

# One-year results of the routine PPP-AR product combination

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# Routine combination at the PPP-AR Pilot Project

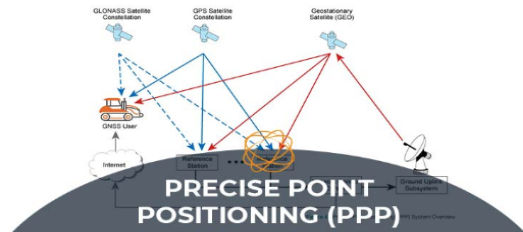
- Enable both rapid and final orbit/clock/bias combination
- Fully automated operation and quality control
- PPP-AR validation using combined and AC-specific products



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IGS | Pilot Projects

## Precise Point Positioning with Ambiguity Resolution



## Precise Point Positioning with Ambiguity Resolution (PPP-AR) Working Group

Established: 2018

Chair: Jianghui Geng

Mailing List: [IGS PPP-AR Working Group Mailing List](#)

# Overview of IGS AC-specific products

- 4 ACs provide rapid phase bias products
- Varying sampling rates of orbit and clock products
- Mixed MGEX and OPS products

ID	Products	Systems	Orbit	Clock	Attitude	Code bias	Phase bias
COD	COD0OPSRAP	GE	300 s	30 s	30 s	GE (OSB)	GE (OSB)
ESA	ESA0OPSRAP	G	900 s	300 s			
GFZ	GFZ0MGXRAP	GEC	300 s	30 s	30 s	GEC (OSB)	GEC (OSB)
GRG	GRG0OPSRAP	GEC	300 s	30 s	30 s	GEC (OSB)	GEC (OSB)
JPL	JPL0OPSRAP	G	300 s	30 s	30 s		
WUM	WUM0MGXRAP	GEC	300 s	30 s	30 s	GEC (OSB)	GEC (OSB)

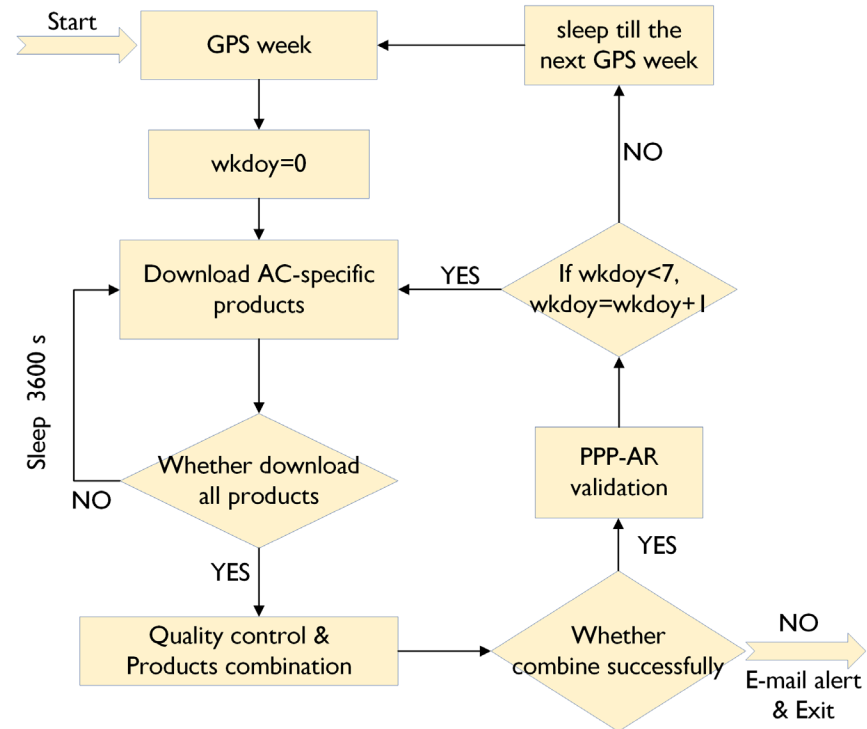
# Overview of IGS AC-specific products

- 3 ACs provide final phase bias products
- Mixed MGEX and OPS products

ID	Products	Systems	Orbit	Clock	Attitude	Code bias	Phase bias
COD	COD0OPSFIN	GE	300 s	30 s	30 s	GE (OSB)	GE (OSB)
ESA	ESA0OPSFIN	GE	300 s	30 s			
GFZ	GFZ0OPSFIN	GE	300 s	30 s			
GRG	GRG0MGXFIN	GEC	300 s	30 s	30 s	GEC (OSB)	GEC (OSB)
JAX	JAX0MGXFIN	GE	300 s	30 s			
JGX	JGX0OPSFIN	GE	300 s	30 s			
JPL	JPL0OPSFIN	G	300 s	30 s	30 s		
WUM	WUM0MGXFIN	GEC	300 s	30 s	30 s	GEC (OSB)	GEC (OSB)

