COMPARISON OF WET DELAY ESTIMATES USING VLBI, GPS, AND WVR DATA AT THE ONSALA SPACE OBSERVATORY DURING SEARCH'92

G. Elgered, J. M. Johansson  
Onsala Space Observatory, Chalmers University of Technology  
S-439 92 Onsala  
Sweden

J. L. Davis  
Harvard-Smithsonian Center for Astrophysics  
60 Garden St., CAMBRIDGE, MA 02138  
USA

ABSTRACT. Unmodeled variations in the wet propagation delay are a major source of error in space geodetic techniques using radio signals, such as VLBI and GPS. The most common method to deal with this error is to estimate the equivalent zenith wet delay at each site. Wet delays estimated using VLBI and GPS data are compared with microwave radiometer measurements.

1. Introduction

It is well known that the varying amount of atmospheric water vapor affects the propagation time of a radio signal. The common method to deal with this excess propagation time in radio based space geodetic techniques is to estimate an atmospheric correction using the geodetic data themselves. This correction may be modelled as a constant, a piece-wise linear function, or a stochastic process. In this study we compare estimates of the wet propagation delay using two space geodetic techniques, Very-Long-Baseline Interferometry (VLBI) and the Global Positioning System (GPS) with estimates from a ground-based microwave radiometer. The model used in both the VLBI and the GPS analysis is a Markov process or more specifically a random walk process.

The variance between values separated by the time $\Delta t$ for a random walk process scales linearly with the separation

$$<(x(t + \Delta t) - x(t))^2> = \sigma^2 \Delta t$$  \hspace{1cm} (1)

In addition to study the influence of the wet delay on the accuracy of VLBI and GPS another goal of this work is to evaluate the use of GPS networks for meteorological measurements (see, e.g., Bevis et al. (1992)).

2. Instrumentation and Estimation Techniques

The maximum distance between the 20 meter radio telescope used for VLBI observations, the GPS antenna and the Water Vapor Radiometer (WVR) is approximately 80 m. The

The intersection of azimuth and elevation axises of the VLBI antenna is 22 m above the mean sea level whereas both the GPS and WVR antenna heights above sea level are 9 m. This means that for a standard atmosphere with a scale height equal to 2 km the VLBI antenna senses a wet delay which is 0.6% less than the other two methods. This effect is of the order of 1 mm and will be ignored in the following.

Three contiguous 24 hour long VLBI experiments were carried out during July 1992. The two first were dedicated mobile experiments and the third was IRIS-A 751. All of them included the mobile VLBI antenna (MV-2) at Hófn, Iceland. Because of the lower sensitivity of the mobile VLBI antenna typically 180 observations were carried out during one 24 hour experiment. For example, the R&D experiments during 1993, using larger antennas, typically include 300 observations at each site.

The GPS receiver, a Rouge SNR-800 with a Dorne-Margolin antenna operated continuously without any problems during this time period.

The WVR, measuring the atmospheric emission at 21.0 and 31.4 GHz was operated in a “sky mapping mode” with a cycle of approximately 8 minutes rather than pointing at each VLBI source. Approximately 60 observations spread over the sky down to an elevation angle of 23° was acquired during one such cycle.

The VLBI estimates use observations down to elevation angles of approximately 7°. The hydrostatic mapping function is used to calculate the actual hydrostatic delay from the equivalent zenith value based on ground pressure observations (Davis et al. 1985). The wet delay is estimated using a special wet delay mapping function (Chao 1972). The VLBI data analysis is carried out with the SOLVK software (Herring et al. 1990). The value of the random walk variance, $\sigma^2$ in (1), is estimated for each site using the delay rate residuals. For the three experiments the estimated values of $\sigma^2$ were 0.19, 0.90, and 0.46 ps$^2$/s, respectively.

The GPS estimates use observations down to an elevation angle of 15°. One mapping function (Lanyi 1984) is used to estimate the total propagation delay in the GIPSY software (Lichten and Border 1987). The standard value used for the data in this study was 0.32 ps$^2$/s. The wet delay is, thereafter, calculated by subtracting the zenith value of the hydrostatic delay based on the ground pressure observations. In this presentation a mean ground pressure has been used for each day but this will be improved in the near future.

The microwave radiometer data are presented as equivalent zenith values of actual observations at different elevation angles using the simple cosecant law. In this data set the radiometer was scanning the entire sky but always above an elevation angle of 23°. Otherwise the typical observation strategy using the WVR is to observe in the same direction as the VLBI antenna and perform so called tip-curves during the time between the VLBI observations.

3. Results

Below we present the estimated wet delays using the three different methods. Figure 1 shows the results when the GPS data were processed in 24 hour long daily data sets independently. It should be noted that when we processed the first two days of GPS data, the large increase in the wet delay around midnight between July 25–26 is in better agreement with the WVR and the GPS data. The VLBI processing has been made independently for each experiment.
Figure 1. Comparison between estimated equivalent zenith wet delays using GPS, VLBI and microwave radiometer data. In order to make it easier to compare the results biases of +5 cm and -5 cm have been added to the GPS (upper curve) and VLBI (lower curve) estimates, respectively. The microwave radiometer data (middle curve) have been acquired by scanning the instrument in azimuth and elevation in a cycle repeated every 12 minutes.

4. Discussion

Slowly varying differences at the centimeter level exist between all data sets. The typical mean biases calculated for one day is about 1 cm. This is true also when the imperfect correction of the hydrostatic delay in the GPS data sets is taken into account.

The WVR data are less accurate when there are large amounts of liquid water in the atmosphere. An advantage is, however, that the liquid water content can be estimated simultaneously with the wet delay using the WVR data. In this presentation we have discarded all data for which the estimated integrated liquid water content is larger than 0.7 mm. In the evening of July 26 the rapid increase suggested by the WVR data is supported by the VLBI data. (The liquid water content at the peak is 0.7 mm.) On the other hand events with a liquid water content of 0.7 mm have been seen in other data sets where the WVR data seem to overestimate the wet delay.

5. Conclusions and Future Work

Variations in the wet propagation delay are in general "detected" by all three methods.
This type of comparison has proven valuable for detecting errors (such as ignored clock-breaks) in the VLBI and the GPS data analysis.

As more data are being analyzed the goal is to search for systematic differences in the wet delay estimates.

References


