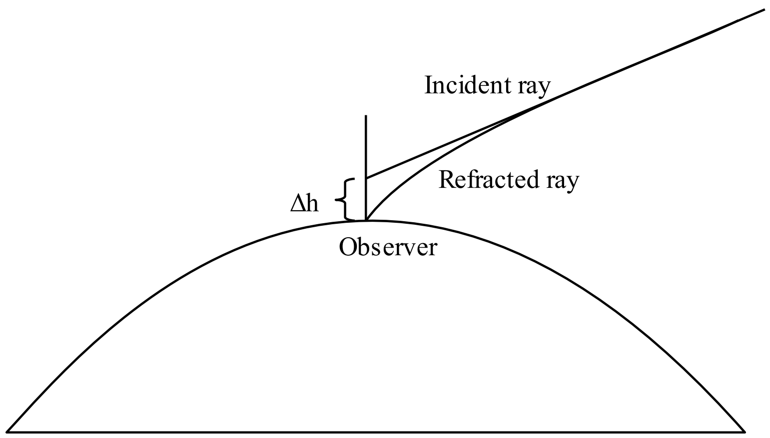
# Refraction corrections for near-earth events

Author: Chris O'Byrne
http://www.chris.obyrne.com/

**Abstract:** Refraction has two effects on the observation of astronomical events – the first is to make objects appear higher in the sky than they actually are, and the second is to make the observation appear as if it is being made from a higher altitude above the surface of the earth than it actually is. The first effect has been widely covered in the literature – however, there appears to be a lack of information about how to deal with the second effect. In this paper, I present an approximation for that second effect. The approximation is $\Delta h \approx (2.35949\text{x}10^{-13}z^2 - 4.08843\text{x}10^{-11}z + 1.77991\text{x}10^{-9})\ e^{0.361751z}$, where $\Delta h$ is the increase in the observer's altitude in metres, and z is the true (geometric) zenith distance (in degrees) of the event.

## Introduction




In the above diagram, we see a ray of light coming from an object outside of the atmosphere. The observer will see that object against the same background stars that they would see it from if the earth were airless and if they were a distance $\Delta h$ above their current location. Hence two objects that are in a geometric line with the observer will not be seen as coincident by the observer – they will only be seen as coincident if they are in a geometric line with the point $\Delta h$ above the observer's head. The distance $\Delta h$ is about 2km for an object observed at the horizon at sea-level, hence this effect is only important for events that occur near the earth.

## Atmospheric model

The atmospheric model used for this paper is that presented in *Explanatory Supplement to the Astronomical Almanac* (USNO, 1992). The starting conditions for the model were $\lambda = 0.5753\mu\text{m}$, $\theta=45.5^{\circ}$, $h_0=0$, $T_0=283.15\text{K}$, $P_0=1013.25\text{mb}$ and $R_h=0.3$.

## Curve fitting

Through trial-and-error, it was found that the best curve to match the output of the atmospheric model was $(Az^2 + Bz + C)\ e^{Dz + E}$. The Levenberg-Marquardt algorithm was used to fit to this function.

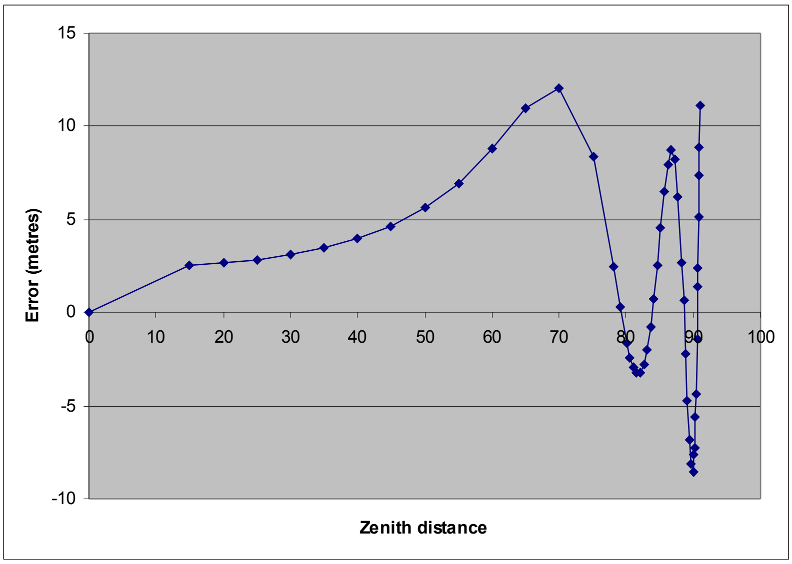
## Result

The best fit found to the function was -

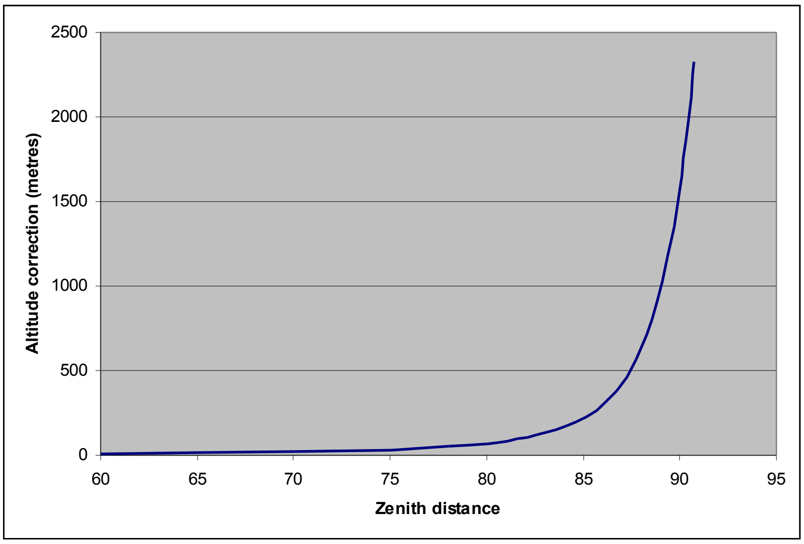
$$\Delta h \approx (2.35949\text{x}10^{-13}z^2 - 4.08843\text{x}10^{-11}z + 1.77991\text{x}10^{-9})\ e^{0.361751z}$$

where $\Delta h$ is the altitude correction in metres, z is the geometric zenith distance measured in degrees, and e is the base of the natural logarithms (2.7182818...).

A comparison with the output of the atmospheric model shows that the error is always less than 15 metres -




The correction is close to zero for most of the sky – it only starts to become noticable in the last few degrees above the horizon –




Of course, it is precisely in these last few degrees that refraction is most variable and hardest to predict.

## Another method of calculating the effect

$\Delta h = \rho\ ((\mu \sin(z\text{-}R) / \sin(z)) - 1)$, where $\rho$ is the distance of the observer from the centre of the earth (the earth's radius of 6378140m can be used), $\mu$ is the refractive index of air (about

1.0002822), z is the geometrical zenith distance and R is the refraction.

## Caution!

Refraction is essentially impossible to model, especially near the horizon, where it is strongly dependent on local atmospheric conditions. The above formula was calculated for someone at sea level, under standard atmospheric pressure, and a temperature of 10ºC, using a model of the atmosphere. Those pre-conditions are unlikely to be replicated in any given situation.

Also, note that I am not a mathematician, hence there may be unseen dangers/errors in the information presented here.

However, I believe applying the formula can be (slightly) better than not applying it, and I hope it proves useful.