

SAINT LUCIA 3.2 MW SOLAR PV RFP PROJECT

Glint and Glare Study Hewanorra International Airport, Saint Lucia

Saint Lucia Air and Sea Port Authority

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Date: 24 July 2015



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1 INTRODUCTION

The Saint Lucia Air and Sea Port Authority (**SLASPA**) and the Carbon War Room (**CWR**) have invited DNV KEMA Renewables Inc. (**DNV GL**) to present a methodology for performing a Glint and Glare study at Hewanorra International Airport, in support of the eventual development of a 3.2 MW Solar Photovoltaic (PV) renewable energy system approximately 300 meters north of the airport (**the Solar PV Project**).

The objective of this report is to provide SLASPA with a summary of the methodology undertaken to perform the independent and verifiable study and to deliver the results from the first iteration of the study. This study is suitable for describing the potential possible glint (a momentary flash of bright light) and/or glare (a continuous source of bright light) issues and other hazards to aviation, surrounding reflectivity of PV panels to be installed near the Hewanorra Airport. The results of the study will indicate if and where any potential glint and glare issues may occur. DNV GL expects these results will be subject to interpretation by SLASPA.

DNV GL understands that SLASPA aims to undergo proper due diligence of the Solar PV project prior to approving the release of the Request for Proposals (RFP) to potential solar PV developers. DNV GL is well-positioned to perform this study given our year-long partnership with the Carbon War Room and our familiarity with the Saint Lucia geography, energy strategy, and the Ministry and LUCELEC's goals for energy transition and a safely constructed Solar PV project.

2 METHODOLOGY AND SCOPE DESCRIPTION

2.1 Development of the Solar Glare Hazard Analysis Tool

In this analysis, DNV GL utilized Sandia National Laboratories' Solar Glare Hazard Analysis Tool (SGHAT) to perform the study. The SGHAT was developed by the U.S. Department of Energy's Sandia National Laboratories in 2012, and has been revised and updated three times since its initial release. The tool is used widely in the United States, notably by the U.S. Federal Aviation Administration as a portion of an airport's application to install solar PV near any Federally Obligated Airport.


Sandia National Laboratories has developed essential science and technology tools and methodologies to resolve the U.S.' most challenging security issues. Sandia is a Federally Funded Research and Development Center (FFRDC) and is widely recognized as the nation's premier science and engineering laboratory for national security and technology innovation.¹

2.2 About the Solar Glare Hazard Analysis Tool

SGHAT employs an interactive Google-based map where the user can locate a site, draw an outline of the proposed PV array, and specify observer locations or paths. Latitude, longitude, and elevation are automatically recorded through the Google interface, providing necessary information for sun position and vector calculations. Additional information regarding the orientation and tilt of the PV panels, reflectance, environment, and ocular factors are entered by the user.

If glare is found, the tool calculates the retinal irradiance and subtended angle (size/distance) of the glare source to predict potential ocular hazards ranging from temporary after-image to retinal burn. The results

¹ Sandia National Laboratories, About. 12 July 2015. <http://www.sandia.gov/about/>



are presented in a simple, easy-to-interpret plot that specifies if/when glare will occur throughout the year, with color codes indicating the potential ocular hazard. The tool can also predict relative energy production while evaluating alternative designs, layouts, and locations to identify configurations that maximize energy production while mitigating the impacts of glare.²

2.3 SGHAT Use and Methodology

DNV GL developed a RFP for a 3 MW Solar PV System for LUCELEC for the purpose to invite interested bidders to propose on providing engineering, construction, and design services for the Solar PV project. In preparing the RFP, DNV GL (in collaboration with LUCELEC and Carbon War Room) developed baseline assumptions regarding Solar PV technology type, installation angle, module layout, and other design assumptions. DNV GL utilized other basic assumptions provided by SLASPA, and can incorporate additional inputs from Airports Council International (ACI) as available and provided by ACI.

2.3.1 Basic Inputs

DNV GL input basic site details about the Solar PV project, including the time zone in which the project site is located, and used the Google Map Search integrated into the tool to geolocate the project site.

2.3.2 PV Array Tool

DNV GL used the PV Array tool to activate the PV array drawing mode to draw an array on the map. Based on the preliminary PV layout developed by DNV GL for the RFP, the polygonal mode was used to manually set each array vertex, as shown in Figure 1.

² SGHAT User's Manual, Version 2. 12 July 2015. https://share.sandia.gov/phlux/static/references/glint-glare/SGHAT_Users_Manual_v2-0_final.pdf

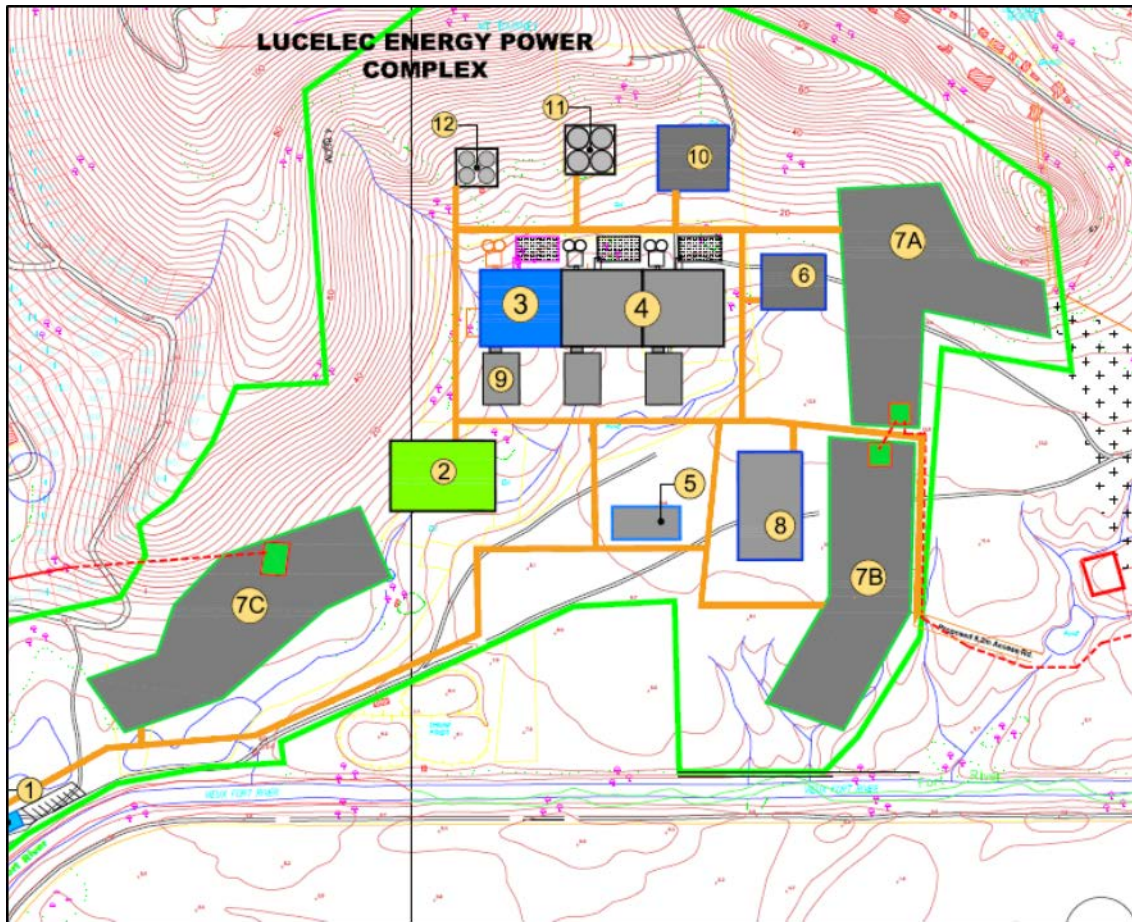


Figure 1. PV Arrays 7A, 7B and 7C, 1 MW each

2.3.3 Flight Path Tool

DNV GL used the flight path tool to activate the flight path drawing mode. Two flight paths were created: One from the west to east and another from east to west, at 100° and 280° per guidance from SLASPA. At this time, DNV GL has considered only landing flight paths, given the visual focus of a pilot on the general airport area during landing. DNV GL can use the tool to create any combinations of flight paths indicated by SLASPA and ACI. Flight Paths 1 and 2 are shown in the Figures below. The proposed Solar PV Project is shown in blue in the Figures below.

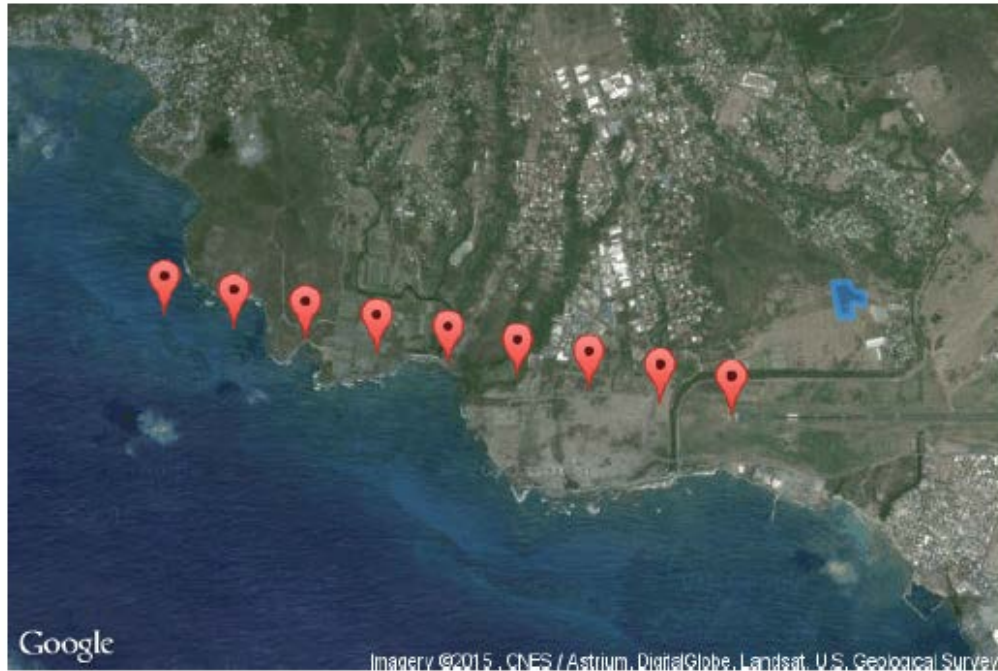


Figure 2. Flight Path 1 (West to East)

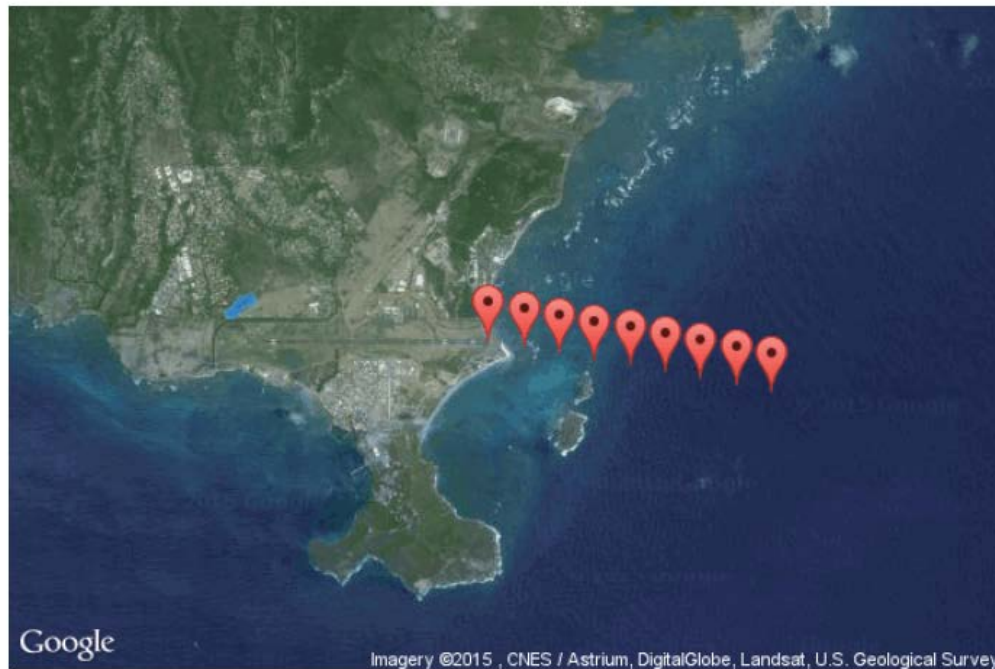


Figure 3. Flight Path 2 (East to West)

2.3.4 Technology Inputs

DNV GL utilized the assumptions from technical specifications contained in the RFP to configure the parameters of the PV array and its vertices. Based on the design parameters, a fixed panel tilt of 12 degrees, an orientation of 180 degrees (facing south) and a rated power of 1000kW per array will be utilized

The 3 MW Solar PV Project development consists of three PV arrays of 1 MW (or 1000kW) each – arrays 7A, 7B, and 7C. The analysis was repeated for each array. The height above ground elevation for each array was assumed to be two feet. DNV GL notes that potential developers may submit a design including a fixed panel tilt at less than 12 degrees, which DNV GL expects would reduce any potential glint and glare occurrences.

2.3.5 Flight Path Assumptions

DNV GL updated the flight path section, which contains entries for each flight path added on the map. Each entry displays the configurable parameters of flight path as well as observation points. In addition, DNV GL can choose to limit the downward and azimuthal angles of view from the flight path observation points to simulate restricted viewing from the cockpit by checking “Consider pilot visibility from cockpit.” DNV GL can alter this input as requested by SLASPA or ACI; generally, DNV GL will leave this box unchecked in order to develop as conservative a result as possible.

3 RESULTS

3.1 Interpreting results

The SGHAT categorizes the potential for glint and glare into the following possible scenarios, relating to the possibility of a viewer to experience a glint or glare from the modules bright enough to create the potential for after-image in their field of vision, as described in the following figure:

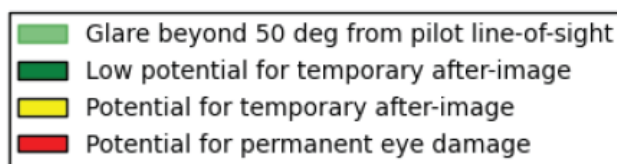


Figure 4. Glint and glare categories









3.2 Summary of Results

DNV GL used the SGHAT to run one analysis each for each flight path and each PV array. For all flight paths, the potential for glare is analyzed along the flight path in 0.25 mile increments from 2.0 miles, to 0.0 miles (referred to as “threshold,” at the runway).

DNV GL has provided the *most conservative* results in Table 3-1 below. For example, for Flight Path 1, PV Array 7A, peak occurrence of glare is at 0.5 miles from the runway, when glare may occur for 45 minutes between April and August. However, at 1.5 miles, glare only occurs for a few minutes per day in late March/early April, and a few minutes per day in September. Similarly, DNV GL has assumed solar PV parameters that are the most conservative, including a fixed tilt PV system at 12 degrees; whereas a less tilted system proposed by the developer (through the RFP process) would create fewer instances of glint and glare.


Full results are presented in Appendix A, including a summary of all inputs to each analyses and a graphs of time of day and year when glint and glare occur at all distances between 2.0 and 0.0 miles.

Table 3-1. Results

Flight path and PV array analyzed	Peak result at approach distance	Approximate peak date and time affected	Approximate percentage of year affected
Flight Path 1, PV Array 7A	 Low potential for after-image from 2.0 miles to 0.25 mile; peak occurrence at 0.5 mile	Mid-April to late August 6:15 AM – 7:00 AM	0.6%
Flight Path 2, PV Array 7A	 Low potential for temporary after-image; peak occurrence at threshold	Mid-April to mid-June; mid-July to mid-August 5:30 PM – 6:15 PM	0.8%
Flight Path 1, PV Array 7B	  Potential/Low potential for temporary after-image; peak occurrence at 0.25 mile	Mid-March to mid-September 6:00 AM – 6:45 AM	1.3%
Flight Path 2, PV Array 7B	 Low potential for temporary after-image; peak occurrence at 0.5 mile	Mid-March to mid-May; mid-August to mid-September 5:30 PM – 6:00 PM	0.3%
Flight Path 1, PV Array 7C	  Low potential/potential for after-image from 2.0 miles to 0.5 miles; peak occurrence at 0.5 mile	Mid-April to early September 6:15 AM – 7:00 AM	1.0%
Flight Path 2, PV Array 7C	 Low potential for after-image; peak occurrence at 0.25 mile	Mid-March to early May; mid-August to mid-September 5:45 PM – 6:15 PM	0.3%

4 CONCLUSIONS

DNV GL has analysed the potential for glint and glare for all three proposed 1 MW Solar PV arrays at Hewanorra International Airport, assuming both flight path approaches from the east and the west. DNV GL finds that for the great majority of the year (98%+), no glint or glare would be visible from the flight path. DNV GL found instances of up to 45 minutes per day during specific times of year when a potential for glare could occur in certain flight paths. During certain times of day and year as noted above, glare may occur from more than one array at the same time of day (for example, glare may occur from 7A, 7B, and 7C in midsummer between 6:15 and 6:45 AM). DNV GL can adjust the parameters of the study, including flight



path direction, approach, angle, and other aviation criteria, at the request of SLASPA or their delegate, which may change the results.



APPENDIX A – SGHAT RESULTS

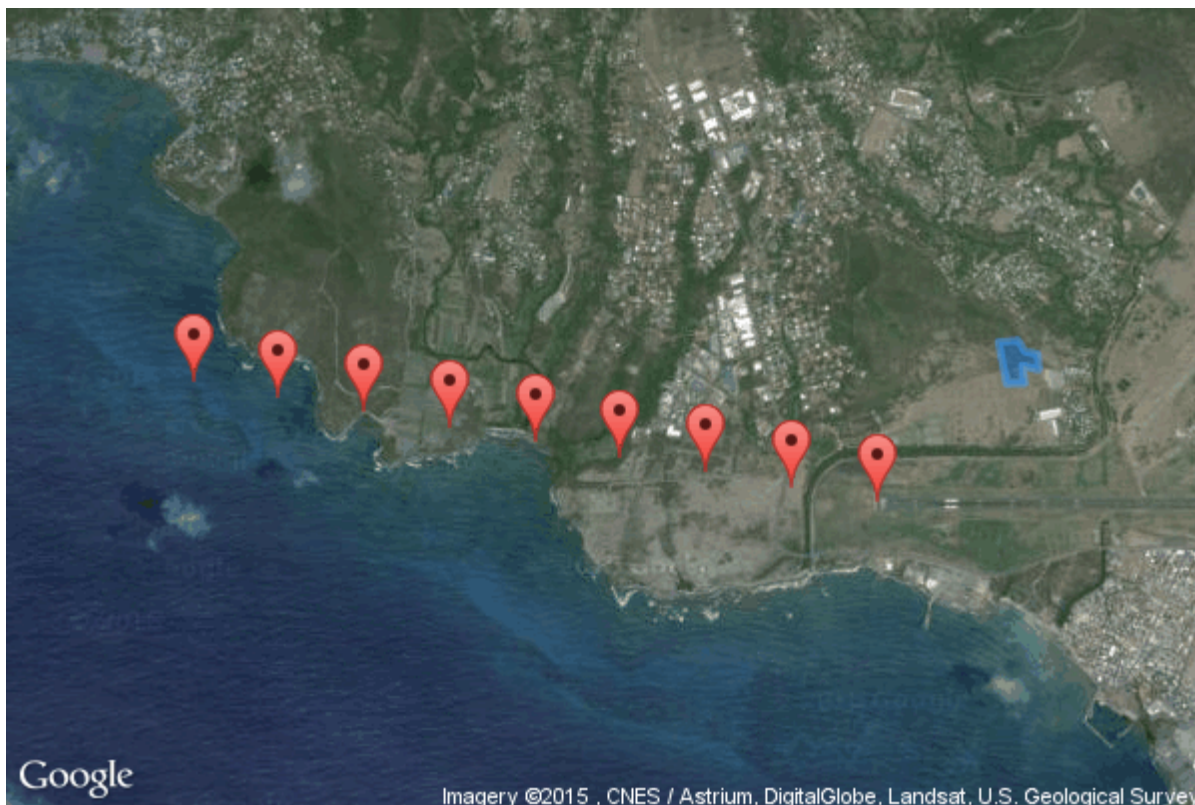
Solar Glare Hazard Analysis Flight Path Report

Generated July 16, 2015, 11:33 a.m.

Flight path: 1

Glare found

 Print



Analysis & PV array parameters

Analysis name	20150716 St Lucia with Input
PV array axis tracking	none
Orientation of array (deg)	180.0
Tilt of solar panels (deg)	12.0
Rated power (kW)	1000.0
Vary reflectivity	True
PV surface material	Smooth glass with ARC

Timezone offset	-4.0
Subtended angle of sun (mrad)	9.3
Peak DNI (W/m ²)	1000.0
Ocular transmission coefficient	0.5
Pupil diameter (m)	0.002
Eye focal length (m)	0.017
Time interval (min)	1
Correlate slope error with material	False
Slope error (mrad)	10.0

Flight path parameters

Direction (deg)	100.0
Glide slope (deg)	3.0
Consider pilot visibility from cockpit	True

Max downward viewing angle (deg)	30.0
Azimuthal viewing angle (deg)	180.0

PV array vertices

id	Latitude (deg)	Longitude (deg)	Ground Elevation (ft)	Height of panels above ground (ft)	Total elevation (ft)
1	13.7383602005	-60.9600234032	55.36	2.0	57.36
2	13.7383810443	-60.959250927	59.79	2.0	61.79
3	13.7391105752	-60.9593582153	74.96	2.0	76.96
4	13.7389438255	-60.9586501122	69.87	2.0	71.87
5	13.73958998	-60.9586930275	91.98	2.0	93.98
6	13.7396941983	-60.959250927	108.74	2.0	110.74
7	13.7401527583	-60.9595298767	125.3	2.0	127.3
8	13.7400902275	-60.9603667259	108.74	2.0	110.74

Flight Path Observation Points

	Latitude (deg)	Longitude (deg)	Ground Elevation (ft)	Eye-level height above ground (ft)	Glare?
Threshold	13.73334034	-60.9655702114	24.65	50.0	No
1/4 mi	13.73396786	-60.9692380772	29.17	114.66	Yes
1/2 mi	13.7345953799	-60.972905943	44.94	168.08	Yes
3/4 mi	13.7352228999	-60.9765738089	50.03	232.16	Yes
1 mi	13.7358504199	-60.9802416747	13.69	337.67	Yes
1 1/4 mi	13.7364779399	-60.9839095405	38.72	381.83	Yes
1 1/2 mi	13.7371054599	-60.9875774063	39.04	450.68	Yes
1 3/4 mi	13.7377329798	-60.9912452721	0.59	558.32	Yes

2 mi	13.7383604998	-60.994913138	0.0	628.08	Yes
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Glare occurrence plots

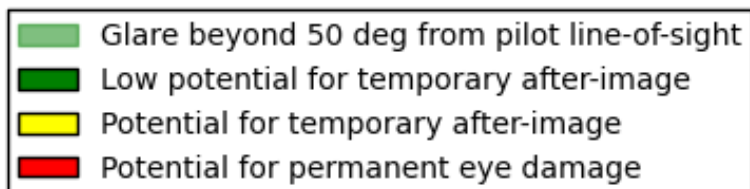
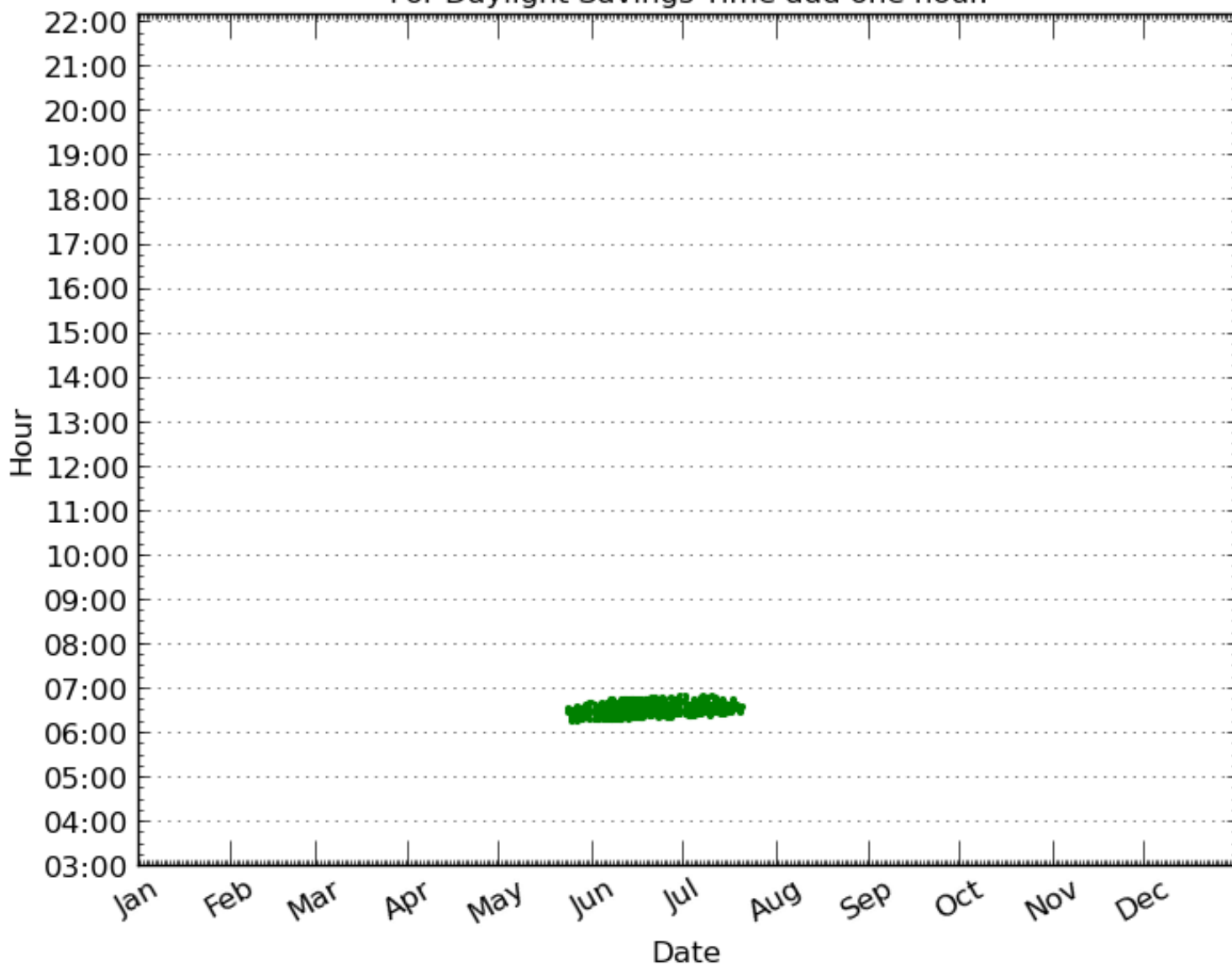
All times are in standard time. For Daylight Savings Time add one hour.

Threshold

No glare

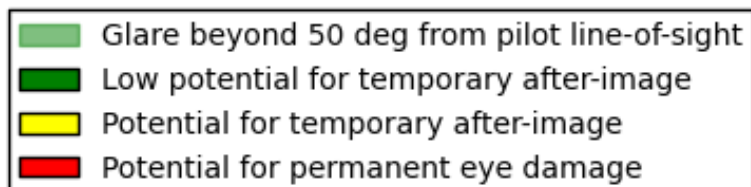
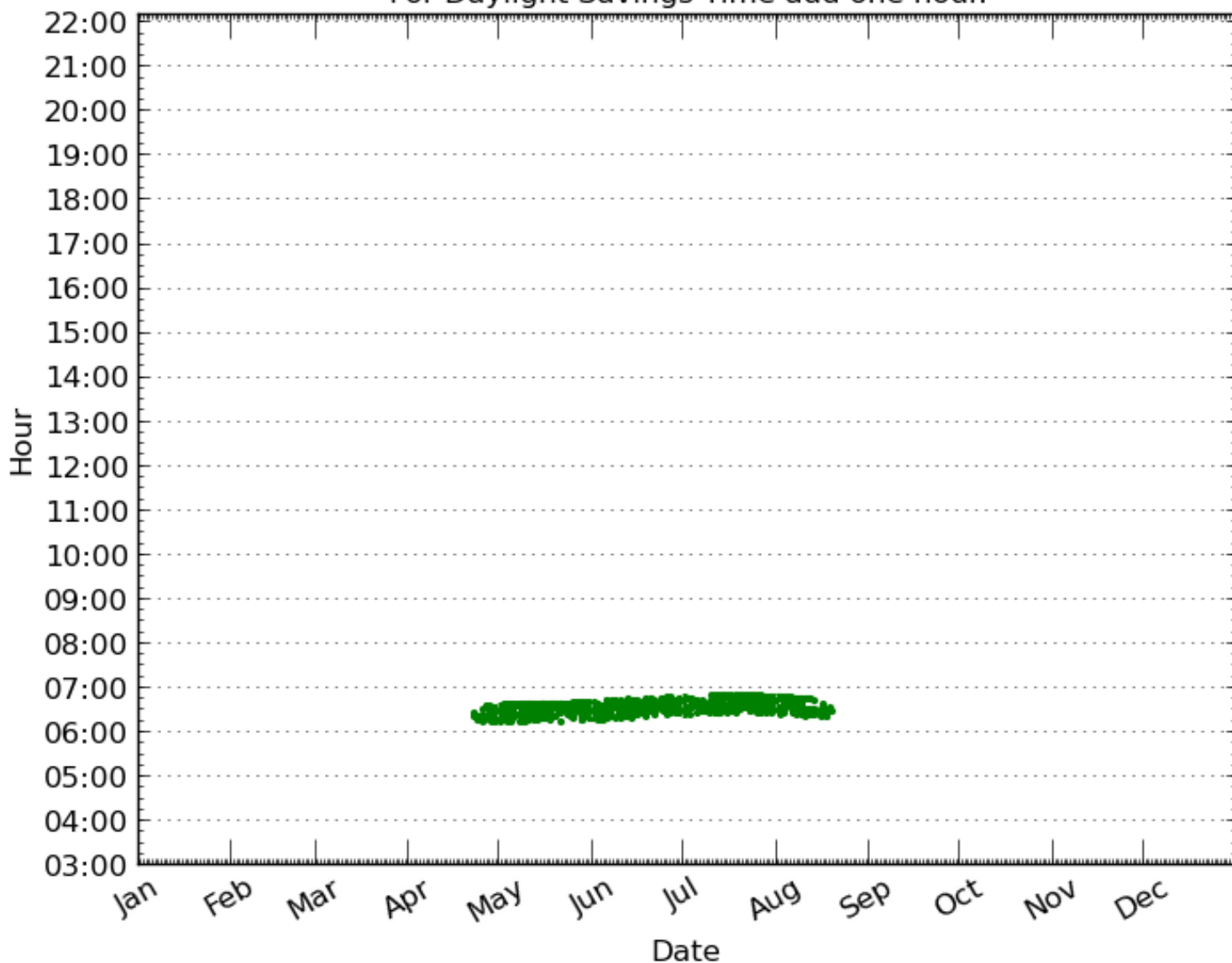
1/4 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



