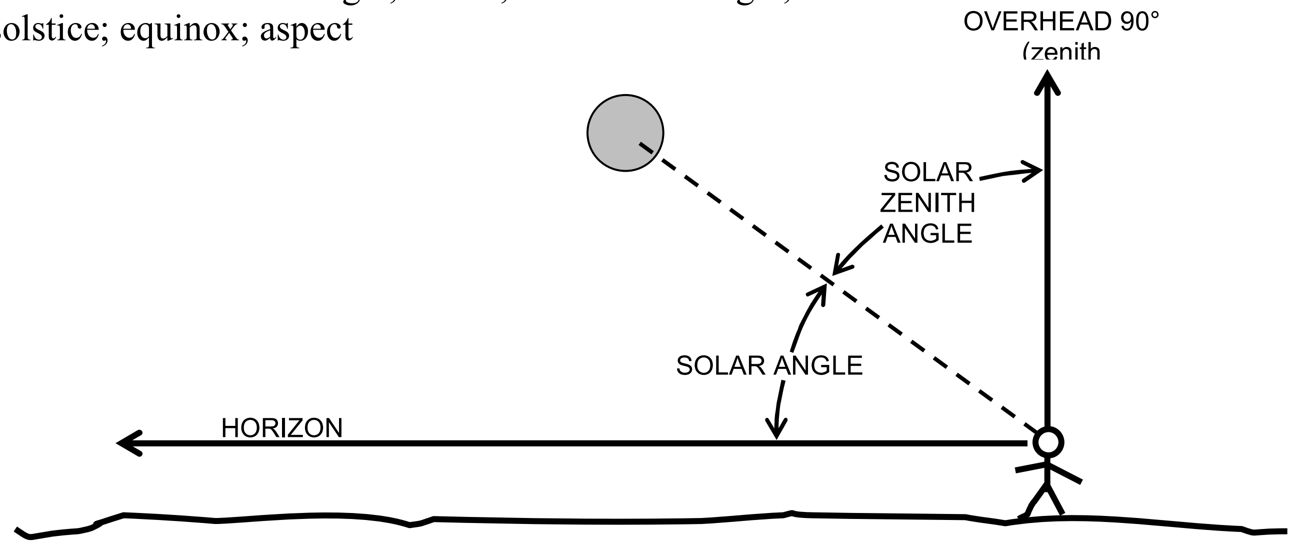
Geography Lab Lesson 4 – Solar Angles

Terms to learn: solar angle; zenith; solar zenith angle; declination solstice; equinox; aspect



The angle at which the sun's radiation reaches the surface of the Earth is one of factors that determine the amount of solar energy available at the surface. Other factors include cloud cover, the amount of particulate matter in the atmosphere, and slope orientation of the land surface (aspect). The sun angle changes during the day and, also, throughout the year (seasons). This exercise looks at the various ways to measure sun angles.

DEFINTIONS:

Solar noon: The time when the sun appears highest in the sky during the day; noon on your particular meridian; usually not noon by the clock.

Noon Solar Zenith Angle (SZA): the angle between the sun and the point directly overhead at your location (your zenith) at solar noon.

Solar Zenith Angle (SZA) = YOUR LATITUDE − DECLINATION

SZA = LAT – DECL (If SZA is negative, sun is in the northern sky.)

Declination: the latitude at which the noon sun is at zenith (directly overhead).
During one year, the declination varies between 23.5°S and 23.5°N, a total of 47°.

Latitude: your latitude where you are observing the sun angle (In calculations, Northern Hemisphere latitudes are positive and Southern Hemisphere latitudes are negative.)

Solar Angle (SA): the angle between the sun and your local horizon

SA = 90 – |SZA| (absolute value for SZA)

