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BeiDou and Galileo Carrier-Phase Time Transfer toward TAI Computation

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Outline

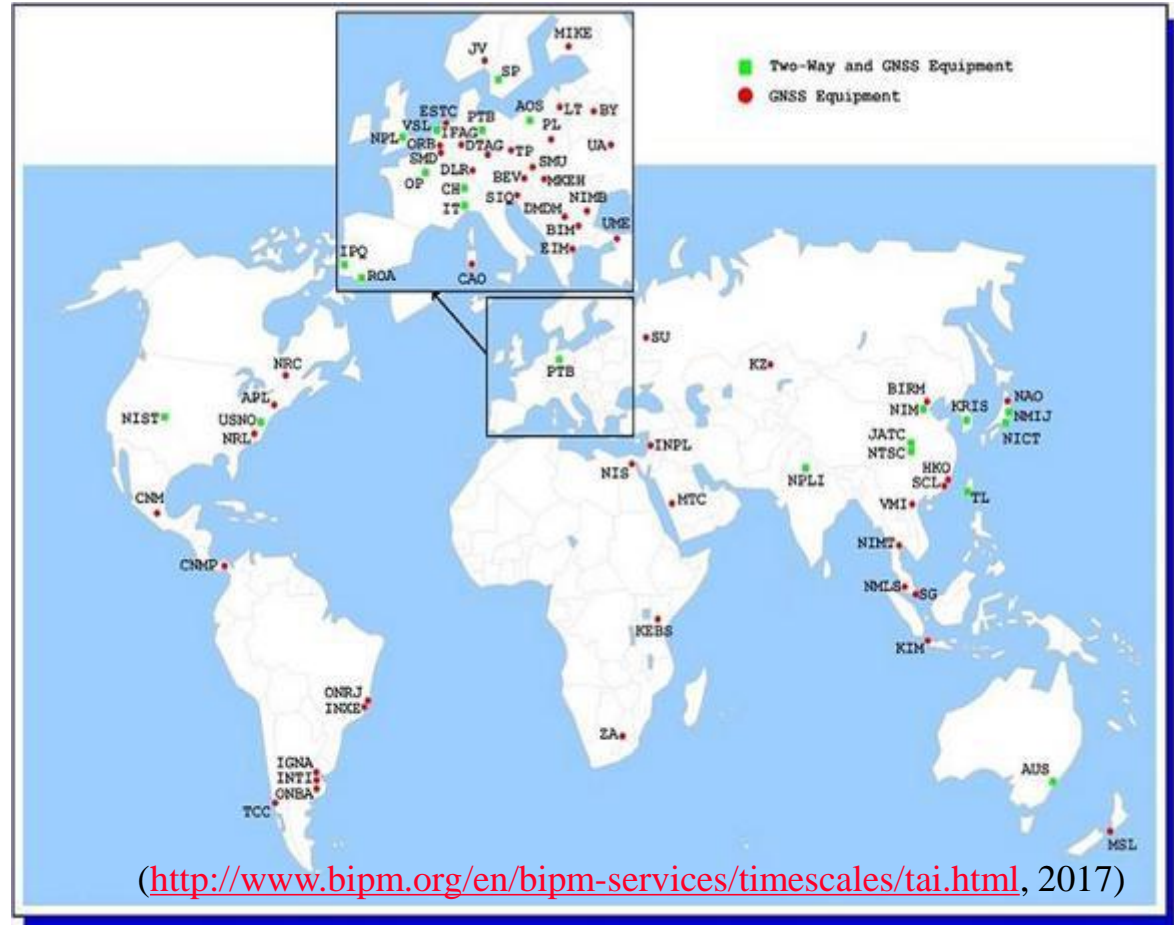
- Motivation
- Software and strategy comparison
- Time transfer based on regional BDS
- Time transfer based on initial serviced Galileo
- Summary and outlook

● Evolution of GNSS based TAI time transfer

- 1981, GPS CV
- 2009, GPS PPP
- 2010, GLONASS CV

Time links used in TAI computation from Circular T Jan 2017

	# of links
GPS PPP	28
GPS P3(AV)	14
GPS MC(AV)	18
TWGPPP	10
TWSTFT	2
Total	72





Motivation

- BDS regional constellation

- Start service since Dec. 2012
- Coverage Asian-Pacific area
 - Time transfer: BDS PPP vs GPS PPP, <0.2 ns
- How is the performance of PPP TAI time transfer based on regional BDS?