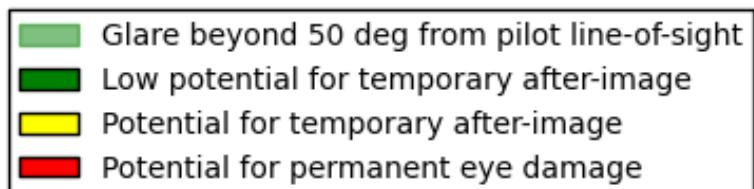
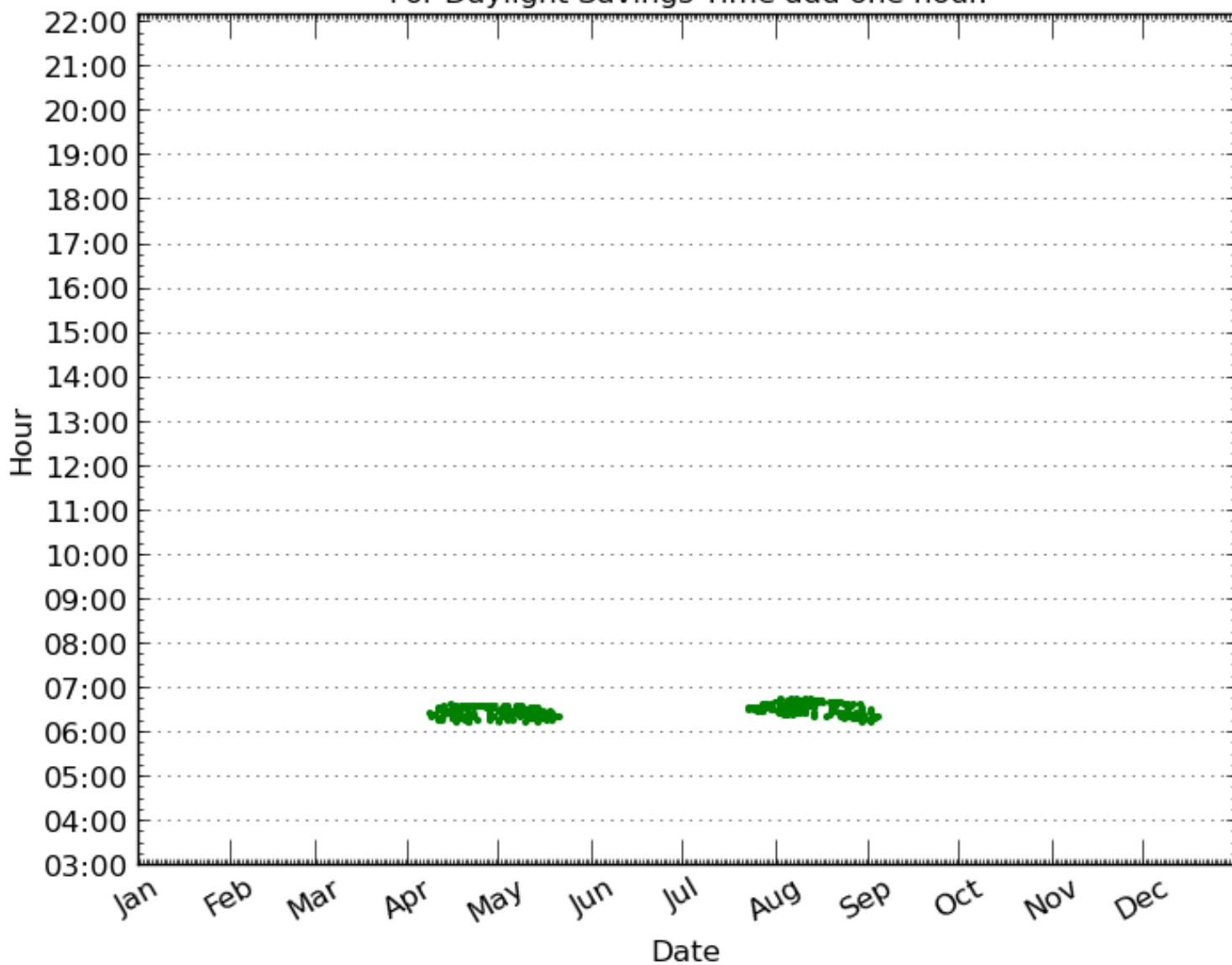
1/2 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



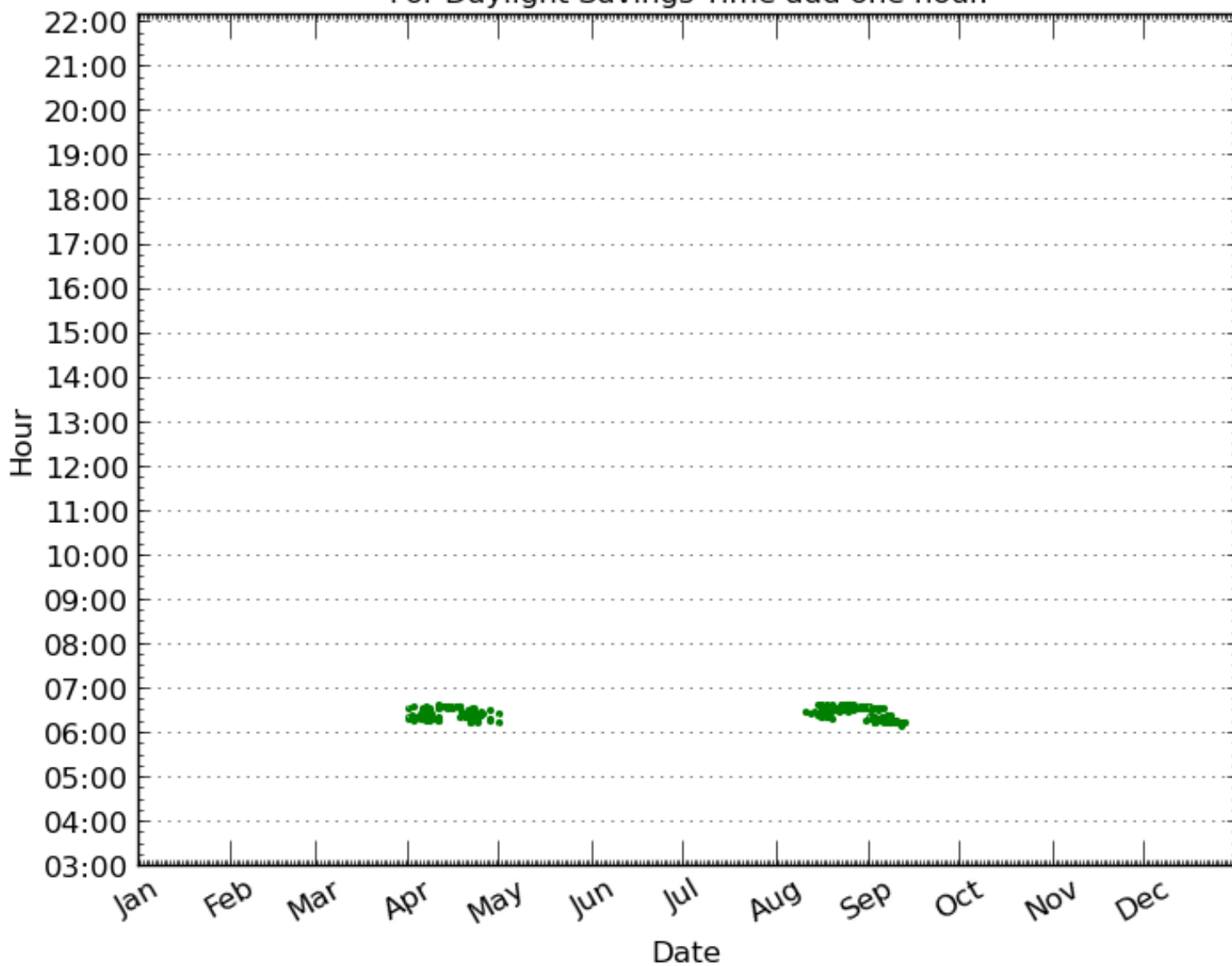
3/4 mi

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All times are in standard time.
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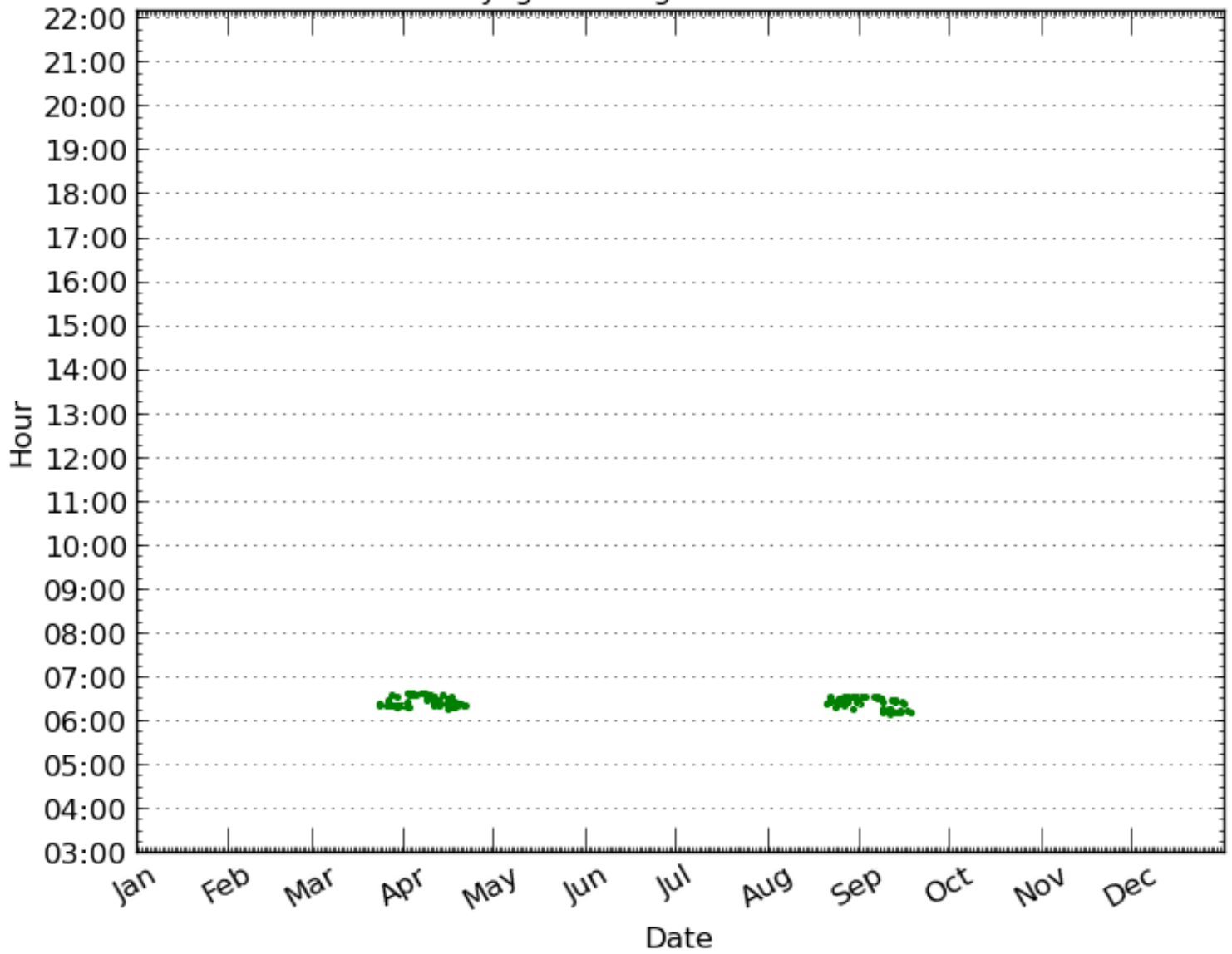
1 mi

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All times are in standard time.
For Daylight Savings Time add one hour.



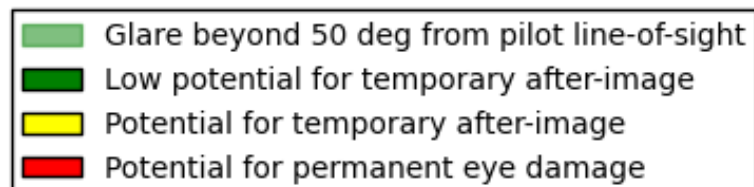
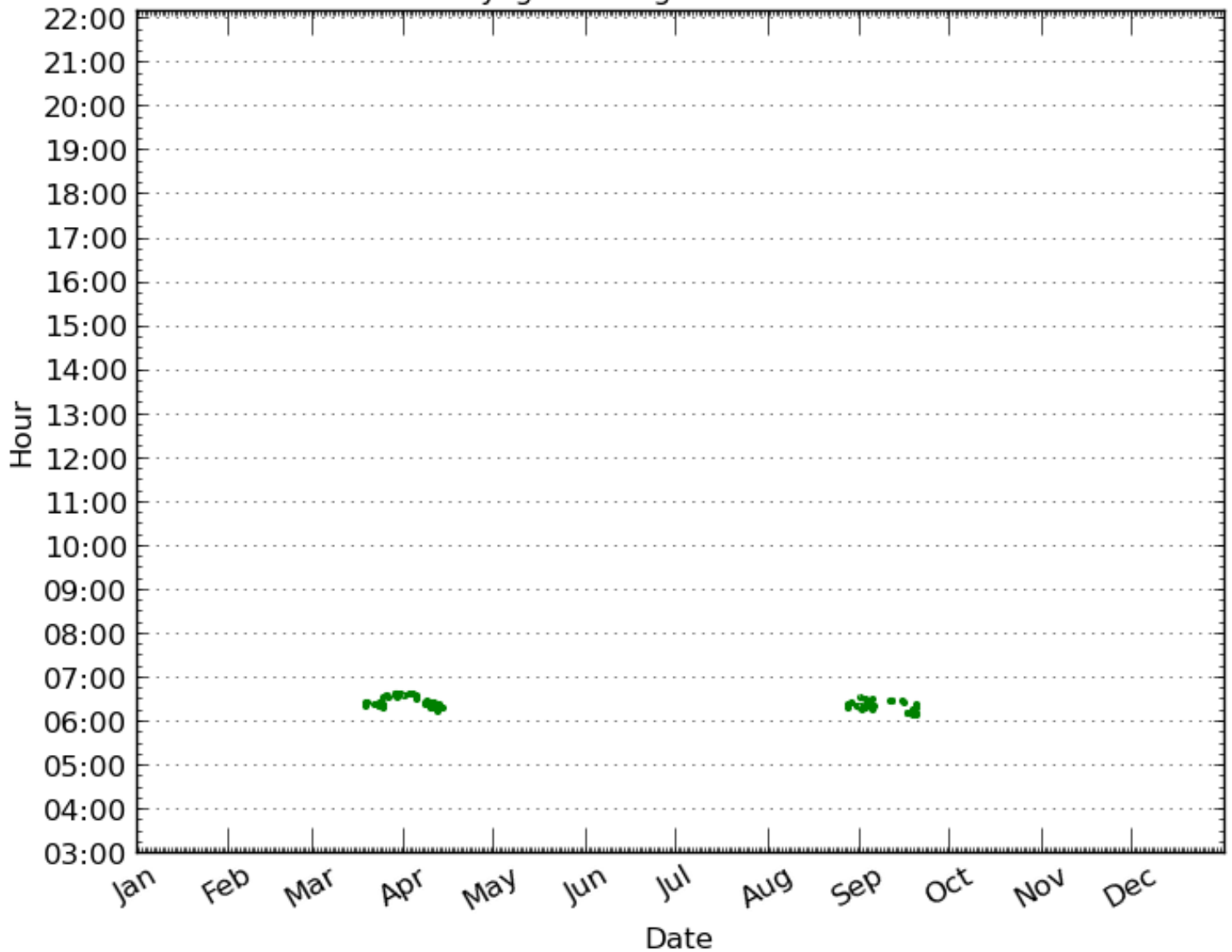
1 1/4 mi

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All times are in standard time.
For Daylight Savings Time add one hour.



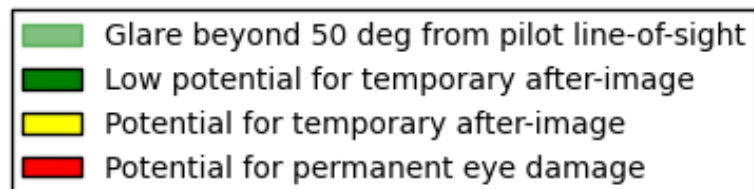
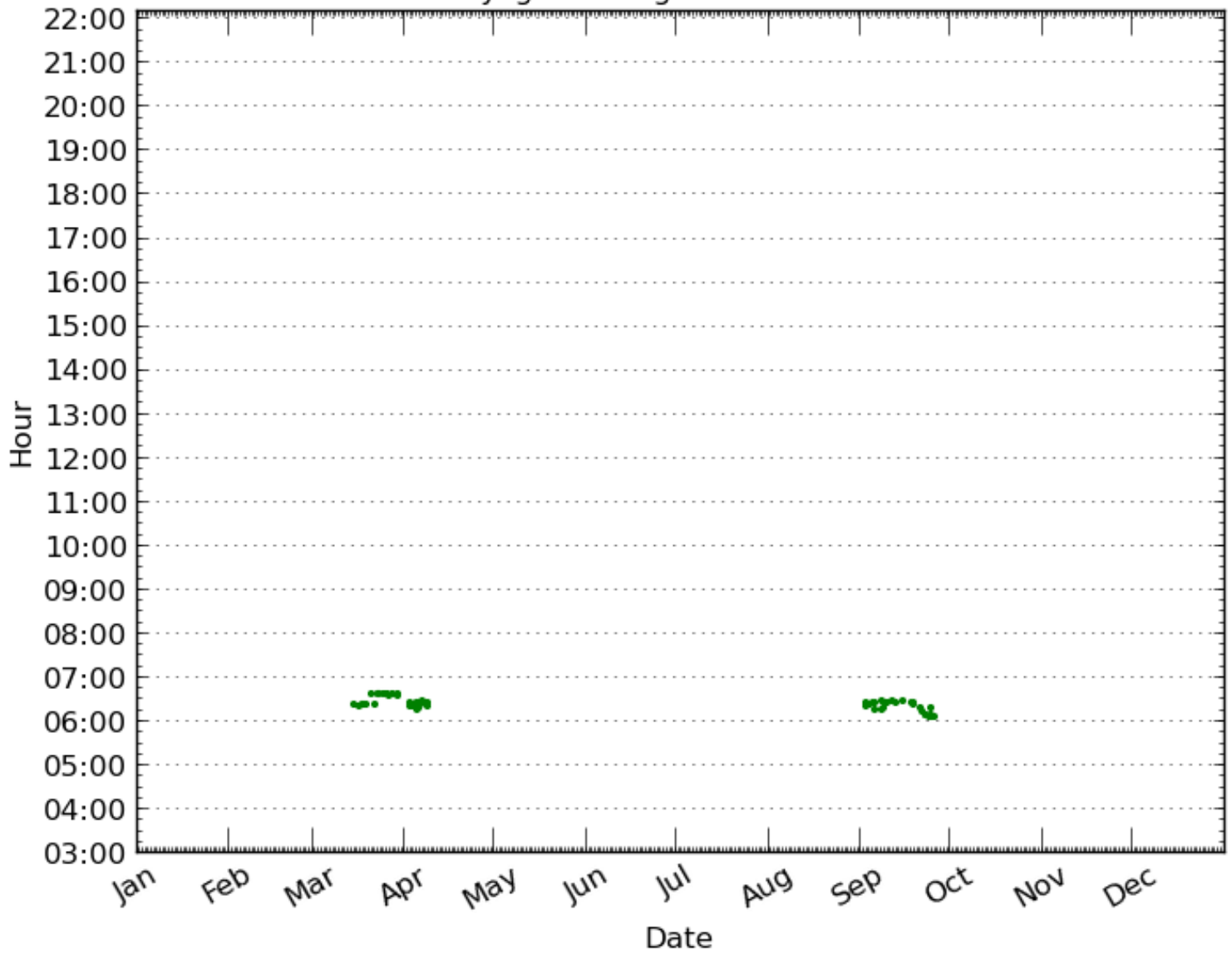
1 1/2 mi

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All times are in standard time.
For Daylight Savings Time add one hour.



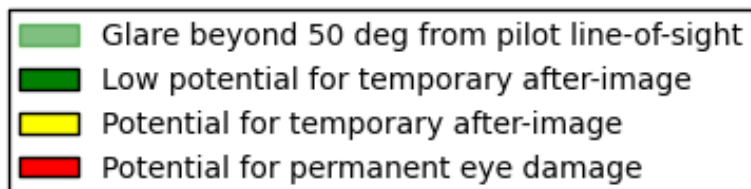
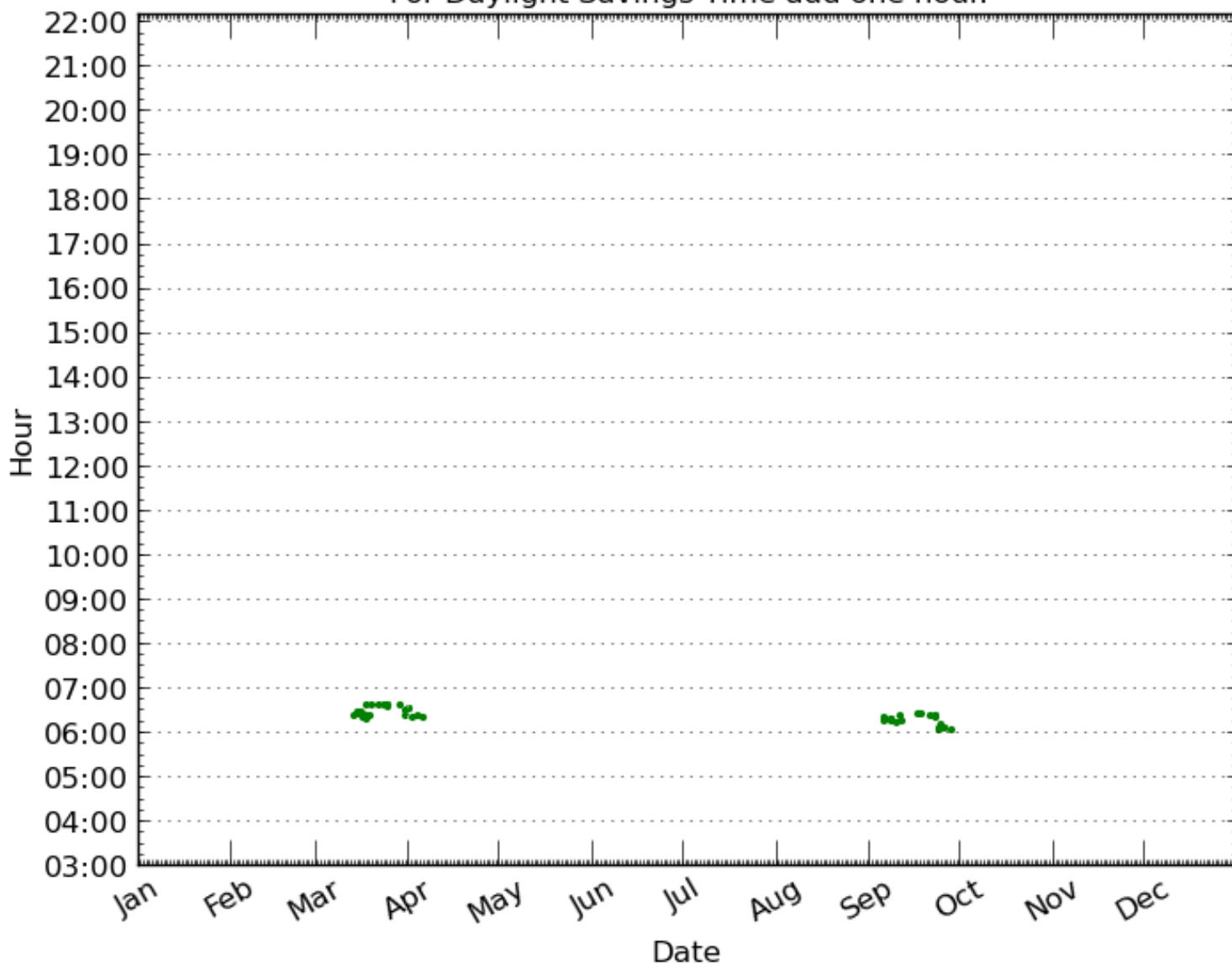
1 3/4 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



2 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



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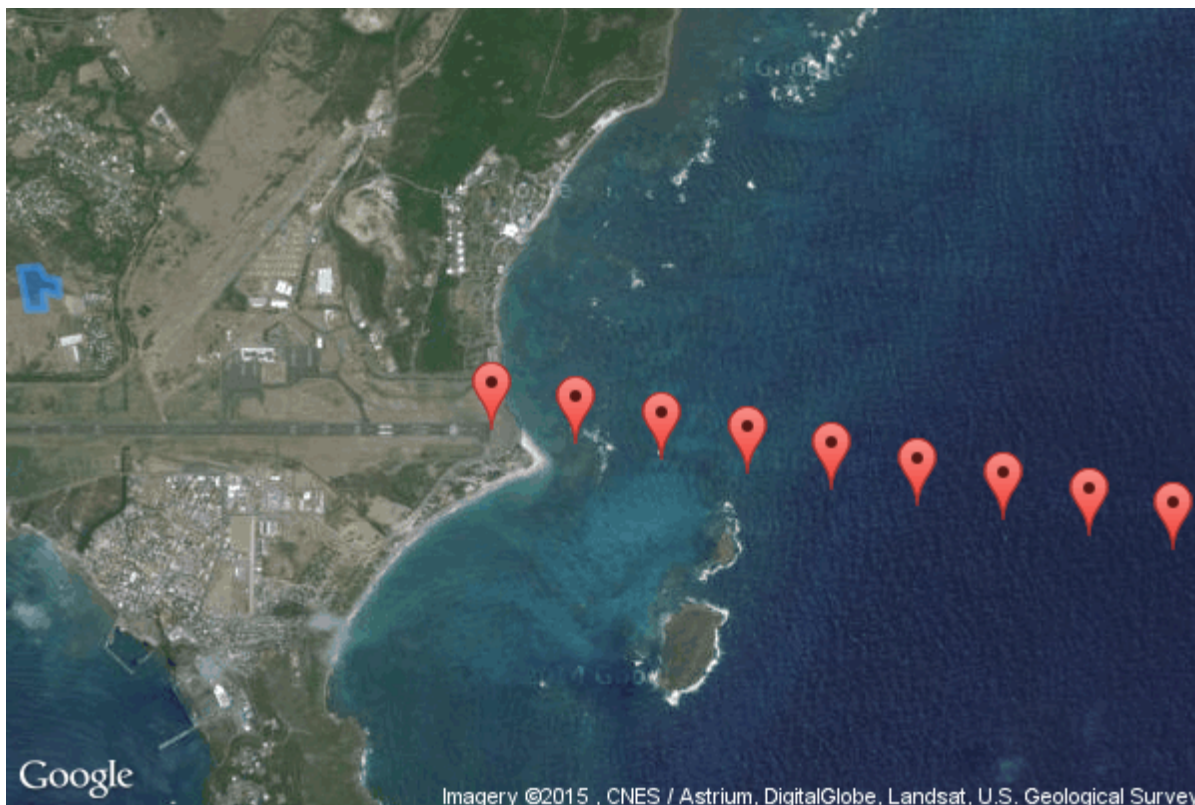
Solar Glare Hazard Analysis Flight Path Report

Generated July 16, 2015, 11:34 a.m.

Flight path: 2

Glare found

 Print



Analysis & PV array parameters

Analysis name	20150716 St Lucia with Input
PV array axis tracking	none
Orientation of array (deg)	180.0
Tilt of solar panels (deg)	12.0
Rated power (kW)	1000.0
Vary reflectivity	True
PV surface material	Smooth glass with ARC

Timezone offset	-4.0
Subtended angle of sun (mrad)	9.3
Peak DNI (W/m ²)	1000.0
Ocular transmission coefficient	0.5
Pupil diameter (m)	0.002
Eye focal length (m)	0.017
Time interval (min)	1
Correlate slope error with material	False
Slope error (mrad)	10.0

Flight path parameters

Direction (deg)	280.0
Glide slope (deg)	3.0
Consider pilot visibility from cockpit	True

Max downward viewing angle (deg)	30.0
Azimuthal viewing angle (deg)	180.0

PV array vertices

id	Latitude (deg)	Longitude (deg)	Ground Elevation (ft)	Height of panels above ground (ft)	Total elevation (ft)
1	13.7383602005	-60.9600234032	55.36	2.0	57.36
2	13.7383810443	-60.959250927	59.79	2.0	61.79
3	13.7391105752	-60.9593582153	74.96	2.0	76.96
4	13.7389438255	-60.9586501122	69.87	2.0	71.87
5	13.73958998	-60.9586930275	91.98	2.0	93.98
6	13.7396941983	-60.959250927	108.74	2.0	110.74
7	13.7401527583	-60.9595298767	125.3	2.0	127.3
8	13.7400902275	-60.9603667259	108.74	2.0	110.74

Flight Path Observation Points

	Latitude (deg)	Longitude (deg)	Ground Elevation (ft)	Eye-level height above ground (ft)	Glare?
Threshold	13.7333090736	-60.9400838614	17.8	50.0	Yes
1/4 mi	13.7326815537	-60.936415996	0.0	136.97	Yes
1/2 mi	13.7320540337	-60.9327481307	0.0	206.16	Yes
3/4 mi	13.7314265137	-60.9290802654	0.0	275.33	Yes
1 mi	13.7307989937	-60.9254124	0.0	344.5	Yes
1 1/4 mi	13.7301714737	-60.9217445347	0.0	413.69	Yes
1 1/2 mi	13.7295439538	-60.9180766694	0.0	482.86	Yes
1 3/4 mi	13.7289164338	-60.9144088041	0.0	552.05	Yes

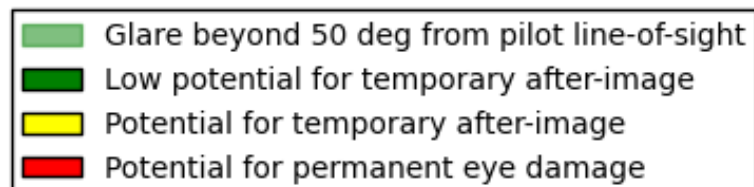
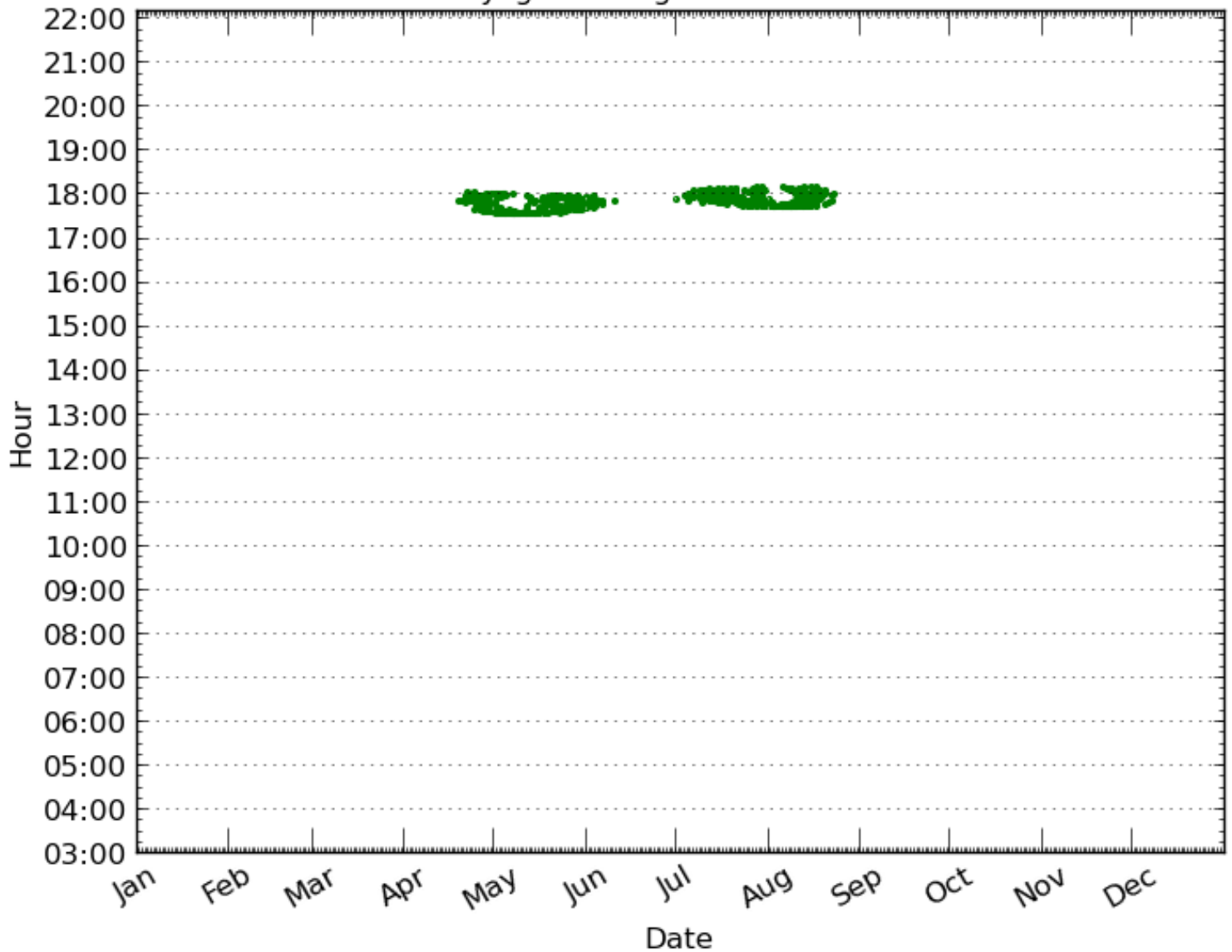
2 mi	13.7282889138	-60.9107409387	0.0	621.22	Yes
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Glare occurrence plots

All times are in standard time. For Daylight Savings Time add one hour.

