

Orbit and Clock Determination – BeiDou

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Contents

- MGEX BeiDou data availability
- BeiDou orbit and clock products at MGEX
- BeiDou processing strategy in ACs
- Orbit performance assessment
 - Broadcast ephemerides
 - SLR residuals (10 cm MEO/IGSO, 0.5 m GEO)
 - BeiDou only PPP solution
- BeiDou specific problems

BeiDou Satellite status



(image credit: CSNO)

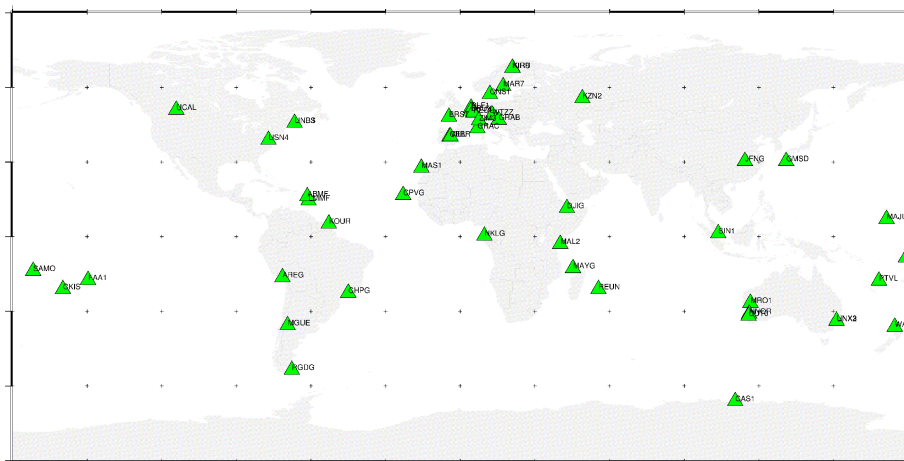
Since 28. December 2012

Satellite type	PRN
GEO	C01 C02 C03 C04 C05
IGSO	C06 C07 C08 C09 C10
MEO	C11 C12 C13 C14

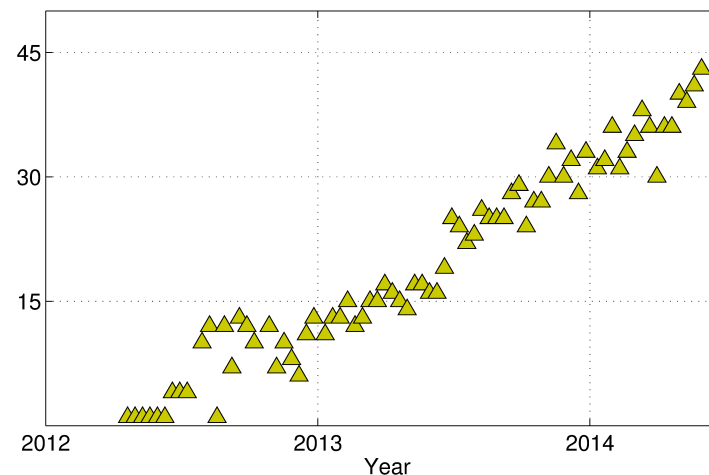


BeiDou Stations in MGEX

49 BDS Station Network for Year 2012~2014



Number of BeiDou Stations in MGEX



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 Orbit and Clock at MGEX

- Currently 5 contributing agencies

Institution	Products	Constellations	Availability (week/day)
CODE	comwwwwd.sp3	GPS+GLO+GAL	1764/0-1784/6
	comwwwwd.clk	+BDS	
	comwwwwd.bia/ dcb	GPS (DCBs) GAL (ISBs) BDS (ISBs)	
ESA	esmwwwwd.sp3	GPS+GLO+GAL	1783/0-1784/6
	esmwwwwd.clk	+BDS+QZS	
GFZ	gfbwwwwd.sp3	GPS+BDS	since 1777/2
	gfbwwwwd.clk		
Wuhan Univ.	wumwwwwd.sp3	BDS	1721/2-1773/3
	wumwwwwd.clk		1783/0-1784/6
TUM/DLR	brdmdddn.yyp	GPS+GLO+GAL +BDS+QZSS +SBAS	since 1721/2