- GALILEO

- Initial Service since Dec 15, 2016
 - How is the performance of PPP TAI time transfer based on initial serviced GALILEO?
-



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Software and Strategy comparison

● BIPM TAIPPP

- Standard data analysis for TAI computation
- NRCan PPP software
- Arc length: 35 days(40 days since May 2017)
- Orbit and clock products: IGR

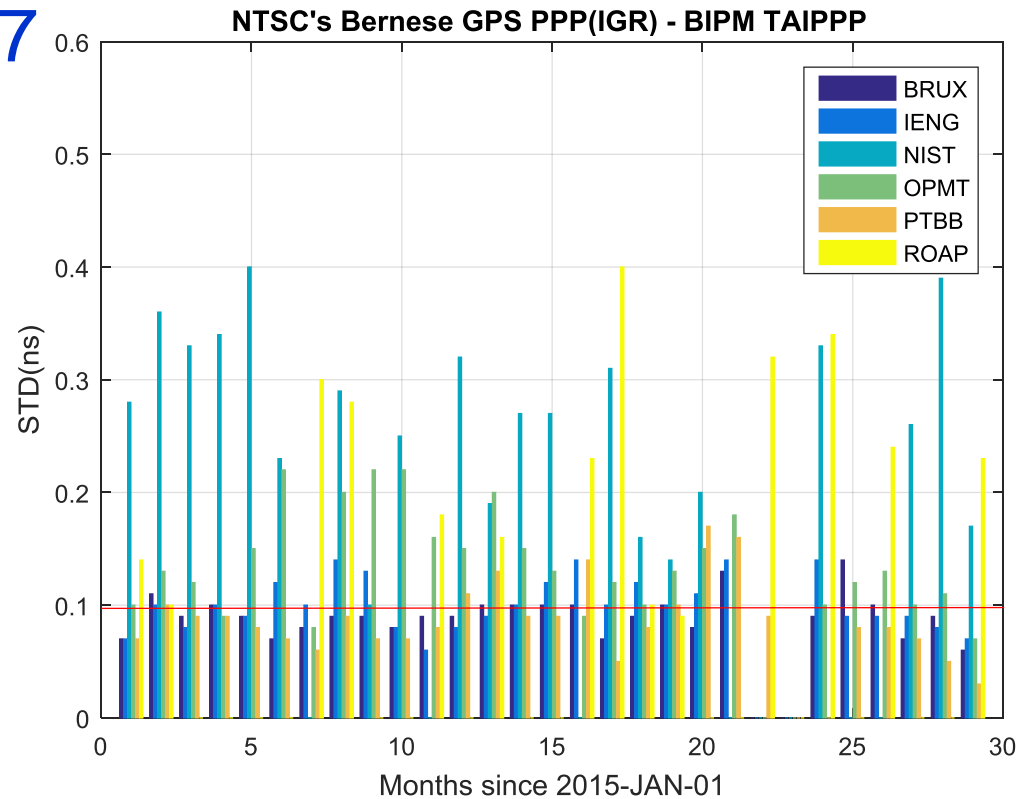
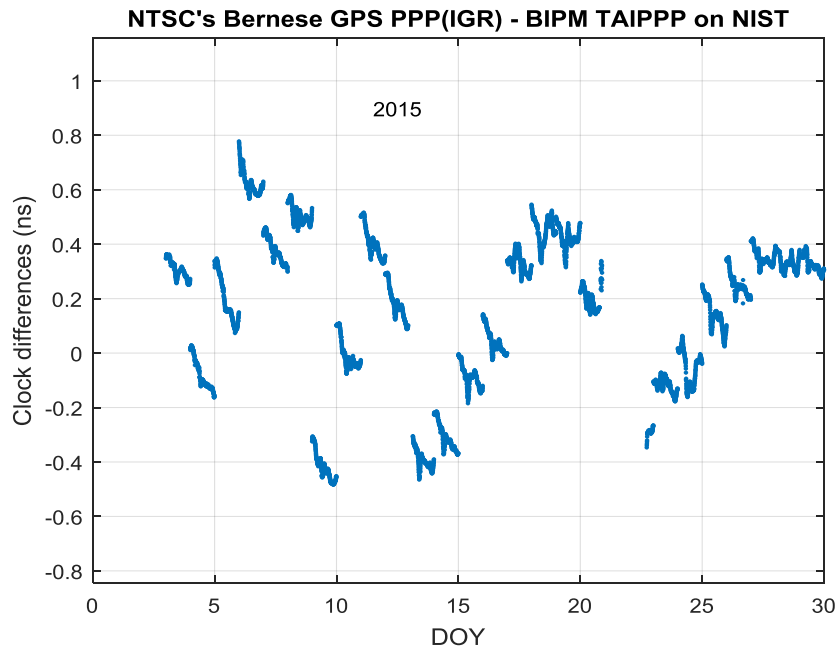
● BDS/GALILEO TAI PPP experiment

- NTSC modified Bernese GNSS Software V5.2
 - Arc length: 1 day
 - Orbit and clock products: GBM/COM
-



