

## Introduction

The poster gives an overview on the BKG activities within the Real Time Service (RTS) of the International GNSS Service (IGS). This includes:

- The infrastructure required to operate the service with a suitable reliability,
- Current developments in standardization at the Radio Technical Commission for Maritime Services, Special Committee 104 on Differential Global Navigation Satellite Systems (RTCM-SC104), and
- Real time data processing.

Limitations and future plans related to standardization and routine operation are addressed as well.

## IGS RTS Analysis Centre

BKG is one of currently eight IGS RTS analysis centres (ACs) and provides precise GPS and GLONASS orbit and clock products supporting dual frequency Precise Point Positioning (PPP) in the meanwhile standardized RTCM v3 format (Table 1).

Table 1: Orbit and clock corrections already defined in RTCM v3.

RTCM Message Type	Description	RTCM Message Type	Description
1057	GPS orbit correction	1063	GLONASS orbit correction
1058	GPS clock correction	1064	GLONASS clock correction
1059	GPS code bias	1065	GLONASS code bias
1060	GPS orbit & clock correction	1066	GLONASS orbit & clock correction
1061	GPS User Range Accuracy	1067	GLONASS User Range Accuracy
1062	GPS high rate clock correction	1068	GLONASS high rate clock correction

Orbit corrections are provided in along-track, cross-track and radial components defined in the Earth-centered, Earth-fixed reference frame of the broadcast ephemerides.

IGS RTS products allow the computation of coordinates in the current ITRF reference frame (ITRF2008). In addition some streams are made available by BKG for regional reference frames by transformation, such as ETRF2000 for Europe, NAD83 for North America or SIRGAS2000 for South America

*Limitation: Hard coded 7 parameter transformation that is limited especially in case of scale differences.*

*Solution: The definition of RTCM messages able to transport the parameter for a 14 parameter transformation is under discussion at RTCM-SC104.*

## IGS RTS Combination Centre

BKG is providing two of three official IGS RTS product combinations (Table 2). The combination is carried out using a Kalman filter approach applying the observation equation:

$$c_a^s = c^s + o_a + o_a^s$$

- $c_a^s$  .. Clock correction for satellite  $s$  estimated by analysis center  $a$
- $c^s$  .. Combined clock correction for satellite  $s$
- $o_a$  .. Analysis center specific offset, common for all satellites
- $o_a^s$  .. Satellite and analysis center specific clock offset

Table 2: Present IGS RTS product streams. The IGSxx products are related to the satellite antenna phase center (APC). The IGCxx products are related to the Center of Mass (CoM); that is not compliant with current RTCM v3 standard but used for product accuracy evaluation.

Stream Name	Description	RTCM Message Types	Reference Point	Combination Center / Software
IGS01 IGC01	GPS only orbit / clock correction, orbit: average value from all contributions clock: weighted average	1059(5),1060(5)	APC CoM	ESA/ESOC / RETINA
IGS02 IGC02	GPS only orbit / clock correction, Kalman filter combination orbit: extracted from one specific AC clock: estimated using clocks from individual ACs as pseudo observations	1057(60), 1058(10), 1059(10)	APC CoM	BKG / BNC
IGS03 IGC03	GPS + GLONASS same procedure as for IGS02/IGC02	1057(60), 1058(10), 1059(10), 1063(60), 1064(10), 1065(10)	APC CoM	BKG / BNC

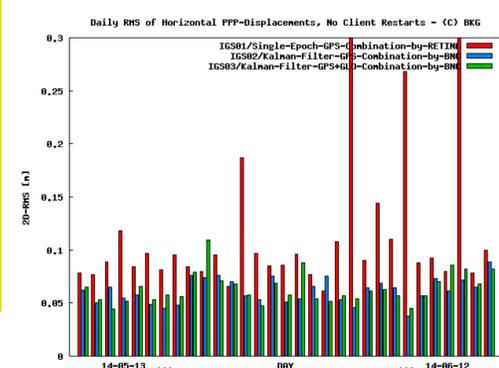


Figure 2 shows a time series of 2D-RMS values, each from 24 hours of real time PPP displacements using different IGS combination products applied for an ever changing selection of about 20 globally distributed IGS reference stations over the period of one month.

Figure 2: IGS RTS product evaluation by PPP processing; RMS of horizontal displacement after convergence.

## Redundancy Concept and Monitoring

In order to guarantee the reliability of IGS RTS product generation redundant maintenance of the most critical infrastructure components is required (Figure 3).