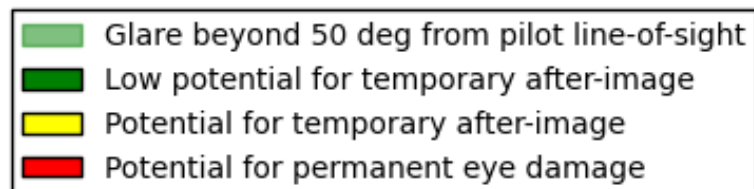
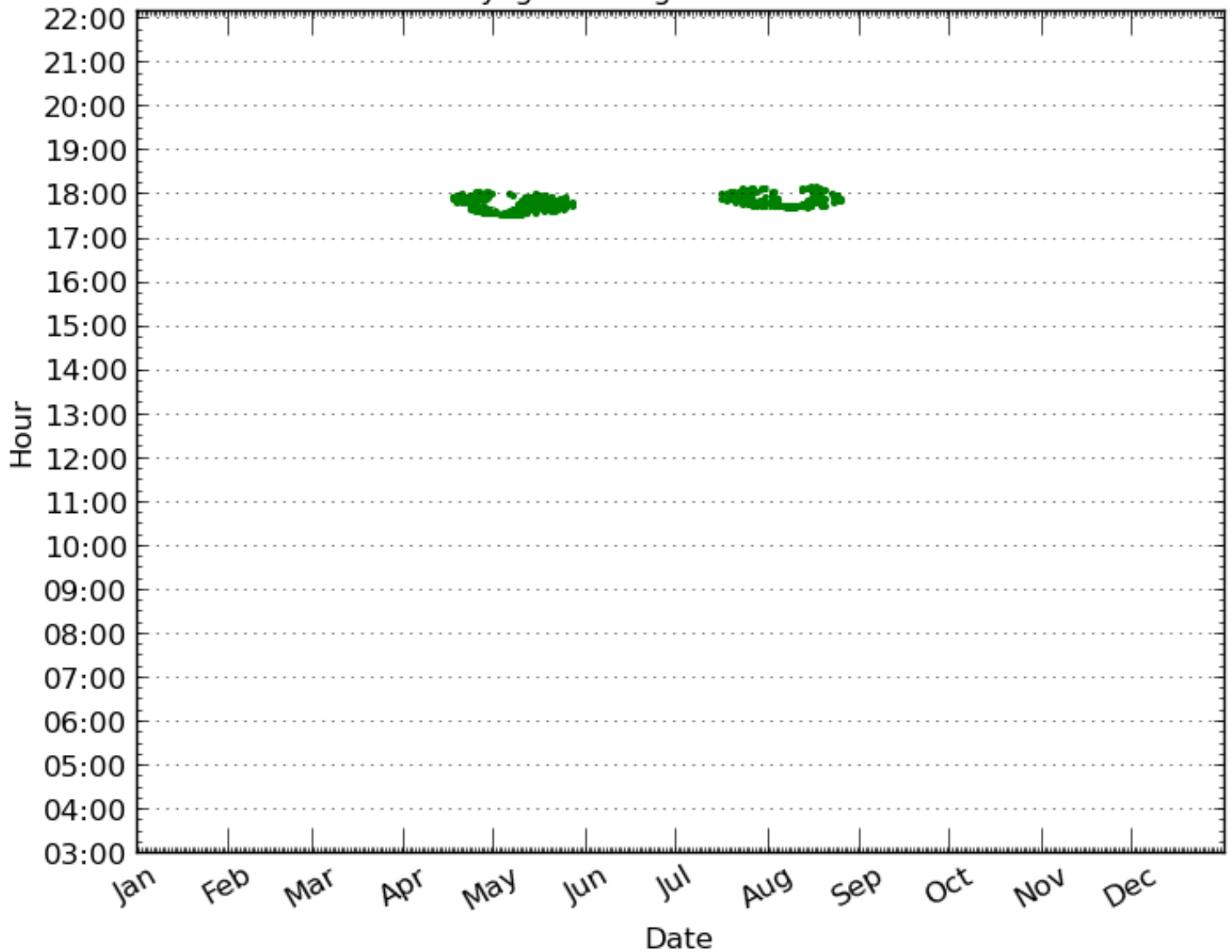
Threshold

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



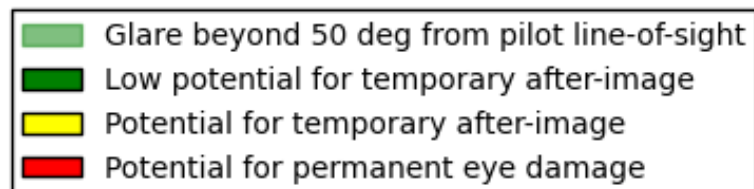
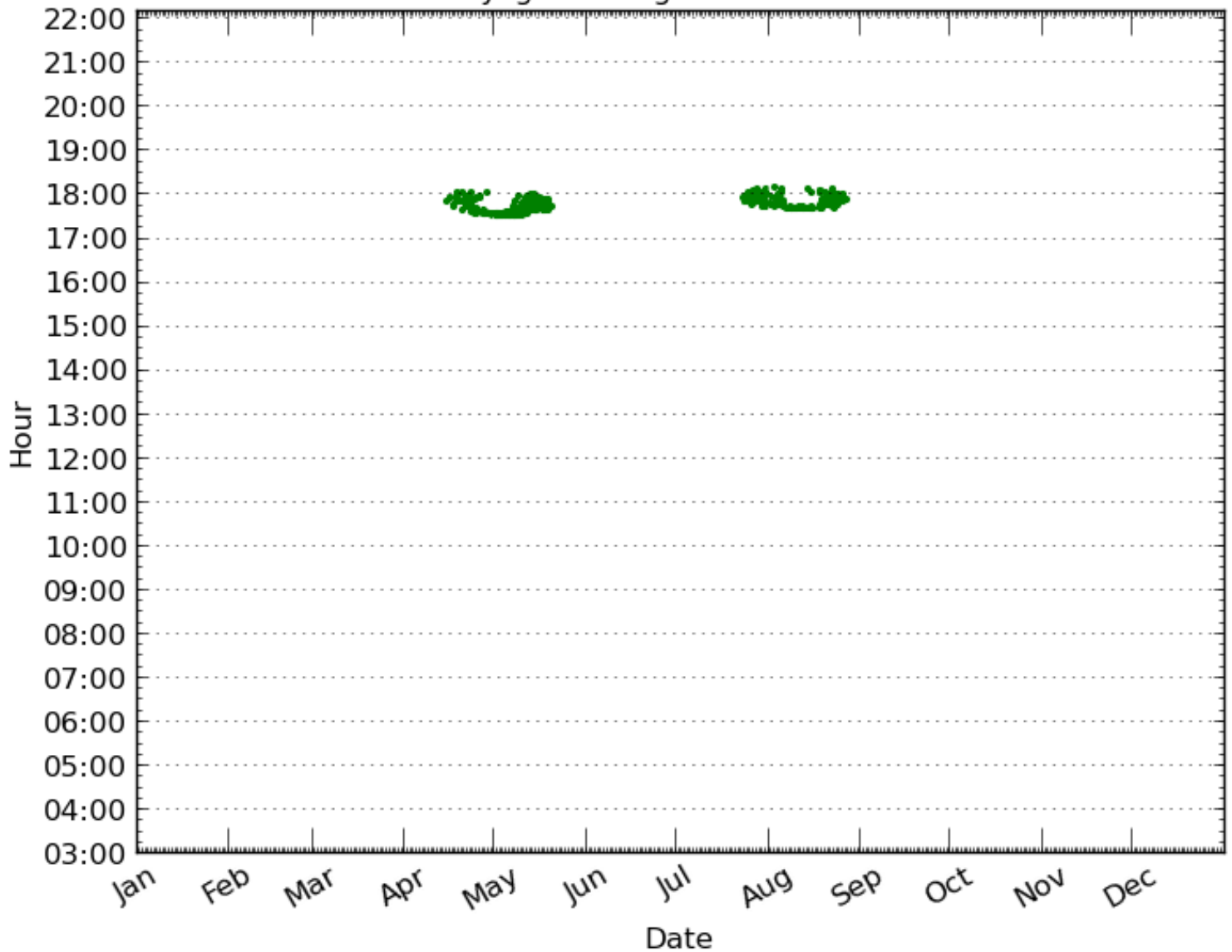
1/4 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



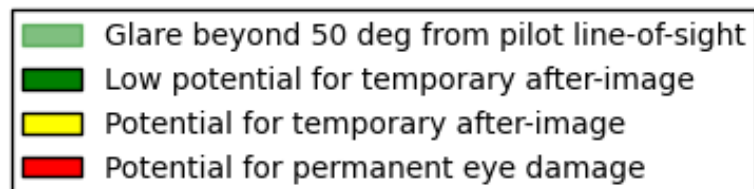
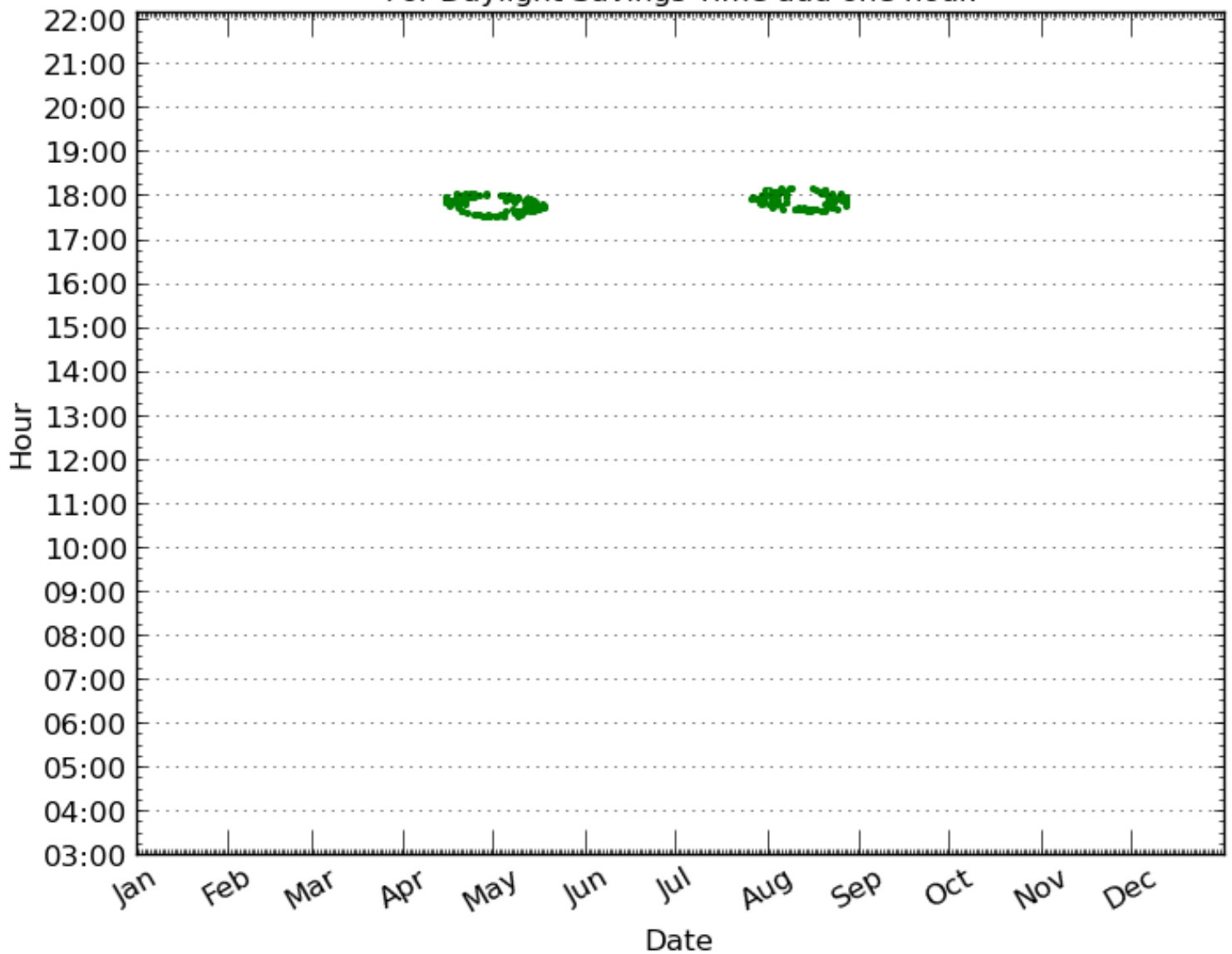
1/2 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



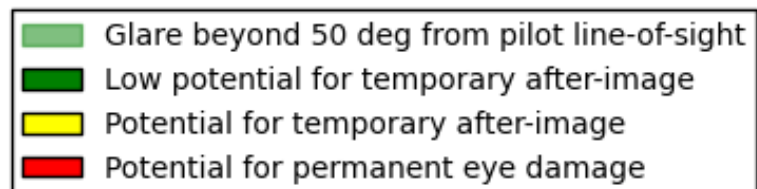
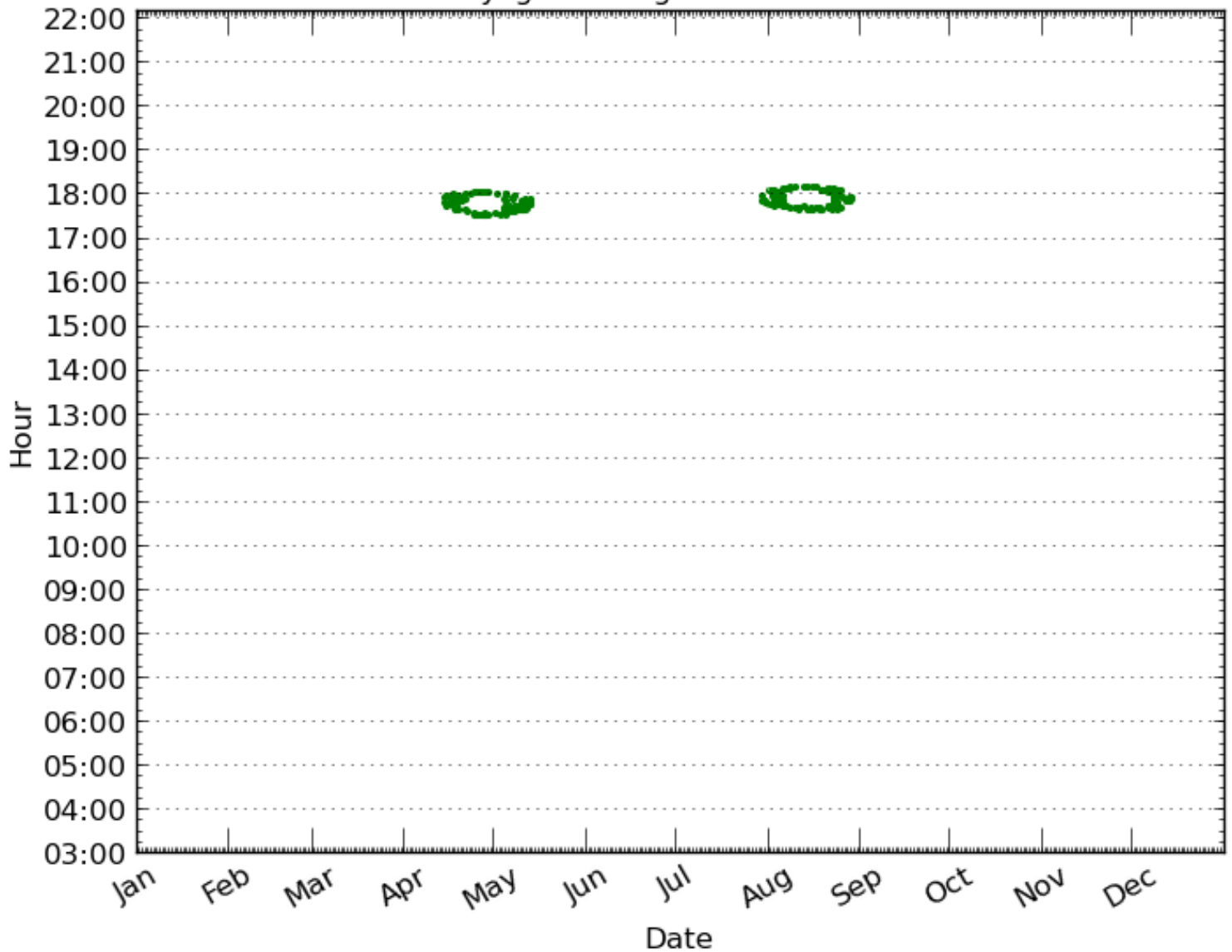
3/4 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



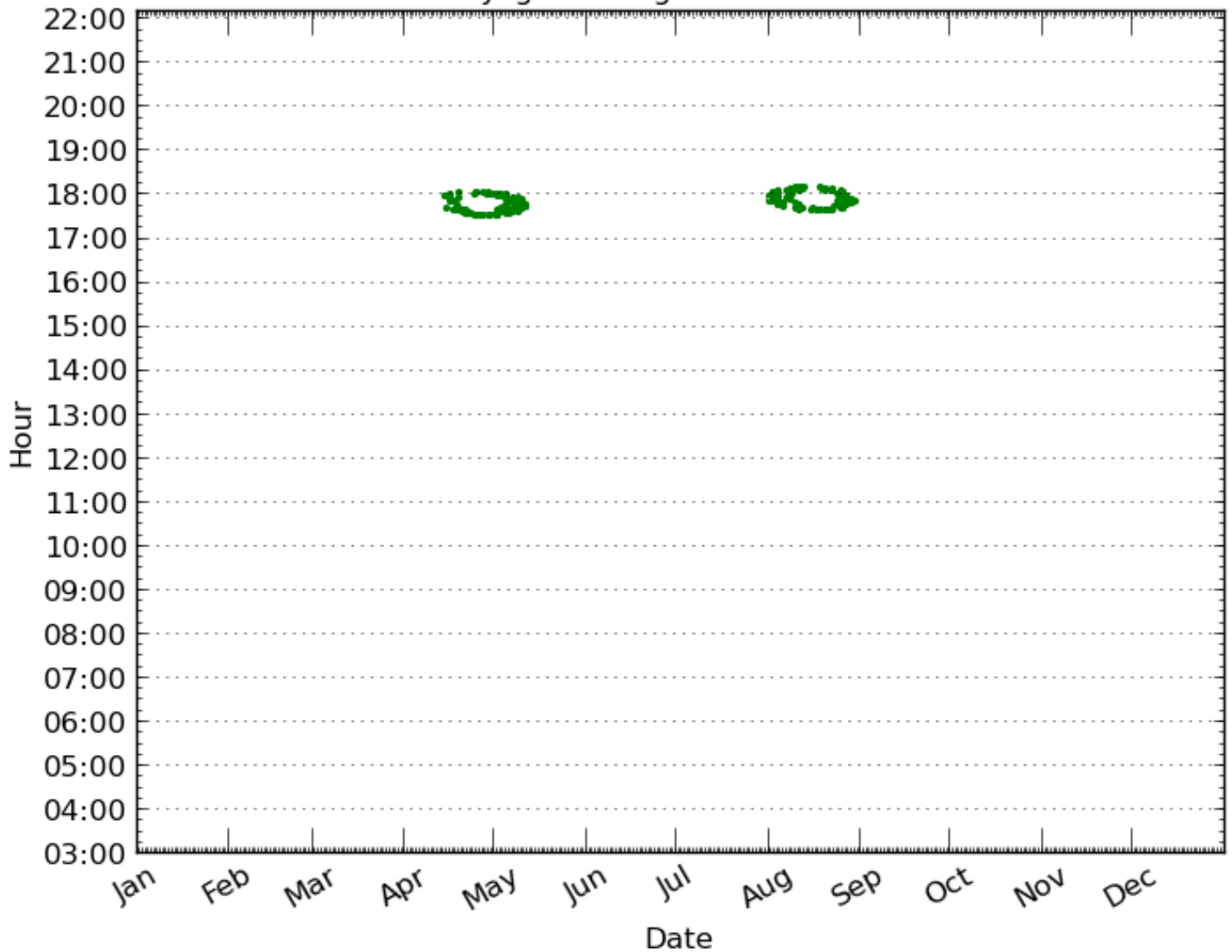
1 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



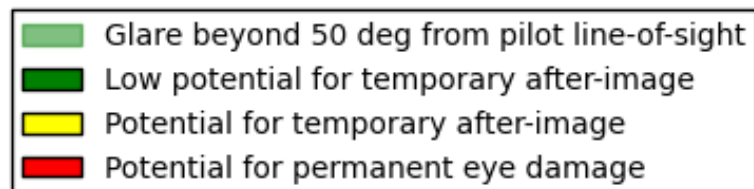
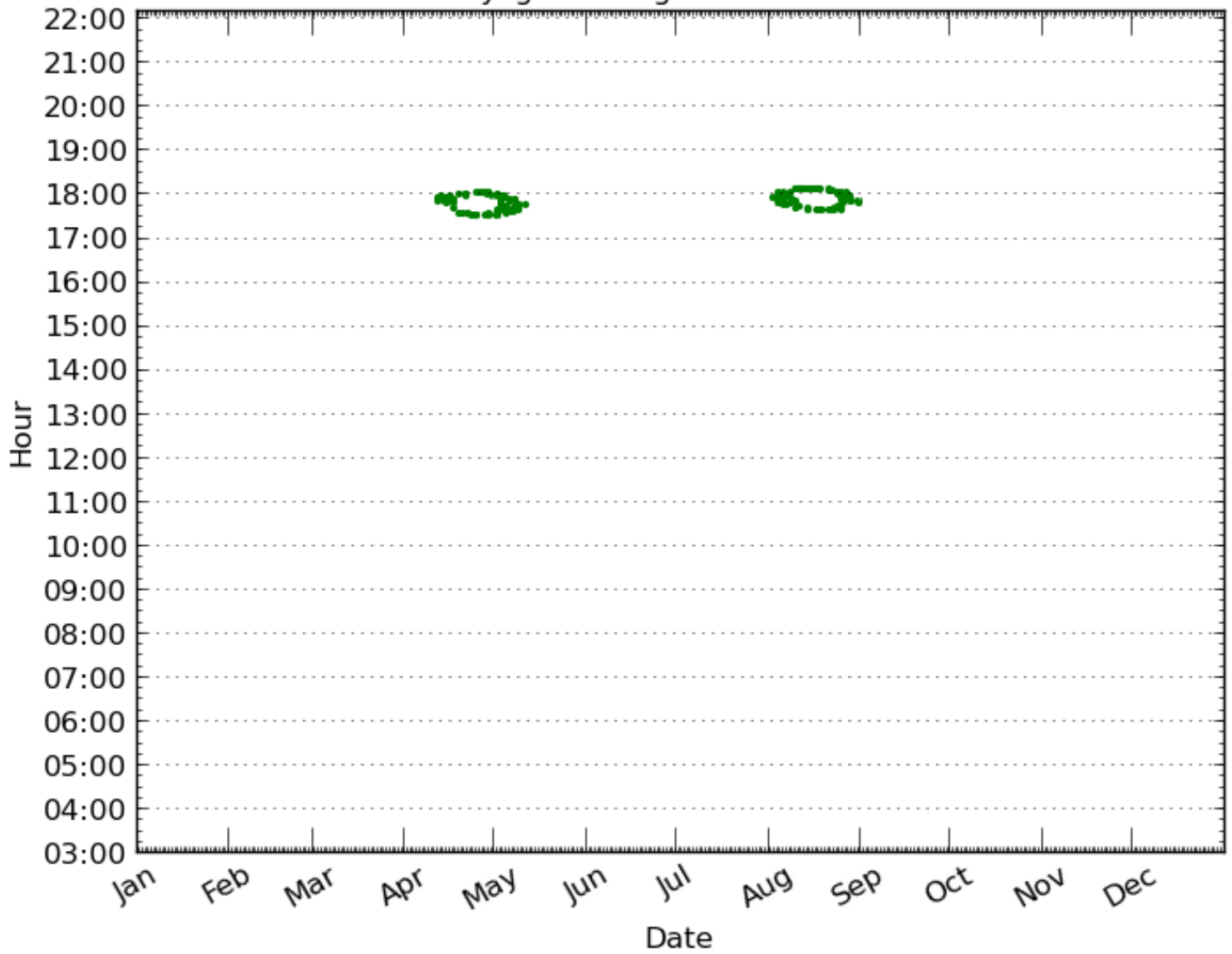
1 1/4 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



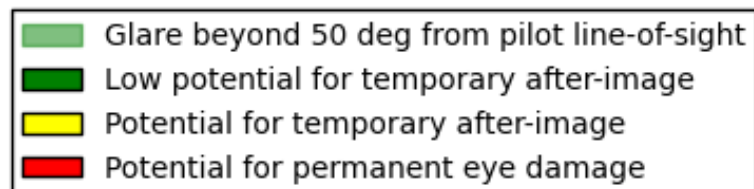
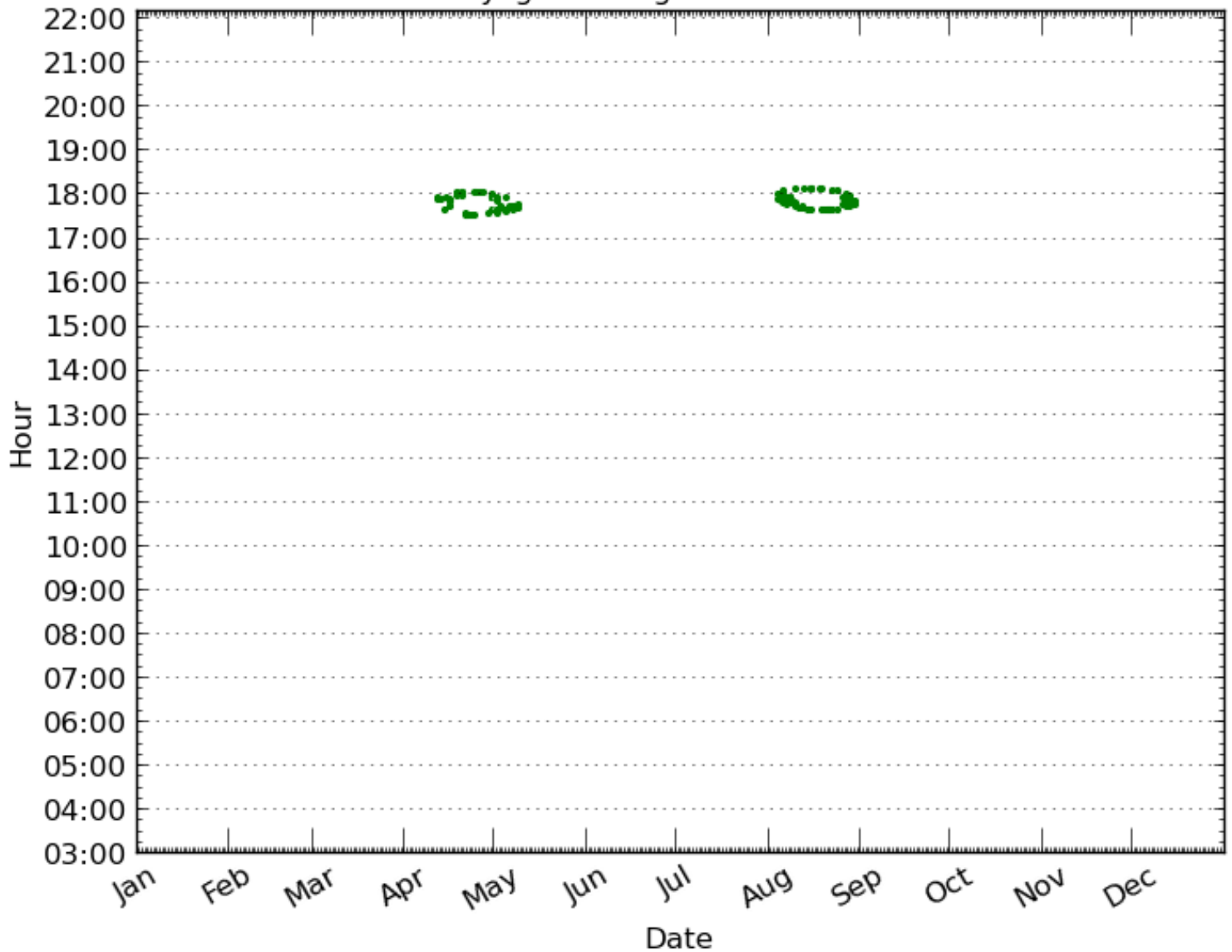
1 1/2 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



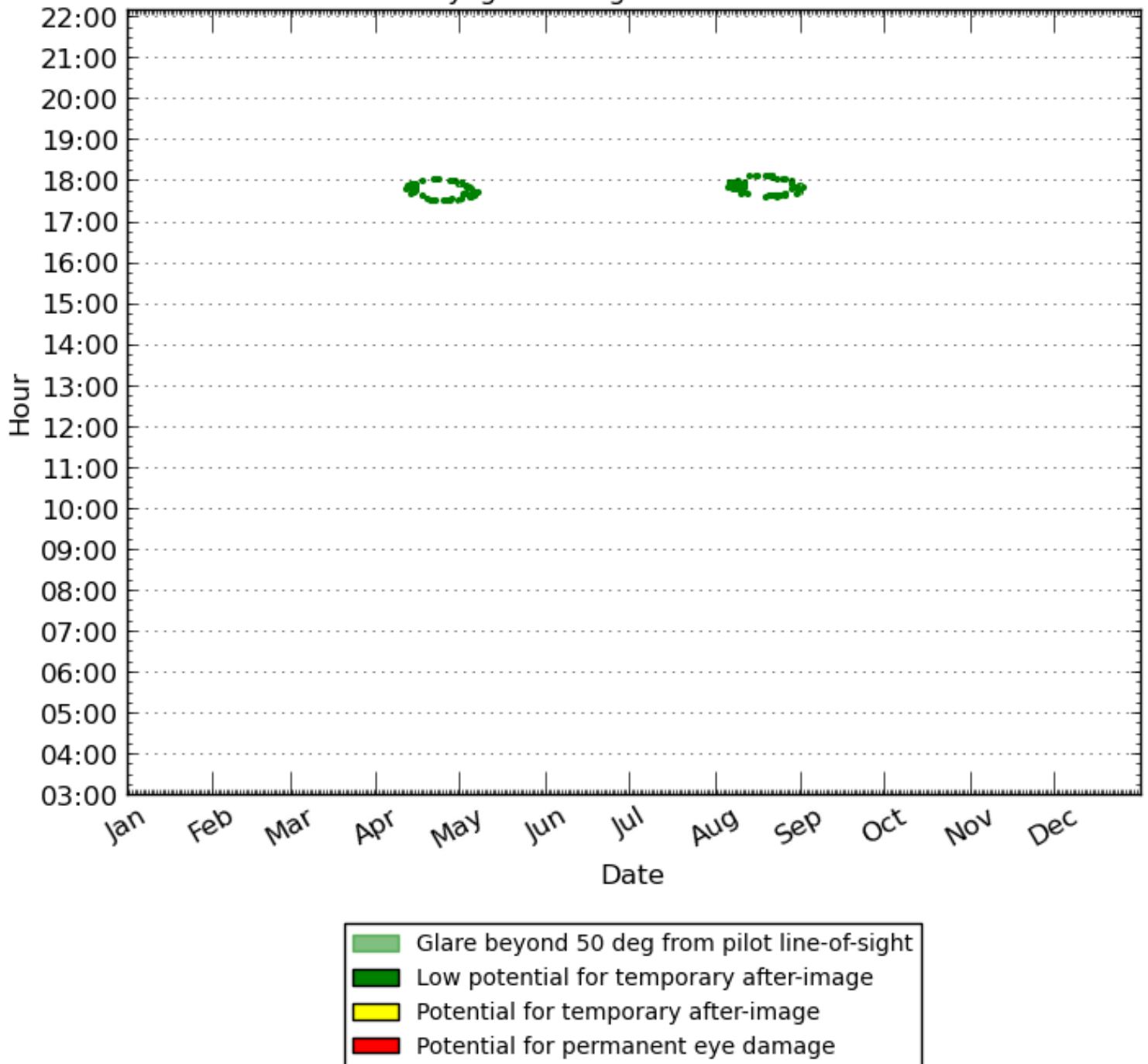
1 3/4 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



2 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



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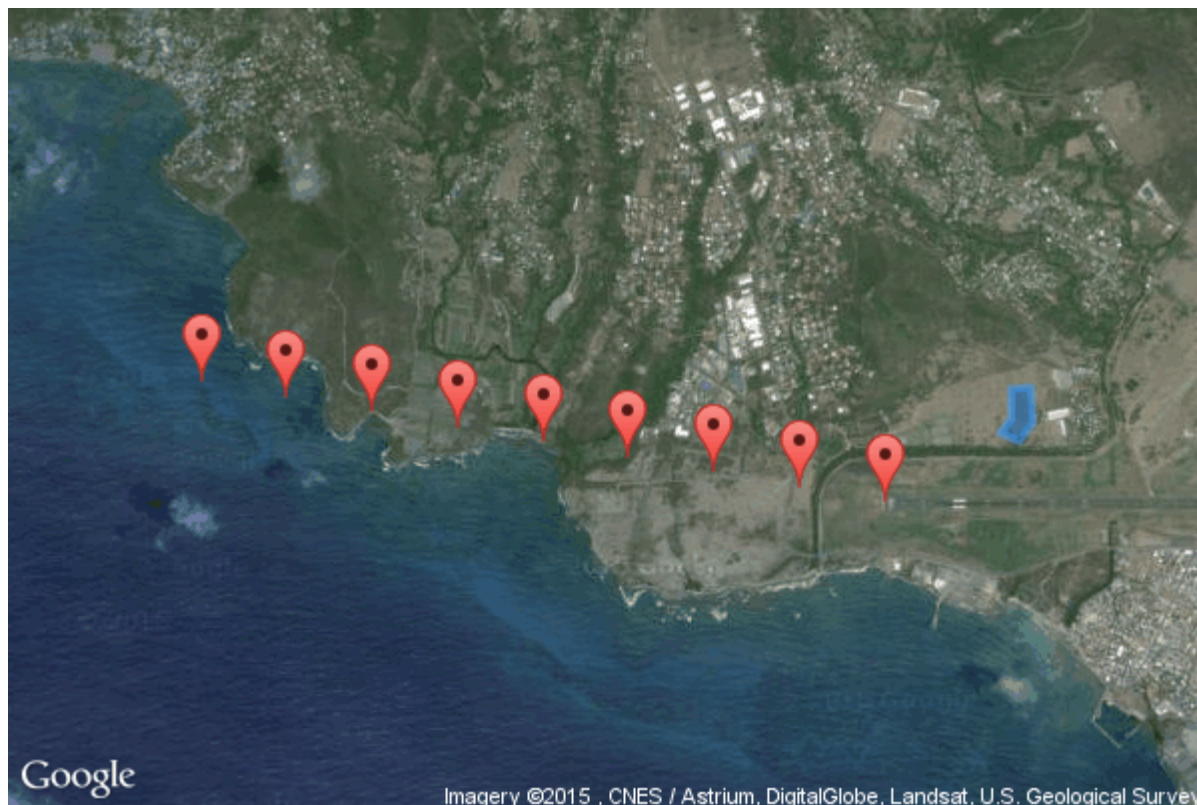
Solar Glare Hazard Analysis Flight Path Report

Generated July 16, 2015, 11:34 a.m.