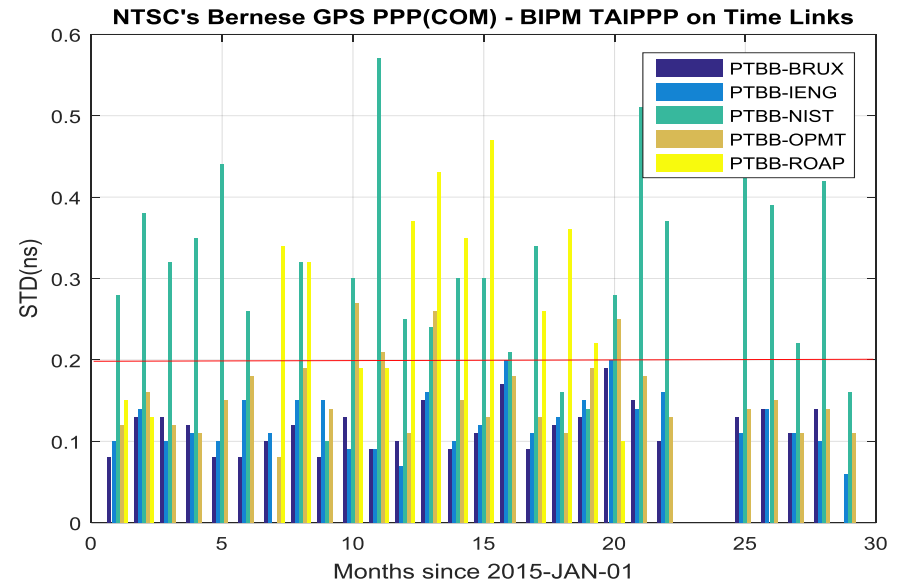
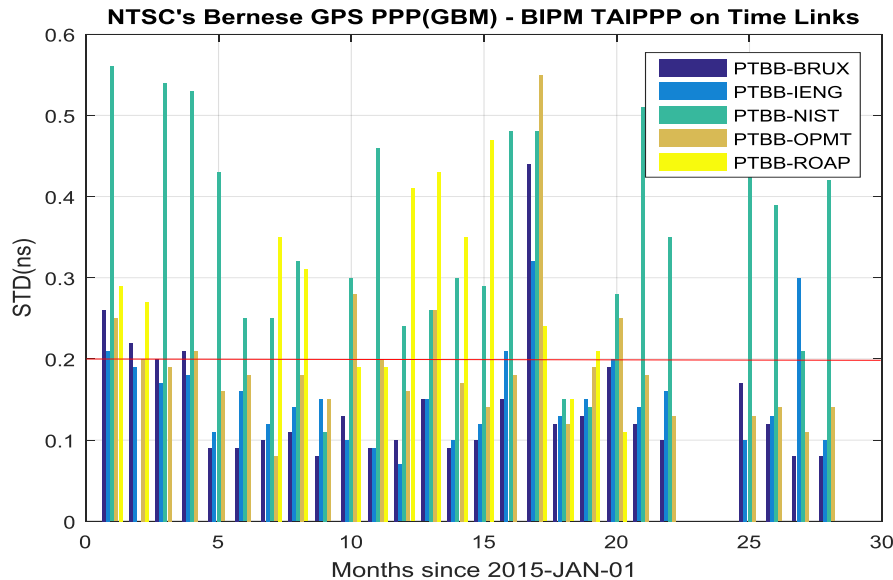
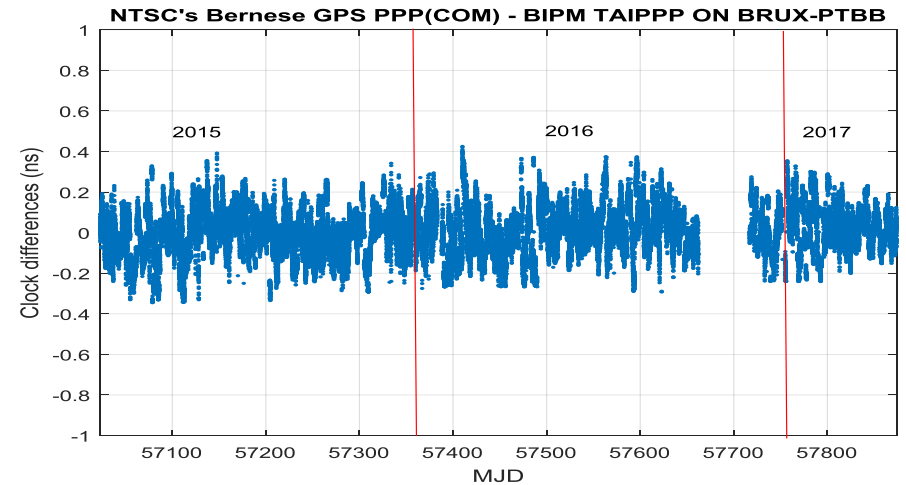
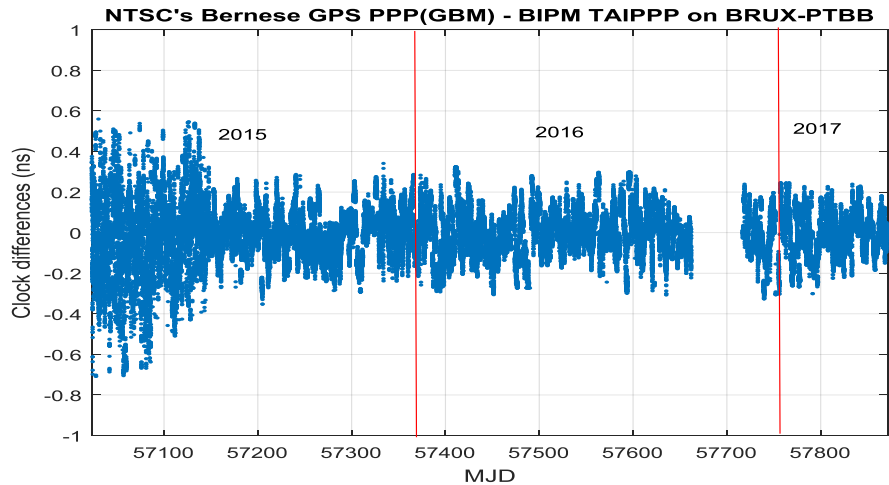
GPS PPP with IGR products

