

# Rapid PPP ambiguity resolution in case of triple-frequency multi-GNSS data

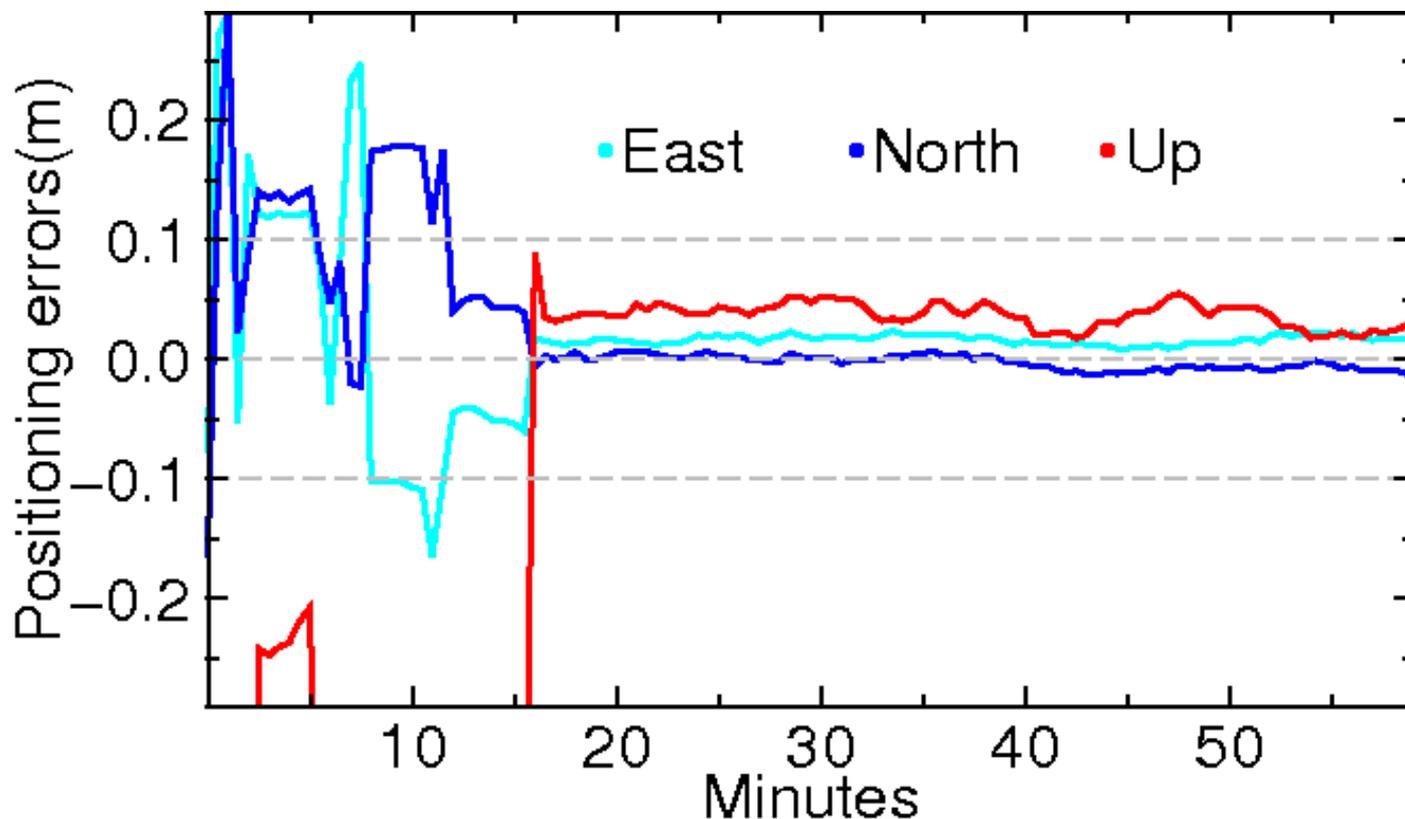
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IGS Workshop 2018  
29 October to 2 November  
Wuhan, China

# Background

- PPP-AR has been suffering from slow convergence
  - Poor precision of pseudorange
  - Slowly-varying satellite geometry



