Analysis and Research at the Haystack Observatory

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Abstract

The new atmosphere mapping functions based on a global numerical weather model reported last year have been evaluated by application to the twelve sessions of the CONT94 (1994 January) VLBI campaign. The anticipated reduction of baseline length scatter, which corresponds to the removal of 4 mm of error from the height coordinate, was confirmed.

The hydrostatic mapping function has been expanded to provide the hydrostatic gradient, based on the tilt of the 200 mb isobar.

The study to evaluate the possibility of measuring the phase center offset of the antennas on the GPS satellites by using VLBI was completed. Unfortunately, it appears unlikely that the offset can be measured with useful accuracy.

1. Geodetic Research at the Haystack Observatory

The primary objectives of analysis activities at Haystack Observatory are to improve the underlying models in order to obtain better accuracy and precision and to better understand the uncertainties that limit the space geodetic techniques. Since there are many similarities between VLBI and GPS, it is natural to investigate both common error sources and those that are unique in order to obtain the best results from both techniques. This has led us to study the atmosphere model, which can be applied to either, and the characteristics of both satellite and receiver antennas of GPS.

Atmosphere models

Gridded global numerical weather models provide *in situ* meteorological information. The geopotential heights of an isobaric surface, for example the 200 hPa surface, serve as a useful parameter for calculating the hydrostatic component of the mapping function [4]. The "tilt" of this surface also can be used as a measure of the hydrostatic gradient. Removal of the hydrostatic component of the atmosphere delay gradient is necessary before the contribution of the wet delay can be estimated.

The improvement of the azimuthally symmetric mapping functions relative to the widely used NMF [3] is shown in Figure 1 for the CONT94 baselines. The reduction in scatter corresponds to the removal of about 4 mm of height error, as shown in Figure 2. A second improvement since the IVS 2000 report, but which is not illustrated here, is the inclusion of atmosphere pressure loading. The removal of the error due to pressure loading increased the relative contribution of the mapping function improvement, making it more apparent than previously reported.

Realization that the slope of the 200 mb isobaric surface corresponds to the "tilt" of the hydrostatic atmosphere led to the proposal that this quantity can provide an apriori model for the hydrostatic gradient. This model has been implemented in *solvk* and the wet gradient estimated as a separate component using the wet gradient model of Chen and Herring [1]. Verification of the model by comparison with three-dimensional raytracing has yet to be done. A second important test is to compare the estimated wet gradients with measurements by WVR. This will be done using the Astrid WVR data taken at Onsala during CONT94.

VLBI, GPS, and the Terrestrial Reference Frame

The direction-specific instrumental delay (phase center variation) of GPS ground antennas differs by antenna model. The Dorne-Margolin choke ring antenna has been assumed to be uniform, but measurement of the phase pattern in anechoic chambers and by a rapid cycling among satellites by a "robot" [5] suggest a large elevation-dependent error. For this error to be reasonable the GPS satellites must have a compensating phase error to avoid a large discrepancy between GPS and VLBI in the scale of the terrestrial reference frame. A joint working group composed of representatives from the IVS, IGS, and ILRS and chaired by Brian Corey studied the feasibility of using differential VLBI observations of GPS satellites and nearby extragalactic sources to measure the phase pattern of the transmitted L1/L2 GPS signals. The aim was both to measure the phase center locations of the GPS phased array transmitters and to "map" the relative magnitudes and phases of the signals from the individual phased array elements. The required accuracy on the VLBI fringe phase is $< 10^\circ$, or < 5 mm in differential range, after correction for propagation media effects, extragalactic source position uncertainty, etc.

The limiting error source presented by the ionosphere appears to be too large to allow the technique to achieve the required accuracy to be useful. Furthermore, the VLBI resolution at the satellite is insufficient to map the individual elements. The report of the Working Group to the IVS Directing Board is in preparation.

2. Outlook

The GPS satellite antenna measurement study has been completed.

For the evaluation of the atmosphere models, the amount of data will be extended to cover at least a full year in order to evaluate any annual components in the results. In addition, validation of the gradient models using three-dimensional raytracing of numerical weather model atmospheres will be pursued.