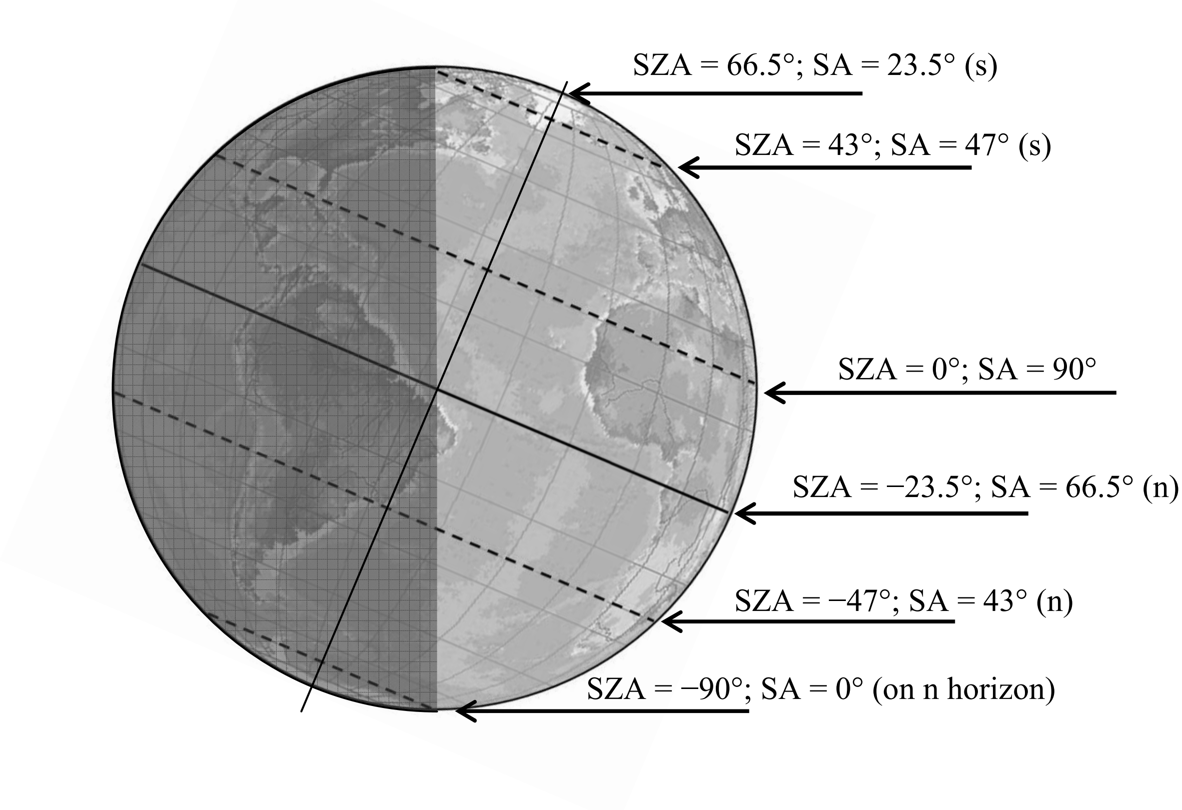
The SA varies between 90° and −23.5° along the noon meridian.
A negative value for the SA indicates that the sun is below the horizon.

The sun's declination can be calculated by a formula for any day of the year. But, there are four times during the year when the declination is well known.