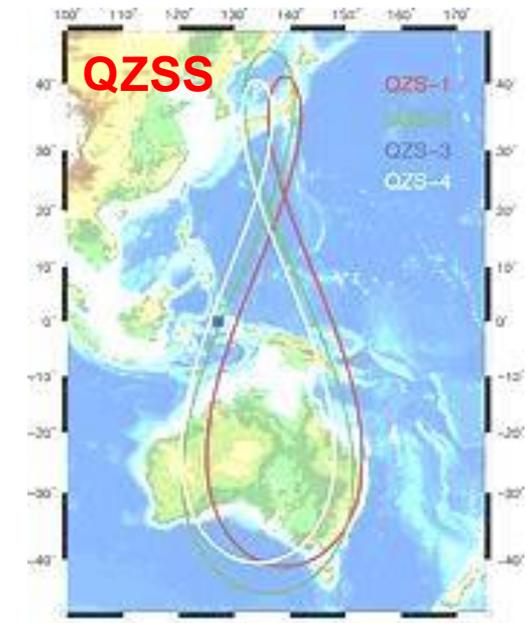
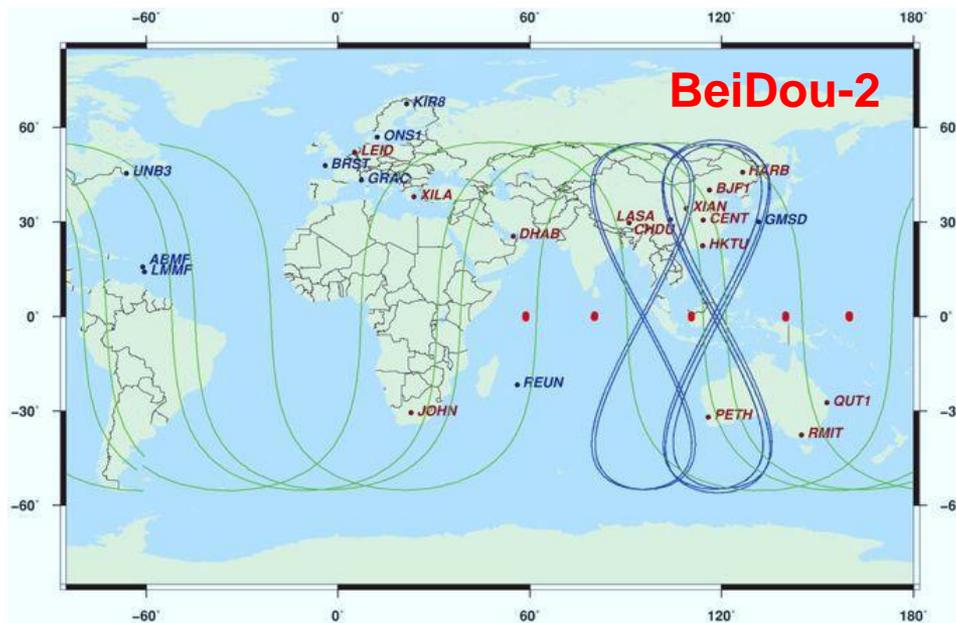
# Background

- Triple-frequency PPP-AR poses new opportunities
  - Geng and Bock (2013) - “Cascading PPP-AR method”
  - Gu (2015) – “Triple-frequency PPP-AR based on raw observations”

Constellation	Wavelength (m)	
	Extra-wide-lane (0,1,-1)	Wide-lane (1,-1,0)
GPS	5.86	0.86
BeiDou	4.88	0.84
Galileo	9.77	0.75
QZSS	5.86	0.86

# Status of multi-frequency satellites

Constellation	Type	Signal	Number
GPS	BLOCK-IIF	L1/L2/L5	12
BeiDou	BeiDou-2	B1I/B2I/B3I	14
Galileo	Galileo	E1/E5a/E5b/E6	22
QZSS	QZSS	L1/L2/L5/L6	4



