.358535356   161.2461   1.1   1.1   0.3   1.1
 POSGPS 2017-10-17 00:30:00     4027883.2868     306997.9522    4919500.2323    50.798058705    4.358553419   160.2447   0.9   0.9   0.2   1.0
. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
 POSGAL 2017-10-17 05:00:00     4027885.8327     306                                                                    4.35
 POSGAL 2017-10-17 05:15:00     4027884.5166     307                                                                    4.35
 POSGAL 2017-10-17 05:30:00     4027882.0961     306                                                                    4.35
 POSGAL 2017-10-17 05:45:00     4027881.3244     306                                                                    4.35
```





XTR output – observation types

- Report of available observation types
  - ➔ from FILE HEADER
  - ➔ from FILE DATA
- easy to grep over sequence of Anubis XTR QC files

sec_obs="1" – summary of satellites per GNSS, observations per system (+ HEADER info)

sec_obs="2" – details of satellite per observation types and GNSS constellation

```
#====== Observation types (v.9)
=GNSSYS 2017-10-17 00:00:00       4 GPS GAL GLO BDS

=GPSSAT 2017-10-17 00:00:00      32 G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G12 G13 G14 G15 G16 G17 G18 G19 G20 G21 G22 G23
=GALSAT 2017-10-17 00:00:00      18 E01 E02 E03 E04 E05   - E07 E08 E09   - E11 E12   - E14   -   -   - E18 E19 E20   - E22   -
=GLOSAT 2017-10-17 00:00:00      24 R01 R02 R03 R04 R05 R06 R07 R08 R09 R10 R11 R12 R13 R14 R15 R16 R17 R18 R19 R20 R21 R22 R23
=BDSSAT 2017-10-17 00:00:00      12   -   -   -   - C05 C06 C07 C08 C09 C10 C11 C12 C13 C14   -   -   -   -   -   -   -   -   -

=BDSHDR 2017-10-17 00:00:00       6 C2I L2I S2I C7I L7I S7I
=GALHDR 2017-10-17 00:00:00      12 C1C L1C S1C C5Q L5Q S5Q C7Q L7Q S7Q C8Q L8Q S8Q
=GPSHDR 2017-10-17 00:00:00      14 C1C L1C S1C C1W S1W C2W L2W S2W C2L L2L S2L C5Q L5Q S5Q
=GLOHDR 2017-10-17 00:00:00       9 C1C L1C S1C C2P L2P S2P C2C L2C S2C
=GPSOBS 2017-10-17 00:00:00      14 C1C C1W C2L C2W C5Q L1C L2L L2W L5Q S1C S1W S2L S2W S5Q
=GALOBS 2017-10-17 00:00:00      12 C1C C5Q C7Q C8Q L1C L5Q L7Q L8Q S1C S5Q S7Q S8Q
=GLOOBS 2017-10-17 00:00:00       9 C1C C2C C2P L1C L2C L2P S1C S2C S2P
=BDSOBS 2017-10-17 00:00:00       6 C2I C7I L2I L7I S2I S7I

