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:

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

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*

SEMI DIAMETER (SD)

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1	16.29'	16.26'	16.17'	16.03'	15.90'	15.79'	15.75'	15.78'	15.88'	16.00'	16.14'	16.25'
3	16.29'	16.25'	16.15'	16.02'	15.89'	15.79'	15.75'	15.79'	15.89'	16.02'	16.16'	16.25'
6	16.29'	16.24'	16.14'	16.00'	15.87'	15.78'	15.75'	15.80'	15.90'	16.03'	16.17'	16.26'
9	16.29'	16.23'	16.13'	15.99'	15.86'	15.78'	15.75'	15.80'	15.91'	16.05'	16.18'	16.27'
12	16.29'	16.23'	16.12'	15.98'	15.85'	15.77'	15.76'	15.81'	15.92'	16.06'	16.19'	16.27'
15	16.28'	16.22'	16.10'	15.96'	15.84'	15.77'	15.76'	15.82'	15.94'	16.07'	16.20'	16.28'
18	16.28'	16.21'	16.09'	15.95'	15.83'	15.76'	15.76'	15.83'	15.95'	16.09'	16.21'	16.28'
21	16.28'	16.20'	16.08'	15.94'	15.82'	15.76'	15.77'	15.84'	15.96'	16.10'	16.22'	16.28'
24	16.27'	16.18'	16.06'	15.92'	15.81'	15.76'	15.77'	15.85'	15.98'	16.11'	16.23'	16.29'
27	16.26'	16.17'	16.05'	15.91'	15.81'	15.76'	15.77'	15.86'	15.99'	16.13'	16.24'	16.29'
30	16.26'		16.04'	15.90'	15.80'	15.75'	15.78'	15.87'	16.00'	16.14'	16.25'	16.29'
Lower Limb, ADD. Upper Limb, SUBTRACT												

Height of Eye Correction		
Meters	Dip '	Feet
0.4	**1.11'**	1.30
0.6	**1.36'**	1.95
0.8	**1.57'**	2.60
1.0	**1.76'**	3.25
1.2	**1.93'**	3.90
1.4	**2.08'**	4.55
1.6	**2.23'**	5.20
1.8	**2.36'**	5.85
2.0	**2.49'**	6.50
2.2	**2.61'**	7.15
2.4	**2.73'**	7.80
2.6	**2.84'**	8.45
2.8	**2.95'**	9.10
3.0	**3.05'**	9.75
3.2	**3.15'**	10.40
3.4	**3.25'**	11.05
3.6	**3.34'**	11.70
3.8	**3.43'**	12.35
4.0	**3.52'**	13.00
Always SUBTRACT		

PARALLAX	
Alt (Ha)	Parallax
0	0.14'
5	0.14'
10	0.14'
15	0.14'
20	0.14'
25	0.13'
30	0.12'
35	0.12'
40	0.11'
45	0.10'
50	0.09'
55	0.08'
60	0.07'
65	0.06'
70	0.05'
75	0.04'
80	0.03'
85	0.01'
90	0.00'
Always ADD	

Hs = Sextant Altitude

Sextant Corrections
Ha = Actual measure altitude
Ha = Hs +/- Index Error (IE) - Dip

Altitude Corrections
Ho = True Observed Altitude
Ho = Ha + Parallax - Refraction +/- SD

ADD Index Error if OFF the arc
SUBTRACT Index Error if ON the arc.

If using an artificial horizon Dip = 0.
Ha = (Hs +/- Index Error)/2

Then apply Altitude Corrections in the normal manner.

	mB & DegC			REFRACTION			mB & DegC		
	1000			1015			1030		
Alt (Ha)	10	20	30	10	20	30	10	20	30
1	24.14'	23.31'	22.54'	24.50'	23.66'	22.88'	24.86'	24.01'	23.22'
2	18.07'	17.46'	16.88'	18.34'	17.72'	17.13'	18.61'	17.98'	17.39'
3	14.23'	13.75'	13.29'	14.44'	13.95'	13.49'	14.66'	14.16'	13.69'
4	11.64'	11.25'	10.87'	11.82'	11.41'	11.04'	11.99'	11.58'	11.20'
5	9.80'	9.47'	9.16'	9.95'	9.61'	9.30'	10.10'	9.75'	9.43'
6	8.44'	8.15'	7.88'	8.57'	8.28'	8.00'	8.69'	8.40'	8.12'
7	7.39'	7.14'	6.91'	7.51'	7.25'	7.01'	7.62'	7.36'	7.11'
8	6.57'	6.34'	6.13'	6.67'	6.44'	6.23'	6.76'	6.53'	6.32'
9	5.90'	5.70'	5.51'	5.99'	5.78'	5.59'	6.08'	5.87'	5.68'
10	5.35'	5.17'	5.00'	5.43'	5.24'	5.07'	5.51'	5.32'	5.15'
12	4.50'	4.34'	4.20'	4.56'	4.41'	4.26'	4.63'	4.47'	4.32'
14	3.86'	3.73'	3.61'	3.92'	3.79'	3.66'	3.98'	3.84'	3.72'
16	3.38'	3.26'	3.16'	3.43'	3.31'	3.20'	3.48'	3.36'	3.25'
18	3.00'	2.89'	2.80'	3.04'	2.94'	2.84'	3.09'	2.98'	2.88'
20	2.68'	2.59'	2.50'	2.72'	2.63'	2.54'	2.76'	2.67'	2.58'
22	2.42'	2.34'	2.26'	2.46'	2.37'	2.30'	2.49'	2.41'	2.33'
24	2.20'	2.13'	2.06'	2.23'	2.16'	2.09'	2.27'	2.19'	2.12'
26	2.01'	1.94'	1.88'	2.04'	1.97'	1.91'	2.07'	2.00'	1.94'
28	1.85'	1.79'	1.73'	1.88'	1.81'	1.75'	1.90'	1.84'	1.78'
30	1.70'	1.65'	1.59'	1.73'	1.67'	1.62'	1.75'	1.69'	1.64'
35	1.41'	1.36'	1.31'	1.43'	1.38'	1.33'	1.45'	1.40'	1.35'
40	1.18'	1.14'	1.10'	1.19'	1.15'	1.11'	1.21'	1.17'	1.13'
45	0.99'	0.95'	0.92'	1.00'	0.97'	0.94'	1.02'	0.98'	0.95'
50	0.83'	0.80'	0.77'	0.84'	0.81'	0.79'	0.85'	0.82'	0.80'
55	0.69'	0.67'	0.65'	0.70'	0.68'	0.66'	0.71'	0.69'	0.67'
60	0.57'	0.55'	0.53'	0.58'	0.56'	0.54'	0.59'	0.57'	0.55'
65	0.46'	0.44'	0.43'	0.47'	0.45'	0.44'	0.47'	0.46'	0.44'
70	0.36'	0.35'	0.34'	0.36'	0.35'	0.34'	0.37'	0.36'	0.35'
75	0.26'	0.26'	0.25'	0.27'	0.26'	0.25'	0.27'	0.26'	0.25'
80	0.17'	0.17'	0.16'	0.18'	0.17'	0.16'	0.18'	0.17'	0.17'
85	0.09'	0.08'	0.08'	0.09'	0.08'	0.08'	0.09'	0.08'	0.08'
90	0.00'	0.00'	0.00'	0.00'	0.00'	0.00'	0.00'	0.00'	0.00'
Always SUBTRACT									