EUREF TWG Multi-GNSS Working Group: Proposal of action items

Background

Today, the EUREF Permanent Network (EPN) is based on the satellite systems of GPS and GLONASS. The data flow of GPS and GLONASS data is well established und the number of combined receivers in the EPN network exceeds the number of GPS-only stations. Nevertheless, the analysis of combined GPS/GLONASS data is still optional and many EPN Local Analysis Centres (LACs) still process GPS-only data.

In the upcoming years, the EPN will be facing a changing landscape with new heterogeneous navigation systems (Galileo, COMPASS), signals and frequencies. How to analyse the data of these new systems as one homogeneous system is major challenge. What new products should be delivered to the users and how to upgrade the GNSS tracking networks without compromising products and the long-term stability are some of the questions that we will need to answer in the following years.

With the start of two Galileo IOV satellites on October 21, 2011 the starting shot for multi-GNSS in Europe was given. A constellation of 18 Galileo satellites is not expected before 2014, or even 2015. However, the urgency of immediately introducing the system into important pan-European projects, once the system is reaching FOC, could be anticipated. This concerns on the one hand the scientific interests but on the other hand the political matters: after the delay of several years compared to the original schedule and the financial burden of the system for the European budget quick progress will be postulated. For the existing national and European networks this means to enhance the present-day infrastructure by installing or updating combined receivers and antennas capable to receive the signals of upcoming satellite systems and the new signals of the existing satellite systems. Additionally, a new data flow based on new formats (RINEX3/RTCM3) needs to be established and software needs to be updated. Might be that even formats like RINEX2.xx may play a role in near future according to recent discussions in the IGS RINEX WG. In this document, we will label the new exchange format generally “RINEX3” which indicates, that this could be

RINEX3.xx and/or RINEX2.xx. The same holds true for the label “RTCM3”. Here, we indicate the agreed-upon format for the data transfer in real-time (high precision data formats supporting 'Multiple Signal Messages' (MSM) and 'High Precision Multiple Signal Messages' (HP MSM), and which are compatible with “RINEX3”).

In the IGS community, the so-called IGS M-GEX (Multi-GNSS Experiment) was initialized and a call for participation was launched in 2011 in order to encourage the setting up of new multi-GNSS receivers and in order to make the first steps towards the analysis of all available data. The EUREF TWG did not start a similar project for the EPN. Nevertheless, topics related to multi-GNSS were treated and were discussed in the TWG as they show up. At the 2010 TWG meeting in Gävle, candidates for a GNSS Working Group volunteered to further discuss open questions and to define concrete steps towards multi-GNSS. This document is a proposal of action items to be treated by the working group.

The establishment of a WG should stimulate further institutions to participate and to actively work towards the goal of this project: to establish EPN data and product provision based on a multi-GNSS approach and to guarantee consistency between various GNSS systems for all EPN products.

This document lists many open questions, and tasks to be fulfilled. Dependencies from e.g. IGS need to be considered. To answer the raised questions and to coordinate its realization is the main task of this WG.

Proposed activities

The activities proposed below should be addressed via several calls for participation to motivate as many individual contributors/agencies. They will consist of monitoring and coordinating the activities, informing about the state-of-art of development, defining specific rules related to multi-GNSS data collection and their analyses, revising current or creating new guidelines, setting up schedules for specific actions (e.g. inclusion of GLONASS to ACs' contributions) etc.

Generally, we see activities in the directions of "tracking the various signals", "including GLONASS completely in the current EPN analysis" as a pre-step for Galileo inclusion and "analysis of new GNSS signals". In the following sections we try to specify details. The order of the items does not necessarily reflect their order of its realization.

1. Tracking of GPS, GLONASS, Galileo and other GNSS signals / enhancing the EPN infrastructure

- Further stimulate the EPN stations to deliver multi-GNSS data for all new available signals for daily, hourly and real-time data streams.
- Enable a parallel infrastructure / data flow (daily, hourly) containing the data of the new GNSS signals.
- Focussing on new GNSS signal types (see Table 1-3 as an example of RINEX 3.0. RINEX3.01 includes Compass, RINEX3.02 includes COMPASS and QZSS, and RINEX2.xx proposal includes also COMPASS and QZSS. As an European sub-commission the main focus is Galileo. Nevertheless, also the other new satellite systems need to be considered (link to the global service provider as IGS).

  → Signals provided already today but not yet used in the processing, e.g.

  - one third of the GPS constellation is providing an additional signal on the second frequency
  - there are two GPS satellites emitting signals on a third frequency and with a better satellite clock performance.