Flight path: 1

Glare found

 Print



Analysis & PV array parameters

Analysis name	20150716 St Lucia with Input
PV array axis tracking	none
Orientation of array (deg)	180.0
Tilt of solar panels (deg)	12.0
Rated power (kW)	1000.0
Vary reflectivity	True
PV surface material	Smooth glass with ARC

Timezone offset	-4.0
Subtended angle of sun (mrad)	9.3
Peak DNI (W/m ²)	1000.0
Ocular transmission coefficient	0.5
Pupil diameter (m)	0.002
Eye focal length (m)	0.017
Time interval (min)	1
Correlate slope error with material	False
Slope error (mrad)	10.0

Flight path parameters

Direction (deg)	100.0
Glide slope (deg)	3.0
Consider pilot visibility from cockpit	True

Max downward viewing angle (deg)	30.0
Azimuthal viewing angle (deg)	180.0

PV array vertices

id	Latitude (deg)	Longitude (deg)	Ground Elevation (ft)	Height of panels above ground (ft)	Total elevation (ft)
1	13.7362872776	-60.9606456757	36.58	2.0	38.58
2	13.735953774	-60.9598302841	30.45	2.0	32.45
3	13.7367250004	-60.9592294693	42.04	2.0	44.04
4	13.7382049141	-60.9593153	56.94	2.0	58.94
5	13.7381423827	-60.9601736069	53.26	2.0	55.26
6	13.7368917517	-60.9601736069	41.31	2.0	43.31

Flight Path Observation Points

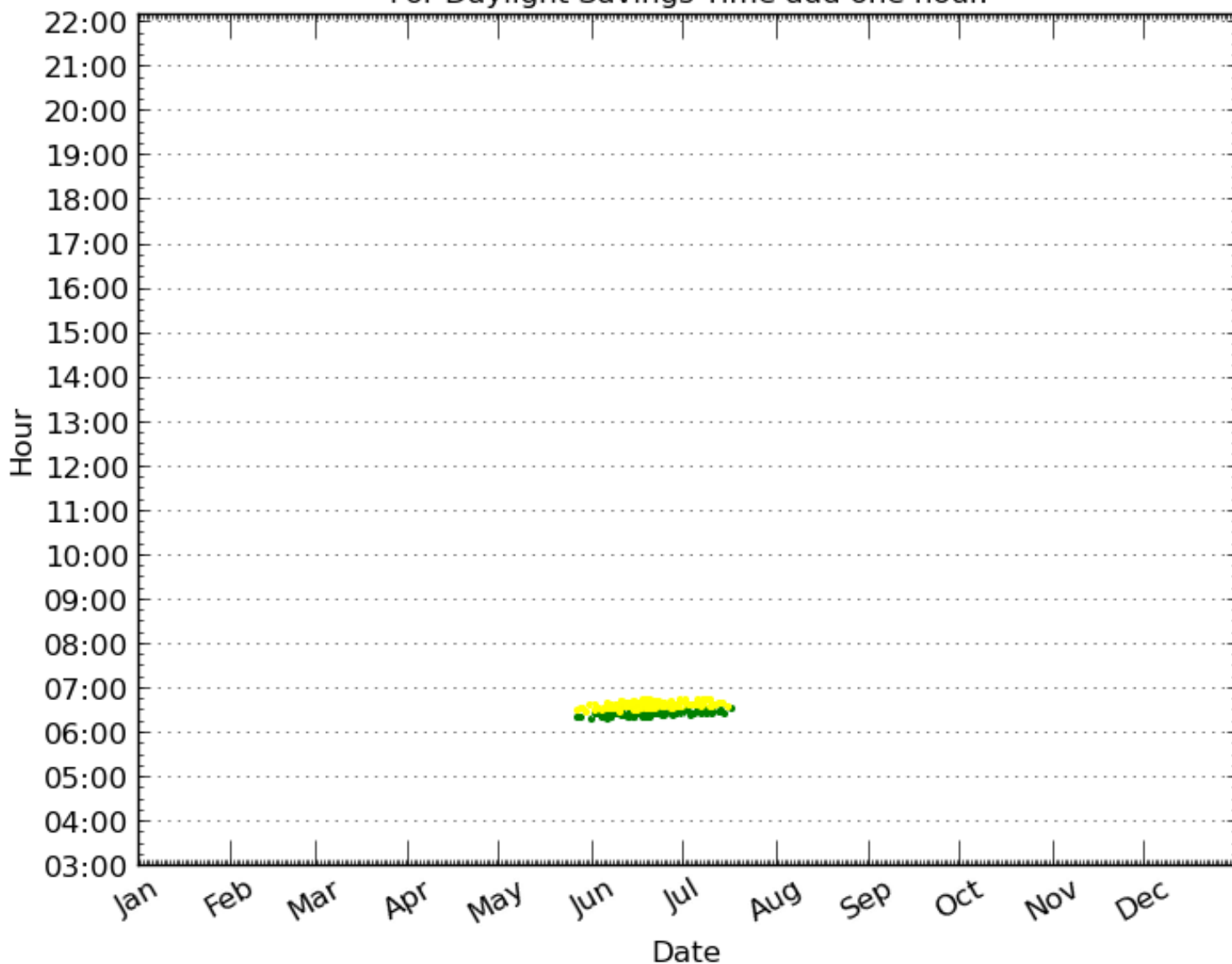
	Latitude (deg)	Longitude (deg)	Ground Elevation (ft)	Eye-level height above ground (ft)	Glare?
Threshold	13.73334034	-60.9655702114	24.65	50.0	Yes
1/4 mi	13.73396786	-60.9692380772	29.17	114.66	Yes
1/2 mi	13.7345953799	-60.972905943	44.94	168.08	Yes
3/4 mi	13.7352228999	-60.9765738089	50.03	232.16	Yes
1 mi	13.7358504199	-60.9802416747	13.69	337.67	Yes
1 1/4 mi	13.7364779399	-60.9839095405	38.72	381.83	Yes
1 1/2 mi	13.7371054599	-60.9875774063	39.04	450.68	Yes
1 3/4 mi	13.7377329798	-60.9912452721	0.59	558.32	Yes
2 mi	13.7383604998	-60.994913138	0.0	628.08	Yes

Glare occurrence plots

All times are in standard time. For Daylight Savings Time add one hour.

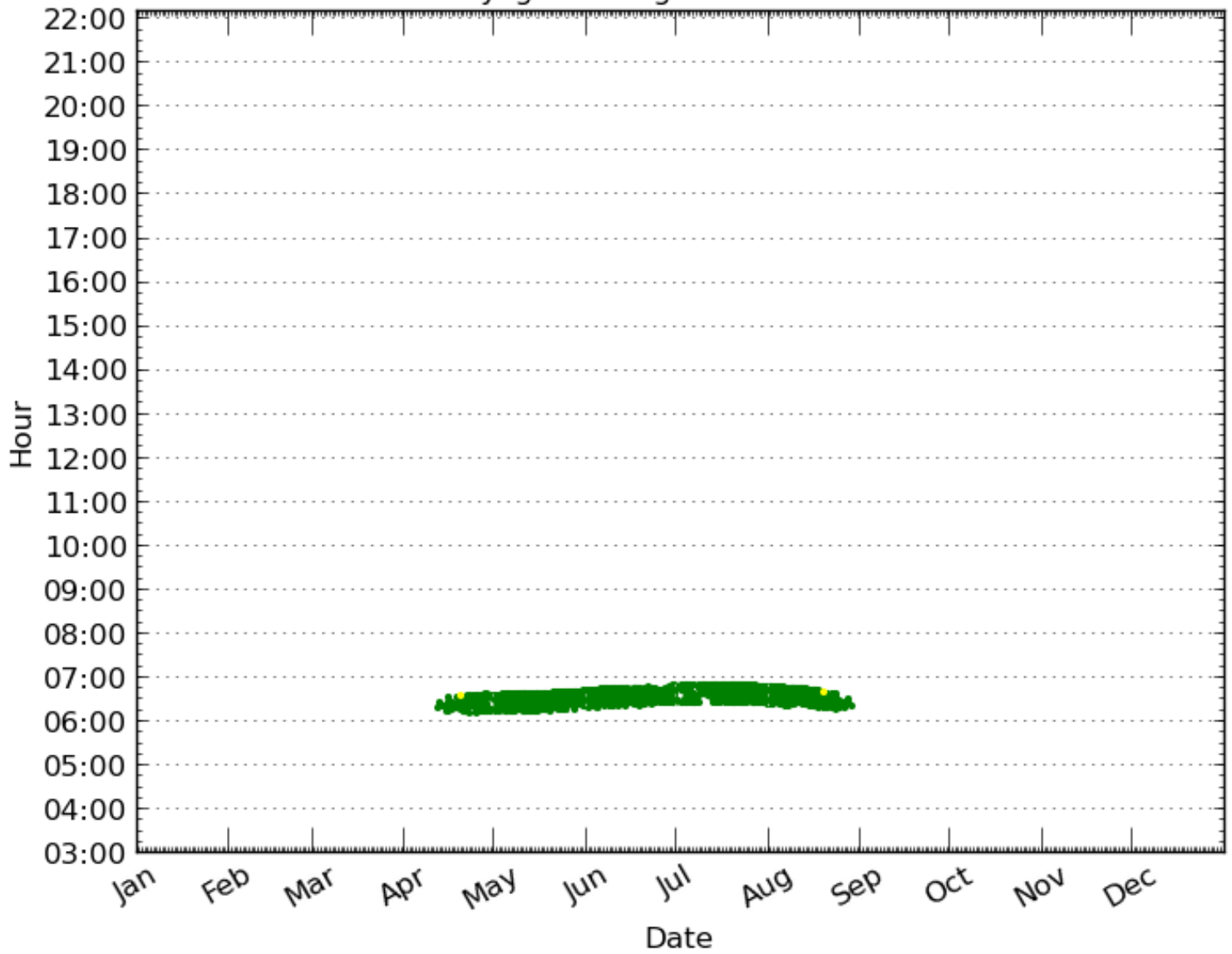
Threshold

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



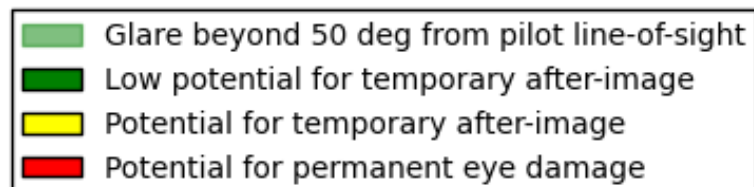
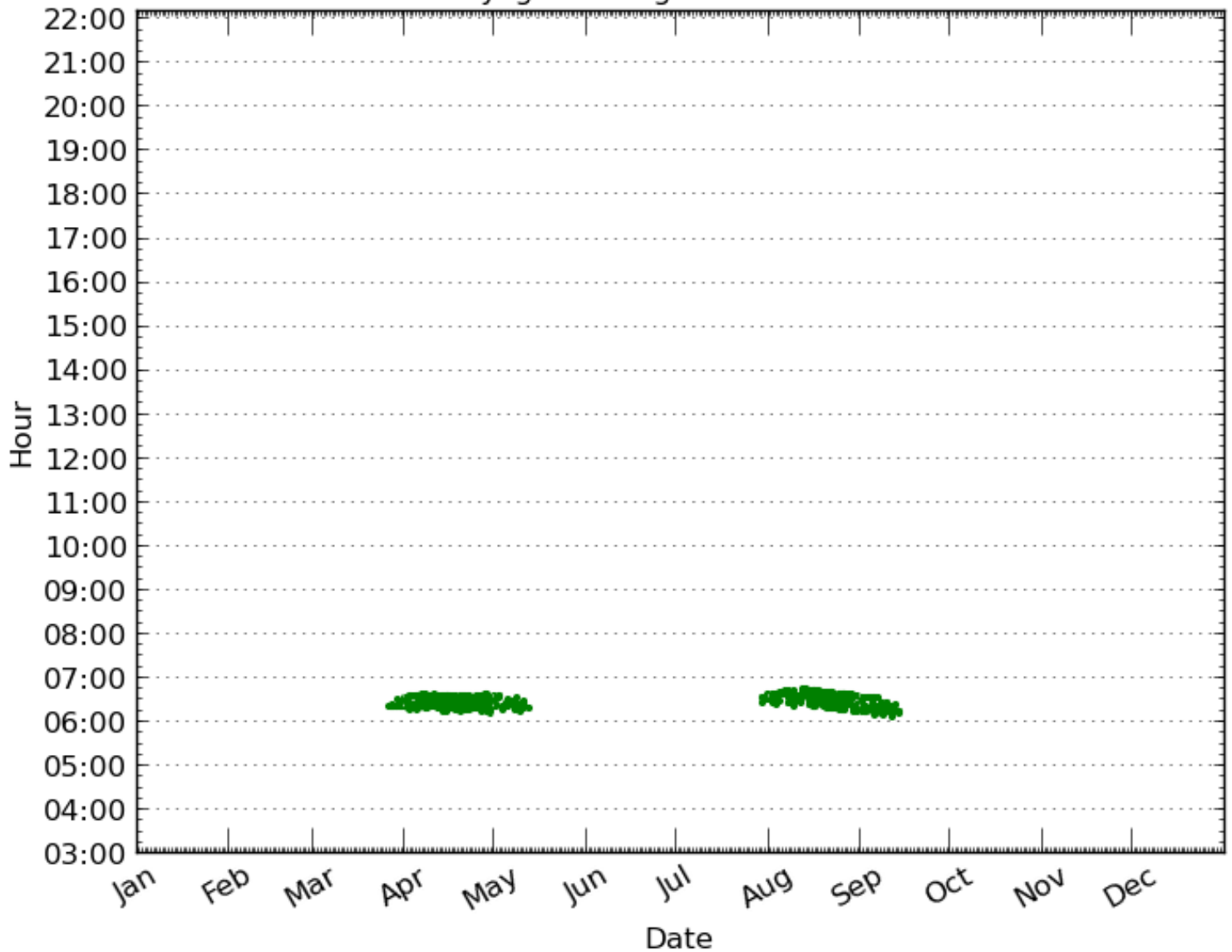
1/4 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



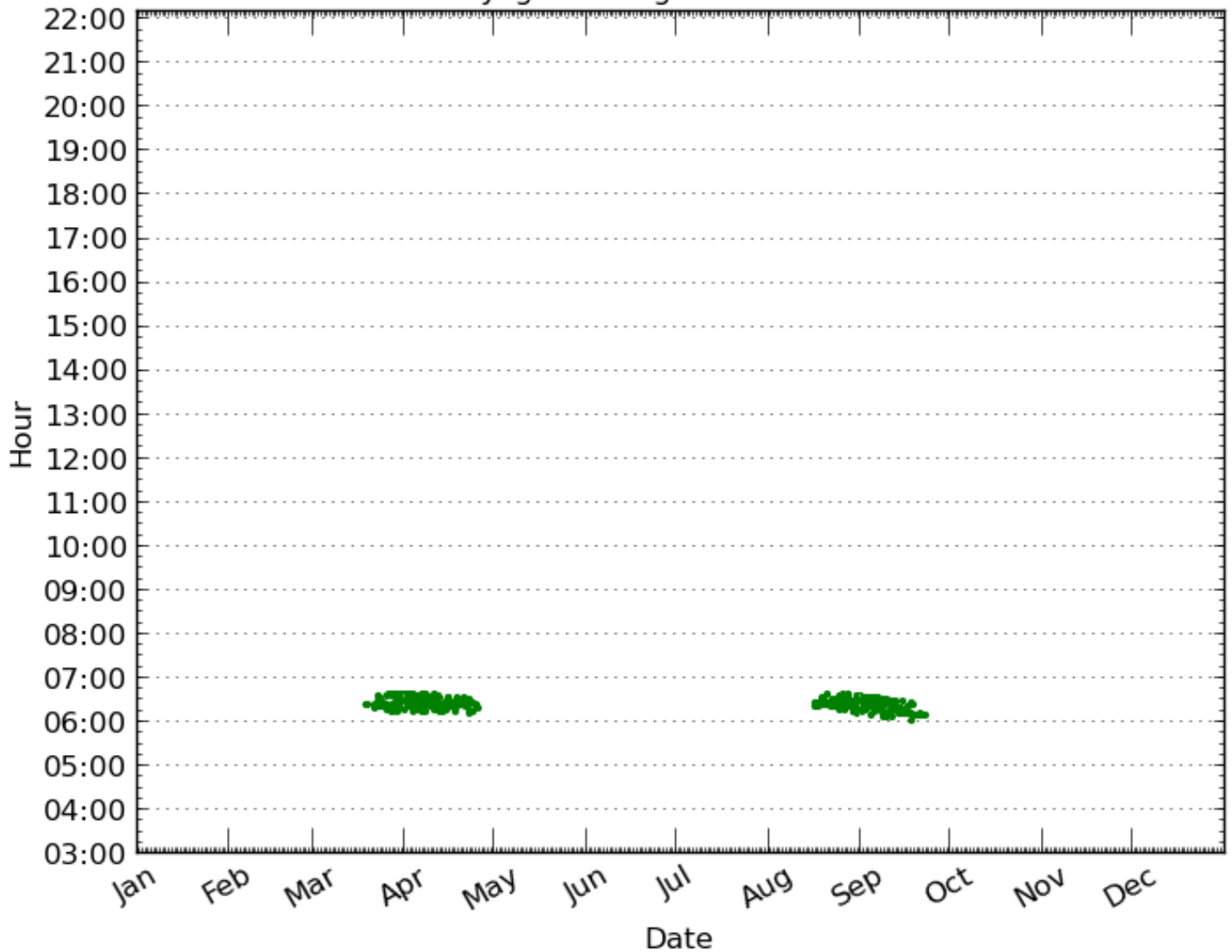
1/2 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



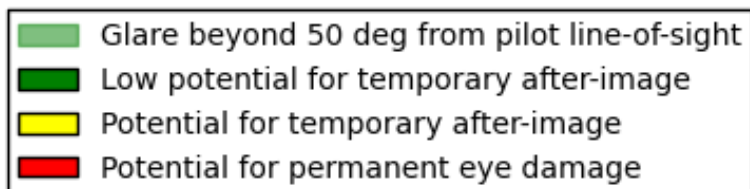
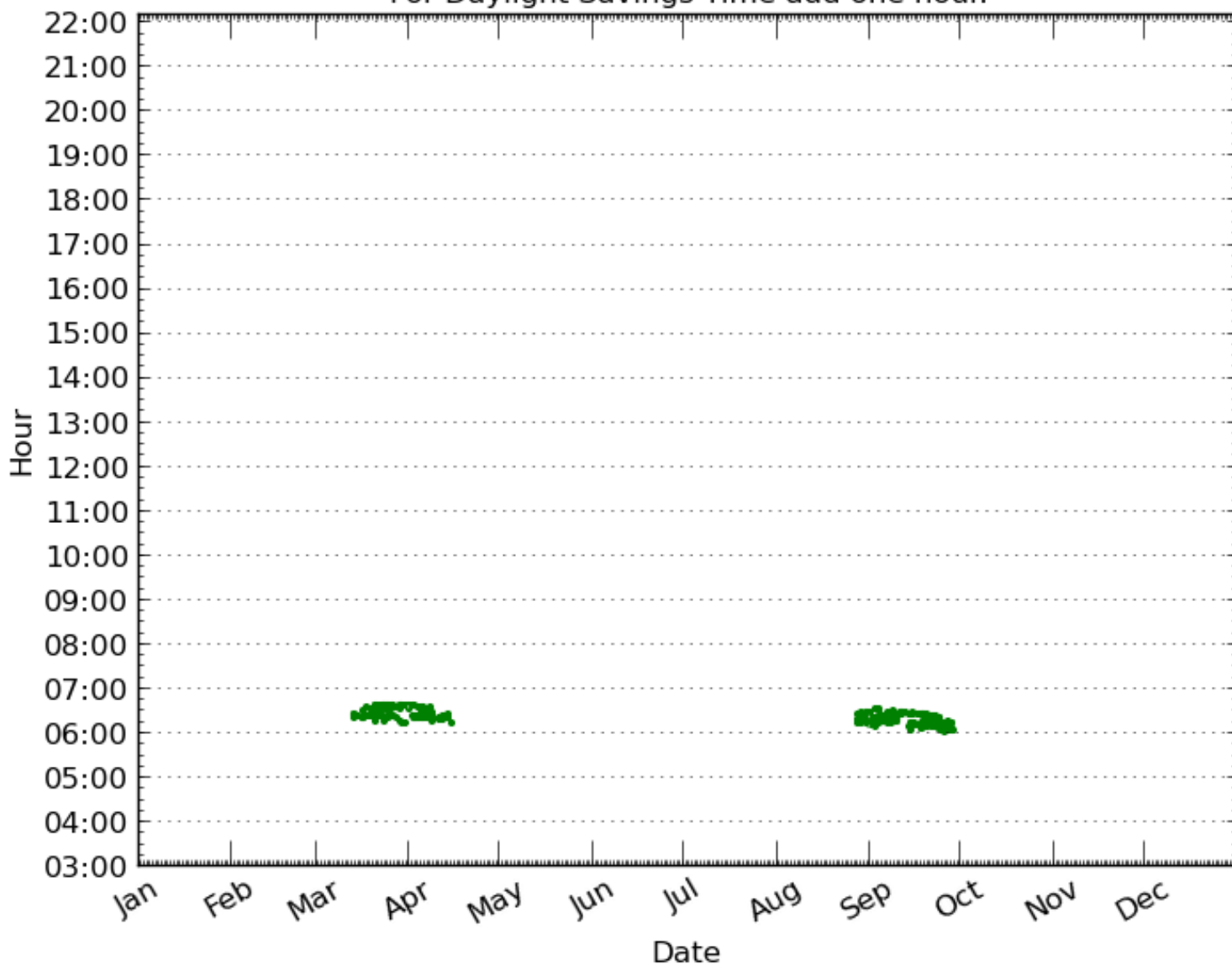
3/4 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



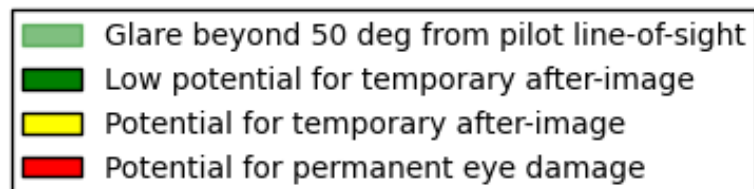
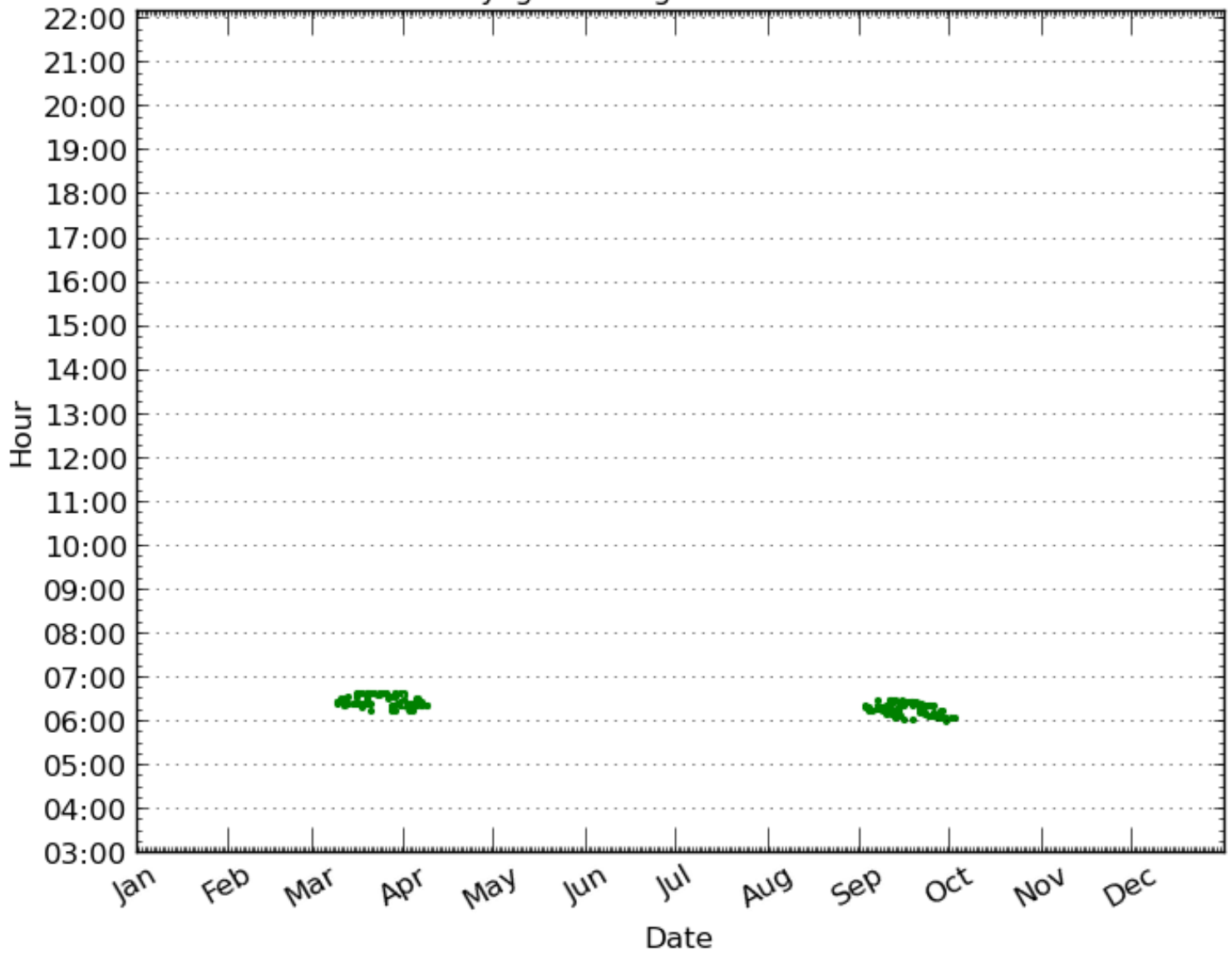
1 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



