Poster-
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Multi-GNSS precise orbit determination with zero-differenced ambiguity resolution

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Introduction

In this contribution, a zero-differenced (ZD) ambiguity resolution (AR) approach for **GPS+Galileo+BDS+GLONASS** combined POD is developed based on a multi-GNSS UPD estimation strategy. The concept of "**carrier range**" is achieved by calibrating both ZD integer ambiguity and ZD UPDs from origin carrier phase observation, and is applied to GECR-combined POD. The validation experiments of over 140 MGEX stations show that ZD AR can obtain better orbit accuracy and less processing time than traditional DD AR.

Principles and algorithms

In zero-differenced (ZD) ambiguity resolution (AR) processing, the ionospheric free (IF) combination ambiguity B_{IF} is usually expressed by wide-lane (WL) and narrow-lane (NL) ambiguities and their UPDs (the WL UPDs are absorbed into NL UPDs) as follows,

$$B_{IF}=\frac{f_i}{f_i+f_j}\cdot\left(N_n+\delta b_{nr}+\delta b_n^s+\frac{f_j}{f_i-f_j}\cdot N_w\right)$$

After resolving the integer WL and NL ambiguities and their UPDs, the ambiguities for L_i and L_j can be expressed as,

$$N_i=N_n;\ N_j=N_i-N_w$$
$$B_i=N_i+\delta b_{nr}+\delta b_n^s;B_j=B_i-N_w$$

Substituting the L_i and L_j with L_i-B_i and L_j-B_j, the new IF observation equation for carrier phase can be rewritten as,

$$\begin{aligned}L'_{IF}&=\frac{f_i^2}{f_i^2-f_j^2}\cdot L'_i-\frac{f_j^2}{f_i^2-f_j^2}\cdot L'_j\\&=\frac{f_i^2}{f_i^2-f_j^2}\cdot(L_i-\lambda_iB_i)-\frac{f_j^2}{f_i^2-f_j^2}\cdot\left(L_j-\lambda_jB_j\right)\\&=\rho_{r\ g}^s+c\left(t_{r,IF}-t_{IF}^s\right)+T_r^s+\varepsilon_{r,IF}^s\end{aligned}$$

Where L'_{IF} refers to the IF carrier-range observation, L'_i and L'_j are the carrier-range observations for L_i and L_j. With ambiguities and UPDs eliminated prior, the ZD AR can be achieved efficiently using the carrier-range observations.

Advantages

- ✓ Only around 23% ZD ambiguities are involved in DD AR for multi-GNSS POD. But over 90% ZD ambiguities for GPS, Galileo, BDS and over 75% for GLONASS are fixed using the new ZD AR. Consequently, higher orbit precision can be obtained.
- ✓ With the carrier-range observations, no more ambiguity or UPD parameters need to be estimated. Thus the processing time can reduce significantly, especially for massive networks.

Challenges and solutions

☐ ISBs/IFBs in multi-GNSS data processing	✓ Estimate or fix with prior values
☐ Satellite-induced code biases for BDS-2	✓ Alleviate the effect with a wavelet filter
☐ GLONASS ambiguity fixing	✓ Divide the network into several subnetworks of homogeneous receivers and perform the UPD estimation respectively
☐ Validation of ambiguity fixing	✓ Before apply the carrier range to POD, the PPP for each station is performed with the carrier range. Then we can detect the wrong-fixing ambiguities through post-fit residuals of PPP

