EES50

Enviroscaping to Conserve Energy: Determining Shade Patterns for Central Florida[1]

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INTRODUCTION

Residential energy use comprises about 26% of the total energy expenditure in the state of Florida (Florida Energy Office, 1992). About 28% of this energy consumption is for cooling homes during central Florida's 5-to-7-month summer. As utility rates escalate, so does the cost of staying comfortable in the home. Before central heating and air conditioning, homes were designed and built to take advantage of natural-cooling and heat-conserving features. Today these methods of control are once again of interest, and new technologies have substantially improved many energy-saving landscaping concepts (known as enviroscaping) from the past.

Discomfort created by heat and high humidity can be countered by good air circulation and shade. Trees are valuable tools for moderating the effects of outside temperatures on the home because they provide shade and effectively modify air movement. How well a particular tree species performs depends on how tall it grows, whether or not its leaves remain all year, and the shape and density of its canopy (Meerow & Black, 1993). Once established, most landscape trees require only periodic maintenance and represent an appreciating investment in the home's value. The correct placement of trees chosen to shade the home involves consideration of the angle of the sun's rays, the mature height and width of the tree canopy, and the height of the structure to be shaded.

MOVEMENT OF THE SUN

The major factor to consider in tree placement for effective shade is the position of the sun. The sun is not in the same place in the sky day after day or even during the day. Once you accurately determine the sun's position, you can do a few calculations to determine proper placement of trees for maximum shade on the structure during the hottest time of the day and year.

The term heat load is often used to describe the total heat accumulated by a structure over the course of the day. The heat load begins to build when the

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morning sun strikes the east walls of a house, and usually peaks in the afternoon, sometime between 3 PM and 5 PM. Not surprisingly, this is also the peak time of energy demands for air conditioning.

The sun is directly over the equator about March 21, after which it appears to move northward until June 21. The sun then begins moving on a more southerly track, reaching its southernmost position about December 21.

The angle of the sun from due south is called an azimuth (Figure 1). From sunrise to noon, the azimuth is measured in negative degrees (Figure 2). From noon to sunset, the azimuth is measured in positive degrees (Figure 2).

A sun-path diagram (Figures 1 & 3) shows the path of the sun over a particular site. This path is determined by the time of the day, the season and the latitude of the site. The altitude of the sun is the angle between the rays of the sun and the horizon (Figure 3). The altitude of the sun changes with the time of day, the seasons and also with latitude.

TYPES OF SHADE TREES

Evergreen trees maintain their leaves throughout the year. There are two types: broad leafed (e.g., Southern Magnolia, *Magnolia grandiflora*; American Holly, *Ilex opaca*), and needle leafed (e.g. pines, *Pinus spp.*; cedars and junipers, *Juniperus spp.*). Broad-leafed evergreens provide dense shade year round, and are most useful as shade trees in south Florida. By contrast, the shade cast by needle-leafed trees is sparse and more open, though pruning can, in some cases, stimulate a denser canopy. Deciduous trees (e.g., Red Maple, *Acer rubrum*) shed their leaves in the fall and are bare during the coldest months of the year. Tree shape also influences the amount of shade cast (Figure 4, p. 3).

WHERE AND WHAT TO SHADE

Shade is cast towards the south during the summer in Florida as the sun rises in the northeast in the morning and sets in the northwest in the evening. Because of this, and the high altitude of the sun in summer, south walls have less exposure to the sun than do walls facing east or west. Tree shade should thus be maximized on the east and west sides of the house. South walls also benefit from tree shade. Southern exposures may be relatively free of direct radiation in June, but by August, the sun has dropped sufficiently in the sky to cause a significant heat load increase on a south wall in the afternoon.

Windows and glass doors are the most direct route for sunlight to enter the home, and trees should be positioned to shade them throughout the day. The outdoor compressor/condenser unit of the air conditioning system uses less energy when it and the surrounding areas are shaded from direct sun during the entire day. A tree can shade the unit when the sun is overhead, while nearby shrubs can provide protection during the early morning and late afternoon hours. Care must be taken, however, not to block the conditioner's air flow (short circuiting). If the warm discharge air is prevented from escaping, the intake air temperature is raised, causing the unit to operate less efficiently.

In winter, the sun is low in the southern sky. Southern exposures of a home can receive the cost-free, energy-saving benefits of passive solar heating, when deciduous trees are used along the southern exposures. However, in south central Florida, where winters are short and mild, greater benefit may be realized by using evergreen trees along the southern exposures to reduce heat build up and lower air-conditioning costs.