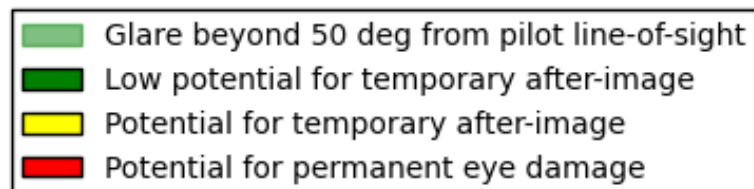
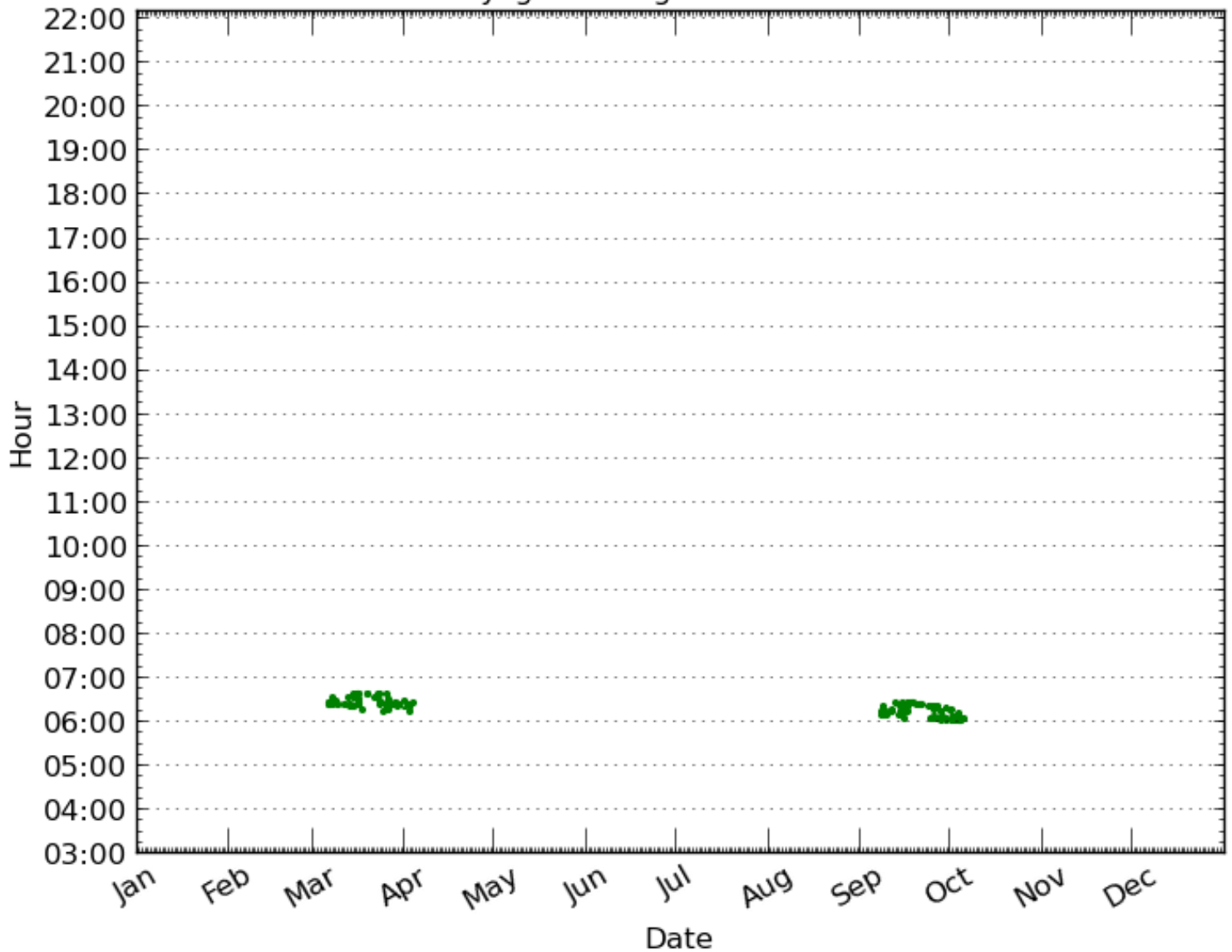
1 1/4 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



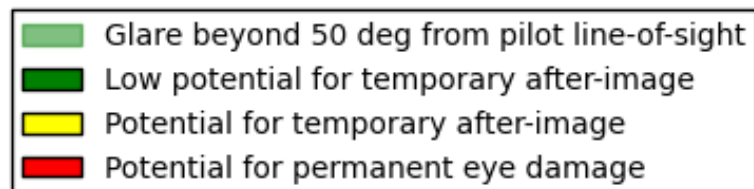
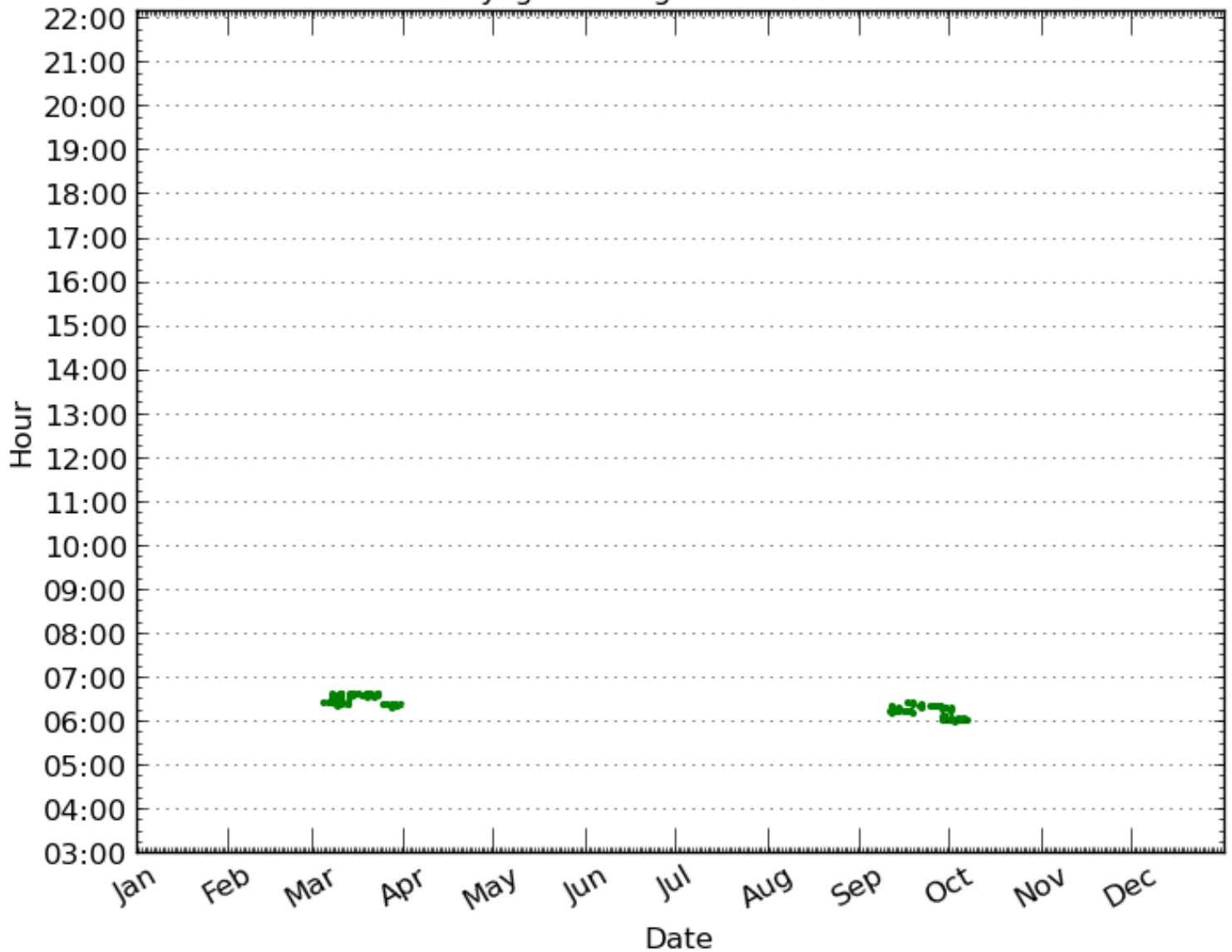
1 1/2 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



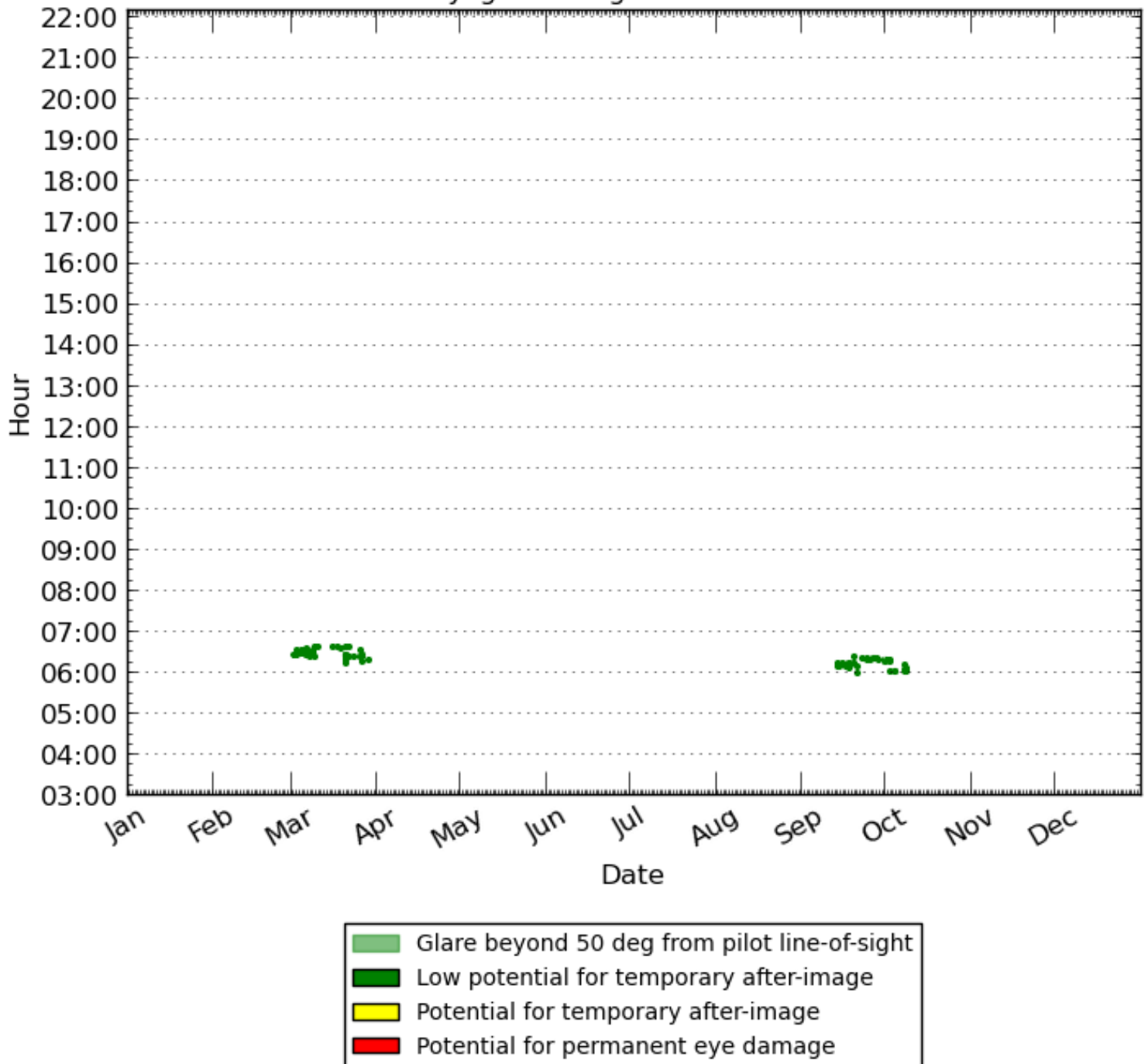
1 3/4 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



2 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



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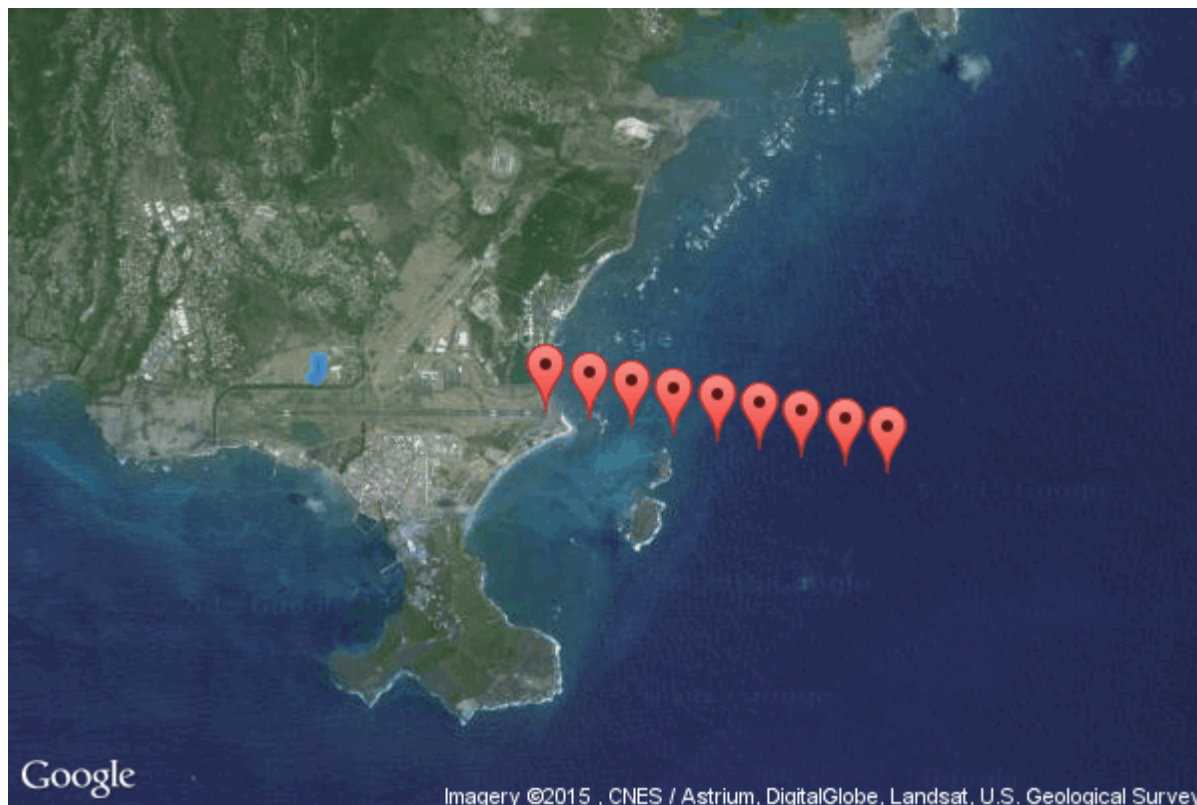
Solar Glare Hazard Analysis Flight Path Report

Generated July 16, 2015, 11:35 a.m.

Flight path: 2

Glare found

 Print



Analysis & PV array parameters

Analysis name	20150716 St Lucia with Input
PV array axis tracking	none
Orientation of array (deg)	180.0
Tilt of solar panels (deg)	12.0
Rated power (kW)	1000.0
Vary reflectivity	True
PV surface material	Smooth glass with ARC

Timezone offset	-4.0
Subtended angle of sun (mrad)	9.3
Peak DNI (W/m ²)	1000.0
Ocular transmission coefficient	0.5
Pupil diameter (m)	0.002
Eye focal length (m)	0.017
Time interval (min)	1
Correlate slope error with material	False
Slope error (mrad)	10.0

Flight path parameters

Direction (deg)	280.0
Glide slope (deg)	3.0
Consider pilot visibility from cockpit	True

Max downward viewing angle (deg)	30.0
Azimuthal viewing angle (deg)	180.0

PV array vertices

id	Latitude (deg)	Longitude (deg)	Ground Elevation (ft)	Height of panels above ground (ft)	Total elevation (ft)
1	13.7362872776	-60.9606456757	36.58	2.0	38.58
2	13.735953774	-60.9598302841	30.45	2.0	32.45
3	13.7367250004	-60.9592294693	42.04	2.0	44.04
4	13.7382049141	-60.9593153	56.94	2.0	58.94
5	13.7381423827	-60.9601736069	53.26	2.0	55.26
6	13.7368917517	-60.9601736069	41.31	2.0	43.31

Flight Path Observation Points

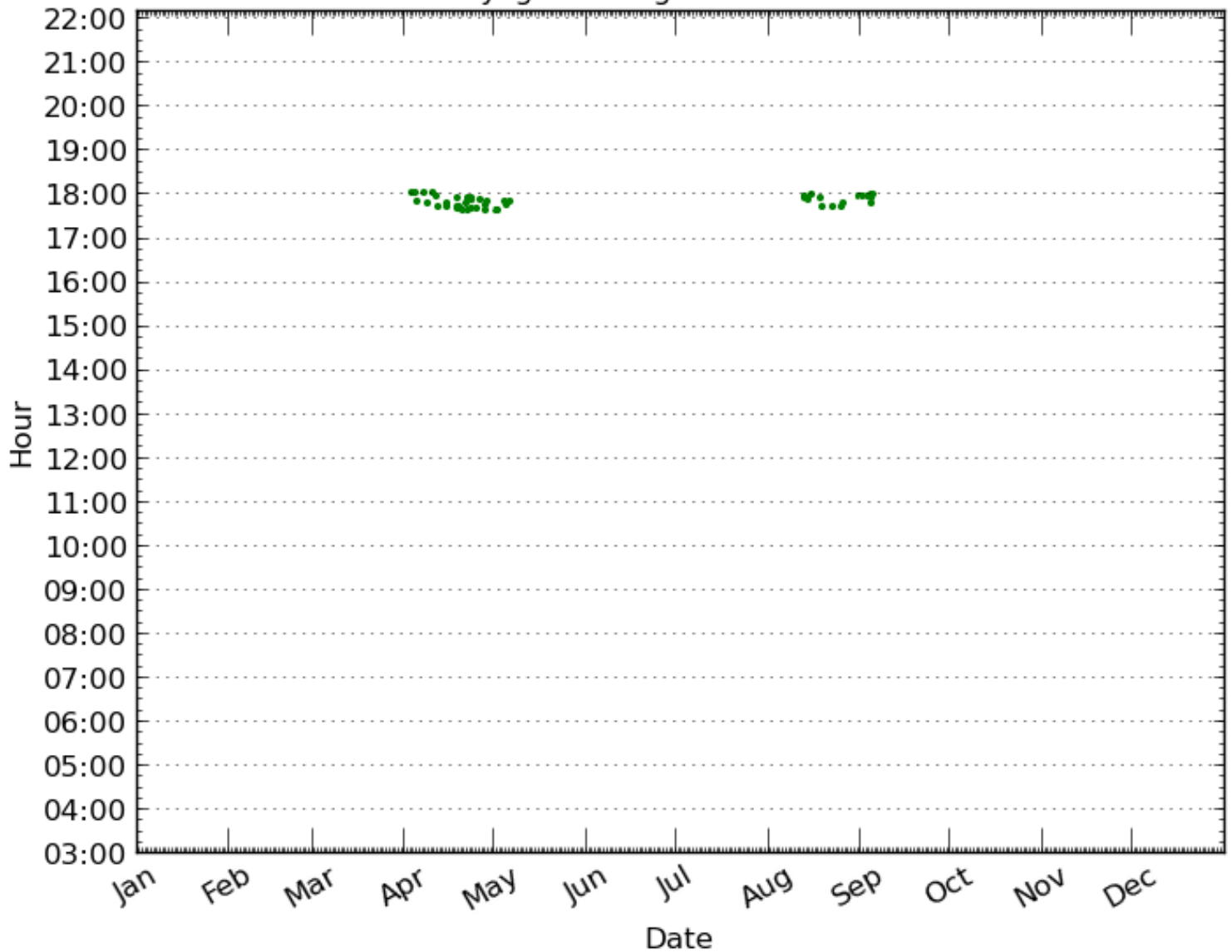
	Latitude (deg)	Longitude (deg)	Ground Elevation (ft)	Eye-level height above ground (ft)	Glare?
Threshold	13.7333090736	-60.9400838614	17.8	50.0	Yes
1/4 mi	13.7326815537	-60.936415996	0.0	136.97	Yes
1/2 mi	13.7320540337	-60.9327481307	0.0	206.16	Yes
3/4 mi	13.7314265137	-60.9290802654	0.0	275.33	Yes
1 mi	13.7307989937	-60.9254124	0.0	344.5	Yes
1 1/4 mi	13.7301714737	-60.9217445347	0.0	413.69	Yes
1 1/2 mi	13.7295439538	-60.9180766694	0.0	482.86	Yes
1 3/4 mi	13.7289164338	-60.9144088041	0.0	552.05	Yes
2 mi	13.7282889138	-60.9107409387	0.0	621.22	Yes

Glare occurrence plots

All times are in standard time. For Daylight Savings Time add one hour.

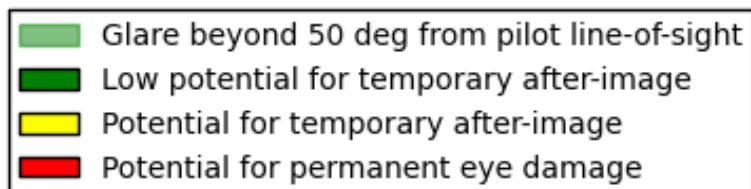
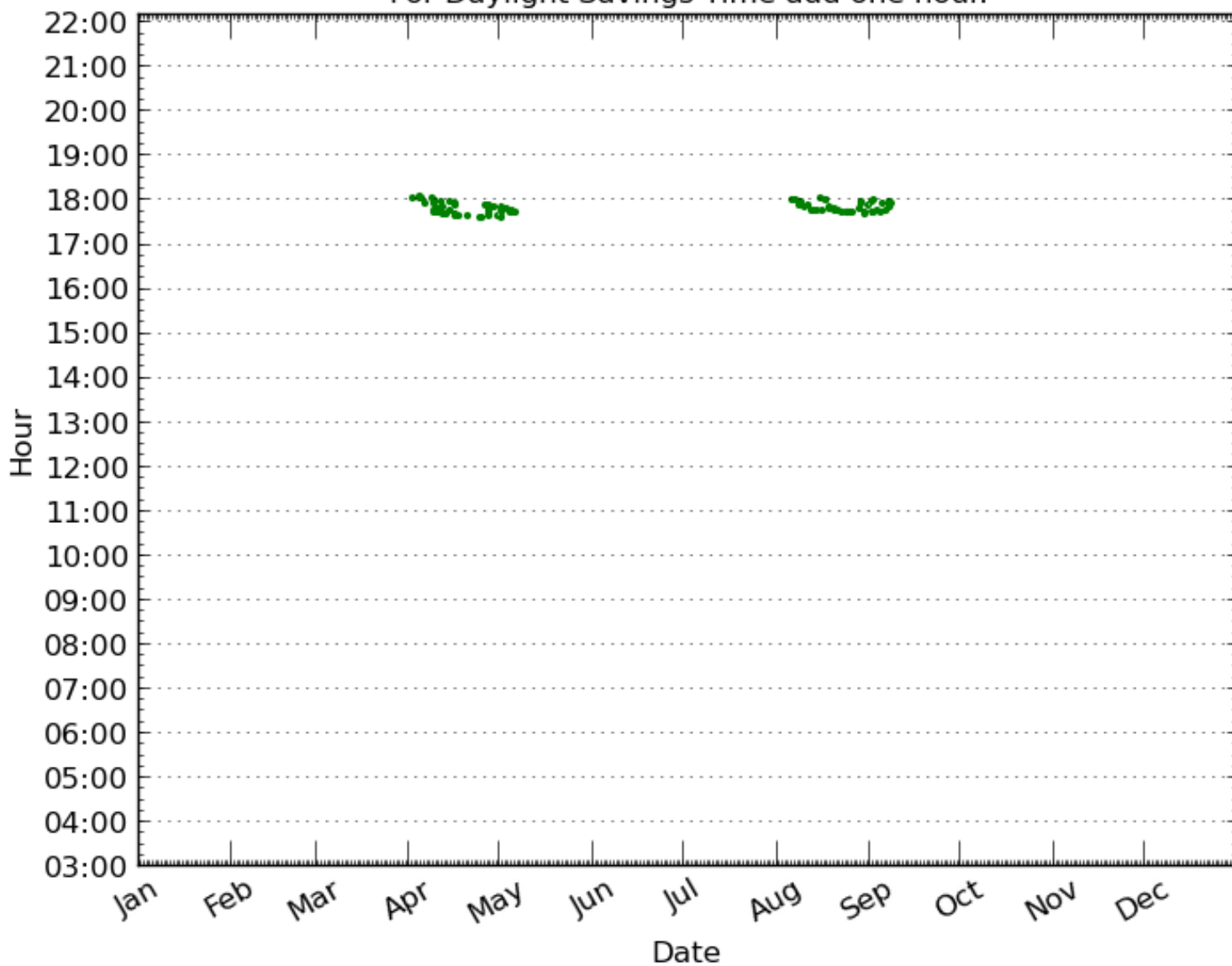
Threshold

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



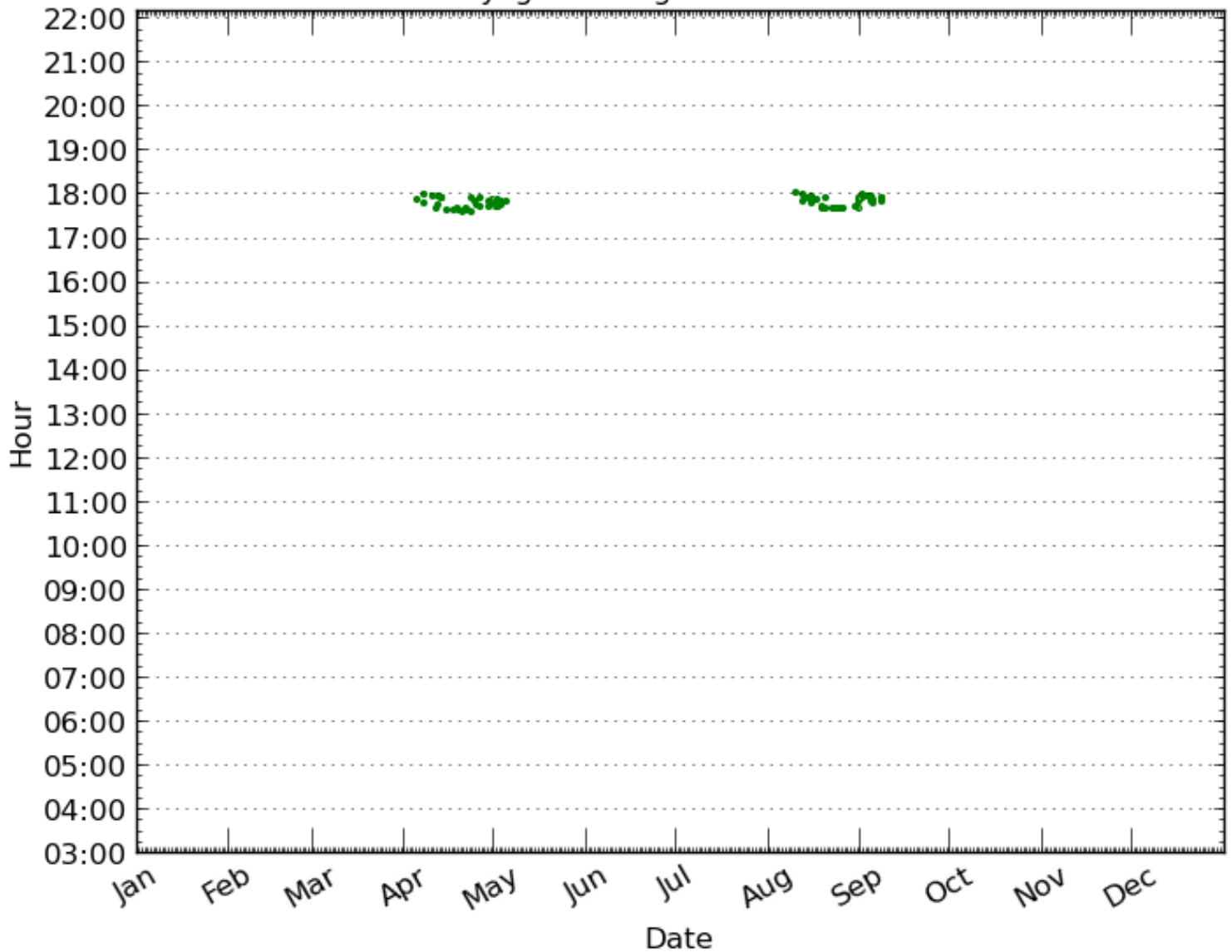
1/4 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



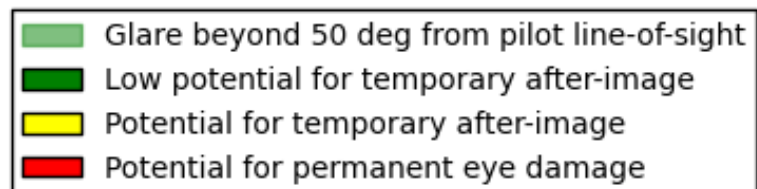
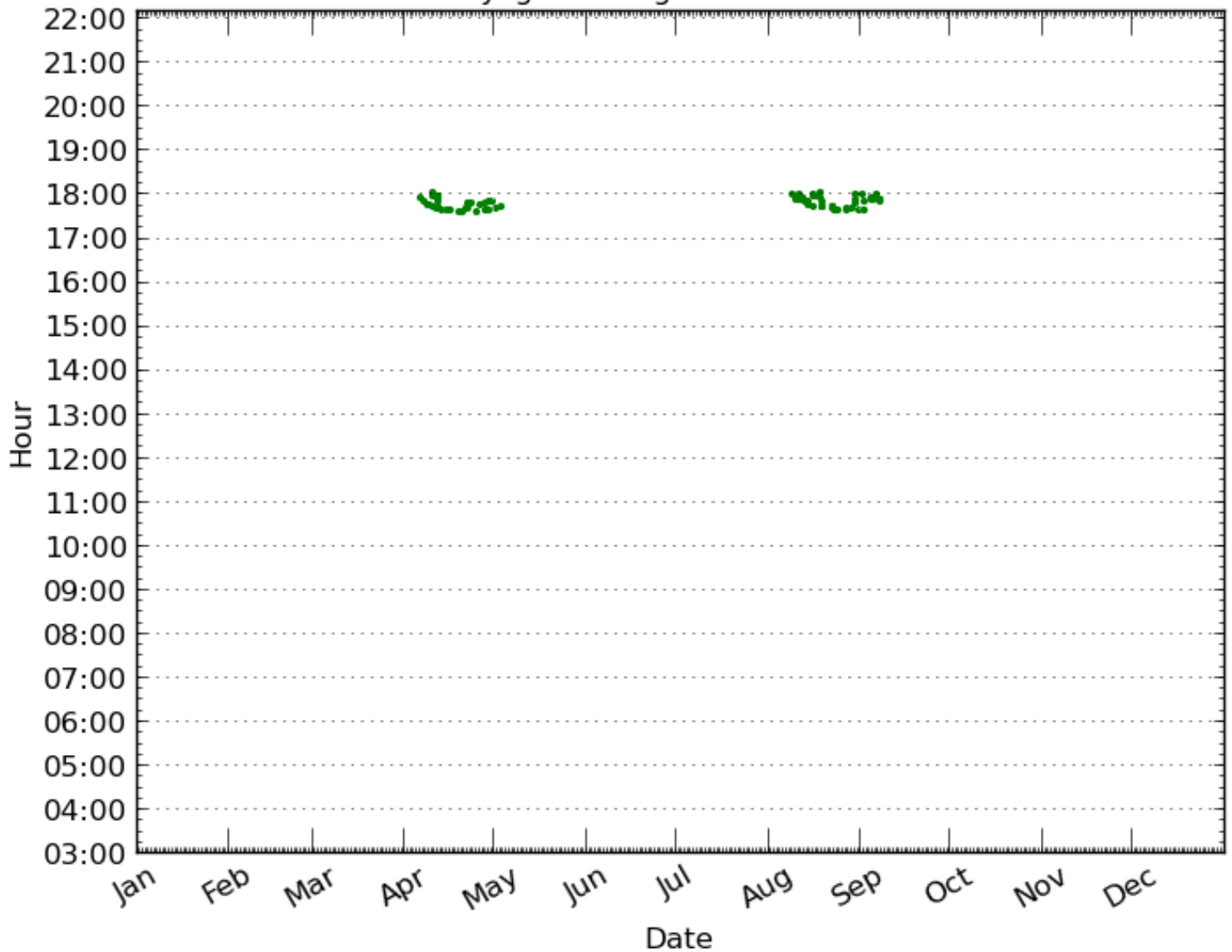
1/2 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



