CHAPTER 9 TROPOSPHERIC MODEL

Optical Techniques

The formulation of Marini and Murray (1973) is commonly used in laser ranging. The formula has been tested by comparison with ray-tracing radiosonde profiles.

The correction to a one-way range is

$$\Delta R = \frac{f(\lambda)}{f(\phi, H)} \cdot \frac{A + B}{\sin E + \frac{B/(A+B)}{\sin E+0.01}},$$

where

$$A = 0.002357P_0 + 0.000141\epsilon_0,$$  \hspace{1cm} (2)

$$B = (1.084 \times 10^{-8})P_0T_0K + (4.734 \times 10^{-8})\frac{P_0^2}{T_0} \left( \frac{2}{3 - 1/K} \right),$$  \hspace{1cm} (3)

$$K = 1.163 - 0.00968 \cos 2\phi - 0.00104T_0 + 0.0001435P_0,$$  \hspace{1cm} (4)

where

$\Delta R$ = range correction (meters),
$E$ = true elevation of satellite,
$P_0$ = atmospheric pressure at the laser site (in $10^{-1}$ kPa, equivalent to millibars),
$T_0$ = atmospheric temperature at the laser site (degrees Kelvin),
$\epsilon_0$ = water vapor pressure at the laser site (10$^{-1}$ kPa, equivalent to millibars),
$f(\lambda)$ = laser frequency parameter ($\lambda$ = wavelength in micrometers), and
$f(\phi, H)$ = laser site function.

Additional definitions of these parameters are available. The water vapor pressure, $\epsilon_0$, can be calculated from a relative humidity measurement, $R_H(\%)$ by

$$\epsilon_0 = \frac{R_H}{100} \times 6.11 \times 10^{\frac{7.5(T_0-273.15)}{237.3(T_0-273.15)}}.$$  

The laser frequency parameter, $f(\lambda)$, is

$$f(\lambda) = 0.9650 + \frac{0.0164}{\lambda^2} + \frac{0.000228}{\lambda^4}.$$  

$f(\lambda) = 1$ for a ruby laser, \textit{i.e.} $f(0.6943) = 1$, while $f(\lambda_G) = 1.02579$ and $f(\lambda_{IR}) = 0.97966$ for green and infrared YAG lasers.

The laser site function is

$$f(\phi, H) = 1 - 0.0026 \cos 2\phi - 0.00031H,$$

where $\phi$ is the latitude and $H$ is the geodetic height (km).

Radio Techniques

The differences between mathematical tropospheric models are often less than the errors which would be introduced by the character and distribution of the wet component and by the departures of
the refractivity from azimuthal symmetry. For this reason it is customary in the analysis of geodetic
data to estimate the zenith atmospheric delay and to model only the mapping function, which is
the ratio of delay at a given elevation angle to the zenith delay. The mapping function may be for
the hydrostatic, wet, or total troposphere delay. Accordingly, the IERS conventional model applies
primarily to the mapping functions. For the most accurate \textit{a priori} hydrostatic delay, desirable when
the accuracy of the estimate of the zenith wet delay is important, the formula of Saastamoinen (1972)
as given by Davis \textit{et al.} 1985 should be used.

Comparisons of many mapping functions with the ray tracing of a global distribution of ra-
diosonde data have been made by Janes \textit{et al.} (1991) and by Mendes and Langley (1994). For
observations below 10° elevation, which may be included in geodetic programs in order to increase
the precision of the vertical component of site position, the mapping functions of Lanyi (1984), Ifadis
(1986), Herring (1992, designated MTT) and Niell (1996, designated NMF) are the most accurate.
Only the last three were developed for observations below an elevation of 6°, with MTT and NMF
being valid to 3° and Ifadis to 2°.

Each of these mapping functions consists of a component for the water vapor and a component
for either the total atmosphere (Lanyi) or the hydrostatic contribution to the total delay (Ifadis, MTT,
and NMF). In all cases the wet mapping should be used as the function partial derivative for estimating
the residual atmosphere zenith delay.

The parameters of the atmosphere that are readily accessible at the time of the observation are
the surface temperature, pressure, and relative humidity. The mapping functions of Lanyi, Ifadis, and
Herring were developed to make use of this information. Lanyi additionally allows for parameterization
in terms of the height of a surface isothermal layer, the lapse rate from the top of this layer to the
tropopause, and the height of the tropopause. Including the surface meteorology without these data
results in larger discrepancies from radiosonde data than the Ifadis and Herring models.

The hydrostatic mapping function of Niell differs from the other three by being independent of
surface meteorology. It relies instead on the greater contribution by the conditions in the atmosphere
above approximately 1 km, which are strongly seasonal dependent. The RMS variation is comparable
to those using Ifadis and MTT, and all three are less than that from the Lanyi model when only
surface data are available. Thus NMF offers comparable precision and accuracy to Ifadis and MTT,
when they are provided with accurate surface meteorology data, but with no dependence on external
measurements.

Thus, if information is available on the vertical temperature distribution in the atmosphere,
Lanyi is preferred. Otherwise one of the other three mapping functions should be used.

References

Interferometry: Effects of Atmospheric Modelling Errors on Estimates of Baseline Length,” \textit{Radio
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