On the Analysis of VLBI Observations to GNSS Satellites

Younghee Kwak[1], Johannes Boehm[1], Thomas Hobiger[2] and Lucia Plank[3]

[1]Vienna University of Technology, [2]Chalmers University of Technology, [3]University of Tasmania

younghee.kwak@geo.tuwien.ac.at

Project Nr. M1592-N29 Supported by FWF Der Wissenschaftsfonds.

1. GPS-VLBI Hybrid Observation for Geodesy

The GPS-VLBI (GV) hybrid system is an observation method to combine GPS, one representative of the GNSS, and VLBI techniques at the observation level. In the GV hybrid system, GPS antennas are regarded as small VLBI antennas that receive GPS satellite signals. In other words, VLBI observations are made to quasars and GPS 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 GPS antennas to receive the GPS signals (Fig 1). Both GPS and VLBI antennas are connected to the same hydrogen maser clock at the site, which will diminish systematic errors between both techniques and reduce the number of clock parameters to be estimated. Since GPS 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.

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)*. Nevertheless, the GV hybrid system is not fully exploited yet and needs further development in the instrument itself and analysis strategies.

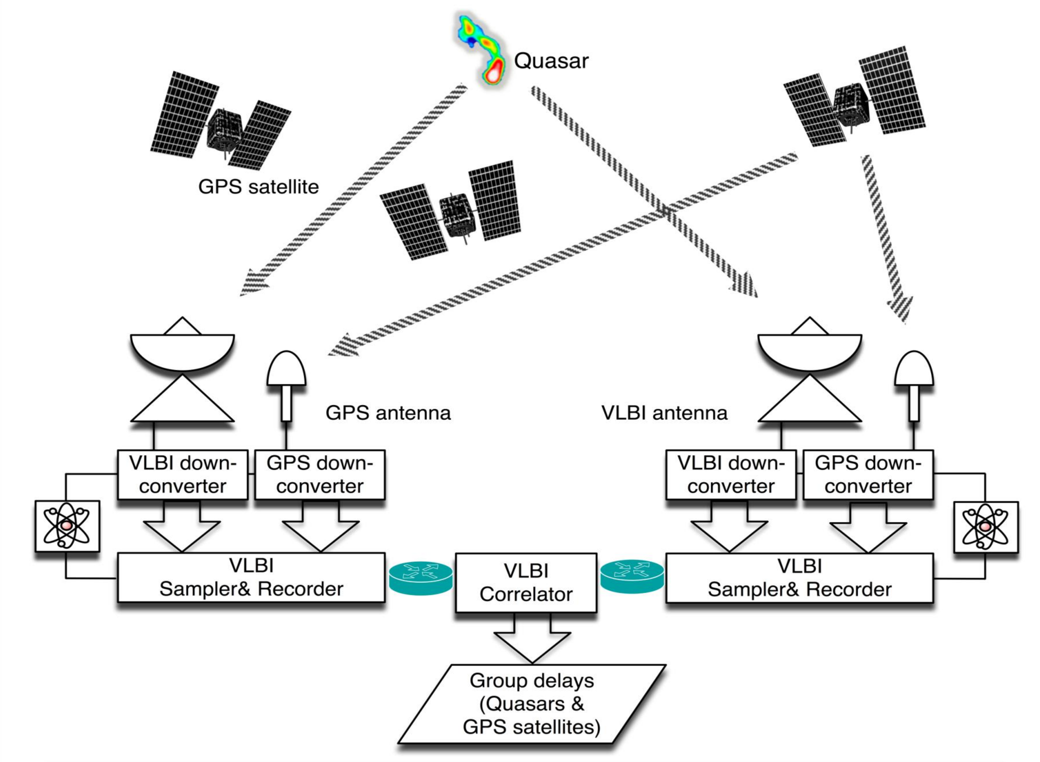


Fig 1 Schematic diagram of the GPS-VLBI hybrid system

The project "GPS-VLBI Hybrid Observation for Geodesy", which is funded by the Austrian Science Fund (FWF), will conduct those developments in the following aspects.

