MIT Haystack Observatory Analysis Center Report

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Abstract

The data from twenty years of the NCEP numerical weather model have been used to calculate the IMF hydrostatic mapping function for several sites distributed in latitude from −66° to +78°. Comparison of heights estimated with the NMF hydrostatic mapping function demonstrates that using NMFh results in height errors at annual and semi-annual periods with amplitudes as large as approximately 8 mm and 4 mm, respectively, when data down to 5° are included. The errors are smallest at the equator and increase towards the poles.

1. Geodetic Research at the Haystack Observatory

The MIT Haystack Observatory is located approximately 50 km northwest of Boston, Massachusetts. Geodetic analysis activities are directed primarily to improving the accuracy of the estimation of atmosphere delay and thus reducing errors in the geodetic analysis. This work, along with operating the geodetic VLBI correlator and with supporting operations at the Westford, GGAO, Gilmore Creek, and Kokee Park geodetic sites, is supported by NASA through a contract with the Goddard Space Flight Center.

2. Periodic Errors in Atmosphere Models

New atmosphere mapping functions have been developed at MIT Haystack Observatory [4] and at Vienna University of Technology [2] that are based on Numerical Weather Models which provide *in situ* values for the atmosphere state variables of temperature, humidity, and pressure. These more accurate mapping functions then allow evaluation of the errors in previous generations of mapping functions.

The NMF hydrostatic mapping function [3] depends only on day of year, latitude, and height above sea level. The time dependence is simply an annual sinusoid with a fixed phase for all sites. Thus, if the phase or amplitude is wrong, or if there are higher order harmonics in the true mapping function, estimates of the local height and zenith atmosphere delay made using NMFh will have errors at those periods.

The IMF hydrostatic mapping function [4] has as the primary input parameter the 200 hPa geopotential height (hereafter referred to as *z200*) above the VLBI site. Values of this parameter from the National Center for Environmental Prediction (NCEP) on a global 2.5° by 2.0° grid for 0, 6, 12, and 18 UT of each day from 1980 through the present are stored at the Goddard Space Flight Center. The values of *z200* have been interpolated to the location of eight VLBI sites and three other locations in order to provide a comparison with NMFh. The surface pressure at each site was also obtained in order to calculate the atmosphere hydrostatic delay at 5°.

In order to convert the path delay at 5° into a height error, a simulation was used to obtain the scaling error of path delay change to height change. This simulation used a twenty-four hour GPS observing schedule, which may not give exactly the same results as current VLBI sessions, but is consistent (within 25 percent) with similar previous evaluations for VLBI data.

The predicted height error for the Fairbanks site is shown in Figure 1. The sum of the annual and semi-annual terms of the series, as calculated by a Fourier transform, is superimposed. The error is minimum in the winter and maximum in the late summer. This is consistent with the other sites in the northern hemisphere included in this evaluation. The error has the opposite sign in the southern hemisphere.

The amplitudes of the annual and semi-annual errors for the eleven sites are shown in Figure 2.

A significant implication of this result is that using the more accurate mapping functions will reduce the annual height change (and baseline length change) that is characteristic of the degree-1 deformations recently studied by [1].

3. Outlook

Preliminary results of using IMF for analysis of the ensemble of VLBI data from 1980 through late 2002 confirm the expected reduction of periodic variation in baseline lengths [5]. The necessary parameters for [2] have been extracted from the ECMWF by Johannes Boehm and can be similarly tested.

Possible improvement could be obtained by raytracing the profiles of the NWMs, but this may require more computing capability than is currently available in the geodetic VLBI community. In the meantime, both IMF and VMF provide atmosphere parameterization that is more accurate than some other error sources for daily solutions.

Future work will address the form of the wet mapping function as determined from much higher resolution numerical weather models.

References

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[4] Niell, A.E.: Improved atmospheric mapping functions for VLBI and GPS, Earth, Planets, and Space, 52, 699-702, 2000.

[5] Niell, A. E., and L. Petrov, Using a Numerical Weather Model to Improve Geodesy, 2004 [available at http:/arxiv.org/abs/physics/0401118]

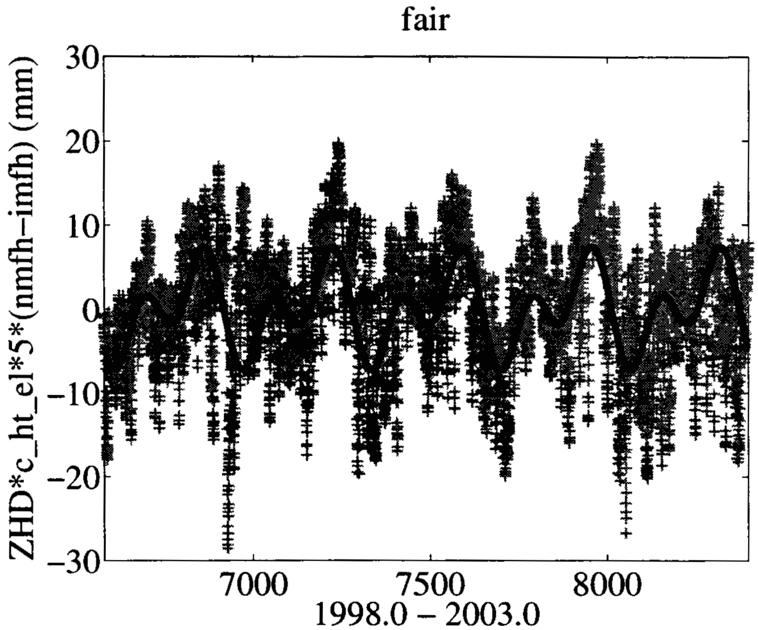

Figure 1. Height error for Fairbanks for 1998.0 - 2003.0 due to using NMFh, by comparison with IMFh, for 5° minimum elevation.

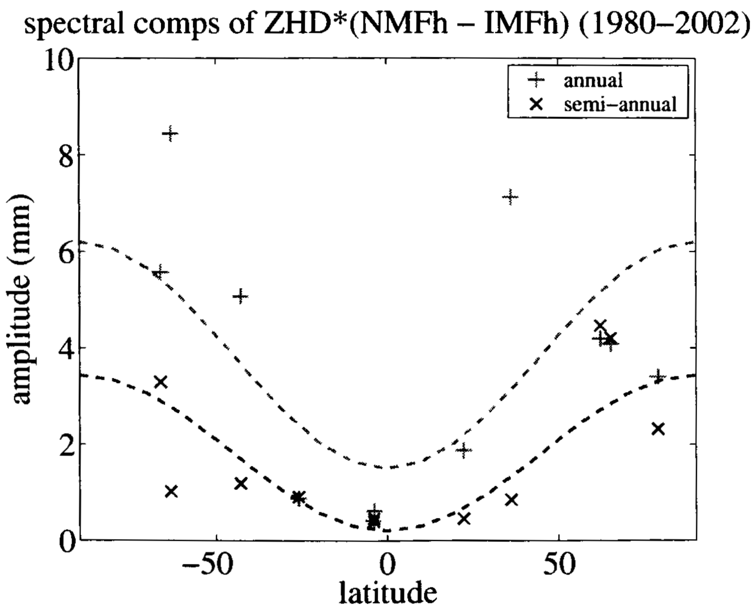

Figure 2. Amplitudes of the annual and semi-annual terms of the height error resulting from using NMFh compared to IMFh for 5° minimum elevation.