- signals of the new GLONASS satellites

→ Signals that will be provided in near future (and are partly already provided from some receivers): SBAS, Galileo, COMPASS, and QZSS

- Monitoring of the data types tracked at permanent stations. Detect dependencies of receiver types, firmware (and maintain their catalogue?). Identify the availability of suitable RINEX conversion and quality monitoring tools and potentially stimulate their development. Define rules which data should be tracked as minimum for EPN contribution.
- Evaluating of format issues e.g.RINEX3 for post-processing and RTCM3-Multiple Signal Messages for real-time)

→ RINEX3:

- encouraging existing stations to deliver RINEX3 data even if new signals are not yet tracked (and define the strategy how this is organized)
- Comparison of RINEX2.11 with RINEX3 raw data and defining actions from the results (contact manufacturers)
- Quality check programs: definition of the quality indicators, algorithm development and testing

→ RTCM3:

- encouraging existing stations to deliver RTCM3 data even if new signals are not yet tracked (and define the strategy how these are organized/disseminated)
- Encourage existing stations to deliver new GNSS signals in real-time in RTCM3.
- Comparison of RTCM3 with RINEX3 data and defining actions from the results (contact manufacturers)
- Quality check programs: definition of the quality indicators, algorithm development and testing

→ Sorting out of specialities (RINEX3 subversions 3.00, 3.01, 3.02, 2.xx)

→ Validation of different options for generation of RINEX files: e.g. via BNC from RTCM, or using

specific software from data files in proprietary binary format (e.g. dat2rnx and similar)

- Stimulating the set up new stations or upgrade of existing EPN stations in order to deliver the new GNSS signals. This goal may conflict with the goal of the long-term maintenance of the reference frame if station equipment is changed and coordinate jumps are introduced in the time series. The working group has to prepare guidelines for which stations the equipment can be changed and for which stations it is recommended to set up a new station.
- Detailed analyses of the new signals
- Analyses of possible errors in the data

2. Analysis of GLONASS data

- Stimulate an inclusion of GLONASS by all EPN analysis centres
  - → consistent GPS+GLONASS processing
  - → further stimulate GLONASS antenna calibrations
  - → improve visibility of GLONASS in EUREF (no other continental Reference Frame services is using GLONASS so far)
- Revision of GNSS-related parameters such as: orbit/ERP products to be used, ground antenna and satellite antenna phase center variations (PCVs), ambiguity resolution, DCBs, baseline creation, station/GNSS-system-dependent coordinates (i.e. EPN LAC processing guidelines, densification campaign guidelines)
- Assess the impact of GLONASS contributions on the coordinates, zenith total delays. Check the consistency of such derived parameters, dependence on adopted PCV models etc.

3. Analysis of new GNSS signals

- Cooperation with scientific software manufacturers to find out which data processing options are already supported and which options where identified to be successful

- Planning of same / similar studies as realized when introducing GLONASS in the analysis (orbit products to be used, processing option, handling of DCBs and PCVs, impact study of multi-GNSS)
- cooperate with Real-Time Analysis WG

4. Other issues

- Learning from results and experiences achieved during the IGS MGEX project
- Developing of software (post-processing and real-time) capable to handle multi-GNSS signals. Planning to use the software in the operational EPN processing
- Define the optimal procedure to have PCV calibrations available which are consistent between the GNSS systems
- Setting up a time schedule in order to plan the operational switch to RINEX3 which also is in line with IGS.
- Concept how to deal with the RINEX2 data archives (support of both formats versus conversion to RINEX3)
- Educational aspects: information to users

Possible outcomes of the WG:

It is not the intention of this charter to finally anticipate the results and conclusions of the WG. However, a minimum list of possible outcomes can be compiled already:

- Detailed recommendations for the EPN LACs how to handle GLONASS data within the routine EPN data processing;
- Detailed recommendations for the EPN Central Bureau on data quality checks and other tools that need to be implemented and routinely run on the EPN stations in order to guarantee the reliability of the new GNSS signals tracked by the EPN stations.

- Detailed recommendations for stations managers on receiver set up for optimal tracking of the new GNSS signals.
- Results of processing and analysis of new GNSS signals through periodic presentations, e.g. at the EUREF symposia;
- Compilation of pros and cons concerning the various RINEX format versions, the reciprocal conversion etc.
- Software, e.g. for quality checking
- Reports (intermediate, final) about the results of the WG.

Proposal for possible WG members:

(list from the Minutes of the Gävle 2010 TWG meeting, list may be extended)

Elmar Brockmann

Carine Bruyninx (Chair TWG, member ex officio)

Alessandro Caporali

Rolf Dach

Jan Douša

Heinz Habrich

Wolfgang Sőhne

Christof Vőlksen

Proposed additional members:

Tim Springer

Version 1, May 14, 2012, compiled by J. Douša and E. Brockmann

Version 2, May 29, 2012, with contributions from C. Bruyninx, A. Caporali, H. Habich, W. Söhne

Version 3, June 14, 2012, modifications according TWG discussions in Paris, WG name changed from ”GNSS WG” to ”Multi-GNSS WG”

Version 4, Nov. 13, 2012, accepted by TWG in Berne; status ”Draft” removed

Attachments:

