GAGE
National Science Foundation's Geodetic Facility for the Advancement of Geoscience

Introduction to Anubis software for GNSS quality control in the GAGE Facility and NOTA

Christine M. Puskas[1] , Charles M. Meertens[1] , David A. Phillips[1] , Frederick Blume[1] , Mike Rost[1]
1. UNAVCO

Network of the Americas

- The federation of the Plate Boundary Observatory (PBO), the Trans-boundary, Land and Atmosphere Long-term Observational and Collaborative Network (TLALOCNet), and the Continuously Operating Caribbean GPS Observational Network (COCONet) comprises the newly envisioned, pan-American Network of the Americas (NOTA) and supports a wide range of scientific applications and stakeholders.
- UNAVCO is in the multi-year process of modernizing NOTA to be fully GNSS-enabled. Modernization requires changes to handle expanded observations, QC analysis, and processing.

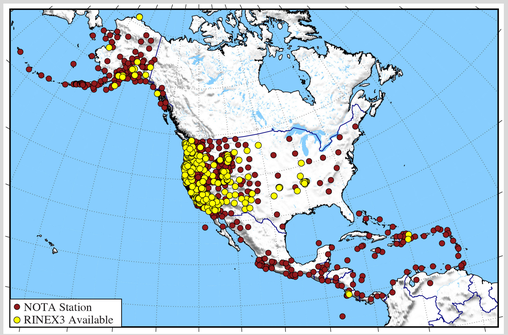

Figure 1. Map of NOTA stations, with fully GNSS-enabled station shown in yellow. These stations have RINEX 3.03 observation and navigation files as well as RINEX 2.11 files from UNAVCO as of fall 2019.

Anubis Software

- Anubis software was evaluated as a tool for quality checking RINEX 3.03 observation files.
- Developed by Geodetic Observatory Pecný at the Research Institute of Geodesy, Topography and Cartography, Department of Geodesy and Geodynamics, University of Pecný, Czech Republic.
- Open source software released under Gnu General Public License version 3.
- Inputs: RINEX observation file (2.11 or 3.03), RINEX navigation file, command line options OR control file.
- Outputs: Statistics for frequency codes, satellites, constellations, satellite and station information, Signal-to-Noise (SNR), and Multipath (MP) data. Output encoded in XML format file (machine readable) and XTR text file (human readable).

TEQC Software

- Translation, editing, and QC software developed at UNAVCO.
- Currently used in NOTA to translate manufacturer-specific data formats to RINEX2 and produce QC files, available from UNAVCO web site.
- TEQC has reached end-of-life with final release on 2019-02-25.
  - Final release will be available for foreseeable future.
  - UNAVCO will continue to host teqc email forum, archives, documentation.
  - UNAVCO will continue to use teqc for foreseeable future.
- Inputs: RINEX observation file (2.11 only), RINEX navigation file, command line options OR control file. Can also read most manufacturer-specific formats and BINEX/IGS/SOC.
- Outputs (for QC mode): QC time plot, summary report with statistics for standard QC files available from UNAVCO web site. Additional output may be specified by users in custom runs.

RINEX2 vs. RINEX3

- Receiver INdependent Exchange format originally developed at the Astronomical Institute of the University of Berne to handle GPS data from multiple receivers.
- RINEX 2.11 currently standard format for processing GNSS data.
- RINEX 3.03 (latest version) developed to better handle additional GNSS constellations.
  - Different nomenclature for frequency codes
  - Observation file has expanded header, different format for observations at each epoch.
  - Navigation file consolidates satellite data into single file (RINEX2 has separate nav file for each constellation when not using composite nav files).

Table 1. RINEX 2.11 and RINEX 3.03 equivalent frequency codes recorded in NOTA observation files.

