Declinations Circles and Earth’s Radiation Budget

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Declination Circles, Diurnal Heating, Seasons, and Climate Regimes

Although there are many uses for declination circles, for Earth Systems Science, they help us conceptualize how the Sun’s energy creates Earth’s diurnal heating (night/day temperature cycles), the seasons, and climate regimes (tropics, temperate regime or midlatitudes, and polar regions). All three are driven by the amount of daylight relative to nighttime, how high the sun gets in the sky, and how both change throughout the year. Key to the changing of these variables is the Earth’s obliquity, which changes the daily position of declination circles (explored in the Using Declination Circles).

The Sun emits near constant electromagnetic energy, and how it intersects with the Earth’s surface determines how the ground/water heats, and the warmed surface in turn warms the air. Imagine a beam of sunlight is 1 mile wide. If it shines perpendicularly onto a 1 mile wide piece of ground. If this same sun beam hits the ground at a 30° angle, then the 1 mile beam is spread over 2 miles of ground, so each piece of illuminated ground receives half the energy compared to when the sun is directly overhead (Figure 1). The ratio of width of the incoming beam and the width of the illuminated ground is called *beam spread* (Table 1).

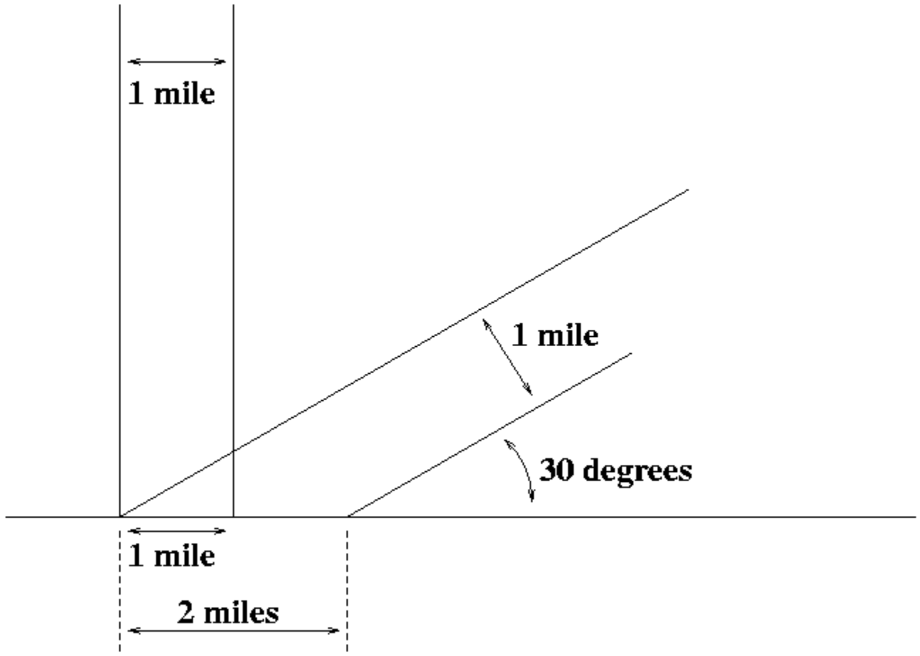

Figure 1. How a beam of sunlight spreads out as it hits the ground when it hits the ground at different angles.

Table 1 shows the beam spread for angles of the sun above the horizon, an angle we can calculate easily for local noon using declination circles. The values are in percent relative to the most intense sun hitting the ground, which is when the sun is directly overhead is graphed in Figure 25.

Angle of Sun Above Horizon	Beam Spread	Percent of Beam
90°	1	100%
80°	1.02	98.5%
70°	1.06	94.0%
60°	1.15	86.6%
50°	1.31	76.6%
40°	1.56	64.3%
30°	2.00	50.0%
20°	2.92	34.2%
10°	5.76	17.4%
0°	∞	0%

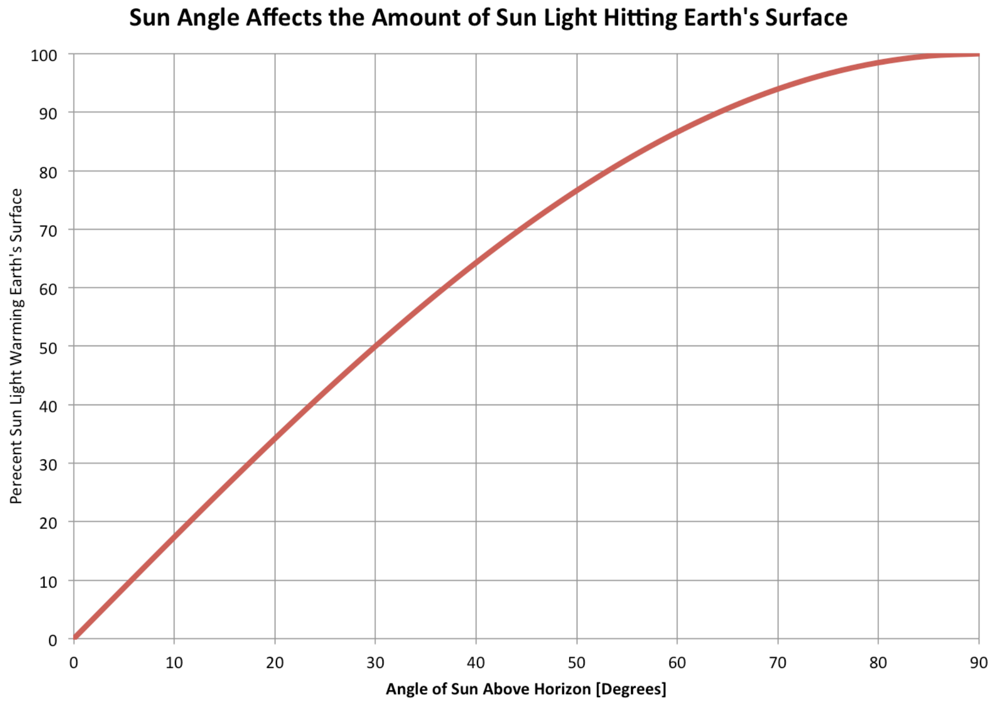

Figure 2. How sun angle affects the intensity of sun hitting the ground. The values are in percent relative to the most intense sun hitting the ground, which is when the sun is directly overhead.

Exploring the graph in Figure 2 illustrates that the maximum warming tends to occur near local noon (not the warmest temperature, this happens several hours after local noon), depending on surface material and timing and amount of clouds and/or precipitation (see the *Black Body Radiation software* at sciencepickle.com to explore these variables). Local noon will have the maximum intensity of sunlight hitting the ground, but compare the sun angle between the summer and winter solstices! The tropics (generally the area between the Tropic of Cancer, 23.5°N, and the Tropic of Capricorn, 23.5°S) don't experience significant change in local noon sun intensity throughout the year – it is quite intense every day! The midlatitudes, generally from the tropic circles to the Arctic/Antarctic Circles, experience quite a range of solar intensity throughout the year, allowing for warm summers and cold winters. The polar regions experience at least 24 hours of darkness and sunlight, but the sun is not that high in the sky to create hot summers despite the long duration of sunlight.