Solar Glare Hazard Analysis Tool (SGHAT)

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SAND2013-1800P

Exceptional service in the national interest

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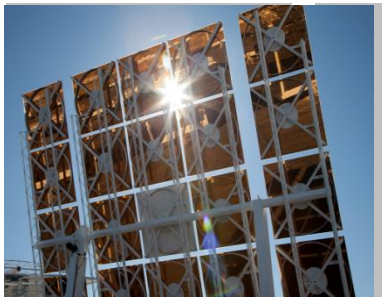

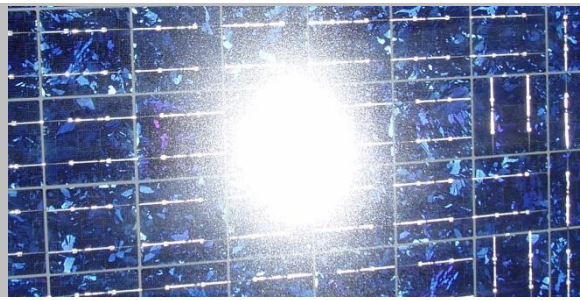

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Introduction

- **Glint and glare may cause unwanted visual impacts**
  - Pilots, air-traffic controllers, workers, motorists
- **Potential visual impacts**
  - Distraction
  - After-image (flash blindness)
  - Retinal burn

Definitions

Glint: Momentary flash of light

Glare: Continuous source of excessive brightness

Objective

Develop quantified analysis of glare to reduce uncertainties associated with visual impacts of solar power installations

Overview

- Examples of Solar Glare
- Ocular Hazard Metrics
- SGHAT Demonstration





Examples of Glare from Solar Technologies

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Photovoltaics

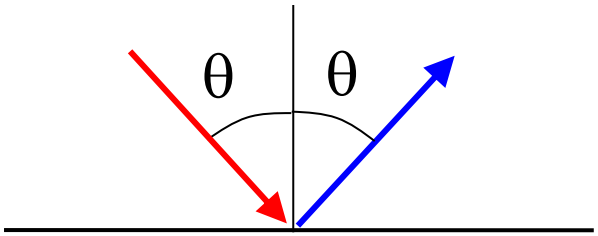
Concentrating Solar Power

Heliostats and Central Receiver at Sandia Labs, Albuquerque, NM

Dish Collectors at Sandia

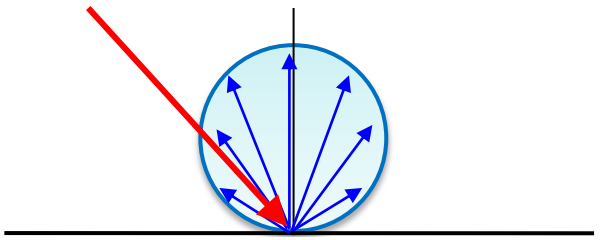
Parabolic Trough Collectors at Kramer Junction, CA

Types of Reflection



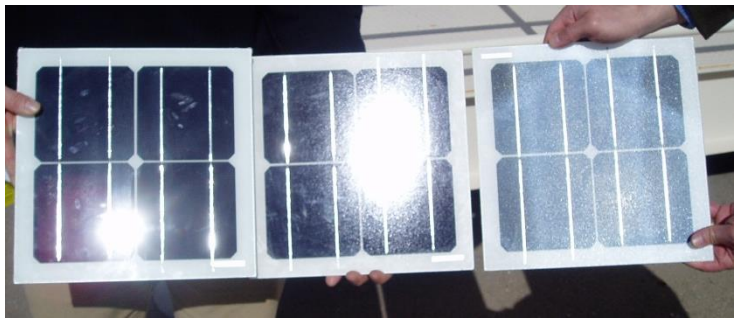
Specular Reflection

Polished Surfaces
(e.g., mirrors,
smooth glass)