Trees planted fairly close to the home provide shade sooner than those planted at greater distances. The benefits of new shade trees should be obtained within 5 years. To accomplish this goal, a distance of 7 to 20 feet from tree to wall is recommended. Lot size and mature tree height directly influence this distance. Trees planted closer will shade for a longer period of time during the day, and over a greater part of the hot season. The shadow of a tree planted 10 feet from the home moves across the target surface four times more slowly than a tree planted 20 feet away (Parker, 1978; Parker, 1983a; Parker, 1983b).

CALCULATING THE LENGTH AND DIRECTION OF TREE SHADOWS

The length and direction of the shadow that a tree casts at a given time of day in a specific season and latitude can be calculated using the azimuth angle and a special variable called a shade-projection factor. Shade-projection factors and azimuth angles are given in Tables 1-15 for 3 central Florida cities for all daylight hours 4 days each month from May to October, the period of greatest heat load in the state. Choose the figures corresponding to the city closest to where you live. Table 1 represents May in Daytona; Table 2 June in Daytona; Table 3 July in Daytona, Table 4 is August in Daytona; Table 5 September in Daytona. Table 6 shows Orlando in May; Table 7 Orlando in June; Table 8 Orlando in July; Table 9 is Orlando in August; Table 10 is Orlando in September. Table 11 represents Tampa in May; Table 12 is Tampa in June; Table 13 is Tampa in July; Table 14 Tampa in August; Table 15 is Tampa in September.

Direction of Shade

The direction in which a shadow is cast at a given time of day is determined by measuring the azimuth angle corresponding to that time (Tables 1-15) from due south.

Step 1

First draw an accurate plot plan of your house on graph paper, including all doors, windows, existing plants, outdoor structures such as trellises, and the outdoor compressor unit of the air conditioner. Draw an accurate north-south line through your house (Figure 5, p. 4). This line is important for later steps.

Step 2

Use a protractor, an inexpensive and widely available device for angle measurement, for this step (Figure 6, p. 4). If you want to shade the sliding-glass door on the west side of the house in Figure 5 between the hours of 3 PM and 5 PM from June 15 through September 15, place the midpoint of the protractor's straight edge at the midpoint of the sliding-glass door (Figure 7, p. 5). (The curved side of the protractor should be pointing west.) The midpoint on the protractor may be indicated by a zero, two cross hairs or some other symbol. Orient the 0° marks at either end of the curved side so that the straight edge of the protractor is pointing due south (Figure 7, p. 5). In other words, a straight line drawn from one 0° mark to the other would be exactly parallel to the north-south line. Be sure that the protractor stays in place during the next step.

Step 3

For the purpose of this example, we suppose that the home in Figure 7 is in Orlando. Using Table 7 for Orlando, find the azimuth angle for June 15 at 3 PM, Eastern Daylight Savings Time. It is at 81.6°. Because you are determining shade for 3PM and all azimuth angles between 12 noon and sunset are measured from south to west, start at the southern end of the protractor and moving northwest, locate the line that is closest to 81.6° on the protractor scale. With a pencil, put a mark on the paper at that point (Figure 7, p. 5). Next, look up the azimuth angle for 5 PM on June 15 (Table 2). It is 96.7°. Again, starting at the southern end and moving northwest up the protractor, locate the line on the protractor scale closest to 96.7°. Put a pencil mark on the paper at this point (Figure 7, p. 5).

Step 4

With a ruler or the straight edge of the protractor, draw two lines connecting the midpoint of the sliding glass door with each of the two points and label them with date and time (Figure 8, p. 5). These two lines indicate the shade angles cast at 3 PM and 5 PM on June 15. In order to shade the sliding-glass door at 3 PM, a tree must be planted directly on the 3 PM line; at 5 PM, along the 5 PM line. To shade from 3 PM to 5 PM, trees may need to be planted across the space between the two lines, though the mature canopies of many species also shade along the intervening sun angles.

