New developments at GOP Analysis Center

J. Douša, L.Zhao, P. Václavovic

Geodetic Observatory Pecný (GOP), Research Institute of Geodesy, Cartography and Topography (RIGTC), Czech Republic

e-mail: jan.dousa@pecny.cz

Abstract

The Geodetic Observatory Pecny (GOP) global analysis center has recently implemented a generation of rapid precise orbit and clock products in order to support Galileo Reference Center - Member States (GRC-MS) consortium established for independent Galileo system monitoring activities. For this purpose, a service for consolidated daily navigation files has been developed using all IGS stations, all GNSS systems and for a full history since 1994. A new procedure of GPS and Galileo orbit determination has been implemented using the Bernese GNSS software V52 and a double-difference solution from a global network. The product is completed with precise clock corrections generated with new in-house G-Nut/Sothis software and a strategy combining undifferenced pseudoranges and epoch-difference phase observations. The software was developed also for real-time clock correction estimation along with a robust clock datum definition and initial clock bias connections, both aimed particularly for the applied mixed-difference strategy. Initial results of precise real-time clock corrections and their validation in a regional network are presented. Within the next step, GOP AC aimed at re-implementing ultra-rapid product contributing to IGS.

Precise orbit and clocks (GPS+Galileo)

POD characteristics:

- Bernese GNSS Software V52, least-square adjustment
- CODE's ECOM orbit model (REF), 12-hour stochastic pulses
- 1/2/3-day solutions (2-day official for GRC-MS)
- Initialized with consolidated navigation data from GOP
- Network solution (~120 stations), dynamically adaptable clusters
- Double-difference observations, RINEX2/RINEX3 inputs
- Accuracy code adjustments according to various QC steps

Precise clock estimates:

- G-Nut/Sothis software, extended Kalman filter
- Mixed code undifference and phase epoch-difference observations
- Estimating epoch-difference clocks and initial clock biases
- New robust clock datum definition (Zhao et al. 2018)
- Satellite attitude models implemented

Quality control and monitoring

- Cross-checking at daily boundaries and within long-arc combination
- Pseudo-kinematic PPP over 30 stations worldwide + statistics
- Validation w.r.t. to IGS products (GPS), MGEX products (CODE,CNES)

Todo: completing ultra-rapids (RT) products, apply CODE's ECOM2 model (Arnold et al. 2016), include other GNSS

