## 2.16 Elevation Angle

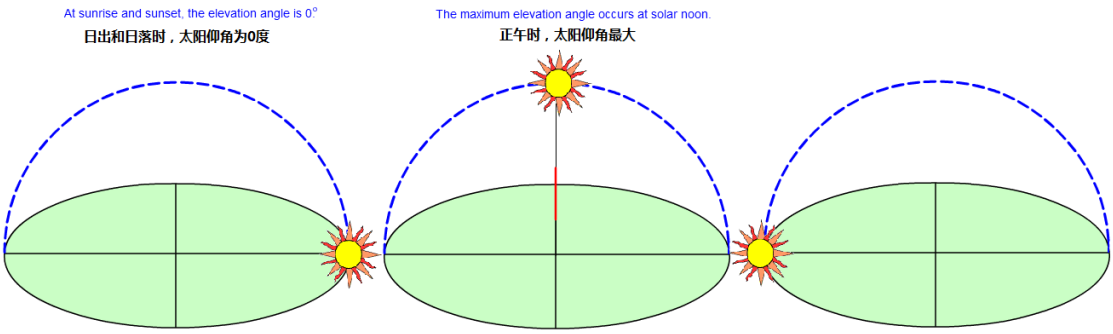
## 太阳仰角

The elevation angle (used interchangeably with altitude angle) is the angular height of the sun in the sky measured from the horizontal. Confusingly, both altitude and elevation are also used to describe the height in meters above sea level. The elevation is 0° at sunrise and 90° when the sun is directly overhead (which occurs for example at the equator on the spring and fall equinoxes).

太阳仰角（elevation angle 有时也用 altitude angle）指的是天空中的太阳相对于水平面的高度角。令人费解是，altitude 和 elevation 这两个词也表示海拔高度。日出时，太阳仰角为 0 度，而当太阳在头顶时（比如赤道地区春分日和秋分日的时候就会出现这种情况），太阳仰角为 90 度。

The elevation angle varies throughout the day. It also depends on the latitude of a particular location and the day of the year.

太阳仰角在一天中会不断变化，它的值也受纬度和一年中的天数的影响。




An important parameter in the design of photovoltaic systems is the maximum elevation angle, that is, the maximum height of the sun in the sky at a particular time of year. This maximum elevation angle occurs at solar noon and depends on the latitude and declination angle as shown in the figure below.

在设计光伏系统时，一个重要的参数是最大的太阳仰角，即一年中太阳在天空中所达到的最大高度对应的角度。一天中，最大的太阳仰角出现在正午，它与所在地区的纬度和太阳倾角的关系如下图所示。

The tilt of the earth compared to the sun, given by the declination angle δ, depends on the season. Shown here is the maximum declination angle, occuring at summer solstice in the northern hemisphere and winter solstice in the winter hemisphere.

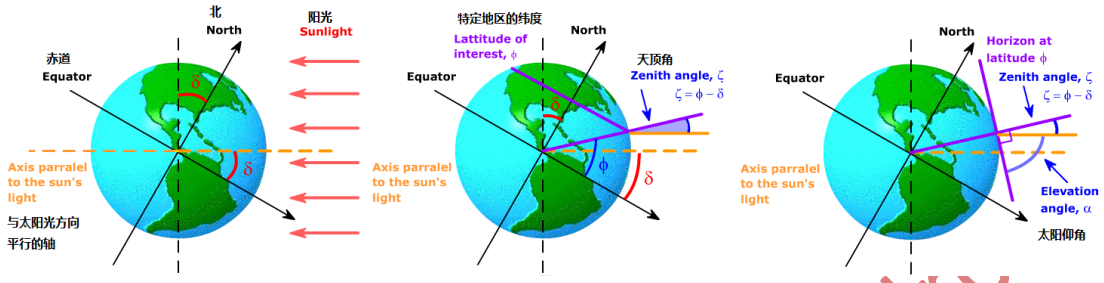
地球相对于太阳光的倾角，用太阳倾角δ表示，它的大小受季节的影响。如图所示，太阳倾角的最大值出现在北半球的夏至日或南半球的冬至日（译者注：原文中将southern写成了winter）。

The zenith angle, ζ, at solar noon is defined as the angle between the incident sunlight and the particular location and is given by $\phi - \delta$.

正午时的天顶角，ζ，指的是入射阳光和特定地点（竖直平面）间的夹角，可以通过公式φ-δ计算。

The elevation or altitude angle, α, is defined from the horizontal plane and is given by 90° – the zenith angle, or $90° - (\phi - \delta)$

太阳仰角，α，指的是入射阳光和水平面之间的夹角。可以通过求天顶角的余角得到，或者通过求φ-δ的余角得到。




The maximum elevation angle at solar noon ($\alpha$) is a function of latitude and the declination angle ($\delta$).

正午时的最大太阳仰角是关于纬度和太阳倾角的函数。

From the previous figure, a formula for the elevation angle at solar noon can be determined according to the formula for locations in the Northern Hemisphere:

$$\alpha = 90 - \varphi + \delta$$

and for the Southern Hemisphere:

$$\alpha = 90 + \varphi - \delta$$

where:

$\varphi$ is the latitude of the location of interest. In the equation for the Northern Hemisphere, it is positive for Northern Hemisphere locations and negative for Southern Hemisphere. In the equation for the Southern Hemisphere, $\varphi$ is positive for Southern Hemisphere locations and negative for Northern Hemisphere locations. $\delta$ is the declination angle, which depends on the day of the year.