BeiDou Analysis in ACs

ACs	Satellite system	OBS TYPES	PCOs & PCVs	
			SAT	STA
COM	G+R+E+C (no GEO)	B1+B2	Nominal PCO ^a (0.634, -0.003, 1.075) m No PCV	Same as GPS
ESM	G+R+E+C+J	Raw B1+B2	Nominal PCO from MGEX (0.600, 0.000, 1.100) m No PCV	
GBM	G+C	B1+B2		
WHU ^b	G,C	B1+B2		

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

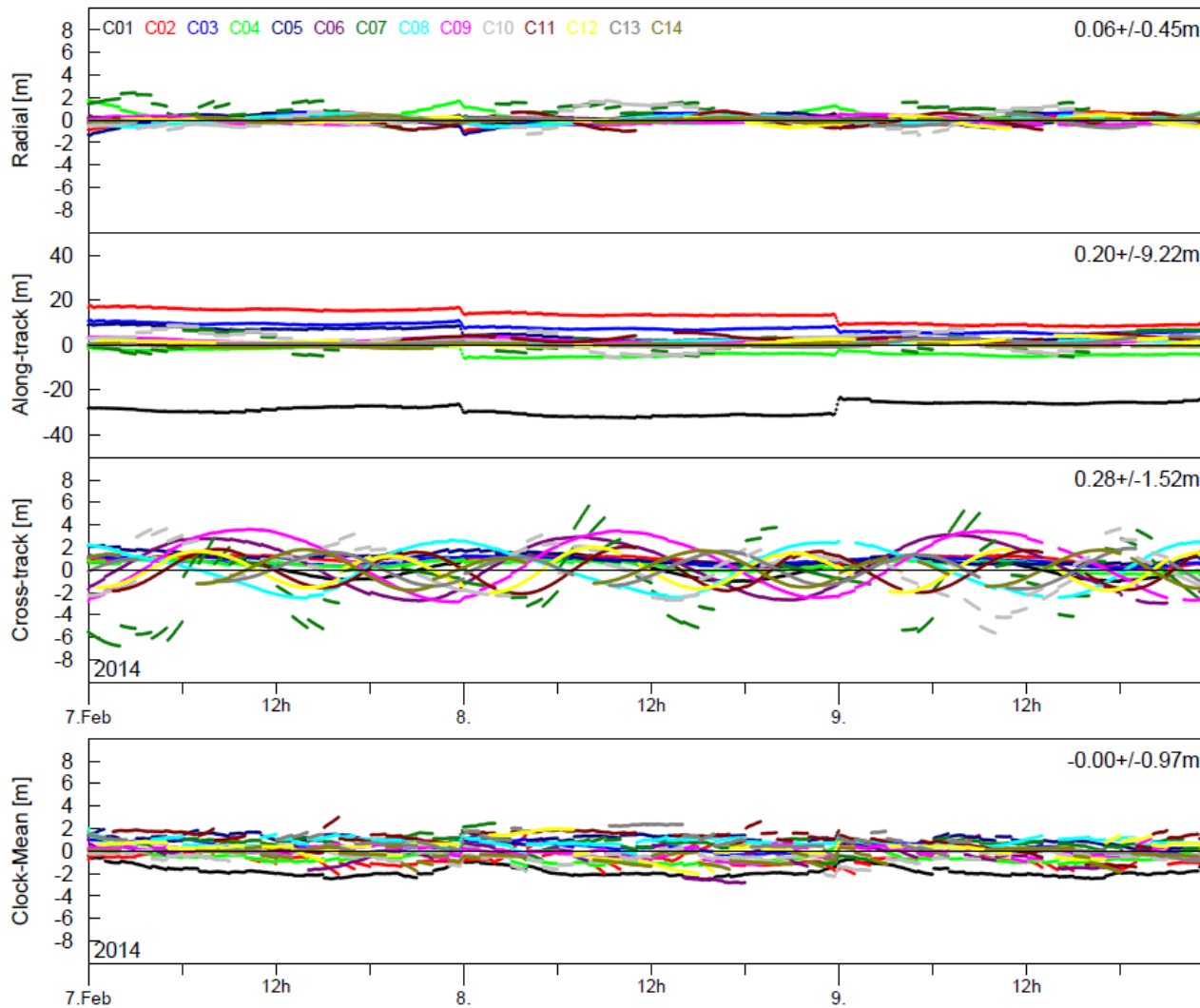
b: MGEX and WHU BeiDou Experiment Tracking Network (BETN)



