General Solar Position Calculations

NOAA Global Monitoring Division

First, the fractional year (γ) is calculated, in radians.

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

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

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

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

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

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.

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

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).

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

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:

$$ha = (tst / 4) - 180$$

The solar zenith angle (ϕ) can then be found from the hour angle (*ha*), latitude (*lat*) and solar declination (*decl*) using the following equation:

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

And the solar azimuth (θ, degrees clockwise from north) is found from:

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

Sunrise/Sunset Calculations

For the special case of sunrise or sunset, the zenith is set to 90.833° (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*