Step 5

Because we wish to provide shade from June 15 through September 15, it is also necessary to determine the sun angles for 3 PM and 5 PM on September 15. In Orlando, these azimuth angles are 47.6° and 74.7°, respectively (Table 2). These

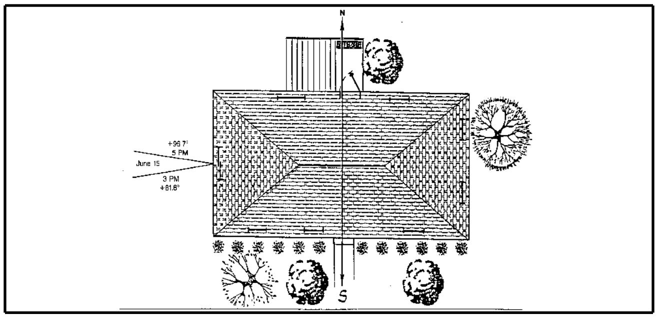

Figure 8.

angles are smaller because the sun is at a more southerly position in the sky in September. Repeat steps 3 and 4 using these angles (Figure 9, p. 6). To effectively shade the sliding-glass doors from 3 PM to 5 PM, June 15 to September 15, trees should be planted in a solid band from the 5 PM/June 15 line (96.7°) to the 3 PM/September 15 line (47.6°). Of course, the actual number of trees necessary depends on the width of the tree canopy (this varies with species) and its distance from the sliding-glass door. For example, a greater number of narrow trees versus spreading trees are required to shade the same area. Also, when the trees are planted closer to the house than the maximum distance allowed (see next section), they shade the door for a longer period of time.

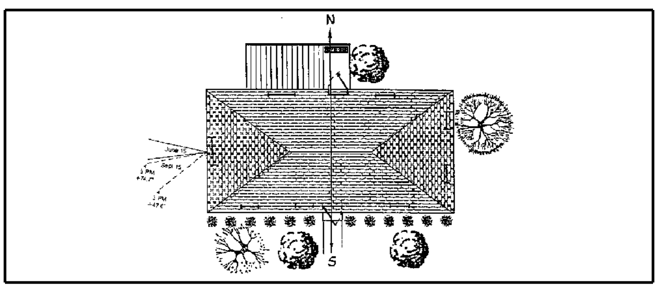

Figure 9.

The direction of shade from trees for windows, doors and walls along any exposure of the house can be determined in exactly the same way. In reality, it may be necessary to shade for a longer period of time during the day or for a greater number of months. In any case, follow steps 1-5 for at least both the first and last days of the year for which you want shade.

Determining Length of Tree Shade

Once you determine the angle lines upon and between which trees should be planted, the next step is to decide exactly where the tree should be located on the angle lines. A simple formula makes this easy: S (h-h') = X where

S = Shade Projection Factor, found in Tables 1-15.

h = mature height of the tree that you wish to plant, in feet.

h' = the height of the wall, window or other area that you wish to shade, in feet, and

X = the length of the tree's shadow or the maximum distance the tree should be planted from the target of the shade, in feet.

Step 1

Let's continue to use the same house in Orlando for which shade directions have been determined. If the sliding-glass door is 7 feet tall, the sycamore, *Platanus occidentalis*, which averages 40 feet high at maturity, is a good choice. The shade projection factor for 3 PM, June 15 is 0.4 (Table 2). Thus, using our formula, calculate X: 0.4 (40 ft. - 7 ft.) = X 0.4 (33 ft.) = X 13.2 ft. = X Therefore, one sycamore should be planted no more than 13.2 feet from the sliding-glass door along the June 15/3 PM angle line (Figure 10, p. 7).

Step 2

Determine X for each shade angle line. Shade projection factors for June 15/5 PM, September 15/3 PM, and September 15/5 PM are 1.1, 0.7, and 1.6 respectively (Table 2). Sycamores should be planted at or less than 36.3, 23.1, and 52.8 feet away respectively from the sliding-glass door along those angle lines. Additional trees, if placed at intermediate distances between these angle lines, will ensure that the sliding-glass door is shaded between 3 PM and 5 PM for those days between June 15 and September 15.

Step 3

To guarantee accuracy, determine sun angles and planting distances (see previous section) for 4 PM on June 15 and September 15. Tree-placement indicators for 4 PM should fall between the 3 PM and 5 PM indicators already determined.

Landscape aesthetics may warrant the use of several different species of trees. If they differ in mature height, must be calculated for each species.

Though sycamores grow relatively quickly, it takes some time for young nursery stock to reach full size. Temporary plantings of faster growing shrubs or trees planted closer to the home can provide quick shade until the permanent trees mature. For example, a fast growing tree or shrub planted 7 feet away from the sliding-glass door along the appropriate shade line needs to be about 24.5 feet tall to shade the door at 3 PM on June 15, and only 11 feet tall to shade the door at 5 PM on September 15.

When determining placement of shade trees, keep in mind that the shadow length is shorter if the area to be shaded slopes upward, longer if the area slopes downward. With planning, landscape plants can beautify the home and save energy dollars.

