
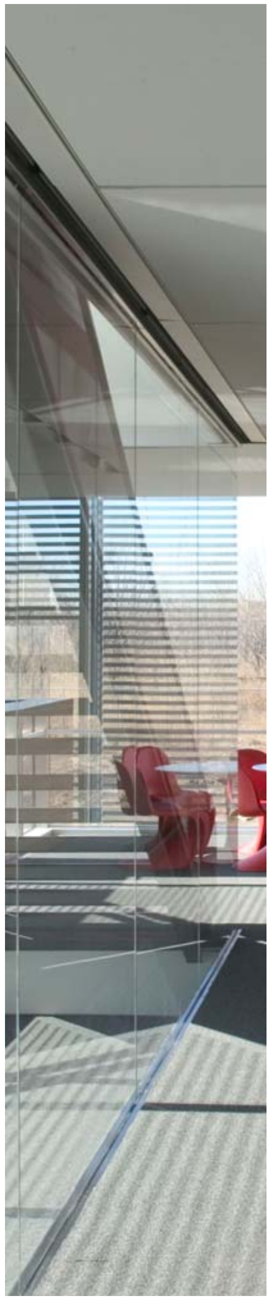

Commissioning and Verification Procedures for the Automated Roller Shade System at The New York Times Headquarters, New York, New York

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Notice

Summary

This document describes the procedures for verification testing of a newly installed automated roller shade system. The automated roller shade system has been designed to control direct sun and window glare while admitting daylight and permitting view out. Procedures in this document focus on verifying that the glare control aspect of this commercially-available system works prior to building occupancy. A high dynamic range luminance measurement tool, developed for this project, is used to verify that the average window luminance is within acceptable limits. Additional spreadsheet and visualization tools are described. The commissioning agent (CxA) and The New York Times will use these procedures during the commissioning phase of the building to verify that the automated control system is operating as intended.

Acknowledgements

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1. Overview of Commissioning/ Verification Test Procedures

1.1. Purpose and scope of verification

This document describes the procedures for verification testing of a newly installed automated roller shade system. The automated roller shade system has been designed to control direct sun and window glare, admit daylight, and permit view out. The overall objective of verification testing is to determine whether the automated shade system works according to the procurement specification *prior to occupancy*. Historically, user rejection rates of automated systems (e.g., daylighting control systems) have been high, due in large part to improper commissioning, resulting in a loss of the potential benefits of the technology investment and negative long-term market impacts on emerging technologies. Unlike the cell phone industry, for example, where poor connectivity was and still is tolerated by the customer, the building industry is risk averse – failures in the industry are not well tolerated due to the cost and longevity of installations.

The term “commissioning” encompasses tasks that ensure that the newly installed control system meets the performance goals. In this project, the manufacturer has been tasked with commissioning the automated roller shade system and verifying that the system works according to the performance specifications. Pre-startup inspections, functional tests, tuning and verification of all control zones, interfaces, and sensors are first conducted by the manufacturer. Verification tests are then conducted by the commissioning agent (CxA) using the procedures described in this report. The owner will use the results from these tests to determine compliance with the performance specifications and whether to sign off and pay the manufacturer.

In this document, the term “commissioning” will be used interchangeably with “verification” to mean the process of verifying that the control system meets the performance goals stated in the procurement specification. While the verification tests will generate data that can be used by the manufacturer to diagnose and fine-tune the performance of their control system, this document does not describe how the control sensors can be re-commissioned or tuned to better meet performance goals.

<u>This document addresses specifically the glare control aspect of the automated system</u>, although the procedures allows the CxA to flag other non-compliant conditions. In an earlier field test [1], the manufacturer proved that the direct sun control component of their algorithm worked satisfactorily over a nine-month test period. The control system is described in Section 1.3.

1.2. Owner specifications for performance

For convenience, the applicable section of the NYT procurement specification is duplicated below. The full specification can be found at: http://windows.lbl.gov/comm_perf/nyt_shades-controls.html.

Excerpt from GMP-Issued for construction, 3/17/06, Gensler 06.1024.000, page 12494-4, 2.4 Shade control system, A:

Primary goals of the shade control system are:

1. Maximize natural light
2. Maximize occupant connectivity with the outdoors, i.e. external views
3. Intercept sunlight penetration so as to avoid direct solar radiation on the occupants
4. Maintain a glare free environment
5. Provide occupant manual override capability
6. On any given façade the shades are as a general rule expected to be controlled together to the same bottom-of-hem height.

Excerpt from GMP-Issued for construction, 3/17/06, Gensler 06.1024.000, page 12494-5, 2.4 Shade control system, D:

Control algorithms and the automatic control system mode:

1. The shades shall block direct sun so that the depth of direct sun penetration is no greater than a specified horizontal depth from the face of the window wall at floor level. The specified maximum penetration distance may vary for different perimeter areas and on different floors. The shades shall not be deployed to block direct sun if the sun is blocked by nearby buildings within an entire shade control zone. The exterior ceramic rods provide direct sun shading. Automated shade control shall account for this shading. The profile angle and solar surface azimuth angle shall be determined by the Shade Controls System Supplier based upon the geometries of the curtain wall.
2. The shades shall control glare so that the window luminance viewed from any angle within the work space is no greater than a specified level during the day. This includes all periods throughout the day when there is or is not direct sun in the plane of the window.
   a. When there is no direct sun in the plane of the window wall, the average luminance of the unobstructed portion of the window wall (the glazing area not shielded by the exterior ceramic rods) shall not exceed 2000 cd/m^2 (candelas per square meter).
   b. When there is direct sun in the plane of the window but the orb of the sun is not within

the immediate field of view, the average luminance of the unobstructed portion of the window wall shall not exceed 2000 cd/m^2.

c. When there is direct sun in the plane of the window and the orb of the sun is within the immediate field of view, the average luminance of any portion of the window wall shall not exceed 2000 cd/m^2 for more than 30 minutes.

3. Daylight admittance shall be maximized by raising the shades when sun control and glare control are not required.

Bullets 4-16 provide additional requirements for delays, retraction for view, etc.

For bullet 1 above, the depth of penetration is 3 ft in all control zones except for those zones at the north and south stair in the west wing of the tower where the allowable depth is 6 ft.

For bullet 2 above, the owner will allow a 10% deadband for the 2000 cd/m^2 limit. See Section 1.4 for the acceptance criteria and procedure.

These setpoints can be changed by the owner during the Cx process as well as after building occupancy.

1.3. Description of the automated roller shade system

MechoShade Systems, Inc. (MSS) is providing the automated shading system in the building. The system is generally described as follows.

Each roller shade **group** consists of one to six 1.52-m (5-ft) wide roller shades (or shade “bands”), which are coupled together at the header and controlled using one motor. A **control zone** consists of one or more motor groups of roller shades. Motor groups and control zones are designated on the MSS shop drawings.

The **shade motor** is a 120-V ac-operated electric tubular motor mounted directly within the roller of the shade. Motor control is done via an Echelon Neuron TM based communication and control network which operates over a 78 kbps free-topology, two-twisted pair backbone. Each motor is individually addressable. Motors are wired to a 2-motor controller bus interface unit (IMCS2-BI) then connected digitally to a manually-operated keypad and the main supervisory control system (MechoShade AAC-PC). The shades are activated so that there is a slight time delay (~0.5 s) before the next shade is deployed. Motors are sound rated for no greater than 47 db per manufacturer’s specification.

The roller shade **fabric** is made up of PVC-coated polyester yarns woven into a shade cloth with flat white yarns in one direction and flat black yarns in the opposing direction. The color of the shade is predominately white on one face and gray on the other face. The gray side is faced toward the exterior.

Despite the tightness of the weave, the shade fabric allows some direct sunlight to pass through the interstitial space between the threads. This occurs for sun angles that are near normal or perpendicular to the fabric. For oblique solar angles, the fabric appears to provide complete diffusion of sunlight and blocks view out. The **openness factor** (percentage of open space to opaque fabric) indicates roughly how much direct sunlight can come through the shade. The amount of view out through the fabric depends on the relative brightness of the interior space to the outdoors and the color and openness of the fabric.

According to shop drawings dated 3/7/06, two **types of fabric** were selected for the building:

1) Mechoshade type S10480A (openness factor of 2%)
2) Mechoshade ThermoVeil type 6020 (openness factor of 3%)

The S10480A fabric was used on the south, east, and west facing facades on all floors of the building. The 6020 fabric was used on the north-facing facades on all floors of the building.

The Times requested that the more open 6020 fabric be used on the lower floors of the building because the urban surroundings block sunlight for the majority of the year.

Six **preset heights** were designated by the building owner:

0 = fully retracted
1 = half way between the fully retracted position and the top of the vision window
2 = top of the vision window
3 = 4 feet above finished floor
4 = bottom of vision window
5 = down to the floor

In the automated mode, all shades in a control zone are always controlled to the same height.
In the manual mode, a single motor can be set to any of the six preset heights. Preset 5 was eliminated later from the automatic control mode.

The actual implementation of the control system's algorithm is not described in this document for proprietary reasons. See MSS documentation for a description of the location and type of control sensors used and for details on how the algorithms were implemented.

1.4. Acceptance criteria and procedure for glare control

The New York Times acceptance criteria for the **glare** portion of the control system are based on measurements of average window luminance. Average window luminance is measured at designated locations on each floor using a high dynamic range (HDR) luminance measurement tool developed by Anyhere Software and LBNL.

The locations of the measurement points are selected so as to yield conservative window luminance values representative of worst case glare. Measurement points were defined for each control zone. The measurements are made typically facing perpendicular to the window at a distance ranging from 5 to 15 ft from the window and at a typical seated eye height of 4 ft above the finished floor. The distance is determined by the location of the workstations nearest the window wall (e.g., 5 ft at most control zones depending on the furniture layout and 15 ft from the north or south facades near the stair).

The location of the measurement point along each of the facades was determined by the extent of the urban obstructions, the shade control zone layout, and the layout of furniture and work areas. Within a control zone (ranging from 5 to 80 ft in width, with typical widths of 30 ft), the location with the least horizon obstructions (due to opposing buildings and/or the building itself) and therefore greatest sky view was selected. Generally, the greater the view of the sky, the greater the potential for glare.

The area of the window from which the average is computed is typically a total of four window bays wide, centered on the window mullion. For areas where the control zone is less than four windows wide, or where there are internal obstructions, the horizontal view is reduced accordingly.

There are two major types of facades: a) upper and lower portion of the façade is shaded by exterior ceramic tubes (“ct-façade”) and b) unobstructed façade with or without frits (“no-ct-façade”). For the ct-façade, the area of the window from which the average luminance is computed is the ~4 ft high unobstructed section of the façade between the upper and lower tube arrays (the “vision” portion of the window wall). The vertical angles at 5 ft from the window are approximately +19° up from the horizon and -13° down from the horizon. For the no-ct-façade, the vertical area is defined by the full height of the unobstructed façade with vertical angles of +52° and -39° at 5 ft from the window. For practical purposes, the height of the glare source is fixed by the vision area and is not varied with shade height.

As defined, the window “glare source” is likely to be perceived by occupants facing the window or having a parallel/ side view of the window at distances of 5 ft up to 35 ft from the window. The majority of the floors have predominantly open plan offices. Occupants within this work environment could experience discomfort or disability glare due to uncontrolled window brightness within their field of view.

A budget of 1 person day per floor total (including preparation and measurement time on other days of the year or sky conditions) has been assigned to verify performance of the shade control system. Due to the practical time limitations of commissioning, the need to pay the manufacturer in a timely manner, and the need to keep to the schedule of completing the building, the CxA will verify performance as the floors are completed and independent of season or sky conditions. If time permits, multiple measurements can be made at different times at the same measurement location.

Verification is scheduled to occur from October 2006 to March 2007. This winter period typically has low sky luminances and low solar angles, making it difficult to fully evaluate whether the shades will close as they should to control glare. For some orientations, the direct sun control mode will be in effect for the majority of sunny winter days (e.g., on the south façade). Measurements taken on overcast days or winter conditions, when glare is unlikely to be a problem, still provide information as to whether the shades are open when they should. These measurements may need to be repeated under partly cloudy or clear sky, spring through fall conditions, to ensure that the shades are closed when they should be under more severe glare conditions.

Measurements at a single location take approximately 10 minutes including the time to document and observe site conditions. The CxA positions a digital camera mounted on a wheeled cart into the correct measurement location, then runs the HDR software. The software asks the CxA to enter the point location and other information, then directs the camera to take the measurement. The digital camera, which is controlled by the laptop computer, takes several photographs, then the HDR software processes these photographs automatically into an HDR image (< 1 minute). The software then prompts the CxA to outline the window with a drawing tool (Adobe Photoshop), then it automatically computes the window's average luminance level and determines whether it is within acceptable levels. A fisheye image of the scene is displayed showing the average window luminance of the scene. Values are automatically recorded in the Cx database.

Determination of the exact mode of the control system during the time of measurement requires access to the manufacturer's control system but because of the stage of installation, access will be too labor intensive (e.g., connect to the system through the ceiling). Instead, the CxA will take the HDR measurement with the shade in automatic mode then again in manual mode if the shade is down and likely to be in the glare control mode. This procedure assumes that the shade can be put into a special Cx mode, where recovery from manual mode back to the automatic mode will occur within a user-specified period (e.g., 5 min), or that a second person is at the main control system to return the control zone back to the automatic mode.

Spreadsheet tools are provided to the CxA to determine what mode the shade control system is likely to be in (i.e., the system may be in a different mode due to variable sky conditions or control delays that prevent shade oscillations or control hysteresis). These tools are described in Section 2.

<u>1.4.1. Pass/fail criteria</u>

Given these measurements, the HDR software determines whether the glare portion of the shade control system passes or fails as follows. (The threshold value of 2000 cd/m^2 defined in the procurement specification is used in the pass/fail criteria with a deadband of ±10%; i.e., 1800-2200 cd/m^2. The Times may choose to alter the threshold and deadband values depending on space use, furniture layout, or other criteria during the Cx process or after occupancy.)

When in the automatic mode:

- If the shade is up (fully retracted or shade preset height 0), then it is in the daylight mode. The shade control zone passes if the average window luminance is below 2200 cd/m^2, and fails if it is above 2200 cd/m^2.
- If the shade is down (covering any portion of the window wall or shade preset heights 1-5), then the shade is in the direct sun and/or glare control mode. The shade control zone passes if the window luminance is below 2200 cd/m^2 and fails if it is above 2200 cd/m^2.

If the shade passes in the automatic mode, then test the system in the manual mode:

- If sunny, check if the shade control zone is in the direct sun control mode by raising the shade(s) to preset 2 and measuring the horizontal depth of sun penetration. If the depth exceeds the maximum allowable distance and passes in the automatic mode, then the shade control system passes.
- If the depth of sun penetration does not exceed the maximum allowable distance or if not sunny, then check if the glare mode is too restrictive with the shade(s) at preset 2 (façade with or without tubes). The shade control zone passes if the average window luminance is above 1800 cd/m^2 and fails if it is below 1800 cd/m^2. An HDR measurement is not made if the sun is in the field of view of the camera (even if the sun is slightly obscured by tubes).

For all measurements taken on one floor, the glare control aspect of the shade control system is determined to have passed on that floor if <u>all</u> of the measurements receive a “pass” rating.

Additional measurements taken at a later time during a different season will not be used to pass the floor. However, the manufacturer may be requested to tune the control system to improve performance.

1.4.2. Flagged conditions

Conditions that are likely to cause discomfort glare but do not fail the average window luminance criteria are flagged in the HDR output image and in the database. The flag is based on the following criteria:

- If the glare source is greater than 0.1 steradian and its average luminance is greater than 2000 cd/m^2, then the glare source is flagged.

The criteria were set assuming that the occupant faces the window or has a side view of the window.

The size of the glare source is determined by:

- Locating each pixel with a value greater than 2000 cd/m^2 within the HDR image's array of 1024x1024 pixels.
- For each pixel, a virtual circle is drawn around each pixel with a 3° diameter. If that "enlarged" pixel overlaps an adjacent enlarged pixel with a value greater than 2000 cd/m^2, then that adjacent pixel is included in the glare source.
- Once the glare sources are defined, the average luminance and size of each glare source is computed.

The top four glare sources (in order of largest size and greatest average luminance) are recorded to the verification database.

1.5. Overview of steps for verification

The following steps should be taken to verify the performance of the shade control system. Details are given in Sections 2 and 3.

Define the **Cx schedule** one week prior to verification in the field (see Section 2):

1. Check weather forecast to determine if the following week will be sunny, partly cloudy, or overcast.
2. For the floor(s) to be verified, create a Cx schedule indicating which points on each floor will be measured and when during the day the measurements should be taken. Create the Cx schedule using the following resources/ tools:
    - R1: indicates the shade control mode under sunny conditions (see Section 2.2.1)
    - R2: indicates whether urban obstructions will shade a façade under sunny conditions (see Section 2.2.2)
    - R3: illustrates how large the sky glare source is at each measurement point (see Section 2.2.3)

- R4: indicates the luminance of an unshaded and unobstructed window under standard clear sky, partly cloudy sky, and overcast sky conditions (but with no sun directly on the window). See Section 2.2.4. The times of day when the values are between approximately 1500 and 2500 cd/m^2 are the most important, as it is during these times that the window shades are likely to be activated/ moved to control glare.

General steps for verification in the field (see Section 3):

1. Each day, check the laptop's clock and verify that its time is the same as the MechoShade Systems (MSS) supervisory computer's clock. If not, correct the HDR computer's time so that its time differs by no more than 1 minute from the MSS clock.
2. Tell MSS to put supervisory control system into the Cx mode. This will enable recovery from manual mode back to automatic mode within a designated period (5-10 minutes).
3. Set up the shade commissioning cart. Never leave the shade cart unattended to avoid theft of the cart and any of its components.
4. The HDR measurements will be taken in sequence at particular locations and at given times, as defined in the Cx schedule. Adjust the Cx schedule if the weather changes.
5. Go to the measurement point. Determine using observation (resource R3 can help) that the sun is not in the field of view of the camera's fisheye lens (view of the sun orb can damage the camera). If the conditions are sunny and the sun is in the field of view, and the shades are not blocking the sun orb (this should not occur) then go to the next point. This measurement cannot be taken at this time.
6. Check direct sun penetration. If the depth exceeds the maximum allowable depth, then document it by taking an HDR image via option 3D in the software, but place the lens so it doesn't see direct sun. When at the verification database (last step in HDR process), insert a "1" in the "direct sun?" column to indicate shade control system failure.
7. If the measurement can be taken, then position the HDR camera at the measurement location.
8. Using the HDR software, under Option 3/ Measurement point, option B/ Change measurement point, input the name of the measurement location.
9. Using the HDR software, under Option 3/ Measurement point, option D/ Take measurement, initiate capture of the HDR image with the shades in the automatic mode (image capture is done automatically from the computer). Record the sky conditions and other information as prompted by the software.
10. Raise all the shades in the control zone to preset 2 using the manual override switches. Apply logic from pass/fail criteria (Section 1.4.1). If the sun is not in the field of view of the camera, then take a second HDR measurement. Return shade control zone back to automatic mode.

11. Review the HDR image and outcome of the evaluation. Take notes of conditions that may have contributed to failure of the glare portion of the shade control system if the outcome is a “fail” (e.g., reflections off opposing buildings).
12. If direct sun penetrates greater than the allowable distance from the window wall, enter a fail designation in the Cx verification database (except if it is 30 minutes before sunset). If the sun is not in the field of view of the camera, take an HDR measurement (if one has not yet been taken) to document the failure.
13. When all measurements are completed at the end of the day, back up the verification database, recharge the batteries for the laptop computer and camera, and send a copy of the database to NYT, LBNL, and MSS for review. Secure the shade cart in a safe location to avoid theft.

1.6. Structure and use of the verification database

The Microsoft Excel verification database/ spreadsheet serves as a record of all measurements taken in the field. It includes not only the measured window luminance data but also the filename of the HDR image (which can be used later for diagnostics, error checking, etc.), solar conditions when the measurement was taken, and observations by the CxA. The database documents if and when the shade control system fails and the degree of failure.

Each measurement point stored in the database is assigned “header” information that is common to all three commissioning carts (shading, lighting controls, and underfloor air distribution), which may be useful to the building owner in the long term. All data are time-stamped so that measurements can be compared to shade control status, mode, and other pertinent data reported by MSS’s supervisory control system. The MSS control system records these data throughout the Cx phase and during building operations.

The verification database could be used by MSS to diagnose and troubleshoot why they received a “fail” at a particular measurement point. Failures could be attributed to software programming errors, given that this is a new product, or to problems with sensor installation, position, or sensitivity. For example, MSS could correlate HDR data to sensor readings to fine-tune sensor settings.

1.7. Coordination

Several different parties will be using the shade cart to commission or verify performance in the field:

- MSS may be using this system to check the calibration of their sensors during the commissioning stage (separate cart with the same instrumentation).
- Multiple CxA operators will use this system to verify performance during the verification stage.

- The facility manager will use this system to verify performance during the verification stage and to check performance after occupancy to troubleshoot occupant complaints.

The HDR software has been set up so that the user enters their initials or user ID prior to taking measurements. All measurements in the verification database will have an ID associated with it.

2. Preparation One Week Before Verification

The purpose of this preparation activity is to determine the schedule for when the measurements should be taken on a particular floor one week prior to verification in the field.

2.1. Select measurement points

For each floor, LBNL has pre-defined measurement points for each shade control zone based on the furniture plans provided by The Times (dated March 17, 2006 GMP issued for construction) and control zone diagrams provided by MSS (dated March 7, 2006). Each measurement point is assigned a level of priority from 0 (very low priority) up to 4 (very high priority). If there is limited time, the CxA should focus on measuring the highest priority locations first.

2.1.1. Basis for point selection

Measurement points were selected based on the location of interior obstructions (e.g., walls, furniture) near the façade, location of attached exterior obstructions (adjacent building wings, cross bracing, columns, etc.), and the view out with the least obstructed sky given the urban cityscape. Generally, the least obstructed location in a control zone was selected.

The priority of the measurement points was set based on:

- Control zones where the occupants have a direct or side view of the window wall had higher priority than those whose occupants faced the core.
- Locations where the primary task was working on a computer with the window in the field of view had higher priority (e.g., desks versus informal meeting areas near the stairs).
- Larger control zones had higher priority.
- Points with the least obstructed sky across the width of the building wing's façade had higher priority.
- Points with the least interior obstructions across the width of the control zone (columns, furniture, etc.) had higher priority.

- Locations where a measurement of four window bays could be taken had higher priority.

For those without immediate access to the job site, Radiance animations were created to help one visualize the extent of urban sky obstructions on every fourth floor of the tower (floors 6 through 26). These movie/ simulations "walk" a person around the full perimeter of the tower floor at a seated height of 4 ft above the floor and a distance of ~4.25 ft from the window wall. The view is aimed primarily perpendicular to the window. Distant obstructions (like the Empire State Building) remain approximately in the same position within the field of view across the 145-ft width of the east and west tower wings, while closer obstructions vary significantly. A similar assessment at the actual job site could be generated simply by walking the floor and making judgments on the spot or by creating a similar movie with a digital video camera mounted on a wheeled tripod after the windows have been installed but prior to the installation of interior walls and furnishings.

These animations can be viewed on the HDR computer in the directory scart/ nytimes animations or at the website:
http://windows.lbl.gov/comm_perf/newyorktimes.htm

Download the animations, then double-click on *.mov files and view using standard movie-viewing software like QuickTime. The filenames indicate the floor of the tower; e.g., L10anim.mov is for the tenth floor. Move the cursor at the bottom for stop-action viewing. The movie starts at the southwest corner of the west wing of the tower, then moves north to the northwest corner of the building.

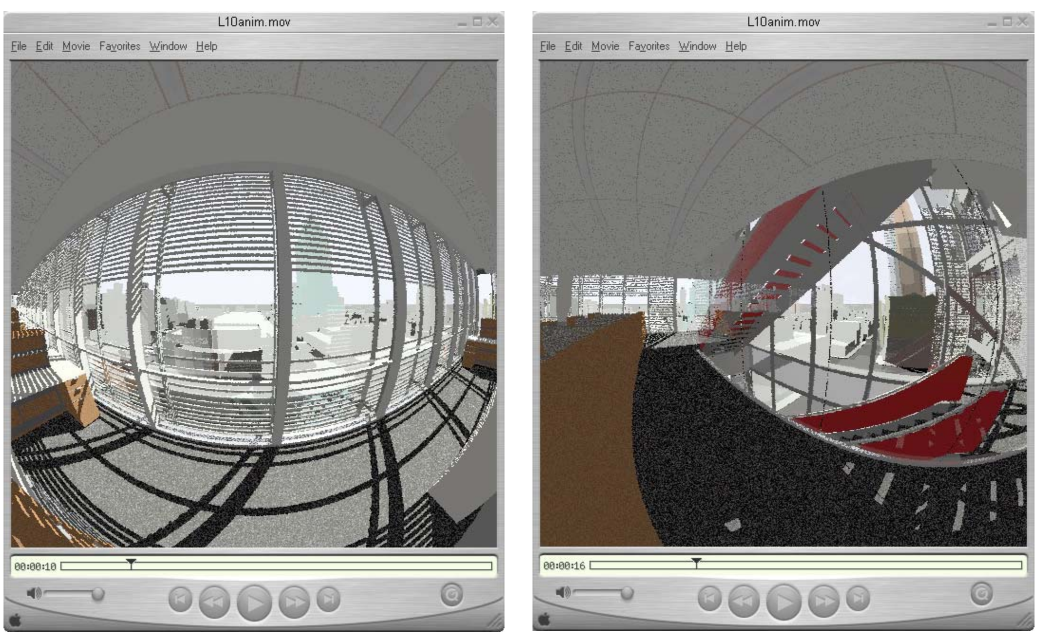


Figure 1. Radiance visualization of urban sky obstructions.

2.1.2. Adding new measurement points

If changes are made to the furniture or control zones, the CxA will need to define a new measurement location for a control zone. To do this, the following procedure should be taken:

2.1.2.1. Consult drawings to determine how the walls/furniture and/or MSS control zones have been changed.

2.1.2.2. Select a measurement point within the new control zone that corresponds to the worst case glare condition (see criteria described in Section 2.1.1 above). If the furniture and/or interior walls have changed but the MSS control zone remains the same, select a new measurement point, if needed, using criteria described in Section 2.1.1.

2.1.2.3. Assign the measurement point a unique name.
The naming convention for the LBNL-designated points is the name of MSS's control zone: [NESW]-[floor number].[MSS control zone number]. For example, for the north wing, floor 6, MSS control zone 2, the point name is "N-06.02". New measurement points within the same control zone should be designated with an additional letter: e.g., "N-06.02a", "N-06.02b", etc. DO NOT alter the information for an existing point. **ALWAYS use the procedure outlined in Section 2.1.2.5 below to modify the information for an existing point (but create a new name for the same point location) or to add an entirely new measurement point.**

Archive old, superceded points if the new measurement point is defined for a new control zone:
If MSS decides to renumber their control zones instead of using the next available unused number, then data for the old measurement points could be mixed up with the new.

- Open up the nytimes/shadecomm/meas folder and click on the applicable verification database. Enter a "1" in the column labeled "superceded point" for all old measurement points.
- Find the folders for the old measurement points under the nytimes/shadecomm/meas folder then move them to a folder in the meas folder labeled: "2006-03-17 superceded", where the date field for the folder name is the date from MSS shop drawings.

If MSS does not renumber their control zones but simply uses the next available number, then enter "1" for the superceded points into the verification database as described above.

2.1.2.4. Determine x-y coordinates.
The x-y coordinates of the point is needed if the CxA wishes to use the fisheye tool (R3) to determine if the sun orb is within view of the fisheye lens. The origin of the x-y coordinates is the southwest corner

of the west wing of the tower. The x-axis is along the east-west axis of the building with positive values to the east. The y-axis is along the north-south axis of the building with positive values to the north. Values are entered in units of feet. Use Adobe Acrobat or a CAD program to determine coordinates for new measurement points.

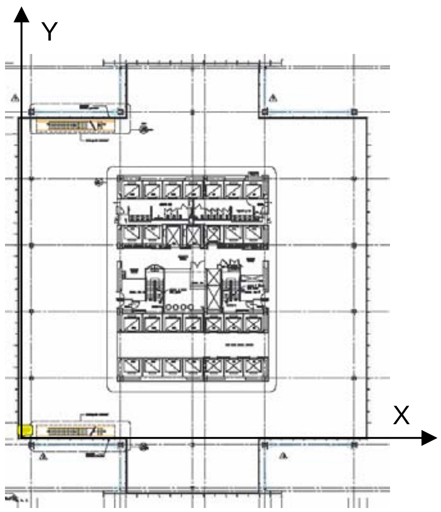


Figure 2. Origin and x-y coordinate system on floor plan. Project north is up.

<u>2.1.2.5. Use the HDR software to input information about the new measurement point</u>

See Section 3.3.1 on how to start up use of the HDR software. Then from the main menu, select Option 3: measurement point:

```
Commissioning Agent: G.Ward
Date: 06/09  First daylight hour: 6 EDT  Last daylight hour: 19 EDT
Tower Shade Commissioning Main Menu
        0. Exit
        1. Change date
        2. View urban shadows
        3. Measurement point

Choice: 3
```

You will then be prompted as follows (in this example, we're creating a new point "SW-16.1a"):

```
Enter point [0] SW-16.1a
New point? [n] y
Enter NYT coordinates: 6X
Enter floor (1-28): 16
Building model/floor16.oct in background [1] 3155 3156 [ignore]
Enter drawing date (MM/DD/YYYY): 3/17/06 GMP & 3/7/06 MSS
Enter wing (NESW): W
Enter view direction (NESW or NE/NW/SE/SW): SW
```

```
Enter x y position (feet from SW corner): 5 10
Enter feet from window: 5
Enter image center (mullion, corner, window): corner
Enter image width: 2S, 1W
Enter image height: floor/ceil
Enter priority (0-4): 2
```

The following information is required for each measurement point:

- NYT coordinates: See NYT coordinate system map and determine coordinates.
- Point: name of point (e.g., SW-05.1). Naming convention described in item 3 above.
- Floor number: 1-26.
- Drawing date: 3/17/06 GMP & 3/7/06 MSS (date on Gensler furniture plans and MSS shop drawings) or update if new drawings are being used.
- Wing: N, E, S, or W of tower or façade orientation on podium floors.
- View direction: orientation of HDR camera; north, south, east or west, or diagonally outwards at the corners.
- X and Y coordinates of the measurement point with origin of SW corner of W wing of tower for floors 1-26. See item 4 above. Z-coordinate will always be 4 ft above the finished floor for all measurement points.
- Distance from window measured perpendicular to the façade or measured at a 45 degree angle (ideally, dependent on furniture placement) from the corner of two adjoining facades.
- Image center: position of HDR camera –
  - centered on the window "mullion" column,
  - centered on the "corner" for the corner condition of the floor plan, or
  - centered on the 5-ft width of the "window" itself.
- Image width: width of the window (glare source) to be measured: designation of the number of window bays to be included when one uses the outlining tool in the HDR software to designate the window area to be measured; e.g., "+-2" bays, or "1N,1W" 1 bay to the north and 1 bay to the west.
- Image height: height of window (glare source) to be measured; either the height of the view portion of the window wall if there are ceramic tubes on the window ("tubes") or floor to ceiling height if there are no tubes ("floor/ceil").
- Priority: 0=very low, 1=low, 2=moderate, 3=high, 4=very high. See criteria in Section 2.1.1 above.

All data for a new point is stored in files called "info.txt" and "descrip.txt" which are located in an individual folder labeled with the measurement point name in the nyt/shadecomm/meas directory.

2.1.2.6. Update the master list of measurement points.

The information entered in Section 2.1.2.5 above can be found for all measurement points in a master list. This list can be found in the directory called nyt/shadecomm/meas. When points are added, the master list must be updated. To do this, open a new Terminal window by clicking on the Terminal icon on the desktop, then type the following commands:

```
Last login: Wed Aug 16 12:31:22 on ttyp2
Welcome to Darwin!
[pathname:~] username% cd nytimes/shadecomm/meas
[pathname:~/nytimes/shadecomm/meas] username% ./combine.csh >
a_master_list.txt
```

A file called "a_master_list.txt" will be generated in the nyt/shadecomm/meas directory. All new points will be appended to the end of this list. Import the tab-delimited file in MS Excel. If you've opened this file previously, go to the Excel File menu (look for filename in list) to re-locate and open the file. Sort the list by floor, tower/ podium, and wing. Save the file to a separate MS Excel workbook with a date in the filename.

Floor	Tower/ Podium	Wing	Dwg date	Point	Priority	X-coord (EW)	Y-coord (NS)	Photo direction	Distance from window (ft)	Image center	Image width	Image height
5	T	East	3/17/06 GMP & 3/7/06 M	E-05.3	3	142	97	East	5	mullion	+/-2	tubes
5	T	East	3/17/06 GMP & 3/7/06 M	E-05.4	1	142	37	East	5	mullion	+/-2	tubes
5	T	East	3/17/06 GMP & 3/7/06 M	N-05.4	3	124	139.5	North	6	mullion	+/-2	floor/ceil
5	T	East	3/17/06 GMP & 3/7/06 M	NE-05.1	0	142	139.5	NorthEast	7	corner	2N-1E	floor/ceil
5	T	East	3/17/06 GMP & 3/7/06 M	S-05.1	3	124	5	South	5	mullion	+/-2	floor/ceil
5	T	East	3/17/06 GMP & 3/7/06 M	SE-05.1	0	142	5	SouthEast	7	corner	2S-1E	floor/ceil
5	T	North	3/17/06 GMP & 3/7/06 M	E-05.2	2	94	159.5	East	5	mullion	+/-2	floor/ceil
5	T	North	3/17/06 GMP & 3/7/06 M	E=05.2	2	94	159.5	East	5	+/-2	floor/ceil	
5	T	North	3/17/06 GMP & 3/7/06 M	N-05.3	4	59	164.5	North	5	mullion	+/-2	tubes
5	T	North	3/17/06 GMP & 3/7/06 M	W-05.4	3	44	159.5	West	5	mullion	+/-2	floor/ceil
5	T	South	3/17/06 GMP & 3/7/06 M	E-05.1	2	94	-14.5	East	5	mullion	+/-2	floor/ceil
5	T	South	3/17/06 GMP & 3/7/06 M	S-05.2	4	59	-19.5	South	5	mullion	+/-2	tubes
5	T	South	3/17/06 GMP & 3/7/06 M	W-05.1	3	44	-14.5	West	5	mullion	+/-2	floor/ceil

Figure 3. Sorted a_master_list.xls file (partial list).

2.1.2.7. Update the measurement point diagrams.

The locations and names of all measurement points are documented by NYT on a master set of electronic drawings. Inform NYT when new points should be added to this master drawing set. Copies of these drawings should be stored on the HDR laptop computer.

If the furniture or MSS control zone plans have been updated, place the old and new measurement point locations on the new furniture plans and generate new measurement point diagrams.

2.1.2.8. Run the HDR software to generate R3 fisheye views for the new point.

For new measurement points, generation of the fisheye views (resource R3) will take a few more minutes. See Section 3.3.6 on how to create fisheye views for the new measurement point.

2.2. Evaluate solar conditions at the measurement points

Use the following four resources to determine the best times to assess glare control at each of the measurement points. A detailed description of the calculation method used for these resources are given in Appendix A.

2.2.1. Resource R1: Determining when shades are in glare mode

Calculations were made to determine approximately what position the shades would be in at various times of the day and year:

- if conditions are sunny,
- if the shades are controlled only to block direct sun, and
- if there are no urban obstructions.

Because the calculations assume an unobstructed site, the data must be used in combination with Resource R2. Calculations were made based on the Benson Industries Curtainwall drawings (MPE-05, May 12, 2003) assuming a height of 2.5 ft from the center of the top tube of the lower array of tubes to the top of the finished floor.

These data are shown in graphs given in Appendix B for each orientation and for the following façade conditions:

- Façade with ceramic tubes and vision window (ct-façade)
- Façade without ceramic tubes (no-ct-façade) with an allowable depth of sun penetration of 3 ft
- Façade without ceramic tubes (no-ct-façade) with an allowable depth of sun penetration of 6 ft

The R1 graphs have the day of year on the x-axis and time of day on the y-axis. Each line on the graph represents the shade position required to control direct sun. Data are given for Standard Time on the left vertical axis, and daylight savings time on the right vertical axis.

For example, on the graph for the north façade with no tubes and 3 ft sun penetration on September 28th (all hours given in EST):

- The shade is down (preset 5) starting at ~6:00 until 7:00. The shade is raised at ~7:00 to preset 4.
- From 7:00 to 7:20, the shade is at preset 4, then is raised to preset 3 at 7:20.

- From 7:20 to 7:35, the shade is at preset 3, then is raised quickly within ~10 min to the fully raised position, preset 0 at 7:45.
- From 7:45 to 8:20, the shade is fully raised, but the sun illuminates the north façade.
- After 8:20 the orb of the sun is no longer in the plane of the north façade, and the shade remains in the fully raised position for the remainder of the day.

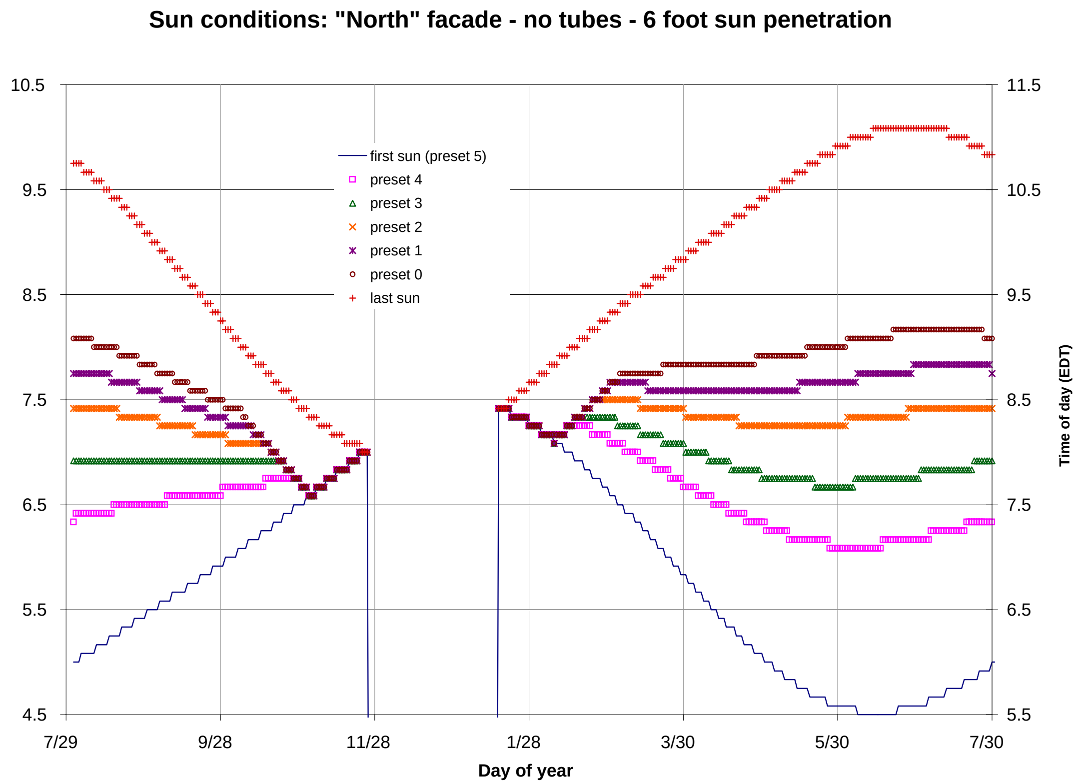


Figure 4. Example of an R1 graph.