 GPSC1C 2017-10-17 00:00:00         G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G12 G13 G14 G15 G16 G17 G18 G19 G20 G21 G22 G23
 GPSC1W 2017-10-17 00:00:00         G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G12 G13 G14 G15 G16 G17 G18 G19 G20 G21 G22 G23
 GPSC2L 2017-10-17 00:00:00         G01   - G03   - G05 G06 G07 G08 G09 G10   - G12   -   - G15   - G17   -   -   -   -   -   -
 GPSC2W 2017-10-17 00:00:00         G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G12 G13 G14 G15 G16 G17 G18 G19 G20 G21 G22 G23
 GPSC5Q 2017-10-17 00:00:00         G01   - G03   -   - G06   - G08 G09 G10   -   -   -   -   -   -   -   -   -   -   -   -   -
 . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
 GALC1C 2017-10-17 00:00:00         E01 E02 E03 E04 E05   - E07 E08 E09   - E11 E12   - E14   -   -   - E18 E19 E20   - E22   -
 GALC5Q 2017-10-17 00:00:00         E01 E02 E03 E04 E05   - E07 E08 E09   - E11 E12   - E14   -   -   - E18 E19   -   - E22   -
 GALC7Q 2017-10-17 00:00:00         E01 E02 E03 E04 E05   - E07 E08 E09   - E11 E12   - E14   -   -   - E18 E19   -   - E22   -
 GALC8Q 2017-10-17 00:00:00         E01 E02 E03 E04 E05   - E07 E08 E09   - E11 E12   - E14   -   -   - E18 E19   -   - E22   -
 . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
```

XTR output – carrier-phase pre-processing

Phase observations at all signals/frequencies and satellite constellations checked for:

- **Clk_Jmp** - number of receiver clock jumps (phase/code inconsistencies)
- **CS_Total** - number of all phase cycle-slips and carrier-phase interruptions
- **CS_Slips** - number of identified real phase cycle-slips during a continuous phase tracking
- **CS_Epoch** - number of phase interruptions due to missing epoch (for available satellites)
- **CS_Satell** - number of phase interruptions due to temporary unavailable satellites
- **CS_Signal** - number of phase interruptions due to temporary unavailable signals

```
#====== Preprocessing results (v.9)
#GNSPRP 2017-10-17 00:00:00      CS_Total       CS_Slip      CS_Epoch     CS_Satell     CS_Signal
=GPSPRP 2017-10-17 00:00:00           378            34             0           138           206
=GALPRP 2017-10-17 00:00:00           393           211             0           121            61
=GLOPRP 2017-10-17 00:00:00           868           598             0           110           160
=BDSPRP 2017-10-17 00:00:00           109             0             0            29            80

#GNSxxx 2017-10-17 00:00:00      CS_Total       CS_Slip      CS_Epoch     CS_Satell     CS_Signal
=GPSL1C 2017-10-17 00:00:00           134            10             0            76            48
=GPSL2L 2017-10-17 00:00:00            82             4             0            17            61
=GPSL2W 2017-10-17 00:00:00           122            15             0            11            96
=GPSL5Q 2017-10-17 00:00:00            40             5             0            34             1
=GALL1C 2017-10-17 00:00:00            96            42             0            27            27
=GALL5Q 2017-10-17 00:00:00           105            59             0            32            14
=GALL7Q 2017-10-17 00:00:00           104            59             0            32            13
=GALL8Q 2017-10-17 00:00:00            88            51             0            30             7