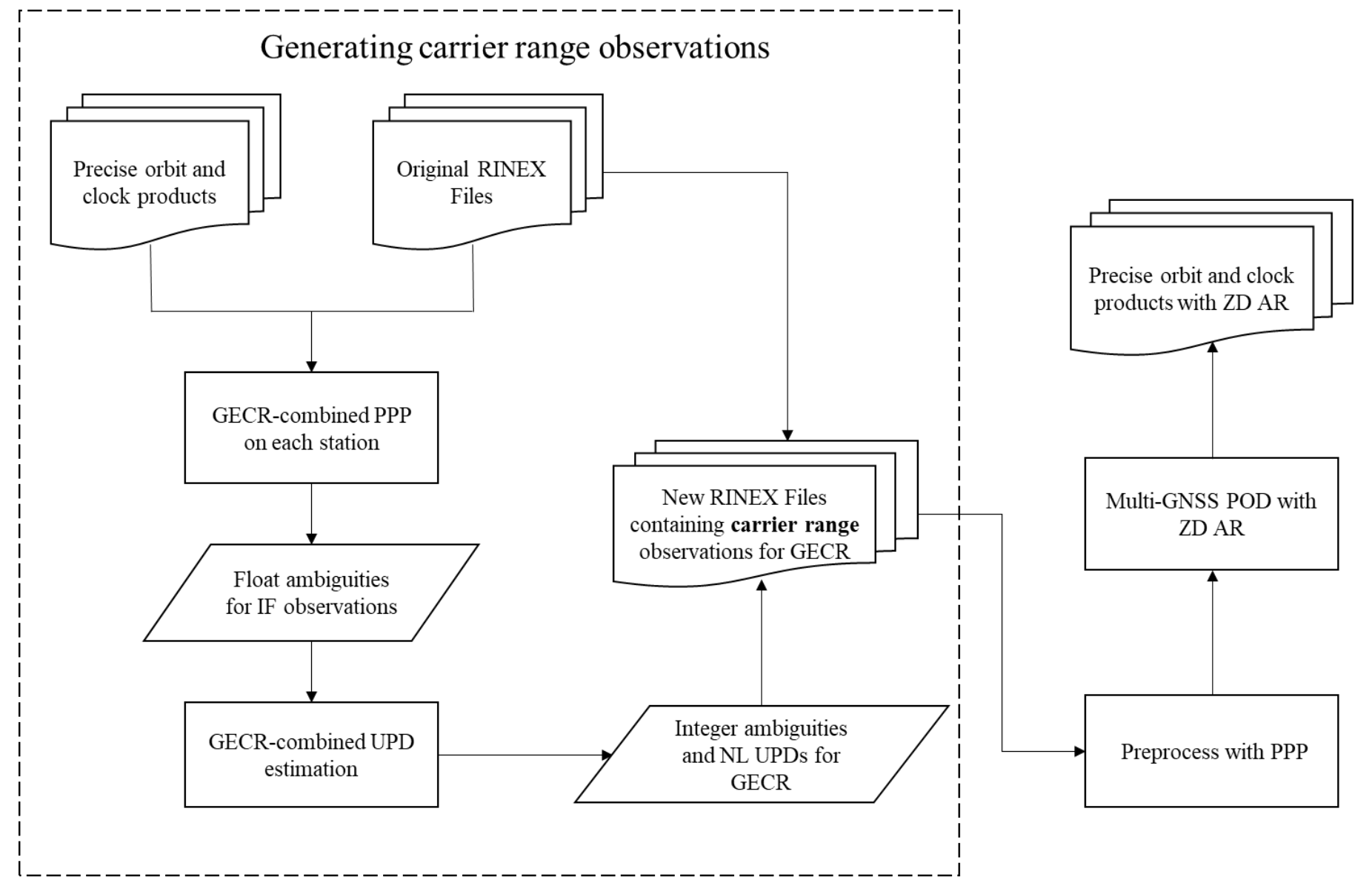

Fig.1 Processing procedure of the new strategy

Validation Experiments

Multi-GNSS datasets from 143 MGEX and IGS stations all over the world during DOY 040-165 in 2017 are processed with three different strategies: POD without AR, POD with DD AR and POD with ZD AR. To achieve higher accuracy in POD, the latest solar radiation pressure (SRP) model **ECOM2** (nine parameters) is applied in this study instead of ECOM (five parameters).

