

# WHU's developments for the MGEX precise products and the GNSS ultra-rapid products

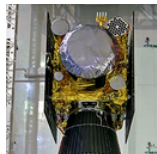
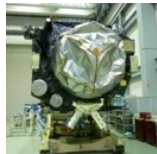
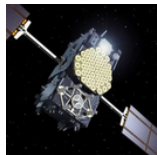
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Presented by Jianghui Geng

GNSS Research Center, Wuhan University

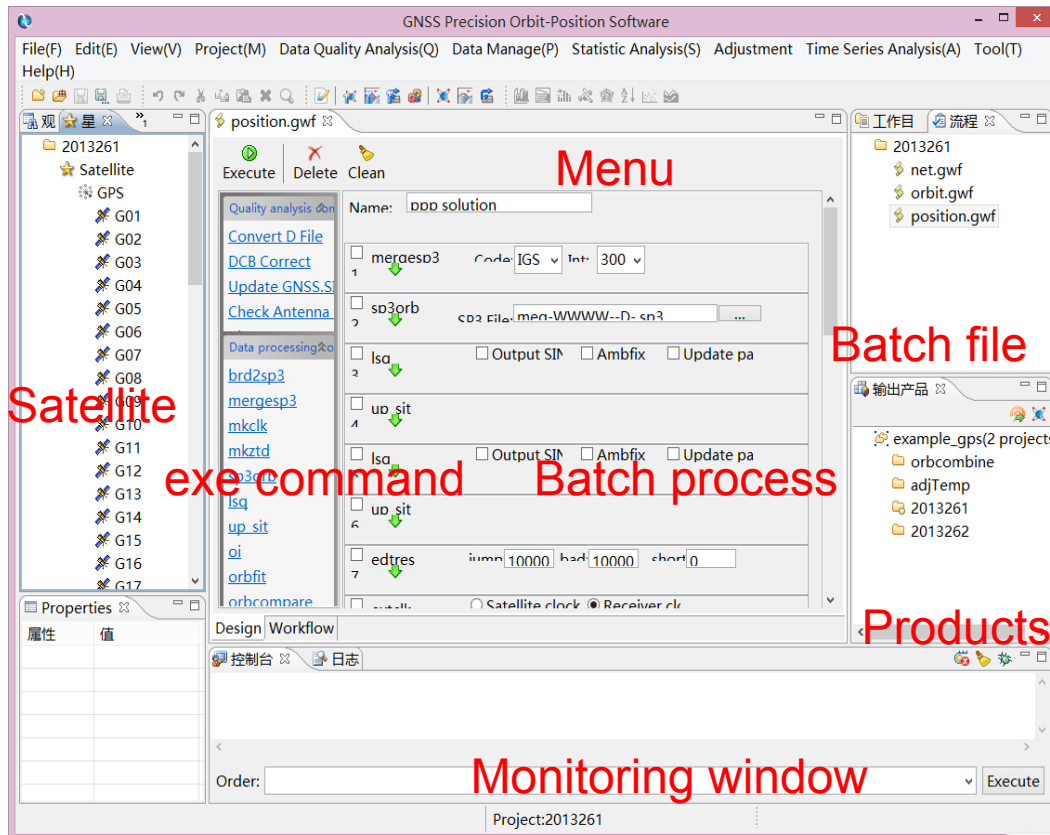
- Ultra-Rapid Products from WHU
- MGEX Precise Products from WHU
- Summary

# GNSS: constellation status



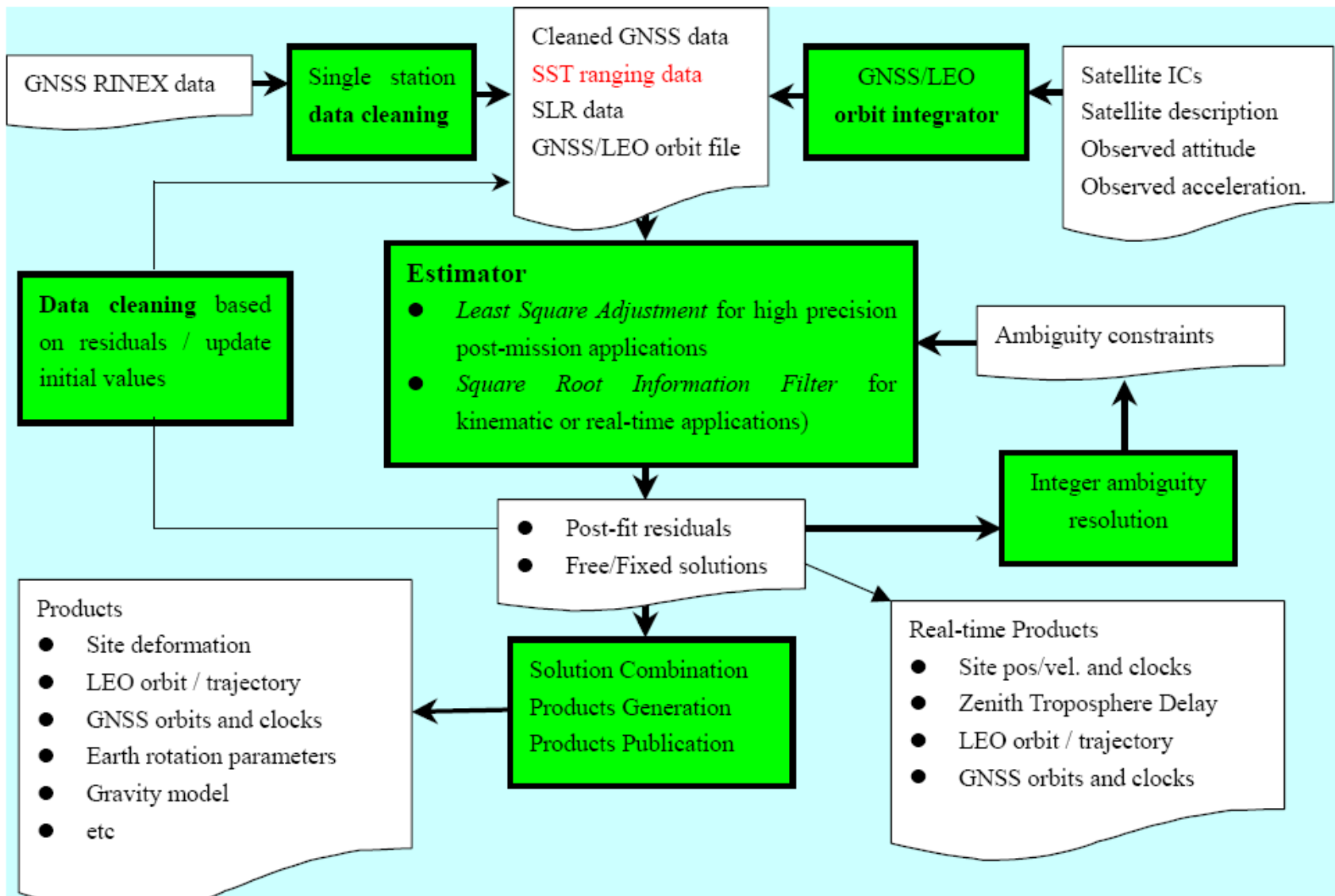
System	Blocks	Signals	Sats
GPS	IIA	L1 C/A, L1/L2 P(Y)	1
	IIR-A/B	Same	12
	IIR-M	+L2C	7
	IIF	+L5	11
GLONASS	M	L1/L2 C/A + P	24
	K	+L3	(2)
BeiDou	GEO	B1, B2, B3	5
	IGSO	same	5
	MEO	same	3(+1)
Galileo	IOV	E1, (E6), E5a/b/ab	3(+1)
	FOV		2(+4)
QZSS	IGSO	L1 C/A, L1C, SAIF L2C, E6 LEX, L5	1
IRNSS	IGSO	L5, S	(4)

