Combination of Two Radio Space Geodetic Techniques at the Observation Level

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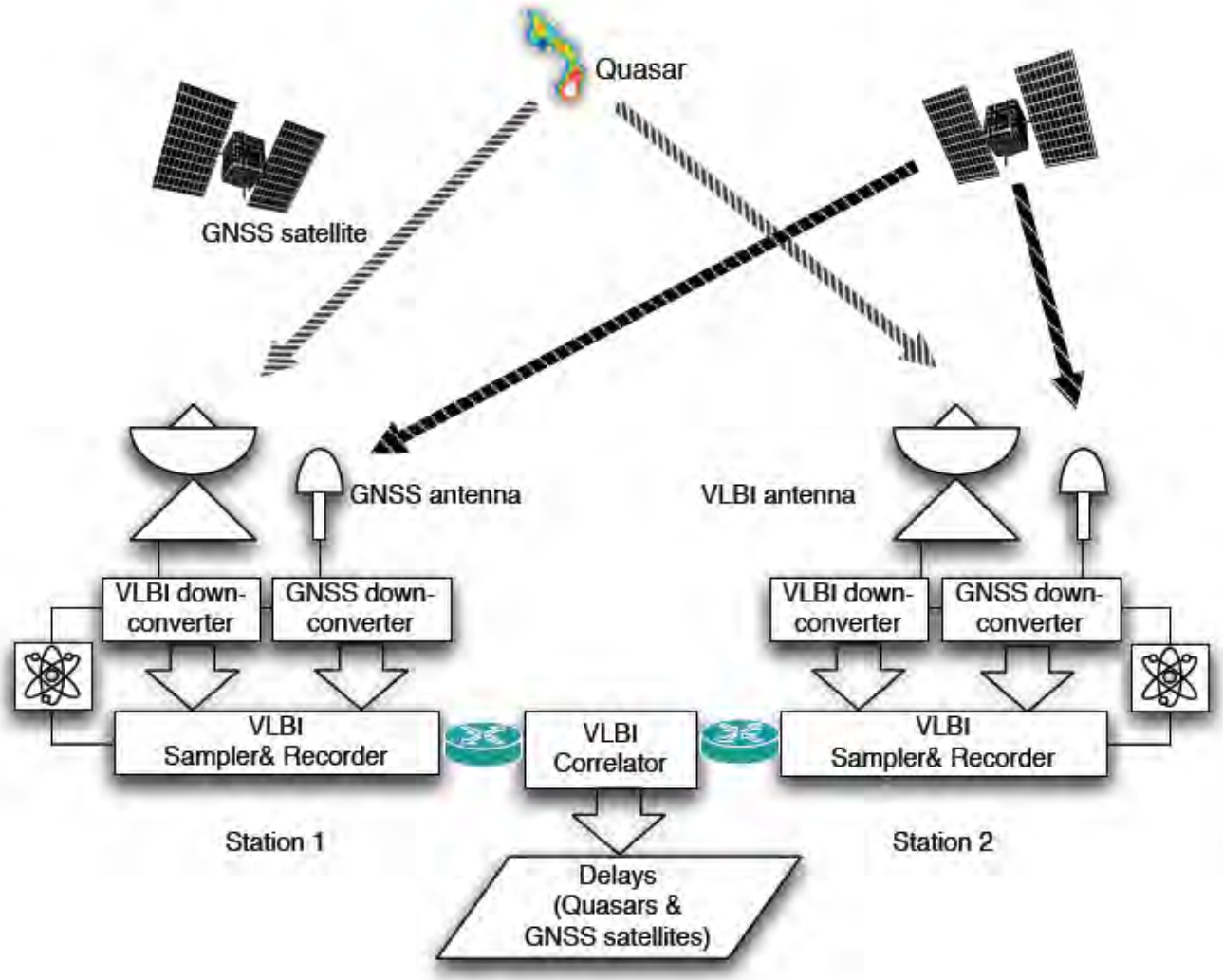
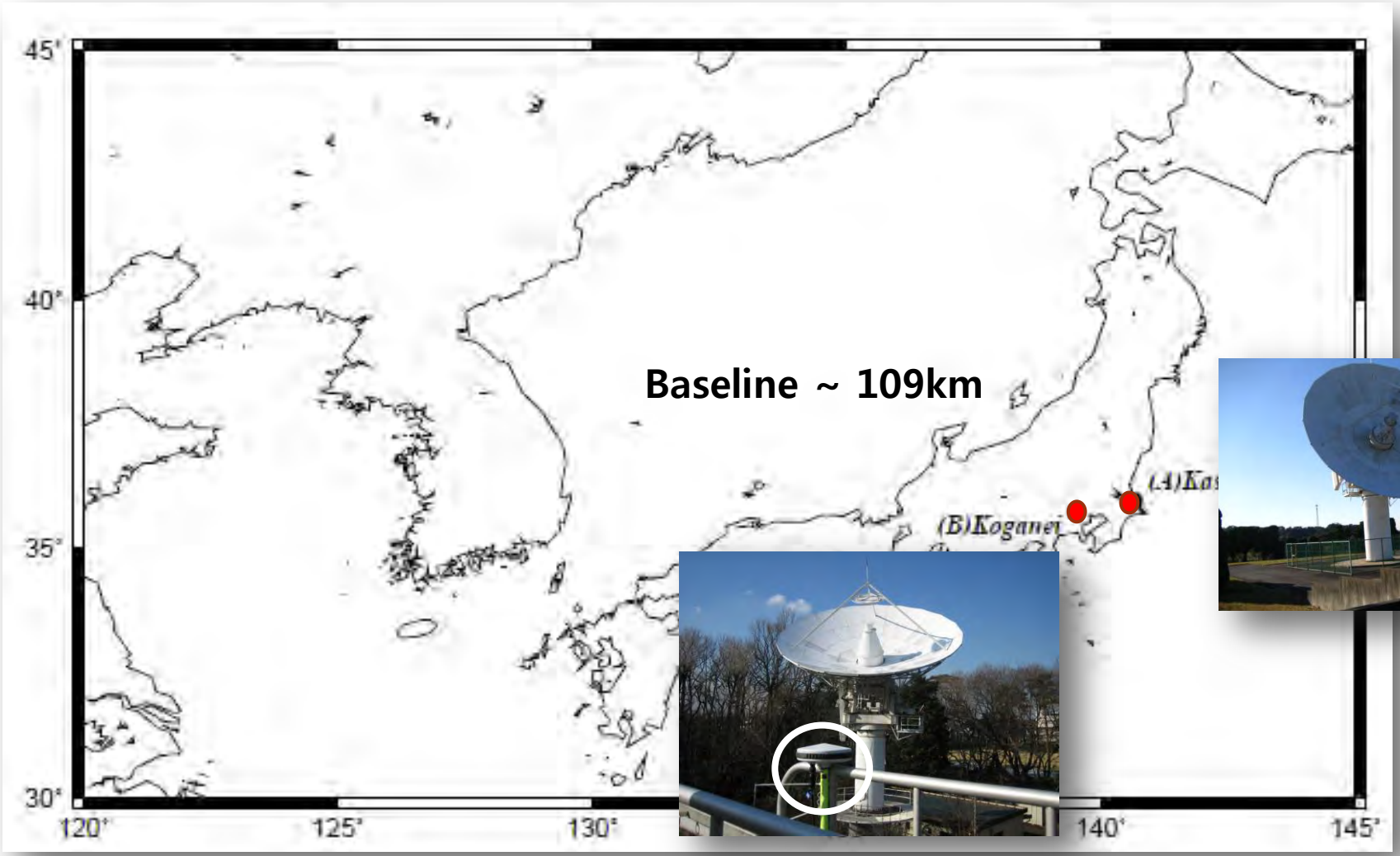
GNSS-VLBI Hybrid System