UPD performance

The NL ambiguity fixing rate for GPS, Galileo, BDS and GLONASS are 95.2%, 94.4%, 92.1% and 75.5%

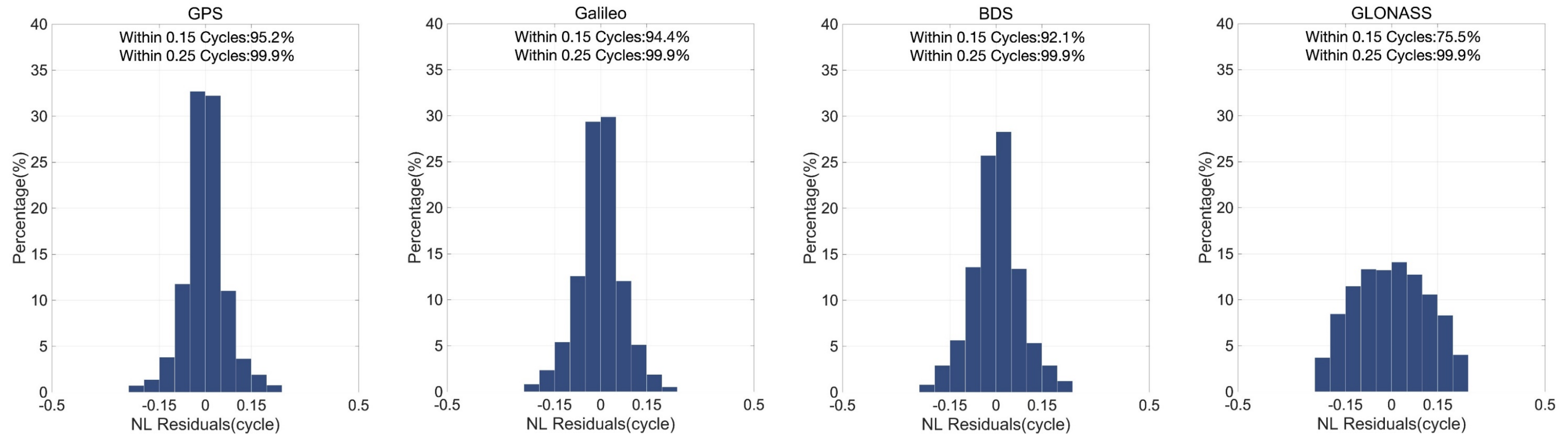

Fig.2 Distribution of the estimated WL (*upper*) and NL (*lower*) UPD fractional parts for GPS, Galileo, BDS and GLONASS (from left to right) in DOY116, 2017.