# PPP-WAR&PPP-AR

- Target ambiguities

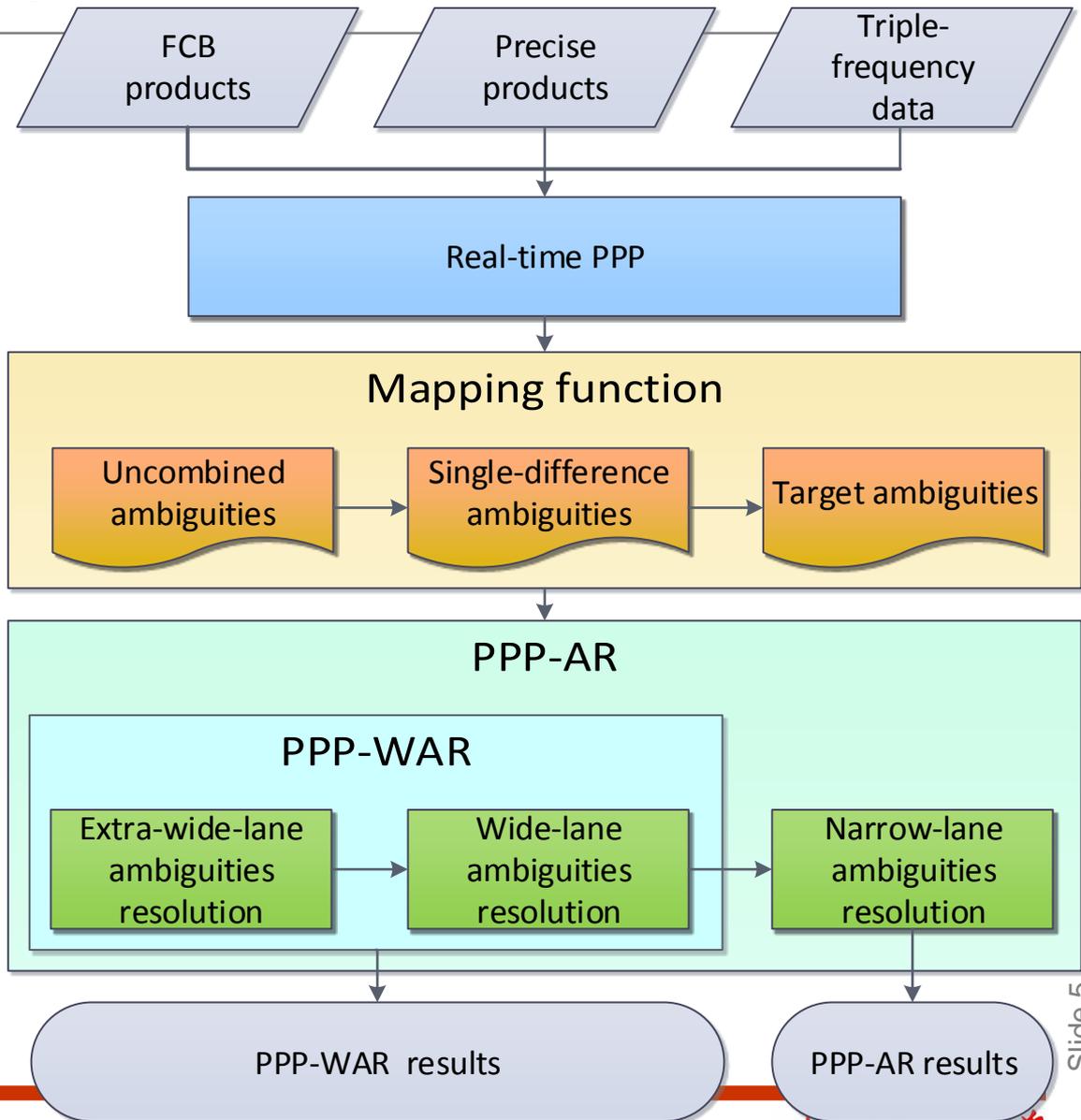
- Extra-wide-lane ...
- Wide-lane ...
- Narrow-lane ...

