Report of the EPN Analysis Centres Coordinator Inclusion of Galileo observations in EPN coordinate products

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with contributions of EPN Analysis Centres

EUREF Symposium Tallinn, Estonia, May 22–24, 2019 The contents of the presentation:

- the inclusion of Galileo observations into EPN official products
- the next EPN analysis centres workshop.

Introduction

- At the EUREF 2016 Symposium in San Sebastian, the Analysis Centres (ACs) of the EPN were urged to make use of the available new GNSS data in their operational submissions to the EPN Analysis Combination Centre (Resolution 1).
 - Following the resolution, in 2016 the LPT analysis centre (swisstopo, Switzerland) started using Galileo (and BeiDou) observations (in addition to GPS and GLONASS used by other EPN ACs) for the generation of the operational products submitted to EUREF.
- At the EUREF Analysis Workshop in 2017 (Brussels, Belgium), three more ACs (BEK, BKG, and ROB) presented the results of the inclusion of Galileo observations into their subnetworks.
 - However, because of the missing antenna calibrations for Galileo observations, it was decided to yet wait with the further inclusions of Galileo observations into operational products.

Introduction

- At the last EUREF symposium held in Amsterdam (taking into account that Galileo is developing into fully deployed GNSS, the efforts of IGS to improve Galileo orbits, and the efforts of station managers to install Multi-GNSS stations) the EPN Analysis Centres were encouraged to build their capabilities for processing Galileo observations (Resolution 1).
- Following the resolution, the Troposphere and Analysis Centres Coordinators decided to start a test phase to analyze the impact of including Galileo on combined positions and tropospheric delays using as many AC solutions as possible.
- The EPN ACs were asked to generate test solutions including Galileo observations and provide them to the coordinators (EUREF LAC Mail 2344, September 24, 2018).

EPN stations tracking Galileo

Presently, Galileo satellites are tracked by 68% of EPN stations.

EUREF Permanent Tracking Network Stations submitting GALILEO data



www.epncb.eu

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The following AC solutions including Galileo observations were provided by EPN ACs during the test phase:

- dedicated test solutions generated by 8 ACs (of 16) in parallel to the operational solutions (a few ACs provided both solutions for more than one year):
 - BEK, GPS weeks 1975–2043
 - **BKG**, GPS weeks 1965–2043
 - **IGE**, GPS weeks 1975–2043
 - **NKG**, GPS weeks 2023–2043
 - **ROB**, GPS weeks 1960–2043
 - **SUT**, GPS weeks 2036–2043
 - **UPA**, GPS weeks 1975–2043
 - **WUT**, GPS weeks 2000–2043
- **LPT** AC operational solutions.

- Galileo orbits from the IGS Multi-GNSS Experiment (MGEX)
- RINEX 3 observations files
 - for some stations RINEX 3 files with short names are only available,
- ground antenna calibrations for Galileo observations:
 - presently, Galileo-specific receiver antenna calibrations are available for only 10% of EPN stations (individual chamber calibrations, epnc_14.atx),
 - for the antennas installed at 90% of stations tracking Galileo, Galileo-specific calibrations are missing, and GPS values of the same antenna have to be used during Galileo data processing,
 - at 40% of the stations type mean calibrated antennas are used (igs14.atx),
 - and at 50% of stations individually calibrated antennas are used (epnc_14.atx).

Combination of AC Galileo solutions

- The AC daily solutions including Galileo were combined in two ways:
 - as a combination of only 9 solutions including Galileo (8 AC test solutions and LPT solution; Galileo-only solution).
 - 95% EPN stations included
 - 45% of stations processed by 2 ACs
 - 17-25% of stations processed by 1 AC only
 - **2** as a common combination of 9 AC Galileo solutions (test solutions + LPT) with the remaining 7 operational GPS/GLONASS-only solutions (mixed solution).
- The resulting combined solutions including Galileo were compared with the operational solution (official EUREF solution based on GPS and GLONASS).