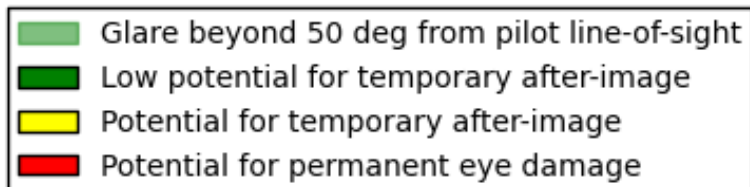
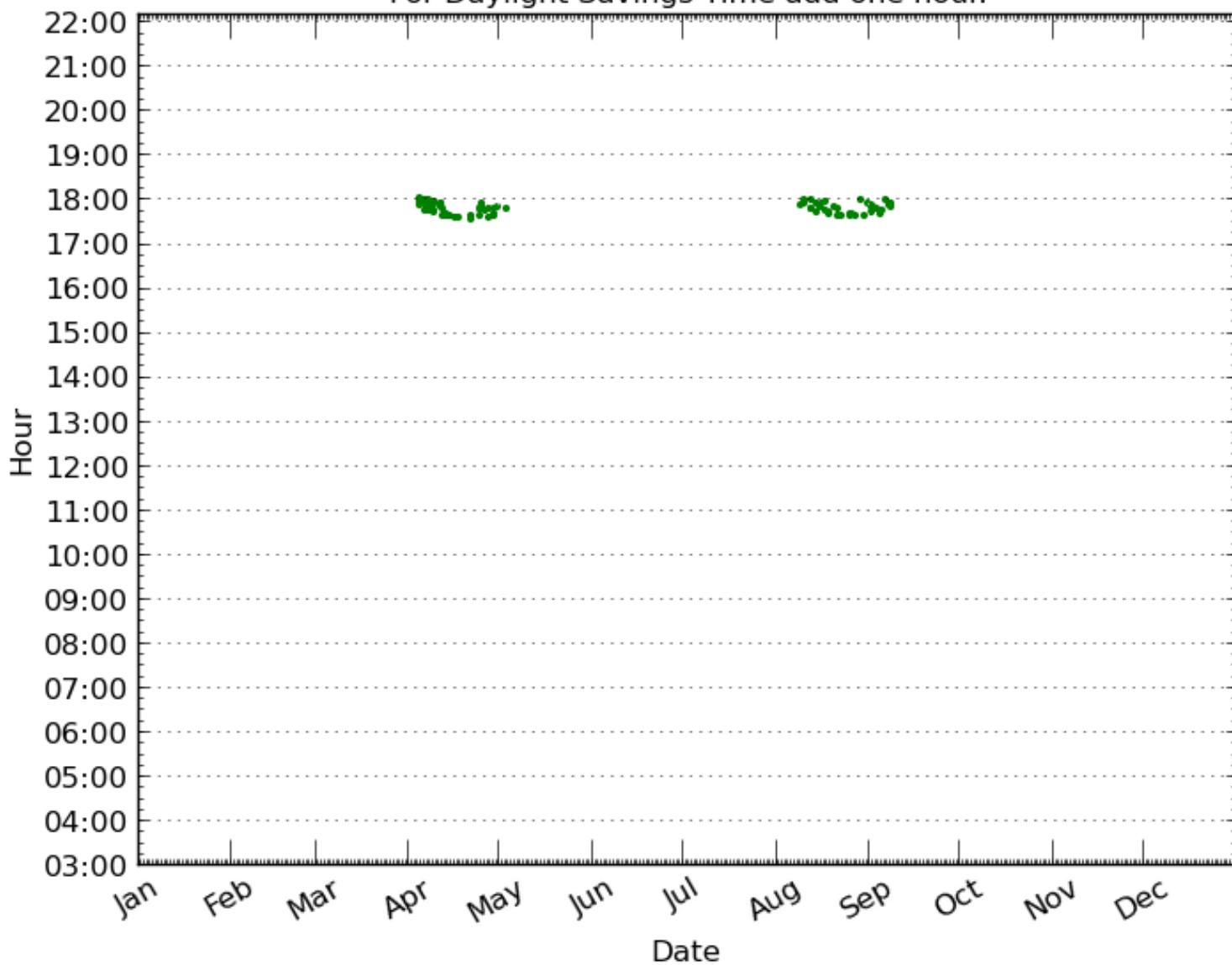
3/4 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



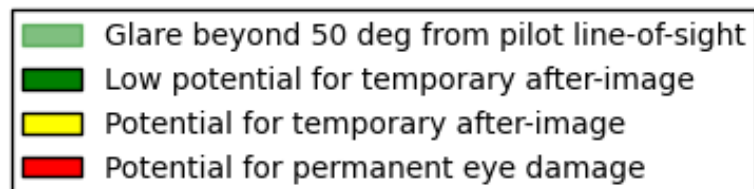
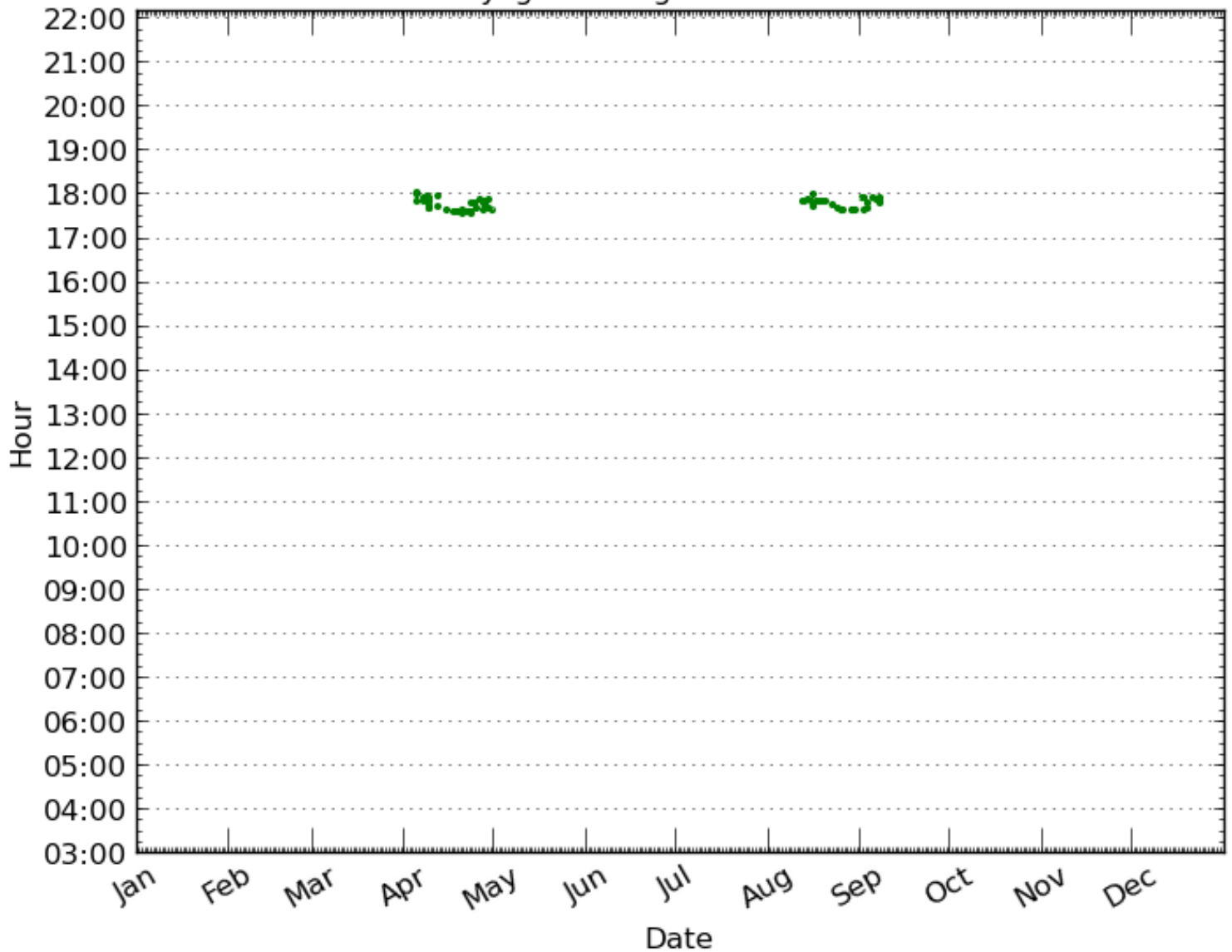
1 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



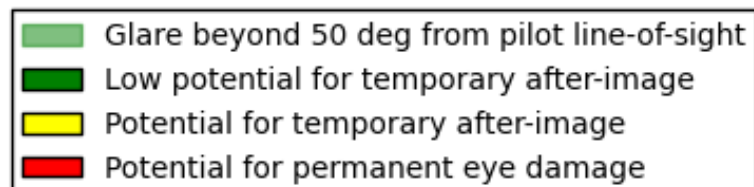
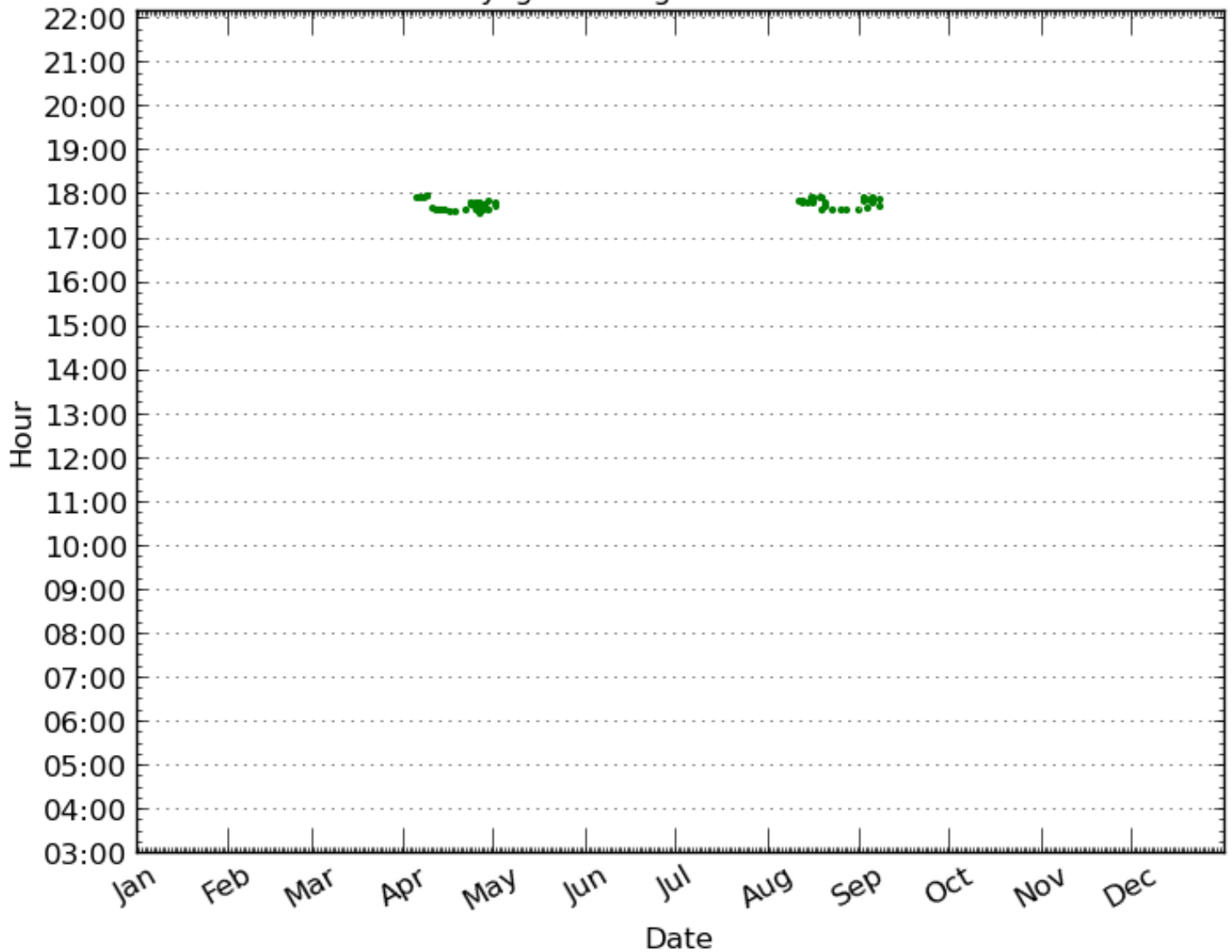
1 1/4 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



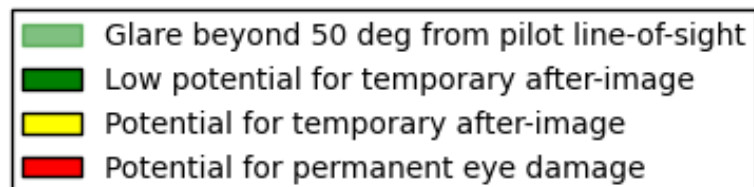
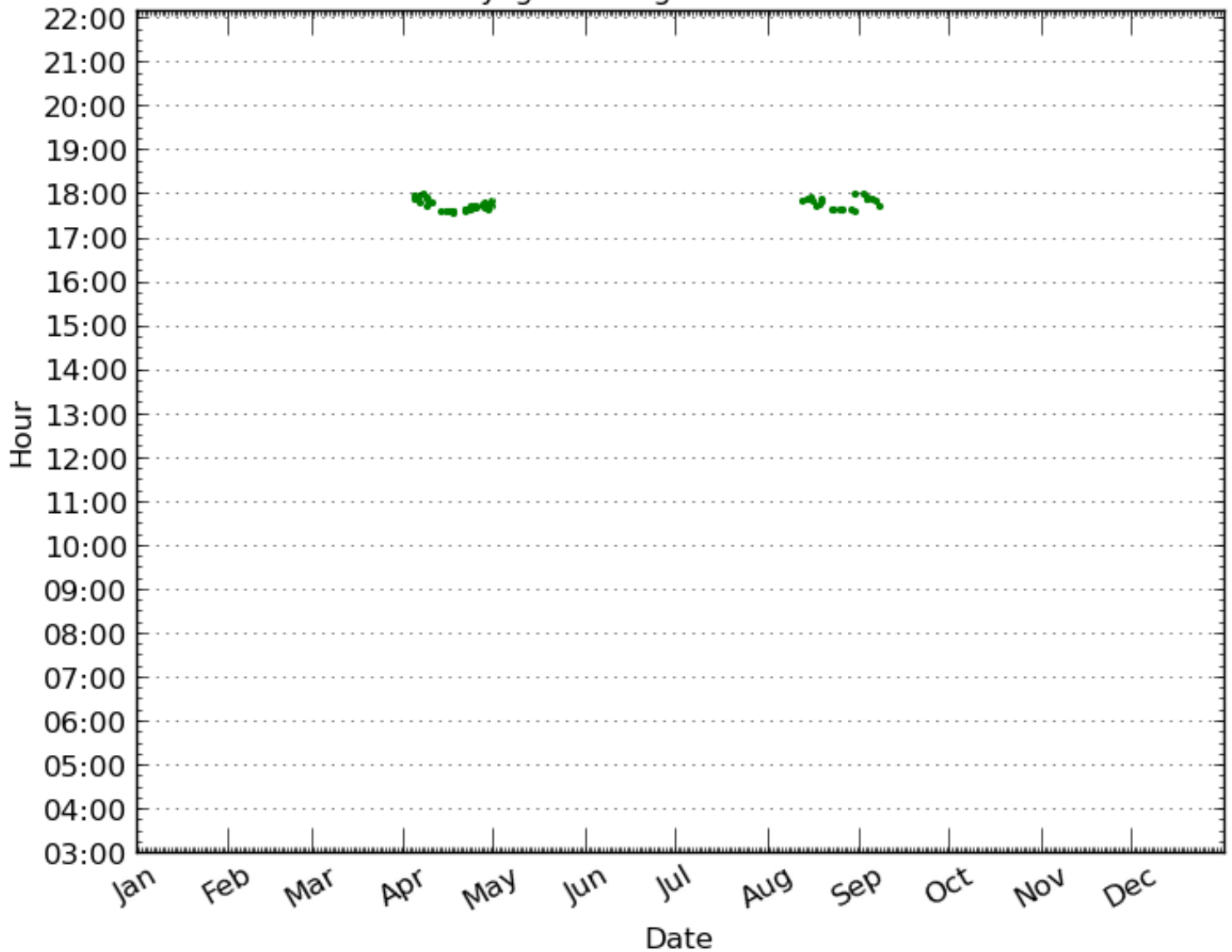
1 1/2 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



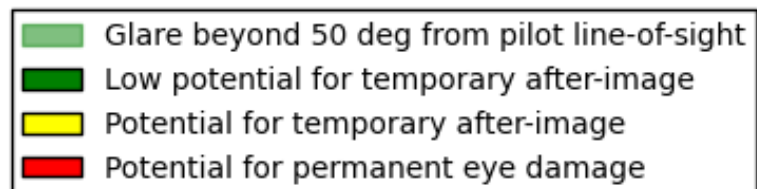
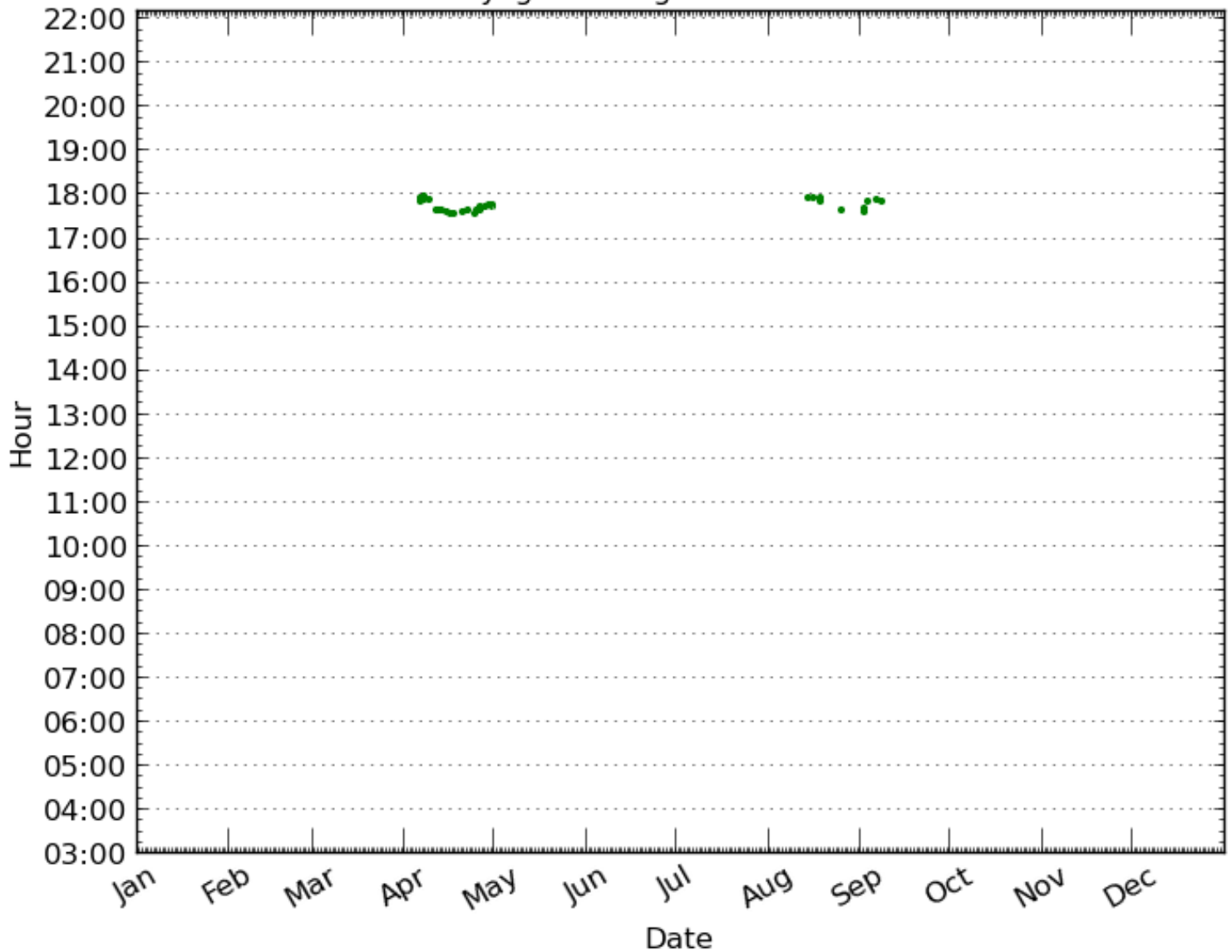
1 3/4 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



2 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



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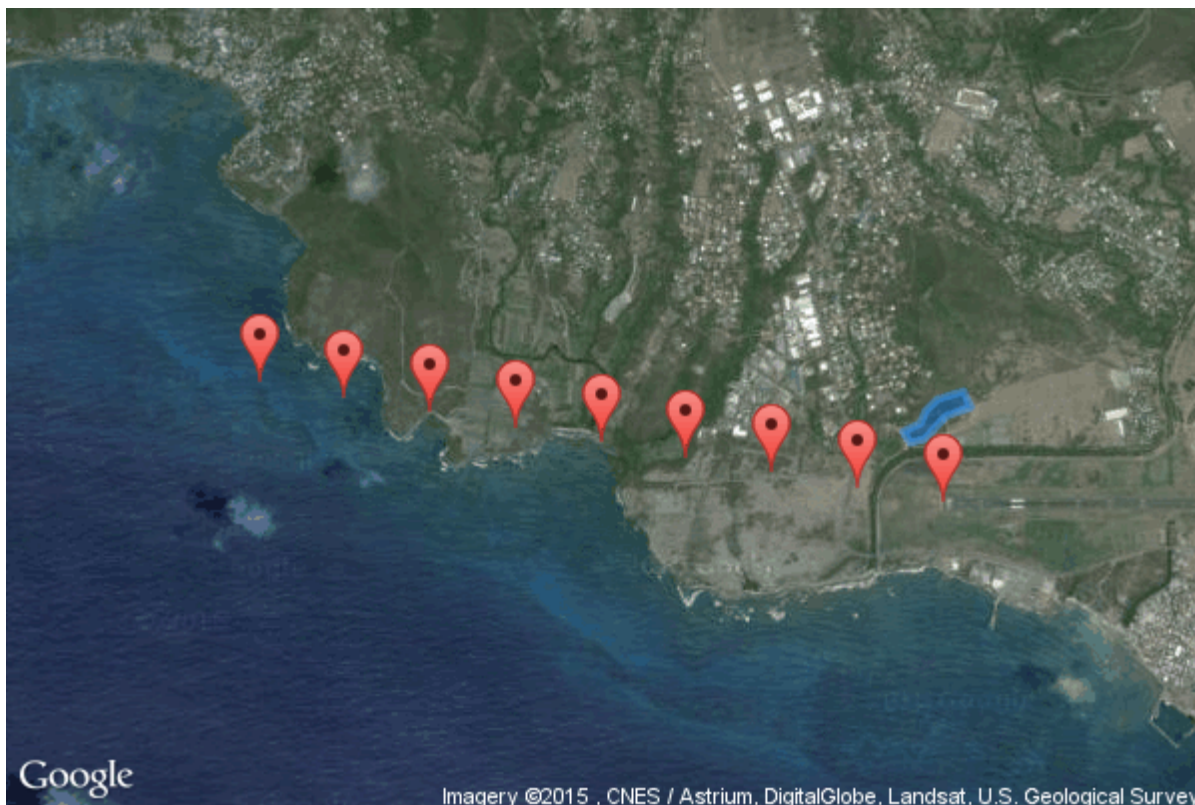
Solar Glare Hazard Analysis Flight Path Report

Generated July 16, 2015, 11:35 a.m.

Flight path: 1

Glare found

 Print



Analysis & PV array parameters

Analysis name	20150716 St Lucia with Input
PV array axis tracking	none
Orientation of array (deg)	180.0
Tilt of solar panels (deg)	12.0
Rated power (kW)	1000.0
Vary reflectivity	True
PV surface material	Smooth glass with ARC

Timezone offset	-4.0
Subtended angle of sun (mrad)	9.3
Peak DNI (W/m ²)	1000.0
Ocular transmission coefficient	0.5
Pupil diameter (m)	0.002
Eye focal length (m)	0.017
Time interval (min)	1
Correlate slope error with material	False
Slope error (mrad)	10.0

Flight path parameters

Direction (deg)	100.0
Glide slope (deg)	3.0
Consider pilot visibility from cockpit	True

Max downward viewing angle (deg)	30.0
Azimuthal viewing angle (deg)	180.0

PV array vertices

id	Latitude (deg)	Longitude (deg)	Ground Elevation (ft)	Height of panels above ground (ft)	Total elevation (ft)
1	13.7358912421	-60.9669756889	29.59	2.0	31.59
2	13.7363498095	-60.967297554	36.3	2.0	38.3
3	13.7367041564	-60.9665465355	52.95	2.0	54.95
4	13.7372252539	-60.9663319588	78.2	2.0	80.2
5	13.7377046626	-60.9658169746	94.58	2.0	96.58
6	13.7380381637	-60.9647011757	64.11	2.0	66.11
7	13.737371161	-60.9644007683	43.73	2.0	45.73
8	13.7370168151	-60.9654521942	50.55	2.0	52.55
9	13.736057994	-60.9663748741	31.47	2.0	33.47

Flight Path Observation Points

	Latitude (deg)	Longitude (deg)	Ground Elevation (ft)	Eye-level height above ground (ft)	Glare?
Threshold	13.73334034	-60.9655702114	24.65	50.0	No
1/4 mi	13.73396786	-60.9692380772	29.17	114.66	No
1/2 mi	13.7345953799	-60.972905943	44.94	168.08	Yes
3/4 mi	13.7352228999	-60.9765738089	50.03	232.16	Yes
1 mi	13.7358504199	-60.9802416747	13.69	337.67	Yes
1 1/4 mi	13.7364779399	-60.9839095405	38.72	381.83	Yes
1 1/2 mi	13.7371054599	-60.9875774063	39.04	450.68	Yes

1 3/4 mi	13.7377329798	-60.9912452721	0.59	558.32	Yes
2 mi	13.7383604998	-60.994913138	0.0	628.08	Yes

Glare occurrence plots

All times are in standard time. For Daylight Savings Time add one hour.

Threshold

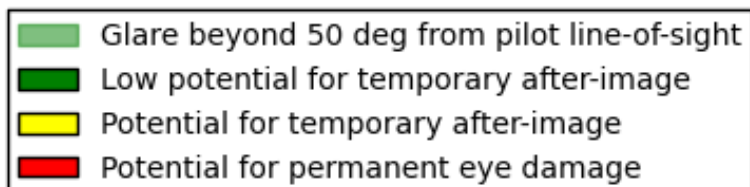
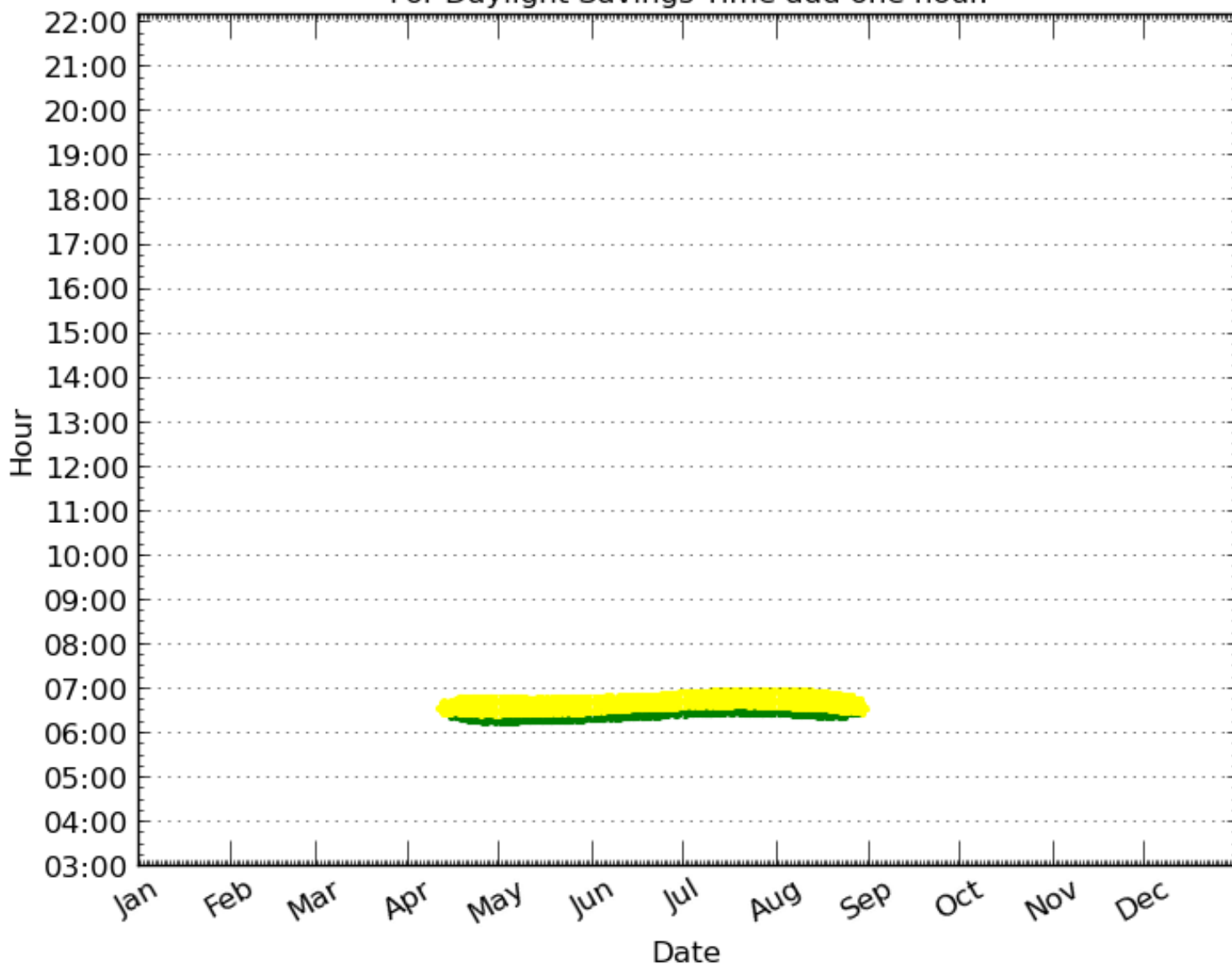
No glare

1/4 mi

No glare

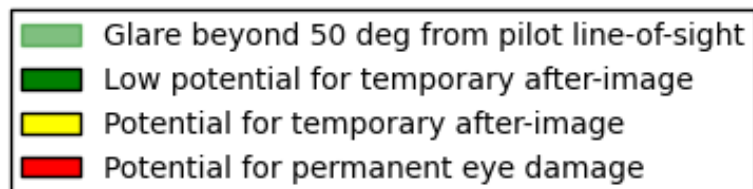
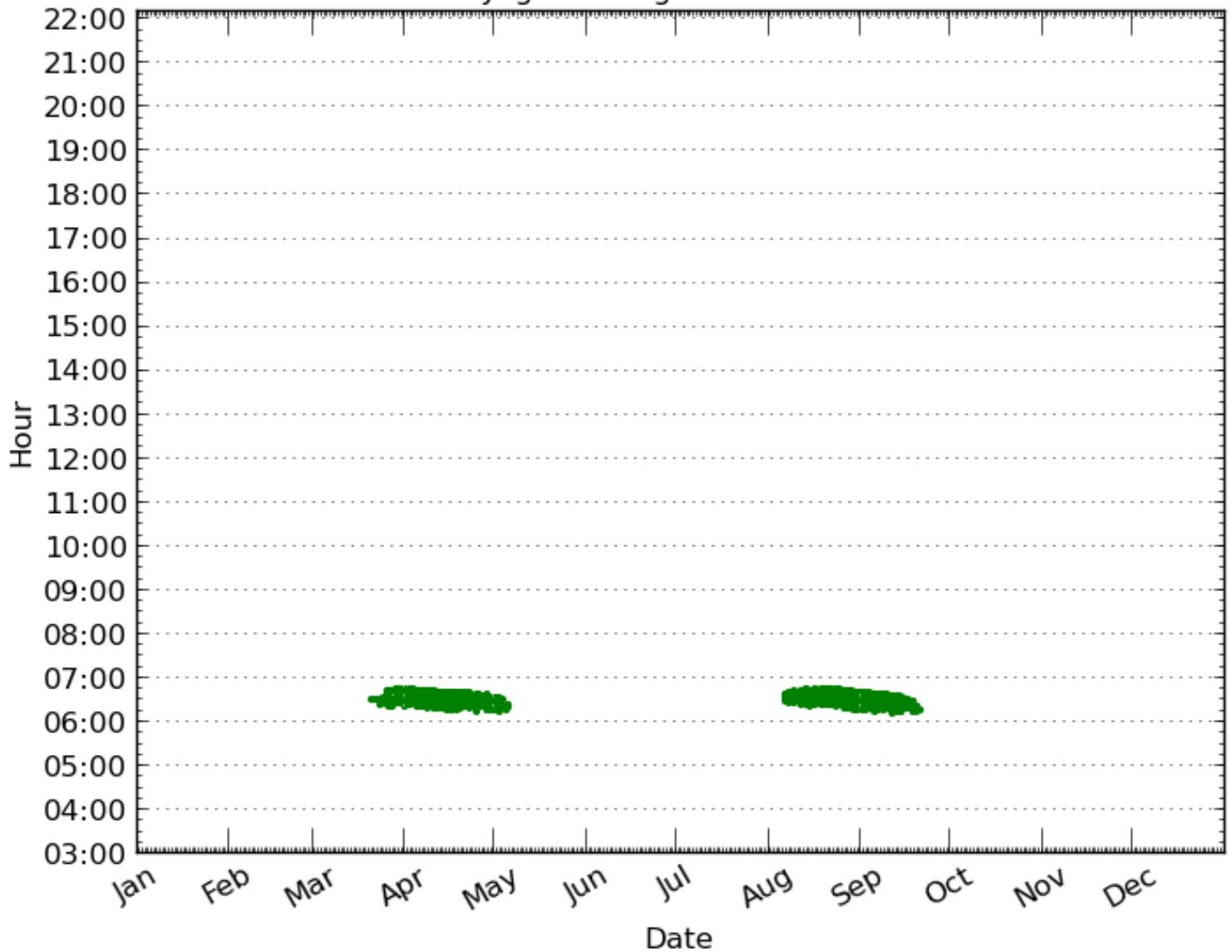
1/2 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



