GFZ
Helmholtz Centre
POTSDAM

HELMHOLTZ CENTRE POTSDAM
GFZ GERMAN RESEARCH CENTRE FOR GEOSCIENCES

GFZ's Global Multi-GNSS Network And First Data Processing Results

M. Uhlemann, M. Ramatschi, G. Gendt

Helmholtz Centre Potsdam - GFZ German Research Centre for Geosciences
Telegrafenberg, 14473 Potsdam, Germany (uhle@gfz-potsdam.de)

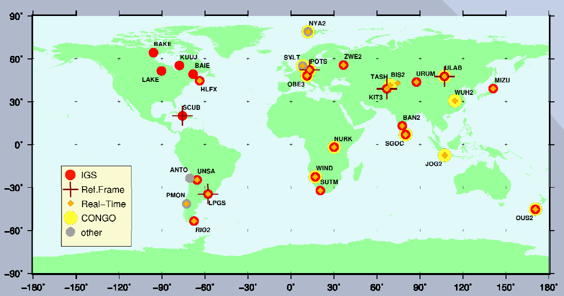
GFZ's Multi-GNSS Station Network

GNSS station network

GFZ is operating a global GNSS station network (currently ~30 stations, see Fig.1) since the early 1990s to support scientific research activities like precise satellite clock & orbit determination, radio occultation measurements and crustal dynamics.

With recent developments in receiver technology and new upcoming navigation satellite systems like Galileo an upgrade of our stations was needed to track all GNSS to support as much as possible research activities.

Through the in-house development of GNSS sensor stations a reliable network performance can be ensured and even a fast adaption to unusual requirements from scientific projects is possible.



Current status

All of the 12 modernized stations are presently also contributing to the CONGO network (led by DLR) as well as to the IGS MGEX campaign.

They are equipped with 'JAVAD TRE_G3TH DELTA' receivers and 'JAV_RINGANT_G3T' choke-ring antennas (Fig. 2). Actually they are tracking GPS (L1/L2/L5), GLONASS (L1/L2) and GALILEO (L1/L5) signals. All installed antennas are individually calibrated using the new anechoic chamber of the University of Bonn (Germany). These stations provide Real-Time measurements in JAVAD proprietary format as well as RTCM-3. For post-processing the observation data are stored in Rinex-2 & Rinex-3 format.

All stations are designed to host any kind of commercial GNSS receiver (Fig. 3), they use a PC with low power consumption and can be controlled fully remotely via a secure VPN connection (which is also tested with VSAT).

Planned network upgrade

The plan for the near future comprises the upgrade of the majority of the GFZ operated stations to fulfill Multi-GNSS capability with focus on South- and Central America.

Fig. 1 (left): Global network of GNSS sensor stations operated by GFZ. Multi-GNSS stations are marked yellow, IGS stations red and Real-Time stations orange.

Fig. 3 (left): The GFZ in-house developed 'Geodetic Sensor Station' in 19" format with integrated Monitor and keyboard. The example is showing the reference station 'POTS' in Potsdam (DE).

Fig. 2 (right): Antenna farm located at Dunedin (NZ). Left antenna belongs to IGS station 'OUS2'.

CONGO Data Processing Setup

Motivation

One of the main goal of this study is the precise orbit & clock determination of GALILEO's Giove (E01/E16) and IOV (E11/E12) satellites and also the investigation of station tracking behavior and orbit issues. The advantage of the modern 'COoperative Network for GIOVE Observation' (CONGO) tracking network can be found in homogeneous observation types and station hardware (almost all with JAVAD receivers, but different antenna types).

Data provision

Rinex-3 files for this studies are generated from Real-Time streams and are kindly provided by DLR/GSOC for an interval of four weeks:

GPS-Week 1680-1683 = DOY 078-105 = 18/03-14/04/2012

The Galileo satellite names (PRN) were unified for data processing to ESA standard: Giove-A/-B = E01/E16 and IOV-PFM/FM2 = E11/E12.

Processing Scheme

- Fully combined GPS/GAL estimation with GFZ's S/W package EPOS.P8
- Technique: Ionosphere-free linear combination, undifferenced carrier phase and pseudo range observations
- Sampling rate: 5 min; Elevation cut-off angle: 7°
- Ambiguity fixing: GPS only
- Inter System Bias (ISB): One bias parameter per station and day; Mean of code biases per station used as a priori value; Very loose constraints
- Observation types:

Network	GPS	GAL	#Stations
IGS	L1 = L1P/L2P	-	110
CONGO	E1 = L1W/L2W	E5a = L1X/L5X	23

- Clock reference station: WTX3
- ISB: UND0 tight constraint (~0) (for better comparisons only)
- Product generation scheme adapted from IGS-Final line, e.g.
  - 3-day orbit stacking
  - Weekly coordinate solution
  - etc.

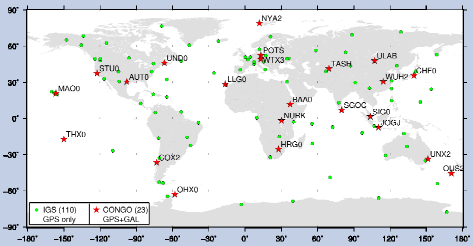


Fig. 4: Global network of IGS (green) and CONGO (red) stations, which were set up for data processing. The 23 CONGO stations realize a good global coverage for practical GALILEO orbit determination purposes.