- 6 stations from IGS network, participated in TAI computation
- Jan 2015 - May 2017





GPS PPP with multi-GNS products





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Data and Strategies

- 10 IGS MGEX stations
 - GPS+BDS observations
 - external clocks
 - 2 located in time laboratory
- Jan 2015 – Dec 2016

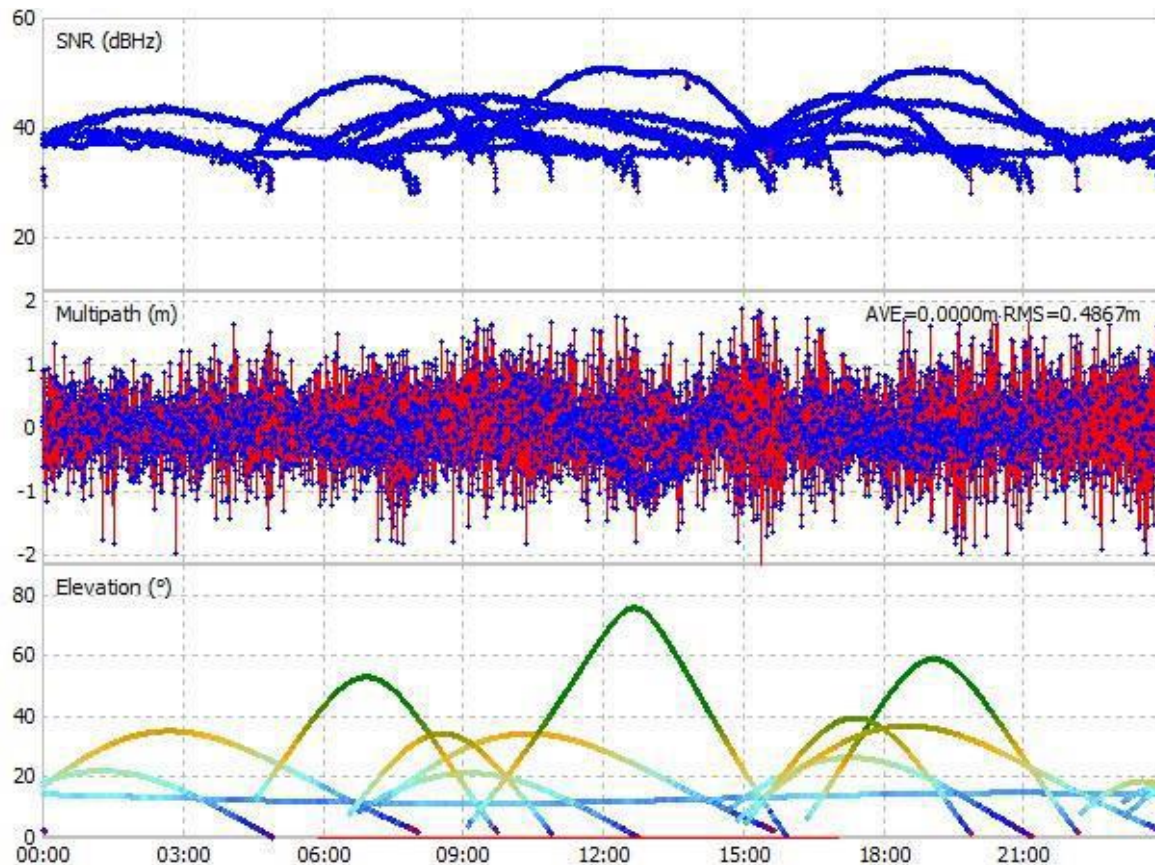


Station	Receiver	External clock
BRUX	SEPT POLARX4TR	CESIUM
DLF1	TRIMBLE NETR9	CESIUM
GMSD	TRIMBLE NETR9	CESIUM
NNOR	SEPT POLARX4	SLAVED CRYSTAL
REDU	SEPT POLARX4	CESIUM
ROAP	SEPT POLARX4TR	H-MASER
TLSG	SEPT POLARX4TR	DORIS
VILL	SEPT POLARX4	Cesium
WARK	TRIMBLE NETR9	H-MASER
WTZR	LEICA GR25	H- MASER



