

## Introduction

The Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences (GFZ) contributes as one of the analysis centers to the International GNSS Service (IGS) for many years. In 2012 the IGS began the "Multi GNSS EXperiment" (MGEX), which supports the new GNSS, such as Galileo, BeiDou and QZSS.

At present, the Chinese BeiDou constellation provides five usable GEO satellites, five usable IGSO satellites and four usable MEO satellites. Totally 14 operational satellites are involved in this experiment: GEOs (C01, C02, C03, C04, C05), IGSOs (C06, C07, C08, C09 and C10), and MEOs (C11, C12, C13 and C14). 4 ACs (CODE, ESA, GFZ and WHU) provide BeiDou orbit and clock products to MGEX. The major models and processing configuration are summarized in Tab. 1.

In this presentation two validation studies are carried out.

1. Based on MGEX and Chinese BeiDou networks (BETS), up to 30 stations and ~125 GPS stations from IGS are selected to estimate 3-day-orbit and clock parameters of the GPS+BDS satellites. The quality of the 3-day-orbit are assessed by means of orbit overlap statistics and comparison with Wuhan ACs for 6 weeks (1743 to 1748) in 2013.

2. An SLR validation of 4 ACs BeiDou orbits is introduced for time period GPS week 1783~1784.

## BeiDou Data Processing

In GFZ an upgraded version of EPOS.P8 software is used for processing dual-frequency GPS+BDS data. Ambiguity-fixing was also set up for BeiDou IGSO and MEO satellites. The ionosphere-free linear combination of B1 (1561.098 MHz) and B2 (1207.140 MHz) is used. The a priori BeiDou orbits are taken from the broadcast navigation message files, which are provided by the MGEX. The observation data are processed in daily batches. 3-day solution can be generated by daily normal equations (NEQs) stacking.

ACs	Satellite system	OBS TYPES	PCOs & PCVs		Attitude Model	Arcs Length	Inter System Bias	AMB FIX
			SAT	STA				
COM	G+R+E+C (no GEO)	B1+B2	Nominal PCO from MGEX, no PCV	Same as GPS	nominal attitude	72 hours	One ISB per BDS station (zero mean condition)	YES (no GEO)
ESM	G+R+E+C +J	Raw B1+B2				24 hours		
GBM	G+C	B1+B2				24 hours	One ISB per BDS station and day	
WHU	G,C	B1+B2				72 hours	NO	
					GEO: yaw-fixed mode IGSO&MEO: yaw-steering mode ( $\beta > 4^\circ$ ) yaw-fixed mode ( $\beta < 4^\circ$ )	One ISB per BDS station	YES (2014) (no GEO)	

