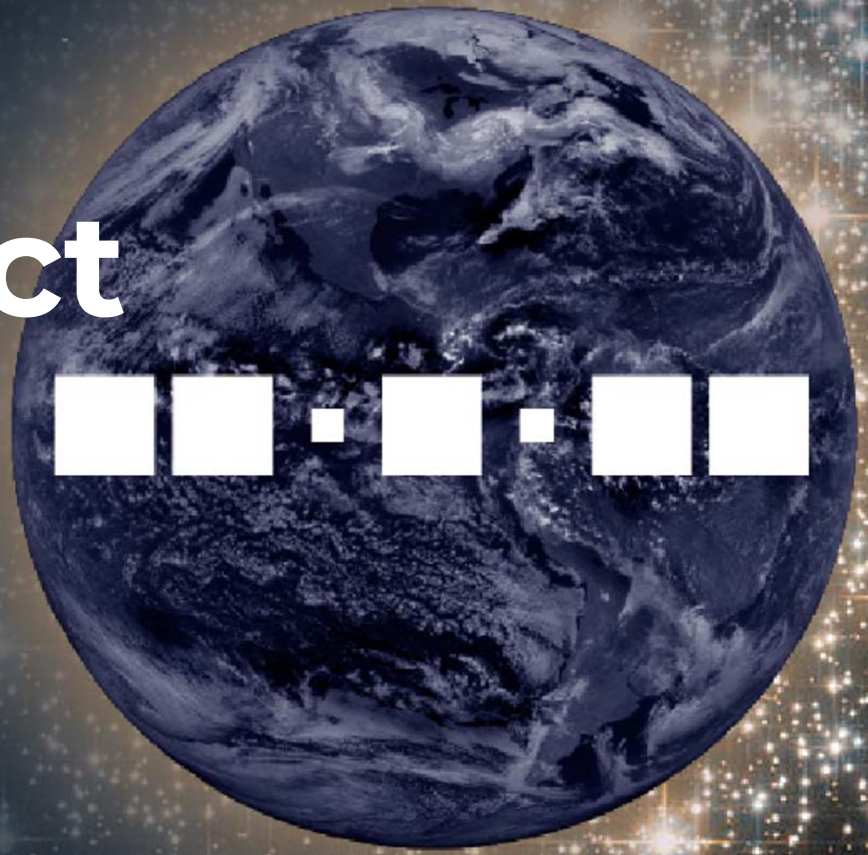
PPP-AR Pilot Project

Jianghui Geng, Qiang Wen, Yahao Zhang,
Qingfeng Wu, Yangyang Wang



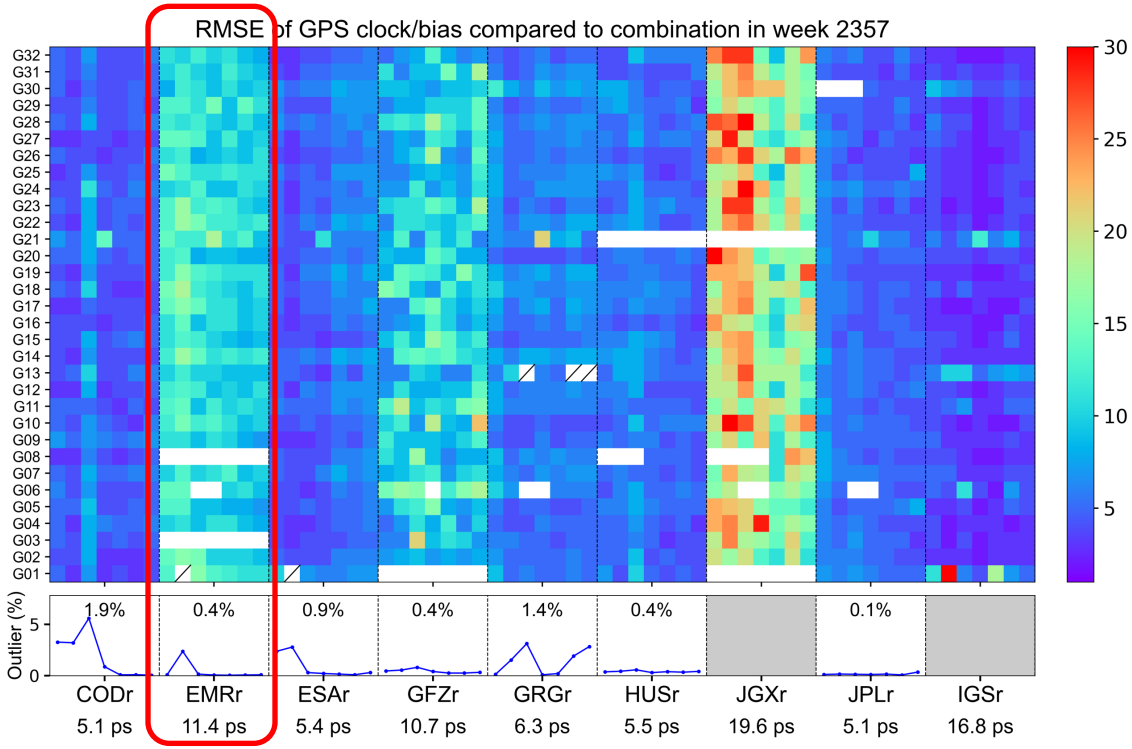
IGS INTERNATIONAL GNSS SERVICE

2025 Virtual Meeting