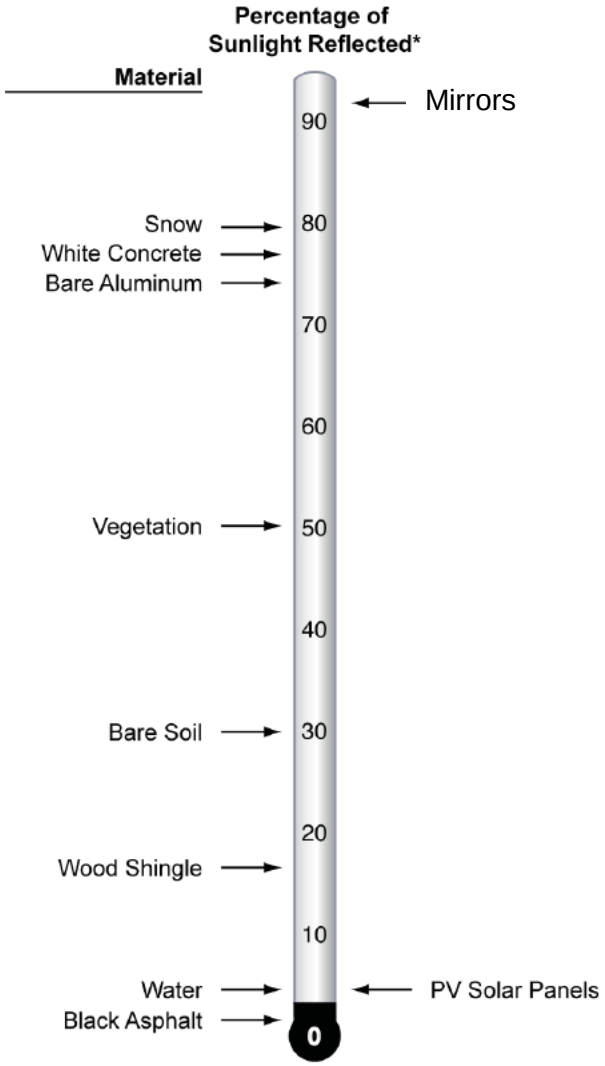


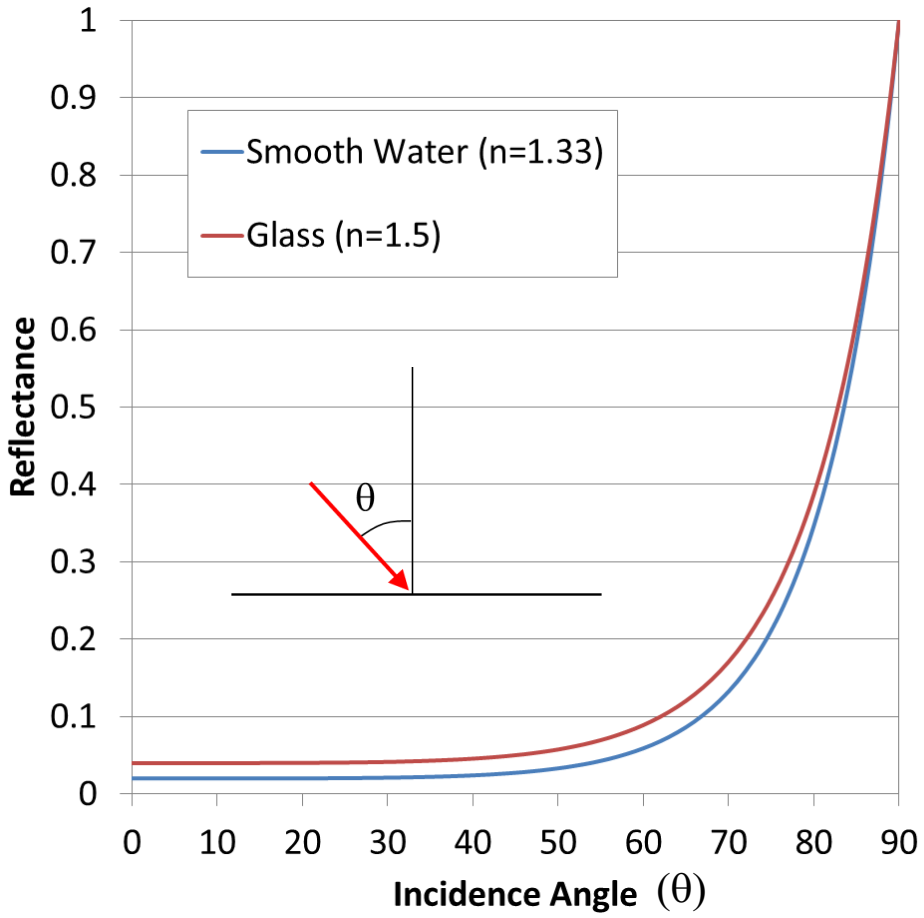
Diffuse Reflection

Rough Surfaces
(e.g., receivers, textured
glass, snow, pavement)



Reflectivity





Adapted from ACRP Synthesis 28 “Investigating Safety Impacts of Energy Technologies on Airports and Aviation”

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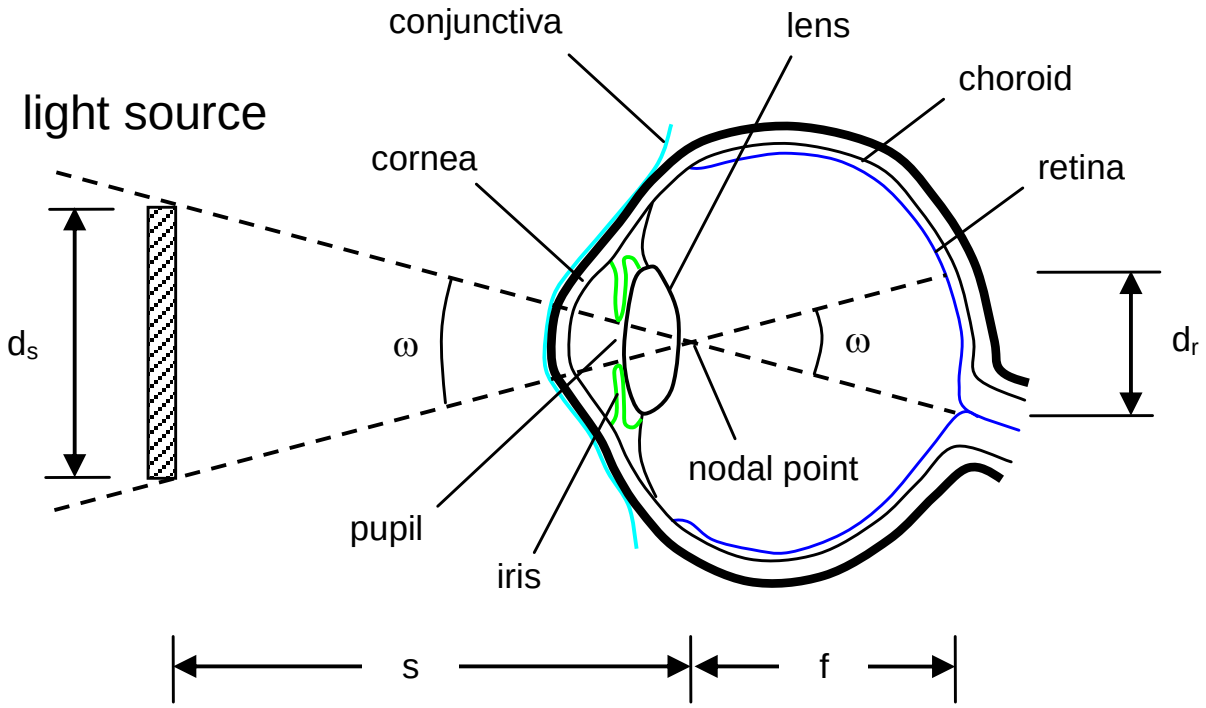
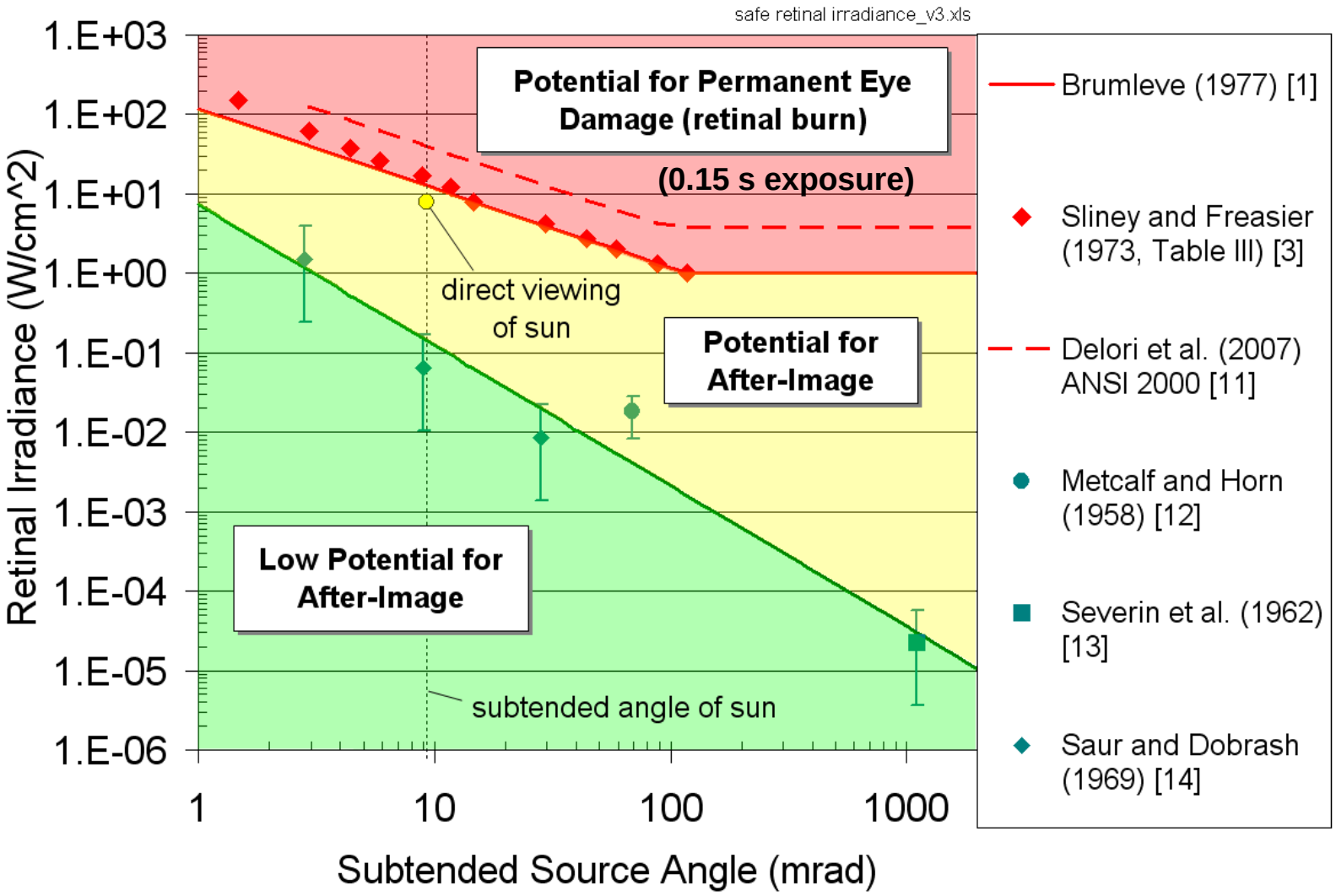
Impact of Light Entering the Eye