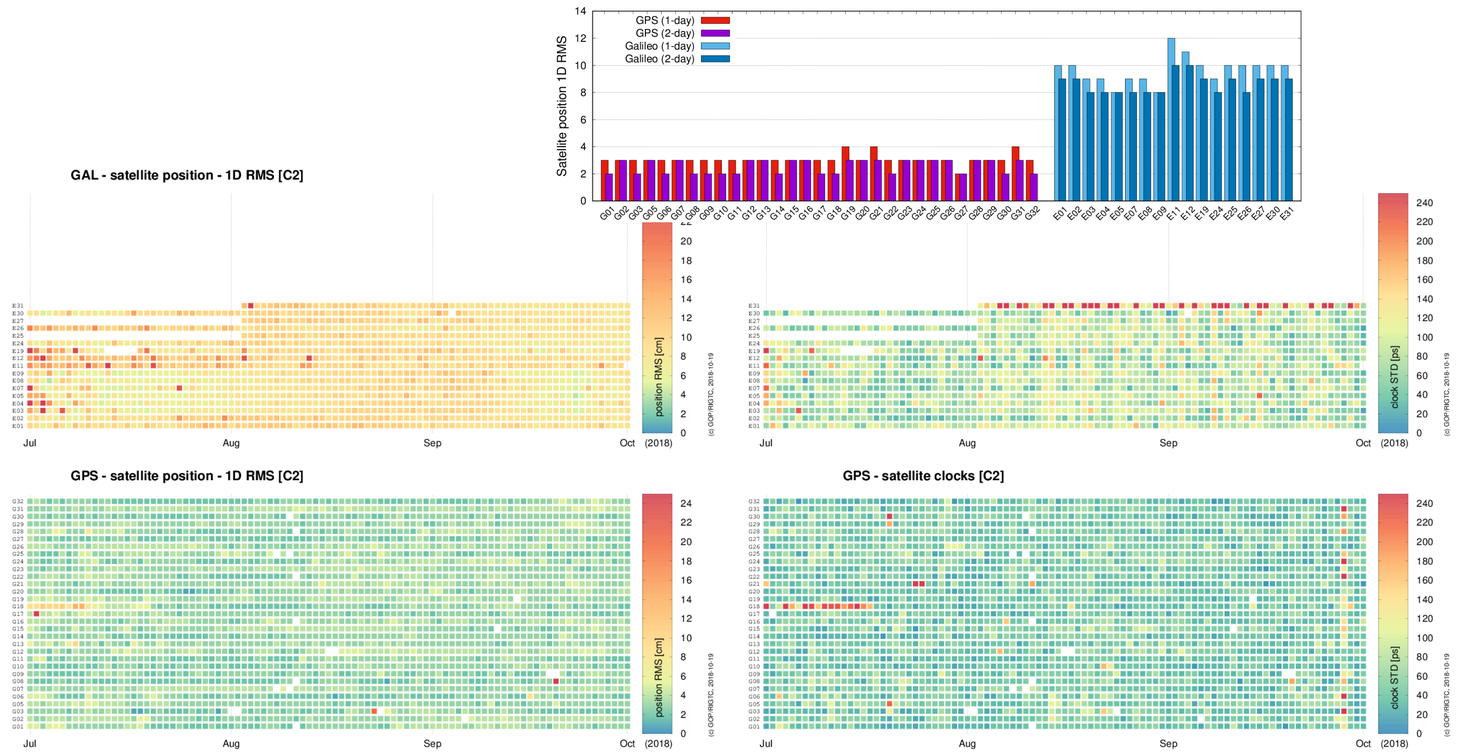

Figure 1: GPS+GAL orbit and clock comparison to CODE MGEX products (C2=GOP2-COM)

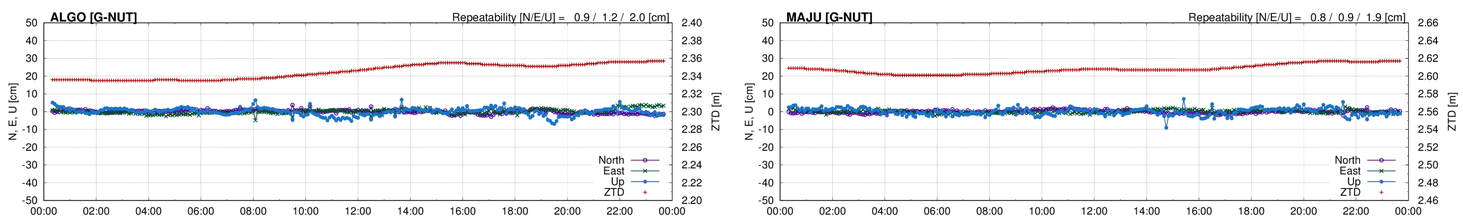

Figure 2: PPP-based monitoring of GOP rapid orbit and clock products using pseudo-kinematic processing of worldwide selected stations

Consolidated navigation messages (multi-GNSS)

- G-Nut/Aset software
- Autonomous strategy of quality control – no external dat
  - ➢ range checking and other static pre-filtering (conservative)
  - ➢ time-series parameter analysis (pre-selected parameters)
  - ➢ header consolidation (RINEX 3)
  - ➢ healthy status consolidation (statistical)
  - ➢ total group delays consolidation (statistical)
  - ➢ Identification of problematic receivers (health status, TGDs etc)
- Collection over 300 files worldwide
- Multi-step procedure: RINEX2, RINEX3, hourly, then merged together
- Full archive since year 1994 (consistent for RINEX2 and RINEX3)
- Support for multi-GNSS data QC, POD, signal-in-space monitoring, etc.
- Daily RINEX3: http://ftp.pecny.cz/LDC/orbits_brd/gop3
- Daily RINEX2: http://ftp.pecny.cz/LDC/orbits_brd/gop2