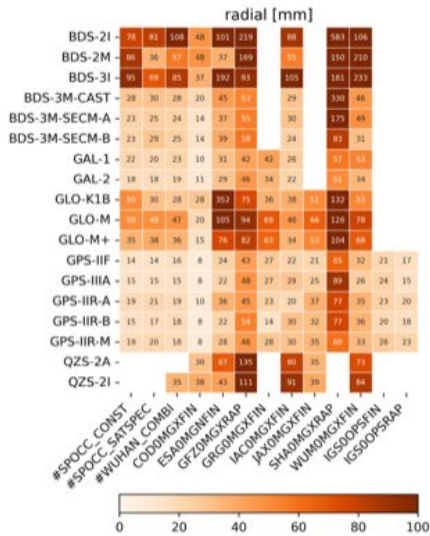
# Flowchart of routine combination

- The routine combination is carried out on a weekly basis
  - One week delay for rapid products
  - Three weeks delay for final products
  - Fully automated operation, and failure will trigger E-mail alert

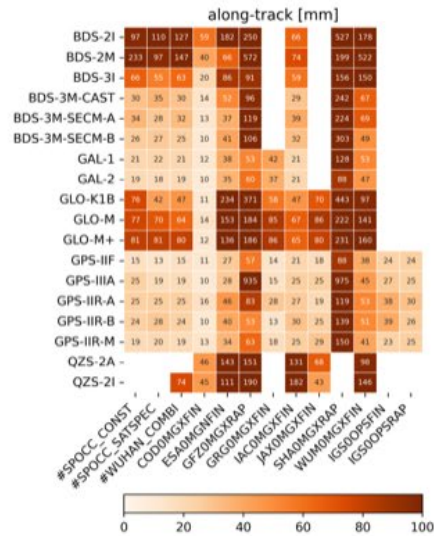


# Combined orbits compared to IGS

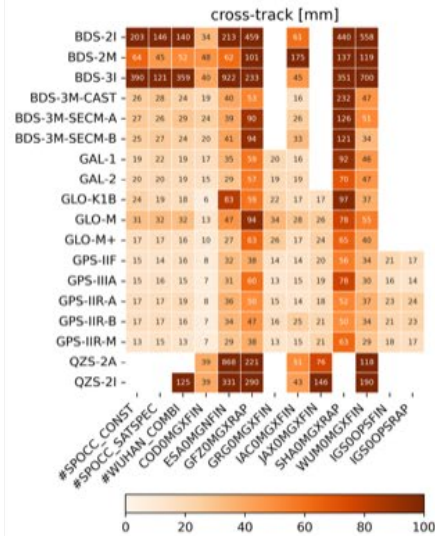
## Orbits comparison provided by Radoslaw