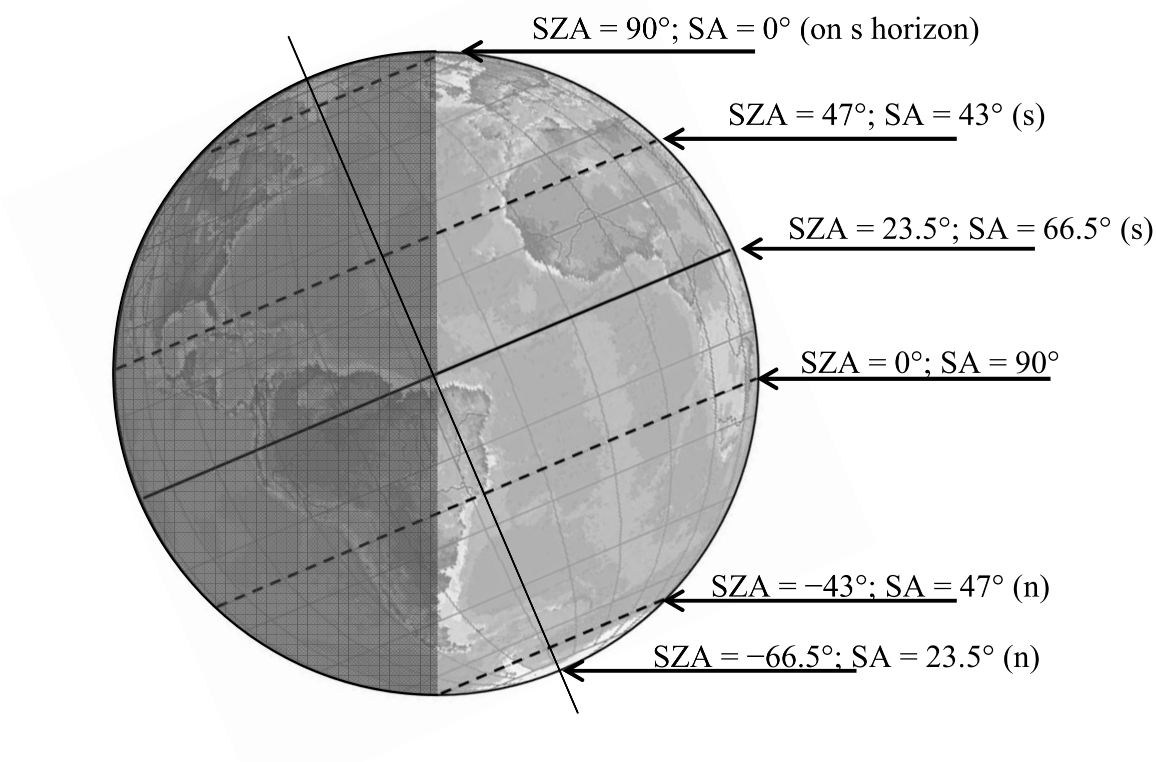
Summer Solstice, around June 21 ± a day or so: DECL = 23.5°
Winter Solstice, around Dec. 21 ± a day or so: DECL = −23.5°
Spring Equinox, around Mar. 21 ± a day or so: DECL = 0°
Fall Equinox, around Sept. 22 ± a day or so: DECL = 0°

Diagrams of Earth with axis, tropics, Arctic and Antarctic circles, Equator, circle of illumination.

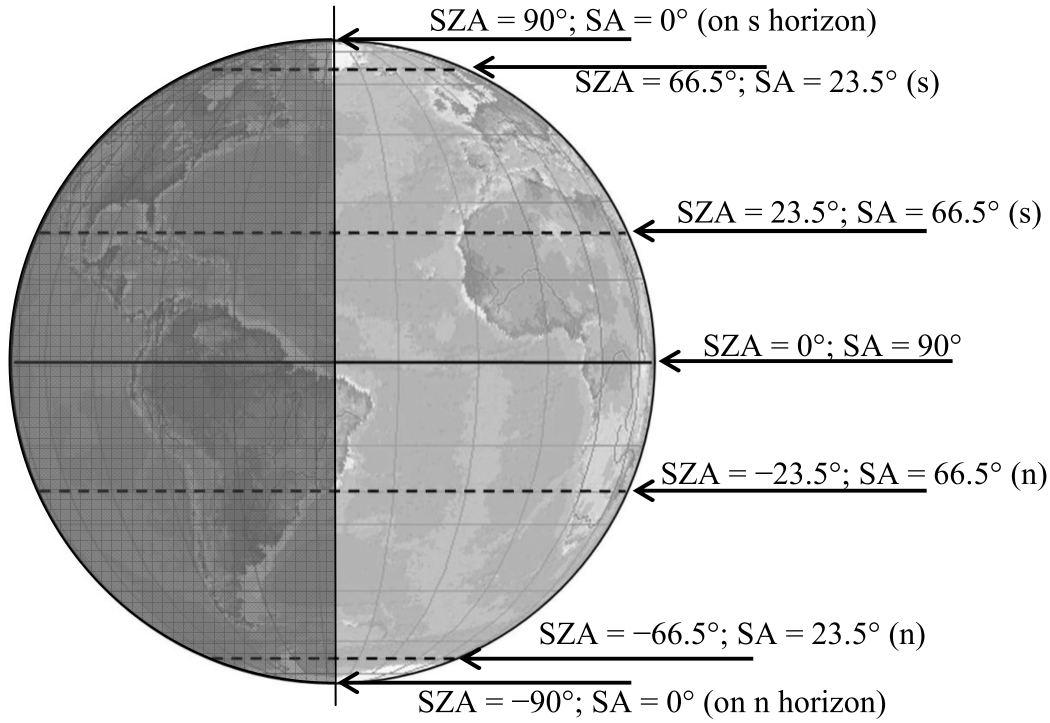
Earth-sunlight orientation at the Summer Solstice, June 21. (DECL = 23.5°)