Todo: hourly update, real-time QC and consolidation

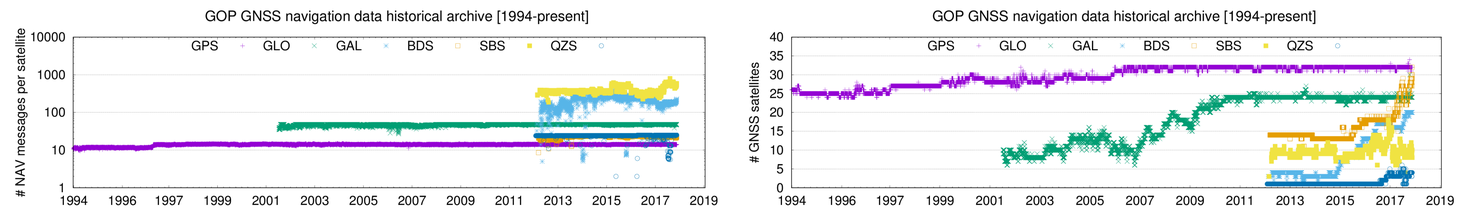

Figure 3: GOP GNSS NAV archive – 1) # of messages/satellite (left), 2) # of satellites per system (right(

Robust clock datum definition for real-time regional clock engine

Currently, the clock datum definition strategies select either

- ➢ stable receiver clocks with high quality hydrogen maser
  - Stations might be unavailable for regional networks
- ➢ single station with a maximum number of observations
  - Large datum variations due to the less stable receiver clocks

New clock datum definition by means of satellite clock corrections considers

- ➢ Coordinates for the reference station are known in the clock estimation
- ➢ Satellite clocks have overall better stability than most receiver clocks

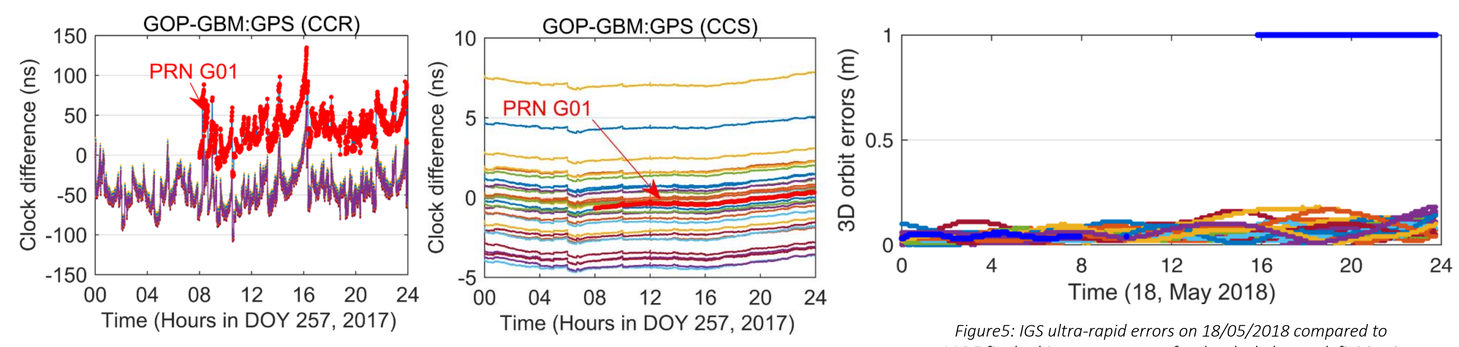

Figure 4: Clock difference with respect to the GBM final clocks using the STR1 receiver clocks (left) and the new proposed datum (right) on DOY 257 of 2017