## PANDA : Positioning And Navigation Data Analyst



- To derive possible information from GNSS/SLR/VLBI/DORIS data
- Real-time Processing function from 2007
- Current Applications
  - POD of GNSS (GPS, GLONASS, BeiDou, GALILEO)
  - POD of LEOs (CHAMP, GRACE, COSMIC, JASON, HY-2A,ZY-3)
  - Ionosphere Modeling
  - Huge Network data processing, PPP
  - SINEX Combination

# PANDA System Structure



# Analysis Strategy Summary



	ESTIMATED PARAMETERS (APRIORI VALUES AND CONSTRAINTS)
Adjustment	Weighted least squares algorithm
Station coordinates	All coordinates are estimated in the IGS08 realization of the ITRF2008. The datum is realized by tightly constraining the processed Reference Frame stations to their current coordinate values.
Satellite clock	solved for at each epoch (white noise process)
Receiver clock	solved for at each epoch (white noise process); one clock fixed and used as a time reference
Orbits	6 parameters for initial position and velocity 5 parameters for solar radiation pressure modeling, 24 hours estimation and 24 hours prediction
Satellite attitude	yaw rate is estimated for BLOCK II/IIA/IIF satellites during shadow crossing
Troposphere	zenith delay: zenith delay parameters for each station with 1 hour intervals mapping function: wet Global Mapping Functions (GMF) zenith delay epochs: each integer hour gradients: north and east horizontal delay are estimated for each station in daily intervals
Ionospheric corrections	Not estimated (ionosphere free based analysis)
Ambiguities	ambiguities are fixed according to Ge et al. (2005)
Earth Orient. Parameters (EOP)	X and Y pole coordinates, and UT1 UTC represented with continuous piece wise linear function

## MGEX Precise Products from WHU

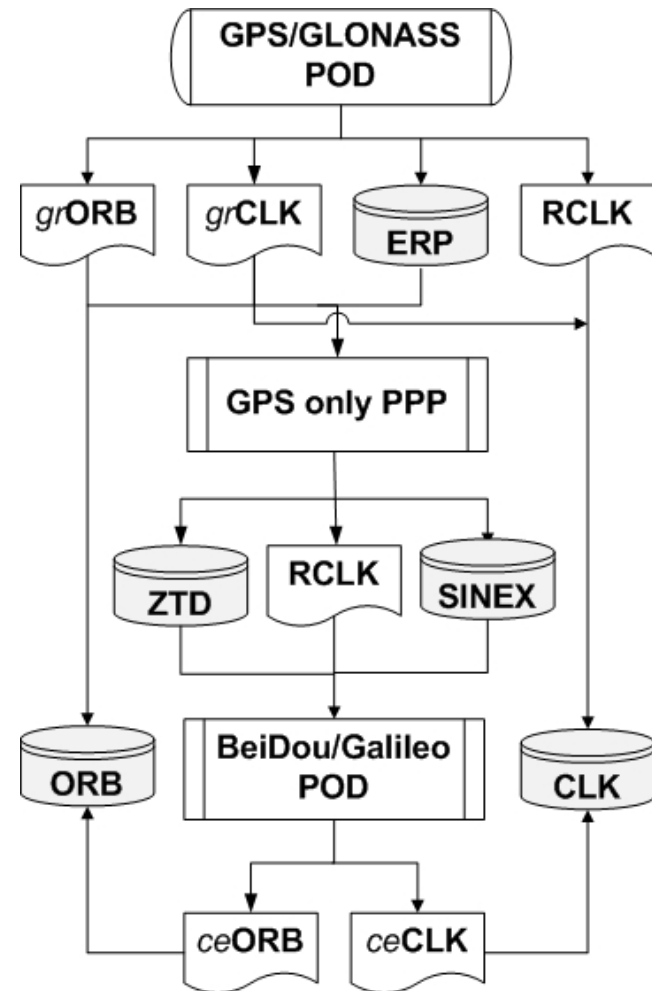
- To provide Multi-GNSS products (orbits, clocks, biases, etc.)
- As one of MGEX analysis centers, Wuhan University has provided Multi-GNSS products since Jan. 1, 2013
- Currently, the products latency is about 4 days.

Institution	ID	Systems	Description
WHU	WUM	C	From Jan. 1, 2013 to Dec. 31, 2013
		G+R+E+C	From Jan. 1, 2014 to Dec. 31, 2015
		G+R+E+C+J	Since Jan. 1, 2015