Earth-sunlight orientation at the Winter Solstice, December 21. (DECL = −23.5°)



Earth-sunlight orientation at the Equinoxes, March 21, and Sept.21. (DECL = 0°)



Part 1: CALCULATING NOON SOLAR ZENITH ANGLE AND SOLAR ANGLE AT SELECTED LOCATIONS AND SEASONS:

EXAMPLE: You are in Tapachula, Chiapas, MX, (Lat. 15°N) and the declination is 23.5°N. What is the noon solar angle and direction?

SZA = Lat – Decl. = 15° – 23.5° = - 8.5° (The negative value indicates northern sky direction.)

SA = 90° - |SZA| = 90° - 8.5° = 81.5° above the horizon

1. Latitude: 32.5°N; Declination: 5.5°N

SZA = ______________________________

Noon sun direction: ______________

SA = ______________________________

2. Latitude: 75°N; Declination: 20°N

SZA = ______________________________

Noon sun direction: ______________

SA = ______________________________

3. Latitude: 90°N; Declination: 0°

SZA = ______________________________

Noon sun direction: ______________

SA = ______________________________

4. Latitude: 90°S; Declination: 20°S

SZA = ______________________________

Noon sun direction: ______________

SA = ______________________________

5. Latitude: 50.5°S; Declination: 23.5°N

SZA = ______________________________

Noon sun direction: ______________

SA = ______________________________

6. Latitude: 0°; Declination: 5.5°N

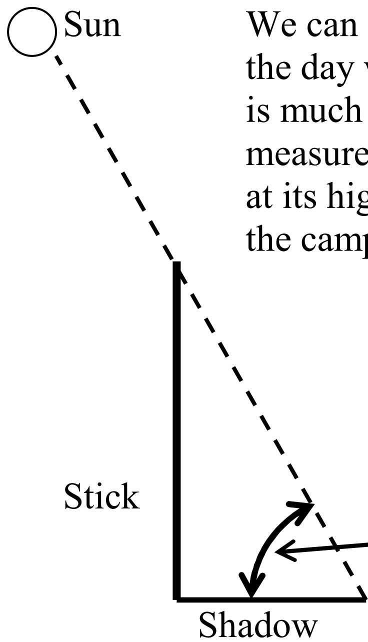
SZA = ______________________________

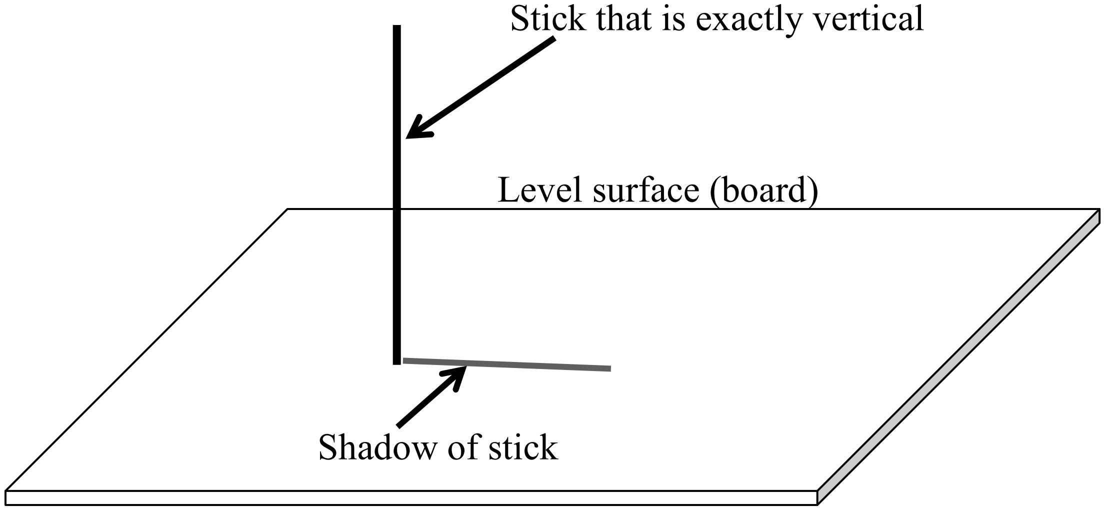
Noon sun direction: ______________

SA = ______________________________

Part 2: MEASURING THE SOLAR ANGLE:

We can measure the solar angle any time during the day when the sun is shining, but this exercise is much more meaningful if we make the measurement at local solar noon when the sun is at its highest angle. When is local solar noon on the campus? This is not a trivial question.

