

# Chinese BeiDou navigation satellite orbit determination by IGS

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# Satellite Systems of Multi-GNSS

GNSS System	Number of Satellites	
	Operational system	Final system
GPS	31 MEO	31 MEO
GLONASS	24 MEO	24 MEO
Galileo	3 MEO	30 MEO
BeiDou	5 GEO + 5 IGSO + 4 MEO	5 GEO + 3 IGSO + 27 MEO

Status: September 2014

GEO: Geostationary orbit

IGSO: Inclined geostationary orbit

MEO: Medium Earth orbit

# MGEX Orbit and Clock

- Currently 7 contributing agencies

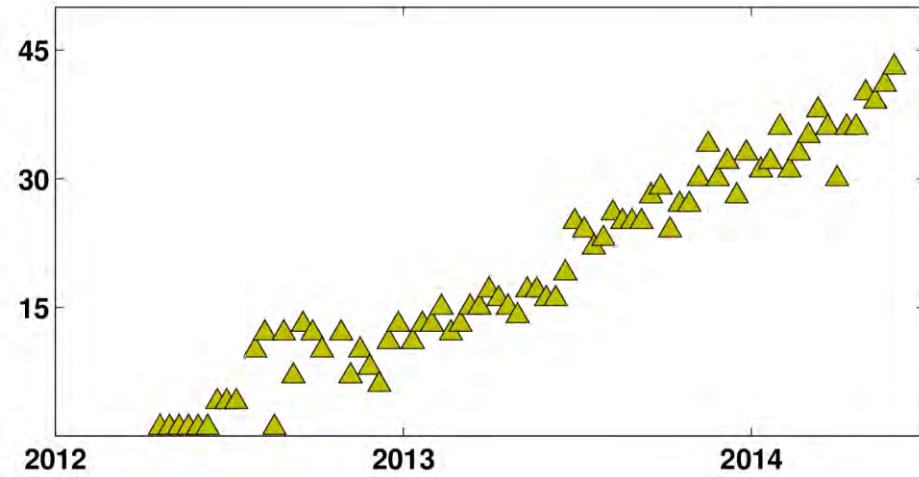
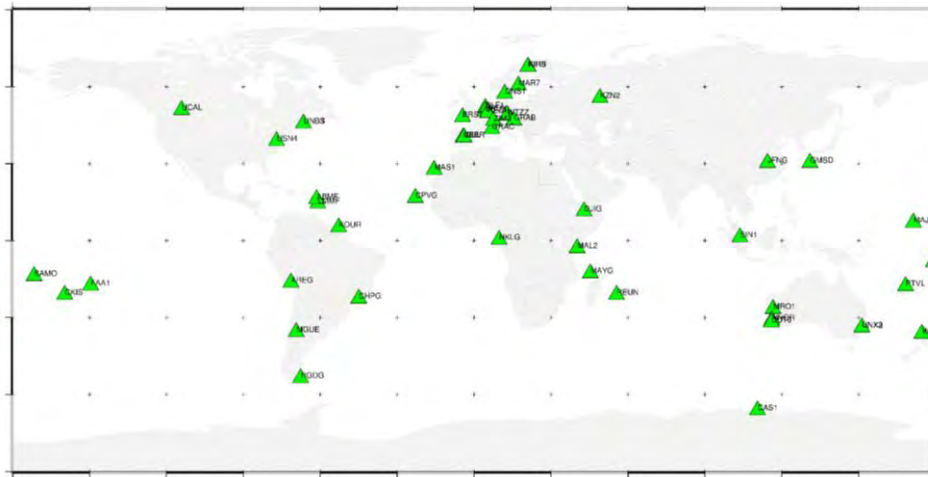
Institution	Products	Constellations	Availability (week/day)
CNES/CLS	grm: sp3 & clk	GAL	since 1692/1
CODE	com: sp3 & clk	GPS+GLO+GAL+BDS	since 1764/0
ESA	esm: sp3 & clk	GPS+GLO+GAL+BDS+QZS	1783/0-1784/6
GFZ	gfm/gbm: sp3 & clk	GPS+GAL GPS+BDS*	since 1680/0 since 1777/2
TUM	tum: sp3 & clk	GAL+QZS	since 1711/1
JAXA	qzf: sp3 & clk	GPS+QZS	since 1751/6
Wuhan Univ.	wum: sp3 & clk	GPS+GLO+GAL+BDS	since 1773/3
TUM/DLR	brdm: navigation file	GPS+GLO+GAL +BDS+QZSS+SBAS	since 1721/2