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	72 hours	NO	NO (2013)
	IGSO&MEO: yaw-steering mode yaw-fixed mode ($\beta < 4^\circ$)		One ISB per BDS station	YES (2014) (no GEO)

BeiDou – Broadcast Ephemerides



Broadcast vs.
GFZ product

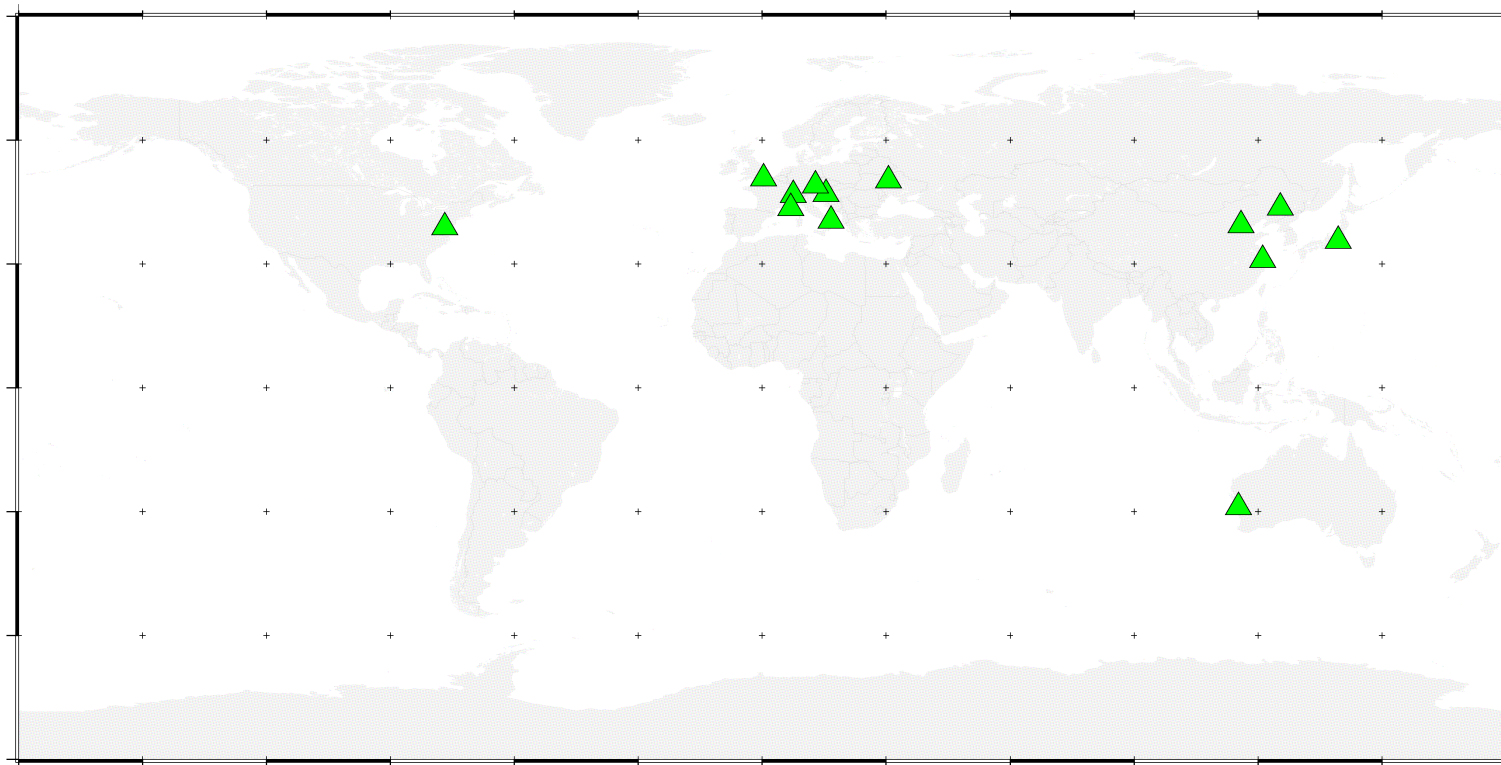
(Montenbruck et al. 2014,
GPS Solutions, submitted)