ADDITIONAL INFORMATION

Detailed guidelines on using landscape plants to reduce energy consumption around the home throughout the year are in the companion publication **EES 43** *Enviroscaping To Conserve Energy: A Guide to Microclimate Modification*. Lists of appropriate trees and how they rate for shade-specific qualities are in **EES 41** *Enviroscaping To Conserve Energy: Trees for Central Florida*. Both publications are available from your county cooperative extension office. A microcomputer program (ENERCON) that determines azimuth angles, shade projection factors, planting distances, and even provides a list of suggested trees is also available at the extension office.

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Table 1.

TABLE 1. DAYTONA - ED=Eastern Daylight Savings Time, SPF=Shade Projection Factor, AA=Azimuth Angle.

	MAY 1		MAY 8		MAY 15		MAY 22	
ED	SPF	AA	SPF	AA	SPF	AA	SPF	AA
7 AM	21.6	-105.5	15.1	-107.2	12.1	-108.8	10.5	-110.2
8 AM	3.6	-98.6	3.4	-100.4	3.2	-102.1	3.1	-103.6
9 AM	1.8	-91.8	1.8	-93.8	1.7	-95.7	1.7	-97.4
10 AM	1.1	-84.1	1.1	-86.5	1.1	-88.7	1.0	-90.7
11 AM	0.7	-74.0	0.7	-76.9	0.7	-79.8	0.7	-82.4
12 PM	0.4	-57.0	0.4	-60.8	0.4	-64.7	0.4	-68.5
1 PM	0.3	-20.1	0.2	-22.2	0.2	-25.1	0.2	-28.9
2 PM	0.3	33.9	0.3	38.4	0.2	42.8	0.2	47.1
3 PM	0.5	63.1	0.5	67.1	0.5	70.7	0.4	74.0
4 PM	0.8	77.3	0.8	80.3	0.8	83.0	0.8	85.3
5 PM	1.3	86.5	1.3	88.9	1.2	91.0	1.2	92.9
6 PM	2.2	93.8	2.1	95.9	2.0	97.7	2.0	99.3

Table 2.

TABLE 2. DAYTONA - ED=Eastern Daylight Savings Time, SPF=Shade Projection Factor, AA=Azimuth Angle.

	JUNE 1		JUNE 8		JUNE 15		JUNE 22	
ED	SPF	AA	SPF	AA	SPF	AA	SPF	AA
7 AM	9.4	-111.8	9.2	-112.7	9.2	-113.3	9.6	-113.6
8 AM	3.0	-105.4	3.0	-106.3	3.0	-106.9	3.0	-107.2
9 AM	1.6	-99.3	1.6	-100.3	1.7	-101.0	1.7	-101.4
10 AM	1.0	-93.1	1.0	-94.3	1.0	-95.1	1.0	-95.5
11 AM	0.6	-85.5	0.6	-87.1	0.6	-88.2	0.7	-88.7
12 PM	0.4	-73.3	0.4	-75.8	0.4	-77.6	0.4	-78.4
1 PM	0.2	-35.4	0.1	-40.2	0.1	-44.2	0.1	-46.8
2 PM	0.2	52.2	0.2	54.6	0.2	55.6	0.2	55.1
3 PM	0.4	77.6	0.4	79.3	0.4	80.2	0.4	80.3
4 PM	0.7	87.8	0.7	89.0	0.7	89.7	0.7	89.8
5 PM	1.2	94.8	1.1	95.8	1.1	96.2	1.1	96.3
6 PM	1.9	101.0	1.9	101.7	1.8	102.1	1.8	102.1

Table 3.

TABLE 3. DAYTONA - ED=Eastern Daylight Savings Time, SPF=Shade Projection Factor, AA=Azimuth Angle.

	JULY 1		JULY 8		JULY 15		JULY 22	
ED	SPF	AA	SPF	AA	SPF	AA	SPF	AA
7 AM	10.5	-113.5	11.7	-113.2	13.5	-112.5	16.2	-111.5
8 AM	3.1	-107.1	3.2	-106.7	3.4	-105.9	3.5	-104.8
9 AM	1.7	-101.2	1.7	-100.7	1.8	-99.8	1.8	-98.6
10 AM	1.1	-95.3	1.1	-94.7	1.1	-93.6	1.1	-92.1
11 AM	0.7	-88.5	0.7	-87.6	0.7	-86.2	0.7	-84.3
12 PM	0.4	-78.1	0.4	-76.9	0.4	-74.8	0.4	-72.0
1 PM	0.2	-47.6	0.2	-46.3	0.2	-43.6	0.2	-40.0
2 PM	0.2	52.1	0.2	48.3	0.2	43.7	0.2	39.0
3 PM	0.4	79.2	0.4	77.4	0.4	74.8	0.4	71.7
4 PM	0.7	89.0	0.7	87.9	0.7	86.2	0.7	84.1
5 PM	1.1	95.8	1.1	94.9	1.1	93.6	1.1	92.0
6 PM	1.8	101.7	1.8	100.9	1.8	99.8	1.8	98.5

Table 4.