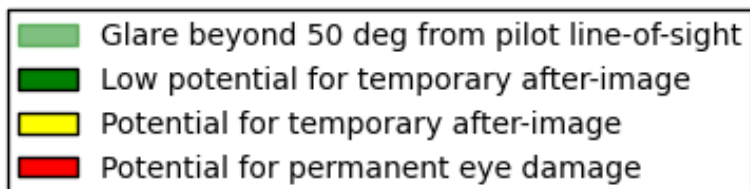
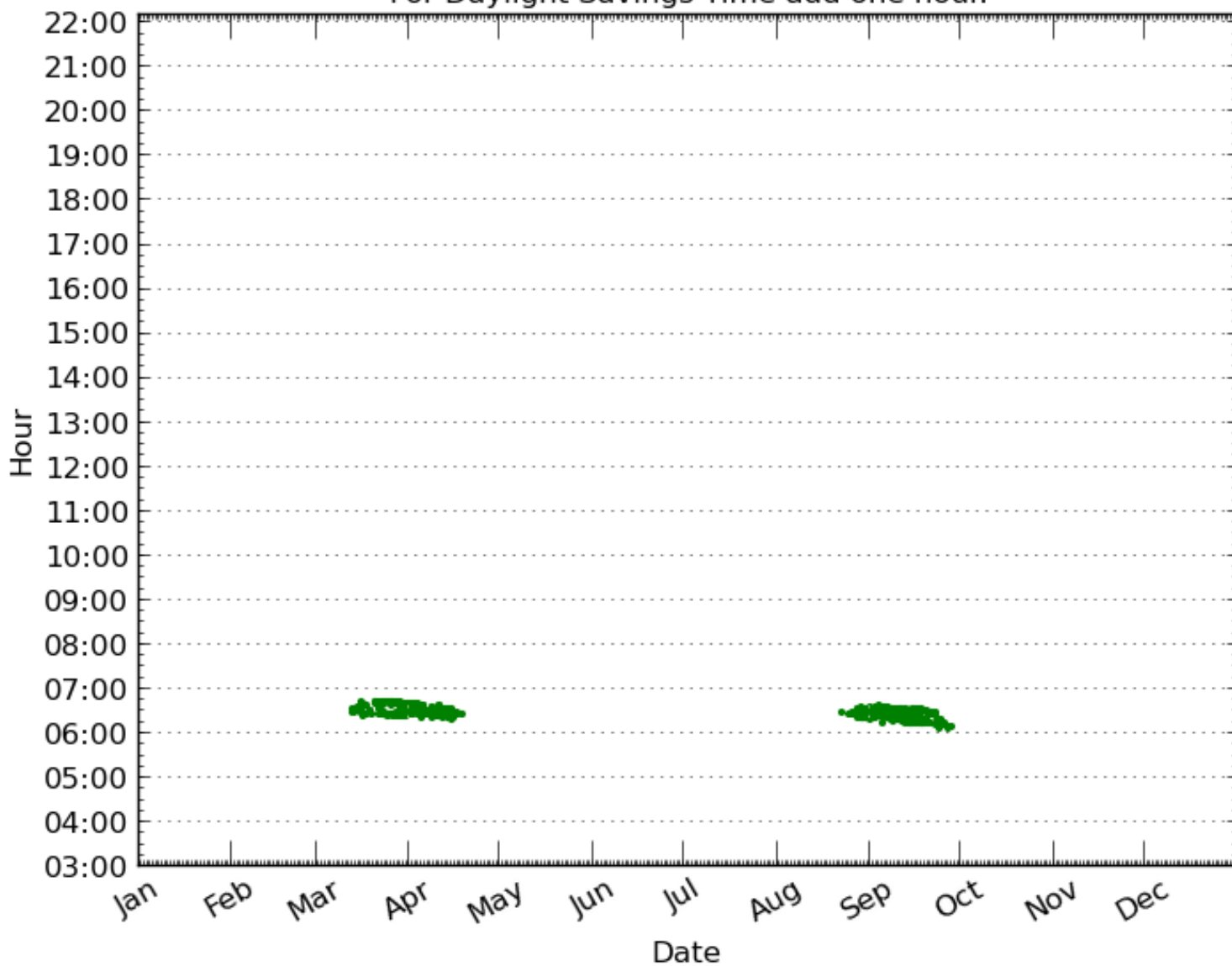
3/4 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



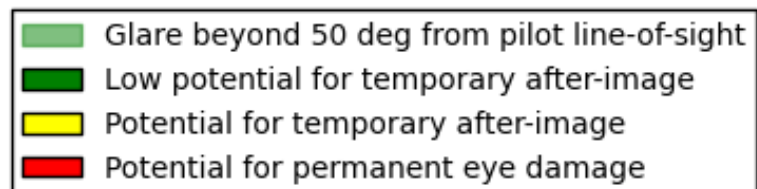
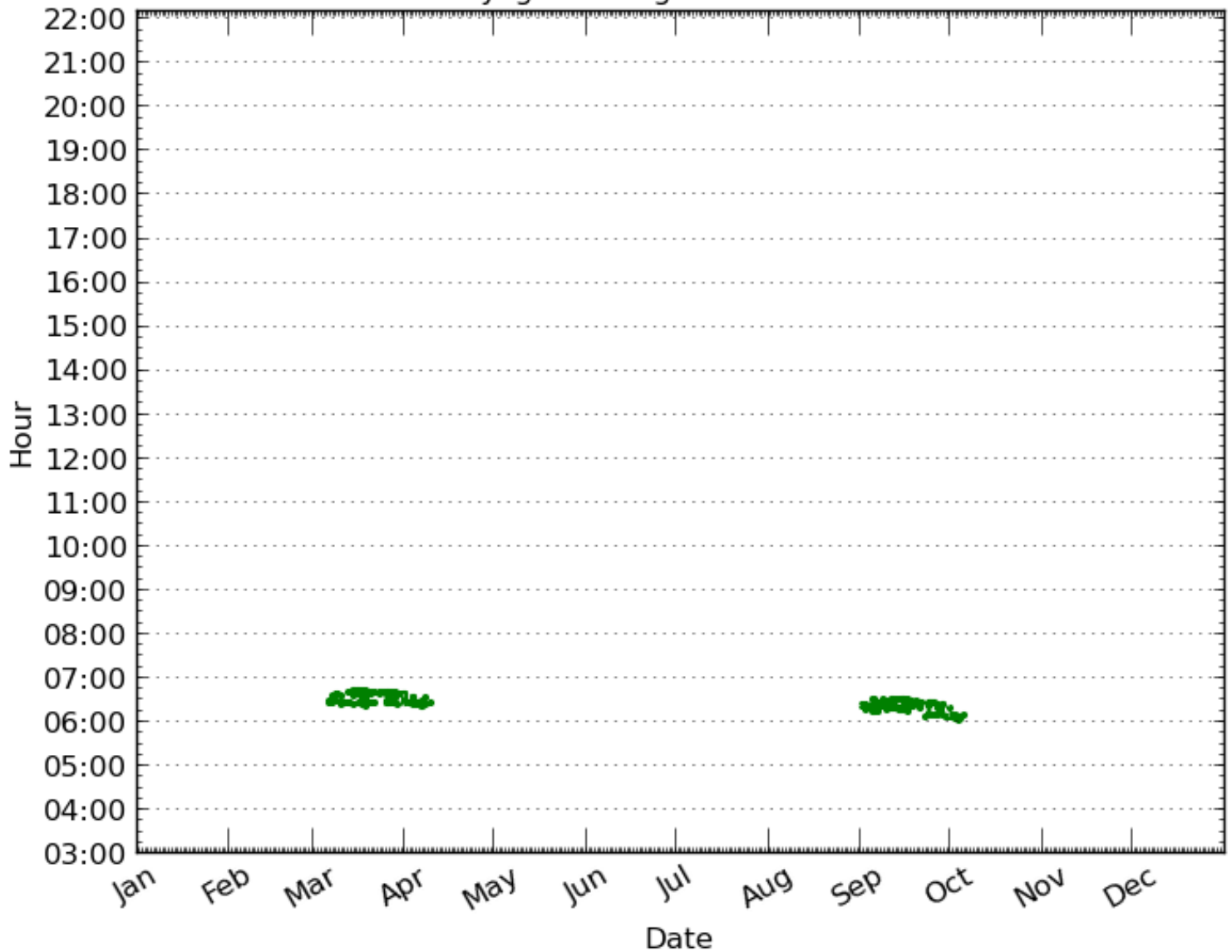
1 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



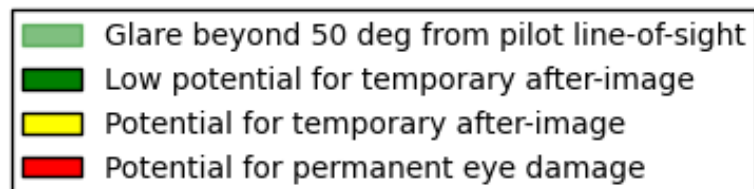
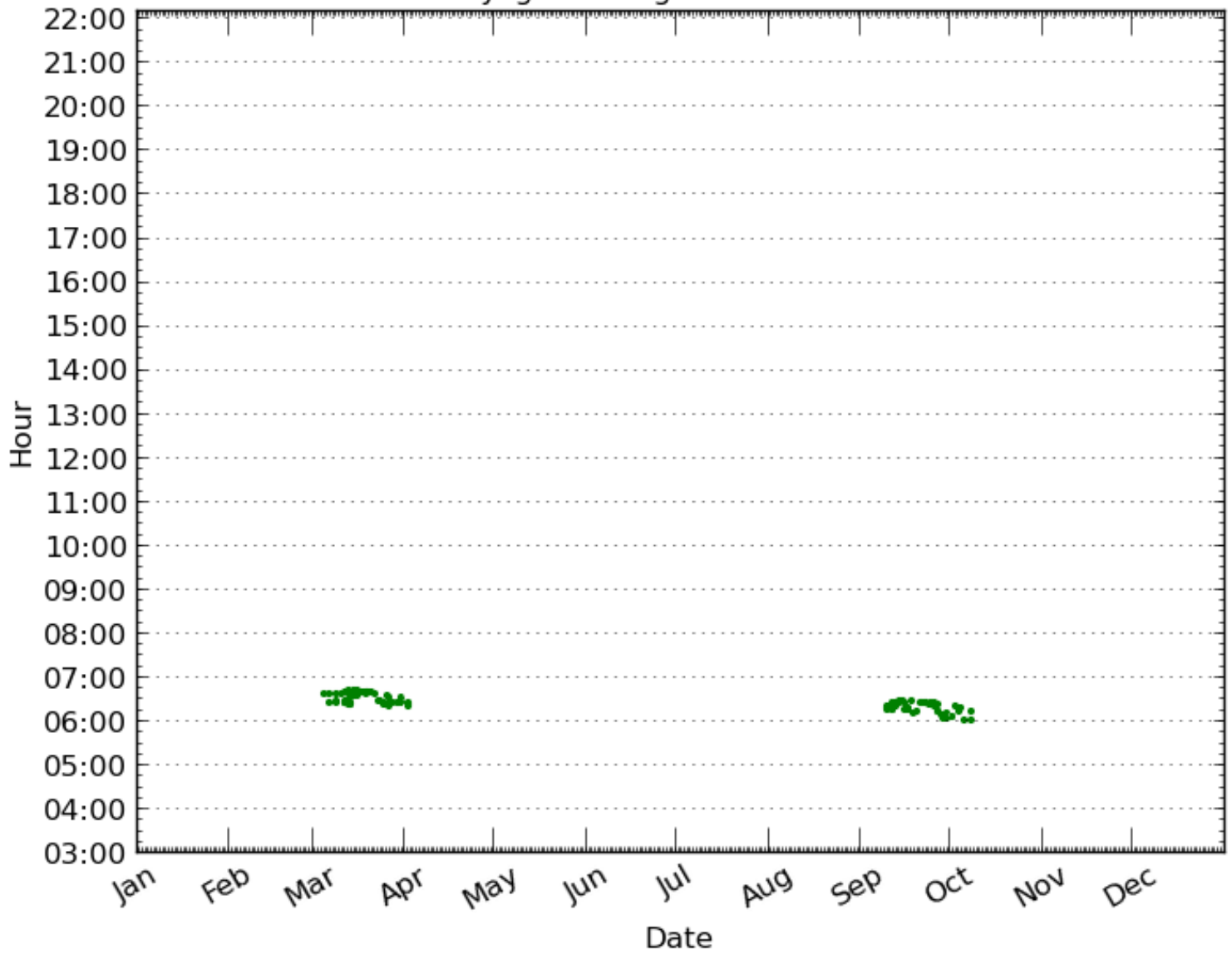
1 1/4 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



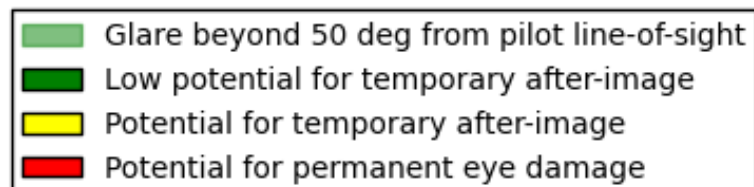
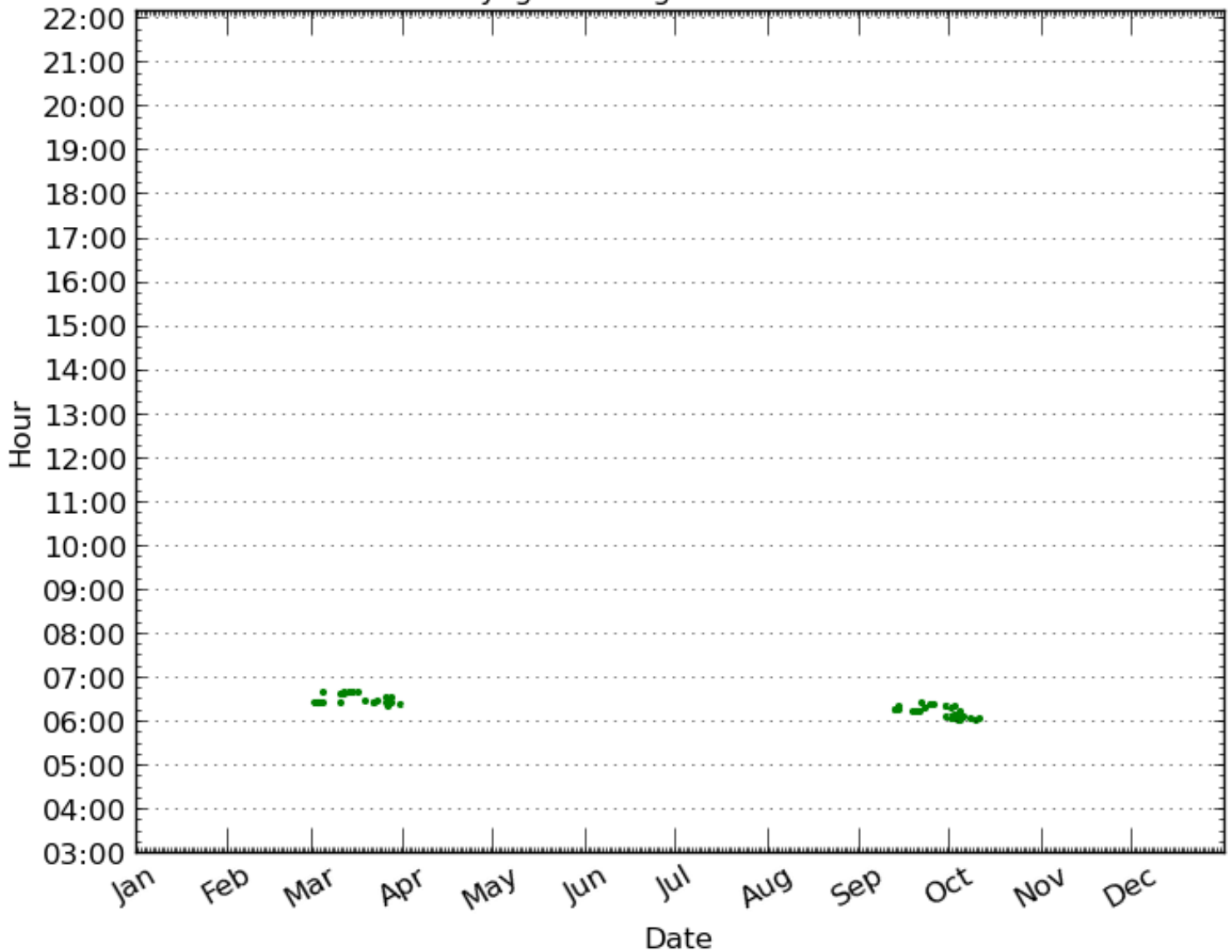
1 1/2 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



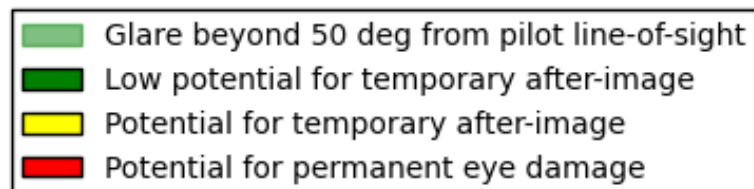
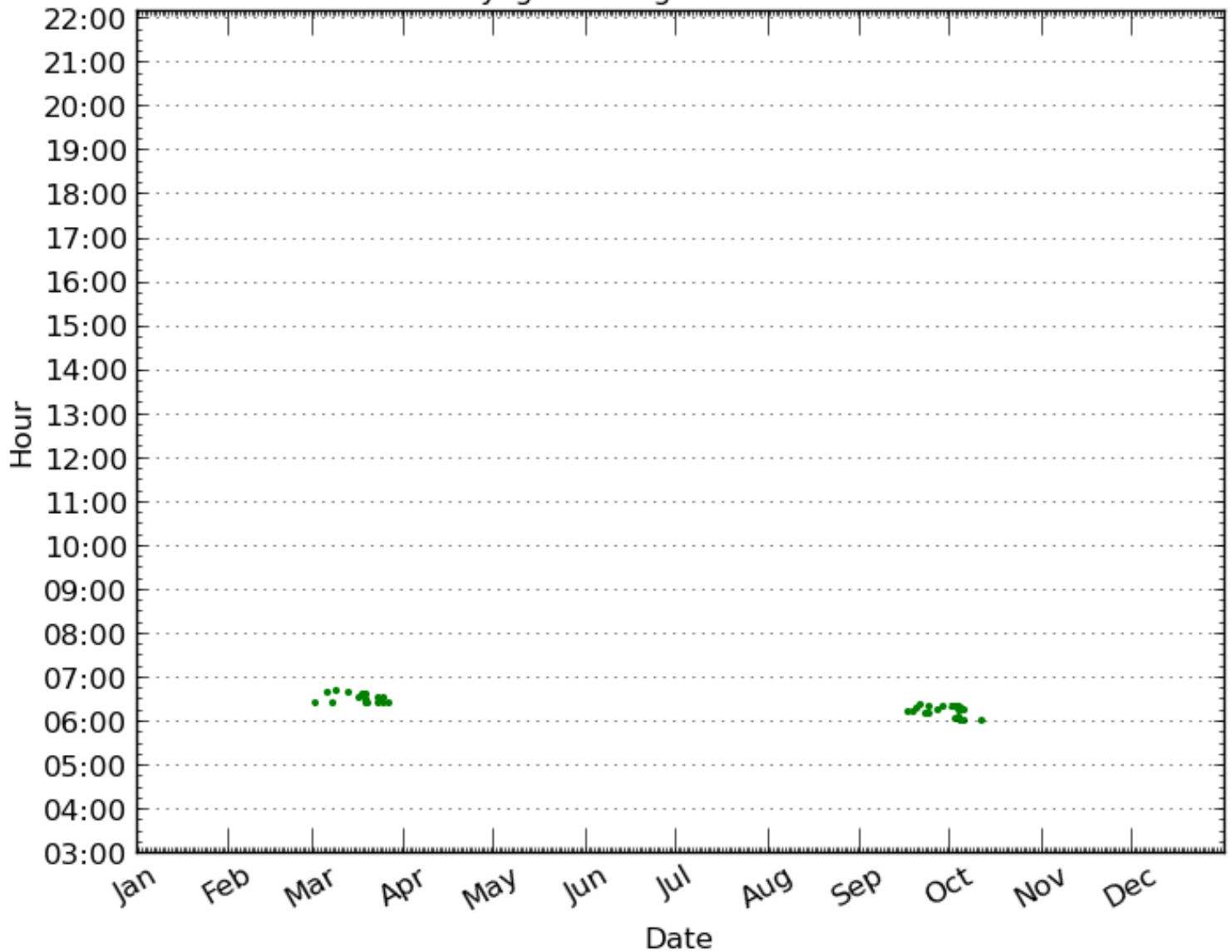
1 3/4 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



2 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



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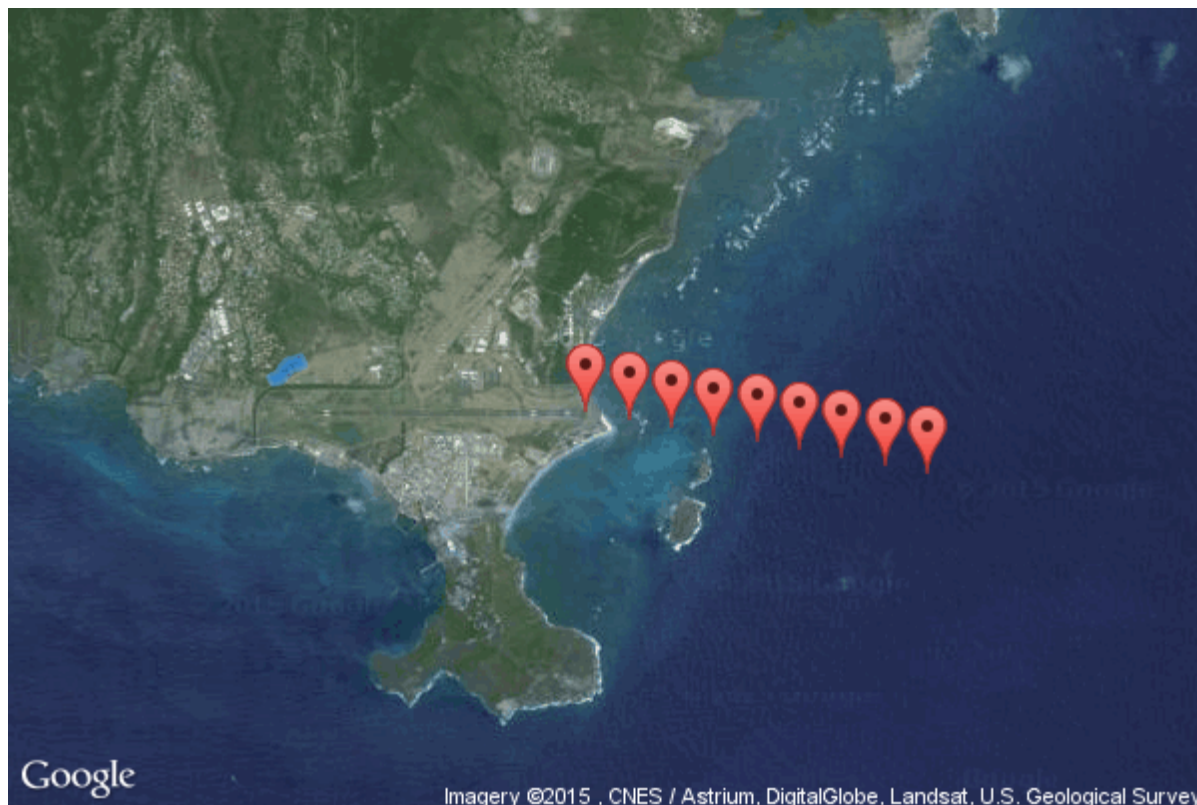
Solar Glare Hazard Analysis Flight Path Report

Generated July 16, 2015, 11:35 a.m.

Flight path: 2

Glare found

 Print



Analysis & PV array parameters

Analysis name	20150716 St Lucia with Input
PV array axis tracking	none
Orientation of array (deg)	180.0
Tilt of solar panels (deg)	12.0
Rated power (kW)	1000.0
Vary reflectivity	True
PV surface material	Smooth glass with ARC

Timezone offset	-4.0
Subtended angle of sun (mrad)	9.3
Peak DNI (W/m ²)	1000.0
Ocular transmission coefficient	0.5
Pupil diameter (m)	0.002
Eye focal length (m)	0.017
Time interval (min)	1
Correlate slope error with material	False
Slope error (mrad)	10.0

Flight path parameters

Direction (deg)	280.0
Glide slope (deg)	3.0
Consider pilot visibility from cockpit	True

Max downward viewing angle (deg)	30.0
Azimuthal viewing angle (deg)	180.0

PV array vertices

id	Latitude (deg)	Longitude (deg)	Ground Elevation (ft)	Height of panels above ground (ft)	Total elevation (ft)
1	13.7358912421	-60.9669756889	29.59	2.0	31.59
2	13.7363498095	-60.967297554	36.3	2.0	38.3
3	13.7367041564	-60.9665465355	52.95	2.0	54.95
4	13.7372252539	-60.9663319588	78.2	2.0	80.2
5	13.7377046626	-60.9658169746	94.58	2.0	96.58
6	13.7380381637	-60.9647011757	64.11	2.0	66.11
7	13.737371161	-60.9644007683	43.73	2.0	45.73
8	13.7370168151	-60.9654521942	50.55	2.0	52.55
9	13.736057994	-60.9663748741	31.47	2.0	33.47

Flight Path Observation Points

	Latitude (deg)	Longitude (deg)	Ground Elevation (ft)	Eye-level height above ground (ft)	Glare?
Threshold	13.7333090736	-60.9400838614	17.8	50.0	Yes
1/4 mi	13.7326815537	-60.936415996	0.0	136.97	Yes
1/2 mi	13.7320540337	-60.9327481307	0.0	206.16	Yes
3/4 mi	13.7314265137	-60.9290802654	0.0	275.33	Yes
1 mi	13.7307989937	-60.9254124	0.0	344.5	Yes
1 1/4 mi	13.7301714737	-60.9217445347	0.0	413.69	Yes
1 1/2 mi	13.7295439538	-60.9180766694	0.0	482.86	Yes

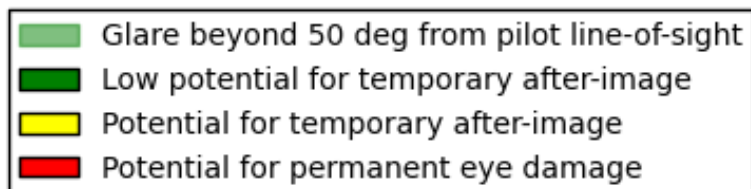
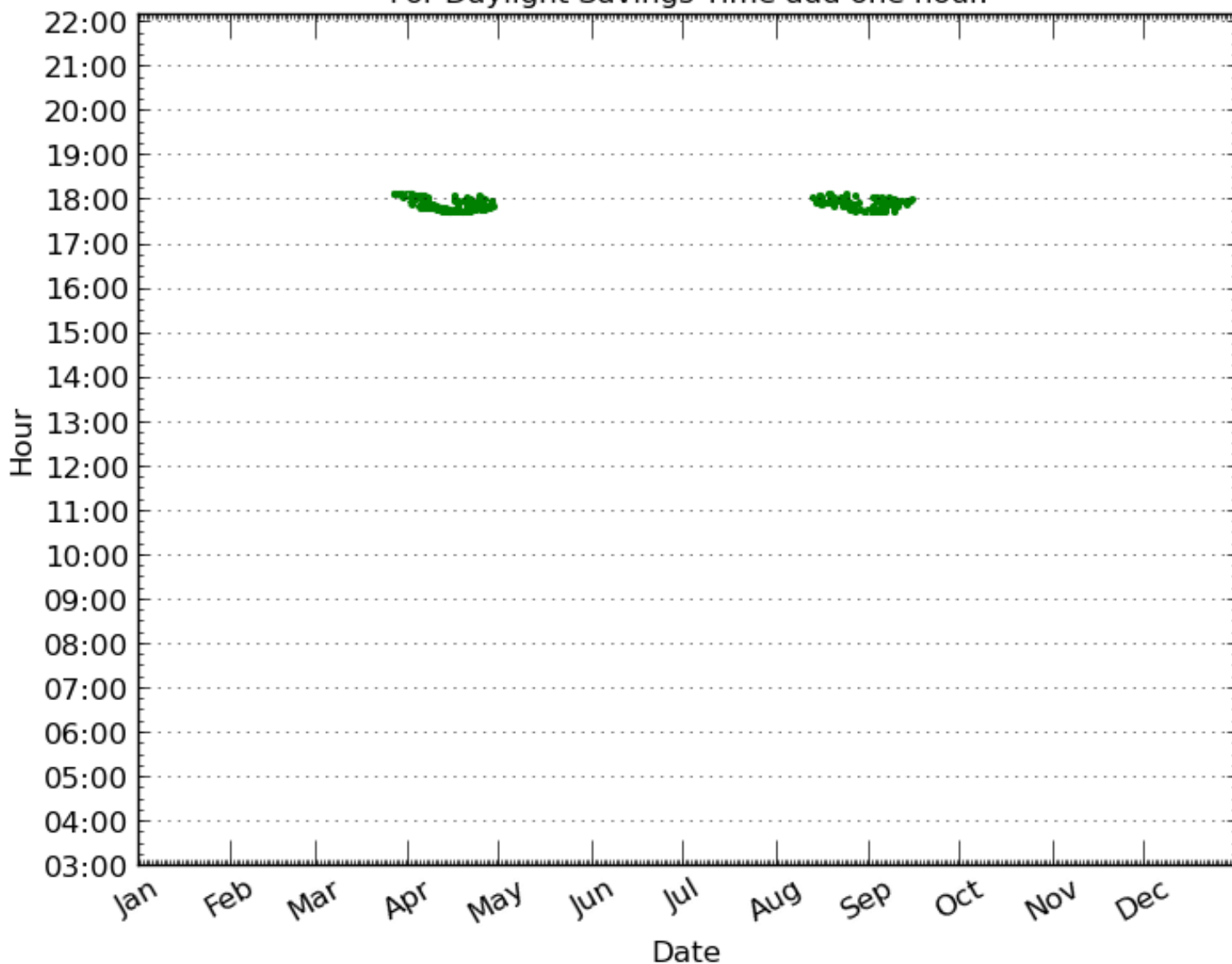
1 3/4 mi	13.7289164338	-60.9144088041	0.0	552.05	Yes
2 mi	13.7282889138	-60.9107409387	0.0	621.22	Yes

Glare occurrence plots

All times are in standard time. For Daylight Savings Time add one hour.