从前面的图中，我们可以给出正午时的太阳仰角公式：

对于北半球：

$$\alpha = 90 - \varphi + \delta$$

对于南半球：

$$\alpha = 90 + \varphi - \delta$$

公式中的$\varphi$表示观测位置的纬度。如果采用北半球公式，北半球的位置的纬度值为正值，南半球为负值。如果采用南半球公式， 南半球的位置的纬度值为正值，北半球的为负值。$\delta$表示太阳倾角，它的值与一年中的天数有关。





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博主邮箱：nkukarl@gmail.com

At the Tropic of Cancer on summer solstice, the sun is directly overhead and the elevation angle is 90°. In summer at latitudes between the equator and the Tropic of Cancer, the elevation angle at solar noon is greater than 90°, implying that the sunlight is coming from the north rather than from the south as in most of the northern hemisphere. Similarly, at latitudes between the equator and the Tropic of Capricorn, during some periods of the year, sunlight is incident from the south, rather than from the north.

北回归线地区夏至日时，太阳位于头顶，太阳仰角为 90 度。在夏天，赤道与北回归线之间的一些区域正午时的太阳仰角大于 90 度，这表明阳光是从北面而非南面照过来而。类似的，对于赤道和南回归线之间的一些区域，在一年中的某些时间，阳光是从南面而非北面照过来。

While the maximum elevation angle is used even in very simple PV system design, more accurate PV system simulation requires the knowledge of how the elevation angle varies throughout the day. These equations are given in the following page.

在设计时简单的光伏系统通常采用的是最大太阳仰角，然而为了更准确地模拟光伏系统，需要用到太阳仰角在一天中的变化情况。相关公式在接下来几页介绍。

The elevation, α, can be found using the following formula:

$$\alpha = \sin^{-1}[\sin\delta\sin\varphi + \cos\delta\cos\varphi\cos(HRA)]$$

太阳仰角可以通过下面的公式给出：

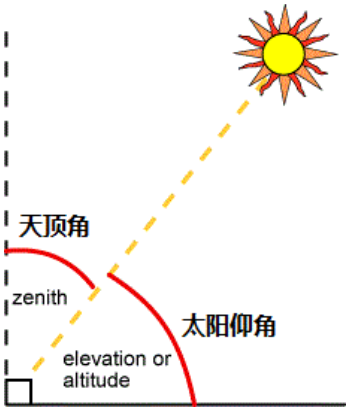
$$\alpha = \sin^{-1}[\sin\delta\sin\varphi + \cos\delta\cos\varphi\cos(HRA)]$$

**Zenith Angle**

天顶角

The zenith angle is the angle between the sun and the vertical. The zenith angle is similar to the elevation angle but it is measured from the vertical rather than from the horizontal, thus making the zenith angle = 90° - elevation.

天顶角与仰角相似，但是天顶角是太阳与竖直平面而非水平面的夹角，因此天顶角等于仰角的余角。$\zeta = 90° - \alpha$





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**Sunrise and Sunset**

日出和日落

To calculate the sunrise and sunset time the elevation is set to zero and the elevation equation above is rearranged to give:

$$\text{Sunrise} = 12 - \frac{1}{15°}\cos^{-1}\left(-\frac{\sin\varphi\sin\delta}{\cos\varphi\cos\delta}\right) - \frac{TC}{60}$$

and sunset:

$$\text{Sunset} = 12 + \frac{1}{15°}\cos^{-1}\left(-\frac{\sin\varphi\sin\delta}{\cos\varphi\cos\delta}\right) - \frac{TC}{60}$$

these equations can be simplified as:

$$\text{Sunrise} = 12 - \frac{1}{15°}\cos^{-1}(-\tan\varphi\tan\delta) - \frac{TC}{60}$$

$$\text{Sunset} = 12 + \frac{1}{15°}\cos^{-1}(-\tan\varphi\tan\delta) - \frac{TC}{60}$$

为了计算日出和日落时间，我们可以把太阳仰角的值设为零，整理上面提到的太阳仰角公式，我们可以得到日出时间公式：

$$\text{Sunrise} = 12 - \frac{1}{15°}\cos^{-1}\left(-\frac{\sin\varphi\sin\delta}{\cos\varphi\cos\delta}\right) - \frac{TC}{60}$$

和日落时间公式：

$$\text{Sunset} = 12 + \frac{1}{15°}\cos^{-1}\left(-\frac{\sin\varphi\sin\delta}{\cos\varphi\cos\delta}\right) - \frac{TC}{60}$$

这两个公式可以简化为：

$$\text{Sunrise} = 12 - \frac{1}{15°}\cos^{-1}(-\tan\varphi\tan\delta) - \frac{TC}{60}$$

$$\text{Sunset} = 12 + \frac{1}{15°}\cos^{-1}(-\tan\varphi\tan\delta) - \frac{TC}{60}$$





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