Figure5: IGS ultra-rapid errors on 18/05/2018 compared to CODE final orbits, new strategy for the clock datum definition is capable to identify orbit outliers in real-time

Procedure implemented in G-Nut/Sothis in GOP for regional real-time analysis:

1. Using loop over all reference stations, positioning errors are calculated using broadcast orbits/clocks and pseudoranges;
2. Iterating the positioning to screen out any satellite that leads to the large errors, e.g. if the positioning errors exceed a given threshold value;
3. Selecting stations providing a 3D positioning error within a given threshold in the station lists, i.e. containing satellites with broadcast errors at a reasonable scale;
4. Creating a reference list of satellites with the elevation angle large than 30 degrees from the station list;
5. Defining zero-mean common clock satellite datum exploiting the reference list of satellites

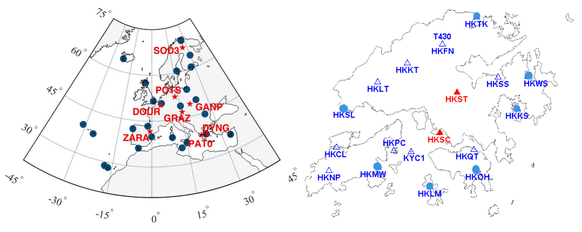

Figure 6: Demonstrator for GOP real-time clock estimation and PPP validation. EUREF stations for GPS/Galileo clock estimation (left), HongKong CORS stations for GPS/BDS clock estimation(right). The circle markers are the reference stations, the red markers are the PPP validation stations

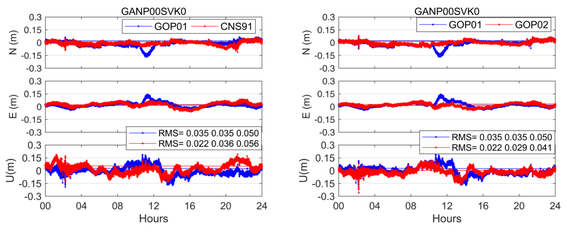

Figure 7: GPS PPP validation with different clock products

Table 1: Real-time clock products

Products Name	*System*	*Reference Stations*
GOP01	GPS	25 EUREF stations
GOP02	GPS/Galileo	25 EUREF stations
GOP03	GPS/BDS	7 HongKong CORS stations
CNS91	GPS/Galileo/GLONASS/BDS	Global stations

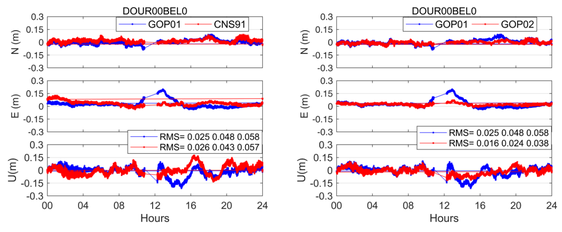

Figure 8: GPS/Galileo PPP validation with different clock products

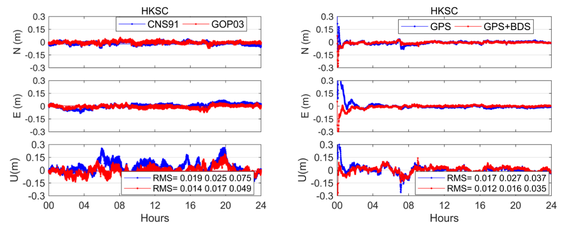

Figure 9: GPS PPP validation with different clock products

Figure 10: GPS+BDS PPP validations with GOP03 clock products

Conclusions

- ❖ New clock definition strategies is flexible for real-time & global/regional clock estimates by providing stable clocks datum and screen out broadcast clocks and ultra-rapid orbits outliers in real-time
- ❖ GPS/Galileo combined clock estimation is able to guarantee better clock products
- ❖ Regional clocks estimation can provide more accurate clocks than global products

We acknowledge the support by the New Technologies for the Information Society (NTIS) Project No. LO1506.