

## General Solar Position Calculations

NOAA Global Monitoring Division

First, the fractional year ( $\gamma$ ) is calculated, in radians.

$$\gamma = \frac{2\pi}{365} * (\text{day\_of\_year} - 1 + \frac{\text{hour} - 12}{24})$$

(For leap years, use 366 instead of 365 in the denominator.)

From  $\gamma$ , we can estimate the equation of time (in minutes) and the solar declination angle (in radians).

$$\text{eqtime} = 229.18 * (0.000075 + 0.001868 \cos(\gamma) - 0.032077 \sin(\gamma) - 0.014615 \cos(2\gamma) - 0.040849 \sin(2\gamma))$$

$$\text{decl} = 0.006918 - 0.399912 \cos(\gamma) + 0.070257 \sin(\gamma) - 0.006758 \cos(2\gamma) + 0.000907 \sin(2\gamma) - 0.002697 \cos(3\gamma) + 0.00148 \sin(3\gamma)$$

Next, the true solar time is calculated in the following two equations. First the time offset is found, in minutes, and then the true solar time, in minutes.

$$\text{time\_offset} = \text{eqtime} + 4 * \text{longitude} - 60 * \text{timezone}$$

where eqtime is in minutes, longitude is in degrees (positive to the east of the Prime Meridian), timezone is in hours from UTC (U.S. Mountain Standard Time = -7 hours).

$$\text{tst} = \text{hr} * 60 + \text{mn} + \text{sc} / 60 + \text{time\_offset}$$

where hr is the hour (0 - 23), mn is the minute (0 - 59), sc is the second (0 - 59).

The solar hour angle, in degrees, is:

$$\text{ha} = (\text{tst} / 4) - 180$$

The solar zenith angle ( $\phi$ ) can then be found from the hour angle ( $\text{ha}$ ), latitude ( $\text{lat}$ ) and solar declination ( $\text{decl}$ ) using the following equation:

$$\cos(\phi) = \sin(\text{lat}) \sin(\text{decl}) + \cos(\text{lat}) \cos(\text{decl}) \cos(\text{ha})$$

And the solar azimuth ( $\theta$ , degrees clockwise from north) is found from:

$$\cos(180 - \theta) = - \frac{\sin(\text{lat}) \cos(\phi) - \sin(\text{decl})}{\cos(\text{lat}) \sin(\phi)}$$

## Sunrise/Sunset Calculations

For the special case of sunrise or sunset, the zenith is set to  $90.833^\circ$  (the approximate correction for atmospheric refraction at sunrise and sunset, and the size of the solar disk), and the hour angle becomes:

$$ha = \pm \arccos \left\{ \frac{\cos(90.833)}{\cos(lat) \cos(decl)} - \tan(lat) \tan(decl) \right\}$$

where the positive number corresponds to sunrise, negative to sunset.

Then the UTC time of sunrise (or sunset) in minutes is:

$$sunrise = 720 - 4 * (longitude + ha) - eqtime$$

where longitude and hour angle are in degrees and the equation of time is in minutes.

Solar noon for a given location is found from the longitude (in degrees, positive to the east of the Prime Meridian) and the equation of time (in minutes):

$$snoon = 720 - 4 * longitude - eqtime$$