- Mean station position differences between combined Galileo-only solution and combined operational solution
- Only stations observing Galileo are shown
- Stations are grouped according to the type of the antenna calibration
- 44 weeks (2000–2043) of daily solutions used for comparison
- Results presented for stations with at least 28 days of observations



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Examples of differences of station positions

 Differences of station positions between Galileo only and operational combined solutions



Since the impact of adding Galileo on combined positions was small, the EUREF Governing Board agreed that EPN analysis centres may start including Galileo observations in the operational products since GPS week 2044 (EUREF LAC Mail no. 2407).

since week 2044, 11 analysis centers have been using Galileo observations for the generation of the official AC products.

Galileo AC operational solutions: present status

AC	Agency	Software	GNSS	Remark
ASI	Centro di Geodesia Spaziale, Italy	Gipsy Oasis	G	
BEK	Bavarian Academy of Sciences & Humanities, Germany	Bernese 5.2	GRE	Galileo
BEV	Federal Office of Metrology and Surveing, Austria	Bernese 5.2	GRE	Galileo
BKG	Bundesamt fuer Kartographie und Geodaesie, Germany	Bernese 5.2	GRE	Galileo
COE	Center for Orbit Determination in Europe, Switzerland	Bernese 5.2	GR	
IGE	Instituto Geografico Nacional, Spain	Bernese 5.2	GRE	Galileo
IGN	Institut Geographique National, France	Bernese 5.2	GR	
LPT	Federal Office of Topography swisstopo, Switzerland	Bernese 5.2	GREC	Galileo
MUT^1	Military University of Technology, Poland	GAMIT/GLOBK	GE	Galileo
NKG	Nordic Geodetic Commision, Sweden	Bernese 5.2	GRE	Galileo
RGA	Republic Geodetic Authority, Serbia	Bernese 5.2	GR	
ROB	Royal Observatory of Belgium, Belgium	Bernese 5.2	GRE	Galileo
SGO	Lechner Knowledge Center, Hungary	Bernese 5.2	GR	
SUT	Slovak University of Technology, Slovakia	Bernese 5.2	GRE	Galileo
UPA	University of Padova, Italy	Bernese 5.2	GRE	Galileo
WUT	Warsaw University of Technology, Poland	Bernese 5.2	GRE	Galileo

 1 MUT AC uses Gamit software for the GNSS analysis. Observations from GPS and Galileo are processed separately, and the resulting solutions are combined on a normal equation level.

RMS of AC residuals wrt. combination (1/3)

 RMS of station position residuals between AC solution and combination for ACs that started using Galileo after week 2044 (LPT is using Galileo since year 2016)



T. Liwosz, A. Araszkiewicz

Report of the EPN Analysis Centres Coordinator

RMS of AC residuals wrt. combination (2/3)

RMS of station position residuals between AC solution and combination for ACs that started using Galileo after week 2044



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Report of the EPN Analysis Centres Coordinator

RMS of AC residuals wrt. combination (3/3)

 RMS of station position residuals between AC solution and combination for ACs that have not started using Galileo yet



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RMS of position differences between all individual AC solutions and the combined solution for north, east and vertical components.



- The tests on the impact of Galileo observations on EPN combined station positions has been finished
 - for majority of stations position differences did not exceed 1 mm for horizontal components, and 3 mm for the vertical component,
 - for stations with type mean calibrated antennas larger differences were noticed than for stations with individually calibrated antennas, especially for the vertical component,
- since week 2044, 11 analysis centers started using Galileo observations for the generation of the operational products,
 - the average consistency of AC solutions (RMS of residuals wrt. the combination) remained at the same level.

We thank EPN ACs that provided test soutions including Galileo observations, in addition to operational solutions, for their great effort!

The next EPN Analysis Centres workshop has been scheduled for October, 16-17, 2019

(EUREF LAC Mail no. 2412 sent on March 22, 2019),

- The workshop will be held at the Warsaw University of Technology, Poland,
- Please save the date in your calendars,
- More information will follow after the Symposium.