SLR Validation for BeiDou



IGS

13 SLR Station Network for Week 1783~1784



PRN	C01	C08	C10	C11
SLR Objectives	compassg1	compassi3	compassi5	compassm3

SLR Validation for BeiDou

WEEK 1783

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

WEEK 1784

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

SLR Validation for BeiDou

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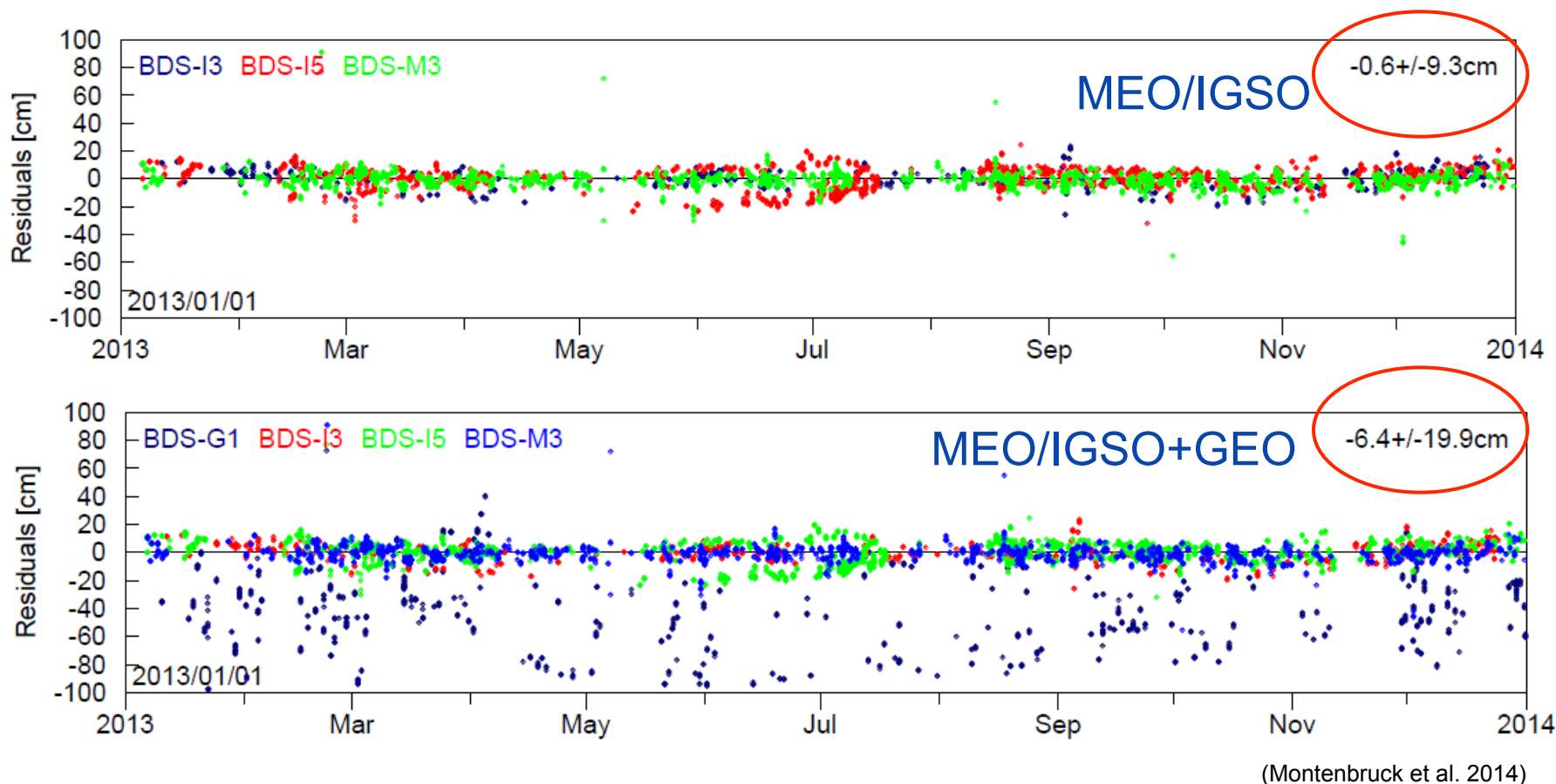
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SLR Validation for BeiDou