From this information, the CxA can derive when the shades might be controlled for glare.

- From 7:00 to 8:20, the shade may be lower than the position shown on the graph if the window luminance exceeds threshold limits.
- From 7:45 to when the sun sets, the shade will be in the daylight or glare control modes. If there is no glare, the shade will be fully retracted (preset 0). If there is glare, the shade may be at any preset height determined by the control system (presets 1-5).

Next, the CxA should combine this information with R2 data to determine if the shades should be raised because urban obstructions shade the façade (see next section).

2.2.2. Resource R2: Shadows cast by urban obstructions

Software was written to show the shadow patterns cast on the tower facades by urban obstructions if it is sunny. If the façade is shadowed by urban obstructions, then the sun orb is blocked by urban obstructions. The direct sun control mode may not be in effect (dependent on control delays). The daylight or glare mode may be in effect.

The procedure for using the software is given in Section 3.3.3.

For the same example (EST is used) on September 28th and using R2, points N-08.4 and N-08.5 only see the sun from 7:45 to 8:15 and then are in shade for the rest of the day. Urban shadows shade the remaining northern façade points for the entire day. From R1, the shades would have been down from sunrise until 7:30 for all points (until 7:45 for N-08.5). With R1+R2, the shades should be retracted for all points on the north side for the entire day because the urban surroundings block direct sun to the façade. The shade may be in a glare control mode during this time if reflections off opposing buildings produce luminance levels that exceed the allowable limit.

2.2.3. Resource R3: Determining size of sky glare source

To visualize how large the glare source is, use Resource R3 (see instructions for use in Section 3.3.6) to generate a fisheye view out from the measurement point location. If the sky glare source is small, it is unlikely to cause the shade to close. Estimates of the fraction of unobstructed sky are made using resource R3, to be used with resource R4 to determine when sky conditions are likely to cause the shades to enter or exit the glare mode.

An example image is shown below for the 8th floor, measurement point N-08.4 where the sky glare source towards the west is large enough to trigger glare control despite the view towards the east being almost completely obstructed by buildings. Approximately 50% of the sky is obstructed at this location. On the 16th floor, the sky view from measurement point N-16.4 (slightly more west) shows significant areas of unobstructed sky and is likely to trigger glare control due to bright sky conditions. The fraction of unobstructed sky for this point is on the border between 50% and 0% obstructed sky.

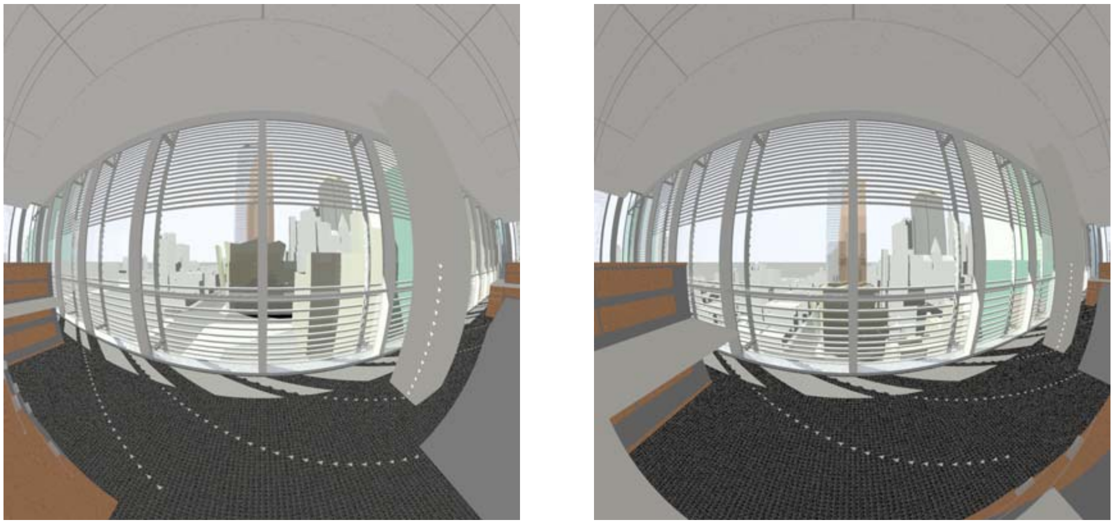


Figure 5. Sky view at N-08.4 (left) and N-16.4 (right).

Estimate the percentage of sky obstruction (0%, 50%, 100%) for the width of the control zone over the height of the vision window (e.g., from the horizon, which is ~4 ft high, to the top of clear zone for the ct-façade, and the top of the window for areas without ceramic tubes), then combine this information with Resource R4.

Additional example images are given in Figure 6 for points E-06.4, W-14.4, and S-20.2, showing sky obstruction levels of approximately 100%, 50%, and 0%, respectively.

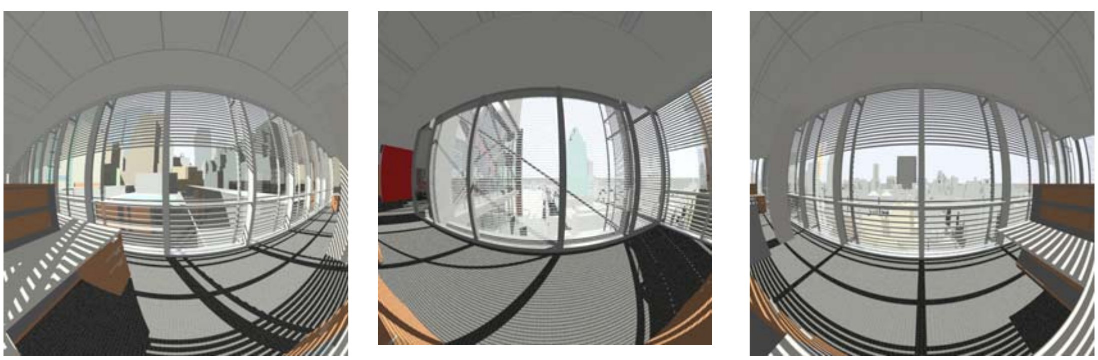


Figure 6. E-06.4, W-14.4, and S-20.2 with 100%, 50%, and 0% sky obstructions, respectively.

2.2.4. Resource R4: Determining when the window luminance is within 1500-2500 cd/m^2

Resource R4 shows the expected window luminance values for three standard types of skies as a function of day of year and time of day. Graphs are given in Appendix C for each façade orientation for:

- Clear sky conditions at a distance of 5 ft from the window, no sky obstructions
- Clear sky conditions at a distance of 15 ft from the window, no sky obstructions
- Clear sky conditions at any distance from window, 50% obstruction of sky view
- Clear sky conditions at any distance from window, 100% obstruction of sky view

- Partly cloudy sky conditions at a distance of 5 ft from the window,no sky obstructions
- Partly cloudy sky conditions at a distance of 15 ft from the window, no sky obstructions
- Partly cloudy sky conditions at any distance from window, 50% obstruction of sky view
- Partly cloudy sky conditions at any distance from window, 100% obstruction of sky view

And for overcast sky conditions (same for all façade orientations):

- Overcast sky conditions at a distance of 5 ft from the window, no sky obstructions
- Overcast sky conditions at a distance of 15 ft from the window, no sky obstructions

The calculations were made using a method described in the Appendix A. Calculations were made for a specific window orientation factoring in a 4-bay wide window, vertical height of vision window with tubes, 4 ft eye height, and 20% ground reflectance.

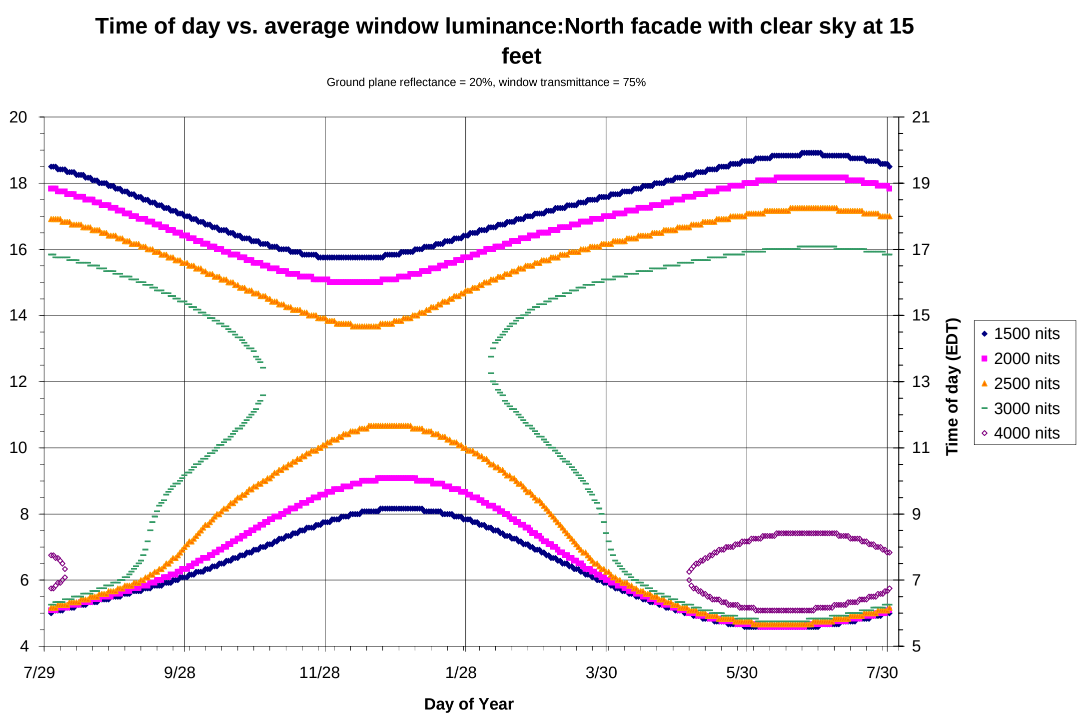


Figure 7. Example R4 graph.

Measurements should be taken when the window luminance is within the “critical range” of 1500-2500 cd/m^2 since the shade is more likely to be activated/ adjusted for glare control during these times. Actual skies may be brighter or less bright than the standard skies, so times may shift by 30-60 minutes given that the standard sky models are theoretically based. Measurements taken during times when the window luminance is less than 1500 or greater than 2500 cd/m^2 will likely not be useful for assessing the glare control mode.

Following the example from above, the forecast is clear skies for September 28th and the CxA is evaluating when to verify shade control performance for the north façade on the 8th floor. For windows with an unobstructed view (Resource R3 shows largely unobstructed sky above the horizon), the luminance at 15 ft from the window is estimated to be between 1500-2500 cd/m^2 during the periods 6:00-7:00 and 15:30-17:00 DST. Points N-08.3 to N-08.5 have sky view obstructions over about half the window. The average luminance for the clear sky with 50% sky obstructions is in the critical range from about 8:00-9:30 in the morning, and 16:15-17:00 in the evening. Since the shade is not in the direct sun control mode at any time during the day on the north façade (derived from R1+R2), the glare control mode can be assessed during these two time periods since the sky glare source was noted to be large enough (from R3) to trigger glare control.

During overcast sky conditions (for any orientation) the orb of the sun is obscured, and the direct sun control mode for the shades should not be active. Resources R1 and R2 are not relevant under this sky condition. Resource R4 shows that during the period from about the beginning of November to the beginning of February the luminance may not exceed 1500 cd/m^2 and thus it is unlikely that measurements under an overcast sky during this period will be useful.

2.3. Set schedule for floor

A budget of 1 day per floor was set for the CxA to verify that the floor was commissioned properly. Measurements on numerous floors could be conducted on the same day, depending on the availability of the hoist or service elevator and level of completion on the floors.

After identifying the best times to verify performance, note times for each measurement point on a paper copy of the measurement point floor plan. Draw a line between points denoting the path of the cart over time and work out logistics. Be prepared to change the schedule if the weather conditions change (very likely!).

2.4. Schedule for an example floor

The level of urban obstructions on each floor cause the major variations in the schedule. Therefore, create a schedule for every other floor on the lower floors making some allowances for changes in the location of the measurement points. For the upper floors where urban obstructions have little influence, create a single schedule also allowing for differences in the location of measurement points.

Look for common sense trends. The lower floors with significant urban obstructions will have less opportunity to check the glare control mode. During some times of the year, there may be no times when the window luminance is expected to exceed the 2000 cd/m^2 limit.

The following provides an example of how the various resources can be used to set a measurement schedule. The example is for September 28th, however the sun positions do not change rapidly, and the times shown should be approximately valid for the week of 9/25 to 9/29.

2.4.1. Example schedule: Resource 1

From Resource R1, the following times were found to potentially have the shades down. Note that many of times are nearly the same between the three façade designs.

Table 1. Times (Eastern daylight time) when the shades first go down and then come up to prevent direct sun penetration

	Tubes: 3 foot penetration		No tubes: 3 foot penetration		No tubes: 6 foot penetration	
	Shade down	Shade up	Shade down	Shade up	Shade down	Shade up
North	6:55	8:20	6:55	8:20	6:55	7:55
East	6:55	11:50	6:55	11:50	6:55	10:05
South	12:25	18:35	12:25	18:35	15:50	18:35
West	15:50	18:35	15:50	18:35	16:40	18:35

2.4.2. Example schedule: Resources 1+ 2

Resource R2 shows that many of the points on the 8^{th} floor are shadowed by urban obstructions during various times of the day. The following table combines the values from the R1 table above, and the information from R2 to give a table of when the shades are expected to be down at each of the measurement locations.

- An entry of “no” means that the shade is not expected to be down at any time during the day.

- At some locations urban shadows blocked the sun for only part of the time, and there were two distinct periods when the shade was expected to be down. For this example there were a maximum of two separate times for any location. The times are shown in the columns labeled, down (1st), and if there are two separate times, down (2nd).

Table 2. Direct sun times after consideration of shadows (R1 + R2)

Zone	down (1st)	down (2nd)
SW-08.1	16:00-18:00	
W-08.2	16:00-17:30	
W-08.3	16:00-18:00	
NW-08.1	no	
N-08.1	no	
N-08.2	no	
N-08.3	no	
W-08.4	no	
N-08.4	no	
E-08.2	9:00-10:30	
N-08.5	no	
NE-08.1	no	
E-08.3	9:30-11:30	
E-08.4	9:00-11:30	
SE-08.1	9:00-11:30	
S-08.1	12:30-14:00	
E-08.1	9:00-11:30	
S-08.2	12:30-13:00	14:00-18:00
W-08.1	16:00-18:00	
S-08.3	13:00-18:00	
S-08.4	12:30-18:00	
S-08.5	12:30-18:00	

2.4.3. Example schedule: Resources 3 + 4

The following table gives an eyeball estimate of the degree of sky obstruction from Resource R3 (none, half and obstructed), and the critical times (luminance estimate between 1500 and 2500 cd/m^2) estimated from Resource R4 for a clear sky with an obstructed, half obstructed, or unobstructed view.

Table 3. Sky obstruction and critical times for glare control (R3 + R4)

Zone	From R3 Sky	From R4 1st Period	From R4 2nd Period
SW-08.1	none	8:00-8:30	none
W-08.2	half	8:00-8:30	14:30-18:00
W-08.3	none	8:00-9:30	none
NW-08.1	none	7:30-8:00	18:00
N-08.1	none	7:30	17:00-17:30
N-08.2	none	7:30	17:00-17:30
N-08.3	half	8:30-10:30	16:30-17:30
W-08.4	none	8:00-9:30	none

N-08.4	half	8:30-10:30	16:30-17:30
E-08.2	obstructed	12:00-17:00	none
N-08.5	half	8:30-10:30	16:30-17:30
NE-08.1	half	8:00-9:00	15:30-17:30
E-08.3	obstructed	12:00-17:00	none
E-08.4	obstructed	12:00-17:00	none
SE-08.1	half	8:00-9:00	16:00-17:30
S-08.1	half	8:30-10:30	17:30-18:00
E-08.1	half	14:00-17:30	none
S-08.2	obstructed	12:30-13:00	none
W-08.1	none	8:00-9:30	none
S-08.3	half	8:30-10:30	17:30-18:00
S-08.4	half	8:30-10:30	17:30-18:00
S-08.5	half	8:30-10:30	17:30-18:00

<u>**2.4.4. Example schedule: Resources 1-4 combined**</u>

Table 2 gives the periods when the shades should be in the direct sun control mode (R1+R2). Table 3 gives the critical range of times when the shades may shift from daylight to glare control or visa versa (R3+R4). Combining the two tables gives the times that are most critical to meeting the shade control specifications. For example, point W-08.2 has the shade down for sun control from 16:00-17:30. The first critical time for luminance is 8:00-8:30, which is clearly not affected by the sun control mode. The second critical time is 14:30-18:00. The period from 14:30-16:00 is not affected by the sun control mode, but the period from 16:00-17:30 is. Finally, this example actually has a third critical period available after 17:30. Table 4 shows these times:

Table 4. Critical times for measuring shade control transitions between glare and daylight harvesting modes

Zone	period 1	period 2	period 3
SW-08.1	8:00-8:30		
W-08.2	8:00-8:30	14:30-15:30	18:00
W-08.3	8:00-9:30		
NW-08.1	7:30-8:00	18:00	
N-08.1	7:30	17:00-17:30	
N-08.2	7:30	17:00-17:30	
N-08.3	8:30-10:30	16:30-17:30	
W-08.4	8:00-9:30		
N-08.4	8:30-10:30	16:30-17:30	
E-08.2	12:00-17:00		
N-08.5	8:30-10:30	16:30-17:30	
NE-08.1	8:00-9:00	15:30-17:30	
E-08.3	12:00-17:00		
E-08.4	12:00-17:00		
SE-08.1	8:00-8:30	16:00-17:30	
S-08.1	8:30-10:30		
E-08.1	14:00-17:30		
S-08.2	none		

W-08.1	8:00-9:30
S-08.3	8:00-10:30
S-08.4	8:00-10:30
S-08.5	8:00-10:30

2.4.5. Example: Sorted Schedule

Table 5 gives the points in clockwise order from the southwest corner. Table 5 gives the same information sorted by time. Second and third possible measurement periods are shown in bold.

Table 5. Critical times sorted by time

Zone	time
N-08.1	7:30
N-08.2	7:30
NW-08.1	7:30-8:00
S-08.3	8:00-10:30
S-08.4	8:00-10:30
S-08.5	8:00-10:30
SW-08.1	8:00-8:30
W-08.2	8:00-8:30
SE-08.1	8:00-8:30
NE-08.1	8:00-9:00
W-08.3	8:00-9:30
W-08.4	8:00-9:30
W-08.1	8:00-9:30
N-08.3	8:30-10:30
N-08.4	8:30-10:30
N-08.5	8:30-10:30
S-08.1	8:30-10:30
E-08.2	12:00-17:00
E-08.3	12:00-17:00
E-08.4	12:00-17:00
E-08.1	14:00-17:30
W-08.2	14:30-15:30
NE-08.1	15:30-17:30
SE-08.1	16:00-17:30
N-08.3	16:30-17:30
N-08.4	16:30-17:30
N-08.5	16:30-17:30
N-08.1	17:00-17:30
N-08.2	17:00-17:30
NW-08.1	18:00
W-08.2	18:00

Tables 4 and 5 provide the information needed to set a measurement schedule for a clear day. The CxA can group the measurements based on time and location in the building. A drawing showing the sequence and times for the point measurements should be constructed. For any particular week the weather forecast is likely to show that it will be sunny on some days and partly cloudy on others. For a partly cloudy or overcast day, Table 3 has to be redone with the appropriate sky, and then combined with Table 2 to give new Tables 4 and 5.

Because the logic of stepping through each of the resources and making sure everything is consistent is complex and prone to error, a template (scheduler.xls) has been written that allows the commissioning agent to assemble the data in one place, and have the logic done automatically. It is strongly recommended that the scheduler be used to reduce the time required to determine useful measurement times, and to reduce the chance of errors. The commissioning agent enters data in the cells with a plum colored background. Rows 3 and 4 require the date and sky type. Cells A11-D28 take information on the points being measured (see Table 6 below):

Table 6. Point information from schedule template

Enter date	9/28	(month/day)
Enter sky	clear	

Time EDT

Zone	Orientation	vertical	Window Distance	Cols E and on
SW-08.1	SW	floor/ceil	11	
W-08.2	west	tubes	5	
W-08.3	west	tubes	5	
NW-08.1	NW	floor/ceil	11	
N-08.1	north	floor/ceil	15	
N-08.2	north	floor/ceil	15	
N-08.3	north	floor/ceil	15	
W-08.4	west	floor/ceil	5	
N-08.4	north	tubes	5	
E-08.2	east	floor/ceil	5	
N-08.5	north	floor/ceil	6	
NE-08.1	NE	floor/ceil	7	
E-08.3	east	tubes	5	
E-08.4	east	tubes	5	
SE-08.1	SE	floor/ceil	7	
S-08.1	south	floor/ceil	5	

There are gaps in the rows where there is a point missing from the point database. After copying the floor data to the template the commissioning agent enters the sky obstruction values from resource R3, and then enters an X in the appropriate time slot whenever the points control zone is shadowed (resource R2). Table 7 shows the first part of this section of the table:

Table 7. Entries for sky obstruction and shadows. Index values are computed in the template and are used in determining the final results.

Zone	Cols B - E	Obstruction	index	index	Time	7	7.5	8	Cols M on
SW-08.1		0%	3	2		X	X	X	
W-08.2		50%	1	3		X	X	X	
W-08.3		0%	1	1		X	X	X	
NW-08.1		0%	3	2		X	X	X	
N-08.1		0%	2	2		X	X	X	
N-08.2		0%	2	2		X	X	X	
N-08.3		50%	2	3		X	X	X	
W-08.4		0%	2	1		X	X	X	
N-08.4		50%	1	3		X	X	X	
E-08.2		100%	2	4		X	X	X	
N-08.5		50%	2	3		X	X	X	
NE-08.1		50%	2	3		X	X	X	
E-08.3		100%	1	4		X	X	X	
E-08.4		100%	1	4		X	X	X	
SE-08.1		50%	2	3		X	X	X	
S-08.1		50%	2	3		X	X	X	

In cells J41-AF66 the template compiles the information that was shown in Table 4. The results are listed by point in half hour intervals. A “0” entry in a cell indicates that the shade is the glare or daylight harvesting modes and the estimated luminance is in the range from 1500 cd/m^2 to 2500 cd/m^2. The cells containing these values have an orange background to make them easy to spot. Entries of 1 or 2 indicate that either the shades are in control mode, the luminance is outside the test range, or both. Because of time and space constraints, the estimated time range for the corner locations is less accurate than for the four main facade orientations. The commissioning agent can refer to the original data if more precise values are needed for these orientations.

3. Verification in the Field

This section describes in detail the procedures to be taken when verifying the performance of the shade control system on a given floor. The procedures in this section are not described in the exact order required to verify system performance, rather in the general order presented by the HDR software. An overview of steps is given in Section 1.5. The “Quick Start” guide summarizes the exact steps in a how-to format.

3.1. Setting up the shade commissioning cart

Figure 8. Photo of the shade commissioning cart

The shade commissioning cart transports the following equipment:

- Digital camera with fisheye lens (called “HDR camera”) and USB cable to computer
- Small digital camera with regular lens and USB cable to computer
- Laptop computer
- Electronic or regular measuring tape
- Tripod mount on an extendable arm
- Document holder
- Backup rechargeable batteries for the computer and camera or uninterruptible power supply (UPS)

The shade cart was designed with sturdy construction to be used during the construction phase of the building, where only hoist elevators and temporary ramps are available to transport the cart from floor to floor. It will also be used later during the occupancy phase of the building.

Figure 9. Cart being transported by hoist

The following paper documents should accompany the shade cart when taking measurements (or could be referenced from the laptop computer:

- 11x17-inch furniture plans showing measurement locations (at scart/ nyt documents)
- 11x17-inch MSS shade control zone, sensor, and motor group shop drawing/ floor plans
- Schedule of when to take measurements (from Section 2)

3.1.1. Starting up the HDR computer and checking the time stamp

Turn on the computer. Login as the user "Shade Cart". Use only the "Shade Cart" login. **Do not log on as a different user** to conduct image capture. Using any other login will cause the image capture program to no longer work.

The shade cart's laptop **must** have the same time stamp as the MSS shade supervisory control computer. The MSS clock should agree with actual local time to within 1 minute. Check the time stamps and align regularly, as often as once per day depending on how the shade supervisory control system is set up to access time.

If the MSS clock is set via the internet, connect the HDR laptop to the internet and align to the same time source (e.g., www.time.gov).

If the MSS clock is not set via the internet, then:

- Set the HDR laptop's time by clicking on the time shown in the upper right hand corner of the desktop, then select "Open Date & Time…"
- Make sure the time zone is set for New York City.
- Click the lock to make changes to the time. Use the Administrator login. Do not make any other changes to the computer setup in any way shape or form using the administrator login.
- Correct the HDR computer's time so that its time differs by no more than 30 seconds from the MSS clock.
- Both the HDR and MSS computers should be set to local time, which observes daylight savings time.

3.2. Setting up the HDR camera

After transporting the cart to the measurement location, set up the HDR camera on the shade cart:

- Place camera on tripod mount being careful not to strip the threads on the camera.
- Adjust height so that the center of the lens is at 4 ft (± 0.5 inches) above the finished floor.
- When you are ready to take a measurement, position the cart in the proper location. The position for the camera is given in the header for the measurement point (see Section 3.3.4 below). Position the camera accurately once you have determined that a) the sun orb is not in the camera's field of view, or b) the orb is in the field of view but is completely obstructed by the interior shades.
- Use the electronic or regular tape measure to measure the distance from the black band (± 0.25 inches) of the fisheye lens to the window glass or frame (keep lens cap on until time of measurement).
- Line the camera up so that the lens is centered on the mullion, corner, or window (centered on the width of the glass).
- Level the camera using the bubble mount (pitch and yaw).

To avoid excessive vibration and potential damage to the camera in rough conditions, remove the camera from the shade cart and hand carry when moving the cart.

The HDR camera must be handled with care:

- **Do not take pictures of the sun** – this will permanently damage the camera. Check if sun is visible through the viewfinder **before** you take any pictures. Caution: with the fisheye lens, the sun may still be visible even if it is to the side of the camera.
- Photographs can be taken if the sun orb is visible behind the densely woven shade fabric. Do not take a photo if the sun is partially unobstructed.
- Keep lens cap and hood on the lens when not taking pictures, especially when handling or moving the camera around and in dusty environments.
- Do not touch the glass of the lens with anything except lens tissue (sold in camera stores). It should be done very gently, to avoid leaving marks or damaging the anti-reflection coating. Should dirt not come off this way, the lens should be cleaned by a professional.

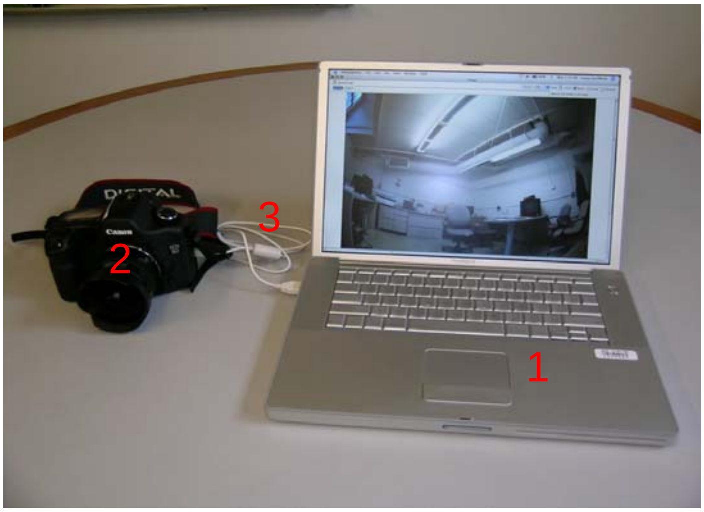


Figure 10. Computer with HDR camera
1. Macintosh laptop with Photosphere and Adobe Photoshop installed
2. Canon EOS 5D digital camera
3. USB connector

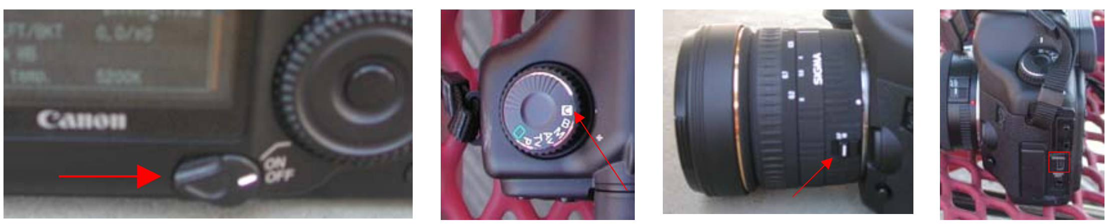


Figure 11. Location of switches and dials (left to right): on/off switch, C mode, M manual focus, and digital port.

The camera must be configured as follows (Figure 11):

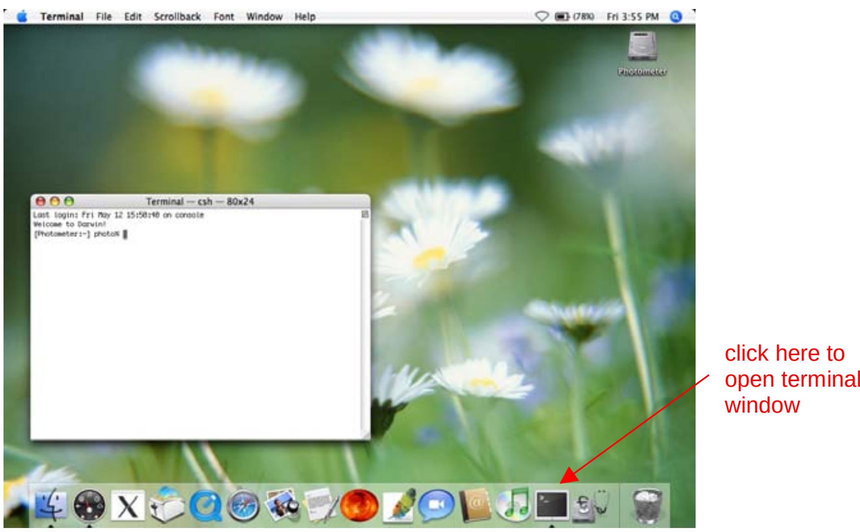
- Confirm round dial on camera top is set to “C”. Do not press any other control on the camera. If the C mode gets inadvertently reprogrammed, configure the manual (M) mode on the camera and use the M mode instead.
- Confirm lens is set to Manual focus (switch on lens set to “M” or “MF”, depending on lens model).
- Using connector cable, connect camera to laptop by attaching cable to USB port on laptop and port labeled “Digital” on the side of the camera (this port is reached by lifting one of the rubber flaps). Be careful when removing cable from side of camera – **once this port is damaged, the camera is useless since it can no longer be remotely controlled by the computer**.
- Check battery level. If battery level is low, the automated capture may not work properly, forcing you to abort the HDR program and in some cases restart the HDR computer.
- When you are ready to take a measurement (see Section 3.3 first on how to run the HDR software), turn the camera on. Remove the lens cap and hood.

- When taking the picture, do not cause the camera to vibrate, do not walk in front of the camera, and do not move the camera while it is capturing its 5 images (you will hear the camera take several photographs over a 30 second period). If the camera is interfered with, then take the measurement again.

3.3. How to use the HDR software

3.3.1. Starting up the HDR software: Main menu

Open the Terminal application on the HDR computer by clicking on the corresponding icon in the lower right of the dock. If dock isn't visible, it will appear when you move the cursor so that it hits the bottom of the screen. Or double-click on the Terminal icon in the Utilities folder, which is inside the Applications folder on the hard drive called "Commissioner 0".



In the Terminal window, enter the following underlined text in blue:

```
Last login: Mon Jun 9 12:19:35 on console
Welcome to Darwin!
[Commissioner0:~]: scart% cd nytimes/shadecomm
[Commissioner0:~/ nytimes/shadecomm]: scart% run
```

Enter your name or ID when asked, followed by a carriage return. (The camera need not be connected at this point.) Use the same spelling and capitalization if you want to sort the final verification database by this field.

```
Agent Name/ID:  G.Ward
```

This brings up the **main menu**, which is shown below.

```
Training database
```

```
Commissioning Agent: G.Ward
Date: 06/09  First daylight hour: 6 EDT  Last daylight hour: 19 EDT
Tower Shade Commissioning Main Menu
        0. Exit
        1. Select date for shadow and sunpath diagrams
        2. View urban shadow
        3. Measurement point
        4. Change database
Choice:
```

At the main menu, the operator enters one of the numbers 0, 1, 2, 3 or 4, followed by a carriage return.

The sequential steps for verification are as follows:

- Make sure the training database is set properly (Option 4, Section 3.3.8).
- Change or select the measurement point (Option 3B, Section 3.3.5).
- Take HDR measurements (Option 3D, Section 3.3.7).
- Check the verification database for pass/fail (Section 3.5).

The other menu options support scheduling activities described in Section 2 and can be used for troubleshooting while in the field.

3.3.2. Option 1: Select date for shadow and sunpath diagrams

The HDR software will start up with today's date. For all HDR measurements taken in the field, the date recorded with each point in the verification database is the HDR computer clock's time – this menu option does not change the date. This option only affects the date for displaying the urban shadows (Resource R2, see Section 3.3.3) and sunpath fisheye views (Resource R3, see Sections 2.2.3 and 3.3.6).

For scheduling activities described in Section 2 that occur one week before verification on the floor, you will likely need to change the date. Enter option 1) then enter new date:

```
New Month/Day [07/27]
```

- The date format is month/ day and accepts: 6/27 or 06/27, for example.
- The date format accepts different time zones but designation is <u>not required</u>: EST, EDT, PST, etc.
- If you simply enter the date with no designation of time zone, the HDR software will assume the local time zone set by the computer clock (see Section 3.1.1).

- Daylight savings time (DT) is generally between April and October. Standard time (ST) is generally between October and April (e.g., EST begins at 0:00 on October 29, 2006). The exact date of the changeover differs from year to year.
- If you enter a date on the other side of a change in daylight savings time, you must enter the corresponding time zone following the date, either "EDT" or "EST" as appropriate. For example, if you want to view urban shadows for next week (e.g., October 31), which is after October 29, 2006, then you should enter: 10/31 EST.

3.3.3. Option 2: View urban shadows (Resource R2)

Uses

This second option (called "Resource R2") displays the sunlit and shadowed areas on each of the four tower facades on the selected date (Option 1). The shadows are cast on the tower facades by the surrounding buildings.

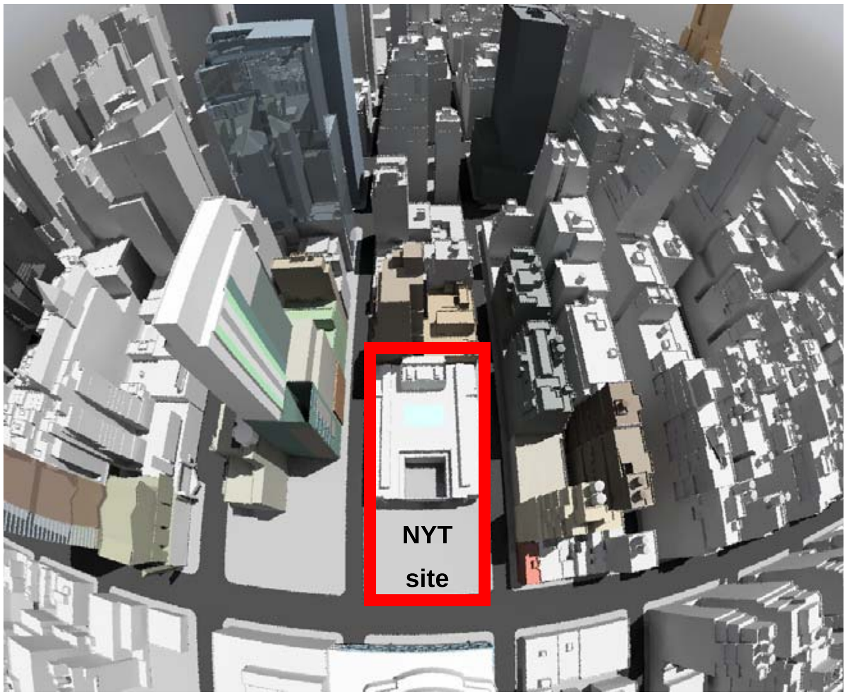


Figure 12. Radiance rendering of the NYT building and urban surroundings.

This option in the software should be used for Section 2 scheduling activities one week before verification in the field. See description of use in Section 2.

This tool could also be used to determine if the shades should have been retracted due to shading from urban obstructions during verification in the field. For this determination:

- The weather must be sunny (including considerations for MSS time delays).
- All windows in the control zone must be fully shadowed by urban obstructions.
- Direct sun control must be in effect (solar penetration limits would have been exceeded had there not been urban shadows).
- Glare control is not required.

If this tool is used for this purpose, then remember:

- The shadows were constructed using a CAD urban model from 2004. Changes to the urban environment will not be reflected in the images.
- The shadow patterns are less accurate at the edges of the shadow. Do not make judgments for a control zone based on the pattern of a small shadow.

<u>How to Use</u>

Shadows have been precomputed for the 21st of each month in eastern local time. Other dates may be computed as desired at 30, 60, 90, or 120 minute intervals, but will take a few minutes to compute the first time they are requested (images will be displayed as they are generated). To save time, change the date to the 21st day that is closest to the period you are evaluating, then view facade shadows.

Once the date is set, view urban shadows. Select option 2 from the main menu, then enter time interval in minutes (default is 60 min):

```
Enter time interval in minutes [60]
```

The HDR software launches the Photosphere program, which displays the images (Figure 13).
Viewing options in Photosphere:

- Click on the up/down arrows on the upper left to advance the “tif” images to different hours. Use this for studying shadows in detail.
- Click on the upper left corner’s green “+” button to enlarge the window to fill the screen.
- On the upper menu bar, select “View”, then “Slide show” (or hit apple-K) to see a slide show of the images. Slide show options include interval of display in seconds (5 seconds is recommended). Move the arrow with the mouse to desired interval, then hit “OK”. The program will display images sequentially, showing shadow patterns over the course of the day.