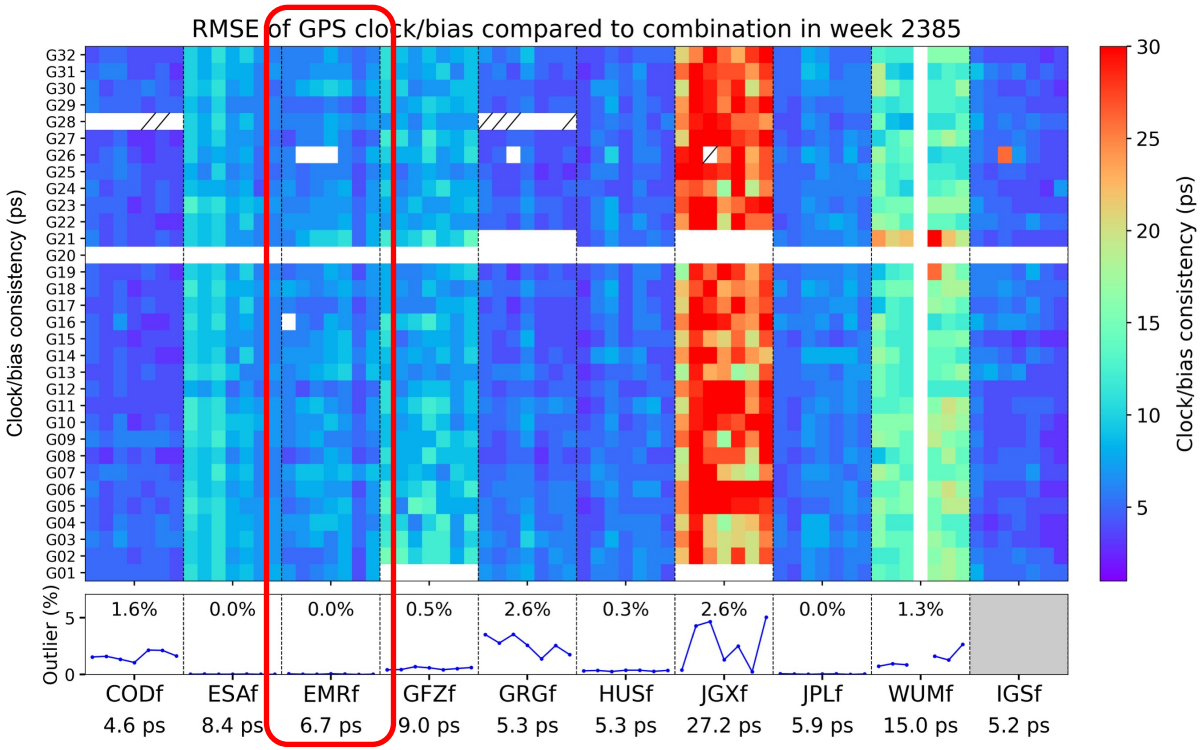
IGS INTERNATIONAL GNSS SERVICE

EMR's PPP-AR products

- EMR include code/phase OSBs in its OPS final products (Only GPS)
  - The consistency with other ACs' products seems to have improved after the release of OSB products