#CLKJMP 2017-10-17 00:00:00  Phase[ms]
 CLKJMP 2017-10-17 00:00:00   -

#GNSSLP 2017-10-17 00:00:00  PRN          L1C          L2L          L2P          L2W          L5Q          L7Q          L8Q
 GPSSLP 2017-10-17 00:03:30  G14          9.0            -            -         -9.0            -            -            -
 GPSSLP 2017-10-17 00:04:00  G14         -5.0            -            -         -1.0            -            -            -
 GPSSLP 2017-10-17 00:05:30  G14            -            -            -         10.0            -            -            -
 GPSSLP 2017-10-17 00:39:30  G15         14.0         11.0            -         11.0            -            -            -
 . . . . . .
 GALSLP 2017-10-17 00:36:00  E19            -            -            -            -        -82.0        -84.0        -82.0
 GALSLP 2017-10-17 02:06:00  E04         -4.0            -            -            -         -3.0         -3.0         -3.0
 GALSLP 2017-10-17 03:38:00  E05            -            -            -            -          1.0          1.0          1.0
 GALSLP 2017-10-17 04:16:00  E03            -            -            -            -         -2.0         -2.0         -2.0
 GALSLP 2017-10-17 04:16:30  E03            -            -            -            -          1.0          1.0          1.0
 GALSLP 2017-10-17 05:30:00  E08            -            -            -            -         80.0         82.0         80.0
```

XTR output – frequency/bands availability

- Performed for a) individual epochs, b) satellites, c) observations (code/phase)
- Epochs with 4 satellites for a GNSS considered as usable
- Epochs with single-frequency code/phase counted
- Satellites with SF code/phase counted

➔ **UseEp** (in Summary)
➔ **xCoEp/xPhEp**
➔ **xCoSv/xPhSv**

sec_bnd="1" - a summary report over % of dual-/multi-band observations

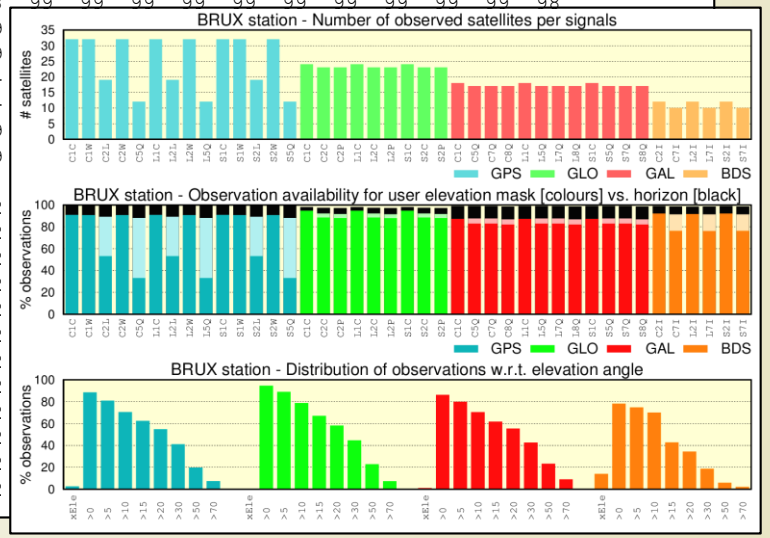
sec_bnd="2" - epoch-wise report over bands of complete dual-/multi-band observations

FewBand – counts of single-frequency observations

GNSCEP/GNSLEP – available bands of code/phase observations at pre-defined epochs

```
#====== Band available (v.9)
#GNSxEP 2017-10-17 00:00:00 FewBand x01 x02 x03 x04 x05 x06 x07 x08 x09 x10 x11 x12 x13 x14 x15 x16 x17 x18 x19 x20 x21 x22 x23
=GPSCEP 2017-10-17 00:00:00     254  98  99  98  99  99  98  99  99  97  98  99  99  99  99  99  99  99  99  99  99  99  98
=GPSLEP 2017-10-17 00:00:00     265  98  99  98  99  99  98  99  99  97  98  99  98  99  99  99  99  99  99  99  99  99  98
=GALCEP 2017-10-17 00:00:00     249  99  99  99  99  99   -  100  99  99   -  99  99
=GALLEP 2017-10-17 00:00:00     249  99  99  99  99  99   -  100  99  99   -  99  99
=GLOCEP 2017-10-17 00:00:00    1866  97  99 100  99  90  99  99  99 100  97  99   -
=GLOLEP 2017-10-17 00:00:00    1890  97  99 100  99  90  98  99  99 100  97  99   -
=BDSCEP 2017-10-17 00:00:00    2074   -   -   -   - 100  99  99  98  99  98  99  99
=BDSLEP 2017-10-17 00:00:00    2148   -   -   -   -  98  99  98  98  98  98  99  99