Tab. 1: Summary of the BeiDou data processing

## BeiDou Orbit Validation 2013

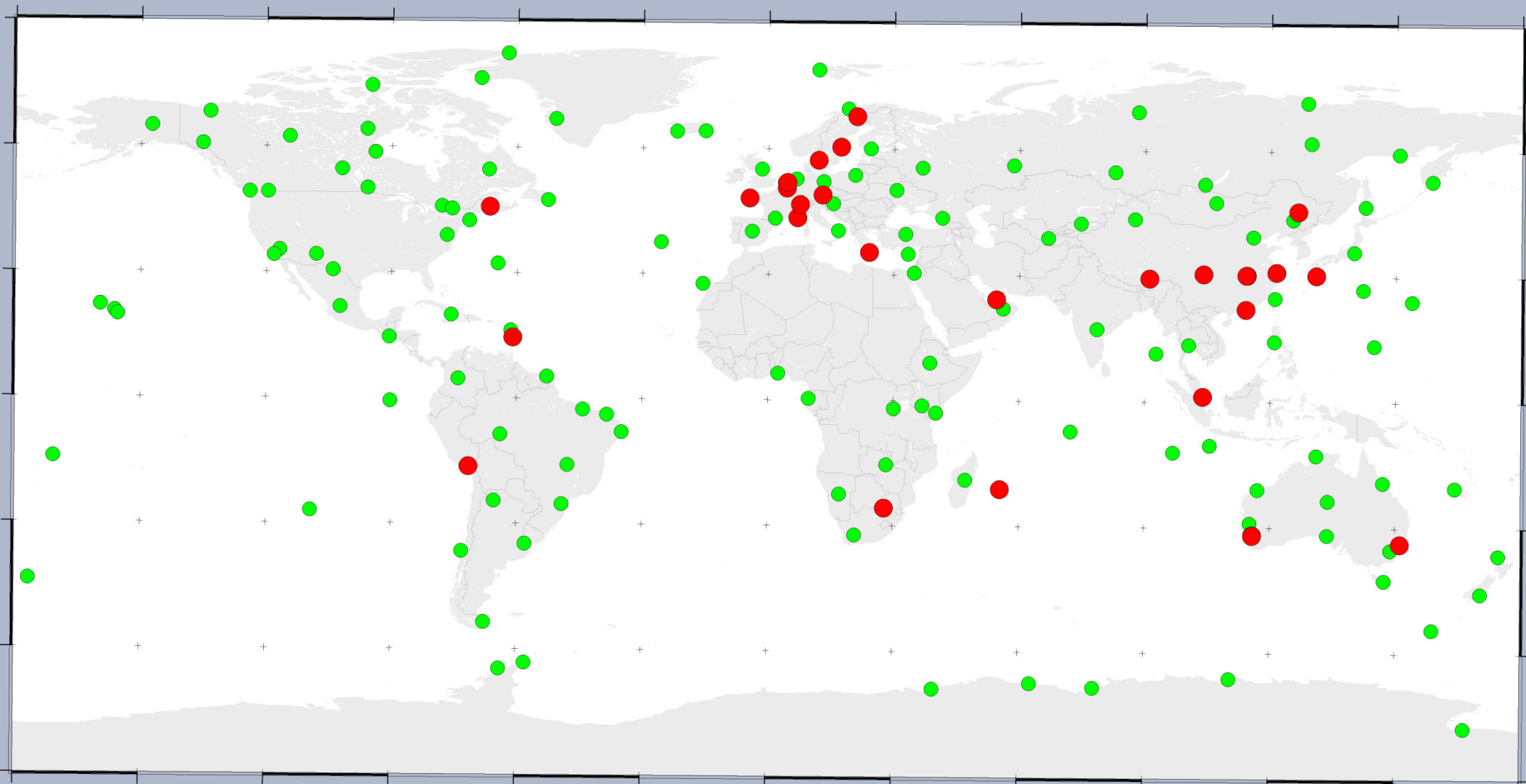


Fig. 1: Global network of IGS (green) and MGEX+BETS (red) stations, which were set up for data processing (2013). The 29 BeiDou stations realize a global coverage for practical BeiDou orbit determination purposes.

To check the orbit quality the RMS of the orbit overlap differences (4 hours) in along-track, cross-track and radial directions are taken. The statistic results are given in Fig 2. Wuhan University BeiDou products for the full year of 2013 are available at the MGEX repository. We compared the our BeiDou orbits with Wuhan's for 6 weeks (1743~1748). The comparison results are given in Fig 3.

Generally the GEOs have a larger RMS, especial in along direction, than IGSOs and MEOs. This is due to the GEO orbit determination suffers clearly from the weak observation geometry and the lack of orbit dynamics. The individual results of the four MEOs are more homogeneous than the others, which are related to our orbit modelling experiences for this kind of satellites.

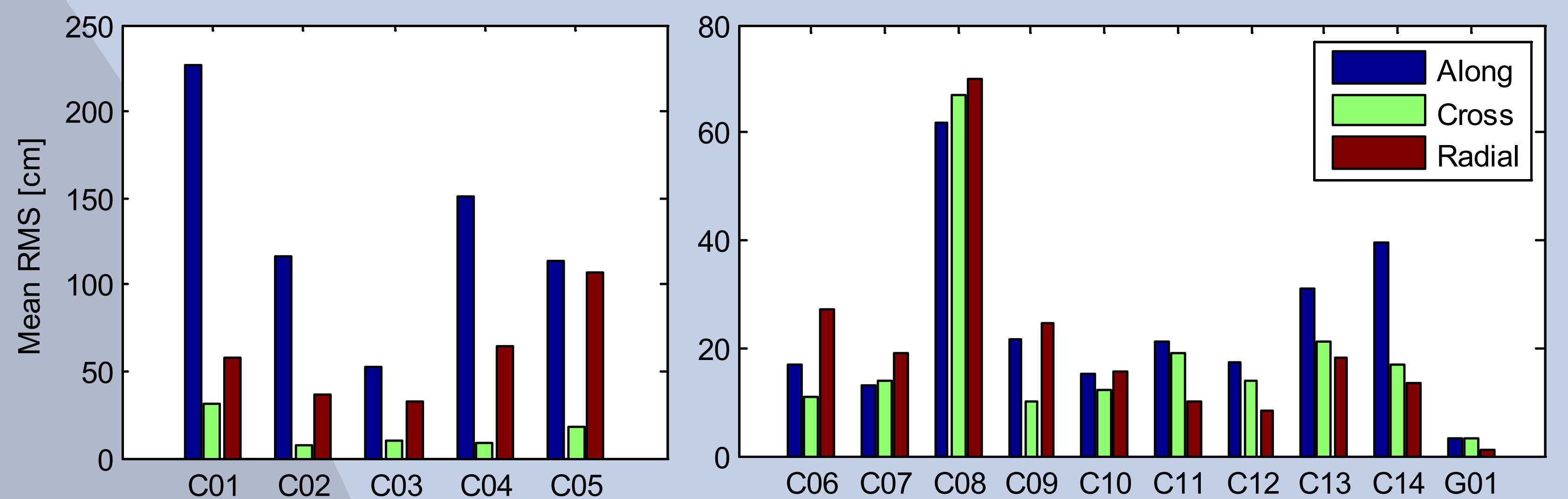


Fig. 2: orbit overlap (4 hours) statistic for BeiDou and GPS satellites in along, cross and radial directions for 6 weeks in 2013