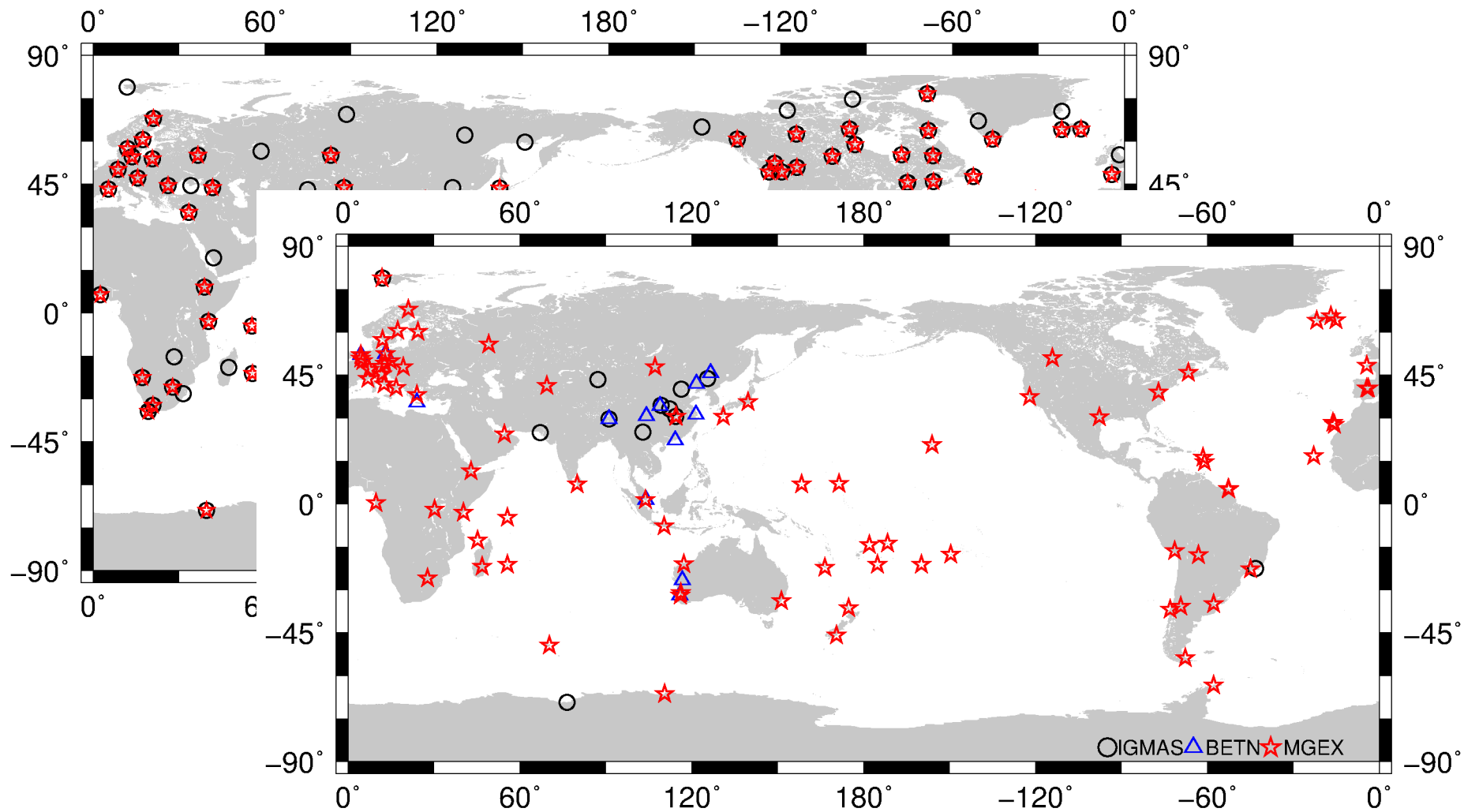


# POD strategy

- The specific measurement mode, reference frame, orbit model follow
  - the recommendations of 2nd IGS reprocess campaign (see <http://acc.igs.org/reprocess2.html>)
- Two steps
  - GPS/GLONASS POD
  - BeiDou/Galileo POD by fixing ZTD, positions, etc.



# Tracking stations



# SRP, PCOs, and PCVs



GNSS	SAT TYPE	SRP	PCOs & PCVs	
			SAT	STA
GPS	All	CODE <sup>a</sup>	igs08_WWWW.atx	igs08_WWWW.atx
GLONASS	All	CODE <sup>a</sup>		
Galileo	IOV	CODE <sup>a</sup> (~2014) Extend CODE model <sup>b</sup> (Since Jan, 1, 2015)	Nominal PCO from MGEX <sup>d</sup>	
	FOC	CODE <sup>a</sup>		
WUM	All	CODE with constant bias in along-track <sup>c</sup>	GEO: Nominal IGSOs and MEOs: WHU calibrated values	Same as GPS
QZSS	All	CODE with constant bias in along-track <sup>c</sup>	Nominal PCO from MGEX	

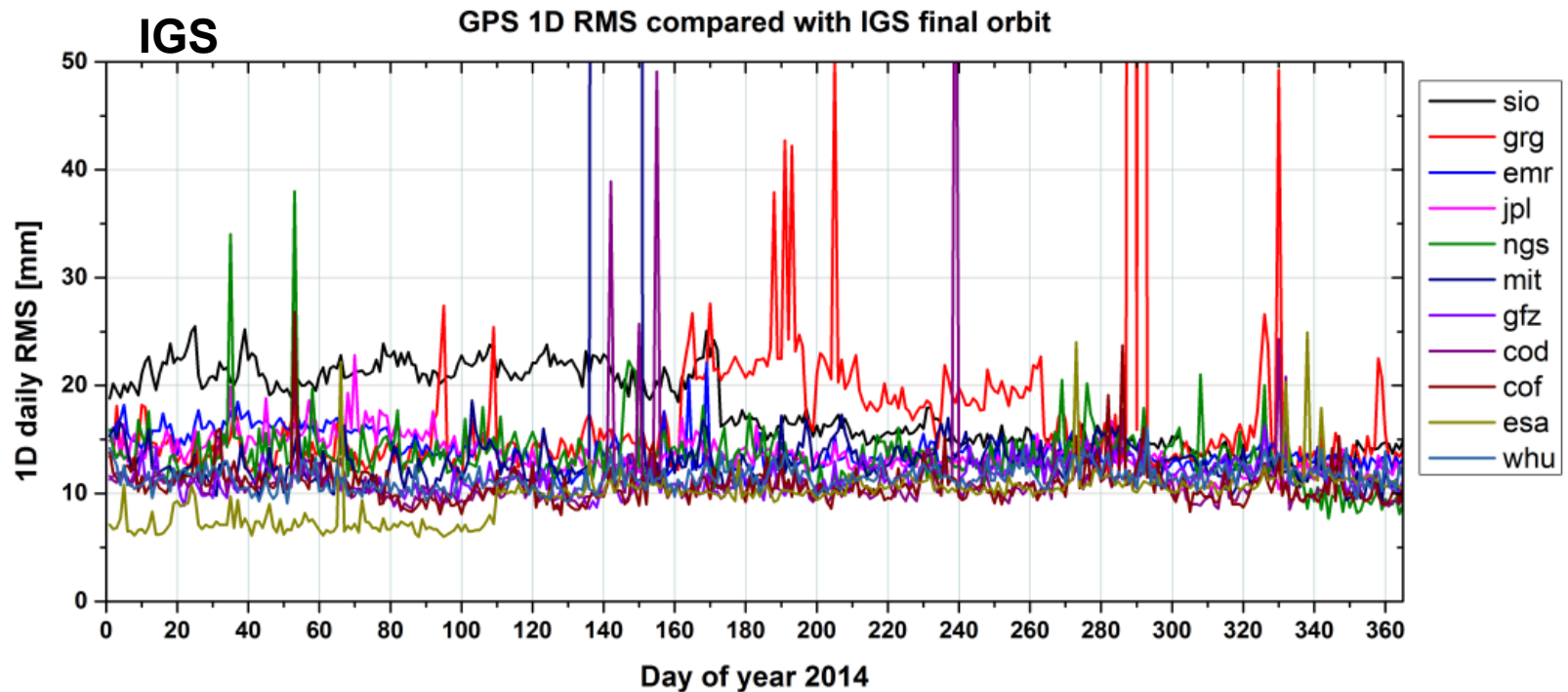
a. Beutler et al (1994) Manuscripta Geodaetica

