

VLBI MEASUREMENTS FOR FREQUENCY TRANSFER

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Content

- ✓ Introduction
 - » *Why VLBI is required?*
 - » Activities at NICT
 - » Previous study : Wettzell - Onsala

- ✓ Intercomparison between VLBI and other techniques
 - » *Can the VLBI measure the right time difference?*
 - Kashima34m - Kashima11m
 - Artificial change by Line Stretcher

- ✓ Conclusions

Introduction

✓ Development of frequency standard

- Atomic fountains



NICT-CsF1
..... developing

2×10^{-15}
@a few days

- Optical clocks



NICT
optical clocks
..... developing

$10^{-16} \sim 10^{-17}$
@a few hours

Background

✓ Time and frequency transfer technique

- » GPS Carrier Phase

2×10^{-15} @1day

- » TWSTFT

$2-4 \times 10^{-15}$ @1day

- » *long averaging period*

- » *insufficient accuracy*

➤ improvements of highly precise time and frequency transfer techniques are strongly desired

VLBI

Activities at NICT

1. Developing a compact VLBI system

» MARBLE SYSTEM

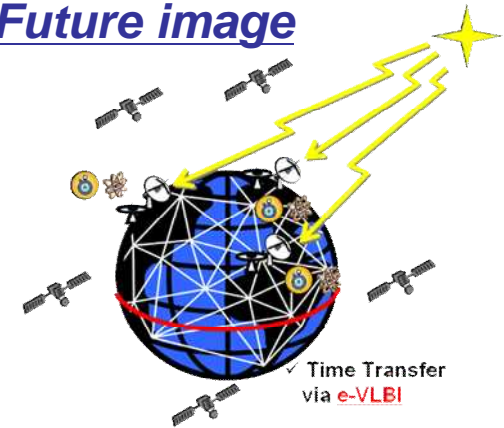
Multiple Antenna Radio-interferometry of Baseline Length Evaluation



- Diameter **1.65m**
- **S/X-band**
- Front-fed paraboloidal reflector
- Az-El mounting
 - Max speed AzEl **5** deg/sec
- **Transportable**
by few person

Collaborating with GSI

Future image



2. Verifying the ability of VLBI frequency transfer

» to show the capability of the current VLBI system

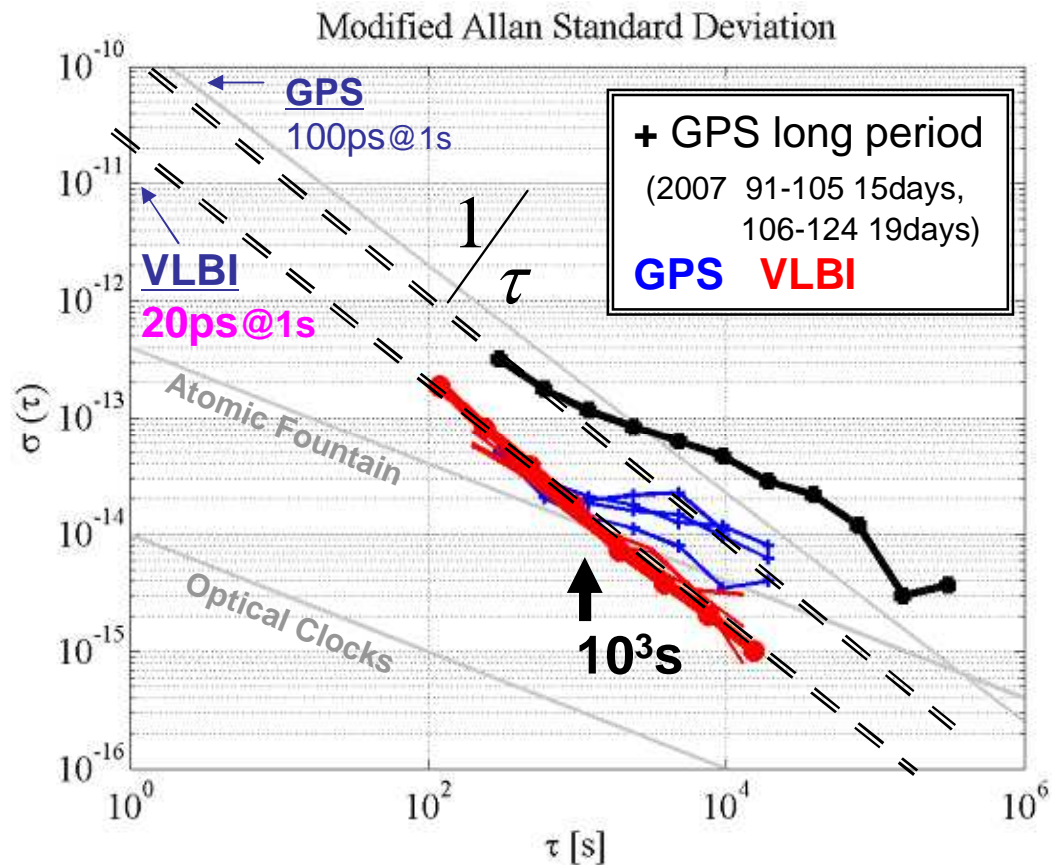
- *Intercomparison* between VLBI and other techniques