TABLE 4. DAYTONA - ED=Eastern Daylight Savings Time, SPF=Shade Projection Factor, AA=Azimuth Angle.

	AUG.1		AUG.8		AUG. 15		AUG. 22	
ED	SPF	AA	SPF	AA	SPF	AA	SPF	AA
8 AM	3.7	-102.8	3.9	-101.0	4.1	-99.0	4.4	-96.7
9 AM	1.9	-96.3	1.9	-94.3	2.0	-92.1	2.1	-89.6
10 AM	1.2	-89.4	1.2	-87.0	1.2	-84.5	1.2	-81.7
11 AM	0.7	-80.8	0.7	-77.9	0.8	-74.6	0.8	-71.2
12 PM	0.4	-67.0	0.5	-63.0	0.5	-58.8	0.5	-54.4
1 PM	0.2	-34.1	0.3	-29.8	0.3	-25.6	0.3	-21.7
2 PM	0.2	33.2	0.3	30.0	0.3	27.5	0.3	25.6
3 PM	0.4	66.7	0.5	63.1	0.5	59.6	0.5	56.3
4 PM	0.7	80.6	0.7	77.9	0.8	75.1	0.8	72.3
5 PM	1.1	89.2	1.2	87.1	1.2	84.8	1.3	82.4
6 PM	1.9	96.2	1.9	94.3	2.0	92.4	2.2	90.3
7 PM	3.7	102.6	3.9	101.0	4.3	99.2	4.8	97.4

Table 5.

TABLE 5. DAYTONA - ED=Eastern Daylight Savings Time, SPF=Shade Projection Factor, AA=Azimuth Angle.

	SEPT. 1		SEPT. 8		SEPT. 15		SEPT. 22	
ED	SPF	AA	SPF	AA	SPF	AA	SPF	AA
8 AM	4.8	-93.2	5.1	-90.6	5.4	-88.0	5.9	-85.3
9 AM	2.1	-85.9	2.2	-83.1	2.3	-80.2	2.4	-77.4
10 AM	1.3	-77.3	1.3	-74.2	1.4	-71.0	1.4	-67.8
11 AM	0.8	-66.0	0.9	-62.3	0.9	-58.6	0.9	-55.1
12 PM	0.5	-48.1	0.6	-43.8	0.6	-39.9	0.7	-36.3
1 PM	0.4	-16.8	0.4	-13.8	0.5	-11.2	0.6	-9.0
2 PM	0.4	23.8	0.5	22.9	0.5	22.2	0.6	21.5
3 PM	0.6	52.2	0.6	49.6	0.7	47.3	0.8	45.2
4 PM	0.9	68.4	1.0	65.8	1.0	63.4	1.1	61.1
5 PM	1.4	79.1	1.5	76.7	1.6	74.4	1.7	72.2
6 PM	2.4	87.3	2.6	85.1	2.9	83.0	3.3	80.8
7 PM	6.0	94.6	7.4	92.5	9.6	90.5	14.1	88.4

Table 6.

TABLE 6. ORLANDO - ED=Eastern Daylight Savings Time, SPF=Shade Projection Factor, AA=Azimuth Angle.

	MAY 1		MAY 8		MAY 15		MAY 22	
ED	SPF	AA	SPF	AA	SPF	AA	SPF	AA
8 AM	3.7	-98.9	3.5	-100.8	3.3	-102.4	3.2	-103.9
9 AM	1.9	-92.3	1.8	-94.3	1.7	-96.2	1.7	-97.9
10 AM	1.1	-84.8	1.1	-87.2	1.1	-89.5	1.0	-91.5
11 AM	0.7	-75.1	0.7	-78.1	0.7	-81.0	0.7	-83.6
12 PM	0.4	-58.8	0.4	-62.7	0.4	-66.7	0.4	-70.6
1 PM	0.3	-22.1	0.2	-24.5	0.2	-27.9	0.2	-32.2
2 PM	0.3	34.4	0.3	39.1	0.2	43.9	0.2	48.5
3 PM	0.5	64.0	0.5	68.1	0.5	71.8	0.4	75.1
4 PM	0.8	77.9	0.8	81.0	0.8	83.7	0.7	86.0
5 PM	1.3	86.8	1.2	89.3	1.2	91.5	1.2	93.3
6 PM	2.2	94.0	2.1	96.1	2.0	97.9	2.0	99.5
7 PM	4.8	100.6	4.5	102.5	4.2	104.2	4.0	105.6

Table 7.