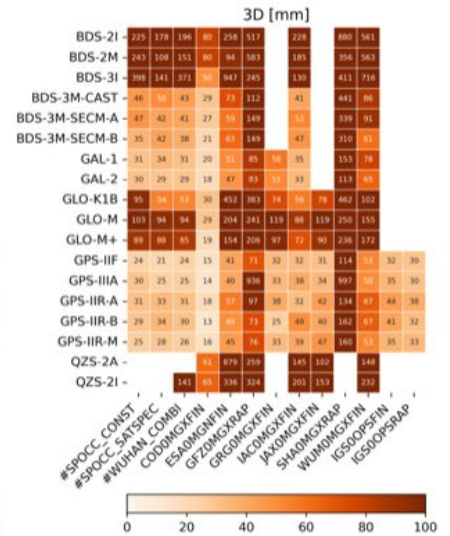
radial



along



cross

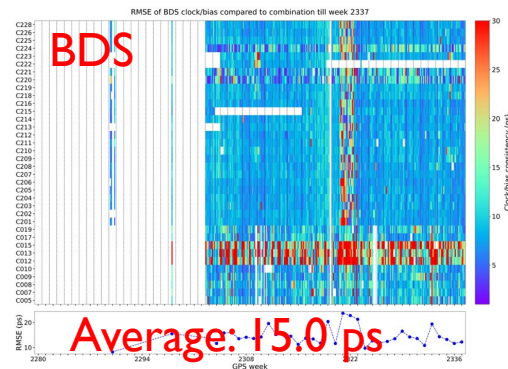
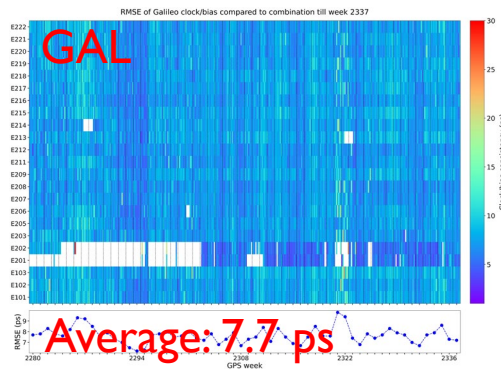
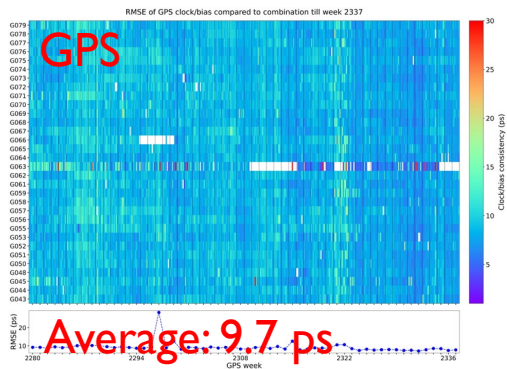


3D

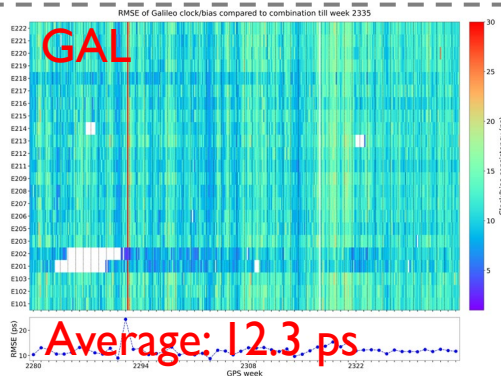
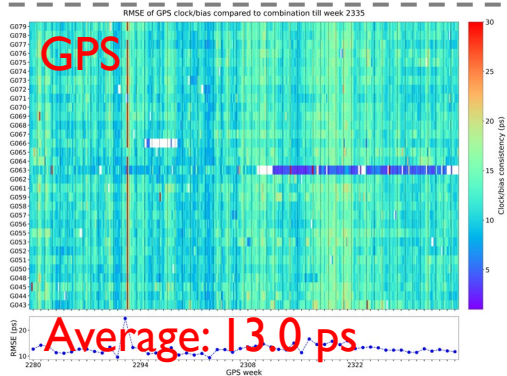
# Consistency among AC clocks