Previous study

Intercomparison: VLBI vs. GPS

1. Wettzell-Onsala

- VLBI vs. GPS CP
- IVS and IGS data



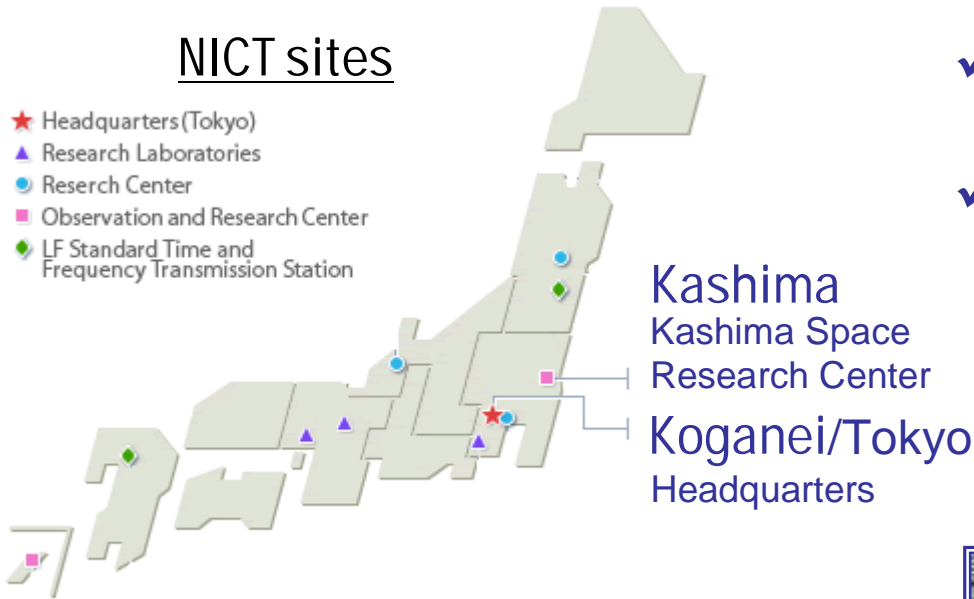
- ✓ VLBI is more stable than GPS
- ✓ surpassing the stability of atomic fountain at 10^3 s
- ✓ VLBI stability : follows a $1/\tau$ law very closely
- ✓ 2×10^{-11} (20ps) @ 1s

at each site
VLBI and GPS
are shown
The geodetic VLBI technique has the potential for precise frequency transfer

Intercomparison: VLBI vs. other techniques

NICT sites

- ★ Headquarters (Tokyo)
- ▲ Research Laboratories
- Reserch Center
- Observation and Research Center
- ◆ LF Standard Time and Frequency Transmission Station



- ✓ Kashima34m – Kashima11m 239m
- ✓ Kashima11m – Koganei11m 109km

Kashima

- VLBI
- MARBLE
- GPS



Koganei



- VLBI
- GPS
- TWSTFT
- TEC (ETS-8)



Please see the poster : **JD06-p:21**

Hosokawa et al., "Recent activities at NICT Space-Time Standards Group"

Can the VLBI measure the right time difference?