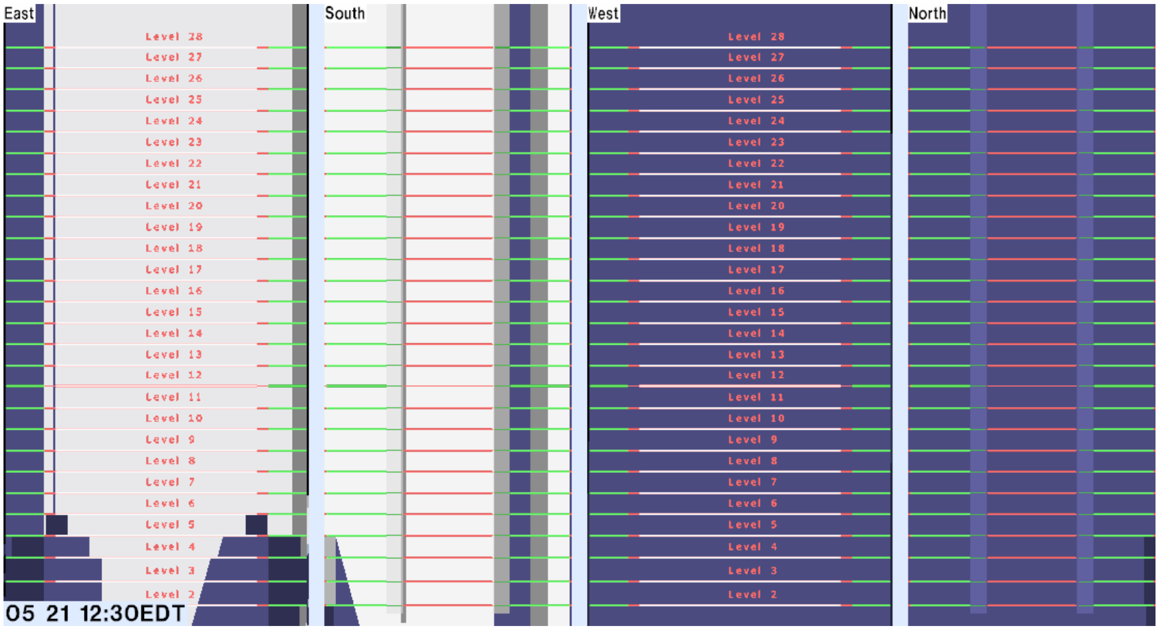


Figure 13. Shadow patterns cast by urban obstructions on NYT tower.

Some notes on the images as follows:

- Images are from the inside looking out, making it easier for the CxA to determine if a particular zone being verified is actually in shadow while walking the floor.
- The dark blue areas are in shadow, either from the tower itself or from neighboring buildings.
- White areas are in full direct sun, lighter gray areas are in partial direct sunlight, and darker gray areas correspond to glancing sunlight.
- A label on the lower left-hand corner of the image shows the date and time of the images.
- Each façade is labeled on its upper left-hand corner with project façade orientations: west, south, east, north.
- The floors of the NYT HQ tower are labeled. The floor plan is a cruciform shape. The red (open and filled with red) horizontal floor lines indicate the forward projecting portion of the floor plan. The green (open and filled with green) horizontal floor lines indicate the side wings to the main façade being viewed. Toggle between images to determine the boundaries of the facades.
- On the north and south facades, the curtainwall ceramic tube screen extends out horizontally from the face of the façade by approximately 5 ft. These are shown as vertical gray or blue lines. The shadows on these gray lines are for the screen, not the façade behind the screen.
- For the east façade elevation, the podium intersects the tower on the first to the fourth floor, which is shown in black. Shadows on these floors should be ignored.
- Images are stored as tiffs under the scart/nytimes/shadecomm/shad folder.

- For a description of the simulations, see “Section 9 Engineering Studies Using Radiance” in the final report (LBNL-57602) under the “Technical reports” section located at http://windows.lbl.gov/comm_perf/nyt_pubs.html.

3.3.4. Option 3: Measurement point

Select Option 3 from the main menu, then the point name from the measurement point diagram (see Section 2.1) (entering default “0” takes you back to the main menu):

```
Enter point [0]
```

After entering the measurement point, “W-22.4”, for example, the **measurement point submenu** is displayed.

```
Point W-22.4, Floor 22, North wing, 5 ft from window, facing West,
centered on mullion, image width +-2, image height floor/ceil, priority 3

        A. Return to main menu
        B. Change measurement point
        C. Show sun path for date 6/9
        D. Take measurement(s)

Choice [A]
```

Default option A returns you to the main menu.

If you enter a bogus name then “n” to the question “Is this a new measurement point”, it will list all existing point names.

Refer to the header to determine how to locate the camera (see Section 2.1.2.5).

3.3.5. Option 3/ B: Change measurement point

When you move the shade cart to a new position, you must change the designated measurement point (using this option) before taking a measurement. This will ensure that the HDR software will include the correct header information (floor level, wing, measurement location, etc.) with the data in the verification database.

After selecting Option B (can be upper or lower case), the software prompts (default 0 takes you back to the main menu):

```
Enter point [0]
```

Similar to when you first entered option 3 from the main menu, enter the name of the next measurement point to be measured.

You can add points if you see something in the field that warrants investigation or if conditions change (different furniture layout, etc.). To do so, see Section 2.1.

When a new point is generated, the HDR software will create a unique folder in the nytimes/shadecomm/meas directory. For example, for point "W-22.4", a folder labeled "W-22.4" contains two files with the information above ("descript.txt" and "info.txt"). HDR measurements taken at this location will have the HDR image files stored in this folder.

3.3.6. Option 3/ C: Show sun path for date

Sun path diagrams are provided at each measurement point so that the CxA can determine:

- Size of sky glare source for Section 2.2.3 scheduling activity.
- If the sun orb is in the field of view of the HDR camera. This may be difficult to determine by eye because of the wide view of the fisheye lens or due to partly cloudy conditions. Photos cannot be taken if the orb is within the field of view – it will permanently damage the HDR camera's sensor and lead to inaccurate measurements.
- Do not use this to evaluate the direct sun control mode with urban obstructions.

Option C provides a fisheye view of the window at the designated measurement point. Overlaid on this view is the sun path. For example, in Figure 14, solar positions are shown as red clocks for each hour in our west-facing view, "O12".

- The actual position of the sun orb at each hour corresponds to the exact center of each clock.
- The blue lines delineate the solar minima and maxima corresponding to the winter and summer solstices, respectively.
- The blue dots in between the two blue lines show the sun positions for the solar equinox at 15-minute intervals.
- The green line indicates the solar elevation above which the upper ceramic tubes block solar penetration at a few feet (< 3 ft) into the space (61.8° cut-off angle). This line is not shown for corner-facing views, since there is no easy formula to determine solar penetration in corners.
- Views are generated looking horizontally at an eye height of 4 ft.
- Ignore the shadow patterns shown on the interior, since these do not correspond to any particular time of day or year.
- The sun path diagrams were generated for specific locations in the space. Match the image to the actual location in the space and check to make sure that the position of view and view out are approximately the same as that generated in the simulations.

If the selected point has not been rendered previously, it may take several minutes to complete the view. This process should not be interrupted or later runs may fail. If the process is interrupted, manually remove the partial image file “nytimes/shadecomm/meas/pt/synth_pt.hdr” where “pt” is replaced by the point ID.

To get the sun path for a different location, return to Option B of the Measurement Point submenu. To look at a different day of the year, return to the Main Menu and choose ‘1’ to change the date.

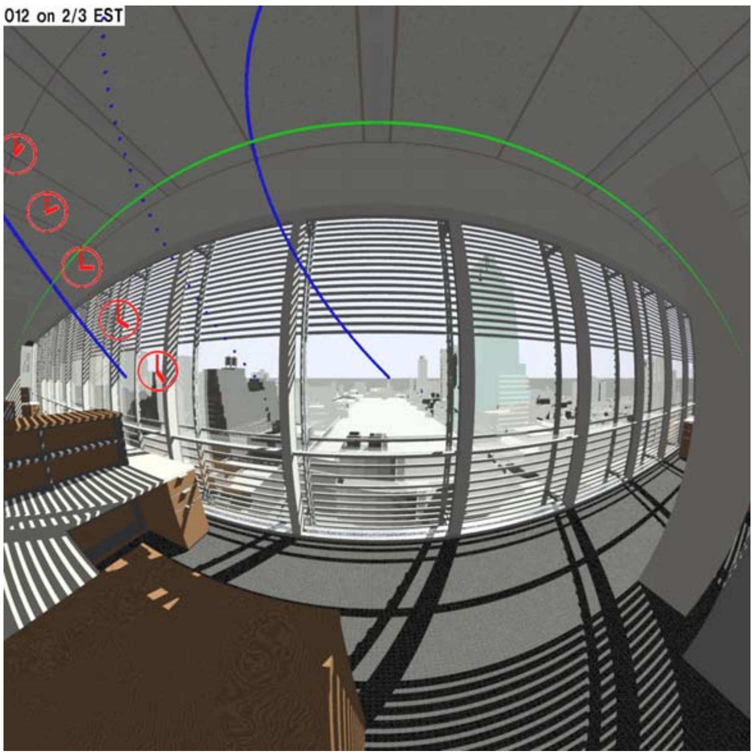


Figure 14. Solar path diagram for the specified date and cart view.

3.3.7. Option 3/ D: Take measurement

3.3.7.1. Image capture

Option D allows you to take HDR measurements at the selected view position. Before you take the measurement:

- **IMPORTANT: BE SURE CAMERA DOES NOT HAVE AN UNOBSTRUCTED VIEW OF THE SUN!** Not only will this undermine the accuracy of the results, but it could permanently damage the camera's sensor and invalidate the warranty, at a cost of $3,000. If the sun is behind a thick cloud or low-transmittance shades, then it may be OK. If you can look from the position of the camera without serious discomfort, then it is probably safe to take a measurement.
- The camera must be connected to the computer via a USB cable and switched on, with the mode dial on the C ("custom") setting. See Section 3.2 for details.
- Position the camera accurately. See Section 3.2 for details.

Take the picture

To start taking pictures, turn the camera on, take off the lens cap and hood, then enter a "1":

```
Number of measurements desired [1] 1
```

The software will immediately start image capture. If you enter a different number, then abort the program (control-C).

The program will open two new Terminal windows. The CanonHDRcap.out window echoes the camera operations during the capture process, then should disappear.

Don't walk in front of the camera or cause the camera to move when image capture is underway. When the camera has stopped clicking (approximately 15-30 seconds), then turn off the camera and replace the lens cap carefully.

If the CanonHDRcap.out window indicates an error ("No camera found!"), then there is a problem with the camera connection and the two new windows will need to be closed manually and the whole process restarted. Turn the camera off, wait a few seconds, then turn it back on, again waiting a few seconds. In the Terminal window, abort the HDR software using the ctrl-C command or click on the red "close" button on the title bar.

If the capture process ends well, there will be a dozen or so lines of output of the form:

```
Loading Canon EOS 5D image from /…/HDRcap/test0004.cr2...
Scaling with black=128, pre_mul[] = 36.58 18.40 26.91 18.40
```

```
Converting to sRGB colorspace...
Writing data to standard output...
```

Followed by:

```
Applying vignetting correction...
Use Photoshop polygon selection tool to outline window...
Computing vertical illuminance…
Vertical illuminance is: 1214 lux
...
```

3.3.7.2. Outlining the glare source

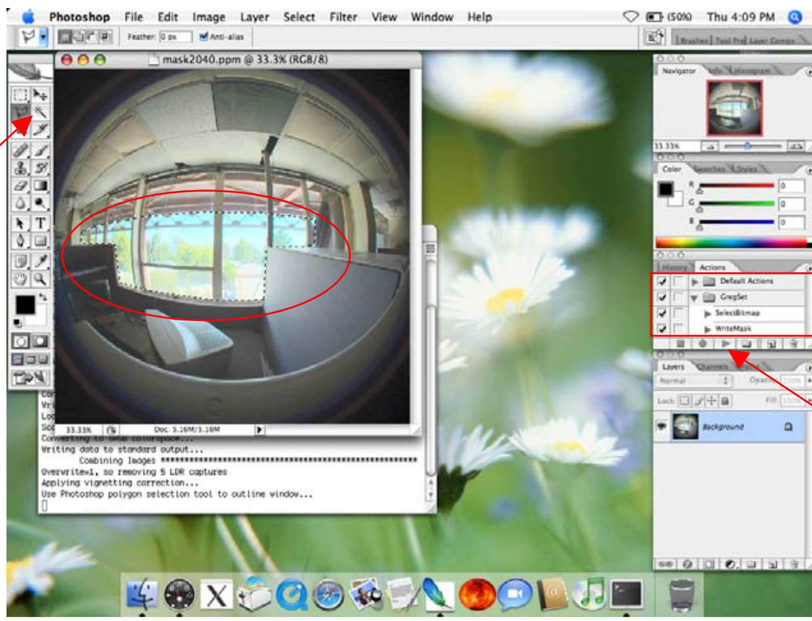


Figure 15. How to outline glare source in Adobe Photoshop.

Adobe Photoshop will then open up and display the image, giving you the opportunity to select the view window region using the “Polygon Lasso” tool. Consult the header on the original Terminal window or the measurement point database to determine which window bays and what vertical portion of the window should be defined as the glare source (see Section 2.1.2.5 for a detailed explanation):

```
Point W-22.4, Floor 22, North wing, 5 ft from window, facing West,
centered on mullion, image width +-2, image height floor/ceil, priority 3
```

On the tool palette – left-hand side of screen – click on the lasso tool. Outline the desired area with the lasso tool, clicking at each vertex. More than one area can be selected by also holding down the Shift key. Use the escape key to retrace the mask. To abort the outline, click on any new location on the photo. In the example header above, the width of the image should include 2 bays on either side of the mullion (“centered on mullion, image width +-2”). The height of the image should be from floor to ceiling.

Go to the “Actions” pane (if not already open, it can be selected from the “View” menu) and click on “WriteMask”. Execute that action by clicking on the “play” button in the “Actions” pane.

Once the mask is written, Photoshop will close the image and the Terminal window will continue to process the images:

```
Computing average luminance on window...
Average window luminance is: 2104 cd/m^2
Computing glare sources (/…/meas/O12/O12_06-06-06@1900.glr)...
940  794  2.19e-01   2.31e+03
Creating record image (/…/meas/O12/O12_06-06-06@1900.jpg)...
66.170u 5.320s …
[Commissioner0:~] scart% logout
[Process completed]
```

3.3.7.3. HDR image display

Photosphere then displays a graphical rendition of the measurement, as shown in Figure 16. At this point, the extra Terminal window that ends with “[Process completed]” may be safely closed using the red button on the title bar.

The date, time and average luminance of the selected region are shown in the upper left hand corner of the Photosphere image. Areas within that region that have an average luminance above 2000 cd/m^2 (nits= cd/m^2) and are therefore potential glare sources are highlighted in pink; each has a label showing average luminance and the solid angle (steradians) that it subtends. The rest of the region is highlighted in yellow. The measurement is passed based on the average luminance of the entire selected region. The pink areas are flagged and recorded in the verification database as well (see Section 3.4).

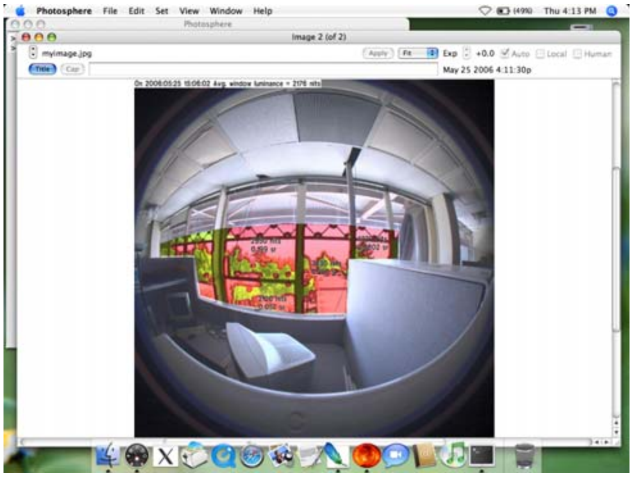


Figure 16. JPG image showing average window luminance and potential glare sources that are greater than 2000 cd/m^2 and 0.1 steradians (pink).

By clicking on the image selector (up/down arrow located in the upper left hand corner) in Photosphere, you can display the high dynamic range (HDR) image on which the glare analysis image is based. The image will have the same name but with an “.hdr” ending.

- Clicking the mouse cursor on a point of the image displays the luminance of that point on the top right-hand corner of the image window.
- A rectangular area of the image can be selected by moving the cursor while holding the mouse button down. In this case, the average luminance of that area will be displayed on the top right-hand corner.

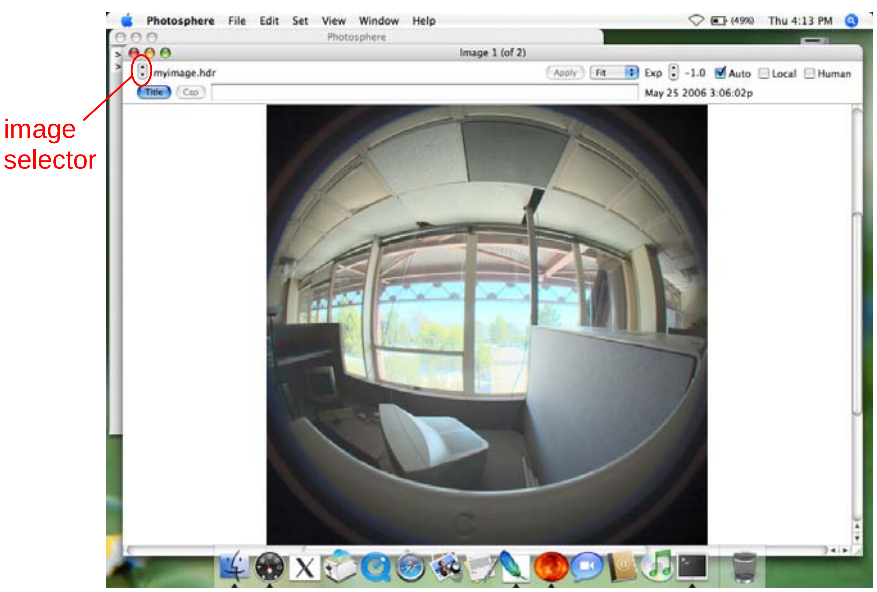


Figure 17. Selecting the image in Photosphere.

A falsecolor luminance image can be generated from the HDR image.

- To display luminance values, use the “False Color” command from the “View” menu. This can also be done by pressing *apple*-“n”. Luminance is displayed in cd/m^2. The scale will be displayed to the right-hand side of the image. The maximum value displayed in the scale is not the maximum for the picture – it is, approximately, the value of the top 1 percentile.
- To find out the maximum luminance for the whole picture, select “Histogram” from the “View” menu and set it to show luminance values (by default it shows RGB components). The value at the right-hand end of the scale is the maximum. The scale used for the histogram is also logarithmic, with the ticks indicating decades (1, 10, 100, 1000, etc.) in cd/m^2.
- In its automatic mode, the scale is logarithmic. Setting the minimum value to zero changes the scale from logarithmic to linear. The scale limits can be changed by directly editing the numbers in the scale window and pressing the return key.

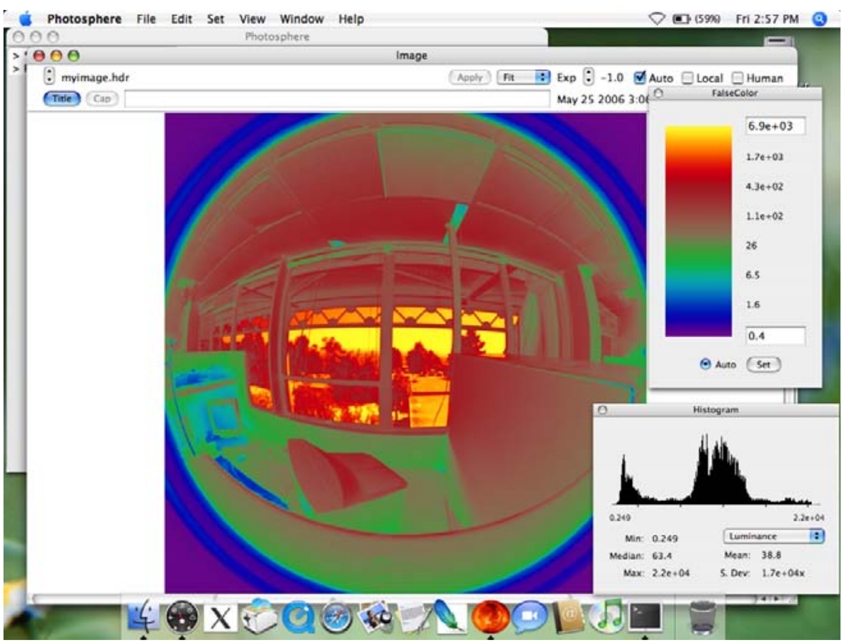


Figure 18. Falsecolor luminance map produced by Photosphere.

3.3.7.4. Answer final questions in Terminal window

During the measurement process, the original window continues to pose questions, which the CxA must answer before the next measurement can be taken. These answers are recorded to the verification database.

```
Starting new measurement for point W-22.4 at 16:22
How clear is the sky? (0-1) 1
```

```
Is the sun in the field of view? (0-1) 0
Are the shades on manual override? [n] n
What is the shade preset height? (0-5) 0
Subjective rating of discomfort glare? (0-100) 70
Additional comment? Glare from reflected light off buildings
```

The questions should be answered as follows:

"How clear is the sky? (0-1)" This describes the overall sky condition viewed from the measurement point. The value entered should be scaled according to below:

0	Completely overcast
0.25	Some blue patches
0.50	Partly cloudy
0.75	A few clouds
1	Nothing but sky

"Is the sun in the field of view? (y/n) " If the sun is visible from the location of the measurement point through the lowered shades, this value should be 1, otherwise 0. Do not take a measurement if the entire orb of the sun is not obstructed by the shade, the building, urban obstructions, or by heavy clouds.

"Are the shades on manual override? [n]". Enter y if yes. Enter n, if no (default).

What is the shade preset height? (0-5)

0 = fully retracted

1 = half way between the fully retracted position and the top of the vision window

2 = top of the vision window

3 = 4 feet above finished floor

4 = bottom of vision window

5 = down to the floor

Subjective rating of discomfort glare? (0-100). If your eye was positioned in the same location as the measurement, how would you rate your level of visual discomfort? Squat down to 4 ft height as if in sitting position then look at the laptop screen with the window behind to make your assessment.

0 = no glare

25 = perceptible glare

50 = noticeable glare

75 = disturbing glare

100= intolerable glare

Additional comment? Add one line of comment and indicate any note-worthy conditions (reflected sunlight off opposing building, pattern of sunlight on worksurfaces, etc.). Check the values in the image (Average window luminance > 2000 cd/m^2? Lots of pink glare sources? If so, note possible reasons why) then add any additional comments or why the system failed if not passed. This field could also be left blank.

3.3.7.5. Correcting or deleting the measurement point

Once all questions have been answered, the window shows:

```
Waiting for capture process to finish...
```

Then, if you've made any errors along this process, the computer allows you to alter your mask or change your answers to the questions:

```
Save measurements with these answers? [y]
```

If you enter n for "no", then the software will prompt:

```
Redraw window mask? [n]
Change answers to questions? [n]
```

For each of these options, the same steps should be used to generate a new mask and answer the questions.

Once you are satisfied with the mask and questions, then type "y" to save the measurement:

```
Save measurements with these answers? [y] y
Done.
```

Enter n for "no" if you would like to delete the measurement and accompanying images entirely due to interference during the picture taking process (kicked the camera, people walked in the camera's view, etc.) or for other reasons. Retake the picture, don't try and "fix" the database or picture. When done, the software will take you back to the main Option 3 menu.

Close the "Completed Command" terminal window after measurement process is complete, if not already. The Photosphere window may also be closed, as the image has been saved to disk.

3.3.8. Option 4: Change Database

The CxA or NYT may want to have separate verification databases for different phases of work; e.g., pre-testing to become familiar with the HDR software, actual verification in the field, and post-occupancy evaluations.

The HDR software enables you to define new databases or select an existing database:
When first starting up the HDR software, the software will default to the last database specified.
A list of existing databases is given. Type in an existing database name or specify a new database (e.g., "Training"). If you put an "a-" in front of the name, it will be easier to find the file in the folder (e.g., "a-Training").

The HDR software stores the data for each measurement point in a file named "db_data.txt", where "db" is the user-specified name. Do not edit this file. See Section 3.4 to understand how to work with the verification database.

3.5. Working with the verification database

If this is a new database, then:

- Copy the file called "a_verif_script.xls" (latest version) from the nytimes resources folder to the nytimes/shadecomm/meas folder and rename the file (e.g., "a-Training.xls").
- Open the MS Excel file, select "Enable Macros", then check to make sure there is a zero in cell AK2.
- The new excel file contains two worksheets: HDR and Observations. Click on the worksheet tab (bottom edge of window) labeled "HDR".
- Hit the "Get Data" button. The MS Excel macro will open a standard file menu enabling you to locate and specify the HDR db_data.txt file in the nytimes/shadecomm/meas directory.

If the verification database already exists, then hit the "Get Data" button to upload new HDR data. The macro will then import the data, update the number of records in cell AK2, determine for each point whether it passes or fails the brightness criteria, and finally computes a brightness rating.

The HDR worksheet contains the following information for each measurement point as a single row entry (this information is protected from accidental modification):

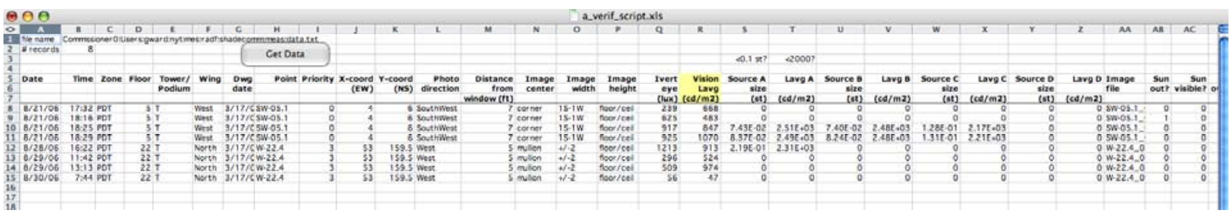
- Descriptive information such as the time and date of the measurement, measurement point location, view direction, etc.
- Data computed from the HDR measurement such as vertical illuminance, average window luminance (area outlined in Photoshop), and flagged glare sources solid angle (steradians) and luminance.

- Observations recorded during the HDR measurement (sky condition, subjective glare impression, etc.).

The CxA can modify the following information and add new columns to the right of the column AJ.

- Pass/fail criteria used by the CxA for evaluating glare control (e.g., threshold value and allowable deadband (e.g., 2000 cd/m^2 ± 10%) in columns AK-AM.
- Flags to exclude points (e.g., special tests).
- Flag for superceded points (e.g., if measurement point is no longer valid due to changes in furniture and/or MSS zoning, see below). Follow the instructions in Section 2.1.2.3 to archive old images and tag data in the verification database as superceded (=1).

Do not unprotect the HDR worksheet then modify the number in cell AK2. This will cause the data to be overwritten by the original data (from "db_data.txt"). All hand modified fields will be overwritten.


a_verif_script.xls

file name Commissioner0:Users:gward:nytimes:radf:shadecommmeas:data.txt

records 8

Get Data

<0.1 st? <2000?

Date	Time	Zone	Floor	Tower/ Podium	Wing	Dwg date	Point	Priority	X-coord (EW)	Y-coord (NS)	Photo direction	Distance from window (ft)	Image center	Image width	Image height	Ivert eye (lux)	Vision Lavg (cd/m2)	Source A size (st)	Lavg A (cd/m2)	Source B size (st)	Lavg B (cd/m2)	Source C size (st)	Lavg C (cd/m2)	Source D size (st)	Lavg D (cd/m2)	Image file	Sun out?	Sun visible?
8/21/06	17:32	PDT	5	T	West	3/17/C	SW-05.1	0	4	6	SouthWest	7	corner	15-1W	floor/ceil	239	668	0	0	0	0	0	0	0	0	SW-05.1_	0	0
8/21/06	18:16	PDT	5	T	West	3/17/C	SW-05.1	0	4	6	SouthWest	7	corner	15-1W	floor/ceil	625	483	0	0	0	0	0	0	0	0	SW-05.1_	1	0
8/21/06	18:25	PDT	5	T	West	3/17/C	SW-05.1	0	4	6	SouthWest	7	corner	15-1W	floor/ceil	917	847	7.43E-02	2.51E+03	7.40E-02	2.48E+03	1.28E-01	2.17E+03	0	0	SW-05.1_	0	0
8/21/06	18:29	PDT	5	T	West	3/17/C	SW-05.1	0	4	6	SouthWest	7	corner	15-1W	floor/ceil	925	1070	8.37E-02	2.49E+03	8.24E-02	2.48E+03	1.31E-01	2.21E+03	0	0	SW-05.1_	0	0
8/28/06	16:22	PDT	22	T	North	3/17/C	W-22.4	3	53	159.5	West	5	mullion	+/-2	floor/ceil	1213	913	2.19E-01	2.31E+03	0	0	0	0	0	0	W-22.4_0	0	0
8/29/06	11:42	PDT	22	T	North	3/17/C	W-22.4	3	53	159.5	West	5	mullion	+/-2	floor/ceil	296	524	0	0	0	0	0	0	0	0	W-22.4_0	0	0
8/29/06	13:13	PDT	22	T	North	3/17/C	W-22.4	3	53	159.5	West	5	mullion	+/-2	floor/ceil	509	974	0	0	0	0	0	0	0	0	W-22.4_0	0	0
8/30/06	7:44	PDT	22	T	North	3/17/C	W-22.4	3	53	159.5	West	5	mullion	+/-2	floor/ceil	56	47	0	0	0	0	0	0	0	0	W-22.4_0	0	0

Figure 19. Verification database.

3.5.1. Superceded points

During the verification process, changes may be made to the furniture or space layout, thus affecting the configuration of the shade control zones. New measurement points will need to be defined for each new control zone (see Sections 2.1 and 2.1.2). If the verification measurements have already been initiated, then the verification process may need to be repeated for the new control zones. To retain prior HDR measurements (may be useful for photosensor diagnostics) but exclude these measurements from the final pass/fail assessment, input a "1" value in the "Superceded point?" column AQ. When making the final assessment of whether a floor passed, sort the HDR database based on floor number and non-superceded points and check that no fails occurred due to glare.

3.5.2. Documenting other shade control problems

When you observe a shade control system or other type of failure (mechanical, addressing, user interface, etc.), then record your observations on the worksheet labeled "Observations" located in the same Excel file as the HDR database:

- Designate which shade(s) were involved using the NYT coordinate system and note the time and date of the observation.
- Take a photograph using the small digital camera if the problem is observable (set the clock of the camera to match that of the HDR computer). For example, photograph the bottom hem if there are shade alignment problems. Photograph direct sun patterns that penetrate deeper than allowable distance (photograph with measuring tape in view). Download the images to the "nytimes field observations" folder and record the filename of the image.

3.6. How to conduct the verification process under unstable shade conditions

At any given time, the shades could move to meet the control objectives or remain static even though solar conditions have changed due to shade control system time delays. The MSS control system imposes delays on the shade movement to prevent unnecessary oscillations that could annoy the occupant.

The delay for extending the shade downwards is minimal (< 1 min). If there is a condition that may cause discomfort, the control response time is virtually instantaneous.
The delays for retracting the shade upwards are staged so that if the shades are to be fully retracted, for example, the shades will pause for 5 min at each intermediate preset height until reaching its final position.
At all times, the direct sun and glare control aspect of the MSS system should be met.
The maximize view/daylight control aspect will not always be met due to the delays.

When verifying MSS control system performance, modify the delay times so the total combined delay is 5 min. This will enable the CxA to take measurements of the window as the shade moves to its final preset height.

Because the CxA will not know when the control system will reach a stable status, measurements will need to be made for each 5 min interval until after no shade movement is detected after 5 minutes. The HDR process takes 3-4 minutes to complete. Control delays could be increased to longer than 5 min if it is too difficult to complete a measurement within 5 min. However, increasing the delay time increases the length of time to do the verification process on a partly cloudy day. An example is given below.

Example: While an HDR measurement is being taken (#1), the shade moves to preset height 4 to block direct sun after the sun comes out from behind a cloud:

12:00	Preset 0	Cloudy, direct sun control not required
12:01		HDR image capture #1 started

12:03		Sun comes out
12:04	Preset 4	Shade moves because direct sun control required (note time and wait until after 12:09 to restart HDR capture)
12:05		HDR image #1 processing completed
12:10		HDR image capture #2 started
12:14		HDR image #2 processing completed
12:15	Preset 2	Put MSS system into manual mode; Preset 2 using floor's keypad or MSS supervisor control system
12:16		HDR image capture #3 started
12:20		HDR image #3 processing completed

Exclude HDR#1 measurement. Use HDR #2 to assess glare. Use HDR #3 to assess view and glare

3.7. How to determine if the floor passed

Using MS Excel, sort data by floor to find all measurements associated with a floor. Scan the column AN for any fails (zero value). If there are any fails, the cell will have an orange background making it easy to spot. If there are no fails, then the floor passes.

If there are fails, check the field "Is the sun in the field of view?" If this field shows yes (1) and the shades are lowered (covering the sun orb – check the HDR image file), then the window luminance may exceed 2000 cd/m^2 because the fabric alone cannot control the sun+sky window luminance. NYT will determine on a case-by-case basis if the point should pass.

4. References

[1] Eleanor S. Lee, Stephen Selkowitz, Glenn Hughes, Robert Clear, Greg Ward, John Mardaljevic, Judy Lai, Mehlika Inanici, Vorapat Inkarojrit. 2005. Daylighting the New York Times Headquarters Building: Final Report. LBNL-57602, Lawrence Berkeley National Laboratory, Berkeley, CA. http://windows.lbl.gov/comm_perf/nyt_pubs.html

Appendix A: Basis for Resources R1-R4

Resource R1

Resource R1 calculates the times during which the sun penetration could exceed the specified sun penetration limits. The calculation is performed with the assumption that there are no external obstructions. The commissioning agent uses resource R1 to determine the likely times that the sun will cause the shade to control sun penetration. Resource R1 is used as filter to limit the times and locations that need to be examined with resource R2, which is slower and harder to use, and has larger time steps. Once the agent knows the range of times of interest, they use resource R2, which shows shadows on the building as a function of time, to check to see if there are shadows on the control zone at the times in question.

Resource R1 includes both graphs of the times for the different shade heights, and a spreadsheet calculator. There are 12 graphs, one for each orientation and each combination of tubes/no tubes and sun penetration depth. The graphs provide an overview of how the times change during the year, but are less easy to use than the calculator for getting the values for any one day.

To use the calculator, the commissioning agent enters the day in month/day format, and the calculator returns the times when the shade is blocking sun penetration for each of the 4 orientations, and the three combinations of tubes/no tubes and sun penetration depths. Sun penetration in the calculator is listed as those times when the shade is at preset height 4 or below (2.5 feet). At the higher preset heights it is important to distinguish whether the shade is in the daylight harvesting or glare control modes. These times are therefore not as significant to the commissioning agent, and are not listed.

The times are given as either standard time or daylight savings time, as appropriate, but the daylight savings adjustment is only valid for the period from 8/1/06 until the end of October of 2007.

The calculations in resource R1 are a function of geometry only. The penetration depth of the sun depends upon the altitude and azimuth of the sun, the orientation, height, and width of the windows, the depth of the mullions, and, in places where there are tubes, the location, diameter and height of the ceramic tubes.

The altitude and azimuth of the sun is computed from the solar declination, the equation of time, and the latitude and longitude of the building location. The declination and equation of time were computed at noon (EST) for each day of the year using Yallop's algorithm, as referenced in Muneer[1]. The calculation of the time t in the equation was simplified to use just the year day number instead of the month and day. The remaining part of the algorithm was used without modification. The use of a single declination and equation of time value for a whole day introduces an error on the order of only 0.1 degrees near sunrise and sunset. In terms of time, this is an error on the order of 30 seconds.

For latitude and longitude for New York city we used the values that were listed in a Google search of 40° 44' and 73° 55' respectively (www.timeanddate.com/worldclock/city.html?n=179). New York city covers an extensive area, and these values are probably not exact for the New York Time's building. Values for the Central Park area of New York differed by 3' in latitude and 1' in longitude. The difference in longitudes is equivalent to a 4 second error in time. The difference in latitudes is equivalent to about a 10 second shift in time. Errors in location are therefore expected to be significantly under one minute.

The orientation of the south facade of the building was taken to be 28.65° west of true south, per an email from E. Lee of 6/8/06. The orientation of the other facades are assumed to be stepped in 90° increments from south. An error of 0.01° is equivalent to a 1 to 2 second error in the time at which a shade reaches a particular profile angle.

Window size, shade heights, mullion dimensions and the ceramic tube locations and dimensions were taken from architectural drawings. Errors in these measurements have a much larger effect on the computed times than the likely errors in the sun position and orientation calculations.

The ceramic tubes above the vision portion of the window were taken to be 3.4375 inches apart, and 1.625 inches in diameter (8.73 cm and 4.12 cm respectively). The sun will not penetrate through the tubes when the angle = $\cos^{-1}(2r/d)$, where r is the radius and d is the distance between tubes. The computed blocking angle is 61.79°. A variation of about 1/16th of an inch (1.59 mm) will make about a 1.2° difference in the blocking angle. Under worst case conditions this is about a 4 minute difference in the time that the sun is blocked. A more typical value is about 2 minutes.

The ceramic tubes are centered 19 inches (48.3 cm) outboard of the inner surface of the window. Sun penetration is supposed to be limited to 36 inches from the inner surface of the window (an additional 91.4 cm). The lowest tube above the vision window appears to be 74.6875 inches above the finish floor (189.7 cm). The angle for which the sun is blocked at the requisite distance is given by the solution to the equation hcos(theta) =r + xsin(theta), where h is the height (74.6875 inches), r is the radius of the tubes (0.8125 inches), and x is the distance to the tubes (55 inches). The computed angle is 53.13°. The angle is relatively insensitive to errors in the radius of the tubes. An error of 1/16th inch produces an angle error of 0.04°. An error of 1 inch in the height or the distance produces errors of 0.37° and 0.5° respectively. The worst case equivalent time errors are 8 seconds, 1.17 minutes, and 1.5 minutes.

The vertical window mullions are shown to be 8.0625 inches deep, and typically 54.5 inches apart (20.48 and 138.4 cm respectively). Light coming from the side is blocked if the azimuthal angle is more than $\tan^{-1}(54.5/8.0625) = 81.58°$ from the normal to the window facade. A 1/16th inch error in the mullion depth, or a one half inch error in mullion spacing, results in a 0.06 to 0.08 degree error in the blocking angle. The resultant time error is on the order of 30 seconds.

There are 5 preset shade heights above the floor: 30, 48, 73, 97 and 125.5 inches (76.2, 121.9, 185.4, 246.4, and 318.8 cm, respectively). The corresponding angles for a 3 foot (91.4 cm) penetration of the sun are 39.8, 53.1, 63.7, 69.6, and 74.0 degrees respectively. For a 6 foot (182.8 cm) penetration the angles are 22.6, 33.7, 45.4, 53.4, and 60.2. A 1 inch error in the measurements produces an angular error of from 0.3 to 0.8 degrees, which is a time error of from 1 to 2.5 minutes.

To generate the data for Resource R1 the solar angles were computed at 5 minute intervals, which is slightly larger than the largest estimated error arising from errors in measurement or calculation. The profile angle was computed for each pair of solar angles, and each facade orientation. The profile angle = $\tan^{-1}$[sin(solar altitude)/cos(incident angle)]. The incident angle = $\cos^{-1}$[cos(solar altitude)cos(solar azimuth - elevation azimuth)].[2] Profile angles were compared to the angles calculated above to determine when, and how much, the shades had to be down to block the sun.

References

1. T. Muneer, "Solar Radiation & Daylight Models", Architectural Press, Linacre House, Jordan Hill, Oxford OX2 8DP, 1997.

2. "Recommended practice for the calculation of daylight availability", JIES, Vol. 13(4), pps 381 - 392, 1984.