POD performance

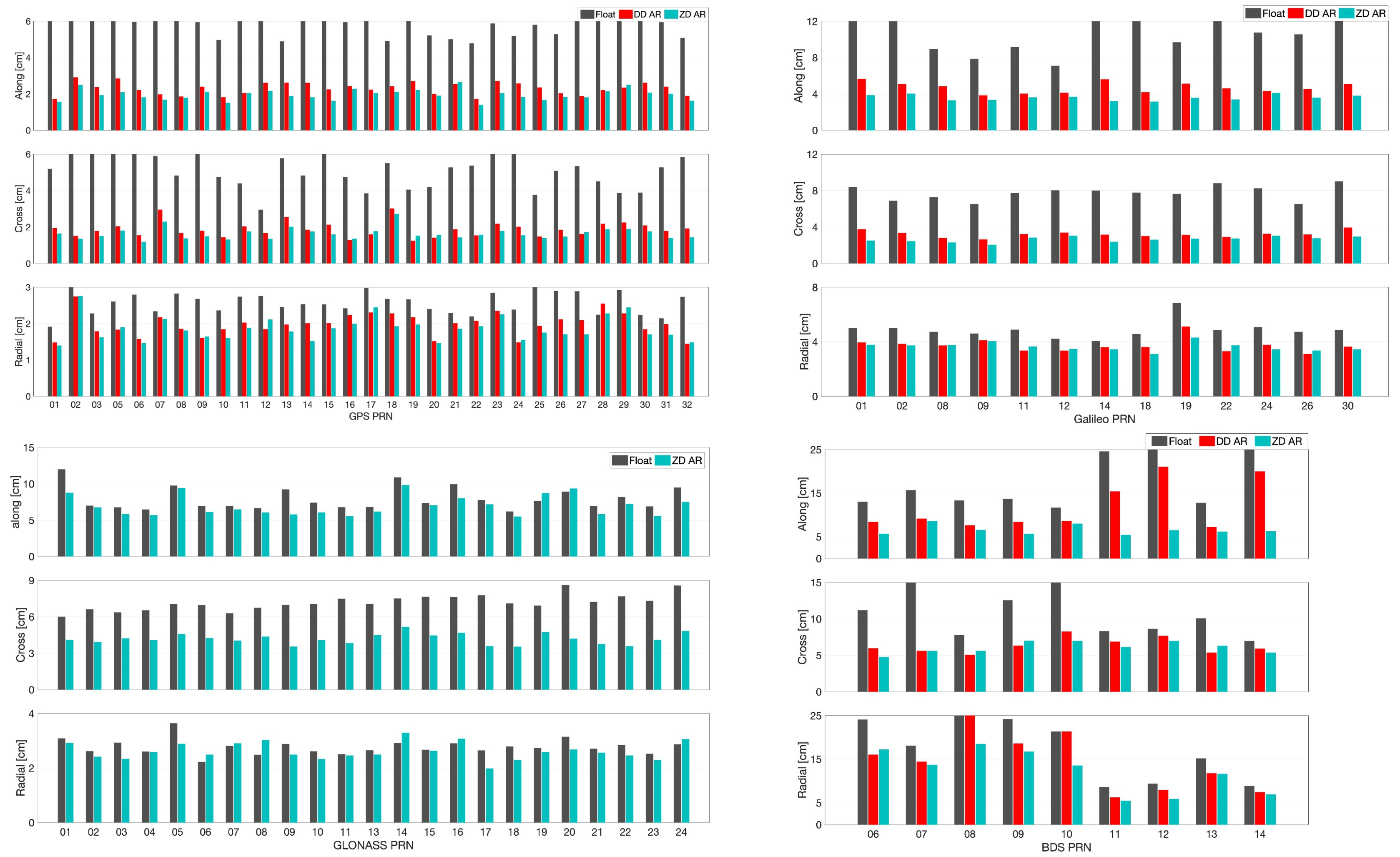

Fig.3 Day boundary RMS values for GPS (*upper left*), GLONASS (*lower left*), Galileo (*upper right*) and BDS (*lower right*) using float strategy (*grey*), DD AR (*red*) and ZD AR (*cyan*). The DD AR is not performed for GLONASS satellites.

PRN	Float		DD AR		ZD AR	
	Mean Bias	STD	Mean Bias	STD	Mean Bias	STD
E01	1.5	3.5	1.2	3.0	1.3	2.9
E02	1.9	2.9	1.5	2.5	1.3	2.4
E08	1.0	5.8	0.9	4.6	0.4	4.5
E09	0.7	4.7	0.8	4.1	0.7	4.1
E11	0.6	4.2	-0.3	3.5	-0.3	3.6
E12	0.8	4.0	-0.3	3.6	-0.4	3.5
E14	0.6	4.4	1.1	4.2	1.3	4.3
E18	0.2	4.2	0.5	4.0	0.6	4.3
E19	0.9	5.0	0.0	4.4	-0.3	4.6
E22	0.7	5.0	1.0	4.3	0.9	4.5
E24	1.2	3.5	0.8	3.1	0.7	3.0
E26	1.4	4.2	1.2	3.6	1.0	3.8
E30	1.6	3.7	1.2	3.2	0.8	2.8
Mean	**1.0**	**4.3**	**0.7**	**3.7**	**0.6**	**3.7**
C08	-2.4	11.6	-4.2	10.4	-3.8	8.7
C10	-2.8	7.6	-0.7	7.2	0.6	7.4
C11	5.8	6.0	4.3	5.7	2.4	5.9
Mean	**0.2**	**8.4**	**-0.2**	**7.7**	**-0.2**	**7.3**

Tab.1 SLR validation results using different ambiguity resolutions (unit: cm)