#NxBAND 2017-10-17 00:00:00 nSatell x01 x02 x03 x04 x05 x06 x07 x08 x09 x10 x11 x12
 GPSCBN 2017-10-17 00:00:00      13   1   -   -   -   -   1   -   -   -   3   -   2
 GPSCBN 2017-10-17 00:20:00      10   -   -   -   -   -   3   -   -   -   3   -   2
 GPSCBN 2017-10-17 00:40:00      12   -   2   -   -   -   3   -   -   -   3   -   2
 GPSCBN 2017-10-17 01:00:00      12   -   2   -   -   -   3   -   -   -   -   -   2
 GPSCBN 2017-10-17 01:20:00      10   -   2   -   -   -   3   -   -   -   -   -   2
 GPSCBN 2017-10-17 01:40:00      11   -   2   3   -   -   3   -   -   -   -   -   2
 GPSCBN 2017-10-17 02:00:00      11   -   2   3   -   -   3   -   -   -   -   -   2
 GPSCBN 2017-10-17 02:20:00       9   -   2   -   -   -   3   -   -   -   -   -   2
 GPSCBN 2017-10-17 02:40:00       9   -   2   -   -   -   3   -   -   -   -   -   2
 GPSCBN 2017-10-17 03:00:00      10   -   2   -   -   -   3   -   -   -   -   -   2
 GPSCBN 2017-10-17 03:20:00      10   -   2   -   -   -   3   -   -   -   -   -   2
```



XTR outputs – elevation/azimuth

- Only if ephemeris available
- Reported in a common sampling to be compliant with other QC reports

sec_ele="1" – satellite mean values only reported *(verbosity 1)*

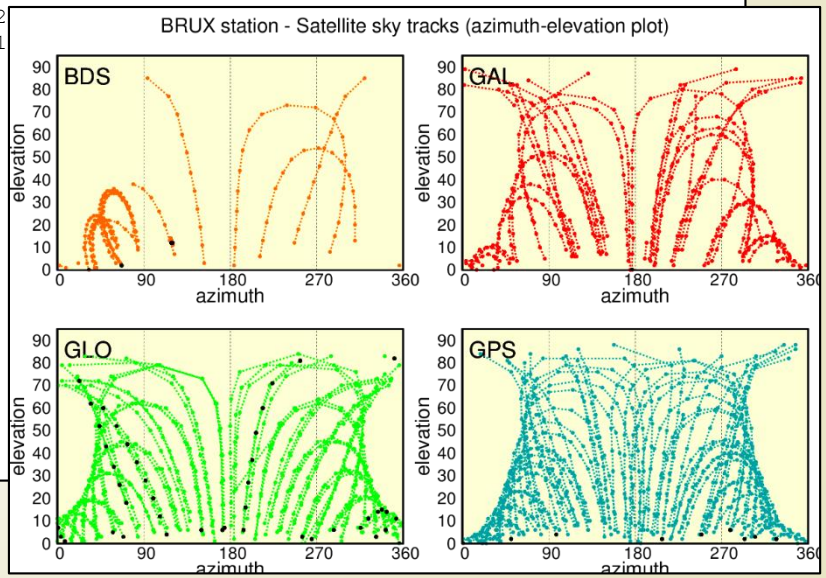
sec_ele="2" – satellite/epoch-wise values reported *(verbosity 2)*

int_smp="20" – requested sampling frequency *(in minutes)*

num_sat="23" – number of columns for satellite *(default:32)*

pos_kin="true" – kinematic data – applies epoch-specific position for the receiver