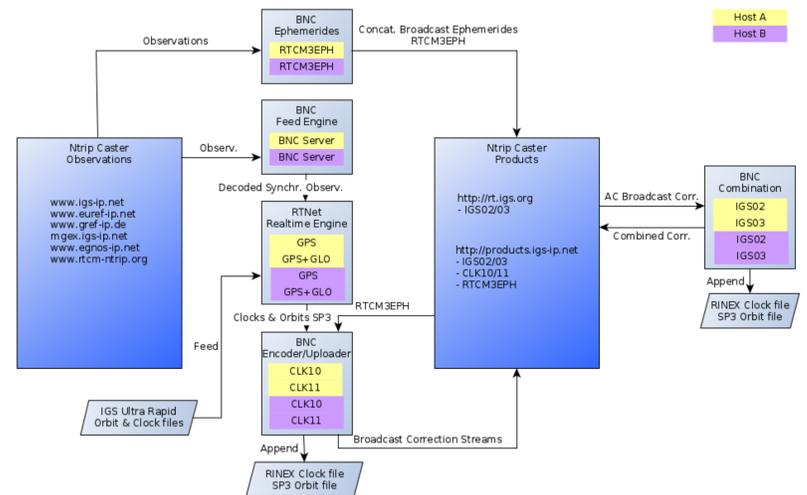


Figure 3: Infrastructure and redundancy concept for BKG's IGS RTS product generation.

*Limitation: For many observation data streams a redundant data delivery is still not realized.*

*Solution: Contact the stream provider to force the observation data delivery to more than one broadcaster.*

## Real Time Access to Broadcast Ephemerides

IGS RTS orbit and clock corrections are related to broadcast messages. BKG provides real time access to broadcast ephemerides for GPS, GLONASS and Galileo satellites.

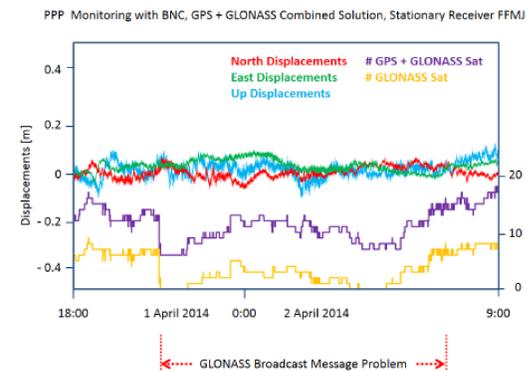


Figure 4: Influence of the GLONASS April 1st incident on a combined GPS + GLONASS PPP solution for IGS station FFMJ using IGS RTS products. The GLONASS contribution collapsed completely at about 9:00 UTC on April 1st and recovered at about 7:00 UTC on April 2nd.

On April 1<sup>st</sup>, 2014, at 9h15m p.m. UTC all GLONASS satellites started to transmit wrong broadcast messages.

The problem disappeared after an hour for two GLONASS satellites. By about 7h UTC on April 2<sup>nd</sup> all GLONASS satellites transmitted again correct broadcast messages.

Figure 4 shows no major problem in Precise Point Positioning with GPS + GLONASS combination because of the reliable contribution from GPS.

*Limitation: Current broadcast message plausibility check is not sufficient.*

*Solution: Establish a more sophisticated broadcast ephemerides monitoring.*

A broadcast ephemerides monitoring could be established as follows:

- Continuously receive up-to-date broadcast ephemerides carrying approximate orbits and clocks for all satellites.
- Continuously receive the best available orbit and clock predictions for all satellites in XYZ Earth-centered, Earth-fixed IGS08 reference system such as IGS ultra rapid products.
- Calculate XYZ coordinates of satellite positions from broadcast ephemerides orbits.
- Calculate differences  $dX$ ,  $dY$ ,  $dZ$  between broadcast ephemeris and IGS08 orbits.
- Upload of only those broadcast ephemerides to an Ntrip broadcaster, whose differences are under an agreed limit.

## Standardization Efforts

Because of its membership in RTCM-SC104, BKG is actively involved in the standardization process. Proposals made in the RTCM-SC104 working groups are implemented in BKG's software tools at an early time to take part in interoperability tests, required to conclude the respective standardization step. Currently, the following message are under discussion at RTCM-SC104:

- Precise orbits, satellite clocks, code biases for Galileo, BDS, QZSS, SBAS satellites
- Vertical Total Electron Content (VTEC) and satellite phase biases

*Limitation: More than one implementation is required to promote the standardization process.*

*Solution: Who is willing to implement one or more proposals on server or client side, is greatly appreciated to contact the RTCM-SC104 State Space Working Group shared by Gerhard Wübbena.*

## Acknowledgement

The IGS Real Time Service is made possible through the support provided by more than 160 station operators, multiple data centers and analysis centers around the world. The effort of all these contributors is gratefully acknowledged.

## IGS Workshop, June 23-27, 2014, Pasadena, California, USA