Before the release of OSBs



After the release of OSBs

WUM's PPP-AR products

- WUM MGEX final products include QZSS phase OSBs
  - Currently, CODE and WUM two ACs provide QZSS code/phase OSBs

```
OSB  JQS2 J02            C1C        2025:250:00000 2025:251:00000 ns          2.752500000000000     0.091000
OSB  JQS2 J02            C1X        2025:250:00000 2025:251:00000 ns          2.559900000000000     0.101300
OSB  JQS2 J02            C2L        2025:250:00000 2025:251:00000 ns          4.427600000000000     0.143900
OSB  JQS2 J02            C2X        2025:250:00000 2025:251:00000 ns          4.321800000000000     0.164800
OSB  JQS2 J02            C5Q        2025:250:00000 2025:251:00000 ns          3.029000000000000     0.114700
OSB  JQS2 J02            C5X        2025:250:00000 2025:251:00000 ns          2.389100000000000     0.125100
OSB  JQS2 J02            L1X        2025:250:00000 2025:251:00000 ns         -2.767264139528239     0.736214
OSB  JQS2 J02            L2X        2025:250:00000 2025:251:00000 ns         -4.557530300906368     0.722094
OSB  JQS4 J03            C1C        2025:250:00000 2025:251:00000 ns          0.759100000000000     0.091100
OSB  JQS4 J03            C1X        2025:250:00000 2025:251:00000 ns          0.529000000000000     0.101200
OSB  JQS4 J03            C2L        2025:250:00000 2025:251:00000 ns          1.160000000000000     0.144000
OSB  JQS4 J03            C2X        2025:250:00000 2025:251:00000 ns          0.961400000000000     0.164800
OSB  JQS4 J03            C5Q        2025:250:00000 2025:251:00000 ns          1.434000000000000     0.114700
OSB  JQS4 J03            C5X        2025:250:00000 2025:251:00000 ns          0.514100000000000     0.123900
OSB  JQS4 J03            L1X        2025:250:00000 2025:251:00000 ns         -1.031168151728678     0.736181
OSB  JQS4 J03            L2X        2025:250:00000 2025:251:00000 ns         -1.698276658777592     0.722003
OSB  JQS5 J04            C1C        2025:250:00000 2025:251:00000 ns         -1.518900000000000     0.120600
OSB  JQS5 J04            C1X        2025:250:00000 2025:251:00000 ns         -0.491700000000000     0.171500
OSB  JQS5 J04            C2X        2025:250:00000 2025:251:00000 ns         -0.841800000000000     0.277200
OSB  JQS5 J04            C5X        2025:250:00000 2025:251:00000 ns         -2.469500000000000     0.198600
OSB  JQS5 J04            L1X        2025:250:00000 2025:251:00000 ns          0.541159295835122     0.840516
OSB  JQS5 J04            L2X        2025:250:00000 2025:251:00000 ns          0.891259295835122     0.983614
OSB  JQS3 J07            C1C        2025:250:00000 2025:251:00000 ns         -2.690900000000000     0.099600
OSB  JQS3 J07            C1X        2025:250:00000 2025:251:00000 ns         -3.001500000000000     0.113700
OSB  JQS3 J07            C2L        2025:250:00000 2025:251:00000 ns         -4.531500000000000     0.158500
OSB  JQS3 J07            C2X        2025:250:00000 2025:251:00000 ns         -4.843700000000000     0.185700
OSB  JQS3 J07            C5Q        2025:250:00000 2025:251:00000 ns         -3.642300000000000     0.125800
OSB  JQS3 J07            C5X        2025:250:00000 2025:251:00000 ns         -4.658600000000000     0.136700
```

Ambiguity fixing rates for QZSS

Station	Wide lane	Narrow lane
AIRA	100	100
GMSD	100	100
STK2	100	100

BDS satellites with PRN numbers higher than C46

- GFZ MGEX rapid and GRG MGEX final include code/phase OSBs for C47-C50 and C59
  - The narrow lane ambiguity fixing rates (C47-C50) are relatively low for GFZ products

```
OSB  C232 C50          C2I       2025:256:00000 2025:257:03600 ns          -60.4567       0.9033
OSB  C232 C50          C6I       2025:256:00000 2025:257:03600 ns          -91.5609       1.3680
OSB  C232 C50          L2I       2025:256:00000 2025:257:03600 ns           62.2092       0.9039
OSB  C232 C50          L6I       2025:256:00000 2025:257:03600 ns           94.2150       0.9039
OSB  C233 C48          C2I       2025:256:00000 2025:257:03600 ns            1.0319       0.9051
OSB  C233 C48          C6I       2025:256:00000 2025:257:03600 ns            1.5628       1.3707
OSB  C233 C48          L2I       2025:256:00000 2025:257:03600 ns            0.0013       0.9057
OSB  C233 C48          L6I       2025:256:00000 2025:257:03600 ns            0.0019       0.9057
OSB  C234 C47          C2I       2025:256:00000 2025:257:03600 ns            1.2072       0.9287
OSB  C234 C47          C6I       2025:256:00000 2025:257:03600 ns            1.8283       1.4065
OSB  C234 C47          L2I       2025:256:00000 2025:257:03600 ns           -0.9433       0.9293
OSB  C234 C47          L6I       2025:256:00000 2025:257:03600 ns           -1.4287       0.9293
OSB  C235 C49          C2I       2025:256:00000 2025:257:03600 ns            3.7774       0.9277
OSB  C235 C49          C6I       2025:256:00000 2025:257:03600 ns            5.7208       1.4050
OSB  C235 C49          L2I       2025:256:00000 2025:257:03600 ns           -2.0249       0.9283
OSB  C235 C49          L6I       2025:256:00000 2025:257:03600 ns           -3.0667       0.9283
```