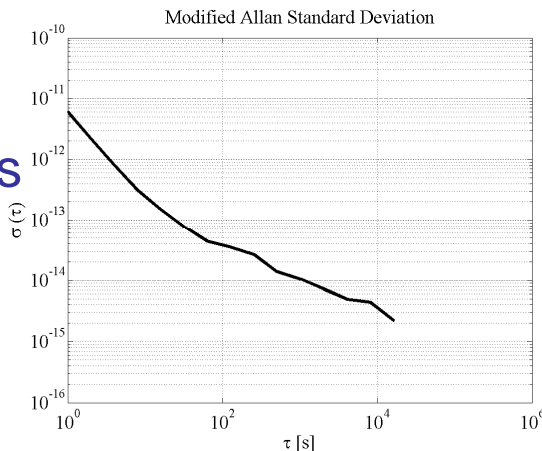
✓ Kashima34m – Kashima11m

» Artificial time difference change

▪ using Line Stretcher

» Intercomparison between VLBI, GPS and **DMTD**

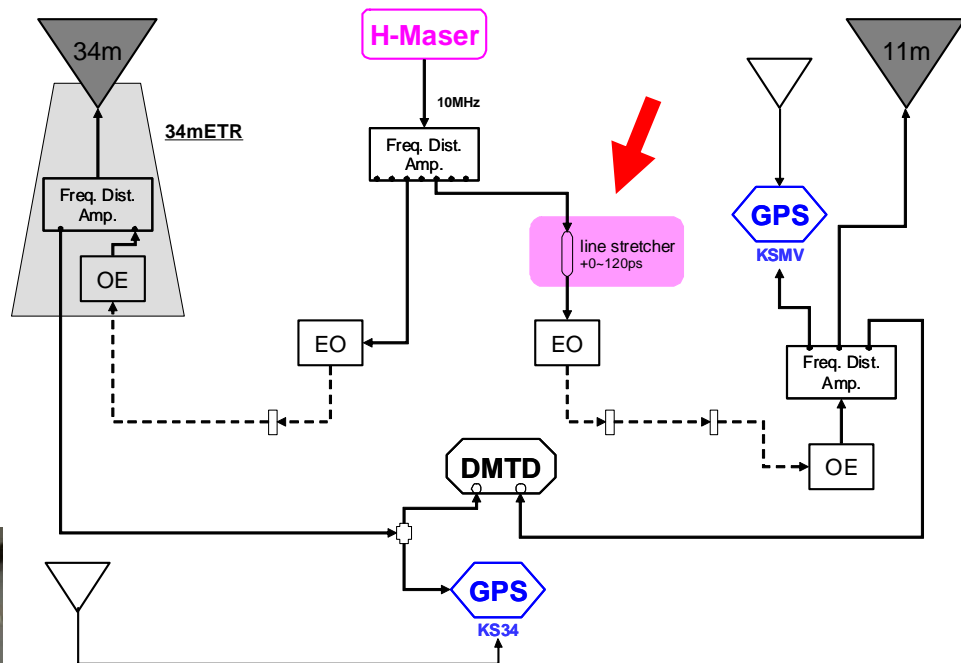
DMTD
 6×10^{-12} @ 1s
 (6ps)



Line Stretcher

A

B



Differences with the normal observation

✓ Normal Geodetic VLBI

- » Observation
 - multiple sources
 - antenna slew time
 - different scan time
 - 24 hours

- » Data Analysis
 - estimate
clock parameter
atmospheric delay
station coordinates

✓ This study

- » Observation
 - **one source** : 3C84
 - no antenna slew time
 - same scan time
 - a few hours

- » Data Analysis
 - estimate only
clock parameter
 - atmospheric delay :
short baseline, one source
 - station coordinates :
fixed to a-priori coordinates

Data analysis

✓ VLBI

- » CALC/SOLVE
- » single baseline
- » S/X ionosphere-free linear combination
 - clock offset / 10sec