Data and Strategies

- BDS visibility and data quality of BRUX on DOY 33/2017





Data and Strategies

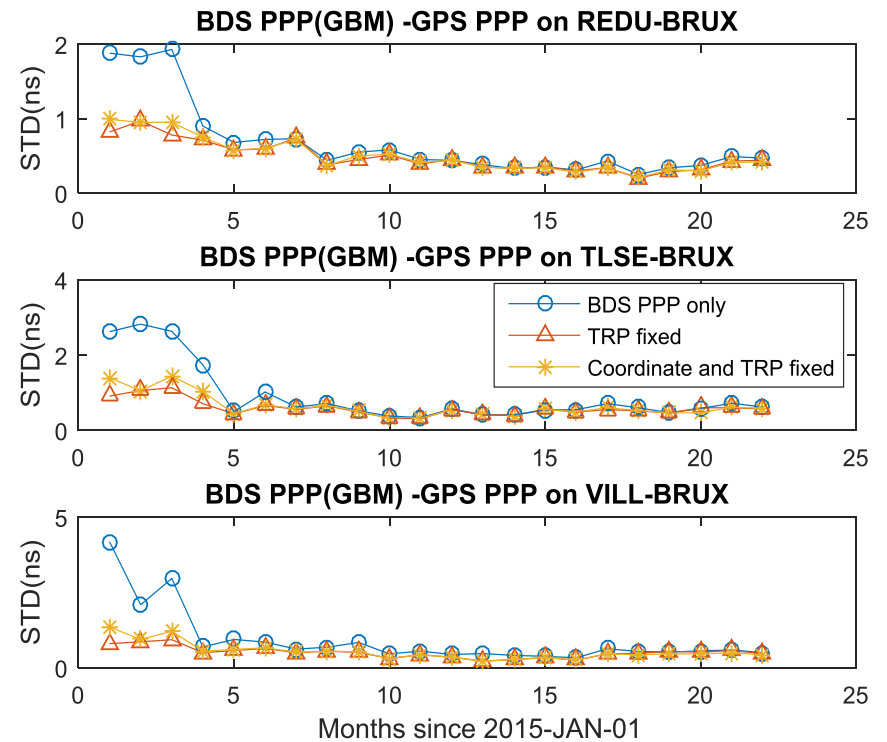
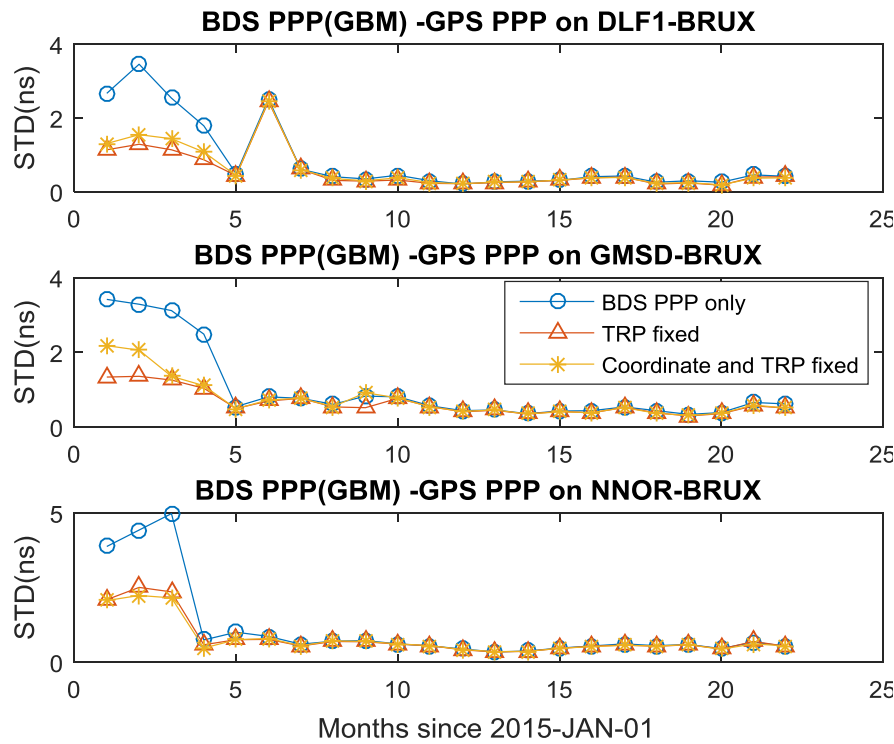
- 4 solutions according to different strategies
 - Estimated parameters
 - Multi-GNSS products
 - GBM: GEO included, 30s clock; COM: no GEO, 300s clock
- GPS PPP with GBM products as reference

	GBM products	COM products	Coordinates fixed	ZTD fixed
solution1	√			
Solution2	√		√	
Solution3	√		√	√
solution4		√	√	√