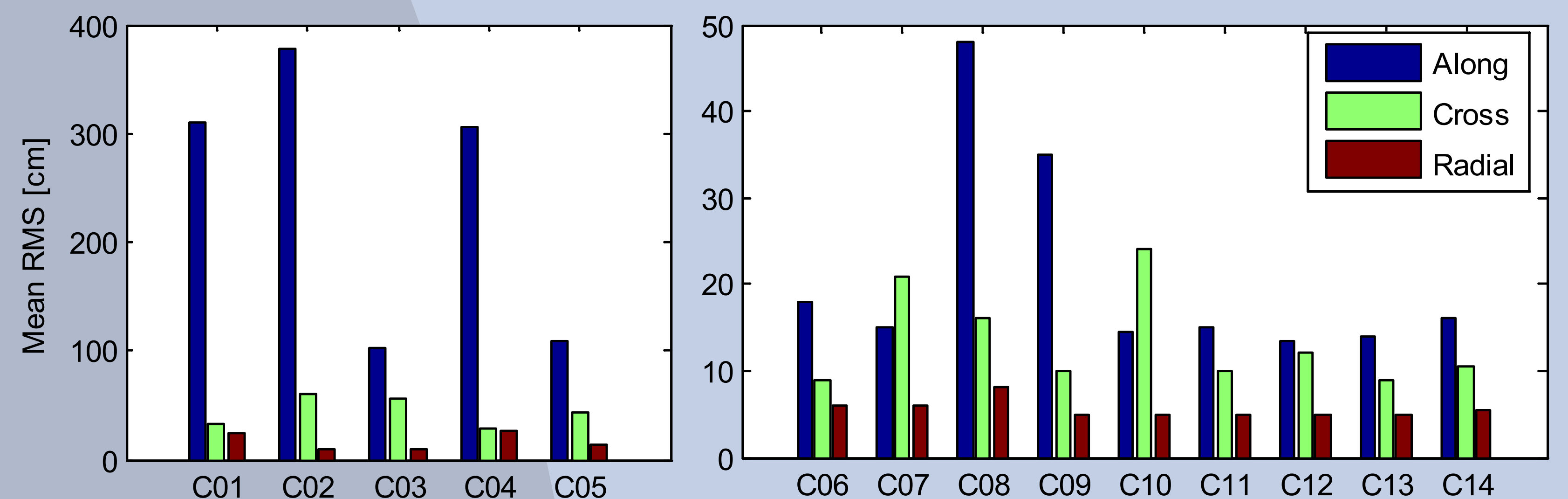


Fig. 3: BeiDou orbit differences between GFZ and Wuhan solutions in along, cross and radial directions for 6 weeks in 2013