c. Guo et al (2015) Journal of Geodesy

b. Montenbruck et al (2015) Journal of Geodesy

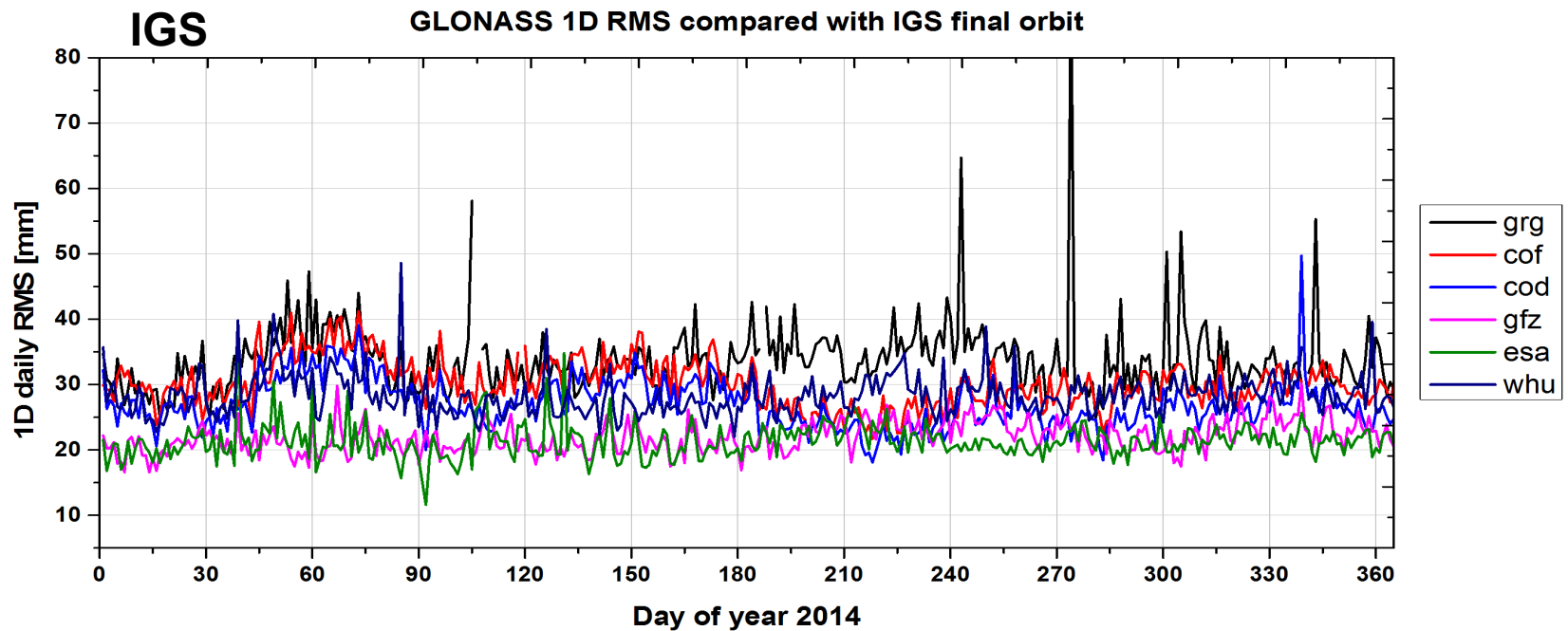
d. Montenbruck (2015) Advances in Space Research

# Orbit Comparison: GPS



Unit [mm]	COM	QZF	WUM	GBM	GFM	ESM
GPS-IGS	14.83	44.87	11.45	13.96	12.83	15.79
Unit [mm]	COD	COF	WUM	GFZ	GFM	ESA
GPS-IGS	11.19	10.80	11.45	11.49	----	9.85

# Orbit Comparison: GLONASS



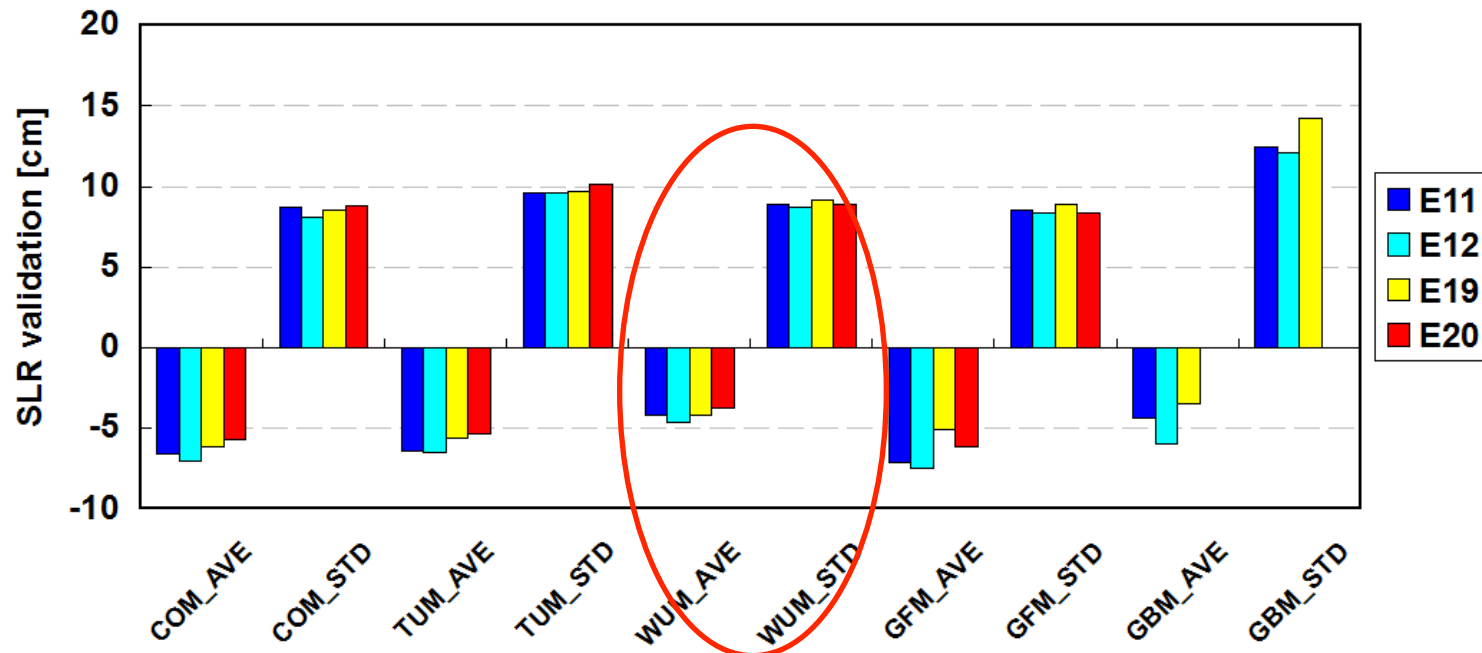
Unit [mm]	COM	WUM	GBM	ESM
GLONASS-IGL	28.72	28.26	29.64	32.09
Unit [mm]	COD	WUM	GFZ	ESA
GLONASS-IGL	27.02	28.26	21.98	21.32

