Multi-GNSS Orbit and Clock Combination: Preliminary Results

Mathias Fritsche
German Research Centre for Geosciences GFZ, Telegrafenberg, 14473 Potsdam, Germany

GFZ Helmholtz Centre POTSDAM

HELMHOLTZ ASSOCIATION

Abstract

In the framework of the Multi-GNSS Experiment (MGEX) a number of Analysis Centers (ACs) extended their software capabilities to process signals from the BeiDou, Galileo, and QZSS systems in addition to the well established systems GPS and GLONASS. Combined orbits and clocks from GPS and GLONASS represent core products of the IGS. The presence of the newly developing GNSS and the fact that a number of individual MGEX-AC products are already available asks also for associated combined MGEX products. This poster provides preliminary results from a multi-GNSS orbit and clock combination.

MGEX AC Product Portfolio

Tab. 1 Parameter types provided to MGEX by different ACs. *(1)* since GPS-week 1843, 5min sampling before. *(2)* extracted from SP3 files, i.e. only satellite clocks available. Files aquired from *ftp://cddis.gsfc.nasa.gov/gnss/products/mgex.*

AC	Institute	Orbit		Clock	Bias	ERP	SNX
com	CODE	SP3	15min	5min	DCB,IFB,ISB	daily	–
gbm	GFZ	SP3	15min	(1)30sec	IFB,ISB	daily	–
grm	GRGS	SP3	15min	30sec	–	–	GPS weeks 1877/78
qzf	JAXA	SP3	5min	(2)*5min*	–	–	–
tum	TU Munich	SP3	5min	(2)*5min*	–	–	–
wum	Wuhan University	SP3	15min	5min	–	daily	–

Tab.1 lists the ACs currently contributing to MGEX and the respective parameter types made available. Only satellite positions and satellite clocks are common to all MGEX-ACs. Fig.1 provides an overview of the actual GNSS contained in each product submission (SP3 content). Data from the year 2015 has been selected for the combination of orbits and clocks.

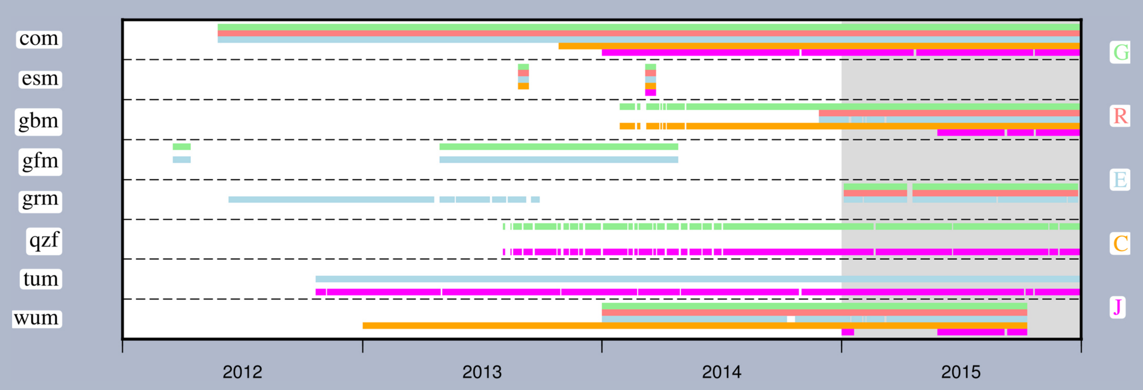

Fig. 1 Overview of GNSS provided by individual MGEX-ACs. AC description provided in Tab.1. RINEX-3 identifiers, G: GPS, R: GLONASS, E: Galileo, C: BeiDou, J: QZSS.