- » Time Defference
clock offset / 10sec

✓ GPS

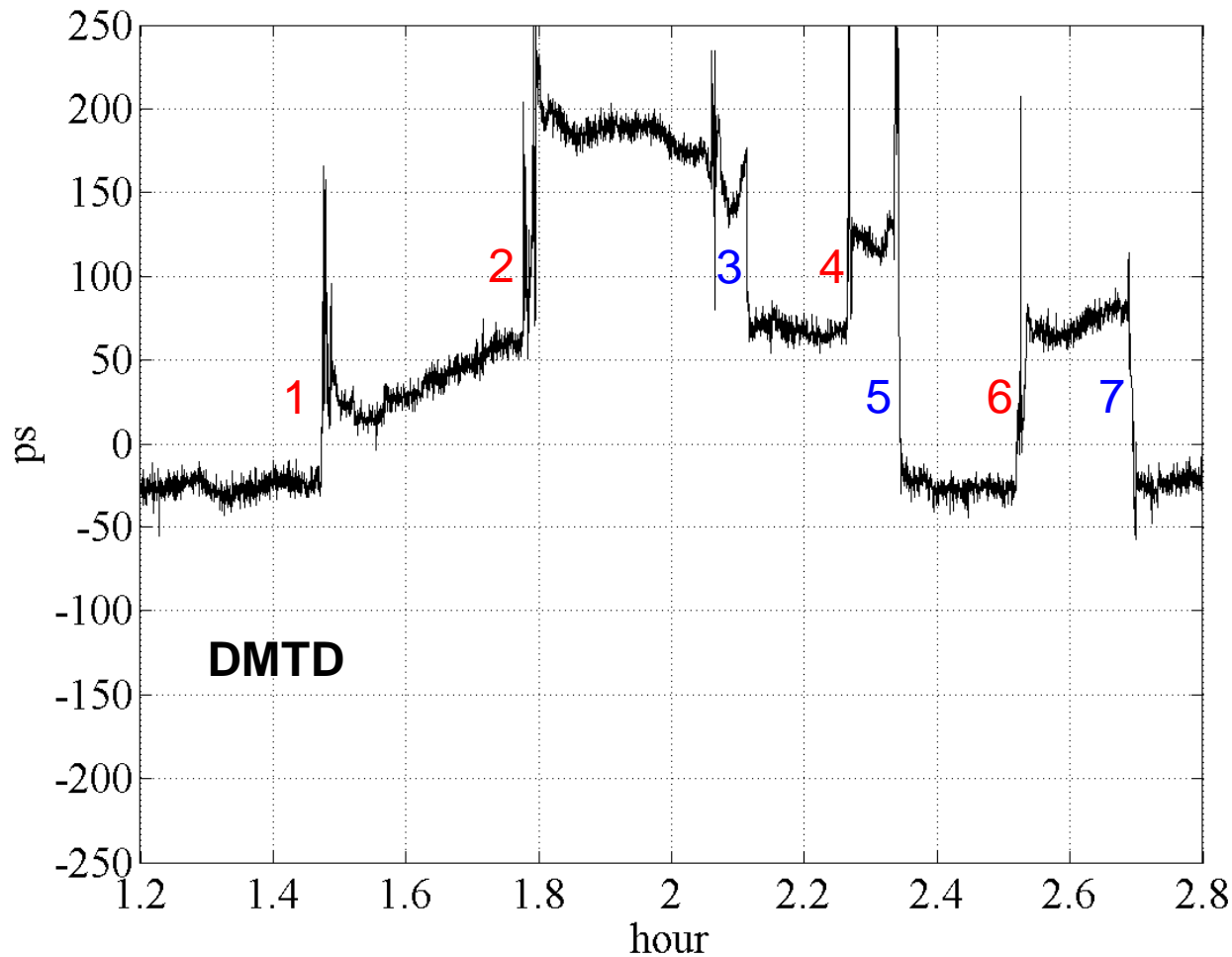
- » NR Canada's PPP
 - IGS Rapid Orbit & Clock
- » Precise Point Positioning
 - satellite clock interpolation
 - clock offset / 30sec