# SLR Residuals: Galileo (2014)

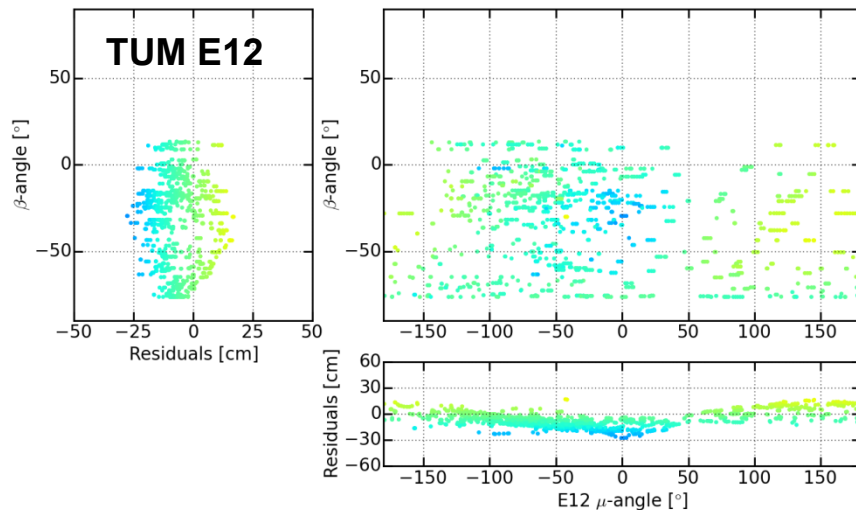
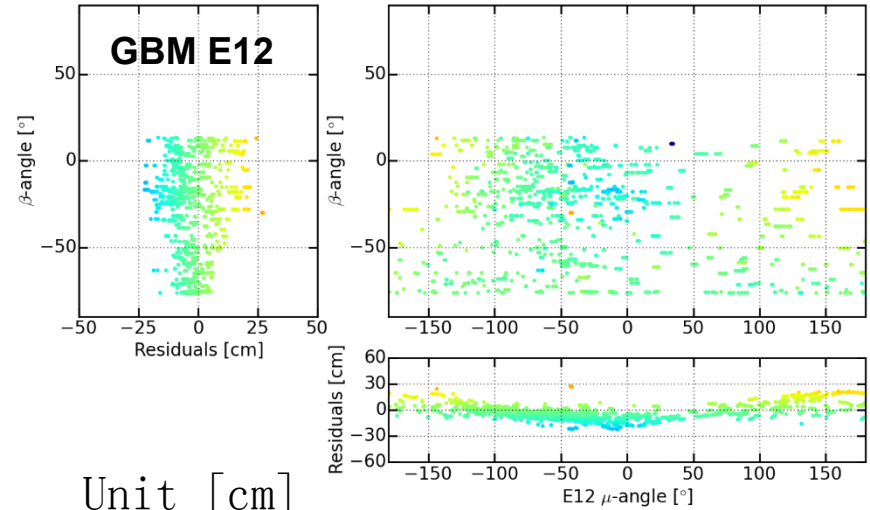
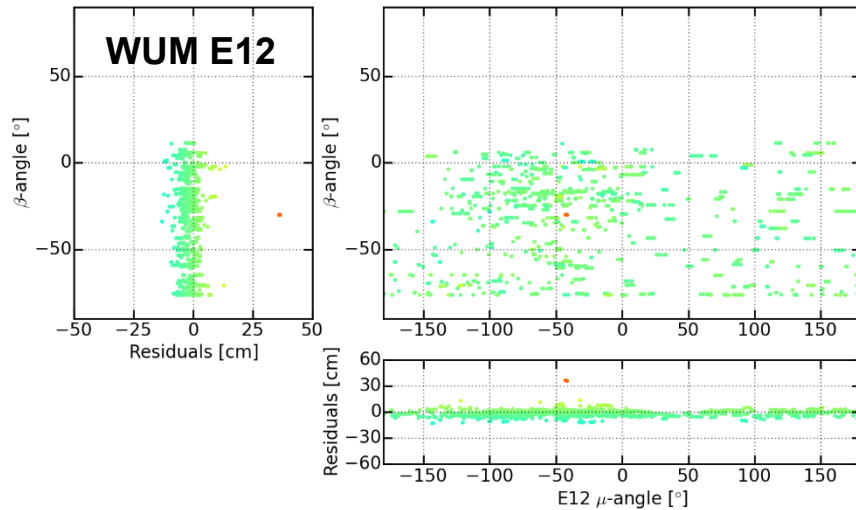


Unit [cm]	COM	TUM	WUM	GBM	GFM
DBD*	9.0	8.2	26.2	18.6	11.2

\*DBD: Day boundary discontinuity



# SLR Residuals: Galileo (2015)



Unit [cm]

		WUM	TUM	GBM
E11	Bias	-2.86	-5.64	-0.84
	STD	3.65	10.19	9.93
E12	Bias	-2.64	-5.39	-1.07
	STD	3.42	9.46	8.8
E19	Bias	-1.74	-6.73	-2.91
	STD	3.87	8.72	9.39

# SLR Residuals: BeiDou



Day boundary discontinuity (unit: cm)

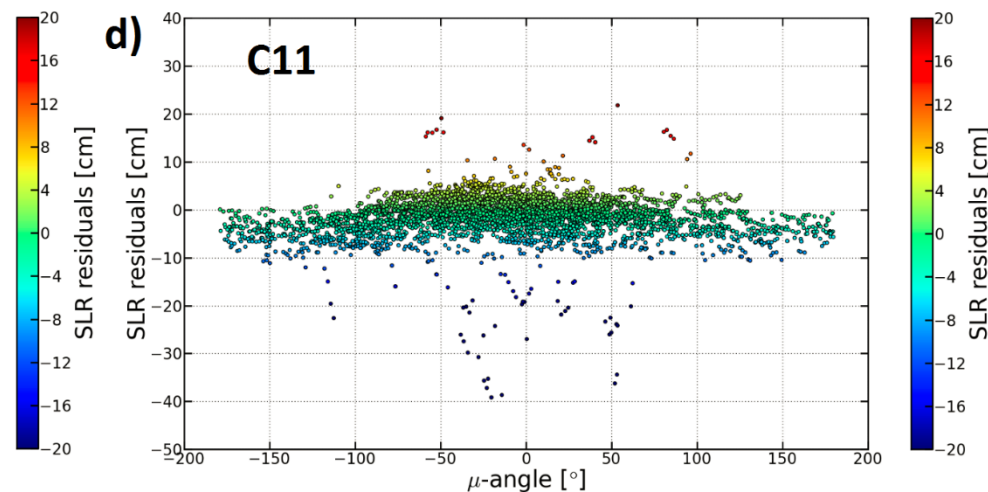
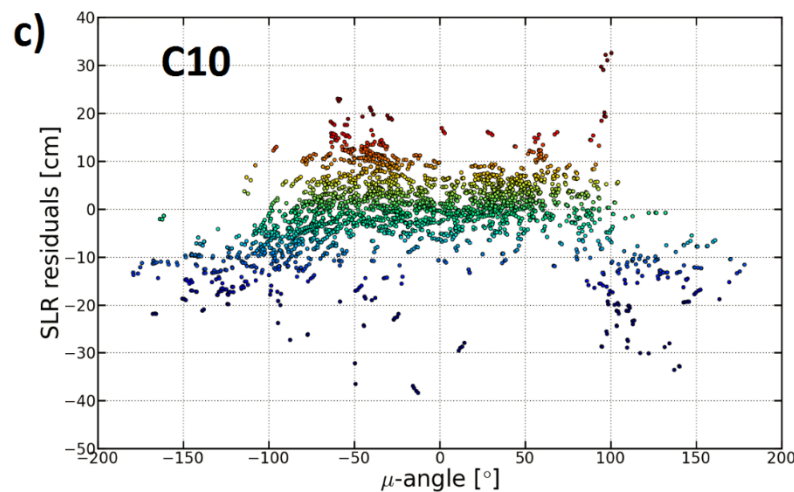
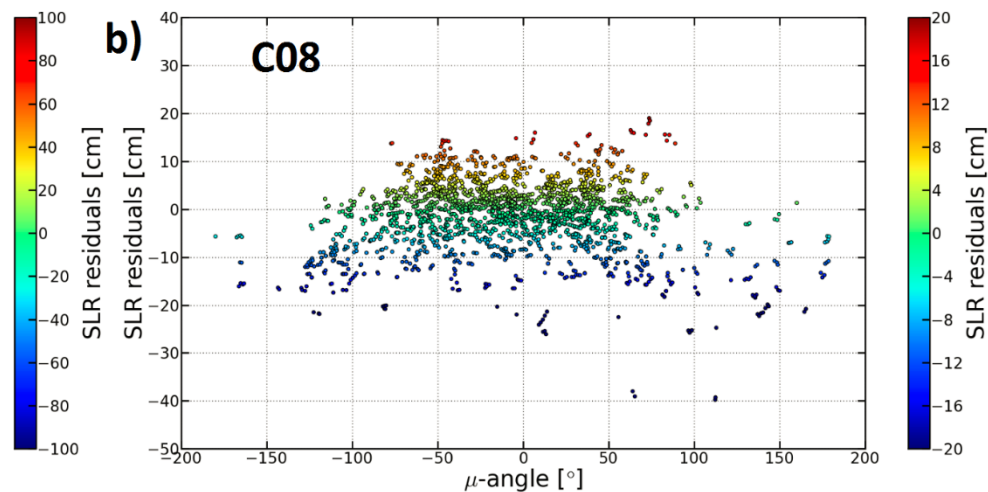
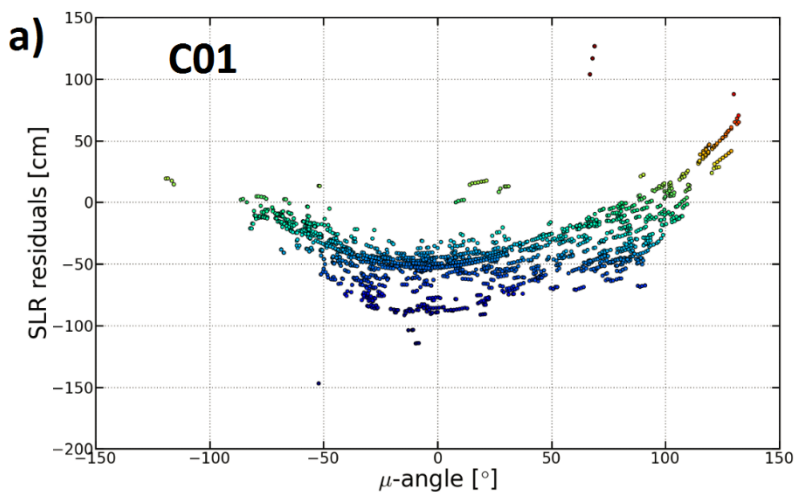
	GEO	IGSO	MEO
WUM	64.8	30.3	14.6
GBM	149.0	32.1	26.6
COM	/	14.9	10.0

