respectively), the sun passes directly overhead at noon. At other times of year, the minimum zenith angle achieved in the course of the day is equal to the angle of tilt of the earth's axis toward or away from the sun, up to a maximum of 23° at the time of the summer and winter solstices (June 21 and December 21, respectively).

At latitudes poleward of 23°, the sun is never directly overhead, and the minimum zenith angle is always greater than zero. During the summer season, the sun can reach a point fairly high in the sky, whereas in the winter season, the maximum elevation angle is much lower. Moreover, the days are longer in the summer hemisphere than in the winter hemisphere. Indeed, poleward of the arctic or antarctic circles, there is a substantial period of time during the winter when the sun never comes up at all, while during the corresponding period of high summer, the sun never sets. At the poles themselves, the situation is very simple: the sun is up continuously for one half of the year, and the solar zenith angle θ_s is nearly constant over a 24-hour period.[7]

The combined effects of the length of day, of the variation in $\cos\theta_s$, and of the slight variation of the earth's distance from the sun on daily insolation (at the top of the atmosphere) are depicted in Fig. 2.9. Blacked-out areas depict dates and latitudes for which the sun never emerges above the horizon. The dashed line ("declination of the sun") indicates the dates / latitudes at which the noontime sun passes directly overhead. Not surprisingly, this curve coincides with the location of maximum daily insolation over most of the year. However, within a week or two of the summer solstice, the maximum daily insolation is found instead near the pole, where there is daylight for a full 24 hours *and* the sun is a relatively high 23° above the horizon for the entire day.

If you integrate the daily insolation at a given latitude over the entire annual cycle and then divide your result by the number of days in a year, you get the *daily average insolation*, as depicted by the heavy curve labeled "Annual" in Fig. 2.10. Also shown is the daily

[7] Atmospheric refraction allows the sun to be visible from a location on the earth's surface when it is actually about 0.5°, or approximately the diameter of the sun's disk, below the horizon. Thus, the sun rises somewhat sooner and sets somewhat later than would be predicted from geometric considerations alone. Therefore, the length of continuous daylight at the North Pole (for example) is actually somewhat longer than the expected six months.