Ambiguity fixing rates for C47-C50 (GFZ/GRG)

Station	Wide lane	Narrow lane
BRUX	100/98	66/100
TLSG	100/98	74/100
CEDU	91/100	59/100
KIRU	89/89	57/88

Overview of current IGS PPP-AR products (rapid)

- 5 ACs provide rapid code/phase bias products
- All of them provide GPS and Galileo products, while 4 of them also provide BDS products

ID	Products	Systems	Orbit	Clock	Attitude	Code bias	Phase bias
COD	COD0OPSRAP	GRE	300 s	30 s	30 s	GE (OSB)	GE (OSB)
GFZ	GFZ0MGXRAP	GREC	300 s	30 s	30 s	GEC (OSB)	GEC (OSB)
GRG	GRG0OPSRAP	GREC	300 s	30 s	30 s	GEC (OSB)	GEC (OSB)
HUS	HUS0MGXRAP	GREC	300 s	30 s	30 s	GEC (OSB)	GEC (OSB)
WUM	WUM0MGXRAP	GREC	300 s	30 s	30 s	GEC (OSB)	GEC (OSB)

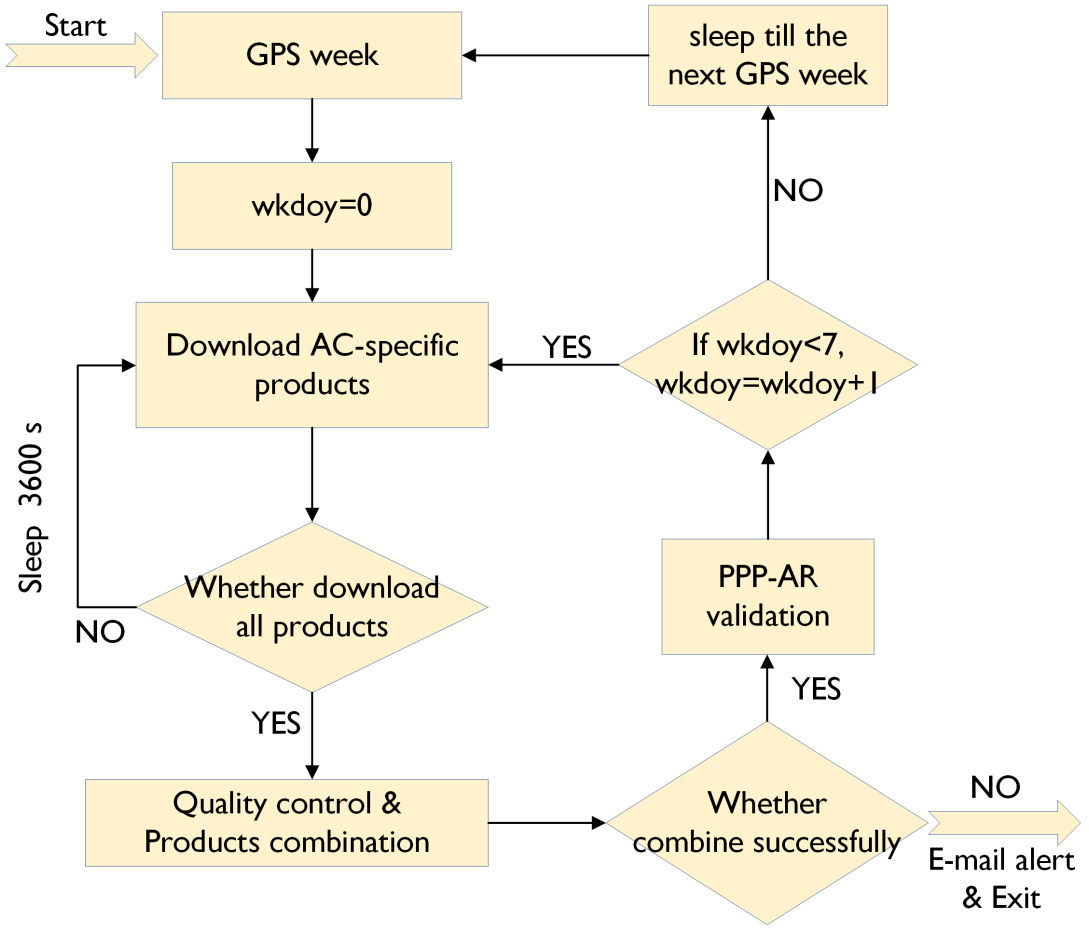
Overview of current IGS PPP-AR products (final)