Results and Comparisons

Observation data statistics

Data quality checks of IGS and CONGO observation data were adopted from GFZ-AC analysis scheme. One of the problems detected during the pre-processing step was a significant rejection of GAL observation data. Usually the ratio of input/output data per station is for GPS >90%, but in this study we achieved for GAL only ~75%.

Satellite:	E01	E16	E11	E12
Data In/Out Ratio [%]	76.5	78.3	71.2	73.7

The reason can be found in erroneous (C)BOC-tracking of IOV satellites on some stations operated by GFZ w/o multipath-mitigation under firmware version 3.4.1b3. The current tracking seems to be ok after an upgrade was done to the latest JAVAD firmware version 3.4.4b0.
Satellite Giove-A in contrast is generally influenced from bad observations.

Orbit overlaps

A first orbit quality assessment can be derived from overlaps at day boundaries determined from 'final' 3-day solution (Fig. 5). It is shown that an orbit accuracy of 5-8 cm can be achieved. Only Giove-A (E01) orbit is worse by factor 2.

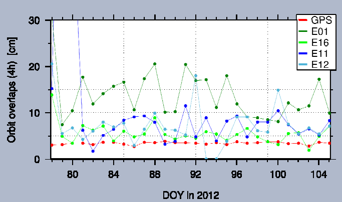


Fig. 5: Orbit overlaps (4 hours) of GAL satellites. For GPS the median of all satellites is given (~3 cm).

Clock performance

During the test interval all GAL satellites were operated on Rubidium Atomic Frequency Standard (RAFS), the modern Passive Hydrogen Maser (PHM) are still inactive. In Fig. 6 it is depicted that only E11 show a 'normal' behavior comparable to GPS. The very noisy E01 values indicate a degraded clock quality next to obviously orbit modeling problems, as it is also the case for E16 & E12 where clear pattern are visible.

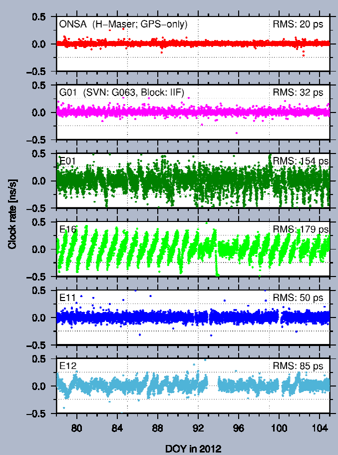


Fig. 6: Clock rates as first derivative of the adjusted clock corrections (daily linear trend removed).

Inter System Biases

It was estimated one common bias parameter per station for system GAL in this study. The ISB median values and their repeatabilities for all CONGO stations are given in Fig. 7. The station UND0 was chosen as reference and is thus zero. OHX0 is the only station with Leica receiver, all other are equipped with Javad. Mean standard deviation of all stations is ~0.5 ns over the whole interval with peak-to-peak variations of ~2 ns.

The Tab. 1 below show some examples of the mean ISB's per station and satellite. It can be seen that no satellite specific limitations were found to set up one common ISB as it was done in this study.

Station \ Satellite:		E01	E16	E11	E12
POTS	(Potsdam)	-2,27	-1,62	-2,52	-1,28
WUH2	(Wuhan)	-6,45	-6,09	-6,67	-5,45
THX0	(Tahiti)	-1,25	-1,49	-1,15	-0,35
HRG0	(Hartebeesthoek)	+3,13	+3,13	+3,32	+3,36

Tab. 1: Satellite specific ISB examples [ns].

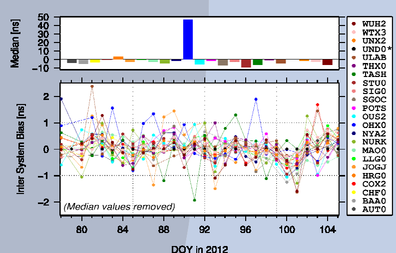


Fig. 7: Inter System Biases (ISB) between GPS and GAL of all CONGO stations.

Orbit validation using SLR

An independent validation of the determined satellite orbits can be assessed via SLR measurements (Fig. 8). Both Giove satellite orbits (E01 & E16) seem degraded as clearly seen from residual patterns. IOV performance (E11 & E12) is quite good and show orbit accuracies of ~10 cm. The systematic bias between Giove (+11 to +12 cm) and IOV (-5 to -8 cm) satellites seem to indicate inaccurate meta information provided from system operator.

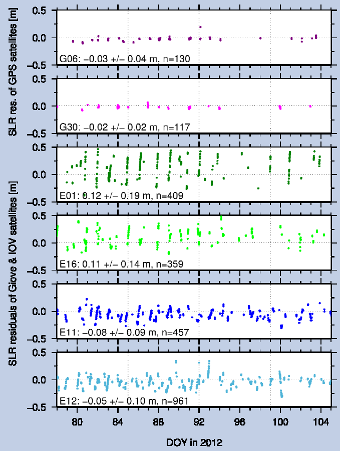


Fig. 8: SLR residuals for GALILEO and GPS satellite orbits (threshold for outlier test: 0.5 m).