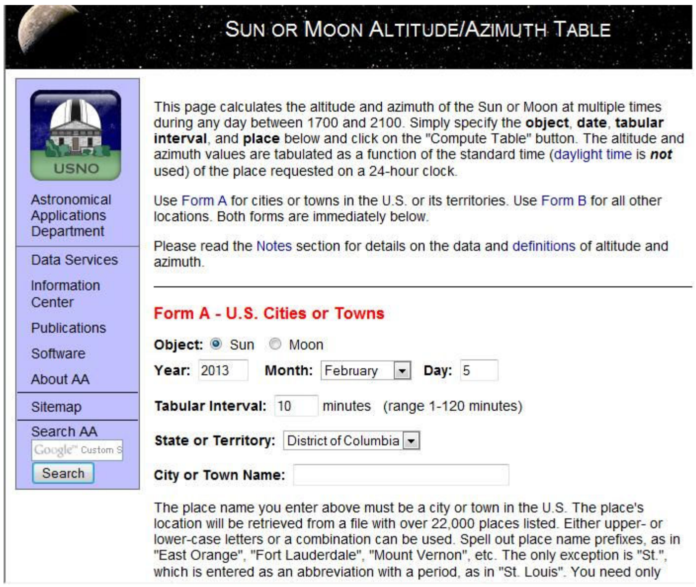




Measure the height of the stick and the length of its shadow (use millimeters).
These two measurements are related to the SA by the tangent trigonometric function, in that the stick length divided by the shadow length is the tangent of the SA.
For example, let's say the stick is 200mm high, and we measure a shadow length of 120mm. 200/120 = 1.67. Now, use the inverse tan function ($\tan^{-1}$) on your calculator to find the angle, which is in this case about 59°. The sun is 59° above the horizon, and, of course, the SZA is 90° − 59° = 31°.

Part 3: Plotting Solar Azimuth and Elevation

Online, go to http://aa.usno.navy.mil/data/docs/AltAz.php
This is the U. S. Naval Observatory site. The home page allows you to generate a table of values for the sun's azimuth (direction relative to North) and elevation (angle above the local horizon) for a location and date of your choosing.
You can use "Form A" in which you select a state and city location, or "Form B" in which you enter the latitude and longitude coordinates of your selected location.



SUN OR MOON ALTITUDE/AZIMUTH TABLE

USNO

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This page calculates the altitude and azimuth of the Sun or Moon at multiple times during any day between 1700 and 2100. Simply specify the **object**, **date**, **tabular interval**, and **place** below and click on the "Compute Table" button. The altitude and azimuth values are tabulated as a function of the standard time (daylight time is ***not*** used) of the place requested on a 24-hour clock.

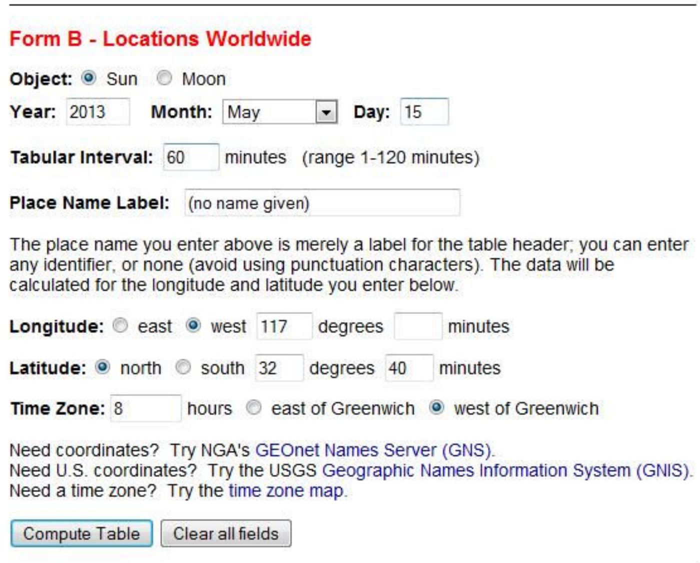
Use Form A for cities or towns in the U.S. or its territories. Use Form B for all other locations. Both forms are immediately below.