SLR validation (unit: cm)

	COM		GBM		WUM	
	AVE	STD	AVE	STD	AVE	STD
C01			-55.61	42.11	-40.85	25.78
C08	-4.32	5.89	-0.72	8.62	-1.72	7.00
C10	-1.06	6.47	1.39	8.12	-1.03	7.81
C11	-2.18	5.93	0.16	5.45	-1.79	4.24

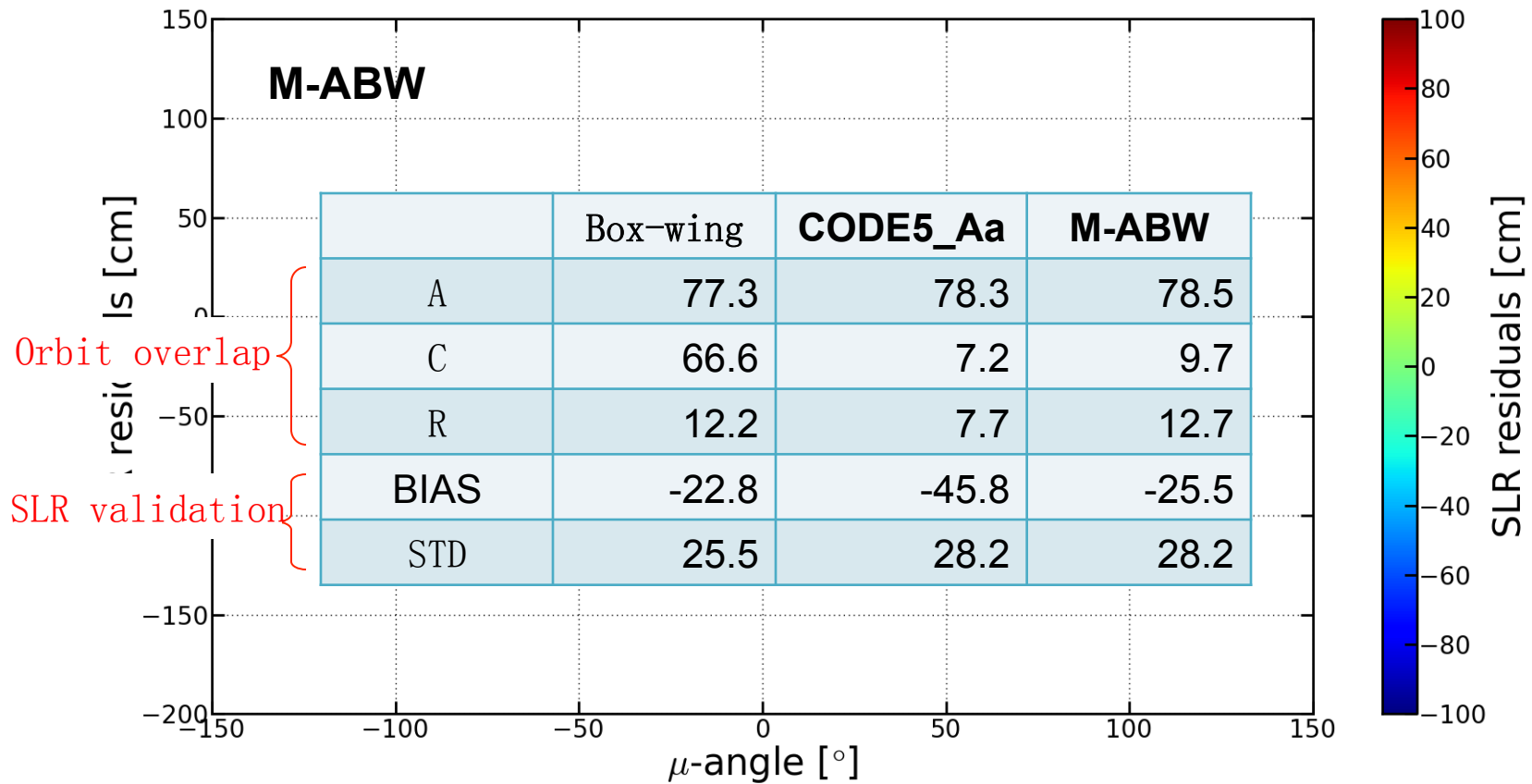


# Orbit: BeiDou

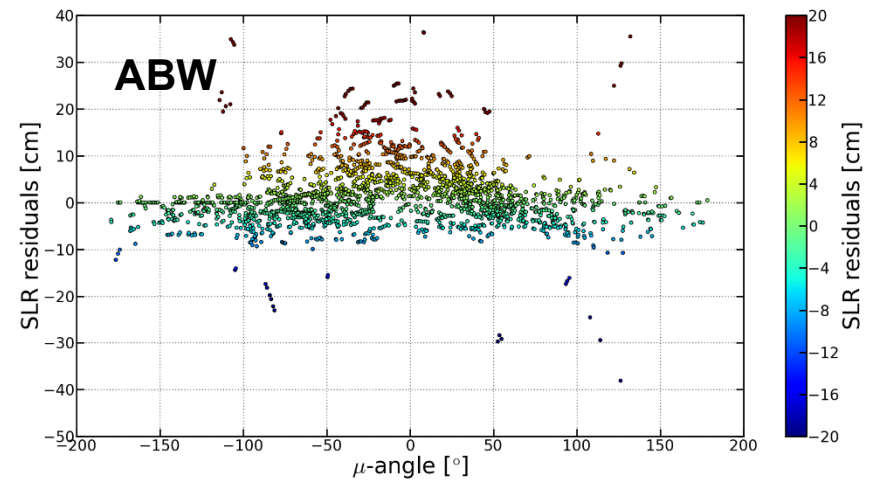