Orbit and Clock Combination Procedure

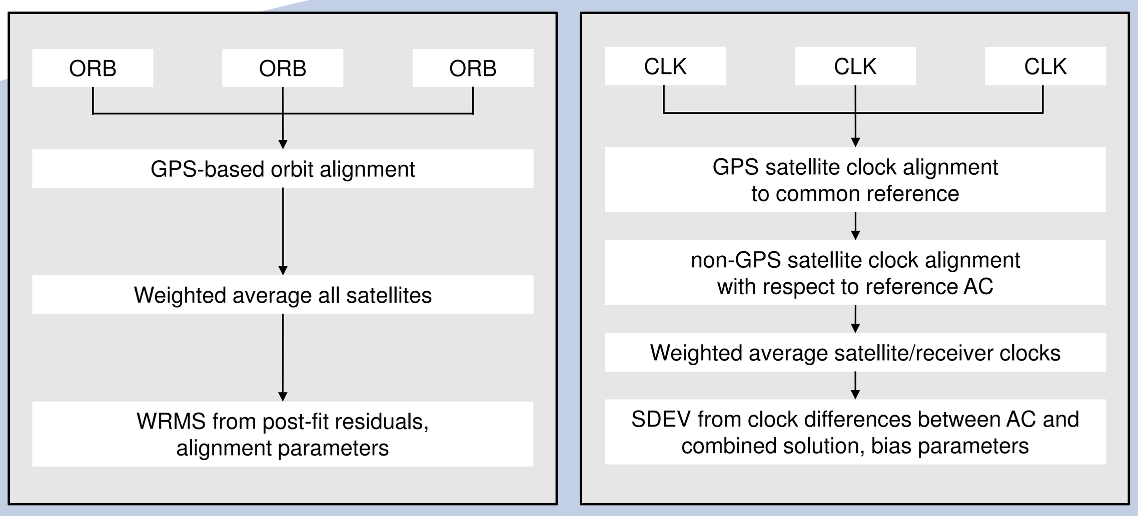

Fig. 2 Generalized schemes for the procedures of satellite orbit (left) and satellite/receiver clock (right) combination.

A generalized workflow for the multi-GNSS orbit combination is illustrated in Fig.2 (left). The detailed procedure is adapted from that applied within the IGS. The AC-individual orbit frames are aligned w.r.t. each other using the GPS constellation only. The finally combined solution is a weighted average for all GNSS included. Fig.3 shows selected transformation parameters resulting from the orbit frame alignment. Fig.4 (top) shows the agreement with the combined MGEX solution for GPS satellites in terms of the weighted RMS of orbit differences.

The workflow for the multi-GNSS clock combination is illustrated in Fig.2 (right). It basically follows the IGS strategy including additional steps to cope with different inter-system bias setups among the ACs. In particular, additional clock offsets and linear drifts are estimated for all non-GPS satellite clocks w.r.t. a selected reference AC. Generally, all satellite and receiver clock parameters are assumed to refer to GPS time scale. For GPS satellites, Fig.4 (bottom) shows the agreement between the combined MGEX and the Final IGS solution in terms of the standard deviation of clock differences.

The **qzf** solution was excluded from the combination due to generally large deviations and kept for comparisons only. Likewise, the **tum** solution was excluded due to the absence of the GPS part. Final IGS GPS orbits are included with zero weight for comparison purposes. The table below provides an overview of the AC in/exclusion from the combination.

	com	gbm	grm	qzf	tum	wum	igs
Orbit/Clock combination	x	x	x			x	
Orbit/Clock comparison	x	x	x	x	x	x	x

