and

$$a_i = -\frac{\sin E}{h_i}\,, \qquad b_i = -\frac{\cos^2 E}{2h_i R_e}\,. \tag{5.118}$$

Substituting i by d, the dry part results, for which in (5.116) for $N_{d,0}^{\mathrm{Trop}}$ Eq. (5.91) and for h_d Eq. (5.94) must be introduced. Analogously, Eqs. (5.92) and (5.100) must be used for $N_{w,0}^{\mathrm{Trop}}$ and for h_w.

Saastamoinen model

The refractivity can alternatively be deduced from gas laws. The Saastamoinen model is based on this approach where again some approximations have been employed (Saastamoinen 1973). Here, any theoretical derivation is omitted. Saastamoinen models the tropospheric delay, expressed in meters,

$$\Delta^{\mathrm{Trop}} = \frac{0.002277}{\cos z}\left[p + \left(\frac{1255}{T} + 0.05\right)e - \tan^2 z\right], \tag{5.119}$$

as a function of z, p, T and e. As before, z denotes the zenith angle of the satellite, p the atmospheric pressure in millibar, T the temperature in kelvin, and e the partial pressure of water vapor in millibar. A numerical assessment using parameters of a standard atmosphere at sea level ($p = 1013.25$ millibar, $T = 273.16$ kelvin, and $e = 0$ millibar) results in a tropospheric zenith delay of about 2.3 m.

Saastamoinen has refined this model by taking into account two correction terms, one being dependent on the height of the observing site and the other one on both the height and the zenith angle. The refined formula is

$$\Delta^{\mathrm{Trop}} = \frac{0.002277}{\cos z}\left[p + \left(\frac{1255}{T} + 0.05\right)e - B\,\tan^2 z\right] + \delta R\,, \tag{5.120}$$

where the correction terms B, δR are interpolated from Tables 5.4 and 5.5.

Models using the mapping function of Marini

In 1972, Marini developed a continued fraction of the mapping function. Herring (1992) specified this function with three constants and normalized to unity at the zenith. For the dry component, the mapping function

$$m_d(E) = \frac{1 + \cfrac{a_d}{1 + \cfrac{b_d}{1 + c_d}}}{\sin E + \cfrac{a_d}{\sin E + \cfrac{b_d}{\sin E + c_d}}} \tag{5.121}$$