- PPP-AR

- Solve both wide-lane and narrow-lane ambiguities

- PPP-WAR

- Solve two wide-lane ambiguities only



Slide 5

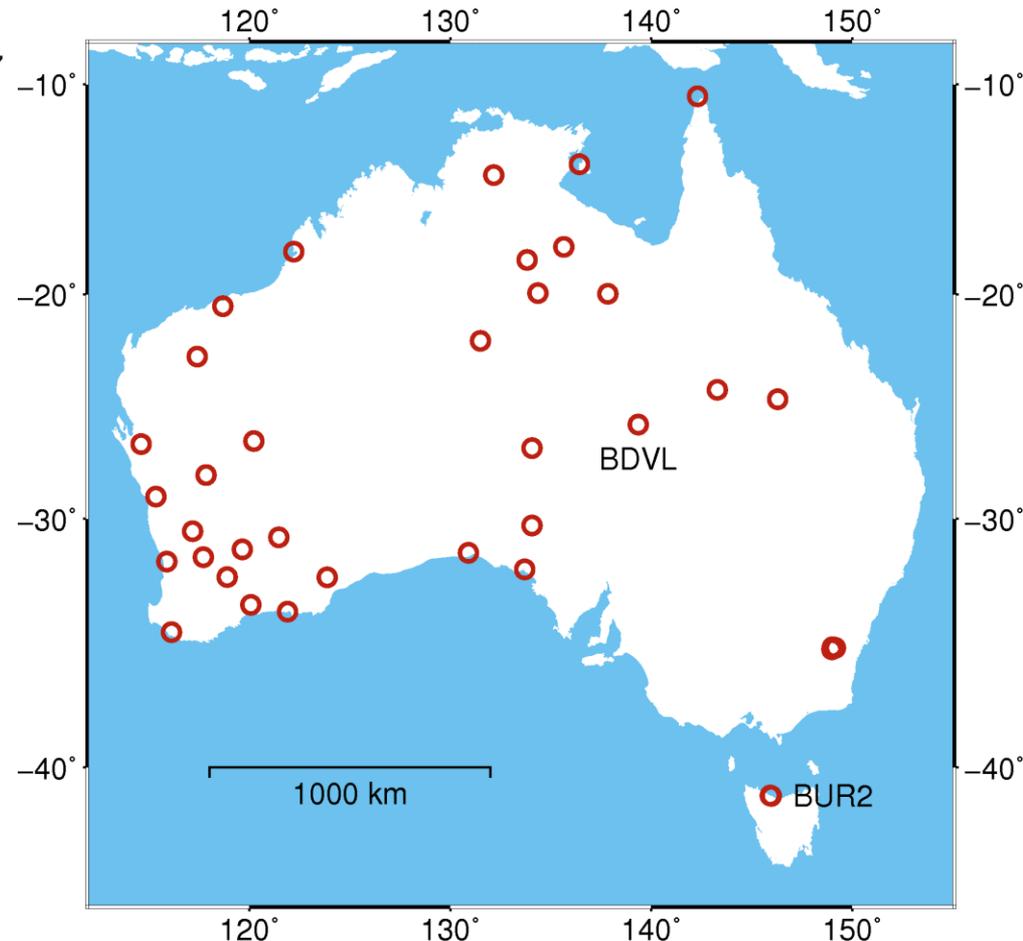
# Positioning experiment

- Data & products

- 31 days from 335-365, 2017
- 35 stations for PPP-AR