## ■ RMSE of clock/bias combination

Rapid



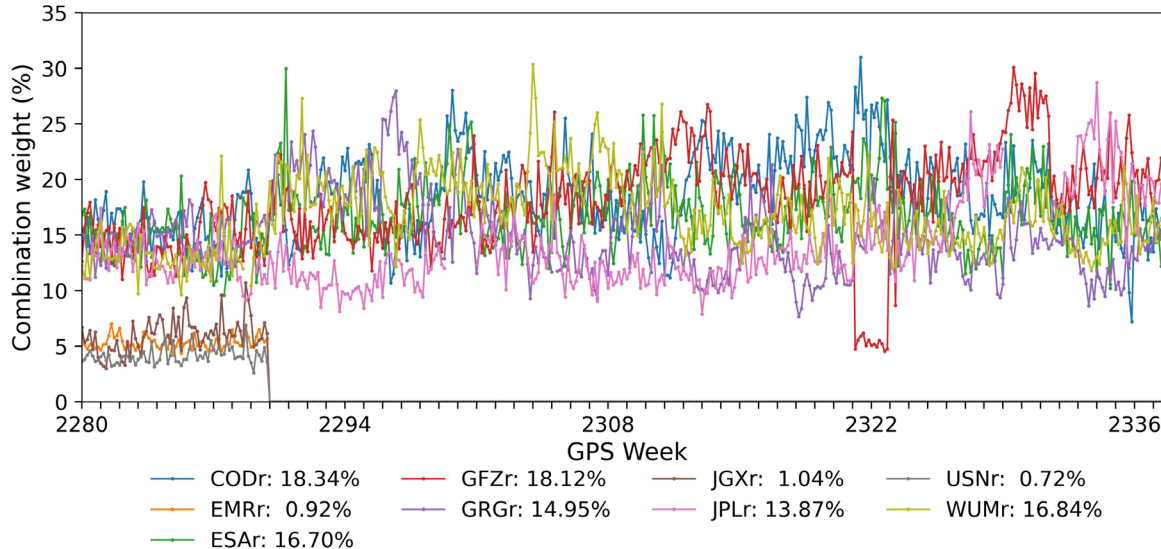
Final



# Combination weights for each AC

## ■ Weights for the clock/bias combination (Rapid)

ACs contribution to the combination till week 2337

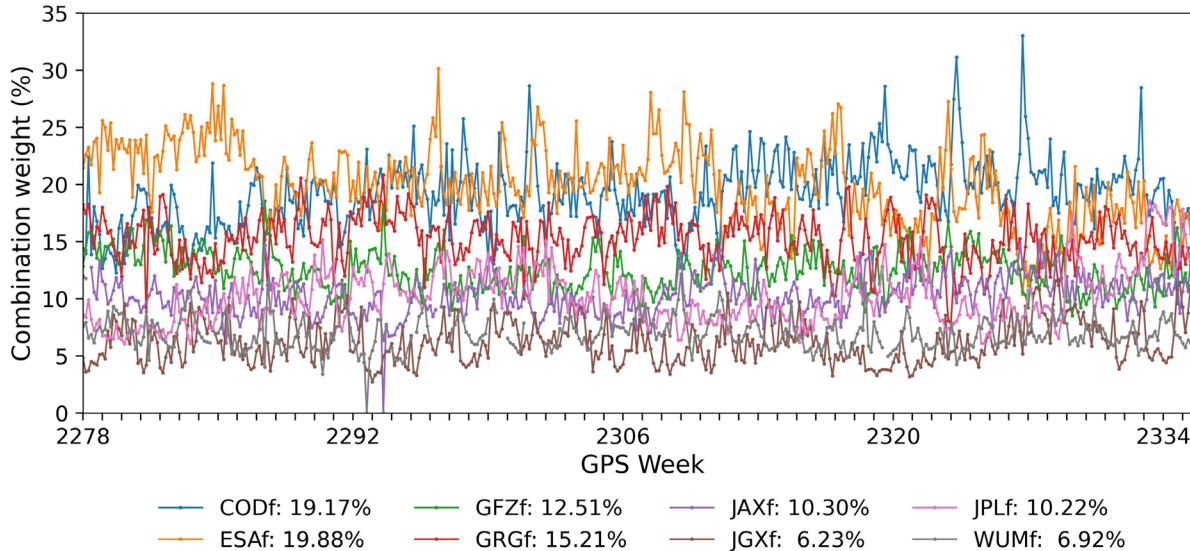


AC	Average weight (%)
COD	18.34
EMR	0.92
ESA	16.70
GFZ	18.12
GRG	14.95
JGX	1.04
JPL	13.87
USN	0.72
WUM	16.84

# Combination weights for each AC

## ■ Weights for the clock/bias combination (Final)

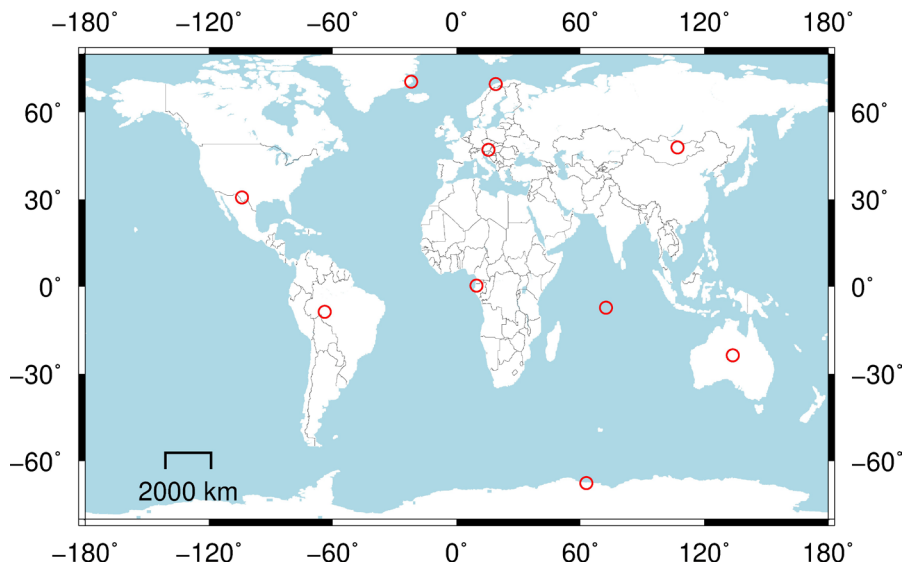
ACs contribution to the combination till week 2335



AC	Average weight (%)
COD	19.17
ESA	19.88
GFZ	12.51
GRG	15.21
JAX	10.30
JGX	6.23
JPL	10.22
WUM	6.92