- 5 ACs provide final code/phase bias products
- 4 of them provide GPS and Galileo products, while 3 of them provide BDS products, and 2 of them provide QZSS products

ID	Products	Systems	Orbit	Clock	Attitude	Code bias	Phase bias
COD	COD0OPSFIN	GRE	300 s	30 s	30 s	GE (OSB)	GE (OSB)
COD	COD0MGXFIN	GREJ	300 s	30 s	30 s	GEJ (OSB)	GEJ (OSB)
EMR	EMR0OPSFIN	G	300 s	30 s	30 s	G (OSB)	G (OSB)
GRG	GRG0OPSFIN	GRE	300 s	30 s	30 s	GE (OSB)	GE (OSB)
GRG	GRG0MGXFIN	GREC	300 s	30 s	30 s	GEC (OSB) C: B1C/B2a	GEC (OSB) C: B1C/B2a
HUS	HUS0MGXFIN	GREC	300 s	30 s	30 s	GEC (OSB)	GEC (OSB)
WUM	WUM0MGXFIN	GRECJ	300 s	30 s	30 s	GECJ (OSB)	GECJ (OSB)

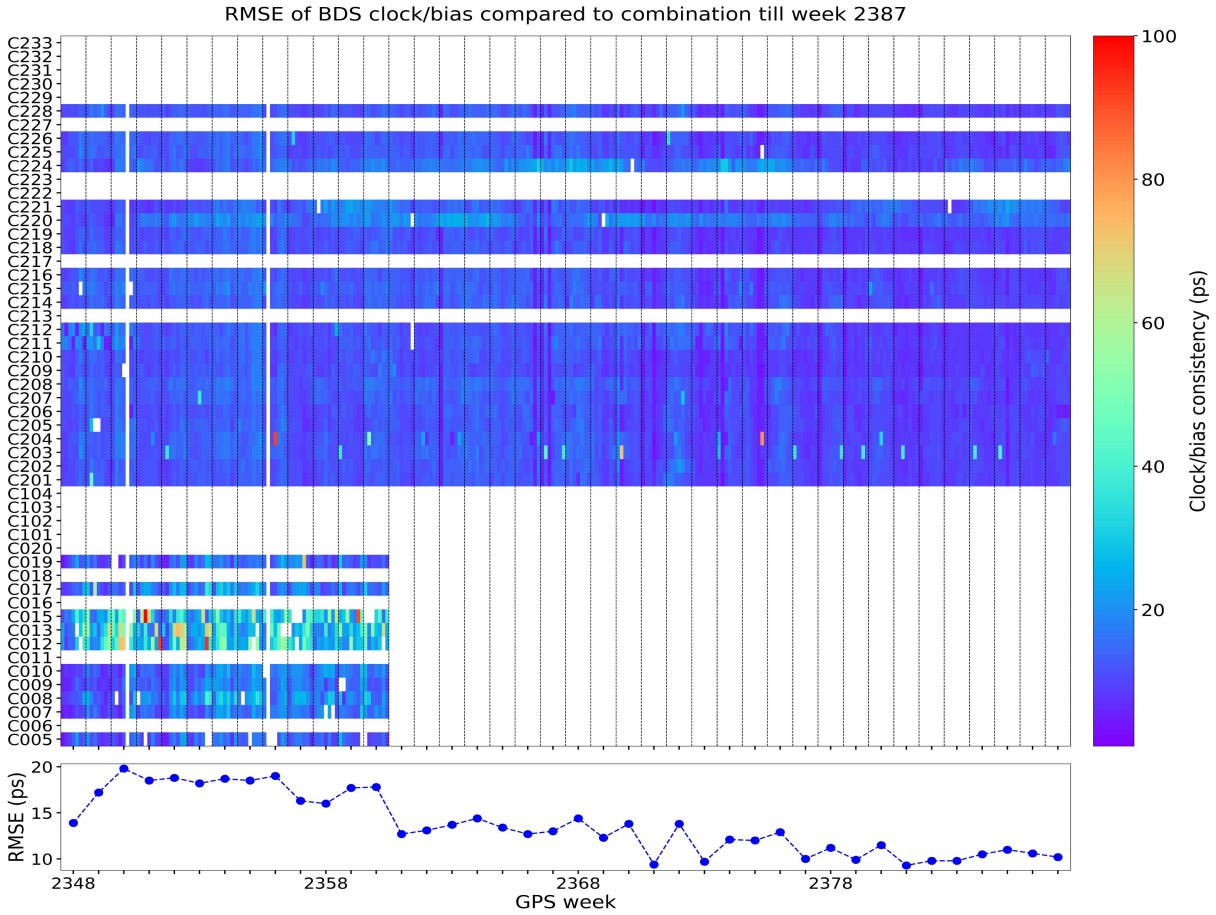
PPP-AR routine product combination

- 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



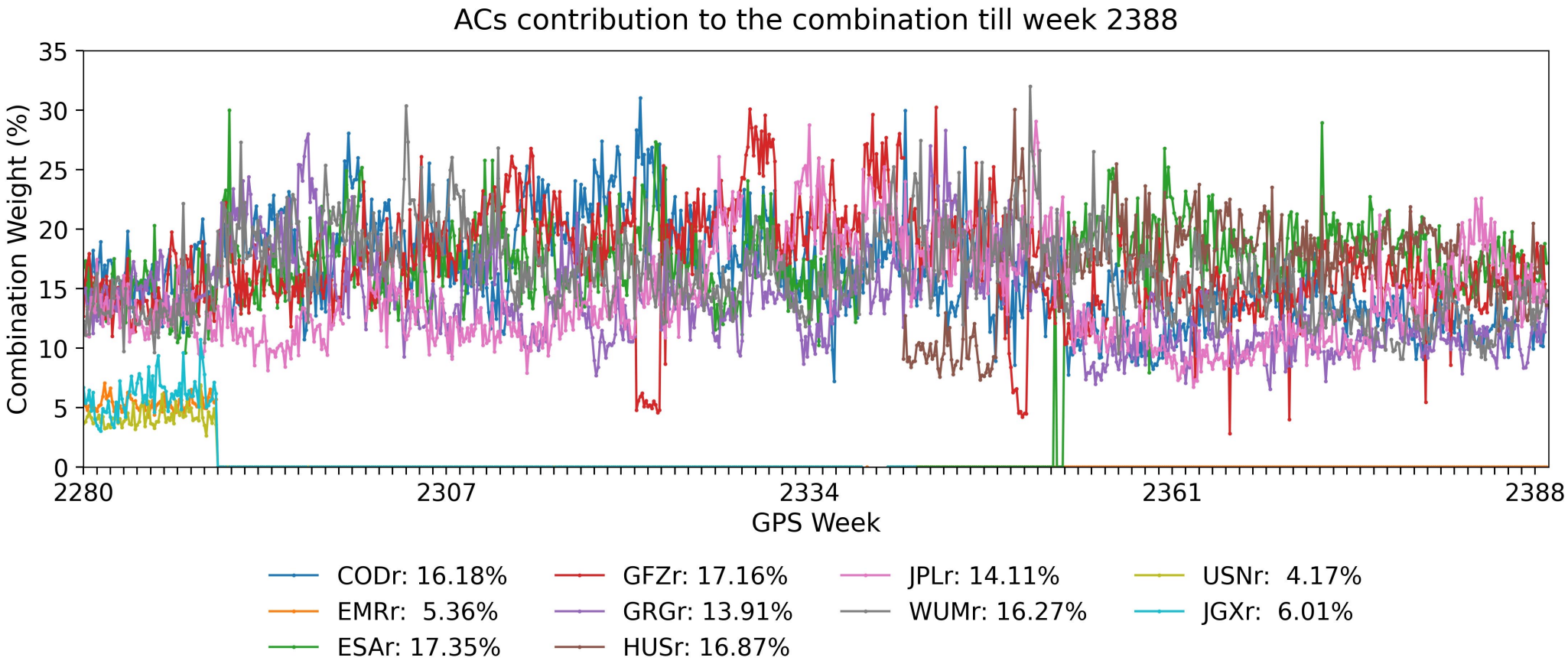
BDS-3 is included for the final combination

- BDS-2 is excluded after GPS week 2360 due to lack of ACs' products
- The combination consistency is about 12 ps