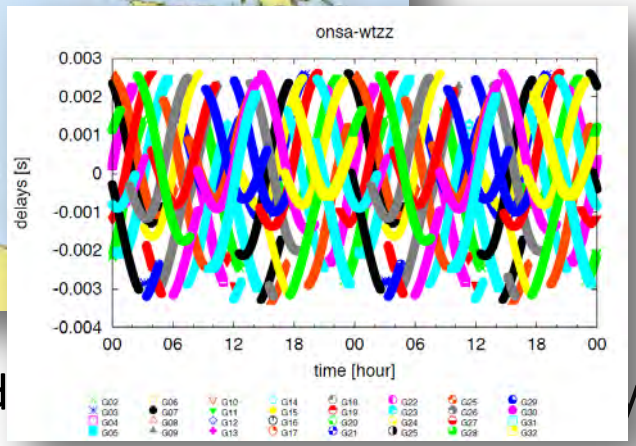


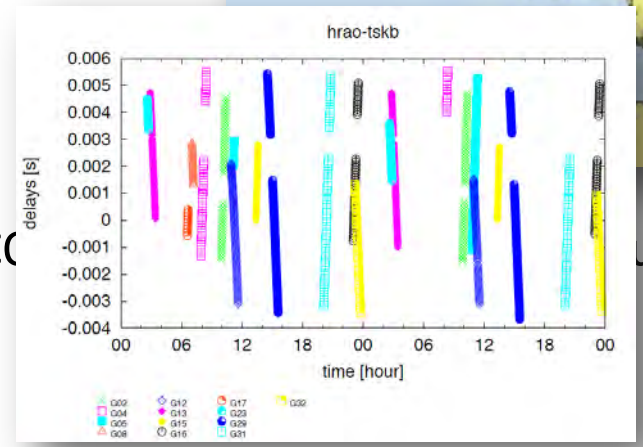
A Pilot 24-h Experiment: Single & Short Baseline



Global Network

- No instrument & no observation
- Simulation based on real observations (CONT11 & co-located GNSS data)
- **7 CONT11 sites using the same clock for both VLBI and GNSS**





CO us VLBI sessions scheduled ys

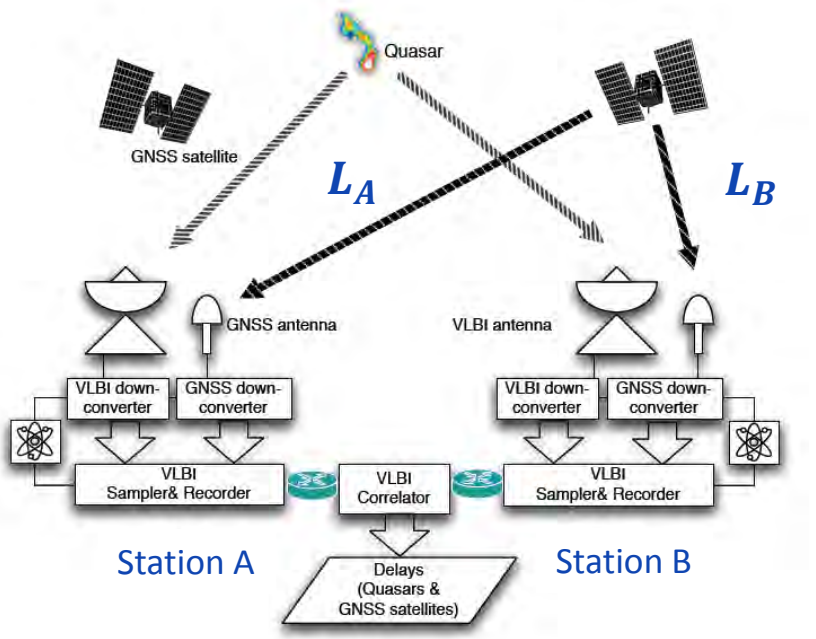
- ✓ No GNSS data between CONZ – TSKB
- ✓ No GNSS data between HRAO – KOKB
- ✓ Data on 19 baselines