Resource R2

Resource R2 calculates the locations of shadows from external obstructions (buildings) on the four facades of the NYT building. The commissioning agent uses resource R2 in conjunction with resource R1, and drawings of locations of the shade control zones, to determine the times when shades are likely to be, or should be, down to block sun penetration. If resource R1 shows that an unobstructed facade will have the shade down, then for each measurement location on the facade, resource R2 is checked to see if there is direct sun anywhere on the control zone. Sun anywhere on the zone means that the shades should be controlled for sun penetration. If the entire control zone is in shadow, then the shades are either in glare or daylight harvesting mode. In this latter cases resources R3 and R4 are checked to see if the luminance levels are in the range where measurements should be taken.

Resource R2 is menu option 2 of the run program in the Shadecomm directory. After selecting option 2, the commissioning agent is prompted to enter the day and month, the time zone (EST for standard time and EDT for daylight savings time), and a time interval (30 minutes or multiples thereof). The program computes the shadow information and then displays a set of images which can be examined separately. Each image shows the facades of the NYT building in
4 side-by-side panels. The view from each panel is from inside the building looking out. For example, if you look at the south panel, the right side is towards the west corner, and the left side is towards the east corner. Shadows are shown as blue or black shading.

Resource R2 is based on a Radiance model of the area surrounding the site of the NYT building. The accuracy of the shadow calculation is primarily dependent upon the accuracy of the model of the surroundings. The accuracy is thought to be on the order of 15 minutes or better, but has not been checked. Changes to the surroundings will of course invalidate calculations that cover areas where the changes are made.

Resource R3

Resource R3 is a set of Radiance views from each of the possible predetermined measurement points. The commissioning agent uses resource R3 as a check that the sun will not be in the field of view when a measurement is taken, and to estimate the fraction of the sky that is visible. The sky fraction is used in conjunction with resource R4 to estimate the time periods when window luminances are in the critical region for control of glare and daylight harvesting.

Resource R3 is menu option 3 of the run program in the Shadecomm directory. The commissioning agent enters the code for the measurement point at the prompt and the program displays a view out the window from the measurement location. The horizon is the centerline of the display. The agent is interested in the area between the horizon and the top of the view portion of the window. If the window is shielded by tubes, the view portion is the area without tubes. For windows without tubes the view portion is the entire height of the window. The spreadsheet documentation for the measurement point lists the width of the measurement area in terms of window bays.

If a third or less of the area between the centerline and the top of the view portion of the window over the specified width is visible as sky, and not buildings, then the agent will look at the 100% obstructed window in resource R4 to determine the times of interest. The agent should use the 50% obstructed sky if from one-third to two-thirds of the sky is visible, and they should use the 0% obstructed sky values if more than two-thirds of the sky is visible.

The degree of obstruction at any point depends strictly on the geometric relations between the point and potential external obstructions. If a location on one floor is free of obstructions, then all locations directly above the first location will be free of obstructions, and need not be examined. If a building obstruction is near the measurement point, then changes in the measurement location may make large changes in the degree of obstruction. Points to the side or immediately above may need to be checked to see if the degree of obstruction is significantly changed. If the obstructions are distant, then shifts in location will not make a major change in the degree of obstruction, and the agent may be able to skip the examination of several floors, or nearby points on the facade. The efficient method of using resource R3 is to start at the lowest floors, eliminate locations along a facade once they become unobstructed, and skip points or floors whenever the slowness of the change in the degree of obstruction permits.

Resource R3 is based on a Radiance model of the NYT building and its surrounding area. The accuracy of the shadow calculation is primarily dependent upon the accuracy of the model of the surroundings, and should be well within the accuracy required for use with resource R4.

Resource R4

Resource R4 calculates the unweighted average of the luminances seen through two standard window layouts. The window shade system is supposed to control average window luminance to below 2200 cd/m^2 (glare control mode), and to harvest daylight when window luminance is below 1800 cd/m^2. Shade location is not specified in the luminance range between 1800 and 2200 cd/m^2. The average luminances computed by resource R4 are for the CIE standard clear sky, partly cloudy sky, and overcast sky luminance distributions. For each sky type, calculations were made for unobstructed sky conditions, fully obstructed sky conditions, and 50% obstructed sky conditions. These calculations should cover the majority of conditions visible through the windows at the NYT. The commissioning agent uses resource R4 in conjunction with the projected sky conditions and an estimate of the degree of obstruction for a given location (from resource R3 or physical examination of the point in question) to estimate the times of day when the window luminances are in the range where window control may switch between glare control and daylight harvesting. These are the times of day when window luminance measurements are most likely to reveal problems with the control system.

Resource R4 consists of graphs showing contour lines for window luminances versus time of day and day of year, and a spreadsheet which takes day and sky condition as input, and returns sets of times for when the window luminance is between 1500 and 2500 cd/m^2. This range of values was chosen to be slightly wider than the critical control range, because actual skies are not identical to standard skies.

The wider range provides a better idea of when measurements may be appropriate.

There are 34 graphs, including 16 for unobstructed clear or partly cloudy skies, eight each for 50% or fully obstructed skies (clear or partly cloudy) and two for overcast skies. The first 16 graphs consist of 2 skies times 4 orientations times two view locations (5 feet from the window and 15 feet from the window). View location was found to be a fairly minor effect, so calculations for the 50% and fully obstructed windows were done only at 15 feet depth. Orientation does not make a difference for overcast skies, and obstruction reduces the luminances to below 1500 cd/m^2. This meant only two calculations were necessary; one for five feet from the window, and one from 15 feet.

The 34 graphs provide a visual image of how luminance varies over both the day and year. The spreadsheet provides a more convenient method of getting the times for the critical luminances (1500 and 2500 cd/m^2) for a particular day and sky condition. The commissioning agent uses the calculator by entering the date in month/day format, and the sky condition. The calculator returns two sets of times for each orientation and window condition (5 or 15 feet with unobstructed sky, plus the half and fully obstructed sky). The first set of times is for when luminances are increasing during the day, and first reach 1500 and then 2500 cd/m^2. The second set of times is for when the luminances are decreasing towards evening, and first reach 2500 and then 1500 cd/m^2.

When there are obstructions the luminance may actually have two maxima with a dip between them. However this dip was never large, and has been ignored in the calculator. It is also possible that window luminance never reaches 2500 cd/m^2, or 1500 cd/m^2. The calculator returns a "not applicable" message if a luminance is not reached. If the luminance never reaches the upper limit there is still a possibility, although it is somewhat reduced, that the shades will shift to a different control mode. The graphs can be consulted to see if the luminance exceeds 2000 cd/m^2, which would make such a shift more likely.

Times are displayed in either EST or EDT as appropriate. Resource R4 shares the same restrictions as resource R1 with regards to the daylight savings adjustment.

Windows in the NYT building see a mix of ground plane, sky and external obstructions, and possible direct sun. Because the shade is supposed to be down when the sun is visible, and measurements are not supposed to be made if the sun is visible from the measurement cart, the direct sun contribution was not included in the calculation. An estimate of the indirect sun contribution from the reflection from the ground plane or external obstructions is included as appropriate. Both ground plane and external obstructions were assumed to have a reflectance of 20%, which is a typical urban value. Glass facades may present problems in that their reflection is specular, and will include a sun image. Specular reflection can make the average window luminance exceed the specified limits.

Sun reflections are mostly likely to be a problem early in the morning or late in the afternoon, when the sun is fairly low in the sky. When the sun is high in the sky (noon) the reflection is at corresponding high angle. For the window areas with tubes the maximum up angle at which the sun will be visible is about 19° (see below), so sun altitudes above this will not produce a sun image visible in the vision portion of the window. At five feet, the unobstructed windows see up to 52°. However, at this angle, the obstruction must be either very close, or substantially higher than the measurement point. For example, an obstruction 100 feet distant would need to be almost 130 feet higher than the measurement point to be visible. Specular sun reflections should not be a problem for the upper floors of NYT building.

The east facade is oriented about 29° south of east, so direct normal reflections would be from 29° north of west, and would be in the afternoon. The sun does not go north of west except in the summer. The commissioning agent should not expect major problems with this facade during the winter.

The west facade is oriented about 29° north of west, so the direct normal reflection is 29° south of east, and would be in the morning. The west facade could suffer from direct reflections year round, but does not appear to have many major obstructions in view. The one major obstruction appears quite distant, and may not be a problem, but this has not been confirmed by calculation.

The north facade sees the reflections from the early afternoon sun. These are likely to be too high to be a problem in the summer. They are a potential problem in the winter.

The south facade sees the reflections from the sun from the north. There is a narrow period where this may be a problem during summer mornings, but it does not appear likely.

Computations of the window luminances were performed by numerically integrating the sky luminance distributions over the window angles. The numerical integration was run over altitude and then azimuth. The inner integral over altitude was run iteratively until the change in the integral was less than 10^{-6}, and the outer integral was run iteratively until the change in the final answer was less than 10^{-5}. Precision is expected to be on the order of 0.01% of the final value. The double integration returns a relative luminance of the sky portion of the window. The relative values are converted to absolute values by multiplying by an estimate of the zenith luminance. Values for the zenith luminances were taken from the IES 1984 recommended practice.[1] The practice does not list an estimate of the expected uncertainty of real skies about the listed values.

Two window layouts were evaluated. Both assumed assumed a view height of 48 inches, a window bottom of 30 inches, and a window top of 74.69 inches (121.9 cm, 76.2 cm, and 189.7 cm). This is the view through the view section of a window with tubes. Two distances from the tubes, 79 inches and 199 inches (200.7, and 505.5 cm) were examined. These distances include the 19 inch space from the inner portion of the window to the tubes, and give distances of 5 and 15 feet from the window. The vertical angles for these two distances are -12.8° to + 18.7°, and -5.2° to +7.6°. Luminances for the non-tube windows were not examined separately, as the two layouts examined did not exhibit major differences. The angles for a full window (bottom at floor level and top at 10' 5") are -14.9° to 23.3° at 15 feet, and -38.7° to +52.2° at 5 feet.

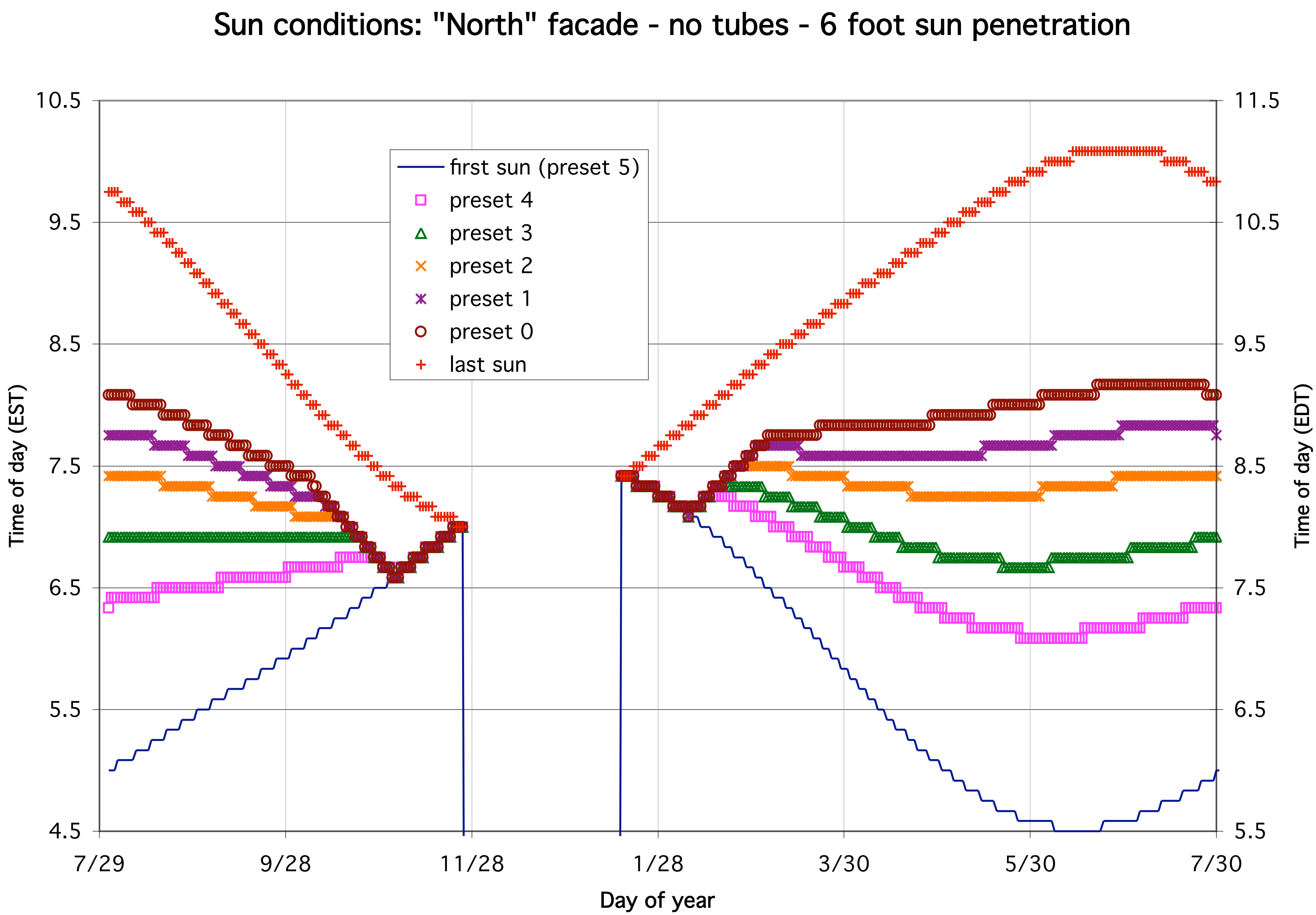
Angular window widths are kept approximately equal for the two distances because the number of window bays that are supposed to be included in the calculation varies with the distance to the window. At 5 feet the calculation covers ±2 window bays, for a width of 117.25 inches (297.8 cm). At 15 feet the calculation covers ± 6 window bays for a width of 357.25 inches (907.4 cm). The angular widths are ± 62.9° and ± 63.2° respectively.

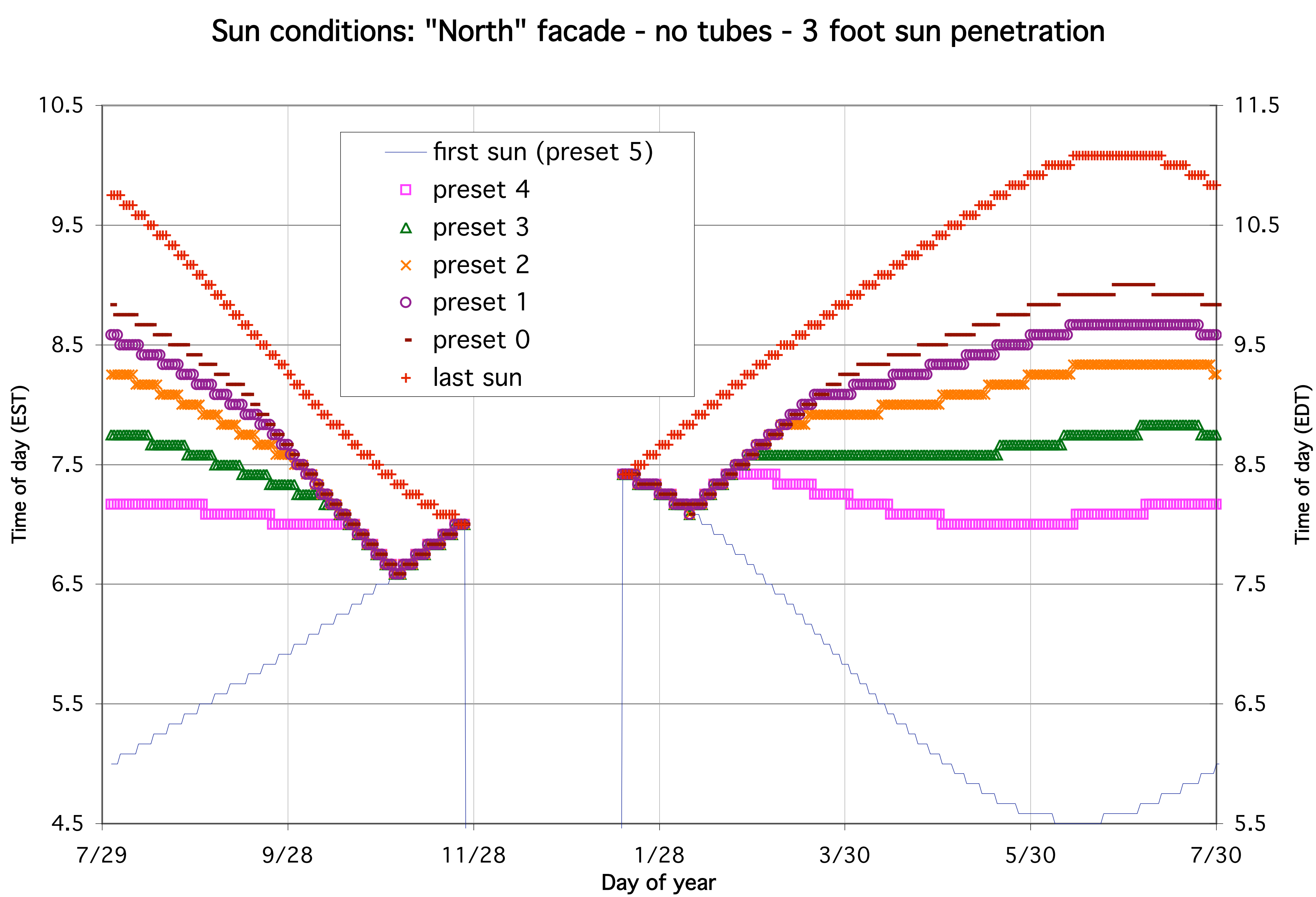
The window mullions are 8.0625 inches deep, and 5.5 inches wide (20.5 cm and 14.0 cm). They block approximately 14.4% of the view at 5 feet, and 15.2% of the view at 15 feet. Window transmission was assumed to 75%. Reflected light from the interior was assumed to contribute 52 cd/m^2 to the computed window luminances.

References

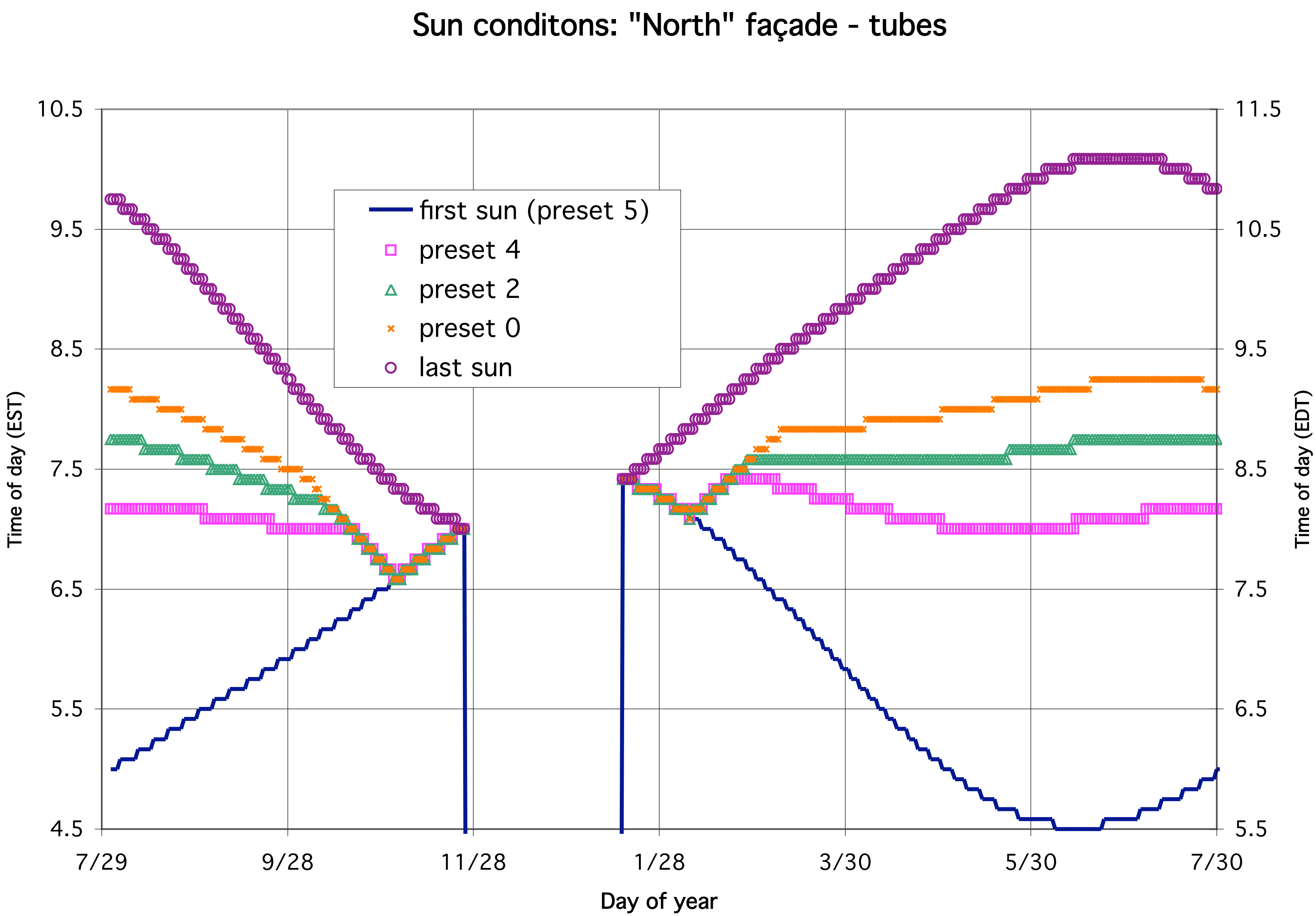
1. "Recommended practice for the calculation of daylight availability", JIES, Vol. 13(4), pps 381 - 392, 1984.

Appendix B: Resource R1 Graphs

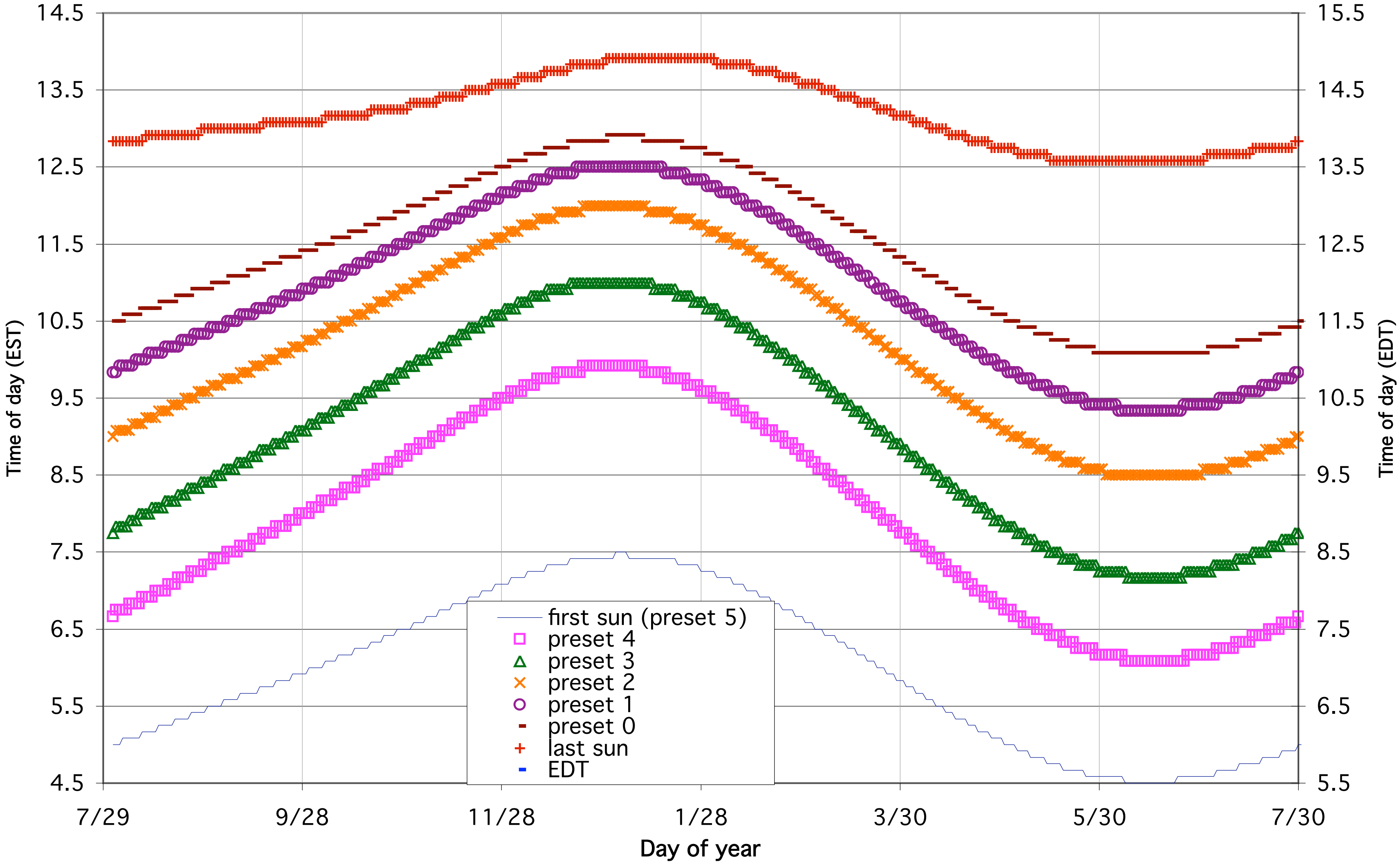

Sun conditions: "North" facade - no tubes - 6 foot sun penetration
first sun (preset 5)
preset 4
preset 3
preset 2
preset 1
preset 0
last sun
Time of day (EST)
Time of day (EDT)
Day of year
10.5
9.5
8.5
7.5
6.5
5.5
4.5
11.5
10.5
9.5
8.5
7.5
6.5
5.5
7/29
9/28
11/28
1/28
3/30
5/30
7/30

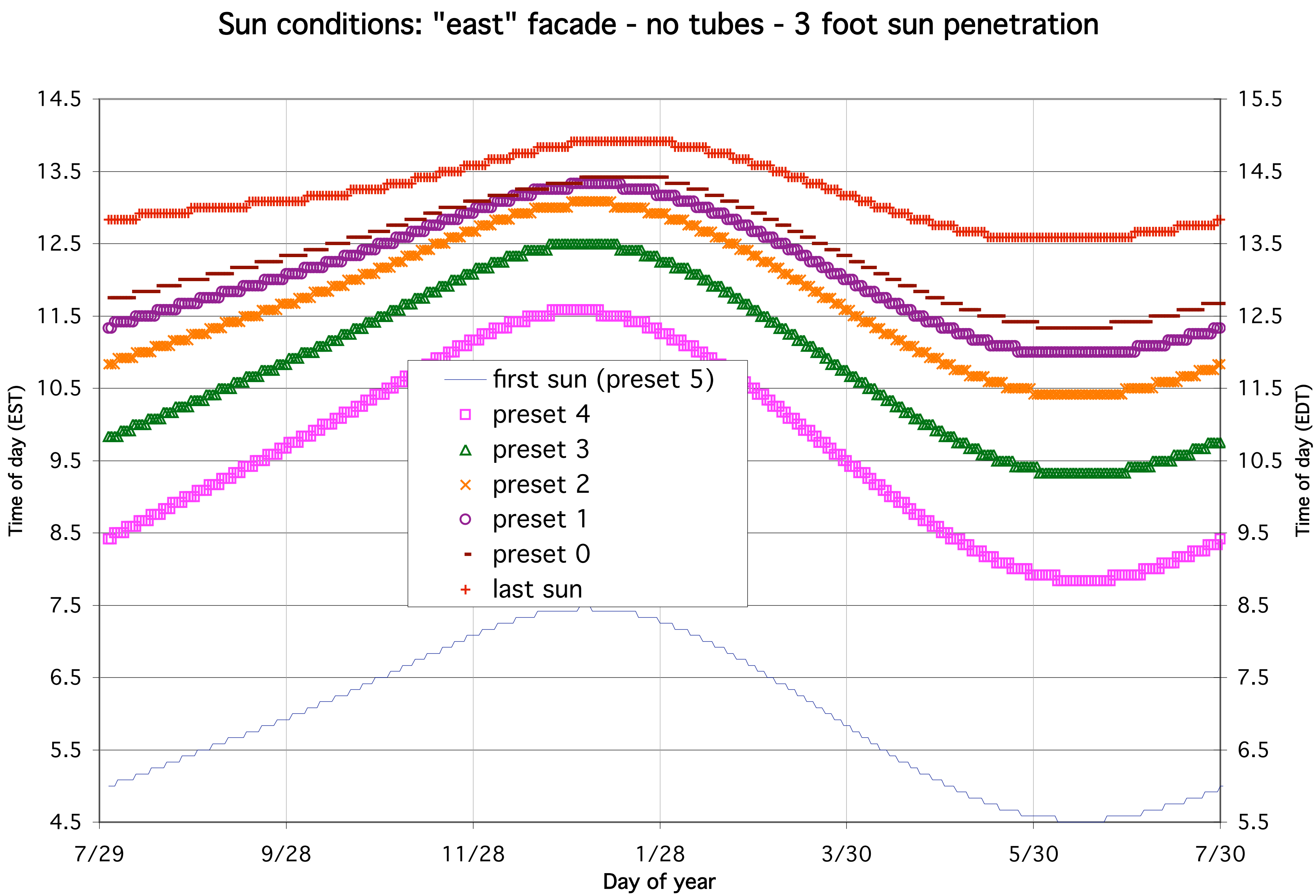


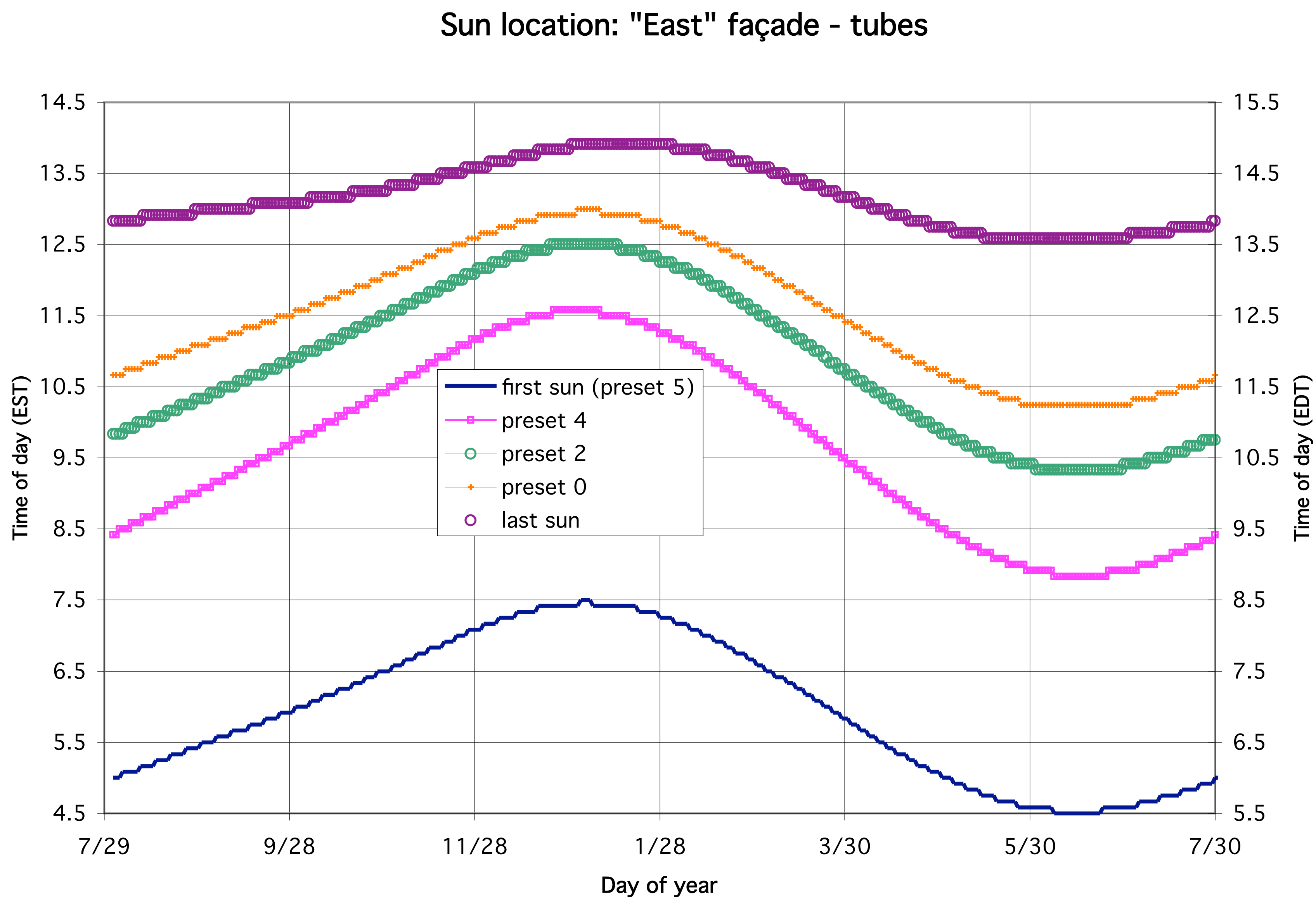
Sun conditions: "North" facade - no tubes - 3 foot sun penetration
first sun (preset 5)
preset 4
preset 3
preset 2
preset 1
preset 0
last sun
Time of day (EST)
Time of day (EDT)
Day of year
10.5
9.5
8.5
7.5
6.5
5.5
4.5
11.5
10.5
9.5
8.5
7.5
6.5
5.5
7/29
9/28
11/28
1/28
3/30
5/30
7/30


Sun conditons: "North" façade - tubes
first sun (preset 5)
preset 4
preset 2
preset 0
last sun
Time of day (EST)
Time of day (EDT)
Day of year
10.5
9.5
8.5
7.5
6.5
5.5
4.5
11.5
10.5
9.5
8.5
7.5
6.5
5.5
7/29
9/28
11/28
1/28
3/30
5/30
7/30

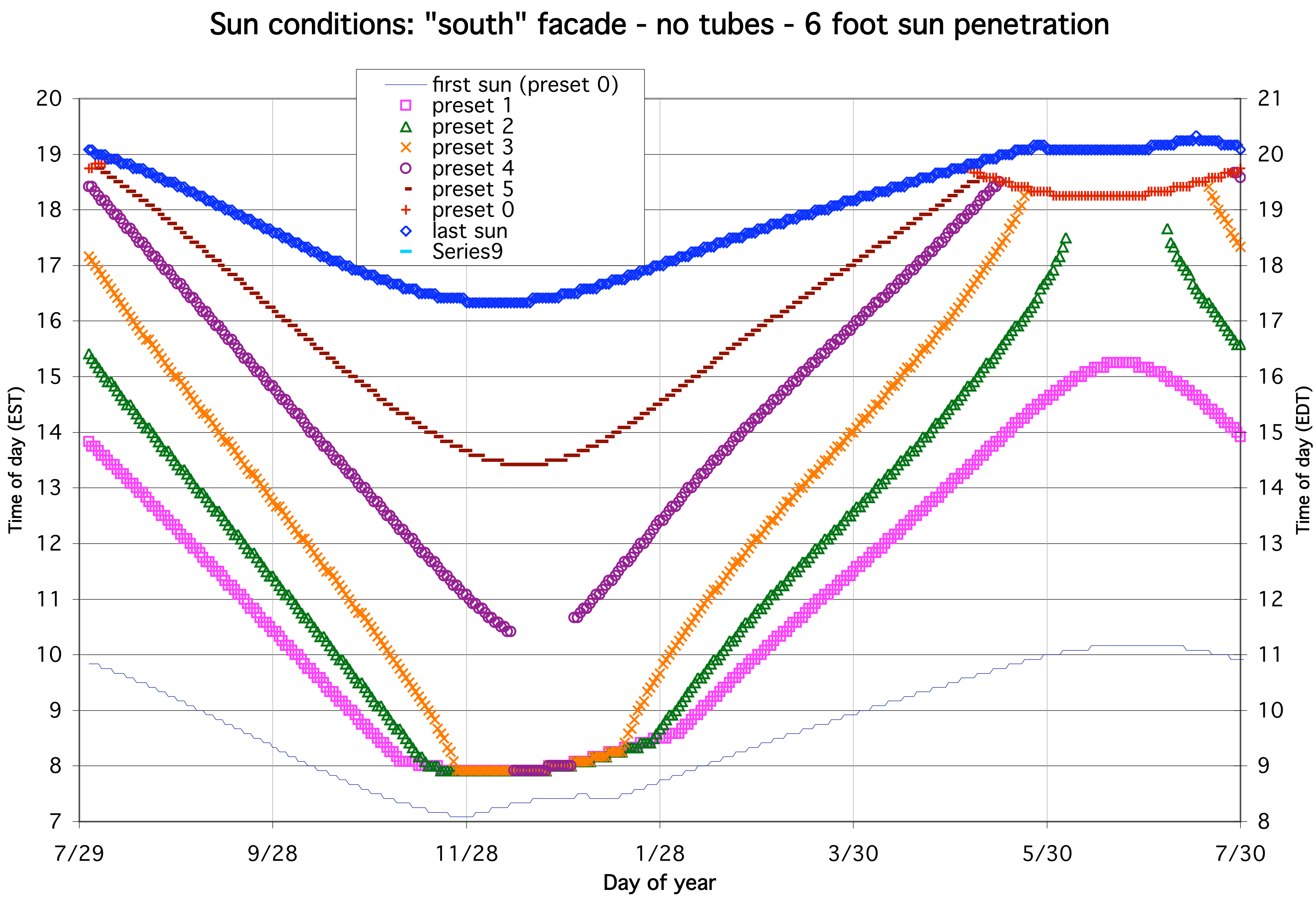
Sun conditions: "east" facade - no tubes - 6 foot sun penetration