Please read the Notes section for details on the data and definitions of altitude and azimuth.

Form A - U.S. Cities or Towns

Object: Sun Moon
Year: 2013 **Month:** February **Day:** 5
Tabular Interval: 10 minutes (range 1-120 minutes)
State or Territory: District of Columbia
City or Town Name:

The place name you enter above must be a city or town in the U.S. The place's location will be retrieved from a file with over 22,000 places listed. Either upper- or lower-case letters or a combination can be used. Spell out place name prefixes, as in "East Orange", "Fort Lauderdale", "Mount Vernon", etc. The only exception is "St.", which is entered as an abbreviation with a period, as in "St. Louis". You need only



Form B - Locations Worldwide

Object: Sun Moon
Year: 2013 **Month:** May **Day:** 15
Tabular Interval: 60 minutes (range 1-120 minutes)
Place Name Label: (no name given)

The place name you enter above is merely a label for the table header; you can enter any identifier, or none (avoid using punctuation characters). The data will be calculated for the longitude and latitude you enter below.

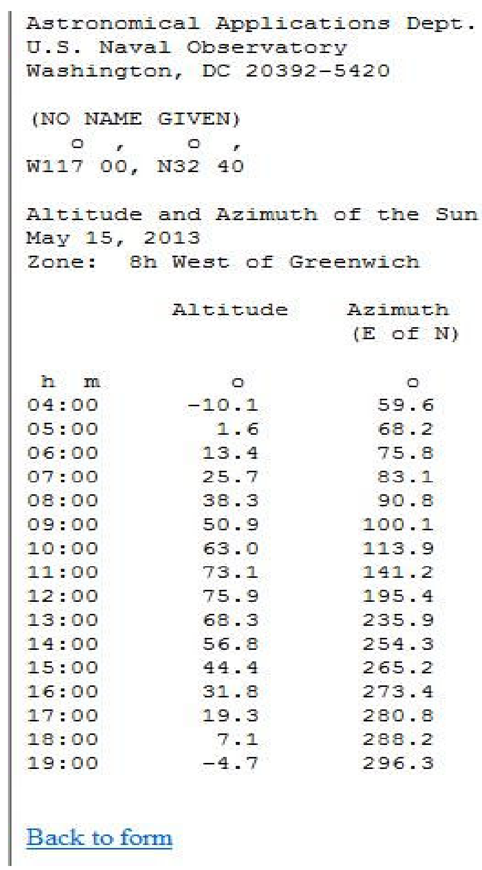
Longitude: east west 117 degrees minutes
Latitude: north south 32 degrees 40 minutes
Time Zone: 8 hours east of Greenwich west of Greenwich

Need coordinates? Try NGA's GEOnet Names Server (GNS).
Need U.S. coordinates? Try the USGS Geographic Names Information System (GNIS).
Need a time zone? Try the time zone map.

Compute Table | Clear all fields

For example, using Form B, and entering the coordinates for San Diego, choosing a date, in this case May 15, and setting the table interval to 60 minutes, and setting the time zone to 8 hours west of Greenwich. Click <u>Compute Table.</u>

You generate a table that looks like this →
These are the Altitude and Azimuth values you will plot on the polar graph. The next page shows these values plotted on the graph.



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Astronomical Applications Dept.
U.S. Naval Observatory
Washington, DC 20392-5420

(NO NAME GIVEN)
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W117 00, N32 40

Altitude and Azimuth of the Sun
May 15, 2013
Zone:  8h West of Greenwich

             Altitude      Azimuth
                           (E of N)

 h  m           o             o
04:00        -10.1          59.6
05:00          1.6          68.2
06:00         13.4          75.8
07:00         25.7          83.1
08:00         38.3          90.8
09:00         50.9         100.1
10:00         63.0         113.9
11:00         73.1         141.2
12:00         75.9         195.4
13:00         68.3         235.9
14:00         56.8         254.3
15:00         44.4         265.2
16:00         31.8         273.4
17:00         19.3         280.8
18:00          7.1         288.2
19:00         -4.7         296.3
```

Back to form

Sun Elevation and Azimuth for

San Diego, CA, May 15