Generate VLBI-like GNSS delays

- ✓ Simulate correlator outputs, GNSS delays, based on real observations
- ✓ GPS phase measurements during CONT11
- ✓ well corrected w.r.t ionosphere, ambiguity, PCV, phase wind-up effect
- ✓ Take a difference (at the same receiving time)

$$\tau = \frac{L_A - L_B}{c}$$

L_A & L_B : corrected phase measurements betw. a satellite and ground station A & B



➔ ***corrected single difference***

How to combine - data

```
                                                    ⋮
                                                    ⋮
2011   9 15   0   5 15.00 WTZZGNSS WES2GNSS PG10     sc    -0.00193562711807780  ...
2011   9 15   0   5 15.00 WTZZGNSS WES2GNSS PG13     sc     0.01079601557621570  ...
2011   9 15   0   6 50.00    KOKEE TSUKUB32 1144-379 qq     0.00732405933076071  ...
2011   9 15   0   6 50.00    KOKEE TIGOCONC 1144-379 qq     0.00542015727254934  ...
                                                    ⋮
```

- ✓ GNSS : differenced values from real GNSS measurements (multiple scans at the same epoch)
- ✓ VLBI : CONT11 data
- ✓ sorted by order of time regardless of data type
- ✓ processed by VieVS

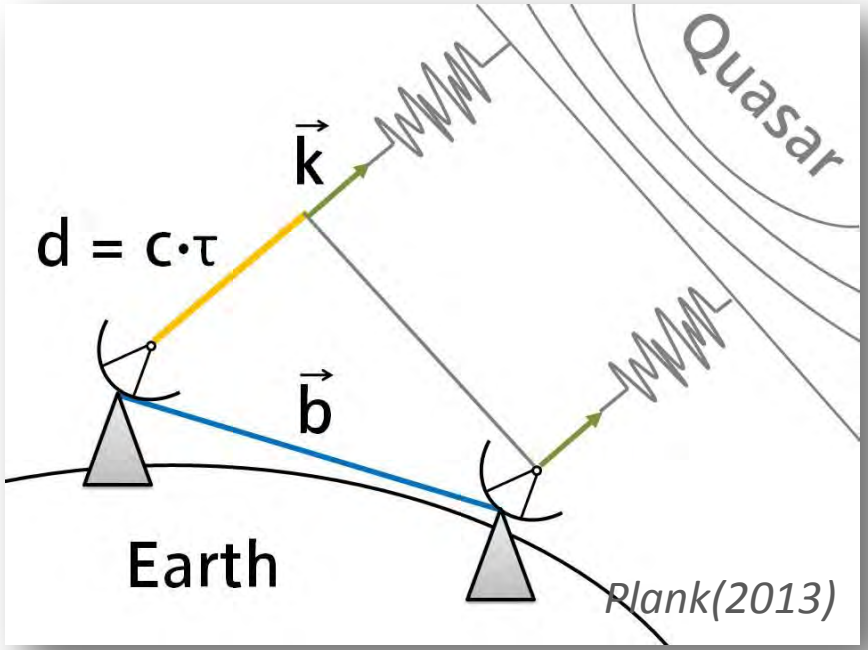
How to combine - models

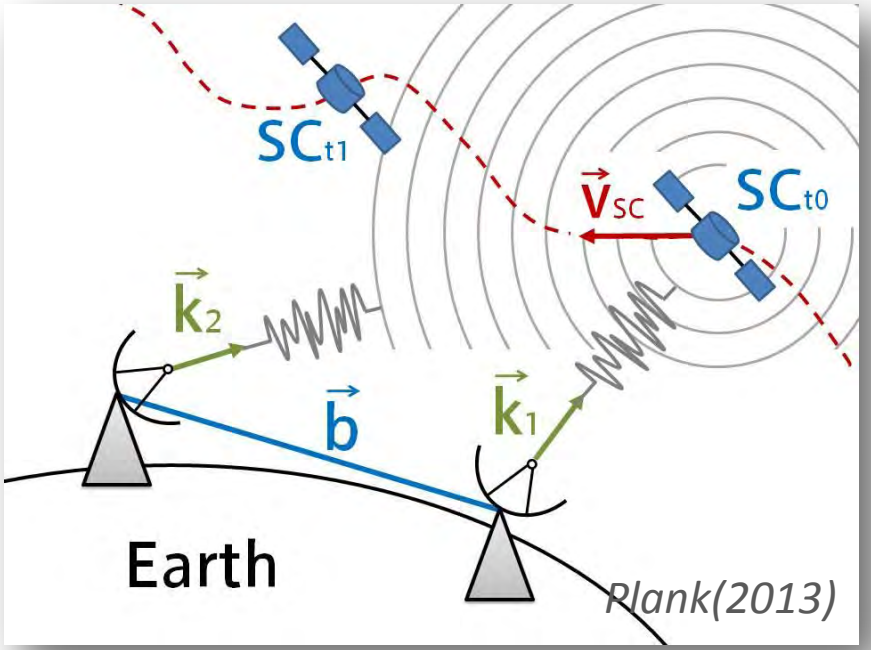
VLBI

- plane wave front
- stable sources

GNSS *Klioner (1991)*

- curved wave front
- fast moving sources





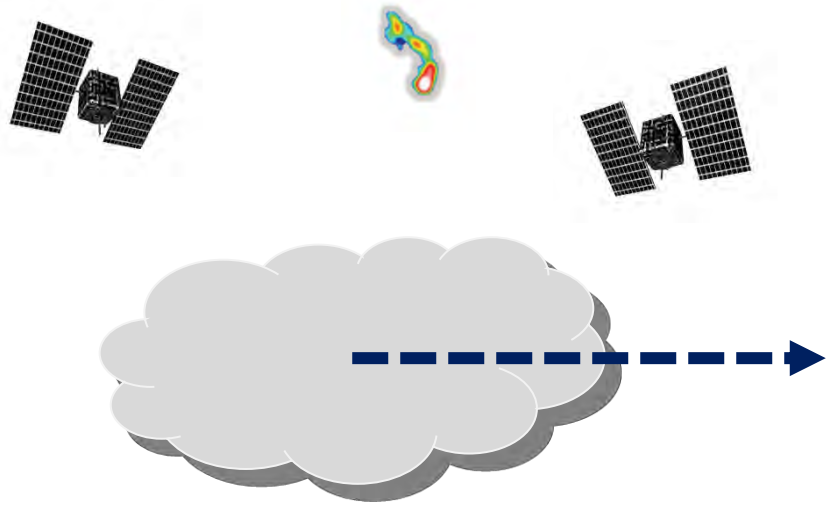
- Other geophysical models are the same
- The constraints for parameters are also the same.

General analysis strategy

	Models & a prioris
Sources	ICRF2/IGS final orbit
Station coordinates	Vienna TRF for VLBI/PPP solution for GNSS
EOP	IERS 08 C04
Solid Earth tide	IERS 2010 conventions

	Parameters	Interval
Clocks	PWL offsets	5 min
	Clock rate and quadratic term	1day
ZWD	PWL offset	2 hr
Gradients	East&west components	6 hr
Station coordinates	NNR/NNT to vievsTrf/PPP solution	1 day
EOP	-	-