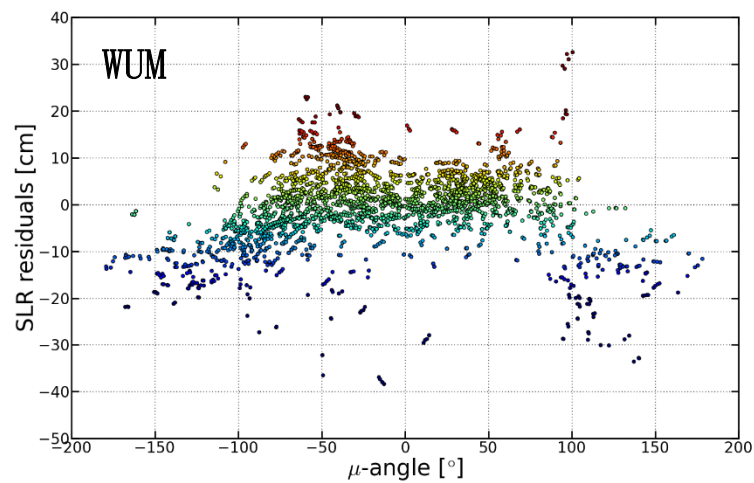
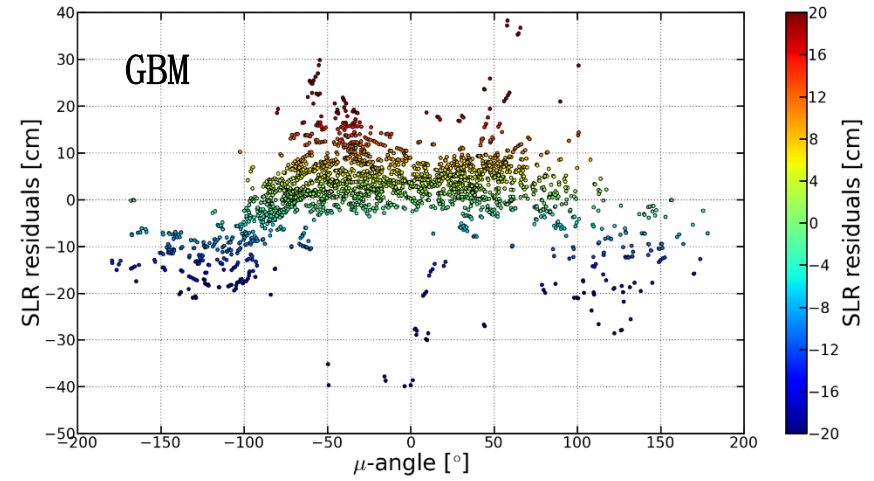
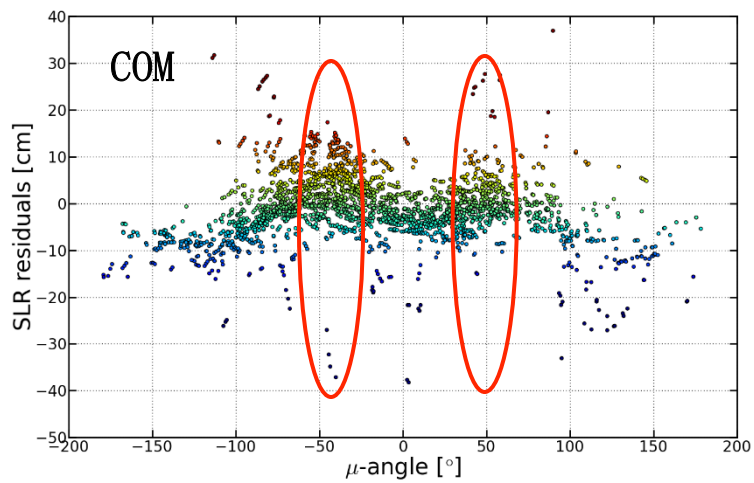


Orbit errors are correlated with orbital angle for C01, C10, and ...

# SRP for BeiDou GEO C01

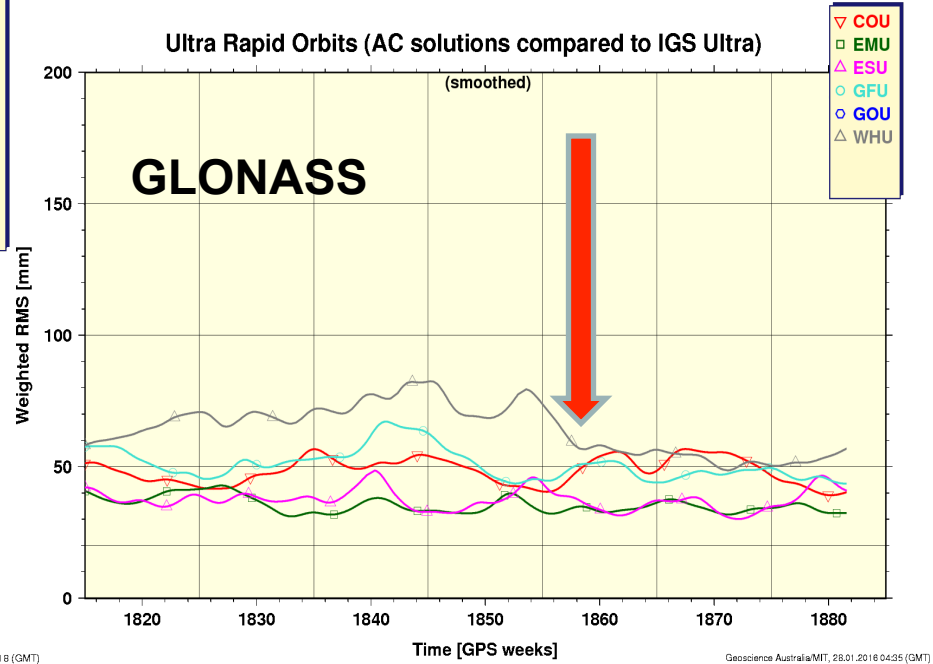
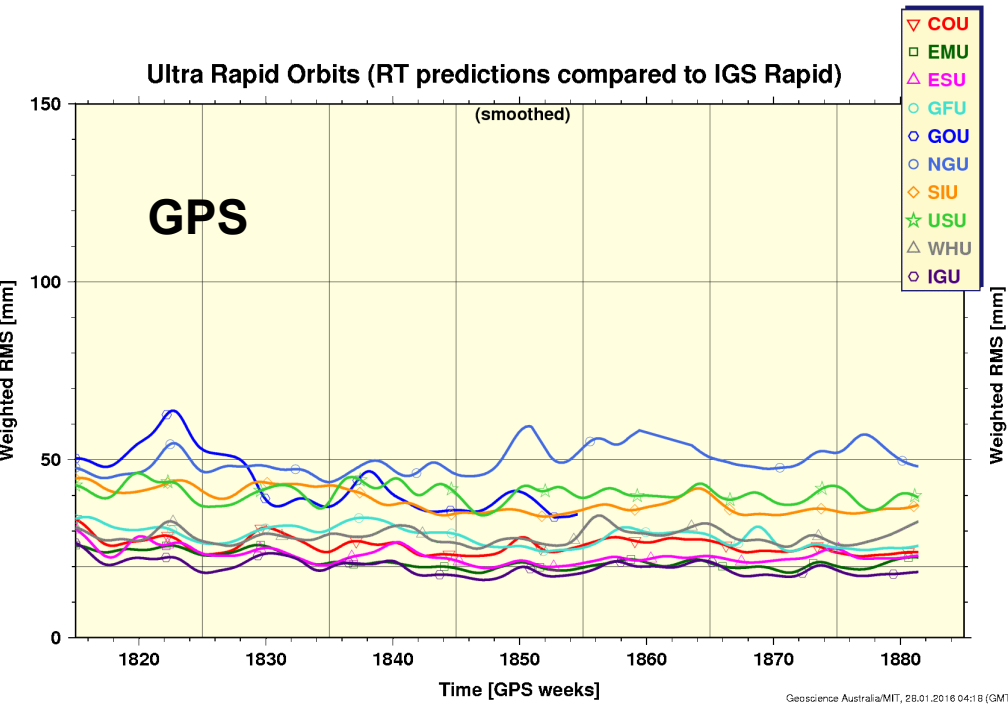