# Overview of PPP-AR validation

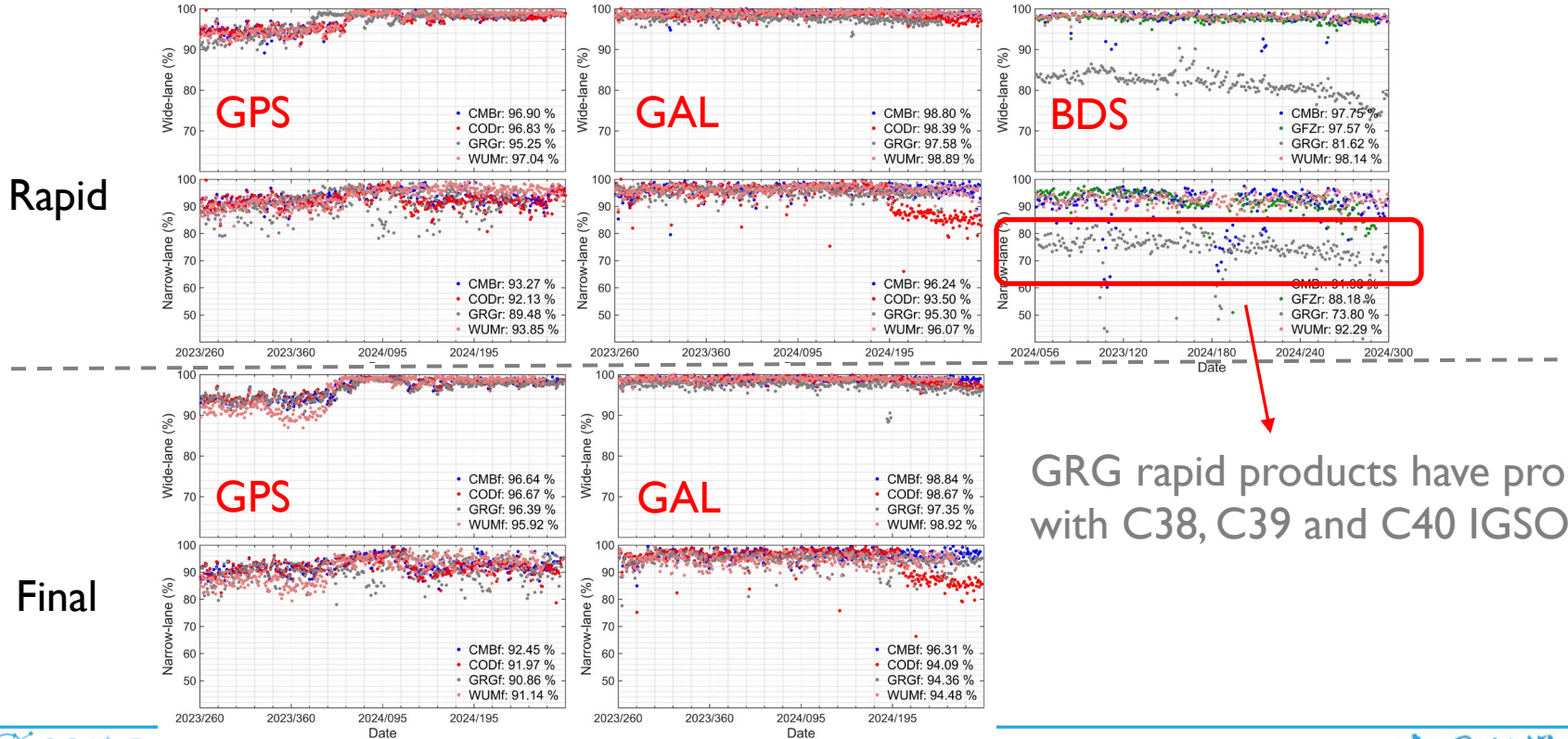
- Software: PRIDE PPP-AR v3.0
- Mode: Static daily PPP-AR
- 10 global stations
- Results:
  - i. Ambiguity fixing rates
  - ii. Daily position RMS