```
#====== Elevation & Azimuth (v.9)
#GNSELE 2017-10-17 00:00:00    Mean x01 x02 x03 x04 x05 x06 x07 x08 x09 x10 x11 x12 x13 x14 x15 x16 x17 x18 x19 x20 x21 x22 x23
 GLOELE 2017-10-17 00:00:00      27   -  13  40  25   -   -   -   -   -   -   7  52  53   9   -   -   -   -   -   -  24  40  11
 GLOELE 2017-10-17 00:20:00      30   -   4  33  29   -   -   -   -   -   -   -  44  61  16   -   -   -   -   -   -  18  44  21
 GLOELE 2017-10-17 00:40:00      31   -   -  24  31   7   -   -   -   -   -   -  36  68  24   -   -   -   -   -   -  10  45  32
 GLOELE 2017-10-17 01:00:00      28   -   -  15  29  13   -   -   -   -   -   -  28  72  32   -   -   -   -   -   -   2  42  42
 GLOELE 2017-10-17 01:20:00      32   -   -   6  25  17   -   -   -   -   -   -  2
 GLOELE 2017-10-17 01:40:00      32   -   -   -  19  20   -   -   -   -   -   -  1
 GLOELE 2017-10-17 02:00:00      30   -   -   -  12  19   4   -   -   -   -   -
 GLOELE 2017-10-17 02:20:00      30   -   -   -   5  16   8   -   -   -   -   -
 GLOELE 2017-10-17 02:40:00      34   -   -   -   -  12  11   -   -   -   -   -
 GLOELE 2017-10-17 03:00:00      36   -   -   -   -   6  12   1   -   -   -   -
 GLOELE 2017-10-17 03:20:00      40   -   -   -   -   -  11   6   -   -   -   -
 GLOELE 2017-10-17 03:40:00      34   -   -   -   -   -   8   9   -   -   -   -
 GLOELE 2017-10-17 04:00:00      33   -   -   -   -   -   -  11   3   -   -   -
 GLOELE 2017-10-17 04:20:00      35   -   -   -   -   -   -  10   8   -   -   -
 GLOELE 2017-10-17 04:40:00      38   -   -   -   -   -   -   7  12   -   -   -
 GLOELE 2017-10-17 05:00:00      38   9   -   -   -   -   -   -  13   -   -   -
 GLOELE 2017-10-17 05:20:00      32  14   -   -   -   -   -   -  12   5   -   -
 GLOELE 2017-10-17 05:40:00      26  18   5   -   -   -   -   -   9  14   -   -
 GLOELE 2017-10-17 06:00:00      29  19  12   -   -   -   -   -   4  23   -   -
 GLOELE 2017-10-17 06:20:00      35  18  20   -   -   -   -   -   -  31   -   -
 GLOELE 2017-10-17 06:40:00      32  15  26   7   -   -   -   -   -  39   -   -
 GLOELE 2017-10-17 07:00:00      31   9  30  16   -   -   -   -   -  44   5   -
```



XTR output – code multipath and noise

- all code signals/constellations with dual-frequency observations
- mean RMS after removing systematic error from multipath LC

sec_mpx="1" – satellite mean values only reported

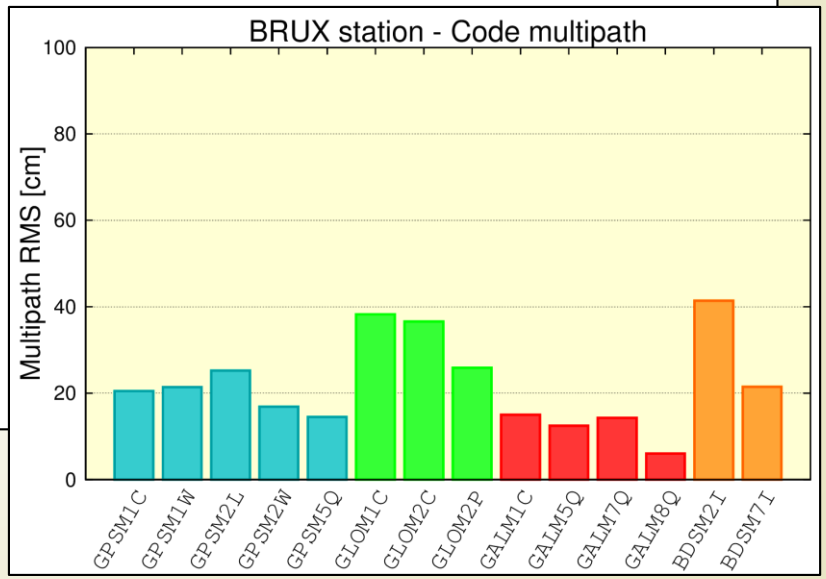
sec_mpx="2" – satellite/epoch-wise values reported

mpx_nep="20" – # epochs for multipath RMS calculation (15-25) recommended)

mpx_lim="3" – sigma multiplication - outliers/cycle-slips detection