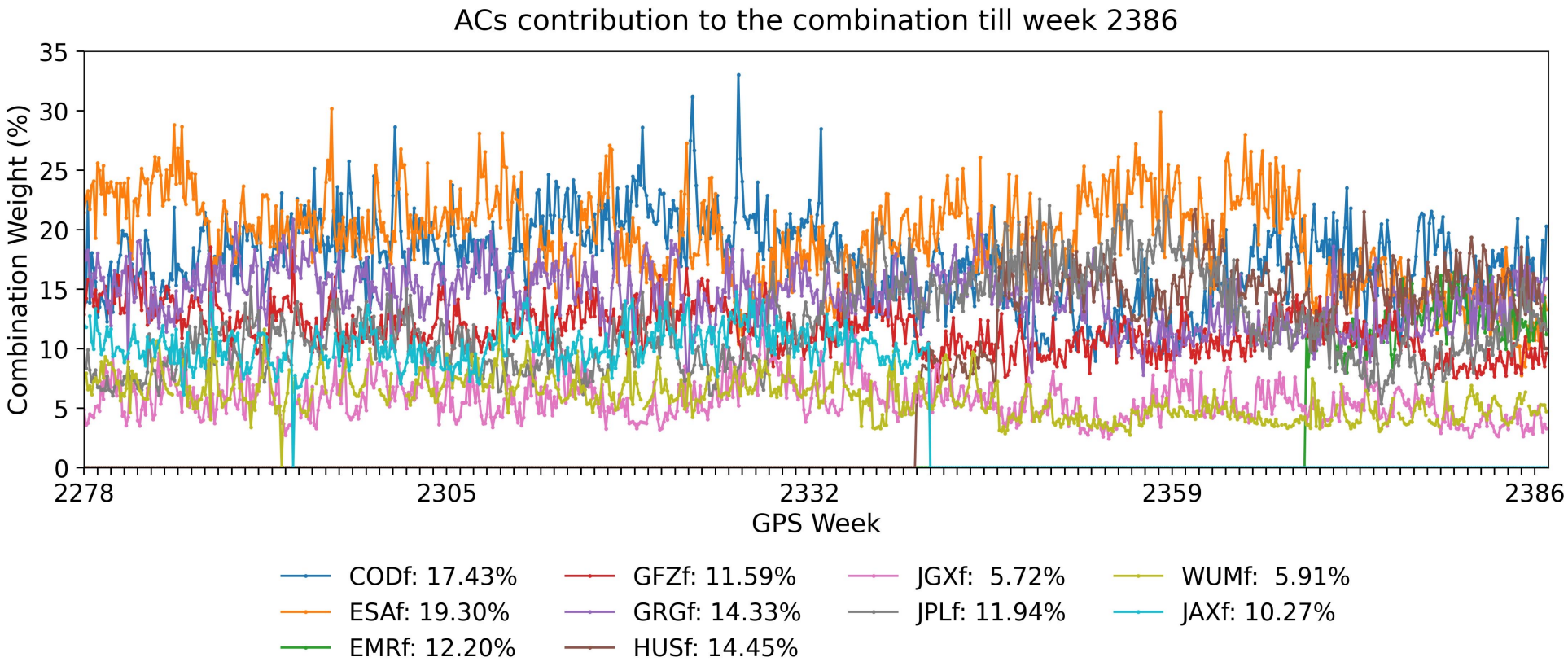
Routine product combination in PPP-AR PP

- ESA/GFZ/HUS/WUM/CODE rapid products contribute comparably to the combination
- USN/EMR/JGX rapid show worse consistency with other ACs' products



Routine product combination in PPP-AR PP

- ESA and CODE final products contribute the most to the combination
- JGX and WUM final still show worse consistency with other ACs' products



Static daily PPP-AR with combined products

- Daily position RMS (mm) for rapid and final solutions

Rapid

	GPS			GAL			BDS		
Products	**E**	**N**	**U**	**E**	**N**	**U**	**E**	**N**	**U**
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
HUSr	2.3	1.8	6.0	2.4	2.4	7.5	3.0	3.1	7.5
WUMr	2.0	1.7	5.9	2.3	2.3	7.6	3.1	3.1	7.6