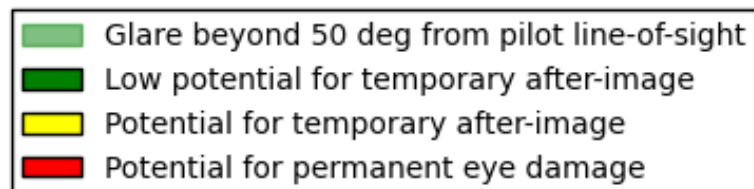
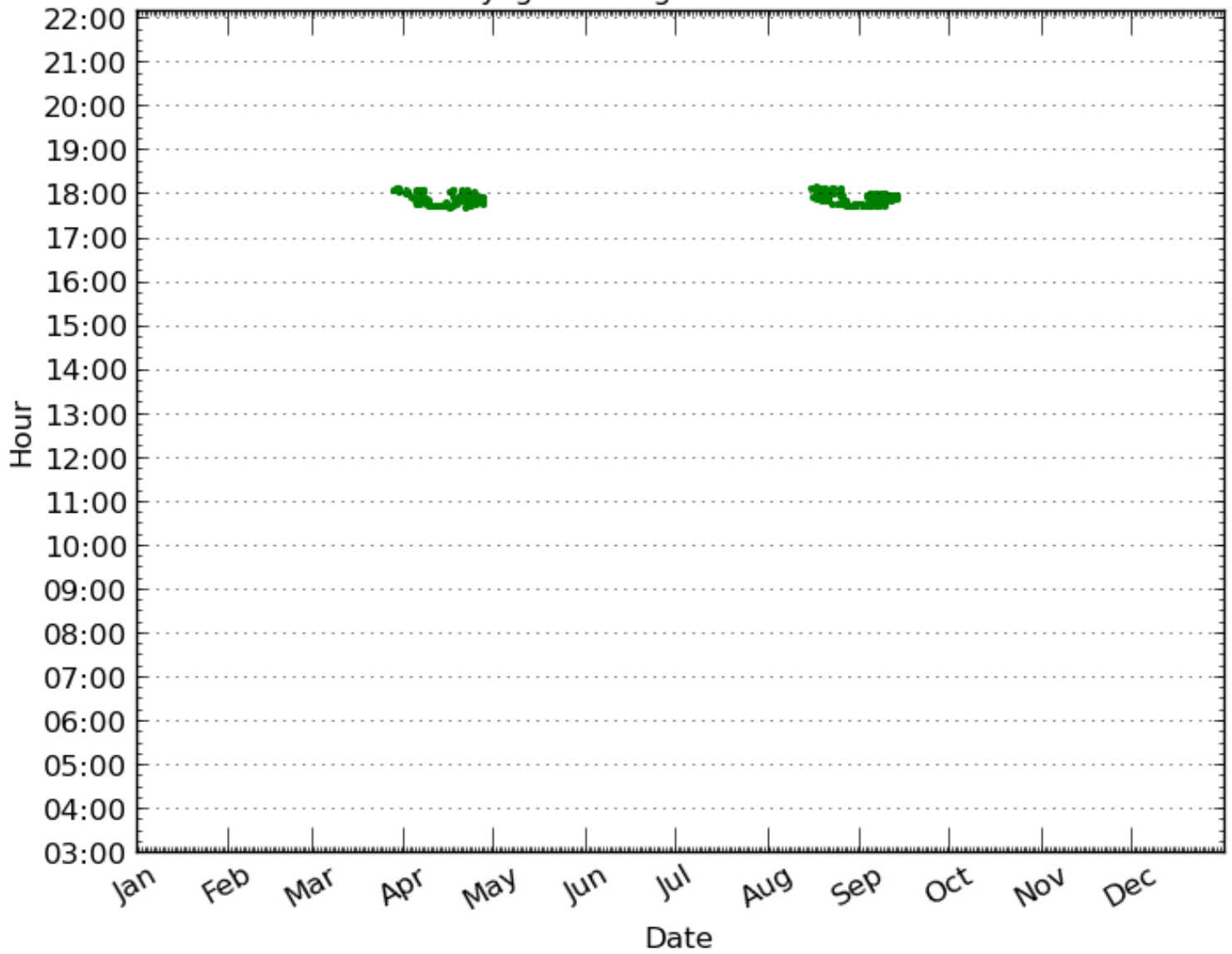
Threshold

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



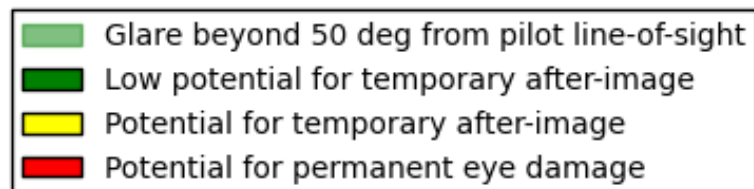
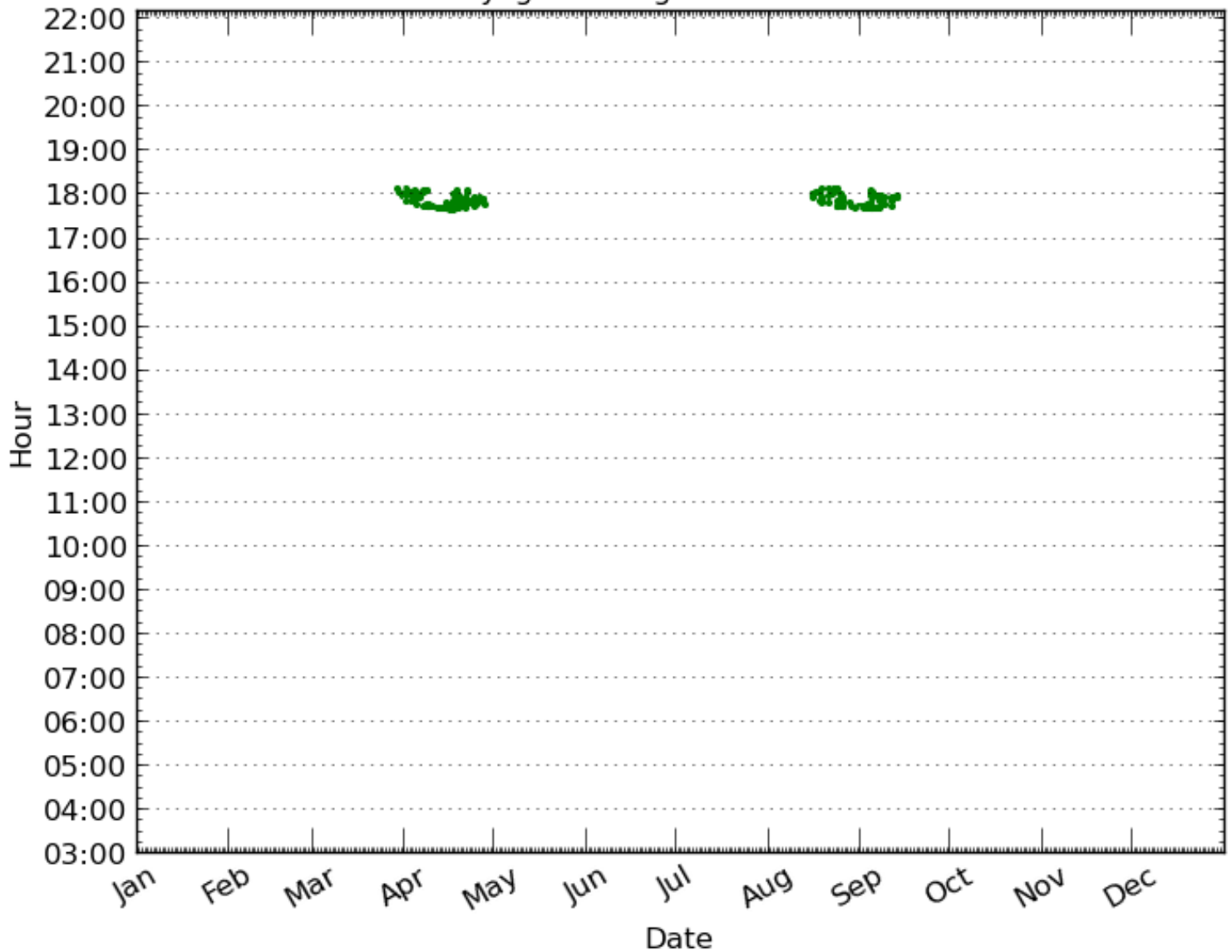
1/4 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



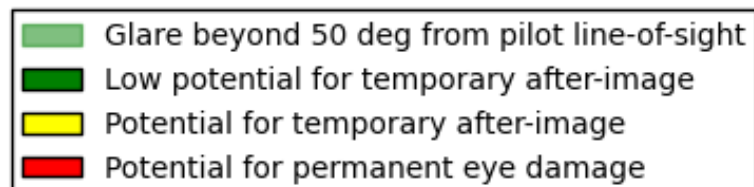
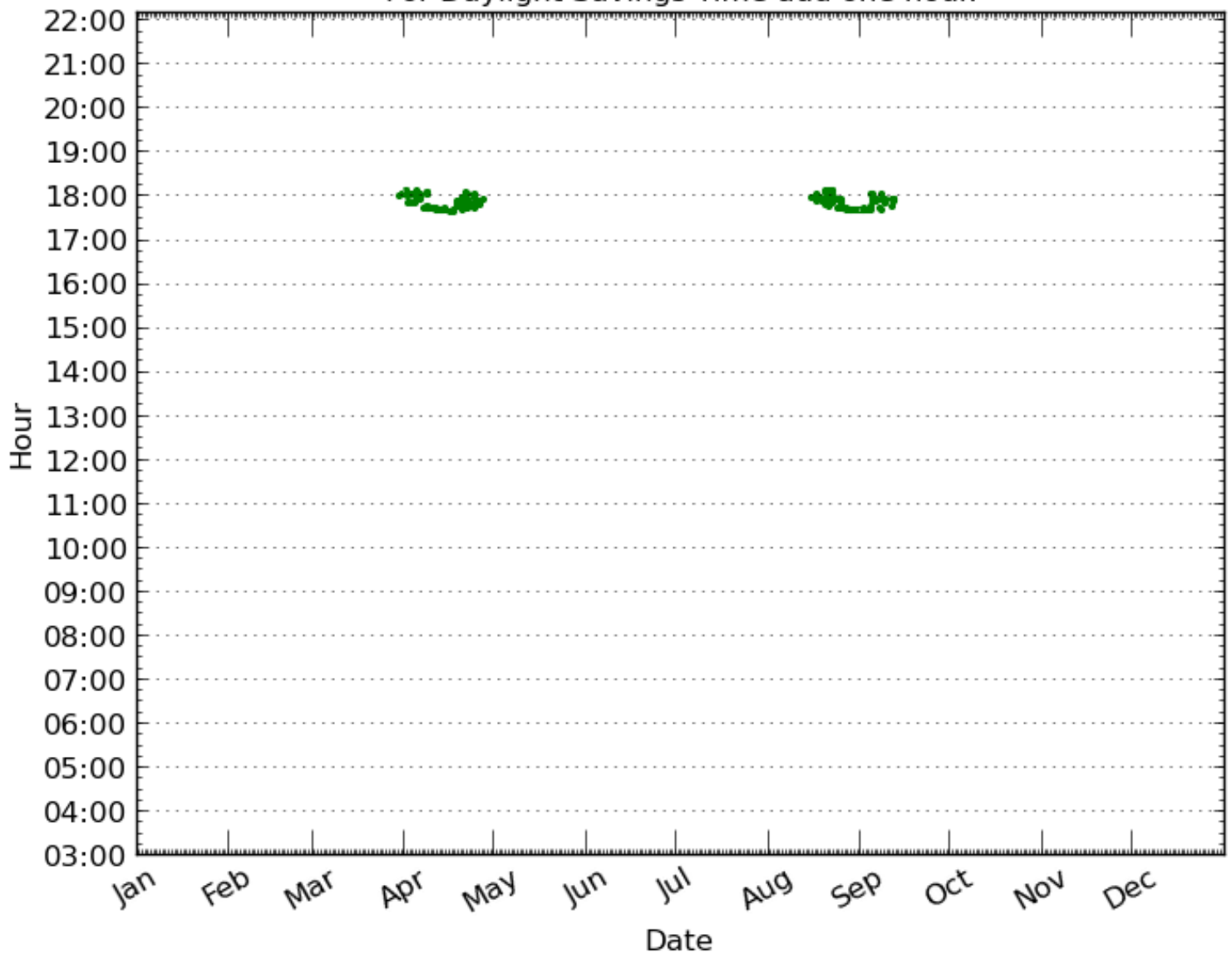
1/2 mi

1-minute time interval.
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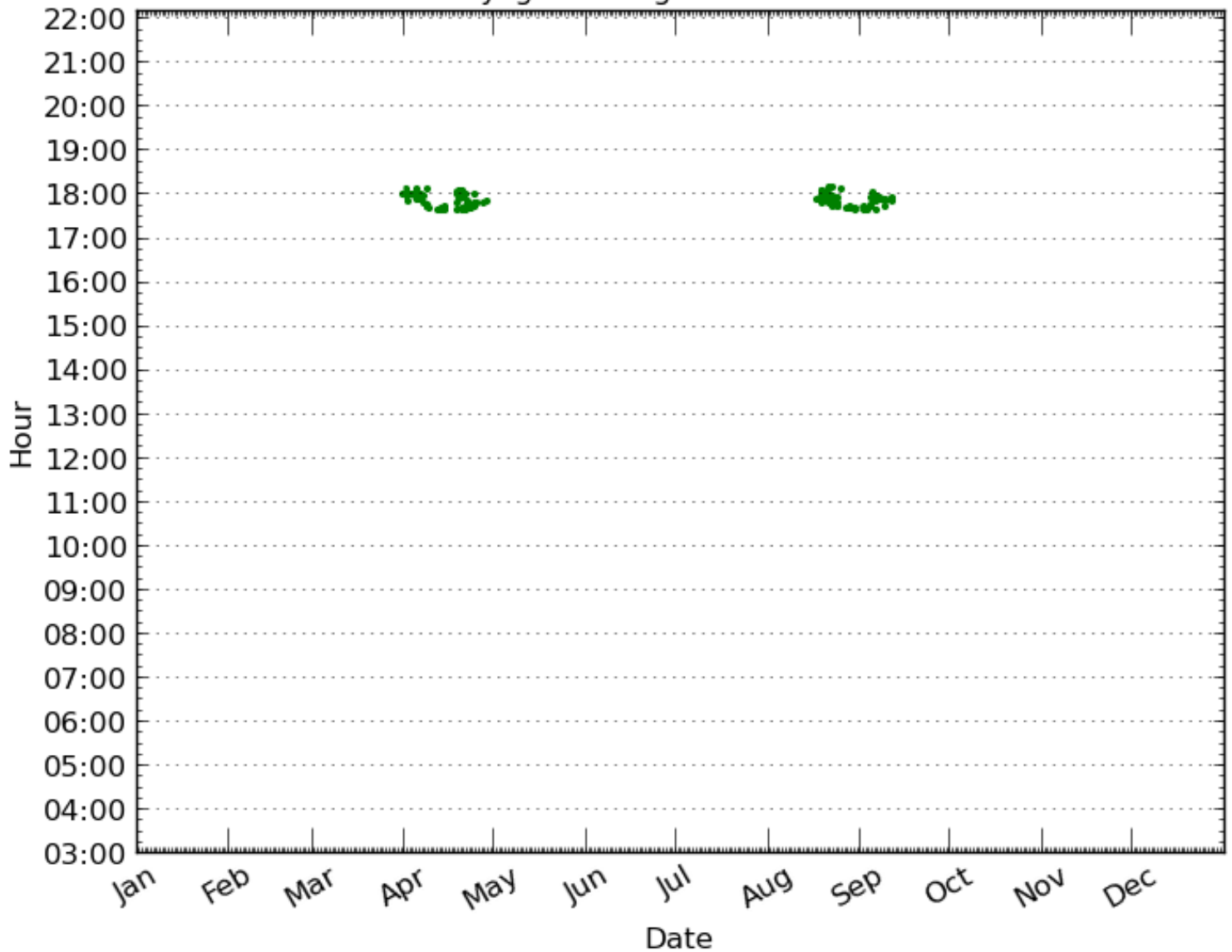
3/4 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



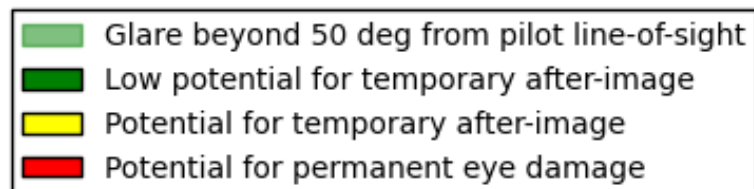
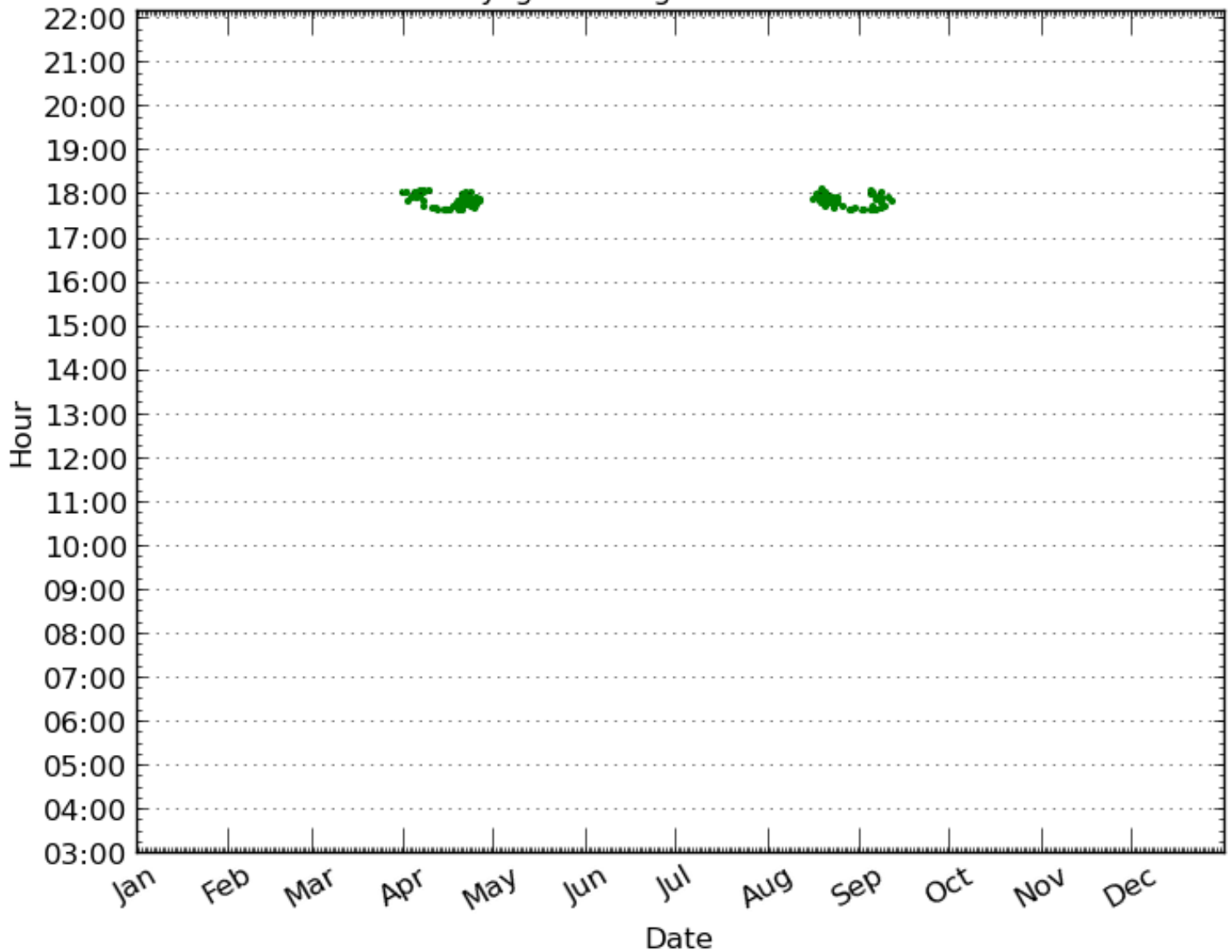
1 mi

1-minute time interval.
All times are in standard time.
For Daylight Savings Time add one hour.



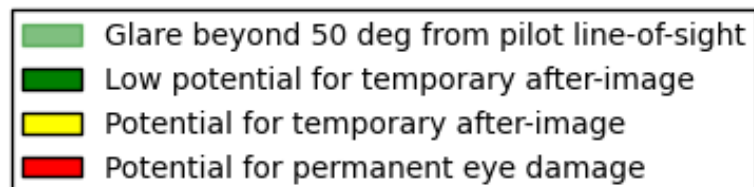
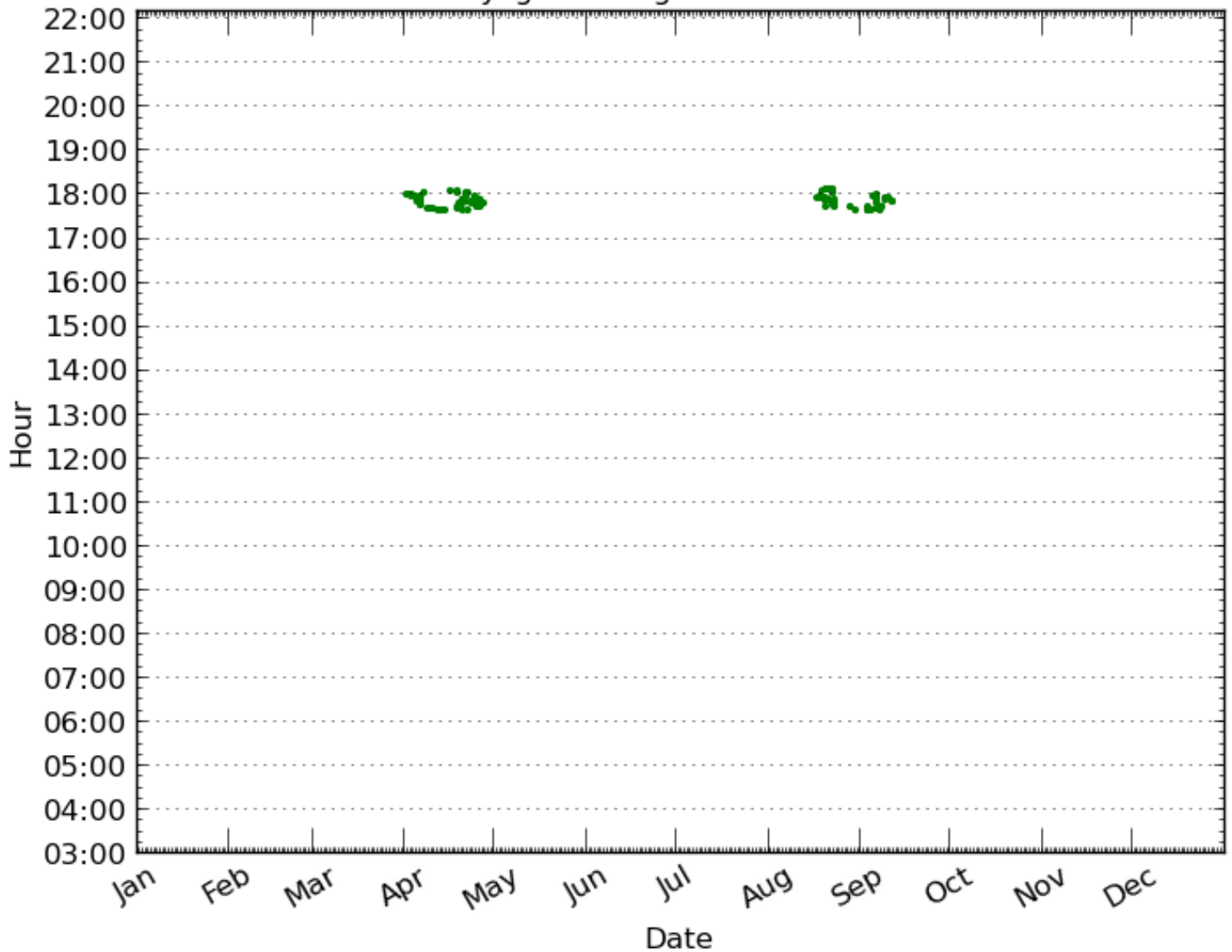
1 1/4 mi

1-minute time interval.
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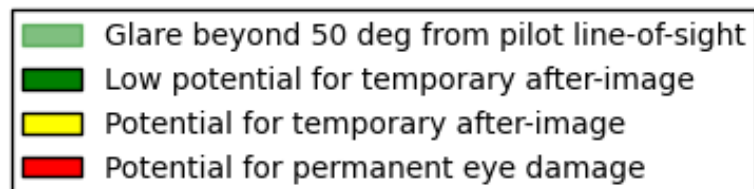
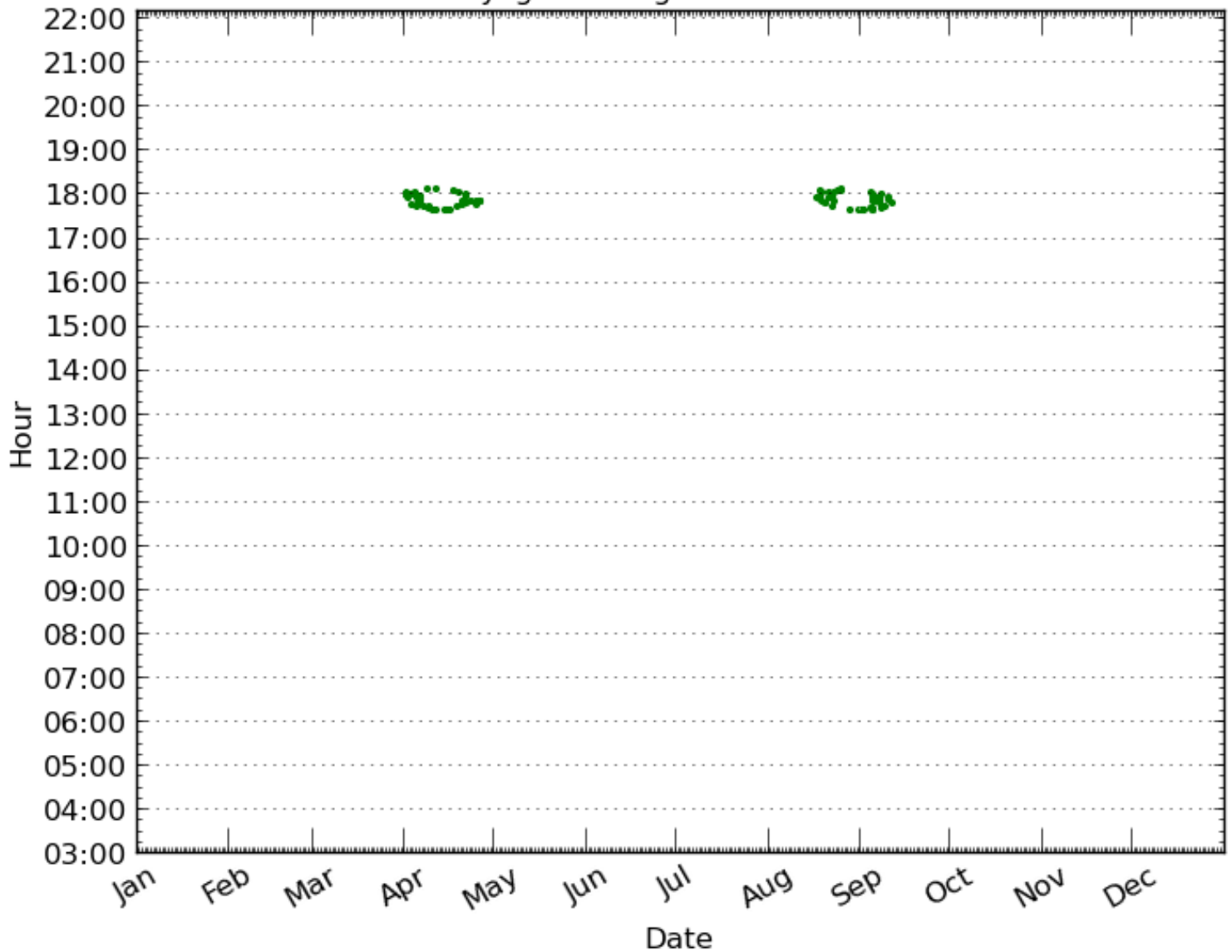
1 1/2 mi

1-minute time interval.
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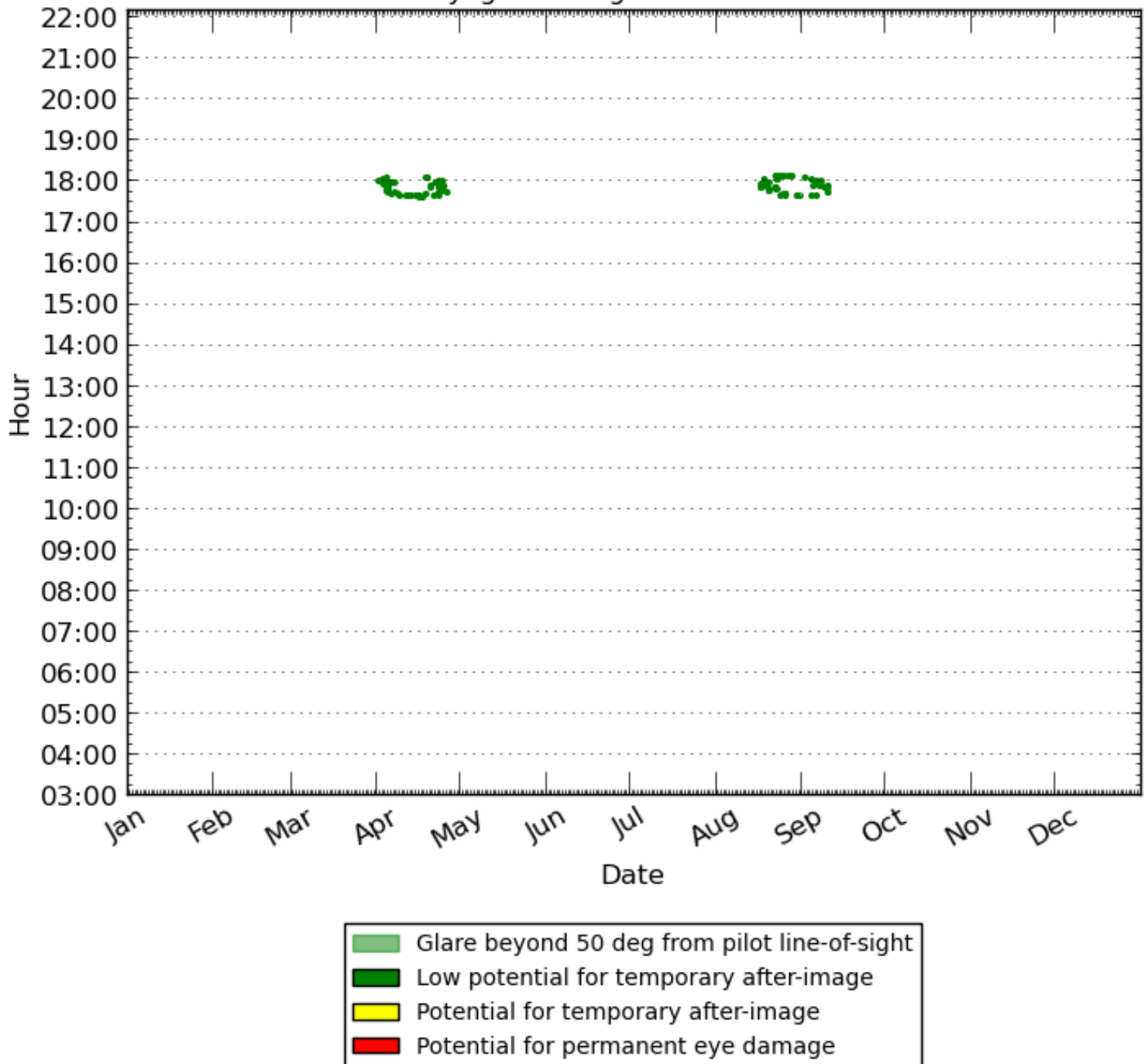
1 3/4 mi

1-minute time interval.
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2 mi

1-minute time interval.
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Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16,000 professionals are dedicated to helping our customers make the world safer, smarter, and greener.