GPS		Galileo		GLONASS		SBAS		BeiDou		QZSS	
RINEX2 Code	RINEX3 Code	RINEX2 Code	RINEX3 Code	RINEX2 Code	RINEX3 Code	RINEX2 Code	RINEX3 Code	RINEX2 Code	RINEX3 Code	RINEX2 Code	RINEX3 Code
C1	C1C	C1	C1C	C1	C1C	C1	C1C	C2	C2I	-	C1C
L1	L1C	L1	L1C	P1	C1P	L1	L1C	L2	L2I	-	L1C
S1	S1C	S1	S1C	S1	S1C	S1	S1C	S2	S2I	-	S1C
P1	C1W	C6	C6C	-	S1P	C5	C5I	-	C7I	-	C2L
S2	S1W	L6	L6C	L1	L1C	L5	L5I	-	L7I	-	L2L
P2	C2W	S6	S6C	-	L1P	S5	S5I	-	S7I	-	S2L
L2	L2W	C5	C5Q	C2	C2C			-	C6I	-	C5Q
-	S2W	L5	L5Q	P2	C2P			-	L6I	-	L5Q
C2	C2L/ L2C	S5	S5Q	-	L2C			-	S6I	-	S5Q
		C7	C7Q	L2	L2P			-	C1P		
-	L2L	L7	L7Q	-	S2C			-	L1P		
-	S2L	S7	S7Q	S2	S2P			-	S1P		
C5	C5Q	C8	C8Q	C7	C3Q			-	C5P		
L5	L5Q	L8	L8Q	L7	L3Q			-	L5P		
S5	S5Q	S8	S8Q	S7	S3Q			-	S5P		

Anubis vs. TEQC

- Both teqc and Anubis can be downloaded for users to make their own runs with customized output.
- Both provide statistics on observation/observable counts, cycle slips, SNR and MP values - but differences in encoding and calculations mean values will not be the same.
- TEQC will combine multiple constellations in MP and SNR calculations.
- Anubis reports statistics by constellation, frequency code, and satellite, depending on settings.

Table 2. RINEX 2.11 frequency codes and constellations used to calculate MP values.

Daily Avg MP	RINEX2 code used in calculations
MP12	C1, L1, L2 (GPS)
MP21	C2, L2, L1 (GPS)
MP15	C1, L1, L5 (GPS, GAL, SBS)
MP51	C5, L5, L1 (GPS, GAL, SBS)
MP16	C1, L1, L6 (GAL)
MP61	C6, L6, L1 (GAL)
MP17	C1, L1, L7 (GAL)
MP71	C7, L7, L1 (GAL)
MP18	C1, L1, L8 (GAL)
MP81	C8, L8, L1 (GAL

Table 3. RINEX 2.11 frequency codes and constellations used to calculate SNR values.

Daily Avg SNR	RINEX2 codes used in calculations
S1	S1 (GPS, GAL, GLO)
S2	S2 (GPS, GLO)
S5	S5 (GPS, GAL, SBS)
S6	S6 (GAL)
S7	S7 (GAL, GLO)
S8	S8 (GAL)

Anubis vs. TEQC (continued)

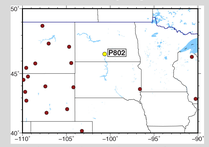

Figure 2. Index map showing location of example station P802 This station was chosen because it was fully GNSS-enabled.

Figure 3. Photo of P802, with no trees or buildings to obstruct the sky view.

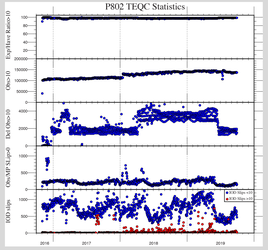

Figure 4. Sample statistics for all observations from TEQC.

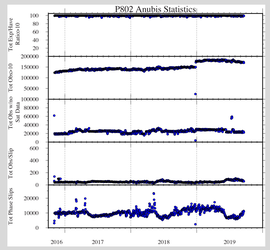

Figure 5. Sample statistics for all observations from Anubis.

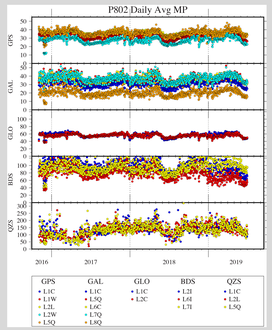

Figure 6. Daily MP values calculated by Anubis for each constellation and frequency code. Note that units are in cm.