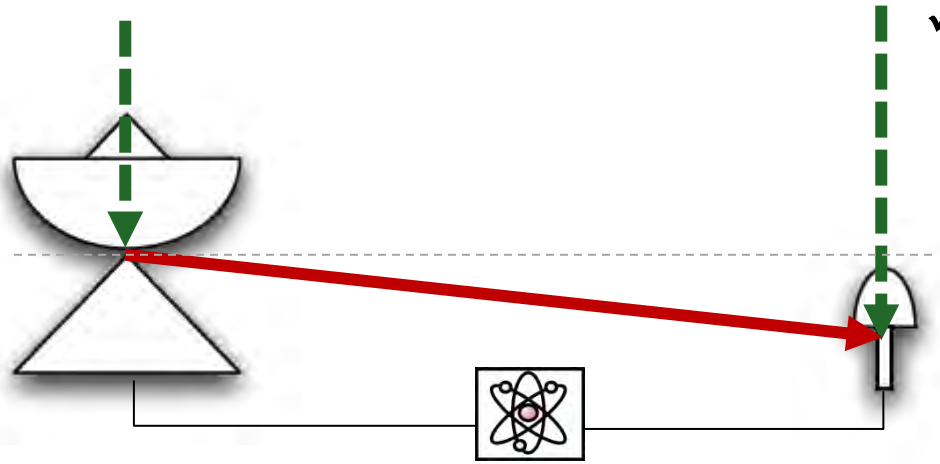
Combination analysis strategy



Separately estimate parameters
+ give constraints for common parameters at the co-located sites

✓ Troposphere gradients

$$NGR_{GNSS} - NGR_{VLBI} = 0 \pm 2cm$$
$$EGR_{GNSS} - EGR_{VLBI} = 0 \pm 2cm$$



✓ ZWD

$$ZWD_{GNSS} - ZWD_{VLBI} = \Delta ZWD \pm 1cm$$

ΔZWD : ZWD difference due to height difference (Teke et al. 2011)

✓ Clock – not constrained

✓ Local tie

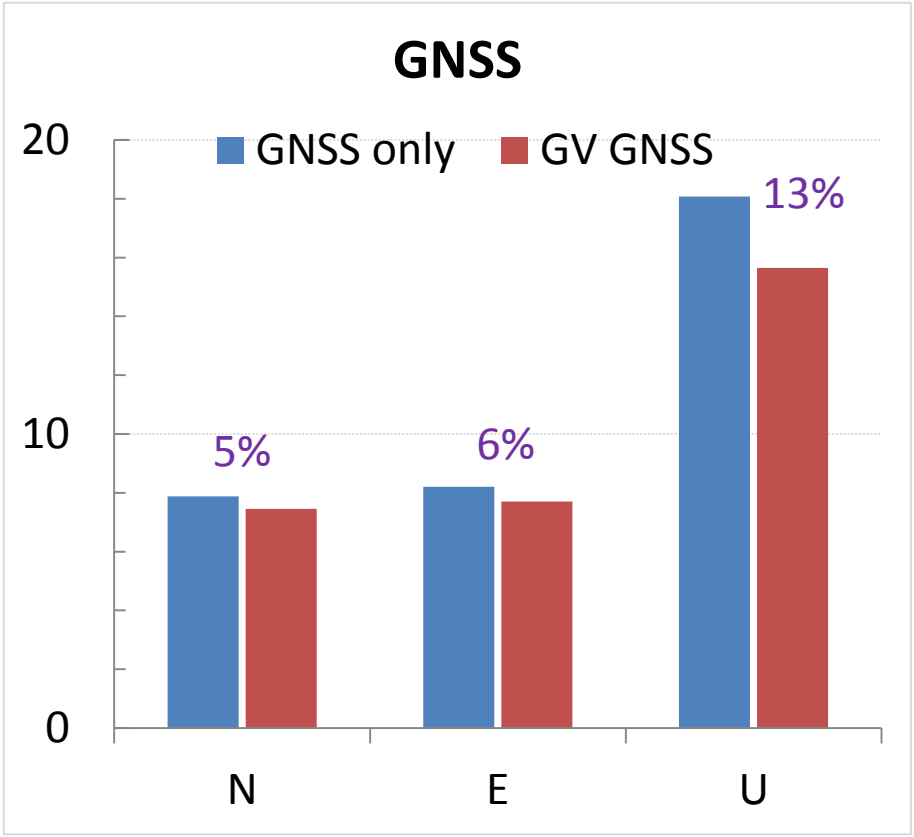
$$dx_{GNSS} - dx_{VLBI} = \Delta x - (x_{GNSS} - x_{VLBI}) \pm 3cm$$

