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# Comparison of Atmospheric Parameters from VLBI, GPS and WVR

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**Abstract**

The comparison of atmospheric parameters (equivalent zenith wet delay and linear horizontal delay gradients) derived from VLBI, GPS, and WVR has been carried out to reveal the limitation of the anisotropic mapping functions. The horizontal delay gradient components from all these techniques at Kashima and Shintotsugawa are not consistent with each other while the agreement for the zenith wet delay estimates are significant. Moreover, we perform a numerical simulation of the atmospheric parameters using a non-hydrostatic numerical weather model to assess the utility of the anisotropic model.

## 1. Introduction

Radio signal delay associated with the neutral atmosphere is one of the major error sources for space-based geodetic techniques such as the Global Positioning System (GPS) and Very Long Baseline Interferometry (VLBI). The comparison of atmospheric parameters (equivalent zenith wet delay and linear horizontal delay gradients) derived from VLBI, GPS, and WVR has been carried out to reveal the limitation of the anisotropic mapping functions. We are also evaluating those parameters by comparing with the ray-traced slant path delay through the two days data sets of the non-hydrostatic numerical weather prediction model with 1.5 km horizontal resolution. We describe our preliminary findings based on these comparisons.

## 2. Observations and Data Analysis

We carried out WVR observations nearby VLBI and GPS stations of the Kashima Space Research Center from June 1998 to October 2001 with several periods of interruption. Kashima station was one of the Key Stone Project (KSP) geodetic network. In addition another WVR observation was carried out at one VLBI station (Shintotsugawa) of Geographical Survey Institute (GSI). These stations are shown in Figure 1. For these observations, we use the Radiometrics$^{TM}$ WVR1100, which has an optional azimuth driver to point to any sky direction.

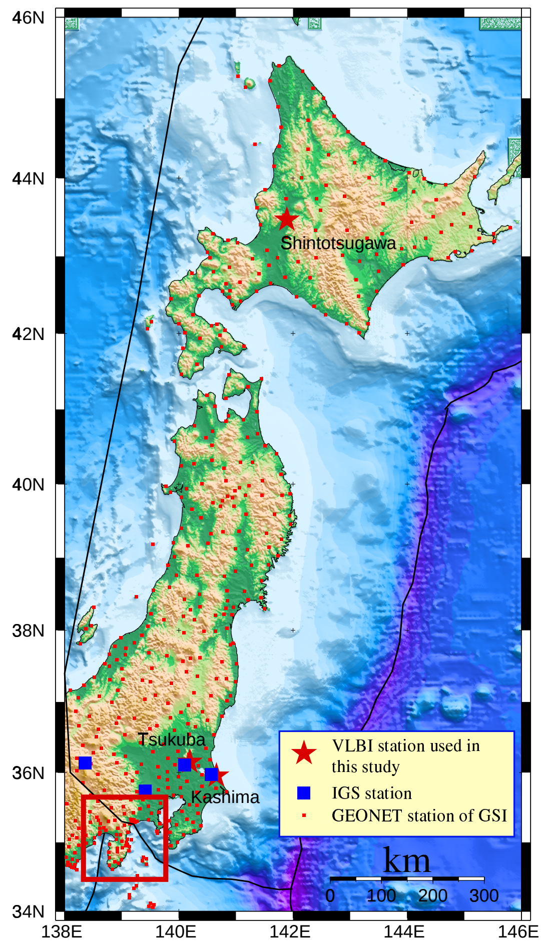


Figure 1. Map showing VLBI stations for the comparison of atmospheric parameters

We analyze atmospheric parameters obtained from all these techniques. The WVR-based gradient vector was estimated as a piecewise linear function with three-hour intervals by fitting the observed slant delays to the Chen and Herring gradient model [2]. The VLBI data were analyzed using the CALC/SOLVE software package [3], applying the Niell mapping functions [5] and the gradient model. The GPS data were analyzed using the Bernese software package [1] applying the same mapping functions as included in SOLVE.