TABLE 7. ORLANDO - ED=Eastern Daylight Savings Time, SPF=Shade Projection Factor, AA=Azimuth Angle.

	JUNE 1		JUNE 8		JUNE 15		JUNE 22	
ED	SPF	AA	SPF	AA	SPF	AA	SPF	AA
8 AM	3.1	-105.7	3.1	-106.6	3.1	-107.2	3.1	-107.5
9 AM	1.7	-99.8	1.7	-100.9	1.7	-101.5	1.7	-101.9
10 AM	1.0	-93.9	1.0	-95.1	1.0	-95.9	1.1	-96.2
11 AM	0.6	-86.7	0.6	-88.4	0.6	-89.4	0.7	-89.9
12 PM	0.4	-75.4	0.4	-78.0	0.4	-79.7	0.4	-80.5
1 PM	0.1	-39.6	0.1	-44.8	0.1	-49.1	0.1	-51.8
2 PM	0.2	54.1	0.2	56.8	0.2	58.0	0.2	57.6
3 PM	0.4	78.9	0.4	80.6	0.4	81.6	0.4	81.8
4 PM	0.7	88.6	0.7	89.8	0.7	90.5	0.7	90.6
5 PM	1.2	95.3	1.1	96.2	1.1	96.7	1.1	96.8
6 PM	1.9	101.2	1.9	102.0	1.8	102.4	1.8	102.4
7 PM	3.7	107.1	3.6	107.8	3.5	108.1	3.4	108.1

Table 8.

TABLE 8. ORLANDO - ED=Eastern Daylight Savings Time, SPF=Shade Projection Factor, AA=Azimuth Angle.

	JULY 1		JULY 8		JULY 15		JULY 22	
ED	SPF	AA	SPF	AA	SPF	AA	SPF	AA
8 AM	3.2	-107.5	3.3	-107.0	3.4	-106.2	3.6	-105.1
9 AM	1.7	-101.7	1.8	-101.2	1.8	-100.3	1.8	-99.1
10 AM	1.1	-96.1	1.1	-95.4	1.1	-94.3	1.1	-92.8
11 AM	0.7	-89.6	0.7	-88.8	0.7	-87.4	0.7	-85.4
12 PM	0.4	-80.2	0.4	-78.9	0.4	-76.7	0.4	-73.9
1 PM	0.1	-52.3	0.2	-50.6	0.2	-47.5	0.2	-43.4
2 PM	0.2	54.5	0.2	50.3	0.2	45.3	0.2	40.1
3 PM	0.4	80.6	0.4	78.8	0.4	76.2	0.4	73.0
4 PM	0.7	89.9	0.7	88.7	0.7	87.1	0.7	84.9
5 PM	1.1	96.3	1.1	95.4	1.1	94.1	1.1	92.5
6 PM	1.8	101.9	1.8	101.2	1.8	100.1	1.8	98.7
7 PM	3.3	107.7	3.3	107.0	3.3	106.0	3.4	104.8

Table 9.

TABLE 9. ORLANDO - ED=Eastern Daylight Savings Time, SPF=Shade Projection Factor, AA=Azimuth Angle.

	AUG. 1		AUG. 8		AUG. 15		AUG. 22	
ED	SPF	AA	SPF	AA	SPF	AA	SPF	AA
8 AM	3.8	-103.0	4.0	-101.3	4.2	-99.2	4.5	-97.0
9 AM	1.9	-96.7	2.0	-94.8	2.0	-92.5	2.1	-90.1
10 AM	1.2	-90.1	1.2	-87.8	1.2	-85.2	1.2	-82.4
11 AM	0.7	-81.9	0.7	-79.0	0.8	-75.7	0.8	-72.2
12 PM	0.4	-68.8	0.4	-64.8	0.5	-60.4	0.5	-55.9
1 PM	0.2	-36.8	0.3	-32.1	0.3	-27.6	0.3	-23.4
2 PM	0.2	33.8	0.2	30.3	0.3	27.7	0.3	25.7
3 PM	0.4	67.8	0.4	64.1	0.5	60.5	0.5	57.0
4 PM	0.7	81.4	0.7	78.6	0.8	75.7	0.8	72.9
5 PM	1.1	89.7	1.2	87.5	1.2	85.2	1.3	82.8
6 PM	1.9	96.4	1.9	94.5	2.0	92.6	2.1	90.5
7 PM	3.7	102.7	3.9	101.0	4.3	99.3	4.8	97.4

Table 10.