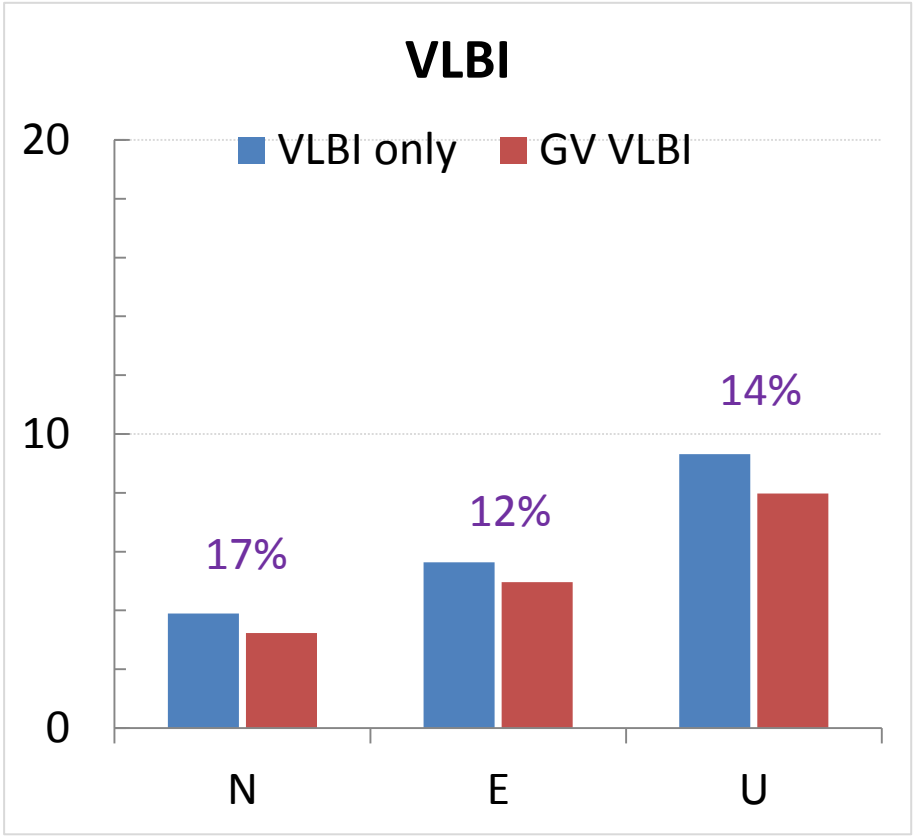
Δx : local tie measurements from the site survey
x_{GNSS}, x_{VLBI} : a priori values for station position