IGS

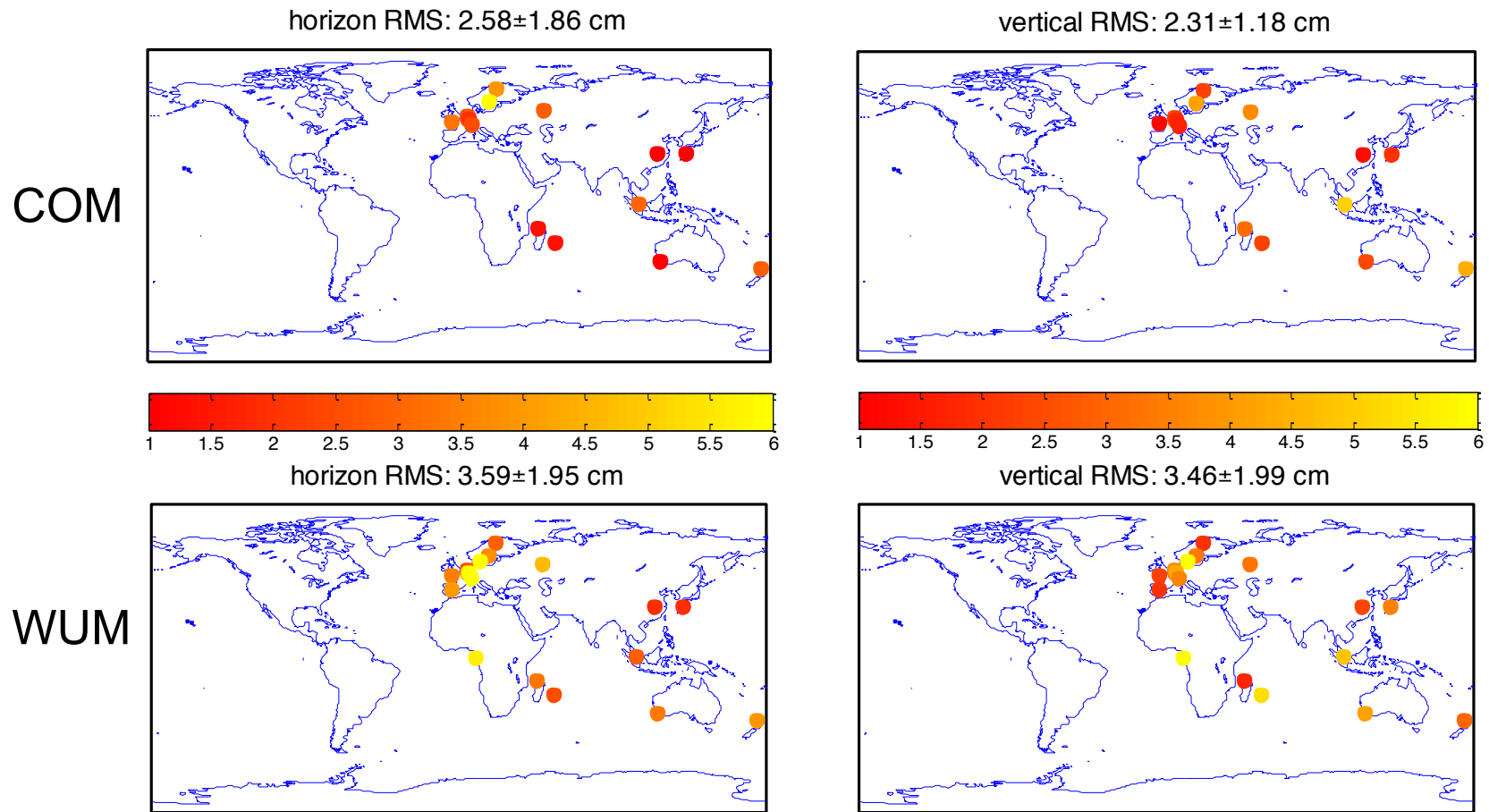
Wuhan orbit product; detailed analysis pending