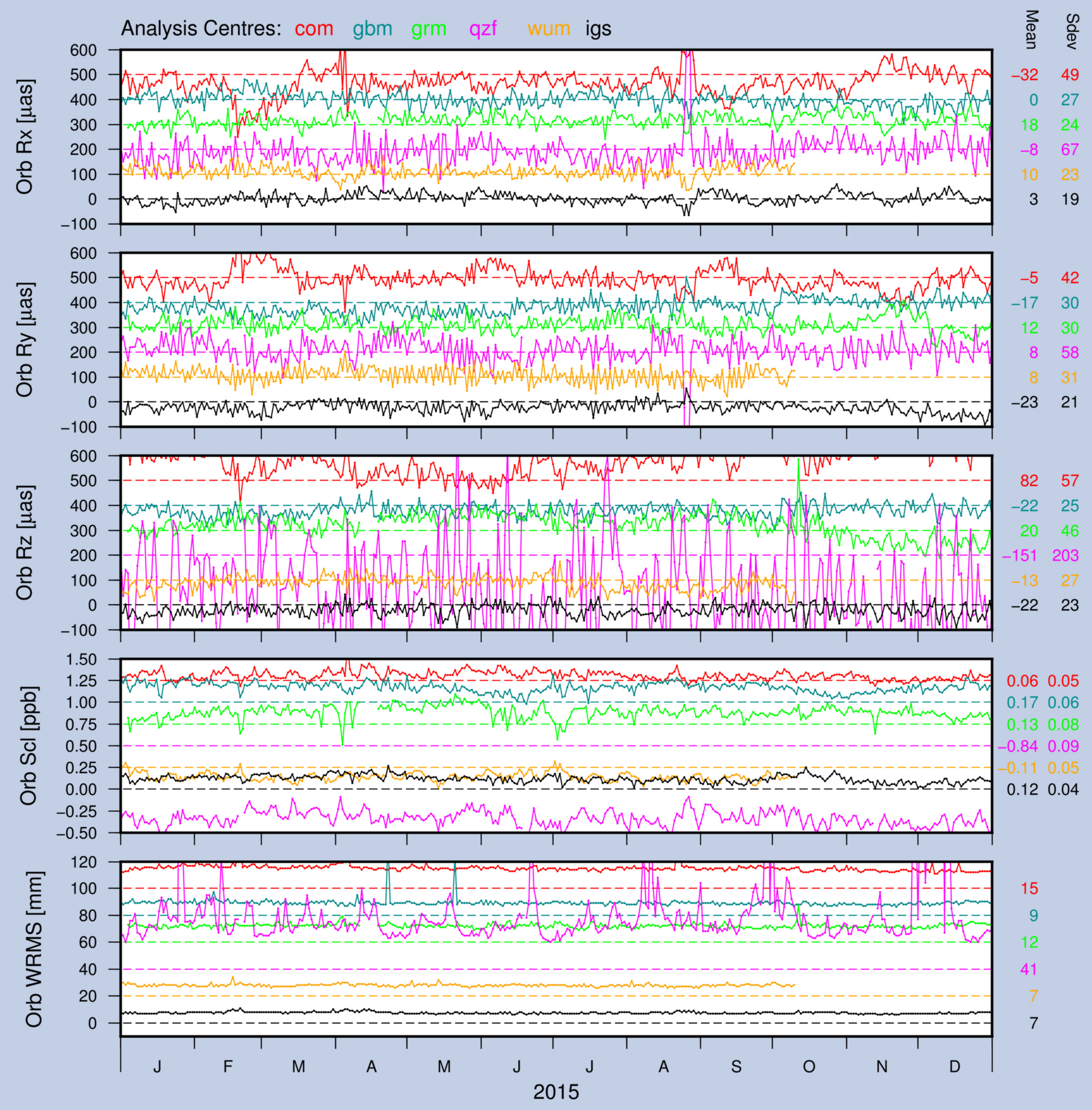

Fig. 3 AC-specific GPS orbit frame transformation parameters (Rx, Ry, Rz, Scl), and weighted RMS (WRMS) from orbit differences for GPS constellation. Note: No comparison for *tum* possible here because only Galileo orbits are provided .