Distribution of 10 global stations

# Static daily PPP-AR validation

## Wide-lane and narrow-lane ambiguity fixing rates



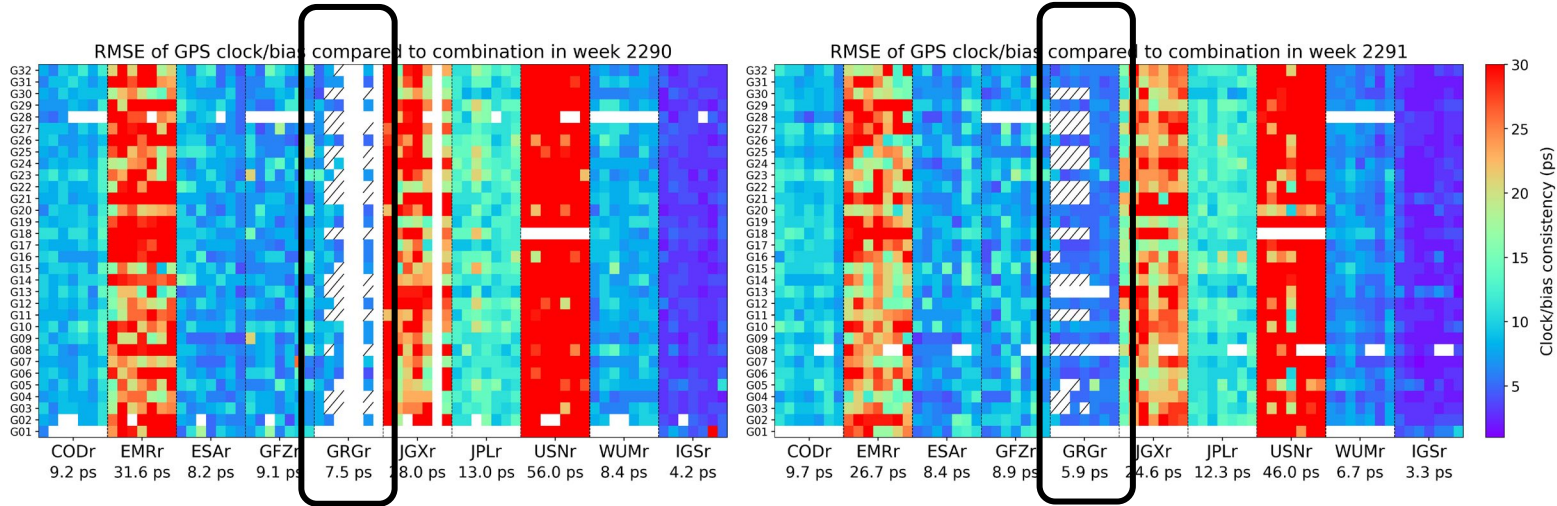
# Static daily PPP-AR validation

## ■ Daily position RMS (mm) for rapid and final solutions

		GPS			GAL			BDS				
		Products	E	N	U	E	N	U	E	N	U	
Rapid	CMBr		2.1	1.6	4.3	2.3	2.0	6.7	3.1	3.1	7.6	
	CODr		2.4	1.7	4.5	2.5	2.0	6.8	N/A	N/A	N/A	
	GFZr		2.7	2.2	6.8	2.2	2.1	8.5	3.5	2.5	7.3	
	GRGr		2.2	2.0	6.4	2.5	2.5	8.1	4.0	3.3	7.5	
	WUMr		2.0	1.7	5.9	2.3	2.3	7.6	3.1	3.1	7.6	
		GPS			GAL							
		Products	E	N	U	E	N	U				
Final	CMBf		2.1	1.6	4.1	2.1	1.8	6.8				
	CODf		2.2	1.8	4.2	2.4	1.9	6.6				
	GRGf		2.5	1.6	4.6	2.1	2.7	6.8				
	WUMf		2.4	2.0	4.7	2.8	2.5	7.0				

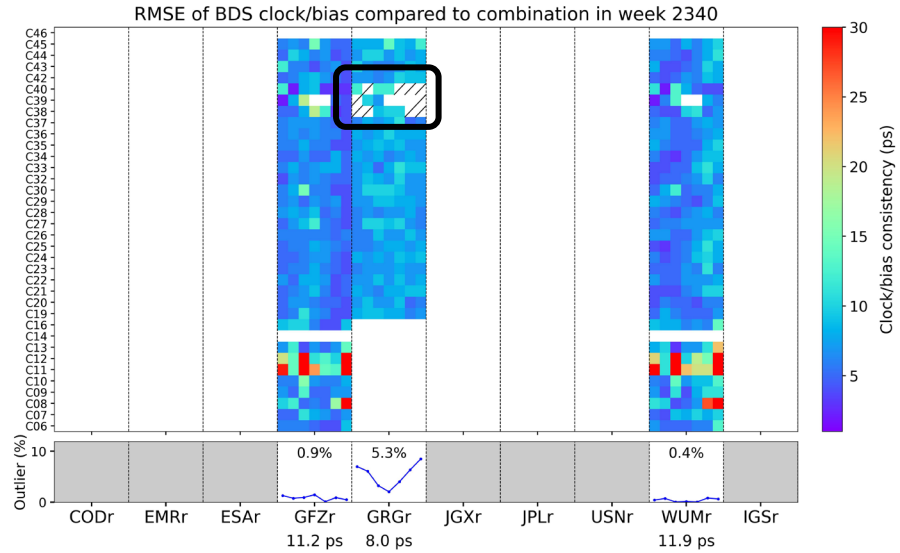
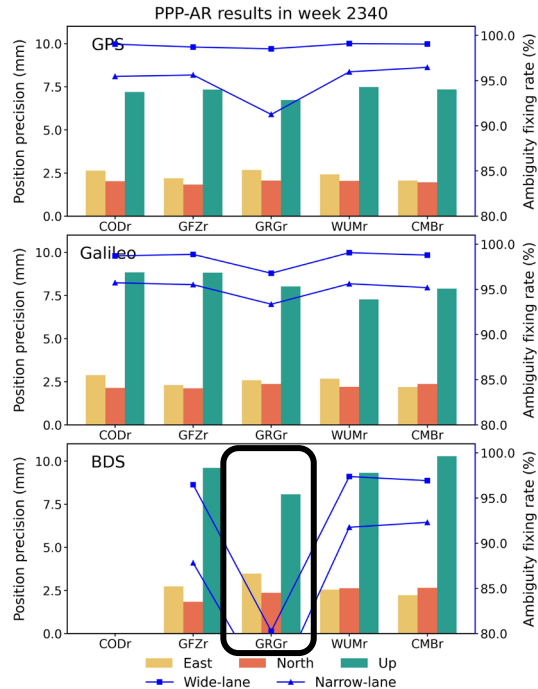
# Problems identified via cross-validation