BeiDou only PPP



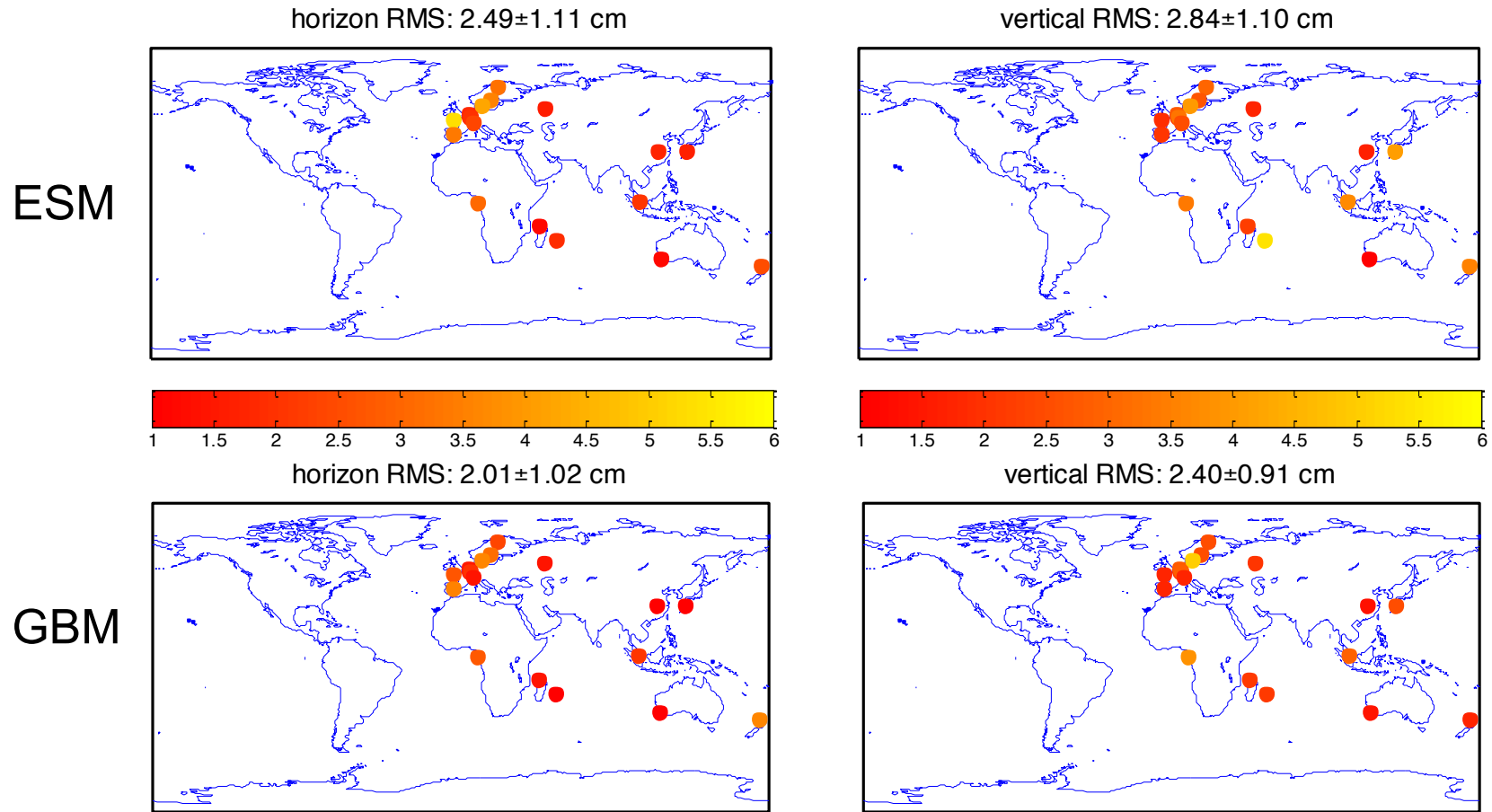
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Repeatability of PPP daily coordinates.