- Need to calculate
  - Power entering eye
    - Function of irradiance at the cornea (front of eye)
  - Subtended angle of glare source (size / distance)

Potential Ocular Impacts



Equations and analysis methods detailed in Ho et al. (2010, 2011)

Overview

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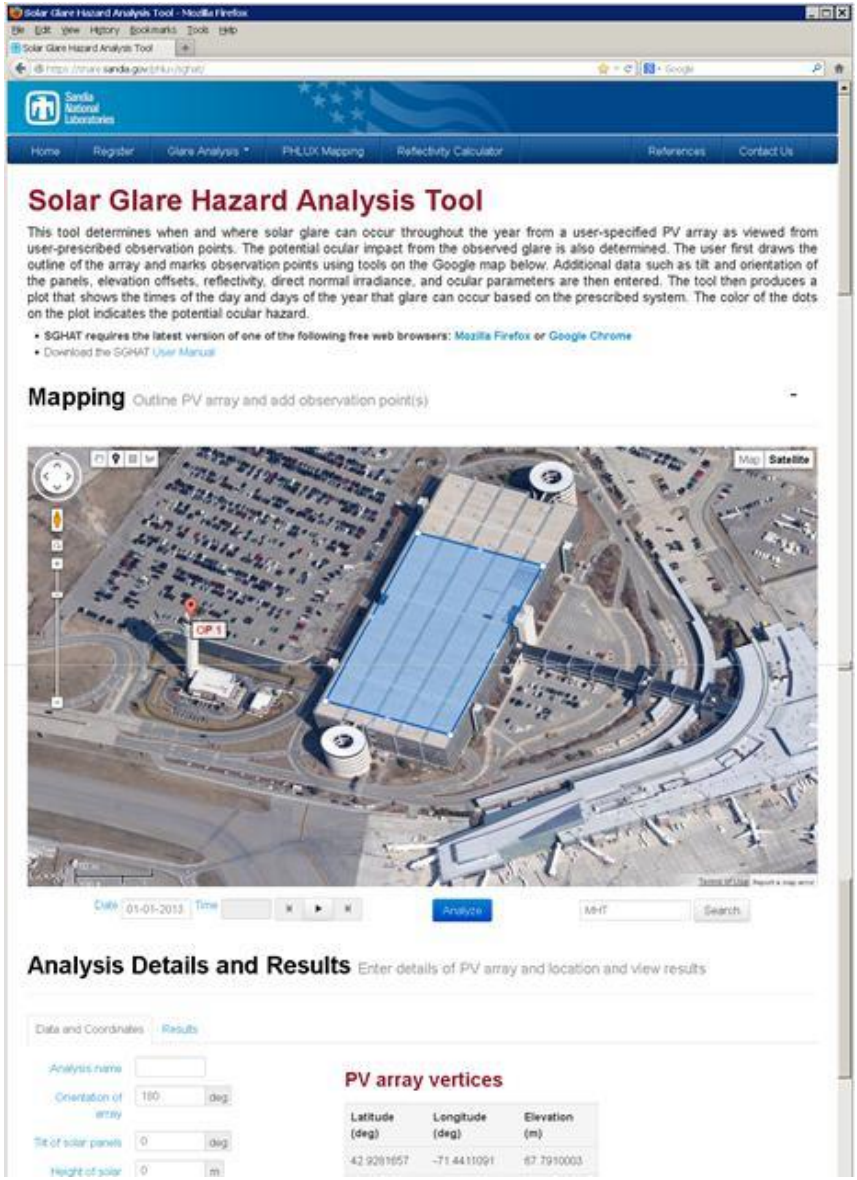
Solar Glare Hazard Analysis Tool (SGHAT)



www.sandia.gov/glare

Interactive Google Maps

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Solar Glare Hazard Analysis Tool