BDS PPP with different parameterizations

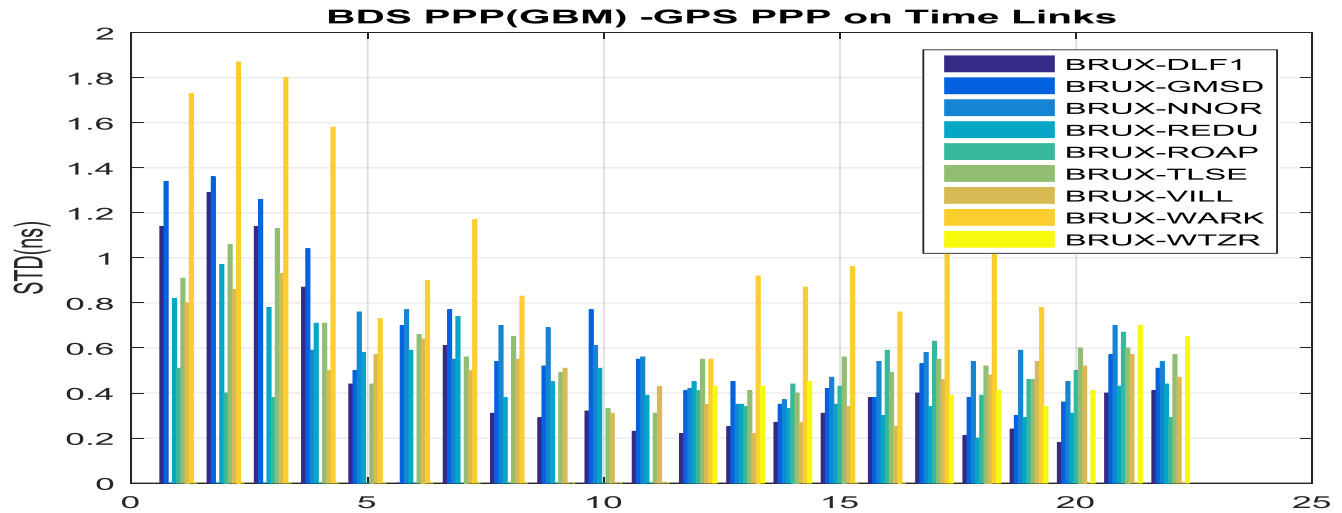
- Since May 2015, PPP results with BDS only has been on the same level with the other two strategies, all < 1.0 ns
- Due to the accuracy improvement of the GBM products?