We are also evaluating those parameters by comparing with the ray-traced slant path delay through the non-hydrostatic numerical weather prediction model (NHM) with 1.5 km horizontal resolution. This NHM provides temperature, humidity and geopotential height at the geosurface and at 38 surfaces of constant pressure (which vary between 1000 and 10 hPa), for each node in a 1.5 km by 1.5 km grid that covers the Izu Peninsula region which is indicated by a gray square as shown in Figure 1.

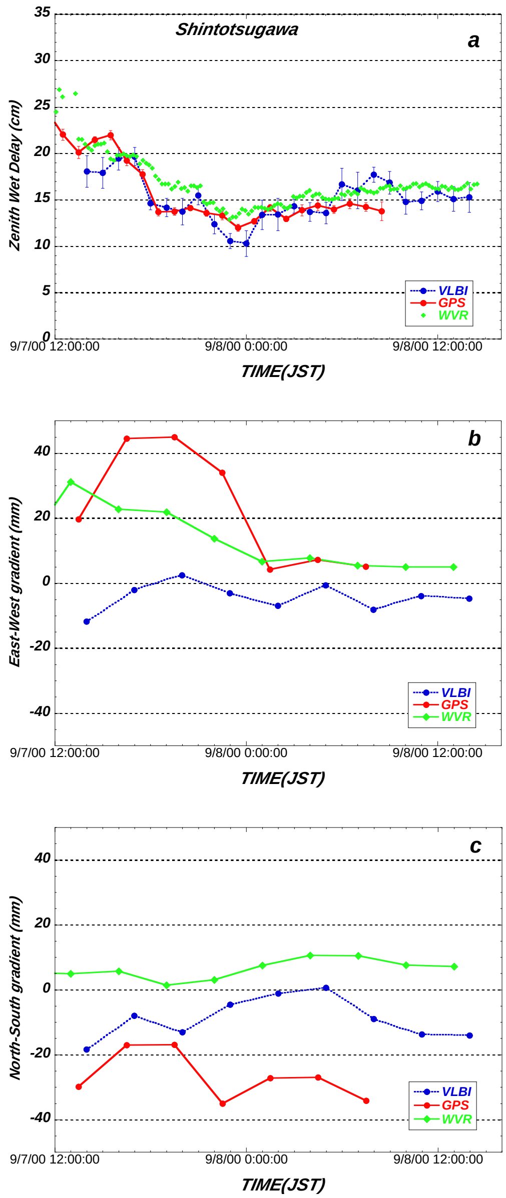


Figure 2. Time series of atmospheric parameters at Shintotsugawa: a), the zenith wet delays, b), the east delay gradients, c) the north delay gradients.

## 3. Results

### 3.1. WVR Observations

We find estimated weighted RMS differences below the 10-millimeter level and correlation coefficients more than 0.8 for the zenith wet delays derived from GPS and WVR in Kashima. However, RMS differences between the zenith wet delays derived from VLBI and those from WVR are more than 50 millimeters. In addition, the agreement for the estimated horizontal delay gradients from these three techniques is less clear. The discrepancy between the VLBI results and other techniques is caused by the difficulty to estimate the vertical position, the clock offset and tropospheric parameters independently due to the relatively short baselines (about 150 km at maximum) of the KSP network. The comparison at Kashima is described in more detail in Ichikawa et al.(2001) [4].

We performed other WVR observations at Kashima and Shintotsugawa in order to investigate atmospheric parameters for the longer baseline. The baseline length between them is about 850 km. Figure 2 shows the time series of the atmospheric delay parameters using WVR at Shintotsugawa. The zenith wet delays (ZWD) obtained by WVR are well consistent with the those estimated from VLBI from 1200JST of 7 September to 1400JST 8 September 2000 as shown in Figure 2(a). GPS-derived ZWDs are also consistent with the other measurements as shown in the same figure. Unfortunately, we could not observe ZWD using WVR at Kashima because it was raining in Kashima at that period.