- Defining a global GV hybrid network and simulate the impact of global GV hybrid observations
- Calibration system design of GPS part
- Correlation model for GPS signals
- Geometric delay model of GPS satellites
- Tying GPS satellites to CRF

For more general purpose, GPS of GV Hybrid observation will be extended to GNSS.

In this poster, we discuss a global GV hybrid network and test the VieVS modules for VLBI Observations to GNSS Satellites based on real GPS observation data.

**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

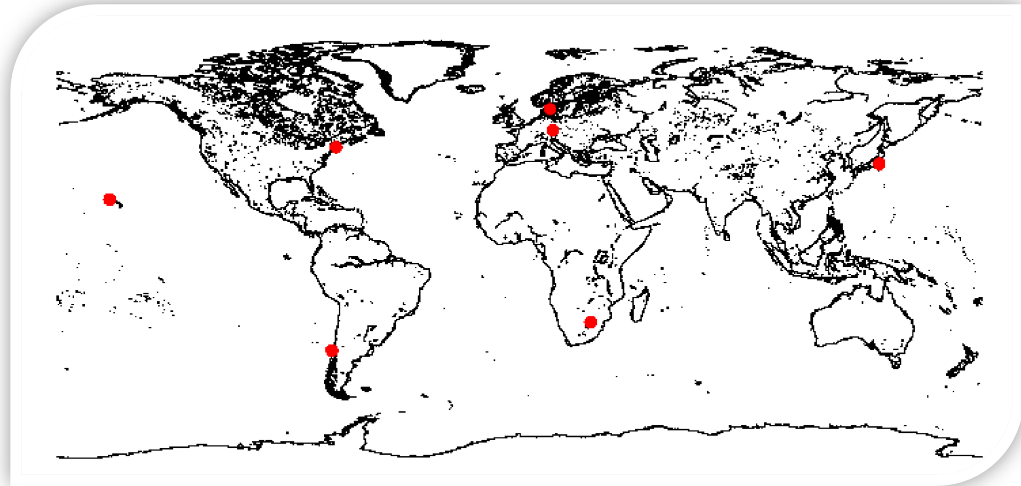


Fig 2 Global network: CONT11 sites using the same clock for both VLBI and GNSS

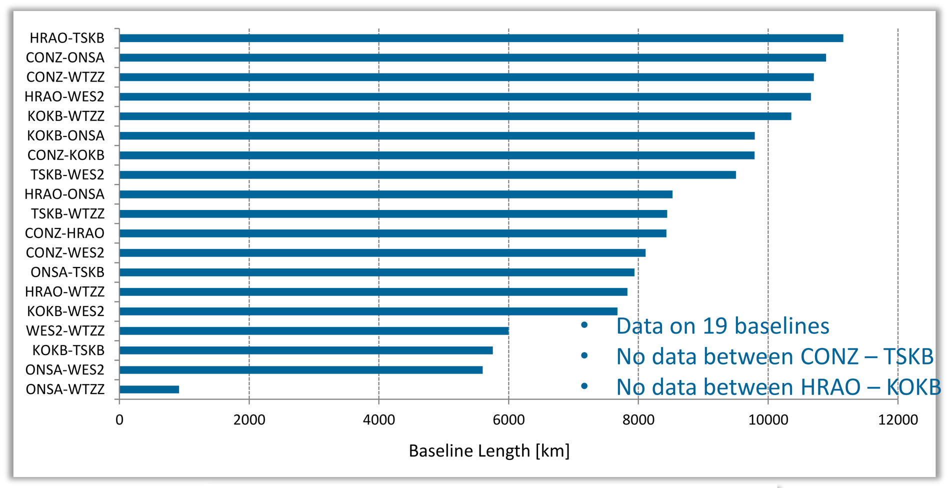


Fig 3 Baselines of global network

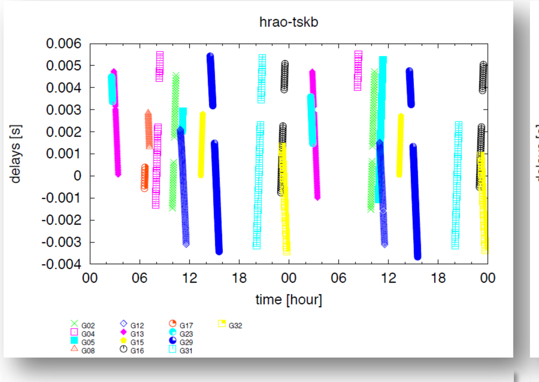


Fig4 Delays from the longest baselines HRAO-TSKB (11158.56 km)