This tool determines when and where solar glare can occur throughout the year from a user-specified PV array as viewed from user-prescribed observation points. The potential ocular impact from the observed glare is also determined. The user first draws the outline of the array and marks observation points using tools on the Google map below. Additional data such as tilt and orientation of the panels, elevation offsets, reflectivity, direct normal irradiance, and ocular parameters are then entered. The tool then produces a plot that shows the times of the day and days of the year that glare can occur based on the prescribed system. The color of the dots on the plot indicates the potential ocular hazard.

- **SGHAT requires the latest version of one of the following free web browsers: Mozilla Firefox or Google Chrome**
- Download the SGHAT User Manual

Mapping Outline PV array and add observation point(s)

Data Entry for PV Tilt/Orientation, Reflectance, DNI, and Elevations

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Data and Coordinates | Results

Hover over fields for helpful information

Height units	○ Feet ◉ Meters
Analysis name	MHT
Orientation of array	200 deg
	Calculate declination
Tilt of solar panels	20 deg
Height of solar panels	21 m
Rated power	500 kW
Reflectivity of PV module	0.1
Slope error	10 mrad
Subtended angle of sun	9.3 mrad
Peak DNI	1000 W/m^2
DNI variability	◉ Variable ○ Fixed
Time interval	1 min
Data output	None

View ocular parameters

PV array vertices

Latitude (deg)	Longitude (deg)	Elevation (m)	Elevation (ft)
42.9292481	-71.4404010	67.8822021	222.7106440
42.9289496	-71.4394032	67.7910003	222.4114256
42.9276219	-71.4401435	67.7910003	222.4114256
42.9279126	-71.4411413	67.7910003	222.4114256

