Preliminary Results of Global GNSS-VLBI Hybrid Observations

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ABSTRACT GNSS-VLBI hybrid observations refer to an approach where GNSS signals are received by GNSS antennas and correlated with VLBI correlators. The VLBI-like GNSS delays are then analyzed together with co-located VLBI observations. As a test, we use GNSS observations during CONT11, a continuous VLBI campaign over 15 days in September 2011. During CONT11, GNSS and VLBI were connected to the identical clocks at seven sites, which mean clock parameters can be regarded as site common parameters. We construct GNSS single differences between the ranges from two stations to a satellite, using post-processed range values from a precise point positioning (PPP) GPS solution with the C5++ software. Combining VLBI and VLBI-like GNSS delays during CONT11, we analyze those data with the Vienna VLBI Software (VieVS). In this poster, we present combined solutions and single technique solutions and compare them.

1. GNSS-VLBI Hybrid Observation for Geodesy

The GNSS-VLBI (GV) hybrid system is an observation method to combine GNSS and VLBI techniques at the observation level. In the GV hybrid system, VLBI observations are made to quasars and GNSS satellites at the same time and processed in the same way, making use of the big radio telescopes for the quasar signals and the comparatively small and cheap GNSS antennas to receive the GNSS signals (Fig 1). Both GNSS and VLBI antennas are connected to the same hydrogen maser clock at the site, which would diminish systematic errors between both techniques. Since GNSS antennas are omni-directional, the GV hybrid system collects many observations from various directions at the same time. Simply by this huge increase in the number of observations compared to VLBI alone, the estimation of the atmospheric delays that vary rapidly with time and space will be improved and atmospheric error sources will be mitigated.

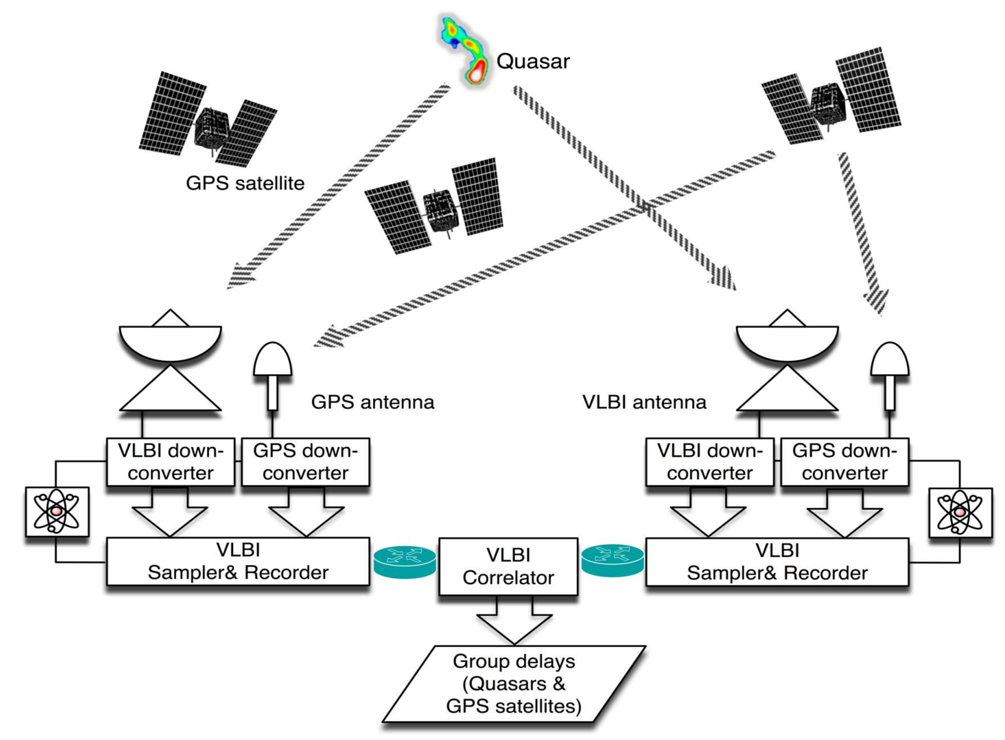

Fig 1 Schematic diagram of the GNSS-VLBI hybrid system

This system has been successfully implemented at two test sites, Kashima and Koganei, and its performance was validated in 24 hour experiments by Kwak et al.(2011)[1].