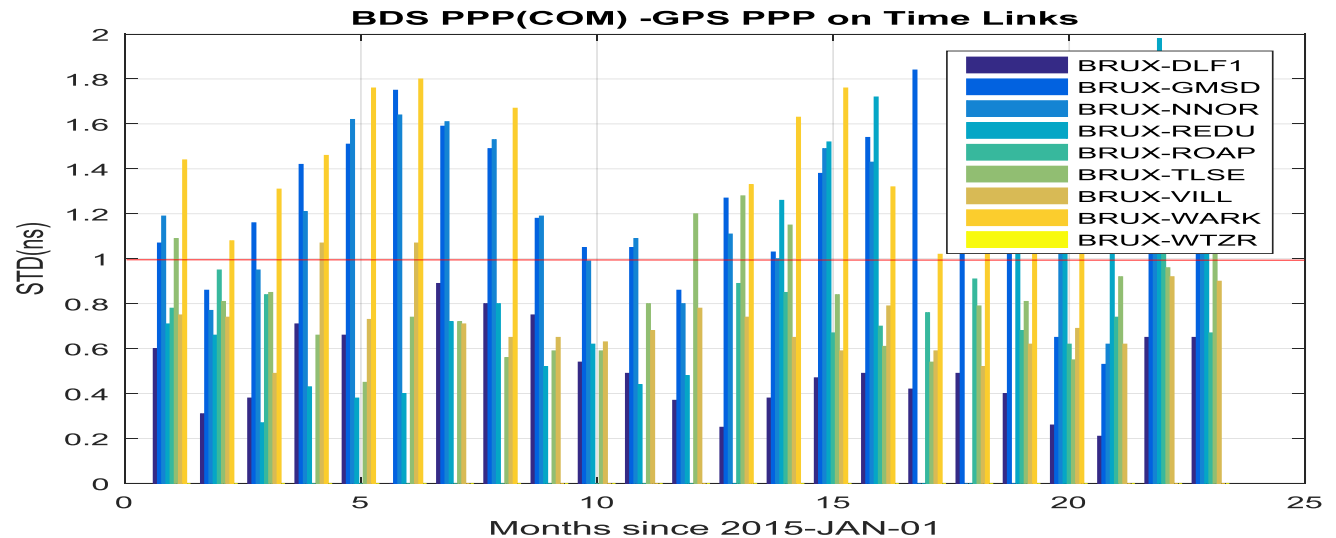


BDS PPP with different products

With GBM products
(GEO included, 30s
clock), < 0.5ns



With COM products
(GEO excluded, 300s
clock), < 0.8ns





Outline

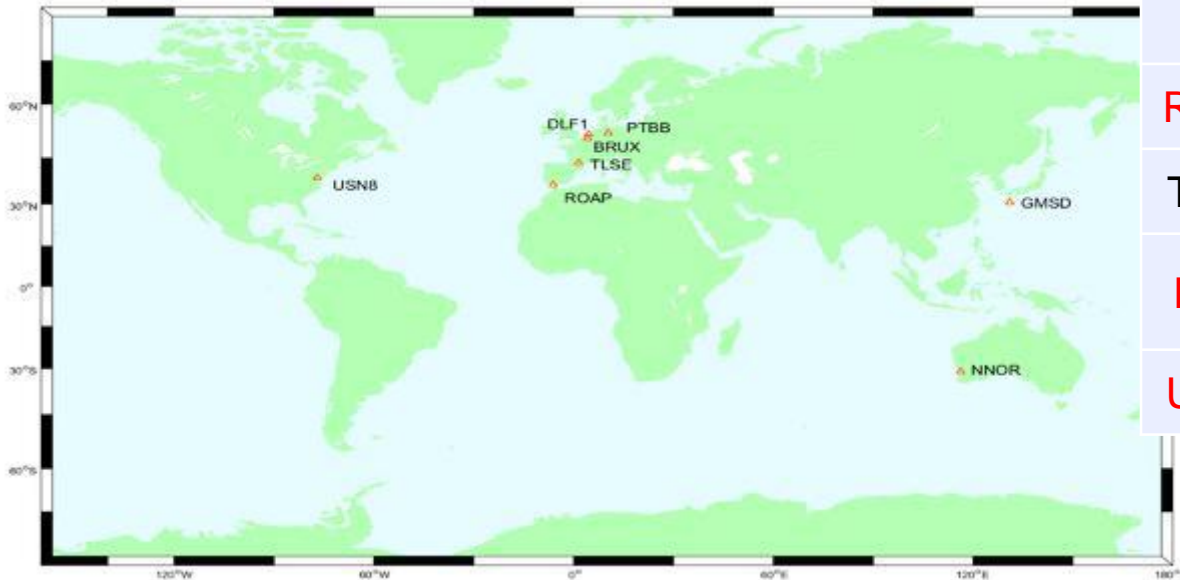
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Data and Strategies

- 8 IGS MGEX stations
 - GPS+GAL observations
 - external clocks
 - 4 located in time laboratory
- 15 Dec 2016 – 1 May 2017

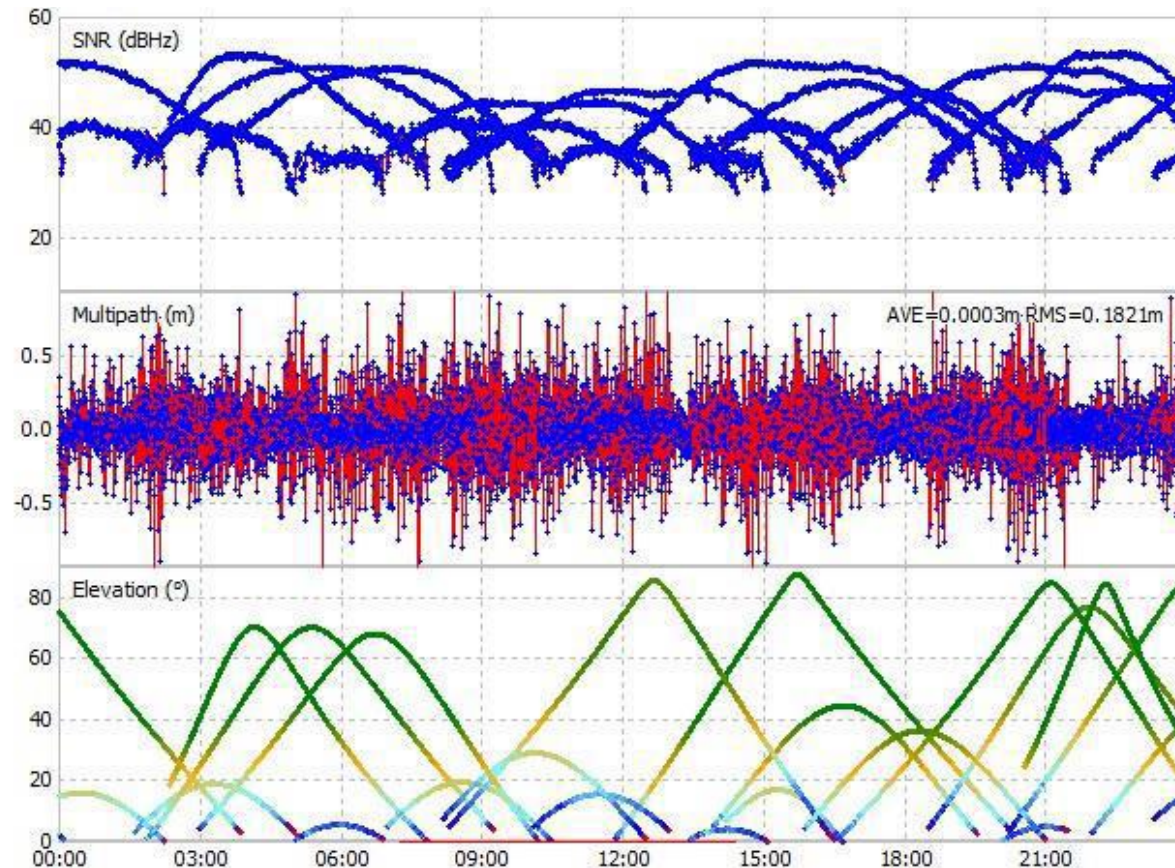
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PTBB	SEPT POLARX4TR	H-MASER
USN8	SEPT POLARX4TR	H-MASER