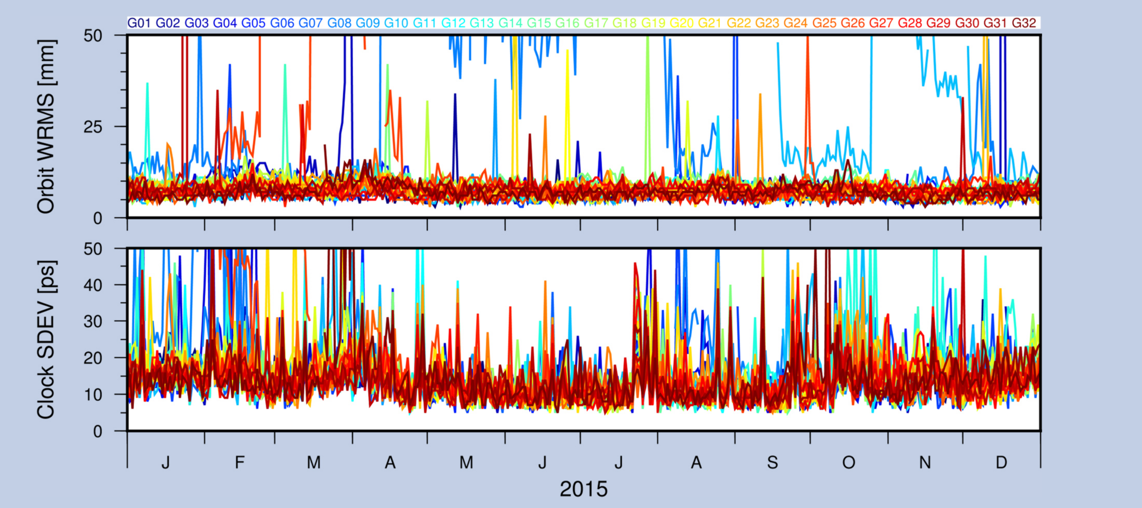

Fig. 4 Weighted RMS (WRMS) from orbit differences (top) and standard deviation (SDEV) from clock differences (bottom) for the GPS constellation based on comparison of IGS operational w.r.t. MGEX combined solution.

GLONASS, Galileo, BeiDou and QZSS Combination Results

Fig. 5 Weighted RMS (WRMS) from orbit differences (left) and standard deviation (SDEV) from clock differences (right) for the GLONASS constellation based on comparison of individual AC solutions w.r.t. MGEX combined solution.