[1] Kwak Y et al. (2011) Validation Experiment of the GPS-VLBI Hybrid System, In Proceedings of the 20th EVGA Meeting

2. A Global GNSS-VLBI Hybrid Network based on CONT11

In the previous validation experiment of Kwak et al. (2011), GV hybrid observations were carried out on a single and short (109km) baseline, which is insufficient to estimate global parameters such as satellite positions, source coordinates, and EOP.

In a global network, sites should be stable and homogeneously distributed and - for budgetary reasons - it is effective to use existing GNSS antennas co-located with VLBI antennas for the GV hybrid system.

In this work, we construct GV hybrid observations (not real measurements) during IVS CONT11 campaign. The IVS CONT network has a reasonably balanced geographical distribution of stations between the northern and southern hemispheres and simultaneously acquires GNSS data through international GNSS Service (IGS) sites.

Fig 2 Global network: CONT11 sites using the same clock for both VLBI and GNSS

Especially seven sites use identical clock for VLBI and GNSS (Fig 2). While we take quasar group delay measurements for VLBI, differenced values of post-processed range values (single differences with most errors corrected) are used for GNSS. We regard those data set as GV hybrid observations in this analysis. Here, we call the observation value "delay" according to VLBI terminology.

3. How to Combine

vie_init

- Modified VieVS to handle multi directional scans for GNSS satellites
- Construct sequential delay values regardless of data types (Fig 3).

vie_mod

- VLBI: the consensus model
- GNSS: the model of Klioner (1991)[2] (Plank et al., 2014[3]).
- Except geometric models, other geophysical models are same for both of them

vie_lsm

- The design matrix contains both VLBI and GNSS partial derivatives (Fig 4).
- The constraint conditions for parameters are also same for both of them.

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                                   :
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  ...
                                   :
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Fig 3 GNSS-VLBI hybrid observation data

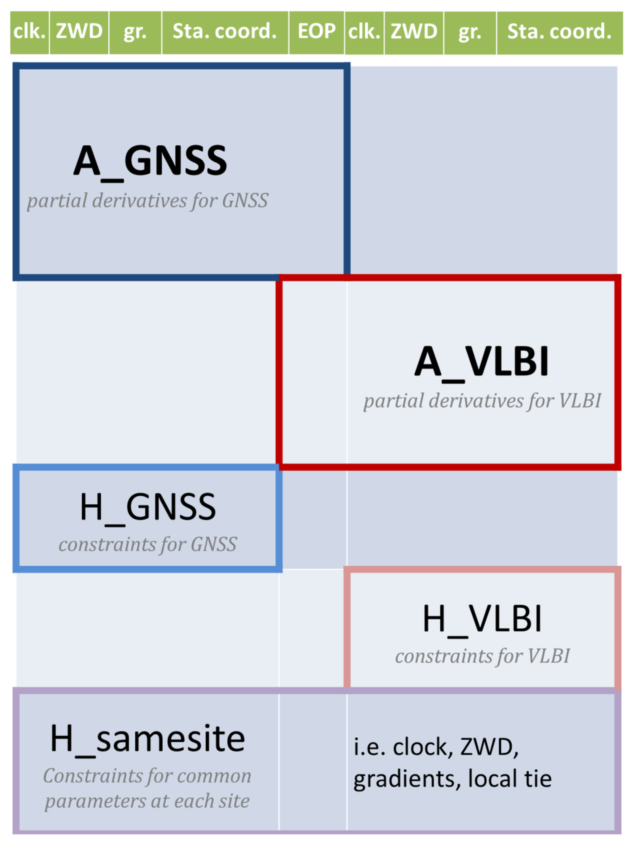


Fig 4 Design matrix combined with GNSS and VLBI

In the future, the parameters under common environments, i.e. same site, will be constrained each other. Local tie vectors between techniques at the same sites will be also added as station coordinate constraints.