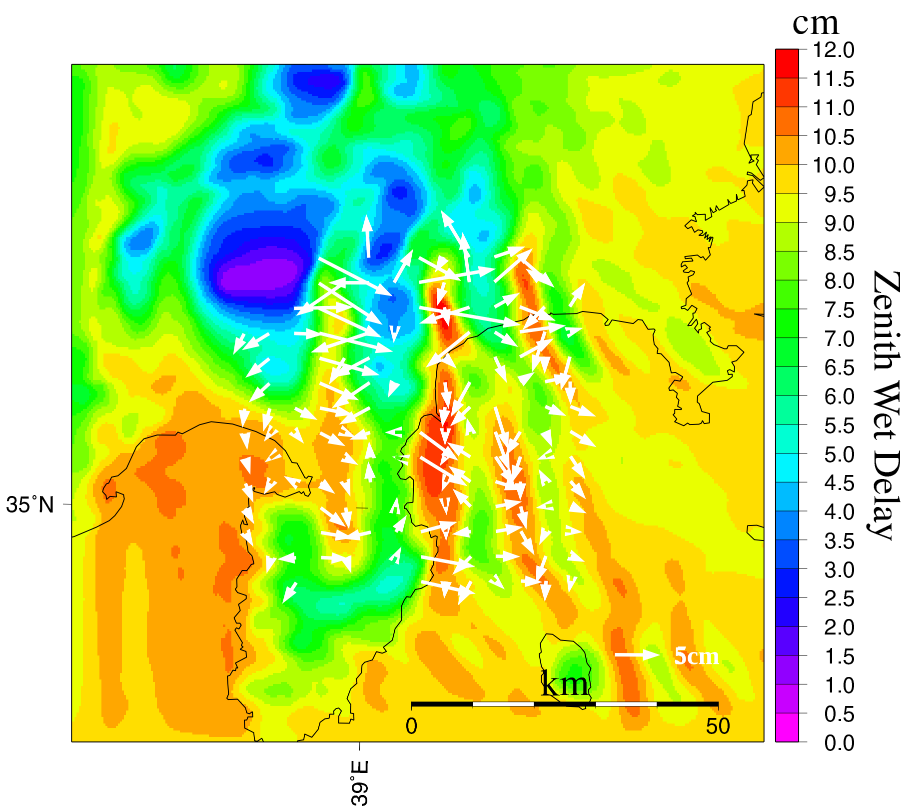


Figure 3. Zenith wet delay retrieved by the 1.5 km NHM at the 1200UT of March 7, 1997. Arrows indicate gradient vectors estimated by the best-fit anisotropic model to the ray-traced pointed delays through the 1.5 km model.

In the Figure 2 we show the estimates of the EW (b) and NS (c) gradient components. The agreement of the results for the gradient components is still less clear as same as the result from KSP network [4]. The WVR results indicate a positive contribution while the VLBI results tend to a negative contribution for both east and north components. However, both time series have a similar pattern. The GPS results present quite different pattern from other results obtained by WVR and VLBI. This cannot be explained by the contamination of the hydrostatic delay gradient which is not sensed by the WVR. It might be caused by the multipath effect of the GPS and/or WVR observations since we use an elevation cut-off angle of 10 degrees which is chosen in the VLBI observation strategy. Further investigations and recomparisons based on the different analysis strategy are necessary.

### 3.2. Numerical Simulation Using NHM

We calculate the slant delay using ray-tracing technique through the one day data set of the 1.5 km NHM at 1200 UT March 7, 1997. At each station we traced about 100 rays to the station with roughly uniform density (count per unit solid angle) on the upper hemisphere, so as to approximate a sampling geometry similar to both GPS and VLBI. The ZWD field in Izu peninsula is illustrated in Figure 3 as an example. This figure demonstrates the significant ZWD gradient in the east of the peninsula. The sharp gradient is caused by a mountain wave. We also represent the gradient vectors retrieved from the best fit anisotropic model to the ray-traced delays in the same figure. Maximum gradient vectors are plotted in the high ZWD region. In addition the directions of the vectors in this region represent complex distribution corresponding with the local variability of the ZWD distribution. In order to assess the slant delay estimations and the utility of the anisotropic model we will perform a statistical analysis.

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