## BeiDou Orbit Validation using SLR 2014

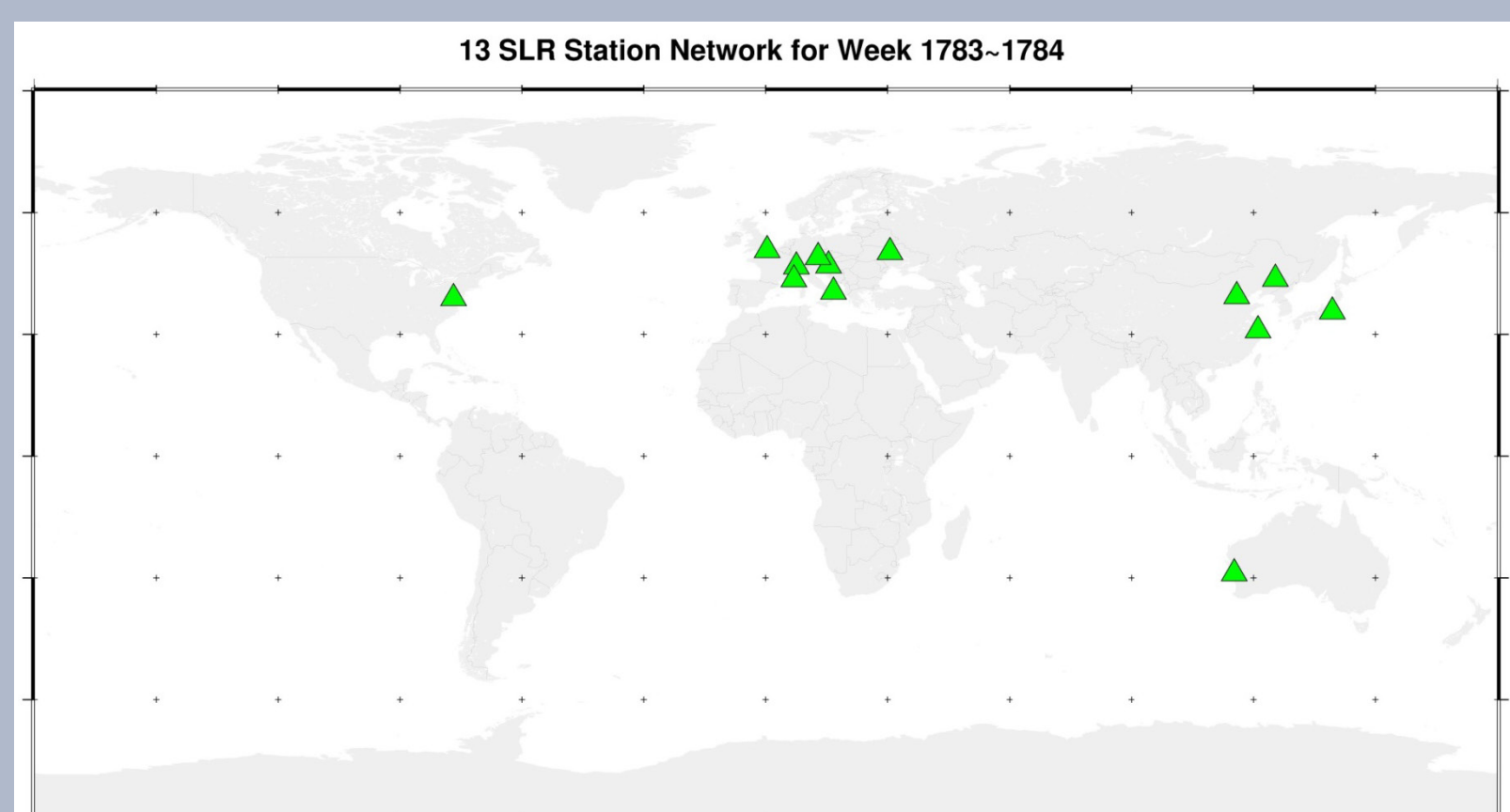


Fig. 4: 13 SLR stations used for BeiDou orbit validation

PRN	C01	C08	C10	C11
SLR Objectives	compass1	compass3	compass5	compassm3

Tab. 2: SLR observed BeiDou satellites

Satellite	BDS .vs. SLR BIAS & STD in mm			
	COM	ESM	GBM	WUM
C01		-435 236	-473 262	-469 99
C08	-29 75	68 52	-27 54	-64 35
C10	38 105	-45 102	-48 102	-50 85
C11	-29 30	57 47	20 34	0 25

Tab. 3: SLR residuals statistic for GPS week 1783 (left) and 1784 (right)

Satellite	BDS .vs. SLR BIAS & STD in mm			
	COM	ESM	GBM	WUM
C01		-614 207	-394 265	-470 164
C08	-39 50	50 44	-34 124	-44 35
C10	-23 160	-46 147	-59 164	-46 132
C11	-12 38	60 35	11 44	1 25

In MGEX, 4 ACs have provided BeiDou orbit and clock products for week 1783 & 1784. SLR observations from ILRS are adopted to validate the quality of the BeiDou orbits. During the two weeks, there are total 13 stations observed 4 BeiDou satellites (Fig. 4 and Tab. 2).

The statistic of the validation show, that the GEO satellite orbits have an accuracy of ~50 cm, while the IGSO and MEO satellite orbits have a level of ~10 cm and ~5 cm, respectively. In the 4 ACs, Wuhan has the smallest standard deviation, which could be resulted from a better attitude control model.

## Summary/Outlook

GFZ provide IGR likely GPS+BeiDou orbit and 5 min. clock products to the MGEX since 28 January 2014 routinely. The GPS and BeiDou data of the MGEX & IGS network is used for the analysis. The BeiDou orbit performant is assessed by comparison with Wuhan's products and orbit overlap test. The 3D RMS of the GEOs, IGSOs/MEOs are 1~4meter, ~20cm, respectively. The SLR validation study based on BeiDou orbits from 4 ACs over 2 weeks shows, that the GEOs have an accuracy of about 50cm, while IGSOs and MEOs are ~10cm and ~5cm, respectively. More detail analysis will be done in the near future.