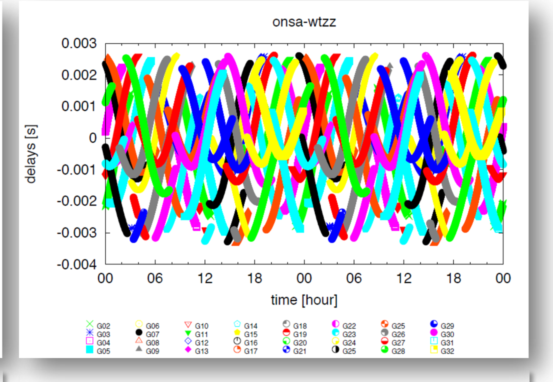


Fig 5 Delays from the shortest baseline (ONSA –WTZZ, 919.7 km)

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 must be stable and homogeneously distributed and - for budgetary reasons - it is effective to use existing GNSS antennas for the GV hybrid system at existing VLBI sites. The IVS CONT network has reasonably balanced geographical distribution between northern and southern hemisphere and simultaneously acquires GNSS data. Therefore, we will use same CONT11 sites for a global GV hybrid network in the further investigations (Fig 2).

3. VieVS for VLBI Observations to GNSS Satellites

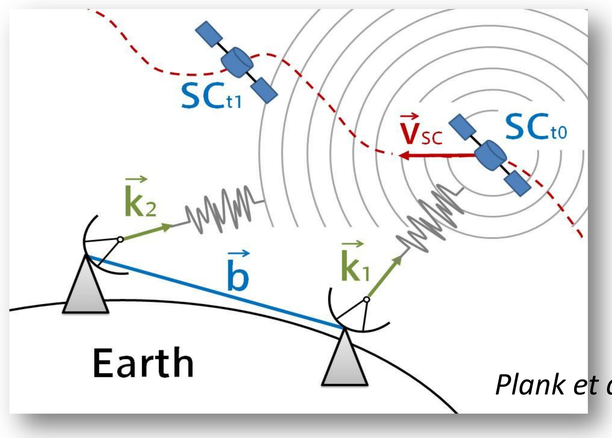


Fig 6 VLBI to moving sources at finite distance

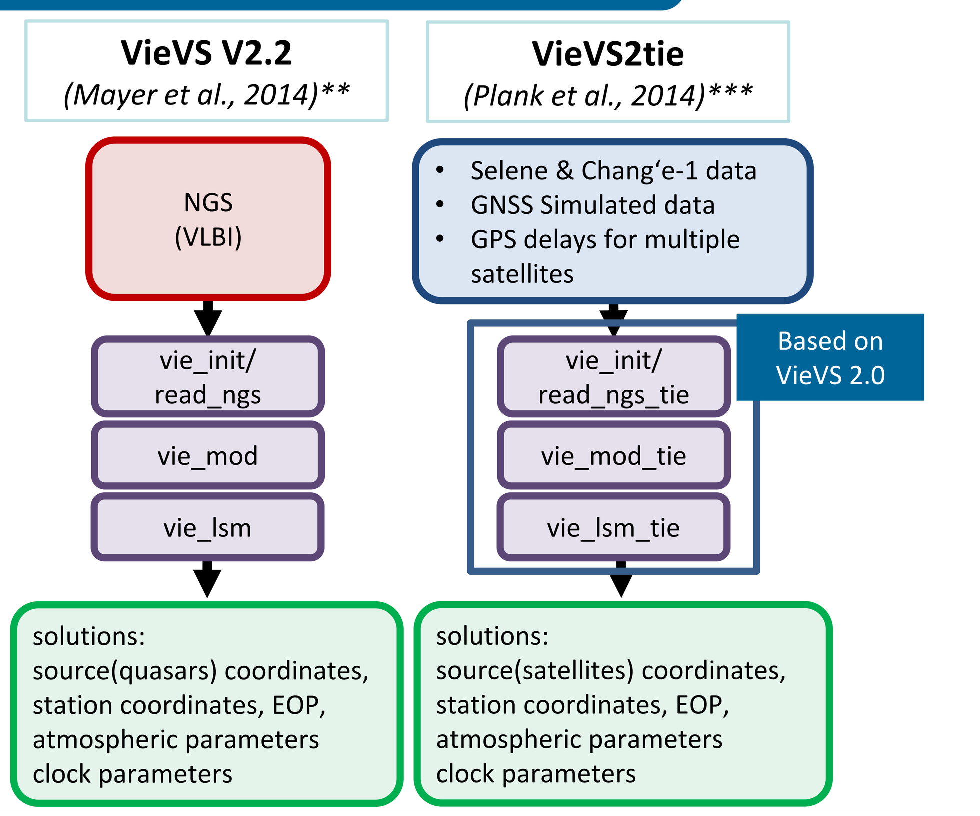


Fig 7 VieVS for processing VLBI data and space craft tracking data

In VieVS, we implemented processing of Selene same beam data, Chang'e-1 VLBI tracking data and Glonass GNSS observation data (Fig 7). All of those space crafts are tracked by big radio telescopes like quasars in VLBI. This type of GNSS observation is