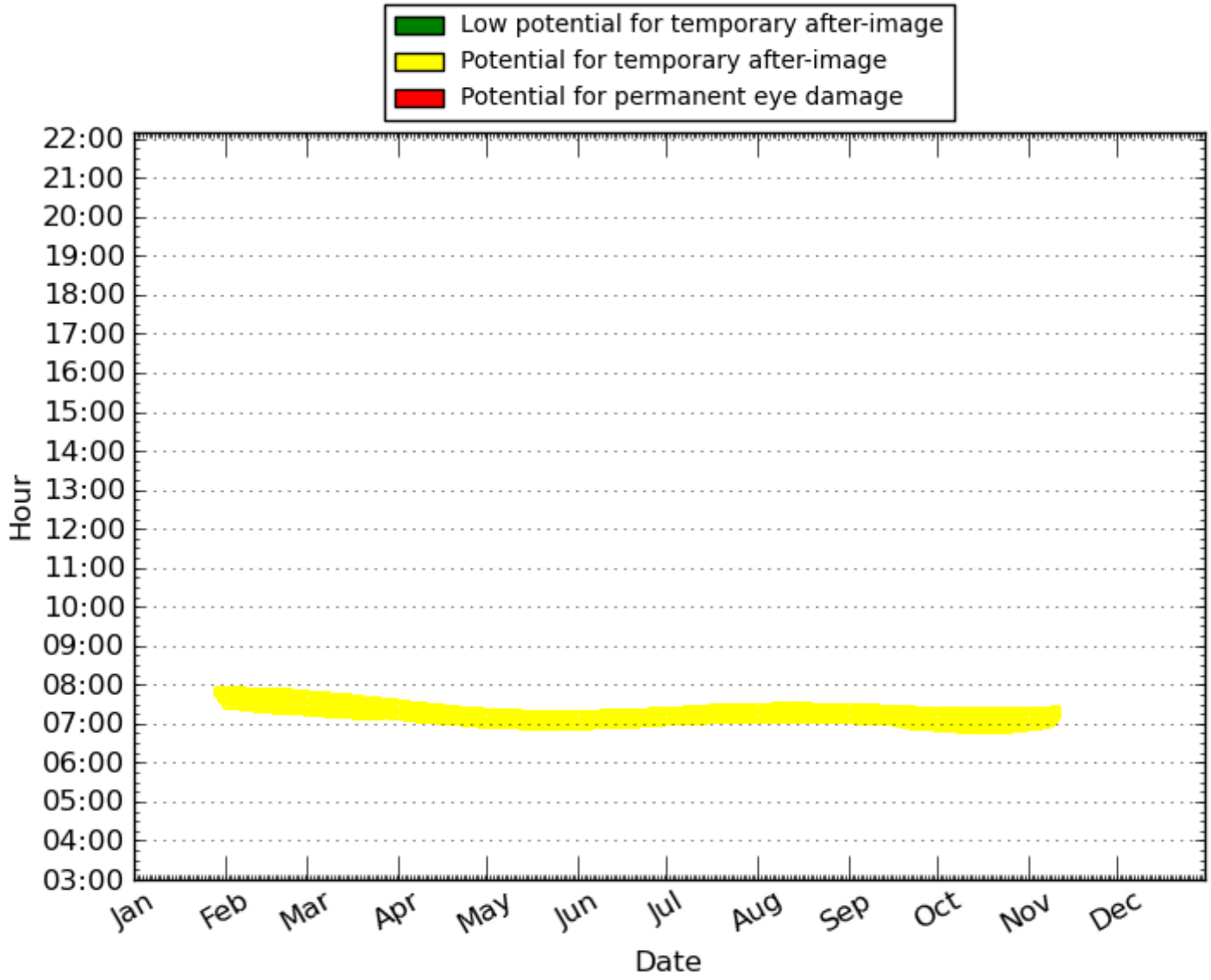
✖ Clear Array

Observation Points

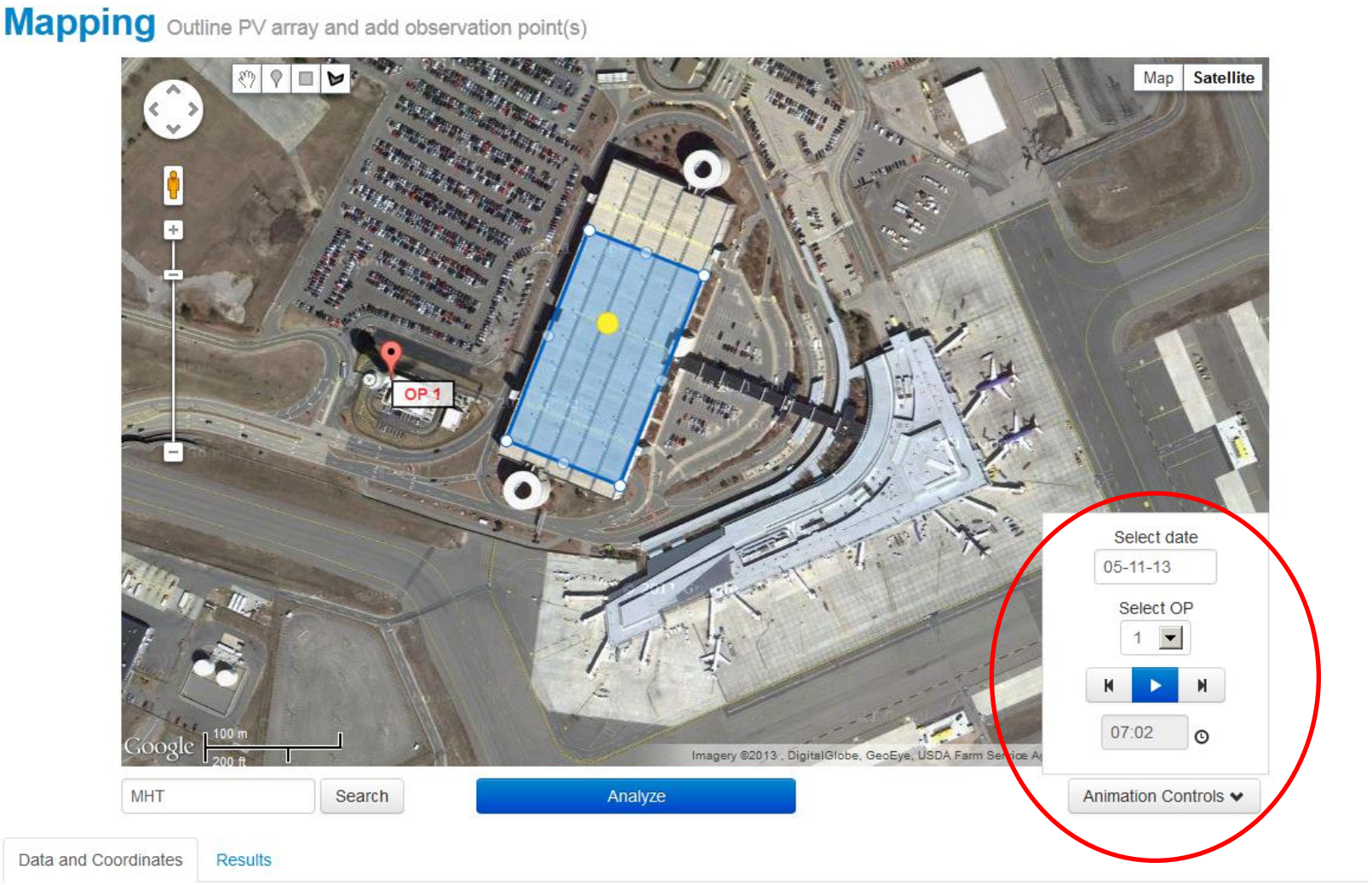
#	Latitude (deg)	Longitude (deg)	Elevation (m)	Elevation (ft)	Height above ground (m)	
1	42.92833	-71.44224	67.79360	222.41998	46	✖

✖ Clear Observations

Glare Occurrence Plot



Glare Animation Feature



Manchester-Boston Regional Airport

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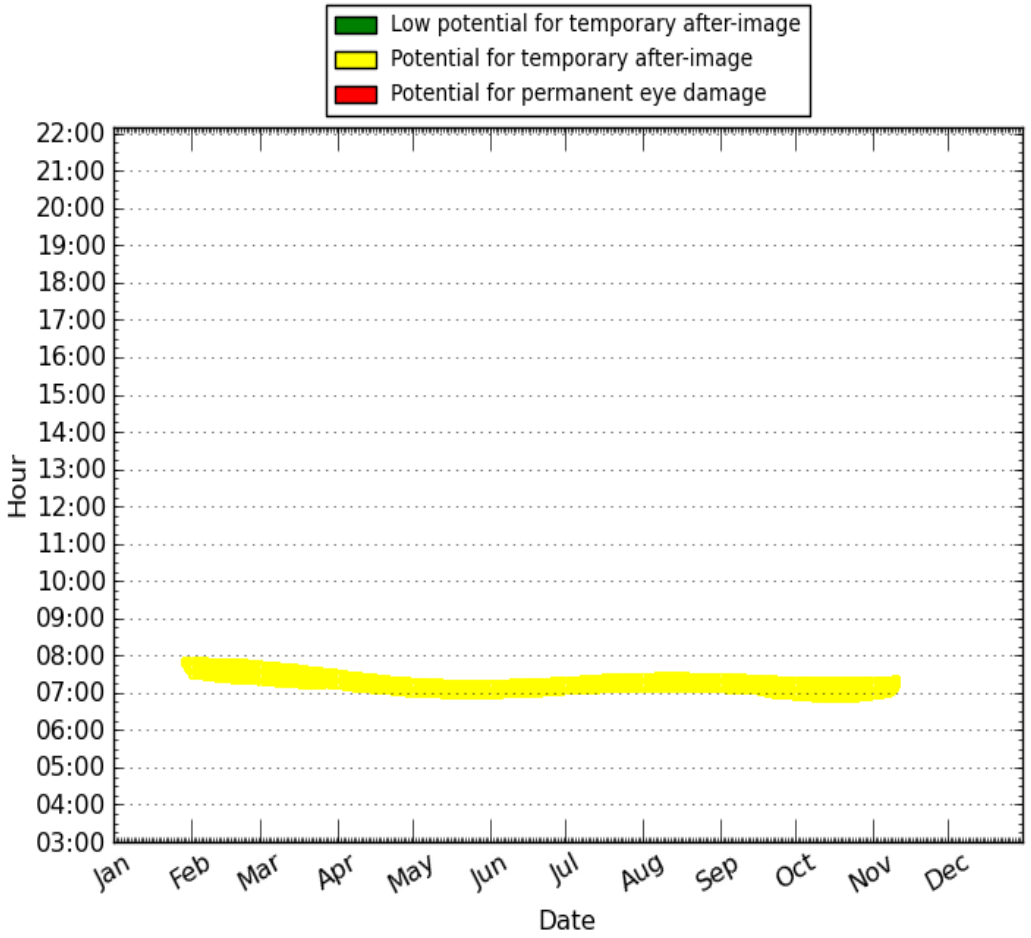
Glare viewed from Air Traffic Control Tower at Manchester/Boston Regional Airport (8:15 AM EDT, 4/27/12).