System	Freq. Band	Frequency	Channel or Code	Observation Codes			
				Pseu-do Range	Carrier Phase	Dopp-ler	Signal Stren-gth
GPS	L1	1575.42	C/A	C1C	L1C	D1C	S1C
			P	C1P	L1P	D1P	S1P
			Z-tracking and similar (AS on)	C1W	L1W	D1W	S1W
			Y	C1Y	L1Y	D1Y	S1Y
			M	C1M	L1M	D1M	S1M
			codeless	--	L1N	D1N	S1N
	L2	1227.60	C/A	C2C	L2C	D2C	S2C
			L1(C/A)+(P2-P1) (semi-codeless)	C2D	L2D	D2D	S2D
			L2C (M)	C2S	L2S	D2S	S2S
			L2C (L)	C2L	L2L	D2L	S2L
			L2C (M+L)[1]	C2X	L2X	D2X	S2X
			P	C2P	L2P	D2P	S2P
			Z-tracking and similar (AS on)	C2W	L2W	D2W	S2W
			Y	C2Y	L2Y	D2Y	S2Y
			M	C2M	L2M	D2M	S2M
			codeless	--	L2N	D2N	S2N
	L5	1176.45	I	C5I	L5I	D5I	S5I
			Q	C5Q	L5Q	D5Q	S5Q
			I+Q	C5X	L5X	D5X	S5X
GLO-NASS	G1	1602+k*9/16 k= -7...+12	C/A	C1C	L1C	D1C	S1C
			P	C1P	L1P	D1P	S1P
	G2	1246+k*7/16	C/A (GLONASS M)	C2C	L2C	D2C	S2C
			P	C2P	L2P	D2P	S2P
Galileo	E1	1575.42	A PRS	C1A	L1A	D1A	S1A
			B I/NAV OS/CS/SoL	C1B	L1B	D1B	S1B

[1]

System	Freq. Band	Frequency	Channel or Code	Observation Codes			
				Pseu-do Range	Carrier Phase	Dopp-ler	Signal Stren-gth
			C no data	C1C	L1C	D1C	S1C
			B+C	C1X	L1X	D1X	S1X
			A+B+C	C1Z	L1Z	D1Z	S1Z
	E5a	1176.45	I F/ NAV OS	C5I	L5I	D5I	S5I
			Q no data	C5Q	L5Q	D5Q	S5Q
			I+Q	C5X	L5X	D5X	S5X
	E5b	1207.140	I I/ NAV OS/CS/SoL	C7I	L7I	D7I	S7I
			Q no data	C7Q	L7Q	D7Q	S7Q
			I+Q	C7X	L7X	D7X	S7X
	E5 (E5a +E5b)	1191.795	I	C8I	L8I	D8I	S8I
			Q	C8Q	L8Q	D8Q	S8Q
			I+Q	C8X	L8X	D8X	S8X
	E6	1278.75	A PR S	C6A	L6A	D6A	S6A
			B C/ NAV CS	C6B	L6B	D6B	S6B
			C no data	C6C	L6C	D6C	S6C
			B+C	C6X	L6X	D6X	S6X
			A+B+C	C6Z	L6Z	D6Z	S6Z
SBAS	L1	1575.42	C/A	C1C	L1C	D1C	S1C
	L5	1176.45	I	C5I	L5I	D5I	S5I
			Q	C5Q	L5Q	D5Q	S5Q
			I+Q	C5X	L5X	D5X	S5X

Table 1: Observation types for the various GNSS systems according RINEX3.0 format.

Compass	E1	1589.74	?	?	?	?	?
	E2	1561.098	I	C2I	L2I	D2I	S2I
			Q	C2Q	L2Q	D2Q	S2Q
			I+Q	C2X	L2X	D2X	S2X
	E5b	1207.14	I	C7I	L7I	D7I	S7I
			Q	C7Q	L7Q	D7Q	S7Q
			I+Q	C7X	L7X	D7X	S7X
	E6	1268.52	I	C6I	L6I	D6I	S6I
			Q	C6Q	L6Q	D6Q	S6Q
			I+Q	C6X	L6X	D6X	S6X

Table 2: Additional observation types in RINEX3.01 (published 2009_06_22).

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+-----------------------------------------------------------------------+
| GPS L1C 1575.42 C7 L7 D7 S7 |
| |
| GLONASS G3 1202.025 C7 L7 D7 S7 |
| |
| Compass B1/E2 I/Q 1561.098 C1 L1 D1 S1 |
| B2/E5b I/Q 1207.14 C7 L7 D7 S7 |
| B3/E6 I/Q 1268.52 C6 L6 D6 S6 |
| B1-2/E1I/Q 1589.742 C2 L2 D2 S2 |
| |
| QZSS L1C/A 1575.42 C1 L1 D1 S1 |
| L1C 1575.42 C7 L7 D7 S7 |
| L1-SAIF 1575.42 C8 L8 D8 S8 |
| L2C 1227.60 C2 L2 D2 S2 |
| L5 I/Q 1176.45 C5 L5 D5 S5 |
| LEX S/L 1278.75 C6 L6 D6 S6 |
+-----------------------------------------------------------------------+
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Table 3: extended observables for version 2.11 (proposal Lou Estey for teqc implementation May 2012; version RINEX2.1x).