

Improved Global Atmospheric Mapping Functions for VLBI and GPS

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1. Introduction

Both hydrostatic and wet mapping functions have been developed which are independent of surface meteorology. Raytracing of actual radiosonde data for a wide range of latitude and for elevation angles down to 3° confirms that the elevation angle dependence of the hydrostatic path delay is better characterized by a seasonal variation than by the surface meteorology (NIELL, 1992). Consequently, hydrostatic and wet mapping functions to be applied globally have been derived from the temperature and relative humidity profiles of the North American Standard Atmospheres. The coefficients of the continued fraction representation of the hydrostatic mapping function depend on latitude, day of year, and height above sea level. The coefficients of the wet mapping function depend only on latitude.

Because the mapping functions have been derived from atmosphere characteristics averaged over time, longitude, and latitude, they must be evaluated by comparison with mapping functions derived from radiosonde data from specific locations and times and by analyzing VLBI data for comparison with established mapping functions.

2. Results

Comparison of the mapping functions with those calculated by raytracing of radiosonde data for five different geographical locations (nine total sites) spanning the latitude range 20° to 65° north indicates a) the biases are smaller than for the MTT (HERRING, 1992) and Ifadis global (IFADIS, 1986) mapping functions and b) averaged over all sites the rms scatter is comparable to MTT and Ifadis. Small biases are very important because the sensitivity of the estimated station vertical (and thus baseline length) is reduced (DAVIS *et al.*, 1985). At five degrees elevation the biases and rms about the bias for nwmf2 (the new wet mapping function), MTT_wet, and Ifadis_wet are (0.000, 0.019), (0.028, 0.022), and (0.028, 0.023), respectively. For the hydrostatic mapping functions the values are (-0.001, 0.010) and (0.007, 0.012) for nhmf2 and MTT_h, respectively. The biases of the wet mapping functions are inconsequential. However, the bias of MTT_h (or Ifadis_h, which is similar) would produce a length bias of approximately 9 millimeters for experiments with a

minimum elevation of 5° on a baseline of 10,000 km.

The new mapping functions have been tested by analyzing VLBI data from the NASA R&D experiments of 1987 through 1991 using both the new mapping functions and MTT. For 1987–1988 the stations involved were Westford, HRAS–085, Mojave, and Gilcreek. In 1989 and 1990 the Pie Town VLBA station replaced HRAS–085. In 1991 Kauai and Wettzell were added. The data were analyzed using SOLVK, the Kalman filter analysis package (HERRING *et al.*, 1990). For the eighteen baselines having more than eight months of data, the rms scatters about a constant rate differed by less than two millimeters. However, the MTT data had generally smaller rms. On the other hand, the expectation of a measurable minimum-elevation-dependent bias for MTT is observed. For the Kauai-Wettzell baseline (10,200 km) the mean length difference for a 3° cutoff relative to the 12° cutoff is 14 mm for MTT. (Shorter baselines have smaller differences.) For nmf the difference is –3 mm. The length difference, MTT_nmf, for the 3° minimum elevation is 12 mm. Assuming that the length difference is due primarily to a change in the vertical, this represents a scale difference of over 1.2 ppb. For a minimum elevation of 5° as currently used by NEOS, the scale difference would be approximately 0.9 ppb.

Why is the rms smaller for MTT if nmf compares more favorably with the radiosonde data? This is possibly related to the correlated errors in MTT_h and MTT_w, both of which show a significant seasonal error (compared to radiosonde derived mapping functions) in the sense of being too large in the winter. On the other hand, the length residuals using either nmf or MTT are highly correlated, indicating that the major source of the rms scatter is not either of the mapping functions. For many of the baselines the rms is dominated by only a few outliers, due either to azimuthal asymmetries in the atmosphere or to weather conditions which produce a mapping function quite different from either MTT or nmf. For these days the errors may be smaller for MTT, relative to the mean value of the mapping function. This is currently under investigation

3. Conclusion

For studies of reference frames and for series of observations which change the minimum elevation irregularly, such as has occurred for IRIS-A, it is important to minimize biases in the atmosphere estimation in order to provide the most accurate scale factor, to reduce systematic errors, and to reduce scatter in the data due to the schedule changes. The new mapping functions have negligible biases compared to those calculated from radiosonde data and also agree better in an rms sense when compared to MTT. When tested with VLBI data, the rms scatter of the baseline length residuals is not reduced by using the new mapping functions, compared to MTT, but the new mapping functions do reduce any elevation dependent baseline length bias to only a few millimeters for 10,000 km baselines.

REFERENCES

DAVIS, J. L., HERRING, T. A., SHAPIRO, I. I., ROGERS, A. E. E. and ELGERED, E., 1985, Geodesy by radio

- interferometry: Effects of atmospheric modeling errors on estimates of baseline length, *Radio Sci.*, **20**, 1593–1607.
- HERRING, T. A., 1992, Modelling Atmospheric Delays in the Analysis of Space Geodetic Data, *Proceedings of Refraction of Transatmospheric Signals in Geodesy*, Netherlands Geodetic Commission Series No. 36.
- HERRING, T. A., DAVIS, J. L. and SHAPIRO, I. I., 1990, Geodesy by radio interferometry: The application of Kalman filtering to the analysis of very long baseline interferometry data, *J. Geophys. Res.*, **95**, 12,561–12,581.
- IFADIS, I., 1986, The atmospheric delay of radio waves: modeling the elevation dependence on a global scale, Technical Report No. 38L, Chalmers University of Technology, Gothenburg, Sweden.
- NIELL, A.E., Annual and intraday variations of VLBI atmosphere corrections from radiosonde data, VLBI Geodetic Technical Memo #006, 1992 January 30 (Haystack Observatory).