References

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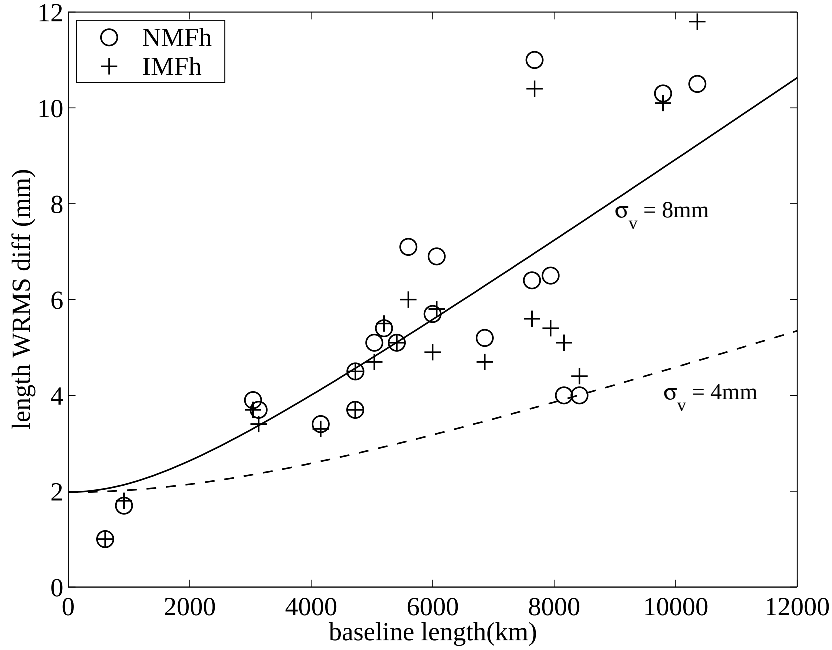

Figure 1. Baseline length repeatability for the CONT94 campaign showing the improvement using IMF instead of NMF. The minimum elevation is 5°.

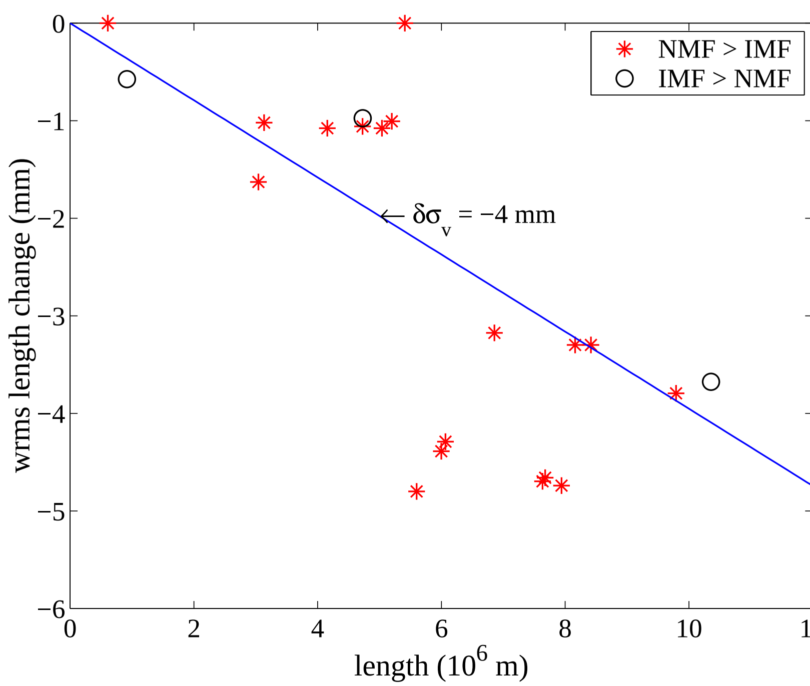

Figure 2. Reduction of baseline length scatter for the CONT94 campaign by using IMF instead of NMF. The line corresponds to removing 4 mm of vertical error at each site.