Manchester-Boston Regional Airport

Glare viewed from Air Traffic Control Tower at Manchester/Boston Regional Airport (~8:17 AM EDT, 5/10/12). Note that a tarp has been placed over some of the modules.



Times shown are Standard Time. Add one hour for Daylight Savings Time.

Mitigation of glare while maximizing energy production

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Azimuthal Angle (degrees)	Elevation Angle (degrees)	Relative Annual Energy Production
180	43	100.0%*
200	20.6	93.9%**
120	40	88.9%
120	50	87.2%
110	20.6	82.4%
110	30	85.0%
110	40	84.7%
120	60	83.7%
110	50	82.8%
130	70	81.5%
100	30	80.9%
100	20	80.8%
100	40	79.9%
110	60	79.3%
120	70	78.3%
100	50	77.6%
90	20	77.5%
210	80	76.9%
90	30	76.4%
220	80	75.8%
90	40	74.5%
110	70	74.2%
100	60	74.1%
130	80	74.0%
90	50	71.8%
120	80	71.3%
100	70	69.2%
90	60	68.1%
110	80	67.7%
90	70	63.4%
100	80	63.2%
90	80	57.8%

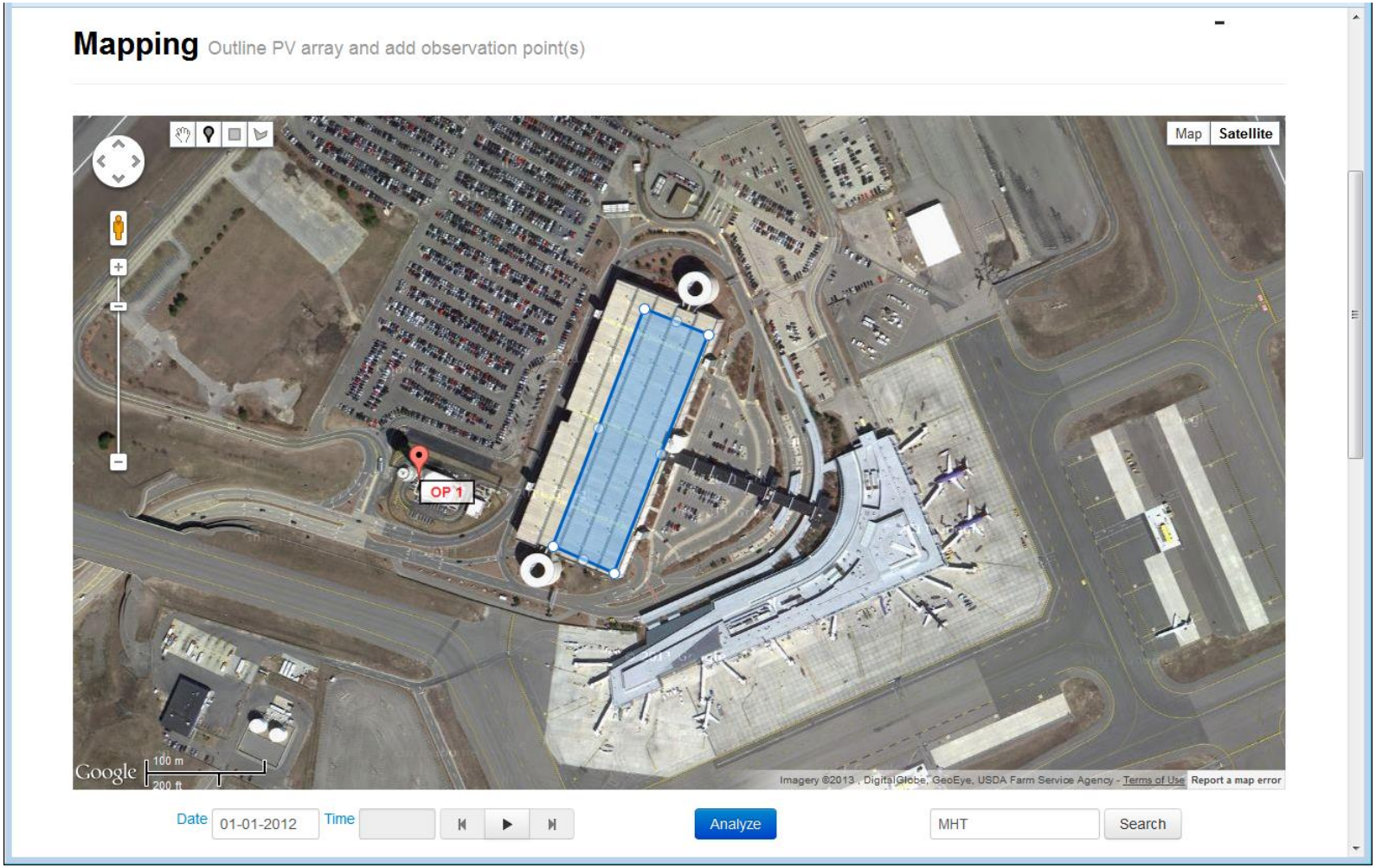
Alternative PV array configurations that are predicted to produce no glare to the ATCT (unless otherwise noted).