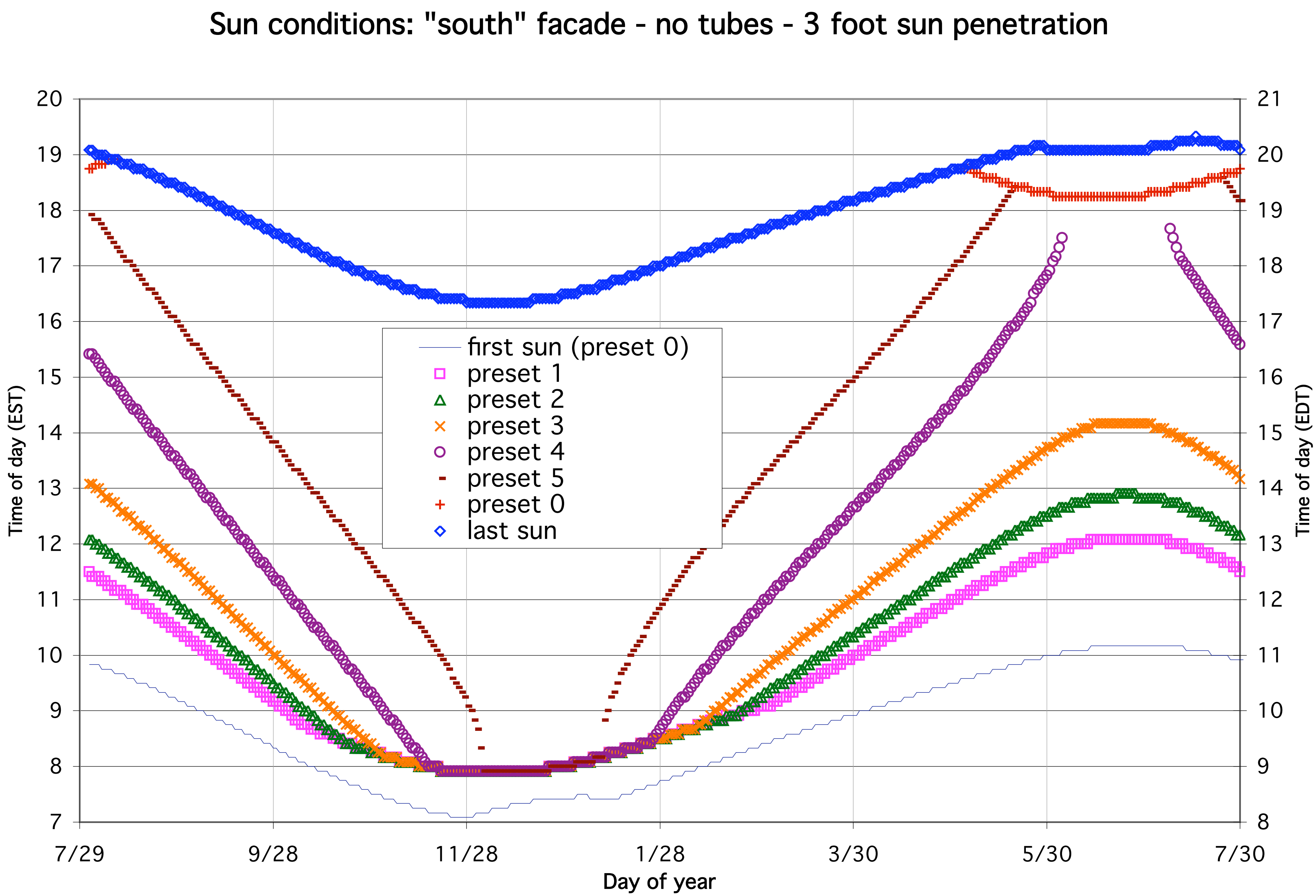

Sun conditions: "east" facade - no tubes - 3 foot sun penetration
14.5
13.5
12.5
11.5
10.5
9.5
8.5
7.5
6.5
5.5
4.5
Time of day (EST)
15.5
14.5
13.5
12.5
11.5
10.5
9.5
8.5
7.5
6.5
5.5
Time of day (EDT)
first sun (preset 5)
preset 4
preset 3
preset 2
preset 1
preset 0
last sun
7/29
9/28
11/28
1/28
3/30
5/30
7/30
Day of year



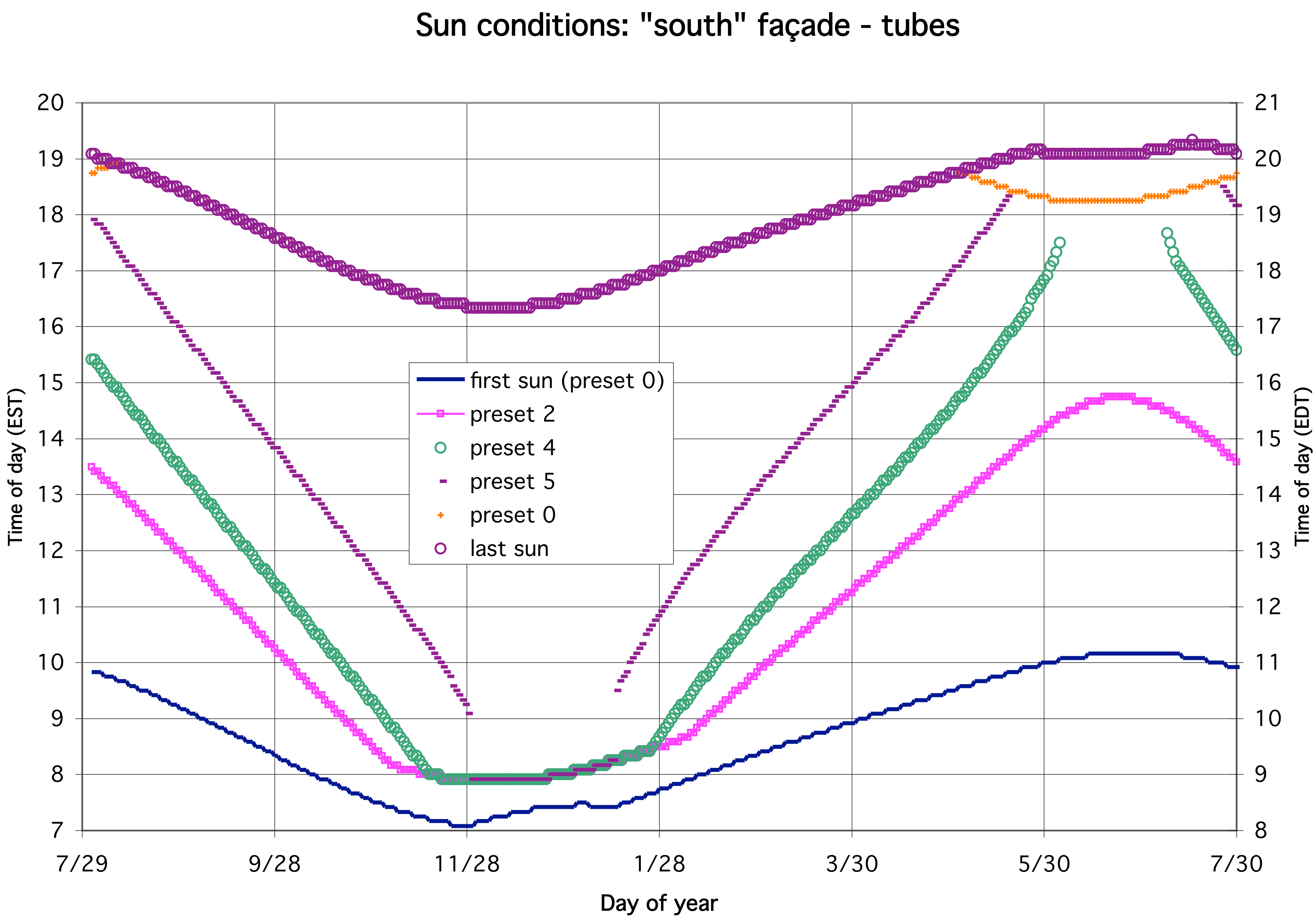
Sun location: "East" façade - tubes
14.5
13.5
12.5
11.5
10.5
9.5
8.5
7.5
6.5
5.5
4.5
Time of day (EST)
15.5
14.5
13.5
12.5
11.5
10.5
9.5
8.5
7.5
6.5
5.5
Time of day (EDT)
7/29
9/28
11/28
1/28
3/30
5/30
7/30
Day of year
first sun (preset 5)
preset 4
preset 2
preset 0
last sun



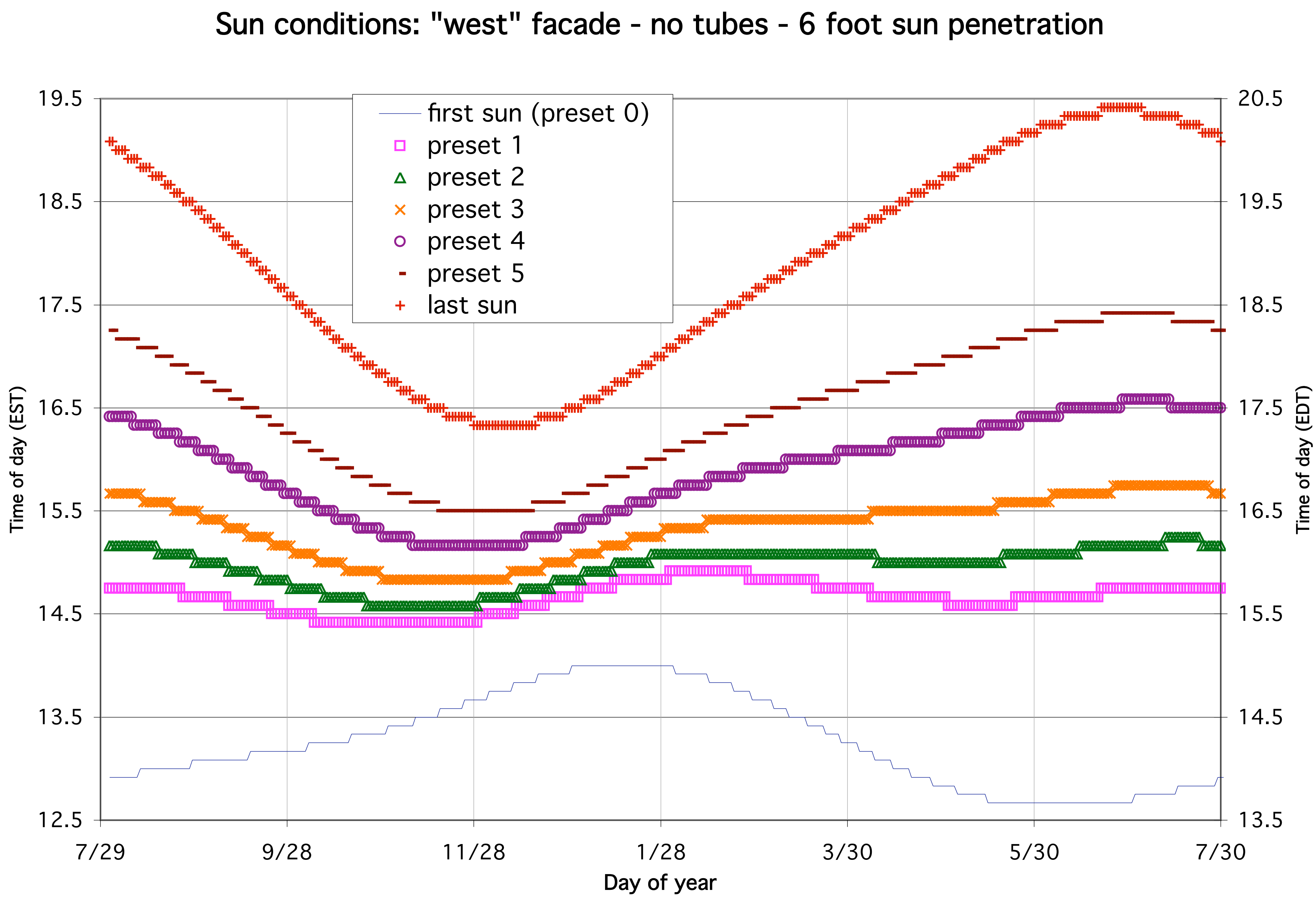
Sun conditions: "south" facade - no tubes - 6 foot sun penetration
first sun (preset 0)
preset 1
preset 2
preset 3
preset 4
preset 5
preset 0
last sun
Series9
Time of day (EST)
Time of day (EDT)
Day of year
7/29
9/28
11/28
1/28
3/30
5/30
7/30



Sun conditions: "south" facade - no tubes - 3 foot sun penetration
Time of day (EST)
Time of day (EDT)
Day of year
7/29
9/28
11/28
1/28
3/30
5/30
7/30
20
19
18
17
16
15
14
13
12
11
10
9
8
7
21
first sun (preset 0)
preset 1
preset 2
preset 3
preset 4
preset 5
preset 0
last sun

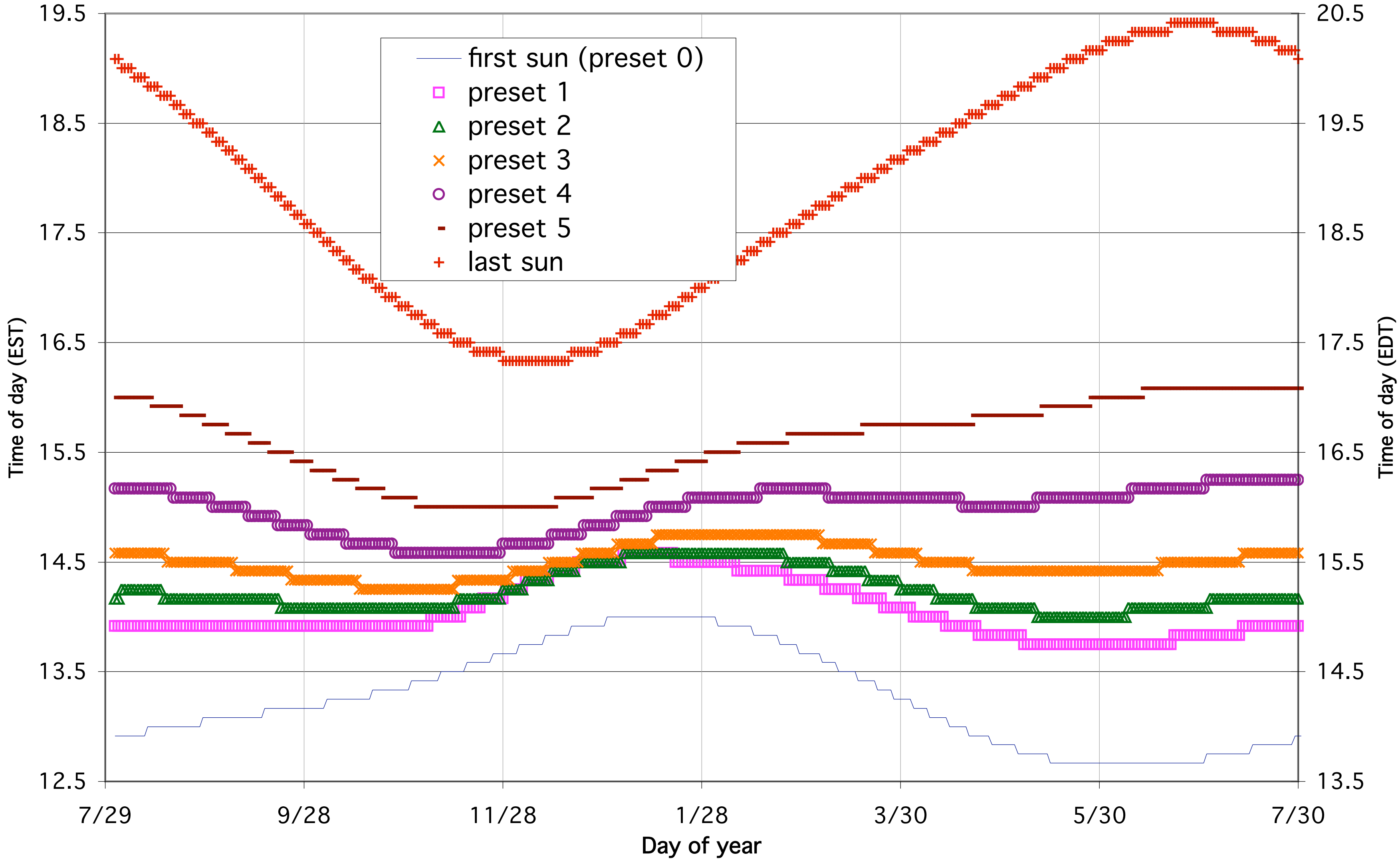


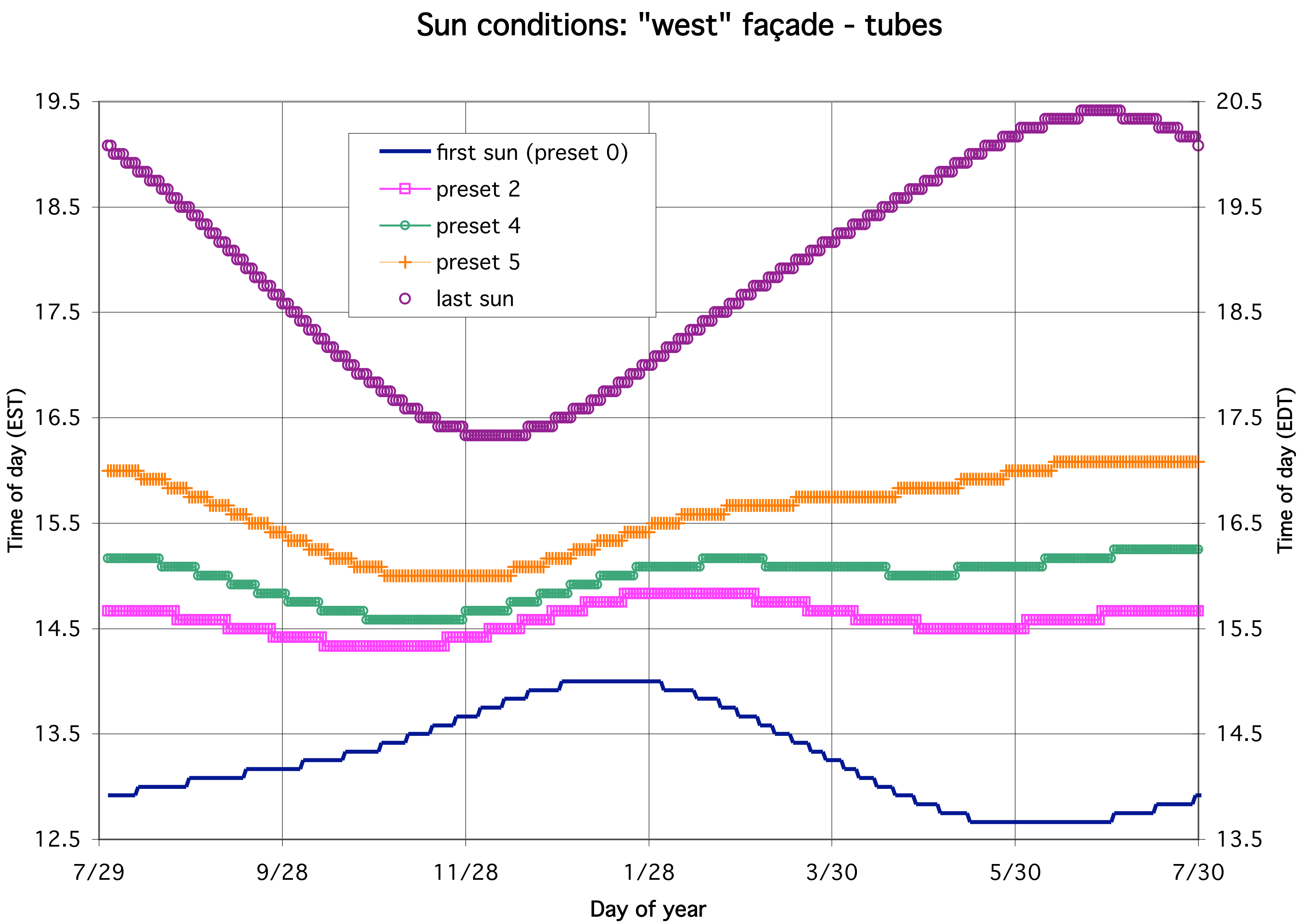
Sun conditions: "south" façade - tubes
Time of day (EST)
Time of day (EDT)
Day of year
7/29
9/28
11/28
1/28
3/30
5/30
7/30
20
19
18
17
16
15
14
13
12
11
10
9
8
7
21
first sun (preset 0)
preset 2
preset 4
preset 5
preset 0
last sun



Sun conditions: "west" facade - no tubes - 6 foot sun penetration
first sun (preset 0)
preset 1
preset 2
preset 3
preset 4
preset 5
last sun
Time of day (EST)
Time of day (EDT)
Day of year
19.5
18.5
17.5
16.5
15.5
14.5
13.5
12.5
20.5
19.5
18.5
17.5
16.5
15.5
14.5
13.5
7/29
9/28
11/28
1/28
3/30
5/30
7/30

Sun conditions: "west" facade - no tubes - 3 foot sun penetration




Sun conditions: "west" façade - tubes
first sun (preset 0)
preset 2
preset 4
preset 5
last sun
Time of day (EST)
Time of day (EDT)
19.5
18.5
17.5
16.5
15.5
14.5
13.5
12.5
20.5
19.5
18.5
17.5
16.5
15.5
14.5
13.5
7/29
9/28
11/28
1/28
3/30
5/30
7/30
Day of year

Appendix C: Resource R4 Graphs

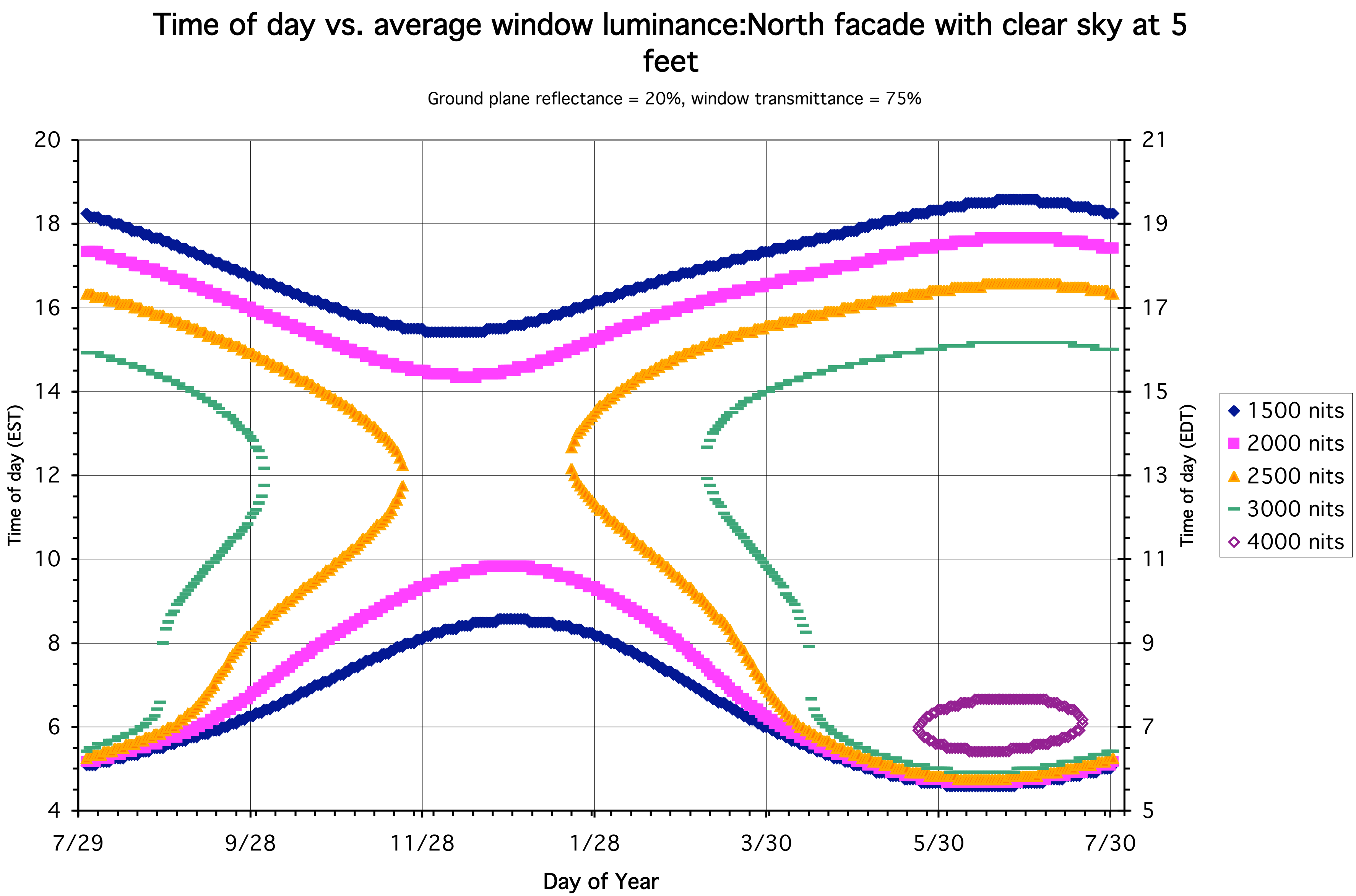
See Section 2.2.4 for an explanation of use for these graphs.

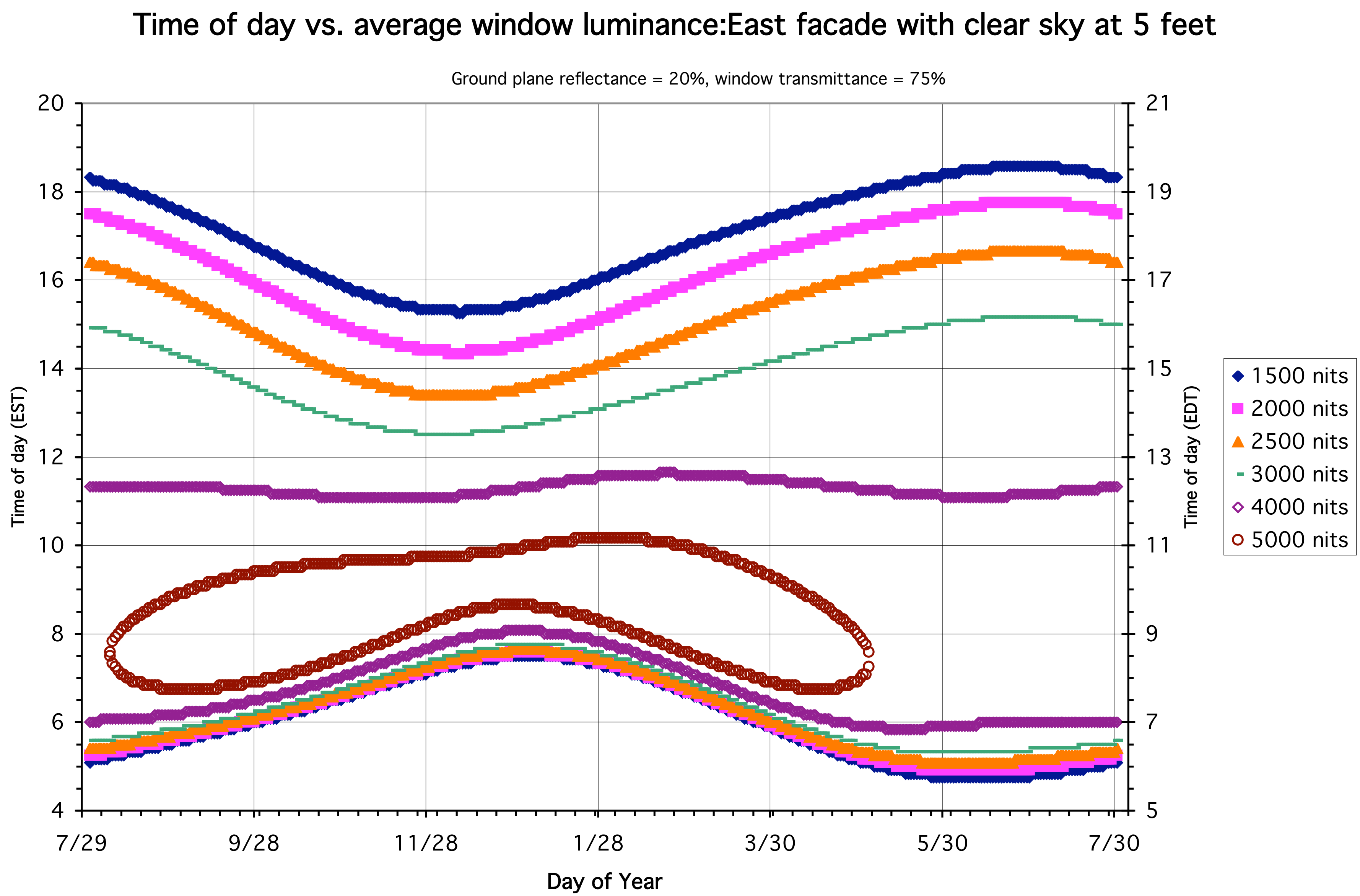
The R4 graphs are presented in the following order:
(For each category, graphs are given for the project North, East, South, and West facades.)

Clear sky conditions at a distance of 5 ft from the window, no sky obstructions
Clear sky conditions at a distance of 15 ft from the window, no sky obstructions
Partly cloudy sky conditions at a distance of 5 ft from the window, no sky obstructions
Partly cloudy sky conditions at a distance of 15 ft from the window, no sky obstructions
Overcast sky conditions at a distance of 5 ft from the window, no sky obstructions
Overcast sky conditions at a distance of 15 ft from the window, no sky obstructions

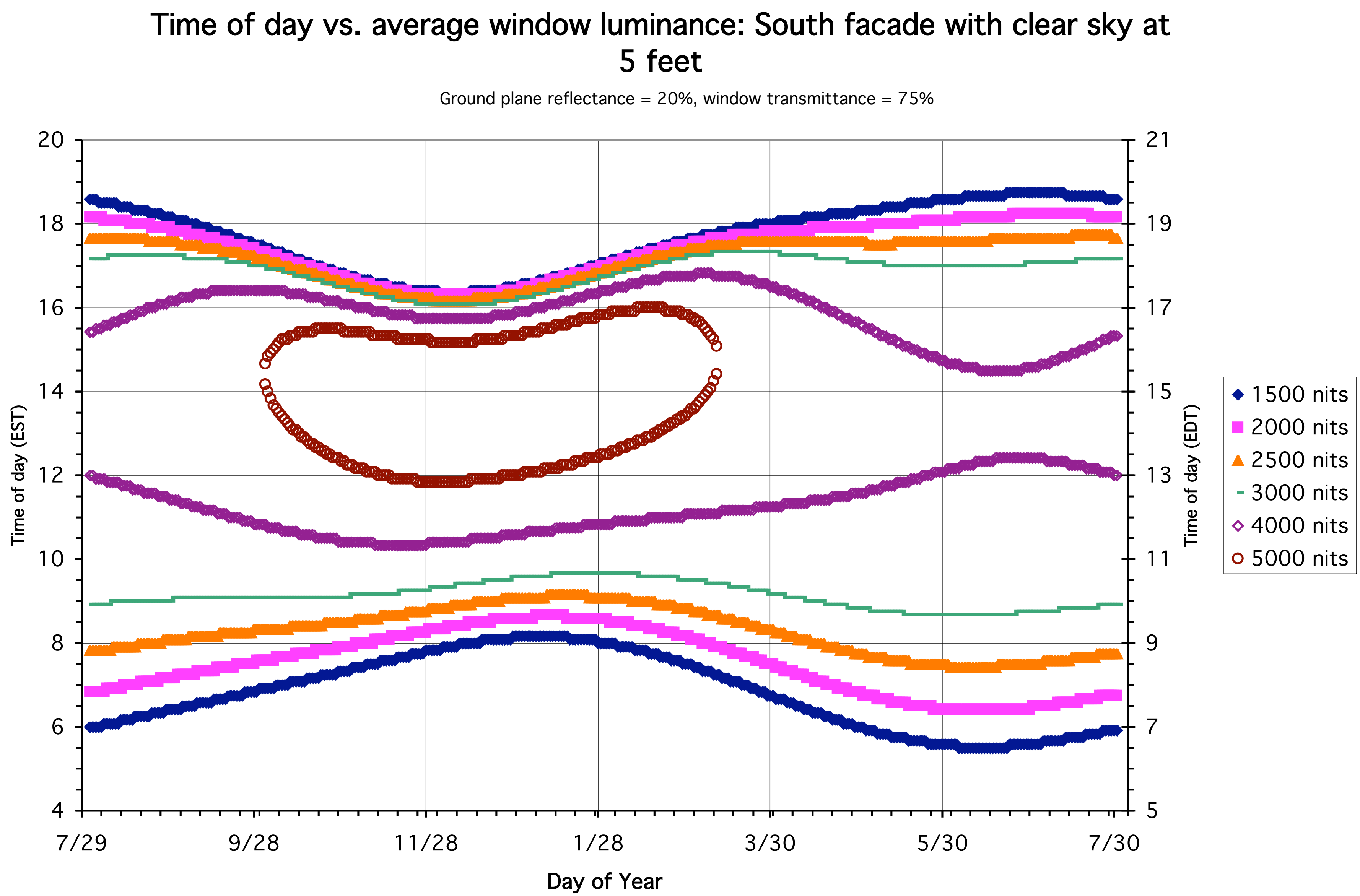
Clear sky conditions at any distance from the window, 50% sky obstructions
Partly cloudy sky conditions at any distance from the window, 50% sky obstructions

Clear sky conditions at any distance from the window, 100% sky obstructions
Partly cloudy sky conditions at any distance from the window, 100% sky obstructions

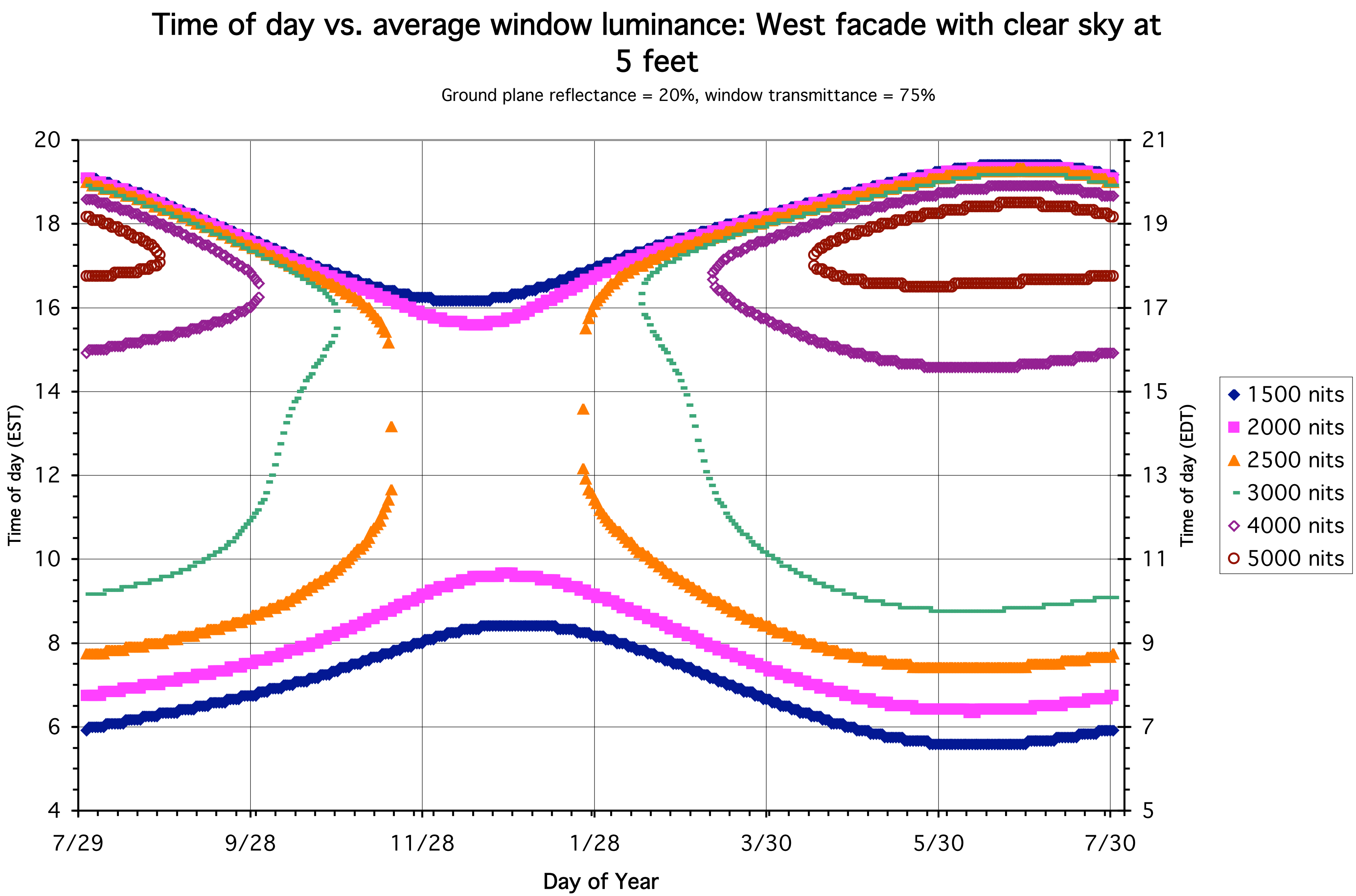

Time of day vs. average window luminance:North facade with clear sky at 5 feet
Ground plane reflectance = 20%, window transmittance = 75%
Time of day (EST)
Time of day (EDT)
Day of Year
20
18
16
14
12
10
8
6
4
21
19
17
15
13
11
9
7
5
7/29
9/28
11/28
1/28
3/30
5/30
7/30
1500 nits
2000 nits
2500 nits
3000 nits
4000 nits



Time of day vs. average window luminance:East facade with clear sky at 5 feet
Ground plane reflectance = 20%, window transmittance = 75%
20
18
16
14
12
10
8
6
4
21
19
17
15
13
11
9
7
5
Time of day (EST)
Time of day (EDT)
7/29
9/28
11/28
1/28
3/30
5/30
7/30
Day of Year
1500 nits
2000 nits
2500 nits
3000 nits
4000 nits
5000 nits