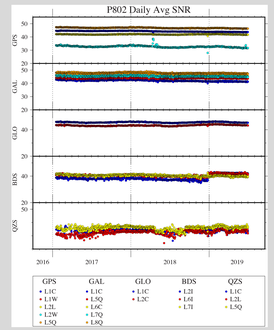

Figure 7. Daily average SNR values calculated by Anubis for each constellation and frequency code.

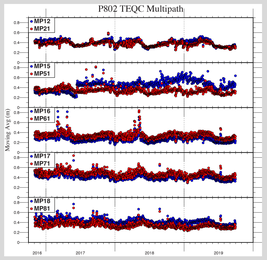

Figure 8. Daily MP values calculated by teqc for selected frequency combinations. Note that unites are in meters.

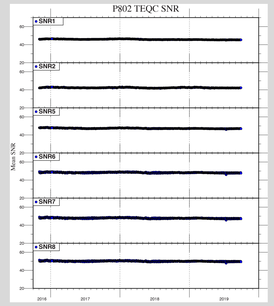

Figure 9. Daily average SNR values calculated by teqc for selected frequency combinations.

Anubis QC Examples

- Anubis has many parameters for QC, multiplied by frequency codes and constellations.

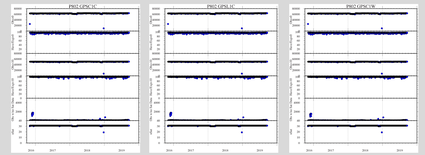

Figure 10. Statistics for GPS frequency codes in the L1 band.

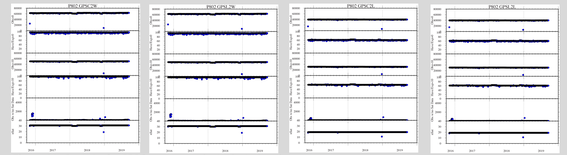

Figure 11. Statistics for GPS frequency codes in the L2 band.

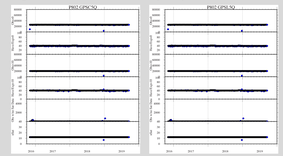

Figure 12. Statistics for GPS frequency codes in the L5 band.

Anubis Customized Example

- Like teqc, Anubis runs can be customized by the user.
- Anubis settings allow increased verbosity, with greater levels of detail saved to the output file.
  - Statistics/MP/SNR/satellite elevation+azimuth can be calculated at each epoch, or user-specified intervals.

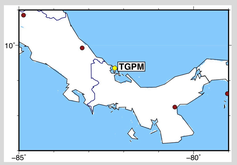

Figure 13. Index map of TGPM, located in Panama.

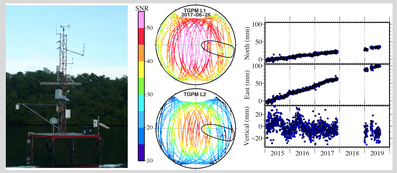

Figure 14. Photo of TGPM (left) showing antenna mast and platform. Sky plot (center) of SNR for GPS satellites shows shadow of mast. Time series (right) is good-quality, with no unusual noise, indicating that the mast does not degrade the position solutions.

Summary

- Anubis is open-source software for QC analysis of RINEX files, available from the Geodetic Observatory Pecný.
  - Developed for multi-constellation GNSS.
  - Calculates the same or similar QC statistics and parameters as teqc, but output is organized based on constellations and frequency codes.
- UNAVCO will use Anubis for RINEX3 QC as NOTA is modernized to be fully GNSS-enabled.
- TEQC has reached end of life at UNAVCO and will no longer be updated.
  - Executable files still work and are available; some support is available through the mailing list forum, archives, and documentation.
  - TEQC-generated QC files are still available for NOTA stations.
- More information: **"UNAVCO Geodetic Data Services Plan for GNSS Modernization: Data Formats and Preprocessing Tools" (March 2016), https://www.unavco.org/community/publications_and_reports/archived-docs/papers/GDS%20Plans%20for%20GNSS%20Modernization.pdf**

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