Azimuthal angle is measured clockwise from due north (0°); elevation angle is measured from 0° (facing up) to 90° (facing horizontal).

*Maximum energy production; produces glare to ATCT

**Current configuration; produces glare to ATCT

MHT – Alternative Design



Rotate modules 90 degrees counterclockwise

Runway Approaches

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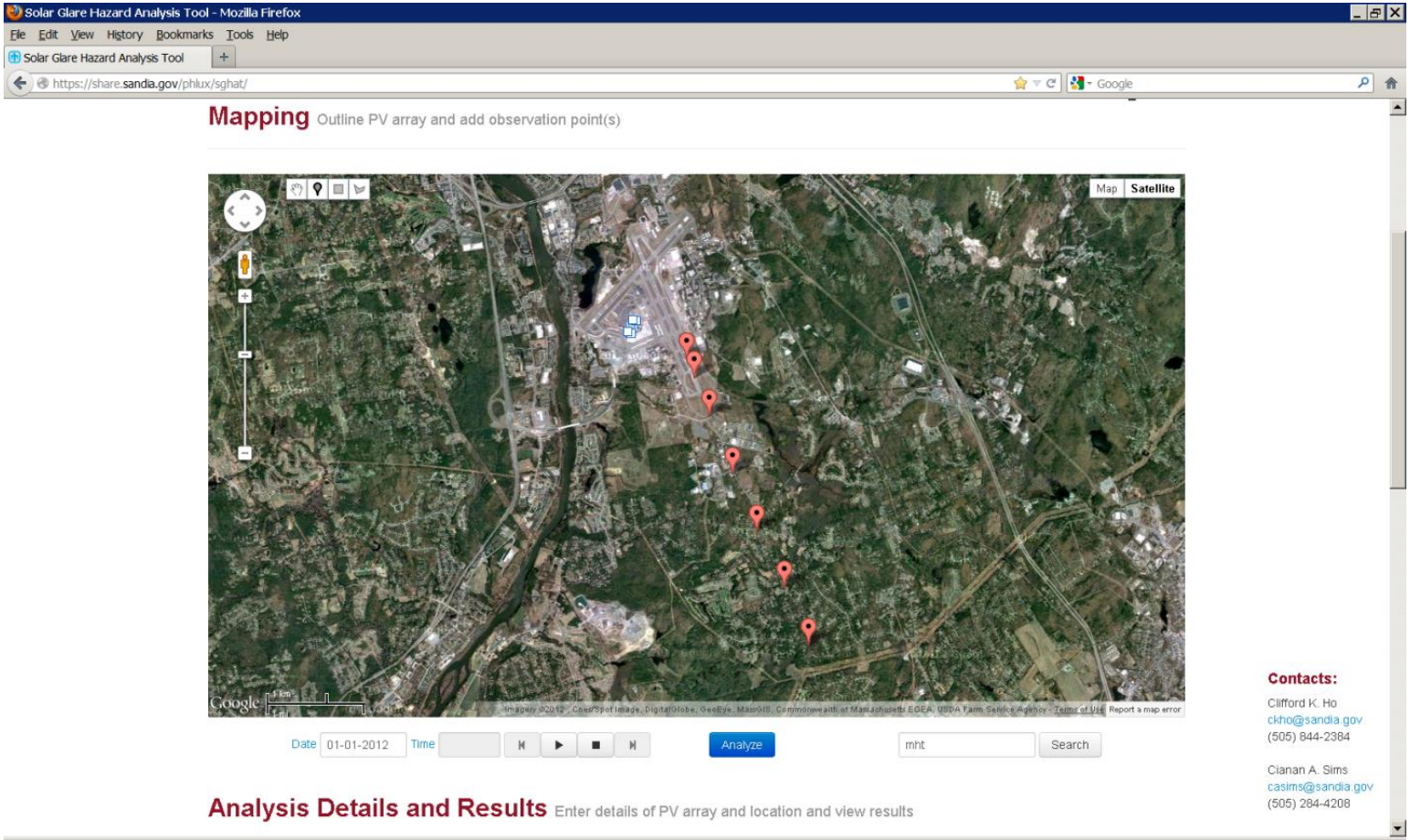
Observation Point #	Description	Distance From Landing Location (meters)	Elevation (meters)
1	Touchdown (TD)	0	0
2	Threshold Point	300	15.72
3	1 km from TD	1000	52.41
4	2 km from TD	2000	104.82
5	3 km from TD	3000	157.22
6	4 km from TD	4000	209.63
7	5 km from TD	5000	262.04