- GRG rapid products during GPS week 2290 and 2291
  - Most of products are detected as outliers through combination
  - Probably due to the transition to standard Bias-SINEX formats



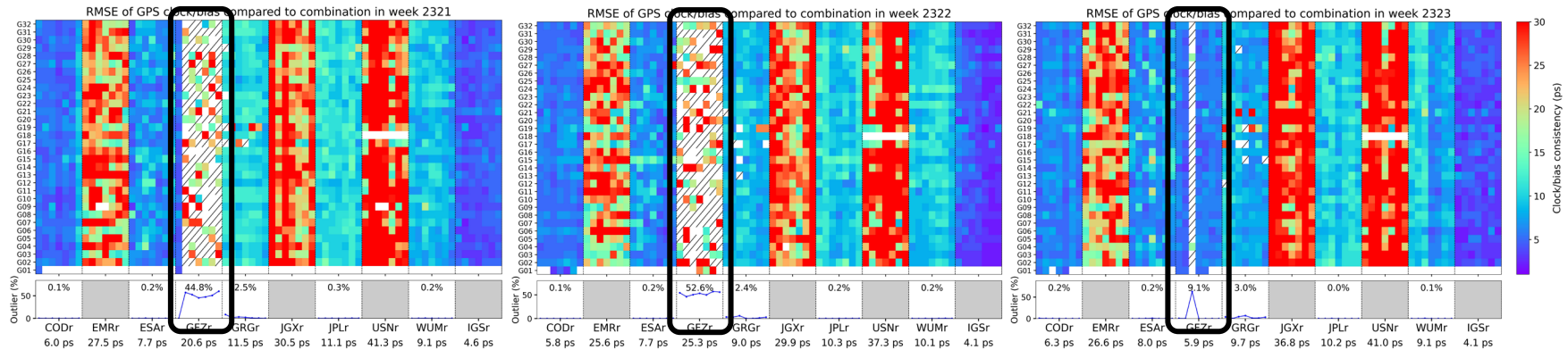
# Problems identified via cross-validation

- Low ambiguity fixing rates for BDS satellites (GRG)
  - Phase OSBs for C38/C39/C40 three IGSO satellites are not precise