especially good for frame tie between VLBI and GNSS. However, the telescopes can watch only one direction (1-2 sources) per scan and need to slew the antenna to continuously track the satellite (Fig 6). For scheduling and analysis, those features are already included in VieVS. In the case of GV hybrid observation, non-directional GNSS antennas will receive every signal from each satellite in the sky at the same time. VieVS is modified to handle multi directional scans.

VieVS has dealt with simulated data, which are composed of zenith wet delay, clock parameters and white noise, for GNSS satellites because there is no real observation data so far. For more realistic application, we generate fake GPS delays based on real GPS observations. For more details, see section 4. Currently, VieVS is able to read and process those GPS delays.

**Mayer D et al. (2014) VieVS 2.2: The new release of the Vienna VLBI Software, REFAG2014
***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

4. Data & Analysis

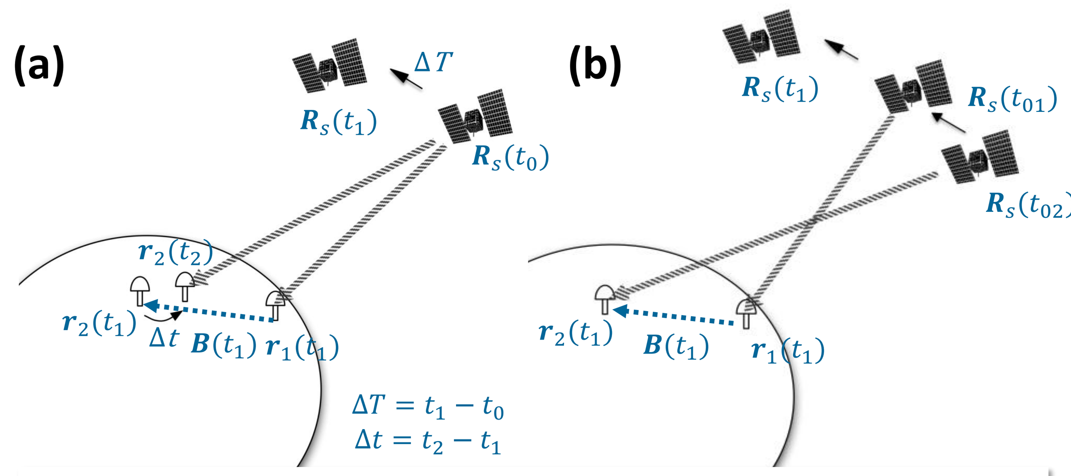
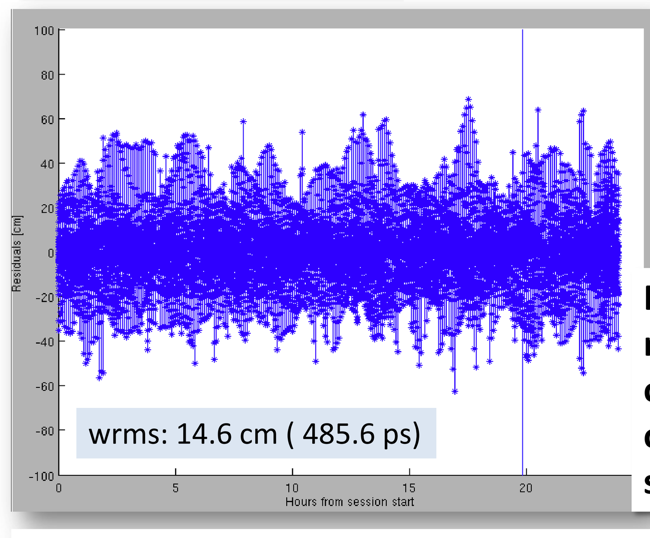