- Predicted orbit from GFZ

- Experiment

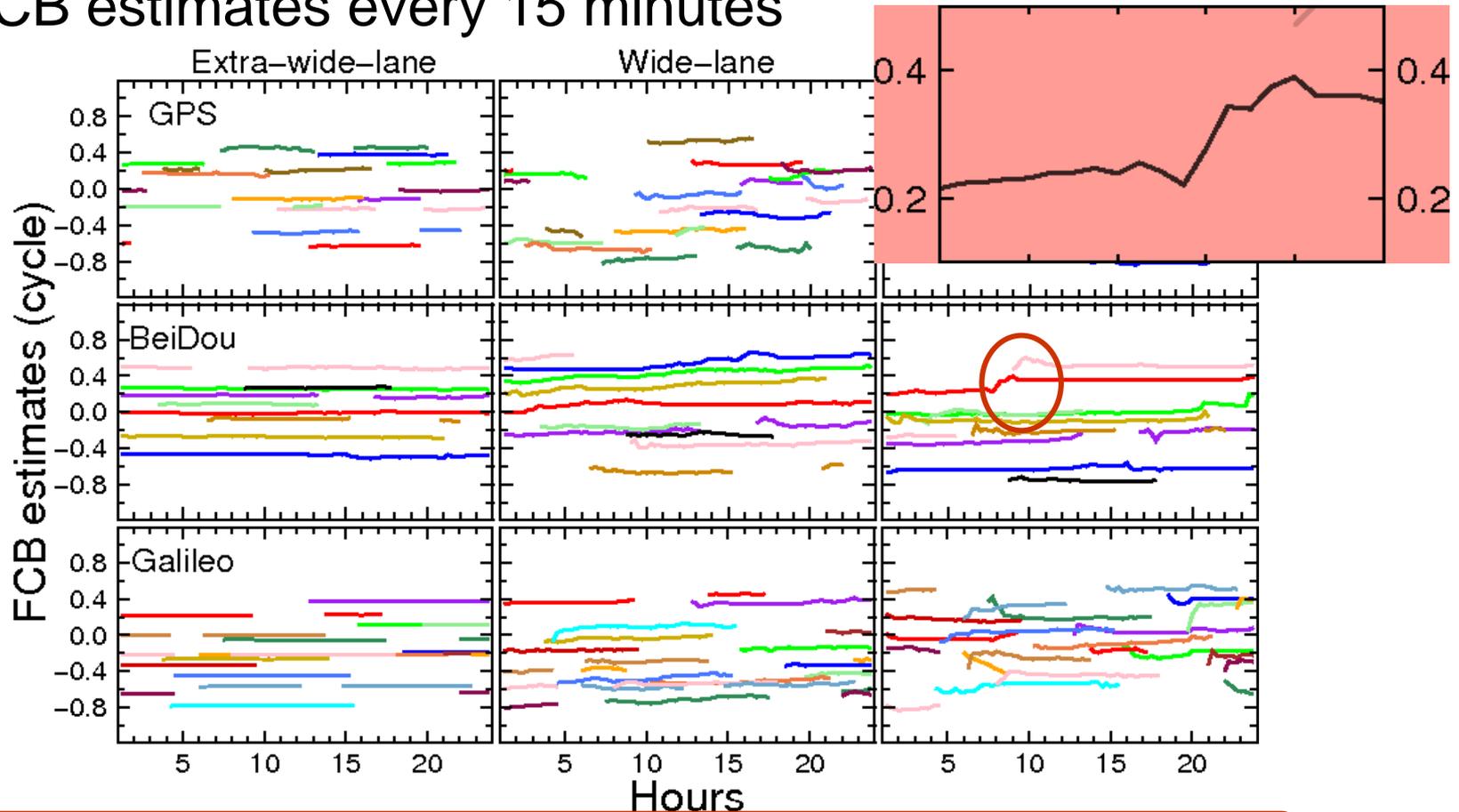
- PPP-WAR
  - Triple-frequency float PPP
- Triple-frequency PPP-AR
- Dual-frequency PPP-AR



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# Stability of satellite FCBs