NOTE: Inconsistent satellite antenna parameter & attitude model!

BeiDou only PPP



Repeatability of PPP daily coordinates.

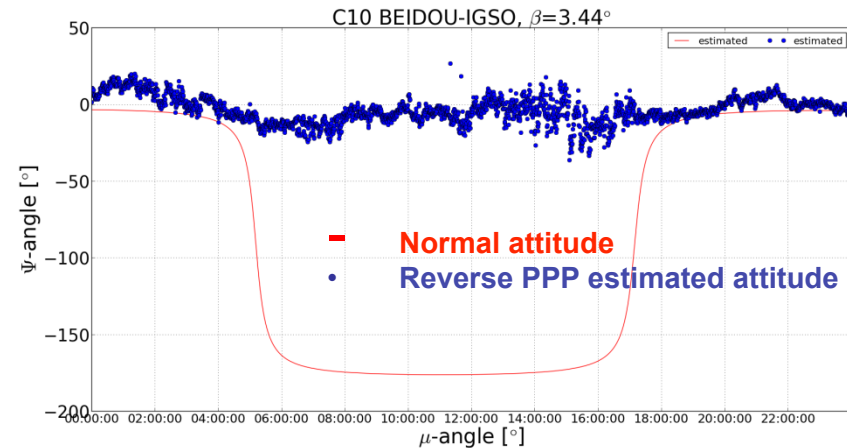
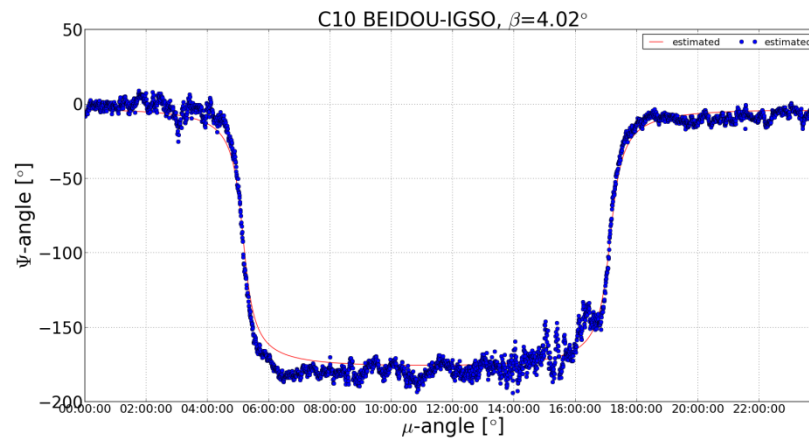
NOTE: Inconsistent satellite antenna parameter & attitude model!

GEO Orbit Determination

- BeiDou is first GNSS using GEO satellites
- Static viewing geometry
 - Creates slowly varying (long-periodic) site multipath
 - Reduces observability of orbit parameters (along-track component badly determined)
- Frequent station keeping maneuvers
- Restricted SLR tracking coverage
 - Regional visibility
 - Large distance
- Need joint GNSS+SLR orbit determination to improve OD performance!?

(Montenbruck et al. 2014)

- MEO/IGSO satellites
 - Yaw-steering
 - Orbit-normal (yaw-fixed) mode for small β angles ($\beta < 4^\circ$)
- GEO satellites
 - Orbit-normal (yaw-fixed) mode



J.Guo, Q. Zhao (2014) „Analysis of Precise Orbit Determination for BeiDou satellites during yaw maneuvers”, CSNC 2014

BeiDou – Open Issues

- Limited coverage of GEO/IGSO satellites by current MGEX network
- Lacking information on antenna phase center offsets and attitude modes
- No maneuver information (NABUs?)
- Solar Radiation Pressure model
- Will B3 signal remain accessible for tracking?
- Need common standard for clock offsets
 - All receivers provide B1/B2, only a subset offers also B3
 - B3 used for broadcast clocks
 - ACs (may) employ different conventions for intersystem biases
- Support SLR tracking for all BeiDou satellites!?



IGS

Thank you for your attention