Combination Results

Mean station position repeatability during 15days

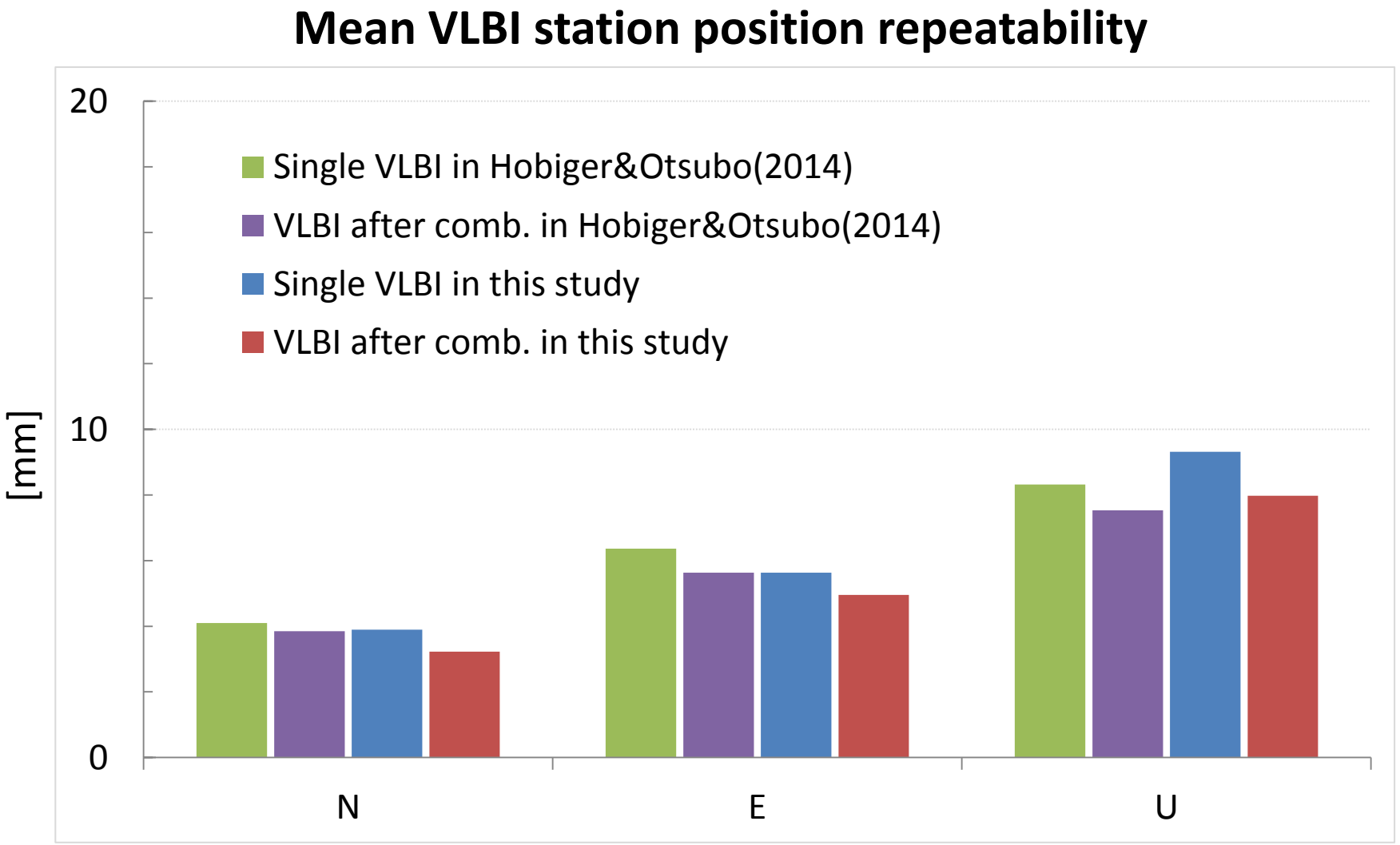
[unit: mm]





cm-level accuracy of the model

Comparison with other combination solutions



Conclusion and Future Works

- The individual & combined VLBI and GNSS data were processed in VieVS.
- We found cm-level accuracy of the model involved for GNSS delays so far.
- ZWD, troposphere gradients and local tie were constrained between two techniques for the combination.
- The combined solutions improve station position repeatability in comparison with single solutions.
- Further development of VieVS for common clock parameters

Thank you for your attention!

This work has been supported by the projects Hybrid GPS-VLBI (M1592) and the Fellowship FS1000100037 by Australian Research Council.