TABLE 10. ORLANDO - ED=Eastern Daylight Savings Time, SPF=Shade Projection Factor, AA=Azimuth Angle.

	SEPT. 1		SEPT. 8		SEPT. 15		SEPT. 22	
ED	SPF	AA	SPF	AA	SPF	AA	SPF	AA
8 AM	4.9	-93.5	5.2	-90.9	5.6	-88.2	6.0	-85.5
9 AM	2.2	-86.3	2.2	-83.5	2.3	-80.7	2.4	-77.8
10 AM	1.3	-78.0	1.3	-74.9	1.4	-71.7	1.4	-68.5
11 AM	0.8	-67.0	0.9	-63.2	0.9	-59.6	0.9	-56.0
12 PM	0.5	-49.4	0.6	-45.1	0.6	-41.0	0.7	-37.3
1 PM	0.4	-18.0	0.4	-14.8	0.5	-12.1	0.5	-9.7
2 PM	0.4	23.8	0.4	22.8	0.5	22.1	0.6	21.4
3 PM	0.6	52.7	0.6	50.0	0.7	47.6	0.8	45.5
4 PM	0.9	68.9	0.9	66.2	1.0	63.7	1.1	61.4
5 PM	1.4	79.4	1.5	77.0	1.6	74.7	1.7	72.4
6 PM	2.4	87.4	2.6	85.2	2.9	83.1	3.2	80.9
7 PM	5.9	94.5	7.2	92.5	9.3	90.4	13.2	88.3

Table 11.

TABLE 11. TAMPA - ED=Eastern Daylight Savings Time, SPF=Shade Projection Factor, AA=Azimuth Angle.

	MAY 1		MAY 8		MAY 15		MAY 22	
ED	SPF	AA	SPF	AA	SPF	AA	SPF	AA
8 AM	4.0	-99.6	3.7	-101.4	3.5	-103.1	3.4	-104.6
9 AM	2.0	-93.1	1.9	-95.1	1.8	-97.0	1.8	-98.6
10 AM	1.2	-85.9	1.1	-88.3	1.1	-90.5	1.1	-92.5
11 AM	0.7	-76.7	0.7	-79.7	0.7	-82.6	0.7	-85.1
12 PM	0.4	-61.6	0.4	-65.5	0.4	-69.5	0.4	-73.3
1 PM	0.3	-27.2	0.2	-30.4	0.2	-34.5	0.2	-39.6
2 PM	0.3	31.7	0.2	36.5	0.2	41.5	0.2	46.3
3 PM	0.5	63.4	0.4	67.7	0.4	71.6	0.4	75.1
4 PM	0.8	77.7	0.8	80.9	0.7	83.7	0.7	86.1
5 PM	1.2	86.6	1.2	89.1	1.2	91.4	1.1	93.2
6 PM	2.1	93.7	2.0	95.8	1.9	97.7	1.9	99.3
7 PM	4.4	100.2	4.2	102.1	3.9	103.8	3.7	105.3

Table 12.

TABLE 12. TAMPA - ED=Eastern Daylight Savings Time, SPF=Shade Projection Factor, AA=Azimuth Angle.

	JUNE 1		JUNE 8		JUNE 15		JUNE 22	
ED	SPF	AA	SPF	AA	SPF	AA	SPF	AA
8 AM	3.3	-106.3	3.3	-107.2	3.3	-107.9	3.3	-108.2
9 AM	1.7	-100.6	1.7	-101.6	1.8	-102.3	1.8	-102.6
10 AM	1.1	-94.8	1.1	-96.0	1.1	-96.8	1.1	-97.2
11 AM	0.7	-88.2	0.7	-89.7	0.7	-90.8	0.7	-91.2
12 PM	0.4	-78.0	0.4	-80.5	0.4	-82.1	0.4	-82.9
1 PM	0.2	-47.7	0.1	-53.1	0.1	-57.2	0.1	-59.5
2 PM	0.2	52.3	0.2	55.3	0.1	56.7	0.1	56.1
3 PM	0.4	79.1	0.4	81.0	0.4	82.0	0.4	82.2
4 PM	0.7	88.8	0.7	90.1	0.7	90.7	0.7	90.8
5 PM	1.1	95.3	1.1	96.2	1.1	96.8	1.1	96.8
6 PM	1.8	101.0	1.8	101.8	1.7	102.2	1.7	102.3
7 PM	3.5	106.8	3.4	107.5	3.3	107.8	3.2	107.8

Table 13.