```
#====== Code multipath (v.9)
#GNSMxx 2017-10-17 00:00:00    mean x01 x02 x03 x04 x05 x06 x07 x08 x09 x10 x11 x12 x13 x14 x15 x16 x17 x18 x19 x20 x21 x22 x23
=GPSM1C 2017-10-17 00:00:00   20.49  19  22  18  19  19  22  20  22  21  21  20  17  22  25  19  22  17  24  21  23  21  15  22
=GPSM1W 2017-10-17 00:00:00   21.42  20  23  18  19  21  22  21  24  22  22  21  18  23  26  20  23  18  25  22  24  22  16  23
=GPSM2L 2017-10-17 00:00:00   25.23  22   -  21   -  26  24  29  24  24  24   -  25   -   -  29   -  28   -   -   -   -   -   -
=GPSM2W 2017-10-17 00:00:00   16.85  13  19  13  12  19  20  16  16  12  19  12  14  15  21  18  19  18  23  21  19  16  11  16
=GPSM5Q 2017-10-17 00:00:00   14.51  14   -  12   -   -  16   -  15  13  15   -   -   -   -   -   -   -   -   -   -   -   -   -
=GALM1C 2017-10-17 00:00:00   14.99  16  13  15  14  14   -  15  15  15   -  18  15   -   9   -   -   -  15  22   -   -  13   -
=GALM5Q 2017-10-17 00:00:00   12.48  11  12  12  14  12   -  11  13  13   -  13
=GALM7Q 2017-10-17 00:00:00   14.31  15  13  14  16  14   -  11  15  14   -  15
=GALM8Q 2017-10-17 00:00:00    6.02   7   6   6   6   5   -   6   6   6   -   7
=GLOM1C 2017-10-17 00:00:00   38.26  35  25  37  46  51  45  40  46  32  27  36
=GLOM2C 2017-10-17 00:00:00   36.57  47  27  27  29  64  51  27  30  28  47  29
=GLOM2P 2017-10-17 00:00:00   25.87  30  20  26  26  30  28  26  27  27  30  24
=BDSM2I 2017-10-17 00:00:00   41.41   -   -   -   -  43  45  57  61  37  38  33
=BDSM7I 2017-10-17 00:00:00   21.49   -   -   -   -  22  27  29  27  20  22  16