<http://www.igs.org/mgex/products>

\* <ftp://ftp.gfz-potsdam.de/GNSS/products/mgex>

# BeiDou Stations in MGEX

Total 49 BeiDou stations from MGEX (2012~2014)



REC.	TRIMBLE NETR9	SEPT POLARX4	SEPT POLARX4TR	SEPT POLARXS	SEPT ASTERX3	JAVAD TRE_G3TH	IFEN SX_NSR_RT_800
#STA	32	10	2	1	1	2	1

# BeiDou Analysis in IGS ACs

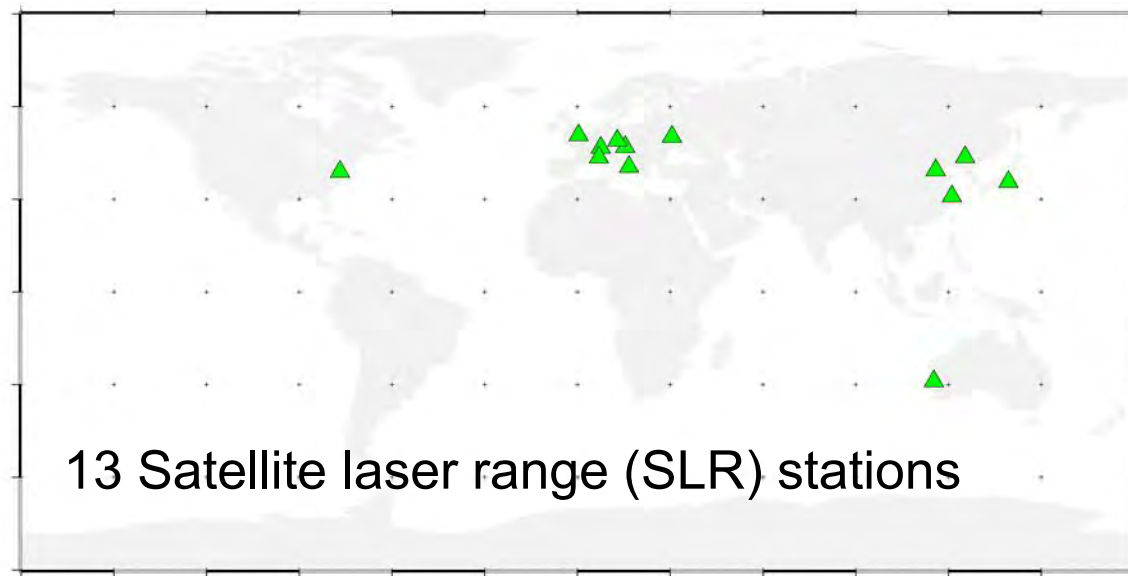
ACs	Satellite system	OBS TYPES	PCOs & PCVs	
			SAT	STA
COM	G+R+E+C (no GEO)	B1+B2	Nominal PCO <sup>a</sup> No PCV	Same as GPS
ESM	G+R+E+C+J	Raw B1+B2	Nominal PCO from MGEX No PCV	
GBM	G+C	B1+B2		
WUM	G+R+E+C	B1+B2		

a: Lou et. al. (2014) Scientific Reports

# BeiDou Analysis in ACs

ACs	Attitude Model	Arcs Length	Inter System Bias	AMB FIX
COM	nominal attitude	72 hours	One ISB per BDS station (zero mean condition)	YES (no GEO)
ESM		24 hours		
GBM		24 hours	One ISB per BDS station and day	
WUM	GEO: yaw-fixed mode IGSO&MEO: yaw-steering mode yaw-fixed mode ( $\beta < \sim 4^\circ$ )	72 hours	One ISB per BDS station	YES (no GEO)