- FCB estimates every 15 minutes

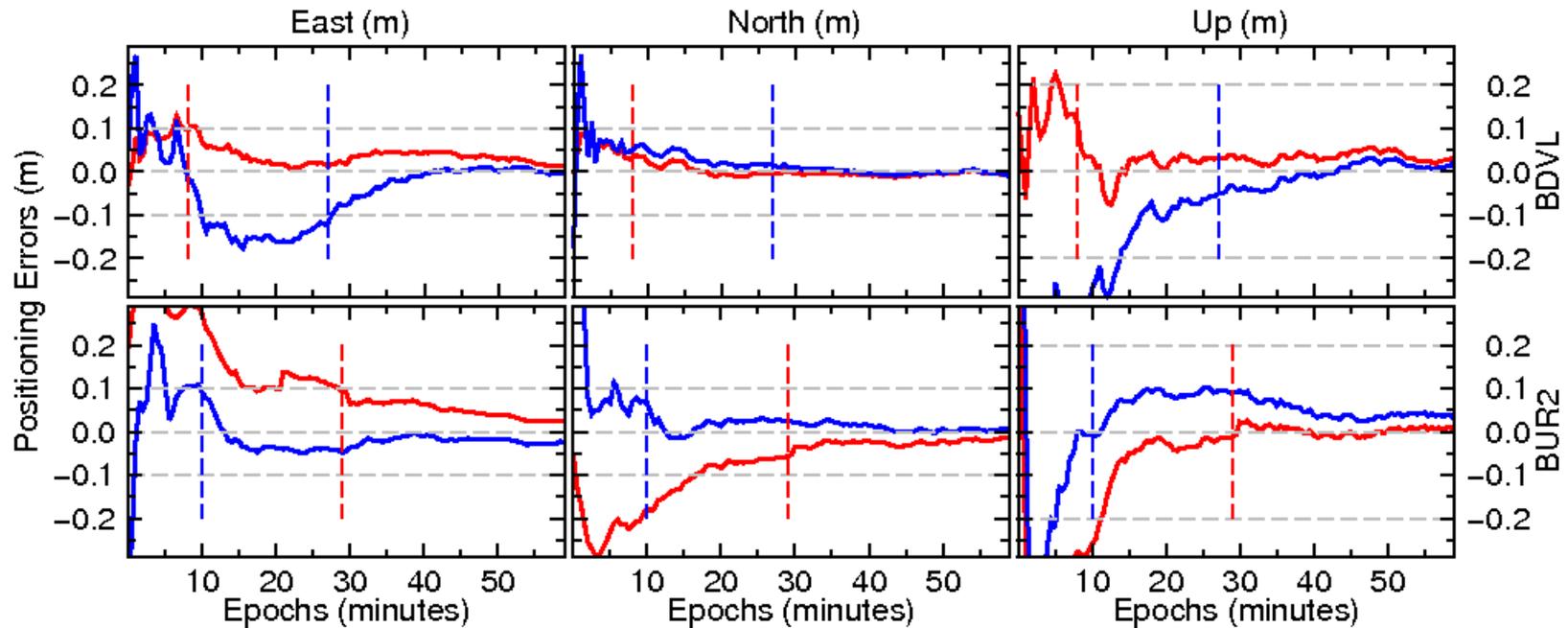


Wide-lane and narrow-lane FCBs should be predicted with cautions

# PPP wide-lane ambiguity resolution(PPP-WAR)

- Hourly solutions of PPP-WAR

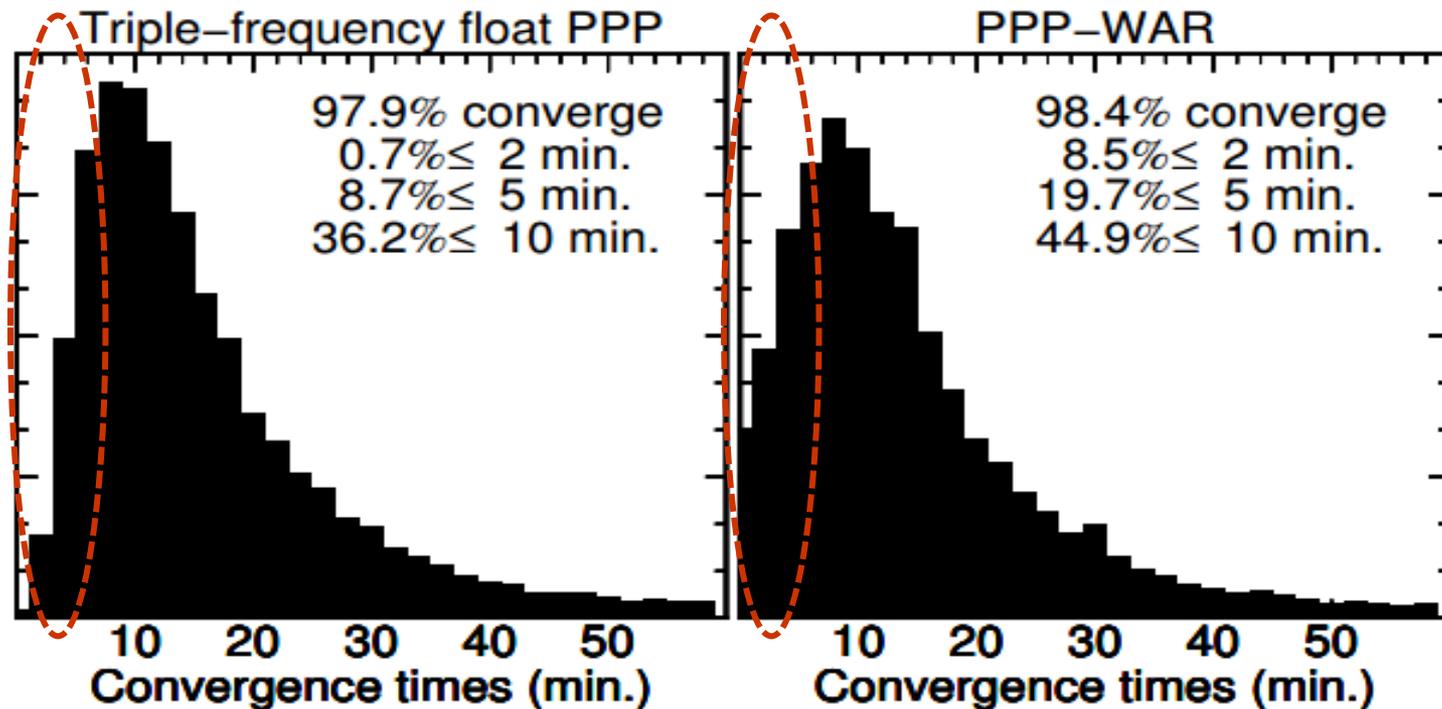
- PPP-WAR
- Triple-frequency float PPP



24.6% of PPP-WAR solutions suffered from deterioration

# PPP wide-lane ambiguity resolution(PPP-WAR)

- Convergence time distribution



20% PPP-WAR converged within 5 minutes while 9% for float PPP

# PPP wide-lane ambiguity resolution(PPP-WAR)

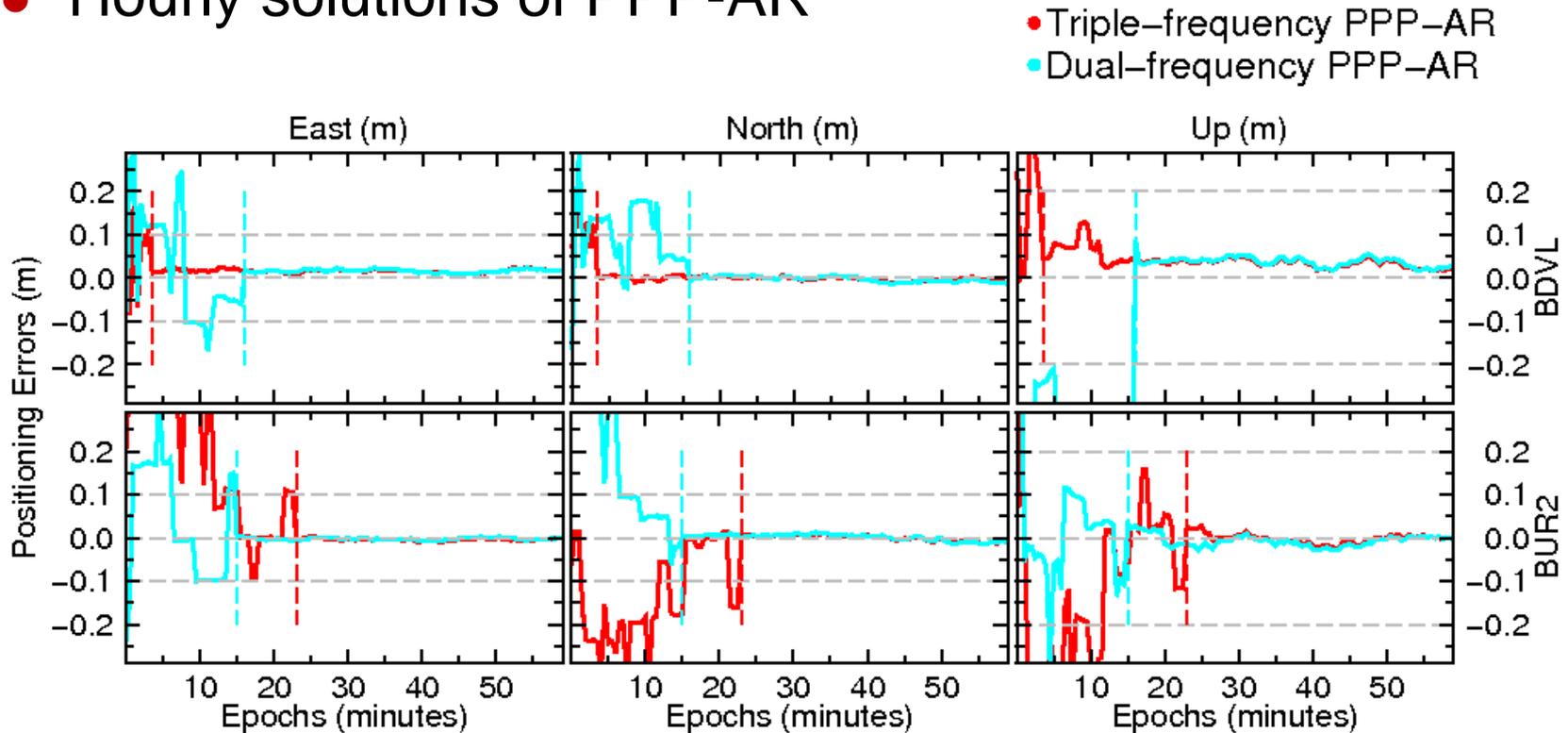
- Mean RMS of positioning errors in the first 10 min.

Satellite number	Triple-freq. float (m)	PPP-WAR (m)
10-11	0.30/0.20/0.50	0.14/0.10/0.30
12-13	0.26/0.20/0.48	0.13/0.10/0.27