 GPSM1C 2017-10-17 00:00:00   20.61   -   -   -   -   -  28   -   -   -  34   -
 GPSM1C 2017-10-17 00:20:00   23.53   -  35   -   -   -  24   -   -   -  41   -
 GPSM1C 2017-10-17 00:40:00   23.49   -  32   -   -   -  31   -   -   -  41   -
 GPSM1C 2017-10-17 01:00:00   16.91   -  17   -   -   -  18   -   -   -   -   -
 GPSM1C 2017-10-17 01:20:00   17.69   -  24   -   -   -  18   -   -   -   -   -
 GPSM1C 2017-10-17 01:40:00   19.65   -  13  56   -   -  17   -   -   -   -   -
 GPSM1C 2017-10-17 02:00:00   17.69   -  18  55   -   -  24   -   -   -   -   -
```



Code multipath and noise estimation

Code+phase multipath linear combination

i, j, k .. three frequencies *(i:code, j, k: carrier-phase)*

(a dual-frequency approach uses i = k)

$$LC_{mp} = P_k - L_i - \beta(L_i - L_j) = P_k + \alpha L_i + \beta L_j$$

$$\alpha = -\frac{f_i^2}{f_k^2}\frac{\left(f_k^2 + f_j^2\right)}{\left(f_i^2 - f_j^2\right)} \qquad \beta = \frac{f_j^2}{f_k^2}\frac{\left(f_k^2 + f_i^2\right)}{\left(f_i^2 - f_j^2\right)}$$

Václavovic P and Douša J (2016)

Preprocessing

- cycle-slips need to be identify and eliminated (or repaired)
- simple CS identification incorporated within the algorithm
- supports all constellations, all code signals and frequencies when exploiting common dual-frequency phase observations (pre-requisite)

XTR output – signal-to-noise ratio

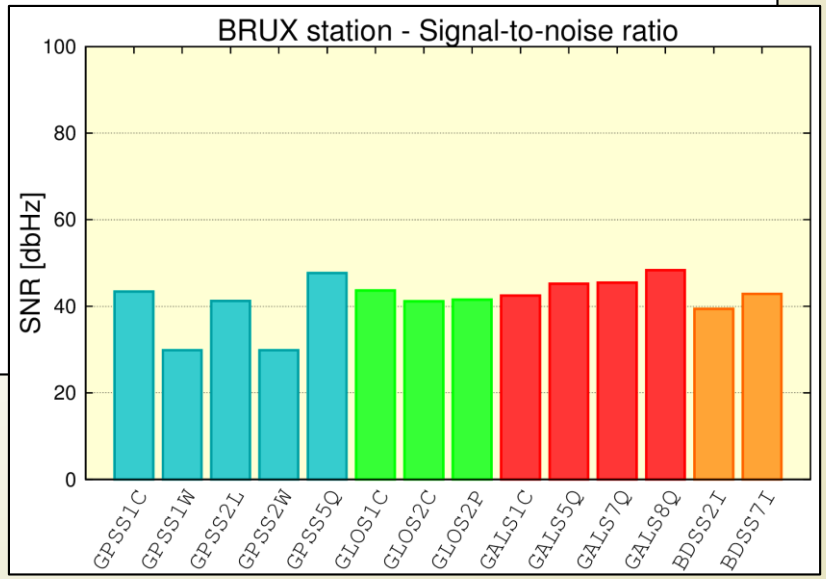
- Signal-to-noise statistics are represented directly by observations
- SNR depends on elevation, receiver and signal type, environment

sec_snr="1" – satellite mean values only reported

sec_snr="2" – satellite/epoch-wise values reported

```
#====== Signal to noise ratio (v.9)
#GNSSxx 2017-10-17 00:00:00    mean x01 x02 x03 x04 x05 x06 x07 x08 x09 x10 x11 x12 x13 x14 x15 x16 x17 x18 x19 x20 x21 x22 x23
=GPSS1C 2017-10-17 00:00:00   43.38  45  41  46  43  44  43  45  44  45  43  42  45  43  40  45  41  44  41  42  42  42  45  43
=GPSS1W 2017-10-17 00:00:00   29.86  33  27  35  30  29  30  29  32  34  30  28  31  29  24  30  27  29  25  29  26  29  34  29
=GPSS2L 2017-10-17 00:00:00   41.26  42   -  43   -  40  41  39  42  43  41   -  42   -   -  40   -  39   -   -   -   -   -   -
=GPSS2W 2017-10-17 00:00:00   29.86  33  27  35  30  29  30  29  32  34  30  28  31  29  24  30  27  29  25  29  26  29  34  29
=GPSS5Q 2017-10-17 00:00:00   47.68  48   -  49   -   -  46   -  48  48  47   -   -   -   -   -   -   -   -   -   -   -   -   -
=GALS1C 2017-10-17 00:00:00   42.48  43  44  44  43  44   -  42  43  44   -  41  41   -  48   -   -   -  42  36  39   -  44   -
=GALS5Q 2017-10-17 00:00:00   45.20  46  46  47  45  46   -  46  46  46   -  43  44   -  50   -   -   -  45  38   -   -  46   -
=GALS7Q 2017-10-17 00:00:00   45.46  46  47  47  45  46   -  46  46  46   -  43  44   -  51   -   -   -  45  38   -   -  47   -
=GALS8Q 2017-10-17 00:00:00   48.34  49  50  50  48  49   -  49  48  49   -  46
=GLOS1C 2017-10-17 00:00:00   43.66  44  45  46  45  40  41  45  44  45  45  45
=GLOS2C 2017-10-17 00:00:00   41.15  39  43  44  44  36  39  44  44  44  38  43
=GLOS2P 2017-10-17 00:00:00   41.51  39  44  45  44  36  39  44  44  44  38  44
=BDSS2I 2017-10-17 00:00:00   39.41   -   -   -   -  36  37  36  37  39  38  43
=BDSS7I 2017-10-17 00:00:00   42.86   -   -   -   -  39  40  40  41  42  42  47