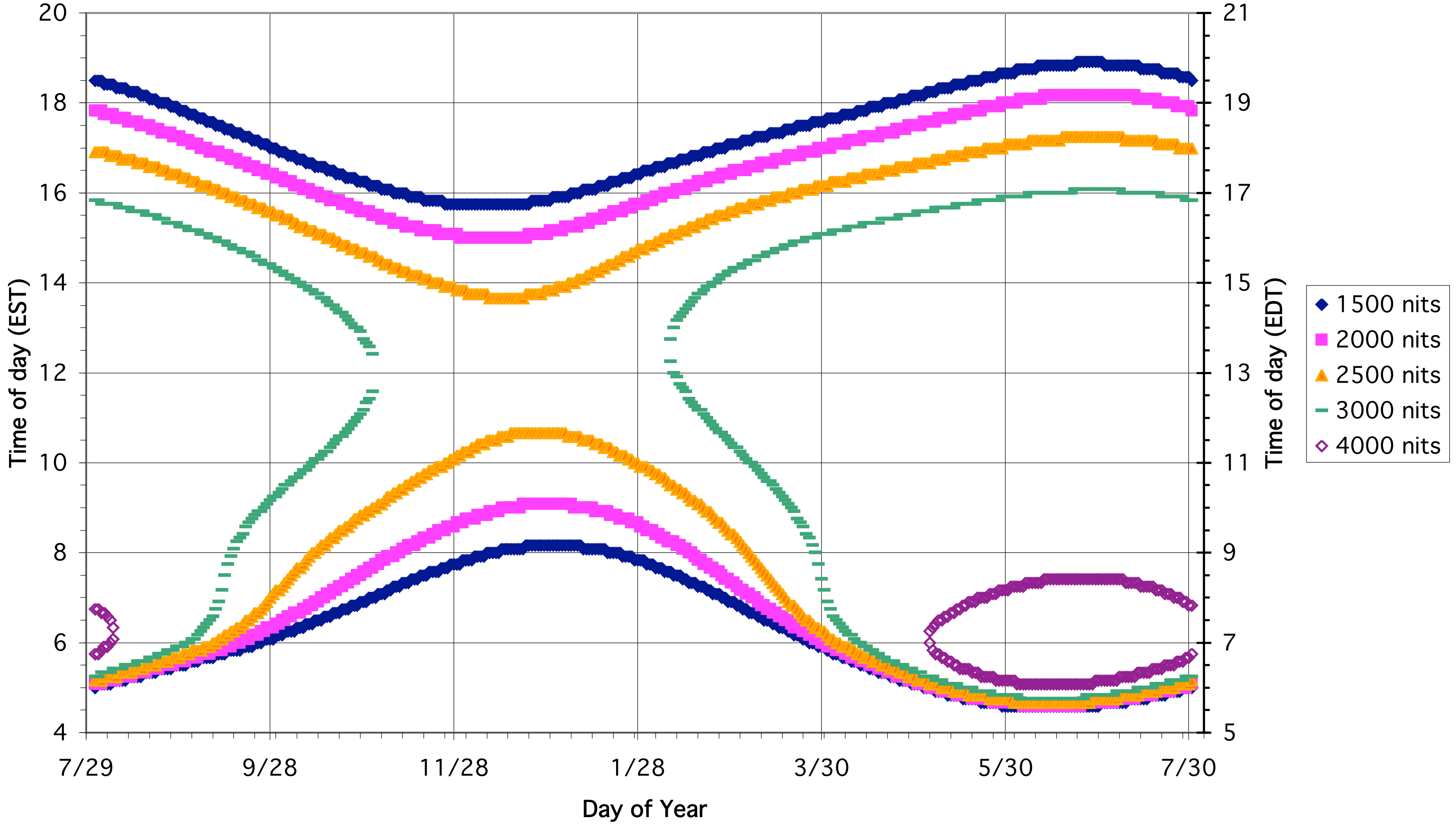


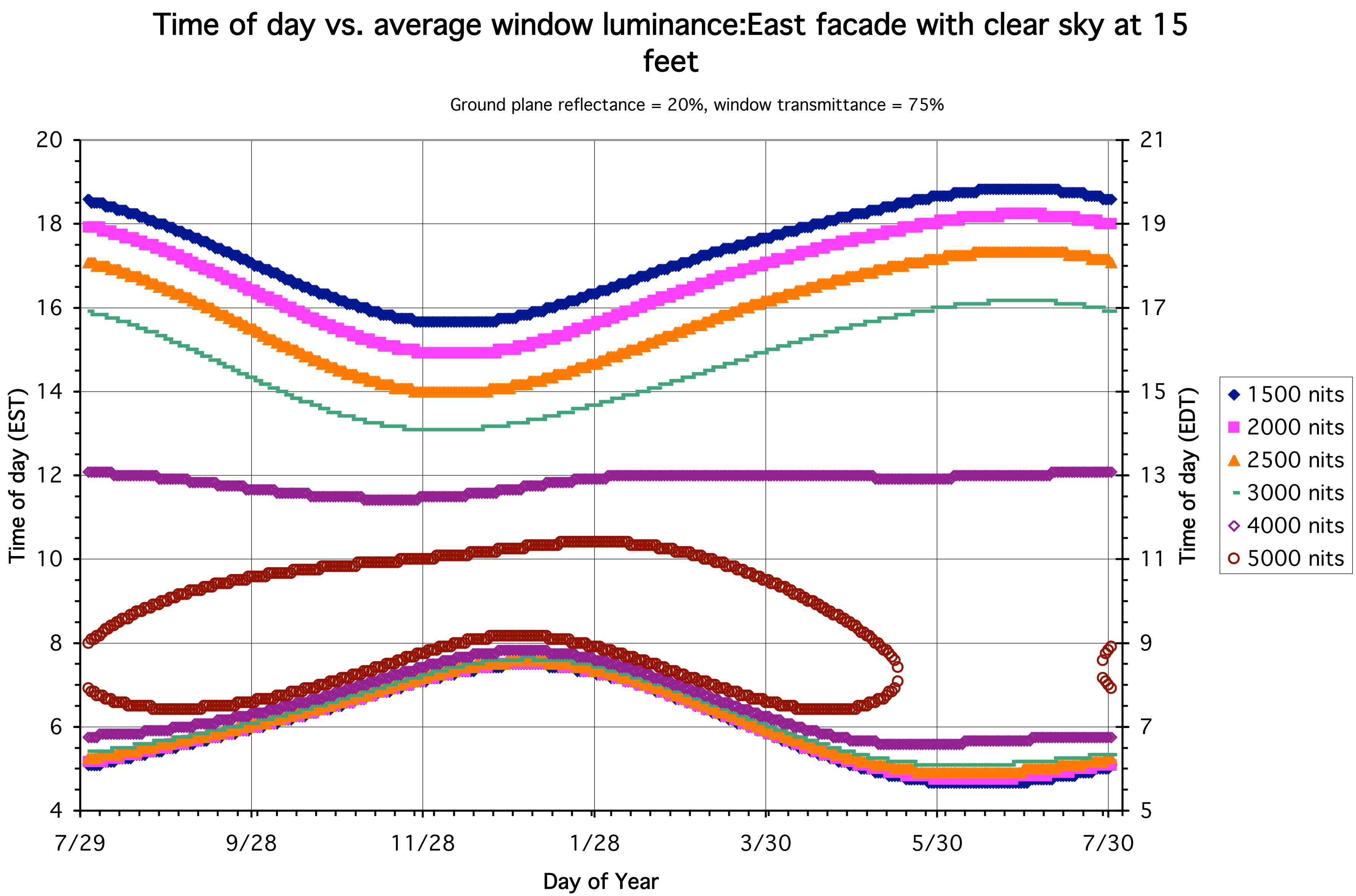
Time of day vs. average window luminance: South facade with clear sky at 5 feet
Ground plane reflectance = 20%, window transmittance = 75%
Time of day (EST)
Time of day (EDT)
Day of Year
7/29
9/28
11/28
1/28
3/30
5/30
7/30
1500 nits
2000 nits
2500 nits
3000 nits
4000 nits
5000 nits


Time of day vs. average window luminance: West facade with clear sky at 5 feet
Ground plane reflectance = 20%, window transmittance = 75%
Time of day (EST)
Time of day (EDT)
Day of Year
7/29
9/28
11/28
1/28
3/30
5/30
7/30
1500 nits
2000 nits
2500 nits
3000 nits
4000 nits
5000 nits

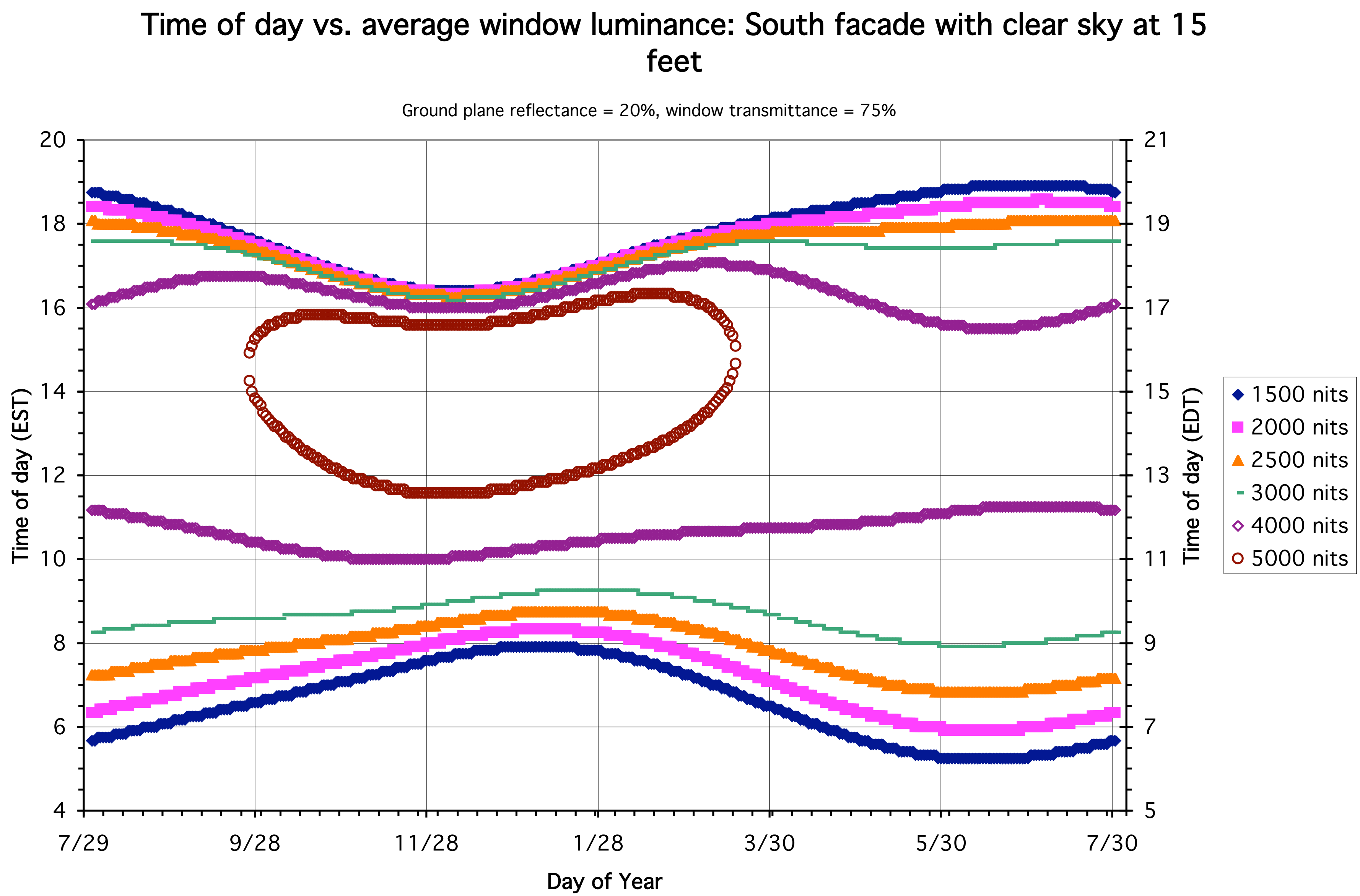
Time of day vs. average window luminance:North facade with clear sky at 15 feet

Ground plane reflectance = 20%, window transmittance = 75%





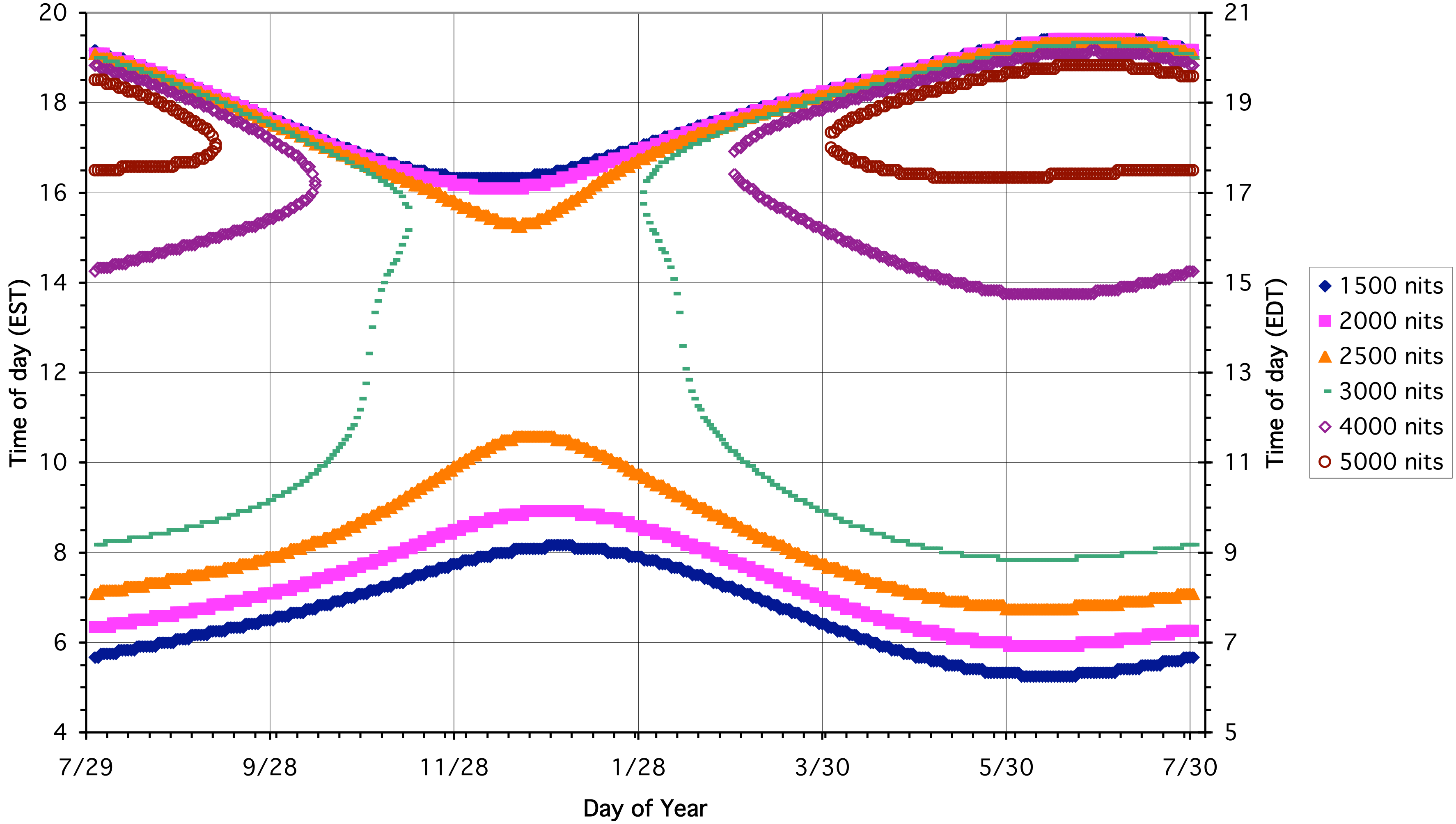
Time of day vs. average window luminance:East facade with clear sky at 15 feet
Ground plane reflectance = 20%, window transmittance = 75%
Time of day (EST)
Time of day (EDT)
Day of Year
20
18
16
14
12
10
8
6
4
21
19
17
15
13
11
9
7
5
7/29
9/28
11/28
1/28
3/30
5/30
7/30
1500 nits
2000 nits
2500 nits
3000 nits
4000 nits
5000 nits

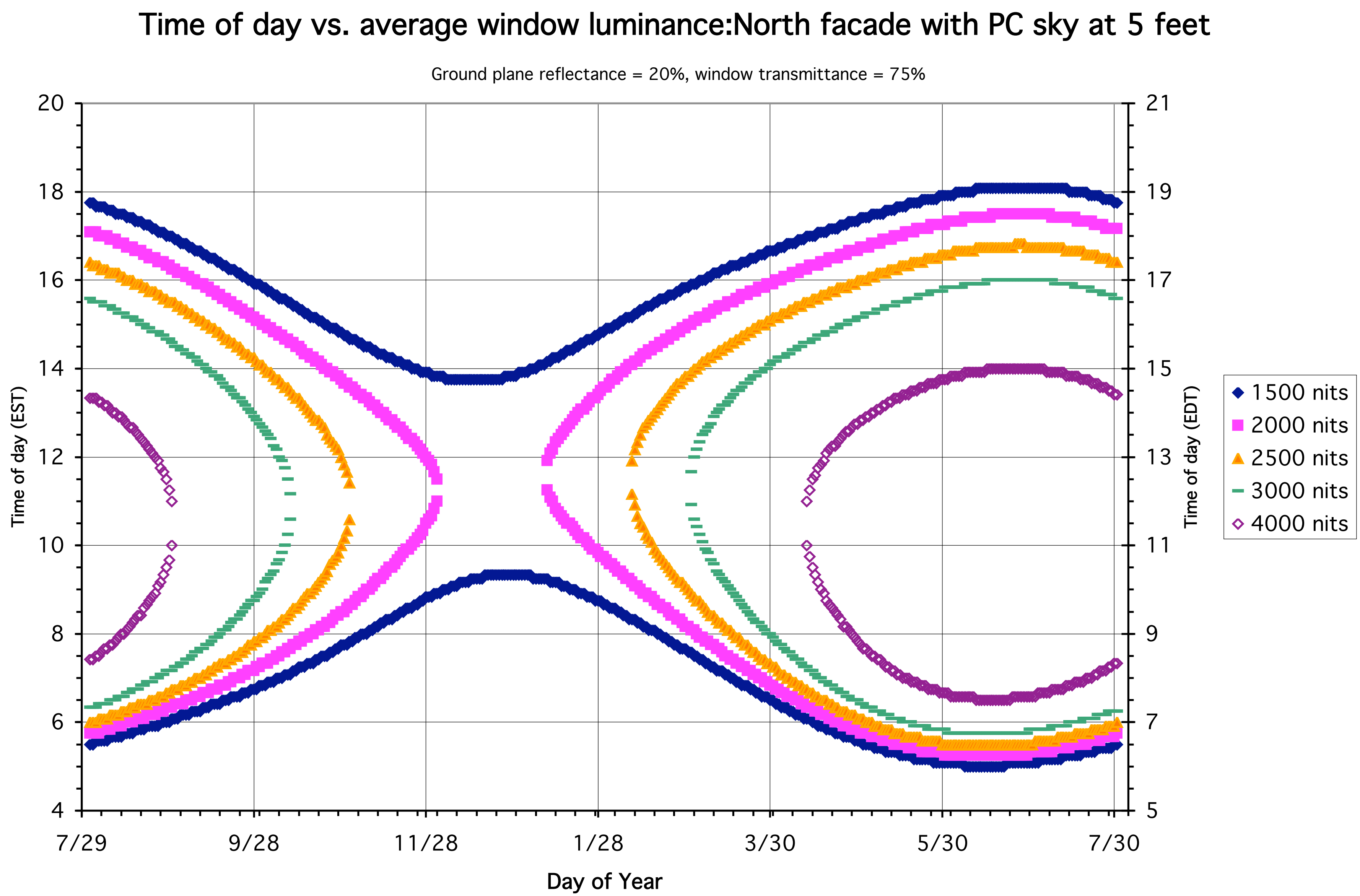


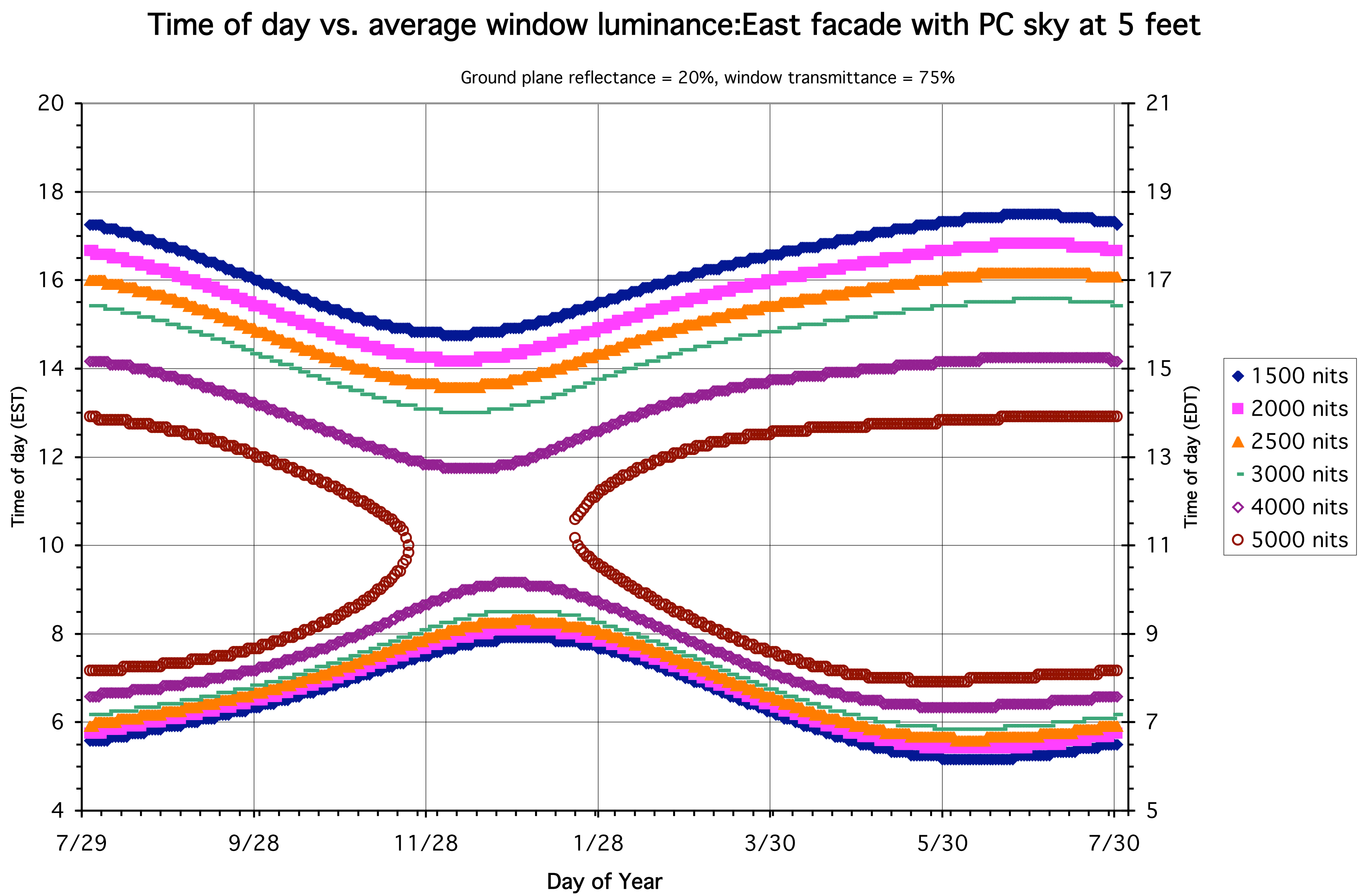
Time of day vs. average window luminance: South facade with clear sky at 15 feet
Ground plane reflectance = 20%, window transmittance = 75%
Time of day (EST)
Time of day (EDT)
Day of Year
20
18
16
14
12
10
8
6
4
21
19
17
15
13
11
9
7
5
7/29
9/28
11/28
1/28
3/30
5/30
7/30
1500 nits
2000 nits
2500 nits
3000 nits
4000 nits
5000 nits

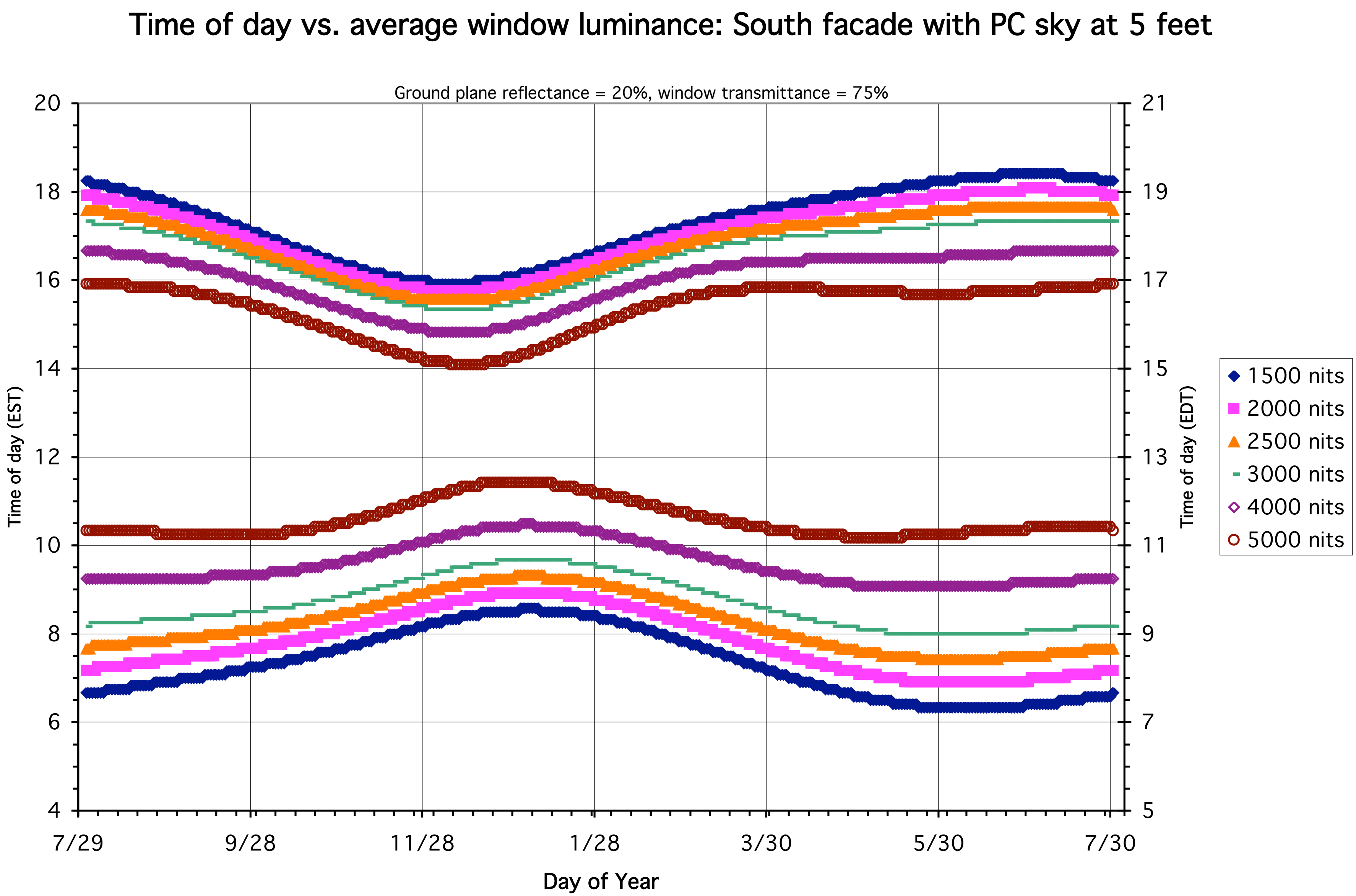
Time of day vs. average window luminance: West facade with clear sky at 15 feet

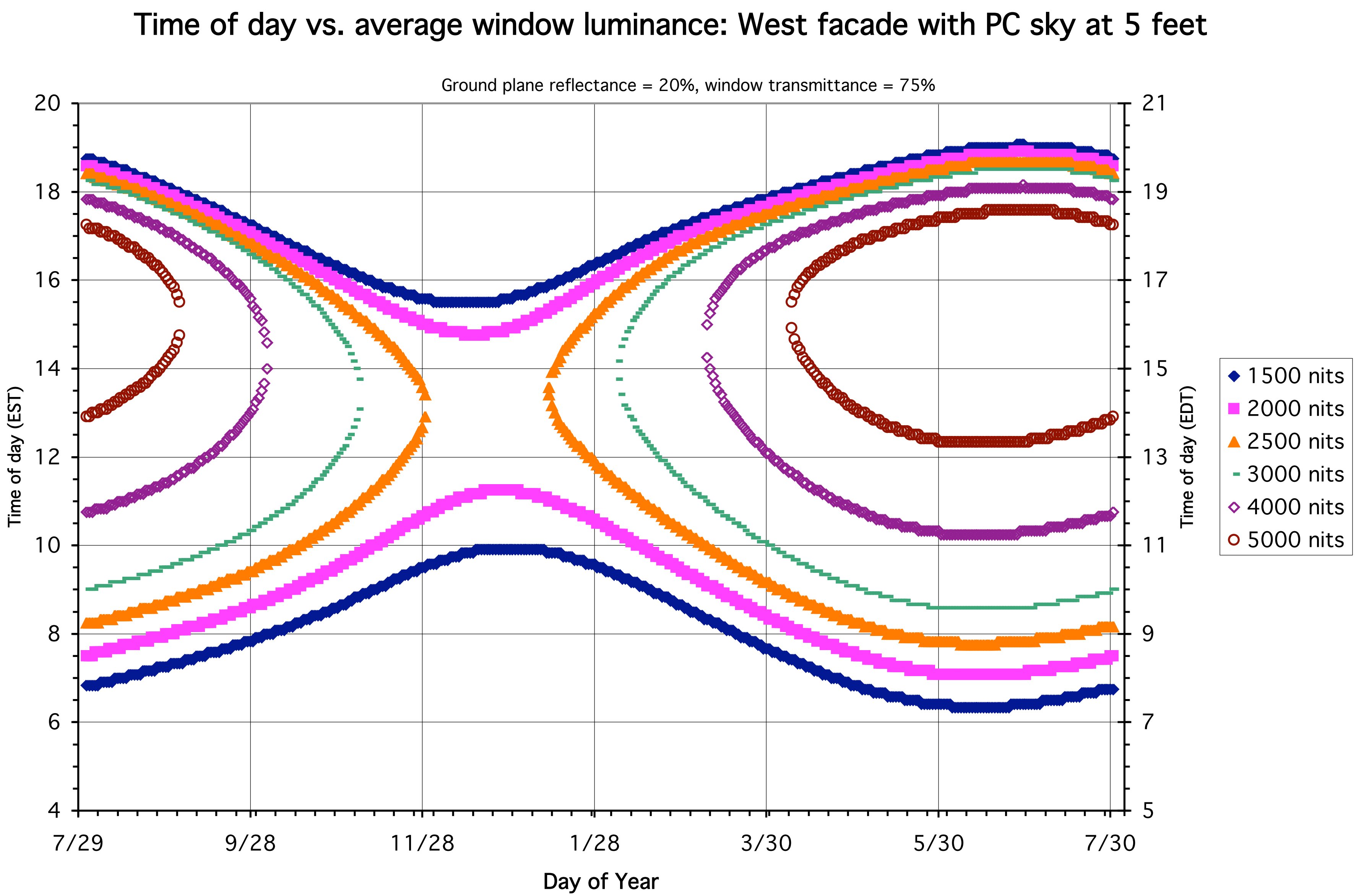
Ground plane reflectance = 20%, window transmittance = 75%



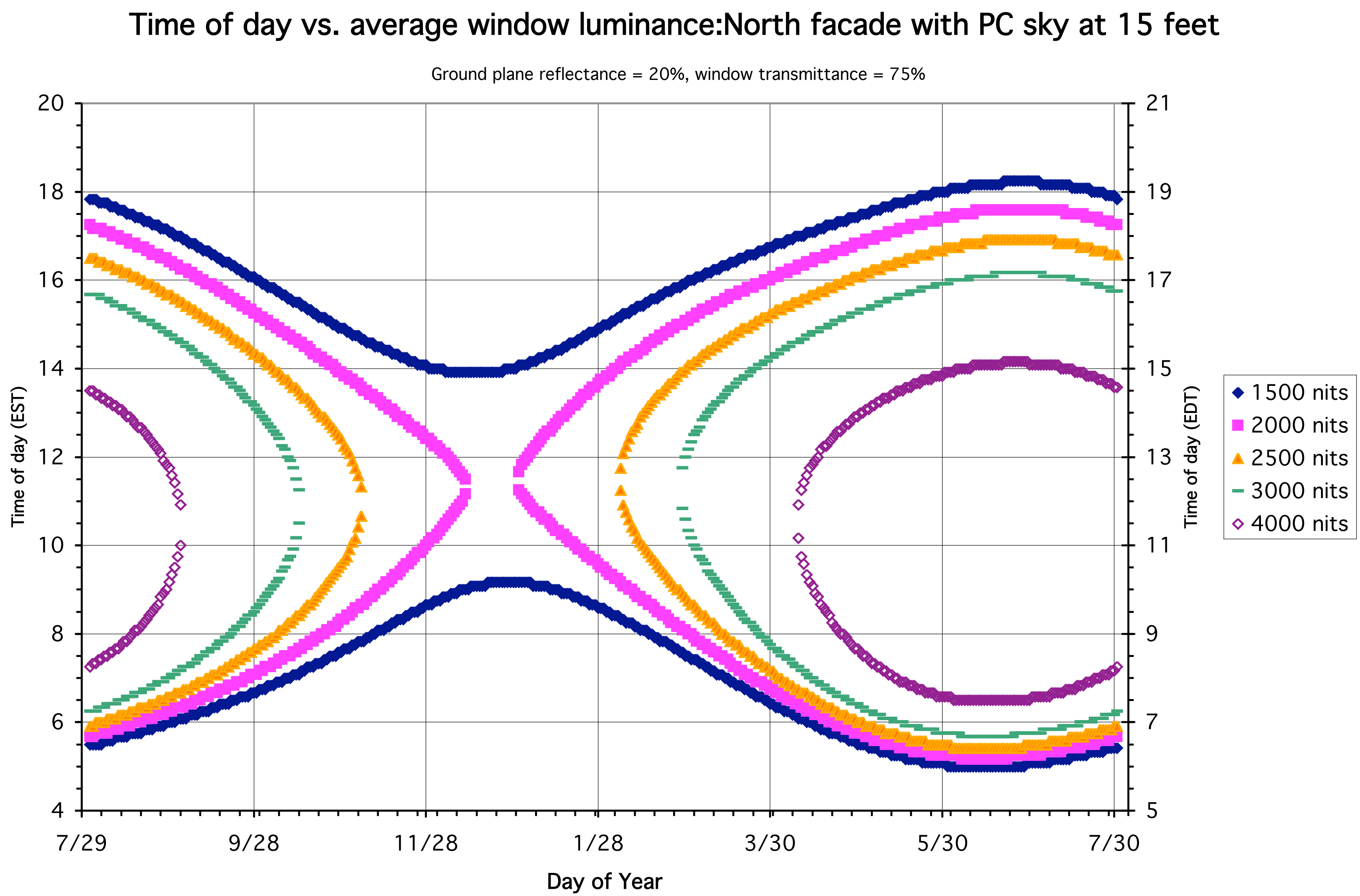

Time of day vs. average window luminance:North facade with PC sky at 5 feet
Ground plane reflectance = 20%, window transmittance = 75%
Time of day (EST)
Time of day (EDT)
Day of Year
7/29
9/28
11/28
1/28
3/30
5/30
7/30
1500 nits
2000 nits
2500 nits
3000 nits
4000 nits


Time of day vs. average window luminance:East facade with PC sky at 5 feet
Ground plane reflectance = 20%, window transmittance = 75%
Time of day (EST)
Time of day (EDT)
Day of Year
7/29
9/28
11/28
1/28
3/30
5/30
7/30
4
6
8
10
12
14
16
18
20
5
7
9
11
13
15
17
19
21
1500 nits
2000 nits
2500 nits
3000 nits
4000 nits
5000 nits

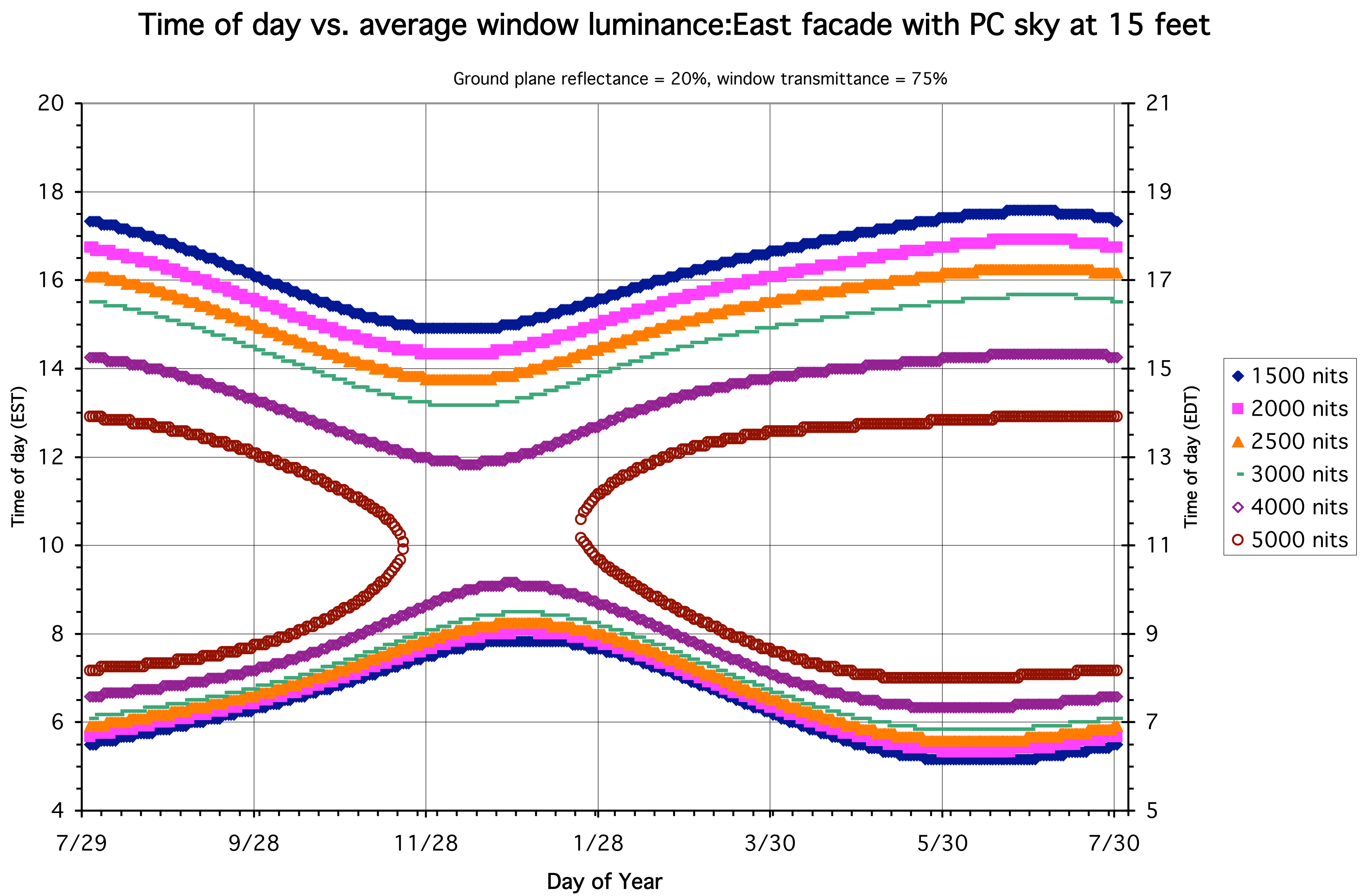

Time of day vs. average window luminance: South facade with PC sky at 5 feet
Ground plane reflectance = 20%, window transmittance = 75%
20
18
16
14
12
10
8
6
4
21
19
17
15
13
11
9
7
5
Time of day (EST)
Time of day (EDT)
7/29
9/28
11/28
1/28
3/30
5/30
7/30
Day of Year
1500 nits
2000 nits
2500 nits
3000 nits
4000 nits
5000 nits



Time of day vs. average window luminance: West facade with PC sky at 5 feet
Ground plane reflectance = 20%, window transmittance = 75%
Time of day (EST)
Time of day (EDT)
Day of Year
7/29
9/28
11/28
1/28
3/30
5/30
7/30
20
18
16
14
12
10
8
6
4
21
19
17
15
13
11
9
7
5
1500 nits
2000 nits
2500 nits
3000 nits
4000 nits
5000 nits