# SRP for BeiDou IGSO C10



## Ultra-Rapid Products from WHU

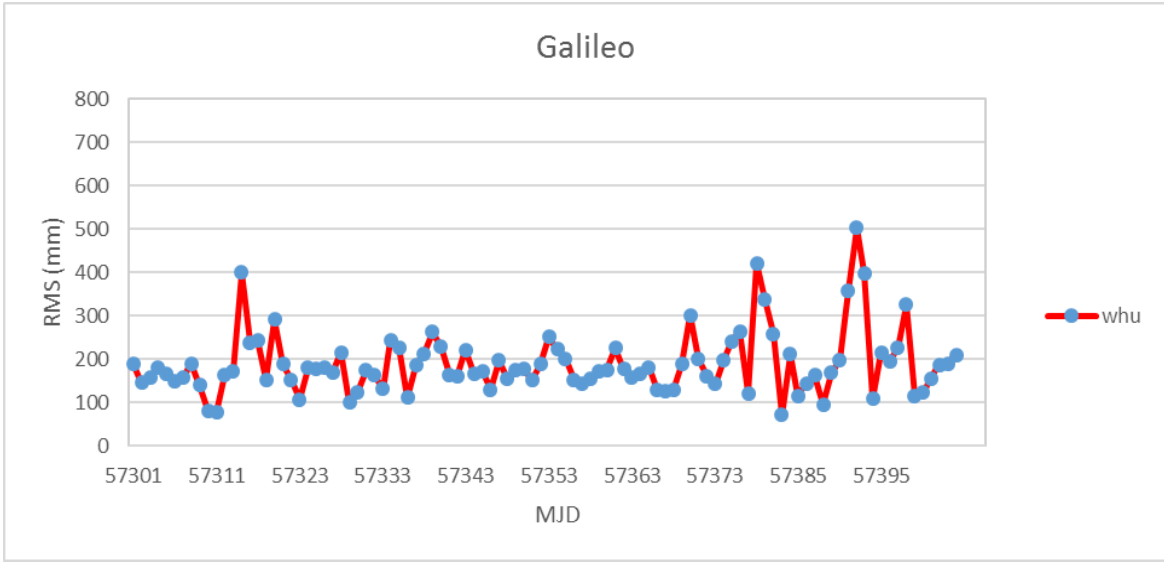
# Ultra-rapid orbit Quality (GPS & GLONASS)



<http://acc.igs.org/>

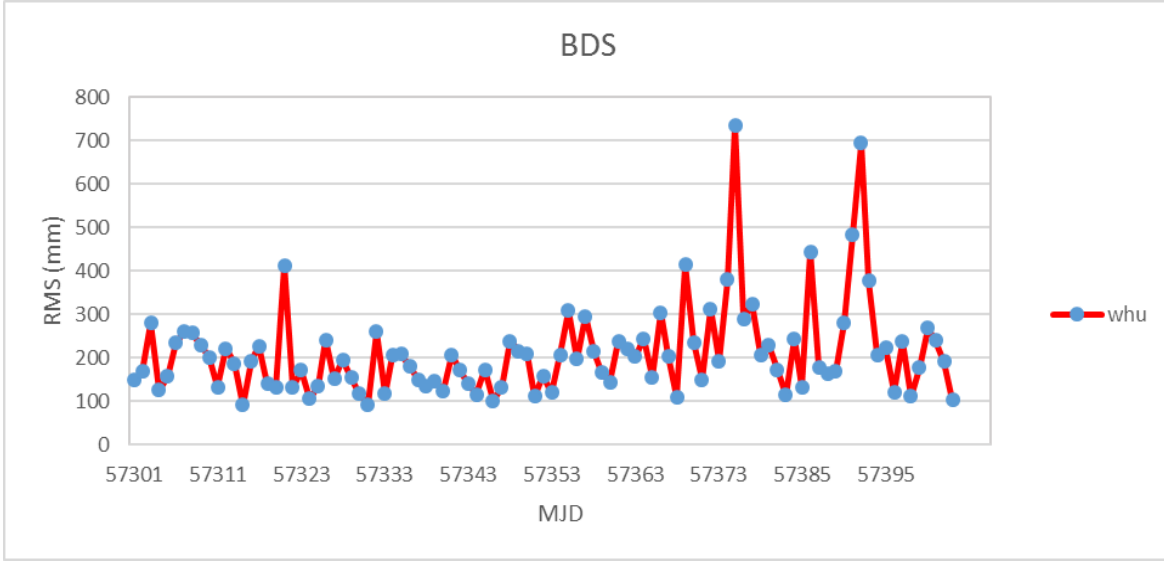
Better than 5cm compared with IGS ultra-rapid orbit

# Ultra-rapid orbit Quality (Galileo & Beidou)



Compared with TUM MGEX final products.

Ultra-rapid orbit (6h prediction):  
**Galileo: 190mm**



Compared with GBM (GFZ) MGEX final products.

Ultra-rapid orbit (6h prediction):  
**BDS(IGSO/MEO): 219mm**

# Summary



- MGEX precise orbit
  - GPS: 11mm compared with IGS
  - GLONASS: 30mm compared with IGS
  - Galileo: 10cm validated by SLR
  - Beidou: 10cm validated by SLR
- Ultra-rapid orbit
  - GPS: 3cm compared with IGR
  - GLONASS: 5cm compared with IGU
  - Galileo: 20cm compared with TUM
  - Beidou: 20cm compared with GBM
- MGEX orbit products
  - WHU provided Multi-GNSS products since Jan. 1, 2013
  - uploaded to IGS (cddis) and iGMAS
  - <ftp://igs.gnsswhu.cn/pub/BDS> releases models and code

Thank You for your attention!