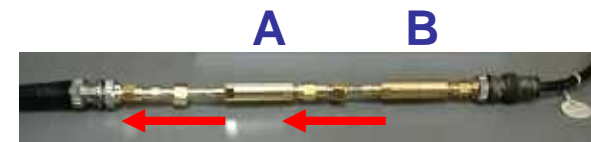
- » Time Defference
clock offset A – clock offset B
/ 30sec

vs. DMTD Time Difference / 1sec

DMTD

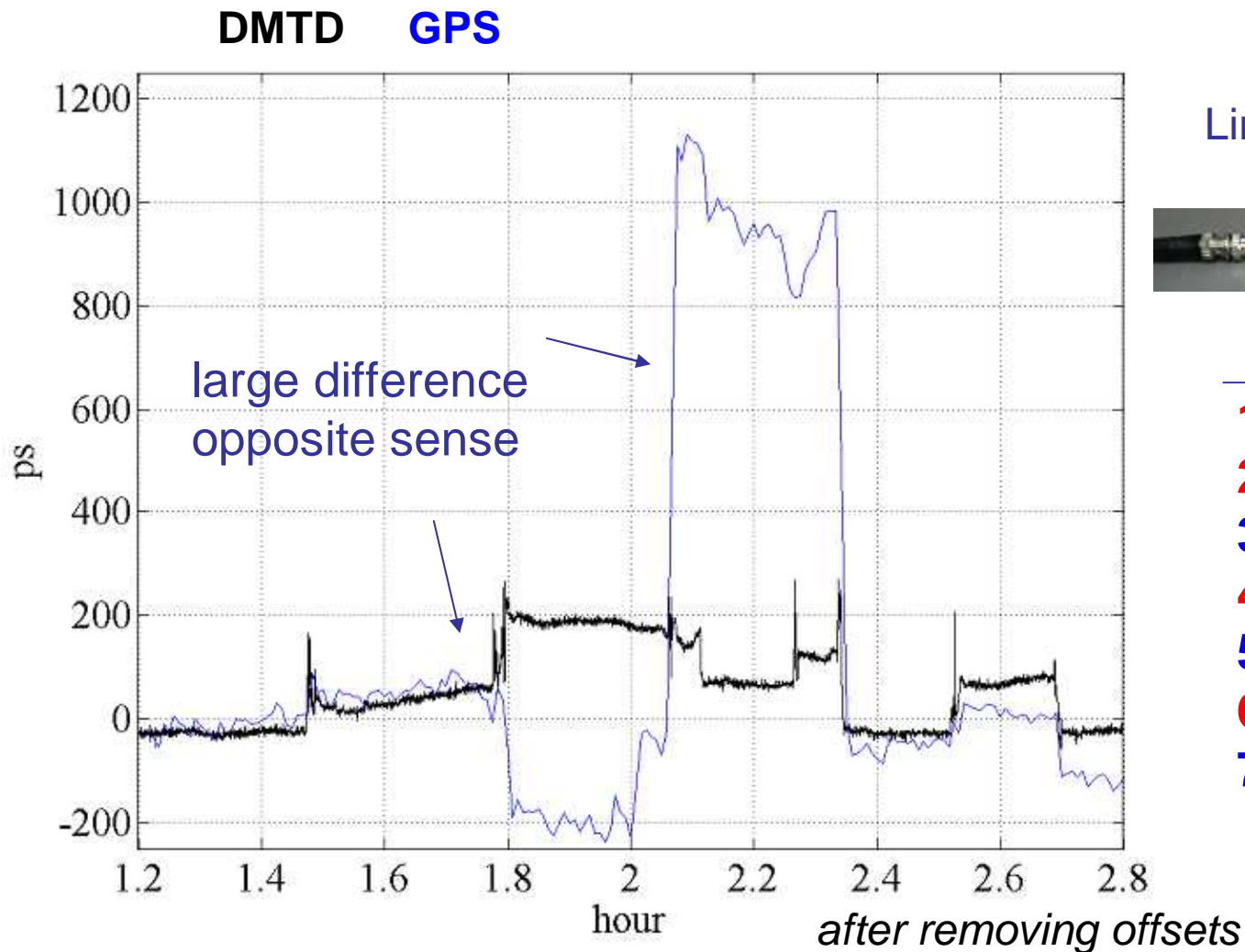


Line Stretcher

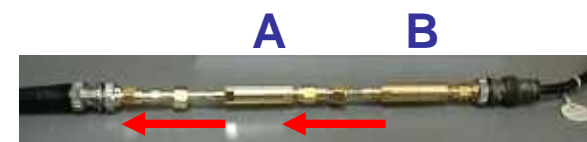


	A	--	B	--
1	A			
2			B	
3			B	
4			B	
5	A		B	
6	A		B	
7	A		B	

GPS vs. DMTD



Line Stretcher

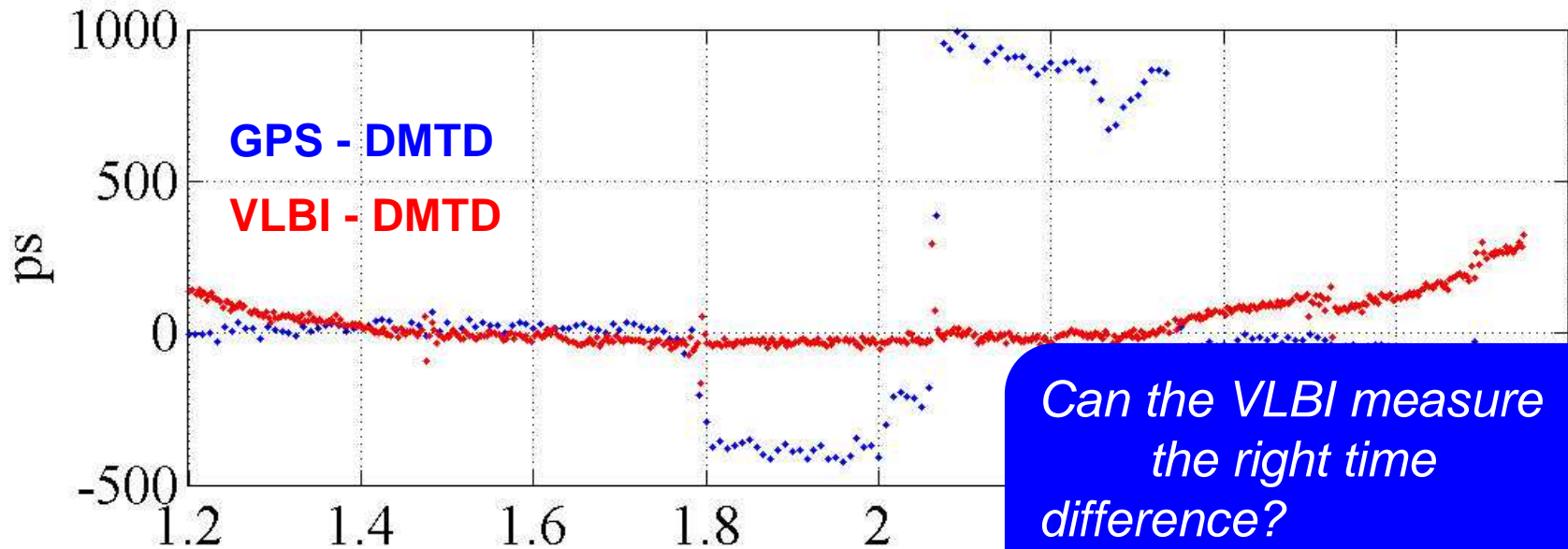


	A	--	B	--
1	A			
2			B	
3			B	
4			B	
5	A		B	
6	A		B	
7	A		B	

VLBI vs. GPS and DMTD



Difference



Can the VLBI measure
the right time
difference?

YES

- ✓ Artificial change
 - » VLBI vs. DMTD: **good agreement (<10ps)**
 - » GPS vs. DMTD: sometimes, **opposite sense**
- ✓ other parts
 - » VLBI vs. DMTD: good agreement (<50ps) for short time range
larger difference for longer time range due to the effect of atmospheric variation
 - » GPS vs. DMTD: good agreement

Conclusions

- ✓ Can the VLBI measure right time difference?
 - » VLBI vs. GPS CP and DMTD
 - » Artificial change
 - VLBI vs. DMTD: **good agreement (<10ps)**
 - GPS vs. DMTD: sometimes, **opposite sense**

» The geodetic VLBI technique can measure the right time difference.

Acknowledgements

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