A Giant Step: from Milli- to Micro-arcsecond Astrometry
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Tropospheric correction in VLBI phase-referencing using GPS data

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Abstract. Comparing the tropospheric zenith delays derived from VLBI and GPS data at VLBA stations collocated with GPS antenna, the systematic biases and standard deviations of the difference are both found to be at the level of a sub-centimeter. Based on this agreement, we used GPS data to correct the tropospheric effects in VLBI phase-referencing, resulting in close peak-to-noise ratios of images after tropospheric correction using GPS and VLBI data.

Keywords. atmospheric effects, astrometry

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1. Introduction

The dominant error source of astrometry involved in VLBI phase-referencing is the small error of the tropospheric delay model, which is applied by the VLBA correlator at observing frequency greater than 5 GHz (Wrobel *et al.* (1999)). The current method applied to correct this error is using geodetic-like observations to determine the residual (Observation - Model) tropospheric zenith delay (Reid & Brunthaler (2004)). However, this method only recovers the global variation, but neglects the local variation of the residual zenith delays, such as fluctuations which might be significant at some VLBI stations (Keihm *et al.* (2004)). Since the GPS measurements near the VLBI site are subject to the same troposphere, those measurements can be used to estimate the tropospheric contribution to VLBI observables. In the data analysis of project BR100, which determines the parallax and proper motions of 12 GHz methanol masers using VLBI phase referencing by VLBA, we used several geodetic-like observation data sets of phase-referencing observations, and among those observations, about six VLBA sites with VLBI and GPS data are available. To study the feasibility of tropospheric correction in VLBI phase-referencing using GPS data, we compared the tropospheric zenith delays derived from VLBI and GPS data at these VLBA stations, and the PNRs (peak-to-noise ratios) of images with tropospheric effects corrected using only VLBI data or combined GPS and VLBI data.

2. Tropospheric correction using combined VLBI and GPS data

Some VLBI stations are collocated with GPS antennas, and many studies indicate that the difference between tropospheric delays derived from VLBI and GPS data is at the sub-centimeter level (Niell *et al.* (2001); Schuh *et al.* (2004)). This motivates us to calibrate the VLBI data using tropospheric estimates from GPS data. At present only six VLBA sites are collocated with GPS receivers. IGS (the International GNSS Service)

Table 1. Biases (front) and standard deviations (back) in cm between VLBI and GPS (VLBI − GPS) residual zenith delays for VLBA BR100 observations.

Obs. Date	BR	FD	MK	NL	PT	SC
2005.10.20	-1.5 ± 1.0	-1.0 ± 0.5	-0.7 ± 1.0	-1.6 ± 1.0	...	...
2005.10.30	-0.6 ± 0.3	0.3 ± 0.6	-1.2 ± 0.8	-1.1 ± 0.3	-1.1 ± 0.2	-0.6 ± 0.7
2006.01.13	-0.6 ± 0.5	-0.3 ± 0.3	-0.6 ± 0.7	-1.2 ± 0.5	-1.2 ± 0.9	-0.7 ± 0.4
2006.03.16	-1.1 ± 0.3	-1.1 ± 0.6	0.1 ± 0.5	-0.9 ± 0.6	-0.9 ± 0.1	-0.8 ± 0.7
2006.04.07	-0.7 ± 0.6	-0.9 ± 0.4	-1.1 ± 0.5	0.1 ± 1.4	...	0.1 ± 0.5
2006.04.15	-1.3 ± 1.1	-0.9 ± 0.5	0.2 ± 1.5	-1.9 ± 0.7	...	-0.9 ± 0.2
2006.07.23	0.3 ± 0.7	1.4 ± 0.2	...	-0.5 ± 1.0	-0.5 ± 0.6	-0.1 ± 0.8
2006.10.04	-1.0 ± 0.3	-0.2 ± 0.6	-0.6 ± 1.0	-2.2 ± 0.5	-1.2 ± 0.3	-0.6 ± 0.9
2006.10.07	-0.6 ± 0.5	0.6 ± 0.9	-1.2 ± 0.4	-0.8 ± 0.1	-0.9 ± 0.5	-1.8 ± 1.0
2006.10.19	0.5 ± 0.6	-0.3 ± 1.5	-0.8 ± 0.4	-0.8 ± 0.2	...	...

Table 2. Comparison of PNR of image

Source	PNR(VLBI)	PNR(GPS)
G35.20-0.74(Maser)	100.1	103.7
J1855+0215(QSO)	15.1	16.4
J1855+0251(QSO)	15.6	14.1
J1907+0127(QSO)	6.7	6.8

publishes routinely the tropospheric zenith delays derived from GPS measurements of each site, offering us an opportunity to estimate the zenith delay at the corresponding VLBA sites based on GPS data. We compared the residual zenith delays derived from VLBI and GPS data of several geodetic-like observations. Table 1 shows the comparison, with the biases and STDs being at the level of sub-centimeter. Table 2 illustrates the PNRs of images of sources with tropospheric effects corrected, with the second and third columns listing PNRs only using geodetic-like VLBI data and combined GPS and VLBI data respectively. (Note that here sites with available GPS data use GPS data only; otherwise only VLBI data are used.) Differences between the PNRs are found to be small. Based on the agreement noted in the above comparison, we suggest to correct the tropospheric effects in VLBI phase-referencing with combined VLBI and GPS data, in which case the precision of correction will be at the sub-centimeter level.

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