[2] Plank L et al. (2014) Precise station positions from VLBI observations to satellites: a simulation study, J Geodesy, doi: 10.1007/s00190-014-0712-1

[3] Klioner S (1991) General Relativistic Model of VLBI Observables. In: Proceedings of the AGU Chapman Conference on Geodetic VLBI: Monitoring Global Change, pp 188–202, NOAA Technical Report NOS 137 NGS 49

4. Preliminary Results

(1) WRMS of post fit residuals of single technique and combined data [cm (ps)]

GNSS only	VLBI only	GNSS +VLBI
3.3 (111.1)	1.5 (51.1)	3.3 (110.7)

(2) Zenith wet delays

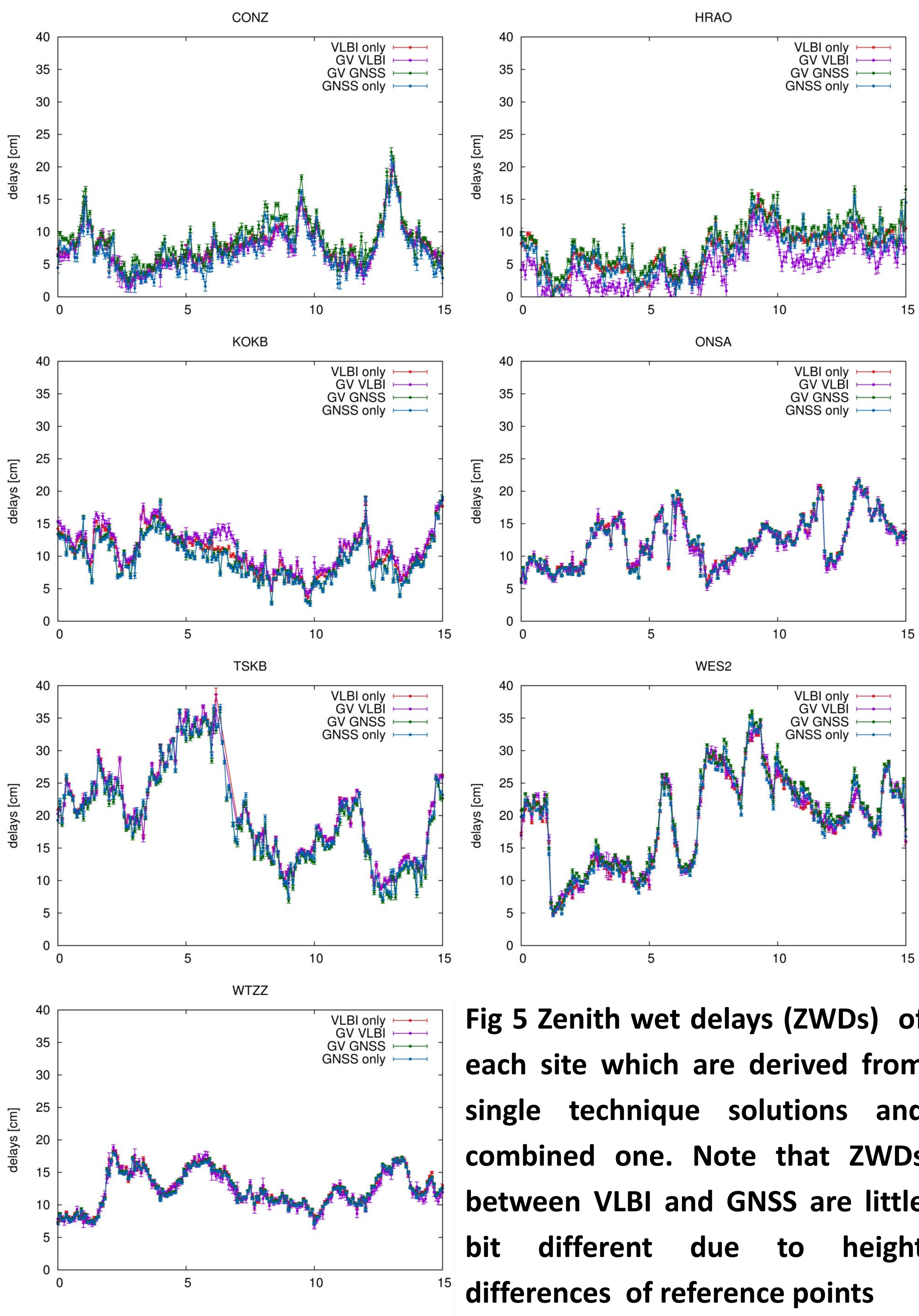
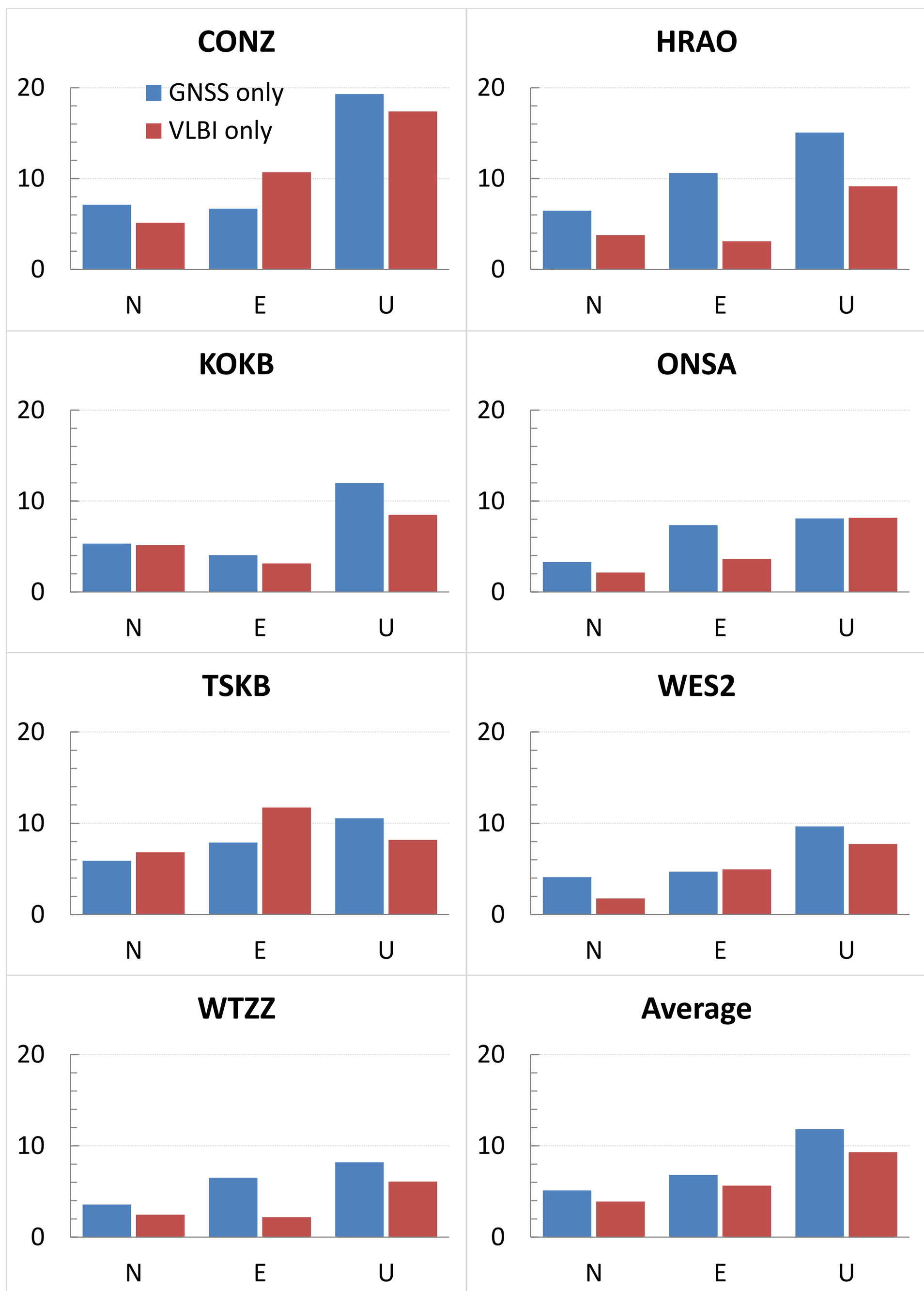


Fig 5 Zenith wet delays (ZWDs) of each site which are derived from single technique solutions and combined one. Note that ZWDs between VLBI and GNSS are little bit different due to height differences of reference points

(3) Station position repeatabilities for single technique solutions during CONT11 period (15days).



- ✓ The purpose of this work is to modify and test VieVS for GV hybrid observations
- ✓ The data were successfully processed in modified VieVS and we found centimeter-level accuracy of the models involved for GNSS delays in terms of post fit residuals.
- ✓ ZWDs are well agree with each other (single vs. combined) within 2cm except HRAO.
- ✓ Most of station position repeatabilities are mm-level for both single techniques.
- ✓ Here, we do not present the other combined solutions since they need further investigation.
- ✓ In future, we will do further development of VieVS for site common parameter handling

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