Data and Strategies

- GALILEO visibility and data quality of BRUX on DOY 33/2017





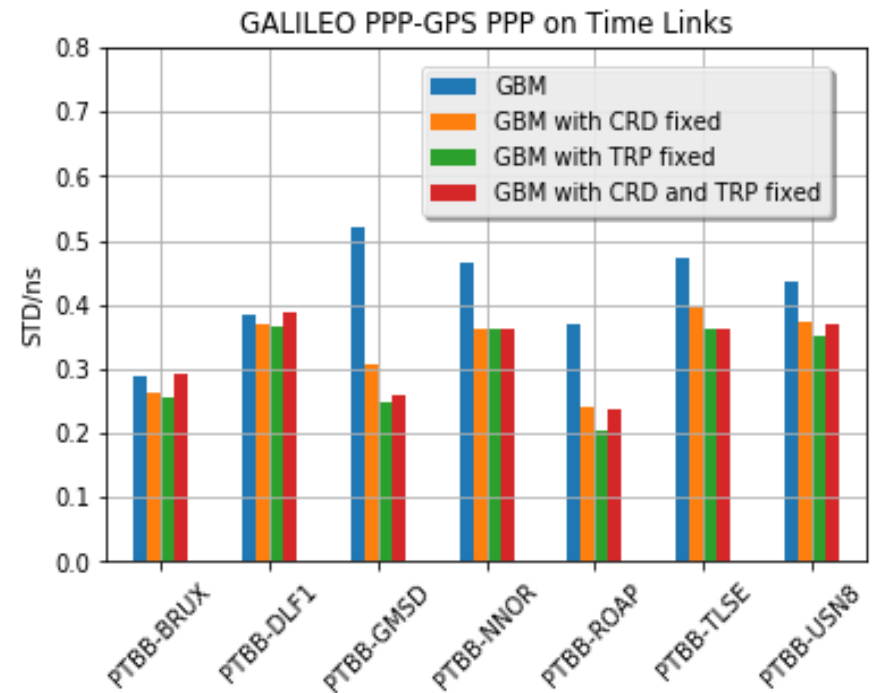
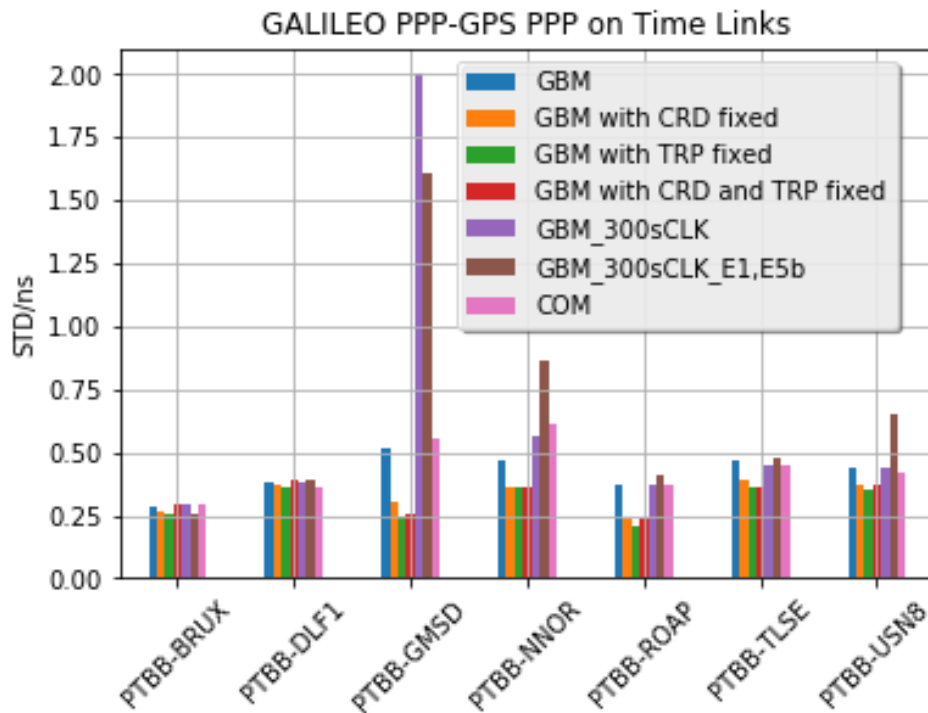
Data and Strategies

- 7 solutions according to different strategies
 - Estimated parameters; selected observations
 - Multi-GNSS products: GBM, 30s clock; COM, 300s clock

	GBM	COM	30s clock	300s clock	E1/E5a	E1/E5b	CRD fixed	TRP fixed
Solution1	√		√		√			
Solution2	√		√		√		√	
Solution3	√		√		√			√
solution4	√		√		√		√	√
solution5	√			√	√			
solution6	√			√		√		
solution7		√		√	√			



GALILEO PPP results





Summary and outlook

- Daily GPS PPP time transfer based on Bernese was tested using data from 6 IGS/time laboratory stations over 2.5 years
- For most stations/time links, the differences compared to BIPM monthly TAIPPP solutions are around 0.1ns, so are daily GPS PPP with GBM and COM products
- The differences of daily BDS PPP and GPS PPP time transfer are less than 0.6ns with GBM products(GEO included, 30s clock), and less than 0.8ns with COM products(GEO excluded, 300s clock)
- For GALILEO in initial service, the best solutions of daily PPP could be less than 0.4ns for the tested links

- A campaign for multi-GNSS TAI time transfer?



Thanks for your attention !

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