# SLR Validation for BeiDou



<b>PRN</b>	C01	C08	C10	C11
<b>SLR Objectives</b>	compassg1	compassi3	compassi5	compassm3



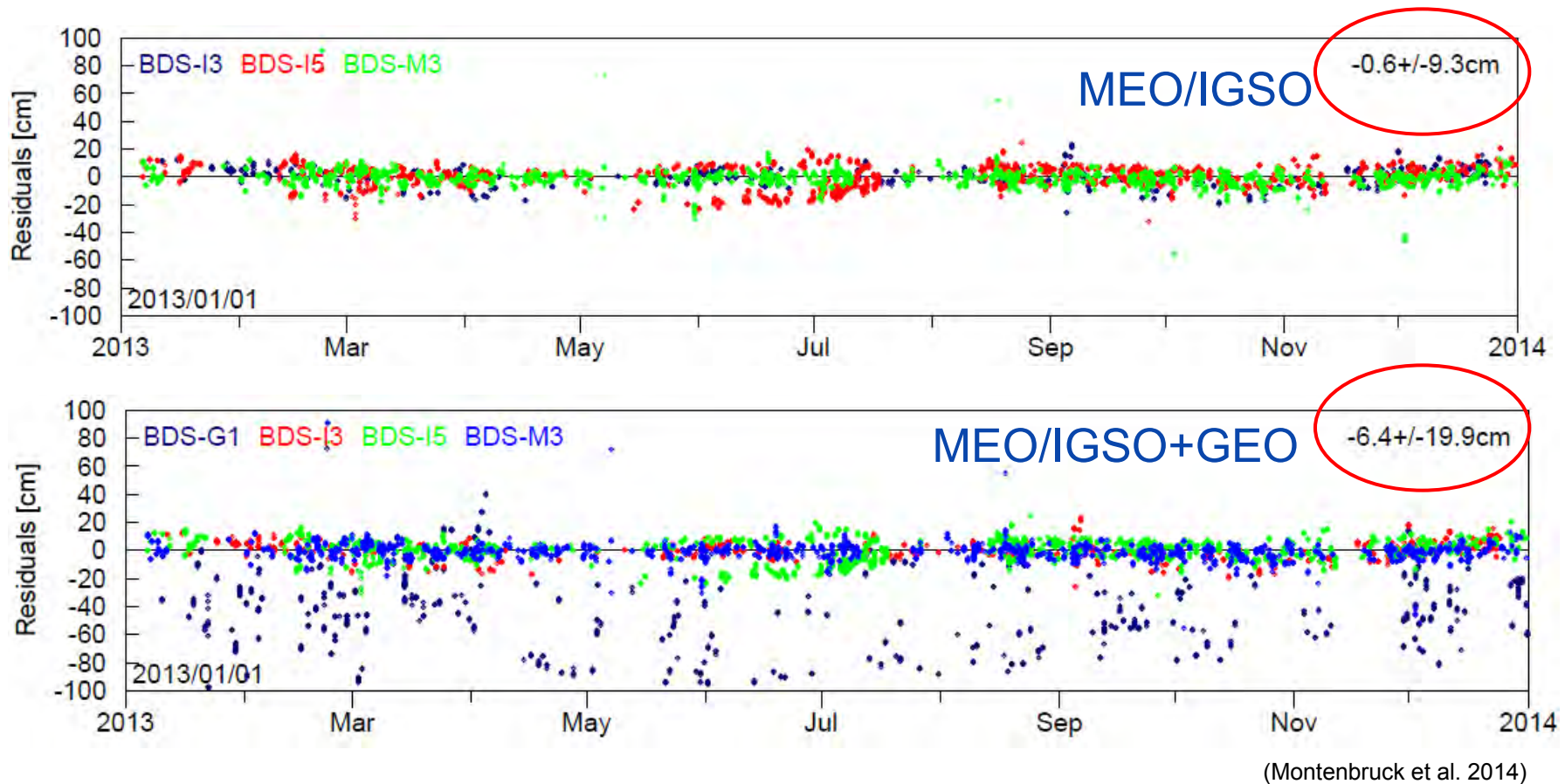
# SLR Validation for BeiDou

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

SLR residuals (10 cm MEO/IGSO, 0.5 m GEO)

# SLR Validation for BeiDou

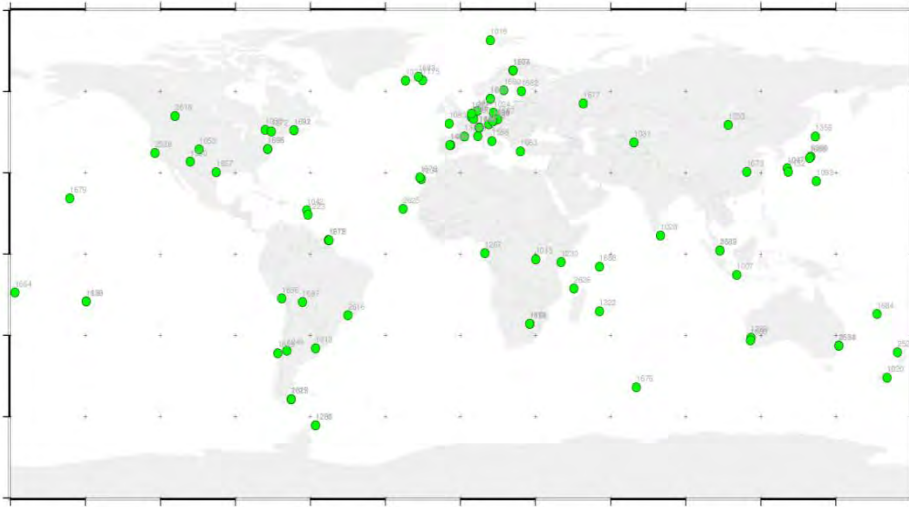
Wuhan orbit product; detailed analysis pending



# BeiDou Orbit Determination

- BeiDou is first GNSS using GEO satellites
- GEOs have static viewing geometry
  - Creates slowly varying (long-periodic) site multipath
  - Reduces observability of orbit parameters (along-track component badly determined)
  - Frequent orbit keeping maneuvers
- MEO/IGSO satellites
  - Yaw-steering
  - Orbit-normal (yaw-fixed) mode for small  $\beta$  angles ( $\beta < \sim 4^\circ$  )

# MGEX activity at GFZ



- Since DOY 200 in 2014
- GPS, GLONASS, Galileo and BeiDou (total 71 satellites)
- About 94 MGEX stations