 GPSS1C 2017-10-17 00:00:00   41.93   -   -   -   -   -   -   -   -   -  39   -
 GPSS1C 2017-10-17 00:20:00   44.12   -   -   -   -   -  39   -   -   -  36   -
 GPSS1C 2017-10-17 00:40:00   42.54   -  36   -   -   -  39   -   -   -  35   -
 GPSS1C 2017-10-17 01:00:00   42.38   -  39   -   -   -  41   -   -   -   -   -
 GPSS1C 2017-10-17 01:20:00   44.50   -  41   -   -   -  41   -   -   -   -   -
 GPSS1C 2017-10-17 01:40:00   43.86   -  42  32   -   -  42   -   -   -   -   -
 GPSS1C 2017-10-17 02:00:00   43.61   -  44  31   -   -  41   -   -   -   -   -
```



XTR output – satellite information

- Satellite information reported from available navigation messages
  - ➔ List numbers of navigation messages (>1 .. redundant messages)
  - ➔ List of satellite healthy status (0 < x < 1 .. ratio of healthy/unhealthy messages)

sec_sat="1" – satellite healthy status code
sec_sat="2" – redundant navigation message

```
#====== Satellite information (v.1)
#GNSSxx 2017-05-02 00:00:00          x01 x02 x03 x04 x05 x06 x07 x08 x09 x10 x11 x12 x13 x14 x15 x16 x17 x18 x19 x20 x21 x22 x23 x24
 GPSHLT 2017-05-02 00:00:00            1   1   1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 GPSHLT 2017-05-02 01:59:44            1   1   1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 GPSHLT 2017-05-02 02:00:00            1   1   1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 GPSHLT 2017-05-02 03:59:44            1   1   1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 GPSHLT 2017-05-02 04:00:00            1   1   1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 GPSHLT 2017-05-02 05:59:44            1   1   1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 GPSHLT 2017-05-02 06:00:00            1   1   1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 GPSHLT 2017-05-02 07:59:44            1   1   1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 GPSHLT 2017-05-02 08:00:00            1   1   1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 GPSHLT 2017-05-02 09:59:44            1   1   1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 GPSHLT 2017-05-02 10:00:00            1   1   1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 GPSHLT 2017-05-02 11:59:44            1   1   1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 GPSHLT 2017-05-02 12:00:00            1   1   1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 GPSHLT 2017-05-02 13:59:44            1   1   1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 GPSHLT 2017-05-02 14:00:00            1   1   1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 GPSHLT 2017-05-02 15:59:44            1   1   1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 GPSHLT 2017-05-02 16:00:00            1   1   1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 GPSHLT 2017-05-02 17:59:44            1   1   1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 GPSHLT 2017-05-02 18:00:00            1   1   1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 GPSHLT 2017-05-02 19:59:44            1   1   1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 GPSHLT 2017-05-02 20:00:00            1   1   1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 GPSHLT 2017-05-02 21:59:44            1   1   1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 GPSHLT 2017-05-02 22:00:00            1   1   1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 GPSHLT 2017-05-02 23:59:44            1   1   1   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
```