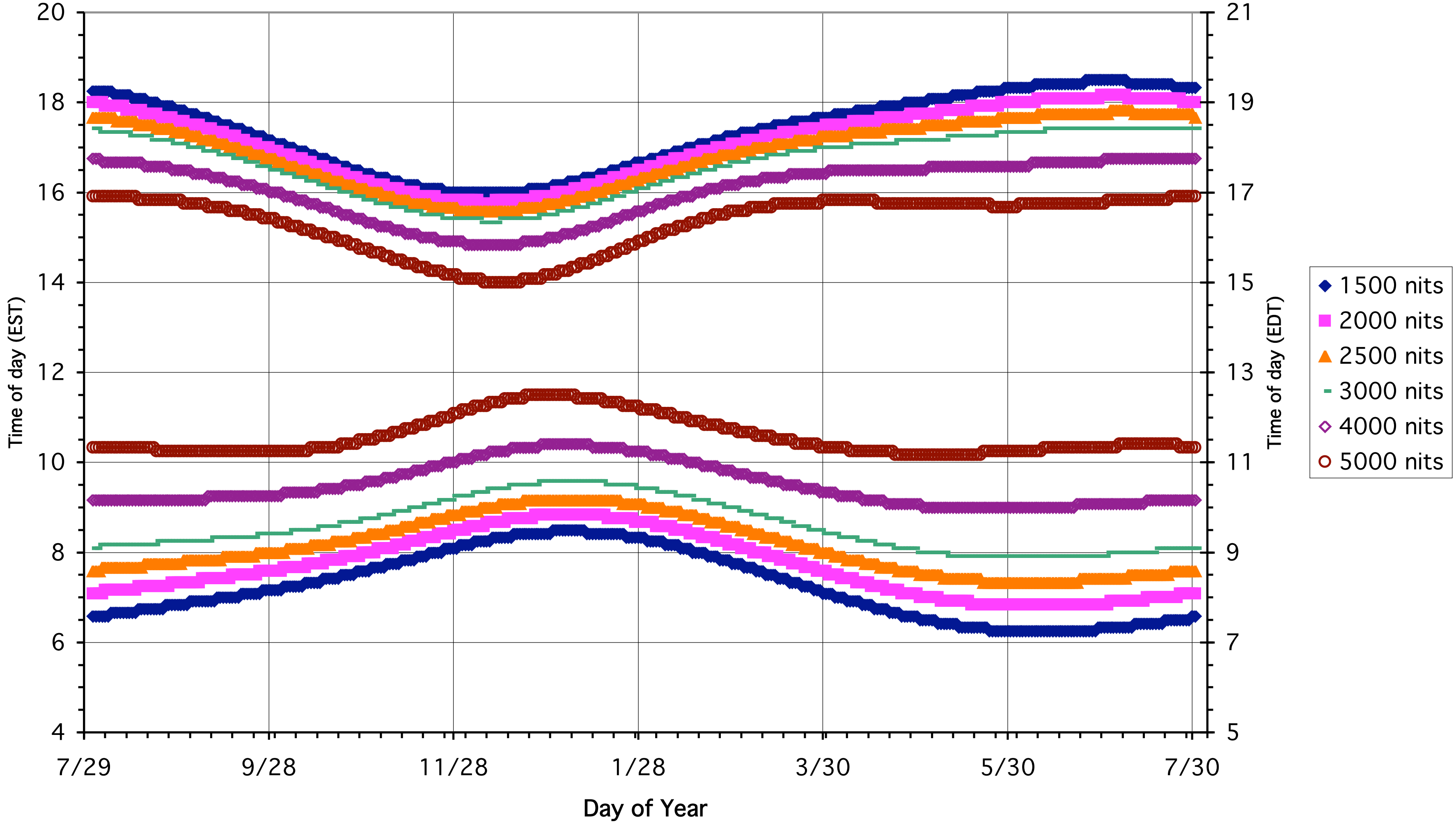
Time of day vs. average window luminance:North facade with PC sky at 15 feet
Ground plane reflectance = 20%, window transmittance = 75%
Time of day (EST)
Time of day (EDT)
Day of Year
20
18
16
14
12
10
8
6
4
21
19
17
15
13
11
9
7
5
7/29
9/28
11/28
1/28
3/30
5/30
7/30
1500 nits
2000 nits
2500 nits
3000 nits
4000 nits

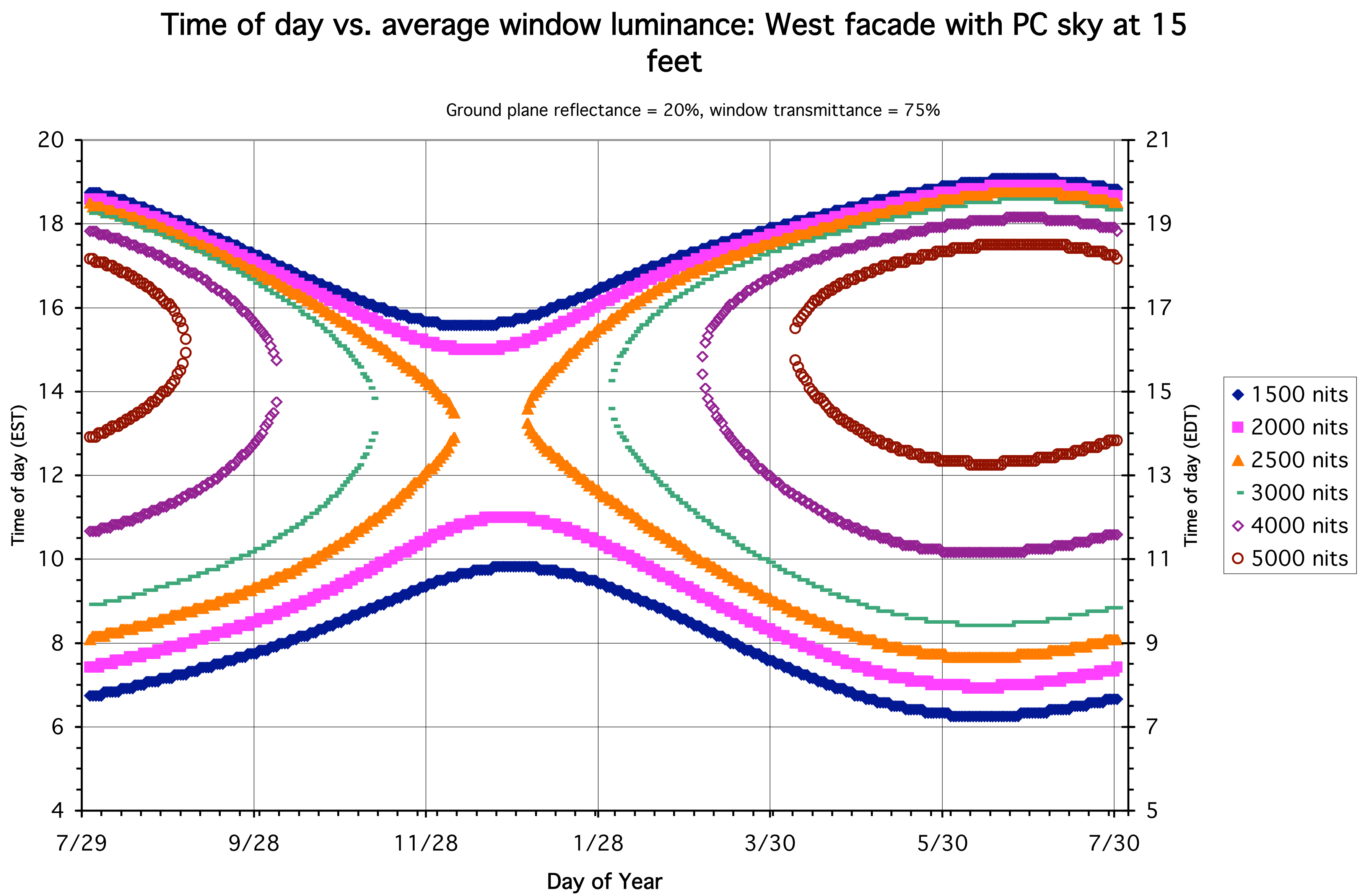


Time of day vs. average window luminance:East facade with PC sky at 15 feet
Ground plane reflectance = 20%, window transmittance = 75%
Time of day (EST)
Time of day (EDT)
Day of Year
7/29
9/28
11/28
1/28
3/30
5/30
7/30
1500 nits
2000 nits
2500 nits
3000 nits
4000 nits
5000 nits

Time of day vs. average window luminance: South facade with PC sky at 15 feet

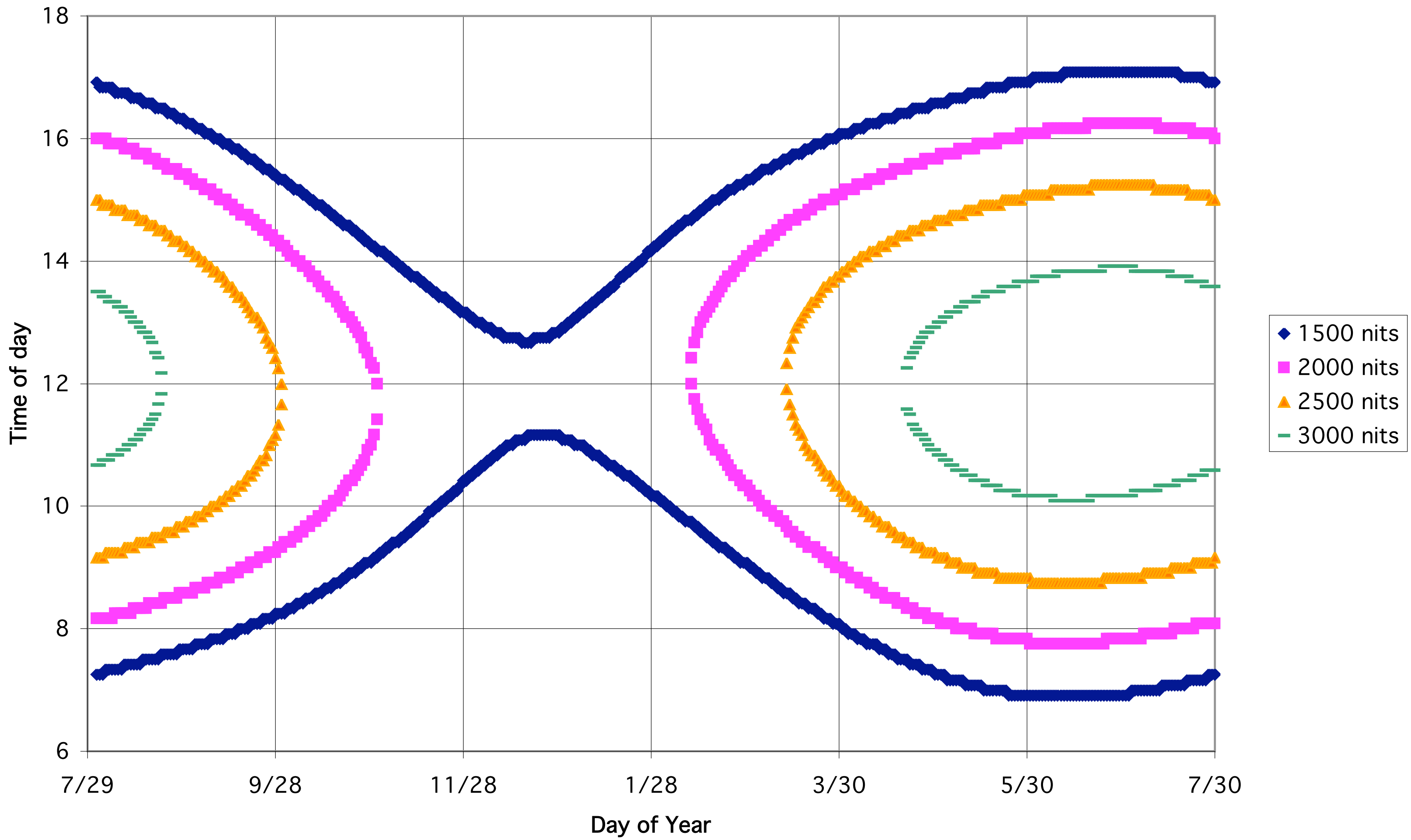
Ground plane reflectance = 20%, window transmittance = 75%

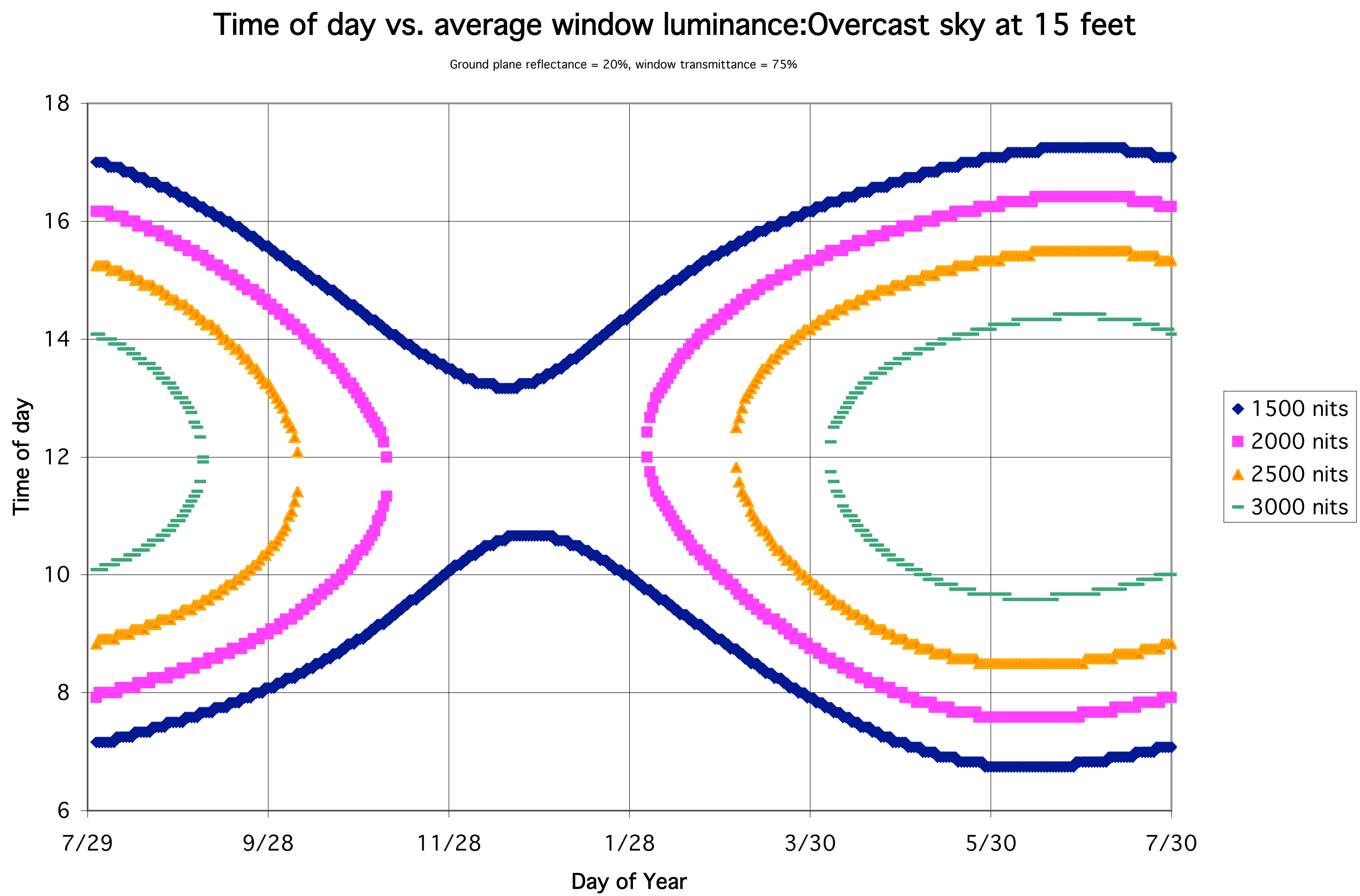



Time of day vs. average window luminance: West facade with PC sky at 15 feet
Ground plane reflectance = 20%, window transmittance = 75%
Time of day (EST)
Time of day (EDT)
Day of Year
7/29
9/28
11/28
1/28
3/30
5/30
7/30
1500 nits
2000 nits
2500 nits
3000 nits
4000 nits
5000 nits

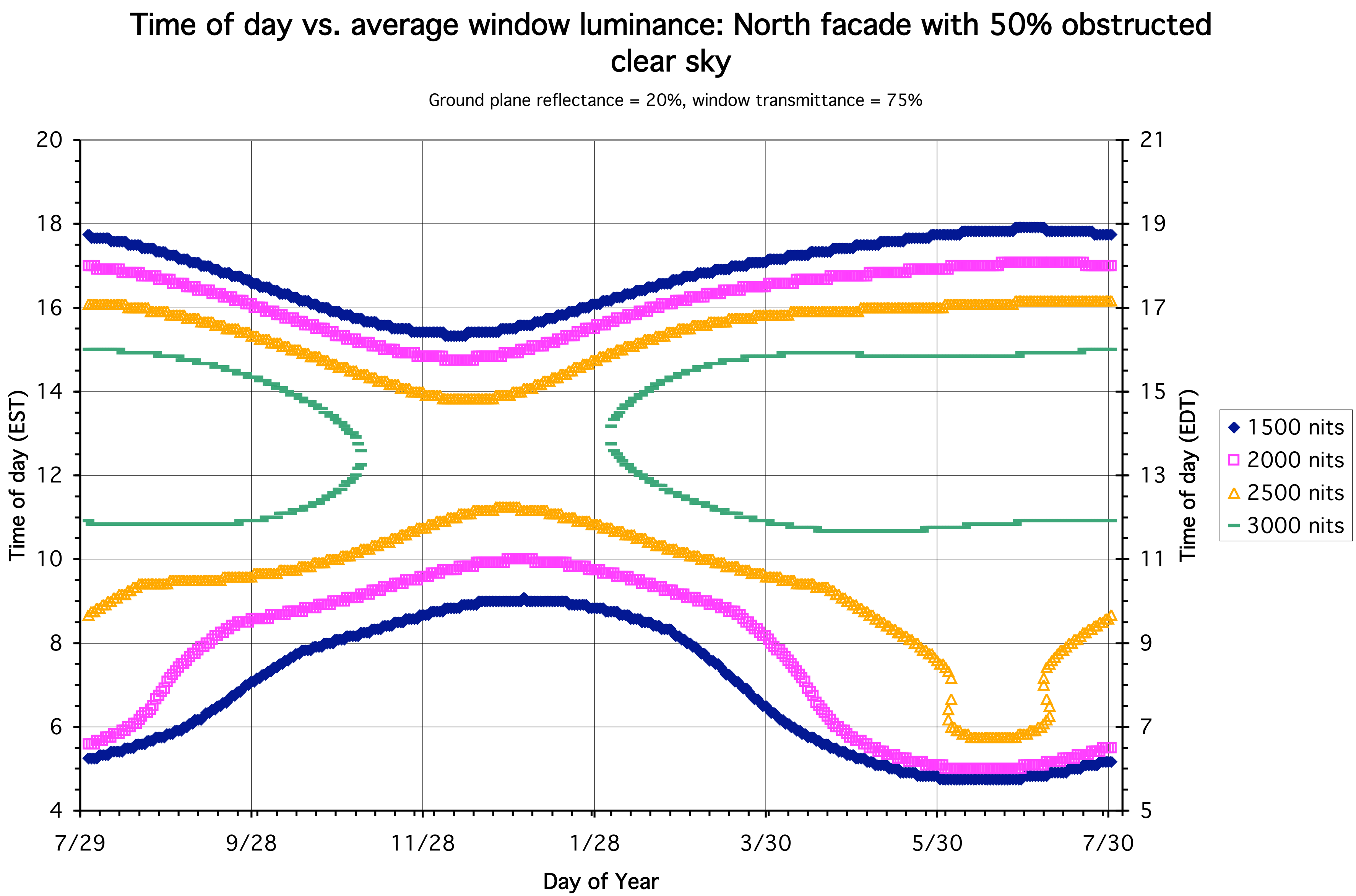
Time of day vs. average window luminance:Overcast sky at 5 feet

Ground plane reflectance = 20%, window transmittance = 75%





Time of day vs. average window luminance:Overcast sky at 15 feet
Ground plane reflectance = 20%, window transmittance = 75%
Time of day
18
16
14
12
10
8
6
7/29
9/28
11/28
1/28
3/30
5/30
7/30
Day of Year
1500 nits
2000 nits
2500 nits
3000 nits


Time of day vs. average window luminance: North facade with 50% obstructed clear sky
Ground plane reflectance = 20%, window transmittance = 75%
Time of day (EST)
Time of day (EDT)
Day of Year
7/29
9/28
11/28
1/28
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1500 nits
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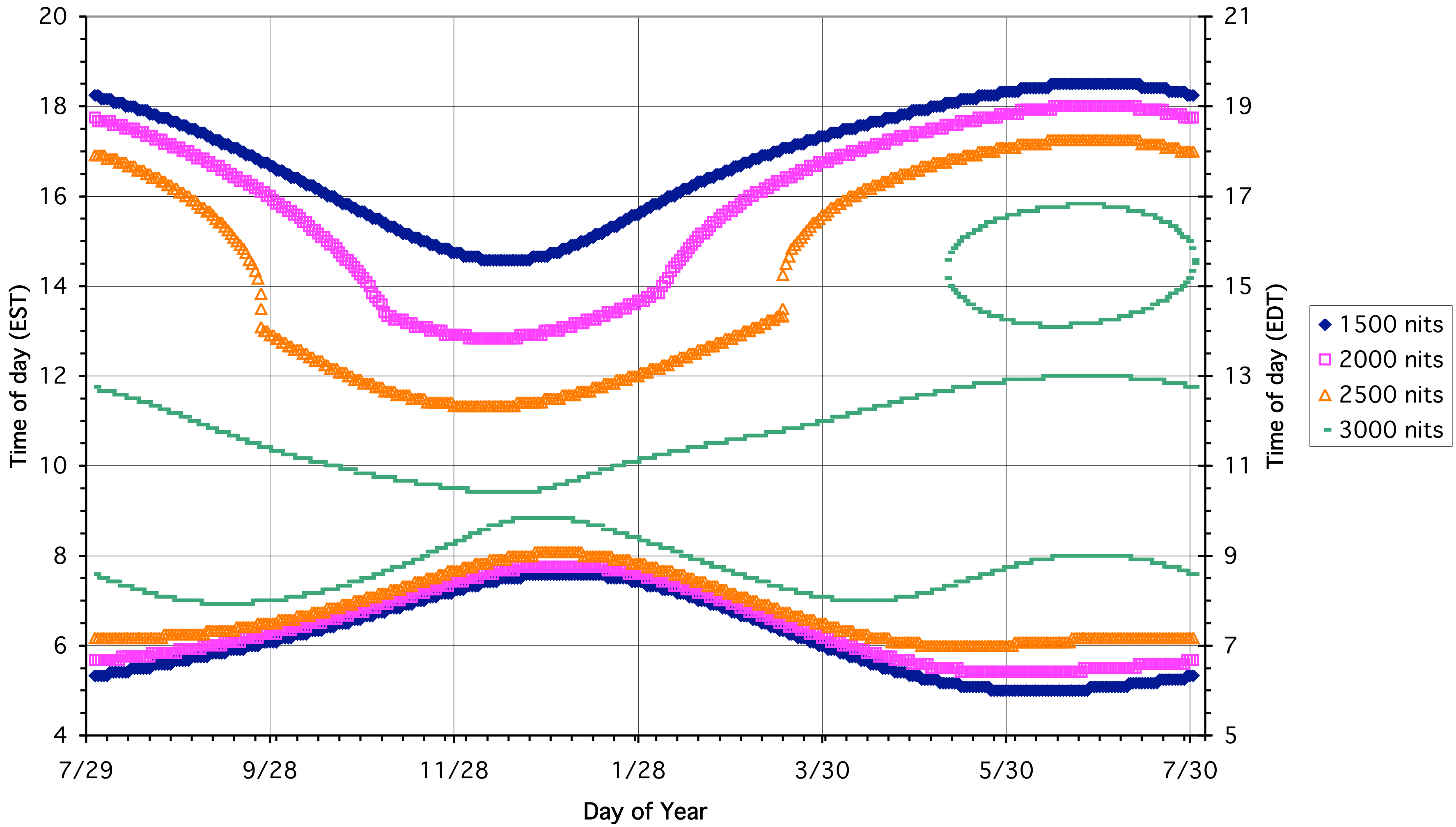
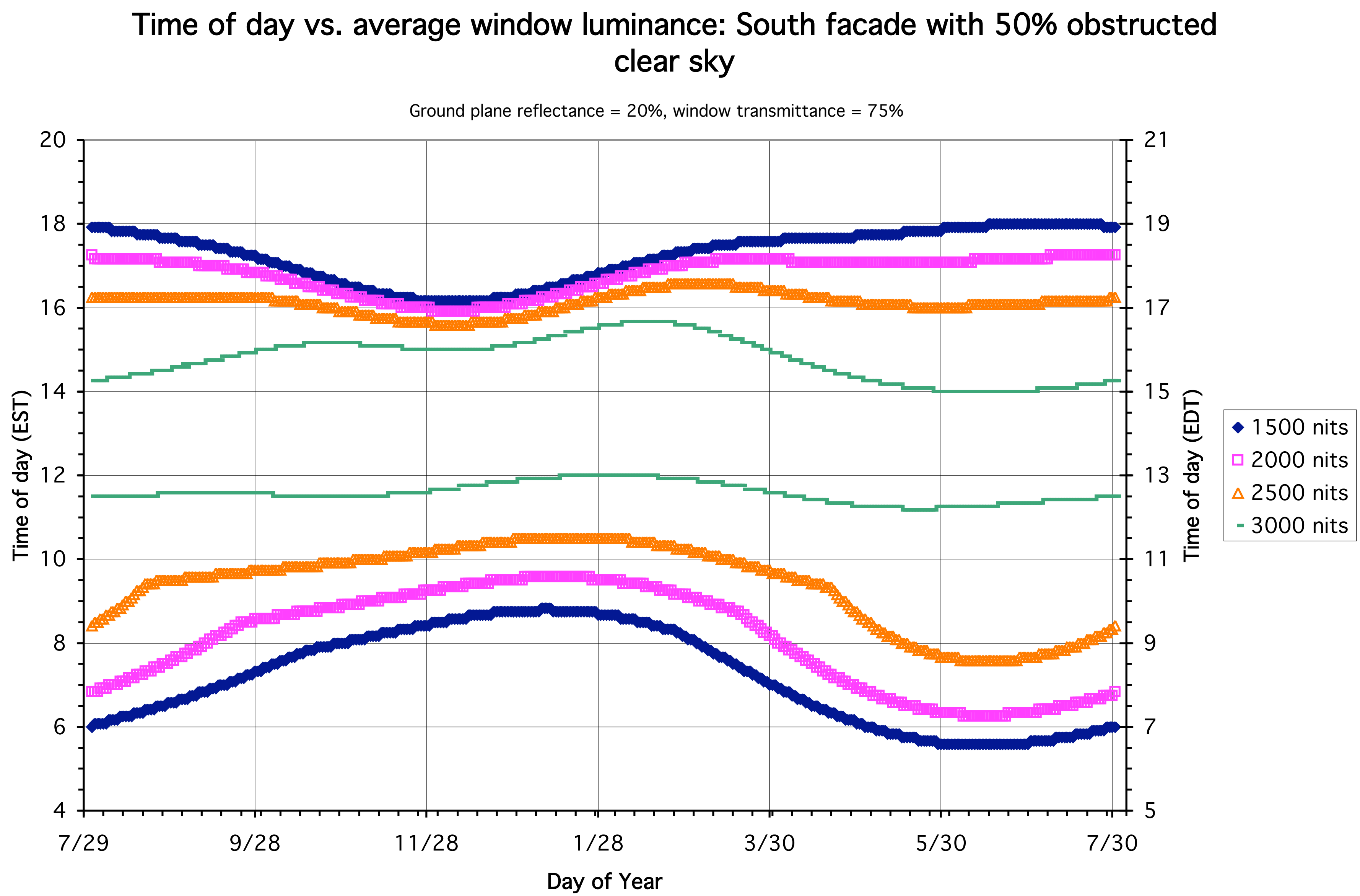
3000 nits

Time of day vs. average window luminance: East facade with 50% obstructed clear sky

Ground plane reflectance = 20%, window transmittance = 75%




Time of day vs. average window luminance: South facade with 50% obstructed clear sky
Ground plane reflectance = 20%, window transmittance = 75%
Time of day (EST)
Time of day (EDT)
Day of Year
7/29
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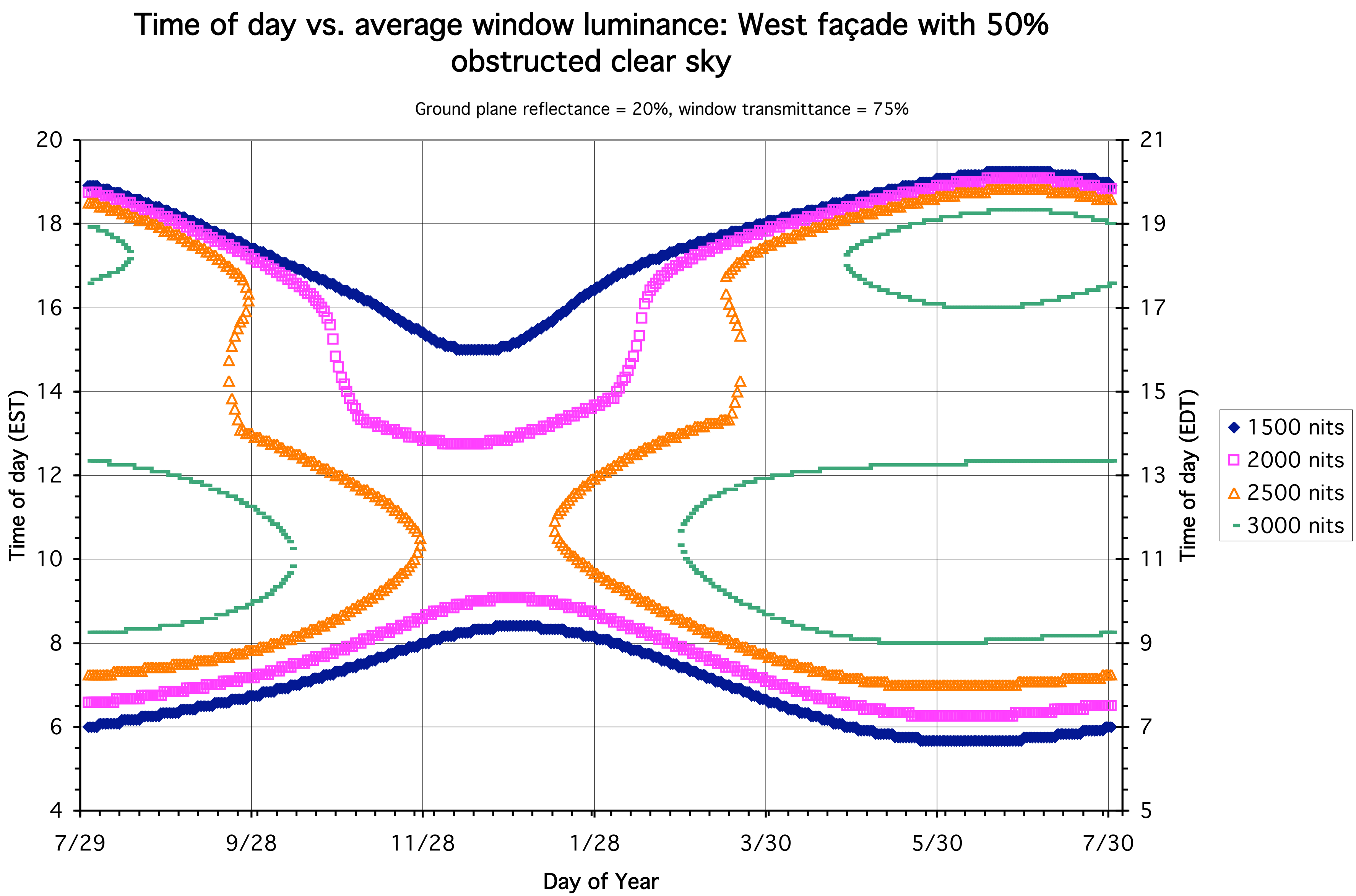

Time of day vs. average window luminance: West façade with 50% obstructed clear sky
Ground plane reflectance = 20%, window transmittance = 75%
Time of day (EST)
Time of day (EDT)
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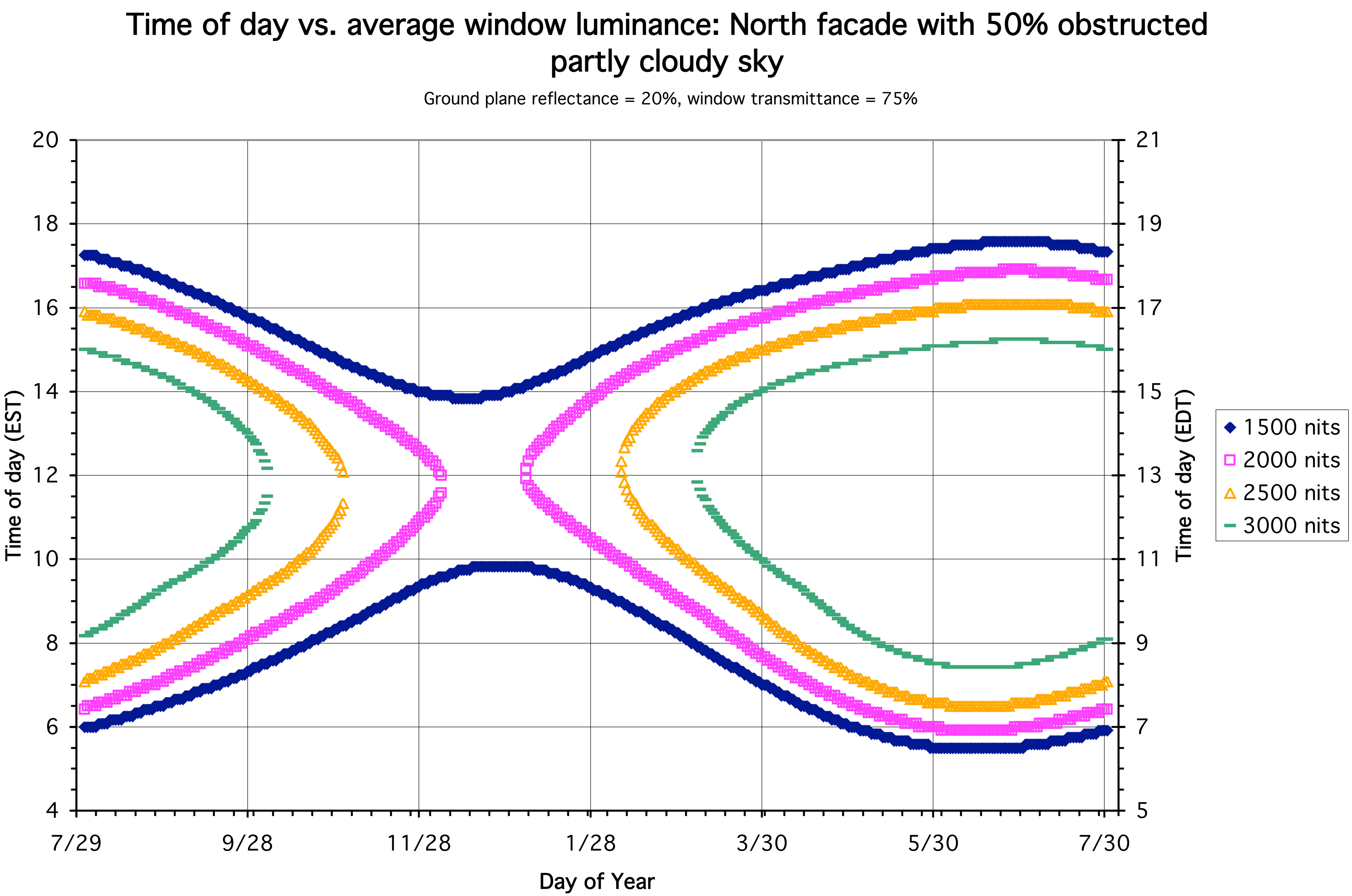