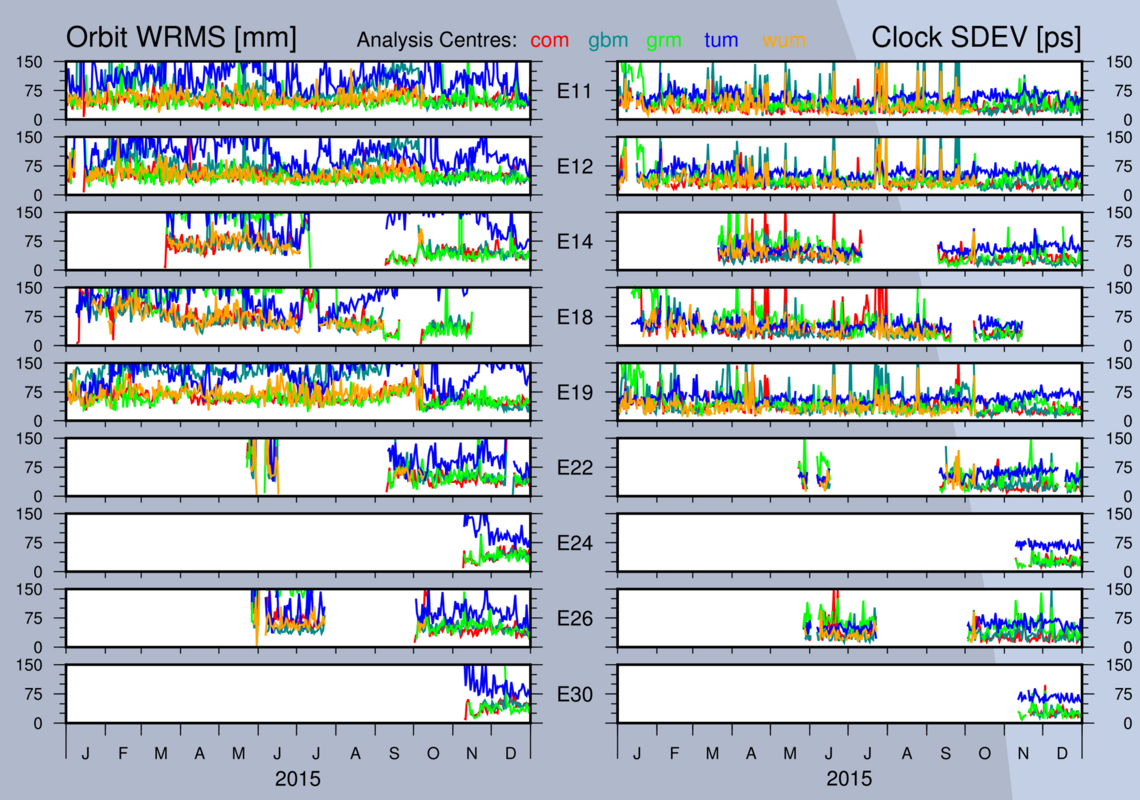

Fig. 6 Weighted RMS (WRMS) from orbit differences (left) and standard deviation (SDEV) from clock differences (right) for the BeiDou constellation based on comparison of individual AC solutions w.r.t. MGEX combined solution.

Orbit and clock comparison results of individual AC solutions w.r.t. the MGEX-combined solution are shown in Fig.5 for GLONASS, Fig.6 for Galileo, Fig.7 for QZSS, and Fig.8 for BeiDou. WRMS values derived from orbit differences (each left subfigure) are also shown for satellites which have been excluded from the combination. Combined satellite clocks are available only if at least two submissions are present.

General remarks:

- Comparison for **com** shows systematic orbit differences for GLONASS constellation w.r.t. average of remaining ACs
- Satellite attitude modelling issues visible for QZSS and BeiDou, e.g. switch from yaw-steering to orbit normal mode
- **tum** orbit solution shows generally larger discrepancy for Galileo satellites probably due to the missing orbit alignment
- Largest orbit differences are identified for BeiDou geostationary (C01…C05) satellites (only two ACs!)

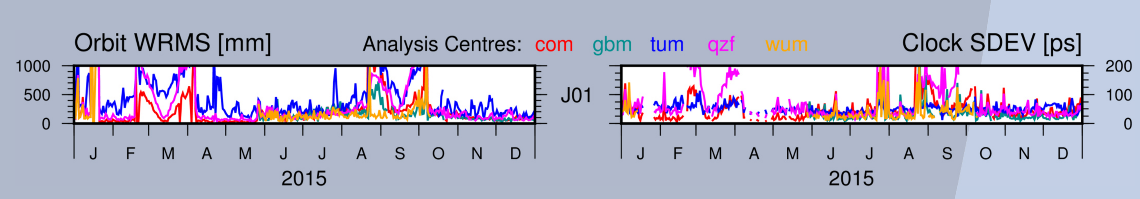

Fig. 7 Weighted RMS (WRMS) from orbit differences (left) and standard deviation (SDEV) from clock differences (right) for the QZSS constellation based on comparison of individual AC solutions w.r.t. MGEX combined solution.

Fig. 8 Weighted RMS (WRMS) from orbit differences (left) and standard deviation (SDEV) from clock differences (right) for the BeiDou constellation based on comparison of individual AC solutions w.r.t. MGEX combined solution.

Outlook

- Fix remaining format issues for MGEX product files
- Make use of operational AC submissions for cross-check analysis
- Incorporate IGS Final GLONASS product (IGV) into comparison
- Unification of inter-system bias (ISB) level for Galileo and BeiDou required, if multiple reference ACs have been selected for same GNSS
- Elaborate possible unified processing standards in order to minimize/eliminate systematic AC-specific differences for non-GPS parameters
- Encourage ACs to provide full set of products files, i.e. to complete product portfolio