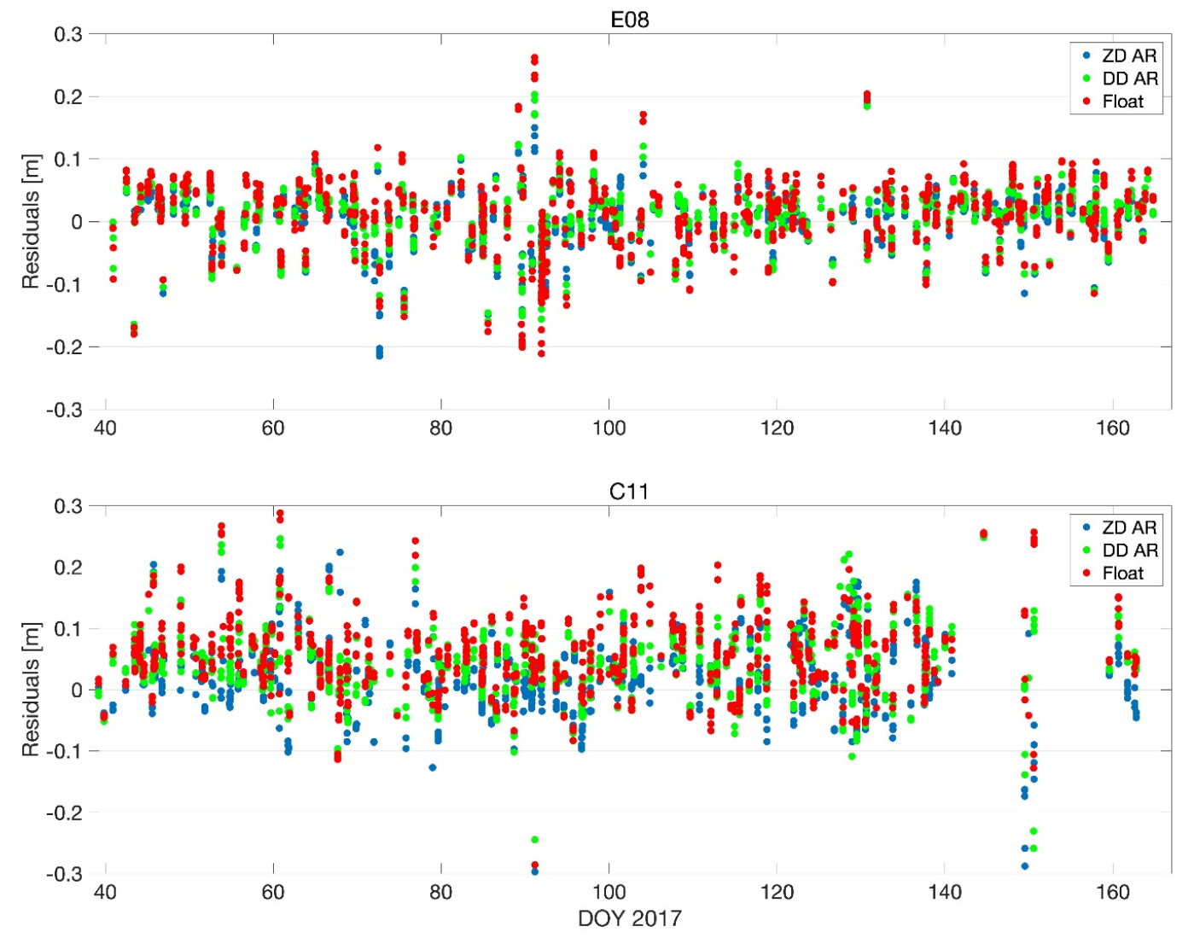

Fig.4 SLR validation results for E08 and C11 using different ambiguity resolutions

Discussion

The day boundary RMS values for GPS, Galileo and BDS satellites with ZD AR are evidently smaller than those of DD AR in along, cross and radial components, **especially for Galileo, BDS IGSO and BDS MEO satellites**, the 3-D RMS improvements of which can reach 15.5%, 15.0% and 50.3%. Moreover, the ZD AR can also improve the GLONASS orbit accuracy mainly in cross-track compared with that of float strategy. In addition, the SLR residuals of Galileo and BDS satellites show slightly better mean biases and STD values in comparison with those of DD AR. With more and more BDS-3 and Galileo satellites launched, the accuracy of multi-GNSS POD with ZD AR is expected to be further improved.

References

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