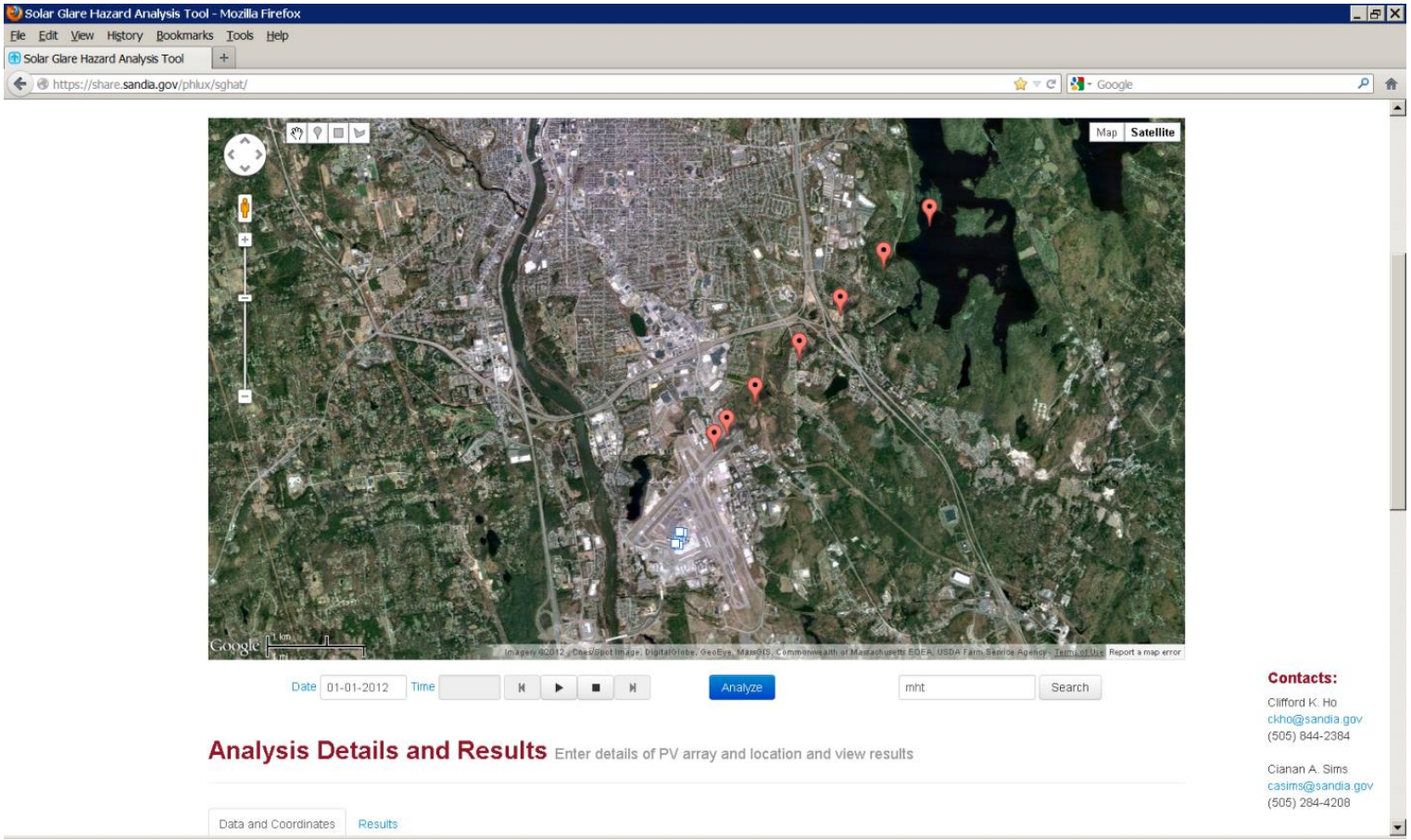
Observation points for straight approaches to runways 35, 6, 17, and 24 assuming 3 degree glide slope.

Approach to Runway 35



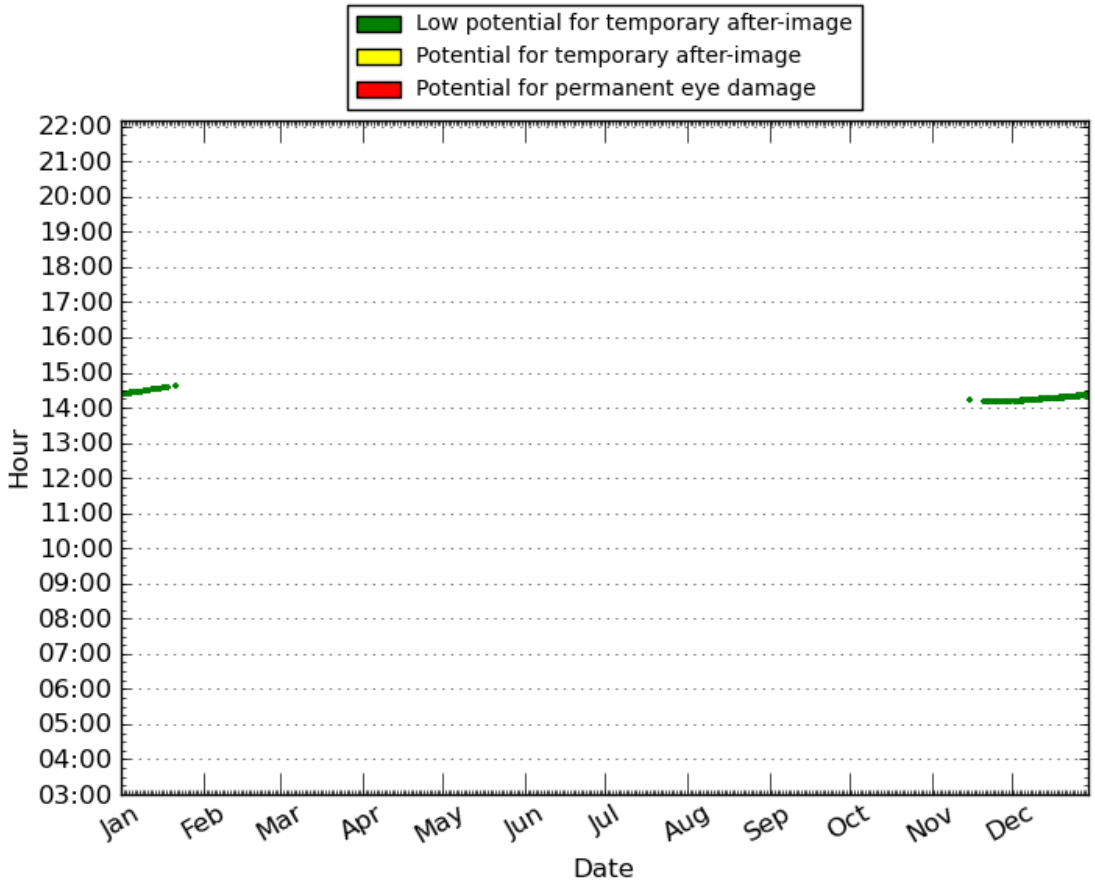
Observation points approaching Runway 35 from the southeast.

Approach to Runway 24



Observation points approaching Runway 24 from the northeast.

Glare Occurrence Plot for Runway 24 (Observation point 5)



Predicted glare and potential ocular hazard from observation point 5 (3 km from touchdown) on approach to Runway 24. A low potential for ocular impact is predicted.

Conclusions

- SGHAT predicts when and where glare will occur from a prescribed PV array at user-defined observation points/paths
  - Google Maps is used for easy user interface
- SGHAT predicts annual energy production
  - Systems can be quickly optimized to mitigate glare while maximizing energy production
- SGHAT can be used to produce analyses and reports to satisfy FAA requirements for solar installations near airports