Time of day vs. average window luminance: North facade with 50% obstructed partly cloudy sky
Ground plane reflectance = 20%, window transmittance = 75%
Time of day (EST)
Time of day (EDT)
Day of Year
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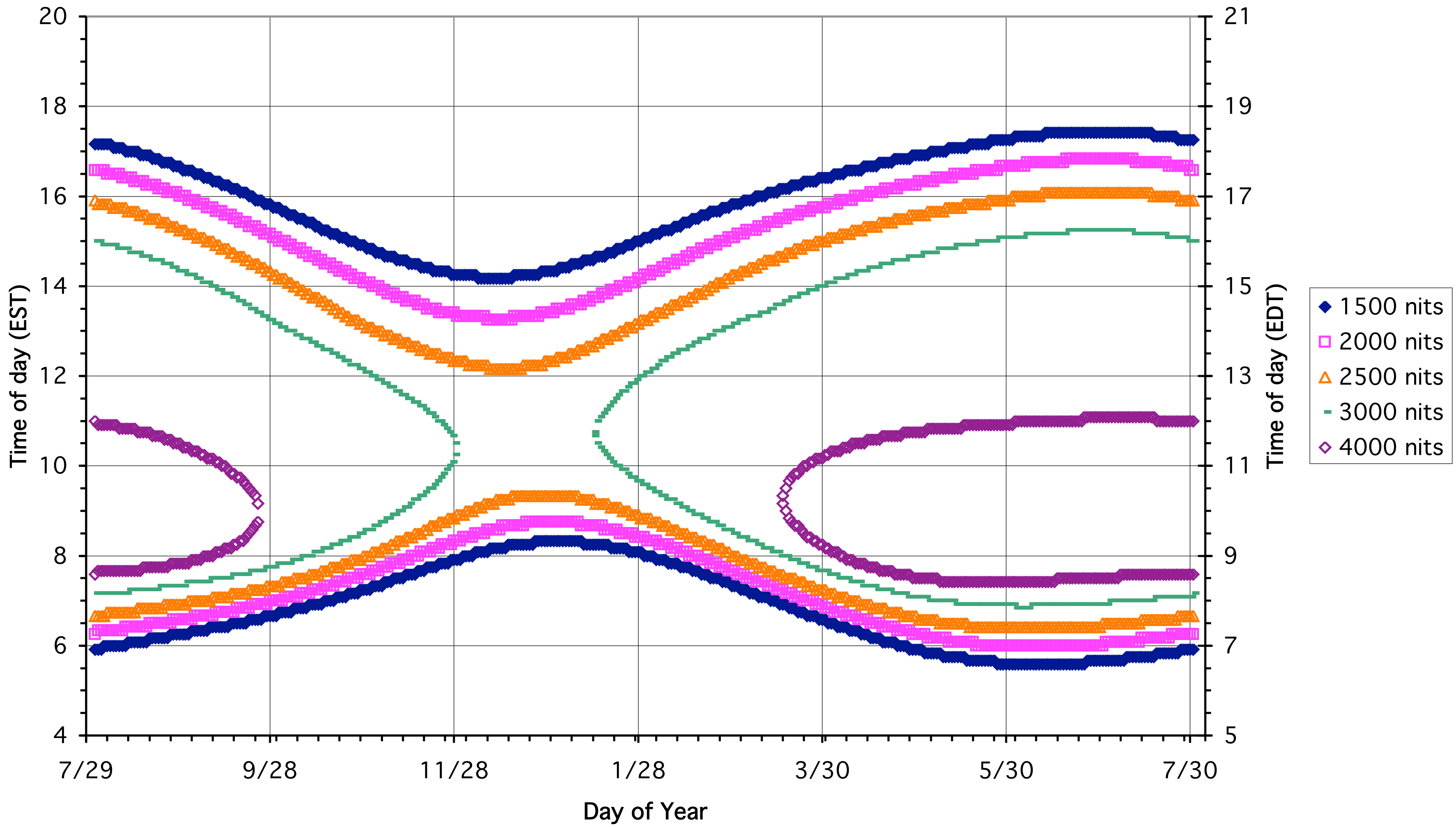
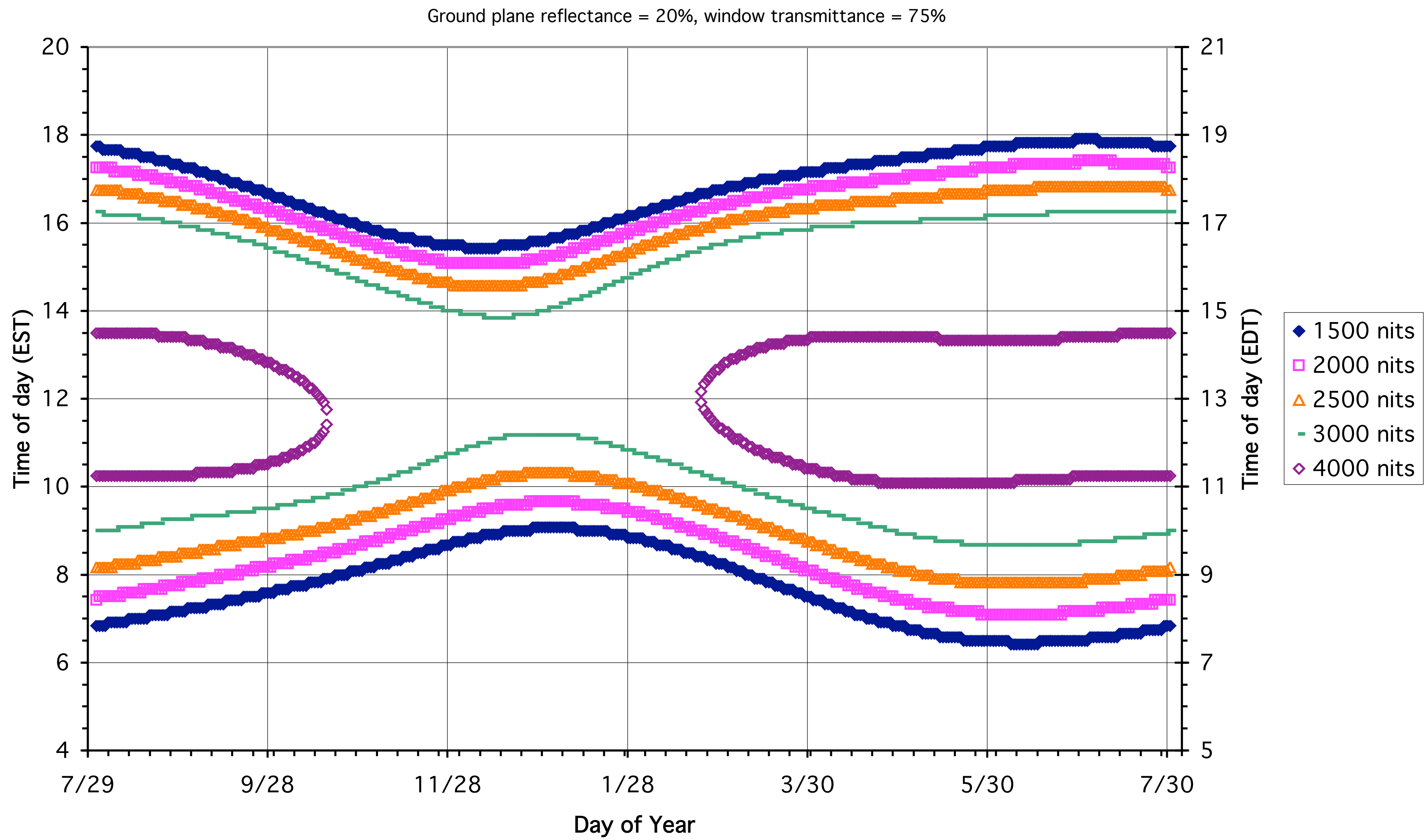
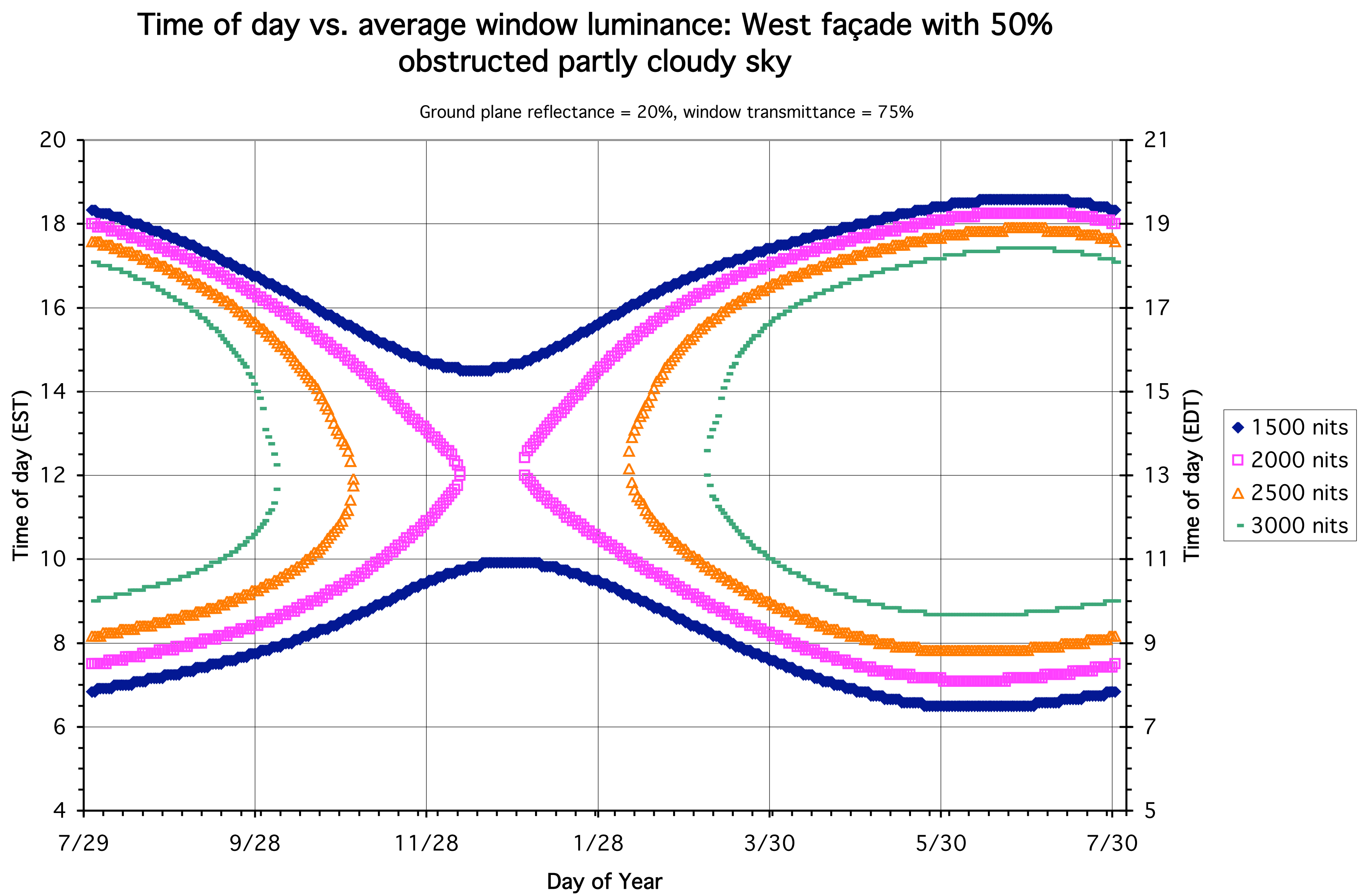
Time of day vs. average window luminance: East facade with 50% obstructed partly cloudy sky

Ground plane reflectance = 20%, window transmittance = 75%



Time of day vs. average window luminance: South facade with 50% obstructed partly cloudy sky





Time of day vs. average window luminance: West façade with 50% obstructed partly cloudy sky
Ground plane reflectance = 20%, window transmittance = 75%
Time of day (EST)
Time of day (EDT)
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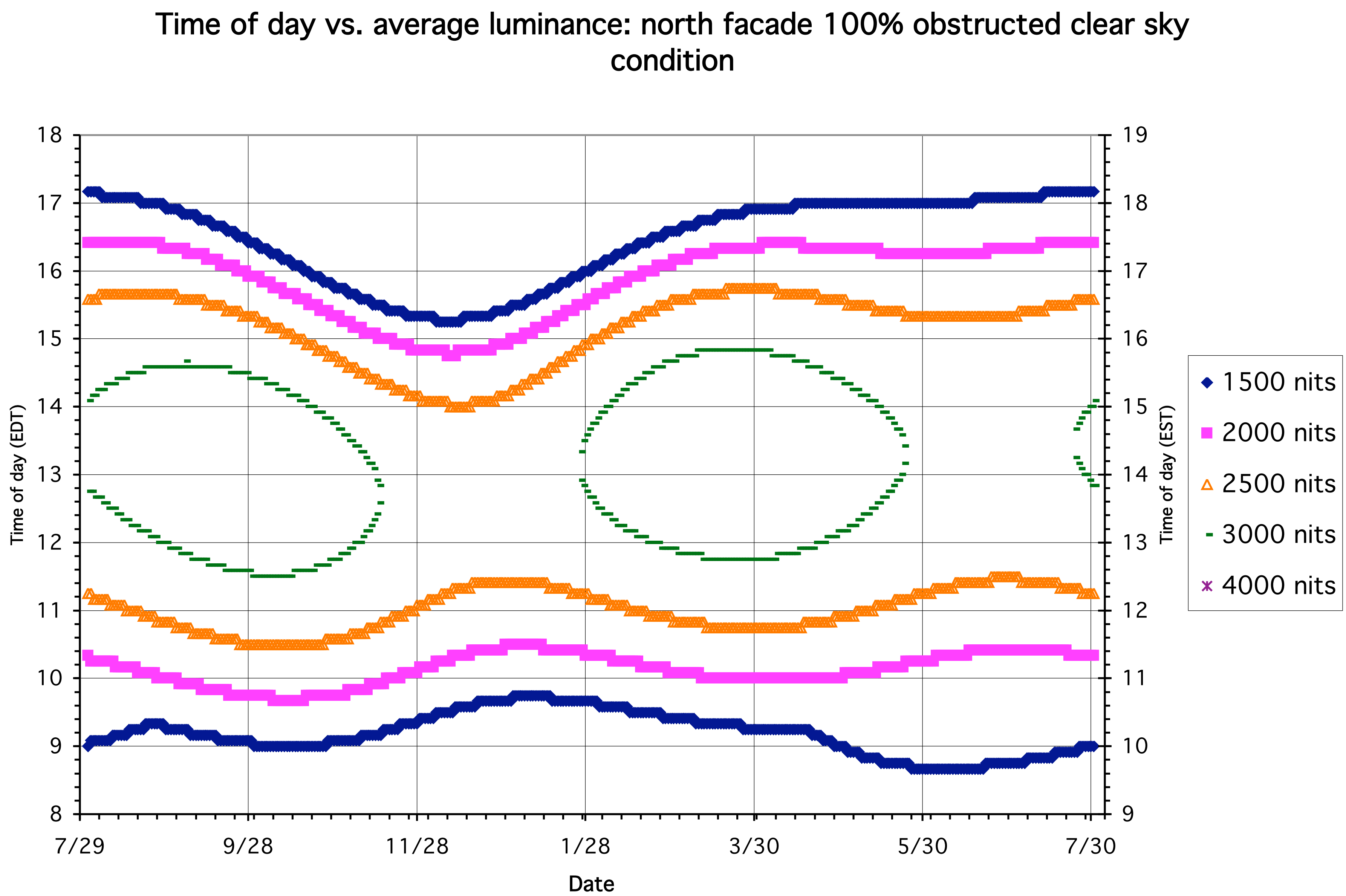
Time of day vs. average luminance: north facade 100% obstructed clear sky condition
Time of day (EDT)
Time of day (EST)
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1500 nits
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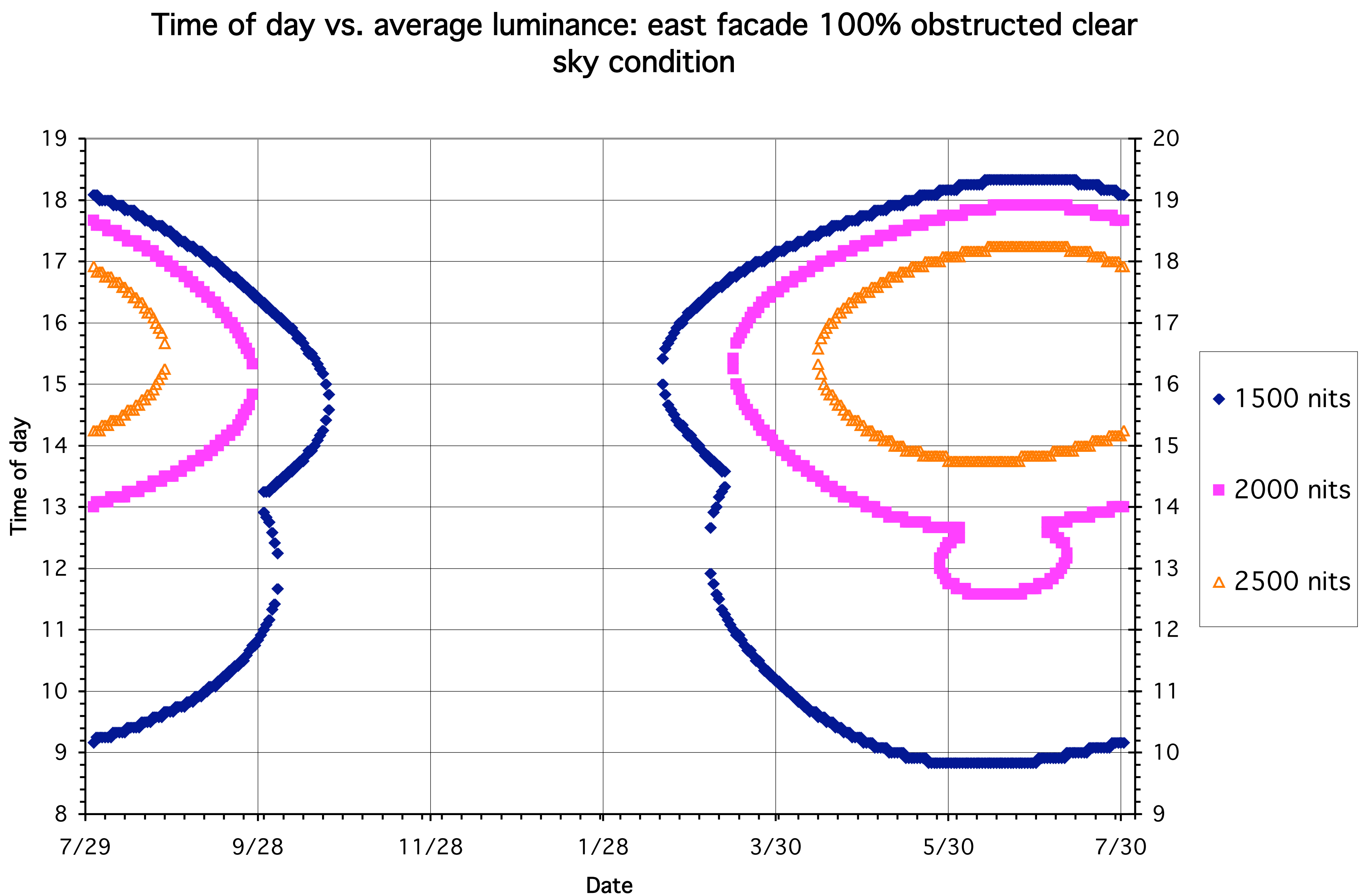

Time of day vs. average luminance: east facade 100% obstructed clear sky condition
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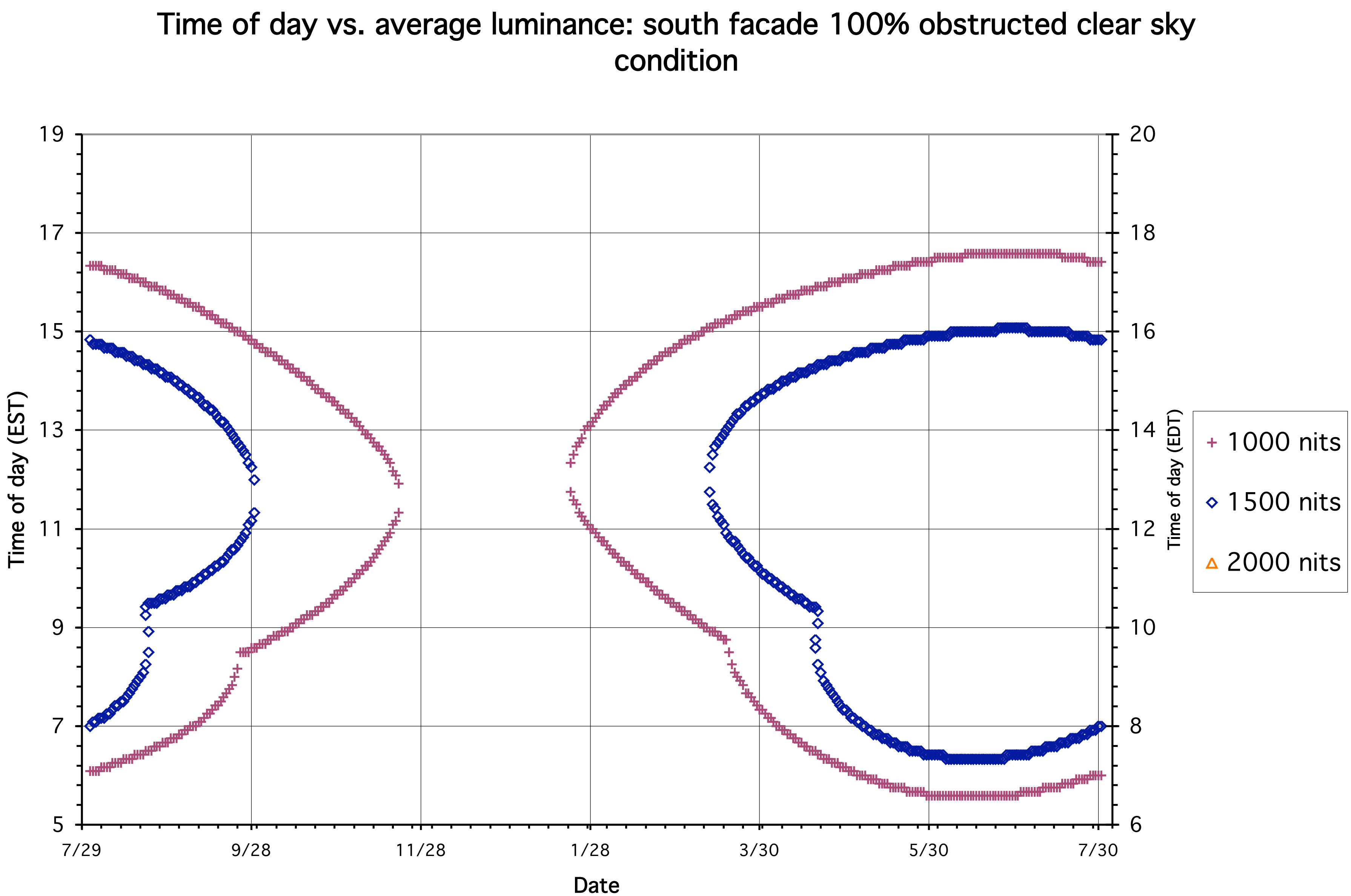
Time of day vs. average luminance: south facade 100% obstructed clear sky condition
Time of day (EST)
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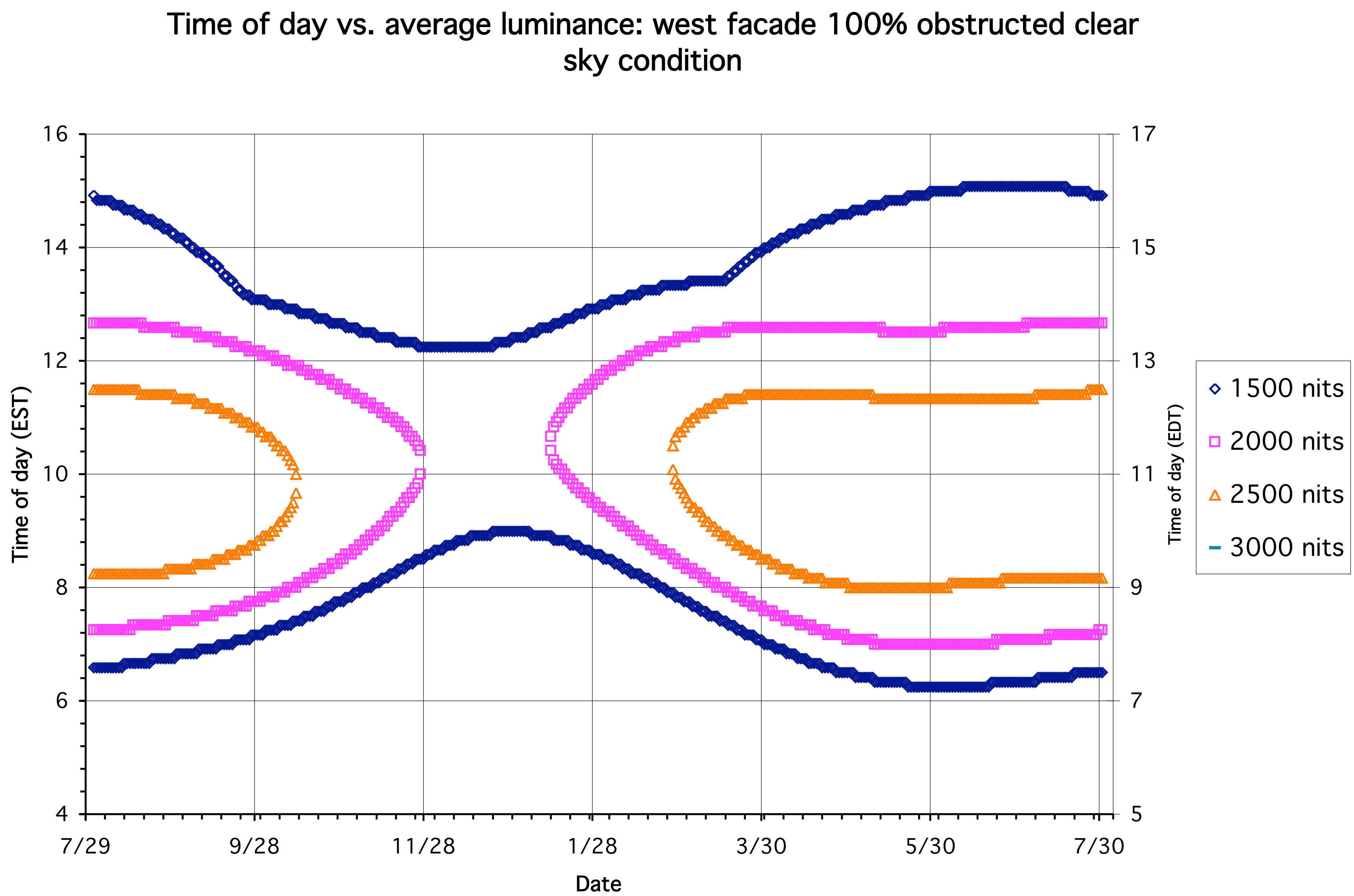
Time of day vs. average luminance: west facade 100% obstructed clear sky condition
Time of day (EST)
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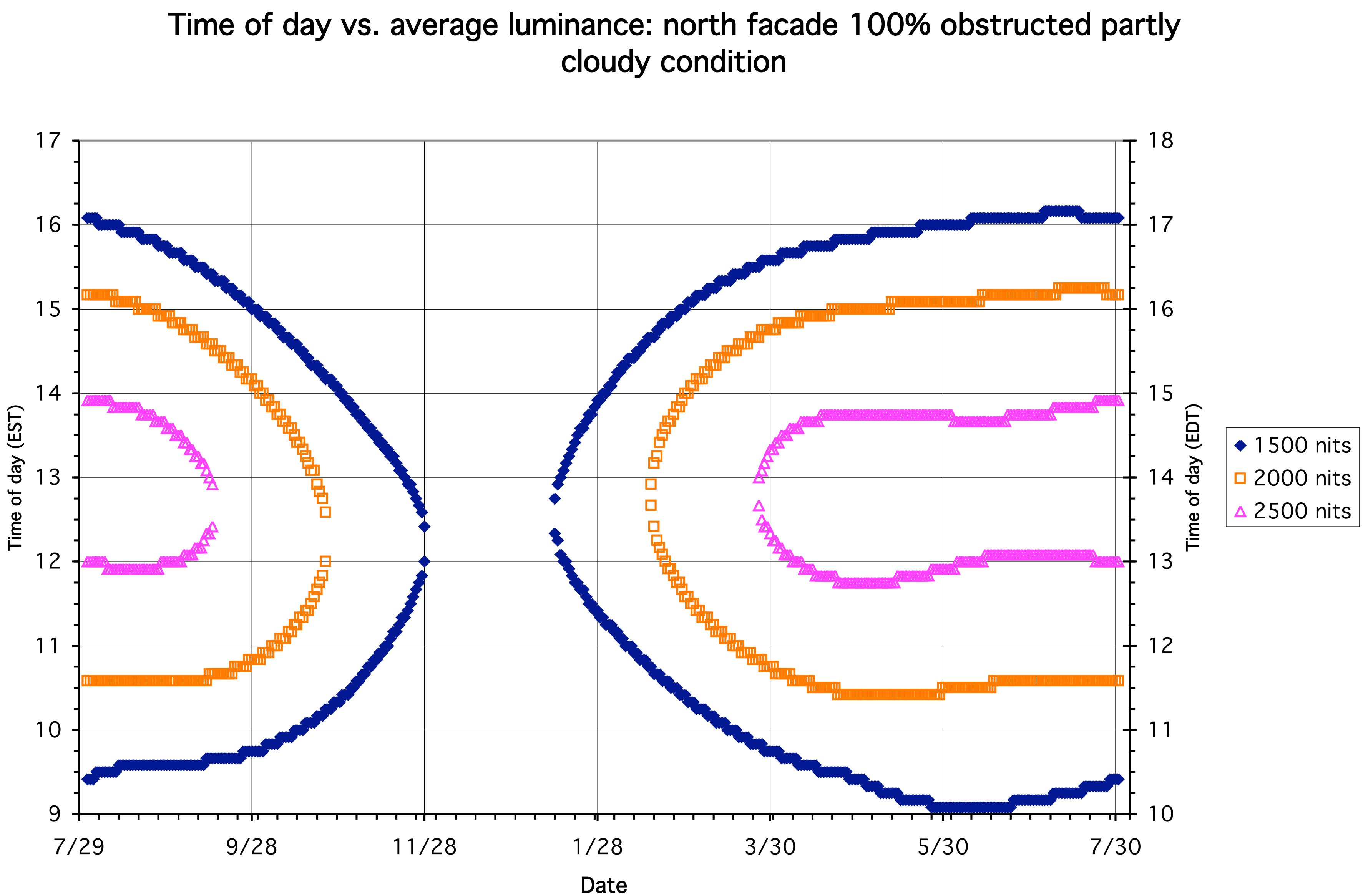

Time of day vs. average luminance: north facade 100% obstructed partly cloudy condition
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Time of day (EST)
Time of day (EDT)
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Date
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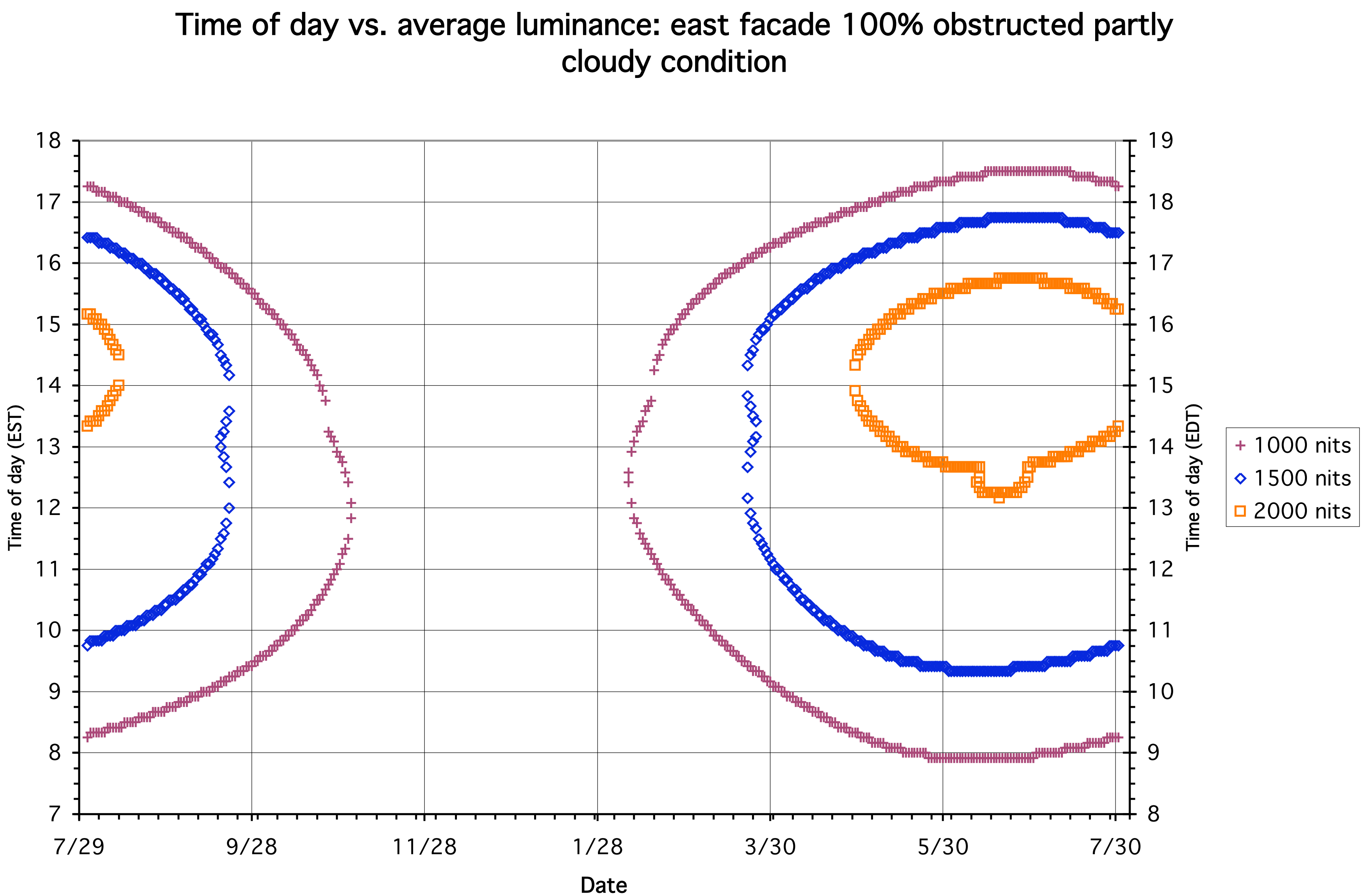

Time of day vs. average luminance: east facade 100% obstructed partly cloudy condition
Time of day (EST)
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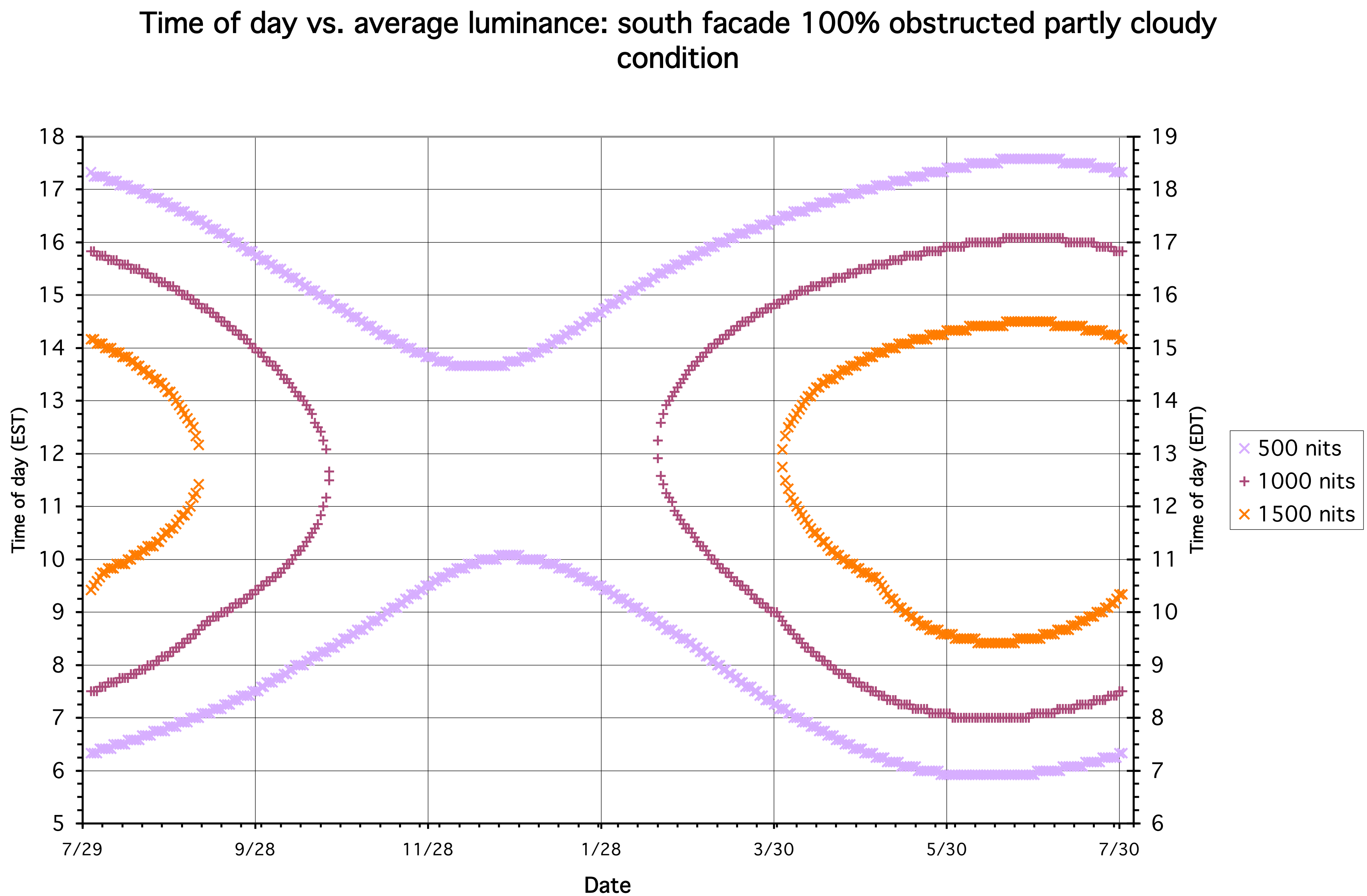

Time of day vs. average luminance: south facade 100% obstructed partly cloudy condition
Time of day (EST)
Time of day (EDT)
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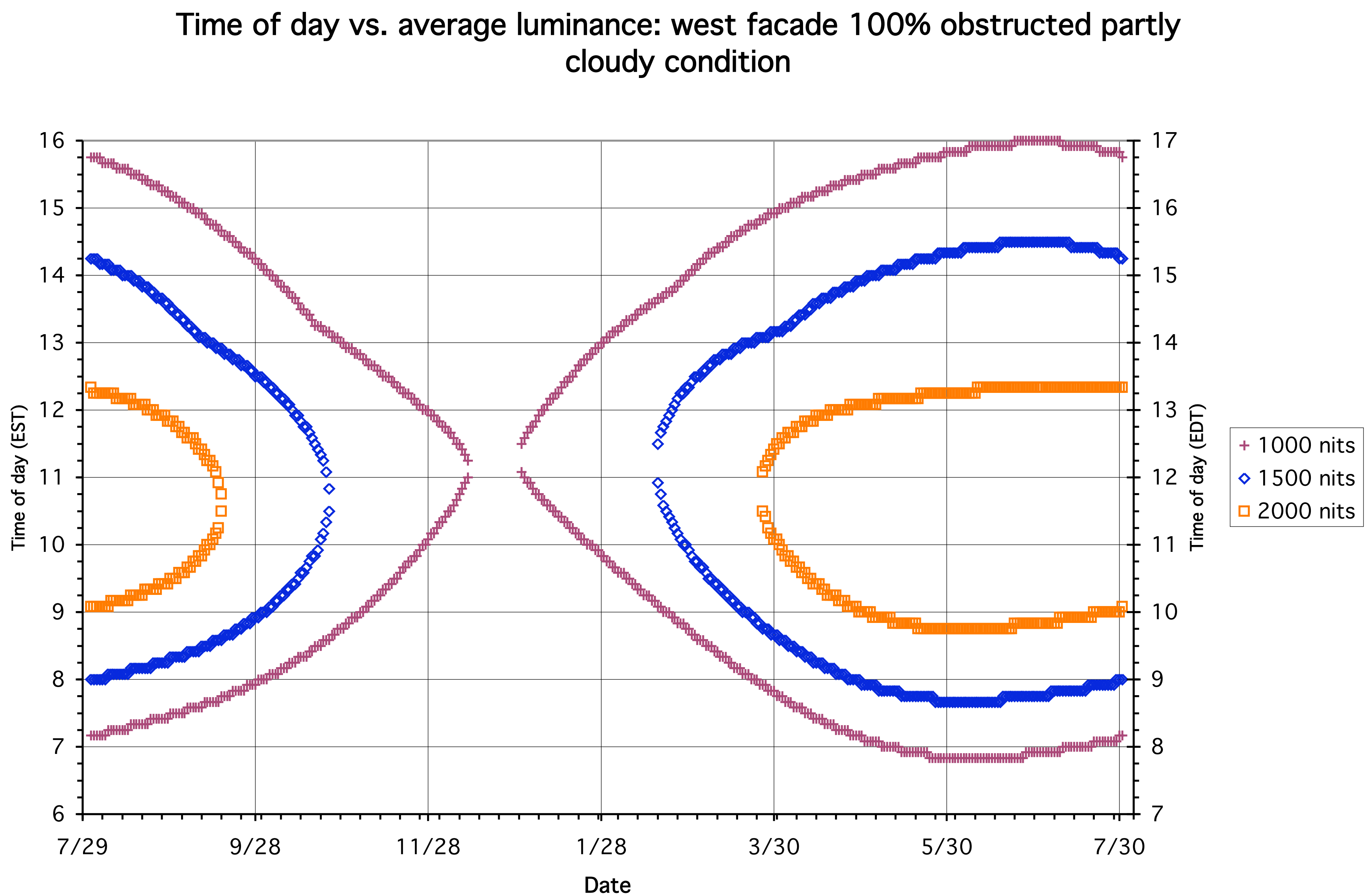
Time of day vs. average luminance: west facade 100% obstructed partly cloudy condition
Time of day (EST)
Time of day (EDT)
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