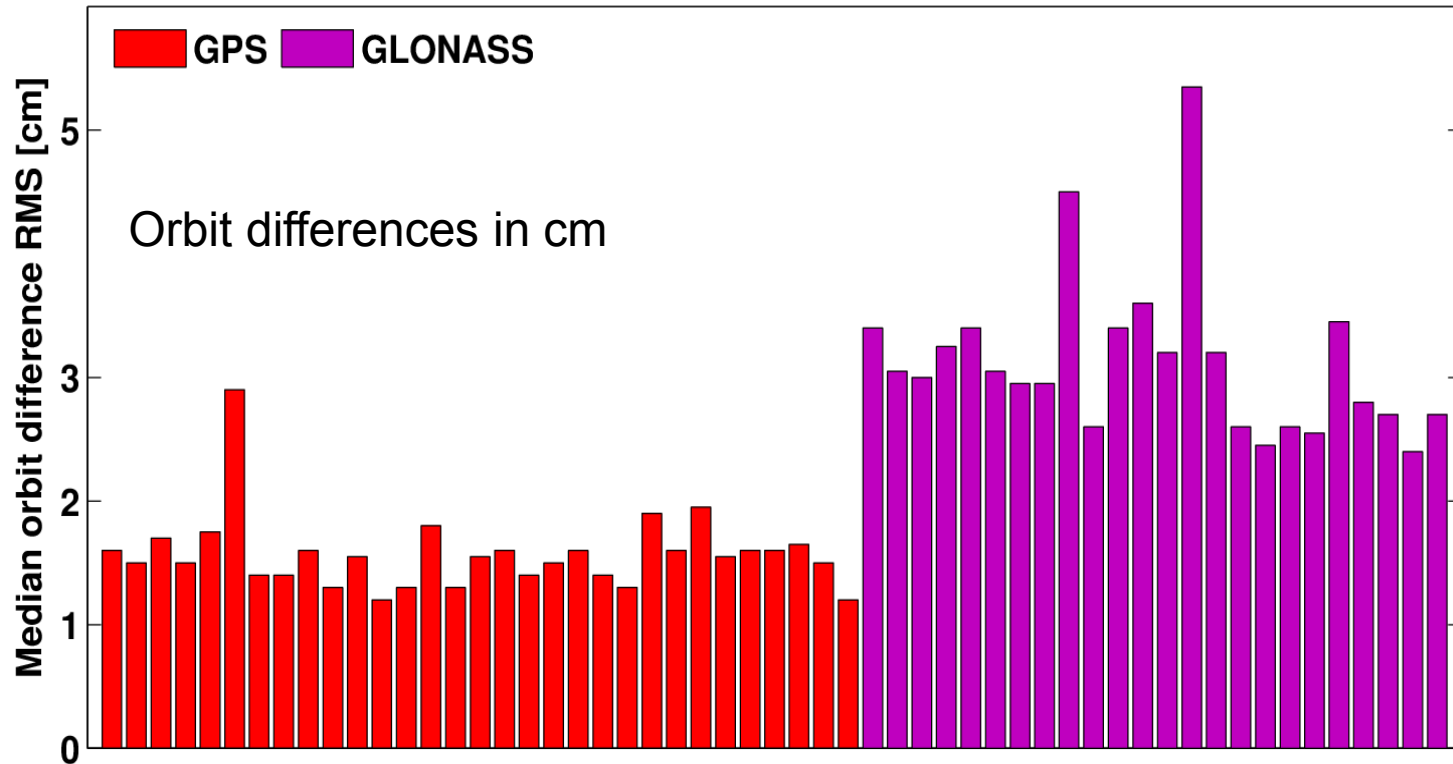
## Products

- 15 min. SP3 orbit
- 5 min. clock

Satellite system	#Satellites	Observation types	#Stations
GPS	31	L1/L2	94
GLONASS	24	L1/L2	94
Galileo	3	E1/E5a	76
BeiDou	14	B1/B2	39