14-15	0.24/0.19/0.43	0.12/0.09/0.26
16-17	0.22/0.17/0.40	0.11/0.08/0.25
18-19	0.21/0.15/0.40	0.10/0.07/0.25
20-21	0.21/0.14/0.40	0.10/0.06/0.24
<b>Mean</b>	<b>0.23/0.18/0.43</b>	<b>0.12/0.08/0.27</b>

PPP-WAR reduces the positioning errors on average by nearly 50%

# Triple-frequency PPP-AR

- Hourly solutions of PPP-AR



12% triple-frequency AR converged slower than dual-frequency counterparts

# Triple-frequency PPP-AR

- Convergence time counted by satellite number

Satellite number	Dual-freq. PPP-AR(min)	Triple-freq. PPP-AR(min)	Reduction
10-11	17.9	14.4	19.6%
12-13	13.6	10.2	25.0%
14-15	10.0	7.2	28.0%
16-17	7.5	5.0	33.3%
18-19	6.4	3.5	45.3%
20-21	5.2	2.7	48.1%
<b>Mean</b>	<b>9.2</b>	<b>6.1</b>	<b>33.7%</b>

Convergence time of triple-frequency PPP-AR is shorten when involving more satellites

# Conclusions

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- FCBs every 15 minutes were quite stable over time
  - The STDs of extra-wide-lane, wide-lane and narrow-lane are less than 0.005, 0.025 and 0.03 cycles respectively
- The resolution of both wide-lane ambiguities can accelerate PPP convergence in the most time
  - 24.5% of hourly solutions suffer from deteriorations
- Triple-frequency PPP-AR converge faster comparing to dual-frequency PPP-AR
  - The mean initialization period was 6.1 and 9.2 minutes for triple-frequency and dual-frequency PPP-AR, respectively
  - The mean initialization period of triple-frequency PPP-AR became clearly shorter when involving more satellites



Thank you for your attention!

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