TABLE 13. TAMPA - ED=Eastern Daylight Savings Time, SPF=Shade Projection Factor, AA=Azimuth Angle.

	JULY 1		JULY 8		JULY 15		JULY 22	
ED	SPF	AA	SPF	AA	SPF	AA	SPF	AA
8 AM	3.5	-108.1	3.6	-107.6	3.7	-106.9	3.9	-105.8
9 AM	1.8	-102.5	1.8	-101.9	1.9	-101.0	1.9	-99.8
10 AM	1.1	-97.0	1.1	-96.3	1.2	-95.3	1.2	-93.8
11 AM	0.7	-91.0	0.7	-90.1	0.7	-88.7	0.7	-86.8
12 PM	0.4	-82.5	0.4	-81.2	0.4	-79.1	0.4	-76.3
1 PM	0.2	-59.6	0.2	-57.6	0.2	-54.1	0.2	-49.7
2 PM	0.1	52.5	0.1	47.8	0.1	42.2	0.2	36.7
3 PM	0.4	81.0	0.4	79.1	0.4	76.3	0.4	72.9
4 PM	0.7	90.1	0.7	88.9	0.7	87.2	0.7	85.0
5 PM	1.1	96.3	1.0	95.4	1.1	94.1	1.1	92.4
6 PM	1.7	101.8	1.7	101.0	1.7	99.9	1.7	98.5
7 PM	3.1	107.4	3.1	106.7	3.2	105.7	3.2	104.5

Table 14.

TABLE 14. TAMPA - ED=Eastern Daylight Savings Time, SPF=Shade Projection Factor, AA=Azimuth Angle.

	AUG. 1		AUG. 8		AUG. 15		AUG. 22	
ED	SPF	AA	SPF	AA	SPF	AA	SPF	AA
8 AM	4.2	-103.7	4.4	-101.9	4.7	-99.9	4.9	-97.7
9 AM	2.0	-97.5	2.1	-95.5	2.1	-93.3	2.2	-90.9
10 AM	1.2	-91.1	1.2	-88.8	1.3	-86.2	1.3	-83.4
11 AM	0.8	-83.3	0.8	-80.5	0.8	-77.3	0.8	-73.8
12 PM	0.4	-71.4	0.5	-67.3	0.5	-63.0	0.5	-58.5
1 PM	0.2	-42.5	0.3	-37.3	0.3	-32.3	0.3	-27.6
2 PM	0.2	30.3	0.2	26.9	0.3	24.5	0.3	22.8
3 PM	0.4	67.5	0.4	63.6	0.4	59.7	0.5	56.2
4 PM	0.7	81.3	0.7	78.5	0.7	75.5	0.8	72.6
5 PM	1.1	89.6	1.1	87.4	1.2	85.0	1.2	82.6
6 PM	1.8	96.2	1.8	94.3	1.9	92.3	2.0	90.2
7 PM	3.4	102.3	3.7	100.7	4.0	98.9	4.4	96.9

Table 15.

TABLE 15. TAMPA - ED=Eastern Daylight Savings Time, SPF=Shade Projection Factor, AA=Azimuth Angle.

	SEPT. 1		SEPT. 8		SEPT. 15		SEPT. 22	
ED	SPF	AA	SPF	AA	SPF	AA	SPF	AA
8 AM	5.4	-94.2	5.8	-91.6	6.2	-88.9	6.8	-86.2
9 AM	2.3	-87.2	2.3	-84.4	2.4	-81.5	2.5	-78.6
10 AM	1.3	-79.2	1.4	-76.0	1.4	-72.8	1.5	-69.7
11 AM	0.9	-68.6	0.9	-64.9	0.9	-61.2	1.0	-57.6
12 PM	0.6	-52.0	0.6	-47.6	0.6	-43.5	0.7	-39.6
1 PM	0.4	-21.7	0.4	-18.1	0.5	-15.1	0.5	-12.4
2 PM	0.4	21.2	0.4	20.5	0.5	19.9	0.5	19.4
3 PM	0.5	51.7	0.6	49.0	0.7	46.6	0.7	44.4
4 PM	0.8	68.5	0.9	65.7	1.0	63.2	1.1	60.7
5 PM	1.3	79.0	1.4	76.6	1.5	74.2	1.6	71.9
6 PM	2.3	87.1	2.4	84.9	2.7	82.7	3.0	80.5
7 PM	5.3	94.1	6.3	92.0	7.9	89.9	10.6	87.8