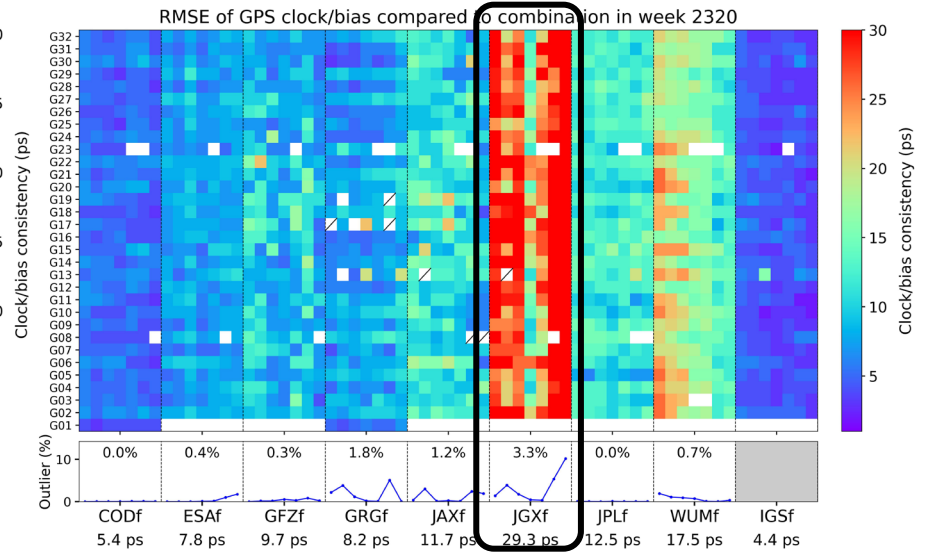
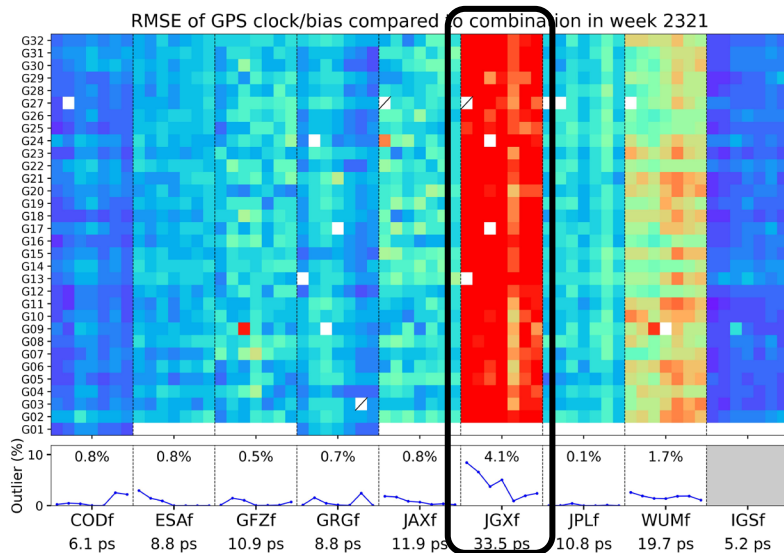
# Problems identified via cross-validation

- GFZ rapid products during GPS week 2321-2323
  - Most of products are detected as outliers through combination
  - The reasons remain unclear



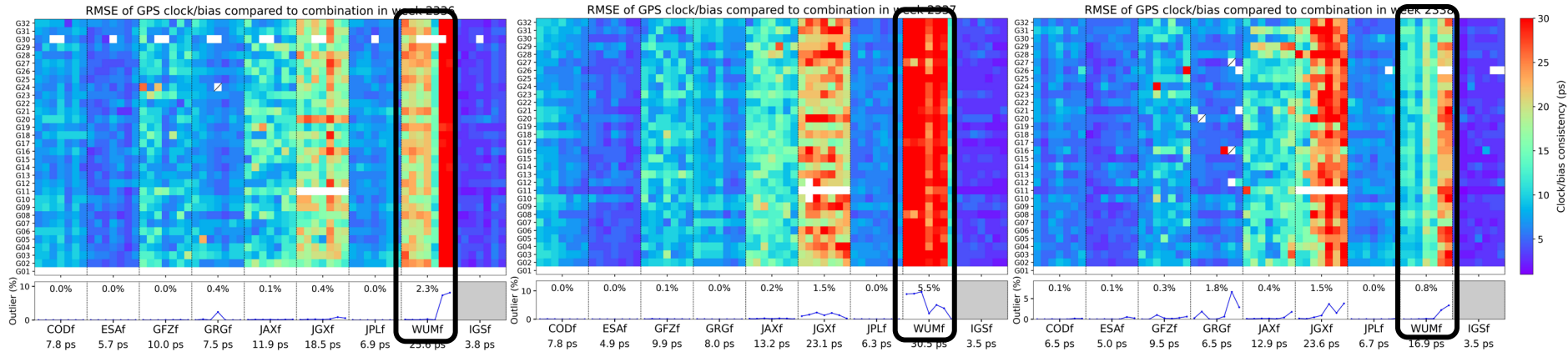
# Problems identified via cross-validation

- JGX final products show low consistency with other ACs
  - RMSE of clock/bias combination exceeds 30 ps for most of weeks



# Problems identified via cross-validation

- WUM final products during recent GPS weeks (2336-2338)
  - RMSE of clock/bias combination increases largely for recent weeks



# Summary

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- Multi-GNSS orbit/clock/bias combination have been routinely performed at Wuhan since GPS week 2280
- A fully automated operation and quality control process are applied, with PPP-AR validation conducted upon completion of the combination
- Orbit combination can achieve a consistency of 0.2 cm with IGS, while clock/bias combination can achieve an inter-AC consistency of 10 ps for GPS and Galileo, and 15 ps for BDS