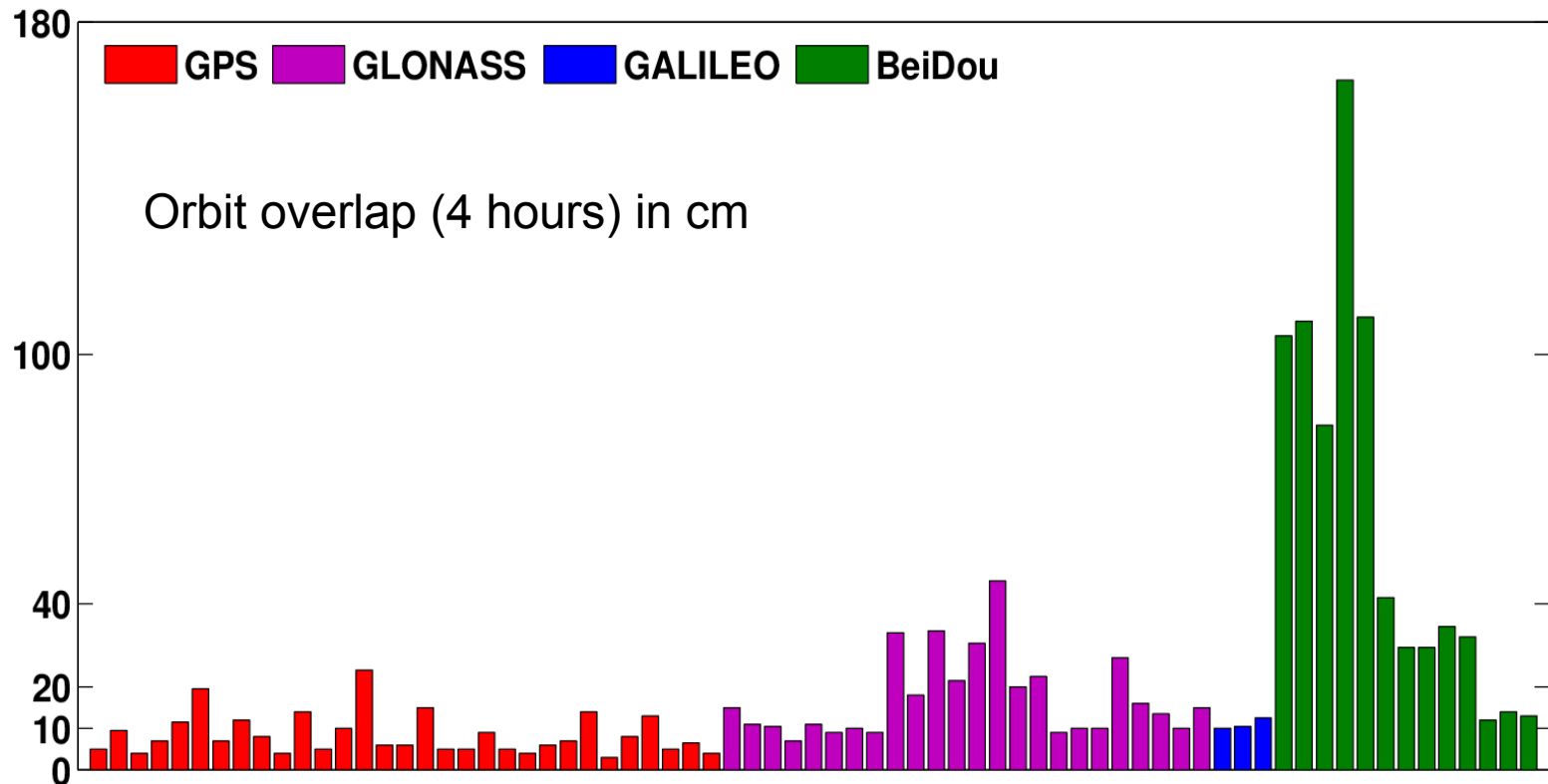
Status: September 2014

# MGEX activity at GFZ



GPS and GLONASS orbit differences: Multi-GNSS vs. IGS rapid (IGR)  
IGR orbit accuracy: ~ 2.5cm (GPS), ~3cm(GLO)  
→ Almost same quality

# MGEX activity at GFZ



Multi-GNSS orbit overlap (4 hours):

→ GPS

< 10 cm

→ BeiDou GEO

~ 100 cm

→ Galileo

~ 10 cm

→ BeiDou IGSO

~ 40 cm

→ BeiDou MEO

~ 12 cm

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Thank you for your attention