Fig 8 Original scheme of VLBI observation to GNSS satellite (a) and the test data in this work (b)

In either case, satellite tracking or GV hybrid system, the data type for GNSS satellites is the difference between the ranges from two stations to a satellite. Those data are attained from VLBI correlator directly and we assume that we receive same signals which are emitted at the same time(t_0) from a source. Therefore, receiving times are different at each site. Moreover, the baseline keeps moving during the time difference (Fig 8a).

However, it is still difficult to acquire those observations. Thus, in this work, we apply post-processed range measurements from a precise point positioning (PPP) GPS solution with the C5++ software to build those difference values (delays) which are then used in VieVS. We use seven CONT11 sites using the identical clock for both VLBI and GNSS (Fig 2). Because we know the range values at receiving time(t_1), we do not need to take account of the retarded baseline effect but should consider the different positions of the satellite at different emission times (Fig 8b). In VieVS, we slightly modified the original model of VLBI observation to GNSS satellites to adapt to those features.

For the estimation, we fixed IGS final orbits for GPS satellite positions and take IERS 08C04 as a priori EOP. We corrected tidal effects only for solid earth tide and pole tide. We estimated clock parameters, zenith wet delays, gradients, X-&Y-pole , DUT1, and station coordinates.



Number of	
scans (every 5min.)	5511
stations	7
sources	32
observations	13732

Fig 9 The post –fit residual plot of VLBI observation to GNSS (GPS) on the first CONT11 session day

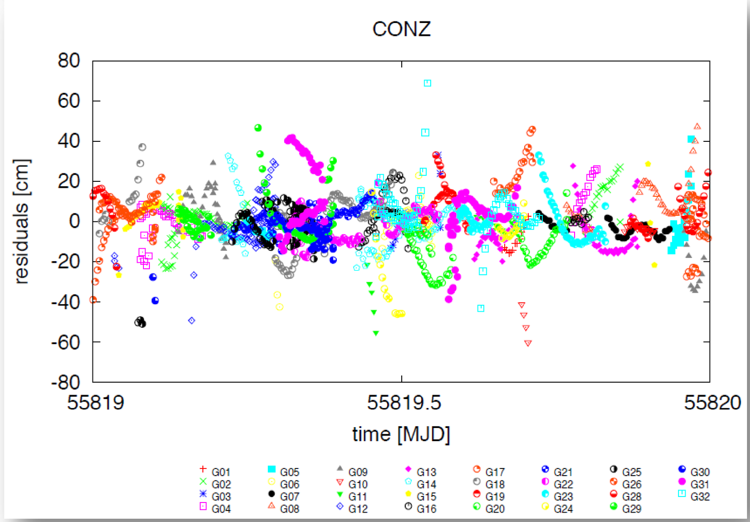


Fig 10 The post –fit residual plot of CONZ site (Concepcion, Chile). Each symbol means each satellites.

Fig 9 shows the post-fit residual plot of the first CONT11 session day. The residuals of the other sessions also have similar amount of statistics except a few sessions. In residuals, there are still some systematic variations, which seem to depend on satellites (Fig 10). Since the satellites moves so fast and thus their positions are quite sensitive to time, the emission time will be revisited. After resolving those systematic effects, we will continue the combination processing of VLBI and GNSS with VieVS.