Final

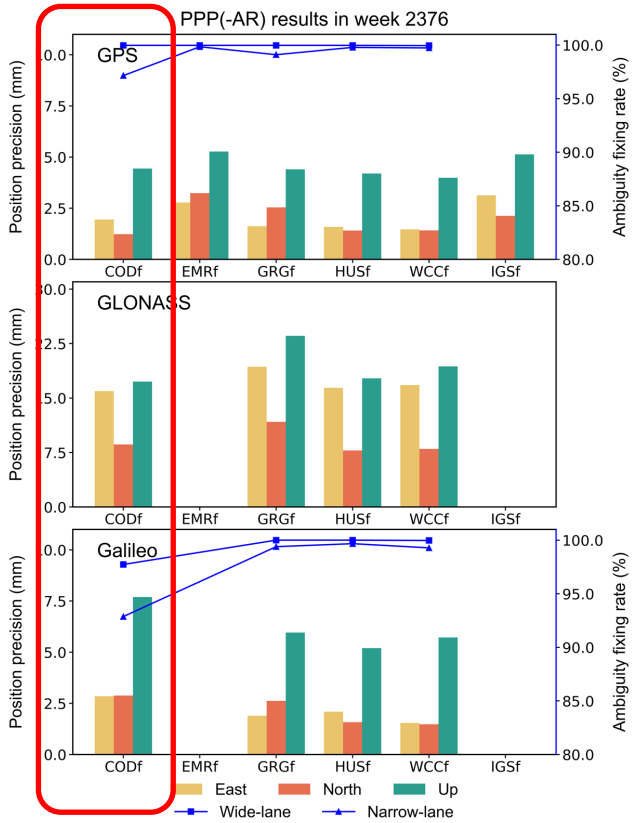
	GPS			GAL			BDS		
Products	**E**	**N**	**U**	**E**	**N**	**U**	**E**	**N**	**U**
CMBf	2.1	1.6	4.1	2.1	1.8	6.8	2.8	2.5	7.8
CODf	2.2	1.8	4.2	2.4	1.9	6.6	N/A	N/A	N/A
GRGf	2.5	1.6	4.6	2.1	2.7	6.8	2.3	2.2	7.7
HUSf	2.2	1.6	4.0	2.1	1.9	6.6	2.4	2.5	8.3
WUMf	2.4	2.0	4.7	2.8	2.5	7.0	4.7	4.6	9.6

IGS INTERNATIONAL GNSS SERVICE

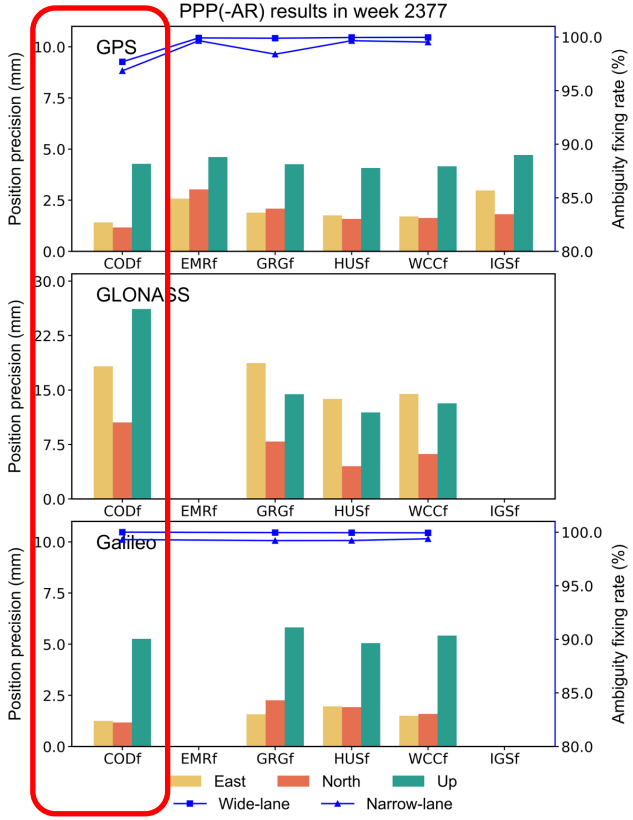
ANTEX indicator in CODE's products

- Only list "IGS20" is prone to cause inaccurate positioning issues
  - Specifying the exact ANTEX file is recommended (e.g. IGS20_2375)

```
+BIAS/DESCRIPTION
*KEYWORD                                  VALUE(S)
 OBSERVATION_SAMPLING                          300
 PARAMETER_SPACING                           86400
 DETERMINATION_METHOD                    CLOCK_ANALYSIS
 BIAS_MODE                               ABSOLUTE
 APC_MODEL                               IGS20
 TIME_SYSTEM                             G
 RECEIVER_CLOCK_REFERENCE_GNSS           G
 SATELLITE_CLOCK_REFERENCE_OBSERVABLES   G  C1W  C2W
 SATELLITE_CLOCK_REFERENCE_OBSERVABLES   R
 SATELLITE_CLOCK_REFERENCE_OBSERVABLES   E  C1C  C5Q
*SATELLITE_ANTENNA_PCC_APPLIED_TO_MW_LC  YES
-BIAS/DESCRIPTION
```



Positioning with IGS20.atx



Positioning with IGS20_2356.atx

Summary

- Several ACs have made updates to their PPP-AR products since last year (e.g., EMRf, WUMf, GRGf)
- The PPP-AR product combination has been routinely operated for two years, and BDS-3 has been included in the final combined products
- Encourage more ACs to produce GPS/Galileo/BDS code/bias products